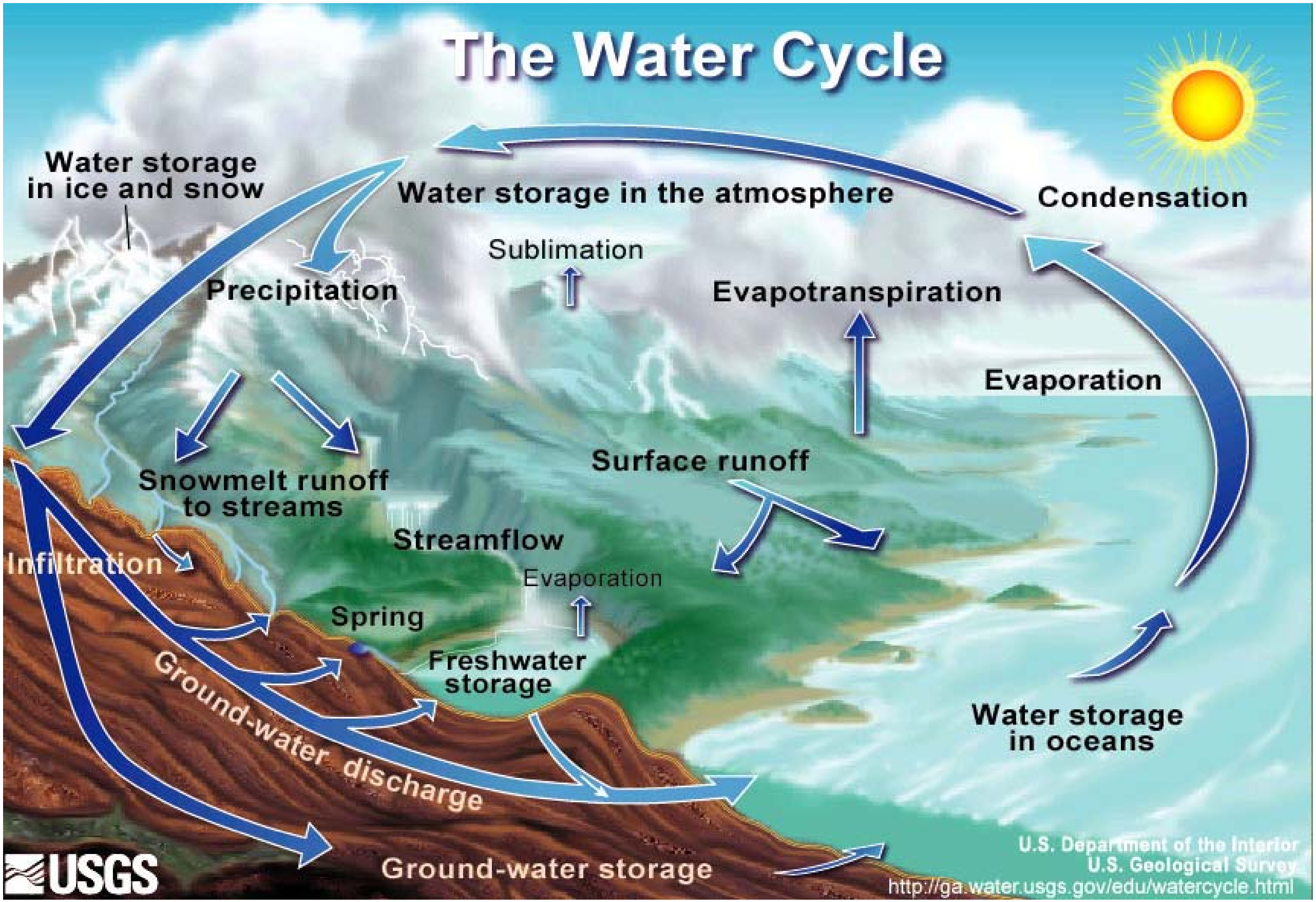
Effect of Land Surface on Runoff Generation

Context: Hydrologic Cycle



Runoff vs Infiltration

- **Infiltration:** Process by which water on the ground surface enters the soil

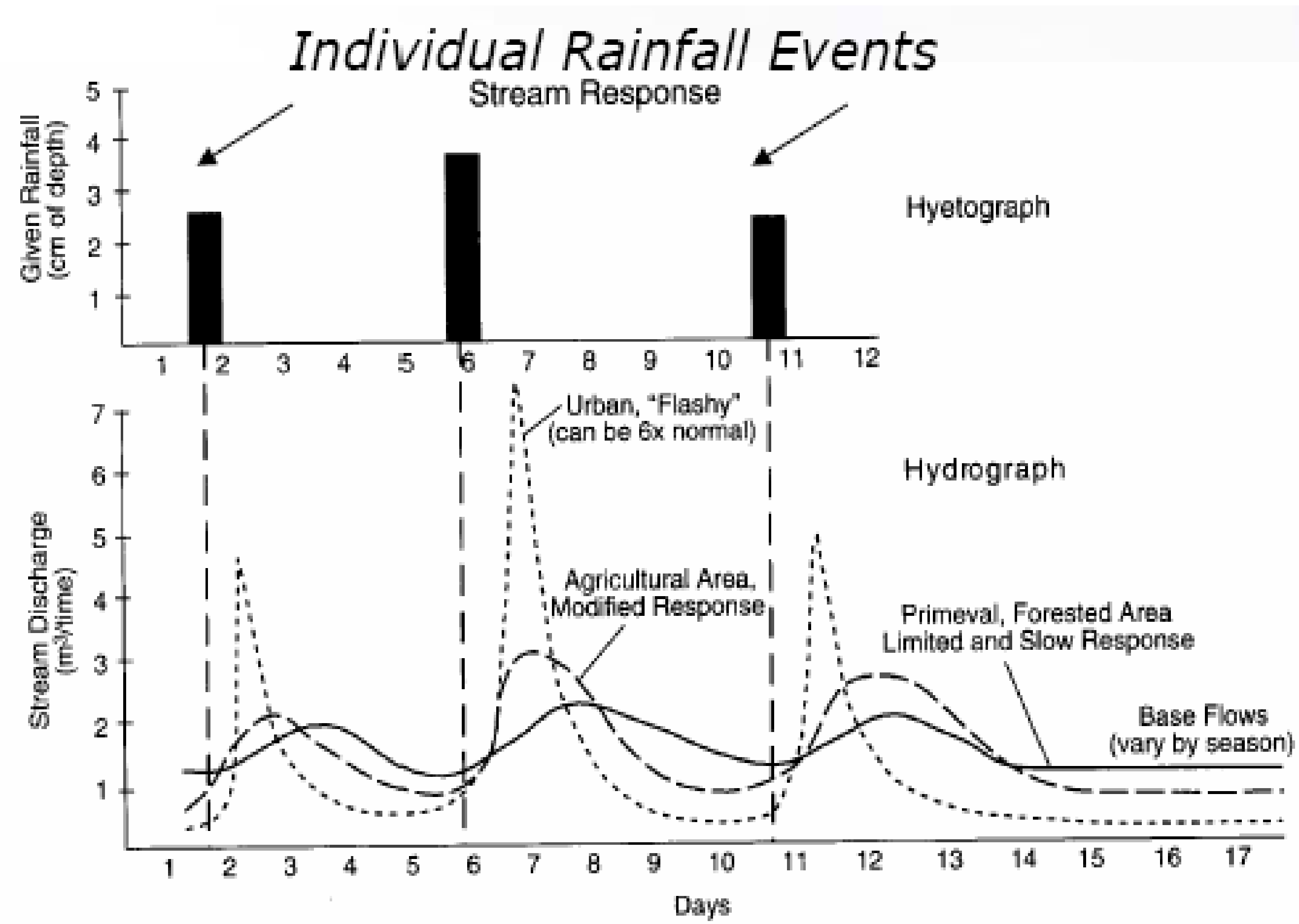
- **Runoff:** Water (from rain, snowmelt, etc) that flows over the land surface (surface) or exfiltrates from the soil into channels (subsurface)
- Runoff + Infiltration = total surface water (minus losses—depression storage, interception)

Depression storage: water is ponded under these trees but will eventually infiltrate

Factors Controlling Infiltration/Runoff

- rainfall rate and volume
- soil type (sand, clay, silt)
- soil moisture (dry vs. wet)
- hydraulic conductivity (permeability)
- depth to water table
- groundcover (looseness of soil, foliage on soil)
- vegetation type (density of vegetation)
- time since start of rainfall

Land Cover and Runoff



Mays

Urban Areas

- Higher peak flows
- fast recession rate
- less baseflow
- flashier response

Forested Areas

- Low peak flows
- Slow recession rate
- More baseflow
- Dampened response

Effect of vegetation on runoff
http://wikiwatershed.org/mmw/mini/

Some Methods to Determine Runoff

- Measurement (challenging)
- Time-based saturation of soil (e.g. Horton method)
- Physically-based (e.g. Phillips/Green-Ampt)
- Simple, lumped, and empirically based (e.g. Rational method, NRCS Curve Numbre Method)
- Model watershed with variable parameters
- MORE

NRCS Direct Method
(National Resources Conservation Service)
"SCS Curve Number Method"

Models runoff as function of
- land cover/cropping practice
- soil type
- antecedent soil moisture

$$Q = \frac{\left(P - I_a\right)^2}{\left(P - I_a + S\right)}$$

$$S = \frac{1000}{CN} - 10$$

Q = accumulated runoff depth over drainage area
P = accumulated rainfall as depth over area
I_a = initial abstractions = 0.2S
S = potential max soil water retention
CN = Curve Number

Curve Number

- Based on Soil Type (A-D)

A	sandy loam, loamy sand, sand	i = 0.3-0.45 in/hr
B	silt loam or loam	i = 0.15 – 0.3
C	Sandy clay loam	i = 0.05-0.15
D	clay loam etc	i = 0-0.15

- Hydrologic condition of area

  Good – factors encourage better than average infiltration

  Fair – normal infiltration

  Poor—factors impair infiltration

- Land Cover (lookup table)
- Weight Curve Number by land cover %
- High Curve Number = more runoff

Curve Numbers: Urban Areas

Table 2: NRCS runoff curve numbers (CN) for selected urban land use[1]

Cover description		***Curve numbers for hydrologic soil group***			
Cover type and hydrologic condition	**Average impervious area[2]**	**A**	**B**	**C**	**D**
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc)[3]:					
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 (excluding ROW)		98	98	98	98
Streets and roads:					
Paved: curbs and storm sewers (excluding ROW)		98	98	98	98
Paved: open ditches (including ROW)		83	89	92	93
Gravel (including ROW)		76	85	89	91
Dirt (including ROW)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1-2 inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]	77	86	91	94	
Idle lands (CN's are determined using cover types similar to those in Table 3)					

1 Average runoff condition and I_a=0.2S.

Parking Lots = 98

Grass (fair) = 49-84

Desert landscaping (artificial) = 96

Curve Numbers: Agricultural

Table 3: NRCS runoff curve numbers (CN) for selected cultivated agricultural land use[1]

Cover description			*Curve numbers for hydrologic soil group*			
Cover type	**Treatment**[2]	**Hydrologic condition**[3]	**A**	**B**	**C**	**D**
Fallow	Bare soil	--	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR+CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C+CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured and terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR+CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C+CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

Bare Soil = 77-94

Crops based on type of crop and type of planting

Curve Number: Other Agricultural

Table 4: NRCS runoff curve numbers (CN) for other agricultural land use[1]

Cover description		*Curve numbers for hydrologic soil group*			
Cover type	**Hydrologic condition**	**A**	**B**	**C**	**D**
Pasture, grassland, or range – continuous forage for grazing[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow – continuous grass, protected from grazing and generally mowed for hay	--	30	58	71	78
Brush – brush-weed-grass mixture with brush the major element[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Woods – grass combination (orchard or tree farm)[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77
Farmsteads – buildings, lanes, driveways, and surrounding lots	--	59	74	82	86

Meadow = 30-78

Woods = 30-83

Example NRCS Calculation

<u>Woods</u> in <u>poor</u> hydrologic condition and <u>loamy</u> soil

Loam = Soil type B
Poor condition
CN = 66 (avg soil moisture)

$$S = \frac{1000}{CN} - 10 = \frac{1000}{66} - 10 = 5.15$$

Lawn, open space, poor condition
Same soil
CN = 79 from table

$$S = \frac{1000}{CN} - 10 = \frac{1000}{79} - 10 = 2.65$$

Example NRCS Calcuation

- Calculate direct runoff for each time after accumulated precipitation has exceeded initial abstraction (Ia) using

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

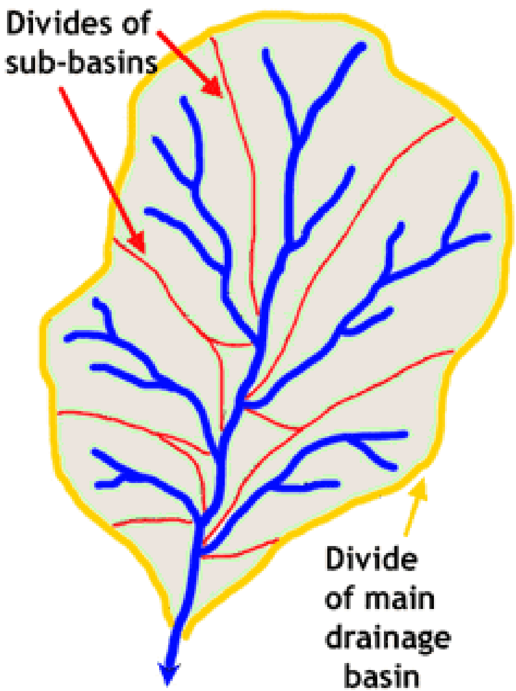
- Woods: S = 5.15, P = 1.5” → Q = 0.04 inches
- Lawn: S = 2.65, P = 1.5” → Q = 0.26 inches
- Should check that P > 0.2 S (1.5 > 1.03 for woods OK!)
- Lawn produces over 6 times the runoff as the woods

Importance of Knowing Runoff Volume

- Streamflow resulting from rainfall event
- Flooding risk
- Resource management
- Design considerations
- Water quality

Watershed Health Related to Runoff

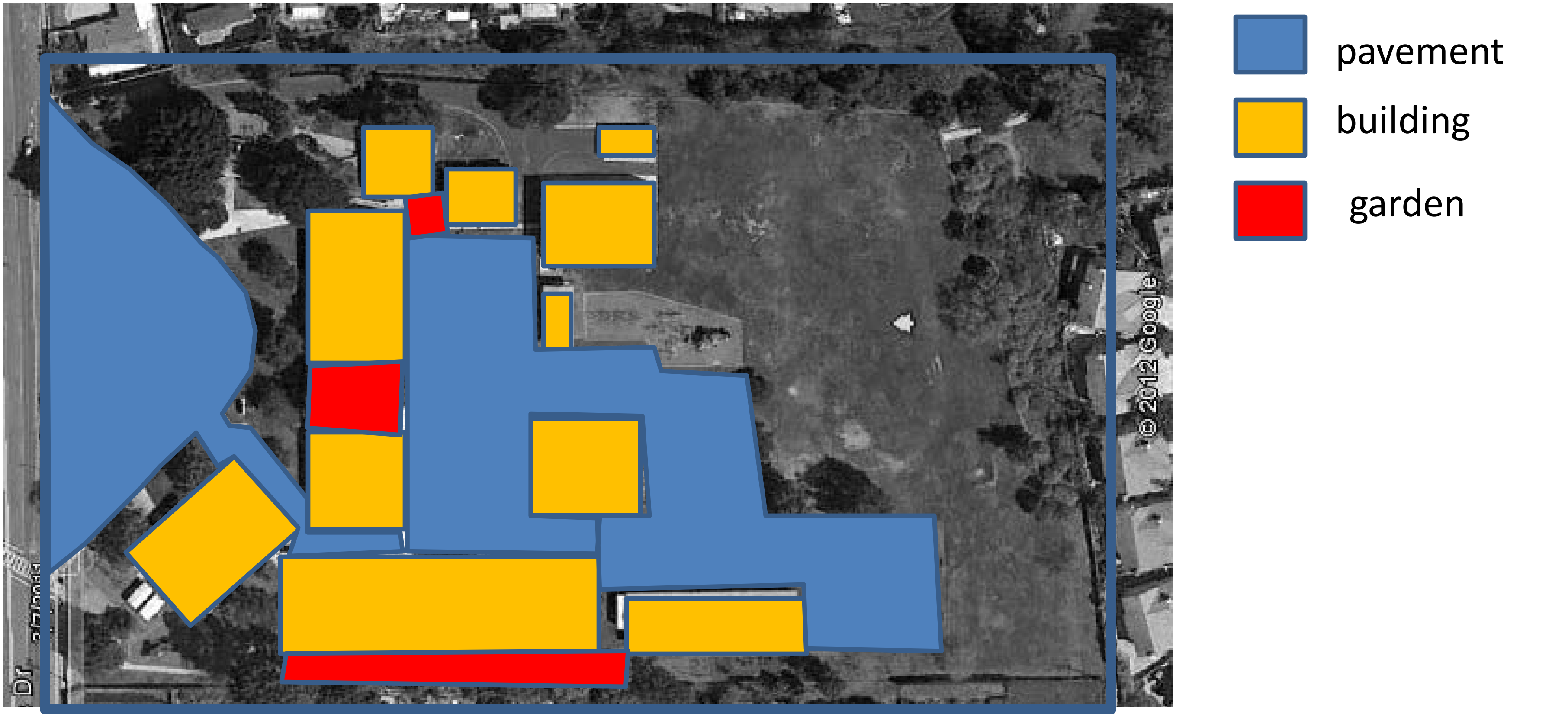
- Runoff becomes streamflow/storm drainage (often untreated)
- Runoff water quality poor
  - Collects chemicals from surfaces
  - Quickly becomes part of watershed
  - Drains to fragile coastline ecosystem



- Low Impact Development (LID) includes minimizing runoff at its source to protect watersheds

EPA http://water.epa.gov/polwaste/green/

Application at a School



Rolling Hills Elementary, Fullerton, California
Surfaces: Buildings, Turfgrass, pavement, garden
Students determined: 40% area grass, 50% buildings/pavement, 10% garden

Determining Runoff for Specific Land Cover

- Three land surfaces: pavement, sod, and garden
- Vary slope, volume of rainfall, rainfall rate

Results:

- Impermeable: 90% runoff
- Turfgrass: 62% runoff
- Garden: 15% runoff

Change in Land Use Reduces Runoff

- Convert turfgrass to garden and decomposed granite area = reduced runoff generation

- Add rain barrel collection points to building rooftops