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re:	**PRELIMINARY EVALUATION OF WET DETENTION POND LAND AREA REQUIREMENTS** When Conventional Wet Detention Ponds Are Used As Sole BMP for Stormwater Quality Treatment (85% Post-development Phosphorus Reduction Criteria)	
date:	September 20, 2009 (revised)	
from:	Devo Seereeram, TAC Member	

This memo provides a quantitative assessment of typical wet detention pond footprint area requirements based on the proposed stormwater quality treatment criteria which requires at least 85% reduction of the annualized post-development phosphorus load.

The current rule of thumb for design practitioners is to allocate 12 to 15% of the development area for a typical pine flatwood project (poorly drained soils) which rely on conventional wet detention ponds.

First note that an annual residence time of 329 days provides an 85% reduction of phosphorus load based on the chart published in the Applicant's Handbook. This is independent of land use.

The water surface footprint area of a wet detention pond is controlled by the more restrictive of the following two (2) design criteria:

❶ the area required to provide the permanent pool volume, at a depth less than or equal to the anoxic depth (to achieve a residence time of 329 days); and

❷ the area required to provide the bleed-down volume, at a height less than or equal to 1.5 ft above the normal water level (with the bleed-down volume being 1 inch of runoff over the contributing basin area).

In addition to the above requirements, civil engineers frequently size wet pond volumes to match the fill needs for raising site grades.

As an aside, in chained ponds, it is better (in terms of maximizing overall efficiency) to use a single large wet pond at the end of the chain instead of using a series of smaller wet ponds. A single large pond will provide the full detention time for all basins.

The following examples calculate the required areas for wet ponds systems to achieve 85% phosphorous removal efficiency for a range of development conditions and locations. The examples in this memo use similar basin parameters (DCIA and Curve Number) and land use as those used in the calculations by England, Thims and Miller, Inc.

The calculations in this memo are based only on the nutrient removal criteria, and do not consider the bleed-down volume requirement. The mean area to provide the bleed-down volume for these examples equates to roughly 5.56 acres (1 inch of runoff over 100 acres = 8.33 ac-ft, divided by a depth of 1.5 ft). For the majority of these examples, the nutrient removal criteria will control (with the exception of some of the low intensity residential development scenarios for which bleed-down criteria will control).

General Assumptions

- The runoff producing area (i.e., developable area) was held constant at 100 acres.
- A wet pond residence time of 329 days was used (85% phosphorous removal).
- A pond length to width ratio of 2 was assumed.
- A pond slope of 4 to 1 was assumed between the top of bank (4 ft above the normal water level) to the slope break point (2 ft below the normal water level)
- A pond slope of 2 to 1 was assumed between the slope break point and the bottom of the pond.
- A maintenance buffer width of 15 ft was assumed around the pond.
- The total area of the wet pond system includes: the area to provide the required permanent pool volume (for the given side slope assumption) plus the area to the top of the side slopes and the maintenance buffer area.
- A variety of postdevelopment land uses were considered: low density residential, single family, multi-family and high intensity commercial
- Curve numbers and DCIA were taken from the sample calculations by England, Thims and Miller, for hydrologic soils groups A and D (bracketing best and worst conditions), as shown in Table 1 below.
- A representative city in each climate zone, with an annual rainfall appropriate for each city
- An anoxic depth reduction factor of 1.0 (no reduction) and 0.75

Table 1. Curve Numbers and DCIA

Land Use	Type A Soils		Type D Soils	
	Curve Number		Curve Number	DCIA (%)
Low Density Residential	43.8	7.5	81.5	7.5
Single Family	48.4	22.8	82.9	22.8
Multi Family	68.1	66.4	88.9	66.4
High Intensity Commercial	66.9	81	88.5	81

Results

Table 2 below summarizes the percentage of the total site area occupied by the wet pond system (including side slopes and buffer) for Type A soils. Calculation details for type A soils are listed in the Calculation Details section at the end of the memo.

Table 2. Percentage of Site Area for Wet Pond System For Type A Soils					
Anoxic Depth Reduction Factor = 1.0					
Land Use	Pensacola (%)	Orlando (%)	Key West (%)	Tampa (%)	Miami (%)
Low Density Residential	3.63	2.73	2.56	2.91	3.38
Single Family	8.88	6.77	5.87	7.08	7.97
Multi Family	22.02	17.36	14.64	17.94	19.64
High Intensity Commercial	21.61	17.17	14.40	17.68	19.24
Anoxic Depth Reduction Factor = 0.75					
Land Use	Pensacola	Orlando (%)	Key West (%)	Tampa (%)	Miami (%)
Low Density Residential	4.26	3.15	2.94	3.38	3.95
Single Family	10.85	8.24	7.11	8.62	9.73
Multi Family	26.67	21.21	17.94	21.89	23.89
High Intensity Commercial	26.11	20.90	17.59	21.50	23.35

Note that Table 2 above does not consider the bleed-down volume requirement. The bleed-down criteria may control pond size for some of the smaller pond sizes (such as those for low density residential land use).

Table 3 below summarizes the percentage of the total site area occupied by the wet pond system (including side slopes and buffer) for Type D soils. Calculation details for type D soils are listed in the Calculation Details section at the end of the memo.

Table 3. Percentage of Site Area for Wet Pond System For Type D Soils					
Anoxic Depth Reduction Factor = 1.0					
Land Use	Pensacola (%)	Orlando (%)	Key West (%)	Tampa (%)	Miami (%)
Low Density Residential	7.73	5.25	4.77	5.75	6.88
Single Family	12.54	9.04	7.84	9.64	11.09
Multi Family	23.82	18.68	15.72	19.34	21.18
High Intensity Commercial	22.46	17.77	14.91	18.33	19.97
Anoxic Depth Reduction Factor = 0.75					
Land Use	Pensacola (%)	Orlando (%)	Key West (%)	Tampa (%)	Miami (%)
Low Density Residential	9.32	6.27	5.66	6.88	8.28
Single Family	15.33	11.26	9.73	12.00	13.84
Multi Family	28.75	22.77	19.25	23.54	25.70
High Intensity Commercial	27.10	21.62	18.20	22.28	24.21

Note that Table 3 above does not consider the bleed-down volume requirement. The bleed-down criteria may control pond size for some of the smaller pond sizes (such as those for low density residential land use).

Based on these example problems, the following should be noted:

① There is a penalty of approximately 20% to 30% on the resulting wet pond area as a result of using an anoxic depth reduction factor of 0.75 versus using the full anoxic depth when calculating the required wet pond area, with the higher end of this range associated with more intense land use (such as multi family and high intensity commercial, in both Type A and Type D soils) and the lower end of the range associated with low intensity land use (low density residential in Type A soils).

② The area of the wet ponds is proportional to the annual rainfall depth, as opposed to rainfall distribution (i.e. climate zone). It has been previously noted that for dry ponds, the required dry pond retention depth is sensitive to the rainfall distribution. For example, a dry pond in Key West will require a greater dry retention depth than a dry pond in Orlando even though there is less rainfall in Key West, because the rainfall distribution in Key West is more heavily weighted towards storms of higher intensity. The opposite is true for a wet pond, where annual rainfall (or annual runoff volume) appears to control the wet pond size.

③ The calculated anoxic depth for these large ponds, particularly for the land uses with lower phosphorous concentration (such as the low density residential), is greater than we have previously considered. Exhibit 1 shows the relationship between residence time and anoxic depth for the land uses in this example, as well as for "clean water" (very low phosphorous concentration). Exhibit 1 assumes 100 acres producing runoff and rainfall conditions for Pensacola.

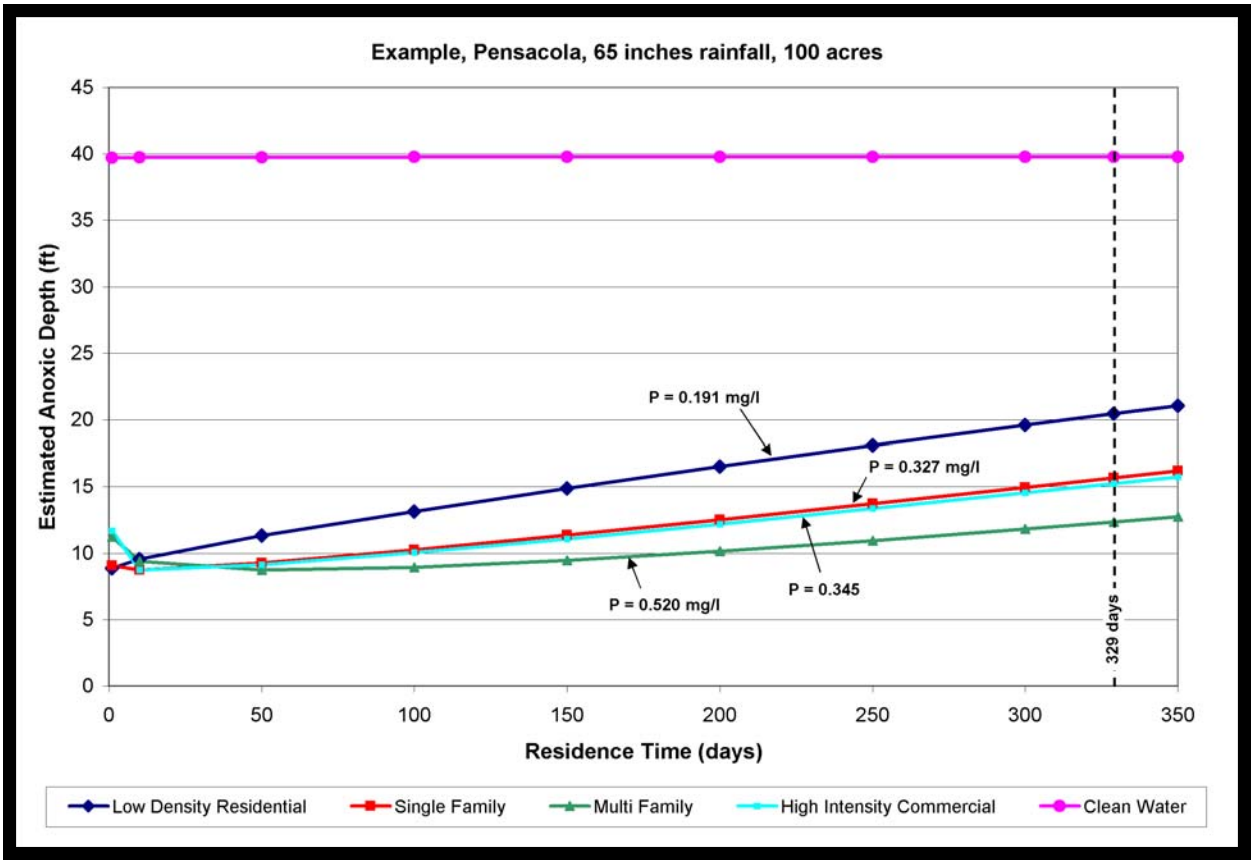

Exhibit 1. Residence Time vs Anoxic Depth

As seen in Exhibit 1, the anoxic depth based on the calculation steps presented in the design methodology appears to have a limiting depth (for clean water) of about 40 ft, and for stormwater runoff the anoxic depth generally increases as the pond size (residence time) increases. For a low density residential development with a residence time of 329 days, the calculated anoxic depth is about 20.5 ft deep (deeper than we had expected based on scenarios we had previously considered).

Based on this result, it appears that the following issues deserve further consideration:

- The validity and/or limitations of the anoxic depth calculations in the design methodology should be verified, including whether they are appropriate for long residence times. If they are valid, the increased anoxic depths will help reduce pond sizes, but if they are not valid then appropriate limitations may need to be applied.
- If there is a real-world depth limit for anoxic depth for conditions in Florida, it should explicitly enter into the calculation for the anoxic depth to avoid calculating unrealistic anoxic depths.
- If there is a real-world anoxic depth limit, then it might be more appropriate to use this limit as opposed to an arbitrary reduction factor, since even with a reduction factor the resulting calculated anoxic depth might exceed the real-world depth.

These issues need to be considered, since the anoxic depth will have an impact on sizing the wet ponds.

Also note that the examples in this memo are based on the calculated anoxic depth (with and without an anoxic depth reduction factor of 0.75). Imposing a maximum anoxic depth, for example, would obviously have an impact on the resulting areas calculated in this memo.

Calculation Details
Type A Soils

Table 4.1. A Soils, Required Wet Pond Areas for Low Density Residential Land Use					
Postdevelopment Land Use	Low Density Residential				
Hydrologic Soils Group	A				
DCIA %	7.5				
non-DCIA Curve Number	43.8				
Phosphorous Concentration in Runoff (mg/l)	0.179				
City	Pensacola	Orlando	Key West	Tampa	Miami
Climate Zone	1	2	3	4	5
Annual Rainfall (inches)	65	50	40	51	58
Runoff Producing Area (acres)	100.00	100.00	100.00	100.00	100.00
Annual Runoff Volume (ac-ft)	43.97	28.87	26.23	31.84	39.60
Required Permanent Pool Volume (ac-ft)	39.64	26.02	23.64	28.70	35.70
Anoxic Depth Reduction Factor = 1.0					
Anoxic Depth (ft) x 1.0	20.45	20.45	20.45	20.45	20.45
Approximate Surface Area of Pond at NWL (acres)	2.66	1.86	1.72	2.02	2.43
Approximate Total Area of Stormwater System (acres)	3.77	2.81	2.63	3.00	3.50
Total Site Area (acres)	103.77	102.81	102.63	103.00	103.50
Percentage of Total Area for Wet Pond (%)	3.63	2.73	2.56	2.91	3.38
Anoxic Depth Reduction Factor = 0.75					
Anoxic Depth (ft) x 0.75	15.34	15.34	15.34	15.34	15.34
Approximate Surface Area of Pond at NWL (acres)	3.23	2.22	2.04	2.42	2.94
Approximate Total Area of Stormwater System (acres)	4.45	3.25	3.03	3.49	4.11
Total Site Area (acres)	104.45	103.25	103.03	103.49	104.11
Percentage of Total Area for Wet Pond (%)	4.26	3.15	2.94	3.38	3.95
Increase in pond area from 1.0 to 0.75 multiplier (%)	21.66	19.69	19.22	20.17	21.19

Table 4.2. A Soils, Required Wet Pond Areas for Single Family Land Use					
Postdevelopment Land Use	Single Family Development				
Hydrologic Soils Group	A				
DCIA %	22.8				
non-DCIA Curve Number	48.4				
Phosphorous Concentration in Runoff (mg/l)	0.327				
City	Pensacola	Orlando	Key West	Tampa	Miami
Climate Zone	1	2	3	4	5
Annual Rainfall (inches)	65	50	40	51	58
Runoff Producing Area (acres)	100.00	100.00	100.00	100.00	100.00
Annual Runoff Volume (ac-ft)	115.86	81.30	67.23	86.19	100.64
Required Permanent Pool Volume (ac-ft)	104.43	73.28	60.60	77.69	90.71
Anoxic Depth Reduction Factor = 1.0					
Anoxic Depth (ft) x 1.0	15.24	15.24	15.24	15.24	15.24
Approximate Surface Area of Pond at NWL (acres)	7.89	5.68	4.77	5.99	6.92
Approximate Total Area of Stormwater System (acres)	9.74	7.27	6.23	7.62	8.66
Total Site Area (acres)	109.74	107.27	106.23	107.62	108.66
Percentage of Total Area for Wet Pond (%)	8.88	6.77	5.87	7.08	7.97
Anoxic Depth Reduction Factor = 0.75					
Anoxic Depth (ft) x 0.75	11.43	11.43	11.43	11.43	11.43
Approximate Surface Area of Pond at NWL (acres)	10.08	7.20	6.02	7.61	8.82
Approximate Total Area of Stormwater System (acres)	12.17	8.98	7.66	9.44	10.78
Total Site Area (acres)	112.17	108.98	107.66	109.44	110.78
Percentage of Total Area for Wet Pond (%)	10.85	8.24	7.11	8.62	9.73
Increase in pond area from 1.0 to 0.75 multiplier (%)	24.89	23.62	22.88	23.84	24.40

Table 4.3. A Soils, Required Wet Pond Areas for Multi Family Land Use					
Postdevelopment Land Use	Multi Family Development				
Hydrologic Soils Group	A				
DCIA %	66.4				
non-DCIA Curve Number	68.1				
Phosphorous Concentration in Runoff (mg/l)	0.520				
City	Pensacola	Orlando	Key West	Tampa	Miami
Climate Zone	1	2	3	4	5
Annual Rainfall (inches)	65	50	40	51	58
Runoff Producing Area (acres)	100.00	100.00	100.00	100.00	100.00
Annual Runoff Volume (ac-ft)	320.51	231.14	183.97	241.55	273.34
Required Permanent Pool Volume (ac-ft)	288.90	208.34	165.82	217.73	246.38
Anoxic Depth Reduction Factor = 1.0					
Anoxic Depth (ft) x 1.0	12.34	12.34	12.34	12.34	12.34
Approximate Surface Area of Pond at NWL (acres)	25.00	18.23	14.64	19.02	21.43
Approximate Total Area of Stormwater System (acres)	28.24	21.01	17.14	21.86	24.44
Total Site Area (acres)	128.24	121.01	117.14	121.86	124.44
Percentage of Total Area for Wet Pond (%)	22.02	17.36	14.64	17.94	19.64
Anoxic Depth Reduction Factor = 0.75					
Anoxic Depth (ft) x 0.75	9.26	9.26	9.26	9.26	9.26
Approximate Surface Area of Pond at NWL (acres)	32.67	23.75	19.03	24.79	27.97
Approximate Total Area of Stormwater System (acres)	36.36	26.91	21.86	28.02	31.39
Total Site Area (acres)	136.36	126.91	121.86	128.02	131.39
Percentage of Total Area for Wet Pond (%)	26.67	21.21	17.94	21.89	23.89
Increase in pond area from 1.0 to 0.75 multiplier (%)	28.79	30.27	29.92	30.33	30.50

Table 4.4. A Soils. Required Wet Pond Areas for High Intensity Land Use					
Postdevelopment Land Use	High Intensity Commercial				
Hydrologic Soils Group	A				
DCIA %	81				
non-DCIA Curve Number	66.9				
Phosphorous Concentration in Runoff (mg/l)	0.345				
City	Pensacola	Orlando	Key West	Tampa	Miami
Climate Zone	1	2	3	4	5
Annual Rainfall (inches)	65	50	40	51	58
Runoff Producing Area (acres)	100.00	100.00	100.00	100.00	100.00
Annual Runoff Volume (ac-ft)	380.59	276.98	218.82	288.22	323.76
Required Permanent Pool Volume (ac-ft)	343.05	249.66	197.24	259.79	291.83
Anoxic Depth Reduction Factor = 1.0					
Anoxic Depth (ft) x 1.0	15.24	15.24	15.24	15.24	15.24
Approximate Surface Area of Pond at NWL (acres)	24.36	17.97	14.35	18.66	20.86
Approximate Total Area of Stormwater System (acres)	27.56	20.72	16.83	21.47	23.83
Total Site Area (acres)	127.56	120.72	116.83	121.47	123.83
Percentage of Total Area for Wet Pond (%)	21.61	17.17	14.40	17.68	19.24
Anoxic Depth Reduction Factor = 0.75					
Anoxic Depth (ft) x 0.75	11.43	11.43	11.43	11.43	11.43
Approximate Surface Area of Pond at NWL (acres)	31.71	23.29	18.55	24.21	27.10
Approximate Total Area of Stormwater System (acres)	35.34	26.42	21.35	27.39	30.46
Total Site Area (acres)	135.34	126.42	121.35	127.39	130.46
Percentage of Total Area for Wet Pond (%)	26.11	20.90	17.59	21.50	23.35
Increase in pond area from 1.0 to 0.75 multiplier (%)	28.24	29.64	29.21	29.71	29.90

Calculation Details
Type D Soils

Table 5.1. D Soils, Required Wet Pond Areas for Low Density Residential Land Use					
Postdevelopment Land Use	Low Density Residential				
Hydrologic Soils Group	D				
DCIA %	7.5				
non-DCIA Curve Number	81.5				
Phosphorous Concentration in Runoff (mg/l)	0.179				
City	Pensacola	Orlando	Key West	Tampa	Miami
Climate Zone	1	2	3	4	5
Annual Rainfall (inches)	65	50	40	51	58
Runoff Producing Area (acres)	100.00	100.00	100.00	100.00	100.00
Annual Runoff Volume (ac-ft)	124.23	73.75	64.47	83.47	106.36
Required Permanent Pool Volume (ac-ft)	111.98	66.48	58.11	75.24	95.87
Anoxic Depth Reduction Factor = 1.0					
Anoxic Depth (ft) x 1.0	20.45	20.45	20.45	20.45	20.45
Approximate Surface Area of Pond at NWL (acres)	6.66	4.17	3.70	4.66	5.79
Approximate Total Area of Stormwater System (acres)	8.38	5.55	5.00	6.10	7.39
Total Site Area (acres)	108.38	105.55	105.00	106.10	107.39
Percentage of Total Area for Wet Pond (%)	7.73	5.25	4.77	5.75	6.88
Anoxic Depth Reduction Factor = 0.75					
Anoxic Depth (ft) x 0.75	15.34	15.34	15.34	15.34	15.34
Approximate Surface Area of Pond at NWL (acres)	8.37	5.16	4.57	5.79	7.24
Approximate Total Area of Stormwater System (acres)	10.28	6.68	6.00	7.39	9.03
Total Site Area (acres)	110.28	106.68	106.00	107.39	109.03
Percentage of Total Area for Wet Pond (%)	9.32	6.27	5.66	6.88	8.28
Increase in pond area from 1.0 to 0.75 multiplier (%)	25.67	23.81	23.28	24.28	25.15

Table 5.2. D Soils, Required Wet Pond Areas for Single Family Land Use					
Postdevelopment Land Use	Single Family Development				
Hydrologic Soils Group	D				
DCIA %	22.8				
non-DCIA Curve Number	82.9				
Phosphorous Concentration in Runoff (mg/l)	0.327				
City	Pensacola	Orlando	Key West	Tampa	Miami
Climate Zone	1	2	3	4	5
Annual Rainfall (inches)	65	50	40	51	58
Runoff Producing Area (acres)	100.00	100.00	100.00	100.00	100.00
Annual Runoff Volume (ac-ft)	186.81	121.67	100.90	132.17	158.84
Required Permanent Pool Volume (ac-ft)	168.39	109.67	90.95	119.13	143.17
Anoxic Depth Reduction Factor = 1.0					
Anoxic Depth (ft) x 1.0	15.67	15.67	15.67	15.67	15.67
Approximate Surface Area of Pond at NWL (acres)	12.06	8.07	6.78	8.71	10.35
Approximate Total Area of Stormwater System (acres)	14.34	9.94	8.51	10.66	12.47
Total Site Area (acres)	114.34	109.94	108.51	110.66	112.47
Percentage of Total Area for Wet Pond (%)	12.54	9.04	7.84	9.64	11.09
Anoxic Depth Reduction Factor = 0.75					
Anoxic Depth (ft) x 0.75	11.75	11.75	11.75	11.75	11.75
Approximate Surface Area of Pond at NWL (acres)	15.53	10.30	8.63	11.15	13.29
Approximate Total Area of Stormwater System (acres)	18.10	12.42	10.57	13.34	15.68
Total Site Area (acres)	118.10	110.30	108.63	111.15	113.29
Percentage of Total Area for Wet Pond (%)	15.33	11.26	9.73	12.00	13.84
Increase in pond area from 1.0 to 0.75 multiplier (%)	26.23	24.86	24.20	25.14	25.73

Table 5.3. D Soils, Required Wet Pond Areas for Multi Family Land Use					
Postdevelopment Land Use	Multi Family Development				
Hydrologic Soils Group	D				
DCIA %	66.4				
non-DCIA Curve Number	88.9				
Phosphorous Concentration in Runoff (mg/l)	0.520				
City	Pensacola	Orlando	Key West	Tampa	Miami
Climate Zone	1	2	3	4	5
Annual Rainfall (inches)	65	50	40	51	58
Runoff Producing Area (acres)	100.00	100.00	100.00	100.00	100.00
Annual Runoff Volume (ac-ft)	358.49	255.29	202.34	267.63	303.60
Required Permanent Pool Volume (ac-ft)	323.13	230.11	182.38	241.23	273.66
Anoxic Depth Reduction Factor = 1.0					
Anoxic Depth (ft) x 1.0	12.34	12.34	12.34	12.34	12.34
Approximate Surface Area of Pond at NWL (acres)	27.86	20.07	16.04	21.00	23.72
Approximate Total Area of Stormwater System (acres)	31.28	22.98	18.66	23.98	26.88
Total Site Area (acres)	131.28	122.98	118.66	123.98	126.88
Percentage of Total Area for Wet Pond (%)	23.82	18.68	15.72	19.34	21.18
Anoxic Depth Reduction Factor = 0.75					
Anoxic Depth (ft) x 0.75	9.26	9.26	9.26	9.26	9.26
Approximate Surface Area of Pond at NWL (acres)	36.46	26.17	20.87	27.40	30.99
Approximate Total Area of Stormwater System (acres)	40.35	29.48	23.84	30.79	34.58
Total Site Area (acres)	140.35	129.48	123.84	130.79	134.58
Percentage of Total Area for Wet Pond (%)	28.75	22.77	19.25	23.54	25.70
Increase in pond area from 1.0 to 0.75 multiplier (%)	29.01	30.41	30.07	30.48	30.64

Table 5.4. D Soils. Required Wet Pond Areas for High Intensity Land Use					
Postdevelopment Land Use	High Intensity Commercial				
Hydrologic Soils Group	D				
DCIA %	81				
non-DCIA Curve Number	88.5				
Phosphorous Concentration in Runoff (mg/l)	0.345				
City	Pensacola	Orlando	Key West	Tampa	Miami
Climate Zone	1	2	3	4	5
Annual Rainfall (inches)	65	50	40	51	58
Runoff Producing Area (acres)	100.00	100.00	100.00	100.00	100.00
Annual Runoff Volume (ac-ft)	402.05	290.33	229.05	302.91	340.91
Required Permanent Pool Volume (ac-ft)	362.39	261.70	206.46	273.04	307.29
Anoxic Depth Reduction Factor = 1.0					
Anoxic Depth (ft) x 1.0	15.24	15.24	15.24	15.24	15.24
Approximate Surface Area of Pond at NWL (acres)	25.68	18.79	14.99	19.57	21.92
Approximate Total Area of Stormwater System (acres)	28.96	21.61	17.52	22.45	24.96
Total Site Area (acres)	128.96	121.61	117.52	122.45	124.96
Percentage of Total Area for Wet Pond (%)	22.46	17.77	14.91	18.33	19.97
Anoxic Depth Reduction Factor = 0.75					
Anoxic Depth (ft) x 0.75	11.43	11.43	11.43	11.43	11.43
Approximate Surface Area of Pond at NWL (acres)	33.45	24.38	19.38	25.40	28.49
Approximate Total Area of Stormwater System (acres)	37.18	27.58	22.24	28.67	31.94
Total Site Area (acres)	137.18	127.58	122.24	128.67	131.94
Percentage of Total Area for Wet Pond (%)	27.10	21.62	18.20	22.28	24.21
Increase in pond area from 1.0 to 0.75 multiplier (%)	28.36	29.72	29.30	29.79	29.98