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TRANSFORMING THE AQUATIC URBAN LANDSCAPE: NUTRIENT STATUS AND MANAGEMENT OF STORMWATER BASINS

by

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B.A. University of Pittsburgh, 2012

A thesis submitted in partial fulfilment of the requirements
for the degree of Master of Science
in the Department of Biology
in the College of Sciences
at the University of Central Florida
Orlando, Florida

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Major Professor: Patrick J. Bohlen

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ABSTRACT

Urbanization is a largely irreversible anthropogenic change that degrades environmental quality, including aquatic ecosystems. Stormwater ponds are a popular best management practice (BMP) to mitigate the effects of urban land use on downstream water bodies and contribute significantly to the total area of aquatic ecosystems in some urban watersheds. My research investigated the distribution of stormwater ponds and examined how different urban land uses influenced biophysicochemical conditions and management of those ponds in a rapidly developing suburban watershed in the Econlockhatchee River basin in Florida, USA. I evaluated limnological and ecological parameters in randomly-selected ponds distributed among three urban land-use classes: high-density residential, institutional, and roadways. Ecological measures included characterizing percentage cover and composition of littoral zone plant community and the extent of any algal mats. Limnological measures included physical parameters (pH, conductivity, dissolved oxygen, and clarity), and nutrient concentrations (nitrate, ammonium, total nitrogen, dissolved reactive phosphorus, total phosphorus, and chlorophyll a). I used a subjective management intensity index to compare pond management among land-use classes. Stormwater ponds represented 40.2% of the total area of non-forested freshwater systems in the watershed, and were dominated by residential land uses (43.7%), followed by roadways (14.7%), industrial (2.7%) and institutional (2.3%). Principal Component Analysis (PCA) revealed that ponds with higher total nitrogen (TN) and chlorophyll *a* (chl*a*) concentrations had lower water clarity, and that both. TN and TP were positively correlated with chl*a*. PCA scores for school ponds, which had the highest water clarity, differed significantly from those of expressway and residential ponds, along the first PCA axis.

Repeated-measures analysis of variance showed that TN concentrations differed significantly between expressway and school ponds, with expressway ponds having TN concentrations 51.7% higher than schools. Both TP and TN varied differently through time in the different lands uses. Management intensity for removal of aquatic vegetation and algae was lower in school ponds than in expressway and residential ponds, and school ponds contained the highest abundance and diversity of vegetation. Different urban land uses had varying impacts on water quality, and more intense chemical use to control vegetation and algae was related to greater nutrient and chl*a* concentrations and lower water clarity.

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CHAPTER ONE: INTRODUCTION

Urbanization is one of the strongest anthropogenic threats to environmental quality (Groom et al. 2006; Paul and Meyer 2001; Yan and Edwards 2013). Currently, >75% of the US population lives in urban centers, and 60% of the world's population is projected to reside in these areas by 2030 (Paul and Meyer, 2001). The built environment comprises 1-3% of the Earth's surface (Adler and Tanner, 2013), but its ecological footprint is substantial (United States Environmental Protection Agency, 2012b). Cities increase the local temperature, emit harmful air pollutants, and destroy habitats of other biota (Alder and Tanner, 2013; Rhodes, Newton and Pufall, 2001). Urban development also significantly alters the hydrology, flow, and quality of rivers, lakes, and streams (Alder and Tanner, 2013). Expansion of impervious surfaces decreases water percolation into the ground during storm events, increases the volume and acceleration of runoff (i.e., stormwater runoff), and reduces evaporation and transpiration (Booth and Jackson, 1997; Brabec et al. 2002). Dramatic changes in the abundance, distribution, and character of surface water features (Steele et al., 2014) produces flashier hydroperiods, flooding, higher nutrient and pollutant loads, altered channel morphology and stability, and reduced biodiversity (Alder and Tanner, 2013; Chocat et al., 2001; Hogan and Walbridge, 2007; Paul and Meyer, 2001; Walsh et al., 2005). These changes profoundly affect the biological integrity of the receiving aquatic habitats, impair their aesthetic and recreational uses (Booth and Jackson, 1997;

Chocat et al., 2001), and create serious implications for the quantity of fresh, clean water for both humans and wildlife (Arnold and Gibbons, 1996).

Stormwater best management practices (BMPs) are implemented into planning and policy at the national, regional, state, and local levels to mitigate the influence of intensive land-use change (Chocat et al., 2001; Hogan and Walbridge, 2007; Thompson and Fryxell, 2007) and protect biological communities from urban stormwater runoff (Olding, 2000). A prevalent BMP is construction of stormwater basins, which are designed based on land availability, cost, climate, catchment hydrology, and pollution control requirements (Behera and Teegavarupa, 2015). During heavy rainfall, these basins control sedimentation and flooding from runoff, and can enhance water quality, before releasing the runoff into adjoining water bodies (Anderson et al. 2002; Bolund and Hunhammer, 1999; Gallagher et al., 2011; Hogan and Walbridge, 2007; Grimm et al., 2008; Orange County Growth Management Department, Planning Division, 2009). In regions with high water tables (e.g., Central Florida), these basins can be permanent ponds that can significantly increase the extent of surface water features in the landscape (Figure 1), creating entirely new habitat for aquatic and terrestrial wildlife (Gallagher et al., 2011; Hamer and Parris, 2011; Marsalek et al., 2005; Maxted and Shaver, 1999; McKinney et al., 2011). Additionally, stormwater basins can provide recreational uses, such as boating or fishing, and enhance aesthetics and increase property value in residential areas (Drescher et al., 2011).

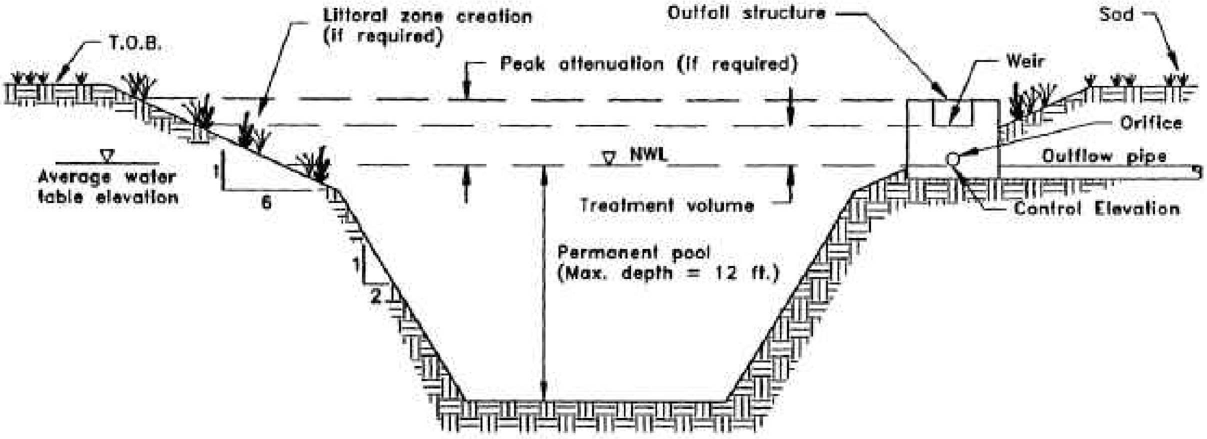


Figure 1: Diagram of stormwater basin from Harper & Baker, 2007.

Policy and Regulatory Issues

The potential for stormwater ponds to detain nutrients and pollutants in runoff, such as phosphorous, nitrogen, pesticides, contaminated sediments, and metals, may cause unfavorable conditions for resident flora and fauna and degrade surface waters (Arnold and Gibbons, 1996; Bishop, 2000a; Bishop, 2000b; Chocat et al, 2001; Gallagher et al., 2011; Paul and Meyer, 2001; Sparling et al. 2004; Walsh et al., 2005). Once degraded, surface waters are at risk of not achieving national water quality goals enacted by the United States Environmental Protection Agency's federal Clean Water Act (Rhodes et al., 2001). This act requires all states to regulate pollutant discharges, and establish Total Maximum Daily Loads (TMDL) for impaired surface waters to meet minimum water quality standards (Seminole County, 2009). A TMDL is the maximum amount of pollutant a water body can receive without adversely affecting its biological integrity (Orange County Growth Management Department, Planning Division, 2009). Although stormwater basins function as habitat for a variety of species and can exceed the areal extent of natural waters and wetland features in some watersheds, they are not considered natural freshwater ecosystems. According to the Clean Water Act, stormwater ponds are engineered treatment facilities and therefore not defined as "waters of the United States." For example, in coastal South Carolina, stormwater basins are a common management practice to mitigate influence of land disturbance activities on receiving waterbodies. However, they are exempt from regulations (Behera and Teegavarapu, 2015; Drescher et al., 2011). Similarly, in countries like Sweden, Australia, Denmark, and Canada, stormwater basins are a popular management strategy built solely to control water quality and quantity (Drake and Guo, 2008; Egemose et al., 2014; Roy et al., 2008; Semadeni-Davies, 2006).

In Florida, governments at the federal, state, and local level have adopted nutrient and pollutant criteria for most streams, spring vents, lakes, and selected estuaries to ensure proper wildlife habitat, aesthetics, and recreational opportunities (Florida Department of Environmental Protection, 2013; United States Environmental Protection Agency, 2013). Stormwater systems are excluded from these criteria. According to the Stormwater Management Program described in the Florida Administrative Code (FAC), stormwater basins are designed to reduce flooding, erosion, sedimentation, and pollution flowing into receiving waters. The basins are required to reduce at least 80% of the mean annual load of pollutants that violate the State Water Quality Standards implemented by Florida Department of Environmental Protection (FDEP). If a stormwater system discharges into an Outstanding Florida Water (OFW), the rate increases to 95% reduction (Harper & Baker, 2007).

Knowledge Gaps

Historically ignored by ecologists, urban areas and cities became a major focus of ecological study during the past few decades (Alberti et al., 2003; Jeong et al., 2014; Mackintosh et al., 2015; Wu and Malmstrom, 2015). Considering that stormwater basins are a dominant aquatic feature in many urban landscapes but are not treated as natural freshwater ecosystems, there is a need for more study using standard protocols to assess their condition. Additionally, because stormwater basins are the initial receiving system for urban runoff, they can provide important information about the influence of different land-uses on stormwater nutrients and pollutants (Kaushal and Belt, 2012). Presence of aquatic ecosystems rarely has been used as a predictor variable of land-use, but stormwater ponds have a close association with specific urban land use classes (Levia and Page, 2000; Turner, Wear and Flamm, 1996; Veldkamp and Fresco, 1996). Few studies evaluated how watersheds changed in land cover over time and what effect these changes had on surface and subsurface watershed systems (Brabec, Schulte and Richards, 2002; Osborne and Wiley, 1988; Walsh, 2000). Most studies investigating the influence of urbanization and development on stormwater basins are intensive and small scale, and focus on one or a few basins (Campbell, 1994; Janke et al., 2014; Marsalek et al, 2002; Pettersson, 1998).

My research investigated how ecological conditions and management of stormwater ponds vary among different urban land-uses at a watershed scale. The specific objectives were to: 1) quantify the distribution of stormwater basins in a rapidly-developing urban/suburban watershed, 2) assess the physical, chemical, and ecological characteristics of stormwater basins based on surrounding urban land-use and land cover, and 3) examine differences in stormwater management practices in the different land uses. My study will serve as a foundation for further ecological research and will inform effective natural resource management and planning for urban stormwater basins.

CHAPTER TWO: RESEARCH METHODS

Study Site

My study site was the Econlockhatchee River Watershed (Figure 2), which is administered by the St. John's River Water Management District and includes parts of Osceola, Orange, and Seminole counties of greater Orlando, Florida (Harvey & Baker, 2007; Orange County Growth Management Department, Planning Division, 2009). Climate in this region is subtropical with a distinct wet season (June – September), with mean temperatures ranging from 20 - 33 ºCelsius and a dry season (October - May) with mean temperatures ranging from 10 - 25 ºCelsius. Mean annual rainfall for 2015 was 135 centimeters. The basin extends over 72,520 hectares and contains two sub-basins, the Econlockhatchee River and the Little Econlockhatchee River. Land use around the Little Econlockhatchee River is primarily residential (USEPA, 2013), whereas urban development is minimal surrounding the Econlockhatchee River basin, which is dominated by grazing and agricultural activities (Florida Department of Environmental Protection, 2000). The Little Econlockhatchee River has been ditched and channelized at its higher reaches, and receives treated sewage effluent. The Econlockhatchee River persists unchannelized and intact (Brown et al., 1990), and was designated an Outstanding Florida Water (OFW) because of its "exceptional recreational and ecological significance" (Florida Department of Environmental Protection, 2000). However, several water bodies (streams, lakes, rivers, and springs) within the watershed are listed as impaired for exceeding TMDL of mercury, fecal coliform, and nutrients (Florida Department of Environmental Protection, 2014b). Lakes in particular are degraded due to receiving untreated storm water and nutrient runoff from intensive land use practices. Some lakes have outflows into tributaries. Similarly, stormwater basins have outfalls into tributaries, but they are not required to adhere to freshwater pollution guidelines, even though they are the dominant surface water features in this landscape (Table 1).

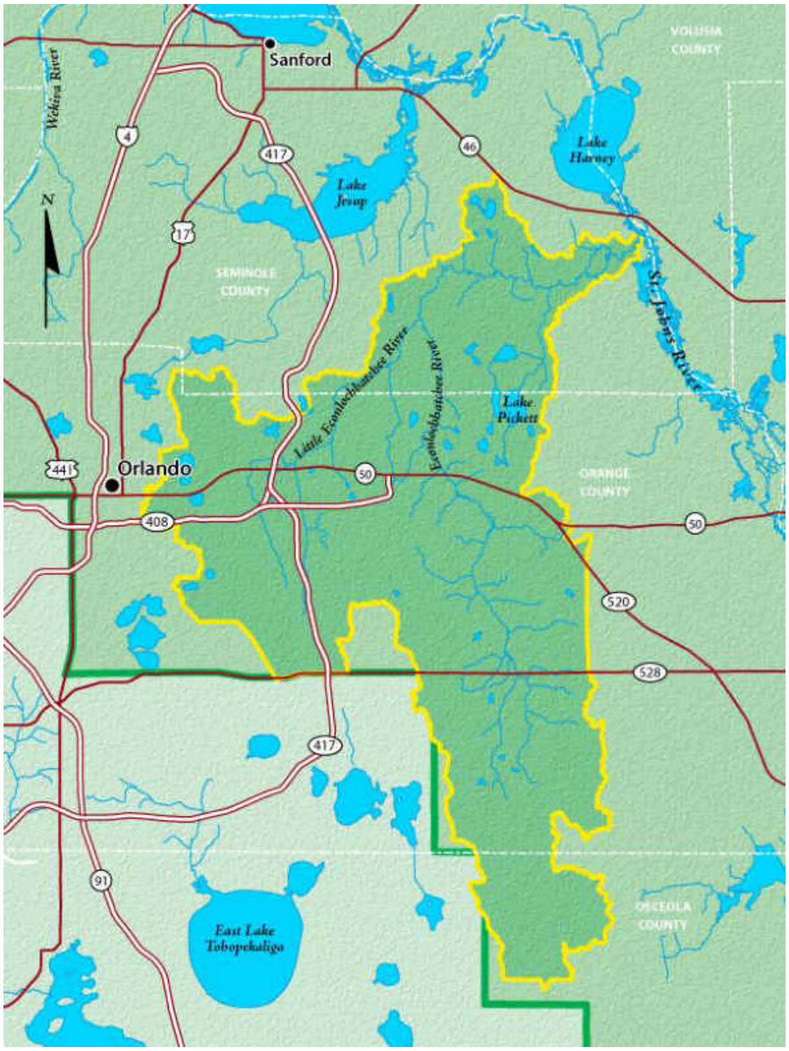


Figure 2: Map of the Econlockhatchee River Watershed (SJRWMD, 2016).

Table 1: Sum and average (mean ± SD) of non-forested freshwater systems in the Econlockhatchee River watershed

Water Body Type	Count	Total Area (ha)	Mean Area (ha)
Lakes	104	1110.7	10.7 ± 31.7
Stormwater Ponds	1,368	1611.2	1.0 ± 1.8
Freshwater marshes	763	1281.6	1.7 ± 12.5
Grand Total	2454	4003.5	13.4 ± 46.0

Sampling Site Selection

I acquired geographic coverages of land use/land cover in the Econlockhatchee River Watershed in east-central Florida from the St. John's River Water Management District GIS database for 2009 (St. John's River Water Management District, 2014). The data included 1,587 features designated as reservoirs or ponds (Figure 3). Through visual interpretation of the aerial photographs, I eliminated features not considered stormwater ponds (e.g. farm ponds, borrow pits), which resulted in 1,368 stormwater detention ponds in the watershed. The total areal extent of stormwater basins in the Econlockhatchee watershed was 1,611 hectares, equaling 1.3% of the total watershed and 40% of the total area of non-forested freshwater systems. The aerial extent of stormwater ponds exceeded that of natural lakes (1,111 ha) by 45%, indicating stormwater ponds contribute substantially to open water habitat in this region.

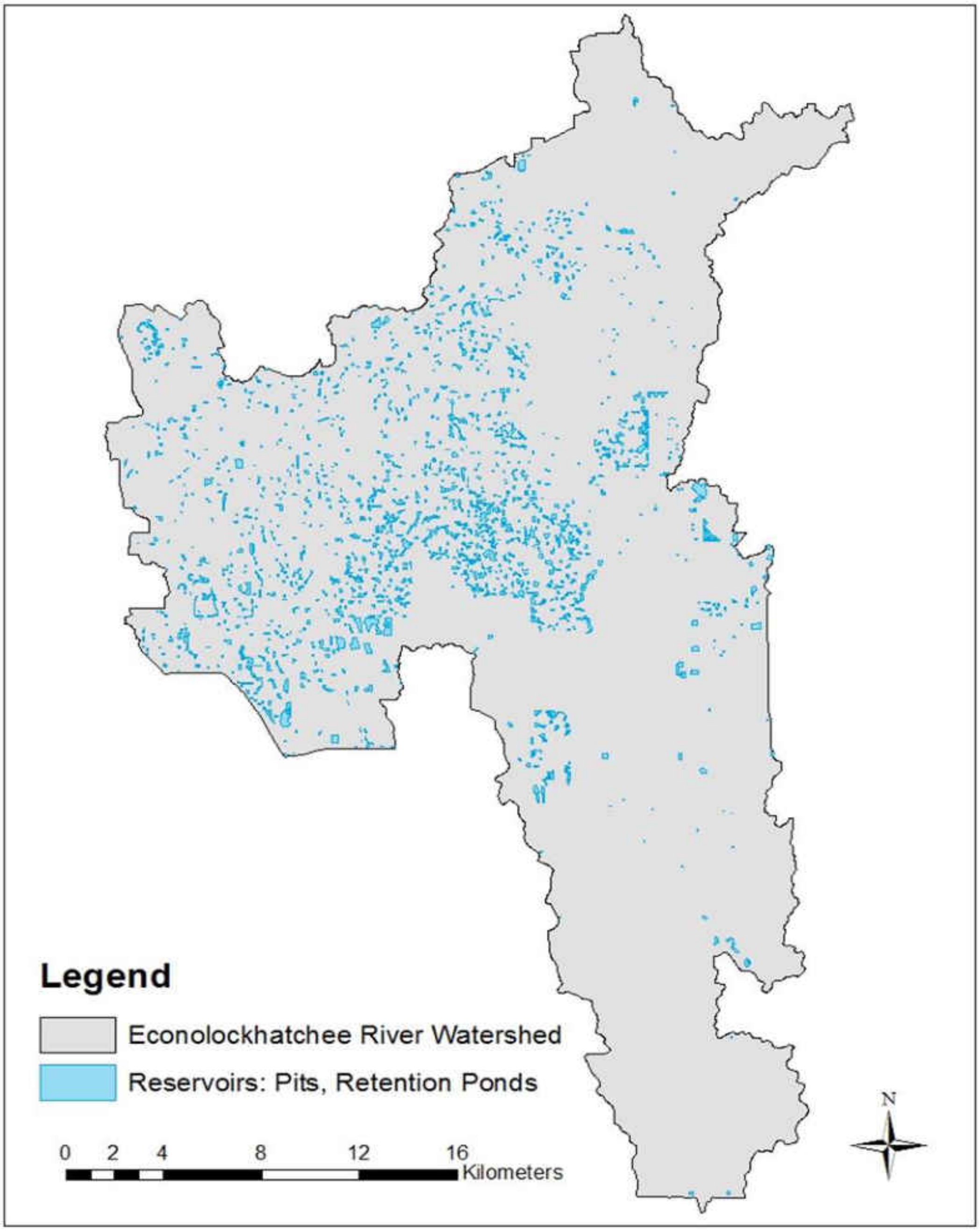


Figure 3: Anthropogenic water bodies in the Econlockhatchee River watershed (Source: SJRWMD 2009 Land Use/Land Cover GIS Data).

To determine the dominant land use surrounding individual stormwater ponds, I made a near table with a 100 m radius to select ponds that would not overlap when clipped with a 50 m buffer. The procedure produced a group of 663 ponds. I then categorized surrounding land-uses within a 50 m buffer to define the mitigated land-use associated with the ponds. The 50 m buffer areas of the subsampled stormwater ponds contained eleven different land-use groups dominated by urban land use covers (63.4%): 43.7% residential; 14.7% roadway; 2.7% commercial and services; and 2.3% institutional (Table 2). This analysis indicates that most stormwater ponds in the watershed were built to mitigate impacts of urbanization, predominantly residential development.

I then randomly selected ponds in residential, roadway, and institutional areas for my field study (Figure 4). I selected ponds surrounded by K-12 schools to represent institutional land use; ponds managed by the Orlando Orange County Expressway Authority (OOCEA) for roadways; and ponds within neighborhoods for residential. I selected institutional land use instead of the commercial and services category because both were similar in percentage of land cover, and it was easier to access institutional sites within the time frame of my study.

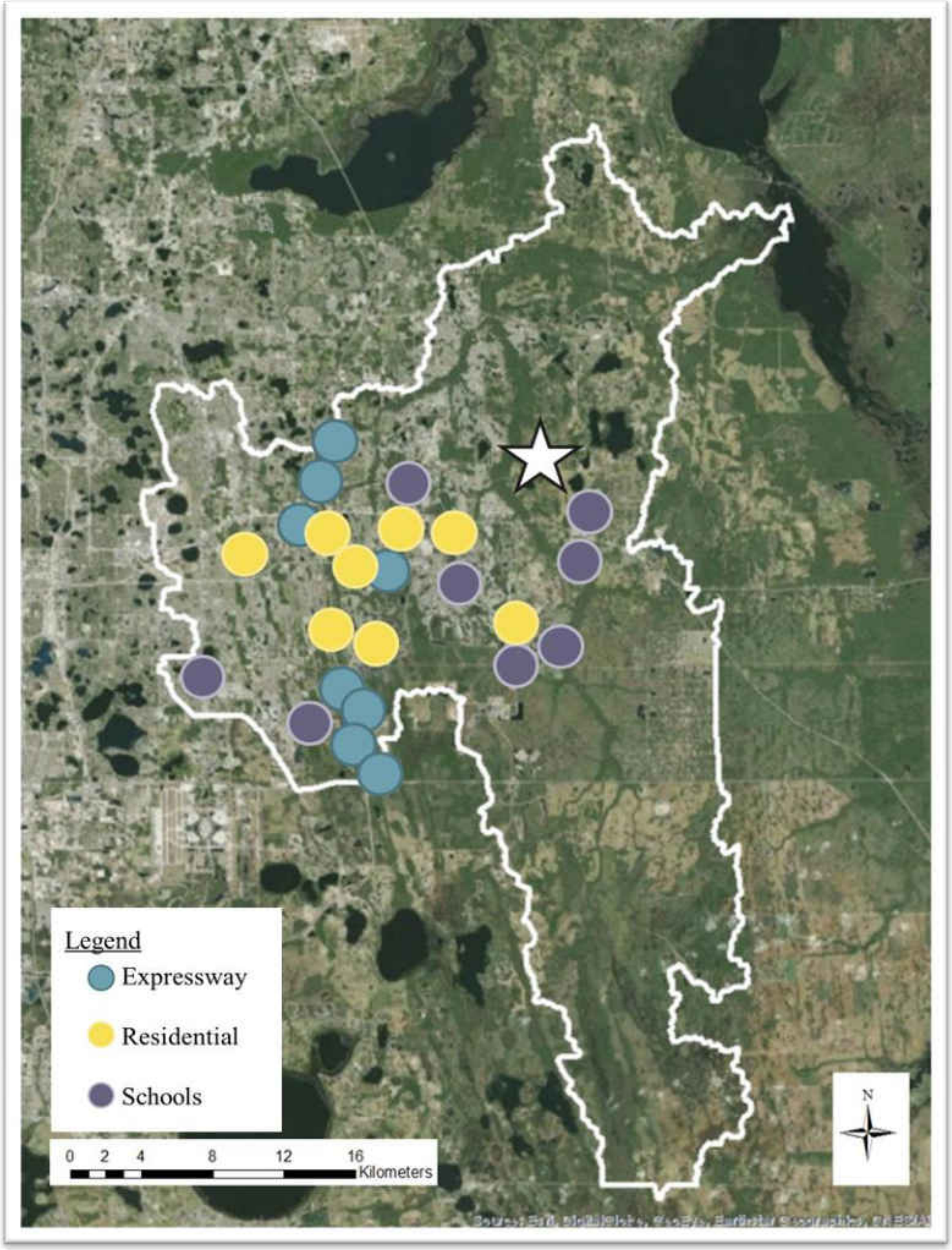


Figure 4: Map of selected study sites in the Econlockhatchee River Watershed. The star represents the University of Central Florida campus.

Table 2: Total area and percentage cover of different urban land uses within a 50 m buffer surrounding stormwater ponds in the Econlockhatchee River watershed.

Land-Use	**Total Area (ha)**	**Percentage Cover (%)**
Commercial and services	984	2.73
Institutional	834	2.32
Residential	15755	43.7
Roadways	5297	14.7
Total	22871	63.5

I used a frequency distribution of stormwater pond area to select ponds of similar area (0.4 to 2.0 hectares), avoiding extremes of the distribution (Appendix D). I used aerial photographs to delineate the area draining into a specific pond. I randomly selected eight ponds from each of the three land-use classes (N = 24; Appendix A) using the subset features (Geostatistical Analysis) tool in ArcGIS (St. Johns River Water Management District, 2014). Residential ponds were blocked into four, geographic zones: North, South, East and West. Within each zone, I randomly selected two ponds, for a total of eight ponds. I compared aerial photographs to the Orange County Property Appraiser map (Orange County Property Appraiser, 2015) to select all public schools within Orange County. From the 63 public schools containing stormwater ponds, I randomly selected eight ponds. I obtained the inventory map of ponds owned and managed by the Expressway Authority from the senior expressway inspector (Appendix B) and used the georeferencing tool in ArcGIS to compare it with aerial photos to determine the total number of ponds. Due to pond distribution limitations, two zones (North and South) were created with an equal number of ponds, and I randomly selected four ponds in each zone (N = 8). I contacted roadway authorities, Orange County Commission, and home owners' associations (HOAs) for permission to access field sites (Appendix C). Orange County Public School System protocol was followed and the necessary paperwork was completed to gain access to school sites (Appendix C). Once selected and approved for inclusion in the study, construction information was retrieved through the St. John's River Water Management District permitting site (St. Johns River Water Management District, 2016) to determine age and surface area of each pond, if available (Table 3). There was no significant difference among land-uses in size of ponds included in the study (one-way ANOVA.$F_{2,21} = 0.52$, $p > 0.05$). However, mean pond age varied significantly among land-uses (one-way ANOVA.$F_{2,18} = 5.08$, $p < 0.05$), with school ponds being younger than expressway ponds.

Table 3: Mean age and size of stormwater ponds based on land-use.

Land Use	Age (y)	Size (ha)
Expressway	25.8^{A}	1.0^{A}
Residential	20.9^{AB}	0.80^{A}
School	17.3^{B}	0.89^{A}

*N = 6 for expressway ages and N = 7 for residential ages;three ponds were of unknown age (2 expressway; 1 residential).

Limnological Measures

I monitored limnological parameters five times from May to September, 2015. Sampling occurred during the end of central Florida's dry season to near the end of the wet season. Differences among land uses are more likely to be apparent during the wet season due to higher runoff from storms. Physical parameters included temperature, pH, and conductivity (YSI Model 63 Handheld pH, Conductivity, Salinity and Temperature System); dissolved oxygen (YSI Environmental ProODO); and Secchi depth. I measured all physical parameters at the center of the pond (Pitt, 2007). Field procedures followed standard protocols used by the Florida Department of Environmental Protection (Florida Department of Environmental Protection, 2014a).

I took a 125 ml filtered water sample and a 1-L unfiltered, water sample at the center and near the outlet and inlet of each pond (Pitt, 2007; United States Environmental Protection Agency, 2012a). I used the filtered sample for dissolved reactive phosphorus (DRP) analysis within 48 h of sampling. I acidified the unfiltered sample with sulphuric acid (H_2SO_4) to below pH 2 and stored it in a refrigerator for later analysis of other nutrient parameters. During June - September sampling sessions, I took an additional 1-L unfiltered sample at the center of the pond to measure chlorophyll *a*. This second unfiltered sample (250 mL) was vacuum-filtered on a glass fiber filter, which was extracted with 90% ethanol on the day of sampling to determine chlorophyll *a* on the day of sampling (Pitt, 2007; United States Environmental Protection Agency, 2012a). I analyzed samples for DRP (D'Angelo, Crutchfield, and Vandiviere, 2001), total nitrogen (TN) and total phosphorous (TP) after persulfate digestion (Johnes and Heathwaite, 1992), nitrate (NO_3) (Schnetger and Lehners, 2014), and ammonium (NH_4) (Sims et al. 1995) using standard colorimetric methods on an Epoch microplate spectrometer (Biotek Instruments, Inc, Winooski, Vermont).

Pond Vegetation

I measured ecological characteristics of pond vegetation at randomly selected 10 m shore lengths centered on points generated in ArcGIS along each pond perimeter. The number of sites per pond was based on sampling approximately 15% of the pond's perimeter, with minimum distances set between points to ensure sampling locations were distributed around the pond and not too close together. I randomly selected three points along the 10 m shore length to measure the littoral zone width, by measuring the perpendicular distance from the shore to the furthest edge of both emergent and submergent littoral vegetation. I determined the percentage coverage and species composition (submergent and emergent) of dominant plants along a 1 m-wide swath centered on the measuring tape at each location. I recorded upland vegetation 3 m shoreward of the water's edge, and recorded algal mat cover determined visually from the shore in four subjectively determined partitions for each pond. I also recorded the conditions (i.e., date, flow conditions, time of day, weather) each time I visited the sites. Vegetation was identified to species when possible using Cho et al. (2014) and Tobe et al. (1998). I recorded detailed vegetation information only once at the end of the study (October 2015).

Pond Management

To determine management practices in the ponds, I developed a standard questionnaire (Appendix E) about aquatic vegetation and algal control practices (e.g., herbicide, mechanical), chemical usage and rates, and frequency of application. I contacted home owners' associations (HOAs) and land and facilities managers to determine who was responsible for pond management. I subjectively developed a pond management intensity index scaling from 1 to 5 that considered whether chemical controls were used, how much chemical was applied, and how frequently controls were applied. Ponds managed frequently (i.e., every 2-6 weeks) with chemicals received a rating between 4 and 5, moderately managed ponds with chemicals a rating between 2 and 3, and ponds infrequently managed with chemicals a rating between 0 and 1. This index provided a quantitative metric of management intensity that I used to compare among land use categories.

Statistical Methods

I tested the null hypothesis that water quality parameters and vegetation did not differ among land uses. The first analysis explored the correlation ($\alpha = 0.05$) and variance among the twelve limnological variables using Principal Component Analysis (PCA). The variables included the overall mean within each pond for pH, temperature, conductivity, dissolved oxygen, Secchi depth, DRP, total nitrogen, nitrate, ammonium, chlorophyll *a,* total phosphorus and total vegetative cover. I used one-way ANOVA on the Principal Component scores to determine whether ponds differ significantly among land uses ($\alpha = 0.05$). Only axis 1 had an eigenvalue greater than one. I then used Repeated Measures Full Factorial Design (Mixed-Model) to analyze the limnological parameters most descriptive of axis 1. I used a Tukey-Kramer HSD post-hoc test to test pairwise comparisons, adjusting the alpha value to $\alpha = 0.01$. I used a one-way ANOVA ($\alpha = 0.05$) to analyze the littoral zone vegetation data. The independent variable was land use, and the dependent variables were mean distance of emergent vegetation from shore, mean distance of submergent vegetation from the shore, mean percent cover of emergent vegetation, mean percent cover of submergent vegetation, and total cover (sq m/m shoreline). Pairwise comparisons were analysed using Tukey-Kramer HSD post-hoc test. All analyses were conducted using JMP Pro 11 software (SAS Institute, Inc., Cary, NC, USA).

CHAPTER FOUR: RESULTS

Differing Management Practices in Expressway, School and Residential Ponds

Based on self-reported vegetation management concerns and treatments, expressway and residential ponds were managed at similar high intensity and school ponds were managed at lower intensity (Table 4). A common management concern for all land uses was vegetation overgrowth. Both chemical and mechanical treatments were applied to control the overgrowth. The Central Florida Expressway Authority contracted with Southern Aquatic Management, Inc., to manage expressway ponds using chemical means. Emergent vegetation was chemically treated eight times per year with Rodeo (glyphosate), Hydrothol 191 (Mono (N, N-dimethylalkylamine) salt of endothall), and Diquat (diquat dibromide), and submerged vegetation was chemically treated three times per year with Fluridone (1-methyl-3-phenyl-5-3-(trifluoromethyl) phenyl|-41H|-pyridinone). Managers at the Expressway Authority stated that they were preparing to introduce grass carp (*Ctenopharyngodon idella*) for vegetation control. Six of the eight residential ponds were managed by the Stormwater Management Division, Orange County Public Works Department through chemical means. Rodeo and Aquatol K (Dipotassium salt of endothall) were used every 4 - 6 weeks for vegetation, and copper sulfate was used as needed for algae. Two residential ponds were managed by the neighborhood homeowners' association, which hired private and public companies (LCAM Aquatic System and Lake Doctors) to manage the ponds chemically every 2 - 4 weeks. The Orange County Public School's Grounds Department maintained school ponds down to the water's edge mechanically and with Round Up (glyphosate). The schools stated that they may hire outside companies for aquatic herbicide treatment on an as needed basis, but much less frequently than for residential and expressway ponds.

Table 4: Management rating of pond maintenance concerns for each land-use and an overall subjective intensity index based on self-reported levels of treatment. N = number of managers maintaining ponds within each land use. Ratings are on a scale from 1 to 5 (1 being least concern or lowest intensity and 5 being of most concern or highest intensity).

Land use	N*	Vegetation Overgrowth	Algal growth	Litter	Sediment build-up/erosion	Drain Clogging	Intensity Index	Comments
Expressway	1	5	5	2	1	1	4	Managed frequently; chemical only
Residential	3	4.3	3.3	3.7	2.3	1.7	4	Managed frequently (2-6 weeks); mostly chemical
Institutional	1	4	2	2	3	3	1	Managed on as needed basis (infrequent) by independent contractor

*Residential pond ratings are based on the mean of three different management companies; expressway and school ponds are based on a single management entity.

Correlations among Limnological Variables

Several limnological variables were significantly correlated at alpha = 0.05 (Table 5). Dissolved oxygen was positively correlated with pH and chlorophyll *a*. Total nitrogen was positively correlated with pH. Secchi depth was negatively correlated with total nitrogen and negatively correlated with chlorophyll *a*. Chorophyll *a* was positively correlated with total phosphorus and total nitrogen. Total phosphorus was positively correlated with DRP. Total vegetative cover was positively correlated with Secchi depth. The three remaining variables were independent of the others (Table 5).

Table 5: Correlations among limnological parameters produced by Principal Component Analysis. Numbers in bold represent correlations significant at α = 0.05. N = 24

	pH	Temp. (ºC)	Cond. (uS)	DO (mg/L)	Secchi Depth	CHLA (ppm)	DRP (ppm)	TN (ppm)	TP (ppm)	Nitrate (ppm)	NH4 (ppm)	Total Veg. (sq m/m)
pH	1	0.2875	0.1481	**0.6172**	-0.4245	0.3791	0.0166	**0.5356**	0.0904	-0.1375	0.1541	0.0899
Temp. (ºC)	0.2875	1	-0.0858	0.4624	-0.171	0.065	-0.2293	0.1738	-0.1052	0.0018	0.0128	0.0236
Cond. (uS)	0.1481	-0.0858	1	0.0538	-0.228	0.1547	0.2335	0.2315	0.1322	-0.2458	0.0299	0.0334
DO (mg/L)	**0.6172**	0.4624	0.0538	1	-0.4921	**0.5275**	0.1513	0.4562	0.1406	-0.1165	-0.0035	0.1448
Secchi Depth (cm)	-0.4245	-0.171	-0.228	-0.4921	1	**-0.7998**	-0.26	**-0.8025**	-0.4538	0.0379	-0.2235	**0.5347**
CHLA (ppm)	0.3791	0.065	0.1547	**0.5275**	**-0.7998**	1	0.3469	**0.7832**	**0.5242**	0.1433	0.1796	-0.3442
DRP (ppm)	0.0166	-0.2293	0.2335	0.1513	-0.26	0.3469	1	0.2447	**0.7664**	0.2374	0.5109	-0.2508
TN (ppm)	**0.5356**	0.1738	0.2315	0.4562	**-0.8025**	**0.7832**	0.2447	1	0.426	-0.0515	0.2415	-0.3359
TP (ppm)	0.0904	-0.1052	0.1322	0.1406	-0.4538	**0.5242**	**0.7664**	0.426	1	0.4825	0.4516	-0.4144
Nitrate (ppm)	-0.1375	0.0018	-0.2458	-0.1165	0.0379	0.1433	0.2374	-0.0515	0.4825	1	0.2163	-0.2110
NH4 (ppm)	0.1541	0.0128	0.0299	-0.0035	-0.2235	0.1796	**0.5109**	0.2415	0.4516	0.2163	1	-0.3553
Total Veg. (sq m/m)	0.0899	0.0236	0.0334	0.1448	**0.5347**	-0.3442	-0.2508	-0.3359	-0.4144	-0.2110	-0.3553	1

Principal Components Analysis (PCA)

Principal Components Analysis showed clear relationships among some suites of limnological parameters. The first four principal components represented the most variance within the data (Table 6). Principal Component 1 (34.9%), Component 2 (19.6%), Component 3 (11.1%), and Component 4 (9.2%) totalled 74.7% of the variance. Secchi depth and total vegetative cover loaded negatively on PC 1, while total nitrogen, dissolved oxygen, pH, DRP, total phosphorus, ammonium, and chlorophyll A loaded positively (Table 7). Total phosphorus, DRP, ammonium, and nitrate loaded negatively on PC2, while temperature, pH, total vegetative cover, and dissolved oxygen loaded positively (Table 7). On PC 3, temperature and nitrate loaded positively and conductivity loaded negatively (Table 7). DRP and total vegetative cover loaded positively on PC 4 (Table 7). All of the first four principal component axes had eigenvalues greater than one and therefore were retained for further analysis.

A one-way ANOVA comparing the Principal Component scores from all four axes for individual ponds revealed significant separation between expressway ponds and school ponds ($F_{2,21} = 9.67$, $p < 0.05$) only with Principal Component 1 (Figure 5). Based on the PCA results and significant differences between ponds from different land uses along axis 1, I used repeated measures analysis for variance on the parameters most strongly related to this axis: total nitrogen, total phosphorus, dissolved oxygen, and Secchi depth. TN was chosen over chlorophyll *a* because they are highly correlated, and TN includes the nitrogen within chlorophyll *a*. I adjusted α to 0.01 to account for multiple tests.

Table 6: Principal Component table containing PC scores, eigenvalues, percent variance, and cumulative percent.

PC Scores	Eigenvalues	Percent	Cum. Percent
1	4.18	34.9	34.9
2	2.35	19.6	54.4
3	1.33	11.1	65.5
4	1.11	9.2	74.7
5	0.856	7.1	81.8
6	0.681	5.7	87.5
7	0.546	4.6	92.96
8	0.332	2.8	94.8
9	0.271	2.3	97.1
10	0.141	1.2	98.3
11	0.116	0.97	99.2
12	0.092	0.76	100

Table 7: Loading Matrix table for significant Principal Component scores.

	PC 1	PC 2	PC 3	PC 4
pH	0.52	0.57	0.03	0.27
Temp (deg C)	0.16	0.52	0.55	0.09
Conductivity (uS)	0.25	0.09	-0.77	0.14
DO (mg/L)	0.56	0.61	0.18	0.33
Secchi Depth (cm)	-0.87	-0.17	0.05	0.35
CHLA (ppm)	0.86	0.10	0.001	-0.16
DRP (ppm)	0.56	-0.54	-0.22	0.43
TN (ppm)	0.84	0.24	-0.08	-0.20
TP (ppm)	0.71	-0.54	0.04	0.21
Nitrate (ppm)	0.17	-0.56	0.57	0.17
Ammonium (ppm)	0.46	-0.43	0.09	0.24
Total Veg. Cover (sq m/m)	-0.48	0.43	-0.13	0.62

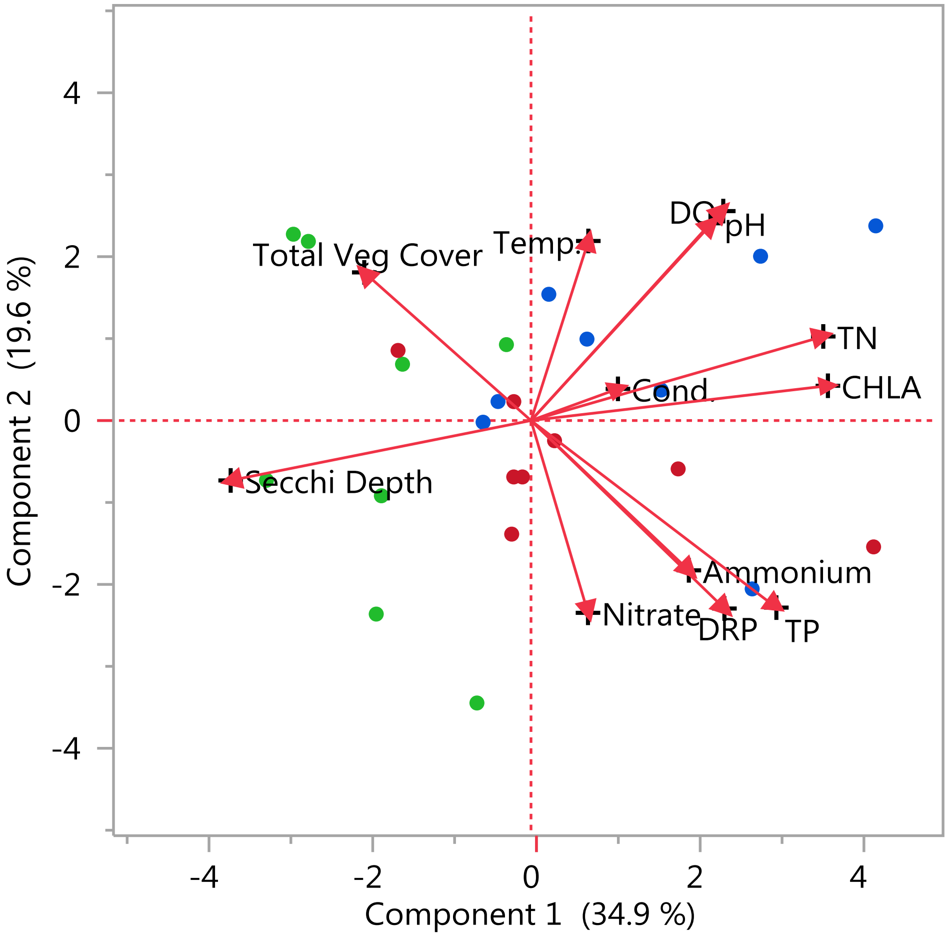


Figure 5: Biplot of Principal Component scores of nutrients concentrations, physical parameter, and total vegetative cover in stormwater ponds (Expressway, blue circles; Residential, red circles; Schools, green circles). N=24.

Repeated Measures Analysis

Two water quality measures differed significantly among land uses: TN and Secchi depth (Table 8). Total nitrogen concentrations differed significantly between expressway and school land uses (Figure 6), with expressway ponds having TN concentrations 51.7% higher than schools. Secchi depth differed significantly between expressway and schools ponds, with expressway ponds being 52.4% lower than school ponds (Figure 7). For both TN and Secchi depth, residential ponds had values intermediate between school and expressway ponds. The other parameters did not differ significantly among land uses. The TN concentrations differed significantly over time (Table 9).

Table 8: Repeated measures results of the influence of land use on limnological parameters. N=sample size. DF=degrees of freedom.

Parameter	N	DF	DF Denominator	F-ratio	Prob >F
Dissolved Oxygen (mg/L)	120	2	21	2.16	0.14
Secchi Depth (cm)	118	2	21	9.50	0.001*
TN (ppm)	120	2	21	5.87	0.009*
TP (ppm)	120	2	21	2.91	0.08

Table 9: Repeated measures results for the influence of time on limnological parameters. N=sample size. DF=degrees of freedom.

Parameter	N	DF	DF Denominator	F-ratio	Prob >F
Dissolved Oxygen (mg/L)	120	4	84	1.02	0.40
Secchi Depth (cm)	118	4	84	1.36	0.25
TN (ppm)	120	4	84	5.89	0.0003*
TP (ppm)	120	4	84	2.39	0.058

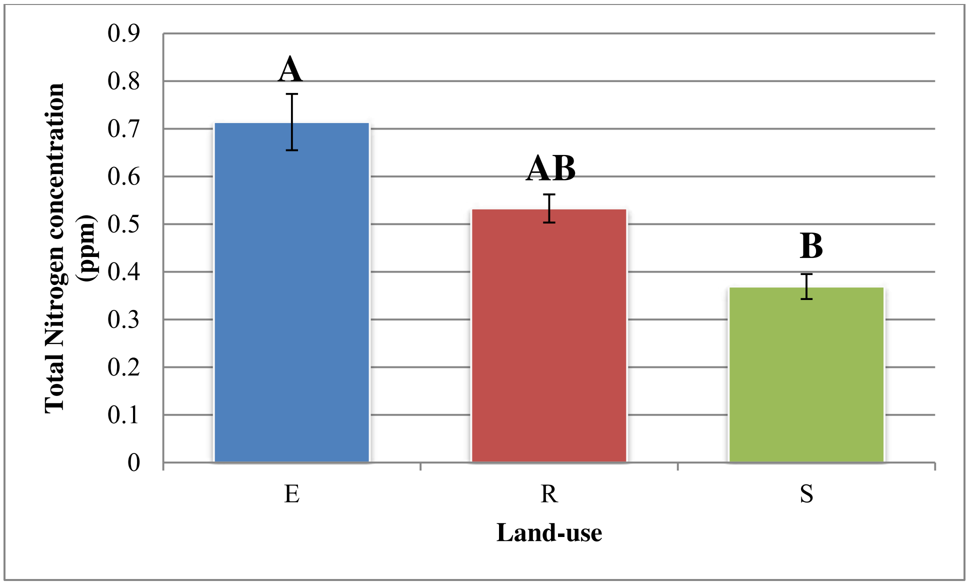


Figure 6: Mean (± SE) total nitrogen concentrations (ppm) in expressway (E), residential (R), and school (S) stormwater ponds.

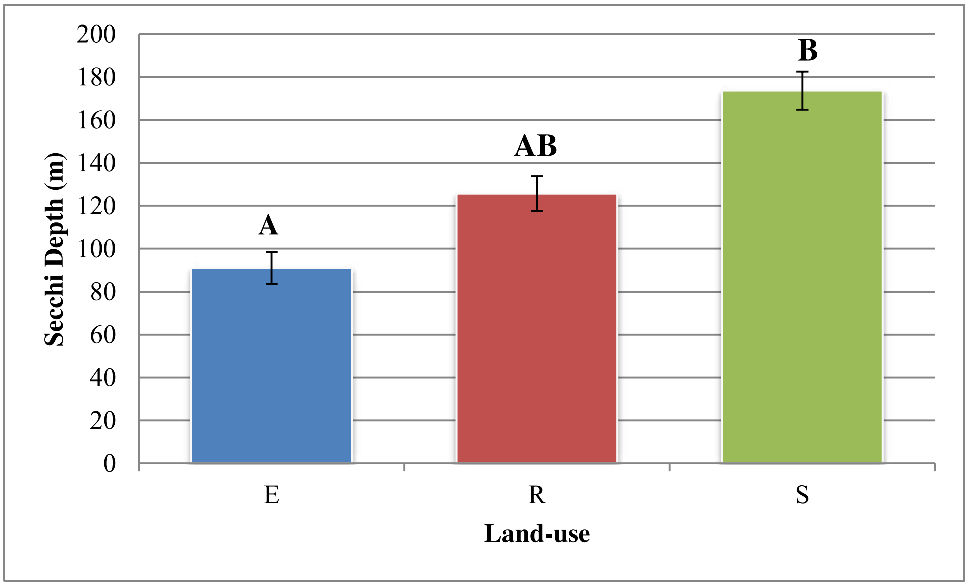


Figure 7: Mean (± SE) Secchi depth (cm) in expressway (E), residential (R), and school (S) stormwater ponds.

Total nitrogen and total phosphorus varied significantly between land use and time (Table 10). Total N declined slightly over time in expressway ponds but increased in July and September in the residential and school ponds, respectively (Figure 8A). Total phosphorus in school ponds increased over time then decreased in September. In contrast, TP in expressway ponds decreased in May and July, increased in August, then decreased in September. In residential ponds, TP increased in June, decreased in July and August then increased in September (Figure 8B).

Table 10: Repeated measures results for the influence of the interaction between time and land use on limnological parameters. N=sample size. DF=degrees of freedom.

Parameter	**N**	**DF**	**DF Denominator**	**F-ratio**	**Prob >F**
Dissolved Oxygen (mg/L)	120	8	84	0.79	0.61
Secchi Depth (cm)	118	8	84	1.37	0.22
TN (ppm)	120	8	84	3.93	0.0006*
TP (ppm)	120	8	84	3.42	0.002*

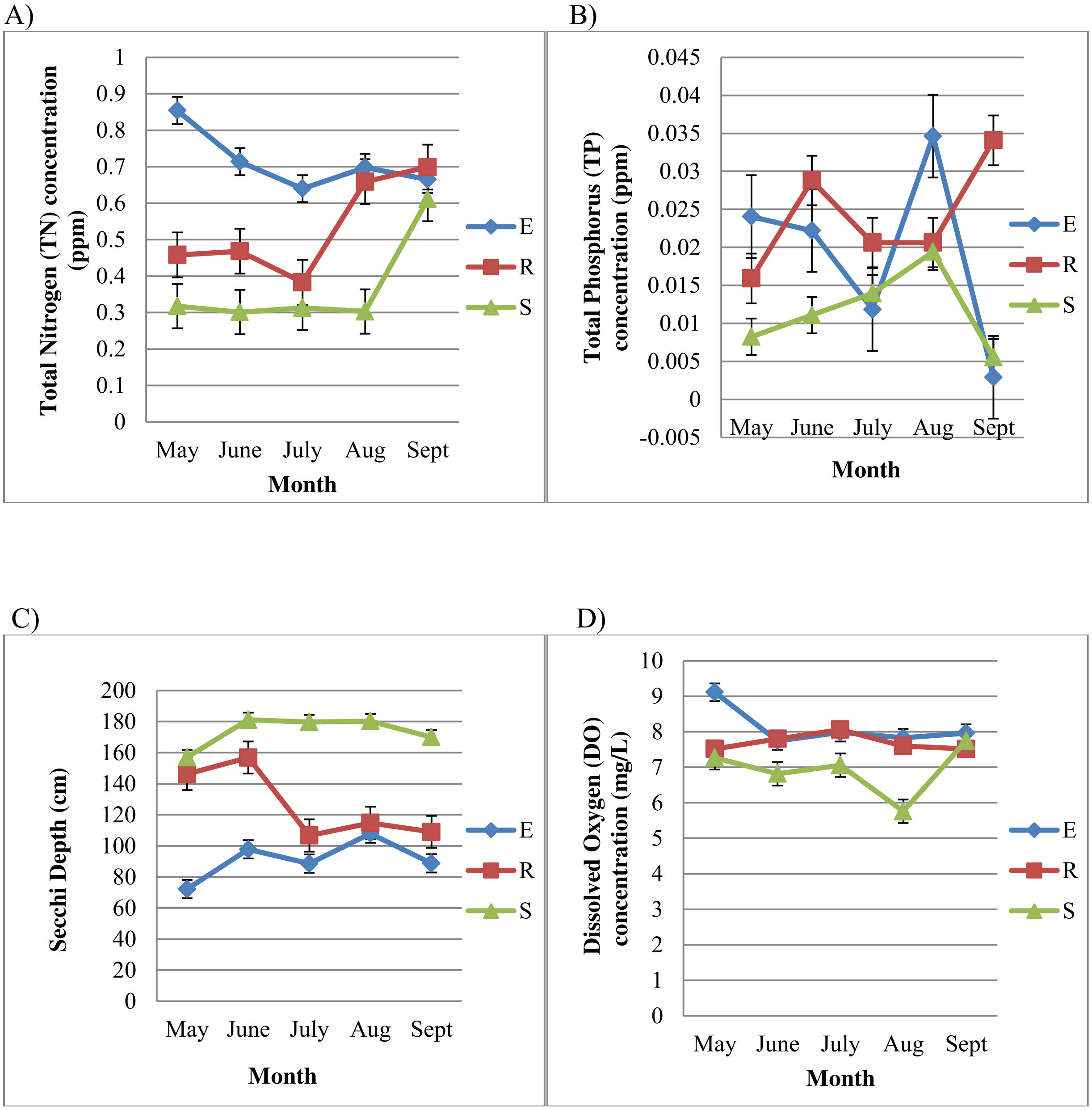


Figure 8: Interactions between time (sampling event) and land use for limnological parameters. Values are means ± SE. N = 8. (E = expressway, R = residential, S = school). A) Total Nitrogen (TN) B) Total Phosphorus (TP) C) Secchi Depth D) Dissolved Oxygen (DO).

Influences of Land Use on Pond Vegetation

The distance from the shoreline of the emergent littoral zone differed significantly among land-uses ($F_{2,21} = 4.17, p < 0.05$), with significantly greater emergent cover in school than in residential ponds (Figure 9). Total vegetation cover in pond littoral zones was significantly greater in school ponds ($F_{2,21} = 3.59, p < 0.05$) than in either residential or expressway ponds (Figure 13). Mean percent algal cover for residential ponds was 2.5% ± 1.1%, school ponds was 4.0% ± 4.5%, and expressway ponds was 6.5% ± 11.4%. There was no significant difference of algal cover between land uses ($F_{2,21} = 0.62, p > 0.05$).

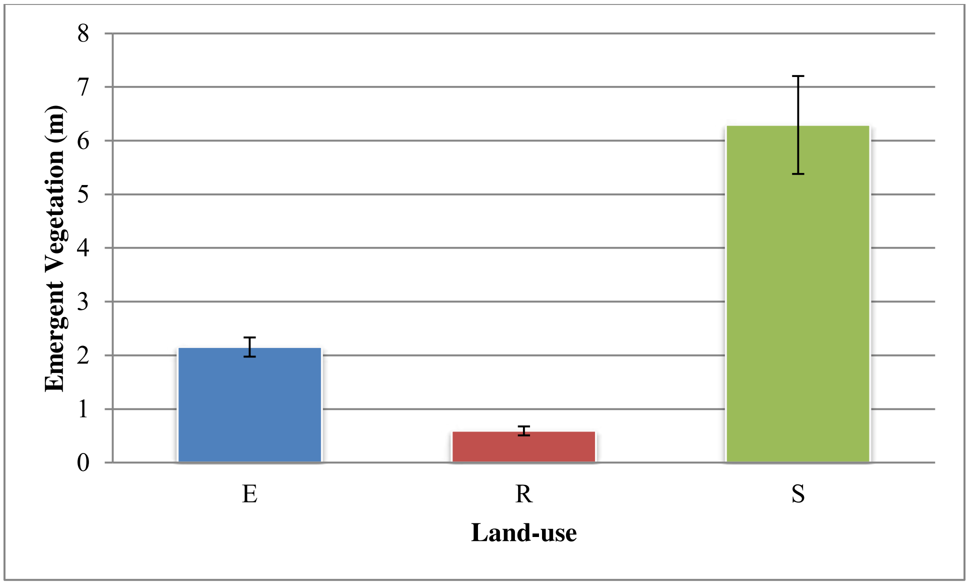


Figure 9: Mean (± 1 SE; N = 24) distance of littoral zone emergent vegetation (m) from shore in ponds of the three different between land-uses (E = expressway; R = residential; S = schools).

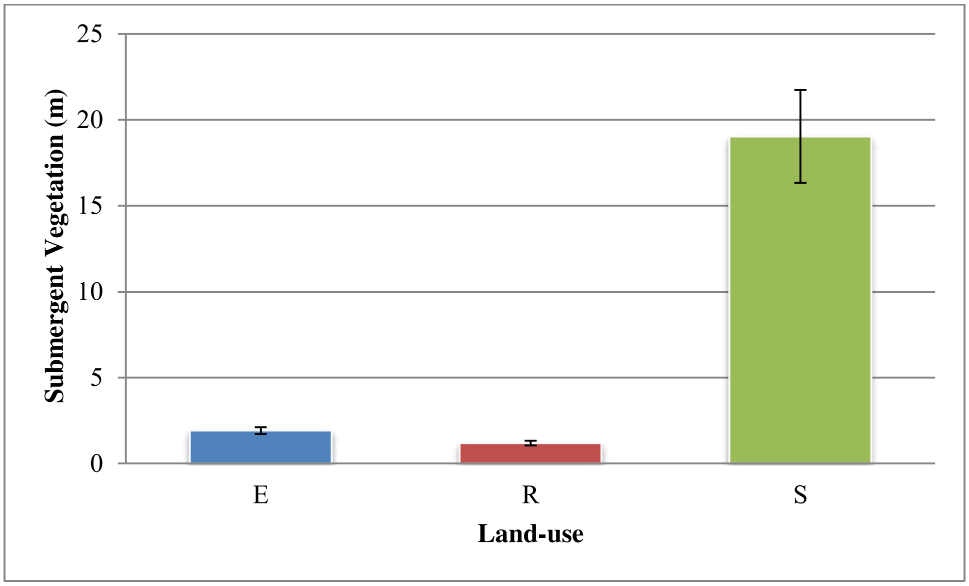


Figure 10: Mean (± 1 SE; N = 24) distance of littoral zone submergent vegetation (m) from shore in ponds of the three different land uses (E = expressway; R = residential; S = schools).

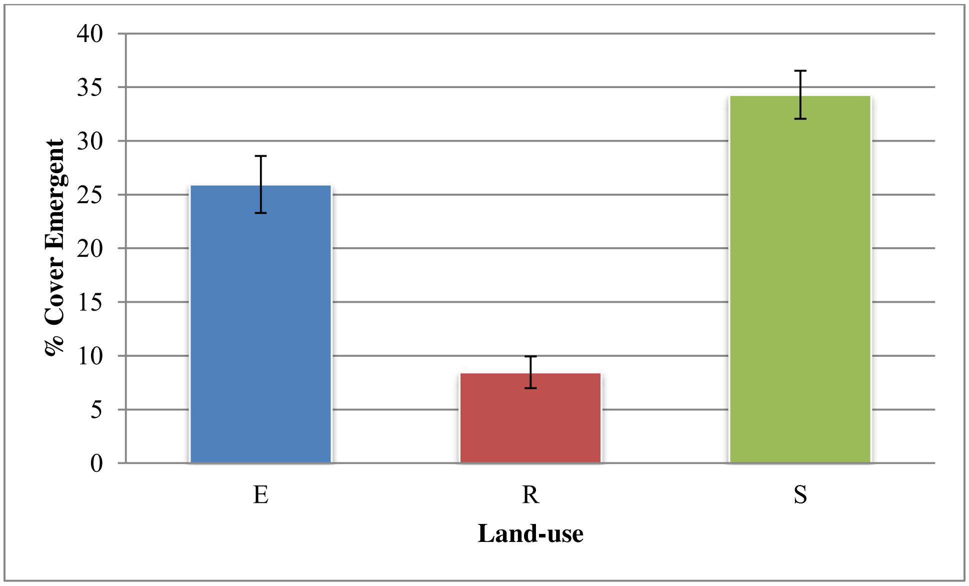


Figure 11: Mean (± 1 SE; N = 24) percentage cover (%) of littoral zone emergent vegetation in ponds of the three different land-uses (E = expressway; R = residential; S = schools).

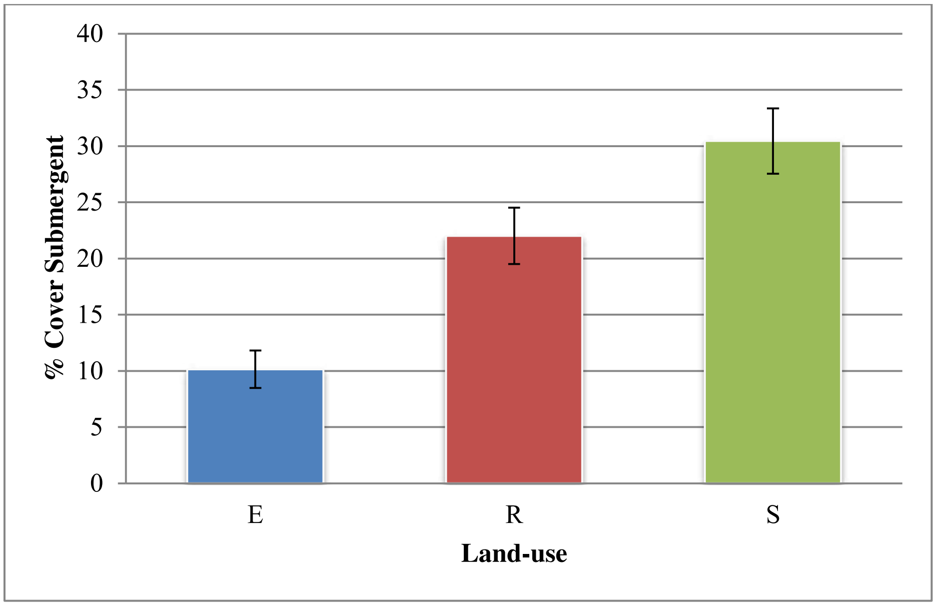


Figure 12: Mean (± 1 SE; N = 24) percentage cover (%) of littoral zone submergent vegetation in ponds of the three different land-uses (E = expressway; R = residential; S = schools).

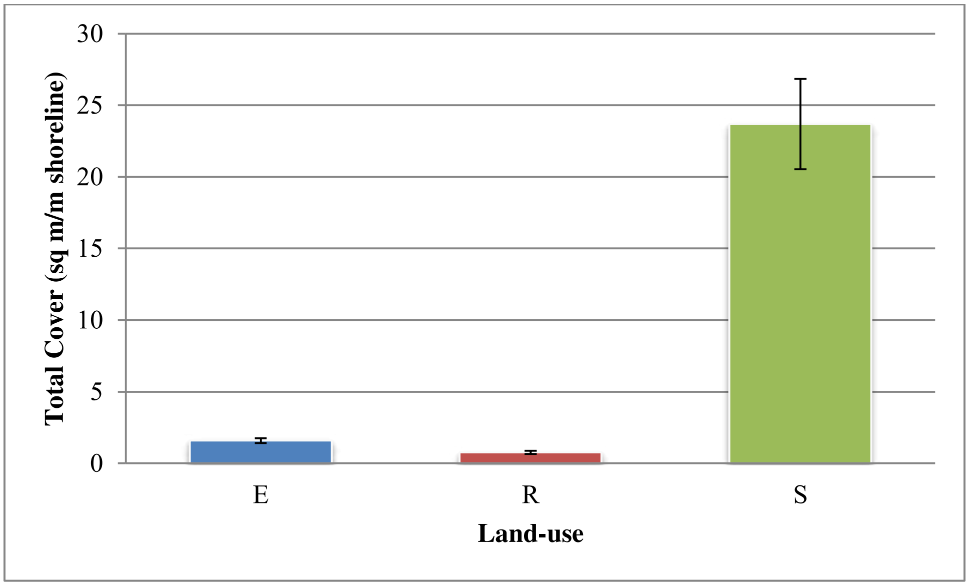


Figure 13: Total vegetation cover (sq m/m shoreline) (± 1 SE; N = 24) of emergent and submergent vegetation in the littoral zone of ponds in the three different land-uses (E = expressway; R = residential; S = schools).

CHAPTER FIVE: DISCUSSION

Distribution of stormwater basins

Stormwater basins in the Econlockhatchee watershed exceeded that of natural lakes indicating they contribute substantially to open water habitat in this region. Furthermore, urban land use covers, particularly residential, expressway, institutional, and commercial, dominated the surrounding landscape of the ponds. The dominance of residential land use was reflected in the number of ponds associated with that land use, and stormwater ponds in the more rural areas of the watershed were limited mainly to those along highways and other roads. These results were expected as stormwater ponds are built primarily to mitigate the impacts of impervious areas associated with urbanization (Hogan & Walbridge, 2007).

Differences in water quality measures among land-uses

The higher nutrient concentrations and lower water clarity of expressway ponds, followed closely by residential ponds may be related to the fact that roadway ponds have more impervious surfaces and traffic flow than residential and institutional areas (Harper & Baker, 2007). This higher impervious area can lead to higher nutrient loads, and more runoff of road surface materials, sediments, and atmospheric fallout, and run off from motor vehicle operations (Campbell, 1994; Harper & Baker, 2007).

Areas drained by residential ponds generally only have 20-40% impervious surfaces and mainly receive nutrient inputs from fertilizer and pet excrement (Carpenter & Vallet, 2014).

Schools receive most of their runoff from parking lots with limited traffic flow (Brattebo & Booth, 2003), and fertilization at schools is minimal except on some athletic fields. It is possible that more limited fertilizer likely contributed to the low TN and chlorophyll *a* and high clarity in school ponds compared to expressway and residential ponds but other factors such as differences in pond management may also have contributed to the differences.

Age of the ponds may have contributed to differences in nutrients between land uses, as school ponds were significantly younger than roadway ponds. Older ponds have the potential to accumulate nutrients over time and become deteriorated. However, in this study, there was not a large distribution of ages for each land use to support a robust test of the effects of age on pond nutrients.

It is uncertain why temporal patterns in certain water quality parameters differed markedly among land uses. Seasonal trends in rainfall (Figure 14) likely had some influence on stormwater constituents due to dilution or flushing effects. For example, TN levels in expressway ponds were elevated even in the dry season, when nutrient levels overall in the other land uses were at their lowest (Figure 8A), but TN concentrations in these ponds dropped in the rainy season, which may have been a dilution effect due to increased volume and flow in the ponds. By contrast, TN levels in residential and school ponds were low in the dry season and actually increased later in the wet season, possibly due to more nutrients flushing into the ponds with increased runoff in the rainy season. It is not known why concentrations of ammonium, nitrate, and DRP increased on the last sample date in residential ponds but not school or residential ponds (September 2015). Residential ponds likely receive the greatest fertilizer inputs but other factors may have been responsible for this difference. The decrease of conductivity through time among all land-uses is indicative of a dilution effect with increased rainfall throughout the rainy season. Secchi depth may also be affected by rainfall patterns, as water clarity can depend upon weather. School ponds had consistently high Secchi depths, whereas expressway ponds remained consistently low. Secchi depths in residential ponds decreased during the July sampling event and remained at that lower level through September. Nutrient levels in residential ponds had the opposite pattern, and the increase in nutrients during the wet season in residential ponds was positively related to the decline in water clarity in those ponds.

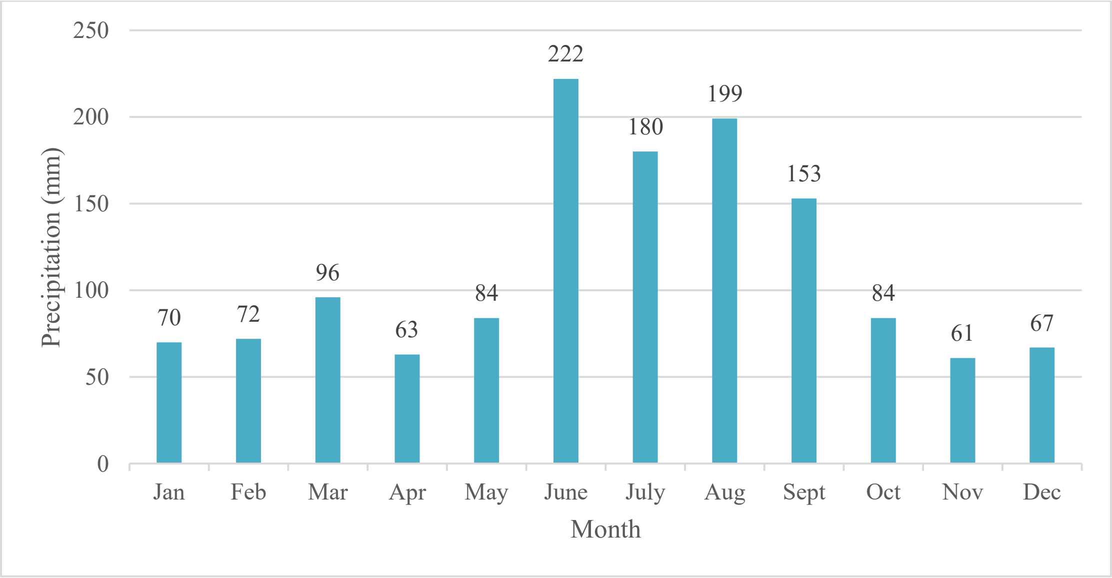


Figure 14: 2015 Mean monthly precipitation (mm) for Orlando, Florida (U.S. Climate Data, 2016).

Relationships among limnological measures

The relationship between TN, TP, and chlorophyll *a* is consistent with known influence of these two nutrients on algal growth, although the relationship between chlorophyll *a* and these factors depends upon many factors including the trophic state of the system (Chin, 2015). Increased chlorophyll *a* can reduce light penetration and negatively influence water clarity, and this strong inverse relationship between chlorophyll *a* and Secchi depth is well documented in the literature (Borkman & Smayda, 2016; Hoyer et al., 2002; US EPA, 2003). The positive correlation between dissolved oxygen and pH was expected because as dissolved oxygen increases with photosynthesis, carbon dioxide decreases, which can increase pH. Although, these patterns were present, observed values for water quality parameters in this study do not indicate the stormwater ponds were eutrophic. The TN, TP, and DRP concentrations observed in this study are lower than the mean values as reported and reviewed by Harper (1994) and Harper & Baker (2007) for stormwater ponds in Florida (Table 9). Although data are available for TN and TP in different land uses, there is limited data on nitrate, ammonium, and ortho-phosphate levels (Harper & Baker, 2007).

The Environmental Protection Agency (EPA) established state-specific water quality criteria for natural bodies of water in adherence to the Clean Water Act. The standards are representative of surface water conditions minimally influenced by humans and protective of aquatic life and recreational uses. Unfortunately, recommendations have not yet been established for stormwater ponds. Although, the standards for natural lakes and wetlands are not necessarily applicable to stormwater ponds due to differing hydrology (e.g. timing and water source) and landscape position, their critical position in the landscape suggests that establishing such standards for stormwater basins is warranted (Rooney et al., 2015).

Table 11: Overall mean value of total nitrogen (TN), total phosphorus (TP) and dissolved reactive phosphorus (DRP) levels in stormwater ponds in Florida.

Land Use	Limnological Parameter	This Study (mg/L)	Harper & Baker, 2007 (mg/L)	Harper, 1994 (mg/L)
Expressway	TN	0.71	1.64	2.08
	TP	0.019	0.22	0.34
	DRP	0.011	-	0.14
Residential	TN	0.53	2.07	2.29
	TP	0.024	0.33	0.30
	DRP	0.013	-	0.15
Schools	TN	0.37	1.18	1.18
	TP	0.018	0.18	0.15
	DRP	0.008	-	0.03

Pond Vegetation

The much greater abundance of submergent and emergent vegetation in school ponds relative to the other two land uses (Figures 9-13) is consistent with lower management intensity in school ponds. Increased vegetation may have contributed to the higher water clarity in school ponds. Surrounding vegetation provides protection from non-point source pollutants and improves water quality through direct chemical uptake and indirect influences, such as supplying chemically active organic matter (i.e., leaf detritus) to soils and channels, modifying water movement and soil stabilization (Dosskey et al., 2010; Hefting et al., 2005). Abundant submergent and emergent vegetation can absorb nutrients within the pond to supress phytoplankton growth and make the water clearer. Appropriate management of pond vegetation can effectively improve water quality, but this depends on land and water resource managers understanding vegetation composition and the aforementioned processes. Eutrophication can occur if these factors are not taken into consideration (Dosskey et al., 2010; Stoler & Relyea, 2015). My results suggest that the lower intensity of herbicide application to ponds supports the most plant growth and diversity among the three different land uses.

Differences in management practices among land-uses

Stormwater ponds are managed to reduce flooding and treat stormwater runoff. To adhere to this purpose and comply with Orange County codes, ponds and their control structures should be routinely monitored and inspected, especially during the rainy season. Orange County's Environmental Protection Division suggests any sediment (polluted and built-up), debris, vegetation, oils, grease, and chemicals obstructing or inhibiting the pond's function be removed and properly disposed. The county also recommends littoral zones be maintained and free of exotic vegetation. Popular management strategies include: mechanical (e.g. mowing, raking, and digging) and chemical (e.g. herbicide and algaecide) treatments. Maintenance is not ubiquitous in Florida and varies based on surrounding land use and the entities responsible for management.

The primary concern across all land uses was removal of aquatic vegetation for aesthetics and function. Chemicals were the primary management tool, but frequency of application differed among land uses. School ponds were the least intensely managed, contained the highest abundance and diversity of vegetation, and had the best water quality. Infrequent management of these ponds is likely due to lack of available funds relative to the other land uses and disinterest on the part of schools. Less intensive management can increase vegetation, which aids in nutrient removal. Nutrient loading also may have been lower in school ponds because the lower intensity of land use provided less favorable conditions for algae.

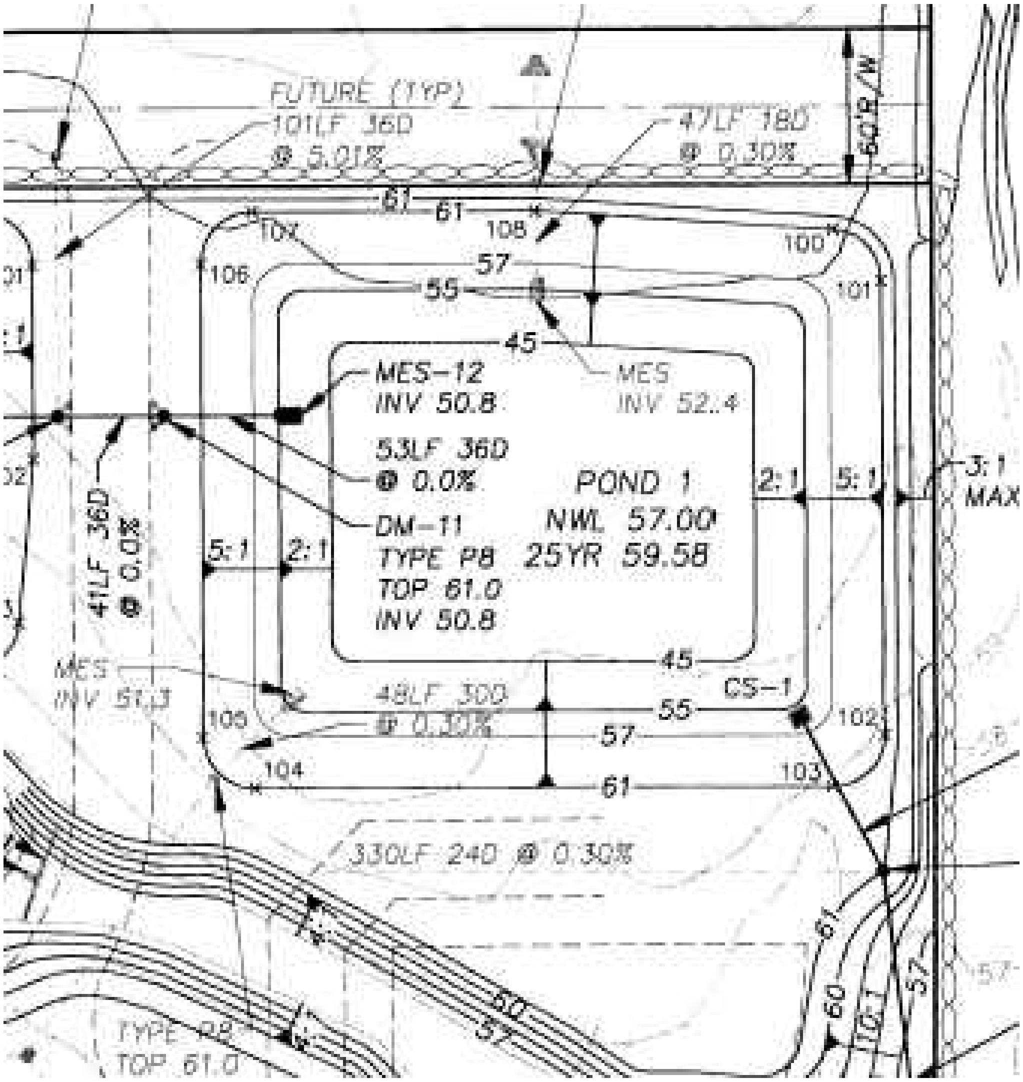
Conclusions

Environmental degradation due to urbanization is a global concern (Yan and Edwards 2013), and the deterioration of water quality from runoff remains a significant challenge. Stormwater basins in the Econlockhatchee River Watershed were dominated by urban land uses and a prominent feature of the urbanized areas within the watershed. On average, school ponds had the highest water quality and the most abundant vegetation, likely due to lower fertilization rates, less impervious surface, and less intense aquatic vegetation management. Conversely, expressway ponds had the lowest water quality and the least abundant vegetation, likely due to higher nutrient inputs from traffic, more impervious surface, and more intense aquatic vegetation management.

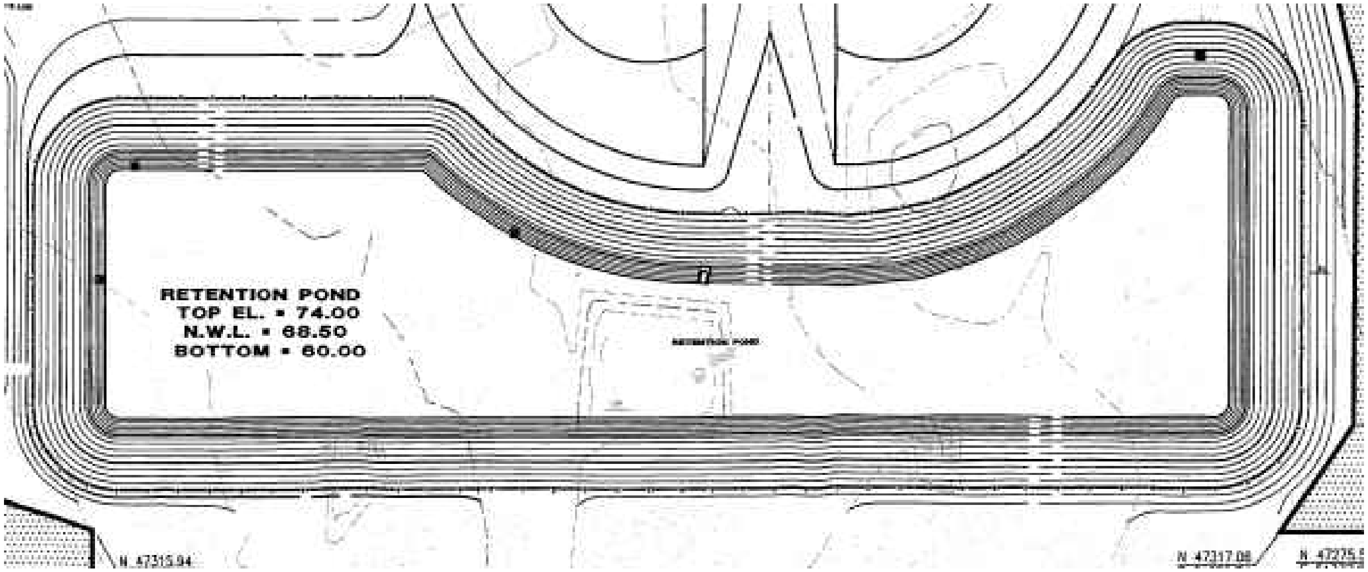
The ponds I studied did not show signs of severe eutrophication or deterioration, but they are relatively young and water quality may decline if they are not maintained properly and if nutrients increase or accumulate over time. Encouraging vegetation growth in the littoral zone may contribute to better water quality (i.e., higher water clarity and lower nutrient concentrations). Other options include designating buffer zones (at least 3.7 meters away) where no fertilizer or chemicals can be sprayed on lawns, constructing permeable pavement where practical, and developing a comprehensive maintenance plan for the entire drainage basin that includes education and outreach to homeowners and management entities. Improving the ecological conditions of urban stormwater ponds is critical for preserving preservation and restoring biodiversity and maintaining sustainable habitat in urban areas (Tixier et al. 2011), as well as protecting human health.

APPENDIX A:
POND CONSTRUCTION SPECS

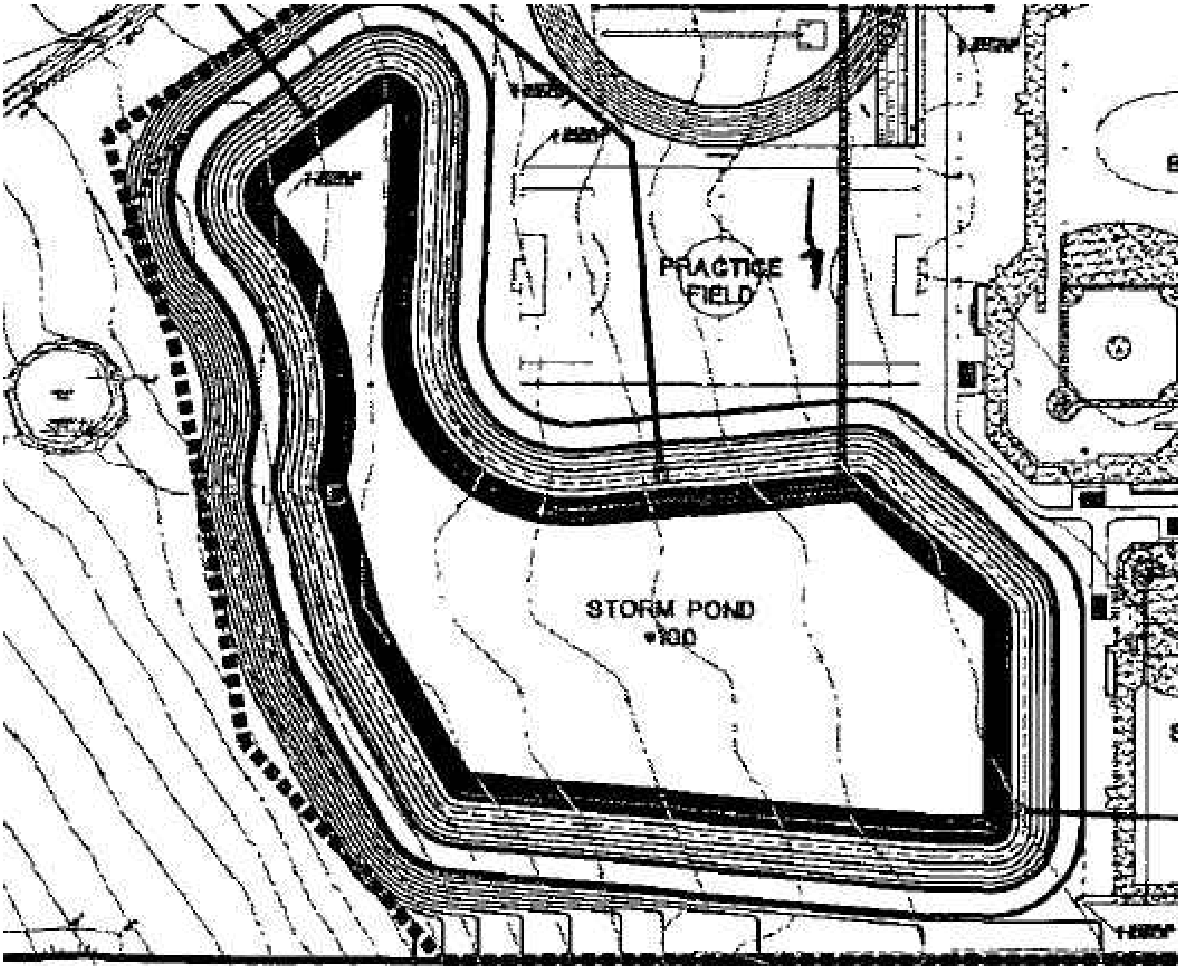
S1: Stone Lakes Elementary School



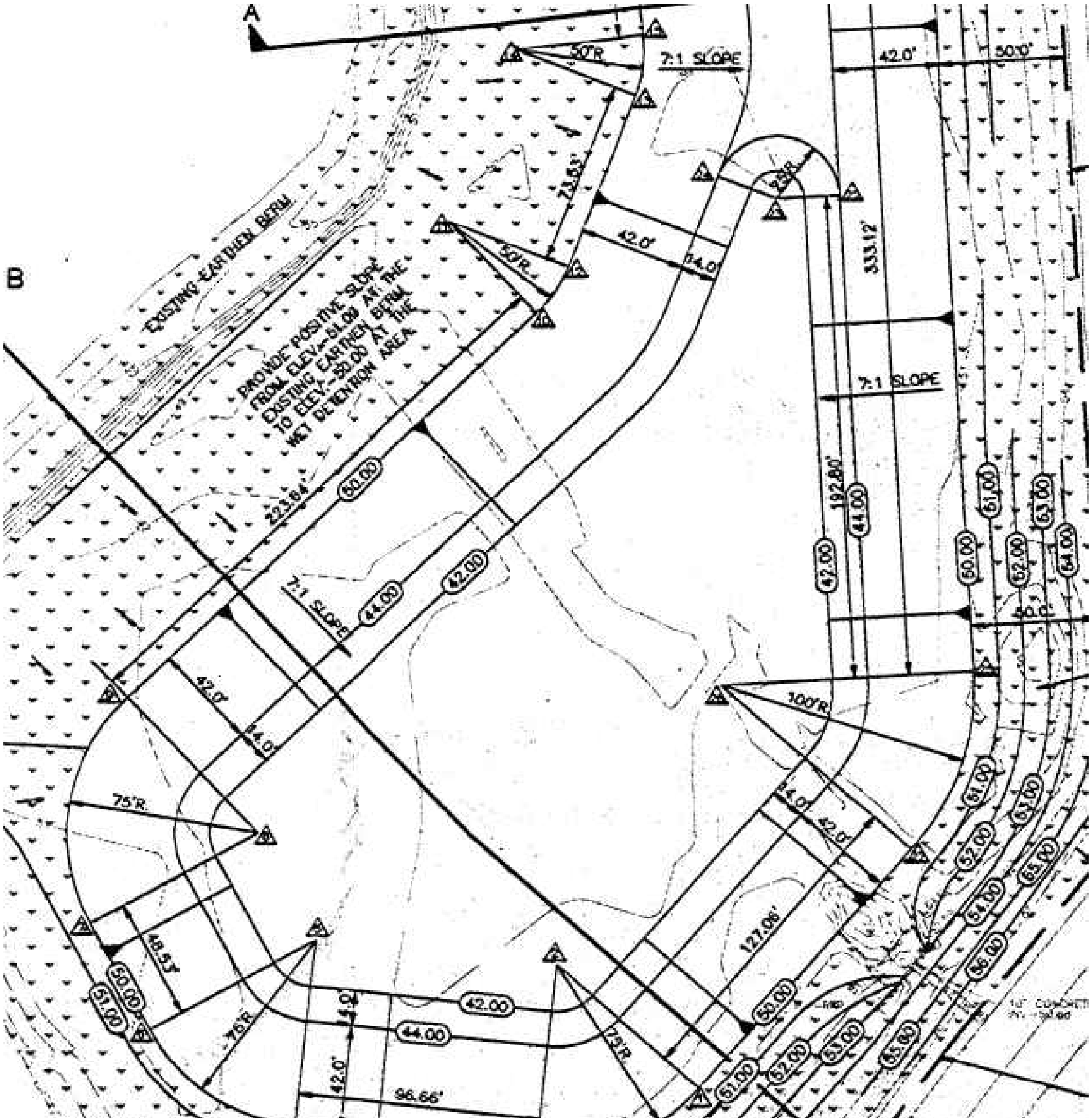
S2: Discovery Middle School



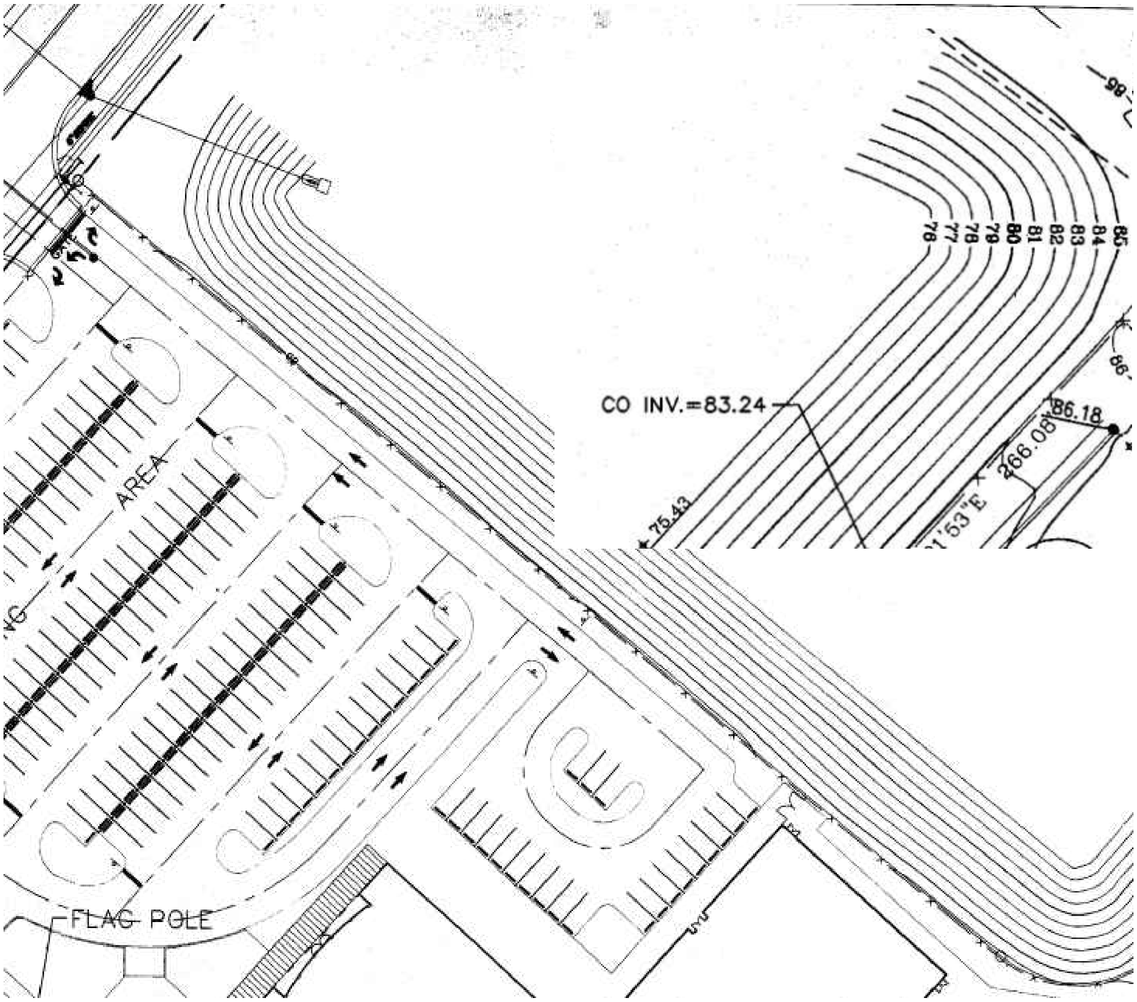
S3: East River High School



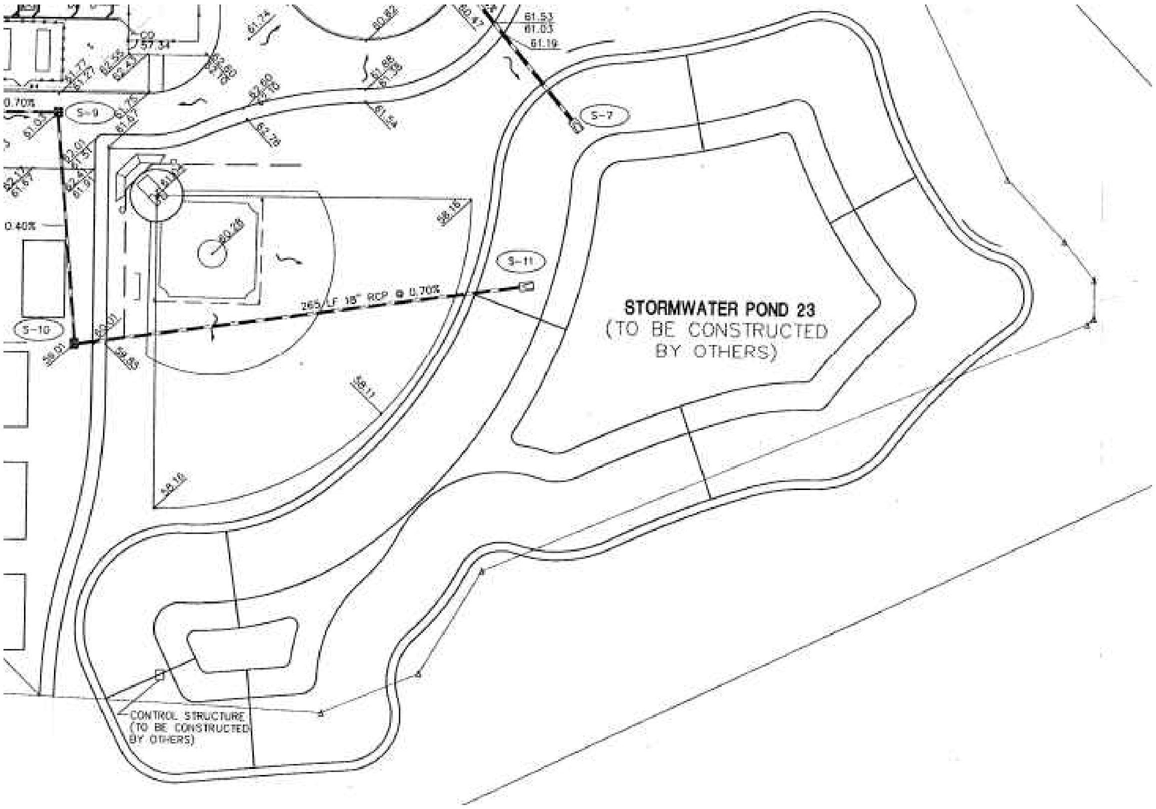
S4: University High School



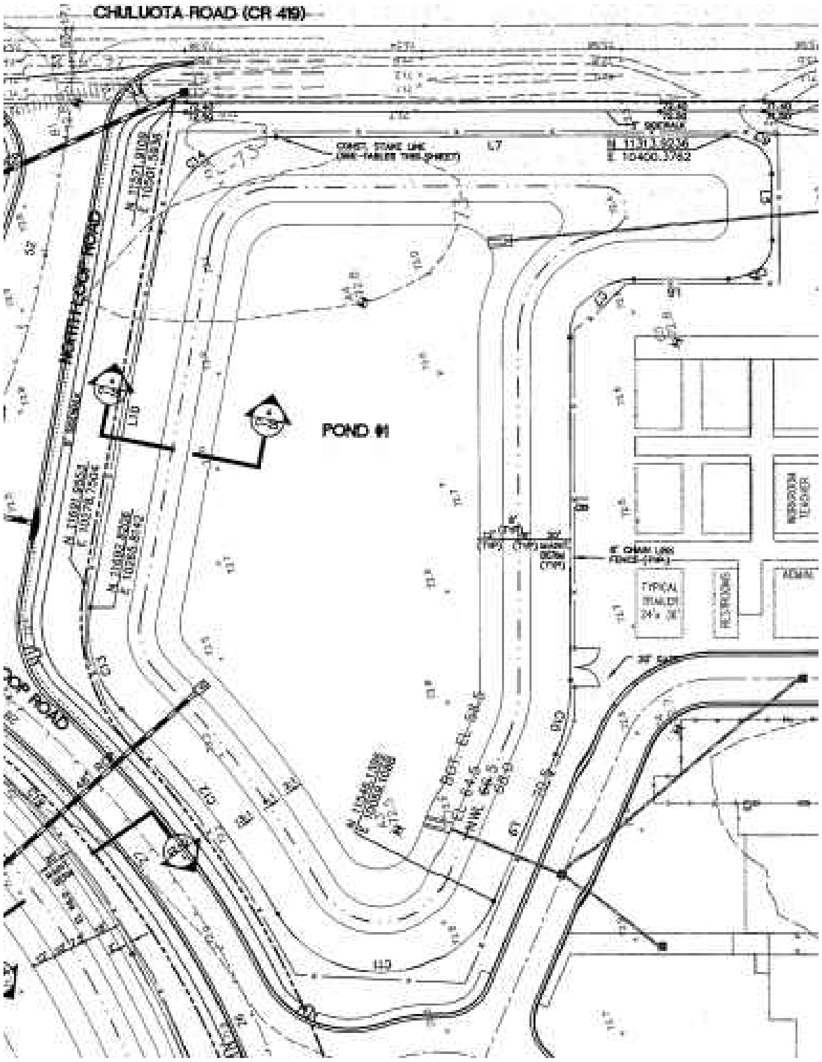
S5: Odyssey Middle School



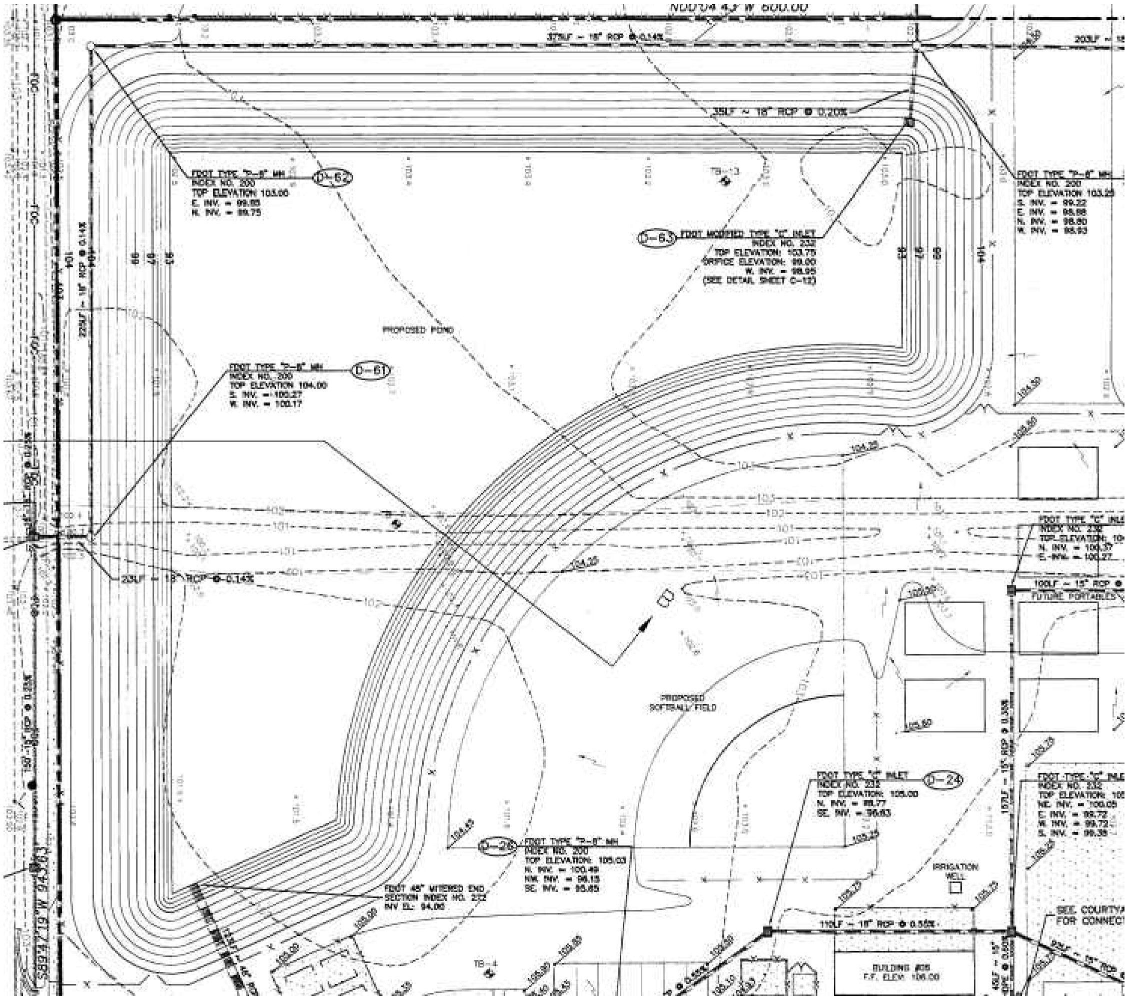
S6: Avalon Elementary School



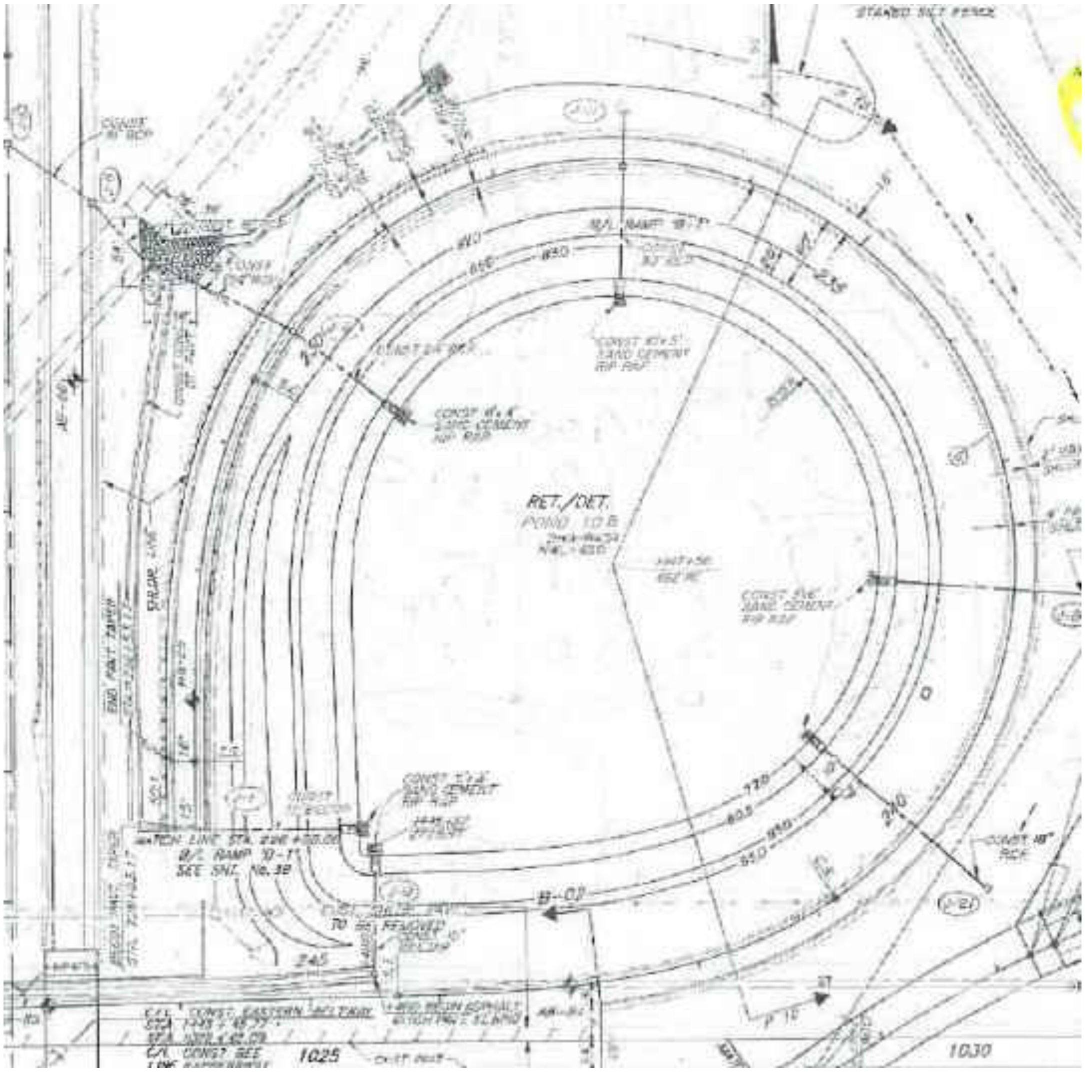
S7: Corner Lake Middle School



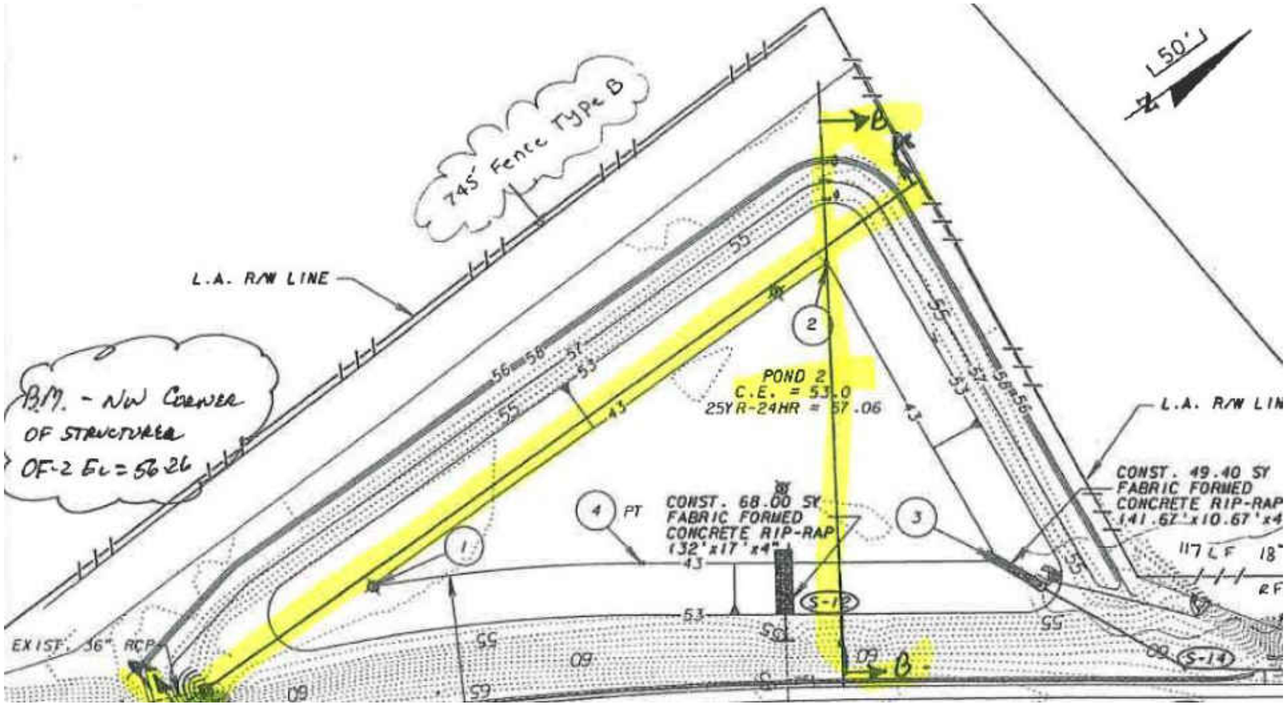
S8: Lake George Elementary School



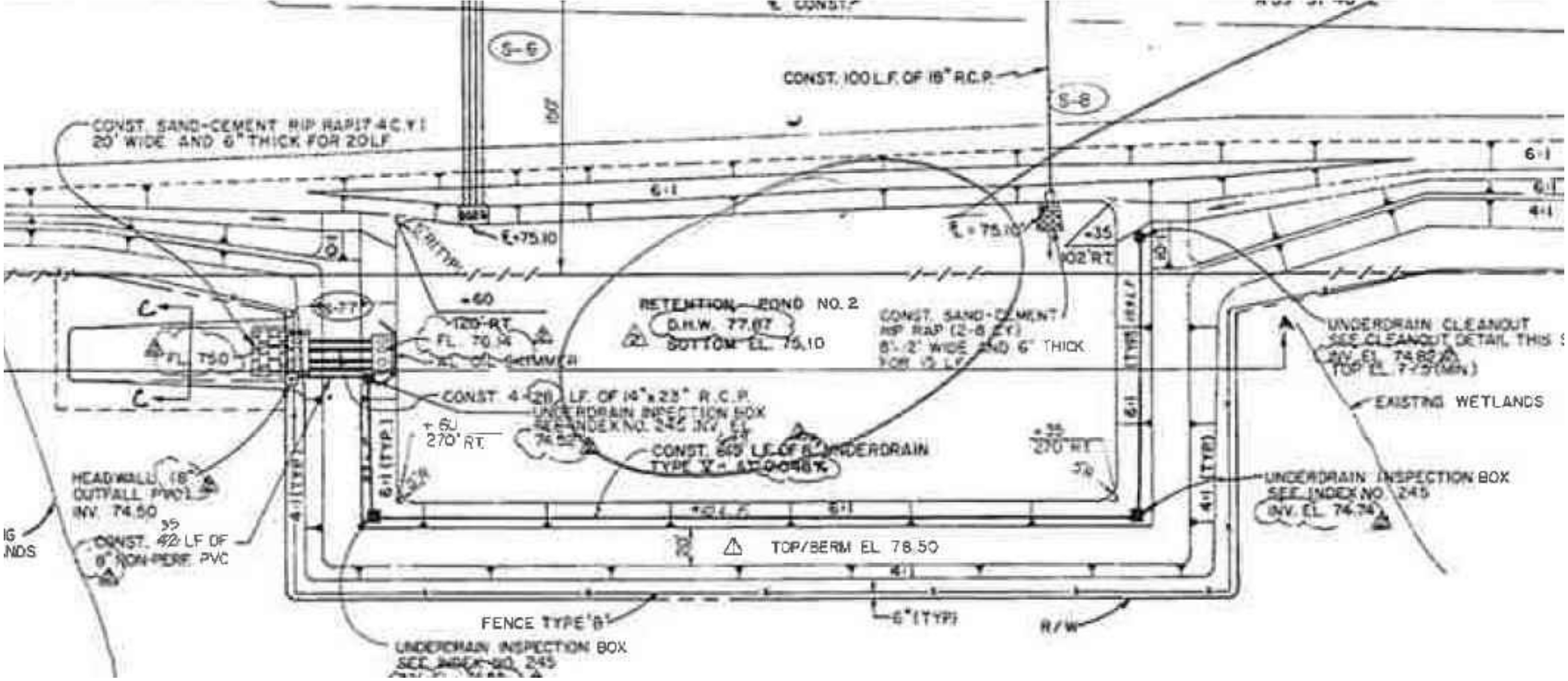
E1: Roadway 1 - North



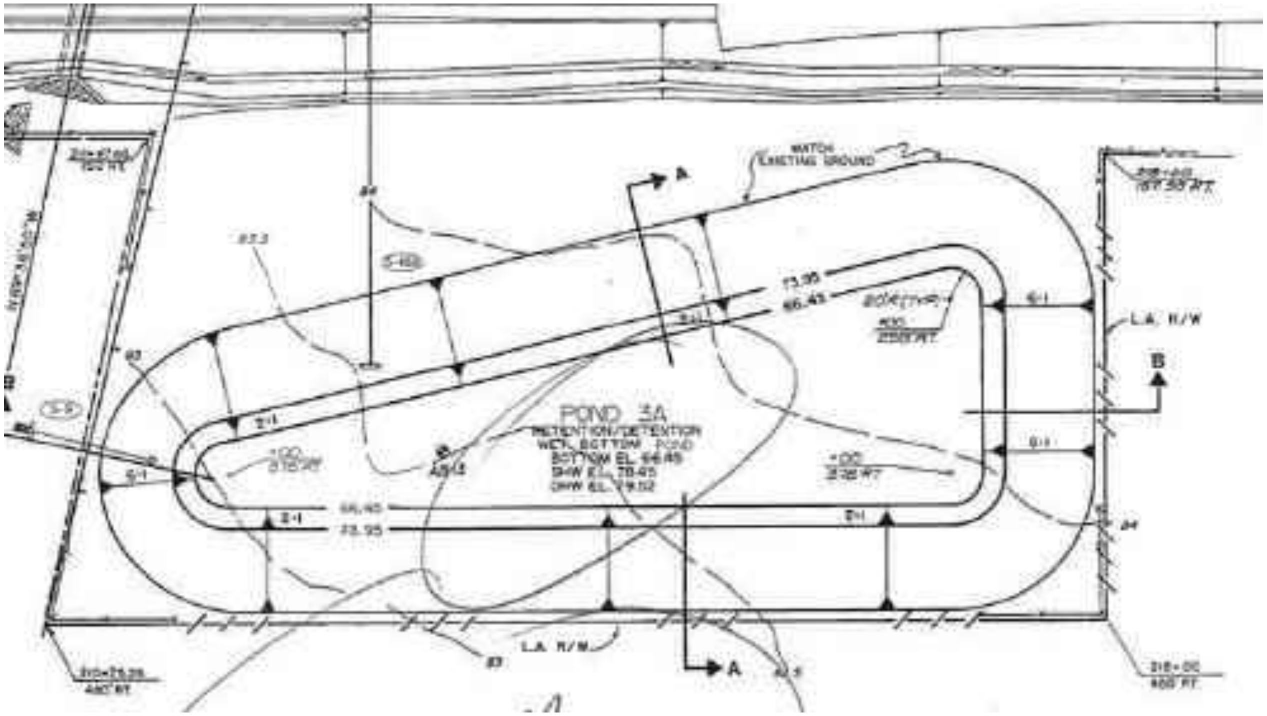
E2: Roadway 2 - North



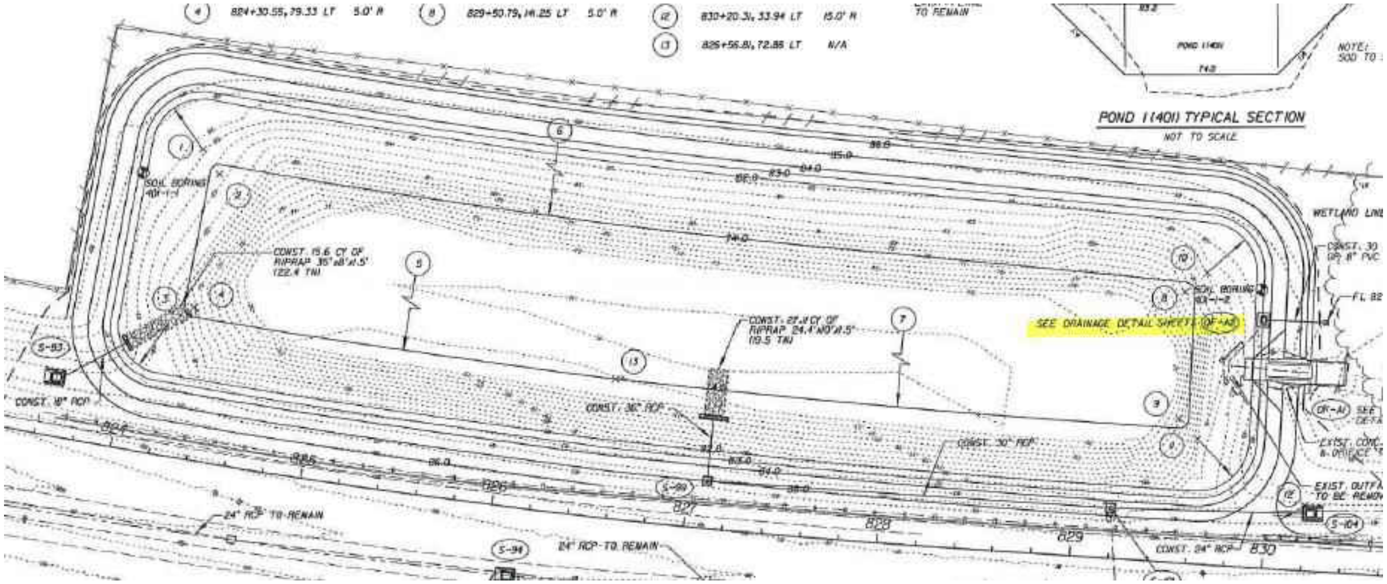
E4: Roadway 4 - North



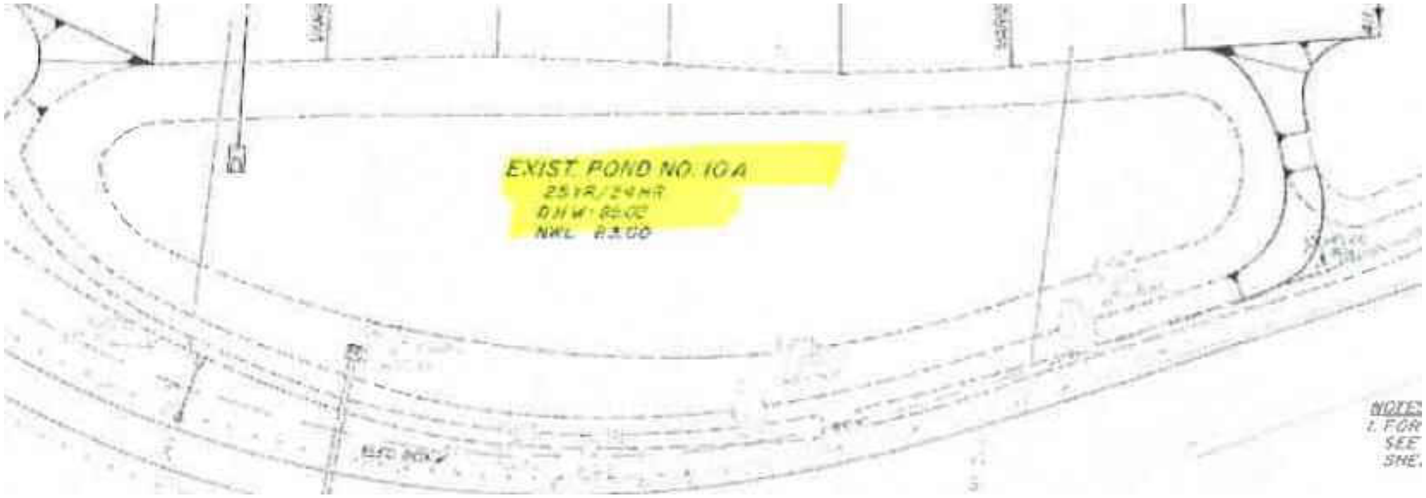
E5: Roadway 1 - South



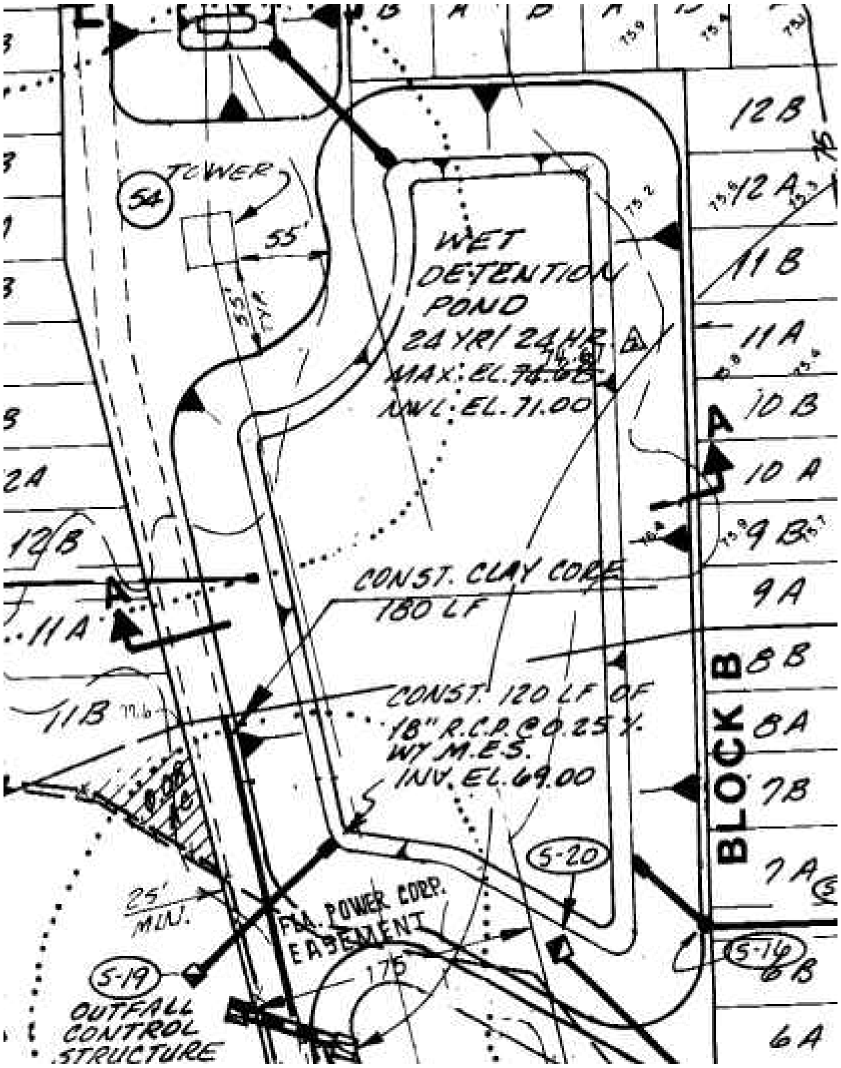
E6: Roadway 2 - South



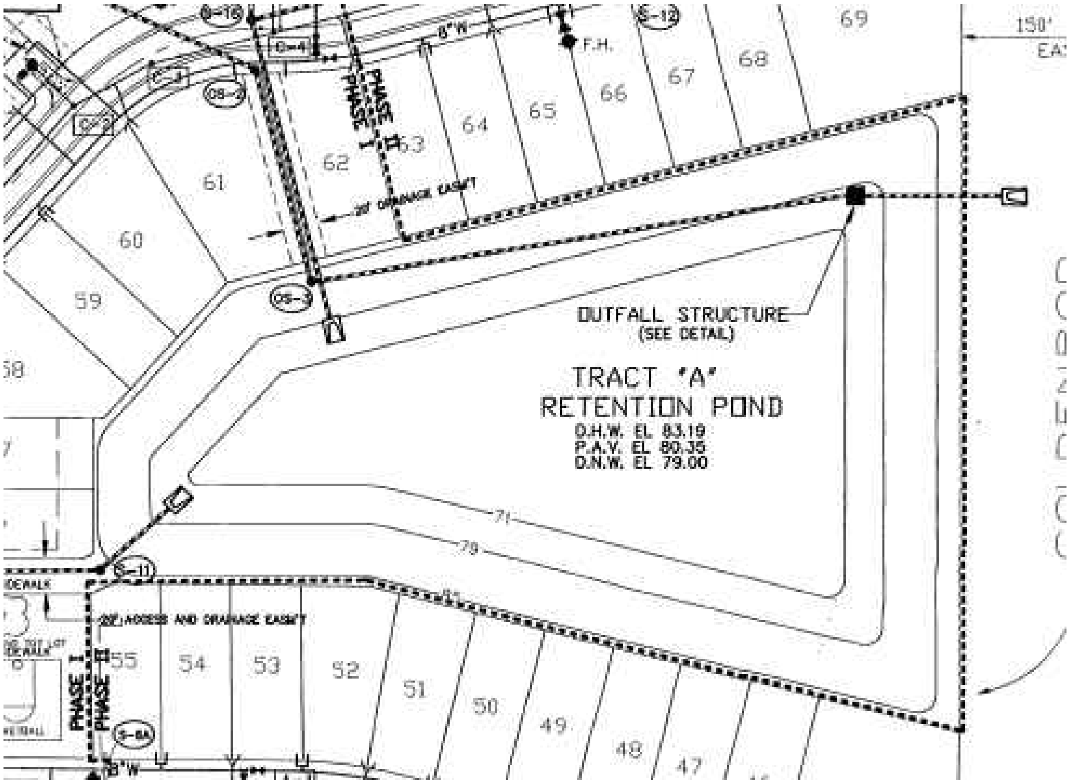
E7: Roadway 3 - South



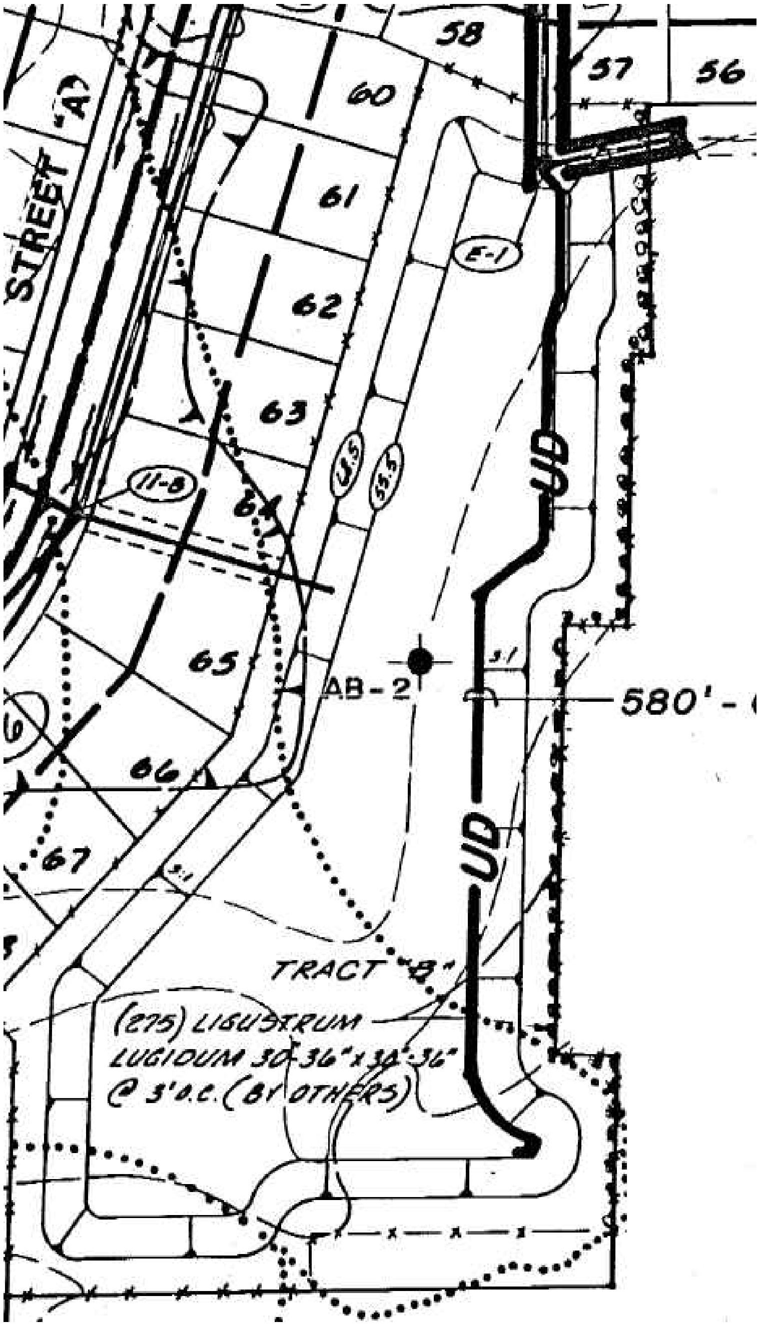
R1: The Islands of Valencia



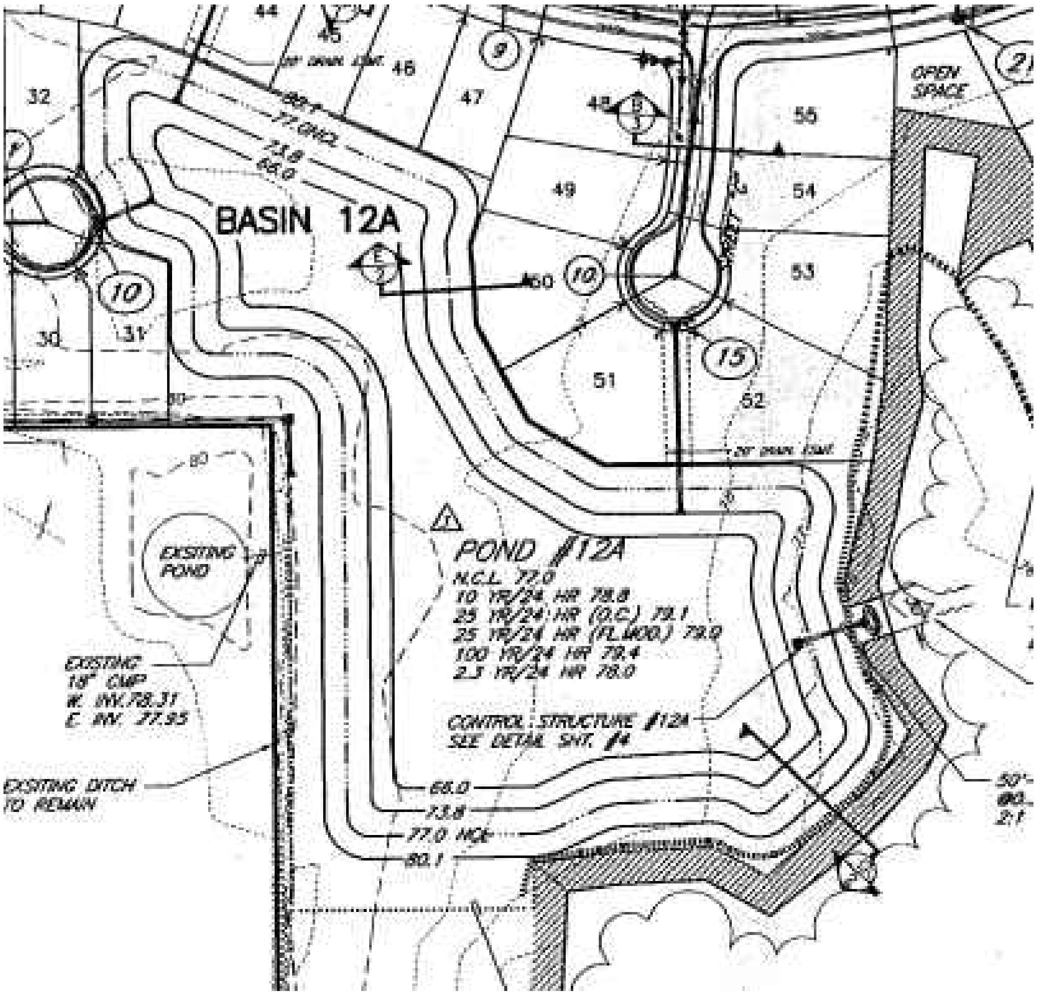
R2: Eban's Preserve



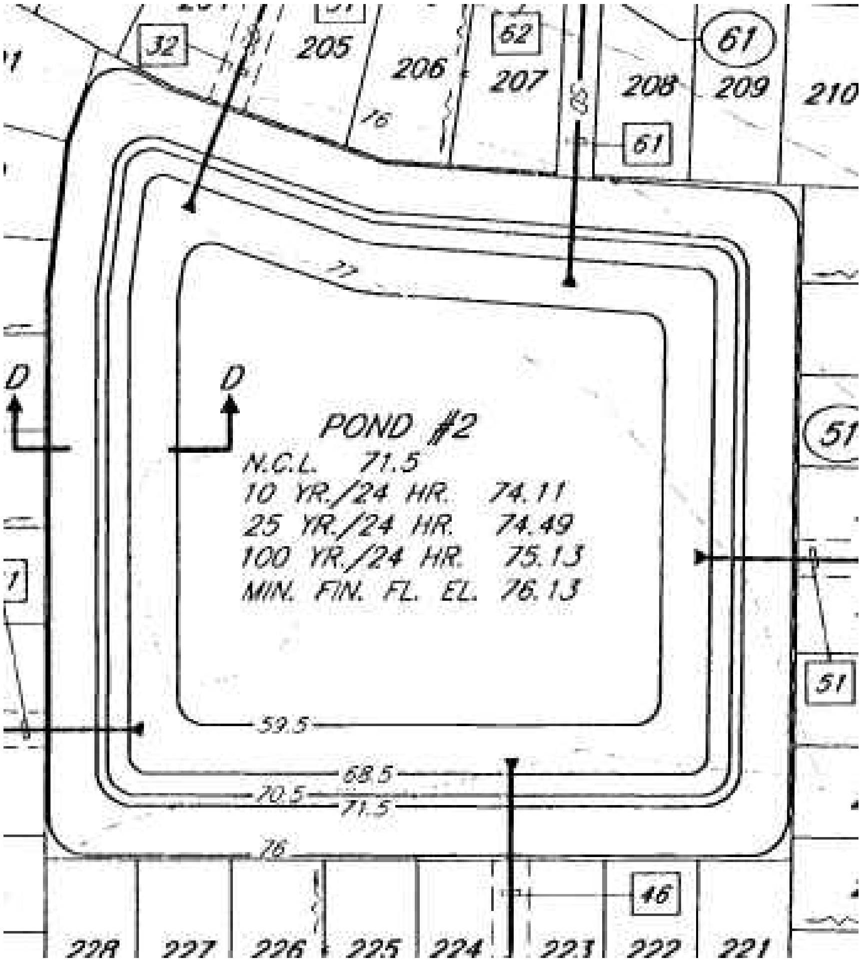
R3: Sturbridge



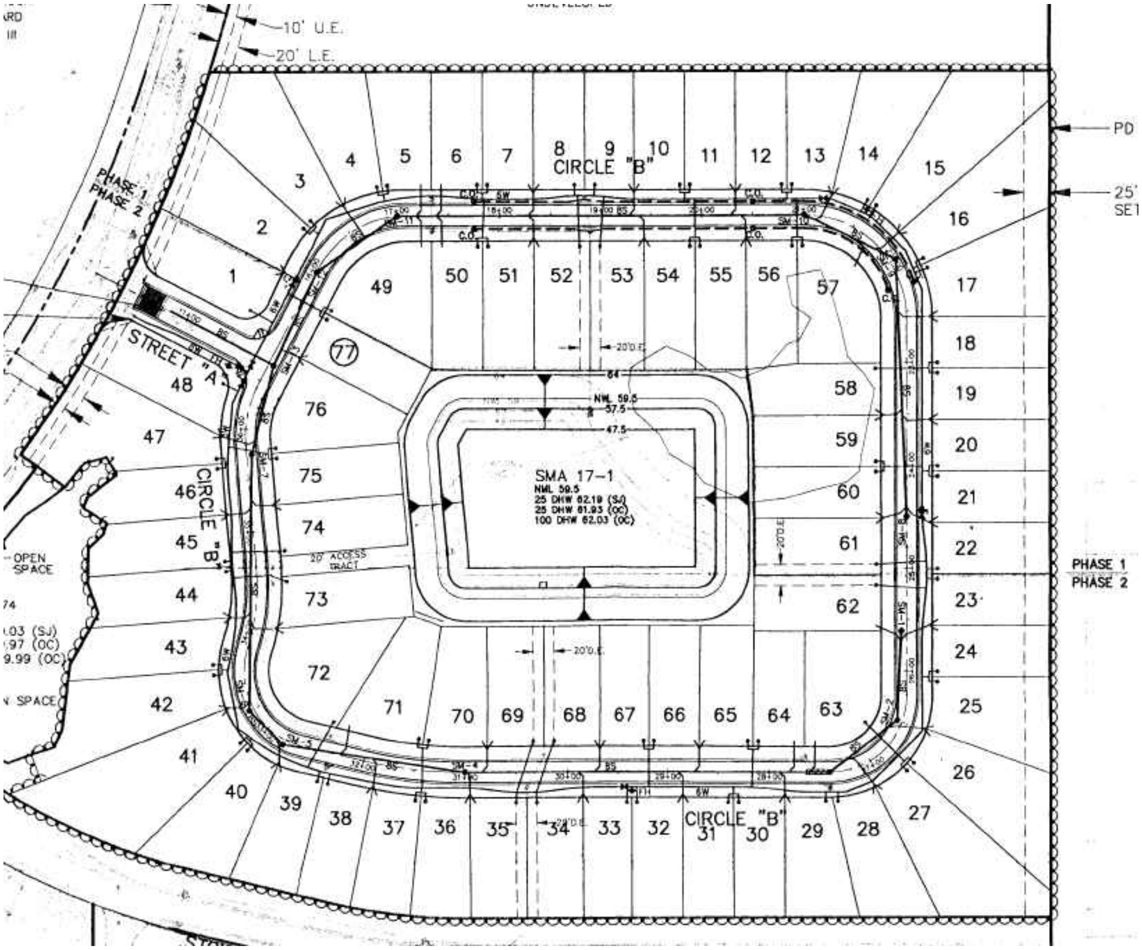
R5: Stonewood Estates



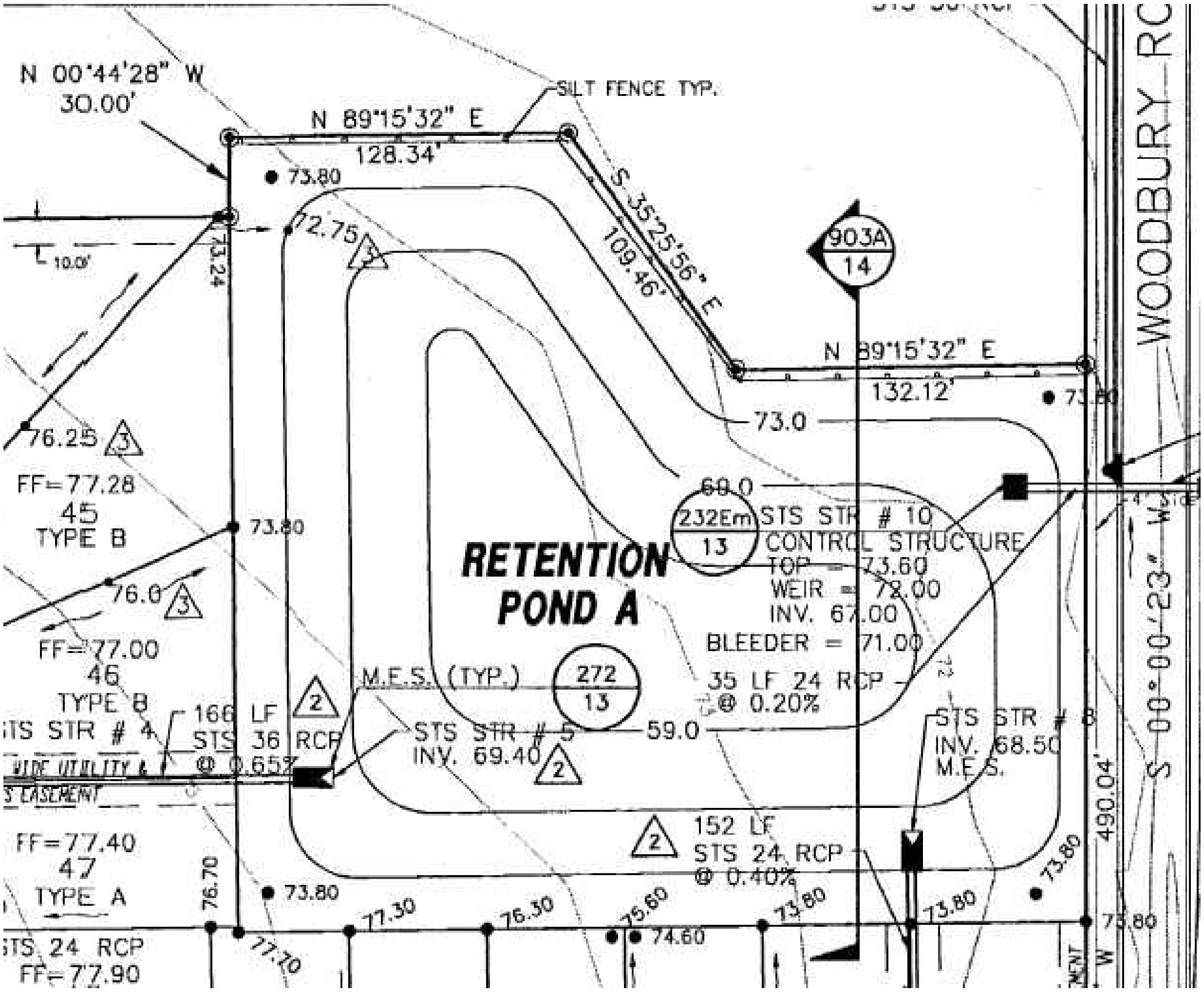
R6: Curry Ford East



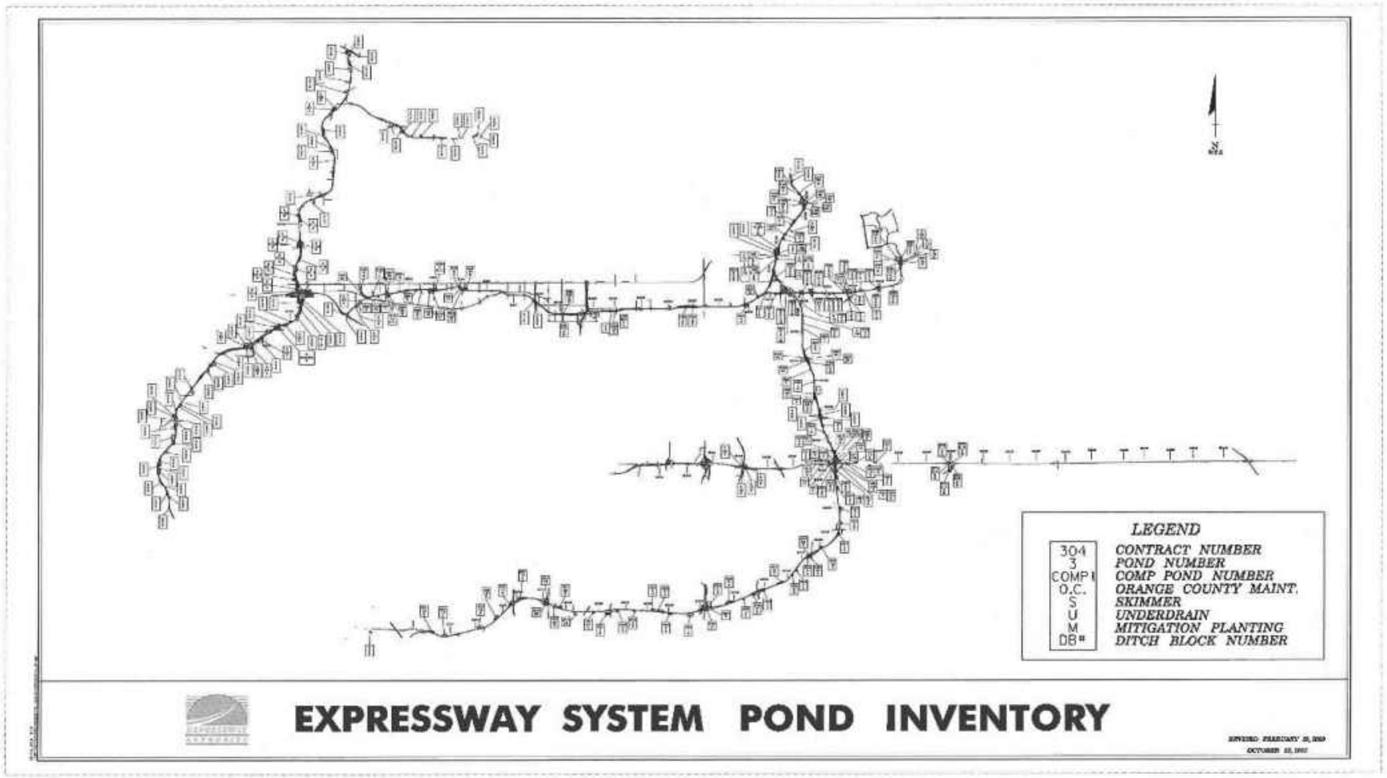
R7: Stoneybrook Golf



R8: Woodbury Glen



APPENDIX B:
EXPRESSWAY PONDS



EXPRESSWAY SYSTEM POND INVENTORY

APPENDIX C:
SITE APPROVAL LETTERS

RIGHT OF ENTRY AGREEMENT

This **RIGHT OF ENTRY AGREEMENT** ("Agreement") is made and entered into on this 9th day of September, 2014, by and **between ORLANDO-ORANGE COUNTY EXPRESSWAY AUTHORITY,** a body politic and corporate and an agency of the State of Florida ("Authority"), and the University of Central Florida ~~Landscape & Natural Resources College~~, by its Board of Trustees, (UCF) whose mailing address is P.O. Box 163600, Orlando, Florida 32816.

RECITALS:

Whereas, Authority is the fee simple owner of certain real property located in Orange County, Florida, more particularly multiple stormwater facilities throughout the entire Authority Limited-Access Right-of-Way ("Property"), and has obtained state approval for such ponds; and

Whereas, UCF has plans to conduct physical measurement of various parameters, pursuant to the attached letter hereto and incorporated herein by reference ("Project"); and

Whereas, UCF desires to enter upon Property in order to collect samples and access conditions for the Project; and

Whereas, UCF has requested, and Authority has agreed to grant to UCF, a temporary non-exclusive right of entry to enter upon the Property to commence such work:

NOW, THEREFORE, in consideration of the above-stated premises, and other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged, the Authority and UCF hereby agree as follows:

1. The above recitals are true and correct and are incorporated herein by reference.

2. Authority hereby authorizes UCF and/or its employees, agents, consulting engineers, contractors and other representatives to enter upon the Property for the sole purpose of ~~constructing~~ conducting the Project.

3. Only to the extent and in the manner provided for in Florida law (Fla. Stat. §768.28), UCF shall indemnify, defend and hold Authority harmless and shall cause UCF's contractors to indemnify, defend and hold Authority harmless from and against any and all costs, expenses, fines, fees, penalties, claims, suits or proceedings (including attorneys' fees at the trial or appellate level), demands, liabilities, damages, injuries (including death) arising from their respective use or work performed on or about the Property or in connection with the Project, excepting only those claims arising from the ~~sole~~ negligence of the Authority, its officials, agents, contractors or assigns. Nothing contained herein shall constitute a waiver of UCF's sovereign immunity or serve as a consent to suit.

4. This Right of Entry will expire upon the earlier to occur of: (1) completion of the Project; or (3) three years from the date first written above.

5. Nothing contained in this Agreement shall be construed as a waiver or attempt at a waiver by the Authority of its sovereign immunity under the Constitution and laws of the State of Florida.

6. The Parties agree that neither this Agreement nor any memorandum or notice of the same shall be recorded in the Public Records of Orange County, Florida or any other County in the State of Florida.

7. UCF shall contact Steve Geiss at 407-690-5335 for scheduling at least 72 hours in advance of the proposed work.

8. Data collected will not identify individual sites.

9. UCF will provide the Authority with a draft report before sharing publicly. The Authority shall have the right to exclude data that may result in water quality monitoring from state or federal regulatory agencies.

IN WITNESS HEREOF, Authority and UCF have executed and delivered this Right of Entry Agreement the date herein first written above.

WITNESSES:

Darleen Mazzillo
Witness: Darleen Mazzillo

Paola Lamaute
Witness: Leigh Lamaute

"AUTHORITY"

ORLANDO-ORANGE COUNTY EXPRESSWAY AUTHORITY, a public corporation under the laws of the State of Florida

By: Joseph A Berenis
Name: Joseph Berenis
Title: Deputy Exe. Dir.

APPROVED AS TO FORM FOR
EXECUTION BY A SIGNATORY OF
THE ORLANDO-ORANGE COUNTY
EXPRESSWAY AUTHORITY

By: Joseph L. Passiatore
Joseph L. Passiatore, General Counsel
Date: 6/3/14

WITNESSES:

Attest:
Name: Patrick Bohlen
Title: Professor
Date: 9-9-2014

Witness:________________

University of Central Florida
UCF

By:
Name: Michael D. Johnson
Title: Dean
Date: 9-9-2014

Approved as to Form and Legality
✓CC 9/5/14
-subject to changes noted

Orange County Public Schools

445 West Amelia Street • Orlando, FL 32801-1129 • Phone 407.317.3200 • www.ocps.net

Notice of Approval

Approval Date: 5/15/15 Approval Number: **0015**

Project Title: The Influence of Different Urban Land Uses on Water Quality and Management of Stormwater Ponds

Requester: Lindsay Skovira

Project Director/Advisor: Dr. Patrick Bohlen

Sponsor Agency/Institutional Affiliation: University of Central Florida

Thank you for your request to conduct research in Orange County Public Schools. We have reviewed and approved your application. This Notice of Approval expires one year after issue, 5/14/16 .

If you are interacting with OCPS staff or students, you should have submitted a Principal Notification Form with your application. You may now email the principals who have indicated interest in participating, including this Notice as an attachment. After initial contact with principals, you may then email any necessary staff. This notice does not obligate administrators, teachers, students, or families of students to participate in your study; participation is entirely voluntary.

OCPS badges are required to enter any OCPS campus or building (see the Security Clearance Flow Chart).

You are responsible for submitting a Change Request Form to this office prior to implementing any changes to the currently approved protocol. If any problems or unexpected adverse reactions occur as a result of this study, you must notify this office immediately by emailing a completed Adverse Event Report Form. On or before 4/14/16 , you must complete a Request for Renewal or Executive Summary Submission. Email all forms to research@ocps.net. All forms may be found at www.ocps.net/cs/services/accountability/Pages/Research.aspx.

Should you have questions or need assistance, please contact Mary Ann White at (407) 317-3201 or mary.white@ocps.net.

Best wishes for continued success,

Tavy Chen, Ed.D.
tavy.chen@ocps.net
Director, Accountability and Research
Orange County Public Schools

Cc: Brandon McKelvey, Senior Director, brandon.mckelvey@ocps.net

"The Orange County School Board is an equal opportunity agency."

APPENDIX D:
POND AGE AND SIZE

Name	**Age (years)**	**Size (hectares)**
S1: Stone Lakes Elementary	17	0.356 (0.433)
S2: Discovery Middle	23	1.11
S3: East River High	8	1.41
S4: University High	25	0.951
S5: Odyssey Middle	16	1.43
S6: Avalon Elementary	11	0.656
S7: Corner Lake Middle	20	0.534
S8: Lake George Elementary	18	0.696
R1: The Islands of Valencia	20	0.996
R2: Eban's Preserve	20	0.676
R3: Sturbridge	27	0.874
R4: Shannon Trace	NA	0.457
R5: Stonewood Estates	18	1.36
R6: Curry Ford	22	1.02
R7: Stoneybrook	16	0.583
R8: Woodbury Glen	23	0.469
E1: Roadway 1-North	29	1.71
E2: Roadway 2-North	15	0.898
E3: Roadway 3-North	NA	1.83
E4: Roadway 4-North	27	0.627
E5: Roadway 1-South	28	1
E6: Roadway 2-South	28	0.724
E7: Roadway 3-South	28	0.583
E8: Roadway 4-South	NA	0.712

APPENDIX E:
MANAGEMENT SURVEY

UCF Thesis Research
Management Stormwater Survey (V3)

Hello, my name is Lindsay Skovira. I'm a graduate student at the University of Central Florida collecting information on urban land management practices to assist a research study. The research project focuses on the impacts of urban land use on the water quality and management of stormwater ponds. This is strictly for educational purposes. This survey is completely voluntary and confidential. The survey is very short – it only takes about 10 minutes.

Questions

1) Who manages the stormwater ponds?

2) What are the major areas of concerns in this pond (e.g. algae growth, vegetation control, litter, other)?
    a. How would you rate the severity of each of the following maintenance concerns on a scale of 1 to 5?
        i. Vegetation overgrowth

        ii. Algal growth

        iii. Litter

        iv. Sediment build-up/erosion

        v. Drain clogging

3) How are the stormwater ponds managed for algae or vegetation control (i.e. mechanical, chemical, etc.)?

    a. If chemical, what types of chemicals are used and how often are they applied?

    b. If mechanical, how often is mechanical treatment applied?

4) How do you establish targets for level of control or management you apply to this pond (HOA requirements, institutional policy or procedures, other)?

5) Do you do any types of water monitoring in the ponds, such as for pH, conductivity, nutrient concentrations?

6) Is there anything else you would like to add about maintenance practices in this pond?

APPENDIX F:
VEGETATION SPECIES LIST

Species Name	Common Name	Expressway	Residential	Schools
Aeschynomene indica	india joint vetch	X	X	X
Alternanthera philoxeroides	alligator weed	X	X	X
Ambrosia		X		
Amphicaroum muehlenbergianum	blue maidencane	X	X	
Andropogon virginicus	broomsedge bluestem	X	X	
Annona reticulata	water spangles			X
Axonopus compressus	pearl grass			X
Bacopa caroliniana	bacopa caroliniana*	X	X	X
Bacopa monnieri	bacopa monnieri	X		X
Bidens alba	shepherd's needle	X		X
Butomus umbellatus	lake rush		X	
Cabomba caroliniana fanwort	fanwort	X		
Centella asiatica	spadeleaf	X	X	X
Commelina communis	dayflower		X	X
Commelina diffusa	climbing dayflower		X	
Cupressaceae	cypress	x		X
Diodia virginiana	virginia buttonweed		X	
Eleocharis	spikerush		X	
Eleocharis baldwinii	baldwins spikerush		X	X
Eleocharis cellulosa	gulf coast spikerush	X		
Eleocharis interstincta	knotted spikerush		X	X
Eleocharis obtusa	blunt spikerush			X
Eleocharis parvula	dwarf spikerush		X	X
Emilia fosbergii	Florida red tasselflower	X	X	X
Erigeron strigosus	prairie flearane			X
Hemianthus glomeratus	hemianthus glomeratum			X
Hydrilla verticillata	hydrilla	X		X

Hydrocotyle	hydrocotyle	X	X	X
Imperata cylindrica	cogon grass			X
Indigofera hirsuta	hairy indigo	X		
Lemna valdiviana	duckweed		X	
Ludwigia	ludwigia	X		
Ludwigia arcuata	piedmont primrose			X
Ludwigia repens	creeping primrose willow	X		X
Luziola fluitans	luziola	X	X	X
Micranthemum glomeratum	micranthemum glomeratum	X	X	X
Mikania scandens	climbing hempvine		X	X
Myrica cerifera	wax myrtyle	X		X
Nitella	nitella		X	X
Nuphar advena	spatterdock			X
Nymphaea alba	white waterlily	X		
Oenothera speciosa	mexican primrose			X
Pancium repens	torpedo grass	X	X	X
Persicaria maculosa	ladys thumb smartweed	X		X
Poaceae	grass	X	X	X
Pontederia	pickerelweed			X
Sabal palmetto	cabbage palm	X		X
Sagittaria lancifolia	bulltongue arrowhead		X	X
Sagittaria latifolia	arrowhead	X	X	
Sesbania drummondii	rattle-bushes			X
Typha	cattail	X		X
Xyris platylepsis	tall yellow eyed grass		X	X

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