Appendix 4E

Additional Studies

Pamlico River
Subbasin HUC 03020104

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

August 7, 2009

MEMORANDUM

TO: Keith Larick, Supervisor, Animal Feeding Operation Unit, North Carolina Division of Water Quality, Raleigh, NC

FROM: Sara Ward, Ecologist, FWS, Raleigh, NC

SUBJECT: Preliminary results of an ongoing investigation of ammonia emissions from a large-scale egg-laying operation near Pocosin Lakes National Wildlife Refuge

The U.S. Fish and Wildlife Service (Service) appreciates your request for information regarding our ongoing field investigation (*Impacts of Airborne Ammonia Emissions from a Large-Scale Commercial Egg-Laying Operation at Pocosin Lakes National Wildlife Refuge*, see attached proposal outlining the goals and methods of the project) during North Carolina Division of Water Quality's (NCDWQ) review of the permit for the Rose Acre Farms Facility (NCA148024) in Hyde County, NC. This technical memorandum focuses on preliminary data assessment for the wet and dry deposition work completed to date by the Service and our partners. These are just a couple parts of the project (which also includes bimonthly surface water quality monitoring and nutrient bioassay work), and even these components are still in progress. Completion of the field data collection is anticipated in the summer of 2010 with a final report (including an integrated interpretation of results from all components of the study) anticipated late next year. We understand your need for timely technical input, so the following preliminary data assessment / interpretation is intended for informational purposes in response to your request. We would be happy to brief NCDWQ staff on these interim results (as well as the final report conclusions when complete).

Wet Deposition

We have deployed several National Atmospheric Deposition Program (NADP) approved rainfall collectors on and adjacent to Pocosin Lakes National Wildlife Refuge (PLNWR) in order to estimate inputs of nutrients via wet deposition. Of particular concern is the potential for enhanced ammonium nitrogen (NH_4^+-N) deposition to the refuge due to the recent construction and operation of the Rose Acre Farms poultry facility (the facility) located less than 2000 m from the southern boundary of the refuge. Design capacity for this facility is over 4 million layers, which represents a new and significant point source of ammonia (NH_3) emissions in the vicinity of the refuge. Deployment of the NADP rainfall collectors is one of several methods we are currently using to assess potential enhanced loading from the facility to the refuge.

Wet deposition monitoring equipment (NADP-type collectors) were deployed between June (PL01 and PL02) and August (PL03) 2005. PL01 is a bucket-type collector located ~7900 meters northeast of the main farm, PL02 is a chimney-style NADP collector (sample train is co-located with North Carolina Division of Air Quality's (NCDAQ) Mercury Deposition Network Site south of Lake Phelps) located ~10,300 meters north of the main farm, and PL03 is a bucket collector located just south of the refuge boundary adjacent to the facility property (by permission of landowner) ~840 meters northeast of the main farm (Figure 1). All three collectors have been sampled weekly between 2005 to present with the exception of 1) occasional sample lapses due to staff limitations or road conditions, and 2) equipment repair at PL01 (11/6/07-1/1/08 and 7/1/08-8/12/08). A fourth collector (PL04) was added as a duplicate sample in September 2008 and is currently co-located with PL03.

A seasonal summary of mean results for weekly NH_4^+-N, nitrogen oxide (NO_x-N = NO_2-N+NO_3-N), phosphate (PO_4-P), and total nitrogen (Total N = NH_4^+-N + NO_x + organic N) samples collected at PL01, PL02, and PL03 is presented in Table 1.

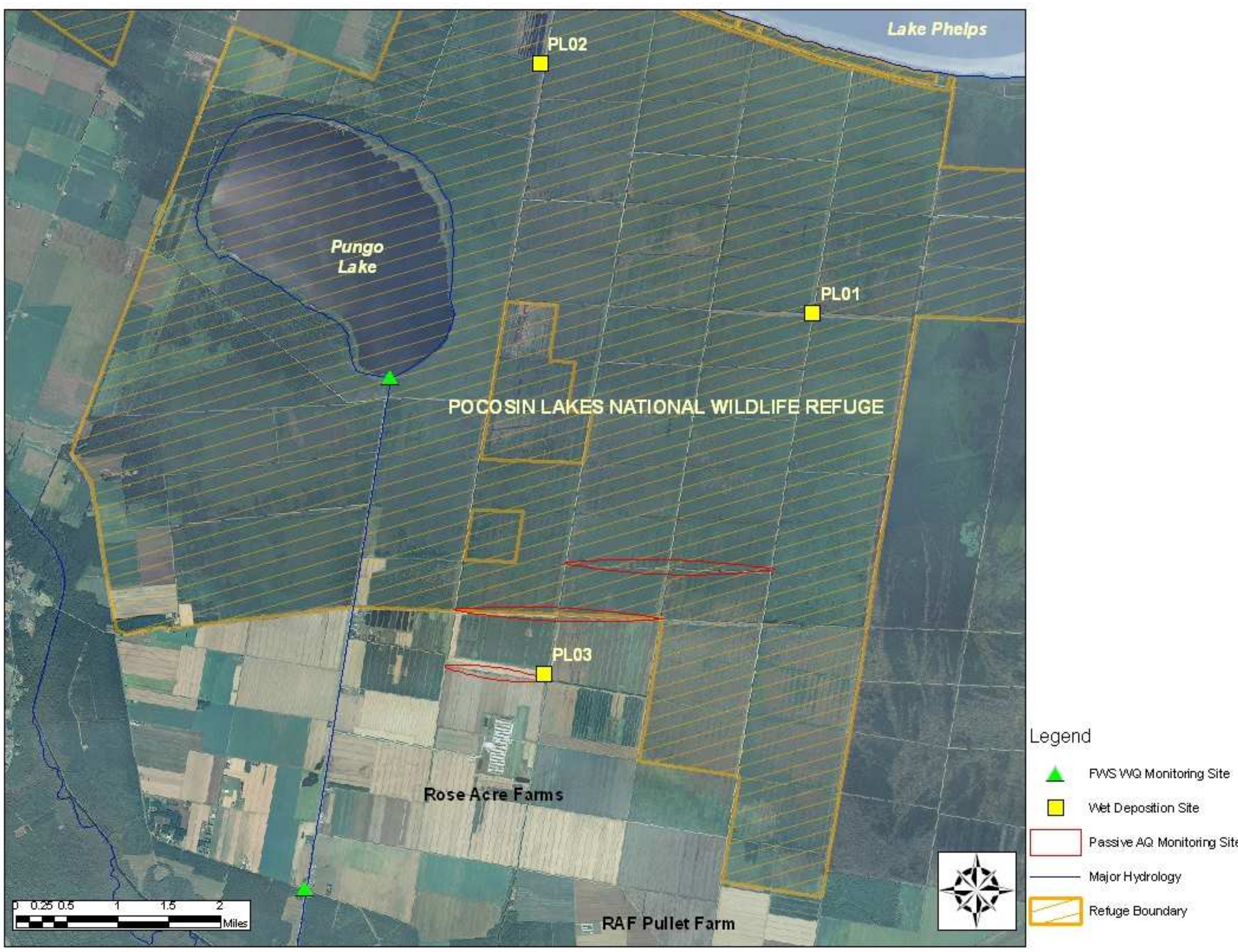

Figure 1. Location of wet deposition monitoring stations (PL01, PL02, and PL03), bimonthly water quality monitoring sites (supplemental to NCDWQ's 8 special study stations), and passive samplers (to measure ambient atmospheric ammonia concentrations) at Pocosin Lakes National Wildlife Refuge.

Table 1. Seasonal summary of mean weekly sample results for ammonium nitrogen (NH_4^+-N), nitrogen oxide (NO_x-N = NO_2-N+NO_3-N), phosphate (PO_4-P), and total nitrogen (Total N = NH_4^+-N + NO_x + organic N) at Pocosin Lakes National Wildlife Refuge. Precipitation (cm) is based on sample volume. Nutrient concentrations are reported in milligrams per liter and wet deposition units are kilograms per hectare. Dashed lines indicate seasons where dataset completeness criteria were not met. NA indicates data that are not available at time of preliminary report. Winter = Dec-Feb, Spring = Mar-May, Summer = June-Aug, Fall = Sept-Nov.

Sample Location	Year	Season	Measured Precipitation	Concentration				Deposition			
			cm	mg N-NO_x/L	mg N-NH_4/L	mg P-PO_4/L	mg Tot N/L	N-Nox kg/ha	N-NH4 kg/ha	P-PO4 kg/ha	Tot N kg/ha
PL01	2005	Fall	----	----	----	----	----	----	----	----	----
	2006	Winter	1.793	0.269	0.164	0.006	0.539	0.039	0.023	0.001	0.074
		Spring	3.052	0.244	0.292	0.005	0.699	0.071	0.090	0.001	0.209
		Summer	3.487	0.279	0.518	0.005	0.921	0.062	0.095	0.001	0.215
		Fall	3.660	0.229	0.135	0.003	0.360	0.047	0.032	0.001	0.087
	2007	Winter	1.422	0.397	0.368	0.010	0.748	0.040	0.038	0.001	0.074
		Spring	1.802	0.433	0.440	0.006	0.876	0.037	0.044	0.000	0.078
		Summer	2.288	0.522	0.814	0.005	1.411	0.053	0.075	0.001	0.134
		Fall	----	----	----	----	----	----	----	----	----
	2008	Winter	----	----	----	----	----	----	----	----	----
		Spring	1.597	0.330	0.578	0.006	0.961	0.029	0.053	0.001	0.083
		Summer	----	----	----	----	----	----	----	----	----
PL02	2005	Fall	NA	0.165	0.231	0.006	0.508	0.021	0.018	0.001	0.040
	2006	Winter	NA	0.258	0.151	0.007	0.537	0.026	0.016	0.001	0.055
		Spring	NA	----	----	----	----	----	----	----	----
		Summer	NA	0.145	0.217	0.003	0.522	0.042	0.069	0.001	0.159
		Fall	NA	0.105	0.062	0.002	0.186	0.023	0.013	0.000	0.045
	2007	Winter	NA	0.175	0.158	0.003	0.327	0.017	0.016	0.000	0.029
		Spring	NA	0.371	0.339	0.007	0.711	0.031	0.033	0.001	0.061
		Summer	NA	0.263	0.423	0.004	0.722	0.048	0.065	0.000	0.113
		Fall	NA	0.069	0.168	0.017	0.153	0.007	0.012	0.001	0.013
	2008	Winter	NA	0.167	0.162	0.001	0.354	0.021	0.018	0.000	0.041
		Spring	NA	0.199	0.272	0.001	0.482	0.031	0.043	0.000	0.073
		Summer	NA	0.189	0.318	0.002	0.503	0.056	0.116	0.001	0.175
PL03	2005	Fall	----	----	----	----	----	----	----	----	----
	2006	Winter	1.377	0.255	0.172	0.007	0.519	0.023	0.014	0.001	0.045
		Spring	3.215	0.265	0.314	0.006	0.737	0.090	0.113	0.002	0.254
		Summer	3.662	0.197	0.388	0.009	0.779	0.068	0.132	0.003	0.267
		Fall	3.450	0.137	0.213	0.012	0.355	0.034	0.047	0.003	0.095
	2007	Winter	1.450	0.217	0.599	0.014	0.804	0.019	0.046	0.001	0.060
		Spring	1.849	0.331	0.528	0.008	0.862	0.023	0.059	0.001	0.078
		Summer	2.371	0.433	1.830	0.166	2.624	0.052	0.142	0.005	0.202
		Fall	1.077	0.465	1.367	0.028	1.927	0.016	0.066	0.001	0.085
	2008	Winter	1.931	0.232	1.139	0.023	1.576	0.032	0.131	0.002	0.179
		Spring	2.126	0.272	0.612	0.007	0.865	0.039	0.101	0.001	0.135
		Summer	2.443	0.274	1.135	0.014	1.439	0.073	0.248	0.003	0.335

The investigation was initiated in 2005 prior to initiation of animal stocking at the adjacent chicken facility. Bird stocking data for the facility appear to be sparse, but based on NCDWQ records, stocking at the main farm began in mid-July 2006 with records showing a population of ~2 million birds in 2007 (max), ~1.75 million birds in May 2008, and ~3 million birds in April 2009. The data collection to date encompassed a baseline period (where measured deposition represents local background "pre-facility" conditions) as well as subsequent years where facility population levels increased up to 75% of the maximum permitted stocking level of 4 million birds. Baseline seasonal deposition means were not determined in Table 1 because NADP data completeness criteria for precipitation were not always met (e.g., precipitation datasets were incomplete greater than 10 percent of the time at two sites); however, overall average concentrations recorded in 2005 reflect a reasonable background condition (Table 2). Seasonal trends in nutrient concentrations in wet deposition samples are shown in Figure 2. In general, increasing trends are evident for all analytes at PL03 (the collector located closest to the farm) while concentrations at PL01 and PL02 remained relatively unchanged or decreased during the period of measurement. For reference, seasonal mean concentrations were compared to the 2005 background concentrations and indicate that background concentrations were exceeded frequently for N-NH_4^+ and total N (except during Spring 2008). Accordingly, increasing trends in nitrogen and N-NH_4^+ concentrations in rainwater at PL03 (and the absence of increasing trends at collectors farther afield) suggest the influence of facility emissions at the closest site and that gradual facility stocking as confinement houses were constructed has resulted in higher rainfall nutrient concentrations over time.

Table 2. Mean weekly concentrations of ammonium nitrogen (NH_4^+-N), nitrogen oxide (NO_x-N = NO_2-N+NO_3-N), phosphate (PO_4-P), and total nitrogen (Total N = NH_4^+-N + NO_x + organic N) on and adjacent to Pocosin Lakes National Wildlife Refuge (June-Dec 2005).

Sample Location	2005 Mean Baseline Concentration			
	mg N-NO_x/L	mg N-NH_4/L	mg P-PO_4/L	mg Tot N/L
PL01 (*n* = 17)	0.445	0.358	0.015	0.887
PL02 (*n* = 23)	0.166	0.190	0.005	0.417
PL03 (*n* = 10)	0.374	0.678	0.017	1.161
Average for all sites	0.328	0.409	0.012	0.822

Wet deposition (kg/ha) also increased at PL03 for NH_4^+-N and Total N during the investigation to date while wet deposition for all analytes at PL01 and PL02 and PO_4-P and NO_x-N at PL03 remained relatively unchanged (Figure 3). Based on these increasing trends in nutrient wet deposition in weekly samples, mean annual wet deposition was determined for NH_4^+-N, NO_x -N, and Total N (Table 3) from sites on and adjacent to PLNWR (Table 3) in 2006 and 2007 (2008 data are not yet available for a complete calendar year).

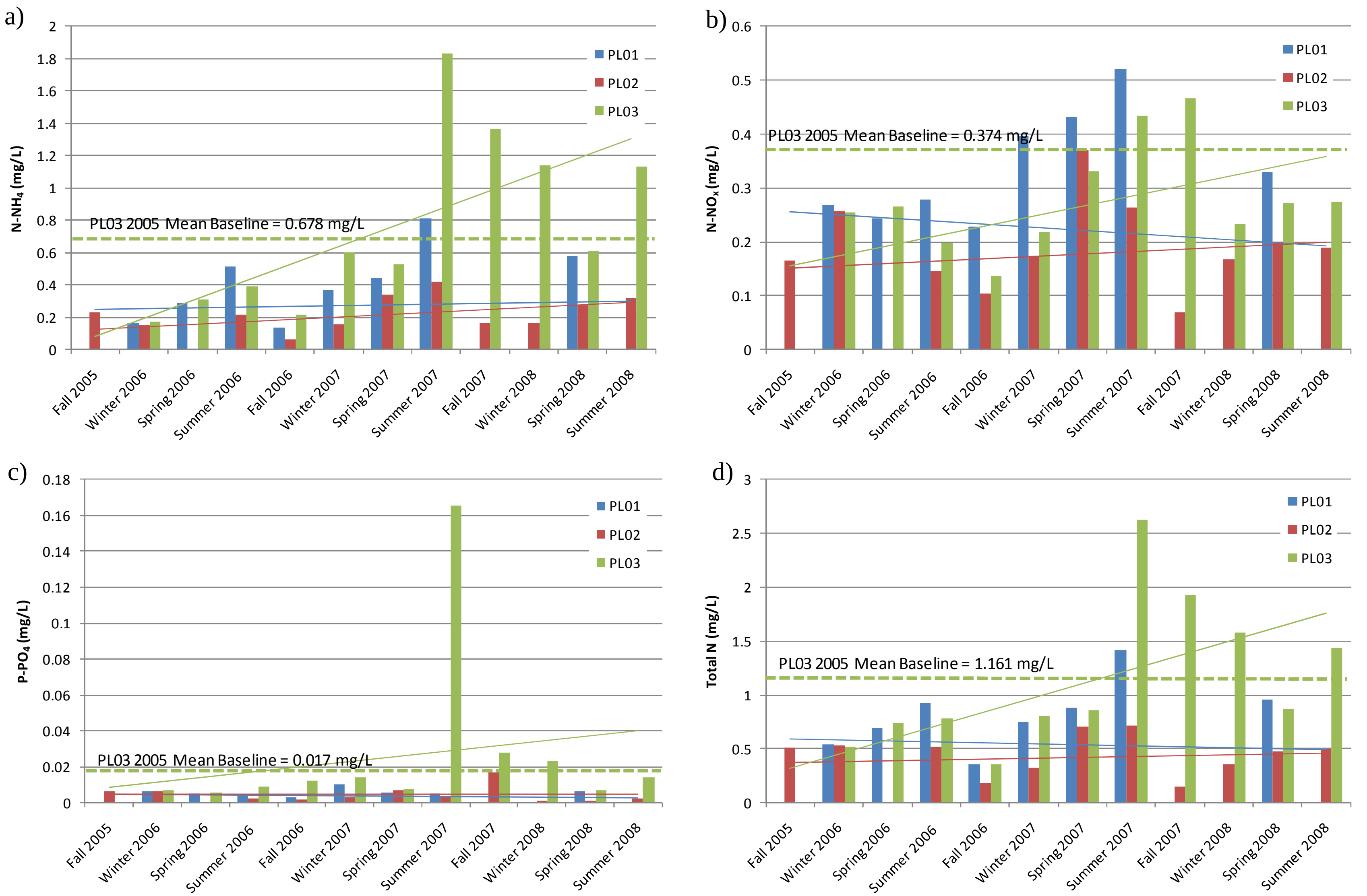

Figure 2. Seasonal average weekly concentrations (mg/L) of ammonium nitrogen, NH_4^+-N (a), nitrogen oxide, NO_x-N (b), phosphate, PO_4 (c), and total nitrogen, Total N = NH_4^+-N + NO_x + organic N (d) on and adjacent to Pocosin Lakes National Wildlife Refuge between late summer 2005 and mid-fall 2008. Dashed green line represents baseline (pre-facility operation) mean concentrations (Aug-Dec 2005) for the PL03 near-field collector. Linear regression lines are color coordinated for respective wet deposition collection stations.

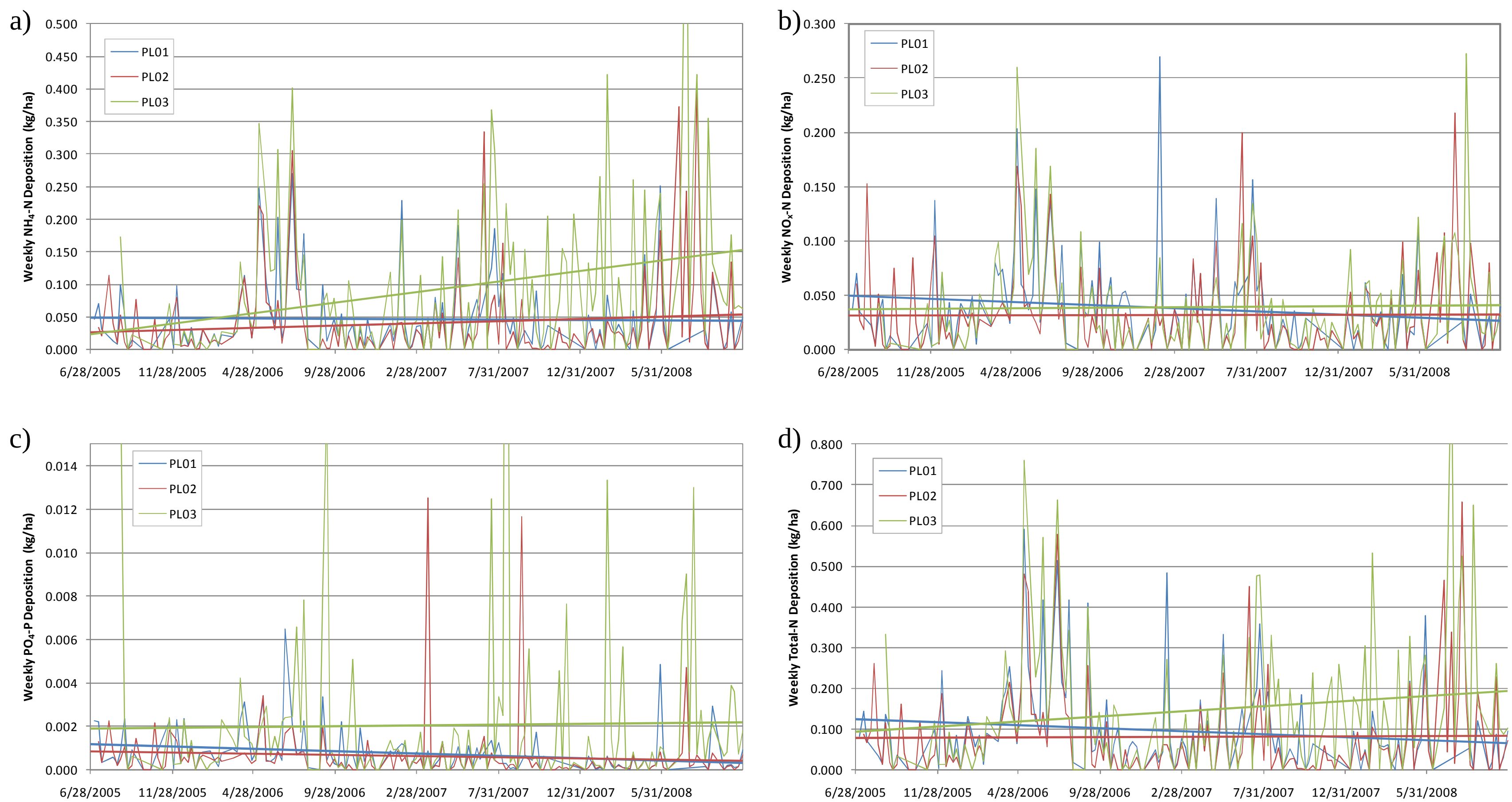

Figure 3. Weekly wet deposition (kg/ha) of ammonium nitrogen, NH_4^+-N (a), nitrogen oxide, NO_x-N (b), phosphate, PO_4 (c), and total nitrogen, Total N = NH_4^+-N + NO_x + organic N (d) on and adjacent to Pocosin Lakes National Wildlife Refuge between late summer 2005 and mid-fall 2008. Linear regression lines are color coordinated for respective wet deposition collection stations.

Table 3. Annual means (+/- standard deviation) of ammonium nitrogen (NH_4^+-N), nitrogen oxide (NO_x-N = NO_2-N+NO_3-N), phosphate (PO_4-P), and total nitrogen (Total N = NH_4^+-N + NO_x + organic N) wet deposition for 2006 and 2007 (the time period for which complete preliminary datasets are available for analysis to date) at wet deposition monitoring sites on and adjacent to Pocosin Lakes National Wildlife Refuge. Units are kg N per hectare**.**

Period	PL01	PL02	PL03
	NH_4^+-N (kg N/ha)		
2006	2.41 (0.07)	1.741 (0.07)	3.03 (0.09)
2007	1.971 (0.06)	1.64 (0.06)	4.29 (0.09)
	NO_x -N (kg N/ha)		
2006	2.22 (0.04)	1.44 (0.04)	2.08 (0.06)
2007	1.56 (0.05)	1.32 (0.04)	1.42 (0.03)
	Total N (kg N/ha; NH_4^+-N + NO_x-N + organic N)		
2006	5.96 (0.14)	4.38 (0.13)	6.51 (0.18)
2007	3.58 (0.11)	2.76 (0.09)	5.84 (0.12)

In order to put the deposition data from this study into context, data from existing NADP sites were reviewed. Although North Carolina has a number of NADP monitoring sites that have been in operation for over 30 years, none of these are located in the northeast corner of the state. In order to detect potential differences in NH_4^+-N loading it is important to consider 1) actual changes it total NH_4^+-N wet deposition prior to and after start up of the facility and 2) changes in the ratio of NH_4^+-N to total N measured in the rainfall. It is important to note that for NADP sites, total N is a calculated sum of NH_4^+-N and NO_x-N measured in rainfall whereas total N reported in this study is a measured total that that includes all dissolved inorganic N (N-NH_4^+ + NO_x-N) plus dissolved and particulate organic N. In PLNWR wet deposition samples, the inorganic component of total N is approximately 90 percent (across all collector sites for the duration of the study). Accordingly, total N reported in wet deposition samples collected at and near PLNWR are likely to be slightly higher than total N reported by NADP; however, in the absence of measured total N data for NADP sites, comparison of measured total N (this study) to calculated total N (NADP) appears to be reasonable because organic N accounts for <10% of total measured N wet deposition samples from the current study.

Because of the presence of a number of NADP wet deposition collectors in the state, it is possible to assess potential changes in NH_4^+-N deposition that should be anticipated within the refuge if a strong ammonia source causes a noticeable impact to rainfall composition. Table 4 contains a list of NADP monitoring locations in the state, their starting date, and a qualitative assessment the potential for impacts from local NH_3 sources. Several NADP sites have been excluded because they are currently very near large urban areas, at high elevation, or may be directly influenced by the coastal marine environment.

Table 4. Summary information for several NADP monitoring sites with the state of North Carolina.

Site ID.	Location	Starting Date	Assessment of Local NH_3 Sources
NC03	Lewiston	1978	Rural agricultural sources; 80 km north of largest density of CAFOs in state and in country
NC25	Coweeta	1978	Western portion of state; remote rural location with limited agricultural activity; elevation ~ 1000 m
NC29	Hofmann Forest	2002	Eastern NC; due east of largest density of CAFOs in state and in country
NC34	Piedmont Research Station	1978	Middle-western portion of state; rural agricultural sources; poultry operations to the south; dairy operations to the northwest
NC35	Clinton Crops Research Station	1978	Eastern NC; located in one of two counties with highest densities of CAFOs in the state; located in center of six counties with highest density of CAFOs in the state and country both swine and poultry
NC36	Jordon Creek	1983	Middle-southern portion of the state; rural region; located west of largest density of CAFOs in the state and country; located east of poultry operations

Selection of this grouping of NADP monitoring sites allows an assessment of trends in wet deposition of NH_4^+-N and total N both in areas without potential impact from NH_3 local sources (e.g. NC25, Coweeta) and in those with definite impact due to relatively large emissions of NH_3 from a high density of confined animal feeding operations (CAFO) (e.g., NC35, Clinton Crops Research Station). Other locations like NC29, NC34, and NC36 afford the opportunity to look for potential trends due to possible nearby NH_3 sources, while NC03 represents a site downwind from a high density of NH_3 emissions (at a separation distance comparable to the distance between the facility and PLNWR). For comparison, deposition collectors at and adjacent to PLNWR should be considered downwind of the high density of CAFO operations like those found near NC35. Lastly, comparison across all these sites illustrate national trends in NH_4^+-N wet deposition and how these can be differentiated from local source impacts (or may tend to mask assessment of a local source impact).

Table 5 lists the mean annual wet deposition amounts for the last three decades for each NADP site referenced in Table 1 along with the corresponding standard deviation. The data in Table 5 is grouped in approximately decade increments to highlight the period from 1980 – 1990, which corresponds approximately to the period before the moratorium on new hog production facilities using the current design of housing units plus anaerobic lagoon went into effect in the state. This pattern is repeated to allow discussion in changes in NH_4^+-N on a decade basis. The data in Table 5 are organized in general according to NADP sites experiencing the highest to the lowest levels of NH_4N wet deposition during the current decade. NC29 is positioned last because in has only been in operation since 2001.

Table 5. Decadal means (+/- standard deviation) of ammonium nitrogen (NH_4^+-N), nitrogen oxide (NO_x-N = NO_2-N+NO_3-N), phosphate (PO_4-P), and total nitrogen (Total N = NH_4^+-N + NO_x) wet deposition for the periods of 1980-1990, 1991-2000, and 2001-2008 for NADP sites NC03, NC25, NC29, NC34, NC35, NC36. Units are kg N per hectare. n/a = not applicable, data unavailable.

Period	NC35	NC34	NC36	NC25	NC03	NC29
	NH_4^+-N (kg N/ha)					
1980 – 1990	1.57 (0.34)	2.26 (0.59)	1.40 (0.55)	1.90 (0.70)	1.49 (0.42)	n/a
1991 – 2000	3.05 (0.82)	2.09 (0.45)	1.65 (0.30)	1.84 (0.30)	1.78 (0.25)	n/a
2001 – 2008	4.00 (0.94)	2.51 (0.86)	2.19 (0.69)	1.90 (0.43)	2.08 (0.43)	1.83 (0.34)
	NO_x-N (kg N/ha)					
1980 – 1990	2.26 (0.30)	2.77 (0.36)	2.51 (0.58)	2.73 (0.40)	2.40 (0.34)	n/a
1991 – 2000	2.25 (0.30)	2.57 (0.28)	2.60 (0.23)	2.68 (0.32)	2.30 (0.19)	n/a
2001 – 2008	1.88 (0.31)	2.16 (0.58)	2.19 (0.52)	2.20 (0.42)	2.01 (0.38)	2.01 (0.34)
	Total N (kg N/ha; NH_4^+-N + NO_x-N)					
1980 – 1990	3.83 (0.57)	5.03 (0.88)	3.91 (1.10)	4.64 (1.03)	3.89 (0.65)	n/a
1991 – 2000	5.30 (1.01)	4.66 (0.68)	4.24 (0.49)	4.52 (0.58)	4.08 (0.40)	n/a
2001 – 2008	5.88 (1.14)	4.68 (1.35)	4.38 (1.18)	4.11 (0.77)	4.09 (0.73)	3.83 (0.55)

Table 5 illustrates an increase in NH_4^+-N in wet deposition captured by NADP collector NC35 near Clinton, NC, where prior to 1990 NH_4^+-N in wet deposition averaged 1.6 kg NH_4^+-N/ha and then quickly doubled to over 3.0 kg NH_4^+-N/ha with the rapid increase in the states swine herd (especially in Sampson and Duplin counties). The data summary indicates that the NH_4^+-N content in wet deposition at the NC35 location is currently 4 kg NH_4^+-N/ha. In contrast, an increase in NH_4^+-N in wet deposition has been less apparent at the other NADP sites in the state. For NC36 and NC03, both sites that are either downwind or relatively near potential NH_3 emission sources, and reflect an increase of ~ 0.7 kg N/ha from NH_4^+-N since the 1980-1990 decade. NC25, located in a relatively remote rural region in western NC appears to have experienced no changes in NH_4^+-N wet deposition.

In regards to the data collected on and near PLNWR, Table 5 suggests that at a minimum wet deposition calculated from the rainfall collectors of at least ~ 2 kg NH_4^+-N/ha per year would reflect inputs from regional and continental sources. Accordingly, NH_4^+-N deposition at PL01 and PL02 (which were between 1.64 and 2.41 kg NH_4^+-N/ha in 2006 and 2007) appear to reflect background regional conditions (Table 3). Values exceeding ~ 2 kg NH_4^+-N/ha per year (and especially over 3 kg NH_4^+-N/ha per year as was evident in annual mean NH_4^+-N deposition at PL03, Table 3) could be considered indicative of enhanced NH_4^+-N deposition from a local source. PL03 NH_4^+-N mean deposition in 2006 (3.03 kg NH_4^+-N /ha) and 2007 (4.29 kg NH_4^+-N /ha) suggests an increase of ~1 kg and 2 kg NH_4^+-N/ha per year, respectively. Trends in total N via wet deposition mirror those for NH_4^+-N. Based on data presented in Table 5, it appears that a background level of 4 kg N/ha per year should be anticipated and amounts over this would be supportive of a conclusion of additional nitrogen deposition arising from a local source. In 2006, annual mean total N deposition exceeded this background level of 4 kg N/ha at all three collectors in the vicinity of PLNWR, and in 2007 background levels were only exceeded at PL03 (Table 3). Accordingly a local source of nitrogen appears to affect total N deposition most substantially at PL03 (where measured wet deposition is ~ 6 kg N/ha per year) and could also be influencing rainfall nutrient levels at the two additional collectors on the refuge (based on 2006 results).

NO_x-N is included in Table 5 as a nitrogen component in rainfall that is not likely to be directly impacted by emissions from CAFOs (e.g., CAFOs do not emit NO_x other than those associated with operation of farm gasoline-powered farm equipment and vehicles servicing the farm). Therefore, it is expected that trends in NO_x-N in wet deposition to be more consistent across the NADP sites. Based on NADP data, we expect calculated deposition amounts from collectors on and near PLNWR to be ~ 2 kg NO_x-N/ha per year and should not vary significantly between years of collection. In general this is true, although the data in Table 5 suggest that across the state NO_x-N wet deposition has decreased for the period 2001-2008 from the period 1980-1990. Within the refuge, annual wet deposition of NO_3-N ranged between 1.32 and 2.22 kg NO_x-N/ha per year and did not vary substantially between sites (Table 3).

The data in Table 5 illustrates that the majority of change in total N wet deposition, especially at NC35, is due to an increase in the NH_4^+-N content of wet deposition. As such, the percent content of NH_4^+-N of Total N in wet deposition is increasing and affords another mode of comparison to separate out potential local sources of NH_3 emissions on rainfall chemistry. Looking at the percent content of NH_4^+-N in wet deposition (NH_4^+-N/total N x 100) will act to normalize out variations in rainfall amounts among collectors that can complicate direct comparisons in total N deposition. Figure 4 illustrates the trends in the percent of NH_4^+-N in annual wet deposition amounts for the NADP sites listed in Table 4 from 1980 to 2008.

As expected, there has been a consistent increase in the percent of NH_4^+-N in wet deposition at the NC35 location since approximately 1990. This number reached 60% around 1995 and has apparently continued to increase, even with the moratorium on construction of new hog facilities. In contrast, there is no consistent trend in percent NH_4^+-N in wet deposition at the remaining NADP sites listed in Table 4 from 1980 till approximately 1998-1999. A qualitative evaluation suggests the percent of NH_4^+-N in wet deposition outside of the NC35 location has been between 40 – 45% since the 1980's. Starting in 1999-2000, however, all of the NADP collectors appear to be recording a consistent and approximately linear increase in the percent NH_4^+-N in wet deposition across the state to where the average value is now over 50% and closer to 55%, suggesting a change of 10% since 1999-2000. Furthermore, this increase is also evident in the data captured at the NC35 location, suggesting that the observed continued increase in percent NH_4^+-N content in wet deposition beyond the year 2000 at NC35 could reflect a major large scale influence and not local NH_3 emission sources.

Closer analysis of the data represented in Figure 4 demonstrates that the average of percent NH_4^+-N in wet deposition among the NADP sites listed in Table 4 (excluding NC35) has been steadily increasing for the last three years, suggesting that comparison of percent NH_4^+-N content in wet deposition between adjacent years (for example "background" samples versus samples collected after start of a process or facility) must take into account the apparent near yearly change in percent NH_4^+-N content that has been occurring as suggested by Fig. 1.

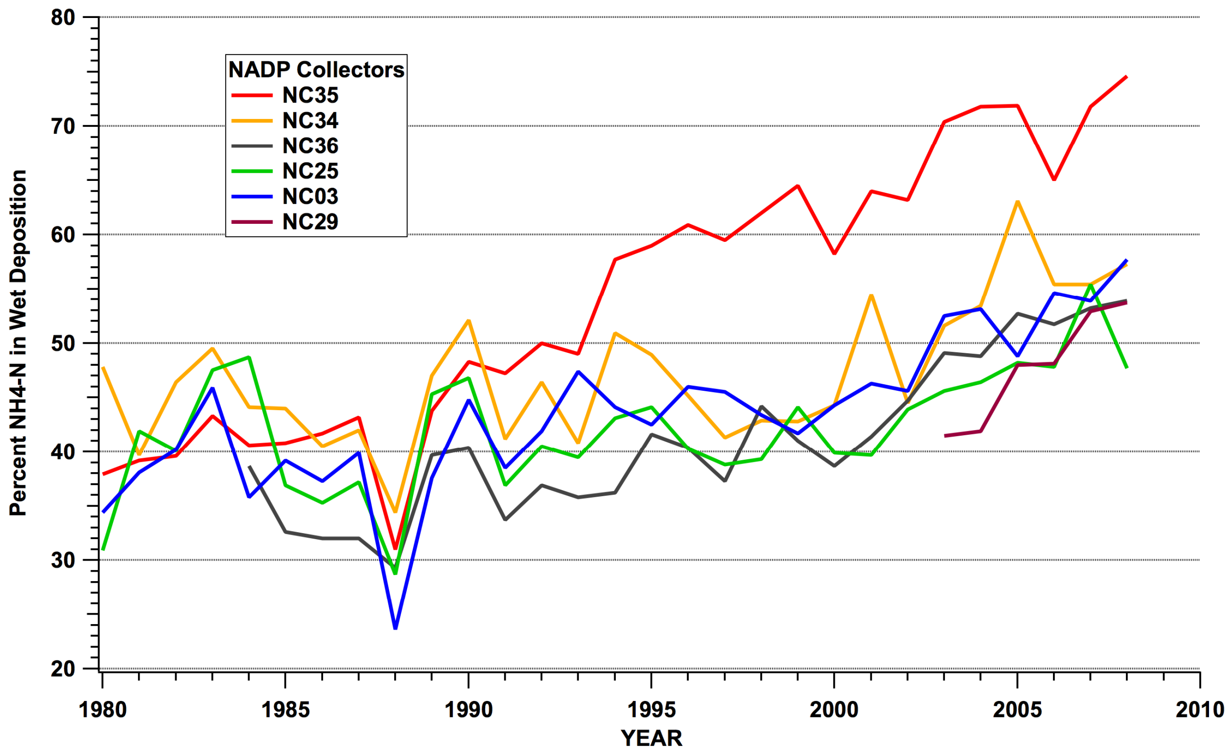

Figure 4. Percent NH_4^+-N of Total N (NH_4^+-N + NO_3-N) in annual wet deposition for NADP sites listed in Table 1 as a function of year.

Figure 4 illustrates that for wet deposition captured at the PLNWR, the percent NH_4^+-N in wet deposition, even for the "background" samples, should be at least 50% or higher. Figure 4 also suggests that a difference in percent NH_4^+-N content between years, especially between "background" samples and samples collected in succeeding years after start up of the facility is perhaps consistent with trends at other "background" NADP stations in the state and not necessarily indicative of impact from a local NH_3 source unless the observed values exceed a certain level or vary over distance among the collectors deployed at the refuge. The cumulative data plotted in Figure 4 suggest that, at least on a yearly basis, percent NH_4^+-N content of wet deposition should be near 60% to be interpreted as being influenced by a local source of NH_3 emissions. Figure 5 illustrates the percent NH_4^+-N in weekly wet deposition samples at and near PLNWR. Weekly data demonstrating the contribution of NH_4^+-N to total N deposition from this study are consistent with conclusions drawn from statewide datasets. Specifically, the percent NH_4^+-N in wet deposition at all sites typically were greater than 50%, and all collectors exhibited an increasing trend in contributions of NH_4^+-N to total N deposition; however, at the collector located closest to the facility, percent NH_4^+-N in wet deposition frequently exceeded 60% (particularly following the summer of 2006 which roughly coincides with available information regarding the start of animal stocking at the facility) as would be anticipated downwind of a strong local source of NH_3 emissions.

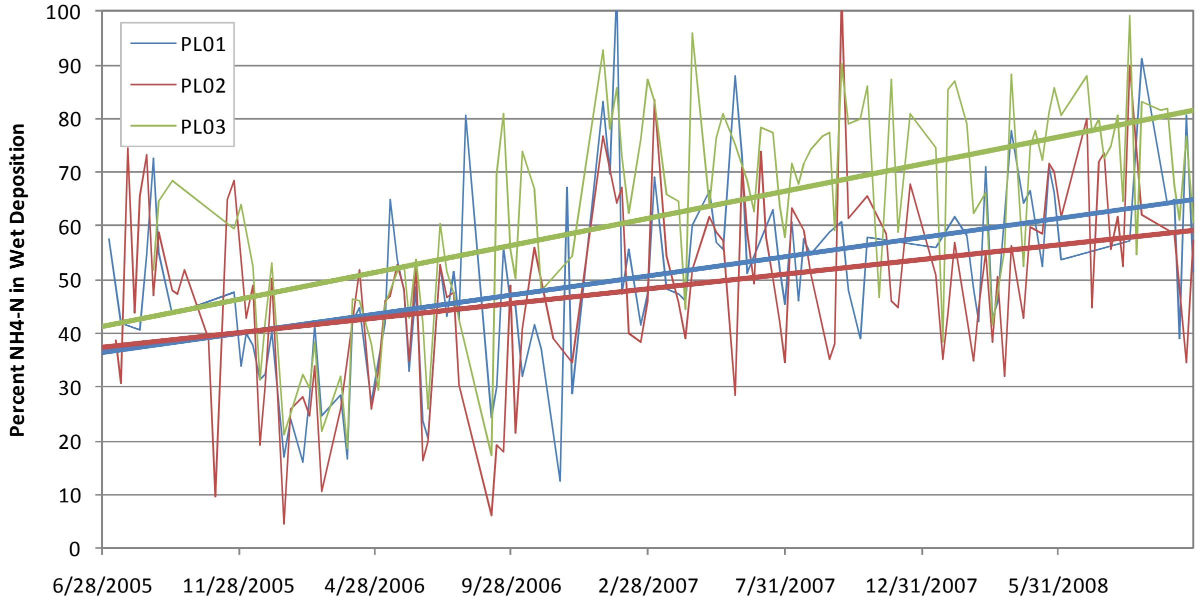

Figure 5. Percent NH_4^+-N of Total N in weekly wet deposition for deposition monitoring sites at Pocosin Lakes National Wildlife Refuge for the duration of the project period. Linear regression lines are color coordinated for respective wet deposition collection stations.

As noted previously, a fourth collector (PL04) was added as a duplicate sample in September 2008 and is currently co-located with PL03. Due to elevated nutrient concentrations in rainfall samples relative to other collection sites in the study and an evident increasing trend of nutrients in deposition at the nearfield PL03 site, we added this additional collector as a means of verifying site data. It is anticipated that PL04 will be run side-by-side with PL02 and PL01 during the remaining period of field collections for a limited duration as well. To date, only eight samples have been analyzed from the PL04 location, so an assessment of potential differences between results from PL03 and PL04 is premature; however, we have determined that the period that the arm and lid mechanism on PL03 remains open after the rain sensor is triggered and subsequently dries is longer than the "recovery period" after a wet event for PL04 (potentially due to equipment age, PL04 was constructed in summer 2008). We understand that NADP protocol neither measures this recovery period nor attempts to standardize it (with no substantive effect on site to site comparisons); however, given the proximity to the facility, we plan to further explore the potential for arm closure time to affect atmospheric exchange with rainwater samples prior to completion of the investigation next year. This information may be important in interpreting measured concentrations of nutrients in rainfall for the PL03 site in our final report; however, because PL03 has been continually used at the location nearest to the facility since 2005, site-specific assessment of relative trends are and will continue to be a meaningful indicator of potential influence from the facility.

Dry Deposition

Dry deposition represents the other major source of nitrogen deposition to the refuge; we are monitoring dry deposition through 1) passive dry deposition samplers to determine the depositional gradient from the source and estimate the source emission strength via modeling, and 2) an annular denuder systems deployed on the refuge to provide a detailed description of ambient atmospheric chemistry in the area.

Ammonia Dry Deposition Model

Passive samplers for NH_3 have been used since 2006 along the northern boundary of the facility and along the southern boundary of PLNWR to collect integrated measures of atmospheric NH_3 concentrations in order to model dry deposition to soil and plants within the refuge. The passive samplers are currently deployed along three transects. The position of the transects relative to the Rose Acres facility and date of deployment are shown in Figure 6.

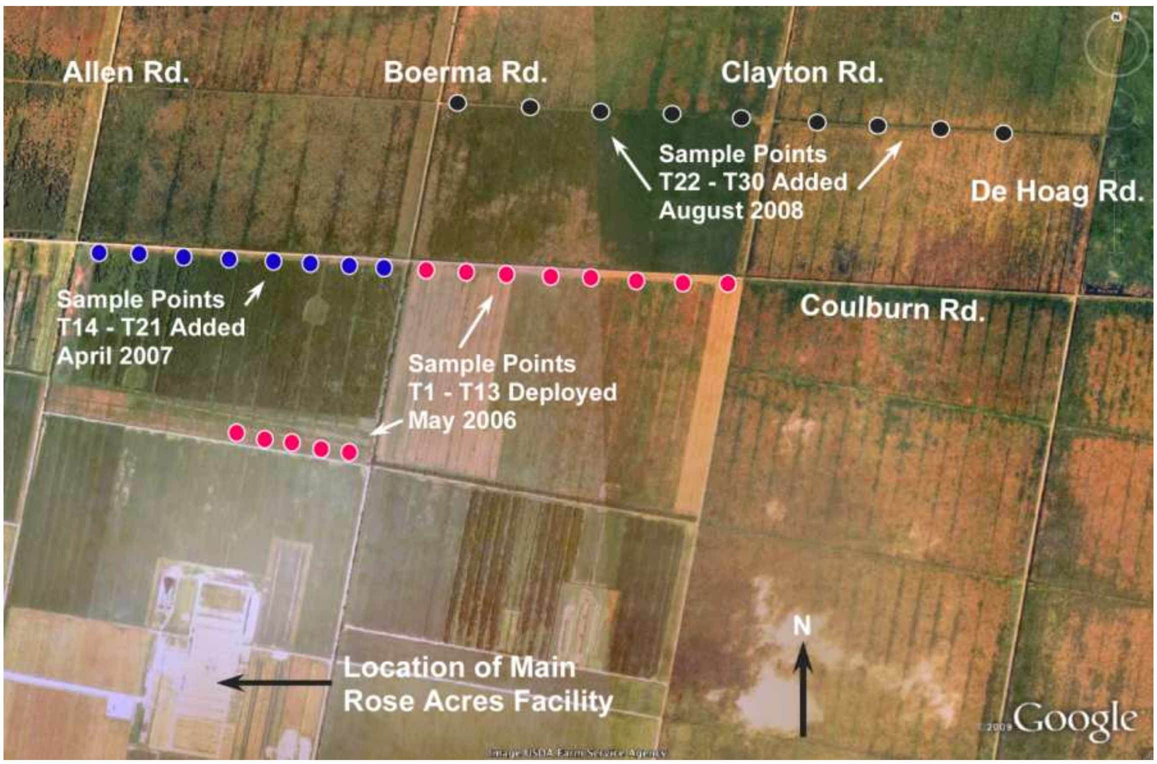

Figure 6. Current location, date of deployment, and number of sampling positions used to monitor atmospheric NH_3 concentrations along the southern boundary of the Pocosin Lakes National Wildlife Refuge. Each sampling position is equipped with ALPHA passive samplers (n=2 per station).

Besides the original 13 monitoring positions deployed in 2006, additional samples were added in 2007 and 2008. The original transect along the southern boundary of the refuge was extended in 2007 by the addition of 8 sampling positions. In August 2008, an additional 9 sampling positions were added inside the refuge along a road parallel to the southern boundary. An attempt has been made to rotate out the passives weekly during the warm months of the year, and bi-weekly during the cold months of the year. Collection of passive samples was suspended for almost a year from July 2007 to August 2008 due to unexpected staff limitations. From August 2008 to present, all sampling positions are being used with placement of passive samplers in duplicate at each position. Collection of samples from the passives collectors will continue through June 2010.

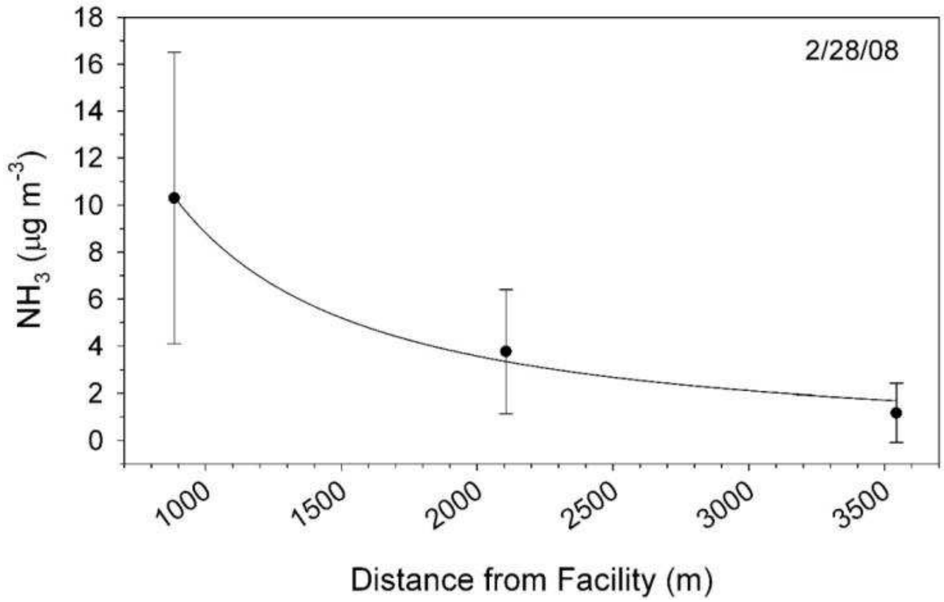

Figure 7. Mean integrated ammonia concentrations as a function of distance moving away from the north boundary of the poultry facility. Bars represent standard deviation of all passive collectors within a given transect. Data collected week of February 28, 2008.

Results to date indicate that ammonia concentrations decay in an exponential fashion moving away from the facility (Figure 7). Integrated ammonia concentrations at the farthest transect from the facility (distance of ~3500 m) are ~ 2 µg NH_3/m^3, which is still ~ 1 µg NH_3/m^3 higher than ambient atmospheric ammonia concentrations measured at the annular denuder tower (~10,300 meters north of the facility). The average integrated ammonia concentrations among all passive samplers within a given transect as a function of time are presented in Figure 8. The data in Figure 8 demonstrate that the deployed passive sampling network is capable of detecting changes in ammonia emissions from the facility over time. Particularly noticeable is an overall increase in integrated ammonia measurements along the northern edge of the facility property starting in December – January 2008. This trend seems to have continued through to April 2008. Visual inspection illustrates that this trend is mirrored by the passives samplers at the second transect (and possibly at the third transect), although at lower ammonia concentrations. The data will need to be further refined to account for wind direction distributions during a given sampling period. However, the data illustrate that continued sampling will likely provide additional evidence of trends if the flock size at the facility expands to its design capacity.

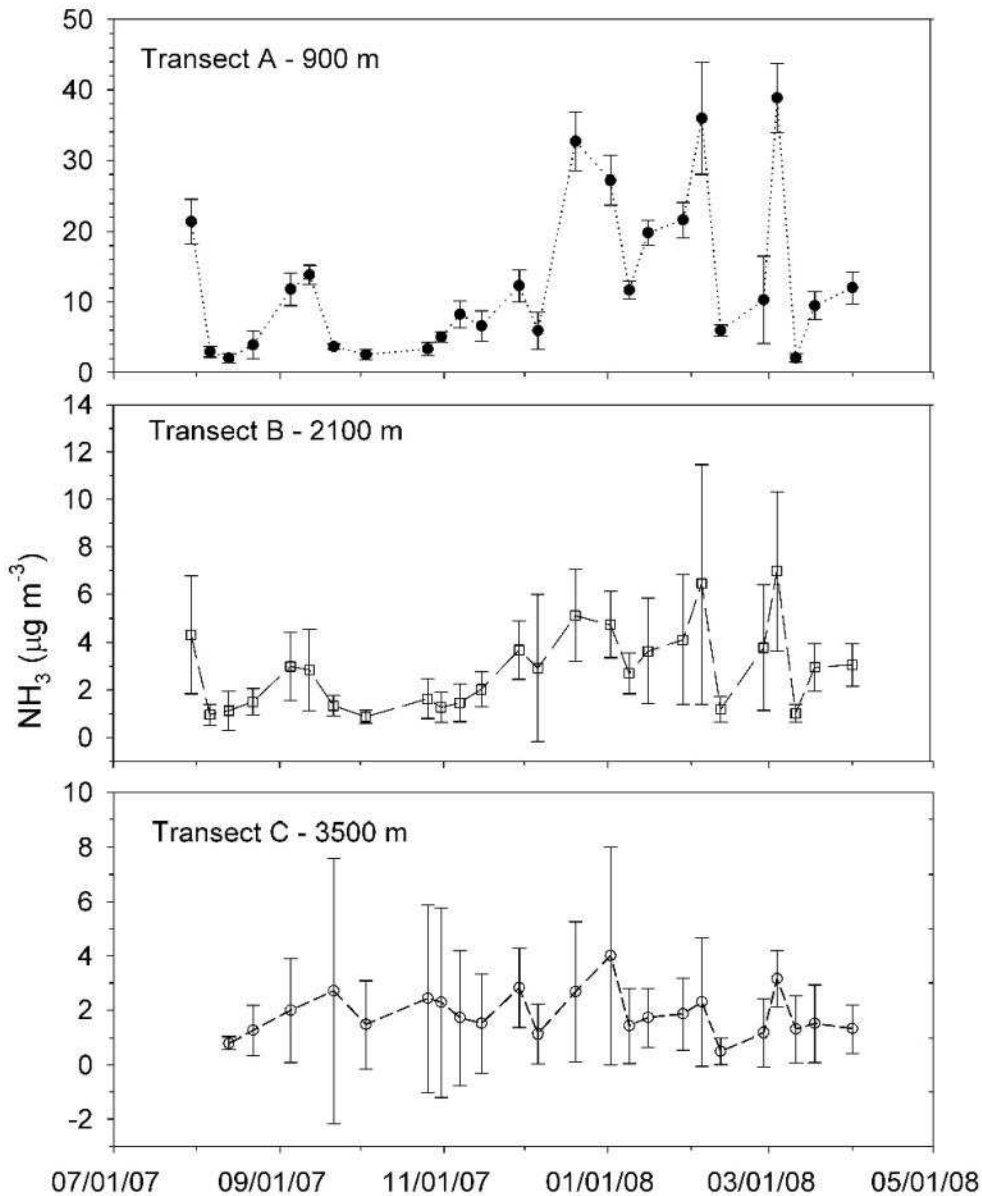

Figure 8. Average integrated ammonia concentrations among all passive samplers within a given transect as a function of time (typically sampling period one week). Distance shown corresponds to distance from the northern boundary of the Rose Acres facility.

In response to NCDWQ's request for information about dry deposition in the vicinity of the facility, ammonia data from the passive samplers to date were evaluated using a preliminary ammonia dry deposition model. Average measured ammonia concentrations since December 2007 were used in a concentration model to predict the distance from the facility at which the ammonia concentration declines to the background concentration, 0.5 µg NH_3/ m^3, which was determined from denuder measurements at a tower located ~10,300 meters north of the facility. The preliminary modeling analysis presented in Figure 9 is intended to demonstrate the spatial scale of the facility's influence on dry deposition to PLNWR, the temporal extent of this influence (fraction of time that PLNWR is influenced), and typical concentrations and dry deposition rates as a function of distance from the facility onto the refuge. Air concentrations are predicted as a nonlinear function of downwind distance based on average measured (passives) concentrations. Deposition vs distance was then calculated by applying a deposition velocity of 1.5 cm/s to the modeled concentration. This deposition velocity is within the range of values measured over short vegetation, but future sampling work is intended to provide site-specific air-surface exchange rates to refine deposition estimates and quantify uncertainty. Site-specific data collection (to be completed in the coming year) intended to reduce uncertainty associated with assumptions made in this preliminary model will allow us to complete a full analysis. That analysis will employ a bi-directional modeling framework (rather than the deposition velocity concept) to parameterize foliage and soil processes separately and will include a sensitivity/uncertainty analysis. The preliminary analysis presented in Figure 9 represents average conditions and does not illustrate the influence of wind direction on the spatial distribution of deposition or temporal variability associated with atmospheric stability, temperature, wind speed, etc., which will be characterized in the full analysis.

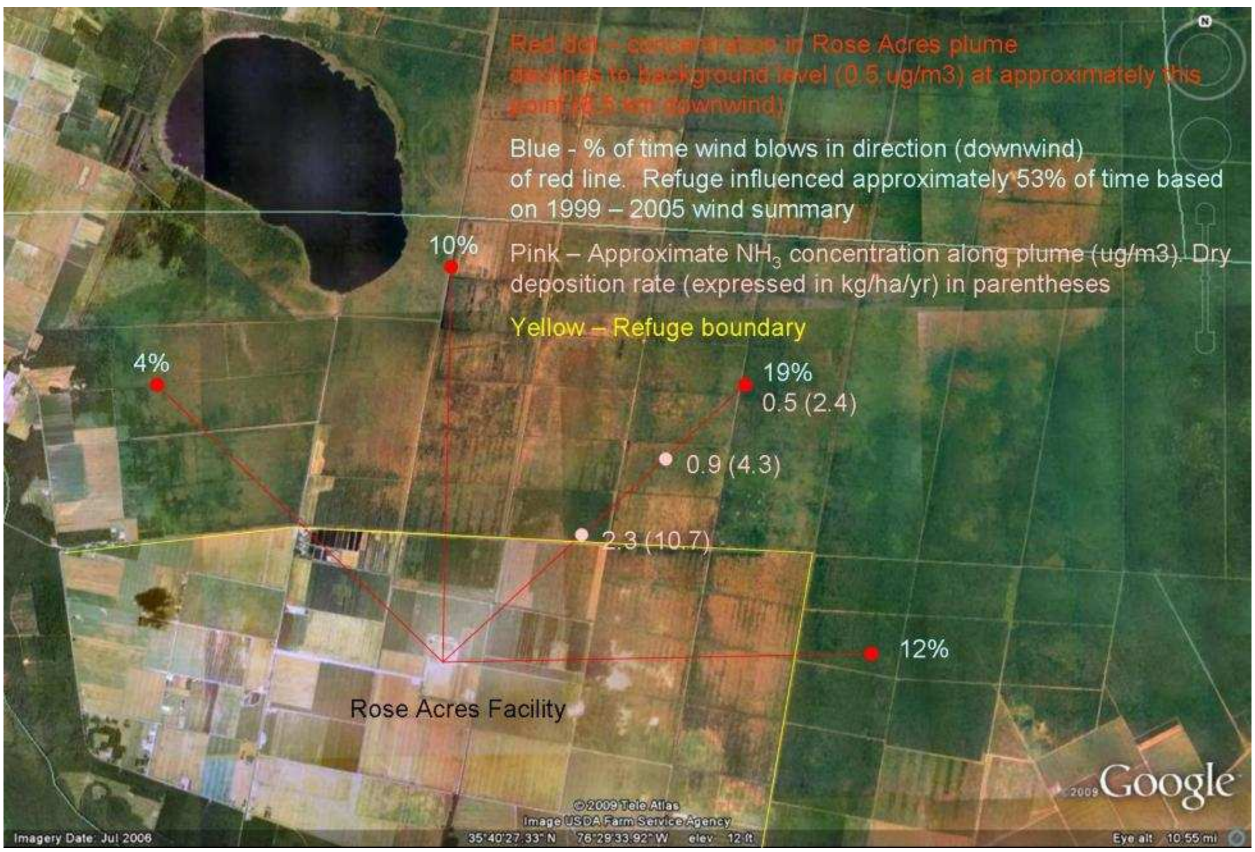

Figure 9. Predicted atmospheric ammonia concentration decay to the background concentration (0.5 µg NH_3/m^3). Model results estimate spatial scale and temporal extent of the facility's influence on dry deposition to Pocosin Lakes National Wildlife Refuge and typical concentrations and dry deposition rates as a function of distance.

Ambient Atmospheric Ammonia Chemistry

Annular denuder technology is being used to monitor ambient atmospheric ammonia chemistry at a fire tower within PLNWR (located approximately one mile south of Lake Phelps and 10,300 meters north of the facility). Operational periods for which samples have been collected include: January 19, 2007 to October 14, 2007, May 28, 2008 to August 20, 2008, and October 31, 2008 to present.

In order to provide a relative comparison of data for gaseous ammonia being collected using annular denuder technology at the PLNWR tower, the data collected in 2006 and 2007 were compared to results obtained using annular denuder technology near the US Environmental Protection Agency (USEPA) offices in the Research Triangle Park, North Carolina, to assess air quality in the Raleigh/Durham, Chapel Hill area of North Carolina. The USEPA site represents a more urban environment as compared to the relatively remote location of the refuge, which is influenced primarily by nearby intensive row crop agriculture. The descriptive statistics (count, mean, median, standard deviation, minimum and maximum) for each annular denuder sampling location are provided in Table 6.

Mean NH_3 concentration at the PLNWR location during 2007 was 0.65 µg NH_3 m^{-3} which was slightly higher than the calculated value of 0.49 µg NH_3 m^{-3} at the United States Environmental Protection Agency (USEPA) compound in the Research Triangle Park. However, sampling at PLNWR was terminated in early September 2007 due to equipment failure, as compared to the February to early December 2007 sampling period at the USEPA compound. Thus the data in Table 6 for 2007 at the refuge are biased towards the warmer months of the year. For comparison purposes, annular denuder data collected at the PLNWR site from July 2005 to August 2006 are also summarized in Table 6. Measured ammonia concentrations during this sampling period, which extended over 365 days, are very similar if not equal to those observed at the USEPA compound. The only difference is that the maximum values recorded at PLNWR are two to three times higher than the maximum value recorded for the USEPA location in 2007. For the period 2005 – 2006 at PLNWR, it was confirmed that poultry litter had been applied to agricultural fields at the southern boundary of the refuge in late October – early November. Temporal plots of the data demonstrated that all observed NH_3 concentrations above 2 µg NH_3 m^{-3} occurred during this brief time period. The maximum concentration of 2.57 µg NH_3 m^{-3} observed at PLNWR location in 2007 may have been influenced to some degree by local agricultural activities as well, but no on-site observations were made to confirm this assumption.

Table 6. Summary of descriptive statistics for annular denuder samplers. PLNWR = Pocosin Lakes Wildlife Refuge, Washington, Co., NC; USEPA Compound = air monitoring compound located near the US Environmental Protection Agency offices in the Research Triangle Park, NC.

Site	Dates	N	Mean	Median	Stdev.	Min.	Max.
			– µg/m3 -	– µg/m3 -	– µg/m3 -	– µg/m3 -	– µg/m3 -
PLNWR	Jan.-Sept. 2007	197	0.65	0.55	0.48	0.01	2.57
PLNWR	July-Aug. 2005/2006	365	0.49	-	0.46	0.01	5.42
USEPA Compound	Feb.-Dec. 2007	318	0.49	0.46	0.31	0.01	1.60

Temporal trends in the measured NH_3 concentrations at both locations in 2007 are shown in Figures 10 and 11. At the US EPA compound, all observations except one, were < 1.5 µg NH_3 m^{-3}, and the majority were < 1 µg NH_3 m^{-3}. There is a suggestion of slightly higher NH_3 concentrations during the warm months of the year, but the trend is relatively weak.

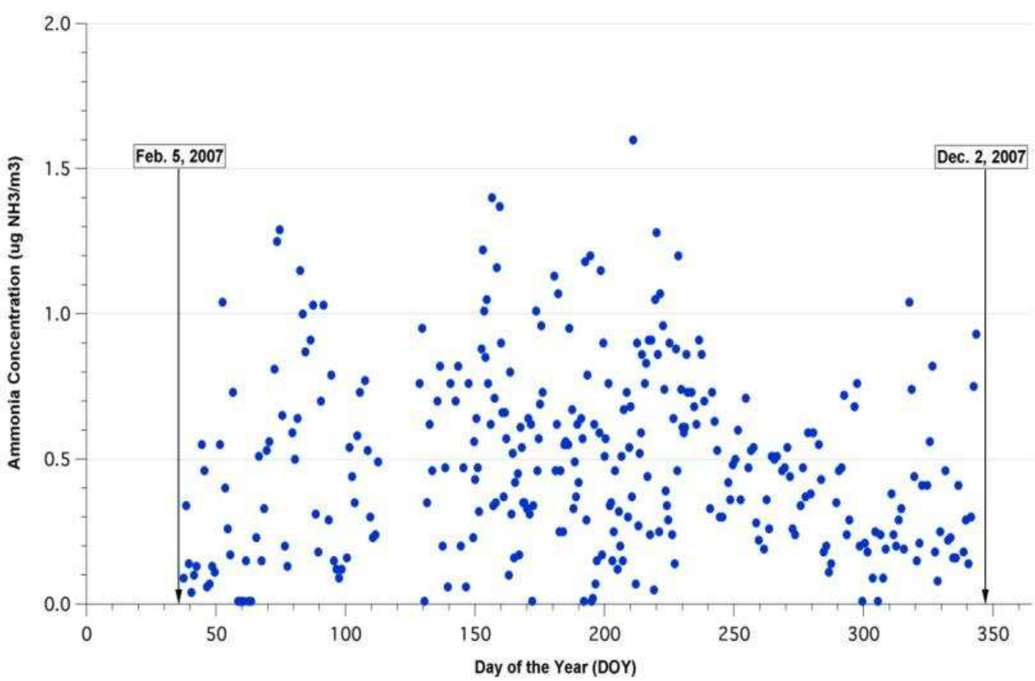

Figure 10. Daily (24 hour integrated average) NH_3 concentrations as measured using annular denuder technology at the air monitoring compound located near the US Environmental Protection Agency offices in the Research Triangle Park, NC. Sampling period: Feb. – Dec. 2007.

As with the USEPA compound samples, the temporal trend in NH_3 concentrations at PLNWR is relatively weak with the majority of observations < 1.5 µg NH_3 m^{-3}. Those observations above 1.5 µg NH_3 m^{-3} are in general scattered throughout the measurement period and not confined to any one season of the year.

Comparison between the PLNWR tower location and the USEPA compound site demonstrate that measurements at the refuge tower continue to provide a valid measure of ambient atmospheric gaseous NH_3 concentrations in the region. Comparison of the data in Table 6 supports the conclusion that there has not been a shift on ambient atmospheric NH_3 in the region over the past several years. However, a more detailed analysis of measured concentration versus dominant wind direction during a given 24-hour measurement period has not yet been conducted. Such an analysis (planned in the upcoming year) could reveal a possible influence in ambient NH_3 concentrations form a strong upwind source.

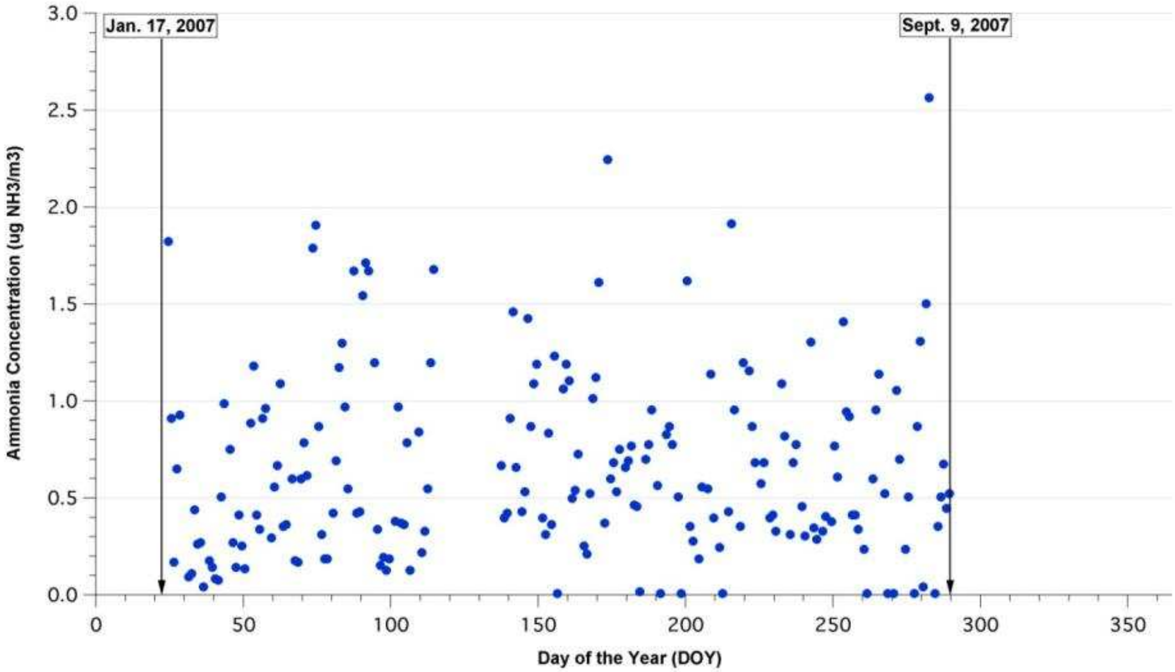

Figure 11. Daily (24 hour integrated average) NH_3 concentrations as measured using annular denuder technology at the Pocosin Lakes Wildlife Refuge, Washington, Co., NC. Sampling period: Jan. – Sept. 2007.

Water Quality Monitoring

Four water quality stations were selected for bimonthly monitoring to complement ten existing biweekly monitoring stations established by NCDWQ for a special study of the water quality conditions in the vicinity of the facility. Service water quality monitoring stations were sited on Hyde Park canal (which drains from the refuge) in two locations: upgradient from the facility at the confluence with Pungo Lake and approximately one mile downgradient from the facility. Remaining sites were located at Lake Phelps (at the Pettigrew State Park boat ramp) and on the Scuppernong River adjacent to refuge headquarters. Samples were collected by Service staff and delivered to NCDWQ labs for analysis. Parameters analyzed are identical to those evaluated at the NCDWQ special study stations with one exception: measurements of chlorophyll *a* were performed on Service samples. A comprehensive review and analysis of available Service water quality data to date is not yet complete. If consideration of these data would be meaningful to NCDWQ during the permit renewal process, we would be happy to complete an interim analysis.

These data are also available through NCDWQ's chemistry lab, which completed the surface water analyses for this study (Station IDs = PLSW-01 through PLSW-04).

Nutrient Enrichment Bioassays

The potential effects of nutrient deposition on algal primary production, biomass and community composition in refuge waters has been examined by completing nutrient addition bioassays to local water samples (conducted seasonally in 2006-2008 on water collected from Lake Phelps and Alligator River). By adding nitrogen and phosphorus incrementally (individually and in combination), it is possible to realistically and accurately gauge the relationship of the phytoplankton community to a range of concentrations of nutrient inputs. This is an important component of the study given that taxa-selective phytoplankton responses to nutrient inputs may induce specific changes at the zooplankton, herbivorous fish, invertebrate, and higher consumer levels. These bioassays were conducted such that the incremental nutrient additions bracketed estimated depositional loads from the facility at full capacity. When deposition sampling and modeling is complete, we will be able to confirm the range of concentrations and responses from our manipulations to predict how the system will respond to chronic nutrient inputs from the new operation over time. All nutrient addition bioassays for the study were completed by Fall 2008; however, final interpretation of these results and potential systemic responses relative to depositional loading is pending completion of the deposition sampling / modeling still underway. Interim results for each bioassay completed to data are available for NCDWQ's review upon request.

The Service appreciates the opportunity to share these interim results with NCDWQ. Our staff and project partners would be pleased to discuss these interim results with NCDWQ further. In general, these interim results indicate that the facility is affecting air quality conditions at PLNWR (particularly near the southern boundary of the refuge); however, the full extent of these effects and any impacts on resources the Service manages in the public trust will not be known until all components of the ongoing study are complete and a comprehensive assessment is performed. Consistent with prior Service comments during the facility permitting (July 14, 2005 letter to Secretary William Ross from Pete Benjamin), the best mechanism to assess potential facility emissions impacts and best management practices (BMP) efficacy is through on-site measurement of NH_3 emissions. Although this study will utilize a weight of evidence approach to assess potential environmental effects of emissions from the facility when complete, the Service maintains that emissions monitoring (at least for a demonstration period encompassing representative seasonal conditions) is essential to gauge the effectiveness of facility BMPs and any potential detrimental impacts to this nutrient sensitive area. If you have any questions regarding our preliminary data assessment / interpretation or would like to meet, please contact me at Sara_Ward@fws.gov or 919/856-4520 (ext. 30).

Enclosure

cc: Howard Phillips, Refuge Manager, PLNWR
Dr. John Walker, USEPA, Research Triangle Park, NC
Dr. Wayne Robarge, NCSU, Raleigh, NC
Dr. Hans Paerl, UNC-IMS, Morehead City, NC