Sources of Nitrate and Estimated Groundwater Travel Times to Springs of the Santa Fe River Basin

February 2013 – AMEC Environmental

SUMMARY (excerpts)

(Page ES-1) The lower Santa Fe River is impaired for nutrients and dissolved oxygen, with a Total Maximum Daily Load (TMDL) target of 0.35 milligrams per liter (mg/L) of nitrate (NO3) to protect aquatic ecosystems. At the request of the Alachua County EPD and to facilitate prioritization of local initiatives for springs protection for the lower Santa Fe River, MACTEC (now AMEC) developed an ArcGIS™ tool designed to estimate nitrate loadings to groundwater in the springsheds. MACTEC also evaluated sources of nitrogen based on land use and loading rates and modeled groundwater travel time in the upper Floridan aquifer.

The springsheds include parts of seven counties and three water management districts and cover approximately 550,000 acres (860 square miles). Groundwater recharge rates in the springsheds were determined by application of the USGS MegaModel. Point source (e.g. septic systems and permitted domestic wastewater treatment plants) loadings were estimated "per unit". The number of septic systems within the springsheds was estimated from FL Dept. of Health data, and the loading from each system was estimated from published, nationwide estimates. Water quality data for domestic wastewater treatment plant effluent was used to calculate loading rates of nitrate to groundwater. Loadings estimates for non-point sources were based on published studies where nitrate has been monitored in groundwater under specific land uses. Uncertainties in loading estimates are presented. Loading estimates of pasture land use (almost half of the total nitrate loading) were based on data from the literature (± 25 to 50% margin of error). Groundwater concentrations for tree plantations are not well documented in this region. Silviculture fertilization practices are variable but may contribute 5-25% of the total loading. Septic systems were estimated to be between 15 and 20% of the total loading. The number of septic systems in the study area is uncertain. Ongoing efforts by FDOH to develop a statewide database of septic system locations should reduce the uncertainty.

One significant recent trend in nitrate loading to groundwater was the conversion of nearly all land in row crop agriculture (vegetable crops) to other land uses from 1995 to 2005. Row crop land use generally produces relatively high nitrate loadings, so the virtual disappearance of this land use reduced loadings from 1995 to 2004.

Estimated groundwater travel times are uncertain because porosity and hydraulic conductivity in karst limestone varies dramatically depending on the development of caves, caverns, fractures, sinking streams and other large solution features in the limestone.

REPORT EXCERPTS

(Page 1-1) This report is an update of a study completed in 2010. MACTEC recently completed a substantially similar project for the SJRWMD on the Wekiva River Basin and its springsheds, (Page 1-5) Travel times from the eastern springshed boundary in Bradford and northern Alachua County are approximately 1,000 years, too long to be of concern for springshed protection.

(Page 1-9) The following source types were identified as potentially important sources of nitrate, and their contribution to groundwater in the Santa Fe River Basin was estimated:

--Domestic wastewater;
--Septic systems;
--Fertilizer – Agriculture;
--Fertilizer – Residential;
--Fertilizer – Golf Course;
--Fertilizer – Other; and
--Livestock.

(Page 1-10) Cohen, *et* al., (2007) state that "nitrates in groundwater are effectively non-reactive (no biological or chemical attenuation) meaning that once nitrate enters the groundwater, it will emerge somewhere. In Florida, this location is primarily springs."

Although it was not feasible in this project to account for all the complex biochemistry of the nitrogen cycle, a limited attempt was made to account for assimilation by plants and other processes that occur in the root zone. Specifically it was not assumed that all fertilizer N applied to the land surface would reach groundwater of the Santa Fe River springsheds as nitrate. Not all nitrogen inputs to the Santa Fe River and springs could be quantified or modeled due to the complexity of the system. (e.g. input from streams along the Cody Scarp or soil storage)

(Page 1-11) The land use layer delivered to the ACEPD uses Florida Land Use and Cover Classification System (FLUCCS) codes and descriptions and is a combination of several county and water management district datasets from the year 2004 that have been merged into a common schema. The recharge layer is taken from the United States Geological Survey (USGS) MegaModel (Sepúlveda, 2002) with recharge measured in inches per year.

(Page 2-1) Nitrate loadings to groundwater attributable to fertilizer use were estimated by reviewing representative research studies where concentrations of nitrate were measured in groundwater or leachate from specific land uses. This information was used to estimate a representative groundwater concentration associated with that land use. (In other words, nitrate concentrations were modeled, not measures)

Approximately 70% of the waste nitrogen discharged from septic systems was assumed to reach groundwater as nitrate. Anderson and Otis (2000) indicate the actual percentage may range from 50 to 90%.

(Page 2-5) Pie chart shows portion of springsheds by land use catgegory.

(Page 2-6) Map shows research rates throughout the springsheads, ranging from 0-4"/year to more than 20"/year.

(Page 2-7) At the request of ACEPD, AMEC conducted additional literature review and estimated groundwater concentrations for tree plantation land uses as part of the scope of work for this study. As a result, the groundwater concentrations for tree plantation land uses differ in the Santa Fe basin model than the values used by MACTEC (2010a) in the Wekiva basin.

Residential Fertilizer: MACTEC (2007) estimated groundwater concentrations associated with residential fertilizer use from monitoring of small artificial turf grass research plots published by Morton, *et al*. (1988) and Snyder *et al*. (1984). These research studies determined leaching from plots that were managed differently (different rates of fertilizer application and irrigation) across a span of possible residential turf grass management practices. MACTEC (2007) interpreted those research studies and estimated the proportion of residents that would use fertilizer and irrigate at different rates. The latter estimates were based on best engineering judgment. This approach was adopted because MACTEC (2007) did not identify any field scale monitoring programs that had actually measured nitrate concentrations in residential areas unaffected by septic system discharges. In 2009, MACTEC drilled wells near Wekiva and determined that the nitrate concentration near fertilized lawns was 2 mg/l (same as silviculture).

(Page 2-8) From the Swancar (1996) data, MACTEC (2010a) estimated that groundwater NO3-N concentrations associated with golf course land use would be 8 mg/L. Representative groundwater concentrations associated with row and vegetable crops, tree crops (citrus), nurseries, pasture, and CAFOs were estimated from field scale monitoring studies of groundwater concentrations associated with these land uses.

(Page 2-10) Table 1 shows representative NO3-N groundwater concentrations assigned by land use in mg/l:

- ☐ Row crop 23.0
- ☐ Citrus (other) 15.0
- ☐ CAFO 13.0
- ☐ Golf course (recreational) 8.0
- ☐ Orchard, nursery 6.0
- ☐ Pasture 5.5
- ☐ Field crop, sod 4.0
- ☐ Commercial/Institutional/Recreational 2.0
- ☐ Residential 2.0
- ☐ Tree Plantations 2.0
- ☐ Industrial/transportation/undeveloped (other) 0.1

(page 2-11) Loading from Major Wastewater Facilities (lbs/year)

- ☐ Lake Butler WWTP1 11,543
- ☐ Alachua WWTP 11,107
- ☐ Newberry WWTP 5,697
- ☐ High Springs WWTP 718
- ☐ Arredondo MH Park 369
- ☐ Several small sources from 11-52
- ☐ Total Annual Loading 29,630

Main St/Gainesville and Kanapaha discharge greater amounts of NO3-N than the facilities quantified in Table 2, but these discharges do not migrate toward the Santa Fe River springs and would be well outside the modeled 100-year groundwater travel time area.

(Page 2-11) The springsheds of the Santa Fe basin encompass portions of several counties, and the FDOH database cannot be used to estimate the number of septic systems within the Santa Fe springsheds. FDOH is constructing a state-wide GIS database that would include septic system locations. The approach used to estimate the number of septic systems in the Santa Fe springsheds was based on the assumption that the density of septic systems (tanks/acre) is a function of land use. During this study, the septic system density procedure was used to estimate the total number of septic systems in Alachua County at 49,828 septic systems, while the FDOH inventory estimated 39,226 in 2004; and the Alachua County Health Department staff estimated 40,000 to 45,000 in 2008.

(Page 2-12) Applying this procedure to the Santa Fe springsheds, the total number of septic systems in the study footprint is estimated to be 39,714. Each tank was assumed to release 20 pounds (lb) of nitrogen per year (N/yr) to the environment (Roeder, 2006; Anderson, 2006). According to Anderson and Otis (2000), 50 to 90% of the N released from septic systems reaches the water table. In this study it was assumed that 70% of the N released by septic systems is delivered to groundwater as NO3-N, i.e., 14 lb/yr per system (0.0064 MT/yr).

(Page 3-1) Table 3 gives N-loadings by source:

Source	#/year	%	uncertainty
Pasture	1,363,000	43	±30%
Septic	557,000	17	±30%
Tree Plantations	445,000	14	±50%
Field crop, sod	297,000	9	
Residential	229,000	7	
Row crop	156,000	5	
Comm/Inst/Rec	39,000	1	
Orchard, nursery	37,000	1	
Other	37,000	1	
Wastewater Facilities	30,000	1	
CAFO	13,000	0	
Total	3,203,000	100	

(Page 3-1) Loadings from septic systems are more uncertain – these are calculated by multiplying an estimated number of septic systems within the springsheds by a loading rate per system. Neither the total number of septic systems nor the loading rate per system is known precisely.

(Page 3-2) The largest portion of the uncertainty in the total loading estimates is derived from uncertainties in the estimated groundwater concentrations (by land use) and in the groundwater recharges rates; more than 80% of the estimated NO3 loading is derived from these data sources.

(Page 4-1) Between 1995 and 2004, the State of Florida, Alachua County, and other private entities have acquired significant acreage as conservation land. These may include land in agriculture, pasture, or tree farms prior to 2004. As a result, the undeveloped category increased in acreage from 1995 to 2004 (increase of approximately 13,000 acres, or 7% of the 1995 acreage). The largest part of this increase came from the tree farm category (7,500 acres). AMEC does not expect this growth in undeveloped acreage to continue. Acreage in pasture was relatively stable from 1995 to 2004, decreasing by 3,600 acres or 3% of the 1995 acreage. A similar decrease in tree farm acreage of 3,000 acres also occurred, due to conversion to undeveloped (presumably conservation land). Residential land use increased by 6,200 acres, an 11% increase from 1995 residential acreage.

(Page 4-2) The largest percentage change in any land use was the substantial loss of acreage in row crop agriculture. This category decreased by 38,000 acres, from 1995 acreage of 42,000. More than 90% of the land used for row crop agriculture in 1995 is now used differently. Row crop agriculture has been converted to field crop agriculture (16,000 acres), pasture (14,000 acres), and tree farms (5,000) acres. These changes, plus conversion of pastureland to field crop, increased field crop acreage by 27,000 acres up to a total of 37,000 acres, a near quadrupling of acreage in this category from 1995 to 2004.

(Page 4-3) Table shows projected change in land uses through 2030.

(Page 4-4) Loadings were probably substantially higher in 1995 than they were in 2004, with a best estimate of 2,071 MT/yr in 1995, 43% higher than in 2004. The most important difference is the much greater contribution from row crop agriculture, a land use that generates high nitrate loading rates, and whose acreage decreased by 91% from 1995 to 2004.

(Page 4-5) Loadings are estimated to remain relatively unchanged between 2004 and 2030.

(Page 5-1) AMEC estimated travel time via the upper Floridan aquifer (UFA) to the Santa Fe River/Springs (SFRS). In the immediate vicinity of the SFRS the UFA consists of numerous solution cavities where flow does not adhere to classical porous media fluid dynamics – Darcy's Law is not satisfied. Cave systems near four springs have been mapped, extending as much as one mile from the main spring vent. Groundwater travel time through such caverns will be very short, one month or less. Martin (2003) found that groundwater travels from Santa Fe River Sink to River Rise in less than 1 week. Swallets are numerous throughout the region. Swallets near Cody Scarp connect directly to the aquifer.

(Page 5-2) Table shows flows in aquifer.

(Page 5-6 and 5-7) Maps show groundwater travel times to SFR Springs.