Performance Efficiencies of Dry Detention and Underdrain Treatment Systems

Florida Stormwater Association
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Environmental Research & Design, Inc.
Discharge of stormwater in Florida has been subject to regulation since the early 1980’s.

Goals are outlined in Chapter 62-40 (FAC), titled “Water Resource Implementation Rule”
  - Stormwater design criteria shall achieve at least 80% reduction of average annual load of pollutants that cause or contribute to violations of State Water Quality Standards
  - If the discharge is to an OFW, the design and performance criteria increases to 95% reduction

The most commonly used stormwater management systems in Florida are:
  - Dry retention
  - Dry detention
  - Wet detention
Project History

During 2006-2007, ERD conducted a review of stormwater design criteria in Florida as part of the proposed Statewide Stormwater Rule

- Develop standard methods and regulations between WMDs
- Included a review of efficiencies for common Florida BMPs:
  - Dry retention – efficiency depends on volume retained
  - Wet detention – efficiency depends on residence time
  - Dry detention – efficiency highly variable

<table>
<thead>
<tr>
<th>Reference</th>
<th>Location</th>
<th>Study Site/ Land Use</th>
<th>Mean Removal Efficiencies (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td>Total N</td>
</tr>
<tr>
<td>Bradfordville Study</td>
<td>Leon County</td>
<td>Comm.</td>
<td>80</td>
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</table>

- ERD study recommended additional evaluations of the performance efficiencies of dry detention systems
In 2010 ERD was selected by FDEP to conduct an evaluation of the performance efficiency of dry detention ponds (SFWMD criteria) and underdrain filtration systems (SJRWMD criteria).

SFWMD and SJRWMD provided lists of project sites with permitted and inspected dry detention and underdrain filtration systems.
- Emphasized low intensity commercial (LIC) land use.

ERD visited each of the sites and evaluated site suitability for:
- Suitability for monitoring – types of inflows, weirs, tailwater impacts
- Site security

Developed a “short list” of suitable sites:
- Dry detention – 8 sites
- Underdrain filtration – 3 sites
Owners of “short list” sites were identified, and contacts were made to obtain permission to study the stormwater system

About half of the contacted owners were not interested
- Liability concerns
- Distrust/dislike for government
- Fear of enforcement if a problem was detected

Site access and permission to monitor dry detention ponds was granted by a “big box” retailer
- Multiple contracts were generated related to liability, site damage, and name disclosure
- 3 dry detention sites – all “big box” commercial projects

Site access and permission to monitor the underdrain filtration site was granted by Lynx
- 1 underdrain filtration site

Site selection process took 14 months
SFWMD water quality volume equal to 0.75-inch over the basin area

Discharges to OFWs and Impaired Waters must provide additional 50% treatment volume

Max discharge of 50% of treatment volume in 24-hours
Off-line water quality volume equal to 0.50-inch runoff or 1.25 inches over impervious area

On-line water quality volume additional 0.5 inch above off-line

Additional volume required for discharges to OFWs or Impaired Waters

Drawdown of treatment volume in 72-hours

Underdrain designed with safety factor of 2
Dry Detention and Underdrain Sites

- Pembroke Pines Dry Detention Site
- Naples Dry Detention Site
- Bonita Springs Dry Detention Site
- Orlando Underdrain Site
- Pembroke Pines Dry Detention Site
Characteristics of the Monitored Sites
Bonita Springs Dry Detention Pond Site
Bonita Springs Stormwater System

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Value</th>
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<tbody>
<tr>
<td>Project Area</td>
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<tr>
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<tr>
<td>Treatment Depth</td>
<td>Inches over basin</td>
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<tr>
<td>Year Constructed</td>
<td>-</td>
<td>2006</td>
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Bonita Springs Dry Detention Ponds

a. Inflow to Pond 1 from parking lot

b. Inflows to Pond 3

Inflow from Parking Area (54" RCP)

Inflow from Pond 1 (48" RCP)

Pond Outfall

c. Inflow to Pond 3 from Vacant Out-Parcel

d. Pond 3 Outfall Structure
Bonita Springs Dry Detention Pond Outfall

- GRT. EL. 9.0
- Pond Bottom – EL. 8.0
- 15" RCP INV. EL. 6.5
- 4"Ø ORIFICE INV. EL. 7.0
- 18" CMP BAFFLE BOT. EL. 6.9
- TYPE C INLET
Naples Dry Detention Site Overview
Naples Site Stormwater System

<table>
<thead>
<tr>
<th>Parameter</th>
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<td>Treatment Depth</td>
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<tr>
<td></td>
<td>over basin</td>
<td></td>
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<tr>
<td>Year Constructed</td>
<td>-</td>
<td>2006</td>
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Naples Dry Detention Ponds

a. Inflow to Pond 1 from parking lot (36" RCP)

b. Inflow to Pond 1 from parking lot (42" RCP)

c. Inflows to Pond 2

d. Pond 2 Outfall Structure
Pembroke Pines Site Stormwater System

Pond 1
(0.23 ac.)
Basin = 11.87 ac.

Pond 2
(0.45 ac.)
Basin = 2.58 ac.
## Pembroke Pines Site Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
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<tbody>
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Pembroke Pines Dry Detention Ponds

a. Inflow to Pond 1 from parking lot

b. Inflows to Pond 2

c. Dual outfall structures in Pond 2

d. Pond 2 under flooded conditions
Pembroke Pines Detention Pond Outfall

Diagram showing various components of the detention pond system, including:
- FLANGE W/ 2.7" Ø ORIFICE
- 3" Ø TEE W/ CAP ON TOP
- 12" FDOT STONE EL. 2.47
- 5' x 5' CONC. SLAB 4" THICK
- OPEN BOTTOM
- STEEL GRATE
- SOLID TOP
- GRT. EL. 6.21
- SKIMMER EL. 2.07
- INV. EL. -2.43
- SKIMMER EL. -2.93
- ½ SECTION 60" CMP SKIMMER
- BOT. EL. -4.64
Lynx Underdrain Site Overview
Lynx Site Stormwater System
## Orlando Underdrain Site Characteristics

<table>
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<td>Year Constructed</td>
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<td>2010</td>
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Lynx Underdrain Pond

a. Inflow to Pond 1 from parking lot

b. 18" RCP inflow to pond

c. 18" RCP inflow to pond

d. 15" RCP to pond from entrance roadway
Lynx Underdrain Pond

a. Underdrain cleanout structure

b. 18” RCP inflow to pond
Field Monitoring
Bonita Springs Monitoring Locations
Bonita Springs Monitoring Sites 1-3

Site 1 – Inflow to Pond 1 from parking lot

Site 1 – Pond 1 inflow monitoring equipment

Site 2 – Inflow

Site 3 – Inflow

Sites 2 & 3 – Inflows to Pond 3

Sites 2 & 3 – Inflows to Pond 3
Bonita Springs Monitoring Sites 4 & 5

Site 4 – Inflow to Pond 3 from Pond 2

Site 4 – Monitoring equipment

Site 5 – System Outfall to Canal

Site 5 – Monitoring Equipment
Schematic of aluminum V-notch structure used to measure pond inflows

Fabricated V-notch Weir
Naples Monitoring Locations

- Inflow (Site 1)
- Inflow (Site 2)
- Inflow (Site 3)
- Inflow (Site 4)
- Outflow (Site 4)

- Water Level Recorder
- Recording Rain Gauge
- GW Monitoring Well

Parking

MW-1

MW-2
Naples Monitoring Sites 3 & 4

Site 3 – Rear Store Area Inflow Site
- Fabricated V-notch Weir

Site 3 – Monitoring Equipment
- Monitoring Well
- Fabricated V-notch Weir

Site 4 – System Outfall
- Equipment Shelter

Site 4 – Monitoring equipment at outfall structure
- Outfall Structure
- Conduit for Tubing and Cables
- Skimmer
Pembroke Pines Monitoring Locations

- Inflow (Site 1)
- Recording Rain Gauge
- Water Level Recorder
- Outflow (Site 3)
- GW Monitoring Well

MW-1
MW-2
MW-3

S.W. 184th AVE.
Pembroke Pines Monitoring Site 1

Site 1 – North pond monitoring equipment

Site 1 – Storm event conditions
Pembroke Pines Monitoring Sites 2 & 3

Site 2 – Overview of south pond

Fabricated V-notch Weir

Site 2 – Monitoring during storm conditions

Site 3 – Dual outfall structures

Outfall Structures

Site 3 – System Outfall and sampling equipment

Equipment Shelter

Conduit for Tubing and Cables
Lynx Underdrain Monitoring Locations

- Water Level Recorder
- Recording Rain Gauge
- GW Monitoring Well

- Inflow (Site 1)
- Inflow (Site 2)
- Inflow (Site 3)
- Inflow (Site 4) (Not Monitored)
- Underdrain Outflow (Site 5)
- MW-2

- Roof Runoff – Bypasses Pond
Lynx Underdrain Monitoring Sites 1-3

Site 1 – 30" RCP Inflow

Site 1 – Inflow Smart Box with Diversion Weir

Site 2 – Equipment Shelter for 15" Inflow

Site 3 – Equipment Shelter for 18" Inflow
Lynx Underdrain Monitoring Sites 4 & 5

Site 4 – 18” RCP from Entrance Roadway

Site 4 – Equipment Shelter, rain gauge, and bulk precipitation collector

Site 5 – Underdrain monitoring site

Site 5 – Underdrain High Level Overflow to Wet Pond
Hydrologic Characteristics of the Monitored Sites

1. Rainfall
2. Inflows/Outflows
3. Groundwater Levels

More than 400,000 individual field hydrologic measurements of flow rate, water levels, and precipitation
Comparison of Average and Measured (12/12-11/13) Rainfall at the Monitoring Sites

FORT MYERS SW FLORIDA REGIONAL AIRPORT (1981 -2010)
Bonita Springs
Measured: 69.94 in.
Average: 52.23 in.
31% above normal

NAPLES (1981 - 2010)
Naples
Measured: 73.92 in.
Average: 55.64 in.
33% above normal

WESTON (1981 -2010)
Pembroke Pines
Measured: 50.20 in.
Average: 61.68 in.
19% below normal

ORLANDO EXECUTIVE AIRPORT (1981 -2010)
Lynx
Measured: 45.25 in.
Average: 53.17 in.
15% below normal
Measured Inflow Hydrographs at Bonita Springs Site 1 from December 2012 to November 2013

Bonita Springs Site 1

Dec  Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

Flow (cfs)

Rainfall (inches)

Discharge

Rainfall
Measured Inflow Hydrographs at Bonita Springs Site 3 (54-inch RCP) from December 2012-November 2013

Bonita Springs Site 3

Dec  Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec
Flow (cfs)
0  10  20  30  40  50  60

Rainfall (inches)
0  2  4  6  8  10

Bonita Springs Site 3

Discharge

Rainfall

Flow (cfs)
Rainfall (inches)
Construction Details for Groundwater Monitoring Wells

- PVC Cap
- Bentonite Seal
- 2” PVC Riser
- Soil Backfill
- 0.01 in. Slotted PVC Screen
- 20-30 Silica Sand
Measured Piezometric Elevations

Bonita Springs

- Water level above pond bottom during wet periods
- Water level below pond bottom during dry periods
Measured Piezometric Elevations

Naples

Date
12/12  2/13  4/13  6/13  8/13  10/13  12/13  2/14

MW Water Elevation (ft)
0
1
2
3
4
5
6

MW 1
MW 2

High Control / Pond Bot. - 5.10 ft
High Low Elev. - 4.60 ft

Upper Orifice Invert / Pond Bottom
Elev. 5.10 ft.

Lower Orifice Invert
Elev. 4.60 ft.

- Water level below pond bottom except during storm events
- Majority of inputs retained in pond

Pond wells
Measured Piezometric Elevations

Pembrooke Pines

Pond Bottom Elev. 5.10 ft.
Orifice/Control Invert Elev. 4.03 ft.

- Water level below pond bottom during most of monitoring period
  - Majority of inputs retained in pond

Off-site/background well
Pond wells
Measured Piezometric Elevations

Lynx

- Water level below pond bottom except during storm events
- All water entering pond retained

Pond Bottom Elev. 98.0 ft
Comparison of Hydrologic Inputs and Losses at the Bonita Springs Dry Detention Site

**Inputs**
- Rainfall: 11%
- Inflow 1: 14%
- Inflow 2: 21%
- Inflow 3: 52%
- Inflow 4: 2%

**Outputs**
- Retained: 43%
- Outflow: 57%
Measured Hydrologic Losses at the Dry Detention Sites

- **Bonita Springs**
  - Outflow: 57%
  - Retained: 43%

- **Naples**
  - Outflow: 17%
  - Retained: 83%

- **Pembroke Pines**
  - Outflow: 74%
  - Retained: 26%
Comparison of Hydrologic Inputs and Losses at the Orlando Underdrain Pond Site

Inputs

- Rainfall: 31%
- Inflow 1: 35%
- Inflow 2: 9%
- Inflow 3: 8%
- Inflow 4: 7%
- Add. Inlet: 10%

Outputs

- Underdrain: 72%
- Bypass: 4%
- Losses: 24%
Water Quality Characteristics of the Monitored Sites
Summary of Water Quality Samples Collected at the Evaluated Monitoring Sites from December 2012-November 2013

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Number of Samples Collected/Site</th>
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<td>Bonita Springs</td>
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<tr>
<td>Runoff/Inflows</td>
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<tr>
<td>Outflows</td>
<td>26</td>
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<td>Bulk Precipitation</td>
<td>25</td>
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<tr>
<td>Groundwater</td>
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<tr>
<td>Totals</td>
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</table>

- Each sample analyzed for general parameters, nutrients, and metals (20 parameters)
- Total of 12,600 lab analyses
Comparison of Inflow and Outflow Concentrations of General Parameters at the Dry Detention Sites
Comparison of Inflow and Outflow Concentrations of Nutrients at the Dry Detention Sites
Comparison of Inflow and Outflow Concentrations of Metals at the Dry Detention Sites

Chromium

Bonita Spring In
Bonita Springs Out
Naples In
Naples Out
Pembroke Pines In
Pembroke Pines Out

Zinc

Bonita Spring In
Bonita Springs Out
Naples In
Naples Out
Pembroke Pines In
Pembroke Pines Out

Copper

Bonita Spring In
Bonita Springs Out
Naples In
Naples Out
Pembroke Pines In
Pembroke Pines Out

Zn (µg/l)
0
20
40
60
80
100
120
140

Cr (µg/l)
0
10
20
30
40
50
60
70

Cu (µg/l)
0
10
20
30
40

Outlier
90
th
Percentile
75
th
Percentile
Median
25
th
Percentile
10
th
Percentile
Mean
## Summary of Changes in Inflow / Outflow Concentrations at the Dry Detention Monitoring Sites

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<thead>
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<th>Parameter</th>
<th>Concentration Change (%)</th>
<th>Mean Change (%)</th>
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<td>Naples</td>
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<td>Conductivity</td>
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<td>Particulate N</td>
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<tr>
<td>SRP</td>
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<td>-40</td>
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<td>Particulate P</td>
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<td>TSS</td>
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<td>-16</td>
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<tr>
<td>Lead</td>
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<td>--</td>
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<tr>
<td>Zinc</td>
<td>-11</td>
<td>-48</td>
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<td>Hardness</td>
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## Overall Mass Removal Efficiencies for the Dry Detention Monitoring Sites from December 2012 - November 2013

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<th>Parameter</th>
<th>Mass Removal (%)</th>
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<th>Mean Removal (%)</th>
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<td></td>
<td>Bonita Springs</td>
<td>Naples</td>
<td>Pembroke Pines</td>
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<tr>
<td>Ammonia</td>
<td>47</td>
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<td>67</td>
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<tr>
<td>NOₓ</td>
<td>64</td>
<td>89</td>
<td>85</td>
<td>79</td>
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<tr>
<td>Dissolved Organic N</td>
<td>53</td>
<td>53</td>
<td>14</td>
<td>40</td>
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<tr>
<td>Particulate N</td>
<td>57</td>
<td>71</td>
<td>46</td>
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<tr>
<td>Total N</td>
<td>59</td>
<td>69</td>
<td>50</td>
<td>59</td>
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<tr>
<td>SRP</td>
<td>73</td>
<td>84</td>
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<tr>
<td>Dissolved Organic P</td>
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<td>82</td>
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<td>Particulate P</td>
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<td>72</td>
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<td>Total P</td>
<td>66</td>
<td>80</td>
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<td>66</td>
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<td>TSS</td>
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<td>73</td>
<td>73</td>
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<td>Chromium</td>
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<td>71</td>
<td>51</td>
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<td>Copper</td>
<td>47</td>
<td>67</td>
<td>50</td>
<td>54</td>
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<td>45</td>
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<td>Zinc</td>
<td>59</td>
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<tr>
<td>Volume</td>
<td>43</td>
<td>83</td>
<td>26</td>
<td>51</td>
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Comparison of Inflow and Outflow Concentrations of General Parameters at the Underdrain Filtration Site

- **pH**: Box plots showing inflow and outflow data with various percentile values.
- **Alkalinity**: Box plots displaying inflow and outflow concentrations.
- **Turbidity**: Box plots illustrating inflow and outflow measurements.
- **Color**: Box plots comparing inflow and outflow color levels.
- **Hardness**: Box plots showing inflow and outflow data.
- **Conductivity**: Box plots for inflow and outflow measurements.
- **Total Suspended Solids (TSS)**: Box plots for inflow and outflow concentrations.
Comparison of Inflow and Outflow Concentrations of Nutrients at the Underdrain Filtration Site

- Ammonia
- NO₃
- Particulate N
- Total N
- SRP
- Dissolved Organic P
- Particulate P
- Total P
Comparison of Inflow and Outflow Concentrations of Metals at the Underdrain Filtration Site
### Overall Mass Removal Efficiencies for the Underdrain Monitoring Site from December 2012-November 2013

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean Removal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>90</td>
</tr>
<tr>
<td>NO&lt;sub&gt;x&lt;/sub&gt;</td>
<td>29</td>
</tr>
<tr>
<td>Dissolved Organic N</td>
<td>92</td>
</tr>
<tr>
<td>Particulate N</td>
<td>18</td>
</tr>
<tr>
<td>Total N</td>
<td>30</td>
</tr>
<tr>
<td>SRP</td>
<td>-194</td>
</tr>
<tr>
<td>Dissolved Organic P</td>
<td>82</td>
</tr>
<tr>
<td>Particulate P</td>
<td>48</td>
</tr>
<tr>
<td>Total P</td>
<td>14</td>
</tr>
<tr>
<td>TSS</td>
<td>66</td>
</tr>
<tr>
<td>Chromium</td>
<td>26</td>
</tr>
<tr>
<td>Copper</td>
<td>57</td>
</tr>
<tr>
<td>Lead</td>
<td>31</td>
</tr>
<tr>
<td>Zinc</td>
<td>83</td>
</tr>
<tr>
<td>Volume</td>
<td>24</td>
</tr>
</tbody>
</table>
## Low Intensity Commercial Land Use Runoff Characterization Data (n=9)

<table>
<thead>
<tr>
<th>Location</th>
<th>Reference</th>
<th>TN</th>
<th>TP</th>
<th>BOD</th>
<th>TSS</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Fe</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orlando Area wide</td>
<td>ECFRPC (1978)</td>
<td>0.89</td>
<td>0.160</td>
<td>3.6</td>
<td>146</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.068</td>
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<tr>
<td>Coral Ridge Mall</td>
<td>Miller (1979)</td>
<td>1.10</td>
<td>0.100</td>
<td>5.4</td>
<td>45.0</td>
<td>0.015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.387</td>
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<tr>
<td>Norma Park-Tampa</td>
<td>US EPA (1983)</td>
<td>1.19</td>
<td>0.150</td>
<td>12.0</td>
<td>22.0</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td>0.046</td>
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<tr>
<td>Internat. Market</td>
<td>Harper (1988)</td>
<td>1.53</td>
<td>0.190</td>
<td>11.6</td>
<td>111</td>
<td>0.008</td>
<td>0.013</td>
<td>0.031</td>
<td>1.100</td>
<td>0.028</td>
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<td>0.136</td>
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<tr>
<td>DeBary</td>
<td>Harper &amp; Herr (1993)</td>
<td>0.76</td>
<td>0.260</td>
<td>6.9</td>
<td>79.1</td>
<td>0.0005</td>
<td>0.003</td>
<td>0.010</td>
<td>0.582</td>
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<tr>
<td>Bradfordville</td>
<td>ERD (2000)</td>
<td>2.14</td>
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<tr>
<td>Cross Creek-Tall.</td>
<td>COT &amp; ERD (2002)</td>
<td>0.93</td>
<td>0.150</td>
<td>8.0</td>
<td>15.0</td>
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<tr>
<td>Sarasota Co.</td>
<td>ERD (2004)</td>
<td>0.88</td>
<td>0.310</td>
<td>4.3</td>
<td>39.9</td>
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<td></td>
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</tr>
<tr>
<td>Fla. Aquarium-Tampa</td>
<td>Teague, et. al. (2005)</td>
<td>0.76</td>
<td>0.215</td>
<td>42.4</td>
<td>42.4</td>
<td>0.003</td>
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<td>0.019</td>
<td>1.170</td>
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<td></td>
<td>0.008</td>
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<tr>
<td>Mean Value</td>
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<td>1.13</td>
<td>0.188</td>
<td>7.6</td>
<td>59.9</td>
<td>0.004</td>
<td>0.008</td>
<td>0.017</td>
<td>0.951</td>
<td>0.028</td>
<td></td>
<td>0.006</td>
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<tr>
<td>Median Value</td>
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<td>0.93</td>
<td>0.160</td>
<td>7.5</td>
<td>42.4</td>
<td>0.003</td>
<td>0.008</td>
<td>0.015</td>
<td>1.100</td>
<td>0.028</td>
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<td>0.008</td>
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<td>Log-Normal Mean:</td>
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<td>1.07</td>
<td>0.179</td>
<td>7.00</td>
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<td>0.002</td>
<td>0.006</td>
<td>0.015</td>
<td>0.908</td>
<td>0.028</td>
<td></td>
<td>0.005</td>
</tr>
</tbody>
</table>

*not included in mean value due to reductions from removal of lead in gasoline*
Comparison of Runoff Characteristics

- Each of the monitored sites conducted maintenance vacuum sweeping approx. twice each week.

- Sweeping appears to have substantially reduced runoff concentrations of total N, total P, TSS, and copper.

- Concentrations of chromium and zinc were low in value at all sites.
Groundwater Impacts

Dry detention ponds

- Increases in concentrations were observed in groundwater for:
  - pH, alkalinity, conductivity, color, and hardness – likely caused by organic matter in highly alkaline soils
  - Ammonia and organic nitrogen – even higher in background well
- Decreases in concentrations observed for phosphorus
  - Soils appear to have affinity for uptake of P
- Metal concentrations in GW similar to runoff
- Overall, no significant impact on groundwater

Underdrain filtration pond

- Increases in concentrations were observed in groundwater for:
  - pH, alkalinity, conductivity, color, and hardness – likely caused by organic matter in soils
  - Ammonia, NOx, and organic nitrogen – source not known
- Decreases in concentrations observed for phosphorus
  - Soils appear to have affinity for uptake of P
- Metal concentrations in GW less than or similar to runoff
- Overall, no significant impact on groundwater
Conclusions

Dry detention ponds provide highly variable and generally low removal efficiencies for runoff constituents

- Fall far short of the 80% load reduction goal outlined in “Water Resource Implementation Rule”
  - Total N: 7% removal
  - Total P: 30% removal
  - TSS: 38% removal
  - Metals: 0 – 32% removal

Significant mass removal efficiencies can only be achieved when a large portion of the runoff infiltrates into the ground

- When infiltration is included, mass removals increase to:
  - Total N: 50-69% - average = 59%
  - Total P: 52-80% - average = 66%
  - TSS: 68-78% - average = 73%
  - Metals: 48-58%

- Falls short of the 80% load reduction goal, even with significant infiltration losses
- With significant infiltration, removals are similar to wet detention
Recommendations

**Dry Detention**
- Increase retention component of dry detention systems by raising water control elevation back to the pond bottom
  - Could be easily tested by raising orifice elevations at evaluated sites
- Incorporate an outlet filtration system
- If it can’t be fixed, eliminate dry detention as an approved BMP

**Underdrain Filtration**
- Replace indigenous soils with a filtration media
  - Perform on-site testing at Lynx site
- If it can’t be fixed, eliminate underdrain filtration as an approved BMP