PEER REVIEW OF THE PROPOSED MINIMUM FLOWS AND LEVELS FOR THE LOWER SANTA FE AND ICHETUCKNEE RIVERS AND ASSOCIATED PRIORITY SPRINGS

Final Panel Report
October 11, 2013

Panel:
Wendy D. Graham (UF Water Institute, Chair)
Mark W. Clark (UF Soil and Water Sciences Department)
Matthew J. Cohen (UF School of Forest Resources and Conservation)
Thomas K. Frazer (UF School of Natural Resources and Environment)
Jonathan B. Martin (UF Geologic Sciences Department)

EXECUTIVE SUMMARY

PANEL TASK

In July 2013 the Suwannee River Water Management District contracted with the University of Florida Water Institute to convene a panel of experts to perform an independent peer review of the data, assumptions, methodologies, and conclusions of the report entitled, "Proposed Minimum Flows and Levels for the Lower Santa Fe and Ichetucknee Rivers and Associated Priority Springs", and to prepare a report summarizing the collective scientific opinions of the group, and identifying disagreements between individual panelists if any.

GENERAL FINDINGS

The peer review panel supports the general approach that the SRWMD has adopted to develop MFLs for the Lower Santa Fe and Ichetucknee Rivers, including the estimation of an "unimpacted" baseline flow regime for each river; identification of relevant water resource values (WRVs) that should be protected for each river; determination of baseline flow metrics required to maintain each WRV; choice of a protection standard that represents prevention of significant harm; and synthesis of the critical flow metrics for the WRVs into a Minimum Flow and Level (MFL) for each river. The panel believes that, with relatively minor and easily reconcilable exceptions noted in the report, the SRWMD utilized the best available data and information in their analyses.

The panel recognizes that much of the biological and ecological data needed to develop well-defended MFLs are currently unavailable and therefore protective thresholds of significant harm are largely presumptive. In particular the adoption of a 15% threshold value as it relates to allowable habitat loss, and the presumption that this value will prevent significant harm, cannot be justified on the basis of the data presented in the report. Although there is a precedent for the adoption of a 15% value, its general applicability is unproven. In the 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 becomes available.

The panel believes that the HECRAS model and Recent and Long-term Positional Hydrograph (RAPLH) analyses used in the development of critical flow regimes to protect WRVs are appropriate and reasonable and were developed using best practices. However the panel identified several assumptions and procedures that were utilized, particularly in the development of the baseline model and the selection of WRV metrics, which should be re-evaluated before the MFLs are adopted for the Lower Santa Fe and Ichetucknee Rivers and associated Priority Springs.

MAJOR RECOMMENDATIONS

The following represent the major recommendations from the peer review panel. Additional significant recommendations can be found at the end of each section of the body of this report. Editorial comments are included in Appendix A.

1. BASELINE FLOW MODEL DEVELOPMENT

a) The assumption of a linear response of baseflow to rainfall, regardless of season or antecedent conditions, is not well-supported in the literature, or by data from the Santa Fe basin. It is the panel's opinion that the model systematically over-predicts low flows and under-predicts high flows, and produces large residuals with extremely high temporal autocorrelation, in large part, because of this assumption. The panel recommends that the SRWMD explore alternative non-linear and/or seasonal models to better account for antecedent moisture conditions in the baseflow model predictions. Examples of possible alternative modeling approaches that could be explored include: 1) use a linear model with parameters that depend on season, hydrologic condition, or climate state; 2) use monthly precipitation (P) minus evapotranspiration (ET) instead of P as the driver for a linear model to account for the seasonality of effective rainfall; 3) include a non-linear component in the model to account for evapotranspiration losses prior to fitting a linear effective rainfall-baseflow model; 4) use a non-linear regression technique (e.g., locally weighted polynomial regression) to develop model coefficients that depend on the state of the system. We have provided literature citations for these methods in the report.

b) The best available groundwater pumping data for the region do not support the assumption that impacts to baseflow due to pumping began only after 1970. The groundwater pumping data presented in the report indicate an approximate linear increase in pumping from 1965 through 1990, and then approximately steady pumping from 1990-2010. This pumping pattern would imply that effects to baseflow should have begun before 1970 and stabilized after 1990. The panel recommends that the SRWMD explore alternative assumptions regarding the timing of anthropogenic influences. For example, baseflow models could be fit for three different periods:
   i. 1935-1950 - a time with presumably minimal pumping (i.e. before widespread use of center pivot irrigation);
   ii. 1950-1990 - a time during which pumping may have increased approximately linearly;
   iii. 1990-2010 - a time of large, but temporally stable pumping.

   A comparison of parameter values and residual behavior across these time periods is likely to provide insight regarding the timing of anthropogenic impacts on baseflow. For example, use of the model fit from 1990-2010 on pre-1990 data might be expected to over predict streamflow such that residuals increase systematically backward in time from 1990 through 1950, then stabilize around a large value in the pre-1950 period. This approach would better account for current best estimates of trends in groundwater pumping.

c) The data presented in the report indicate that spatial variability of rainfall in the region is substantial. The panel recommends that an analysis be conducted to evaluate the sensitivity of the revised baseline model parameters, predictions and residuals to the rainfall data used to develop them. In particular, use of only the Lake City rainfall gage data, rather than the average of Lake City and Gainesville gage data, for the Ichetucknee baseline model should be considered since the Lake City gage is within the springshed. The Gainesville gage is much further away and exhibits marked differences from both Lake City and High Springs rainfall time series.

d) After an improved baseline flow model with lower residual variance and less correlated residuals is developed, a block bootstrapping procedure should be used to estimate model uncertainty. A variety of block lengths, that are longer than the new model residual correlation time (ideally zero), should be investigated to evaluate the effect of block size on uncertainty estimates. After this analysis the assumption that the "10^{th} percentile of the 10^{th} percentile" end-of-record flow prediction is an appropriate choice for the flow reduction due to groundwater pumping should be revisited.

2. WATER RESOURCE VALUE (WRV) PROTECTION

a) To prevent significant harm MFLs should include considerations of duration and return interval of both low-flow and high-flow events in addition to cumulative frequency, which was considered in the report. The panel recommends a multi-metric approach that considers more comprehensive temporal and spatial hydrologic drivers of a WRV with the realization that all metrics are not equally protective.

b) The panel recommends that the most vulnerable WRV should be protected when setting the MFLs, rather than using aggregate WRV data in a "best-fit" approach as is currently the case. Failure to do so explicitly fails to protect some WRVs at the pre-selected threshold value.

c) Although the MFL process is not intended to mitigate water quality impacts caused by increased pollutant loads in the watershed, relationships between flow and water quality related parameters are evident in data provided in this report. Recent literature also suggests that there are likely relationships between flow and water quality related parameters (e.g. dissolved oxygen, iron, nitrate) in the Ichetucknee River. Thus, the water quality WRV merits a more detailed investigation to ensure that the proposed MFL will not cause a violation of any relevant water quality standard.

Table of Contents

I. INTRODUCTION AND SCOPE OF REVIEW

In July 2013 the Suwannee River Water Management District contracted with the University of Florida Water Institute to convene a panel of experts to perform an independent peer review of the data, assumptions, methodologies, and conclusions of the report entitled "Proposed Minimum Flows and Levels for the Lower Santa Fe and Ichetucknee Rivers and Associated Priority Springs", and to prepare a report summarizing the collective scientific opinions of the group, and identifying disagreements between individual panelists if any. In particular the scope of the review consisted of the following tasks:

1. Task 1: Determine whether the conclusions in the MFL report are supported by the analyses presented.

a) Supporting Data and Information**:** Review the data and information that supports the conclusions made in the report to determine:
   i. the data and information used was properly collected;
   ii. reasonable quality assurance assessments were performed on the data and information;
   iii. exclusion of available data from analyses was justified; and
   iv. the data used was the best information available.

Note: The reviewers are not expected to provide independent review of standard procedures used as part of institutional programs that have been established for the purpose of collecting data, such as the USGS and SRWMD hydrologic monitoring networks.

b) Technical Assumptions: Review the technical assumptions inherent to the analysis used in the MFL report to determine whether:
   i. the assumptions are clearly stated, reasonable and consistent with the best information available;
   ii. other analyses that would require fewer assumptions but provide comparable or better results are available.

c) Procedures and Analyses: Review the procedures and analyses used in the MFL report to determine whether:
   i. the procedures and analyses were appropriate and reasonable, based on the best information available.
   ii. the procedures and analyses incorporate all necessary factors;
   iii. the procedures and analyses were correctly applied;
   iv. limitations and imprecision in the information were reasonably handled;
   v. the procedures and analyses are repeatable;
   vi. conclusions based on the procedures and analyses are supported by the data.

2. Task 2: If a proposed method used in the MFL report is not scientifically reasonable:

a) List and describe scientific deficiencies and, if possible, describe potential implications of the error associated with the deficiencies;
b) Determine if the identified deficiencies can be remedied.
c) If the identified deficiencies can be remedied, then describe the necessary remedies and, if possible provide an estimate of time and effort required to develop and implement each remedy.
d) If the identified deficiencies cannot be remedied, then, if possible, identify one or more alternative methods that are scientifically reasonable. If an alternative method is identified, provide a qualitative assessment of the relative strengths and weaknesses of the alternative method(s) and the effort required to collect data necessary for implementation of the alternative methods.

II. REVIEW OF DESCRIPTION OF THE LOWER SANTA FE AND ICHETUCKNEE RIVER BASINS

1. FINDINGS (TASK 1)

a) DATA AND INFORMATION

Chapter 2 provides much of the background information required for subsequent development of the conceptual model of the Lower Santa Fe River Basin, data and statistical analyses, and ultimately the development of minimum flows for the Lower Santa Fe and Ichetucknee rivers. It includes descriptions of the geology, physiography and hydrogeology, hydrology and rainfall records, riverine and riparian wetland habitats, and land use within the Lower Santa Fe and Ichetucknee rivers and surrounding basin. These descriptions are consistent with the purpose of the chapter, but in addition to this descriptive information, Chapter 2 also includes a large amount of information describing how rainfall and flow data were prepared, manipulated and modified for hydrologic data analyses and modeling described in Chapter 4. Chapter 4 also includes descriptions of these data manipulations, which are somewhat redundant. Since Chapter 2 is supposed to be background information, it may be more appropriated to consolidate the descriptions of data manipulation and modification into the later chapter. Consolidating all of these descriptions should improve the flow of the text and simplify the descriptions of these analyses.

The description of the geology and physiography of the Lower Santa Fe River region provides important details needed for subsequent understanding of the modeling effort that results in the proposed minimum flow standard. The geologic framework of this basin is particularly important to the development of its minimum flow criteria because of the underlying karst geology and lack of confinement of the Floridan aquifer over most of the basin. These characteristics result in interactions between surface water and groundwater that are sufficiently extensive that the two water systems must be considered as "one resource" (page 2-9). Consequently, complete, accurate and detailed descriptions of the geology and hydrogeology of the region are critical for subsequent conceptual and numerical modeling, and thus are appropriate for this report. However, information provided in this chapter concerning geologic framework, hydrogeology, and hydrology should be expanded, clarified, or corrected in various places in the text. Specific areas needing attention are described below.

i) Geologic information. The geologic map presented in Figure 2-1 provides a good description of the surface and near-surface occurrences of the formations in the region, but no information is provided in the report about their subsurface distributions. Since the characteristics of groundwater flow are controlled by the distribution of the formations, and their hydrogeologic characteristics, a cross section of the region would be useful to show elevations and thicknesses of the various formations. This cross section would provide the most useful information about hydrogeologic characteristics within the basin if it were oriented approximately east-west so that it was perpendicular across the Cody Scarp. In lieu of, or in addition to such a cross section, more information about the subsurface distributions of the various formations could be provided in Table 2-1, particularly the range of thickness of the formation. Furthermore, this table is missing the Statenville Formation, which should be included in the table to be consistent with the description and distribution of formations in the region.

The description of the geologic evolution of the region that led to the deposition of undifferentiated quaternary sediments and formation the Cody Scarp requires some modification to improve the understanding of the behavior of the hydrologic system in the Santa Fe River Basin. Accurate presentation of how these features formed, particularly the Cody Scarp, is important to the overall goal of the document because of their contributions to and modifications of flow in the Lower Santa Fe River. As pointed out in the document, undifferentiated Quaternary sediments that form beach ridges may have been deposited at higher sea levels (§ 2.1.1.2, p. 2-3). However, sea level has not been as high as the current elevation of the beach ridges during or since their formation, and thus this statement could be misinterpreted to indicate that the Santa Fe Basin was inundated by higher sea levels at the time of the formation of the beach ridges, which is incorrect. The current understanding of how the beach ridges formed is that the land surface was uplifted to its current elevation through isostatic rebound following dissolution of the underlying carbonate rocks (Opdyke et al., 1984; Adams et al., 2010). The relationships between uplift, relative sea level, erosion and deposition of beach ridges is especially important for the formation of the Cody Scarp, which is perhaps the most important geomorphic feature in the region in terms of controlling the hydrogeology.

The Cody Scarp is referred to as a "karst escarpment" in several locations in the report, particularly on p. 2-4. This term implies that subsurface dissolution (e.g., karst processes) were responsible for forming the scarp. Instead, the Cody Scarp is the erosional edge of the Hawthorn Group rocks (Scott, 1988; Scott, 1992) and thus it is not formed by dissolution. To the contrary, the Cody Scarp represents a location of intense recharge via sinking streams and sinkholes of surface water to the Floridan aquifer, and thus in part controls the water chemistry in and dissolution of the Floridan aquifer (Lawrence and Upchurch, 1984). This recharge is an important source of water (mostly through spring discharge) to the Lower Santa Fe and Ichetucknee rivers. The impact on river flows is most pronounced where the Santa Fe River flows underground at the River Sink and re-emerges at the River Rise. Although this impact is mentioned in §2.1.2.3 of the report, the magnitude of the impact is not described fully, although it has been well studied. Particularly important to development of MFL criteria for the Lower Santa Fe River is the relative fraction of water in the Lower Santa Fe River that derives from runoff of surface water from the upper basin where the Floridan aquifer is confined, versus from diffuse recharge through the epikarst to the Upper Floridan Aquifer in the unconfined portion of the basin. The source of water flowing to the River Rise is known to alternate between these two sources depending on the discharge of the Upper Santa Fe River Martin and Dean, 1999; Martin and Dean, 2001). Recently two sources of groundwater have been identified to contribute to the Lower Santa Fe River: one source originating from shallow, recently recharged water and other from deep (i.e., at the level of the Avon Park Formation) portions of the Floridan Aquifer (Moore et al., 2009).

ii) Hydrology and hydrologic information. Although the role of interactions between surface water and groundwater is stressed in the report, minimum flows in the rivers are set through statistical analyses between rainfall and river flow. Since the Lower Santa Fe River basin is underlain by the unconfined Floridan aquifer, little surface runoff to the rivers exists, and instead their flows are largely derived from spring discharge. The report emphasizes the importance of the relationship between groundwater and surface water and the impact of the Cody Scarp, for example in Figure 2-5. However neither the description of the figure, nor the figure caption, adequately describes what the lines of the potentiometric surface represent. Presumably the bottom of the river is at the thalweg and the difference between the elevation of the potentiometric surface and the bottom of the river represents the depth of the river. But it is unlikely that the river elevation was above the ground surface at the Santa Fe Land Bridge during May 2005, as indicated on the figure, considering data presented in Figure 4-4, which shows only a small spike in groundwater elevation. A more thorough explanation of this figure would be valuable, particularly the location of the transect along which the potentiometric surface was estimated. Of particular importance to setting of minimum flows in a groundwater-dominated system is that there will be variable timing delays between precipitation events and discharge to the river. The length of the delay will differ at different springs with the shortest delay at the Sink-Rise systems (e.g., Martin and Dean, 1999), and longer delays at other springs (Florea and Vacher, 2007). The length of the delay is likely to be important for the statistical analyses between rainfall events and streamflow.

Rainfall records used to estimate the baseline flow regime used to set the minimum flow criteria originated at two primary gaging stations, including Gainesville and Lake City. Use of the two records was justified in part by stating that the two records better represent “spatial variability” of the rainfall (p. 2-13), but subsequently, the two records were averaged and the single record was used in the statistical analysis. Figure 1 shows cumulative rainfall for the Lake City, Gainesville, and the average of the Lake City and Gainesville stations from 1931-1970. Figure 2 shows the cumulative rainfall for the Lake City, Gainesville, and High Springs stations from 1970-2000 (note High Springs data is available from 1945 to present and this gage is directly within the lower Santa Fe River basin). These figures indicate that the data from the Gainesville and Lake City gages were similar to each other in the pre-1970 period for which the baseline model was developed. Similarly the Lake City and High Springs data are similar for 1970-2000, regardless of whether the missing High Springs data were filled from Lake City (HS -999=LC) or Gainesville (HS -999=GNV) . However the Gainesville gage apparently received significantly less rainfall than the Lake City and High Springs gages in the 1970-2000 period, accumulating a 200 in deficit over the 40 year period. This rather large difference should be checked against other rainfall stations in the region that have data records for the 1970-2000 period (e.g. Live Oak, Suwannee County, 1898-2013; Mayo, Lafayette County, 1949-2013; Usher Tower, Levy County, 1956-2013) to determine if difference is due to the gages straddling a climate divide line (see e.g. Kelly, 2004 and Section IV.1.b.i below) or if the Gainesville gage is an anomaly in the region. Since spatial variability of the rainfall is apparently substantial, an analysis should be conducted to demonstrate the sensitivity of the baseline model parameters, predictions and residuals to the rainfall data used to develop them (e.g. Lake City, Gainesville, average of Lake City and Gainesville, or other stations). In particular, the use of the Lake City rainfall alone for the Ichetucknee baseline model should be considered since the Lake City gage is within the springshed and the Gainesville gage is much further away.

Tables 2-2 and 2-3 present metadata about stream gages included in the analysis. These tables need to be rearranged so that the stream gages are in the same sequences in both tables. (It appears they are out of order because of the differences in the numeric designation of stream gage 023218982 in the Table 2-2). Since stream flow is derived from stage information via rating curves, it would also be good to switch the order of the tables. Additional information should be provided about why there are different periods of record for these two sets of data. Tables 2-2 and 2-3 indicate there are several stations for which more flow data is available than stage data. For example at gage 02321975 the oldest date for stream stage data is 11/2/2002, but flow data extends to 10/1/1992. It is unclear how flow data would be available at any location without having accompanying stage data.

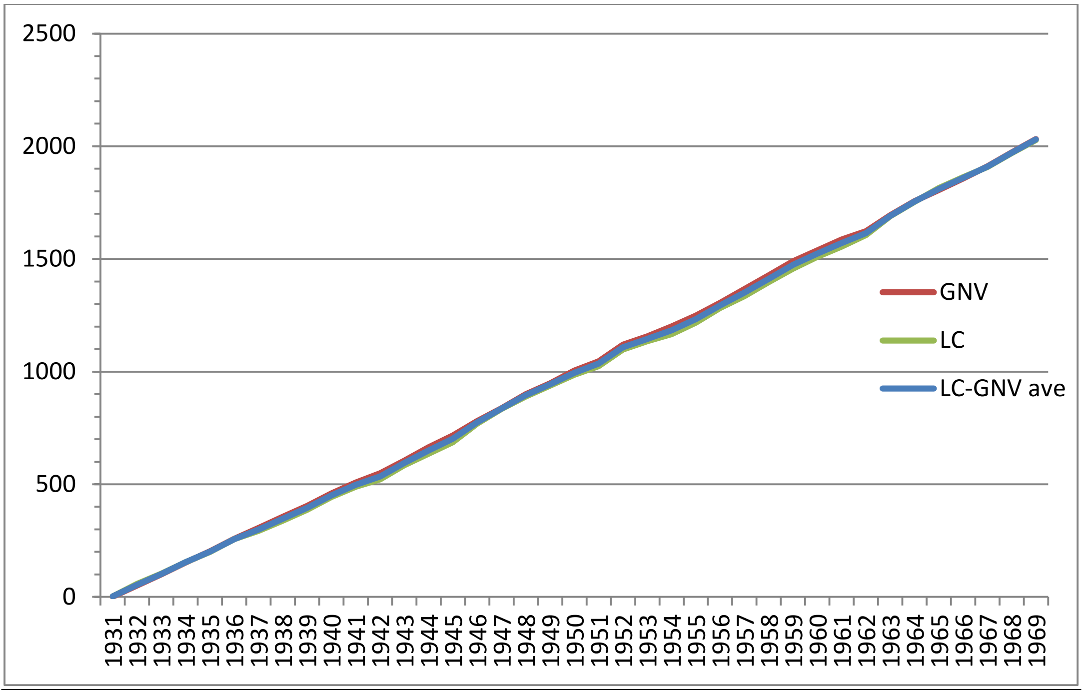

Figure 1: Cumulative rainfall from 1931 to 1970 for Lake City (LC), Gainesville (GNV) and the average of the Lake City and Gainesville (LC-GNC ave) rain gages.

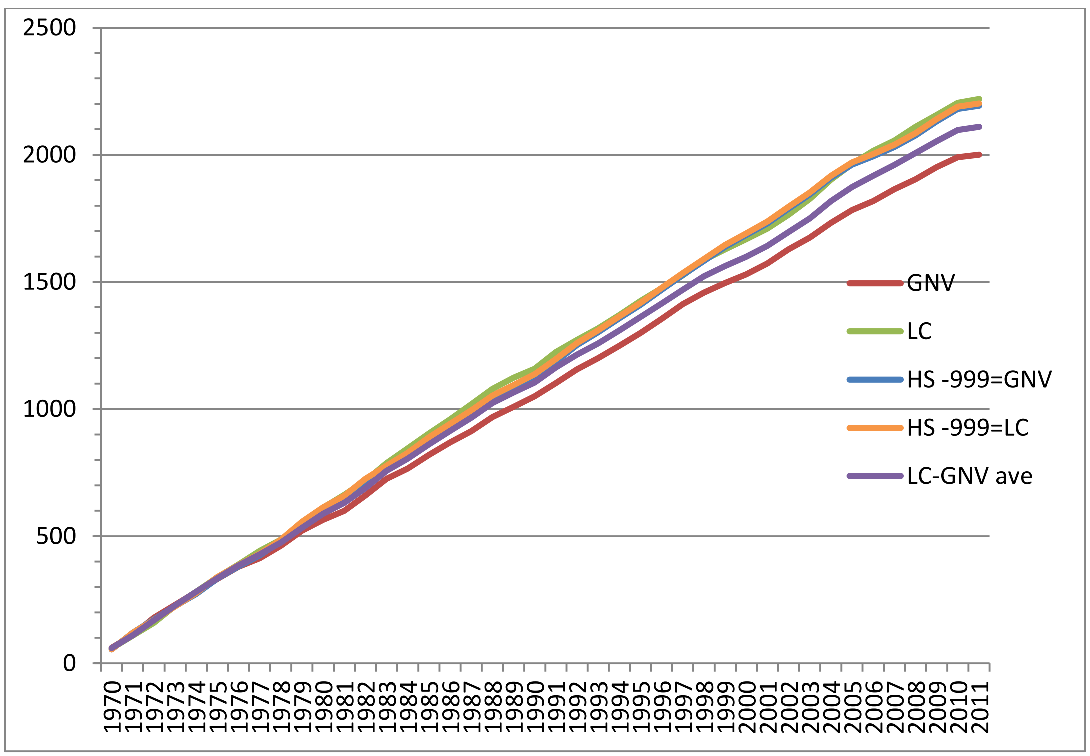

Figure 2. Cumulative rainfall from 1970 to 2011for Lake City (LC), High Springs (HS), Gainesville (GNV) and the average of the Lake City and Gainesville (LC-GNC ave) rain gauges. The High Springs data gaps were filled with both Gainesville gage data (HS -999 = GNV) and Lake City gage data (HS -999 = LC).

iii) River Habitats and Land Use data. The river habitats and land use discussions (e.g., Figures 2-29, 2-30, and 2-31) appear to be fairly complete and provide useful information, but the legends accompanying these figures indicate the information provided is for the Lower Santa Fe River only, although the maps cover the entire watershed. Mislabeling the captions to these figures raises the question of whether the captions for Table 2-11 and Figure 2-32 are also correct. If these data are derived from data shown on the previous three figures, then the data represents land use over the entire basin, rather than just the Lower Santa Fe River as indicated in their captions. Whether these land uses represented by the maps are the entire basin or just the Lower Santa Fe River is an important distinction because of the major difference in geology and land use between the upper and lower basin and their control on runoff, infiltration, and evapotranspiration. The implications from these sections of the report are that the Lower Santa Fe River has "significant surface water input" (p. 2-36) and that this runoff may be increased during peak flows as a result of "ditching and draining" related to silviculture and increases in urbanized land cover (p. 2-38). As pointed out previously in the report, few tributaries directly contribute to flow in the Lower Santa Fe River because of the lack of confinement of the Floridan aquifer. Surface flow contributions from the Upper Santa Fe River pass through the sink-rise system before reaching the Lower Santa Fe River which can significantly attenuate their influence, depending on antecedent moisture conditions. The discussion of the influence of land cover on surface runoff mechanisms in the Lower Santa Fe Basin (p. 2-37 to 2-38) should be revised to clearly distinguish land use and surface runoff generation processes that occur in the Upper Basin from those that occur in the Lower Basin, and their interaction through the sink-rise system.

b) TECHNICAL ASSUMPTIONS

Because this section deals largely with background information, it contains few technical assumptions. However, one assumption presented in the section that should be more thoroughly justified is the use of the average of the Lake City and Gainesville rain gages to develop the baseline time series for the Ichetucknee and Lower Santa Fe Rivers. It is particularly important to justify the assumptions that 1) averaging Lake City and Gainesville rain gages are represents the best available estimate of rainfall over the basin; 2) the use of the average Lake City and Gainesville gages for Ichetucknee modeling is better than using Lake City alone, even though the Lake City gage is within the springshed and Gainesville is much further away; and 3) other rainfall records (e.g. High Springs, Live Oak, Mayo, Usher Tower) should not be included in the analyses of the relationship between rainfall and flow, particularly for the post-1970 time period.

c) PROCEDURES AND ANALYSES

The descriptive nature of this section means that few procedures and analyses are presented. However, in Section 2.2.2 the procedure for estimating baseflow is briefly mentioned and the trend analyses conducted on the annual average streamflows and annual average baseflows are presented. Because these analyses provide the basis for the statistical analyses presented later in the report, it is important that they are sufficiently explained and justified. In particular, the details of the low pass filter used to estimate baseflow should be presented here, in addition to in Appendix 4-1 where they are described more clearly. In addition a stronger justification for choosing a low pass filter with a 120-day window should be provided, and a plot of the total streamflow and estimated baseflow for the two long term stations (Ichetucknee and Santa Fe at Ft White) should be presented the first time the base flow procedure is discussed.

For the trend analyses a clearer description of the null hypotheses being tested and the meaning of the test statistics should be presented (much of this information is given on p 2-23 but the presentation is not well structured so it is difficult to follow). In addition the period of record included in the trend analysis for each streamflow station should be included in Table 2-5.

2. RECOMMENDATIONS (TASK 2)

To address the points raised, the following major modifications are recommended for this section. Additional editorial recommendations are included in Appendix A.

- Include a geologic cross section across the basin to clarify the hydrogeologic characteristics of the stratigraphic units in the basin. Because of the close relationship between groundwater and surface water, the presentation of the characteristics of the aquifer, and how its karst characteristics may affect flow, needs to be improved.
- Conduct an analysis to evaluate the sensitivity of the baseline model parameters, predictions and residuals to the rainfall data used to develop them (e.g. Lake City, Gainesville, average of Lake City and Gainesville, or other stations in the region with long-term data). In particular, consider the use of the Lake City rainfall alone for the Ichetucknee baseline model. Include an analysis of the High Springs rainfall and other relevant rainfall data from the region in the discussion of historical rainfall conditions.
- Provide the additional details and justifications requested for the data manipulation and modification procedures (e.g., baseflow estimation and trend analyses) and consolidate their presentation into Chapter 4. Consolidating all of the data analysis method into one section should improve the flow of the text and simplify the descriptions of these analyses.

III. REVIEW OF CONCEPTUAL MODEL AND APPROACH FOR THE DEVELOPMENT OF MINIMUM FLOWS FOR THE LOWER SANTA FE AND ICHETUCKNEE RIVERS AND PRIORITY SPRINGS

1. FINDINGS (TASK 1)

a) DATA AND INFORMATION

Chapter 3 of the report establishes the conceptual framework that underlies the approach used to establish MFLs for the Lower Santa Fe and Ichetucknee rivers and priority springs. Introductory text (§3.0) indicates clearly that in order to be protective, the MFLs must adequately safeguard natural flow regimes, i.e. the flow regimes should retain as many of the characteristics of the natural flow regime as possible. *Such characteristics, from the perspective of the peer-review panel, include the timing, frequency and duration of both low-flow and high-flow events* and this is elaborated on more fully in subsequent sections of this review. Moreover, the report suggests that a MFL should apply to the entire ecosystem of interest and not be focused on a single attribute (species or habitat type) or water resource value (WRV). The peer-review panel agrees and notes that the relevance of multiple WRVs is discussed in §3.1, though the specific discussion sections are brief and, in many cases, not well developed nor well supported with either technical data or scientific literature. In fact, only §3.1.9 Water Quality is supported with any literature citations. Additional comments as they relate to specific WRVs deemed relevant to the MFLs are provided below:

i) Fish and Wildlife Habitats and the Passage of Fish (§3.1.2) – This section of the report focuses on fish passage with no reference to specific fishes that might be expected to be negatively affected by reduced flows. Of particular interest are species not mentioned including the Suwannee Bass (*Micropterus notius)* that are reported by the Florida Fish and Wildlife Conservation Commission to "prefer rapidly flowing water along rocky shoals" (http://myfwc.com/wildlifehabitats/profiles/fish/freshwater/suwannee-bass/). Suwannee Bass are endemic to the basin and are a species of special concern (Gilbert 1992). Moreover, Suwannee Bass feed almost exclusively on crayfish (Schramm and Maceina 1986) that are, in turn, likely affected by flow mediated effects on habitat. The panel suggests that the District place additional emphasis on the effects of river/stream flow on in-channel habitats, vegetative habitats in particular. As written, it is not clear (in Chapter 3 or elsewhere in the report) how flow effects on in-channel habitats were evaluated other than for depth of fish passage. In addition, the potential indirect effects of flow mediated alterations in habitat should be acknowledged. Finally, we note that there are other species of particular interest that merit some discussion, e.g., Gulf sturgeon, oval pigtoe and silt snail. Both the Gulf sturgeon and oval pigtoe are listed as endangered and the silt snail is restricted in its range to the Ichetucknee River. The silt snail and pigtoe mussel are later discussed in section 5.2.2.7 but would benefit from preliminary discussion in §3.1 of how these protected species would be considered.

ii) Aesthetic and Scenic Attributes (§3.1.6) The report indicates there are no available data relating aesthetic and scenic attributes to flow. However, it is well established that filamentous algae at present levels are considered to be a nuisance (e.g., Heffernan et al. 2010) and there are recent data (King 2012) that suggest flow is likely to exert a significant influence on the abundance and distribution of filamentous algae in Florida's spring-fed systems. Additional data for the Ichetucknee River are suggestive of a negative relationship between flow and periphyton associated with SAV (Kurz et al 2004). The panel believes that some discussion of these findings is warranted.

iii) Filtration and Absorption of Nutrients and Other Pollutants (§3.1.7) Reference is made to "phosphorus fixation" and "nitrogen fixation" as a mechanism whereby nitrogen and phosphorus are retained in the floodplain as a result of flooding. Although the term "phosphorus fixation" can be used to represent the combined sorption and precipitation processes associated with removal of phosphorus compounds from the water column and accumulation of these compounds in the soil, the term "nitrogen fixation" represents a more specific process whereby certain types of bacteria and archea (Diazotrophs) are able to "fix" atmospheric nitrogen gas into a more usable form such as ammonia. The term "fixation" as used in this section appears to be representing the removal of both phosphorus and nitrogen compounds from the water column to the soils as a result of flooding, yet nitrogen fixation would actually represent potential inputs of nitrogen from atmospheric sources to the floodplain that may or may not be increased as a result of flooding. Use of the terms phosphorus retention and nitrogen retention are suggested to more accurately describe the collective removal mechanisms that may occurring in response to flooding with regard to these nutrients.

iv) Water Quality (§3.1.9) – In addition to considerations of nitrate-nitrogen loading that are referenced in paragraph 3.1.9, flow-related variations in other important water quality parameters, e.g. dissolved oxygen, iron, and phosphorus, which have the potential to affect algal production require attention. This should be noted in this section and analyses should be undertaken to ensure that the proposed MFL will not cause a violation of any relevant water quality standard or cause an increase in algal production.

The Conceptual Model (§3.2), as depicted in Figure 3-1, is not well described and there are 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 regimes are frequently recognized in the literature when assessing environmental flows: (1) magnitude, (2) return interval, (3) duration, (4) timing and (5) rate of change (see, e.g., Poff et al. 1997; Richter et al 1996, Richter et al 1997, Tharme 2003). These potential inadequacies should be acknowledged.

MFL Development (§3.3) The justification for the proposed threshold of a 15% habitat loss in the establishment of the MFLs is based on precedent alone and cannot be justified on the basis of the data presented in the report. Although there is a precedent for the adoption of a 15% value, its general applicability is unproven.

b) TECHNICAL ASSUMPTIONS

Given the descriptive nature of Chapter 3, there are few technical assumptions to assess. One major assumption, however, is that flow durations curves (FDCs) are an adequate tool to characterize and capture the variability inherent in the flow regime. The peer-review panel would agree with the District that "FDCs are a convenient tool for the visualization, simplification and comparison of stream flow data", but notes also that FDCs, as employed in the MFL report, fall far short of capturing the full suite of variation in both time and space that is relevant to the WRVs. This shortcoming should be acknowledged in the report.

The assumption that a 15% loss in habitat as a threshold value will be protective of environmental and water resource values is, as indicated above, untested. The 15% threshold as adopted here is based on analogous work carried out by the Southwest Florida Water Management District (SWFWMD) as part of its minimum flows and levels program. A review of several SWFWMD MFL reports indicates that this value, i.e. 15%, was originally used as a means to interpret the results of PHABSIM analysis for the Upper Peace River MFL (Gore et al. 2002; SWFWMD 2002). When developing MFLs for the Middle Peace River, Alafia River and Myakka Rivers, the SWFWMD more broadly defined "significant harm" as either a 15% change in the area of available habitat (spatial change) or a 15% change in the number of days habitat is accessible to fish and other aquatic organisms (temporal change) (SWFWMD 2005a, 2005b, 2005c). Shaw et al. (2005), as part of their review of the Middle Peace River MFL, were supportive of the more broadly applied 15% threshold indicating "*the 15% threshold is reasonable and prudent, especially given the absence of clear guidance in statute or in the scientific literature on levels of change that would constitute significant harm.*" Cichra et al. (2005), in their review of the Alafia and Myakka MFLs, also supported the use of the 15% threshold in the Alafia and Myakka Rivers for similar reasons. However, even though many reviews have accepted the use of a 15% threshold, most have indicated that this value is, in large part, accepted *de facto* and its representation of the point at which significant harm actually occurs is presumptive. Moreover, many of these earlier reviews go on to encourage further investigation of this threshold value through monitoring, natural experiments and other analyses as part of an adaptive management process. We echo these previous review panels' comments that recognize the practicality of adopting a value such as 15% yet strongly encourage the SRWMD to investigate the applicability of this threshold for water bodies within the District.

Related to the assumption that a 15% loss in habitat constitutes a threshold for significant harm is whether or not this threshold value is applied to the appropriate flow regime factor affecting the habitat or WRV of interest. For example, it appears as if the threshold was only considered for out-of-bank flows as a reduction in the number of days that exceeded the critical flow values identified (one type of temporal change) and for in-channel flows by determining a 15% reduction in the weighted usable area as predicted by RHABSIM. As previously noted, an application of the 15% threshold as an indicator of significant harm was first applied to interpret results of the PHABSIM analysis (which was principally a threshold value based on spatial data), but later expanded and used to evaluate effects of the MFL in a temporal context. We suggest, as did Cichra et al. (2005) in their review of the Alafia River and Myakka River MFL, that "*… a 15% change in habitat availability based on a reduction in spatial extent of habitat (as was used in the PHABSIM analysis)* ***may not*** [emphasis added] *be equivalent to a 15% change in temporal availability of habitat, and it is recommended that this issue be more fully investigated in the future*". It is not evident to the panel that this was considered by the District in the preparation of this MFL report.

We note also that other factors related to time, such as contiguous periods of floodplain inundation (Casanova and Brock 2000; Epting 2007; Vepraskas et al 2004) or the return frequency of a critical duration or extreme flow event (Tharme 2003), may be important to consider. Some of these alternative metrics have been considered by other WMDs in developing MFLs and as part of the North Florida Regional Water Supply Partnership Interagency Agreement (http://northfloridawater.com/pdfs/NFRWSP_MOA.pdf). A comparison of the impact that reductions in critical flow can have on cumulative days of inundation (this MFL) vs. the return interval of a critical duration event (approach used by SJRWMD) indicates clearly why multiple habitat metrics of space and time may need to be evaluated as part of the MFL process. Table 1 (this report, below) compares allowable flow reductions based on a 15% decrease in cumulative days of inundation (taken from Tables 5-1 to 5-10 main report) vs. the impact of those same flow reductions on the recurrence interval of what the SJRWMD suggests are minimum contiguous inundation periods that maintain a particular WRV (taken from Table 1, Appendix 6, main report). These data show that the percent change between baseflow and the resulting metric flow or MFL can be quite different. In particular, the effect of the proposed MFL compared to the modeled baseline flow would result in a change (increase or decrease) in the return frequency of the critical event duration by between 14% and 45%. Therefore, although the proposed allowable reduction in flows is not expected to result in significant harm (as determined by a temporal change in cumulative days of inundation of no more than 15%), these same flows may exceed the 15% threshold when a different metric for temporal change is analyzed (change in return frequency of a critical duration event).

c) Procedures and Analyses

No procedures or analysis are presented in this chapter.

2. Recommendations (Task 2)

To address the points raised above, the following major modifications are recommended for this section. Additional editorial recommendations are included in Appendix A.

- To prevent significant harm MFLs should include considerations of duration and return interval of both low-flow and high-flow events in addition to cumulative frequency, which was considered in the report. The panel recommends a multi-metric approach that considers more comprehensive temporal and spatial hydrologic drivers of a WRV with the realization that all metrics are not equally protective.

- The panel recommends that the 15% threshold of change be more fully justified as it applies specifically to the Santa Fe and Ichetucknee Rivers.
- In the 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 becomes available.

Table 1. Comparison of allowable flow reductions based on a 15% decrease in the 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 allowable flow reductions.

			Values based on 15% decrease in # of days critical flow exceeded*		Values based on return interval of critical event duration **			
MFL Metric	Waterbody	Critical Flow (cfs)	Allowable flow reduction (%)	resulting metric flow (cfs)	Critical event duration, (days)	Return interval based on baseline flow (yrs)	Return interval based on MFL flow (yrs)	change in return interval***
Hydric Hardwood Hammock Community	Santa Fe	2693	5	2558	30	4.9	6.3	29% less frequent
Hardwood Cypress Community	Santa Fe	1940	6	1824	30	2.1	2.4	14 % less frequent
Cypress Swamp Community	Santa Fe	1840	6	1730	30	1.7	2.1	24 % less frequent
Exposed Roots	Santa Fe	1463	8	1346	30	1.4	1.6	14 % less frequent
Hardwood Swamp Community	Santa Fe	1390	8	1279	30	1.2	1.4	17 % less frequent
Fish Passage	Santa Fe	1110	8	1021	60	1.7	1.4	18% more frequent
Hydric Soils	Ichetucknee	407	3	395	30	2.9	4.2	45% less frequent
Exposed Roots	Ichetucknee	368	3	358	30	1.7	2.4	41% less frequent
Fish Passage	Ichetucknee	284	11	253	60	5.7	3.9	32% more frequent
Recreation (Tuber Passage)	Ichetucknee	282	12	250	90	7.1	5.2	27% more frequent

**Data from tables 5-1, 5-2, 5-4, 5-6 and 5-10.*

*** Values used or recommended by SJRWMD, data from table 1 appendix 6*

**** Change in return interval may be more or less frequent. A less frequent return interval results from a high flow critical duration (exceedance event) not occurring as often due to a reduction in flow. A more frequent return interval results from a low flow critical duration (non-exceedance event) not occurring as often due to a reduction in flow.*

IV. REVIEW OF HYDROLOGIC DATA ANALYSES AND MODELING

1. FINDINGS (TASK 1)

a) DATA AND INFORMATION

Comments and recommendations concerning the rainfall, streamflow and groundwater data used, the baseflow estimation procedures applied, and the trend analyses conducted are provided in Section II above. Many of these details that were presented in Chapter 2 of the MFL report are repeated in Chapter 4, with the same deficiencies. Consolidating the data analyses methods in Chapter 4, and providing the additional detail requested above in one location, will improve the conciseness and clarity of the document.

b) TECHNICAL ASSUMPTIONS

i) Assumption that impacts of groundwater pumping on the Ichetucknee and Lower Santa Fe River baseflows began in 1970 and increased linearly from 1970-2010. Locally Weighted Scatterplot Smoothing (LOWESS) for multi-year moving average data from the Lake City rain gage

(Figure 59 Appendix 2-1), the 2-year moving average of the average of the Lake City and Gainesville rainfall data (Figure 4-6 main report), Ichetucknee baseflow (Figure 4-6 main report) and Ft White baseflow (Figure 70 Appendix 2-1) all show a tendency to increase from 1930 until about 1960-1970 and to decrease thereafter. The 1960-1970 period corresponds to the transition of the Atlantic Decadal Oscillation (AMO) from a warm phase to a cool phase (see Figure 3 below). Enfield et al. (2001) and Kelly (2004) have previously established that warm AMO periods lead to increased rainfall and streamflow and cool AMO periods lead to decreased rainfall and streamflow, in South Florida, while the reverse is true in North Florida and much of the SE USA. Kelly (2004) showed that the Santa Fe Basin lies in a transition region where summer streamflow behavior tends to follow the South Florida pattern, while winter streamflow behavior tends to follow the North Florida pattern.

A major assumption made in the development of the baseline flow time series for the MFL analyses was that the timing of this climate transition between warm and cool AMO also corresponds to the time when anthropogenic activities (primarily groundwater pumping) began to have an effect on baseflows in the Ichetucknee and Lower Santa Fe Rivers. This assumption was based on the apparent similarity of the upward slopes of the rainfall and baseflow LOWESS curves in the pre-1970 period, and the apparent steeper downward slopes of the baseflow curves compared to the rainfall curve in the post-1970 period (Figure 4-6 main report and Figure 70 Appendix 2-1). Although it is asserted that there is a “stark” difference in the post-1970 rainfall and streamflow slopes (p4-10), no statistical tests of the significance of the differences in slopes were conducted, nor is it clear *a priori* why they should have the same slope given likely non-linearities present in the flow generation process.

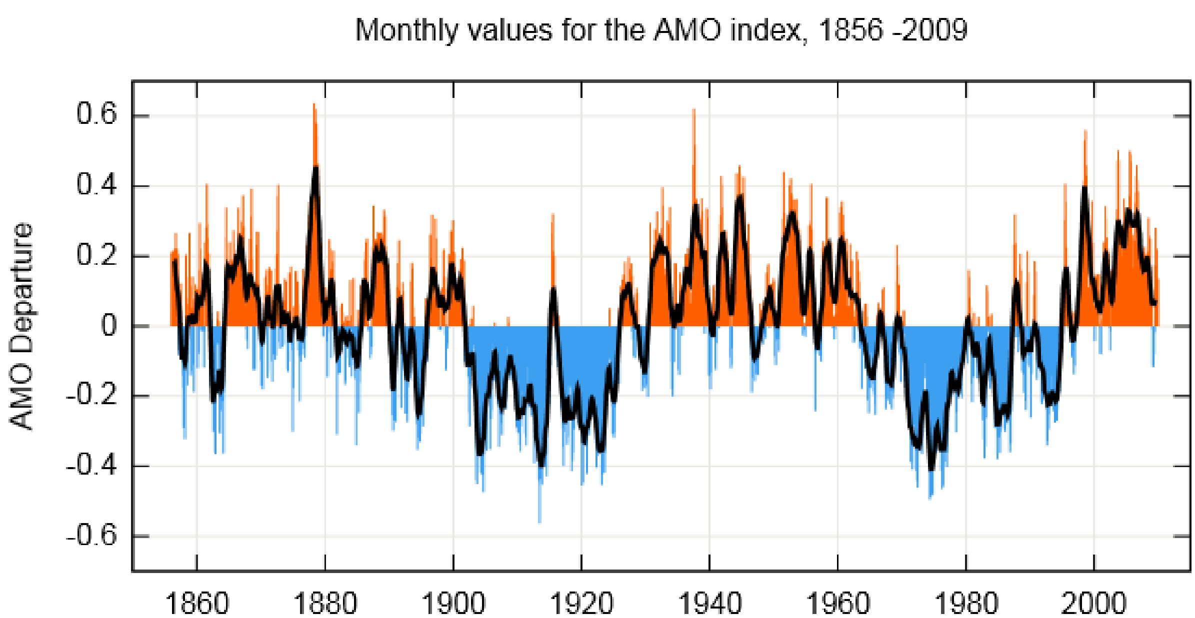

Figure 3. Monthly values for the unsmoothed Atlantic Multidecadal Oscillation (AMO) index. Bold black line represents 12-month moving average. (from http://www.cdc.noaa.gov/Correlation/amon.us.long.data)

Furthermore the best available pumping data presented for the Santa Fe River Basin Counties (Figure 2-20 main report), the Suwannee River Water Management District (Figure 2-19 main report) and the area encompassed by the North Florida Region Water Supply Partnership (Figure 2-22 main report) do not support the assumption that changes in baseflow response to rainfall due to changes in groundwater pumping should begin after 1970. The groundwater pumping data presented indicate an approximate linear increase in pumping from 1965 through 1990, and then approximately steady pumping from 1990-2010. *This pumping pattern would imply that effects to baseflow should have begun <u>before</u> 1970 and <u>stabilized</u> after 1990.* We note however that the accuracy of the estimated pumping data is uncertain. Improvement of groundwater use estimates, particularly for agriculture, is essential for effective water resource planning and management.

According to the data presented in Chapter 2 of the MFL report pumping increased in the counties comprising the Santa Fe Basin from approximately 50 MGD in 1970 to approximately 120 MGD in 1990, then remained roughly constant at about 120 MGD thereafter. Assuming a Santa Fe basin watershed area of approximately 3700 km^2 , this is equivalent to an increase from about 18.6 mm/year to about 44.4 mm/year over the Santa Fe Basin. Total excess rainfall (Precipitation - Evapotranspiration) available for runoff and/or recharge over the Santa Fe Basin is estimated to be approximately 300-500 mm/yr (Grubbs, 1998; Srivastava, 2013). While increasing pumping from approximately 4-6% of excess rainfall (in 1970) to approximately 10-15% excess rainfall (in 1990) could certainly lower groundwater levels and thus reduce baseflows, it is the panel's opinion that the magnitude of the increase is insufficient to put the basin into a net recharge deficit situation that would lead to a continuous regional decline in groundwater levels. *Given the high transmissivity of the Floridan Aquifer, and the fact that net recharge is still positive, pumping effects would be expected to reach a new dynamic equilibrium in the region fairly quickly (<< decade) after pumping stabilized in 1990.*

ii) Assumption that baseflow should respond linearly to precipitation. As a result of the observation that the slopes of the rainfall and baseflow LOWESS curves were apparently similar before 1970 but different after 1970, it was postulated that the relationship between rainfall and baseflow changed at that time due to groundwater pumping. It was further assumed that the relationship between precipitation and baseflow was linear in the 1930-1970 period, and that the errors in using the pre-1970 model to predict post-1970 baseflow could be attributed to the effects of groundwater pumping.

The assumption of a linear response of baseflow to rainfall, regardless of season or antecedent conditions, is not well-supported in the literature or by data from the Santa Fe basin. Most empirical models relating rainfall to streamflow include a non-linear component to represent the effects of antecedent moisture conditions or basin storage capacity (see e.g. Jakeman and Hornberger, 1993; Long, 2009; Ebtehaj et al., 2010). Furthermore many empirical models include a periodic structure to represent seasonal and/or interannual patterns (see e.g. Bras and Rodriguez-Iturbe, 1985; Tankersley and Graham, 1993; Srinivas and Srinivasan, 2001, 2005). Figure 4 shows the average monthly rainfall (measured), average monthly actual evapotranspiration (estimated for the Santa Fe Basin by Srivastava (2013) using the Community Land Model, http://www.cesm.ucar.edu/models/clm/) and the average monthly difference between rainfall and actual evapotranspiration from 2000-2008 for the Santa Fe River Basin. These data show that during December through March, and during June through September, rainfall exceeds actual evapotranspiration. Thus during these periods there is excess rainfall available to produce streamflow either directly by runoff in the upper basin or indirectly through recharge to groundwater and subsequent baseflow in the lower basin. However during April, May, October and November actual evapotranspiration equals or exceeds rainfall, i.e. the basin dries down and rainfall generally does not produce runoff or recharge. Similarly, rainfall occurring after an extended dry period (e.g. 1953-1957 or 1999-2003) does not have the same potential to produce streamflow (via either runoff or baseflow) as rainfall occurring after an extended wet period (e.g. 1964-1968). In other words, recharge potential (and thus baseflow potential) is driven not just by accumulated rainfall, but also by accumulated ET. *The panel thus recommends that the assumption of a linear, seasonally invariant response of baseflow to rainfall in the Santa Fe basin be revisited.*

c) PROCEDURES AND ANALYSES

i) Baseline Model development. Because the baseline model developed in Chapter 4 of the MFL report does not incorporate the non-linear effects of antecedent moisture conditions, or any seasonal or interannual periodicity, the resulting residuals are large (-600 to +500 cfs; Figure 72 in Appendix 2 and Figure 5 below) with extremely high temporal autocorrelation (Figure 6 below). Moreover the baseline model systematically over-predicts low flows and under-predicts high flows (Figure 7 below). These residual behaviors are well accepted indicators of inadequacies in model structure: a well-fit model will generally have residuals that show no systematic bias, have low standard deviation compared to the original time series, and minimize temporal autocorrelation (i.e., approach white noise).

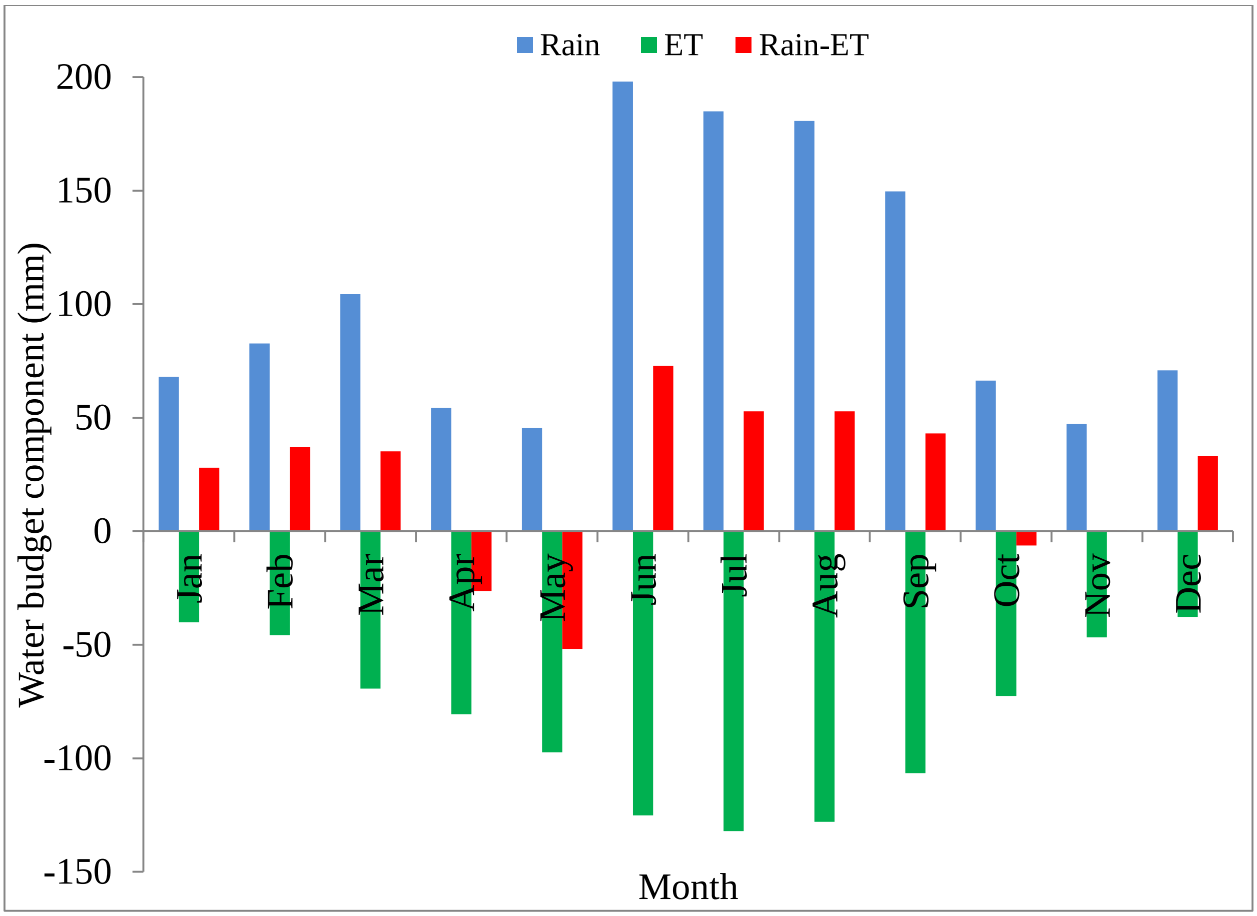

Figure 4: Average monthly rainfall, evapotranspiration, and rainfall- evapotranspiration for 2000-2008 in the Santa Fe Basin (Srivastava, 2013)

Figure 5 indicates that peak observed baseflows and large negative MLR baseflow residuals generally follow strong El Nino periods, and minimum baseflows and large positive residuals generally follow strong La Nina periods. This behavior is an indication that the 6-7 year periodicity shown in Figure 6 is a likely related to ENSO cycle effects. This figure also shows that MLR baseflow residuals appear to vary fairly regularly around zero from 1935-2000, then appear to increase abruptly beginning in 2001 and remain high for the duration of the study period. That is, they do not show a persistent linear increase beginning in 1970, but may show a step change occurring in about 2000. Enfield et al. (2001) showed that in North Florida, and throughout most of the SE USA, winter rainfall during El Nino events tends to be lower during warm AMO periods. Thus the transition of the AMO from cool to warm phase in approximately 1995 may contribute to the lower baseflows and higher residuals observed in the 1999-2010 period. Figure 8 shows the temporal autocorrelation structure of the various multidecadal (AMO), interannual (ENSO), and seasonal climate cycles that affect streamflow at station 2500 on the Santa Fe River and underscores the strong, complex, cyclical climate signals that affect streamflow in the Santa Fe Basin.

The tendency for the baseline model to over-predict low flows (Figure 7) is particularly significant because ~1999-2010 was a persistent dry period, exhibiting drier conditions than occurred at any time during the pre-1970 model calibration period (Figure 5). Furthermore this time period exerts high leverage on the estimated linear trend in the post-1970 MLR residuals which provides the basis for adjustment of the historic baseflow time series for the effects of groundwater pumping. Table 2 presents the linear regression parameters and statistics for the MLR residual time series over various time periods. Shaded rows in the table indicate time periods over which the slopes of the residuals are not significantly different than zero. While the p-values and confidence intervals must be interpreted with caution given the non-white noise structure of the residual time series, conventional test statistics indicate that if the series is broken up into 1935-1970, 1970-2000, and 2000-2010 time periods, none of these periods have residuals with a statistically significant slope (although the 2000-2010 residuals appear to have a significantly different mean value). Furthermore the R^2 value for the linear fit of the post-1970 residuals (figure 73, Appendix 2-1) is only 0.153, indicating that a linear relationship does not explain much of the variation. *All of these factors indicate that it would be prudent to investigate alternative, non-linear baseline model structures and alternative assumptions about the onset and structure of anthropogenic impact.*

Table 2: Linear Regression Parameters and Statistics for Baseline Model Residual Time Series.

Time Period	Best Fit Linear Slope	p-value	-95% CI	+95% CI	R^2
1935-1969	0.0029 cfs/day	0.1352	-0.0010	0.0076	0.004
1970-2010	0.0157 cfs/day	<<0.0001	0.0124	0.0190	0.153
1970-2000	-0.0013 cfs/day	0.5660	-0.0058	0.0032	0.0009
2001-2010	0.0015 cfs/day	0.8836	-0.0193	0.0224	0.0002
1935-2010	0.0103 cfs/day	<<0.0001	0.0090	0.0117	0.204

ii) The block bootstrapping procedure. A non-parametric bootstrapping procedure was used to examine uncertainty of the linear baseline model fit in the pre-1970 period and the uncertainty of the linear slope of the residuals in the post-1970 period. This procedure was required because traditional parametric methods typically assume normally distributed, independent (i.e. uncorrelated) residuals (p. 86

Appendix 2-1) and thus could not be used for hypothesis testing or uncertainty analysis. A fixed block of 7 months was used based on guidelines for estimating confidence intervals for estimating the mean, variance and cdf of a "weakly correlated" time series (Hall et al, 1995; Hardle, 2001). Block size is typically selected to balance the need for independence among the sampled blocks and the need to have enough different blocks to randomly select from the original time series. Thus longer blocks are required for more strongly correlated time series (Vogel and Shallcross, 1996; Srinivas and Srinivasan, 2005; Ebtehaj et al, 2010). The MLR baseflow residuals are correlated over approximately 2 years for the pre-1970 data, and over 7 years for the post-1970 data and the complete 1935-2010 time series (Figure 6). *In the panel's opinion the assumption of weak autocorrelation over a 7 month period is poorly supported and it is likely that a longer block size would produce more reliable results.*

The bootstrapping procedure was used to generate an ensemble of models that were fit to 500 resampled pre-1970 baseflow data sets. These 500 models were then used to predict post-1970 baseflow, and model prediction residuals were assumed to represent the degradation of the model fit due to the influence of factors other than rainfall. A linear trend was fit to each of the 500 post-1970 model residual time series to produce an ensemble of end-of -record flow adjustments that were approximately normally distributed. To account for uncertainties in the linear trend fit to the post-1970 model residuals, a bootstrapping procedure was again conducted using the model that produced the 10th percentile end-of - record residual. In this case the bootstrapping procedure again used 7 month blocks to generate an ensemble of 500 model residual time series for the 10th percentile pre-1970 model and a linear trend was fit to each of these 500 residual time series. Finally, the 10th percentile end-of-record flow adjustment from the post-1970 model prediction uncertainty analysis of the 10th percentile pre-1970 model fit was selected to adjust the post-1970 baseflow time series to produce the baseline model. It was stated that the "10th percentile of the 10th percentile" result was assumed to represent a lower bound for the estimate of changes due to non-rainfall influences. *It is unclear why 10th percentile estimates from normal distributions are a better choice than median estimates. In the panel's opinion further justification of this approach to estimating the end-of period flow adjustment should be provided.*

iii) HEC-RAS modeling procedures. The HEC-RAS model (U.S. Army Corps of Engineers, 2010) was used to develop relationships between flow, velocity, stage and wetted perimeter in the Ichetucknee and Lower Santa Fe Rivers. The HEC-RAS model is a well-accepted tool for this purpose, and it appears that good HEC-RAS modeling practices and the best available data were used to develop the model. A transient model was developed for the 2002- 2011 time period and Manning's roughness coefficients and flow roughness factors were manually calibrated to observed stage and discharge data. A series of steady-state models, using the calibrated model coefficients, were then run for input flow regimes ranging from the 2nd percentile condition to the 98th percentile condition, and downstream stage boundary conditions at the Suwannee River ranging from 20th percentile condition to 80th percentile condition, for MFL development. The HEC-RAS modeling procedures are well-described in Appendix 4-1. However, the summary in the main MFL report is somewhat difficult to follow. The main MFL report should be revised to more clearly present the overall purpose of the HEC-RAS modeling; exactly how the steady-state HEC-runs were used to determine the critical flow for each water resource value and why; and to more clearly justify the choice of the 20th percentile downstream flow boundary condition for use in the MFL development.

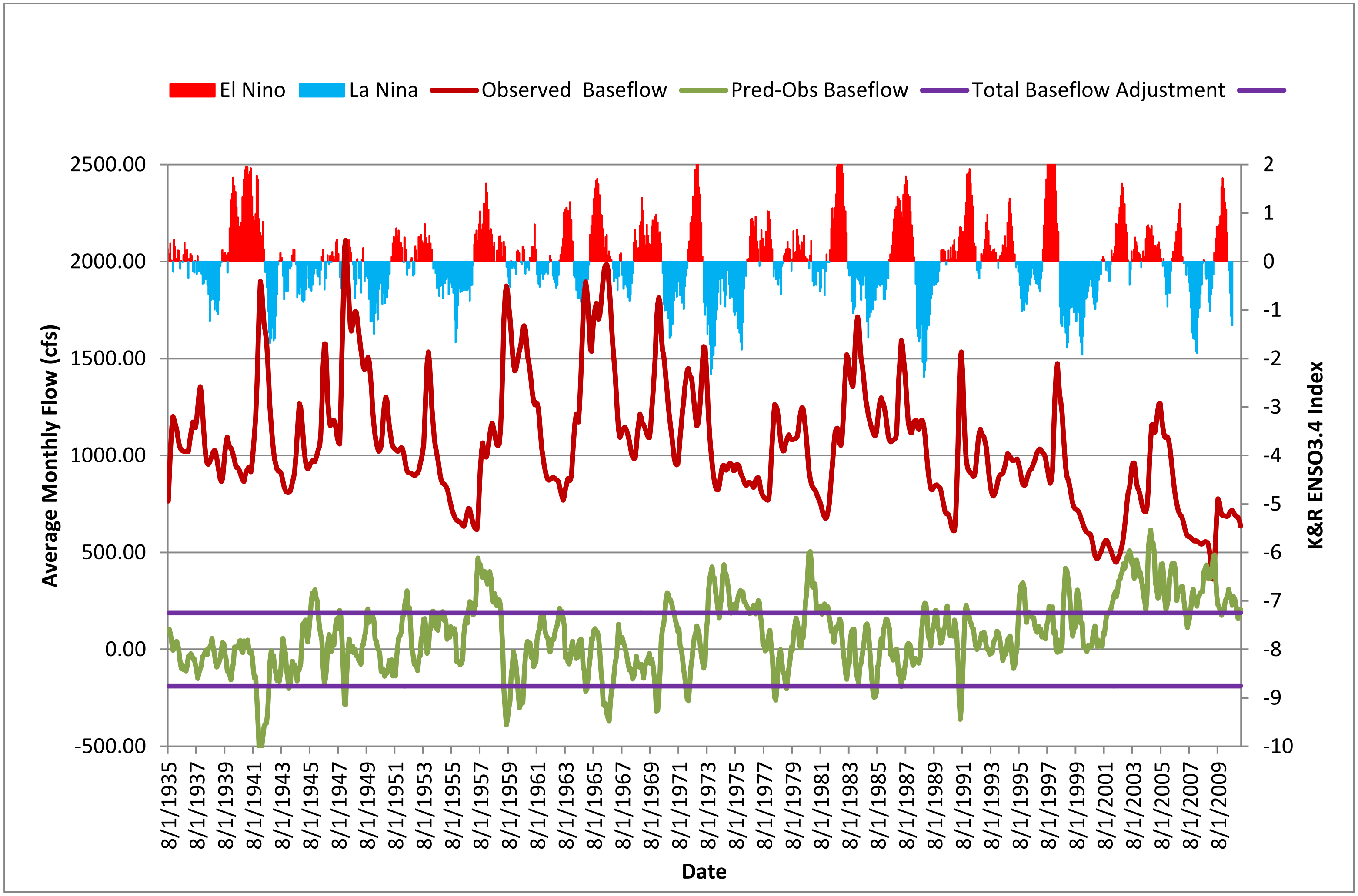

Figure 5: Time series of average monthly baseflow and MLR residuals (predicted – observed baseflow) for the Ft White station. Also shown are the +/- the 189 cfs total baseflow adjustment at the end of 2010 and the Kaplan and Reynolds ENSO3.4 index. The standard deviation of the residuals for the pre-1970 period (160 cfs) and for the post –1970 period (175 cfs) are large (~50-60%) compared to the standard deviation of observed baseflow (317cfs) and compared to the 189 cfs baseflow reduction assumed for 2010.

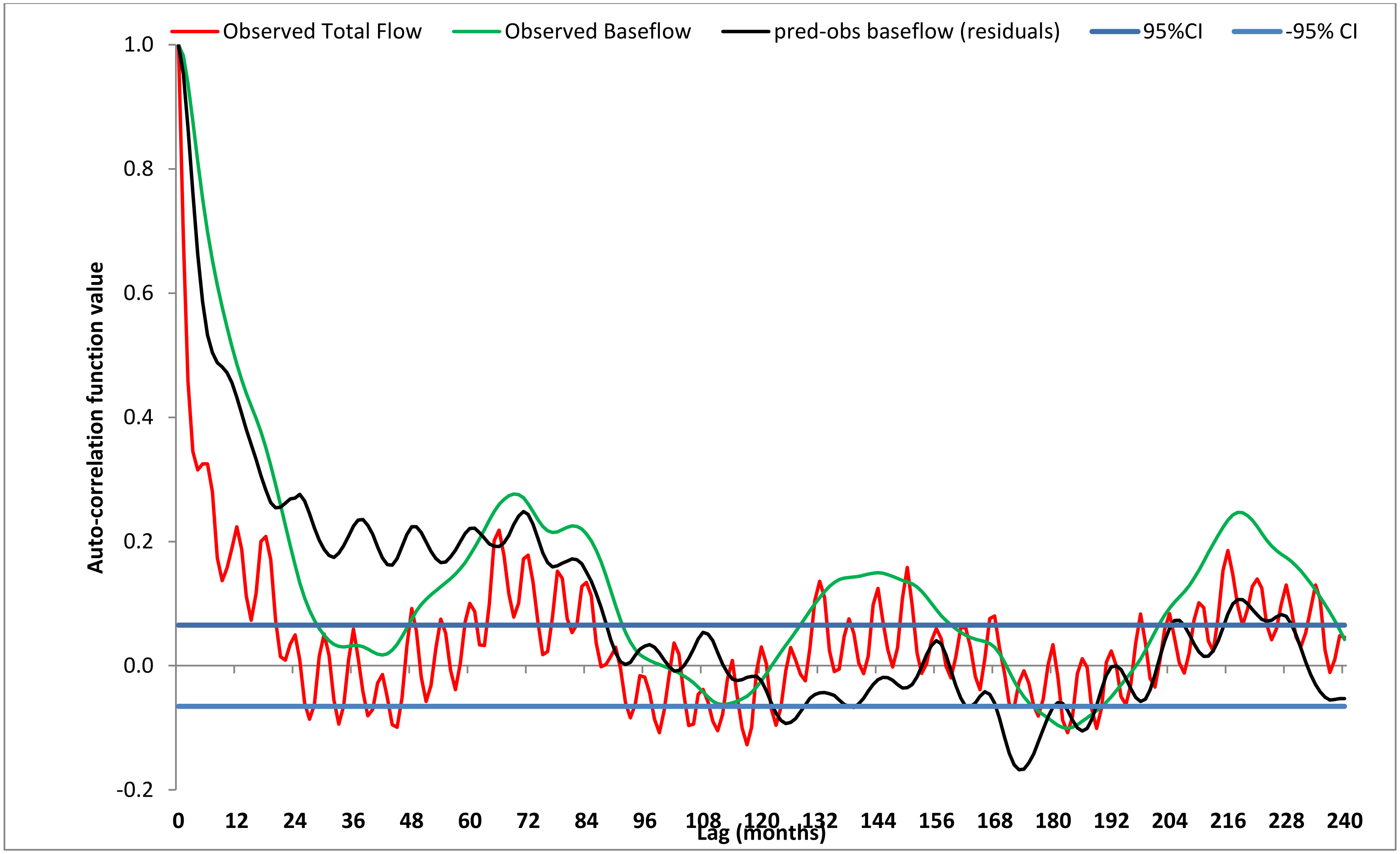

Figure 6: Autocorrelation for the total streamflow (red line, showing strong autocorrelation over approximately 24 months as well as seasonal and interannual (~6-7 year) periodicity); baseflow (green line, showing strong autocorrelation for approximately 30 months and strong interannual (~6-7 year) periodicity, and MLR residuals (black line showing strong temporal autocorrelation for approximately 7 years) for the Ft. White Station. Note that the MLR model residuals accentuate the autocorrelation in the flow signal instead of creating white-noise residuals. Blue lines show approximate 95% confidence intervals for accepting the hypotheses that the time series are uncorrelated white noise.

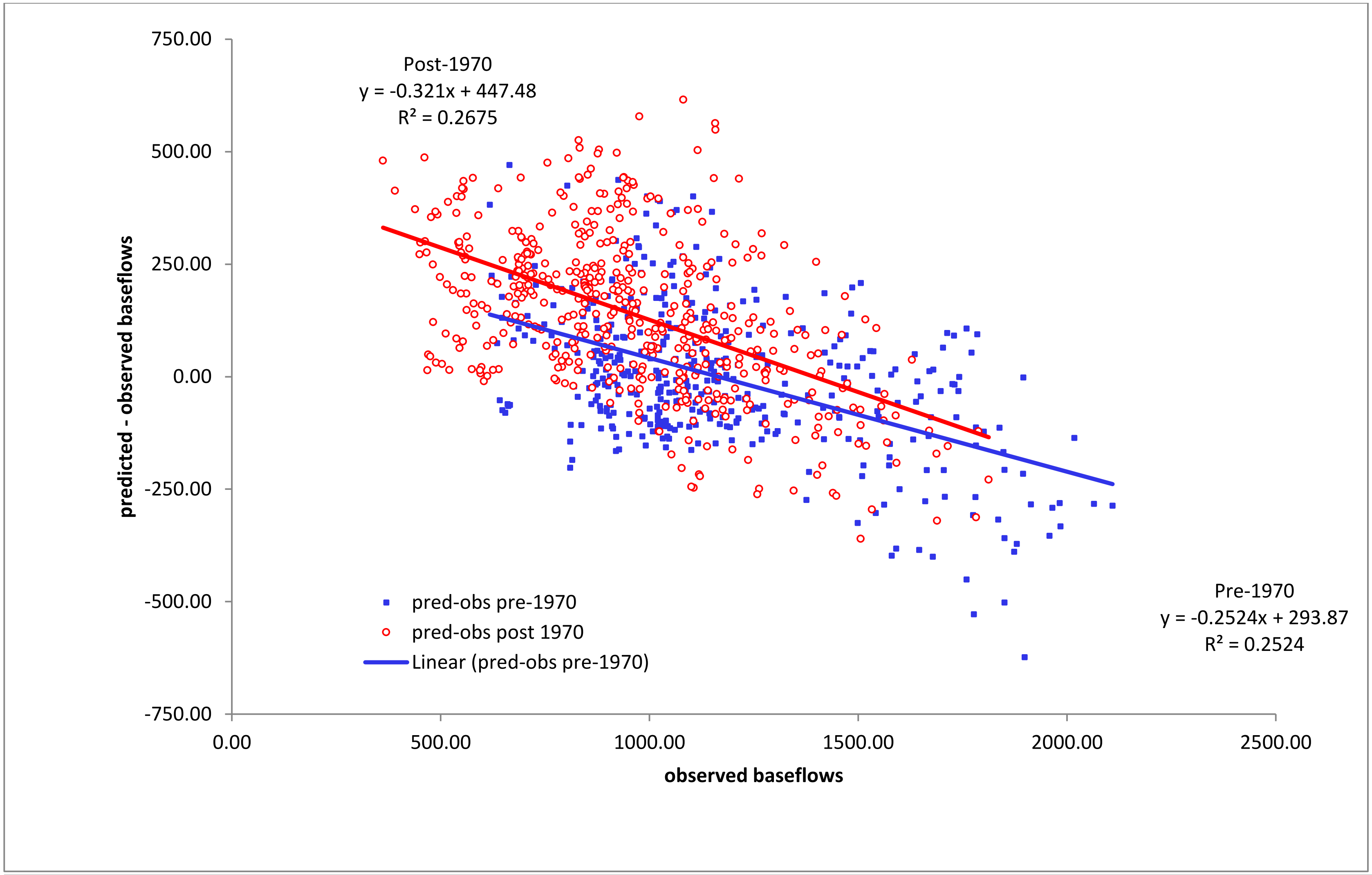

Figure 7: Magnitude of MLR residuals as a function of baseflow. Low flows are systematically over predicted and high flows are systematically under predicted for both the pre and post-1970 periods

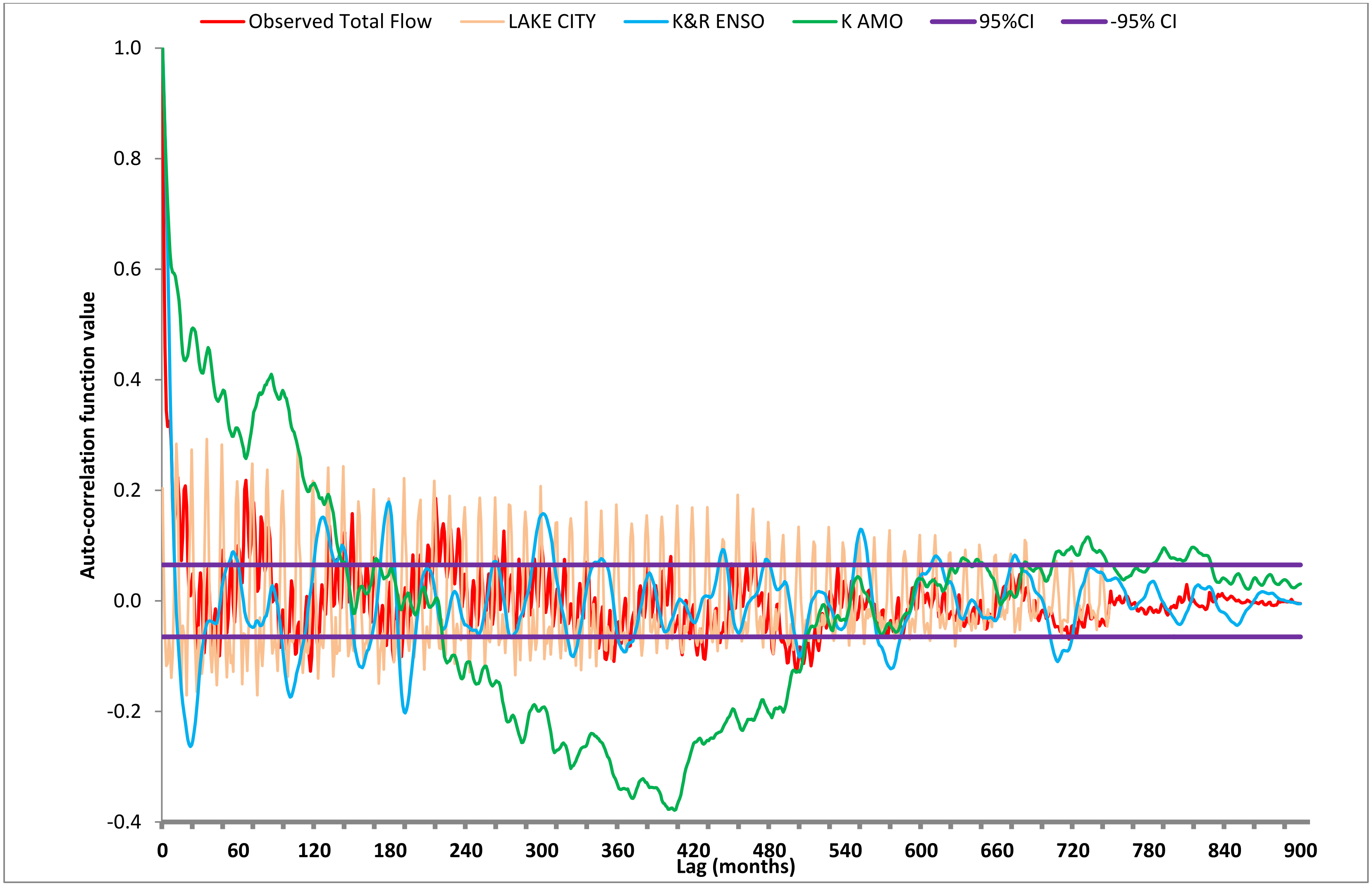

Figure 8: Autocorrelation for the total streamflow for the Ft. White Station, rainfall for the Lake City gage, the Kaplan and Reynolds ENSO3.4 Index and the Kaplan v2 AMO index. Approximate 95% confidence intervals for accepting the hypotheses that the time series are uncorrelated white noise are shown in purple.

2. RECOMMENDATIONS (TASK 2)

To address the points raised above the following major modifications are recommended for this section. Additional editorial recommendations are included in Appendix A.

- Explore alternative non-linear and/or seasonal models to better account for antecedent moisture conditions in the baseflow model predictions. Examples of possible alternative modeling approaches that could be explored include:
    - Use a linear model with parameters that depend on season , hydrologic condition, or climate state (e.g. Srinivas and Srinivasan (2001, 2005), Stagge and Moglen (2013))
    - Use monthly P-ET instead of P as driver for a linear model to account for the seasonality of effective rainfall. ET could be calculated using Blaney-Criddle which just requires day of year (for % daytime hours) and temperature.
    - Include a non-linear component in the model to account for evapotranspiration losses prior to fitting a linear effective rainfall-baseflow model (e.g. Jakeman and Hornberger (1993), Long (2009), Ebtehaj et al. (2010)).
    - Use a non-linear regression technique (e.g. locally weighted polynomial regression) to develop model coefficients that depend on the value of the predictors (i.e. lagged and current rainfall and/or other climate indices) using a nearest neighbor approach based on closely matching rain/flow conditions and/or similar season/climate cycle (e.g. Moon et al. (2008), Lall et al (2006), Grantz et al., (2005)).
- After an improved model (with lower residual variance and less correlated residuals) is developed, use a block bootstrapping procedure (if necessary based on serial correlation in the model residuals) to estimate model uncertainty using a variety of block lengths (longer than the new model residual correlation time) to evaluate effect of block size on uncertainty estimates.
- After uncertainty analysis of the improved model using well-justified block sizes is conducted, revisit the assumption that the 10^{th} percentile of the 10^{th} percentile prediction of the end-of-record flow target is appropriate.
- Explore alternative assumptions regarding the timing of anthropogenic influences. For example models could be fit for three different periods:
    - 1935-1950 - a time with presumably minimal pumping (e.g. use of center pivot irrigation increased in the 1950s http://www.livinghistoryfarm.org/farminginthe50s/water_02.html),
    - 1950-1990 - a time during which pumping may have increased approximately linearly
    - 1990-2010 - a time of large, but temporally stable pumping

  A comparison of parameter values and residual behavior across these time periods could provide insight regarding the timing of anthropogenic impacts on baseflow. For example, use of the model fit from 1990-2010 on pre-1990 data might be expected to over predict streamflow such that residuals increase systematically backward in time from 1990 through 1950, then stabilized around a large value in the pre-1950 period.
- Use a physically-based groundwater model to evaluate whether groundwater contributions to streamflow predicted by the empirical baseline model are consisted with the physically-based model, in order to increase the weight of evidence supporting the selected baseline flow regime. Presuming only steady-state runs are currently possible, a suite of steady-state scenarios could be run with all possible combinations of warm-AMO/cold-AMO phase climate, El Nino/La Nina phase climate, and no pumping/post-1990 pumping. Groundwater flow contributions to streamflow under each regime

could be evaluated to determine the relative magnitude of changes in groundwater contributions to streamflow expected due to changes in climate versus changes in pumping.

- Add an introductory paragraph to Section 4.2 explaining the overall purpose of the HEC-RAS modeling and the various ways the model was used.
- Add a table which summarizes how the HECRAS steady-state models were used for each water resource value.
- Clarify whether the input flow and downstream boundary condition percentiles used to run HEC-RAS were taken from the full historic record or the 2002-2011 transient model time period.
- More clearly justify the use of the 20th percentile downstream stage boundary condition when HEC-RAS was used to determine the critical flows for the various water resource values.

V. DEVELOPMENT OF MINIMUM FLOWS FOR THE LOWER SANTA FE AND ICHETUCKNEE RIVERS AND PRIORITY SPRINGS

1. FINDINGS (TASK 1)

a) DATA AND INFORMATION

Chapter 5 of the report provides additional detailed discussion of relevant WRVs introduced in Chapter 3 and also information as it relates to data sources used in the establishment of the MFLs. General comments and concerns as they relate to the Conceptual Model and Approach are provided by the panel in Section III of this report. Specific comments are provided below:

i) With regard to the watershed-wide vegetation and soils information used (§5.1.1 Floodplain Vegetation and Soils; p 5-1), the panel notes that study area vegetation and land use information were obtained from ARC-GIS shape files. It is not clear, however, how this information was used in the development of the MFLs. Moreover, the latest available data set (2006-2008) was collected during a period of low rainfall and may not be representative of the longer-term floodplain vegetation community or soils conditions (see below).

ii) Also in §5.1.1, it is not clear that there were any objective criteria employed to establish the floodplain transects used to assess relationships between water levels and flood plain vegetation and soils elevations. As a consequence, it is difficult to determine if the data are representative of the systems being investigated. In addition, the panel notes that the transect data were collected over a relatively short time interval in 2012, in a low rainfall period.

iii) In §5.1.1 (p 5-2), it is indicated that "Hydrologic indicators of flooding were also surveyed", but it is not clear what these "indicators" were.

iv) With regard to §5.1.2.1. Water Quality, the panel notes that only water quality data collected between 1991 and 2002 were analyzed for site ICH001C1. Additional data collected by SRWMD since 2002 exist (e.g., analyzed in Heffernan et al 2010a) that might allow for a more complete evaluation of the relationship between flow and water quality related parameters in this river.

v) With regard to §5.1.2.2 In stream Habitat, Fish Passage, the panel could find no justification for the following: "The flow resulting in a water depth of no less than 0.8 feet over 25% of the river channel at each transect was determined to be the Critical Flow for fish passage". The Critical Flow determination, in this instance, appears to be adopted from earlier work in another system without justification.

vi) In §5.1.2.2, Habitat Suitability, literature values of species' habitat condition preferences were used in the RHABSIM model (see p 5-6). An inspection of Appendix 5 (HSI Curves) suggests, however, that data were only available for the following fishes: largemouth bass, bluegill and spotted sunfish. Again, it appears to the panel that the RHABSIM analysis has been adopted from previous work and applied here without full consideration of the biological or ecological characteristics specific to the Lower Santa Fe and Ichetucknee rivers. Are these species representative of the fish assemblage in these systems and can their preferences be generalized?

vii) P 5-10, Fish, the report suggests that "Habitat suitability modeling with RHABSIM was used to specify conditions most advantageous to important fish species including largemouth bass and Suwannee bass…". The panel could not find any evidence that this was done for Suwannee bass.

viii) In development of the MFL metric for many of the Out-of-Bank and Bankfull flows assessments, the critical flow was determined by averaging the flows estimated to occur at the target station to inundate the mean elevation of the community or condition being assessed at each of the transects along the Ichetucknee River or Santa Fe Rivers. Understanding the variability in estimated critical flows among transects would be desirable yet this data could not be located.

b) TECHNICAL ASSUMPTIONS

i) In this Chapter of the report it is generally assumed that models and input data are transferable among systems without adequate justification. For example, the Critical Flow for fish passage, and generic input data for RHABSIM as indicated above.

ii) Throughout §5.2, it is assumed that the cumulative number of days over an 80 year period in which a critical flow is exceeded captures the full effects of the actual flow regime on the WRVs of interest. Limitations associated with this assumption should be acknowledged prominently and explicitly in the report.

iii) In §5.2.2.1 Water Quality, the statement that "the water quality within the Ichetucknee River is likely to be relatively consistent and not vary significantly with changing flows unless the underlying groundwater quality varies" is a poor assumption and fails to consider in-stream processes that are likely flow related (see, e.g., Heffernan et al. 2010a).

iv) Flow and water quality relationships for both the Ichetucknee and Santa Fe rivers were not considered to be of adequate strength to use them in the development of the MFLs. The panel suggest based on recent data (see Heffernan et al 2010a) that there are, in fact, significant relationships between nutrient concentrations (nitrate in particular), though we generally agree that those relationships are not necessarily useful for MFL development in these systems.

c) PROCEDURES AND ANALYSES

The panel supports the use of HEC-RAS and Recent and Long-term Positional Hydrograph (RALPH) analyses and plots for visualizing and interpreting the annual inundation characteristics of each of the WRV assessments relative to the critical Q values determined.

2. RECOMMENDATIONS (TASK 2)

- Water quality is a WRV of substantial importance in the development of MFLs. Apparent visual trends in some water quality parameters in relation to flow are evident in Appendix 5-3, and recent research findings on the spring-fed rivers in question (Heffernan et al 2010a), suggest there are relationships between flow and commonly measured water quality parameters (e.g. dissolved oxygen, iron, nitrate). Therefore, the panel recommends that a further assessment of possible changes in water quality in relation to flow be evaluated to ensure that the proposed MFL will not cause a violation of any relevant water quality standard.

- The panel recommends that further justification and clarification of the criteria used to determine in-stream habitat and fish passage criteria be provided.
- With regard to RALPH plots, the panel suggests providing two scales on the y-axis for these plots; one showing the cumulative number of days during the period of record that the critical Q flow was exceeded (present axis), the other showing the number of days critical Q would be exceeded in an average year (present axis divided by the number of years in the period of record).

VI. REVIEW OF FINAL MFL, ASSESSMENT OF CURRENT BASIN STATUS AND RECOMMENDATIONS

This chapter of the report restates the hydrogeologic setting of the two rivers being considered, the conceptual workflow for MFL development, and the development of baseline flow conditions. The data, technical assumptions, and procedures/analysis for this process are considered elsewhere, and are not restated here. This chapter focuses on determination of the proposed MFL for the Ichetucknee and Santa Fe Rivers, and a determination for MFLs for the priority springs that feed both rivers. It concludes by evaluating the current basin status in comparison with the proposed MFLs.

1. FINDINGS (TASK 1)

a) DATA AND INFORMATION

No new data is presented in this chapter.

b) TECHNICAL ASSUMPTIONS

The review committee identified three technical assumptions that need to be better justified in the report, or amended.

i) The assumption that the MFL flow reduction should be constant over the entire range of flows. It is not clear to the panel why the allowable MFL reduction cannot be discharge specific. We surmise from the report (pg 6-8) that the main reason is the intended use of steady-state groundwater models (perhaps using average climate conditions) to evaluate compliance with the MFL. The limitations of this assumption should be discussed, with particular attention to the fact that the most significant impact of groundwater withdrawals will likely occur during drought conditions when flow is low, demand is high and the constant flow reduction of 137 cfs for the Santa Fe River represents the highest percentage of baseflow. While steady-state models do not make flow predictions under transient conditions, and thus are unable to address discharge-varying MFL targets, it is possible to simulate multiple scenarios for steady-state groundwater conditions, reflecting various climate (and thus baseflow) regimes.

ii) The averaging of the flow reductions required for individual Water Resource Values (WRVs) to determine a constant permissible flow reduction over the flow duration curve. The WRVs were evaluated independently for the impacts of reduced flows; a threshold of 15% reduction in critical flow frequency was adopted uniformly. It is critical to recognize that acceptable flow reductions vary across the WRVs. Some WRVs (e.g., protection of the hydrologic conditions in hydric hardwood hammocks along the Santa Fe, woody habitat protection along the Ichetucknee) will be significantly impacted with small flow reductions, while harm to other WRVs (e.g., spotted sunfish habitat in the Santa Fe, fish passage in the Ichetucknee) occurs with larger reductions. The approach adopted was to identify a constant flow reduction across all discharge conditions and WRVs that would minimize the deviation between the fitted MFL and the critical WRV metric flows. *This necessarily weakens protection for the most vulnerable WRVs by essentially averaging the flow reductions allowed with those WRVs that are not as vulnerable.* The MFL is intended to protect all relevant WRVs, and up to 15% reduction is presumed *a priori* to cause no significant harm. However, the proposed MFL will, in both cases (Santa Fe and Ichetucknee), allow flow reductions that cause significant harm (i.e., greater than a 15% reduction) to some WRVs. *Based on the analysis presented an MFL that protects ALL WRVs would allow a reduction of 89 cfs from baseline flow on the Santa Fe River (driven by fish passage) and a reduction of 10 cfs from baseline flow on the Ichetucknee (driven by woody habitat flow requirements).*

The committee surmised that the rationale for this approach was that the uncertainty associated with any one of the critical flows is large, and poorly constrained. However, this uncertainty is quantifiable, and impacts to the MFL of adopting an approach that protects all WRVs can be ascertained. We suggest that the rationale for this technical assumption be better justified, or the approach revised.

iii) The protection of priority springs (for which insufficient flow data exist to develop an independent MFL) will be accomplished by adopting a "uniform percent" flow reduction standard. The permissible percent flow reduction was determined to be the percent flow reduction allowed by the "constant flow" standard in the receiving water body (i.e., the Santa Fe and Ichetucknee Rivers) at median discharge in that water body. For example, 137 cfs (the constant flow MFL for the Santa Fe River) is 10.7% of median flow in the Santa Fe River, thus 10.7% flow reduction is allowed for all the springs that feed the Santa Fe River. The panel was sensitive to the data gaps that may have motivated this approach, but were concerned that this assumption was not adequately explored. The choice to base the percentage reduction allowed on the median flow, and in particular the median total flow, rather than the median baseflow (to which spring flows are presumably more closely related), should be justified. To illustrate this discrepancy, we note that 137 cfs is 10.7% of median total flow, but 13.4% of median baseflow. The flow reductions that are allowed under the percentage flow MFL are never compared to the flow reductions permitted under the main river MFL. As such, it is not clear whether the sum of the allowable 10.7% flow reduction on the Santa Fe River priority springs is larger or smaller than the flow reductions allowed for the river at low flows (when springs are the dominant source). Absent formal evaluation of this scenario, it seems possible that adopting the proposed MFLs may lead to conditions where the river is in violation, but the springs that are the source to the river are not (or vice versa).

We note that, while the Santa Fe and Ichetucknee rivers are protected by a MFL based on constant deviation from baseline flow over their entire flow regime, the priority springs are apparently protected by a constant "percentage flow" MFL that would apply throughout their flow regime, leading to smaller permissible flow reductions at lower flow. This inconsistency should be rectified or clarified. *The panel believes that further exploration of the impact of this uniform percent flow reduction MFL assumption is warranted.*

c) Procedures and Analyses

The procedures and analyses to determine the MFL were evaluated. The committee identified several areas where revisions or clarifications were needed.

i) The procedure used to determine the current status of the water body in relation to the MFL. To determine the current regulatory status of the Lower Santa Fe and Ichetucknee Rivers, an MFL flow regime was produced by subtracting the allowed MFL flow reduction from the predicted baseline flow over the entire period of record. Next the annual means of the observed and MFL flow regimes were computed, and the difference between the observed and the MFL annual mean values at the end of the period of record values were computed. If the difference at the end of record was positive (as for the Ichetucknee) it was assumed that the waterbody was meeting the MFL and had additional water available. If the difference at the end of record was negative (as for the lower Santa Fe) it was assumed that the water body had a flow deficit and was in violation of the MFL. *This methodology puts more confidence than is warranted in the predictions of the baseline model given its shortcomings discussed above*.

Using FDCs to determine current status is also untenable because changes in the FDCs can be detected only over time scales too long to be of regulatory relevance. Figure 9 shows FDCs for the observed 1935-2010 time series, the baseline 1935-2010 time series, the MFL 1935-2010 time series , the 1933-1970 observed time series and the1970- 2010 observed times series. This figure indicates that FDCs for the complete observed data series and the pre-1970 observed data series meet the MFL, but that the FDC post-1970 violates the MFL at flows above approximately 1250 cfs. We note also that all FDCs meet the MFL at median flow, which is presumably the condition simulated by existing steady state groundwater models. The fact that post-1970 data meet the MFL at low and median flows but not high flows is counter-intuitive to the expectation that the most critical periods for the rivers will be during drought periods when antecedent recharge is low and demand for groundwater is high. *The methodology for determining the current status of the water body with regard to the MFL warrants additional consideration.*

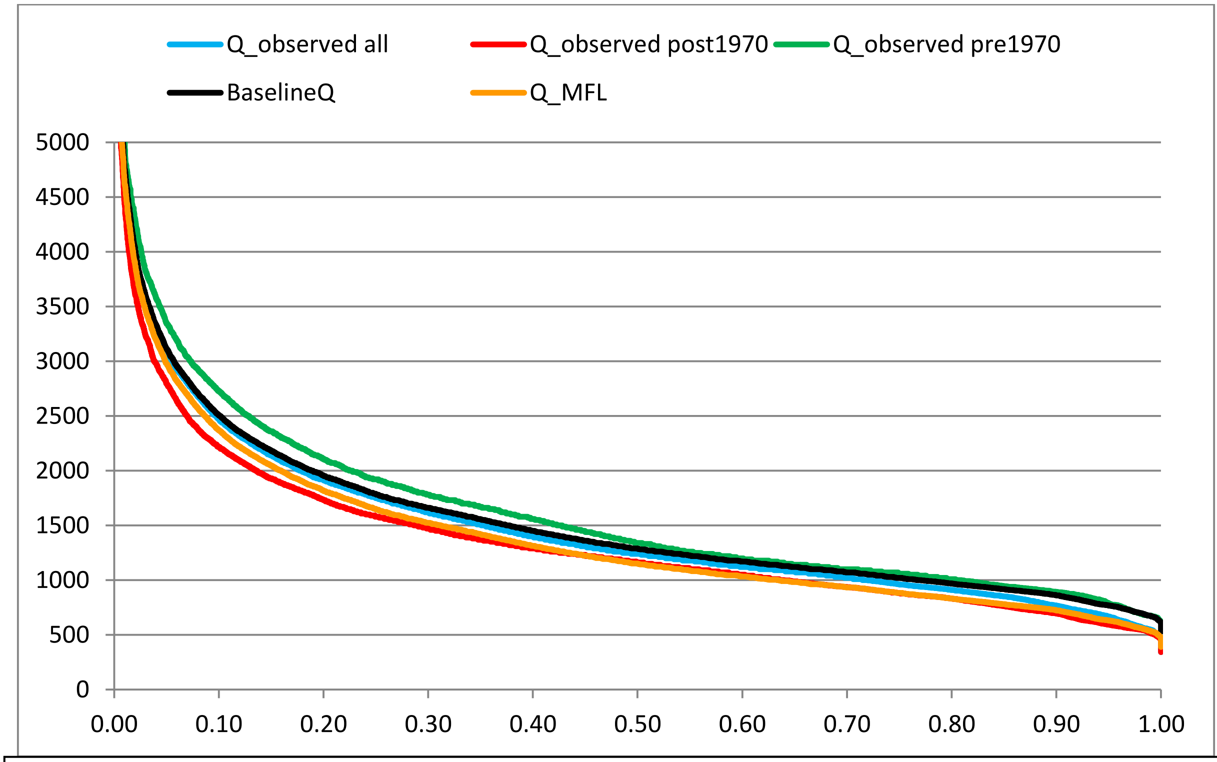

Figure 9: Flow Duration Curves for the Ft. White station complete data series, pre-1970 data, post-1970 data, baseline flow, and MFL flows. FDCs for the complete data series and the pre-1970 data series meet the MFL. FDC for the post-1970 data series violates the MFL at flows above ~ 1250 cfs.

ii) Predicting future departures of flows from the baseline. The panel is curious whether the District expects the modeled departure of observed flows from baseline flows (Fig. 6-9 and 6-10) to continue, and what the implications are if it doesn't. In other words, it appears that the designation of prevention and recovery depends on the slope of the long term MLR regression, which is clearly strongly influenced by flows in the period 2000-2009 in both rivers (Fig. 4-12 and 4-13). Extrapolating that slope into the future implies continued worsening of baseflow conditions. While this may be the case, the model residuals during the period 1970-1999 suggest that there is also a potential to enter a period during which the model residuals are smaller (or even negative). As recent rainfall (since June 2012) begins to influence the MLR model, the slope of the model residuals with time may change without any change in pumping regime. If this happens, it's not clear how, or whether, the designation of prevention or recovery will change.

2. RECOMMENDATIONS (TASK 2)

- The panel expects that the most critical periods for the rivers will be during drought periods when antecedent recharge is low and demand for groundwater is high. Modeling consumptive use impacts during these periods seems integral to the implementation process. The panel recommends that a suite of steady-state models be run with a range of climate, boundary and pumping conditions to explore the impacts of various climate and pumping regimes on baseflow. This suite of models would be particularly important for the priority springs, where a fractional decline in flow is the MFL approach, rather than a constant flow reduction, as adopted for the two rivers.
- The panel strongly recommends that the MFL be adopted to protect the most vulnerable water resource values (WRVs), and not the "average" WRVs as is currently the case.
- The panel believes that the current methodology for determining the status of the water body with regard to the MFL, based on the departure of the observed end of record flow from the predicted baseline flow (for the Lower Santa Fe), or the linear future projection of the departure of observed flow from the predicted baseline flow (for Ichetucknee), puts more confidence than is warranted in the predictions of the baseline model. The panel recommends that alternative methodologies be explored to determine the current status of these rivers in order to increase the weight of evidence supporting the classification of their status.

REFERENCES:

Adams, P.N., Opdyke, N.D., Jaeger, J.M., 2010. Isostatic uplift driven by karstification and sea-level oscillation: Modeling landscape evolution in north Florida. Geology, 38: 531-534.

Bras, R. L. and I. Rodriguez-Iturbe, Random Functions and Hydrology, 1985. Addison-Wesley Publishing Company, Reading MA.

Casanova, M.T. and M.A. Brock. 2000. How do depth, duration and frequency of flooding influence the establishment of wetland plant communities. Plant Ecology, 147:237-250.

Cichra, C. E., C.N. Dahm, and D.T. Shaw. 2005. A Review of "Alafia River Minimum Flows and Levels Freshwater Segment including Lithia and Buckhorn Springs", and "Proposed Minimum Flows and Levels for the Upper Segment of the Myakka River, From Myakka City to SR 72". 33pp.

Ebtehaj,M.,Moradkhani, H. and H. Gupta, 2010. Improving robustness of hydrologic parameter estimation by the use of moving block bootstrap resampling, Water Resources Research, Vol. 46, W07515, doi:10.1029/2009WR007981.

Enfield, D.B., A.M. Mestas-Nunez, and P.J. Trimble, 2001. The Atlantic Multidecadal Oscillation and its relationship to rainfall and river flows in the continental U.S., Geophys. Res. Lett., 28: 2077-2080.

Epting, R.J. 2007. An Assessment of the Hydrologic Signatures of Hydric soil and Wetland Community Indicators from a Network of Natural Plant Communities in Northeastern Florida. Special Publication SJ2007-SP14. St. Johns River Water Management District, Palatka FL. pp 130.

Florea, L.J., Vacher, H.L., 2007. Eogenetic karst hydrology: Insights from the 2004 hurricanes, peninsular Florida. Ground Water, 45: 439-446

Gilbert, C. R. 1992. Rare and endangered biota of Florida, volume II. Fishes. University Press of Florida, Gainesville.

Gore, J.A., C. Dahm and C. Klimas. 2002. A review of "Upper Peace River: and analysis of minimum flows and levels". Prepared for the Southwest Florida Water Management District. Brooksville, FL. 30pp.

Grantz, K. , Rajagopalan, B., Clark, M. and E. Zagona, 2005. A technique for incorporating large-scale climate information in basin-scale ensemble streamflow forecasts Water Resources Research, Vol. 41, W10410, doi:10.1029/2004WR003467.

Grubbs, J. W., 1998. Recharge rates to the Upper Floridan Aquifer in the Suwannee River Water Management District, U. S. Geological Survey, Water-Resources Investigations Report 97-4283.

Hall, P., J. Horowitz, and B. Jing, 1995. On blocking rules for the bootstrap with dependent data, Biometrika, 82:561-574.

Hardle, W., Horowitz, J., and J. Kreiss, 2001. Bootstrap Methods For Time Series**,** Institute for Mathematical Stochastics Technical University of Braunschweig , Braunschweig, Germany, August 2001. (Accessed at http://edoc.hu-berlin.de/series/sfb-373-papers/2001-59/PDF/59.pdf on August 28, 2013).

Heffernan, J.B., M.J. Cohen, T.K. Frazer, R.G. Thomas, T.J. Rayfield, J. Gulley, J.B. Martin, J.J. Delfino and W.D. Graham. 2010a. Nitrogen dynamics in a spring-fed Florida river. Limnology and Oceanography. 55(1):249-263.

Heffernan, J.B., D.M. Liebowitz, T.K. Frazer, J.M. Evans and M.J. Cohen. 2010b. Algal blooms and the nitrogen-enrichment hypothesis in Florida springs: evidence, alternatives, and adaptive management. Ecological Applications 20(3):816-829.

Jakeman, A.J. and G. M. Hornberger, 1993. How much complexity is warranted in a rainfall-runoff model?, Water Resources Research, Vol. 29, NO. 8, p. 2637-2649.

Kelly, M., 2004. Florida river flow patterns and the Atlantic Multidecadal Oscillation, Ecologic Evaluation Section Report, Southwest Florida Water Management District.

King, S.A. 2012. Effects of flow on filamentous algae and nutrient limitation in lotic systems. PhD Dissertation, University of Florida, Gainesville. 162 p.

Kurz, , R.C., D.C. Woithe, S.K. Notestein, T.K. Frazer, J.A. Hale and S.R. Keller. 2004. Mapping and monitoring submerged aquatic vegetation in Ichetucknee Springs – 2004. Final Report, Suwannee River Water Management District, Live Oak, FL.

Lall, U., Moon, Y., Kwon, H. and K. Bosworth, 2006. Locally weighted polynomial regression: Parameter choice and application to forecasts of the Great Salt Lake, Water Resources Research, Vol. 42, W05422, doi:10.1029/2004WR003782.

Lawrence, F.W., Upchurch, S.B., 1982. Identification of recharge areas using geochemical factor analysis. Ground Water, 20: 680-687.

Long, A., 2009. Hydrograph separation for karst watersheds using a two-domain rainfall–discharge model, Journal of Hydrology 364:249–256.

Martin, J.B., Dean, R.W., 1999. Temperature as a natural tracer of short residence times for ground water in karst aquifers. In: Palmer, A.N., Palmer, M.V., Sasowsky, I.D. (Eds.), Karst Modeling. Karst Waters Institute Special Publication #5, pp. 236-242.

Martin, J.B., Dean, R.W., 2001. Exchange of water between conduits and matrix in the Floridan Aquifer. Chemical Geology, 179: 145-165.

Milly, P. C. D., Betancourt, J., Falkenmark,M, Hirsch, R., Kundzewicz,Z, Lettenmaier,D., and R. Stouffer, 2008. Stationarity is dead: Whither water management?, Science, Vol 319, 573-573.

Moon, Y., Lall, U. and H. Kwon, 2008. Non-parametric short-term forecasts of the Great Salt Lake using atmospheric indices, International Journal Of Climatology, 28: 361–370.

Moore, P. J., Martin, J. B. & Screaton, E. J., 2009. Geochemical and statistical evidence of recharge, mixing, and controls on spring discharge in an eogenetic karst aquifer, Journal of Hydrology, 376, 443–455.

Opdyke, N.D., Spangler, D.P., Smith, D.L., Jones, D.S., Lindquist, R.C., 1984. Origin of the epeirogenic uplift of Pliocene-Pleistocene beach ridges in Florida and development of the Florida karst. Geology, 12: 226-228.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K. L. Prestegard, B.D. Richter, R.E. Sparks, J. C. Stromberg. 1997. The Natural Flow Regime. Bioscience 47:769-784 .
Richter B.D., J. V. Baumgartner, J. Powell, D. P, Braun. 1996. A method for assessing hydrological alterations within ecosystems. Conservation Biology, 10:1163-1174.

Richter, B.D., J.V. Baumgartner, R. Wigington, D.P. Braun. 1997. How much water does a river need? Freshwater Biology 37:231-249.

Schramm, H. L. and M. J. Maceina. 1986. Distribution and diet of Suwannee ba
ss and largemouth bass in the lower Santa Fe River, Florida. Environmental Biology of Fishes 15(3):221–228.

Scott, T.M., 1988. The lithostratigraphy of the Hawthorn Group (Miocene of Florida), No. 59. Florida Geological Survey Bulletin, 147 pp.

Scott, T.M., 1992. A Geological Overview of Florida, Open File Report No. 50. Florida Geological Survey, 78 pp.

Shaw, D.T., C.N. Dahm, and S. W. Golladay. 2005. A Review of "Proposed Minimum Flows and Levels for the Middle Segment of the Peace River, from Zolfo Springs to Arcadia." Report prepared for Southwest Florida Water Management District, June 2005, 23pp.

Srinivas, V., and K. Srinivasan, 2005. Matched block bootstrap for resampling multiseason hydrologic time series, Hydrologic Processes, 19:3659-3682.

Srinivas, V.,and K. Srinivasan, 2001. Post-blackening approach for modeling periodic streamflows, Journal of Hydrology 241: 221-269.

Srivastava, V, 2013. Vegetative and climatic controls on coupled hydrologic processes in a complex river basin: Lessons learned from a fully integrated hydrologic model, Ph. D. dissertation, University of Florida.

Stagge, J. H. and G. E. Moglen, 2013. A nonparametric stochastic method for generating daily climate-adjusted streamflows, Water Resources Research, 'Accepted Article', doi: 10.1002/wrcr.20448.

SWFWMD (Southwest Florida Water Management District). 2002. Upper Peace River: An analysis of minimum flows and levels. Ecological Evaluation Section. Southwest Florida Water Management District, Resource Conservation and Development department. Brooksville, FL

SWFWMD (Southwest Florida Water Management District). 2005a. Proposed minimum flows and levels for the middle segment of the Peace River, from Zolfo Springs to Arcadia. Ecologic Evaluation Section. Resource Conservation and Development Department. Brooksville, FL.

SWFWMD (Southwest Florida Water Management District). 2005b. Alafia River Minimum Flows and Levels Freshwater Segment including Lithia and Buckhorn Springs. Ecologic Evaluation Section, Resource conservation and Development Department. Brooksville, FL.

SWFWMD (Southwest Florida Water Management District). 2005c. Proposed Minimum Flows and Levels for the Upper Segment of the Myakka River, from Myakka City to SR72. Ecologic Evaluation Section, Resource conservation and Development Department. Brooksville, FL.

Tankersley, C.D., W.D. Graham, and K. Hatfield, 1993. Comparison of Univariate and Transfer Function Models of Groundwater Fluctuations, Water Resources Research, 29(10), 3517-3533.
Tharme, R.E. 2003. A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River Research Applications 19:397-441

Vepraskas, M. J., X. He, D. L. Lindbo and R. W. Skaggs, 2004. Calibrating hydric soil field indicators to long-term wetland hydrology. Soil Sci. Soc. Am J. 68(4):1461-1469

Vogel, R.M., and A. L. Shallcross, A.L., 1996. The moving blocks bootstrap versus parametric time series models, Water Resources Research 32(6),1875-1882.

APPENDIX A: ERRATA AND EDITORIAL COMMENTS

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s): A. Reviewer's Specific Comments	To be completed by Reviewer(s): B. Reviewer's Specific Recommended Corrective Action	To be completed by report author(s): C. Action to be Taken in Response to Comment
Ch. 2					
1	p. 2-1, § 2.1.1.	no	The Hawthorn Group is made of sedimentary rocks, not sediments	Modify terminology	
2	p. 2-1 § 2.1.1.1	No	Outcrops is not a verb,	Modify terminology to "crops out"	
3	p. 2-1 § 2.1.1.2	No	The Statenville Formation occurs near the northern border of the basin, rather than northeastern according to figure 2-1.	Modify text	
4	p. 2-4 § 2.1.2	No	White, 1970 not in reference list	include	
5	Table 2-2 and 2-3	No	The lists of Station IDs are not in comparable order making it difficult to compare;	Reorder lists; Check station ID for 23218982. Does it start with a zero	

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)		To be completed by report author(s)
			A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action	C. Action to be Taken in Response to Comment
6	P. 2-23	No	Include alpha symbol		
7	Tables 2-5;2-8; 2-9;	No	Correct headers		
8	P 2-30	No	NFRWSP not included in acronym list	include	
9	Figures 2-33; 2-34, 2-35	Yes	Figures are cited but missing from the document	include	
10	Through out		Figures are numbered incorrectly (chapter designated as 0)		
Ch. 3					
1	p. 3-1, § 3.0 Para 3	No	…which, in turn, affect	Insert commas before and after "in turn"	
2	p. 3-2 § 3.1.2	No	No discussion of structural habitat, SAV in	Expand discussion to include	

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)		To be completed by report author(s)
			A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action	C. Action to be Taken in Response to Comment
			particular		
3	p. 3-2 § 3.1.4	No	…river channel "is" an important…	Replace "is" with "can be"	
4	p. 3-3 § 3.1.6	No	Filamentous algae are considered a nuisance and aesthetically undesirable	the potential for flow/algal relationships should be discussed in this section (e.g. King 2012)	
5	p. 3-3 § 3.1.7	No	"phosphate fixation"	Consider alternative wording…e.g., "provides a substrate for P-sorption"; also provide a supportive reference	
6	p. 3-3 § 3.1.7	No	"nitrogen fixation"	Provide a supportive reference specific to these systems	
7	p. 3-4 Figure 3-1	No	Figure is labeled as 0-1	Should be Figure 3-1	
8	p. 3-5 Para 2	No	Period is missing at end of paragraph	include	
9	p. 3-5 Para 2,	No	Searcy (1959), Vogel and Fennessey (1995),	include	

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)		To be completed by report author(s)
			A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action	C. Action to be Taken in Response to Comment
	4, and 5		Jacobs and Ripo (2002, and FGS (2005) are not in reference list		
10	p. 3-5 Para 4 Line 3	No	"they" refers to FDCs	Replace "they" with FDCs	
11	p. 3-5 Para 6	No	Metrics listed are not consisted with those given on p 3-4 in bulleted form above § 3.2	Modify text for consistency	
12	p. 3-6	No	Figure is labeled as 0-2	Should be Figure 3-2	
13	p. 3-6 § 3.3 Line 1	No	"an MFL"	Rplace with "a MFL"	
14	p. 3-6 § 3.3 Line 4	No	Extraneous "in"	omit	
15	p. 3-6 § 3.3 Line 6	No	SWFWMD 2005 not in reference list	include	
16	p. 3-7 Para 2 Line 2	No	JEA 2012 not in reference list	include	

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)		To be completed by report author(s)
			A. Reviewer's Specific Comments	**B. Reviewer's Specific Recommended Corrective Action**	**C. Action to be Taken in Response to Comment**
17	p. 3-7 Para 2 Line 4	No	Period after Cichra et al., (2005)	Remove and change "In" to "in"	
18	p. 3-7	No	Shaw et al. 2005 not in reference list	include	
19	p. 3-7	No	JEA 2005 not in reference list	include	
Ch. 4					
1	4-12	Y	Add a bullet to specifically state that the baseline flows were taken to be identical to observed flows for pre-1970 and observed flows minus linear factor*time after post 1970. i.e. SLR/MLR predictions were not used directly. This is not clear from the report or appendix.		
2	4-12	N	Need a sub-heading before uncertainty analysis is introduced. The summary of uncertainty analysis methodology and results on 4-12 needs to be improved. The last		

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)		To be completed by report author(s)
			A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action	C. Action to be Taken in Response to Comment
			parapgraph on p. 4-12 is not understandable without a full reading of the appendix.		
3	4-12	Y	Need further explanation/justification of use of 10^{th} percentile of 10^{th} percentile flow reductions.		
4	4-12	N	Why do baseline flow time series begin at different times for the Santa Fe and Ichetucknee rivers? Similarly why does the post-1970 adjustment begin at different times?		
5	Section 4-2 p4-16	N	Include an introductory paragraph summarizing the purpose of the HECRAS modeling. See main report for detailed recommendations		
6	4-19	N	Last two paragraphs of this page are repetitive. Revise and consolidate. Define "short-term" and "long-tem" periods.		

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)		To be completed by report author(s)
			A. Reviewer's Specific Comments	**B. Reviewer's Specific Recommended Corrective Action**	**C. Action to be Taken in Response to Comment**
7	Figure 4-13	N	Fig 4-13… why doesn't 2002-2011 flow reach 100%?		
8	P4-23	N	I assume calibration was done manually? If so please state. How were relative deviations of flows and stages handled in the calibration?		
9	P4-28	N	Briefly describe what a pilot channel is (how it works) here.		
10	Section 4..2.4	N	Add introductory text to explain what steady-state simulations were used for. Be clear that 2% adjustments were made over the 2002-2011 record.		
11	4-28	Y	Exactly which results show how far up the tailwater effect is propagated? Point reader to the figure (and characteristics of the figure) that shows this. Justify use of 20th percentile downstream condition here.		

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s) A. Reviewer's Specific Comments	To be completed by Reviewer(s) B. Reviewer's Specific Recommended Corrective Action	To be completed by report author(s) C. Action to be Taken in Response to Comment
12	4-30	N	Figure 4-18 and 4-19 need more descriptive captions and discussion in the text. They are difficult to interpret without going to the Appendix.		
Ch. 5					
1	p. 5-1 § 5.1.1	No	Citation (FWC,2009), not found in § 8.0	Provide reference	
2	p.5-2 § 5.1.2.1	No	"…1989 through the current year…"is relative to the time the document is read.	Provide the actual year range for the period of record.	
3	p. 5-5 § 5.1.2.2	No	What is the source of the value "…0.8 feet over 25% of the river channel"	Provide reference for this threshold value.	
4	p. 5-6 § 5.1.2.2	No	What citation can be provided for the RHABSIM ecological model?	Provide reference for this model	
5	p. 5-7 § 5.1.2.2	No	Inference is made to HSIs being obtained from SWFWMD or SWFWMD contractor, yet no	Reference to an appendix or table that include these indices long with	

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)		To be completed by report author(s)
			A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action	C. Action to be Taken in Response to Comment
			specific indices are provided.	justification for application to the SFR and IR would be useful.	
6	p. 5-10 § 5.1.2.2	No	Reference is made to "… it is critical to maintain an inundation frequency that allows for…". Hydrologic regime critical to fish includes more than just the frequency of flooding. Depth, duration and frequency are also critical components to protect habitat.	Modify text accordingly	
7	p.5-16 § 5.2.11	No	Reference made to "Section 1.1". There is no Section 1.1 of relevance?	Change reference or create a Section 1.1	
8	p. 5-17 § Figure 5-9	No	Figure redundant with Figure 5-2	Change figure reference to 5-2 and delete figure 5-9	
9	p. 5-18 § Figure 5-10	No	figure redundant with Figure 5-1	Change figure reference to 5-1 and delete figure 5-10	

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)		To be completed by report author(s)
			A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action	C. Action to be Taken in Response to Comment
10	P 5-22 Figure 5-15	No	y-axis represents total days over period of record. normalizing days typical days exceeding critical Q in one year would be useful and allow for comparison between graphs of different periods of record.	Add an axis to the graph with a data normalized to days per year exceeding critical Q.	
11	p. 5-26 § 5.2.1.2	No	Wetland communities were not thought to be influenced by river flooding on the Ichtucknee River and instead developed as a result of groundwater, yet hydric soils were assessed for IR flows? Isn't it likely that if flooding is sufficient to develop hydric soils that wetland communities would also be influenced? Or conversely, if wetland communities were not directly influenced by inundation and instead influenced principally by groundwater then why doesn't it make sense that the hydric soils are also developing in response to groundwater and not to river flooding?	Resolve discrepancy. This can presumably be done by comparing mean elevations of wetland communities and hydric soils. This should also take into account the bankfull discharges which begins at 328 for the IR and are presumably the point at which hydric soils <u>and</u> a wetland community is beginning to be inundated suggesting that at least some of the wetland communities on the IR are indeed influenced by direct river inundation.	
12	p.5-35 §	No	"X" should be lower case in "(NOX)"	Change to (NOx)	

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)		To be completed by report author(s)
			A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action	C. Action to be Taken in Response to Comment
	5.2.2.1				
13	p. 5-62 § 5.2.2.5	No	A section of the paragraph in the middle of the page reads that the Critical Flow for snags was met …" I believe the word "snags" should read recreation	Check and change accordingly.	
14	p. 5-63 Figure 5-67	No	Caption reads "RALPH plot for snags in the …" I believe this word "snags" should read recreation.	Check and change accordingly.	
15	p. 5-70 § 5.2.2.7	No	End of first line on page reads ".. and a stream flow of 351 cfs)."	Need to close parenthesis	
16	p. 5-73 § Oval Pigtoe	No	Extra line in second paragraph	Delete line	
17	p. 5-73 § FL Manatee	No	Species name (*Trichechus manatus latirostris*) should be italicized throughout section.	Correct accordingly	

Comment No.	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)		To be completed by report author(s)
			A. Reviewer's Specific Comments	**B. Reviewer's Specific Recommended Corrective Action**	**C. Action to be Taken in Response to Comment**

NOTE: Insert additional lines as needed.

APPENDIX B: BIOGRAPHICAL SKETCHES

Mark W. Clark
Soil and Water Science Department, University of Florida, Gainesville, FL 32611
Phone: (352) 394-3115; Fax (352) 392-3399; Email: clarkmw@ufl.edu

Professional Preparation:

BS	University of Massachusetts (N. Dartmouth)	Marine Biology	1986
MS	University of Florida, Env. Engineering Sciences	Wetlands Ecology	1999
PhD	University of Florida, Soil and Water Science	Wetland Biogeochemistry	2000

Appointments:

2010-present	Associate Professor, Soil and Water Science Department, Univ. of Florida
2002-present	Extension Specialist of Wetlands and Water Quality, Univ. of Florida
2004-2010	Assistant Professor, Soil and Water Science Department, Univ. of Florida
2001-2004	Research Assistant Professor, Soil and Water Science Department, Univ. of Florida

Five Most Relevant Products:

Schmidt, C.A. and M.W. Clark 2012. Evaluation of a denitrificatoin Wall to Reduce Surface Water Nitrogen Loads. J. Env. Qual. 41(3):724-731

Schmidt, C.A. and M.W. Clark. 2012. Efficacy of a denitrification wall to treat continuously high nitrate loads. Ecological Engineering 42: 203– 211.

Watts, D.L., M.J. Cohen, J.B. Heffernan, T. Osborne, and M.W. Clark. 2010. Hydrologic modification and the loss of self-organized patterning in the Everglades ridge-slough mosaic. *Ecosystems* 13(6):813-827

Locke, A., B. Johnson and M. Clark 2010. A Review of *"Proposed Minimum Flows and Levels for the Upper and Middle Withlacoochee River"* Southwest Florida Water Management District. Brooksville, FL. pp. 33

Reddy, K. R. and M. W. Clark, 2008. "*Methods for Evaluating Wetland conditions: #18 Biogeochemical Indicators*", United States Environmental Protection Agency, Office of Water. pp. 44

Five Other Recent Products:

Schmidt, C.A., M.W. Clark. 2013. Deciphering and modeling the physicochemical drivers of denitrification rates in carbon-based bioreactors. Ecological Engineering, 60:276-288

Clark, M.W., C.S. Schmidt, and T. Yeager 2012. Reducing Nonpoint Source Loss of Nitrate within the Santa Fe Basin: Efficacy of Container Nursery BMPs and Denitrification Wall, Final Report, Florida Department of Environmental Protection contract #G0217. pp 160

Clark, M.W., W. Graham, K. McKee and J. Ullman 2012. Tri-County Agricultural Area Water Quality Data Review and Information-Sharing Program. Final report, Florida Department of Agricultural and Community Services**.** pp 54

E.J.Dunne, M.W.Clark, J. Mitchell, J.W. Jawitz, K.R.Reddy 2010. Soil Phosphorus flux from emergent marsh wetlands and surrounding grazed pasture uplands. Ecological Engineering. 36(10):1392-1400.

A. Mukherjee, V.D. Nair, M.W. Clark, and K.R. Reddy. 2009 Development of Indices to Predict Phosphorus Release from Wetland Soils. J Environ Qual 38(3): 878-886

Synergistic Activities (up to 5):

- Member of Numeric Nutrient Criteria Technical Advisory Committee to Florida Department of Environmental Protection 2004-2011.
- Member of Technical Support Team to evaluate Water Management Partnership projects in Tri-County Agricultural Area 2011-present.
- As an Extension Specialist I am actively involved around the state in disseminating pertinent research and policy information related to wetlands and water quality to County Extension Agents and stakeholders. In the past year I have been involved in 13 workshops, 32 presentations, 4 continuing education programs and 5 In-Service Training events.
- Undergraduate, graduate and post-doctoral training are integral and core to my research activity. I have served on 73 graduate student committees, chaired 6 Ph.D., 15 MS and 7 MS non-thesis students. I have also sponsored 2 post-doctoral fellows.

Collaborators & Other Affiliations:

- *Collaborators and co-editors in last five years*: Patrick Bohlen; University of Central Florida; Matthew Cohen, University of Florida; Michael Dukes, University of Florida; Edward Dunne; St. Johns River Water Management District; Tom Frazer, University of Florida; Donald Graetz, University of Florida;; James Heffernan, Duke University; James Jawitz, University of Florida; Jonathan Martin, University of Florida; Christopher Martinez, University of Florida; Vimala Nair, University of Florida; Todd Osborne, St. Johns River Water Management District; Ramesh Reddy, University of Florida; Casey Schmidt, Desert Research Institute; Leonard Shabman, Resources for the Future; Sanjay Shukla, University of Florida; Daniel Watts; Stanford University; Thomas Yeager, University of Florida

- *Graduate Students Advised in last 5 years*: *Current students* - Neal Beery, Eunice Eshun, Cynthia Gates, Hollie Hall, Charlie Nealis, Jason Seitz, Alexandra Rozin. *Graduates* – Jason Hood (Southwest Florida Water Management District); Sylvia Lang (University of Florida); Italo Lenta (University of Florida); John Linhoss (Mississippi State University); Stephen McCullers, (USACOE); Jason Neumann (University of Florida); Tae-Goo Oh (South Korea); Kevin Ratkus (Alachua County Environmental Protection Division); Joseph Sewards (Volusia County Extension Service); Casey Schmidt (Desert Research Institute)

Matthew J. Cohen, Associate Professor of Ecohydrology
School of Forest Resources and Conservation, University of Florida
PO Box 110410, Gainesville, FL 32611-0410
Phone: (352) 846-3490, Fax: (352) 846-1277 Email: MJC@UFL.EDU

Professional Preparation

B.S. (with Distinction) Environmental Engineering	1995 Swarthmore College, Swarthmore, PA
M.E. Environmental Engineering Sciences	1999 University of Florida, Gainesville, FL
Ph.D. Environmental Engineering Sciences	2003 University of Florida, Gainesville, FL
Post-Doctoral Fellow Soil and Water Science	2005 University of Florida, Gainesville, FL

Appointments

Associate Professor (Forest Resources & Conservation, UF)	*July 2011 – present*
Assistant Professor (Forest Resources & Conservation, UF)	*March 2006 – June 2011*
Assistant Research Scientist (Soil and Water Science, UF)	*January 2005 – March 2006*
Lecturer (Natural Resources and Environment, UF)	*January 2004 – March 2006*
Post-Doctoral Researcher (Soil and Water Science, UF)	*August 2003 – January 2005*
Graduate Teaching Associate (Env. Eng. Sciences, UF)	*June - August 2003*

Products (5 most relevant)

Cohen, M.J., M.J. Kurz*, J.B. Heffernan, J.B. Martin, R.L. Douglass*, C.R. Foster and R.G. Thomas. 2013. Diel Phosphorus Variation and the Stoichiometry of Ecosystem Metabolism in a Large Spring Fed River. Ecological Monographs 83:155–176. http://dx.doi.org/10.1890/12-1497.1

McLaughlin, D.L. †, D.R. Kaplan† and M.J. Cohen. 2013. Managing forests for increased regional water yield. Journal of the American Water Resources Association 49:953-965

Hensley, R.T. and M.J. Cohen. 2012. Controls on solute transport in large spring-fed karst rivers. Limnology and Oceanography 57:912-924

Heffernan, J.B. †, and M.J. Cohen. 2010. Direct and indirect coupling of primary production and diel nitrate dynamics in a sub-tropical spring fed river. Limnology and Oceanography 55:677-688

Heffernan, J.B. †, D.M. Liebowitz*, T.K. Frazer, J.M. Evans and M.J. Cohen. 2010. Algal blooms and the nitrogen-enrichment hypothesis in Florida springs: Evidence, alternatives and adaptive management. Ecological Applications 20:816-829

Products (5 other significant)

Heffernan, J.B., A.R. Albertin, M.L. Fork, B.G. Katz and M.J Cohen. 2012. Denitrification and inference of nitrogen sources in the karstic Floridan Aquifer. Biogeosciences 9:1671-1690

Heffernan, J.B.†, M.J. Cohen, T.K. Frazer, R.G. Thomas, T.J. Rayfield, J. Gulley, J.B. Martin, J.J. Delfino and W.D. Graham. 2010. Hydrologic and biotic influences on nitrate removal in a subtropical spring-fed river. Limnology and Oceanography 55:249-263

McLaughlin, D.L. and M.J. Cohen. 2011. Thermal Artifacts in Measurements of Fine Scale Water Level Variation. Water Resources Research 47: 3 PP., 2011 doi:10.1029/2010WR010288

Cohen, M.J., D.L. Watts, J.B. Heffernan and T.Z. Osborne. 2011. Reciprocal Biotic Control on Hydrology, Nutrient Gradients and Landform in the Greater Everglades. Critical Rev in Env Sci Tech 35:392-409

De Montety, V., J.B. Martin, M.J. Cohen, C. Foster and M.J. Kurz. 2011. Influence of diel biogeochemical cycles on carbonate equilibrium in a karst river. Chemical Geology 283:31-43

Synergistic Activities

Outreach: Global Wetland Ecohydrology Network (GWEN) founding member; Active participant in Everglades MAP/Recover landscape assessment working group and Florida Springs Working Groups

Technical and Faculty Advisory Committees: Florida Forestry BMPs Technical Advisory Committee; Florida DEP Technical Advisory Committee for Dissolved Oxygen Criteria; UF Analytical Research Lab oversight committee member; UF Water Institute faculty advisory committee

Scientific Review: Panelist and ad hoc reviewer for National Science Foundation (Water Sustainability and Climate, Ecosystems, Hydrology); Reviewer for scholarly journals – Ecology, Journal of Geophysical Research – Biogeosciences, Ecological Applications, Wetlands, Geoderma, Science of the Total Environment, Environmental Pollution, Ecological Economics, Vadose Zone Journal, Soil Science Society of America Journal.

Society Memberships: Ecological Society of America, American Geophysical Union, Society of Freshwater Science, Society of Wetland Scientists, Society of American Foresters, Sigma Xi, American Society for Limnology and Oceanography, American Water Resources Association.

Collaborators and Other Affiliations

PhD. Advisors: Dr. Mark T. Brown (University of Florida); Dr. Keith Shepherd (ICRAF – Kenya); Dr. Michael Binford (University of Florida)

Collaborators (last five years): Jim Heffernan (Duke), Brian Pellerin (USGS), Jon Martin (UF); Jason Evans (UGa), Brian R. Roth, Gemma Shepherd (UNEP); Joe Delfino (UF); Todd Osborne (UF); K. Ramesh Reddy (UF); Mark Clark (UF); Martha Monroe (UF); Ed Dunne (St Johns River Water Management District); Erich Marzolf (SJRWMD); Susan Newman (South Florida Water Management District); Brian Katz (USGS); Ray Thomas (UF); Markus Walsh (Earth Institute – Kenya); Greg Bruland (UHawaii); Jason Evans (UGa); Erik Schilling (NCASI); Tom Frazer (UF); Kelly Reiss (UF); Joseph Prenger (Florida Fish and Wildlife Commission); Thiago Romanelli (Embrapa – Brazil); Sergio Ulgiati (University of Naples – Italy); Tor Vagen (ICRAF – Mali); Veronique de Montety (U-Rennes).

Graduate Students Past and Present: Chad Foster (MS 2008), Justin Vogel (MS 2008), Lauren Long (MS2009), Lizzy Deimeke (MS 2009), Danielle Watts (PhD 2013), Dina Liebowitz (PhD 2013), Bobby Hensley (PhD current), Yuan Jing (PhD current), Rachel Douglass (PhD current), Joseph Delasantro (MS 2013), Jake Diamond (MS 2013), Courtney Reijo (PhD current).

Post-Doctoral Researchers: Subodh Acharya (current), Daniel McLaughlin (now research faculty at University of Florida), David Kaplan (now faculty at University of Florida), Andrea Albertin (senior scientist, Monteverde Field Station, CR), Jason Evans (now faculty at University of Georgia), Jim Heffernan (now faculty at Duke University), Sanjay Lamsal (now senior scientist at International Livestock Research Institute)

Thomas K. Frazer
School of Natural Resources and Environment, University of Florida, Gainesville, FL 32611
Phone: 352-392-9230; Fax: 352-392-9748; Email: frazer@ufl.edu

Professional Preparation

Humboldt State University	Marine Fisheries (cum laude)	BS, 1986
University of Florida	Fisheries and Aquatic Sciences	MS, 1990
UC Santa Barbara	Biological Sciences	PhD, 1995

Appointments

2012-present	Interim Director, School of Natural Resources and Environment, Univ. of Florida
2010-present	Professor, School of Forest Resources and Conservation, Univ. of Florida
2008-2012	Associate Director, School of Forest Resources and Conservation, Univ. of Florida
2008-2012	Program Leader, Fisheries and Aquatic Sciences Program, Univ. of Florida
2008	Associate Chair, Department of Fisheries and Aquatic Sciences, Univ. of Florida
2007-2010	Research Foundation Professor, Univ. of Florida
2004-2009	Associate Professor, Department of Fisheries and Aquatic Sciences, Univ. of Florida
1998-2004	Assistant Professor, Department of Fisheries and Aquatic Sciences, Univ. of Florida
1996-1998	Research Assistant Professor, Dept. of Fisheries and Aquatic Sciences, Univ. of Florida

Five Most Relevant Products

LAURETTA, M.V., E.V. CAMP, W.E. PINE & T.K. FRAZER. 2013. Catchability model selection for estimating the composition of fishes and invertebrates within dynamic aquatic ecosystems. *Canadian Journal of Fisheries and Aquatic Sciences* **70:**381-392.

CAMP, E.V., D.C. GWINN, W.E. PINE & T.K. FRAZER. 2012. Changes in submersed aquatic vegetation affect predation risks of common prey fish *Lucania parva* (Cyprinodontiformes: Fundulidae) in a spring-fed coastal river. *Fisheries Management and Ecology* **19:**245-251.

DUARTE, C.M., R. MARTINEZ, Y.T. PRAIRIE, T.K. FRAZER, M.V. HOYER, S.K. NOTESTEIN & D.E. CANFIELD. 2010. Rapid accretion of dissolved organic carbon in the springs of Florida: the most organic-poor natural waters. *Biogeosciences* **7:**4051-4057.

HEFFERNAN, J.B., M.J. COHEN, T.K. FRAZER, R.G. THOMAS, T.J. RAYFIELD, J. GULLEY, J.B. MARTIN, J.J. DELFINO & W.D. GRAHAM. 2010. Nitrogen dynamics in a spring-fed Florida river. *Limnology and Oceanography* **55(1):**249-263.

HEFFERNAN, J.B., D.M. LIEBOWITZ, T.K. FRAZER, J.M. EVANS & M.J. COHEN. 2010. Algal blooms and the nitrogen-enrichment hypothesis in Florida springs: evidence, alternatives, and adaptive management. *Ecological Applications* **20(3):**816-829.

Five Other Significant and Relevant Products

MINTZER, V.J., A.R. MARTIN, V. M.F. DA SILVA, A.B. BARBOUR, K. LORENZEN & T.K. FRAZER. 2013. Effect of illegal harvest on apparent survival of Amazon River dolphins (*Inia geoffrensis). Biological Conservation* **158:**280-286.

JACOBY, C.A. & T.K. FRAZER. 2009. Eutrophication: time to adjust expectations. *Science* **324:**723–724.

DE BRABANDERE, L., T.K. FRAZER & J.P. MONTOYA. 2007. Stable nitrogen isotope ratios of macrophytes and associated periphyton in two subtropical, spring-fed streams. *Freshwater Biology* **52:**1564–1574.

FRAZER, T.K., S.K. NOTESTEIN, C.A. JACOBY, C.J. LITTLES, S.R. KELLER & R.A. SWETT. 2006. Effects of storm-induced salinity changes on submersed aquatic vegetation in Kings Bay, Florida. *Estuaries and Coasts* **29:**943–953.

HAUXWELL, J.A., C.W. OSENBERG & T.K. FRAZER. 2004. Conflicting management goals: manatees and invasive competitors inhibit restoration of a native macrophyte. *Ecological Applications* **14:**571–586.

Synergistic Activities

- I have held 21 **collaborative research grants** in the last five years. Past and present collaborators include aquatic ecologists, biogeochemists, environmental chemists, ecohydrologists, biological oceanographers, physical oceanographers, geologists, fisheries biologists and ecologists, limnologists, paleontologists, phycologists, and ecological modelers. Subjects of these grants include broad-scale water quality assessments, nutrient dynamics, biogeochemical processes, population-level investigations, food web interactions, restoration of aquatic ecosystems, and fisheries ecology.
- **Undergraduate, graduate, and post-doctoral training** are critical to my professional goals. I have served on more than 90 Ph.D. and M.S. committees, involved numerous undergraduates in my research programs, and sponsored 2 international PhD-level students and 4 post-doctoral fellows.
- **Professional Service and other activities.** I regularly review manuscripts for a broad suite of scientific journals, frequently serve as a panelist to review research proposals submitted to state and federal agencies, serve as member of the faculty advisory committee for the University of Florida's Water Institute and also the UF Climate Institute, and am a current member of the Science Advisory Board for the Central Caribbean Marine Institute. Other recent service activities include: council member for the QSE3 IGERT program; Chair the University of Florida's Oil Spill Task Force; member of the US EPA's Oil Spill Research Strategy Review Panel, member of the LOICZ working group on "Global Environmental Change in the Coastal Zone: A Socio-Ecological Integration", FDEPs Technical Advisory Committee on Marine Numeric Nutrient Criteria, FDEP Peer-review panel for Dissolved Oxygen Criteria, Advisory Council member (FDEP; Office of Water Policy and Ecosystem Restoration), member of the Florida Aquaculture Interagency Coordinating Council, member of the US Scientific Committee for 9th INTECOL International Wetlands Conference, External Review Team – California Polytechnic University

Collaborators and Other Affiliations

- **Collaborators and Co-Editors (past 4 years):** S. Agusti (IMEDEA, Spain), M. Allen (UF), J. Beets (U Hawaii), D. Behringer (UF), M. Binford (UF), M. Catalano (Auburn U), R. Chant (Rutgers, IMCS), M. Cohen (UF), L. DeBrabandere (U Southern Denmark), C. Duarte (IMEDEA, Spain), J. Evans (U Georgia), J. Frost (U. Hamburg), W. Graham (UF), J. Greenawalt-Boswell (Johnson Engineering), R. Grober-Dunsmore (MBSF), D. Gwinn (UF), J. Hauxwell (WDNR), J. Heffernan (Duke), C. Jacoby (SJRWMD/UF), W. Lindberg (UF), K. Lorenzen (UF), C. Manfrino (CCMI), A. Martin (U. Dundee), J. Martin (UF), M. Moline (U. Deleware), J. Montoya (Georgia Tech), C. Osenberg (UF), W. Pine (UF), Y. Prairie (U. Montreal, Canada), I. Reche (U. Granada, Spain), S. Ruiz (IMEDEA, Spain), J. Reinfelder (Rutgers), O. Schofield (Rutgers; IMCS), J. Shima (Victoria University Wellington), V. Da Silva (INPA; Brazil), C. St.Mary (UF), J. Torres (USF), A. Tovar-Sanchez (IMEDEA, Spain), T. Van Holt (ECSU), D. Wright (LSSU), M. Youngbluth (HBOI), A. Zimmerman (UF), P. Zwick (UF)
- **Graduate Advisors and Post-doctoral advisors:** Alice Alldredge (UC Santa Barbara), Langdon Quetin (UC Santa Barbara), Robin Ross (UC Santa Barbara), Barbara Prezelin (UC Santa Barbara)
- **Thesis Advisor and Postgraduate-Scholar Sponsor (past 5 years): Current graduate students –** Savanna Barry, Vanessa Mintzer; Chanda Littles, Joelle Laing, Dane Huge, Jenny Adler, Cassandra Newkirk, Jana Huebner, Jing Guan, Jessica Diller, Jackie Langston; **Graduates (last 5 years) -** Matt Lauretta (NOAA), Ed Camp (Cornell/UF), Katherine Lazar (Elsevier), Rikki Grober-Dunsmore (NOAA), Jake Tetzlaff (NOAA), Zanethia Choice (US Forest Service), Morgan Edwards (UF), Patrick Gardner (UF), Savanna Barry (current UF), Kelly Robinson (U. Southern Mississippi), Meredith Montgomery (UF College of Veterinary Medicine), Kristin Dormsjo (NOAA), Vince Politano (NOAA), Darlene Saindon (SRWMD), Mike Randall (USGS).**Total number of graduate students advised: 35 (chair); 61 (committee member)**; **Past Post-doctoral Scholars (last 5 years) -** Lisa Chambers (U. St. Louis), Loreto. DeBrabandere (U. Southern Denmark), Emily Hall (Mote Marine Laboratory); **Total number of Post-doctoral Scholars advised: 4**.

WENDY D. GRAHAM, DIRECTOR
WATER INSTITUTE, UNIVERSITY OF FLORIDA, GAINESVILLE FLORIDA 32611-0570

Professional Preparation:
University of Florida, Environmental Engineering, B.S., 1981
Massachusetts Institute of Technology, Civil Engineering, Ph. D. 1989

Appointments:
2006-pres Carl S. Swisher Eminent Scholar and Director, Water Institute, University of Florida, Gainesville, FL
2003-2006 Professor and Chair, Agricultural and Biological Engineering, University of Florida, Gainesville, FL.
1999-2003 Professor, Agricultural and Biological Engineering, University of Florida, Gainesville, FL.
1994-1999 Associate Professor, Agricultural and Biological Engineering, University of Florida, Gainesville, FL.
1989-1994 Assistant Professor, Agricultural and Biological Engineering, Univ.ersity of Florida, Gainesville, FL.

Five Most Relevant Products:
- Heffernan , J.B., M.J. Cohen, T.K. Frazer, R.G. Thomas, T.J. Rayfield, J. Gulley, J.B. Martin, J.J. Delfino & W.D. Graham. 2010. Nitrogen Dynamics In A Spring-Fed Florida River. Limnology And Oceanography 55(1):249-263.
- De Rooij, R., W. Graham and R. Maxwell, A particle-tracking scheme for simulating pathlines in coupled surface-subsurface flows, Advances in Water Resources, doi:10.1016/j.advwatres.2012.07.022, in press, 2012.
- Meyerhoff, S., M. Karaoulis, F. Fiebig, R. Maxwell, A. Revil, J.B. Martin, and W. D. Graham. 2012. Visualization of conduit-matrix exchange in a karst aquifer using time-lapse electrical resistivity. Geophysical Research Letters, in press, 2012.
- De Rooij, P. Perrochet, and W. Graham, From rainfall to spring discharge: Coupling conduit flow, subsurface matrix flow and surface flow in karst systems with a discrete-continuum model, Advances in Water Resources, in press, 2013.
- Srivastava, V., W. Graham, and R. Maxwell, Geologic and climatic controls on streamflow generation processes in a complex eogenetic karst basin, Advances in Water Resources, in revision, 2013.

Five Other Recent Products:
- Monsivais, A., W. Graham, J. Judge, and D. Agrawal, Effect of simultaneous state-parameter and forcing uncertainties on root-zone soil moisture for dynamic vegetation using EnKF, Advances in Water Resources, 33: 468–484, 2010.
- Nagarajan, K., J. Judge, W.D. Graham, and A Monsivais-Huertero, Particle Filter-based Assimilation Algorithms for Improved Estimation of Root-Zone Soil Moisture under Dynamic Vegetation Conditions, Advances in Water Resources, 34, 433-447, doi: 10.1016/j.advwatres.2010.09.019., 2011.
- Hwang, S., W. Graham, J. Hernández, C. Martinez, J. Jones, and A. Adams, Quantitative Spatiotemporal evaluation of dynamically downscaled MM5 precipitation predictions over the Tampa Bay region, Florida, Journal of Hydrometeorology, 12, 1447–1464, doi: 10.1175/2011JHM1309.1, 2011.
- Hwang, S., and W. Graham, Development and comparative evaluation of a stochastic analog method to downscale daily GCM precipitation, Hydrol. Earth Syst. Sci. Discuss., 10, 2141–2181, doi:10.5194/hessd-10-2141-2013.

- Hwang, S., W. Graham, A. Adams, and J. Guerink, Assessment of the utility of dynamically-downscaled regional reanalysis data to predict streamflow in west central Florida using an integrated hydrologic model, Regional Environmental Change, doi: 10.1007/s10113-013-0406-x, 2013.

Synergistic Activities (up to 5):

- Member of the Board of Directors, Consortium of Universities for the Advancement of Hydrologic Science Inc, 2001-2008, Member of Executive Committee 2003-4; Chair of the Executive Committee 2005-2007.
- American Society of Agricultural and Biological Engineers, Member P-204 & P-210 National Committees 2003-present; Elected Member of the Board of Trustees 2005-2007.
- Member of National Research Council's Committee on Review of EPA's Economic Analysis of Final Water Quality Standards for Nutrients for Lakes and Flowing Waters in Florida, 2011-2012
- Member of National Research Council's Committee on Independent Scientific Review of Everglades Restoration Progress (CISRERP), 2009-2012.
- Member, Florida Agricultural Water Policy Advisory Council, 2011-present.

Collaborators & Other Affiliations:

- Collaborators and co-editors in last five years: Shirish Bhat, University of Florida; Matthew Cohen, University of Florida; Joseph Delfino, University of Florida; Michael Dukes, University of Florida; Tom Frazer, University of Florida; Donald Graetz, University of Florida; Kirk Hatfield, University of Florida; Jianqiang He, Northwest A&F University, Yangling, China; James Heffernan, Duke University; Jennifer Jacobs, University of New Hampshire; Jim Jones, University of Florida; Jasmeet Judge, University of Florida; Jawoo Koo, University of Florida; Jonathan Martin, University of Florida; Christopher Martinez, University of Florida; Reed Maxwell, Colorado School of Mines; Monsivais, A , ESIME Unidad Ticoman, Insitituto Polictenico; Mexico; Rafael Munoz-Carpena, University of Florida; Nagarajan K; University of Florida; Suresh Rao, Purdue University; Ramesh Reddy, University of Florida; Andre Revil, Colorado School of Mines; Sanjay Shukla, University of Florida; Ray Thomas, University of Florida.
- Thesis Advisor: Dennis McLaughlin, Massachusetts Institute of Technology
- Post Doctoral Associates advised in last 5 years (5 total) : Rob de Rooij, University of Florida; Syewoon Hwang, University of Florida, Vibhava Srivastava, University of Florida
- Graduate Students Advised in last 5 years (29 total) : Syewoon Hwang, University of Florida; Vibhava Srivastava, University of Florida; Wesley Henson, University of Florida; Seungwoo Chang University of Florida; Steven Meyerhoff, Colorado School of Mines.

Jonathan B. Martin

Professor – Department of Geological Science, University of Florida

Professional Preparation

Wesleyan University	Environmental Science	BA, 1980
Duke University	Geology	MS, 1987
UCSD (Scripps)	Earth Sciences	PhD, 1993
Post-doc, USGS	Geologic Division	1994 (6months)

Academic Appointments

8/07 – Present	Professor, University of Florida
8/00 – 8/07	Associate Professor, University of Florida
8/94 – 8/00	Assistant Professor, University of Florida

5 related products

Martin, J.B., *Gulley, J., *Spellman, P., 2012, Tidal pumping of water between Bahamian blue holes, aquifers, and the ocean, *J. Hydrology* doi: 10.1016/j.jhydrol.2011.11.033; 416-417, 23-38.

**Bailly-Comte, V., Martin, J.B. and Screaton, E.J., 2011, Time variant cross-correlation to assess residence time of water, implication for hydraulics of a sink/rise karst system, Water Resources Research, v. 47 W05547, doi: 10.1029/2010WR009613.

**Bailly-Comte V., Martin, J.B., Jourde, H., Screaton, E.J., Pistre, S., *Langston, A., 2010, Influence of pressure transfer and water exchange between matrix and conduits on karst spring hydrographs, *J. Hydrology* 386: 98-114.

*Moore, P.J., Martin, J.B., Screaton, E.J., and Neuhoff, P.S., 2010, Conduit enlargement in an eogenetic karst aquifer, *J. Hydrology*, **393**: 143-155, doi: 10.1016/j.jhydrol.2010.08.008.

Martin, J.B., and *Dean, R.A., 2001, Exchange of water between conduits and matrix in the Floridan Aquifer, *Chemical Geol.*, **179**:145-166.

5 other products

*Langston, A.L., Screaton, E.J., Martin, J.B., Bailly-Comte, V., 2012, Interactions of diffuse and focused allogenic recharge in an eogenetic karst aquifer, Hydrogeology Journal, v. 20, p. 767-781.Martin, J.B., *Gulley, J., *Spellman, P., 2012, Tidal pumping of water between Bahamian blue holes, aquifers, and the ocean, *J. Hydrology* doi: 10.1016/j.jhydrol.2011.11.033; 416-417, 23-38.

**deMontety, V., Martin, J.B., Cohen, M.J., Foster, C., *Kurz, M.J., 2011, Influence of diel biogeochemical cycles on carbonate equilibrium in a karst river, *Chemical Geol*., doi: 10.1016/j.chemgeo.2010.12.025.

*Gulley, J., Martin, J.B., Screaton, E.J., and *Moore, P.J., 2011, River reversals into karst springs: A model for cave enlargement in eogenetic karst aquifers, *Geol. Soc. Am. Bull.*, **123:**457-467, doi: 10.1130/B30254.1

*Ritorto, M., Screaton, E.J., Martin, J.B., and *Moore, P.J., 2009, Relative importance and chemical effects of diffuse and focused recharge in an eogenetic karst aquifer: An example from the unconfined upper Floridan Aquifer, *Hydrogeol. Journal*, DOI 10.1007/s10040-009-0460-0.

Screaton, E., Martin, J.B., *Ginn, B., *Smith, L., 2004, Conduit properties and karstification in the Santa Fe River Sink-Rise System of the Floridan Aquifer, *Ground Water*, **42**: 338-346.

*Student co-authors
**Post-doctoral associate

Five Synergistic Activities

Member, US Science Advisory Committee, ODP, 1999 – 2002
Member, Board of Governors, Karst Waters Institute, 2002 – present
Guest Editor, Ground Water: Special Issue on Ground Water Discharge to Estuaries and Coastal Zones
Member Florida Springs Task Force, 1999 – present.
Associate Editor, Ground Water, 2005- present

Collaborators and Other Affiliations

(i) Collaborators: Vincent Bailly-Comte (BRGM, France); Joan Bernhard (WHOI), Dave Burdige (Old Dominion Univerisity), Jaye Cable (LSU), Ginnie Catania (UT Austin), Jennifer Cherier (FAMU), Matt Cohen (UF), Tom Frazer (U. Florida); Vero de Montety (U Montpelier, France), Joris Gieskes (Scripps), Jason Gulley (Mich Tech), Scott Ishman (Southern Illinois University) , Jim Heffernan (FIU), Herve Jourde (U Montpellier, France); Karen Johannesson (Tulane), PJ Moore (Exxon-Mobil); Phil Neuhoff (consultant); Olivier Rouxel (IFREMER, France); Tony Rathburn (Indiana State University), Mou Roy (Arizona State University), Liz Screaton (University of Florida); Patricia Spellman (Michigan Tech).

(ii) Graduate and Postdoctoral Advisors: Paul Baker (Duke University), Carolyn Isaacs (retired USGS); Miriam Kastner (UCSD),

(iii) Thesis Advisor and Postgraduate-Scholar Sponsor: Jango Bahda (MS-Research Faculty UF), Vincent Bailly-Comte (post-doc, now at BRGM, Montpellier, France), Amy Brown (PhD – current), John Catches (MS-Industry), Carolyn Ball (MS – Shell Production Company), Shelley Day (MS - Industry), Eric Davis (MS – Industry), Randy Dean (MS-Industry), Kelly Deuerling (PhD – current), John Ezell (PhD – current), Sheryl Gordon (MS-Industry), Jason Gulley (PhD – now Assistant Professor, Michigan Tech), Rezaul Huq (PhD-current), Mitra Khadka (PhD – current), Marie Kurz (PhD – Post-doc Liepzig, Germany), Mary Lindenberg (MS - USGS), Dylan Minor (MS – Teaching), Veronique de Montety (Post-doc – now Assistant Professor at University of Montpellier, France), PJ Moore (PhD –ExxonMobil), Andrea Pain (PhD-current), Moutusi Roy (PhD – now at Arizona State University), Rick Rymerson (MS-BLM), Cecilia Scribner (MS-current), Lauren Smith (MS - Industry), Brooke Sprouse (MS – Industry)

(iv) Total Graduate students completed = 16; total Post-docs sponsored = 2, Current graduate students = 7

APPENDIX C: BRIEF RESPONSES TO PUBLIC COMMENT

As part of the MFL review process, the panel received considerable public comment, all of which was read and considered as part of this document. To demonstrate that those public comments received thorough consideration, we elected to provide a brief summary of the panel's deliberations about each point raised. We present these in the order that they were given to us.

- Comment 1:
    - Inclusion of recreation for the Lower Santa Fe MFL – the panel's view on this is that recreation is an important water resource value for the Lower Santa Fe, and that its omission was likely made by assuming that the permissible flow reductions associated with other WRVs would be far more stringent than a recreation based standard.
    - Santa Fe springs need more attention – the panel shared this concern, and raised the issue in our assessment of the priority springs MFL. In particular, the absence of baseline data, and the use of a percentage flow reduction were assumptions that merit additional information in the report.
- Comment 2:
    - MFL fails to protect priority springs – The panel agrees in principle with this comment, but fully acknowledges the significant data gaps that limit the setting of MFLs for each individual spring. We share some concern, articulated in the document, with how and at what flow the impacts will be evaluated for compliance.
    - MLR model shortcomings – The panel has included numerous critiques and suggestions for improvements on the MLR model that sets the flow baseline.
    - 15% reduction – The panel shared the concern about citations being missing and was promptly sent the relevant citations; this simple oversight will be corrected in the final version. It continues to be a matter of policy, not science, that 15% harm is the standard for "significant"; there is no a priori way to determine the adequacy of that standard for the Lower Santa Fe and Ichetucknee rivers; we have discussed this at length in the document.
    - Use of flows, not levels – While there is strong evidence of backflooding effects in the Santa Fe and Ichetucknee, the USGS stage discharge curves are corrected for backflooding effects.
    - Wetland plant community relationship with surface water versus groundwater – The panel believes that this is important but acknowledges that there is limited information on which to assess the importance of differences in these two sources of water to wetland communities.
    - Location of transects – While the panel shared some concern about the links between stage and wetland community development, we note that the critical flows are generally well below flood stage. While inundation can also be induced by back-water events from high stage conditions on the Suwannee, we are unclear on the frequency of these events, and thus their role in setting an MFL. It is unclear from the comment what revised strategy the commenter proposes for establishing the link between Ft. White flow and floodplain vegetation. The panel commented on the assumption of equivalence between area and time for the vegetation metrics in the document.
    - Flows vs. levels for in channel metrics – The use of flows or levels for the in channel metrics is supported by the strength of the rating curves that have been developed for this area. Indeed, in many cases, the in stream metrics were evaluated based on stage requirements, and these were converted to flows.
- Comment 3:
    - Climate change – The panel considers non-stationary climate to be a major challenge. As such, we recommend adopting a modeling approach that incorporates the effects of seasonal and climatic cycles of both rainfall and evapotranspiration on antecedent

moisture conditions (water storage) in the basin. Climate change projections for Florida are quite uncertain, so the approach of incorporating changing climate cycles from historic data (rainfall, ET, and flow) seems the most robust approach for actually dealing with a changing climate.

- Comment 4:
    - Use of 10th percentile flows for MFL – The panel shares this concern about adopting an MFL based on "conservative" estimates of the impacts. A more defensible approach, as articulated in this document, is to use the 50th percentile. Given the recommended changes in the MLR model, this may or may not be different from the proposed MFL, but will be far more statistically defensible.
- Comment 5:
    - In channel vegetation surveys – In channel vegetation is an important predictor of riverine habitat quality, nutrient processing, and flow control. The panel shares the opinion that these are important measurements. The fact that there are no systematic surveys of benthic vegetation and controls on density, composition, growth, and impacts is of concern.
- Comment 6:
    - Structural alterations to the channel – After considerable effort, the panel was unable to recreate the analysis provided. Moreover, what data were available (with a change in the reference elevation for the gage in 1994) suggested much stronger relationships between stage and discharge than those presented. While this may prove to be an issue on further analysis, we were unable to determine the significance of the alleged gage height error. This may be an issue that the District should pass along to the USGS.
    - Take into account feasibility of MFL – The panel is not in a position to evaluate the legal obligations of the District, but our reading of the statute suggests that the District is charged with setting an MFL, not on determining the economic or technical feasibility of that MFL, which is a discussion that could take place during development of recovery or prevention strategies.
    - 1970 as the onset of human impacts – The panel shares this concern, and has articulated this in the document, along with some potential analyses that may obviate the need for this assumption. In particular, the use of a climatologically wet period to develop baseline rainfall-discharge relationships is something that we have proposed be further evaluated.
    - MLR model concerns and systematic bias in the model residuals – The panel shares many of the concerns, particularly with regard to the bias evident in the model residuals when plotted vs. flow. We have made numerous recommendations in this document for how this modeling approach could be improved, and what the criteria for a successful model might be. Among them is the idea that the residuals should be uncorrelated in time, and should contain no bias with flow. Moreover, our analysis concluded that the impacts of high leverage observations (2000 – 2010) be reconciled with pumping information from Marella (2010) that suggests that consumptive use has not changed in the region since 1990.
    - Baseflow separation – The panel shares the concern that the 120-day low pass filter is an arbitrary method from which to determine baseflow. Similarly, changes in the flow duration curve (FDC) can be detected only over time scales too long to be of regulatory relevance, after careful review of the proposed alternative (based on a USGS Report by Grubbs 1998), we have concluded that this approach is not an improvement. That protocol, which is loosely based on a small number of specific conductance measurements and the difference in flow between Ft. White and Worthington Springs, predicts massive and highly unlikely variation in baseflow between months. Indeed, baseflows can be as low as 200 cfs, which is lower than the lowest spring-dominated flow

observed during the drought of 2010-2011. While there is no "true" way to establish baseflow separation, the proposed alternative approach does not appear to be a methodological improvement. Further work on the use of specific conductance as a tracer of groundwater, and perhaps other more specific tracers, might merit consideration for future research in the basin.

  - Regional pumping – The idea that some non-trivial fraction of the required use reductions will be outside the watershed is important. While the panel did not share the view that the "achievability" of the standard was a factor to consider at the stage of setting the MFL, we share the enthusiasm for a regional and transient groundwater model that can integrate activities well outside the watershed, and can track the impacts of changing climate conditions.

- Comment 7
  - Absence of a trend in rainfall – The panel agrees that there is no systematic trend in rainfall over the period 1905 to today; however, we believe the rainfall data show distinctive patterns that vary with AMO and ENSO phase. The District has been quite clear about the trends that they have observed in the gages used (Lake City and Gainesville), and the panel found their analysis to be compelling. We note that the LOESS curves provided contain the same shorter-term trends (specifically, increases in rainfall between 1930 and 1970, and a decline in rainfall since. These are subtle trends compared to inter-annual variation, but they appear to be real.
  - Flow reduction trends – The panel's review of the graphs provided suggests that they arrive at the same conclusion as the District, albeit with the latter accounting for long term rainfall trends. The resulting flow deviations are thus different. We note that the flow declines appear to have begun in earnest in 1999-2000, and it is this period (to 2010) that creates the large model residuals that drive the MFL. During this time, the USGS estimates that consumptive use of water in the region and within the basin was static. Further understanding the origin of these flow reductions is the highest priority uncertainty that has emerged from this review.
  - Min 7-day average analysis – This analysis further makes the case that the period between 2000 and 2010 saw far lower flows than previous periods. The location of the temporal break occurs, coincidentally, at the climate temporal divide determined by the District (1970), and appears to be consistent with their analysis that flows have responded. The model that the District has developed to predict flows given antecedent rainfall has been critiqued in this review; inclusion of other metrics of low flow conditions like this one may be warranted in a reanalysis of that model.
  - Rainfall vs. flow – This plot suggests that monthly rainfall has declined 21% from 1992 to 2010, approximately in line with District estimates, while flow has declined far more dramatically. One of the critiques that the panel has provided of the existing rainfall-discharge model is that it assume that the flow generation process is a linear function of rainfall, an assumption that is untenable given the rich literature on this topic. The analysis provided appears to make the same assumption in concluding that a larger fractional decline in flow than rainfall implies pumping. While this is clearly possible, it is also possible, indeed likely, that flow generation is non-linear; these non-linearities need to be accounted for in the model that establishes the baseline flow expectations.
  - Flow and rainfall in the Ichetucknee – This analysis appears to parallel the one provided by the District, and again provides evidence of climate variation playing at least a role in flow variation in the Ichetucknee. The panel has commented on this issue in two ways. First, we echo the comment above that the expectation of a linear rainfall-discharge relationship is not necessarily expected. Second, we have argued that rainfall inputs at Lake City have declined less than presented here, perhaps suggesting more substantial flow impacts from regional consumptive use.

- Regional groundwater effects – The panel shares the concern that the impacts are not localized, and may result from regional drawdown of the aquifer. Our primary recommendation in this regard is to begin development of a regional, transient groundwater model for evaluating far-field pumping effects and impacts that occur in response to climate variability.
- Water quality vs. quantity – The panel shares the concerns that the links between consumptive use and water quality and insufficiently treated in the MFL document, and have made some suggestions for remedying that condition. Specifically, there appears to be a positive flow-nitrate correlation in Ichetucknee Springs, and this has been observed on other springs as well. There are also important links between flow and a suite of water quality metrics related to water age (mineralization, dissolved oxygen) that could be ecologically relevant but are not considered in the current document.