Special Publication SJ2001-SP3

WATER SUPPLY NEEDS AND SOURCES ASSESSMENT: ALTERNATIVE WATER SUPPLY STRATEGIES INVESTIGATION: APPLICATION OF PLANNING-LEVEL COST ESTIMATING PROCEDURE

by

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2001

EXECUTIVE SUMMARY

St. Johns River Water Management District (SJRWMD) is evaluating the potential impacts of several water supply alternatives, one of which is changes to sensitive natural systems, particularly wetlands. Municipal water supply within the majority of the District is provided by high-quality, reliable, and inexpensive ground water. However, it is inevitable that increasing demands on ground water resources will affect the hydrology of existing wetland and aquatic ecosystems, resulting in environmental changes that may be considered unacceptable impacts under current regulatory policy. Through planning and evaluation, unacceptable impacts to wetlands and other natural systems may be avoided or mitigated to acceptable levels.

BACKGROUND

As part of its needs and sources evaluation, SJRWMD has identified the potential impacts of increased ground water withdrawals on natural resources within the District through the year 2010. Based on this evaluation, areas in which water supply problems are critical or will become critical have been identified. For several reasons, in addition to drawdown impact, these areas of concern are designated by SJRWMD as Water Resource Caution Areas (WRCAs). In general, SJRWMD's analysis predicts that increases in ground water withdrawals within the WRCAs could result in adverse impacts to water resources and native ecosystems, especially wetland and aquatic systems located near water supply wellfields. To reduce potential impacts, SJRWMD is investigating the technical, environmental, and economic feasibility of alternative water supply strategies, which include methods for preventing, minimizing, and mitigating environmental harm.

PURPOSE AND SCOPE

Because the previous analysis by SJRWMD predicted that wetland communities within the WRCAs were more susceptible to harm than upland communities, the focus in this technical memorandum (TM) is on developing planning-level cost estimates for mitigating potential impacts to wetland and aquatic communities. The primary purpose of this TM is to apply the impact assessment and cost estimating methodology developed in TM E.1.f, *Wetlands Impact, Mitigation, and*

Planning-Level Cost Estimating Procedure, prepared by CH2M HILL (1996).

IMPACT ASSESSMENT AND COST ESTIMATING METHODOLOGY

SJRWMD generated an input file of the potentially impacted wetland and aquatic communities in the study area. These data are categorized in two ways: by major wetland type within each county within the WRCAs, and by degree of predicted water table drawdown within each wetland type within each county.

SJRWMD's data file was imported in a spreadsheet, which automated the eight-step impact assessment and cost estimating methodology established in TM E.1.f and shown in Figure ES-1.

SPREADSHEET DEVELOPMENT

The eight-step process was automated as an interactive spreadsheet program using Microsoft Excel software. The spreadsheet reads an input file and, using user-supplied decisions, calculates a planning-level estimate for cost of mitigation.

DATA INPUTS

As part of its needs and sources survey, SJRWMD developed a preliminary screening process review in which land areas within the District were identified by geographic information system (GIS) analysis as having a moderate-to-high likelihood of harm resulting from ground water development (Kinser and Minno 1996). The input file was generated using the same screening process for areas that would be negatively affected by future water supply withdrawals. These areas are predicted to experience a moderate-to-high likelihood of harm to native vegetation as a result of projected year 2010 ground water withdrawals.

From their overlay analysis of these coverages, SJRWMD provided data on baseline hydrological conditions, estimated water table drawdown, and acreage of impact. SJRWMD staff also conducted a GIS analysis to estimate the acreage of wetlands subject to impact from ground water withdrawal. Three GIS data layers were used: wetlands, estimated drawdown, and soils.

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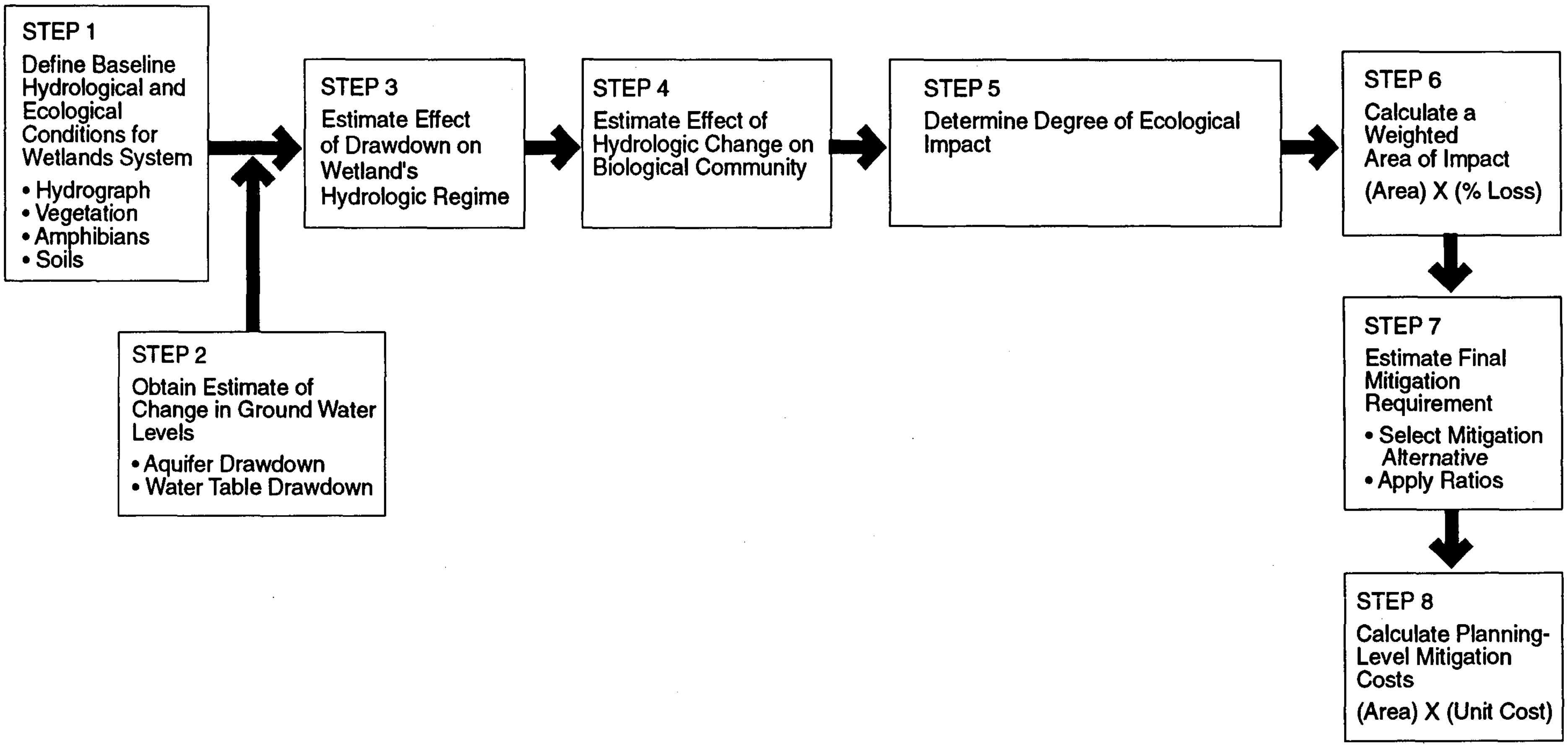

ES-1. Impact Assessment and Mitigation Cost Estimating Methodology

INITIAL ESTIMATES OF EXTENT OF DRAWDOWN IMPACTS AND MITIGATION COSTS

Initial application of the impact assessment and costing spreadsheet model was used to develop planning-level costs for SJRWMD's projected 2010 water supply scenario. This analysis is summarized below:

1. **Unweighted Impact Area.** The total unweighted estimate of the wetland area affected is 693,000 acres, or 1,083 square miles (sq. mi.). This area is roughly equivalent in size to Volusia County (1,115 sq. mi.). The between-county range for the unweighted wetland impact area covers approximately five orders of magnitude, ranging from 5 acres (St. Johns County) to 220,000 acres (Volusia County).
2. **Weighted Impact Area.** Applying the Ecological Loss Coefficient (ELC) results in a weighted affected area of 108,425 acres. The between-county range for the weighted impact area is 0.3 acres (St. Johns County) and 39,000 acres (Volusia County).
3. **Impact Area by Wetland Type.** Forested wetland impacts account for 74 percent of the total amount of impacted acreage for all the counties. Scrub/shrub wetlands account for 6 percent of the total weighted area, with herbaceous wetlands comprising the remaining 20 percent.
4. **Impact Area by Extent of Drawdown.** From an analysis of the frequency of distribution area impacted by drawdown in the total weighted area of 108,425 acres:
   - Six percent can be attributed to projected drawdowns of less than 0.25 feet.
   - Twenty-one percent is covered by drawdowns of 0.5 feet or less.
   - The 1-foot drawdown is approximately the middle of the distribution, with half the affected area having lesser drawdown values and half the area having greater values.
   - Predicted drawdowns of more than 1.5 feet and 2.0 feet affect approximately 20 percent and 10 percent, respectively, of the total weighted area.

5. **Planning-Level Cost Estimate by County.** The total mitigation cost for the project area (all counties combined) is $6.36 billion. Like the projections for area, mitigation cost by individual county varies over five orders of magnitude, from $16,000 for St. Johns County to $2.4 billion for Volusia County. Approximately 92 percent of the total estimated cost is attributable to Lake, Orange, Seminole, and Volusia counties.

6. **Planning-Level Cost Estimate by Wetland Type.** Forested wetland impacts account for 76 percent of the total estimated mitigation cost. Scrub/shrub wetlands account for 6 percent of the total weighted area, and herbaceous wetlands comprise the remaining 18 percent.

7. **Planning-Level Cost Estimate by Drawdown.** Of the $6.36 billion total estimated mitigation cost for the 2010 conditions:

    - Six percent is covered by projected drawdowns of less than 0.25 feet.
    - Twenty-two percent is covered by drawdowns of 0.5 feet or less.
    - The 1-foot drawdown is approximately the middle of the distribution, with half the affected cost attributable to lesser drawdown values and half attributable to greater values.
    - Predicted drawdowns of more than 1.5 feet and 2.0 feet contribute approximately 20 percent and 10 percent, respectively, of the total cost.

Because the confidence intervals of the projected drawdown are uncertain, impacts calculated for drawdowns of 0.125 feet or less were questioned. Likewise, the significance of drawdown predictions in the interval 0.125 to 0.5 feet was questioned. One rationale for limiting the range of impact and mitigation cost should be to successively discount the lower drawdown intervals (i.e., successively exclude drawdowns of <0.125 feet, < 0.25 feet, and < 0.5 feet).

SENSITIVITY ANALYSIS OF MITIGATION COST ESTIMATION

Sensitivity analysis is a procedure for investigating the behavior of a calculation procedure or model. For the purposes of this TM, the assessment and cost estimating methodology is the model. The methodology is based on a series of parameters, each with one or more assumptions. The key parameters in the methodology are evaluated for their effect on costs.

For this analysis, the parameter varied was predicted drawdown. Table ES-1 summarizes the effect of incrementally varying this parameter. Upon varying the predicted drawdown values, a similar trend in the data occurred in each county. That is, estimated mitigation costs increased as the base drawdown value was increased, and costs decreased as the base value decreased. The results indicate that the response of the cost estimates to the incremental changes in predicted water table drawdown is nearly linear.

CONCLUSIONS AND RECOMMENDATIONS

Impacts to wetlands and other natural systems are one of several potential consequences of the water supply alternatives being evaluated by SJRWMD. This TM provides planning-level estimates of the extent of potential impact to wetland and aquatic communities and the cost of mitigating impacts resulting from projected 2010 surficial aquifer drawdowns.

Conclusions

The following conclusions can be drawn from the evaluation described in this TM:

- On the regional scale used in this application, the estimate of water table drawdown within individual wetlands has a moderate-to-high level of uncertainty. The level of uncertainty is acceptable for a planning-level estimate. The sensitivity analysis shows that even discounting predicted drawdowns of less than 0.5 feet removes only 20 percent of the projected impact area.
- The uncertainty of the regional drawdown estimates limits the use of the present application for evaluating site-specific conditions, such as those required for individual permitting.
- This application of the methodology clearly demonstrates that pursuit of a "pump now and mitigate later" approach to water supply development would result in unacceptable impacts to wetland and aquatic systems. Likewise, the projected costs of mitigating the impacts would be prohibitive. Thus, post-impact

mitigation is unlikely to provide a regional solution to large-scale wetland and aquatic system impacts.

- The projected impacts and associated mitigation cost for a "pump and mitigate" strategy clearly indicate that impact avoidance is the more prudent, cost-effective, and socially acceptable water supply development strategy.
- Impact mitigation is likely to be most applicable when addressing small-scale, site-specific impacts, such as those that may be found on an individual wellfield.
- The value of the methodology is as a screening and estimating tool that provides two general kinds of information: (1) a means of generating estimates of the extent of impact and potential cost of mitigation actions and (2) a means of comparing alternatives.
- This application shows that the methodology can be a sound planning and evaluation tool at a regional level.
- Use of the methodology as a tool in the regulatory process will require the use of more detailed input files that reflect conditions at specific locations, such as the localized conditions of a certain wellfield.
- Testing with site-specific data will provide a means of evaluating the value of the methodology for assessing localized effects.

Recommendations

On the basis of the information in this TM, the following recommendations are presented for SJRWMD's consideration:

- SJRWMD should refine the method for estimating water table drawdowns to improve the accuracy of the impact estimates.
- The current methodology, which relies on regional drawdown estimates, should not be used as a tool for regulatory decision-making. Refinement and testing using site-specific, detailed, input files is necessary to evaluate the use of the method for regulatory reviews.
- In comparison to the pump and mitigate strategy, impact avoidance strategies are likely to be more cost-effective. For ongoing work in the alternative water supply strategies investigations, SJRWMD should develop a future water supply

plan that significantly reduces the nature and extent of the 2010 projected impacts to natural systems by developing alternative sources and the use of impact avoidance.

- Application of the methodology using site-specific data from a wellfield should be done to test the accuracy of impact assessment.

- For future applications of the impact assessment and mitigation costing methodology, the spreadsheet functions should be converted to data base format. The use of the spreadsheet for regional analysis was difficult and inefficient because of the large number of records.

Table ES-1. Results of Sensitivity Analysis on Estimated Total Mitigation Cost by Varying the Value of Predicted Drawdown by County

	Estimated Mitigation Cost ($)				
County	**Base Minus 20%**	**Base Minus 10%**	**Base Value**	**Base Plus 10%**	**Base Plus 20%**
Brevard	73,606,950	93,634,977	104,079,166	116,171,090	124,932,684
Flagler	245,790,537	316,913,507	383,080,755	413,807,881	445,235,616
Lake	1,084,404,618	1,268,857,430	1,354,100,923	1,567,252,777	1,703,191,271
Orange	727,623,606	909,408,997	1,059,560,796	1,139,866,073	1,270,221,615
Seminole	877,004,823	981,696,876	1,118,969,750	1,212,927,923	1,272,628,898
St. Johns	16,182	16,182	16,182	16,182	16,182
Volusia	1,521,252,683	1,912,908,254	2,336,290,008	2,721,199,530	2,968,865,472
Total	**4,529,699,399**	**5,483,436,222**	**6,356,097,580**	**7,171,241,456**	**7,785,091,739**
Cost Ratio (Value/Base)	**0.71**	**0.86**	**1.0**	**1.13**	**1.22**

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TABLES

INTRODUCTION

Ground water is the primary source of municipal water supply in the St. Johns River Water Management District (SJRWMD). While ground water has been a generally high quality, reliable, and inexpensive source of municipal water supply, it is unlikely that all additional future municipal water supply needs can be met by this source without causing some level of ecological change. For this reason, SJRWMD is investigating the feasibility of alternative water supply strategies.

This technical memorandum (TM) focuses on applying a methodology for assessing the potential ecological impacts associated with water table declines, and then estimating the costs of mitigating these ecological impacts. The impact assessment and costing methodology is described in detail in TM E.1.f, *Wetlands Impact, Mitigation, and Planning-Level Cost Estimating Procedure* (CH2M HILL 1996).

A summary of the mitigation cost estimating procedure is presented in the subsection below, while the purpose and scope of this TM are presented in the remainder of this subsection.

PROJECT BACKGROUND

As part of its water supply needs and sources survey, SJRWMD previously evaluated the potential impacts of increased ground water withdrawals through the year 2010 (Vergara 1994). Based on the information obtained from this evaluation, several areas in which water supply problems are critical, or will become critical, were identified (Figure 1). For numerous reasons, in addition to ground water drawdown, these areas have been called Water Resource Caution Areas (WRCAs). Without careful planning, future ground water withdrawals from these WRCAs could adversely affect surface water resources and the natural environment dependent on those resources. In particular, wetland and aquatic communities in portions of the WRCAs have been identified as being at risk for adverse impacts.

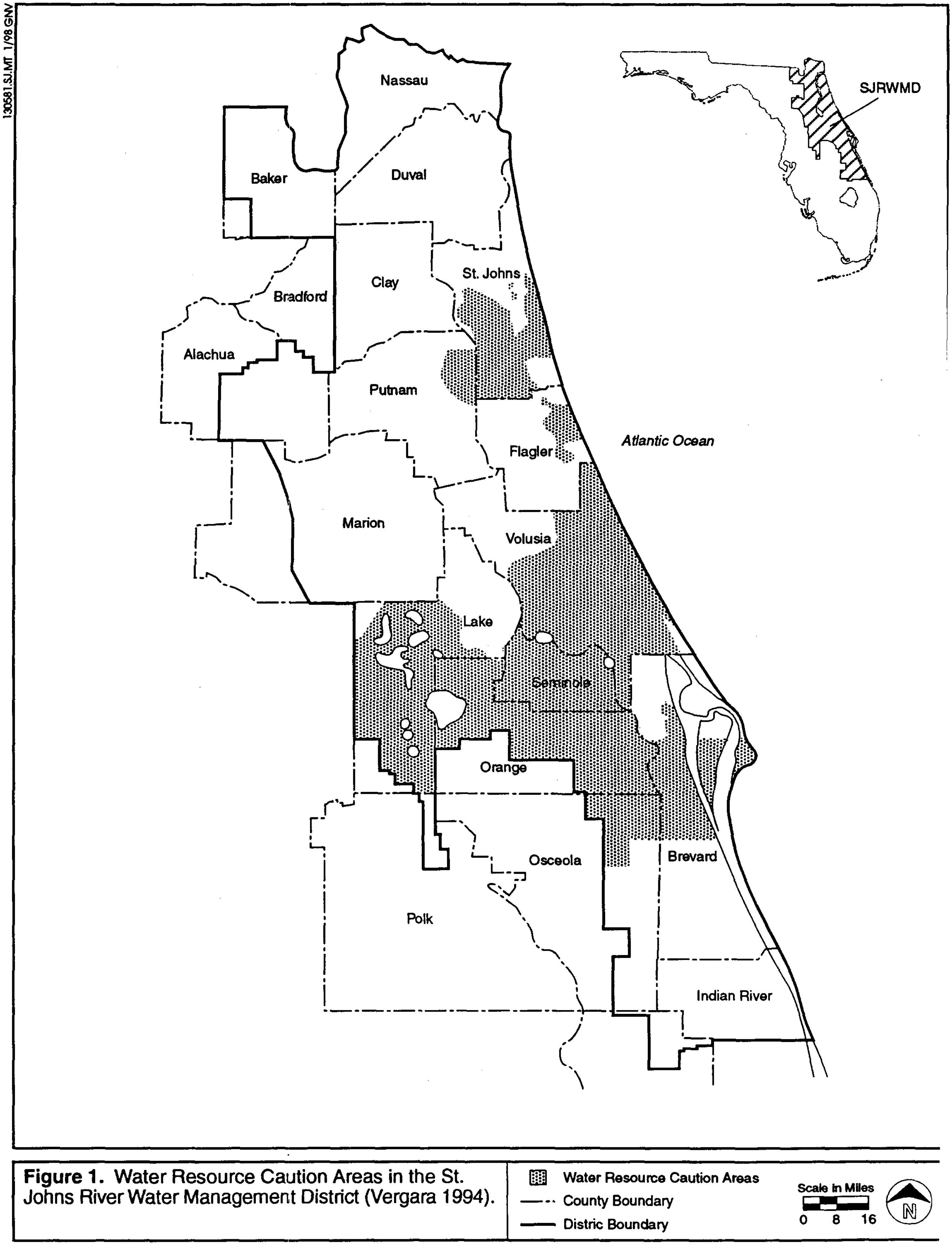

Figure 1. Water Resource Caution Areas in the St. Johns River Water Management District (Vergara 1994).

PURPOSE AND SCOPE

The overall scope of Task E, of which this TM is a part, assesses the technical, environmental, and economic feasibility of mitigating or avoiding impacts to native vegetative communities and especially wetland communities, which could result from projected future (2010) ground water withdrawals in the WRCAs (Figure 1).

This TM develops planning-level costs for mitigating potential adverse effects on native vegetation within the WRCAs, as predicted in SJRWMD's modeling scenarios of aquifer and water table drawdowns expected by the year 2010.

Planning-level costs are estimated using an electronic spreadsheet that automates the impact assessment and costing methodology developed in TM E.1.f, *Wetlands Impact, Mitigation, and Planning-Level Cost Estimating Procedure* (CH2M HILL 1996). The inputs to the spreadsheet are summary data provided by SJRWMD. The data records are based on land use mapping units in SJRWMD's Geographic Information System (GIS); that is, each record is associated with a specific mapped feature or polygon. The input files provides wetland polygon-specific attributes for vegetation/land use type, polygon location and size, soil type, general percolation characteristics, and predicted water table drawdown.

Because the previous analysis by SJRWMD predicted that wetland communities within the WRCAs were more susceptible to harm than upland communities, the focus of this TM is on developing planning-level cost estimates for mitigating potential impacts to wetland communities. This TM has two basic purposes: to provide a planning-level application of the quantitative evaluation of wetland system impacts and to develop planning-level cost estimates for potential mitigation actions.

METHODS

To evaluate the potential cost of mitigating wetland impacts associated with ground water withdrawals in the District, the following tasks were performed:

- Adapt impact assessment and costing methodology.
- Develop spreadsheet.
- Develop input file.
- Develop sensitivity analysis methodology.

These tasks are described below.

ADAPTATION OF IMPACT ASSESSMENT AND COSTING METHODOLOGY

An eight-step impact assessment and cost estimating methodology was established in TM E.1.f (Figure 2). The methodology estimates the ecological changes that will occur in various types of wetland communities as a result of changes in hydrological conditions. The only refinement of the methodology was in the sequence of values used in Step 5 to estimate change in ecological value. This refinement resulted from extensive discussions among the project's technical staff. During the review linear, exponential, and sigmoid distributions were considered (Figure 3). The consensus among the technical staff was that ecological change typically proceeds slowly, then shifts to a period of rapid change, followed by a leveling off to a new equilibrium condition. For this reason, it was decided that a sigmoid distribution of change would be used for estimating impacts and costs.

SPREADSHEET DEVELOPMENT

An electronic spreadsheet was developed in Microsoft Excel software to automate the impact assessment and cost estimating procedure developed in TM E.1.f (Table 1). The spreadsheet uses input data and user input to execute the methodology.

Key aspects of the application were developed in consultation with SJRWMD staff, such as the type and format of data inputs, structure and format for the costing spreadsheet, desired outputs from the spreadsheet, and protocol for the sensitivity analysis. The sensitivity analysis will compare the relative effects of selected input parameters on final mitigation costs.

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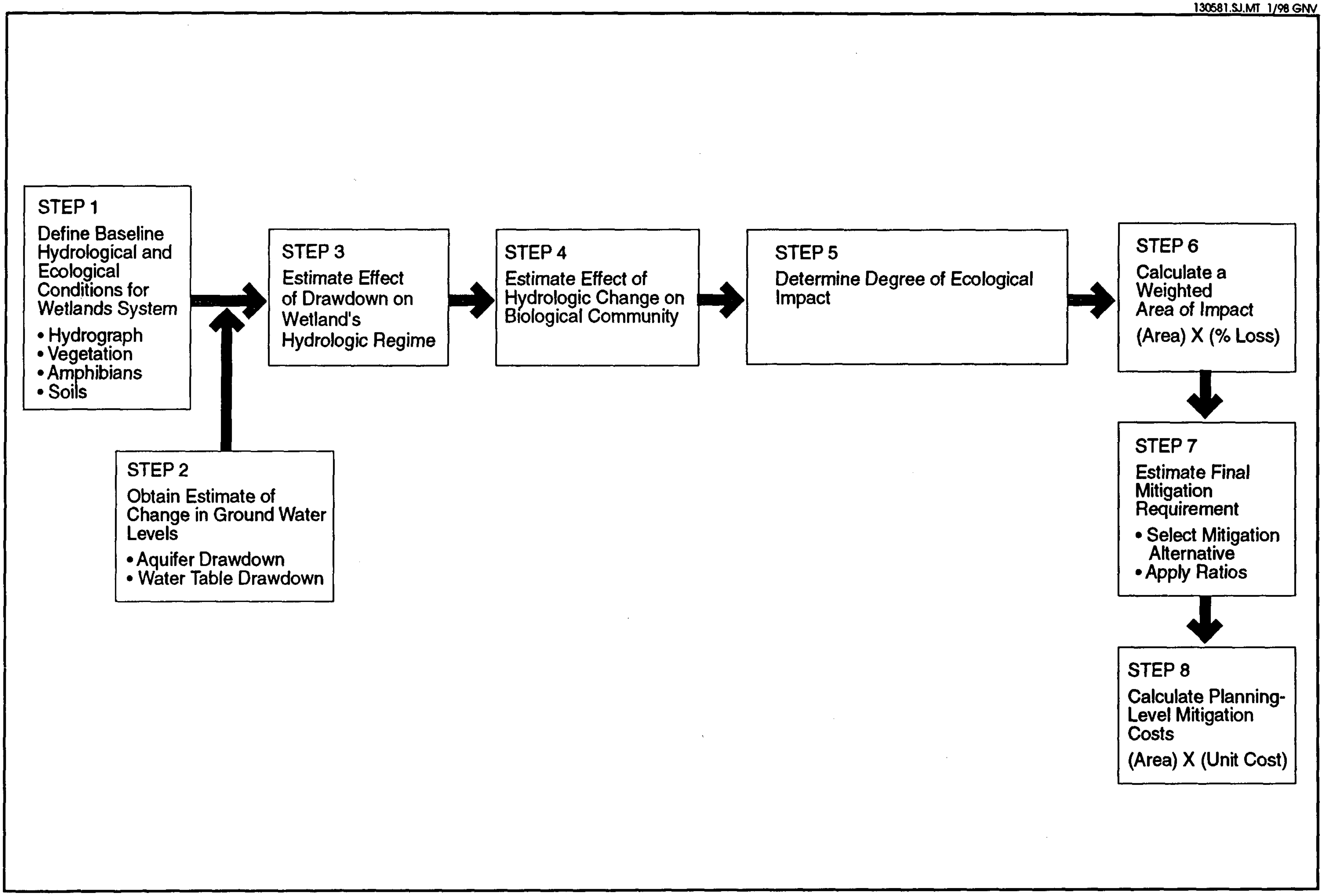

Figure 2. Impact Assessment and Mitigation Cost Estimating Methodology.

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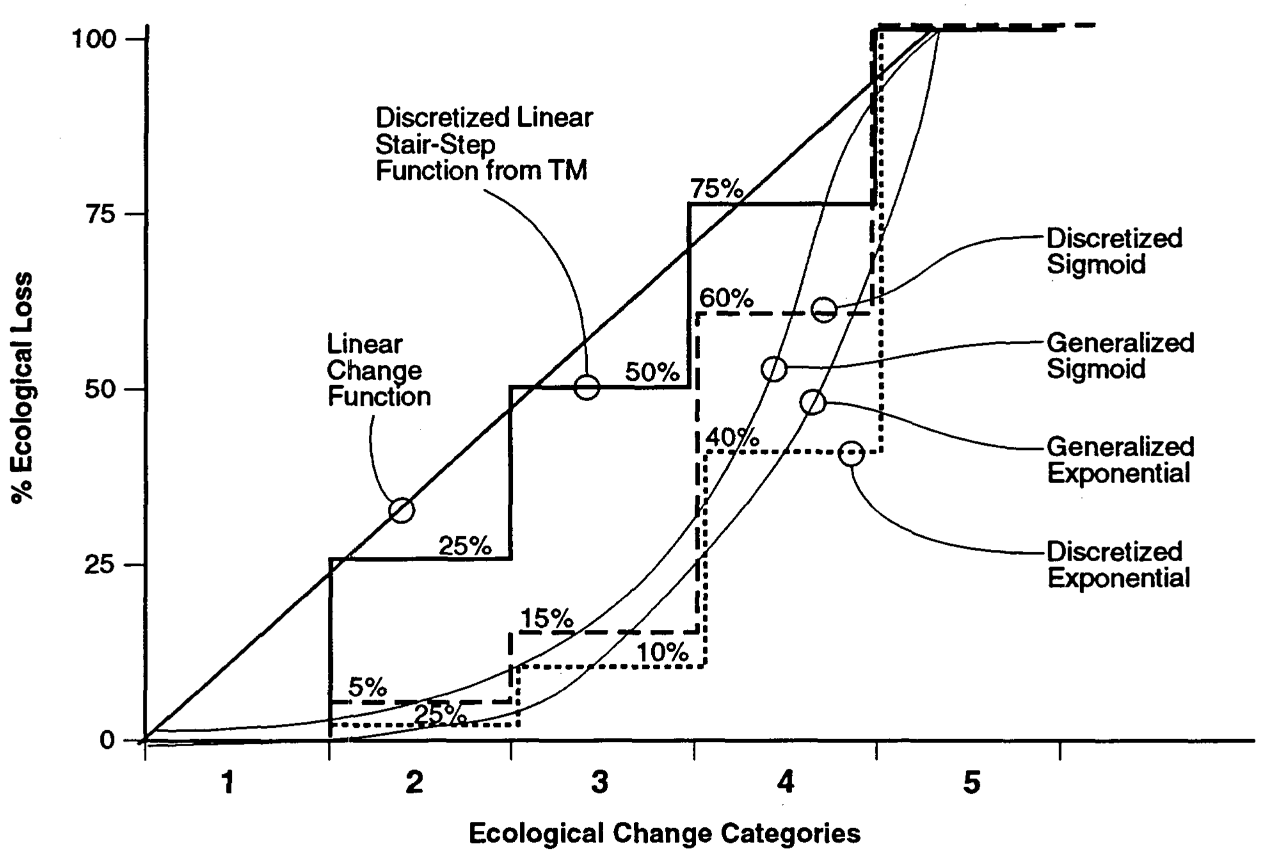

	Ecological Change Value by Category				
Discretized "Equation" Type	**1**	**2**	**3**	**4**	**5**
Linear	0.0	0.25	0.50	0.75	1.0
Sigmoid	0.0	0.05	0.15	0.60	1.0
Exponential	0.0	0.025	0.10	0.40	1.0

Figure 3. Linear, Sigmoid, and Exponential Distribution Alternatives for Defining the Ecological Loss Coefficient.

Table 1. Sixteen-Item Template of the Impact Assessment and Mitigation Cost Estimating Spreadsheet[a]

County	Soil Type	MUID	Polygon Area GIS Data (acre)	Wetland Type	Initial Hydrologic Regime (by type, max. depth)	Predicted Drawdown	New Hydrologic Regime	Category of Ecological Change	% Loss of Ecological Function	Sensitivity Values	Area Impacted	Mit. Method Code	Mitigation Method	Mitigation Ratio	Unit Mitigation Cost ($)	Total Cost ($)
St. Johns	Hontoon	1090035	5.284	617	0.50	0.125	0.38	Category 2	5	Base IHR Value	0.264	WRF	Wetland Restoration - Forested	3.5	17,500	16,182
St. Johns	Hontoon	1090035	5.284	617	0.50	0.125	0.38	Category 2	5	Base IHR - 20%	0.211	WRF	Wetland Restoration - Forested	3.5	17,500	12,945
St. Johns	Hontoon	1090035	5.284	617	0.50	0.125	0.38	Category 2	5	Base IHR - 10%	0.238	WRF	Wetland Restoration - Forested	3.5	17,500	14,564
St. Johns	Hontoon	1090035	5.284	617	0.50	0.125	0.38	Category 2	5	Base IHR + 10%	0.291	WRF	Wetland Restoration - Forested	3.5	17,500	17,800
St. Johns	Hontoon	1090035	5.284	617	0.50	0.125	0.38	Category 2	5	Base IHR + 20%	0.317	WRF	Wetland Restoration - Forested	3.5	17,500	19,418

[a]Example uses a single wetland polygon.

The greatest challenge during spreadsheet development was to automate the selection of appropriate fields of data from the summary tables in Appendix C of TM E.1.f.

Description of Mitigation Costing Spreadsheet

The mitigation costing spreadsheet implements the eight-step impact assessment and costing process described in TM E.1.f. This methodology takes into account such factors as baseline wetland condition and hydrologic regime, the effect of hydrologic change on dominant plant and animal species, and degree of ecological change. The spreadsheet then computes an acreage and dollar value for specific types of mitigation.

The spreadsheet performs the following functions:

- Reads a file of GIS polygon attribute data and predicted wetland water table drawdown data supplied by SJRWMD.
- Uses the derived percent Ecological Loss Coefficient (ELC) to calculate the number of acres for which mitigation will be required.
- Selects the type of mitigation and, from that selection, the associated mitigation ratio and unit mitigation cost per acre.
- Calculates the total cost of mitigation for each wetland (i.e., polygon).

The user is asked to select the mitigation option per polygon or for a suite of polygons, which in turn is used to define the mitigation ratio(s) and calculate unit cost(s) per acre. Unit mitigation costs are contained in internal look-up tables and programmed modules. Also embedded in the spreadsheet is a mechanism for performing a sensitivity analysis on the defined parameters to assess their relative effect on the total cost of mitigation.

Process Steps

Table 1 provides a template of the costing spreadsheet. Within the spreadsheet, a 16-item, user-input-driven process returns a final acreage number and total cost for selected mitigation options. The following itemized descriptions define each step in the process:

1. **County.** This column contains the name of the county of concern.

2. **Soil Type.** These data, which are supplied by SJRWMD, identify the soil type.
3. **MUID.** These data, which are supplied by SJRWMD, are the numerical codes for the soil types.
4. **Polygon Area (GIS Data).** These data are supplied by SJRWMD in an agreed-upon format. The area may be confined to a single wetland or expanded to include additional wetlands within an area or entire region.
5. **Wetland Type.** A look-up table contains the agreed-on nomenclature/Florida Land Use Cover Classification System (FLUCCS) designation for each wetland type and is used to link each type to a maximum depth (Table 2). (Also, see Appendix C in TM E.1.f.)
6. **Initial Hydrologic Regime (Max. Depth).** Each wetland type is linked within a look-up table (Table 2) to an associated annual maximum depth of inundation value. (See Appendix C in TM E.1.f.)
7. **Predicted Drawdown.** These estimated water table drawdown values are supplied by SJRWMD for each wetland area and have a permeability factor applied.
8. **New Hydrologic Regime.** The new annual maximum depth of inundation for the wetland area(s) is calculated in the spreadsheet by subtracting Item 7 from Item 6.
9. **Category of Ecological Change.** The category is provided from an associated module that links wetland types to ecological change categories. (See Appendix C in TM E.1.f.)
10. **Percent Loss of Ecological Function.** Each category of ecological change (Item 9) is linked through a module to a specific percent loss that returns this value. This value is subsequently used to calculate the required mitigation acreage per wetland polygon in Item 12.
11. **Sensitivity Values.** This placeholder shows the calculation of the sensitivity ranges of base value, base value ± 10 percent, and base value ± 20 percent. This column is for sorting and array formula use only.
12. **Area Impacted.** The area of required mitigation is automatically calculated by multiplying Item 4 by Item 10.

Table 2. Look-Up Table—Wetland Type and Hydrologic Regime Maximum Depth

Wetland Type	FLUCCS	Max. Depth	Hydroperiod
Hydric Oak Hammock	615	0.5	60
Gum Swamp	613	1.25	240
Aquatic Slough	616	2	360
Hardwood Swamp	617	0.5	150
Mixed Scrub/Shrub	619	1	180
Hydric Flatwoods	3241	0.5	60
Shallow Cypress	6211	0.5	150
Cypress	6212	1.25	240
Deep Cypress	6213	1.7	300
Hydric Palm Hammock	6242	0.5	120
Shallow Marsh	6411	0.5	150
Marsh	6412	1.25	240
Deep Marsh	6413	1.8	330
Dry Prairie	6431	0.5	60
Wet Prairie	6432	0.5	90
Deep Prairie	6433	1	180

13. **Mitigation Method/Code.** The user chooses the method by entering a code located within an associated look-up table (Table 3).
14. **Mitigation Ratio.** This is a median value from an established range of ratios supplied in TM E.1.f (p. 91) and contained within the associated look-up table (Table 3).
15. **Unit Mitigation Cost per Acre.** This value is a predetermined value, also located within the associated look-up table (Table 3) and supplied in TM E.1.f (p. 92).
16. **Total Mitigation Cost.** The spreadsheet multiplies Items 12, 14, and 15 to calculate a final mitigation cost per mitigation option.

INPUT FILE DEVELOPMENT

The input data file provided by SJRWMD was obtained from the following two sources:

- Polygon attribute data from SJRWMD's GIS analysis
- Estimate of water table drawdown within each wetland from SJRWMD's regional ground water model

The input file was processed in two steps—input file generation and post-processing. These two steps are described below.

Input File Generation by SJRWMD

A detailed description of the manner in which the input file was generated is summarized below and described in detail in Appendix A. The input file was generated using a screening process similar to that used by Vergara et al. (1994) to identify areas of native vegetation that would probably be adversely impacted by future water supply withdrawals. These areas are associated with the development of proposed new wellfields and the expansion of existing wellfields in the following counties:

- St. Johns County
- Flagler County
- Volusia County
- Lake County
- Orange County
- Seminole County
- Brevard County

Table 3. Look-Up Table—Mitigation Method, Ratio, and Unit Cost

Code	Method	Ratio	Unit Cost per Acre ($)
WCF	Wetland Creation - Forested	3.50	37,500
WCH	Wetland Creation - Herbaceous	2.75	37,500
WRF	Wetland Restoration - Forested	3.50	17,500
WRH	Wetland Restoration - Herbaceous	2.75	17,500
WE	Wetland Enhancement	12.00	13,750
WP	Wetland Preservation	35.00	800
UP	Upland Preservation	11.50	2,800

A GIS model was developed by Kinser and Minno (1996) to estimate the likelihood of harm to native plant communities from ground water withdrawals. The model was developed using soil permeability, plant community sensitivities to dewatering, and projected declines in the water table of the surficial aquifer system. SJRWMD staff provided data on baseline hydrological conditions, estimated water table drawdown, and acreage of wetland impact.

To estimate the acreage of impacted wetlands, SJRWMD conducted a GIS analysis. Three GIS data layers—wetlands, estimated drawdown, and soils—were used and are described below.

Wetlands. The wetlands layer was derived from SJRWMD's 1990 land use/cover layer. Features were classified according to FLUCCS (Florida Department of Transportation 1985). To create the needed wetlands layer, all water (5000 series) and wetlands (6000 series) features were extracted and processed to create a separate GIS coverage containing only these features.

Drawdown. A projected drawdown layer was created from regional models of ground water use and resultant water table declines. Declines were estimated to the nearest quarter-foot. Drawdown for areas located between adjacent regional models was interpolated, and irregular or angular contours were smoothed.

Soils. To create a soils layer, the detailed soils layer (SURGO) was clipped to boundaries of the wetlands and then classified by the least permeable layer. Three permeability classes were used: low (less than 0.6 inches per hour [iph]), moderate (0.6 to 6.0 iph), and high (greater than 6.0 iph). Because soil layers with low permeability may reduce the susceptibility of wetlands to ground water withdrawal, this GIS layer was created to allow soil permeability to be used as a modifier in the spreadsheet mitigation costing model.

Input Data Processing Steps

CH2M HILL manipulated the structure and content of the files so that they could be used as inputs to the costing spreadsheet. SJRWMD provided separate files for each county that contained WRCAs (Brevard, Flagler, Lake, Orange, Seminole, St. Johns, and Volusia). Each file contained several to thousands of records. Each record consisted of a polygon identification number, land use code, soil series designation, soil permeability value, projected drawdown interval, and area value.

Several additional post-processing steps were needed to format the files so that they could be imported into the costing spreadsheet. These additional post-processing steps were as follows:

1. **Convert area values from square meters to acres.** The costing methodology is based on acres as the unit of area.

2. **Eliminate splinter polygons.** The overlay process from SJRWMD's GIS analysis resulted in many "splinter" polygons, which are artifacts of the process. All polygons of less than 1 acre were eliminated from the initial data set because of the assumption that any polygon less than 1 acre is unlikely to be a real mapped entity.

3. **Add a midrange value for drawdown.** SJRWMD provided a projected drawdown range with 0.25-foot intervals. The impact assessment methodology described in TM E.1.f requires a single value as opposed to range, so the midpoint value of each range was used as the estimate.

4. **Add a soil permeability modifier.** The potential drawdown within a wetland is influenced by the permeability of its underlying soil. The data file from SJRWMD contained the permeability class, given as a range, for the most restrictive layer in the soil profile; however, this information had not been used to adjust the projected drawdown. CH2M HILL developed a permeability coefficient (PC) for each permeability class. The PCs, ranging between 0.05 and 1.0, were assigned to the soil permeability classes as follows: very slow (0.05), slow (0.2), moderately slow (0.7), and moderate to very rapid (1.0).

5. **Calculate an adjusted drawdown value based on the soil permeability coefficient.** The water table drawdown (in feet) predicted by SJRWMD was modified by multiplying the initial value by the corresponding PC. The resulting value—the adjusted drawdown—was then used in the remaining calculations.

SENSITIVITY ANALYSIS OF COST ESTIMATING METHODOLOGY

Sensitivity analysis is a means of investigating the behavior of a calculation procedure or model. For the purposes of this TM, the assessment and cost estimating methodology is the model. The methodology is based on a series of parameters, each with one or more assumptions. For a given application, the key parameters in the methodology can be incrementally varied and evaluated for their effects on costs. For this analysis, the parameter that varied was predicted drawdown.

The sensitivity analysis module embedded within the costing spreadsheet is based on a user-determined number of cost-affecting parameters. The protocols for the analysis have been established in consultation with SJRWMD staff, as was the following series of assumptions:

- The sensitivity analysis would be performed on one or more key parameters.
- For each parameter, the analysis would consist of comparing the following five costing values: the initial estimated value of the parameter, two additional higher values, and two additional lower values.

For the analysis, the suite of five values were as follows: the initial value, the initial value plus 10 percent, the initial value plus 20 percent, the initial value minus 10 percent, and the initial value minus 20 percent (Table 4).

Table 4. Summary of Ecological Loss Coefficients for Base Run and Sensitivity Analysis

Category of Ecological Change	Base -20%	Base -10%	Base Value	Base +10%	Base +20%
1	0.0	0.0	0.0	0.0	0.0
2	0.04	0.045	0.05	0.055	0.06
3	0.12	0.135	0.15	0.165	0.18
4	0.48	0.54	0.60	0.66	0.72
5	0.8	0.9	1.00	1.0 [a]	1.0 [a]

[a] Value of ELC is limited to ≤1.0 because the Ecological Loss Coefficient has an upper limit of 100 percent.

RESULTS AND DISCUSSION

The impact assessment and costing methodology described in TM E.1.f was applied at two levels: first, as the best parameter estimate model, based on assumptions detailed in TM E.1.f and further described in the preceding sections of this document and, second, as an analysis of the sensitivity of the cost estimate to a key parameter (predicted drawdown).

BASE RUN—BEST PARAMETER ESTIMATE

The base cost estimating run or best parameter estimate of the impact assessment and costing spreadsheet was run using the following information:

- The initially recommended parameter values from TM E.1.f
- SJRWMD's estimates of the surficial aquifer drawdown by wetland community type within the WRCAs
- Other assumptions (e.g., adjusted drawdown calculated using the soil permeability coefficient; using a sigmoid distribution for assigning ELC), as detailed in preceding sections of this TM

The results are summarized by the three general categories: (1) first, by the unweighted areal extent of wetland and aquatic systems affected by surficial aquifer drawdown, (2) by the areal estimates weighted by the ELC, and (3) by a planning-level cost estimate of mitigating SJRWMD's projected impacts. Within these general categories, the results are subsequently broken out by county or area, wetland/ aquatic community type, and vertical extent of predicted surficial aquifer drawdown.

Area Impacted by Projected 2010 Water Table Drawdowns

Summaries of the estimated areas of wetland and aquatic systems impacted within the WRCAs are provided in the following tables and figures:

- By amount (i.e., areal extent) in Table 5 and Figure 4
- By type of wetland community affected in Table 6 and Figure 5
- By degree of drawdown in Table 7 and Figure 6

Table 5. Weighted and Unweighted Acreage Affected by County

County	Unweighted Acreage	Weighted Acreage[a]	Ratio of Weighted to Unweighted Acreage
Brevard	108,956.6	1,884.2	0.02
Flagler	95,097.2	6,331.4	0.07
Lake	139,246.1	24,703.3	0.18
Orange	84,064.5	17,974.8	0.21
Seminole	49,351.2	18,811.5	0.38
St. Johns	5.3	0.3	0.05
Volusia	216,276.8	38,717.5	0.18
Total Area	**692,997.8**	**108,422.9**	**0.16**

[a] Weighted acreage = (unweighted acreage) x (Ecological Loss Coefficient).

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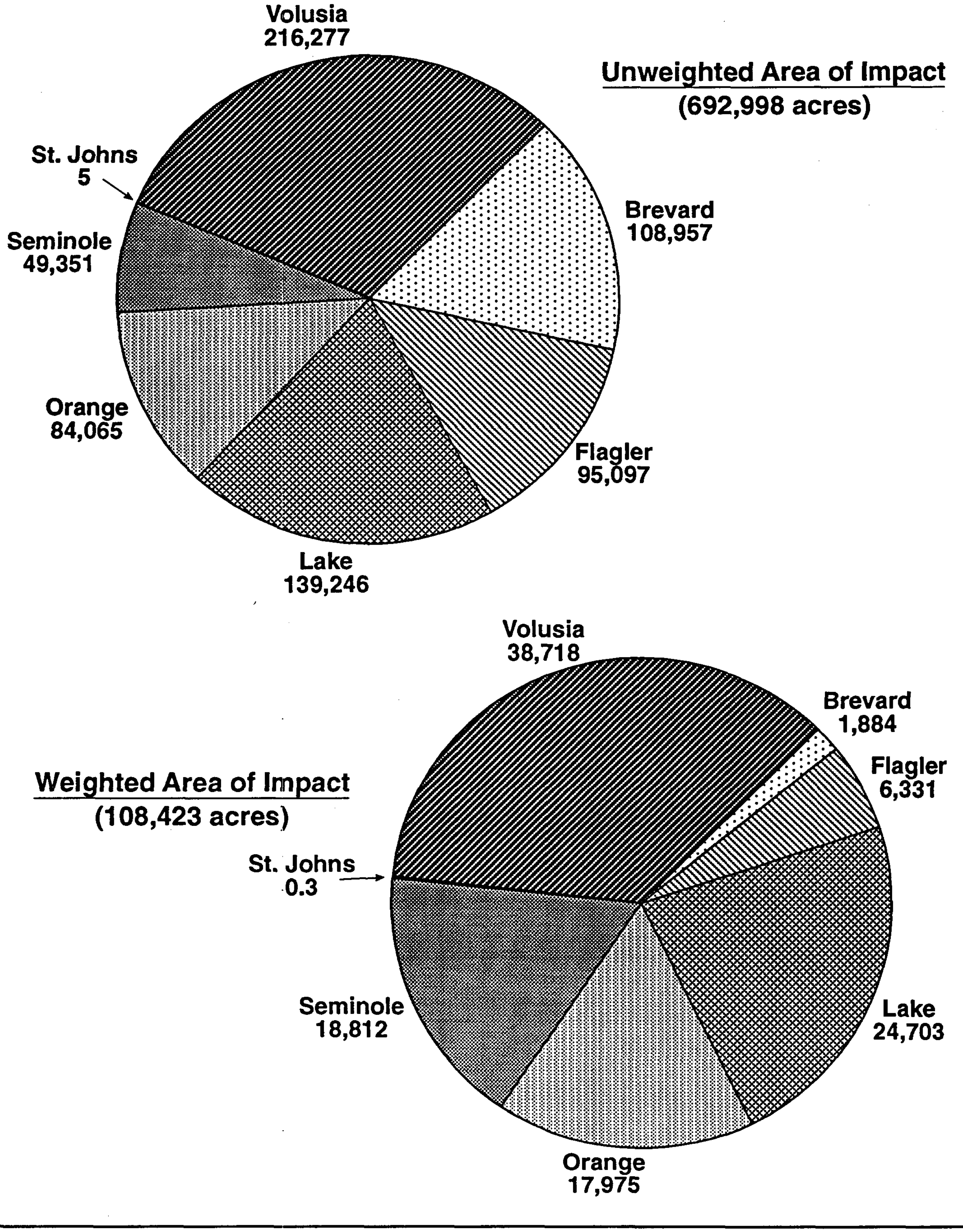
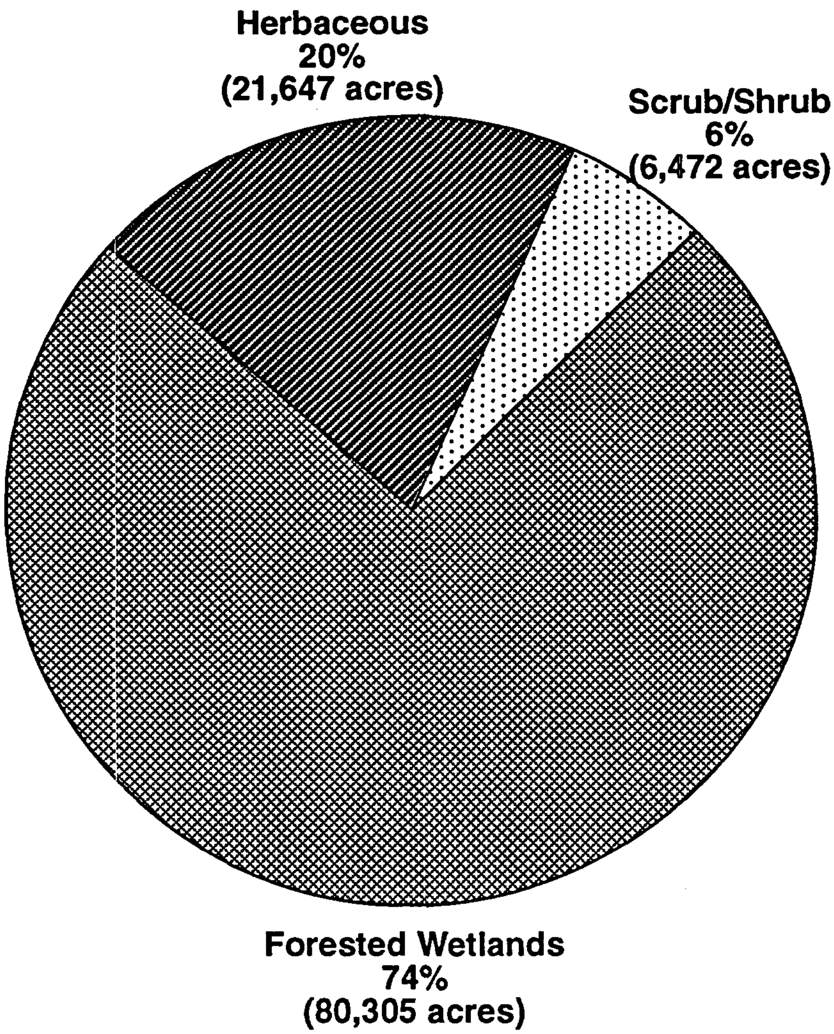


Figure 4. Summary of Unweighted and Weighted Estimates of Impact Area by County.

Table 6. Weighted Estimate of Impact Area by Wetland Type Within Each County

Wetland Type	Impact Area (Acres)							Total by Wetland Type
	Brevard	Flagler	Lake	Orange	Seminole	St. Johns	Volusia	
Gum Swamp	0	0	1	0	0	0.0	0	1
Aquatic Slough	46	0	0	1	0	0.0	1	48
Hardwood Swamp	512	4,233	9,567	5,543	3,580	0.3	19,630	43,066
Mixed Scrub/ Shrub	212	55	835	1,915	870	0.0	2,585	6,472
Shallow Cypress	2	105	285	114	49	0.0	321	876
Cypress	300	1,579	1,902	7,249	11,780	0.0	13,503	36,314
Marsh	368	222	8,724	2,064	1,729	0.0	1,784	14,891
Wet Prairie	444	137	3,388	1,090	803	0.0	893	6,756
Total by County	**1,884**	**6,331**	**24,703**	**17,975**	**18,812**	**0.3**	**38,717**	**108,423**



Forested:	Gum Swamp, Aquatic Slough, Hardwood Swamp, Shallow Cypress, Cypress
Herbaceous:	Marsh and Wet Prairie
Scrub/Shrub:	Mixed Scrub/Shrub

Figure 5. Summary of Weighted Acreage Values for Impact to Forested, Scrub/Shrub, and Herbaceous Wetlands in Water Resource Caution Areas.

Table 7. Estimated Impact Area in Acres by Degree of Drawdown Within Each County

Drawdown Interval (ft)	Drawdown Value (ft)	Brevard	Flagler	Lake	Orange	Seminole	St. Johns	Volusia	Total	% of Total
	0.025	6	351	9	218	0	0	26	611	
	0.034	0	0	4	0	0	0	0	4	
	0.075	0	113	0	210	16	0	10	349	
	0.088	0	0	0	0	0	0	9	9	
≥ 0.25	0.106	126	4	0	15	0	0	0	145	5.5
	0.125	453	490	2,343	181	22	0.3	1,351	4,840	
	0.135	0	36	1	9	6	0	7	58	
	0.175	0	39	2	3	20	0	36	100	
	0.225	0	58	0	3	29	0	0	89	
	0.263	0	0	0	0	0	0	71	71	
	0.275	0	54	0	2	20	0	0	76	
	0.319	0	11	0	98	0	0	0	108	
	0.335	0	40	0	0	1	0	0	41	
> 0.25 - 0.5	0.375	336	1,777	0	2,270	2,280	0	9,013	15,676	15.4
	0.425	0	385	0	0	3	0	0	388	
	0.450	21	0	0	0	0	0	0	21	
	0.473	0	0	0	0	0	0	90	90	
	0.574	0	19	0	115	0	0	0	134	
	0.613	0	0	0	0	0	0	268	268	
	0.675	107	1,256	7,232	2,404	1,753	0	7,922	20,674	
> 0.5 - 1.0	0.744	0	13	0	66	0	0	0	80	30.5
	0.788	0	0	0	0	0	0	176	176	
	0.875	116	271	4,506	916	1,074	0	4,517	11,401	
	0.956	0	33	0	122	0	0	0	154	
	0.963	0	0	0	0	0	0	186	186	

Table 7 (Continued). Estimated Impact Area in Acres by Degree of Drawdown Within Each County

Drawdown Interval (ft)	Drawdown Value (ft)	Brevard	Flagler	Lake	Orange	Seminole	St. Johns	Volusia	Total	% of Total
	1.125	151	408	3,987	3,719	1,745	0	6,953	16,963	
	1.169	0	14	0	57	0	0	0	71	
	1.173	0	0	0	0	0	0	14	14	
> 1.0 - 1.5	1.313	0	0	0	0	0	0	11	11	30.5
	1.375	60	339	5,354	3,710	2,050	0	4,453	15,968	
	1.424	0	8	0	87	0	0	0	95	
	1.594	0	2	0	11	0	0	0	14	
	1.675	121	138	1,265	1,585	1,328	0	1,592	6,028	
> 1.5	1.806	0	24	0	21	0	0	0	45	18.0
	1.875	45	112	0	1,173	939	0	799	3,067	
	2.125	0	338	0	980	7,526	0	1,213	10,059	
	2.250	340	0	0	0	0	0	0	340	
Total Acreage		1,884	6,331	24,703	17,975	18,812	0.3	38,717	108,423	

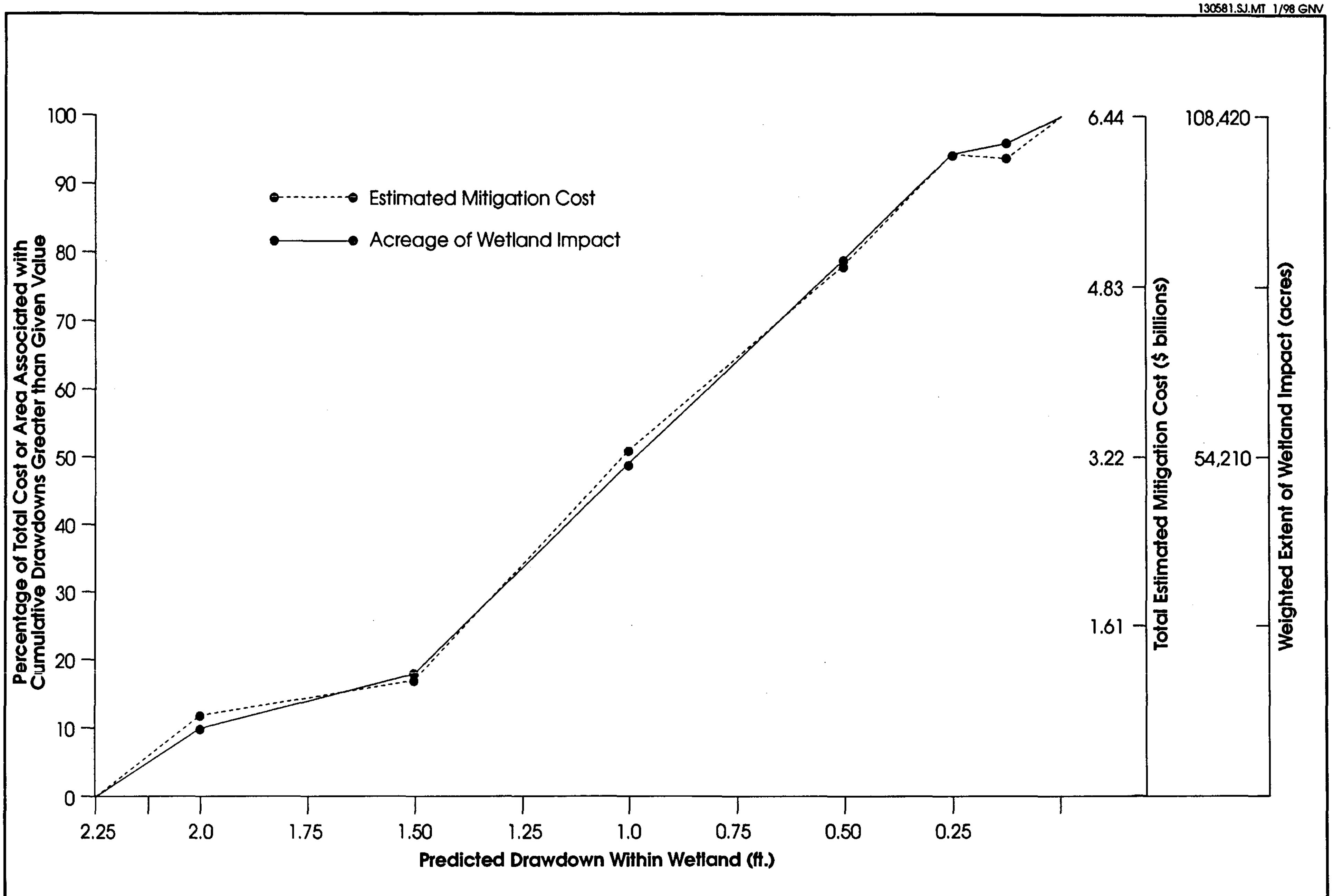


Figure 6. Drawdown Frequency Plots for Impact Area and Mitigation Cost.

Extent and Degree of Impact. Table 5 and Figure 4 provide summaries of the cumulative wetland area affected within each county by the 2010 projected drawdowns. Estimates of the extent and degree of impact are provided as "unweighted" and "weighted" values. Estimated unweighted acreages are defined as the wetland acreage within a study area that will experience water table drawdown (Figure A-4 in Appendix A). Much of the affected area within the unweighted estimate will be expected to lose only a portion of its ecological function. The estimate of the fraction of ecological function lost is provided by the ELC. Thus, multiplying the unweighted area value by the ELC results in a weighted estimate of impact acreage.

The total unweighted estimate of the wetland area affected is 693,000 acres, or 1,083 sq. mi. This area is roughly equivalent to the total land surface area of Volusia County (1,115 square miles). The approximately between-county range for the unweighted wetland impact area covers five orders of magnitude, ranging from 5 acres (St. Johns County) to 220,000 acres (Volusia County).

Applying the ELC to the unweighted estimate results in a weighted impact area of 108,425 acres. The between-county range for the weighted impact area is 0.3 acres (St. Johns County) and 39,000 acres (Volusia County). Volusia County wetlands constitute the largest percentage (36 percent) of the total study area (all seven counties combined) associated with loss of ecological function.

The ratio of weighted to unweighted area for the entire study area (all counties) is 0.16. This ratio is an aggregate ELC value, which indicates that over the study area the projected loss of wetland ecological function is 16 percent, with a range for the individual counties of 2 percent (Brevard) to 38 percent (Seminole) (Table 5). Thus, the analysis estimates that 38 percent of the potentially affected wetland area in Seminole County in the year 2010 will have some degree of loss of ecological function. In contrast, only 2 percent of the potentially affected wetland area in Brevard County is predicted to have a loss of ecological function. For the seven-county group, the aggregate values for projected loss of ecological function can be divided into the following three subgroups:

- Two percent to 7 percent loss, Brevard, Flagler and St. Johns counties
- Eighteen percent to 21 percent loss, Lake, Orange and Volusia counties

- Thirty-eight percent loss, Seminole County

Wetland Community. Table 6 summarizes the drawdown impact area (weighted affected area) for each wetland community type. Eight major types of wetland and aquatic systems are projected to be affected by 2010 drawdowns. These systems, in order of decreasing weighted area of impact, are as follows: hardwood swamp, cypress swamp, marsh, wet prairie, shrub swamp, shallow cypress swamp, aquatic slough, and gum swamp. Absent from the SJRWMD input data and, thus, from the list of affected community types are hydric hammocks and hydric flatwoods, both of which are common ecosystem types in the study area.

The eight community types can be aggregated into three broader wetland categories: forested, scrub/shrub, and herbaceous. Forested wetland impacts account for 74 percent of the total acreage (Figure 5). Scrub/shrub wetlands account for 6 percent of the total weighted area, with herbaceous wetlands comprising the remaining 20 percent.

Drawdown Intervals. Table 7 summarizes the weighted, affected areas categorized by the vertical extent of drawdown within each county. Figure 6 is a plot of the cumulative area of all drawdowns less than or greater than a given drawdown value. For example, for a drawdown of 0.5 feet, the plot indicates that approximately 20 percent of the total affected area is accounted for by drawdowns of less than 0.5 feet, and 80 percent is attributable to drawdowns of more than 0.5 feet. From the plot, it can be seen that out of the total weighted area of 108,425 acres:

- Six percent is covered by projected drawdowns of less than 0.25 feet.
- Twenty-one percent is covered by drawdowns of 0.5 feet or less.
- The 1-foot drawdown is approximately the middle of the distribution, with half the affected area having lesser drawdown values and half having greater values.
- Predicted drawdowns of more than 1.5 feet and 2.0 feet affect approximately 20 percent and 10 percent, respectively, of the total weighted area.

Figure 6 provides a summary of estimated mitigation cost by ecosystem type and by county. This information provides a basis for discussing the following two issues:

1. Will the predicted drawdowns have adverse ecological effects?
2. Is the size of the area expected to experience significant drawdown a cause for concern?

Low-level drawdowns raise questions regarding the accuracy of both the prediction and its ecological consequence. One way to address this uncertainty is to remove the values with higher associated uncertainties from the analysis and assess the effect on the results. Thus, one can assess the results in terms of successively discounting the lowest drawdowns, and then determining the magnitude of the effect on the remaining area of impact.

Drawdowns of less than 0.25 feet and even up to 0.5 feet are associated with a greater uncertainty regarding their validity and accuracy and, thus, their degree of ecological impact. For drawdowns in the range of 0.5 to more than 2.0 feet, there is greater certainty that the drawdown will induce demonstrable ecological change.

The sensitivity of the overall estimate to the distribution of drawdowns can be assessed by using Figure 6. Discounting drawdowns of less than 0.25 feet eliminates 5 percent of the impact area; discounting the interval from 0.25 to 0.5 eliminates another 15 percent. Thus, projected drawdowns of more than 0.5 feet account for 80 percent of the weighted total acreage.

Planning-Level Estimate of Mitigation Costs

The estimated cost of mitigating for the projected 2010 drawdown impacts is summarized in the following tables and figures:

- By county in Table 8 and Figure 7
- By wetland type in Table 8 and Figure 7
- By degree of drawdown in Table 9 and Figure 6

County. Table 8 provides a summary of the estimated planning-level mitigation costs for each affected wetland type within each county. The total mitigation cost for the project area (all counties combined) is $6.36 billion. Like the projections for area, mitigation cost by individual county varies over approximately five orders of magnitude, from $16,000 for St. Johns County to $2.4 billion for Volusia County (Figure 7). Approximately 92 percent of the total estimated cost is attributable to Lake, Orange, Seminole, and Volusia counties.

Ecosystem Type. The planning-level mitigation cost is presented by wetland community type in Table 8. Forested wetland impacts

Table 8. Estimated Cost of Mitigating Projected Wetland Impacts by County

Community Type	Costs per County ($)							Total Cost per Wetland Type ($)
	Brevard	Flagler	Lake	Orange	Seminole	St. Johns	Volusia	
Gum Swamp	0	0	58,157	0	0	0	0	**58,157**
Aquatic Slough	2,208,264	0	0	24,846	0	0	59,915	**2,293,025**
Hardwood Swamp	31,373,838	259,255,857	585,993,517	339,529,980	219,303,893	16,182	1,202,311,777	**2,637,785,044**
Mixed Scrub/Shrub	12,972,496	3,397,285	51,173,831	117,270,498	53,295,908	0	158,319,442	**396,429,459**
Shallow Cypress	143,087	6,411,447	17,450,859	6,965,585	2,986,658	0	19,681,526	**53,639,163**
Cypress	18,383,197	96,725,521	116,521,938	444,018,812	721,517,780	0	827,078,711	**2,224,245,959**
Marsh	17,695,427	10,678,128	419,846,352	99,312,920	83,198,327	0	125,825,325	**756,556,478**
Wet Prairie	21,375,118	6,612,517	163,056,270	52,438,154	38,667,184	0	92,065,667	**374,214,909**
Restoration Cost by County	**104,151,427**	**383,080,755**	**1,354,100,923**	**1,059,560,796**	**1,118,969,750**	**16,182**	**2,425,342,362**	**6,356,097,580**

Note: Mitigation cost assumes restoration will consist of mitigation with a unit cost of $17,500/acre and a ratio of 3.5 for forested and 2.75 for herbaceous wetlands.

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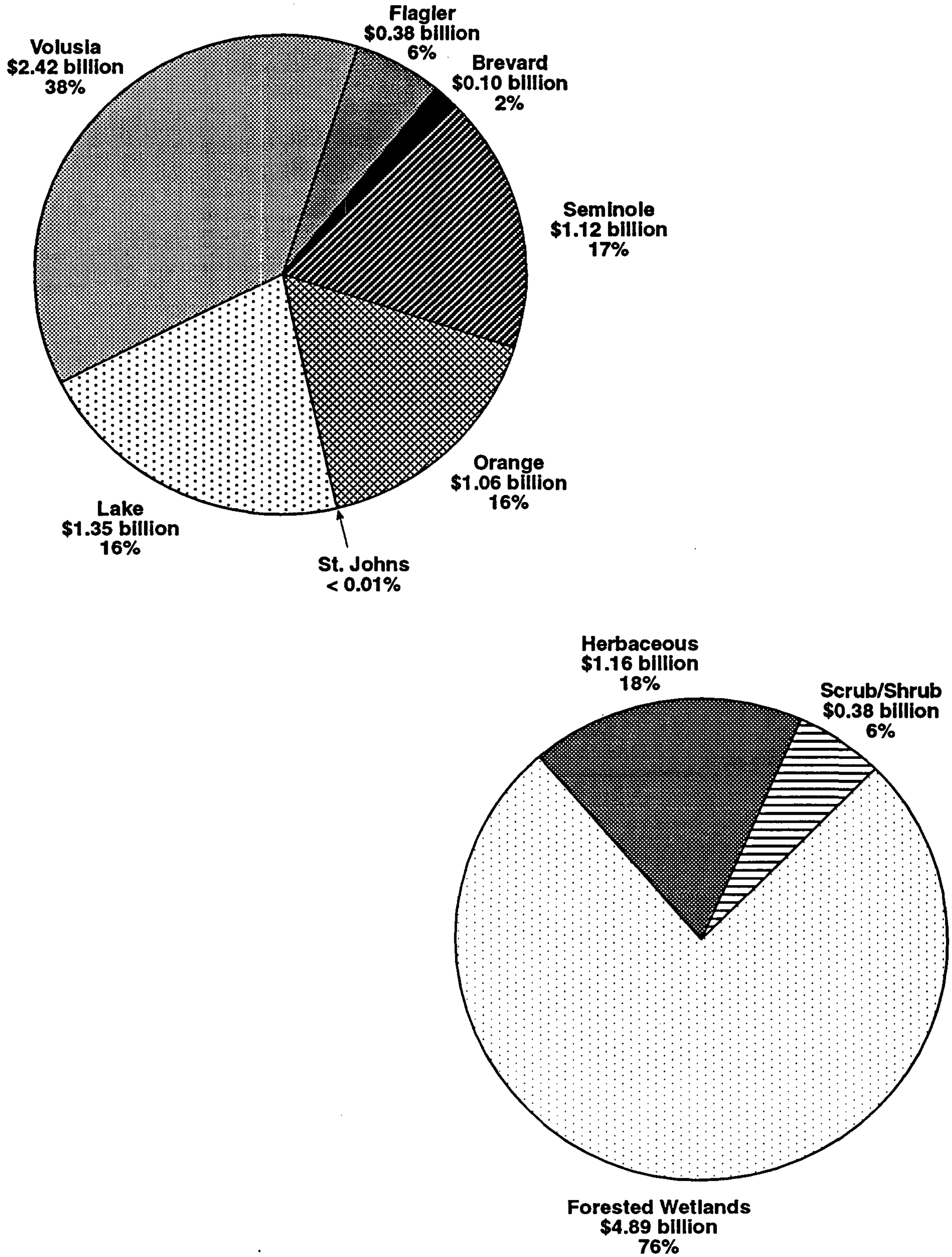

Figure 7. Summary of Estimated Mitigation Cost by Ecosystem Type and by County.

Table 9. Estimated Cost of Mitigating Projected Wetland Impacts by Drawdown Interval Within Each County

	Estimated Mitigation Cost by County ($)								Total $ by
Drawdown (ft)	Brevard	Flagler	Lake	Orange	Seminole	St. Johns	Volusia	Total Cost	Drawdown Interval
0.025	395,310	21,514,627	561,653	13,326,848	13,855	0	1,616,449	37,428,741	
0.034	0	0	217,487	0	0	0	0	217,487	
0.044	0	0	16,223	0	0	0	0	16,223	0.0 to 0.25 ft.
0.075	13,595	6,938,600	0	12,857,761	988,189	0	603,380	21,401,524	
0.088	0	0	0	0	0	0	576,867	576,867	373,181,177
0.106	6,332,963	241,895	0	818,236	0	0	0	7,393,093	
0.125	24,438,431	29,499,223	141,452,470	10,748,224	1,167,802	16,182	84,320,205	291,642,537	6%
0.135	22,737	2,169,164	24,880	515,360	304,142	0	466,989	3,503,272	
0.175	4,609	2,353,926	109,263	160,323	984,339	0	2,209,460	5,821,920	
0.225	0	3,516,638	0	166,373	1,496,501	0	0	5,179,513	
0.263	0	0	0	0	0	0	4,871,181	4,871,181	
0.275	0	3,283,805	0	115,161	1,112,266	0	0	4,511,232	
0.319	0	638,179	0	5,759,792	0	0	0	6,397,971	> 0.25 to 0.5 ft.
0.335	0	2,454,287	0	7,936	42,152	0	0	2,504,376	
0.375	17,911,939	106,818,333	0	137,867,387	138,249,660	0	570,674,922	971,522,242	1,020,643,743
0.425	0	23,564,009	0	3,568	175,311	0	0	23,742,889	16%
0.45	1,259,142	0	0	0	0	0	0	1,259,142	
0.473	0	0	0	0	0	0	5,834,709	5,834,709	
0.574	0	1,139,265	0	6,245,075	0	0	0	7,384,340	
0.613	0	0	0	0	0	0	19,403,558	19,403,559	
0.675	6,058,308	75,801,022	415,703,749	143,863,967	102,966,255	0	522,157,362	1,266,550,663	> 0.5 to 1.0 ft.
0.744	0	750,850	0	3,838,345	0	0	0	4,589,196	
0.788	0	0	0	0	0	0	10,857,356	10,857,357	1,995,858,308
0.875	6,901,259	16,488,813	251,256,787	53,754,007	60,350,200	0	278,192,933	666,944,000	31%
0.956	0	1,971,446	0	7,253,401	0	0	0	9,224,848	
0.963	0	0	0	0	0	0	10,904,344	10,904,344	

Table 9 (Continued). Estimated Cost of Mitigating Projected Wetland Impacts by Drawdown Interval Within Each County

	Estimated Mitigation Cost by County ($)								Total $ by
Drawdown (ft)	Brevard	Flagler	Lake	Orange	Seminole	St. Johns	Volusia	Total Cost	Drawdown Interval
1.125	8,885,666	24,923,944	207,812,314	221,288,574	103,739,181	0	421,679,514	988,329,195	
1.169	0	844,500	0	3,333,745	0	0	0	4,178,246	> 1.0 to 1.5 ft.
1.173	0	0	0	0	0	0	763,971	763,971	
1.313	0	0	0	0	0	0	677,788	677,788	1,907,439,729
1.375	3,258,205	20,741,453	275,308,309	215,485,107	122,499,466	0	270,860,634	908,153,175	30%
1.424	0	464,294	0	4,873,055	0	0	0	5,337,351	
1.594	0	139,706	0	676,097	0	0	0	815,805	
1.675	6,688,115	8,387,373	61,637,789	90,086,127	79,142,539	0	96,194,738	342,136,683	> 1.5 ft.
1.806	0	1,439,491	0	1,283,139	0	0	0	2,722,631	
1.875	2,283,945	6,702,705	0	67,911,912	55,656,931	0	48,515,939	181,071,434	1,148,099,268
2.125	0	20,293,207	0	57,321,275	450,080,960	0	73,960,064	601,655,508	18%
2.25	19,697,205	0	0	0	0	0	0	19,697,207	
Total ($)	**104,151,427**	**383,080,755**	**1,354,100,923**	**1,059,560,796**	**1,118,969,750**	**16,182**	**2,425,342,362**	**6,356,097,580**	

account for 76 percent of the total estimated mitigation cost (Figure 7). Scrub/shrub wetlands account for 6 percent of the total weighted area, and herbaceous wetlands make up the remaining 18 percent.

Drawdown Intervals. Table 9 provides a summary of estimated mitigation costs by amount of drawdown, the results of which are similar to the acreage distribution by drawdown. This relationship is also summarized graphically in Figure 6, which shows that the distribution of cost as a function of drawdown amount is nearly identical to that already discussed for area.

Of the total estimated mitigation cost for 2010 conditions of $6.36 billion:

- Six percent can attributed to projected drawdowns of less than 0.25 feet.
- Twenty-two percent can be attributed to drawdowns of 0.5 feet or less.
- The 1-foot drawdown is approximately the middle of the distribution, with half the cost attributable to lesser drawdown values and half attributable to greater values.
- Predicted drawdowns of more than 1.5 feet and 2.0 feet contribute approximately 20 percent and 10 percent, respectively, to the total cost.

The range of mitigation costs that would be generated by the more than 0.5-foot drawdown interval is from $0 (0 percent) for St. Johns County to $1.7 billion for Volusia County. Estimated mitigation costs from drawdowns of less than 0.5 feet range from $16,000 for St. Johns County to $0.7 billion for Volusia County.

In comparing the mitigation costs between the counties, excluding Flagler and St. Johns, the majority of the mitigation costs can be attributed to wetlands predicted to have more than a 0.5-foot drawdown. In Lake County, 90 percent ($1.2 billion) of its total mitigation cost occurs in the more than 0.5-foot drawdown interval. Conversely, the majority of Flagler County's mitigation costs (53 percent; $0.2 billion) are generated by the less than 0.5-foot drawdown interval. All of St. Johns County's mitigation costs are from the less than 0.25-foot drawdown interval.

SENSITIVITY ANALYSIS

The sensitivity analysis tested the effect of varying the key parameter of predicted water table drawdown in the costing procedure. The analysis was conducted to test the sensitivity of the cost estimates to the incremental variation in SJRWMD's predicted drawdown values. The initial values for predicted drawdown were varied incrementally to yield the following additional four values: -10 percent, -20 percent, +10 percent, and +20 percent.

The results of varying the predicted drawdown at the projected area of impact and, thus, the planning-level mitigation costs, are provided in Table 10. The effect on total costs is as expected: there is a nearly linear response to the variation in the degree of drawdown. A similar trend is seen for total costs by county. The cost estimates are sensitive to the accuracy of the drawdown estimate. However, over the range of incremental variation, the totals for the estimated cost maintain a nearly linear response.

The plots in Figure 8 generally have the same shape and trend. The between-plot nuances are caused by the differences in distribution of drawdown. In this analysis, the effect of the resulting new hydrologic regime may or may not be masked by the limits of the category of change designation, depending on where the value occurs within the category. For example, if the base value of the predicted drawdown amount is near the upper limit of Category 3, a 10- or 20-percent decrease in the drawdown value will not result in a new designation. Thus, the costs for that polygon will remain the same under the three conditions (base, variation of -10 percent, and variation of -20 percent). However, an increase of 10 or 20 percent in the drawdown value will result in a category change (Category 4), yielding a larger impact on acreage and, subsequently, a larger mitigation cost. The change in category from 3 to 4 will cause a 400-percent increase in costs (see Figure 3 for the sigmoid equation ecological change values of 0.15 and 0.60), whereas a shift from Category 4 to 5 (values 0.60 to 1.0) will result in a 67-percent increase in costs.

The effect of varying the predicted drawdown values is shown graphically in Figure 8 and numerically in Table 11. The data for Orange County are presented as an example of the sensitivity analysis. The same trend is expected in all counties, except for St. Johns because of its extremely small data set. The plot in Figure 8 shows that the

Table 10. Results of Sensitivity Analysis on Estimated Total Mitigation Cost by Varying the Value of Predicted Drawdown by County

	Estimated Mitigation Cost ($)				
County	**Base Minus 20%**	**Base Minus 10%**	**Base Value**	**Base Plus 10%**	**Base Plus 20%**
Brevard	73,606,950	93,634,977	104,079,166	116,171,090	124,932,684
Flagler	245,790,537	316,913,507	383,080,755	413,807,881	445,235,616
Lake	1,084,404,618	1,268,857,430	1,354,100,923	1,567,252,777	1,703,191,271
Orange	727,623,606	909,408,997	1,059,560,796	1,139,866,073	1,270,221,615
Seminole	877,004,823	981,696,876	1,118,969,750	1,212,927,923	1,272,628,898
St. Johns	16,182	16,182	16,182	16,182	16,182
Volusia	1,521,252,683	1,912,908,254	2,336,290,008	2,721,199,530	2,968,865,472
Total	4,529,699,399	5,483,436,222	6,356,097,580	7,171,241,456	7,785,091,739
Cost Ratio (Value/Base)	**0.71**	**0.86**	**1.0**	**1.13**	**1.22**

Table 11. Results of Sensitivity Analysis on Estimated Mitigation Cost per Drawdown Interval by Varying the Predicted Drawdown Value in Orange County

Drawdown Interval (ft)	Estimated Mitigation Cost ($)				
	Base Minus 20%	Base Minus 10%	Base Value	Base Plus 10%	Base Plus 20%
0.0 - 0.25	23,629,843	38,243,666	38,593,124	38,608,574	39,641,340
0.0 - 0.5	85,773,307	96,936,756	182,346,968	198,188,658	199,681,503
0.0 - 1.0	348,601,895	304,541,849	397,301,763	467,924,052	353,866,053
0.0 - 1.5	602,390,419	692,806,544	842,282,246	702,229,360	832,584,902
0.0 - 2.0	727,623,606	909,408,997	1,002,239,521	1,014,632,885	1,053,619,162
> 2.0	727,623,606	909,408,997	1,059,560,796	1,139,866,073	1,270,221,615
Cost Ratio (Value/Base)	**0.70**	**0.86**	**1.0**	**1.08**	**1.20**

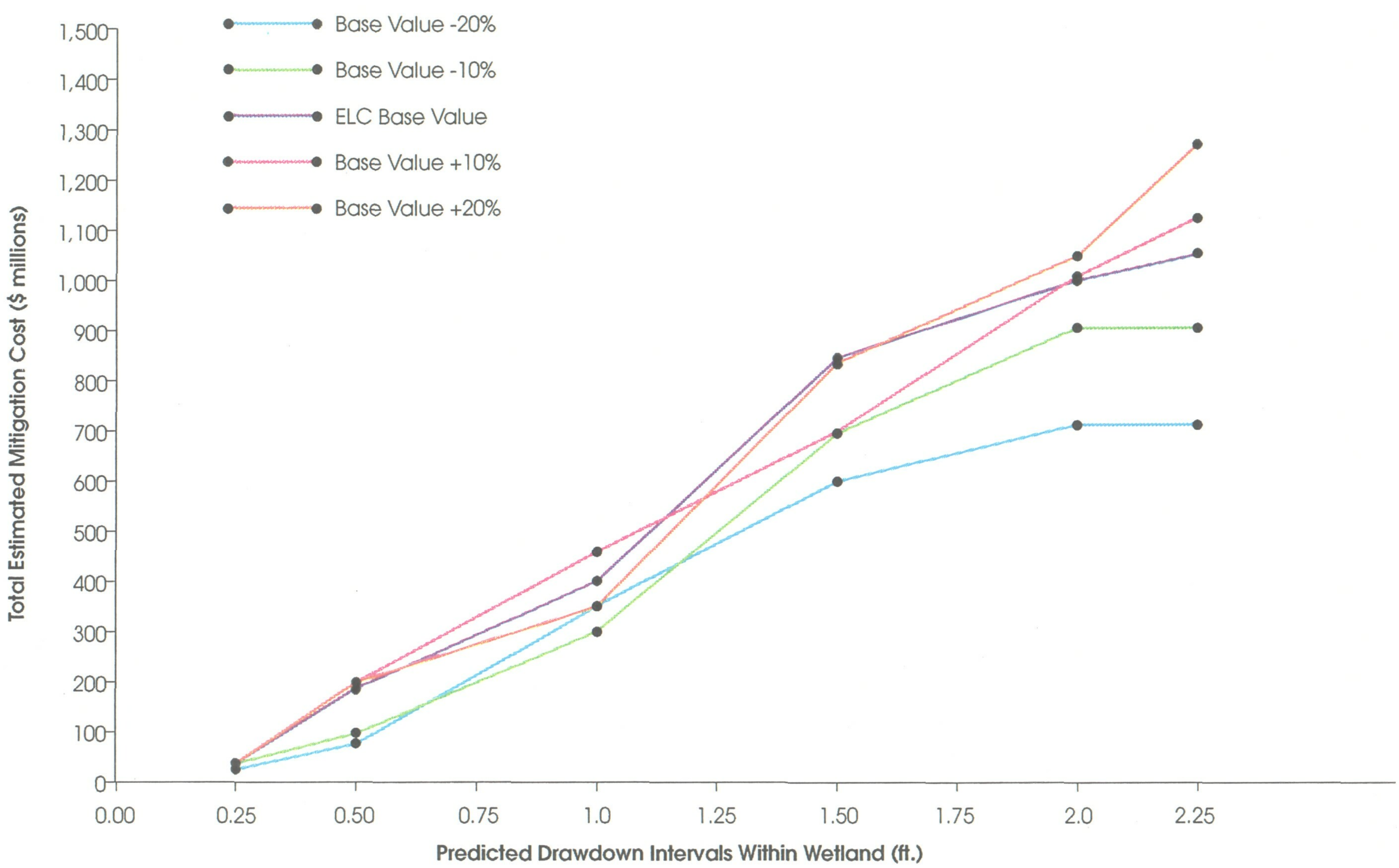

Figure 8. Sensitivity Analysis for Estimated Mitigation Cost by Varying the Predicted Drawdown Values in Orange County.

increases and decreases in predicted drawdown cumulatively follow the same trend as the base value associated costs. The analysis shows that for a given drawdown interval, costs shift between intervals as the distribution of drawdowns is incrementally changed. The total costs, however, follow a nearly linear response to the incremental change in drawdown.

SUMMARY DISCUSSION OF PLANNING-LEVEL APPLICATION OF METHODOLOGY

This initial application of the impact assessment and mitigation costing methodology was a planning-level exercise. This section of the TM summarizes the value of the methodology in meeting SJRWMD's future water supply planning and water use permitting needs. Specifically, the summary addresses the following three issues:

- Soundness of the methodology, as demonstrated by the results obtained
- Value of the methodology to SJRWMD's ongoing water supply planning process
- Value to SJRWMD's water use permitting program

Soundness of Methodology

Based on this application, the methodology can be a sound planning and evaluation tool. The user and those interpreting the results must, however, do the following:

- Understand how the methodology "works."
- Define the purpose and scope of the application.
- Match the scales of inputs, expected outputs, and other expectations in the application.
- Clearly define how the results will be used.
- Clearly define how the inputs and outputs will be checked, verified, and refined.
- Establish whether the application is done as an interactive process.

Based on this initial application, the methodology provides a planning-level evaluation of the extent and degree of impacts to wetland communities and estimates costs for likely mitigation actions. The results also provide useful input to SJRWMD's regional water supply planning process. Because the input data are based on regional ground water models and large-scale GIS coverages, they will not reflect small-scale phenomena. For example, during our site visit to the Tillman Ridge Wellfield in St Johns County, SJRWMD staff discussed the potential role that breaches in the confining layers contributed to the observed wetland system impacts on the wellfield. If this is indeed the case and the anomaly is not accounted for in the drawdown analysis, then there will likely be a discrepancy between the input data and actual phenomenon. Thus, anomalies should be expected and their causes should be investigated.

The methodology is rather straightforward in operation. The results of a given application are the product of the input file. While the concerns of SJRWMD staff are important, they should be focused on the input file of predicted drawdowns. Estimates of acreage of impact are largely driven by the drawdown estimates and GIS overlay analysis. Likewise, predicted costs are driven by the derived nature and extent of the predicted impact.

Value to SJRWMD's Water Supply Planning Process

The value of the methodology to the water supply planing process is as a screening and estimating tool that provides two general kinds of information: (1) a means to generate estimates of extent of impact and potential cost of mitigation actions and (2) a means to compare alternatives. The types of applications within the planning process include the following:

1. Develop regional projections of extent of impact and cost of mitigation actions.
2. Categorize projected regional effects by severity.
3. Project effects of a single ground water withdrawal alternative.
4. Evaluate relative differences between water supply alternatives that differ in their degree of effect on the shallow water table.
5. Tie to the decision model and use impact or cost as constraints.
6. Define a starting point for defining significant harm, which can be subject to revision.
7. Evaluate the effect of varying the definition of harm.

8. Use the starting element of adaptive management program; refine the methodology and its application through time.

The accuracy of the estimates of extent and degree of impact and, therefore, also cost, is driven in large part by the accuracy of the input data. For planning-level applications, this accuracy will probably be less than for a more site-specific application in which a more detailed aquifer response can be modeled and for which site-specific monitoring data are available. If scaling is correct, then the method should provide useful planning-level estimates of the extent of ecological harm and the cost of mitigation for environmental resource permit-type actions. If multiple water supply options are available for a given planning area, then the impact to wetland and aquatic systems under each option can be compared.

Value to SJRWMD's Regulatory Process

Use of this planning-level methodology as a regulatory tool will require using detailed input files reflecting conditions at a specific location, such as the localized conditions of a wellfield. Some guidelines for developing a regulatory application are as follows:

1. Verification of goals and inputs is an important part of applying the methodology.
2. Application should be refined to account for site-specific conditions, including known anomalies.
3. The methodology can be used to prioritize efforts or the focus of further investigations.
4. Delays between the onset of a significant change to the hydrological regime and an ecological reflection of the change must be considered.
5. Definition of harm is a key element of the application: changing the definition will likely change the results, but to what degree has not been determined.
6. Input files are the key driver of results. Input files generated from regional and aggregated data should not be expected to accurately predict localized effects.
7. Methodology development will be an ongoing, iterative process; therefore, a "learn as you go," adaptive management approach is needed. The methodology and its use can be refined to meet the specific needs of SJRWMD's staff.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Impacts to wetlands and other natural systems are one of several potential consequences of the water supply alternatives being evaluated by SJRWMD. This TM provides planning-level estimates of the extent of potential impact to wetland and aquatic communities and the cost of mitigating impacts resulting from projected 2010 surficial aquifer drawdowns.

The following conclusions can be drawn from the evaluation described in this TM:

1. **Impact Area Unweighted.** The total unweighted estimate of the wetland area affected is 693,000 acres, or 1,083 square miles. This area is roughly equivalent to the total land surface area of Volusia County (1,115 square miles). The between-county range for the unweighted wetland impact area covers five orders of magnitude, ranging from 5 acres (St. Johns County) to 220,000 acres (Volusia County).

2. **Impact Area Weighted**. Applying the ELC results in a weighted impact area of 108,425 acres. The between-county range for the weighted impact area is 0.3 acres (St. Johns County) and 39,000 acres (Volusia County).

3. **Impact Area by Wetland Type.** Of the eight habitat types that will be affected (hardwood swamp, cypress swamp, marsh, wet prairie, shrub swamp, shallow cypress swamp, aquatic slough, and gum swamp), forested wetland impacts account for 74 percent of the total acreage impacted for all counties combined. Scrub/shrub wetlands account for 6 percent of the total weighted area, with herbaceous wetlands comprising the remaining 20 percent.

4. **Impact Area by Extent of Drawdown.** From an analysis of the frequency of distribution of area impacted by drawdown, of the total weighted area of 108,425 acres:

   - Six percent can be attributed to projected drawdowns of less than 0.25 feet.

   - Twenty-one percent can be attributed to drawdowns of 0.5 feet or less.

- The 1-foot drawdown is approximately the middle of the distribution, with half the affected area having lesser drawdown values and half having greater values.
- Predicted drawdowns of more than 1.5 feet and 2.0 feet are responsible for approximately 20 percent and 10 percent, respectively, of the total weighted area.

5. **Planning-Level Cost Estimate by County.** The total mitigation cost for the project area (all counties combined) is $6.36 billion. Like the projections for area, mitigation cost by individual county varies over five orders of magnitude, from $16,000 for St. Johns County to $2.4 billion for Volusia County. Approximately 92 percent of the total estimated cost is attributable to Lake, Orange, Seminole, and Volusia counties.

6. **Planning-Level Cost Estimate by Wetland Type.** Forested wetland impacts account for 76 percent of the total estimated mitigation cost. Scrub/shrub wetlands account for 6 percent of the total weighted area, with herbaceous wetlands comprising the remaining 18 percent.

7. **Planning-Level Cost Estimate by Drawdown.** Of the total estimated mitigation cost for 2010 conditions of $6.36 billion:
   - Six percent is attributed to projected drawdowns of less than 0.25 feet.
   - Twenty-one percent is covered by drawdowns of 0.5 feet or less.
   - The 1-foot drawdown is approximately the middle of the distribution, with half the affected cost attributable to lesser drawdown values and half attributable to greater values.
   - Predicted drawdowns of more than 1.5 feet and 2.0 feet are responsible for approximately 20 percent and 10 percent, respectively, of the total cost.

8. **Effect of Varying Predicted Drawdown on Estimated Mitigation Costs.** The cost estimates are sensitive to the accuracy of the drawdown estimate. Based on the analysis conducted using data for Orange County, the estimated mitigation costs show a nearly linear response to changes in the predicted drawdown. A relatively small change in drawdown may or may not result in a

change in costs, depending on where within the ecological change category the adjusted and varied hydrologic regime are located.

9. On the regional scale used in this application, the estimate of water table drawdown within individual wetlands has a moderate-to-high level of uncertainty. The level of uncertainty is acceptable for a planning-level estimate. The sensitivity analysis shows that even discounting predicted drawdowns of less than 0.5 feet removes only 20 percent of the projected impact area.

10. The uncertainty of the regional drawdown estimates limits the use of the present application for evaluating site-specific conditions, such as those required for individual permitting.

11. This application of the methodology clearly demonstrates that pursuit of a "pump now and mitigate later" approach to water supply development would result in unacceptable impacts to wetland and aquatic systems. Likewise, the projected costs of mitigating the impacts would be prohibitive. Thus, post-impact mitigation is unlikely to provide a regional solution to large-scale wetland and aquatic system impacts.

12. The projected impacts and associated mitigation cost for a "pump and mitigate" strategy clearly indicate that impact avoidance is the more prudent, cost-effective, and socially acceptable water supply development strategy.

13. Impact mitigation is likely to be most applicable when addressing small-scale, site-specific impacts, such as those that may be found on an individual wellfield.

14. The value of the methodology is as a screening and estimating tool that provides two general kinds of information: (1) a means of generating estimates of the extent of impact and potential cost of mitigation actions and (2) a means of comparing alternatives.

15. This application shows that the methodology can be a sound planning and evaluation tool at a regional level.

16. Use of the methodology as a tool in the regulatory process will require the use of more detailed input files that reflect conditions at specific locations, such as the localized conditions of a certain wellfield.

17. Testing with site-specific data will provide a means of evaluating the value of the methodology for assessing localized effects.

RECOMMENDATIONS

On the basis of the information in this TM, the following recommendations are presented for SJRWMD's consideration:

- SJRWMD should refine the method for estimating water table drawdowns to improve the accuracy of the impact estimates.
- The current methodology, which relies on regional drawdown estimates, should not be used as a tool for regulatory decision-making. Refinement and testing using site-specific, detailed, input files is necessary to evaluate the use of the method for regulatory reviews.
- In comparison to the pump and mitigate strategy, impact avoidance strategies are likely to be more cost-effective. For ongoing work in the alternative water supply strategies investigations, SJRWMD should develop a future water supply plan that significantly reduces the nature and extent of the 2010 projected impacts to natural systems by developing alternative sources and the use of impact avoidance.
- Application of the methodology using site-specific data from a wellfield should be done to test the accuracy of impact assessment.

  For future applications of the impact assessment and mitigation costing methodology, the spreadsheet functions should be converted to data base format. The use of the spreadsheet for regional analysis was difficult and inefficient because of the large number of records.

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Appendix A

SJRWMD Summary of Input File Development

TASK E.1
MITIGATION OF IMPACTS

WATER TABLE DRAWDOWN ESTIMATES FOR WETLANDS IN THE WATER RESOURCE CAUTION AREAS

BY

MARC C. MINNO, PALMER KINSER, PATRICK BURGER,
FRANK DERBY, AND CHRIS OMAN

St. Johns River Water Management District
Palatka, Florida

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FIGURES

INTRODUCTION

In Technical Memorandum E.1.f (Wetlands Impact, Mitigation, and Planning-Level Cost Estimating Procedure), CH2M HILL proposed a procedure to estimate the cost of impacts to wetlands from ground water withdrawal. The procedure consisted of the following steps:

1. Define baseline hydrological and ecological conditions.
2. Obtain estimate of water table drawdown.
3. Estimate effect of water table drawdown on the wetland's hydrological regime.
4. Estimate effect of hydrologic changes on dominant plant and animal species.
5. Determine degree of ecological change.
6. Calculate acreage of impact.
7. Calculate final mitigation requirement.
8. Calculate planning-level mitigation costs.

This procedure was applied by CH2M HILL to the Water Resource Caution Areas of the District in order to develop a planning-level estimate of the total cost of mitigating unacceptable effects on native vegetation (Technical Memorandum E.1.h). For this analysis, St. Johns River WMD provided data on baseline hydrological conditions, estimated water table drawdown, and acreage of impact. The procedures used by District staff to estimate acreage of impact follow.

METHODS

Frank Derby and Patrick Burger of SJRWMD conducted a GIS analysis to estimate the acreage of wetlands subject to impact from ground water withdrawal. Three GIS data layers were used: wetlands, estimated drawdown, and soils. Each is described below.

DATA LAYERS

Wetlands

The wetlands layer was derived from the District's 1990 landuse/cover layer. Features were classified according to the "Florida Land Use, Cover, and Forms Classification System," (Florida Department of Transportation 1985). To create the needed wetlands layer, all water (5000 series) and wetlands (6000 series) features were extracted and processed to create a new GIS coverage containing only these features (Figure A-1).

Drawdown

A projected drawdown layer was created from regional models of ground water use and resulting water table declines. Declines were estimated to the nearest quarter-foot. Drawdown for some areas lying between adjacent regional models was interpolated and irregular or angular contours were smoothed (Figure A-2).

Soils

To create a soils layer, the detailed soils layer (SURGO) was clipped to boundaries of the wetlands boundaries and then classified by the least permeable layer. Three permeability classes were used: low (less than 0.6 inches per hour), moderate (0.6 to 6.0 iph), and high (greater than 6.0 iph) (Figure A-3). Since soil layers with low permeability may reduce the susceptibility of wetlands to ground water withdrawal, this GIS layer was created to allow soil permeability to be used as a modifier in the spreadsheet mitigation costing model developed by CH2M HILL.

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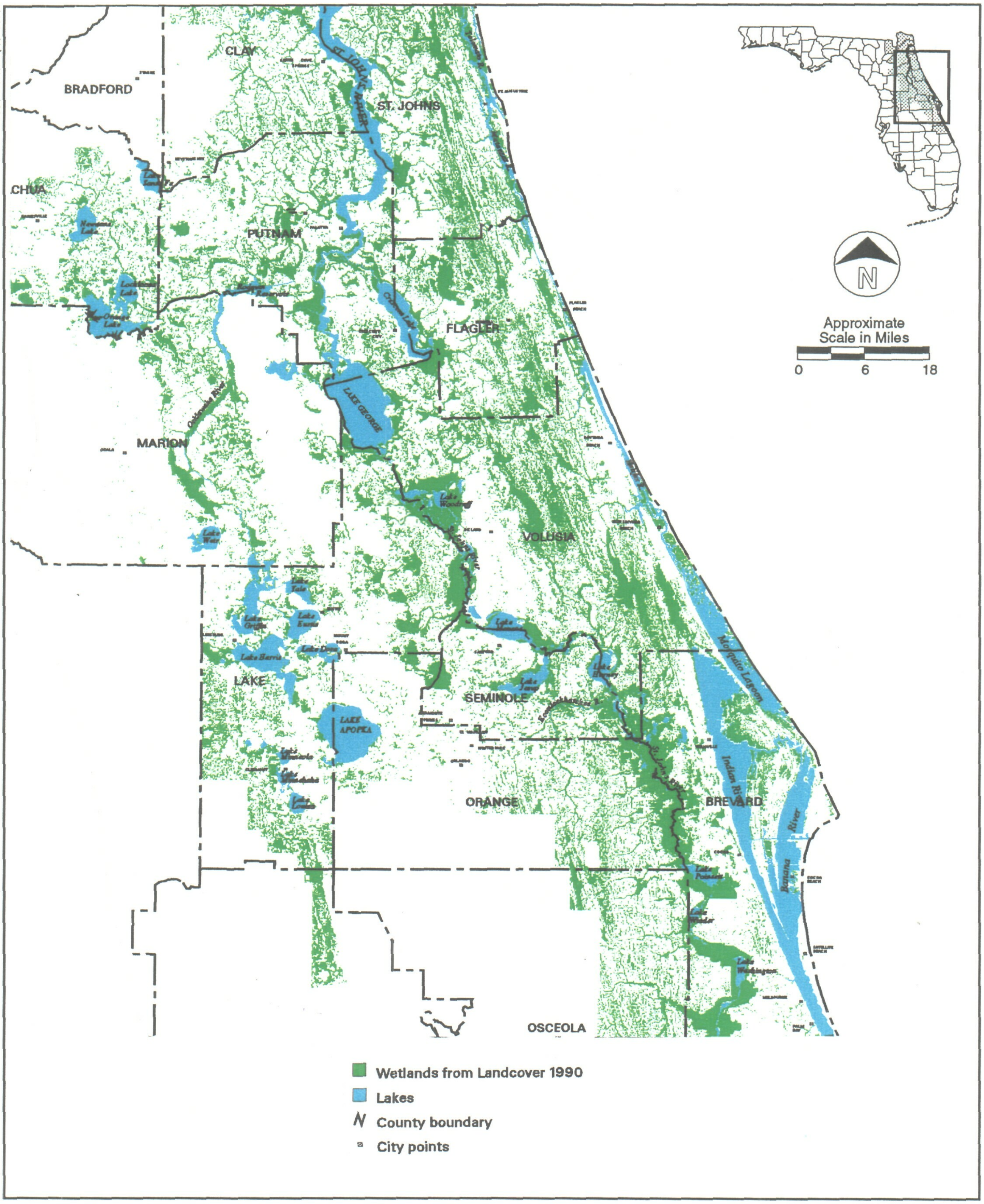

Figure A-1. Wetlands in the St. Johns River Water Management District.

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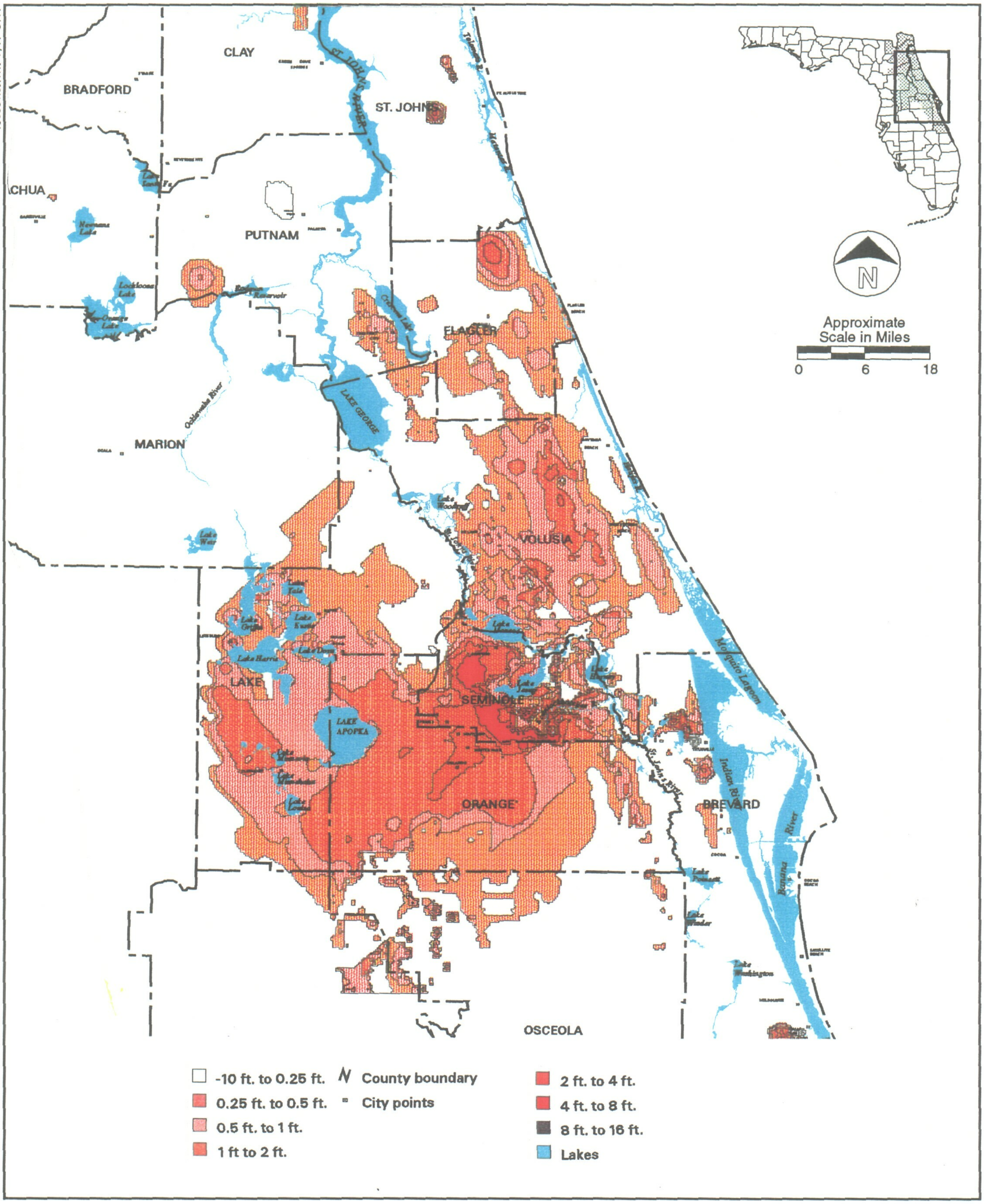

Figure A-2. Drawdown in the St. Johns River Water Management District.

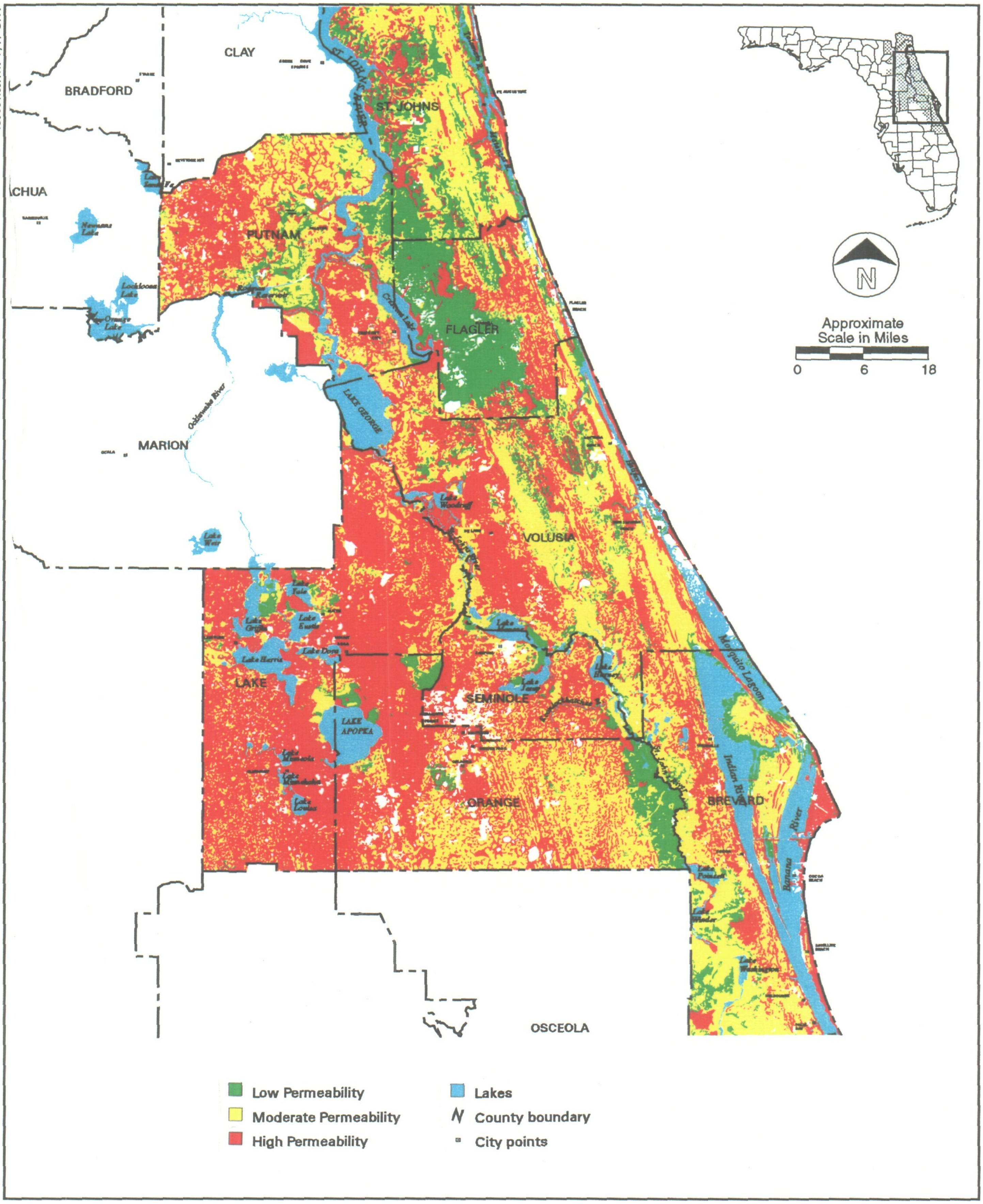

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Figure A-3. Soils in the St. Johns River Water Management District.

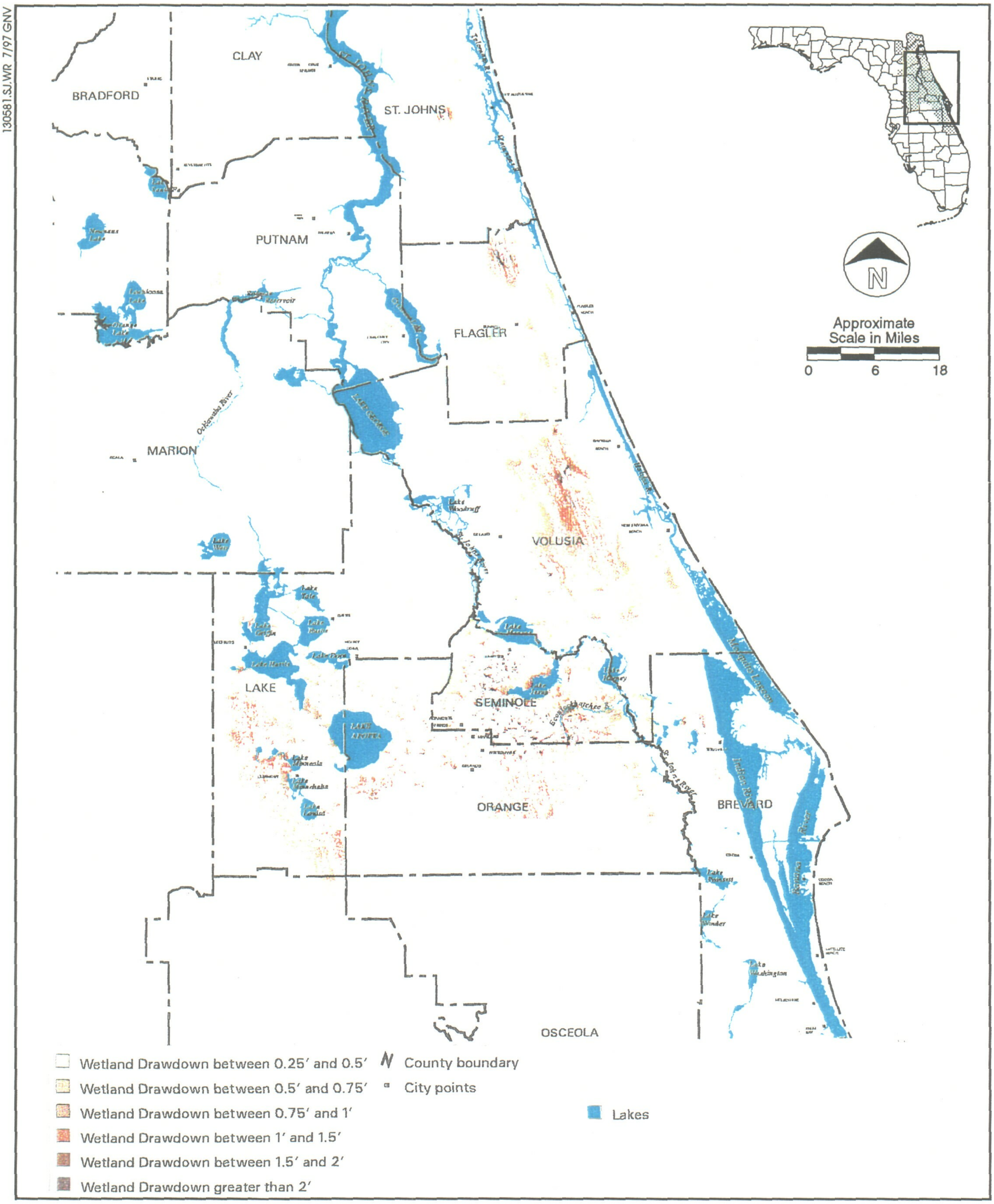

Figure A-4. Wetland Drawdown in the St. Johns River Water Management District.