

Appendices

Appendix A: Method for Evaluating the “Lost” Storage Component of the Surficial Aquifer—by Dave A. Tomasko, Ph.D., Senior Scientist, PBS&J

Both conceptually and as is pointed out in various landscape-level hydrologic process models, there is agreement that the increased urbanization of a watershed should result in both an increase in the amount of stormwater runoff generated, and a concurrent reduction in the amount of rainfall that percolates into the surficial aquifer. Determining the amount of rainfall that becomes runoff, versus that available for percolation, depends in large part on the amount of directly connected impervious area (DCIA) associated with various land use categories. There is a subtle, yet important, distinction between DCIA and the “percent impervious” nature of a landscape.

For example, rainfall on a low-density residential neighborhood occurs on impervious features such as rooftops, sidewalks, and driveways; these areas comprise perhaps a third of the total area of any neighborhood (as an example, **Table A.1** lists the DCIA values used by the Florida Department of Environmental Protection [FDEP] [2003] to estimate runoff from the Orange Lake watershed, in Alachua County). However, runoff from a roof can then drain to a grassed yard that then infiltrates to the surficial aquifer, or it can run off the property and go to either a street or a dry retention pond for later percolation. For this reason, FDEP and other entities use DCIA as the primary method for determining stormwater runoff quantities with various landscapes (e.g., FDEP, 2003). The pollutant loading model for Sarasota Bay also calculated hydrologic loads by considering the DCIA component of the landscape (Heyl, 1992).

Table A.1. Directly connected impervious area (DCIA) for various land use types (Orange Lake watershed, Alachua County). Source: FDEP, 2003

Land Use Categories	DCIA	Reference
Forest/Rural Open	0.5%	Watershed Management Model (WMM) User's Manual, 1998
Urban Open	0.5%	WMM User's Manual, 1998
Agriculture	3.7%	Brown, 1995
Low-Density Residential	12.40%	Brown, 1995
Medium-Density Residential	18.70%	Brown, 1995
High-Density Residential	29.60%	Brown, 1995
Communication and Transportation	36.20%	Brown, 1995
Rangeland	3.7%	Camp Dresser & McKee (CDM)
Water/Wetlands	30%	Harper and Livingston, 1999

Residential landscapes typically have between 12 and nearly 30% of their surface area as DCIA. In the Sarasota Bay area, estimated DCIA values for residential neighborhoods range between 20 and 40% (Heyl, 1992). Of that amount of landscape that is DCIA, it is further assumed that the amount of runoff generated is in the range of 80% or higher (Heyl, 1992; FDEP, 2003). Therefore, a DCIA value of 30%, combined with a presumed 80% runoff coefficient, means that 24% of rainfall is expected to become stormwater runoff from the “typical” rain event falling on the DCIA portion of a high-density residential landscape ($0.30 \times 0.80 = 0.24$). This 24% value is then added to the expected runoff from the non-DCIA portion of the landscape. Assuming (for high-density residential landscapes) that 70% of the area is non-DCIA, and assuming a runoff coefficient of 15% for pervious areas (Heyl, 1992; FDEP, 2003), these portions of the landscape would add an additional 10.5% of rainfall ($0.70 \times 0.15 = 0.105$), for a total expected runoff amount of 34.5% of rainfall ($24 + 10.5 = 34.5$) from a high-density residential landscape.

For the Orange Lake watershed, FDEP (2003) used a DCIA value for forested landscapes of less than 1%, similar to the values used for Sarasota Bay (Heyl, 1992). The runoff from non-DCIA areas is expected to be approximately 15%. Thus, for forested (nondeveloped) landscapes, the total runoff amount is the sum of the DCIA ($0.01 \times 0.80 = 0.08$) plus the non-DCIA ($0.99 \times 0.15 = 0.15$), which equals approximately 15.8%.

Consequently, the conversion of the watershed from a forested landscape to one entirely dominated by high-density residential neighborhoods is expected to increase the amount of runoff from 15.7% of rainfall to 34.5% of rainfall, a more than twofold increase.

With most landscapes, increased development thus increases stormwater runoff amounts from relatively small percentages of rainfall to larger percentages. However, in the Winter Haven Chain of Lakes (WHCOL), there is some question as to whether or not **any** runoff occurred under natural conditions. Within the description of the techniques used for developing a water budget for the Winter Haven Chain, the University of South Florida (USF) report (McCary and Ross, 2005) stated, "In general, pervious runoff was negligible due to ... the sands that are predominant in the Winter Haven area." Elsewhere in that report, the authors state that runoff was "insignificant." As such, it seems that the developers of the pollutant loading model for the WHCOL (McCary and Ross, 2005), upon which was based the Total Maximum Daily Load (TMDL) for the WHCOL (FDEP, 2006), concluded that there was likely no surface runoff at all (or very little) occurring for most of the WHCOL watershed. In contrast, there is at present a substantial amount of surface water runoff generated in the watershed, as would be expected from such a highly urbanized area.

This then allows for the application of a technique to estimate the "lost" storage quantity associated with decreased percolation into the surficial aquifer, as follows:

- *Under predevelopment conditions, runoff would have been negligible to absent in the WHCOL region;*
- *Thus, under predevelopment conditions, rainfall would have mostly resulted in percolation into the surficial aquifer and/or temporary storage via isolated wetlands;*
- *To estimate the volume of "lost" storage in the surficial aquifer, one could estimate the volume of rainfall that is no longer percolating into the surficial aquifer;*
- *Direct stormwater runoff into the WHCOL represents rainfall that would likely have percolated into the aquifer in predevelopment conditions;*
- *Therefore, the volume of stormwater runoff into the WHCOL lakes themselves can be used as an estimate of the amount of water no longer able to percolate into the surficial aquifer; and*
- *The volume of stormwater runoff into the WHCOL can be used as an estimate of the amount of "lost" storage in the surficial aquifer.*

The Pollutant Load Reduction Goal (PLRG) report for the WHCOL (McCary and Ross, 2005) summarizes the data and techniques used to develop the water budget for the Chain of Lakes, as the development of a water budget is the first step in developing a pollutant loading model. The water budget (McCary and Ross, 2005) included estimates of rainfall, seepage into the aquifer, lake-to-lake water movement (via canals), evaporation, and direct stormwater runoff. For the reasons outlined above, the metric of most interest for this effort is the determination of the amount of direct runoff to the lakes. **Table A.2** displays the results of the water budget.

Table A.2. Summary of findings for the water budget for the WHCOL. Source: McCary and Ross, 2005

Lake	Area (acres)	Runoff Volume (acre-feet/year)	Runoff Volume (million gallons/year)
Winterset	548	206	67
Eloise	1,163	533	174
Summit	64	98	32
Lulu	307	468	153
Roy	74	174	57
Shipp	277	584	190
May	52	617	201
Howard	625	911	297
Cannon	328	640	208
Blue	54	438	143
Mirror	126	175	57
Spring	23	128	42
Idylwild	93	232	76
Jessie	186	521	170
Marianna	511	971	316
Hartridge	415	533	174
Conine*	233	384	125
Rochelle*	573	196	64
Haines*	689	402	131
Smart*	274	82	27
Fannie*	738	191	62
Average	350	404	132
Sum	7,353	8,483	2,764

* Located in the Northern Chain of Lakes.

Based on these results, the average lake in the WHCOL receives approximately 132 million gallons of direct stormwater runoff per year. The range of values lies between 32 million gallons per year of direct runoff for Lake Summit to 316 million gallons per year for Lake Marianna. Lake Howard, a large lake near the center of Winter Haven, receives approximately 297 million gallons per year of direct stormwater runoff. The very high rates of runoff into Lakes May, Blue, and Spring reflect the finding that sufficient runoff occurs into these lakes that they “export” surface flows to adjacent lakes via interconnected canals. In total, the WHCOL is estimated to receive an average of approximately 2.7 billion gallons of stormwater runoff per year.

However, the lakes in the Northern Chain of Lakes system (Haines, Rochelle, Conine, Smart, and Fannie) are problematic, in that they are thought to receive a substantial amount of their water via groundwater inflows. The water budget estimates in the PLRG study (McCary and Ross, 2005) indicate that approximately five times as much water enters these lakes via groundwater inflow than as direct stormwater runoff. As the water budget was somewhat compromised by the lack of sufficient data on groundwater inflows (McCary and Ross, 2005), FDEP felt it was premature to develop TMDLs for the Northern Chain (FDEP, 2007). Consequently, a conservative approach would be to eliminate the lakes of the Northern Chain from further consideration for the purposes of developing a “lost percolation” estimate. **Table**

A.3 revises the information in **Table A.2**, by omitting the lakes of the Northern Chain of Lakes system.

Table A.3. Summary of findings for the water budget for the WHCOL (from McCary and Ross, 2005) minus Lakes Haines, Rochelle, Conine, Smart, and Fannie.

Lake	Area (acres)	Runoff Volume (acre-feet/year)	Runoff Volume (million gallons/year)
Winterset	548	206	67
Eloise	1,163	533	174
Summit	64	98	32
Lulu	307	468	153
Roy	74	174	57
Shipp	277	584	190
May*	52	617	201
Howard	625	911	297
Cannon	328	640	208
Blue*	54	438	143
Mirror	126	175	57
Spring*	23	128	42
Idylwild	93	232	76
Jessie	186	521	170
Marianna	511	971	316
Hartridge	415	533	174
Average	303	452	147
Sum	4,846	7,229	2,357

* Lakes with enough runoff that they “export” surface flows to adjacent lakes via interconnected canals.

Upon the removal of the Northern Chain of Lakes from this analysis, the estimated surface runoff into the remaining lakes of the WHCOL system is approximately 2.4 billion gallons per year. As there was likely little to no surface water runoff coming into these lakes in a predevelopment condition (McCary and Ross, 2005), it is likely that the amount of water now routed to the lakes via stormwater runoff—a consequence of the highly urbanized watershed—represents water that no longer percolates into the surficial aquifer.

It is thus likely that a rainfall amount on the order of 2 billion gallons per year (5.5 million gallons per day) no longer percolates into the surficial aquifer in the WHCOL watershed, and instead is now routed to the lakes via direct stormwater runoff. If redirected toward percolation, this amount would likely be available to recharge the surficial aquifer. Water reintroduced into the surficial aquifer would then potentially recharge the adjacent lakes via groundwater seepage, or contribute to deeper aquifer recharge. Vegetation would also use a portion of this water for transpiration. In effect, reestablishing percolation and surficial aquifer recharge as the primary method for water to enter the WHCOL lakes could result in a less “flashy” system, where wet season inflows would be moderated, and dry season lake levels could be maintained at higher levels via increased groundwater seepage during periods of reduced rainfall.

Prior work has shown that the “Ridge-type” lakes of the WHCOL would benefit from higher water levels during the dry season (PBS&J, 2008). Additionally, routing water from surface water runoff into the surficial aquifer would allow for additional treatment of stormwater runoff via the filtration of particles, the absorption of phosphorus onto any carbonate sediments, and (potentially) nitrogen reduction via denitrification. A recent study in the WHCOL (PBS&J, 2009)

showed that lake levels in Lake Haines fluctuated in correlation with the level of the surficial aquifer, but only when the surficial aquifer was at a higher elevation than the lake itself.

Combined, these findings suggest that maintaining higher water table levels in the WHCOL watershed could be a useful strategy for improving water quality via maintaining lake levels via groundwater seepage during the dry season and via the improved treatment of water during seepage through the soil itself (rather than direct discharge via runoff). The total quantity of stormwater runoff that could potentially be rerouted to percolation is estimated as close to 2 billion gallons a year.

References

- FDEP, 2003. *Final Nutrient Total Maximum Daily Load*. Watershed Assessment Section Florida Department of Environmental Protection. Tallahassee, FL.
- Watershed Management Model, Version 4.1. *User's manual*. November 1998. RPO-NPS-TM27.02. Wayne County, MI: Rouge River National Wet Weather Demonstration Project.
- Brown, 1995. South Dade Watershed Project. University of Miami/SWFWMD.
- Camp Dresser & McKee. 1990. *Point and non-point source loading assessment, phase I*. Report to Sarasota Bay National Estuary Program.
- Harper and Livingston, 1999. *Everything you always wanted to know about stormwater management practices but were afraid to ask*. Biennial Stormwater Research Conference, Tampa, Florida.
- Heyl, 1992. *Point and nonpoint source loading assessment of Sarasota Bay*. Pp. 12.1-12.19. In: P.Roat, C. Ciccolella, H.Smith, and D. Tomasko (eds.). Sarasota Bay: Framework for Action. Sarasota Bay National Estuary Program, Sarasota, FL.
- McCary, J.P., and M.A. Ross. 2005. *Winter Haven Chain of Lakes PLRG study*. Final Report to the Southwest Florida Water Management District. Tampa, FL: University of South Florida, Center for Modeling Hydrologic and Aquatic Systems.
- FDEP, 2007. *TMDL Report: Nutrient TMDL for the Winter Haven Southern Chain of Lakes (WBIDs 1521, 1521D, 1521E, 1521F, 1521G, 1521H, 1521J, 1521K)*. Division of Water Resource Management, Bureau of Watershed Management, Tallahassee, Florida.
- USF, 2005. Winter Haven Chain of Lakes PLRG Study. Final Report to: Surface Water Improvement and Management (SWIM) Program, Southwest Florida Water Management District, Tampa, FL.
- PBS&J, 2008. Winter Haven Chain of Lakes Pre-BMAP Assessment: An Interpretative Synthesis of Existing Information. Final Report to Florida Department of Environmental Protection, Division of Water Resource Management, Bureau of Watershed Management, Tallahassee, FL.
- . February 2009. *Winter Haven Chain of Lakes groundwater seepage study*. Final draft. Prepared for the Florida Department of Environmental Protection, Bureau of Watershed Management, Tallahassee, FL.

Appendix B: Estimate of Wetland Losses in the Peace Creek Watershed from Predevelopment to the Postdevelopment Condition Today

Physiographic Region	Historical Wetlands (hydric soils, acres)	Existing Wetlands (FLUCFCS, acres)	Wetland Loss (acres)	Percent Change
Polk Uplands	29,587	20,606	-8,981	-30%
Winter Haven Ridge	3,835	2,895	-940	-25%
Total	33,422	23,501	-9,921	-30%

Sources: U.S. Department of Agriculture, Natural Resources Conservation Service soils map (hydric soils) Geographic Information System (GIS) coverage; Florida Land Use, Cover and Forms Classification System (FLUCFCS), Southwest Florida Water Management District 2006 land use GIS coverage.

Appendix C: Simulation Modeling of the Winter Haven Ridge and Polk Uplands— *by Mark T. Brown, Ph.D., and David Pfahler*

Introduction

Macroscopic mini-models are simulation models that are macroscopic in detail and small in complexity, so as to capture the behavior of relatively complex systems without resorting to large numbers of components and complicated mathematical equations to express relationships. The process of modeling in itself is a process of simplifying the complex, for a model represents a simplification of the systems that are being studied. Many simulation models, seeking to reproduce reality, strive for ever-greater complexity with the conviction that the more complex the model, the better it can predict the future.

A macroscopic mini-model, on the other hand, is an aggregation (not a simplification) of the real world designed to capture the fundamental nature of the system being studied, without the complexity. Macroscopic is the opposite of microscopic; thus the macroscopic model strives to grasp overall system behavior by considering the whole system rather than by trying to build understanding from the pieces up. Macroscopic modeling is sometimes called top-down modeling to draw attention to the idea that its perspective is that of an overview, blurring detail in favor of overall system behavior.

The models discussed in this appendix are macroscopic mini-models intended to explore and explain the behavior of the Peace Creek watershed's hydrologic system, rather than predict the future. Using past rainfall data and general relationships between surface water, the surficial aquifer, and the deep Floridan aquifer, the models explore how changes in several important parameters affect the overall behavior of the hydrologic system.

In the simulations, different parameters are varied, such as the area of impervious surface, stormwater discharges to the lakes, the lowering of surficial aquifer levels through drainage practices, and the lowering of the Floridan aquifer's potentiometric surface. Varying these parameters illustrates their effects on the overall system—for instance, the storage of water in lakes and aquifers—and provides better insight into the management implications of human actions.

The intent of the simulations is not to predict the future, but to learn from the models how human actions affect the hydrologic system. These macroscopic mini-models illustrate the effects of different management alternatives, thus highlighting in a more holistic manner the interconnections between the various parts of the hydrologic system and the effects of human activities. As a result, they help humans to make better management decisions.

Estimating the Flow and Storage of Water in the Winter Haven Southern Chain of Lakes

Historical Flows and Storage

Figure C.1 shows a systems diagram used to model the historical flows and storage in the Winter Haven Southern Chain of Lakes. Each of the pathways of water flow has been estimated. The values on the pathways are in billions of gallons per year, and the quantities in storage (the tank-like symbols) are in billions of gallons. The assumptions used to estimate the flows and storage are as follows:

*Total area = 11,580 acres, including 300 acres of wetlands and 4,280 acres of lakes;
 Annual average rainfall = 50.2 inches per year;
 Average water depth in lakes = 8 feet overall;
 Average water depth in wetlands = 1.5 feet overall;
 Depth of surficial aquifer = 50 feet, with 40% porosity;
 Runoff from uplands to lakes and wetlands = nonexistent in historical condition;
 Evapotranspiration (ET) = 66% of rainfall overall;
 Outflows from wetlands as percentage of inflows = 34% to lakes and 66% ET;
 Outflows from lakes as percentage of inflows = 0% as surface outflow, 35% to Floridan aquifer, and 65% to evaporation
 Outflows from surficial aquifer as percentage of inflows = 23% to recharge of Floridan aquifer, 14% to recharge lakes, 56% as ET, and 7% as seepage;
 Groundwater inflow = negligible, since Winter Haven Ridge is elevated recharge area.*

Total rainfall over the 11,580 acre Southern Chain watershed area equals 15.8 billion gallons per year (average rainfall of 50.2 inches per year). Of the total rainfall, about 31% (4.9 billion gallons per year or 15.6 inches per year) is deep recharge of the Floridan aquifer. Outflow from the surficial aquifer toward the lower-lying Polk Uplands area is about 3% of rainfall (600 million gallons or 2 inches per year) and evapotranspiration accounts for approximately 66% of rainfall (10.3 billion gallons or 32.6 inches per year).

The diagram shows that the flow between the surficial aquifer and the lakes can change direction based on the relative amount of water stored in different parts of the system. If the surficial aquifer water level is higher than the lake water level, there is seepage into the lakes; if the surficial aquifer level drops below the lake water level, water leaks from the lakes into the surficial aquifer. The flow may be in different directions at different times of the year. In the model, the annual net flow is from the surficial aquifer into the lakes.

Current Flows and Storage

Figure C.2 is the same systems diagram, except that flows are changed to estimate the impacts of urbanization on the hydrologic system of the Southern Chain (the changes are shown in red). A summary of the changes is as follows:

*Decrease in average lake storage = 16% (from 11.2 to 9.4 billion gallons/year);
 Decrease in surficial aquifer storage = 16% overall (from 188.7 to 138.5 billion gallons/year);
 Increased urbanization = 30% of rainfall falling on uplands flows directly into lakes because of surface runoff; and a 20% decrease in ET from the surficial aquifer due to loss of vegetation.
 Decreased surficial aquifer levels = decrease of 57% in seepage from the surficial*

aquifer to lakes (from 1.4 to 0.6 billion gallons/year) and a decrease of 18% of recharge to the Floridan aquifer due to lower head potential (2.2 to 1.8 billion gallons/year).

Regional drawdown of Floridan aquifer due to increased withdrawals = induced 41% increase of recharge from the lakes because of higher head potential between Floridan and lake conduits (from 2.7 to 3.8 billion gallons/year).

The most notable effect is the decline in rainfall recharge of the surficial aquifer (from 9.5 to 7 billion gallons/year). Historically, little if any rainfall ran off the land surface into the lakes, but instead infiltrated into the surficial aquifer. Urbanization alters the imperviousness of the land surface (represented by the gray box in the center of the figure), increasing the surface water inflow into lakes and decreasing infiltration into the surficial aquifer. The net effect of this inflow has been to replace infiltration that would have entered the lakes from the surficial aquifer, however, the surficial aquifer level continues to decline with time. It is estimated that seepage to the Polk Uplands may have decreased as a result of the lower surficial aquifer levels in the Southern Chain of Lakes area.

A regional drawdown of the Floridan aquifer over the last 50 years has increased the net recharge of the Floridan from the lakes by 41%. This is because the lakes are modeled as having a direct conduit to the Floridan aquifer. When level in the Floridan aquifer drop, the head potential of the lakes increases, which increases recharge. While the water level of the Floridan aquifer is not explicitly modeled here, it should be noted that this increased recharge is likely not sufficient to compensate for the regional drawdown of the aquifer.

Simulation Models

To understand the factors affecting the integrated hydrologic system of the Winter Haven area, two hydrologic simulation models were undertaken that can be used to visualize the interconnected nature of this dynamic system and the net effects of historical alterations.

Simulation of the Winter Haven Ridge Lake Model

The Winter Haven Ridge Lake Model (**Figure C.3**) is a conceptual simulation model based on average historical conditions for lakes in the Winter Haven Ridge area. The system has been aggregated somewhat from the Southern Chain of Lakes diagram, and the wetlands component has been eliminated from the model to simplify the simulation parameters. The simulation model does not represent any particular lake, but instead an average lake with a surrounding watershed.

The assumptions used in the model are as follows:

Total area = 1,770 acres, of which 700 acres is lake and 1,070 acres is watershed;
Annual average rainfall = 50.2 inches per year;
Water depth in lake = average 8 feet overall;
Depth of surficial aquifer = 50 feet, with 40% porosity;
Runoff from uplands to lakes = nonexistent in historical condition and increases to 50% in current condition;
ET = 66% of rainfall overall;
Outflows from lakes as percentage of inflows = 0% as surface outflow, 34% to Floridan aquifer, and 66% to evaporation;
Outflows from surficial aquifer as percentage of inflows = 23% to recharge of Floridan aquifer, 7% as lateral seepage, 56% as ET, and 14% recharge to the lake.
Groundwater inflow = negligible, since Winter Haven Ridge is elevated recharge area.

A main assumption of the model is that under historical conditions, there was no surface runoff into the lakes and the only water inputs to the lakes were rainfall and surficial aquifer seepage. The actual lake water level elevation is arbitrary, although it represents an elevation similar to that of Winter Haven's lakes (approximately 135 feet North American Vertical Datum [NAVD]).

The most important relationship is between lake level and surficial aquifer level (SAL). The model was calibrated with the SAL an average of 4 feet above the lake level. Seepage in and leakage out of the lake is driven by the difference between the relative elevations of the lake and SAL. When the elevation of the SAL is above that of the lake, seepage into the lake is driven by the difference in elevation times a soil conductivity coefficient. When the lake level is above that of the SAL, the recharge of the SAL is driven by the difference in elevation times the soil conductivity coefficient.

Both the lake and the surficial aquifer are affected by evaporation and transpiration (evapotranspiration). The model assumes that if the surficial aquifer is deeper than 4 feet from the surface, there is no evaporation. Recharge to the Floridan aquifer from the lake is driven by the head difference (or difference in elevation) multiplied by a seepage coefficient, which considers the rate at which water moves through different types of soil. When the potentiometric surface of the Floridan declines, the head difference increases, thus increasing recharge. The surface outflow elevation from the lake was set at 136 feet NAVD.

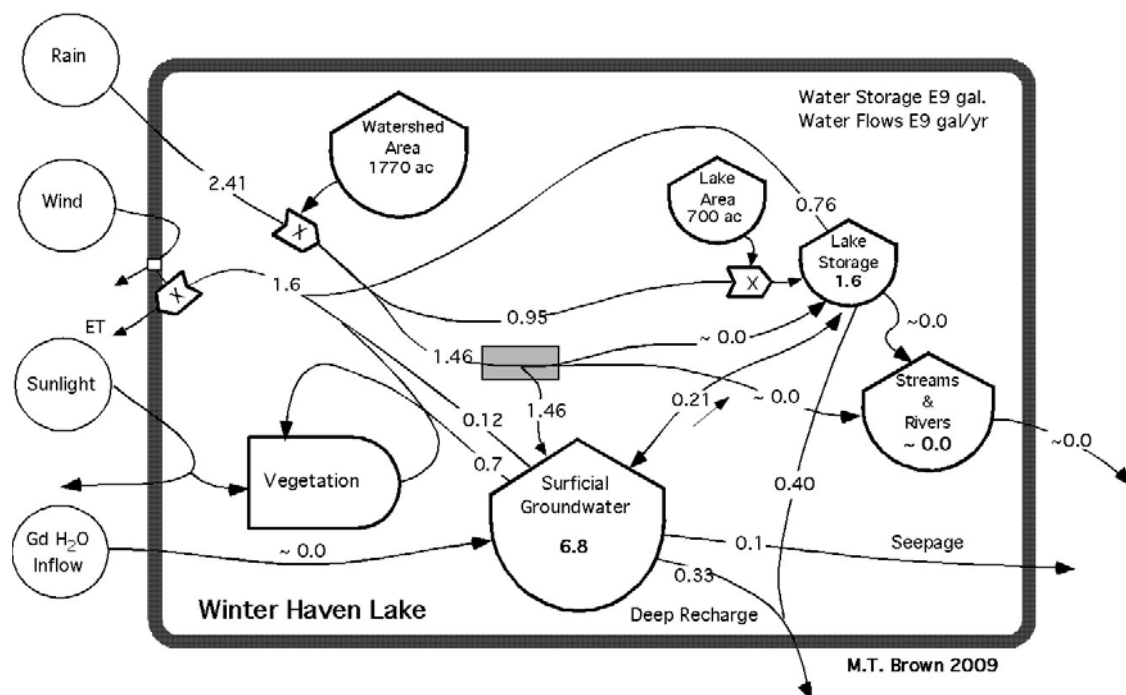


Figure C.3. Aggregated system diagram of historical water movement and storage in the Winter Haven Ridge Lake Model, showing the conceptual relationships between the amount of rainfall, the amount of water stored in lakes and surficial groundwater, and the amount of water leaving the system through evapotranspiration and surface flow. The model is calibrated for an “average lake” in the Southern Chain of Lakes. Flows are in billions of gallons per year and storage is in billions of gallons.

North American Vertical Datum

A geodetic datum, or scientific system, such as NAVD measures elevation as accurately as possible using a specific reference coordinate—usually a tidal gauge along the ocean shore.

Figures C.4 and C.5 show the simulation results of the Winter Haven Ridge Lake Model using rainfall records for Winter Haven between 1941 and 2007.

First Simulation of Ridge Lake Model: Changes Due to Lowered Floridan Aquifer

The first simulation, **Figure C.4(a)**, assumes no development in the watershed and no decline in the Floridan aquifer during the period of record. This simulation serves as the “base condition” with which to compare the impacts on surficial aquifer and lake water levels and declines in the potentiometric surface of the Floridan.

Figure C.4 shows the elevation (NAVD) of the surficial and Floridan aquifers (left) and lake stage (right). In the base condition simulation, **Figure C.4(a)**, (no declines in the Floridan aquifer), the surficial aquifer varies overall about 5 feet between its lowest level around 1956 and its highest level around 2004. Overall, lake levels average around 132 feet in elevation, varying between a low of 130 feet NAVD in 1956 and a high of 135 feet NAVD in 2004. All variation in aquifer and lake levels in this simulation is due to the variation in rainfall. It is interesting to note that the surficial aquifer rarely goes below 134 feet.

When the model is simulated incorporating declines in the Floridan aquifer beginning in 1950, **Figure C.4(b)**, both surficial aquifer and lake levels decline. The dry years at the end of the simulation show precipitous declines in all water levels. By the end of the simulation in 2007, the Floridan is 11 feet lower, and the surficial aquifer is 4 feet lower. The decline in lake levels is even more accentuated since the lakes act as conduits for water to reach the Floridan. Simulated lake levels drop between 5 and 6 feet. As we will see in the next model, these dramatic impacts to lake levels have not been seen in current lake levels because of the mitigating effects of urbanization in the watershed. This model illustrates the importance of the Floridan aquifer on sustaining lake levels, particularly during dry periods with low rainfall as seen at the end of the simulation between 2005 and 2007.

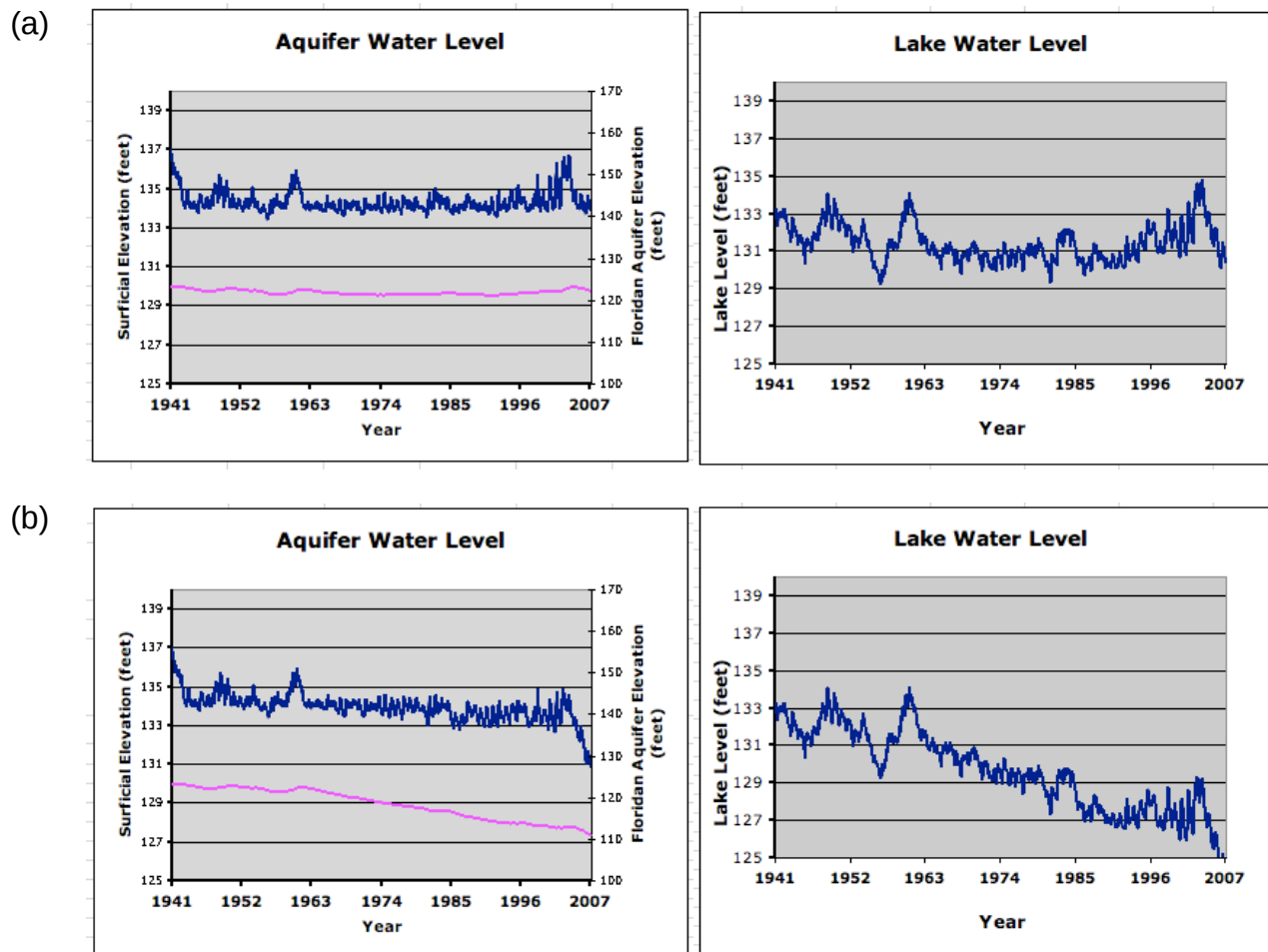


Figure C.4. Effects of the Decline in the Potentiometric Surface of the Florida Aquifer. Simulation results of the Winter Haven Ridge Lake Model, showing the average elevation (NAVD) of the surficial aquifer (left) and lake level and lake discharge (right) from 1941 to 2007, assuming (a) no declines in the potentiometric surface of the Floridan aquifer, and (b) declines in the Floridan beginning in 1960, such that by 2007 it is lower by approximately 11 feet. With the decline in the Floridan (shown in the purple line on the left graphs), there is a significant decline in both the surficial aquifer and overall lake levels.

Second Simulation of Ridge Lake Model: Effects of Increased Stormwater Runoff due to Urbanization

The simulation results in **Figure C.5** illustrate the combined effects of a decline in the Floridan aquifer and increased urbanization of the watershed. The increased urbanization helps to mitigate the impact of the lowered potentiometric surface of the Floridan. In this model, stormwater is discharged from impervious surfaces directly to the lakes. This model represents the system as it exists today. **Figure C.5(a)**, shows that lake levels are maintained higher than in the case of Floridan aquifer decline without urbanization as shown in **Figure C.4(b)** on the previous page. This is because the lakes recharge to the aquifer more quickly than the surficial aquifer, and support a higher Floridan level. The runoff into the lakes helps to replenish the Floridan aquifer. Note that even the surficial aquifer level improves slightly in this scenario due to higher water levels in the Floridan than in **Figure C.4(b)**. Lake levels are maintained at acceptable levels up until the end of the simulation. The dry years of 2005-2007 continue to show a rapid drop in the surficial aquifer and lake levels. With little rain, there is not enough stormwater runoff to maintain the lake levels.

The bottom pair of graphs, **Figure C.5(b)**, illustrates the effect of routing some stormwater to infiltration basins that increase recharge to the surficial aquifer, which in turn gradually flows through groundwater seepage into lakes. This model shows that surficial aquifer levels do increase, exhibiting much healthier levels. However, there is a lowering of lake levels due to less direct stormwater runoff entering the lakes. The next set of simulations explore this effect in increased detail and show how under most circumstances, lake levels will improve over time.

While it appears that the net effect of routing stormwater to the lakes is higher water levels, it is important to notice the precipitous declines in the surficial aquifer in the last 5 years of the simulation, as it is starved for recharge. The bottom two graphs show that the increased recharge from the infiltrated stormwater maintains higher surficial aquifer levels and gradually flows through groundwater and seeps into the lakes. Lake levels are slightly lower during dry periods as they receive less stormwater runoff.

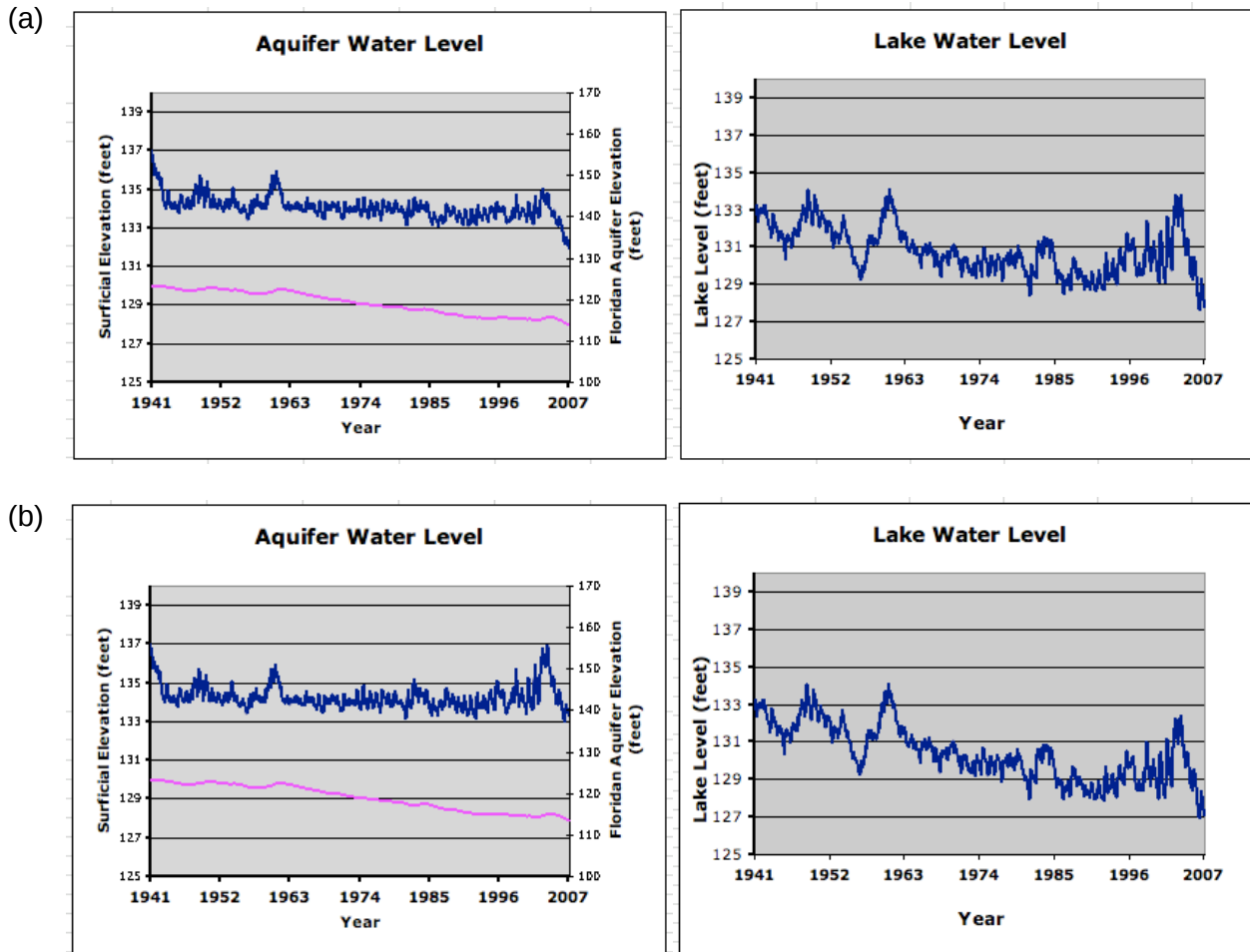


Figure C.5. Combined Effects of Lowered Potentiometric Surface and Development. Simulation results of the Winter Haven Ridge Lake Model, showing the average elevation (NAVD) of the surficial and Floridan aquifers (left) and lake levels (right) from 1941 to 2007, assuming the combined effects of declines in the potentiometric surface of the Floridan aquifer starting in the 1950s and development increasing beginning in 1960 until the amount of impervious surface equals 60%. These simulations illustrate (a) the effects of stormwater runoff discharged directly into the lakes, and (b) the effects of stormwater routed to infiltration basins, rather than directly discharged to lake surface waters. While it appears that the net effect of routing stormwater to the lakes is higher water levels, it is important to notice the precipitous declines in the surficial aquifer in the last 5 years of the simulation, as it is starved for recharge. The bottom two graphs show that the increased recharge from the infiltrated stormwater maintains higher surficial aquifer levels and gradually flows through groundwater and seeps into the lakes. Lake levels are slightly lower during dry periods as they receive less stormwater runoff.

Third Simulation of Ridge Lake Model: Extending Results and Including Reuse Water

To highlight more recent trends, the graphs in **Figure C.6** show the last 10 years of the data record (1997 to 2007) and add an additional 10 years into the future (2007-2017) by reusing the same rainfall data from the previous 10 years. They show (a) the effects of development runoff discharging directly into the lakes, (b) the effects of using stormwater infiltration basins instead of direct discharge into the lakes and, finally, (c) the effects of using stormwater basins **and** applying reuse water (highly treated wastewater effluent) to the landscape.

Figure C.6(a) shows the system with all stormwater directed into the lakes. The second half of the graph shows that after a dry period such as seen from 2005 to 2007, neither the surficial aquifer nor the lake levels rebound to equivalent levels even though the rainfall used in the two time periods are identical. Instead, surficial aquifer levels have decreased by 1.5 feet, and lake levels have decreased by 2 feet.

Figure C.6(b) shows the system with a portion of the stormwater infiltrated into the aquifer. At the end of the second 10 year period, surficial aquifer levels have lost only 0.5 feet as compared with the drop of 1.5 feet in the first 10 years. Lake levels have lost only 1 foot compared to the 2 foot drop in the first 10 years. Compared to **Figure C.6(a)**, lake levels are lower at the end of the first 10 years, but higher at the end of the second 10 year period by 1 foot. This model suggests that increasing surficial aquifer levels by stormwater recharge will improve lake levels over the long term.

Figure C.6(c) shows the impact of further improving surficial aquifer levels by infiltrating reclaimed wastewater into the surficial aquifer, beginning in the year 2010. Surficial aquifer levels are brought back up to historic levels, and lake levels are improved by almost 2 feet. This simulation suggests that restoring surficial aquifers with reclaimed water should be explored as a method to rebuild the sustainability of the Winter Haven lake system.

With the drier years beginning in 2005, the surficial aquifer declines precipitously and lake levels follow. The middle two graphs **(b)** illustrate the effect of stormwater infiltration basins and surficial aquifer recharge instead of direct discharge to the lakes. While the surficial aquifer still declines because of the low rainfall, the decline is not as steep and overall lake water levels are higher. In the bottom two graphs **(c)**, not only is stormwater stored and recharged to the surficial aquifer instead of being directly discharged to the lakes, but 5 million gallons per day of wastewater is recycled to the landscape beginning in 2010. This has the significant effect of raising the surficial and Floridan aquifer levels and the net effect of higher lake water levels.

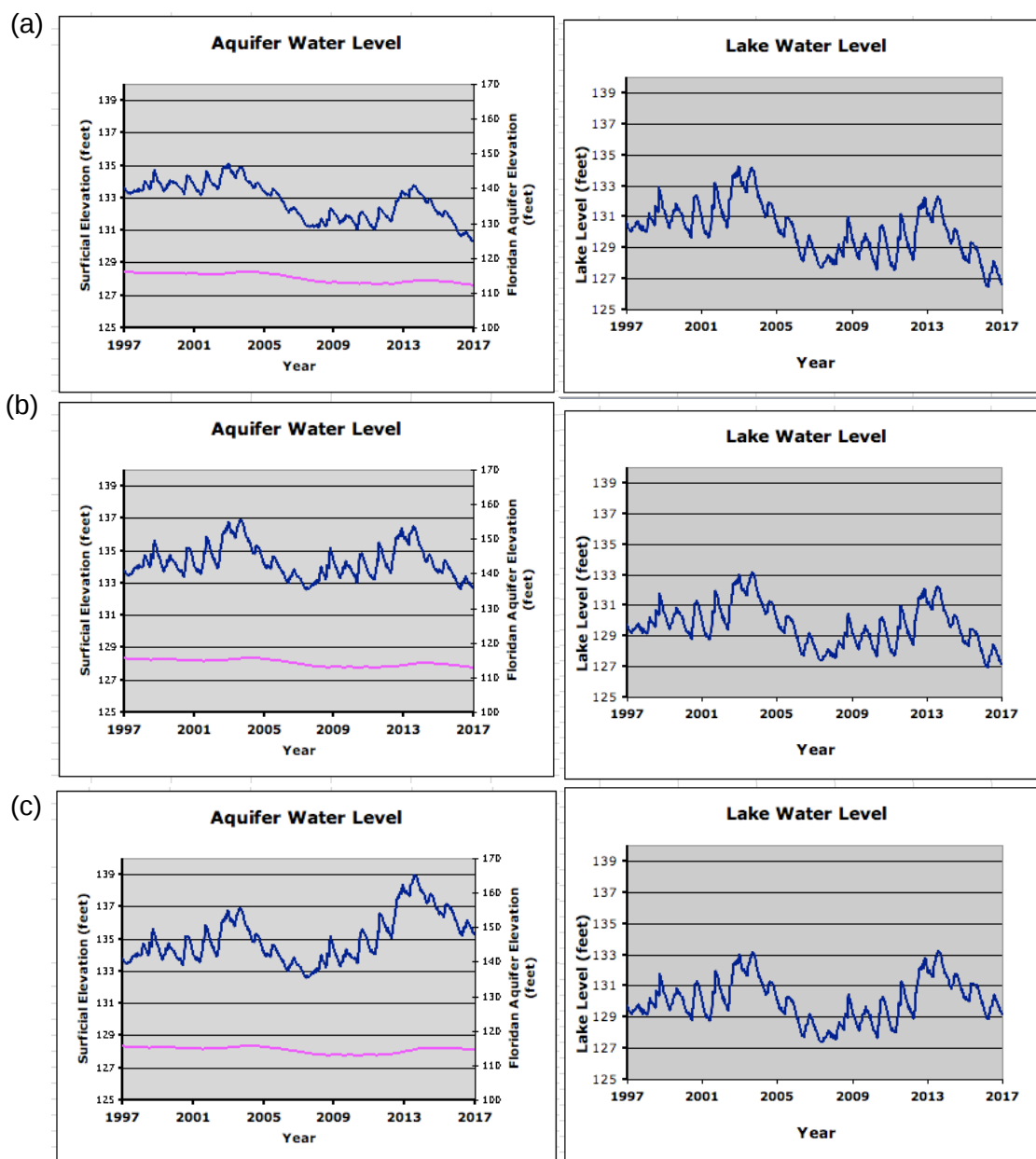


Figure C.6. Evaluation of Recent Trends.

Simulation results of the Winter Haven Ridge Lake Model, showing the average elevation (NAVD) of the surficial (blue line) and Floridan aquifers (pink line) (left) and lake levels (right) from 1997 to 2017, assuming declines in the potentiometric surface of the Floridan aquifer and urbanization increasing until the amount of impervious surface totals 60%. The simulation is driven by 10 years of actual rainfall data (from 1997-2007) that is repeated in the second 10 years of the simulation. The top two graphs (a) illustrate the current condition (i.e., stormwater discharged directly to the lakes). With the drier years beginning in 2005, the surficial aquifer declines precipitously and lake levels follow. The middle two graphs (b) illustrate the effect of stormwater infiltration basins and surficial aquifer recharge instead of direct discharge to the lakes. While the surficial aquifer still declines because of the low rainfall, the decline is not as steep and overall lake water levels are higher. In the bottom two graphs (c), not only is stormwater stored and recharged to the surficial aquifer instead of being directly discharged to the lakes, but 5 million gallons per day of wastewater is recycled to the landscape beginning in 2010. This has the significant effect of raising the surficial and Floridan aquifer levels and the net effect of higher lake water levels.

Winter Haven Ridge Lake Model: Summary of Simulation Results

These simulations are analogous to the overall situation in the Winter Haven Southern Chain of Lakes. Floridan aquifer levels have been declining over the past several decades as a result of both regional water use and withdrawals in the Peace Creek watershed area.

Simultaneously with the Floridan aquifer declines, the amount of impervious surface area has increased. While some of the newest development uses best management practices (BMPs) that reduce stormwater runoff, stormwater is discharged directly to the lakes from a significant portion of the urban area.

The simulations show that if some stormwater is used to recharge the surficial aquifer, this results in higher lake water levels in the long run—not to mention the water quality benefits that are derived through better treatment of these waters as they infiltrate through the sands of the surficial aquifer. Management of this system for high lake levels might require discharging directly to the lakes during low rainfall periods to maintain lake levels, and recharging the surficial aquifer during high rainfall periods to build a buffering reservoir that will generate higher lake levels during dry periods. If this water is infiltrated into the surficial aquifer, it becomes a storage reservoir that slowly recharges lake levels over a longer period, thus minimizing the water quality impacts of stormwater discharge to the lakes and providing a buffering effect that allows the lakes to fluctuate naturally with the wet and dry seasons.

When the model is simulated to include the recycling of treated wastewater on the landscape, significant benefits are experienced in all three components of the Winter Haven hydrologic system: the surficial aquifer is maintained at a much higher level; the Floridan aquifer elevation improves; and lake water levels remain higher than they do with direct discharge.

The simulations are models of how we believe the Winter Haven system is operating. They are based on real rainfall data for Winter Haven, and are calibrated to records of lake levels measured over the last 20 years. The models have to assume relationships in flow rates between lakes and aquifers for which little or no data is available. These rates are average rates for the entire system, and they are chosen based on experience with similar hydrologic systems and reviews of past studies on the Winter Haven system. The simulations are best used to develop and test hypotheses about how changes to the system will affect lake and aquifer levels. They can be used to test management strategies and show which are the most promising based on a current understanding of the system. The models should be viewed as a synthesis of current knowledge, and not as actual measurements of flows within the system.

Simulation of the Polk Uplands Model

A simulation model of Polk Uplands (Storage and Conveyance Areas) was undertaken to determine whether increased storage within the landscape would positively affect downstream wetlands or base flow to the Peace River.

The Polk Uplands is a broad relatively flat basin, defined by the Winter Haven Ridge to the west and the Lake Wales Ridge to the east. The slope of the basin from the north near Lake Hamilton to the south at the Peace River is a very gradual 1.4 feet per mile. Historically, the Polk Uplands was dominated by shallow expansive wetlands that fed wet season rains to slowly draining wetland sloughs, which in turn passed the waters on to Peace Creek and the Peace River.

The Polk Uplands is a landscape that historically acted as a storage reservoir, receiving wet season rains, temporarily storing them in the extensive area of wetlands (nearly 30% of the surface area), and then slowly releasing them over the next several months. The hydrologic

system functioned to maintain water in wetlands and upland soils for long periods. The considerable friction that slows down the water meandering through wetland sloughs ensured that the landscape remained wet well into the dry season, and that baseflow to Peace Creek and eventually the Peace River was also maintained. Of course, as a result, the landscape remained flooded for long periods, rendering it unsuitable for agriculture or other forms of development.

The diagram in **Figure C.8** illustrates the hydrologic system of the Polk Uplands, with estimates of the average quantities of water stored in the surficial aquifer, wetlands, and Peace Creek, as well as average annual flows. The assumptions used to estimate flows and storage are as follows:

Total area = 78,750 acres, including 29,587 acres of wetlands and 800 acres of stream;
Annual average rainfall = 50.2 inches per year;
Water depth in wetlands = 2 feet;
Depth of surficial aquifer = 20 feet, with 40% porosity;
ET = 66% of rainfall;
Groundwater inflow = 5x inflow from Winter Haven Ridge based on linear distance of Lake Wales Ridge compared with Winter Haven Ridge;
Surface runoff = 23% of rainfall;
Wetland recharge of surficial aquifer = 12% input (from model);
Wetland surface discharge = input – (recharge + ET);
Recharge to surficial aquifer = rainfall - surface runoff;
Deep recharge = 10% of rainfall;
Evaporation from surficial aquifer = 5% of input;
Groundwater outflow = 2% of inflows;
Surficial aquifer discharge to surface water = inflows - outflow; and
Peace Creek discharge = sum of outflows from wetlands, surficial aquifer, and runoff.

To accommodate agriculture and other development, the Polk Uplands was drained. Networks of ditches were dug, and Peace Creek was straightened and deepened. The result is illustrated in **Figure C.9**, which diagrams the estimates of the current hydrologic system. The flows that have changed are indicated in red. The assumptions used to estimate flows and storage are as follows:

Total area = 78,750 acres, including 20,600 acres of wetlands and 800 acres of channelized creek;
Annual average rainfall = 50.2 inches per year;
Water depth in wetlands = 2 feet;
Depth of surficial aquifer = 16 feet, with 40% porosity;
ET = 53% of rainfall;
Groundwater inflow = 5x inflow from Winter Haven Ridge based on linear distance of Lake Wales Ridge compared with Winter Haven Ridge;
Surface runoff = 32% of rainfall;
Wetland recharge of surficial aquifer = 17% of input;
Wetland surface discharge = input – (recharge + ET);
Recharge to surficial aquifer = rainfall - surface runoff;
Deep recharge = 8% of rainfall;
Evaporation from surficial aquifer = 5% of input;

Groundwater outflow = 2% of inflows;

Surficial aquifer discharge to surface water = inflows - outflow; and

Peace Creek discharge = sum of outflows from wetlands, surficial aquifer, and runoff.

The ditching and draining resulted in a decrease in wetland area of nearly 9,000 acres (a reduction of over 30%) that has led to a loss of about 6 billion gallons of wetland storage and declines in the surficial aquifer of nearly 10% (or a loss of about 21 billion gallons of storage). In all, the total loss of storage is estimated at about 27 billion gallons.

The loss of wetland and surficial aquifer storage, as well as ditching and draining, have increased surface runoff almost 70%, resulting in a 24% increase in Peace Creek discharge. While an increased discharge from Peace Creek might be viewed by some as a positive result, bear in mind that the timing of much of the increased discharge is not advantageous, as it comes when the creek and river need it the least. The models illustrate that during times of decreased average rainfall, the discharge can fall below historic trends because the flows are no longer buffered by storage in the wetlands and surficial aquifer.

This analysis indicates that the recharge to the Floridan aquifer has decreased by approximately 18% (from 11 to 9 billion gallons/year, or the equivalent of 5.4 MGD) as a result of alterations to storage within the Peace Creek watershed. Historically, water stored in the wetlands and surficial aquifer was available to recharge the deeper Floridan aquifer. When water is drained from the system and discharged as surface water, this water is no longer available to recharge the Floridan aquifer.

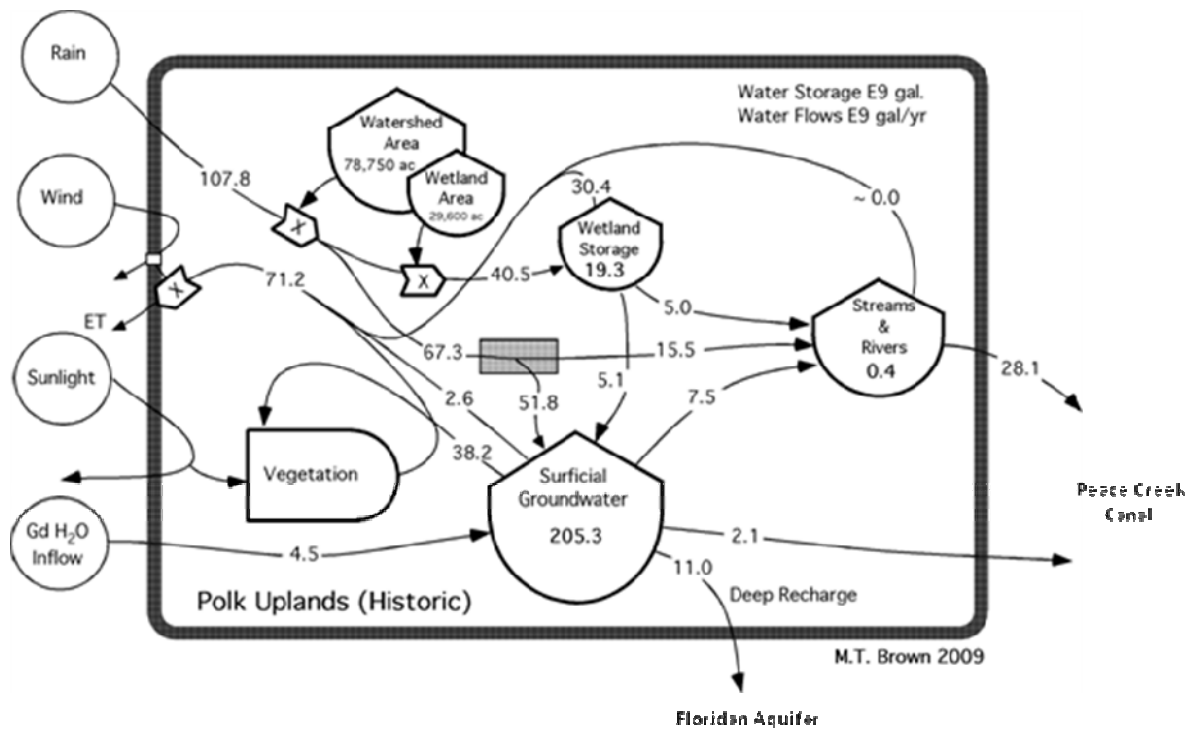


Figure C.8. Diagram of the historical hydrologic system of the Polk Uplands. Water storage is in billions of gallons and flows are in billions of gallons per year.

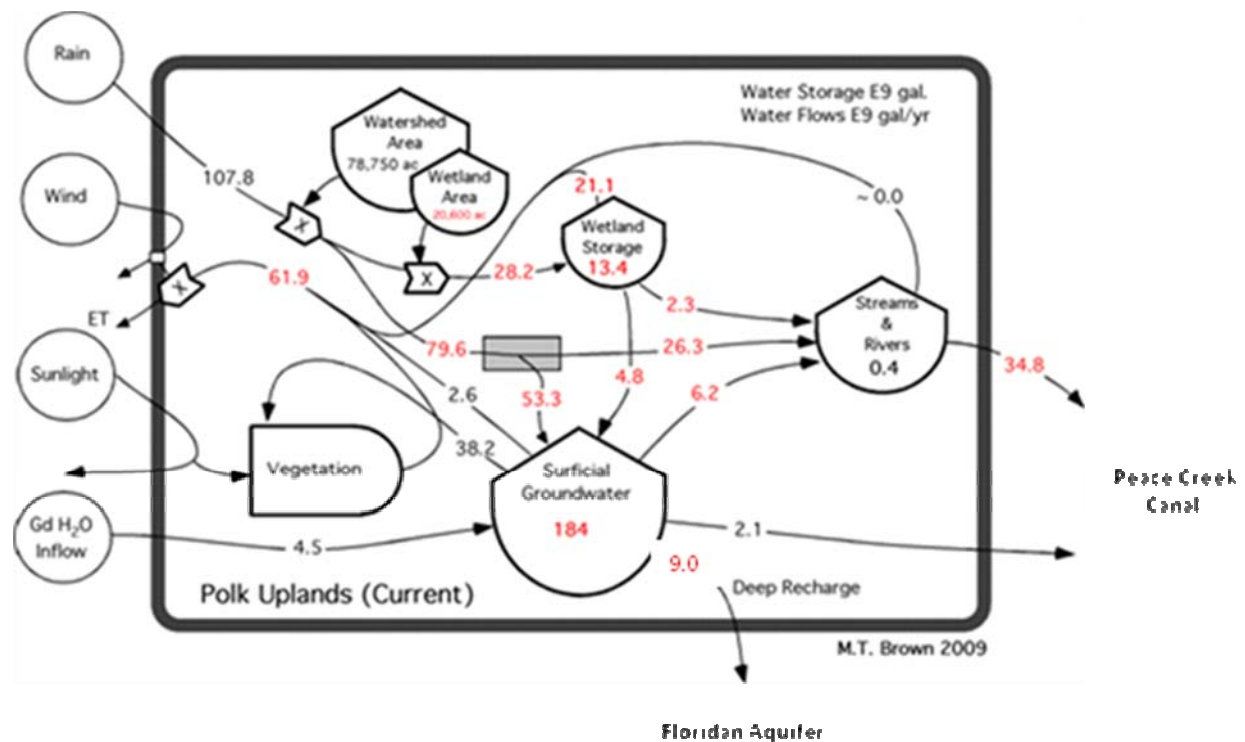


Figure C.9. Diagram of the current hydrologic system of the Polk Uplands. Water storage is in billions of gallons and flows are in billions of gallons per year.

Simulations

To better illustrate the hydrodynamics of the system, a simulation model of the Polk Uplands was developed using the main storage and flows in **Figures C.8** and **C.9**. The model uses the entire rainfall record beginning in 1941 to the present. However, to illustrate the impacts of ditching and draining on the hydrologic behavior of the system, only the last 5 years of data (2002 to 2007) are presented. The graphs in **Figures C.10** and **C.11** show the simulation results from the model.

The results in **Figure C.10** depict the historical condition prior to development (using rainfall data from 2002 to 2007, but with all other coefficients and flows set to mimic historical conditions). It should be noted that these five years have a lower than average rainfall of 48.5 inches, almost 3 inches below the 50.2 inch average. The surficial aquifer shows a slight decline through the 5 years of the simulation as a result of the decrease in rainfall during that period. Wetland water levels also exhibit declines. The Peace Creek discharge follows rainfall patterns, with the highest discharges immediately following the rainy season. Baseflow in Peace Creek would have averaged about 100 cubic feet per second (or a total of about 64 million gallons per day).

The results in **Figure C.11** depict the current condition. The surficial aquifer has about 10% less storage as a result of the lowered water tables precipitated by the network of ditches and "improvements" to Peace Creek. The effects on wetland storage and the Peace Creek discharge illustrated in the right-hand graph are far more dramatic. Wetland water levels decline so that there are longer periods of dry conditions, and Peace Creek discharges are significantly greater in number and higher in magnitude following rainfall events; both consequences will stress downstream ecosystems.

Also of importance is the large number of very low discharge periods, for without the buffering capacity of wetland storage and the friction of meandering wetland sloughs, stormwater is shunted toward the Peace River at times of the year when the river little needs the additional water. Once discharged during the wet season, stormwater is not available to feed and enhance baseflow during the dry season. Baseflow averages less than 50 cubic feet per second or less than 30 million gallons per day under current conditions in the simulation. While it appears as if the total discharge is larger than would have occurred under historical conditions, because there are many more peaks, overall discharge to the Peace River is actually 22% less than would have occurred historically.

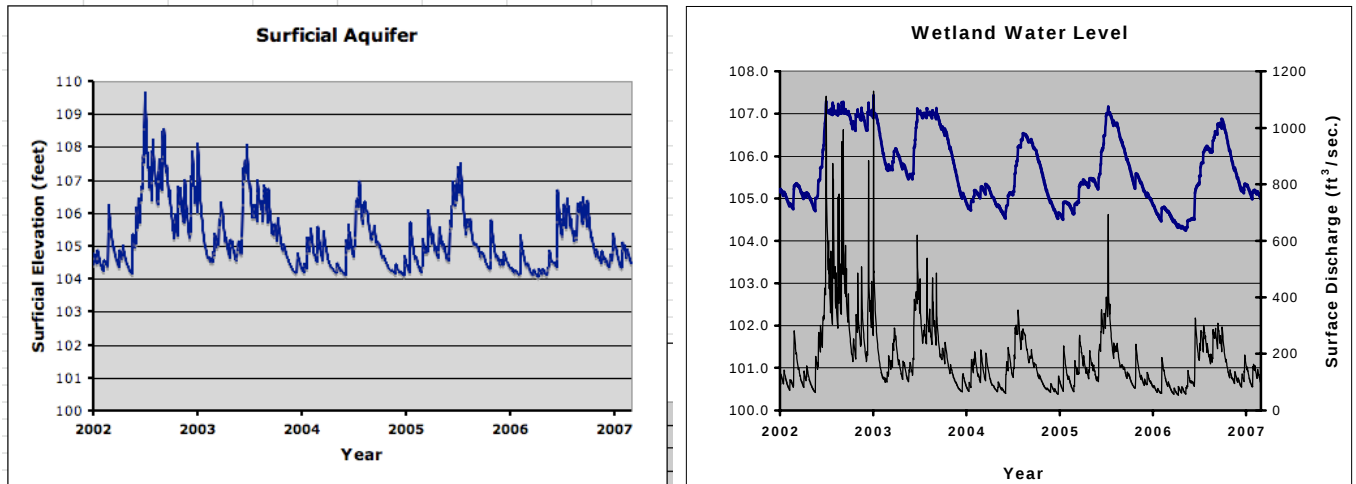


Figure C.10. Simulation results of the model depicted in Figure C.8 (i.e., assuming historical conditions with no ditching and draining) for the period from 2002 to 2007. The graph on the left shows the water level of the surficial aquifer varying about 3 feet per year. The graphs on the right show the water levels in wetlands (top blue line) and Peace Creek discharges (bottom black line). Water levels in the wetlands vary about 2 feet between the wet season and dry season.

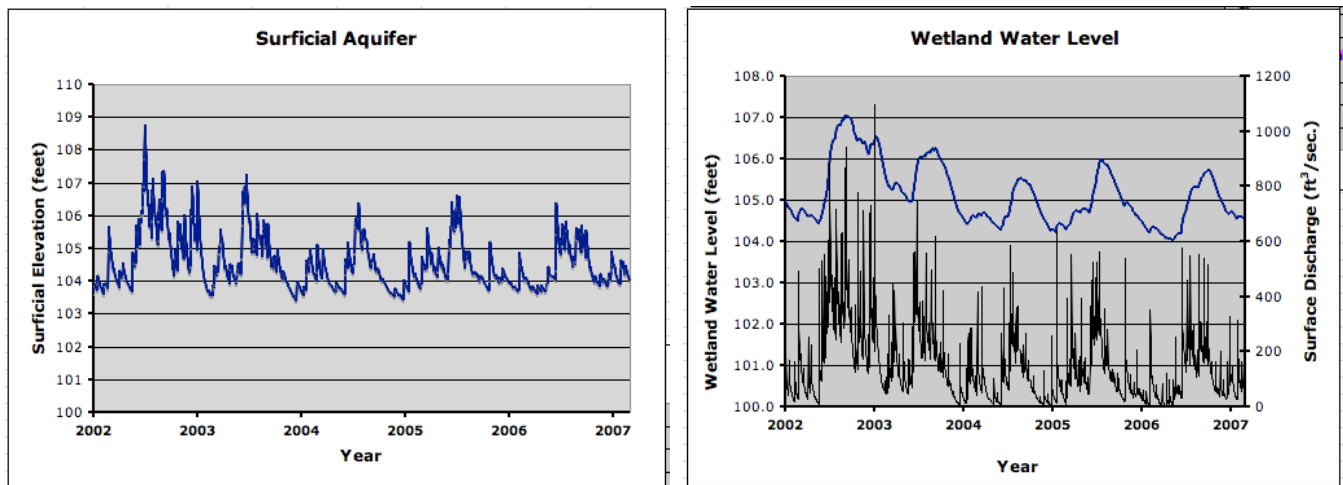


Figure C.11. Simulation results of the model depicted in Figure C.9 (i.e., assuming current conditions) for the period from 2002 to 2007. The graph on the left shows the water level of the surficial aquifer varying about 2½ feet per year. The graphs on the right show the water levels in wetlands (top blue line) and Peace Creek discharges (bottom black line). Water levels in the wetlands vary about 1½ feet between the wet season and dry season.

Polk Uplands Model: Summary and Conclusion

The future condition of the Polk Uplands, and ultimately the future of the Peace River depend on two things: developing increased storage that mimics the historical condition, and dechannelizing Peace Creek (and other tributaries). These simulations were undertaken to demonstrate, first, the lost functions that have resulted from improper land and water management in the past and, second, that restoration can accomplish significant improvements. The magnitude of potential improvement is illustrated by comparing the historical condition with the current condition, and in essence reversing trends and conditions to those characteristic of the Polk Uplands 75 years ago.

Historically the watershed used to store vast amounts of water. Today, the watershed is managed to efficiently and effectively get rid of water for flood protection. Restoring parts of the watershed using the natural landscape can recreate lost storage and help contribute flows to the Peace River during the dry season and drought conditions and help increase recharge to the Floridan aquifer.

Appendix D: Assessing the Feasibility of Mitigation Banking—by Ed Cronyn, Senior Scientist, PBS&J

Introduction

All human land uses—such as agricultural, industrial, commercial, and residential development—affect the movement and storage of water. Federal and state regulations seek to minimize or compensate for the impacts of those land uses through a process called mitigation. Mitigation means that the amount and type of lost hydrologic function must be calculated and then re-created somewhere else. Examples include mitigation for wetland losses, losses of habitat essential to threatened and endangered species, and impacts to riverine systems.

Historically, mitigation occurred on site; however, isolated mitigation projects resulted in the fragmentation of the hydrologic system. The cumulative impacts of many individual projects reduced the resilience of the natural system to act as a buffer against droughts and other environmental stresses, and often led to flooding. The U.S. Army Corps of Engineers (Corps) and state and local governments are now encouraging mitigation at a watershed scale, to ensure that water resources are preserved as part of a larger hydrologic system and to retain that system's essential hydrologic function. The Conceptual Plan is consistent with current rules that encourage the use of watershed-scale mitigation instead of on-site mitigation.

This appendix provides additional information on the basic concepts of mitigation banking, the mitigation banking process, regulatory criteria, financial considerations, the mitigation service area, and the ecological feasibility of the Winter Haven mitigation bank. It also summarizes the major tasks involved in assessing the feasibility of mitigation banking as the principal approach to funding the restoration of wetlands in the Peace Creek watershed.

Summary

- Mitigation funding for the City of Winter Haven project is potentially available through two routes: mitigation banking and specific Southwest Florida Water Management District funding as a Surface Water Improvement and Management Program project to offset FDOT wetland impacts
- Mitigation banking requires authorizations from the U.S. Army Corps of Engineers (known as a Mitigation Banking Instrument) and SWFWMD (via the Environmental Resource Permit Program)
- The service area for mitigation banking would likely consist of the Peace River Basin.
- The SWFWMD could also create a “nested regional watershed” in the Peace River Basin. There is no precedent within SWFWMD for this designation. However, the St. Johns River Water Management District, with identical statutory authority and nearly identical regulations, has established nested regional watersheds in that District.
- Funding as a mitigation bank would occur through the sale of mitigation credits, whose current market value is approximately \$125,000 per UMAM credit.
- Funding as a SWFWMD-sponsored SWIM project would occur through a FDOT escrow fund, at a value of over \$100,000 per acre of FDOT wetland impact, translating to approximately \$167,000 per UMAM credit.
- A UMAM credit represents approximately 2 acres of restoration/enhancement at a mitigation bank and offsets a little more than 1 ½ acres of typical wetland impact. CSX and/or other anticipated private and public projects within the Peace River Basin would be the customers for this mitigation bank.

Basic Wetland Mitigation Banking Concepts:

Mitigation Credits – The degree of improvement in ecological value expected to result from the establishment and operation of a mitigation bank, as determined using a functional assessment methodology (such as the Uniform Mitigation Assessment Method [Rule 62-345, Florida Administrative Code], or UMAM). Functional assessment methods are used to establish the value of an improvement, representing units roughly equivalent to acres of fully successful wetland creation or restoration from uplands, which can then be sold to third parties who need to offset their own proposed impacts.

Mitigation Service Area (MSA) – The geographic region within which wetland impacts can be offset via the purchase of credits at the mitigation bank. SWFWMD has consistently authorized MSAs comprising solely the regional watershed within which the bank is located. **Figure A-1** shows the SWFWMD map of 16 regional watersheds (Exhibit 1 in its mitigation bank rule). However, impacts for linear projects such as roadways, pipelines, and utilities are not bound by the MSA; they may be mitigated at any mitigation bank with the appropriate type of credits.

Nested Regional Watershed – A watershed within a watershed, created for the purpose of concentrating mitigation in a smaller region than the larger regional watershed. To date, SWFWMD has not designated any nested regional watersheds. However, the St. Johns River Water Management District, with identical statutory authority and regulations that are substantially equivalent to those of SWFWMD, has recognized five nested watersheds via the following notation on its adopted watersheds map:

NOTE FOR NESTED BASINS:

Basins 5, 6, 13, 15, and 19 above are designated as nested basins, which means that these areas are both individual basins and part of larger basins. The effect of this designation is that, for impacts that are outside of a nested area, but within the larger basin of which it is a part, mitigation within the nested area will be considered to be in the same drainage basin for cumulative impact review purposes. For impacts that are located within a nested area, mitigation that is located outside of the nested area but within the larger basin of which it is a part will be considered to be outside of the drainage basin for cumulative impact review purposes.

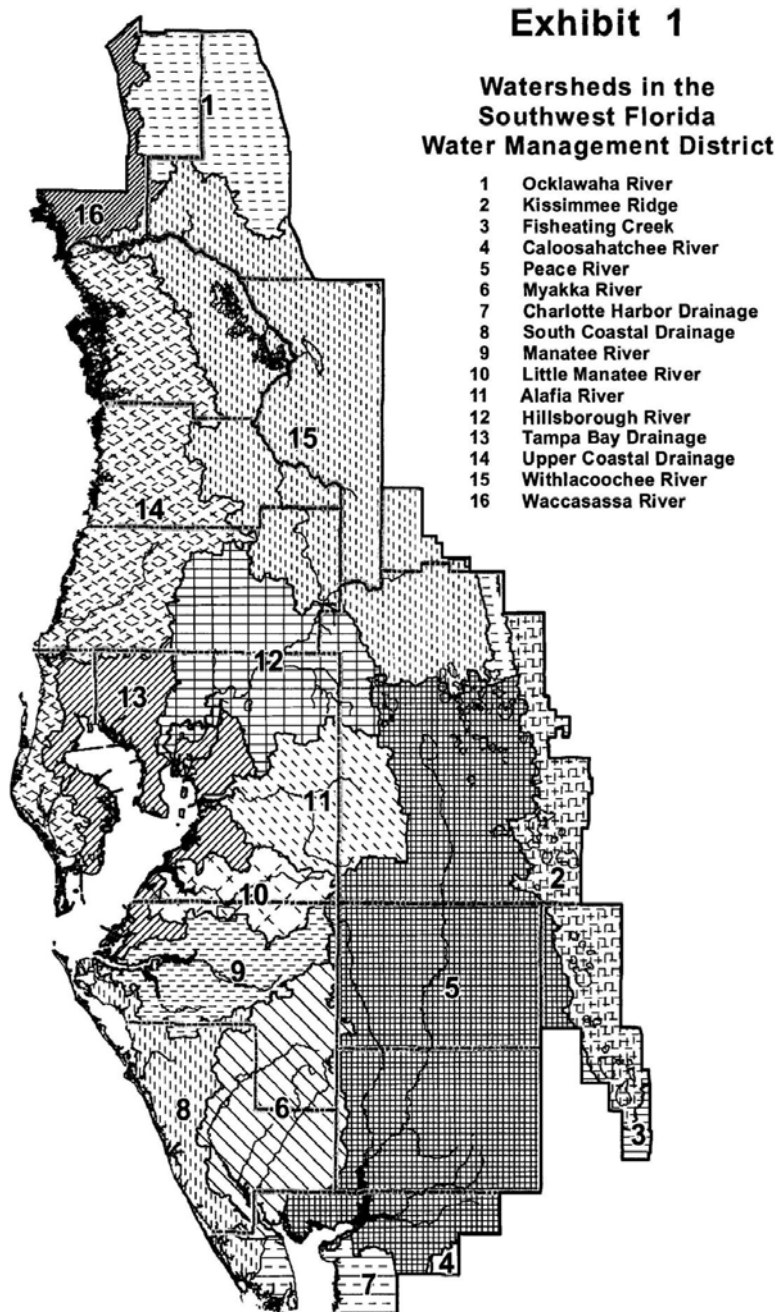
Credit Release Schedule – The timing of allowable credit sales, dependent on meeting the conditions established in the mitigation bank permit. Typically, around 10% of credits are available for sale after the bank receives the permit, records a conservation easement, and establishes the financial assurance mechanism (generally a bond or letter of credit guaranteeing that the authorized work will be performed). The remaining amounts are released in phases upon the completion of construction activities (such as weir construction and scrapedown/vertical relocation), the removal of exotic/invasive plants, the planting of native species, and the achievement of a certain percentage of coverage by appropriate native vegetation.

Uniform Mitigation Assessment Method (UMAM) – A procedure adopted by rule and binding on the Florida Department of Environmental Protection (FDEP), water management districts, and local regulatory agencies that require wetland mitigation. UMAM evaluates three ecological parameters—location/landscape position, water environment (water quality and hydrology), and community structure (vegetation and contours)—at two points in time: “existing condition” before the bank is implemented, and “with bank” anticipated conditions upon the successful completion of restoration activities.

To determine the “existing condition” score, these three parameters are each scored on a scale of 0 to 10, and then averaged together and divided by 10 to arrive at a score between 0 and 1. This score is then subtracted from the “with bank” condition score to arrive at a “delta,” representing the amount of ecological improvement. The “delta” is then adjusted by two additional factors to account for the amount of time necessary to achieve full restoration and the degree of risk involved. All of the ecological parameters, time lag, and risk factors are assigned according to criteria established in the UMAM rule, as interpreted by the reasonable professional judgment of the reviewing agency.

For example, a hypothetical 1,000-acre proposed mitigation bank site has a current UMAM value of 0.3 per acre (that is, a low, degraded ecological condition). The property owner proposes a restoration plan that will result in an eventual UMAM value of 0.8 per acre (a very good but not perfect ecological condition). The “delta” in this case is 0.5 UMAM units per acre (0.8 minus 0.3). However, because a moderate amount of time is necessary for the hydrology, vegetation, and soils to achieve restoration goals (a UMAM score of 0.8), and the risk that the project will not achieve this score, the adjusted “delta” reflecting time and risk becomes 0.4 per acre. This mitigation bank can sell a total of 400 credits (0.4 times 1,000 acres), assuming that the criteria laid out in the permit are met.

Figure A-1. SWFWMD map of regional watersheds



Mitigation Banking Process

The basic process for obtaining a mitigation bank permit is as follows (**Figure A-2** provides a flow chart):

1. Conduct a Feasibility Assessment

Interested landowners generally hire an experienced mitigation banking consultant to conduct a feasibility study before determining whether to proceed with a mitigation bank permit application. The feasibility study includes a review of the site's suitability from the following perspectives:

Ecological (approximately how much UMAM improvement can be reasonably expected);

Technical (various engineering, construction, and hydrologic constraints);

Financial (the amount, value, and timing of credits to be sold versus the cost of the restoration plan and other reasonable and beneficial land uses); and

Regulatory (the compatibility of the restoration plan with state and federal regulatory criteria).

2. Regulatory Process

Two agencies have primary authority for reviewing and authorizing mitigation banks—the U.S. Army Corps of Engineers (Corps) for the federal government and the appropriate water management district for the state of Florida. FDEP only reviews and issues a state permit if a water management district sponsors or owns the project. The Corps also consults other federal and state agencies in a forum known as the Interagency Review Team (IRT). Federal agencies typically participating in the IRT include the Corps, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S. Department of Agriculture's Natural Resources Conservation Service, and occasionally the National Oceanic and Atmospheric Administration's National Marine Fisheries Service.

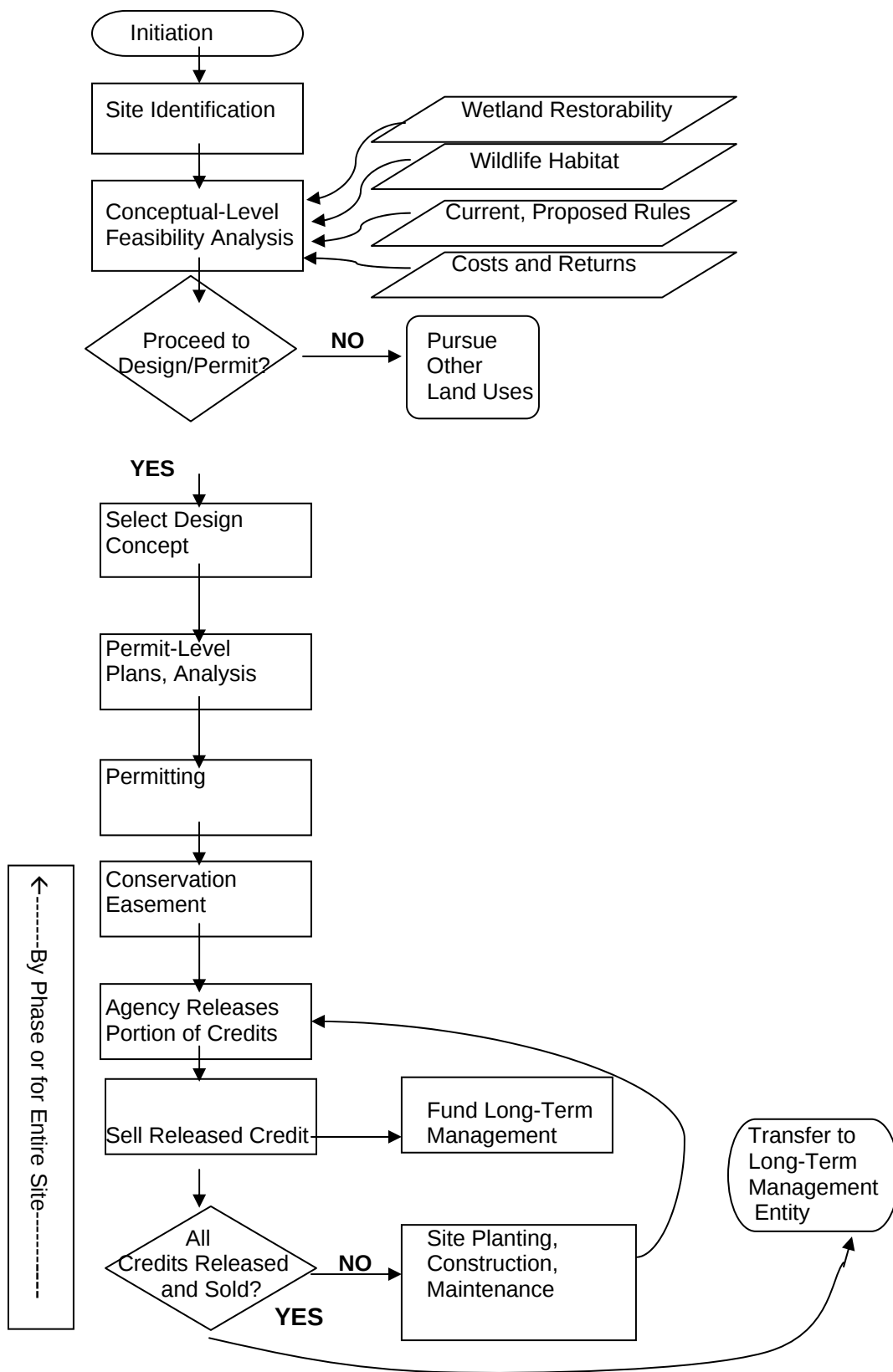
Mitigation bankers usually conduct one or more preapplication meetings with state and federal agencies. The IRT, convened by the Corps, is one forum for this discussion to occur. The purpose of the preapplication discussion is to identify the agencies' perspective on the overall mitigation banking concept, service area, and restoration plan, as well as any particular issues of concern that should be resolved during the permitting process. Failure to obtain IRT approval before an application is submitted to the Corps generally results in a difficult process.

Federal application process:

The federal process consists of the following four steps:

- ***Development of the prospectus, or preliminary mitigation banking instrument (PMBI)***— Provides basic summary information for presentation to the IRT.
- ***Preparation of the draft MBI***— Contains all the information necessary to demonstrate consistency with federal regulatory criteria, credit assessment, MSA, etc. The submittal of this document initiates the federal review process.
- ***Receipt of Letters and responses***— This process often takes a year, during which the Corps and mitigation bank applicant fine-tune the MBI.
- ***Preparation of the final MBI***— Prepared by the applicant in response to comments and adopted by the Corps.

Figure A-2. Mitigation Bank Process



State application process:

The state agency—either the water management district or FDEP—reviews mitigation bank permit applications within the same process and timelines as required by any other Environmental Resource Permit. State agencies (water management districts, Florida Fish and Wildlife Conservation Commission) are encouraged to participate in the federal IRT to ensure that this forum includes all agencies' comments, but their participation is not required.

The state process is similar to the federal process, except that agency review timelines are mandated, so that the state process is often completed months in advance of the federal. The applicant submits an Environmental Resource Permit application for a mitigation bank, and the agency reviews and comments on the application, until the application is deemed complete and approved. A state agency may award a different amount of credits than the federal agency, due to differences in regulations and the interpretation of UMAM.

Operation and management:

- Credits released in phases according to criteria in the federal MBI and state permit
- Mitigation banker implements restoration plan to achieve additional releases
- Marketing and sales of credits to applicants requiring mitigation for state and/or federal wetland impacts (two different ledgers—one for the state, one for the federal)
- Ongoing maintenance activities for compliance with permit
- Portion of proceeds from credit sales is directed into long-term management fund
- Landowner (if not a government or non-profit conservation organization) turns land over to a long-term management entity (government or non-profit conservation organization) along with the management funds

Regulatory Criteria

The state and federal criteria are substantially similar, although the process and outcomes may differ. One important difference is the new federal emphasis on watershed-level mitigation and concomitant de-emphasis on on-site mitigation. State rules still emphasize on-site or nearby mitigation, but practices and policies have become more favorable to the use of mitigation banks due to the relatively poor success rate of many on-site mitigation projects.

Federal (33 CFR Parts 325 and 332; 40 CFR Part 230):

- Watershed planning emphasized
 - o “Watershed plan means a plan developed by federal, tribal, state, and/or local government agencies or appropriate non-governmental organizations, in consultation with relevant stakeholders, for the specific goal of aquatic resource restoration, establishment, enhancement, and preservation”
- Twelve fundamental components of all mitigation plans:
 - o Objectives
 - o Site selection
 - o Site protection instrument (conservation easement)
 - o Baseline information
 - o Determination of credits (UMAM)
 - o Mitigation workplan
 - o Maintenance plan
 - o Performance standards
 - o Monitoring requirements

- o Long-term management plan
 - o Adaptive management plan
 - o Financial assurances (bond/letter of credit/trust fund)
- “Soft” preference for mitigation banks vs. other forms of mitigation
- Commitment (but not hard-and-fast requirement) to review mitigation banks within timelines
- IRT review, with dispute-resolution process
- Umbrella mitigation banking instrument allows multiple sites to be authorized with one instrument

State Mitigation Bank Statute (373.4136, F.S.):

Provide reasonable assurance that the mitigation bank will--

- Improve ecological conditions of the regional watershed;
- Provide viable and sustainable ecological and hydrological functions for the proposed mitigation service area;
- Be effectively managed in perpetuity;
- Not destroy areas with high ecological value;
- Achieve mitigation success;
- Be located adjacent to lands that will not adversely affect the perpetual viability of the mitigation bank due to unsuitable land uses or conditions;
- Meet regulatory requirements for any constructed, operated or abandoned surface water management system;
- Have sufficient legal or equitable interest in the property to ensure perpetual protection and management of the land; and
- Meet the financial responsibility requirements prescribed for mitigation banks.

FDOT/FDEP/WMD Work Plan (373.4137, F.S.):

This statute provides an alternative route for FDOT mitigation that does not utilize mitigation banks.

- FDOT and certain other transportation authorities annually submit three-year work plan, indicating estimated wetland impacts and mitigation needs
- FDOT and other authorities each fund an escrow account to pay for the estimated mitigation needs, updated quarterly
- WMD's each annually update a plan to provide mitigation for FDOT's mitigation needs within their jurisdictional boundaries, in consultation with FDEP, USACE, and other agencies
- SWIM and other projects defined by WMD's via their annual FDOT workplan are implemented, using the escrowed funds
- FDOT cost for this is currently over \$100,000 per acre of impact
- FDOT may opt-out of the FDEP/WMD program on a project-by-project basis if approved by FDEP and WMD. SFWMD is the only WMD that routinely authorizes this opt-out.

Financial Considerations

- Complexity of permitting often requires substantial up-front investment for design and permitting. These costs should be estimated and budgeted, accordingly.

- The length of the permitting process, plus the pre-permit preparation and discussions, may mean a waiting period of several years between the time of initial concept and the sale of the first credit
- UMAM credits currently sell for ~\$125,000-\$145,000 in central Florida
- Sale of credits depends on development
- Upcoming development includes CSX project: should include this and other known/anticipated development in market demand projections

Mitigation Service Area

- Peace River Basin is one of the largest watersheds in SWFWMD—this is good for a broad market area, but also represents large areas where competing mitigation banks can be established (including an existing Peace River Mitigation Bank operated by EarthBalance).
- A nested regional watershed as defined by SJRWMD establishes a potential precedent for SWFWMD to establish a nested regional watershed for the Peace Creek basin. This would add value to mitigation credits sold for projects within this smaller basin.

Ecological Feasibility of Winter Haven Project

- The proposed project anticipates improvements to hydrology, water quality, connectivity, and vegetation of the wetlands
- Anticipate UMAM credits equivalent to approximately 0.4 to 0.6 UMAM credit per acre, based on similar mitigation bank projects (e.g., 1000 acres would generate 400 to 600 credits).
- Presenting this as a single, cohesive mitigation bank would improve the regulatory feasibility (rather than as several individual parcels, each permitted separately)
- Improvements should be geared towards eventual self-sustaining wetland systems (e.g., not requiring pumps, operable weirs, etc.).

Proposed Scope of Work—Feasibility of Mitigation Banking

The feasibility of mitigation banking or FDOT/SWFWMMD mitigation funding for this project relies on several factors. The following plan summarizes the major tasks involved in mitigation feasibility assessment for this project.

Task 1: Conceptual Restoration Plan(s)

This task flows directly from the work completed to date for the City of Winter Haven and would include specific conceptual-level plans for restoring wetlands, including improvements in the hydrology and vegetation resulting from those plans.

Task 2: Ecological Feasibility

This task would include review of the information already gathered, the conceptual restoration plans, GIS and other data sources, and additional data gathered through site visits. This baseline ecological data assessment provides the necessary understanding of the existing condition of the sites in order to better determine which restoration concepts are most likely to be successful. A key element of the ecological feasibility assessment will be ballpark estimation of achievable UMAM mitigation credits under each of the conceptual restoration plans.

Task 3: Technical Feasibility

This task complements Tasks 2 and 3 by reviewing the conceptual restoration plans from engineering, hydrological, and constructability perspectives. Key elements will include evaluation of various design elements to determine whether they can be constructed using readily available materials and techniques, whether they will result in measurable improvements in wetlands' hydrology, and whether they would result in adverse changes in flood protection of other property.

Task 4: Financial feasibility

This task consists of two basic functions: 1) estimation of design, permitting, construction, and operation costs associated with the conceptual restoration plans, in parallel with Tasks 1 through 3, as well as marketing and land management; and 2) estimation of the return-on-investment, including anticipated market value, timing of demand, and amount of mitigation credit sales. These ballpark estimates of costs and returns will help to further refine the selection of one or more restoration conceptual plans to further develop.

Estimates of the market value and future demand for mitigation credits are typically based on review of recent and long-term trends in wetland impacts within the mitigation service area (e.g. SWFWMD and FDEP permitting databases); known public and private developments in the planning stages (e.g., CSX Intermodal project, highway projects, etc.); Realtors' and economists' projections of future growth; local governments' comprehensive plans; and known and anticipated mitigation alternatives (e.g., the Boran Ranch and Peace River Mitigation Banks operated by EarthBalance). Currently, the Boran Ranch Mitigation Bank has 50-60 mitigation credits available to offset impacts to herbaceous wetlands, at a cost of \$97,000 per credit. The Peace River Mitigation Bank has over 100 credits available to offset impacts to forested wetlands, at a cost of \$149,000 per credit. As indicated above, each credit offsets impacts to slightly less than 2 acres of typical wetland impact. Mitigation charges for FDOT projects via the

SWFWMD mitigation program are currently slightly more than \$100,000 per acre of wetland impact, with future increases or decreases pegged to the Consumer Price Index.

Finally, this task includes evaluation of public-private partnership opportunities. Publicly-owned banks are typically designed, permitted, operated, and marketed by private consultants. In some cases, the consultant provides some of these services at limited no up-front charge, with their fees paid as a percentage of mitigation credit sales.

Task 5: Regulatory Feasibility

This task includes review of the degree to which the proposed wetland restoration plans are consistent with the mitigation banking criteria summarized above and/or the FDOT/SWFWMD mitigation program.

One component of particular importance for mitigation banking is the possibility for SWFWMD to designate the Peace Creek basin as a “nested regional watershed” within the larger Peace River Watershed. SJRWMD and SWFWMD have nearly identical rules regarding mitigation bank service areas. However, SJRWMD recognizes five nested regional watersheds within their District and SWFWMD has none. Recognition of the Peace Creek basin as a nested regional watershed would simply require a revision to SWFWMD map of regional watersheds (Exhibit 1 above) to add the boundaries of the Peace Creek basin and a footnote within that map denoting that basin as a nested regional watershed, similar to language used by SJRWMD in their map of regional watersheds. If successful, the designation of a nested regional watershed would provide significantly greater value to the credits generated by banks within the nested basin. Banks within nested regional watersheds in SJRWMD charge twice as much per credit as other banks within the same larger regional watershed but outside of the nested regional watershed.

State statute also requires publicly-owned mitigation banks to charge “full cost” for mitigation bank credits, meaning that the price needs to generate a net profit for the land-owning government agency, including the value of the land. The intent of this statutory provision is to avoid a public “subsidy” that would enable a government agency to undercut the price charged by private mitigation banks by using free public lands already owned by taxpayers. Other states have enacted provisions outright prohibiting publicly-sponsored mitigation banks, so regulatory feasibility assessment also needs to include the analysis of the likelihood and severity of the effect of potential legislation.

Another option, substantially similar to mitigation banking, would be to pursue a permit for a portion or the entire restoration plan as a “regional off-site mitigation area.” This option entails the development of a phased mitigation plan, implemented on a pay-as-you-go basis from credit sales. State and federal statutory requirements for a regional offsite mitigation area are increasingly identical to those for a mitigation bank, such that there is no tangible benefit to pursue this approach rather than a mitigation bank.

Evaluation of one or more projects’ compatibility with the FDOT/SWFWMD mitigation program, as an alternative to traditional mitigation banking, would focus on FDOT’s need for mitigation in the Peace River watershed and SWFWMD’s interest in designating one or more projects for this purpose via their SWIM program. One notable limitation on use of the SWIM program is that the lands must be publicly owned. Therefore, private lands would not be eligible unless the mitigation plan includes public acquisition of those lands.

Task 6: Alternative and Emerging Markets

This task includes evaluation of markets other than wetland mitigation. One currently available opportunity is the sale of credits based on improvements to endangered species' habitat. In Florida, endangered species' credits have included panthers, scrub jays, sand skinks, gopher tortoises, and wood storks. Additional rules that are currently under development will provide other market opportunities. Ongoing development of rules and criteria for Total Maximum Daily Loads, a statewide water quality trading rule, and a statewide stormwater quality rule all provide potential market opportunities if the project will reduce nutrient loads to downstream waterbodies. As implemented for the Lower St. Johns River and in other states, water quality trading allows landowners within the same basin to buy and sell water quality credits representing reductions in nutrient loadings. There is no statutory prohibition to using a single parcel of land to provide multiple forms of mitigation credits (e.g., wetlands, endangered species, and water quality). However, to date, the common practice preferred by regulatory agencies and adopted by most mitigation bankers is to modify their wetland mitigation bank permit to delete any acreage that is used for other mitigation purposes.

Task 7: Selection of Concept for Design and Permitting

This task consists of a comprehensive analysis of the results from the first six tasks, to determine which conceptual plan(s), if any, provide(s) the greatest opportunities for design and permitting as a mitigation bank and/or FDOT/SWFWMDC mitigation program. At this stage, it may be necessary to develop additional details to more accurately project costs and return-on-investment, such as a *pro forma* projecting the costs and revenues for a ten-year period.

Recommendations for Directing the Location of and Funding for Restoration Activities

1. All hydrologic impacts from dev should be mitigated in the PC watershed. To accomplish this goal, the district would need to identify the PC watershed as a nested regional watershed within the larger PR Basin.
2. The city should seek to have the district identify the PC watershed and specifically the areas identified in the conceptual plan as the receiving areas for mitigating FDOT wetland impacts, both within the watershed and also could include impacts from the larger PR Basin.
3. The state could also identify the PC watershed as a receiving area for other impacts throughout the PR Basin as a pilot for implementing a pilot program for implementing watershed-scale restoration. Other impacts & mitigation of those impacts could be directed to PC watershed, as part of restoring the headwaters of the PR Basin.
4. Then evaluate the value of that bank & that opportunity. How many acres & million dollars of credit are available in the PC watershed.

Evaluating the Feasibility of Mitigation Banking, either for the city as owner of mitigation bank or private interests

Interested landowners generally hire an experienced mitigation banking consultant to conduct a feasibility study before determining whether to apply for a mitigation bank permit or FDOT/SWFWMDC mitigation funding. The study evaluates the suitability of the mitigation site from a number of perspectives, including the following:

The degree of ecological improvement that can be reasonably expected;

Technical issues such as engineering, construction, and hydrology;
Financial issues, such as the amount, value, and timing of credits to be sold versus the cost of the restoration plan and other reasonable and beneficial land uses; and
Regulatory issues, such as the compatibility of the restoration plan with state and federal regulatory criteria.

The following major steps are recommended to evaluate whether to use mitigation banking or FDOT/SWFWMD mitigation funding for restoration work:

1. Develop Specific Conceptual Restoration Plan(s)

The restoration plan(s) would be based on the *Conceptual Plan for Sustainable Water Resource Management* prepared for the City of Winter Haven, and would include specific, conceptual-level plans for restoring wetlands, including improvements in hydrology, water quality, connectivity, and wetland vegetation anticipated from those plans.

2. Evaluate Ecological Feasibility

The information already gathered, the conceptual restoration plans, Geographic Information System (GIS) and other data sources, and additional data gathered through site visits would be reviewed. This baseline assessment provides a detailed understanding of the existing condition of the sites to better determine which restoration approaches are most likely to succeed. A key element of this assessment is a general estimate of achievable mitigation credits under each of the conceptual restoration plans.

3. Evaluate Technical Feasibility

The conceptual restoration plans would be reviewed from the perspectives of engineering, hydrology, and construction. Key elements include evaluating various design elements to determine whether they can be constructed using readily available materials and techniques, whether they will measurably improve wetland hydrology, and whether they will adversely affect flood protection on other property. Restoration activities should focus on wetland systems that are self-sustaining and low maintenance, and that do not require pumps, operable weirs, or other equipment and structures.

4. Evaluate Financial Feasibility

In parallel with the steps listed above, the design, permitting, construction, and operation costs associated with the conceptual restoration plans would be evaluated, as well as marketing and land management issues. The amount of return on investment, including anticipated market value, the timing of demand, and the amount of mitigation credit sales would also be calculated. These general projections of costs and returns help to refine the selection of one or more conceptual restoration plans for further development.

The complexity of permitting often requires substantial an up-front investment for design and permitting. These costs should be estimated and budgeted for accordingly. Also, the length of the permitting process, plus the pre-permit preparation and discussions, may require a waiting period of several years between the initial concept and the sale of the first credit.

UMAM credits currently sell for between \$125,000 and \$145,000 in central Florida. The sale of credits depends on development. Market demand projections should include known and anticipated future development, including the proposed CSX intermodal facility. Based on similar mitigation bank projects, UMAM credits equivalent to approximately 0.4 to 0.6 credits per acre are anticipated—that is, 1,000 acres would generate 400 to 600 credits.

Finally, public-private partnership opportunities would be evaluated. Publicly owned mitigation banks are typically designed, permitted, operated, and marketed by private consultants. In some cases, the consultant provides some of these services at a limited no-up-front charge, with fees paid as a percentage of mitigation credit sales.

5. Evaluate Regulatory Feasibility

The degree to which the proposed wetland restoration plans are consistent with mitigation banking criteria and/or FDOT/SWFWMD mitigation funding would be evaluated. Carrying out the restoration work using a single, cohesive mitigation bank improves regulatory feasibility (rather than as several individual parcels, each permitted separately)

One particularly important issue for mitigation banking is the possibility of designating the Peace Creek watershed as a “nested regional watershed” within the larger Peace River Basin. SJRWMD and SWFWMD have nearly identical rules on mitigation banking service areas. However, SJRWMD recognizes five nested regional watersheds, and SWFWMD has none. Recognizing the Peace Creek watershed as a nested regional watershed would simply require the SWFWMD to revise its map of regional watersheds.

If successful, this designation would significantly add to the value of the credits generated by mitigation banks in the nested watershed. Mitigation banks in nested regional watersheds in SJRWMD charge twice as much per credit as other banks within the same larger regional watershed but outside the nested regional watershed.

State statute also requires publicly owned mitigation banks to charge “full cost” for mitigation bank credits, meaning that the price needs to generate a net profit for the land-owning governmental agency, including the value of the land. This avoids a public “subsidy” that would enable an agency to undercut the price charged by private mitigation banks by using free public lands already owned by taxpayers. Other states have enacted provisions prohibiting publicly sponsored mitigation banks, and thus the regulatory feasibility assessment also needs to include an analysis of the likelihood and severity of the effect of potential legislation.

Another option that should be evaluated, which is similar to mitigation banking, is pursuing a permit for part of or for the entire restoration plan as a “regional off-site mitigation area.” This entails the development of a phased mitigation plan, implemented on a pay-as-you-go basis from credit sales. Generally, however, state and federal statutory requirements for a regional offsite mitigation area are increasingly identical to those for a mitigation bank, so that there is no tangible benefit to pursue this approach rather than a mitigation bank.

Evaluation of one or more projects’ compatibility with the FDOT/SWFWMD mitigation program, as an alternative to traditional mitigation banking, would focus on FDOT’s need for mitigation in the Peace River watershed and SWFWMD’s interest in designating one or more projects for this purpose via its SWIM Program. One important limitation on use of the SWIM Program is that the lands must be publicly owned. Private lands would not be eligible unless the mitigation plan includes the public acquisition of those lands.

6. Evaluate Alternative and Emerging Markets

Markets other than wetland mitigation would be evaluated. One currently available opportunity is the sale of credits based on improvements to endangered species’ habitat. In Florida, these credits have included panthers, scrub jays, sand skinks, gopher tortoises, and wood storks. Additional rules currently under development will provide other market opportunities. Ongoing development of rules and criteria for Total Maximum Daily Loads, a statewide water quality

trading rule, and a statewide stormwater quality rule all provide potential market opportunities if the project will reduce nutrient loads to downstream waterbodies. As implemented for the Lower St. Johns River and in other states, water quality trading allows landowners in the same basin to buy and sell water quality credits representing reductions in nutrient loadings. There is no statutory prohibition to using a single parcel of land to provide multiple forms of mitigation credits (e.g., wetlands, endangered species, and water quality). However, to date, the common practice preferred by regulatory agencies and adopted by most mitigation bankers is to modify their wetland mitigation bank permit to delete any acreage that is used for other mitigation purposes.

7. Select Concept for Design and Permitting

The results from the first six steps would be comprehensively analyzed to determine which conceptual plan(s), if any, provide(s) the greatest opportunities for design and permitting as a mitigation bank and/or an FDOT/SWFWMD mitigation program. At this stage, it may be necessary to develop additional details to more accurately project costs and return on investment, such as a *pro forma* projecting the costs and revenues for a 10-year period.

Appendix E: Summary of Relevant State Reuse Regulations and Considerations for the City of Winter Haven—by Cheryl Wapnick, Senior Scientist, PBS&J

Indirect aquifer recharge involves the application of reclaimed water to an unsaturated ground surface, so that it will be treated as it flows through the plant-soil matrix before infiltrating through the surficial aquifer and eventually reaching the upper Floridan aquifer. Current methods for indirect recharge include, but are not limited to, the following:

1. *Sprayfields/irrigation—slow rate land application;*
2. *Rapid infiltration basins (RIBs)—percolation ponds;*
3. *Unlined storage ponds—evaporation or storage ponds;*
4. *Discharge to percolation wetlands—treatment wetlands; and*
5. *Vadose wells—wells in the nonsaturated part of the subsurface (Montgomery Watson Harza [MWH], 2009).*

Summary of Relevant Regulations

The Florida Administrative Code (F.A.C.) describes the permitting requirements for reclaimed water recharge projects. More specifically, Rule 62-610, F.A.C. addresses the primary regulations for the reuse of reclaimed water and land application. Key elements of the regulations for each type of reuse are summarized below, along with specific issues that should be considered by the City of Winter Haven. Although setback distances are described for potable water wells and surface waters, additional regulations may also apply.

Slow-Rate Land Application Systems—Restricted Public Access

Slow-rate land application systems generally involve the use of reclaimed water that has received, at a minimum, secondary treatment and basic disinfection. Subsurface application systems can also be used, but must be designed and operated to prevent saturated conditions on the land surface. The design application rate is typically less than 2 inches per week annual average, depending on specific site characteristics regarding the ability of the plant-soil system to remove pollutants (Florida Department of Environmental Protection [FDEP], 2004).

These systems must also meet an additional Total Suspended Solids (TSS) criterion of no more than 10 milligrams per liter (mg/L) at all times, unless FDEP approves alternative control measures to ensure that clogging will be prevented. A 500-foot setback is required from the edge of the reclaimed water application area to existing or approved potable water supply wells, as well as Class I and Class II surface waters. Setback distances for Class I waters can be reduced to 200 feet if the facility reliability requirements specified in Subsection 62-610.462(1), F.A.C., are met, and to 100 feet if high-level disinfection is also provided.

In general, facilities that provide high-level disinfection should be designed to result in reclaimed water or effluent in which 75% of fecal coliform values over a 30-day period are below detectable limits in 100 milliliters (mL) of a sample; any single sample should not exceed 25 fecal coliform values per 100 mL. Prior to disinfection, effluent should have a TSS of no more than 5.0 mg/L.

In cases where chlorine is used for disinfection, a total chlorine residual of at least 1.0 mg/L should always be maintained, and contact times must be at least 15 minutes at the peak hourly

flow. More specific regulations on total chlorine residuals and contact times are outlined in Subsection 62-600.440(c), F.A.C., for new or expanded wastewater treatment facilities (WWTFs) that use chlorine for disinfection. Due to the possible harmful effects of chlorine for disinfecting wastewater, FDEP encourages the use of alternative methods of disinfection (e.g., ultraviolet light). Criteria for establishing disinfection resulting from these alternative methods that demonstrate the appropriate microbiological criteria and that reasonable assurance that public health is protected should be provided by the permittee.

Considerations for the City of Winter Haven in implementing slow-rate land application systems without public access include the following:

- o Determining surface area requirements;
- o Determining the extent of the confining unit for subsurface application (its thickness increases from north to south);
- o Restricting application during rainfall to prevent ground saturation and ponding;
- o Establishing setbacks based on transmissivity rates; and
- o Reducing total nitrogen (TN) in applied reclaimed water to 10.0 mg/L (FDEP recommendation) in areas with a thin confining unit or high leakage to lakes.

Slow-Rate Land Application Systems–Public Access Areas

Because of public health considerations, the regulations for slow-rate land application systems in public access areas such as golf courses, residential areas, parks, and agricultural areas growing edible crops are more stringent than for nonaccessible areas. For example, preapplication water must meet, at a minimum, secondary treatment and high-level disinfection levels and should not contain over 5.0 mg/L TSS before the application of the disinfectant. Filtration should also be provided to control TSS levels.

As treatment standards are higher for sites with public access, setback distances are considerably lower than for application sites without public access. For public access sites, a minimum 75-foot setback distance is required from the edge of the wetted areas of the application site to existing or approved potable water wells. There are no setback requirements for surface waters.

Considerations for the City of Winter Haven in implementing slow-rate land application systems with public access include the following:

- o Determining surface area requirements;
- o Determining the extent of the confining unit for subsurface application (thickness increases from north to south);
- o Restricting application during rainfall to prevent ground saturation and ponding;
- o Restricting use through agreements with local users or by local ordinance;
- o Preserving public health, providing public education;

- o Not allowing use to be controlled by any one user (because demand often exceeds supply in dry times, volumetric rate schedules should be implemented for users to achieve more effective and efficient use of reclaimed water);
- o Determining setbacks based on transmissivity rates; and
- o Reducing TN in applied reclaimed water to 10.0 mg/L (FDEP recommendation) in areas with a thin confining unit or high leakage to lakes.

Rapid-Rate Land Application Systems

Rule 62-610, F.A.C., also covers rapid-rate land application systems, including RIBs and absorption fields. The use of RIBs involves spreading reclaimed water in a system of basins or percolation ponds that may have subsurface drains below them. The percolation area must be divided into at least two basins so that alternate loading and resting can be achieved.

Subsurface absorption fields are used to apply large volumes of domestic reclaimed water at high application rates. As with RIBs, these systems are designed so that alternate loading and resting can occur without disrupting the application process.

Application rates for both systems may be as high as 9 inches per day annual average. Because these systems provide limited treatment, these projects must meet ground water criteria at the edge of the zone of discharge. At a minimum, the preapplication reclaimed water must meet secondary treatment and basic disinfection levels.

In general, facilities providing basic disinfection should be designed to result in no more than a monthly mean of 200 fecal coliform values per 100 mL of reclaimed water or effluent sample in an annual period. In addition, no more than 10 percent of samples collected during a 30-day period should exceed 400 fecal coliform values per 100 mL, and any single sample should not exceed 800 fecal coliform values per 100 mL. If chlorine is used for disinfection, at least 0.5 mg/L total chlorine residual should be maintained after at least 15 minutes of contact time at the peak hourly flow.

Nitrate concentrations should not exceed 12 mg/L (as nitrogen), unless it can be demonstrated that nitrate levels greater than 10 mg/L (or background levels in the receiving groundwater, whichever is less stringent) will occur at the edge of the zone of discharge. For systems using absorption fields, TSS should not exceed 10 mg/L in the reclaimed water prior to discharge, unless specific provisions are made to ensure that the system is reliably operated and maintained.

As with slow-rate land application systems, a setback distance of 500 feet is necessary from the edge of the RIB or absorption field to existing or approved potable water supply wells, as well as Class I and Class II surface waters. Setback distances may be reduced to 100 feet of Class I and Class II waters if high-level disinfection is used. Unlike slow-rate land application systems, setback distances can be reduced to 200 feet from potable water wells if provisions are made to ensure Class I reliability, high-level disinfection, and reasonable assurance that the applicable water quality standards will not be violated at the point of withdrawal.

Considerations for the City of Winter Haven in implementing rapid-rate application systems include the following:

- o Reducing TN to 3.0 mg/L in applied reclaimed water (FDEP recommendation) in areas with a thin confining unit or high leakage to lakes;
- o Reducing TN to 6.0 mg/L in applied reclaimed water (FDEP recommendation) in areas with a thicker confining unit and less leakage to lakes;
- o Providing limited, if any, additional treatment after discharge;
- o Determining the added costs of providing additional treatment before discharge;
- o Determining the environmental impacts of the increased chlorination needed for treatment prior to discharge;
- o Only certain pathogens are tested for; are there others that should be tested?
- o Influence of reuse applications on lake levels?

Projects for which additional levels of preapplication treatment are necessary include, but are not limited to, the following:

1. *Projects located over groundwater in aquifers used for public water supply, where the rapid movement of reclaimed water into the aquifer will occur;*
2. *Projects where new rapid-rate land application projects involve continuous loading to a single basin or absorption field; and*
3. *Projects where annual loading rates exceed 9 inches per day.*

In these instances, the requirements of Rule 62-610.525, F.A.C., must be followed, including the requirement that the preapplication water must meet, at a minimum, secondary treatment and high-level disinfection and contain no more than 5.0 mg/L TSS before the application of the disinfectant. The low level of TSS before disinfection is required to help inactivate viruses and other pathogens. TN levels must also be limited to a maximum annual average of 10 mg/L, and WWTFs must meet primary and secondary drinking water standards.

Overland Flow Systems

Overland flow systems, also regulated by Rule 62-610, F.A.C., involve the land application of wastewater by sprinkling or flooding the upper portions of terraced, sloped, vegetated surfaces before discharging to surface waters via a runoff conveyance system. For these systems, reasonable assurance must be provided that, at a minimum, effluent discharged to surface waters from land treatment sites will meet secondary treatment and basic disinfection levels over the long term.

Preapplication effluent should not exceed 40 to 60 mg/L of 5-day carbonaceous biological oxygen demand (CBOD₅), 40 to 60 mg/L of TSS, and 2,400 fecal coliform values per 100 mL. A setback distance of 500 feet is necessary from the edge of the wetted area to existing or approved potable water supply wells, as well as Class I and Class II surface waters. These setbacks for potable water wells should only be applied for new or expanded overland flow systems and are not necessary for permit renewal.

Considerations for the City of Winter Haven in implementing overland flow systems include the following:

- o Determining surface area requirements;
- o Determining the extent of the confining unit for subsurface application (thickness increases from north to south);
- o Restricting use during rainfall to prevent ground saturation and ponding, to maintain secondary treatment levels before discharging; and
- o Reducing TN in applied reclaimed water to 10.0 mg/L (FDEP recommendation) in areas with a thin confining unit or high leakage to lakes.

Wetlands Application

Rule 62-611, F.A.C. describes the state's wetland discharge regulations for the treatment and application of domestic wastewater reuse to wetlands and surface water. Treatment wetlands may not include areas in Outstanding Florida Waters, locations designated as Areas of Critical State Concern (as of October 1, 1985), Class I or Class II waters, or herbaceous wetlands, unless the *Typha* spp. (cattail) comprises more than 50% of the herbaceous groundcover of the entire wetland, or the wetland has been hydrologically altered. The last two requirements also apply to the use of wetlands as receiving wetlands.

Hydraulic loading rates should not exceed 2 inches per week; hydrologically altered wetlands may accept up to 6 inches per week depending on the design and associated approval by FDEP. Reclaimed water must be detained within a treatment wetland for a minimum of 14 days, unless the required level of water quality can be demonstrated for the discharged water within a shorter period. In addition, to maximize the assimilative capacity of the wetlands, TN should not exceed 25 grams per square meter per year ($\text{g/m}^2/\text{yr}$), except for hydrologically altered wetlands where TN can reach up to $75 \text{ g/m}^2/\text{yr}$, and total phosphorus (TP) should remain below $3.0 \text{ g/m}^2/\text{yr}$, or $9.9 \text{ g/m}^2/\text{yr}$ for hydrologically altered wetlands.

All reclaimed water discharged to treatment wetlands must receive secondary treatment with nitrification. The discharge limits, on an annual average basis, to receiving wetlands are as follows:

CBOD ₅	5 mg/L
TSS	5 mg/L
TN (as N)	3 mg/L
TP (as P)	1 mg/L

In addition, reuse water discharged to a treatment or receiving wetland must not exceed a monthly average of 2.0 mg/L total ammonia (as N).

In cases where wetlands are being used for the discharge or treatment of reclaimed water or effluent, public access is restricted, and the resulting reclaimed water is not permitted. Under Part III of Rule 62-610, F.A.C., intermediate disinfection criteria can be used to replace the high-level disinfection criteria described above. For example, facilities designed under these conditions should result in no more than a monthly mean in an annual period of 14 fecal coliform values per 100 mL of reclaimed water or effluent; the median fecal coliform values for at least 10 samples, all collected on different days within a 30-day period, should also not exceed this level. In addition, no more than 10 percent of the samples collected during a 30-day period should exceed 43 fecal coliform values per 100 mL, and any single sample should not exceed 86 fecal coliform values per 100 mL. If chlorine is used for disinfection, a total chlorine residual

of at least 1.0 mg/L should be maintained after at least 15 minutes of contact time at the peak hourly flow. These criteria can also meet the requirement for high-level disinfection in cases where the discharge is to surface waters; is serving as a back-up disposal system associated with a reuse system permitted under Part III of Rule 62-610, F.A.C.; and the effluent is not subject to regulation as a discharge to Class I waters or tributaries to Class I waters.

Unless Water Quality Based Effluent Limitations (WQBELs) have been established, the discharge from treatment and receiving wetlands is limited to an annual average of 3 mg/L (as N) for TN concentration, of which only 0.02 mg/L (as N) may be in the form of unionized ammonia, or a TP concentration of 0.2 mg/L. FDEP may waive compliance levels for phosphorus if it is demonstrated that phosphorus is not a limiting nutrient or a contaminant. If this is not the case, FDEP will require plans for the additional removal of phosphorus.

Section 62-611.500, F.A.C., discusses standards for the environmental and biological quality of treatment and receiving wetlands. For example, the flora and fauna of the wetland, including benthic macroinvertebrates, fish, and vegetation, should be maintained so that the ability of the wetland to support the propagation and maintenance of healthy, well-balanced populations of fish and wildlife is not impaired.

Man-made Wetlands

The criteria for natural wetlands do not apply to reclaimed water discharged to man-made wetlands, assuming that the surface water quality standards for heavy metals described in Rule 62-302, F.A.C., are applied. Although discharges to man-made wetlands are not required to meet all surface water quality standards described in Rule 62-302, F.A.C., those criteria described in Section 62-302.500, F.A.C., are applicable. In general, discharges to these wetland systems would have to meet secondary treatment and basic disinfection (described above) and pH control standards. Secondary treatment should result in effluent after disinfection that contains no more than 20 mg/L CBOD₅ and 20 mg/L TSS, or, if more stringent, 90% removal of each of these pollutants from the influent. A pH between 6.0 and 8.5 must also be maintained in the reclaimed water or effluent after disinfection. In addition, water discharged from the man-made wetlands would have to meet the standards for the receiving water (personal communication with J. Hilton, FDEP, June 16, 2009).

If the man-made wetland is contiguous to other waters, reasonable assurance is necessary that the discharge limits for treatment and receiving wetlands will be met at the boundary between the two systems. If this cannot be achieved, a permit is necessary for the discharge of reclaimed water to wetlands and for the associated discharge from the man-made wetland to waters of the state. Lastly, a man-made wetland created for mitigation as part of a dredge-and-fill permit authorized by FDEP may not be used as a treatment wetland, though it may be used as a receiving wetland.

Summary of Existing Winter Haven WWTPs and Associated Water Reuse Practices

The City of Winter Haven currently operates two permitted Type I activated sludge domestic wastewater treatment plants (WWTPs), WWTP #2 and WWTP #3, both of which have a slow-rate land application-based reuse component. The City is not currently using any RIB systems.

WWTP#2, located just north of the City of Winter Haven's downtown area, has an annual average daily flow (AADF) permitted capacity of 2.0 million gallons per day (MGD) for a public-

access reuse system (R-001). This facility is operated to achieve secondary treatment with high-level disinfection, including liquid chlorine, for public access reuse. The primary users are businesses, commercial and industrial operations, farms and other agricultural activities, and golf courses. Other uses include residential and lawn irrigation.

According to Permit No. FLA129747, a setback distance of 75 feet must be maintained between the edge of the wetted area and potable water supply wells. In addition, the reclaimed water limits for TSS and nitrate in a single sample are 5.0 mg/L and 12.0 mg/L, respectively, and over a 30-day period, at least 75% of fecal coliform values should be below detection limits, with no single sample exceeding 25 fecal coliform values per 100 mL. Intervals for sampling for *Giardia* and *Cryptosporidium* should not exceed 2 years. The annual average flow allowed is 2.0 MGD. There are 8 surficial groundwater monitoring wells that should be sampled quarterly in association with Reuse System R-001. These wells range in depth from 10 to 20 feet. Compliance levels for nitrogen, nitrate, and TN (as N) are 10 mg/L.

WWTP#3 is located just north of State Road 60 and south of downtown Winter Haven at 4400 Pollard Road. In February 2007, FDEP gave notice of its intent to revise Permit No. FL0036048, originally dated July 13, 2005, for WWTP#3 to be upgraded to advanced wastewater treatment (AWT) and to relocate the sampling point for one of the outfalls. In addition, the overland flow system was to be decommissioned and has since been sold. This facility is operated to achieve an AADF permitted capacity of 0.7 MGD for a slow-rate restricted public access land application system (R-001 comprises an 86-acre, onsite irrigation sprayfield).

An onsite overland flow treatment system connected to a surface water discharge was originally permitted for effluent reuse and disposal. Effluent from the overland flow system was permitted to discharge to the Peace Creek Canal. Wet weather storage is not required with the existence of the surface water discharge component.

The annual average hydraulic loading rate to the restricted access sprayfields is limited to no more than 2.25 inches per week and should not result in surface runoff or ponding. The annual effluent flow of surface water discharge before and after permit modification is not to exceed an annual average of 7.5 MGD.

Prior to permit modification, only unionized ammonia (as N) had a specific effluent limit: not to exceed 0.02 mg/L in a single sample. This limit did not change with the permit modification. Both TN and TP did not have assigned effluent limitations. As of March 1, 2008, effluent limitations for TN were assigned as 3.0, 3.75, 4.5 and 6.0 mg/L for an annual average, monthly average, weekly average and single sample, respectively. Similarly, TP levels were not to exceed 1.0, 1.25, 1.5 and 2.0 mg/L (using the same intervals as for TN). In addition, the arithmetic mean of monthly fecal coliform values collected during an annual period should not exceed 200 per 100 mL of effluent sample, and no more than 10% of samples during a 30 consecutive days should exceed 400 fecal coliform values per 100 mL. Any one sample should not exceed 800 fecal coliform values per 100 mL.

The reclaimed water limits for TSS and nitrate in a single sample are 60.0 and 12.0 mg/L, respectively, and did not change with permit modification. The limitations for fecal coliform in reclaimed water samples are the same as those for surface water discharge effluent.

For the duration of the permit, reclaimed water or effluent are to be monitored annually for primary and secondary drinking water standards (except for turbidity, total coliform, color, and corrosivity).

There are six surficial ground water monitoring wells that should be sampled quarterly in association with Reuse System R-001. These range in depth from 12 to 17 feet. Compliance levels for nitrogen, nitrate, TN (as N) are 10 mg/L.

Conclusions

The most important wastewater and reuse considerations for the City of Winter Haven are as follows:

- *Impacts to groundwater are not restricted to reuse. Surface water and groundwater contributions from other sources (contaminants from human activities on the land surface, including stormwater from crops, pastures, residences, and recreational land uses; as well as septic tanks) all need to be considered and addressed in terms of the nutrients and bacteria levels they carry.*
- *Areas to the north have a more direct influence or more rapid impact on the Floridan aquifer due to a thin and discontinuous confining unit and increased soil permeability, and therefore require a higher level of protection:*
 - o Define protection zones, as done in the Wekiva springshed; and
 - o Use a target of 0.2 mg/L of nitrate-nitrogen as a goal to determine the level of treatment necessary in each zone.
- *The Peace River above Bowlegs Creek is highly characterized by karst features, and the aquifer in this area requires a higher level of protection because it is extremely vulnerable to contamination from overland flow and infiltration into depressions.*
- *Buffer zones should be used around karst features.*
- *Siting of reuse applications should consider that areas of greater head difference between the surficial aquifer and Floridan aquifer indicate a greater potential for downward recharge to the Floridan (higher aquifer vulnerability).*
- *State regulations protect public health by setting standards for groundwater used as drinking water. However, those standards are not protective of surface waters in places where groundwater flows to surface water—which is the case in the headwaters of the Peace Creek watershed where groundwater seeps into the lakes. Preventing increased quantities of nutrients from making their way to the lakes in Winter Haven is critical, as many of the lakes have been identified as impaired for nutrients.*

Table E.1. Summary of Reuse Water Criteria for Parameters of Interest in winter Haven, FL

Discharge Monitoring Reports (DMRs) were obtained for WWTP#2 and WWTP#3 from September 2008 to February 2009. Monitoring data reported for WWTP#3 reflect the results from Station EFD-01, located at the discharge of the postaeration basin, before discharge to D-001, unless otherwise indicated. NA = not available

Current Facility	Parameter (unit of measurement)	DMR Levels	Current Permitted Criteria	RIB Criteria	Wetlands Criteria	Man-made Wetlands Criteria
WWTP#2 @EFA-01	CBOD ₅ (mg/L)	3.85 – 5.76 (Monthly Average)	20 (Annual Average) 30 (Monthly Average)	NA	5.0 (Annual Average)	20 (Maximum) or 90% removal from influent (whichever is more stringent)
WWTP#3	CBOD ₅ (mg/L)	2.223 – 2.985 (Monthly Average)	3.0 – 10.0 (Monthly Average) 3.0 – 12.0 (Weekly Average)	NA	5.0 (Annual Average)	20 (Maximum) or 90% removal from influent (whichever is more stringent)
WWTP#2 @ EFB-01	TSS (mg/L)	<1.0 – 7.75	5.0 (Maximum)	5.0 (Maximum) before disinfectant if annual average loading rate >9 inches/year	5.0 (Annual Average)	20 (Maximum) or 90% removal from influent (whichever is more stringent)
WWTP#3	TSS (mg/L)	1.565 – 2.419 (Monthly Average) 6.80 (Maximum)	20.0 (Annual Average) 30.0 (Monthly Average) 45.0 (Weekly Average) 60.0 (Maximum)	5.0 (Maximum) before disinfectant if annual average loading rate >9 inches/year	5.0 (Annual Average)	20 (Maximum) or 90% removal from influent (whichever is more stringent)
WWTP#2 @EFA-01	Fecal Coliform (#/100mL)	<1.00 (Monthly Average) 2.0 (Maximum)	75% below detection limits; no sample exceeding 25	200 (Annual Average) 200 (Monthly Geometric Mean) 400 (90%) 800 (Maximum)	14 (Monthly Average) 43 (90%) 86 (Maximum)	200 (Monthly Average) 400 (90%) 800 (Maximum)
WWTP#3	Fecal Coliform (#/100mL)	<1.00	200 (Annual Average) 200 (Monthly Geometric Mean) 400 (90%) 800 (Maximum)	200 (Annual Average) 200 (Monthly Geometric Mean) 400 (90%) 800 (Maximum)	14 (Monthly Average) 43 (90%) 86 (Maximum)	200 (Monthly Average) 400 (90%) 800 (Maximum)
WWTP#2 @EFA-01	Nitrate Nitrogen (mg/L)	0.350 – 7.630	12.0 (Maximum)	12.0 (Maximum)	NA	12.0 (Maximum)
WWTP#3	Nitrate Nitrogen (mg/L)	NA	NA	12.0 (Maximum)	NA	12.0 (Maximum)
WWTP#2	TN (mg/L)	NA	NA	NA	3.0 (Annual Average)	NA
WWTP#3	TN (mg/L)	0.856 – 1.544 (Monthly Average)	3.0 (Annual Average) 3.75 (Monthly Average)	NA	3.0 (Annual Average)	NA

Current Facility	Parameter (unit of measurement)	DMR Levels	Current Permitted Criteria	RIB Criteria	Wetlands Criteria	Man-made Wetlands Criteria
		2.87 (Maximum)	4.5 (Weekly Average) 6.0 (Maximum)			
WWTP#2	TP (mg/L)	NA	NA	NA	1.0 (Annual Average)	NA
WWTP#3	TP (mg/L)	0.067 – 0.169 (Monthly Average) 0.590 (Maximum)	1.0 (Annual Average) 1.25 (Monthly Average) 1.5 (Weekly Average) 2.0 (Maximum)	NA	1.0 (Annual Average)	NA
WWTP#2	Nitrogen, Total Ammonia (as N) (mg/L)	NA	NA	NA	2.0 (Monthly Average)	NA
WWTP#3	Nitrogen, Total Ammonia (as N) (mg/L)	0.098 – 0.210 (Monthly Average)	1.0 – 10.0 (Monthly Average) 3.6 – 12.0 (Weekly Average)	NA	2.0 (Monthly Average)	NA
WWTP#2 @EFA-01	Total Residual Chlorine (for disinfection) (mg/L)	1.00 (Minimum)	1.0 (Minimum)	0.5 (Minimum)	1.0 (Minimum.)	0.5 (Minimum)
WWTP#3 @ EFA-01	Total Residual Chlorine (for disinfection) (mg/L)	0.51 (Minimum)	0.5 (Minimum)	0.5 (Minimum)	1.0 (Minimum.)	0.5 (Minimum)
WWTP#2	Total Residual Chlorine (for dechlorination) (mg/L)	NA	NA	NA	NA	NA
WWTP#3	Total Residual Chlorine (for dechlorination) (mg/L)	<0.01	0.01 (Maximum)	NA	NA	NA
WWTP#2	Flow (MGD)	0.930 – 1.123 (Monthly Average)	2.0 (Annual Average)	NA	NA	NA
WWTP#3 (@ FLW-02, at discharge from postaeration basin)	Flow (MGD)	3.633 – 4.402 (Monthly Average)	7.5 (Annual Average) Report (Monthly Average)	NA	NA	NA

Source: FDEP, 2004; MWH, 2009.