The RECARGA Model

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RECARGA Background

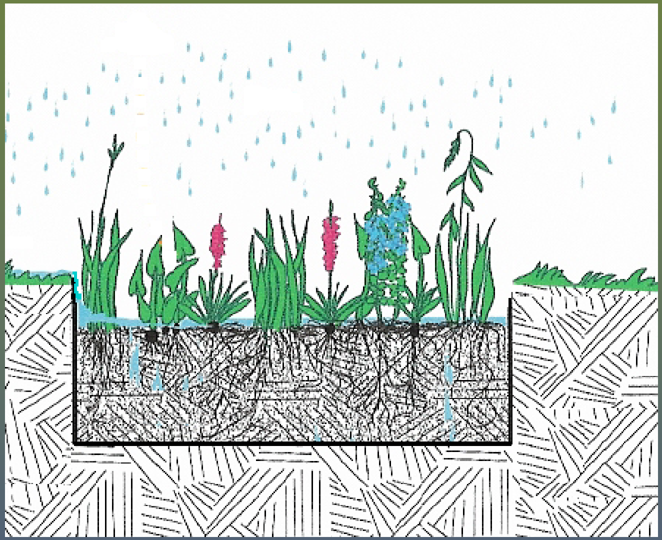
- Hydrologic modeling of Bio/Infiltration systems
  - Quantify ponding, infiltration, overflow, ET, and recharge
- Does not directly model water quality but many inferences on water quality performance can be obtained from quantifying runoff reduction and adsorption / filtration

Table 2.1 Typical Pollutant Removal Rates for Bioretention Facilities

Pollutant	Removal Rate (%)[1]
Total Suspended Solids (TSS)	90[2]
Metals (Cu, Zn, Pb)	>95[3]
Total Phosphorus	80[3]
Total Kjeldahl Nitrogen	65-75[4]
Ammonium	60-80[4]
Organics	90[2]
Bacteria	90[2]

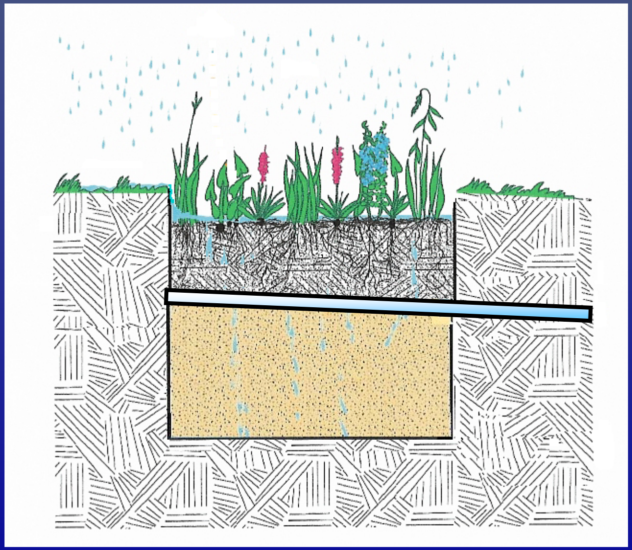
1. Data Compiled by Wisconsin DNR (Bioretention Tech. Note 1004, draft)
2. Prince George's County, Md., Department of Environmental Resources, 1999
3. Davis et al. 2003
4. Davis et al. 2001

Basic Bio-Infiltration Systems (Raingardens)



- Work best in well drained soil.
- Small drainage area.

Enhanced Bio-Infiltration Systems



- Extra storage layer and and underdrain
- Reduces ponding time
- More groundwater recharge
- Just use as Filter

Montgomery Associates
Resource Solutions, LLC


Infiltration Basin -
West Bend, WI

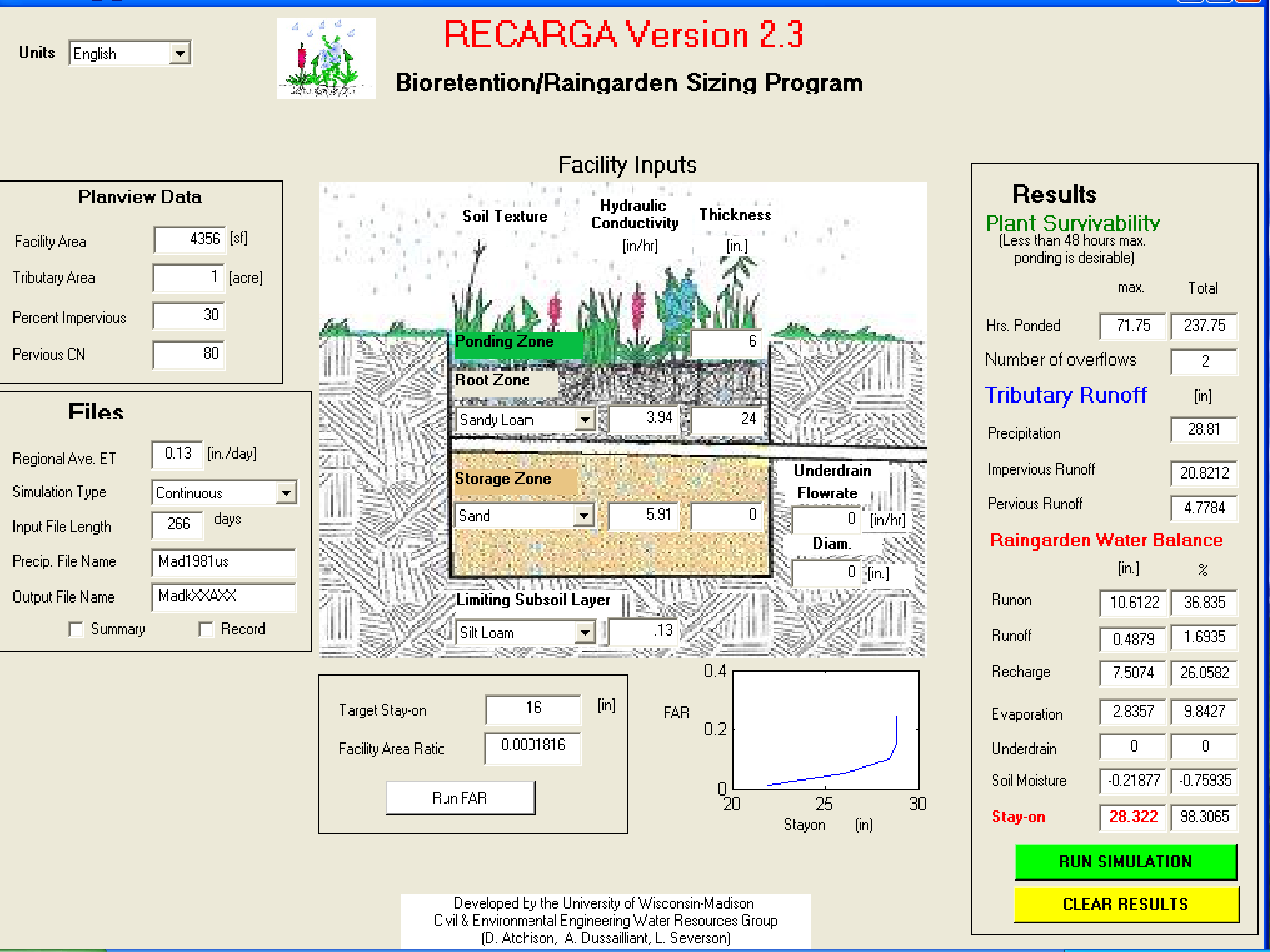
RECARGA Versions

- Version 1.0: Developed by UW-Department of Civil and Environmental Engineering in 2002 by Alejandro Dussaillant
- Version 2.0: Incorporated tributary pervious surfaces, an underdrain, a Graphical User Interface (GUI), continuous variable ET, and output files
- Version 2.1: Added design storm events and a user-supplied inflow hydrograph
- Version 2.2: Enhanced the GUI and made metric mode updates
- **Version 2.3**: Added a design module
- **LA_RECARGA Version 1.0**: Increased input/output flexibility, modified code structure to reduce model execution time, and enhanced the evapotranspiration routine

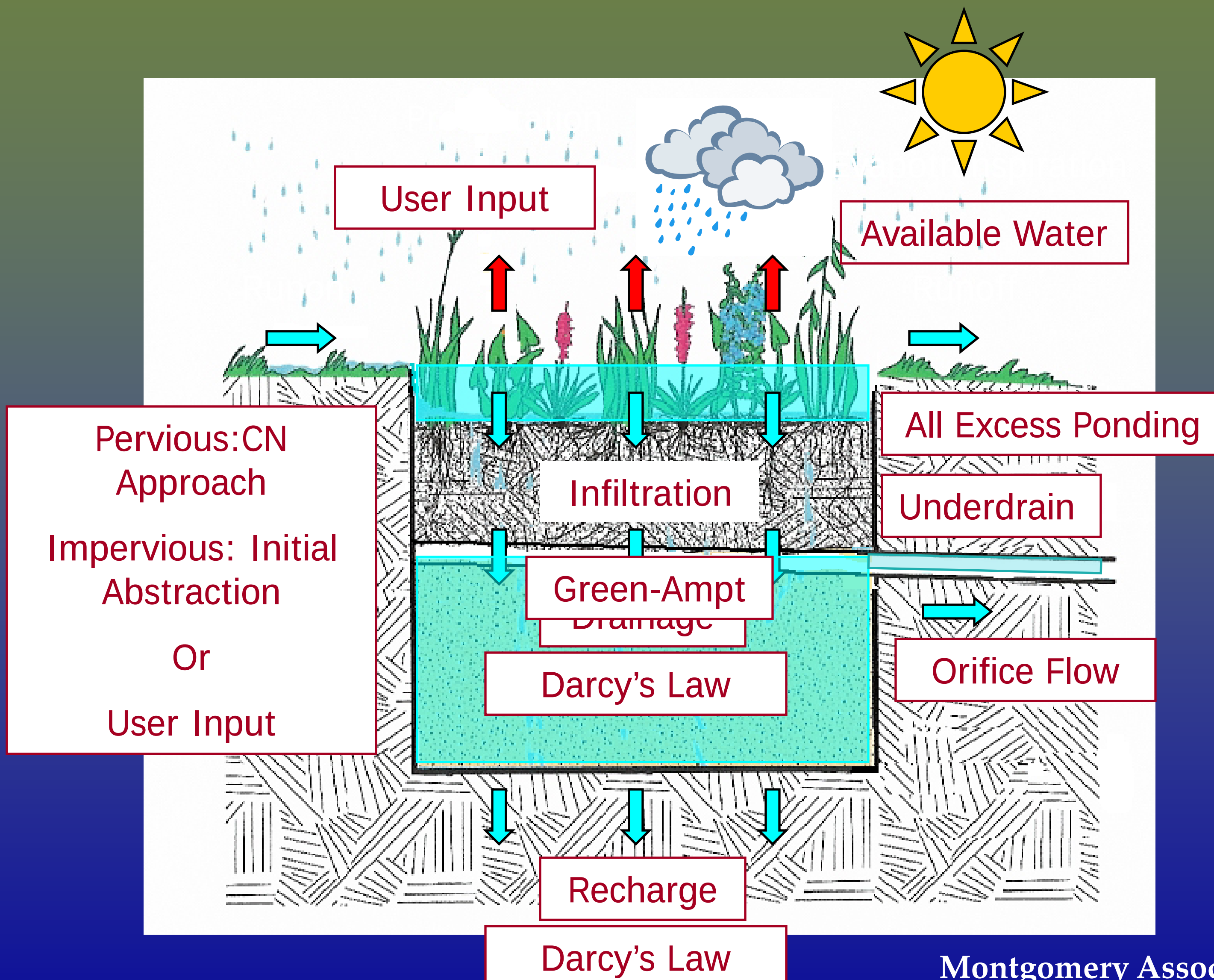
RECARGA Model Download

- Wisconsin Version 2.3 is available for download from the Wisconsin Department of Natural Resources website:

http://dnr.wi.gov/runoff/models/


Units
English
RECARGA Version 2.3
Bioretention/Raingarden Sizing Program
Facility Inputs
Planview Data
Facility Area 4356 [sf]
Tributary Area 1 [acre]
Percent Impervious 30
Pervious CN 80
Files
Regional Ave. ET 0.13 [in./day]
Simulation Type Continuous
Input File Length 266 days
Precip. File Name Mad1981us
Output File Name MadkXXAXX
Summary
Record
Soil Texture
Hydraulic Conductivity [in/hr]
Thickness [in.]
Ponding Zone 6
Root Zone
Sandy Loam 3.94 24
Storage Zone
Sand 5.91 0
Underdrain Flowrate 0 [in/hr]
Diam. 0 [in.]
Limiting Subsoil Layer
Silt Loam .13
Target Stay-on 16 [in]
Facility Area Ratio 0.0001816
Run FAR
FAR
0.4
0.2
0
20
25
30
Stayon (in)
Results
Plant Survivability
(Less than 48 hours max. ponding is desirable)
max. Total
Hrs. Ponded 71.75 237.75
Number of overflows 2
Tributary Runoff [in]
Precipitation 28.81
Impervious Runoff 20.8212
Pervious Runoff 4.7784
Raingarden Water Balance
[in.] %
Runon 10.6122 36.835
Runoff 0.4879 1.6935
Recharge 7.5074 26.0582
Evaporation 2.8357 9.8427
Underdrain 0 0
Soil Moisture -0.21877 -0.75935
Stay-on 28.322 98.3065
RUN SIMULATION
CLEAR RESULTS
Developed by the University of Wisconsin-Madison
Civil & Environmental Engineering Water Resources Group
(D. Atchison, A. Dussailliant, L. Severson)

RECARGA Model Theoretical Framework



Moisture Flux Below the Surface

- Drainage is assumed to be gravity driven only
- User supplies Saturated Hydraulic Conductivity
- Program calculates Unsaturated Hydraulic Conductivity from Van Genuchten Relationship based on moisture content (Van Genuchten, M. T. 1980)

$$Drainage = K_{sat}\Theta^{\frac{1}{2}}\left[1-\left(1-\Theta^{\frac{1}{2}}\right)^{m}\right]^{2}$$

K_{sat} = Saturated Hydraulic Conductivity
Θ = dimensionless water content
m = 1-1/n
n = Van Genuchten Parameter

RECARGA Modeling Modes

- Continuous Simulation
  - Model-generated runoff
  - User-supplied inflow to the rain garden
  - Evaporation and percolation simulated between storm events
- Design-Storm
  - SCS Type I, IA, II, III
  - 24- hour storm event plus 2 additional days without rain
  - Summarizes mass balance terms over 3-day period
  - Unit hydrographs scaled by rainfall depth
  - Regional daily ET value read from GUI

Precipitation

- Precipitation
  - Hourly data entered into a tab-delimited text file which also contains an hourly time step and maximum potential evapotranspiration for the region of interest

Mad1981US.txt - Notepad

File Edit Format View Help

time (hr)	rain (in.)	evap (in.)
0	0	0.003753051
1	0	0.003753051
2	0	0.003753051
3	0	0.003753051
4	0	0.003753051
5	0	0.003753051
6	0	0.003753051
7	0	0.003753051
8	0	0.003753051
9	0	0.003753051
10	0	0.003753051
11	0	0.003753051
12	0	0.003753051
13	0	0.003753051
14	0	0.003753051
15	0	0.003753051
16	0	0.003753051
17	0	0.003753051
18	0	0.003753051
19	0	0.003753051
20	0	0.003753051
21	0	0.003753051
22	0	0.003753051
23	0	0.003753051
24	0	0.003753051
25	0	0.003753051
26	0	0.003753051
27	0	0.003753051
28	0	0.003753051

Runoff

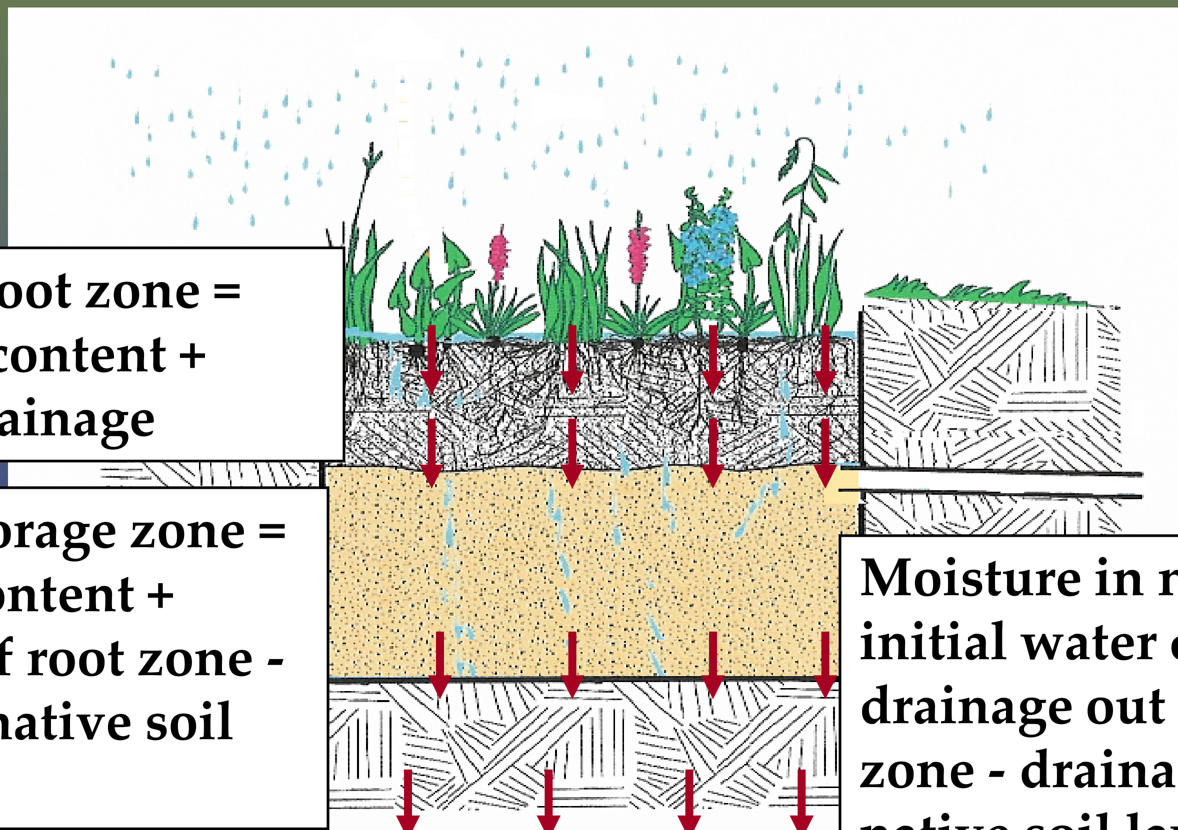
- Impervious Tributary Surfaces
  - Runoff=rainfall at each time step-available depression storage
- Pervious Surface: SCS curve number methodology
  - User characterizes pervious surface with a CN
  - SCS calculation to find the cumulative runoff for each time step
  - Each timestep the runoff is calculated as the difference in cumulative runoff between timesteps

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

$$s = \frac{100}{CN} - 10$$

$$Q_i = Q - Q_{i-1},$$

Mass Balance



Moisture in root zone = initial water content + infiltrated-drainage

Moisture in storage zone = initial water content + drainage out of root zone - drainage into native soil layer

Moisture in native soil = initial water content + drainage out of storage zone - drainage out of native soil layer (assumed 10 ft)

- **Saturated zones limit drainage from above layer**

Summary Screen

RECARGA 2.3
Date: 12-Jan-2004 10:51:45
Output File: Example.txt
Input File: Mad1981.txt
Number of time steps= 25537
CPU elapsed time (s)= 46

INPUT TERMS
%Impervious= 60
Pervious CN= 80
Facility Area (m2)= 100
Trib. Area (m2)= 1000
RATIOimp2rg= 6
RATIOperv2rg= 4

LAYER	DEPTH (cm)	Ksat (cm/hr)	TEXTURE
Depression	15	---	---
Root Zone	45	10.00	2
Storage	30	15.00	1
Native	---	0.34	5

Init. Cond.: suction head (cm)= -100
Max. Underdrain flow (cm/hr)= 0.31
Underdrain diam (mm)= 7

WATER BALANCE TERMS

	Volume(m3)	Depth (cm)	%of Inflow
Inflow	400.52	36.41	100.00
Runoff	23.66	2.15	5.91
Recharge	208.58	18.96	52.08
Evaporation	79.38	7.22	19.82
Underdrain	95.73	8.70	23.90
Storage	-6.83	-0.62	-1.71
Infiltrated	376.86		
Precip.		73.18	
Imp. Inflow	317.31	52.89	79.23
Perv.Inflow	30.32	7.58	7.57
Basin Stayon(cm)		38.41	

Mass Balance Checks:
Vinsoil=input-roff-dvh
Vinsoil (m3)= 3.768642e+002
Vinf difference (%)= -0.0
Vrecharg1=inf-et-dsws
Vrecharg1 (m3)= 2.085808e+002
Vrech difference (%)= 0.0
dVsoil=inf-rech-et
dVsoil= 8.889862e+001
dVsfce (m3)= 0.000000e+000
dVs2=input-roff-inf

PLANT SURVIVABILITY TERMS
total time ponded (h)= 129.8
max time ponded (h)= 27.5
total time RZ saturated (h)= 146.5
total time RZ at wilting point (h)= 1851.3
total time TZ saturated (h)= 252.3
max time RZ saturated (h)= 28.8
max time RZ at wilting point (h)= 648.5
max time TZ saturated (h)= 45.8
near saturated times for simulation= 11

727.8	9.5
2319.8	28.8
2946.0	0.5
2981.3	27.0
3764.0	28.8
4043.8	4.5
4058.8	12.5
4073.0	8.5
4172.3	22.3
4310.0	0.8
5276.3	3.5

wilting point times for simulation= 11

554.3	145.3
652.3	25.3
1132.0	75.5
1884.8	648.5
2128.5	141.8
2233.0	11.5
2918.0	187.5
3727.3	67.3
4012.5	34.3
4643.8	54.5
6068.0	460.0

ponded times for simulation= 10

726.3	8.0
2318.5	27.5
2945.8	0.3
2979.8	25.3
3762.5	27.3
4042.3	2.3
4057.3	10.8
4071.8	7.0
4170.8	20.8
5274.8	0.8

overflow times for simulation= 3

2294.3	2.8
2956.0	0.3
3738.5	1.3

Record Output

Time(hr)	Runon(cm)	Ponding(cm)	Infil(cm)	Runoff(cm)	Drain(cm)	Recharge(cm)	ET(cm)	ThetaRZ	ThetaSZ	ThetaCZ
653	0.817	0	0.817	0	0	0.002	0	0.134	0.194	0.39
654	1.978	0	1.978	0	0	0.002	0	0.204	0.194	0.39
655	4.385	0	4.385	0	0.028	0.002	0	0.292	0.194	0.39
656	2.559	0	2.559	0	0.201	0.002	0	0.327	0.199	0.39
657	0.6	0	0.6	0	0.239	0.002	0	0.322	0.209	0.39
658	0	0	0	0	0.236	0.002	0.017	0.312	0.216	0.39
659	0	0	0	0	0.232	0.002	0.017	0.304	0.219	0.39
660	0	0	0	0	0.228	0.002	0.017	0.297	0.221	0.391
661	0	0	0	0	0.225	0.002	0.017	0.292	0.221	0.391
662	0	0	0	0	0.206	0.002	0.017	0.287	0.221	0.391
663	0	0	0	0	0.18	0.002	0.017	0.283	0.221	0.391
664	0	0	0	0	0.159	0.002	0.004	0.279	0.221	0.392
665	0	0	0	0	0.143	0.002	0	0.276	0.221	0.392
666	0.422	0	0.422	0	0.132	0.002	0	0.289	0.221	0.392
667	1.778	0	1.778	0	0.203	0.002	0	0.33	0.224	0.393
668	2.2	0	2.2	0	0.241	0.002	0	0.353	0.244	0.393
669	0.956	0	0.956	0	0.249	0.002	0	0.343	0.27	0.395
670	0.111	0	0.111	0	0.245	0.002	0	0.328	0.286	0.398
671	0	0	0	0	0.239	0.003	0.017	0.317	0.293	0.403
672	0	0	0	0	0.234	0.004	0.017	0.308	0.296	0.41

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