

# Urban Stormwater Runoff as Pathway of Extensive Mixed Contaminants to Surface and Groundwaters in the United States



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## Acknowledgements

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- The views expressed are those of the author[s] and do not necessarily represent the views or policies of the U.S. Geological Survey or U.S. Environmental Protection Agency.



# Presentation Overview:

- Importance of understanding the urban stormwater contaminant profile and potential impacts to receiving water bodies (SW and GW) and exposure to aquatic organisms.
- Project and research design.
- Compositions and concentrations of organic and inorganic chemicals measured in urban stormwater.
- Implications of organic and inorganic chemical mixtures in urban stormwater runoff.



# Why Study Urban Stormwater Runoff?

- SCM and GI used to reduce stormwater volumes, minimize contaminants to waterbodies, and increase GW recharge.
- Little research on CECs and some inorganics in urban stormwater (i.e. exposure and effects).
- In water-limited regions stormwater is considered untapped urban water resource.
- To provide an enhanced understanding of the contaminant profile for better management of urban stormwater.



# Broad Suite of Organic (438) and Inorganic (64) Chemicals Targeted

- PAHs (20): chrysene
- Prescription pharms (88): metformin
- Nonprescription pharms (19): acetaminophen
- Household chemicals (21): galaxolide
- Industrial chemicals (58): triphenyl phosphate
- Pesticides (183): imidacloprid
- Hormones (21): estrone
- PCBs (28): polychlorinated biphenyl 180
- Inorganics (64) and methyl mercury

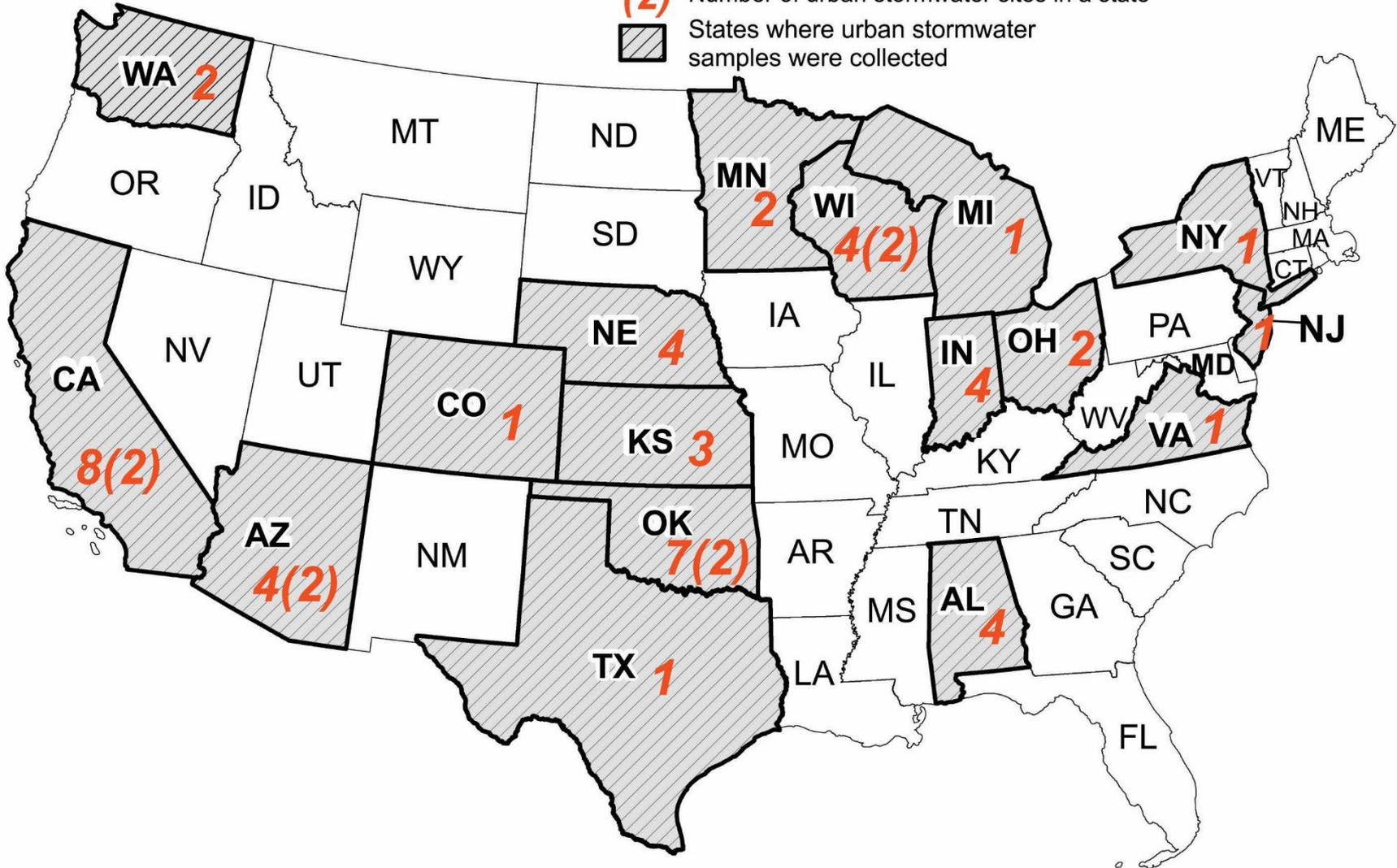


# Phase I- Sampling Network -57 samples, 21 field sites in 17 states

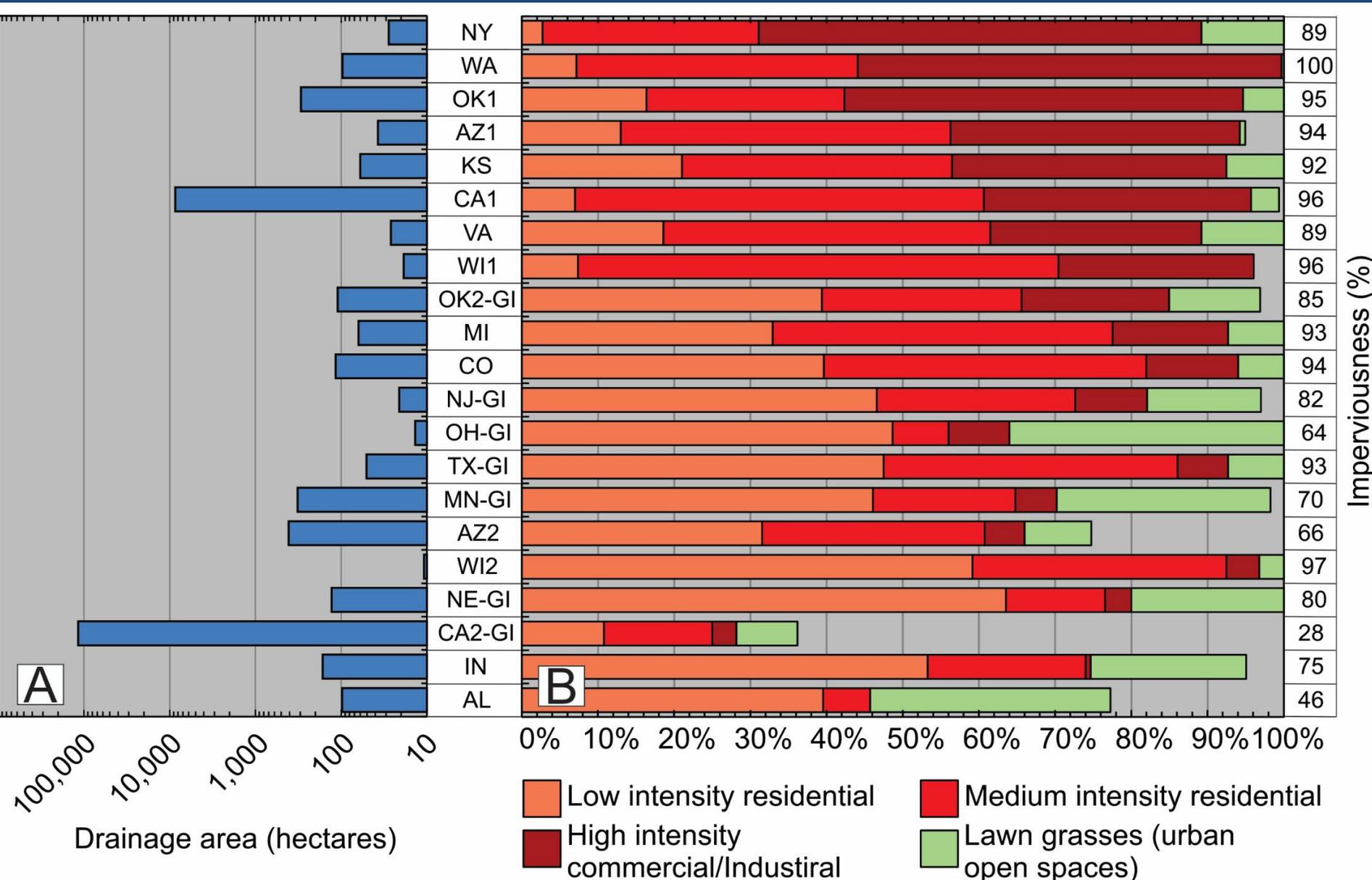
## Urban stormwater samples collected in the United States, 2016 - 2017

### Explanation

- 4** Number of urban stormwater samples collected at individual field site
- (2)** Number of urban stormwater sites in a state
-  States where urban stormwater samples were collected



# Watershed Area and NLCD 2011 LULC

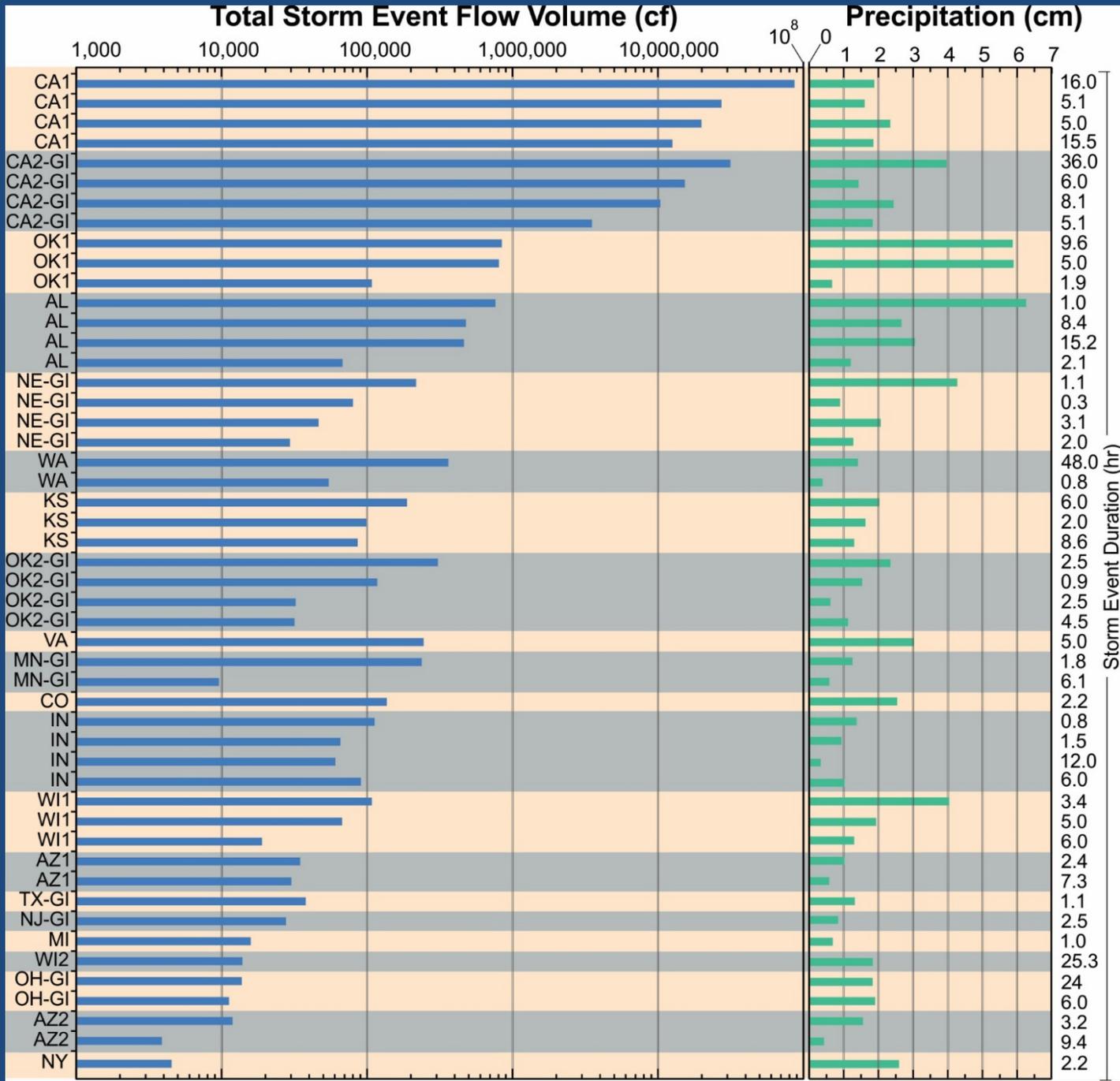


# Network and Sampling Details

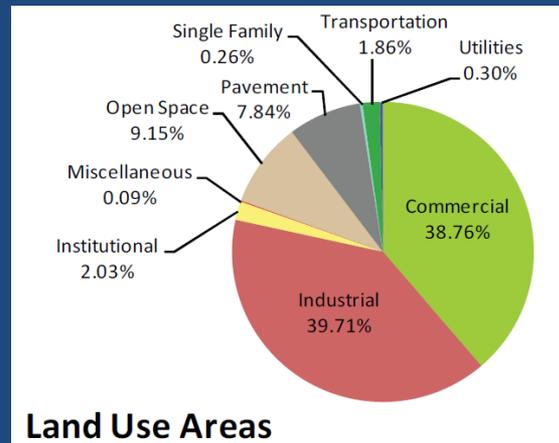
- Goal was to sample urban stormwater runoff, no combined sewage/storm infrastructure.
- 40% of sites infiltrated urban stormwater to GW via GI.
- Auto sampler used for flow-weighted composite samples.
- 3 sites used DH-81 sampler for time-weighted isokinetic samples.



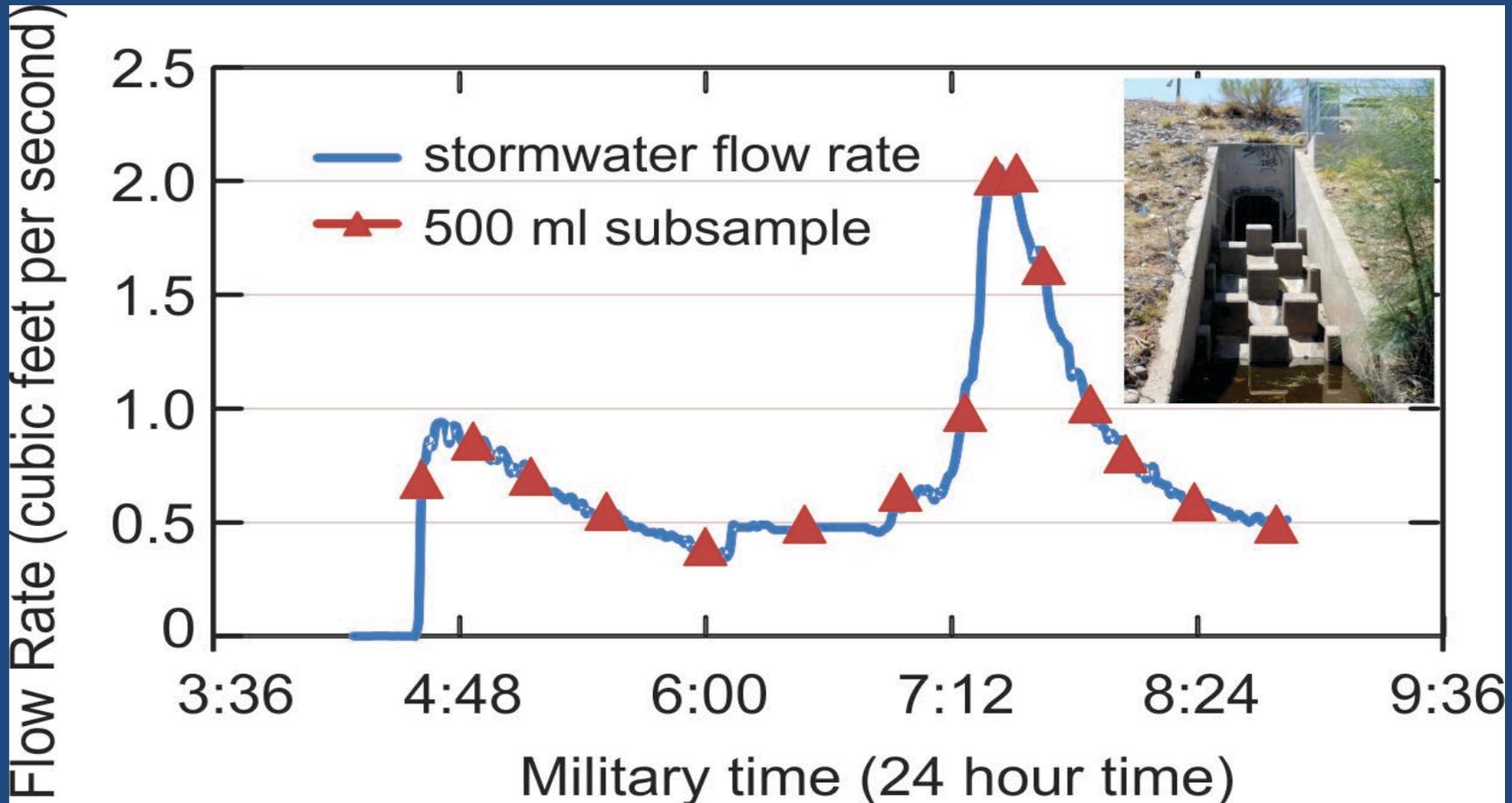
# Storm Event Hydrology



# Arizona Site, 2-18-2017



**Drainage Area = 356 hectares**



# Organic Chemical Results

438 organics analyzed, 215 detected

Household  
chemicals

- DEET (98%, max concentration of 109,000 ng/L)
- Bisphenol A (90%, 2,770 ng/L)

PAHs

- Fluoranthene (90%, 36,700 ng/L)
- Pyrene (90%, 29,100 ng/L)\*
- Caffeine (96%, 32,300 ng/L)

NP-pharms

- Nicotine (98%, 18,300 ng/L)
- Cotinine (92%, 550 ng/L)

Pesticides

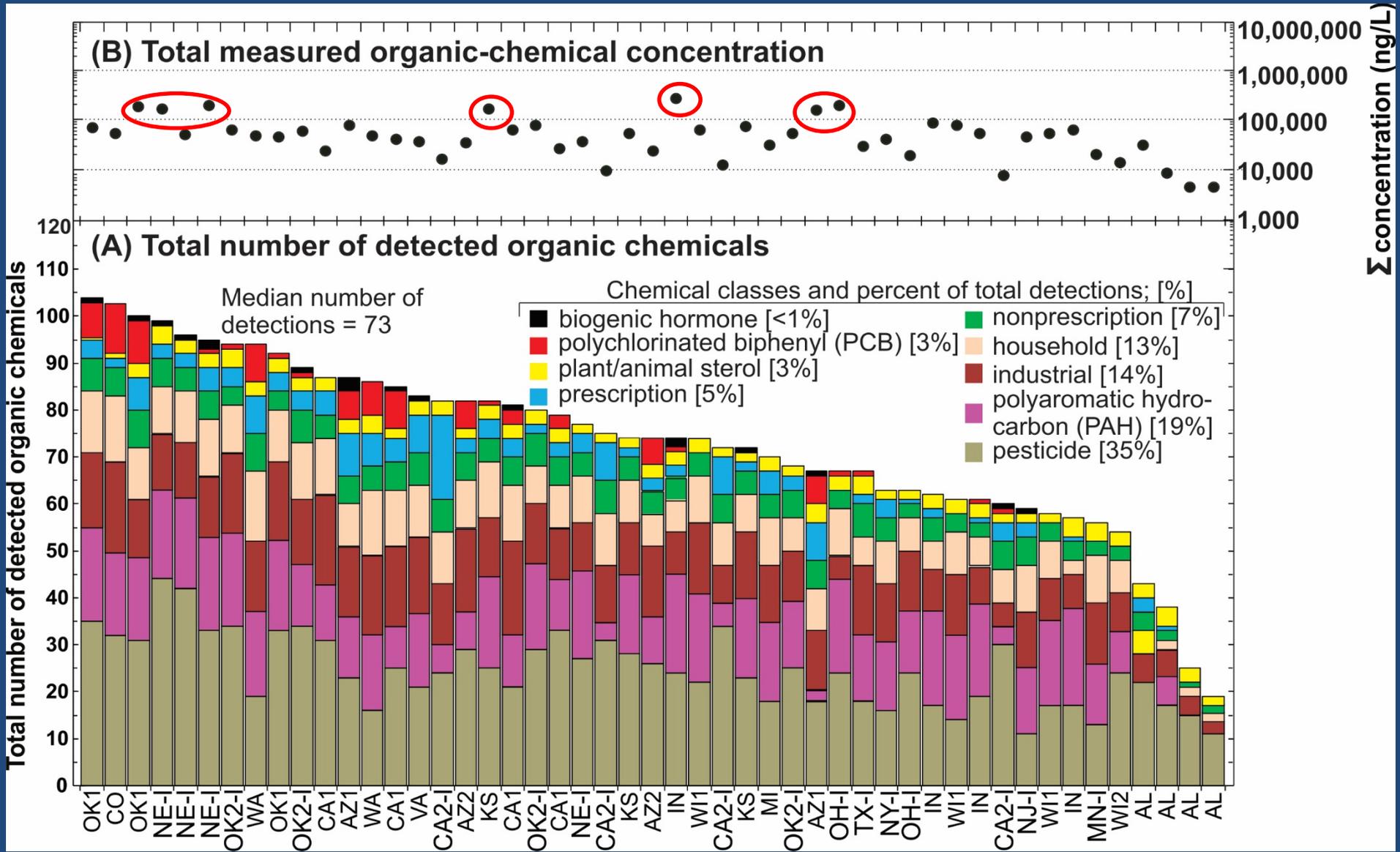
- Carbendazim (94%, 9,580 ng/L)\*
- Desulfinylfipronil (90%, 20 ng/L)

Industrial  
chemicals

- Methyl-1H-benzotriazole (92%, 6,790 ng/L)
- P-cresol (92%, 1,310 ng/L)

# Number of Detected Organics by Chemical Class

- Detected in every sample (18 to 103)
- Median CECs detected = 73

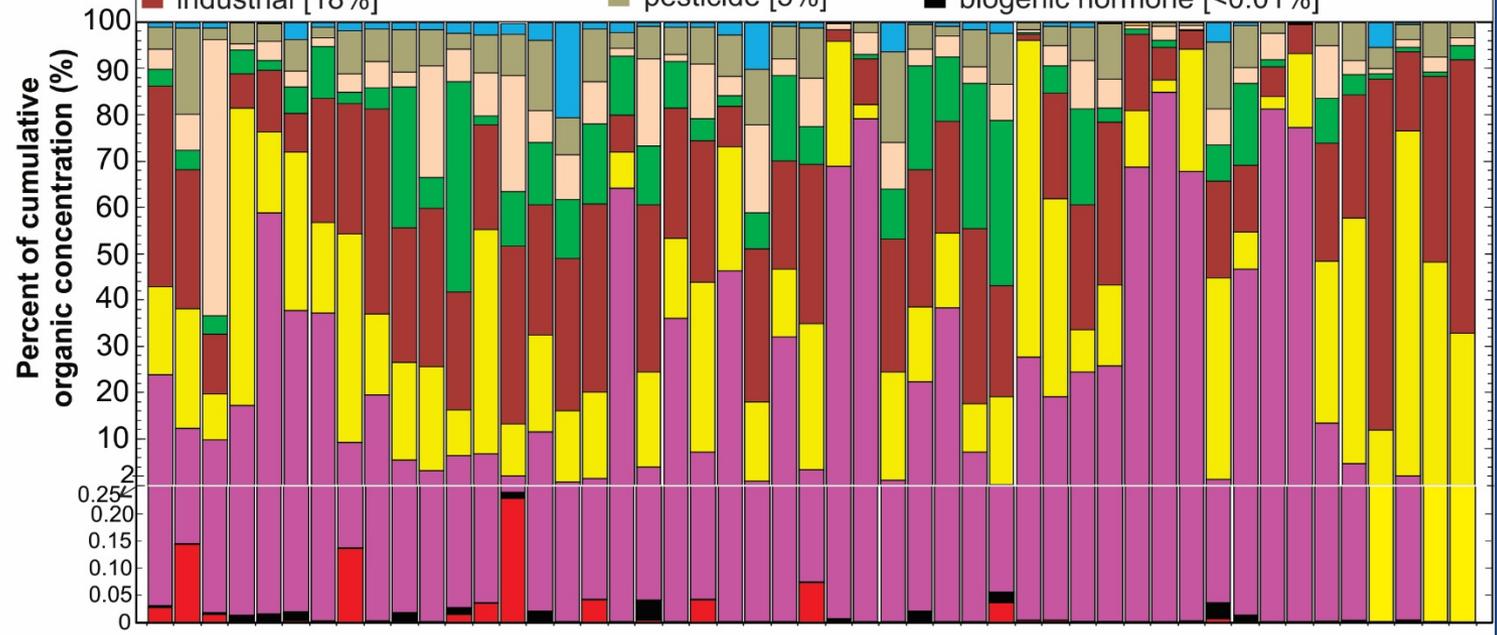


# Organic Concentrations by Site

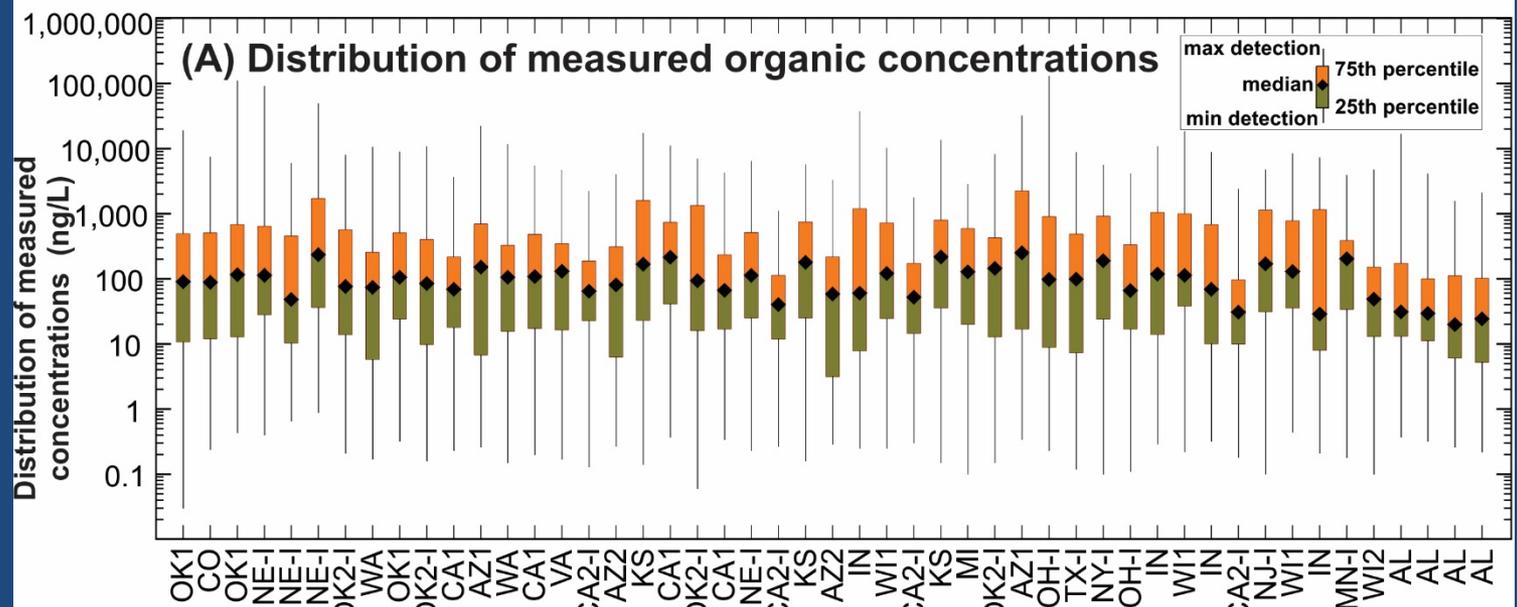
## (B) Chemical classes and percent of cumulative concentration by site

[%], percent of total measured organic chemicals concentration

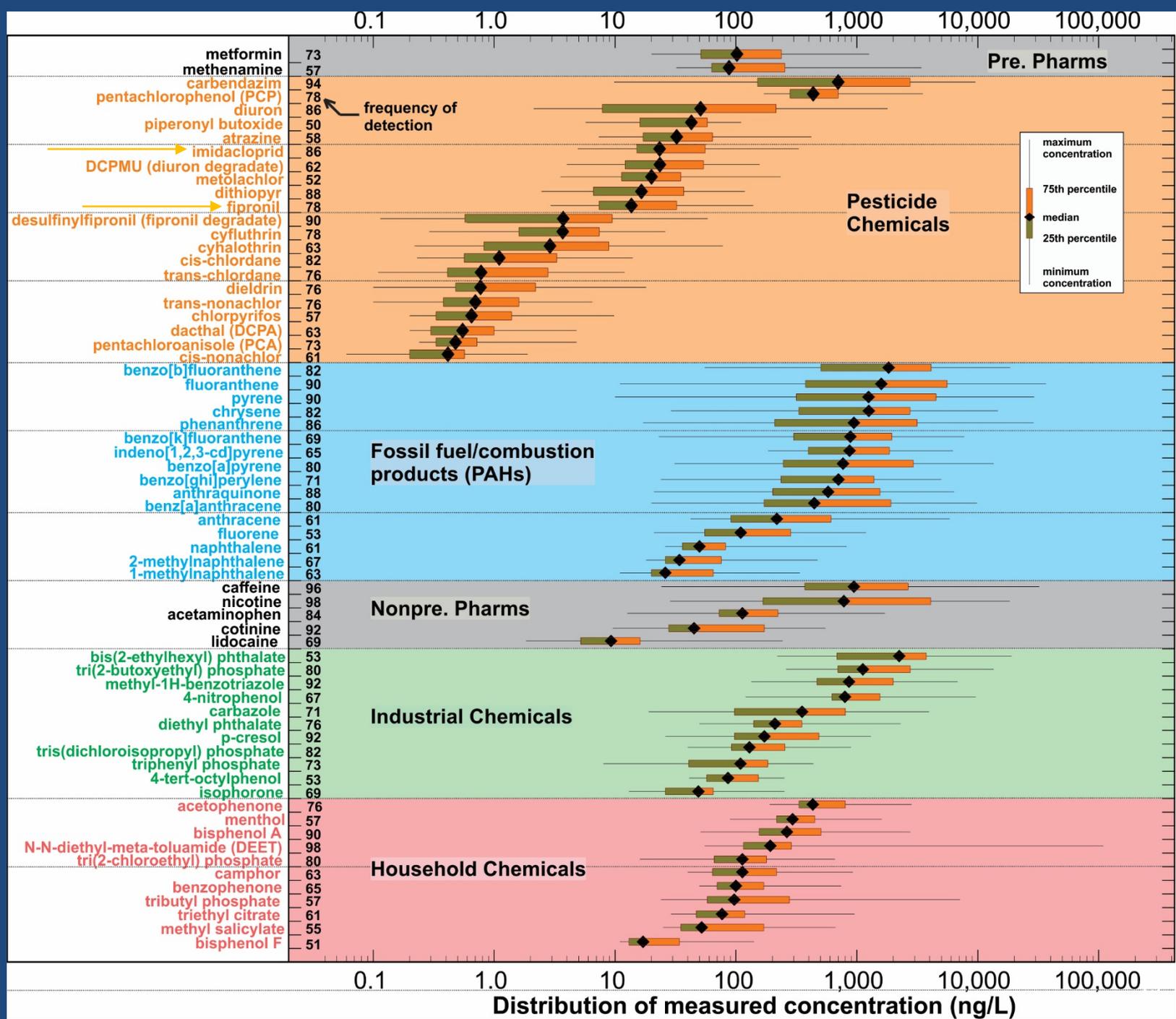
- polyaromatic hydrocarbon (PAH) [33%]
- nonprescription [9%]
- prescription [1%]
- plant/animal sterols [25%]
- household [8%]
- polychlorinated biphenyl (PCB) [<0.01%]
- industrial [18%]
- pesticide [5%]
- biogenic hormone [<0.01%]



## (A) Distribution of measured organic concentrations



# 66 Organics Detected in >50% of Samples

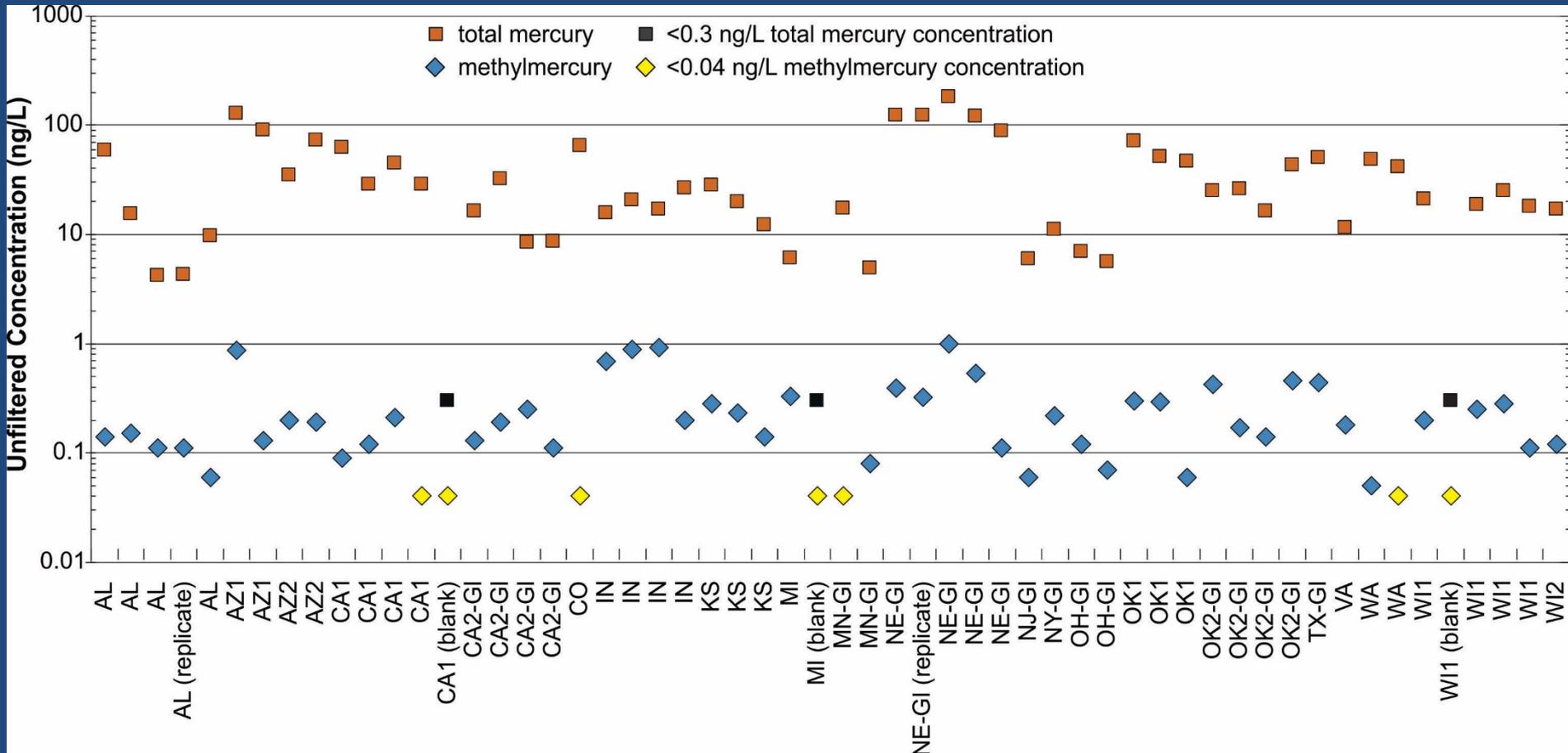


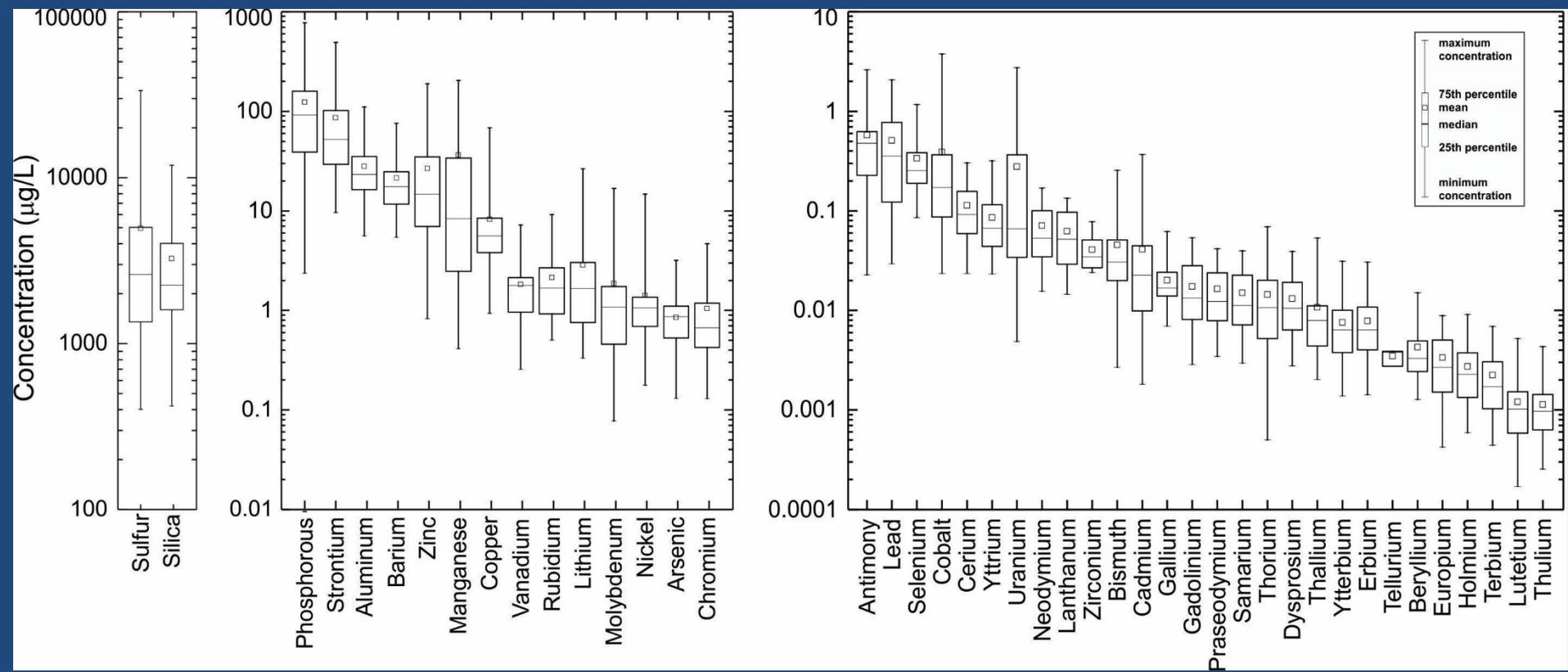
# Inorganic Hg

# Organic MeHg

- Stormwater is substantial source.
- 4.2--180 ng/L, med. = 25.6 ng/L.
- Concentrations > than reported in USA streams.

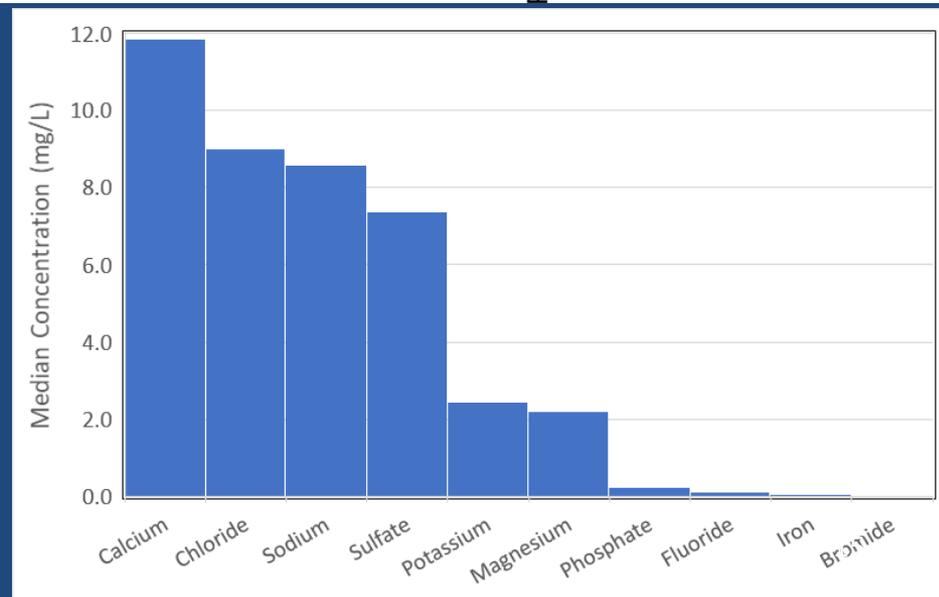
- MeHg in 90% of samples.
- 0.05--1.0 ng/L, med. = 0.19 ng/L.
- Concentrations similar to USA streams.



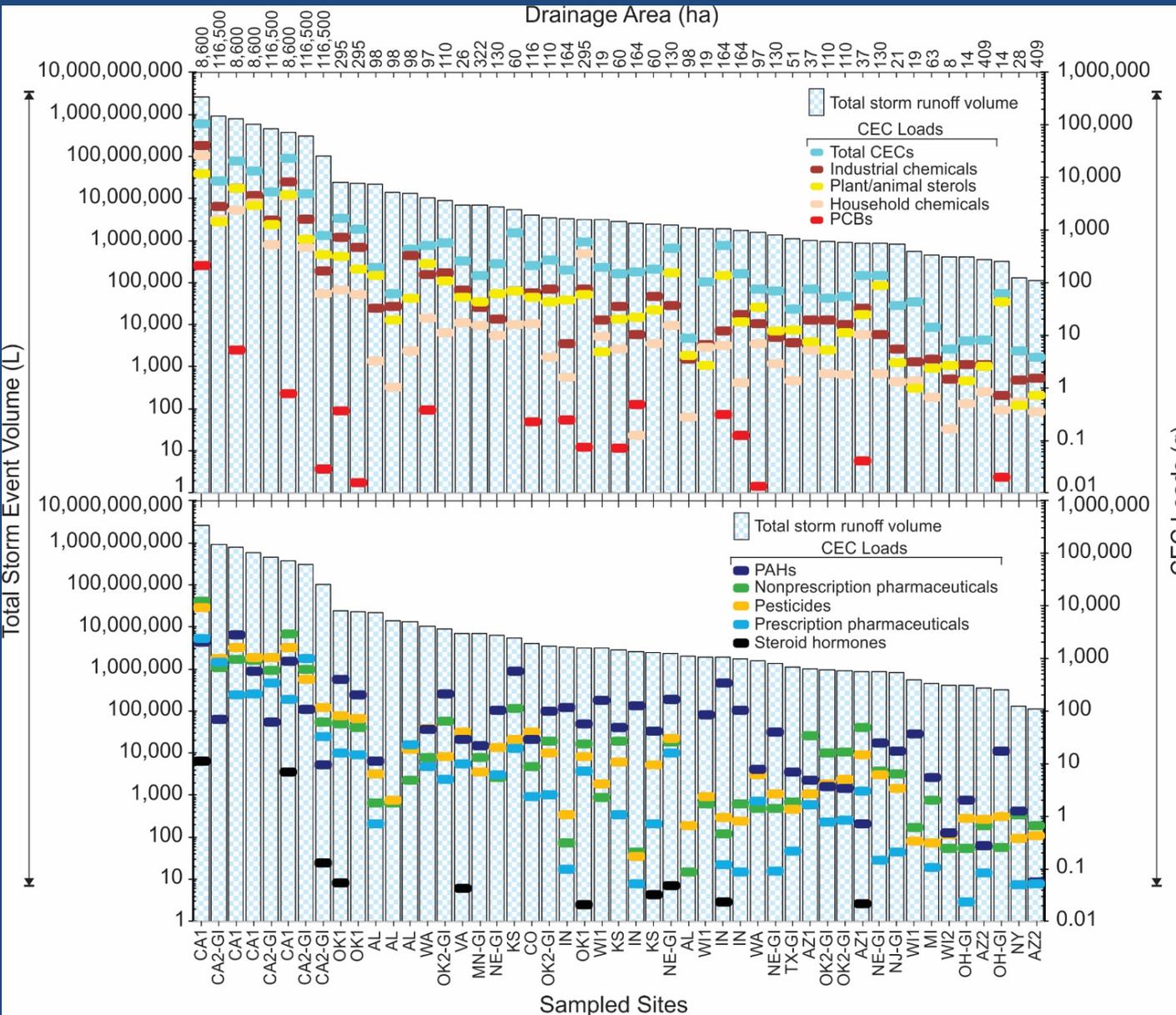


# Inorganic Chemicals

- Stormwater fairly dilute for most inorganics as indicated by SC values, med= 164 uS/cm, 38–1,074 uS/cm.
- 73% of samples for dissolved P were above 37 ug/L total P criterion set for OK scenic rivers.
- $\text{Cl}^-$  and  $\text{HCO}_3^-$  (m60 mg/L) most abundant anions.
- $\text{Na}^+$  and  $\text{Ca}^{2+}$  most abundant cations.
- No inorganic concentrations exceeded any aquatic life BMs for freshwater species.



# Single Event Total CEC Loads: 4 to 104,000 g (104 kg)



## Median CEC Load

- 176 g = all CECs
- 43 g = sterols
- 41 g = PAHs
- 32 g = industrial chems
- 9 g = nonpres. pharms
- 6 g = pesticides
- 6 g = house chems
- 1 g = presc pharms
- <0.1 g = PCBs, hormones

# Quantitative Comparison of Organic Loads in Untreated Stormwater and Treated Wastewaters

- 28 single-event storms (5 hours) with runoff volumes (1 - 25 M L/event), comparable to daily treatment capacity of small WWTP (30 M L/d).
- 8 single-event storms (12 hours) with runoff volumes (0.1 – 2.5 B L/event), comparable to daily treatment capacity of medium to large WWTP (870 M L/d).
- Organic loads from single-event (med duration = 7 hours) stormwater runoff volumes compared to daily WWTPs volumes indicate that episodic stormwater runoff events can potentially contribute:
  - substantially larger loads of PAHs and pesticides;
  - similar loads of household chemicals, industrial chemicals, and nonprescription pharmaceuticals;
  - substantially smaller loads of prescription pharmaceuticals, biogenic hormones, and plant animal sterols.

# Implications for Stormwater Management

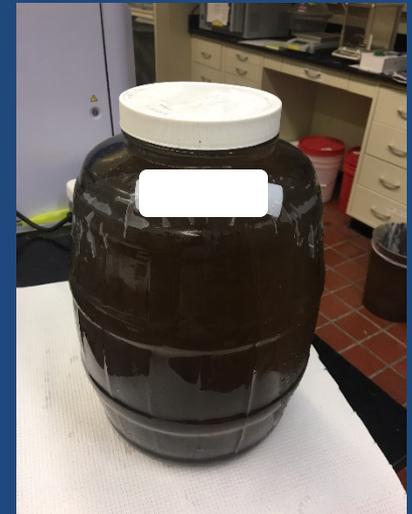
- Stormwater is transporting a extensive mixture of organic chemicals.
  - Detections: pesticides > PAHs > industrial chems > household chems > nonpres pharms > pres pharms > sterols > PCBs > biogenic hormones.
  - Numerous detections per site (median of 73 compounds).
  - Many known or suspected carcinogens, endocrine disrupting, and bioactive.
- Organic chemicals are present in stormwater at widely variable individual-component and cumulative-mixture concentrations.
  - Concentrations: PAHs > sterols > industrial chems > nonpres pharms > household chems > pres pharms > pesticides > PCBs ~ biogenic hormones.
  - Concentrations spanned 6 orders of magnitude < 1 to 100,000 ng/L.
  - Little is known about mixture-effects from exposure of low ng/L concentrations.
  - Some PAHs and pesticides exceeded aquatic BM levels.
  - 7 samples had cumulative-mixture concentrations >100,000 ng/L.
- Organic concentrations and single storm-event loads were comparable to and often exceeded those of daily WWTP discharges.

# Implications--continued..

- Largest organic-contaminant sources originate from impervious surfaces and developed medium-intensity and high-intensity urban centers.
- Evidence from anthropogenic/background gadolinium ratios coupled with frequent detections of metformin, lidocaine, and acetaminophen in urban stormwater, indicates a human sewage source.
- Stormwater is a consistent source of inorganic Hg and could pose negative implications for some SCM and GI projects (wetlands/bioretention ponds) that may provide conditions for methylation to MeHg.
- MeHg concentrations in urban stormwater indicate that stormwater infrastructure provides favorable conditions for conversion of inorganic Hg to highly toxic organic form (MeHg).



**Thank you!, Questions?  
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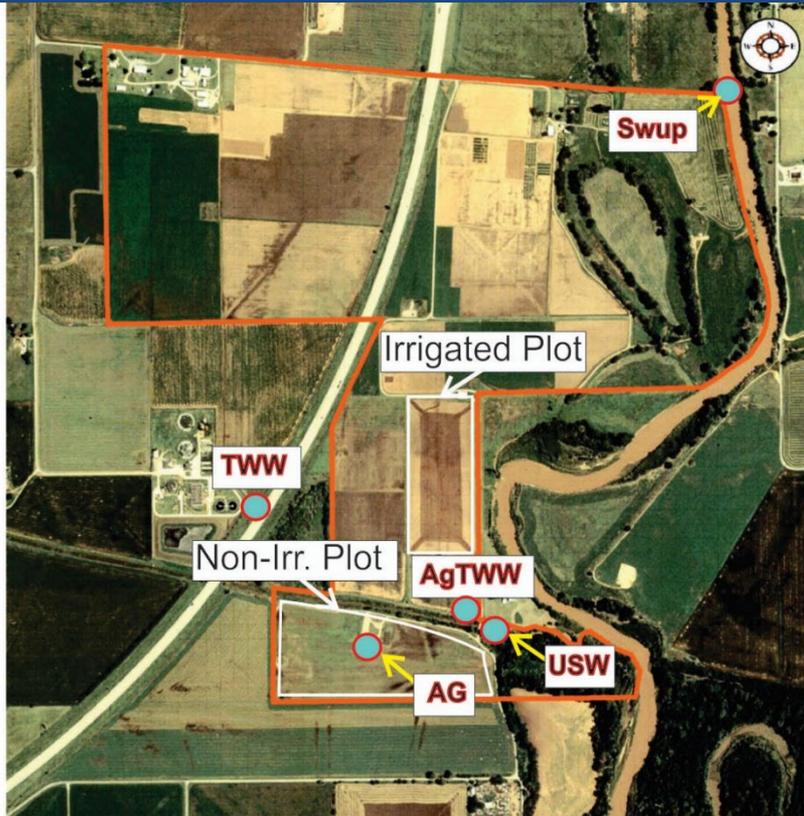
# Wastewater Recycling to Irrigated Crops



## Oklahoma South Central Research Station, OSU-Chickasha

## Sampling Details

- Auto samplers used to collect stormwater runoff flow-weighted composite samples from:
  - treated WW irrigated Ag field
  - non-irrigated Ag field
  - urban stormwater (50% DA of City of Chickasha)
- Source water (WWTP effluent)
- Upstream surface water (Washita River) not affected from WWTP effluent and stormwater discharges
- Samples analyzed for broad suite of organic and inorganic chemicals (~500 parameters), microbial



**TWW** = Treated wastewater site (irrigation source water).  
**AgTWW** = Ag storm water runoff site from **treated WW irrigated** Ag plot.  
**AG** = Ag storm water runoff site from **non-irrigated** Ag plot.  
**Swup** = **Surface-water** site upstream of field activities.  
**USW** = Urban stormwater runoff (2/3 of the entire City of Chickasha runoff).



# Science Hypotheses:

- No statistical difference in contaminant signature in runoff between dryland farming and irrigation with WWTP effluent
- Contaminants in urban stormwater runoff are more frequent and in larger concentrations compared to both runoff from dryland farming and irrigation farming
- Contaminants/effects in ag runoff from fields irrigated with treated wastewater do not pose negative affects to surface water or aquatic organisms.

