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INTERPRETATION OF BULK ATMOSPHERIC DEPOSITION AND STORMWATER QUALITY DATA IN THE TAMPA BAY REGION

November 1998

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Acknowledgments

It should be fully recognized that this report makes use of an extensive data set gathered by the combined and dedicated efforts of many people and organizations. Bulk atmospheric samples were collected by divisions from five counties (Manatee, Hillsborough, Pasco, Pinellas, and Polk Counties). Some counties instituted new stormwater sampling programs in support of this project. All participants made data from existing sampling programs available, including the extensive stormwater and rainfall analysis projects performed by the Southwest Florida Water Management District, Environmental Section. Analyses for the project were performed either by the collecting agency or by the Environmental Protection Commission of Hillsborough County, the Southwest Florida Water Management District, and Mote Marine Laboratory. The following agencies and individuals, in alphabetical order, contributed their time and professional talents to this project.

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I. Background

The Florida Department of Transportation (FDOT) and the Cities of Tampa, Temple Terrace, and St. Petersburg, and the Counties of Hillsborough, Manatee, Pasco, Pinellas and Polk are jointly and severally holders of a permit from the U.S. Environmental Protection Agency (USEPA) for a National Pollutant Discharge Elimination System (NPDES) permit to operate Municipal Separate Stormwater Sewer Systems. Following required wet weather characterization of runoff quality, many applicants have chosen to develop site- or regionally-specific event mean concentrations of stormwater rather than use existing data from other regions. The relatively important role of direct atmospheric deposition to Tampa Bay (Zarbock *et al.*, 1994; Dixon *et al.*, 1996), and the spatial variability in deposition (Dixon *et al.* 1996; Whung, 1998) has led to questions regarding the influence of atmospheric deposition on stormwater quality and indirect atmospheric loadings to Tampa Bay. The Southwest Florida Water Management District (SWFWMD) has investigated the relationship of rainfall and stormwater quality at a number of stormwater treatment sites (Rushton, 1998), but dry deposition was not included.

For the purposes of formulating management policies for stormwater improvements, FDOT and the other co-applicants sponsored or supported the investigation of linkages between bulk atmospheric deposition and stormwater quality. The Tampa Bay Regional Planning Council agreed to administer the work and coordinate the agencies involved. Project goals were to investigate the spatial variability in deposition and the influence of atmospheric deposition on stormwater quality.

In order to fund as many sites and to cover as broad a spatial area as possible, bulk deposition (rather than wetfall and ambient air concentrations to calculate dry deposition) was used to quantify atmospheric loadings. While the dry deposition of certain gaseous nitrogen species are not well represented when using an artificial substrate, bulk data was estimated to represent a large portion (67%) of the total load (Dixon at al., 1996) and can be an economical way to evaluate potential spatial variation. These bulk data are less useful for calculating mass balances or if the unsampled gaseous species exhibit strong spatial gradients. In order to further examine the utility of bulk deposition, one of the bulk deposition sites was co-located with an intensive atmospheric deposition site measuring wetfall and ambient air concentrations (to compute dry deposition).

Stormwater loadings of nutrients, particularly nitrogen, were of primary interest. Large mobile and stationary sources of NO_x within the watershed made spatial variations in deposition a possibility. Nitrogen is also of interest due to the demonstrated link between nitrogen loadings and recovery of degraded seagrass habitat in Tampa Bay (Janicki and Wade, 1996). Contaminated sediments indicate some sources of toxic metals as well (Long *et al.*, 1994; Frithsen *et al.*, 1995; Zarbock *et al.*, 1996). As a result, selected parameters of interest in the study, for both stormwater and atmospheric deposition, were total nitrogen, total phosphorus, copper, cadmium, lead, and zinc.

Since weekly sample collection was the most frequent atmospheric field effort that could be supported, total nitrogen quantities were emphasized over the variety of inorganic nitrogen species. Project scope allowed atmospheric metals samples, although collected weekly, to be analyzed on monthly composites. Where new stormwater programs were instituted, stormwater samples were analyzed weekly for nutrients and monthly for metals. Existing stormwater programs were generally sampling individual storm events. Project funding limited the study to a 40 week period from April 30, 1997 through February 3, 1998.

II. Project Summary

Over a 40 week period, bulk atmospheric deposition collections were performed weekly at ten locations for total nitrogen (total Kjeldahl nitrogen and nitrate-nitrite-nitrogen) and total phosphorus, and copper, cadmium, lead, and zinc. Nutrient samples were analyzed weekly, while metals samples were volume composited into approximately monthly intervals. Stormwater samples were generally flow-weighted composites, either over a weekly period, or by individual events. Individual event data were mathematically flow-weighted to obtain equivalent weekly or monthly values for nutrients and metals, respectively. Weekly stormwater samples were either analyzed directly for nutrients, or combined, by flow-weighting, into monthly samples for metals analysis. Concentrations were converted to loading and runoff rates, which were further normalized by watershed areas. Stormwater runoff loadings were compared with watershed characteristics and atmospheric loading rates to describe net watershed processes.

III. Methods

Coordination With Existing Programs

The entire scope of the project was only possible through the cooperation of several existing stormwater sampling programs. The goals of the project were summarized in a quality assurance project plan (QAPP) prepared and administered by Bromwell Carrier, Inc. (Kelly and Schreiber, 1997) addressing both the bulk atmospheric deposition collection and analysis and the operation of the stormwater sampling sites. Existing stormwater programs followed their own protocols which were incorporated into the QAPP; analyses were performed under existing arrangements. Stormwater sampling performed exclusively for this project was designed to capture flow-weighted samples from the entire runoff volume; samples were analyzed by the Environmental Protection Commission of Hillsborough County (EPCHC) for nutrients and by the SWFWMD Chemical Laboratory for metals.

Bulk Atmospheric Deposition

Bulk atmospheric sites were installed by Bromwell Carrier, Inc. (BCI) for the sampling agencies following protocols detailed in the QAPP (Kelly and Schreiber, 1997), and modeled after the procedures of Dixon et al. (1996) and the bulk collection procedures employed by the Florida

Atmospheric Mercury Study (Landing, et al. 1995). Mote Marine Laboratory (MML) provided training for samplers and initial site visits to all sampling agencies. Cleaned equipment was provided to each sampling agency by MML. Sampling crews deployed 113 cm^2 polycarbonate funnels at 3 m above grade for one week periods. Nylon monofilament was stretched near funnel mouths to reduce bird contamination. Samples were collected in polyethylene bottles attached to funnels via teflon tubing. Separate funnels were used for nutrient and metals samples. Funnels were covered with polyethylene bags prior to and following deployment. The funnels of atmospheric samplers were rinsed into the sample bottles with preacidified rinse water whenever possible to collect dry as well as wet deposition. Particulates or contaminated sections of the funnels were not rinsed into the sample bottle. If sample bottles were full, rinses were collected in a second sample bottle for the week. Potential contamination was assessed on each sample for bird, insect, frog, distinct but unidentifiable particulates, and pollen contamination. (Rinse water was supplied by MML and each batch was also analyzed for possible contaimination.) Sampling funnels could collect approximately 9.5 cm of rain before overflow. Each agency also prepared a weekly equipment blank with rinse water and a cleaned but unused funnel apparatus. Samples were shipped to analytical laboratories where samples were fully acidified for preservation until analysis. All bulk atmospheric samples were analyzed by EPCHC for nutrients and by MML for metals.

Stormwater Sampling

Stormwater samples were all collected with automated equipment, typically operated in a flow-weighted mode upstream of a control section (weir) or within a drainage structure for which discharges could be calculated. Some installations employed doppler flow sensors. Samplers were generally not refrigerated. The goals of the stormwater sampling instituted for this project were to collect a flow-weighted composite sample over the entire week. The seasonal range in rainfall:runoff relationships at several sites resulted in the preferential sampling of the early part of the week for some installations, particularly during the latter part of the study when baseflows increased. Existing stormwater programs were sampling individual events. Some programs sampled as many events as possible, others had defined antecedent dry criteria (for NPDES), limiting the number of storms sampled. NPDES sampling protocol samples only the first three hours of any given event and requires specified antecedent dry conditions.

Site Descriptions

Ten locations were selected in and near the Tampa Bay watershed (Figure 1) to represent a variety of potential atmospheric sources, land uses, and to take advantage of existing stormwater sampling programs. The following site names, agencies collecting the atmospheric samples, and site descriptions summarize activities or sampling strategy at each site, as well as documenting data characteristics which may affect data interpretation.

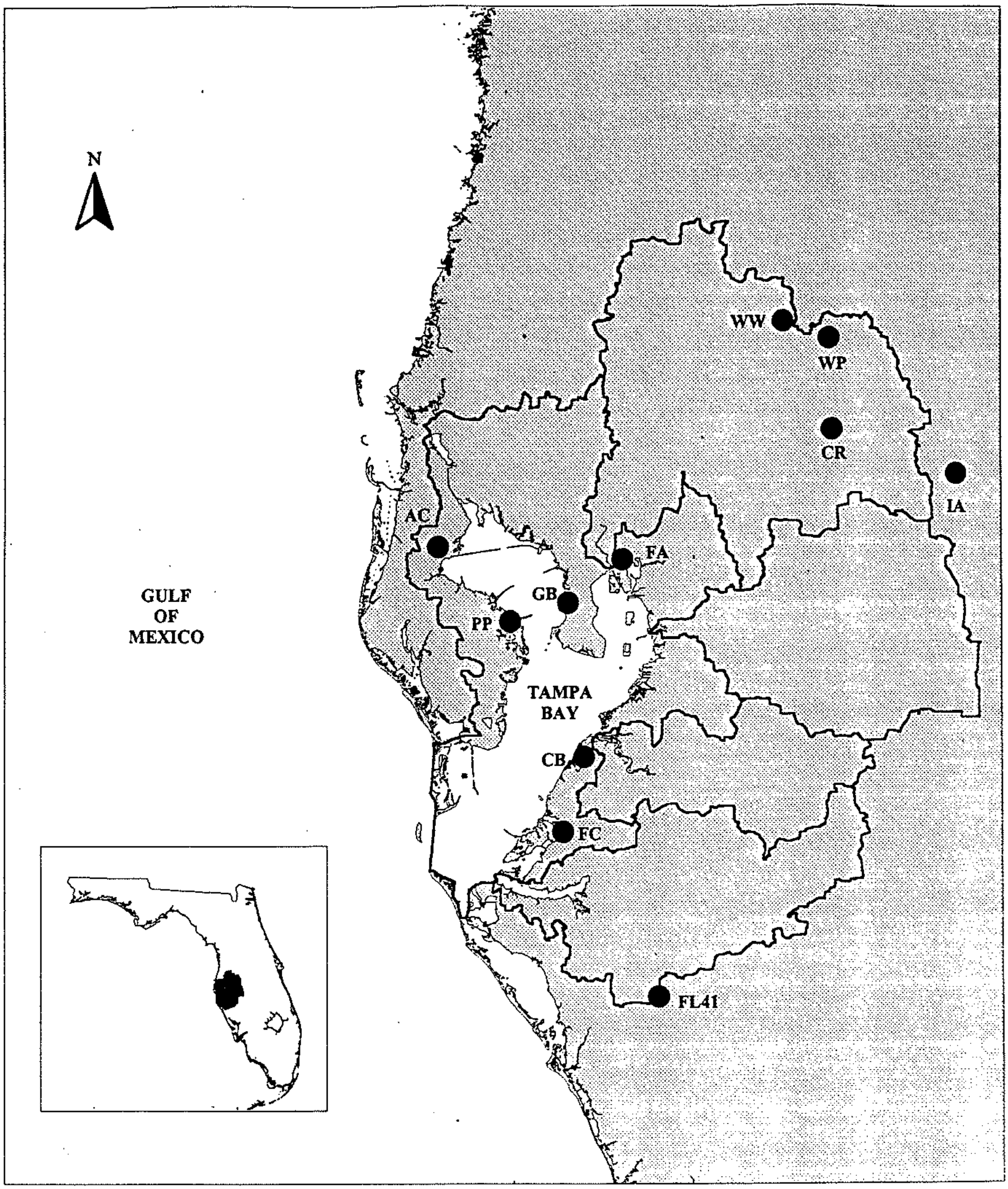

Figure 1. Tampa Bay watershed illustrating the location of bulk atmospheric deposition sites and of the NADP/NTN Verna Wellfield site (FL-41).

Alligator Creek, sampled by Pinellas County (AC). A 152 hectare (376 acre) basin located in Clearwater, Pinellas County and described as 80% residential with half of the residential consisting of mobil homes with no stormwater treatment. The remaining 20% is classified as commercial/light industrial; the St. Petersburg Junior College, library, churches, and a small amount of roadside commerce. The sampling site was located after the first of several ponds in an off-line, vegetated stormwater treatment facility. Little vegetation is present in the first pond, which would provide settling for suspended loads. Base flow through the facility was typically present and was included in weekly stormwater samples. Peak flows in the channel bypass the treatment facility by overtopping an in-channel weir which forces lower flows through the facility. As a result, total flows recorded and sampled likely underestimate total basin runoff. The stormwater samples were collected as weekly flow-weighted composites using an existing installation, but operated for this project. Some roadwidening was being conducted during the project with sediment from the activity reported in Channel H. Stormwater samples were analyzed by EPCHC (nutrients) and SWFWMD (metals).

Cockroach Bay, sampled by Manatee County (CB). A 85 hectare (210 acre) basin, primarily in agricultural land use (>90%). Impervious area was estimated at less than 5%. Some agricultural practices incorporate plastic sheeting for mulch and weed control. The existing stormwater sampling program was conducted by SWFWMD to evaluate the effectiveness of a recently constructed, large stormwater treatment facility. Delays in obtaining instrumentation brought the stormwater site on-line some time after the atmospheric sampling had begun. Due to malfunction of the flow meter at the inflow site, inflow samples were not flow-weighted composites, requiring this project to utilize to outflow data and concentrations instead. Substantial stormwater treatment was assumed to have occurred in the data from this site. The SWFWMD laboratory analyzed stormwater samples for many parameters, including inorganic and total nitrogen and phosphorus species, as well the metals of interest in this study.

Cone Ranch, sampled by Hillsborough County (CR). A 1176 hectare (2906 acre) site, with 100% agricultural land use, primarily improved pasture used for ranching. Numerous subbasins and relic wetlands provided a complex hydrological picture, and significant storage obscured typical rainfall:runoff relationships. Baseflow was present seasonally, but only after substantial rainfall had occurred. Stormwater data was from an existing installation which did not sample the first flush of runoff due to the number of cattle on the property. Most samples available from the site were grab samples. Flow weighted composite samples were collected weekly during the latter portion of the wet season when flows became more regular. A phosphate plant, CF Industries, is located within approximately 3 km of the site. Stormwater samples were analyzed by EPCHC (nutrients) and SWFWMD (metals).

Florida Aquarium, sampled by Hillsborough County (FA). A small (0.11 hectares, 0.26 acre) parking lot located in downtown Tampa at the Florida Aquarium. No swales were present, but the design incorporated small areas of landscaping. An existing SWFWMD stormwater study collected flow-weighted samples and rainfall from all events possible. A variety of industries with potential impacts on atmospheric deposition occur in the downtown region. Within 6 km are located shipyards and scrap metal shipping, a municipal incinerator, five phosphate or fertilizer shipping facilities, and a power plant The SWFWMD laboratory analyzed stormwater samples for many parameters, including inorganic and total nitrogen and phosphorus species, as well the metals of interest in this study.

Frog Creek, sampled by Manatee County (FC). A 22 hectare (55 acre) site almost exclusively comprised of manufactured housing (~500 lots), with a relatively high impervious area. Two small lakes within the basin provide wet detention and some stormwater treatment. Stormwater samples were weekly, flow-weighted composites collected specifically for this project. Stormwater samples were analyzed by EPCHC (nutrients) and SWFWMD (metals).

Gandy Bridge, sampled by Hillsborough County (GB). The bulk atmospheric sampler was co-located with an intensive atmospheric monitoring site at the eastern end of the Gandy Bridge, in order to permit comparisons of bulk deposition loads with the wet-only and dry deposition loadings (calculated from ambient air concentrations and meteorological parameters). The intensive site was operated as part of the national network with support through the Tampa Bay National Estuary Program (TBNEP) and the EPA Great Waters Program. The lag between sample collection and data availability for the intensive atmospheric site limited the period of comparison. Stormwater data for the site were from an existing installation, operated under a TBNEP project to examine stormwater and atmospheric deposition on an event basis. The 4 hectare (10 acre) basin used for this project was designated as Trask and Lawn, was the site closest to the atmospheric sites (1.3 km, 0.8 miles), and was 100% residential (7-8 units per acre) with an estimated 40-50% impervious area. Samples were collected daily, as necessary, and data on flow and concentrations reported on an event basis. Some difficulty with flow characteristics and backwater at the site required estimates of flow from hydrological approaches. Phosphorus was not analyzed and metals were added during the latter portion of the project. Stormwater samples were analyzed by Thornton Laboratory under contract to BCI, Inc.

Inwood Alum Injection, sampled by Polk County (IA). The 194 hectare (479 acre) basin includes a natural lake providing stormwater detention and treatment to much of the basin. Land uses of the basin were primarily medium density residential (96%), with some commercial (3%), and industrial and low-density residential (0.7%, combined). Total impervious area was near 38%. An existing stormwater sampling program was used which collected upstream of an alum injection stormwater treatment facility. Storms were sampled by NPDES criteria with specified antecedent dry periods and so not all events were sampled. Timed composite samples were collected over the first three hours of each sampled event. Baseflow was a substantial portion of both sampled and weekly flows at this site. Stormwater samples were analyzed through arrangements made by Polk County.

Pinellas Park Alum Injection, sampled by Pinellas County (PP). A 37 hectare (91 acre) basin in Pinellas Park, an urbanized portion of Pinellas County. Impervious area is estimated at 31% while land use was ~48% high density residential, ~44% commercial and services, and ~6% transportation. Approximately 0.7% of the basin is described as a small reservoir, implying some small degree of stormwater treatment. An existing stormwater sampling program (operated to evaluate the effectiveness of alum injection for stormwater treatment) was conducted by SWFWMD. Samples were generally collected as flow-weighted composites on an event basis. The alum injection was not operational for the duration of the study and so outflow analytical values and flows were used as they were more complete. Stormwater samples were analyzed by SWFWMD.

Wildlife Preserve, sampled by Pasco County (WP). A 270 hectare (666 acre) undeveloped parcel of conservation lands located in the northeastern portion of the Tampa Bay watershed. Impervious area was estimated at 0%. The atmospheric sampler was located in a clearing of a mixed pine-palmetto flatwood. Stormwater samplers were installed for this project and collected nearby where a small swale drained into a seasonal wetland of cypress and other wetland hardwoods. Stormwater samples were collected as weekly, flow-weighted composites, but during the wet season represented only a small portion of the total recorded flow. Baseflow was present seasonally. Stormwater samples were analyzed by EPCHC (nutrients) and SWFWMD (metals).

Wastewater Plant, sampled by Pasco County (WW). A 19 hectare (47 acre) basin, was also located in the northeastern section of the watershed, and incorporated the grounds of a municipal wastewater treatment plant. Two percolation ponds are part of the facility. Land use was described as major public/semi-public and impervious area estimated at 2.9%. Stormwater samplers were installed and operated for this project, with samples collected as weekly, flow-weighted composites. Baseflow was present seasonally. Samples during the wet season represented only a small portion of the total flow. Stormwater samples were analyzed by EPCHC (nutrients) and SWFWMD (metals).

Analytical Methods

Bulk atmospheric samples were analyzed by EPCHC and MML. Methods, data quality objectives and method detection limits (MDLs) appear below in Table 1. Stormwater analyses were performed by several entities, summarized in Table 2.

Table 1. Analytical methods and detection limits for bulk atmospheric deposition samples.

Parameter	Method Reference	MDL
EPCHC		
Nitrate-nitrite nitrogen	EPA 353.2, SM 4500 NO3-F	0.002 mg/l
Total Kjeldahl Nitrogen	EPA 351.2	0.02 mg/l
Total Phosphorus	EPA 365.1, SM 4500 P-F	0.03 mg/l
MML		
Copper	SM 3030F, 3113B	0.2 μg/l
Cadmium	SM 3030F, 3113B	0.05 μg/l
Lead	SM 3030F, 3113B	0.3 μg/l
Zinc	SM 3030F, EPA 289.2	0.4 μg/l

Table 2. Analytical methods and detection limits for stormwater samples.

Parameter	Method Reference	MDL
EPCHC		
Nitrate-nitrite nitrogen	EPA 353.2, SM 4500 NO3-F	0.002 mg/l
Total Kjeldahl Nitrogen	EPA 351.2	0.02 mg/l
Total Phosphorus	EPA 365.1, SM 4500 P-F	0.03 mg/l
SWFWMD - Chemical Laboratory		
Nitrate-nitrite nitrogen	EPA 353.2, SM 4500 NO3-F	0.01 mg/l
Total Kjeldahl Nitrogen	EPA 351.2	0.06 mg/l
Total Nitrogen	ASTM D5176 (since 8/97)	0.08 mg/l
Total Phosphorus	EPA 365.1	0.01 mg/l
Copper	SM 3113B	1 μg/l
Cadmium	SM 3113B	0.3 μg/l
Lead	SM 3113B	2 μg/l
Zinc	SM 3113B	30 μg/l
Polk County		
Nitrate-nitrite nitrogen	SM 4500 NO3-F	0.01 mg/l
Total Kjeldahl Nitrogen	EPA 351.2	0.25 mg/l
Total Phosphorus	EPA 364.5	0.025 mg/l
Copper	SM 3113B	20 μg/l
Cadmium	SM 3113B	2 μg/l
Lead	SM 3113B	5 μg/l
Zinc	SM 3113B	10 μg/l
BCI (Thornton Laboratories, Inc.)		
Nitrate-nitrite nitrogen	EPA 353.2	0.02 mg/l
Total Kjeldahl Nitrogen	EPA 351.2	0.06 mg/l
Copper	EPA 220.1	5 μg/l
Cadmium	EPA 213.1	2 μg/l
Lead	EPA 239.2	10 μg/l
Zinc	EPA 289.1	5 μg/l

EPA - EPA 600/4-79-020, Methods for Chemical Analysis of Water and Wastes. 1979. US EPA.
SM - Standard Methods for the Examination of Water and Wastewater. 18th Edition, APHA, AWWA, WPCF.

Data Reduction

In all data reductions, analytical values reported as less than the method detection limit (<MDL) were converted to one half of the limit of detection, even where numerical values were reported. For atmospheric nutrient data, analytical concentrations were converted to milligrams of analyte using sample weights (volumes). Total milligrams of deposition at a site were summed from all bottles for the week, if more than one bottle was used. Deposition was then corrected for the milligrams present in the equipment blanks specific for each collecting agency and week. Where blanks were not available, average equipment blank values for the project were used. From corrected weights of deposition, areal rates of depositions over the deployment period and extrapolated to an annual basis were computed using funnel areas and days of deployment. In addition to computing the corrected weekly and annualized deposition values of nutrients by site, the mean deposition of all sites pooled (a "watershed" mean) was determined for each sampling week. Individual weekly site values were compared to the weekly watershed means to reduce the site variance produced by episodic deposition.

Atmospheric samples for metals were composited on an approximately monthly basis for cost savings. Compositing periods ranged between one and seven weeks. Periods were selected such that the final week of any composite contained a measurable rain event and to maximize the percentage of sampled stormwater within any one compositing period. Atmospheric samples were volume composited after accounting for rinse water volumes. Atmospheric loads of metals were corrected for equipment blanks similar to nutrient samples. Weekly equipment blanks were composited over the same time periods as were samples, often with a separate blank for each site. Again, areal deposition and annualized rates were computed.

From event-based stormwater sampling programs, event concentration data for nutrients and metals were used to calculate weekly volume-weighted concentrations and loads sampled using reported sampled flow. Where total flow was greater than sampled flow, sampled loads are an underestimate of total loads. Total loads were then estimated from total runoff flow and sampled concentrations, in essence assuming that unsampled flows were at equivalent concentrations. Total loads so estimated may represent overestimates if trailing limbs of the stormwater hydrographs were unsampled, may be roughly approximate if entire and comparable events were unsampled, or may represent underestimates if baseflow formed the bulk of the sample.

Event-based metals data were additionally composited (flow-weighted) via computation over the same period used for atmospheric sample compositing. For stormwater samples collected exclusively for this project, the compositing of weekly samples was performed prior to analysis using total flows, generally over the same time periods used for atmospheric samples. Stormwater loads computed for both nutrients and metals were normalized by the size of the contributing watershed. In some instances, stormwater events were composited over more than one of the atmospheric weekly collection periods. In these instances, loads from the collected storms were assigned to the week with the most rainfall. Data were selectively analyzed using those samples in which the sampled flow was a large portion of the total flow for the period.

IV. Sources of Other Data

The EPA Great Waters Program sponsored an intensive atmospheric monitoring site, designated as the Tampa Bay Atmospheric Deposition Study (TBADS). Managed by the TBNEP with support from the EPCHC and PCDEM, the site has been operational at the Gandy Bridge since August 1996. Operated under NADP/NTN and AIRMon (Atmospheric Integrated Research Monitoring) protocols, daily wetfall samples were collected as necessary, while every six days a 24 hour sample of particulate and gaseous nitrate, ammonia, and sulfate in ambient air was collected via annular denuders and filter packs. Dry deposition rates (to the surface of Tampa Bay) were computed from continuous meteorological data (wind speed, air and water temperature, and relative humidity) gathered from a mid-Bay installation. Data available which overlapped the project included a 17 week period for wetfall data (May 6 through August 26, 1997 for inorganic nitrogen; May 6 through June 3, 1997 for inorganic phosphorus) and an 11 week period (May 6 through July 15, 1997) for dry deposition. Daily values of both dry and wet deposition gathered under the AIRMon protocols were summed into weekly values for comparison with bulk deposition data collected at the Gandy Bridge site.

The National Atmospheric Deposition Program / National Trend Network (NADP/NTN) data were retrieved on-line from http://nadp.sws.uiuc.edu/ for the Sarasota County Verna Wellfields site (FL41, Figure 1), located immediately to the south of the Tampa Bay watershed. Samples are collected weekly as wet deposition only samples and are analyzed for a number of major ions, including nitrate and ammonium. The two inorganic nitrogen species were converted to a nitrogen basis, summed for total inorganic nitrogen in wetfall, and used for comparison with bulk deposition data on total nitrogen. Phosphorus data are not typically available and metals data are not part of the analytical suite. Data available which overlapped the project included 15 weekly data points between May 13 and September 2, 1997.

The Resource Projects Department, Environmental Section, of SWFWMD was operating an extensive stormwater treatment project at the Florida Aquarium. Multiple sites and treatment approaches were being investigated for efficiency of pollutant removal and the SWFWMD project was operating during the entire 40 week sampling period. Data gathered on direct runoff from a parking lot were used to calculate stormwater loadings for evaluation against bulk deposition. In addition, wet-only deposition was collected by SWFWMD and quantified for a number of parameters, including the metals and nutrients of interest, enabling comparisons between bulk and wet-only deposition at the Florida Aquarium site.

V. Results and Discussion - Bulk Atmospheric Deposition

Rainfall

Annual rainfall within the Tampa Bay watershed by the close of the study period totaled approximately 198 cm (78.1 in), compared to historical annual averages of 133 cm (52.4 in) (SWFWMD, 1997a, 1997b, 1997c, 1998). The period was marked by unusual patterns of rainfall. Cumulative rainfall deficits were between 13 to 34 cm (5-13 in) below normal in May 1997. Several large storm systems in September and December 1997 brought high amounts of rainfall to the area, bringing rainfall totals to 2 to 17 cm (0.6 to 6 in) below normal in September, and 27 to 44 cm (10.65-17.37 in) above normal in December. By February, annual rainfalls were between 54 and 80 cm (21-31 in) above normal.

Atmospheric samplers collected rainfall amounts detailed in Table 3, between 93 and 127 cm over the 40 week study, or, on average, about 85% of long term annual averages for the region. Rainfall amounts are the average of the amounts in both nutrient and metals sample bottles for the week. The weekly amounts, if in excess of 9.5 cm, would overflow the sample bottles and so the rainfall totals in Table 3 should be viewed as a lower limit. A total of 23 of the 400 data points were above 9.0 cm and comparison with stormwater installation rainfall data indicated an additional 10-30 cm of rainfall was received during weeks with rainfall greater than 9.5 cm. Notable events were received during the weeks of September 30, December 16, and December 30, 1997, when average rainfall amounts recorded by stormwater installations were 14.9, 14.0, and 11.8 cm, respectively.

Table 3. Rainfall amounts collected by atmospheric samplers over the 40 week study.

Site	(cm)	(in)
Alligator Creek	117.9	46.4
Cockroach Bay	114.6	45.1
Cone Ranch	112.5	44.3
Florida Aquarium	93.1	36.7
Frog Creek	111.2	43.8
Gandy Bridge	100.3	39.5
Inwood Alum	114.5	45.1
Pasco WWTP	121.8	48.0
Pinellas Park	118.4	46.6
Wildlife Preserve	127.4	50.2

For rainfall at or below 9.0 cm, amounts collected by atmospheric samplers were generally in good agreement with rainfall recorded by stormwater installations. Regression of atmospheric as a function of stormwater site rainfall produced significant relationships for all sites with an overall slope of 0.91. Figure 2 illustrates the seasonal distribution of weekly rainfall amounts (as the average of all stormwater site installations) over the course of the study. Despite a factor of 1.3 between the high rainfall site (Wildlife Preserve) and the low rainfall site (Florida Aquarium), there were no significant differences in weekly rainfall distribution between sites.

Bulk Atmospheric Deposition

Appendix A contains uncensored results for nitrogen and phosphorus by site of weekly bulk atmospheric deposition rates. Also listed are rainfall computed from sample volumes collected, site runoff volumes (total and sampled), and rainfall from stormwater installations. Appendix B contains atmospheric loads of metals.

Sample completeness for samples returned for analysis was 98.8% for nutrients. Severe storms which either blew samplers down or prevented site access accounted for the missing samples. Data for nutrients were censored from analysis, however, if bird contamination or color were present in any amount. This conservative approach still resulted in 88.5% completeness for the project's 400 planned samples, with completeness at individual stations ranging from 52.5% to 100% of the scheduled 40 weekly samples per site. Many of the bird contamination events reportedly occurred when the monofilament bird deterrents were not in place. Summaries of censored data for the period of study (40 weeks) appear in Table 4 below. By site, annualized total nitrogen deposition for the study ranged from 5.03 to 9.66 kg ha^{-1} yr^{-1}, while phosphorus values were between 0.62 and 1.06 kg ha^{-1} yr^{-1}. For nitrogen, the higher average weekly loads (the mean of all sites) received during the summer (Figure 3) should be noted, despite the large rainfall amounts received later in the study (Figure 2). Average weekly loads of phosphorous appear in Figure 4, where seasonal variations are not as apparent as for nitrogen.

Individual metals samples were not composited if obvious contamination was present. Resulting metals values from the remaining samples showed no relationship when plotted against average contamination assessment values (bird, color, etc.) for the composite, indicating no further censoring was necessary. There are, however, several outlier values (two for cadmium [Cone Ranch and Pasco WWTP] , one each for copper [Florida Aquarium] and lead [Inwood Alum]) which have no evidence of bird or other contamination. Since atmospheric deposition can be highly episodic these values were maintained in the data base, but means computed in their absence are presented in parentheses with the summary data below in Table 4. While median values may better represent the expected weekly loadings, mean values incorporate the episodic events which often comprise large portions of the total load and are a better indication of total loads received by the watershed.

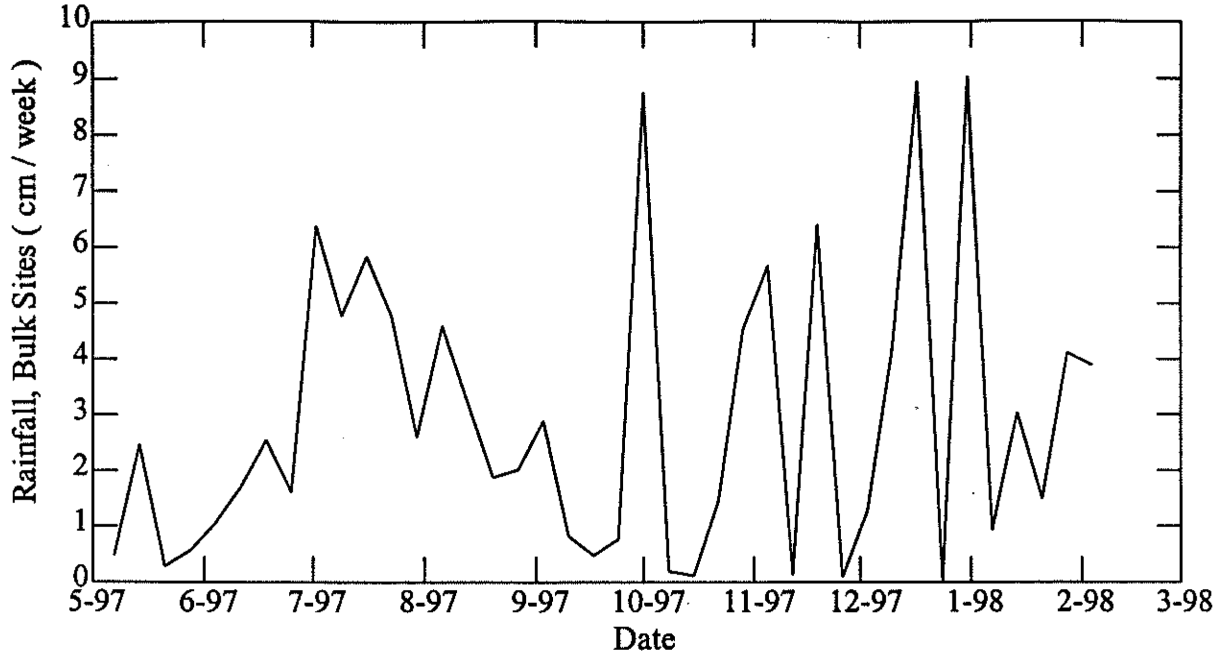

Figure 2. Average weekly rainfall recorded by bulk deposition sites. Rainfall amounts over 9.5 cm truncated due to sampler design.

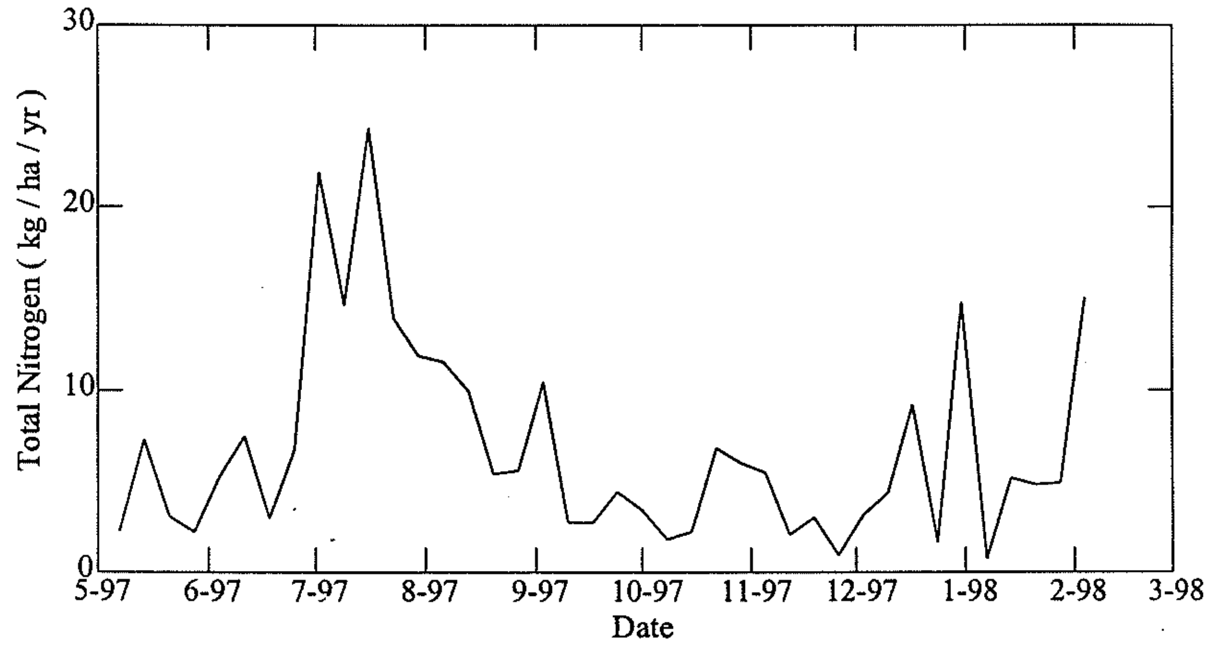

Figure 3. Watershed average of weekly bulk deposition of total nitrogen; values annualized based on collection period.3

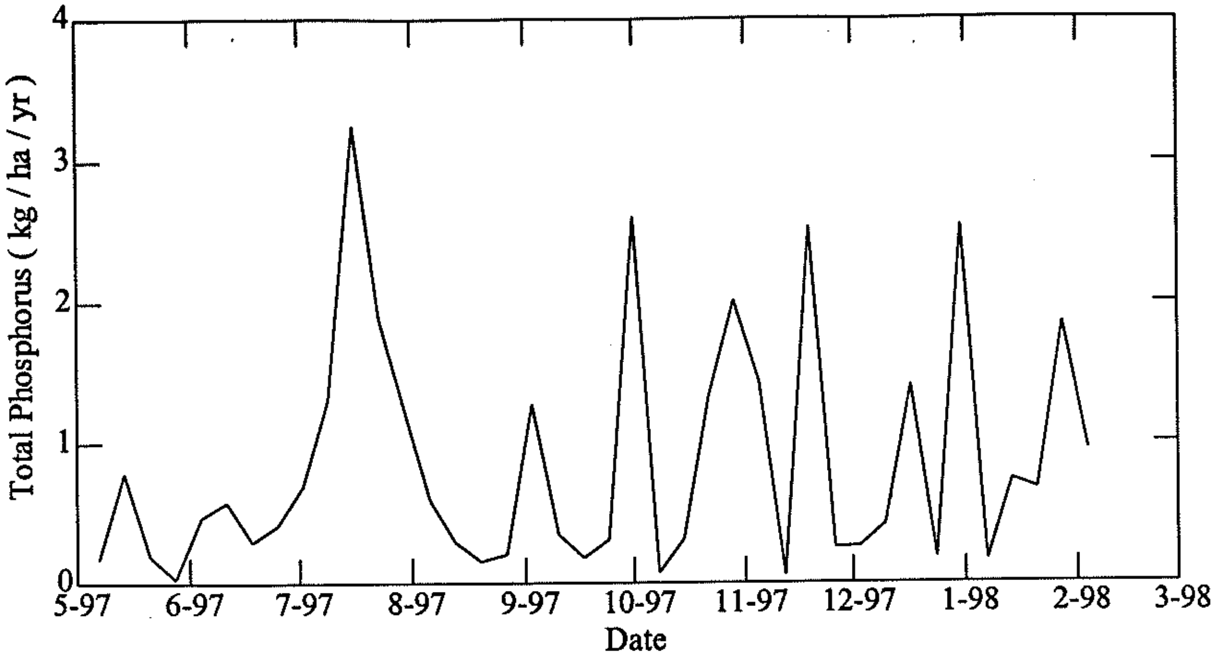

Figure 4. Watershed average of weekly bulk deposition of total phosphorus; values annualized based on collection period.

Table 4. Annualized bulk deposition rates, based on a 40 week sampling period. Values in parentheses are computed without outlier values.

Site	Total N	Total P	Copper	Cadmium	Lead	Zinc
	$kg\ ha^{-1}yr^{-1}$	$kg\ ha^{-1}yr^{-1}$	$g\ ha^{-1}yr^{-1}$	$g\ ha^{-1}yr^{-1}$	$kg\ ha^{-1}yr^{-1}$	$kg\ ha^{-1}yr^{-1}$
Alligator Creek	5.81	0.65	30.70	0.23	10.31	73.26
Cockroach Bay	5.03	0.80	12.64	0.34	6.50	58.31
Cone Ranch	5.10	0.66	26.50	2.30(0.43)	7.02	261.95
Florida Aquarium	5.64	0.62	223.72(87.13)	0.69	29.44	634.15
Frog Creek	5.53	1.01	6.68	0.27	4.25	71.82
Gandy Bridge	6.07	0.92	17.11	0.72	10.06	93.27
Inwood Alum	9.66	1.06	17.22	0.36	18.05(9.77)	69.21
Pasco WWTP	6.75	0.92	6.19	2.39(0.40)	6.46	56.85
Pinellas Park	7.21	0.87	13.25	0.55	16.40	143.65
Wildlife Preserve	7.99	0.87	9.18	0.40	5.17	40.40
Station Mean	6.48	0.84	36.31(22.66)	0.83(0.44)	11.37(10.54)	150.29
Minimum	5.03	0.62	6.68	0.23	4.25	40.40
Maximum	9.66	1.06	223.72(87.13)	2.39(0.72)	29.44	634.15

Comparison with Intensive Monitoring Site

Available data from concurrent monitoring at the TBADS Gandy Bridge intensive site were limited to those collected during May, June, July, and August and were summed to weekly totals for comparison with rainfall and atmospheric loadings measured as bulk deposition. During the time the bulk sampler was operational, phosphorus data in wet deposition was only available for three events within a two week period and so was not addressed. Wet deposition of inorganic nitrogen (ammonium and nitrate) was available for a 17 week period; daily dry fluxes (to a water surface) were computed for an 11 week period from ambient air measurements of inorganic nitrogen species made for 24 hours, once every six days, and continuous meteorological parameters. The intensive site data wet and dry data were summed over the weekly periods used for bulk collection, and units were converted to annualized values.

Rainfall amounts collected at the two sites were significantly related (Figure 5). The bulk collector was at 3 m elevation, and was 12 cm diameter; the rainfall collector of the intensive site was at approximately 1 m elevation and 29 cm (11.6 in) in diameter. The two collectors were located within 10 meters of one another. The slope of the relationship indicates that the bulk rainfall collected was consistently 90% of that recorded by the intensive site. No adjustments were made for differing rainfall collection efficiencies. A total of 45.6 cm of rain was recorded by the intensive site during this period, or 33% of the expected annual norm.

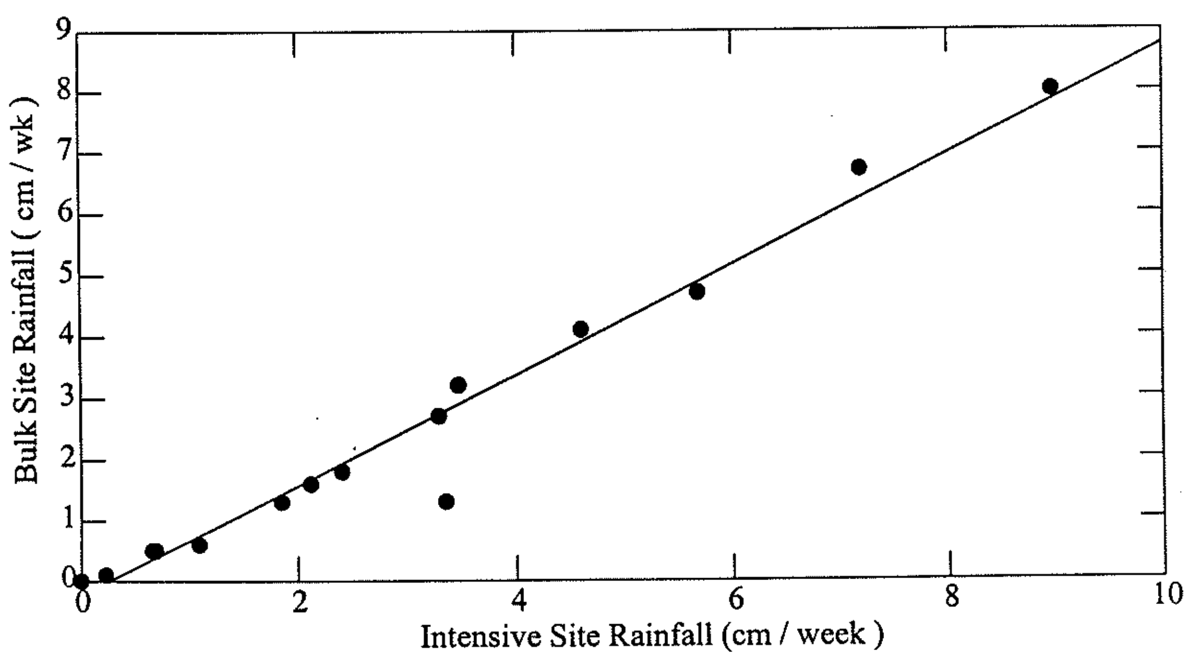

Figure 5. Concurrent weekly rainfall data collected by the TBADS intensive monitoring site and the bulk atmospheric deposition samplers (May-August, 1997).

As expected, the intensive site wet deposition of inorganic nitrogen was significantly related to rainfall amounts (Figure 6) during the period examined and averaged 7.04 kg ha^{-1} yr^{-1} for the period. Weekly rates ranged from 0.00 to 31.9 kg ha^{-1} yr^{-1}. Dry deposition was relatively constant at 3.46 kg ha^{-1} yr^{-1} ($\sigma = 1.12$) and unrelated to rainfall (Figure 7). Dry deposition of nitrogen over the period examined constituted approximately 30% of total atmospheric loadings as measured by the intensive site.

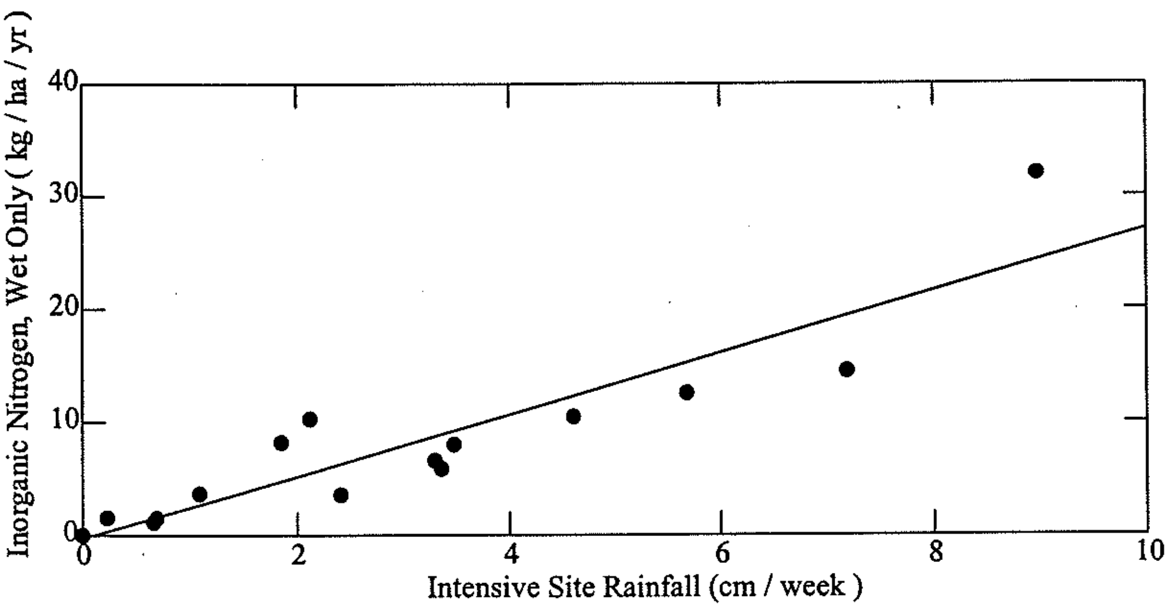

Figure 6. Weekly, wet-only nitrogen deposition at the TBADS intensive monitoring site and the relationship to weekly rainfall totals (May-August, 1997).

Weekly loads collected by the two installations are in remarkable agreement (Figures 8 and 9), with highly significant relationships between bulk deposition of total nitrogen and both wet-only and wet plus dry deposition of inorganic nitrogen. Results are consistent with the two assumptions that 1) some of the gaseous inorganic nitrogen species contributing to dry deposition are not well collected by the artificial substrate of the bulk collector, and that 2) organic nitrogen loads (as measured in daily samples) are either minimal and/or constant. If the average dry deposition of 3.46 kg ha^{-1} yr^{-1} is extrapolated to the entire period compared, then the intensive site total deposition of nitrogen was 10.50 kg ha^{-1} yr^{-1}, while loading rate determined from bulk values was 9.62 kg ha^{-1} yr^{-1}. (The wet deposition of organic nitrogen is not determined.)

The regression of bulk nitrogen deposition against wet only inorganic nitrogen (Figure 8) has a slope of 0.988 and a y-intercept of 0.678. If bulk deposition is assumed to represent an adequate collection of wet inorganic and organic nitrogen plus some unknown fraction of dry deposition, then the wet deposition of organic nitrogen plus the unknown dry deposition contained in the bulk sampler should total near 0.678 kg ha^{-1} yr^{-1}. The comparison of bulk deposition with wet

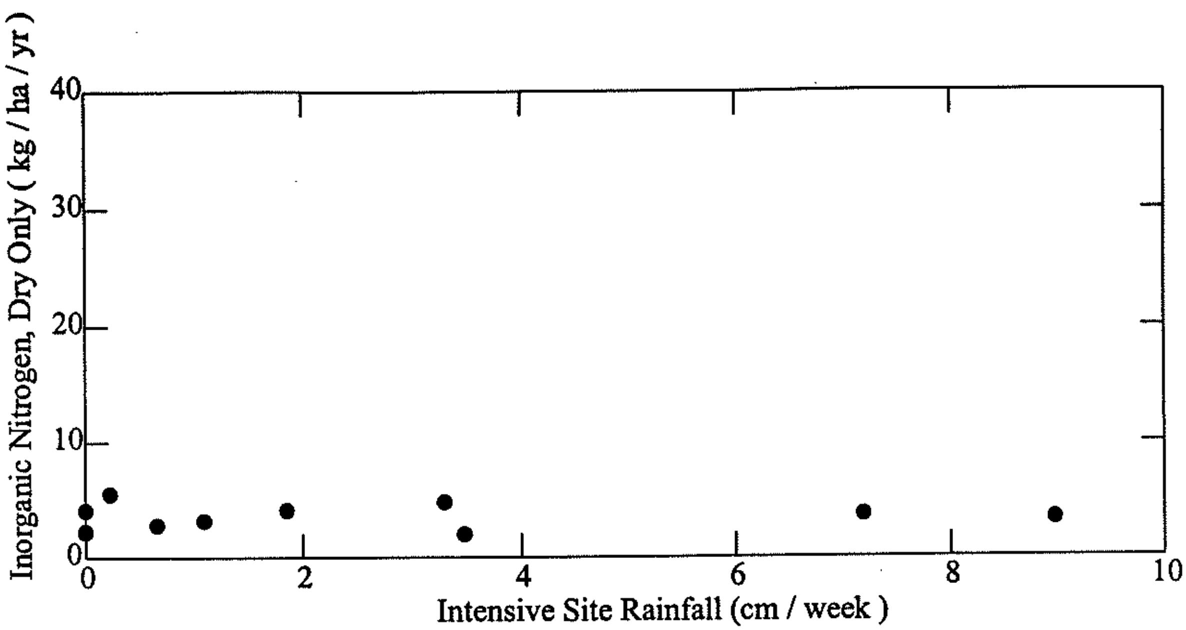

Figure 7. Weekly, dry-only nitrogen deposition at the TBADS intensive monitoring site and the relationship to weekly rainfall totals (May through mid-July, 1997).

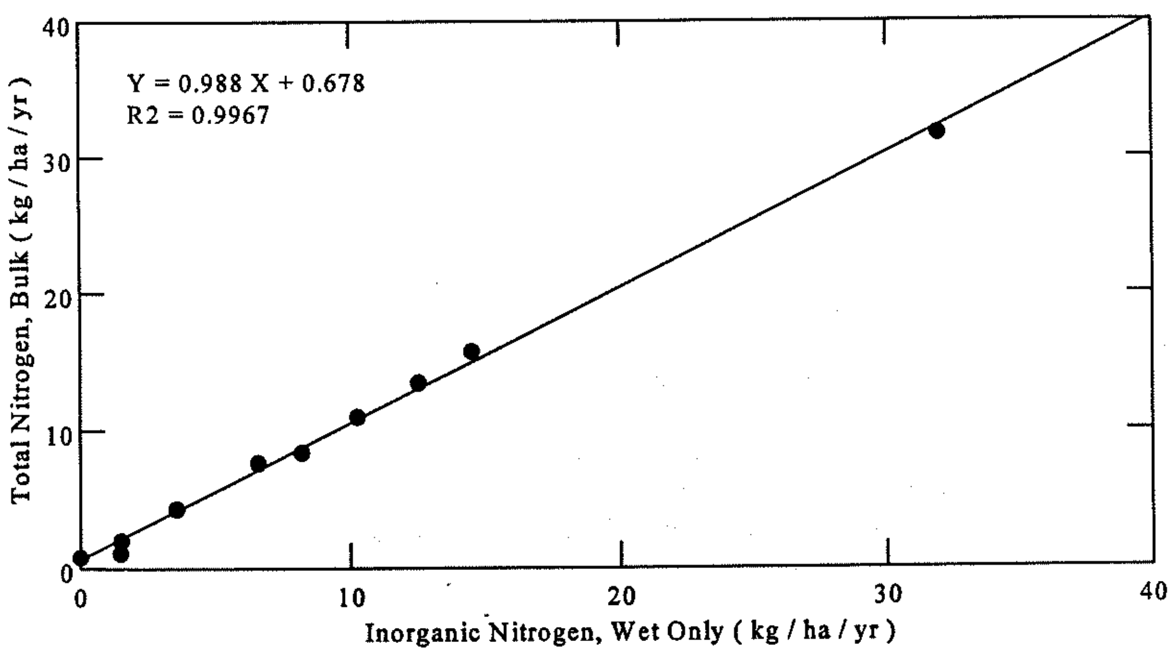

Figure 8. Relationship of bulk deposition of total nitrogen (inorganic plus organic) to wet-only deposition of inorganic nitrogen (May-August, 1997) at the TBADS intensive monitoring site.

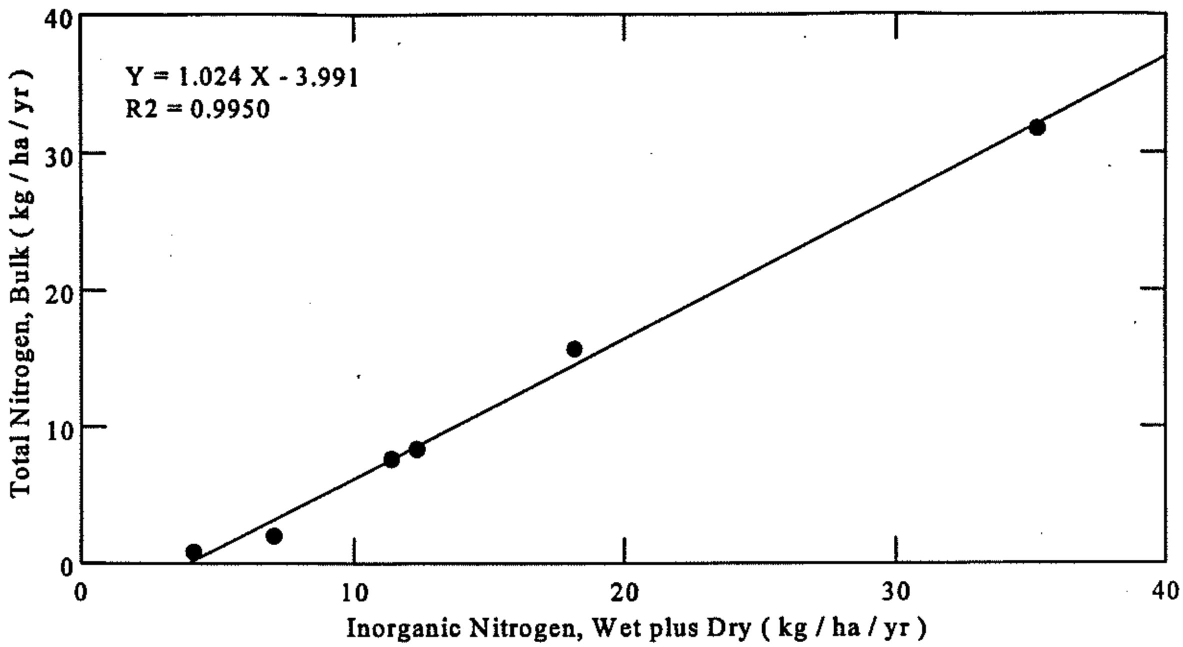

Figure 9. Relationship of bulk deposition of total nitrogen (inorganic plus organic) to wet plus dry deposition of inorganic nitrogen (May through mid-July, 1997) at the TBADS intensive monitoring site.

plus dry values (Figure 9) show a y-intercept of -3.991, with a slope of 1.024. If both slopes are simplified to a value of 1.00, and all quantities are assumed to be positive (*i.e.*, deposited rather than released), wet deposition of organic nitrogen can be estimated to range between 0.000 and 0.678 kg ha^{-1} yr^{-1}, total dry deposition near 4.669 kg ha^{-1} yr^{-1}, and the fraction of dry deposition captured by the bulk sampler to range between 0% and 14% (Table 5). The derivation of the fraction of dry deposition sampled is appropriate only for the Gandy Bridge site, as other sites with lower ambient air concentrations would be expected to provide differing results.

In previous bulk collections of weekly samples (Dixon *et al.*, 1997), organic nitrogen constituted approximately 40% of total nitrogen (ranging from 26% to 56% at individual stations). Nitrate-nitrite-nitrogen comprised near 36% of total bulk nitrogen (ranging from 22% to 46%). Undoubtedly, some fraction of inorganic loadings can be converted to organic compounds by bacterial action during the weekly compositing period, but the previously observed range between stations argues for some spatial variation in organic loading of nitrogen in wet deposition as well. It should be emphasized that the possible magnitude of wet deposition of organic nitrogen at the Gandy Bridge site (up to 6% of total loads or up to 0.678 kg ha^{-1} yr^{-1} out of a total of 10.50 plus 0.678 kg ha^{-1} yr^{-1}) is specific for the Gandy station and the relatively short period examined.

Table 5. Computation of approximate ranges of dry deposition collected by the bulk sampler co-located with the TBAS intensive monitoring site.

Defining deposition collected by bulk samplers as:

W_i = wet deposition, nitrogen deposited in rainfall as inorganic nitrogen and which remains as inorganic during the week compositing period

W_{io} = wet deposition, nitrogen depostied in rainfall as inorganic species, but which converts to organic species during the week compositing period

W_o = wet deposition, nitrogen deposited in rainfall as organic nitrogen, and which remains as organic nitrogen

D_1 = dry deposition, fraction collected by bulk sampler

and deposition collected and measured by the intensive site consisting of:

W_{it} = wet deposition, inorganic fraction only (with $W_{it} = W_i + W_{io}$)

D_1 = dry deposition, fraction collected by bulk sampler

D_2 = dry deposition, fraction uncollected by bulk sampler, but collected by intensive site.

The linear relationships described in Figure 8 and 9, can be restated in terms of the individual variables as:

$$W_i + W_o + W_{io} + D_1 = 0.988 * W_{it} + 0.678$$

and

$$W_i + W_o + W_{io} + D_1 = 1.024 * (W_{it} + D_1 + D_2) -3.991$$

Assuming slopes to be equivalent to 1.000, the equations reduce to:

$$W_o + D_1 = 0.678 \text{ and } \quad W_o = D_2 -3.991$$

or

$$D_1 + D_2 = 3.991 + 0.678 = 4.669$$

If both W_o and D_1 are positive, then from $W_o + D_1 = 0.678$, D_1 can range from 0 to 0.678, as can W_o. From $W_o = D_2 -3.991$, if W_o ranges from 0 to 0.678, then D_2 can be a quantity between 3.991 and 3.313, with the fraction of dry deposition collected by the bulk sampler ranging between 0/4.669 (0%) and 0.678/4.669 (14%). It should be emphasized that the percentage of dry deposition captured by the bulk sampler as estimated from the above equations is valid only for this site and that bulk collections at other sites with differing ambient air concentrations may be expected to collected differing fractions.

Spatial Variation in Bulk Deposition

Of the bulk deposition parameters, all annualized data were non-normal in distribution, either for the study as a whole, or for the individual sites. Although sample numbers were large, especially for nutrient data, statistical testing between sites relied primarily on non-parametric procedures.

It should also be stated that the sampling design, with few exceptions, in effect collected a complete census of atmospheric deposition at each site, by collecting **all** materials which fell into the sampler. Differences in the total atmospheric loads between sites, therefore, no matter how small, are absolute and can be considered a true result. Whether the magnitude of the differences between sites is of practical significance (rather than of statistical significance) remains unknown. As replication of bulk collections at sites was not possible, confidence intervals around total loadings at a site (as a statistical sample of the general site region and including measurement errors) are not possible. Differences in total loadings between sites, therefore, cannot be tested with inferential techniques while differences in weekly loadings can be tested.

Sites were not randomly selected as particular land uses were of interest. In addition, mobile and stationary sources were believed to vary substantially over the study area. As a result, total deposition at a site can only be viewed as a single 40 week long sample that is representative of some larger group of 40 week periods extending over a much longer period of time. If requirements for random selection can be relaxed and if station locations can be assumed to be random, then the variance around the total deposition at all sites combined can be used to represent watershed conditions during the 40 week period of the study.

The distribution of weekly bulk deposition of total nitrogen and phosphorus (transformed to annualized values), by site, appears in Figures 10 and 11. Due to the episodic nature of deposition, differences in weekly bulk deposition among stations as a whole are not significant over the period of study. Individual site variations from watershed means (the average of all sites for the week) were significant (Mann-Whitney rank sum) for nitrogen with median values at the Wildlife Preserve (Table 6) higher than five other stations (Cockroach Bay, Gandy Bridge, Frog Creek, Florida Aquarium, and Alligator Creek). There were no coherent spatial distributions apparent in either bulk deposition or in the differences from the watershed mean, indicating that local activities are important in controlling deposition of nutrients.

It should be emphasized , however, that the above tests for spatial variation are performed on weekly values. Sites can and did receive vastly different loadings over the course of the project, with the weekly variation among sites obscuring the bias between sites. In the case of total nitrogen, the Inwood Alum site received 9.66 kg ha^{-1} yr^{-1}, nearly double that of Cockroach Bay (5.03 kg ha^{-1} yr^{-1}). This is illustrated in Figure 12, in which cumulative total nitrogen deposited over the 40 week sampling is illustrated by site for those sites with 85% or better sample completeness. While the range between sites emphasizes the effect of localized activities, the fact that all sites have at least 5.03 kg ha^{-1} yr^{-1} of total nitrogen deposition is also an indication of

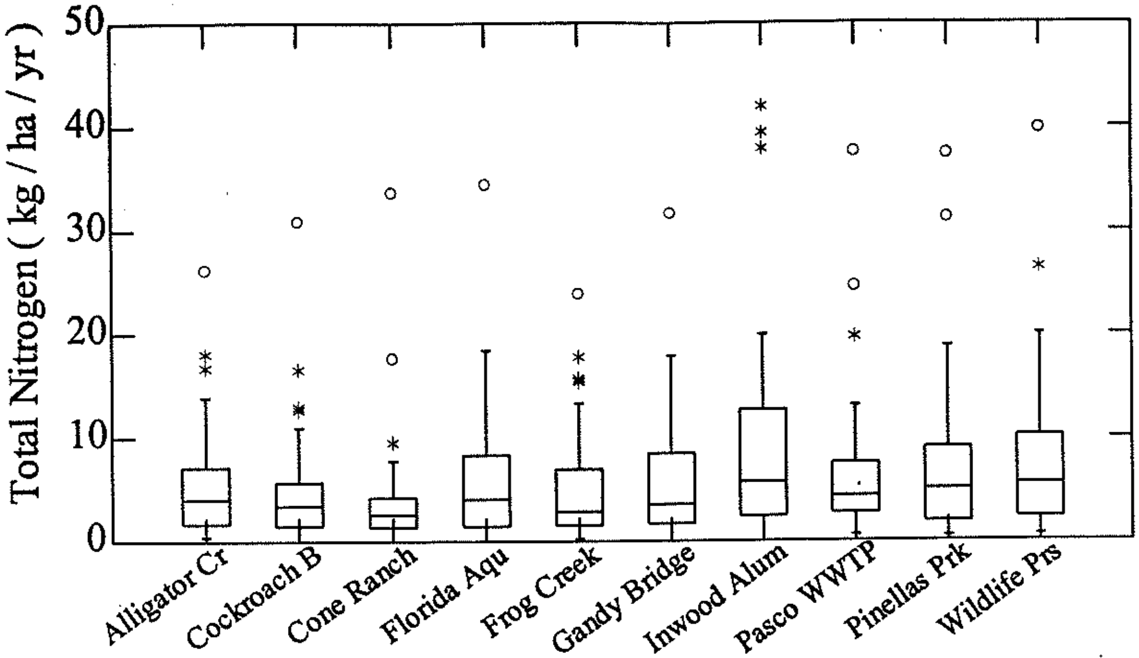

Figure 10. Distribution of weekly bulk deposition of total nitrogen; annualized values.

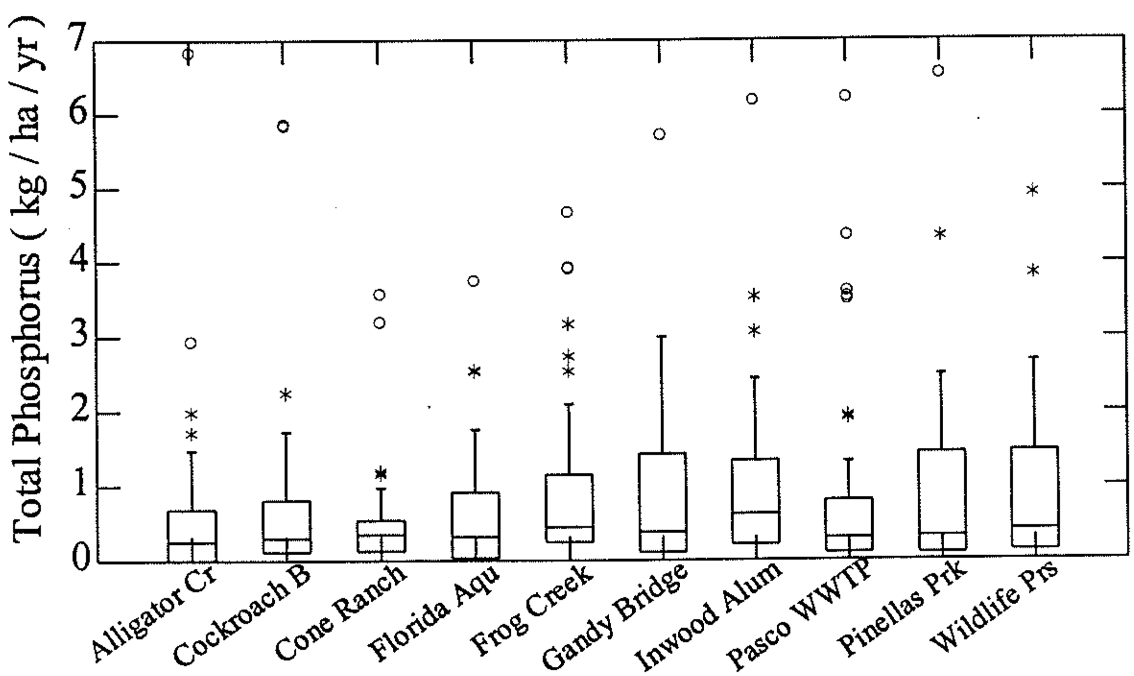

Figure 11. Distribution of weekly bulk deposition of total phosphorus; annualized values.

Table 6. Summary data on differences of individual site total nitrogen deposition from weekly watershed means.

Site	Mean	Median
Alligator Creek	-0.49	-0.80
Cockroach Bay	-0.60	-1.33
Cone Ranch	-0.30	-0.82
Florida Aquarium	-0.96	-0.90
Frog Creek	-1.00	-1.00
Gandy Bridge	-1.30	-1.00
Inwood Alum	2.94	-0.08
Pasco WWTP	-0.03	-0.16
Pinellas Park	0.53	-0.09
Wildlife Preserve	1.15	0.36

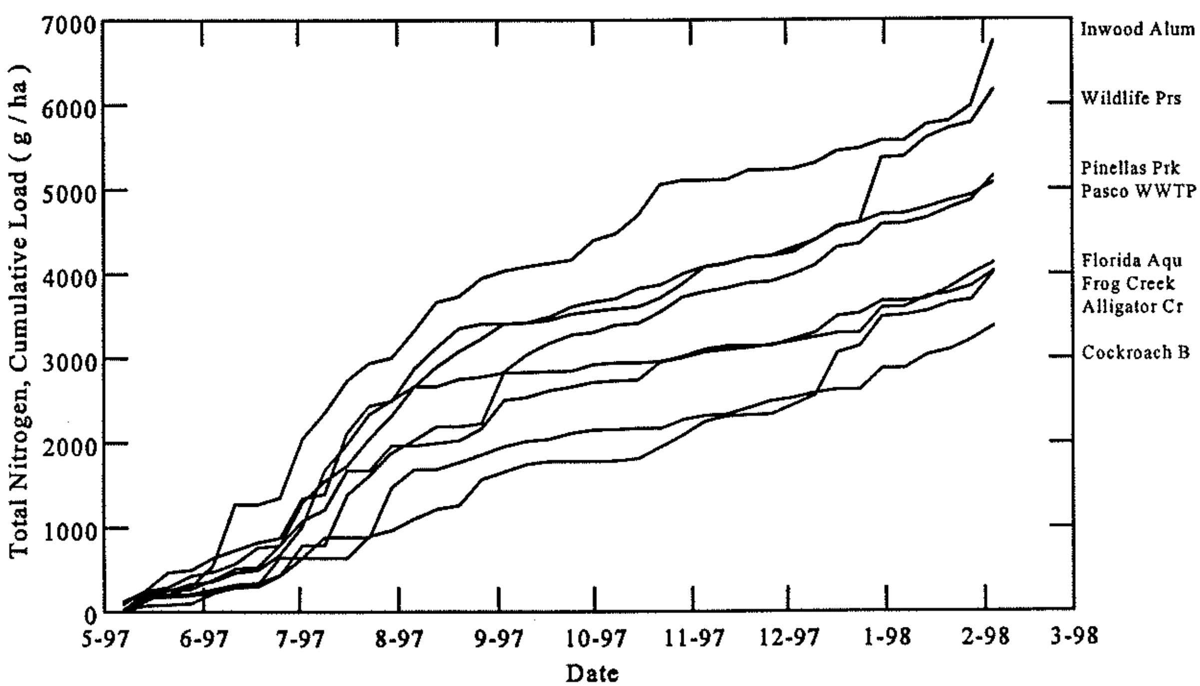

Figure 12. Cumulative atmospheric loadings of total nitrogen (measured as bulk deposition) for station with greater than 85% completeness of uncontaminated samples. (See data, Table 4.)

a substantial background level of atmospheric deposition. The **range** in nitrogen results for individual stations is comparable to previous bulk sampling of the Tampa Bay watershed (Dixon, *et al.*, 1996) in which total nitrogen deposition spanned between 6.02 and 12.85 kg ha^{-1} yr^{-1} at individual sites. The range in phosphorus values obtained previously (0.52 to 1.76 kg ha^{-1} yr^{-1}) are also similar to the results of this study in which phosphorus values at the 10 sites ranged between 0.62 and 1.06 kg ha^{-1} yr^{-1} (Figure 13). (Comparing the total deposition during the current project with prior data are problematic due to varying rainfall conditions and periods of study). Again no coherent spatial gradient among the 10 sites was evident for either nitrogen or phosphorus total loadings. _

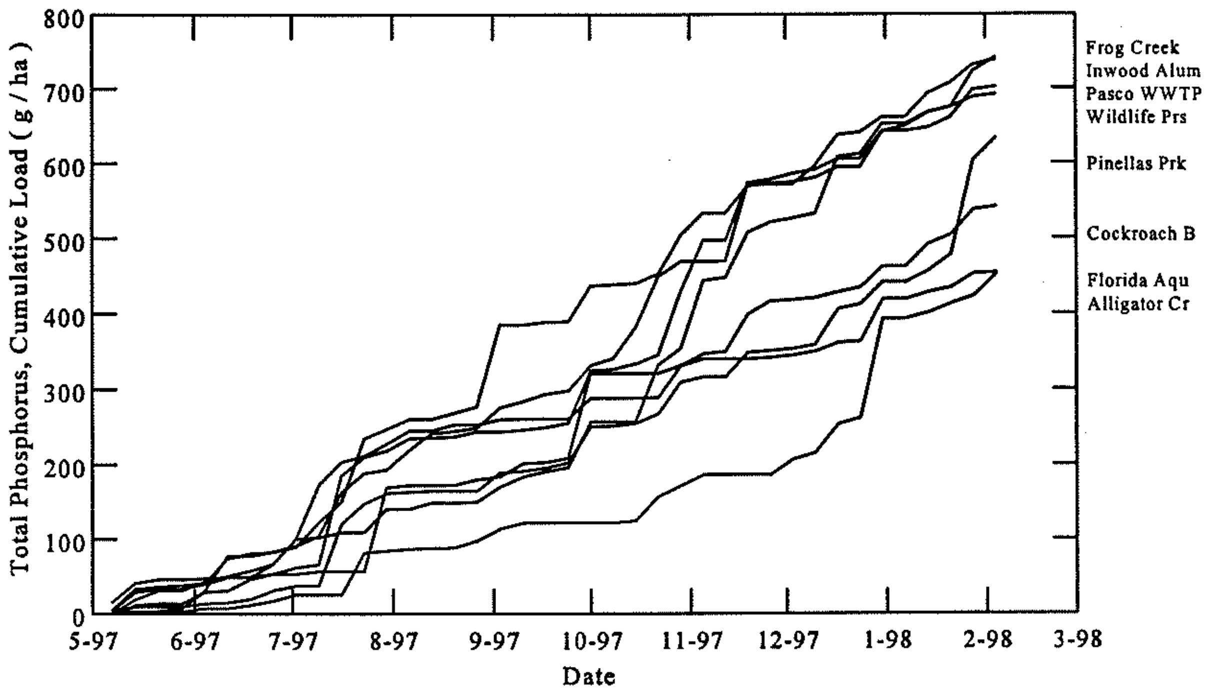

Figure 13. Cumulative atmospheric loadings of total phosphorus (measured as bulk deposition) for station with greater than 85% completeness of uncontaminated samples. (See data, Table 4.)_

Weekly bulk deposition of metals displayed more variation among stations than did nutrients. (Analyses included even apparent outlier data since non-parametric rank sum analyses are highly resistant to the effect of outliers.) Figures 14 through 17 illustrate the distribution of annualized deposition for cadmium, copper, lead, and zinc, as determined from monthly samples, but for visualization only, outlier data are not plotted for cadmium, copper, and zinc. Monthly deposition of copper, lead, and zinc were all significantly different between stations. The Florida Aquarium site, in particular, was noted for the consistently higher loadings of these metals. Although loadings of cadmium were not significantly different between stations, Figure 14 indicates that there were clearly stations receiving greater amounts, including not only the

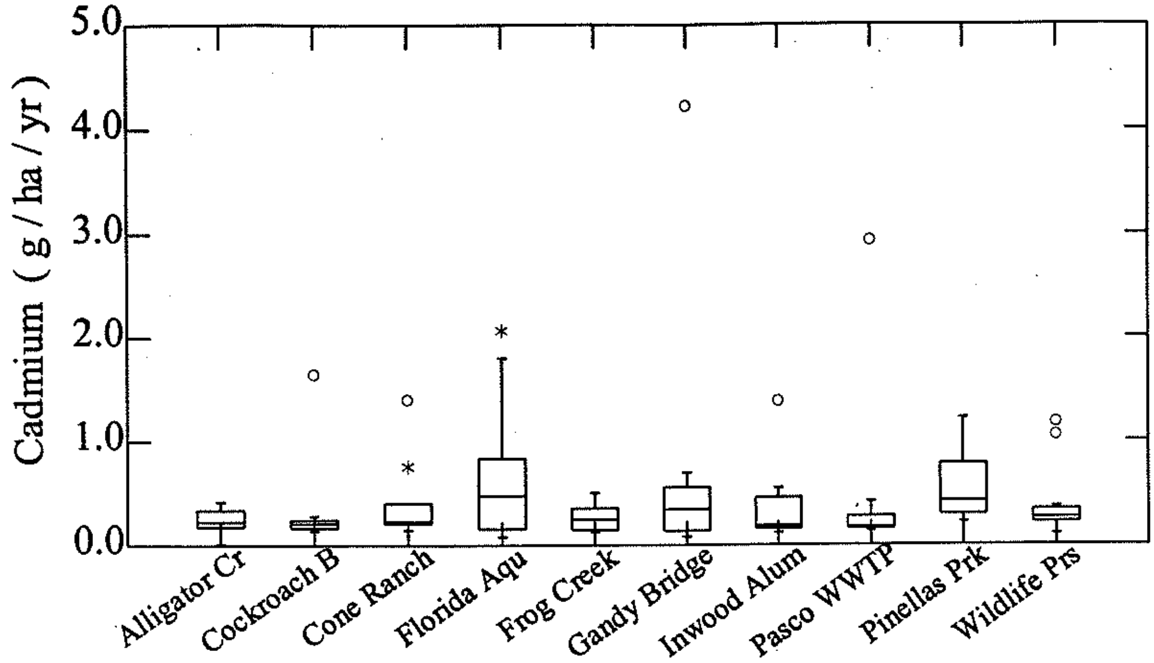

Figure 14. No significant site variations in the distribution of weekly cadmium loads measured in bulk atmospheric deposition.

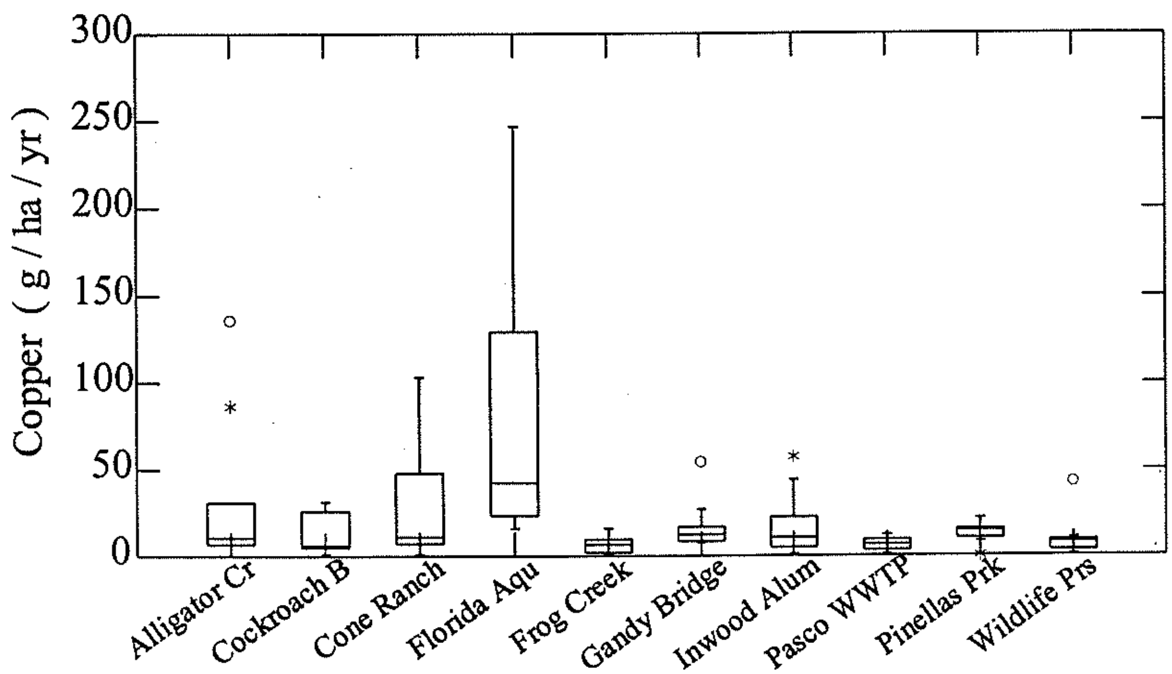

Figure 15. Significant site variations in the distribution of weekly copper loads measured in bulk atmospheric deposition.

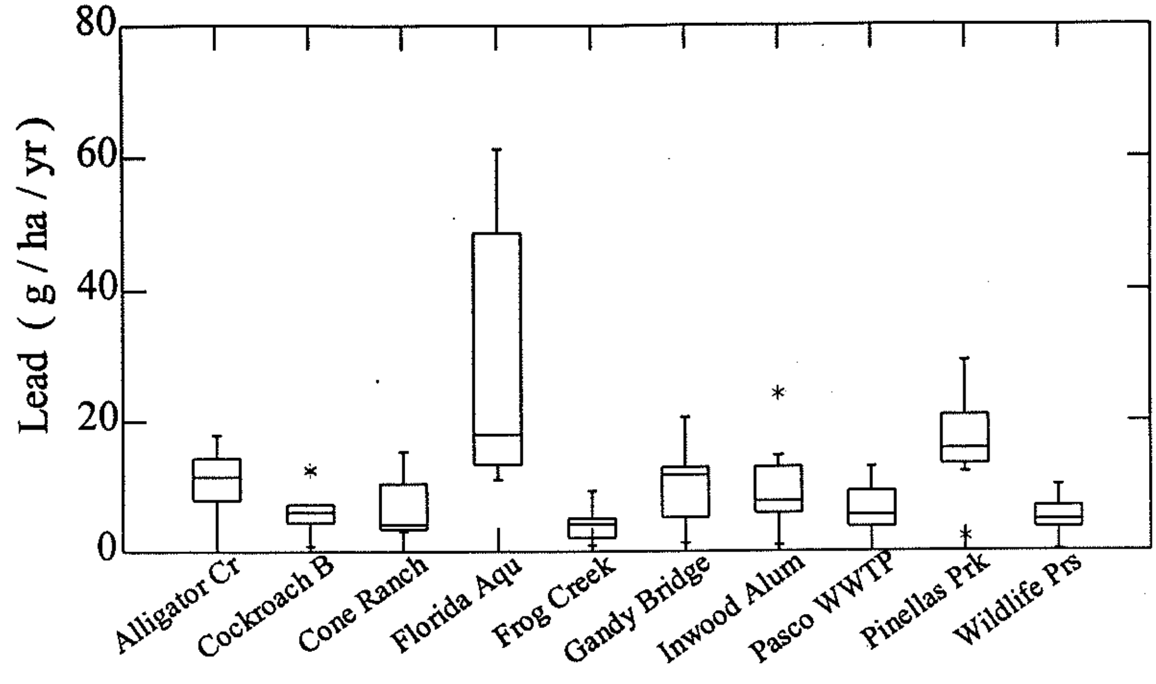

Figure 16. Significant site variations in the distribution of weekly lead loads measured in bulk atmospheric deposition.

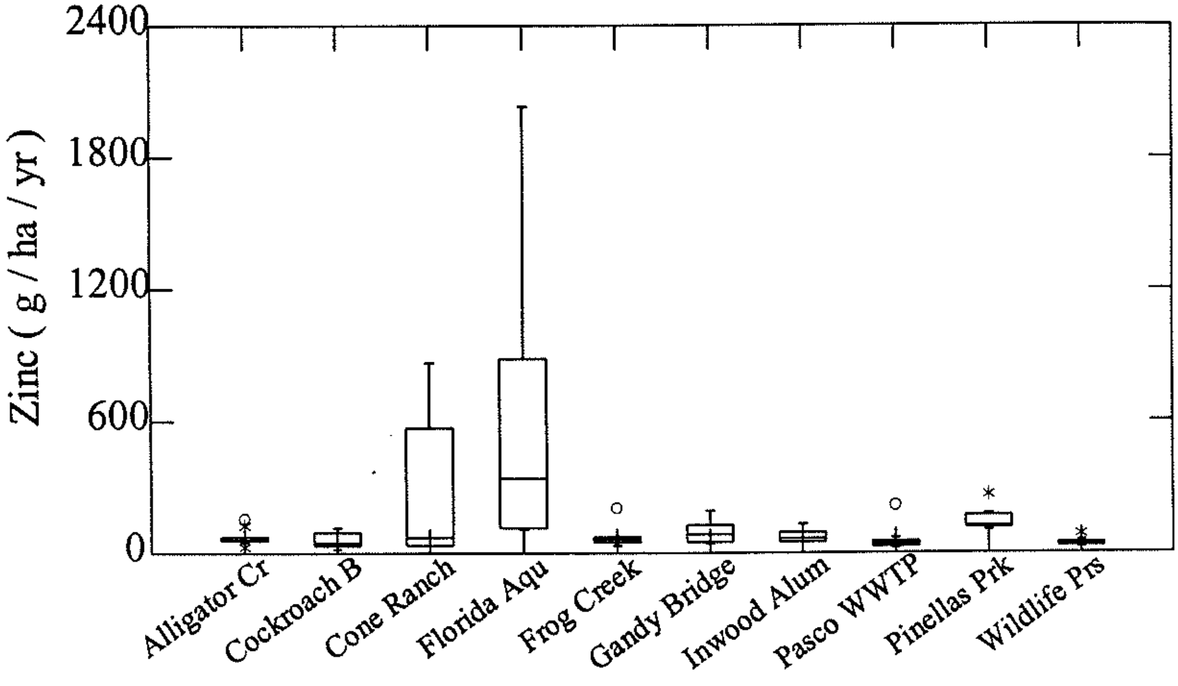

Figure 17. Significant site variations in the distribution of weekly zinc loads measured in bulk atmospheric deposition.

Florida Aquarium, but also the Pinellas Park site, both highly urban environments. The range between stations for individual metals was substantial, again implying localized influences. Annualized cadmium values between the stations with the greatest and least deposition differed by a factor of 3-10; copper by 14-36, lead by a factor of 7, and zinc by a factor of 16. The ranges in metals deposition values, with the exception of the Florida Aquarium site, were generally comparable to previous work, in which copper loadings were between 4.82 and 13.87 g ha^{-1} yr^{-1}, lead between 5.14 and 10.56 g ha^{-1} yr^{-1}, and zinc between 34.26 and 113.80 g ha^{-1} yr^{-1} (Dixon *et al.*, 1996).

Seasonal Variation in Bulk Deposition

Data collected were assigned to seasonal quarters following NADP/NTN conventions of spring = March, April, and May , summer = June, July, and August, fall = September, October, and November , and winter = December, January, and February. Because of study timing, minimal data were collected during the spring quarter, and these data were not included in the following analysis. Seasonal variations in nitrogen loads were significant for all data pooled with the lowest loadings falling within the fall quarter and the highest during summer (Figure 18). Mean loading rates were 10.73 kg ha^{-1} yr^{-1} for summer, 3.90 kg ha^{-1} yr^{-1} for fall, and 6.36 kg ha^{-1} yr^{-1} during the winter quarter. Illustration of weekly means (of all sites, Figure 3 above) also show

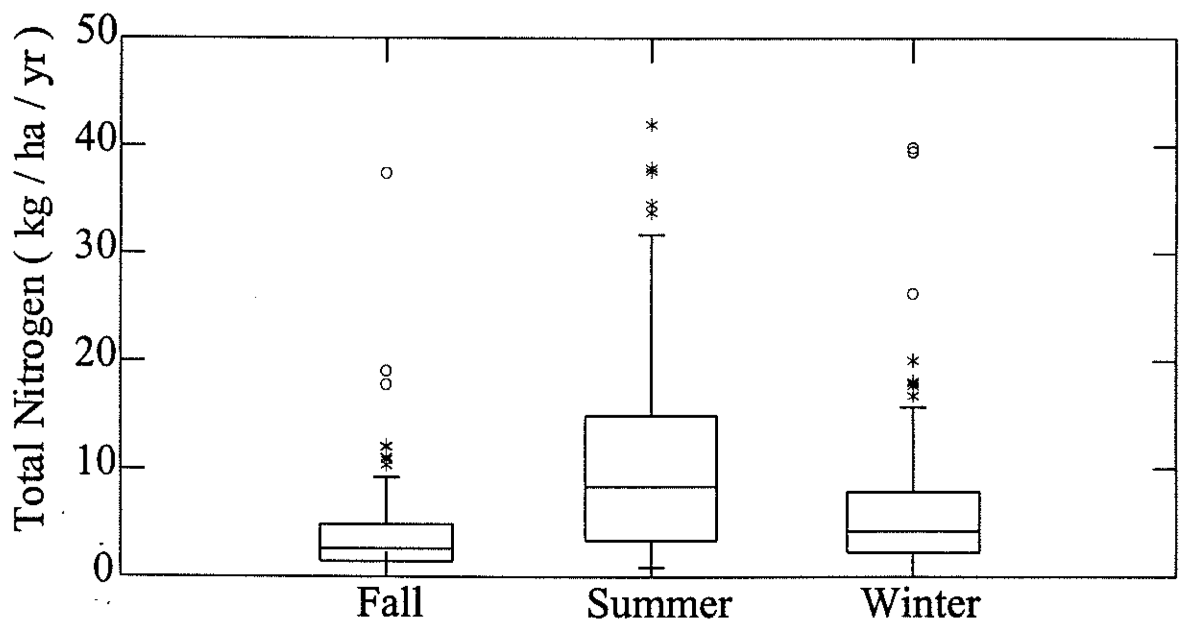

Figure 18. Distribution of weekly total nitrogen loads, measured as bulk atmospheric deposition, by season for all sites combined.

the seasonality in loadings. Individually, however, only four stations received significantly higher nitrogen loads during the summer (Cockroach Bay, Florida Aquarium, Inwood Alum, and the Wildlife Preserve). Where nitrogen loads differed by season, loadings during the summer were between 1.4 and 2.0 times higher than annualized totals over the entire project. Winter loadings during this project may have been higher than is typical due to the unusually large rainfall events in December. Phosphorous loads showed no significant distribution by season either as a whole or for individual stations.

Cadmium was the only metal to display significant seasonal variations overall, specifically at the Gandy Bridge and Inwood Alum sites. At these locations, cadmium loadings were highest in the summer. Other individual seasonal variations observed were also at Inwood Alum (copper), the Florida Aquarium (lead), Cone Ranch (lead), and the Wildlife Preserve (zinc). In all cases where seasonal differences were significant, loadings were highest in the summer and generally lowest in the fall.

Variation of Bulk Deposition with Rainfall

Weekly deposition of both nitrogen and phosphorus was significantly linearly correlated with rainfall amounts, both for the project overall and for individual stations, with the exception of the Cone Ranch. Nitrogen deposition by station (log transformed) as a function of rainfall is illustrated in Figure 19. Differences in slope are apparent and the higher slope at Inwood Alum, for example, is the product of the overall higher loadings at this site. Variability in loadings from large events is also visible, particularly at the Florida Aquarium. Seasonal variations in deposition:rainfall relationships were also examined for nitrogen and phosphorus and clearly show a coherent and significant pattern of increased loading with increased rainfall during all quarters. Figure 20 illustrates that, for nitrogen, with comparable amounts of rainfall, loadings are highest during the summer, with up to an 8 times greater than loading from a comparable rainfall event in the fall. This result is consistent with the seasonal distribution of ambient air concentrations of inorganic nitrogen which are typically higher during the summer months. Additionally, increased incidence of lightning during convective thunderstorms, and formation of NO_x from molecular nitrogen (N_2) may also play a role in elevating summer atmospheric loads of nitrogen. A similar seasonal variation in deposition:rainfall relationships was seen for phosphorus, but with fall loadings higher for given amounts of rainfall. The seasonality of phosphorus loadings may reflect seasonal agricultural practices and tillage captured during the study. (Although a spring planting is typical for the region, little of the study was performed during spring, perhaps missing a second seasonal signal.)

The seasonal variation in atmospheric loading of nitrogen with rainfall (Figure 20) initially appears to indicate that loading reductions to receiving waters could be achieved by preferentially retaining summer rainfall events, with loading reductions directly proportional to the rainfall retained. The examination of event mean concentrations of stormwater, however, (for the stations with no stormwater treatment) show no relationship of nitrogen concentrations in

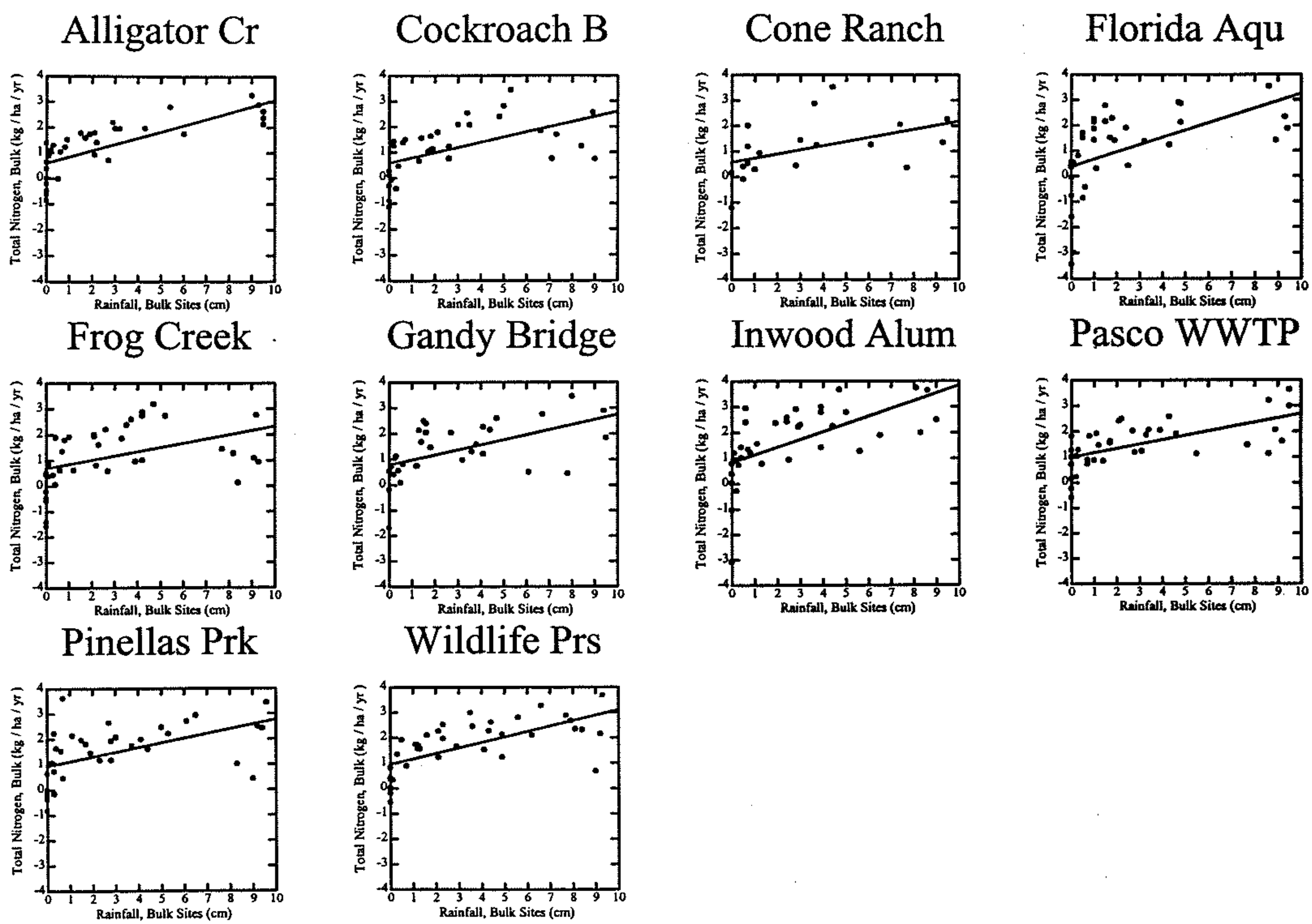

Figure 19. Relationship of total nitrogen in weekly bulk deposition to weekly rainfall totals at individual sites. The relationship at the Cone Ranch is not significant.

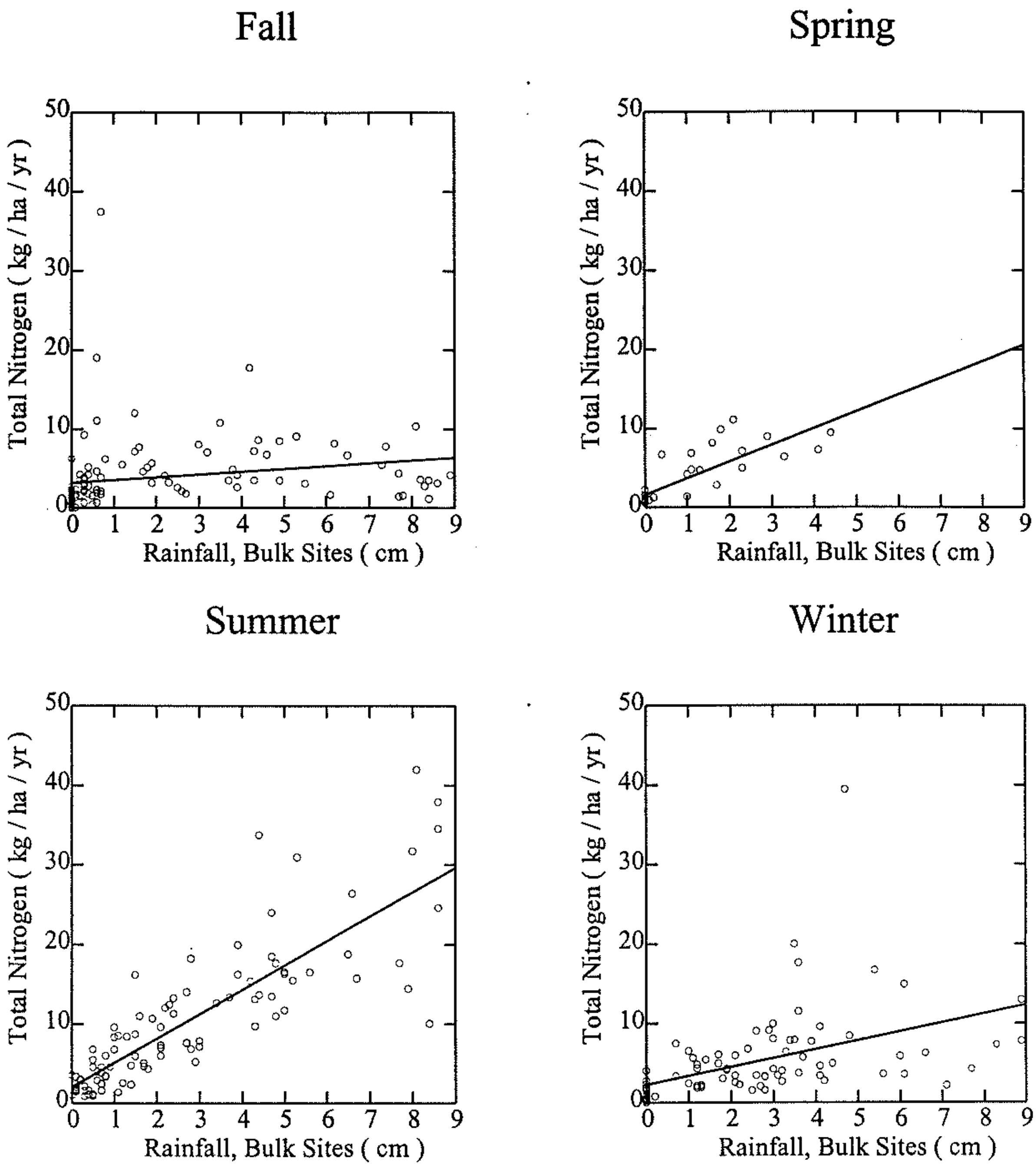

Figure 20. Seasonal variation in weekly total nitrogen loads measured in bulk deposition as a function of weekly rainfall.

runoff with either weekly rainfall amounts or season. As a result, retention of stormwater is equally effective in any season, and regardless of the size of the event, is effective in direct proportion to the volume of runoff retained

Comparison with Wet-only NADP/NTN Deposition

Overlap between the bulk deposition collections and available NADP/NTN data was limited to a 16 week period between May 13 and Sept 2, 1997. The NADP/NTN site (Verna Wellfields - FL41) collects wet-only, weekly samples with analyses for inorganic nitrogen species. These data are expected to be less than the deposition obtained from weekly bulk samples analyzed for total nitrogen. (During the study period, wet-only deposition from 47 events at the Florida Aquarium indicated organic nitrogen comprised 26% of total nitrogen in rainfall. Weekly compositing periods may be expected to increase the percentage of organic nitrogen to near the 40% observed in previous bulk deposition collection programs.) The wet only inorganic nitrogen loading provided by the NADP/NTN weekly samples should be viewed as an underestimate of total wet deposition of nitrogen.

Again due to the highly variable nature of atmospheric deposition, there were no significant differences in weekly nitrogen deposition over this period between the bulk atmospheric stations and the NADP/NTN site. Total deposition recorded at FL41, however, totaled only 68% (1.90 kg ha^{-1}) of that recorded by the bulk sites over the period, with remaining bulk sites recording on average, 2.79 kg ha^{-1} (from 1.95 to 4.04 kg ha^{-1}). In prior years at FL41, wet-only inorganic nitrogen loads have ranged between 1.00 and 2.9 kg ha^{-1}.

Temporal Trends in Wet-Only Deposition

The NADP/NTN site FL41 has a period of record from August 1983, to September 1997. The data base was examined for relationships and for trends over time using both parametric and non-parametric approaches. Data were censored if NADP/NTN quality assurance procedures indicated a compromised sample. Monthly loads of inorganic nitrogen and rainfall totals were computed for 1984 through 1996, the years with completed data sets. Log:log transformations provided the most linear relationships between rainfall and loads (Figure 21). Residuals from the relationship in Figure 21 displayed no trend with time using either parametric or non-parametric tests against time. Again using log transformed data, nonparametric seasonal Kendall tests indicated significant increasing trends with time for both nitrogen and rainfall.

Trend analyses also employed LOWESS (LOcally WEighted Scatterplot Smooth; Cleveland, 1979) to smooth monthly inorganic nitrogen loads against the independent variables of rainfall and season (month). This robust smoothing procedure computes general tendencies of data with respect to the selected independent variable (or forcing function), describing the relationship between nitrogen concentration and month, for example, while not requiring either linearity of relationship or normality of residuals. The procedure is also resistant to outlier data, periodicity,

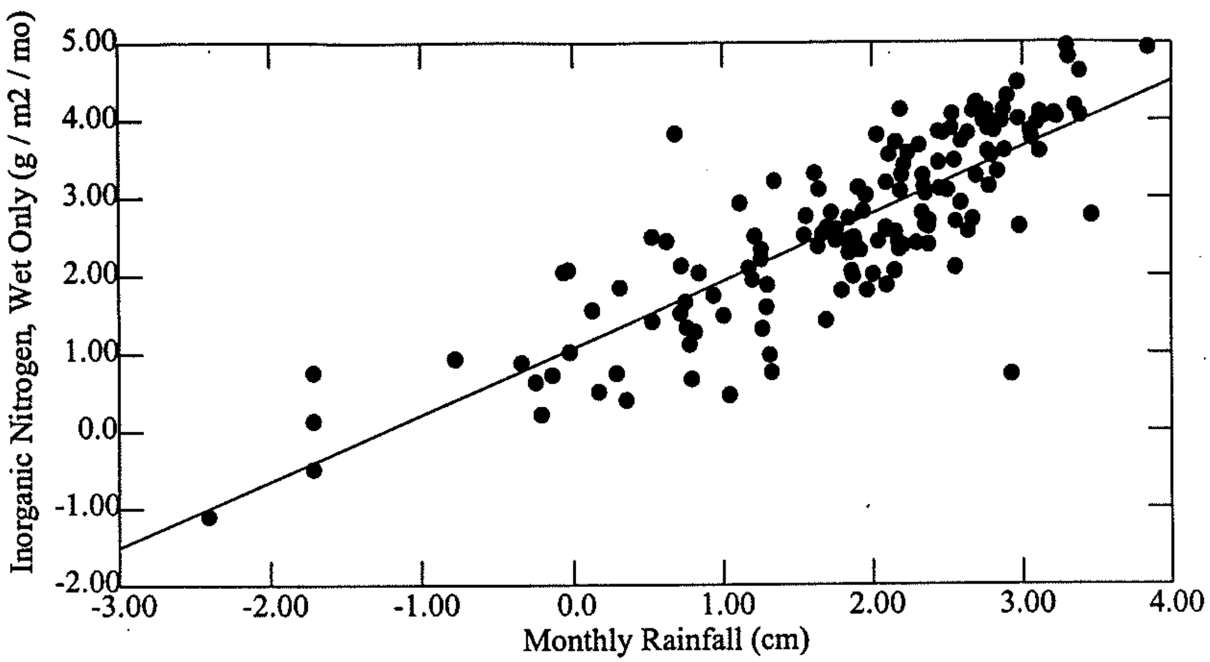

Figure 21. Relationship between monthly loadings of inorganic nitrogen in rainfall and monthly rainfall amounts at the NADP/NTN FL41 site, 1984-1996. Log transformed data.

missing and censored data, and serial correlation. Once the influence of a selected forcing functions such as month is evaluated in the LOWESS smooth, residuals from the curve are then evaluated against time to detect temporal trends. An increasing trend noted for residuals against date indicate that more recent data fall above the LOWESS curve, and further indicate that for a given set of independent variable conditions, the dependent variable has increased significantly over time. There are no statements implied regarding the frequency or distribution of the independent variable. Residuals were tested using Kendall's tau.

The time series of wet-only inorganic nitrogen deposition (Figure 22A) is obviously highly variable, while the seasonal loadings (Figure 22B) demonstrate that higher loadings are typically received during the summer months. The LOWESS curve in Figure 22B indicates that loadings typically reach a maximum during July. Residuals from the LOWESS relationship are redistributed by time and tested for monotonic trend (Kendall's tau). Figure 22C has a linear smooth illustrated through the residuals to signify a significant increasing trend in inorganic nitrogen deposition, despite high levels of seasonal variability. A similar analysis of rainfall (Figure 23) reveals that after seasonal variability is accounted for, there is no significant trend (at the $p=0.05$ level) in monthly rainfall amounts. In examining inorganic nitrogen loading in rainfall as a function of rainfall amounts (Figure 24), it becomes clear that changes in rainfall amounts, while not statistically significant, appear to account for much of the increase in nitrogen deposition. The residuals from the relationship between inorganic nitrogen and rainfall display no temporal trend.

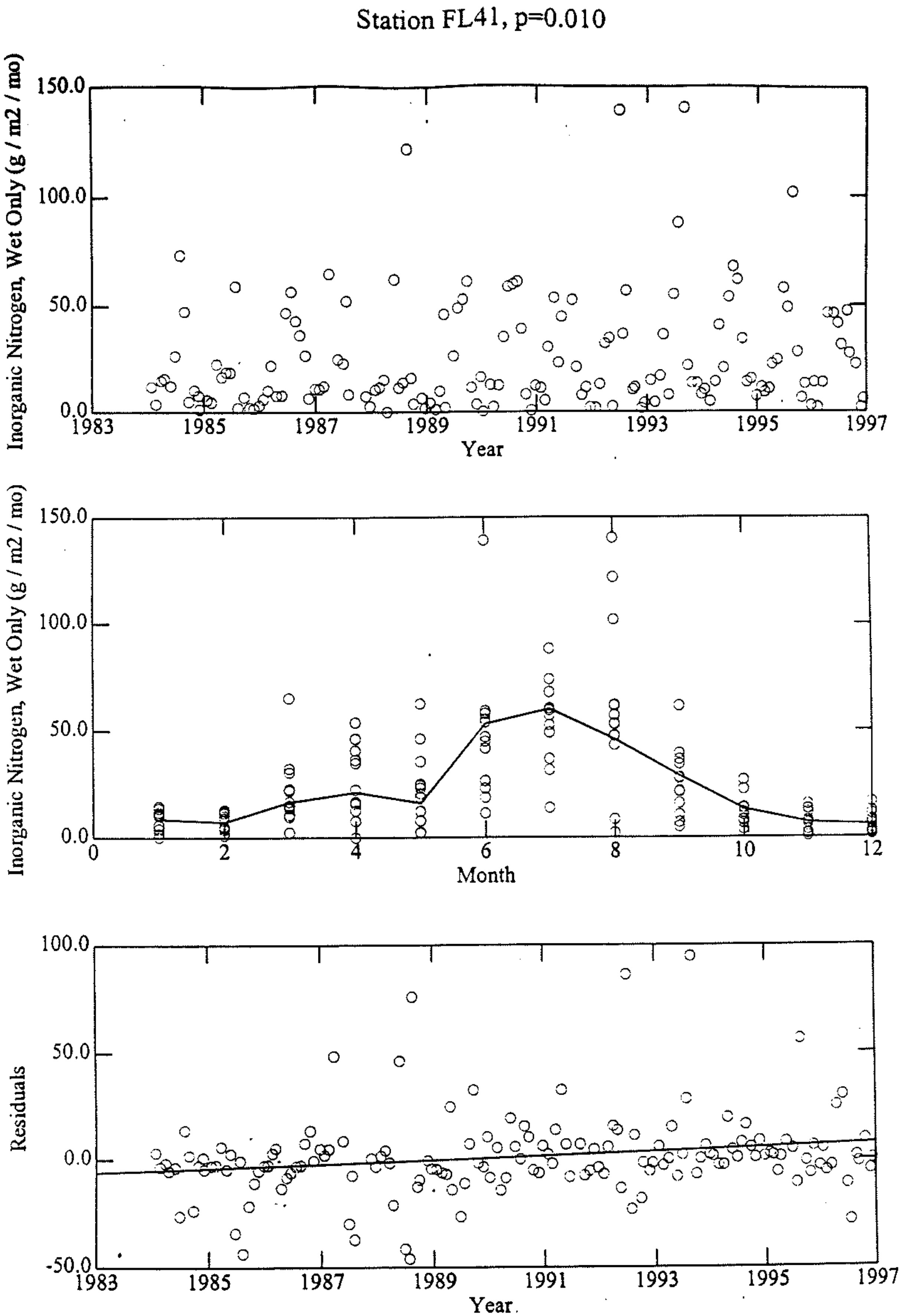

Figure 22. Inorganic nitrogen in rainfall against time (22A), LOWESS smooth of the parameter against month (22B), and analysis of residuals from the LOWESS smooth against time (22C) to determine trend. Linear representation only, as significance of trends was detected with non-parametric rank-correlation analyses.

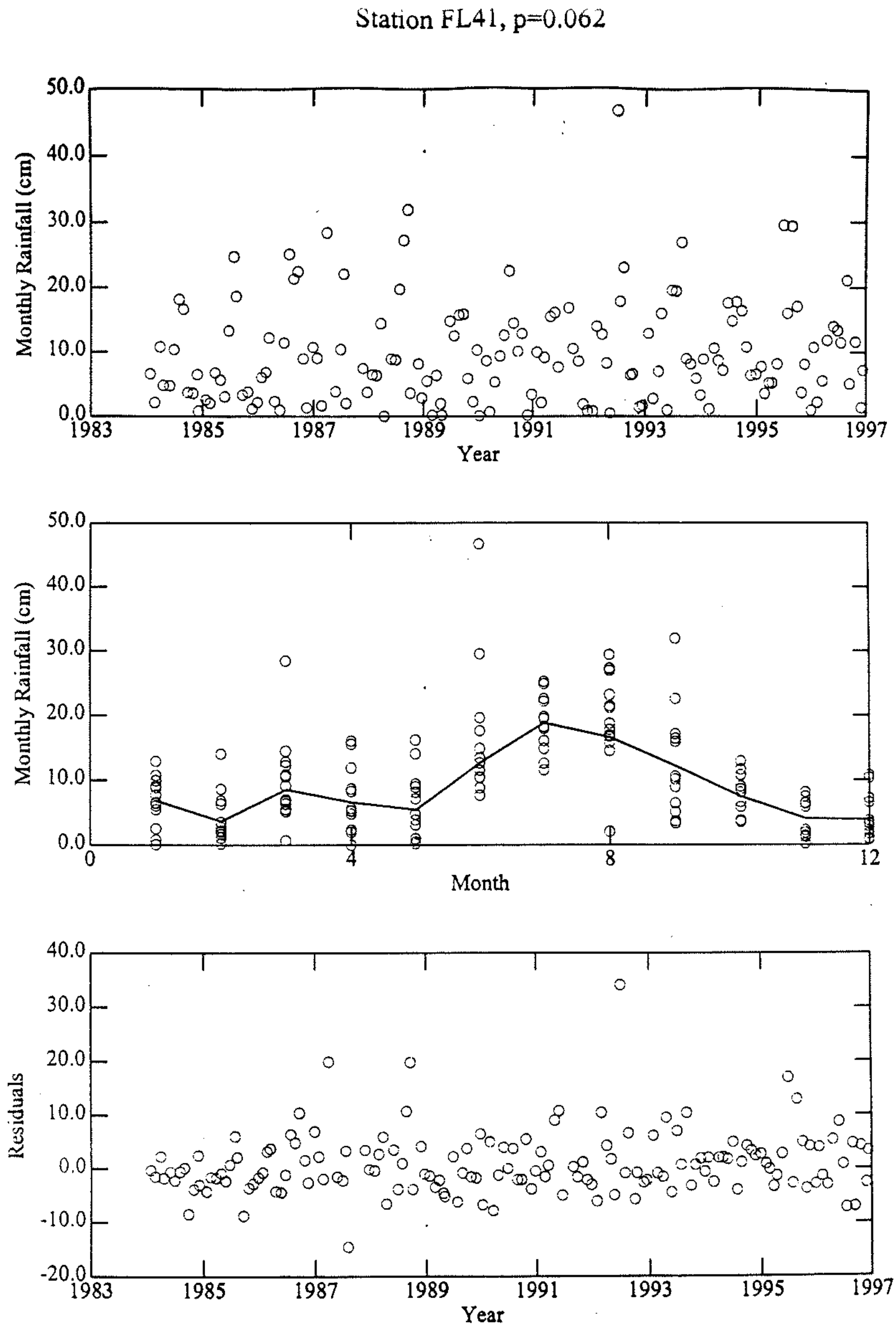

Figure 23. Monthly rainfall against time (23A), LOWESS smooth of the parameter against month (23B), and analysis of residuals from the LOWESS smooth against time (23C) to determine trend. No significant trend.

Station FL41, p=0.361

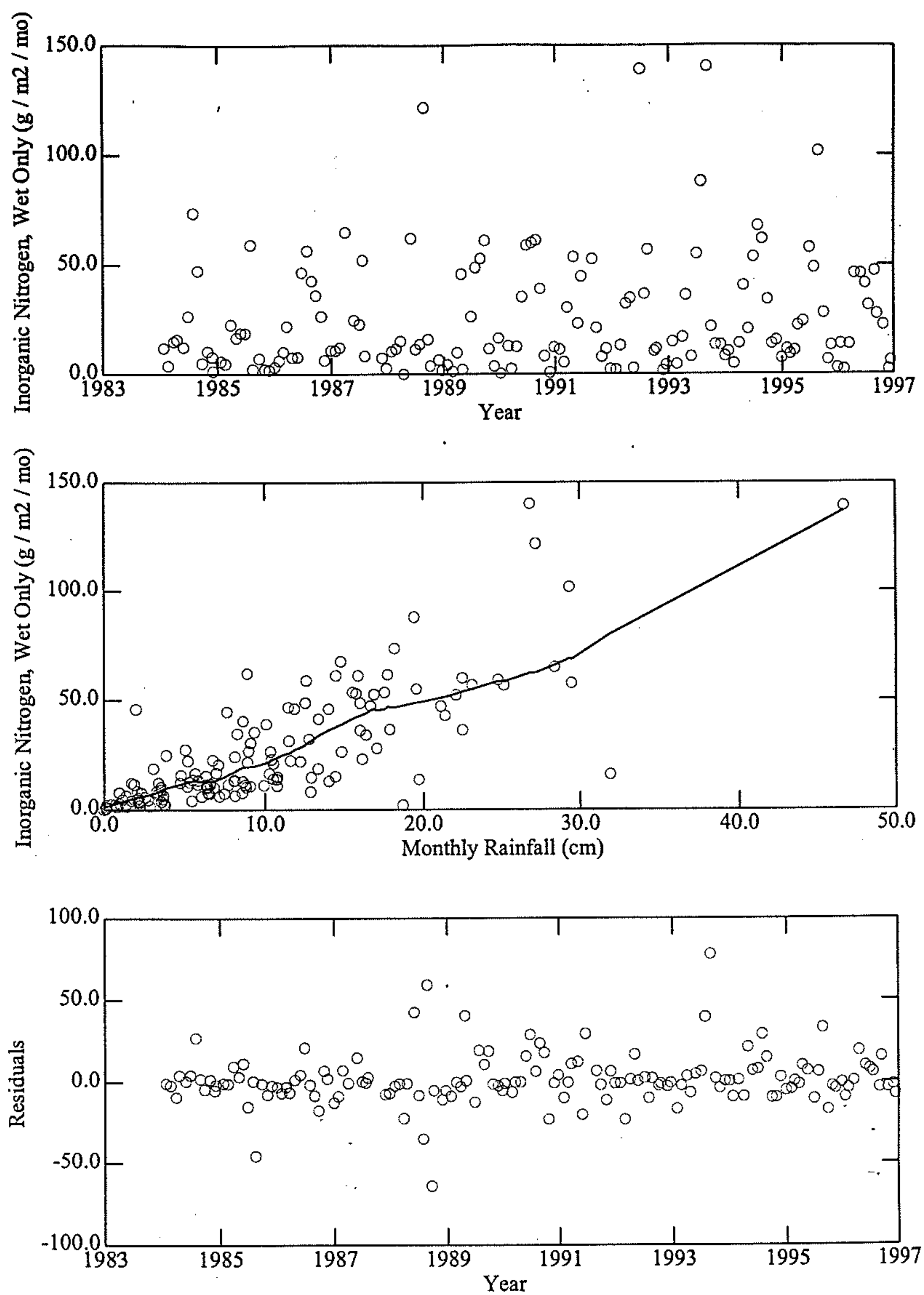

Figure 24. Inorganic nitrogen in rainfall against time (24A), LOWESS smooth of the parameter against monthly rainfall (24B), and analysis of residuals from the LOWESS smooth against time (24C) to determine trend. No significant trend.

Comparison with Rainfall Loadings at the Florida Aquarium

The SWFWMD rainfall and stormwater site was operating continuously during the 40 week study period and the SWFWMD rainfall collector was within 75 m of the bulk collector. Rainfall concentrations from individual events were obtained from SWFWMD and weekly loadings computed for comparison to bulk atmospheric depositions. There were no significant relationships between weekly loadings of nutrients and metals and the loads collected in rainfall alone. This is due in part to the unusually large rainfall events which are not completely collected by the bulk apparatus. Elimination of the five weeks in which rainfall amounts totaled over 9.5 cm resulted in significant correlations between rainfall loadings of nitrogen (Figure 25) and phosphorus and bulk loadings. Relationships between bulk and wet-only deposition were not as uniform as observed for the data at the TBADS intensive site (Figure 8), however, and could indicate a higher and variable proportion of dry deposition at the Florida Aquarium site. The intercept in the relationship of Figure 25 indicates that dry deposition collected by the bulk sampler was on the order of 0.03 kg ha^{-1} $week^{-1}$ or 1.5 kg ha^{-1} yr^{-1}, as compared to a maximum of 0.7 kg ha^{-1} yr^{-1} estimated at the Gandy Bridge site.

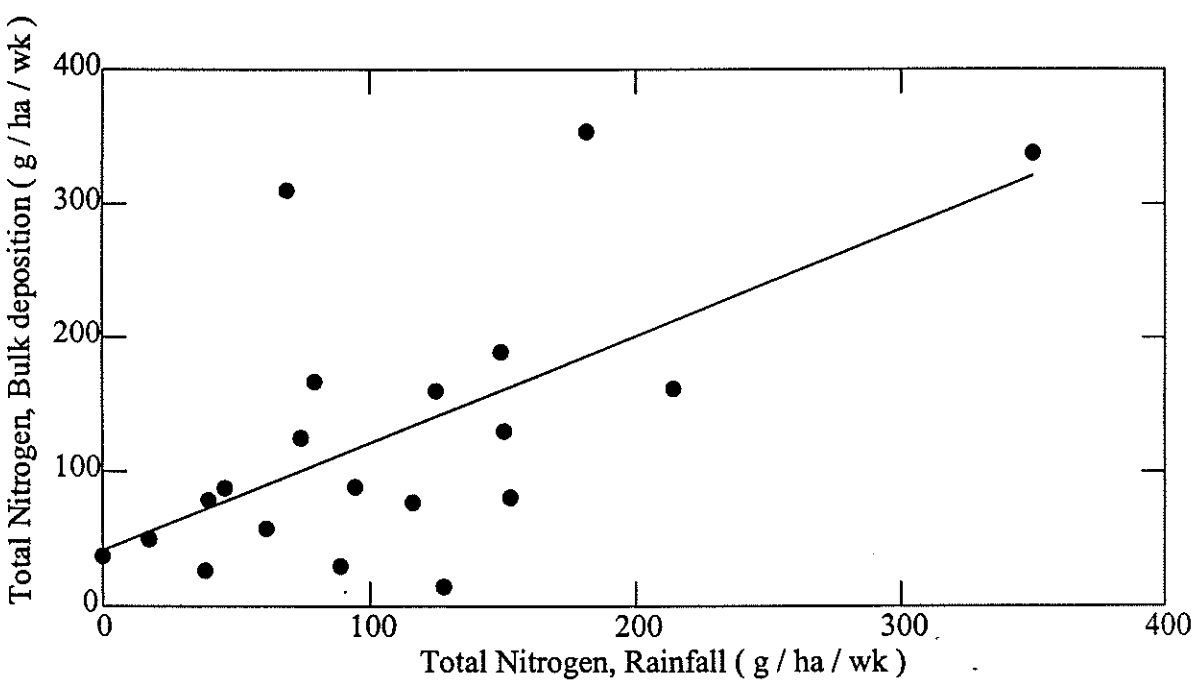

Figure 25. Relationship between weekly loadings of nitrogen in bulk deposition and in rainfall at the Florida Aquarium site.

Total loadings received by the SWFWMD and bulk installations were in general agreement. With rainfall events over 9.5 cm censored, Table 7 presents the results as total loads received over the remaining 35 weeks of the study.

Table 7. Comparison of bulk and wet-only deposition loads received at the Florida Aquarium site when rainfall amounts did not exceed 9.5 cm; n=35 weeks.

Parameter	Units	Bulk	Rainfall
Rainfall	cm	48.9	67.4
Total Nitrogen	g ha^{-1}	3013	3088
Total Phosphorus	g ha^{-1}	284	157
Cadmium	g ha^{-1}	0.3	0.8
Copper	g ha^{-1}	80.5	24.1
Lead	g ha^{-1}	10.2	5.8
Zinc	g ha^{-1}	229.2	96.9

Similar to other results, the rainfall collection efficiency for the bulk collector was near 75% that of the larger wet-only collection device. Even if rainfall collection efficiencies are ignored, it is clear that a substantial portion of total phosphorus is dry deposited, as is copper, lead, and zinc. Rainfall loads are 55%, 30%, 57% and 42% of the phosphorus, copper, lean, and zinc loads collection as bulk deposition. While more cadmium appears to be contained in rainfall than in bulk deposition, this result is most likely the result of the much higher analytical detection limits used for rainfall analyses and the high proportion of non-detectable values (33 of 38) for this analyte. If bulk collections are increased by an amount to account for under collection of rainfall, the dry deposited fraction increases even further. Total nitrogen bulk deposition, adjusting for rainfall collection efficiency, could be as high as 3860 g ha^{-1} over the study with the dry portion of bulk deposition accounting for up to 20% of the total.

VI. Results and Discussion - Stormwater

Summary data of stormwater concentrations and basin normalized runoff loadings appear in Tables 8 and 9. Local conditions were compared with the results of the Nationwide Urban Runoff Program (NURP) conducted by EPA in the 1970's and with recently acquired results from the EPA Municipal Separate Stormwater System (MS4) stormwater permitting program. Table 8 is adapted from the NURP results (EPA, 1983). The loads (kg/ha/yr) reported by EPA have been increased by 30% to account for the higher annual rainfall in Florida. Local data from the present studies are included as a comparison.

Table 8. Event mean concentrations (EMC's) of stormwater, computed as the geometric mean of individual events for NURP and NPDES, and as the geometric mean of weekly or monthly flow-weighted concentrations from the present study. Units of mg/l for all parameters.

Nationwide Urban Runoff Program (1)	TKN	NO_{2+3}-N	TN	TP	Cd	Cu	Pb	Zn
RESIDENTIAL	--	0.96	--	0.47	--	0.05	0.18	0.18
MIXED	--	0.67	--	0.33	--	0.04	0.19	0.20
COMMERCIAL	--	0.63	--	0.24	--	0.04	0.13	0.33
OPEN / NONURBAN	--	0.73	--	0.23	--	--	0.05	0.23
HIGHWAY	--	0.83	--	0.44	--	0.05	0.53	0.37
RAINFALL	--	0.60	--	0.03	--	0.00	0.00	0.11

Phase 1 MS4 NPDES (2)	TKN	NO_{2+3}-N	TN^3	TP	Cd	Cu	Pb	Zn
FOREST, OPEN, PARK	1.00	0.85	1.85	0.33	0.0010	0.01	0.02	0.03
RESIDENTIAL	2.43	1.25	3.68	0.53	0.0039	0.03	0.03	0.11
MULTIFAMILY	1.45	0.50	1.95	0.49	0.0005	0.01	0.02	0.11
LIGHT INDUSTRIAL, COMMERCIAL	2.39	0.98	3.37	0.40	0.0030	0.02	0.03	0.15

Present Study	TKN	NO_{2+3}-N	TN^3	TP	Cd	Cu	Pb	Zn
Alligator Creek	--	--	0.79	0.11	0.0002	0.014	0.004	0.046
Cockroach Bay	--	--	0.99	0.62	0.0001	0.006	0.001	0.016
Cone Ranch	--	--	1.90	0.70	0.0004	0.008	0.001	0.055
Florida Aquarium	--	--	0.68	0.09	0.0003	0.020	0.005	0.065
Frog Creek	--	--	1.15	0.50	0.0002	0.012	0.002	0.045
Gandy Bridge	--	--	1.58	--	0.0010	0.005	0.010	0.030
Inwood Alum	--	--	2.34	0.61	0.0006	0.010	0.010	0.029
Pasco WWTP	--	--	2.58	0.29	0.0003	0.006	0.001	0.023
Pinellas Park	--	--	0.62	0.13	0.0002	0.004	0.005	0.043
Wildlife Preserve	--	--	1.86	0.11	0.0002	0.010	0.001	0.031
Mean, All Sites			1.27	0.22	0.0003	0.009	0.003	0.036

(1) - EPA, 1983. Final Report of the Nationwide Urban Runoff Program (All stations evaluated in NURP Program)
(2) - CDM, unpublished data. Results from 192 municipal sites sampled as part of MS4 NPDES applications.
(3) - Approximate values from the sum of TKN and NO_{2+3}-N

Table 9. Reported annual stormwater loadings by general land use (NURPS) and by site (present study).

		NURPS Data			Present Study Sites									
Parameter		**All Urban**	**Residential**	**Commerical**	**Alligator Cr**	**Cockroach B**	**Cone Ranch**	**Florida Aqu**	**Frog Creek**	**Gandy Bridge**	**Inwood Alu**	**Pasco WWTP**	**Pinellas Prk**	**Wildlife Prs**
Total P	kg / ha / yr	2.0	1.7	4.5	1.68	4.36	2.26	1.24	1.30	--	5.66	4.73	0.60	0.72
TKN	kg / ha / yr	8.6	7.6	20.2	--	--	--	--	--	--	--	--	--	--
NO2+3-N	kg / ha / yr	4.7	3.4	9.2	--	--	--	--	--	--	--	--	--	--
TN, Calculated	kg / ha / yr	13.4	11.0	29.3	6.90	6.54	6.01	11.44	2.30	8.24	19.62	18.82	2.90	12.65
Copper	kg / ha / yr	0.2	0.2	0.5	0.14	0.05	0.02	0.30	0.00	0.03	0.31	0.03	0.03	0.03
Lead	kg / ha / yr	0.9	0.7	1.9	0.04	0.01	0.00	0.07	0.00	0.05	0.24	0.00	0.03	0.01
Zinc	kg / ha / yr	0.9	0.8	2.1	0.39	0.11	0.47	0.99	0.08	0.19	0.65	0.06	0.20	0.08
Cadmium	kg / ha / yr	--	--	--	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00

Stormwater metals concentrations are uniformly lower than the older data gathered under the NURP program, with differences beyond what one would expect from improvements in analytical detection limits over the years. Metals are comparable to the more recent NPDES data, except for zinc which appears lower during the present study. Some phosphorus values are higher than the NPDES data, not surprising in view of the geology of the area, and considering that the NDPES data are collated from around the United States. Nitrogen concentrations are typically lower than would be expected from either residential or light industrial/commercial land uses.

Loadings from the present study were annualized (the total cumulative load recorded times the fraction of the year represented by the sampling period) and adjusted for the basin area to obtain kg ha^{-1} yr^{-1} for each site sampled.

- Metals loadings from the ten sites were uniformly much lower than would be expected from other urban, residential, or commercial land uses.

- Cockroach Bay, Inwood Alum, and the Pasco WWTP recorded comparable phosphorus loads to commercial land uses.

- Some nitrogen loading rates were much lower than previous residential values, while other sites (Florida Aquarium, Gandy Bridge, Inwood Alum, Pasco WWTP, and the Wildlife Preserve) were closer to what is expected for urban or residential land uses.

It should be re-emphasized that the total loadings and resultant unit loadings are estimated from the ratio of (total flow/sampled flow) times the measured loadings. This approach was necessary because of the absence of continuous flow-weighted quality samples. The individual weekly estimates of loading were divided by the contributing area, and summed over the period of study. These runoff loads were compared with the cumulative bulk atmospheric load developed for the same period. The results should be interpreted within the sampling framework, and to the extent that the collection periods agree. For example, most of the relatively pervious sites retained a significant amount of the atmospheric loading during the early part of the sampling period which began in the dry season. Had the sampling commenced later in the year, the results might be quite different, and sites which were started later in the program should not be directly compared with sites having longer sampling periods.

Further, the analytical procedures used do not identify the source of contaminants in the runoff. For example, a copper molecule which was exported in runoff during the sampling period may actually have been deposited years before the program began and at a time when deposition rates were quite different. As a corollary, some of the atmospheric deposition during the present study may not have been exported during the study period. For this reason, the term 'export ratio' is preferred to the term 'watershed transfer coefficient' and was computed as the stormwater runoff load divided by the atmospheric deposition loading.

Comparison of Stormwater with Bulk and Intensive Atmospheric Deposition

The planned comparison of runoff from the Trask and Lawn site near the Gandy Bridge to both bulk and wet-only deposition from the intensive site at the Gandy Bridge was limited by the number of weeks for which intensive site data were available, the start date of the Trask and Lawn stormwater site, and the number of weeks rainfall occurred. Data were recorded for all parameters for four weeks (Table 10). The close agreement between bulk and wet-only deposition at the site has been previously described (Figure 8) and is apparent in the data below. Accordingly, loadings as a result of deposition are essentially identical whether bulk or wet-only deposition is employed. Using individual event data does not increase the number of points to evaluate, as the four weeks shown in Table 10 each represent a single event captured. Further evaluation of runoff as a function of deposition appears below.

Table 10. Comparison of Gandy (Trask and Lawn) stormwater runoff yield of nitrogen with bulk atmospheric and wet-only deposition. Deposition measurements made approximately 1.3 km from stormwater site.

Week	Total Nitrogen, Runoff Yield (g ha^{-1})	Total Nitrogen, Bulk Deposition (g ha^{-1})	Inorganic N, Wet-only Deposition (g ha^{-1})
7/15/97	43.9	608.3	612.7
7/22/97	21.6	258.3	240.3
7/29/97	5.6	210.6	197.1
8/5/97	2.9	82.9	68.3

Sampled flows and Site Selection

For descriptive purposes, the cumulative stormwater flow and cumulative unit loadings were calculated to estimate the net impact of stormwater from individual sites. As previously described, stormwater sampling protocols and sampling periods differed among sites. Due to instrumental problems, flow measurements (and samples from these periods) were not always available for the duration of the study. In some cases, site installation occurred after atmospheric sampling had begun. The period of accumulation consequently varies by site, but atmospheric loads used for comparisons are limited to the same time period for which stormwater flow measurements are generally available. In addition, some sampling protocols collected samples only during a small fraction of the time that flow occurred or site hydrological characteristics produced very minimal runoff amounts until late in the study, resulting in minimal stormwater data for the study period.

Figure 26 illustrates the ratio of sampled flow to total site runoff as a function of time. In the absence of flow (no rainfall) or a failure to measure flow and/or to sample, a ratio was not calculated. As a result, the flow sampled ratio for each site does not include the periods of time when the flow measuring device was inoperative. Table 11 gives the resulting beginning and ending dates of load accumulation for each site, along with an estimate of the percent of total flow actually measured during the respective sampling period. The median ratio of sampled to total flow is 56% but the flow actually sampled at a significant number (4/9) of the sites was 10% or less of the total flow measured at the site.

Special note should be made of the Cone Ranch results. For unidentified reasons, the relationship of runoff to rainfall at this site was an inverse function as illustrated in Figure 27, a fact that others have noted in previous reports regarding the hydrology of this site. The numerous depression storage features and relic wetlands, as well as the low impervious area of the property, resulted in runoff and flow weighted sampling commencing late in the program and lasting only four weeks. (Grab samples had been collected previously to evaluate baseflow conditions in the absence of stormwater events, but could not be used to evaluate runoff loadings as they were collected when no flow was present.) While the sampling effort captured 90% of the flow during this period, compositing of atmospheric samples for metals only allowed a single value for comparison to stormwater loading. Due to the aberrant rainfall/runoff relationship and the relatively short sampling period, no further analyses were conducted with stormwater data from this site.

Prior to statistical analyses, an attempt was made to combine similar sites. Sites were ranked by the ratio of flow sampled to total flow and two obvious groups resulted. The first group included four sites (Gandy Bridge, Florida Aquarium, Alligator Creek and Pinellas Park) which sampled 85% or more of total flow recorded, as well as having accumulation periods over at least 65% of the study period. The second group consisted of stations representing sampled to total /flow ratios of 30% or less. Subsequent evaluations focused largely on data from the high ratio (high sample rate) group of sites.

Site Characteristics

For use in later multivariate analyses, sites were evaluated for land use and the amount of impervious area (expressed as Directly Connected Impervious Area, DCIA). For several sites, an estimate of imperviousness was provided by the agency performing the sampling. DCIA was estimated for the remaining sites, according to the land use and typical DCIA for the land uses shown in Table 12. The DCIA for all sites range from 0% to 86% (Wildlife Preserve and the Florida Aquarium). The sites with high sampling rates ranged between 31-86 % DCIA (mean = 50 %), while the group of stations with lower sample rates ranged from 0 - 58 % (mean = 21%) .

DCIA has a direct impact on the volume of runoff produced. Most stormwater models assume that 95 % of the rain falling on an impervious surface will be converted to runoff. The exceptions are water bodies and wetlands, which are considered to be DCIA, but export (on an annual basis) approximately 25-30 % of the rainfall. On an annual basis, for flat pervious areas found in the study area, approximately 10-20 % of the rainfall will be converted to runoff. While the

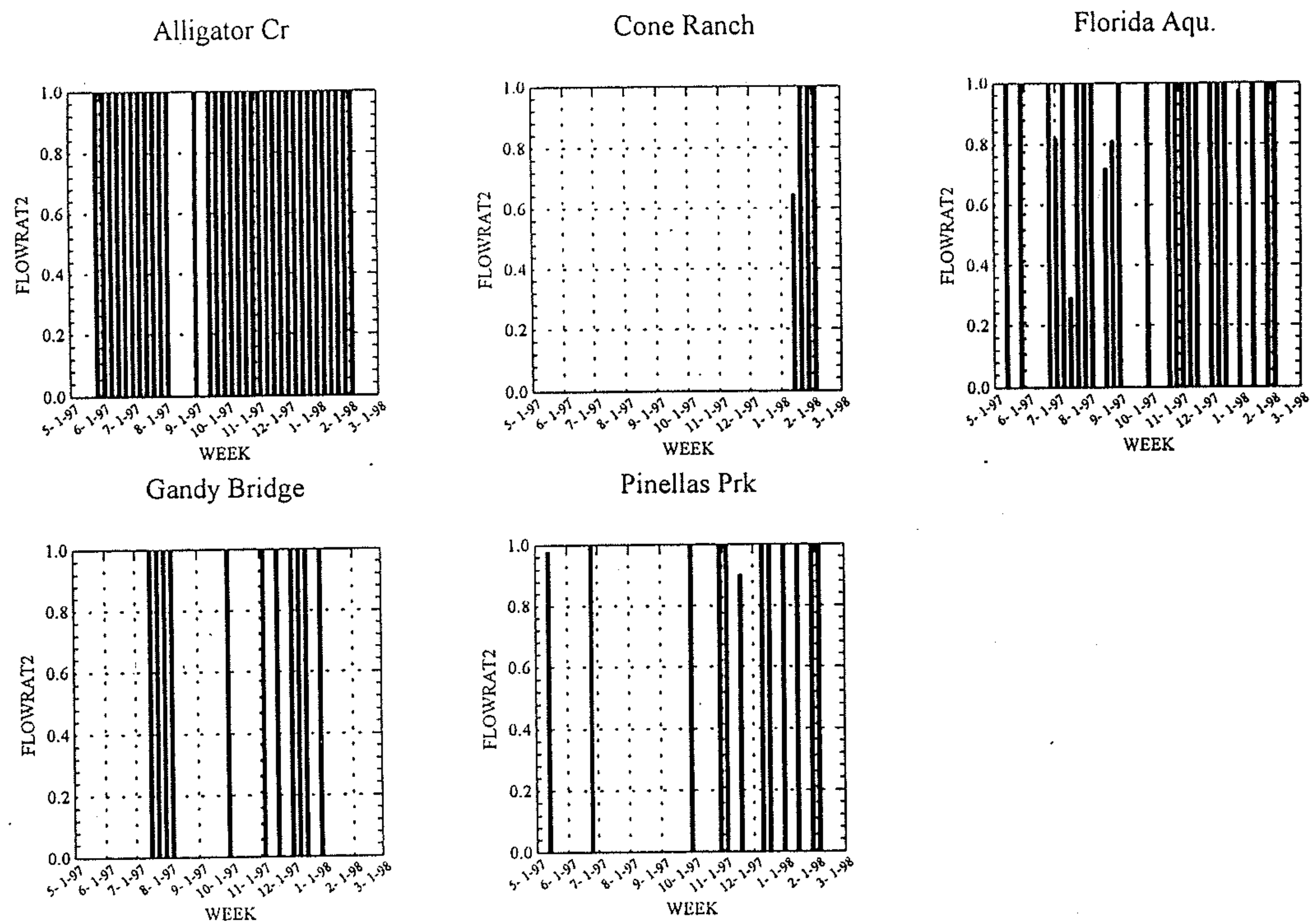

Figure 26. Fraction of stormwater sampled over the study period, by site.

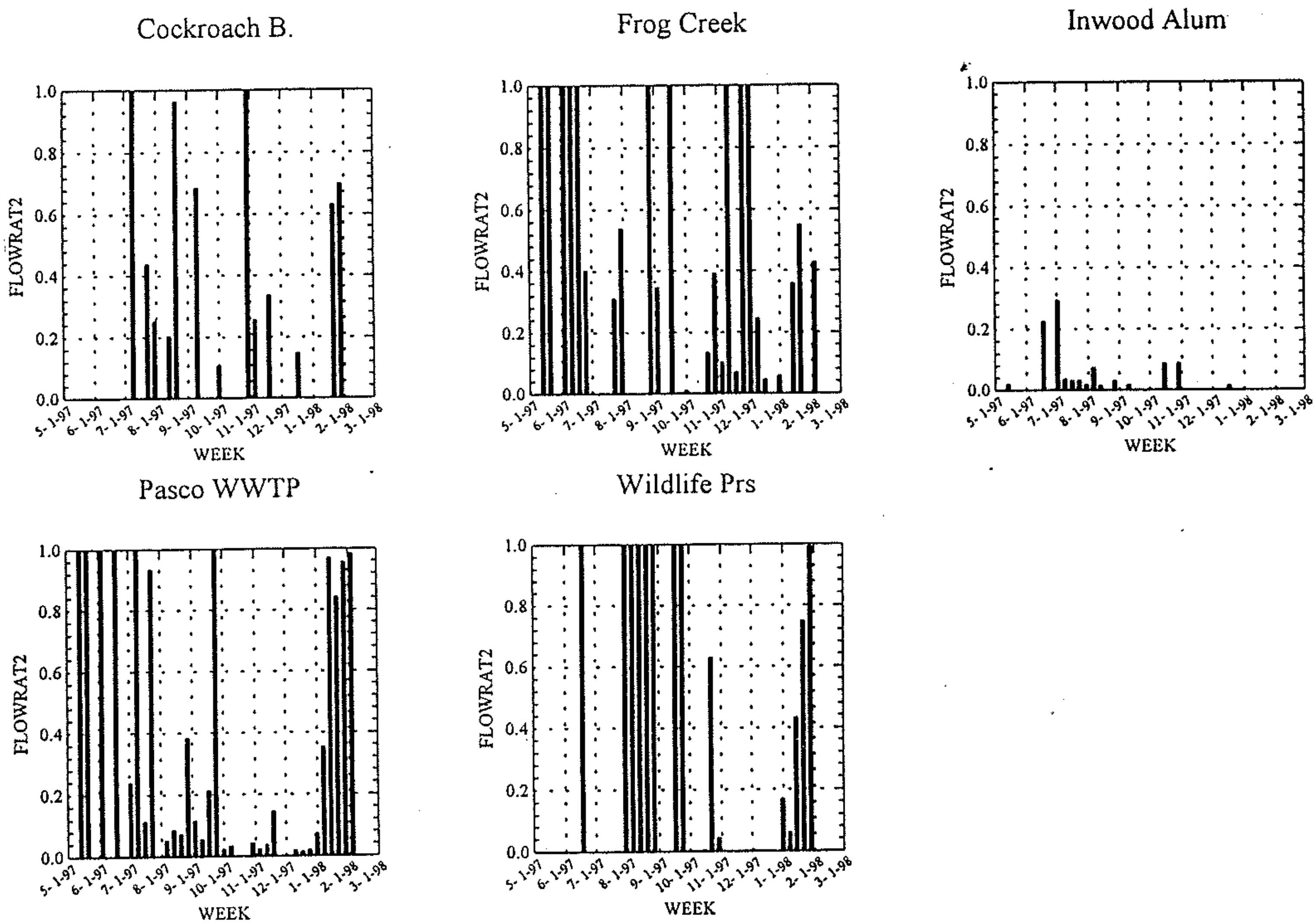

Figure 26. (Continued)

Table 11. Sample period (period of accumulation) and ratio of flow sampled to total stormwater flow. Study period totaled 280 days.

Site Name	Begin Sampling	End Sampling	Sample Period (days)	Total Flow at Site (cf)	Sampled Flow at Site (cf)	Flow Sampled Ratio
Gandy Bridge	07/15/97	01/13/98	182	387,650	387,650	1.0
Florida Aquarium	05/06/97	02/03/98	273	50,679	48,299	1.0
Alligator Creek	05/20/97	02/03/98	259	33,490,804	30,573,794	0.9
Pinellas Park Alum Inj.	05/06/97	02/03/98	273	4,960,471	4,192,387	0.8
Cone Ranch	01/13/98	02/03/98	28	9,376,317	8,158,535	0.9
Cockroach Bay	07/08/97	02/03/98	210	12,340,911	3,417,000	0.3
Frog Creek	05/13/97	02/03/98	266	1,207,359	154,819	0.1
Pasco WWTP	05/06/97	02/03/98	273	1,149,955	97,890	0.1
Wildlife Preserve	05/06/97	01/27/98	266	33,992,163	2,780,578	0.1
Inwood Alum Inj.	05/06/97	02/03/98	273	160,021,924	1,182,300	0.0
		median	266			0.56

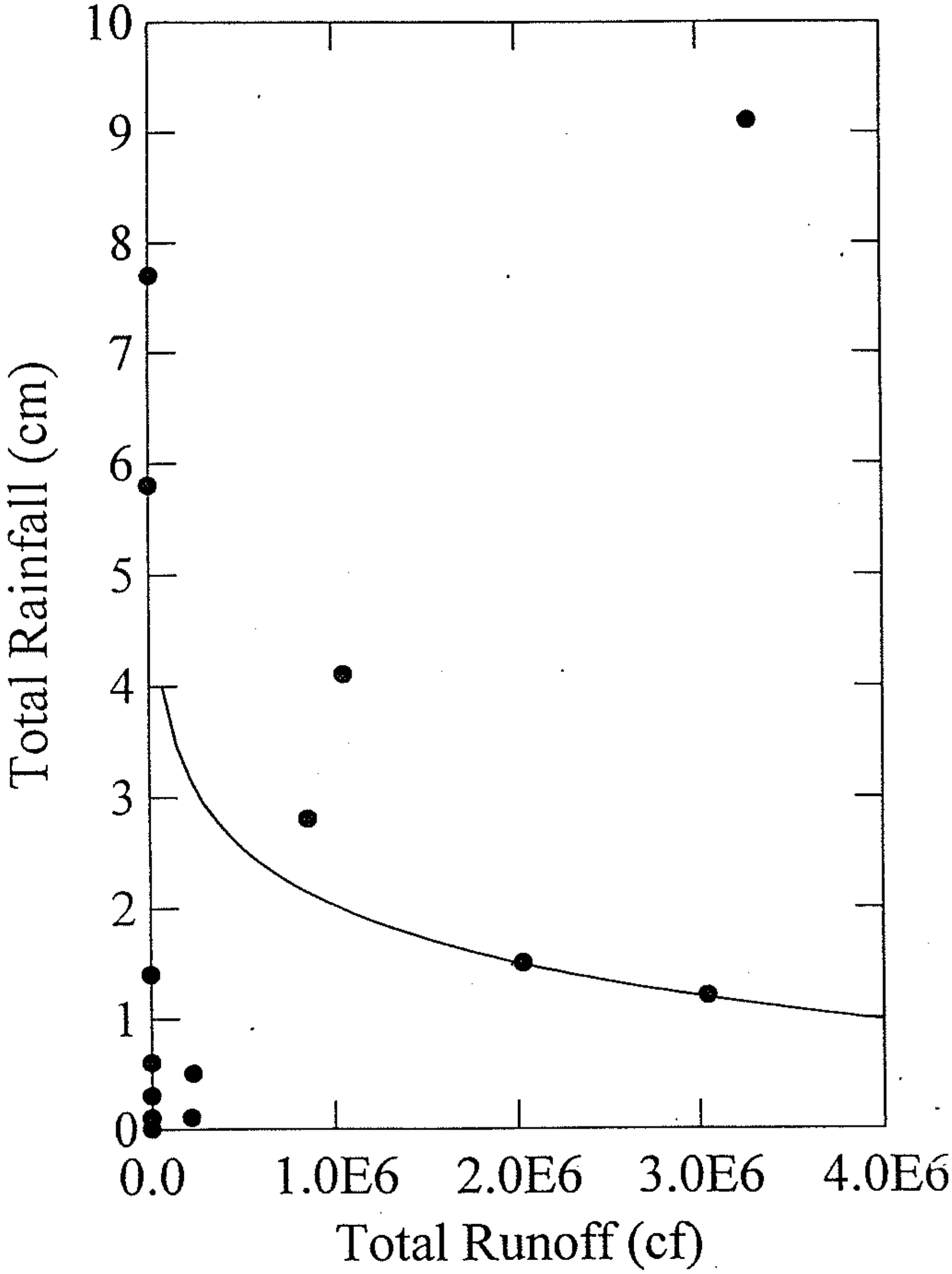

Figure 27. Relationship of stormwater runoff to rainfall at the Cone Ranch Site.

Table 12. Estimates of directly connected impervious area (DCIA) by land use for each sampling site.

Site Name	Hectares	MDR	HD-SFR	Manufactured Home	Commercial/ Light Industry	WWTP/ Power Plants	Parking/ Roads	Agriculture	Open	Water	Basin Weighted DCIA	% Impervious (Reported)
Gandy Bridge (GB-HC)	4.0		100%									45%
Florida Aquarium	0.1						95%		5%		86%	
Alligator Creek	152.2	85%			15%						38%	
Cone Ranch	1176.0							100%			1%	
Pinellas Park Alum Inj.	37.0		48%		44%		6%			1%		31%
Cockroach Bay	85.0							90%	10%			5%
Frog Creek	32.4			95%						5%	58%	
Pasco WWTP	18.9					100%						3%
Wildlife Preserve	269.4								100%			0%
Inwood Alum Inj.	194.0	96%			3%							38%
	Land Use DCIA	30%	40%	60%	85%	40%	90%	1%	1%	25%		

conversion of atmospheric loads to runoff loads varies by land-use, the loadings are expected to generally follow the pattern of runoff volumes. Thus, the ratio of DCIA derived runoff to pervious runoff is a factor of approximately 8. Loading ratios are expected to be similar.

Export Ratios

Parameter-specific total export ratios, calculated from the total cumulative loadings over each sites' sampling period, appear in Table 13. In the case of nitrogen, a few of the sites (2/9, Frog Creek and Pinellas Park) exhibited export ratios less than 1.0. Possible explanations for the lower ratios include uptake and incorporation as biomass, although impervious areas are relatively high for these locations, especially compared to the Wildlife Preserve. It can also be conversely argued that nitrogen fixation is equally as possible. The median export ratio of nitrogen among all sites (excluding Cone Ranch) was 1.49.

Nitrogen and phosphorus exhibited similar export ratios over the study period. For phosphorus, the ratio was over one for all sites except the Wildlife Preserve and the Pinellas Park site. The latter is an inactive alum injection site, and samples were collected at the outflow. It is unknown if residual alum in the water column or in the sediments contributed to the low ratios. For the remainder of the sites, there is more phosphorus leaving the sites in runoff and baseflow than can be accounted for by the atmospheric deposition which occurred during the study period. Median phosphorus export ratio of all sites (excluding Cone Ranch) was 2.36.

As a general rule, more metal is exported than can be accounted for in the atmospheric deposition. For copper, only Frog Creek exhibited a ratio of 0.5 implying that this site was acting as a net sink over the study period. Similar results were obtained for cadmium (Pasco WWTP ratio= 0.2) and zinc (Pasco WWTP =0.9). For lead, Pasco WWTP (ratio = 0.3) and Cockroach Bay (ratio =0.9) also exhibited ratios below 1.0. Overall, the Inwood alum injection site had the highest export ratios for metals (Cu=17, Cd=25, Pb=13 and Zn=9), although this may also be the result of the sampling strategy at this site (the first three hours after a rainfall) and the extrapolation of observed concentrations to the extensive baseflow present at this site. In general, however, it appears that there are other sources of metals in addition to atmospheric deposition contributing to runoff loadings at virtually all of the sites. These sources are transported into the watershed via routes other than atmospheric deposition and are likely related to land use and anthropogenic activities. One likely factor, for instance, are automotive brake linings, which shed large quantities of copper, zinc and cadmium and which would generally not become sufficiently airborne to be captured in the bulk deposition samplers. Another example of site processes overriding atmospheric deposition are the export ratios observed at the Florida Aquarium. Even though the site consistently experienced by far the highest metals loading from atmospheric deposition, the metals export ratio from this highly impervious site was generally near the median value of all sites, and indicate that the land use activities at this site did not contribute the amounts of metals observed at other locations.

Table 13. Export ratios (cumulative stormwater unit loads / bulk atmospheric deposition loads) over the sampling period at each site.

Site	TN-Ratio	TP-Ratio	Cd-Ratio	Cu-Ratio	Pb-Ratio	Zn-Ratio
Gandy Bridge (GB)	1.5	no data	6.3	2.5	5.2	1.8
Florida Aquarium (FA)	2.1	2.0	7.6	1.9	2.4	1.9
Alligator Creek (AC)	1.3	2.7	8.1	4.8	4.7	5.6
Pinellas Park Alum Inj. (PP)	0.4	0.7	1.3	2.0	2.0	1.3
Cockroach Bay (CB)	1.4	5.1	2.5	4.0	0.9	1.7
Frog Creek (FC)	0.4	1.3	1.6	0.5	1.2	1.2
Pasco WWTP (WW)	2.8	5.0	0.2	4.4	0.3	0.9
Wildlife Preserve (WP)	1.5	0.8	1.6	4.6	1.1	1.8
Inwood Alum Inj. (IA)	2.2	5.7	25.3	17.3	12.8	8.8
median	1.49	2.36	2.46	3.95	1.97	1.80

Plots of the cumulative runoff loadings vs cumulative atmospheric loadings are given for all sites and parameters in Appendix C. A LOWESS fit was added to help visualize the general patterns. Recall that the period of accumulation may represent differing lengths of time for different sites (See "Sample Period", Table 11).

With regard to the statistical significance of the cumulative ratios, it should be noted that when the entire population is measured, the resultant value is a census and no longer a sample. Any difference in the resultant values can be directly compared instead of inferred. For example, if the number of storms were counted at each site over the same period, the results could be directly compared to determine if the site received an equal number of events. Thus, under the context of completing a census, the Florida Aquarium export ratios could be directly compared with Alligator Creek as both measured virtually all of the atmospheric load and runoff load. For purposes of this report, the following sites are assumed to have measured virtually all of the runoff and atmospheric loads and thus are capable of direct comparison without the need for inferential statistical procedures: Gandy Bridge, Florida Aquarium, Alligator Creek, and Pinellas Park.

Seasonal and Site Differences - Export Ratio

Weekly export ratios were developed by deriving a ratio of runoff:atmospheric loading for each week of sampling. (Metals were evaluated on approximately monthly time steps.) If the site rainfall (average captured by the bulk atmospheric samplers) was less than 0.5 cm (0.2 inches) for the week prior and no stormwater runoff was measured, the atmospheric loadings were carried over to the next consecutive week. If rainfall in excess of 0.5 cm occurred, but (presumed) runoff was not measured or sampled, the accumulation of atmospheric loading was presumed to have been cleared from the site, and the atmospheric total reset to zero. When consecutive weeks with no runoff occurred, the atmospheric loadings were accumulated across weeks until the sum of weekly rainfall events totaled 0.5 cm. The atmospheric load received over the several weeks without rainfall were then included in comparisons with the stormwater loads. A maximum of two prior weeks of atmospheric data were summed.

Figures 28 to Figure 33 were developed as exploratory graphics of the seasonal changes in the weekly export ratios for the high sample rate or census group of sites. A linear fit has been added to visualize the general relationship between atmospheric and stormwater loadings. The figures suggest that there may be seasonal differences in the rate of export. Due to study timing, few data exist for the "Spring" seasonal category. Some portion of the variation in the seasonal relationships may be attributable to site differences among the group members, coupled with a different number of observations at each site. (The combined influence of season and atmospheric load on stormwater loads were evaluated as part of the multivariate investigations described later.)

The apparent site differences in export ratios summarized in Table 13 were further investigated. Such differences could be the result of differences in atmospheric deposition (Table 4), or of site differences in land use, impervious area, rainfall characteristics, or other parameters affecting runoff. Figure 34 gives a box plot showing the degree of overlap for the median (horizontal line) and the upper 75th quartile (top of box) and 25th percentile (bottom of box). In several cases, the data envelopes do not overlap, further suggesting that some of the sites differ. Figure 34 also indicates the severe departures from normality for several site/parameter combinations.

The weekly (or monthly, in the case of metals) export ratios were compared among sites and among seasons using a one-way analysis of variance (ANOVA) performed upon the weekly export ratios. Box plots indicated that the export data are not normally distributed (a requirement for most parametric tests such as ANOVA and linear regression). In order to meet the assumptions, the weekly export ratios were grouped and rank-transformed prior to further evaluation. If there were no differences in export ratios, then the mean rank of each station should be equivalent to all others. Stations which routinely differ in export ratio can be detected with an ANOVA as differences in the mean rank. The dependent variable was the rank of the weekly export ratio (individually normalized for drainage area), and the category for comparison was site and quarter or season.

Results appear in Table 14 for site and in Table 15 for season or quarter. At '*p*' values ≤ 0.05, the null hypothesis of 'no difference in sites' is rejected. Differences in export ratios among sites (Table 14) were restricted to phosphorus (Florida Aquarium - Pinellas Park), lead (Gandy Bridge - Florida Aquarium, and Gandy Bridge - Pinellas Park), and cadmium (Gandy Bridge - Pinellas Park). (It should be restated that differences tested are between the populations of weekly export ratios, i.e. is the export ratio at a given site consistently different from that at another site. The weekly export ratios may not differ statistically, but episodic events both of atmospheric deposition and of runoff may still contribute loads such that the net of total ratio over the period of study or years could be substantially different.)

Significant differences in the ranks of export ratios by season (Table 15) were relatively few and limited to total nitrogen (fall - spring and fall - summer). As seasonal variations in deposition were noted for nitrogen and selected other parameters (Figure 20) the technique of examining export ratios in effect normalizes for differences in atmospheric deposition between sites. Despite the normalization, however, some remaining seasonality is present in nitrogen export.

Export Ratios - Comparison with Literature

Export ratios, as defined in this study, are computed as the ratio of total stormwater loads to total atmospheric deposition, as measured at the individual sites. For the sites with a high sampling rate, at which uncertainty due to extrapolation of sampled concentrations to unsampled flows is least, export ratios for nitrogen ranged between 0.4 and 2.1. For all sites, nitrogen export ratios ranged between 0.4 and 2.8. (Bulk atmospheric deposition ranged between 5.0 and 9.7 kg ha^{-1} yr^{-1} [Table 4], while stormwater loadings ranged between 2.3 and 19.6 kg ha^{-1} yr^{-1} [Table 9].)

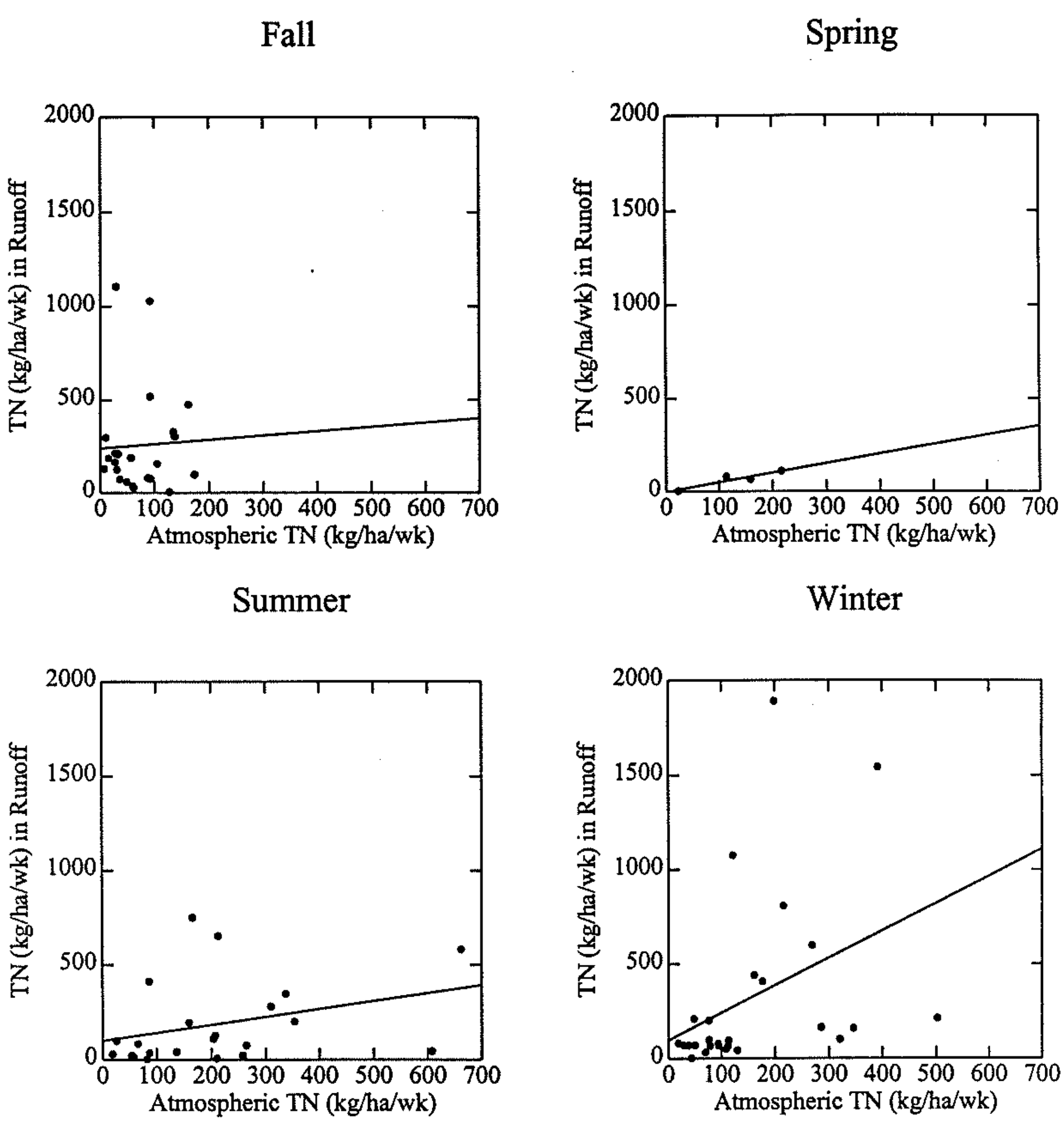

Figure 28. Seasonal variation in export (stormwater loading:atmospheric loading) of total nitrogen from sites with high sampling rates. Linear relationship for visualization only.

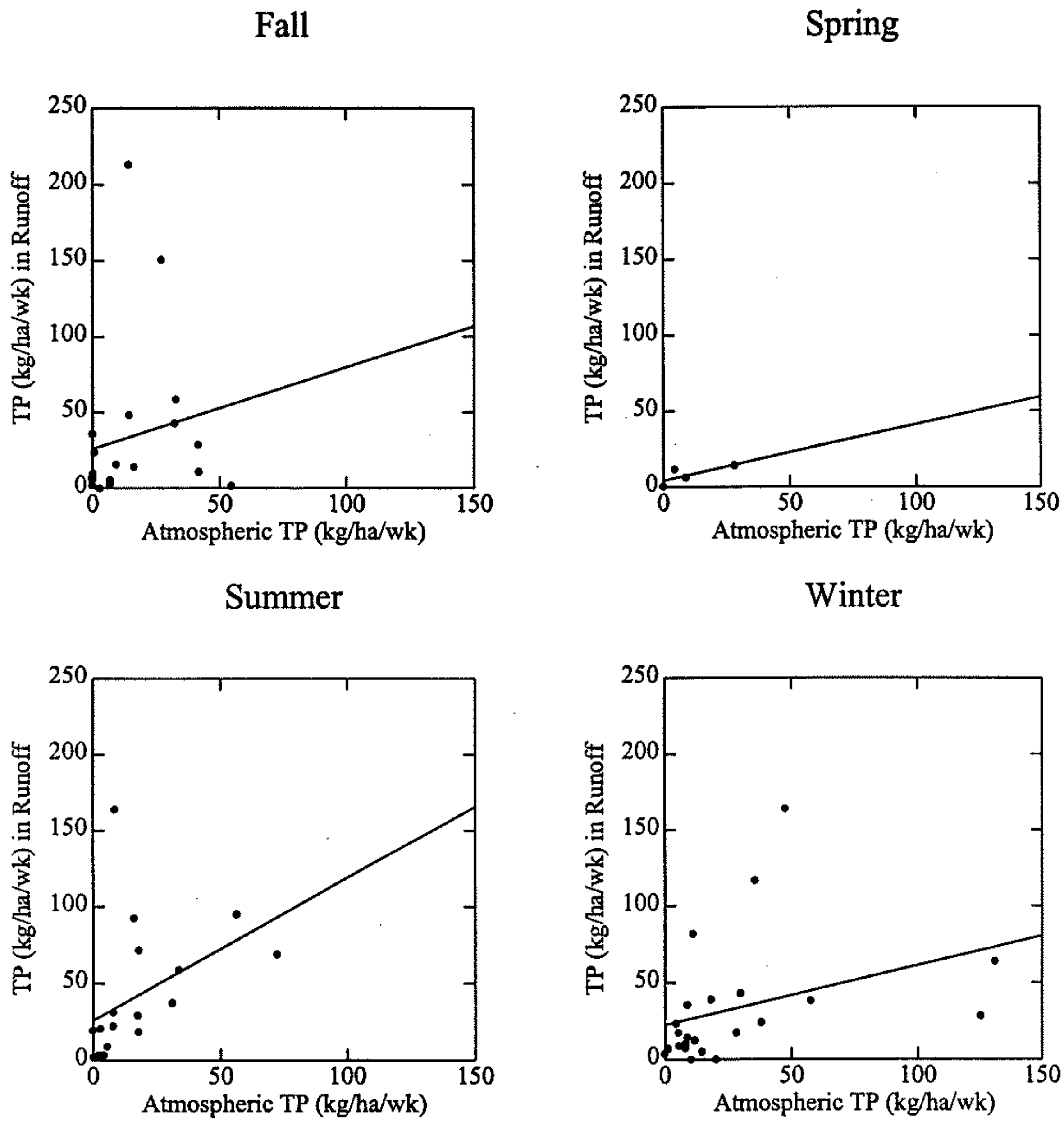

Figure 29. Seasonal variation in export (stormwater loading:atmospheric loading) of total phosphorus from sites with high sampling rates. Linear relationship for visualization only.

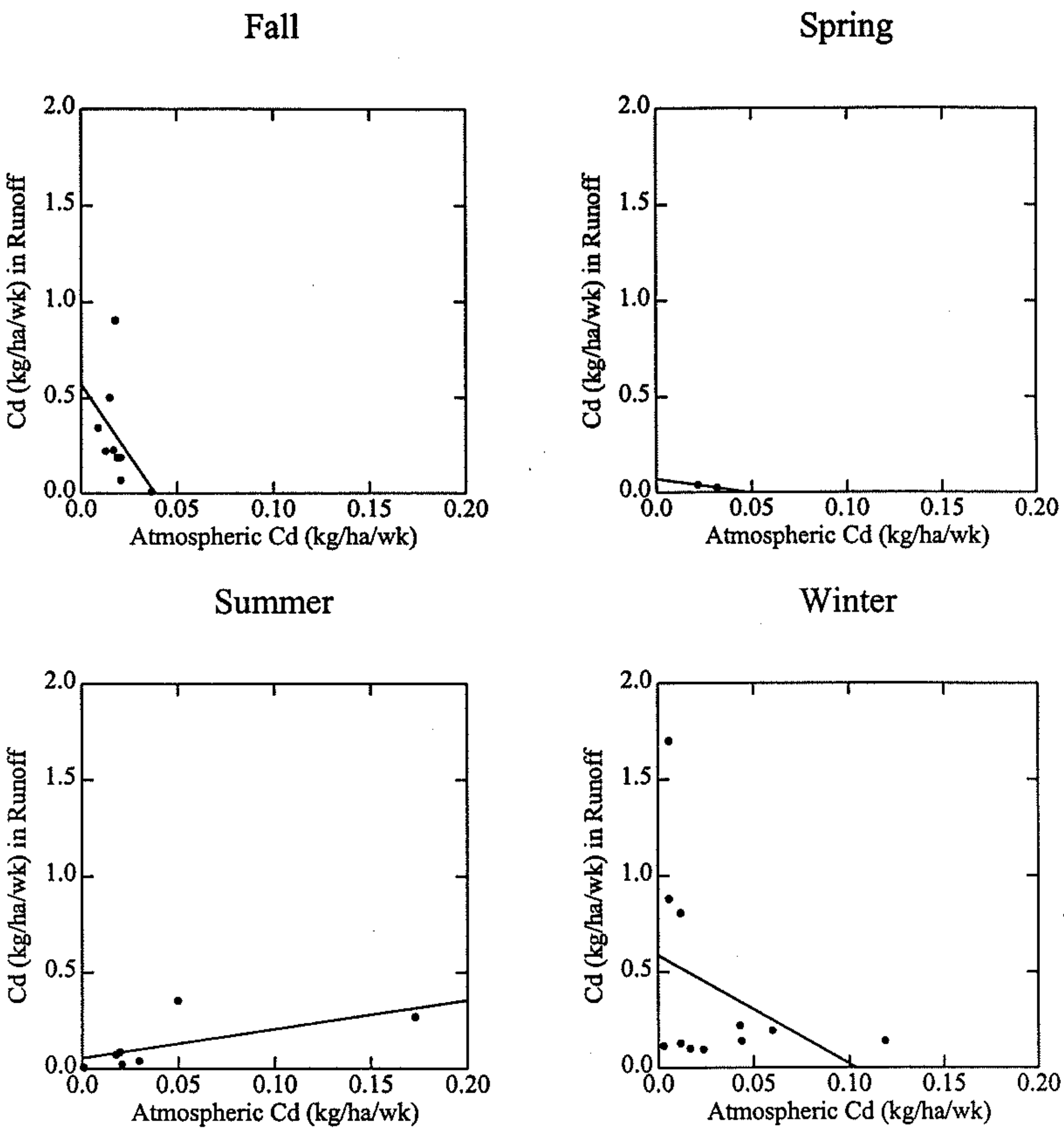

Figure 30. Seasonal variation in export (stormwater loading:atmospheric loading) of cadmium from sites with high sampling rates. Linear relationship for visualization only.

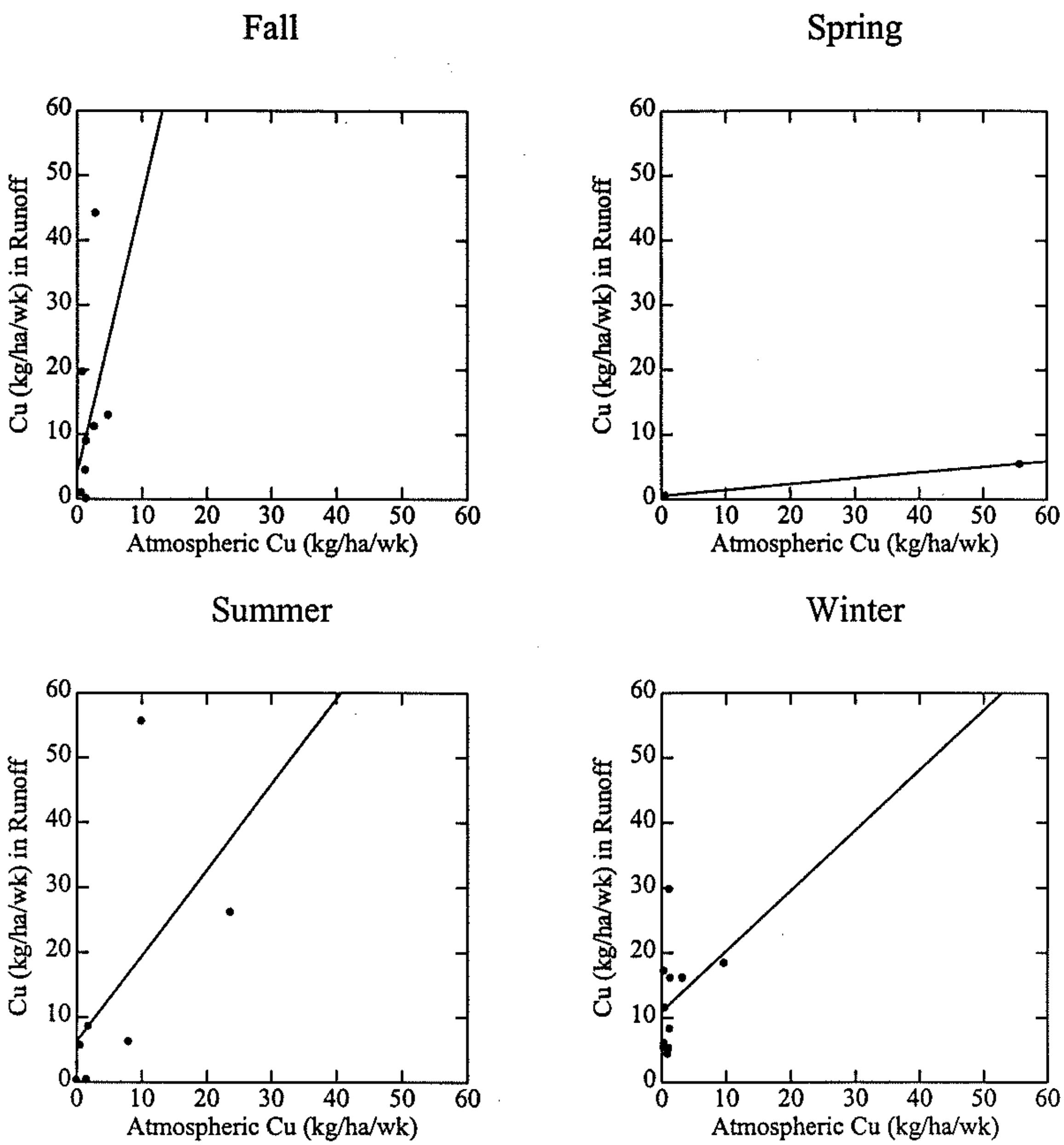

Figure 31. Seasonal variation in export (stormwater loading:atmospheric loading) of copper from sites with high sampling rates. Linear relationship for visualization only.

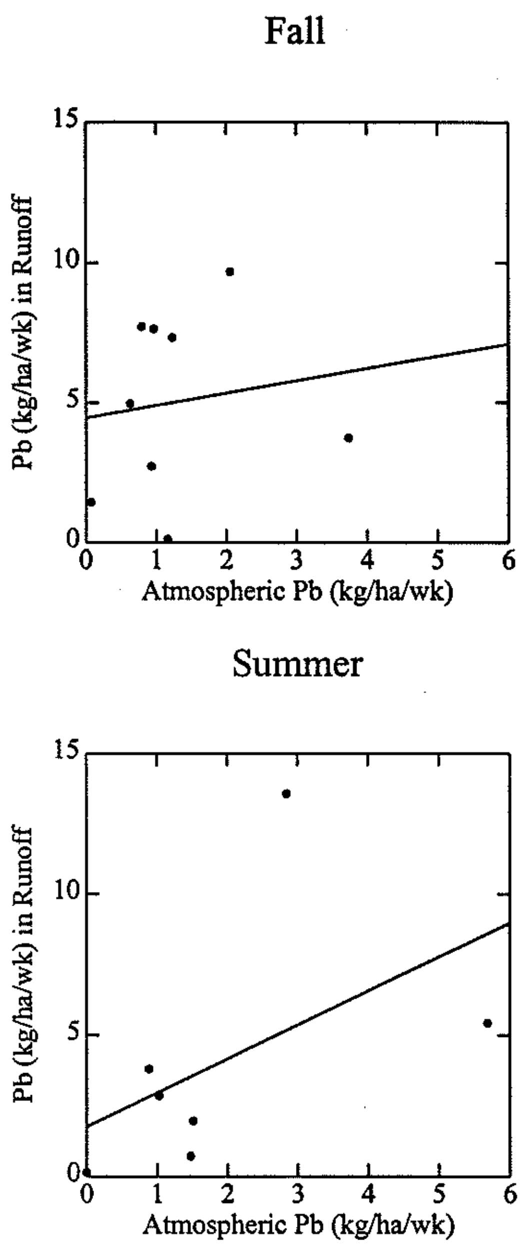

Figure 32. Seasonal variation in export (stormwater loading:atmospheric loading) of lead from sites with high sampling rates. Linear relationship for visualization only.

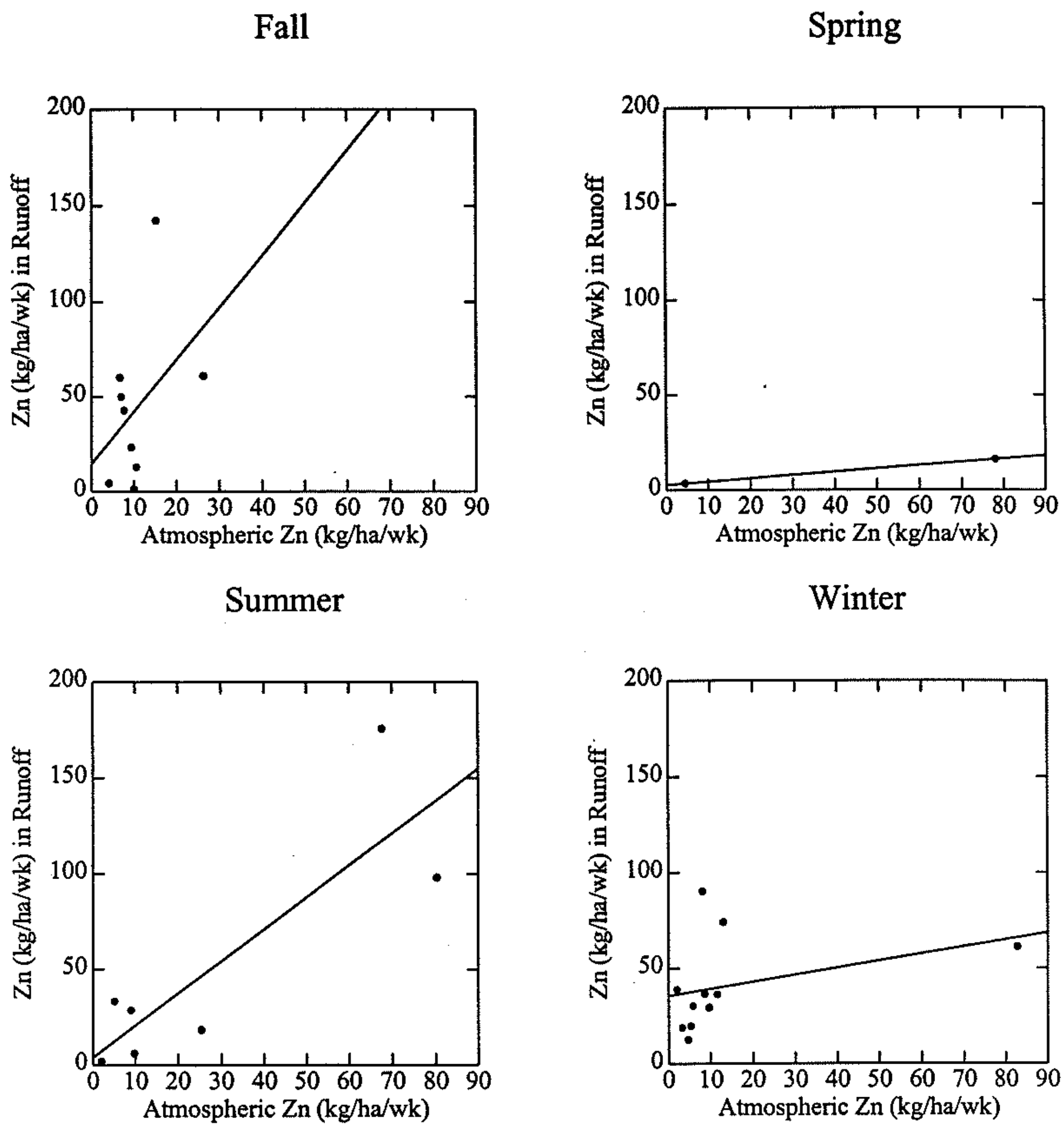

Figure 33. Seasonal variation in export (stormwater loading:atmospheric loading) of zinc from sites with high sampling rates. Linear relationship for visualization only.

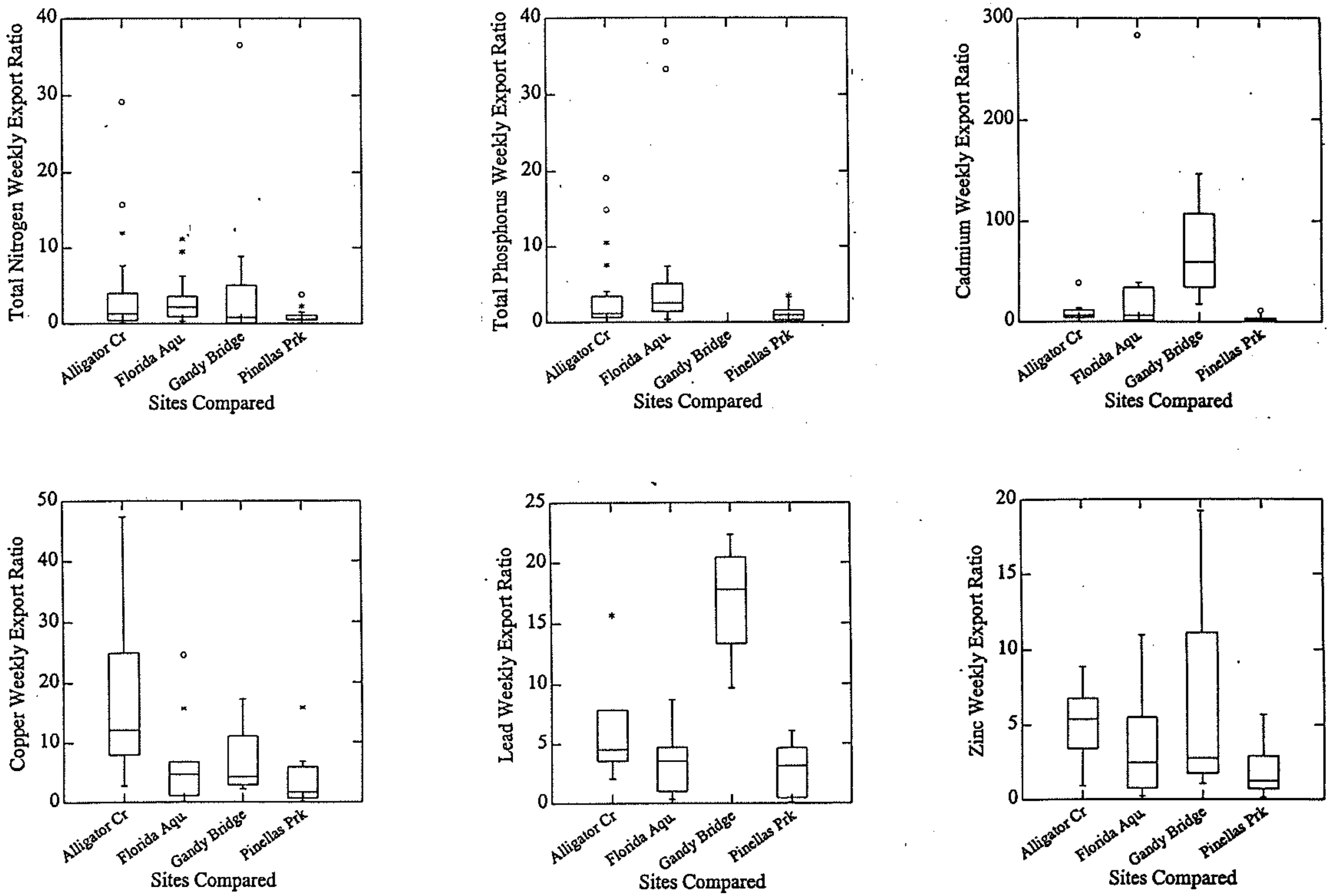

Figure 34. Site comparisons of weekly and monthly export ratios for sites with high sampling rates.

Table 14. ANOVA results. Probability of differences in ranks of weekly export ratio by site.

Total Nitrogen ($r^2 = 0.094$, $p = 0.068$)

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	1.000	1.000	0.653
Florida Aqu.		0.587	0.072
Gandy Bridge			1.000

Total Phosphorus ($r^2 = 0.135$, $p = 0.020$)

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	0.195	—	0.704
Florida Aqu.		—	0.022
Gandy Bridge			—

Lead ($r^2 = 0.472$, $p = 0.006$)

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	1.000	0.190	0.974
Florida Aqu.		0.011	1.000
Gandy Bridge			0.008

Cadmium ($r^2 = 0.398$, $p = 0.015$)

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	1.000	0.314	0.608
Florida Aqu.		0.102	1.000
Gandy Bridge			0.011

Copper ($r^2 = 0.340$, $p = 0.044$)

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	0.103	0.319	0.056
Florida Aqu.		1.000	1.000
Gandy Bridge			1.000

Zinc ($r^2 = 0.122$, $p = 0.448$)

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	1.000	1.000	0.830
Florida Aqu.		1.000	1.000
Gandy Bridge			1.000

Multiple r^2, Bonferroni adjusted p.

Table 15. ANOVA results. Probability of differences in ranks of weekly export ratios by season.

Total Nitrogen

Qtr	Spring	Summer	Winter
Fall	**0.017**	**0.002**	0.195
Spring		1.000	0.312
Summer			0.421

$r^2 = 0.212$, $p = 0.001$

Total Phosphorus

Qtr	Spring	Summer	Winter
Fall	1.000	1.000	1.000
Spring		0.955	1.000
Summer			0.468

$r^2 = 0.073$, $p = 0.255$

Lead

Qtr	Spring	Summer	Winter
Fall	0.327	1.000	1.000
Spring		1.000	0.203
Summer			1.000

$r^2 = 0.234$, $p = 0.159$

Cadmium

Qtr	Spring	Summer	Winter
Fall	0.413	1.000	1.000
Spring		1.000	0.351
Summer			1.000

$r^2 = 0.194$, $p = 0.221$

Copper

Qtr	Spring	Summer	Winter
Fall	1.000	1.000	0.406
Spring		1.000	0.083
Summer			1.000

$r^2 = 0.330$, $p = 0.051$

Zinc

Qtr	Spring	Summer	Winter
Fall	0.916	1.000	0.839
Spring		1.000	0.123
Summer			0.781

$r^2 = 0.285$, $p = 0.076$

Multiple r^2, Bonferroni adjusted p.

Uncertainties in the nitrogen export ratios developed for this study could arise from undersampling gaseous species, thus producing a falsely high export ratio. The agreement between the bulk deposition and the wet and dry deposition measured at the TBADS Gandy Bridge intensive site, however, demonstrates that in at least one case, bulk deposition is a good estimate of total nitrogen deposition. At the Gandy site, the export ratio of 1.5 should be falsely high only if stormwater flows were overestimated for runoff load calculations. For sites with a relatively low proportion of the flow sampled, additional uncertainty could arise from the extrapolation of sampled flow concentrations to the entire flow measured.

It should be emphasized that the sampling sites for this study were relatively small watersheds, with a mean size of 87 hectares (215 acres), excluding the Cone Ranch site. Watershed transfer coefficients computed from much larger watersheds may be substantially smaller, as the coefficients will include the reductions accomplished by in-stream removal processes of particulate settling and biological uptake. Estimates are that as much as 50-80% of nitrogen entering a stream can be removed (Baker *et al.*, 1993), with removal efficiency undoubtedly related to residence time.

Fu (1991) gathered data on the Apalachicola, Sopchoppy, and Ochlocknee Rivers in which annual average export ratios for nitrogen (computed as for the present study) were 0.67, 1.00, and 0.75, respectively. Watershed areas were large in comparison to the Tampa Bay sites (4.9×10^6, 2.6×10^4, and 2.6×10^5 hectares, respectively). Much of the Apalachicola drainage lies upstream of numerous dams which are effective sediment traps. Note that the smallest watershed, described as relatively undisturbed, has the highest export ratio with a value of 1.00. Atmospheric loads were estimated as between 4.9 and 5.4 kg ha^{-1} yr^{-1}, with fluvial loads estimated as 3.5 to 4.9 kg ha^{-1} yr^{-1}.

More recently, Jaworski *et al.*, (1992) quantified a nitrogen mass balance for the upper Potomac River, identifying a variety of nitrogen inputs, exports, and internal sinks. Using the quantities anaogous to the bulk atmospheric and stormwater loads measured in this study, export ratios for this relatively non-urban (5%), agricultural (40%), and large (2.9×10^6 hectare) watershed were on the order of 0.63. Additionally, export ratios computed with wet deposition only varied seasonally between 0.00 and almost 5.00, with the watershed releasing stored nitrogen during periods of high flow. Atmospheric loads were estimated at 13.6 kg ha^{-1} yr^{-1}, and river export at 8.5 kg ha^{-1} yr^{-1}. Land use changes which increase either rate or total runoff were noted as likely to reduce the nitrogen retention capacity of a watershed (i.e. increasing the export ratio).

Smaller watersheds were examined by McDowell and Asbury (1994) in Puerto Rico. In tropical, forested watersheds of 326, 262, and 16 hectares, nitrogen export ratios were 3.9, 2.2, and 2.2. Human activities were limited to scattered small farms and tree harvesting. Bulk atmospheric loads were estimated between 1.9 and 2.6 kg ha^{-1} yr^{-1} (substantially lower than estimates for the Tampa Bay region), with riverine loads of 4.3 to 9.4 kg ha^{-1} yr^{-1}. Riverine loads were additionally considered to be an underestimate, which would further elevate the resulting export ratio.

Nitrogen export ratios appear very sensitive to in-stream removal processes and time of travel within a particular watershed. Nitrogen export ratios reported for this study are within the range observed in both temperate and tropical climates. Applying in-stream removal rates of 65%, would bring all nitrogen export ratios to 1.00 or below for the 40 week study. Variation of nitrogen export ratio with watershed size may not be apparent within the Tampa Bay sites due perhaps to the variety of stormwater treatments and impervious areas represented.

Few of the export ratios for metals are less than 1.0, i.e metals export in stormwater exceeded metals atmospheric deposition. This result is consistent with surface weathering and/or ground level anthropogenic influences.

Site and Seasonal Differences - Runoff Loading

To further evaluate whether site differences are more likely if variation in atmospheric deposition is not accounted for, ANOVAs on weekly stormwater runoff loadings were performed. Similar to the analysis of export ratios, weekly loadings were rank transformed prior to analysis. This comparison differs from the previous by focusing on the actual loading, normalized for drainage area but not taking into account the atmospheric loadings as was done with the export ratio evaluation described in Tables 14 and 15. As shown in Table 16 and 17, the number of significantly different site and seasonal combinations was much greater (23 of a potential 33 for site comparisons, 30 of 33 for seasonal comparisons) than for the export ratio (4 of 33 and 2 of 33 for site and season). As the comparisons of export ratios in essence normalize runoff loads for atmospheric loads, the fact that comparisons of runoff loadings have many more differences between sites and seasons than do comparisons of export ratios implies a distinctive role for atmospheric deposition.

Multivariate Evaluation

The results of the site and season comparisons both indicate that there are some significant differences in rate of export and stormwater loading because of those factors. In addition, the relative lack of differences in export ratios compared to area-normalized loadings indicate that atmospheric deposition also affects stormwater loadings. To isolate what factor(s) are most important in determining the runoff loads, a multivariate regression was developed using additional available parameters such as rainfall characteristics, impervious area, site, and season .

The evaluation was conducted for a sub-set of the census group : Florida Aquarium, Alligator Creek and Pinellas Park. (There were no rainfall characteristics associated with the Gandy Bridge dataset, and thus it could not be included in the evaluation). The following independent variables were included : rank of weekly atmospheric load, total rainfall (in), season, maximum rainfall intensity (in /15 min) , rainfall duration (hrs/wk), antecedent dry days, DCIA, site, and season. The dependent variable chosen was the rank of the weekly runoff loads.

Table 16. ANOVA results. Probability of differences in ranks of weekly runoff loads by site.

Total Nitrogen

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	0.024	0.235	0.000
$r^2 = 0.301$	Florida Aqu.	0.000	0.000
$p = 0.000$		Gandy Bridge	0.692

Total Phosphorus

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	0.952	—	0.000
$r^2 = 0.315$	Florida Aqu.	—	0.000
$p = 0.000$		Gandy Bridge	—

Lead

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	0.019	0.153	0.047
$r^2 = 0.242$	Florida Aqu.	0.000	0.000
$p = 0.000$		Gandy Bridge	1.000

Cadmium

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	0.124	1.000	0.028
$r^2 = 0.179$	Florida Aqu.	0.300	0.000
$p = 0.000$		Gandy Bridge	0.046

Copper

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	0.000	0.000	0.000
$r^2 = 0.522$	Florida Aqu.	0.000	0.000
$p = 0.000$		Gandy Bridge	1.000

Zinc

Site	Florida Aqu.	Gandy Bridge	Pinellas Park
Alligator Cr.	0.001	0.000	0.000
$r^2 = 0.437$	Florida Aqu.	0.000	0.000
$p = 0.000$		Gandy Bridge	1.000

Multiple r^2, Bonferroni adjusted p.

Table 17. ANOVA results. Probability of differences in ranks of weekly runoff loads by season.

Total Nitrogen

Qtr	Spring	Summer	Winter
Fall	**0.000**	**0.000**	**0.000**
Spring		**0.017**	**0.000**
Summer			**0.000**

$r^2 = 0.494$

$p = 0.000$

Total Phosphorus

Qtr	Spring	Summer	Winter
Fall	**0.000**	**0.000**	**0.003**
Spring		**0.006**	**0.000**
Summer			**0.000**

$r^2 = 0.522$

$p = 0.000$

Lead

Qtr	Spring	Summer	Winter
Fall	**0.000**	**0.000**	**0.000**
Spring		0.071	**0.000**
Summer			**0.000**

$r^2 = 0.530$

$p = 0.000$

Cadmium

Qtr	Spring	Summer	Winter
Fall	**0.000**	**0.000**	**0.000**
Spring		0.134	**0.000**
Summer			**0.000**

$r^2 = 0.524$

$p = 0.000$

Copper

Qtr	Spring	Summer	Winter
Fall	**0.003**	0.076	**0.002**
Spring		0.279	**0.000**
Summer			**0.000**

$r^2 = 0.279$

$p = 0.000$

Zinc

Qtr	Spring	Summer	Winter
Fall	**0.000**	**0.017**	**0.000**
Spring		0.134	**0.000**
Summer			**0.000**

$r^2 = 0.346$

$p = 0.000$

Multiple r^2, Bonferroni adjusted p.

A step-wise approach allowed the determination (and inclusion) of which variables significantly improved the model without introducing co-linearity among the independent variables. Not only does the step-wise procedure allow establishing the criteria of model improvement to be imposed for all variables, it also allows selection of the best among any correlated variables. In the present study, alpha-to-remove/alpha-to-add was set at 0.15. A step-wise evaluation was conducted for each of the nutrient and metal parameters (Table 18). Variables which were not evaluated because of a significant correlation with another independent variable are identified as "collinearity". Table 18 also contains the standardized coefficients for the non-categorical parameters. The standardized coefficient is a measure of how the dependent variable varies with a variation in the independent variable. The units of measurement are standard deviation units. As a result, the standardized coefficients can be used to compare the relative effect of independent variables on the model outcome.

The antecedent dry period was the most frequent parameter contributing significantly to stormwater runoff loads (for all except total nitrogen). Site was significant for all but nitrogen and zinc, while season was significant for all but cadmium and zinc. Atmospheric deposition was retained as a significant explanatory variable for nitrogen , phosphorus, and zinc stormwater loadings. The results of the multi-variate analysis are summarized in Table 19.

Table 18. Step-wise multivariate regression results. Dependent variable is the rank of weekly runoff loads.

Total Nitrogen	Multiple : r^2 = 0.516	
	p=	Std. Coeff.
Rank of Weekly Atmospheric Load (kg/ha)	0.000	0.385
Total Rain (in / wk)		
Maximum Intensity (in / 15 min) during week		
DCIA	0.001	0.122
Site		
Season	0.035	(categorical)
Antecedant Dry (d)		
Rain Duration (hr / wk)	0.025	0.264

Total Phosphorus	Multiple : r^2 = 0.632	
	p=	
Rank of Weekly Atmospheric Load (kg/ha)	0.063	0.429
Total Rain (in / wk)		
Maximum Intensity (in / 15 min) during week	0.045	0.242
DCIA		
Site	0.095	(categorical)
Season	0.084	(categorical)
Antecedant Dry (d)	0.050	0.332
Rain Duration (hr / wk)		

Lead	Multiple : r^2 = 0.799	
	p=	
Rank of Weekly Atmospheric Load (kg/ha)		
Total Rain (in / wk)		
Maximum Intensity (in / 15 min) during week		
DCIA		
Site	0.001	(categorical)
Season	0.019	(categorical)
Antecedant Dry (d)	0.000	1.000
Rain Duration (hr / wk)		

Cadmium	Multiple : r^2 = 0.808	
	p=	
Rank of Weekly Atmospheric Load (kg/ha)		
Total Rain (in / wk)		
Maximum Intensity (in / 15 min) during week	0.001	0.558
DCIA	(collinearity)	
Site	0.001	(categorical)
Season		
Antecedant Dry (d)	0.012	0.000
Rain Duration (hr / wk)		

Copper	Multiple : r^2 = 0.921	
	p=	
Rank of Weekly Atmospheric Load (kg/ha)		
Total Rain (in / wk)		
Maximum Intensity (in / 15 min) during week	0.031	0.310
DCIA	(collinearity)	
Site	0.001	(categorical)
Season	0.006	(categorical)
Antecedant Dry (d)	0.049	0.000
Rain Duration (hr / wk)	0.094	0.564

Zinc	Multiple : r^2 = 0.636	
	p=	
Rank of Weekly Atmospheric Load (kg/ha)	0.021	0.573
Total Rain (in / wk)	0.135	0.281
Maximum Intensity (in / 15 min) during week		
DCIA	0.904	0.028
Site		
Season		
Antecedant Dry (d)	0.025	0.432
Rain Duration (hr / wk)		

(collinearity) = variable rejected due to correlation with another independent variable

(categorical) = No standardized coefficients calculated.

Table 19. Factors significant in estimating weekly runoff loads, based on step-wise multiple regression.

	TN	TP	Pb	Cd	Cu	Zn
Rank of Weekly Atmospheric Load (kg/ha)	x	x				x
Total Rain (in / wk)						x
Maximum Intensity (in / 15 min) during week		x		x	x	
DCIA	x			collinear	collinear	x
Site		x	x	x	x	
Season	x	x	x		x	
Antecedant Dry (d)		x	x	x	x	x
Rain Duration (hr / wk)	x				x	

(Collinear = Significant correlation with another variable - not evaluated.)

VII. Summary and Conclusions

The Florida Department of Transportation sponsored the investigation of linkages between bulk atmospheric deposition and stormwater quality. Project goals were to investigate the spatial variability in deposition and the determine if atmospheric deposition influences stormwater quality and resultant loadings to receiving waters. The collection of bulk atmospheric deposition at ten sites throughout the Tampa Bay watershed was coordinated with several existing programs and supported by a number of agencies. Stormwater samples were collected concurrently, although under a variety of protocols. Sites represented a variety of different land uses and potential sources of atmospheric depositions. Nitrogen, phosphorus, cadmium, copper, lead, and zinc were the parameters of interest. Other data sets (gathered by SWFWMD, NADP/NTN, and TBADS) were incorporated into the analysis as appropriate.

The study was conducted for a 40 week period, which received above average rainfall. Sample completeness for atmospheric samples was quite good (99%) with uncontaminated samples determined to be 89%. Spatial differences were observed in bulk atmospheric deposition. Weekly deposition varied by station for metals. For nutrients, significant site to site differences were apparent when the site was compared to the watershed mean for the week. Annualized atmospheric nitrogen loading varied by a factor of 2 between the sites with the lowest and highest loading rates. The magnitude of the lowest site implies substantial background deposition rates of nitrogen, even in the absence of anthropogenic activities. Ranges of deposition were even greater for metals loading, and values observed for metals and nutrients were comparable to previous bulk data collected in the Tampa Bay watershed. There were no coherent spatial distributions apparent in either bulk deposition or in the differences from the watershed mean, indicating that local activities are also important in controlling deposition of both nutrients and metals. There were seasonal variations in atmospheric loadings, particularly for nitrogen, with the lowest loadings during the fall quarter and the highest during summer.

During a short period of comparison, bulk deposition of nitrogen displayed remarkable agreement with an intensively instrumented site (TBADS) measuring both wetfall and ambient air concentrations for dry deposition calculations. Dry deposition represented about 30% of total nitrogen loadings at the intensive site. Comparison of bulk deposition of nitrogen, phosphorus, and metals with a wet-only deposition site at the Florida Aquarium (SWFWMD) displays significant relationships, but with greater variances than observed at the TBADS site. It is possible that dry deposition may be two or three times greater at this site than the TBADS site.

No significant differences were observed between the NADP/NTN site and the bulk deposition sites during the period available for comparison. Total deposition recorded at the Verna Wellfield, however, totaled only 68% (1.90 kg ha^{-1}) of that recorded by the bulk sites over the period. Based on other analyses of rainfall and previous bulk deposition data, it is quite likely that total nitrogen in rainfall is under-reported by the weekly composite NADP/NTN samples which measure only inorganic nitrogen species. De-seasonalized inorganic nitrogen deposition in rainfall has significantly increased at the NADP/NTN site since 1983. While seasonal rainfall amounts have not increased significantly , the relationship between rainfall and deposition indicates that much of the trend in nitrogen deposition can be explained by rainfall amounts.

For the analysis of stormwater data, it should be re-emphasized that the total loadings and resultant unit loadings are estimated from the ratio of (total flow/sampled flow) times the measured loadings. This approach was necessary because of the absence of continuous flow-weighted quality samples. The individual weekly estimates of stormwater loading were divided by the contributing area and paired with atmospheric loads computed since the last week with any rainfall events. The results should be interpreted within the sampling framework, and to the extent that the collection periods agree. While atmospheric collections were excellent, unusual hydrology, and mechanical difficulties provided a smaller data set for stormwater loadings. Most of the statistical analyses of stormwater were limited to sites which collected a larger portion of the total runoff and which were in operation for the majority of the study period.

Most sites and parameters exhibited significant differences in area-normalized stormwater loadings. Seasonal variations were also apparent and significant for many parameters. To examine site differences, total or cumulative export ratios were computed as the sum of all stormwater loadings estimated from the site, divided by the total atmospheric loadings during the period of site operation. By examining the export ratios, stormwater loadings are in effect normalized for differences in atmospheric deposition between sites. Site and season were still occasionally significant variables affecting stormwater loadings, even after data are normalized for atmospheric loadings.

In almost all sites and for almost all parameters, export ratios were greater than 1.00, indicating that stormwater loadings are greater than the atmospheric loads can account for. The median export ratio of nitrogen was 1.49. Nitrogen and phosphorus exhibited similar export ratios over the study period. Similarly, more metals are exported than are measured in atmospheric deposition. Few of the watersheds acted as sinks of materials over the study period. Several statistical approaches were used to determine what factors affected a given site's export. Multivariate analyses indicate that site and seasonal variations are more frequently significant in determining stormwater loadings, but that atmospheric deposition is also significant for nitrogen, phosphorus, and zinc.

Evaluation of the available data indicates that atmospheric loading alone cannot account for the pollutant loads found in stormwater. For several of the sites, a census of both atmospheric and runoff loads was achieved. The raw data from those sites indicates export ratios of greater than one for most parameters. Since monitoring of several of these sites represents a census, statistical procedures are unnecessary to verify that site differences exist and the range of differences between sites is substantial. Wide-spread site and season differences were noted for both the weekly export ratio (runoff / atmospheric loads, normalized for area) and for the normalized runoff load in the absence of correction for atmospheric loads.

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APPENDIX A

Week	Site	Total Flow (cf)	Flow Sampled (cf)	Rain (Bulk) (cm)	Stormwater Total N (g/ha)	Stormwater Total P (g/ha)	Atmospheric Total N (kg/ha/yr)	Atmospheric Total P (kg/ha/yr)	Contamination Bird (0=absent,1=present)	Contamination Color (0=absent,1=present)
05/06/97	Alligator Cr		0	0.0			0.81	0.00	0	0
05/13/97	Alligator Cr		0	2.9			8.98	0.15	0	0
05/20/97	Alligator Cr	172683	0	0.0			0.62	0.00	0	0
05/27/97	Alligator Cr	90907	90907	0.0	3.05	0.34	0.59	0.00	0	0
06/03/97	Alligator Cr	133442	133442	0.6	22.35	3.48	2.85	0.21	0	0
06/10/97	Alligator Cr	111358	111358	0.2	14.71	1.87	3.01	0.01	0	0
06/17/97	Alligator Cr	262543	262543	0.5	28.34	3.42	0.99	0.22	0	0
06/24/97	Alligator Cr	440747	440747	0.9	33.71	9.02	4.57	0.29	0	0
07/01/97	Alligator Cr	967911	967911	9.5	126.98	163.91	10.81	0.45	0	0
07/08/97	Alligator Cr	1660459	1660459	6.1	205.48	108.15	62.81	11.25	0	1
07/15/97	Alligator Cr	755172	755172		108.07	26.70				
07/22/97	Alligator Cr	1343626	1343626	9.5	75.01	95.01	13.81	2.93	0	0
07/29/97	Alligator Cr	852604	852604	0.8	82.66	20.63	3.43	0.14	0	0
08/05/97	Alligator Cr	358605	358605	3.0	39.77	3.34	7.13	0.11	0	0
08/12/97	Alligator Cr			1.5			5.91	0.07	0	0
08/19/97	Alligator Cr			0.1			2.40	0.00	0	0
08/26/97	Alligator Cr			9.5			13.91	0.44	0	0
09/02/97	Alligator Cr	1877503	1877503	1.9	518.84	13.98	5.65	0.99	0	0
09/09/97	Alligator Cr	2744327	0	2.2			4.08	0.36	0	0
09/16/97	Alligator Cr	712825	712825	0.0	123.36	7.30	1.90	0.00	0	0
09/23/97	Alligator Cr	1025315	1025315	3.6	156.46	52.47	24.42	0.26	3	0
09/30/97	Alligator Cr	2302558	2302558	9.5	231.81	141.40	10.89	4.81	5	0
10/07/97	Alligator Cr	1207970	1207970	0.0	296.50	5.62	0.53	0.00	0	0
10/14/97	Alligator Cr	589540	589540	0.0	212.61	0.00	1.46	0.15	0	0
10/21/97	Alligator Cr	1015229	1015229	3.2	328.35	58.57	7.03	1.71	0	0
10/28/97	Alligator Cr	1332562	1332562	4.3	302.53	48.36	7.18	0.75	0	0
11/04/97	Alligator Cr	2575827	2575827	9.5	475.02	213.31	8.50	0.75	0	0
11/11/97	Alligator Cr	265269	265269	0.3	36.04	6.17	3.66	0.00	0	0
11/18/97	Alligator Cr	1927642	1927642		186.17	35.87	1.42	0.00	0	0
11/25/97	Alligator Cr	285314	285314	0.0	129.39	1.86	0.43	0.00	0	0
12/02/97	Alligator Cr	780448	780448	2.1	93.82	0.00	5.95	1.06	0	0
12/09/97	Alligator Cr	814339	814339	6.0	63.65	35.61	5.85	0.47	0	0
12/16/97	Alligator Cr	1441686	1441686	9.0	211.95	24.15	26.23	1.98	0	0
12/23/97	Alligator Cr	281162	281162	0.0	97.11	10.20	4.02	0.43	0	0
12/30/97	Alligator Cr	1631514	1631514	9.3	157.88	63.76	18.07	6.83	0	0
01/06/98	Alligator Cr	179018	179018	0.0	80.75	3.83	1.00	0.00	0	0
01/13/98	Alligator Cr	659816	659816	2.1	208.98	7.37	2.55	0.42	0	0
01/20/98	Alligator Cr	614343	614343	1.7	77.74	12.58	4.94	0.62	0	0
01/27/98	Alligator Cr	736976	736976	2.7	68.57	0.00	2.04	0.55	0	0
02/03/98	Alligator Cr	1339564	1339564	5.4	99.71	17.45	16.72	1.48	0	0

Week	Site	Total Flow (cf)	Flow Sampled (cf)	Rain (Bulk) (cm)	Stormwater Total N (g/ha)	Stormwater Total P (g/ha)	Atmospheric Total N (kg/ha/yr)	Atmospheric Total P (kg/ha/yr)	Contamination Bird (0=absent,1=present)	Contamination Color (0=absent,1=present)
05/06/97	Cockroach B		0	0.1			0.93	0.00	0	0
05/13/97	Cockroach B		0	1.7			2.81	0.60	0	0
05/20/97	Cockroach B		0	0.0			0.72	0.11	0	0
05/27/97	Cockroach B		0	0.0			0.75	0.00	0	0
06/03/97	Cockroach B		0	2.1			6.00	0.80	0	0
06/10/97	Cockroach B		0	0.6			4.01	0.12	0	0
06/17/97	Cockroach B		0	0.4			1.60	0.77	0	0
06/24/97	Cockroach B		0	5.0			16.56	0.37	0	0
07/01/97	Cockroach B		0	8.4			126.16	14.62	1	0
07/08/97	Cockroach B	300000	300000	3.4	150.74	16.99	12.68	0.18	0	0
07/15/97	Cockroach B	475600	0	6.0			16.11	0.48	2	1
07/22/97	Cockroach B	221800	97000	4.8	120.90	24.76	75.84	20.11	1	0
07/29/97	Cockroach B	357500	90000	5.3	86.24	46.10	30.93	5.86	0	0
08/05/97	Cockroach B	125900	270000	4.8	42.20	26.68	10.99	0.16	0	0
08/12/97	Cockroach B	541300	110000	2.3	145.01	108.94	83.71	63.06	2	1
08/19/97	Cockroach B	270200	260000	0.7	75.17	58.70	4.50	0.03	0	0
08/26/97	Cockroach B	123300	0	1.4			4.76	0.38	0	0
09/02/97	Cockroach B	158500	220000	1.8	100.92	33.22	5.14	0.22	0	0
09/09/97	Cockroach B	175100	120000	1.9	76.25	41.13	3.15	0.92	0	0
09/16/97	Cockroach B	21300	0	0.0			1.33	0.07	0	0
09/23/97	Cockroach B	0	0	0.2			3.49	0.28	0	0
09/30/97	Cockroach B	3992500	430000	9.0	1415.41	1021.65	2.10	5.84	0	0
10/07/97	Cockroach B	90300	130000	0.0	22.69	36.32	0.41	0.00	0	0
10/14/97	Cockroach B	7100	0	0.3			0.66	0.00	0	0
10/21/97	Cockroach B	400	0	1.1			6.59	2.20	3	0
10/28/97	Cockroach B	250600	250000	7.3	62.12	61.37	5.44	0.56	0	0
11/04/97	Cockroach B	507000	130000	2.6	137.51	124.84	2.13	0.82	0	0
11/11/97	Cockroach B	31200	0	0.0			1.11	0.18	0	0
11/18/97	Cockroach B	1042900	350000	8.4	384.32	245.32	3.47	2.24	0	0
11/25/97	Cockroach B	55400	0	0.2			4.22	0.89	0	0
12/02/97	Cockroach B	17500	0	1.3			1.95	0.09	0	0
12/09/97	Cockroach B	10500	0	1.8			3.03	0.15	0	0
12/16/97	Cockroach B	2368100	350000	7.1	793.77	538.91	2.13	0.40	0	0
12/23/97	Cockroach B	19500	0	0.0			0.00	0.30	0	0
12/30/97	Cockroach B	697200	0	8.9			12.96	1.45	0	0
01/06/98	Cockroach B	6500	0	0.0			0.32	0.00	0	0
01/13/98	Cockroach B	4800	0	3.5			7.93	1.58	0	0
01/20/98	Cockroach B	95000	60000	2.6	15.29	32.16	3.42	0.64	0	0
01/27/98	Cockroach B	358500	250000	6.6	132.11	93.89	6.25	1.73	0	0
02/03/98	Cockroach B	15411	0	3.0			8.07	0.21	0	0

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05/06/97	Cone Ranch	0	0	0.0			1.17	0.13	0	0
05/13/97	Cone Ranch	0	0	1.5			432.54	98.79	10	1
05/20/97	Cone Ranch	0	0							
05/27/97	Cone Ranch	0	0	1.0			1.35	0.01	0	0
06/03/97	Cone Ranch	0	0	0.2			2.72	0.27	1	0
06/10/97	Cone Ranch	0	0	1.2			2.55	0.36	0	0
06/17/97	Cone Ranch	6747	0	7.8			12.39	0.41	1	0
06/24/97	Cone Ranch	0	0	0.5			0.91	0.14	0	0
07/01/97	Cone Ranch	0	0	4.4			33.75	0.54	0	0
07/08/97	Cone Ranch	0	0	4.4			932.32	88.28	5	1
07/15/97	Cone Ranch	0	0	7.3			700.91	45.11	1	1
07/22/97	Cone Ranch	0	0	1.9			278.58	31.53	1	0
07/29/97	Cone Ranch	0	0	2.4			1251.07	164.41	5	1
08/05/97	Cone Ranch	0	0	7.4			760.17	88.97	3	1
08/12/97	Cone Ranch	0	0	8.2			145.57	108.48	1	0
08/19/97	Cone Ranch	0	0	2.8			45.90	4.49	3	1
08/26/97	Cone Ranch	0	0	0.5			1236.00	193.60	10	1
09/02/97	Cone Ranch	0	0	1.2			2517.18	415.93	8	1
09/09/97	Cone Ranch	0	0	0.2			290.62	25.60	10	1
09/16/97	Cone Ranch	209	0	0.0			200.27	51.19	10	1
09/23/97	Cone Ranch		0							
09/30/97	Cone Ranch	1058384	0	7.7			1.43	1.16	0	0
10/07/97	Cone Ranch		0	0.7			1.71	0.05	0	0
10/14/97	Cone Ranch	219675	0	0.0			0.00	0.05	0	0
10/21/97	Cone Ranch	227414	0	0.5			1.52	0.28	0	0
10/28/97	Cone Ranch	3833	0	3.9			156.00	24.19	1	0
11/04/97	Cone Ranch		0	7.4			7.78	0.44	0	0
11/11/97	Cone Ranch		0	0.0			0.91	0.00	1	0
11/18/97	Cone Ranch		0	3.7			3.46	3.57	0	0
11/25/97	Cone Ranch		0	0.0			0.00	0.00	0	0
12/02/97	Cone Ranch		0	0.7			3.33	0.35	0	0
12/09/97	Cone Ranch	3279667	0	6.1			3.53	0.48	0	0
12/16/97	Cone Ranch		0	9.5			9.55	0.51	0	0
12/23/97	Cone Ranch		0	0.0			0.30	0.05	0	0
12/30/97	Cone Ranch		0							
01/06/98	Cone Ranch		0	9.3			3.85	1.19	0	0
01/13/98	Cone Ranch	3442643	2224861	2.8	224.55	101.13	1.56	0.20	0	0
01/20/98	Cone Ranch	3044666	3044666	0.7	145.01	49.12	7.48	0.18	0	0
01/27/98	Cone Ranch	862830	862830	3.0	37.91	17.04	4.22	0.97	0	0
02/03/98	Cone Ranch	2026178	2026178	3.6	53.32	6.34	17.65	3.20	0	0

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05/06/97	Florida Aqu	0	0	0.0			1.44	0.17	0	0
05/13/97	Florida Aqu	291	291	1.8	109.49	14.09	9.87	1.30	0	0
05/20/97	Florida Aqu	0	0	0.0			1.53	0.21	0	0
05/27/97	Florida Aqu	219	219	1.0	78.13	11.54	4.21	0.00	0	0
06/03/97	Florida Aqu	18	0	0.1			1.73	0.41	0	0
06/10/97	Florida Aqu	57	0	0.5			5.45	0.47	0	0
06/17/97	Florida Aqu	50	0	0.1			1.56	0.00	0	0
06/24/97	Florida Aqu	803	803	1.0	652.78	71.55	9.56	0.94	0	0
07/01/97	Florida Aqu	1213	993	4.8	346.92	58.75	17.61	1.76	0	0
07/08/97	Florida Aqu	3120	3120	8.6	580.94	68.84	34.55	3.76	0	0
07/15/97	Florida Aqu	634	185	1.5	279.40	37.39	16.16	1.62	0	0
07/22/97	Florida Aqu	915	915	4.7	201.15	22.16	18.46	0.41	0	0
07/29/97	Florida Aqu	2370	2370	1.5	750.57	92.46	8.70	0.84	0	0
08/05/97	Florida Aqu	771	771	1.0	195.04	29.04	8.35	0.92	0	0
08/12/97	Florida Aqu		0	8.0			54.00	2.40	1	0
08/19/97	Florida Aqu	1087	784	0.5	411.73	31.29	4.56	0.41	0	0
08/26/97	Florida Aqu	850	690	1.1	98.85	19.45	1.37	0.00	0	0
09/02/97	Florida Aqu	76	76	0.3	57.88	2.40	2.26	0.31	0	0
09/09/97	Florida Aqu	166	0	0.5			0.43	0.05	0	0
09/16/97	Florida Aqu	49	0	0.0			0.47	0.00	0	0
09/23/97	Florida Aqu	113	0	0.0			0.20	0.00	0	0
09/30/97	Florida Aqu	10165	10165	8.9	1028.53	150.45	4.16	1.42	0	0
10/07/97	Florida Aqu	0	0	0.0			0.96	0.00	0	0
10/14/97	Florida Aqu	321	0	0.1			0.05	0.00	0	0
10/21/97	Florida Aqu	629	629	0.6	208.17	23.54	0.65	0.03	0	0
10/28/97	Florida Aqu	2214	2214	4.3	188.27	28.60	3.48	2.54	0	0
11/04/97	Florida Aqu	824	824	1.7	80.22	15.51	4.61	0.48	0	0
11/11/97	Florida Aqu	550	550	0.1	71.52	9.77	1.68	0.01	0	0
11/18/97	Florida Aqu	2086	2086	5.9	99.37	21.90	56.55	15.46	1	0
11/25/97	Florida Aqu	140	0	0.0			0.03	0.10	0	0
12/02/97	Florida Aqu	1376	1376	1.9	67.04	23.33	4.10	0.14	0	0
12/09/97	Florida Aqu	1848	1848	3.2	199.93	17.40	4.01	0.29	0	0
12/16/97	Florida Aqu	8941	8941	9.3	1891.27	81.81	10.40	0.58	0	0
12/23/97	Florida Aqu	0	0	0.0			1.76	0.09	0	0
12/30/97	Florida Aqu	4578	4465	9.4	406.55	38.19	6.54	2.55	0	0
01/06/98	Florida Aqu	0	0	0.0			0.00	0.00	0	0
01/13/98	Florida Aqu	804	804	2.5	69.64	14.28	1.53	0.47	0	0
01/20/98	Florida Aqu	221	0	1.0			6.50	0.33	0	0
01/27/98	Florida Aqu	2795	2795	4.8	438.46	39.11	8.43	0.96	0	0
02/03/98	Florida Aqu	385	385	2.4	41.60	7.03	6.78	0.07	0	0

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05/06/97	Frog Creek		0	0.0			1.55	0.00	0	0
05/13/97	Frog Creek	7133	7133	2.3	6.32	4.27	4.99	0.98	0	0
05/20/97	Frog Creek	1453	1453	0.4	4.00	0.81	6.70	0.64	0	0
05/27/97	Frog Creek	0	0	0.0			0.63	0.00	0	0
06/03/97	Frog Creek	2811	2811	0.8	7.12	3.54	6.00	0.64	0	0
06/10/97	Frog Creek	848	848	1.0	1.06	0.28	6.79	0.36	0	0
06/17/97	Frog Creek	1240	1240	0.4	1.35	0.74	1.07	0.37	0	0
06/24/97	Frog Creek	23404	9400	3.7	44.63	16.38	13.35	0.47	0	0
07/01/97	Frog Creek		0	4.2			15.40	1.77	0	0
07/08/97	Frog Creek	895	0	2.1			6.98	0.11	0	0
07/15/97	Frog Creek		0	4.7			23.98	0.35	0	0
07/22/97	Frog Creek	30256	9400							
07/29/97	Frog Creek	17442	9400	5.2	19.06	11.09	15.46	1.64	0	0
08/05/97	Frog Creek		0	2.8			6.30	0.24	1	0
08/12/97	Frog Creek		0	0.3			1.54	0.43	0	0
08/19/97	Frog Creek	0	0	0.1			1.47	0.00	0	0
08/26/97	Frog Creek	6650	6650	2.1			7.35	0.06	0	0
09/02/97	Frog Creek	27089	9400	4.2			17.78	1.06	0	0
09/09/97	Frog Creek	0	0	2.7			1.79	0.70	0	0
09/16/97	Frog Creek	778	778	0.7	2.53	0.62	3.86	0.33	0	0
09/23/97	Frog Creek	54	0	0.1			2.33	0.30	0	0
09/30/97	Frog Creek	350555	3400	9.1	445.52	414.75	2.95	3.17	0	0
10/07/97	Frog Creek	0	0	0.0			0.80	0.00	0	0
10/14/97	Frog Creek	0	0	0.0			0.56	0.00	0	0
10/21/97	Frog Creek	23770	3200	3.5	45.27	26.01	10.81	3.92	0	0
10/28/97	Frog Creek	23934	9400	3.9	48.84	17.05	2.61	1.15	0	0
11/04/97	Frog Creek	90507	9400	8.2	146.35	50.66	3.58	4.68	0	0
11/11/97	Frog Creek	5	5	0.0			1.68	0.24	0	0
11/18/97	Frog Creek	131554	9400	8.4	294.89	184.10	1.15	2.74	0	0
11/25/97	Frog Creek	1052	1052	0.6	1.35	0.74	1.86	0.70	0	0
12/02/97	Frog Creek	4049	4049	1.2	2.60	2.01	1.86	0.26	0	0
12/09/97	Frog Creek	38129	9400	4.2	36.57	14.07	2.75	0.33	0	0
12/16/97	Frog Creek	199323	9400	9.3	220.61	76.07	2.56	3.93	0	0
12/23/97	Frog Creek	0	0	0.0			0.20	0.21	0	0
12/30/97	Frog Creek	159138	9400	9.2	267.64	87.06	15.70	2.10	0	0
01/06/98	Frog Creek	26	0	0.0			0.24	0.00	0	0
01/13/98	Frog Creek	26179	9400	3.3	27.34	13.65	6.40	0.80	0	0
01/20/98	Frog Creek	17097	9400	2.2	26.14	10.66	2.26	0.36	0	0
01/27/98	Frog Creek		0	7.7			4.22	2.54	0	0
02/03/98	Frog Creek	21988	9400	2.6	27.08	9.79	9.04	0.97	0	0

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05/06/97	Gandy Bridge		0	0.0			3.18	0.13	3	1
05/13/97	Gandy Bridge		0	3.2			388.49	51.54	6	1
05/20/97	Gandy Bridge		0	0.0			1.03	0.05	1	0
05/27/97	Gandy Bridge		0	0.0			0.83	0.00	0	0
06/03/97	Gandy Bridge		0	0.6			0.99	0.00	1	1
06/10/97	Gandy Bridge		0	0.1			2.02	0.16	0	0
06/17/97	Gandy Bridge		0	0.5			25.26	3.83	2	0
06/24/97	Gandy Bridge		0	1.3			8.41	0.79	0	0
07/01/97	Gandy Bridge		0	2.7			7.67	0.15	0	0
07/08/97	Gandy Bridge		0	6.7			15.74	2.50	0	0
07/15/97	Gandy Bridge	1948	1948	8.0	43.89		31.72	5.72	0	0
07/22/97	Gandy Bridge	2273	2273	4.7	21.63		13.47	2.16	0	0
07/29/97	Gandy Bridge	347	347	1.6	5.63		10.98	0.43	0	0
08/05/97	Gandy Bridge	207	207	1.8	2.90		4.32	0.55	0	0
08/12/97	Gandy Bridge		0	1.3			42.28	11.08	1	0
08/19/97	Gandy Bridge		0	4.1			10.87	18.91	1	0
08/26/97	Gandy Bridge	0	0	0.5			1.10	0.00	0	0
09/02/97	Gandy Bridge	0	0	0.3			3.07	0.00	0	0
09/09/97	Gandy Bridge	0	0	0.0			1.72	0.29	0	0
09/16/97	Gandy Bridge	0	0	0.4			1.75	0.03	0	0
09/23/97	Gandy Bridge	0	0	1.5			12.03	1.02	0	0
09/30/97	Gandy Bridge	110359	110359	7.8	1105.77		1.58	1.58	0	0
10/07/97	Gandy Bridge	0	0	0.2			1.52	0.00	0	0
10/14/97	Gandy Bridge		0	0.0			0.00	0.14	0	0
10/21/97	Gandy Bridge	0	0	1.6			7.69	0.58	0	0
10/28/97	Gandy Bridge	0	0	4.4			8.60	2.87	0	0
11/04/97	Gandy Bridge	9268	9268	3.8	75.22		4.86	0.26	0	0
11/11/97	Gandy Bridge	0	0	0.6			2.27	0.02	0	0
11/18/97	Gandy Bridge	22246	22246	6.1	164.84		1.66	1.48	0	0
11/25/97	Gandy Bridge	0	0	0.0			0.18	0.32	0	0
12/02/97	Gandy Bridge	258	258	1.2	2.33		2.12	0.07	0	0
12/09/97	Gandy Bridge	7460	7460	3.2	69.01		2.67	0.25	0	0
12/16/97	Gandy Bridge	118065	118065	9.5	1073.94		6.34	0.59	0	0
12/23/97	Gandy Bridge	0	0	0.0			0.20	0.37	1	0
12/30/97	Gandy Bridge	115219	115219	9.4	1542.24		17.89	3.00	0	0
01/06/98	Gandy Bridge	0	0	0.0			0.00	0.00	0	0
01/13/98	Gandy Bridge	0	0	3.6			3.71	0.29	0	0
01/20/98	Gandy Bridge		0	1.4			5.40	1.54	0	0
01/27/98	Gandy Bridge		0	4.1			3.37	1.38	0	0
02/03/98	Gandy Bridge		0	4.1			9.58	1.20	0	0

Week	Site	Total Flow (cf)	Flow Sampled (cf)	Rain (Bulk) (cm)	Stormwater Total N (g/ha)	Stormwater Total P (g/ha)	Atmospheric Total N (kg/ha/yr)	Atmospheric Total P (kg/ha/yr)	Contamination Bird (0=absent,1=present)	Contamination Color (0=absent,1=present)
05/06/97	Inwood Alum	728200	0	0.0			0.00	0.00	1	0
05/13/97	Inwood Alum	1029400	21446	4.4	346.09	112.66	9.43	0.00	0	0
05/20/97	Inwood Alum	1209100	0	0.0			1.05	0.18	0	0
05/27/97	Inwood Alum	414600	0	1.1			4.79	0.15	0	0
06/03/97	Inwood Alum	757740	0	2.4			13.23	1.25	0	0
06/10/97	Inwood Alum	1169540	0	8.6			37.90	2.44	0	0
06/17/97	Inwood Alum	362460	82209	5.3	79.92	23.91	18.99	2.72	0	1
06/24/97	Inwood Alum	1825259	0	0.7			3.83	0.27	0	0
07/01/97	Inwood Alum	176308	51960	8.1	45.49	14.12	41.96	0.48	0	0
07/08/97	Inwood Alum	1221847	46545	3.9	356.95	62.05	16.22	0.70	0	0
07/15/97	Inwood Alum	888317	28750	3.9	349.08	101.63	19.92	3.07	0	0
07/22/97	Inwood Alum	2055741	67888	1.9	670.46	83.99	10.66	1.32	0	0
07/29/97	Inwood Alum	2205753	36689	0.8	1195.11	320.59	3.34	0.24	0	0
08/05/97	Inwood Alum	3179072	235522	5.0	1165.32	377.62	16.32	1.36	0	0
08/12/97	Inwood Alum	5044036	83515	2.8	1581.02	603.56	18.23	1.14	0	0
08/19/97	Inwood Alum	5262177	0	0.1			3.33	0.16	0	0
08/26/97	Inwood Alum	5104289	159983	2.4	2020.74	547.45	11.29	0.24	0	0
09/02/97	Inwood Alum	1652322	0	3.9			4.15	1.23	0	0
09/09/97	Inwood Alum	4043665	73705	0.4	1316.43	356.99	2.77	0.47	0	0
09/16/97	Inwood Alum	2469421	0	0.3			2.09	0.54	0	0
09/23/97	Inwood Alum	738518	0	0.0			2.23	0.22	0	0
09/30/97	Inwood Alum	1037592	0	9.0			12.07	1.74	0	0
10/07/97	Inwood Alum		0	0.4			4.18	0.48	0	0
10/14/97	Inwood Alum	618441	53343	0.6	187.35	24.82	11.06	2.12	0	0
10/21/97	Inwood Alum		0	0.6			19.05	3.53	0	0
10/28/97	Inwood Alum	412019	36691	2.5	202.25	70.28	2.57	1.06	0	0
11/04/97	Inwood Alum		0	5.5			7.39	2.03	1	0
11/11/97	Inwood Alum	5837323	0	0.0			0.36	0.00	0	0
11/18/97	Inwood Alum	5374527	0	6.5			6.65	6.18	0	0
11/25/97	Inwood Alum	7144149	0	0.0			0.05	0.00	0	0
12/02/97	Inwood Alum	5626121	0	0.2			0.76	0.00	0	0
12/09/97	Inwood Alum	1190181	0	5.6			3.59	1.31	0	0
12/16/97	Inwood Alum	15455198	204054	8.3	5155.56	1535.84	7.30	2.15	0	0
12/23/97	Inwood Alum	15090820	0	0.0			1.48	0.20	0	0
12/30/97	Inwood Alum	17378477	0	7.4			4.82	1.06		
01/06/98	Inwood Alum	16186786	0	0.0			0.00	0.00	0	0
01/13/98	Inwood Alum	16490532	0	3.0			9.95	1.67	0	0
01/20/98	Inwood Alum	966656	0	1.3			2.21	0.73	0	0
01/27/98	Inwood Alum		0	2.9			9.12	1.28	0	0
02/03/98	Inwood Alum	9675337	0	4.7			39.44	0.37	0	0

Week	Site	Total Flow (cf)	Flow Sampled (cf)	Rain (Bulk) (cm)	Stormwater Total N (g/ha)	Stormwater Total P (g/ha)	Atmospheric Total N (kg/ha/yr)	Atmospheric Total P (kg/ha/yr)	Contamination Bird (0=absent,1=present)	Contamination Color (0=absent,1=present)
05/06/97	Pasco WWTP	8190	0	3.3			6.40	0.80	0	0
05/13/97	Pasco WWTP	590	590	1.1	1.74	0.14	6.87	1.32	0	0
05/20/97	Pasco WWTP	1650	1650	2.1	5.21	0.32	11.11	0.26	0	0
05/27/97	Pasco WWTP	0	0	0.2			1.25	0.01	0	0
06/03/97	Pasco WWTP	530	530	2.7	1.63	0.09	7.57	0.06	0	0
06/10/97	Pasco WWTP	0	0	1.7			5.04	0.09	0	0
06/17/97	Pasco WWTP	360	360	1.7	0.14	0.01	4.66	0.05	0	0
06/24/97	Pasco WWTP	0	0	0.2			2.87	0.17	0	0
07/01/97	Pasco WWTP	8070	1920	8.6	15.40	0.48	24.62	0.45	0	0
07/08/97	Pasco WWTP	340	340	0.7	0.84	0.06	2.44	0.24	0	0
07/15/97	Pasco WWTP	16829	1920	9.5	32.05	3.77	37.62	6.22	0	0
07/22/97	Pasco WWTP	1050	980	2.5	2.22	0.17	14.73	1.12		
07/29/97	Pasco WWTP	0	0	0.0			3.54	0.51	0	0
08/05/97	Pasco WWTP	37752	1920	9.5	62.37	4.51	19.69	0.86	0	0
08/12/97	Pasco WWTP	22656	1920	4.3	37.84	1.02	13.10	0.05	0	0
08/19/97	Pasco WWTP	26424	1920	2.2	55.19	8.30	12.03	0.06	0	0
08/26/97	Pasco WWTP	5364	2060	1.4	12.56	1.28	2.34	0.30	0	0
09/02/97	Pasco WWTP	16150	1860	8.4	54.71	7.49	27.39	9.03	1	0
09/09/97	Pasco WWTP	34700	1920	0.0	103.55	8.82	1.16	0.21	0	0
09/16/97	Pasco WWTP	280	60	0.3	3.00	0.93	3.60	0.18	0	0
09/23/97	Pasco WWTP	500	500	0.8	2.32	0.11	6.19	0.29	0	0
09/30/97	Pasco WWTP	81190	1920	8.6	253.46	20.64	3.13	3.61	0	0
10/07/97	Pasco WWTP	58890	1920	0.0	99.23	23.77	2.04	0.10	0	0
10/14/97	Pasco WWTP	1240	0	0.0			6.20	0.37	0	0
10/21/97	Pasco WWTP	0	0	0.7			2.09	0.65	0	0
10/28/97	Pasco WWTP	44980	1920	4.6	886.35	63.89	6.74	4.36	0	0
11/04/97	Pasco WWTP	83840	1920	7.7	1664.13	114.07	4.37	3.53	0	0
11/11/97	Pasco WWTP	52180	1920	0.0	567.94	74.89	2.71	0.00	0	0
11/18/97	Pasco WWTP	13090	1920	5.5	31.33	4.89	3.08	3.50	0	0
11/25/97	Pasco WWTP	0	0	0.0			0.79	0.22	0	0
12/02/97	Pasco WWTP	0	0	1.0			2.41	0.38	0	0
12/09/97	Pasco WWTP	107960	1920	3.9	230.17	22.60	7.73	0.30	0	0
12/16/97	Pasco WWTP	140000	1920	8.9	2149.01	604.92	7.78	0.74	0	0
12/23/97	Pasco WWTP	101750	1920	0.0	3476.53	460.94	2.76	0.00	0	0
12/30/97	Pasco WWTP	209250	15360	9.2	3420.36	1845.80	5.04	1.94	0	0
01/06/98	Pasco WWTP	43490	15360	0.0	778.05	230.83	0.56	0.00	0	0
01/13/98	Pasco WWTP	16840	16320	3.1	97.51	23.16	3.41	0.24	0	0
01/20/98	Pasco WWTP	2280	1920	1.2	8.43	2.62	4.31	0.76	0	0
01/27/98	Pasco WWTP	5030	4800	2.8	8.59	3.38	3.29	1.91	0	0
02/03/98	Pasco WWTP	6510	6400	3.4	12.83	3.50	7.85	0.20	0	0

Week	Site	Total Flow (cf)	Flow Sampled (cf)	Rain (Bulk) (cm)	Stormwater Total N (g/ha)	Stormwater Total P (g/ha)	Atmospheric Total N (kg/ha/yr)	Atmospheric Total P (kg/ha/yr)	Contamination Bird (0=absent,1=present)	Contamination Color (0=absent,1=present)
05/06/97	Pinellas Prk	0	0	0.0			1.01	0.00	0	0
05/13/97	Pinellas Prk	98431	96358	4.1	63.45	6.10	7.29	0.47	0	0
05/20/97	Pinellas Prk	0	0	0.0			0.81	0.00	0	0
05/27/97	Pinellas Prk	0	0	0.0			0.70	0.00	0	0
06/03/97	Pinellas Prk	687	0	0.3			2.10	0.22	0	0
06/10/97	Pinellas Prk	0	0	0.2			2.93	0.07	0	0
06/17/97	Pinellas Prk	0	0	0.3			0.86	0.25	0	0
06/24/97	Pinellas Prk	74025	74025	2.8	110.62	18.53	6.84	0.61	0	0
07/01/97	Pinellas Prk		0	6.5			18.77	0.31	0	0
07/08/97	Pinellas Prk		0	7.4			15.48	0.30	2	1
07/15/97	Pinellas Prk		0	9.6			31.24	4.34	0	0
07/22/97	Pinellas Prk	277639	0	5.0			11.72	1.44	0	0
07/29/97	Pinellas Prk	129557	0	2.7			14.00	0.70	0	0
08/05/97	Pinellas Prk	97756	0	3.0			7.86	0.09	0	0
08/12/97	Pinellas Prk	7808	0	1.1			8.51	0.06	0	0
08/19/97	Pinellas Prk	86789	0	3.8			38.25	1.67	1	1
08/26/97	Pinellas Prk		0	0.7			1.59	0.00	0	0
09/02/97	Pinellas Prk		0	0.7			37.42	1.51	0	0
09/09/97	Pinellas Prk		0	0.3			9.23	0.10	0	0
09/16/97	Pinellas Prk	62941	0	3.0			8.03	0.26	0	0
09/23/97	Pinellas Prk	0	0	0.4			5.13	0.35	0	0
09/30/97	Pinellas Prk	12888	12888	9.0	3.55	1.39	1.53	2.49	0	0
10/07/97	Pinellas Prk	0	0	0.6			4.62	0.05	0	0
10/14/97	Pinellas Prk	0	0	0.0			1.00	0.18	0	0
10/21/97	Pinellas Prk	7443	0	1.5			7.12	0.66	0	0
10/28/97	Pinellas Prk	115457	115457	5.3	97.23	10.69	9.06	2.18	0	0
11/04/97	Pinellas Prk	81414	81414	2.3	26.80	5.17	3.23	0.36	0	0
11/11/97	Pinellas Prk	0	0	0.3			2.76	0.00	0	0
11/18/97	Pinellas Prk	392114	353608	8.3	156.09	42.93	2.75	1.48	0	0
11/25/97	Pinellas Prk	5431	0	0.0			0.84	0.09	0	0
12/02/97	Pinellas Prk	14678	0	1.9			4.27	0.14	0	0
12/09/97	Pinellas Prk	121884	121884	3.7	48.52	8.86	5.71	0.29	0	0
12/16/97	Pinellas Prk	1529362	1529362	9.4	807.84	163.91	11.24	2.48	0	0
12/23/97	Pinellas Prk	0	0	0.0			1.90	0.32	0	0
12/30/97	Pinellas Prk	1097227	1097227	9.2	596.38	116.76	12.14	1.54	0	0
01/06/98	Pinellas Prk	0	0	0.0			0.44	0.00	0	0
01/13/98	Pinellas Prk	99439	99439	2.8	31.21	4.95	3.23	0.77	0	0
01/20/98	Pinellas Prk	36776	0	1.7			6.05	1.13	0	0
01/27/98	Pinellas Prk	254483	254483	4.4	66.24	28.25	4.95	6.53	0	0
02/03/98	Pinellas Prk	356242	356242	6.1	163.63	43.09	14.92	1.56	0	0

Week	Site	Total Flow (cf)	Flow Sampled (cf)	Rain (Bulk) (cm)	Stormwater Total N (g/ha)	Stormwater Total P (g/ha)	Atmospheric Total N (kg/ha/yr)	Atmospheric Total P (kg/ha/yr)	Contamination Bird (0=absent,1=present)	Contamination Color (0=absent,1=present)
05/06/97	Wildlife Prs	0	0	1.3			4.72	0.28	0	0
05/13/97	Wildlife Prs	0	0	1.6			8.17	1.45	0	0
05/20/97	Wildlife Prs	0	0	0.0			2.25	0.13	0	0
05/27/97	Wildlife Prs	0	0	2.3			7.11	0.12	0	0
06/03/97	Wildlife Prs	0	0	0.7			2.43	0.15	0	0
06/10/97	Wildlife Prs	0	0	2.9			5.22	1.69	0	0
06/17/97	Wildlife Prs	180	180	8.4	0.00	0.00	10.04	0.39	0	0
06/24/97	Wildlife Prs	0	0	0.0			0.97	0.09	0	0
07/01/97	Wildlife Prs	0	0	6.6			26.38	0.35	0	0
07/08/97	Wildlife Prs	0	0	4.4			13.66	1.71	0	0
07/15/97	Wildlife Prs	0	0	2.1			9.61	1.48	0	0
07/22/97	Wildlife Prs	0	0	7.9			14.42	3.84	0	0
07/29/97	Wildlife Prs	445	445	5.6			16.48	0.76	0	0
08/05/97	Wildlife Prs	477	477	7.7	0.17	0.01	17.66	0.68	0	0
08/12/97	Wildlife Prs	921	921	2.3	0.18	0.01	12.42	0.00	0	0
08/19/97	Wildlife Prs	821	821	4.3	0.20	0.01	9.72	0.41	0	0
08/26/97	Wildlife Prs	100	100	0.5	0.03	0.00	6.78	0.41	0	0
09/02/97	Wildlife Prs	0	0	6.2			8.18	4.92	0	0
09/09/97	Wildlife Prs	0	0	0.0			0.58	0.00	0	0
09/16/97	Wildlife Prs	80	80	0.0	0.02	0.00	1.53	0.20	0	0
09/23/97	Wildlife Prs	250	250	0.3	0.06	0.00	3.85	0.02	0	0
09/30/97	Wildlife Prs	180	0	9.0			1.97	2.52	0	0
10/07/97	Wildlife Prs	1410940	942	0.0	275.60	25.16	1.43	0.04	0	0
10/14/97	Wildlife Prs	231630	942	0.1	58.65	5.11	1.39	0.10	0	0
10/21/97	Wildlife Prs	1500	942	1.2	0.38	0.04	5.47	0.65	0	0
10/28/97	Wildlife Prs	21470	942	4.9	3.43	0.20	8.45	2.67	0	0
11/04/97	Wildlife Prs	1529720	942	8.1	310.65	33.78	10.36	1.53	0	0
11/11/97	Wildlife Prs	1087450	942	0.0	267.94	20.55	2.29	0.00	0	0
11/18/97	Wildlife Prs	1329630	942	4.9	369.95	19.62	3.46	1.65	0	0
11/25/97	Wildlife Prs	666700	942	0.0	164.91	8.42	1.03	0.18	0	0
12/02/97	Wildlife Prs	168340	942	1.2	42.14	1.23	4.80	0.10	0	0
12/09/97	Wildlife Prs	342940	942	4.1	104.99	1.46	4.61	0.32	0	0
12/16/97	Wildlife Prs	9216630	942	9.2	4692.46	116.43	8.63	0.74	0	0
12/23/97	Wildlife Prs	4844100	942	0.0	489.55	50.91	2.30	0.00	0	0
12/30/97	Wildlife Prs	5689990	960000	9.3	1307.77	125.57	39.82	2.45	0	0
01/06/98	Wildlife Prs	4805609	300000	0.0	778.76	75.75	0.83	0.42	0	0
01/13/98	Wildlife Prs	1661270	720000	3.6	222.77	27.93	11.53	0.91	0	0
01/20/98	Wildlife Prs	769390	576000	1.1	96.38	8.89	5.63	0.40	0	0
01/27/98	Wildlife Prs	211400	210000	2.1	34.61	2.67	3.42	0.69	0	0
02/03/98	Wildlife Prs		0	3.5			20.02	0.21	0	0

APPENDIX B

Week	Site	Stormwater Copper (g/ha)	Stormwater Cadmium (g/ha)	Stormwater Lead (g/ha)	Stormwater Zinc (g/ha)	Total Flow (cf)	Atmospheric Copper (g/ha/yr)	Atmospheric Cadmium (g/ha/yr)	Atmospheric Lead (g/ha/yr)	Atmospheric Zinc (g/ha/yr)
05/13/97	Alligator Cr						12.98	0.34	12.28	60.93
05/27/97	Alligator Cr	0.13	0.00	0.06	0.51	90907				
06/10/97	Alligator Cr	0.41	0.01	0.15	1.82	244800	0.00	0.01	0.00	26.76
06/17/97	Alligator Cr	0.49	0.01	0.11	3.91	262543				
07/08/97	Alligator Cr	8.68	0.09	2.86	28.56	3069117	30.92	0.35	17.92	157.12
07/15/97	Alligator Cr	1.80	0.02	0.60	5.62	755172				
08/12/97	Alligator Cr	5.75	0.07	3.80	33.28	2554835	6.83	0.23	11.52	66.94
09/02/97	Alligator Cr	3.56	0.21	0.35	20.96	1877503				
09/09/97	Alligator Cr						135.77	0.21	7.93	47.63
09/30/97	Alligator Cr	13.01	0.23	4.96	60.16	4040698	86.38	0.31	11.53	123.68
11/04/97	Alligator Cr	19.76	0.19	7.63	50.03	6721128	7.92	0.22	10.13	73.81
12/09/97	Alligator Cr	17.28	0.11	3.79	30.32	4073012	3.81	0.03	2.52	61.15
12/30/97	Alligator Cr	11.61	0.09	3.75	18.73	3354362	8.46	0.42	14.41	58.42
02/03/98	Alligator Cr	16.16	0.10	2.89	19.71	3529717	13.92	0.18	14.87	56.19
06/03/97	Cockroach B						7.00	0.18	5.63	37.51
06/24/97	Cockroach B						14.50	0.14	7.23	47.28
07/22/97	Cockroach B	2.27	0.05	0.33	5.02	997400	31.30	1.64	12.62	93.82
08/19/97	Cockroach B	1.58	0.06	0.43	6.51	1294900	27.52	0.23	12.41	114.19
09/30/97	Cockroach B	10.11	0.22	1.49	22.49	4470700	5.15	0.17	4.68	32.78
10/28/97	Cockroach B	0.79	0.02		1.75	348400	0.87	0.14	0.86	16.27
11/18/97	Cockroach B	4.88	0.08	0.38	11.01	1581100	4.43	0.24	4.45	21.45
12/16/97	Cockroach B	7.01	0.12	0.82	12.33	2451500	4.90	0.20	3.49	60.79
01/13/98	Cockroach B					728000	4.91	0.22	7.10	44.17
02/03/98	Cockroach B	3.69	0.02	0.16	2.36	468911	25.86	0.28	6.48	114.89

Week	Site	Stormwater Copper (g/ha)	Stormwater Cadmium (g/ha)	Stormwater Lead (g/ha)	Stormwater Zinc (g/ha)	Total Flow (cf)	Atmospheric Copper (g/ha/yr)	Atmospheric Cadmium (g/ha/yr)	Atmospheric Lead (g/ha/yr)	Atmospheric Zinc (g/ha/yr)
06/03/97	Cone Ranch						10.74	0.39	7.33	176.05
06/24/97	Cone Ranch						9.02	0.21	10.41	74.04
07/22/97	Cone Ranch						47.88	19.10	15.30	760.27
08/12/97	Cone Ranch						56.75	0.40	15.21	569.40
09/16/97	Cone Ranch						103.09	1.40	4.27	864.99
10/28/97	Cone Ranch						7.09	0.18	3.42	42.57
11/18/97	Cone Ranch						0.87	0.23	4.07	29.91
12/16/97	Cone Ranch					3279667	11.20	0.14	3.34	34.52
01/06/98	Cone Ranch						0.80	0.21	3.13	1.60
02/03/98	Cone Ranch	1.85	0.18	0.23	36.12	9376317	17.55	0.76	3.77	66.13
05/13/97	Florida Aqu	5.50	0.02	0.81	16.05	291	1453.07	0.83	61.32	2033.39
06/10/97	Florida Aqu	6.30	0.04	1.96	18.36	294	103.52	0.39	19.71	332.62
07/08/97	Florida Aqu	55.70	0.35	13.57	175.58	5186	129.30	0.65	37.16	883.00
08/12/97	Florida Aqu	26.26	0.27	5.43	98.06	4690	246.81	1.80	59.32	837.65
09/30/97	Florida Aqu	44.24	0.50	9.67	142.18	12506	20.95	0.11	15.34	114.95
10/28/97	Florida Aqu	11.29	0.19	3.73	60.95	3164	34.22	0.25	48.81	344.73
11/18/97	Florida Aqu	9.07	0.34	2.73	42.78	3460	23.41	0.16	16.30	134.96
12/16/97	Florida Aqu	29.86	1.70	7.36	90.32	12306	15.83	0.08	11.03	107.26
01/13/98	Florida Aqu	16.20	0.22	4.13	36.50	5382	42.24	0.56	12.01	113.46
02/03/98	Florida Aqu	18.48	0.14	3.19	61.10	3400	167.90	2.07	13.40	1439.46

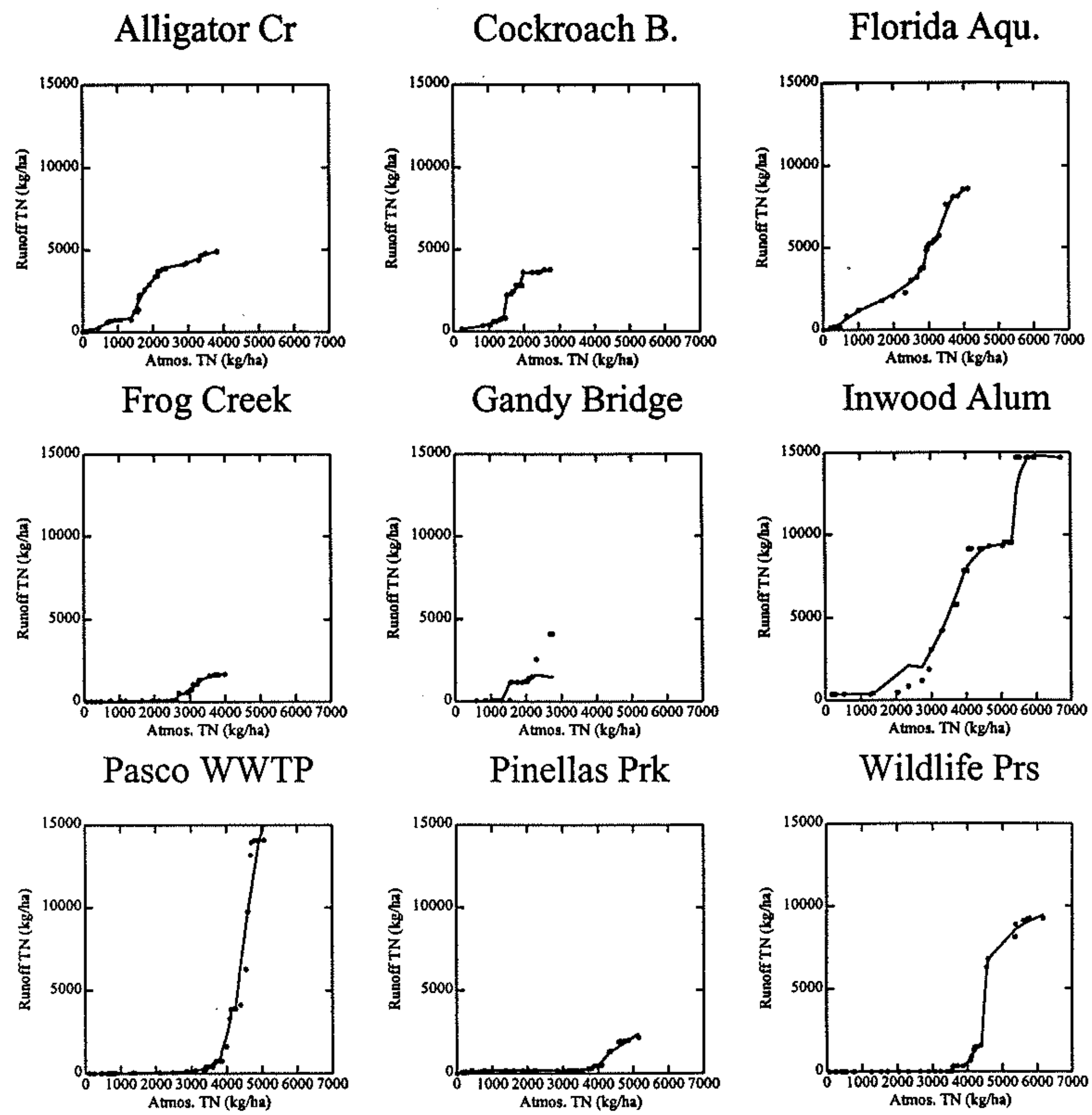
Week	Site	Stormwater Copper (g/ha)	Stormwater Cadmium (g/ha)	Stormwater Lead (g/ha)	Stormwater Zinc (g/ha)	Total Flow (cf)	Atmospheric Copper (g/ha/yr)	Atmospheric Cadmium (g/ha/yr)	Atmospheric Lead (g/ha/yr)	Atmospheric Zinc (g/ha/yr)
06/03/97	Frog Creek	0.01	0.00	0.04	0.87	11397	5.03	0.42	3.95	40.34
06/24/97	Frog Creek	0.04	0.01	0.10	3.50	25492	8.29	0.12	4.48	48.34
07/15/97	Frog Creek						9.61	0.24	9.30	73.17
07/22/97	Frog Creek	0.04	0.01	0.04	1.15	30256				
08/12/97	Frog Creek	0.03	0.01	0.05	0.89	17442	9.47	0.50	3.41	64.40
09/02/97	Frog Creek	0.05	0.01	0.09	1.72	33739				
09/09/97	Frog Creek						11.28	0.14	7.17	73.03
10/21/97	Frog Creek	0.78	0.07	0.96	14.32	375103	2.78	0.15	0.91	32.74
11/11/97	Frog Creek	0.07	0.02	0.36	4.37	114446				
11/18/97	Frog Creek						1.39	0.35	2.11	74.67
12/16/97	Frog Creek	0.73	0.09	1.11	15.43	242553	0.99	0.25	1.51	55.85
01/20/98	Frog Creek	0.38	0.08	0.64	12.88	202414	2.01	0.20	5.11	51.92
02/03/98	Frog Creek	0.06	0.01	0.09	1.40	21988	15.90	0.34	4.51	203.80
06/03/97	Gandy Bridge						54.16	0.55	12.33	48.26
06/24/97	Gandy Bridge						26.87	0.49	14.08	134.65
07/22/97	Gandy Bridge					4221	16.69	4.22	20.65	190.28
08/12/97	Gandy Bridge					554	15.59	0.70	12.57	103.75
09/30/97	Gandy Bridge	4.48	0.90	7.72	23.17	110359	9.26	0.13	5.95	70.65
10/28/97	Gandy Bridge					0	12.57	0.39	12.94	94.61
11/18/97	Gandy Bridge	0.96	0.22	1.43	4.28	31514	7.63	0.23	1.34	72.25
12/16/97	Gandy Bridge	4.45	0.88	8.96	29.39	125783	12.10	0.08	5.23	127.02
12/30/97	Gandy Bridge	5.48	0.81	7.90	38.78	115219	7.74	0.29	11.29	49.10
02/03/98	Gandy Bridge					0	8.49	0.12	4.21	42.10

Week	Site	Stormwater Copper (g/ha)	Stormwater Cadmium (g/ha)	Stormwater Lead (g/ha)	Stormwater Zinc (g/ha)	Total Flow (cf)	Atmospheric Copper (g/ha/yr)	Atmospheric Cadmium (g/ha/yr)	Atmospheric Lead (g/ha/yr)	Atmospheric Zinc (g/ha/yr)
05/06/97	Inwood Alum					728200	0.94	0.26	5.27	0.00
06/03/97	Inwood Alum	4.98	0.49	7.17	14.98	3410840	43.97	0.55	13.04	111.51
06/17/97	Inwood Alum	2.24	0.22	2.35	4.94	1532000	24.66	0.44	14.76	97.25
07/15/97	Inwood Alum	5.30	0.60	5.40	15.12	4111731	57.04	1.38	100.87	131.22
08/12/97	Inwood Alum	17.08	0.75	21.15	75.58	12484602	19.74	0.18	12.14	73.16
09/02/97	Inwood Alum	54.87	0.78	22.93	74.70	12018788	7.93	0.13	8.26	65.73
09/30/97	Inwood Alum	125.79	0.48	14.76	31.21	8289196	5.87	0.16	5.95	56.01
11/04/97	Inwood Alum	2.41	0.06	1.56	4.02	1030460	3.73	0.11	5.94	42.77
12/09/97	Inwood Alum					25172301	3.41	0.16	0.96	28.84
12/30/97	Inwood Alum	20.29	3.50	104.21	267.84	47924495	11.77	0.47	24.19	65.65
02/03/98	Inwood Alum					43319311	10.36	0.16	7.22	89.20
05/13/97	Pinellas Prk	0.60	0.04	0.23	3.47	98431	14.81	0.57	14.81	118.23
06/03/97	Pinellas Prk					687	0.00	0.30	2.24	114.33
07/08/97	Pinellas Prk	0.43	0.02	0.72	6.06	74025	15.31	0.22	15.41	102.50
08/12/97	Pinellas Prk					512760	21.40	1.22	29.23	179.31
09/16/97	Pinellas Prk					149730	20.87	1.02	16.22	262.21
10/21/97	Pinellas Prk	0.10	0.01	0.11	1.35	20331	14.81	0.39	12.17	105.06
11/18/97	Pinellas Prk	1.06	0.07	7.31	12.89	588985	8.25	0.27	16.06	138.96
12/16/97	Pinellas Prk	5.34	0.19	9.69	74.06	1671355	14.13	0.78	20.86	170.40
12/30/97	Pinellas Prk	6.11	0.13	3.02	12.60	1097227	10.04	0.31	23.54	123.71
02/03/98	Pinellas Prk	8.35	0.14	4.00	36.35	746940	12.89	0.46	13.42	121.80

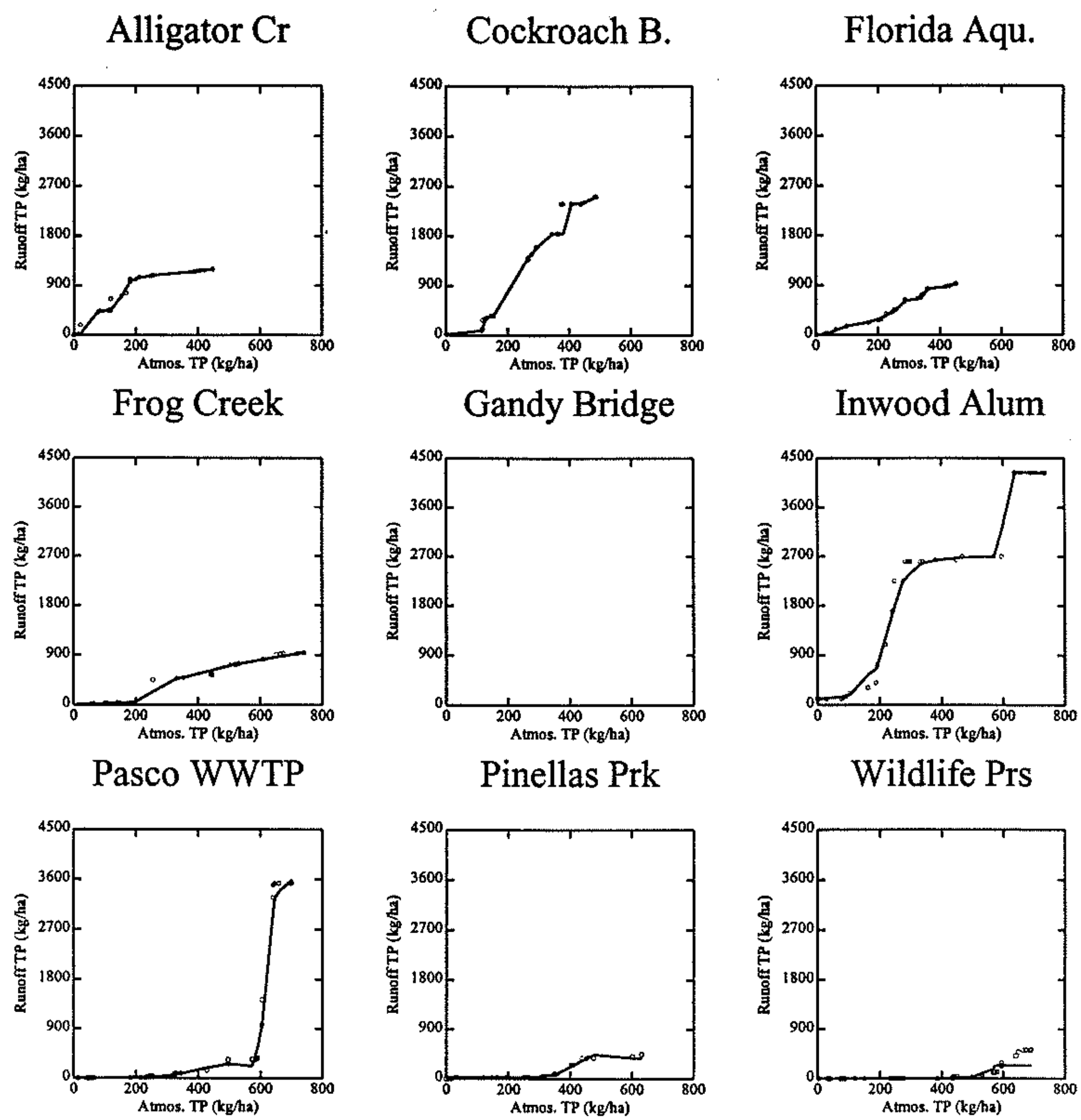
Week	Site	Stormwater Copper (g/ha)	Stormwater Cadmium (g/ha)	Stormwater Lead (g/ha)	Stormwater Zinc (g/ha)	Total Flow (cf)	Atmospheric Copper (g/ha/yr)	Atmospheric Cadmium (g/ha/yr)	Atmospheric Lead (g/ha/yr)	Atmospheric Zinc (g/ha/yr)
05/27/97	Wildlife Prs						10.22	0.37	8.10	35.26
06/17/97	Wildlife Prs	0.00	0.00	0.00	0.00	180	8.19	0.26	0.21	45.75
07/29/97	Wildlife Prs	0.00	0.00	0.00	0.00	445	9.91	1.17	7.27	57.17
08/19/97	Wildlife Prs	0.00	0.00	0.00	0.04	2219	7.98	0.31	10.12	83.36
09/23/97	Wildlife Prs	0.00	0.00	0.00	0.00	430				
09/30/97	Wildlife Prs						8.23	1.05	3.65	30.96
10/28/97	Wildlife Prs	1.37	0.04	0.18	2.61	1665540	1.47	0.10	3.19	26.19
11/18/97	Wildlife Prs	2.65	0.00	0.42	6.28	3946800	1.11	0.28	5.58	31.30
12/16/97	Wildlife Prs	5.24	0.28	1.10	16.28	10394610	0.70	0.23	4.81	35.24
01/06/98	Wildlife Prs	9.19	0.24	1.61	24.18	15339699	4.62	0.23	3.88	22.58
01/27/98	Wildlife Prs	6.75	0.04	0.89	8.33	2642060	5.98	0.14	3.55	44.11
02/03/98	Wildlife Prs						42.55	0.21	6.57	32.43
06/03/97	Pasco WWTP	0.01	0.00	0.00	0.02	530	9.42	2.93	7.05	37.65
06/10/97	Pasco WWTP						3.13	0.16	0.00	23.31
07/15/97	Pasco WWTP	0.53	0.03	0.04	1.15	25599	11.93	19.27	12.99	214.05
08/12/97	Pasco WWTP	0.10	0.01	0.09	1.38	61458	8.56	0.27	9.26	67.43
09/02/97	Pasco WWTP	0.24	0.01	0.07	1.08	47938	9.16	0.22	12.08	52.34
09/30/97	Pasco WWTP	0.75	0.05	0.18	2.62	116670	2.92	0.17	4.11	33.99
11/04/97	Pasco WWTP	1.85	0.04	0.28	11.23	187710	0.64	0.16	3.79	24.33
12/09/97	Pasco WWTP	0.72	0.04	0.26	3.89	173230	3.52	0.14	3.18	43.18
12/30/97	Pasco WWTP	15.71	0.20	0.67	20.23	451000	6.33	0.42	8.15	28.09
02/03/98	Pasco WWTP	1.27	0.07	0.11	3.33	74150	6.33	0.14	3.96	44.13

APPENDIX C

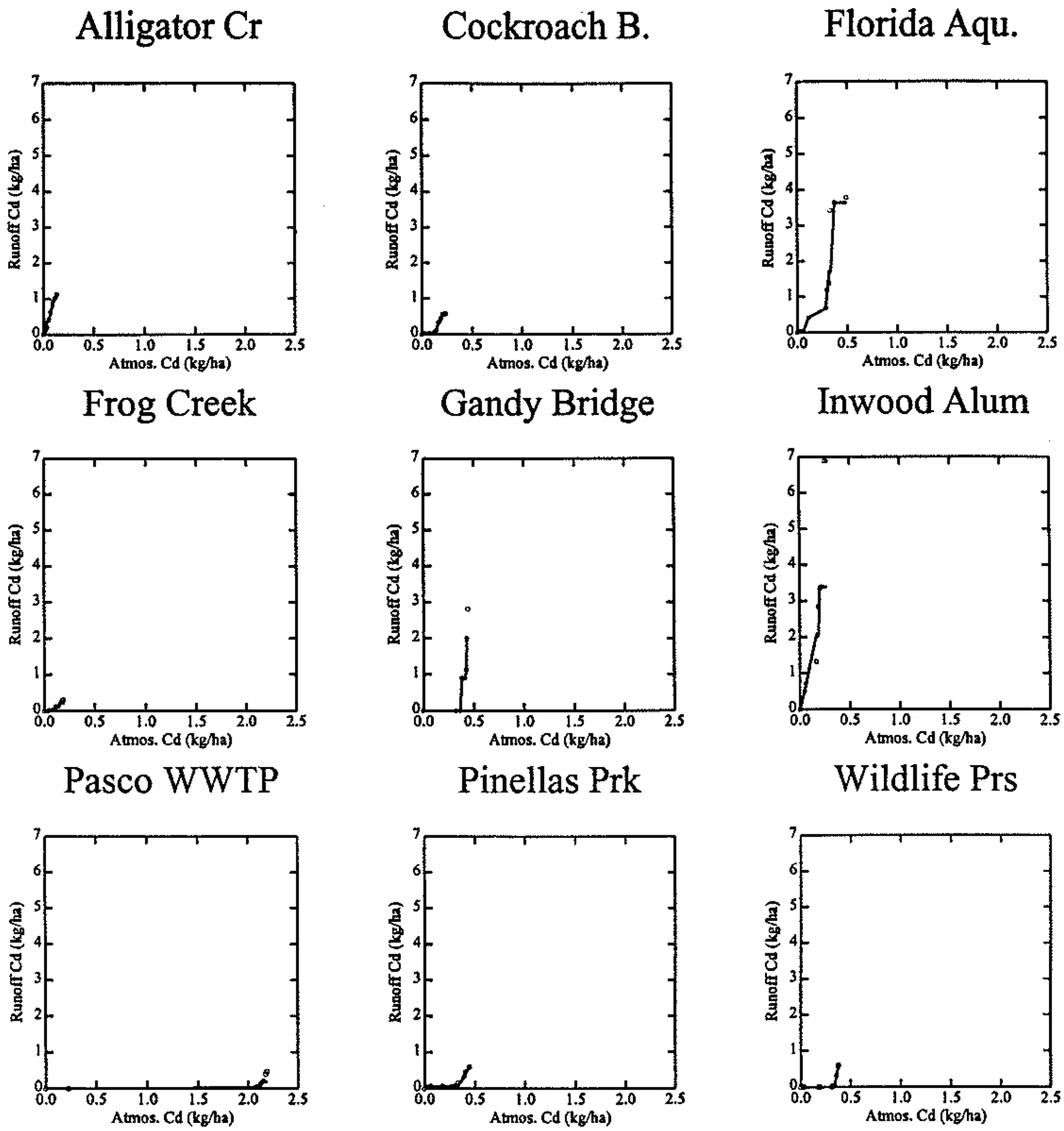
Cumulative Total Nitrogen



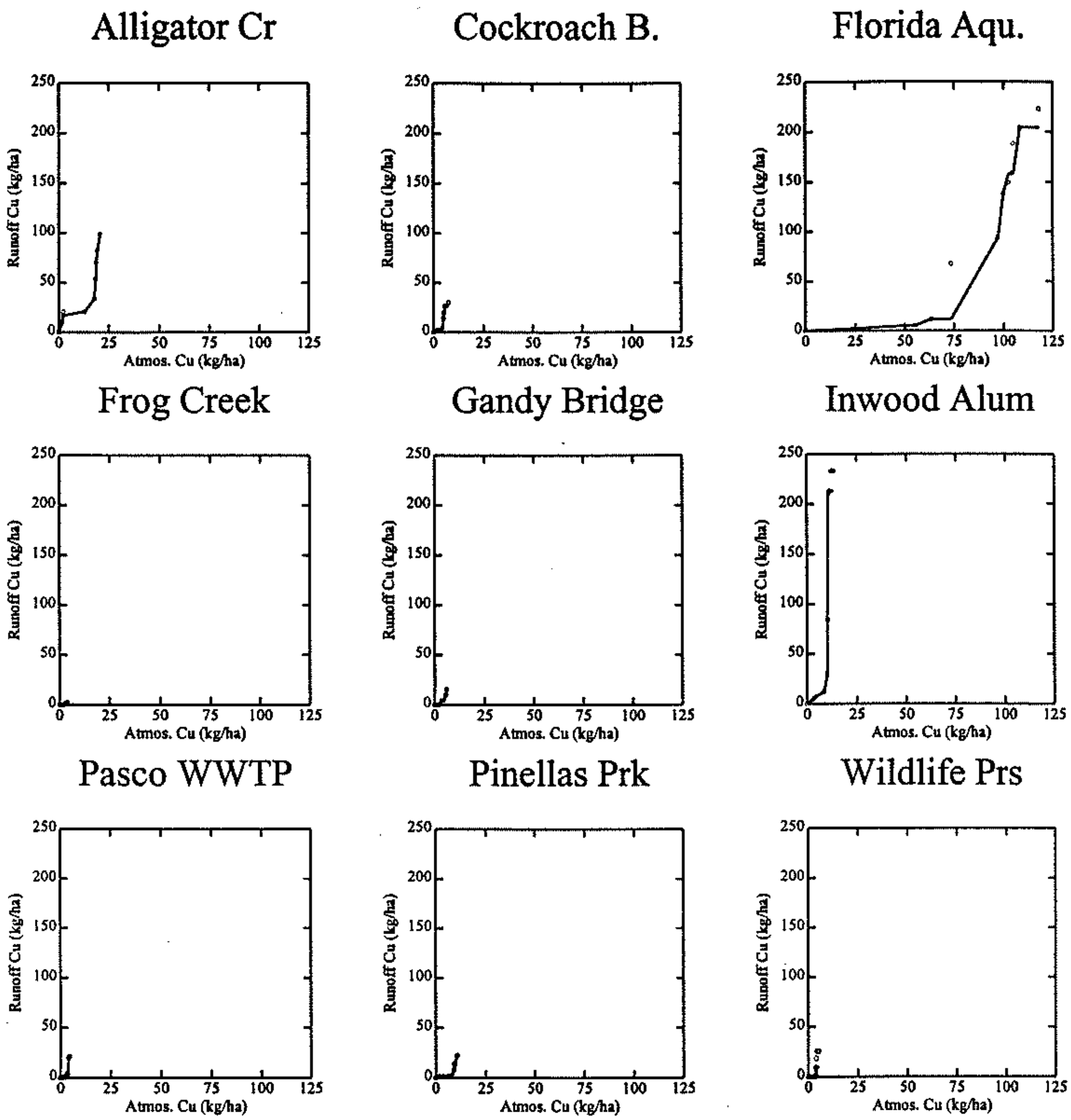
Cumulative Total Phosphorus



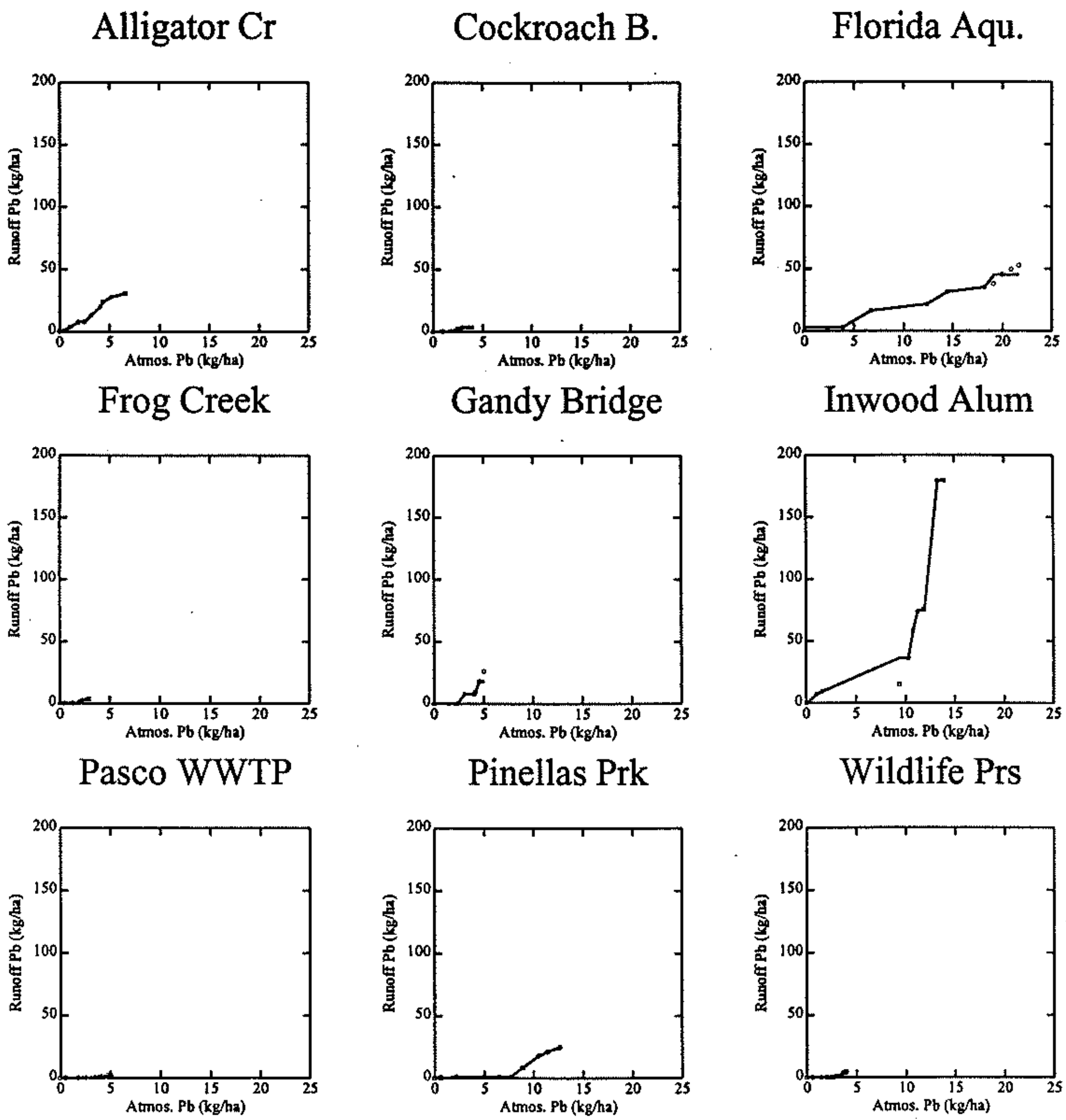
Cumulative Total Cadmium



Cumulative Total Copper



Cumulative Total Lead



Cumulative Total Zinc