Pre-construction water quality monitoring of the *Upper Susquehanna River Watershed-Cooperstown Area Ecosystem Restoration Feasibility Study And Integrated Environmental Assessment*

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ABSTRACT

From March to September 2003, the Biological Field Station conducted weekly pre-construction water quality monitoring at three sites selected in the United States Army Corps of Engineers *Upper Susquehanna River Watershed-Cooperstown Area Ecosystem Restoration Feasibility Study And Integrated Environmental Assessment.* The sites monitored were Daley, Palumbo and Rum Hill (the latter serving as a reference site). Monitoring consisted of chemical, physical and biological parameters designed to measure the ability of the restored sites to retain nutrients, bacteria, and sediment as compared to the 'pristine' reference site. Values for total nitrogen, nitrate, ammonia, total phosphorus and fecal coliform were significantly higher (ANOVA, $P<0.05$) at the Daley site with no significant differences between Palumbo and Rum Hill. For suspended sediments, both Daley and Rum Hill were similar while both were significantly higher than Palumbo. No significant differences were found between sites for temperature, dissolved oxygen or pH. However, conductivity was significantly different between sites in the order of Daley>Palumbo>Rum Hill. Land use during the sampling period differed substantially between sites. Although site comparisons have limited value at this time, pre-construction data will serve as a baseline with which post-construction data sets, collected annually hereafter, can be compared.

INTRODUCTION

Agricultural and urban development causes nutrients to become concentrated at upland sites (Drexler and Bedford 2002; Detenbeck et al 2002). The subsequent flux of these nutrients through ground and surface water flow often overwhelms the receiving waters; the ability of lakes, rivers, and streams to normally assimilate and transport these nutrients is limited and often results abnormally high productivity (Kadlec and Knight 1996). Historically, wetland ecosystems have occupied a position in the natural landscape between upland sites and down-slope water bodies (Mitsch and Gosselink 2000) often putting the water table at, or very close to, the soil surface. This condition, often combined with poor drainage, gives wetlands their characteristic hydric soils, as well as making them the repository of dissolved nutrients and particulate matter. However, where wetlands once occupied approximately 1 million hectares in 18th century New York State, by the mid – 1980s a reduction of 60% had been recorded (Dahl 1990).

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Naturally, this drastic reduction in overall area was coupled with an equally severe reduction in function. In recent decades, the scientific community has begun to identify and quantify the many beneficial functions that natural wetlands provide to the surrounding landscape. Termed ‘ecosystem services’, these functions include product export, flood attenuation, wildlife habitat, and retention of sediments, nutrients, and harmful pathogens (Mitch and Gossselink 2000). With this new appreciation and the realization of the scope of wetland destruction that has taken place over the previous century, large scale efforts at all levels of government have been initiated to replace these lost ecosystems.

In 2001, data recovered during the reconnaissance phase of the study identified eight *Field Assessed Benefit and Design Strategy* sites (FABADS) in Otsego County. These are the physical locations of the “degraded” wetlands, defined by the National Resource Conservation Service (NRCS) as being wetlands subject to extensive agricultural uses within the last 100 yrs. One purpose of the FABADS restorations is to provide the data that will validate the assumptions made in the current scientific literature about the ability of wetland ecosystems to retain nutrients and thus evaluate the effectiveness of the project. Additionally, the data will be used to allow for design and operation adjustments to be made before initiating additional projects in the area (ACE 2001).

In 2002, the SUNY Oneonta Biological Field Station (BFS) contracted with the U.S. Fish and Wildlife Service through the US Army Corp of Engineers (ACE) to participate in the 1.6 million dollar *Upper Susquehanna River Watershed-Cooperstown Area Ecosystem Restoration Feasibility Study And Integrated Environmental Assessment.* Authorized by the U.S. Congress, the pilot program is to “use wetland restoration, soil and water conservation practices, and non-structural measures to…improve water quality…in the Upper Susquehanna River Basin…” (ACE 2001).

In March 2003, the Biological Field Station began weekly water quality (WQ) monitoring at three of the eight areas selected as FABADS sites. The sites being monitored are Daley, Palumbo and Rum Hill (which serves as a reference site). Monitoring consists of a suite of chemical, physical and biological parameters designed to measure the ability of the restored sites to retain nutrients, bacteria, and sediment over time and as compared to the ‘pristine’ reference site. Although site comparisons support no conclusions at this time, the pre-construction data presented here will serve as a baseline with which post-construction data sets, collected annually hereafter, can be compared.

METHODS

Water samples were hand collected weekly at the main outflows of each site monitored from March to September 2003. Samples were transferred from the field to the lab and refrigerated immediately. Analysis of all chemical parameters took place within 72 hours and under the maximum storage recommended by the EPA (EPA 1984).

Samples were analyzed at the BFS for total phosphorus (TP) using persulfate digestion followed by single reagent ascorbic acid method (APHA 1992). Nitrate+nitrite nitrogen (NO_2+NO_3) levels were tested by using the cadmium reduction technique (APHA 1992). Additionally, samples were analyzed for total nitrogen (TN) using persulfate oxidation followed by ultraviolet spectrophotometric screening and ammonia (NH_3) concentrations were determined using the phenate method (APHA 1992).

Samples were also tested for fecal coliform bacteria (FC) using the membrane filter technique (APHA 1992) within 12 hrs of collection. Total suspended solids (TSS) were calculated as the difference of the initial and final weight of a pre-weighed standard glass-fiber filter after filtration (APHA 1992). Physical parameters, such as pH, temperature (T), dissolved oxygen (DO) and conductivity (COND) were recorded on site with the use of a Hydrolab Scout 2® or a Surveyor 4® multiprobe digital microprocessor which had been calibrated according to manufacturer's instruction immediately prior to use (Hydrolab Corp.1993).

Analysis of variance (ANOVA) was performed on all parameters to detect significant differences between sites. All parameters measured are reported as means for each data set (± 1 SE).

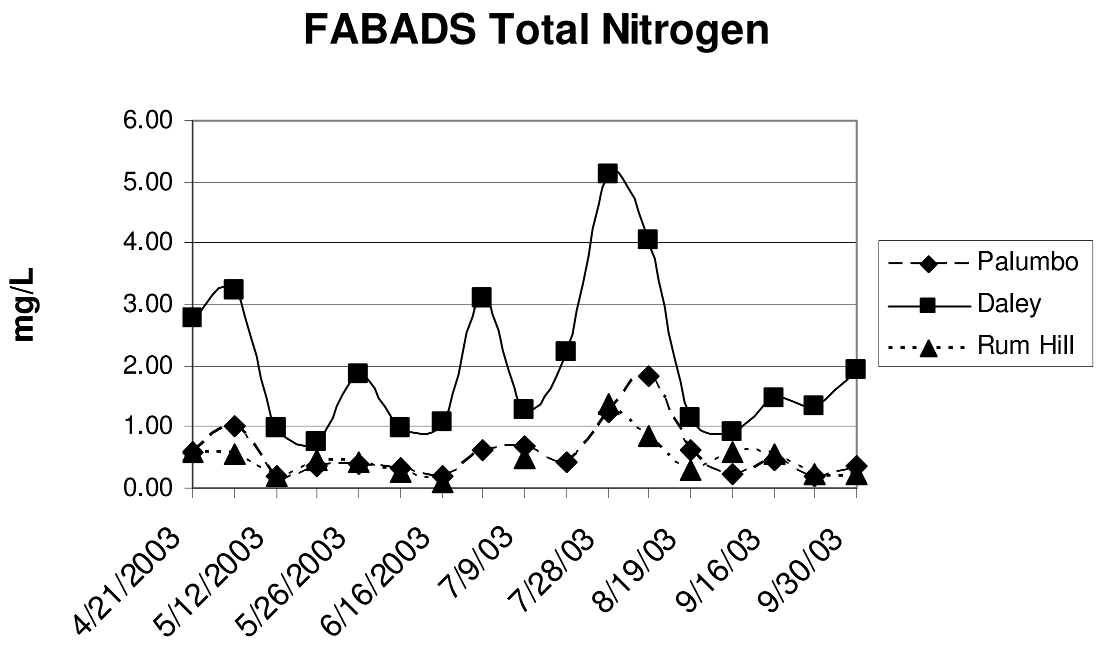
RESULTS

The Daley site had the highest concentrations of all nutrient parameters measured, the most suspended sediments and fecal coliform and the highest conductivity ($P<0.05$) of the three sites. Table 1 below shows significant differences between sites for the parameters measured. Temporal trends for each parameter are shown in Figures 1-4. Monthly means (±SE) of each site and all parameters are shown in Tables 1 and 2.

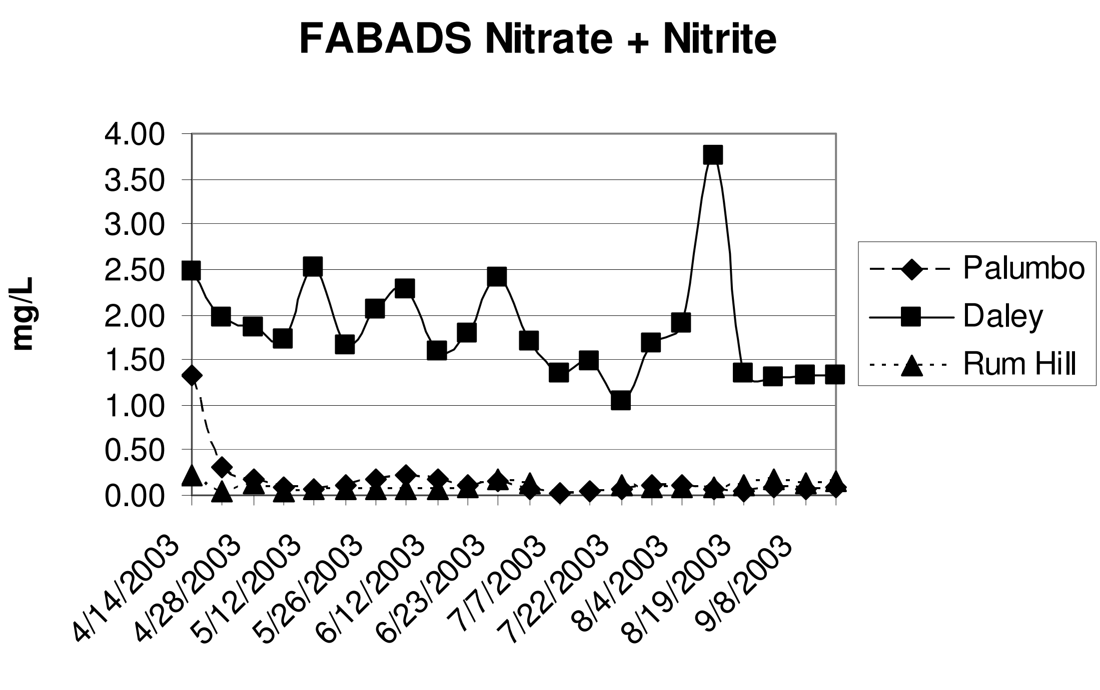
Parameter	FABADS Comparisons
Total Nitrogen	Daley>Palumbo=Rum Hill
Nitrate+Nitrite	Daley>Palumbo=Rum Hill
Ammonium	Daley>Palumbo=Rum Hill
Total Phosphorus	Daley>Palumbo=Rum Hill
Fecal Coliform	Daley>Palumbo=Rum Hill
Total Suspended Solids	Daley=Rum Hill>Palumbo
PH	NS
Temperature	NS
Conductivity	Daley>Palumbo>Rum Hill
Dissolved Oxygen	NS

Table 1. The statistical relationships of the FABADS sites for all parameters measured (NS = no significant difference).

FIGURE 1. Total nitrogen and nitrate+nitrite concentrations for Daley, Palumbo, and Rum Hill during 2003. ANOVA results, shown below, are significant differences (P<0.05) between sites.

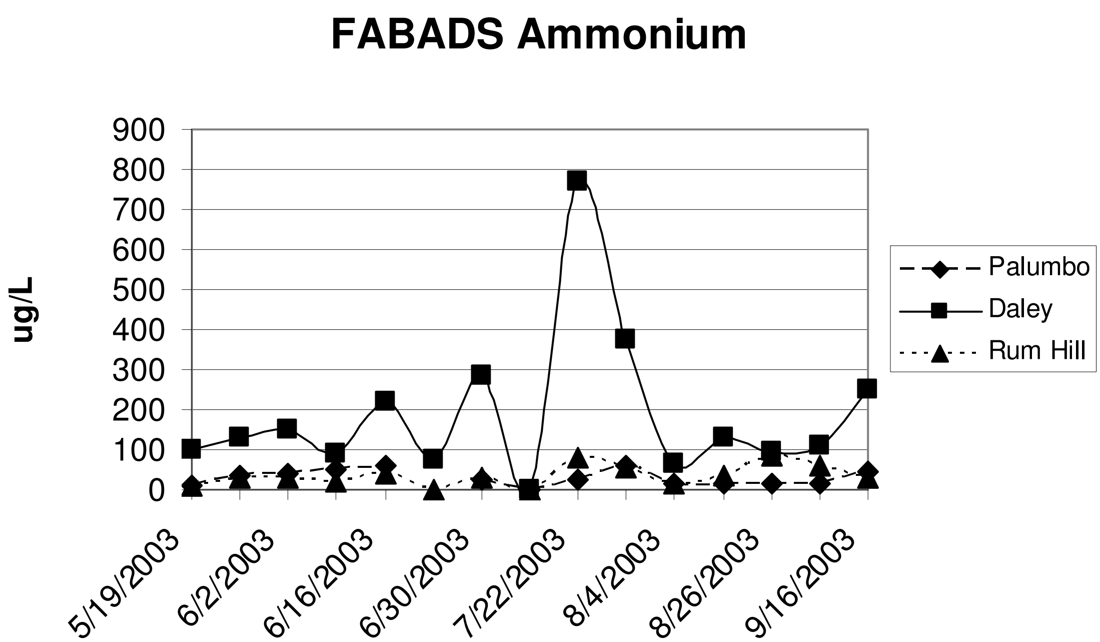


Daley > Palumbo > Rum Hill (N=46, P < 0.001)

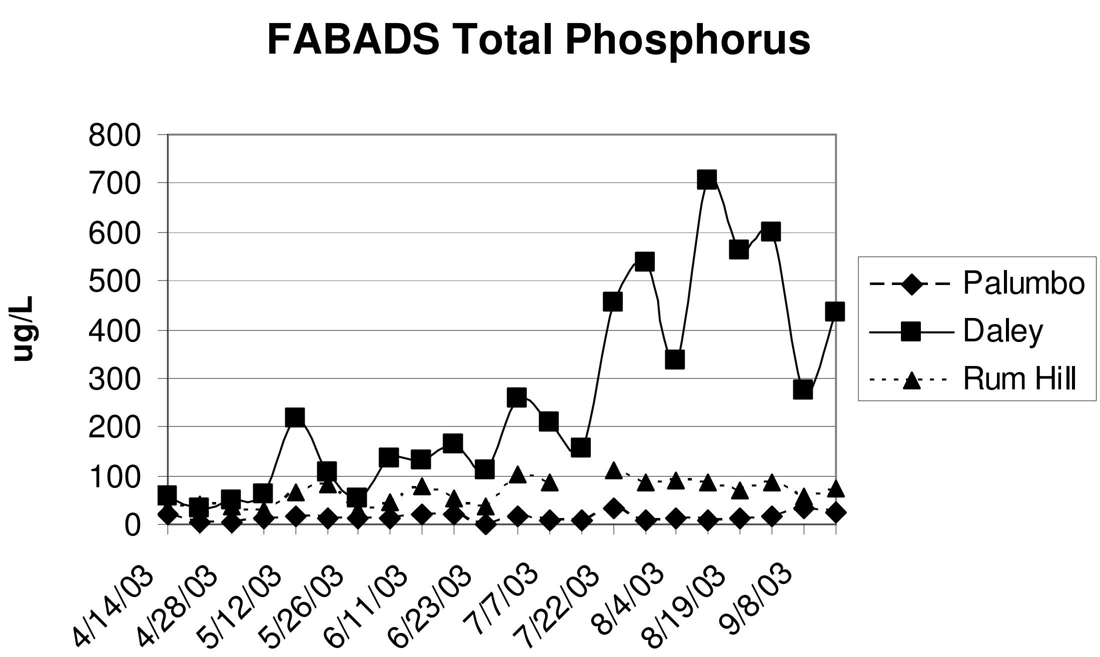


Daley > Palumbo > Rum Hill (N=61, P < 0.001)

FIGURE 2. Ammonium and total phosphorus concentrations for Daley, Palumbo, and Rum Hill during 2003. ANOVA results, shown below, are significant differences (P<0.05) between sites.

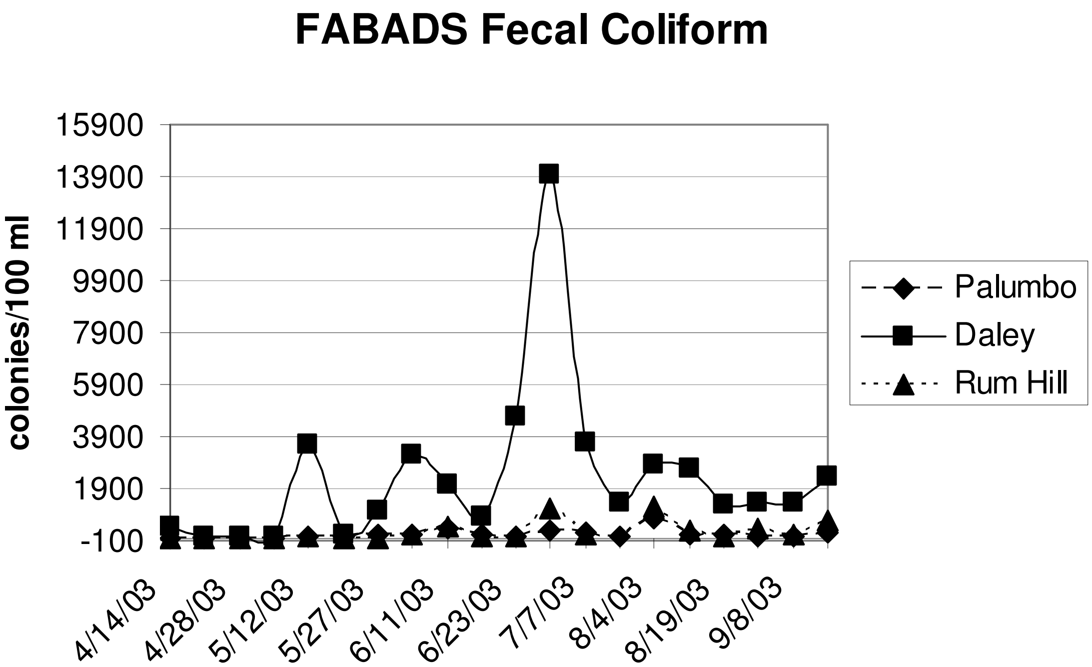


Daley > Palumbo = Rum Hill (N=41, P=0.001)

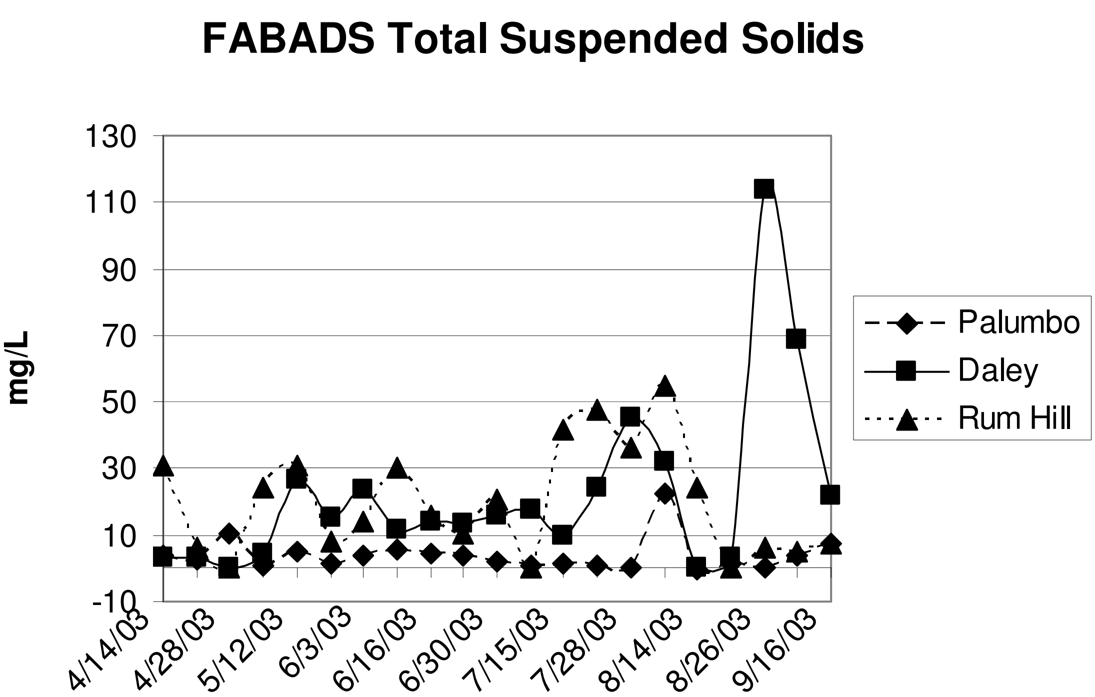


Daley > Palumbo = Rum Hill (N=62, P<0.001)

FIGURE 3. Fecal coliform and total suspended solids concentrations for Daley, Palumbo, and Rum Hill during 2003. ANOVA results, shown below, are significant differences (P<0.05) between sites.

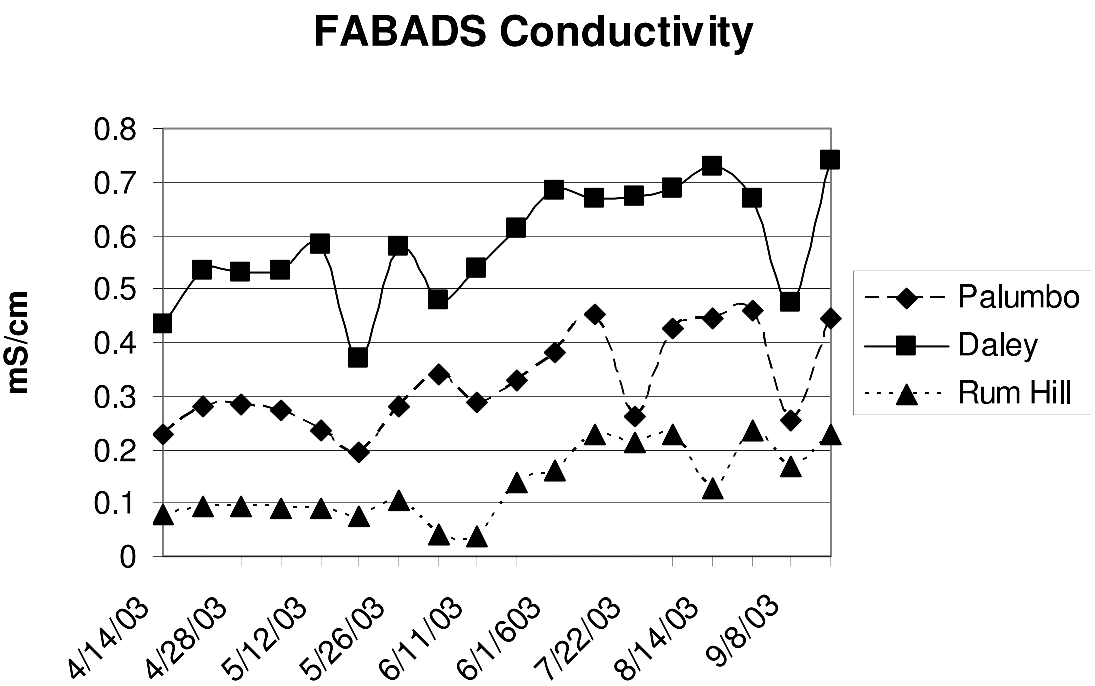


Daley > Palumbo = Rum Hill (N= 59, P<0.001)



Daley = Rum Hill > Palumbo (N=60, P=0.004)

FIGURE 4. Conductivity and pH for Daley, Palumbo, and Rum Hill during 2003. ANOVA results, shown below, are significant differences (P<0.05) between sites.



Daley > Palumbo > Rum Hill (N=51, P<0.001)

Table 2. Nitrate + Nitrite (NO3), ammonium (NH4), total nitrogen (TN), total phosphorus (TP), total suspended sediment (TSS) and fecal coliform (FC) counts for FABADS sites between April and September 2003. Data are means ± SE.

	Parameter					
Site/Month	NO_3 (mg/L)	NH_4 (ug/L)	TN (mg/L)	TP (ug/L)	TSS (mg/L)	FC (#/L)
April						
Palumbo	0.65±0.20	NA	0.79±0.22	10.67±2.58	4.15±2.18	5.11±3.13
Daley	2.13±0.11	NA	2.99±0.22	47.31±3.18	1.50±0.87	192.67±138.03
Rum Hill	0.14±0.03	NA	0.58±0.01	36.32±5.90	9.20±7.34	1.78±0.56
May						
Palumbo	0.11±0.02	23.71±7.03	0.31±0.06	13.60±2.72	2.40±1.22	55.83±24.12
Daley	1.99±0.11	115.28±8.61	1.19±0.34	112.94±20.94	15.33±6.41	1207.67±8.35.29
Rum Hill	0.05+0.01	19.57+4.28	0.35±0.08	53.36+10.64	21.00+6.69	26.42+20.34
June						
Palumbo	0.16±0.01	36.36±6.69	0.38±0.13	13.26±2.83	3.91±0.66	185.13±52.53
Daley	1.93±0.09	160.49±24.42	1.71±0.69	153.56±13.33	12.59±2.07	4921.73±2351.02
Rum Hill	0.10±0.02	25.47±4.93	0.19±0.08	60.06±6.87	18.10±3.40	356.00±210.61
July						
Palumbo	0.06±0.01	41.69±10.55	0.78±0.24	13.70±3.82	0.95±0.29	125.50±67.50
Daley	1.39±0.10	572.97±93.67	2.87±1.16	318.55±57.49	24.25±7.58	2513.95±1168.98
Rum Hill	0.10±0.02	67.78±17.42	0.92±0.44	94.92±9.68	31.35±10.72	153.00±0.00
August						
Palumbo	0.08±0.02	14.60±8.85	0.89±0.49	11.95±2.39	5.95±5.43	255.17±157.38
Daley	1.84±0.34	95.38±14.55	2.03±1.01	416.75±93.75	37.35±26.54	2039.17±417.21
Rum Hill	0.12±0.02	45.47±14.66	0.58±0.16	83.30±4.89	21.30±12.29	466.00±255.33
Sept						
Palumbo	0.09±0.01	69.66±22.09	0.34±0.08	27.59±9.70	5.60±1.80	136.33±89.67
Daley	1.20±0.05	192.47±36.26	1.57±0.18	258.03±9.83	45.40±23.40	1860.00±466.67
Rum Hill	0.14±0.02	54.36±18.00	0.34±0.11	101.26±30.29	6.40±1.20	422.18±268.86

Table 3. Conductivity (COND), pH, temperature (TEMP), and dissolved oxygen (DO) for the FABADS sites between April and November 2003. Data are means ± SE.

	Parameter			
Site/Month	pH	COND (mS/cm)	TEMP (C)	DO (mg/L)
April				
Palumbo	8.02±0.14	0.263 ± 0.018	14.17±1.74	8.73±0.62
Daley	8.11±0.05	0.500±0.033	12.24±2.29	11.03±0.72
Rum Hill	8.11±0.11	0.089±0.005	12.91±1.72	10.39±0.73
May				
Palumbo	7.66±0.04	0.247±0.020	12.35±1.04	6.78±0.61
Daley	7.90±0.05	0.518±0.050	12.38±0.87	8.39±1.00
Rum Hill	7.26±0.08	0.089±0.007	14.84±0.67	8.29±0.95
June				
Palumbo	7.81±0.03	0.335±0.019	13.64±0.36	7.66±0.77
Daley	7.67±0.24	0.579±0.045	13.74±0.68	7.62±0.61
Rum Hill	7.72±0.15	0.094±0.032	15.13±0.44	7.12±0.83
July				
Palumbo	7.81±0.03	0.357±0.079	19.45±1.39	7.57±0.14
Daley	7.67±0.24	0.670±0.002	19.38±2.84	5.73±0.68
August				
Palumbo	7.37±0.06	0.368±0.086	16.78±0.77	6.43±1.21
Daley	7.55±0.09	0.695±0.024	17.27±0.83	6.80±0.55
Rum Hill	7.47±0.16	0.272±0.136	19.23±0.90	4.65±0.23
Sept				
Palumbo	7.37±0.1	0.349±0.096	16.14±0.53	7.94±0.14
Daley	7.68±0.13	0.607±0.132	15.99±0.62	5.66±0.45
Rum Hill	7.68±0.07	0.200±0.030	15.23±0.90	5.64±0.56

DISCUSSION

FABADS

The high values observed at the Daley site (Table 1, Figs. 1-3) are most likely the result of the site being used as an active cow pasture that is surrounded by agriculture. During pre-construction monitoring the site had no barrier preventing the cattle from entering the main above-ground channalized stream flow from which the samples were taken. Observations in the field confirm the frequent presence of cows in the stream. Naturally, when not contributing nutrients (i.e. defecating) directly into the stream, the cows use the pasture along both sides. These soils, in addition to those of the surrounding corn crops, are the main nutrient input to the stream. The high variation over time may be the result of precipitation events and localized disturbances occurring upstream from the sampling point.

It is hoped that by changing the landscape to form shallow pools, conditions will promote the retention of N and P. As the site with the highest N and P concentrations, the Daley site has the greatest potential to show the nutrient reductions intended by the wetland restoration. The main mechanism responsible for P uptake is chemical adsorbtion - precipitation, that is, the bonding of phosphate to the ion exchange sites of elements such as iron (Fe), aluminum (Al), calcium (Ca), and clay particles found in the soil (Nichols 1983). However this simple chemical reaction is influenced by pH, ambient P concentrations in standing water, soil organic matter (SOM), and the duration and quantity of P loading. To a lesser extent, P retention is influenced by vegetative and microbial uptake and immobilization.

The shallow pools created are also intended to promote N reduction which is primarily biologically mediated. Plant communities serve to some degree to take up N temporarily, but mainly influence retention by their ability to resorb the nutrient to below ground biomass and in the quantity and quality of the litter they return to the soil for mineralization (Findlay et al. 1990; Windham 2001; Meuleman et al. 2002). Many of the pools and pathways of N cycling are microbial. Therefore, the wetland restoration is intended to create the anoxic conditions necessary for the microbially mediated process of denitrification (Groffman and Hanson 1997), whereby N is lost directly to the atmosphere as the result from anaerobic respiration (Nichols 1983).

By slowing the velocity of the aboveground water flowing through the system, the creation of standing water will also help to reduce the high total suspended sediment export, as well as associated P, of the Daley site. In addition, removal of dairy animals from the catchment of the restored wetland will reduce the amount of fecal coliform, present in their gut and feces, entering the system.

The Palumbo site, which is also surrounded by crop land, had relatively low nutrient concentrations (Tables 1-3) and was most consistently near or below the values recorded at Rum Hill (Figs. 1-3). This is most likely the result of a lack of physical disturbance and the dense vegetative cover buffering the main stream that flows through the site. The restoration effort at this site is intended to produce similar conditions as for the Daley site. Because of the low initial values for N, P, TSS, and FC, the degree of improvement to WQ can be expected to be small. However, these consistently low values will provide excellent baseline data for evaluating the disturbance of restoration. Although necessary, the use of heavy excavating equipment for moving large amounts of soil may release N, P and TSS from the newly submerged soil and vegetation. This potential scenario presents the opportunity to measure ecosystems functioning as nutrient sinks as the wetland develops the biogeochemical pools and pathways necessary for nutrient retention.

It's important to note the substantial differences in landscape between the Rum Hill site and the FABADS sites during pre-construction monitoring. Whereas the Rum Hill site is an established wetland that is surrounded by land that has been free from agriculture for over 60 years, the FABADS sites were not wetlands per se, but rather wet areas impacted by agriculture suitable for restoration. As such, the low values recorded at the Rum Hill site reflect its age, stability and isolation from anthropogenic influence. An exception to these characteristically low values exists for TSS (Table 1 and 2, Fig. 2). Although the TSS (mg/L) for the 'pristine' Rum Hill wetland was similar to the amount at the Daley site, the conditions influencing both differ between sites. The TSS coming off the Daley site was most likely the result of the high velocity of the channalized flow carrying sediment from localized disturbances. The Rum Hill site has had years to accumulate detritus and sediment that is easily displaced despite the increased residence time (reduced flow) created by the wetland.

While not nearly as high as the Daley site, Figure 2 shows TP concentrations at the Rum Hill wetland to be greater than that of the Palumbo site. However, the typical positive correlation between TSS and TP for urban storm water runoff does not exist. This may be the result of material lower in P (detritus) constituting the bulk of the suspended particulate matter rather than phosphate bonded to the ion exchange sites of clay particles.

Another interesting relationship is the significant difference in COND between sites (Table 1, Fig. 4). Although not the only ion that would have such an effect, a possible explanation for this relationship comes from a one-time measurement of calcium content from the waters of each site. Determined by the EDTA titrimetric method (EPA 1983), the trend in calcium concentrations was identical to that of COND; Daley>Palumbo>Rum Hill (93.8, 68.9 and 34.5 mg Ca/L respectively).

<u>Future Monitoring</u>

As of December 2003, FABADS sites were surveyed, designed, and constructed under the supervision of Ducks Unlimited, Inc. (DU). In general, the overall design for all the FABADS sites was to create a berm at the outflow of the site that will serve to restrict aboveground flow. Each berm was fitted with a flood control device that allows water to flow once a predetermined water table level has been surpassed. The flood control devices installed at the three wetlands to be monitored will be fitted with v-notch weirs, flow meters and auto-samplers (models). This instrumentation will enable the BFS to calculate the amount of nutrients, nitrogen (N) and phosphorus (P), in the inflow and out flow of the wetland as well as many other physical parameters. These data will then be used in calculating the overall nutrient budget and nutrient retention ability (nutrients in minus nutrients out) for each restored wetland and the reference.

The nutrient budgets, and the results they yield, will be an indirect measurement of the collective processes that function to retain nutrients and sediment. Not surprisingly, the main factor influencing all nutrients cycling in wetland ecosystems is water (Carter 1986; Mitsch and Gosselink 2001). The hydrology of the system reflects flood duration, water table fluctuations, retention times, redox potentials, nutrient cycling and erosion as well as being a major vector for the transportation of nutrients (Ponnamperuma 1972; Mitsch and Gosselink 2001; Seybold et al. 2002). Additionally, hydrology will determine the vegetative composition by exclusion of all species not adapted to hydric soils, and influence microbial activity by limiting oxygen availability (DeLaune and Pezeshki 1991).

Success will be measured as the degree to which the restored wetlands approximate the reference site and improve in their ability to retain each nutrient fraction over time. How much time is required before a conclusion can be made and what is actually practiced is still a matter of some disagreement. Current estimates in the literature range from 5 to 20 years before the ecosystem can stabilize after the disturbance of the restoration, and develop long term representative floral and faunal communities (Mitsch and Wilson 1996; Cambell et al. 2002). Determining the appropriate timeframe can be further confounded by the natural variability inherent in these systems on a seasonal and annual basis. Nevertheless, the program's success will help reduce the threat of eutrophication of the watersheds receiving water bodies by 'filtering' the nutrient rich runoff associated with urban and agricultural uses. In addition to the documentation of these ecological benefits will be the demonstration that this unique collaborative effort between Federal, State, and local agencies is practical for implementation of large-scale environmental initiatives.

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