What We Know (or Think We Know) about Sediment and Nutrient Dynamics from Urban Source Area Sampling

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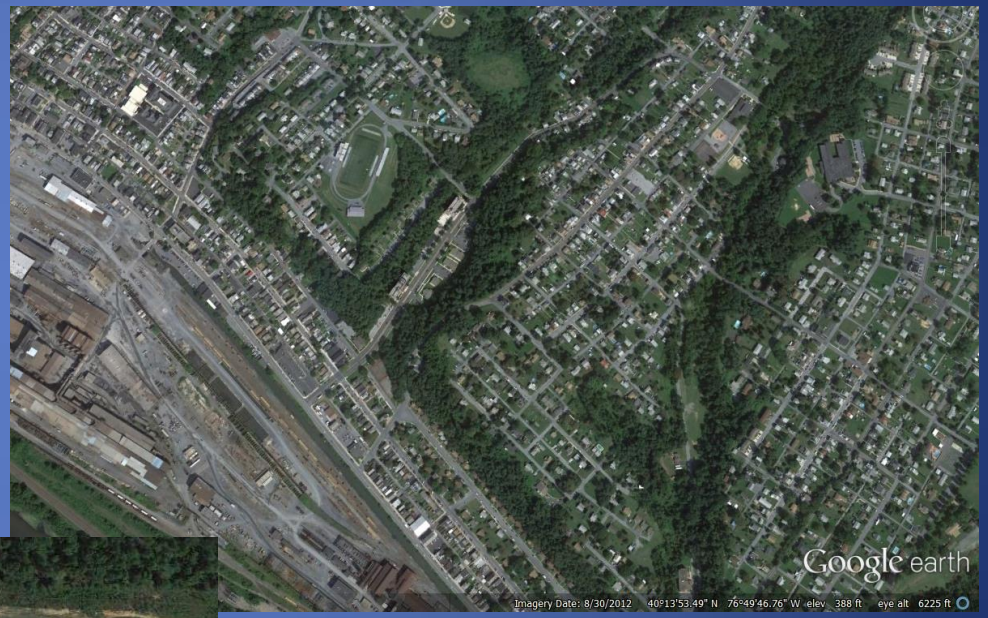
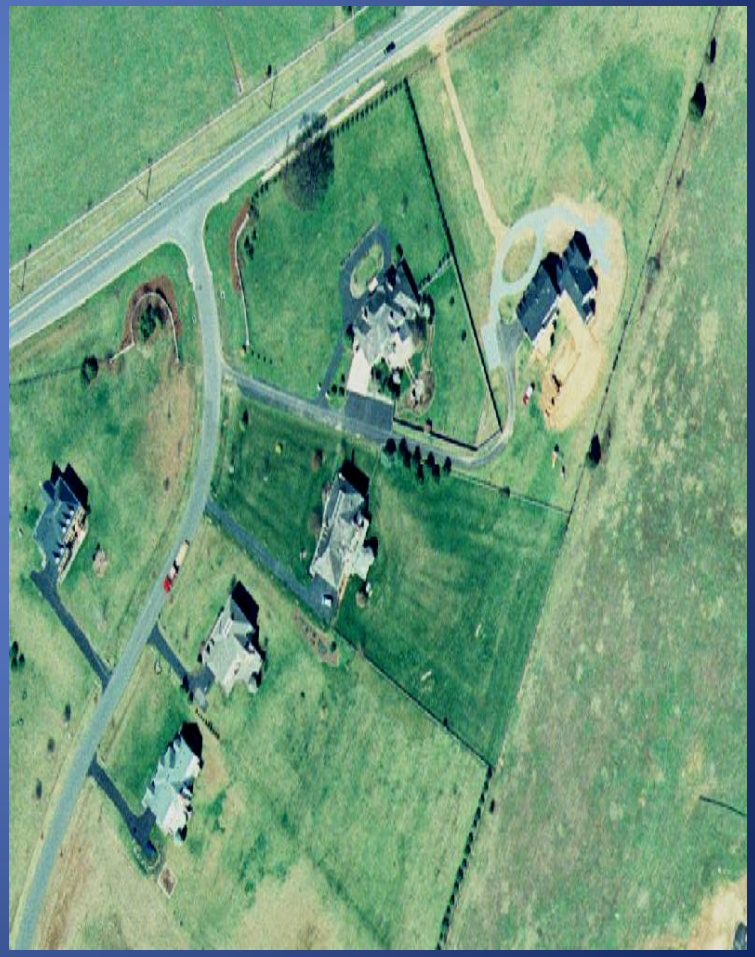


The Peculiarities of Perviousness: STAC Workshop

April 22 – 23, 2014

Nitrogen sources in urban runoff include:

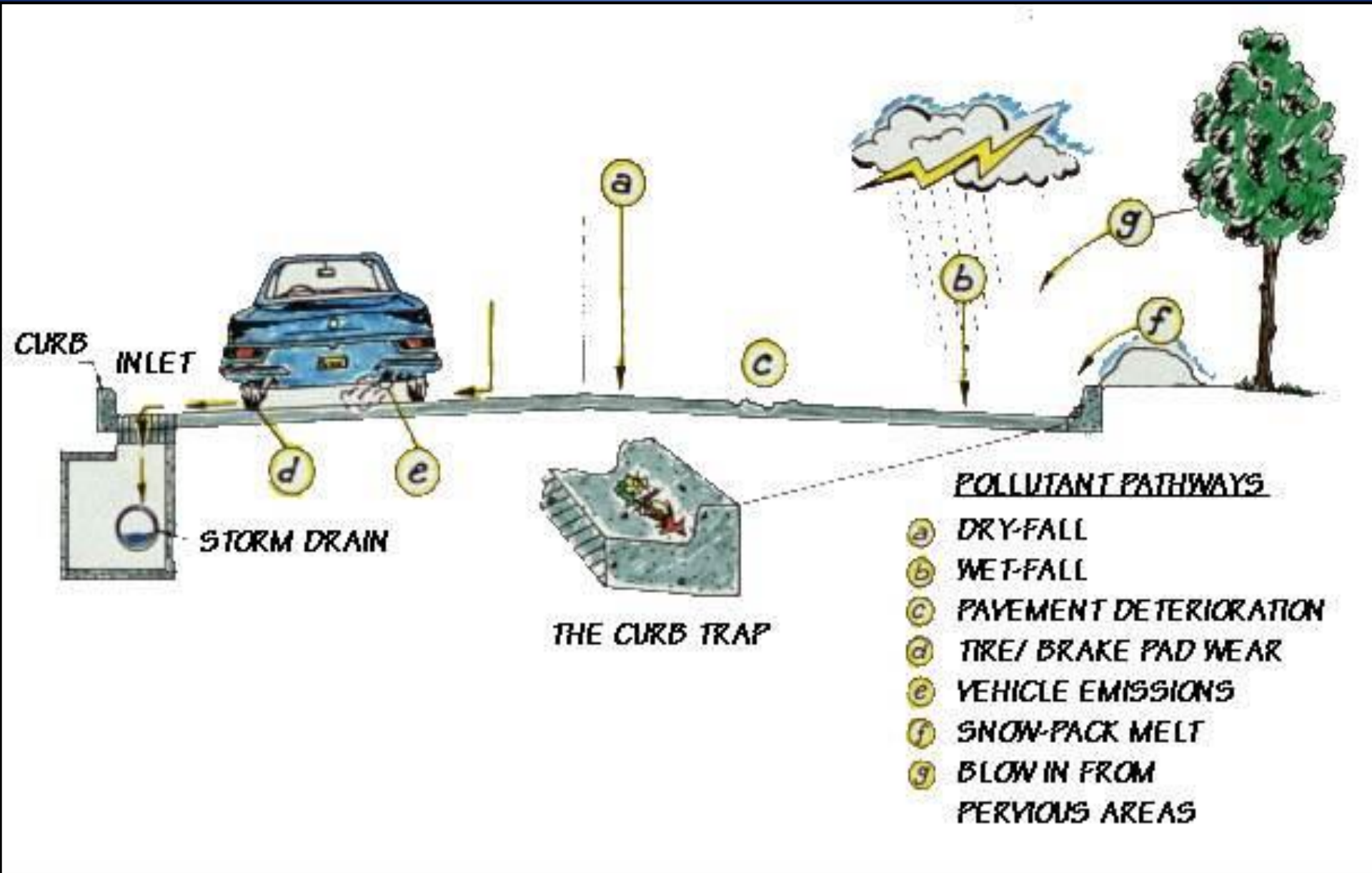
- Atmospheric deposition
- Washoff of fertilizers
- Nitrogen attached to eroded soils and streambanks
- Organic matter and pet wastes on IC
- Septic system leachate



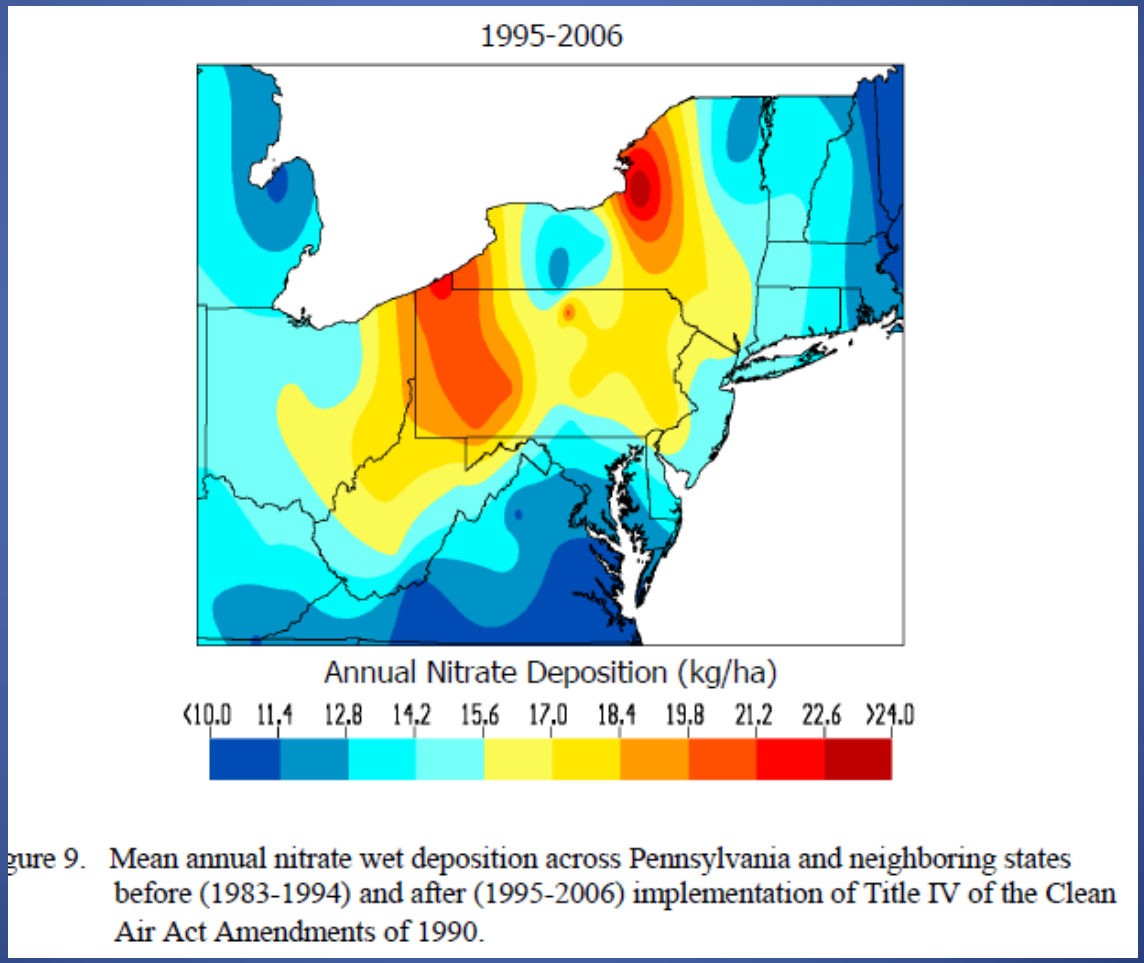
Many sources of TP in urban runoff

- Blow in of organic matter onto impervious surfaces (leaves, pollen, clippings, flowers, etc.)
- Phosphorus attached to eroded soils and streambanks
- Fertilizer washoff
- Atmospheric deposition

Unlike some pollutants, there are many sources of N and P in the urban environment



Looking Up: Atmospheric Deposition (Dryfall or Wetfall)



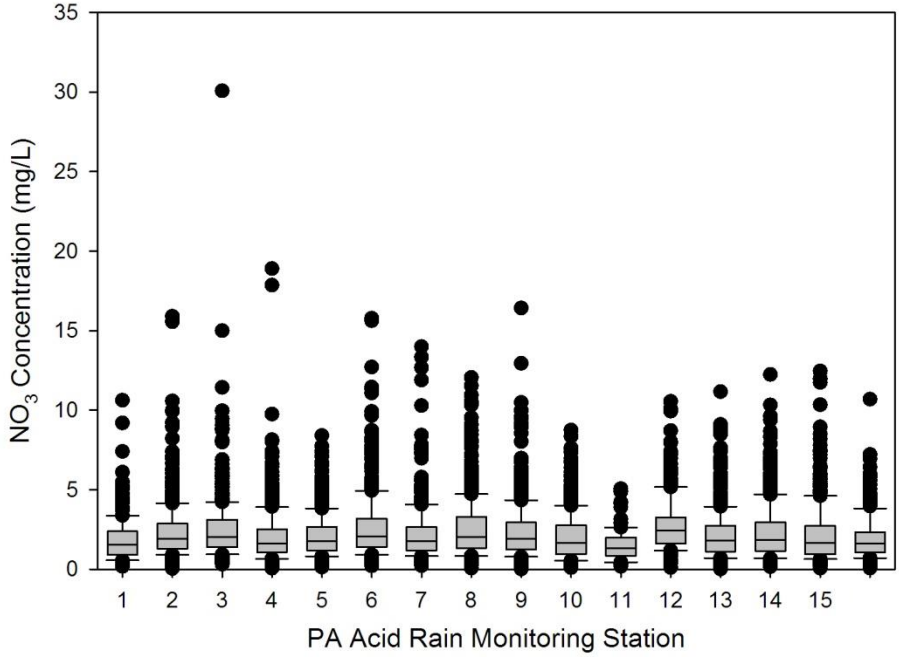
gure 9. Mean annual nitrate wet deposition across Pennsylvania and neighboring states before (1983-1994) and after (1995-2006) implementation of Title IV of the Clean Air Act Amendments of 1990.

Data from PA DEP
http://www.dep.state.pa.us/dep/DEPUTATE/AIRWASTE/AQ/acidrain/isomaps.htm

Looking Up: Atmospheric Deposition (Dryfall or Wetfall)

Relationship of Atmospheric Deposition to Urban Runoff Quality			
Nutrient	**Atmospheric Deposition [1]**	**Stormwater Runoff Load [1]**	**Atmospheric Deposition**
	Pounds per impervious acre per year		***Pounds per acre per year***
Total Phos.	0.7	2.0	0.06 – 0.09 [2]
Total Nitrogen	13 to 17.0	15.4	
1 measured rates during Washington NURP Study (MWCOG, 1983) 2 NJADN reported rates (2004)			
Nitrate	PAADN (approximately 10 yrs of data up to 2012)		22.7
Ammonium			4.43

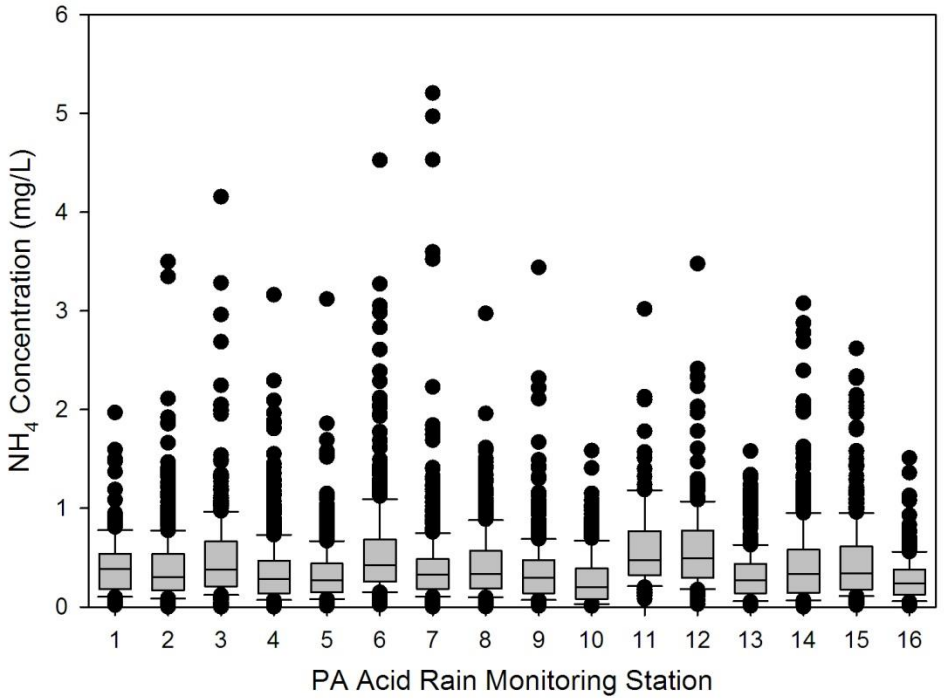
Nitrogen Concentrations in Atmospheric Deposition in PA



Median Concentrations:

NO_3: 1.8 mg/L

NH_4: 0.32 mg/L

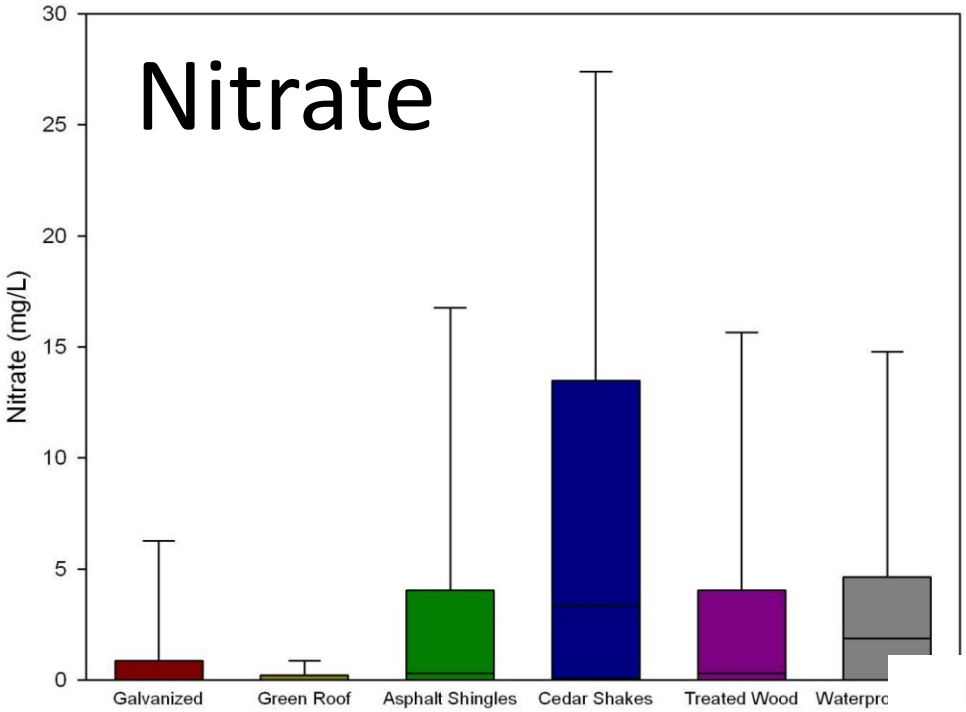


Looking Up: Vehicle Emissions (Westerholm and Egeback, *Environmental Health Perspectives*, 1994)

	Carburetor no exhaust		Three-way catalyst system	
	70 km/h	90 km/h	70 km/h	90 km/h
NOx (g/km)	1.2	1.2	0.11	0.42
Particles (mg/km)	2.8	30	0.7	4.2
	Bus (diesel)	Truck (diesel)	Bus (bus diesel)	Truck (bus diesel)
NOx (g/km)	13.2	16.4	11.9	15.4
Particles (g/km)	0.51	0.58	0.47	0.47

Looking Up: Roofing as a Source of Nutrients

Nitrate



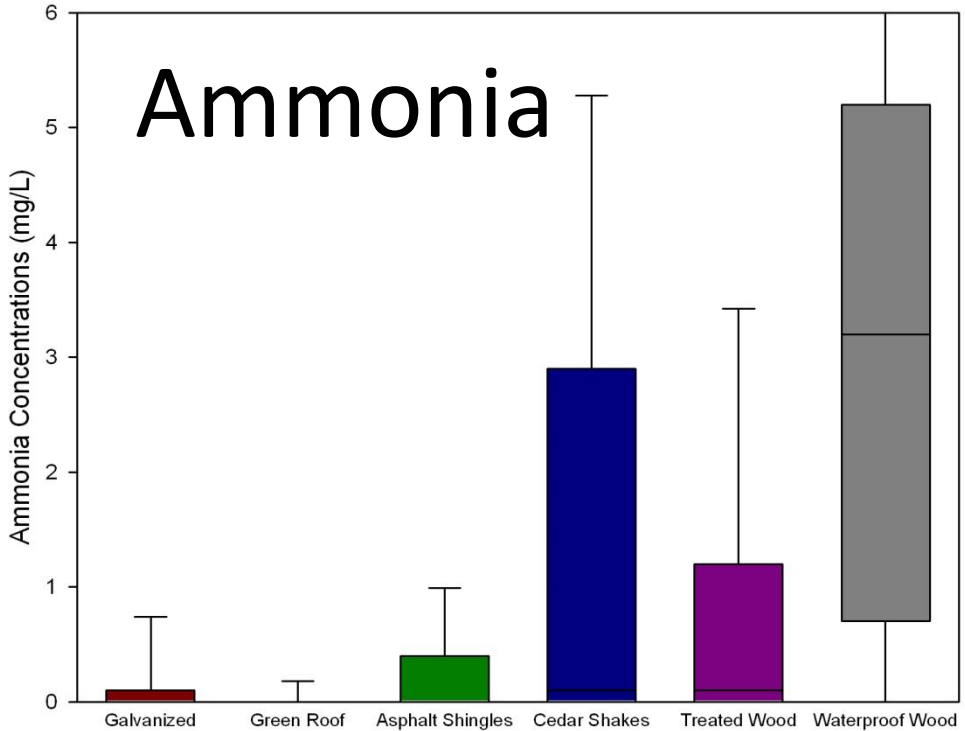
Drinking Water Standard = 45 mg/L (10 mg/L as N)

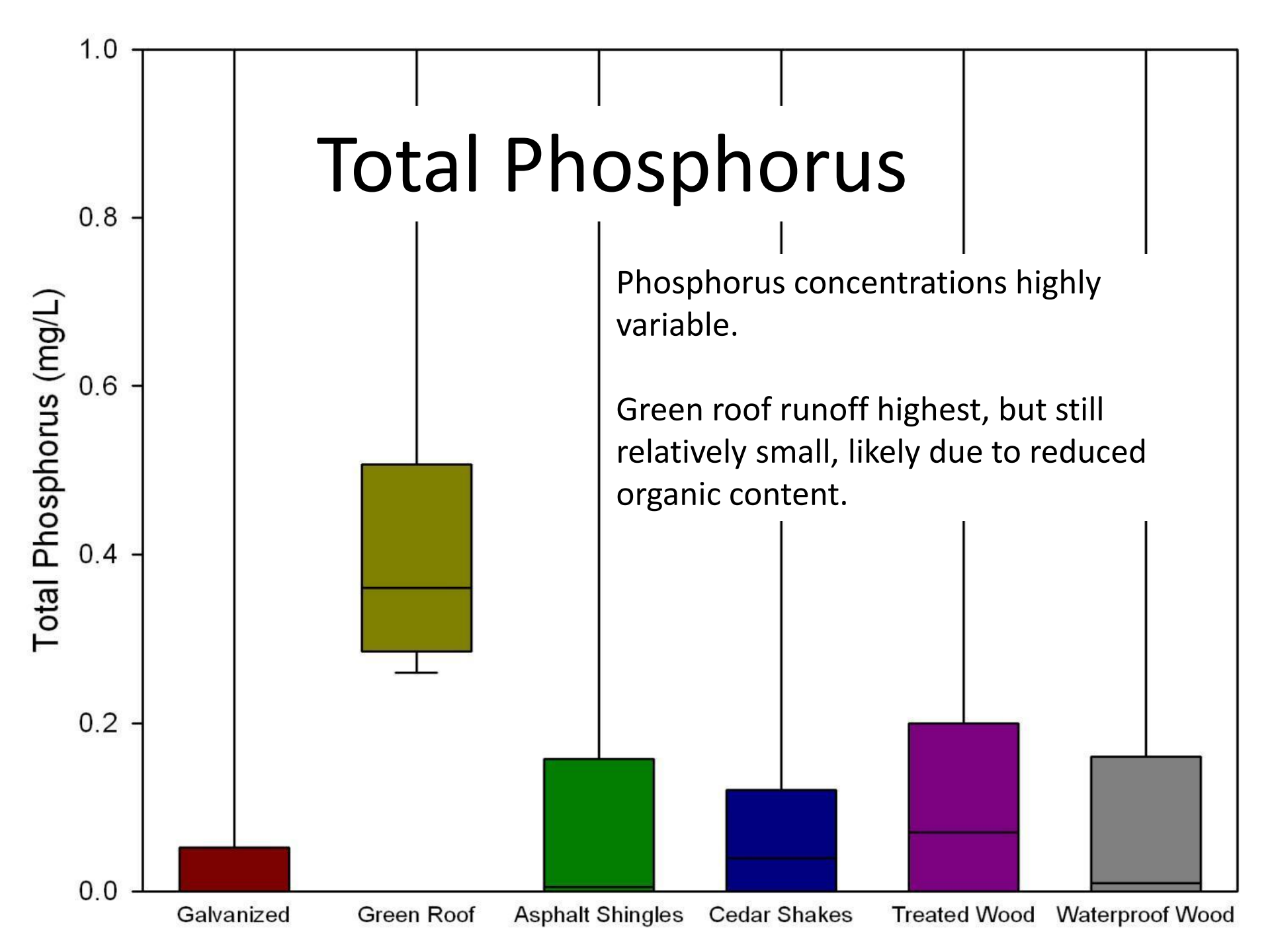
Stream Data = 0.58 mg/L

Wood products source of nitrate.

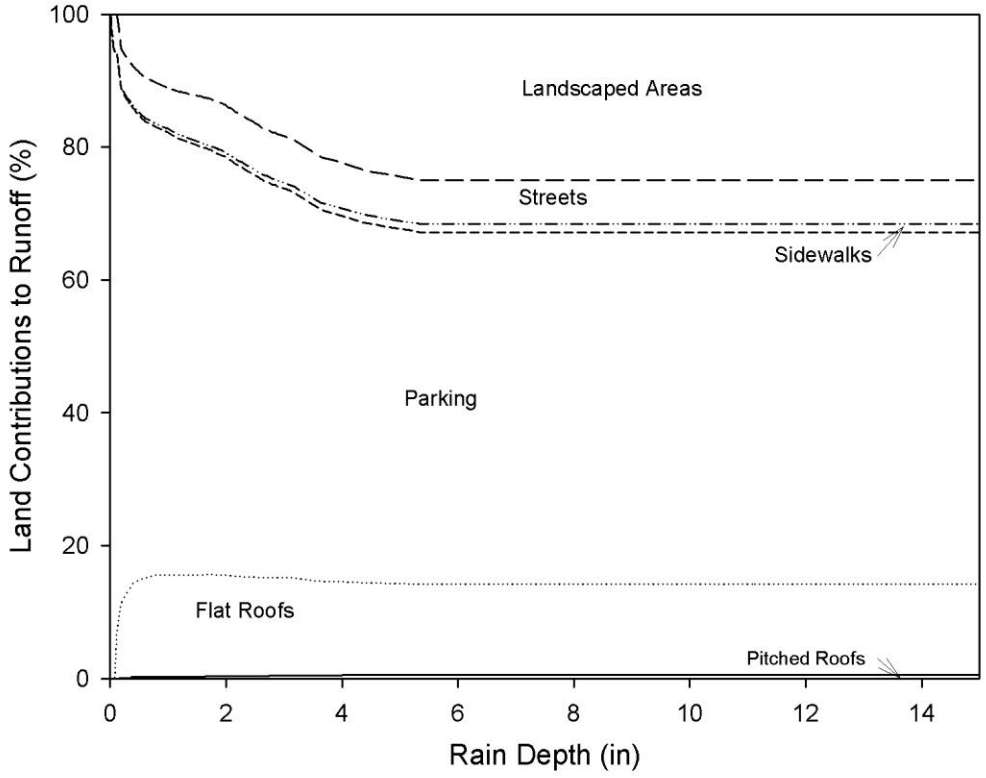
Highest ammonia concentrations from wood-based products.

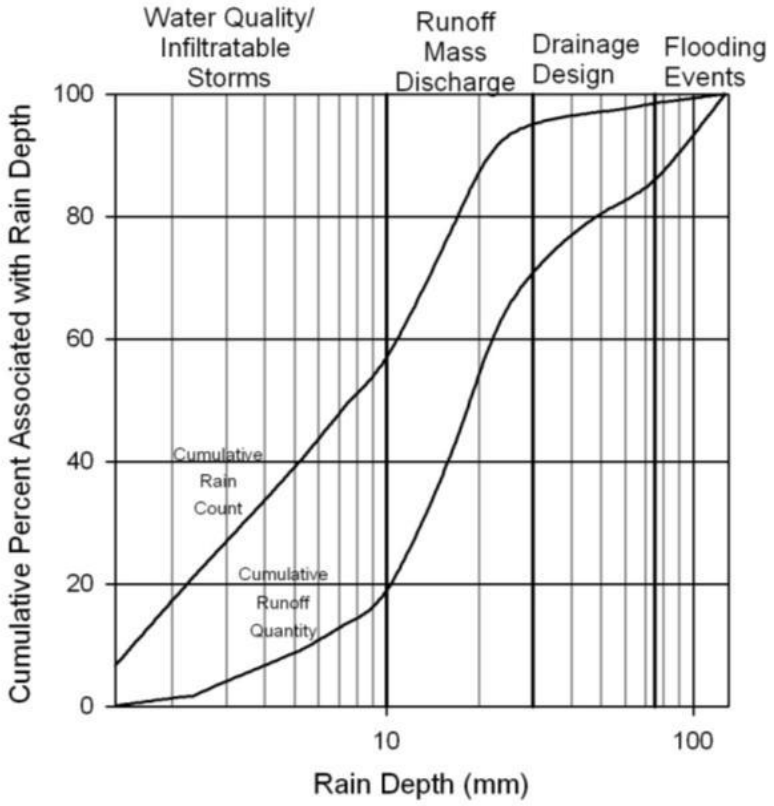
Ammonia




Total Phosphorus
Phosphorus concentrations highly variable.
Green roof runoff highest, but still relatively small, likely due to reduced organic content.
Total Phosphorus (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
Galvanized
Green Roof
Asphalt Shingles
Cedar Shakes
Treated Wood
Waterproof Wood

Looking Down: Roads, Soils and Lawns





Assuming Conventional Soil Infiltration Numbers based on HSG, Pervious Areas Contributed 15% of Runoff at Rain Depths of 0.5”.

Looking Down: Roads

Sansalone, J.J., and S.G. Buchburger. (1997). Partitioning and First Flush of Metals in Urban Roadway Stormwater. *Journal of Environmental Engineering*. 123(2):134.

- Sampled interstate runoff in Cincinnati OH.
- 5 storms across approximately 6 months.

	Storm 1	Storm 2	Storm 3	Storm 4	Storm 5
Total Solids (mg)	924.3	61.8	21.4	199.6	285.6
Volatile Solids (mg)	292.1	51.1	N/A	107.4	130.3
Total Dissolved Solids (mg)	235.5	43.9	10.8	132.8	113.3
Volatile Dissolved Solids (mg)	135.2	43.1	N/A	72.3	65.4

Looking Down: Roads

Pagotta, C., M. Legret, and P. Le Cloirec. (2000). Comparison of the Hydraulic Behavour and Quality of Highway Runoff Water According to Type of Pavement. *Water Research*. 34(18):4446-4454.

Analyte	Conventional Pavement Mean (n=25)	Standard Deviation	Porous Pavement Mean (n=25)	Standard Deviation	Relative Difference (%)
TSS (mg/L)	46	40	8.7	9.0	-81
TKN (mg N/L)	2.1	1.6	1.2	0.9	-43
NO_3^- (mg/L)	6.7	6.8	2.1	1.9	-69
NH_4^+ (mg/L)	1.0	1.2	0.27	0.40	-74
TSS (kg/ha)	81		18.5		-77
TKN (kg/ha)	3.6		2.5		-30 (NSS)
NO_3^- (kg/ha)	10.6		4.4		-58 (NSS)
NH_4^+ (kg/ha)	1.8		0.6		-68 (NSS)

Looking Down: Roads

M. Kayhanian, A. Singh, C. Suverkropp, and S. Borroum. (2003). *Journal of Environmental Engineering*. 129(11):975-990.

Constituent	Non-Urban (AADT <30,000)	Urban Low (30,000 < AADT < 60,000)	Urban Medium (60,000 < AADT) < 100,000	Urban Medium High (100,000 < AADT < 200,000)	Urban High (AADT > 200,000)
TSS (mg/L)	168	360	149	129	127.8
TDS (mg/L)	297.2	338.2	95.3	93.4	108.7
Ammonia (mg N/L)	2.3	N/A	0.91	1.2	0.4
Nitrate (mg N/L)	0.6	0.8	1.22	1.13	1.18
Orthophosphate (mg/L	0.1	0.14	0.10	0.11	0.12
TKN (mg/L)	2.0	2.2	1.8	1.99	2.2
TP (mg/L)	0.2	0.8	0.21	0.32	0.34

Looking Down: Comparisons

Bannerman, R.T., D.W. Owens, R.B. Dodds, N.J. Hornewer. (1993). Sources of Pollutants in Wisconsin Stormwater. Water Science and Technology. 28(3-5):241-259.

Contaminant	Feeder Streets	Collector Streets	Arterial Streets	Lawns	Driveways	Roofs	Parking Lots	Outfalls
Residential Source Areas								
TSS (mg/L)	662	326		397	173	27	N/A	262
TP (mg/L)	1.31	1.07		2.67	1.16	0.15	N/A	0.66
DP (mg/L)	0.37	0.31		1.45	0.49	0.06	N/A	0.27
Commercial Source Areas								
TSS (mg/L)			232			15	58	N/A
TP (mg/L)			0.47			0.20	0.19	N/A
DP (mg/L)			0.10			0.08	0.05	N/A
Industrial Source Areas								
TSS (mg/L)		763	690			41	312	146
TP (mg/L)		1.50	0.94			0.11	0.39	0.34
DP (mg/L)		0.51	0.20			0.02	0.05	0.14

Gross Solids Capture in CDS

Rushton, B., and R. James. (2004). Quantifying Pollutant Removal by Swirl Concentrators. 2004 World Environmental and Water Resource Conference Proceedings.

- CDS Unit effective at removing larger particles.
- Gross solids estimated using mass of material captured in CDS unit.
- Captured:
  - 3.96 kg TP
  - 5138.0 kg TS
  - 20.4 kg TKN
  - No removal or releases seen for TN, OP, NH_3, NO_3+NO_2

In sufficiently compacted soil, pervious area runoff is a major factor

Chemical Composition of Municipal Leaf Waste and Hand-Collected Urban Leaf Litter

J. R. Heckman and D. Kluchinski. (1996). *Journal of Environmental Quality*. 25(2):355-362.

Element	Range (g/kg)	Median (g/kg)
Carbon	363 – 516	480
Nitrogen	6.6 – 16.2	9.4
Phosphorus	0.2 – 0.9	1.0

- "…high (>30) C/N ratio (range: 26.8–71.8; median: 48.5) suggests that heavy applications are likely to cause immobilization of available soil N."

Nitrogen EMCs for different urban land covers

Source; CWP, 2003

Urban Land Cover	Total N (mg/L)
Lawns	**9.70**
Highway	2.95
Streets (Variable)	1.40
Parking Lots	1.94
Rooftops	**1.50**

Runoff sampling shows that lawn runoff is very high in nitrogen. Rooftop runoff concentration shows effect of atmospheric deposition and material composition.

Phosphorus EMCs for different urban land covers

Source; CWP, 2003

Urban Land Cover	Total P (mg/l)
Lawns	1.90
Highway	0.60
Streets (Variable)	0.50
Parking Lots	0.16
Rooftops	0.12

The sources of phosphorus are more complex. While lawn runoff is high in phosphorus, atmospheric deposition is less important as a source of TP

Nutrient Runoff Concentrations as a Function of Fertilizer Use

USGS, Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Lakeshore Lawns, Lauderdale Lakes, Wisconsin. USGS Water-Resources Investigation Report 02-4130, July 2002)

	Regular Fertilizer Application	Non-P Fertilizer Application	Unfertilized Lawns	Unfertilized Wooded Sites
Ammonia (mg/L)				
Geometric Mean	1.11	1	0.76	2.95
Median	1.07	0.93	0.63	4.38
Mean	2.18	3.95	1.12	5.33
TKN (mg/L)				
Geometric Mean	5.9	6.5	4.08	12.7
Median	5.9	5.2	5.1	9.8
Mean	8.6	12.2	5.85	29.3
NO_2+NO_3 (mg/L)				
Geometric Mean	0.09	0.14	0.12	0.16
Median	0.12	0.14	0.14	0.24
Mean	0.17	0.57	0.17	0.9

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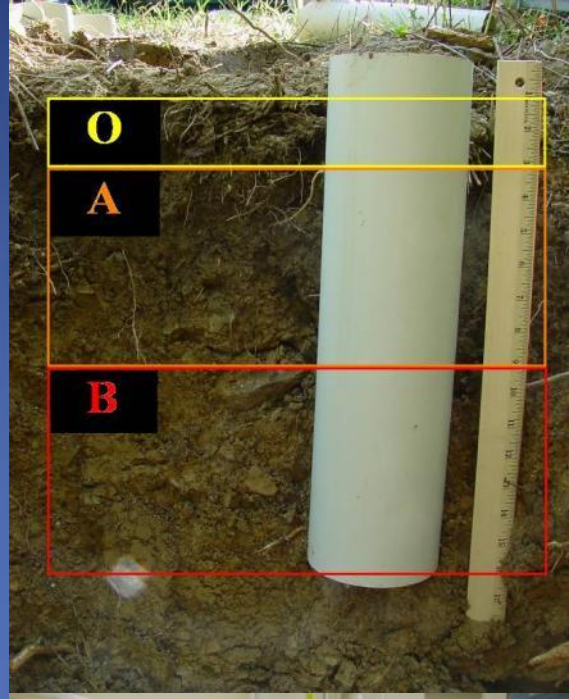
USGS, Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Lakeshore Lawns, Lauderdale Lakes, Wisconsin. USGS Water-Resources Investigation Report 02-4130, July 2002)

	Regular Fertilizer Application	Non-P Fertilizer Application	Unfertilized Lawns	Unfertilized Wooded Sites
TP (mg/L)				
Geometric Mean	2.57	1.89	1.73	3.52
Median	2.85	1.58	1.81	3.98
Mean	4.02	3.3	2.33	6.78
Dissolved P (mg/L)				
Geometric Mean	0.7	0.34	0.4	1.04
Median	0.77	0.33	0.38	1.99
Mean	0.93	0.46	0.43	1.4

Laboratory Investigations of Subsurface Contamination Concerns

Daniel P. Treese,
Graduated Student, M. Eng. ENVE



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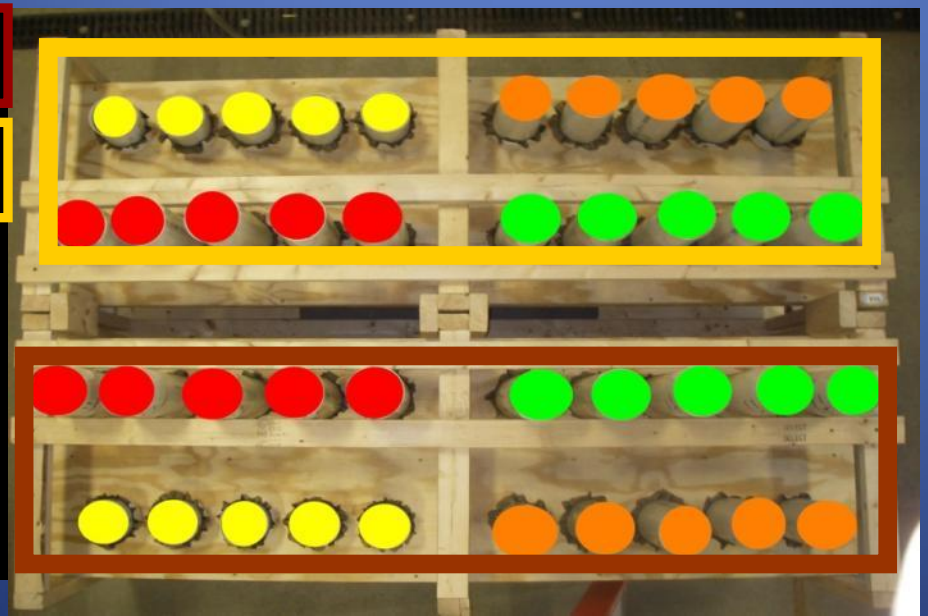
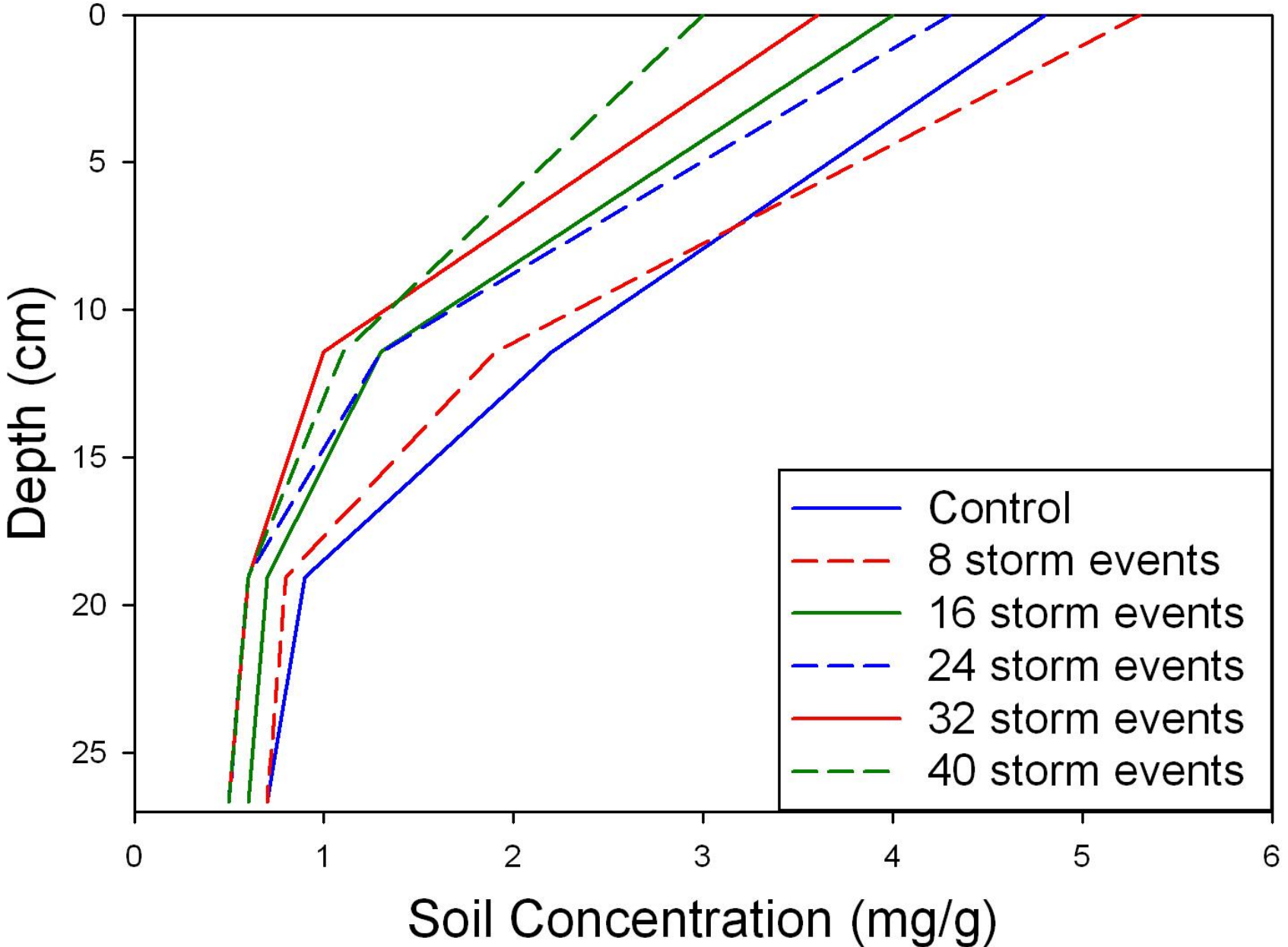
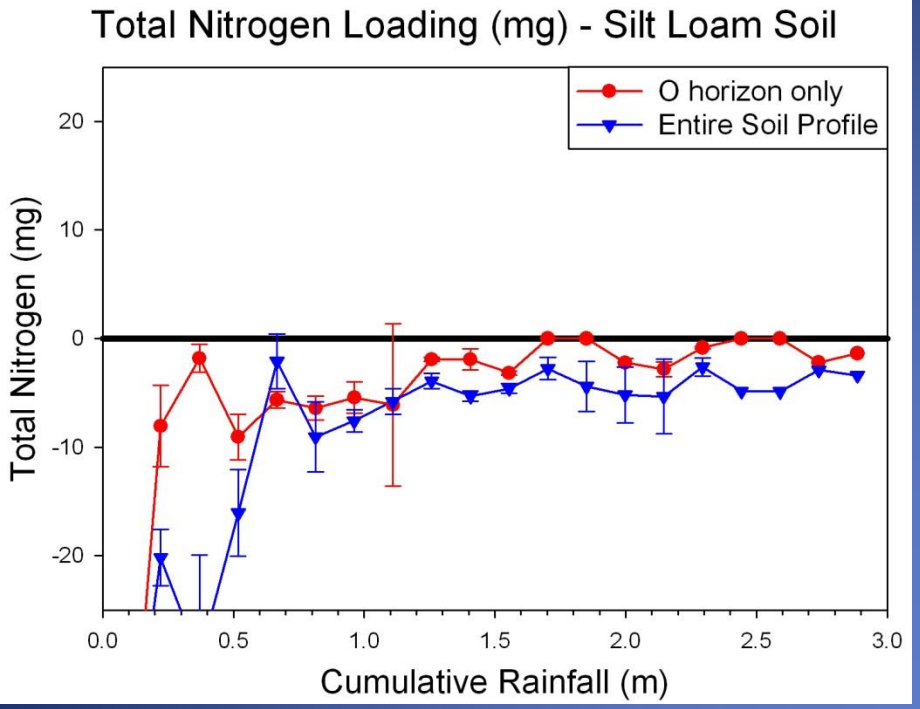
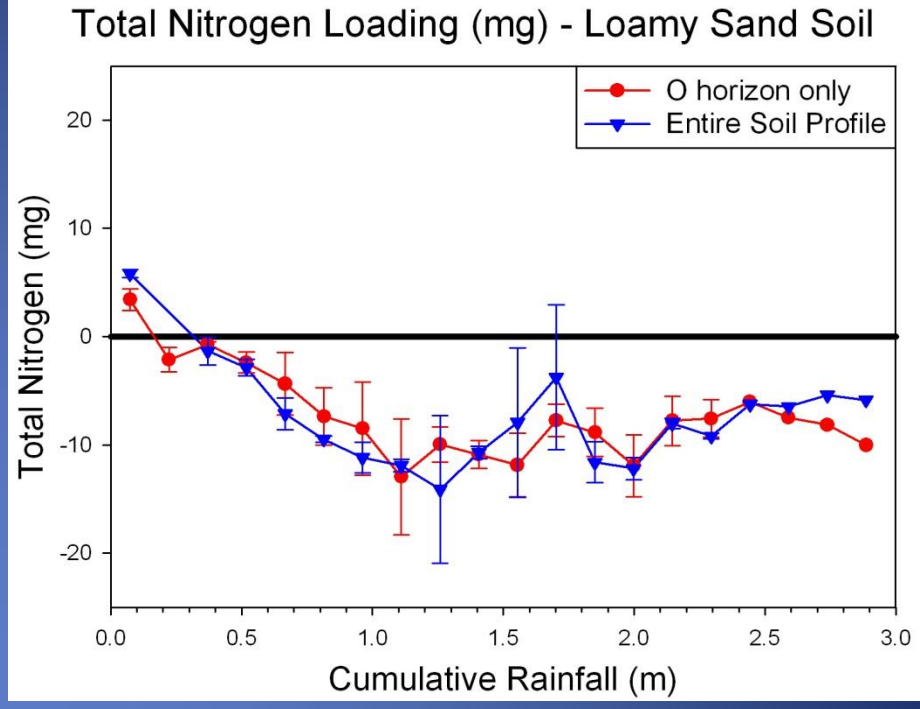
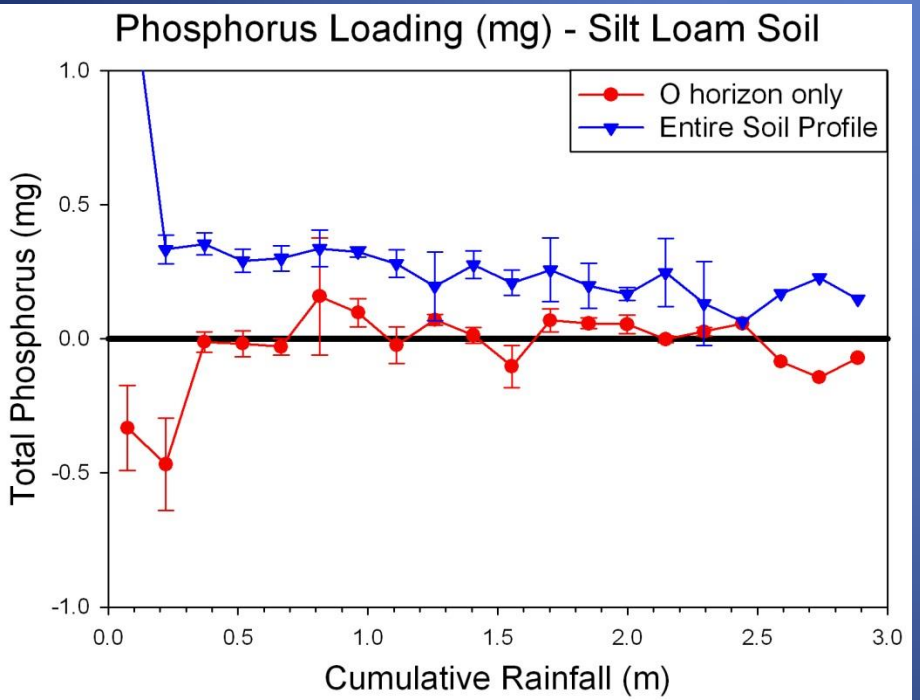


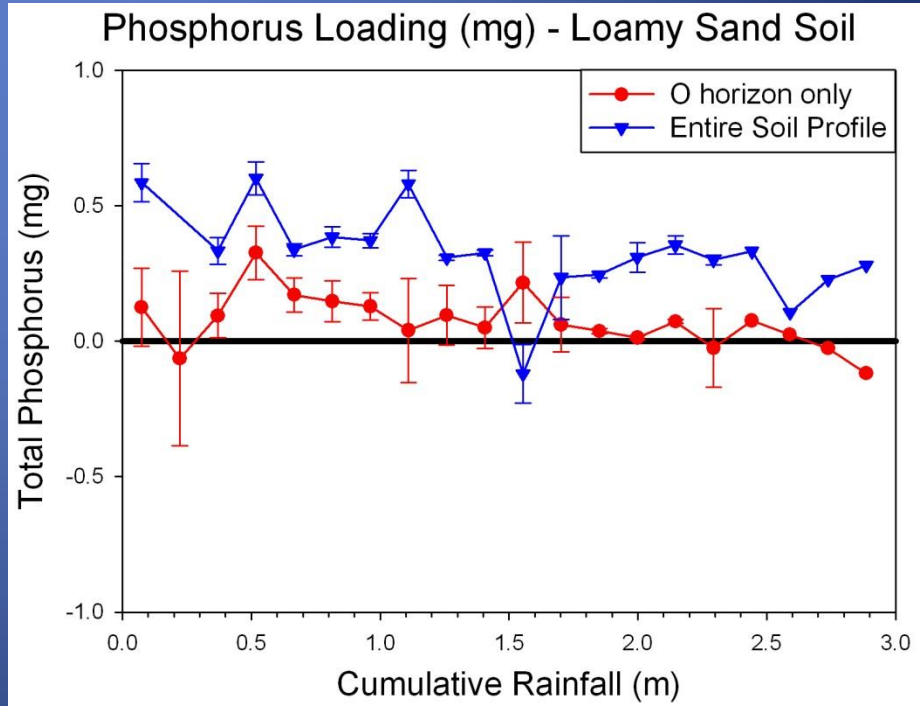
Total Nitrogen Concentration (mg/g): Loamy Sand Soil

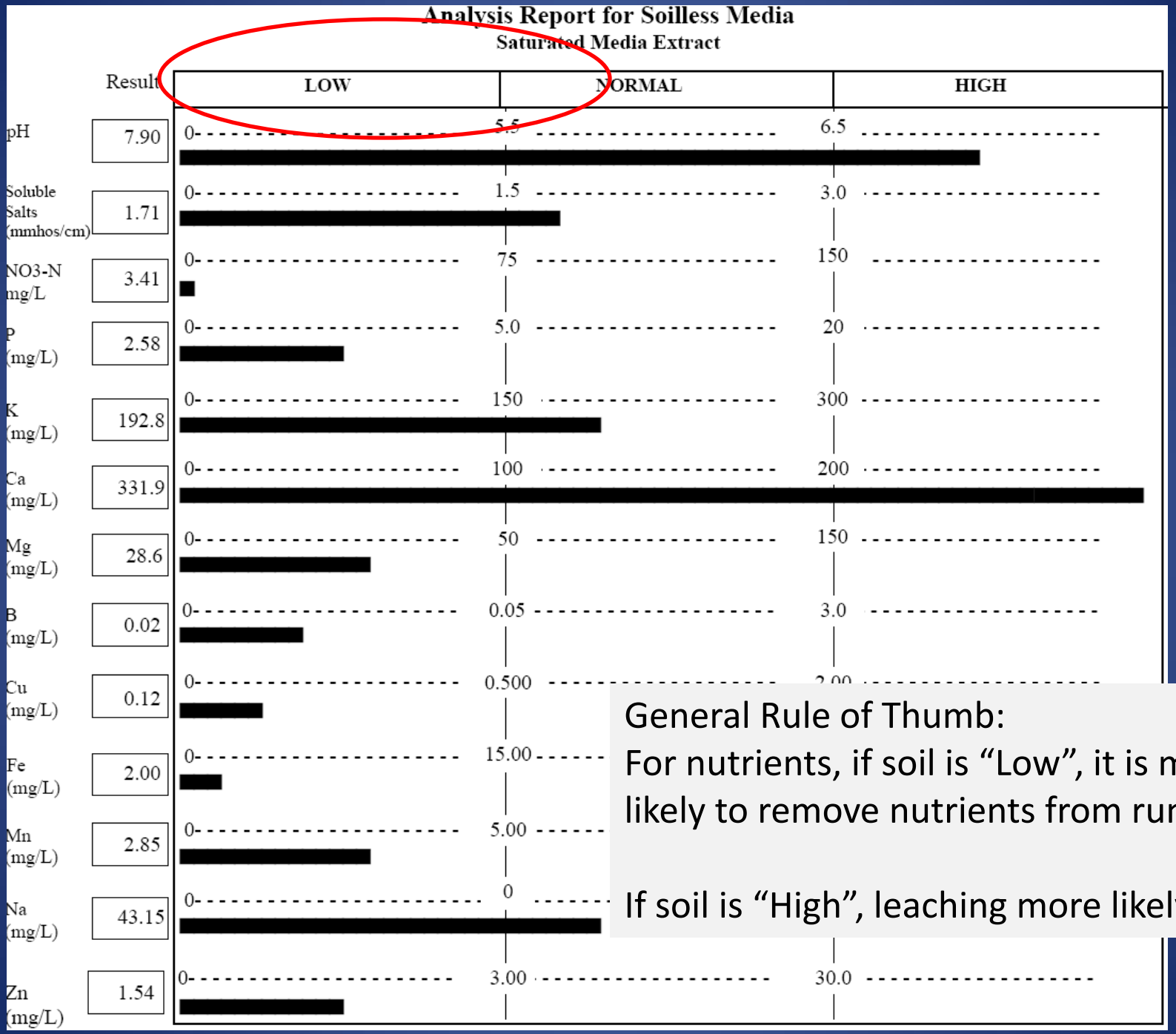



Total Nitrogen Loading (mg) - Silt Loam Soil
O horizon only
Entire Soil Profile
Total Nitrogen (mg)
Cumulative Rainfall (m)


Total Nitrogen Loading (mg) - Loamy Sand Soil
O horizon only
Entire Soil Profile
Total Nitrogen (mg)
Cumulative Rainfall (m)


Phosphorus Loading (mg) - Silt Loam Soil
O horizon only
Entire Soil Profile
Total Phosphorus (mg)
Cumulative Rainfall (m)


Phosphorus Loading (mg) - Loamy Sand Soil
O horizon only
Entire Soil Profile
Total Phosphorus (mg)
Cumulative Rainfall (m)

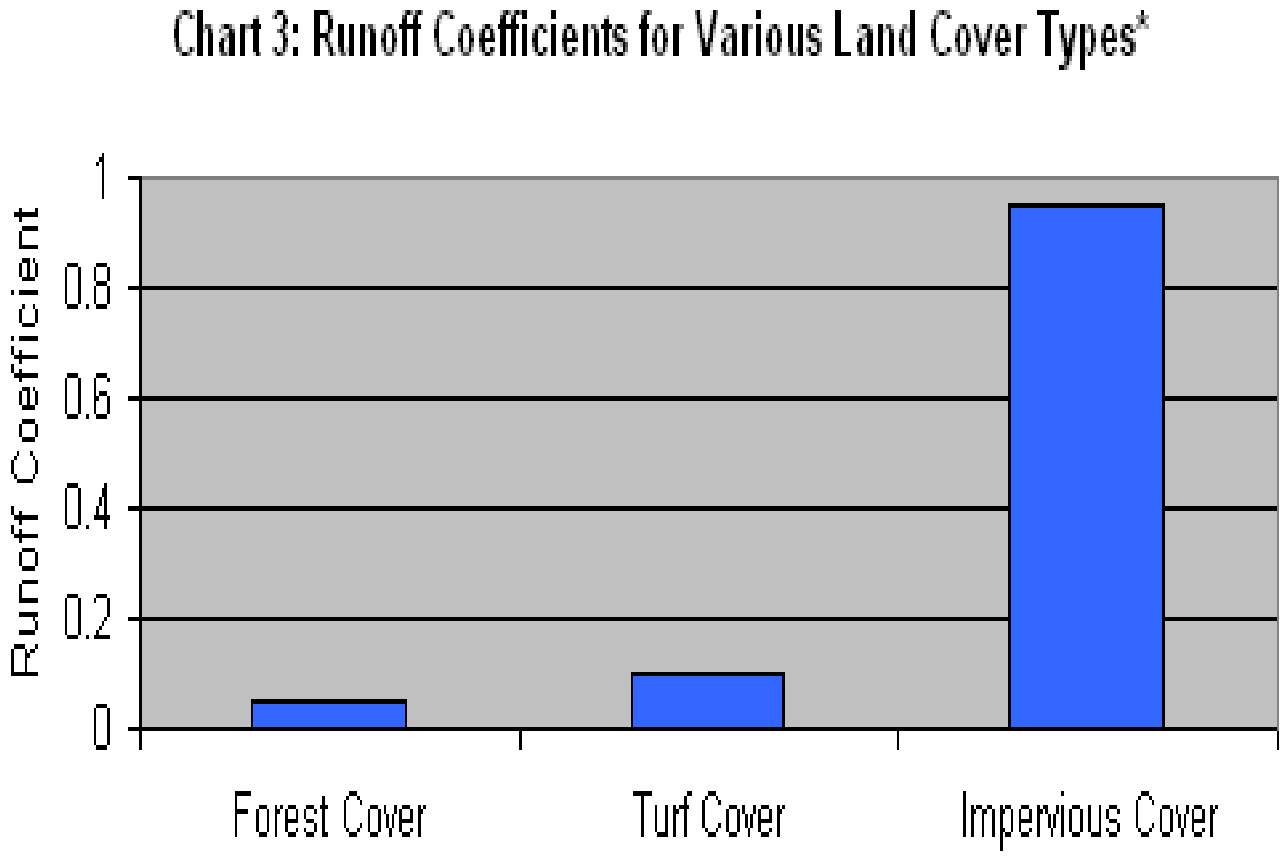


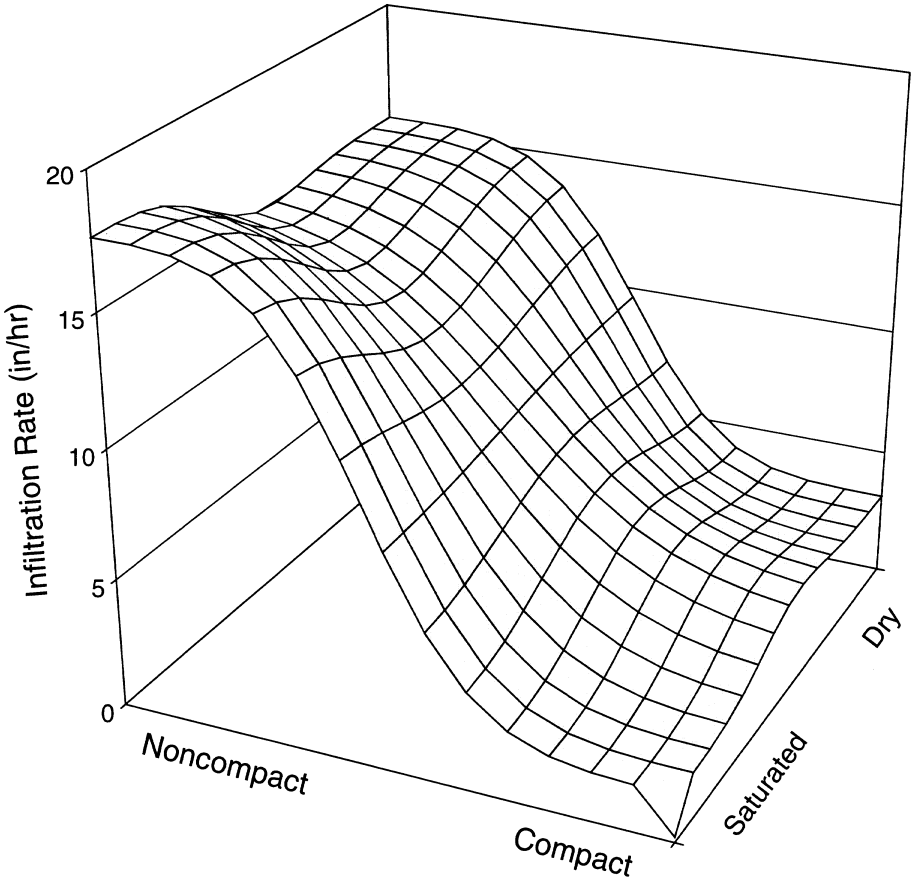
General Rule of Thumb:
For nutrients, if soil is “Low”, it is more likely to remove nutrients from runoff.

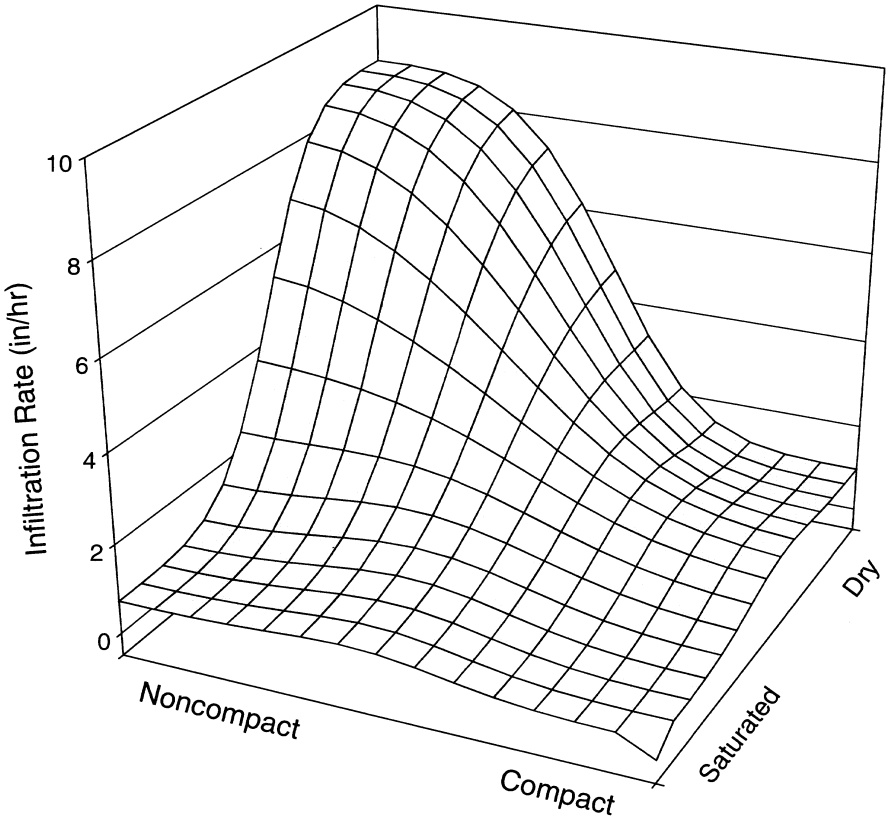
If soil is “High”, leaching more likely.

Urban Nutrient Loads

Higher Runoff Coefficient for Turf…





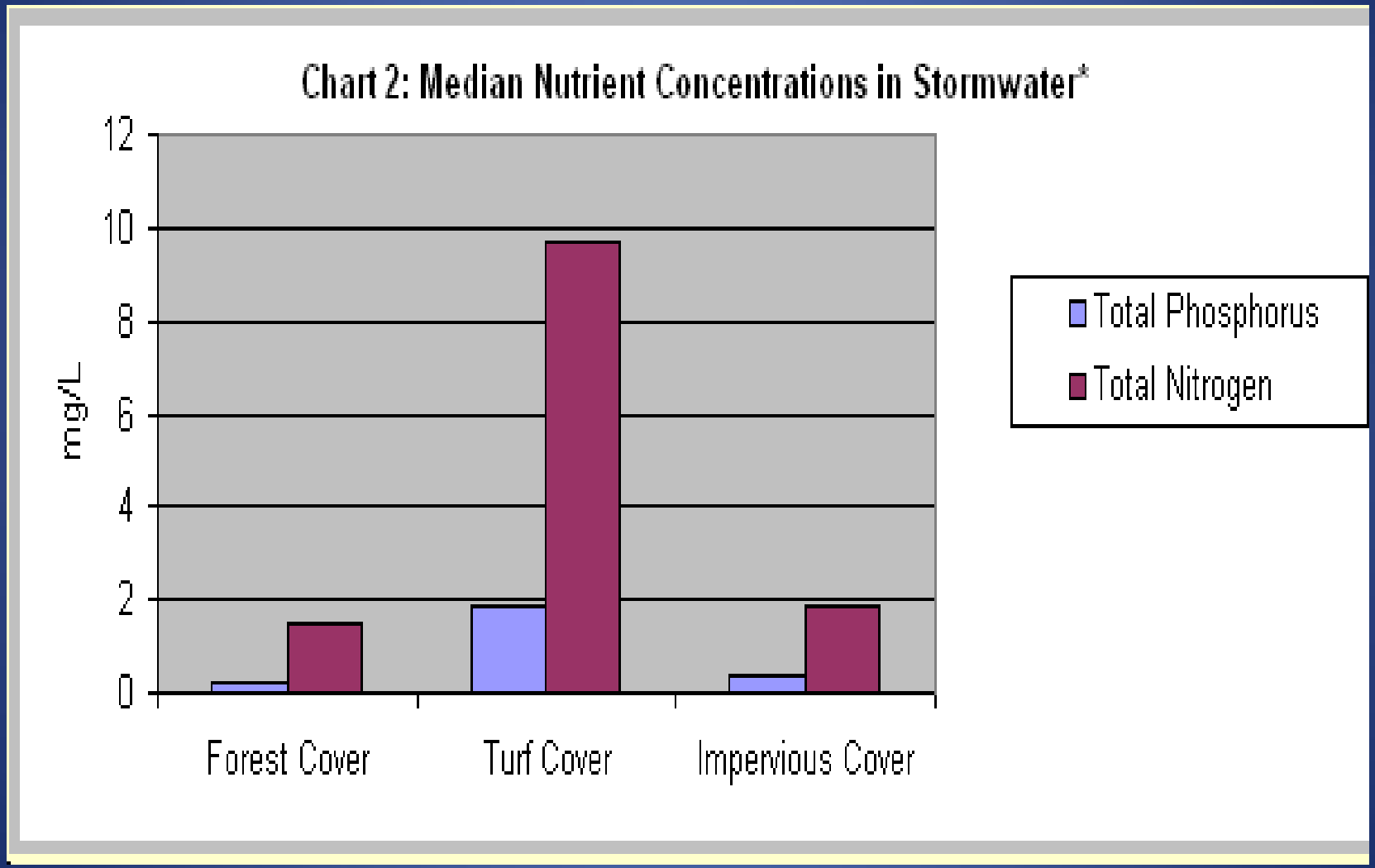


Sandy Soils

Clayey Soils

Three dimensional plot of infiltration rates.

Combined with its Higher Nutrient Concentration…



Leads to…

- Many opportunities for source control
  - Fertilizer education
    - Soil testing prior to application
  - Improvements in air quality equipment and fuels for mobile sources
  - Improvements in building materials
  - Reduction in litter generation/Improvement in trash capture