

Final Report

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Peer Review of the Prevatt Lake HSPF Model

Prepared for:



The St. Johns River
Water Management District

Prepared by:



August 2009



Prevatt Lake HSPF Model Review

Prevatt Lake is located in Orange County, two miles north of Apopka in Wekiva Springs State Park. To support the development of Minimum Flows and Levels (MFLs), the Hydrologic Simulation Program for Fortran (HSPF) with the use of Special Actions was selected as the preferred hydrologic model for this system because it meets the selection criteria established for the MFL program (CDM, 2001). HSPF is a comprehensive hydrologic and water quality model that is typically used to perform continuous simulations of hydrology. It is included in the EPA BASINS package, and it can use Arc/Info coverages, National Hydraulic Datasets (NHD), and plot the model results in a graphical environment. It is well documented and supported by the EPA.

This technical memorandum evaluates the current HSPF model for Prevatt Lake with regard to model selection, input data, calibration, and simulation results. The input data and model assumptions are examined, and the potential impacts of these assumptions on the MFL will be discussed.

Task A: Assess adequacy of hydro-meteorological records in terms of quality, spatial coverage, and length of record.

- 1) Was "best information available" utilized to develop the hydrologic model?
- 2) Are there any deficiencies regarding data availability?

There is a limited amount of information available for Prevatt Lake. Given the limited data, the best available information was utilized to develop the model. For the construction and calibration of the model, the following data was utilized:

Daily Rainfall. Daily rainfall totals were utilized for the model calibration and long term simulation. The calibration of the model utilized an aggregated daily rainfall recorded at Wekiva Springs and the City of Sanford. It appears the long term simulation utilized the same stations. The data processing of the rainfall seems to be produced with common engineering practices. The use of daily rain data will not allow the pervious land segments to produce runoff since the input intensities (averaged over the entire day) will never exceed typical soil infiltration rates. To compensate, either more runoff will be produced from the impervious basin or the soil infiltration will be unrealistically low. Compensating for poor physical representation in the model will reduce the predictive capability of the model.

1995 Land Use. Land use distributions from 1995 were utilized in order to determine the amount of impervious area draining into the lake. The various pervious land use conditions were lumped together forming one lumped parameter computational element. This parameter lumping will average the hydrologic properties together. The lumped parameters will also reduce the predictive capability of the model. Given the lack of data, the parameter lumping is justified. If calibration data (such as flows) were available, the use of hydrologic response units (HRUs) would reduce the effects of parameter lumping and improve the model representation.



Overall Basin Boundary. The USGS 5 foot contour topographic maps were utilized to develop the overall watershed of the Prevatt Lake. Using the 5 foot contours to define the basin gives a good overall description of the basin. Given the shallow slopes in Florida, higher resolution is desired. For example, the road crown for 435 may serve as a hydrologic divide unless a culvert is present to allow the water to pass under the road. The Prevatt Lake basin also shows signs of additional storage. The wetlands west of Prevatt Lake can provide a great deal of basin storage. This storage can significantly alter the basin response upstream of the wetlands. This storage can impact the models only source of basin discharge to the lake which is the impervious land on the western end of the basin (upstream of the wetland storage).

Soils. The Orange County Soils Survey was used to approximate the infiltration rates and storage capacity for the pervious basin. The basin is treated as a lumped parameter, so the soil properties were adjusted in the calibration of the model. Given the lack of calibration data this is an acceptable engineering methodology.

Best Available Bathymetry. Bathymetry was not available for Prevatt Lake. The stage, storage capacity, discharge curve was derived from the available stage data and aerial maps. Give the lack of data, common engineering practices were followed. A site visit of the lake outfall was made helping estimate the invert elevation (again no survey data) and the discharge capacity.

Observed Stages at Prevatt Lake. Stage data was available for more than 40 years. The interval of the collected stage data varied from sporadic to regular monthly. This represents the best available stage data for Prevatt Lake and will serve as data for the calibration targets. No discharges into or out of the lake are available.

Lake Outlet. There is no observed data at the Prevatt Lake Outlet. The photograph in the report clearly shows stain lines in the exit culverts, making it clear that the discharge is fairly regular. The uncertainty for this component of the model construction is high given the lack of data.

Potentiometric Surface. The model conceptualization includes lake leakage to the regional aquifer. HSPF only includes local contribution from the watershed. Through HSPF special actions, leakage to the regional aquifer was included in the model conceptualization and calibration. Well S-125 is located 7.5 miles from the lake. It was used as a measure of the head in the aquifer and therefore the gradient from the lake to the aquifer. It was estimated that the well would have to be shifted by 4 feet to more accurately represent the Floridan elevation under the lake. Common engineering practices were followed to obtain the best available data.

Pan ET Data. Pan evaporation data is the measurement of evaporation from a standard size pan. From the Pan ET measurements an estimate can be made to atmospheric potential ET (PET). Usually this is done by simply factoring the Pan ET by approximately .7-.8 to yield PET. The PET is then used by the models to simulate the Actual Evapotranspiration (AET). The AET is always less than PET because it is limited by available moisture and plant types. For these reasons hydrologic models are not always sensitive to PET data as it is the available moisture and the plant communities that control the AET or ET flux in the water balance.



There are some discrepancies when it comes to the PET used in the HPSF model. First, on June 7, 1992 the PET in the model was 1.42 inches, as shown in Figure 1. Clearly this value is erroneous. Also, the graph clearly shows a discontinuity in 1976 that displays an unusual trend towards increased PET rates. This unusual behavior might be related in part to the scaling of PET in the winter months as described in the report. It seems if the Lisbon gauge needs such extensive corrections, another source of PET data should be used.

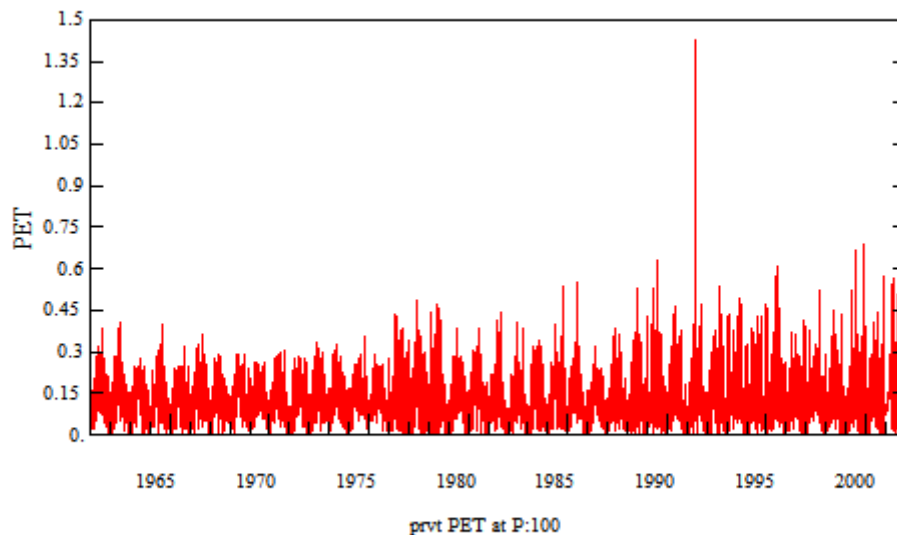


Figure 1. PET input time series

Task B: Assess methods and procedures for data analysis.

- 1) Are the analytical methods and procedures appropriate?
- 2) Are there any deficiencies and/or errors in the analytical methods?

Model Conceptualization. Overall, the analytical methods and procedures utilized were appropriate and used sound engineering principles. When conceptualizing a model, the available data and the ultimate purpose of the model should be considered. HSPF is a numerical hydrologic model that simulates rainfall-runoff while accounting for interception, evapotranspiration, soil moisture, baseflow, infiltration, and routing of runoff into the stream system. HSPF is well documented and well accepted in the modeling community. The model was developed and support by the USEPA CEAM. HSPF has been applied to many environmental flows, water supply, and general watershed modeling applications. This is an appropriate model selection for the current purpose given the available data, however, given the complexity of the model and the lack of observed data there will be associated uncertainties.

The conceptualization of the model included 2 basins (1 pervious and 1 impervious) draining into a reach/reservoir representing Prevatt Lake. Dividing the computation of seperate land uses is a good engineering practice to follow. Lumping regions of different hydrologic processes, such as



pervious and impervious, will produce very poor results. From the lake, water was routed to the outfall using the estimated stage discharge relationship. One seepage sink was computed using special actions. This leakage was represented as a negative inflow to the lake.

There were several assumptions with regard to the conceptualization of the model. These assumptions include the following:

- Baseflow from outside the immediate basin is small compared to the overall water budget. Despite this assumption of the model, the inclusion of the groundwater fluxes from the potentiometric surface does account for the regional water budget and therefore flows from outside the immediate basin.
- Bathymetry or the lakes stage storage relationship was estimated using only the lake area as mapped.
- The potentiometric surface beneath Lake Prevatt can be estimated using the District's S-125 well.

Additional assumptions were made regarding the calibration of the model. All the noted assumptions follow typical engineering practices. Given the lack of data, best available methodologies were used in the hydrologic analysis. It was assumed that the calibration covers a wide enough range of flow regimes and hydrologic conditions to ensure that the long-term model simulation will be realistic.



Task C: Assess hydrologic models.

- a. Determine if the model is appropriate, defensible, and valid, given the District's MFLs approach.
- b. Was there adequate data to develop, calibrate and apply the model?
- c. Given the available data and the District's MFLs approach, are there more appropriate models for assessing the water body?
- d. Evaluate the validity and appropriateness of all assumptions used in the development of the hydrologic model.
 - Are the assumptions reasonable and consistent given the "best information available"?
 - Is there information available that could have been used to eliminate any of the assumptions? Would the use of this additional information substantially change the model results?
 - Are the assumptions stated clearly?
 - What, if any, additional assumptions are implied or inherent in the development of the model?
 - Are other methodologies (modeling or non-modeling) available that would require fewer assumptions but could provide comparable or better results? Are adequate data available to support using these alternative methodologies?
- e. Are there deficiencies and/or errors in model development, calibration, or application?
 - If so, describe each deficiency and/or error and enumerate and describe the necessary remedies, and provide an estimate of the time and effort required to develop and implement each remedy.
 - If the identified deficiencies cannot be remedied, then identify and describe one or more alternative methodologies (modeling or non-modeling) that are scientifically defensible given the available data. Provide an estimate of the time and effort required to develop and implement them.

Validity of Using HSPF. The hydrologic model HSPF is well documented and accepted by a large user base. The model has been applied to a wide variety of watersheds for a variety of reasons. The model has been applied for development of MFLs within the state of Florida and within the SJRWMD. Given the broad support base and its numerical representation of a watershed, HSPF is an acceptable tool to simulate the water budget of watersheds and lakes.

Validity of Available Data. The hydrologic data available for this study was very scarce. Typically hydrologic modeling applications will rely on a time series of outflows as a calibration comparison. Looking at a comparison of the observed data to simulated data and improving the agreement through calibration will build confidence in the model's performance. Long time series for are required to compare the model performance to a wide range of conditions (i.e., wet years, dry



years, seasonal changes, etc.). The application of the developed models for MFL enters a new twist. The Florida statutes require the MFL to be set given the best available data. This forces the application of models even though data might not exist for model calibration. The models are then forced into application without the advantage of becoming comfortable with the model's performance.

Model Conceptualization. The model conceptualization is fairly simple. There is a pervious segment (PERLND) that simulates the aggregate of all pervious portions of the watershed. The aggregate of the impervious land use conditions is simulated with an impervious land segment (IMPLND). The Prevatt Lake was represented in the model with a reach reservoir (RCHRES). The three computational components used the same rainfall time series and PET time series. The networking of these computational elements directed the outflow of both the pervious block and the impervious block to the inflow of the reach.

The model is currently run at a 1-hour time step. The input data is daily (daily precipitation and ET). The daily values are evenly divided into the hourly time step of the model. Using daily time steps to define the precipitation time series while modeling infiltration excess, such as the pervious basin, results in model calibration that tends under estimate flows. In effect, the long time steps average a wide range of hydrologic conditions. There is no way for the model to differentiate the difference between 2 inches of rain in .5 hour versus 2 inches over 12 hours. Based on the available data however, a daily time step is appropriate, especially given the lack of flow data to use as a calibration target.

Model Adequacy and Assumptions. There was adequate data to develop, calibrate and apply the model. It would be desired to have more calibration data, especially basin flows for an additional calibration target (not just lake stage). Given the requirement that MFLs be defined using the best available data, the model development followed proper engineering procedures. There are several simplifying assumptions made in the conceptualization of the model which may affect the model's performance. These assumptions could potentially have implications to the performance of the model for the historical simulation period. In fact, the certainty of the groundwater leakage term in the water balance hinges on the accuracy and certainty of the other inflow and outflow terms.

Change in Basin Area based on Lake Stage. HSPF allows the surface area of the water bodies to change due to the quantity of water stored (given the defined stage storage relationship). This occurs in the Prevatt Lake model. The model does not offset this change by increasing the area of the basin. This effect actually causes a small mass balance error as the total area of the catchment is not maintained. The mass balance error can be large if the change in lake area is significant compared to the upland basin area. The lake averages around 94 acres but fluctuates from 130 to 0 acres, as shown in Figure 2. This mass balance error essentially changes the amount of inflow to the basin from precipitation. On the same note, the model documentation inconsistently states the basin area; first the basin is reported as 1131 acres in section 2.2 on page 2 but then the model uses 1110 acres in section 3 on page 7. The combined error in basin area ranges up to 10%. This error is directly passed to the water balance as the basin area defines the principle inflow volume from rainfall.

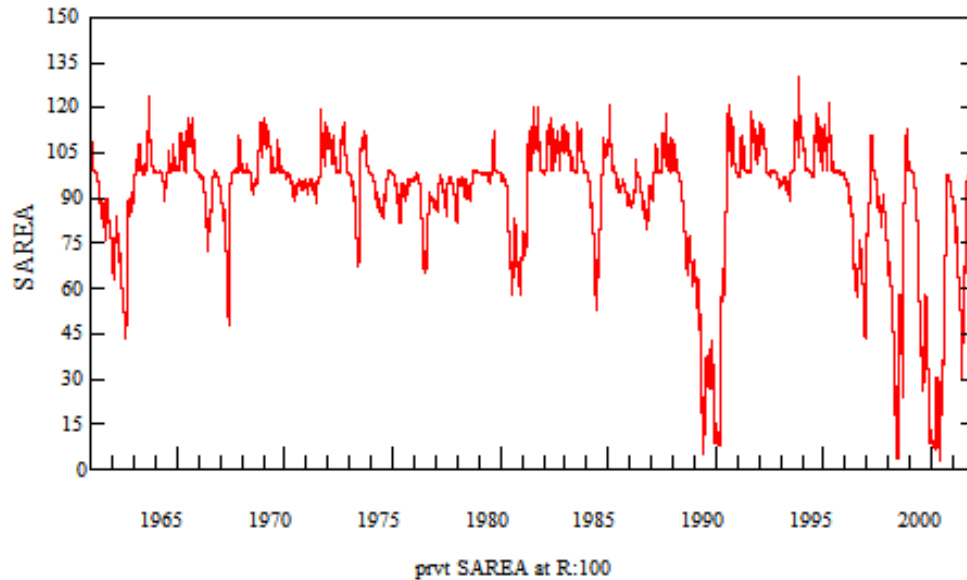


Figure 2. Lake Surface Area during Simulation

Basin Surface Runoff. The current Prevatt Lake model derives most of the basin inflows from the impervious basin. It is standard practice to assume the impervious basin would produce more runoff compared to the pervious basin since the pervious basin loses water to infiltration. Essentially no direct runoff occurs from the pervious basin within the simulation. Figure 3 shows the annual accumulated runoff from the pervious basin and impervious basin on the primary y-axis and rainfall (SUPY) on the auxiliary axis. Notice the pervious basin runoff is very small. The maximum annual runoff from the pervious basin was only .425 inches. In contrast, the impervious runoff exceeds expectation, averaging over 37 inches a year. Comparing the impervious runoff to precipitation shows almost 80% of impervious precipitation becomes runoff.

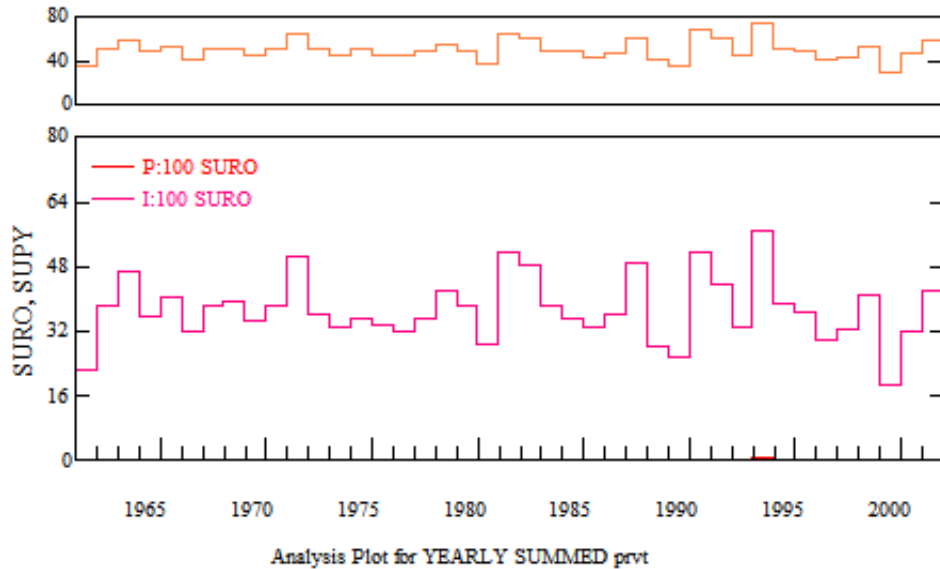


Figure 3. Surface Runoff (SURO)

The pervious outflow in HSPF is comprised of surface runoff, interflow, and baseflow. As stated earlier, the pervious basin simulates almost no runoff, while the baseflow (active groundwater outflow) is almost 5 inches (see Table 1 below). The simulated interflow is small (1.17 inches on average), which follows standard engineering estimates. The baseflow averaging 4.6 inches is hard to defend, especially given that runoff is practically zero. The use of a daily rainfall time series causes this situation since the daily rainfall intensity rarely exceeds the infiltration capacity of the soil.

Table 1. Water Balance Annual Averages, inches

Surface Outflow	Interflow Outflow	Active Groundwater Outflow	Pervious Outflow
0.0335	1.17	4.6	5.8

Given the fact that there is no discharge data, it is difficult to definitively come to a conclusion on the model performance. Based on standard engineering practices and judgment, it seems the impervious runoff is too high while the pervious is too low. The net effect of these issues over the simulation might simply balance out and not be an issue with regard to the lake stage.

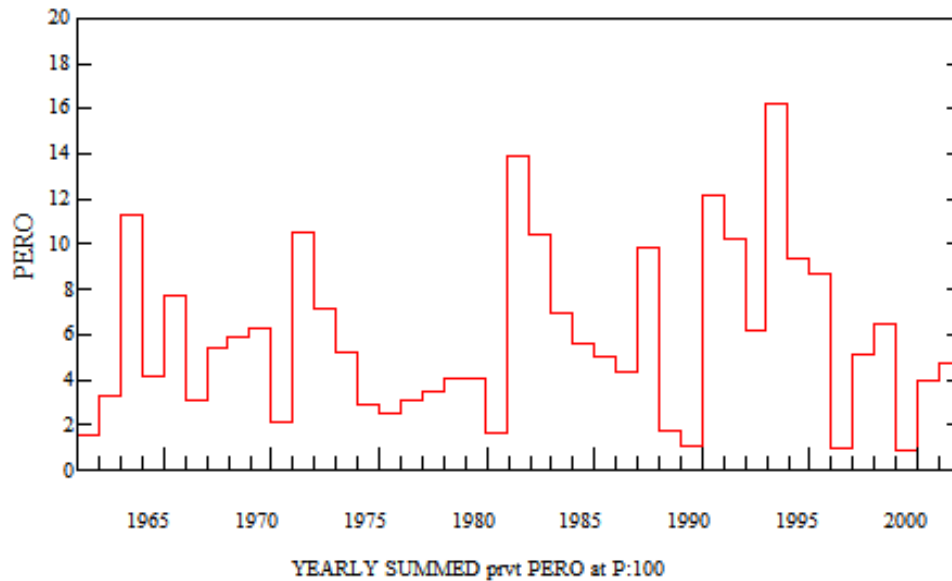


Figure 4. Total Pervious Outflow (PERO)

In addition to the numerical uncertainties, there are physical uncertainties with the model construction. The model assume all pervious land segment and impervious land segment discharges are immediately available for inflow to Prevatt Lake. This is not true as clearly noted on the aerial (see figure 5) there is plenty of wetland storage that can significantly modify the basin water budget by potentially attenuating and even capturing runoff events.

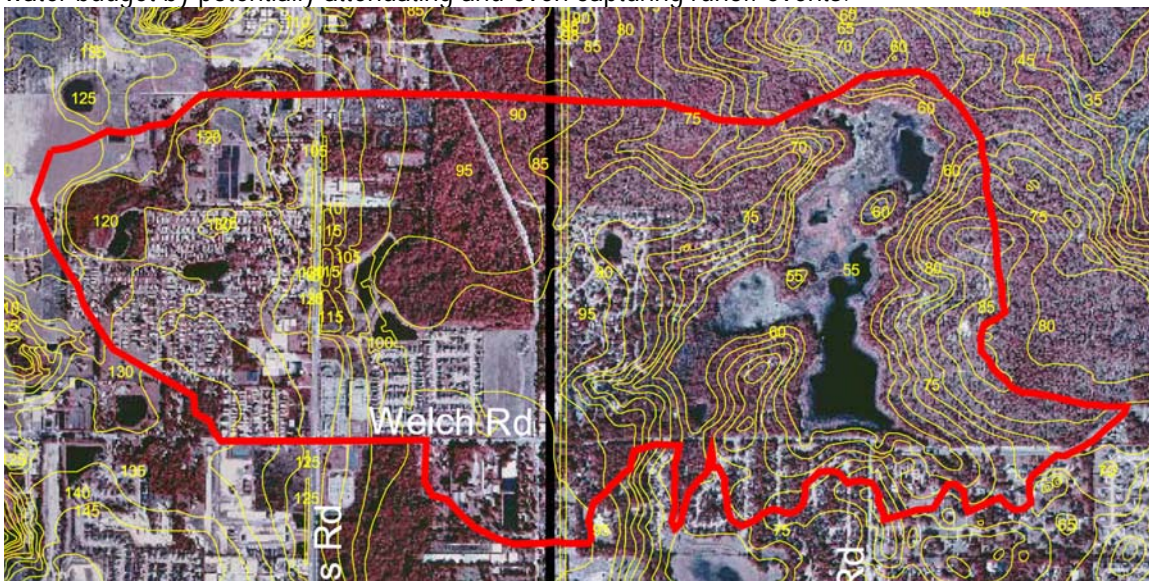


Figure 5 Prevatt Lake Watershed

Basin and Lake Water Balance. The documentation for Prevatt Lake poorly documented basin and the lake water balance. To verify the model's appropriateness, a comprehensive water



balance is required and should be included in the report. Extracting the major water balance terms from the model results gives the following table for the pervious land segment.

Table 2. Pervious Water Balance Annual Average, inches

Precipitation	Outflow	Total ET	Recharge
50	5.8	42.2	1.99

The overall water balance of the pervious basin is within acceptable ranges given the uncertainty of the measured rates but they are at the limits of what is considered acceptable. The 2 inches of recharge seems to be low especially since the report states the recharge to the Floridan should in fact be approximately 4-8 inches based on Figure 3-2 of the report. This is offset with the high ET rates which should be more in the area of 37-39 inches or lower.

The impervious budget is shown in the table below. Mass is intrinsically conserved in HSPF. As shown in the table a significant volume of the water budget is runoff contributing to Prevatt Lake inflows while only 10% goes to ET. This is within the limits of acceptable engineering practices.

Table 3. Impervious Water Balance Annual Averages, inches

Rainfall	Runoff	Impervious ET
50	37.3	12.7

Sources of Model Uncertainty. There are several sources of uncertainty in the model, including, but not limited to:

1. Lake leakage or potentiometric surface estimation,
2. Stage Storage relationship of Prevatt Lake,
3. Basin contributions to Prevatt Lake,
4. Rainfall and ET

The lake leakage is a significant component of the Prevatt Lake Water budget. The amount of flux to the aquifer is uncertain and can only be estimated through observing and reducing the uncertainty in the other water balance terms.

Conclusions and Recommendations



HSPF is a continuous simulation lumped parameter rainfall runoff model. The selection and utilization of this model to support Prevatt Lake MFL development was an appropriate use of the model and followed sound engineering principles. The development of the model included the utilization of best available data. The HSPF model developed for Prevatt Lake is well documented and contains detailed descriptions of all input data sets and model assumptions including the special actions, which simulates the groundwater fluxes. The model performs well during the calibration period and adequately predicts the lake stages.

Based on the model developed, there are no recommendations for additional data collection at this time, instead, the majority of the recommendations for the Prevatt Lake model focus on processing the existing data and running additional simulations or displaying additional model results. Given the fact that MFLs are to be defined using best available data, these recommendations are really suggestions for future MFL revisions. The recommendations include:

- Examining additional potentiometric surface maps for Prevatt Lake in order to verify the assumption of the 4 foot offset for the S-125 well. The use of seasonal corrections should be investigated in order to assure the range in the external head is adequately represented.
- Examining and addressing potential magnitude of the impervious basin and pervious basin contribution to the Prevatt Lake water budget. Maybe use model parameters from a calibrated basin?
- Scrutinizing the Prevatt Lake watershed and the potential modification of the basin flows due to wetland storage attenuations.
- Conducting sensitivity and uncertainty analysis for model parameters.

It should be noted that while all of these recommendations will improve the confidence in the predictive capability of the model and may (through additional calibration) improve the performance of the model, the implementation of these recommendations must be considered within the context of available data and the District's MFL program. The final goal of the model is to determine stages that can be used to develop MFL curves and evaluate impacts of consumptive use withdrawals on the MFL. Ultimately, the determination of whether or not an MFL is being met is made through frequency analysis. This frequency analysis relies heavily on the selection and definition of key ecological signatures. These ecological features define the stages in the lake that will be considered as "significant harm". It is the selection of these features which the defined MFL will heavily rely upon. The frequency analysis, which is a component of the hydrologic modeling, is the optimal method for assessing environmental impacts. Harm in any system can be defined in terms of exposure to events. It is the frequency, duration, and intensity of the events that allow accurate assessment of "significant harm" in numerical terms. That being said, given the available data, the overall modeling methodology in defining the MFLs for Prevatt Lake follows sound engineering practices.

It is highly recommended that the District adopt a standard report format for all MFL studies, which must include both a lake water budget and a basin water budget. Given the lack of data, especially for calibration targets, it is desired to review the basin water balance to assure the reader the basin simulations are reasonable. It is highly recommended to include a water balance report of all basins and basin budget terms. Careful examination of both of these water budgets will give



confidence in the reliability of the model for predictive purposes, and hence, in the ability of the model to evaluate the MFL and potential future MFL impacts.

References

CDM. (2004). *Hydrologic Model Development for MFL Evaluation of Prevatt Lake, Orange County*. Report for the St. Johns River Water Management District, October 2004.