Appendix B

REVIEW OF MINIMUM FLOWS AND LEVELS FOR THE LITTLE MANATEE RIVER, FLORIDA

Scientific Peer Review Report

February 20, 2012

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Scientific Peer Review of the Determination of Minimum Flows and Levels for the Little Manatee River, Florida

EXECUTIVE SUMMARY

The Southwest Florida Water Management District (the District) conducted studies on the Little Manatee River in compliance with Florida Statutes (§373.042). These statutes mandate evaluation of minimum flows and levels (MFLs) by the District to protect water resources and the ecology of the Little Manatee River from "significant harm" caused by inappropriate water use. Potential sources of water overuse include municipal, industrial and agricultural activities in the Little Manatee watershed. Well designed and scientifically–based and vetted MFL rules will ensure that the District manages the Little Manatee River and its associated wetland and riparian habitats in a manner that will maintain their ecological health and productivity for existing and future generations of Floridians to enjoy.

The District's goals, indicators, definitions and technical approaches, as described in the draft MFL report entitled "Proposed Minimum Flows and Levels for the Little Manatee River" (SWFWMD 2011), appear reasonable and appropriate to the Panel. The Panel also agrees with the District's decision to examine the MFLs for this river in two separate processes because of ecological differences between the freshwater and tidal estuarine segments. The focus of this MFL review is on the freshwater segment above the U.S. Highway 301 Bridge. The Panel finds that the proposed MFL, which calls for no water withdrawals that will cause habitat or fish and wildlife population losses greater than 15% from the river's baseline condition, is reasonable but somewhat weak. The Panel also concluded that the data for this study was only minimally adequate, due to a lack of direct information on aquatic species and habitats in the river. Although habitat simulations were performed for various life-history stages of spotted sunfish, bluegill sunfish, largemouth bass, a shallow-fast fish guild, a deep-slow fish guild, and macroinvertebrate diversity, the District's prescribed MFL flow reduction limit of 9%

was based on a projected 15% habitat loss for a single species (adult spotted sunfish), at only two "representative" sites on the entire river segment, somewhat reducing scientific confidence in the MFL. Nevertheless, given the data constraints faced by the District, the Panel concurs with the District's selection of a low-flow threshold of 35 cfs at the USGS streamgage near Wimauma, believing that it is both reasonable and essential to the success of the MFL in protecting the ecological resources of the Little Manatee River.

The Panel appreciates the District's understanding of the interrelationships and differences between freshwater flows, levels and volumes. In general, flow velocities are most important to freshwater fishes and macroinvertebrates, water levels are most important to fringe wetlands and flood forests, while water volumes are most important to the larger receiving water bodies, such as inland lakes and coastal bays and estuaries. However, water users often find they are affected by all three measures of flow.

The District used generally appropriate criteria for estimating minimum flow needs and the Panel believes that these flows should protect the native flora and fauna under most conditions. The Panel also finds that the "minimum flow for fish passage" criterion, previously established by the District and approved by various other scientific review panels, and the "no reduction in flow that would produce a habitat loss greater than 15% of available habitat under baseline conditions," are both suitable criteria. However, the latter criterion has a level of imprecision because of the lack of a statistically derived relationship between flow and biologically important aquatic species or their habitats. Nonetheless, this problem was recognized by the District and discussed appropriately in the MFL report. Perhaps future efforts could be directed towards quantification of specific flow/habitat relationships, especially because structurally complex habitats are very important for both vertebrates and invertebrates in this system, and the amount of submerged structurally complex habitat is likely to vary in a nonlinear manner with flow.

Overall, the Panel finds that the District's technical assumptions, ecological criteria, and analytical results that were used to develop the proposed MFL rule for the Little Manatee River are appropriate, reasonable and minimally adequate, especially given the District's required use of a "best available data" standard. However, the Panel strongly recommends continued study and especially monitoring to verify that the MFL is actually protecting the ecological health and productivity of the Little Manatee River.

INTRODUCTION

The Southwest Florida Water Management District (the District) is mandated by Florida statutes to establish minimum flows and levels (MFLs) for state surface waters and aquifers within its boundaries for the purpose of protecting water resources, living natural resources and the ecology of the area from "significant harm" (Florida Statutes, 1972 as amended, Chapter 373, §373.042). The District implements the statute directives by annually updating a list of priority water bodies for which MFLs are to be established and identifying which of these will undergo a voluntarily independent scientific review. Under the statutes, MFLs are defined as follows:

1. A minimum flow is the flow of a watercourse below which further water withdrawals will cause significant harm to the water resources or ecology of the area; and
2. A minimum level is the level of water in an aquifer or surface water body at which further water withdrawals will cause significant harm to the water resources of the area.

Revised in 1997, the Statutes also provide for the MFLs to be established using the "best available information," for the MFLs "to reflect seasonal variations," and for the District's Board, at its discretion, to provide for "the protection of nonconsumptive uses." In addition, §373.0421 of the Florida Statutes states that the District's Board "shall consider changes and structural alterations to watersheds, surface waters and aquifers, and the effects such changes or alterations have had, and the constraints such changes or alterations have placed on the hydrology of the affected watershed, surface water, or aquifer…." Consequently, the District has identified a baseline condition that realistically considers the changes and structural alterations in the hydrologic system when determining MFLs. This is particularly important for rivers, such as the Little Manatee, where up to 17% of the entire watershed will have been strip-mined for phosphates by 2020, where agricultural discharges augment streamflows with groundwater from the Floridan Aquifer, and where an electrical power plant removes substantial amounts of water, reducing inflows to the tidal estuarine segment.

Current Florida water policy, as expressed by the State Water Resources Implementation Rule (Chapter 62-40.473, Florida Administrative Code) contains additional guidance for the establishment of MFLs, providing that "…consideration shall be given to the protection of water resources, natural seasonal fluctuations, in water flows or levels, and environmental values associated with coastal, estuarine, aquatic and wetlands ecology, including:

1. Recreation in and on the water;
2. Fish and wildlife habitats and the passage of fish;
3. Estuarine resources;
4. Transfer of detrital material;
5. Maintenance of freshwater storage and supply;
6. Aesthetic and scenic attributes;
7. Filtration and absorption of nutrients and other pollutants;
8. Sediment loads;
9. Water quality; and
10. Navigation."

The District is to be commended for recognizing that independent scientific peer review of proposed MFLs is essential for public confidence in the scientifically-based management of these important water resources. The Panel also believes that it is good public policy when dealing with essential resources like water.

After a site visit on November 18, 2011 to perform a reconnaissance survey of the Little Manatee River study area, the Scientific Review Panel discussed the scope of the review and subsequently prepared their independent scientific reviews of the draft report and associated study documents. The reviews were compiled by the Panel Chair and edited by all Panel Members into the consensus report presented herein.

BACKGROUND

The quantity, quality and timing of freshwater flows are characteristics that define a river and its living resources. These instream flows affect riverine habitats at all levels; that is, with physical, chemical and biological effects that create and maintain a vast and complicated network of ecological relationships that affect the health and productivity of the ecosystem. Because hydrology drives the ecosystem and plays an important role in determining the composition, distribution, and diversity of aquatic communities, a central focus of instream flow studies is to relate the biology of a lotic system to its flow regime. (Bovee et al. 1998; Grossman et al. 1982, Annear et al. 2004, Grossman et al. 2010). The Panel finds that the scientific literature amply demonstrates how alteration of natural freshwater flows can have a profound impact on riverine conditions. Moreover, a river's velocity patterns, mixing and stratification, transit and residence times, concentration of dissolved and particulate materials, size and shape (geomorphology) of the river channel and its aquatic habitats, and the abundance and distribution of fish and wildlife may all be altered in ways that negatively effect the ecological health and productivity of the river.

Riverine biota have evolved life history strategies that correspond to natural flow regimes. Identification of biotic flow requirements in key habitats, such as shallow water habitats, during critical time periods (spawning and rearing) is an essential element of most instream flow studies. Fishes are excellent organisms for instream flow investigations because they are relatively easy to identify; use a variety of habitats, including flow-sensitive habitats; offer a wide range of life histories, many of which are tied to flow dynamics; are generally well studied, especially in comparison to other aquatic taxa; are good integrators of ecosystem health; and frequently have a high public profile or are of economic importance. However, Gore et al. (2001) have demonstrated that the inclusion of macroinvertebrate flow requirements in instream flow studies often dramatically alter decisions on flow allocations previously based on fish alone.

There are a number of highly variable approaches for setting the instream flow or MFL requirements of a river. One conceptual approach involves the development of base flow recommendations from results of multidisciplinary studies and analyses (Figure 1).

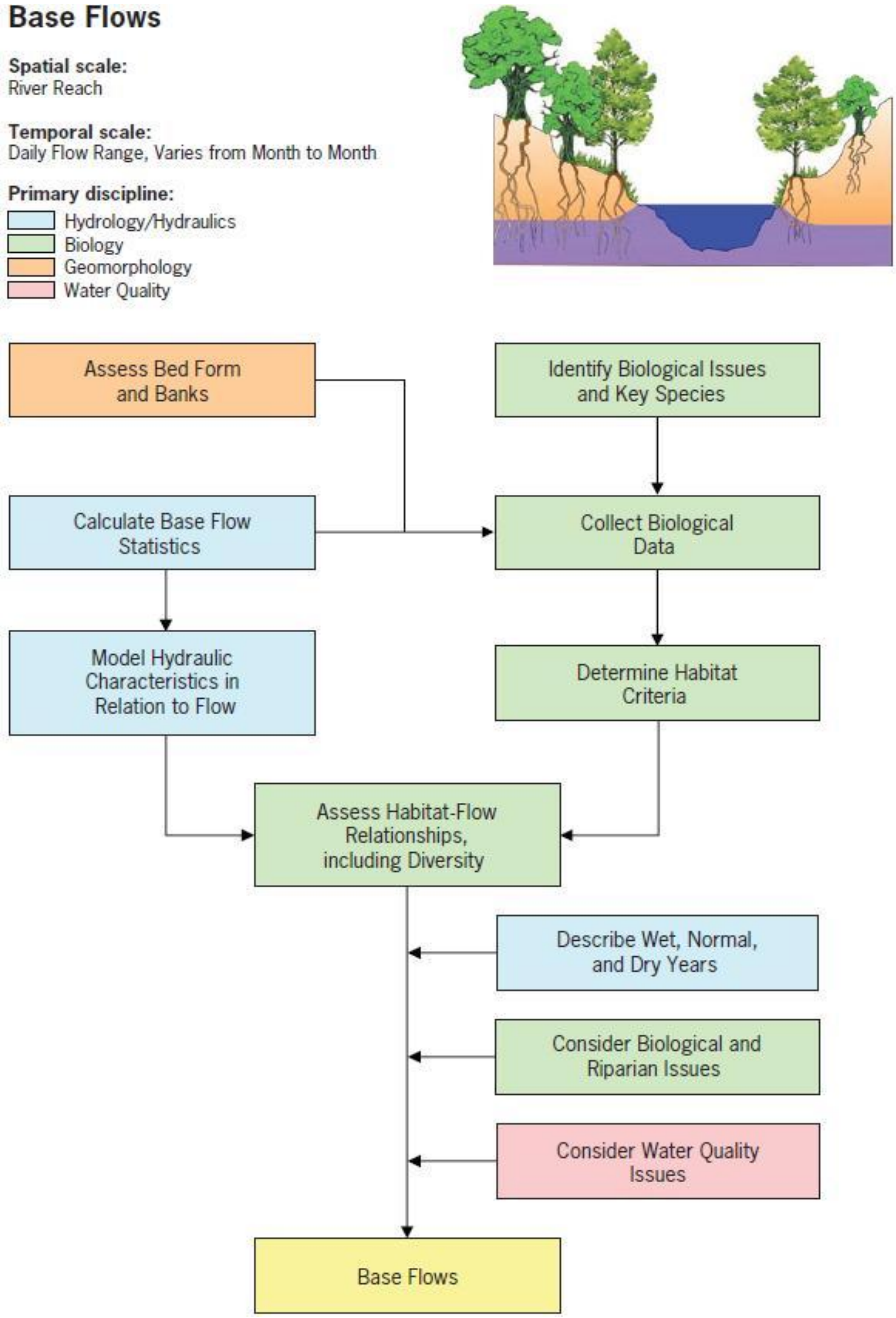

Figure 1. Multidisciplinary studies for developing base flow recommendations. (TWDB 2008)

Where the emphasis is on flow withdrawal impacts on plankton and higher trophic levels, a conceptual model for assessment of flow needs might look like Figure 2 below.

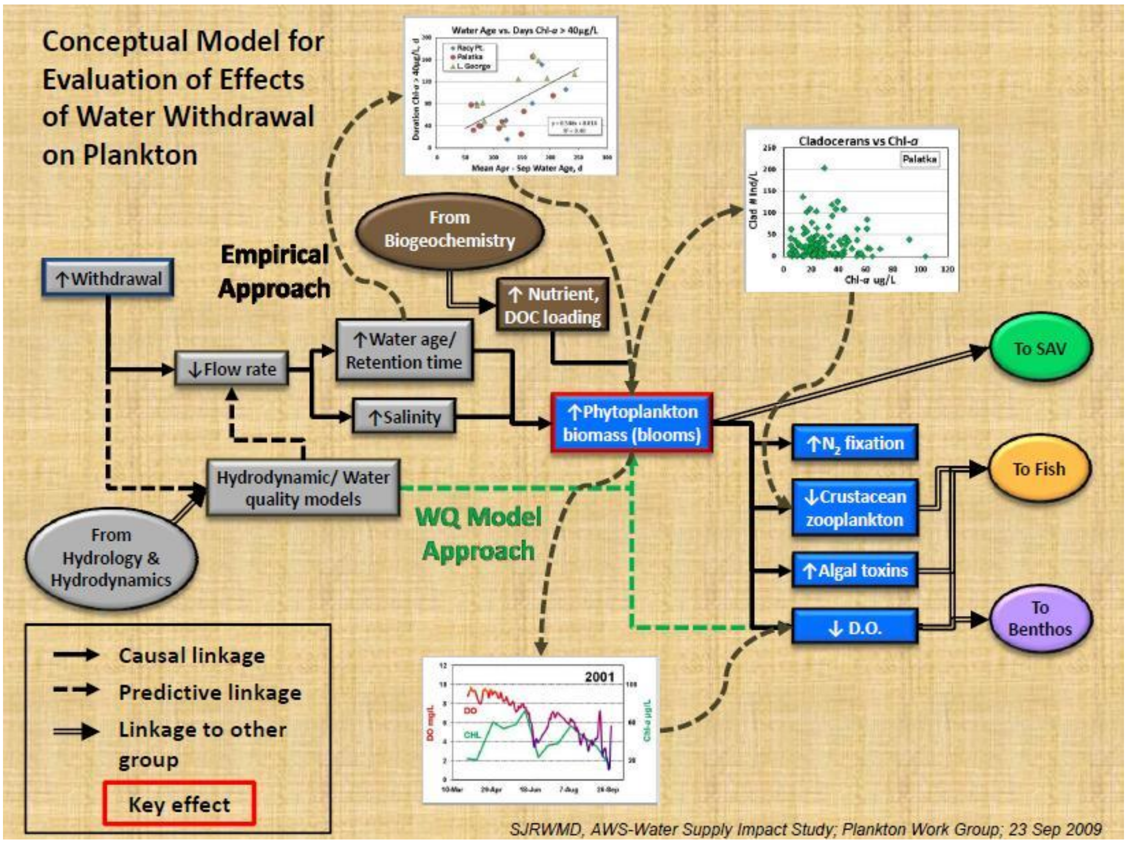

Figure 2. Multidisciplinary studies for assessing water withdrawal impacts on plankton. (SJRWMD 2009)

And finally, watershed withdrawals can be addressed with sophisticated watershed models, such as shown in Figure 3. The Panel recognizes that there are other conceptual models detailing freshwater flow interactions and needs to maintain aquatic habitats, particular species, and overall ecological health and productivity.

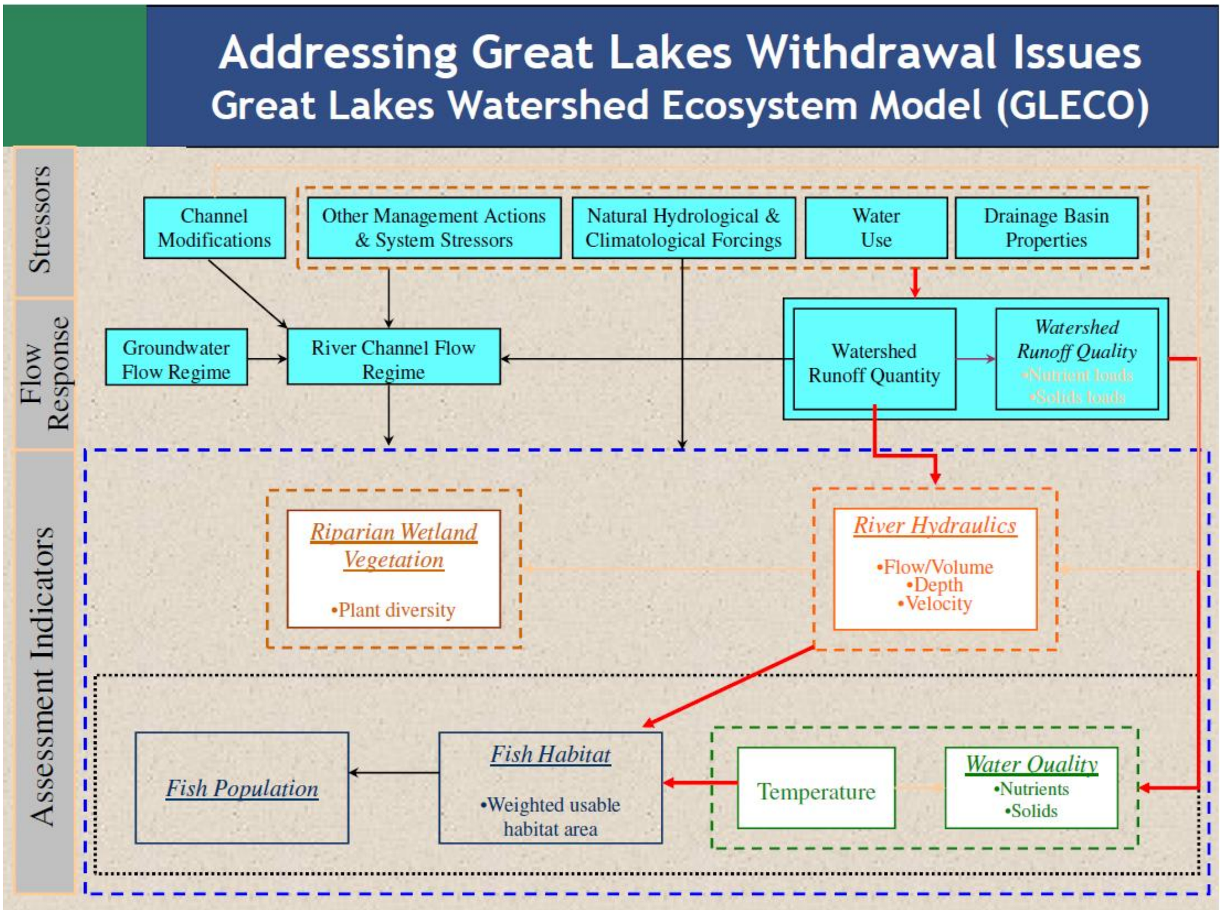

Figure 3. Multidisciplinary studies for assessing water withdrawal issues with a watershed ecosystem model (Depinto et al. 2009).

The District has selected a "percent-withdrawal" method that sets limits on water supply diversions as a proportion of river flow. This method links daily withdrawals to daily inflows, thereby preserving natural streamflow variations to a large extent. This inflow-based policy is consonant with the approach that is most often utilized for scientifically-based river management, where flow is considered a master variable because it is correlated with many other factors in the ecosystem (Poff et al. 1997; Richter et al. 1997). In this case, the emphasis is on maintaining the natural flow regime while skimming off excess flows along the way to meet water supply needs. Normally, regulations are designed to prevent impacts to living resources during sensitive low-flow periods and to allow water supplies to become gradually more available as flow increases. The rationale for the District's MFL, along with some of the underlying biological studies that support the percent-of-flow approach, is detailed in Flannery et al. (2002).

MFL REVIEW

Given the District's charge of using the "best available information" to formulate minimum flow requirements, the Panel has evaluated the MFL report in light of that criterion, which represents an important qualification on the Panel's review because there appears to be little extant biological information on the Little Manatee River. In the Panel's review, the Panel Members have tried to identify areas where data are lacking or techniques can be improved, with the intent of providing the District with valuable guidance regarding future study efforts.

Setting minimum flow rules requires several steps: (1) setting appropriate management goals; (2) identifying indicators to measure characteristics that can be mechanistically linked to the management goals; (3) reviewing existing data and collecting new data on the indicators; and (4) assembling conceptual, qualitative, and quantitative models to predict behavior of the indicators under varying flow regimes.

The District's management goals for the Little Manatee River were developed to identify allowable streamflow reductions based on limiting potential damage to aquatic habitats while preserving natural seasonal flow variation. The MFL also incorporates a low-flow threshold based on a minimum water level required for fish migration and inflection points in the wetted perimeter curves. Seasonal intervals were constructed using the District's "building block" approach wherein a low flow season (Block 1: a 65-day period from April 18 to June 21), an intermediate flow season (Block 2: a 181-day period from October 19 to April 17), and a high-flow season (Block 3: a 119-day period from June 22 to October 18) were identified by analyzing median daily flows for the period of record (1940-2009). In actual practice, the Panel recommends that water management operations by the District and the permitted water users switch between seasonal blocks based upon actual flows that year rather than the fixed calendar dates used in the MFL analysis. This should help reduce unintended negative impacts on biological communities in years where the seasonal flows are not well-matched to the fixed start and end dates of the seasonal blocks.

The Review Panel agrees that the District has conducted a reasonably comprehensive technical study to determine minimum streamflow requirements for use in managing water resources of the Little Manatee River. Although the use of a 15% loss in habitat or species abundance as a threshold for "significant harm" is a more or less arbitrary policy decision, the Panel agrees that it is a reasonable approach for avoiding the most serious negative impacts on the ecosystem. The remainder of this report is focused on review of the data, methods and analyses used as a basis for the District's recommended MFL with suggestions for improvement where applicable and appropriate.

The MFL analysis used two flow periods—a wet climatic period (1940-1969) and a drier climatic period (1970-2009). The District reports that the overwhelming majority of the MFL analyses resulted in more restrictive flow reductions during the dry period. The Panel acknowledges that although there have been major changes in the land and water use in the 244 square mile watershed of the Little Manatee River, there have not been any major structural modifications (e.g., channelization or impoundment) of the main channel below the areas excavated by the phosphate strip mining in the upper watershed.

General Comments and Criteria

Land Use Change

It is significant that the District has performed a long term analysis of land use change in the basin. Several important trends have been identified including significant decreases in grazing and significant increases in urban development, row crop agriculture, and phosphate mining. This historical analysis aids in predicting how land use changes might affect river flows, water usage, and living resources; therefore, the Panel recommends continued monitoring of these land use trends every decade or so. Currently, the most recent data are seven years old. Perhaps more recent data could be obtained via the tax assessor's office or satellite data where appropriate. Significant changes in the economy may also affect future land use trends and these need to be explored. There was no indication of how often the MFL determination would be periodically reevaluated. Perhaps this could be specified by considering the changing economic and land-use conditions that are occurring at present.

Anthropogenic Impacts

The primary anthropogenic influences on flows of the Little Manatee River are row crop agriculture, which increases flows due to run-off of irrigation water from groundwater sources, water abstraction by Florida Power and Light that is used to cool a power plant, and potential contamination via run-off from phosphate mining operations and spoils (i.e., gypsum stacks, etc.). The agricultural discharges and the water use diversions have opposing effects on the river and the Panel believes that such divergent impacts should be considered when proposing minimum flows. Obviously, agricultural operations in this area have a positive effect on wetted habitats by augmenting surface water flows with discharges of groundwater, as long as they do not introduce excess nutrients or contaminants into the river. The District recognizes this issue and is to be commended for actively trying to reduce agricultural inputs via improved irrigation techniques and water conservation measures. Nonetheless, the hydrological analysis includes these inputs and their changes; therefore, the effects of decreasing (or increasing) agricultural inputs need to be considered when evaluating the results of hydrological analyses based on historical data. In addition, the increasing trends seen in many nutrients in the Little Manatee River (see 5-3 to 5-9) appear to be a result of increased agricultural run-off or increased phosphate mining, or both.

Water diversions by Florida Power and Light are used for power plant cooling and the Panel understands that they are permitted for "emergency" diversions when their cooling reservoir drops below 62 feet. The District has developed a minimally acceptable withdrawal plan for Florida Power and Light that has protected the Little Manatee River in the past. However, Florida Power and Light should be encouraged to develop a formal plan for diversion of river waters that will ensure that MFL standards will be complied with, and more importantly, that the schedule of withdrawals is optimized in such a manner that minimizes the necessity for emergency diversions during low flow periods.

Phosphate mining in particular has the potential to contribute to significant cultural eutrophication of this system and it was not apparent to the Panel that there were serious efforts by mining company to prevent run-off from entering either the river or the aquifer. Certainly, best management practices would include retention systems and probably the development of artificial wetlands to help ensure that mining contaminants do not reach the river or the water table.

Water Quality

Some of the nutrient graphs have a single point between 2,000 and 12,000 cfs flows and this limits the use of regression or establishment of flow nutrient relationships (see sodium and chloride graphs 5.4-5.5). It is typical when statistical relationships are highly influenced by a single point to rerun such analyses without the outlier(s) to ascertain the effect of unusual data structures on statistical relationships, or the lack thereof.

Animal Assemblages and Habitat Data

The Little Manatee River has a fairly diverse mixture of freshwater and estuarine species with a total species richness of 25 (Dutterer and Allen 2006). Five of these species are of marine origin and found primarily in the tidally influenced section of the river. The fish fauna is dominated by centrarchids, with few cyprinids, and no percids occurring in this river, at least as reported so far. The river only has one invasive species, the Asian swamp eel (*Monopterus albus*).

Although MacDonald et al. (2007) assessed relationships between freshwater flows and fish and macroinvertebrates in the lower (tidal and estuarine) portion of the Little

Manatee River, the Panel could locate only one study that described the fish fauna of the freshwater portion of the river (Dutterer and Allen 2006). As a result, the Panel recommends that more extensive faunistic studies be conducted in the future. This is particularly salient because the sampling method used for both fish and habitat sampling involved boat electroshocking, which limited sampling to areas deep enough to allow passage by an electrofishing boat. The upstream sections of the river are quite shallow and sampling in these reaches with other techniques (e.g., backpack electroshocking, seining, trapping, or underwater observation by snorkeling) may reveal species that have not been collected so far. The Panel notes that previous work has not identified any threatened or endangered fish species in this system.

In addition, there is little information on the habitat requirements or usage patterns of freshwater fishes in the Little Manatee River. Dutterer and Allen (2006, 2008) provided the only information on habitat use of species in this system and these data represent much of the underlying data for the District's MFL analysis. They found that both fish species richness and spotted sunfish (*Lepomis punctatus*) abundance were positively correlated with the abundance of structurally complex habitats such as submerged timber, root wads and beds of aquatic plants. This association has been observed in other Coastal Plain rivers of the Eastern United States. The District recognizes the importance of these habitats and has done well to incorporate them specifically into the MFL analyses. The Little Manatee is a small river and future work could easily involve direct observation of habitat use patterns using snorkeling. Other techniques to be considered are trapping and backpack electroshocking. The Panel believes that these methods offer a more accurate way of quantifying habitat use here than boat electroshocking in this stream.

Apparently no other habitat use data were available for other species in the system, although data exist and was used for several centrarchids (e.g., bluegill and largemouth bass) from other river systems. Previous river research in Florida has shown that year class strength or abundance of several centrarchids, including spotted sunfish, are affected by river flows. Specifically, year-class strength or abundance for multiple common centrarchids exhibited positive relationships between mean flow and abundance, and negative relationships between abundance and sustained low flows, such as those that occur during the emergency conditions we call "drought" (Bonvechio & Allen 2005, Rogers et al. 2005). Although some of these relationships are based on a long time period (1983-1994), the District should recognize that within this time period only five years of biological data were collected (Rogers et al. 2005). Nevertheless, basing minimum flow levels primarily on data for centrarchids is reasonable because they dominate the fish fauna, although the lack of data on non-centrarchid species, even from other regional stream systems, limits the robustness of the analysis presented in the District's MFL report.

Apparently there is also no available information on invertebrate, amphibian, or reptile assemblages associated with the Little Manatee River; consequently, this information was not included in the report. Aquatic macroinvertebrates were included in the habitat analysis using general relationships from other systems and, given the lack of specific data, this is a reasonable course of action. The District clearly recognizes the biological importance of structurally complex habitat for invertebrates in the Little Manatee, especially because this system is dominated by shifting sandy substrata that do not provide suitable habitat for many invertebrate species which typically provide the prey base for aquatic vertebrates. The exposed portion of submerged timber and rocky banks also may represent important hunting and basking habitats for aquatic snakes (i.e., *Nerodia* spp.). Future efforts should be directed to obtaining information on the distribution, abundance and habitat requirements of invertebrates, amphibians and reptiles in this system. The river headwaters and floodplains are likely important reproductive habitat for amphibians and reptiles.

Instream Flow Methods

The PHABSIM/IFIM approach to quantifying fish habitat is the standard for many fish management agencies. Nonetheless, it is not without shortcomings, including lack of quantification of the effects of population size, predator/competitor effects and food availability. In short, PHABSIM only considers habitat to be comprised of physical factors. Nonetheless, there is no doubt that biological factors influence habitat use in riverine fishes, including several centrarchid species found in the Little Manatee River (Gido and Jackson 2010). The PHABSIM analysis is appropriate, given the "best available data" standard; however, physical data were based on only two sites and it is unclear if these sites represent the complete range of habitats present in the system, especially those that represent important habitat for aquatic vertebrates and invertebrates.

An important finding of the analysis is that reductions in flow greater than 20% generally result in ~15-30% loss of habitat during the periods of April–August and October–December (Figure 7-5). It appears that some historical withdrawals have been above this level and if continued in the future, may violate the proposed MFL standard. With respect to the IFIM analysis, it is unclear to the Panel why habitat suitability curves for spotted sunfish were developed using a Delphi technique rather than from the information contained in Dutterer and Allen (2006, 2008). This should be clarified in the District's MFL Report.

In addition, analyses were run for a "shallow-fast" guild and a "deep-slow" guild, but it is unclear whether these guilds are represented in the Little Manatee River, especially given the fish fauna described in Dutterer and Allen (2006). The Panel recommends that the District identify the resident fishes represented by these guilds in its MFL Report. Nonetheless, as previously mentioned, it is unlikely that Dutterer and Allen (2006) sampled the uppermost sections of the river, where members of any shallow-fast guild would be likely to occur. Given the caveat of "best available data" and the dominance of centrarchids in the middle freshwater portions of the Little Manatee River, the PHABSIM / IFIM analysis is reasonable from a biological perspective, but could be improved with the inclusion of data from other systems on some of the remaining species. Alternatively, it is possible that the guild analysis covered this shortcoming, but without identification of the species involved it is difficult for the Panel to evaluate.

Verification Monitoring

As the District moves forward in the future to implement its MFL rule, manage and supply water to the people, their economy and their environment, the Panel strongly recommends that the District continue to monitor the Little Manatee River for the purpose of verifying that the MFL is having its intended effect of adequately protecting the ecological health and productivity in this tributary of the Tampa Bay System.

More Areas where the MFL study could be improved:

Inclusion of consideration of sediment transport / physical processes.

The Panel believes the study and report would benefit from some analysis of how the proposed minimum flows and levels may impact sediment transport processes in the Little Manatee River. Both the Florida statutes and the scientific literature related to environmental flows recognize the importance of providing flow regimes that maintain both the biotic and physical components of the aquatic ecosystem. The District's MFL report lists factors that the Florida Administrative Code stipulates shall be considered when setting minimum flows and levels (SWFWMD 2011, p. 1-2). Number 8 on this list is "sediment loads." The background literature cited in the District's report also recognizes the importance of maintaining physical processes dependant on the sediment transport characteristics of the river system. Hill et al. (1991), referenced on pages 1-3 and 1-4 of the report, is representative of the "state of the art" related to the description of flow requirements to sustain stream ecosystems. As noted in the report, Hill et al. (1991) summarize the importance of physical processes by saying "maintenance of stream ecosystems rests on streamflow management practices that protect physical processes." They recommend that minimum flow methodologies consider "how streams affect channels, transport sediments, and influence vegetation." The Panel agrees with these recommendations.

On the other hand, the District's approach for developing minimum flows and levels does not appear to incorporate any consideration of the impact of flow recommendations on sediment transport and geomorphology. As described on page 1-6, the District's approach does consider impacts on ten potential resources of interest. These ten resources mirror the factors listed in the Florida Administrative Code, with one exception—"sediment loads," which are included in the list on page 1-2 but are missing from the list of elements the District included in its study approach on page 1-6.

Analysis of how minimum flow recommendations would impact sediment transport also appears to be missing from the study of the Little Manatee River. Extensive geomorphic studies to evaluate how proposed future flow regimes may change channel shape and resulting aquatic habitat can be time consuming and expensive. Fortunately, such studies are probably unnecessary for evaluating the proposed flow recommendations for the Little Manatee River at this time. During the Panel's November 18, 2011 site visit to the river, the Panel did not observe signs of active or unusual degradation or aggradation. Further, stakeholders and other investigators have not raised excessive degradation or aggradation as an issue for the river system. And preliminary review of channel measurement data at USGS gage locations in the basin do not indicate substantial changes in channel bed elevation over time.

As can be seen in Figure 4, the stage associated with very low and zero flows at the USGS gage on the Little Manatee River near Fort Lonesome (gage number 02300100) has changed only about one foot in 40 years, indicating a very modest rate of channel change (in this case incision). Similar data from the USGS gage on the Little Manatee River near Wimauma (gage number 02300500), shown in Figure 5, shows little to no change in the stage discharge relationship for low flows, indicating no significant change in the elevation of the channel bed. Therefore, the Panel finds that the main channel of the Little Manatee River appears to be relatively stable over time.

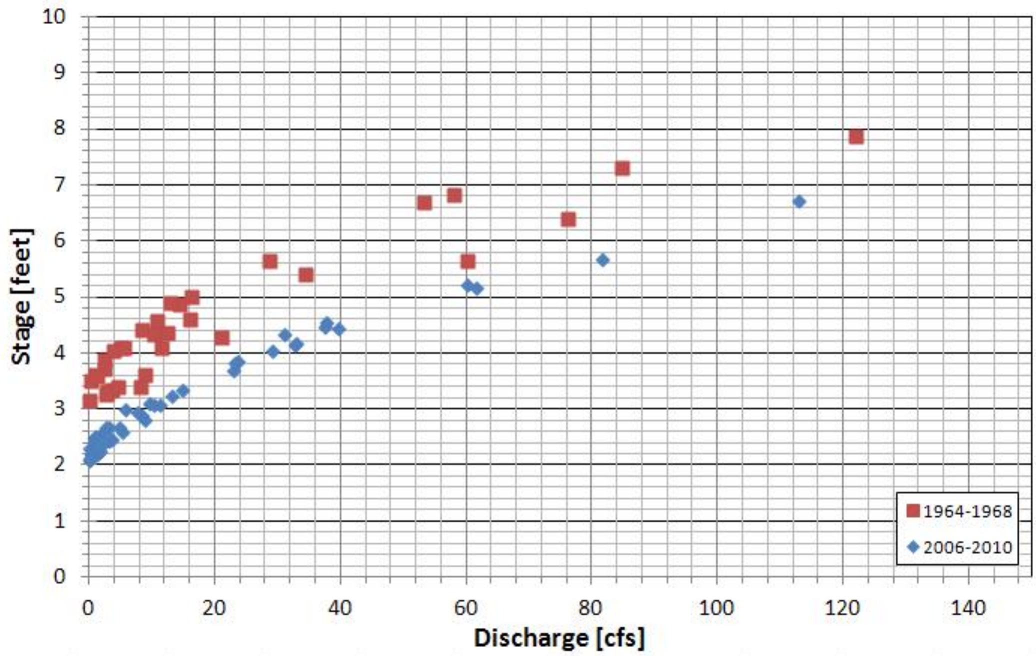

Figure 4. Stage discharge data from the periods 1964-1968 and 2006-2010 for USGS gage 02300100 (Little Manatee River near Ft. Lonesome, FL).

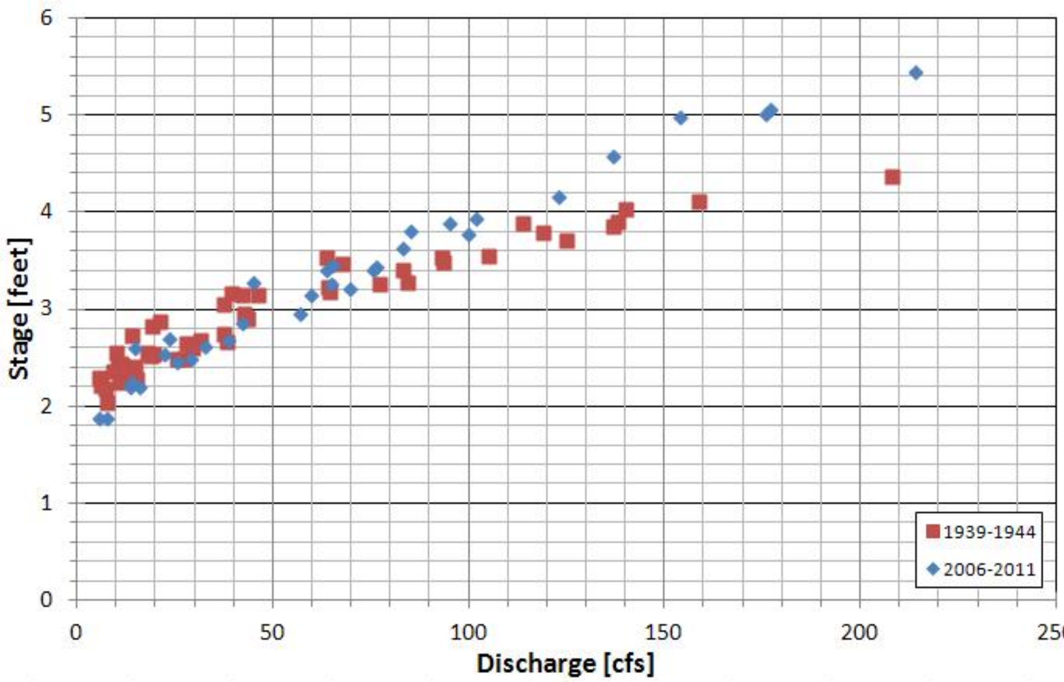

Figure 5. Stage discharge data from the periods 1939-1944 and 2006-2011 for USGS gage 02300500 (Little Manatee River near Wimauma, FL).

When river channels are relatively stable, some relatively simple and inexpensive analyses can be carried out to estimate potential impacts on sediment transport due to proposed changes to the flow regime. These analyses, based on comparison of the bed material sediment transport capacity of the current and proposed future flow regime (as estimated by the long term average annual bed material sediment load) is described by TSAC (2009 and 2011). These techniques utilize data that can be collected relatively quickly (cross section, bed material, channel slope) and standard sediment transport equations (or sediment transport data if it is available) to develop site specific sediment transport relationships at USGS gage locations. The relationships are then combined with daily average stream flow data to estimate average annual sediment load for alternative hydrologic scenarios.

The relative change in average annual sediment load between current conditions and a proposed flow scenario can then be used to estimate potential geomorphic change. Large negative changes in average annual sediment load indicate the channel would degrade (or incise), at least to the point of refusal where the bottom is armored by rock. Large positive changes indicate the channel would aggrade. TSAC (2011) was unwilling to quantify a change in average annual sediment load that would be cause for concern. However, guidance from the US Army Corps of Engineers (Biedenharn et al. 2000 and Biedenharn et al. 2001) states that a channel should remain relatively stable if change in the average annual sediment load is less than 10%.

In view of these facts, the Panel recommends that the District consider inclusion of sediment transport analysis (using average annual sediment load) as a part of its approach for determining minimum flows and levels of rivers. Based on results from other river systems, the Panel anticipates that a proposed maximum daily flow reduction of 9%, as recommended for the Little Manatee River, will not result in sediment transport changes that will cause significant channel change. To support this conclusion, the Panel provides Table 1, which shows diversion rates and resultant changes in average annual bed material sediment load for a number of river sites in Texas. All of the sites listed in Table 1 are low gradient, sand (or predominantly sand) bedded channels. The changed sediment load from the baseline condition was a function of how the water was diverted (i.e., maximum diversion rates, maximum storage volume, operations relative to senior water rights, etc.), not just the total volume diverted. The results presented in Table 1 may not be for diversions tailored to minimize the change in average annual bed material sediment load. Results in this table indicate that diversions of 11% or less of flow volume could be implemented in these streams without causing major changes in the channel shape. Including such analysis in the approach used by the District would provide assurance that this important component of aquatic ecology has been considered.

Table 1. Changes in flow and resultant changes in average annual bed material sediment load in comparison to baseline conditions for riverine sites in Texas.

River	Site	Change in Flow	Change in Sediment Load	Reference
Colorado	San Saba	23%	8%	CLBBEST 2011
Colorado	Columbus	19%	11%	CLBBEST 2011
Lavaca	Edna	7%	5%	CLBBEST 2011
Guadalupe	Cuero	18%	10%	GSABBEST 2011
San Antonio	Goliad	16%	11%	GSABBEST 2011

Correct application of PHABSIM model

As part of the approach for developing minimum flows and levels for the Little Manatee River, the District developed PHABSIM models to estimate fish and macroinvertebrate habitat versus flow relationships. Based on the description in the Study Report, the Panel has some concerns that this modeling may not have been performed correctly. First, the study sites included portions of the river channel that are probably too short to be representative of the Little Manatee River and second, the number of transects used at each site may have been too few to characterize habitat within the study sites.

According to Bovee and Milhous (1978), "As a general rule, a representative reach should be 10 to 14 times longer than the average channel width in order to include two sequences of channel features." Study reaches less than the recommended length run the risk of being unrepresentative of the overall river. The USGS measurement data for the streamgages on the Little Manatee River at Fort Lonesome (02300100) and Wimauma (02300500) indicate that the width of the channel at median flow conditions is about 20 and 40 feet, respectively. Using this standard, PHABSIM sites near Fort Lonesome should have a reach length of from 200 to 280 feet. Sites near Wimauma should have a reach length of from 400 to 560 feet. According to the District, cross-sections for assessing instream habitats were examined at 10 sites—eight were vegetation only and two were PHABSIM / Vegetation cross-sections. The District's MFL Report states that three transects were established at each site, with one transect co-located with "the floodplain vegetation transect line and the other two replicate cross-sections … located 50 ft upstream and downstream" (page 7-3, SWFWMD 2011). If in fact the length of the river represented by the study site was only on the order of 100 feet in length each, then the Panel is concerned that the resulting PHABSIM models may not be truly reflective of habitat conditions in the Little Manatee River. The Panel encourages the District to consider extending the PHABSIM study boundaries at each site upstream and/or downstream as appropriate in order to encompass a sufficient length of river that equates to 10 to 14 times longer than the average channel width, and includes at least one meander wavelength of the channel.

The number of transects (or cross-sections) used to characterize a PHABSIM study site is generally much more than three. According to Bovee and Milhous (1978), "too few or improperly placed transects will give a distorted view of the stream. Transect placement is a critical determinant in the reliability of an instream flow model." They go on to describe PHABSIM models as requiring three types of transects: hydraulic control, mesohabitat, and transitional. These three types of cross-sections are illustrated in Figure 6 below. The downstream boundary of a PHABSIM model should be located on a hydraulic control, which may or may not correspond to a particular mesohabitat type. A transect should be placed in all other hydraulic controls in the study site (here a river reach with a length of from 10 to 14 channel widths).

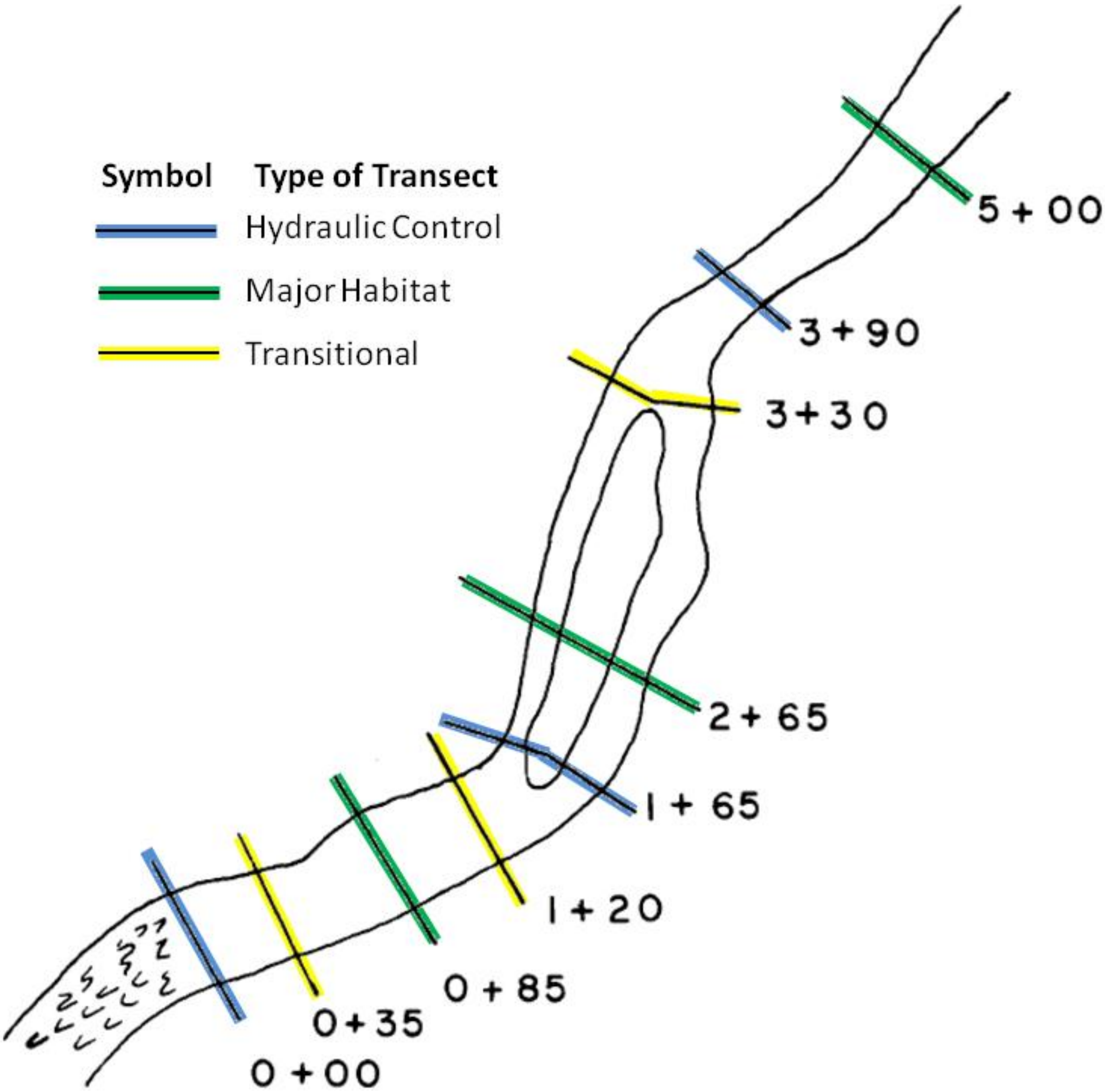

Figure 6. Example PHABSIM transects and configurations for characterization of stream study sites (adapted from Bovee and Milhous 1978).

At least one transect should be located in each mesohabitat type (e.g., run, riffle, pool, etc.) present at the study site. A second (duplicate) transect in each type of mesohabitat is preferred in order to provide some measure of the variety of conditions that may be present in individual mesohabitat types. Bovee and Milhous (1978) also state that "Depending on the level of detail desired, additional transects may be added to define the transition zones from one type of habitat to another." Based on reviews of many PHABSIM studies and their own extensive experience conducting PHABSIM studies, Bovee et al. (1998) conclude the number of transects required to adequately characterize each mesohabitat type (the equivalent of mesohabitat and transitional transects in Bovee and Milhous 1978) ranges from two (for mesohabitats with the highly uniform hydraulic characteristics) to five or six (for mesohabitats with a complex combination of hydraulic characteristics).

It is not clear from the MFL Report what mesohabitats were identified at each of the PHABSIM sites (no listing was provided in the report or in the appendix). However, from the Panel's November 18, 2011 fieldtrip to the sites, the Panel observed at least three; namely, flowing pools, riffles (or ripples) and runs (or glides). Assuming these mesohabitats exhibited very uniform hydraulic characteristics and at least one mesohabitat transect was co-located with the hydraulic control transect at the downstream boundary of the site, at least 6 transects would be necessary to model habitat conditions at each study site. If additional mesohabitats, such as backwater areas or hydraulic controls, were identified at the PHABSIM study sites, even more transects would be necessary. Therefore, the Panel recommends that the District consider revising the PHABSIM studies at some point in the future by extending the length of the study reaches and adding sufficient transects to be in compliance with the guidance of Bovee and Milhous (1978) and Bovee et al. (1998) who developed the technique.

The PHABSIM was used in lieu of the application of more modern methods and advanced 2-D and 3-D hydraulic models, which were considered either too difficult or too expensive for fisheries workers to employ (the Panel acknowledges that an interdisciplinary team of scientists and engineers is best). The velocity and depth information measured by hand at the PHABSIM cross-sections was used to determine the amount of habitat available for the various species of interest here. This is different than, for example, using the 1-D HEC-RAS hydraulic model as an integral part of the modeling to determine low flow thresholds for fish passage and maintenance of wetted perimeters, which are key indicators of biological habitat. Without an adequate hydraulic model, PHABSIM tends to revert to the somewhat controversial and error-prone habitat simulation technique found in the instream flow incremental methodology (IFIM) developed decades ago by the U.S. Fish and Wildlife Service (Bovee and Milhous 1978, Milhous et al. 1984). Moreover, the substantial effort required to provide more accurate and reproducible results with PHABSIM involves increasing time, money and manpower, and probably decreasing the amount of stream that can be assessed if budgets are limited. In the end, 2-D hydraulic modeling may be a more accurate and cost-effective method of instream flow analysis. The Panel acknowledges that PHABSIM represents only one of several tools used to evaluate flow in the Little Manatee River, but urges the District to use more accurate hydraulic models in future efforts.

Confirm suitability of benchmark flow periods (pre- and post-1970)

The Panel believes the study could benefit from a trend analysis of the hydrology that considers more possibilities than just time periods prior to and after 1970. Section 1.5 (pages 1-6 and 1-7) of the District's MFL Report (SWFWMD 2011) states that an approach has been adopted that uses these two periods as separate benchmarks for analysis. Rather than accepting this division of the entire time period by default, the Panel recommends that additional trend analysis for the Little Manatee River be performed to confirm the appropriateness of this time division, or perhaps even refine it.

Specifically, the District could carry out a cumulative departure from the means analysis for the average daily flow at the Wimauma and Fort Lonesome gages on the Little Manatee River to quantify any temporal patterns of flow. The Panel provides results for the Wimauma gage in Figure 7. These results demonstrate that a significant difference exists in the hydrology of the first and second half of the time period 1940-2009. Figure

7 also provides a more refined description of hydrologic changes during this period. The steep positive slope of the cumulative departure curve indicates two periods with larger than average flow from 1945-1948 and 1957-1960. The steep negative slope of the cumulative departure curve indicates a period with lower than average flow from 1975-1977. Any partitioning of the time period from 1940 through 2009 that keeps the two wet periods on one side of the division and the dry period on the other side of the division would result in large differences in flow statistics for the two periods. In other words, the assumption that flow conditions for the Little Manatee River have changed only once over the 1940 to 2009 time period (presumably caused by "climate change") will be supported by placing a break year anywhere between1960 to 1975. The key element to achieving statistical significance for the division of the "prior to" and "after" time periods is to include the two wet periods in one division and the dry period in the other.

Figure 7. Cumulative departures from the mean for average daily flow at the Little Manatee River near Wimauma, FL (USGS gage 02300500).

In reality, flow conditions in the Little Manatee River appear to be more complex than can be accounted for by identifying only two time periods (prior to and after 1970). The Panel's review of Figure 7 reveals several periods with different flow conditions. The period from 1940 to 1944 appears to be a period with relatively high flow variability centered around average conditions. The 1945 to 1948 interval is a relatively high flow period; whereas, the 1949 to 1956 is a period of relatively low flow variability centered around average conditions. The 1957 to 1960 interval is another relatively high flow period, while 1961 to 1974 is another period of low flow variability centered around average conditions. The 1975 to 1977 interval is a relatively low flow period. And finally, 1978 to 2009 is another period of relatively high flow variability centered around average conditions.

The causal factors for this more complex pattern of hydrology in the Little Manatee River may be changes in weather patterns associated with multi-decadal oscillations of sea surface temperatures in the Pacific and/or Atlantic Oceans. Climate change may be responsible for the increased variability in the 1978 to 2009 time period; however, there is another period of high variability in the early part of the record (1940 to 1944) that would presumably be less impacted by climate change. Flow statistics for these periods are shown in Table 2. For comparison purposes, statistics for the entire period 1940 to 2009 and prior to and after 1970 are also shown in Table 2.

Thus, the Panel believes the District's MFL study of the Little Manatee River would benefit from evaluation of benchmark flow periods that went beyond simply accepting default periods prior to and after 1970. Such an evaluation would identify more flow variability than is captured by only two benchmark periods. For example, the following flow regimes may prove more beneficial and explanatory about past flows in the river:

1. High flow period (1945-1948 and 1957-1960),
2. Low flow period (1975-1977),
3. Average flow with low variability (1949-1956 and 1961-1974), and
4. Average flow with high variability (1940-1944 and 1978 to 2009).

Table 2. Flow statistics for various time periods based on average daily flow data from the Little Manatee River near Wimauma, FL (USGS gage 02300500).

Period	Wet	Dry	Average, Low Variability	Average, High Variability	Entire Period	Pre 1970	Post 1970
Calendar Years	1945-1948, 1957-1960	1975-1977	1949-1956, 1961-1974	1940-1944, 1978-2009	1940-2009	1940-1969	1970-2009
Average	272	80	151	166	170	184	159
1%	2737	734	1613	1590	1733	2020	1510
5%	1100	380	634	621	673	783	598
10%	662	178	363	356	384	441	350
30%	189	52	97	123	117	116	118
50%	75	31	46	70	61	51	67
70%	37	20	26	44	36	28	41
90%	17	9.6	14	24	17	13	22
95%	11	6.7	9.5	16	12	9	17
99%	3.2	1.4	5.1	8.5	5.8	4.8	8.4

Overall, the Panel finds that there are additional scientific methods, analyses, data integrations and interpretations that could improve the District's technical evaluation of minimum flows and levels in the Little Manatee River. As the District moves forward to set the MFL into rules for water management, the Panel strongly recommends continued study and especially monitoring to verify that the proposed MFL is actually protecting the ecological health and productivity of the Little Manatee River.

ERRATA and EDITORIAL COMMENTS

Page	Paragraph	Line	Comment
ix	1	last	When referring to USGS streamgages for the first time in a report section, it's good practice to include the gage numbers.
x	2	1	The phrase "when flows are below and above 280 cfs, respectively" seems completely out of context. If this phrase is removed, the first sentence summarizes the Panel's understanding of the MFL flow recommendations supported by this study. The flow rate of 280 cfs was not mentioned in the rest of the document and maybe should be removed here.
1-5	4	1	Seerley et al. 2006 is not in Literature Cited section.
1-7	1	1	Probably should provide a reference here describing how the "prior to and after 1970" demarcation was established and/or verified.
1-8	1		Three seasonal flow blocks were defined strictly based on hydrologic conditions. Perhaps the consideration of biological or ecological criteria would strengthen the definition of the blocks. Also, once the MFL is set and approved, the Panel recommends that water management operations by the District and the permitted water users switch between seasonal blocks based upon actual flows that year rather than the more or less arbitrary calendar dates used in the MFL analysis. This should help reduce unintended impacts on the biological communities in years where the seasonal flows are not well-matched to the fixed start and end dates of the seasonal blocks.
1-8	1 & 2		These paragraphs provide somewhat conflicting definitions of the seasonal flow blocks—the first paragraph defines the blocks by day of the year, while the second defines the blocks based on their median daily flow statistics. If the second paragraph is meant to be a justification for the first, it could be stated more explicitly by saying something like "The days of the year that define each Block were selected after analyzing…." Also, change the tense of the paragraph from present to past tense.
2-3	1	last	Missing citation.
2-3	3		It would be helpful to have a map of the physiographic provinces and their intersection with the Little Manatee River watershed. The provinces could be identified in Figure 2-1 or a separate figure could be added to the MFL report.
4-9	last		When referring to USGS stream gages for the first time in a report chapter/section, it is advisable to include the specific gage number in the description.

Page	Paragraph	Line	Comment
4-11			Figure 4-8 includes data from 1939-2009, while Table 4-2 refers to data from 1940-2009. It is probably best to select one time period. The Panel notes that the 1940-2009 time period matches the time period used in the analysis of precipitation data in Section 4.2.2.
4-11			Since the authors have mentioned 1970 as being an important division in the hydrology of the region, it would be meaningful to see flow duration curves similar to Figure 4-8 for the periods 1940-1969 and 1970-2009, as well as the entire 1940-2009 time period. Similarly, Table 4-2 could be expanded to include data for the 1940-1969 and 1970-2009 time periods, as well as the entire 1940-2009 time period.
4-12	1	1	"…and there is considerable…."
4-13	last	last	"…established by three of…."
4-18	1	9-10	Sentence is missing a time period (as noted in text) and punctuation mark (period).
4-21			To be consistent with format, Figure 4-16 caption should have period at the end.
4-22			Figure 4-17 caption is missing final year of the time period, as well as a period at the end.
4-22	2	3	This sentence should be reworded to include the following information in the explanation of why mining effects were not further analyzed. As noted on page 4-20, mining discharges are high during wet periods (when river flows are high naturally). As noted on page 4-37, there is no evidence that high flows have increased. Therefore, it's valid to conclude that any impact on the hydrology of the Little Manatee River due to mining discharges is small and analysis of mining impact on hydrology is not necessary at this time.
4-24			It would be very difficult (if not impossible) to recognize a trend in monthly flow values for a system with flow variation throughout the year when data for all twelve months are plotted on the same figure (as is the case for Figure 4-19). To provide any opportunity for visual inspection to detect possible trends in monthly flows, the reader should be referred to the figures in Appendix 2A, where the same data are displayed as twelve different figures corresponding to individual months. Perhaps one of the figures from Appendix 2A could be used to replace Figure 4-19 in the main body of the report to give the reader a general idea of what can be seen from plotting this data. The Panel notes that months such as May, July, October, and December visually appear to show a trend over time using the common "eyebolic method."

Page	Paragraph	Line	Comment
4-32			Section 4.2.7 adjustments of the flow record from 1978 to 2009 essentially move the 5 to 50 percentile exceedance flows back to their same statistics from the 1940 to 1969 period. The Panel suspects the same MFL recommendations would be generated by declaring the period from 1940 to 1969 as representative of the desired future condition and using statistics from that period to guide the rest of the District's analysis.
4-32	2	1	"…goal of minimum flow analysis is to determine…."
4-32	3	last	Please provide a basis for the statement that the river channel remains "in good condition," particularly since the river is later described as "primarily well incised with very high banks (page 6-5, 1st paragraph, last sentence). Is the assessment of the river being in good condition based on historical observations (it has been incised long before European settlement), comparison to other rivers in the area (incision is common in this part of Florida), or some other analysis?
4-32	4	5	Replace "irritation" with "irrigation."
4-33	1		The second sentence implies that the goal of the proposed MFL is the natural condition of the river, while the third sentence suggests that a goal of maintaining the current condition is also acceptable. The Panel recommends that the District (in consultation with its stakeholders) choose a single desired outcome (either natural or current conditions) and communicate that goal consistently. In view of the number of agencies and stakeholders who influence the Little Manatee River, having a single, agreed upon goal makes achievement of that goal more likely. However, incoherent action from the parties involved may make the achievement of either goal (natural or current conditions) less likely or even impossible.
4-33	1	5	Remove word "to" in phrase "…should also to be protective…."
4-39	last	2	Replace word "or" with "for" in phrase "…adjusted flow record for the years…."
4-40	4	4	Replace word "here" with "there" in phrase "…observed when there was no trend…."
4-40	4	5	Replace "Table 2-10" with "Table 4-9."
4-40	4	6	Replace word "we" with "were" in phrase "…flows were not adjusted…."
4-40	4	8	"…where there were significant…."

Page	Paragraph	Line	Comment
4-40	4		Agricultural return flows from groundwater sources are assumed to be the driving factor behind increases in surface water flows post-1970; therefore, the District made adjustments in the river flows starting in 1978. Precipitation shows little or no trend (Section 4.2.4), lending credence to the argument that increases in flow are due to agricultural return flow. However, an analysis of changes in rainfall intensity pre- and post-1970 would be helpful to confirm this argument. Changes due to intensity of precipitation events (same overall total precipitation but more or fewer events with minor runoff producing intensity) should be considered. Perhaps the available precipitation data can be analyzed for changes in intensity in order to strengthen the conclusion that increased flows are due to agricultural return flows.
4-41	2	5	"…which has a significantly increasing trend…."
4-41	3	7	"…adjust these very low flows…."
4-41	4	5	"...used a seasonal basis for adjusting the flow…."
4-41	5	last	Replace word "rive" with "river."
4-42	1	1	"…flows were not adjusted at high flows…."
5-1 to 5-10			Section 5.1.1 and the Water Quality Appendix. The Panel agrees that the inclusion of data from one or two high flow measurements can make it visually difficult to really see what's going on in the constituent concentration versus flow graphs. To correct the scale and enable the reader to better see the results of the graphical analysis, the Panel recommends dropping these few high flow data points from the plots or maybe switching to a log-log axis format, whichever makes the clearest graph. For example, the Panel suggests removing the two data points for flows of about 4,500 cfs from the Phosphorus concentration versus flow chart of Figure 5-1 and reformatting the x-axis to range from 0 to about 1100 cfs. This would make it much easier to evaluate visually if there is a trend in the data related to flow. In Figure 5-2, the Panel suggests removing the data for three outlier points (flow rates of about 11,400 and 4,200 cfs) from the Nitrate + Nitrite concentration versus flow chart to similarly improve this graphical analysis. Most of the constituent versus flow graphs could benefit from similar editing of the data outliers that make the graphs obscure.
7-2	3	4	Reference to "Figure 7-22" should be corrected to "Figure 7-2."

Page	Paragraph	Line	Comment
7-5			The first paragraph of Section 7.3 states that there were two representative sites, as shown in Figure 7-2. Figure 7-2 does show two PHABSIM study sites in green labeled "Masonic Park" and "ELAPP." However, the last sentence of the top paragraph on page 7-3 states that "Upon modeling the three PHABSIM sites, the Masonic Park site did not calibrate properly and had to be discarded." If the Masonic Park site was indeed discarded, and assuming the ELAPP site was kept, where is the second PHABSIM site? Figure 7-2 should be updated to show the actual PHABSIM sites that were studied, and especially the ones that were kept and used, in the MFL analysis.
7-9	3	7	Reference to "Figure 7-44" should be corrected to "Figure 7-4."
7-12	4	3	If regional fish experts were "unfamiliar with development of habitat suitability criteria," or more likely don't find them useful in studying fish and their communities, then perhaps the District should be cautious about their use.
7-15	1-2		Again, the first and second paragraphs appear to provide conflicting descriptions (calendar date versus flow characteristics) of when you are in each seasonal flow Block. See the Panel's previous comments on how to reword this for better clarity, as well as how the Panel recommends the District should apply it in MFL rules and water use permits.
7-16			The cross-section data displayed in Figure 7-7 is described as coming from River Station 79400. However, in the Appendix, the cross-section for a location 79,399.86 feet upstream of the Wimauma gage does not look like the cross-section in Figure 7-7. Please confirm which cross-section (the Figure in the Report or the Appendix) is correct and make any necessary changes.
8-13			Normally each chapter starts with page 1, as in 8-1, but this chapter starts on page 8-13. What happened to pages 8-1 thru 8-12?
8-14	1	6	Replace "35 cfs" with "30 cfs" as shown in Figure 8-2 on the next page.
8-15	2	3	Unless there are more PHABSIM sites than the Panel knows about, replace "four" with "two" representative sites.
8-16	2	6	"…available historic record…."
8-17	1	2	The second sentence is incomplete.
8-18	1	2	To drive home the point that analysis of this type is not needed during the other seasonal flow blocks, the Panel recommends modifying this sentence to read "Based on historic flow records, inundation of exposed roots and snag habitat occurs regularly during Block 2 flows, and infrequently during Block 1 and 3 flows."
8-18			Maximum allowable flow reduction recommendation in Table 8-2 for wetted perimeter analysis is 30 cfs, not 5 cfs as shown.

Page	Paragraph	Line	Comment
8-19	2		This paragraph has been indented and does not match the rest of the text.
8-19			In Figure 8-3, Block 3 is referred to only as “Block” and needs to be labeled like the other seasonal flow blocks. Also, consider revising the figure caption to “Flow prescription and historical mean daily flows….”
8-19	3	5	Remove word “the” so that the phrase reads “…flow records for each gage….”
9-21			Pages 9-21 thru 9-29 should be renumbered as 9-1 thru 9-9.

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