The Hydrologic Case for Green Infrastructure

Northern Michigan Green Infrastructure Conference

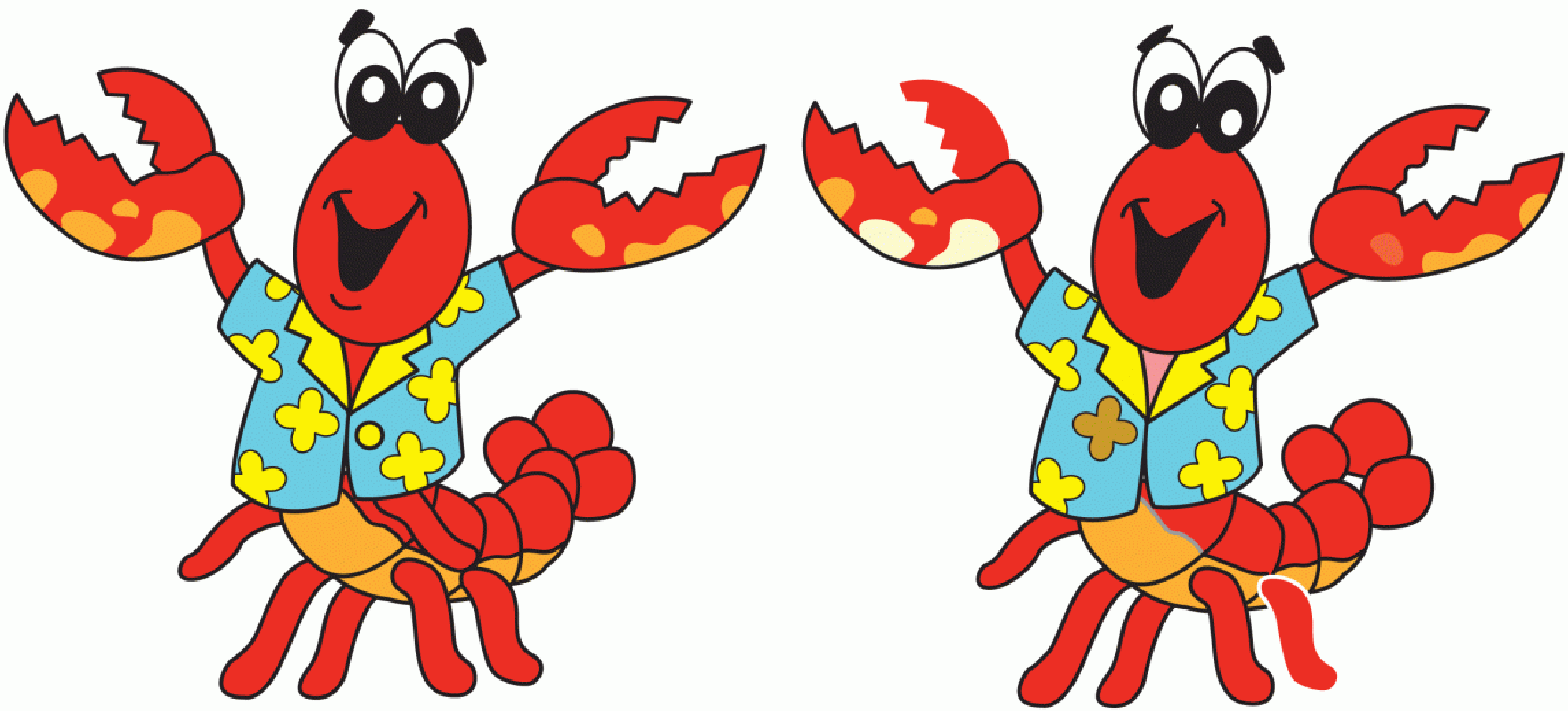
Traverse City, MI

June 4, 2015

Let’s start with a game

What's Different?

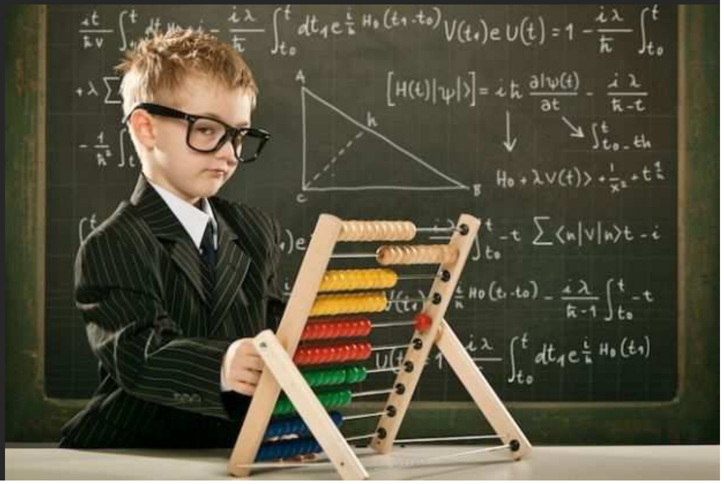
Can you find the differences in the image on the right from the image on the left?



What’s Different?

Can you find the differences in the image on the right from the image on the left?

How do we quantify the runoff change for the site development?

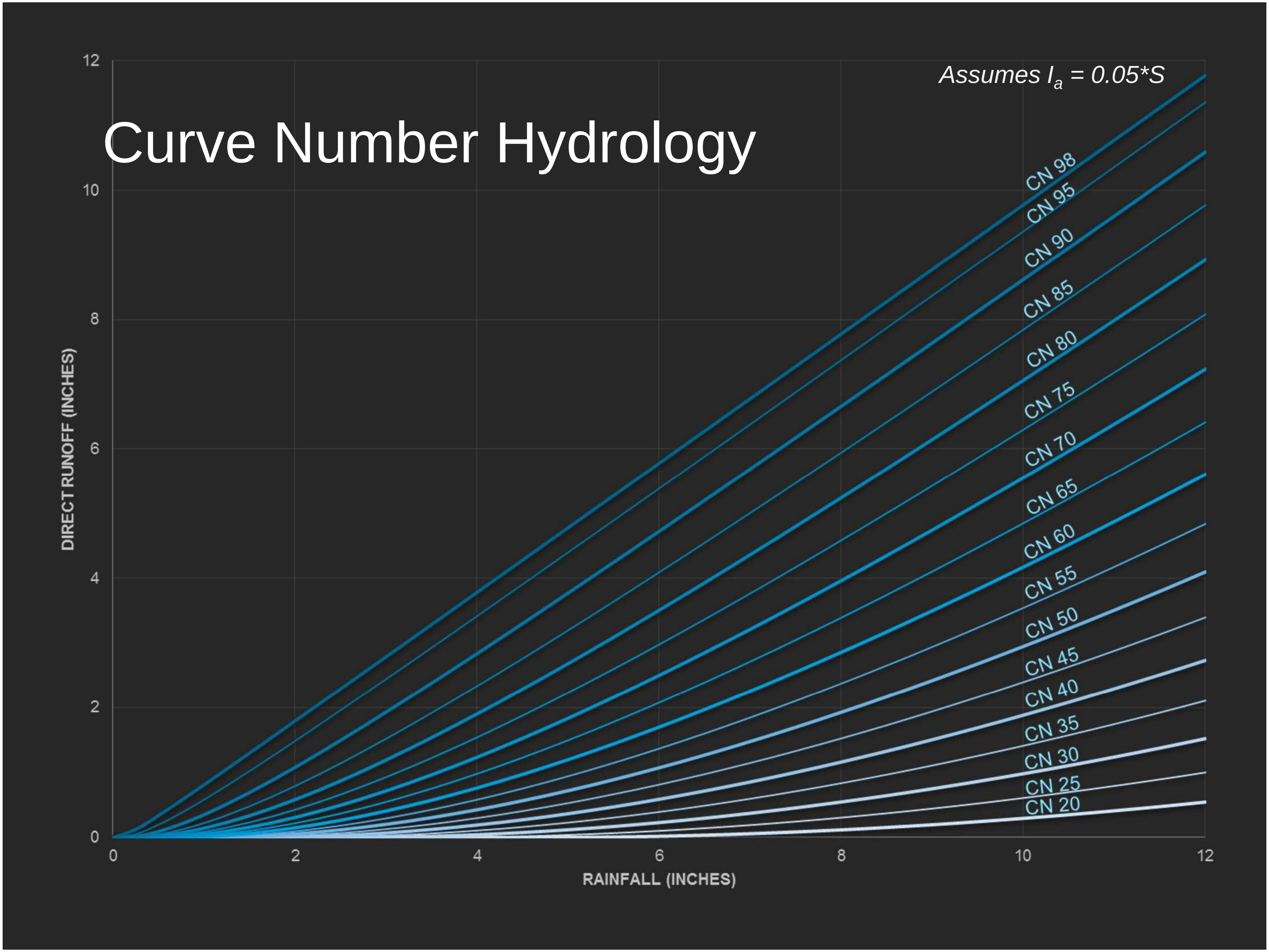


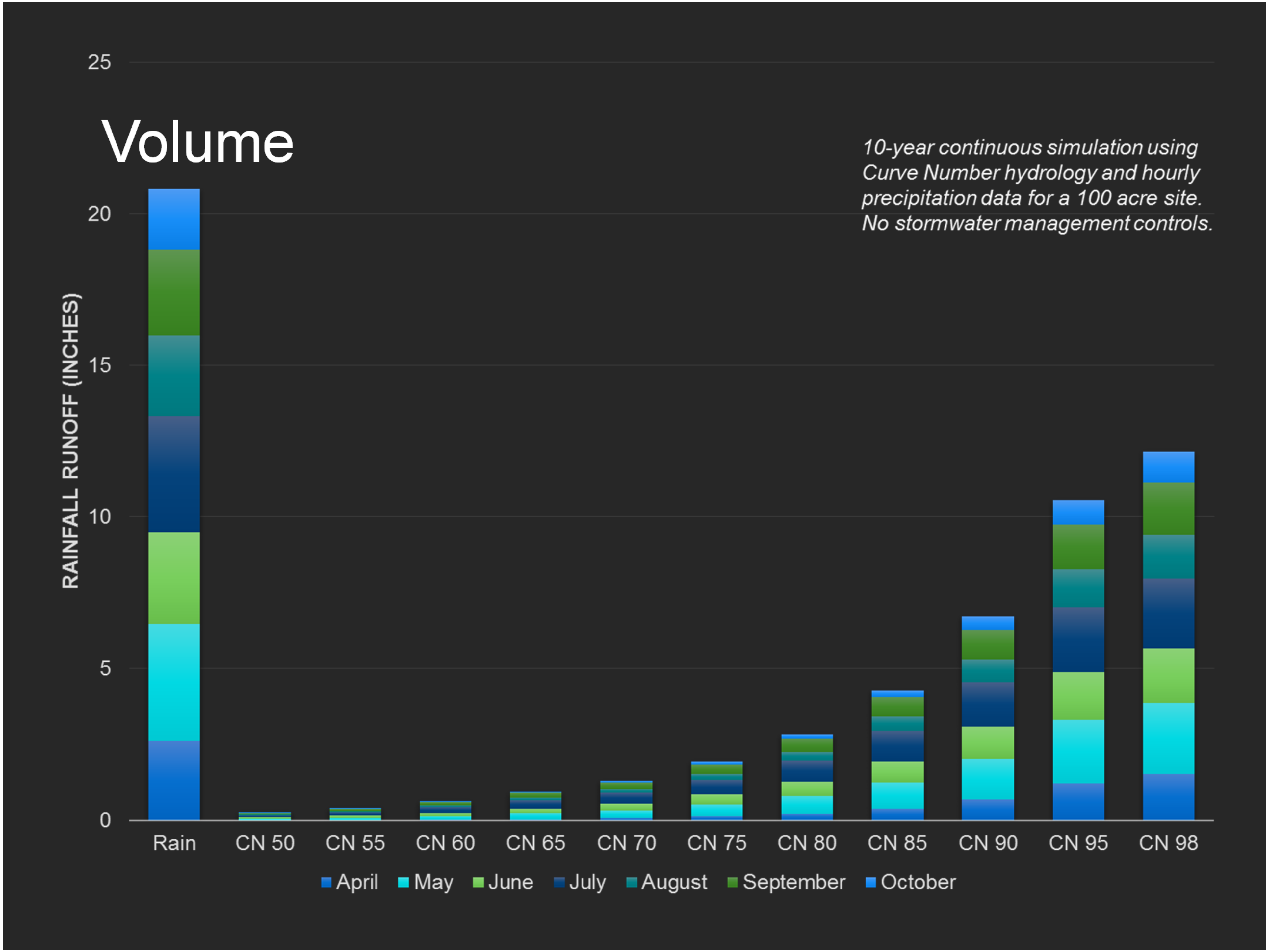
Calculation Options

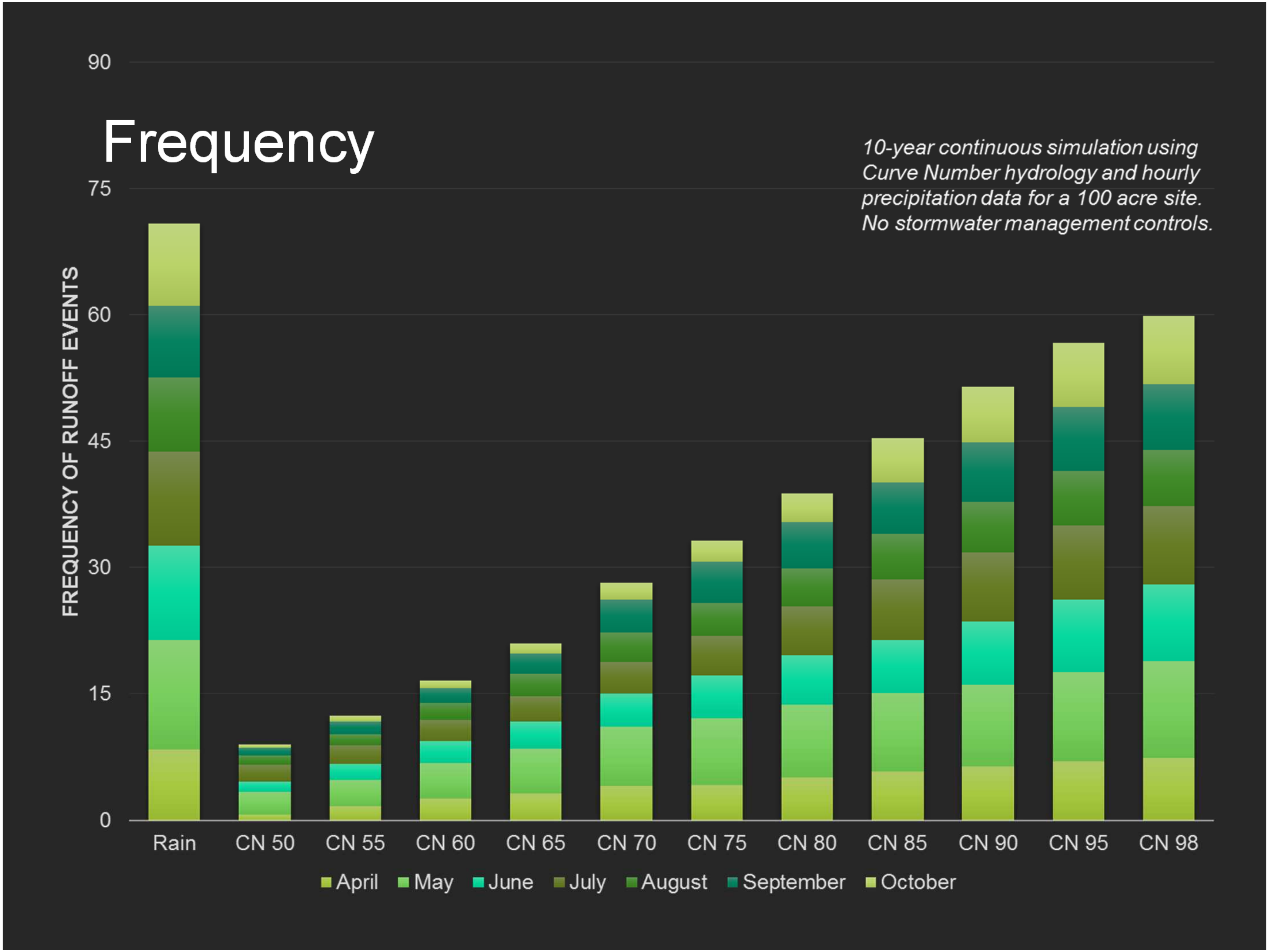
Method	Peak Flow	Runoff Volume	Hydro-graph	Complexity
Rational	Yes	No	No	Simple
Modified Rational	Yes	Detention Size	No	Simple
Curve Number	No	Yes	No	Simple
Curve Number with Unit Hydrograph	Yes	Yes	Yes	Moderate
SWMM	Yes	Yes	Yes	Complex

Curve Number Hydrology

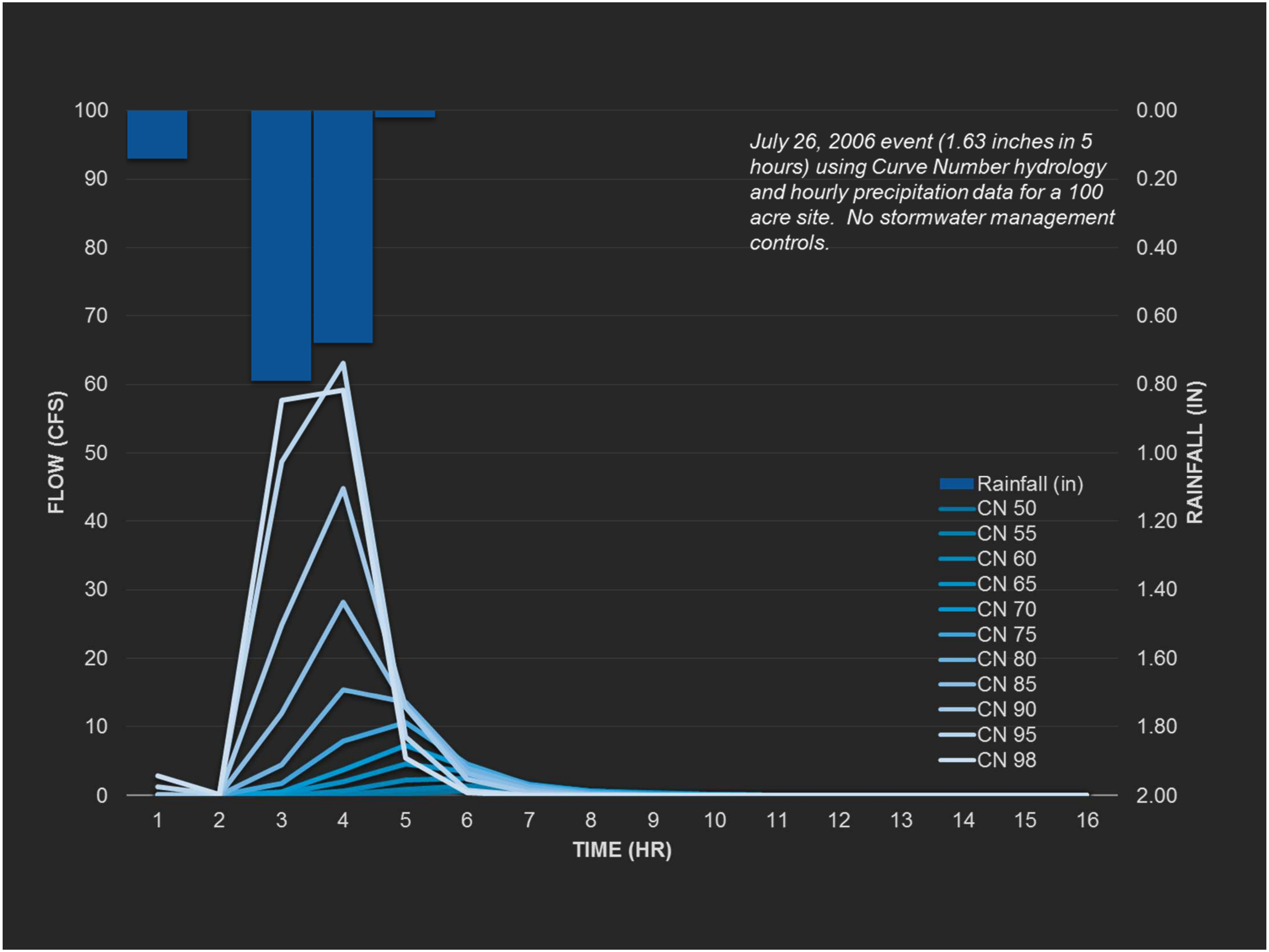
	Cover Description	A Sand	B	C	D Clay
Natural	Brush, forb, grass mix - Good	30	48	65	73
Natural	Brush, forb, grass mix - Fair	35	56	70	77
Natural	Brush, forb, grass mix - Poor	48	67	77	83
Natural	Woods protected from grazing, litter/brush cover soil	30	55	70	77
Natural	Woods grazed but not burned, some forest liter	36	60	73	79
Natural	Woods destroyed by grazing or burning	45	66	77	83
Rural farmstead-building, lanes, driveways, and surrounding lots		59	74	82	86
Open Space	Lawns, parks - Good (grass cover >75%)	39	61	74	80
Open Space	Lawns, parks - Fair (grass cover 50% to 75%)	49	69	79	84
Open Space	Lawns, parks - Poor (grass cover <50%)	68	79	86	89
Residential	2 acre lot (est. 12% impervious)	46	65	77	82
Residential	1 acre lot (est. 20% impervious)	51	68	79	84
Residential	1/2 acre lot (est. 25% impervious)	54	70	80	85
Residential	1/3 acre lot (est. 30% impervious)	57	72	81	86
Residential	1/4 acre lot (est. 38% impervious)	61	75	83	87
Residential	1/8 acre lot (town houses) (est. 65% impervious)	77	85	90	92
Industrial (est. 72% impervious)		81	88	91	93
Commercial and Business (est. 85% impervious)		89	92	94	95
Streets & Roads	Dirt (incl. ROW)	72	82	87	89
Streets & Roads	Gravel (incl. ROW)	76	85	89	91
Streets & Roads	Paved; open ditches (incl. ROW)	83	89	92	93
Streets & Roads	Paved; curbs and storm sewers (excl. ROW)	98	98	98	98
Paved Parking, Roofs, Driveways (excl. ROW)		98	98	98	98


Curve Number Hydrology
Assumes I_a = 0.05*S
CN 98
CN 95
CN 90
CN 85
CN 80
CN 75
CN 70
CN 65
CN 60
CN 55
CN 50
CN 45
CN 40
CN 35
CN 30
CN 25
CN 20
DIRECT RUNOFF (INCHES)
RAINFALL (INCHES)
0
2
4
6
8
10
12

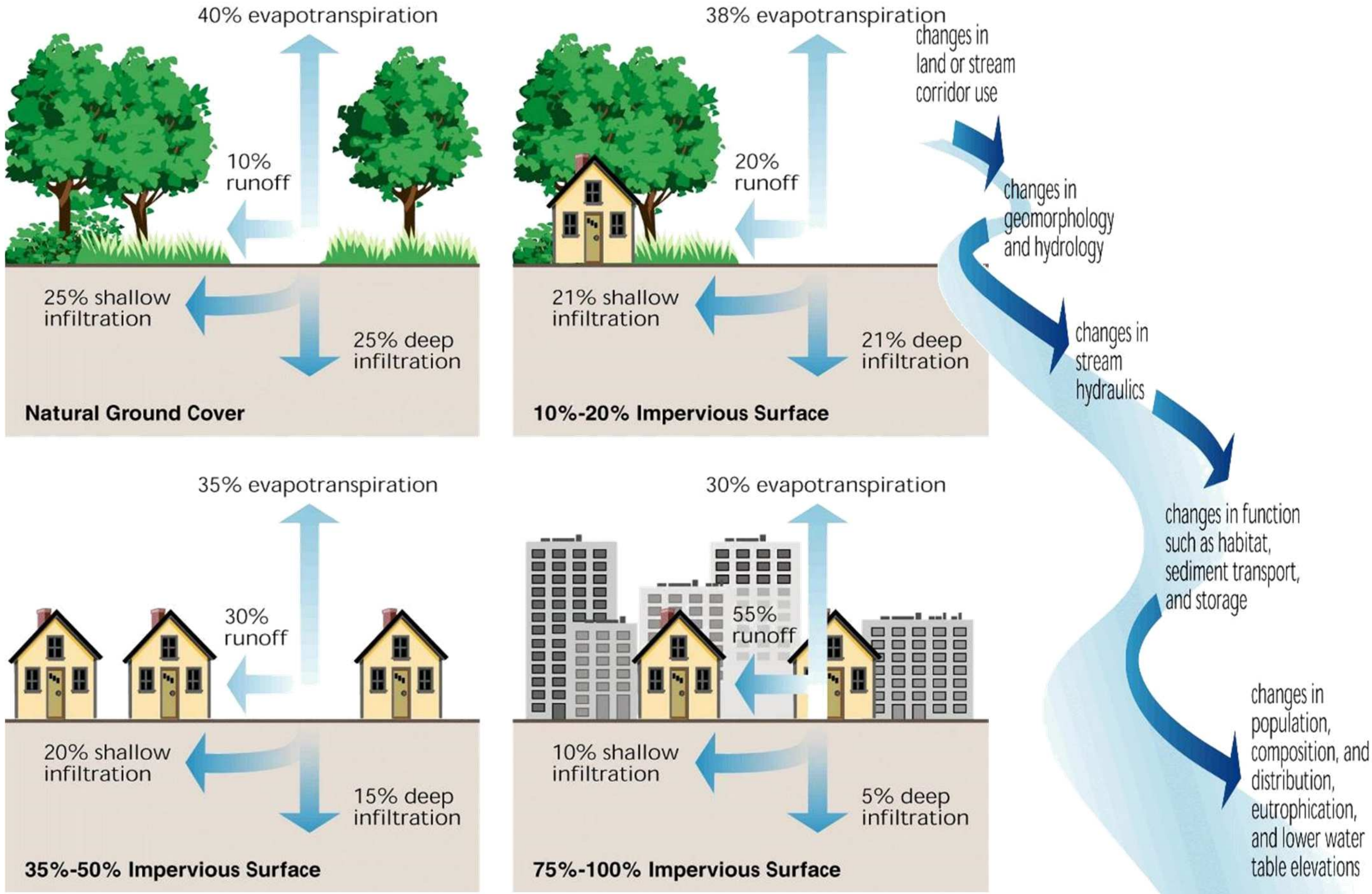

Volume
10-year continuous simulation using Curve Number hydrology and hourly precipitation data for a 100 acre site. No stormwater management controls.
RAINFALL RUNOFF (INCHES)
25
20
15
10
5
0
Rain
CN 50
CN 55
CN 60
CN 65
CN 70
CN 75
CN 80
CN 85
CN 90
CN 95
CN 98
April
May
June
July
August
September
October



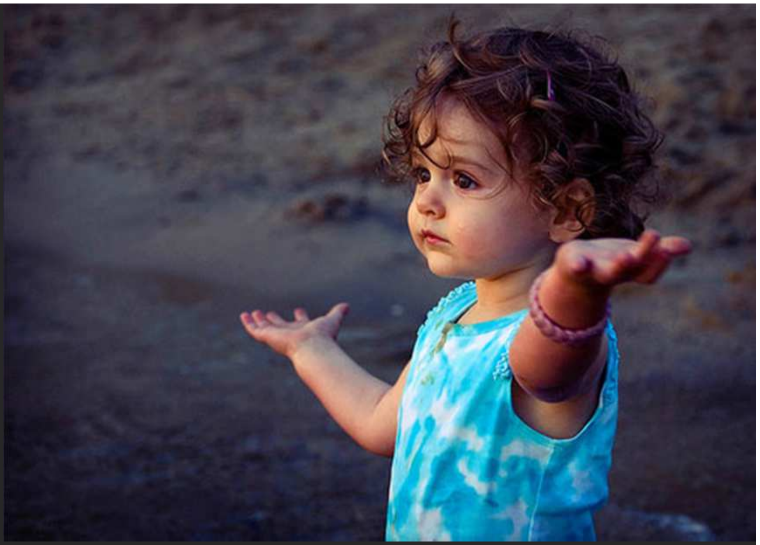
Frequency
10-year continuous simulation using Curve Number hydrology and hourly precipitation data for a 100 acre site. No stormwater management controls.
FREQUENCY OF RUNOFF EVENTS
90
75
60
45
30
15
0
Rain
CN 50
CN 55
CN 60
CN 65
CN 70
CN 75
CN 80
CN 85
CN 90
CN 95
CN 98
April
May
June
July
August
September
October



July 26, 2006 event (1.63 inches in 5 hours) using Curve Number hydrology and hourly precipitation data for a 100 acre site. No stormwater management controls.
FLOW (CFS)
RAINFALL (IN)
TIME (HR)
Rainfall (in)
CN 50
CN 55
CN 60
CN 65
CN 70
CN 75
CN 80
CN 85
CN 90
CN 95
CN 98
100
90
80
70
60
50
40
30
20
10
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

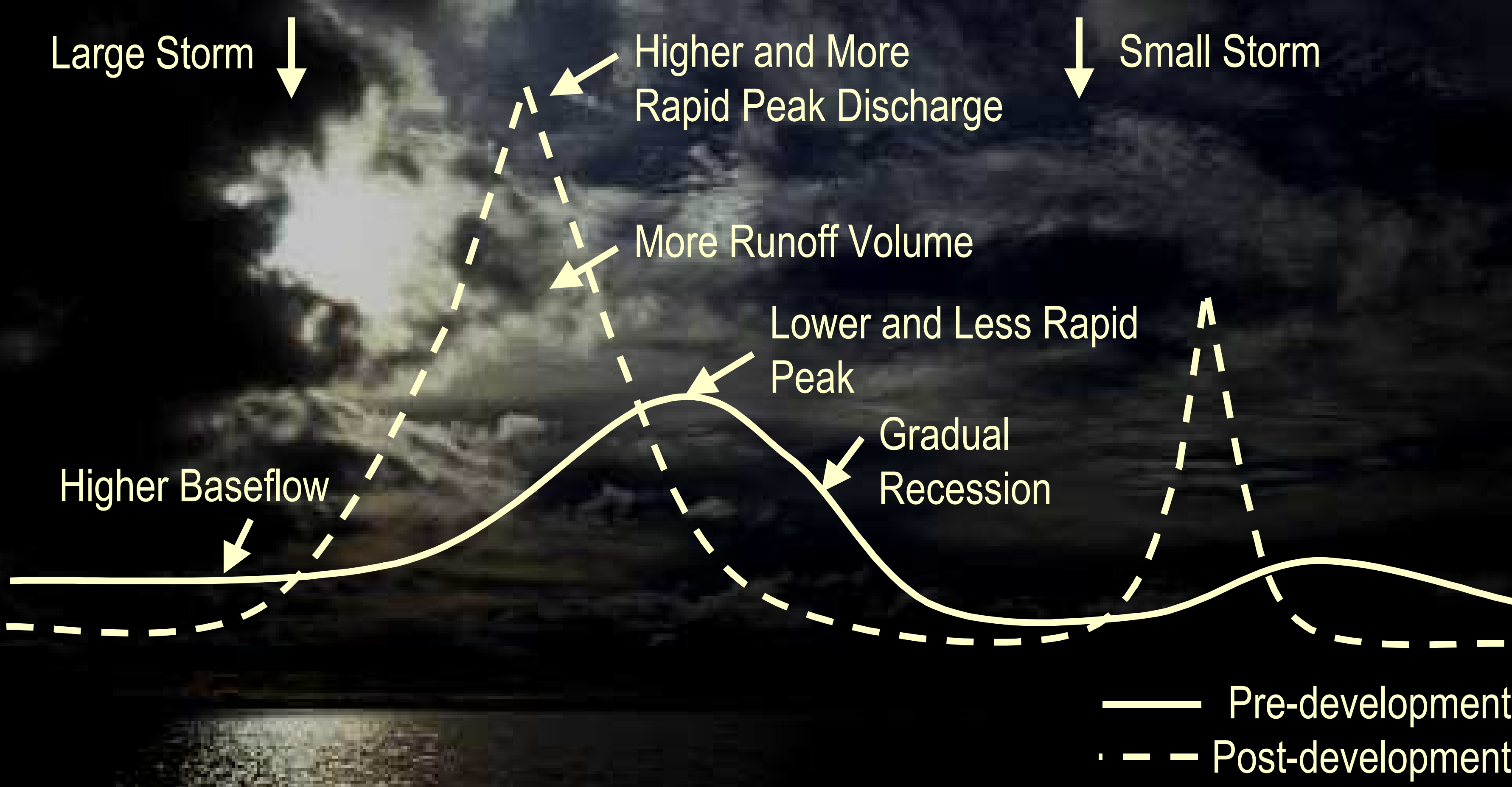


FISRWG (10/1998). Stream Corridor Restoration: Principles, Processes, and Practices.
By The Federal Interagency Stream Restoration Working Group.

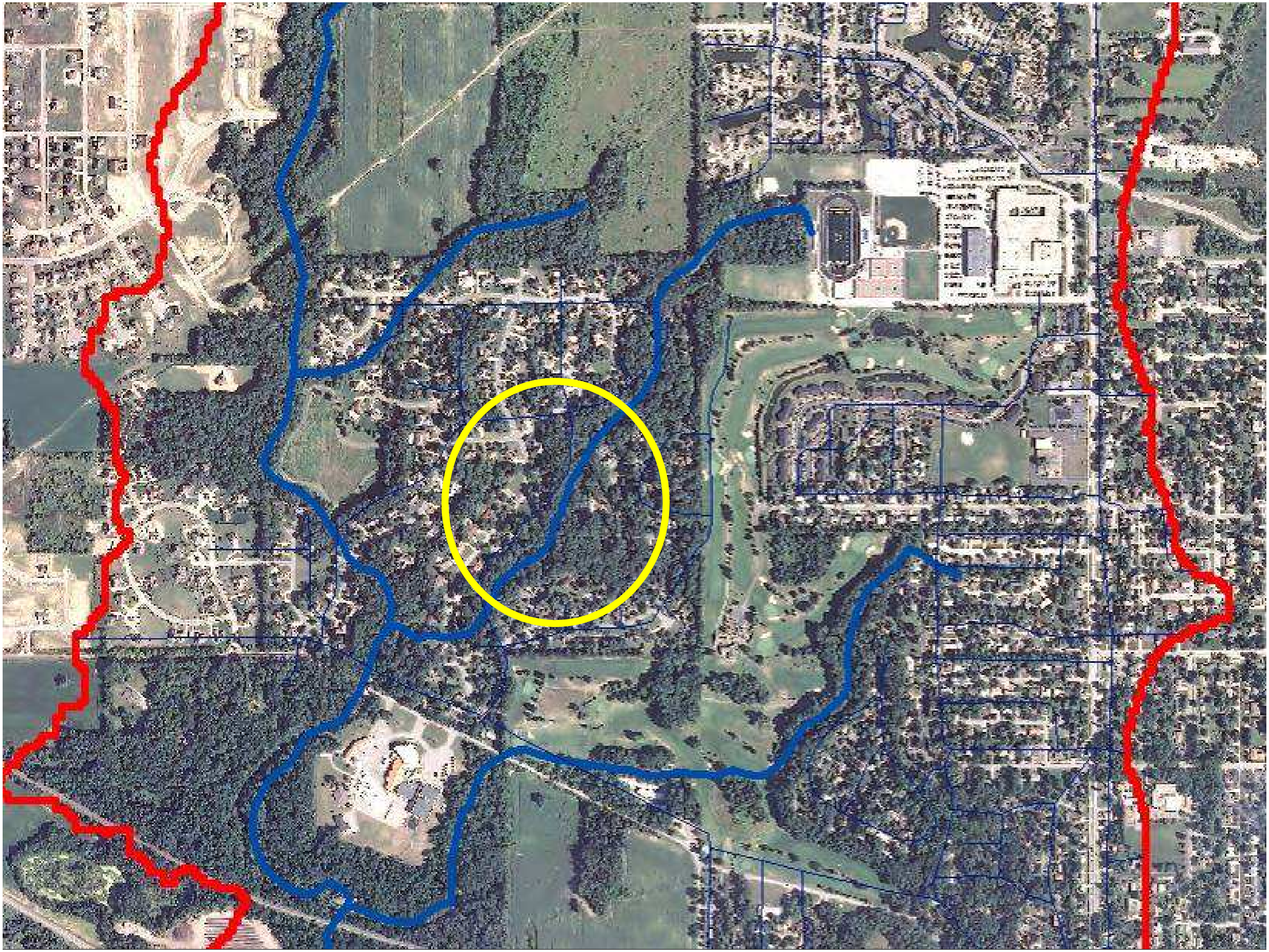


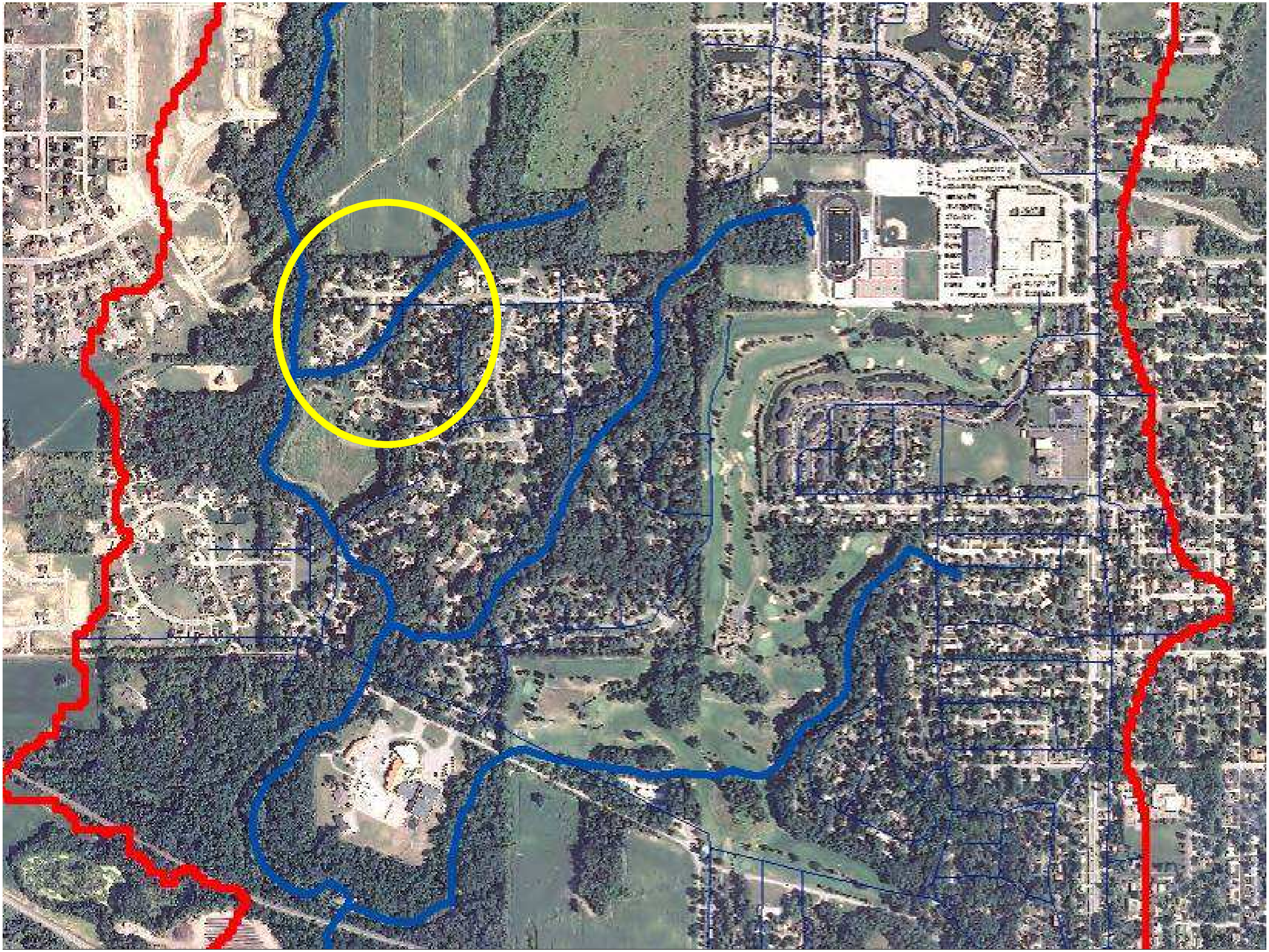
Okay.
So what?
Why do I care if the site runoff changes?

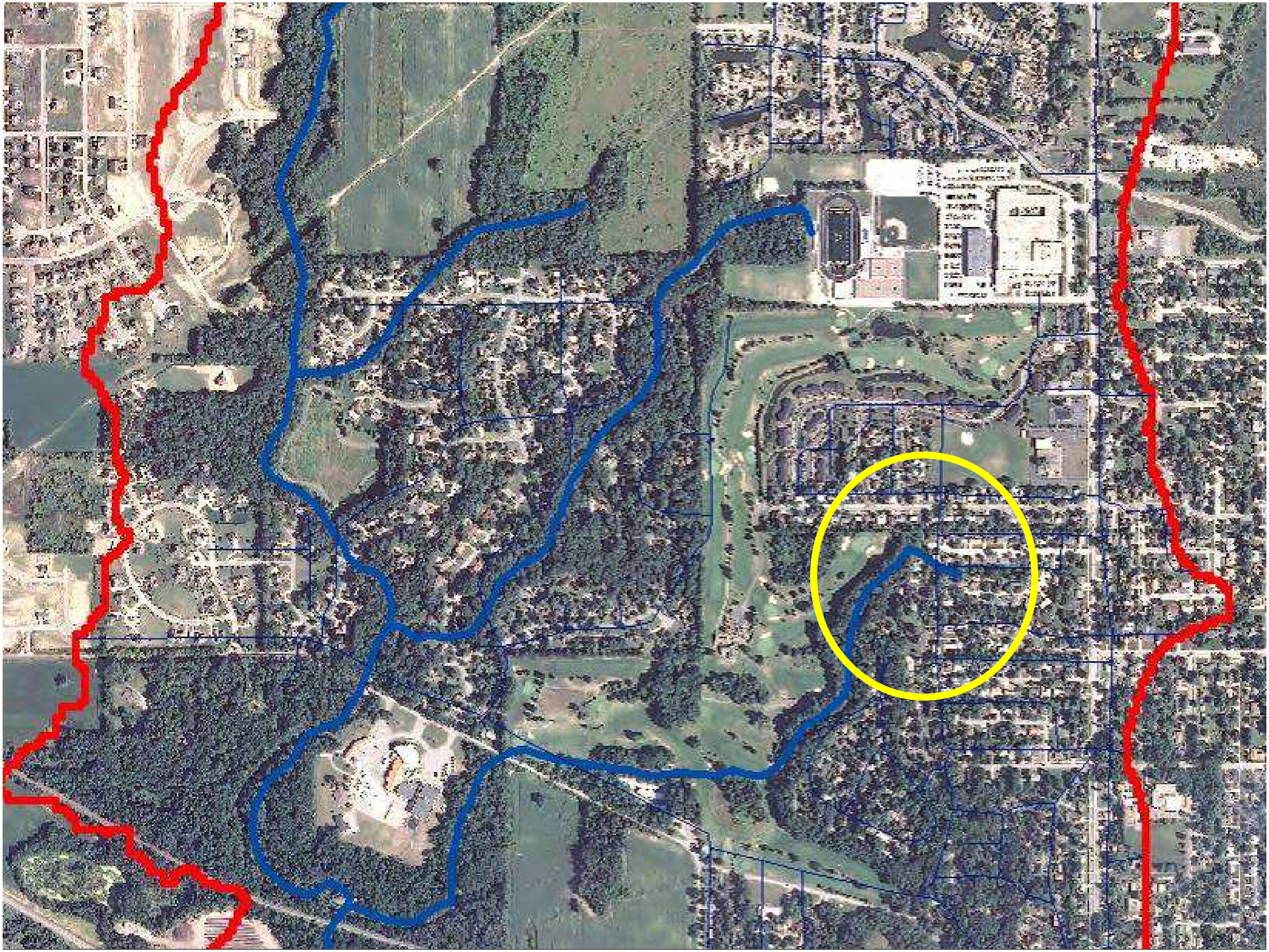
Consequences of Development to Urban Streams

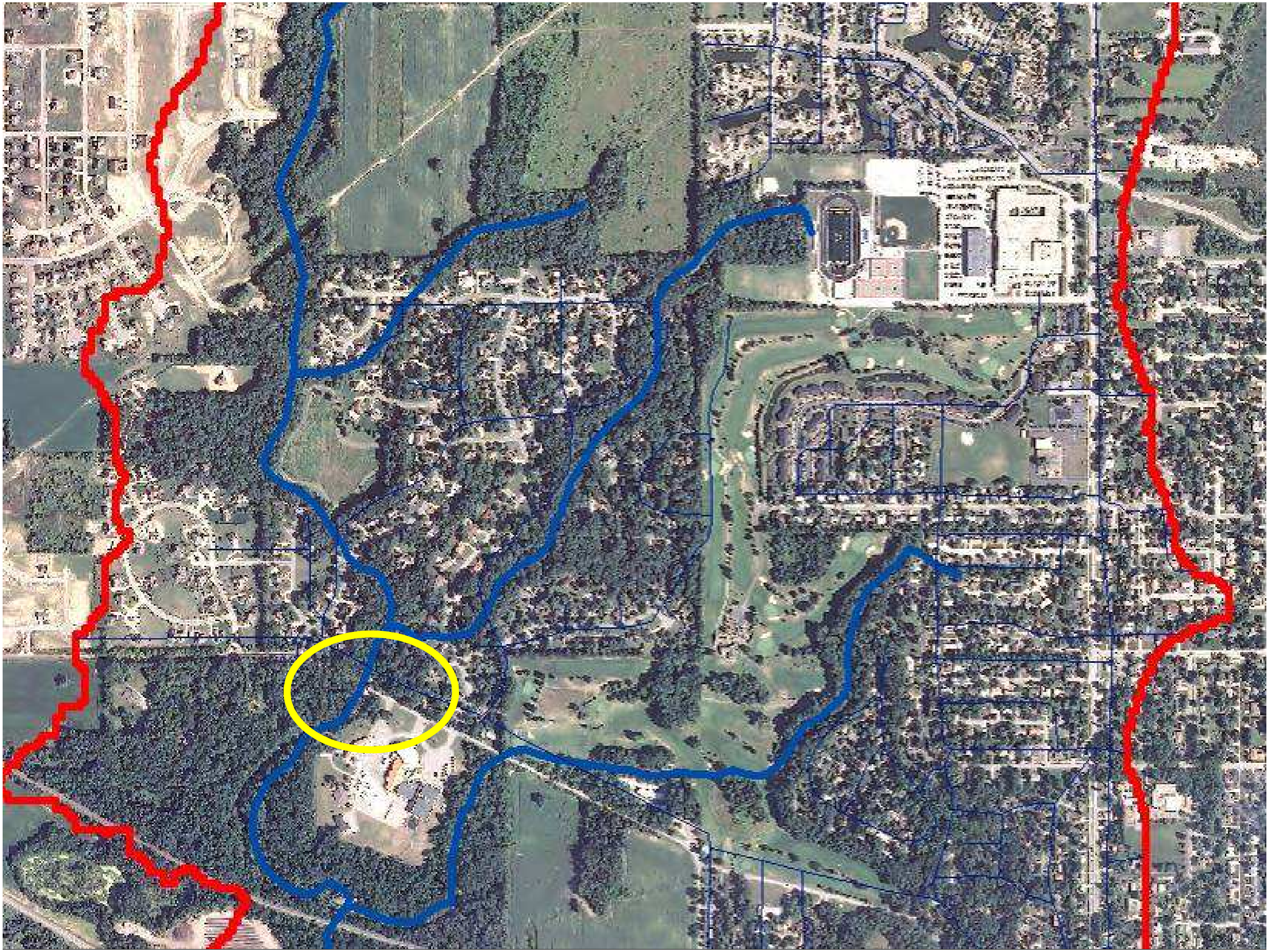






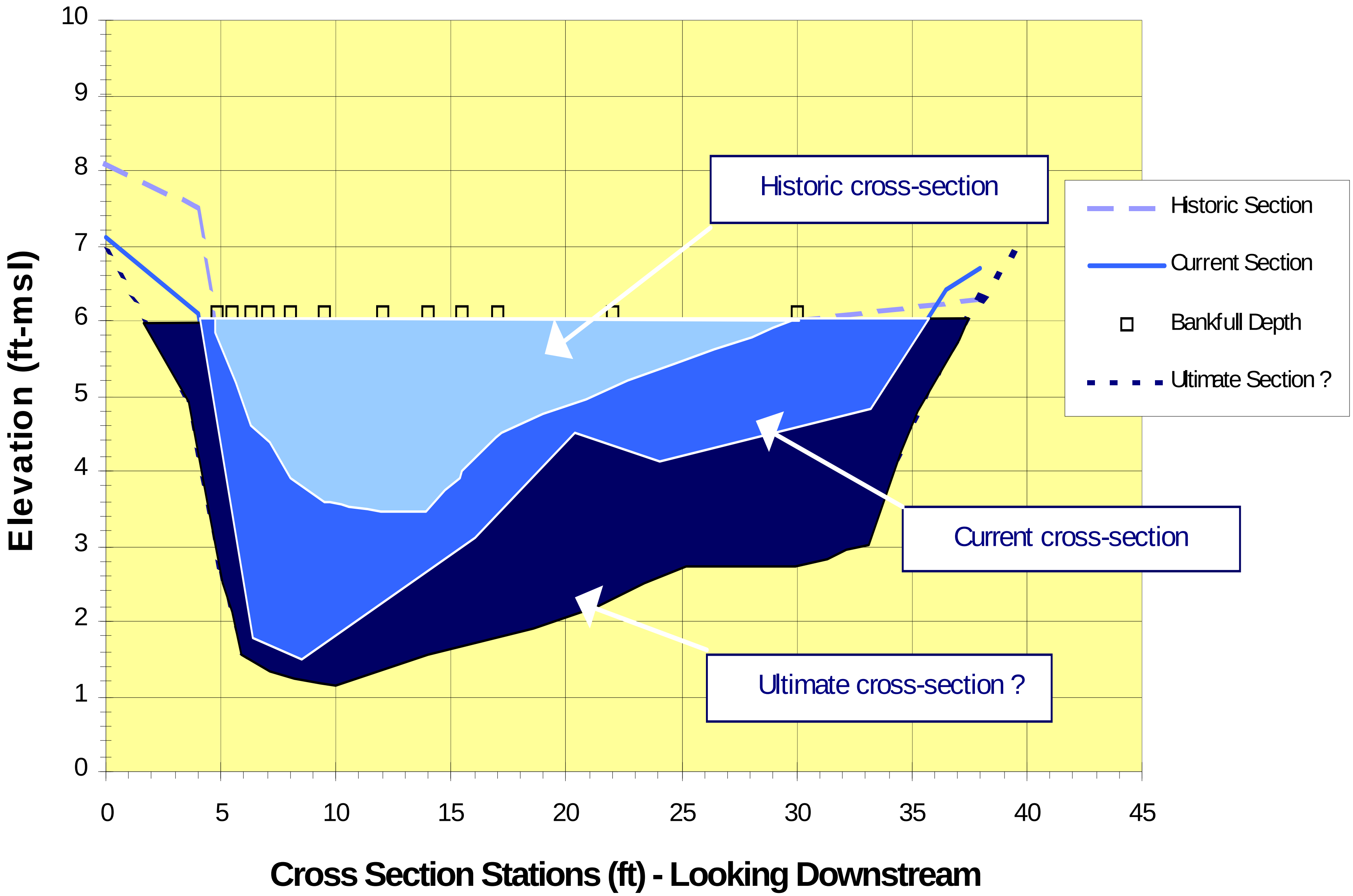







PRIVATE
KEEP OUT

The stream pictured here has downcut several feet in elevation because of the increased stormwater flow. In this case, the forested wetland in the floodplain is now hydraulically disconnected from the stream that sustained it.



Increased rates and volumes of storm water discharges lead to stream widening and down-cutting, or incision.

Geomorphological Effects of Urbanization

- Stream widening & erosion
- Reduced fish passage
- Degradation of habitat structure
- Decreased channel stability
- Loss of pool-riffle structure
- Fragmentation of riparian tree canopy
- Embeddedness
- Decreased substrate quality

Effects of Urbanization on Habitat

- Decline in habitat value of streams
- Loss of buffer zones
- Loss of large woody debris
- Creation of fish barriers
- A shift in the energy source that drives streams
- Increased algae growth

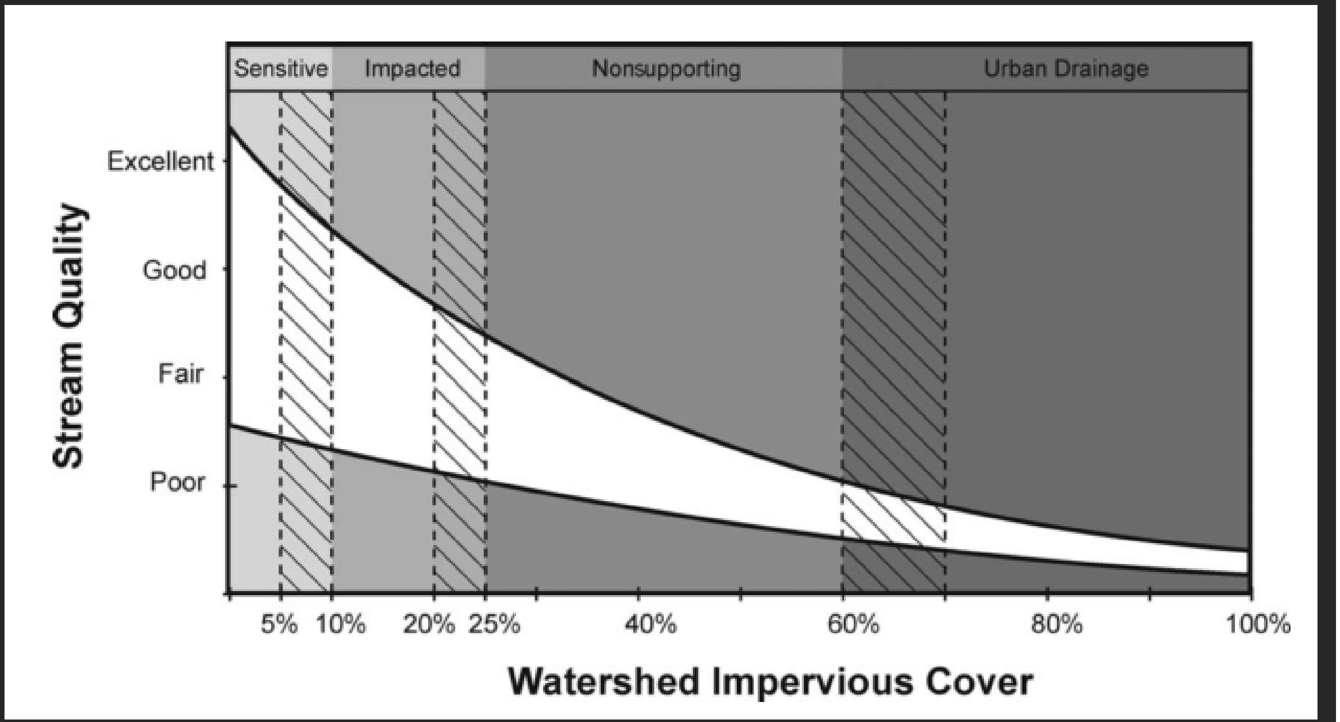
Consequences of Habitat Decline

- Decline in aquatic insect diversity
- Decline in fish habitat quality
- Decline in fish diversity
- Loss of sensitive coldwater & salmonoids
- Reduced spawning of anadromous & resident fish
- Decline in wetland plant & animal community diversity

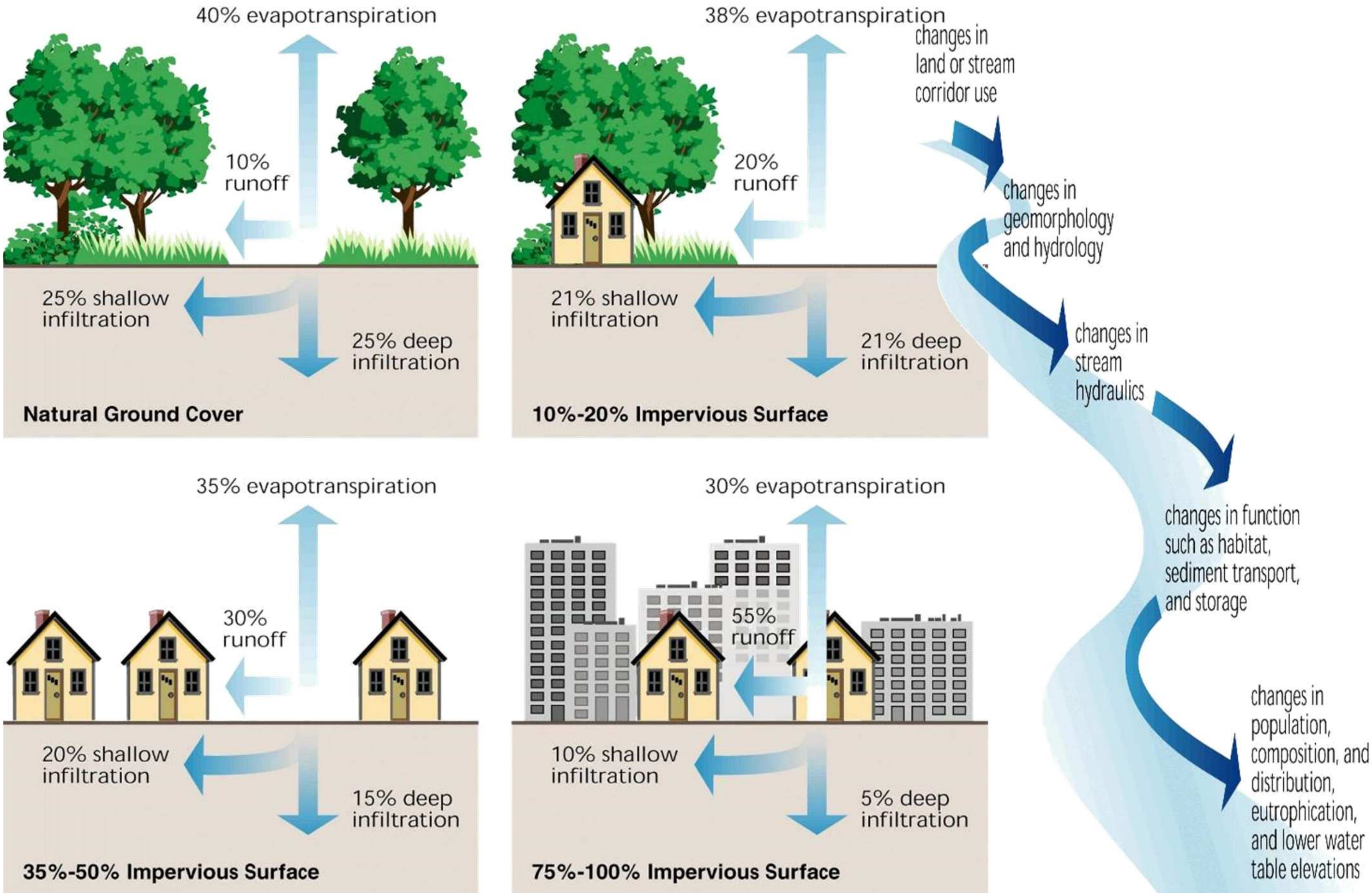
Impervious Cover Model

- 61 research papers, 2,500 subwatersheds, 25 states
- 35 different environmental quality indicators (hydrology, geomorphology, habitat, water quality, benthic macros, fish, etc.)
- Variability observed, particularly at low IC
- Most applicable on 1st, 2nd and 3rd order streams

Schueler, T., L. Fraley-McNeal, and K. Cappiella. (2009) “Is Impervious Cover Still Important: Review of Recent Research” Journal of Hydrologic Engineering April 2009.



So how do we “fix” it?



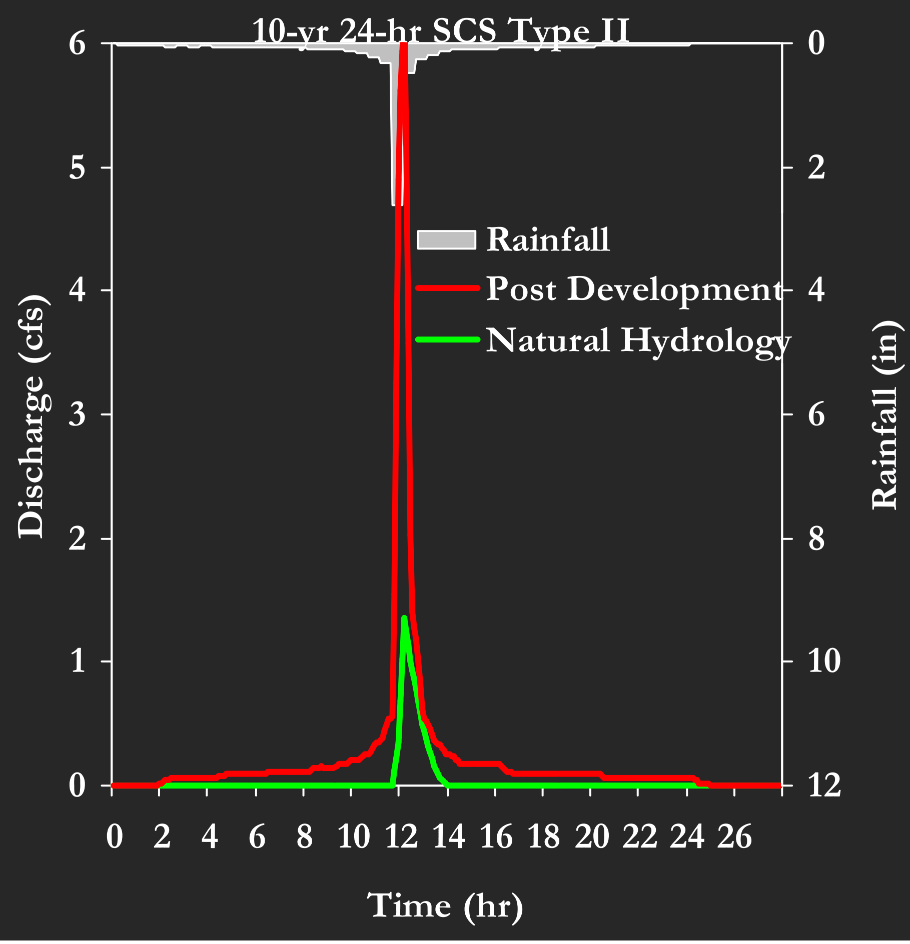
FISRWG (10/1998). Stream Corridor Restoration: Principles, Processes, and Practices.
By The Federal Interagency Stream Restoration Working Group.

Consider a typical development example

- Area = 2.98 ac
  - Building Footprint = 20.9%
  - Parking/sidewalk = 36.5%
  - Turf grass = 42.6%
- B/C soil
- Flat
- EPA-SWMM V5 model

No Stormwater Controls

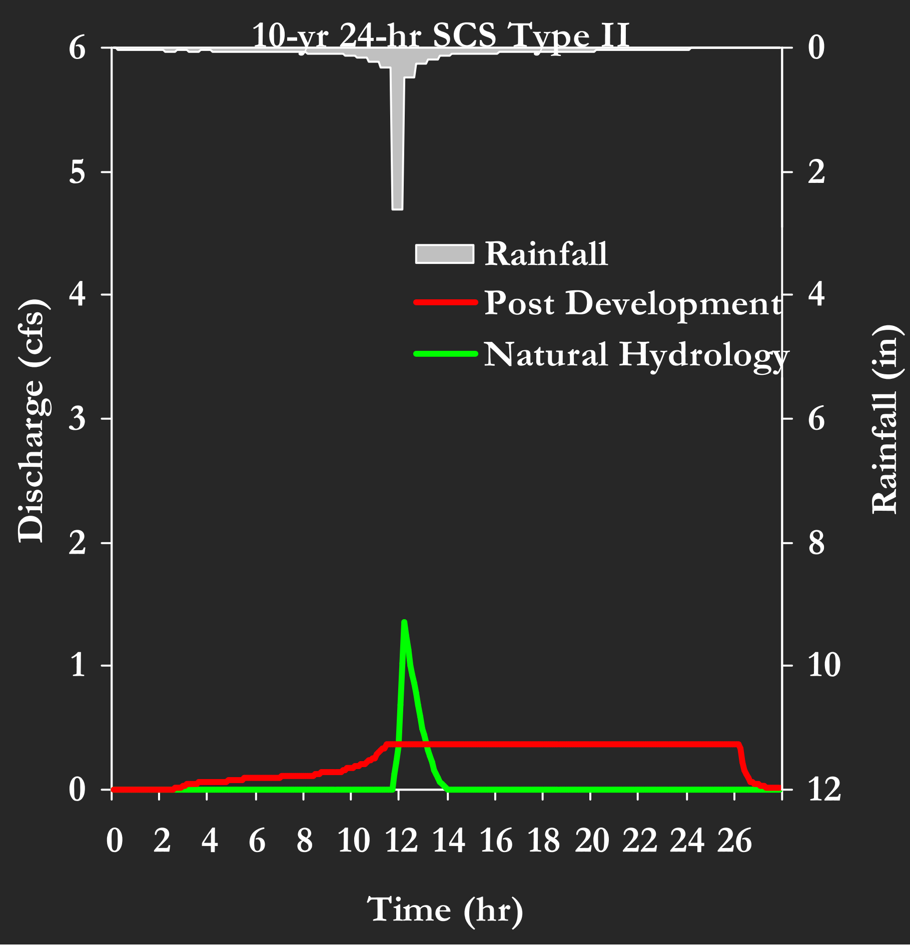
- Traditional development with no stormwater controls

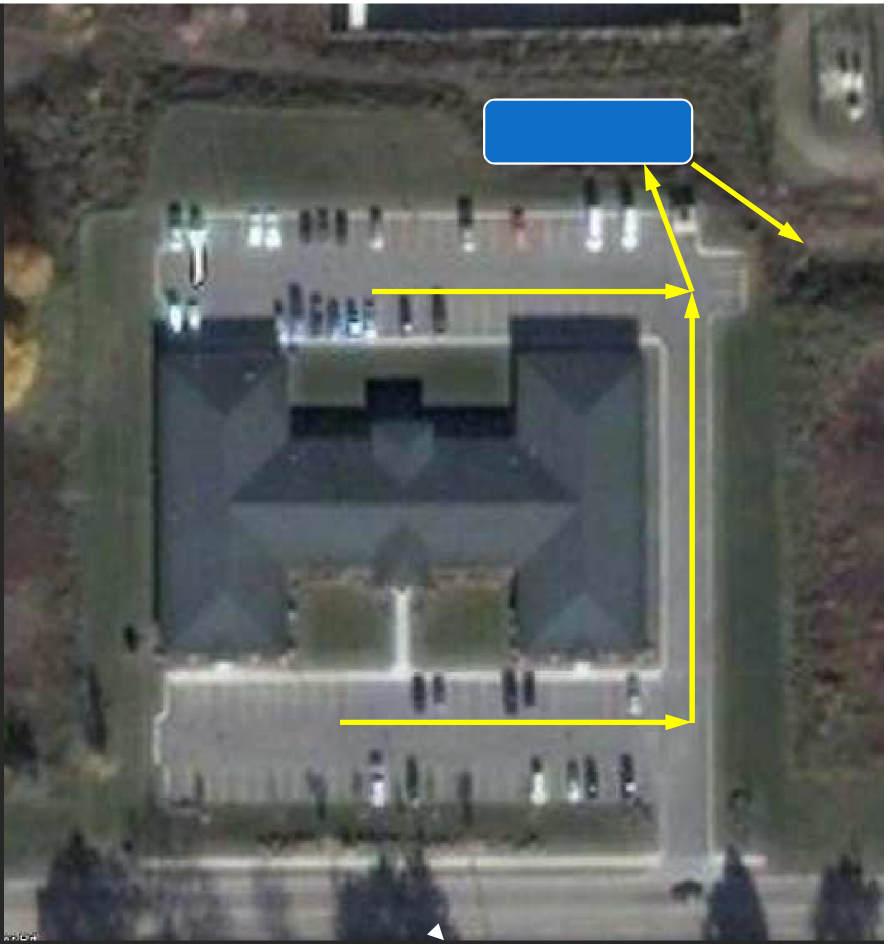


Average Annual (from 50-years)	Natural Hydrology	Post Development
Evaporation	10%	19%
Infiltration	90%	38%
Surface Runoff	**<1%**	**43%**

Traditional Detention

- Traditional drainage system
- Detention sized with 0.15 cfs/acre maximum release rate
- No change in average annual surface runoff

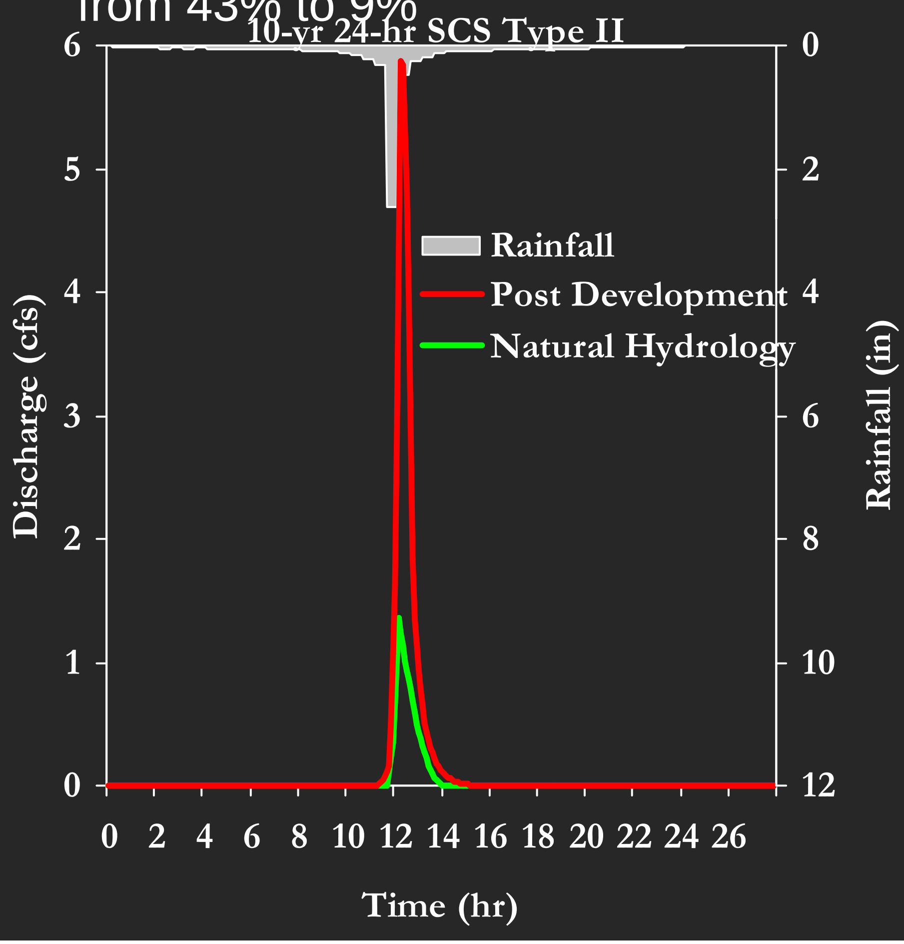


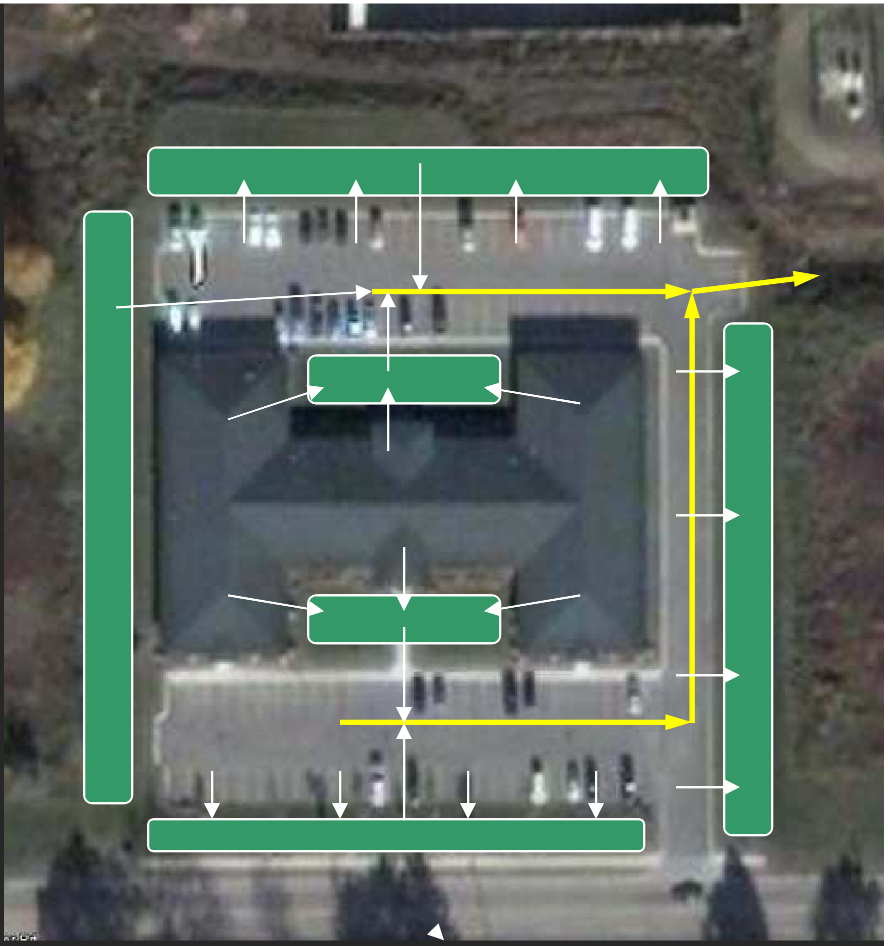


Average Annual (from 50-years)	Natural Hydrology	Post Development
Evaporation	10%	19%
Infiltration	90%	38%
Surface Runoff	**<1%**	**43%**

Impervious → Pervious

- Impervious surfaces discharge to green areas
- Green areas discharge to drainage system
- Decreased average annual surface runoff from 43% to 9%

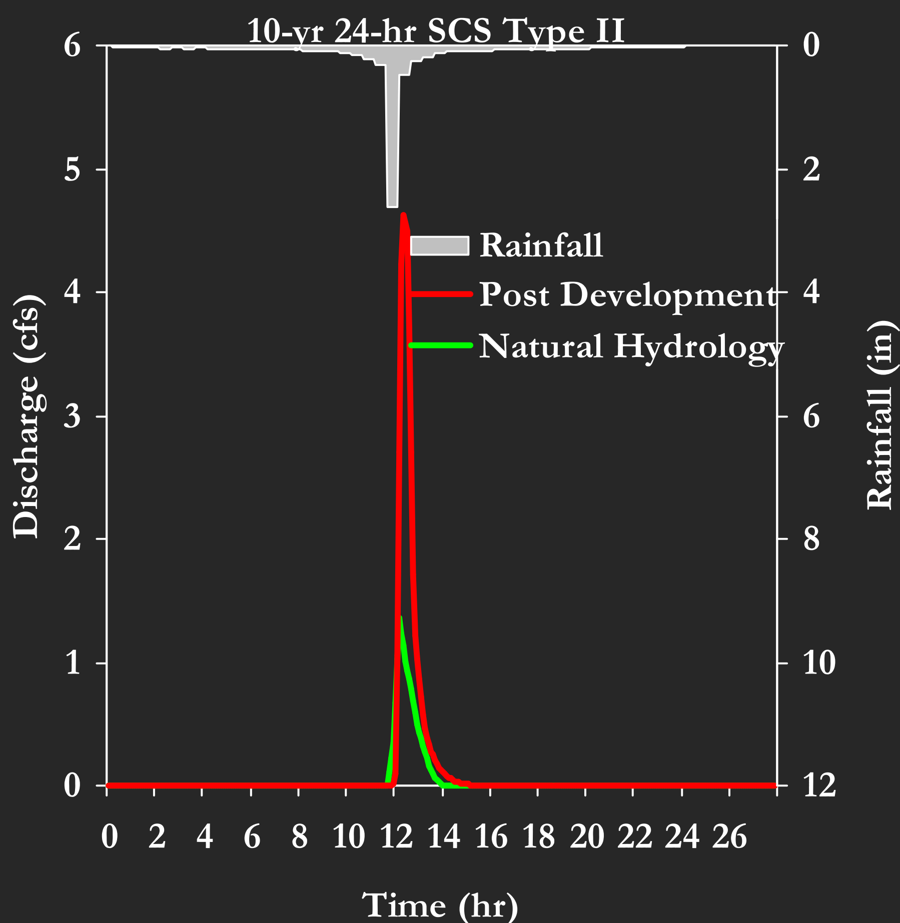


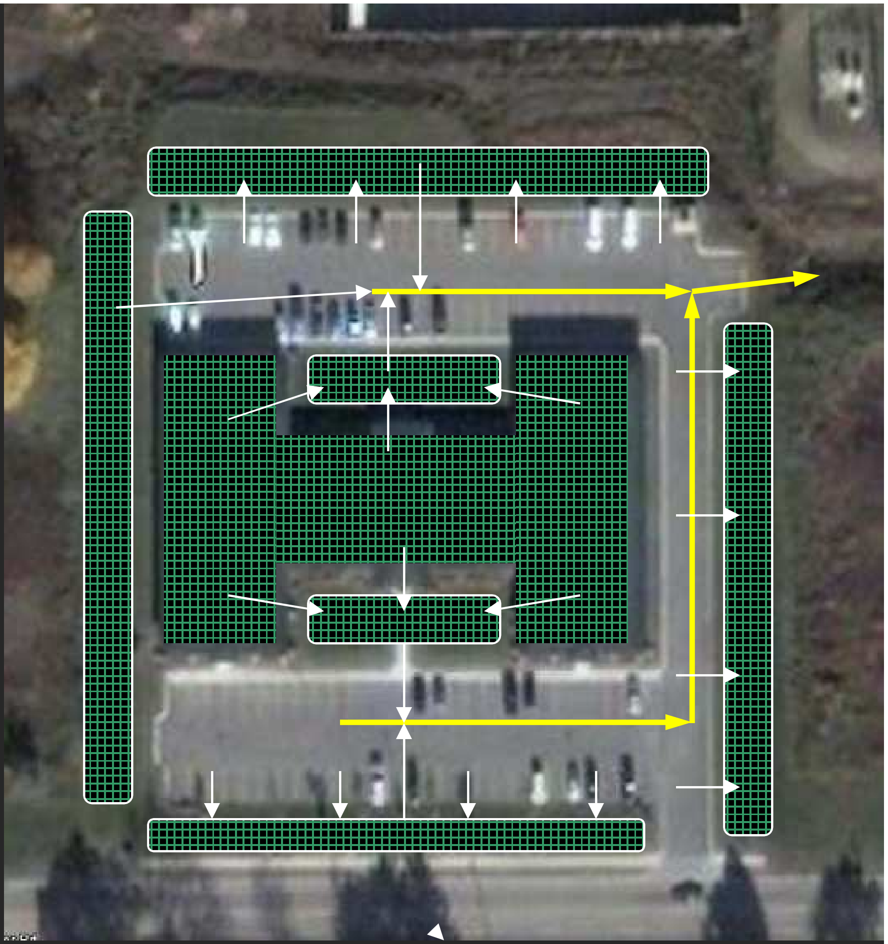


Average Annual (from 50-years)	Natural Hydrology	Post Development
Evaporation	10%	20%
Infiltration	90%	72%
Surface Runoff	**<1%**	**9%**

Added Storage

- Impervious → Pervious
- 1-inch roof storage (or equiv)
- 1-inch storage on pervious areas

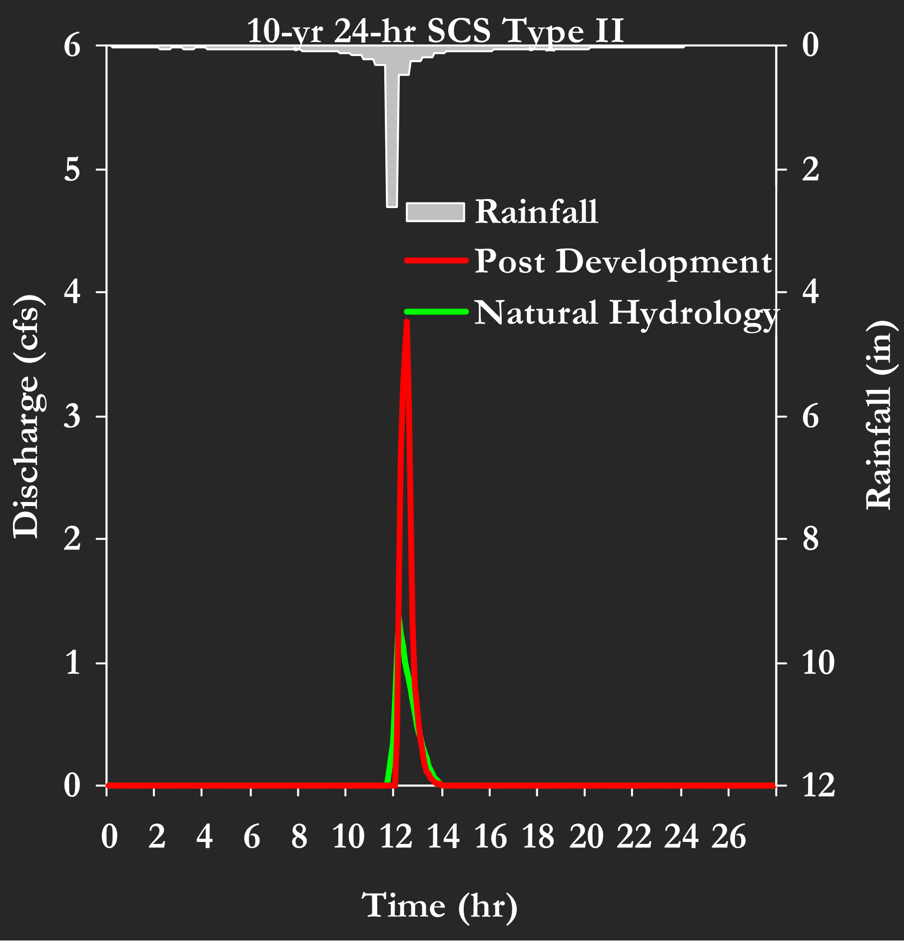


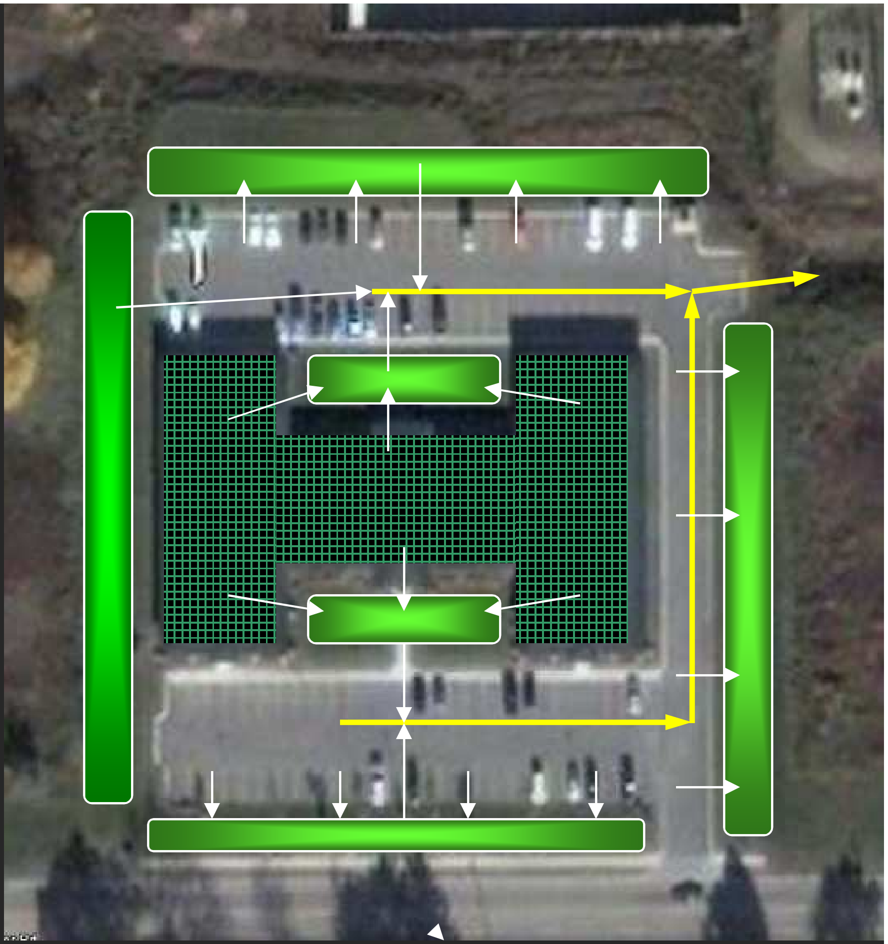


Average Annual (from 50-years)	Natural Hydrology	Post Development
Evaporation	10%	32%
Infiltration	90%	66%
Surface Runoff	**<1%**	**3%**

Enhanced Infiltration and Evapotranspiration

- Impervious → Pervious
- 1-inch roof storage (or equivalent)
- 1-inch storage on pervious areas with enhanced rates





Average Annual (from 50-years)	Natural Hydrology	Post Development
Evaporation	10%	32%
Infiltration	90%	67%
Surface Runoff	**<1%**	**1%**

Green Infrastructure

Systems and practices that use or **mimic natural processes** to infiltrate, evapotranspirate (the return of water to the atmosphere either through evaporation or by plants), or reuse stormwater or runoff on the site where it is generated. Green infrastructure can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements to support the principles of LID.

Roofs and Walls

Downspouts and Water Harvesting








Bioretention




Parking Lots







Trees





Roads, Alleys and Trails

Bioretention, linear





Bioretention, curb extension






Bioretention, dense urban areas

Smart Growth

A range of development and conservation strategies that help protect our natural environment and make our communities more attractive, economically stronger and more socially diverse

Jordan Cove Watershed Project
NEMO Program, University of Connecticut

Sounds reasonable but where’s the proof?

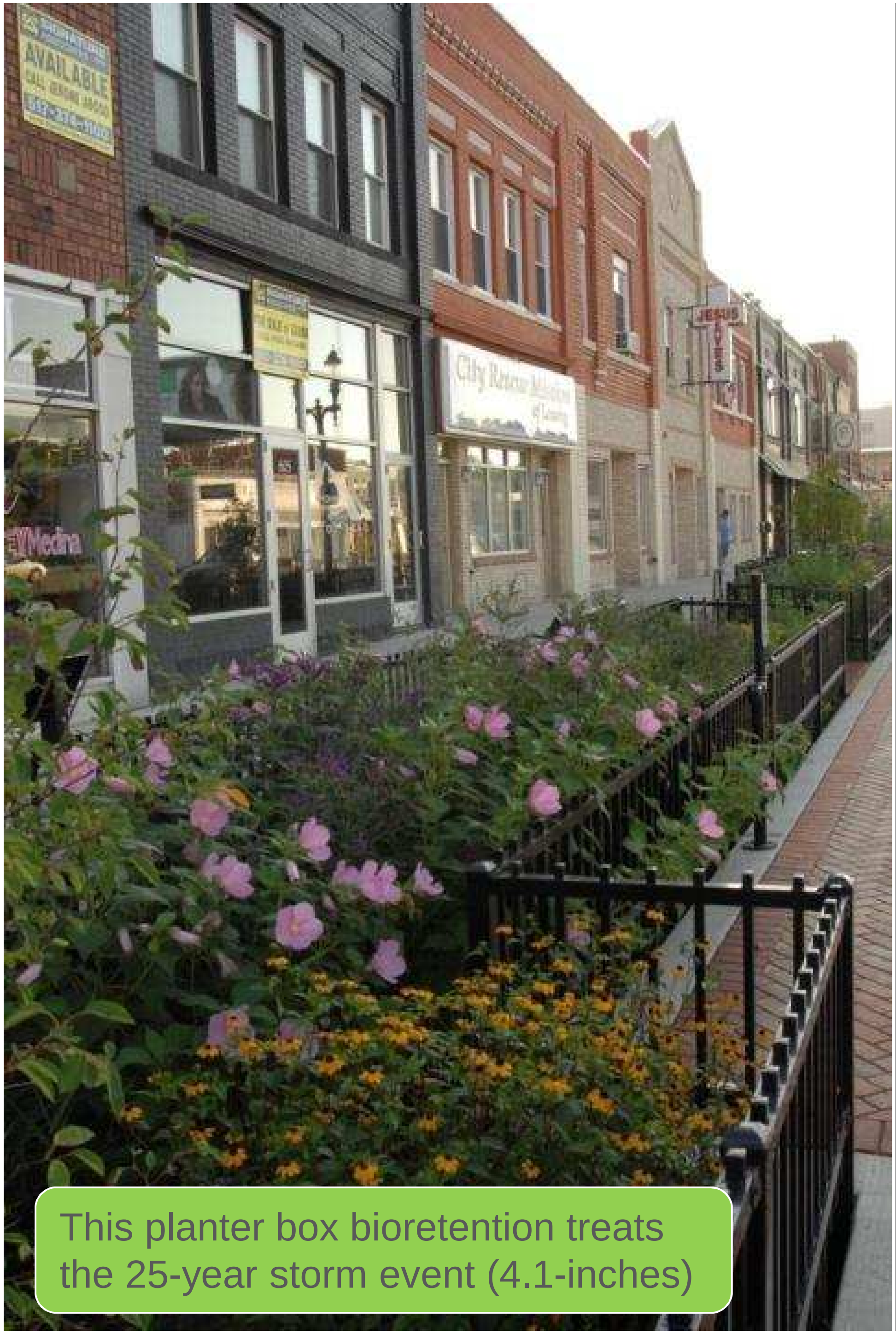
Where’s the proof that these “green infrastructure” practices can really affect the runoff from a site?

Maywood Ave, Toledo OH

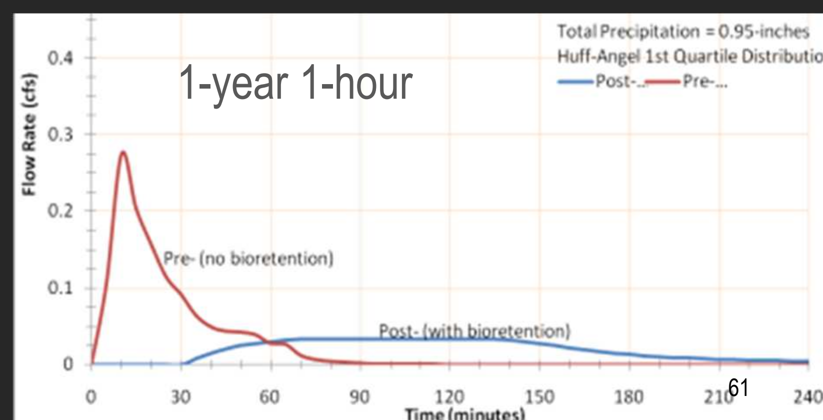
- SFR low income (25% ownership)
- Heavy clay soils
- Engineered system under greenbelt and sidewalk
- Bioswale $150 per linear foot
- 64% average annual volume reduction
- 60 to 70% peak flow reduction
- Eliminated street flooding and basement backups
- Maintenance: turf grass and trees

Michigan Ave, Lansing MI

- Ultra Urban Application
- 4 blocks, 30 bioretentions
- Cost $122/sf ($30/sf without urban constraints)
- 90% Storm Design (+/-)
- 75% decrease in average annual runoff volume



This planter box bioretention treats the 25-year storm event (4.1-inches)



Guess what…

Environmental

- Energy
- Water quality
- Urban heat island
- Improve air quality
- Flood protection
- Drinking water source protection
- Replenish groundwater
- Protect or restore wildlife habitat
- Reduce sewer overflow events
- Restore impaired waters

- 10 sf green roof removes ½ pound particulate per year
- Equivalent to capture from 10,000 vehicle miles traveled
- Approximately 800 million tons of carbon are stored in U.S. urban forests with a $22 billion equivalent cost
- Planting trees remains one of the cheapest, most effective means of drawing excess CO_2 from the atmosphere.

Social

- Traffic calming
- Place making
- Crime reduction
- Provide pedestrian and bicycle access
- Enhance livability and urban green space
- Urban heat island mitigation
- Educational value
- Projects bring people together
- Inspire civic commitment

- Compared with areas that had little or no vegetation, buildings with high levels of greenery had 52% fewer crimes.
- Views of nature reduce the stress response (Parsons et. al., 1998).
- Trees (along with other plants) absorb high-frequency noise which is the most distressing frequency range for humans (Miller, 1997).
- Hospital patients that see trees need less medication and have faster recovery times following surgery (Ulrich, 1985).

Economics

- Reduce hard infrastructure construction costs
- Longer infrastructure life (improved subsurface drainage)
- Increase land values
- Encourage economic development
- Reduce energy consumption and costs
- Increase life cycle cost savings
- Job creation

University of Pennsylvania

- Vacant land improvements increased surrounding housing values by as much as 30%
- New tree plantings increased surrounding housing values by approximately 10%

Commercial Benefits

- More frequent shopping
- Longer shopping trips
- Shoppers spend more

Thank you

Questions?

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