Harper Methodology Workshop
Morning Session

Orlando Airport Renaissance Hotel
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&

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Florida Water Resource Implementation Rule Chapter 62-40 FAC

- Requirements for stormwater management in Florida are outlined in Chapter 62-40.432
- FDEP is responsible for coordinating the statewide stormwater management program by establishing goals, objectives and guidance for the development and implementation of stormwater management programs by the Districts and local governments.
- The Districts shall be the chief administrators of the state stormwater management program. The Department shall implement the state's stormwater management program in Districts that do not have the economic and technical resources to implement a comprehensive surface water management program.

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Florida Water Resource Implementation Rule Chapter 62-40 FAC – cont.

- Minimum Stormwater Treatment Performance Standards:

  1. Achieve at least 80 percent reduction of the average annual load of pollutants that would cause or contribute to violations of state water quality standards.
  2. Achieve at least 95 percent reduction of the average annual load of pollutants that would cause or contribute to violations of state water quality standards in Outstanding Florida Waters.

- FDEP provides guidance to Districts for treatment systems to meet these objectives

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Florida Water Resource Implementation Rule Chapter 62-40 FAC – cont.

- Individual Districts develop specific design criteria for stormwater BMPs
  - Every District has a different set of standards
  - Design criteria vary widely throughout the State
  - Performance efficiencies also vary widely
- Rebuttable presumption that the discharge from such systems will comply with state water quality standards
- During the mid 2000s, FDEP began consideration of a Statewide Stormwater Rule to unify design criteria and effectiveness throughout the State
- Developed RFP for a study to evaluate current design standards and effectiveness

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Study Objectives

- In 2006, FDEP issued a contract to ERD to evaluate current stormwater design criteria within Florida
- Performed as part of FDEP Agreement S0108, titled "Evaluation of Current Stormwater Design Criteria within the State of Florida"
- The Scope of Work included the following:
  - Determine if current stormwater design criteria meet the performance standards outlined in Ch. 62-40.432 FAC.
  - If design criteria fail to meet Ch. 62-40, then recommend changes to meet performance criteria
  - Also evaluated design criteria to achieve no net increase in post development loadings
  - Analysis performed for nitrogen and phosphorus
    - If performance criteria are met for nitrogen and phosphorus, then they will be met for other significant pollutants (BOD, TSS, heavy metals, etc.) as well

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Study Objectives – cont.

- Develop scientifically defensible and reproducible design methodologies
  - Use proven methodologies familiar to design engineers
- This work did not include:
  - Evaluation of alternative stormwater management techniques such as:
    - Low Impact Design (LID)
    - Stormwater Reuse
    - Street Sweeping
    - Pervious Pavement
    - Gross Pollutant Separators
  - Evaluation of wetland loadings

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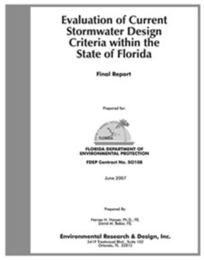
Study Objectives – cont.

- Study results provided in June 2007 Report
  - Report provided a series of tables, figures, methods of calculation, and design examples to achieve
    - 80% removal
    - 95% removal
    - Pre vs. post loadings
  - Method was vetted by the Districts and interested parties in a series of Public Workshops
- Districts adopted the methods as a standard method of calculating reductions for use in pre vs. post analyses
- Method is often referred to as the Harper methodology


Evaluation of Current Stormwater Design Criteria within the State of Florida

Final Report

Prepared for:

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

FDEP Contract No. SO108

June 2007

Prepared By:

Environmental Research & Design, Inc.

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Eric Livingston, M.S.

Watershed Management Services, LLC.

AKA: Godfather of Florida Stormwater

- 35 years at FDEP in Tallahassee
- Helped develop, administer, and evolve Florida's stormwater management and treatment program.
- Funded and managed hundreds of stormwater BMP projects
- Developed a 10 year LID BMP research and monitoring program in 1999
  - Results of these projects have been used to refine conventional BMPs and create design criteria for LID BMPs
  - The updated designs are in the recently approved Pinellas County and Alachua County Stormwater Treatment Manuals.

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Morning Session Topics

1. Rainfall Characteristics
2. Runoff Generation and Estimation
3. Runoff Characteristics
4. Calculation of Runoff Loadings

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Part 1

Rainfall Characteristics in Florida

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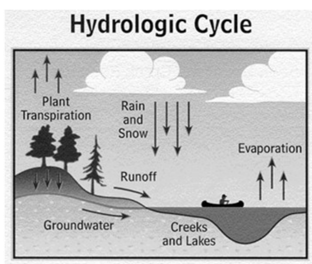
Precipitation

- Precipitation drives the hydrologic cycle
- The runoff component must be conveyed and treated
- Understanding precipitation is essential to understanding and quantifying runoff



Basic Hydrologic Equation for Runoff:

Rainfall = Runoff + Infiltration

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Rainfall Data

- Since rainfall drives the hydrologic cycle, the ERD study included an evaluation of rainfall characteristics throughout the State, including
  - Annual and event rainfall depths
  - Rainfall variability throughout Florida
    - Total annual rainfall
    - Variability in individual events
  - Inter-event dry periods
- Rainfall data included in the BMPTRAINS Model are based on the ERD study

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Available Meteorological Data

Meteorological Monitoring Sites Used to Generate Rainfall Isopleths

- Data obtained for 1971-2000
- 160 sites total
- 111 sites in Florida
- 49 sites n perimeter areas

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Average Annual Florida Precipitation 1971 – 2000

- Rainfall isopleths were developed for 1971 – 2000 based on the historical data
- Florida rainfall is highly variable ranging from ~ 38 – 66 in/yr, depending on location
- Isopleths are used to determine project rainfall in BMPTRAINS

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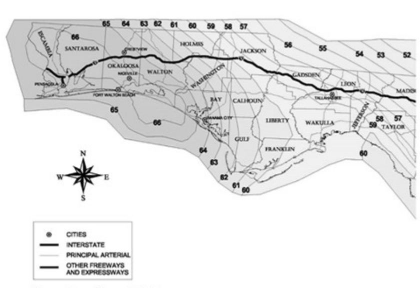
Expanded View of Rainfall Isopleths



- Expanded view plots are available in BMPTRAINS for the entire State
- Use expanded plots to determine annual rainfall for project site

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Evaluation of Individual Rain Events

- Obtained historical 1-hour rainfall data from the National Climatic Data Center (NCDC) for each available meteorological station – 45 of 111 Florida stations
  - Data availability ranged from 25 – 59 years per site
- Grouped data into individual rain events
  - Used 3 hour separation to define individual events
- Created historical data set of daily rain events over period of record for each site
- Developed annual frequency distribution of individual rain events for each monitoring site

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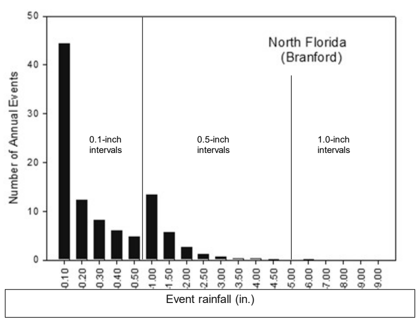
Typical Rainfall Frequency Distribution

- A large number of annual rain events are small depths

- A relatively small number of annual events are large depth

- Similar, but variable, patterns for stations throughout Florida



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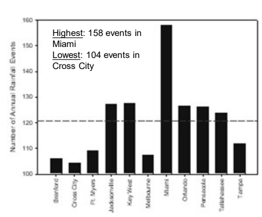
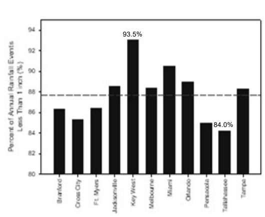
Characteristics of Rainfall Events at Selected Meteorological Sites





- Rainfall is highly variable in the number of “small” and “large” events at sites around the state

-This impacts both runoff generation as well as treatment system performance efficiency

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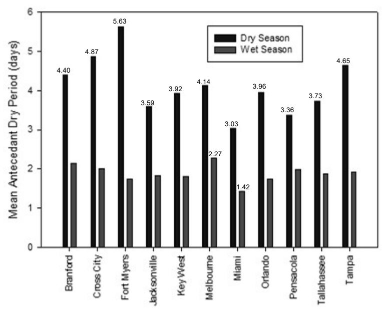
Variability in Inter-Event Dry Period

Variability in rainfall frequency impacts:

- Runoff C values
- Recovery and performance efficiency of stormwater management systems, especially dry retention



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Summary

- Rainfall in Florida is highly variable
  - Annual rainfall
    - Ranges from 38in/yr in Key West to 68 in/yr in Tallahassee and Pensacola
  - Number of annual rain events
    - Ranges from 104 events/yr in Cross City to 158 events/yr in Miami
  - Rain event depths
    - Most rain events in Florida are less than 0.5 inch
    - Approximately 84 – 94% are less than 1 inch
  - Inter-event dry period
    - Wet season – 1.42 days (34 hrs.) – 2.27 days (54 hrs.)
- Rainfall variability impacts runoff volumes and BMP efficiencies throughout the State

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Part 2

Runoff Generation and Estimation

ERD

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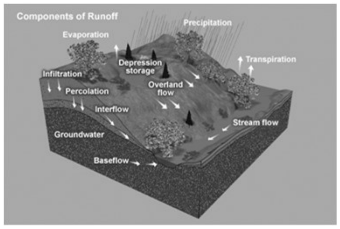
Runoff Generation

- Runoff is a part of the hydrologic cycle
- Runoff generation is a function of:
  - Precipitation
  - Soil types
  - Land cover



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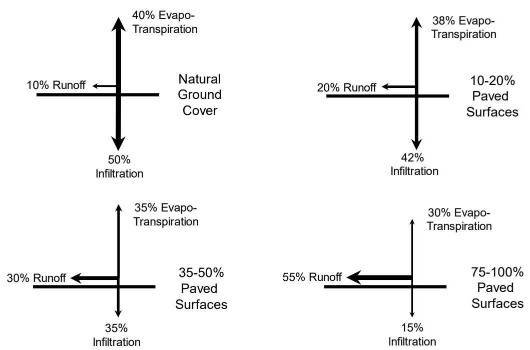
Development Impacts on Hydrology



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Runoff Volume Estimation

- Runoff generation is a function of a variety of factors, including:
  - Land use
  - Impervious surfaces
  - Soil types
  - Topography –
    - Basin slope
    - Depressional areas
  - Precipitation amount and event characteristics
- Runoff model must be capable of incorporating each of these factors
  - Many models are available that calculate runoff volumes
    - Soil Conservation Service (SCS)
    - ICPR – Proprietary model
    - SWMM – EPA Model
    - Areal relationships

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Runoff Coefficients

Runoff coefficients (C values)

- Runoff coefficients reflect the proportion of rainfall that becomes runoff under specified conditions
- Tabular C values are used to size pipes using the Rational Formula:
- $Q = C \times i \times A$

  Where: C = estimate of runoff proportion for a design storm event (typically 10 yr)
- Runoff coefficients are often improperly used for estimation of runoff volumes for non design storm conditions
- Tabular runoff coefficients were never intended to reflect estimates of annual rainfall/runoff relationships

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Common Rational Formula Runoff Coefficients

Area	Runoff Coefficient
Business (Downtown)	0.70 to 0.95
Business (Neighborhood)	0.50 to 0.70
Residential (Single-Family)	0.30 to 0.50
Residential (Multi-Units, Detached)	0.40 to 0.60
Residential (Suburban)	0.25 to 0.40
Apartment	0.50 to 0.70
Industrial (Light)	0.50 to 0.80
Industrial (Heavy)	0.60 to 0.90
Parks, Cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Unimproved, Natural Areas	0.10 to 0.30

- Common C values reflect runoff potential under design storm event conditions
- Rational runoff coefficients do not reflect the proportion of annual rainfall which becomes runoff

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Runoff Estimation

- Needed a runoff model for use in evaluating rainfall/runoff relationships for Harper methodology
  - Multiple models were evaluated
- Modeling was conducted using the SCS Curve Number (CN) methodology
  - Common method used by most civil engineers and proprietary models
  - Model used to calculate annual runoff coefficients (C values) for meteorological sites throughout Florida

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SCS Curve Number Methodology

- SCS Curve Number (CN) methodology
  - Outlined in NRCS document TR-55 titled “Urban Hydrology for Small Watersheds”
  - Common methodology used in many public and proprietary models
  - Curve numbers (CN Values) are empirically derived values which predict runoff as a function of soil type and land cover
  - Can be used to predict event specific runoff depths and volumes
  - Runoff generation based on impervious area, soil types and land cover

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SCS Method

- SCS method is based on Hydrologic Soil Groups (HSG)
  - Hydrologic Soil Groups (A,B,C & D) are determined by the minimum infiltration rate for bare soils after thorough wetting

Hydrologic Soil Group (HSG)	Description	Soil Infiltration Rate	Runoff Potential
A	deep, well to excessively drained sands with a high rate of water transmission.	very high	very low
B	moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures	high	low
C	soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure	low	high
D	clay soils, soils with a permanent high water table, soils with a hardpan or clay layer at or near the surface	very low	very high

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Typical Curve Numbers (TR-55)

Cover Type and Hydrologic Condition	Curve Number			
	A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.):				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50% to 75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc. (excl. ROW)	98	98	98	98
Streets and roads:				
Paved; curbs and storm sewer (excl. ROW)	98	98	98	98
Paved; open ditches (including right-of-way)	83	89	92	93
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89
Pasture, grassland, or range:				
Poor condition	68	79	86	89
Fair condition	49	69	79	84
Good condition	39	61	74	80
Brush—brush-weed-grass mixture:				
Poor	48	67	77	83
Fair	35	56	70	77
Good	30	48	65	73
Woods:				
Poor	45	66	77	83
Fair	36	60	73	79
Good	30	55	70	77

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Typical Curve Numbers (TR-55)

Cover Type and Hydrologic Condition	Imp. (%)	Curve Number			
		A	B	C	D
Residential					
Lot size: 1/8 acre or less ……………………...........	65	77	85	90	92
Lot size: 1/4 acre …………..................	38	61	75	83	87
Lot size: 1/3 acre ……………………...........	30	57	72	81	86
Lot size: 1/2 acre	25	54	70	80	85
Lot size: 1 acre	20	51	68	79	84
Lot size: 2 acre	12	46	65	77	82
Water/wetlands	0	0	0	0	0

- General curve numbers for available for residential and urban areas
  - General CN values reflect the combined runoff potential for the combined pervious and impervious areas
- Water areas are assigned a CN and C-value of zero since precipitation and evaporation are approximately equal over an annual cycle
  - Harper Methodology evaluates loadings on an average annual basis

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Hydrologic Conditions

- In the SCS method, hydraulic conditions sub-sets within a Hydrologic Soil Group
- Defined as poor, fair, and good based on a combination factors that affect infiltration and runoff
  - density and canopy of vegetative areas
  - amount of year-round cover
  - amount of grass or close-seeded legumes
  - percent of residue cover on the land surface (good ≥ 20%)
  - degree of surface roughness.
- Poor condition
  - Factors impair infiltration and tend to increase runoff
- Fair condition
  - Typical or average runoff conditions
- Good condition
  - Factors encourage average and better than average infiltration and tend to decrease runoff.

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SCS Method of Calculating Runoff

- Estimation of runoff in the SCS Method is conducted using the following equations:
  - Soil storage is calculated using a weighted-average CN value for each combination of landuse and soil type

$$\text{Soil Storage, } S = \left(\frac{1000}{\text{[illegible]}} - 10\right)$$

  - Runoff is then calculated using the following equation:

$$Q = \frac{(P_i - 0.2S)^2}{(Pi + 0.8S)}$$

- However, the SCS Method can be subject to large errors due to averaging CN values
- To reduce this error, the Harper Methodology calculates separate runoff volumes for the DCIA and non-DCIA areas

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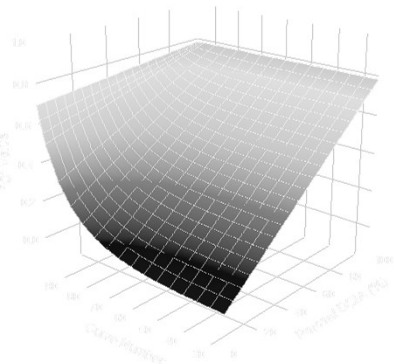
Relationship Between Curve Number, Percent DCIA, and C Value

- Linear relationship between C Value and DCIA

- Exponential relationship between C Value and CN value

- Implies that averaging CN values is statistically invalid and leads to over-estimation of runoff volume



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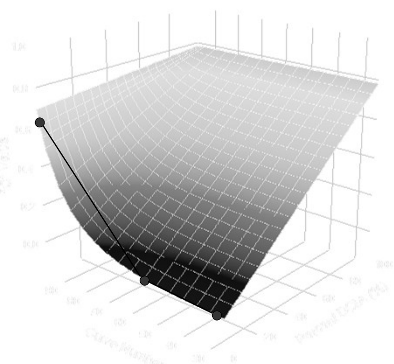
Impacts of Averaging Curve Numbers

- At low CN values the impact of averaging CN values is small

- Impact becomes much greater when averaging high CN values



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Directly Connected Impervious Areas (DCIA)

- Harper Method calculates separate runoff volumes for the DCIA and non-DCIA areas
- Definition of DCIA varies depending on the type of analysis
  - Flood routing – Major events
    - DCIA includes all impervious areas from which runoff discharges directly into the drainage system
    - Also considered to be DCIA if runoff discharges as a concentrated shallow flow over pervious areas and then into the drainage system
      - Ex. – Shallow roadside swales
    - Often generously estimated to provide safety factor for design
  - Annual runoff estimation – Common daily events
    - DCIA includes all impervious areas from which runoff discharges directly into the drainage system during small events
    - Does not include swales
    - Generally results in a lower DCIA value than used for flood routing

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Non-DCIA Area Calculations

- Non-Directly Connected Impervious Areas (non-DCIA):
  - Includes pervious areas + impervious areas which are not considered to be DCIA
- Non-DCIA Curve Number (non-DCIA CN Value):

$$\text{Non-DCIA CN Value} = \frac{(Area_{perv.}) \times (CN_{perv.}) + (Area_{non\text{-}DCIA}) \times 98}{(Area_{perv.}) + (Area_{non\text{-}DCIA})}$$

- The Non-DCIA CN Value is then used to calculate the soil storage:

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Calculation of Runoff Volumes

Separate calculations are conducted for the DCIA and non-DCIA areas
- Using an overall CN value for the area would lead to significant errors in estimating runoff

1. Runoff from non-DCIA areas is calculated by:

CN = curve number for pervious area
Imp. = percent impervious area
DCIA = percent directly connected impervious area
non-DCIA CN = curve number for non-DCIA area
P_i = rainfall depth for event (i)
R_{nDCIAi} = rainfall excess for non-DCIA for event **(i)**

2. Runoff from DCIA is calculated as:

$$Q_{DCIAi} = (P_i - 0.1)$$

When P_i is less than 0.1, Q_{DCIAi} is equal to zero

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Curve Number Adjustments

CN values were adjusted based on Antecedent Moisture Condition (AMC

Antecedent Moisture Condition (AMC)	Total Antecedent 5-Day Rainfall (inches)	
	Dormant Season (October – February)	Growing Season (March – September)
I – Dry Conditions	< 0.5	< 1.4
II – Normal	0.5 – 1.1	1.4 – 2.1
III – Wet Conditions	> 1.1	> 2.1

Typical CN adjustments for varying AMC conditions

CN for Condition II	Corresponding CN for Condition	
	I	III
100	100	100
90	78	98
80	63	94
70	51	87
60	40	79
50	31	70
40	23	60
30	15	50

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Hydrologic Modeling

- Continuous simulation of runoff from a hypothetical 1 acre site using SCS curve number methodology and historical rainfall data set for 45 rainfall sites with hourly data
  - Data ranged from 13 – 64 years per site, but most contained 30+ years of data per site (mean of 4,685 events/site)
  - Data separated into individual events using 3 hour separation
- Runoff modeled for all rain events at each site
  - Mean of 4,685 rain events/site
  - DCIA percentages from 0-100 in 5 unit intervals
  - Non-DCIA curve numbers from 25-95 in 5 unit intervals
  - 350 combinations per rainfall site x 45 sites = 15,750 model runs
- Total generated runoff depth compared with rainfall depth for each site to calculate runoff coefficient:

$$\text{C Value} = \frac{\text{Total Runoff Depth Over Simulation Period}}{\text{Total Rainfall Depth Over Simulation Period}}$$

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Meteorological Sites Included in Runoff Modeling

Hourly Rainfall Sites Used for Runoff Modeling

- 45 sites total

- Runoff modeling conducted for each rain event at each site over available period of record

- 350 combinations of DCIA and non-DCIA per rainfall site x 45 sites = 15,750 model runs

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Modeled C Values for Various Combinations of CN and DCIA

Modeled C values for Miami – 64 years from 1942 - 2005

NDCIA CN	Percent DCIA																				
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	0.008	0.048	0.088	0.128	0.168	0.208	0.248	0.288	0.328	0.368	0.408	0.448	0.488	0.528	0.568	0.608	0.648	0.688	0.728	0.768	0.808
35	0.012	0.052	0.092	0.132	0.171	0.211	0.251	0.291	0.331	0.370	0.410	0.450	0.490	0.529	0.569	0.609	0.649	0.689	0.728	0.768	0.808
40	0.018	0.057	0.097	0.136	0.176	0.215	0.255	0.294	0.334	0.373	0.413	0.452	0.492	0.531	0.571	0.611	0.650	0.690	0.729	0.769	0.808
45	0.025	0.064	0.103	0.142	0.182	0.221	0.260	0.299	0.338	0.377	0.417	0.456	0.495	0.534	0.573	0.612	0.651	0.691	0.730	0.769	0.808
50	0.034	0.072	0.111	0.150	0.189	0.227	0.266	0.305	0.343	0.382	0.421	0.460	0.498	0.537	0.576	0.614	0.653	0.692	0.731	0.769	0.808
55	0.044	0.082	0.121	0.159	0.197	0.235	0.273	0.312	0.350	0.388	0.426	0.464	0.502	0.541	0.579	0.617	0.655	0.693	0.732	0.770	0.808
60	0.057	0.095	0.132	0.170	0.207	0.245	0.282	0.320	0.357	0.395	0.433	0.470	0.508	0.545	0.583	0.620	0.658	0.695	0.733	0.770	0.808
65	0.073	0.110	0.147	0.183	0.220	0.257	0.294	0.330	0.367	0.404	0.441	0.477	0.514	0.551	0.588	0.624	0.661	0.698	0.735	0.771	0.808
70	0.093	0.129	0.165	0.201	0.236	0.272	0.308	0.344	0.379	0.415	0.451	0.486	0.522	0.558	0.594	0.629	0.665	0.701	0.737	0.772	0.808
75	0.120	0.155	0.189	0.223	0.258	0.292	0.327	0.361	0.395	0.430	0.464	0.498	0.533	0.567	0.602	0.636	0.670	0.705	0.739	0.774	0.808
80	0.157	0.189	0.222	0.254	0.287	0.319	0.352	0.385	0.417	0.450	0.482	0.515	0.547	0.580	0.613	0.645	0.678	0.710	0.743	0.775	0.808
85	0.209	0.239	0.269	0.299	0.329	0.359	0.389	0.419	0.449	0.479	0.509	0.538	0.568	0.598	0.628	0.658	0.688	0.718	0.748	0.778	0.808
90	0.292	0.318	0.343	0.369	0.395	0.421	0.447	0.472	0.498	0.524	0.550	0.576	0.602	0.627	0.653	0.679	0.705	0.731	0.756	0.782	0.808
95	0.445	0.464	0.482	0.500	0.518	0.536	0.554	0.572	0.590	0.609	0.627	0.645	0.663	0.681	0.699	0.717	0.736	0.754	0.772	0.790	0.808
98	0.614	0.624	0.633	0.643	0.653	0.662	0.672	0.682	0.692	0.701	0.711	0.721	0.730	0.740	0.750	0.760	0.769	0.779	0.789	0.798	0.808

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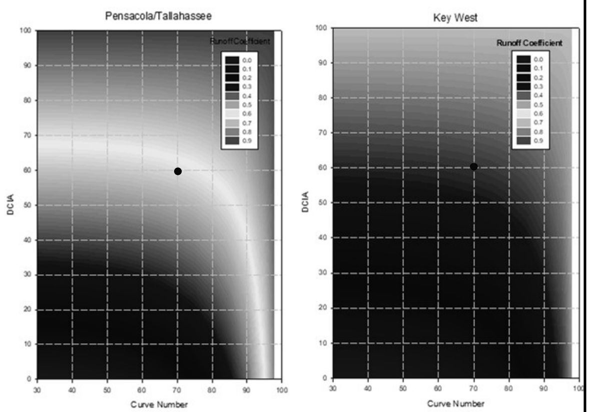
Annual C Values as a Function of DCIA and non-DCIA Curve Number



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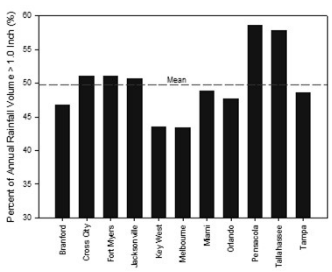
Impacts of Rainfall Characteristics on Runoff Generation



- Key West and Melbourne have a large percentage of small events and a lower percentage of large rain events
  - Results in less annual runoff volume

Pensacola and Tallahassee have a low percentage of small events and a higher percentage of large events
  - Results in more annual runoff volume

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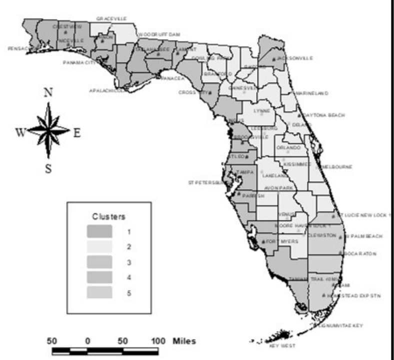
Similar Meteorological Zones

- Cluster analysis used to identify areas with similar annual rainfall/runoff relationships (C values)
- Analysis identified 5 significantly different areas
- Differences due to rainfall distribution rather than annual rainfall depth



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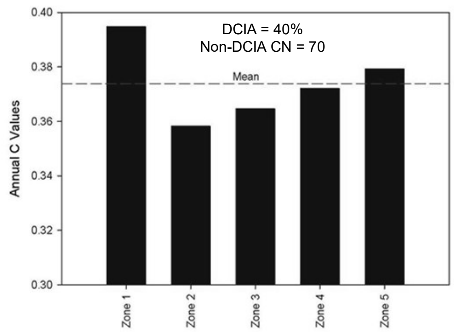
Comparison of State-Wide Annual C Values for a Hypothetical Residential Development



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Runoff Calculation Data

- Rainfall/runoff relationships for the 5 meteorological zones are provided in Appendix C of Harper and Baker (2007)

Zone 1 - Panhandle

NDCIA	Percent DCIA																				
CN	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	0.006	0.048	0.090	0.132	0.175	0.217	0.259	0.301	0.343	0.386	0.428	0.470	0.512	0.554	0.596	0.639	0.681	0.723	0.765	0.807	0.849
35	0.009	0.051	0.093	0.135	0.177	0.219	0.261	0.303	0.345	0.387	0.429	0.471	0.513	0.555	0.597	0.639	0.681	0.723	0.765	0.807	0.849
40	0.014	0.056	0.098	0.139	0.181	0.223	0.265	0.307	0.348	0.390	0.432	0.474	0.515	0.557	0.599	0.641	0.682	0.724	0.766	0.808	0.849
45	0.020	0.062	0.103	0.145	0.186	0.228	0.269	0.311	0.352	0.394	0.435	0.476	0.518	0.559	0.601	0.642	0.684	0.725	0.767	0.808	0.849
50	0.029	0.070	0.111	0.152	0.193	0.234	0.275	0.316	0.357	0.398	0.439	0.480	0.521	0.562	0.603	0.644	0.685	0.726	0.767	0.808	0.849
55	0.039	0.079	0.120	0.161	0.201	0.242	0.282	0.323	0.363	0.404	0.444	0.485	0.525	0.566	0.606	0.647	0.687	0.728	0.768	0.809	0.849
60	0.052	0.092	0.132	0.172	0.212	0.252	0.291	0.331	0.371	0.411	0.451	0.491	0.531	0.570	0.610	0.650	0.690	0.730	0.770	0.810	0.849
65	0.069	0.108	0.147	0.186	0.225	0.264	0.303	0.342	0.381	0.420	0.459	0.498	0.537	0.576	0.615	0.654	0.693	0.732	0.771	0.810	0.849
70	0.092	0.130	0.167	0.205	0.243	0.281	0.319	0.357	0.395	0.433	0.471	0.508	0.546	0.584	0.622	0.660	0.698	0.736	0.774	0.812	0.849
75	0.121	0.158	0.194	0.230	0.267	0.303	0.340	0.376	0.412	0.449	0.485	0.522	0.558	0.595	0.631	0.667	0.704	0.740	0.777	0.813	0.849
80	0.162	0.196	0.230	0.265	0.299	0.334	0.368	0.402	0.437	0.471	0.506	0.540	0.574	0.609	0.643	0.678	0.712	0.746	0.781	0.815	0.849
85	0.220	0.252	0.283	0.315	0.346	0.378	0.409	0.441	0.472	0.503	0.535	0.566	0.598	0.629	0.661	0.692	0.724	0.755	0.787	0.818	0.849
90	0.312	0.339	0.366	0.393	0.419	0.446	0.473	0.500	0.527	0.554	0.581	0.608	0.634	0.661	0.688	0.715	0.742	0.769	0.796	0.823	0.849
95	0.478	0.496	0.515	0.533	0.552	0.571	0.589	0.608	0.626	0.645	0.664	0.682	0.701	0.719	0.738	0.757	0.775	0.794	0.812	0.831	0.849
98	0.656	0.666	0.676	0.685	0.695	0.705	0.714	0.724	0.734	0.743	0.753	0.763	0.772	0.782	0.792	0.801	0.811	0.821	0.830	0.840	0.849

- Required input data include:
  - Rainfall meteorological zone based on rainfall zone map
  - Annual rainfall depth from isopleth maps
  - Basin DCIA
  - Non-DCIA curve number
- BMPTRAINS conducts iterations for uneven values of DCIA and CN
  - Calculates annual runoff coefficient (C value) and annual runoff volume

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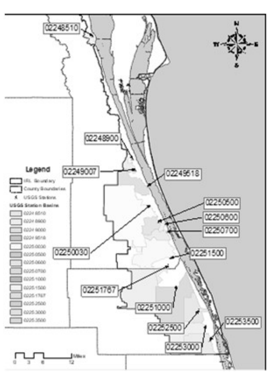
User Identified C Values in BMPTRAINS

USGS Tributary Gauging Sites and Associated Watershed Areas in the Central and Southern IRL

~ 42% of Overall Basin Area

- Most of the watersheds are agriculture and natural areas



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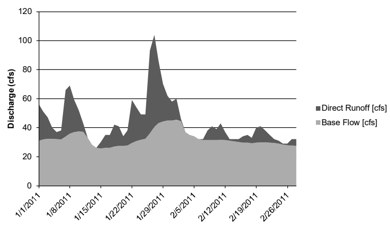
Comparison of Runoff and Baseflow at USGS Station 02251767

- Runoff and baseflow separation conducted using the WHAT program from Purdue University
- Approx 33% of total discharge is runoff with 67% baseflow
- C value obtained from this station would include both runoff and baseflow



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Runoff Volume

- Runoff models calculate the runoff volume generated within the modeled area
- However, this does not represent the volume of runoff which may actually reach the ultimate receiving water body
- The delivery ratio (fraction of generated runoff which reaches the waterbody) varies widely
  - Values can range from 0.0 – 1.0
- Delivery ratios are a function of:
  - Watershed size
    - Large watersheds have smaller delivery ratios
  - Depressional storage
    - Large amount of depressional storage decreases delivery ratio
  - Internal waterbodies
    - Provides internal storage which reduces delivery ratio
- Few models incorporate the concept of delivery ratios
- Lack of consideration of delivery ratio combined with initial overestimation of runoff volume results in significant errors in runoff volume estimation

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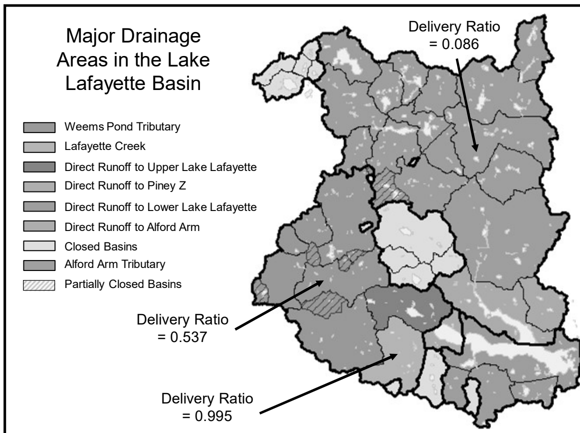
Major Drainage Areas in the Lake Lafayette Basin



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Calculated Delivery System Reduction Factors for Verification Sub-Basins in Tallahassee Urban Watershed Study

Sub-Basin	Area (ac)	Delivery Ratio
John Knox Road	80	0.453
Franklin Blvd.	423	0.450
Betton Road	333	0.545
Dorset Way	458	0.272
Mean	324	0.430

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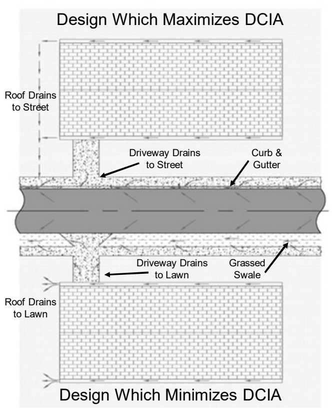

Impacts of Disconnecting DCIA on Annual C Values

Parameter	Standard Design	Disconnect DCIA
% Imp.	40	40
DCIA (%)	20	0
Hydrologic Soil Group (HSG)	D	D
Pervious CN	80	80
Non-DCIA CN	84.5	87.2
C Value		
-Zone 1	0.341	0.261 (-23%)
-Zone 2	0.286	0.196 (-31%)
-Zone 3	0.297	0.210 (-29%)
-Zone 4	0.306	0.219 (-28%)
-Zone 5	0.325	0.245 (-25%)

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Example Calculations

1. Land Use: 90 acres of single-family residential
   5 acres of stormwater management systems
   5 acres of preserved wetlands

2. Ground Cover/Soil Types

   A. Residential areas will be covered with lawns in good condition
   B. Soil types in HSG D

3. Impervious/DCIA Areas

   A. Residential areas will be 25% impervious, 75% of which will be DCIA

   Impervious Area = 25% of developed site = 90 ac x 0.25 = 22.50 acres

   DCIA Area = 22.50 acres x 0.75 = 16.88 acres

   DCIA Percentage = (16.88 ac/90.0 ac) x 100 = 18.7% of developed area

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Example Calculations – con't.

4. Calculate composite non-DCIA curve number from TR-55:

Curve number for lawns in good condition in HSG D = 80

Areas of lawns = 90 acres total – 22.50 ac impervious area = 67.50 acres of pervious area

Impervious area which is not DCIA = 22.50 ac – 16.88 ac = 5.62 ac

Assume a curve number of 98 for impervious areas

$$\text{Non-DCIA curve number} = \frac{67.50\ ac\ (80)\ +\ 5.62\ ac\ (98)}{67.50\ ac\ +\ 5.62\ ac} = 81.4$$

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Example Calculations – con't.

5. Calculate annual runoff volume for developed area

The proposed developed area for the project is 90 ac. Estimation of runoff volumes is not included for the 5-acre stormwater management area since runoff generated in these areas is incorporated into the performance efficiency estimates for the stormwater system.

a. Pensacola (Zone 1) Project: The model calculates the annual runoff coefficient based on the meteorological zone and the hydrologic characteristics.

Pensacola = Zone 1, DCIA = 18.75%, and non-DCIA CN = 81.4

Annual C value = 0.304

The annual rainfall for Pensacola = 65.5 inches (From Isopleth Map)

Annual generated runoff volume = 90 ac x 65.5 in/yr x 1 ft/12 in x 0.304 = **149.3 ac-ft/yr**

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Example Calculations – cont.

5. Calculate annual runoff volume for developed area – cont.

b. Key West (Zone 3) Project: The BMPTRAINS model calculates the annual runoff coefficient based on the meteorological zone and the hydrologic characteristics.

Key West = Zone 3, DCIA = 18.75%, and non-DCIA CN = 81.4

Annual C value = 0.266

Annual rainfall for Key West = 40.0 inches (From Isopleth Map)

Annual generated runoff volume = 90 ac x 40.0 in/yr x 1 ft/12 in x 0.266 = **79.8 ac-ft/yr**

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Summary

- Like rainfall, runoff in Florida is highly variable
  - Impervious area
    - Direct relationship between runoff and impervious percentage
  - Non-DCIA CN value
    - Exponential relationship between CN value and runoff
  - Characteristics of rain events
- Harper Method and BMPTRAINS Model calculate annual C value and runoff volume based on hydrologic and meteorological characteristics of the project site

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Part 3

Runoff Characteristics

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Runoff Characteristics

- Runoff concentrations are characterized by a high degree of variability:
  - From event to event
  - During storm events
- Variability is caused by variations in:
  - Rainfall Intensity
  - Rainfall Frequency
  - Soil Types
  - Land Use
  - Intensity of Land Use
  - Weather Patterns
- Variability must be included in the monitoring protocol for runoff collection to determine annual emc values
- NPDES data should not be used since these data reflect runoff characteristics for specific rain event conditions
  - NPDES data are useful for comparing different sites because the data are collected in a similar manner

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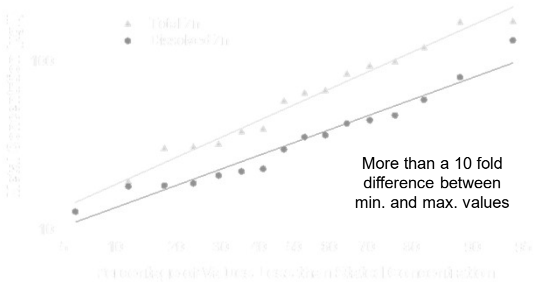
Highway Runoff
(I-4 and Maitland Ave from 1980-82)

Zinc



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Runoff Characterization Data Availability

Parameter Group	Species	Data Availability	Available Land Uses
Suspended Solids	TSS	Good	All
Nutrients	Total N Total P	Good	All
	NH_3 NO_x TKN Ortho-P	Limited	Limited
Metals	Zinc Lead Copper	Fair to Good	Commercial Residential Highway
	Cadmium Nickel Diss. Metals	Poor to Fair	Commercial Residential Highway

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Runoff Characterization Data Availability – cont.

Parameter Group	Species	Data Availability	Available Land Uses
Oxygen Demanding Substances	BOD	Fair to Good	Commercial, Residential, Highway
	COD	Poor to Fair	Commercial, Residential, Highway
Oils, Greases And Hydrocarbons	Oil and Grease TRPH	Poor	Commercial, Residential, Highway
	Specific Compounds	Extremely Poor	Commercial, Residential, Highway
Pathogens	Total Coliform Fecal Coliform	Poor to Fair	Commercial, Residential, Highway
	E. Coli	Extremely Poor	Commercial, Residential, Highway

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Runoff Characteristics and Loadings

- Runoff characteristics are used in many engineering analyses, including:
  - Pollutant loading analyses
  - TMDL calculations
  - Pre/post loading evaluations
- Runoff concentrations are commonly expressed in terms of an event mean concentration (emc):

$$\text{emc} = \frac{\text{pollutant loading}}{\text{runoff volume}}$$

- An annual emc value is generally determined by evaluating event emc values over a range of rainfall depths and seasons
  - Generally estimated based on field monitoring
  - Usually requires a minimum of 7-10 events collected over a range of conditions
- Annual mass loadings are calculated by:

Annual mass loading = annual runoff volume x annual emc

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History of Florida emc Database

- The original database was developed by ERD in 1990 in support of the Tampa Bay SWIM Plan
  - A literature review was conducted to identify runoff emc values for single land use categories in Florida
  - Approximately 100 studies were identified
    - Each study was evaluated for adequacy of the data, length of study, number of monitored events, completeness, and monitoring protocol
  - Original selection criteria
    - Monitoring site included a single land use category – most difficult criterion
    - At least 1 year of data collection; minimum of 5 events monitored in a flow-weighted fashion
    - Wide range of rainfall depths and antecedent dry periods included in monitored events
    - Seasonal variability included in monitored samples
  - Approximately 40 studies were selected for inclusion in the data base
  - Values were summarized by general land use category
  - First known compilation of emc data for Florida
  - Emc values calculated as <u>simple arithmetic means</u>

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History of Database – cont.

- Based on the literature survey, common land use categories were developed based on similarities in anticipated runoff characteristics:
  - Pre-Development
    - Agriculture (pasture, citrus, row crops)
    - Open Space / Forests
    - Mining
    - Wetlands
    - Open Water / Lake
  - Post-Development
    - Low-Density Residential
    - Single-Family Residential
    - Multi-Family Residential
    - Low-Intensity Commercial
    - High-Intensity Commercial
    - Industrial
    - Highway

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Land Use Categories

- Land use category descriptions:
  - Low Density Residential (LDR) – rural residential with lot sizes >1 acre or less than one unit per acre
  - Single Family Residential (SFR) – typical detached family home with lot <1 acre, includes duplexes in 1/3 to 1/2 acre lots, golf courses
  - Multi-Family Residential (MFR) – residential units consisting of apartments, condominiums, and cluster-homes
  - Low Intensity Commercial (LIC) – commercial areas with low traffic levels, cars parked for extended periods, includes schools, offices, and small shopping centers
  - High Intensity Commercial (HIC) – commercial areas with high traffic volumes, includes downtown areas, malls, commercial offices
  - Industrial (Ind.) – manufacturing, shipping and transportation services, municipal treatment plants
  - Highway (HW) – major road systems and associated ROW, including interstate highways, major arteries
  - Agriculture (Ag) – includes cattle, grazing, row crops, citrus, general ag.
  - Recreation/Open Space - includes parks, ball fields, open space, barren land, does not include golf courses
  - Mining (M) – general mining activities such as sand, lime rock, gravel, etc.

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Single Family Residential Runoff Characterization Data (n = 17)

Location	Reference	Reported EMC (mg/l)										
		TN	TP	BOD	TSS	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Pompano Beach	Mattraw,et.al.,(1981)	2.00	0.310	7.9	26.0			0.008	0.298		0.167	0.086
Tampa-Charter St.	US EPA (1983)	2.31	0.400	13.0	33.0						0.490	0.053
Maitland (3 sites)	German (1983)	2.20	0.340	7.1	43.0			0.014	0.350	0.008	0.230	0.016
St. Pete-Bear Creek	Lopez,et.al. (1984)	1.50	0.200	4.7				0.009			0.128	0.083
Tampa-Kirby St.	Lopez,et.al. (1984)	2.20	0.250	4.5							0.050	
Tampa-St. Louis St.	Lopez,et.al. (1984)	3.00	0.450	6.1				0.016			0.213	0.133
Orlando-Duplex	Harper (1988)	4.62		9.5	63.2	0.005	0.015	0.033	0.464	0.020	0.058	0.089
Orlando-Essex Pointe	Harper (1988)	1.85	0.200	6.5	30.1	0.002	0.017	0.027	0.420	0.029	0.132	0.045
Palm Beach-Springhill	Greg,et.al. (1989)	1.18	0.307		3.5							
Tampa-102nd Ave.	Holtkamp (1998)	2.62	0.510	13.4	36.8			0.019			0.005	0.060
Bradfordville	ERD (2000)	1.30	0.280	2.7	57.1							
Fl. Keys-Key Colony	ERD (2002)	1.20	0.281	2.0	26.9	0.002	0.003	0.010	0.067		0.001	0.020
Tallahassee-Woodgate	COT & ERD (2002)	1.29	0.505	15.0	76.0			0.007			0.007	0.039
Sarasota Co.	ERD (2004)	1.17	0.506	4.4	10.1							
Orlando-Krueger St.	ERD (2004)	3.99	0.182	17.1	41.8							
Orlando-Paseo St.	ERD (2004)	1.02	0.102	4.0	12.0							
Windemere	ERD (2007)	1.69	0.402		65.0							
Mean Value		2.07	0.327	7.9	37.5	0.003	0.012	0.016	0.320	0.019	0.004	0.062
Median Value		1.85	0.309	6.5	34.9	0.002	0.015	0.014	0.350	0.020	0.005	0.057
Log-Normal Mean:		1.87	0.301	6.6	29.3	0.002	0.009	0.014	0.267	0.017	0.003	0.052

(shaded) not included in mean or median value due to dramatic reductions in lead from removal of lead in gasoline

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Commercial Runoff Characterization Data

Low Intensity Commercial Land Use Runoff Characterization Data (n=9)

Location	Reference	Reported EMC (mg/l)										
		TN	TP	BOD	TSS	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Orlando Area wide	ECFRPC (1978)	0.89	0.160	3.6	146						0.068	
Coral Ridge Mall	Miller (1979)	1.10	0.100	5.4	45.0			0.015			0.387	0.128
Norma Park-Tampa	US EPA (1983)	1.19	0.150	12.0	22.0						0.046	0.037
Internat. Market	Harper (1988)	1.53	0.190	11.6	111	0.008	0.013	0.031	1.100	0.028	0.136	0.168
DeBary	Harper & Herr (1993)	0.76	0.260	6.9	79.1	0.0005	0.003	0.010	0.582		0.009	0.028
Bradfordville	ERD (2000)	2.14	0.160	9.0	38.3							
Cross Creek-Tall.	COT & ERD (2002)	0.93	0.150	8.0	15.0			0.008			0.002	0.045
Sarasota Co.	ERD (2004)	0.88	0.310	4.3	39.9							
Fla. Aquarium-Tampa	Teague,et.al.(2005)	0.76	0.215		42.4	0.003		0.019	1.170		0.008	0.090
Mean Value		1.13	0.188	7.6	59.9	0.004	0.008	0.017	0.951	0.028	0.006	0.083
Median Value		0.93	0.160	7.5	42.4	0.003	0.008	0.015	1.100	0.028	0.008	0.068
Log-Normal Mean:		1.07	0.179	7.00	47.51	0.002	0.006	0.015	0.908	0.028	0.005	0.067

(shaded) not included in mean value due to reductions from removal of lead in gasoline

High Intensity Commercial Land Use Runoff Characterization Data (n=4)

Location	Reference	Reported EMC (mg/l)										
		TN	TP	BOD	TSS	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Broward County	Mattraw,et.al.,(1981)	1.10	0.100	5.4	45.0	0.009		0.015	0.334		0.387	0.128
Orlando-Downtown	Wanielista, (1982)	2.81	0.310	17.2	94.3						0.056	0.165
Dade Co.	Waller (1984)	3.53	0.820								0.187	0.183
Broward County	Howie,et.al.(1986)	2.15	0.150								0.241	0.162
Mean Value		2.40	0.345	11.3	69.7	0.009		0.015	0.334			0.160
Median Value		2.48	0.230	11.3	69.7	0.009		0.015	0.334			0.164
Log-Normal Mean:		2.20	0.248	9.6	65.1	0.009		0.015	0.334			0.158

(shaded) not included in mean value due to reductions from removal of lead in gasoline

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Highway Runoff Characterization Data (n=15)

Location	Reference	Reported EMC (mg/l)										
		TN	TP	BOD	TSS	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Broward Co. (6 lane)	Mattraw,et.al.,(1981)	0.96	0.080	9.0	15.0	0.007		0.007	0.207		0.282	0.090
Miami I-95	McKenzie,et.al.(1983)	3.20	0.160		42.0	0.001	0.010	0.040			0.590	0.330
Maitland	German (1983)	1.30	0.240		27.0			0.012	0.350	0.009	0.092	0.055
Maitland I-4	Harper (1985)	1.40	0.170			0.003	0.004	0.038	0.341	0.003	0.163	0.071
Maitland Blvd.	Yousef,et.al.(1986)	1.40	0.170			0.002	0.004	0.039	0.354	0.004	0.181	0.074
I-4 EPCOT	Yousef,et.al.(1986)	3.16	0.420			0.002	0.003	0.024	0.205	0.003	0.026	0.024
Winter Park I-4	Harper (1988)	1.60	0.230	6.9	34.0	0.008	0.013	0.050	1.120	0.046	0.224	0.170
Orlando I-4	Harper (1988)	2.15	0.550	4.2	66.5	0.008	0.014	0.067	1.450	0.020	0.343	0.272
Bayside Bridge	Stoker (1996)	1.10	0.100		20.0	0.000	0.003	0.008	0.530	0.003	0.011	0.050
Tallahassee (6 lane)	ERD (2000)	1.10	0.166	1.9	70.6							
Orlando US 441	ERD (2007)	0.68	0.085	4.2	23.1							
Flamingo Dr. Collier, County	Johnson Eng. (2009)	0.94	0.060		18.5	0.0008	0.001	0.002	0.277	0.002	0.001	0.029
SR-80, Hendry County	Johnson Eng. (2009)	1.31	0.168		120	0.0003	0.001	0.011	1.235	0.004	0.008	0.155
Richard Rd, Lee Co.	Johnson Eng. (2006)	1.60	0.282		76.0	0.0003	0.002	0.010	1.244	0.001	0.007	0.130
US 41, Lee County	Johnson Eng. (2008)	0.82	0.120		39.0	0.0000	0.003	0.012	0.341	0.001	0.002	0.061
Mean Value		1.515	0.200	5.2	46.0	0.003	0.005	0.025	0.638	0.009	0.006	0.116
Median Value		1.310	0.168	4.2	36.5	0.001	0.003	0.012	0.352	0.003	0.007	0.074
Geometric Mean		1.371	0.167	4.8	38.1	0.001	0.004	0.017	0.498	0.004	0.004	0.087

not included in mean value due to reductions from removal of lead in gasoline

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Summary of Runoff Characterization Data

Land Use Category	No. of Studies 1994	2003	2007	2012
1. Low-Density Residential	0 – calc.[1]	0 – calc.[1]	0 – calc.[1]	0 – calc.[1]
2. Single-Family Resid.	9	16	17	17
3. Multi-Family Residential	6	6	6	6
4. Low-Intensity Comm.	5	9	9	9
5. High-Intensity Comm.	3	4	4	4
6. Light Industrial	2	2	4	4
7. Highway	6	10	11	15
8. Agricultural				
a. Pasture	3	3	3	4
b. Citrus	7	7	7	7
c. Row Crops	7	8	8	8
9. Undeveloped/Rangeland/ Forest	4	3	4	33
10. Mining	1	1	1	1

1. Calculated as mean of SFR and undeveloped land

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Comparison of 2007 and Current (2012) emc Values

Land Use Category	2007 Values (mg/l)		Revised (2012) Values (mg/l)	
	Total N	Total P	Total N	Total P
Low Density Residential[1]	1.61	0.191	1.51	0.178
Single Family	2.07	0.327	1.87	0.301
Multi-Family	2.32	0.520	2.10	0.497
Low Intensity Commercial	1.18	0.179	1.07	0.179
High Intensity Commercial	2.40	0.345	2.20	0.248
Light Industrial	1.20	0.260	1.19	0.213
Highway	1.64	0.220	1.37	0.167
Agricultural				
Pasture	3.47	0.616	3.30	0.621
Citrus	2.24	0.183	2.07	0.152
Row Crops	2.65	0.593	2.46	0.489
Undeveloped/Rangeland/Forest	1.15	0.055	Natural Area Values	
Mining/Extractive	1.18	0.150	1.18	0.150

Changes from 2007 to 2012 datasets:

- Central tendency expressed as geometric (log-normal) means rather than arithmetic means
- Additional emc values added for highway and natural areas

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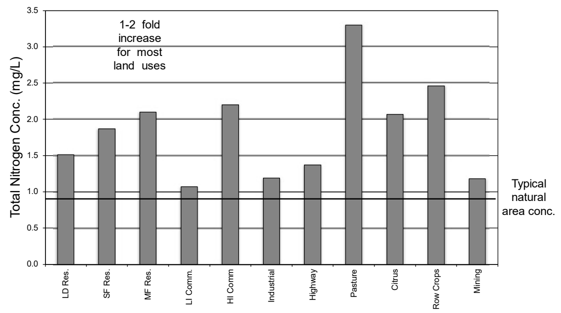
Comparison of Typical Nitrogen Concentrations in Stormwater



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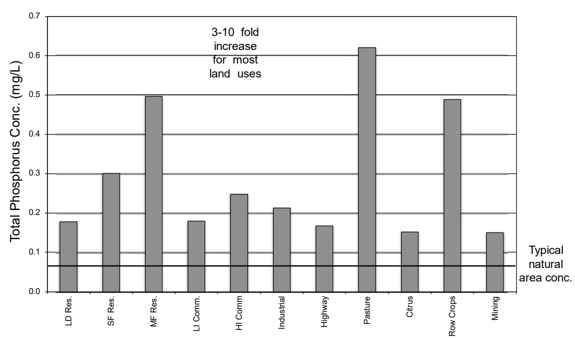
Comparison of Typical Phosphorus Concentrations in Stormwater



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Impacts of Reuse Irrigation on Runoff Characteristics

- The chemical characteristics of reuse water are highly variable, depending on location and level of treatment
- Characteristics of secondary effluent – minimum level of treatment
  - Nitrogen ~ 4-20 mg/l, mostly as NO_3^- and organic N (2-15 times higher than urban runoff)
  - Phosphorus ~ 2-15 mg/l (8-60 times higher than runoff)
  - On average, secondary reuse water is similar in characteristics to septic tank leachate
  - No requirement to measure nutrient levels, except NO_x
  - Approximately 2/3 of WWT plants in Florida provide secondary treatment

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Impacts of Reuse Irrigation on Runoff Characteristics – cont.

- Characteristics of tertiary effluent – adds nutrient removal
  - Nitrogen - < 3 mg/l
  - Phosphorus - <1 mg/l
  - Tertiary reuse is similar in characteristics to HDR stormwater runoff
  - Approximately 1/3 of WWT plants in Florida provide tertiary treatment
- Impact assessments for reuse only give a cursory look at nutrient impacts
  - Most simply state that the presence of nutrients will increase the value of the water

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Comparison of Mean Stormwater Characteristics of Basin Areas with and without Reuse Irrigation (ERD, 1994)

Parameter	Units	Without Reuse[1]	With Reuse[1]	Enrichment By Reuse (%)
Alkalinity	mg/L	40.5	58.1	44
Ammonia	µg/L	87	537	520
NOx	µg/L	218	456	109
Total N	µg/L	1,526	2,355	54
SRP	µg/L	192	241	25
Total P	µg/L	376	569	51
BOD	mg/L	4.8	7.7	59

1. Geometric mean values

Conclusion: Secondary reuse irrigation increases concentrations of nutrients by approximately 50%

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Natural Area Monitoring Project

Objectives

- FDEP funded project to characterize runoff quality from common natural undeveloped upland vegetative communities in Florida
- Data to be used to support pre-development runoff quality for Statewide Stormwater Rule

Work Efforts

- Total of 33 automated monitoring sites established in 10 State parks throughout Florida
- Monitoring conducted over 14 month period from July 2007 – August 2008 to include variety of seasonal conditions
- Total of 318 samples collected and analyzed for general parameters, nutrients, demand parameters, fecal coliform and heavy metals

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Monitored State Parks

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Summary of Florida Upland Land Use Classifications
(Source: FFWCC)

Classification	Area (acres)	Percent of Total
Coastal Strand	15,008	0.1
Dry Prairie	1,227,697	11.4
Hardwood Hammock/Forest	980,612	9.1
Mixed Pine/Hardwood Forest	889,010	8.3
Pinelands	6,528,121	60.7
Sand Pine Scrub	194,135	1.8
Sandhill	761,359	7.1
Tropical Hardwood Hammock	15,390	0.1
Xeric Oak Scrub	146,823	1.4
Totals:	10,758,155	100.0

Monitored natural areas include more than 92% of upland land covers in Florida

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Alfred B. Maclay Gardens State Park
Natural Communities

Community Characteristics

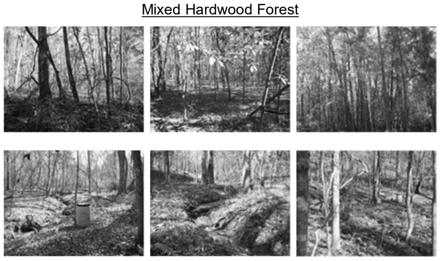
- Well-developed, closed canopy forests of upland hardwoods on rolling hills

- Most common in northern panhandle Florida

- Generally lack shortleaf pine, American beech and other more northern species

-Occur on rolling hills that often have limestone or phosphatic rock near the surface

Mixed Hardwood Forest



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Faver-Dykes State Park

Natural Communities

Community Characteristics

- Characterized as an open canopy forest of widely spaced pine trees with dense ground cover of herbs and shrubs
- Occur on relatively flat, moderately to poorly drained
- Soils typically consist of 1-3 feet of acidic sands generally overlying an organic hardpan or clayey subsoil
- Most widespread biological community in Florida

Mesic Flatwoods/Pinelands

Synonyms: Pine flatwoods, pine savannah, pine barrens

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Jonathan Dickinson State Park

Natural Communities

Community Characteristics

- Relatively open-canopy forests of scattered pine trees or cabbage palms
- Relatively flat, poorly drained terrain
- Soils consist of 1 to 3 feet of acidic sands overlying an organic hardpan or clay layer

Wet Flatwoods

Synonyms: Low flatwoods, moist pine barren, hydric flatwoods, pond pine fltwoods, cabbage palm/pine savannah/flatwoods

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Silver River State Park

Natural Communities

Community Characteristics

- Well-developed, closed canopy forests of upland hardwoods on rolling hills
- Most common in northern and central peninsula Florida

Upland Hardwood Forest

Synonyms: Mesic hammock, climax hardwoods, upland hardwoods, beech-magnolia climax, oak-magnolia climax, pine-oak-hickory association, southern mixed hardwoods, clay hills hammocks, Piedmont forest

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Lake Louisa State Park
Natural Communities

Ruderal/Upland Pine Forest
Synonyms: Longleaf pine upland forest, loblolly-shortleaf upland forest, clay hills, high pineland

Community Characteristics

- Rolling forest of widely spaced pines with few understory shrubs and a dense ground cover of grasses and herbs
- Occurs on the rolling hills of extreme northern Florida
- Soils are composed of sand with variable amounts of Miocene clays

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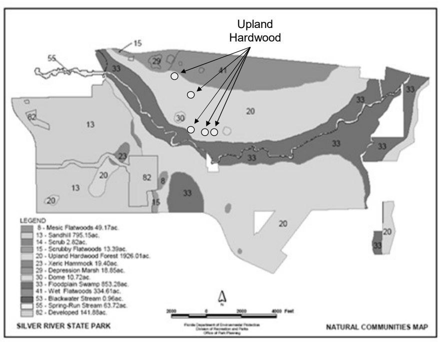
Silver River State Park
Monitoring Site Natural Communities



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Fakahatchee Strand State Park
Natural Communities

Strand Swamp
Synonyms: Cypress strand, stringer

Community Characteristics

- Shallow, forested, usually elongated depressions or channels dominated by bald cypress
- Situated in troughs in a flat limestone plain
- Soils are peat and sand over limestone
- Occur mainly in Collier County

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San Felasco Hammock Preserve State Park

Natural Communities

Upland Mixed Forest

Synonyms: Mesic hammock, climax hardwoods, upland hardwoods, beech-magnolia climax, oak-magnolia climax, pine-oak-hickory association, southern mixed hardwoods, clay hills hammocks, Piedmont forest

Community Characteristics

- Well-developed, closed canopy forests of upland hardwoods on rolling hills
- Most common in northern and central peninsula Florida north of Ocala
- Generally lack shortleaf pine, American beech and other more northern species

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Myakka River State Park

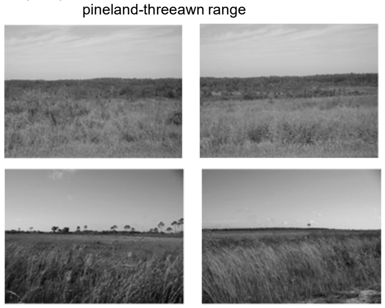
Natural Communities

Dry Prairie

Synonyms: Palm Savannah, palmetto prairie, pineland-threeawn range

Community Characteristics

- Nearly treeless plain with a dense ground cover of wiregrass, saw palmetto, and other grasses, herbs, and low shrubs
- Relatively flat, moderately to poorly drained terrain
- 1 to 3 feet of acidic sands generally overlying an organic hardpan or clayey subsoil



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Wekiva River State Park

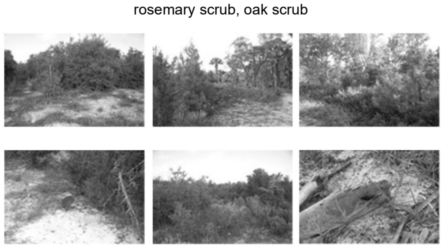
Monitoring Site Communities

Xeric Scrub

Synonyms: Sand pine scrub, Florida scrub, sand scrub, rosemary scrub, oak scrub

Community Characteristics

- Closed to open canopy forest of sand pines with dense clumps or vast thickets of scrub oaks and other shrubs dominating the understory
- Occurs on sand ridges along former shorelines
- Well washed deep sands



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Natural Land Use Runoff Characteristics

Land Type	N	Total N (µg/l)	Total P (µg/l)	Iron (mg/l)	Fecal Coliform (cfu/100ml)
Dry Prairie	12	1,950	107	1.259[1]	72
Hydric Hammock	17	1,072	26	0.537	43
Marl Prairie	3	603	10	0.162	83
Mesic Flatwoods	26	1,000	34	0.598	363[1]
Mixed Hardwood Forest	39	288	501	1.479[1]	166
Ruderal/Upland Pine	2	1,318	347	3.311[1]	17
Scrubby Flatwoods	17	1,023	27	0.741	295[1]
Upland Hardwood	79	891	269	0.776	155
Upland Mixed Forest	16	676	2,291	0.437	372[1]
Wet Flatwoods	77	1,175	15	0.347	117
Wet Prairie	9	776	9	0.069	68
Xeric Hammock	1	1,318	2,816	0.814	108
Xeric Scrub	3	1,158	96	0.060	1533[1]

1. Values which exceed Class III criterion

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Natural Community Indices

1. Florida Vegetation and Land Cover (FFWCC)
   - Reflects existing land cover based on aerial photography – both developed and natural areas
   - Original survey conducted in 1990s included:
     - 17 natural and semi-natural cover types
     - 4 land cover types reflecting disturbed land
     - 1 water class
   - Survey updated in 2003 and included:
     - 26 natural and semi-natural cover types
     - 16 land cover types reflecting disturbed land
     - 1 water class
   - Coverage maps are available for all of Florida

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Natural Community Indices – cont.

2. Florida Natural Areas Inventory (FNAI) - 2010
   - Developed by Florida Department of Natural Resources (DNR)
   - Reflects original, natural vegetation associations in Florida
   - Natural communities are characterized and defined by a combination of physiognomy, vegetation structure and composition, topography, land form, substrate, soil moisture condition, climate, and fire
   - Named for their most characteristic biological or physical feature
   - Grouped into 6 Natural Community Categories with 13 Natural Community Groups and 66 sub-groups based on hydrology and vegetation
   - FNAI is system used by State Park system
   - Coverage maps are not available for all of Florida
   - This coverage index selected for natural area characterization study

   - http://fnai.org/PDF/AA_Short_Descriptions_Final_2010.pdf

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Estimating Natural Area Loadings

- A wide variability was observed in nutrient concentrations from natural areas
  - Natural areas with deciduous vegetation were characterized by higher runoff concentrations
- After the community is identified, the annual mass loading is calculated by:

  Annual Loading = emc conc. for community type x annual runoff volume

- To simplify calculations, the measured concentrations were converted to annual areal mass loadings based on the hydrologic characteristics of the sites
  - The resulting data fell into two distinct groups with a narrow range of values within each group

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Florida Land Use and Cover Classification System (FLUCCS)

- FLUCCS codes contain too much detail and often misclassify land use activities
- Insufficient data exist to provide emc values for all FLUCCS codes
- FLUCCS codes can be converted to the general categories based on anticipated runoff characteristics

FLUCCS Code	Description
1100	Residential, Low Density-Less than 2 du/acre
1200	Residential, Medium Density-Two-five du/acre
1300	Residential, High Density
1400	Commercial and Services
1700	Institutional
1820	Golf Course
2110	Improved Pasture
2120	Unimproved Pastures
2130	Woodland Pasture
2210	Citrus groves
3100	Herbaceous Dry Prairie
3200	Shrub and Brushland
3300	Mixed Rangeland
4110	Pine flatwoods
4340	Hardwood Conifer Mixed
6120	Mangrove swamp
6170	Mixed wetland hardwoods
6420	Saltwater marshes
6460	Mixed scrub-shrub wetland
7410	Rural land in transition w/o indicators of intended activity

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Use of FLUCCS Codes in Loading Calculations

Problems:

- Runoff emc data are not available for all of the listed land use categories

- FLUCCS codes can be converted to one of the general categories based on anticipated runoff characteristics

FLUCCS Code	Description
1110	Fixed Single Family Units
1290	Medium Density Under Construction
1320	Mobile Home Units
1460	Oil and Gas Storage
1530	Mineral Processing
1562	Pre-stressed concrete plants
1620	Sand and Gravel Pits
1730	Military
1750	Governmental
2610	Fallow cropland
2320	Poultry feeding operations
2420	Sod farms
2600	Other Open Lands – Rural
2610	Fallow cropland
4280	Cabbage palm
5250	Marshy Lakes
6500	Non-vegetated Wetland
8115	Grass Airports
8130	Bus and truck terminals
8180	Auto parking facilities
8330	Water supply plants

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Summary

- Runoff emc values are available for a wide range of landuse categories in Florida
  - Urban land uses
  - Natural land uses
- Estimation of annual runoff loadings requires
  - Estimation of annual runoff volume
  - Runoff emc value which reflects runoff characteristics
- BMPTrains Model calculates loadings based on user input data for
  - Location
  - Annual rainfall
  - Project physical characteristics
  - Pre/post Land use and cover
  - Soil types – CN values

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Part 4

Calculation of Runoff Loadings

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Calculation of Runoff Loadings

- Pollutant loadings can be calculated using two methodologies:
  - Areal loading method (kg/ac-yr)
    - Very general approach that has minimal data requirements
    - Assumes that the hydrologic characteristics for a given land category are the same
    - Subject to large errors
    - Only for general loading comparisons
  - Concentration-based method
    - Requires information on runoff volumes and concentrations
    - More accurate approach
    - Method used in Harper Methodology and BMPTRAINS Model

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Areal Loading Rate Method

Annual Loading = Areal Loading Rate x Land Use Area

Land Use	Area (acres)		Total P Loading Rate (kg/ac-yr)		Total P Mass (kg/yr)
Single Family	100	x	0.594	=	59.4
Low Intensity Commercial	50	x	0.650	=	32.5
Industrial	20	x	1.24	=	24.8
Totals	170				116.7

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Concentration-Based Method

Annual Loading = emc conc. x annual runoff volume

<u>Advantages</u>

- Considers site-specific hydrologic characteristics
- More accurate than areal loading method

<u>Disadvantage</u>

- More difficult and time-consuming than areal loading method

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Concentration-Based Method

Annual Loading = Runoff Concentration x Annual Runoff Volume for Each Land Use

Land Use	Total P Conc. (mg/L)		Runoff Volume (ac-ft/yr)		Total P Mass (kg/yr)
Single Family	0.30	x	120	=	44.4
Low Intensity Commercial	0.15	x	160	=	29.6
Industrial	0.31	x	64	=	24.5
Totals			344		98.5

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Calculation of Pollutant Loadings

Load (kg/yr) =

$$\sum_{i=1}^{n} \left[(A_i) \times \frac{43{,}560\ ft^2}{acre} \times R \times (CV_i) \times \frac{1\ ft}{12\ inches} \times \frac{7.48\ gal}{ft^3} \times \frac{3.785\ liter}{gal} \times (C_i) \times \frac{1\ kg}{10^6\ mg} \right]$$

where:

- A_i = area of land use category, $_i$ (acres)
- n = number of different land use categories
- C_i = concentration of runoff constituent in land use category, $_i$ (mg/l)
- R = annual rainfall at site (inches/yr)
- CV_i = runoff "C" value for land use category, $_i$ (dimensionless)

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Example Calculation

1. Land Use: 90 acres of single-family residential
   5 acres of stormwater management systems
   5 acres of preserved wetlands
2. Ground Cover/Soil Types
   A. Residential areas will be covered with lawns in good condition
   B. Soil types in HSG D
3. Impervious/DCIA Areas
   A. Residential areas will be 25% impervious, 75% of which is DCIA

   Impervious Area = 25% of developed site = 90 ac x 0.25 = 22.50 acres

   DCIA Area = 22.50 acres x 0.75 = 16.88 acres

   % DCIA = (16.88 ac/90.0 ac) x 100 = 18.7% of developed area

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Example Calculations – cont.

4. Post Development Annual Runoff Generation

   The post development loading reflects the loading discharging to the stormwater management system from the watershed and does not include the area of the treatment system

   The post development area is 90 acres. The wetland area is not included since it is the same under pre and post conditions

Project Location	Area (acres)	Impervious Areas		DCIA		Non-DCIA CN Value	Annual Rainfall (in)	Annual C Value	Runoff (ac-ft/yr)
		%	acres	acres	%				
Pensacola	90	25	22.5	16.68	18.75	81.4	65.5	0.304	149.3
Orlando	90	25	22.5	16.68	18.75	81.4	50.0	0.253	94.8
Key West	90	25	22.5	16.68	18.75	81.4	40.0	0.266	79.8

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Example Calculations – cont.

5. Generated Loading to Stormwater Pond:

Under post-development conditions, nutrient loadings will be generated from the 90-acre developed single-family area.

Stormwater management systems are not included in estimates of post-development loadings since incidental mass inputs of pollutants to these systems are included in the estimation of removal effectiveness.

Assume mean emc values for total nitrogen and total phosphorus in single-family residential runoff of:

TN = 1.87 mg/l TP = 0.301 mg/l

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Example Calculations – cont.

5. Generated Loading to Stormwater Pond:

a. Pensacola (Zone 1) Project

TN load from single-family area:

$$\frac{149.3\ \text{ac-ft}}{\text{yr}} \times \frac{43{,}560\ \text{ft}^2}{\text{ac}} \times \frac{7.48\ \text{gal}}{\text{ft}^3} \times \frac{3.785\ \text{liter}}{\text{gal}} \times \frac{1.87\ \text{mg}}{\text{Liter}} \times \frac{1\ \text{kg}}{10^6\ \text{mg}} = \frac{344\ \text{kg}}{\text{TN/yr}}$$

TP load from single-family area:

$$\frac{149.3\ \text{ac-ft}}{\text{yr}} \times \frac{43{,}560\ \text{ft}^2}{\text{ac}} \times \frac{7.48\ \text{gal}}{\text{ft}^3} \times \frac{3.785\ \text{liter}}{\text{gal}} \times \frac{0.301\ \text{mg}}{\text{liter}} \times \frac{1\ \text{kg}}{10^6\ \text{mg}} = 55.4\ \text{kg TP/yr}$$

Location	TN Loading (kg/yr)	TP Loading (kg/yr)
Pensacola	344	55.4
Orlando	219	35.2
Key West	184	29.6

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Example Calculations – cont.

6. Pre-Development Runoff and Mass Loadings:

- The pre-development area for calculating loadings is 95 acres (100 acres – 5 acres of preserved wetlands)
- The natural vegetation on the area to be developed (95 acres) consists of 60% mesic flatwoods and 40% wet flatwoods in fair condition on HSG D soils.
- From TR-55, the CN value for wooded areas in fair condition on HSG D soils = 79

Project Location	Area (acres)	Impervious Areas		DCIA		Non-DCIA CN Value	Annual Rainfall (in)	Annual C Value	Runoff (ac-ft/yr)
		acres	%	acres	%				
Pensacola	95	0	0	0	0	79	65.5	0.154	79.9
Orlando	95	0	0	0	0	79	50.0	0.105	41.6
Key West	95	0	0	0	0	79	40.0	0.125	39.6

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Example Calculations – cont.

6. Pre-Development Runoff and Mass Loadings – cont.

- Composite runoff concentrations should be calculated on a weighted basis based on annual runoff volumes
- Since the CN values for the 2 land covers are the same, the annual runoff volumes are also the same
- Mean emc values for total nitrogen and total phosphorus under pre-development conditions:

Land Cover	Percent Cover (%)	Runoff emc Values (mg/L)		Weighted emc Values (mg/L)	
		Total N	Total P	Total N	Total P
Mesic flatwoods	60	1.000	0.034	1.070	0.026
Wet flatwoods	40	1.175	0.015		

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Example Calculations – cont.

6. Pre-Development Runoff and Mass Loadings – cont.

a. Pensacola (Zone 1) Project

TN load from pre-developed areas:

$$\frac{79.9\ \text{ac-ft}}{\text{yr}} \times \frac{43{,}560\ \text{ft}^2}{\text{ac}} \times \frac{7.48\ \text{gal}}{\text{ft}^3} \times \frac{3.785\ \text{liter}}{\text{gal}} \times \frac{1.07\ \text{mg}}{\text{liter}} \times \frac{1\ \text{kg}}{10^6\ \text{mg}} = \underline{105.4\ \text{kg TN/yr}}$$

TP load from pre-developed areas:

$$\frac{79.9\ \text{ac-ft}}{\text{yr}} \times \frac{43{,}560\ \text{ft}^2}{\text{ac}} \times \frac{7.48\ \text{gal}}{\text{ft}^3} \times \frac{3.785\ \text{liter}}{\text{gal}} \times \frac{0.026\ \text{mg}}{\text{liter}} \times \frac{1\ \text{kg}}{10^6\ \text{mg}} = \underline{2.56\ \text{kg TP/yr}}$$

Location	TN Loading (kg/yr)	TP Loading (kg/yr)
Pensacola	105.4	2.56
Orlando	54.9	1.33
Key West	52.3	1.27

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Example Calculations - cont.

7. Calculate required removal efficiencies to achieve post- less than or equal to pre-loadings:

Summary of pre- and post-loadings and required removal efficiencies

Project Location	Total Nitrogen			Total Phosphorus		
	Pre-Load (kg/yr)	Post-Load (kg/yr)	Required Removal (%)	Pre-Load (kg/yr)	Post-Load (kg/yr)	Required Removal (%)
Pensacola (Zone 1)	105.4	344	69.3	2.56	55.4	95.4
Orlando (Zone 2)	54.9	219	74.9	1.33	35.2	96.2
Key West (Zone 3)	52.3	184	71.6	1.27	29.6	95.7

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Questions?

Copies of research reports available on ERD website

erd.org

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