MINIMUM FLOWS AND MINIMUM WATER LEVELS RE-EVALUATION FOR THE

LOWER SANTA FE AND ICHETUCKNEE RIVERS AND PRIORITY SPRINGS

PEER REVIEW RESOLUTION DOCUMENT

FINAL

DECEMBER 2020

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CONTENTS

Executive Summary

Chapter 373 F.S. and 62-40 F.A.C. provide the policy framework and authority for the Suwannee River Water Management District (District) and the Florida Department of Environmental Protection (FDEP) to set Minimum Flows and Minimum Water Levels (MFLs). Rule 62-42.300, F.A.C. (Minimum Flows and Levels and Recovery and Prevention Strategies) initially established MFLs for the Lower Santa Fe and Ichetucknee Rivers (LSFI) and associated priority springs in accordance with Section 373.042, F.S. Pursuant to Rule 62-42.300(1)(e), a re-evaluation of the MFLs was completed in December of 2019.

The District initiated Peer Review of the Draft MFL Report titled "Minimum Flows and Minimum Water Levels Re-Evaluation for the Lower Santa Fe and Ichetucknee Rivers and Priority Springs" in December of 2019 (SRWMD, 2019). During the peer review process, the District also received comments from stakeholders. Both the Peer Review Panel (PRP) Report (Dunn, 2020) and the various stakeholder submissions are on file at the District.

The primary purpose of this Resolution Document is to provide the District's response to the PRP Report. The District will respond to stakeholder comments separately. A secondary purpose of this Resolution Document is to compare the fundamental differences between the technical evaluations reported in 2013 (SRWMD, 2013b) and 2019 (SRWMD, 2019) and to discuss these differences in the context of water management.

The District has evaluated comments and used the best information available as directed by Florida Statute 373.042(1)(b). The District received many constructive comments, recommendations, and suggestions from the reviewers which, to the extent feasible and warranted, were incorporated into the final MFL Report. As required by Florida Statute 373.042(6)(b), significant consideration was given to the recommendations of the Final Peer Review Panel report in finalization of the MFL Report.

The PRP Chair called for a complete MFL re-evaluation based on the magnitude-duration-return inter (MDR) Event Approach. Furthermore, assertions that the literature review should be updated to include a "state of science and practices" imply that the District team is somehow deficient in its knowledge of the various approaches that can be used to evaluated MFLs. The District respectfully disagrees on both items.

The Chair's *Summary of the Panels' Findings and Recommendations* identifies other topics that are inferred in the re-evaluation MFL report but not explicitly discussed (e.g., Managing Uncertainty and Adaptive Management) or are not related to withdrawals (e.g., climate change). The District team agrees that these topics are important and exemplify challenges that stakeholders, and the District, will continue to consider when conducting water resource planning and water supply evaluations. Substantial responses to the PRP comments regarding those topics are provided herein.

The MFL re-evaluation is a substantive demonstration of adaptive management in which the original MFL's analysis was completed (SRWMD, 2013b) pursuant to the Florida Department of Administrative Hearings (DOAH) Findings of Fact and Conclusions of Law (DOAH, 2014) and then further expanded to:

a) create a Reference Timeframe Flow (RTF) baseline record through Water Year (WY) 2015 using the North Florida Southeast Georgia Regional Groundwater (NFSWG) Flow Model to adjust upward the historical flow records for groundwater withdrawal impacts on flow in contrast to the 2013 LSF MFL assessment for which a pre-1991 time period was used as the baseline flow record,

b) utilize an expanded instream habitat evaluation using a more robust modeling software, the System for Environmental Flow Analysis (SEFA), and

c) apply justifiable flow proportioning methods to evaluate MFLs for the Priority Springs and LSFR upstream of US441 that currently lack sufficient data for more quantitative assessment.

The District asserts that the current Draft MFL Report should be appraised within these re-evaluation requirements and improvements. It was not the Districts' objective to revisit methods that were deliberated in the previous review and hearing process, and resulted in the current MFLs Rule 62-42.300, F.A.C.

The District approach for its river system MFL evaluations has been two-pronged – 1) to use a cumulative frequency method for relatively high flows, developed by authors formerly with the SWFWMD (Munson & Delfino, 2007), and 2) to perform in-stream habitat modeling (e.g., SEFA), a method for low to moderately high flows that evaluates the change in in-stream suitable habitat area for various aquatic species and life stages. The District utilizes a top-down approach that requires identifying a baseline condition presumed to be unimpacted by withdrawals (i.e., RTF) from which some water is available for withdrawal. The District did not contemplate changing its approach for the re-evaluation of the LSFI MFL. Of key importance, is that the current District evaluation is consistent with and supported by the Event Approach and Indicators of Hydrologic Alteration (IHA) demonstrations described in this response document.

The District is committed to developing scientifically based MFLs to prevent significant harm to the LSFI natural resources caused by withdrawals, and to ensure current and future water availability. The District acknowledges that differences of opinion may arise regarding various methods of analysis, which are not defined by the MFL statute. However, the cumulative frequency method and 15%-change criterion are the basis for far more MFLs adopted in the State of Florida than any other method, including the Event Approach promoted by the PRP Chair.

The 15%-change criterion when applied to the change in frequency of higher flows and the change in viable instream habitat is a conservative approach that yields an allowable withdrawal of less than 8% from the median Reference Timeframe Flow (RTF) and <u>not</u> the historical flow. Literature documenting case studies of environmental flow assessments performed worldwide (Richter, Davis, Apse, & Konrad, 2011), associate the following tiers of protection of natural ecosystem structure and function, based on percent-of-flow reductions and risk tolerance of adverse environmental change, as a presumptive standard "… intended for application only where detailed scientific assessments of environmental flow needs cannot be undertaken in the near term."

- < 10% – high level of protection, low risk
- 10-20% – moderate level of protection, moderate risk
- 20% – low protection, high risk

Using this standard applied to RTF values, the percent reductions associated with the proposed MFLs at high to median LSFI flows would be low risk and afford a high level of protection. During low-flow conditions, the percent RTF reduction could temporarily exceed the 10% presumptive threshold; however, low flow WRVs are evaluated using in-stream habitat metrics.

The 15% presumptive criterion is continually being vetted. It is widely used as a significant harm criterion in setting MFLs in Florida, and therefore is built into studies re-evaluating habitat condition, permitting, and recovery strategies – in other words, adaptive management.

The realities and uncertainties associated with a changing climate and increasing water use are such that MFLs and reservations implemented throughout the state by the FDEP and Water Management Districts will need to be re-evaluated as the body of knowledge of hydrometeorological and ecological conditions grows with continuing data collection, research, and adaptive management.

Introduction

BACKGROUND

Chapter 373, Florida Statutes (F.S.) and 62-40, Florida Administrative Code (F.A.C.) provide the policy framework and authority for the State's Water Management Districts or Department of Environmental Protection (FDEP) to set Minimum Flows and Minimum Water Levels (MFLs). Rule 62-42.300, F.A.C. (Minimum Flows and Levels and Recovery and Prevention Strategies) was adopted by the FDEP effective June 10, 2015. The rule established Minimum Flows and Minimum Water Levels for the Lower Santa Fe and Ichetucknee Rivers and Associated Priority Springs (LSFI) in accordance with Section 373.042, F.S. The rule was adopted subsequent to a thorough peer review (Graham et al. 2013), the District's response to comments (SRWMD, 2013a), and an administrative hearing (DOAH, 2014).

Pursuant to Rule 62-42.300(1)(e):

> "Upon completion of the North Florida Southeast Georgia Regional Groundwater Flow Model currently under development, the Department, in coordination with the Suwannee River Water Management District and the St. Johns River Water Management District, shall re-evaluate the Minimum Flows and Levels and the present status of the Lower Santa Fe and Ichetucknee Rivers and Associated Priority Springs pursuant to Section 373.0421(3), F.S., using the **best available** scientific or technical data, methodologies, and models."

Pursuant to DOAH guidance, the Draft MFL Report titled "Minimum Flows and Levels for the Lower Santa Fe and Ichetucknee Rivers and Priority Springs," which describes the re-evaluation, was completed in December of 2019 (SRWMD, 2019). Shortly thereafter, the District disseminated the Draft Report and initiated an independent scientific peer review of the draft pursuant to Section 373.042(6)(a), F.S. By definition in this section, independent scientific peer review means "review by a panel of independent, recognized experts in the fields of hydrology, hydrogeology, limnology, biology, and other scientific disciplines, to the **extent relevant** to the establishment of the minimum flow or minimum water level."

The District is committed to developing scientifically based Minimum Flows and Minimum Water Levels (MFLs) to prevent significant harm to the area's natural resources and to ensure current and future water availability. The District's process includes the voluntary use of technical peer reviewers that independently comment on the MFL assessment methodology. The District also includes opportunities for public review. The intent of the District's process is to develop scientifically defensible MFLs that have been comprehensively evaluated.

A Peer Review Panel (PRP) of three members was contracted by the District to determine whether the methods used for establishing the minimum flows are **scientifically reasonable**. During the peer review period, the District also solicited comments from stakeholders. Three publicly noticed PRP meetings were conducted and the Peer Review Report (Dunn, 2020), and the various stakeholder submissions are on file at the District.

Initially the District received a first draft of the PRP Chair's Consensus Report that was submitted to the District on March 9, 2020. The first draft was comprised of five parts:

- PRP Chair's *Summary of Substantive and Non-Substantive Review Comments*,
- PRP Chair's *Summary of Panels' Findings and Recommendations*, and

- 3 attachments with independently submitted spreadsheet tabulations of each PRP member's specific review comments and specific recommended actions.

Subsequently, the District received a Final PRP Chair's Consensus Report that was submitted to the District on September 30, 2020. The final report comprises multiple parts:

- PRP Chair's *Summary of Substantive and Non-Substantive Review Comments*,
- PRP Chair's *Summary of Panels' Findings and Recommendations*, and
- 3 attachments with independently submitted spreadsheet tabulations of each PRP member's specific review comments and specific recommended actions.

PURPOSE

The primary purpose of this Resolution Document is to provide the District's response to the PRP Report, which is a compendium of comments tendered by three independent technical peer reviewers. Comments were provided by each peer reviewer in tabular format, and the Peer Review Chair (chair) summarized the Findings and Recommendations comments into 18 sets of Recommended Actions. District responses are provided to the Recommended Actions in Section 1, either with discussion or by referencing attachments. Responses to individual peer reviewer comments are provided in Section 2.

RESPONSE SUMMARY

The MFL re-evaluation itself is a substantive demonstration of adaptive management in which the original MFLs analysis (SRWMD, 2013b) was revisited pursuant to the Final Order Findings of Fact and Conclusions of Law (DOAH, 2014) and further expanded to:

a) create a Reference Timeframe Flow (RTF) baseline record through Water Year (WY) 2015 using the North Florida Southeast Georgia Regional Groundwater (NFSWG) Flow Model to adjust upward the historical flow records for groundwater withdrawal impacts on flow in contrast to the 2013 LSF MFL assessment for which a pre-1991 time period was used as the baseline flow record,

b) utilize an expanded instream habitat evaluation using a more robust modeling software, the System for Environmental Flow Analysis (SEFA), and

c) apply justifiable flow proportioning methods to evaluate MFLs for the Priority Springs and LSFR upstream of US441 that currently lack sufficient data for more quantitative assessment.

The District asserts that the final MFL Report should be appraised with these re-evaluation requirements and improvements in view. It was not the Districts' objective or requirement to revisit methods that were deliberated and defended in the previous review and hearing process, and resulted in the current MFL Rule 62-42.300, F.A.C. However, this re-evaluation did compare results obtained with a modified baseline record (RTF flow versus pre-1990 flow record) with those of the previous work that resulted in the existing rule, as part of an adaptive management process.

The District incorporated peer review comments into the MFL Report or appendices when deemed appropriate. When a comment recommended editorial changes for clarity, the report was changed to make the section more easily understood. When comments led the District to better data, the District obtained and used that data for analyses. When improvements to models (e.g., US441 flow estimates) were feasible, those changes were made. The District has evaluated comments and used the best information available as directed by Florida Statute 373.042(1)(b).

As required by Section 373.042(6)(b), F.S., significant weight was given to the recommendations of the Final Peer Review Panel report. The District received many constructive comments, recommendations, and suggestions which, to the extent warranted, were incorporated into the final MFL Report. The District also prepared this Resolution Document to provide the District team's response to the chair's Final Consensus Report.

The District acknowledges that the Final Peer Review Panel Consensus Report summarizes an expansive review. However, there are certain review comments in the Chair's Consensus Report that the District team has recognized as requiring a more detailed response. The District acknowledges that differences of opinion may arise through the interpretation of terminology which is not defined by MFL statute, such as "best available", "extent relevant", "scientifically reasonable", and "significant harm". However, the District affirms the voluntary use of the peer review process to improve MFL evaluations and that the comments provided were given substantial consideration.

By the chair's calculation, the PRP Consensus Document contained 177 specific comments, of which 66% were tendered by the chair and the remaining 34% the combined specific comments tendered by the two other PRP members, who did not find critical fault with the proposed MFLs and only requested more clarity on some components of the re-evaluation (Dunn, 2020). The chair advocated for the application of another MFL methodology using a magnitude-duration-frequency (MDR) approach (i.e., Event Approach), noting that the MFLs setting process "is incomplete" and that "reasonable assurance is not provided" because the statistical event approach was not applied. Furthermore, the chair advised that the District team to make current its knowledge of the "science of environmental flows".

The District addresses the chair's concerns in Section 1 of this Resolution Document. As done in the 2013 MFLs assessment, the re-evaluation utilized the two methods (%Time and %Area) that are more appropriate and more frequently used for Florida's MFL evaluations than the MDR approach. The book *Water for the Environment* (Horne et al. 2017) was reviewed as recommended by the chair. While the book includes a substantive review of current literature and state of knowledge, it does not expand the means for assessing MFLs that are already known to the District. Absent from the book is any reference to Florida's MFLs programs, a notable shortcoming due to the hundreds of assessments performed, and the corresponding MFLs rules adopted during the past several decades.

The Chair's *Summary of the Panel's Findings and Recommendations* identifies other topics that are inferred in the re-evaluation MFL report but not explicitly discussed (e.g., Managing Uncertainty and Adaptive Management) or are not related to an allowable change in hydrology associated with withdrawals that would prevent significant harm to the LSFI ecosystems and its component communities (e.g., Climate Change). The District agrees that these topics are relevant, particularly to the broader subject of water resource management.

The LSFI System is a dynamic river system with flows and ecosystems that are affected by stochastic hydrometeorological processes and cultural (land and water use) practices. MFL rules are by their very nature deterministic and primarily utilized for water supply planning and water use permitting. Florida's DEP and Water Management Districts are statutorily compelled and will continue to implement, re-evaluate, and revise adaptive water resource management programs to address the uncertainties associated with these dynamic processes as legal, policy, and/or fiscal constraints permit.

While there may be complementary overlap among water management programs and initiatives, the District respectfully argues in Section 1 that many of the PRP Chair's comments fall outside the purview of MFLs assessments and, in particular, the current LSFI System MFLs re-evaluation. Sections 1 and 2 that follow includes responses to comments in the final PRP consensus report, including those comments deemed outside the purview of the MFLs re-evaluation.

Section 1. Responses to Recommended Actions

Responses follow for each of the 18 sets of "Recommended Actions" listed in the final PRP Report (Dunn, 2020). Each response is prefaced by the numbered action (which is a direct quote from the final PRP Report), then followed by the District team's response (preceded by "Response"). Detailed responses are provided for some recommended actions that are broad in nature and oftentimes repeated by a peer reviewer. Other recommended actions are addressed succinctly with a simple reference to Section 2 and or Attachment(s) provided in this resolution document.

1. **Groundwater levels and spring flows—**Reviewer recommends that additional groundwater levels (Motz Comment 5) and spring discharge data (Motz Comments 6 and 7) should be analyzed to determine changes and trends in groundwater levels and spring discharges.

   Response: Please refer to comment responses in Section 2.

2. **Impacts of historic groundwater use—**Reviewer requests additional explanation concerning estimates of impacts of historic groundwater use (Motz Comments 13, 14 and15).

   Response: Please refer to comment responses in Section 2.

3. **Generation of RTFs—**Reviewer asks questions and makes suggested text changes in HSW's coverage of the development of the Reference Timeframe Flows at three gages (Motz Comments 12, 13, 14, 15 and 19).

   Response: Please refer to comment responses in Section 2.

4. **Rating curves for springs—**Reviewer comments on problems encountered with rating curves for springs and questions the conclusion that it is practical (sic) ". .to designate spring specific MFLs…at this time." (Motz Comments 22, 24 and 26).

   Response: Please refer to comment responses in Section 2.

5. **Historical groundwater use and impacts on surface-water discharges at three gages** – Reviewer concludes that better explanations are needed to justify how historical groundwater use (Appendix A) and RTF's were developed for flows at three gages (Santa Fe River near Ft. White and at US HWY 41 and the Ichetucknee River at HWY 27) using the NFSEG groundwater model (Appendix B) (Motz Comments 28-32, and 3442).

   Response: Please refer to comment responses in Section 2.

6. ***Infilling Data*—**Dr. Munson provided the following revision: "*Reviewer asks questions and requests additional supporting analyses for infilling data in hydro time series using multiple linear regression (MLR) method (Munson Comments 4 and 5), After reviewing public comment and seeing the residuals from the MLR provided by the NFUCG (prepared by Liquid Solutions) the MLR used to hindcast the US441 gage likely does not represent the best possible analysis. The hindcast is not necessarily inadequate, given the Districts charge to use the best available data and that it is responding to an earlier peer review by including its best effort to generate a US441 record. However, better modeling is potentially easily obtainable, and Dr Munson recommends the district consider models other than an MLF using an ordinary least square (OLS) fit. The fact is the report does not provide enough information to assess adequately assess the MLR. R^2 above .7 is generally*

acceptable in such regressions. However, with evidence of OLS assumptions being violated the District could consider weighted least square (WLS), or more specifically Generalized Least Square (GLS) models to recreate the time series. GLS models have the advantageous of potentially dealing with the heteroskedasticity and the autocorrelation suggested by Liquid Solutions analysis. Dr. Munson points out that in their discussion of time-series recreation on the St. Marks River the NWFWMD explored OLS, GLS, non-parametric and non-linear locally weighted regression (LOESS), as well as ARIMA modeling (an auto-regressive generalized model). In that case the LOESS model and the ARIMA model both performed well. The LOESS model was selected because it never predicted negative flow (which had never been observed) and so no further treatment of the results was needed. Their analysis was performed by Janicki Environmental and presented in the St. Marks River Rise and Spring Run MFL document. (Northwest Florida Water Management District, 2018: Recommended Minimum Flows for the St. Marks River Rise and Spring Run Leon County, Florida Appendix B: Development of Baseline Timeseries for the St. Marks River Raise Minimum Flows Evaluation)".

Response: Please refer to Attachment A and comment response in Section 2 and the following summary items.

- Allowing estimated negative flows was purposeful. The LSF at this location is a baseflow dominated system at low flows. Measured flow at US441 often is similar to the combined spring flow of springs above the gage. A negative flow estimate implies a flow deficit. The more negative the flow estimate the greater the flow deficit. This is important when adjusting flows for withdrawals. If only estimated flow values >= zero are allowed, then adding water back into the measured flow record to adjust for withdrawals would always result in a positive flow. This would not be correct.
- Similarly, including measured flows of zero in the regression analysis is not appropriate. A flow value of zero is not expected to be uniquely associated with flow at Fort White. Rather a flow value of zero is expected when the flow at Fort White is less than some value. So as not to bias the slope of the association between US441 and Fort White when US441 flow is positive, flow values of zero were excluded from the regression analysis and model in the draft report and some of the models tested.
- Issues raised regarding residuals are mostly not applicable. A number of assumptions may apply to the residuals of a regression model depending on the model application, including (1) homoskedasticity (i.e., residuals vary evenly over the range of predictions), (2) independence (i.e., residuals are minimally autocorrelated over time), and (3) normality (i.e., residuals should be normally distributed). Each of these assumptions relate to drawing inference into model coefficients and deriving prediction intervals. Residual assumptions are not required to predict y (i.e., flow at US 441) given x (i.e., flow at nearby gages) (see Table 9.1 in (Helsel & Hirsch, 2002)).

7. **AMO signal—**Reviewer cautions that report should not so easily dismiss the presence of an AMO signal. He points to the range of AMO patterns observed by Kelly 2004 for rivers in Florida. Dr. Munson specifically notes that the AMO pattern may be bimodal (Munson Comments 6 and 7).

   Response: Please refer to comment responses in Section 2.

8. **Development of RTFs—**Reviewer requests additional discussion clarifying: 1) choices made for period of record for annual water use estimates for groundwater use (Munson Comment 9), and issues concerning estimates of RTFs (Munson Comment 10).

   Response: Please refer to comment responses in Section 2.

9. **Use of the reach apportionment method—**Reviewer requests additional discussion of the appropriateness of using reach apportionment methods for setting MFLs (Munson Comments 17 and 18).

   Response: Please refer to comment responses in Section 2.

10. **The MFLs Setting Process is Incomplete—**Reviewer finds that the MFLs setting process for the Lower Santa Fe and Ichetucknee Rivers and their priority springs is incomplete. Overall, Dr. Dunn finds that the proposed re-evaluated MFLs are yet incomplete, since the latter parts of the process are problematic. He recommends that that problem areas be reevaluated and redone. Specific problems are identified in the definition and setting of indicators and metrics for WRVs, specifically the parameterization of the WRVs as they are used as the defining protective criteria for setting minimum flows and levels. Protective thresholds are set to prevent significant harm. Beyond identifying problems specific recommendations are given to address each problem. These remedial actions if implemented can significantly improve the scientific rigor of this MFLs setting effort. Dr. Dunn's specific comments on this topic are: G2, G3, 6.1, 6.2, 6.4. 6.5, 6.7, 6.8, 6.9, 6.10, 6.11, 6.15, 7.5, and 7.6.

    Response: Please refer to the following response to item #11.

11. **Parameterizing WRVs—**Reviewer finds that HSW's MFLs report has a major shortcoming in setting the proper indicators and metrics for several of the fourteen key WRVs elements. From this he concludes that reasonable assurance is not provided that the sensitive water resources of the LSFR & IR and their associated springs will be protected by the proposed MFLs. Dr. Dunn recommends that the WRV parameterization process be redone following specific recommendations. This recommendation thus calls for the MFLs development process be rolled back to this point, the WRV parameterization step. Dr. Dunn's specific comments on this topic are: G4, G6, G14, 4.1, 4.5, 4.16, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13, 5.14, 5.15, 5.16, 5.17, 5.18, 5.19, 5.20, 5.21, 5.22, 5.23, 5.25, 5.26, 5.27, 5.28, 5.29, 5.30, 5.31, 5.32, 5.33, 6.1, 6.4, 6.5, 6.7, 6.8, and 6.9.

    - On the question of setting proper metrics for WRV of interest Dr. Dunn strongly recommend that whenever relevant and possible protective metrics for the MFLs be based on statistically defined protective hydrological events composed of 1) a magnitude (flow and/or level), 2) continuous duration for the specific inundation or drying period, and 3) with a return interval.
    - The report's authors selected and applied only a single approach to setting metrics for WRVs, the 15% allowable change developed by SWFWMD. This is identified as key shortcoming.
    - He advocates that a toolbox of methods be used to screen and select the best approach to setting WRV metrics. The toolbox should include a full array of options available and used by practitioners. Abundant examples exist from numerous from other MFL WRV metrics

developed by the SRWMD and other sister districts. In addition, recent technical reviews of the field can help define the contents of the toolbox.

- Analysis by Graham et al. (2013) clearly show that sensitivity of flow and levels reductions can be quite different for WRV threshold metrics set using 15% change versus event metrics that include components of magnitude, duration and return interval (MDR). This strongly advocates for the reevaluated all the relevant WRV for both rivers, and their associated springs.

Response: Following is a collective response to Recommended Actions #10 and #11; starting with an interpretation of the multitude of specific review comments associated with these actions.

The PR panel Chair noted that "…Two reviewers did not find critical fault with the proposed MFLs. The Chair did, however, call for a step back to the WRV parameterization process. This is a call for a redo. The redo can proceed quickly once the WRV re-parameterization is done…" (Dunn, 2020). The District acknowledges the difference of opinion between the PRP Chair and other panel members, and the District and responds to the PRP Chair's opinions with the following.

The Panel Chair's Recommended Action #10 asserts the "MFLs setting process is incomplete" and follows up with Recommended Action #11 regarding methodology (i.e., WRV parameterization) to:

- Parameterize WRVs based on an event approach[1]
- Use multiple approaches to set WRV metrics
- Screen and select a "best approach" for setting WRV metrics
- Follow key recommendations from the 2013 peer review (UF, 2013) which included specifically applying the event approach and adopting an adaptive management (AM) approach
- Update the literature review to include a "state of science and practices"

On the topics of the MFLs Setting Process and setting proper metrics for WRVs of interest, Dr. Dunn strongly recommended that whenever relevant and possible, protective metrics for the MFLs be based on statistically defined protective hydrological events composed of 1) a magnitude (flow and/or level), 2) continuous duration for the specific inundation or drying period, and 3) with a return interval. These topics are addressed in greater detail below and in Attachments B and C.

Furthermore, Dr. Dunn indicated that the report's authors selected and applied only a single approach to setting metrics for WRVs, the 15% allowable change developed by SWFWMD. This is identified as a key shortcoming. This is not accurate; the re-evaluation considered two approaches (%Time and %Area).

Dr. Dunn advocates that a toolbox of methods be used to screen and select the best approach to setting WRV metrics. The toolbox should include a full array of options available and used by practitioners. Abundant examples exist from numerous from other MFL WRV metrics developed by the SRWMD and other water management districts in Florida. In addition, recent technical reviews

[1] A statistically defined protective hydrological events composed of 1) a magnitude (flow and/or level), 2) continuous duration for the specific inundation or drying period, and 3) with a return interval.

of the field can help define the contents of the toolbox. A toolbox of methods was considered as explained in greater detail below and in Attachments B and C.

Dr. Dunn noted that an analysis by Graham et al. (UF, 2013) clearly shows that sensitivity of flow and levels reductions can be quite different for WRV threshold metrics set using 15% change versus event metrics that include components of magnitude, duration and return interval (MDR). This strongly advocates for the re-evaluation of all the relevant WRV for both rivers, and their associated springs. The purposeful decision not to use a MDR approach is explained further below and supported by a demonstration (Attachment C).

<u>Completeness of MFLs setting process</u>

As explained in the preceding Response Summary section, the Draft MFL Report describes a re-evaluation that expands on the initial MFLs setting process that concluded with the promulgation of Rule 62-42.300, F.A.C. However, given the interest in an event-based (MDR) approach, several WRV metrics were evaluated to demonstrate an event-based method (Neubauer, et al., 2008) for comparison with the cumulative frequency approach (SRWMD, 2019). This work is discussed In Attachment C.

<u>WRV Parameterization and Multiple Approaches</u>

The District's MFL team is well versed in approaches used to set MFLs in the State of Florida and the national and international state of the science regarding the protection of resource values generally and environmental flows specifically (Attachment B). The decision to not use an event-based approach was purposeful, logical, and well founded. As in 2013, the District has elected to continue using the cumulative frequency approach to evaluate <u>high flows</u> in river systems in the District, like the LSFI. An in-stream habitat area change approach is used for lower flows and can also be applied in the floodplain.

The District acknowledges the peer review panels' approval of using instream habitat modeling (SEFA) for low to medium flows and note that this is an area based metric approach making use of a critical allowable change of 15% (see page 6 (Dunn, 2020)). This 15% threshold has been used to determine numerous MFLs in Florida (Attachment B) and discussed with the authors of SEFA and determined to be a reasonable allowable shift from baseline to avoid significant harm. We also note that the results for the SEFA work, if used solely for setting the MFL, would be very similar to the proposed MFL (e.g., 99 cfs for percent of flow reduction applied at median flow and 115 cfs for constant flow reduction).

The cumulative frequency approach, with a 15% threshold, has been shown to be conservative when compared to other approaches (e.g., area change) and provides a creditable quantitative metric for adaptively managing complex systems (Munson & Delfino, 2007). The use of this approach is not unique to SRWMD as the SWFWMD and NWFWMD also use this threshold resulting in peer reviewed MFL documents applying a cumulative frequency approach, primarily at high flows (Attachment B). These documents currently support about 25 MFL Rules spanning a period from 2006 to 2018. In comparison, MFLs have been adopted for 7 riverine systems in Florida based on an event approach ((SJRWMD, 2019) and Attachment C).

Moreover, because there is some uniformity in using these approaches (area, cumulative frequency, and instream habitat modeling, all coupled with a 15% threshold), there are now many sources of comparable data from actively managed river systems in Florida.

The District concurs that many responses associated with Water Resource Values (WRVs) are the result of a change in the flow regime such that important events are altered beyond some threshold. With current available information, what those events and thresholds are, in a complex river system like the LSFI, are currently too uncertain (Attachment C).

In addition to these MFL setting approaches, cross checks also were made using Instream Habitat Analysis (IHA) software (The Nature Conservancy, 2009). IHA is used to compare baseline (RTF) and MFL flow scenarios for statistical differences (Attachment C). While statistical difference is not a decision threshold, the IHA metrics can point to flow events (and event changes) that may be a concern.

The relative flow reductions associated with the proposed MFLs also were compared to literature summarizing case studies of water management. The percent-of-flow reduction (POFR) approach is a management approach that limits withdrawals from a river or groundwater (baseflow) to a percentage of flow at the time of withdrawal. The POFR approach reportedly has several strong advantages over other approaches (Richter, Davis, Apse, & Konrad, 2011). It is more protective of flow variability than minimum constant-threshold standards that can allow flow variability to diminish as water allocation pressure increases. For an unregulated system, the POFR approach results in a pattern of flow change that maintains the natural intra-annual seasonality and inter-annual periodicity of the resource.

Following a case study review (Richter, Davis, Apse, & Konrad, 2011), the following tiers of protection of natural ecosystem structure and function, based on percent-of-flow reductions and risk tolerance of adverse environmental change, were proposed as a presumptive standard "…intended for application only where detailed scientific assessments of environmental flow needs cannot be undertaken in the near term."

- < 10% – high level of protection, low risk
- 10-20% – moderate level of protection, moderate risk
- 20% – low protection, high risk

The District notes that the proposed MFL falls in the low risk category. The District is sensitive to the article's quote regarding intention, presented above, but maintains that the flow categories provide a useful and important check.

Where feasible, the SRWMD uses an event-based approach when developing MFLs for lakes because the systems are less complex, and information gained from similar types of water bodies in a similar hydrogeologic setting often is transferable. Use of an event-based approach for rivers systems should rely on site-specific data or Florida specific data as (Poff & Zimmerman, 2010) summarized:

> "4. Our analyses do not support the use of the existing global literature to develop general, transferable quantitative relationships between flow alteration and ecological response;

however, they do support the inference that flow alteration is associated with ecological change and that the risk of ecological change increases with increasing magnitude of flow alteration.

5. New sampling programs and analyses that target sites across well-defined gradients of flow alteration are needed to quantify ecological response and develop robust and general flow alteration–ecological response relationships. Similarly, the collection of pre- and post-alteration data for new water development programs would significantly add to our basic understanding of ecological responses to flow alteration."

Among other concerns, pre- and post-alteration biological data across well-defined gradients of flow alteration are not available for the LSFI, for example. The District asserts, based on the current lack of sufficient site-specific data of this type on these complex unregulated river systems, the percent of time/area approach utilized is appropriate. The lack of site-specific floodplain data would require use of non-site-specific data for an event-based approach which would be inappropriate for this system.

In conclusion, Section 373.042(1), F.S. (Florida Statutes) and Rule 40B-8.011, F.A.C. (Florida Administrative Code) prescribe that MFLs shall be calculated based on "best information available". It is arguable that a best method exists for evaluating MFLs, hence a weight-of-evidence approach based on multiple methods was used.

12. UF Peer Review Panel—Reviewer finds that major recommendations from 2013 peer review for MFLs that are now being re-evaluated (Graham et al. 2013) have not been fully followed. Key recommendations from the previous peer review (Graham et al. 2013) were not fully addressed in the previous peer review for the initial MFLs adopted in 2015. Furthermore, all of these remain problematic in this re-evaluation. Dr. Dunn's specific comment on this topic is G5. Graham et al. (2013) as yet not fully addressed significant concerns were:

- To prevent significant harm MFLs threshold metrics should include consideration of duration and return interval of both low flow and high flow events in addition to cumulative frequency. They state concerns with the use of flow duration curves (FDCs) alone to characterize the flow regime as they may not adequately relate important biological, or ecological responses to variations in the flow regime. Five critical components of flow regime are frequently recognized in the it when assessing environmental flows: 1) magnitude, 2) return interval 3), duration 4), timing, and 5) rate of change.
- The Panel recommended that the 15% threshold of change be more fully justified as it applies specifically to the LSF and Ichetucknee Rivers. They found that justification for the proposed threshold of a 15% habitat loss in the establishment of MFLs is based on precedent and cannot be justified based on the data presented in the report. So, while there is a precedent for the adoption of the 15% threshold, its general applicability is unproven.
- Panel found that quite different outcomes result from applying the % change method versus events with return intervals. Their Table 1 table is comparison of 15% allowable flow reductions by WRV for LSFR range from 5-8 percent but change in return interval for WRV events range from 14 to 29 percent, for the IR the numbers are 3-12%, versus 27-45%.
- In the face of uncertainties caused by absence of key supporting data, the panel urged the District to adopt an adaptive management (AM) approach allowing decisions based on limited

data to be reinforced or modified as new research and monitoring information become available.

Response: There are no specific comments related to this Recommended Action and most is covered in other responses. The District points out that responses were provided to the previous Peer Review of the 2013 MFL report (SRWMD, 2013a), including the preceding bulleted items. Furthermore, the re-evaluation comports with the DOAH's Findings of Fact and Conclusions of Law (DOAH, 2014).

13. **Seasonality—**Reviewer finds that report needs to address seasonality issues when they are relevant to defining WRVs and setting their metrics. How seasonality is handled should be stated in the approach for defining WRVs. Seasonality typically adds components of seasonal occurrence and duration of that seasonal window. So, using an event-based metric seems both prudent, and a scientifically defensible choice. Also, if this were being done by the SJRWMD, then the event would be defined. I am sure that SJR District has many examples from established MFLs. Dr. Dunn's specific comments on this topic are: G11, 3.18, 5.9, and 5.10.

    Response: Please refer to comment responses in Section 2.

14. **Water Quality Nexus to Flow Regime –**Reviewer notes that there are clearly identified water quality impairments of concerns in these rivers and springs. These key water quality issues remain largely divorced from consideration in this MFL. Several recent research findings indicate however, that some water quality problems do have link with flow regimes. As WRV metrics will now be assessed anew we may have the opportunity to incorporate meaningful water quality thresholds in one or more WRV metrics. Dr. Dunn's specific comments on this topic are: G14, 5.30, and 7.6.

    Response: Please refer to comment responses in Section 2.

15. **Climate Change is Upon Us—**Reviewer asks about impact of climate change. Climate change is not addressed in the document. MFLs are by their nature our estimates of sustainable resource management. If we are indeed in a time of climate change, then the assumptions upon which we base MFL type sustainability may not hold in the future. In statistical hydrology this is a question of stationarity of the statistical populations comprising our climate driven time series data for temperature, rainfall, runoff, aquifer recharge, etc. The consensus of climate experts is that key time series are in flux, that is they are statistically non-stationary. Climate change is another element of uncertainty, it needs to be discussed, and likely impacts identified and planned for. Dr. Dunn's specific comment on this topic is G16. In addition, Dr. Motz notes that the draft MFL report (HSW Engineering 2019) does not address the impacts that climate change will have on stream flows and groundwater and surface-water levels in the Lower Santa Fe River and Ichetucknee River Basins. Also, impacts of climate change on the Priority Springs are not addressed. Future increases in rainfall and temperature should be considered as well as related increases in evapotranspiration due to rising temperatures. An investigation by Swain and Davis (2016) describes the application of a downscaled global climate model to a groundwater model of the Suwannee River Basin. Another investigation by Swain et al. (2014) describes the application of a downscaled global climate model to a surface-water/groundwater model of southern Florida including sea-level rise. These and other applicable references should be used as guides to address the impacts of climate change in the Lower Santa Fe and Ichetucknee River Basins.

Response: A response follows, although the recommended action is considered not applicable relative to the evaluation of an allowable change in hydrology caused by withdrawals.

Climate change (defined here as a change in global or regional climate patterns, in particular a change apparent from the mid- to late-20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels) is creating new challenges for environmental water science as it obfuscates an assumption of stationarity. Stationarity means that the statistical properties of hydrologic variables in future time periods will be similar to past time periods. Stationarity allows a reasoned future expectation based on historical data. This type of change differs from seasonal patterns and multiyear patterns (e.g., Atlantic Multidecadal Oscillation, AMO) in that these patterns are still generally repeated over a relatively short period such that current available data are representative.

As the definition implies, climate change has and is expected to continue to result in an increase in near surface temperature as well as changing rainfall patterns that may differ from recent historical climatic variables. An international team of researchers stated succinctly “Stationarity Is Dead” (Milly, et al., 2008). A general pattern of increasing low flows in the northeast and decreasing low flows in the southeast was evident in time series of low flows at 508 USGS streamflow stations evaluated over a common period from 1951 through 2005 (Sadri, Kam, & Sheffield, 2016). Nonstationarity in climate and other environmental conditions such as temperature and nutrients and ecological features such as non-native species spread also represent challenges to environmental flow assessments (Poff L. N., 2017). The author notes that “a new imperative of managing for resilience is emerging” because of “shifting hydro-climatic and ecological conditions.”

Estimated impacts from climate change have not been incorporated into any MFL rules. Most MFL evaluations have not incorporated climate change in the evaluation process because it is not directly related to a withdrawal impact. The SWFWMD has incorporated examples of possible impacts into some of their coastal MFLs (Leeper, et al., 2012). In the Homosassa River example, sea level rise scenarios were incorporated into hydrodynamic model runs to estimate the impacts to salinity concentrations in the coastal river system. It was found that seal level rise would increase the river systems salinity substantially more than the effects of future consumptive water use.

In the District and current study area, a discernible increase in average daily high temperatures is observed in the temperature record (NOAA zone 2 – northern Florida, Figures 1 and 2). This follows a more stable record from about 1920 to 1990. Whether or not this is evidence of “climate change” is uncertain, but elevated ambient temperatures are likely to correspond to increased evapotranspiration rates and may result in reduced river flow. Researchers at the U.S. Department of Agriculture recently reported that “changes in climate will increase atmospheric water demand by crops and increase the potential for limitations in soil water availability, because of the increased variation in precipitation during the growing season and even more so in soils with limited water holding capacity” (Hatfield & Dold, 2019). Since a changing atmospheric water demand by crops is not a withdrawal impact, it is not incorporated into the MFL assessment.

The application of stochastic streamflow models (SSMs) based solely on streamflow observations has fallen out of favor, partly due to the inability of SSMs to account for anthropogenic influences on streamflow (Vogel, 2017). Stochastic watershed models (SWMs) are deterministic watershed models implemented using stochastic meteorological data. The application of SWMs is emerging as a means for considering the integrated impacts of changes in factors such climate, land use, and water withdrawals (Vogel, 2017). The use of SSMs and SWMs is clearly outside the scope of the current MFLs re-evaluation but could be considered for future MFLs and or water supply assessments.

Climate change topics that would support future water resource evaluations include:

- Influence of changing temperature trends on regional evapotranspiration and net recharge values.
- Sensitivity of streamflow, spring flow, and groundwater levels to changing deep percolation simulated using the linked HSPF-MODFLOW NFSEG model.
- Opportunities to collaborate in the University of Florida's public-private partnership with NVIDIA (NVIDIA, 2020) on Artificial Intelligence (AI)-centric data processing using supercomputers for adaptive management to evaluate the integration and refinement of hydrometeorological monitoring programs maintained by a variety of agencies.

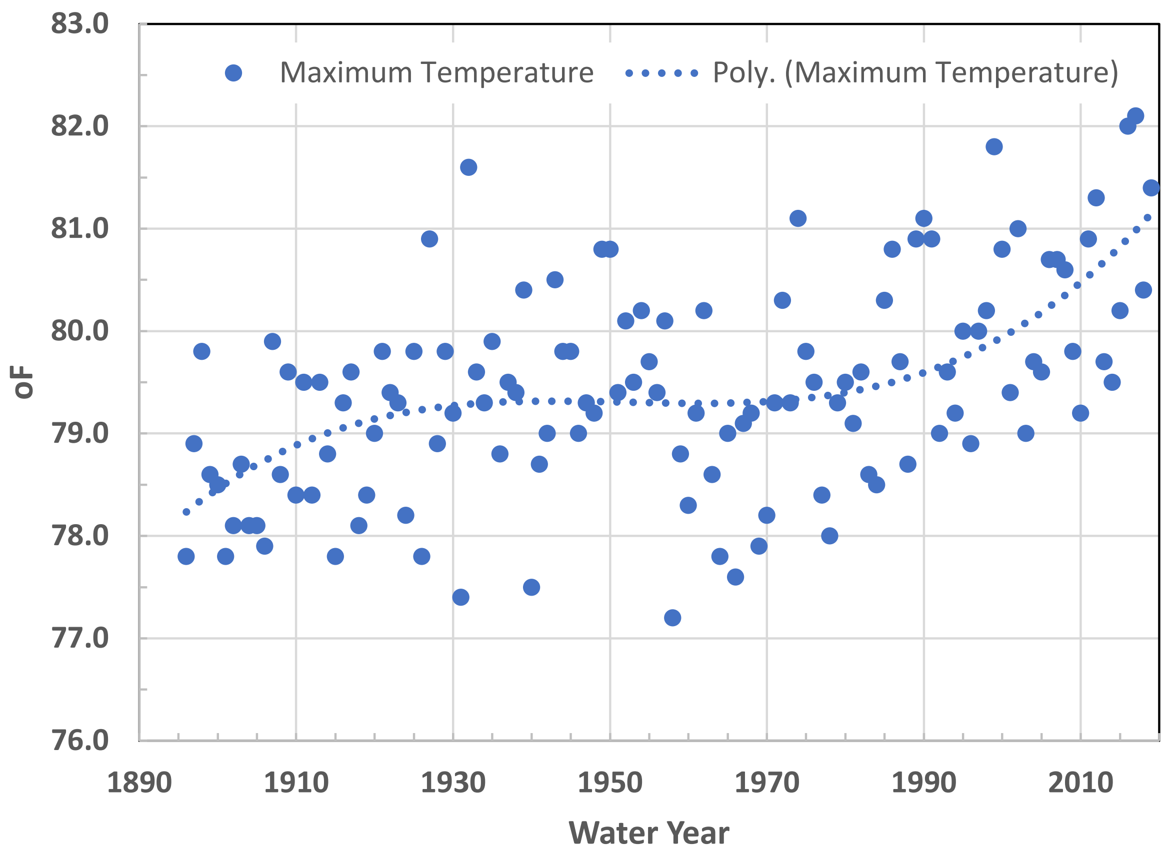

Figure 1. Annual average daily maximum temperature, Florida, NOAA Region 2 (North FL)

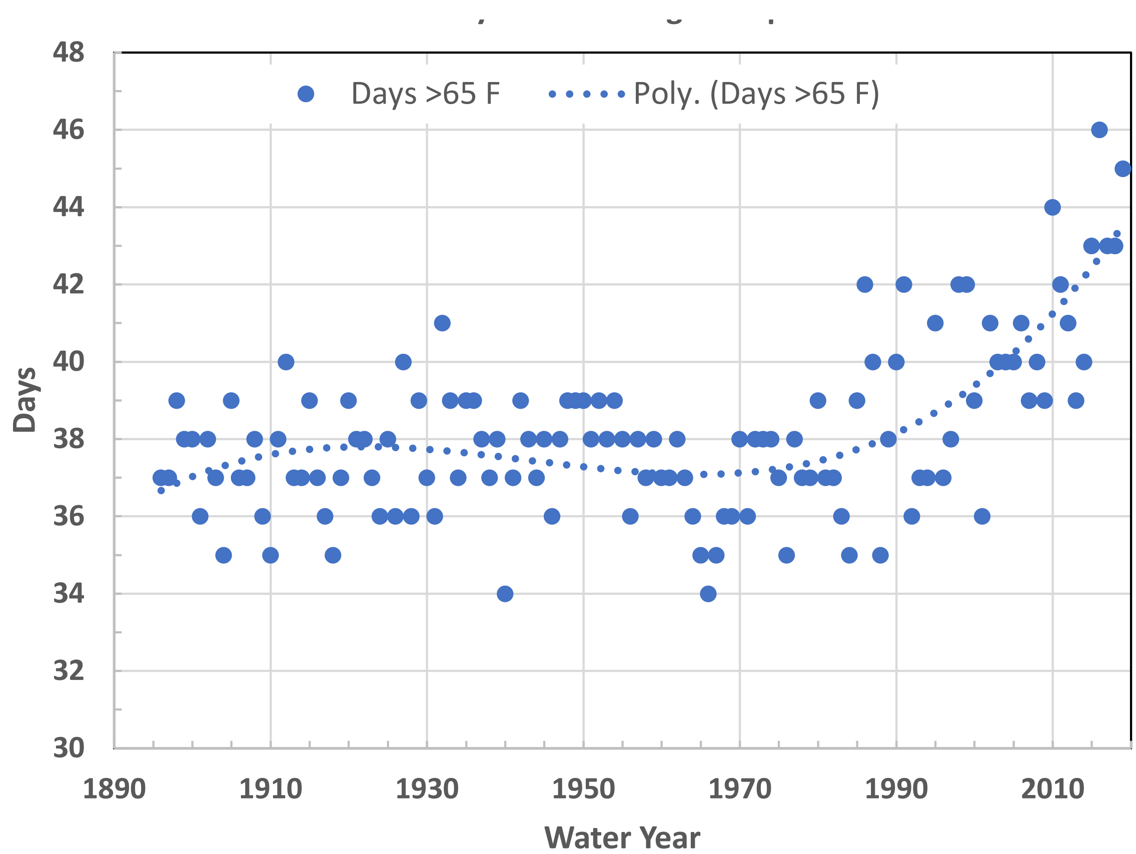

Figure 2. Annual number of days with average temperature greater than 65°, Florida, NOAA Region 2

[Source of data for Figures 1 and 2 (NOAA, 2020)]

16. **Update Science on Environmental Flows –**Reviewer states that the process and methods used to match WRVs to proper indicators and metrics must be better matched with the current state of state of the science of environmental flows. Thus, the authors need to update their literature review, and science for methods used to set minimum flows and levels, specifically the WRV metrics. A particularly good, very detailed review of the state of science and practices is a recent book *Water For The Environment* (Horne et al. editors, 2017) provides in depth reviews of current status of theory practice, research and application. This book's citation is: Water for the Environment: From Policy and Science to Implementation and Management, Edited by Avril C. Horne, J. Angus Webb, Michael J. Stewardson, Brian Richter, and Mike Acreman. Academic Press, 2017, 720 pages. Dr. Dunn's specific comments on this topic are: G8 and G18.

    Response: Please refer to Attachment B that elaborates on the District team's response to this Recommended Action and includes some language excerpted/adapted from a recent Georgia statewide environmental-flow regimes assessment-methodology review (ARCADIS and HSW Engineering, 2019).

    The book *Water for the Environment* (Horne et al. 2017) was reviewed as recommended by the Peer Review Panel Chair. The book is a compendium covering multiple aspects of environmental water management as a multidisciplinary practice. Current challenges and potential solutions are highlighted to help define the future direction for environmental water management. Section IV (How Much Water Is Needed: Tools for Environmental Flows Assessment) includes the following four chapters that describe various means for assessing MFLs:

11. Evolution of Environmental Flows Assessment Science, Principles, and Methodologies
12. Tools for Sediment Management in Rivers
13. Physical Habitat Modeling and Ecohydrological Tools
14. Models of Ecological Responses to Flow Regime Change to Inform Environmental Flows Assessment

While the book includes a substantive review of current literature and state of knowledge, it does not expand the means for assessing MFLs that are not known to the District's MFLs assessment team or already incorporated in the Draft MFL Report. Absent from the book is any reference to Florida's MFLs and water reservation programs and associated rules that have been adopted during the past several decades, and ongoing adaptive water resource planning and management programs involving data collection, analysis, and reporting that have been implemented by the State's five water management districts. In contrast, Florida's MFLs statute is one of four case studies selected for detailed review and documentation after a world-wide search for leaders in incorporating Environmental Flow Needs (EFNs) into water policy and management tools (Harwood, Girard, Johnson, Locke, & Hatfield, 2014).

17. **Managing Uncertainty—**Reviewer notes that the report lacks an integrated treatment of the sources of uncertainty. This leaves a reviewer unable to determine the significance of impact of uncertainties. And lacking an inventory and sensitivity assessment of sources, then there is not a plan to manage uncertainty effectively, such that its negative effects can reduced, or eliminated. Uncertainty issues are discussed throughout the report, and are key to many of key decisions made for choosing methods of analysis, time series data, etc. Management of uncertainty moving forward is not highlighted, and it should be. Dr. Dunn's specific comments on this topic are: G10, 4.3, and 6.13. Sources of uncertainty in this MFL setting process include:

    - Groundwater and surface water modeling
    - Surface water modeling
    - Water budget develop, including hydrologic time series needed
    - Reference flow developed for assess impacts of historic consumptive use
    - Selection of relevant WRVs, and subsequent parameterization of the assessment's metrics
    - Water quality Impairments affected by flow or level
    - Effects of climate change

    Response: Please refer to the following response to item #18.

18. **Applying Adaptive Management (AM)—**reviewer notes that the report lacks an explicit adaptive management (AM) framework. He recommends that AM approach be applied to this MFL setting effort and used as a guiding principle. This is a repeat of a major recommendation by UF's peer review panel's finding and recommendations from seven years ago (Graham et al. 2013). Dr. Dunn's specific comments on this topic are G9 and G15.

    Response: A new section (4.5) with the following information was added to the report

Uncertainty is an unavoidable consequence of the ever-changing natural and anthropogenic processes within and affecting the LSFI. From both scientific and management perspectives, there is uncertainty associated with determining withdrawal impacts on physical, biological, and chemical aspects of the system. As noted in Response #15, nonstationarity in climate and other environmental conditions such as temperature and nutrients and ecological features such as non-native species spread also represent challenges to environmental flow assessments (Poff L. N., 2017). The author notes that “a new imperative of managing for resilience is emerging” because of “shifting hydro-climatic and ecological conditions.”

Uncertainties are widely acknowledged but they are rarely quantified, and it is not the District’s intent to do so here. However, identifying sources of uncertainty can help with reducing uncertainty by collecting additional data and through additional targeted studies and adaptive management.

With that in mind, some sources of uncertainty in the current re-evaluation are:

- Flow and stage data (error associated with collecting and processing basic hydrologic data).
- Infilling and record extension. Often data are not available for a complete or desired period of record for a particular gage/location and associations between flow/stage at one gage are used to estimate the flow/stage at another gage with a limited record. This source of error generally can be quantified using parametric (if certain criteria are met) or non-parametric (less restrictive criteria) means.
- Functional relationship between flow/stage and system response. For example, the SEFA model used for instream habitat modeling depends on a hydraulic model of the study area and an association between input variables (velocity, depth, and substrate) and habitat suitability indices (curves) for a variety of species and life stages. There are uncertainties associated with the input data, the model application, and the response functions.
- Varying influence of climatological variables (rainfall and air temperature) on surface and groundwater hydrology, ecosystems, primary productivity, and important water-quality constituents such as dissolved oxygen.

This re-evaluation of minimum flows in the LSF River System demonstrates the application of an adaptive management strategy for dealing with uncertainty in this complex, dynamic river system and associated stochastic processes. Adaptive management is a standard approach for reducing the inherent uncertainty associated with natural resource management (Williams & Brown, 2014) and is recommended by the U.S. Department of the Interior for decision making in the face of uncertainty about management impacts (Williams, Szaro, & Shapiro, 2009). Adaptive management is a systematic, iterative approach to meeting management objectives in the face of uncertainty through continued monitoring and refinement of management actions based on consideration of alternatives and stakeholder input (Figure 3).

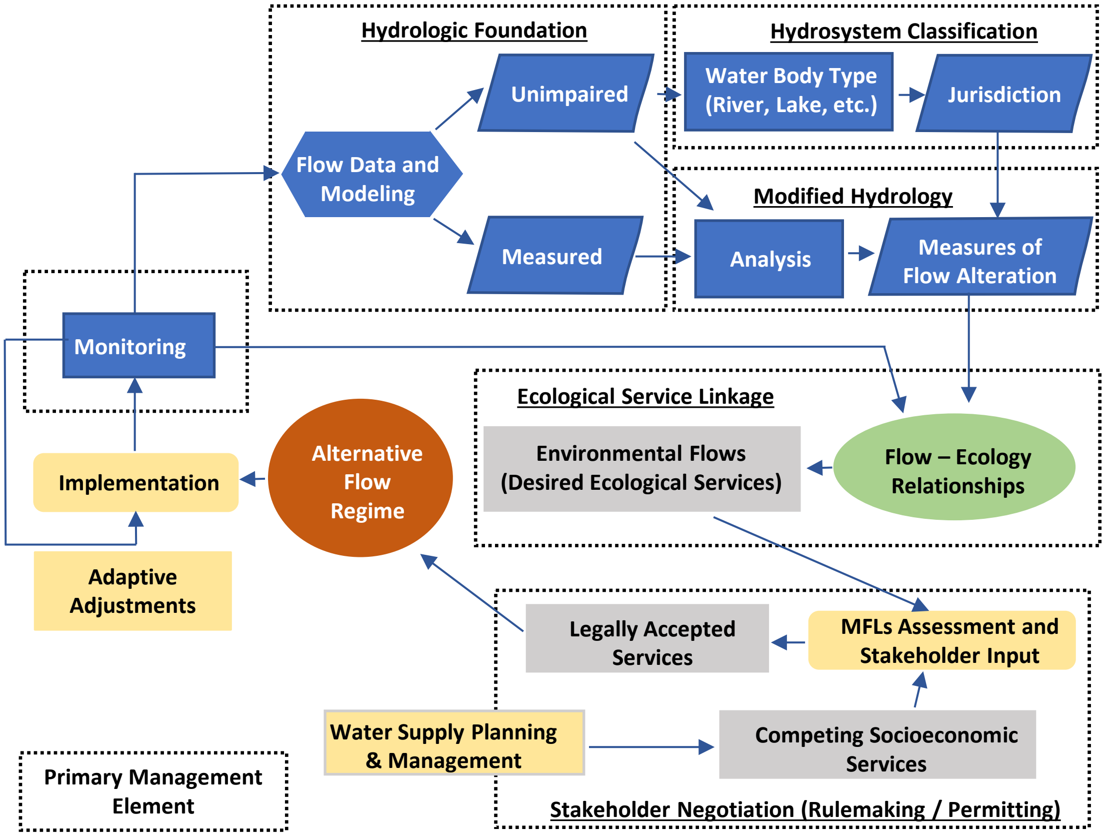

Figure 3. Modified from (Poff & Zimmerman, 2010)

The adoption of Rule 62-42.300, F.A.C. closed the loop for a single iteration of an adaptive management process maintained by the District. The current 2019 re-evaluation of minimum flows is closing the loop on another iteration of the adaptive management process (Figure 3) by assembling, evaluating and using the best information currently available to develop revised, recommended minimum flows for the LSF River System. The minimum flow recommendations resulting from this re-evaluation are made while acknowledging the continued, unavoidable uncertainty in our understanding of natural patterns and processes inherent to the system as well as uncertainty associated with predicting the consequences of future water withdrawals.

The continued adaptive management of the LSF River System will require ongoing monitoring, assessment, and periodic re-evaluation of minimum flows. Examples of future monitoring that could support future MFL assessments include:

- SEFA data collection and modeling upstream from US441,
- Systematic stream- and spring-flow water quality monitoring tailored specifically to characterize changes in base flow that can be attributed to withdrawals, and
- Baseline and recurring synoptic surveys of floodplain vegetation, instream submerged aquatic vegetation, fish, and other aquatic biota of interest.

Section 2. Specific Comments and Responses Table

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
Commenter – Dr. Bill Dunn					
G1	General comment	Yes	Overall the proposed re-evaluated MFLs are yet incomplete based on this technical peer review. Very specific recommendations are given to address problems. These actions if implemented can significantly improve the scientific rigor of this MFLs setting proves. Until the issues identified are resolved, I conclude that this re-evaluation is incomplete, and I cannot support the recommended MFLs.	Follow recommendations provided in this peer review.	Acknowledged. Recommendations deemed appropriate to District team were followed.
G2	General comment	Yes	Shortcomings lead me to conclude that reasonable assurance is not provided that the sensitive water resources of the LSFR & IR and their associated springs will be protected.	Follow recommendations provided in this peer review.	Acknowledged. Recommendations deemed appropriate to District team were followed.
G3	General comment	Yes	Sections 1, 2, 3, and parts of 4 are on solid basis technically. The resource inventories, data and analytical approaches are scientifically reasonable and appropriate, including data collection, development hydrological data time series, surface water (HEC-RAS) modeling, and the development of the reference flow regime are acceptable. The WRV screening process is well done. The general approach to habitat modeling and assessment using SEFA is also excellent. Problematic decisions begin in Section 4.2 Indicators and Response Functions, on page 58 and continue onward to end of document.	Follow recommendations provided in this peer review.	Acknowledged.
G4	General comment	Yes	I very strongly recommend that whenever possible protective metrics for the MFLs be based on statistically defined protective hydrological events composed of 1) a magnitude (flow and/or level), 2) continuous duration for the specific inundation or drying period, and 3) with a return interval.	Follow recommendations provided in this peer review.	Please see general response in Section 1 to Comments 10 and 11. Respectfully disagree that metrics be based on events whenever possible.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
G5	General comment	Yes	1. Major recommendations from 2013 peer review (Graham et al. 2013) have not been followed. Key recommendations from the previous peer review (Graham et al. 2013) were not addressed in peer review process for the initial MFLs adopted in 2015. Furthermore, these remain problematic in this re-evaluation. 2. To prevent significant harm MFLs threshold metrics should include consideration of duration and return interval of both low flow and high flow events in addition to cumulative frequency. They state concerns with the use of flow duration curves (FDCs) alone to characterize the flow regime as they may not adequately relate important biological, or ecological responses to variations in the flow regime. Five critical components of flow regime are frequently recognized in the it when assessing environmental flows: 1) magnitude, 2) return interval 3), duration 4), timing, and 5) rate of change 3. The Panel recommends that the 15% threshold of change be more fully justified as it applies specifically to the LSF and Ichetucknee Rivers. They find that justification for the proposed threshold of a 15% habitat loss in the establishment of MFLs is based on precedent and cannot be justified based on the data presented in the report. So, while there is a precedent for the adoption of the 15% threshold, its general applicability is unproven 4. Comparison of allowable flow reductions based on a 15% decrease in number of days a critical flow is exceeded and the percent change in return interval of a critical event duration that would occur when applying the proposed	Peer panel provided specific recommendations for hydrology and for setting metrics for WRV elements.	Please see general responses in Executive Summary and in Section 1 to Comments 10 and 11.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
			allowable flow reductions… their Table 1 table is comparison of allowable flow reductions by WRV for LSFR range from 5-8 percent, but change in return interval for WRV events range from 14 to 29 percent, for the IR the numbers are 3-12%, versus 27-45%. 5. In absence of key supporting data, the panel urges the District to adopt an adaptive management approach allowing decisions based on limited data to be reinforced or modified as new research and monitoring information become available		
G6	General comment	Yes	The report's authors considered only a single approach to setting metrics for WRVs. Rather as a general approach, a toolbox of methods should be screened for the best available method/approach. Examples are numerous from other MFL WRV metrics developed by the SRWMD and other sister districts.	Follow recommendations provided in this peer review. Toolbox actual ant thought process needs to be developed and used.	The primary method for evaluating in stream habitat (WRV-2) was %area (SEFA) not %time. Please see general response in Section 1 to Comments 10 and 11.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
G8	General comment	Yes	Update the science for methods used to set minimum flows and levels, specifically the WRV metrics.	Water for the Environment: From Policy and Science to Implementation and Management, Edited by Avril C. Horne, J. Angus Webb, Michael J. Stewardson, Brian Richter and Mike Acreman. Academic Press, 2017, 720 pages. Chapter 11—Evolution of Environmental Flows Assessment Science, Principles and Methodologies by Poff, N.F., and R.E. Tharme, and A.H. Arthington. 13—Physical Habitat Modeling and Ecohydrological Tools by Lamoureux, N., C.H. Hauer, M.J. Stewardson, and N.L. Poff. 14—Models of Ecological Responses to Flow Regime Change to Inform Environmental Flows Assessments by Webb, J.A., A.H. Arthington, and J.D. Olden. 15—Uncertainty and Environmental Water	Please see response to Comment 16 in Section 1. Regarding suggested reference, note conclusion on page 311 (Box 14.3): "7. We are as yet short of a general ability to make quantitative predictions concerning ecological responses to changing flow regimes, but the tools and data exist for the much greater uptake of statistical ecology modeling into the environmental flows assessment" Page 309 (Box 14.2) also includes a synopsis of a purposeful study to collect and analyze floodplain inundation data, and quantify ecosystem response.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
				by Lowe, L., J. Szemis, and J.A. Webb 16 Water Budgets to Inform Sustainable Water Management by Richter, B. and S. Orr 25--Principles of Monitoring, Evaluation, and Adaptive Management of Environmental Water Regimes by Webb, J.A., R.J. Watts, C. Allan, and A.T. Warner. 27--Moving Forward: The Implementation Challenge for Environmental Water Management by Horne, A.C., E.L. O'Donnell, M. Acreman, M.E. McClain, N.L. Poff, A.J. Webb, M.J. Stewardson, N.R. Bond, B. Richter, A.H. Arthington, R,E. Tharme, D.E. Garrick, K.A. Danielli, K.C..Conallin, G.A. Thomas, and B.T. Hart.	

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
G9	General comment	Yes	An explicit adaptive management (AM) framework is missing, it should be added and used as a guiding principle. This is a repeat of a major recommendation by UF's peer review panel's finding and recommendations from five years ago (Graham et al. 2013).	Follow recommendations provided in this peer review.	Please see general response in Section 1 to Comments 17 and 18. Similar language was added as new Section 4.5 of the MFL report.
G10	General comment	Yes	Report lacks an integrated treatment of the sources of uncertainty. Uncertainty issues are discussed throughout the report, and are key to many of key decisions made for choosing methods of analysis, time series data, etc. Management if uncertainty moving forward is not highlighted, and it should be.	Add a discussion on the major sources of uncertainty, and their respective and collective uncertainty effect on the development of the recommended minimum levels.	Please see general response in Section 1 to Comments 17 and 18. Similar language was added as new Section 4.5 of the MFL report.
G11	General comment	Yes	Report needs to address seasonality issues when defining WRV and setting their metrics. How seasonality is handled should be stated in the approach for defining WRVs. Seasonality typically adds components of seasonal occurrence and duration. So, using an event-based metric seems both prudent, and a scientifically defensible choice. Also, if this were being done by the SJRWMD, then the event would be defined. I am sure that SJR District has many examples from established MFLs.	Revise report to include more comprehensive treatment of seasonality. Seasonality as a component of WRV metrics should be expected, or likely based on experience with the applying the WRVs to riverine and spring run systems.	See response to commenter's Comment 5.10. Seasonality was expected, and many of the species/life stages screened in the SEFA analysis are season specific. Area weighted suitability was evaluated for select species and life stage during a spawning season. See draft report section 4.3.2 and Table 17.
G12	General comment	Yes	Analysis by others clearly show that sensitivity of flow and levels reductions can be quite different for WRV metrics set using 15% change versus event metrics that include components of magnitude, duration and return interval (MDR).	Follow recommendations provided in this peer review. The District has used event-based criteria for setting WRV metrics for MFLs for lakes (Lakes Brooker, Hampton, Santa Fe, and Alto.	Please see general response in Section 1 to Comments 10 and 11; the team respectfully disagrees. Global analyses of riverine systems by others clearly shows the MDR approach is best used with site-specific data.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
G13	General comment	Yes	Significant revisions to the MFLs setting process for the LSFR, IR and their associated priority springs is needed. The WRV response functions, indicators and metrics used in this report must be re-evaluated, and then revised if warranted. At a minimum this should include significant revision to Sections 4, 5, 6 and 7 of HSW's report. The sequence of steps necessary to do this is covered in Recommendations section of this report.	Detailed recommendations on how the this do are provided. The District has used event based criteria for setting WRV metrics for MFLs for lakes (Lakes Brooker, Hampton, Santa Fe, and Alto.	Please see general response Executive Summary and in Section 1 to Comments 10 and 11. Respectfully disagree that significant revisions to the MFLs setting process are needed.
G14	General comment	Yes	Key water quality issues reflecting the health of these two rivers and their associated springs remain largely divorced from consideration in this MFL. Several recent research findings indicate however, that some water quality problems do have link with flow regimes. As WRV metrics will now be assessed anew we may have the opportunity to incorporate meaningful water quality thresholds in one or more WRV metrics.	Follow recommendations provided in this peer review.	Acknowledged. Correlations between flow and key water quality parameters have been addressed in the report and are supported with references to published literature.
G15	General comment	Yes	An explicit AM framework for the process is recommended as the tool for addressing and managing uncertainty. Sources of uncertainty in this MFL setting process include: · Groundwater modeling · Surface water modeling · Water budget develop · Reference flow developed for assess impacts of historic consumptive use · Selection of relevant WRVs · Water quality · Effects of climate change	Follow recommendations provided in this peer review.	We agree that uncertainty can be reduced with more data, which in turn provides us with more confidence in decision-making. Please see Section 1 response to Comments 17 and 18. Similar language was added as new Section 4.5 of the MFL report.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
G16	General comment	Yes	What about impact of climate change? Climate change is not addressed. MFLs are by their nature our estimates of resource sustainability. If we are in time of change, then the assumptions upon which we base MFL type sustainability may not hold. In statistical hydrology this is a question of stationarity of the statistical populations comprising our climate driven time series data for temperature, rainfall, runoff, aquifer recharge, etc. The consensus of climate experts is that key time series are in flux, that is they are statistically non-stationary. This is another element of uncertainty, it needs to be discussed, and likely impacts identified and planned for.	Follow recommendations provided in this peer review.	Please see Section 1 response to Comment 15. District team would note that resource sustainability is a primary objective of the Regional Water Supply Plans prepared periodically by the State's water management districts and public water supply utilities, more so than MFL assessments. Furthermore, reviewer appears to imply that MFLs assessments assume stationarity, which is not the case.
G17	General comment	Yes	Setting individual MFLs for priority springs is problematic due to uncertainty	Follow recommendations provided in this peer review.	Acknowledged.
G18	General comment	Yes	The overall science behind this process of setting environmental flows for the rivers and springs in north Florida needs to be updated. The state of the science is evolving. The field has moved considerably beyond change threshold metrics based solely on a percent allowable change. A good start might be with a recent book Water for The Environment (Horne et al. editors, 2017) provides in depth reviews of current status of theory practice, research and application.	Follow recommendations provided in this peer review.	Please see general response in Section 1 to Comments 10 and 11, and 16. The referenced book was reviewed and contains many of the concepts presented in the response to general comment 15 in Section1 and the referenced appendix. However, the current data do not support a "redo", and the current approach is a responsible conservative approach for preventing significant harm.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
1.0 Introduction: pages1-3 with Figure 1.					
1.1		No	I accept the content of this section. It covers: the rule-based peer review process, the list water resource values the ten WRVs identified in the Water Resource Implementation Rule (62-40.473, FAC), and an overview of the watershed and study area.	No further action required.	Acknowledged.
2.0 Hydrology: pages 4-28.					
2.1	Page 4	No	First paragraph—I agree starting assumption about approach.	No further action required.	Acknowledged.
2.2	Pages 4-8	No	I accept the content of these report sections. Including supporting Figures 2, 3 and 4.	No further action required.	Acknowledged.
2.3	Page 8	No	I accept the focus on the Ft. White and US441 on the LSFR, and HWY 27 gage on IR.	No further action required.	Acknowledged.
2.4	Page 9, Table 1	No	Most recent gage data I cited as 2015. Is there more recent data that can added? Will extending the respective time series help?	If the most current available data is not being used, then please provide reason why.	The period of record used was limited by the availability of QA-reviewed groundwater withdrawal data.

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2.5	Page 11	No	Bottom paragraph—states an assumption about LOESS procedure. I agree with the choice of a smoothing parameter of 0.33.	No further action required.	Acknowledged.
2.6	Page 12	No	Section covers the need for infilling data series using multiple linear regression (MLR) I concur that need exists, and I concur with the method selected.	No further action required.	Acknowledged.
2.7	Page 12, 2.3.3 Watersh ed Yield	No	I agree that watershed yield is a useful parameter to characterize flow changes in the watershed.	No further action required.	Acknowledged.
2.8	Page 13	No	Figures 6 and 7. Figure 6 flow exceedance for Ft White, US441, and Hwy 27 gages. Figure 7 annual average flows at Ft White and Hwy 27 gages. It appears that LOESS is included for Ft White, but this is not labeled, or otherwise indicated.	Please complete the labeling.	Label added to LOESS in Figure 7. A LOESS curve was not used in Figure 6 - red line represents the Ichetucknee FDC. Legend edited to match the Ichetucknee line type.
2.9	Pages 14-15, discussio n of AMO	No	2.3.4 Atlantic Multidecadal Oscillation—authors conclude that AMO is not observed in time series. Do I agree? Maybe, I am not certain. Page 15—Figures 8 and 9. Fig. 8 is AMO surface temperature sequence. Figure 9 is flow exceedances for AMO warm vs cool periods for SFR at Ft White and Worthington Springs. Appears to be no apparent AMO effect.	Please confirm that District staff agree with authors conclusion that the AMO cycle is not a strong signal in the data.	AMO and other weather patterns (e.g., El Nino) are acknowledged and should be considered with regard to period of record (POR) observations. Long-term POR, such as the POR considered in LSFI MFLs re-evaluation, are assumed to include AMO oscillations (which includes wet and dry periods). Rainfall patterns are of interest in relation to stationarity assumptions, but it would not be surprising if climate changes results in "new normal".

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					Evidence of an AMO signal was further evaluated for the Fort White gage. An AMO signal was apparent, but the POR is sufficient to embody a complete wet and dry cycle. Text added in Sections 2.3.4 and 3.4.10. Please see response to Munson Comment 6.
2.9	Pages 14-15, discussion of AMO	No	2.3.4 Atlantic Multidecadal Oscillation—authors conclude that AMO is not observed in time series. Do I agree? Maybe, I am not certain. Page 15—Figures 8 and 9. Fig. 8 is AMO surface temperature sequence. Figure 9 is flow exceedances for AMO warm vs cool periods for SFR at Ft White and Worthington Springs. Appears to be no apparent AMO effect.	Beyond the AMO issues the authors do need to also address the potential effect of climate change on the health of the LSFR and IR, and their associated artesian springs. This is covered in comment G16.	Please see general response in Section 1 to Comment 15.
2.10	Page 14, Section 2.3.5 Rainfall and Air Temperature	No	2.3.5 Rainfall and Air Temperature—first paragraph—agree with use of PRISM? Yes	No further action required.	Acknowledged.
2.12	Page 18	No	2.3.6 Groundwater Level—do I agree with choices for GW monitor wells? Yes, I do, but I am interested response by Dr. Motz my fellow panel member and a groundwater modeling expert.	No further action required.	Acknowledged.
2.13	Pages 22, Section 2.5 Surface Water Quality	No	Surface water quality: Page 22—Figure 16 in part. Fig. 16 Nitrate levels in LSFR, cited source as Florida Springs Institute (2012). Question—any data more recent than what appears to be 2010?	Please provide answers to questions.	Yes, this figure has been updated with data through 2015.

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2.13	Pages 22, Section 2.5 Surface Water Quality	No	Next, two locations plotted High Springs and Ft White-both trend lines appear to be declining over period 1987 to 2010.	Please provide answers to questions.	Nitrate data provided by the District were used to update Figure 16 for 1989 through 2015. The text of the report (Section 2.5) was revised to indicate that nitrate concentrations at Ft White show little change while the trendline for High Springs continues to be declining.
2.13	Pages 22, Section 2.5 Surface Water Quality	No	Also, concentrations at FW look to be twice that at High Springs. Please discuss.	Please provide answers to questions.	Yes, the text has been revised to acknowledge and address the differences in nitrate concentrations at the two locations.
2.13	Pages 22, Section 2.5 Surface Water Quality	No	2.5—Surface Water Quality—text covers nitrate issues and	Please provide answers to questions.	Commenter's comment spanned two cells. Response provided in next cell below.
2.14	Page 23	No	TMDLs, and the FDEP threshold of 0.35 mg/L. Secondly, it seems that this section should be referencing Appendix B: Water Use Hindcasting.	Please provide answers to questions.	Figure 17 has been updated with data through 2015, with the text revised to evaluate trendlines relative to the FDEP threshold for nitrate. Appendix B is referenced in Section 2.6 (Groundwater Use).
2.14	Page 23	No	Figure 17. Nitrate levels in LSFR springs, source cited as Florida Springs Institute (2012). Question—any data more recent than what appears to be 2010? Data from Seven springs: some trendlines declining others rising. trend lines appear to be declining over period 1990 to 2010. Agree?		Figure 17 has been updated with data through 2015. We agree that some trendlines are declining while others appear to be rising. The text has been revised accordingly.
2.14	Page 23	No	Also, concentrations at Blue and Ginnie look to be 2-4X that at the remaining 5…agree? So, looks like Blue and Ginnie are not in compliance with the 0.35 mg/L standard. Agree?		Yes, we agree that nitrate concentrations at Gilchrist Blue and Ginnie Springs are not in compliance with the TMDL of 0.35 mg/L and are roughly two to four times greater than concentrations at the other five

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					springs. The text has been revised to acknowledge these observations.
2.14	Page 23	No	Also, concentrations at Blue and Ginnie look to be 2-4X that at the remaining 5…agree? So, looks like Blue and Ginnie are not in compliance with the 0.35 mg/L standard. Agree?		Duplicate of preceding comment. See response in preceding cell.
2.15	Page 23, Section 2.6 Groundwater Use	No	Content of this section is very important feed into this exercise. For this review however none of it can be verified from what is in the report. That includes the single paragraph of text and supporting Figures 19 and 20.	Add text to reference Appendix B	Acknowledged. Appendix B has been updated.
2.16	Pages 24-28, Section 2.7 Reference Timeframe Flow	No	Content of this section is very important feed into this exercise. For this review however none of it can be verified from what is in the report. That includes the single paragraph of text and supporting Figure 21.	No further action required	Acknowledged.
2.17	Pages 24 and 26, Section 2.7 Reference Timeframe flow	No	Text for intro to 2.7 Reference Timeframe Flow (RTF). I concur with approach to generate the RTF. It appears to be reasonable approach. See the remaining pages in this section and supporting material in Appendix B and C.	No further action required	Acknowledged.

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2.18	Page 25, Section 2.7.1 Flow Characteristics	No	Figures 19 and 20. Breakout of water use in planning area. Both figures look reasonable.	No further action required	Acknowledged.
2.19	Page 27, Figures 22 and 23	No	Figures 22 and 23. Fig 22—flow exceedances for Ft. White and US441. Fig 23 flow exceedances for IR at HWY 27. Plots show that the RTF vs measured flows differ very little. Can hardly see differences.	No further action required	Acknowledged.
2.20	Page 28, Figure 24	No	Figure 24--Temporal change in relative difference between RTF and measured flow at FW, US441, and Hwy27. Plots by gage have data overlying each other, so this is difficult figure to interpret. May help to drill down on residuals.	Can clarity of figure be improved?	Data are plotted for each gage in a separate graph to improve the clarity of figures.
3.0 Biology: pages 29-55					
3.1	Page 29	Yes	3.1 intro to the Conceptual Ecological model. This CES is a simple linear flow diagram of cascading influences. It is an effective visual for this introduction Text for introductory paragraph list of six effects of flow alteration on ecosystems. Text in section 3.1 references Poff et al. 1997, this reference is foundational to the field, but it is a bit old. Suggest that the science update can carry over to the conceptual framing of the biological communities.	Introduction covering the conceptual ecological model in text on pages 29 and 30 and including Figure 25 are acceptable. Consider updating this conceptual overview following the update the science. A more detailed recommendation on how to move this forward is included as comment G8.	Please see response to Comment 16 in Section 1.

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3.2	Page 31	No	Page 31—Figure 26 in part, Conceptual trophic model. This a another very simple trophic pyramid but highlights the major taxonomic groups of aquatic insects the Ephemeroptera, Plecoptera, and Trichoptera (EPS). Arrows in the figure are not labeled, so it not clear what the transfers represent.	Please annotate the figure or legend to make it clear what the arrow flows represent.	Figure is annotated.
3.3	Pages 37-38	Yes	Table 4, Effects of hydrologic factors on floodplain vegetation. Neither table nor text cover the dewatering and stays-dry end of the full hydrologic regime. This is an oversight that needs to be corrected.	Please revise Table 25 and supporting text to cover the critical need for dewatering events. There are very good review articles covering this topic in detail.	Narrative regarding dewatering with new references was added to Table 5. Please see general response in Section 1 to Comments 10 and 11, under the headings Completeness of MFLs Setting Process and Adaptive Management.
3.4	Page 39	No	Text 3.4.1 SAV—details of SAV coverage are given, but these are not directly verified. Historic SAV survey covered in reports by FDEP and others. Figure 33, two maps showing extent of LSFR floodplain wetlands, and 10-year flood zone. Legend shows emergent wetlands, but I do not see that in either of the two figures. It would help to know the acreage area values for the different vegetation types displayed.	Can summary acreage value be added to figure?	Summary acreage added to the figures.
3.5	Page 40	No	Figure 34. Extent of IR floodplain wetlands, and Flood Zone A. It would help to know the acreage area values for the different vegetation types displayed.	Can summary acreage value be added to figure?	Summary acreage added to the figure.

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3.6	Page 41	No	Table 5 in part. List of SAV species identified during a 2017 survey of LSFR (Morris et al 2017). Text following highlights SAV. Notes effect of recreational use on SAV, by the tubers. Table 4--Check scientific name for Chara. The name scientific name provided appears to be an error. Species lists on page 41 lists look good and as complete as needed. Lists are acceptable but cannot be independently verified. Lists comport with my knowledge of these habitats, the rivers and springs of the SR district, and observation from the two field trips in May 2019 covering the IR and LSJR respectively. Final para comments on impacts of recreational use, especially during long-term drought conditions. This begs the question…do the MFLs address this? Do they protect from impact during long-term drought? What about climate change?	Please check the Latin name for species, the specific epithet, of Chara. Please an answer the question about long-term drought and potential effects of climate change.	Scientific name of *Chara* revised to *Chara sp.* The MFLs addresses the impact on SAV due to low flows as part of Recreation WRV. An assessment of adequate conditions for tubing down the Ichetucknee River is based on the average individual being able to tube without damaging SAV regardless of hydro-climatological condition. Please see general response in Section 1 to Comment 15.
3.7	Page 42	No	Figure 35, Location of SAV transects on IR. Visited a couple of these transects. Number and spatial distribution appear to be a good plan to characterize the habitats in the IR. I visited a number of these transects during field inspection. This page is fine as is.	No further action required.	Acknowledged.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
3.8	Page 43	No	Figure 36 in part, Upper IR SAV transect summary, from FSI 2016. Figure is a good visual time series summary of SAV dynamics. Shows that species change occurs through time. Note the demise of Chara from 1998 to 2004. Is this significant? Are SAV species interchangeable? Is some better habitat? Several paragraphs of new text covering factors that affect SAV. Last paragraph of page mentions research by Hensley and Cohen 2017 on effect of flow reversals, that is there may be negative effects on algal consumers. This argument may need to be carried forward as explanatory, or exploratory. Authors certainly suggest causal relationship that should be explored further.	Please provide answers to questions.	The change in muskgrass is likely not significant to the MFL re-evaluation for the overall river, given its widespread occurrence and tendency to fluctuate in abundance. The MFL re-evaluation was focused more on the presence/absence of SAV as a whole, than on particular species and their relative importance for habitat, forage, and streambed stabilization. The draft report (page 42) notes recreational impacts on SAV abundance. Water-quality changes such as ionic composition (e.g., calcium) may also play a role. Insufficient data were available for time period illustrated in Figure 37 to evaluate an association but may be a valuable future line of inquiry. Text to this effect was added to section 3.4.1 after Figure 37. The relationship between flow reversals and their negative effects is carried forward in the Draft Report. Effect of flow reversals on SAV was explored for MFL development in Section 5.2.8.
3.9	Page 44	No	Table 6 starts at bottom of page. List of species of fish found in the SFR 1972-2018. There are 50+ species. Table is fine as is.	No further action required.	Acknowledged.
3.10	Page 44	No	Begins text on Aquatic Macroinvertebrates 3.4.2. First sentence states these populations in the LSFR are healthy based on water quality and community sampling, the work done by others. Cannot verify by what is in report, I assume that these studies are interpreted correctly for the LSFR and IR	No further action required.	Acknowledged.

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3.11	Pages 45-46	No	Begin text, 3.4.3 Fish. Basic descriptions of fish sampling on SFR and IR. Table 6 continued listing fish species found in the SFR. Also, Table 7 in part, Fish species in IR. Some text, 3.4.4 intro to T&E Species. Table 7 is fine as is.	No further action required.	Acknowledged.
3.12	Page 47	No	Section3.4.4 Threatened and Endangered Species. The content of this is fine Table 8. Species deemed likely to be at risk from LSJR/IR flow and water level reductions. Also, paragraph on T&E species. Both Table 8 and text coverage are fine as is, and therefore acceptable.	No further action required.	Acknowledged.
3.13	Pages 48-49	No	Lower page begin text on manatee, 3.4.5. Frames manatee habitat as for thermal refuge. Question--should thermal refuge be an event-based criterion, such as SJRWMD does for Volusia Blue Springs? Figure 37 mostly, Comparison of water temps in 2017 and 2018 at Blue Hole, The IR, and LSFR. What should we conclude from these data time series summaries? Both figures in Figure 37 look to be fine/acceptable. Cannot independently validate.	Pleas provide responses to questions.	Please see general response in Section 1 to Comments 10 and 11. District team is of the opinion that the risks of manatee passage over shoals near the IR mouth associated with Suwannee River flow condition and to low water temperature associated with IR flow has been adequately evaluated and described in the 2013 and 2019 reports. Manatee access to IR springs is influenced at times by conditions of the Suwannee River which is outside the scope of the LSFI MFLs reevaluation. Narrative added to the 2nd paragraph of Section 3.4.5 with a conclusion from the data time series summaries.

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3.14	Pages 50-51	No	Tables 9 and 10. Table 9 manatee counts in LSFR (2005-2018). Table 10 Counts in IR (1992-2018). Cannot independently verify manatee sighting records. Tables are thus acceptable. Table 8 continued in part. Text 3.4.6 on silt snail. Text covers protective criteria for thermal refuge. I agree.	No further action is required.	Acknowledged.
3.15	Page 52	No	Text begins, 2.4.6 Ichetucknee silt snail. Biology of species and habitat preference are covered. Cannot independently verify silt snail information. Text is therefore presumed to be accurate, and thus acceptable. Based on observations of Coffee Spring, concur that habitat is quite small. Species designated as species of greatest conservation need by FF&WCC. It is not clear that the species is at risk, but since it is included in this report, then yes, the concern is stated. And I concur	No further action is required.	Acknowledged.
3.16	Page 53	No	Text on Oval pigtoe mussel, Gulf sturgeon, Suwannee bass continues. Text covers the basic threat to these species. I concur with these threat assessments. For Suwannee bass, the basic research cited is 35 years old. Is that OK? Content of page is fine as is.	Please answer question about Suwannee bass.	Two references were added to Section 3.4.9; Bonvechio, Allen, Cailteux (2006) and Cailteux, Nordaus, Dobbins (2002).
3.17	Page 54	No	Figure 40 Extent of gulf sturgeon critical habitat. Figure 40 is a bit confusing as it is reproduced from and references other reports.	Is there a better figure to use in place of this one?	Figure replaced.

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3.18	Page 55	Yes	Table 11. Seasonality of fish spawning for select species. Brief text on seasonality in section 3.4.10. Figure shows spawning seasons for six major fish species. Should all this seasonal info be captured in the protective events? I say yes.	Please respond to question.	Please see Executive Summary and general response in Section 1 to Comments 10 and 11 regarding protective events.
4.0 Approach to Setting MFLs: pages 56-74					
4.1	Page 56	Yes	Text 4.0 Approach to setting MFLs, two paragraphs. Last sentence in second paragraph mentions flow duration curves as the organizing idea for assessing hydrologic change. I disagree, as already noted this is too simplistic to protect the flow regime in these rivers and springs, and I know where this leads in the rest of the document. So, this is an opportunity emphasize the hydrologic regime. I do however concur with this basic coverage of the ten WRVs and the breakout to the 14 WRV elements in Table 12.		Please see general response in Section 1 to Comments 10 and 11. The District team takes exception to an assertion that the approach taken was "too simplistic."
4.2	Page 56	No	Text: 4.0 Intro, two short paragraphs that describe approach. First is mention of the RTFs, and key assumptions: RTFs are protective of the systems and WRVs, and that some amount of water is available within the RTF regime. Do I agree? Mostly yes. This is the basis of most MFLs for rivers, springs, lakes, and wetlands.	This MFL setting process must be re-evaluated and updated. At a minimum this should include significant revision to Sections 4, 5, 6 and 7 of HSW's report. The	Please see Executive Summary and general response in Section 1 to Comments 10 and 11.

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			Second paragraph has a few more key assumptions in how to identify the most relevant WVs. I concur with the approach. Final sentence mentions flow duration curve, which may be a subtle warning	sequence of steps necessary to do this is covered in Recommendations section of this report.	
4.3	Page 57	Yes	Section 4.1.8, WRV 8 sediment loads—report notes that there is lack of data regarding sediment loads for these rivers. This is uncertainty issue. Do they eventually make recommendations for reducing uncertainty? Does the uncertainty make this WRV less valuable? Less Reliable?	Please provide answers to questions.	District team is of the opinion that sediment transport is not a substantial concern or driver of an MFL in this river system compared, for example, to other rivers with substantial bed load and sand bars such as the upper Suwannee River.
4.4	Page 58	No	Section 4.2, Indicators and response functions. I generally agree with the examples they have listed. And these carry over to the details in Table 12.	No further action required.	Acknowledged.
4.5	Pages 60-61	Yes	Table 12 Selected indicators, response functions, and MFLs assessment metrics for WRVs Table 12 Table is the creation of each indicator for each WRV selected. I concur with the content of the first two columns, the indicators, and their relevance. The next two columns become more problematic: the WRV's response function, and its metric. Authors choose an across the board percent change approach to response functions and metric for all 14 proposed protective metrics.	This MFL setting process must be re-evaluated and updated. At a minimum this should include significant revision to Sections 4, 5, 6 and 7 of HSW's report. The sequence of steps necessary to do this is covered in Recommendations section of this report.	Please see general response in Section 1 to Comments 10 and 11.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
			I strongly disagree with the % change approach.		
4.6	Pages 62-63	No	Section 4.3 HEC-RAS Modeling: I agree with choice of HEC_RAS model. I have no sound technical reason to reject the choice. Text, 4.3.1 HEC-RAS Modeling. See also Appendix D Text, 4.3.1.1 Model development—I accept the choices and assumptions made for selection of HEC-RAS model, model development, and model revisions from the version used for the previous MFL.	No further action required.	Acknowledged.
4.7	Page 64	No	Text, coverage of calculating values of model fit, based on Nash & Sutcliff 1970). I agree with the method.	No further action required.	Acknowledged.
4.8	Page 65	No	HEC-RAS model Second paragraph, I do agree with premise laid out on ranking and acceptance of efficiency coefficient values. I find that Section 4.3 for the report is general summary of the more extensive coverage of the HEC_RAS model in Appendix D. I do not identify any inconsistencies between this text and Appendices D and D1.	No further action required.	Acknowledged.

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4.9	Page 65	No	It appears that the HEC-RAS used for the initial MFLs is revised here. If so, then does the update address the issues raised by Graham et al. (2013)? Is uncertainty being addressed in the model revision process?	Please answer the questions.	The update addressed the two primary "issues", one requesting clarification of the overall purpose of the modeling and a second regarding a "20th percentile boundary condition" in the steady state model at the SFR mouth. The modeling purpose is more clearly stated, and the 20th percentile boundary condition was replaced with a normal depth/energy slope boundary condition that varies as a function of SFR discharge at Hildreth. Please see general response in Section 1 to Comments 17 and 18 regarding uncertainty and adaptive management.
4.10	Page 66	No	I find that text in report agrees with information that is presented in more detail in Appendix D.	No further action required.	Acknowledged.
			Table 13 presents the Final Transient Model Results. I have no reason to doubt the veracity of results presented		Acknowledged.
4.11	Page 67	No	Table 14: Nash Sutcliff coefficient of model fit efficiency for streamflow gages on LSFR and IR. Table 15 Proportion of all simulated value daily water depths values within 10, 15 and 20% of the measured values of Nash-Sutcliff coefficients. Content of both tables is acceptable as is. For Table 15 what problems and/or uncertainties arise from the two gages rated as unsatisfactory?	Please answer the question.	Graphs presented in Appendix D Attachment 1 indicate the uncertainty is associated with the magnitude and timing of low flow reported for the two gages, neither of which the District team deems to be a problem. The gage at O'Leno Park is upstream of LSFR study reach which begins at River Rise (see report page 2). Water availability upstream of the US441 gage was evaluated at the median discharge. Systematic ongoing streamflow monitoring by the District and USGS at two gages (02321898 - SFR @ I-75 nr O'Leno State Park and 02321975 - SFR @ US441) will provide additional data for future evaluations of SFR WRV metrics between US441 and Worthington Springs.
4.12	Page 68	No	Section 4.3.1.3 HEC-RAS Steady State Model Development and predictive simulations: I agree with use of the steady state model to generate the flow profiles that follow in Figure 43.	No further action required.	Acknowledged.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
4.13	Page 69	No	Figure 43, two-part plot of flow profiles for select non-exceedance frequencies for LSFR and IR, respectively. Cannot independently verify, so I accept as	No further action required.	Acknowledged.
4.14	Page 70	No	Figures 44 and 45. Figure 44, steady state water profiles for select flow non-exceedance for LSFR. Figure 45, steady state water profiles for select flow non-exceedance for IR. Cannot independently verify, so I accept as valid representations.	No further action required.	Acknowledged.
4.15	Page 71-73	Yes	As a general comment on SEFA I support the use of this habitat analysis method. SEFA is a good choice. SEFA is much highlighted in the Horne et al. 2017 review volume. Next, I found that the SFA analyses presented are scientifically reasonable, and reproducible, for: 1) taxa-species-life stage used 2) transect locations, and 3) data inputs from the HEC_RAS model	In general, the use and application of SEFA is acceptable. If habitat relevant WRVs must be reevaluated, then SEFA analyses will likely have to be re-done too. Findings, outcomes, and recommendations may change as result.	Acknowledged.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
4.16	Pages 73-74	Yes	Text, 4.4 MFLs Assessment Methods. I have significant disagreement on methods used. Beginning in third paragraph, the adoption of the % change method is invoked. The final sentence in the paragraph claims that this is an event-based approach, citing Neubauer et al. 2008. I find this misleading. The two methods are quite different. I explain this in detail elsewhere. Text continues MFLs Assessment Method. I have significant disagreement on methods used. Significant disagreement in choice made to use only frequency change criteria for WRV indictors. And adoption of SWFWMD's 15% allowable change. Authors make no mention of other approaches, such as event based. In fact, text on the event-based method that was included in the April draft document has been deleted. In addition, Graham et al. 2013 included a major recommendation for change to approach for setting metrics for a group of the WRVs. Their recommendation was not acted on then, and so remains relevant still. Finally, in Poff et al. 2017 review of the state of science in setting environmental flows shows that frequency change measures are much earlier generation of hydrologic change method. The simple frequency change method has shortcomings that are better addressed by event-based methods that can address more detailed aspects of the hydrologic regime.	This MFL setting process must be re-evaluated and updated. At a minimum this should include significant revision to Sections 4, 5, 6 and 7 of HSW's report. The sequence of steps necessary to do this is covered in both the Recommendations section of this report, and in General comments 1 through 18 above.	Please see general response in Section 1 to Comments 10 and 11.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
5.0 Evaluation of WRVs, Section 5, pages 75-98					
5.1	Page 75	Yes	Figure 47 Threshold flow translation between Ft White and US441 (percent of time that flow is exceeded). It is helpful to see all the threshold flows for both rivers arrayed on FDCs from their respective RTFs. So, the figure itself is an illustrative visual. But where did the threshold values come from? The threshold values were not directly presented in Table 12. I agree with assumption regarding level of protection WRVs provide to the river and spring systems state in the first paragraph. Second paragraph: I accept the method used for the translation of threshold flows from US441 to Ft. White gage. Text indicates the emphasis of the percent change approach using flow duration curves (FDCs). I do not agree with the reliance upon this approach for all WRVs. This is a major problem with this how the WRV indicators and measurement metrics are developed for this set of MFLs.	This MFL setting process must be re-evaluated and updated. At a minimum this should include significant revision to Sections 4, 5, 6 and 7 of HSW's report. The sequence of steps necessary to do this is covered in both the Recommendations section of this report, and in General comments 1 through 18 above.	Please see general response in Section 1 to Comments 10 and 11. Note also the Executive Summary which points out that some peer review comments are outside the scope of authority for establishing an MFL pursuant to Chapter 373 F.S. and 62-40 F.A.C.
5.2	Page 76	Yes	Text for Section 5.1 Recreation In and On the Water. This is where HSW's approach becomes problematic. Authors assume that the % change approach is best method, and that the threshold for significant harm can be defined using the SWFWMD's 15% allowable change. This is the first WRV covered, but the same format is carried through the other WRVs/indicators selected in Section 4 and detailed in Table 12.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in both the Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

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5.3	Page 76	Yes	Text on page includes 5 paragraphs on WRV1 for the LSFR. Several assumptions are given with which I agree: · Paragraph 1—general guidance available from paddlers guides · Paragraph 2—allowable change defined by change in time, that is amount of time the activity is precluded. As an application of the %change method, then this sounds like a standard application. · Paragraph 3—define passage for paddling, boating and tubing.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.
5.4	Page 77	Yes	Report section addressing the IR: Text on IR notes that impacts to SAV beds are most worrisome and have been since early work by Charlie Dutoit in 1979. Tubing season is Memorial Day to Labor Day. Paragraph 2 notes critical concern over extreme low water conditions—does this warrant an extreme low water protective regime?	Please answer the question.	The applicable event would likely be an extreme low flow event. Please see general response in Section 1 to Comment 11 under the heading "WRV Parameterization and Multiple Approaches"
5.5	Page 78	Yes	Table 17. Flow reductions associated with 15% decrease in exceedance for paddling/boating/tubing. Key assumptions in this analysis is problematic. And it does not seem that the Threshold for tubing on the IR covers the seasonality of use. Shouldn't it? Should it be an MDR event? Text, top one third of page. Second paragraph covers the threshold estimates under RTF conditions. Do I agree? Yes.	Please answer the questions. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
5.6	Sequence of Ten Tables on various pages	Yes	Ten tables covering the WRVs are or may be problematic. Included are: Table 17, page 78 Table 19, page 80 Table 20, page 81 Table 23, page 86 Table 24, page 87 Table 25, page 88 Table 26, page 90 Table 27, page 91 Table 28, page 92 Table 29, page 94	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.
5.7	Page 79	Yes	Figure 49, RTF flow duration curve depicting threshold flows protective of paddling on the LSFR at FW. Content of this figure is acceptable if the % change method is appropriate metric here for flows protective of paddling.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.
5.8	Page 80	Yes	Text, 5.2 Fish passage, 5.2.1 Fish Passage. Paragraph 2 defines fish passage conditions. I concur with depth and width recommendation. Table 19—Flow reductions associated with 15% decrease in time that threshold stages for fish passage on LSFR and IR were exceeded. If %change metric is valid, then this presentation is acceptable. I cannot verify that values in table were entered properly, but values look correct based on the array of threshold plotted for LSFR and IR in Figure 47, page 75.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
5.9	Pages 80-81	Yes	Text, 5.2.2 Gulf Sturgeon Passage covers two paragraphs. First paragraph covers recommended channel depth and width for sturgeon passage. I concur with these habitat values. Question—what do sturgeon do between the two spawning periods? Does the downriver movement of juveniles require protection? Other life stages? Spawning habitat?	Please answer the questions regarding spawning. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Text was added to the first paragraph of Section 5.2.2 to describe what sturgeon do between the spawning periods. Please see general response in Section 1 to Comments 10 and 11.
5.10	Pages 80-81	Yes	Question—in general how should seasonality issue be handled? Seasonality adds another component of seasonal occurrence and duration. So, using an MDR event makes a lot of sense. Also, if this were being done by the SJRWMD, then the event would be defined. I am sure that SJR District has many examples from established MFLs.	Please answer the questions.	Both the FDC and MDR approaches would consider seasonality similarly. A bi-modal flow distribution is apparent in the high-flow regime more so than the low-flow regime. As such, the District team is of the opinion that a seasonal analysis is not necessary for WRV metrics associated with high flows (e.g., floodplain inundation/dewatering and the Gulf sturgeon spawn during March/April and September/October). However, the smaller fish spawn, primarily during March through August (Table 12), occurs over a fairly large range of flow, and seasonality is an optional consideration. Additional text and a new figure were inserted in Section 3.4.10 (Seasonality).
5.11	Pages 80-81	Yes	Last para estimates the critical flow threshold associated with criterion for LSJR at FW and US441 gages. I accept these values as estimated.	Please answer the questions.	Acknowledged; no question was posed.

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5.11	Pages 80-81	Yes	Table 20 Flow reductions associated with 15% decrease in time that threshold stages for Gulf sturgeon passage on LSFR and IR were exceeded. Since an MDR event may be useful here, I note that the %change approach collapses a lot of detail that may be important. Spawning season is two part and must be captured. Also begs the question as to need for protection of other life stages of the Gulf sturgeon, and quantity and quality of spawning habitat. When do young move down to estuary or coast?	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11. Text added after the second sentence in Section 5.2.2 regarding the migratory habits of young sturgeon and the response to Comment 5.10.
5.12	Page 81	No	Text bottom of page, 5.2.3 Instream Habitat, this is the SEFA habitat modeling and assessment step. I agree with choice of SEFA as the habitat analysis tool. SEFA is also a broadly supported habitat analysis tool by series of authors in Horne et al. 2017. The multiple authors in this volume are enthusiastic supporters and users of SEFA and its historical evolution from PHABSIM. Six sites selected SEFA modeling, four on LSFR and two on IR. Site selection is acceptable	No further action required.	Acknowledged.
5.13	Pages 83	Yes	Table 21 General characteristics of LSFR SEFA Sites. Table is acceptable as is. SEFA Site Characteristics—basic descriptions of LSFR SEFA sites. Text acceptable, no problems. Two paragraphs on SEFA sites are acceptable Text, Flow Reduction Assessment, one paragraph. Assessment method explained. I question the %change approach on this. Need to drill down on this some more, Big point is that an MDR, or other approach was not considered. So, is the %change method appropriate for this use?	Please answer the questions. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

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5.14	Page 84	Yes	Text covers six paragraphs on SEFA. SEFA analysis gets boiled down to allowable 15% reduction average weighted score (AWS) for each species and life stage at each SEFA site. I find this approach to be problematic. Beyond the problematic application of the % change method, the remaining summary on how the mechanics of the SEFA modeling and analysis was performed is acceptable.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11. Authors have discussed with the SEFA authors, and it was agreed that 15% is a conservative and appropriate threshold criterion. And there is insufficient information to do otherwise.
5.15	Page 84	Yes	Section 5.2.4 Woody Habitat begins at bottom of page. First paragraph provides summary of the importance of woody habitats in these flowing water systems. I concur with this summary. Question—can this be developed as an event-based MDR metric?	Please answer the question. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11. Given the interest in the MDR approach, several metrics under WRV-2 were evaluated using the MDR approach demonstration (Attachment C) and compared to the FDC approach.
5.16	Page 85	Yes	Table 22, Basis for SEFA based hydrologic shifts for LSFR at FW and US441 gages. Table has a seasonal window of April to July in reference to SEFA analyses, why is that? Also, table has five footnotes detailing how values were estimated. All five are individually and collectively logical in this use. If any step is called into question, then the value of these estimates must be reviewed.	Please answer the question. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	The seasonal window spans the bulk of the spawning period for fish species ubiquitous to the LSFI system (see report Table 12). Please see the Section 1 Executive Summary and general response to Comments 10 and 11.

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5.17	Page 85	Yes	Text has three paragraphs on woody habitat quality evaluation. Paragraph 1—this paragraph lays out why this WRV should be an assessed using an MDR metric I agree with arguments for importance of magnitude of inundation + duration + seasonality issues. All these critical components however are not addressed by the % change method. By contrast MDR metrics will capture these components of the hydrologic regime. Paragraph 2—more detail on the ecological functions provided by woody habitats, such as submergent and emergent woody habitats. Again, this difference can be accomplished with an MDR metric. Paragraph 3—agree that data for three locations were reviewed. The 15% change is problematic. So, I do not agree that the threshold values applied are the best available for the protection of woody habitat. The choice of method and metric may be problematic. This choice should be re-evaluated. Specifically, the authors should use a metric that addresses magnitude, duration, seasonality and return interval.	Please comment on the recommended action. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.
5.18	Page 86	Yes	Table 23 Flow reductions associated with 15% decrease in time that threshold stages for woody habitat sustainability on LSFR and IR were exceeded. The 15% presumption method is problematic. Thresholds are problematic.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

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5.19	Pages 86	Yes	Text, 5.2.5 Manatee Thermal Refuge, text covers two short paragraphs: Paragraph 1—temperature data used. But again, it seems that this manatee protection metric needs to be an MDR metric that addresses seasonality and return. The return interval is likely annual, but that can be verified by manatee experts. See also the SJRWMD work on manatee protection for Volusia Blue Springs, that will be event based. Paragraph 2—15% change is problematic. So, I do not agree with the thresholds developed. Strongly recommend that authors consider using the manatee thermal refuge event developed by SJRWMD for the Blue Spring in Volusia County.	Please comment on the recommended action. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11 and response to Dunn Comment 3.13.
5.20	Page 87	Yes	Table 24 Flow reductions associated with 15% decrease in exceedance corresponding to manatee thermal threshold flow on IR. 15% change is problematic. So, I do not agree with the thresholds developed. Strongly recommend that authors consider using the manatee thermal refuge event developed by SJRWMD for the Blue Spring in Volusia County.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	15% has been used by SWFWMD for manatee but it was a 15% volume change. District team is of the opinion that an event analysis is not apprpriate for reasons stated in response to Dunn Comment 3.13.
5.21	Page 88	Yes	Section 5.2.6 Floodplain Habitat—Based on my own experience strongly recommend that the two critical structural features of floodplain habitat, the vegetative communities and hydric soils should be protected by MDR metrics.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

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5.22	Page 88	Yes	Table 25, Threshold flows for four predominant vegetative types in LSFR floodplain. The %change method used is particularly problematic for the floodplain system. The MDR criteria from SJRWMD should be applied for each relevant community type, and cover the typically relevant MFLs for infrequent high (IH), frequent high (FH), minimum average (MA, and frequent low (FL), etc.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.
5.23	Page 88	Yes	Text, floodplain, two paragraphs—I strongly disagree with 15%change method. Bottom of page, text on 5.2.7 Hydric soils. Absolutely disagree with method used and request MDR following SJRWMD methods. Many examples exist covering application to floodplain hydric soils on rivers and springs throughout north and central Florida.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.
5.24	Page 89	No	Figures 52 and 53. Figures are explanatory and are fine as is.	No further action required.	Acknowledged.
5.25	Pages 90	Yes	Table 26, Flow reductions associated with 15% reduction in time of threshold flows for the four predominant vegetation types in the LSFR floodplain at FT. White and US441.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.
			I strongly disagree with this analysis. Do the MDR following SJRWMD methods, then compare.		Acknowledged and agree to compare in a demonstration of the MDR approach (Attachment C).

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5.26	Page 91	Yes	Table 27 in part, Flow reductions associated…threshold flows for hydric soils in LSFR and IR floodplains I strongly disagree with this analysis. Do the MDR following SJRWMD methods, then compare.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.
5.27	Page 91	Yes	Text for Section 5.2.8 SAV. Three paragraphs on SAV communities in IR. I strongly disagree with this analysis.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.
5.28	Page 92	Yes	Table 28, I strongly disagree with this SAV analysis. Please apply the MDR events following SJRWMD methods, then compare.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

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5.29	Pages 93	Yes	Sediment and load classification categories (FISRWG 1998). Figure is acceptable, looks to be from a standard reference, cited as FISRWG 1998. Text includes two paragraphs on sediment loads. Para 2—describes the 15% change threshold applied to bankfull discharges. I am not sure that I agree with this choice. And so, I ask if an MDR event-based approach is better? I recall the SJRWMD using a mass sediment balance method on the Silver River. To that end I ask Is a mass balance approach needed for long term sustainability? What other approaches have been used by the district's for sediment dynamics?	Please answer the questions. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11 and response to commenter's Comment 4.3.
5.30	Page 93	Yes	Text, 5.4 Water Quality. Water quality is addressed in two short intro paragraphs.	Please consider addressing water quality impairments and their known relation to the flow regime of these rivers and spring runs. Impairments and flow reductions are both threats to the sustainability of these spring and river systems. There is then an opportunity to do this comprehensive assessment of relationship between flow regime and water quality.	We agree that WQ impairment is an important issue. Additional text was added to Sections 2.5 and 5.4 to expand the discussion beyond its current sole focus on nitrate.

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5.30	Page 93	Yes	Water quality remains a significant issue of concern in both rivers and all artesian springs. Document side steps this issue for the most part. The relegation of water quality issues to the realm of TMDLs and BMAPs does not benefit the LSFR and IR, and their associated springs.		As explained in the report, including the narrative to address the preceding comment, the challenge from the perspective of a MFLs assessment is demonstrating that water quality degrades when flow diminishes. Changes in the frequency of the lowest flow recorded for seven consecutive days within a ten-year return interval, a commonly used low-flow index (Pyrce, 2004), could be evaluated at the Fort White, High Springs/441, and Hildreth/Hwy 27 gages under the currently proposed 15% reduction in flow for other, limiting WRVs. However, the exercise would not be particularly relevant because the SFR basin contains no NPDES or MS4 point sources that are directly discharging to surface waters and impacting the Santa Fe River (FDEP 2012).
5.31	Page 94	Yes	Figure 55 and Table 29. Figure 59, Lane's diagram of balance of dynamic river forces effects on sediment load. Figure acceptable, it is illustrative one from Rosgen 1996 Table 29 Flow reductions associated with 15% decrease in time that viable bankfull flows in LSFR and IR are exceeded. As with similar comments on several previous WRV metrics, these thresholds were developed using the 15%change metric. If that is valid, then all of this is OK. But I ask if the sediment issues are best handled with an MDR metric, or something else? It seems that the sediment load issue is addressed on many flowing water MFLs (SR, SWF, and SJR WMDs) so it would be helpful to check/survey those.	Please answer the questions. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11 and response to Dunn Comment 4.3.

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5.32	Page 95	Yes	Text page, 5.5 Resources Upstream from US441. First of two full pages of text covering the topic. Four paragraphs on this page. I agree with rational and detail provided in support of protection of resources upstream from US441.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

5.33	Page 97	Yes	Text page includes five paragraphs on resources upstream of US441.Method described for proportioning flows seems reasonable and logical.	Recommend that WRV metrics selected to protect the upstream resources be appropriately chosen. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

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6.0 River MFLs Development, Section 6, pages 99-107					
6.1	General comment	Yes	For the numerous reasons already enumerated in comments on sections 4 and 5 of the report I cannot approve of the approach chosen to define most of WRV metrics used in the critical sensitivity analysis. Because of this, then I cannot approve of the respective MFLs developed. If my recommendations are followed then many key WRV metrics for both rivers will be redefined as MDR events, following the SJRWMD method, and possibly some other forms too. District has applied these event metrics to floodplain communities and hydric soils on lake MFLs. Analysis by Graham et al. 2013 clearly show that we get strikingly different results for floodplain wetland communities and their associated hydric soils using proposed 15% change versus MDR metrics. They point out that in their test case, the MDR metrics were much more sensitive to flow reductions compared to the proposed 15% change metric So, at this stage of the peer review process I find that I cannot support the proposed MFLs as being protective of the LSFR and IR and their associated springs and providing strong assurance that the thresholds for significant harm for al WRVs will be scientifically sound. I am very confident however that a re-evaluation of this re-evaluation can address the shortcomings found. My full list of recommendations is given elsewhere. My remaining comments on Section 6 follow below, all with the caveat that if WRV analysis is	This MFL setting process must be re-evaluated and updated. At a minimum this should include significant revision to Sections 4, 5, 6 and 7 of HSW's report. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11. Similar response was provided in the District's resolution document in 2013.

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			redone as recommended then results are likely to be different.		

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6.2	Page 99	Yes	Section 6.0 River MFLs Development, 6.1 Introduction: Four paragraphs provide summary of the sensitivity of MFL metrics, and the most limiting one. This is distillation of results from Section 5. Text cites Tables 30, 31, and 32, and Figures 57, 58, 59. I don't concur with this since I do not approve of the approach chosen to define most of WRV metrics used in the sensitivity analysis. I am confident however that a re-evaluation of this re-evaluation can address the shortcomings found.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.
6.4	Page 99	Yes	***Note: It is my expectation that once the WRV analyses are redone, then the revised MFLs for the LSFR and IR will be quite different. As part of this next level review I include the following evaluation of this section of the report***: Document states that woody habitat and hydric soils are the most conservative WRVs with hydrologic shifts of 10cfs at the Hwy 27 gage. I don't concur with this since I do not approve of the approach chosen to define most of WRV metrics used in the sensitivity analysis. As noted, if my recommendations are followed then many key WRV metrics for both rivers will be redefined as MDR events, and maybe some other forms too. So, at this stage of the peer review process I find that I cannot support the proposed MFLs as being protective of the LSFR and IR and their associated springs and providing strong assurance that the thresholds for significant harm for al WRVs will be scientifically sound.	This MFL setting process must be re-evaluated and updated. At a minimum this should include significant revision to Sections 4, 5, 6 and 7 of HSW's report. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
			I am confident however that a re-evaluation of this re-evaluation can address the shortcomings found.		
6.5	Page 100	Yes	***Note: It is my expectation that once the WRV analyses are redone, then the revised MFLs for the LSFR and IR will be quite different. As part of this next level review I include the following evaluation of this section of the report:*** Page 100—Table 30 in part, Summary of WRV metrics and hydrological shifts for the LSFR at Ft. White gage. Table 30 is a good summary for 15% change metric, but I strongly disagree with HSW's choice to apply across the board for All WRV metrics. There are 13 WRV metrics listed in Table 30: 1) paddling, 2) boating, 3sturgeon spring and fall spawns, 4) general fish passage and general instream habitat, % time, and 5) SEFA, 6) woody habitat, 7) woody habitat snags, 8) hardwood swamp, 9) cypress swamp, 10) hardwood cypress, 11) hydric hammock, 12) hydric soils, and 13) sediment loads. All thirteen can be and have been developed and applied as MDR metrics. All should be evaluated as candidates for an MDR metric. I feel very strongly that the five floodplain habitat elements/components, covering the four dominant vegetative communities and hydric soils, should be MDR metrics. Previous comments have noted that SJRWMD has applied MDR metrics to all 13. This re-evaluation is critically needed. For Table 30 the smallest, therefore most conservative hydrologic shifts are for general fish passage at 103-115 cfs, but cypress swamp is not far off at 110 cfs. See hydrologic shifts	This MFL setting process must be re-evaluated and updated. At a minimum this should include significant revision to Sections 4, 5, 6 and 7 of HSW's report. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11, and response above to Dunn comment 5.17. This comment is what has prompted the District to do a demonstration of the MDR approach. Also, the District chose to use the SEFA software for instream habitat evaluations and the cumulative frequency approach for multiple reasons already discussed.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
			plotted by WRVs in Figure 60. This indicates that recasting WRV criteria as MDR may have an impact.		
6.7	Page 101	Yes	***Note: It is my expectation that once the WRV analyses are redone, then the recommended MFLs for the LSFR and IR will be quite different. As part of this next level review I include the following evaluation of this section of the report:*** Table 31, Summary of WRV metrics and hydrologic shifts for the LSFR at US441 gage. This table, like the previous one Table 30, is deeply problematic for the same reasons as noted above in comments for page 100, above. For Table 31 the smallest, therefore most conservative hydrologic shifts are for general fish passage at 53 cfs, but cypress swamp is not far off at 110 cfs. See WRVs plotted with hydrologic shift on Figure 61. This may indicate that recasting WRV criteria as MDR may have an impact.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
6.8	Page 102	Yes	***Note: It is my expectation that once the WRV analyses are redone, then the recommended MFLs for the LSFR and IR will be quite different. As part of this next level review I include the following evaluation of this section of the report:*** Table 32 and Figure 57. Table 32, Summary of WRV metrics….IR at Hwy 27 gage. For Table 32 there are four WRV metrics with low hydrologic shifts in range of 10-15 cfs, these are woody habitat, hydric soils sediment loads and SAV. See hydrologic shifts plotted by WRVs in Figure 62. This indicates that recasting WRV criteria as MDR may have an impact. Table 32 does not include WRV metrics for floodplain vegetation. And subsequently these are not included in plot on Figure 62. The IR flood plain does indeed support these wetland plant communities. Why are the wetland community types not included? Figure 57, Flow duration curves and WRV metrics determined for LSFR at Ft. White gage. For reasons enumerated already above, I do not concur with the all the content of either table or figure. The placement of the WRV metrics on the FDC is helpful. It provides a means of comparison with other river and springs in the Florida, across the SR, SWF and SJR districts.	Please answer question regarding omission of wetland plan communities. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Based on 2013 MFL report "…maximum water surface elevations identified by HEC-RAS modeling indicated that out-of-bank flows do not support the riparian vegetation …". Decisions made to define threshold values (or the absence thereof) established in the 2013 MFL report were not revised. Field work to refute this assertion was not performed. There are other WRVs which were evaluated at high flow conditions which afford protection to the river.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
6.9	Page 103	Yes	***Note: It is my expectation that once the WRV analyses are redone, then the recommended MFLs for the LSFR and IR will be quite different. As part of this next level review I include the following evaluation of this section of the report:*** Page 103—Figures 58 and 59. Flow duration curves and WRV metrics for LSFR at US441, and IR at Hwy 27 gages, respectively For reasons enumerated already above, I do not concur with the all the content of either figure.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.
6.10	Page 104	Yes	***Note: It is my expectation that once the WRV analyses are redone, then the recommended MFLs for the LSFR and IR will be quite different. As part of this next level review I include the following evaluation of this section of the report:*** Page 104—Figures 60 and 61. WRV hydrologic shifts at the Ft. White and US441 gages, respectively. These figures plot hydrologic shifts provided in Tables 30 and 31, respectively. Visual picture given is useful, but I don't agree with much of the basis. Again, for reasons enumerated already above, I do not concur with the all the content of either figure.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
6.11	Page 105	Yes	***Note: It is my expectation that once the WRV analyses are redone, then the recommended MFLs for the LSFR and IR will be quite different. As part of this next level review I include the following evaluation of this section of the report:*** Page 105—Figure 62 and Table 33. Figure 62, WRV hydrologic shifts at the Hwy 27 gage. Table 33, RTF and MFL flow values at the medians for the LSFR and IR. Based on the % change metric which I do not support. Also, there is no discussion on the relevance/significance of the 10 cfs limit for IR. Within the range of error, this may mean that the MFL is at its threshold. MFLs for IR are problematic for a number of concerns: 1) wrong assessment metric applied to some WRVs, 2) floodplain vegetative communities left out of list of relevant WRVs, but they are included for both LSFR MFL sites, Ft White and US441, and 3) no discussion the significance of the 10 cfs estimate of available water. If the estimate is this close to limit, what is the uncertainty? Does this imply that the UFA is at its limit? What if WRV metrics that are recast as MDR are found to be exceeded? That could trigger a recovery plan. Text begin 6.2.1 Summary. Highlights the 15% change metric, which I do not support.	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
6.13		Yes	***Note: It is my expectation that once the WRV analyses are redone, then the recommended MFLs for the LSFR and IR will be quite different. As part of this next level review I include the following evaluation of this section of the report:*** Section 6.2.3 Future Considerations. Provide four bulleted examples of ongoing work. This is a big opportunity to give the AM uncertainty reduction efforts. But that is not what this is. I would expand this considerably.	Expand future considerations into part of a more comprehensive analysis of uncertainty with recommendations for reducing effects in future. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11. On-going and future work discussion has been added to the report and in the general response in Section 1 to Comments 15, 17, and 18.
6.15		Yes	***Note: It is my expectation that once the WRV analyses are redone, then the recommended MFLs for the LSFR and IR will be quite different. As part of this next level review I include the following evaluation of this section of the report:*** ***Section 6:3 Future Considerations*** ***Overall, I conclude that MFLs development for the LSFR and IR watersheds, including the priority springs, is incomplete. Specific recommendations are made to address the concerns raised. Many comments made throughout the document, but very strong recommendations for further work on the WRV metrics. Until this re-evaluation is completed, I cannot endorse the MFLs as proposed. I expect that this will result in some changes to the metrics, and therefore with an array of other***	This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report, and General comments G1 though 18, above.	Please see general response in Section 1 to Comments 10 and 11. Regarding evaluating event-based WRV metrics, this recommendation given by the peer review panel was not rejected without consideration in 2013. On this basis, the District elected to continue using the cumulative frequency approach. On-going and future work discussion, based in part on peer review comments, has been added to Section 6.3.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
			dependent factors, like the amount of water potentially available without violating MFLs.		
7.0 Priority Springs Assessment and MFLs Development, Section 7, pages 108-114					
7.1	Page 108	No	Text, 7.1 Priority Springs Description. Three short paragraphs. Content of all three paragraphs and Table 34 is acceptable, no changes required	Content is acceptable as is, no corrective is action required.	Acknowledged.
7.2	Page 109	No	Figure 63 is a conceptual model of hydraulic spring-flow regimes. This is a very helpful conceptual summary of interactions possible between surface and groundwater.	Content is acceptable as is, no corrective is action required.	Acknowledged.
7.4	Page 111	Yes	Table 35, Number of zero and negative spring flow measurements. This appears to be a new parameter to use to assess conditions at springs based on some new research.	As part of the re-evaluation recommended these low and no flow issues at the priority springs should be explored more thoroughly. This a new element of uncertainty.	Conditions for low to no flow were evaluated but there were insufficient data on which to base an MFL. At this time, the District team recommends using the apportionment method to protect the springs. Collecting additional information is recommended to critically examine zero flow and flow reversal conditions in future re-evaluations. See Section 7.3.2 Future Considerations of the draft report update.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
7.5	Page 114	Yes	Page 114—text page, 2.3.1 Proposed MFL Rule Language. HSW takes a big punt on setting MFLs for the 11 individual springs, due to uncertainties, best way to afford protection is to group the priority springs together collectively for a defined river reach such that river hydrology at a reference gage is maintained. So, they mimic the river MFLs for LSFR at Ft. White, and IR at Hwy 27. Each set as median flow with some estimated percent reduction for the respective RTFs. The estimated headroom of available water these medians are 103 cfs (8.1%) for LSFR, and 10 cfs (2.8%) for IR. WOW, the values for the IR at the limit. Does this mean that the system is at the limit of potential for harm? Also need to consider that the headroom estimates may look different if some key WRV metrics, such as for the floodplain vegetative communities and hydric soils, are changed to MDR metrics.	Please answer the questions regarding potential exceedance of WRV metrics. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report.	Please see the synopsis of risk (Richter et al., 2011) in the general response in Section 1 to Comments 10 and 11 under the heading "WRV Parameterization and Multiple Approaches" and report Section 6.2.1. The noted relative available water (8.1% and 2.8% of baseline (RTF)) can be interpreted as providing a high level of protection based on Richter langue and preventing significant harm. Please see general response in Section 1 to Comments 10 and 11 regarding re-evaluation.

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7.6	Page 114	Yes	Section7.3.2 Future Consideration to Support Spring-Specific MFLs: Six bulleted examples are given. I agree with the six recommendations.	Consider adding water quality as issue of ongoing concern for the priority springs. This MFL setting process must be re-evaluated and updated. The sequence of steps necessary to do this is covered in Recommendations section of this report.	We agree that WQ is an issue of ongoing concern for the priority springs and, in fact, do include, as one of the bulleted items in Section 7.3.2, the recommendation that systematic sampling of spring water quality continue and that additional constituents that may be indicators of flow reversal (e.g., bacteria) be added, as feasible. The WQ data for the springs and rivers is limiting but, going forward and with available funding, can be remedied by increasing the number of locations for continuous monitoring of such indicator parameters as nitrate and conductivity, as well as increasing the collection frequency of grab samples for confirmation purposes and supplemental analyses (e.g., bacteria).
7.6	Page 114	Yes	I note that water quality, however, is not addressed. Setting MFL setting in this impaired watershed should address the link between system health and water quality, especially in a system with such intimate linkage between the surface water and the UFA. And this future consideration section ought to be expanded into a full AM uncertainty management exercise.		Note: reviewer's comment in this row is a carryover from the preceding row. See response in preceding cell.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
7.6	Page 114	Yes	And as I have advocated time and time again, an explicit AM umbrella should be applied by the District in each setting each MFL, and for re-evaluations. A first step is simply bringing a full discussion of sources of uncertainty in every stage of the process, and identifying specific actions that can be undertaken or implemented to reduce the negative effects of uncertainty on our ability to protect and manage the water resources and the WRVs of the LSFR and IR watersheds.		Please see response to general comment 17 and 18 in Section 1. The topic of uncertainty associated with stochastic variables, while always important, has not typically been brought into the MFLs setting process and is very difficult to quantify. Instead, a deterministic central tendency, by inference, often is used to in the process and the most conservative metric and WRV threshold is used to set the MFLs. FDCs and event metrics are generally the result of data collected at gages and directly or indirectly converted to stage and flow through a rating process. That process itself has uncertainty as does any infilling. Hydraulic modeling (e.g., HEC-RAS) and habitat modeling (e.g., SEFA) add an additional layer of uncertainty. On the stress/response side, the uncertainty can be great and yet an answer and a deterministic rule are needed - hence the central tendency is used that will fall within some error bound. Our heuristic argument is that the cumulative frequency approach coupled with certain checks described in the response to general comments is sufficient to prevent significant harm. The District team contends that in evaluations without site-specific pre-/post-alteration data, the MDR approach may not be appropriate.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
7.6	Page 114	Yes	My key concern was also raised by the UF team in their peer review of the initial set of MFLs back in 2013. Those comments were not acted upon by the District then in establishing the initial MFLs for the LSFR and IR in 2013, and it appears that this specific and very pointed peer review recommendation to evaluate event based WRV metrics was rejected outright. I consider this an error. It was an error in 2013, it was an error ignored in 2013, and it is an error that persists in 2020. The same issues are before us again. I note that any real comment on this matter were deleted from the earlier April 2019 draft of this MFL documents. So, there is a concerted effort now over 7 years to discount any method other than the %change. Further, as the field of E flows develops (see document) it is important to keep abreast of the state of the science. It is my opinion that a reliance on %change metrics, and specifically the 15% change method is not the best available approach		The reviewer's statement that comments from the UF team in 2013 appeared to be "rejected outright" is not substantiated by the record. In the resolution document, for Comment B4, the District's response to the 2013 peer review on this topic noted that "... the revised MFL has been cross-checked with the event-based hydrologic methods used by the SJRWMD and the results were found to be comparable." Please see general response in Section 1 to Comments 10 and 11 under the heading "Completeness of MFLs setting process and Adaptive Management". The District team is of the opinion that commenter's assertion of "a concerted effort…." is over-stated and misguided. The District is abreast of current relevant research topics. Please see response to general comment 16 in Section 1. The state of the science and more specifically, the availability of site-specific information is not sufficient to apply an MDR approach. The District contends that taking a consistent approach and implementing adaptive management is a better expenditure of resources than applying an event-based approach without appropriate site-specific information. It is noteworthy to the District team that the book referenced by commenter (*Water for the Environment, Horne et al. 2017) makes no reference to Florida's MFLs and water reservations programs and the associated rules that have been adopted by the State legislature during the past several decades based on substantial data collection, research, evaluation, peer review, and legal proceedings by many knowledgeable environmental scientists and engineers.*

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
Appendix A					
	Appendix A	No	Appendix A Priority Springs Description Document is very well written summary of the priority springs in the LSFR and IR watersheds. Table 1 provides summary characteristics for all 17 springs, 11 in the LSFR and six in the IR. Includes list of references. Includes a very nicely composed and formatted 1-page description for each spring with photo, and text covering: location, physical description of spring system, and utilization. Overall, this is a well written, easy to read document. It that serves its purpose admirably. I do not recommend changes`	No further action required.	Acknowledged.
Appendix B					
	Appendix B	No	Appendix B1 Water Use Hindcasting (Author: SRWMD, 2019) Fourteen pages. Into, Overview of Process, Timeseries of groundwater use data, sources, break out of use types, summary of state by state tailored approach (FL, GA, SC). List of references. Since this GW use assessment was done in support of the NFSEG model, which was also peer reviewed, then I assume this work has already been deemed acceptable for use in the NFSEG model.	No further action required.	Acknowledged.

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	Appendix B	No	Appendix B2 Injection Well Hindcasting (Author: SRWMD, 2019) It appears that this is the same activity that District did in support of NFSEG model. There is a lot of hindcasting done here, and the text reads like it is part of a larger document. So, I expect that it is part of what was done for development and validation-calibration of NFSEG. Apparent error—page 3 first paragraph—ratio is off by order of magnitude. It should be 0.0795	Please answer questions and make correction noted.	Acknowledged.
Appendix C					
	Appendix C	No	Appendix C Reference Timeframe Flow Methodology Four pages of text. This is a very concise description of RT flows/heads. Generating the time series is largely done using NFSEG. It all sounds like a reasonable approach to get to the RT flows and heads.	No further action required.	Acknowledged.

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Appendix D					
	Appendix D	No	Appendix D-Attachment 1 Transient Model Calibration Results Graphics Fifty-one+ pages. Fifty-one graph figures see the content list on pages 2 and 3. Figures are grouped by river/spring gage/logger location. Twenty-one different sites in the LSFR 7IR watersheds are covered. Fourteen locations on the LSFR from Worthington Springs down to Hildreth. Seven locations on the IR, five of these at priority springs. Most figures address stage, but seven figures cover flows: on the five on the LSFR: Worthington Springs, Olene SP, US441, Ft. White, Hildreth, and two on the IR: Blue Hole Spring, Dampier's Landing, and Hwy 27. The sets by location have 2-3 supporting figures., One is a scatter plot and the second a time series of daily simulated and observed flows at the given location. Makes for set of three plots the scatter plot of simulated versus observed stage, time series of simulated and observed stages at that gage, and residuals plot for stage difference at that site location. The sequence of three figures do given a good visual picture of the transient model calibration results. Each set tells us quickly how well the simulated match the observed. Moving beyond this section/document, this information forms the basis for doing the species and habitat analysis for SEFA. So, a basic question is, did HSW do the job robustly enough so that we are confident in the using this modeling as the basis for SEFA?	No further action required	Acknowledged.

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			Appendix E		
	Appendix E	No	Appendix E WRV Duration Curves Seventeen pages of plots, Figures 1 through 33. Each is flow duration curve with threshold flows for a particular WRV metric.	No further action required.	Acknowledged.
			Appendix F		
	Appendix F	No	Appendix F SEFA Rating Curves and Area Weighted Suitability Evaluation Results Twenty-five pages of plots and tables. Overall this section is simple presentation of results with no supporting text. Tables and figures are straight forward, but I cannot independently verify that results are correct. So, I accept them with that caveat.	No further action required.	Acknowledged.
			Commenter – Dr. Lou Motz		
1	p. 1, Section 1	No	"Because these water bodies have the potential to be affected by withdrawals in *an adjacent water management district*…."	Identify the adjacent water management district(s).	Text (page 1) revised to reference SJRWMD.
2	p. 9, Heading for Table 1	No	"listed by decreasing river mile, per river"	The river miles should be included in Table 1.	River miles added to Table 1.
3	p. 11, line 3	No	"A non-parametric regression model, LOESS (LOcal RegrESSion), is fitted…."	Please provide a reference for this model.	Reference added-to Section 2.3.1.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
4	p. 12, 2.3.2 Infilling of Ichetucknee River Data at HWY 27 Near Hildreth Gage, last sentence	No	Is "local monitoring well (FDOTS041705001)" on p. 12 the same well as the "…Florida DOT monitoring well in Lake City…" on p. 18?	If so, use the same name for this well on pp. 12 and 18 and elsewhere in the report and appendices.	Name made consistent.
5	p. 18, Section 2.3.6, Figure 13	Yes	"Figure 13 …groundwater levels in the UFA at Lake City and near Lake Butler, Florida." Are there any other UFA wells in or adjacent to the Ft. White combined surface and groundwater basins (Figure 10) that could be included in this report?	If data are available, add addition UFA wells to illustrate historical changes in groundwater levels in or adjacent to the Ft. White basin similar to what is shown in Figure 13.	Figure updated with City of High Springs well.
6	p. 19, Section 2.4, Figure 14	Yes	The timeline of flow measurements at Poe Spring (137 manual measurements) indicates measurements that date back nearly to 1915.	Plot the flow measurements at Poe Spring and discuss whether there are any long-term trends in the discharge record.	Select spring flow hydrographs (including Poe Spring) with trend lines are included in report Appendix H.
7	p. 19, Section 2.4, Figure 14	Yes	The timelines of flow measurements for many of the other springs in Figure 14 indicate that springflow data from the mid-1990's to 2015 may be available.	Evaluate whether there are sufficient data for any of the other springs in Figure 14 to plot and indicate whether there are any trends in the (short-term) discharge records.	See response to Comment 6.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
8	p. 22, Section 2.5 Surface Water Quality, second paragraph	No	These two sentences require editing for clarity: "…nitrate concentrations in the Santa Fe River at US 47 near Ft. White averaged about 0.70 mg/L in 2011 (Figure 16). The average nitrate levels…have not increased significantly at several LSFR USGS stations (High Springs, Ft. White) during the 1990-2011 period (Figure 16)."	Suggested re-write: "Based on recent data, nitrate concentrations averaged about 0.70 mg/L during 1990-2011 in the Santa Fe River near Ft. White and decreased slightly from about 0.3 mg/L in 1990 to slightly less than 0.2 mg/L in 2011 in the Santa Fe River near High Springs (see Figure 5 for locations of gages)."	Acknowledged and agreed. The text has been revised as suggested (but revised further still as Figure 16 now includes data through 2015).
9	p. 22, Section 2.5 Surface Water Quality, last sentence	No	This sentence needs editing for clarity: "Nitrate concentrations are on the rise in two downstream springs including Gilchrist Blue but are declining in the springs that are farther east (upstream) (Figure 17)."	The names of the downstream and upstream springs that are listed in Figure 17 should be specifically identified in this sentence, along with reference to their locations that are shown in Figure 15.	Acknowledged and agreed. The text was revised accordingly.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
10	p. 23-25, Section 2.6 Ground-water Use	Yes	Groundwater use in the NFSEG model area also may have "…potentially influence[d] flows along the LSFR and IR." [p. 23].	In place of the pumping illustrated for the North Florida Regional Water Supply Planning Area, consider illustrating historical groundwater use in the NFSEG model area in Figures 19 and 20. This would be more consistent with the development of groundwater use for the NFSEG model area described in Appendix B and the use of the NFSEG pumpage used in the development of the reference timeframe (RTF) flow and groundwater head time-series at groundwater monitoring locations, springs, and/or stream gage locations described in Appendix C. Also, discuss the historical trend of pumpage, particularly recent trends, in the NFSEG model area.	Acknowledged and agreed. This section was revised to reflect the NFSEG model area, accordingly, based on corresponding changes to Appendix B.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
11	p. 23, Section 2.6 Ground-water Use	Yes	The first part of this section on p. 23 describes groundwater use in the North Florida Regional Water Supply Planning area, in which groundwater use "has stabilized…at about 500 million gallons per day (MGD)", and the last sentence in this section indicates that "Long-term historical water demands are summarized in Appendix B." Long-term historical water demands in Appendix B are described for the entire NFSEG model area in which net groundwater withdrawals were approximately 1,150 MGD in 2010 (Durden et al., 2019, p. 5-12). It is confusing to the reader for both North Florida Regional Water Supply Planning area pumpage and NFSEG pumpage to be included in the same paragraph, particularly since the last sentence does not indicate which "long-term historical water demands" are summarized in Appendix B.	Similar to comment 10 above, the pumping illustrated for the North Florida Regional Water Supply Planning Area should be replaced by pumpage in the NFSEG model area in Figures 19 and 20, which would be more consistent with the NFSEG model area pumpage described in Appendices B and C.	Acknowledged and agreed. This section was revised to reflect the NFSEG model area, accordingly, based on corresponding changes to Appendix B.
12	pp. 24 and 26, Section 2.7 Refer-ence Time-frame Flow	Yes	The RTF's for the rivers were developed using the pumpage for the NFSEG model, not the pumpage for the North Florida Regional Supply Planning area.	This is another reason to consider replacing the North Florida Regional Water Supply Planning Area pumpage in Figures 19 and 29 with the NFSEG pumpage. Also, it should be indicated that the determination of groundwater use in the NFSEG model area is described in Appendix B.	Acknowledged and agreed. This section was revised to reflect the NFSEG model area, accordingly, based on corresponding changes to Appendix B.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
13	p. 26, Figure 21. Estimated Impacts at Fort White, US441, and HWY 27 gages	Yes	Figure 21 indicates the impacts of groundwater pumping in terms of combined (Q_{RTF} – $Q_{measured}$) flows for each of the three gages. It would be helpful to be able to see plots that show the Q_{RTF} flows and $Q_{measured\ flows}$ separately for each of the three gages.	Consider adding a figure (or figures) in which the Q_{RTF} flows and $Q_{measured\ flows}$ are plotted separately for each of the three gages.	Q_{RTF} flows and $Q_{measured}$ flows are plotted separately in Figures 22 and 23 as flow duration curves for the three gages. Time series plots with daily measured and RTF flows overlain would be difficult to discern the differences illustrated in the FDCs.
14	pp. 24-26, Section 2.7 Reference Time-frame Flow	Yes	Figure 21 illustrates the estimated impacts of historical groundwater pumping on discharge measured at the Fort White, US441, and Hwy 27 stream gages, but there are no corresponding results shown for the impacts of pumping on groundwater levels in the Fort White surface-water and groundwater basin (Figure 10).	Consider illustrating the impacts of groundwater pumping on groundwater levels by calculating RTF's for UFA wells at Lake City and near Lake Butler (Figure 13) and (if data are available) for other UFA wells in the Fort White surface-water and groundwater basin.	A new figure that illustrates the impacts of groundwater pumping on groundwater levels for FDOT Lake City well was added in Section 2.7.1.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
15	pp. 24-26, Section 2.7 Reference Time-frame Flow	Yes	Are there any long-term impacts due to groundwater pumping in the historical discharge measurements for any of the springs listed in Figure 14?	If sufficient data are available for any of the springs listed in Figure 14, consider illustrating the impacts of groundwater pumping on spring discharge by calculating RTF's for a selected spring (or springs).	Sufficient data are available (observed and estimated) for the Ichetucknee River which is a spring-sourced system. The estimated groundwater withdrawal impacts for this system is provided in Figure 21. The Santa Fe River flow is predominantly baseflow, which derives from springs and other groundwater contributions. Figure 21 illustrates withdrawal impacts over time estimated at the river gages. It is expected that spring flows would be proportionally reduced over same time period, albeit with spatial variability due to hydrogeologic variation and spatial distance from pumping stresses.
16	p. 56, Section 4. Approach to Setting MFLS, first paragraph	No	"The technical approach makes use of the RTF flows presented in Section 2."	Consider adding reference to Appendix C in this sentence: "The technical approach makes use of the RTF flows presented in Section 2 ***and described in detail in appendix C."***	Reference to Appendix C added.
17	p. 63, 4.3.1 HEC-RAS Modeling, Second Paragraph	No	"The SFR portion of the model is composed of ten model reaches (Figure 42) …." Is the Ichetucknee River divided into reaches or treated as one reach?	Indicate whether or not the Ichetucknee River is divided into reaches and, if so, list the names of the reaches.	Text revised to indicate Ichetucknee River is modeled as a single reach.
18	4.3.1.3, HEC-RAS Steady State Model	No	"Predictive steady-state simulations were made for the ***49*** RTF flow scenarios…."	Please explain how "49" was obtained, i.e., what does it represent?	Steady-state simulations were made for non-exceedance frequencies ranging from 2 to 98 percent, at a 2-percentile interval (49 scenarios). Third paragraph in p. 68 edited for clarification.

Comment No.	Report location	Substantial Affect? (Yes/No)[1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
	Develop-ment and Predictive Simulations, p. 68, fourth paragraph				
19	p. 99, Section 6. River MFLs Develop-ment, Second paragraph	Yes	"A[n] RFT time series of daily flows was developed for…the Ft. White and US441 gages on the LSR and for the Hwy 27 gage on the IR…."	Indicate on p. 96 that these flows are plotted in Figures 22 and 23 in Section 2.7.1.	References to Figure 22 and Figure 23 added to second paragraph in Section 6.
20	p. 106, Third paragraph	No	Typo: "Richter, et al.	Replace with: "Richter et al. (2011)."	Replacement made.
21	p. 108, last line in text and Table 34	No	The average measured flow of the Santa Fe River Rise is "about 553 cfs" in the text and its "mean flow" is "552 cfs" in Table 34.	There should be only one value for these flows.	Mean flow in Table 35 updated.
22	pp. 108-113, Section 7. Priority Springs Assessment and MFLS Develop-ment	Yes	Equations of rating curves developed for 11 of the 17 priority springs are in Table 36, but the plots of the rating curves are not included.	The plots of the rating curves developed for 11 of the 17 priority springs should be included in the text or in an appendix.	New Appendix H added with rating curves.

Comment No.	Report location	Substantial Affect? (Yes/No)[1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
23	p. 108, Table 34	No	"Ten of the 17 Priority Springs on the LSFR and IR are classified as historical first-magnitude springs…." First-, second-, and third magnitude springs are not identified in Table 34.	Add a column to Table 34 identifying first, second, and third magnitude springs.	Table updated to include spring magnitude.
24	p. 111, Section 7.3 Springs MFLs Develop-ment, two paragrap hs	Yes	"While it is desirable to designate spring-specific MFLs, it is Impractical to do so at this time." and "These relative uncertainties are substantially greater than the corresponding flow reductions associated with the proposed LSFR and IR MFLs…." These conclusions are not supported by any results.	One or more examples of the results of calculating spring-specific MFL's should be included in the text or an appendix to illustrate and substantiate this conclusion.	The conclusion is supported by comparing the rating reliability values in Table 38 with the relative flow reduction values at the MFL gages in Table 34. An example of spring specific MFL calculated using the apportionment method. (e.g., 8.1%) will be included in the revised report. The District acknowledges the need for more individual spring-by-spring information, particularly for Outstanding Florida Springs, and is actively undertaking efforts to accomplish this with a desired goal of spring-specific MFLs based on spring-specific flow data and Water Resource Values in the future.
25	p. 113. Table 37, heading for third column	No	Typo: "Flow Rating…from **Table 37** (cfs)" should be **Table 36**.	Make correction.	Correction made.
26	p. 113, Section 7.3.2 Future Conside-rations to Support Spring-Specific MFLs, last paragrap h.	Yes	"…an appropriate way to afford protection from significant harm at this time is to treat the Priority Springs collectively for a defined river reach…." This conclusion is not supported by any results.	See comment 24 above. One or more examples of the results of calculating spring-specific MFL's should be included in the text to illustrate and substantiate this conclusion, i.e., that it is necessary to treat the priority springs collectively for a defined river reach.	See response to Comment 24.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
27	Appendix B – Water Use Hindcasting and Injection Well Hindcasting	No	Pages in Appendix B – Water Use Hindcasting and Injection Well Hindcasting are not numbered.	Number the pages in Appendix B – Water Use hindcasting and Injection Well Hindcasting.	Acknowledged. Appendix B has been updated.
28	Appendix B – Water Use Hindcasting, p. 1	Yes	Groundwater in Appendix B is developed for the NFSEG model area, but groundwater use in the report is illustrated for the North Florida Regional Water Supply Planning Area.	Consider replacing the pumpage for the North Florida Regional Water Supply Planning Area shown in the text in Figures 19 and 20 with the pumpage for the NFSEG model area described in Appendix B. For consistency, the NFSEG pumpage should be described in the report and in Appendix B (and also in Appendix C).	Acknowledged. The available information was provided for the planning area in the main body of the report to provide a general background of water use in the area near the Lower Santa Fe River and Priority Springs. The total use estimates in Appendix B and C however are necessarily presented in those sections to document the data supporting the Reference Timeframe process.
29	Appendix B – Water Use Hindcasting, p. 11 Moving Average Calculation	Yes	"Results…were then merged into one dataset." Where are these results?	The dataset for the 5-year moving average pumpage "for each state, county, and use-type combination in the model domain" should be made available, perhaps on a web site.	Acknowledged. Will be taken into consideration by District management.

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30	Appendix B – Water Use Hindcasting, p. 11 Moving Average Calculation	Yes	Where are the quantitative results for pumpage?	The groundwater with-drawals through time and ground-water use by category for a current year such as 2015 should be represented in the report in figures similar to the bar graph and pie chart shown in Figures 19 and 20 or preferably in a line graph illustrating the pumpage versus time for the various water-use categories and total pumpage. It would be more consistent with appendices B and C if the pumpage for the NFSEG model area were represented in Figures 19 and 20 instead of the pumpage for the planning area (see comment 28 above).	Acknowledged. Appendix B has been updated.
31	Appendix B – Water Use Hindcasting, p. 11 Moving Average Calculation	Yes	Are the pumpage results in the dataset in agreement with the pumpage in the NFSEG model (Durden et al., 2019, Table 5-1)?	Compare pumpage results in the dataset to pumpage in NFSEG model (Durden et al., 2019, Table 5-1).	Acknowledged. Appendix B has been updated.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
32	Appendix B – Water Use Hindcasting	Yes	How were well locations determined in previous years when no detailed water use records and well locations were kept?	Explain how individual well locations were determined in previous years.	Acknowledged. Appendix B has been updated.
33	Appendix B – Water Use Hindcasting, pp. 12-13 References	No	Is each reference listed in this section also indicated in the text where it is used?	Make sure that each reference listed in this section is also indicated in the text where it is used.	Acknowledged. Appendix B has been updated.
34	Appendix B – Injection Well Hindcasting	Yes	Where are the quantitative results for the injection rates?	The 5-year moving average injection rates for the NFSEG model area versus time should be plotted and discussed.	Acknowledged. Appendix B has been updated.
35	Appendix B – Injection Well Hindcasting	Yes	Are the injection rates in the dataset in agreement with the injection rates in the NFSEG model (Durden et al., 2019, Table 5-1)?	Compare injection rates in the dataset to pumpage in NFSEG model (Durden et al., 2019, Table 5-1).	Acknowledged. Appendix B has been updated.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
36	Appendix C	Yes	Is "reference timeframe" a concept developed for this project or has it been used before?	Discuss the origin of the reference timeframe process, including references in published reports and peer-reviewed papers and previous water resource investigations that involve setting minimum flows and levels (MFL's).	The terminology used in the prior Lower Santa Fe and Ichetucknee Rivers MFL report (2013) to represent the initial hydrologic time series from which reductions are made to arrive at an MFL time series was "baseline". Baseline has been used by the St. Johns River Water Management District to represent a different hydrologic 'state' and can thus lead to unnecessary confusion, especially for an MFL with the potential to be affected by withdrawals in an adjacent district. The term "reference timeframe" used here is part of the definition of "Baseline" as presented by the Instream Flow Council (IFC) in the glossary of their book "Integrated Approaches to Riverine Resource Stewardship" (2008). The term was appropriated to provide an independent term for the hydrologic starting point for setting an MFL.
37	Appendix C, p.1, 1. Intro-duction, first two paragrap hs.	Yes	"This reference time series process incorporated data from two versions of the North Florida Southeast Groundwater Model…." i.e., NFSEGv1.1 (007h) and NFSEGv1.1 (007h1) (first paragraph), and "The response of the groundwater system…was evaluated through application of the NFSEG v1.1 groundwater model…." (second paragraph). Why were two different versions of the NFSEG model used? This suggests that there may be two different results based on whichever version of the NFSEG model is used to develop reference timeframe flows and groundwater heads.	The text in Section 1. Introduction should more clearly explain how two versions of the NFSEG model were used to produce the results described in this appendix.	Acknowledged. Appendix C has been updated.
38	Appendix C, p.1, 1.Intro-duction, second paragrap h.	Yes	"The response of the groundwater system to changes in groundwater use was evaluated through application of the NFSEG v1.1 groundwater model in a manner that did not require development of a transient version of the model."	This is a major assumption that requires further explanation. See comment 40 below.	Acknowledged. Appendix C has been updated.

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39	Appendix C, p.1, 2. General Approach, first paragraph.	Yes	"Changes in …flows at an MFL site of interest in response to changes in groundwater withdrawals were estimated on a yearly basis from 1933 through 2015." How were changes in surface-water flows calculated using the NFSEG model, which is a groundwater model?	Provide more explanation concerning how changes in river flows were determined using results from the NFSEG model.	Acknowledged. Appendix C has been updated.
40	Appendix C, p. 4, 2.4 Development of Reference Time-frame Flow or Head Time-Series	Yes	"Thus, the historical groundwater withdrawals time-series used to develop the reference timeframe time-series was smoothed using a five-year moving average." This is a major assumption that does appear to be reasonable. However, the validity of this assumption needs to be demonstrated.	Provide the graphical results of an analysis that demonstrates whether using a five-year moving average is sufficient to smooth variations in pumpage from 1933 through 2015.	Acknowledged. Appendix C has been updated.
41	Appendix C	Yes	Appendix C describes a very detailed, somewhat confusing process that includes "…estimating historical impacts from groundwater withdrawals…" (p. 1), determining "…flow and head sensitivities…" (p. 2), and developing "…sensitivity maps for each model layer and waterbody of interest." (p. 2). The process by which impacts on river flows are determined using the NFSEG groundwater model needs further explanation as well as the purpose and use of the sensitivity maps.	This process should be more clearly explained in Appendix C, particularly illustrating how impacts on river flows at the three river gages (Santa Fe River near Ft. White and at US HWY 41 and the Ichetucknee River at HWY 27 in Figures 22 and 23, pp. 26-27 were determined from changes in heads and flows in the NFSEG groundwater model. The purpose and use of the sensitivity maps also requires further explanation.	Acknowledged. Appendix C has been updated.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
Commenter – Dr. Adam Munson					
1	P5, P8 Figure 4	No	Page 5 refers to the use of the "best available elevation data" and the cited table refers to the "surveyed cross sections" for the creation of the thalweg. This is a re-eval and there is interest in what information has changed between the 2013 and 2019 reports.	It would be useful to define the origins cross-sections either directly or through reference so the reader knows if any new data is included in this graphic. It looks like the same graph as the 2013 report so I assume no underlying changes to the data? But the HC cross sections did undergo some changes?	HEC-RAS cross-sections (29) for IR in the floodplain were updated using the new LIDAR data. Section 4.3.1.1 mentions updating the cross-sections. Additional language was added to Appendix D. There was no underlying change to the data depicted in the general thalweg profile (figure 4).
2	P9	Not Likely	WY 1933-2015 was selected as the POR "based on the flow data available". Table 1 suggest that the Ft. White Gage data goes back to 1927 while the US441 and HWY27 gage go back only 1992 and 2002, respectively. The longest concurrent data (Worthington Springs and Ft. White) data date back to WY 1932. The report does not specify why WY 1932 was omitted.	The report might benefit from discussion on the omission of WY1932 from the POR which is defined in the second paragraph of page 8 as WY 1933-2015.	1932 was not a complete Water Year. Data gap from 1930-02-01 until 1932-06-01 for the Fort White gage.
3	P 11	No	The report states that "for all LOESS curves presented in this report, a smoothing value of 0.33 was used". The smoothing value represents the proportion of the data that is used. Essentially controlling the number of points used. Because .33 is a proportion of the size of the data set when the POR changes the span in time that influences local smoothing changes and in fact the number of points considered changes. The net effect is that longer PORs are smoothed to a greater extent than shorter PORs which will be more heavily influenced by a small number of points temporally closer to the smoothed point. This effect is visible in Figure 13 where the two	The authors should consider how many points (years) should be considered when smoothing PORs rather than applying a constant proportion to records of varying length.	Acknowledged. The LOESS curves are used to depict the time trend rather than the extent of smoothing. The District team feels the default value (0.33) is sufficient to show a time trend adequately and is used for all LOESS curves.

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			smoothed curves show different levels of response to near term changes in water level.		
4	P 12	Yes	A MLR was used to infill a few months of missing data from 2000 and 2001 in the flow record of the US441 gage. It was also used to extend the 441 back to WY 33 (the POR). This seems a critical step in the formation of the RFT and it is treated fairly casually in the report. It would be useful to present information beyond the R-squared. t-stats and p-values for the two coefficients as well as a scatter plots to establish the appropriateness of the linear relationships. Residual plots might also be insightful. This data is important since it is an MFL. The infilling of the Hildreth gage has been reviewed prior to this re-evaluation.	This seems like an important component of the MFL and would benefit from greater discussion and documentation.	Agree; detail added to report Section 2.3.1. Please also see general response in Section 1 to Comment 6.

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5	Page 12, 1st Paragraph	Yes	"A truncated dataset" was used to omit flows at or below zero and above 3500 cfs from the regression. I assume this is due to non-linearity observed above the flow or at least excessive heteroskedasticity of the residuals but no reason is given in the text.	Please explain the rational for the truncated dataset and weather the resulting equation is ever used to predict values outside of the regression bounds. The nature of multiple WRVs rely on high or low flow conditions so extremes can be important in MFL development (especially low flows)	The impact of including all data is not great but truncating the data reduces the error in the region of flow we are most interested in. Flows at US441 when flow at Ft White>3500 were not used in any analyses, but these flows tend to be more scattered for a variety of reasons - e.g., hysteresis, sampling difficulties, lag. When flow at US441 is zero, flow at FT White is expected to be < some value so it is not an expected constant value. Using flow values of zero tends to pull the intercept to a lower value and underestimate the occurrence of zero flow. Regardless, including all flow values makes little difference between exceedance values of 0.1 and 0.90. The frequency of flow values of 0.0 at US441 may be of interest, but should be analyzed using procedures other than MLR. An alternative model was evaluated using piecewise linear regression that allows for zero flows to be more explicitly modeled (Attachment A Exhibit C). The influence of Ft White is set to zero when flow at Ft White is < knot1, a model derived coefficient. High flows at Ft White also were retained in the model. RMSE was improved some, mostly due to using a lagged flow at Worthington as an independent variable. There is little change in the estimate of median flow at the US441 gage, which is the primary estimate of interest.

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6	P14 section 2.3.4	Yes	The reports sites Kelly 2004 noting that the AMO patterns are not displayed at the Ft White or Worthington Springs Gage. But Kelly's works noted that rivers between the northern flow pattern and southern flow patter might exhibit a bi-modal pattern with influences from both the norther and southern rain flow patterns. In the initial 2013 document Figure 2-31 clearly shows the bi-model pattern Kelly identified. By using annual flow duration curves this nuance is obfuscated. It is possible that while the annual flows are unchanged between the two AMO cycles the timing of flows has changed between early and late year peaks. This may have meaningful effect on seasonal evaluations such as for specific life stage analysis in the SEFA methods.	Look at intra-annual flows between the two periods to assess if the timing of flow events has changed. It is likely that through discussions with Kelly you have already considered this but the document would be improved with a discussion of any rational involved in dismissing the AMO as relevant to the development of the historic record.	The AMO appeared to influence the magnitude but not the time of low flow conditions. Report text language in Sections 2.3.4 (AMO) and 3.4.10 (Seasonality) was reviewed and edited; two new figures illustrating flow duration hydrographs were added to Section 3.4.10. See response to Dunn Comment 5.10. We agree with the concern, which is why SEFA is run using specific time periods that are important to the species/life stage. The control species is largemouth bass fry. A 4-month period (April - July) was used in the SEFA analysis.
7	P14 Section 2.3.5	Yes	The last sentence on the page note that the annual rainfall averaged the same in the "wet" and "dry" periods identified by Kelly. My comment is the same as above. On the boundary you might expect a shift in timing as you move from a northern to a southern dominated pattern resulting in a long term bi-model hydrograph which will show alternating dominate peaks when examined over the two periods.		Agree. See response to Dunn Comment 5.10.
8	P 24, P=Last Paragrap h	No	Published data was used "where available" and by estimating water use based on population where not available. What % of the land area "counties" were from data and what percent was estimated based on population and what per capita use rate was used. I think this is meant to be details in Appendix B. If so, please cite appendix B here.	I think this is somewhat detailed in Appendix B. If so, please cite appendix B here. Given the importance of the RTF this section might benefit from some expansion in the body of the report.	Acknowledged. Appendix B has been updated. Methodology used provided in the District's 2018 Water Supply Assessment 2015-2035.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
9	Page 25 Figure 19	Yes	The table estimates water use through time but only goes back to 1965. Figure 2 in appendix B suggest a longer estimate (hindcast) was developed back to 1900 and the water use estimates were used to recreate the RTF back to WY 1933 so why does the graph not show the estimated back to at least WY 1933?	Extend graph to show estimates back to WY 1933 (or 1930 if 5-year blocks are used or even 1900 if that is the entire period estimated) or explain why the graph only goes back to 1965.	Acknowledged. Appendix B has been updated.
10	Page 25 and Appendix C	Unknown	The RTF development is referenced here in the second paragraph and the reader is directed to Appendix C. Appendix C does a reasonable job of outlining the logic of the RTF creation but is devoid of number or graphs or examples. I will defer to the opinion of the groundwater experts on the Panel but I at least feel some sample values or summary values would be beneficial to the discussion in Appendix C given the importance of the RTF in measuring compliance with the MFL.	No action requested other than consideration of additional information/examples.	Acknowledged. Appendix C has been updated.
11	P 106 Section 6.6.2	No	Recalling Figure 21 – It might be nice section 6.6.2 to add a graph similar to Figure 21 and impose the suggested MFLs. It would show clearly and quickly the relationship of the proposed MFLs with the estimated impacts over time.	Add a graphic	Comparing estimated impacts vs MFL is part of the MFL status report and is outside the scope of current MFL update.
12	P 48	No	The report cites the Warm Water Task Force 2004. This citation is a draft report. Presumably, since the draft was 2004, there is a final report available in which the FFWCC would have confirmed their draft assessment?	If a final report is available please cite the final version of the report in support of the 68-degree threshold. If the report was never finalized perhaps cite (Last and Reynolds, Coastal Management 33:279-295, 2005; Irving, Biological Conservation 25:314-334 1983; or Bossart,	Unable to verify if the draft report was approved. Citation and reference are updated as suggested by the reviewer.

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				Handbook of Marine Medicine, 2001)	
13	P 48	No	It is commendable that the District continues to improving modeling as new data is available. The HEC-RAS model has evolved allot since 2002.	No Action	Acknowledged.
14	P 76, Second paragrap h	No	32 NGVD is cited as being recommended for paddling. The last sentence states "if river levels are below 31.5" at US 441 paddlers may encounter some shallow spots. This seems like a random statement that play no other roll in the discussion. Why is 31.5 ft of interest? It seems only the 32 ft NGVD guidance is used so the mention of the 31.5 ft clutters the discussion.	Suggest either removing the sentence with 31.5 ft or explaining why it is mentioned.	Sentence with 31.5 ft removed.
15	P 72 Table 16	No	It would be helpful to have easily available the periods of time for which each of the 42 habit curves were evaluate. I have found in the text where it state that fry were evaluated for April through July. It would be helpful if in Table 16 you could list the period of the year for which each curve was evacuated in SEFA	Append table 16	Existing text (page 84) describes the approach. Table 17 was revised to include periods of time each of the 42 habitat curves were evaluated.
16	P 83	No	It is reported that flows above 3,200 cfs were not used in the SEFA evaluations. Traditionally in stream habitat modeling has been used for low flows and only evaluated seasonally so a cutoff probably makes sense.	A discussion of why flow were limited to 3,200 cfs and not some other flow might benefit the reader. Also the text might benefit from a discussion of which months were evaluated for which life stages or were all but the	At the time of the draft, 3200 was the highest flow used in HEC-RAS (98% not exceeded). Based on some additional analyses performed as a result of comments, flows as high as about 4,000 are included in the HEC-RAS model - a flow that inundates the hydric hardwood hammock transects. Also see response to Munson Comment 15.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
				spawning evaluated annually?	
17	P 84 Third Paragrap h	Yes	For apportionment the "reach methodology" was used. This is stated to be because the SEFA sites are all downstream of the US441 gage. Therefore the "sensitivity to the flow reductions of instream habitat upstream from US441 gage was evaluated implicitly." This seems more a policy assumption than an assessment of instream habitat sensitivity. Especially when the report notes that 75% of the downstream (of US441) weight is based on cross sections dissimilar to the one at and the next closest to the 441 gage.	Consider the wording to not overstate the representative nature of the assumption.	Text has been revised to explain the concept of apportionment when data above a gage are lacking. A table of median flows at the gages and ratio of median flow at US441 and Fort White gage is added in section 2.7.1.

Comment No.	Report location	Substantial Affect? (Yes/No) [1]	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommendation	C. Action to be Taken in Response to Comment (Report Authors)
18	Page 84	Yes	Apportionment 1) Both times Jacobs and Romesser (2006) is cite there is a hedge saying this application is "similar" and that it is "largely consistent". Please explain differences. 2) At seems Good and Mattson (2004) proposed, and Jacobs and Romesser (2006) tested the reach methodology for apportioning withdrawals within a stream based on ecologically derived limitations at a downstream gage to guarantee greater restriction at an upstream gage to assure compliance above the reach (Nash 2007). 3) However, we have POFR and CFR standards developed at US441 (figure 61.) They include a SEFA site which is basically at the US441 gage. The downstream river is quite different than the upstream.	Additional discussion of the appropriateness of apportionment for setting an MFL in this case.	The interest is affording a level of protection between US441 and Worthington Springs where few data are available. We concur that the river characteristics are different between the two reaches, yet it is appropriate to have some level of protection upstream of the US441 gage, and the Fort White gage is not sufficient. For example, a 100 cfs withdrawal of water upstream of US441 would not be protective, yet allowable if only Ft White is used as a reference gage. Text has been changed to indicate available water is apportioned using ratio of median flow rather than referencing reach method.
19	Appendix C		Seems data and graphs might be useful.		Acknowledged. Appendix C has been updated.
20	Section 7	No	The conclusion that " an appropriate was to afford protection from significant harm at this time is to treat the Priority Springs collectively for a defined reach" is reasonable and consistent with other adopted MFLs. The districts on ongoing efforts listed in section 7.3.2 are commendable and reflective of their commitment to improving spring protection.		Acknowledged.

Attachment A

Infilling and Record Extension for USGS gage at US441

CONTENTS

INTRODUCTION

The purpose of this work effort is to examine associations between daily flow records for the US 441 gage (USGS gage 02321975) and two other long-term gages, the Fort White (USGS gage 02322500) and Worthington Springs (USGS gage 02321500), to improve streamflow predictions at the US 441 gage for the purpose of infilling and extending the flow record. Daily flow records are available for the US 441 gage from WY 1993 through WY 2018. During that period of record, there were a total of 137 missing daily flow records from October 1 to November 9, 2000 and from February 2 to May 9, 2001. Both periods of missing records occurred during drought conditions. No continuous flow records are available before 2001.

The 2019 Draft MFL Period of Record (POR) flows for the US 441 gage (Q_{US441}) were infilled and extended using a Multiple Linear Regression (MLR) relationship with the flow at Fort White and Worthington Springs gages (Q_{FW} and Q_{WS}, respectively) as explanatory variables (SRWMD, 2019), similar to what was done in 2013 (SRWMD, 2013). However, a truncated dataset (when $Q_{US441} > 0$ and $Q_{FW} < 3{,}500$ cfs) was used for the MLR. The MLR equation:

Q_{US441} = -503.69+0.854*(Q_{FW}) +0.0974*(Q_{Ws})………….. (Model 6 as listed at the end of Section 2)

has an adjusted R-square of 0.86.

MODEL EVALUATION

An exploratory analysis of 145 models was conducted to examine associations and to improve streamflow predictions at the US 441 on the Lower Santa Fe River. The analysis was conducted to improve on a multiple linear regression model previously used to predict flow at the US 441 gage based on two other gages on the Lower Santa Fe River (SRWMD, 2013) (SRWMD, 2019). The initial LSFR MFLs assessment (SRWMD, 2013) used daily average streamflow data between October 1, 1992, and September 30, 2010 (Water Years 1993-2010) to develop a multiple linear regression model for US 441 gage flow prediction. The 2019 Draft LSFR MFL (SRWMD, 2019) and this study used daily average streamflow data between October 1, 1992, and September 30, 2018 (Water Years 1993-2018). Flows at the same two gages on the Lower Santa Fe River near Fort White (and at Worthington Springs were used as independent variables to predict flow at the US 441 gage. Streamflow data at the three gages were screened for the regression analysis as follows:

1. All data
2. Fort White ≥ 3,500 cfs omitted
3. Fort White ≥ 3,500 cfs and US 441 = 0 omitted
4. Fort White ≥ 3,500 cfs and US 441 ≤ 31.2 cfs (flow exceeded 95% of the time) omitted
5. US 441 = 0 omitted

Flow values equal to zero at US 441 were excluded from the analyses because they are not expected to be uniquely associated with flow at Fort White. Rather flow at US 441 is expected to be zero when flow at Fort White is equal to or less than some value (e.g., the intercept in a linear model). Flow values at Fort White greater than 3,500 cfs were excluded because these high flows are not used in the MFL evaluation and are associated with very infrequent high flow events that are difficult to record accurately. A model that includes flows at Fort White greater than 3,500 cfs is provided for comparison only.

The independent variables (gage data) were used individually in a univariate regression and together in a multivariate regression (i.e., three different models). The effects of a daily time lag between the two independent variable gages and the US 441 gage was estimated using Pearson and Spearman correlation coefficients at 0-30 days before and after the observed measurement at US 441. The greatest correlations with the US 441 gage occurred at zero days (i.e., no lag) for Fort White and three days before for Worthington Springs. No lag was also applied at Worthington Springs to repeat the previous work (SRWMD, 2013) (SRWMD, 2019), for a total of three different daily time lags evaluated in this work (i.e., no lag at Fort White, three days lag at Worthington Springs, and no lag at Worthington Springs).

The various preparations for the data (screened and lagged) were used to develop the following six forms of models:

- Linear regression models of the same form as in the previous work fit using ordinary least squares
- Same as above with outliers removed using a Cook's distance (Cook, 1977) > four times the mean Cook's distance
- Regression using Box-Cox transformation (Box & Cox, 1964) on the dependent variable
- Linear regression models fit using generalized least squares based on autoregressive model of residuals at a lag of one (i.e., the greatest autocorrelated lag of residuals)
- Linear regression models fit using robust regression based on iterated re-weighted least squares
- Regression including a quadratic term for flow at the Fort White gage (i.e., Fort White flow squared)

The various combinations of data and model forms generated a total of 145 models, the statistics of which can be viewed in an Excel spreadsheet and summarized in Exhibit A).

Comparing the models predicting flows at US 441, most improvements can be attributed to using a lag at Worthington Springs and a quadratic term for flow at Fort White. The lag at Worthington Springs is due to its location upstream of US 441 (i.e., flows at US 441 have a net delayed response to flows contributed from Worthington Springs). The quadratic term for Fort White flow accounts for some high flows at US 441 that are attenuated at Fort White. Outlier removal based on Cook's distance also improved model fit, but the outliers cannot be confirmed as erroneous measurements. The Box-Cox transformation was abandoned because it did not correct unevenly varying (heteroskedastic) residuals, which is the purpose of applying the transformation. Generalized and robust regression did not improve model fit.

Final candidate models (Exhibit B) predicting flows at US 441 apply ordinary least squares regression, a lag of three days at Worthington Springs, and a quadratic term to Fort White and outlier removal. The final candidate models (equations 1-4, Fort White flow < 3,500 cfs and US 441 flow > 0 cfs as in the previous work, except model 5) are:

1. -435.2 + 0.766*FtWhiteFlow + 0.218*LaggedWorthingtonFlow
2. -352.3 + 0.602*FtWhiteFlow + 1.055E-4*$FtWhiteFlow^2$
3. -380.5 + 0.653*FtWhiteFlow + 8.598E-05*$FtWhiteFlow^2$ (outliers removed)
4. -330.7 + 0.597*FtWhiteFlow + 6.111E-05* $FtWhiteFlow^2$ + 0.194*LaggedWorthingtonFlow
5. -324.3 + 0.628*FtWhiteFlow – 8.037E-06*$FtWhiteFlow^2$ + 0.433*LaggedWorthingtonFlow (All Fort White data used)

Compared to previous 2019 draft work:

6. -503.7 + 0.854*FtWhiteFlow + 0.0974*WorthingtonFlow (SRWMD, 2019) (screened Fort White <3,500 and US441 > 0 for water years 1993-2018)

RESIDUALS EVALUATION

A number of assumptions may apply to the residuals of a regression model depending on the model application, including (1) homoskedasticity (i.e., residuals vary evenly over the range of predictions), (2) independence (i.e., residuals are minimally autocorrelated over time), and (3) normality (i.e., residuals should be normally distributed). Each of these assumptions relate to drawing inference into model coefficients and deriving prediction intervals. Residual assumptions are not required to predict *y* (i.e., flow at US 441) given *x* (i.e., flow at nearby gages) (see Table 9.1 in (Helsel & Hirsch, 2002)).

Issues raised regarding residuals are however addressed in the context of improving predictions. Heteroskedastic (unevenly varying) residuals were raised as a concern that flows at US 441 could not be explained using a linear relation to nearby gages. To address this concern, a Box-Cox transformation was applied on US 441 flows to evaluate nonlinear relations between gages. This did not correct heteroskedastic residuals or improve predictions, because the heteroskedasticity was largely due to errors at higher flows. When a quadratic term was introduced to account for higher flows at US 441, it reduced the error at higher flows and some of the heteroskedasticity. Note that "errors" in this context are large differences between observed and calculated daily flow values that may be attributable to natural unsteady flow conditions (e.g., flood events), or due to measurement error.

Autocorrelated residuals were raised as another concern, suggesting a term is missing from the regression model. To address this concern, a generalized least squares regression was conducted to estimate the missing term based on an autoregressive model of residuals. Although the generalized least squares regression reduced autocorrelation among residuals (no visible patterns), the additional term to correct autocorrelated residuals did not improve model predictions.

The final concern raised regarding non-normally distributed residuals is addressed by previous model forms (Box-Cox, quadratic, and generalized least squares), because correcting heteroskedastic and autocorrelated residuals often corrects non-normal residuals. A third model form, robust regression, may correct non-normal residuals by moderating the influence of extreme values. Utilizing robust regression did improve normality but did not improve model predictions.

In summary, model forms that satisfy residual assumptions generally did not improve predictions (Box-Cox, generalized least squares, and robust regression), except for a quadratic term introduced to reduce errors at higher flows (Exhibit A, models with highlighted “FtWhite^2” variable2 and Exhibit B, Models 3-5).

MODEL APPLICATION

The purpose of developing a regression model for the MFLs assessment is to estimate a period of record (POR) flow series coincident with those of the Fort White and Worthington Springs gage records. Flow duration curves (FDCs) and tabular flow and exceedance values for the US 441 gage model for WY 1993-2018 and WY 1933-2018 are provided in Tables A 1, A 2, and A 3 and Figures A 1a through A 2b. As discussed in the previous section, there is very little change in the model fit between what was presented in the 2013 MFL document or the draft 2019 update (*i.e.*, Model 6), and Models 1-4. However, it was noted that flow at Worthington lagged 3 days provided some model improvement (Table A 1).

Tables A 2 and A 3 and Figures A 1 and A 2 depict flow exceedance information, which is the basis for evaluating some of the Water Resource Value (WRV) used by the District to set Minimum Flows and levels (MFLs). The District desires to use the US 441 gage as a reference gage for setting MFLs so it is important to be able to reliably estimate the flow record at this gage. Figures A 1 and A 2 depict generally good estimates of values across a range of flows; however, close inspection of Table A 2 shows that the estimates vary over the range of flows depending on which model is used.

Overall, models 1 and 4 provide the best rating reliability across the range of flows (except for model 3 which excludes outliers). Model 1 better estimates the high flows during the model period while model 4 estimates the median more accurately. Given the desire to apportion available water between the Fort White gage and the US 441 gage using the ratio of median flows for the two gages, model 4 or model 5 would be most suitable for that purpose. It is notable that the poorest fit model (model 6) still estimates the median within about 5%.

Based on graphical presentations of residuals for all models (Exhibit B), residuals are reasonably uniformly distributed about the zero line for daily hydrologic flow data. Since the objective of the regression model is only to predict y given x, it only is necessary that the equation form be appropriate, and that the data used are representative of the data of interest (Helsel & Hirsch, 2002). Regarding the latter point, estimated values at US 441 for flow values at Fort White greater than 3,500 cfs (exceeded about 3% of the time) should be viewed qualitatively when these values are excluded from the model, as these data were excluded from the recommended regression models.

Table A 1. Model statistics for US441 gaged flow for water years 1993-2018

Model[1]	number of observations	RMSE[4]	Adj R-squared	Rating[5] Reliability
US 441 Flow data	9359	NA	NA	NA
Model 1 linear Ft White and Worthington (lag 3)	8704	180	0.874	49
Model 2 Quadratic Fort White	8707	188	0.863	52
Model 3 Quadratic Fort White, outliers removed	8590	130	0.911	36
Model 4 Quadratic Fort White, linear Worthington (lag3)	8704	178	0.877	49
Model 5 Quadratic Fort White, linear Worthington (lag3)[2]	8855	278	0.904	75
Model 6 linear Fort White and Worthington (no lag)[3]	8707	186	0.865	51

1. Unless noted, US441 flow > 0 and FORT White flow<3500 used
2. All Fort White data used
3. Draft 2019 update (SRWMD, 2019)
4. RMSE means root mean square error
5. Rating Reliability equals RMSE/Median flow

Table A 2. Estimated flow exceedances for US441 gaged flow for model calibration period Water Years 1993-2018

Model[1] /Exceedance	1	5	10	25	50	75	90	95	99
US 441 Flow data	3754	1600	1184	676	343	130	30	0	0
Model 1 linear Fort White and Worthington (lag 3)	3658	1640	1186	690	354	147	20	-12	-62
Model 2 Quadratic Fort White	4682	1645	1153	680	354	159	38	9	-35
Model 3 Quadratic Fort White, outliers removed	4470	1628	1150	684	356	157	33	3	-43
Model 4 Quadratic Fort White, linear Worthington (lag3)	4259	1659	1170	669	348	159	46	18	-25
Model 5 Quadratic Fort White, linear Worthington (lag3)[2]	3467	1689	1180	663	342	158	54	24	-19
Model 6 linear Fort White and Worthington (no lag)[3]	3754	1621	1184	705	361	141	1	-34	-88

1. Unless noted, US441 flow > 0 and Fort White flow<3500 used
2. All Fort White data used
3. Draft 2019 update (SRWMD, 2019)

Table A 3 Estimated flow exceedances for US441 gaged flow (infilled and extended) for Water Years 1933-2018

Model[1] /Exceedance	1	5	10	25	50	75	90	95	99
Model 1 linear Fort White and Worthington (lag 3)	3907	2220	1625	972	535	303	134	63	0
Model 2 Quadratic Fort White	4743	2429	1712	996	539	308	139	65	0
Model 3 Quadratic Fort White, outliers removed	4528	2375	1692	996	544	310	138	65	0
Model 4 Quadratic Fort White, linear Worthington (lag3)	4389	2319	1647	963	525	301	139	66	0
Model 5 Quadratic Fort White, linear Worthington (lag3)[2]	3937	2183	1578	915	503	293	138	66	0
Model 6 linear Ft White and Worthington (no lag)[3]	3789	2240	1656	1006	554	309	132	61	0

1. Unless noted, US 441 flow > 0 and Fort White flow<3500 used
2. All Fort White data used
3. Draft 2019 update (SRWMD, 2019)

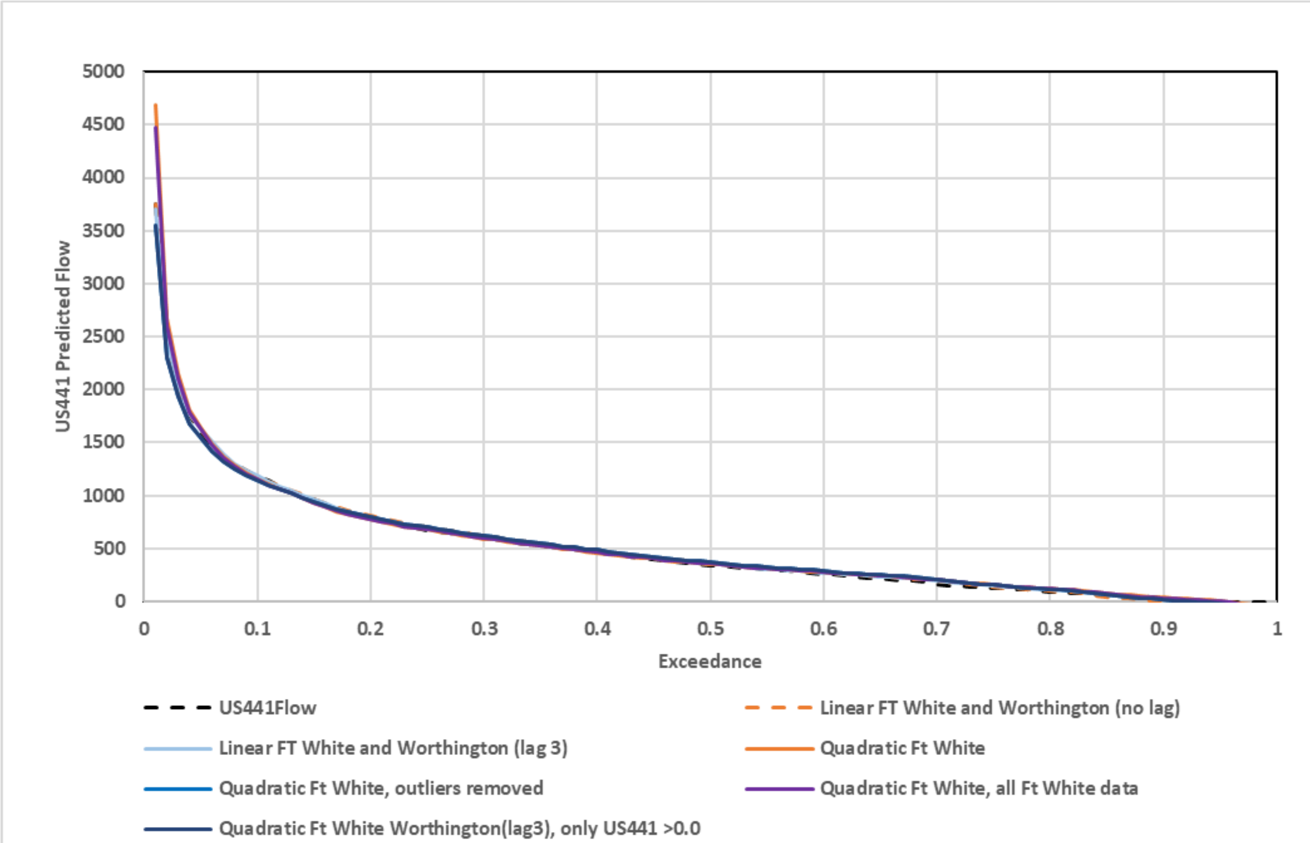


Figure A 1a. FDCs for Model POR (WY 1993-2018).

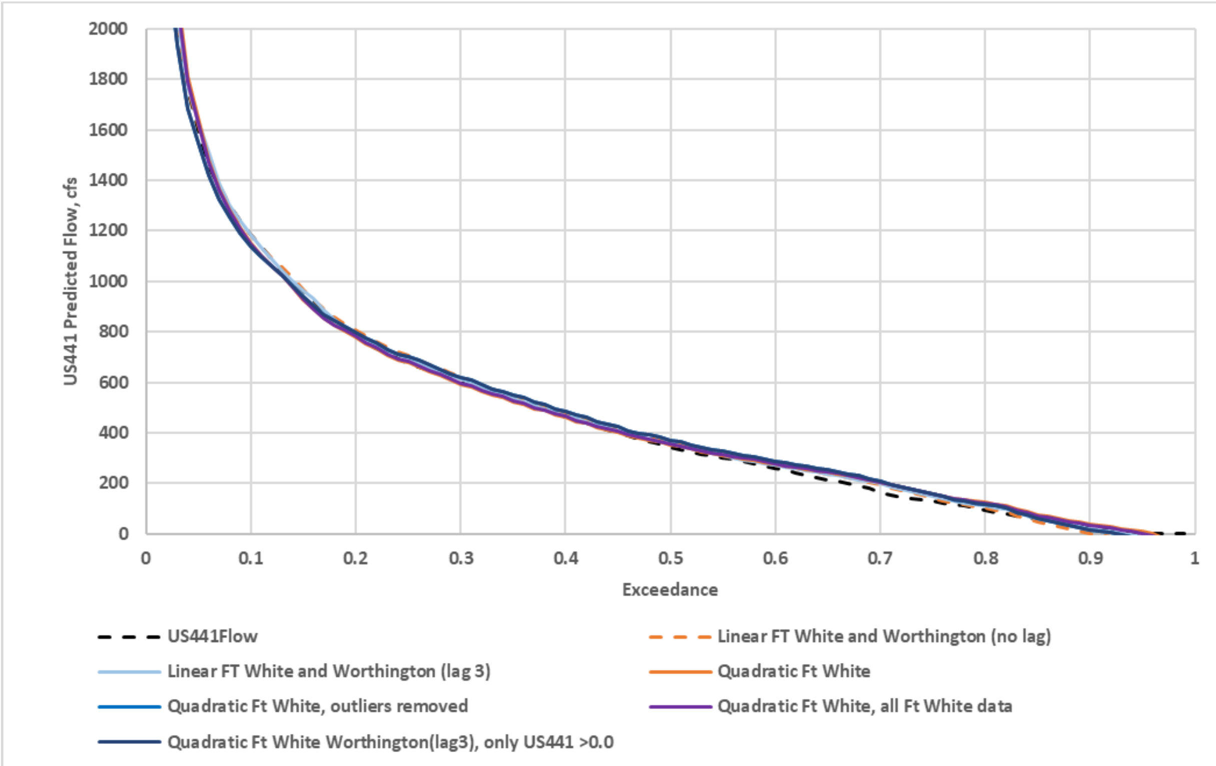


Figure A 1b. FDCs for Model POR (WY 1993-2018), US 441 Predicted Flow < 2,000 cfs.

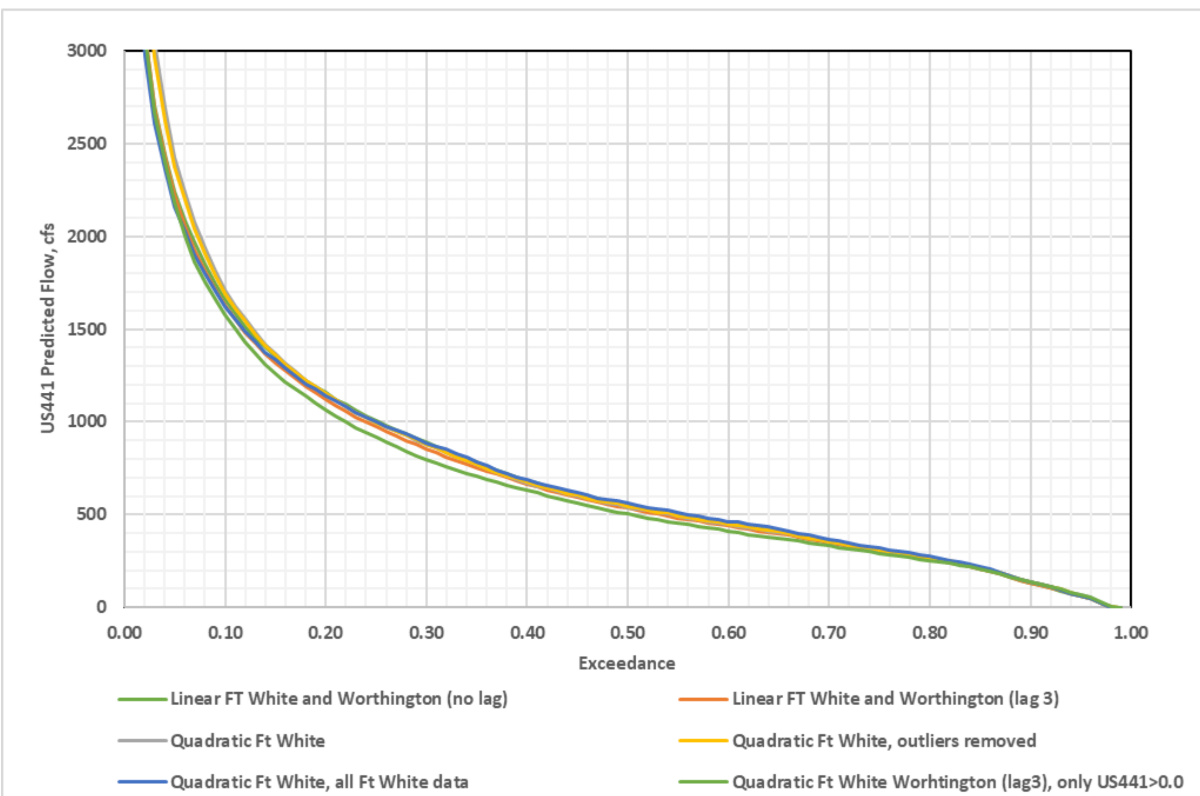


Figure A 2a. FDCs for POR (WY 1993-2018).

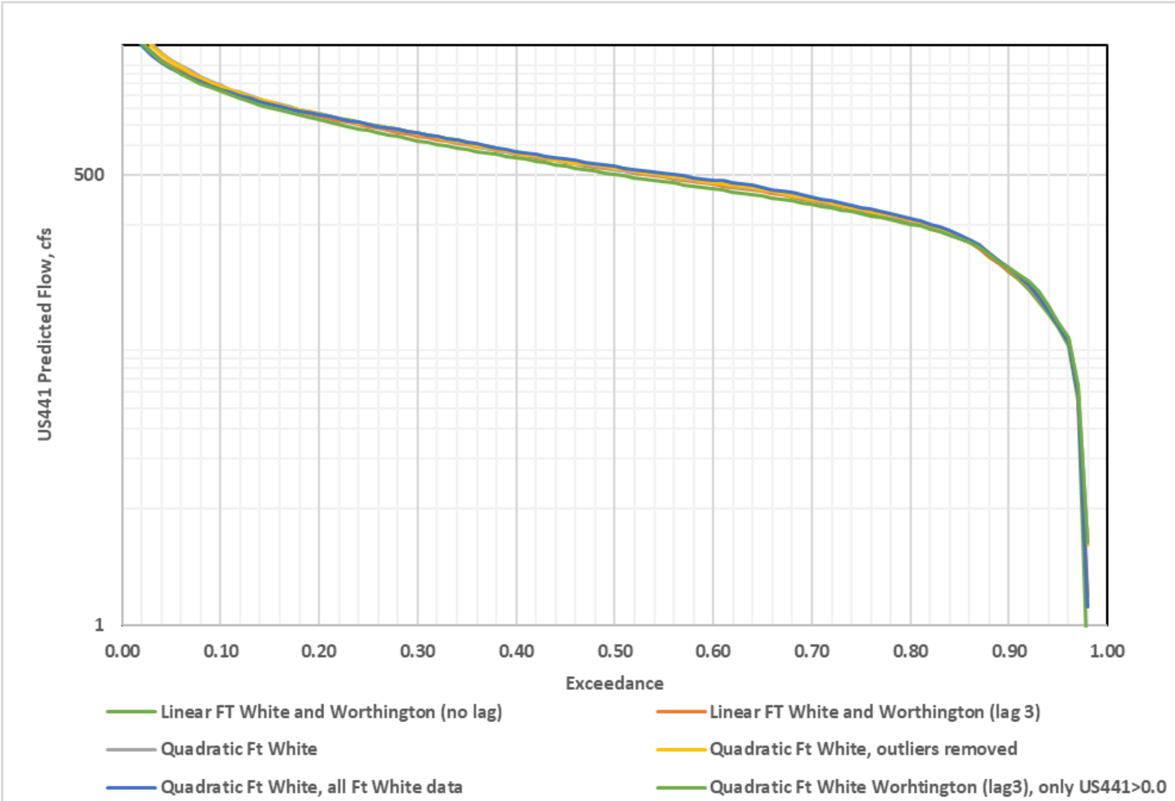


Figure A 2b. FDCs for POR (WY 1993-2018) (log scale – Y axis)

EXHIBIT A

Statistical model summary output model

(yellow highlight models are discussed in text and Exhibit B)

Data[2]	Variable 1	Variable 2	Variable 3	Lag 1	Lag 2	Lag 3	Observations	Model type	Adjusted R-squared	Root mean squared error	Median reference timeframe flow	Rating reliability relative to median flow
1	FtWhiteFlow	NA	NA	0	NA	NA	9359	Linear	0.861	329.5	343.2	96.0
1	FtWhiteFlow	NA	NA	0	NA	NA	9287	Linear - outliers removed	0.915	168.7	341.1	49.5
1	FtWhiteFlow	NA	NA	0	NA	NA	9359	Box Cox	0.787	21.5	52.1	41.2
1	FtWhiteFlow	NA	NA	0	NA	NA	9359	Generalized least squares	0.861	330.8	343.2	96.4
1	FtWhiteFlow	NA	NA	0	NA	NA	9359	Robust	0.861	329.6	343.2	96.0
1	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	9356	Linear	0.905	272.6	342.9	79.5
1	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	9283	Linear - outliers removed	0.936	152.1	341.1	44.6
1	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	9356	Box Cox	0.813	26.5	62.4	42.5
1	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	9356	Generalized least squares	0.898	285.2	342.9	83.2
1	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	9356	Robust	0.894	287.9	342.9	84.0
1	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	9359	Linear	0.872	316.0	343.2	92.1
1	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	9289	Linear - outliers removed	0.928	164.7	341.2	48.3
1	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	9359	Box Cox	0.804	23.6	57.0	41.5
1	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	9359	Generalized least squares	0.859	332.9	343.2	97.0
1	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	9359	Robust	0.871	317.7	343.2	92.6
1	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	9359	Quadratic - FtWhiteFlow	0.861	329.2	343.2	95.9
1	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	9305	Quadratic - FtWhiteFlow - outliers removed	0.923	176.7	342.0	51.7
1	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	9356	Quadratic - FtWhiteFlow	0.906	270.5	342.9	78.9
1	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	9291	Quadratic - FtWhiteFlow - outliers removed	0.937	155.0	341.3	45.4

Data[2]	Variable 1	Variable 2	Variable 3	Lag 1	Lag 2	Lag 3	Observations	Model type	Adjusted R-squared	Root mean squared error	Median reference timeframe flow	Rating reliability relative to median flow
1	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	0	9359	Quadratic - FtWhiteFlow	0.873	315.6	343.2	92.0
1	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	0	9299	Quadratic - FtWhiteFlow - outliers removed	0.931	169.5	341.5	49.6
2	FtWhiteFlow	NA	NA	0	NA	NA	9208	Linear	0.862	188.0	335.5	56.0
2	FtWhiteFlow	NA	NA	0	NA	NA	9063	Linear - outliers removed	0.919	124.3	329.0	37.8
2	FtWhiteFlow	NA	NA	0	NA	NA	9208	Box Cox	0.883	12.9	51.6	25.1
2	FtWhiteFlow	NA	NA	0	NA	NA	9208	Generalized least squares	0.862	188.2	335.5	56.1
2	FtWhiteFlow	NA	NA	0	NA	NA	9208	Robust	0.862	189.1	335.5	56.4
2	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	9205	Linear	0.880	175.1	335.3	52.2
2	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	9090	Linear - outliers removed	0.927	120.0	330.0	36.4
2	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	9205	Box Cox	0.886	13.5	53.5	25.2
2	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	9205	Generalized least squares	0.880	176.5	335.3	52.6
2	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	9205	Robust	0.879	176.5	335.3	52.7
2	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	9208	Linear	0.871	182.1	335.5	54.3
2	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	9175	Linear - outliers removed	0.915	138.5	335.0	41.4
2	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	9208	Box Cox	0.884	13.1	52.2	25.1
2	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	9208	Generalized least squares	0.869	183.1	335.5	54.6
2	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	9208	Robust	0.871	182.8	335.5	54.5
2	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	9208	Quadratic - FtWhiteFlow	0.870	182.9	335.5	54.5
2	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	9089	Quadratic - FtWhiteFlow - outliers removed	0.916	126.8	330.0	38.4

Data[2]	Variable 1	Variable 2	Variable 3	Lag 1	Lag 2	Lag 3	Observations	Model type	Adjusted R-squared	Root mean squared error	Median reference timeframe flow	Rating reliability relative to median flow
2	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	9205	Quadratic - FtWhiteFlow	0.882	173.5	335.3	51.7
2	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	9095	Quadratic - FtWhiteFlow - outliers removed	0.926	120.8	330.0	36.6
2	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	0	9208	Quadratic - FtWhiteFlow	0.875	178.8	335.5	53.3
2	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	0	9162	Quadratic - FtWhiteFlow - outliers removed	0.919	133.2	334.9	39.8
2	FtWhiteFlow	NA	NA	0	NA	NA	8265	Linear	0.850	196.7	392.0	50.2
3	FtWhiteFlow	NA	NA	0	NA	NA	8133	Linear - outliers removed	0.910	130.2	384.0	33.9
3	FtWhiteFlow	NA	NA	0	NA	NA	8265	Box Cox	0.876	8.6	44.1	19.4
3	FtWhiteFlow	NA	NA	0	NA	NA	8265	Generalized least squares	0.850	196.7	392.0	50.2
3	FtWhiteFlow	NA	NA	0	NA	NA	8265	Robust	0.850	197.5	392.0	50.4
3	WorthingtonFlow	NA	NA	-3	NA	NA	8413	Linear	0.800	408.0	402.5	101.4
3	WorthingtonFlow	NA	NA	-3	NA	NA	8341	Linear - outliers removed	0.719	313.0	399.0	78.5
3	WorthingtonFlow	NA	NA	-3	NA	NA	8413	Box Cox	0.520	8.3	24.9	33.4
3	WorthingtonFlow	NA	NA	-3	NA	NA	8413	Generalized least squares	0.800	569.4	402.5	141.5
3	WorthingtonFlow	NA	NA	-3	NA	NA	8413	Robust	0.800	408.5	402.5	101.5
3	WorthingtonFlow	NA	NA	0	NA	NA	8416	Linear	0.510	638.0	403.3	158.2
3	WorthingtonFlow	NA	NA	0	NA	NA	8371	Linear - outliers removed	0.582	428.2	399.0	107.3
3	WorthingtonFlow	NA	NA	0	NA	NA	8416	Box Cox	0.318	2.8	11.6	24.0
3	WorthingtonFlow	NA	NA	0	NA	NA	8416	Generalized least squares	0.510	918.2	403.3	227.7
3	WorthingtonFlow	NA	NA	0	NA	NA	8416	Robust	0.510	644.1	403.3	159.7

Data[2]	Variable 1	Variable 2	Variable 3	Lag 1	Lag 2	Lag 3	Observations	Model type	Adjusted R-squared	Root mean squared error	Median reference timeframe flow	Rating reliability relative to median flow
3	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8262	Linear	0.869	183.7	392.0	46.9
3	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8158	Linear - outliers removed	0.919	125.8	384.2	32.7
3	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8262	Box Cox	0.880	9.9	49.3	20.0
3	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8262	Generalized least squares	0.868	185.2	392.0	47.2
3	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8262	Robust	0.867	185.2	392.0	47.2
3	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8265	Linear	0.858	190.8	392.0	48.7
3	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8236	Linear - outliers removed	0.906	145.4	392.0	37.1
3	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8265	Box Cox	0.877	9.0	45.8	19.7
3	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8265	Generalized least squares	0.857	191.8	392.0	48.9
3	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8265	Robust	0.858	191.5	392.0	48.9
3	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	8265	Quadratic - FtWhiteFlow	0.857	192.1	392.0	49.0
3	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	8152	Quadratic - FtWhiteFlow - outliers removed	0.906	133.1	384.0	34.6
3	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	8262	Quadratic - FtWhiteFlow	0.871	182.0	392.0	46.4
3	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	8158	Quadratic - FtWhiteFlow - outliers removed	0.917	127.2	384.0	33.1
3	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	0	8265	Quadratic - FtWhiteFlow	0.863	187.7	392.0	47.9
3	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	0	8225	Quadratic - FtWhiteFlow - outliers removed	0.910	140.6	391.6	35.9
4	FtWhiteFlow	NA	NA	0	NA	NA	8707	Linear	0.856	192.4	363.0	53.0
4	FtWhiteFlow	NA	NA	0	NA	NA	8568	Linear - outliers removed	0.914	127.2	356.0	35.7
4	FtWhiteFlow	NA	NA	0	NA	NA	8707	Box Cox	0.882	11.9	52.4	22.8

Data[2]	Variable 1	Variable 2	Variable 3	Lag 1	Lag 2	Lag 3	Observations	Model type	Adjusted R-squared	Root mean squared error	Median reference timeframe flow	Rating reliability relative to median flow
4	FtWhiteFlow	NA	NA	0	NA	NA	8707	Generalized least squares	0.856	192.4	363.0	53.0
4	FtWhiteFlow	NA	NA	0	NA	NA	8707	Robust	0.856	193.3	363.0	53.2
4	WorthingtonFlow	NA	NA	-3	NA	NA	8855	Linear	0.799	403.0	371.0	108.6
4	WorthingtonFlow	NA	NA	-3	NA	NA	8783	Linear - outliers removed	0.718	312.0	369.8	84.4
4	WorthingtonFlow	NA	NA	-3	NA	NA	8855	Box Cox	0.529	13.2	31.4	42.1
4	WorthingtonFlow	NA	NA	-3	NA	NA	8855	Generalized least squares	0.799	563.6	371.0	151.9
4	WorthingtonFlow	NA	NA	-3	NA	NA	8855	Robust	0.799	403.6	371.0	108.8
4	WorthingtonFlow	NA	NA	0	NA	NA	8858	Linear	0.513	627.0	371.0	169.0
4	WorthingtonFlow	NA	NA	0	NA	NA	8813	Linear - outliers removed	0.584	423.5	370.0	114.5
4	WorthingtonFlow	NA	NA	0	NA	NA	8858	Box Cox	0.336	6.5	17.9	36.4
4	WorthingtonFlow	NA	NA	0	NA	NA	8858	Generalized least squares	0.513	904.8	371.0	243.9
4	WorthingtonFlow	NA	NA	0	NA	NA	8858	Robust	0.513	634.1	371.0	170.9
4	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8704	Linear	0.874	179.5	363.0	49.5
4	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8594	Linear - outliers removed	0.923	122.9	358.3	34.3
4	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8704	Box Cox	0.885	13.1	56.7	23.1
4	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8704	Generalized least squares	0.874	181.0	363.0	49.9
4	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8704	Robust	0.873	181.0	363.0	49.9
4	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8707	Linear	0.865	186.5	363.0	51.4
4	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8677	Linear - outliers removed	0.910	142.3	363.0	39.2
4	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8707	Box Cox	0.883	12.3	53.9	22.9
4	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8707	Generalized least squares	0.863	187.5	363.0	51.7

Data[2]	Variable 1	Variable 2	Variable 3	Lag 1	Lag 2	Lag 3	Observations	Model type	Adjusted R-squared	Root mean squared error	Median reference timeframe flow	Rating reliability relative to median flow
4	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8707	Robust	0.865	187.2	363.0	51.6
4	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	8707	Quadratic - FtWhiteFlow	0.863	187.7	363.0	51.7
4	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	8590	Quadratic - FtWhiteFlow - outliers removed	0.911	130.0	357.0	36.4
4	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	8704	Quadratic - FtWhiteFlow	0.877	178.0	363.0	49.0
4	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	8598	Quadratic - FtWhiteFlow - outliers removed	0.921	124.3	358.4	34.7
4	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	0	8707	Quadratic - FtWhiteFlow	0.869	183.4	363.0	50.5
4	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	0	8664	Quadratic - FtWhiteFlow - outliers removed	0.915	136.9	363.0	37.7
5	FtWhiteFlow	NA	NA	0	NA	NA	8858	Linear	0.858	338.3	371.0	91.2
5	FtWhiteFlow	NA	NA	0	NA	NA	8788	Linear - outliers removed	0.913	173.4	370.0	46.9
5	FtWhiteFlow	NA	NA	0	NA	NA	8858	Box Cox	0.801	22.8	58.9	38.7
5	FtWhiteFlow	NA	NA	0	NA	NA	8858	Generalized least squares	0.858	339.5	371.0	91.5
5	FtWhiteFlow	NA	NA	0	NA	NA	8858	Robust	0.858	338.3	371.0	91.2
5	WorthingtonFlow	NA	NA	-3	NA	NA	8855	Linear	0.799	403.0	371.0	108.6
5	WorthingtonFlow	NA	NA	-3	NA	NA	8783	Linear - outliers removed	0.718	312.0	369.8	84.4
5	WorthingtonFlow	NA	NA	-3	NA	NA	8855	Box Cox	0.529	13.2	31.4	42.1
5	WorthingtonFlow	NA	NA	-3	NA	NA	8855	Generalized least squares	0.799	563.6	371.0	151.9
5	WorthingtonFlow	NA	NA	-3	NA	NA	8855	Robust	0.799	403.6	371.0	108.8
5	WorthingtonFlow	NA	NA	0	NA	NA	8858	Linear	0.513	627.0	371.0	169.0
5	WorthingtonFlow	NA	NA	0	NA	NA	8813	Linear - outliers removed	0.584	423.5	370.0	114.5

Data[2]	**Variable 1**	**Variable 2**	**Variable 3**	**Lag 1**	**Lag 2**	**Lag 3**	**Observations**	**Model type**	**Adjusted R-squared**	**Root mean squared error**	**Median reference timeframe flow**	**Rating reliability relative to median flow**
5	WorthingtonFlow	NA	NA	0	NA	NA	8858	Box Cox	0.336	6.5	17.9	36.4
5	WorthingtonFlow	NA	NA	0	NA	NA	8858	Generalized least squares	0.513	904.8	371.0	243.9
5	WorthingtonFlow	NA	NA	0	NA	NA	8858	Robust	0.513	634.1	371.0	170.9
5	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8855	Linear	0.903	279.7	371.0	75.4
5	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8782	Linear - outliers removed	0.934	155.8	370.0	42.1
5	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8855	Box Cox	0.840	33.1	80.4	41.2
5	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8855	Generalized least squares	0.896	292.7	371.0	78.9
5	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8855	Robust	0.891	296.2	371.0	79.8
5	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8858	Linear	0.870	324.6	371.0	87.5
5	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8789	Linear - outliers removed	0.926	169.1	370.0	45.7
5	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8858	Box Cox	0.819	25.7	65.6	39.1
5	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8858	Generalized least squares	0.856	341.6	371.0	92.1
5	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8858	Robust	0.868	326.5	371.0	88.0
5	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	8858	Quadratic - FtWhiteFlow	0.858	338.1	371.0	91.1
5	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	8804	Quadratic - FtWhiteFlow - outliers removed	0.921	181.0	370.0	48.9
5	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	8855	Quadratic - FtWhiteFlow	0.904	277.7	371.0	74.9
5	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	8791	Quadratic - FtWhiteFlow - outliers removed	0.935	159.0	370.0	43.0
5	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	0	8858	Quadratic - FtWhiteFlow	0.870	324.1	371.0	87.4
5	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	0	8798	Quadratic - FtWhiteFlow - outliers removed	0.929	173.6	370.0	46.9

Data[2]	Variable 1	Variable 2	Variable 3	Lag 1	Lag 2	Lag 3	Observations	Model type	Adjusted R-squared	Root mean squared error	Median reference timeframe flow	Rating reliability relative to median flow
1. Models presented in the Memorandum and Exhibit B												
1	FtWhiteFlow	WorthingtonFlow	NA	0	-3	NA	8704	Linear	0.874	179.5	363.0	49.5
2	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	8707	Quadratic - FtWhiteFlow	0.863	187.7	363.0	51.7
3	FtWhiteFlow	FtWhiteFlow^2	NA	0	0	NA	8590	Quadratic - FtWhiteFlow - outliers removed	0.911	130.0	357.0	36.4
4	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	8704	Quadratic - FtWhiteFlow	0.877	178.0	363.0	49.0
5	FtWhiteFlow	FtWhiteFlow^2	Worthington Flow	0	0	-3	8855	Quadratic - FtWhiteFlow	0.904	277.7	371.0	74.9
6	FtWhiteFlow	WorthingtonFlow	NA	0	0	NA	8707	Linear	0.865	186.5	363.0	51.4

2. Data Used

1. **Combined data_1992to2018**
2. **Combined data_1992to2018_Screened_Fort_White_3500**
3. **Combined data_1992to2018_Screened_Fort_White_3500_and_US_441_95_Percent_Exceedance**
4. **Combined data_1992to2018_Screened_Fort_White_3500_and_US_441_Zero**
5. **Combined data_1992to2018_Screened_US_441_Zero**

EXHIBIT B

Select Regression Model Output in SPSS

Model 1 linear Ft White and Worthington (lag 3)

Model 2 Quadratic Ft White

Model 3 Quadratic Ft White, outliers removed

Model 4 Quadratic Ft White, linear Worthington (lag3)

Model 5 Quadratic Ft White, linear Worthington (lag3), All Ft White Data

Model 6 linear Ft White and Worthington (no lag)

Model 1 Linear Ft White and Worthington (lag 3)

Regression Model 1

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.926[a]	.857	.857	191.705	.857	52088.834	1	8702	.000	
2	.935[b]	.874	.874	179.552	.018	1218.863	1	8701	.000	.193

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, Lag3Worth

c. Dependent Variable: US441Flow

ANOVA[c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.914E9	1	1.914E9	52088.834	.000[a]
	Residual	3.198E8	8702	36750.979		
	Total	2.234E9	8703			
2	Regression	1.954E9	2	9.768E8	30298.818	.000[b]
	Residual	2.805E8	8701	32239.057		
	Total	2.234E9	8703			

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, Lag3Worth

c. Dependent Variable: US441Flow

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-554.899	5.091		-108.992	.000		
	FtWhiteFlow	.923	.004	.926	228.230	.000	1.000	1.000
2	(Constant)	-435.198	5.873		-74.100	.000		
	FtWhiteFlow	.766	.006	.768	130.048	.000	.414	2.416
	Lag3Worth	.218	.006	.206	34.912	.000	.414	2.416

a. Dependent Variable: US441Flow

Excluded Variables[b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance	Collinearity Statistics VIF	Collinearity Statistics Minimum Tolerance
1	Lag3Worth	.206[a]	34.912	.000	.351	.414	2.416	.414

a. Predictors in the Model: (Constant), FtWhiteFlow

b. Dependent Variable: US441Flow

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	FtWhiteFlow	Lag3Worth
1	1	1.915	1.000	.04	.04	
	2	.085	4.745	.96	.96	
2	1	2.448	1.000	.01	.01	.03
	2	.512	2.187	.07	.00	.39
	3	.040	7.829	.92	.99	.57

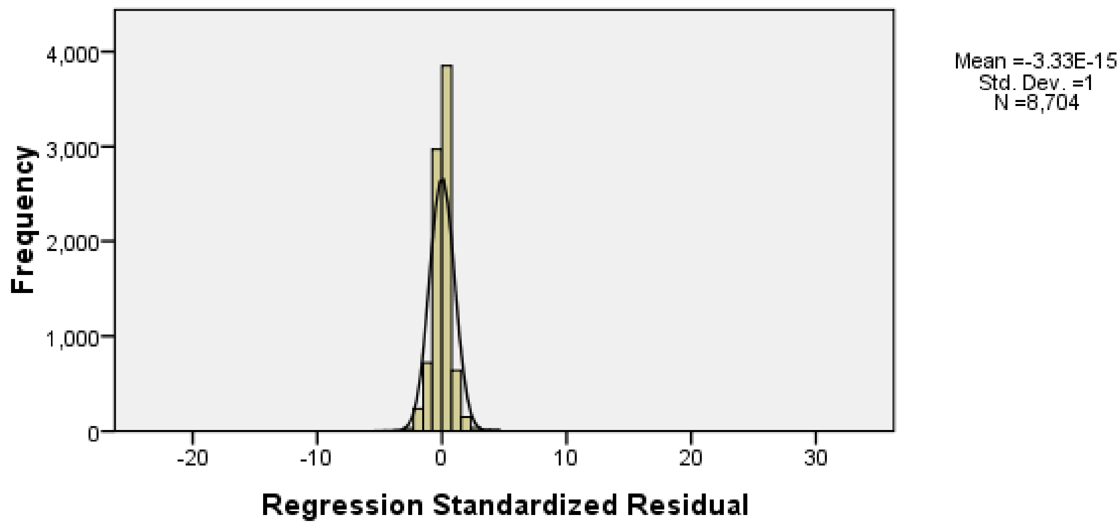
a. Dependent Variable: US441Flow

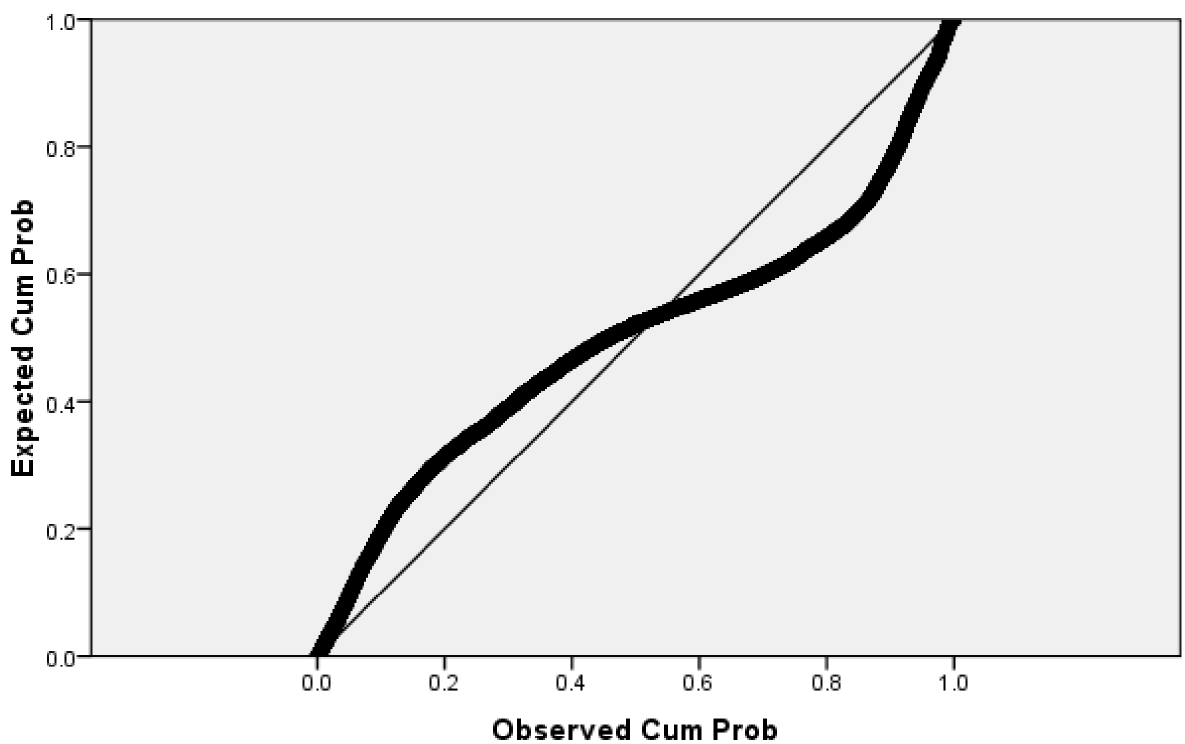
Residuals Statistics[a]

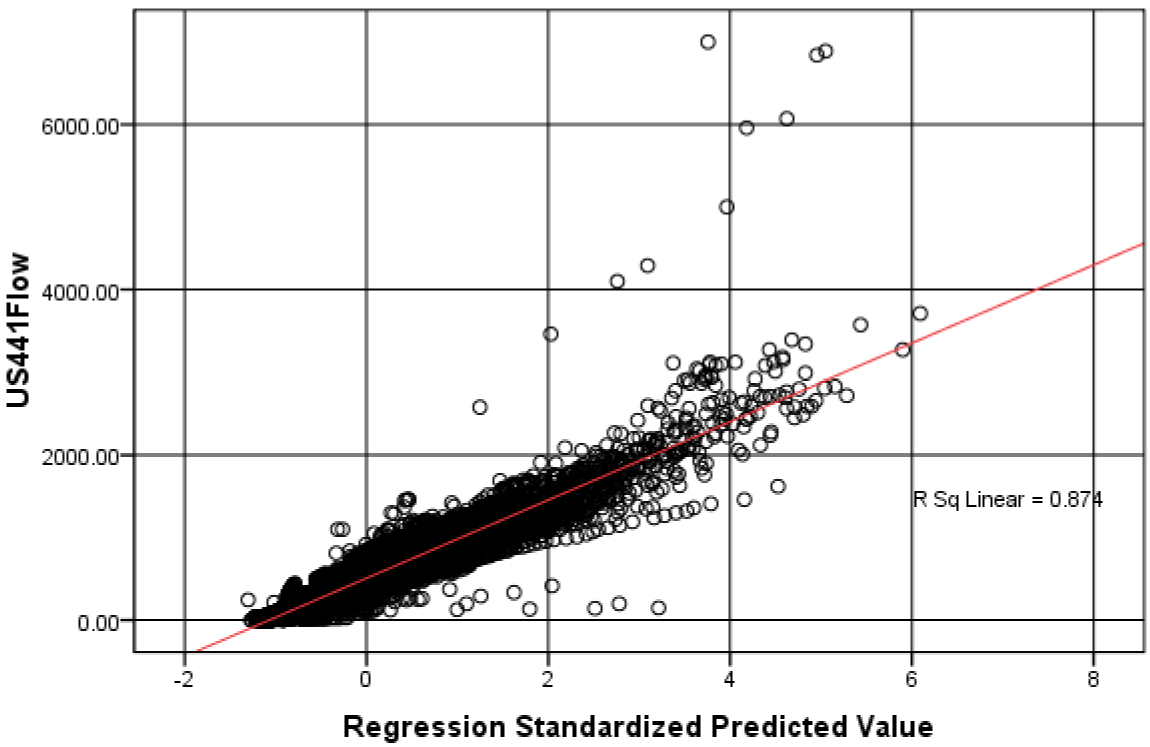
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-109.52	3394.34	508.22	473.788	8704
Residual	-1882.391	4711.710	.000	179.532	8704
Std. Predicted Value	-1.304	6.092	.000	1.000	8704
Std. Residual	-10.484	26.241	.000	1.000	8704

a. Dependent Variable: US441Flow

Dependent Variable: US441Flow



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4000.00
2000.00
0.00
US441Flow
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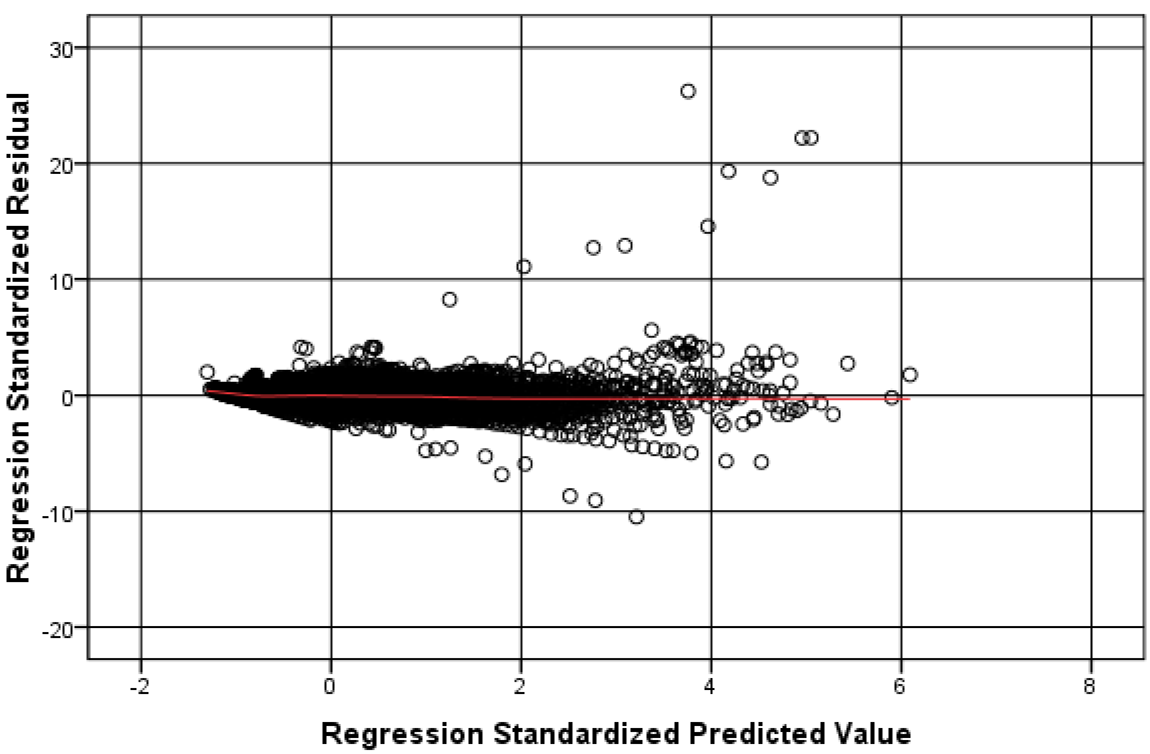
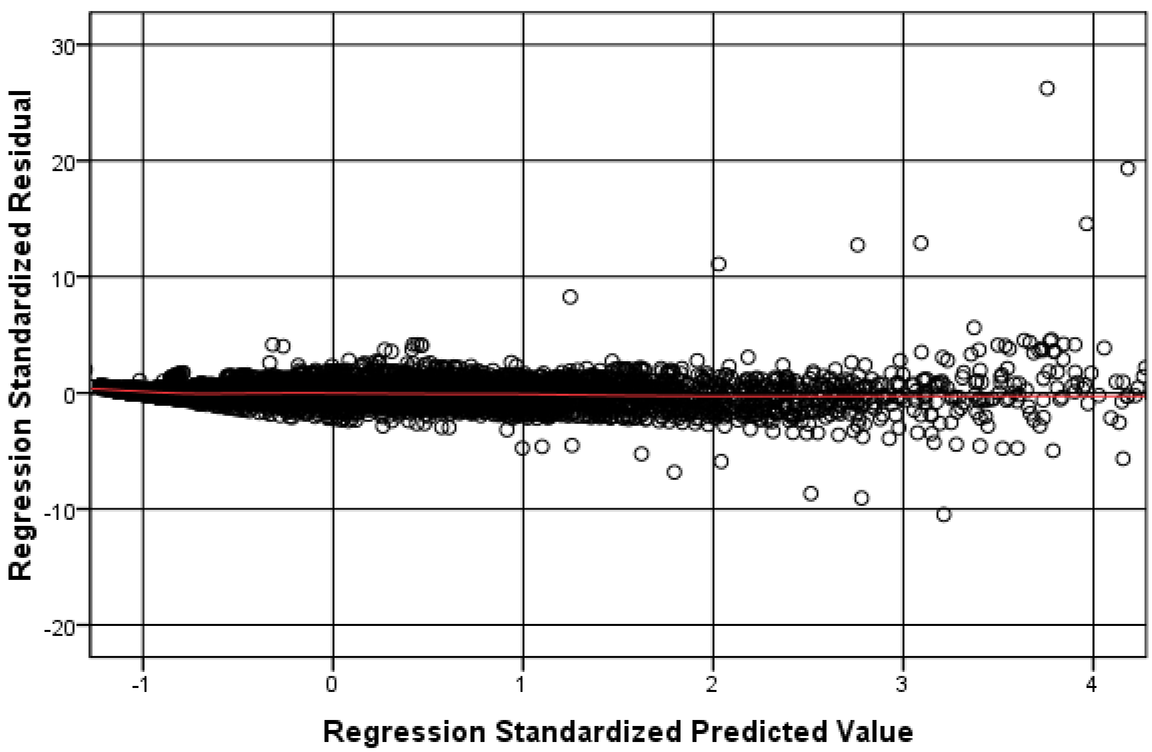
0
2
4
6
8
Regression Standardized Predicted Value
R Sq Linear = 0.874


30
20
10
0
-10
-20
Regression Standardized Residual
-2
0
2
4
6
8
Regression Standardized Predicted Value



Regression Standardized Residual
30
20
10
0
-10
-20
-1
0
1
2
3
4
Regression Standardized Predicted Value

Model 2 Quadratic Ft White

Regression Model 2

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.925[a]	.856	.856	192.384	.856	51828.453	1	8705	.000	
2	.929[b]	.863	.863	187.689	.007	441.973	1	8704	.000	.186

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, FtWhite2

c. Dependent Variable: US441Flow

ANOVA[c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.918E9	1	1.918E9	51828.453	.000[a]
	Residual	3.222E8	8705	37011.768		
	Total	2.240E9	8706			
2	Regression	1.934E9	2	9.669E8	27447.960	.000[b]
	Residual	3.066E8	8704	35227.248		
	Total	2.240E9	8706			

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, FtWhite2

c. Dependent Variable: US441Flow

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-555.438	5.109		-108.723	.000		
	FtWhiteFlow	.924	.004	.925	227.659	.000	1.000	1.000
2	(Constant)	-352.270	10.874		-32.397	.000		
	FtWhiteFlow	.602	.016	.603	38.102	.000	.063	15.936
	FtWhite2	.000	.000	.333	21.023	.000	.063	15.936

a. Dependent Variable: US441Flow

Excluded Variables[b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	FtWhite2	.333[a]	21.023	.000	.220	.063	15.936	.063

a. Predictors in the Model: (Constant), FtWhiteFlow

b. Dependent Variable: US441Flow

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	FtWhiteFlow	FtWhite2
1	1	1.915	1.000	.04	.04	
	2	.085	4.745	.96	.96	
2	1	2.698	1.000	.00	.00	.00
	2	.296	3.019	.06	.00	.05
	3	.006	20.442	.94	1.00	.94

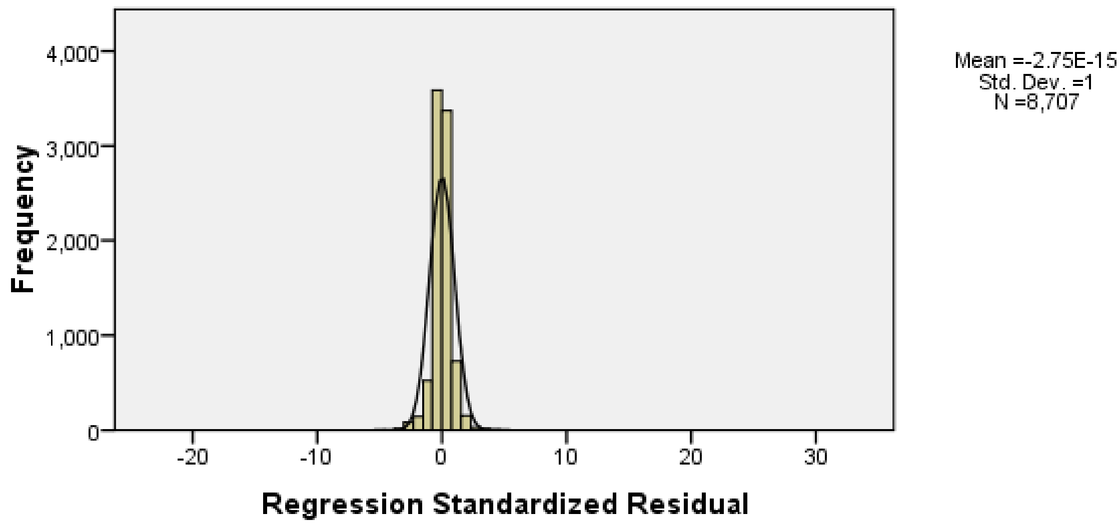
a. Dependent Variable: US441Flow

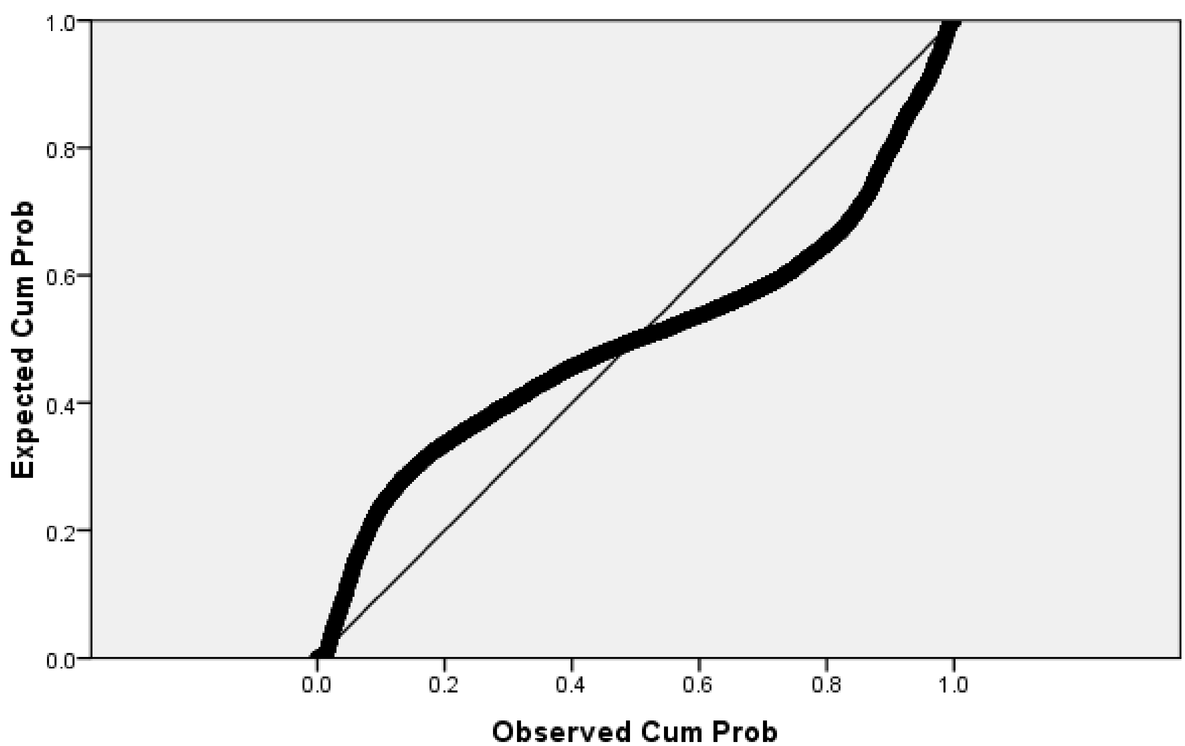
Residuals Statistics[a]

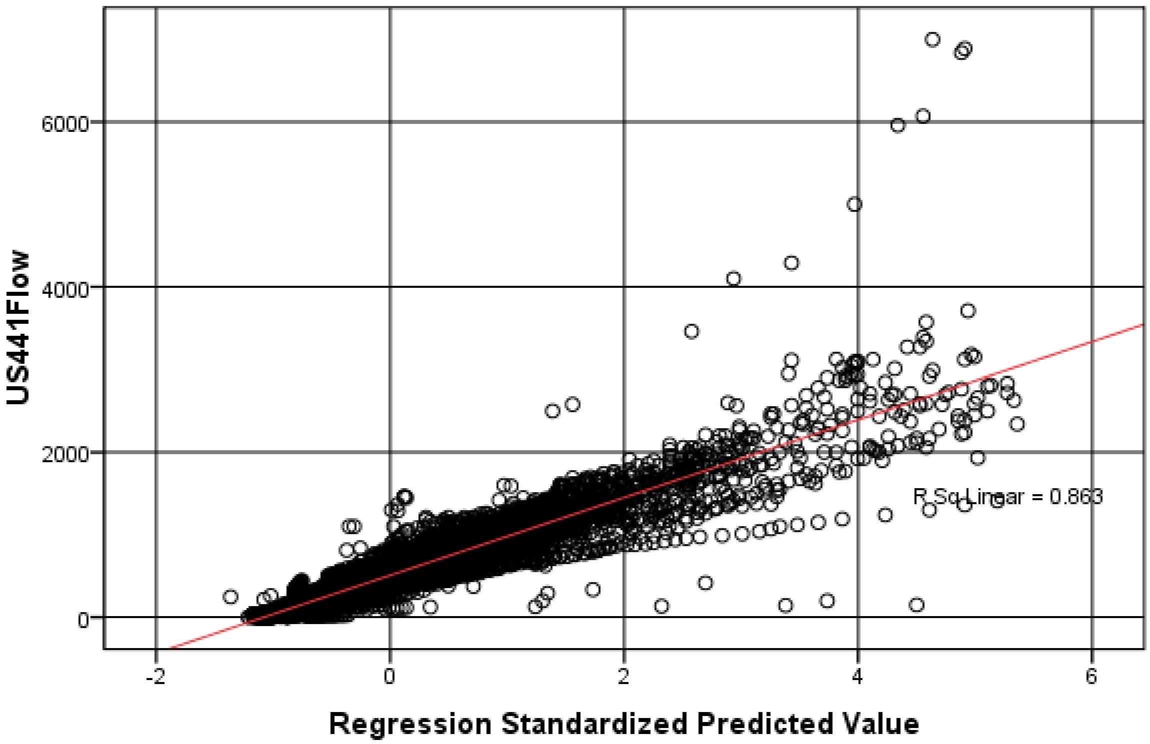
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-134.02	3034.51	508.70	471.303	8707
Residual	-2481.414	4306.438	.000	187.668	8707
Std. Predicted Value	-1.364	5.359	.000	1.000	8707
Std. Residual	-13.221	22.945	.000	1.000	8707

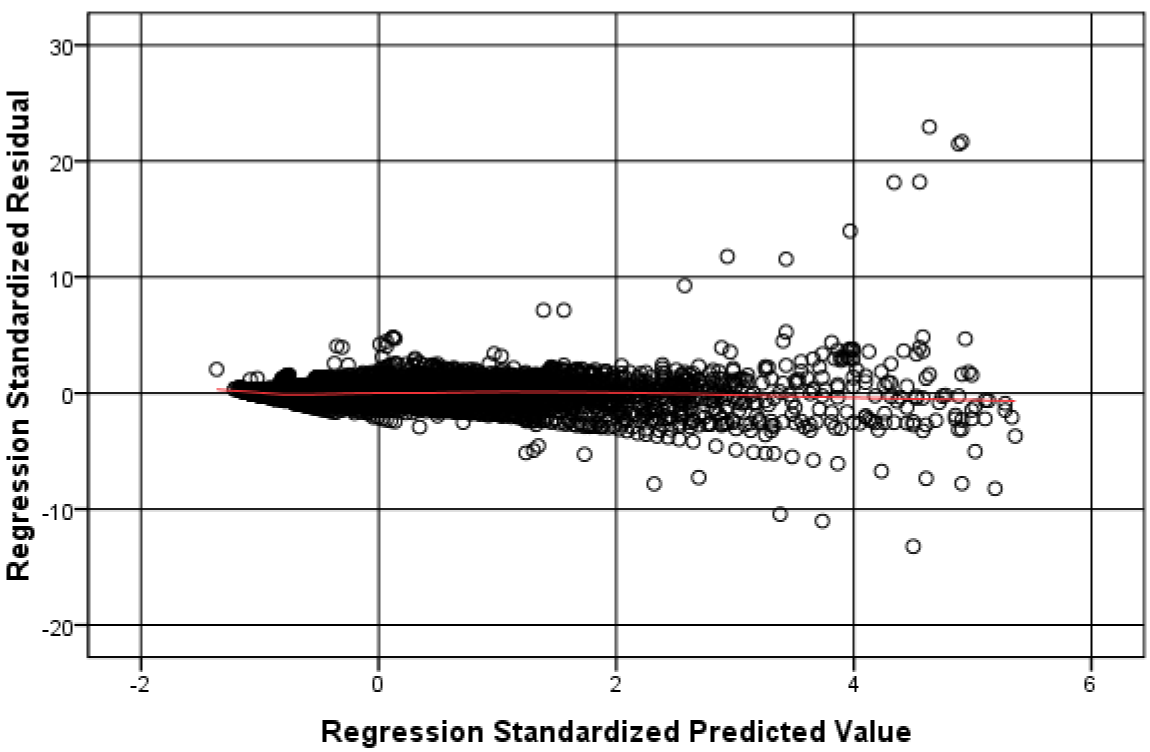
a. Dependent Variable: US441Flow

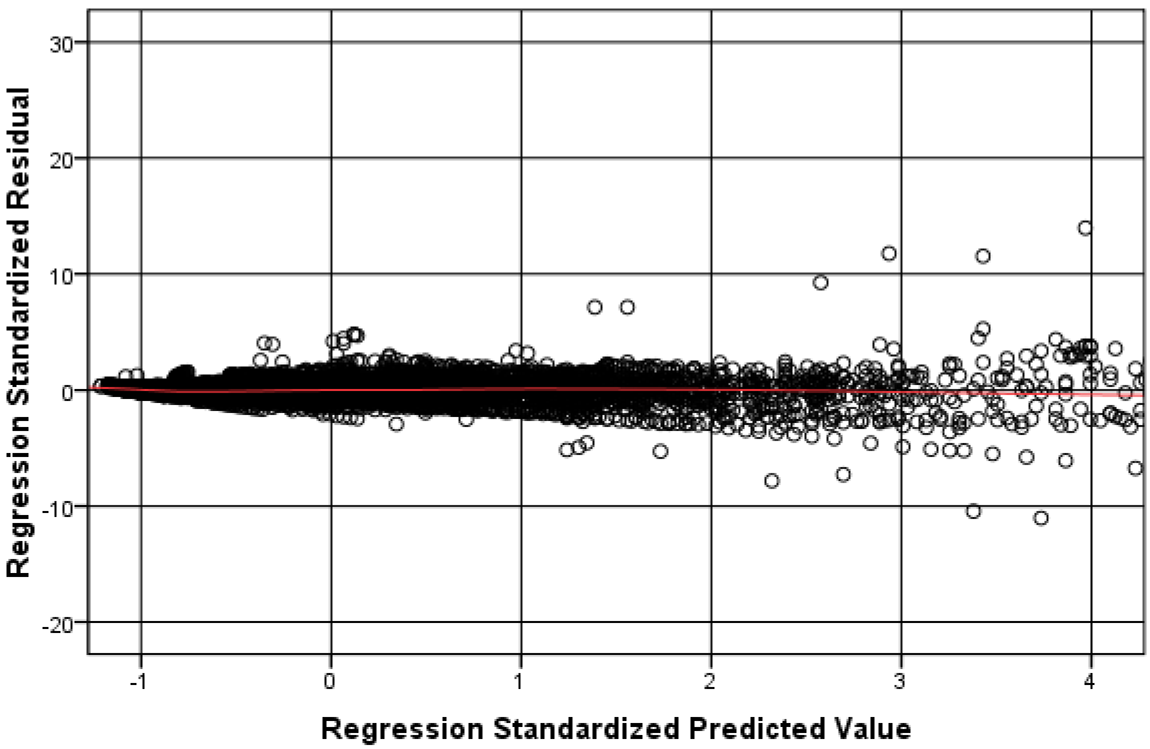
Dependent Variable: US441Flow






6000
4000
2000
0
US441Flow
-2
0
2
4
6
Regression Standardized Predicted Value
R Sq Linear = 0.863


30
20
10
0
-10
-20
Regression Standardized Residual
-2
0
2
4
6
Regression Standardized Predicted Value


Regression Standardized Residual
30
20
10
0
-10
-20
-1
0
1
2
3
4
Regression Standardized Predicted Value

Model 3 Quadratic Ft White, outliers removed

Regression Model 3

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.953[a]	.907	.907	132.770	.907	84112.179	1	8588	.000	
2	.955[b]	.911	.911	129.979	.004	373.814	1	8587	.000	.094

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, FtWhite2

c. Dependent Variable: US441Flow

ANOVA[c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.483E9	1	1.483E9	84112.179	.000[a]
	Residual	1.514E8	8588	17627.855		
	Total	1.634E9	8589			
2	Regression	1.489E9	2	7.445E8	44068.697	.000[b]
	Residual	1.451E8	8587	16894.449		
	Total	1.634E9	8589			

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, FtWhite2

c. Dependent Variable: US441Flow

ANOVA[c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.483E9	1	1.483E9	84112.179	.000[a]
	Residual	1.514E8	8588	17627.855		
	Total	1.634E9	8589			
2	Regression	1.489E9	2	7.445E8	44068.697	.000[b]
	Residual	1.451E8	8587	16894.449		
	Total	1.634E9	8589			

a. Predictors: (Constant), FtWhiteFlow

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-526.621	3.765		-139.891	.000		
	FtWhiteFlow	.896	.003	.953	290.021	.000	1.000	1.000
2	(Constant)	-380.512	8.408		-45.257	.000		
	FtWhiteFlow	.653	.013	.694	50.493	.000	.055	18.280
	FtWhite2	8.599E-5	.000	.266	19.334	.000	.055	18.280

a. Dependent Variable: US441Flow

Excluded Variables[b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	FtWhite2	.266[a]	19.334	.000	.204	.055	18.280	.055

a. Predictors in the Model: (Constant), FtWhiteFlow

b. Dependent Variable: US441Flow

Collinearity Diagnostics[a]

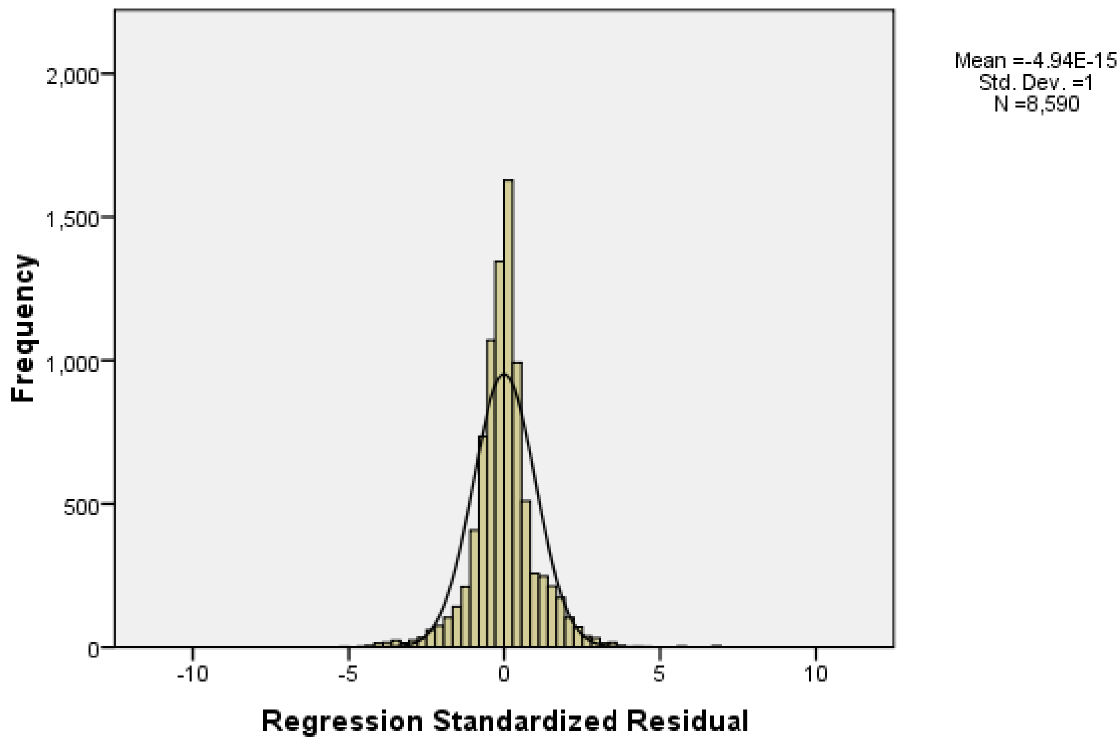
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	FtWhiteFlow	FtWhite2
1	1	1.925	1.000	.04	.04	
	2	.075	5.058	.96	.96	
2	1	2.736	1.000	.00	.00	.00
	2	.259	3.247	.06	.00	.05
	3	.005	23.300	.94	1.00	.95

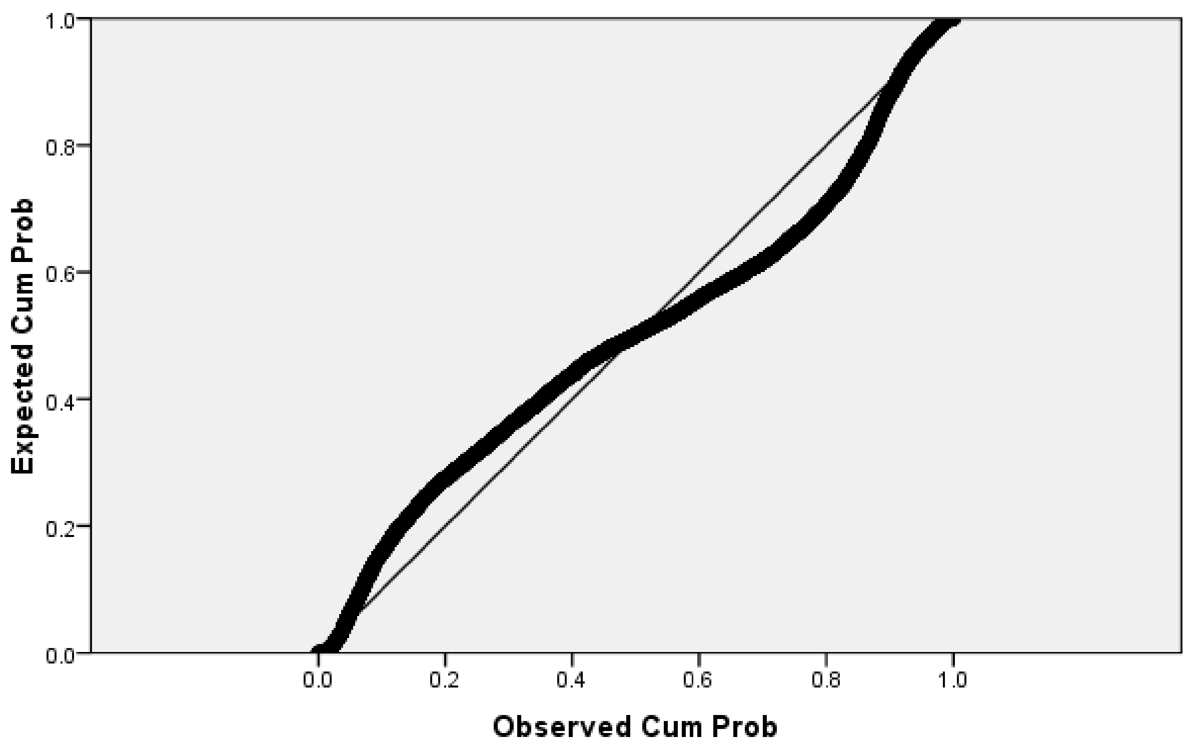
a. Dependent Variable: US441Flow

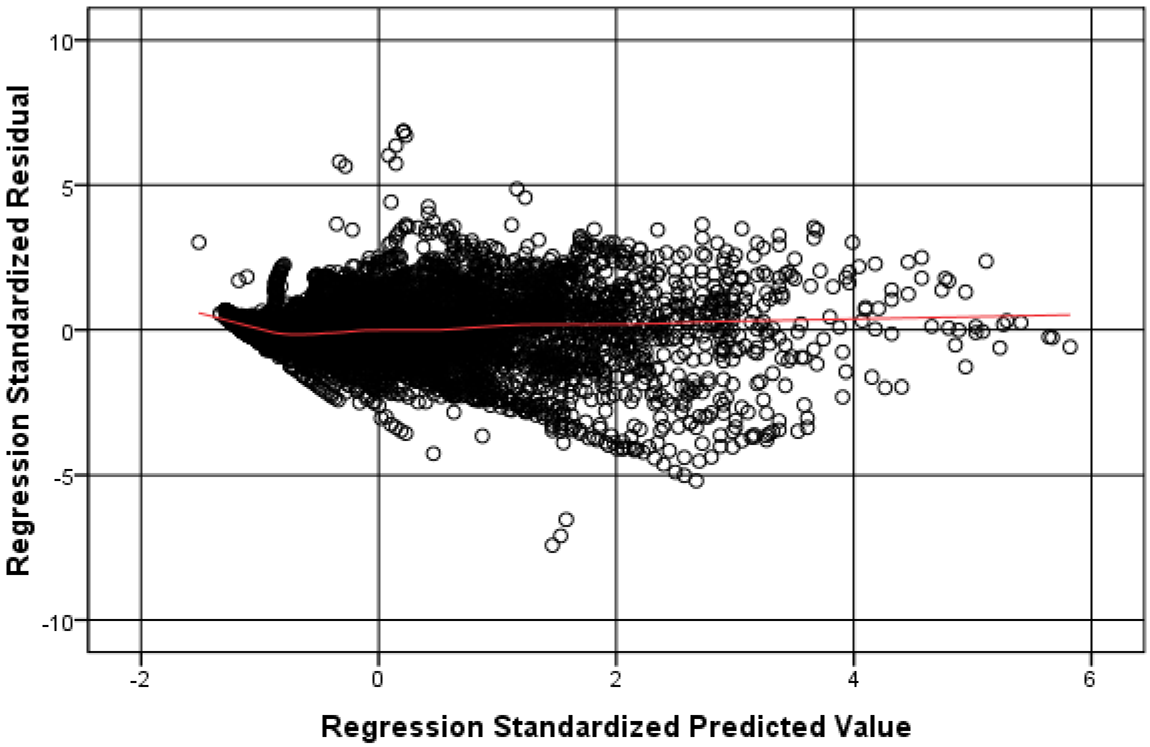
Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-134.02	3034.51	508.70	471.303	8707
Std. Predicted Value	-1.364	5.359	.000	1.000	8707
Standard Error of Predicted Value	2.183	19.832	3.125	1.541	8707
Adjusted Predicted Value	-134.44	3042.34	508.69	471.289	8707
Residual	-2481.414	4306.438	.000	187.668	8707
Std. Residual	-13.221	22.945	.000	1.000	8707
Stud. Residual	-13.260	23.020	.000	1.001	8707
Deleted Residual	-2496.110	4334.891	.003	188.212	8707
Stud. Deleted Residual	-13.395	23.753	.000	1.009	8707
Mahal. Distance	.178	96.203	2.000	5.902	8707
Cook's Distance	.000	1.290	.001	.026	8707
Centered Leverage Value	.000	.011	.000	.001	8707

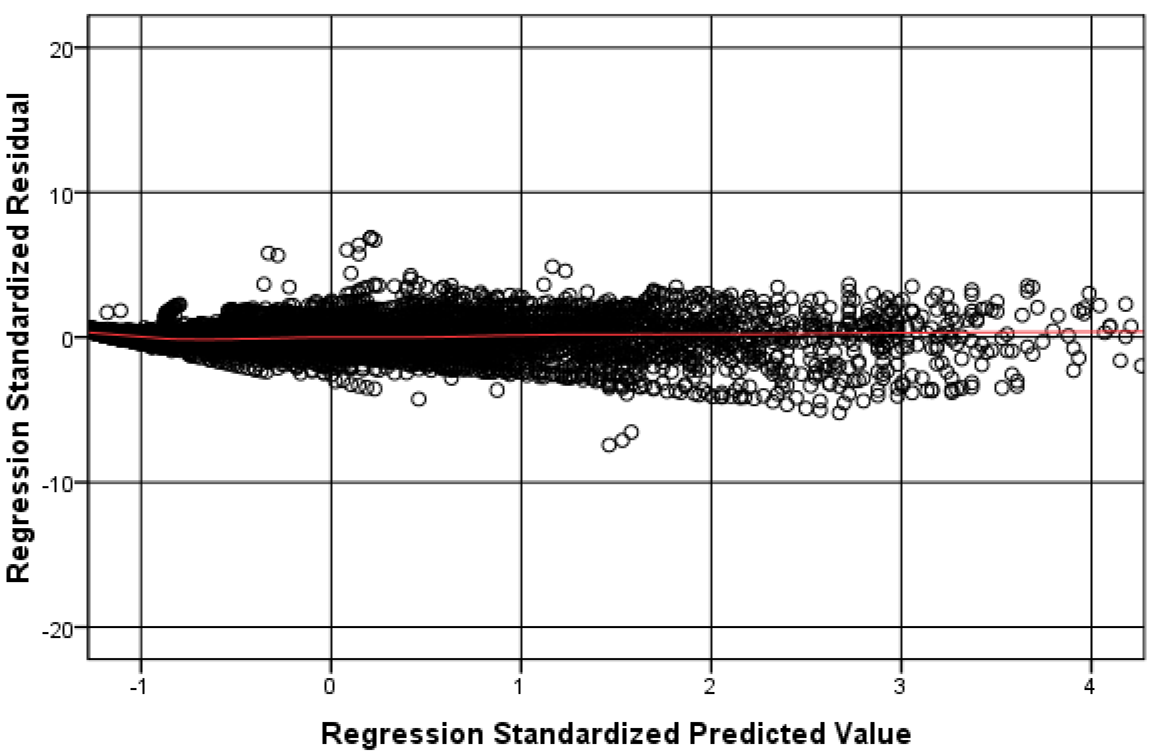
a. Dependent Variable: US441Flow


Mean =-4.94E-15
Std. Dev. =1
N =8,590
Frequency
2,000
1,500
1,000
500
0
-10
-5
0
5
10
Regression Standardized Residual


Expected Cum Prob
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Observed Cum Prob



10
5
0
-5
-10
Regression Standardized Residual
-2
0
2
4
6
Regression Standardized Predicted Value



20
10
0
-10
-20
Regression Standardized Residual
-1
0
1
2
3
4
Regression Standardized Predicted Value

Model 4 Quadratic Ft White, linear Worthington (lag3)

Regression Model 4

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.926[a]	.857	.857	191.705	.857	52088.834	1	8702	.000	
2	.935[b]	.874	.874	179.552	.018	1218.863	1	8701	.000	
3	.936[c]	.877	.877	178.038	.002	149.632	1	8700	.000	.192

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, Lag3Worth

c. Predictors: (Constant), FtWhiteFlow, Lag3Worth, FtWhite2

d. Dependent Variable: US441Flow

ANOVA[d]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.914E9	1	1.914E9	52088.834	.000[a]
	Residual	3.198E8	8702	36750.979		
	Total	2.234E9	8703			
2	Regression	1.954E9	2	9.768E8	30298.818	.000[b]
	Residual	2.805E8	8701	32239.057		
	Total	2.234E9	8703			
3	Regression	1.958E9	3	6.528E8	20594.135	.000[c]
	Residual	2.758E8	8700	31697.595		
	Total	2.234E9	8703			

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, Lag3Worth

c. Predictors: (Constant), FtWhiteFlow, Lag3Worth, FtWhite2

d. Dependent Variable: US441Flow

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-554.899	5.091		-108.992	.000		
	FtWhiteFlow	.923	.004	.926	228.230	.000	1.000	1.000
2	(Constant)	-435.198	5.873		-74.100	.000		
	FtWhiteFlow	.766	.006	.768	130.048	.000	.414	2.416
	Lag3Worth	.218	.006	.206	34.912	.000	.414	2.416
3	(Constant)	-330.715	10.338		-31.991	.000		
	FtWhiteFlow	.597	.015	.598	39.800	.000	.063	15.935
	Lag3Worth	.194	.006	.183	29.882	.000	.376	2.658
	FtWhite2	6.111E-5	.000	.193	12.232	.000	.057	17.528

a. Dependent Variable: US441Flow

Excluded Variables[c]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	FtWhite2	.335[a]	21.219	.000	.222	.063	15.935	.063
	Lag3Worth	.206[a]	34.912	.000	.351	.414	2.416	.414
2	FtWhite2	.193[b]	12.232	.000	.130	.057	17.528	.057

a. Predictors in the Model: (Constant), FtWhiteFlow

b. Predictors in the Model: (Constant), FtWhiteFlow, Lag3Worth

c. Dependent Variable: US441Flow

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	FtWhiteFlow	Lag3Worth	FtWhite2
1	1	1.915	1.000	.04	.04		
	2	.085	4.745	.96	.96		
2	1	2.448	1.000	.01	.01	.03	
	2	.512	2.187	.07	.00	.39	
	3	.040	7.829	.92	.99	.57	
3	1	3.324	1.000	.00	.00	.02	.00
	2	.547	2.465	.03	.00	.23	.00
	3	.123	5.198	.05	.00	.75	.11
	4	.006	22.714	.92	1.00	.00	.88

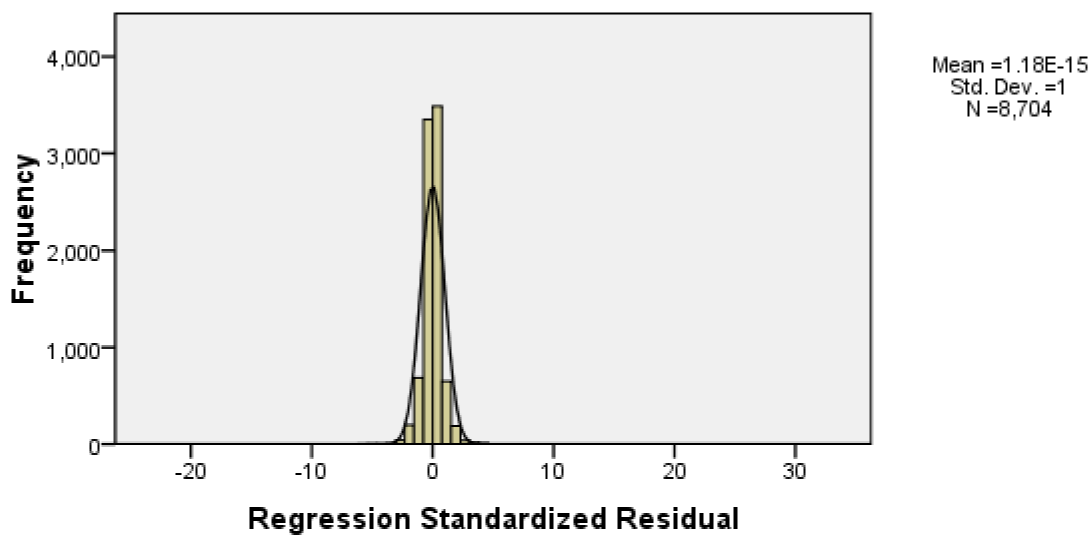
a. Dependent Variable: US441Flow

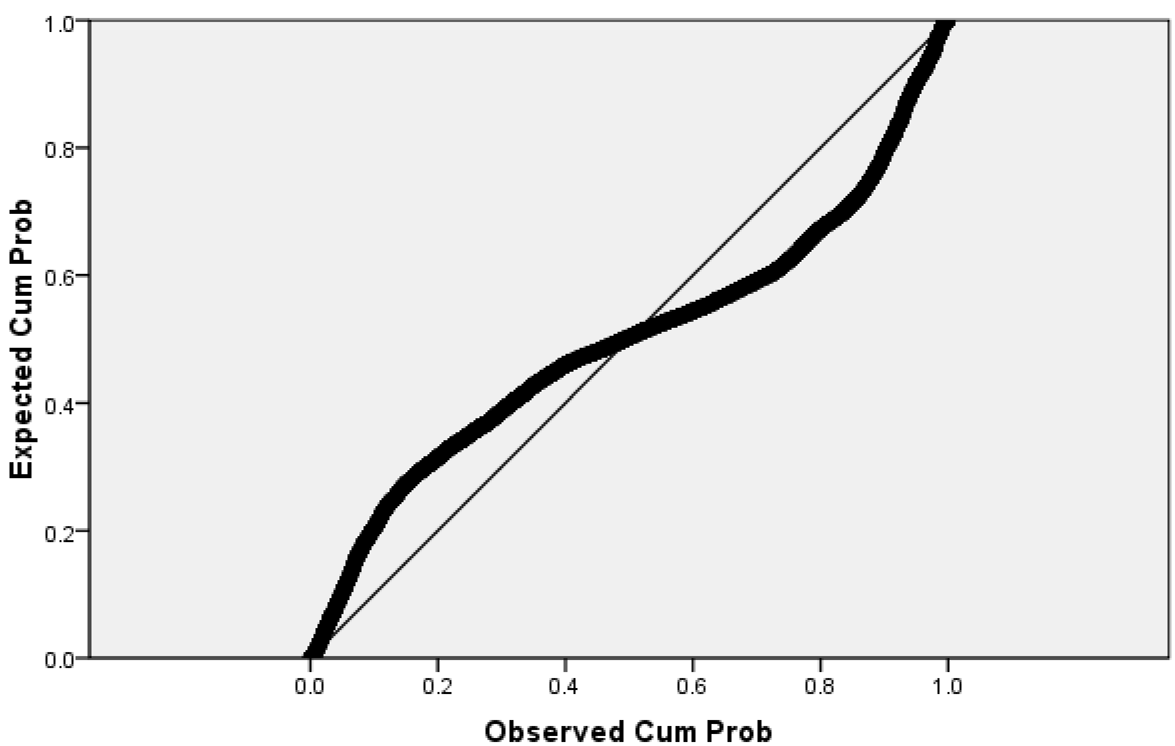
Residuals Statistics[a]

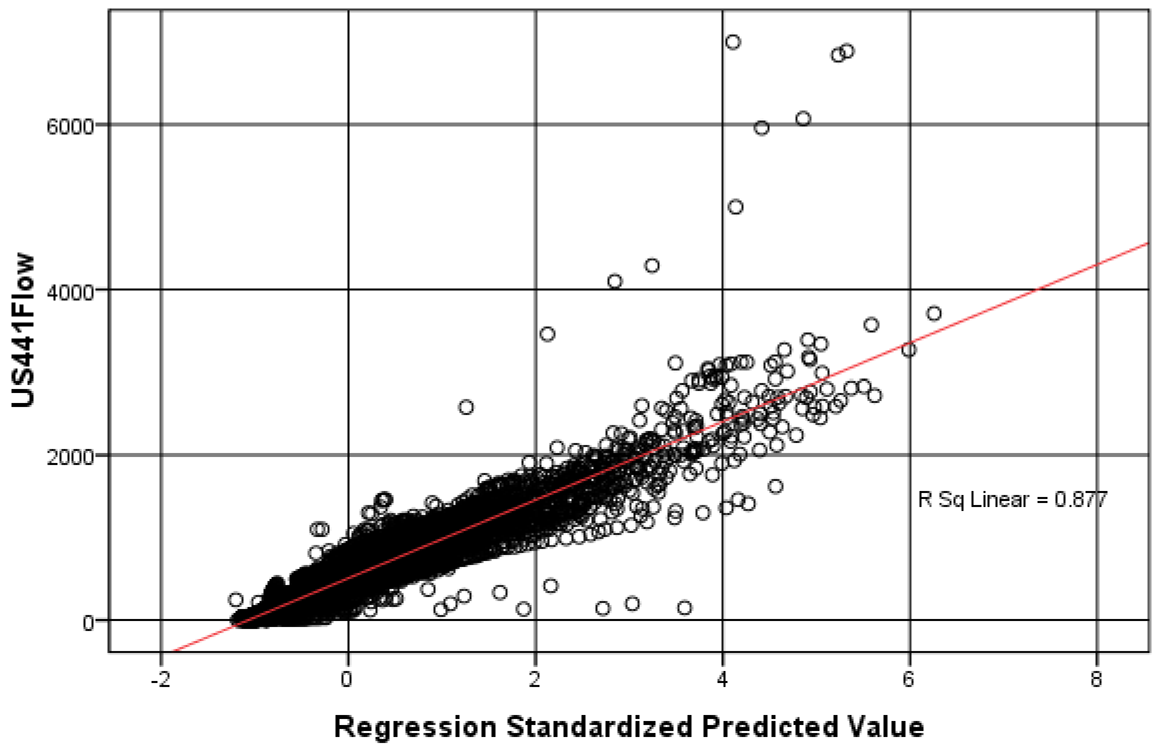
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-62.68	3476.49	508.22	474.363	8704
Residual	-2064.210	4542.860	.000	178.007	8704
Std. Predicted Value	-1.203	6.257	.000	1.000	8704
Std. Residual	-11.594	25.516	.000	1.000	8704

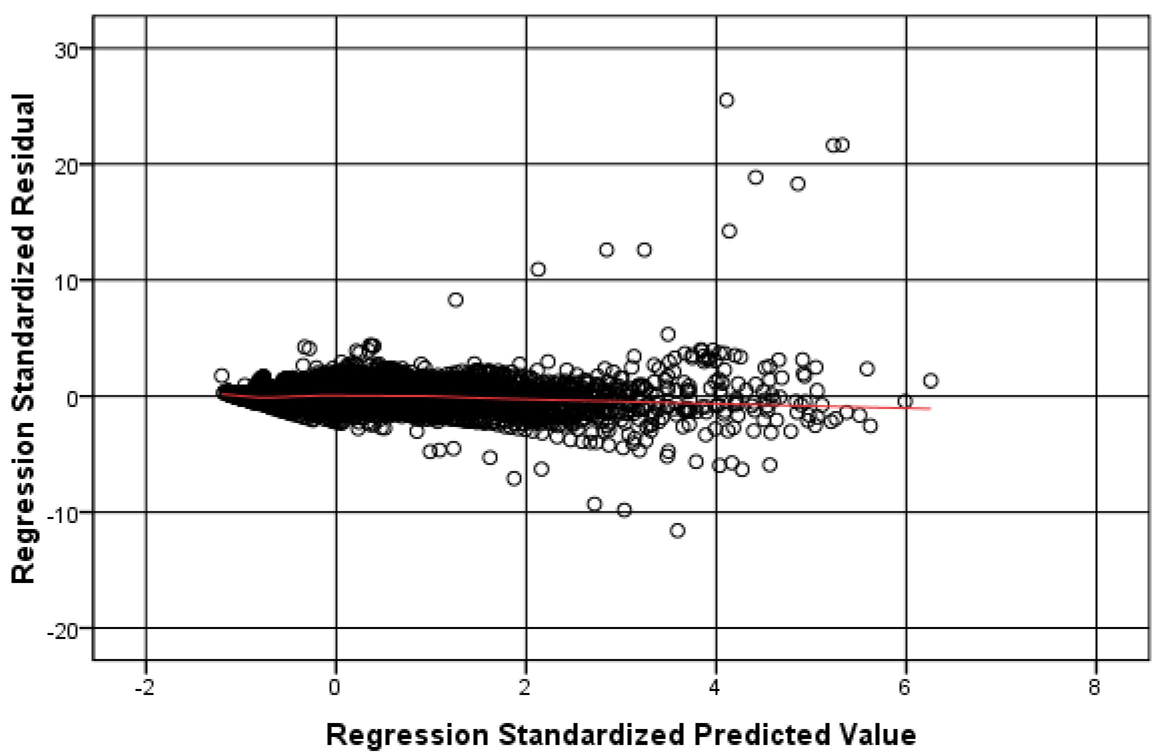
a. Dependent Variable: US441Flow

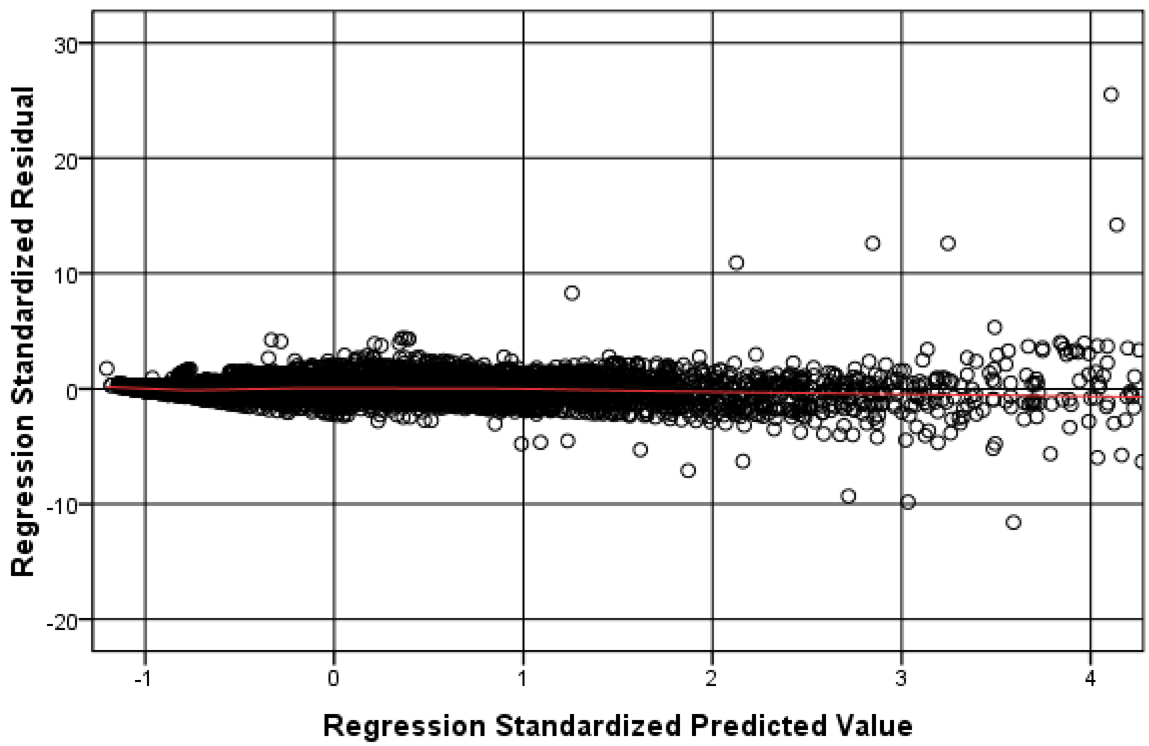
Dependent Variable: US441Flow






6000
4000
2000
0
-2
0
2
4
6
8
US441Flow
Regression Standardized Predicted Value
R Sq Linear = 0.877


30
20
10
0
-10
-20
-2
0
2
4
6
8
Regression Standardized Residual
Regression Standardized Predicted Value



30
20
10
0
-10
-20
Regression Standardized Residual
-1
0
1
2
3
4
Regression Standardized Predicted Value

Model 5 Quadratic Ft White, linear Worthington (lag3), All Ft White Data

Regression Model 5

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.927[a]	.859	.859	337.936	.859	53726.312	1	8853	.000	
2	.950[b]	.903	.903	279.788	.045	4063.155	1	8852	.000	
3	.951[c]	.904	.904	277.804	.001	127.927	1	8851	.000	.241

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, Lag3Worth

c. Predictors: (Constant), FtWhiteFlow, Lag3Worth, FtWhite2

d. Dependent Variable: US441Flow

ANOVA[d]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6.136E9	1	6.136E9	53726.312	.000[a]
	Residual	1.011E9	8853	114200.431		
	Total	7.147E9	8854			
2	Regression	6.454E9	2	3.227E9	41220.758	.000[b]
	Residual	6.929E8	8852	78281.401		
	Total	7.147E9	8854			
3	Regression	6.464E9	3	2.155E9	27917.184	.000[c]
	Residual	6.831E8	8851	77174.810		
	Total	7.147E9	8854			

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, Lag3Worth

c. Predictors: (Constant), FtWhiteFlow, Lag3Worth, FtWhite2

d. Dependent Variable: US441Flow

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-515.188	5.959		-86.457	.000		
	FtWhiteFlow	.887	.004	.927	231.789	.000	1.000	1.000
2	(Constant)	-268.134	6.274		-42.738	.000		
	FtWhiteFlow	.572	.006	.598	97.597	.000	.292	3.427
	Lag3Worth	.415	.007	.391	63.743	.000	.292	3.427
3	(Constant)	-324.394	7.972		-40.694	.000		
	FtWhiteFlow	.628	.008	.656	82.180	.000	.169	5.910
	Lag3Worth	.433	.007	.407	65.064	.000	.276	3.625
	FtWhite2	-8.039E-6	.000	-.082	-11.310	.000	.206	4.861

a. Dependent Variable: US441Flow

Excluded Variables[c]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	FtWhite2	.028[a]	3.298	.001	.035	.218	4.596	.218
	Lag3Worth	.391[a]	63.743	.000	.561	.292	3.427	.292
2	FtWhite2	-.082[b]	-11.310	.000	-.119	.206	4.861	.169

a. Predictors in the Model: (Constant), FtWhiteFlow

b. Predictors in the Model: (Constant), FtWhiteFlow, Lag3Worth

c. Dependent Variable: US441Flow

Collinearity Diagnostics[a]

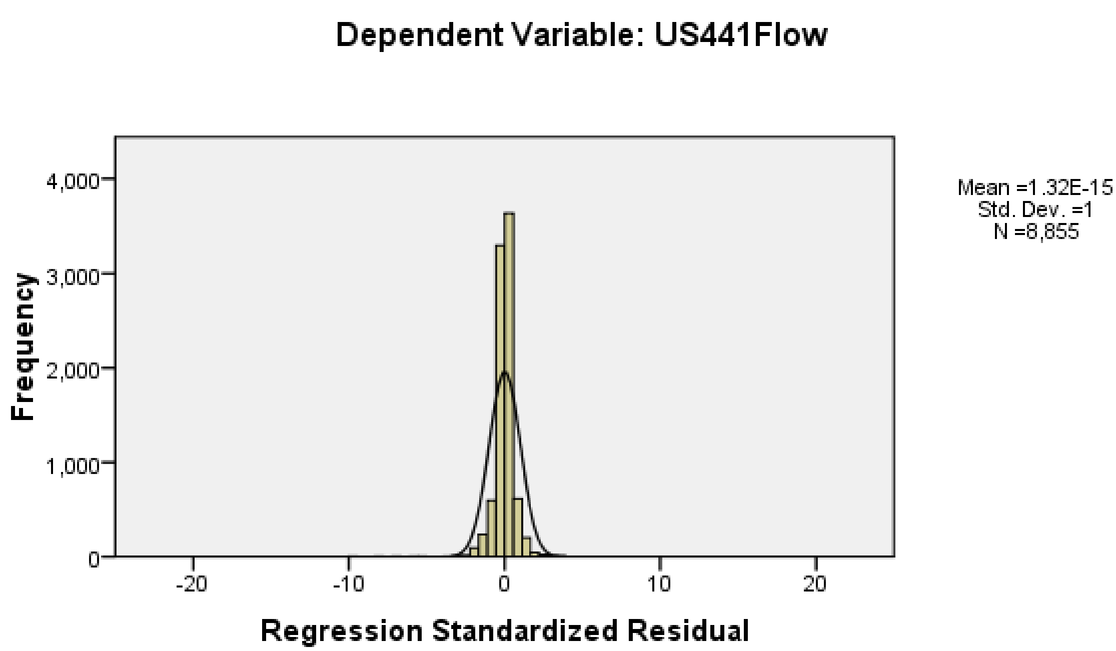
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	FtWhiteFlow	Lag3Worth	FtWhite2
1	1	1.798	1.000	.10	.10		
	2	.202	2.983	.90	.90		
2	1	2.316	1.000	.03	.02	.03	
	2	.621	1.931	.17	.00	.21	
	3	.063	6.058	.80	.98	.76	
3	1	2.906	1.000	.01	.01	.02	.02
	2	.878	1.819	.09	.00	.03	.06
	3	.177	4.056	.00	.00	.77	.44
	4	.039	8.668	.90	.99	.17	.48

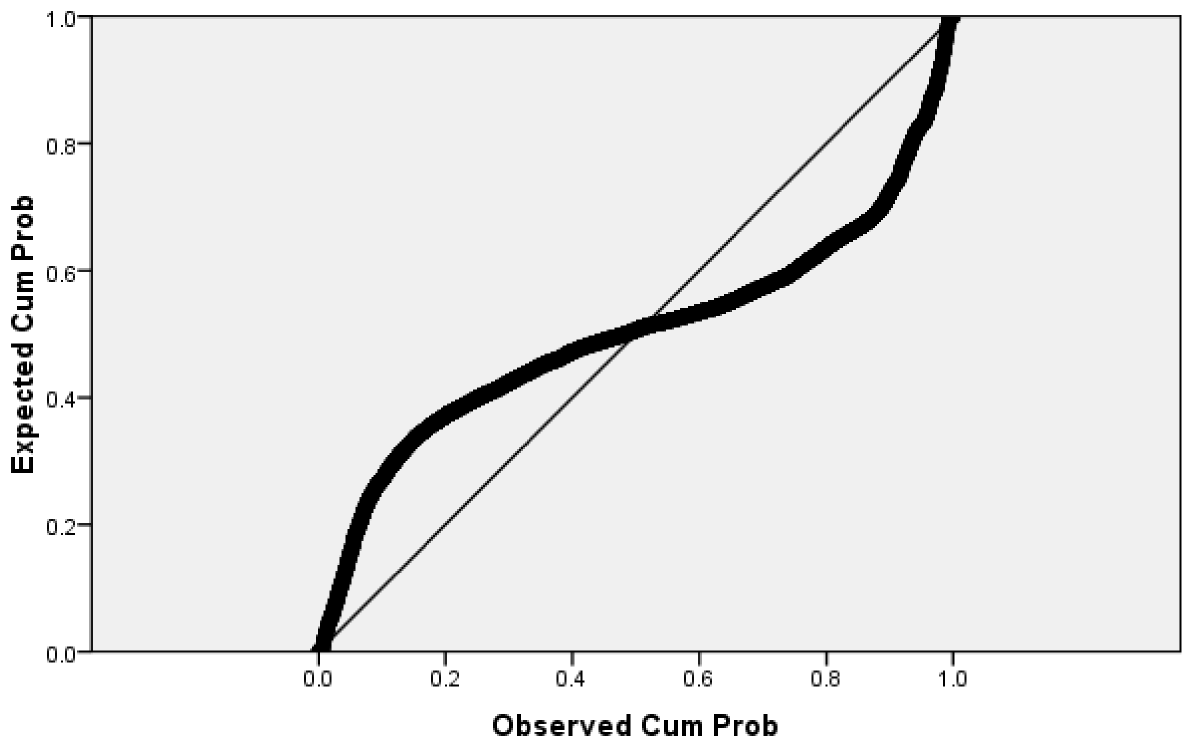
a. Dependent Variable: US441Flow

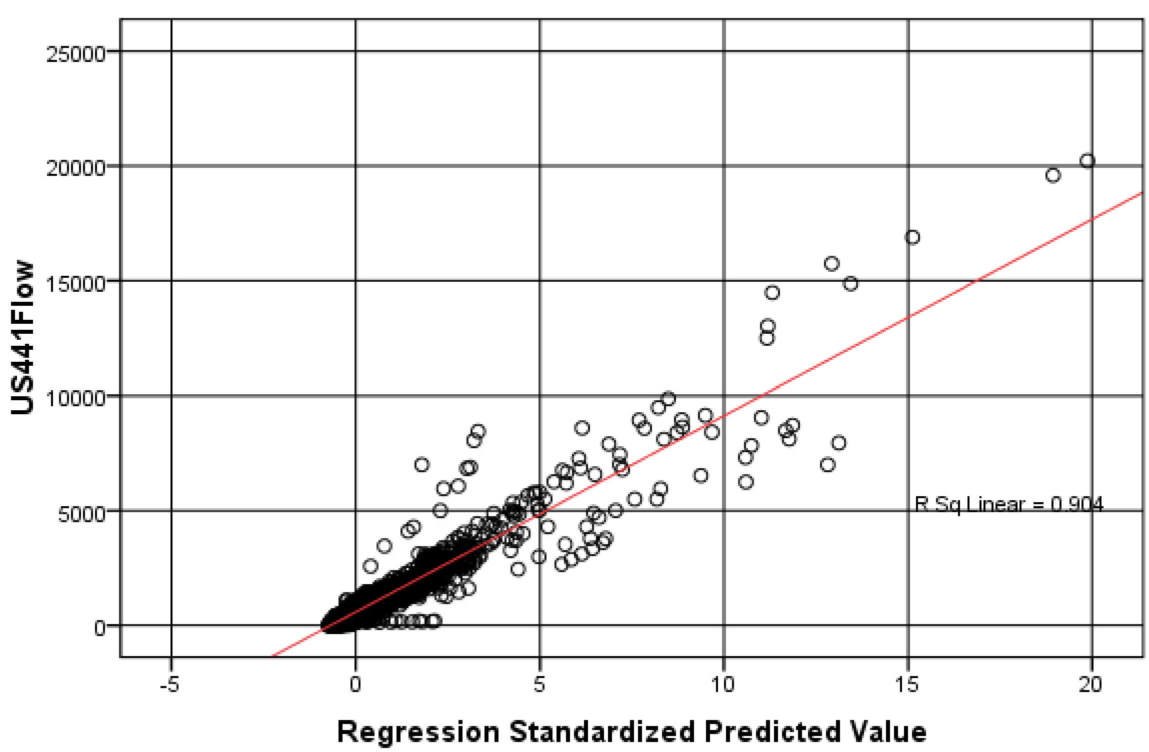
Residuals Statistics[a]

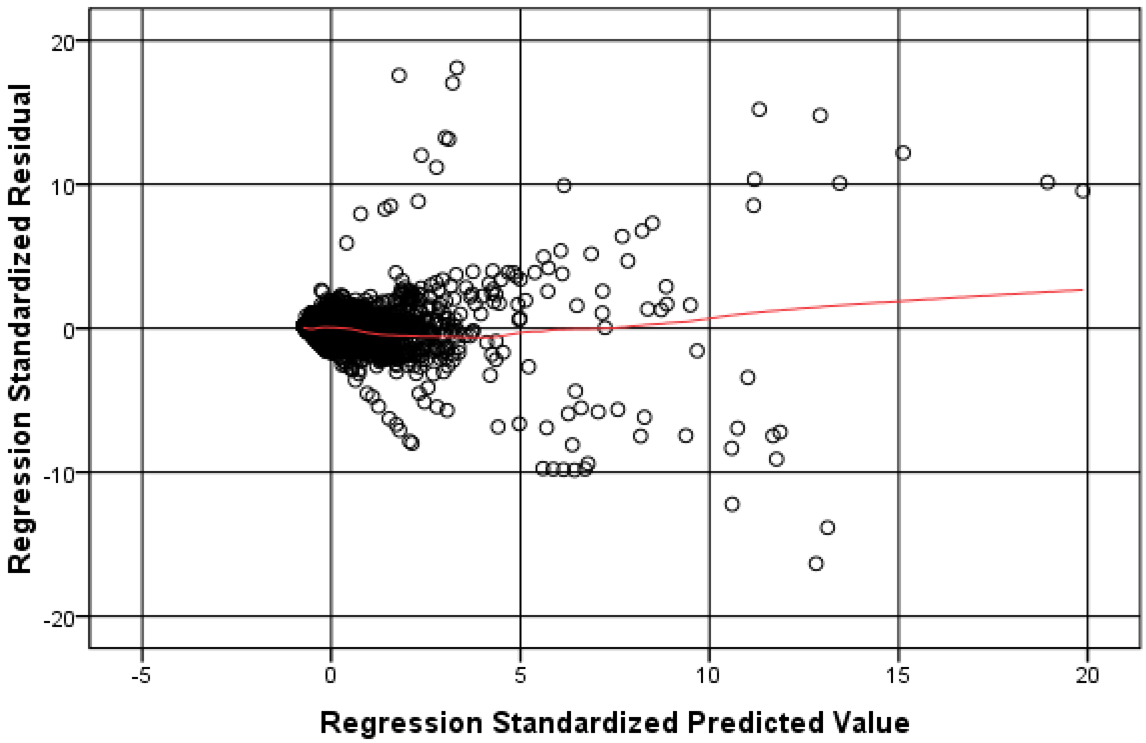
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-44.83	17569.03	587.00	854.406	8855
Residual	-4538.996	5026.955	.000	277.756	8855
Std. Predicted Value	-.740	19.876	.000	1.000	8855
Std. Residual	-16.339	18.095	.000	1.000	8855

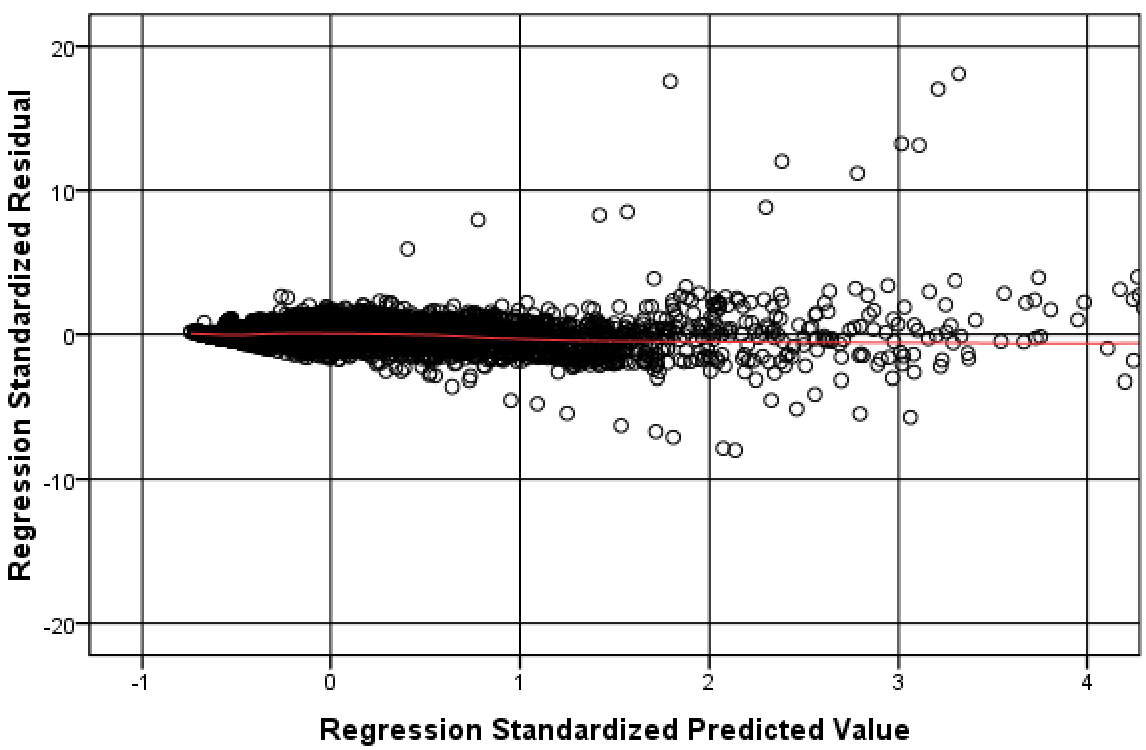
a. Dependent Variable: US441Flow




1.0
0.8
0.6
0.4
0.2
0.0
Expected Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0
Observed Cum Prob


25000
20000
15000
10000
5000
0
US441Flow
-5
0
5
10
15
20
Regression Standardized Predicted Value
R Sq Linear = 0.904


Regression Standardized Residual
Regression Standardized Predicted Value
20
10
0
-10
-20
-5
0
5
10
15
20


Regression Standardized Residual
Regression Standardized Predicted Value
20
10
0
-10
-20
-1
0
1
2
3
4

Model 6 Linear Ft White and Worthington (no lag)

Regression Model 6

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.925[a]	.856	.856	192.384	.856	51828.453	1	8705	.000	
2	.930[b]	.865	.865	186.516	.009	557.421	1	8704	.000	.189

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, WorthingtonFlow

c. Dependent Variable: US441Flow

ANOVA[c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.918E9	1	1.918E9	51828.453	.000[a]
	Residual	3.222E8	8705	37011.768		
	Total	2.240E9	8706			
2	Regression	1.938E9	2	9.688E8	27849.366	.000[b]
	Residual	3.028E8	8704	34788.122		
	Total	2.240E9	8706			

a. Predictors: (Constant), FtWhiteFlow

b. Predictors: (Constant), FtWhiteFlow, WorthingtonFlow

c. Dependent Variable: US441Flow

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-555.438	5.109		-108.723	.000		
	FtWhiteFlow	.924	.004	.925	227.659	.000	1.000	1.000
2	(Constant)	-503.689	5.416		-92.996	.000		
	FtWhiteFlow	.854	.005	.856	173.680	.000	.640	1.563
	WorthingtonFlow	.097	.004	.116	23.610	.000	.640	1.563

a. Dependent Variable: US441Flow

Excluded Variables[b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance	Collinearity Statistics VIF	Collinearity Statistics Minimum Tolerance
1	WorthingtonFlow	.116[a]	23.610	.000	.245	.640	1.563	.640

a. Predictors in the Model: (Constant), FtWhiteFlow

b. Dependent Variable: US441Flow

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	FtWhiteFlow	WorthingtonFlow
1	1	1.915	1.000	.04	.04	
	2	.085	4.745	.96	.96	
2	1	2.332	1.000	.02	.02	.05
	2	.608	1.958	.05	.01	.62
	3	.060	6.258	.93	.98	.33

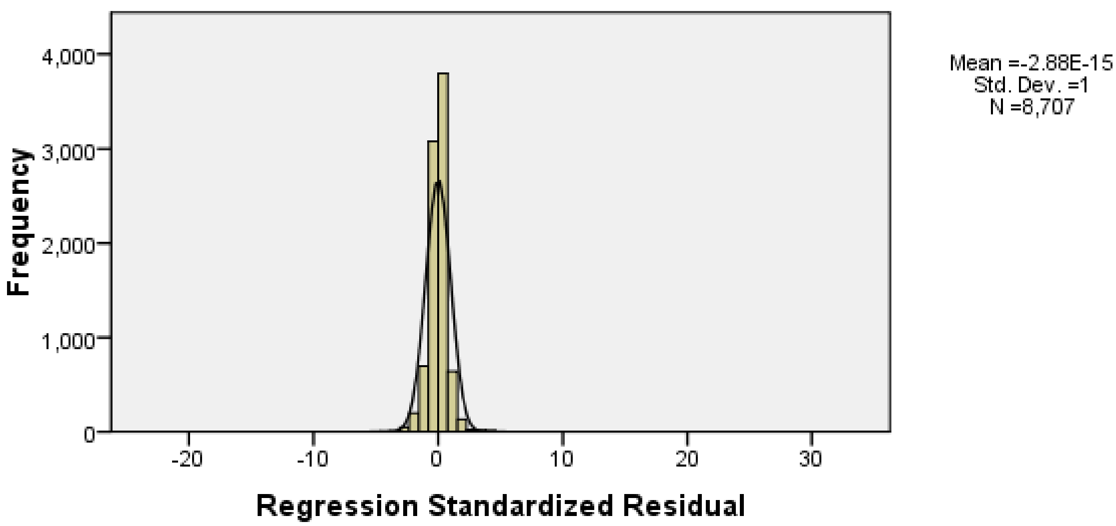
a. Dependent Variable: US441Flow

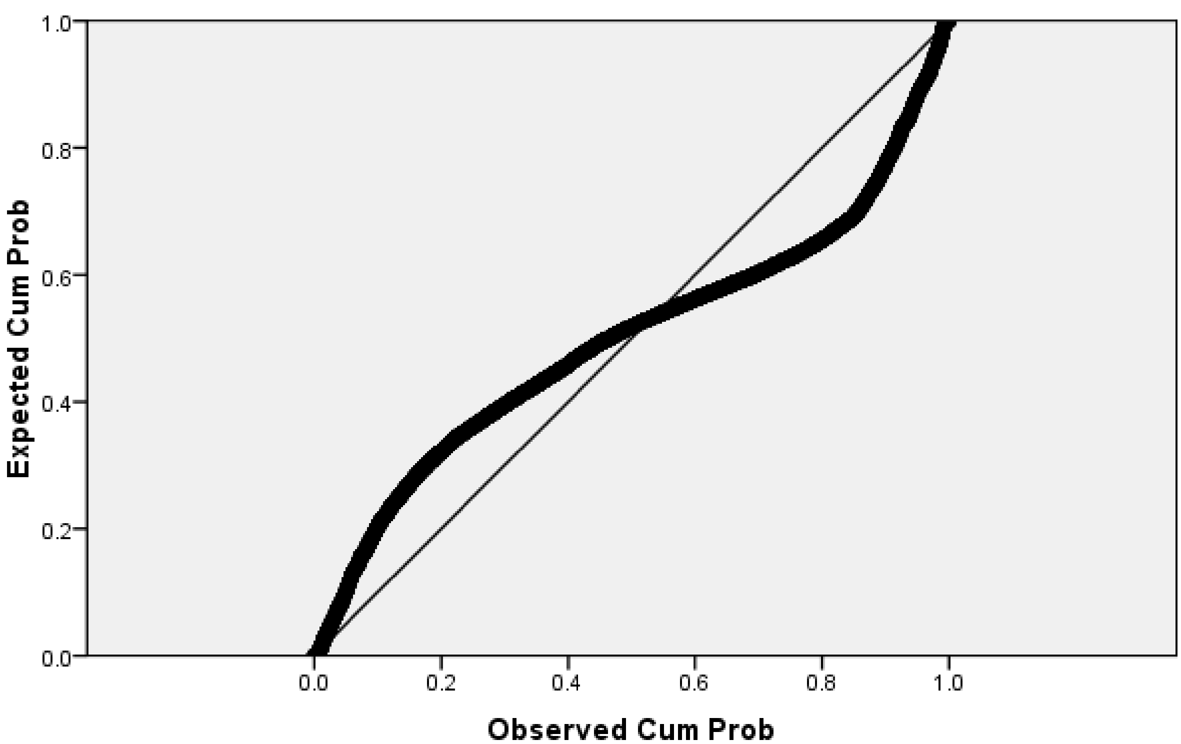
Residuals Statistics[a]

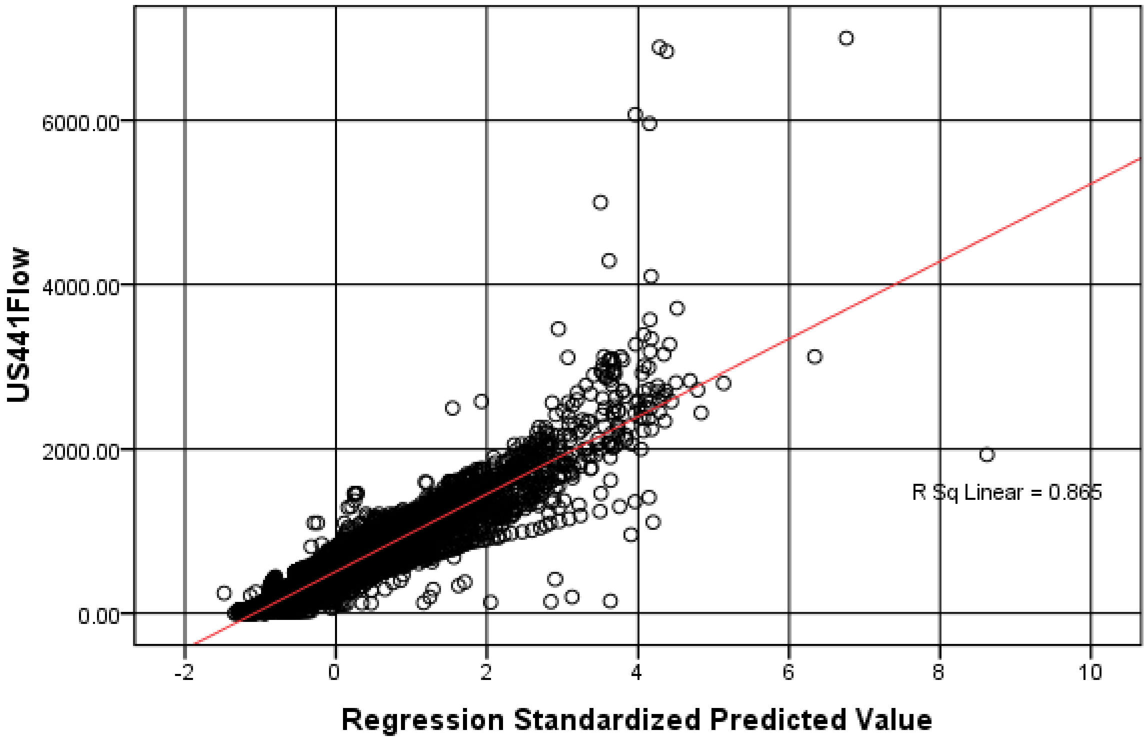
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-190.18	4576.27	508.70	471.768	8707
Residual	-2644.273	4361.791	.000	186.494	8707
Std. Predicted Value	-1.481	8.622	.000	1.000	8707
Std. Residual	-14.177	23.386	.000	1.000	8707

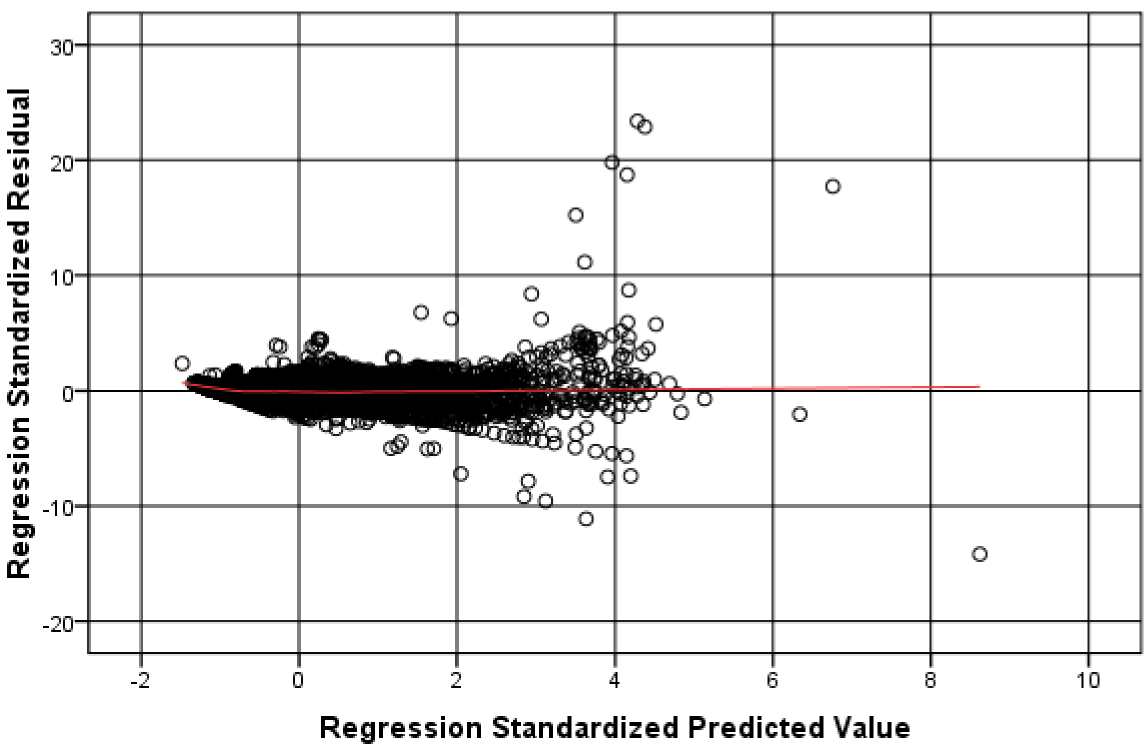
a. Dependent Variable: US441Flow

Dependent Variable: US441Flow






US441Flow
6000.00
4000.00
2000.00
0.00
-2
0
2
4
6
8
10
R Sq Linear = 0.865
Regression Standardized Predicted Value


Regression Standardized Residual
30
20
10
0
-10
-20
-2
0
2
4
6
8
10
Regression Standardized Predicted Value

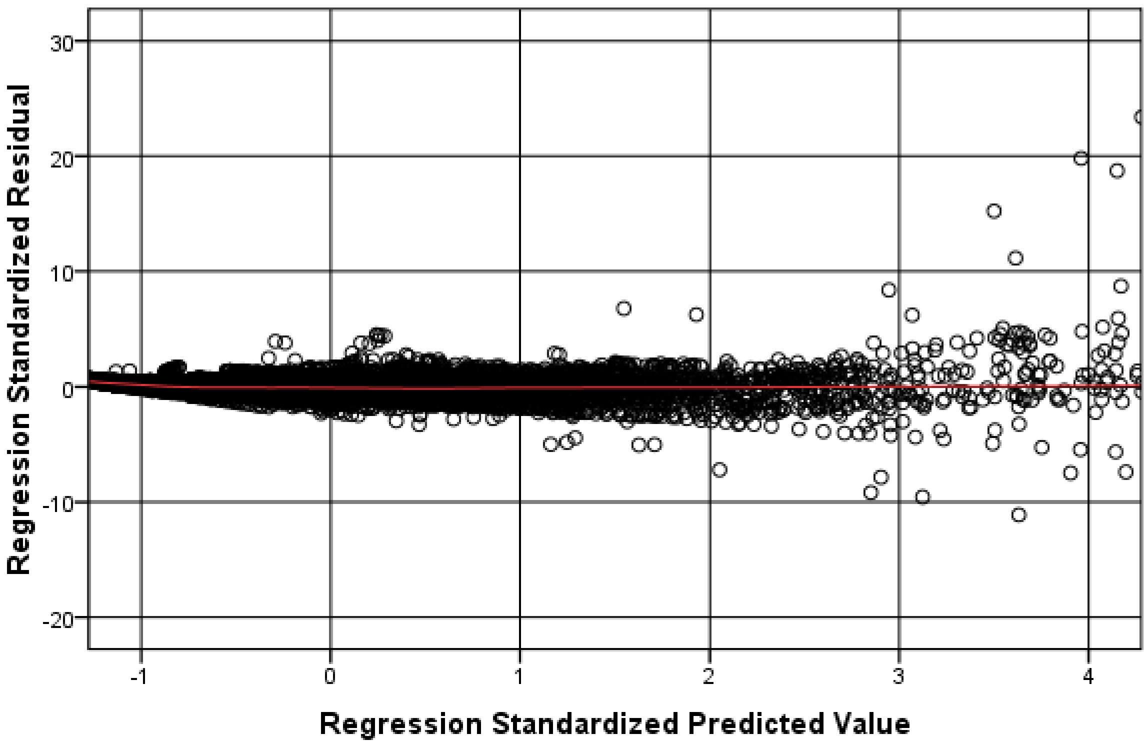

30
20
10
0
-10
-20
-1
0
1
2
3
4
Regression Standardized Residual
Regression Standardized Predicted Value

EXHIBIT C

US441 Piecewise Regression

INTRODUCTION

A piecewise linear regression model was evaluated for the US 441 gage to determine if an improved fit could be obtained for flows near zero. This equation is of the form:

US441_Q = b0*(FtWhite_Q<knot1)+ b1*(FtWhite_Q-knot1) * (FtWhite_Q>=knot1)+ b2*(FtWhite_Q-knot2) * (FtWhite_Q>=knot2) + b3*Worthington_Q_lag3 (Eq. 1)

Where:

- US441_Q = daily flow at Santa Fe River at the US Hwy 441 Near High Springs, FL. (02321975)
- Worthington_Q_lag3 = daily flow at Santa Fe River at Worthington Springs gage (02321500), lagged three days
- FtWhite_Q = daily flow at Santa Fe River at the Fort White gage (02322500)
- Knot1 and knot2 are inflection points for flow at Fort White where the linear form slope changes
- $b_{0,}$ $b_{1,}$ b_2 and b_3 are regression coefficients

Estimated model parameters were developed using the non-linear procedure in the statistical software SPSS (Version 16.0) and are included in Table AC 1 and Annex A. Selected exceedance flow estimates for the model period of record (POR) (1992-May 1, 2019) for the US 441 gage data and the piecewise model is included in Table AC 2.

The inflection values (knots) are only related to Fort White flow – flow at Worthington Springs is weighted by a constant coefficient (b3). For flows less than knot1 (559.4 cfs) the slope associated with flow at Fort White is zero. Between a flow of 559.4 cfs and knot2 (1479.9 cfs) the slope is 0.682, which means for every cfs increase in flow at Fort White, flow at US 441 increases by 0.682 cfs, plus the influence of flow at Worthington Springs. When flows at Fort White are greater than 1479.9, the slope decreases slightly from 0.682 by 0.142. For example, if flow at Fort White is less than 559.4 cfs (knot 1) and flow at Worthington Springs is zero, then flow at US441 is estimated to be zero. The small decline in slope at Fort White flows greater than about 1480 cfs likely is due some relative loss of water (i.e., decreased gain) between US 441 and Fort White under high hydraulic head in the river. The piecewise linear regression model is in good agreement with the data across a range of flows from zero to between 5% and 1% exceeded where it underestimates about 10 % (Table AC 2).

Confidence intervals

Confidence intervals (i.e., of the mean response flow at US441) were estimated around fitted values of the piecewise linear regression model using a standard error of the fit approach assuming normal residuals, and a bootstrapped approach to assess the influence of a non-normal distribution of residuals. The bootstrapped approach (1) randomly sampled model residuals with replacement (i.e., duplicates allowed), (2) added the resampled residuals to observed flow values at US441, and (3) refit the piecewise regression model 10,000 times. The fitted values (10,000 bootstrap replicates × 9,572 flow values) were used to estimate confidence intervals since they represent a random distribution of residuals that do not follow the original (non-normal) distribution of residuals. The bootstrapped confidence intervals were estimated as the lower 2.5% and upper 97.5% of residuals calculated for each flow value.

The resulting 95% confidence intervals not assuming a normal distribution of residuals (i.e., bootstrapped confidence intervals) were compared to the 95% confidence intervals assuming a normal distribution of residuals (i.e., non-bootstrapped confidence intervals). The widths of bootstrapped and non-bootstrapped confidence intervals are similar (Figure AC 1), with average widths of 12 cfs (bootstrapped) and 15 cfs (non-bootstrapped) and widths of approximately 9 cfs (bootstrapped) and 11 cfs (non-bootstrapped) around the median fitted value.

The similarity in confidence intervals follows the central limit theorem in that a random sample drawn from a sufficiently large sample, such as 9,572 flow values, will generate results that conform to a normal distribution. This applies here as the original large sample of flow values and the bootstrapped, random sample generated residuals evenly centered around fitted values, with minor deviations around that central point (like a normal distribution around the mean).

Table AC 1. Model (Eq. 1) parameter estimates for the US441 gage using a 2-knot piecewise linear regression

Parameter	Parameter Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
knot1	559.4	8.9	541.9	576.8
b1	0.682	0.013	0.656	0.708
knot2	1479.9	71.299	1340.2	1619.7
b2	-0.142	0.014	-0.169	-0.115
b3	0.425	0.006	0.412	0.437

Table AC 2. Estimated flow exceedances calculated using a 2-knot piecewise linear regression model for US441 compared to gaged flow for Water Years 1993-2019 (May 1, 2019)

Model/Exceedance	1	5	10	25	50	75	90	95	99
US441 gaged flow data	3701	1648	1212	696	356	133	33	0	0
Piecewise 2 knots	3347	1693	1191	695	352	148	33	7	0

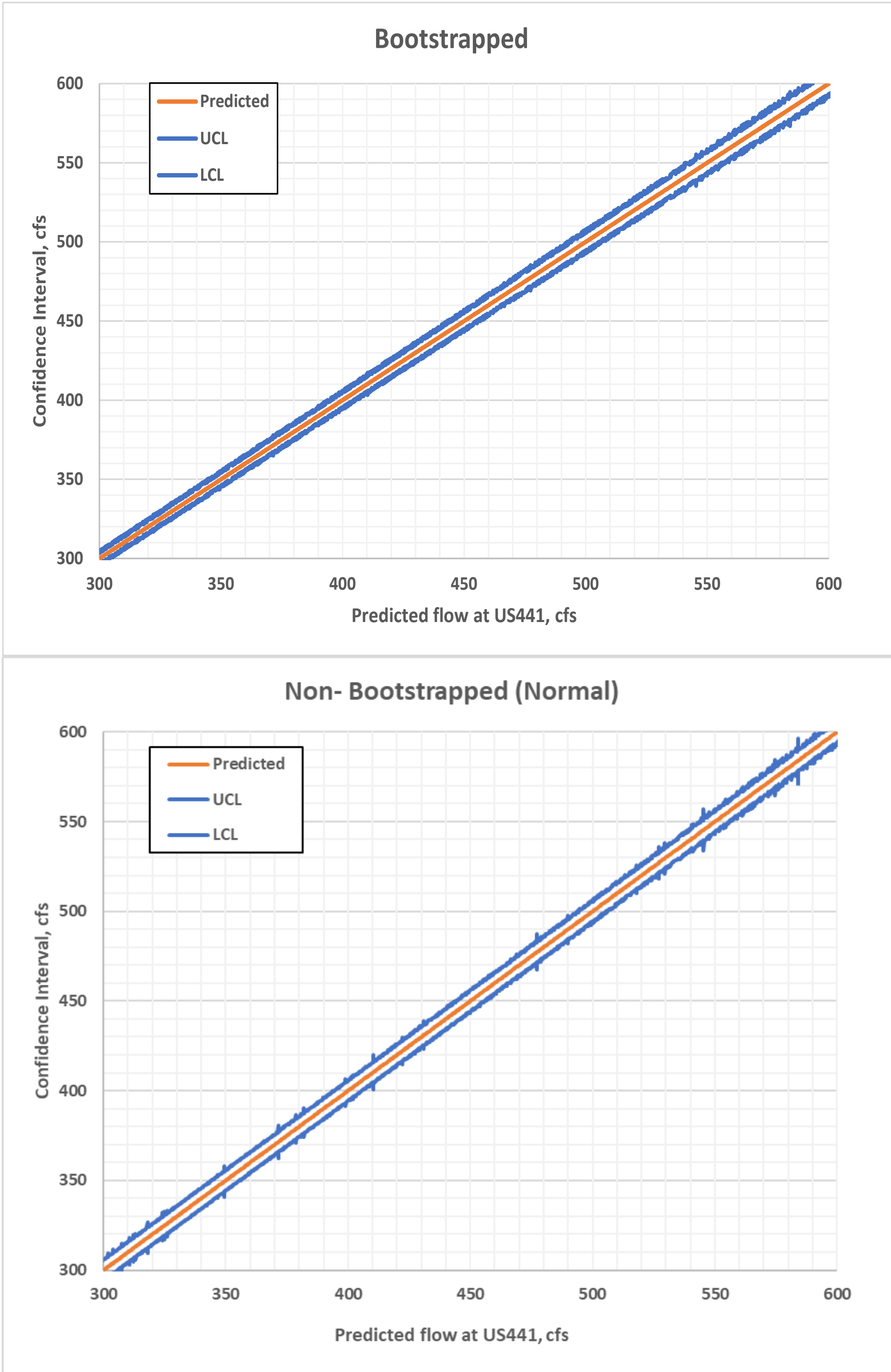


Figure AC 1. Bootstrapped and non-bootstrapped (normal distribution) confidence intervals around fitted values of the piecewise linear regression model output for the US441 gage.

Annex A

Nonlinear Regression Analysis (Model 2 Knots)

```
* Non-Linear Regression.
MODEL PROGRAM knot1=500 b1=.6 knot2=900 b2=0 b3=.4.
COMPUTE  PRED_=0*(FtWhite_Q<knot1)+ b1*(FtWhite_Q-knot1) * (FtWhite_Q>=knot1)+ b2*(FtWhite_Q-
knot2) * (FtWhite_Q>=knot2) + b3*Worthington_Q_lag3.
NLR US441_Q
/OUTFILE='C:\Users\kww\AppData\Local\Temp\spss193488\SPSSFNLR.TMP'
/PRED PRED
/SAVE PRED RESID
/CRITERIA SSCONVERGENCE 1E-8 PCON 1E-8.
```

Iteration History[b]

Iteration Number[a]	Residual Sum of Squares	Parameter				
		knot1	b1	knot2	b2	b3
1.0	7.029E8	500.000	.600	900.000	.000	.400
1.1	6.976E8	587.092	.797	900.000	-.236	.421
2.0	6.976E8	587.092	.797	900.000	-.236	.421
2.1	6.986E8	564.470	.668	1108.146	-.113	.422
2.2	6.986E8	564.470	.668	1108.146	-.113	.422
2.3	6.947E8	573.374	.712	1080.532	-.157	.422
3.0	6.947E8	573.374	.712	1080.532	-.157	.422
3.1	6.911E8	561.275	.681	1332.380	-.134	.424
4.0	6.911E8	561.275	.681	1332.380	-.134	.424
4.1	6.901E8	559.790	.682	1471.048	-.140	.425
5.0	6.901E8	559.790	.682	1471.048	-.140	.425
5.1	6.901E8	559.303	.682	1482.477	-.142	.425
6.0	6.901E8	559.303	.682	1482.477	-.142	.425
6.1	6.901E8	560.131	.684	1465.029	-.143	.425
6.2	6.901E8	559.466	.683	1472.498	-.142	.425
6.3	6.901E8	559.273	.682	1477.732	-.142	.425
7.0	6.901E8	559.273	.682	1477.732	-.142	.425
7.1	6.901E8	559.303	.682	1482.386	-.142	.425
7.2	6.901E8	559.316	.682	1478.952	-.142	.425
8.0	6.901E8	559.316	.682	1478.952	-.142	.425
8.1	6.901E8	559.353	.682	1481.605	-.142	.425
8.2	6.901E8	559.334	.682	1479.390	-.142	.425
9.0	6.901E8	559.334	.682	1479.390	-.142	.425
9.1	6.901E8	559.367	.682	1480.283	-.142	.425
9.2	6.901E8	559.346	.682	1479.668	-.142	.425
10.0	6.901E8	559.346	.682	1479.668	-.142	.425
10.1	6.901E8	559.367	.682	1480.232	-.142	.425
10.2	6.901E8	559.351	.682	1479.795	-.142	.425
11.0	6.901E8	559.351	.682	1479.795	-.142	.425
11.1	6.901E8	559.361	.682	1480.051	-.142	.425
11.2	6.901E8	559.356	.682	1479.918	-.142	.425

12.0	6.901E8	559.356	.682	1479.918	-.142	.425
12.1	6.901E8	559.365	.682	1480.165	-.142	.425
12.2	6.901E8	559.357	.682	1479.949	-.142	.425

Derivatives are calculated numerically.

a. Major iteration number is displayed to the left of the decimal, and minor iteration number is to the right of the decimal.

b. Run stopped after 34 model evaluations and 12 derivative evaluations because the relative reduction between successive residual sums of squares is at most SSCON = 1.00E-008.

Parameter Estimates

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
knot1	559.357	8.900	541.911	576.804
b1	.682	.013	.656	.708
knot2	1479.949	71.299	1340.188	1619.710
b2	-.142	.014	-.169	-.115
b3	.425	.006	.412	.437

Correlations of Parameter Estimates

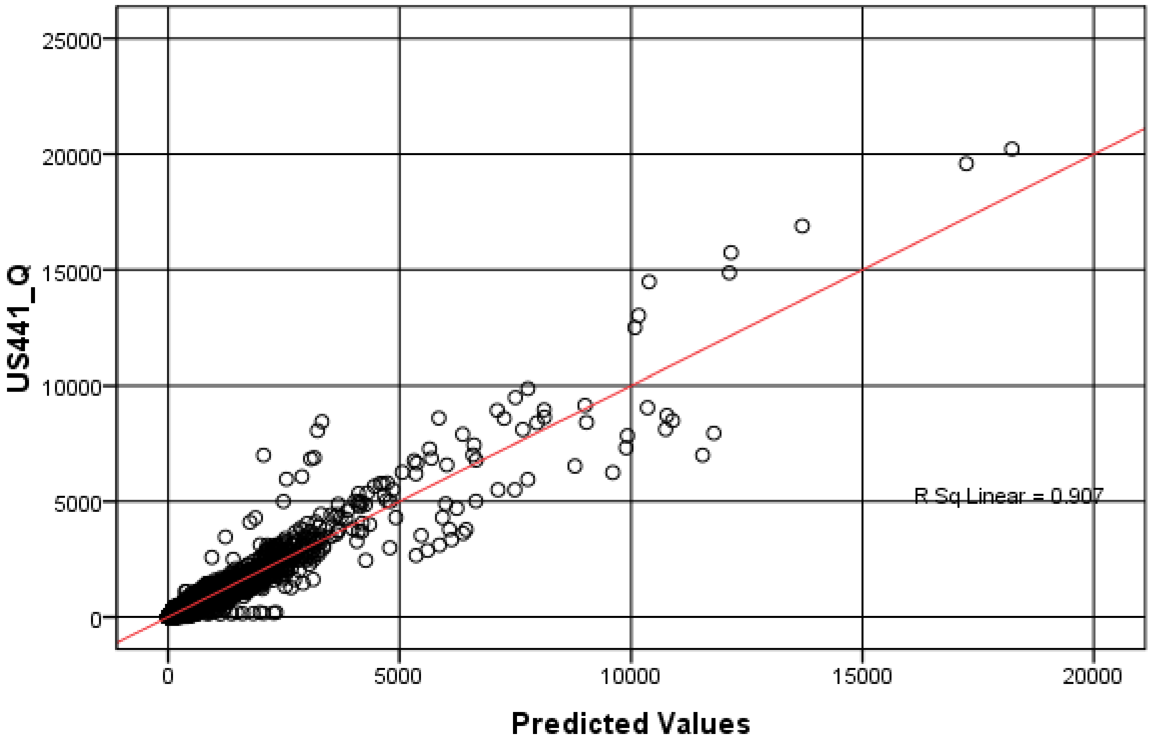
	knot1	b1	knot2	b2	b3
knot1	1.000	.837	-.393	-.788	-.029
b1	.837	1.000	-.642	-.885	-.189
knot2	-.393	-.642	1.000	.546	-.071
b2	-.788	-.885	.546	1.000	-.192
b3	-.029	-.189	-.071	-.192	1.000

ANOVA[a]

Source	Sum of Squares	df	Mean Squares
Regression	9.865E9	5	1.973E9
Residual	6.901E8	9567	72136.485
Uncorrected Total	1.056E10	9572	
Corrected Total	7.454E9	9571	

Dependent variable: US441_Q

a. R squared = 1 - (Residual Sum of Squares) / (Corrected Sum of Squares) = .907.


US441_Q
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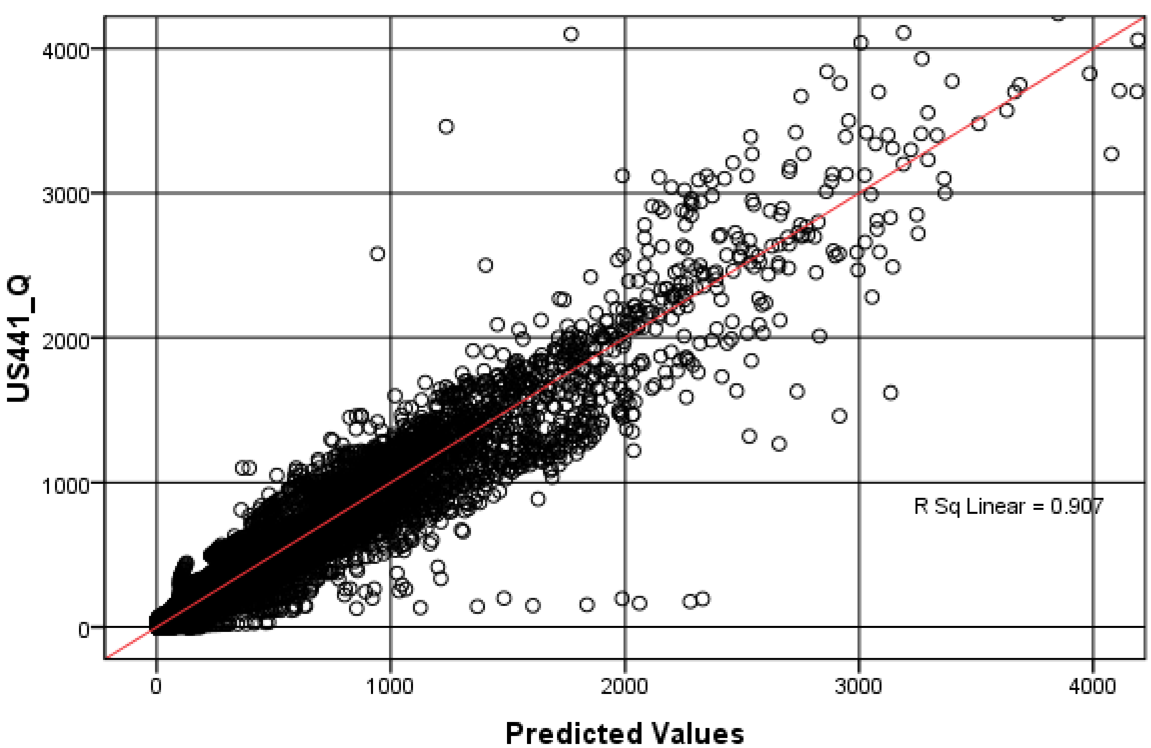
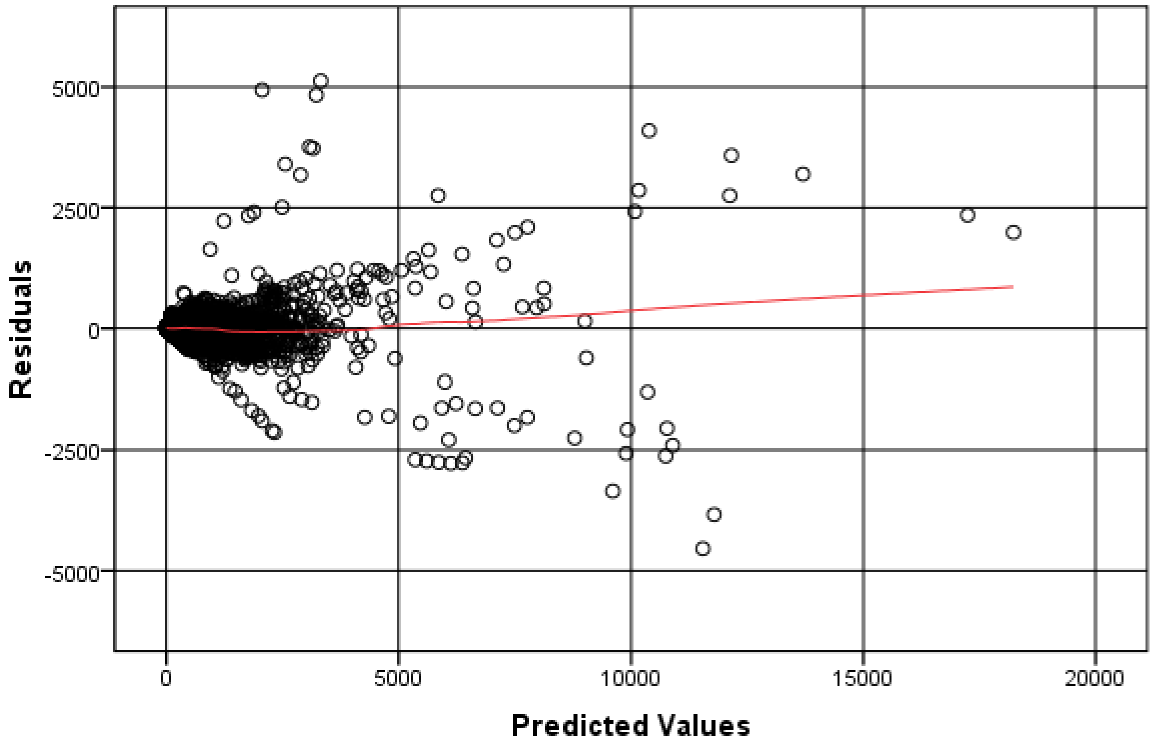
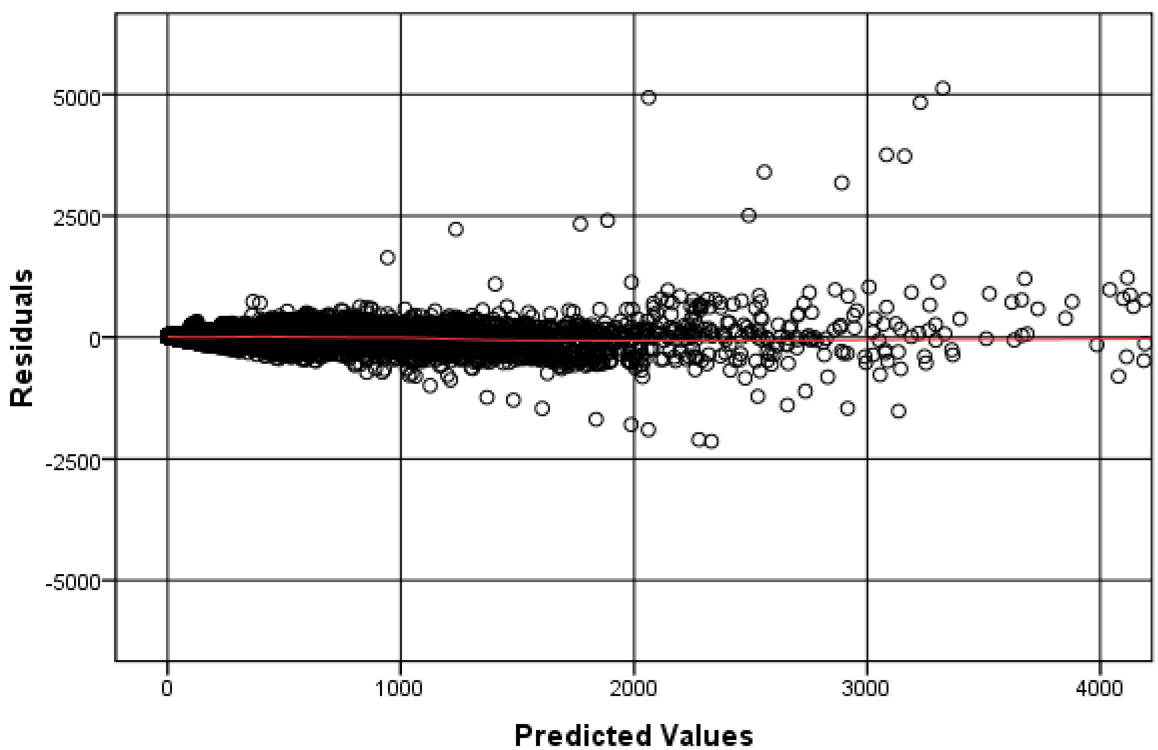
20000
15000
10000
5000
0
0
5000
10000
15000
20000
Predicted Values
R Sq Linear = 0.907


US441_Q
4000
3000
2000
1000
0
0
1000
2000
3000
4000
Predicted Values
R Sq Linear = 0.907


5000
2500
0
-2500
-5000
Residuals
0
5000
10000
15000
20000
Predicted Values


5000
2500
0
-2500
-5000
Residuals
0
1000
2000
3000
4000
Predicted Values

Attachment B

Environmental Flow Assessment Methods

CONTENTS

INTRODUCTION

In response to the Lower Santa Fe and Ichetucknee (LSFI) River Systems Peer Review Panel consensus report, Attachment B – Environmental Flow Assessment Methods was prepared. Attachment B specifically addresses Summary Comment Group #16 and a recommendation to "Update Science on Environmental Flows." Sections 2 and 3 below are largely excerpts of the final environmental flows report for an evaluation of approaches and tools which could be used in a new program for developing alternative flow regimes (*i.e.*, MFLs) that are protective of environmental, economic, and social uses of water (ARCADIS and HSW Engineering, 2019). Some of the language from the environmental flows report included in this Attachment was revised as needed to conform with the objective of the LSFI MFLs re-evaluation and Peer Review Panel comments regarding the science of environmental flows. Section 4 describes example applications of three different MFLs assessment methods.

Sound water planning recognizes environmental and socioeconomic values of water, and the need for associated management of water resources that appropriately balances these values (Loucks & Beek, 2017). The overarching premise when evaluating and setting environmental flows is that flow alteration is directly associated with a change in river services, both ecological (Poff & Zimmerman, 2010) and socioeconomic. Crucial to effective planning are methods for evaluating alternative water management strategies and formulating flow regimes that protect these values. These methodologies should be (1) sufficiently practical for potential application to the flow regimes of regulated and unregulated river basins and (2) robust and versatile for adaptation to changing conditions and social preferences following water plan implementation.

For purposes of the LFSI MFLs re-evaluation, methodology is defined as a system of methods, data and assumptions, or a set of procedures (methods); and protective flow regimes are hydrologic components of strategies for sustainable management of the LSFI River Systems for environmental and non-environmental uses.

METHODOLOGIES SUMMARY

Over the past 40 years, hundreds of studies and investigations have been conducted to develop and apply methods and approaches for environmental flow assessments (EFAs). Most begin with a brief review of relevant previous studies, though documents are periodically prepared summarizing previous studies in detail. In addition, organizations including the Nature Conservancy (https://www.conservationgateway.org/Pages/default.aspx) and the Instream Flow Council (https://www.instreamflowcouncil.org/) are excellent resources for EFA information. Many methodologies have been used worldwide for developing recommended environmental flow regimes. Most of these methodologies have been reviewed extensively and typically grouped into four distinct categories

(Linnansaari, Monk, Baird, & Curry, 2012) and (Tharme R. E., 2003), namely:

- Hydrological
- Hydraulic rating
- Habitat simulation
- Holistic

These four categories of methodologies reflect the evolution in thinking and planning for protective flow regimes. The scope of work associated with utilizing these methods ranges from reconnaissance-level hydrological investigations to more detailed field and modeling investigations. Considering assessment duration, effort, and scale, each category has its own advantages and disadvantages. Hydrological and hydraulic methods are generally less resource-intensive, and habitat simulation and holistic methods are more resource-intensive and time-consuming (Figure B 1). Hydraulic and habitat simulation methods are typically applied to individual sites or river segments, whereas hydrological and holistic methods may be applied on whole river or regional scales (Table B 1).

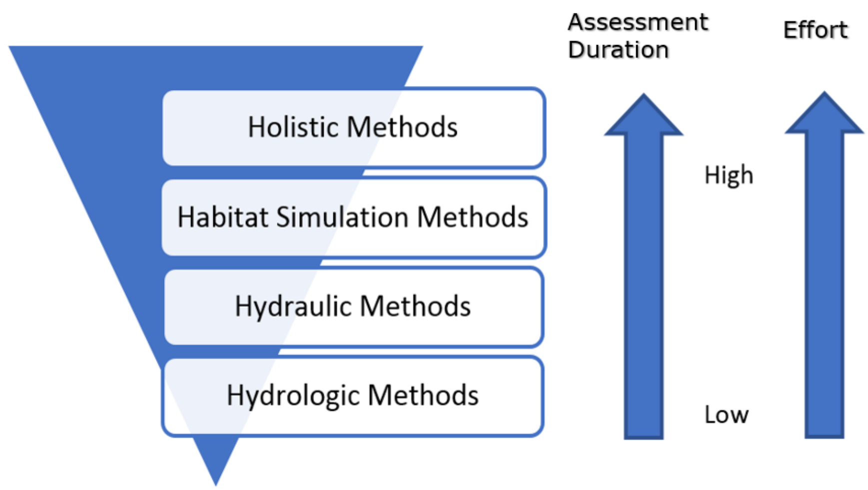


Figure B 1. Environmental flow methodologies comparison
[Blue triangle is a qualitative indicator of the breadth of the method application]

Table B 1. Comparison of methodologies for assessing environmental flows

Method Category	Purpose	Scale
Hydrological	Assessment of flow data to define “safe” thresholds for flow reduction	Whole rivers, applicable for regional assessments
Hydraulic rating	Assessment of change in a hydraulic variable (e.g., wetted perimeter as proxy for habitat) as a function of flow	Applied at a study site/river segment scale; upscaling to whole river based on “representative site” assumption
Habitat simulation	Assessment of change in physical habitat for a selected set of target species as a function of flow	Applied at a study site/river segment scale; upscaling to whole river based on “representative site” assumption
Holistic	Assessment of flows using a variety of tools that are evaluated in an expert opinion workshop; flows are recommended for all components of the riverine ecosystem (e.g., recreational and economic)	Whole rivers, applicable for regional or river-specific scales

Environmental flow assessment methodologies have evolved over time from simple to more comprehensive methods. Today, application of environmental flow methodologies is often hierarchical, with at least two stages to the framework (Tharme R. E., 2003) as follows:

- Reconnaissance-level assessment (using hydrological or hydraulic methodologies)
- Comprehensive assessment (adding habitat simulation or holistic methodologies)

Key features of four categories of environmental flow assessment methodology examples (ARCADIS and HSW Engineering, 2019) are summarized in Table B 2 at the end of this section.

A recently published compendium covers multiple aspects of environmental water management as a multidisciplinary practice (Horne, Webb, Stewardson, Richter, & Acreman, 2017). Current challenges and potential solutions are highlighted to help define the future direction for environmental water management. Section IV (How Much Water Is Needed: Tools for Environmental Flows Assessment) includes the following four chapters that describe various means for assessing MFLs:

15. Evolution of Environmental Flows Assessment Science, Principles, and Methodologies
16. Tools for Sediment Management in Rivers
17. Physical Habitat Modeling and Ecohydrological Tools
18. Models of Ecological Responses to Flow Regime Change to Inform Environmental Flows Assessment

While the book includes a substantive review of current literature and state of knowledge, it does not expand the means for assessing MFLs that are not known to the District's MFLs assessment team or already incorporated in the Draft MFLs Re-evaluation Report. Absent from the book is any reference to Florida's MFLs and water reservation programs and associated rules that have been adopted during the past several decades and the ongoing adaptive water resource planning and management programs implemented by the State's five water management districts. In contrast, Florida's MFLs statute is one of four case studies selected for detailed review and documentation after a world-wide search for leaders in incorporating Environmental Flow Needs (EFNs) into water policy and management tools (Harwood, Girard, Johnson, Locke, & Hatfield, 2014).

HYDROLOGICAL METHODOLOGIES

Hydrological, hydraulic rating, and habitat simulation methodologies have a more restrictive scope in comparison to the more comprehensive nature of holistic methods. Hydrological methodologies are the simplest and least expensive, predominantly based on desktop studies. These methods rely on historical monthly or daily flow records for determining environmental flow recommendations (Tharme R. E., 2003), using flow as an indicator of ecological and biological functions. They are often referred to as prescriptive methods, in which flow requirements to maintain fish habitat, other ecological features, or river health are defined as a minimum value or a proportion of annual, seasonal, or monthly flow. They can be divided into two types: (1) standard-setting methods, using a single fixed rule for minimum flow over different time periods (month, season, year), and (2) range-of-variability methods, which statistically characterize a flow regime with indices and flow targets set as percentages of flow or ranges of variation of the indices.

Although designed to protect some ecological components of the river, both types have been criticized for not accurately representing nor fully protecting ecological values (Linnansaari, Monk, Baird, & Curry, 2012). Hydrological methodologies are also used to evaluate duration and frequency of ecologically important hydrologic events.

HYDRAULIC RATING METHODOLOGIES

Hydraulic rating methodologies are based on relationships between flow regime and hydraulic parameters and channel geometry of a river, e.g., wetted perimeter or depth measured across a single location where habitat is limiting the target biota (Jowett J. , 1997). Hydraulic parameters are surrogates for instream habitat factors that potentially limit target species. Hydraulic rating methods select a threshold in the hydraulic parameter, below which habitat is potentially degraded, to define the limiting flow. These methods are recommended when historical flow records are sparse and can be used in conjunction with hydrological methods.

HABITAT SIMULATION METHODOLOGIES

Habitat simulation methodologies are an extension of hydraulic rating methods. Flow requirements are based on hydraulic parameters important to the habitat requirements of pre-selected target species (or species guild), and these methods do not rely on single hydraulic parameters and thresholds. These methods measure the quantity and quality of habitat available (e.g., weighted usable area) under different flow regimes. Habitat simulation methods are more accurate and flexible than hydrological/hydraulic rating methods, but they require additional fieldwork and are more expensive to develop. Microhabitat simulation methods determine flow requirements in consideration of relationships between local hydraulic conditions (e.g., depth, velocity) and habitat suitability for the target biota (Bovee, et al., 1998).

Habitat simulation methodologies involve quantification of habitat variables using field-collected data (depth, velocity, cover, substrate) from multiple cross-sections along a stream (Tharme R. , 1996). Hydraulic and hydrological models combined with microhabitat models can predict the amount of suitable habitat area available over time under various flow regimes, using field data to calibrate the models. Mesohabitat simulation methodologies map habitat types in stream reaches and consider water quality and temperature as well as physical habitat characteristics (depth, velocity, cover, substrate).

The System for Environmental Flow Analysis (SEFA) program (Aquatic Habitat Analysts, Inc., 2012), a component of the Instream Flow Incremental Methodology (IFIM), comprises a set of tools for a more holistic approach to habitat simulation, incorporating micro- or mesohabitat modeling, analysis of limiting habitats by life stage, and creation of habitat time series using alternative flow regimes to evaluate and negotiate among competing uses. Habitat simulation methodologies such as SEFA do not evaluate effects to study organism populations – only habitat available for use. Bioenergetic models simulate habitat but address populations more directly by predicting spatial distribution of fish in streams based on food availability and energy required to maintain the foraging position (Linnansaari, Monk, Baird, & Curry, 2012). Population and bioenergetic models typically focus on quantifying effects of inputs other than flows and levels. Changes in habitat availability that support ecosystems and not just selected species remain the standard for environmental flows evaluations.

HOLISTIC METHODOLOGIES

Holistic methodologies are based on the premise that spatial and temporal variability of a modified flow regime should be similar to the historical flow regime to sustain stream morphology, habitats, and diversity of organisms and their interactions, and to ensure the stream's ecological integrity (Arthington A. , 1998). These methods account for many flow-dependent ecosystem needs, and by 2003 many holistic methodologies were well-established (Tharme R. E., 2003). Assessments of this kind may take years to complete for a single river or reach of a larger river system. Holistic methodologies can be abbreviated by incorporating expert panels to efficiently evaluate existing data. Holistic flow assessments have evolved and expanded in scope, from focusing on the needs of fish to sustaining ecosystems and the livelihoods and well-being of stakeholders who depend on them.

Holistic methodologies (e.g., IFIM, Building Block Method [BBM], Downstream Response to Imposed Flow Transportation [DRIFT], Ecological Limits of Hydrologic Alteration [ELOHA] and associated Savannah Process) that integrate social, cultural, and economic values within ecosystem protection goals are considered to have several advantages over other methodologies (Linnansaari, Monk, Baird, & Curry, 2012) and (Kendy, Apse, & Blann, 2012). One advantage is that holistic methodologies provide a scientific framework for developing environmental flow guidelines at a regional scale and involve sharing of common approaches to achieve and maintain ecological sustainability. Holistic methodologies engage stakeholders in negotiations, or other decision-making processes, to develop alternative flow regimes that are protective of environmental, economic, and societal uses of water.

A holistic methodology such as ELOHA is applicable and scalable with modifications to rivers and water bodies throughout Florida and can provide meaningful performance measures that support regional water planning and management programs. ELOHA is adaptable to classes of rivers and streams. It is a top-down approach that starts with evaluating modifications relative to unaltered flows. The approach is more conservative than a bottom-up approach that requires knowledge of important river functions in advance, whereas some important functions may be unknown. Finally, it allows development of an integrated multipurpose river system analysis as a decision-support tool.

Table B 2. Summary of representative methodologies for assessing environmental flows

Method Category	Method	Comments	References
Hydrological/ desktop methods (rely on historical or synthetic flow data)	Tennant	• Developed specifically for needs of fish in low-gradient streams (slope < 1%) • Uses hydraulic data from transects and data on streams generally north of Mason-Dixon line and east of Rocky Mountains combined with subjective assessments of habitat quality to define habitat suitability versus flow relationships • Assumes that a proportion of mean flow is needed for healthy stream environment (e.g., 25-30% in Canada) • Average depth of 0.3 meters (m) and velocity of 0.25 meters per second (m/s) are considered to the lower limit for short-term survival and an average depth of 0.45 to 0.6 m and velocities of 0.45 to 0.6 m/s to be optimal for fish. These levels were obtained at 10% and 30% of the mean annual discharge respectively, in the streams studied by Tennant. • Single hydrological statistic • Limited or no fieldwork required • Applied in many countries (Reiser, Wesche, & Estes, 1989) • No consideration of seasonal variation and species lifecycle requirements • Not applicable to LSFI River Systems	(Tennant, Instream Flow Regimes for Fish, Wildlife, Recreation and Related Environmental Resources, 1975)
	Tessman Rule	• Considers natural variations in monthly flow • Flow requirements for each month ○ MMF (Mean Monthly Flow), if MMF < 40% MAF (Mean Annual Flow) ○ 40% of MAF, if 40% MAF<MMF<MAF; and, ○ 40% MMF, if MMF>MAF ○ 200% of MAF is required during the month of highest flow for channel maintenance • Widely applied to regions with different hydrological and biological cycles • Applicable to LSFI River Systems	(Tessman, 1980)
	The British Columbia (BC))- Instream Flow Threshold	• Requires an assessment of fish presence or absence and adequate daily time series data (≥ 20 years) • Two thresholds are recommended ○ **Streams without fish** - a minimum flow release equivalent to the median monthly flow during low-flow months ○ **Streams with fish** - a seasonally adjusted threshold calculated as percentiles of mean daily flows for each month (e.g., 20% during the month of highest median flow and 90% during the month of lowest median flow) • Applicable to LSFI River Systems	(Hatfield, Lewis, Olson, & Bradford, 2003)

Method Category	Method	Comments	References
Hydrological/ desktop methods – Cont'd	Alberta Desktop	• Objective is full protection of the riverine environment, in the absence of site-specific studies • Recommends 15% instantaneous reduction from unaltered flow, or the lesser of either the flow or the 80% exceedance flow • Recommended flows do not consider stream size/type (Hatfield, Wright, Buchanan, & Faulkner, 2013) • Applicable to LSFI River Systems	(Locke & Paul, 2011)
	Flow index	• 7Q10 (lowest flow recorded for 7 consecutive days within a 10-year return period) is a commonly low flow index used worldwide. It was originally developed for protection of water quality from wastewater discharges. • Other low flow indices used worldwide – 7Q1, 7Q2, 7Q5, 7Q20, and 7Q25 • Instream Flow Council and many other studies have opined that most of the low-flow indices could have adverse effects on biological habitats due to lack of scientific basis behind the indices (Annear, Chisholm, Beecher, Locke, & Wentworth, 2004) (Caissie & El-Jabi, 1995) • Applicable to LSFI River Systems	(Pyrce, 2004)
	Indicators of Hydrologic Alteration (IHA)	• Free software available from The Nature Conservancy • Evaluates many ecologically important hydrological parameters aggregated into five main attributes of hydrological variability (amplitude, duration, frequency, and timing) • Facilitates comparison of baseline and impacted flow scenarios • Is a type of presumptive standard • Applicable to LSFI River Systems	(Richter B. , Baumgartner, Powell, & Braun, 1996)
	Presumptive Standard	• A tiered set of standards based on percent of flow and risk tolerance • < 10% – high level of protection, low risk • 10-20% – moderate level of protection, moderate risk • < 20% – low protection, high risk • Applicable to LSFI River Systems	(Richter, Davis, Apse, & Konrad, 2011)
Hydraulic rating methods (rely on hydrological, river channel, and floodplain geometric data)	Wetted perimeter	• Developed for Montana streams but applied in Florida • Focuses on protection of aquatic invertebrate habitat, which occurs in riffle areas • Multiple wetted perimeter-discharge relationships needed within study reach • Deeper, lower velocity pools are not considered • Applicable to LSFI River Systems	(Gopal, 2016)
	Riffle analysis	• Water depth is measured at multiple locations across the riffle's shallowest cross-section • Species-specific and life stage-specific water depth criteria are needed to determine the percent total and percent contiguous proportion of the critical riffle width that satisfies the criteria • Locally applicable to LSFI River Systems	(California Department of Fish and Game, 2012)

Method Category	Method	Comments	References
Hydraulic rating methods – Cont'd	Stage-duration curve	• Requires assessment of riparian and floodplain habitat at representative location(s) • Flow duration (or annual flow-frequency) curve and stage-discharge rating needed at these locations • Hydroperiod information needed to identify range in stage and duration essential to sustaining habitat • Applicable to LSFI River Systems	(HSW, 2016)
	Stage-inundated area method	• Requires assessment of riparian and floodplain habitat at representative location(s) • Flow duration (or annual flow frequency) curve and stage-discharge rating needed at these locations • Hydroperiod information needed to identify range in stage and duration essential to sustaining habitat • Regional, stream-corridor analysis can be facilitated using a geographic information system (GIS) to integrate hydraulic model (e.g., HEC-RAS) output with land-cover and/or soil maps • Applicable to LSFI River Systems	(HSW, 2016)
Habitat simulation methods (rely on hydrological and hydraulic data, and species-specific habitat suitability metrics)	PHABSIM (Physical Habitat Simulation) RHYHABSIM (River Hydraulic and Habitat Simulation) RHABSIM (River Habitat Simulation)	• Software that calculates changes in microhabitat as a function of flow; PHABSIM is Windows and DOS based; RHYHABSIM and SEFA are Windows based; RHABSIM is Windows and DOS-based. • The two primary components are hydraulic and habitat simulation models • Habitat suitability is characterized for fish life stages or macroinvertebrates by suitability indices ranging between 0 and 1 for water depth, water velocity, and channel index (substrate type and/or cover) • Calculates composite suitability spatially in the stream, summed over the stream areas between transects to produce a habitat index of Weighted Usable Area (WUA) for each flow (outputs are flow versus WUA curves) • Field data (or HEC-RAS output) are needed to calibrate a site-specific, two-dimensional hydraulic model and to characterize substrate • RHABSIM allows for modeled flow inputs • RHYHABSIM is simplified, limiting the number of variable inputs, and easier to use than PHABSIM or RHABSIM • Windows-based versions (e.g., PHABSIM-type module within SEFA (as mentioned below)) are appropriate because they have been upgraded to run efficiently on modern-day computer platforms. • Applicable to LSFI River Systems	(Bovee, et al., 1998) (Gordon, McMahon, Finlayson, Gippel, & Nathan, 2004)
	MesoHABSIM (Mesohabitat Simulation)	• Software that calculates changes in mesohabitat as a function of flow • Data acquisition technique and analytical resolution are much broader in scope than PHABSIM such that the spatial dimension of applicability is expanded • Habitat suitability is characterized by water depth, water velocity (mean and bottom), and substrate type • Applicable to LSFI River Systems	(Parasiewicz & Dunbar, 2001)

Method Category	*Method*	*Comments*	*References*
Habitat Simulation Methods – Cont'd	IFIM (Instream Flow Incremental Methodology)	• Five stages (Problem Identification, Study Planning, Study Implementation, Alternatives Analysis, Problem Resolution) • Applies PHABSIM to develop flow versus habitat index curves. These curves are used with hydrological time series data to develop microhabitat time series and duration curves for amount of effective habitat for target species. Proportions of microhabitat available for each fish life stage are evaluated against population data to find the limiting life stages, or more advanced population models are linked with the habitat simulation models. Water quality data including temperature are evaluated at the macrohabitat scale. IFIM includes negotiation tools as it does not provide one recommended flow regime but shows effects of incremental changes to assist negotiators in decision making. • Stakeholder input is essential, particularly when addressing multiple objectives for conjunctive use, some of which may be incongruent.	(Bovee, et al., 1998)
	SEFA (System for Environmental Flow Analysis)	• Additional analysis tools have been developed, as SEFA now incorporates all aspects of IFIM • SEFA combines PHABSIM with the IHA (Index of Hydrologic Alteration) codes designed to facilitate pre- and post-processing. It also includes habitat suitability criteria development modules, fish passage evaluation, water temperature and dissolved oxygen modeling, sediment analysis, riparian vegetation assessment, dynamic time series analysis that produces habitat time series and flow duration curves. • In SEFA, water surface elevations can be calibrated and simulated with log stage-log discharge rating curves, channel conveyance parameters, or step-backwater models. Water velocities are calibrated and simulated from measured patterns, derived from water depth relationships, or created from experience and professional judgment. Velocity simulation methods can use a "Manning's n" for each measurement point (as in PHABSIM and RHABSIM), velocity distribution factors (as in RHYHABSIM)	(Payne & Jowett, 2013) (Jowett, Payne, & Milhouse, 2014)
	HEC-EFM	• HEC-EFM is another software program that uses depth, and rate of change in flows and vegetation to model habitat availability dynamically in a time series. It uses input of flow-species relationships as well as hydraulic models such as HEC-RAS. The flow-species relationships could be generated in SEFA. HEC-EFM can incorporate comparisons to unaltered flows and is integrated with a key suite of modeling tools for reservoir management. • All are applicable to LSFI River Systems	(Hickey, 2017)

Holistic methods (rely on multi-dimensional hydrological, hydraulic, and ecological data)	BBM (Building Block Methodology)	• Three stages (Information Gathering, Stakeholder Workshop([s)], Follow-up) • Assumes river biota can cope with frequent low-flow conditions, natural low- and high-flow components (i.e., building blocks) are important to maintain, and certain flows influence channel morphology and structure more than other flows • Framework is essentially a bottom-up approach developed by panel of experts • Applicable to LSFI River Systems	(Arthington, et al., 1992) (Bovee, et al., 1998)
	DRIFT (Downstream Response to Imposed Flow Transformation)	• Four modules – Biophysical (to describe present ecosystem), Sociological (to identify water users and potential user impacts), Scenarios Creation (a bridge between the Biophysical and Sociological modules), and Economic (to determine effort, mitigation, and compensation) • Uses natural flow regime for comparative purposes • Decision-Support System (separate software) facilitates application • Framework is essentially a top-down approach and can be expert-based or highly quantitative • Applicable to LSFI River Systems	(Tharme R. , 1996) (Arthington, et al., 1992)
	ELOHA (Ecological Limits of Hydrologic Alteration)	• Flexible framework for determining and implementing environmental flows at a regional scale • Five-step framework (Hydrologic Modeling, River Classification, Determine Alteration Extent, Develop Flow-Ecological Standards, Establish/Refine Environmental Flow Standards) • Uses existing hydrological and biological information and can incorporate the more restrictive hydrologic, hydraulic, and habitat methods • Natural flow variability is retained • Framework is essentially a top-down approach • Applicable to LSFI River Systems	(Poff & Zimmerman, 2010)
	Savannah Process	• A Level 2 process compared to the ELOHA Level 1 process • Designed to address riverine ecosystem water needs proactively by reserving a portion of flow for ecosystem support • Five-step framework (Orientation Meeting, Literature Review, Stakeholder Workshops, Trial Testing of Hypotheses and Uncertainty, Monitoring and Follow-up) • Uses existing hydrological and biological information • Natural flow variability is retained • Framework is essentially a top-down approach • Applicable to LSFI River Systems	(Richter, Warner, Meyer, & Lutz, 2006)

ASSESSING MFLS WITHIN ELOHA FRAMEWORK

ELOHA, a top-down approach (Poff N. , et al., 2010), is well suited for assessing MFLs pursuant to Chapter 373.042, Florida Statutes guidance because it considers socioeconomic and ecological river services. The Florida legislature contemplated a constantly evolving body of knowledge requiring that "minimum flow and minimum water level shall be calculated by the department and the governing board using the best information available." Furthermore, by Florida Administrative Code Rule 62-40.473 Minimum Flows and Levels,

> *(1) In establishing minimum flows and levels pursuant to Sections 373.042 and 373.0421, F.S., consideration shall be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology, including:*
>
> *(a) Recreation in and on the water;*
> *(b) Fish and wildlife habitats and the passage of fish;*
> *(c) Estuarine resources;*
> *(d) Transfer of detrital material;*
> *(e) Maintenance of freshwater storage and supply;*
> *(f) Aesthetic and scenic attributes;*
> *(g) Filtration and absorption of nutrients and other pollutants;*
> *(h) Sediment loads;*
> *(i) Water quality; and,*
> *(j) Navigation*.

A modified ELOHA framework is adaptable to water bodies in the District for MFLs assessment. The framework comprises five primary elements (Figure B 2).

- Hydrologic Foundation
- Hydrosystem Classification
- Modified Hydrology
- Ecological Service Linkage
- Stakeholder Negotiation

The modified ELOHA method integrates the scientific process to address both socioeconomic and ecological river services. The scientific elements of the framework are linked to negotiation elements that include evaluating social values, determining acceptable ecological conditions, and promulgating water-management rules. The MFLs Assessment and Stakeholder Input are key activities within the broader Stakeholder Negotiation element.

Early stakeholder involvement is essential throughout the holistic process and includes the following steps:

- Identification of stakeholders to be involved
- Identification of objectives, issues, challenges, and risks important to stakeholders

- Information and data sharing, consultation, and advising
- Development/adaptation of processes and tools to meet objectives

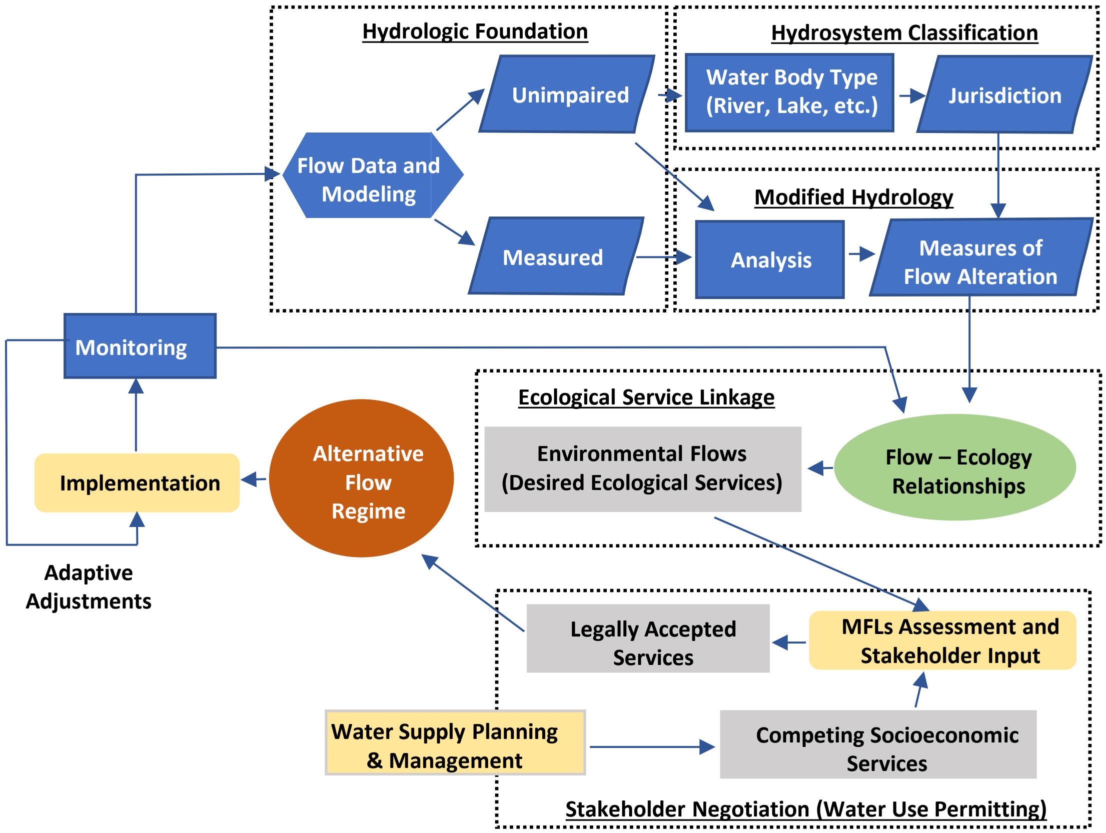


Figure B 2. Conceptual holistic framework for the LSFI River Systems Assessment
[Source: modified from (Poff N. , et al., 2010))]

HYDROLOGIC FOUNDATION

The natural flow regime and associated characteristics of magnitude, frequency, duration, timing, and rate of change are critical in sustaining the full diversity and integrity of aquatic ecosystems (Poff N. L., et al., 1997). Streamflow can be considered a control variable that effects the distribution, abundance, and diversity of many aquatic species. In evaluating environmental flows, it is assumed that unaltered flows (or minimally altered flows) are protective of natural stream ecological functions and that some water could be made available for human needs by some reduction in ecological/ socioeconomic functions agreed upon by stakeholders. Unaltered flows are those that would occur naturally without alteration by anthropogenic activities including water withdrawals, discharges, and flow regulation by dams. Unaltered flows determine the maximum amount of water naturally available for services provided by rivers. The database of daily streamflow time series representing unaltered flows is the foundation of ELOHA, and as such its development is considered the first step of the ELOHA framework. Unaltered flows are typically developed for locations for which flow data have been collected, will be monitored to ensure compliance with flow standards, and the amount of flow reductions from anthropogenic impacts can be quantified.

HYDROSYSTEM CLASSIFICATION

Hydrosystems in Florida that are subject to MFLs assessment are classified by type and jurisdiction. Rivers, estuaries, lakes, wetlands, and aquifers are specific types of hydrosystems subject to regulation for water use and environmental protection.

It is a policy of the Florida Legislature that the state's water resources be managed at a state and regional level. The Department of Environmental Protection (FDEP), responsible for the administration of the water resources at the state level, exercises general supervisory authority over the state's five water management districts, which are responsible for the administration of the water resources at the regional level.

The state's five water management districts include the Northwest Florida Water Management District, the Suwannee River Water Management District, the St. Johns River Water Management District, the Southwest Florida Water Management District, and the South Florida Water Management District. The FDEP exercises general supervisory authority over the districts through a cooperative working relationship and guidance memos.

The four core mission areas of the water management districts are: (1) water supply, (2) water quality, (3) flood protection and floodplain management, and (4) natural systems. The districts administer flood protection programs and perform technical investigations into water resources. They also develop water supply plans for water shortages in times of drought and acquire and manage lands for water management purposes. Delegated regulatory programs include management of the consumptive use of water, aquifer recharge, well construction and surface water management.

MFLs are established by the water management district governing boards or the FDEP and are calculated by the governing boards and the FDEP (Chapter 373.042(1). When the geographic area of a project or local government crosses water management district boundaries, the affected districts may designate pursuant to Chapter 373.046, F.S. a single affected district by interagency agreement to:

- implement in that area, under the rules of the designated district, all or part of the applicable regulatory responsibilities (subsection 373.046(6)) and
- conduct all or part of the applicable resource management responsibilities ((subsection 373.046(7)) with the exception of those regulatory responsibilities that are subject to subsection 373.046(6).

Other methods have been used to classify rivers in the southeastern United States. Rivers can be classified as unregulated, peaking hydropower, other regulated, and special needs (e.g., endangered species) rivers (Evans & England, 1995). This classification structure is adaptable to water planning objectives. Within each of these four types, the streams can be further classified using hydrologic statistics for unaltered daily streamflow data to identify streams with similar hydrologic regimes that may respond similarly to management. Such hydrologic statistics can be calculated using Indicators Hydrologic Alteration, IHA, (The Nature Conservancy, 2009); the Hydrologic Index Tool (HIT) and

Hydroecological Integrity Assessment Process (HIP), (Henriksen, Heasley, Kennen, & Niewsand, 2006); or similar methods and software.

MODIFIED HYDROLOGY

Flow alteration is described as a change in any of the aforementioned streamflow characteristics from a reference timeframe condition. For the LSFI River Systems MFLs re-evaluation, observed flows reflect a deviation from a condition that has been minimally altered by withdrawals, or reference timeframe flow (RTF) condition, and characterizes a modified hydrology.

The sensitivity of change in the river services may be linear or nonlinear to one degree or another (Figure B 3). Quantifying this association first requires quantification of flow change and the change in associated hydrologic variables, e.g., stage.

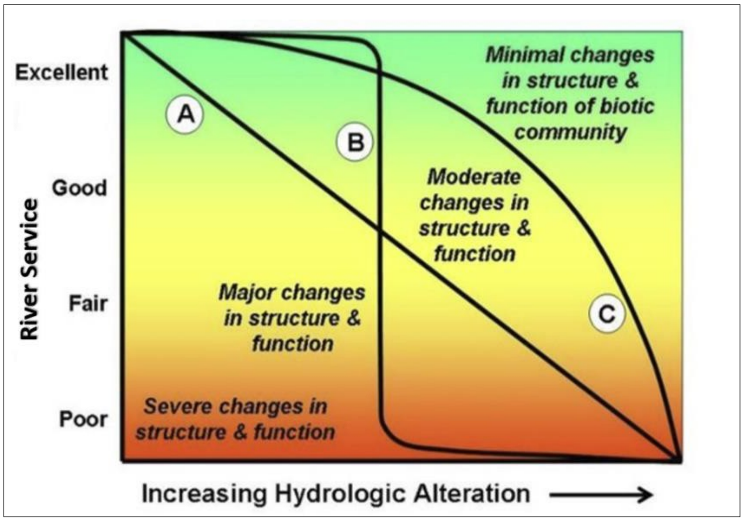


Figure B 3. Conceptual flow-ecological service curves; A: linear, B: threshold, C: Curvilinear (Davies & Jackson, 2006)

ECOLOGICAL SERVICE LINKAGE

The overall approach for developing environmental flows is characterized as the weight-of-evidence approach, which begins with identifying riverine services (Table B 3) and making use of various modeling efforts. Stakeholder input is used to identify important current and potential future river services and their objectives, which are associated with measurable indicators to form the basis for developing environmental flows. A key element of ELOHA methodology is the quantification of relationships between flow change (i.e., unaltered vs. altered flow) and anticipated ecological service responses.

The development of flow-river service relationships begins with hypotheses derived from the literature, expert, and stakeholder input on how each environmental flow component influences the ecosystem and socioeconomic needs within a river class (Poff & Zimmerman, 2010), followed by quantitative analyses to test these hypotheses. Understanding attributes including life histories, habitat preferences and requirements, and resource utilization strategies of biological species and human needs associated with a river or river segment can be used to infer effects due to flow alterations (Poff & Zimmerman, 2010).

A range in flows is maintained, as river services sustained during low flows could be different from the functions that require high flows. In terms of river services, high flows are often needed to maintain wetlands in the floodplain and channel scouring, whereas low flows are important for fish passage (Figure B 4) or water supply and boating needs. For this reason, multiple ecological functions and socioeconomic river services should be considered across the full range of flows and seasons to develop all the flow-service relationships. Snag habitat may be important to consider between the dry season and wet season conditions, and connections between the river and the floodplain via sloughs and aquatic habitats may provide flow requirements for medium- to high-flow conditions. Some of these relationships could be generalized to apply the relationship regionally. For example, although the specific rate of change in wetted channel width (surrogate of habitat area) will depend on the cross-sectional geometry at any given stream section, broadly similar trends in habitat loss with flow may be observed within a region (Tennant, 1976). Examples of the flow-river service relationships that could be evaluated to characterize metrics of river service in rivers and estuaries over a range of flows (low, medium, and high) are listed in Table B 3.

Table B 3. Examples of flow-river service relationships

River Service	Service Metric	Flow-River Service Relationship
Fish passage or boating	Minimum area or depth required for passage (low flows important)	Flow alteration – Change in length of passage or frequency of restricted river access
Fish and wildlife habitat, sport-fishing	Physical habitat index (wetted area/area-weighted suitability; mid flows important)	Flow alteration – Change in physical habitat index
Riparian habitat	Riparian wetted area/wetted perimeter (mid and bank-full flows important)	Flow alteration – Change in wetted area/wetted perimeter
Channel maintenance	Bank-full flow important	Flow alteration – Change in amount of time bank-full flow is exceeded
Floodplain habitat for wildlife	Floodplain wetland inundation area and frequency (high flows important)	Flow alteration – Change in wetland inundation area and frequency
Salinity habitat (for tidal reaches of coastal rivers)	Salinity and salt-tolerant flora and fauna (low and mid flows important)	Flow alteration – Change in salinity regime volume/area/shoreline length
Surface-water supply (for drinking water, irrigation, and industrial uses)	Minimum depth for intake pipe (low flows important)	Flow alteration – Change in depth at withdrawal locations

The current state of environmental flow science does not have readily usable, quantitative models that can reliably predict regional effects on a variety of specific ecological processes or specific biological species/guilds[2] (Poff L. N., 2017) due to flow alteration. Hydrologic and ecological databases for many rivers within a region are required to generate flow-river ecological service relationships for different types of rivers. Although the natural flow regime perspective of managing for historical variability will remain important to understand ecological response to hydrologic alterations, a new imperative of managing for resilience is emerging (Poff L. N., 2017). Shifting hydro-climatic and ecological conditions will require identifying and prescribing environmental flows to sustain persistent and socially valued ecological characteristics in a flexible and adaptive management framework.

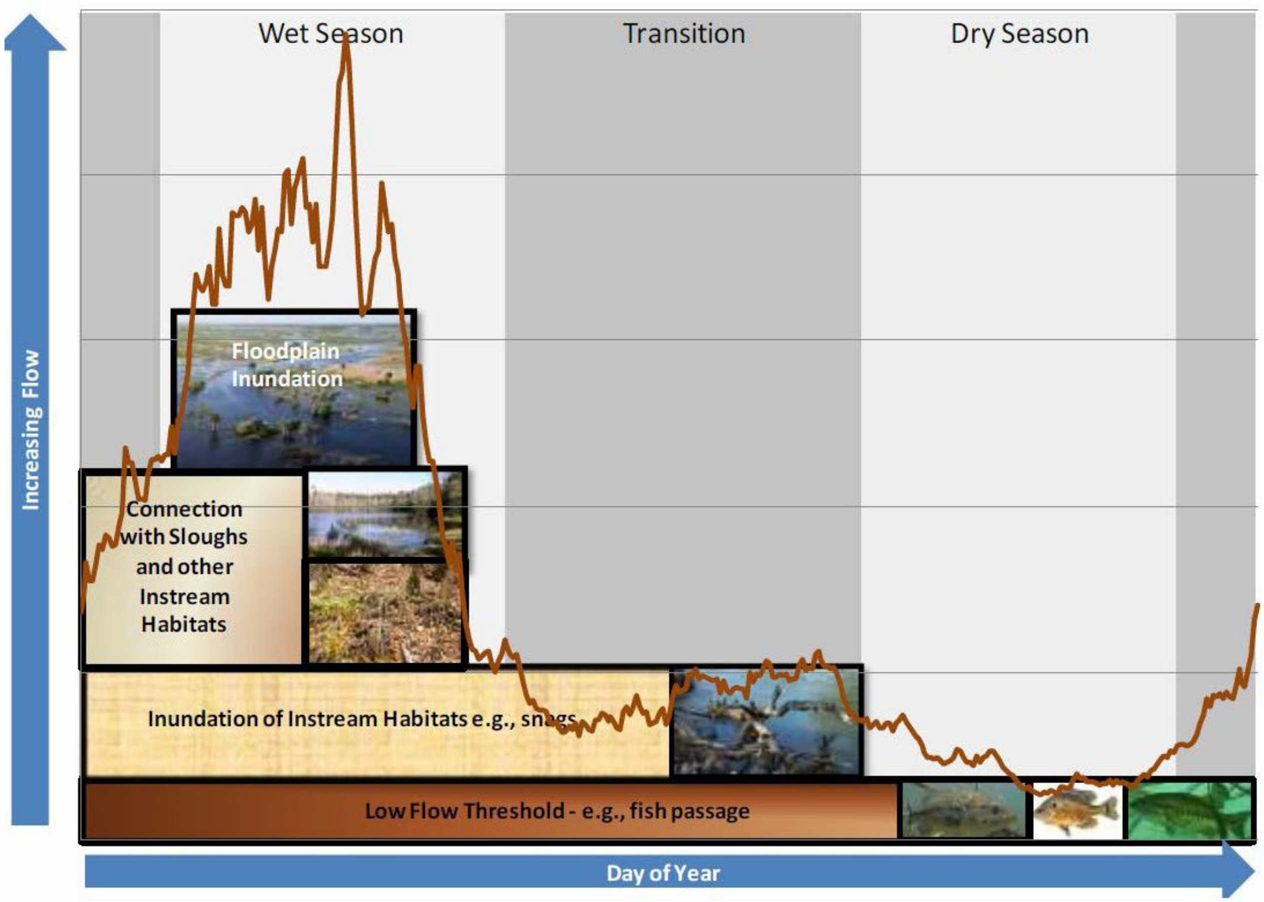


Figure B 4. Figure 4. Conceptual model illustrating ecological functions at various flows
[Source: (NWFWMD, 2014)]

Agencies such as the Florida Fish and Wildlife Conservation Commission (FWC) have periodically assessed fish assemblages in rivers and streams throughout Florida. These data are typically the type of biological data available. The effort and difficulty associated with measuring aquatic biota population responses attributable to flow alteration have historically led to the adoption of mechanistic models of suitable habitat area (e.g., SEFA for instream flows) for evaluating flow-ecological service relationships.

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[2] A guild is any group of species that exploit the same resources, or that exploit different resources in related ways. For example, a group of fish species may use fast-flowing, deep water and another group, shallow, slow waters.

Physical habitat simulation approaches (e.g., PHABSIM) simulate the effects of flow alteration on physical habitat characteristics, and do not directly measure population responses to microhabitat-characteristic flow inputs, e.g., velocity or depth. The output is a flow (or depth) vs. habitat index curve. While changes in habitat index may not represent changes in population responses, there is strong evidence that changes in available habitat have population consequences when habitat is limiting (Magoulick & Kobza, 2003). An assumption required to use habitat changes as a surrogate for population changes is that the population is at carrying capacity, more often true when the physical habitat is limiting the population size. An example would be a decrease in suitable habitat which results in higher population density, leading to higher mortality due to increased competition and predation, and ultimately a lower population size. Given that riverine flora and fauna have innumerable top-down and bottom-up influences on their population sizes, the use of physical habitat simulation models to predict populations should not be the goal of MFL evaluations.

STAKEHOLDER NEGOTIATIONS

Both current and future river service condition goals underlie the establishment of an alternative flow regime. Each river may be valued differently depending on the ecological and anthropogenic/ socioeconomic services provided by the river. A future river service goal for some rivers could be to maintain them in pristine condition, while highly regulated rivers may be expected to maintain a basic level of river services or an increase in these services. One of the objectives of stakeholder negotiation is to develop a tiered set of goals and standards, and to have different standards for rivers with different river service goals.

The process of developing acceptable river services depends on the flow-river service relationships and a stakeholder process that includes river users and resource experts to determine desirable river service goals and corresponding standards (Figure B 2).

MFLS ASSESSMENT METHODS

Water resource and human use values have been identified that collectively are protected if a broad range of flows are maintained. The approach used for setting MFLs can make use of one or more methods for estimating allowable flow reductions that are described in this section.

The guiding premise is that high flow occurrences are not decreased too much and low flow occurrences are not increased too much such that significant harm (Angelo, Hamann, & Klein, 2008) occurs. High flow-related (e.g., flood or inundation) water resource values (WRVs) are considered to be protected if, under the MFL flow regime, the high flow event of an associated magnitude and duration does not occur too infrequently. Low flow-related (e.g., drought or drawdown) WRVs are considered to be protected if, under the specified flow reduction conditions, the low flow event of a specified magnitude and duration does not occur too frequently when compared to the low flow event occurrence under a long-term baseline condition. Implicit in the evaluation of WRVs is the concept of recovery time, which can be viewed as the time between events (or the return interval) sufficient for the WRV to recover.

Different approaches have been used by Florida's water management districts to meet these objectives. One approach considers a change in number of days, and explicit in this premise is an allowable change in time (hereinafter percent time) that a particular flow rate is exceeded (Munson & Delfino, 2007). A second approach considers a change in area, and implicit in this premise is comparing the change in area that is inundated for a fixed amount of time (e.g., application of PHABSIM). The authors refer to the two approaches as evaluations of temporal loss and spatial loss, respectively. A third approach is an event approach that considers the frequency (number of occurrences per century) that an event defined by a particular flow being exceeded (or not exceeded) for a prescribed duration (number of consecutive days) (Neubauer, et al., 2008). Compared to the first approach, the third approach considers duration and the occurrence frequency of annual minimum or maximum values in an N-year period of record, instead of the entire set (i.e., 365xN) of daily values.

It also may be appropriate to consider the seasonal variations affecting flow when developing MFLs. A "building block" approach that identifies seasonal blocks corresponding to periods of low, medium, and high flows has been used to evaluate rivers and estuaries in west-central Florida, such as the Alafia River (Kelly, Munson, Morales, & Leeper, 2005). The MFL compliance standards include allowable flow reductions based on limiting potential changes in aquatic and wetland habitat availability associated with seasonal changes in flow. A low flow cutoff; i.e., a flow below which no withdrawals would be allowed, also may be included. The allowable flow reductions associated with the MFL generally are associated with a 15% reduction in habitat area, a 15% reduction in the number of inundation days (Munson & Delfino, 2007), or a low flow cutoff (e.g., associated with fish passage). Any of these criteria may be applied seasonally.

The event approach utilized to evaluate the protection of the WRVs and setting MFLs (Neubauer, et al., 2008) comes under the general heading of frequency analysis, whereby statistics of long-term hydrology such as magnitude (flow and/or level), duration (days), frequency (number of events per 100 years) or return interval (years) of hydrologic events are evaluated. The assumption under this approach is that hydrologic processes that may affect the WRVs are event-driven (e.g., flood events facilitate sediment transport and river-building processes) or can be characterized by annual extreme events (e.g., minimum annual depth, for a biologically-relevant duration, at hydraulic control locations to protect fish passage). When sufficient data are available, a range of event frequencies (e.g., a discharge of specific magnitude and duration) that is protective of a WRV may be known with some level of confidence. In other instances, there may be insufficient information on the frequency of an event that is reliably protective. Another concern with event metrics, is that most of Florida's waterbodies and watercourses have had hydrologic alterations during the last century; and the habitats, flora, and fauna present do not represent unimpacted hydrologic conditions (i.e., comparison of unimpacted and impacted hydrology are being made with habitat/species metrics that have already changed).

In the following example analyses prepared for the SRWMD, each assessment method is used to characterize sensitivity to flow reduction at a flow essential to maintaining floodplain habitat on the Upper Suwannee River (USR). Results determined using the different methods in a preliminary MFLs assessment using existing data illustrate the sensitivity of the assessment methodology.

The USR is surrounded by a nearly mile-wide floodplain made up of a complex landscape of forested cypress and mixed hardwood wetlands, intertwined in a matrix of pine and hardwood forests and agricultural uplands. The forested wetlands include four general community types typically identified using FLUCCS (Florida Land Use and Cover Classification System) codes (FWC, 2012); i.e., gum swamp (6130), mixed wetland hardwoods (6170), cypress (6210), and wetland forested mixed (6300). Each of these four community types is dominated by characteristic tree species and has a typical hydrologic regime that sustains the communities. These general floodplain vegetation communities were used to assess possible flow reductions that would remain protective of floodplain habitat and associated forest composition, wetland biogeochemical processes, and fish and wildlife habitat.

PERCENT AREA EXAMPLE

The areas of inundated wetland vegetation community types were determined using ArcGIS to overlay and merge the FLUCCS coverage shapefile and HEC-RAS derived inundation area shapefiles (Figure B 5). The process was performed for each of 20 flow regimes simulated using HEC-RAS to characterize the association between flow and total wetland vegetation area inundated (Figure B 6). An inflection point on the total Wetland FLUCCS line is apparent at 9,400 cfs where the curve begins to depart from a line tangent to the curve. Relatively little increase in wetland community area occurs at flows exceeding 9,400 cfs because there are fewer wetlands at the elevations associated with these high and less-frequent flows. The change in wetland area is much more sensitive to reduction in flows less than 9,400 cfs; hence, it is referred to as a threshold flow condition. The total wetland vegetation community area inundated by a flow of 9,400 cfs is about 6.63 square miles (Figure B 6).

For this example, the floodplain wetland communities are assumed to be protected if the total wetland vegetation area at the inflection point is not reduced by more than 15%. A reduction of 15% results in an area of 5.63 square miles and an associated flow of 8,670 cfs (Figure B 6), a flow reduction of 730 cfs or 7.8 % (Table B 4). The area change represents a potential loss of the vegetation community as it functioned under a presumed baseline hydrologic condition and does not represent a predicted loss in wetland area.

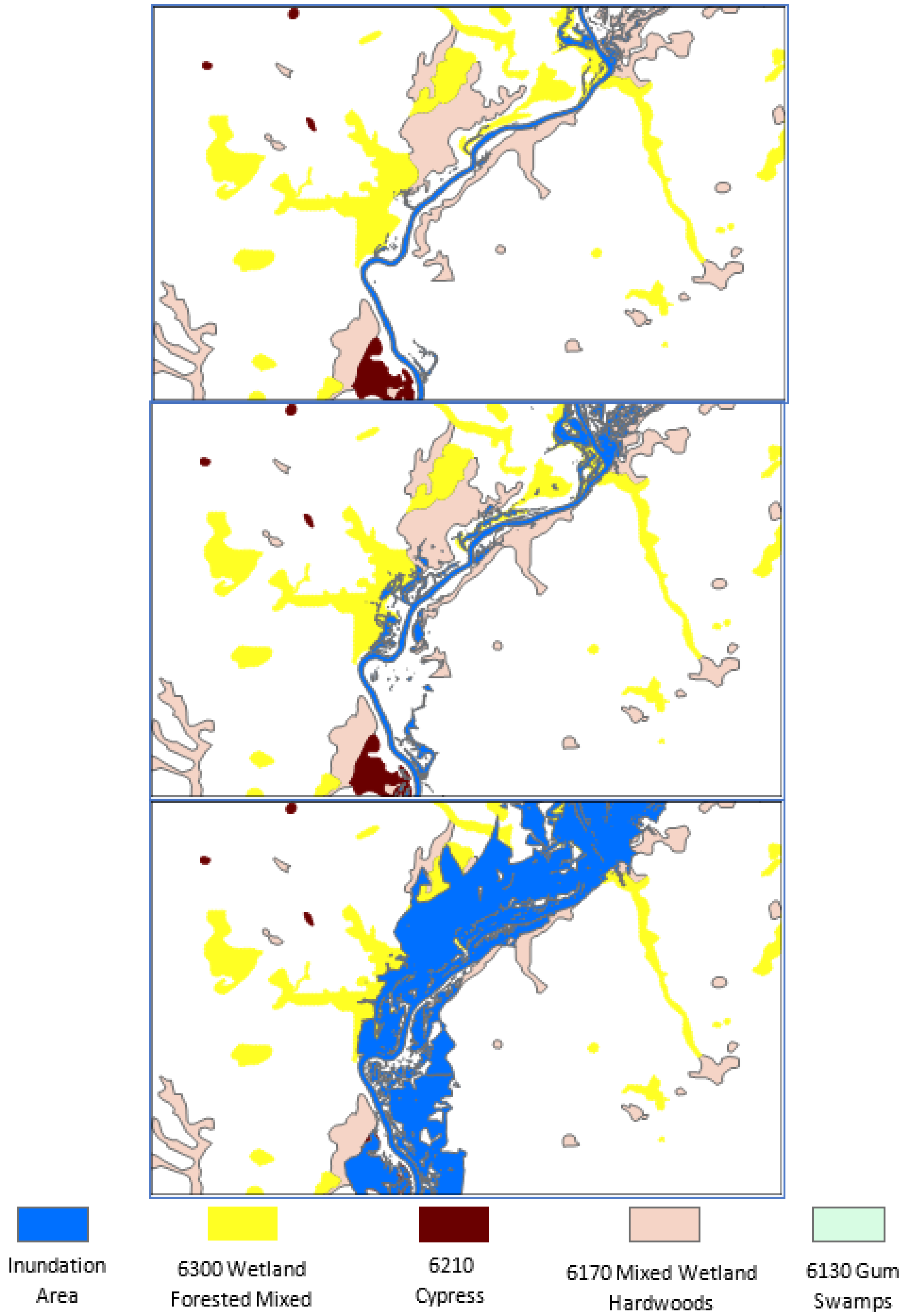

Figure B 5. Inundation maps at flows of 4,670 cfs (top), 7,219 cfs (middle), and 9,947 cfs (bottom), with vegetative communities indicated by FLUCCS codes

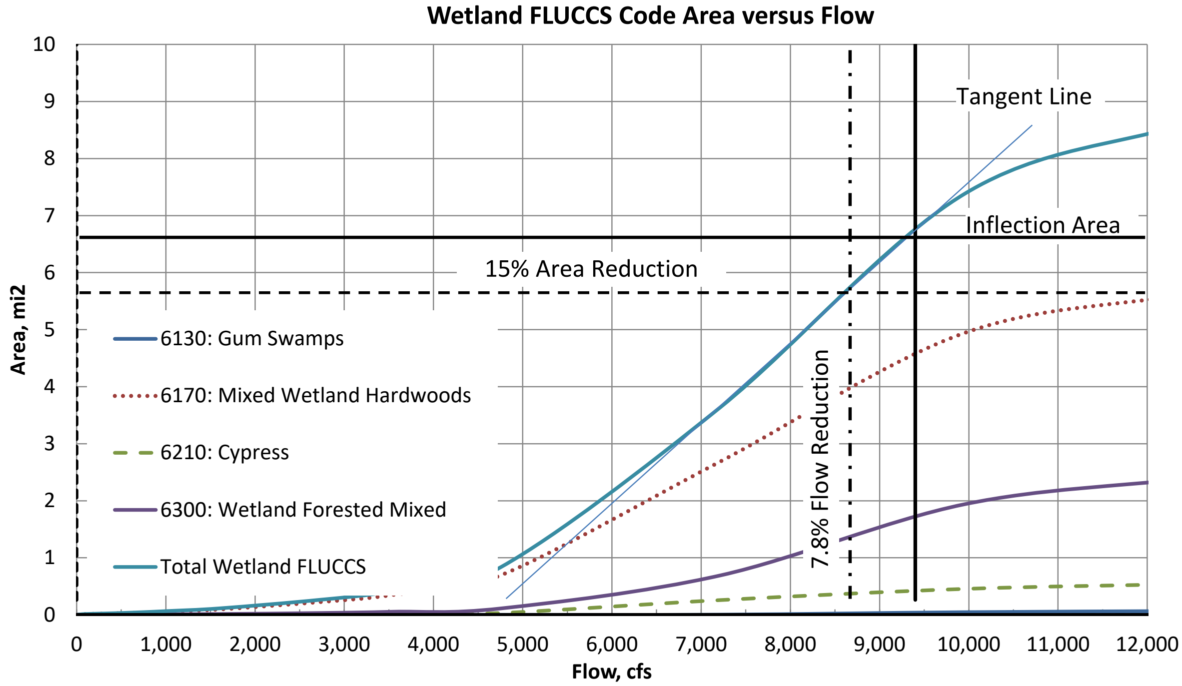

Figure B 6. Association between USR flow and general wetland vegetation community area

Table B 4. Change in discharge resulting from a 15% decrease in total floodplain wetland vegetation area

Baseline				Change Metrics		
Threshold Condition[1]		15% Reduction in Area		Discharge (cfs)	Area Inundated	Discharge Change (%)
Discharge (cfs)	Vegetation Area Inundated (mi^2)	Discharge (cfs)	Vegetation Area Inundated (mi^2)			
9,400	6.63	8,670	5.63	8,670	5.63	7.8
1 Discharge and area at threshold discharge						

PERCENT TIME EXAMPLE

Under baseline conditions, the threshold flow of 9,400 cfs at White Springs is exceeded 2.5 % of the time, or about 9 days per year on average (Figure B 7). A 15% reduction in the time that flow equals or exceeds the threshold condition results in an exceedance of 9,400 cfs about 2.1% of the time (i.e., 0.85 x 0.0246 = 0.0209). This reduced flow exceedance scenario is associated with a flow difference of 420 cfs when discharge at the White Springs gauge is 9,820 cfs (Figure B 7 and Table B 5), a flow reduction of 4.3 %. The inundation time is reduced by about 1.5 days per year, on average.

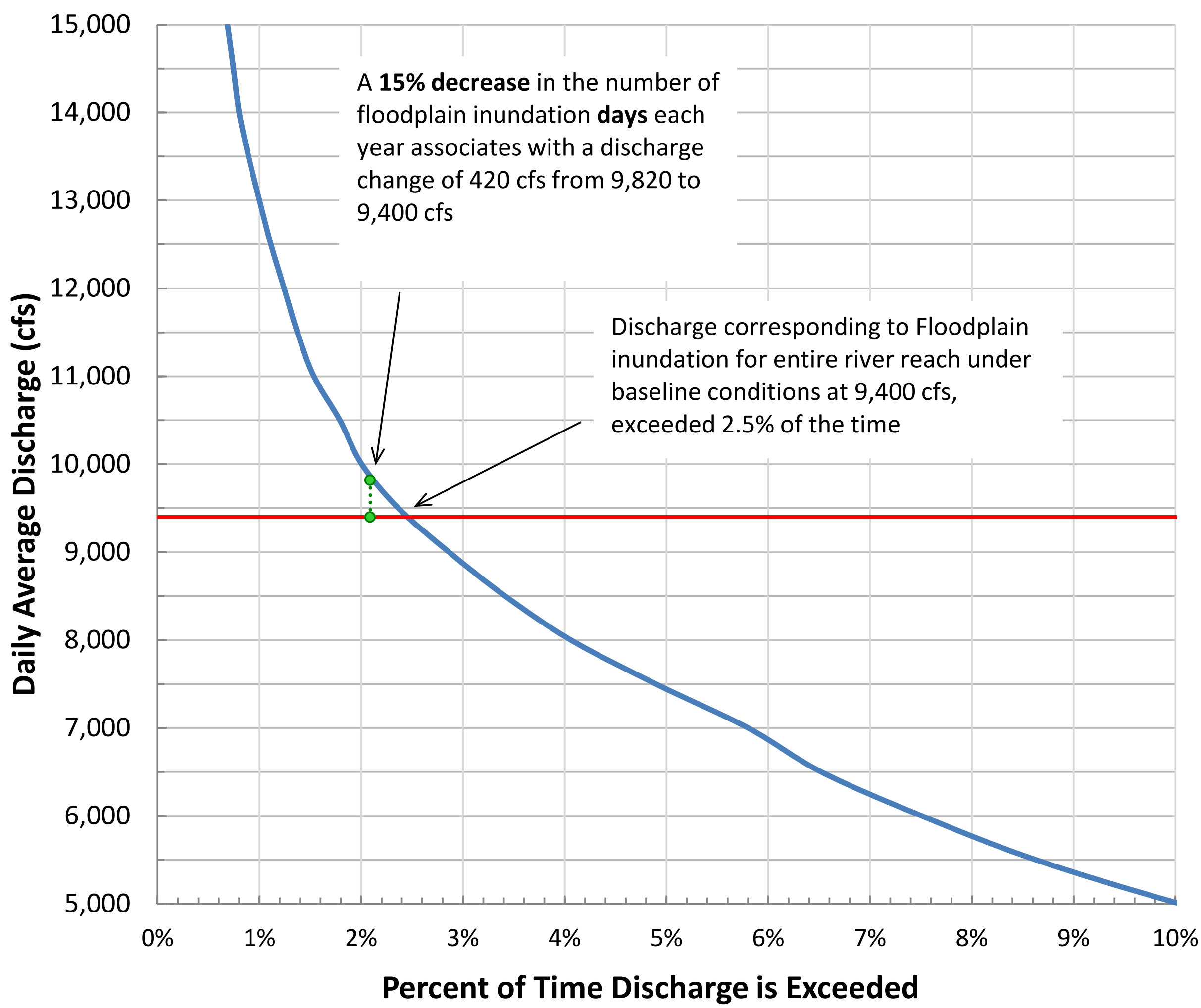

Figure B 7. Baseline flow duration curve and exceedance frequencies associated with the USR floodplain vegetation community. [White Springs gauge baseline (WY 1939-99) flow duration curve]

Table B 5. Change in discharge resulting from a 15% decrease in the time flow is greater than the threshold condition

Baseline				Change Metrics		
Threshold Condition[1]		15% decrease in time exceeded		Discharge (cfs)	% time Exceeded	Discharge Change (%)
Discharge (cfs)	% time Exceeded	Discharge (cfs)	% time Exceeded			
9,400	2.46	9,820	2.09	9,400	2.09	4.28
1- Discharge and percent of time discharge is exceeded at threshold discharge						

The relatively small allowable flow reduction (and change in inundation duration) is a function of the method used to calculate the change in inundation time and the shape of the duration curve. A 15% reduction in the time a flow is exceeded will be greater for a flow that is exceeded often than a flow that is exceeded infrequently. For example, a 15% reduction in the time for a flow exceeded 10% of the time is associated with a flow exceeded 8.5% of the time, or a difference of 5 days per year, on average. Conversely, a 15% reduction in time for a flow exceeded 50% of the time (the median flow) is associated with a flow exceeded 42.5% of the time, or a difference of 27 days per year, on average. The much greater change in inundation duration is somewhat tempered by the fact that the median portion of the duration curve tends to be flatter than the extremes so the change in flow per change in duration time is less.

Using the time flow is exceeded versus not exceeded depends somewhat on what is driving the WRV. Is the concern a reduction in the amount of time a habitat is inundated, as in high flow conditions, or is the concern the increase in the number of days fish cannot pass a limiting cross section under a low flow condition? Flow exceedance values tend to be used for high flow concerns and non-exceedance values tend to be used for low flow concerns.

EVENT EXAMPLE

Wetland plant community health is influenced by occasional dry conditions and sustained periods of wet conditions. The inflection points of the individual wetland vegetation community area curves (Figure B 6) generally reflect the community associations with flow. The inflection point for cypress at about 7,100 cfs identifies a community that requires wetter conditions (longer duration) than the mixed hardwood community with an inflection point at about 10,350 cfs that occurs less frequently than 7,100 cfs.

For some WRVs, best available data may provide evidence that there is a threshold flow (or stage) magnitude that must persist for some finite duration and occur with some minimum (or maximum) frequency to protect the WRV from degradation.

Flood depths maintained continuously for a period of 14 days that occur every 2 to 5 years were determined to be important descriptors of general flood conditions affecting upland tree regeneration in riverine floodplain forests (Light, Darst, Lewis, & Howell, 2002). These floods restrict upland plant regeneration in wetland forests because seedlings of upland vegetation and hardwoods are unable to gain enough height during the period to survive the next flood. Floods greater in magnitude occur less frequently, thus allowing more time for young trees to reach heights that exceed flood depths. Note that the metric used for evaluating the WRV is not the flood magnitude itself but the time between the flood events that restricts the growth of upland plant species.

The recurrence interval (RI) of an inundation event in which flow equals or exceeds 9,400 cfs for 14 consecutive days is 4.8 years under baseline conditions (Figure B 8). For discussion purposes, it is presumed that a recurrence interval of up to 5 years for these seedling-suppressing flood events would be protective of that function and baseline floodplain wetland habitat. A less frequent occurrence, i.e., fewer than 20 events per 100 years, would presumably lead to the succession of an upland plant community into the higher-elevation fringes of the existing floodplain community reflected in the FLUCCS maps.

Increasing flow reductions would shift the annual-exceedance frequency distribution in Figure B 8 downward, thus increasing the recurrence interval and reducing the event frequency for any given flow magnitude. A flow reduction of 132 cfs, or 1.4% (9,532 to 9,400 cfs), would shift the recurrence interval from 4.8 to 5.0 years, thus decreasing frequency from 21 to 20 events per 100 years (Table B 6) with no reduction in wetland vegetation community area.

A flow reduction of 7.8% (area method) or 4.3 % (time method) would each result in a recurrence interval greater than 5 years. A similar analysis could be performed for the individual wetland vegetation communities.

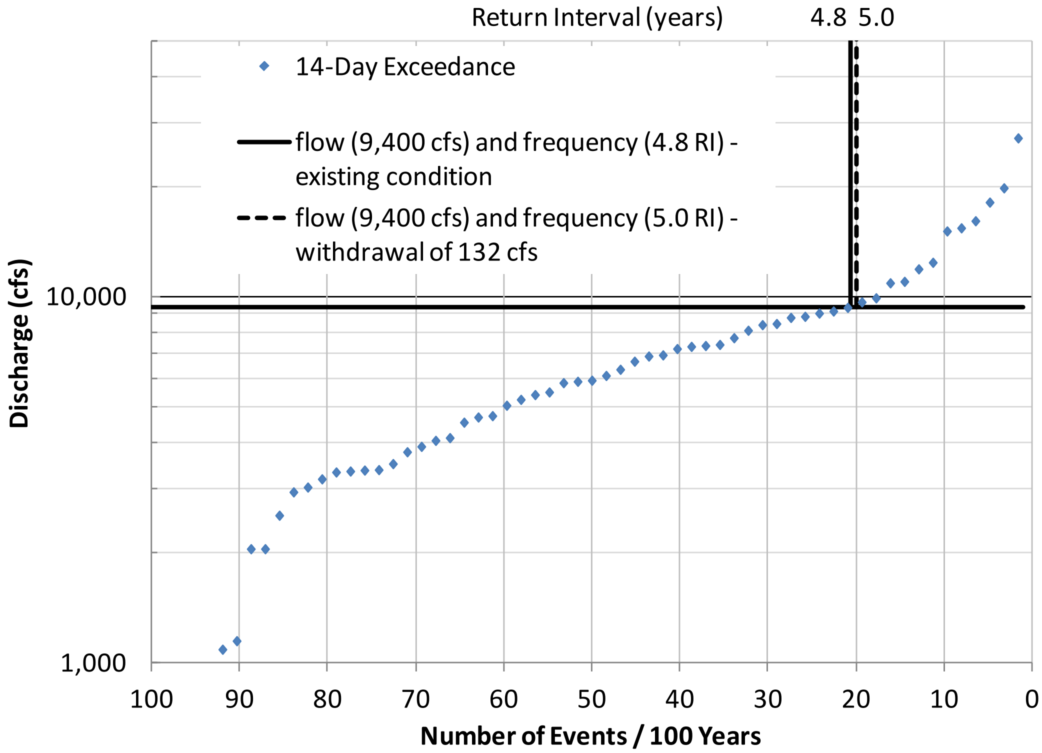

Figure B 8. Frequency of 14-day duration high-flow events – Floodplain inundation with no area reduction

Table B 6. Annual exceedance analysis of 14-day duration event of baseline and changes in discharge that restrict upland plant seedlings and promote young tree growth in the floodplain

Baseline				Change Metrics		
Threshold Condition[1]		Limiting events per 100 years (RI)		Discharge (cfs)	Events per 100 years (RI)	Discharge Change (%)
Discharge (cfs)	Events per 100 years (RI)	Discharge (cfs)	Events per 100 years (RI)			
9,400	21 (4.8)	9,530	20 (5.0)	9,400	20 (5.0)	1.4
8,670	28 (3.6)	9,530	20 (5.0)	8,670	20 (5.0)	9.0

1 Discharge and number of events per 100 years baseline threshold discharge

Table B 6 clearly illustrates that additional water becomes available for consumptive use if some loss of habitat is acceptable. A 15% reduction in total wetland area was associated with a flow reduction from 9,400 to 8,670 cfs. The 14-day 8,640 cfs flow event occurs about every 3.6 years under baseline conditions. A flow reduction of about 9.0 % (9,530 to 8,670 cfs), comparable to the Percent Area approach (Table B 4), would result in a recurrence interval of 5 years, or 20 events per 100 years (Table B 6 and Figure B 9).

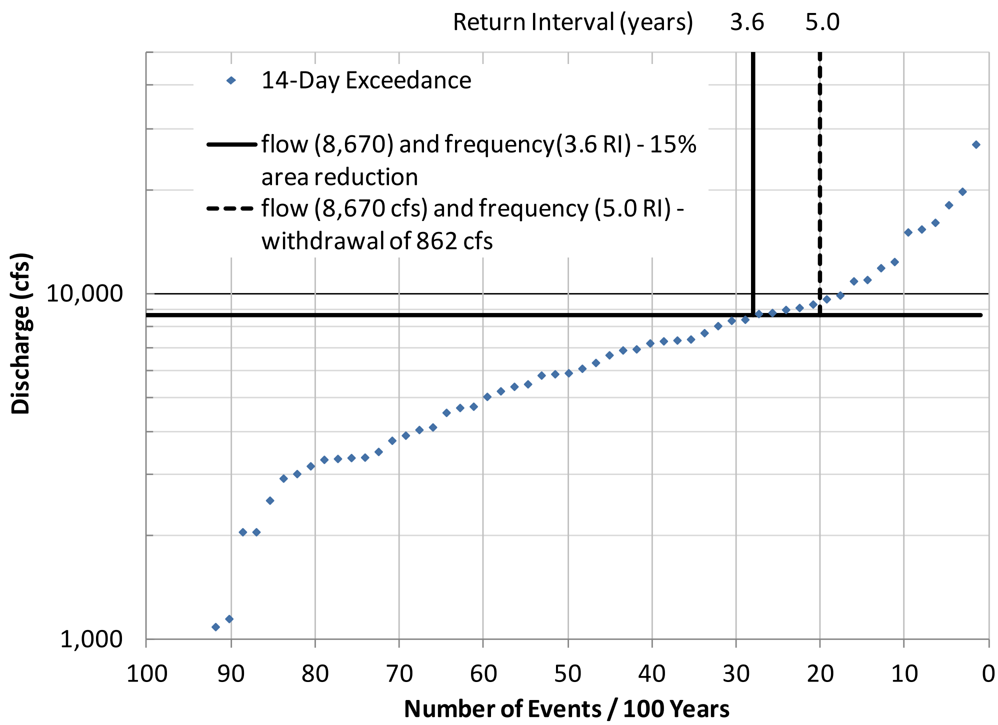

Figure B 9. Frequency of 14-day duration high-flow events – Floodplain inundation with 15% area reduction

When applying the event approach, it is important to view the results of analysis in the context of the information that supports the magnitude, duration, and recurrence interval of the threshold event. For example, the substantial work of Light and others (2002) on the lower Suwannee River is presumed to be transferable to the USR. However, the floodplain vegetation communities along the USR may have adapted under the baseline conditions to a threshold recurrence interval somewhat different than the 5-year threshold considered in this example.

In summary, using the inundation of the floodplain wetland vegetation community as an example, a range of potential flow reductions was determined for a threshold high flow of 9,400 cfs using three different MFLs assessment approaches that have been used frequently to evaluate MFLs for water bodies throughout central and north Florida. Using a 15% reduced-area method results in a potential allowable flow reduction of 7.8%, while a 15% reduced-time method results in a potential allowable flow reduction of 4.3%.

STATEWIDE APPLICATION FOR ADOPTED MFLS

One of the objectives of stakeholder negotiation is to develop a tiered set of goals and standards, and to have different standards for rivers with different river service goals. The process of developing acceptable river services depends on the flow-river service relationships conceptually illustrated in Figure B 3 and a stakeholder process that includes river users and resource experts to determine desirable river service goals and corresponding standards (Figure B 2). A uniform statewide application does not currently exist in Florida. However, the Central Florida Water Initiative (CFWI) is a collaborative process being implemented through adaptive management principles in central Florida with a stated process goal of establishing “a single, consistent process, as appropriate, to set MFLs and water reservations” (CFWI Steering Committee, 2017).

MFLs have been evaluated and in many cases adopted for numerous river and spring systems throughout Florida. A partial list totaling 37 systems (Table B 7) documents the variety of assessment methods that have used to evaluate MFLs of which 24 are based on the Percent Time method. This multi-faceted approach by the water management districts to assess MFLs utilizing alternative methods and multiple lines of evidence is robust and provides meaningful information regarding the sensitivity of the WRV value metrics to flow reductions. Most of the MFLs adopted by the SRWMD governing board for rivers have been based on the Percent Time method and Percent Area method using PHABSIM (Table B 7).

Table B 7. Partial list of MFLs adopted or evaluated for select Florida rivers and springs by Water Management District.
[Sources: Chapters 40A-8 (NWFWMD), 40B-8 (SRWMD), 40C-8 (SJRWMD), 40D-8(SWFWMD), 62-42.300 (FDEP)]

District	Study Area	Date of Rule	Method used	Reference
Northwest Florida Water Management District	St. Marks River Rise	June 2019	Percent Time	Northwest Florida Water Management District (2019, March). Minimum flows for the St. Marks River Rise.
Suwannee River Water Management District	Lower Suwannee River & Estuary, Little Fanning, Fanning, and Manatee Springs	August 2006	Percent Area	Water Resource Associates, Inc. (2005 October). MFL Establishment for the Lower Suwannee River and Estuary, Little Fanning, Fanning, and Manatee Springs.
Suwannee River Water Management District	Waccasassa River, Estuary, and Levy (Bronson) Blue Spring	July 2007	Percent Time	Water Resource Associates, Inc. (2006, November). MFL establishment for the Waccasassa River, Estuary, and Levy (Bronson) Blue Spring.
Suwannee River Water Management District	Upper Santa Fe River	December 2007	Wetted Perimeter Inflection	Water Resource Associates, Inc. (2007). MFL Establishment for the Upper Santa Fe River.
Florida Department of Environmental Protection / Suwannee River Water Management District[1]	Lower Santa Fe and Ichetucknee Rivers/Priority Springs	June 2015	Percent Time	Suwannee River Water Management District (2013). Minimum Flows and Levels for The Lower Santa Fe and Ichetucknee Rivers and Priority Springs.
Florida Department of Environmental Protection / Suwannee River Water Management District[1]	Lower Santa Fe and Ichetucknee Rivers/Priority Springs	December 2019	Percent Time, Percent Area	HSW Engineering, Inc. (2019, December). Minimum flows and minimum water levels re-evaluation for the Lower Santa Fe and Ichetucknee Rivers and Priority Springs
Suwannee River Water Management District	Econfina River	May 2016	Percent Time	Janicki Environmental, Inc. (2015, December). Minimum flows and levels Econfina River.
Suwannee River Water Management District	Aucilla River, Wacissa River, and Priority Springs	May 2016	Percent Time	HSW Engineering, Inc. (2016 January). Minimum flows and levels for the Aucilla River, Wacissa River, and Priority Springs.
Southwest Florida Water Management District	Lower Alafia River	November 2009	Percent Time	Flannery, et al., (2008 December). The determination of minimum flows for the Lower Alafia River Estuary

Southwest Florida Water Management District	Alafia River Freshwater Segment	April 2020	Percent Time	Kelly, et al., (2005 November). Alafia River Minimum Flows and Levels; Freshwater Segment.
Southwest Florida Water Management District	Anclote River	May 2010	Percent Time	Heyl, et al., (2010 February). Anclote River System Recommended MFLs.
Southwest Florida Water Management District	Upper segment of the Braden River	December 2007	Percent Time	Munson, et al., (2007 December), Proposed minimum flows and levels for the Upper Segment of the Braden River.
Southwest Florida Water Management District	Dona Bay/Shakett Creek	October 2009	Percent Time	Heyl, et al., (2009 August). Proposed minimum flows and levels for Dona Bay/Shakett Creek.
Southwest Florida Water Management District	Chassahowitzka River System	October 2019	Percent Time	Herrick, G. et al., Southwest Florida Water Management District (2019, October). Reevaluation of minimum flows for the Chassahowitzka River System.
Southwest Florida Water Management District	Crystal River/Kings Bay System	April 2020	Percent Time	Herrick, G. et al., Southwest Florida Water Management District (2017, June). Recommended minimum flow for the Crystal River/Kings Bay System.
Southwest Florida Water Management District	Gum Slough Spring Run	March 2016	Percent Time	Basso, R. et al., Southwest Florida Water Management District (2011, October). Proposed minimum flows and levels for the Gum Slough Spring Run.
Southwest Florida Water Management District	Homosassa River	October 2019	Percent Time	Herrick, G. et al., Southwest Florida Water Management District (2019, October). Reevaluation of minimum flows for the Homosassa River System.
Southwest Florida Water Management District	Lower Peace River and Shell Creek	May 2010	Percent Time	Ghile, Y. et al., Southwest Florida Water Management District (2020, March). Proposed minimum flows for the Lower Peace River and Lower Shell Creek.
Southwest Florida Water Management District	Upper Segment of Hillsborough River (Crystal Springs to Morris Bridge)	December 2007	Percent Time	Munson, et al., Southwest Florida Water Management District (2007, December).

				Proposed MFLs for the upper Segment of Hillsborough River.
Southwest Florida Water Management District	Lower Hillsborough River	August 2007	Salinity Range / Low Flow Cutoff	Southwest Florida Water Management District (2006, August). Lower Hillsborough River MFL Recommendation.
Southwest Florida Water Management District	Little Manatee River	N/A[1]	Percent Time	Hood, et al., Southwest Florida Water Management District (2011, November). Proposed Minimum flows and levels of Little Manatee River.
Southwest Florida Water Management District	Lower Myakka River	July 2012	Percent Time	Flannery, et al., Southwest Florida Water Management District (2011, December). Determination of Minimum flows for the lower Myakka River.
Southwest Florida Water Management District	Upper Myakka River	November 2005	Percent Time	Kelly, et al., Southwest Florida Water Management District (2005, November). Proposed MFLs for the Upper segment of the Myakka River.
Southwest Florida Water Management District	Middle Peace River	N/A[2]	Percent Time	Kelly, et al., southwest Florida Water Management District (2005 October). Proposed MFLs for the middle segment of Peace river.
Southwest Florida Water Management District	Pithlachascotee River	March 2020	Percent Time	Leeper, et al., Recommended Minimum Flows for Pithlachascotee River (2018 March).
Southwest Florida Water Management District	Rainbow River	March 2019	Percent Time	Holzwart, et al., Southwest Florida Water Management District (2017 June). MFL for Rainbow River System.
Southwest Florida Water Management District	Sulphur Springs	August 2007	Salinity Incursions	Southwest Florida Water Management District (2004 September). The determination of minimum flows for Sulphur Springs.
Southwest Florida Water Management District	Northern Tampa Bay Bypass Canal	August 2007	Salinity Range	Southwest Florida Water Management District (2005 March). Minimum flows for the Tampa Bypass Canal.

Southwest Florida Water Management District	Weeki Wachee River	April 2010	Percent Time	Heyl, Southwest Florida Water Management District (2008 October). Weeki Wachee River recommended MFLs.
St. Johns River Water Management District	Silver Springs	April 2017	Event Approach	Sutherland, et al. St. Johns River Water Management District (2017). Minimum Flows Determination for Silver Springs.
St. Johns River Water Management District	Alexander Springs	May 2017	Mean flow reduction allowed for springs-based MFLs within Florida as of 1/26/2017	Freese and Sutherland, St. John's River Water Management District (2017). Minimum flow determination for Alexander Springs.
St. Johns River Water Management District	Silver Glen Springs	January 2019	USFWS and FWC agreement of allowable reduction (from current condition) of manatee thermal refuge habitat	Harris, et al., St. John's River Water Management District (2017). Determination of Minimum Flows for Silver Glen Springs.
St. Johns River Water Management District	Gemini Springs	May 2017	15% increase in residence time (from no pumping condition) of water in Gemini Springs artificial pool, to maintain water quality	Mace, St. John's River Water Management District (2017 April). Determination of Minimum Flows for Gemini Springs.

St. Johns River Water Management District	De Leon Springs	December 2016	USFWS and FWC agreement of allowable reduction (from non-impacted condition) of manatee thermal refuge habitat	Harris, et al., St. John's River Water Management District (2016). Determination of minimum flows for De Leon Springs.
South Florida Water Management District	Caloosahatchee River	July 2018	Salinity Range	South Florida Water Management District (2018 January). Reevaluation of the minimum flow criteria for the Caloosahatchee River.
South Florida Water Management District	St. Lucie River and Estuary	November 2002	Salinity Range	South Florida Water Management District (2002 May). Development of minimum flows for the St. Lucie River.
South Florida Water Management District	Northwest Fork of the Loxahatchee River	April 2003	Salinity Range	MFLs for the Northwest Fork of the Loxahatchee River (2002 November). South Florida Water Management District.
[1] **MFL evaluated but not adopted as of August 2020.** [2] **Adoption date not listed in rule.**				

Attachment C

Event Approach and Indicators of Hydrologic Alteration Demonstration
for Lower Santa Fe River System

CONTENTS

1. INTRODUCTION

1.1 Background

The draft Peer Review Panel consensus report for the 2019 draft Lower Santa Fe River (LSFR) system MFLs re-evaluation (SRWMD, 2019) included recommendations for an event-based approach (i.e., magnitude, duration, and frequency of hydrologic events) to compare with the percent-of-time approach used in the 2013 MFLs assessment and current MFLs re-evaluation reports.

The Panel Chair's Summary and Findings Group 9 comment (Dunn, 2020) asserts the "MFLs setting process is incomplete" and follows up with comments in Group 10 regarding methodology and recommendations to:

- Parameterize WRVs (Water Resource Values) based on an event approach[3]
- Use multiple approaches to set WRV metrics
- Screen and select a "best approach" for setting WRV metrics
- Follow key recommendations from the 2013 peer review (Graham et al. 2013) which included specifically applying the event approach and adopting an adaptive management (AM) approach
- Update the literature review to include a "state of science and practices"

Activities described in Task 3 of Task Work Assignment (TWA) 19/20-009.010 include:

- Assisting the District in identifying appropriate events for the protection of instream and floodplain habitat and other key WRVs against Significant Harm
- Assisting the District with verifying and or developing key metrics (e.g., wetland habitat boundaries, floodplain inundation depth, instream depth, etc.) for evaluating the occurrence of important hydrologic event durations and the change in the frequency of these events under alternative flow regimes
- Demonstrating one, or more, event analyses
- Comparing the approach and results to the methods and results in the 2013 MFL report (SRWMD, 2013) and the 2019 Draft MFLs re-evaluation report
- Using the Indicators of Hydrologic Alteration (IHA) software to characterize the change in hydrology associated with one or more flow-reduction scenarios

HSW submitted a draft Memorandum dated July 12, 2020, that generally describes an approach for applying an event-based analysis (hereafter Event Approach) and demonstrating its use to evaluate select water resource values (WRVs) for the LSFR system.

1.2 Purpose

The District's MFL team is well versed in approaches used to set MFLs in the State of Florida and the national and international state of the science regarding the protection of resource values generally and environmental flows specifically. The District concurs that many responses associated with

[3] A statistically defined protective hydrological event composed of 1) a magnitude (flow and/or level), 2) continuous duration for the specific inundation or drying period, and 3) with a return interval.

environmental and human use values are the result of a change in the flow regime such that important events are altered beyond some threshold. The District decision to not use an Event Approach was purposeful, logical, and well-founded for reasons described herein.

The purpose of this Attachment is to inform about the Event Approach and substantiate the decision to not plan for or use the approach for the LSFR system MFLs re-evaluation. This Attachment summarizes demonstrations based on available data of the:

- Event Approach applied to three distinctly different hydrologic events (Minimum Frequent High, Minimum Average, and Minimum Frequent Low) measured at the Santa Fe River (SFR) near Fort White (FW) gaging station (No. 02322500).
- IHA software (The Nature Conservancy, 2009) used to characterize the differences in a variety of statistical streamflow characteristics between long-term time series of observed flow adjusted to account for groundwater withdrawals and the projected flows associated with the proposed MFLs at the Fort White gage.

There is no plan currently to demonstrate the Event Approach and IHA at a different stream-gaging station such as Ichetucknee River (IR) at Highway 27 (HWY27) near Hildreth (station No. 02322700).

1.3 Best Available Data

- Daily flow (or discharge) recorded at the Santa Fe River (SFR) at Fort White (FW) gaging station (Figure C 1).
- Floodplain vegetation survey data collected in 2010 along 11 transects on the SFR floodplain (Figure C 1); (Atkins, 2012)
- SEFA instream microhabitat survey data collected at 4 sites in the SFR channel circa 2011/2012 (Figure C 2); limited to channel geometry and substrate data; HEC-RAS used to characterize water velocity and depth for different flows at each site; (SRWMD, 2013)
- Output from steady state (SS) HEC-RAS models of the LSFR system that were re-worked per TWA 19/20-009.009 (referred to as 2020 HEC-RAS models)
- Literature collated and used to support the event analyses described herein

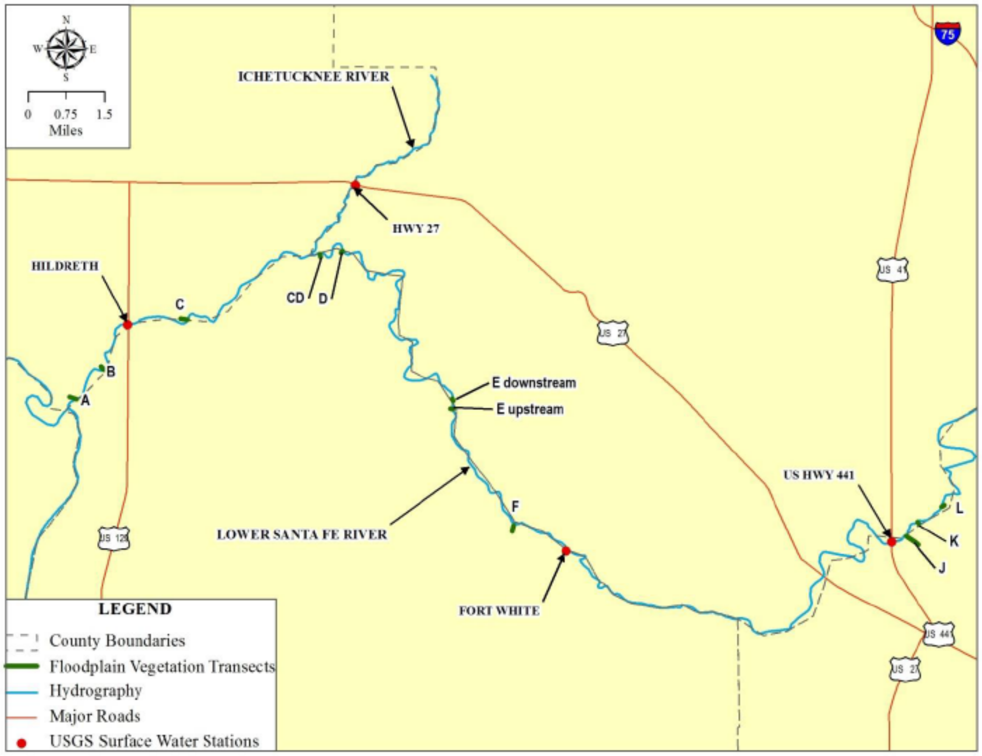

Figure C 1. Location of floodplain vegetation transects on the LSFR system
[Three transects (AA, BB, CC) on Ichetucknee River not shown]

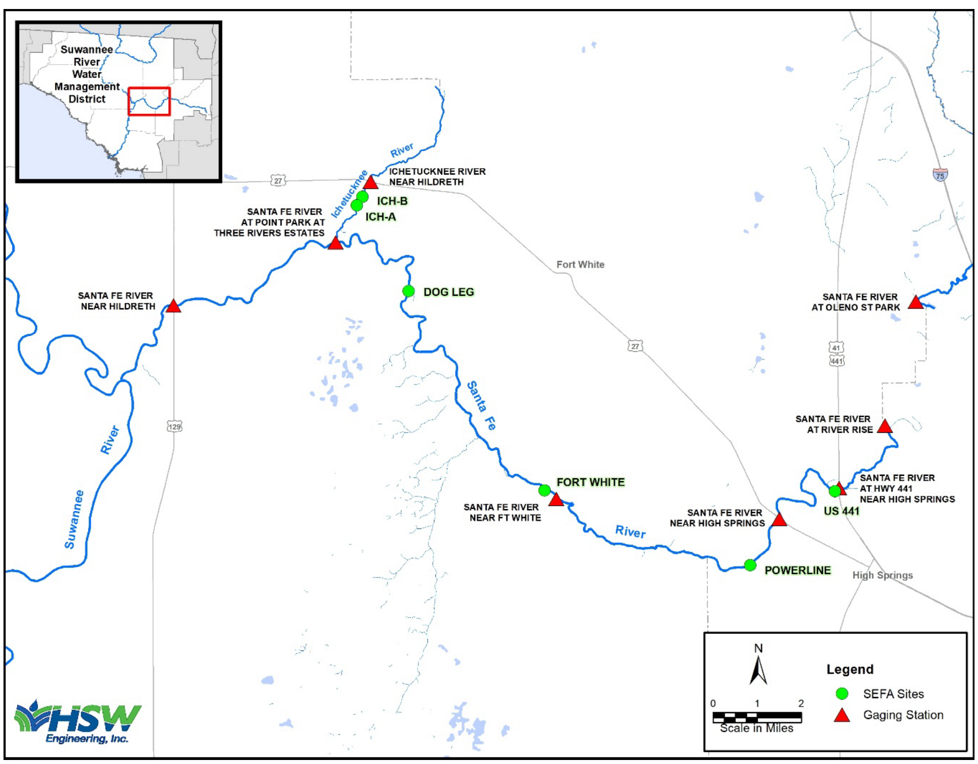

Figure C 2. Location of SEFA instream habitat transects on the LSFR system

1.4 Definition of Terms

- Event Approach: The application of annual extreme value frequency analysis (Chow, Maidment, & Mays, 1988) to calculate annual streamflow "events" that are defined by magnitude, duration, and frequency (MDR) and meaningful to a water resource value (WRV) indicator; usually applied to annual values; assumes that the individual events in a time series of events are independent of each other.
- Probability Plot: X-Y plot of event magnitude (Y axis) versus event frequency (X axis).
- Flow-Duration Frequency: Probability that a flow is exceeded; usually based on daily values that may be serially correlated to one degree or another.
- Flow-Duration Curve (FDC), more generally referred to cumulative frequency distribution: X-Y plot of frequency of value being exceeded (X axis) versus flow magnitude (Y axis).
- Period of Record (POR): Time period considered in the 2019 MFLs re-evaluation; specifically, Water Years 1933-2015 (10/1/1932 – 9/30/2015).
- Period of Analysis (POA): Time period considered for a specific event analysis; equals POR unless otherwise stated.
- Observed Flow (or discharge): Daily stream discharge determined using documented stream-gaging and quality-assurance methods; records published by the District and U.S. Geological Survey (USGS); usually expressed as cubic feet per second (cfs).
- Reference Timeframe Flow (RTF): Daily observed flows adjusted to account for groundwater withdrawals by adding in the NFSEG groundwater model flow adjustments to the POR flow dataset
- Magnitude: The observed flow or RTF value.
- Event Frequency (or Probability, P): Probability of occurrence of an event.
- Exceedance Frequency (or Exceedance Probability, P_E): Probability of occurrence of an event that exceeds a given value; expressed as a percentage or equivalently as a number of events per century.
- Non-exceedance Frequency (or Non-exceedance Probability, P_{NE}): Probability of occurrence of an event that does not exceed a given value; expressed percentage or equivalently as number of events per century.
- Recurrence Interval (RI), often referred to as return interval: The time, on average, between events; RI = 1 / P_E or 1 / P_{NE} . RI for annual extreme value analyses is expressed in years.
- Duration (D): Continuous period of time associated with an event, typically in days.
- Critical Magnitude, Duration, Frequency: A prescribed discharge (or related stage), duration, and frequency that characterize an "event" selected to evaluate a particular water resource value (WRV)
- Inundation event: A condition when river stage is continuously at, or above, a designated critical elevation such as land surface.
- Dewatering event: A condition when river stage is continuously below a designated critical elevation.
- SWIDS (Surface Water Inundation / Dewatering Signature): The location-specific relationship between RI and D for a prescribed event magnitude.
- Baseline – An unimpacted hydrologic condition: from (Neubauer, et al., 2008). "The Event Approach is described as a top-down approach originating with a presumed unimpacted baseline flow regime." From the 2013 (SRWMD) considered a pre-1991 period defined as a

"period of time when the rainfall-streamflow relationships were relatively stable, with no reference to presumed anthropogenic effects." The 2019 evaluation considered a pre-2016 period of historical observed flows adjusted for the effects of withdrawals. Currently the SWFWMD, SJRWMD and SRWMD treat historical flows adjusted for groundwater withdrawals as a baseline hydrologic condition.

2. METHODS

2.1 Basis for an Event-Based Approach Applied to Florida Rivers

The St. Johns River Water Management District (SJRWMD) has adopted MFLs for six river systems (three reaches of St. Johns River, Black Water Creek, Taylor Creek, and Wekiva River. A seventh river system, Silver River, was evaluated to determine MFLs for Silver Springs. The technical reports supporting the MFLs describe applications of the SJRWMD event-based approach (see (Neubauer, et al., 2008) and (SJRWMD, 2006)). Select excerpts from a recent assessment of Silver Springs (Sutherland, et al., 2017) that described the basis for the approach follow (**bold** added for emphasis).

> Hydroperiod is a primary driver of wetland plant distribution and diversity, hydric soils type and location, and to a lesser degree freshwater fauna [(Foti, del Jesus, Rinaldo, & Rodriguez-Iturbe, 2012) and (Murray-Hudson, Wolski, Murray-Hudson, Brown, & Kashe, 2014)]. Hydroperiod is often described as the inter-annual and seasonal pattern of water level resulting from the combination of water budget and storage capacity (Welsch, et al., 1995). **Wetland hydroperiods vary spatially and temporally** and consist of multiple components, including: return interval, duration and magnitude. Native wetland and aquatic communities **have adapted to and are structured by this natural variability** [(Poff N. L., et al., 1997), (Richter B. D., Baumgartner, Wigington, & Braun, 1997), and (Murray-Hudson, Wolski, Murray-Hudson, Brown, & Kashe, 2014)].
>
> Because of the role of hydroperiod in structuring and maintaining wetland and aquatic communities, the SJRWMD MFLs approach is centered around the concept of protecting a minimum number of flooding events **or** preventing more than a maximum number of drying events for a given ecological system.
>
> Five critical components of hydrological events are typically recognized: return interval, duration, magnitude, rate of change and timing (Poff et al., 1997). However, because the latter two are thought to be a function of climate, only the first three are a focus of the SJRWMD approach. **Magnitude and duration components define the critical ecological events that affect species at an individual level** (i.e., individual organisms). The return interval of an event is what changes due to climate and/or water withdrawal. Therefore, by assessing the effects of water withdrawal on the return interval of MFLs events a determination is made regarding whether additional water is available. By **comparing the frequency of ecologically critical events to** the **allowable frequency** of these same events, the **SJRWMD MFLs method is able to determine the amount of water that is available** (or needed for recovery) within a given ecosystem under different withdrawal conditions.

Variable flooding and/or drying events are necessary to maintain the extent, composition, and function of wetland and aquatic communities. For example, the long-term maintenance of the maximum extent of a wetland may require an infrequent flooding event, of sufficient duration and return interval, to ensure that upland species do not permanently shift downslope into that wetland. In addition to flooding events, some aspects of wetland ecology (e.g., plant recruitment, soil compaction, nutrient mineralization) are also dependent upon drying events, as long as they do not occur too often. Because hydroperiods vary spatially and temporally (Mitsch & Gosselink, 1993), multiple MFLs are typically used to address and protect different portions of a system's natural hydrologic regime (Neubauer, et al., 2008).

For many systems SJRWMD sets three MFLs: a minimum frequent high (FH), minimum average (MA), and minimum frequent low (FL) flow and/or water level. In some cases (e.g., for sandhill-type lakes) a minimum infrequent high (IH) and/or minimum infrequent low (IL) may also be set.

Terminology associated with the Event Approach and a generic association of extreme value probability plots with a conventional flow duration curve are illustrated in Figure C 3 followed by an example SWIDS plot (Figure C 4). Two of the five targeted flow regimes evaluated by SJRWMD are associated with continuously exceeded events, and typically high-flow conditions. Similarly, two targeted flow regimes are associated with continuously not-exceeded conditions, and typically low-flow conditions. A minimum average (MA) event, associated with a long-term period within a year (e.g., 180 days), is associated with flows that are likely greater or less than the MA, but equal the MA when averaged.

2.2 Event Parameterization

Wetland and aquatic species, and hydric soils require a minimum frequency of critical hydrologic (drying and/or flooding) events for long-term persistence. Wetland communities require a range of flooding and drying events to fulfill many different aspects of their life history requirements (Sutherland, et al., 2017). SJRWMD has compiled a substantial body of knowledge documented in special publications prepared for various MFLs assessments (SJRWMD, 2020). The documents include references to field surveys, event-based analyses, and numerous technical reports and papers published in refereed sources. In 2000, Congress approved the Comprehensive Everglades Restoration Plan (CERP) to restore, preserve, and protect the South Florida Ecosystem, while providing for other water-related needs of the region (U.S. Department of the Interior, 2020). Numerous ecological investigations supported by field surveys and scientific evaluations are another source of information that could support an ecological event analysis.

The seven riverine MFLs adopted by SJRWMD to date are based on multiple events ((SJRWMD, 2019) and (Table C 1)). The hydrologic regimes considered range from Infrequent High (IH) to Infrequent Low (IL) with breaks of:

- 5-year RI (i.e., 20 occurrences per century) appearing to be the threshold between IH and FH and
- 15-year RI (i.e., 6.7 occurrences per century) the apparent threshold between FL and IL.

Critical durations range between 7 and 180 days with 30 days specified for nearly all the FH events.

The SJRWMD will sometimes evaluate WRVs other than Fish and Wildlife Habitats and the Passage of Fish (WRV-2, Table C 2) as a back-check on a proposed MFL that is based on WRV-2. Seven WRV's including WRV-2 were evaluated for the Lower Ocklawaha River (HSW, 2011) (Table C 2).

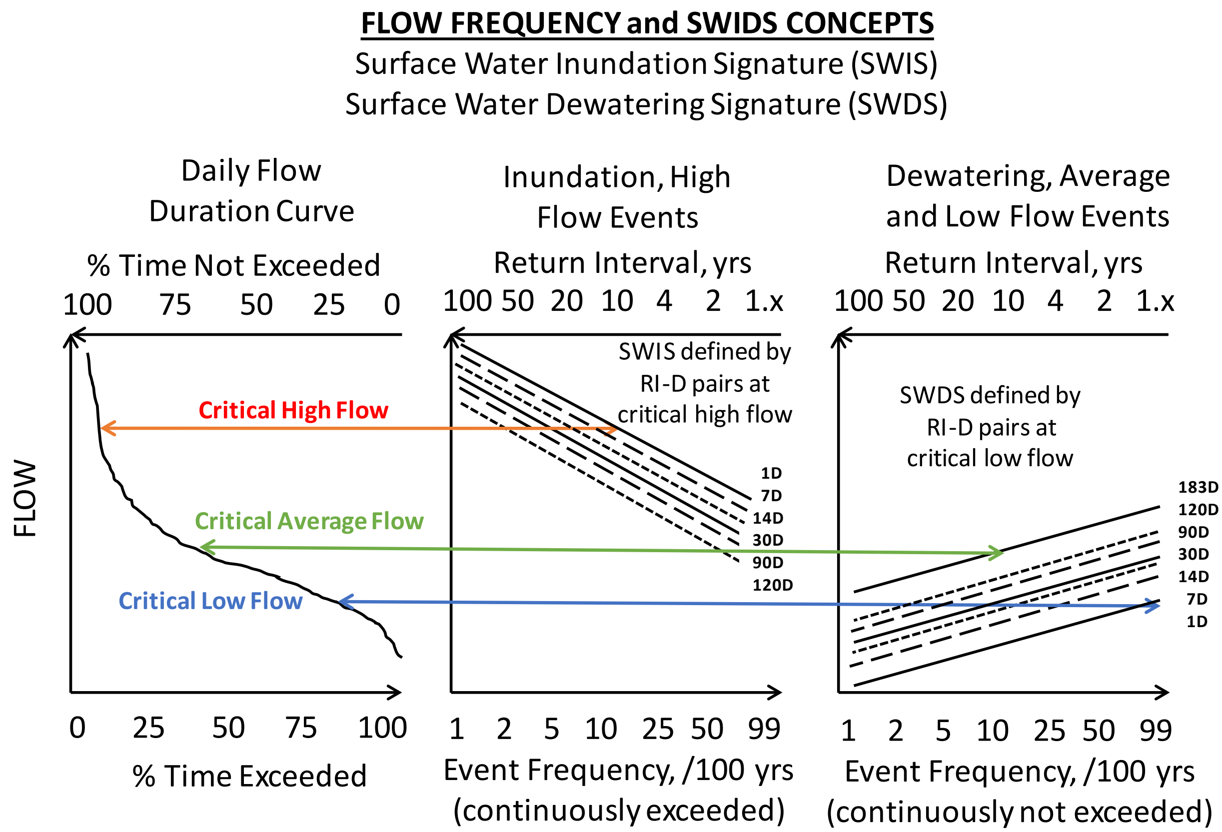

Figure C 3. Example of flow duration curve and event analysis probability plots for a range of durations

[Exceedance, or non-exceedance, probability = event frequency / 100; An inundation SWIDS (Table C 4) represents the set of P_E-D tuples associated with the intersection of the Critical High Flow line and set of probability plots ranging from 1 day (1D) to 120 D]

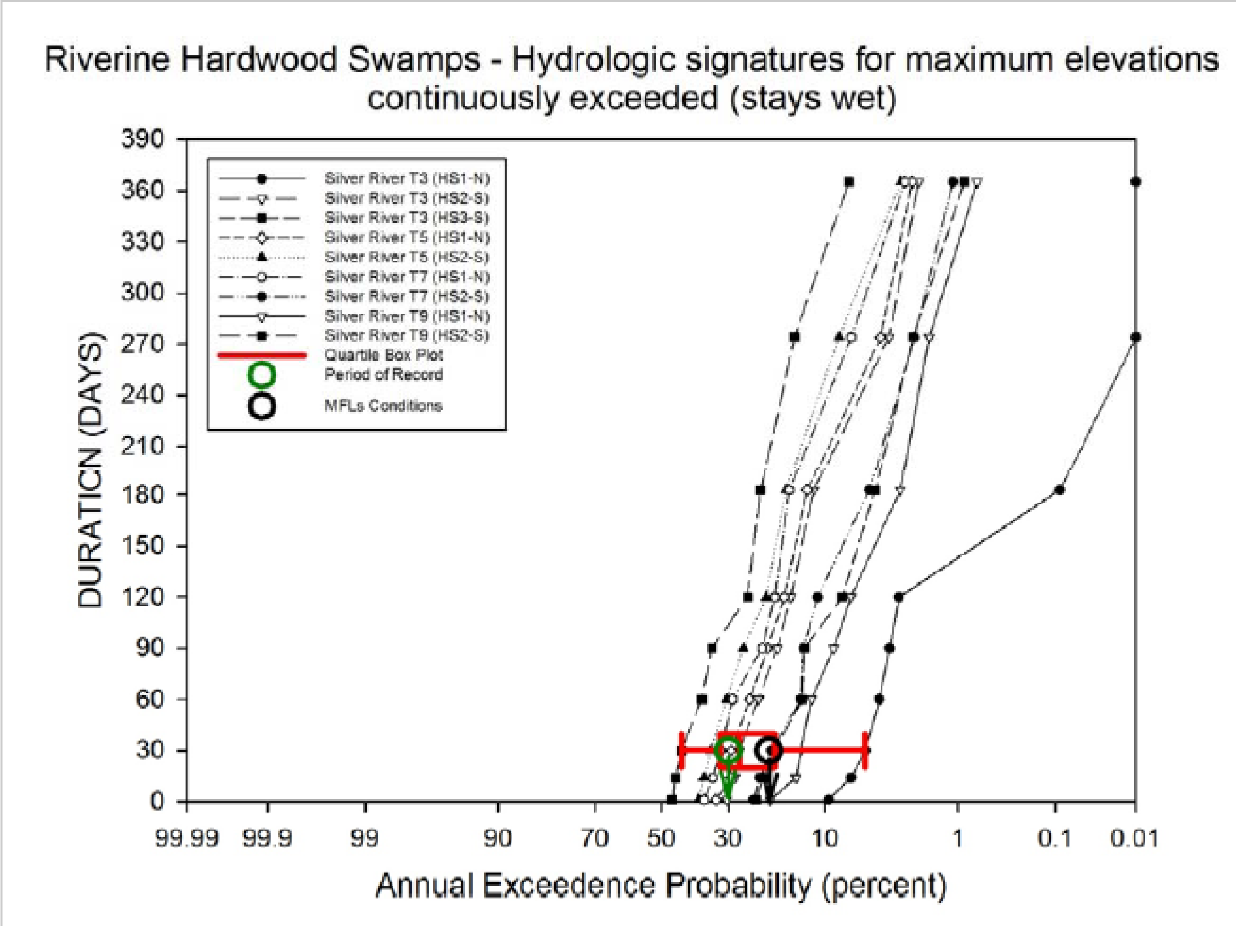

Figure C 4. Example of nine surface water inundation signatures developed for the Silver River MFLs assessment

[Notes: Source (Sutherland, et al., 2017); Each line represents a surface water inundation signature (SWIS); Box-and-whisker diagram illustrates the quartiles and range of P_E associated with a 30-day duration; Circle represents the average P_E]

Table C 1. Event criteria and parameters by hydroperiod category that define riverine MFLs adopted by SJRWMD [Sources: (NewFields Companies, 2012), modified for completeness and footnote added by HSW; (SJRWMD, 2019)]

River System	Reach Location	Flow Regime (Event Descriptor)	Critical Duration (days)	Allowable Return Interval (years)	Hydroperiod Category	Reported Ecological Basis
Wekiva River (WR)	WR @ SR46 Bridge	Minimum Infrequent High (IH)	7	5	Temporarily flooded	Riparian wetland flooding
Black Water Creek (BWC)	BWC @ SR44	Minimum Infrequent High (IH)	7	5	Temporarily flooded	Riparian wetland following
St. Johns River (SJR)	SJR @ SR 44 DeLand	Minimum Frequent High (FH)	30	3	Seasonally flooded	Floodplain inundation
St. Johns River	SJR @ SR 50	Minimum Frequent High (FH)	30	2	Seasonally flooded	Floodplain inundation
Silver River (SR)[2]	USGS station 02239501 (SR near Ocala)	Minimum Frequent High (FH)	30	5	Seasonally flooded	Floodplain inundation
Taylor Creek	TC 1.7 miles below S-164	Minimum Frequent High (FH)	NS[1]	NS	Seasonally flooded	Floodplain inundation
St. Johns River	SJR Downstream of Lake Washington	Minimum Frequent High (FH)	NS	NS[1]	Seasonally flooded	Floodplain inundation
Wekiva River	WR @ SR46 Bridge	Minimum Frequent High (FH)	30	2	Seasonally flooded	Hydric hammock flooding
Black Water Creek	BWC @ SR44	Minimum Frequent High (FH)	30	2	Seasonally flooded	Hydric hammock flooding
St. Johns River	SJR @ SR 44 DeLand	Minimum Average (MA)	180	1.5	Typically saturated	Maintain hydric soils and wetland plant communities
St. Johns River	SJR @ SR 50	Minimum Average (MA)	180	1.5	Typically saturated	Maintain hydric soils and wetland plant communities
Taylor Creek	TC 1.7 miles below S-164	Minimum Average (MA)	NS	NS	Typically saturated	Maintenance of floodplain community
St. Johns River	SJR Downstream of Lake Washington	Minimum Average (MA)	NS[1]	NS[1]	Typically saturated	---

Silver River (SR)[2]	USGS station 02239501 (SR near Ocala)	Minimum Average (MA)	180	1.7	Typically saturated	Prevent excessive drying of deep organic soils of the floodplain
Wekiva River	WR @ SR46 Bridge	Minimum Average (MA)	180	1.7	Typically saturated	Maintain hydric soils and wetland plant communities
Black Water Creek	BWC @ SR44	Minimum Average (MA)	180	1.7	Typically saturated	Maintain hydric soils and wetland plant communities
St. Johns River	SJR @ SR 44 DeLand	Minimum Frequent Low (FL)	120	5	Semi- permanently flooded	Floodplain drawdown
St. Johns River	SJR @ SR 50	Minimum Frequent Low (FL)	120	5	Semi- permanently flooded	Floodplain drawdown
Taylor Creek	TC 1.7 miles below S-164	Minimum Frequent Low (FL)	NS	NS	Semi- permanently flooded	Maintenance of floodplain community
St. Johns River	SJR Downstream of Lake Washington	Minimum Frequent Low (FL)	NS[1]	NS[1]	Semi-permanently flooded	Floodplain drawdown
Silver River (SR)[2]	USGS station 02239501 (SR near Ocala)	Minimum Frequent Low (FL)	120	3	Semi-permanently flooded	Maintain riparian marsh ecotone and water table in organic soils within hardwood swamp
Wekiva River	WR @ SR46 Bridge	Minimum Frequent Low (FL)	90	3	Semi-permanently flooded	Protection of eelgrass beds
Black Water Creek	BWC @ SR44	Minimum Frequent Low (FL)	90	15	Semi- permanently flooded	Floodplain drawdown and fish passage
St Johns River	SJR @ SR 50	Minimum Infrequent Low (IL)	60	50	Infrequently flooded	Fish passage

[1] Not Specified (NS) in Chapter 40C-8, F.A.C.
[2] Codified in Chapter 40C-8, F.A.C. as MFLs for Silver Springs in Marion County

Table C 2. Example hierarchical classifications to quantitatively evaluate various water resource values (WRVs) for the Lower Ocklawaha River [Source: (HSW, 2011)]

Relevant WRV	Criteria	Representative Functions	General Indicators	Specific Indicators	Magnitude	Duration (Days)
WRV-1 (Recreation In and On the Water)	Legal water sports and activities	Boat passage and boat clearance	Water depth needed to allow for safe recreational boating	Stage associated with safe boat launch, boat propeller clearance, and safe boat passage	2.0 ft water depth for propeller clearance	7
WRV-2 (Fish and Wildlife Habitats and the Passage of Fish)	Aquatic and wetland environments required by fish and wildlife	Fish and wildlife habitat requirements and fish passage for a large species such as largemouth bass or sunfish	Fish passage in the main channel, fish and wildlife habitats, usage of floodplain by wading birds	Minimum depth to allow for sufficient passage for largemouth bass	1.6 ft water depth for largemouth bass	Not limiting
				Elevation associated with the spatially predominant floodplain vegetation community	Mean elevation of hardwood swamp	30
				Depth associated with usage of floodplain for wading birds	0.5 ft above the mean elevation of hardwood swamp	30
WRV-4 (Transfer of Detrital Material)	The transfer of loose organic material	Detrital supply and distribution associated with floodplain inundation	Depth of water to maintain detrital transfer	Water depth necessary for floodplain inundation for adequate detrital transfer	Mean elevation of hydric hammock	7

Table C 2. Hierarchical classifications for evaluating the WRVs for the study reach (cont'd)

Relevant WRV	Criteria	Representative Functions	General Indicators	Specific Indicators	Magnitude	Duration (Days)
WRV-6 (Aesthetic and Scenic Attributes)	Passive recreation	Visual setting of the river at selected hydraulic control points	Stage of the river reach	Stage associated with optimal scenic and wildlife viewing	1.5 ft below top of bank elevation	60
WRV-7 (Filtration and Absorption of Nutrients and Other Pollutants)	Process of filtration and absorption	Ability of water/ecosystem to promote nutrient removal in adjacent floodplain wetlands	Depth and duration of floodplain inundation	Water depth associated with selected duration sufficient to maintaining floodplain inundation	Minimum elevation in hydric hammock	30
WRV-8 (Sediment Loads)	Transport of inorganic materials	Maintenance of sediment transport	Stage, velocity, and bed shear stress associated with maintaining channel geomorphology	Bankfull stages associated with channel maintenance	Bankfull stage	30
WRV-9 (Water Quality)	Chemical and physical properties of the water	Maintenance of concentrations of water quality parameters	Dissolved oxygen recovery	Reaeration potential	Flow for maximum reaeration capacity	1 and 7

3. EVENT APPROACH DEMONSTRATIONS

Three events were selected to demonstrate the Event Approach (Table C 3). Two target the frequent high flow regime, one targets the mid-flow range, and two target the low-flow regime.

The primary steps taken to demonstrate the Event Approach applications are:

1. Perform extreme value frequency analysis to calculate annual streamflow characteristics defined by magnitude, duration, and frequency (MDR) for a specified index gaging station and period of analysis. R scripts developed by the District were used to create exceedance and non-exceedance probability plots for selected durations based on the Weibull plotting position (Stedinger, Vogel, & Foufoula, 1993).
2. Specify the water resource value being investigated and the associated specific indicator variable (e.g., depth, elevation, etc.) and location(s) selected to evaluate the WRV.
3. Determine the critical flow magnitude (M) referenced to the index gaging station. When multiple monitoring locations are evaluated for a specific WRV indicator, translate the critical flow (and or stage) at each monitoring location to the index gaging station.
4. When a single monitoring location is evaluated for a specific WRV, translate the critical flow determined for the monitoring location to the index gaging. Proceed to step 7.
5. When multiple monitoring locations are evaluated for a specific WRV indicator, after translating the critical flow for each monitoring location to the index gaging station, use the probability plots developed for a range of selected durations to develop a set of SWIDS.
6. Evaluate the SWIDS set to characterize either the range of recurrence intervals associated with a specified duration (Figure C 4), or a range of durations associated with a specified recurrence interval.
7. Prescribe a critical D and range of relevant of environmentally sensitive RI's based on field data (SWIDS) or literature if possible.
8. Repeat step 1 for alternative periods of analysis and/or flow scenarios (e.g., observed, RTF, and MFL) and compare the alternative return intervals associated with the critical M and D to determine the water that might be available for withdrawal.

An alternative approach to steps 4 and 5 is to translate the critical stage(s) at the monitoring station(s) to stage(s) and associated discharge(s) at the index station.

Multiple time periods are considered to demonstrate the Event Approach. Probability plots were developed and evaluated for the following daily flow conditions and periods that are labeled:

- Observed Discharge (1933-2010): Period preceding the July 2011 floodplain vegetation and soil surveys (Atkins, 2012). Previously referred to as Floodplain Vegetation Survey Baseline (VSB) flow in the 7/12/20 draft Memorandum.
- Observed Discharge (1933-2015): Period assessed in the MFLs re-evaluation, specifically 10/32 – 9/15.
- Reference Timeframe Flow, RTF (1933-2015): Daily POR flows adjusted by adding in the NFSEG groundwater model flow adjustments to POR flow dataset.
- MFL Flow (1933-2015): Daily RTF flow adjusted to represent the proposed MFL (SRWMD, 2019).
- Baseline Flow (1933-1990): Period of observed discharge assessed for the initial MFLs (SRWMD, 2013), specifically 10/32 – 9/90.

Table C 3. Characteristics of events selected to demonstrate the Event Approach

Example No.	Type of Flow/level	Duration, D (days)	Recurrence Interval, RI (years)	Magnitude (cfs)	Period of Analysis	Site Category	Hydroperiod Category	Ecological Basis for RI and D (Reference)
1.1	Minimum Frequent High (FH)	14	2 to 5	3,852	1933-2010 historic[1]	Maximum elevation of Hydric Hardwood Hammock (HHH)	Seasonally flooded floodplain	Floodplain inundation (Light, Darst, Lewis, & Howell, 2002)
1.2	Minimum Frequent High (FH)	30	2	3,852	1933-2010 historic[1]	Maximum elevation of hydric hardwood hammock (HHH)	Seasonally flooded floodplain	Floodplain inundation (SJRWMD, 2019), (Table C 1)
2	Minimum Average (MA)	180	1.5 to 2	1,178	1933-2010 historic[1]	Hardwood Swamp (HS)	Typically saturated low-level floodplain	Mean elevation of hardwood swamp at transect F
3.1	Minimum Frequent Low (FL)	120 days	3	1,059	1933-2015 RTF	LSFR SEFA sites, spawning area	Seasonally flooded channel	3 to 4 ft depth over spawning area, SEFA instream habitat sites (E. Nagid, FWC)
3.2	Minimum Frequent Low (FL)	120 days	1.5	1,059	1933-2015 RTF	LSFR SEFA sites, spawning area	Seasonally dewatered channel	3 to 4 ft depth over spawning area, SEFA instream habitat sites (E. Nagid, FWC)

[1] Floodplain vegetation/soil survey baseline (Atkins, 2012)

3.1 Demonstration Example No. 1.1 (Minimum Frequent High)

Purpose:

- Demonstrate an evaluation of a Frequent High event
- Demonstrate SWIDS development based on field survey of wetland vegetation
- Characterize the variability of water availability associated with recurrence interval based on literature compared to field-survey (SWIDS) results
- Characterize the variability of the critical magnitude associated with survey results

Definition: "Minimum frequent high" means a chronically high surface water level or flow with an associated frequency and duration that allows for inundation of the floodplain at a depth and duration sufficient to maintain wetland functions. (Chapter 40C-8.021(7), F.A.C.)

Relevant WRV: **WRV-2** (Fish and Wildlife Habitat)

General indicator: Hydric floodplain habitat

Specific indicator: Elevation of ecotone between upland and wetland communities

Goal: Protecting a minimum number of flooding events to sustain the ecotone

Vegetation classes sampled along the Lower Santa Fe River were distinct in terms of species composition, and measurable environmental parameters such as elevation can provide a basis for establishing MFLs (Atkins, 2012). Within wetlands, depth to seasonal high saturation (SHS) appeared to differentiate "drier" (hammocks) from "wetter" wetlands (swamps). Hydric hardwood hammock (HHH) was the highest/driest floodplain wetland vegetation class observed during the 2011 floodplain vegetation survey.

Maximum land-surface elevations associated with HHH presumably define the ecotone between upland and wetland habitat. The mean land-surface elevation associated with HHH would be expected to be inundated more frequently for the same inundation duration compared to maximum HHH elevations.

Probability plots were developed for the maximum annual flow continuously exceeded for selected durations ranging from 1 to 270 days (Figure C 5). Example 1.1, described in this subsection, considers a duration of 14 days. Example 1.2, described in following subsection, considers an inundation duration of 30 days. A LOESS smoothing factor of 0.07 was used to generate the smoothed lines shown on all the probability plots presented herein.

Critical Magnitude

Maximum HHH elevations observed during the field survey at 7 transects ranged between 39 feet NAVD88 at the upstream transect L and 18.9 feet at transect D (Table C 4). Rating curves calculated by HEC-RAS were used first to translate each maximum HHH elevation to a discharge at each transect. Each transect flow was then translated to a flow at Fort White associated with the same flow-duration frequency. The set of flows at Fort White, termed critical maximum HHH flows, ranged between 2,750 and 4,665 cfs and averaged 3,852 cfs (Table C 4 and Figure C 14).

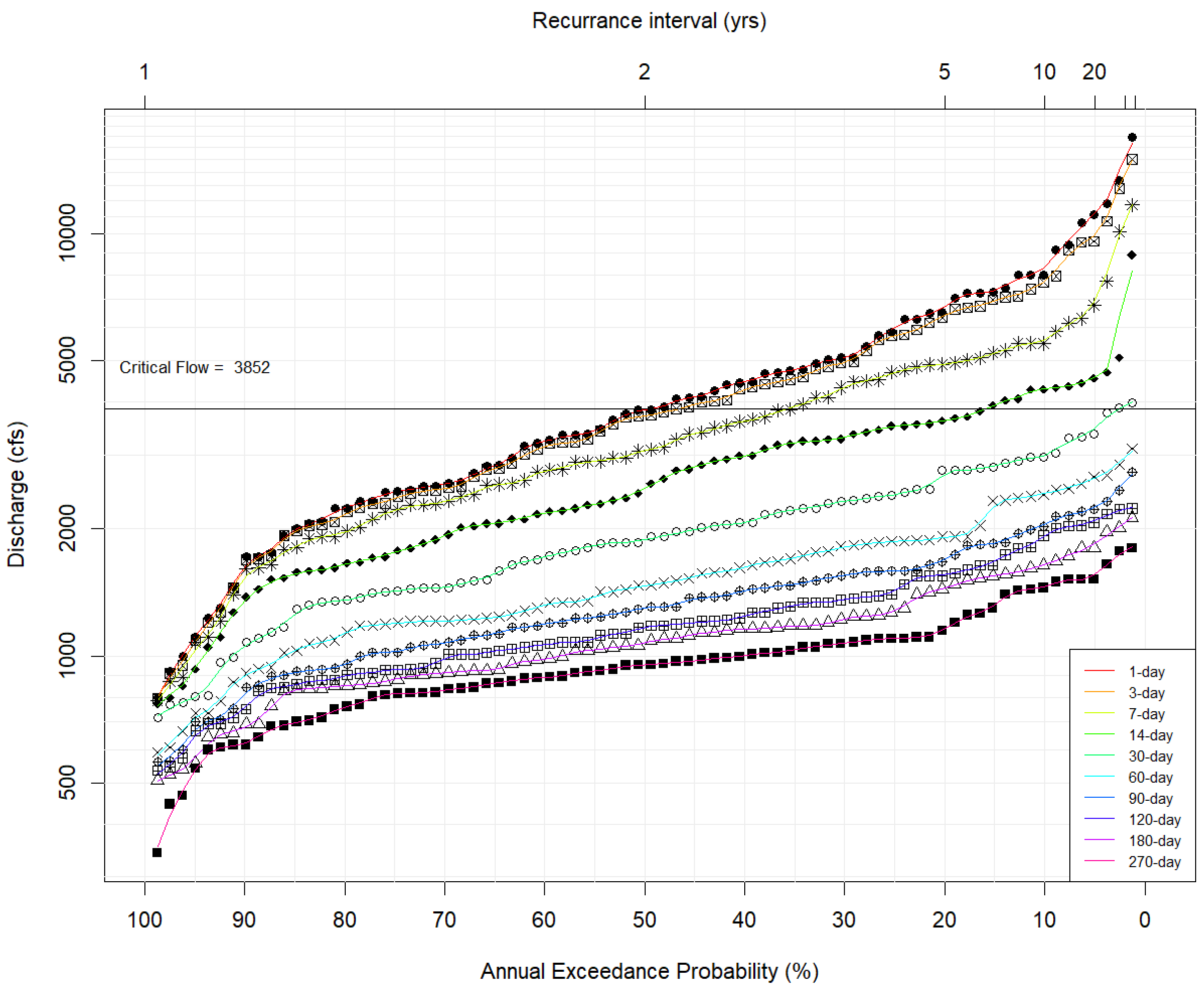

Figure C 5. VSB period probability plots for annual maximum high flow continuously exceeded at the Fort White gage for various durations

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Table C 4. Critical maximum elevations and flows associated with HHH surveyed along the SFR
[Sorted by increasing flow magnitude]

Transect ID	HEC-RAS Station ID	Critical maximum elevation at transect (ft NAVD88)	Critical flow at Fort White translated from transect (cfs)
J	152723	35.5	2,750
F	89916.2	23.7	3,284
L	158287	38.9	3,750
E down	73244	20.6	3,814
D	42107.5	18.9	4,212
E up	74474.5	22.2	4,492
K	154931	39.0	4,665
Average (Critical Maximum HHH Flow):			3,852
Note: Transect CD was excluded due to a discrepancy in 2012 field notes confirmed during 2020 site visit			

Critical Duration and Recurrence Interval

Flood depths maintained continuously for a period of 14 days that occur every 2 to 5 years were determined to be important descriptors of general flood conditions affecting tree regeneration in riverine floodplain forests in the lower Suwannee River (Light, Darst, Lewis, & Howell, 2002). These floods restrict upland plant regeneration in wetland forests because seedlings of invasive exotic species and opportunistic hardwoods are unable to gain enough height during the period to survive the next flood. Floods greater in magnitude occur less frequently, thus allowing more time for young trees to reach heights that exceed flood depths. Note that the metric used for evaluating the WRV is not the flood occurrence itself but the average time between the flood events that restricts the growth of invasive plant species.

The work by Light (Light, Darst, Lewis, & Howell, 2002) was based on the median elevation of the wetland habitat. We also are interested in the maximum elevation of HHH to evaluate the position and condition of the ecotone between the wetland and upland habitat. This event demonstration is based on the maximum elevation of the HHH, so it was expected that the return intervals of important events will be greater than the 2 to 5-year range.

A SWIDS was developed for each transect (Figure C 6) based on the critical maximum HHH flows (Table C 4) and inundation probability plot (Figure C 5). The box-and-whisker plot in Figure C 6 illustrates the range in P_E associated with a critical event D of 14 days (

Table C 5). Return intervals associated with a 14-day event ranged between 2.16 and 22.65 years with a median RI of 6.11 years. Eliminating the highest and lowest RIs in Table C 5 (i.e., 28% of the sample), the median would be bracketed by clipped range of 3.27 to 17.29 years. Expressed as frequencies (% or events per century), the median exceedance frequency is 16.36 events per century, and the interquartile (i.e., clipped) range is 30.61 to 5.78 events per century.

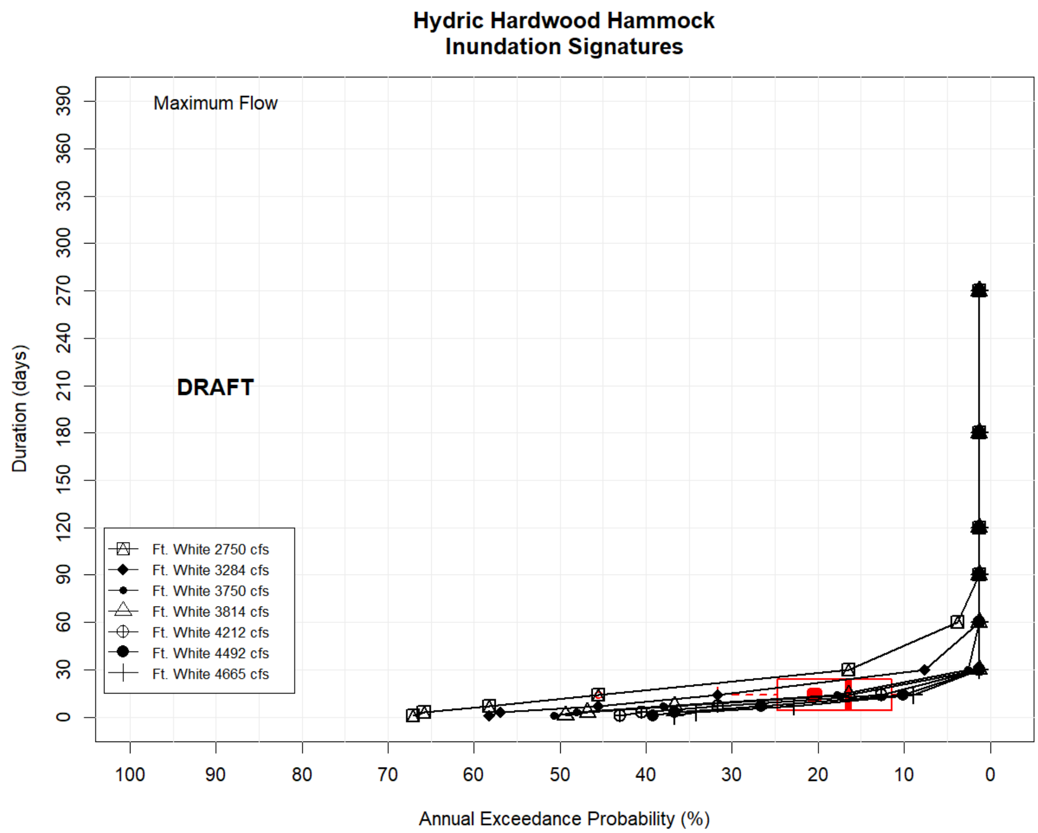

Figure C 6. VSB period SWIDS inundation signatures based on critical flows at Fort White associated with maximum HHH elevations
[Red box-and-whisker plot and square added to illustrate the range, quartiles and mean of P_E associated with a 14-day critical duration]

Table C 5. Statistics for magnitude and frequency of 14-day continuously exceeded high flows at Fort White [See Figure C 6]

Transect	Flow at Fort White (cfs) [2020 HEC-RAS Model]	Frequency (P_E), % or events per century[1]	Return interval (RI), years[2]
J	2,750	46.27	2.16
F	3,284	30.61	3.27
L	3,750	17.21	5.81
E down	3,814	16.36	6.11
D	4,212	11.50	8.70
E up	4,492	5.78	17.29
K	4,665	4.41	22.65
Average	3,852		
Median		16.36	6.11
Notes: [1] P_E = 100/RI [2] RI = 100/P_E			

Available Flow Analysis

The Frequent High Flow event is characterized by the mean maximum HHH critical flow of 3,852 cfs (Table C 5) and critical duration of 14 days. Probability plots (Figure C 7) were created to characterize the water potentially available assuming the six following flow conditions:

- Discharge (1933-2010): Floodplain vegetation survey baseline (VSB)
- Discharge (1933-2015): POR historical flow considered impacted by withdrawals
- RTF (1933-2015): POR historical flow considered unimpacted by withdrawals
- MFL (1933-2015): POR flow associated with the proposed MFL (SRWMD, 2019)
- Discharge (1933-1990): Baseline period considered in the 2013 MFLs assessment (SRWMD, 2013)
- Discharge (1991-2015): Recent conditions observed subsequent to the 2013 baseline period

Since the goal is to protect a minimum number of flooding events, the cross-hatched portion of the Figure C 7 and Figure C 8 represents a viable range of flows and exceedance frequencies. In other words, water is available if the frequency of the annual FH exceeds 3,852 cfs, for no less than about 16 times per century (i.e., about every 6.3 years). Water availability is inferred by the vertical difference between the corner of the cross-hatched area and the intersection of the FH line with any given probability plot.

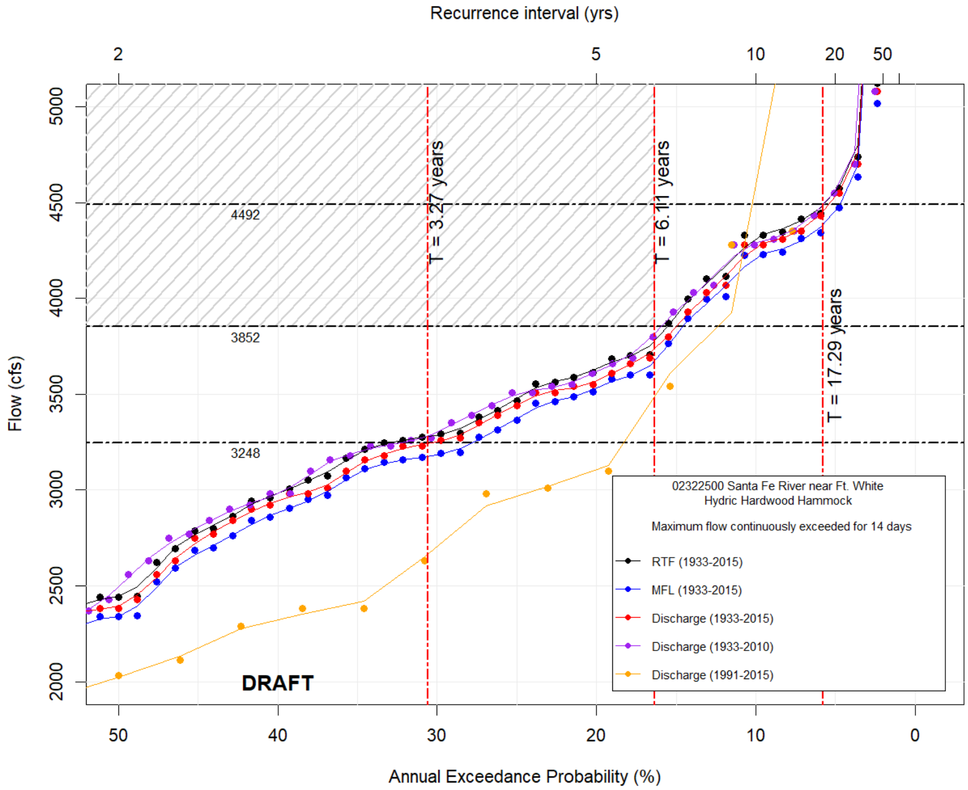

Figure C 7.Probability plots for annual maximum high flow continuously exceeded for 14 days at the Fort White gage for various flow scenarios

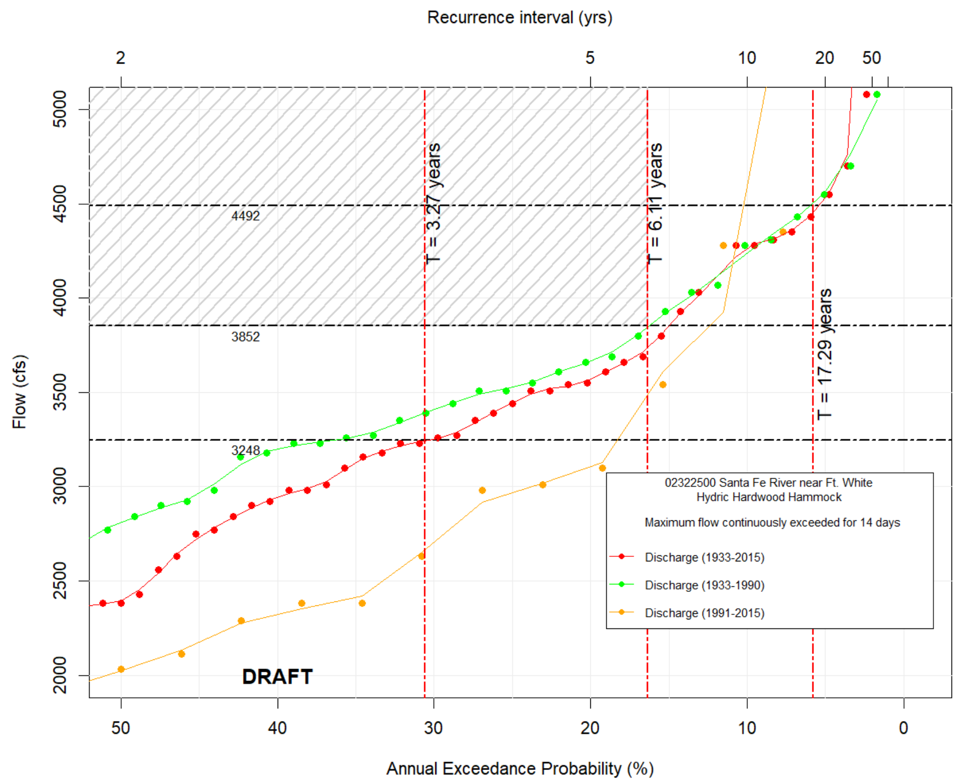

Figure C 8. Probability plots for annual maximum high flow continuously exceeded for 14 days at the Fort White gage for various flow time periods

By construct, the corner of the viable region intersects the VSB probability plot at an RI of 6.11 years. The corner of the viable region sometimes is represented by a literature-based value if that information is transferable to the system of interest. The intersects for the RTF and Baseline probability plots are nearly coincident with the VSB intersection, and the POR intersect is almost imperceivably lower than the VSB intersection. This would be expected since the NFSEG flow adjustments at the Fort White gage ranged between about 15 and 75 cfs (Figure 21 in (SRWMD, 2019)). The MFL intersect reflects the 103-cfs hydrologic shift (downward) from the RTF flow condition (Table 33 in (SRWMD, 2019)).

What is most notable in Figure C 7 is how much lower the annual high-flow events were during recent (1991-2015) times. During this period, the NFSEG flow adjustments declined from about 75 to 62 cfs, so there is clearly something else going on. The District team's draft response to the draft peer review comments posit that a long-duration change in meteorological conditions since the late 1990's may be a factor.

Similar to other approaches used to evaluate MFLs, the Event Approach requires selection of the allowable change in event frequency. The RI's and associated exceedance frequencies relevant to this consideration are:

- 6.11-year RI (16.4 events/century) based on the floodplain vegetation survey
- 5-year RI (20 events/century) based on literature (note – based on median elevation)
- 6.9-year RI (14.5 events/century) based on the proposed MFL condition

It is doubtful that a frequency change of <2 events per century (i.e., median observed (16.4) compared to MFL (14.5)) would have been sufficient to alter the ecotone between upland and wetland vegetation communities. A 2.7% (103 cfs) relative flow reduction at the critical flow (3,852 cfs) is associated with about a 12% reduction in occurrence frequency. Following a case study review (Richter, Davis, Apse, & Konrad, 2011), the following tiers of protection of natural ecosystem structure and function were proposed by the authors as a presumptive standard "…intended for application only where detailed scientific assessments of environmental flow needs cannot be undertaken in the near term."

- < 10% – high level of protection, low risk
- 10-20% – moderate level of protection, moderate risk
- > 20% – low protection, high risk

It is concluded that the proposed MFLs would remain protective of the HHH upland/floodplain ecotone.

Although the relative change in RI is about 20%, the difference is negligible when compared to the variability of RI and critical flows associated with the biometric survey data that is discussed next.

Sensitivity Analysis

The sensitivity of the FH analysis to the natural variability in field survey data was evaluated by superimposing the inter-percentile (dropped the maximum and minimum flows) critical maximum HHH flows (Table C 4) on probability plots (Figure C 7) for the following flow conditions:

- Discharge (1933-2010): Floodplain vegetation survey baseline (VSB)
- RTF (1933-2015): POR historical flow considered unimpacted by withdrawals
- MFL (1933-2015): POR flow associated with the proposed MFL (SRWMD, 2019)
- Discharge (1991-2015): Recent conditions observed subsequent to the 2013 baseline period

The intersection of the median RI (6.11 years) and critical flow (3,852 cfs) relative to each probability plot is the starting point for this discussion. As before, the intersections of the RTF and VSB plots are nearly coincident, and the MFL intersection is 103 cfs lower than the RTF and VSB plots. The recent conditions plot, however, is substantially lower than the other three.

The range in RI associated with the clipped lower and upper percentile maximum HHH flows, i.e. from 3.27 to 17.29 years, is equivalent to 24.8 (i.e., 30.61 – 5.78) events per century (Table C 5). The range is more than 10 times the 2-event per year difference between the median observed and MFL RI's that might be considered when evaluating water availability. Whether the variability in RI associated with the vegetation survey is associated with natural variability or anthropogenic factors is beyond the scope of this MFLs re-evaluation.

3.2 Demonstration Example No. 1.2 (Minimum Frequent High)

Purpose:

- Demonstrate the prudence to apply the Event Approach meaningfully

Definition: “Minimum frequent high” means a chronically high surface water level or flow with an associated frequency and duration that allows for inundation of the floodplain at a depth and duration sufficient to maintain wetland functions. (Chapter 40C-8.021(7), F.A.C.)

Relevant WRV: **WRV-2** (Fish and Wildlife Habitat)

General indicator: Hydric floodplain habitat

Specific indicator: Elevation of ecotone between upland and wetland communities

Goal: Protecting a minimum number of flooding events to sustain the ecotone

The FH analysis demonstrated in Example No. 1.1 considers a duration of 14 days based on a field study of floodplain wetland plant communities in the middle and lower reaches of the Suwannee River. Similar to the Suwannee River, the LSFR channel is more incised compared to the IR channel. Hence it might be anticipated that overbank events occur less frequently than in less-incised channels. Lacking suitable literature, e.g., (Light, Darst, Lewis, & Howell, 2002), the critical durations used to establish the SJRWMD riverine system MFLs might be assumed as an initial estimate. The duration used most frequently by SJRWMD to establish FH MFLs is 30 days (Table C 1).

For this demonstration and discussion purposes, it is sufficient to inspect the set of inundation probability plots (Figure C 5) relative to the maximum HHH critical flow for transect L that is 102 cfs lower than the average maximum HHH critical flow. The critical flow of 3,750 cfs intersects the 30-day duration probability plot at an exceedance frequency of about 4 events per century (Figure C 9). The 25-year RI associated with this exceedance frequency is indicative of an Infrequent High event and not the presumed Frequent High event.

Further inspection would reveal that the HHH at Transect L is located on Oleno Clay [see (Atkins, 2012) page 175]. The online NRCS Web Soil Survey (WSS) mapping for Columbia County indicates that Oleno Clay is a hydric soil group with “Frequency of flooding = Occasional, None” and “Frequency of ponding = None” (NRCS, 2020). Thus, it would be erroneous to consider a 30-day duration as sufficient for protecting the ecotone between upland and floodplain wetland vegetation habitat. The takeaway from this demonstration is that prudence is required to meaningfully apply the 3-parameter Event Approach.

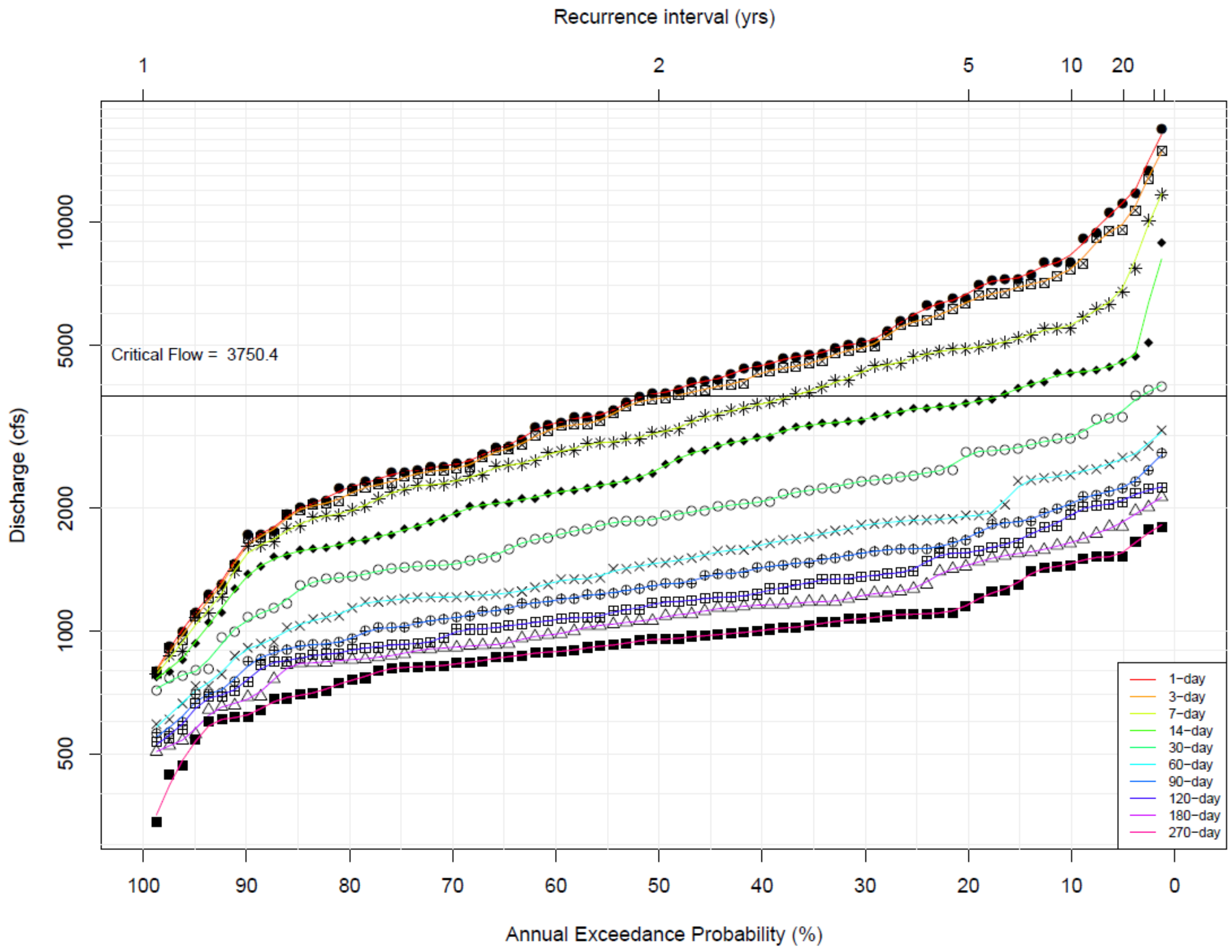

Figure C 9. VSB period probability plots for annual maximum high flow continuously exceeded and transect L critical flow for various durations

3.3 Demonstration Example No. 2 (Minimum Average)

Purpose:

- Demonstrate an evaluation of a Minimum Average event
- Demonstrate the subjectivity in selecting an “allowable frequency”

Definition: “Minimum average” means the surface water level or flow necessary over a long period to maintain the integrity of hydric soils and wetland plant communities. (Chapter 40C-8.021(9), F.A.C.)

Relevant WRV: **WRV-7** (Filtration and Absorption of Nutrients and Other Pollutants)

General indicator: Biologically and chemically reactive floodplain substrate

Specific indicator: Elevation of hydric soil across the lower elevation of the floodplain

Goal: Preventing a maximum number of drying events

The following excerpt from the Silver Springs MFLs assessment describes the biogeochemical and water quality functions associated with stream hydrology (Sutherland, et al., 2017).

> The interaction of floodwaters with biologically and chemically reactive substrates (e.g., soils, vegetation, detritus, microbial mats, etc.) promotes denitrification and nutrient cycling processes across the floodplain. The FH also affects carbon sequestration by providing long duration floods that promote organic soil accrual, which balance losses of organic matter that may occur during droughts. Although the FH event occurs for only 30 days at the maximum elevation of hardwood swamp, it occurs for a much greater duration at the mean elevation of hardwood swamp, and for a still greater duration at the mean elevation of deep organic soils.
>
> Floodplain soils alternate between aerobic and anaerobic conditions depending on the balance of atmospheric oxygen supply and oxygen demand of the soils. (Wharton & Brinson, 1979) emphasized that temporal changes between reducing and oxidizing conditions at the soil surface is one of the most unique attributes of wetlands. The cyclic wet/dry regime imparts a unique chemical environment that has profound effects on nutrient cycling (Wharton, Kitchens, Pendleton, & Sipe, 1982). Reducing conditions favor metabolic pathways such as methanogenesis, sulfate reduction, and denitrification, while ammonium and phosphate will tend to diffuse from the soils to overlying water (Wharton et al. 1982). Aerobic conditions favor soil decomposition, and many of the products of anaerobic metabolism are oxidized (Wharton, Kitchens, Pendleton, & Sipe, 1982). This has important implications for nutrient cycling in floodplains.

Soil morphology descriptions for transect F show that several hydric soil indicators are present: F13 (Umbric Surface), A11 (Depleted below Dark Surface), and F3 (Depleted Matrix), see (Atkins, 2012). Each soil profile has indicators of seasonal high saturation, with soils at transect F classified as typically “Fluvaquents, frequently flooded”, see (NRCS, 2020) and Figure C 10.

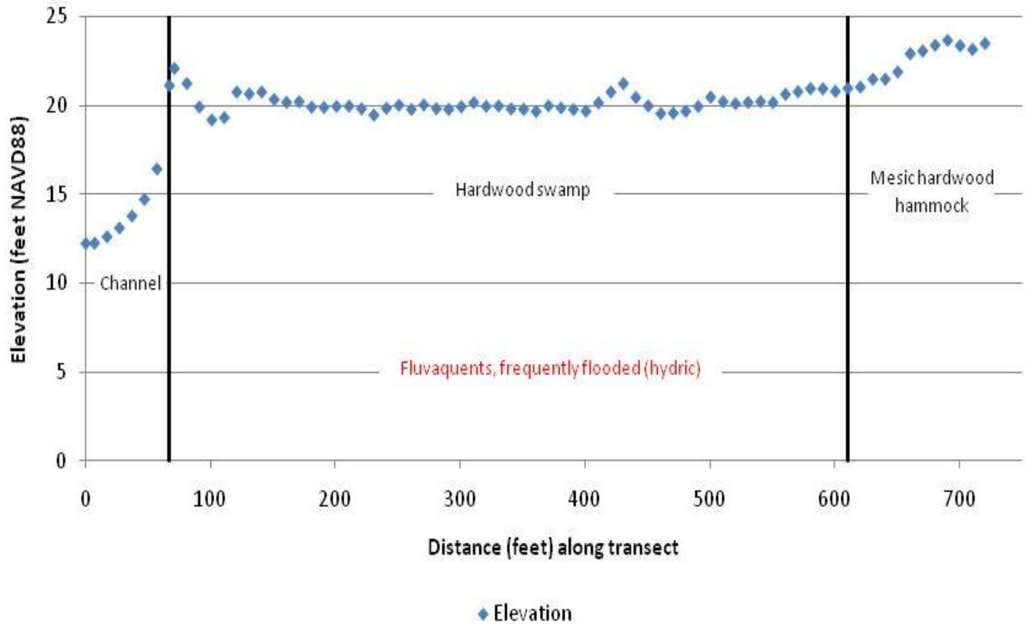

Figure C 10. Land-surface elevation, vegetation communities and hydric soil observed at Transect F in July 2011 [Source: (Atkins, 2012)]

The Minimum Average event is characterized by the mean elevation of Hardwood Swamp (HS) at transect F. The critical discharge associated with that mean elevation at the transect when translated to the Fort White gage is 1,178 cfs. Since aerobic conditions promote organic soil decomposition and a potential loss of organic compounds by sublimation, the event is considered a drying event for which a maximum number should be prevented.

The assumed critical duration is 180 days, which is based on the critical durations associated with 6 of the 7 riverine MFLs adopted by SJRWMD (Table C 1). The duration is also supported by the NRCS Gilchrist County soil characteristics for “Fluvaquents, frequently flooded” which indicates the water table is at the surface during wet periods and recedes to a depth of 20 inches during dry periods (Weatherspoon, Cummings, & Wittstruck, 1992). Furthermore, “most areas support natural vegetation, mainly bald cypress, sweetgum, sweetbay, red maple, and water oak”. The hydroperiod (inundation) reported for swamps supporting these tree species range from 200-300 days (FNAI, 1990). Thus, the communities would be expected to experience drying conditions ranging from about 65-165 days. For this demonstration, the organic soil structure is presumed to be protected by assuming a 180-day duration of dewatering.

“Frequently flooded” is interpreted as being expected to occur, on average, every year or two; thus, the maximum frequency to be avoided, as generally described, would be 50 occurrences per century (i.e., RI = 2 years).

A set of probability plots for annual minimum 180-day average flows (Figure C 11) was created to characterize the water potentially available assuming the following four flow conditions:

- Discharge (1933-2010): Floodplain vegetation survey baseline (VSB)
- Discharge (1933-2015): POR historical flow considered impacted by withdrawals
- RTF (1933-2015): POR historical flow considered unimpacted by withdrawals
- MFL (1933-2015): POR flow associated with the proposed MFL (SRWMD, 2019)

The intersections of the critical flow with each probability plot are as follows in Table C 6.

Table C 6. Frequency of critical Minimum Average flow for different periods of analysis

Flow condition	Frequency (P_{NE}), % or occurrences/century	Recurrence interval (RI), years	Relative difference of P_{NE} compared to VSB
VSB (1933-2010)	57	1.75	---
POR (1933-2015)	59	1.7	3.5%
RTF (1933-2015)	57	1.75	0.0%
MFL (1933-2015)	64	1.55	12%
P_{NE} and RI determined by the intersection of the 1178 cfs critical flow with each probability plot in Figure C 11			

All four plots fall below the intersection of critical flow (1,178 cfs) and a vertical line (not shown) at 50 occurrences per century (i.e., 50% or RI=2 years). This begs the question, “Is every other year too generic for defining a threshold frequency?”.

The VSB and RTF plots intersect the critical flow at a RI of 1.75 years (i.e., 57 times per century). Thus, a RI threshold of 1.75 years is assumed for discussion purposes. The threshold is comparable to the 1.7-year allowable return interval described in Chapter 40C-8, F.A.C. for Black Water Creek at SR44 and Wekiva River at SR46 (Table C 1). Note, also, that the allowable RI for other rivers is 1.5 years (Table C 1).

The POR flows (1933-2015) plot reflects a somewhat drier hydrology. The critical MA flow occurred 3.5% more frequently (i.e., 2 events per century) compared to the VSB and RTF periods.

The MFLs flow (1933-2015) plot reflects a downward shift of the RTF plot by 103 cfs (the hydrologic shift associated with the proposed MFLs (SRWMD, 2019). The critical MA flow would occur 12% more frequently (i.e., 7 events per century) compared to the RTF period. It could be arguable that a 103-cfs shift would be protective of floodplain hydric soils.

An 8.7% relative flow reduction at the critical flow (1,178 cfs) is associated with a 12% increase in event frequency. Following a case study review (Richter, Davis, Apse, & Konrad, 2011), the following tiers of protection of natural ecosystem structure and function were proposed by the authors as a presumptive standard “…intended for application only where detailed scientific assessments of environmental flow needs cannot be undertaken in the near term.”

- < 10% – high level of protection, low risk
- 10-20% – moderate level of protection, moderate risk
- > 20% – low protection, high risk

It is concluded that the proposed MFL would remain protective of organic soil and plants in the low-level floodplain wetlands.

A second set of probability plots (Figure C 12) was prepared to illustrate the substantial difference in MA flows between the baseline period evaluated in the 2013 MFLs assessment, the POR evaluated in the 2019 MFLs re-evaluation, and recent conditions (1991-2015).

Recent conditions compared to the baseline (1933-1990) period evaluated in the initial MFLs assessment indicate a substantial shift to drier conditions (Figure C 12). The recurrence interval shifted from 2 years (50 events/century) during the baseline period to 1.25 years (80 events/century) during the recent (1991-2015) period. Future monitoring, discussed in Section 5, would be needed to determine if a shift of this magnitude has had a measurable effect on the hydric soil at transect F or, more generally, the plant community associated with areas the NRCS has mapped as fluvaquent, frequently flood (hydric) soil; and if measurable, whether that shift appears to be temporary or not.

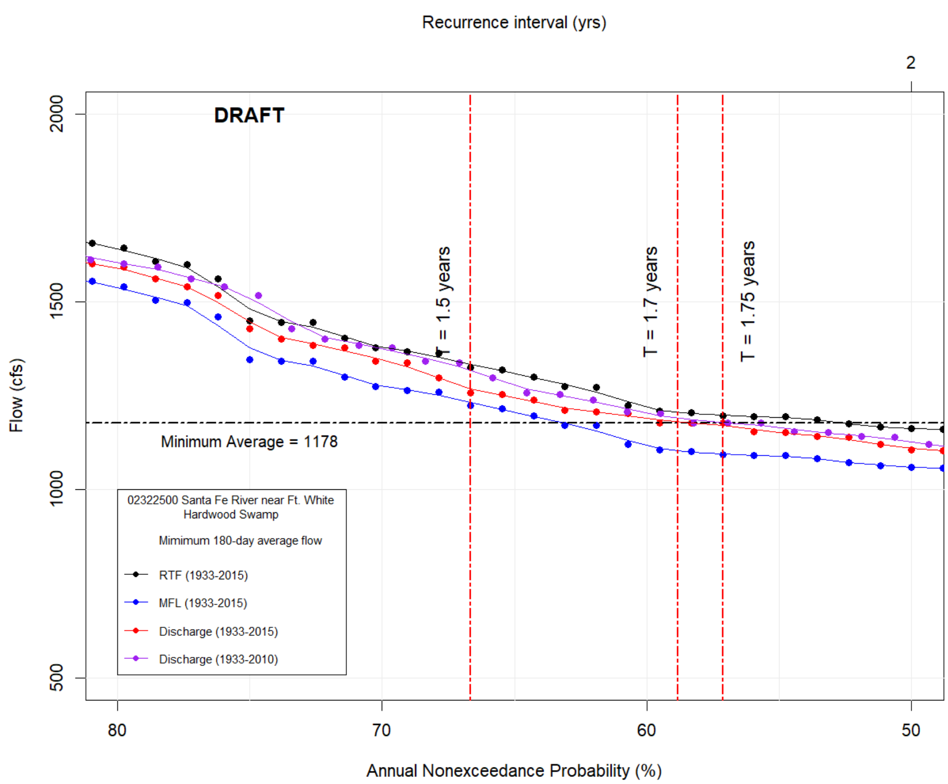

Figure C 11. Probability plots for annual minimum average flow at the Fort White gage for various flow regimes

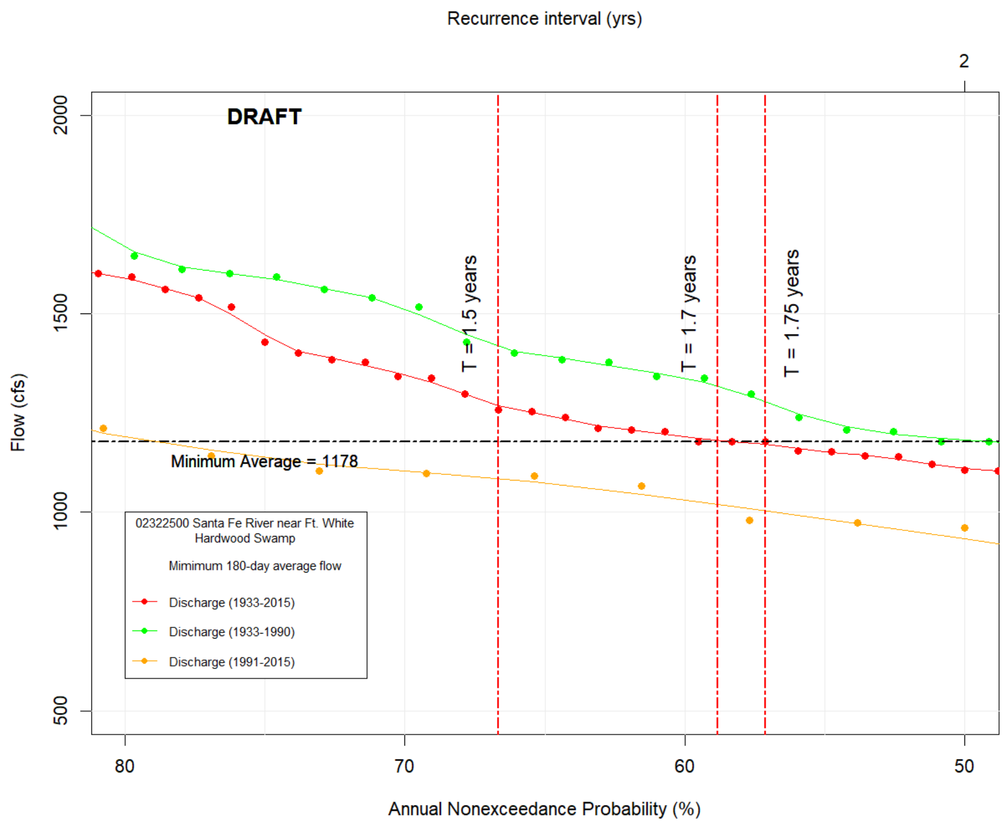

Figure C 12. Probability plots for annual minimum average flow at the Fort White gage for select periods of analysis

3.4 Demonstration Example No. 3.1 (Minimum Frequent Low)

Purpose:

- Demonstrate an evaluation of a Minimum Frequent Low event

Definition: "Minimum frequent low" means a chronically low surface water level or flow that generally occurs only during periods of reduced rainfall. This level is intended to prevent deleterious effects to the composition and structure of floodplain soils, the species composition and structure of floodplain and instream biotic communities, and the linkage of aquatic and floodplain food webs. (Chapter 40C-8.021(10), F.A.C.

Relevant WRV: **WRV-2** (Fish and Wildlife Habitat)

General indicator: Fish spawning habitat

Specific indicator: Elevation of viable depth for the seasonal largemouth bass spawn

Goal: Protecting a minimum number of instream flooding events

SEFA modeling performed for the MFLs re-evaluation determined that the fry of largemouth bass (LMB), a valued game fish, was sensitive to flow reductions at the four LSFR SEFA sites (Figure C 2). The District in early July 2020 consulted Eric Nagid, Freshwater Fisheries Research Leader at Florida Fish and Wildlife Conservation Commission (FWC), for relevant information regarding LMB that could be used to demonstrate the Event Approach. Mr. Nagid, via written communication, offered the following:

> I included another reference specific to largemouth bass that can be used for nest depth (2-4 feet). It's quite dated but it's specific to Florida and the focus is early life history. The spawning season is about 3 months as we discussed (depending on latitude), and the total duration of spawning to swim-up fry is about 2 weeks. So, fry from different hatch dates will be in the system during that 3-month window, and you're on solid ground by using a 3 ft depth and a 90-120-day duration for bass fry.
>
> The 3-year return interval is a bit harder to support with literature, mainly because most studies are focused on determining what it takes to maximize year-class strength rather than the return interval that leads to harm. Still, considering that largemouth bass on average have a lifespan of 9 years, and they reach sexual maturity at age 3-4, a 3-year return interval ensures that any one individual has conditions suitable to spawning at least twice in its lifetime. This model has been used successfully on Rodman Reservoir where water level can be manipulated, and it can be argued that return intervals greater than that would have an impact on recreational fishing and the associated economy.

The references cited in Mr. Nagid's communication are (Chew, 1994) regarding early life history and nesting depth and (Nagid, Tuten, & Johnson, 2015) regarding return interval. Many fish species in the LSFI system spawn during a 3-to-5 month period in spring and early summer (SRWMD, 2019); thus, a 5-month period of March through July was selected as the seasonal period of analysis for the demonstration of a FL flow analysis.

Critical flow is presumed to be associated with a hydraulic depth of 3 feet; i.e., the midpoint of the nest-depth range. Critical flows at the SEFA sites and translated to the Fort White gage were extracted from the 2020 HEC-RAS Steady State model output. Critical flows associated with viable largemouth bass habitat calculated by HEC-RAS at the LSFR SEFA sites range between 542 and 961 cfs. Eliminating the low value (Powerline-run) that is distinctly different, the average of other three threshold flows is 886 cfs (Table C 7). Reference is made later to the average critical depth associated with a hydraulic depth of 4 feet (Table C 7). For comparison, the 3- and 4-foot average values (886 and 1,420 cfs, respectively), are 20% lower and 28% higher than the 1,110 cfs threshold flow determined for fish passage in the LSFR (SRWMD, 2019).

Table C 7. Critical flows associated with 3- and 4-foot hydraulic depths at the LSFR SEFA sites

HEC-RAS station	SEFA Site ID	Hydraulic Depth, feet	Flow at site, cfs	HEC-RAS simulated non-exceedance probability (%)	Flow at Fort White gage, cfs
Hydraulic Depth 3 feet					
150082.7	US441-pool	3.0	344	~28	923
129212.6	Powerline-run	3.4	84.0	2	542
100692.3	FW gage	--	--	--	--
96930.06	Ft. White-pool	3.0	867	~14	775
55554.55	Dog Leg-shoal	3.0	1,110	~32	961
Average (US441, Ft. White, Dog Leg)					886
Hydraulic Depth 4 feet					
150082.7	US441-pool	4.0	1,070	~78	1,700
129212.6	Powerline-run	4.0	143	~6	631
100692.3	FW gage	--	--	--	--
96930.06	Ft. White-shoal	4.0	1,490	~64	1,390
55554.55	Dog Leg-shoal	4.0	1,340	~52	1,170
Average (US441, Ft. White, Dog Leg)					1,420

A threshold recurrence frequency of no fewer than 2 events per 6-year life span of mature LMB is 33.3% (a 3-year RI) was evaluated as an inundation event when viable spawning habitat is afforded by a depth greater than 3 feet for a continuous 120-day period. Alternative RIs could be considered but may not be characteristic of a frequent low. For example, if just 1 spawn occurred during that 6-year period of maturity, the 6-year recurrence interval and associated frequency of 16.7 events per century would be characteristic of an infrequent low.

Probability plots were developed for the maximum annual seasonal flow continuously exceeded for selected durations ranging from 30 to 150 days (Figure C 13). Unlike the FH analysis demonstrations that considered vegetation survey data, no ecological field data are considered for this FL demonstration. As such, the RTF (1933-2015) period is assumed to be a representative flow condition unimpacted by withdrawals. Both Example 3.1, described in this subsection, and Example 3.2 (following subsection) consider a duration of 120 days recommended by Mr. Nagid.

A set of probability plots for annual maximum seasonal flows continuously exceeded for 120 days (Figure C 14) was created to characterize the water potentially available assuming the following three flow conditions:

- RTF (1933-2015): POR historical flow considered unimpacted by withdrawals
- Discharge (1933-2015): POR historical flow considered impacted by withdrawals
- MFL (1933-2015): POR flow associated with the proposed MFL (SRWMD, 2019)

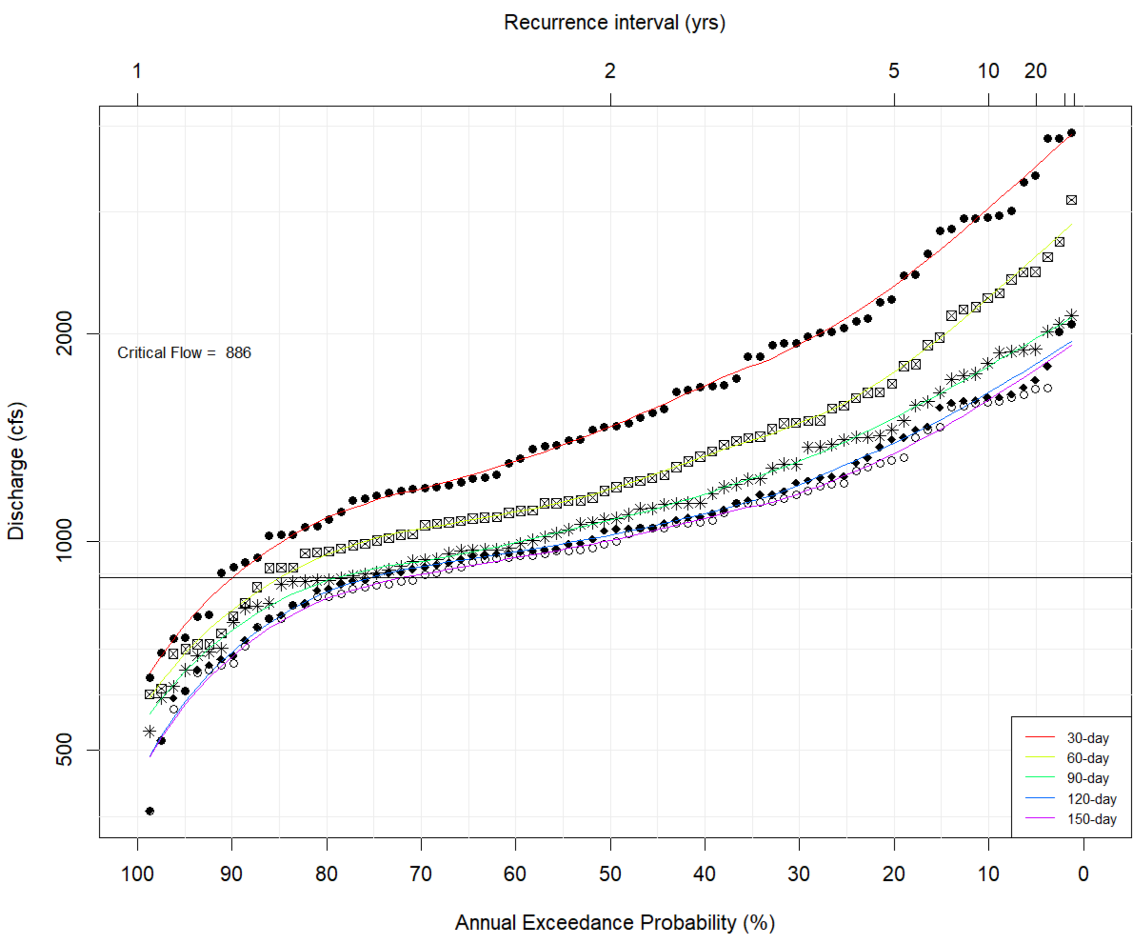

Figure C 13. RTF period probability plots for annual maximum seasonal high flow continuously exceeded at the Fort White gage for various durations
[Critical flow is the average of flows associated with a 3-foot hydraulic depth at three SEFA sites translated to the Fort White gage]

The intersections of the critical flow line with each 120-day duration probability plot (Figure C 14) are as follows.

Table C 8. Frequency of critical seasonal flow continuously exceeded for 120 days for different periods of analysis

Flow condition	Frequency (P_E), % or occurrences/century	Recurrence interval (RI), years	Relative difference of P_E compared to RTF
RTF (1933-2015)	74	1.35	---
POR (1933-2015)	65	1.54	-12%
MFL (1933-2015)	52	1.92	-30%
P_E and RI determined by the intersection of the 886 cfs critical flow with each probability plot in Figure 23.			

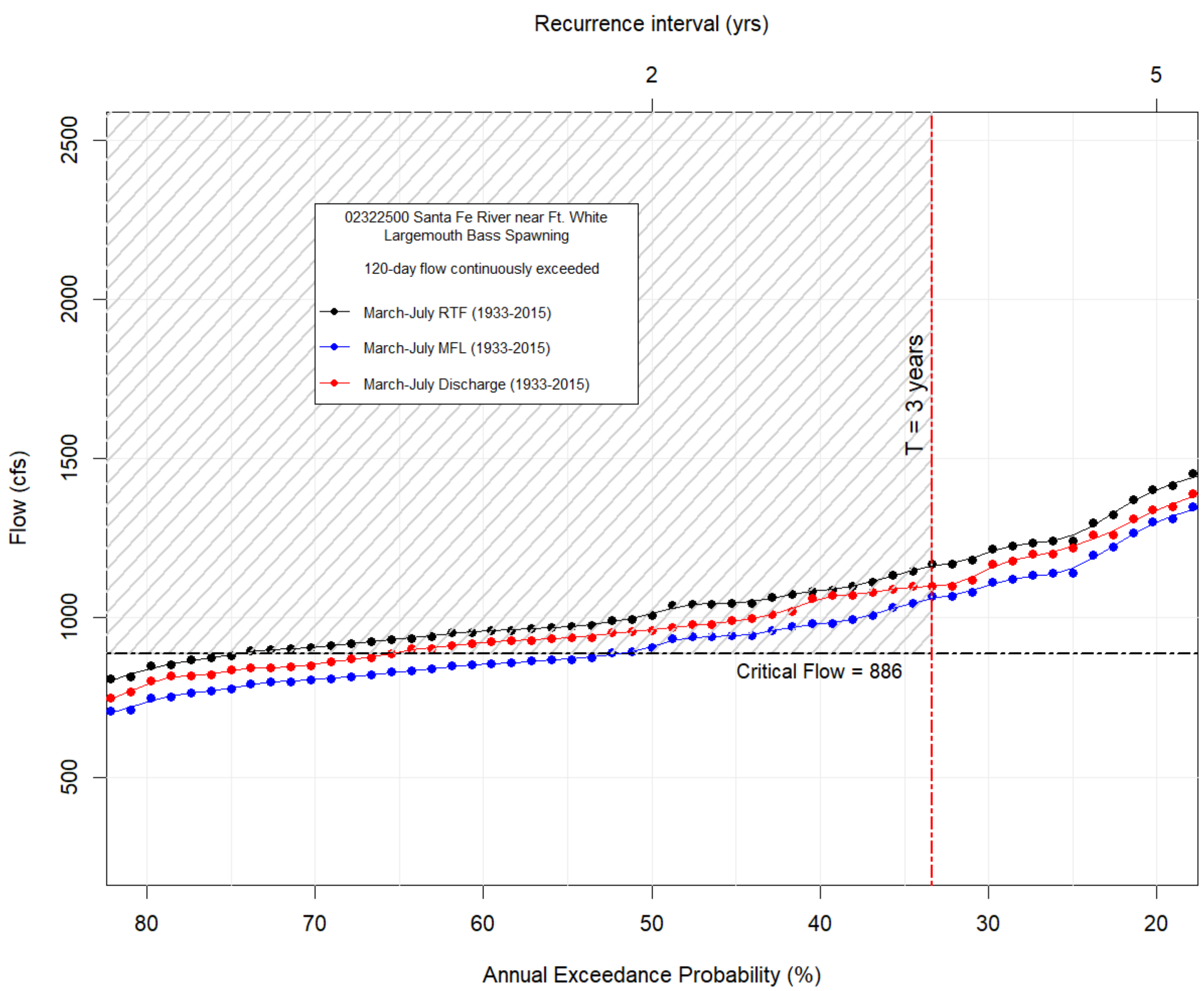

Figure C 14. Probability plots for annual maximum seasonal flow continuously exceeded for 120 days at Fort White gage for various flow regimes

The RTF plot (Figure C 14) intersects the critical flow at a RI of 1.35 years (i.e., 74 events per century (Table C 8). Thus, a RI threshold of 74 years is assumed for discussion purposes.

Figure C 14 is noteworthy for several reasons. Noting the y-axis range, the probability plots for low-flow conditions (Figure C 13) are flatter than for high-flow conditions (Figure C 5). Thus, the same relative change in flow (e.g., 10%) will associate with a larger change in RI on a low flow probability plot than on a high flow probability plot. Secondly, the probability plots for all three flow regimes intersect the threshold RI of 3 years at flows higher than the critical discharge. The Event Approach is described as a top-down approach originating with a presumed unimpacted flow regime (Neubauer, et al., 2008). Water potentially available for withdrawal is the difference between the 1,160 cfs intersection and 886 cfs or 274 cfs which is clearly infeasible for such a low-flow condition. This calls into question whether the MDR parameters are reasonable.

The RI of 3 years has a sound ecological basis and was suggested by scientist who has studied largemouth bass for conservation purposes in Rodman Reservoir about 50 miles southeast of the LSFR study area. The critical magnitude of 886 cfs is based on the average of critical discharges determined assuming a critical hydraulic depth of 3 feet at each of the three SEFA sites. An alternative magnitude greater than 886 cfs could be determined by selecting either the highest critical discharge (i.e., 961 cfs at the Dog Leg site, Table C 7) or by considering the upper limit for nest depth recommended by Mr. Nagid (4 feet). Assuming the highest critical discharge, the water potentially available is 199 cfs (i.e., 1,160 – 961). A withdrawal of this magnitude, about 17% of the RTF intersection, would be categorized as a "moderate risk" (Richter, Davis, Apse, & Konrad, 2011) and is considered infeasible for an Outstanding Florida Water like the SFR. Assuming that critical discharge is based on the average site critical discharges for a 4-foot hydraulic depth (Table C 7), no water would be potentially available under all flow regimes, including the RTF regime (i.e., 1,160 – 1,420 = -260 cfs).

Mr. Nagid also commented that a duration of 90 to 120 days would be reasonable. Selecting a shorter critical spawning period, 90 days, would shift the probability plot upward from the 120-day plot (Figure C 13). It would shift the corner of the feasible region (Figure C 14) resulting in even more water potentially being available for withdrawal.

In this example, the analyst must select the critical MDR parameters. However, compared to the FH analysis, the low-flow hydrology and the associated flatter probability plots, the FL parameters may be influenced more by a risk-based, percent-change-in-flow consideration than on empirical information. The remainder of this FL inundation demonstration is based on an 886 cfs critical discharge, 120-day duration, and 3-year recurrence interval.

The POR flows (1933-2015) plot (Figure C 8, Figure C 14) reflect the influence of historical withdrawal impacts compared to the RTF regime (i.e., withdrawal impacts added to the historical POR). Compared to the RTF regime, the critical FL flow occurred 12% less frequently (i.e., 9 fewer events per century) for the POR regime.

Not unexpectedly, the results demonstrate that instream habitat represented by largemouth bass spawning criterion at the three LSFR SEFA sites is sensitive to flow reduction and could be exposed to an increasing risk of change. The MFLs flow (1933-2015) plot reflects a downward shift of the RTF plot by 103 cfs (the hydrologic shift associated with the proposed MFLs (SRWMD, 2019). The critical FL flow would occur 30% less frequently (i.e., 22 fewer events per century) compared to the RTF regime. The 103-cfs shift, which is 12% of the critical discharge, would be categorized a "moderate risk" in the 3-tier level of protection (Richter, Davis, Apse, & Konrad, 2011).

A second set of probability plots (Figure C 15) was prepared to illustrate the substantial difference in FL flows between the baseline period evaluated in the 2013 MFLs assessment, the RTF (1933-2015) period evaluated in the 2019 MFLs re-evaluation, and recent conditions (1991-2015). The recent condition plot indicates that viable largemouth bass spawning habitat has been occurring much less frequently than during the baseline periods evaluated for the 2013 MFLs assessment and 2019 re-evaluation. With a recurrence frequency greater than the threshold RI (i.e., 42 vs. 33 events per century), the results indicate the uncertainty associated with this demonstration of the Event Approach. The critical MDR spawning-event parameters may need to be further evaluated before basing a withdrawal decision on this particular demonstration. One example; Do LMB spawn at these sites?

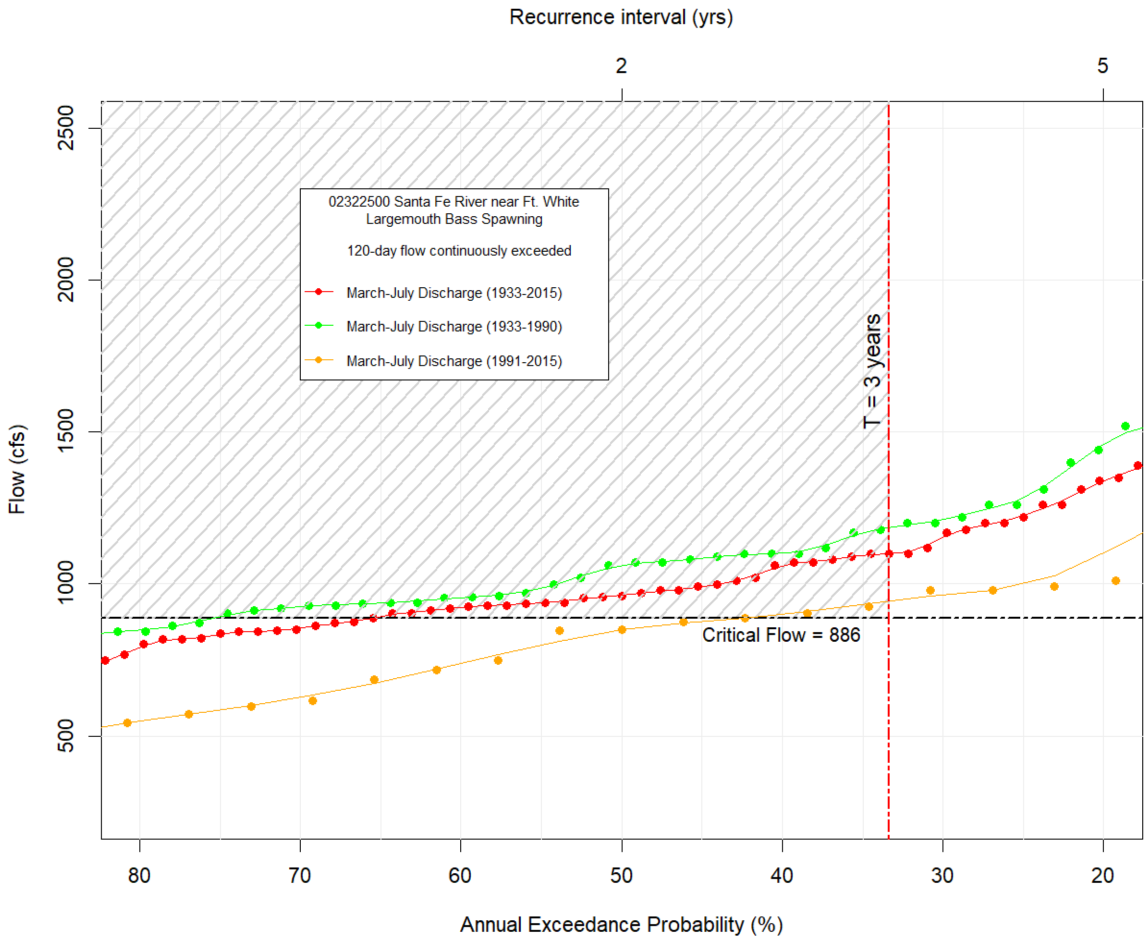

Figure C 15. Probability plots for annual maximum seasonal flow continuously exceeded for 120 days at the Fort White gage for select periods of analysis

3.5 Demonstration Example No. 3.2 (Minimum Frequent Low)

Purpose:

- Demonstrate an alternative approach for evaluating a Minimum Frequent Low event assuming the same MDR parameters

Definition: “Minimum frequent low” means a chronically low surface water level or flow that generally occurs only during periods of reduced rainfall. This level is intended to prevent deleterious effects to the composition and structure of floodplain soils, the species composition and structure of floodplain and instream biotic communities, and the linkage of aquatic and floodplain food webs. (Chapter 40C-8.021(10), F.A.C.

Relevant WRV: **WRV-2** (Fish and Wildlife Habitat)

General indicator: Fish spawning habitat

Specific indicator: Elevation of viable depth for the seasonal largemouth bass spawn

Goal: Preventing a maximum number of instream drying events

The FL event analysis described in Section 3.4 considers an inundation event that should occur no less frequently than twice per 6-year life span of mature LMB. Duration hydrographs for the Fort White gage POR indicate the critical flow (886 cfs) was exceeded about 75% of the time during the spawning period (March-July), Figure C 16. Relative to that threshold, an inundation event occurs when flow is less than the critical discharge, increases above the threshold for a period of time, and then decreases below the critical discharge. The March/April period of the P75 line in Figure C 16 is an example.

An alternative approach is to view the issue in terms of a drying (or dewatering) event. There are also periods during the spawning period when flow is greater than the critical discharge, decreases below the threshold for a period of time, and then increases above the critical discharge. The April-June period of the P75 line in Figure C 16 is an example.

Probability plots were developed for the annual minimum seasonal flow continuously not exceeded for selected durations ranging from 30 to 150 days (Figure C 17). Similar to Example 3.1, the RTF (1933-2015) period is assumed to be a representative flow condition unimpacted by withdrawals. Note that the discussion in Section 3.4 of potentially available water and appropriateness of the critical MDR parameters is relevant to this demonstration example as well.

A set of probability plots for annual minimum seasonal flow continuously not exceeded for 120 days (Figure C 18) was created to characterize the water potentially available assuming the following four flow conditions:

- RTF (1933-2015): POR historical flow considered unimpacted by withdrawals
- Discharge (1933-2015): POR historical flow considered impacted by withdrawals
- MFL (1933-2015): POR flow associated with the proposed MFL (SRWMD, 2019)

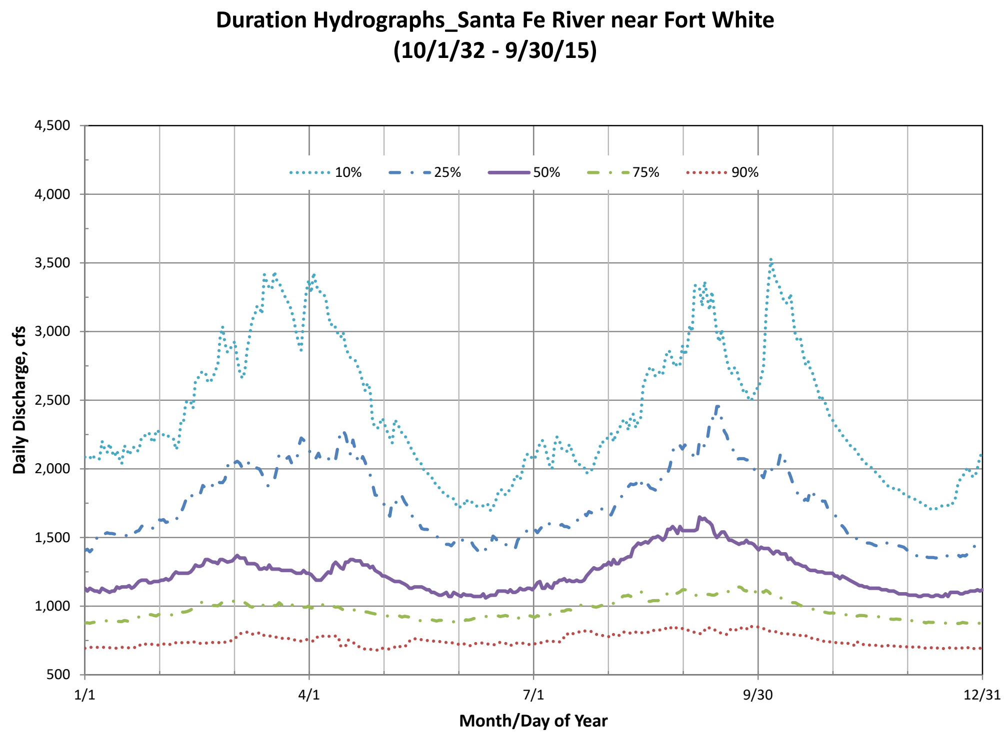

Figure C 16. POR duration hydrographs for the Fort White gage

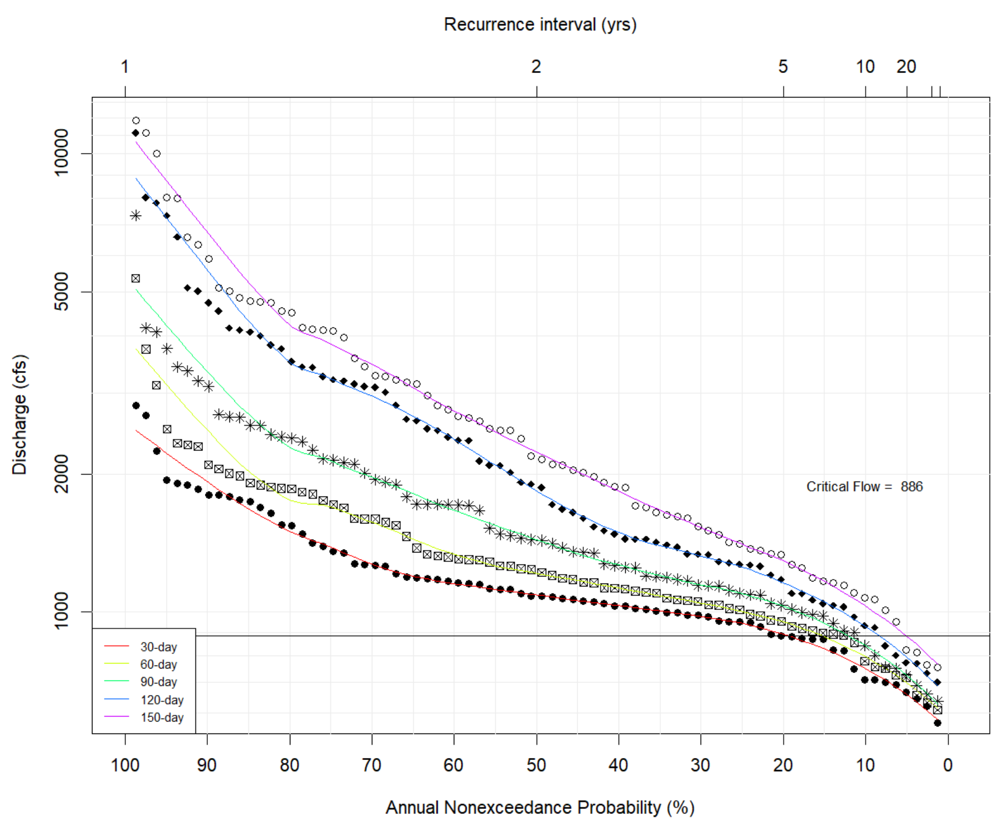

Figure C 17. RTF period probability plots for annual minimum seasonal low flow continuously not exceeded at the Fort White gage for various durations

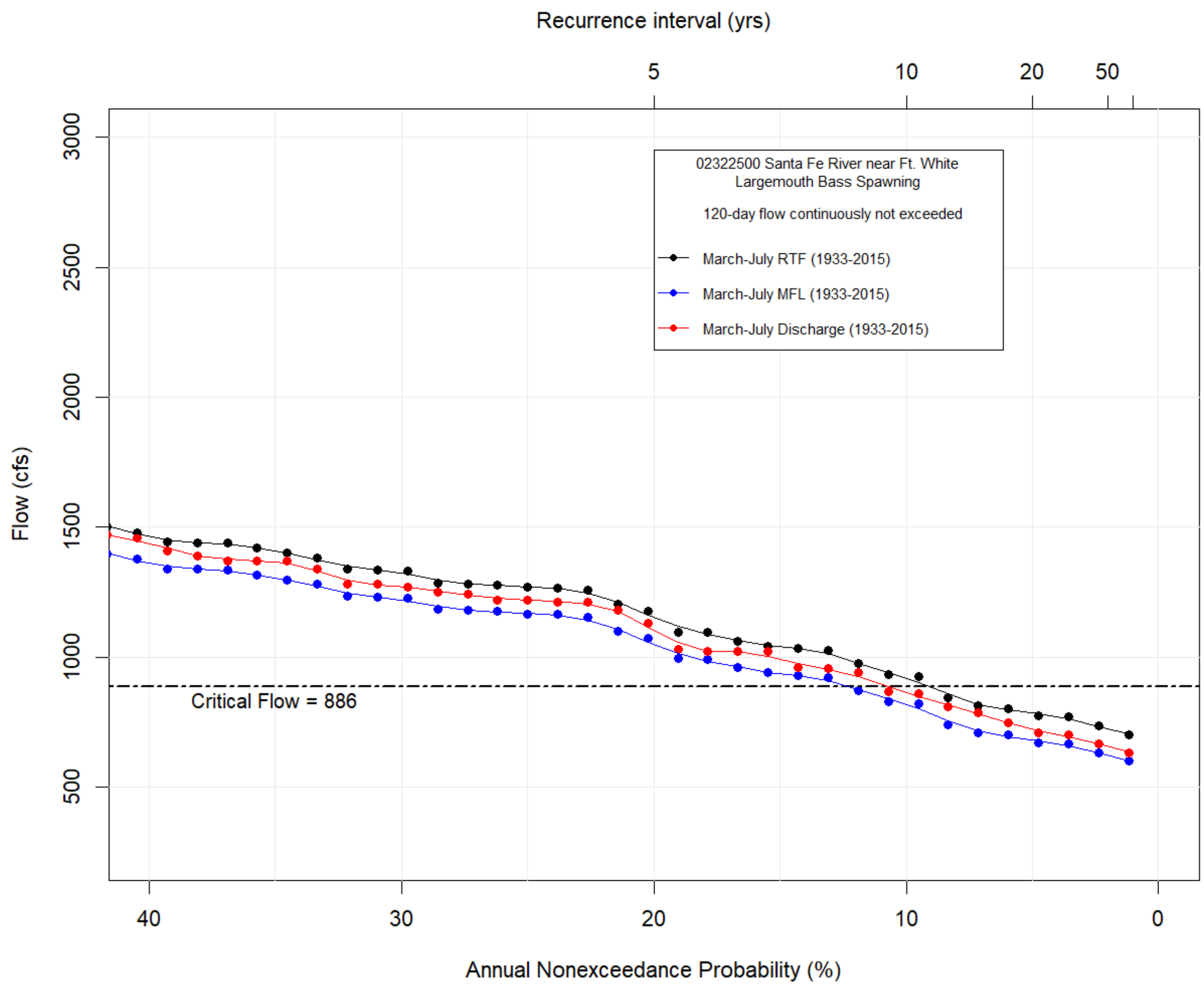

Figure C 18. Probability plots for annual minimum seasonal 120-day continuously not exceeded flow at the Fort White gage for various flow regimes

The intersections of the critical flow with each probability plot in Figure C 18 are as follows.

Table C 9. Frequency of critical minimum seasonal flow continuously not exceeded for 120 days for different periods of analysis

Flow condition	Frequency (P_E), % or occurrences/century	Recurrence interval (RI), years	Relative difference of P_E compared to RTF
RTF (1933-2015)	9.1	11.0	---
POR (1933-2015)	10.9	9.2	20%
MFL (1933-2015)	12.5	8.0	37%
P_E and RI determined by the intersection of the 886 cfs critical flow with each probability plot in Figure C 17			

Noteworthy in Table C 9 is that the occurrence frequencies (fewer than 13 events per century) and associated RIs for all three flow conditions are more characteristic of infrequent low events than of frequent low events. That could change if a higher critical flow and or a shorter duration is specified for analysis, such that the plot intersections with the critical flow line shift left to a greater occurrence frequency (and lower RI).

Similar to the FL inundation demonstration (Section 3.4), the POR flows (1933-2015) plot (Table C 8, Figure C 18) reflect the influence of historical withdrawal impacts. Compared to the RTF regime (withdrawal impacts added to the historical POR), the critical FL flow occurred 20% more frequently (i.e., 1.3 events per century) for the POR regime.

Also similar to the FL inundation demonstration, the results demonstrate that instream habitat represented by largemouth bass spawning habitat at the three LSFR SEFA sites is sensitive to flow reduction and could be exposed to an increasing risk of change. The MFLs flow (1933-2015) plot reflects a downward shift of the RTF plot by 103 cfs (the hydrologic shift associated with the proposed MFLs (SRWMD, 2019). The critical FL flow would occur 37% more frequently (i.e., about 3 events per century) compared to the RTF regime. And the 103-cfs shift (12% of the critical discharge) would be categorized a “moderate risk” in the 3-tier level of protection (Richter, Davis, Apse, & Konrad, 2011).

A second set of probability plots (Figure C 19) was prepared to illustrate the substantial difference in FL flows between the baseline period evaluated in the 2013 MFLs assessment, the RTF (1933-2015) period evaluated in the 2019 MFLs re-evaluation, and recent conditions (1991-2015). Similar to the inundation analysis, the recent condition plot indicates that viable largemouth bass spawning habitat has been occurring much less frequently than during recent conditions compared to the baseline periods evaluated for the 2013 MFLs assessment and 2019 re-evaluation.

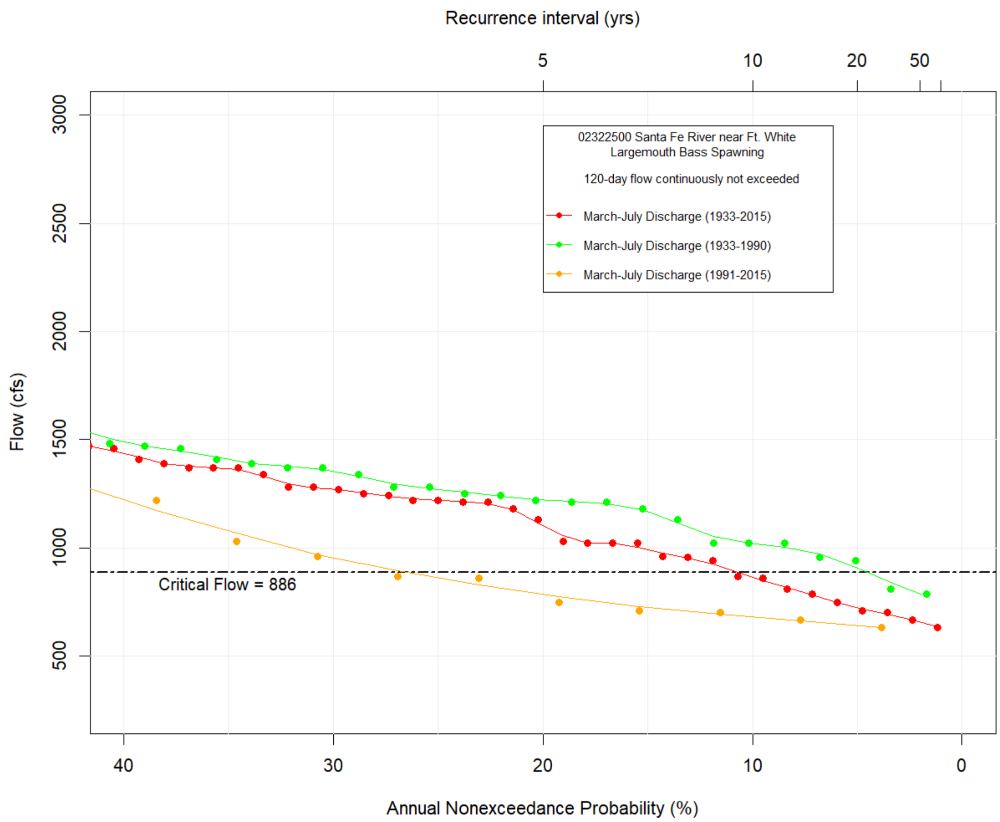

Figure C 19. Probability plots for annual minimum seasonal 120-day continuously not exceeded low flow at the Fort White gage for select periods of analysis

4. IHA DEMONSTRATION

The Indicators of Hydrologic Alteration (IHA) software (The Nature Conservancy, 2009) was used to quantify the degree of alteration from RTF (WY 1933-2015) to MFL flow regimes of LSFR at the Fort White gage. The software uses daily flow time series data to generate multiple sets of hydrologic statistics. Version 7.1 of the IHA software was used to quantify the degree of hydrologic alteration between the RTF and MFL flow regimes.

The five principal attributes of flow data variability (magnitude, duration, amplitude, frequency, and timing) are programmed in IHA because of their influence on aquatic species at various life stages. IHA calculates two types of flow statistics; the first type includes 33 IHA statistics and the second type includes 34 flow statistics calculated for five different environmental flow components (EFCs). EFCs are a more recent suite of hydrologic flow parameters and were developed by the Nature Conservancy in version 7.1 (released in 2009) to identify and compute statistics on hydrological events such as floods and droughts. The 33 IHA statistics and 34 EFCs together describe flow attributes deemed to be ecologically relevant.

4.1 IHA Components

The IHA components characterize within-year variation in streamflow based on a series of hydrologic attributes (IHA statistics) organized into five groups (Table C 10).

Group 1. The IHA Group 1 statistics (mean monthly streamflow) characterize seasonal patterns in the magnitude and timing of streamflow. They describe the normal condition and provide a measure of availability or sustainability of habitat or flows for various river services.

Group 2. The IHA Group 2 statistics focus on the magnitude and duration of annual extreme flow conditions. In addition to maximum and minimum flows over specified periods of time, it includes the base flow index, defined as 7-day minimum flow/mean flow for the year and number of almost zero flow days. Group 2 statistics provide a measure of the amount of environmental stress and disturbance during the year.

Group 3. The IHA Group 3 statistics characterize the timing (dates within a year) of the annual 1-day minimum and 1-day maximum flows. Timing is important to assess the degree of stress or mortality from extreme events during key periods in a species life cycle. It is also important to compare against timeframes needed for recreation or other socioeconomic services.

Group 4. The IHA Group 4 statistics include frequency of high- and low-flow pulses. A pulse is defined as a daily mean flow above or below selected thresholds. The annual number of daily mean flows greater than the 80th percentile and the annual number less than the 20th percentile over the period of record were selected as thresholds for the analysis on LSFR. The duration of time over which a specific water condition exists may determine whether a particular life cycle phase can be completed or the degree to which inundation or desiccation can occur.

Group 5. Group 5 IHA statistics (rise rate, fall rate and number of reversals) characterize the number and mean rate of positive (rise) and negative (fall) flow changes on two consecutive days. The rate of change in water condition affects stranding of certain organisms along the water edge or ability of plant roots to maintain contact with phreatic water supplies.

Table C 10. Summary of hydrologic attributes and regime characteristics used in the Indicators of Hydrologic Alteration
[Source: (The Nature Conservancy, 2009)]

IHA statistics group	Regime characteristics	Hydrologic attributes
Group 1: Magnitude of monthly water conditions	Magnitude, Timing	Mean for each calendar month (median in this application)
Group 2: Magnitude and duration of annual extreme water conditions	Magnitude, Duration	Annual minimums of 1-day means Annual maximums of 1-day means Annual minimums of 3-day means Annual maximums of 3-day means Annual minimums of 7-day means Annual maximums of 7-day means Annual minimums of 30-day means Annual maximums of 30-day means Annual minimums of 90-day means Annual maximums of 90-day means
Group 3: Timing of annual extreme water conditions	Timing	Julian data of each annual 1-day maximum Julian data of each annual 1-day minimum
Group 4: Frequency and duration of high and low flow pulses	Magnitude, Frequency, Duration	Number of high-flow pulses each year Number of low-flow pulses each year Mean duration of high-flow pulses in each year Mean duration of low-flow pulses in each year
Group 5: Rate and frequency of water condition changes	Frequency, Rate of change	Means of all positive differences between consecutive daily means Means of all negative differences between consecutive daily means Number of rises Number of falls

4.2 Environmental Flow Components

The IHA software calculates 34 EFC parameters grouped into five different types of Environment Flow Components (EFCs): low flows, extreme low flows, high flow pulses, small floods, and large floods. The five EFC types are described in more detail in section 2.3 of the IHA manual (The Nature Conservancy 2009). This categorization of flow into five EFCs is based on the realization by research ecologists that river hydrographs can be divided into a repeating set of ecologically important hydrographic patterns that should be considered to sustain riverine ecological integrity. Not only is it important to maintain adequate flows during low-flow periods, but also higher flows and floods and extreme low-flow conditions that perform important ecological functions.

The IHA software incorporates default parameters for delineating the five EFCs as well as an interface for users to modify the default values (The Nature Conservancy, 2009), see Figure C 20. The thresholds that can be modified include flow exceedances (e.g., 10th percentile), recurrence intervals (e.g., 2-year event), and rate of change (e.g., 25% flow increase from previous day).

In the IHA EFC model, all daily flows fall within one of the five categories, and an algorithm parses the hydrograph accordingly based on the delineation thresholds being employed. The program logic (Figure C 21) separates flow into base flows and flow pulse periods using a base-flow separation method. Pulses are subsequently classified by flow rate-of-change (i.e., percent difference from previous day), and base flows classified by magnitude (expressed as recurrence interval).

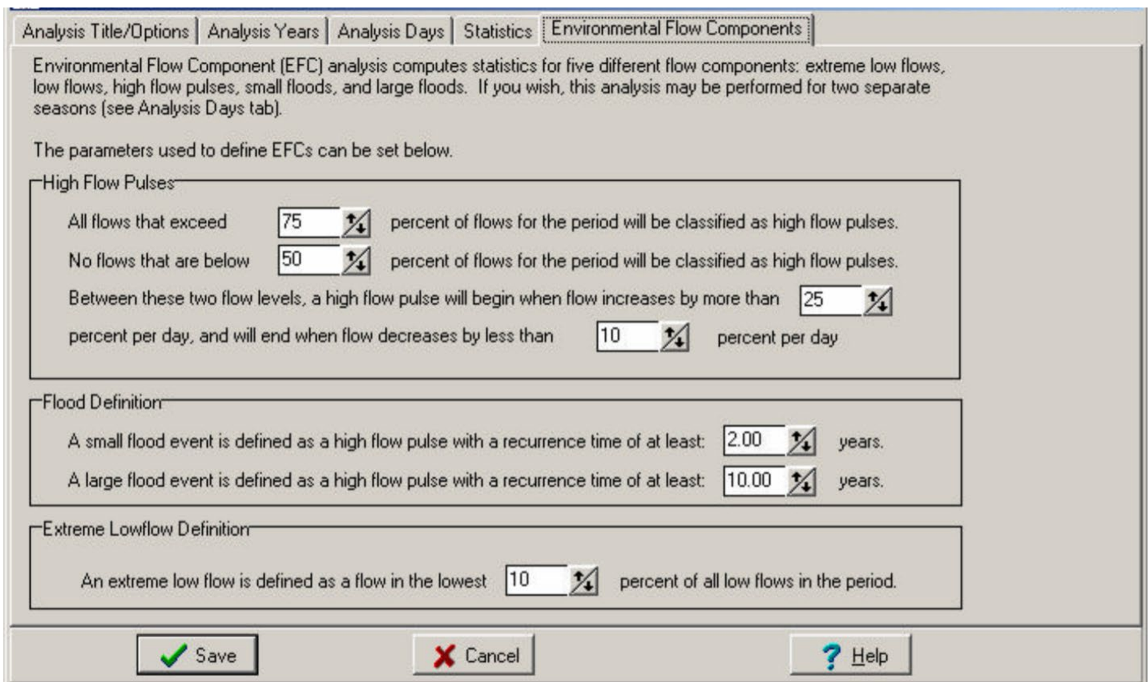

Figure C 20. IHA EFC definitions interface screen, displaying default thresholds

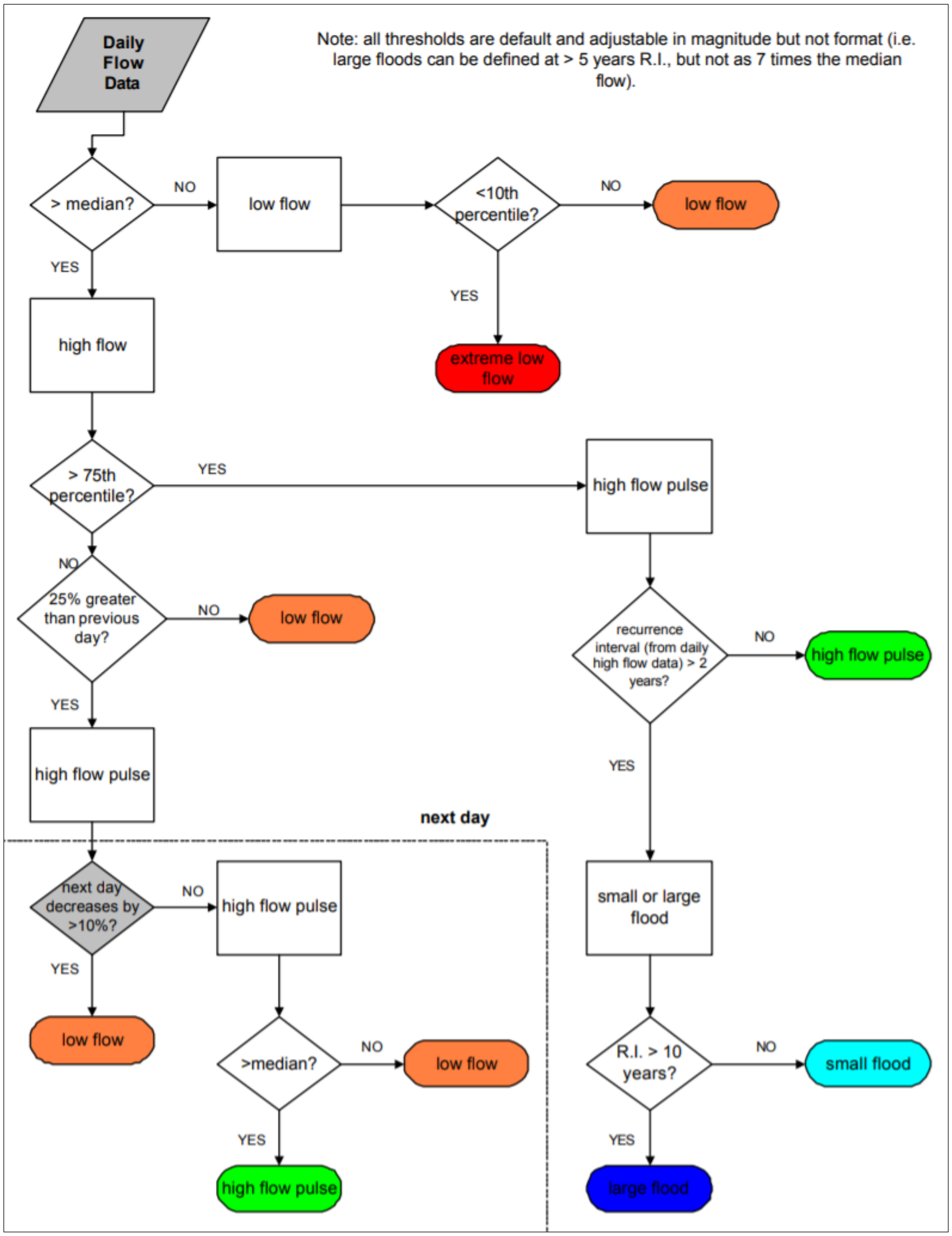

Figure C 21. IHA environmental flow component algorithm flow chart
[Source: (Hersh & Maidment, 2006)]

4.3 IHA Results for LSFR at Fort White

IHA was used to compare the hydrologic characteristics of two time series of flow at the Fort White gage: Reference Timeframe Flow (RTF) for WYs 1933-2015 and MFL flow for WYs 1933-2015.

The program calculated deviation factors and corresponding significance counts for the 33 IHA and 34 EFC parameter medians and coefficients of dispersion ((75th percentile-25th percentile)/50th percentile), (Table C 9). The coefficient of dispersion (C.D. in Table C 9) is a nonparametric interquartile spread normalized to the median. Deviation factors are calculated by comparing MFL values with RTF values for each parameter, as shown in the equation below, which is interpreted as the proportional change in the median (or coefficient of dispersion) relative to the RTF value.

$$\text{Deviation factor} = \frac{\text{RTF value} - \text{MFL value}}{\text{RTF value}}$$

For example, the median 1-day minimum flow values (underlined in Table C 9 Parameter Group #2) for RTF and MFL flows are 941 and 838 cfs, respectively. Using the above equation, the deviation factor is 0.11 ((941-838)/941), i.e., a 11-percent change from the RTF value. Similarly, a deviation factor of 0.12 is calculated for the coefficient of dispersion using the RTF and MFL coefficient of dispersion values of 0.273 and 0.306, respectively.

The significance count for the deviation values can be interpreted similar to a p-value in parametric statistics and indicates whether the difference between RTF and MFL flows (deviation factor) is significant. A low significance count (minimum value is 0) implies that the difference between the two flow regimes is significant. The IHA software calculates the significance count values by randomly shuffling all years of input data and recalculates fictitious RTF and MFL medians and coefficient of dispersions 1,000 times (The Nature Conservancy, 2009). The significance count is the fraction of trials for which the deviation values for the medians or coefficient of dispersions were greater than for the real case. So, a high significance count (maximum value of 1) means that there is little difference between the RTF and MFL data. The significance counts may differ slightly each time the IHA analysis is completed, since a new set of randomized cases is generated each time.

The IHA analysis quantifies the extent of possible hydrologic alteration (attributable to withdrawal) between RTF and MFL flows. The proposed MFL is implemented as a constant withdrawal, thus the influence of the MFL would be most apparent in the low- to moderately low flow statistics. Assuming a 5-percent level of significance (i.e., probability of rejecting the null hypothesis when it is true), the Group #2 1-day, 3-day, 7-day, 30-day, and 90-day minimums have statistically significant deviation factors for the medians (10% for 90-day minimum and 11% for others) and associated significance counts (i.e., p-values) ranging between 0.005 and 0.012 (Table C 10). Similar to the frequent low MDR analysis, a higher deviation factor approaching or even exceeding 10% would be an indicator that instream habitat is sensitive to flow reduction and could be exposed to an increasing risk of change. The significance counts for all but two coefficients of determination exceed 0.05 (Table C 10 and Table C 13) indicating there is no significant change in the variability of flow. The two exceptions are the low pulse count (0.021 in Table C 10) and extreme low duration (0.008 in Table C 13). While the median low pulse and high pulse count deviation factors of 1 and 0.5, respectively, are statistically significant, the flow magnitudes are much higher; and the significance counts (p-values) of all five Group #2 median x-day maximums exceed 0.45, indicating the change in flow magnitude is not significant (Table C 10).

Table C 11. IHA output for LSFR at Fort White pre-impact period (RTF) and post-impact period (MFL) flows [underlined cell is referenced in text]

Non-Parametric IHA Scorecard								
FW_RTF_MFL								
IHA Parameters								
Pre-impact (RTF) period: 1933-2015 (83 years)				**Post-impact (MFL) period: 1933-2015 (83 years)**				
Normalization Factor	1			1				
Mean annual flow	1526			1423				
Non-Normalized Mean Flow	1526			1423				
Annual C. V.	0.59			0.63				
Flow predictability	0.6			0.57				
Constancy/predictability	0.97			0.97				
% of floods in 60d period	0.28			0.28				
Flood-free season	0			0				
	MEDIANS		**COEFF. of DISP.**		**DEVIATION FACTOR**		**SIGNIFICANCE COUNT**	
	Pre	**Post**	**Pre**	**Post**	**Medians**	**C.D.**	**Medians**	**C.D.**
Parameter Group #1								
October	1351	1248	0.6155	0.6663	0.076	0.083	0.20	0.76
November	1191	1088	0.4901	0.5365	0.086	0.095	0.18	0.71
December	1141	1038	0.4044	0.4446	0.090	0.099	0.27	0.62
January	1174	1071	0.5288	0.5797	0.088	0.096	0.12	0.79
February	1314	1211	0.5807	0.63	0.078	0.085	0.43	0.58
March	1302	1199	0.8163	0.8864	0.079	0.086	0.31	0.63
April	1312	1209	0.8618	0.9352	0.079	0.085	0.48	0.73
May	1158	1055	0.6291	0.6906	0.089	0.098	0.27	0.70
June	1118	1015	0.5041	0.5553	0.092	0.10	0.072	0.72
July	1266	1163	0.51	0.5551	0.081	0.089	0.25	0.62
August	1541	1438	0.5735	0.6145	0.067	0.072	0.27	0.74
September	1580	1477	0.6525	0.698	0.065	0.070	0.55	0.87
Parameter Group #2								

1-day minimum	941.2	838.2	0.2725	0.3059	0.11	0.12	0.006	0.50
3-day minimum	943.6	840.6	0.2817	0.3162	0.11	0.12	0.005	0.50
7-day minimum	947.2	844.2	0.287	0.322	0.11	0.12	0.008	0.52
30-day minimum	953.1	850.1	0.2987	0.3348	0.11	0.12	0.010	0.54
90-day minimum	1008	904.7	0.3317	0.3694	0.10	0.11	0.012	0.55
1-day maximum	3793	3690	0.8938	0.9188	0.027	0.028	0.91	0.93
3-day maximum	3746	3643	0.9057	0.9313	0.028	0.028	0.91	0.92
7-day maximum	3531	3428	0.8584	0.8842	0.029	0.030	0.87	0.89
30-day maximum	2539	2436	0.7792	0.8121	0.041	0.042	0.68	0.79
90-day maximum	1985	1882	0.5388	0.5683	0.052	0.055	0.50	0.75
Number of zero days	0	0	0	0				
Base flow index	0.6764	0.6518	0.2135	0.2195	0.036	0.028	0.15	0.87
Parameter Group #3								
Date of minimum	183	183	0.3607	0.3607	0	0	0.99	1.00
Date of maximum	236	236	0.4891	0.4891	0	0	1.00	0.98
Parameter Group #4								
Low pulse count	1	2	3	1.5	1	0.5	0.001	0.021
Low pulse duration	46.75	30	1.572	2.75	0.36	0.75	0.60	0.097
High pulse count	2	3	1	1	0.5	0	0.001	0.48
High pulse duration	23.75	19.25	1.679	1.182	0.19	0.30	0.17	0.18
Low Pulse Threshold	999.1							
High Pulse Threshold	1773							
Parameter Group #5								
Rise rate	24	24	1.125	1.125	0	0	1	1.00
Fall rate	-20	-20	-1	-1	0	0	0.70	0.86
Number of reversals	56	56	0.375	0.375	0	0	0.94	1.00
EFC Low flows								
October Low Flow	1317	1243	0.3727	0.3688	0.056	0.010	0.42	0.96
November Low Flow	1180	1130	0.3698	0.374	0.042	0.011	0.45	0.97
December Low Flow	1183	1107	0.3459	0.3502	0.064	0.013	0.35	0.93
January Low Flow	1164	1114	0.3323	0.4084	0.043	0.23	0.42	0.28
February Low Flow	1268	1214	0.3903	0.4107	0.043	0.052	0.50	0.72
March Low Flow	1279	1186	0.3604	0.3963	0.072	0.099	0.21	0.54
April Low Flow	1226	1143	0.3896	0.4163	0.067	0.068	0.33	0.72

May Low Flow	1151	1128	0.4081	0.4281	0.020	0.049	0.60	0.83
June Low Flow	1146	1086	0.3669	0.4326	0.053	0.18	0.32	0.57
July Low Flow	1217	1178	0.3282	0.4475	0.032	0.36	0.49	0.09
August Low Flow	1372	1366	0.3604	0.3857	0.004	0.070	0.92	0.75
September Low Flow	1319	1272	0.3467	0.4021	0.036	0.16	0.50	0.32
EFC Parameters								
Extreme low peak	744.2	728.1	0.188	0.2531	0.022	0.35	0.64	0.35
Extreme low duration	58	27.75	1.345	5.464	0.52	3.1	0.45	0.008
Extreme low timing	71	154.3	0.4221	0.3402	0.45	0.19	0.22	0.46
Extreme low freq.	0	0	0	0				
High flow peak	2211	2188	0.1939	0.2374	0.010	0.22	0.57	0.31
High flow duration	15.25	13	0.8607	0.8173	0.15	0.050	0.36	0.82
High flow timing	149	183.3	0.4372	0.4341	0.19	0.007	0.60	0.96
High flow frequency	1	2	3	1.5	1	0.5	0.00	0.27
High flow rise rate	75.9	87.89	1.089	0.8974	0.16	0.18	0.52	0.43
High flow fall rate	-43.96	-43.51	-0.4375	-0.732	0.010	0.67	0.96	0.052
Small Flood peak	4746	4754	0.4138	0.3819	0.002	0.077	0.92	0.79
Small Flood duration	68	70	1.145	1.257	0.029	0.098	0.89	0.79
Small Flood timing	195.8	176	0.4536	0.4679	0.11	0.032	0.92	0.79
Small Flood freq.	0	0	0	0				
Small Flood rise rate	211.7	185	1.148	1.319	0.13	0.15	0.87	0.74
Small Flood fallrate	-63.57	-71.97	-0.6285	-0.6098	0.13	0.030	0.38	0.95
Large flood peak	11400	11290	0.2876	0.2902	0.009	0.009	0.93	0.99
Large flood duration	94.5	62.5	2.217	1.288	0.34	0.42	0.65	0.59
Large flood timing	271.5	271.5	0.4775	0.4775	0	0	0.98	0.99
Large flood freq.	0	0	0	0				
Large flood rise rate	1234	1311	1.317	1.336	0.063	0.015	0.84	0.98
Large flood fall rate	-126.5	-228.6	-1.314	-0.784	0.81	0.40	0.16	0.39
EFC low flow threshold:								
EFC high flow threshold:		1773						
EFC extreme low flow threshold:		806.3						
EFC small flood minimum peak flow:		3338						
EFC large flood minimum peak flow:		8726						

Table C 12. Summary of 33 IHA parameters for LSFR
[**Bold** indicates a statistically significant change at 5 percent level of significance]

	EFC Parameter	Median		Coefficient of dispersion	
		Deviation Factor	Significance Count*	Deviation Factor	Significance Count*
Group#1	January	0.088	0.12	0.096	0.79
	February	0.078	0.43	0.085	0.58
	March	0.079	0.31	0.086	0.63
	April	0.079	0.48	0.085	0.73
	May	0.089	0.27	0.098	0.70
	June	0.092	0.072	0.10	0.72
	July	0.081	0.25	0.089	0.62
	August	0.067	0.27	0.072	0.74
	September	0.065	0.55	0.070	0.87
	October	0.076	0.20	0.083	0.76
	November	0.086	0.18	0.095	0.71
	December	0.090	0.27	0.099	0.62
Group#2	**1-day minimum**	**0.11**	**0.006**	0.12	0.50
	3-day minimum	**0.11**	**0.005**	0.12	0.50
	7-day minimum	**0.11**	**0.008**	0.12	0.52
	30-day minimum	**0.11**	**0.010**	0.12	0.54
	90-day minimum	**0.10**	**0.012**	0.11	0.55
	1-day maximum	0.027	0.91	0.028	0.93
	3-day maximum	0.028	0.91	0.028	0.92
	7-day maximum	0.029	0.87	0.030	0.89
	30-day maximum	0.041	0.68	0.042	0.79
	90-day maximum	0.052	0.50	0.055	0.75
	Number of zero days				
	Base flow index	0.036	0.15	0.028	0.87
Group#3	Date of minimum	0	0.99	0	1.00
	Date of maximum	0	1.00	0	0.98
Group#4	**Low pulse count**	**1**	**0.001**	**0.5**	**0.021**
	Low pulse duration	0.36	0.60	0.75	0.097
	High pulse count	**0.5**	**0.001**	0	0.48
	High pulse duration	0.19	0.17	0.30	0.18
Group#5	Rise rate	0	1	0	1.00
	Fall rate	0	0.70	0	0.86
	Number of reversals	0	0.94	0	1.00
*Deviation factor is significant if significance count<0.05 Bolded values have significance count<0.05					

Table C 13. Summary of 34 IHA environmental flow component parameters for LSFR
[**Bold** indicates a statistically significant change at 5 percent level of significance]

	EFC Parameter	Median		Coefficient of dispersion	
		Deviation Factor	**Significance Count***	**Deviation Factor**	**Significance Count***
Low flow	January low flow	0.043	0.42	0.23	0.28
	February low flow	0.043	0.50	0.052	0.72
	March low flow	0.072	0.21	0.099	0.54
	April low flow	0.067	0.33	0.068	0.72
	May low flow	0.020	0.60	0.049	0.83
	June low flow	0.053	0.32	0.18	0.57
	July low flow	0.032	0.49	0.36	0.09
	August low flow	0.004	0.92	0.070	0.75
	September low flow	0.036	0.50	0.16	0.32
	October low flow	0.056	0.42	0.010	0.96
	November low flow	0.042	0.45	0.011	0.97
	December low flow	0.064	0.35	0.013	0.93
Extreme low flow	Extreme low peak	0.022	0.64	0.35	0.35
	Extreme low duration	0.52	0.45	**3.1**	**0.008**
	Extreme low timing	0.45	0.22	0.19	0.46
	Extreme low frequency				
High flow pulse	High flow peak	0.010	0.57	0.22	0.31
	High flow duration	0.15	0.36	0.050	0.82
	High flow timing	0.19	0.60	0.007	0.96
	High flow frequency	**1**	**0.00**	0.5	0.27
	High flow rise rate	0.16	0.48	0.18	0.43
	High flow fall rate	0.010	0.96	0.67	0.052
Small flood	Small flood peak	0.002	0.92	0.077	0.79
	Small flood duration	0.029	0.89	0.098	0.79
	Small flood timing	0.11	0.92	0.032	0.79
	Small flood frequency				
	Small flood rise rate	0.13	0.87	0.15	0.74
	Small flood fall rate	0.13	0.38	0.030	0.95
Large flood	Large flood peak	0.009	0.93	0.009	0.99
	Large flood duration	0.34	0.65	0.42	0.59
	Large flood timing	0	0.98	0	0.99
	Large flood frequency				
	Large flood rise rate	0.063	0.84	0.015	0.98
	Large flood fall rate	0.81	0.16	0.40	0.39

*Deviation factor is significant if significance count<0.05
Bolded values have significance count<0.05

5. DISCUSSION

Two different event-based approaches are demonstrated in this Attachment. First, demonstrations of the MDR Event Approach are provided for three distinctly different hydrologic events using the same flow data (RTF) considered in the 2019 MFLs re-evaluation. Second, the IHA software was used to calculate the relative differences in the medians and coefficients of dispersion for 67 different streamflow characteristics associated with the same 83-year RTF hydrology and the hydrology resulting from the proposed MFL.

The Minimum Frequent High Flow event considers the frequency of flooding to maintain the ecotone between the upland and wetland floodplain vegetation communities. An event evaluation of the hydrology associated with the proposed MFLs condition supports a conclusion that the proposed MFL would be protective of that goal. IHA results corroborate that conclusion.

A Minimum Average Flow event analysis considers the frequency of drawdown that could adversely affect the organic soils in lower floodplain areas where swamp exists. The conclusion of the event analysis is that the proposed MFL would be protective of that goal. IHA results corroborate that conclusion as well.

Two Minimum Frequent Low Flow events were evaluated; one as an inundation event and the other as a dewatering event. Both evaluations consider the protection of nesting habitat for the fry of largemouth bass, a popular fish species. The conclusion of the FL analysis is that the proposed MFL could pose a moderate risk to the instream habitat metric considered for this demonstration, i.e., a goal of maintaining viable largemouth bass nesting habitat at the LSFR SEFA sites. As would be expected, IHA results indicate a statistically significant change in the low-flow characteristics, whereas the change in higher-flow statistics was not significant.

The anticipation that instream habitat under lower flow conditions could be a limiting factor on withdrawals was the primary reason for selecting SEFA and the %area approach at the onset of the LSFI MFLs re-evaluation. Unlike the more robust SEFA analysis that incorporates depth, velocity and substrate, the FL demonstration considers only depth. The 103 cfs hydrologic shift associated with the proposed MFLs was limited by fish passage and suitable instream habitat simulated using the SEFA software. Area weight suitability- based on depth, velocity, and substrate, was simulated for a number of fish species including largemouth bass and life stages such as fry.

Comparing an IHA application to the Event Approach demonstrates that considerable care is necessary when applying the Event Approach, particularly when site specific data are not available for the purpose of characterizing important events. It begins with selecting specific indicators and monitoring locations for which meaningful information and/or data must be available for analysis. Lacking such data, the analyst must rely on other methods.

The Event Approach relies on three degrees of freedom, i.e., event parameters: magnitude, duration, and frequency. Recent applications of the Event Approach by SJRWMD for MFLs assessment, identify a critical magnitude and critical duration; both are substantiated by considerable research. Once established for the event analysis, both parameters remain unchanged.

Frequency, however, is evaluated in several steps. The first step is to identify a threshold frequency, akin to the critical magnitude and duration, that is also substantiated by monitoring and or research. If the baseline frequency is considerably different than anticipated, it calls into question whether a meaningful WRV indicator or threshold metric has been selected for the analysis. The second step might be to consider an “allowable change in frequency” that would prevent significant harm. If the baseline frequency indicates that water may be available for withdrawal, the actual magnitude of the withdrawal and basis for the MFL would be tempered by other factors such as the relative change in flow and associated levels of risk for adverse impact (Richter, Davis, Apse, & Konrad, 2011) and the relative proportion of the hydrologic shift compared to a presumed unimpaired flow condition.

The Event Approach is often-times based on identifying an acceptable degree of departure from a natural flow regime (Tharme R. E., 2003). The assumption that field data collected recently, particularly ecological data, are representative of pre-withdrawal conditions may, or may not, be reasonable considering that assumption. As previously documented, the post-1990’s conditions appear to be substantially dryer than pre-1990’s conditions. Care must be taken when interpreting field data collected during a single synoptic ecological monitoring event under such conditions.

Concurrent systematic ecological and hydrometeorological monitoring coupled with periodic re-evaluation will be necessary to differentiate the influence of natural and anthropogenic factors. Water Management Districts have implemented wetland monitoring programs focused on that objective.

In response to concerns related to the possible impact of projected increases in water use on wetlands, a monitoring effort was begun by SJRWMD to better understand relationships between hydrology and plant community structure and hydrology and soil morphology (Epting, 2007). A network of surficial aquifer (SA) monitoring wells was established in 1995 in natural areas in northeastern Florida that had experienced little hydrologic alteration from groundwater drawdown. A preliminary analysis based on five years of data confirmed the correlation of frequency and duration of water levels with plant community types with wetter community types having higher water levels for longer durations. By 2006, a sufficient period of record existed to apply frequency analysis methods to define the hydrologic signatures of wetland plant communities and hydric soil indicators. Hydrologic signatures of this network of natural area wetlands were re-assessed and provide a preliminary estimate of the natural variation of the hydrologic signatures of wetland plant communities and hydric soil indicators (Epting, 2007). The SJRWMD goal is to use a POR >50 years for wetland hydrology signatures. Epting cautions against using 10 years of data, but notes that these shorter POR signatures should provide a reasonable estimate of hydrology between 10% and 90% probability for the plant communities and hydric soil indicators.

The Southwest Florida Water Management District (SWFWMD) maintains a palustrine wetland monitoring program that combines systematic water-level monitoring with periodic assessments of wetland health and condition (HSW, 2012). A total of 36 wetlands were evaluated using 6 years of hydrologic data collected from October 1989 through September 1995 along with qualitative observations of wetland conditions made during early 1997 to establish MFLs for isolated cypress wetlands. In 2011, HSW was requested by SWFWMD to evaluate more recent hydrologic and ecosystem data collected for additional wetlands and apply the original procedure for setting the MFLs to the data collected for the additional wetlands. Similar to the SJRWMD monitoring goal, the uncertainty associated with frequency analysis can be reduced through site-specific, long-term wetland monitoring.

6. CONCLUSION

The District concurs that many withdrawal responses associated with environmental and human use values are the result of changes in the flow regime such that important events are altered beyond some threshold. With current available information, what those events and thresholds are in a complex river system like the lower Santa Fe River system are too uncertain to utilize with the data currently available.

The Peer Review Panel Chair called for a complete MFL re-evaluation based on the MDR Event Approach. Furthermore, assertions that the literature review should be updated to include a “state of science and practices” imply that the District team is somehow deficient in its knowledge of the various approaches that can be used to evaluated MFLs. The District respectfully disagrees on both items.

As stated in the introduction, the purpose of this document is to inform on two event-based approaches. The decision to not use an event-based approach for the MFLs re-evaluation was purposeful, logical, well founded, and with ample precedent. The District approach for its river systems has been to use a cumulative frequency method for relatively high flows, developed by authors formerly with the SWFWMD, and in-stream habitat modeling (e.g., SEFA), a method for evaluating the change in in-stream suitable habitat area for various aquatic species and life stage. Bathymetry and floodplain elevation data are utilized as they become available to supported updated riverine and estuarine hydraulic models. Habitat suitability curves for key species are developed for important species such as Gulf sturgeon. Field surveys are used to verify existing regional floodplain soils and wetland vegetation maps. The District did not contemplate changing its approach for the re-evaluation of the LSFI MFL. That decision is supported by the Event Approach and IHA demonstrations described herein.

References

for the Peer Review and Public Comment Resolution Document

and associated Attachment, Exhibits, and Annexes

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