1

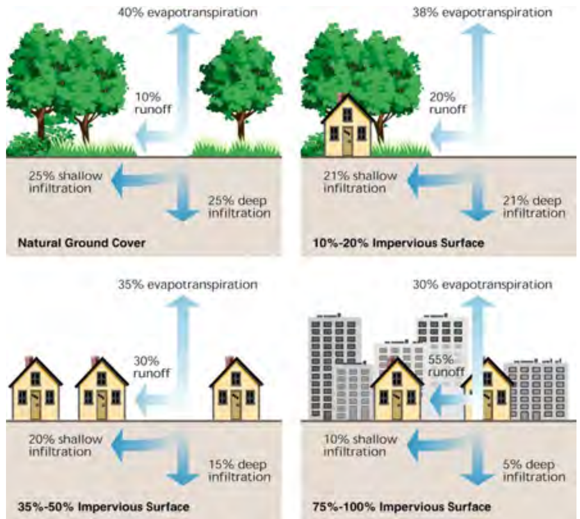
Presentation Overview

- Hydrology 101
- Introduction to GSI
- Example GSI Techniques

DRUMMOND CARPENTER engineering + research

2

Hydrologic Cycle



DRUMMOND CARPENTER engineering + research

3

Stormwater Management

- Stormwater Runoff = f (Rain, Soil, Landcover)

engineering + research

4

Rain

5

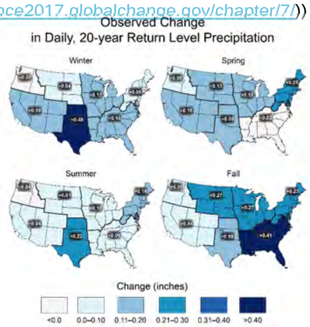
Value of Rain

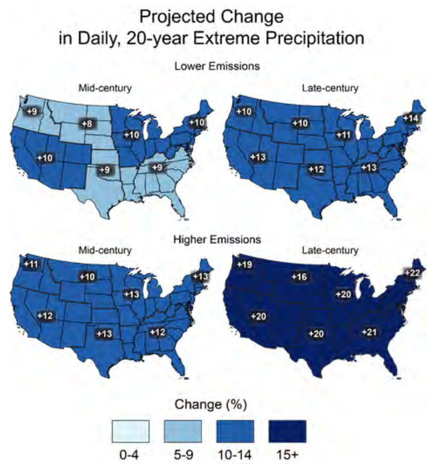
- Rain is naturally filtered by atmosphere (less dissolved solids).
- Rain is soft (no calcium or magnesium)
- Rain is a natural fertilizer (sulfur and nitrogen)
- Rain has a low salt content and no chlorine (plant growth)
- It’s free!

6

Precipitation Increases

Projected change in the 20-year return period amount for daily precipitation (right) and observed changes (below). Results are shown for two different climate change scenarios (see report for details) (Figure source: CICS-NC and NOAA NCEI https://science2017.globalchange.gov/chapter/7/))





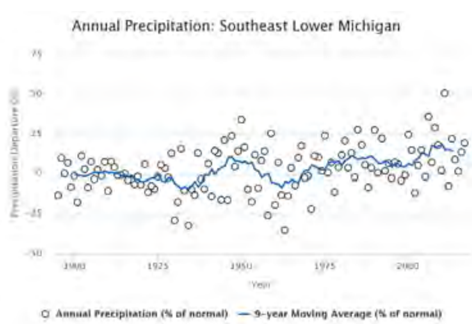
DRUMMOND CARPENTER engineering + research

7

Precipitation Changes

Linear best-fit changes (shown in the Table below) are for the period of 1950-2017 based on the historical reference period of 1951-1980. On average, annual precipitation has increased 16% with the greatest change being in fall which has seen a 24% increase in precipitation. The graph on the right has a nine year moving average which is documenting an increase in annual precipitation in SE Michigan. (http://glisa.umich.edu/division/mi10)

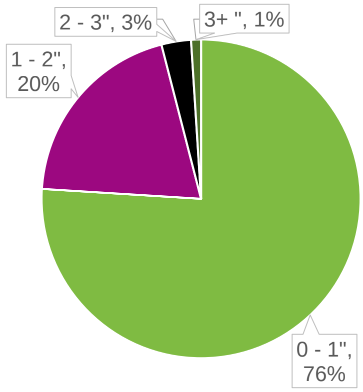
	in.	cm.	%
Annual	4.9	12.3	16.10
Winter	0.6	1.5	10.75
Spring	1.4	3.6	17.12
Summer	1.2	3.0	12.60
Fall	1.6	4.2	23.39



DRUMMOND CARPENTER engineering + research

8

Rainfall Distribution



The 10-year 24-hour storm event of the past (1992) is the 5-year 24-year storm event of the future (2037).

The 25-year 24-hour storm event of the past is the 10-year 24-hour event of the future.

24 Hour Duration	1-yr Event	2-yr Event	10-yr Event	100-yr Event
SE MI (1992)	1.87”	2.26”	3.13”	4.36”
SE MI (2016)	2.04”	2.30”	3.24”	5.62”
SE MI High	2.33”	2.63”	3.74”	6.62”

9

Soil

DRUMMOND CARPENTER engineering + research

10

Hydrologic Soil Groups

Soil Group	Soil Type	Drainage Capacity
A	sand, loamy sand, sandy loam	very well drained and highly permeable
B	silt loam, loam	good
C	sandy clay loam	fair
D	clay loam, silty clay loam, sandy clay, silty clay, clay	poorly drained and generally situated in a valley bottom or floodplain

HSG	Infiltration Rate (in/hr)
A	2.0+
B	0.5
C	0.2
D	<0.1

DRUMMOND CARPENTER engineering + research

11

"A" Soils

DRUMMOND CARPENTER engineering + research

12

"B" and "C" Soils

DRUMMOND CARPENTER engineering + research

13

"D" Soils

DRUMMOND CARPENTER engineering + research

14

Landcover

15

Land Cover (2” rainfall)

	Hydrologic Soil Group			
	A	B	C	D
Meadow	0.0”	0.0”	0.3”	0.5”
Park/Golf Course	0.0”	0.1”	0.4”	0.6”
¼ Ac. Residential	0.1”	0.4”	0.7”	0.9”
1/8 Ac. Residential	0.5”	0.8”	1.1”	1.3”
Paved Surface	1.8”	1.8”	1.8”	1.8”

16

Urbanization

DRUMMOND CARPENTER
engineering + research

17

Urbanization

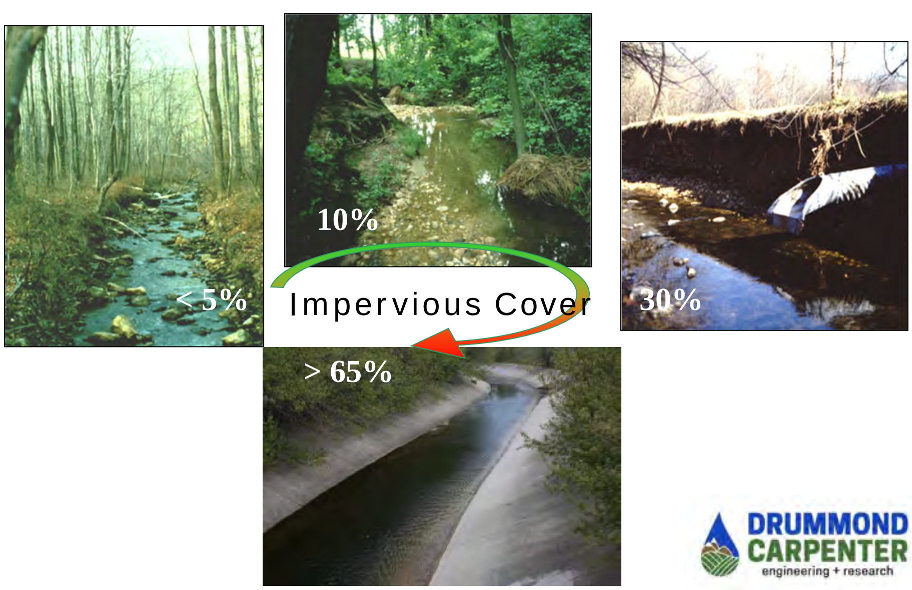
DRUMMOND CARPENTER
engineering + research

18

Impervious Cover

19

Stream Degradation



DRUMMOND CARPENTER engineering + research

20

Pollutants in Urban Runoff

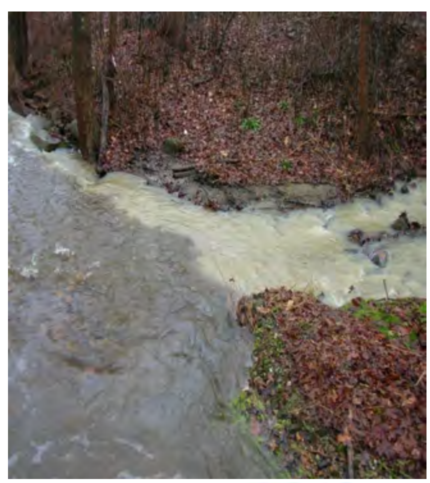
- Suspended Sediment
- Nutrients (phosphorus and nitr
- Pesticides/herbicides
- Heavy Metals
- Hydrocarbons (o oline/grease)
- Bacteria/pa s
- Trash/F les
- Salt

Non-Point Source Pollution

DRUMMOND CARPENTER engineering + research

21

Result of Excess Sediments



Courtesy of Steven Trinkaus, Trinkaus Engineering

DRUMMOND CARPENTER

22

Excess Nutrients

Courtesy of NOAA

23

Pollutants from Vehicles

Courtesy of Steven Trinkaus, Trinkaus Engineering

24

Source of Bacteria and Pathogens (besides CSO)

25

What can we do?

DRUMMOND CARPENTER
engineering + research

26

What is Green Stormwater Infrastructure?

Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. Green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site***, green stormwater infrastructure*** refers to stormwater management systems that mimic nature by soaking up and storing water.

- United States Environmental Protection Agency

DRUMMOND CARPENTER engineering + research

27

What is Low Impact Development?

The term *low impact development* (LID) is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions.

- United States Environmental Protection Agency

DRUMMOND CARPENTER engineering + research

28

Infiltration Based Green Infrastructure Techniques

- Bioretention Cells (Rain Gardens)
- Planter Boxes
- Vegetated Swales and Bioswales
- Street Trees and Tree Box Filters
- Infiltration Galleries or Swales
- Permeable Pavement
- Vegetated Roofs and Walls
- Cisterns, Water Harvesting, and Reuse

DRUMMOND CARPENTER engineering + research

29

Bioretention Cells and Rain Gardens

DRUMMOND CARPENTER engineering + research

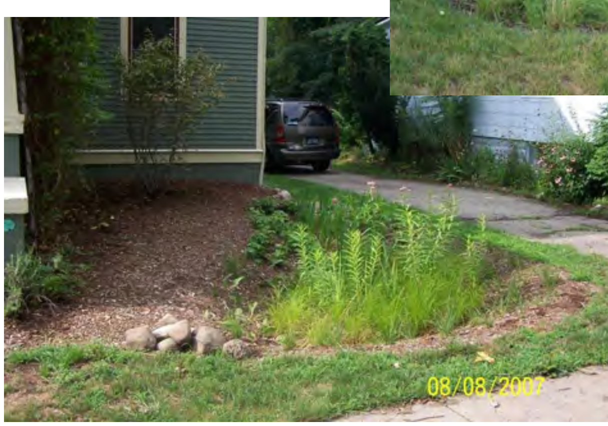
30

Bioretention Cells or Rain Gardens?

31

Rain Gardens

Ann Arbor, MI



DRUMMOND CARPENTER engineering + research

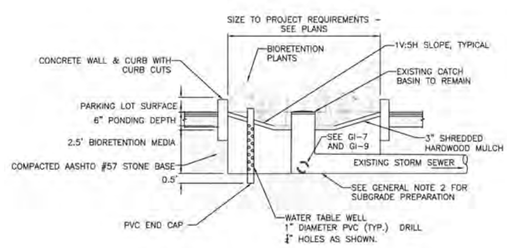
32

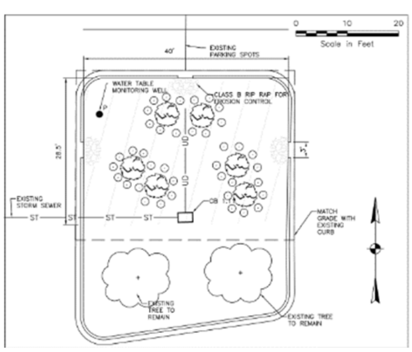
Bioretention Cells

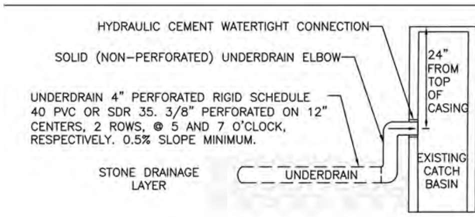
Macomb Co. Municipal Bldg
Mount Clemens, MI

33

Bioretention Design







DRUMMOND CARPENTER
engineering + research

34

Bioretention Construction

35

Planter Boxes

DRUMMOND CARPENTER
engineering + research

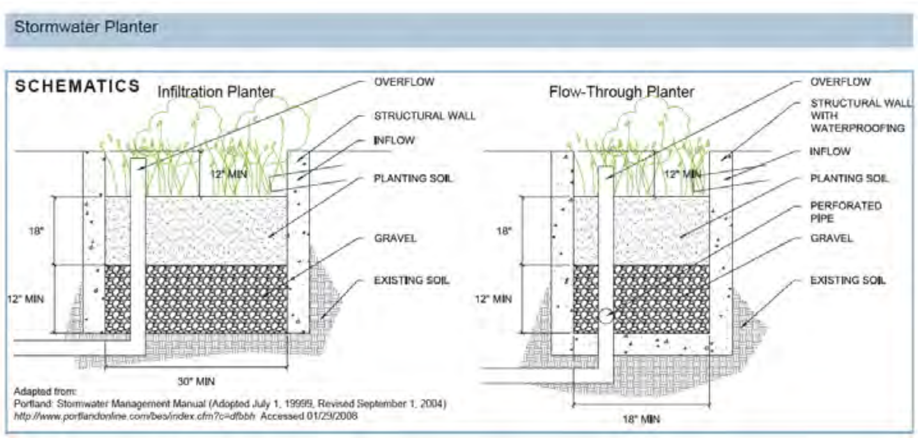
36

Planter Boxes

DRUMMOND CARPENTER engineering + research

37

Planter Boxes



DRUMMOND CARPENTER engineering + research

38

Street Trees and Tree Box Filters

39

Street Trees

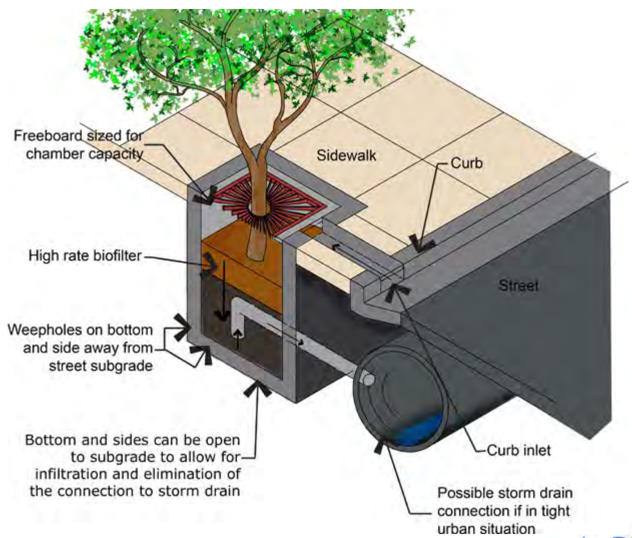
40

Tree Box Filters

© LID Center

41

Tree Box Filters



42

Infiltration Trench and Gallery

43

Infiltration Trench

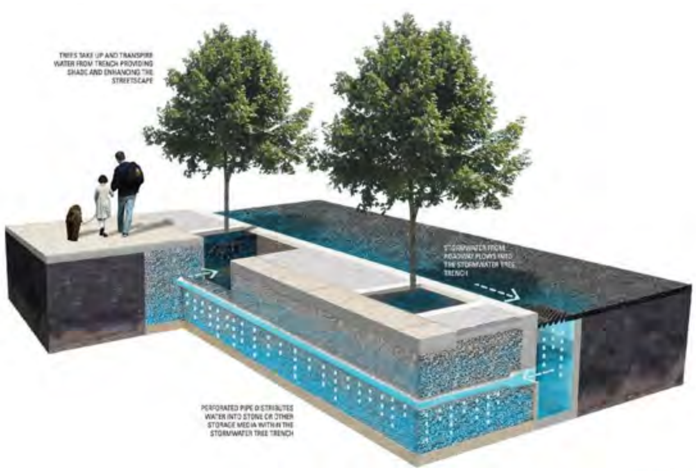
44

Infiltration Gallery

Bryant Park, Suttons Bay
NMC, Traverse City
Courtesy of Sarah U'Ren

45

Infiltration Trench with Trees



DRUMMOND CARPENTER
engineering + research

46

Permeable Pavement

DRUMMOND CARPENTER engineering + research

47

Permeable Asphalt

DRUMMOND CARPENTER engineering + research

48

Porous Concrete

DRUMMOND CARPENTER
engineering + research

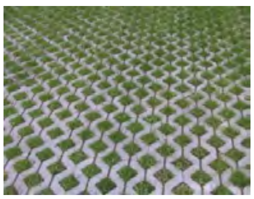
49

Concrete Block Pavers

DRUMMOND CARPENTER
engineering + research

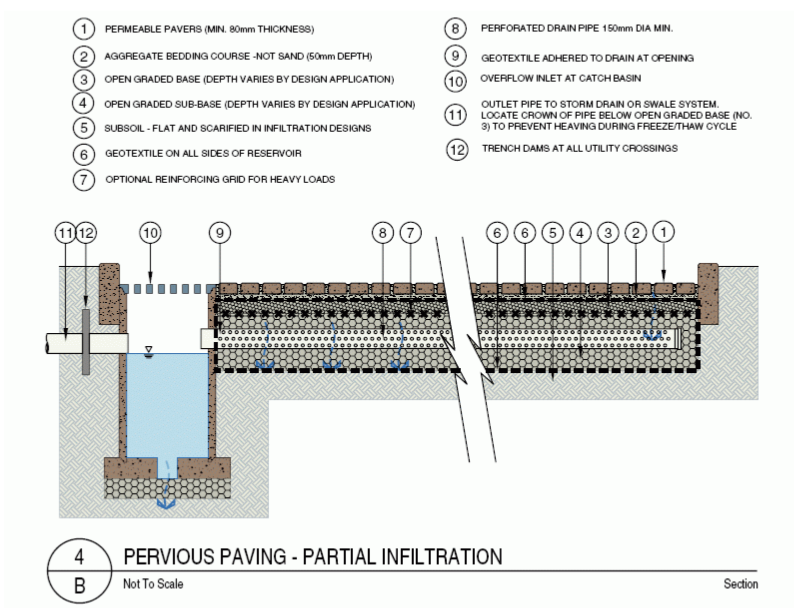
50

Concrete Block Pavers



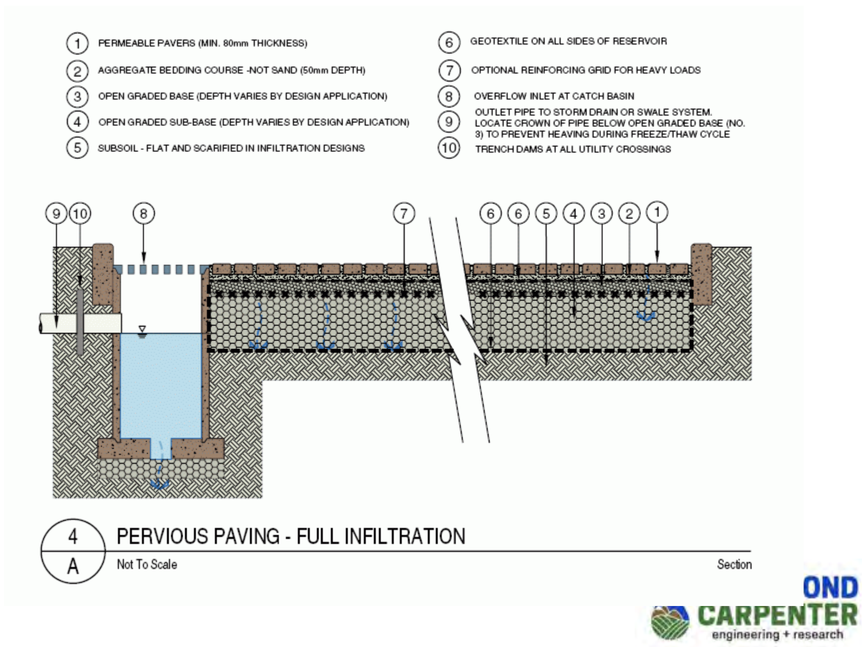
DRUMMOND CARPENTER
engineering + research

51



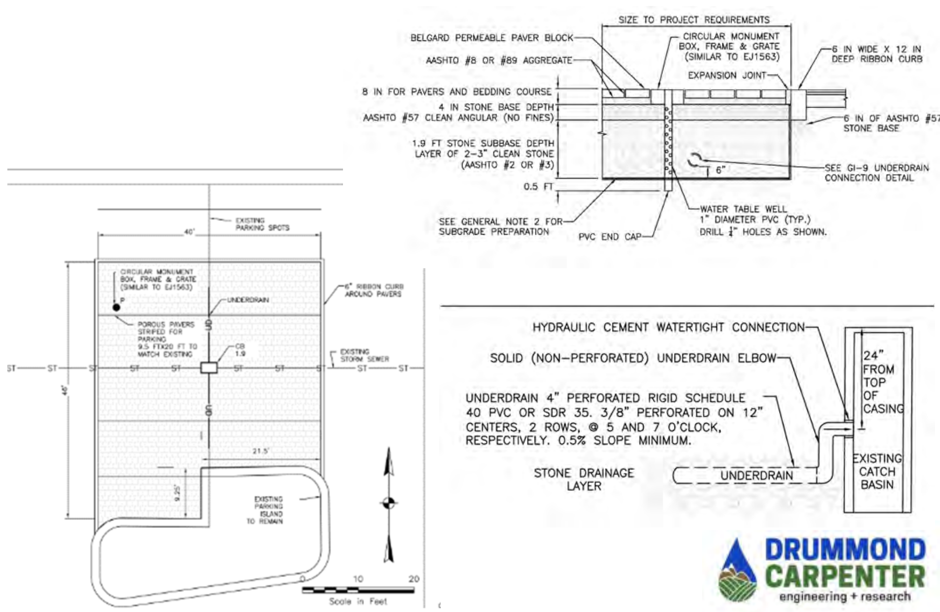
OND
CARPENTER
engineering + research

52



53

Permeable Pavement Design



54

Permeable Pavement Construction

55

Vegetated Roofs and Walls

DRUMMOND CARPENTER
engineering + research

56

Cisterns, Water Harvesting and Reuse

57

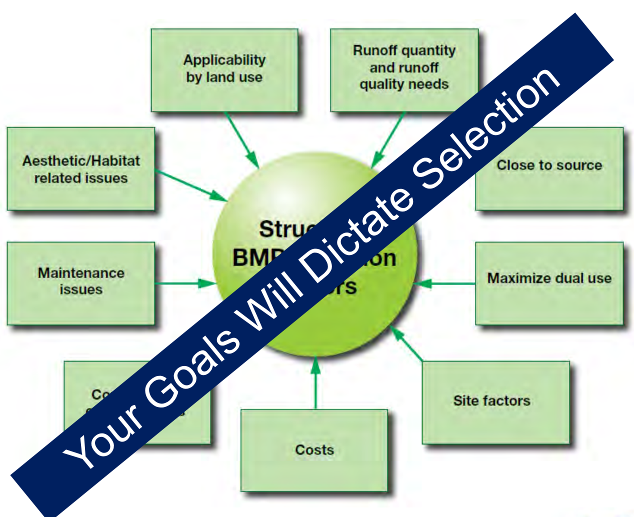
Rain Barrels

58

Cisterns

59

Ideas and Approach for Project



DRUMMOND CARPENTER engineering + research

60

Runoff from 2" Storm

	Hydrologic Soil Group			
	A	B	C	D
Meadow	0.0"	0.0"	0.3"	0.5"
Woods	0.0"	0.0"	0.2"	0.4"
Park/Golf Course	0.0"	0.1"	0.3"	0.6"
¼ Ac. Residential	0.1"	0.4"	0.7"	0.9"
~~Impervious~~	~~1.8"~~	~~1.8"~~	~~1.8"~~	~~1.8"~~

DRUMMOND CARPENTER engineering + research

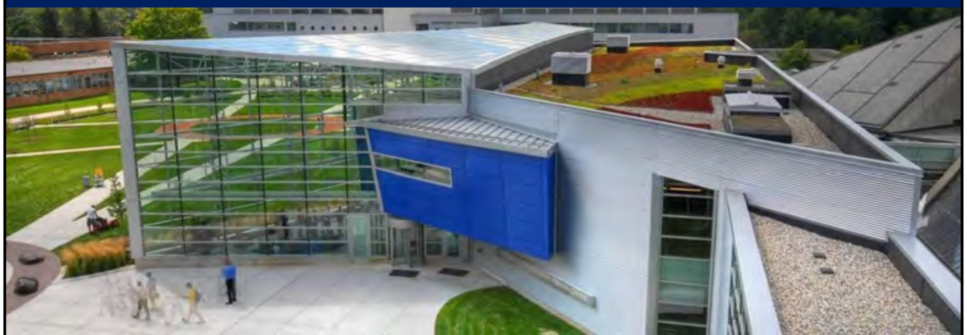
61

Hydrologic Principles for LID

- Groundwater Recharge Volume
  - Annual pre-development recharge rate for site specific soils, rainfall, and natural cover
- Water Quality Protection
  - Protect quality of watersheds
  - "First flush" (1" rainfall = 90% exceedence)
- Channel Protection
  - Protect streams and rivers
  - 2-year 24-hour
- Flood Protection
  - Protect life and property from extreme events

DRUMMOND CARPENTER engineering + research

62



Questions?

63