Scientific Peer Review of the Proposed Minimum Flows and Levels for the Weeki Wachee River System

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EXECUTIVE SUMMARY

The Southwest Florida Water Management District (District) has completed a study to establish Minimum Flows and Levels (MFL) for the Weeki Wachee River System (WWRS). The approach was to determine a flow regime that would protect the ecology of the river system by analyzing data on historical flows, current flows, water quality and biological responses to flows dominated by artesian spring discharges from the groundwater aquifer.

The proposed MFL starts with a management goal, as directed by Section 373.042 of the Florida Statues, to provide environmental streamflows wherein "the minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." Since what constitutes "significant harm" is not legally defined in the statutes, it could be presumed that one purpose of the MFL report is to define it scientifically. The methodology to meet this goal depends on linking assumptions, past practices, data analyses, and salinity models. The District starts with the assumption that a 15% loss of habitat is acceptable as being protective of the natural resources. This assumption is not thoroughly explored in the study, but is explained as being based on previous management practices with some support from the scientific literature. The Panel believes that one size probably does not fit all and that some ecosystems may well tolerate reductions greater than 15% while others may tolerate considerably less, especially if they are already stressed by physical, chemical or biological factors other than streamflow. A more defensible goal might be the maintenance of ecological health and productivity, but it is unlikely to be easier to estimate.

Rivers and estuaries exist in a continuum from fresh water to marine habitats; alteration of inflow causes spatial shifts in salinity relative to existing habitat. This fact implies that in order to determine the limit at which further withdrawals would be significantly harmful to the ecology of the area, the District must make a policy decision about what is an acceptable loss of habitat (or resources) from further withdrawals. Choosing 15% as an allowable level of resource loss is

such a public policy decision. More importantly, the percent-of-flow reduction approach ensures that historical hydrological regimes will be maintained, albeit with some reductions in flow.

Overall, the District is to be commended for preparing an excellent report that summarizes a large quantity of data and analyses, produced from many studies, into a document that is coherent and relatively easy to read. The District is also to be commended for voluntarily seeking peer review of its technical documents.

Although the numbering of the appendices is somewhat confusing, they are well written and reasonably thorough as well. The supporting data and information used to develop the proposed MFL is technically sound. As described in the District's report, the data collection methods were appropriate, as were the findings and interpretations made from all analyses reviewed by the Panel.

During the initial meeting of the Panel, District representatives indicated that the MFL was intended to protect the springs and their discharges that dominate flows of the WWRS. With few exceptions, the data presented for development of the WWRS MFL also support MFLs for the springs, although these were not specifically defined in the District's report. Since Florida statutes direct the District to adopt MFLs for "all first magnitude springs, and all second magnitude springs within state or federally owned lands purchased for conservation purposes," the Panel believes that the District should consider revising this document in such a way that it covers the MFLs for the associated springs, as well as the river and estuary.

The Panel noted concerns about the salinity regression equations and the numerical modeling that were employed in estimating the allowable flow reductions. The salinity regressions did not include salinity at the estuary mouth as an independent variable and the numerical modeling did not include salinity as a boundary condition at Mud Springs. In addition, the numerical model did not appear to include the effect of a substantial slope in the bathymetry of the WWRS, resulting in simulations with virtually no tidal dampening upstream, a potentially serious hydraulic error.

Determining a low flow need during a high flow period is virtually impossible. This accounts for much of the problem with the District's evaluations of fish and invertebrates. The District used 16 of the best or most applicable sets of results to establish flow reductions that met threshold criteria for freshwater habitat, salinity habitat, benthos and mollusks. In addition, the District presents a graphical summary of the results that includes 32 measures of resource loss due to streamflow reductions. Several of these, particularly those that are most conservative, involved extrapolations beyond the river reach of concern, including some extrapolations into the Gulf of Mexico. Because they are beyond the domain of the regressions, or were biased by high flow study conditions, the District decided to base the MFL for the WWRS on the mean percent-of-flow reduction allowed for seasonal Block 1 (10.1 % flow reduction) and seasonal Block 3 (10.7% flow reduction).

In the end, the District recommended that both the wet and dry season flows for the WWRS be maintained at 90% of the baseline (read: naturalized) flows after the effects of human usage have been eliminated from the flow record. The fact that existing human usage is presently at or near the 10% limit means that little or no additional flow reductions will be allowed. After review, the Panel concurs with this recommendation.

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INTRODUCTION

The Southwest Florida Water Management District (the District) is mandated by Florida statutes to establish minimum flows and levels (MFLs) for certain surface waters and aquifers within its boundaries for the purpose of protecting the water resources and the ecology of the aquatic ecosystems from "significant harm" (Florida Statutes, 1972 as amended, Chapter 373, §373.042). What constitutes "significant harm" is not legally defined by the statutes; therefore, the Panel believes that one purpose of the District's MFL report should be to define it scientifically.

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…." As a result, the District has identified a baseline condition that realistically considers the changes and structural alterations in the hydrologic system when determining MFLs.

Current state 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's Board also has continued to voluntarily commit its MFLs determinations to independent scientific peer review as a matter of good public policy.

After a site visit on June 10, 2008 to perform a reconnaissance of the Weeki Wachee River System (WWRS) study area, the Scientific Review Panel discussed their initial observations, the assigned scope of the peer review, and subsequently prepared their independent scientific reviews of the draft report and associated study documents. The independent reviews were compiled by the Panel Chair and edited by all Panel Members into the consensus peer review report presented herein. This review assesses the strengths and weaknesses of the overall scientific approach, its conclusions and recommendations. The scope also allows the panel to suggest additional data and/or approaches that might be incorporated into the process used for establishing minimum flows. This peer review is provided to the District with the Panel's encouragement to continually enhance the scientific basis of the decision-making process.

GENERAL COMMENTS

Overall, the District has prepared an excellent report that summarizes a large quantity of data and analyses, produced from many studies, into a document that is coherent and relatively easy to read. This is no small task because of the legal, social, and economic constraints of recommending a resource-use strategy on such a complex ground water/surface water ecosystem. Many people support the view that setting MFLs in rivers and estuaries is one of the most daunting tasks facing resource managers today. The District's commitment to sound public policy is further illustrated by the voluntary submission of its MFL determinations for scientific peer review.

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

The panel is not aware of any essential data that were excluded from analyses of the river and the estuary. It is clearly evident that the data used for the development of the MFL was the best information available. Technical assumptions are inherent in data collection and analysis. Throughout the report, the District makes reasonable attempts to describe these assumptions.

Further, the analytical procedures and technically interpretations are reasonable and generally based on the best information available. Most importantly, the District has a clear management goal that is widely supported by scientists, managers, and stakeholders. That goal, as stated in the MFL document, involves the use of a 15% change in habitat availability as a measure of significant harm for the purpose of MFLs development.

Chapter 373.042(2) of the Florida Statutes directs the state water management districts to adopt MFLs for "all first magnitude springs, and all second magnitude springs within state or federally owned lands purchased for conservation purposes." Therefore, in addition to establishing MFLs for the Weeki Wachee River System, the District is required to set MFLs for Weeki Wachee

Spring, Twin Dees Spring and possibly Salt Spring and Mud Spring, depending on land ownership. The District should consider revising this document in such a way that it covers the MFLs for the appropriate springs as well as the river and estuary.

Clearly, the work that's been done relative to the river includes the majority of the scientific information necessary for a Weeki Wachee Spring MFL. The additional information needed to address MFLs for the springs themselves may be relatively minor. In fact, additional investigations may be limited to evaluation criteria for (1) maintenance of groundwater flows for contact recreation at Weeki Wachee Spring and (2) the relationship of groundwater flows to nitrogen enrichment of the river. The latter issue is included because most Florida springs show a positive correlation of nitrate and spring discharge, so maintenance of flow cannot always be used for control of this nutrient. Public perception is often the opposite; therefore, a discussion of nutrients and their relationship to flow is recommended. In the end, the MFLs for Weeki Wachee and the other springs will probably be based on their contributions to flow in the river itself. This is implied in the District's report (page 36, SWFWMD 2008) that states "the MFL for the Weeki Wachee, expressed as an allowable percent reduction, will be applied to the Weeki Wachee estuarine system which includes Mud and Salt springs." The Panel notes that Twin Dees Spring is not mentioned here, but apparently should be.

The quantity, quality and timing of freshwater input are characteristics that define an estuary. Freshwater inflows affect estuarine (tidal) areas at all levels; that is, with physical, chemical and biological effects that create a vast and complicated network of ecological relationships (Longley 1994). The effects of changes in inflows to estuaries are also described in Sklar and Browder (1998) and reviewed in Alber (2002). This scientific literature describes and illustrates how changing freshwater inflows can have a profound impact on estuarine conditions: circulation and salinity patterns, stratification and mixing, transit and residence times, the size and shape of the estuary, and the distribution of dissolved and particulate material, which may all be altered in ways that negatively affect the ecological health and productivity of coastal bays and estuaries.

Inflow-related changes in estuarine conditions consequently will affect living estuarine resources, both directly and indirectly. Many estuarine organisms are directly linked to salinity:

the distribution of plants, benthic organisms and fishery species can shift in response to changes in salinity (Drinkwater and Frank 1994; Ardisson and Bourget 1997). If the distributions become uncoupled, estuarine biota may be restricted to areas that are no longer suitable habitat for their survival, growth and reproduction. Potential effects of human activities, particularly freshwater diversion and groundwater pumpage, on the adult and larval stages of fish and invertebrates include impacts on migration patterns, spawning and nursery habitats, species diversity, and distribution and production of lower trophic (food) level organisms (Drinkwater and Frank 1994; Longley 1994). Changes in inflow will also affect the delivery of nutrients, organic matter and sediments, which in turn can affect estuarine productivity rates and trophic structure (Longley 1994).

There are a number of approaches for setting the freshwater inflow requirements of an estuary. The District has selected to use a "percent-withdrawal" method that sets upstream limits on water supply diversions and groundwater pumpage as a proportion of river flow. This links daily withdrawals to daily inflows, thereby preserving natural streamflow variations to a large extent. This type of inflow-based policy is very much in keeping with the approach that is often advocated for 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 flows along the way to meet water supply needs. Normally, regulations are designed to prevent impacts to estuarine resources during sensitive low-inflow periods and to allow water supplies to become gradually more available as inflow increases. The rationale for the District's MFL, along with some of the underlying biological studies that support the percent-of-flow approach for the WWRS, is built upon the analyses previously performed on the Upper Peace River (SWFWMD 2002) as peer reviewed by Gore et al. (2002) and in other scientific literature summarized by Flannery et al. (2002).

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 first two steps above represent the overall approach to setting a minimum flow rule.

A standard of no more than a 15% change in any biological relevant resource, as compared to the estuary's baseline (i.e., naturalized flow) condition, was used as the threshold for "significant harm." While some may argue that the use of 15% as a threshold is a more or less arbitrary management decision, the Panel agrees that, in the absence of specific physiological or ecological thresholds which might reflect significant harm to the living resources, this is a reasonable approach for avoiding the more serious negative impacts on the ecosystem.

PHYSICAL/CHEMICAL DRIVING FACTORS

The MFL for the WWRS is built on estimating the percentage flow reduction causing 15% loss of resource or habitat. The main physical/chemical drivers for these resources and habitats are:

1. Spring Discharge
2. Groundwater Pumpage
3. Seasonal Patterns (Blocks)
4. Mud River Discharge
5. Tidal Forcing
6. Salinity Distribution
7. Water Quality
8. Temperature Regime

Spring Discharge and Groundwater Pumpage

Annual discharge since 1929 has fluctuated between 117-253 cfs. Trend analysis has shown that declines in discharge between 1970 and 1999 were due to anthropogenic and climactic factors. Various models in the District's MFL report (2008) show that groundwater pumpage has an estimated impact on spring discharge from 9.7 to 25.2 cfs. Yet an empirical data plot does not show pumpage to significantly affect flow (Figure1).

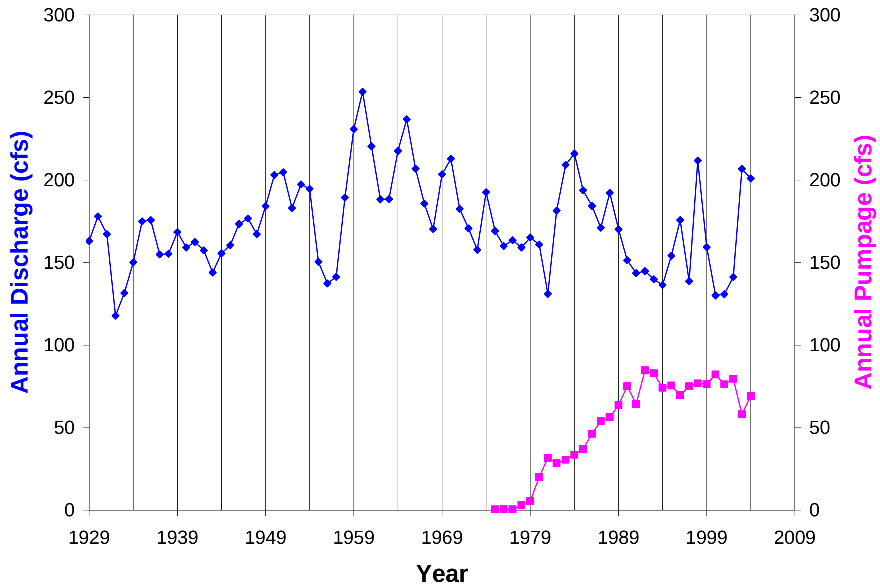

Figure 1. Time series plot of Weeki Wachee annual discharge (cfs) and pumpage (cfs).

A plot of rainfall, springflows and pumpage from 1975 to 2004 (data from Schultz 2007) only suggests a weak relationship between rainfall and springflows with one to two year lags in response (Figure 2). Further, the District's MFL report (SWFWMD 2008) states that "Annual pumpage was compared with annual spring discharge and a significant inverse relationship was found." However, a graphical analysis of the data prepared by the Panel did not confirm this finding (Figure 3).

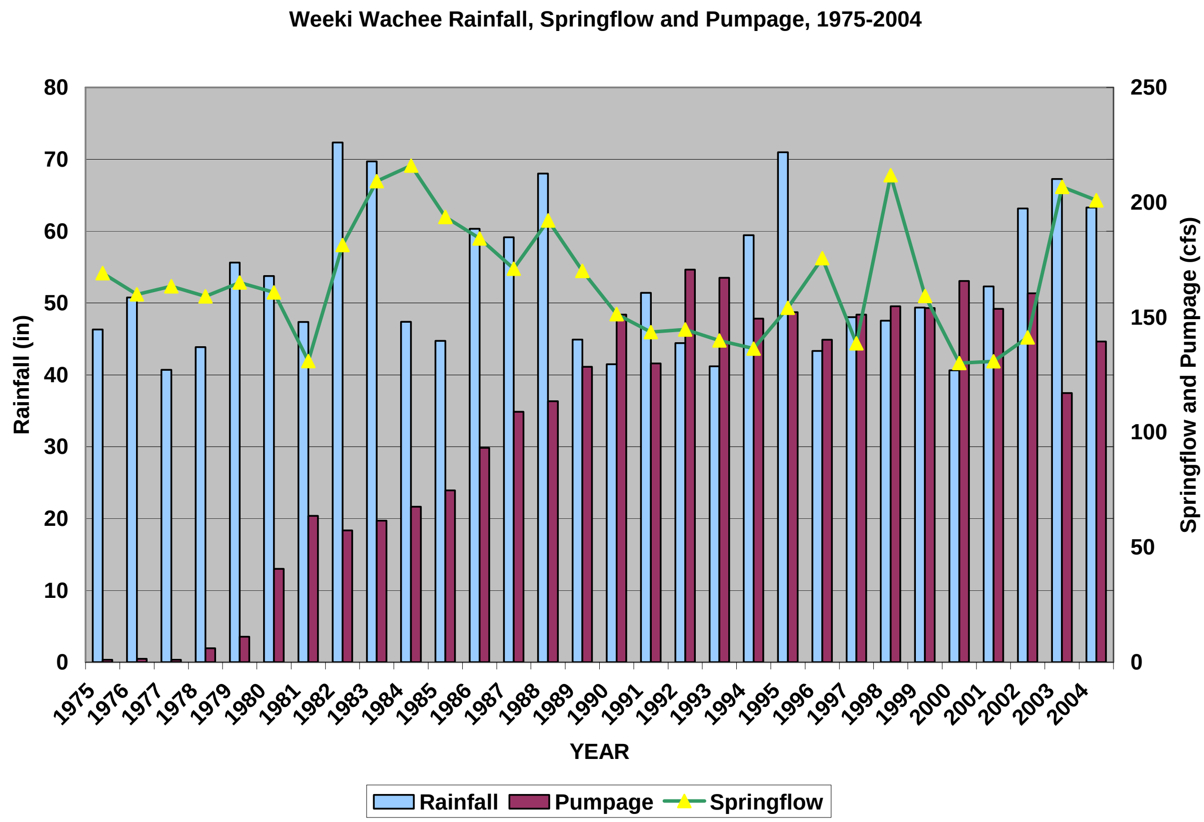

Figure 2. Weeki Wachee Springflow, Pumpage and Rainfall, 1975 − 2004.

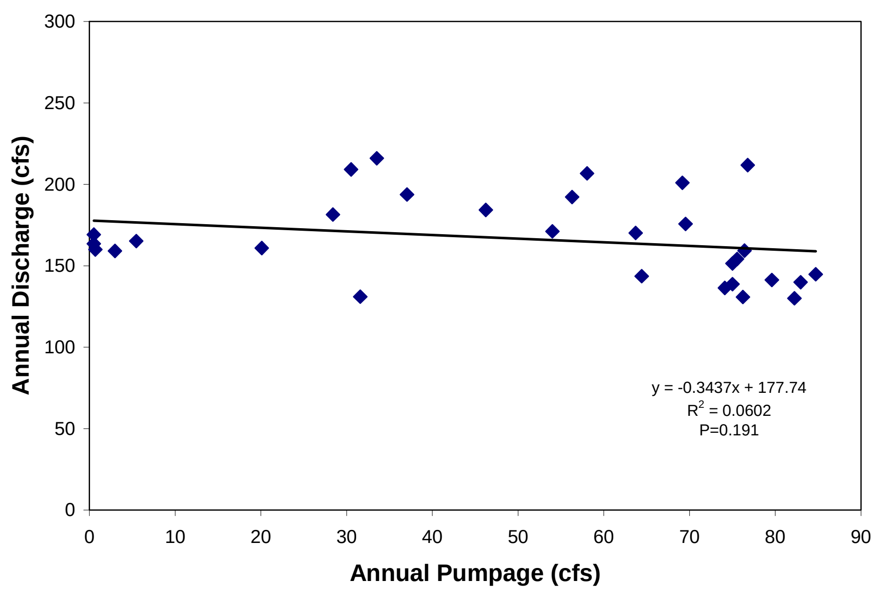

Figure 3. Regression of Weeki Wachee Spring annual discharge and pumpage.

It is possible that the effect of pumpage is countered by an increase in precipitation over the last 30 years. The Panel examined the relationship between discharge and precipitation as a possible indicator (Figure 4). One would expect that under similar conditions, rainfall and discharge would be related. Discharge and precipitation are significantly related but not very predictive. Perhaps a lag term needs to be applied because of the long residence time of the aquifer.

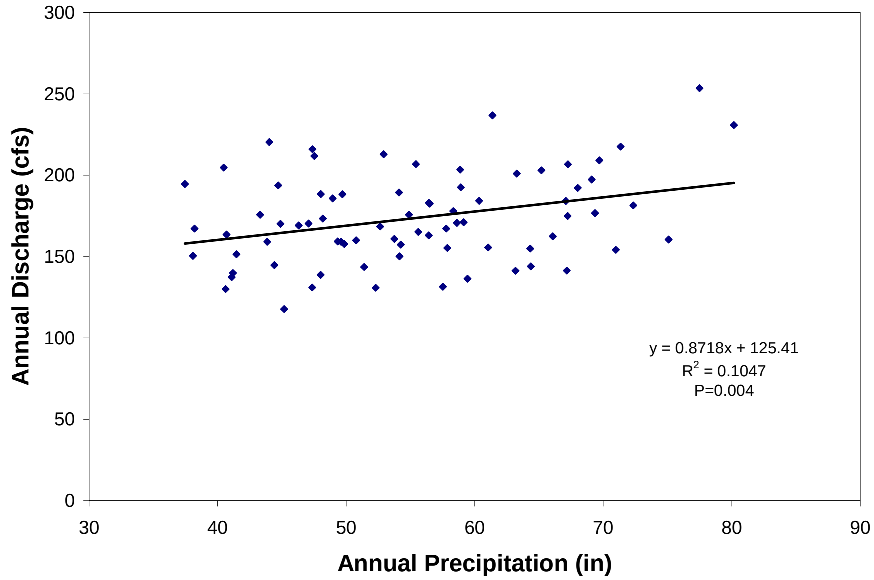

Figure 4. Regression of annual precipitation and Weeki Wachee Spring discharge.

Another way to look at this is by plotting the discharge:precipitation ratio (Figure 5). It is clear that there has been no great change in the relative amount of discharge. While the ratio has been declining since the 1960s, it is not any lower than it was prior to then. If pumpage was having a significant effect on discharge, it should be evident from this graph.

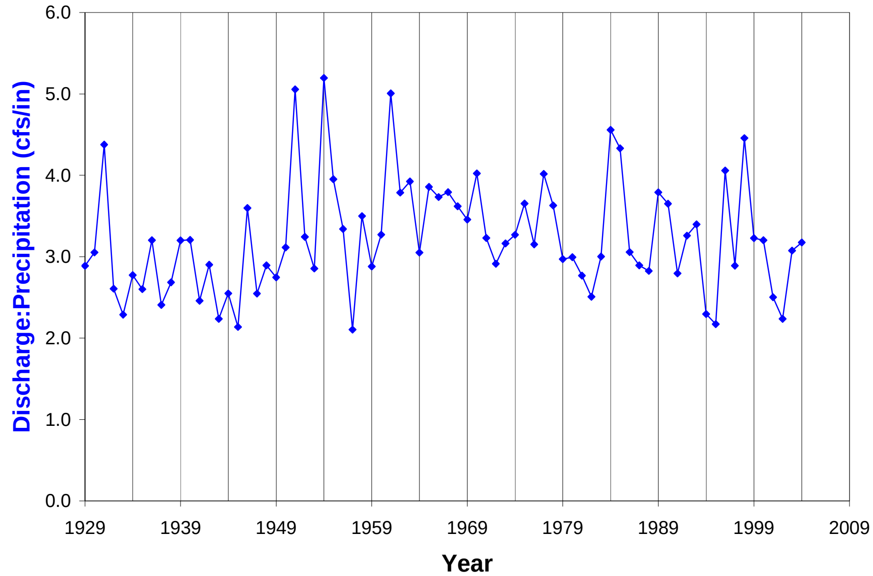

Figure 5. Time series plot of Weeki Wachee Spring annual discharge:precipitation ratio.

One potential explanation for the lack of a strong relationship between groundwater pumpage and spring discharge is the pumpage data itself. The surface drainage basin for Weeki Wachee Spring covers ~38 square miles (mi^2), but the springshed is much larger (~260 mi^2) and extends into adjacent Pasco County. This means that land use, water management practices and hydrogeological conditions outside the local area are affecting the Weeki Wachee Spring discharge. The District's report indicates that the pumpage data are from Hernando County, yet the largest wellfields in or near the springshed, in terms of pumpage, are in Pasco County. Therefore, inclusion of the Pasco County pumpage data, coupled with appropriate response lags, might strengthen the apparent relationships. Moreover, a thorough characterization of the springshed, rather than the surface-water basin, will assist in establishing the background and basis for the District's development of MFLs for Weeki Wachee and the other springs in the system, as required by Florida statutes.

Regression Equations for Tide and Salinity

The District needed to develop regressions for predicting salinity in the system since many of the biological impacts of reduced flow are related to salinity. Initially the thinking was that the salinity regressions would likely have the tide at Bayport as an independent variable. Thus, a regression equation for the harmonic constituents of the tide at Bayport was developed (page 49, SWFWMD 2008). It appears that this equation contains an error of omission; that is, it omits the phase-lag term for each tidal constituent, which would be added to the time term. The tidal signal could have been removed by applying an approximate 60-hr low pass filter to the water level data. The addition of the two low frequency constituents is important because this seasonal water level change has been found to affect salinities in other Gulf Coast estuaries. However, in the final development of the salinity regression equation that was used by the District in determining the MFL, the predicted tide at Bayport was not used.

Before developing regression equations to predict salinity at a particular point on the WWRS and to predict the longitudinal location along the river of bottom isohalines, a regression analysis was undertaken to predict the salinity at Bayport. Various components were considered as independent variables (e.g., springflows, flow from the Withlacoochee River, Gulf tides, wind, etc.). It was found that springflows have virtually no impact on salinity at Bayport. Although a regression equation was developed with a coefficient of determination (r^2) of ~0.6, predicted salinity at Bayport was not included as an independent variable in the regressions for salinity in the WWRS.

Regressions were developed for salinity at a particular river location and for the location of a particular bottom isohaline. These ended up with the following equational forms:

$$\text{Salinity} = \beta_0 + \beta_1 * \text{Flow} + \beta_2 * R_{km}$$

$$R_{km} = \beta_0 + \beta_1 * \text{Flow} + \beta_2 * \text{Bottom Salinity Isohaline}$$

Obviously, many regression equation forms are possible; however, one particular form containing an auto-regressive salinity term with appropriate time lag is often used to improve salinity regression equations in estuarine systems. With this form of the equation it is simple to solve for one of the variables (e.g., flow) given values for the other two. This character of the isohaline equation was of great utility in determining the MFLs. The r^2 for the regression equation used to predict the location of an isohaline zone has a reasonable value of 0.66.

Nevertheless, a major concern with the salinity regression equation is that the salinity at the river mouth is not included as an independent variable. Although the analysis described in the District's report concluded that flow from Weeki Wachee Spring did not have a significant impact on salinity at the river's mouth near Bayport, the salinity level in the river system is obviously dependent on the salinity level in the nearshore Gulf waters. This is an important boundary condition in the numerical model, described below, which was applied to assess the impact of flow reductions on the thermal regime. The regression equation for the location of salinity isohalines is used extensively in determining what flows result in a 15% reduction of various biological resources. It seems clear to the Panel that boundary salinity at the river mouth should have been included as an independent variable in the predictive equations.

Application of the EFDC Numerical Model to WWRS

The Environmental Fluid Dynamics Code (EFDC), a three-dimensional finite difference hydrodynamic model, was applied to the WWRS by Applied Technology and Management, Inc. (ATM 2007). The purpose of the modeling effort was to determine the level of flow reduction that would result in a 15% reduction of the thermal regime that is tolerable by the West Indian manatees. Manatee habitat refuge areas and volumes were defined as waters that met the following criteria:

- Daily average temperatures were greater than 20° C over a critical 3-day period
- Passage for manatee was available upstream based upon District defined minimum depths

When conducting a review of numerical modeling, the review is initially focused on the following questions:

- Are the mathematical model's physics adequate for its intended use?
- Is the numerical grid adequate to resolve the spatial component?
- Are sufficient data available for model calibration and validation?
- Has model calibration and validation been achieved?

A Task Committee of the American Society of Civil Engineers (ASCE) is currently in the process of publishing a monograph describing model verification, calibration and validation. Verification is the process of demonstrating that the proper physical equations are correctly solved and that the computer code is free from errors. The EFDC is a well known model that is supported by the EPA and contains all the basic physics required to make hydrodynamic computations in estuaries and coastal areas. As such, users can be confident that the EFDC is a well-verified numerical hydrodynamic model. Calibration and validation are part of the user's application of the verified model's code to a particular water body. Specifically, calibration is the process of varying model parameters so that the simulation matches the observed data. In the strictest sense, validation is then the process of taking the calibrated model and applying it to a different data set in order to demonstrate its accuracy using the same model parameters set in the calibration phase.

In practice, the demarcation between calibration and validation can become a little fuzzy. If the model is calibrated to a relatively short data set (perhaps a month or two) that does not cover a period in which all processes governing the hydrodynamics of the water body occur, the model should be applied to a separate data set to make sure it is still working correctly. However, if the model simulation covers a long enough period of time (i.e., many months or even years) during which virtually all processes occur, if the model's parameters are within acceptable ranges, and if the parameters stay the same during the long simulation period, the case can be made that both calibration and validation have been achieved.

The Panel's comments on the calibration and validation of the EFDC model, as applied by ATM to the WWRS, are given below. These observations are based on results presented in the consultant's report "Impacts of Withdrawals on the Thermal Regime of the Weeki Wachee River" (ATM 2007).

The ATM report shows the curvilinear numerical grid in the horizontal plane (Figure 4-1) and with the river's bathymetry displayed on the grid (Figure 4-2). Strictly speaking, the EFDC is only applicable on grids that are completely orthogonal. It can be seen that the Weeki Wachee system grid is not totally orthogonal; however, there have been many applications of orthogonal grid-based models, such as the EFDC and the Princeton Ocean Model (POM), to computational grids that aren't totally orthogonal with satisfactory results. The length of grid cell sides in the horizontal dimension ranges from about 100 – 200 feet (30.5 – 61 meters, m). In the estuarine portion of the grid, there are 3 cells across the river's channel. The middle cell represents a central portion of the channel that is on the order of 6.6 – 9.8 feet (2 – 3 m) deep; whereas, the two lateral cells on either side represent shallow areas on the order of 3.3 feet (1 m) or less. The EFDC employs what is called a "sigma stretched grid" in the vertical dimension. This is a model grid where the top of the top layer follows the water surface and the bottom of the bottom layer follows the estuary's bathymetry. Four sigma layers were used in the model's application to WWRS.

The period from November 1, 2003 through February 28, 2004 was used in the calibration of the numerical model. Water surface elevation, salinity and temperature data were available to drive the Gulf boundary of the grid. Water discharge and temperature of the Weeki Wachee Spring were specified at the head of the river. In addition, a constant discharge of 45 cfs and a constant temperature of 73.4 ºF (23 ºC) were specified at Mud Spring. Although salinity at Mud Spring can often be quite high (e.g., 20 parts per thousand salt, ppt, or about 57% seawater salinity), there is no discussion in the ATM report about an assumed or measured salinity boundary condition at Mud Spring. If the modelers assumed that artesian groundwater discharges from Mud Spring were fresh, then this could be a serious error.

Interior data for comparison with model results were available at 3 stations. Water surface elevation, salinity, and temperature were available at Station No. 02310551 (river kilometer 2.3 = R_{km} 2.3). At Stations Nos. 02310545 (R_{km} 3.6) and 02310530 (R_{km} 7.3) only water surface elevations were available. In the ATM report, Figure 3.12 clearly shows that the tide is essentially damped out at Station No. 02310530, 4.5 miles (7.3 km) above the river's mouth, which is expected from the river's slope over the distance inland from the Gulf of Mexico.

Figures 4.11 and 4.12 in the ATM report show the comparison of computed water elevations with the observed data at R_{km} 3.6 and R_{km} 2.3, respectively. Although it is difficult to see the comparison very well in these plots because of the compressed time scale, the comparison does not appear to be very good. In addition, the ATM report states, without explanation, that at R_{km} 7.3 (Station No. 02310530) the model still computes a strong tide, although the tide at this point should be essentially damped out.

Figure 3-2 in the ATM report shows the bottom elevation along the river, while Figures 3.10 and 3.12 show observed water surface elevations. These graphs reveal a rather strong slope in the water surface from R_{km} 2.3 to 7.3. This slope is on the order of 3 – 4 m (9.8 – 13.1 ft) over a distance of 5 km (3.1 miles). This significant slope in the water surface probably results in the observation that the tide is mostly dampened at Station No. 02310530 (R_{km} 7.3). Unfortunately, the discordant bathymetries shown in Figures 3-2 and 4-2 of the ATM report suggest by comparison that the impact of this slope is not included in the EFDC model, another potentially serious error.

EFDC was developed for application in estuarine and coastal areas. In those areas, when starting the model "cold," the water surface is assumed to be flat. If the model's application to the WWRS was set up to have a flat water surface as the initial condition, then the riverine portion will not behave correctly. The ATM report does not show a plot of the water surface elevation at the head of the river, but the Panel suspects that the model functions such that the tide propagates all the way up the river and, thus, the model's calibration for water surface elevation is questionable.

ATM report Figures 4.13a and 4.13b show comparisons of computed and observed salinities at R_{km} 2.3 (Station No. 02310551). At this point close to the Gulf, the salinity is characteristically "spiky" as saline Gulf water moves in on flood tides and then moves out on the ebb each day. The time series plots indicate that the comparison of observed and predicted salinities is not very good in a dynamic sense, with the model under-predicting salinity levels at a point fairly close to the mouth of the river and the influence of the Gulf. The Panel believes that at least some of this problem with salinity simulation may be due to the numerical grid and the Mud Spring boundary condition.

In a hydrodynamic model study, one generally makes runs on grids with varying resolution to determine the impact of the grid on the accuracy of the solution. Apparently, this was not done, or at least not reported, in the present study. While the longitudinal resolution of the horizontal dimension is probably sufficient in the computational grid (Figure 4-1, ATM 2007), the Panel believes that the number of sigma layers should have been varied to understand the impact of using more than 4 layers on the model's solution.

Another potential issue with the numerical grid relates to what is commonly called the "sigma problem." When applying a model using a sigma stretched grid to represent the vertical dimension in an estuary with a channel having shallow areas on the sides, false motions of streamflow can occur along with false horizontal diffusion. If the water column is stratified in the channel by fresher water overriding more saline water, the important stratification and resulting density currents can be eroded away during long term simulations. It is widely recognized among modelers that a substantial amount of lateral resolution in the horizontal dimension of the model's grid is required to minimize this problem. As noted above, the EFDC model application to the WWRS is only three cells wide. Since only the last few kilometers of the river are estuarine, and since vertical stratification of salinity in the water column doesn't appear to be large in most of the river, the "sigma problem" may be small yet still play a role in the salinity simulations.

The agreement between computed and recorded temperatures at Station No. 02310551, 2.3 km (1.4 miles) above the river's mouth, is generally fair (Figures 4.14a and 4.14b, ATM 2007). However, matching temperature in a model that does not have the hydrodynamics well calibrated is easier than matching salinity since surface heat exchange plays a big role in the temperature of the water body. Perhaps the study's focus on estimating the temperature refuge area for Manatees is why a greater effort was not made to improve the simulation of circulation and salinity patterns in the WWRS.

Determining the Impact of Flow Reductions on the Thermal Regime

In the application of the numerical model to determine the impact of flow reductions on the thermal regime, an analysis of the air temperature record at Weeki Wachee Spring was performed to select a critical condition period. The winter of 2000 – 2001 was identified as a critical condition period when the mean daily air temperatures ranged as low as 1.7 ºC (35.1 ºF). Since temperatures at Bayport were not available to drive the boundary condition, a regression equation was developed ($r^2 = 0.90$) which relates water temperature at Bayport to three-day average air temperatures as the independent variable. It is possible that testing different averaging intervals and including the day of the year as an independent variable might have yielded even better results.

Two baseline conditions of high and low flows were simulated over the representative period from October 2004 to March 2005 when temperatures might become critical for Manatee health and survival. With each baseline condition, Weeki Wachee flows were reduced to determine the impact on the river's thermal regime in terms of the volume and area of water with a three-day average temperature ≥ 20 ºC (≥ 68 ºF). Only those cells with a minimum depth greater than 3.8 ft (1.2 m) were considered adequate for the Manatee. As can be seen in Figure 6.1 of the ATM report, only a few of the cells in the numerical model actually met the 3.8 ft criterion at minimum tide. It was found that a 10% reduction in the high flow scenario reduced the volume by more than 15%; however, only a 5% reduction in the low flow scenario reduced the volume of the thermal refuge by more than 15%. Nevertheless, even when the 15% loss limit is violated, it appears that the WWRS can support far more manatees than have ever been observed to utilize the river's thermal refuge. This outcome tends to negate, at least in part, the uncertainties the Panel found in the presented EDFC model application.

Water Quality

The District merged and integrated some 23 disparate datasets spanning the 1984 through 2005 period of record into one comprehensive database. As such, the District is to be commended for its effort to use the best available data. On the other hand, the District's water quality data analysis was rather cursory. The District did provide a decent discussion of the overall chemical characteristics of the system; however, only one graph was provided (i.e., nitrate versus salinity) and that was for the entire period of record. The Panel would like to have seen some representative constituent concentration – salinity plots for other variables over specific sampling events, seasons and flow regimes.

The District's primary conclusion about water quality was that nitrate had increased dramatically in the artesian spring discharges over time. This is consistent with studies of other spring systems in Florida and does not bode well for future water quality conditions. As reported by the District (SWFWMD 2008), the saving grace for the WWRS is that total phosphorous levels are almost always below 0.01 parts per million, ppm (0.3 μM). Therefore, primary (plant) production in these ecosystems is strongly phosphorus-limited causing phytoplankton chlorophyll-*a* concentrations to remain very low (~1.0 parts per billion, ppb) and the water to be clear. Nevertheless, it is important to recognize that any increase in phosphorus loading will cause a tremendous increase in phytoplankton biomass (i.e., algal blooms), probably resulting in low dissolved oxygen (hypoxic) events that can greatly increase the mortality of fish and other aquatic animals.

The District did not include water quality *per se* in setting the MFL. This was because, unlike many other riverine estuaries, the limiting nutrient (i.e., phosphorus) is supplied from the marine end of the system. As a result, it is important that the MFL not be set too low because the resulting encroachment of marine waters into the WWRS will also bring in phosphorus. If the nitrogen-phosphorus mixing zone occurs within the river, then it will promote increased phytoplankton biomass and all the inherent problems that come with excessive nutrient enrichment (i.e., eutrophication) of tidal river segments.

Submerged Aquatic Vegetation

There are five generally accepted natural controllers affecting the distribution and production of submerged aquatic vegetation (SAV): light penetration, salinity regime, sediment physical characteristics, sediment depth, and dissolved nutrient regime. Light is generally the primary factor in SAV production, while the other factors are usually considered more important in species distribution. Only species distribution as related to salinity was presented by the District, and only from the 2005 survey, in spite of the fact that there have been four surveys of SAV in the WWRS since 1995.

According to the MFL report (SWFWMD 2008), the District originally wanted to develop a resource criterion based on salinity but found that salinity was not the dominant factor. As a result, they did not pursue any type of habitat requirements or modeling using other factors. The Panel suggests that the District consider putting more effort into addressing SAV habitat requirements so that they can be included in the MFLs of coastal waters associated with tidal (estuarine) river segments.

Benthic Organisms

Bottom-dwelling organisms, such as aquatic insects, worms, mollusks and crustaceans, occupy an important intermediate level in an estuary's food-chain between primary producers (e.g., phytoplankton and vascular plants) and higher levels of secondary production (e.g., fishes). Benthic organisms are generally considered to be sessile or weakly motile, and are often used as indicators of change in water bodies. While benthic community structure typically is influenced more by salinity and substrates, benthic production is most often a function of food generated from nutrients. However, high nutrient levels (i.e., eutrophication) can cause low dissolved oxygen (hypoxia) to occur near the bottom, which results in higher mortalities and can drastically limit benthic production.

The WWRS is dominated by spring discharges that are more or less of constant flow and temperature. In addition, the river exhibits low nutrient levels (i.e., oligotrophic conditions), causing it to have low levels of primary production. Since the observed water quality (i.e., salinity, temperature and nutrient) variations in the WWRS are relatively small, the benthic communities are not normally exposed to widely variable conditions. Nevertheless, analysis of pooled benthic data from 1984-1985 (Culter 1986) and 2005 (Janicki Environmental 2006) did produce significant relationships between salinity and benthic abundance, diversity and species (taxa) richness in the WWRS. If the salinities typically found in the downstream areas with fine sediments utilized by the benthic infauna were displaced upstream into areas with hard limestone substrates as a result of flow reductions, then the effects on the benthos would be magnified.

Janicki Environmental (2007) also compiled and reanalyzed benthic data from samples taken in 12 tidal rivers in Southwest Florida over a 20+ year period of record using cluster analysis and principal components analysis. Univariate logistic regressions were used additionally to estimate the probability of species occurrence as a function of salinity. The resulting salinity optimums and tolerances for selected benthic species were considered in the District's MFL determination, particularly in relation to flow reductions that could potentially reduce the availability of low (< 7 ppt, oligohaline) and medium (7-18 ppt, mesohaline) salinity habitats by more than 15%.

Mollusks

Mollusk surveys of the WWRS were conducted by Estevez (2005). While the total number of taxa found, only 15, was similar to that previously reported by Culter (1986), the overall species diversity and abundance in the WWRS is low, probably for the same reasons discussed above for the benthos; namely, oligotrophic waters and the prevalence of rocky substrates. Relative to 8 other tidal rivers along the west coast of Florida analyzed by Montagna (2006), the WWRS exhibits a fauna so depauperate that it makes analysis and interpretation of species data relative to flows and associated measures difficult and largely unsatisfactory. Nevertheless, Estevez (2005) suggests that significant reductions in flows could cause infilling of the lower river bottom with algae and other organic material that would create very unfavorable habitat conditions for mollusks and other benthic organisms. In the end, the District utilized significant relationships between salinity and the species abundance of two intertidal species (*Polymesoda caroliniana* and *Littoraria irrorata*) in the lower river, and the oyster (*Crossostrea virginicia*) at the mouth of the river, to compute a 15% loss of peak abundance for these species under reduced WWRS flows.

Fish and Planktonic Invertebrates

Matheson et al. (2005) sampled fishes by seine and trawl, and planktonic organisms by plankton net from May 2003 through December 2004. Unfortunately, this sampling occurred during a period when WWRS flows were higher than the mean average flow for the prior 9 years. Determining a low flow need during a high flow period is virtually impossible. Further, this difficulty is enhanced by the fact that the estuarine portion of the river is very compressed and extends upstream less than 2 km (1.2 miles) from the river's mouth under normal conditions. As a result, important fish species, such as the bay anchovy and sand seatrout that typically dominate fish assemblages in estuarine (tidal) river segments of the region, were in extremely low abundance in the WWRS.

Zooplankton net samples were dominated by larval fishes (killifish, gobies and blennies) and larval invertebrates (crabs, shrimp and mysids). Matheson et al. (2005) report that planktonic invertebrates that were common in other tidal rivers of the region were uncommon or even absent in the WWRS, again probably because of the high flow period sampled. One interesting capture in the upper river involved two specimens of the rare mysid, *Spelaeomysis*, a species normally associated with underground aquifers. Invertebrate collections by seine in the WWRS were dominated by grass shrimp, daggerblade shrimp and blue crabs.

The District attempted to relate fish and zooplankton abundance, and location of maximum occurrence, to flows in the WWRS; however, the results were generally weak with coefficients of determination below the District's assumed acceptable threshold (i.e., $r^2 \geq 0.30$). The most interesting significant positive relationship found was that between the abundance of harpacticoid copepods, which are prey (food) for young estuarine-dependent fishes, and 120-day lagged flows on the WWRS. Unfortunately, the fish and invertebrate analyses were not used by the District to determine the WWRS MFL because of the confounding high flows underlying the sampling period and the unusual or unreasonable responses suggested by most of the statistical regressions, including the predicted elimination of typical estuarine species under more normal (e.g., median) flow conditions.

Freshwater Habitats

Approximately 1.2 miles (2 km) above the mouth of the WWRS the estuarine portion of the river gives way to a freshwater reach that continues upstream to the headwaters at Weeki Wachee Spring. The District evaluated this segment of the WWRS using the Physical Habitat Simulation (PHABSIM) Model. Specifically, a time-series analysis was conducted on the 1967 − 2004 period of record. Using habitat suitability curves from the PHABSIM, freshwater flow needs were established that met a goal of maintaining 85% of the specific habitat requirements of largemouth bass, spotted and bluegill sunfishes, and the diversity of benthic macroinvertebrates. Although the PHABSIM has been criticized as being error-prone due to its low level methods and hydraulics, and somewhat controversial because the associated habitat suitability curves lack the sophistication to deal with common species interactions (e.g., competitive displacements, predator-prey), and other ecological relationships among freshwater species, the Panel accepts the District's rationale for using this method to estimate flow reductions in the freshwater reach of the study area that result in a 15% loss in each of the 13 habitat measures tested.

Integration of Results to Determine WWRS MFL

The District used 16 of the best or most applicable sets of results discussed above to establish flow reductions that met threshold criteria for freshwater habitat, salinity habitat, benthos and mollusks (Table 8-1, SWFWMD 2008). Allowable streamflow reductions in the low flow seasons (Block 1) varied from 6.0% for 15 ppt salinity habitat to 15.8% for 2 ppt salinity bottom habitat. Similarly, allowable streamflow reductions during the higher flow seasons (Block 3) varied from 4.2% for 15 ppt salinity habitat (based on extrapolation into Gulf waters) to 17.2% for 2 ppt salinity bottom habitat.

In addition, the District presents a graphical summary of the results (Figure 8-1, SWFWMD 2008) that includes 32 measures of resource loss due to streamflow reductions. Several of these, particularly those that are most conservative, involve extrapolations beyond the river reach of concern, including some into the Gulf of Mexico. Because they are beyond the domain of the regressions, or were biased by high flow study conditions, the District decided to base the MFL for the WWRS on the mean percent-of-flow reduction allowed for seasonal Block 1 (10.1 %

flow reduction) and seasonal Block 3 (10.7% flow reduction). In the end, the District recommended that both the wet and dry season flows for the WWRS be maintained at 90% of the baseline (read: naturalized) flows after the effects of human usage have been eliminated from the flow record. The fact that existing human usage is presently at or near the 10% limit (Figure 2-18, SWFWMD 2008) means that little or no additional flow reductions will be allowed from groundwater use. After review, the Panel concurs with this recommendation.

Additional Spring MFL Development

The report does not develop background information necessary to characterize groundwater conditions relative to the four springs. If the District decides to revise the report to support MFLs for the springs, then a better discussion of the groundwater system including regional (springshed) geology, hydrogeology, karsts, and groundwater quality is needed. For example, considerable work has been done by the District on the position of the salt-water transition zone, including potentiometric and salinity analyses. Discussions of how the potentiometric surface has varied over time will assist in developing the historic changes in spring flow. Further, characterization of coastal potentiometric and interface configurations will assist in understanding capture zones and why the springs vary in salinity. The effects of tides (if any) on groundwater elevations should also be considered. This is especially important with respect to the well used to characterize discharges of the Weeki Wachee Spring.

Finally, the Panel doubts that the MFLs would affect Hospital Hole, a major karst feature with stratified water quality located within the Weeki Wachee River. However, since Hospital Hole is a popular dive site that provides important evidence concerning the saltwater transition zone, it also should be discussed.

ERRATA and EDITORIAL COMMENTS

Page	Paragraph	Line	Comment
5	2		This paragraph deals with an ideal situation where there is a clear "break point" that identifies significant harm. The discussion is problematic because only the most limiting criterion would have a break point that represents significant harm. Other break points might include criteria that are subject to the harm standard or may not represent any significant diminution in ecological function at all. Also, this paragraph sets up the expectation that a break point exists and, if it is not present, some readers will feel this is either indicative of the District's failure to identify significant harm or that there is no significant harm to be identified in the system. Perhaps this paragraph could be revised in such a way as to set up expectations that are consistent with the report's results.
6	2	11	It is preferable to cite the Texas methodology as Powell et al. (2002). Also, note that this scientific journal paper illustrates the methods by using their application to Galveston Bay and the Trinity-San Jacinto Estuary.
6	3		The paragraph speaks to biological data being collected at near natural flows and not at the point of resource collapse. As written it suggests that significant harm corresponds with resource collapse. Of course the whole purpose of establishing significant harm is to prevent resource collapse and, hopefully, the District's standard for "harm" prevents it from permitting anything close to flows or levels that could cause resource collapse.
7	2		In complex environmental multivariate systems, it is rare to get high correlation coefficients or coefficients of determination. Even so, many scientists believe that the Comrey and Lee (1992) correlation coefficient classification scheme is pretty weak and should not be relied upon as a benchmark for quality of goodness of fit. Significance levels have been developed for bivariate and multivariate coefficients of determination and correlation coefficients, and these would be better for discussions of statistical significance. Indeed, Comrey and Lee's thresholds for coefficients of determination may not be adequate descriptors of the quality or goodness of fit of the District's data.

Page	Paragraph	Line	Comment
8			As a practical matter, the number of observations per parameter is case and variance driven, and is not applicable to every situation. Further, emphasizing the fact that scientists working on "real world" problems in nature rarely have enough samples to meet the criteria listed here opens the MFL determination for criticism and weakens the strength of an otherwise excellent report. Perhaps it would be better to simply discuss the significance of the correlations based on alpha levels or probabilities derived from goodness-of-fit criteria and let the number of degrees of freedom and the tests for significance in the parametric and non-parametric statistics drive whether or not the observations are significant and useful.
9			Section 1.5 summarizes the District's approach for developing minimum flows for riverine and estuarine systems. If the District agrees with the Panel's suggestion to revise its report so that it can stand for the MFLs for the springs as well, then a discussion of the application to the springs needs to be included as well.
10	2		PHABSIM is not an "ecological model" *per se*. Rather, in its original formulation, it was a simplified and error-prone one dimensional method to estimate amounts of wetted usable area (read: aquatic habitat) in Rocky mountain coldwater streams. In its current form, the PHABSIM model represents, at best, a quasi-two dimensional technique that has largely been replaced with more advanced and accurate hydraulic models that can be applied with a lot less brute force labor.
12	5		While the report notes that English units are used in accordance with the Governor's requirement for simplicity in writing, in many cases metric units still are used rather than common English units. The District noted two exceptions − distance, expressed in kilometers, and water depth, expressed in meters. Many readers would probably say these are the wrong exceptions, finding river miles and depth in feet much more readily understandable by the public. Metric units should probably be reserved for chemical concentrations and related water quality parameters that are not familiar to the general public anyway.

Page	Paragraph	Line	Comment
14			Some additional things that the District should consider for inclusion are, in no particular order: • Whether or not the springs serve act as estavelles and backflow during storm surges and the like. Discuss the cave system and the cave exploration that has been undertaken by Underwater Research. • Note that there were issues concerning dredging part of the Weeki Wachee River in 2004 by the Attraction. • Note describing the 1976 turbidity event, what was determined to be the cause, and how it relates to the closed drainage basins that exist in the Spring Hill area. • Briefly discuss the Weeki Wachee Attraction and its impact on both water quality and water use in the area. • If there have been any dye tests or other testing to make connections between sinkholes or water wells and the springs, then those should be discussed. • Discuss the distribution and sources of nitrate. Time series showing nitrate concentrations over time is already within the report and could be pulled in as part of the discussion of the springs. • Discuss the dimensions and geological conditions of each of the four named springs in this system. • Discuss the internally drained basins and the distribution of sinkholes and karsts within the springshed. • Provide an overall geology discussion that includes the geological strata that constitute the aquifer system(s) in the area and, equally important, the large Plio-Pleistocene sand dunes that underlie this Spring Hill development.

Page	Paragraph	Line	Comment
14			• Discuss the Kohout circulation system at the salt-water transition zone and why Salt Springs and Mud Springs are saline. This discussion could include the work done by USF on the depth to the saltwater transition zone in the area and the pattern of the regional potentiometric surface, which shows reentrants where the freshwater springs are located and salients where the saltwater springs are located. • Discuss the flow pattern of water to the springs based on the potentiometric surface. This should be coupled with the springshed map. • Discuss the effects of tides, not only in terms of salinity, but in terms of water levels in the groundwater system and in the spring. The effect of tides on spring discharge and the discharge record is important. How do tides affect the discharge measurements from the spring? Is there any chance of aliasing or other uncertainties in the discharge record? • The effects of land use and the location of well fields should be included as part of the springshed description. Land uses in the near-field areas of the spring are discussed, but not in detail. • The attendance and history of the Weeki Wachee Attraction should probably lead to a discussion of the number of bathers in the spring and especially the maximum bathing load and its relationship to spring discharge.
14	1	10	The definition of a first magnitude (not “order”) spring in Florida is a median discharge of 100 cfs or greater based on historical data (Copeland 2003). The definition provided in the District’s report is somewhat erroneous in that it is described in terms of an “average flow.”

Page	Paragraph	Line	Comment
21			The reliance on just Wolf (1990) and Knochenmus and Yobbi (2001) as the only sources for Section 2-3 is somewhat disappointing. The District has published a number of excellent works that include significant information about the springshed. The Weeki Wachee springs and watershed have also been studied by the Florida Geological Survey and the USGS. Also, if this document is to deal with the MFLs for Twin Dees and Weeki Wachee (and perhaps Mud and Salt Springs as well), then considerably more information needs to be provided relative to the springshed and the regional geology. Again, while Mud and Salt Springs are mentioned several times prior to this section, we do not know what the magnitude of the springs are and whether or not they must be considered as part of the MFL process under Florida statutes. Perhaps this should be addressed in the report's introduction. In addition, the District has funded a number of geophysical studies through the University of South Florida that document a salt-water transition zone along the Springs Coast. The position of the salt-water transition zone is important to know because it explains why Mud and Salt springs are salty and why Weeki Wachee Spring is not. Also, the potentiometric surfaces that are developed twice a year by the District in cooperation with the U.S. Geological Survey show reentrants and salients that correspond to the saline- and fresh-water springs along the coast. It is important to understand and explain this plumbing system in simple terms because it affects the behavior of the river, the estuary and the springs.

Page	Paragraph	Line	Comment
21	1		The platform to which the District's report is referring is known as the "Florida Platform" and that term should be utilized throughout because there are other names for other features that utilize the term platform in Florida. Also, the sentence that starts with "The limestone and dolomite…" should read "The near surface limestone and dolostone…." Dolostone is a better term than dolomite for the rock. These strata were deposited between the beginning of the Eocene Epoch at 55 (not 58) million years ago and early Miocene time ending at approximately 15 million years ago. This would include the Tampa member of the Peace River formation. The Miocene Epoch extended to about 5 million years ago and was characterized by deposition of sand and clay deposits that are developed in portions of the springshed. These and the Tampa Member constitute the Hawthorn Group. The Floridan Aquifer is that portion of the Eocene to Miocene section that consists of limestone and dolostone, but is not the only material deposited during the Eocene and Miocene Epochs.
21	2		This section cries for a map showing the geomorphic features within the springshed. There are several that are very important including the Brooksville Ridge and the coastal dunes that underlie much of the modern town of Spring Hill.
22			The regressions shown in Figure 2-7 were made by the USGS to estimate spring discharges from water levels in the Weeki Wachee Well. It is important to know whether or not changes in the rating between the Weeki Wachee Well and discharge at the springs has any effect on the long term data. Obviously, the differences in the regressions over time suggest that something has changed. What was it?
26	1	13	The sentence states that Figure 2-13 depicts the pumpage in Hernando County as an example of the accumulation of pumpage within the springshed. The District should consider adding pumpage in Pasco county to this analysis since large wellfields that are within the springshed are located in Pasco County. The pumpage reflected in Figure 2-13 apparently does not include these wellfields and, therefore, minimizes the issue of pumpage as a controlling factor on the discharge from the spring.

Page	Paragraph	Line	Comment
26			The implication of the regression line in Figure 2-12 is that it represents a reduction in flow from the spring(s). It's important to ask the question about how much of any trend that is present in the post-1960 data is reflective of pumpage as opposed to climatic events. 1960 was a significant tipping point in terms of rainfall as well as water levels in the area. There is a wide-spread pattern similar to the Weeki Wachee discharge pattern with a peak in water levels and/or discharge in the 1960s all the way from the Georgia line to the southern part of the District's service area. You can relate that pattern to rainfall and, in some cases, to changes in gages, measurement methods, and human activities. To simply place a regression line on a graph and then jump into talking about change from 1960 to present begs the question as to why the discharge increased from 1930 to 1960. This is also a good place to talk about the AMO and the different process that may affect water levels and discharges.
27	1	4	Remove the word "and" at the end of the line.
27	1	5	Location of the Sharpes Ferry Well, in relationship to the Weeki Wachee Well and Spring, should be given. Also provide some justification for saying that it is unimpacted.
30-31			References for the Northern Tampa Bay Model and Northern District Model are needed here.
31	2	5	If UFA stands for "upper Floridan aquifer," does that mean SAS stands for "surficial aquifer system?"
32	1	2	Why is the average 17 cfs of anthropogenic impact linearly proportioned over the 1961-2004 period? Why not allocate proportions according to the increases in pumpage or rainfall patterns? Does this mean that years with high discharge have the same percent flow reduction as low-flow years? This seems doubtful.
33			The District used three different methods for estimating a baseline flow condition that is as free of anthropogenic impacts as possible. This is variously referred to as "normalized" annual discharge, "standardization" of springflows, and "adjusted" flows. However, most hydrologists would recognize the adjusted discharge plot in Figure 2-17 as an attempt to create a "naturalized" flow record, wherein human impacts have been removed by adding back to the observed record any water withdrawals, such as pumpage, and subtracting out any water additions, such as wastewater discharges that could supplement aquifer recharge.
35	2	6	Indicate that the 12.7 cfs pumpage adjustment is an average and that it is being added to flow blocks based on medians. The appropriateness or effect of mixing these central tendency values is not addressed in the report.

Page	Paragraph	Line	Comment
36	2	7	Replace word "allied" with "applied."
44			An attempt should probably be made to explain the "spike" in % organic sediment of Weeki center line (red) at R_{km} ~ 1.5.
59	4	1	The use of Cox polynomials (Cox 1967, Jaegar 1973) represents an older method of estimating salinity from conductivity measurements that has an accuracy of about ± 0.003, where the error is due to seawater constituents, such as SiO_2, which cause changes in density but no change in conductivity. In 1978, the Practical Salinity Scale (PSS) was introduced to refine the traditional definition of salinity in uniform terms of a new international equation of state for seawater based on the conductivity ratio of a seawater sample to a standard KCl solution (Lewis and Perkin 1978) with an error of ± 0.001 across the world's oceans (Hill et al. 1989). However, errors rise to ± 0.01 or more in the lower salinity waters of coastal bays and estuaries where the use of the PSS caused many concerns (Parsons 1982). Moreover, since ratios have no units, Millero and Poisson (1981) noted that the new PSS is dimensionless and scales such as parts per thousand (either ppt or ‰) should not be used. The correct way to report practical salinity is as a number (e.g., the sample had a salinity of 35). This has caused some confusion and even led to the introduction of another scale referred to as "practical salinity units" (psu) that is also technically invalid. Although considered incorrect by many oceanographers and scientific journal editors, the Panel's peer review used the same convention as the District in this report and referred to salinity values as ppt with apologies to Millero and Poisson, and virtually all the major oceanographic groups (i.e., ASLO, CERF, IAPSO, ICES, IOC, UNESCO, SCOR, etc.).
71	1		The text refers to Figures 5-1a and 5-1b; however, the figure title on page 72 only refers to "top" and "bottom" panels, and the figures themselves are not labeled.

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