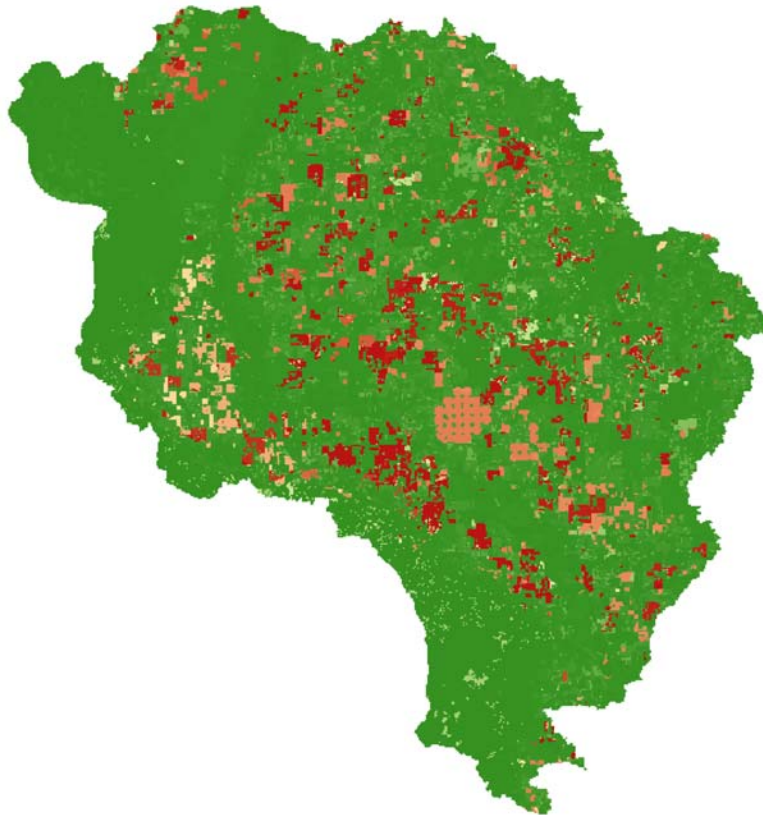


Final Report for Project Entitled
Computer Modeling Services
for the Suwannee River Watershed
FDACS #7148



Submitted by
Soil and Water Engineering Technology, Inc.
In association with
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Table of Contents

Table of Contents.....	ii
List of Figures.....	iii
List of Tables	iv
Introduction.....	1
Methods.....	4
Pre-BMP Land Uses	4
Urban, Commercial, Industrial, and Residential.....	4
Mining Operations	4
Row Crops	5
Dairies and Poultry	7
Post-BMP Land Uses.....	10
Improved Pasture BMP.....	10
Poultry BMP	10
Row Crops BMP	10
Dairies BMP.....	10
WAM Simulation.....	11
Results.....	12
Conclusions.....	14
References.....	14
Appendix A. GIS Grid Coverages of Nitrogen Loads.....	16
Appendix B. Pre-BMP Nitrogen Loads by Land Use.....	21
Appendix C. Post-BMP Nitrogen Loads by Land Use.....	29

List of Figures

Figure 1. Middle Suwannee River Basin Locator Map	2
Figure 2. Land Uses	3
Figure 3. Attenuated Groundwater Nitrogen	16
Figure 4. Unattenuated Sediment Nitrogen	17
Figure 5. Attenuated Sediment Nitrogen	18
Figure 6. Unattenuated Soluble Nitrogen	19
Figure 7. Attenuated Soluble Nitrogen	20

List of Tables

Table 1. Crop Statistics within the SRWMD for 1992 ¹	6
Table 2. IFAS Fertilizer Recommendations for Selected Crops in the SRWMD ¹	6
Table 3. Simulated Ground Water Nitrogen for Selected Row Crops in the SRWMD.....	8
Table 4. Summary of Pre-BMP Land Use Parameters	9
Table 5. Total Nitrogen Reduction Due to First Scenario BMPs by Land Use.....	13
Table 6. Total Nitrogen Reduction Due to Second Scenario BMPs by Land Use	13
Table 14. Pre-BMP Groundwater Nitrogen Load by Land Use	21
Table 15. Pre-BMP Sediment Nitrogen Load by Land Use	22
Table 16. Pre-BMP Soluble Nitrogen Load by Land Use	23
Table 17. Pre-BMP Total Nitrogen Load by Land Use	24
Table 18. Pre-BMP Groundwater Nitrogen Load per Hectare by Land Use.....	25
Table 19. Pre-BMP Sediment Nitrogen Load per Hectare by Land Use.....	26
Table 20. Pre-BMP Soluble Nitrogen Load per Hectare by Land Use.....	27
Table 21. Pre-BMP Total Nitrogen Load per Hectare by Land Use	28
Table 6. Groundwater Nitrogen Reduction Due to First Scenario BMPs by Land Use	29
Table 7. Groundwater Nitrogen Reduction Due to Second Scenario BMPs by Land Use.....	29
Table 8. Sediment Nitrogen Reduction Due to First Scenario BMPs by Land Use	30
Table 9. Sediment Nitrogen Reduction Due to Second Scenario BMPs by Land Use.....	30
Table 10. Soluble Nitrogen Reduction Due to First Scenario BMPs by Land Use	31
Table 11. Soluble Nitrogen Reduction Due to Second Scenario BMPs by Land Use.....	31
Table 22. Groundwater Nitrogen Reduction Due to First Scenario BMPs per Hectare by Land Use	32
Table 23. Groundwater Nitrogen Reduction Due to Second Scenario BMPs per Hectare by Land Use	32
Table 24. Sediment Nitrogen Reduction Due to First Scenario BMPs per Hectare by Land Use	33
Table 25. Sediment Nitrogen Reduction Due to Second Scenario BMPs per Hectare by Land Use	33
Table 26. Soluble Nitrogen Reduction Due to First Scenario BMPs per Hectare by Land Use ..	34
Table 27. Soluble Nitrogen Reduction Due to Second Scenario BMPs per Hectare by Land Use	34
Table 28. Total Nitrogen Reduction Due to First Scenario BMPs per Hectare by Land Use	35
Table 29. Total Nitrogen Reduction Due to Second Scenario BMPs per Hectare by Land Use..	35

Introduction

Issues have been raised over the impacts of land uses and management practices on water quality in the Suwannee River Management District (SWRMD). Nitrogen has been the nutrient of most concern. Best Management Practices (BMPs) have been created and evaluated to help reduce the nutrient loads from key land uses in the District.

In 1997, the SWRMD contracted with Soil and Water Engineering Technology, Inc., (SWET) to develop a Watershed Assessment Model (WAM) as a tool for assessing the current nutrient loadings and the impacts of various BMPs on these loadings. The project was completed in January 1998 with the delivery of WAM to the District and the development of the “GIS Watershed Assessment Final Report” (SWET, 1998).

Nitrogen continues to be of concern in the District. In order to address these concerns, a partnership with the agricultural community was developed with the Florida Department of Agriculture (FDACS), the SRWMD, the USDA-Natural Resources Conservation Service (NRCS), the Florida Department of Environmental Protection (FDEP), the Soil and Water Conservation Districts and other partners within the watershed. This partnership has concluded that the creation and implementation of BMPs is the best approach to control nitrogen levels in the District’s ground and surface water.

Also, FDEP will be re-evaluating Florida water bodies on the Environmental Protection Agency (EPA) 303(d) list this year. Water bodies on this list are required to have Total Maximum Daily Loads (TMDLs) developed for them. If FDEP has “reasonable assurance” that a water body will meet its designated use through the implementation of alternative pollution control programs, FDEP will not be required to include that water body on their submitted 303(d) list.

Both the partnership, in general, and FDEP, in particular, have a strong interest in determining the potential impacts of BMPs. In order to address this issue, FDACS has contracted with SWET to use WAM to evaluate the impacts of key agricultural BMPs to be implemented in the basin by 2008 in the Middle Suwannee River Basin (see Figure 1 for location).

Many land uses are represented in the Middle Suwannee River Basin (see Figure 2); however, much of the basin is in agricultural land. The following four key agricultural land uses were chosen by FDACS for these analyses due to these land uses making up a majority of the agriculture land uses in the District:

- Improved pastures (44,346 ha)
- Poultry (18,157 ha)
- Row crops (12,102 ha)
- Dairies (4,953 ha)

For poultry and dairies, these areas represent their area of influence, that is, the land over which the manure is being applied. For example, 12.2 ha of spreading area are associated per 100 m of poultry barn.

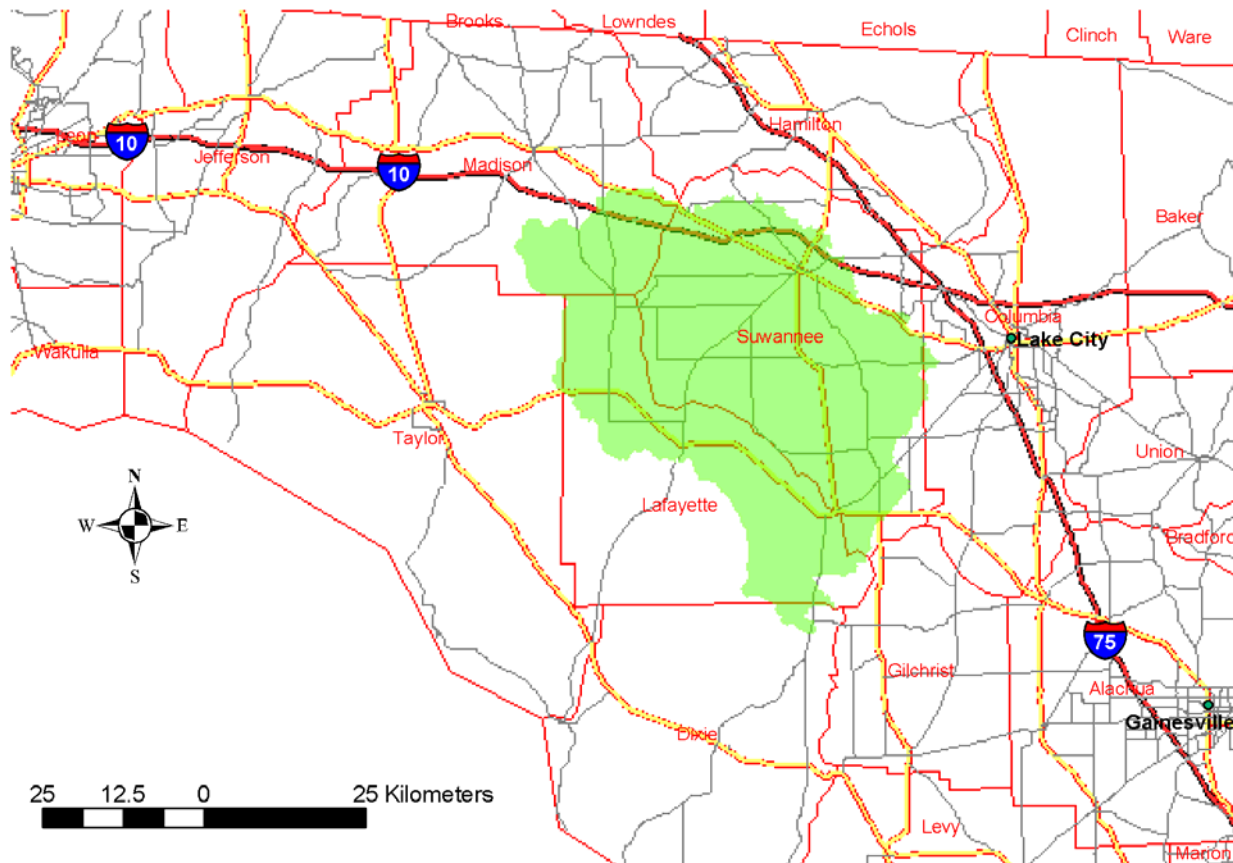


Figure 1. Middle Suwannee River Basin Locator Map

By 2008, the Suwannee River Partnership expects that 80% of these land uses in the Middle Suwannee River Basin will be using the prescribed BMPs. These BMPs include fertilization and animal density reductions for improved pasture, poultry, and dairies and a fertilization reduction for row crops. A second BMP for poultry is the removal of the litter from the basin. A second BMP for dairies includes the fertilization and animal density reductions plus the lining of dairy waste lagoons. All of these BMPs were developed based on input from local extension agents and members of the Suwannee River Partnership. These BMPs will need to be adjusted over time to reflect actual implementation rates and practices.

WAM was selected for use in this study because of its ability to evaluate the impacts of management practices and changes in management practices on nutrient loads for a basin. WAM is a “process-based” model. This means that the underlying models are based on current understanding of the physical processes that control water and nutrient loads. Being process-based is key to WAM’s ability to determine the impacts of BMP implementations.

Landuse

- Animal Race Tracks
- Aquaculture
- Barren Land
- Bay Swamps
- Blueberries
- Commercial and Services
- Coniferous Plantations
- Cypress
- Dairies
- Freshwater Marshes
- Hardwood Conifer Mixed
- Hardwoods
- High Density Residential
- Horse Farms
- Improved Pasture
- Industrial
- Kennels
- Low Density Residential
- Managed Landscape
- Medium Density Residential
- Mining
- Mixed Wetland Hardwoods
- Multiple Dwelling Units
- Open Water
- Ornamental Nurseries
- Peach and Pecan Orchards
- Phosphate Mines
- Poultry Feeding Operations
- Prisons
- Ranchettes
- Row Crops
- Rural Land in Transition
- Scrub and Brushland
- Sewage Treatment
- Solid Waste Disposal
- Transportation Corridors
- Tree Nurseries
- Undeveloped Urban Land
- Wetland Forested Mixed
- Woodland Pasture

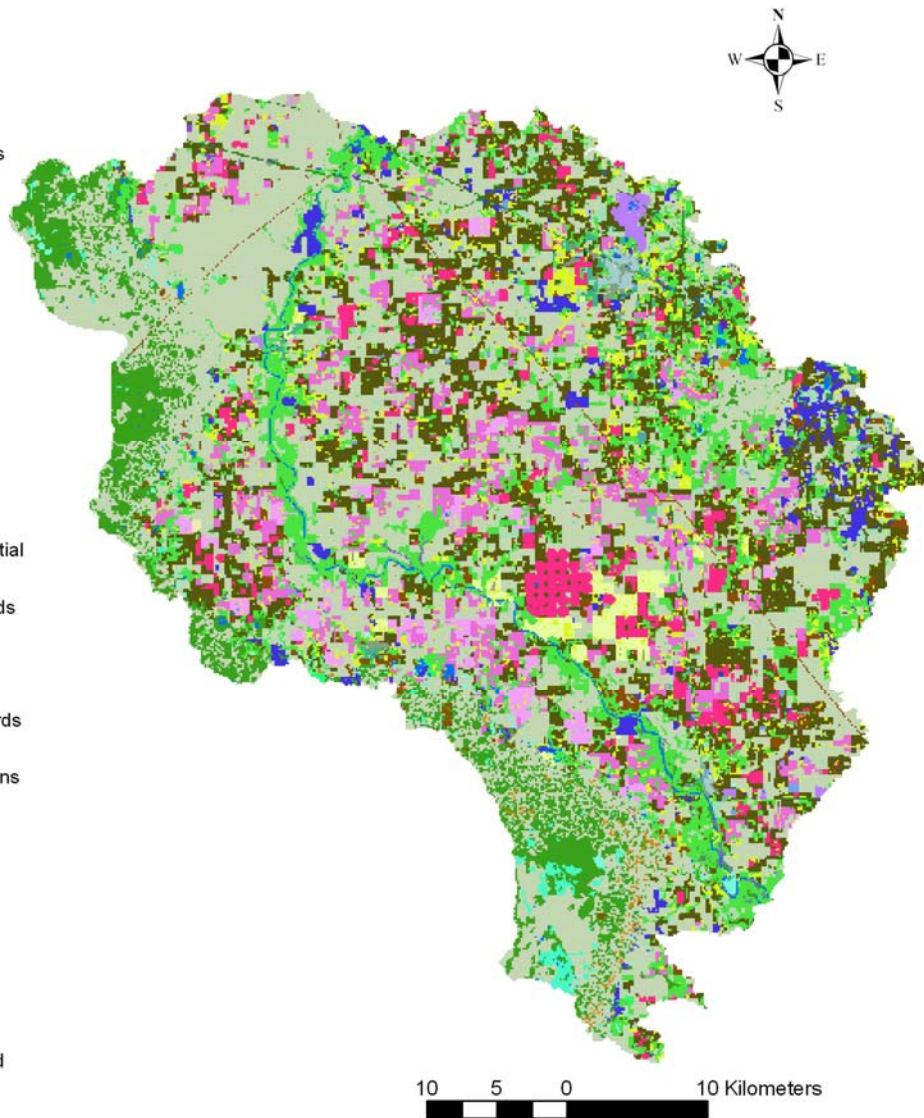


Figure 2. Land Uses

The purpose of this report is to present the WAM simulations for the pre-BMP and post-BMP nitrogen loads leaving the Middle Suwannee River Basin. The data were analyzed to show the potential percent nitrogen load reductions that can be achieved through BMPs. Two sets of post-BMP scenarios are presented. The first set includes the following BMPs:

- Improved pasture – reduced fertilization and animal density
- Row crop – reduced fertilization
- Dairy – reduced fertilization and animal density
- Poultry – reduced fertilization and animal density

The second set includes the following BMPs:

- Improved pasture – reduced fertilization and animal density
- Row crop – reduced fertilization
- Dairy – reduced fertilization and animal density plus lining of lagoons
- Poultry – litter removal

Methods

WAM was set up and run for the pre-BMP and both post-BMP scenarios. A detailed description of the assumptions and methods used for simulating basins in the Suwannee River Management District is given in the “Technical Reference Manual” section of the final report from the 1998 project (SWET, 1998).

Pre-BMP Land Uses

Urban, Commercial, Industrial, and Residential

These land uses are characterized by the following parameters: assumed fraction of impervious surface, assumed water quality concentrations for impervious surface runoff, a human density on a specific waste treatment system, a grass cover on the pervious areas, and the existence of a retention pond. The water quality concentrations for the impervious surfaces were derived from values provided by Harper (1992). The retention ponds are not used under existing conditions but are employed as a first-level BMP. The GLEAMS model produces runoff from the pervious areas then it is combined with the impervious surface runoff before being routed through a retention pond (if it exists).

Mining Operations

Mining operations are handled using four land use groups: Mining, Phosphate Mining, Phosphate Processing, and Industrial. The first two categories are for open mining operations while the third is specific to phosphate processing plants. Phosphate Mining and Phosphate Processing were considered separately from the general Mining category because of the higher expected phosphorus discharge. Other mining processing plants are set to the Industrial category because permit data from these operations show no high levels of nutrient loads.

Mining and Phosphate Mining are simulated using a special case land use. The values for these special cases are specified in the *luspec.bnz* file. This approach was adopted because discharge

from these mining sites cannot be appropriately simulated using GLEAMS. Discharge from mining sites is highly controlled because of their de-watering, recycling, and water storage pond systems. SWET met with PCS Phosphate in White Springs to obtain the best available discharge data for phosphate mining. PCS had excellent records and were able to provide 1995 estimates of annual average TSS, P, and flow from the opening mining areas. In order to match P discharge levels, the discharge data had to be corrected for the differences in area between actual data and the District's GIS land use data.

Phosphate Processing plants are handled by GLEAMS by setting the area in the *landuse.bnz* file to an impervious surface plus a point source discharge of P. Although there is some water and P load from the impervious surface, the point source load dominates. Data were obtained from the processing facility of PCS Phosphate in White Springs. Constituent and flow characteristics of the phosphate processing point source discharge are set in the *default.bnz* file as a new waste type (52). Predicted discharges matched the observed data.

Row Crops

The Row Crop land use category is extremely general and can represent many different crops including corn, watermelons, cotton, vegetables, soybeans, tobacco, etc. A review of the last agricultural census (USDCBC, 1992) for Florida showed that corn was the most common row crop (47%) for the District; therefore, it was chosen to represent the row crop land use category. Vegetable crops (including watermelons) were 43% of the row crops (see Table 1).

A comparison of ground water nitrogen under various row crops was simulated. The simulations assumed a single crop, a fallow off-season, and used the IFAS recommended fertilizer rates (see Table 2) as a guide. This table also includes recommended rates for pasture for comparison.

For the simulations, the phosphorus fertilizer rate was set at the medium level. The nitrogen levels were set at 25% higher than the recommended rates except for corn, which was set at the highest value in the recommended range. The values were set high to represent the high value of these crops and to account for uneven application of fertilizer. Even spreading of fertilizer will reduce nutrient losses from a field.

Table 3 presents the average annual ground water loads under these scenarios. The values for soybean and peanut appear to be unrealistically high and might represent a problem in the N-fixation algorithm in GLEAMS. As seen in the table, field corn appears to have average ground water nitrogen loads among the other row crops. It is difficult to estimate what constitutes a typical row crop situation because some of these crops are double cropped or followed by different cover crops; however, single-season corn does seem to be a reasonable choice.

One could calculate the average row-crop fertilization rates from the crop areas in Table 1 and the IFAS recommended fertilization rates in Table 2. This exercise would not be appropriate for estimating the input value of fertilizer for row crops unless we could simulate an "average" crop using GLEAMS. The fertilizer applied must be matched to the crop type and its uptake rate. Otherwise, the simulation could be meaningless. A better choice is to use the most common crop with an appropriate fertilization rate for that crop.

Table 1. Crop Statistics within the SRWMD for 1992¹

County	Harvested (ac)	Corn (ac)	Wheat (ac)	Soybeans (ac)	Hay & Grass (ac)	Vegetables (ac)
Alachua	29566	3514	0	N/A	10819	7058
Bradford	4447	541	0	0	2745	817
Columbia	14402	3021	0	689	5535	2203
Dixie	1805	180	0	0	686	936
Gilchrist	19366	1135	N/A	0	5510	4130
Hamilton	11805	6335	N/A	294	2068	919
Lafayette	7917	438	0	0	3900	1547
Levy	24494	872	N/A	0	10420	2814
Madison	25666	6513	N/A	4734	7078	1152
Suwannee	40934	5920	194	860	16722	4139
Taylor	1237	76	0	0	794	251
Union	3626	531	0	0	1446	630
Basin Total	185265	29076	194	6577	67723	26596
Harvested (%)		15.7	0.1	3.6	36.6	14.4
Row Crops (%)		47	-	10	-	43

¹ after Census of Agriculture (1992)

Table 2. IFAS Fertilizer Recommendations for Selected Crops in the SRWMD¹

Crop	Recommended N (kg/ha/yr) ²	Recommended P as P ₂ O ₅ (kg/ha/cropping Season) ²				
		VL < 10	L 10 – 15	M 16 - 30	H 31 - 60	VH > 60
Soil Phosphorus (ppm soil)						
Hay & Grass	56 – 179	0 - 45	0 – 45	0	0	0
Tobacco	90	112	90	67	0	0
Peanut	0	112	90	45	0	0
Soybean	0	67	45	22	0	0
Cotton	67	134	101	67	0	0
Corn	134 – 269	112 – 224	90 – 179	45 - 90	0	0
Vegetables						
Watermelon	134	179	179	112	0	0
Snap Bean	101	134	134	90	0	0
Pepper	179	179	146	112	0	0

¹ Kidder et al. (1989, 1990)

Dairies and Poultry

Within the District land use coverage, dairies and poultry represent only the barn and milking areas, therefore, only a fraction of the true land area for these land uses is manifested. The GIS land use coverage does, however, contain information on the number of dairy cows and poultry barn lengths. WAM uses the cow numbers and barn lengths to estimate an appropriate land area for the dairies and poultry operations. The land area estimation, or expansion, is controlled so that only existing agricultural land uses are converted and no two dairies share the same land. The amount of land converted and the characteristics of these land uses are described below.

Dairies – For dairies, the number of cows/acre is based on an FDEP survey (Bardolph, 1991) of 81 dairies in the SRWMD. The average cow density is 4.2 cows/ha (1.7 cows/ac). A value of 5 cows/ha (2 cows/ac) is used to reflect the greater environmental impact associated with the high intensive areas. The survey also showed that most dairies have about 50% of their dairy in pastures and the other 50% in hay or forages. Pasture is assumed to be the representative crop for the expansion algorithm.

For dairies, about 50% of nitrogen (N) is lost between the excretion site and the land application site (SWET, 1995). The N losses could be from either ammonification or volatilization on concrete or soil surfaces. To reflect the N losses, a new manure type was created for dairy in the *default.bnz* file. The new manure type has 50% of the N values specified in the Pre-BMP GLEAMS dairy manure. No losses are assumed for phosphorus.

The cow density and new manure characteristics give manure application rates of 14,016 kg/ha/yr (6.2 t/ac/yr), 308 kg/ha/yr (274 lb/ac/yr), and 115 kg/ha/yr (102 lb/ac/yr) for dry matter, nitrogen, and phosphorus, respectively. An additional 30/5 kg/ha/yr of N/P commercial fertilizer is applied. These fertilizer amounts were determined through conversations with extension agents and dairymen in the region and through examination of fertilizer sales records for the region. While fertilization rates vary between fields, these values were chosen to represent typical fertilization rates.

Poultry – All poultry barns are assumed to be broiler operations. The land expansion should include areas that will likely receive the broiler litter from barn clean-outs. The required land application area is determined per unit length of barn. The estimates for litter production and land area requirements were provided by a local county agent and verified by Norstedt (1997).

Poultry litter application area is set at 12.2 ha/100-m (9.2 ac/100-ft) of barn and pasture is assumed to be the representative crop for the expansion algorithm. These choices are based on the following assumptions and calculations:

Chicken density = 24,000 chickens per 480-ft barn = 50 chickens/ft of barn
 Growth rate per growout = 4.5 lbs in 7.5 wk
 Number of growouts/yr = 6
 Number of days for growouts = 7.5 wk x 6 = 45 wk
 Average chicken weight during growout = 2.25 lb.
 Corrected annual average weight = $2.25 * 45\text{wks}/52\text{wks} \cong 2 \text{ lb/chicken}$
 Chicken density = 50 chickens/ft x 2 lb/chicken = 100 lb of chickens/ft
 Nitrogen production/day = 0.11 lb-N/day/100 lb of chickens (ASAE Standards 1996)
 Nitrogen production/year = $365 \times 0.11 \cong 40 \text{ lb-N/yr/ft}$
 Transport losses from barn to field = 35% (Kay and Hammond, 1985)
 Nitrogen available for uptake $\cong 26 \text{ lb-N/yr/ft}$
 Recommended N application rate for pasture grass = 160 lb-N/ac/yr (Table 3)
 Recommended N application rate for double forage crop = 400 lb-N/ac/yr (Table 3)
 Assume 20-25% over-application with 70% grass/30% forage mix
 Effective N application rate $\cong 283 \text{ lb-N/ac/yr}$
 Land requirements for grass/forage crop mix = 9.2 ac/100-ft of barn
 Chicken density = 50 chickens/ft / 0.092 ac/ft = 543 chickens/ac = 1340 chickens/ha

The chicken density is approximated at 1,300 poultry/ha. This chicken density gives manure application rates of 9,965 kg/ha/yr (4.4 t/ac/yr), 309 kg/ha/yr (275 lb/ac/yr), and 289 kg/ha/yr (257 lb/ac/yr) for dry matter, nitrogen, and phosphorus, respectively. An additional 30/5 kg/ha/yr of N/P is applied as a commercial fertilizer to the application areas.

Table 3. Simulated Ground Water Nitrogen for Selected Row Crops in the SRWMD

Row Crop	Ground Water N (kg/ha/yr)
Tobacco	34.4
Peanut	119.4
Soybean	138.6
Cotton	34.2
Corn	52.5
Watermelon	72.7
Snap Bean	26.9
Pepper	37.3

Table 4. Summary of Pre-BMP Land Use Parameters

LU* Num	Land Use Name	Other Information	Land Surface	Irrig- ation	Fertilization	Organic Nutrient Load	SW* Pond
1	Initialization	Initializes GLEAMS.					
2	Low Density Residential	Mobile homes	85% pervious with grass	N	25/5 kg/ha/yr N/P	4.1 people/ha septic	N
3	Commercial and Services	Commercial property	15% pervious with grass	N	25/5 kg/ha/yr N/P	10 people/ha secondary tmt.	N
4	Pastureland and Rural Land in Transition	Unmanaged meadow	100% pervious with grass	N	30/5 kg/ha/yr N/P	1.2 beef cows/ha	N
5	Scrub and Brushland	Mixed vegetation	100% pervious with small trees	N	unfertilized	no waste	N
6	Hardwoods	Unmanaged	100% pervious with hardwoods	N	unfertilized	no waste	N
7	Hardwood Conifer Mixed	Unmanaged	100% pervious with mixed trees	N	unfertilized	no waste	N
8	Coniferous Plantations	Managed	100% pervious with tilled conifers	N	5/0.5 kg/ha/yr N/P	no waste	N
17	Barren Land	Barren	100% pervious with bare soil + high erosion	N	unfertilized	no waste	N
18	Transportation Corridors	Unmanaged meadow with roads	50% pervious with grass	N	20/2 kg/ha/yr N/P	no waste	N
19	Medium Density Residential	Houses	75% pervious with grass	N	50/20 kg/ha/yr N/P	14.4 people/ha septic	N
20	High Density Residential	Houses	50% pervious with grass	N	70/20 kg/ha/yr N/P	49 people/ha secondary tmt.	N
21	Multiple Dwelling Units	Apartments	25% pervious with grass	N	70/20 kg/ha/yr N/P	197 people/ha secondary tmt.	N
22	Industrial	Industrial buildings	15% pervious with grass	N	20/5 kg/ha/yr N/P	10 people/ha secondary tmt.	N
23	Managed Landscape	Managed lawn	100% pervious with grass	Y	90/20 kg/ha/yr N/P	2 people/ha septic	N
24	Animal Race Tracks	Lawn with buildings	80% pervious with grass	N	100/50 kg/ha/yr N/P	10 people/ha septic and 3 horses/ha	N
25	Row Crops	Field crop	100% pervious with corn	N	270/30 kg/ha/yr N/P	no waste	N
26	Improved Pasture	Managed	100% pervious with grass	N	30/5 kg/ha/yr N/P	1.2 beef cows/ha	N
27	Unimproved Pasture	Low management	100% pervious with grass	N	15/3 kg/ha/yr N/P	0.5 beef cows/ha	N
28	Woodland Pasture	Low mgmt. wooded meadows	100% pervious with grass	N	15/2 kg/ha/yr N/P	0.5 beef cows/ha	N
29	Zoos	Lawn with buildings	75% pervious with grass	N	150/50 kg/ha/yr N/P	10 people/ha sec. tmt.+10 beef cow eq./ha	N
30	Peach and Pecan Orchards	Managed orchard	100% pervious with fruit trees	N	70/10 kg/ha/yr N/P	no waste	N
31	Blueberries	Managed small fruits	100% pervious with fruit trees	Y	100/20 kg/ha/yr N/P	no waste	N
32	Cattle Feeding Operations	Open lot	100% pervious with bare soil	N	unfertilized	20 beef cows/ha	N
33	Poultry Feeding Operations	Housing with meadow	100% pervious with grass	N	30/5 kg/ha/yr N/P	1300 poultry/ha	N
34	Swine Feeding Operations	Open lot	100% pervious with bare soil	N	unfertilized	44 swine/ha	N
35	Tree Nurseries	Highly managed trees	100% pervious with trees	Y	240/50 kg/ha/yr N/P	no waste	N
36	Sod Farms	Highly managed lawn	100% pervious with double-crop grass	Y	300/70 kg/ha/yr N/P	no waste	N
37	Ornamental Nurseries	Highly managed plants	100% pervious with plants	Y	300/100 kg/ha/yr N/P	no waste	N
38	Horse Farms	Open meadow	100% pervious with grass	N	50/10 kg/ha/yr N/P	6 horses/ha	N
39	Dairies	Open meadow with buildings	100% pervious with grass	N	30/5 kg/ha/yr N/P	5 dairy cows/ha	N
40	Kennels	Housing with lawn	75% pervious with grass	N	unfertilized	164 animals/ha	N
42	Salt Barrens	Open land	100% pervious with bare soil	N	unfertilized	no waste	N
43	Sewage Treatment	Building with lawn	80% pervious with grass	N	50/10 kg/ha/yr N/P	no waste	N
44	Solid Waste Disposal	Open site	100% pervious with bare soil	N	unfertilized	0.5 people/ha septic	N
70	Undeveloped Residential	Open land with some roads	95% pervious with grass	N	unfertilized	0.1 people/ha septic	N
71	Ranchettes	Mobile homes on large lots	95% pervious with grass	N	5/5 kg/ha/yr N/P	0.7 people/ha septic	N
72	Prisons	Prison buildings and fields	80% pervious with grass	N	25/5 kg/ha/yr N/P	27 people/ha secondary tmt.	N
75	Phosphate Processing	Phosphate Processing	100% impervious	N	P point source	no waste	N

Post-BMP Land Uses

These BMPs were developed based on input from local extension agents and members of the Suwannee River Partnership. These BMPs will need to be adjusted over time to reflect actual implementation rates and practices.

Improved Pasture BMP

The improved pasture BMP includes reduction of both fertilization and animal densities. The N fertilization is reduced from 30 kg/ha/yr to 20 kg/ha/yr. The P fertilization is reduced from 5 kg/ha/yr to 3.4 kg/ha/yr. The animal densities are reduced from 1.2 beef cows/ha to 0.9 beef cows/ha. The fertilization rates and animal densities were reduced in order to more closely match the nutrient requirements of the grass.

Poultry BMP

Two poultry BMPs are used for the analyses. The first BMP is to reduce fertilizer applications to IFAS recommended rates. This is accomplished by eliminating the 30 kg/ha/yr N application and 5 kg/ha/yr P application and by reducing the litter application rates from 1,300 to 1,000 poultry per hectare.

The second BMP is to remove all poultry litter from the basin. The fields that were receiving litter are converted to the land use for improved pastures with the fertilization and animal density BMP described earlier. The removal of litter has a greater impact on reducing nitrogen because the fertilization rates for improved pastures in the Suwannee River Management District are substantially lower than the IFAS recommended rates.

Row Crops BMP

The row crops BMP includes reduced fertilizer applications. The N fertilization is reduced from 270 kg/ha/yr to 200 kg/ha/yr. The P fertilization is reduced from 30 kg/ha/yr to 20 kg/ha/yr. These reduced fertilization rates will still meet the fertilizer requirements of the crop and will reduce nutrient loads leaving the fields.

Dairies BMP

Two dairy BMPs are used for the analyses. The first BMP includes reduction of both fertilization and animal densities. The N fertilization is reduced from 30 kg/ha/yr to 0 kg/ha/yr. The P fertilization is reduced from 5 kg/ha/yr to 0 kg/ha/yr. The fertilizer application was eliminated because the field is receiving adequate N and P rates from manure. The animal densities are reduced from 5 dairy cows/ha to 4 dairy cows/ha in order to reduce the manure loads to more appropriate levels for maintaining a nutrient balance.

Animal densities in the pastures are reduced through freestall barns or other confinement facilities. Improved manure management and crop uptakes are achieved through sprayfields. This also has the benefit of increased nitrogen volatilization.

The second BMP includes the same reduction of fertilization and animal densities plus the lining of lagoons. Little data have been collected on dairy lagoon leakage rates. One lagoon in the District had a measured leakage rate of 305 cm/yr. The NRCS leakage rate assumed for a lined

lagoon is 3.2 cm/yr. This lagoon was being agitated and the lagoon was being drawn down and refilled regularly. Both of these practices will increase leakage rates.

Anecdotal evidence has indicated large variations between pond leakage rates for earthen lagoons. SWET has constructed pond leakage testing apparatus and is currently performing pond leakage testing of dairy lagoons in the South Florida Management District.

WAM Simulation

The pre-BMP scenario was simulated using WAM with no BMPs being applied to any land use. This provides the base scenario in order to determine the BMP effectiveness.

The post-BMP scenario in 2008 assumes an 80% BMP adoption rate for poultry, row crop, dairy, and improved pastures. Since the Middle Suwannee Basin has a large amount of these four land uses, this should result in a large nitrogen load reduction. Since WAM is set up to simulate a 100% adoption rate, the 80% BMP adoption rate is calculated by interpolating between the 0% and 100% adoption scenarios.

The second set of BMP scenarios are calculated through a post-simulation adjustment of the nitrogen loads. The second poultry BMP is to remove all litter from the basin so that the land designated for poultry litter application will become improved pasture. Therefore, the second BMP is calculated by substituting the improved pasture loads for the poultry loads on a land use area basis.

The second dairy BMP involves the lining of lagoons. The values used in calculating the nitrogen loading from earthen lagoons were based on leakage rates measured in a dairy's earthen lagoon in the SRWMD, nitrogen measurements in manure lagoons, and typical design parameters. An approximate earthen lagoon nitrogen loading rate per cow was calculated based on the following assumptions:

- 305 cm/yr of leakage depth
- 305 cm pond depth
- 454 L/cow/d liquid reaching pond
- 7 day pond retention time
- 300 ppm N pond concentration
- 0.9 cows per hectare

Using these assumptions, the nitrogen leakage rate per cow per year can be calculated.

$$\begin{aligned}\text{Leakage} &= [\text{liquid reaching pond}] [\text{retention time}] / [\text{leakage depth}] [\text{pond depth}] [\text{N concentration}] \\ &= [454 \text{ L/cow/d}] * [7 \text{ d}] / [305 \text{ cm}] [305 \text{ cm/yr}] [300 \text{ ppm}] [\text{mg L} / \text{ppm}] [\text{kg}/1\text{e6 mg}] \\ &= 0.954 \text{ kg N/cow/yr}\end{aligned}$$

$$\begin{aligned}\text{Leakage} &= [0.954 \text{ kg N/cow/yr}] [0.9 \text{ cows per hectare}] \\ &= 0.859 \text{ kg N/ha/yr}\end{aligned}$$

The loads from lined lagoons are calculated by reducing the first dairy BMP loads by 0.859 kg N/ha/yr.

Results

WAM produces a number of outputs. Grid coverages of the nitrogen loads are shown in Appendix A. These results are shown for both unattenuated and attenuated loads. The unattenuated loads represent the nitrogen leaving each source cell. The attenuated loads represent the nitrogen reaching the basin outlet.

Nitrogen loads leaving the basin based on the pre-BMP scenario are shown in Appendix B. Results are shown both as total lands and on a per hectare basis. Poultry, row crops, dairies, and improved pasture do not rank in the top four land uses for total nitrogen loads on a per hectare basis; however, they hold the top four spots when ranked on total loads leaving the basin.

Tables 5 and 6 show the reduction in total nitrogen loads due to 80% BMP adoptions to poultry, row crops, dairies, and improved pastures for the two BMP scenarios. These results are for attenuated loads leaving the basin. Groundwater, soluble, and sediment loads as well as loads on an area basis are presented in Appendix C. The land uses are ranked by the reduction in kg of nitrogen leaving the basin. The percentage load reduction in nitrogen leaving the basin due to each land use's BMP relative to the pre-BMP load for that land use is presented.

Also, the percent load reduction in nitrogen leaving the basin due to each land use's BMP relative to the pre-BMP load from all land uses is presented. This value is crucial for assessing potential load reductions leaving the basin due to BMPs. The first level BMPs resulted in a 36% overall nitrogen load reduction leaving the basin. The second level of BMPs resulted in a 46% overall nitrogen load reduction.

Most of this nitrogen load reduction is due to reductions in groundwater nitrogen loads. This is to be expected since groundwater is by far the largest contributor of nitrogen. Sediment nitrogen loads are reduced by 45% for row crops, but remain unchanged or slightly increase for the other three land uses. The slight increase in sediment loads is probably due to slightly lower ET rates and slightly higher erosions due to decreasing crop vigor with lowered fertility. Sediment nitrogen represents a very small fraction of total nitrogen.

Soluble nitrogen loads decrease by 20 to 24% for row crops, poultry (IFAS rates BMP), and dairies (both BMPs). Poultry litter removal decreases soluble nitrogen by 59%. Improved pasture soluble nitrogen is virtually unchanged.

As expected, the removal of poultry litter has a much larger nitrogen reduction than reducing litter applications to IFAS recommended rates (78.4% versus 45.6%). The addition of lining lagoons to the dairy BMP slightly improved the BMP effectiveness (43.6% versus 42.5%).

All of these forecasts are based on the basin having reach equilibrium, that is, that the BMPs have been in place long enough for the previous nitrogen levels to have left the surface and groundwater. While the surface water will reach equilibrium in a relatively short period of time, the groundwater will take substantially longer. Benefits will be seen in shallow groundwater within a few years; however, data taken on time of water to reach springs suggest that several decades will be required for the impacts of the BMPs to be fully realized.

Table 5. Total Nitrogen Reduction Due to First Scenario BMPs by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	BMP N Load (kg/y)	N Reduction (kg/y)	N Reduction (% of highest reduction)	N Reduction (% of Pre-BMP land use N load)	N Reduction (% of Pre-BMP basin-wide N load)
Poultry Feeding Operations (IFAS rates)	15,181	860,893	467,842	393,051	100.0%	45.7%	19.0%
Row Crops	10,121	501,302	255,254	246,048	62.6%	49.1%	11.9%
Dairies	4,141	292,369	170,467	121,902	31.0%	41.7%	5.9%
Improved Pasture	37,079	68,541	46,902	21,639	5.5%	31.6%	1.0%
Total	66,522	1,723,105	940,465	782,640		45.4%	37.9%

Table 6. Total Nitrogen Reduction Due to Second Scenario BMPs by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	BMP N Load (kg/y)	N Reduction (kg/y)	N Reduction (% of highest reduction)	N Reduction (% of Pre-BMP land use N load)	N Reduction (% of Pre-BMP basin-wide N load)
Poultry Feeding Operations (removal BMP)	15,181	860,893	185,769	675,124	100.0%	78.4%	32.7%
Row Crops	10,121	501,302	255,254	246,048	36.4%	49.1%	11.9%
Dairies (BMP + lined lagoons)	4,141	292,369	167,528	124,841	18.5%	42.7%	6.0%
Improved Pasture	37,079	68,541	46,902	21,639	3.2%	31.6%	1.0%
Total	66,522	1,723,105	655,453	1,067,652		62.0%	51.7%

In the “Surface Water Quality Annual Report – 2001” (Hornsby et al., 2002), a nitrate-nitrogen loading of 1,240 tonnes was reported for WY 2001 for this basin. This is considerably less than the 2,064 tonnes of nitrogen per year reported by the model. A number of factors could account for this difference. The reported values were for a single year rather than the long-term average simulated by the model. The single year, 2001, was a dry year which would result in smaller loads. Another important factor is the lag between management practices and loads in the streams. The loads currently being measured are being strongly influenced by the land uses and management practices from decades ago which were producing smaller loads than current conditions.

In the previous study using WAM in the SRWMD (SWET, 1998), the model validation showed that the prediction of surface and ground water TN concentrations were generally in close agreement with measured values.

Conclusions

Based on previous validations in the Suwannee River Watershed Management District, WAM is an appropriate tool for evaluating BMP effectiveness in the District. WAM was used to simulate the impact of 80% adoption rates of row crop, poultry, dairy, and improved pasture BMPs on nitrogen loads leaving the basin.

These BMPs have the potential of reducing nitrogen loads leaving the basin by between 36% and 46%, depending on the level of poultry and dairy BMPs. Poultry BMPs had the largest impact on nitrogen load reductions. Reducing poultry litter applications to IFAS recommended rates reduced the total nitrogen load of all land uses leaving the basin by 13.6% and removing the poultry litter reduced the load by 23.4%. This highlights the importance of poultry BMPs on reducing nitrogen loads in the basin. The row crops BMP of reducing fertilization ranked second in importance for reducing nitrogen loads with a 13.1% reduction in total nitrogen loads.

The dairy BMP was nearly as effective as the row crop BMP on an area basis; however, the dairy BMP was only slightly more than half as effective due to the greater land area in row crops. The lining of dairy lagoons improved the effectiveness by 1%. However, this analysis was based on very limited data on dairy pond leakage. More information on pond leakage rates in the basin would be needed to better estimate this value.

Even though improved pasture represents over half of the land area represented by these four land uses and the improved pasture BMP reduced nitrogen loads by 31%, it was a distant fourth in overall effectiveness because of the relatively small loads produced by this land use. Total nitrogen loads were reduced by 1.3%.

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Appendix A. GIS Grid Coverages of Nitrogen Loads

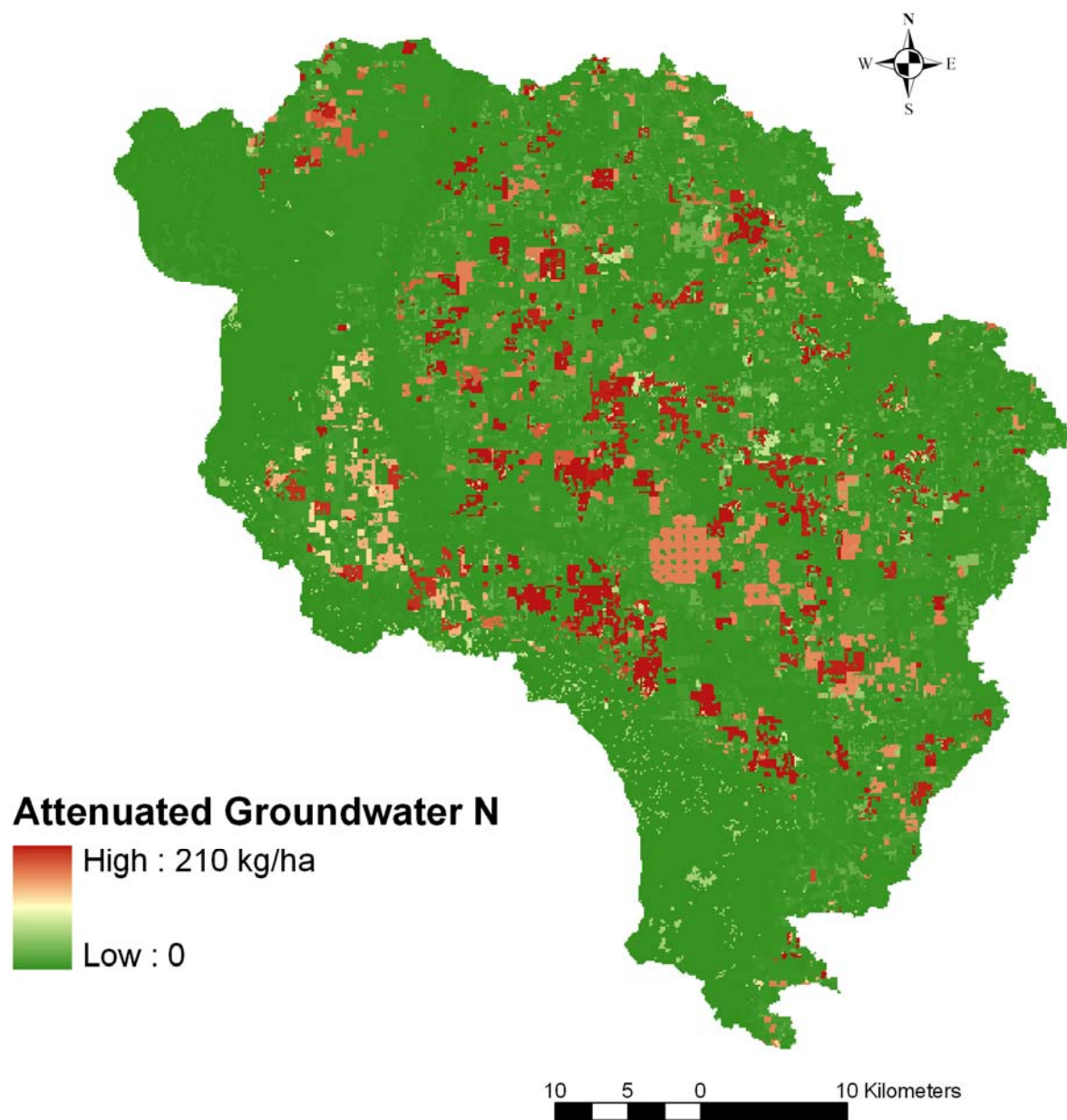


Figure 3. Attenuated Groundwater Nitrogen

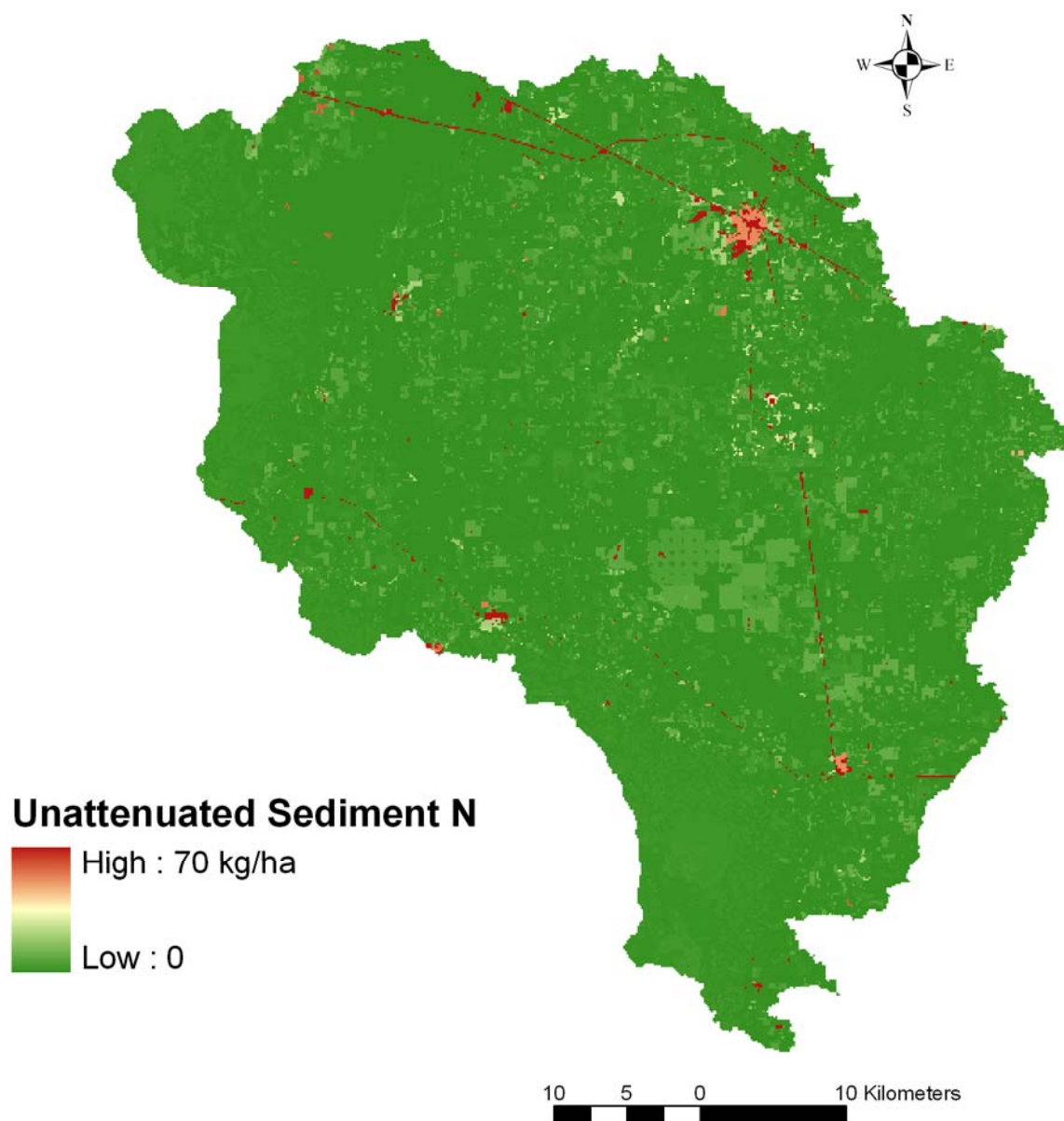


Figure 4. Unattenuated Sediment Nitrogen

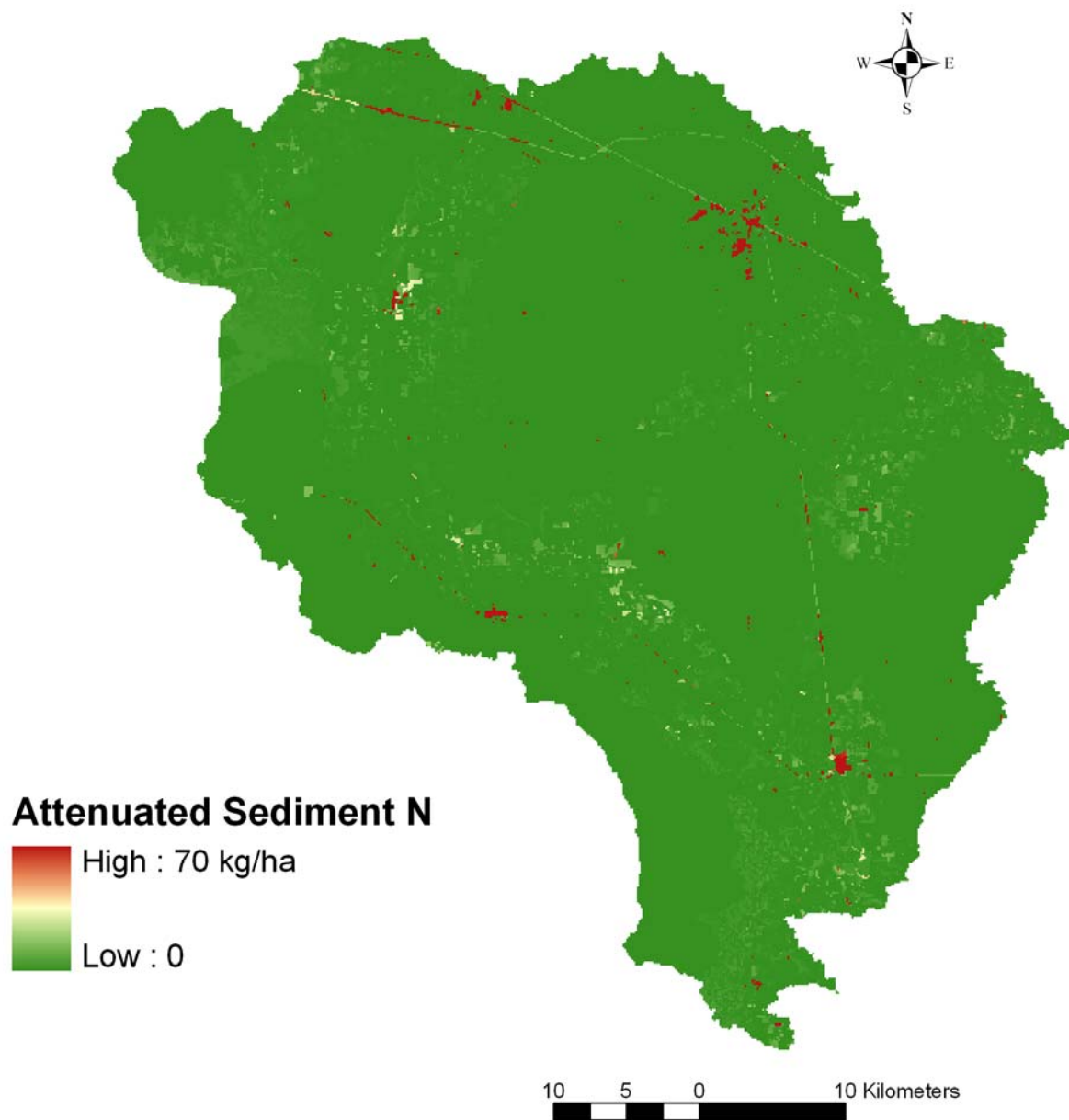


Figure 5. Attenuated Sediment Nitrogen

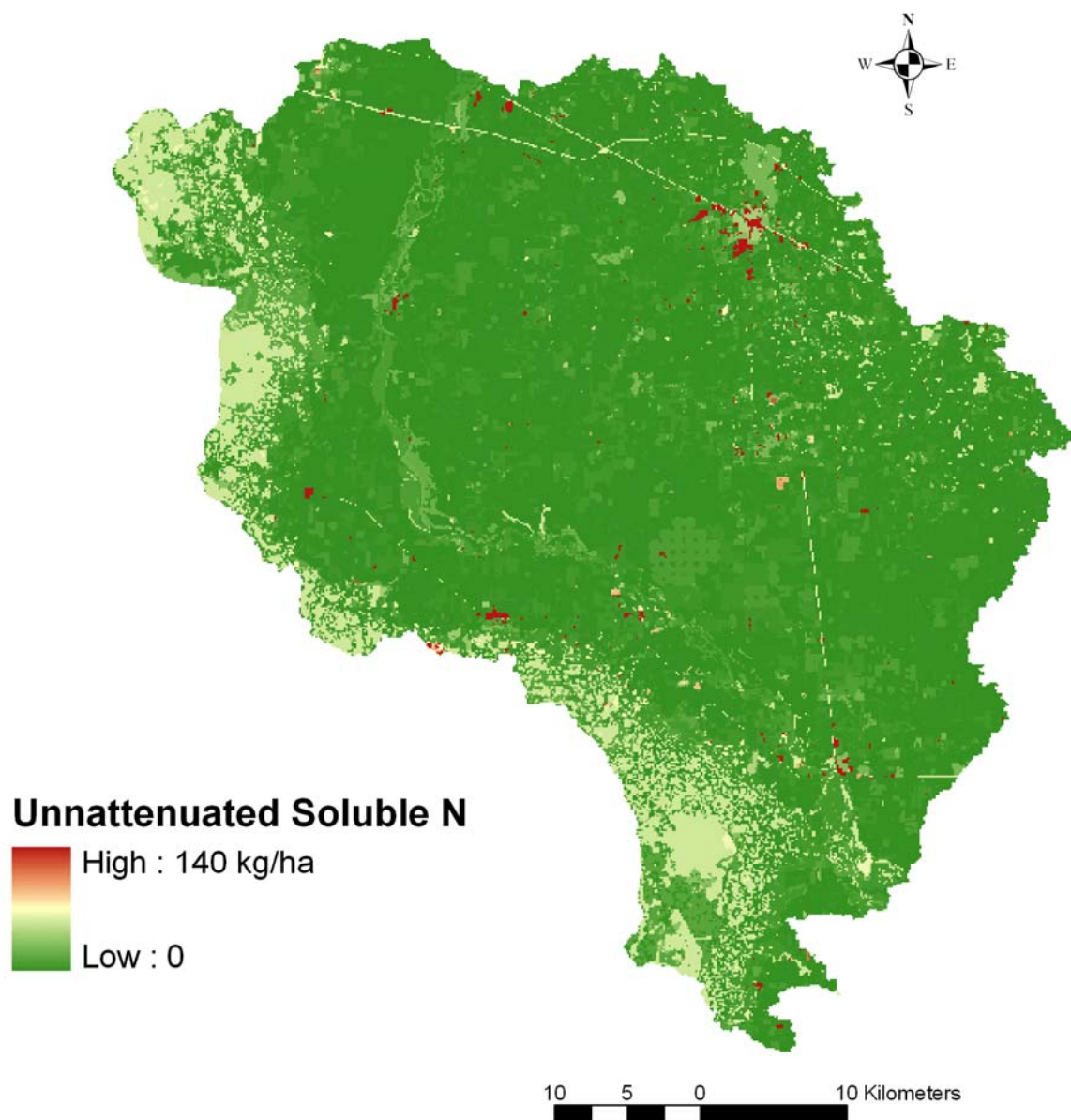


Figure 6. Unattenuated Soluble Nitrogen

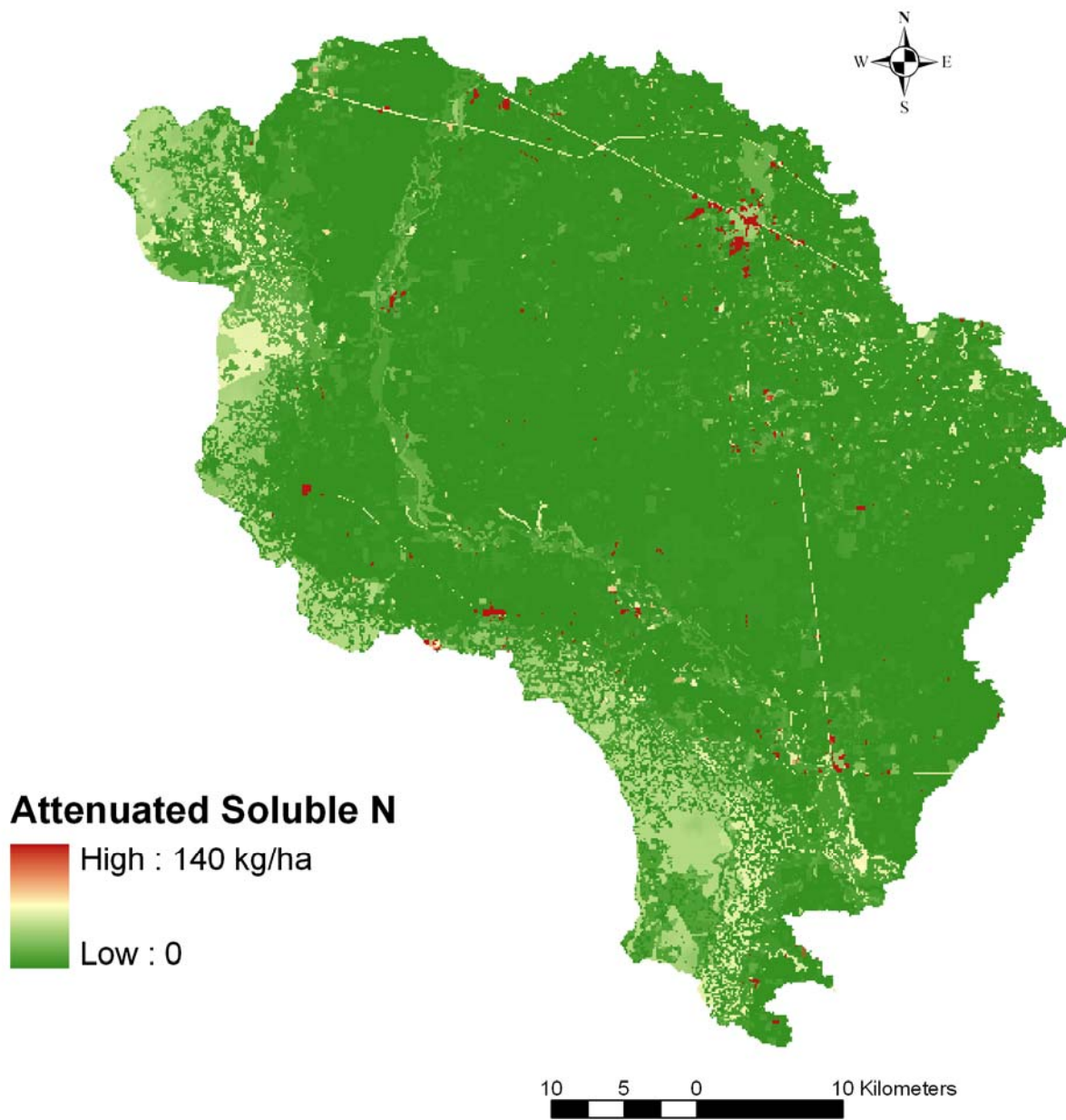


Figure 7. Attenuated Soluble Nitrogen

Appendix B. Pre-BMP Nitrogen Loads by Land Use

Table 7. Pre-BMP Groundwater Nitrogen Load by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	Pre-BMP N Load (percent of highest load)
Poultry Feeding Operations	15,181	856,894	100.0%
Row Crops	10,119	497,666	58.1%
Dairies	4,141	291,832	34.1%
Ranchettes	11,598	43,811	5.1%
Tree Nurseries	219	41,795	4.9%
Improved Pasture	37,078	65,647	7.7%
Medium Density Residential	505	37,290	4.4%
Coniferous Plantations	94,559	27,767	3.2%
Ornamental Nurseries	107	24,953	2.9%
Peach and Pecan Orchards	428	20,368	2.4%
Low Density Residential	904	20,180	2.4%
Hardwoods	29,969	10,705	1.2%
Kennels	103	10,173	1.2%
Scrub and Brushland	5,166	3,081	0.4%
Animal Race Tracks	40	2,840	0.3%
Woodland Pasture	4,048	2,708	0.3%
Horse Farms	45	2,069	0.2%
Undeveloped Urban Land	2,702	2,011	0.2%
Hardwood Conifer Mixed	5,316	1,510	0.2%
Barren Land	265	1,306	0.2%
Managed Landscape	96	1,200	0.1%
Blueberries	15	1,107	0.1%
Transportation Corridors	969	907	0.1%
Mining	990	468	0.1%
Solid Waste Disposal	41	412	0.0%
Commercial and Services	761	187	0.0%
Sewage Treatment	34	137	0.0%
Prisons	46	78	0.0%
Multiple Dwelling Units	42	70	0.0%
Pastureland and Rural Land in Transition	25	40	0.0%
Industrial	159	29	0.0%
High Density Residential	11	28	0.0%
Aquaculture	5	2	0.0%
Total	225,687	1,969,271	

Table 8. Pre-BMP Sediment Nitrogen Load by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	Pre-BMP N Load (percent of highest load)
Commercial and Services	761	3,922	100.0%
Multiple Dwelling Units	42	2,045	52.1%
Transportation Corridors	969	1,214	31.0%
Industrial	159	1,076	27.4%
Ranchettes	11,598	556	14.2%
Coniferous Plantations	94,568	369	9.4%
Improved Pasture	37,079	319	8.1%
Wetland Forested Mixed	18,083	322	8.2%
Row Crops	10,121	651	16.6%
Barren Land	265	250	6.4%
Poultry Feeding Operations	15,181	211	5.4%
Medium Density Residential	505	152	3.9%
Low Density Residential	904	147	3.7%
Undeveloped Urban Land	2,702	134	3.4%
High Density Residential	11	82	2.1%
Cypress	1,016	79	2.0%
Woodland Pasture	4,050	65	1.7%
Kennels	103	57	1.5%
Hardwoods	29,972	41	1.0%
Sewage Treatment	34	28	0.7%
Dairies	4,141	25	0.6%
Mixed Wetland Hardwoods	389	25	0.6%
Freshwater Marshes	860	22	0.6%
Bay Swamps	1,346	17	0.4%
Hardwood Conifer Mixed	5,316	17	0.4%
Prisons	46	16	0.4%
Animal Race Tracks	40	14	0.4%
Mining	990	9	0.2%
Open Water	1,911	5	0.1%
Ornamental Nurseries	107	3	0.1%
Solid Waste Disposal	41	3	0.1%
Aquaculture	5	3	0.1%
Scrub and Brushland	5,166	2	0.1%
Peach and Pecan Orchards	428	0	0.0%
Managed Landscape	96	0	0.0%
Tree Nurseries	219	0	0.0%
Horse Farms	45	0	0.0%
Blueberries	15	0	0.0%
Total	249,284	11,881	

Table 9. Pre-BMP Soluble Nitrogen Load by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	Pre-BMP N Load (percent of highest load)
Wetland Forested Mixed	18,083	28,774	100.0%
Commercial and Services	761	9,382	32.6%
Coniferous Plantations	94,568	7,512	26.1%
Multiple Dwelling Units	42	6,313	21.9%
Hardwoods	29,972	3,155	11.0%
Poultry Feeding Operations	15,181	3,788	13.2%
Improved Pasture	37,079	2,575	8.9%
Row Crops	10,121	2,985	10.4%
Transportation Corridors	969	2,178	7.6%
Bay Swamps	1,346	2,015	7.0%
Industrial	159	1,992	6.9%
Cypress	1,016	1,828	6.4%
Ranchettes	11,598	1,811	6.3%
Freshwater Marshes	860	1,647	5.7%
Mixed Wetland Hardwoods	389	810	2.8%
Mining	990	727	2.5%
Prisons	46	717	2.5%
Medium Density Residential	505	579	2.0%
Barren Land	265	534	1.9%
High Density Residential	11	456	1.6%
Low Density Residential	904	423	1.5%
Hardwood Conifer Mixed	5,316	398	1.4%
Dairies	4,141	512	1.8%
Woodland Pasture	4,050	321	1.1%
Undeveloped Urban Land	2,702	318	1.1%
Open Water	1,911	315	1.1%
Scrub and Brushland	5,166	307	1.1%
Kennels	103	154	0.5%
Ornamental Nurseries	107	132	0.5%
Solid Waste Disposal	41	90	0.3%
Sewage Treatment	34	45	0.2%
Animal Race Tracks	40	41	0.1%
Aquaculture	5	9	0.0%
Peach and Pecan Orchards	428	9	0.0%
Tree Nurseries	219	9	0.0%
Managed Landscape	96	4	0.0%
Blueberries	15	1	0.0%
Pastureland and Rural Land in Transition	25	0	0.0%
Horse Farms	45	0	0.0%
Total	249,309	82,866	

Table 10. Pre-BMP Total Nitrogen Load by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	Pre-BMP N Load (percent of highest load)
Poultry Feeding Operations	15,181	860,893	100.0%
Row Crops	10,121	501,302	58.2%
Dairies	4,141	292,369	34.0%
Improved Pasture	37,079	68,541	8.0%
Ranchettes	11,598	46,178	5.4%
Tree Nurseries	219	41,804	4.9%
Medium Density Residential	505	38,021	4.4%
Coniferous Plantations	94,568	35,648	4.1%
Wetland Forested Mixed	18,083	29,096	3.4%
Ornamental Nurseries	107	25,088	2.9%
Low Density Residential	904	20,750	2.4%
Peach and Pecan Orchards	428	20,377	2.4%
Hardwoods	29,972	13,901	1.6%
Commercial and Services	761	13,491	1.6%
Kennels	103	10,384	1.2%
Multiple Dwelling Units	42	8,428	1.0%
Transportation Corridors	969	4,299	0.5%
Scrub and Brushland	5,166	3,390	0.4%
Industrial	159	3,097	0.4%
Woodland Pasture	4,050	3,094	0.4%
Animal Race Tracks	40	2,895	0.3%
Undeveloped Urban Land	2,702	2,463	0.3%
Barren Land	265	2,090	0.2%
Horse Farms	45	2,069	0.2%
Bay Swamps	1,346	2,032	0.2%
Hardwood Conifer Mixed	5,316	1,925	0.2%
Cypress	1,016	1,907	0.2%
Freshwater Marshes	860	1,669	0.2%
Mining	990	1,204	0.1%
Managed Landscape	96	1,204	0.1%
Blueberries	15	1,108	0.1%
Mixed Wetland Hardwoods	389	835	0.1%
Prisons	46	811	0.1%
High Density Residential	11	566	0.1%
Solid Waste Disposal	41	505	0.1%
Open Water	1,911	320	0.0%
Sewage Treatment	34	210	0.0%
Pastureland and Rural Land in Transition	25	40	0.0%
Aquaculture	5	14	0.0%
Total	249,309	2,064,018	

Table 11. Pre-BMP Groundwater Nitrogen Load per Hectare by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/ha/y)	Pre-BMP N Load (percent of highest load)
Ornamental Nurseries	107	233.16	100.0%
Tree Nurseries	219	190.06	81.5%
Kennels	103	98.12	42.1%
Medium Density Residential	505	73.72	31.6%
Blueberries	15	73.60	31.6%
Animal Race Tracks	40	70.78	30.4%
Dairies	4,141	70.47	30.2%
Poultry Feeding Operations	15,181	56.44	24.2%
Row Crops	10,119	49.18	21.1%
Peach and Pecan Orchards	428	47.58	20.4%
Horse Farms	45	45.83	19.7%
Low Density Residential	904	22.31	9.6%
Managed Landscape	96	12.37	5.3%
Solid Waste Disposal	41	9.86	4.2%
Barren Land	265	4.91	2.1%
Sewage Treatment	34	4.02	1.7%
Ranchettes	11,598	3.78	1.6%
High Density Residential	11	2.46	1.1%
Improved Pasture	37,078	1.77	0.8%
Prisons	46	1.67	0.7%
Multiple Dwelling Units	42	1.65	0.7%
Pastureland and Rural Land in Transition	25	1.55	0.7%
Transportation Corridors	969	0.94	0.4%
Undeveloped Urban Land	2,702	0.74	0.3%
Woodland Pasture	4,048	0.67	0.3%
Scrub and Brushland	5,166	0.60	0.3%
Mining	990	0.47	0.2%
Aquaculture	5	0.47	0.2%
Hardwoods	29,969	0.36	0.2%
Coniferous Plantations	94,559	0.29	0.1%
Hardwood Conifer Mixed	5,316	0.28	0.1%
Commercial and Services	761	0.25	0.1%
Industrial	159	0.19	0.1%
Total	225,687	1,081	

Table 12. Pre-BMP Sediment Nitrogen Load per Hectare by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/ha/y)	Pre-BMP N Load (percent of highest load)
Multiple Dwelling Units	42	47.97	100.0%
High Density Residential	11	7.02	14.6%
Industrial	159	6.74	14.1%
Commercial and Services	761	5.15	10.7%
Transportation Corridors	969	1.25	2.6%
Barren Land	265	0.94	2.0%
Sewage Treatment	34	0.85	1.8%
Aquaculture	5	0.66	1.4%
Kennels	103	0.56	1.2%
Animal Race Tracks	40	0.36	0.8%
Prisons	46	0.35	0.7%
Medium Density Residential	505	0.30	0.6%
Low Density Residential	904	0.16	0.3%
Cypress	1,016	0.08	0.2%
Solid Waste Disposal	41	0.08	0.2%
Row Crops	10,121	0.06	0.1%
Mixed Wetland Hardwoods	389	0.06	0.1%
Ranchettes	11,598	0.05	0.1%
Undeveloped Urban Land	2,702	0.05	0.1%
Freshwater Marshes	860	0.03	0.1%
Ornamental Nurseries	107	0.03	0.1%
Wetland Forested Mixed	18,083	0.02	0.0%
Woodland Pasture	4,050	0.02	0.0%
Improved Pasture	37,079	0.01	0.0%
Poultry Feeding Operations	15,181	0.01	0.0%
Dairies	4,141	0.01	0.0%
Bay Swamps	1,346	0.01	0.0%
Mining	990	0.01	0.0%
Blueberries	15	0.01	0.0%
Coniferous Plantations	94,568	0.00	0.0%
Hardwoods	29,972	0.00	0.0%
Hardwood Conifer Mixed	5,316	0.00	0.0%
Open Water	1,911	0.00	0.0%
Scrub and Brushland	5,166	0.00	0.0%
Peach and Pecan Orchards	428	0.00	0.0%
Managed Landscape	96	0.00	0.0%
Tree Nurseries	219	0.00	0.0%
Horse Farms	45	0.00	0.0%
Total	249,284	73	

Table 13. Pre-BMP Soluble Nitrogen Load per Hectare by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/ha/y)	Pre-BMP N Load (percent of highest load)
Multiple Dwelling Units	42	148.04	100.0%
High Density Residential	11	39.02	26.4%
Prisons	46	15.33	10.4%
Industrial	159	12.47	8.4%
Commercial and Services	761	12.32	8.3%
Transportation Corridors	969	2.25	1.5%
Solid Waste Disposal	41	2.16	1.5%
Mixed Wetland Hardwoods	389	2.08	1.4%
Barren Land	265	2.01	1.4%
Aquaculture	5	1.96	1.3%
Freshwater Marshes	860	1.91	1.3%
Cypress	1,016	1.80	1.2%
Wetland Forested Mixed	18,083	1.59	1.1%
Bay Swamps	1,346	1.50	1.0%
Kennels	103	1.49	1.0%
Sewage Treatment	34	1.32	0.9%
Ornamental Nurseries	107	1.24	0.8%
Medium Density Residential	505	1.15	0.8%
Animal Race Tracks	40	1.03	0.7%
Mining	990	0.73	0.5%
Low Density Residential	904	0.47	0.3%
Row Crops	10,121	0.29	0.2%
Poultry Feeding Operations	15,181	0.25	0.2%
Open Water	1,911	0.17	0.1%
Ranchettes	11,598	0.16	0.1%
Dairies	4,141	0.12	0.1%
Undeveloped Urban Land	2,702	0.12	0.1%
Hardwoods	29,972	0.11	0.1%
Coniferous Plantations	94,568	0.08	0.1%
Woodland Pasture	4,050	0.08	0.1%
Improved Pasture	37,079	0.07	0.0%
Hardwood Conifer Mixed	5,316	0.07	0.0%
Blueberries	15	0.07	0.0%
Scrub and Brushland	5,166	0.06	0.0%
Tree Nurseries	219	0.04	0.0%
Managed Landscape	96	0.04	0.0%
Pastureland and Rural Land in Transition	25	0.03	0.0%
Peach and Pecan Orchards	428	0.02	0.0%
Horse Farms	45	0.01	0.0%
Total	249,309	254	

Table 14. Pre-BMP Total Nitrogen Load per Hectare by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/ha/y)	Pre-BMP N Load (percent of highest load)
Ornamental Nurseries	107	234.43	100.0%
Multiple Dwelling Units	42	197.66	84.3%
Tree Nurseries	219	190.10	81.1%
Kennels	103	100.17	42.7%
Medium Density Residential	505	75.17	32.1%
Blueberries	15	73.68	31.4%
Animal Race Tracks	40	72.17	30.8%
Dairies	4,141	70.60	30.1%
Poultry Feeding Operations	15,181	56.70	24.2%
Row Crops	10,121	49.53	21.1%
High Density Residential	11	48.50	20.7%
Peach and Pecan Orchards	428	47.60	20.3%
Horse Farms	45	45.84	19.6%
Low Density Residential	904	22.94	9.8%
Industrial	159	19.40	8.3%
Commercial and Services	761	17.72	7.6%
Prisons	46	17.35	7.4%
Managed Landscape	96	12.41	5.3%
Solid Waste Disposal	41	12.10	5.2%
Barren Land	265	7.86	3.4%
Sewage Treatment	34	6.19	2.6%
Transportation Corridors	969	4.44	1.9%
Ranchettes	11,598	3.99	1.7%
Aquaculture	5	3.09	1.3%
Mixed Wetland Hardwoods	389	2.14	0.9%
Freshwater Marshes	860	1.94	0.8%
Cypress	1,016	1.88	0.8%
Improved Pasture	37,079	1.85	0.8%
Wetland Forested Mixed	18,083	1.61	0.7%
Pastureland and Rural Land in Transition	25	1.58	0.7%
Bay Swamps	1,346	1.51	0.6%
Mining	990	1.21	0.5%
Undeveloped Urban Land	2,702	0.91	0.4%
Woodland Pasture	4,050	0.77	0.3%
Scrub and Brushland	5,166	0.66	0.3%
Hardwoods	29,972	0.47	0.2%
Coniferous Plantations	94,568	0.37	0.2%
Hardwood Conifer Mixed	5,316	0.35	0.1%
Open Water	1,911	0.17	0.1%
Total	249,309	1,407	

Appendix C. Post-BMP Nitrogen Loads by Land Use

Table 15. Groundwater Nitrogen Reduction Due to First Scenario BMPs by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	BMP N Load (kg/y)	N Reduction (kg/y)	N Reduction (% of highest reduction)	N Reduction (% of Pre-BMP land use N load)	N Reduction (% of Pre-BMP basin-wide N load)
Poultry Feeding Operations (IFAS rates)	15,181	856,894	464,591	392,303	100.0%	45.8%	19.9%
Row Crops	10,119	497,666	252,533	245,133	62.5%	49.3%	12.4%
Dairies	4,141	291,832	170,025	121,807	31.0%	41.7%	6.2%
Improved Pasture	37,078	65,647	44,019	21,628	5.5%	32.9%	1.1%
Total	66,519	1,712,039	931,168	780,871		45.6%	39.7%

Table 16. Groundwater Nitrogen Reduction Due to Second Scenario BMPs by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	BMP N Load (kg/y)	N Reduction (kg/y)	N Reduction (% of highest reduction)	N Reduction (% of Pre-BMP land use N load)	N Reduction (% of Pre-BMP basin-wide N load)
Poultry Feeding Operations (litter removal)	15,181	856,894	184,026	672,868	100.0%	78.5%	34.2%
Row Crops	10,119	497,666	252,533	245,133	36.4%	49.3%	12.4%
Dairies (BMP + lined lagoons)	4,141	291,832	167,085	124,747	18.5%	42.7%	6.3%
Improved Pasture	37,078	65,647	44,019	21,628	3.2%	32.9%	1.1%
Total	66,519	1,712,039	647,663	1,064,376		62.2%	54.0%

Table 17. Sediment Nitrogen Reduction Due to First Scenario BMPs by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	BMP N Load (kg/y)	N Reduction (kg/y)	N Reduction (% of highest reduction)	N Reduction (% of Pre-BMP land use N load)	N Reduction (% of Pre-BMP basin-wide N load)
Row Crops	10,121	651	361	290	100.0%	44.5%	2.4%
Dairies	4,141	25	25	0	3.2%	0.0%	0.0%
Poultry Feeding Operations (IFAS rates)	15,181	211	212	-1	2.9%	-0.4%	0.0%
Improved Pasture	37,079	319	329	-10	0.0%	-3.0%	-0.1%
Total	66,522	1,206	927	279		23.2%	2.3%

Table 18. Sediment Nitrogen Reduction Due to Second Scenario BMPs by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	BMP N Load (kg/y)	N Reduction (kg/y)	N Reduction (% of highest reduction)	N Reduction (% of Pre-BMP land use N load)	N Reduction (% of Pre-BMP basin-wide N load)
Row Crops	10,121	651	361	290	100.0%	44.5%	2.4%
Poultry Feeding Operations (removal BMP)	15,181	211	151	60	23.4%	28.6%	0.5%
Dairies (BMP + lined lagoons)	4,141	25	25	0	3.2%	0.0%	0.0%
Improved Pasture	37,079	319	329	-10	0.0%	-3.0%	-0.1%
Total	66,522	1,206	866	340		28.2%	2.9%

Table 19. Soluble Nitrogen Reduction Due to First Scenario BMPs by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	BMP N Load (kg/y)	N Reduction (kg/y)	N Reduction (% of highest reduction)	N Reduction (% of Pre-BMP land use N load)	N Reduction (% of Pre-BMP basin-wide N load)
Poultry Feeding Operations (IFAS rates)	15,181	3,788	3,039	749	100.0%	19.8%	0.9%
Row Crops	10,121	2,985	2,359	626	83.1%	21.0%	0.8%
Dairies	4,141	512	418	94	10.1%	18.4%	0.1%
Improved Pasture	37,079	2,575	2,554	21	0.0%	0.8%	0.0%
Total	66,522	9,860	8,370	1,490		15.1%	1.8%

Table 20. Soluble Nitrogen Reduction Due to Second Scenario BMPs by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/y)	BMP N Load (kg/y)	N Reduction (kg/y)	N Reduction (% of highest reduction)	N Reduction (% of Pre-BMP land use N load)	N Reduction (% of Pre-BMP basin-wide N load)
Poultry Feeding Operations (removal BMP)	15,181	3,788	1,592	2,196	100.0%	58.0%	2.6%
Row Crops	10,121	2,985	2,359	626	27.8%	21.0%	0.8%
Dairies (BMP + lined lagoons)	4,141	512	418	94	3.4%	18.4%	0.1%
Improved Pasture	37,079	2,575	2,554	21	0.0%	0.8%	0.0%
Total	66,522	9,860	6,924	2,936		29.8%	3.5%

Table 21. Groundwater Nitrogen Reduction Due to First Scenario BMPs per Hectare by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/ha/y)	BMP N Load (kg/ha/y)	N Reduction (kg/ha/y)	N Reduction (percent of highest reduction)	N Reduction (% of Pre-BMP basin-wide N load)
Dairies	4,141	70.47	41.05	29.42	100.0%	41.7%
Poultry Feeding Operations (IFAS rates)	15,181	56.44	30.60	25.84	87.8%	45.8%
Row Crops	10,121	49.18	24.96	24.22	82.3%	49.3%
Improved Pasture	37,079	1.77	1.19	0.58	2.0%	33.0%

Table 22. Groundwater Nitrogen Reduction Due to Second Scenario BMPs per Hectare by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/ha/y)	BMP N Load (kg/ha/y)	N Reduction (kg/ha/y)	N Reduction (percent of highest reduction)	N Reduction (% of Pre-BMP basin-wide N load)
Poultry Feeding Operations (litter removal)	15,181	56.44	12.12	44.32	100.0%	78.5%
Dairies (BMP + lined lagoons)	4,141	70.47	40.34	30.13	68.0%	42.7%
Row Crops	10,121	49.18	24.96	24.22	54.7%	49.3%
Improved Pasture	37,079	1.77	1.19	0.58	1.3%	33.0%

Table 23. Sediment Nitrogen Reduction Due to First Scenario BMPs per Hectare by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/ha/y)	BMP N Load (kg/ha/y)	N Reduction (kg/ha/y)	N Reduction (percent of highest reduction)	N Reduction (% of Pre-BMP basin-wide N load)
Row Crops	10,121	0.06	0.04	0.02	100.0%	40.0%
Dairies	4,141	0.01	0.01	0.00	0.0%	0.0%
Poultry Feeding Operations (IFAS rates)	15,181	0.01	0.01	0.00	0.0%	0.0%
Improved Pasture	37,079	0.01	0.01	0.00	0.0%	0.0%

Table 24. Sediment Nitrogen Reduction Due to Second Scenario BMPs per Hectare by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/ha/y)	BMP N Load (kg/ha/y)	N Reduction (kg/ha/y)	N Reduction (percent of highest reduction)	N Reduction (% of Pre-BMP basin-wide N load)
Row Crops	10,121	0.06	0.04	0.02	100.0%	40.0%
Poultry Feeding Operations (litter removal)	15,181	0.01	0.01	0.00	0.0%	0.0%
Dairies (BMP + lined lagoons)	4,141	0.01	0.01	0.00	0.0%	0.0%
Improved Pasture	37,079	0.01	0.01	0.00	0.0%	0.0%

Table 25. Soluble Nitrogen Reduction Due to First Scenario BMPs per Hectare by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/ha/y)	BMP N Load (kg/ha/y)	N Reduction (kg/ha/y)	N Reduction (percent of highest reduction)	N Reduction (% of Pre-BMP basin-wide N load)
Row Crops	10,121	0.29	0.23	0.06	100.0%	19.3%
Poultry Feeding Operations (IFAS rates)	15,181	0.25	0.20	0.05	99.4%	19.2%
Dairies	4,141	0.12	0.10	0.02	69.0%	13.3%
Improved Pasture	37,079	0.07	0.07	0.00	0.0%	0.0%

Table 26. Soluble Nitrogen Reduction Due to Second Scenario BMPs per Hectare by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/ha/y)	BMP N Load (kg/ha/y)	N Reduction (kg/ha/y)	N Reduction (percent of highest reduction)	N Reduction (% of Pre-BMP basin-wide N load)
Poultry Feeding Operations (litter removal)	15,181	0.25	0.11	0.14	100.0%	57.6%
Row Crops	10,121	0.29	0.23	0.06	33.5%	19.3%
Dairies (BMP + lined lagoons)	4,141	0.12	0.10	0.02	23.1%	13.3%
Improved Pasture	37,079	0.07	0.07	0.00	0.0%	0.0%

Table 27. Total Nitrogen Reduction Due to First Scenario BMPs per Hectare by Land Use

Land Use	Area (ha)	Pre-BMP N Load (kg/ha/y)	BMP N Load (kg/ha/y)	N Reduction (kg/ha/y)	N Reduction (percent of highest reduction)	N Reduction (% of Pre-BMP basin-wide N load)
Row Crops	10,121	49.53	25.23	24.30	100.0%	49.1%
Poultry Feeding Operations (IFAS rates)	15,181	56.70	30.81	25.89	93.0%	45.7%
Dairies	4,141	70.60	41.17	29.43	85.0%	41.7%
Improved Pasture	37,079	1.85	1.27	0.58	64.3%	31.6%

Table 28. Total Nitrogen Reduction Due to Second Scenario BMPs per Hectare by Land Use

Land Use	Area (ha)	Original N Load (kg/ha/y)	BMP N Load (kg/ha/y)	N Reduction (kg/ha/y)	N Reduction (percent of highest reduction)	N Reduction (% of Pre-BMP basin-wide N load)
Poultry Feeding Operations (litter removal)	15,181	56.70	12.24	44.46	100.0%	78.4%
Row Crops	10,121	49.53	25.23	24.30	62.6%	49.1%
Dairies (BMP + lined lagoons)	4,141	70.60	40.46	30.14	54.4%	42.7%
Improved Pasture	37,079	1.85	1.27	0.58	40.3%	31.6%