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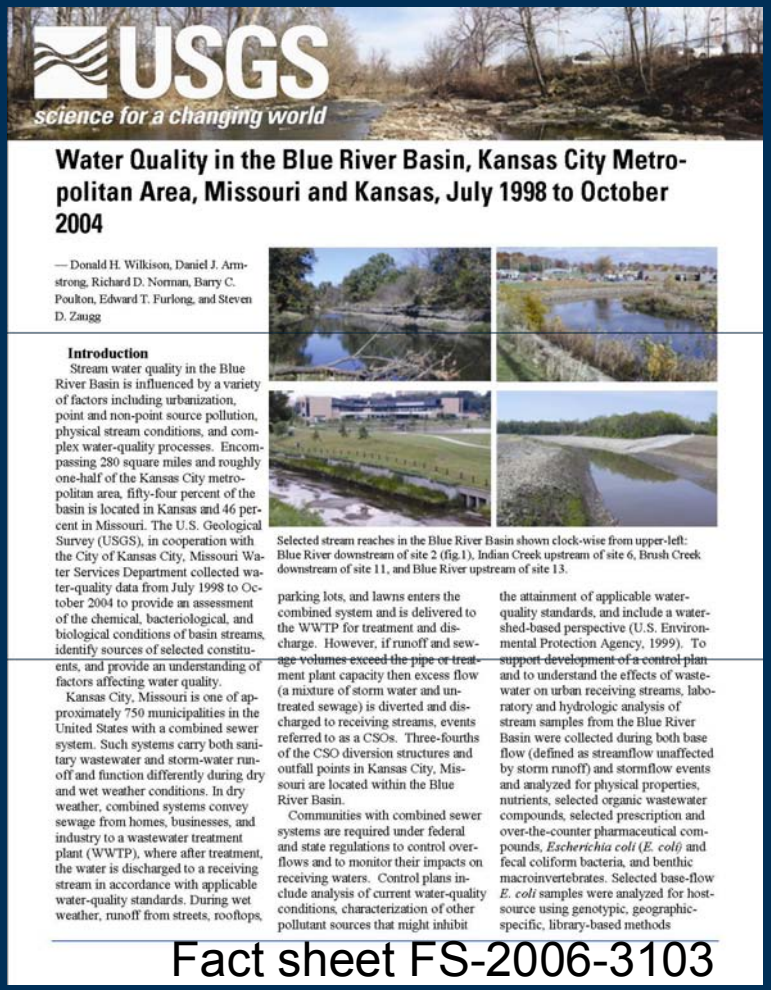
Water Quality in the Blue River Basin, Kansas City Metropolitan Area, Missouri and Kansas, July 1998 to October 2004

Don Wilkison, Hydrologist
USGS KC Water Science Center
wilkison@usgs.gov

U.S. Department of the Interior
U.S. Geological Survey



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— Donald H. Wilkison, Daniel J. Armstrong, Richard D. Norman, Barry C. Poulton, Edward T. Furlong, and Steven D. Zaugg

Selected stream reaches in the Blue River Basin shown clock-wise from upper-left: Blue River downstream of site 2 (fig.1), Indian Creek upstream of site 6, Brush Creek downstream of site 11, and Blue River upstream of site 13.

Introduction

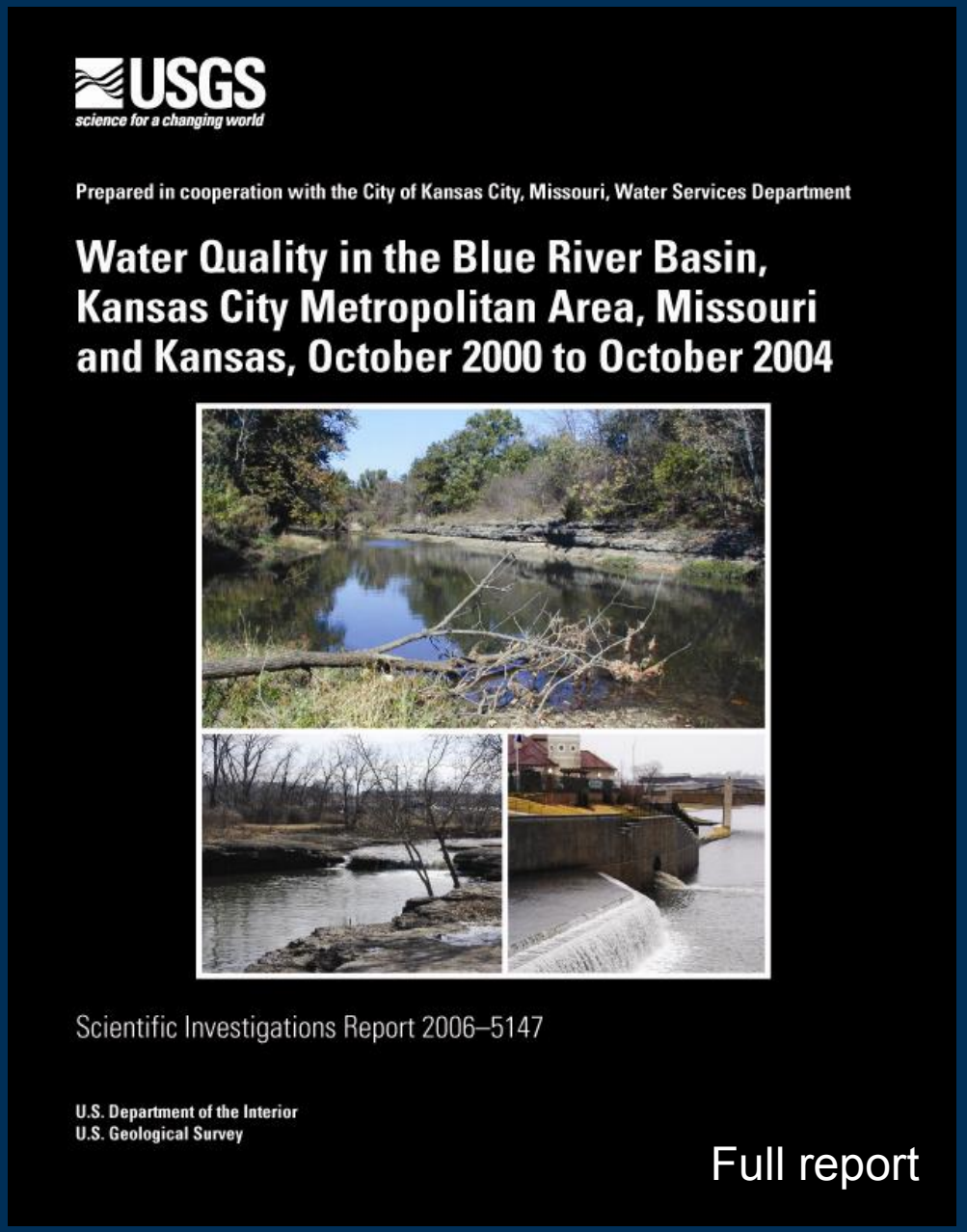
Stream water quality in the Blue River Basin is influenced by a variety of factors including urbanization, point and non-point source pollution, physical stream conditions, and complex water-quality processes. Encompassing 280 square miles and roughly one-half of the Kansas City metropolitan area, fifty-four percent of the basin is located in Kansas and 46 percent in Missouri. The U.S. Geological Survey (USGS), in cooperation with the City of Kansas City, Missouri Water Services Department collected water-quality data from July 1998 to October 2004 to provide an assessment of the chemical, bacteriological, and biological conditions of basin streams, identify sources of selected constituents, and provide an understanding of factors affecting water quality.

Kansas City, Missouri is one of approximately 750 municipalities in the United States with a combined sewer system. Such systems carry both sanitary wastewater and storm-water runoff and function differently during dry and wet weather conditions. In dry weather, combined systems convey sewage from homes, businesses, and industry to a wastewater treatment plant (WWTP), where after treatment, the water is discharged to a receiving stream in accordance with applicable water-quality standards. During wet weather, runoff from streets, rooftops, parking lots, and lawns enters the combined system and is delivered to the WWTP for treatment and discharge. However, if runoff and sewage volumes exceed the pipe or treatment plant capacity then excess flow (a mixture of storm water and untreated sewage) is diverted and discharged to receiving streams, events referred to as a CSOs. Three-fourths of the CSO diversion structures and outfall points in Kansas City, Missouri are located within the Blue River Basin.

Communities with combined sewer systems are required under federal and state regulations to control overflows and to monitor their impacts on receiving waters. Control plans include analysis of current water-quality conditions, characterization of other pollutant sources that might inhibit the attainment of applicable water-quality standards, and include a watershed-based perspective (U.S. Environmental Protection Agency, 1999). To support development of a control plan and to understand the effects of wastewater on urban receiving streams, laboratory and hydrologic analysis of stream samples from the Blue River Basin were collected during both base flow (defined as streamflow unaffected by storm runoff) and stormflow events and analyzed for physical properties, nutrients, selected organic wastewater compounds, selected prescription and over-the-counter pharmaceutical compounds, *Escherichia coli* (*E. coli*) and fecal coliform bacteria, and benthic macroinvertebrates. Selected base-flow *E. coli* samples were analyzed for host-source using genotypic, geographic-specific, library-based methods

Fact sheet FS-2006-3103

mo.water.usgs.gov



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Prepared in cooperation with the City of Kansas City, Missouri, Water Services Department

Water Quality in the Blue River Basin, Kansas City Metropolitan Area, Missouri and Kansas, October 2000 to October 2004

Scientific Investigations Report 2006–5147

U.S. Department of the Interior
U.S. Geological Survey

Full report

Outline

- Introduction
  - Purpose and scope
- Methods
- Basin water quality
  - Hydrologic effects
  - Nutrient loads and yields
  - Bacteria
  - Impoundments
- Aquatic community assessments
- Conclusions

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Introduction

- Blue River Basin covers roughly ½ of the metro, south of MO river
- Water quality influenced by variety of factors:
  - Point and non-point pollution
  - Physical stream conditions
  - Complex water-quality processes
- Wastewater (treated and untreated) is hydrologically important
  - Parts of basin receive WWTP effluent discharges
  - Parts of basin in combined sewer system
- What factors effect water quality?
- Basin approach

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Cooperative Science Program

- Partnership with stakeholders
- Provides science to support management decisions
- Cost-sharing program
- Combines local, state, and national expertise using an interdisciplinary approach
- Coupled analytical development to applied science
  - Organic wastewater compounds in water and sediment
  - Pharmaceutical compounds in water and sediment
  - Microbial-source tracking
  - Urban biological assessments

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Purpose and scope

- Detailed assessment of basin water quality
  - Nutrients, suspended sediment, ions, trace elements
  - Physical properties
    - pH, temp., SC, dissolved oxygen, turbidity
  - Organic wastewater compounds
  - Over-the-counter and prescription drugs
  - Fecal indicator bacteria
  - Aquatic communities
- Contaminant loading patterns
- Conceptual models

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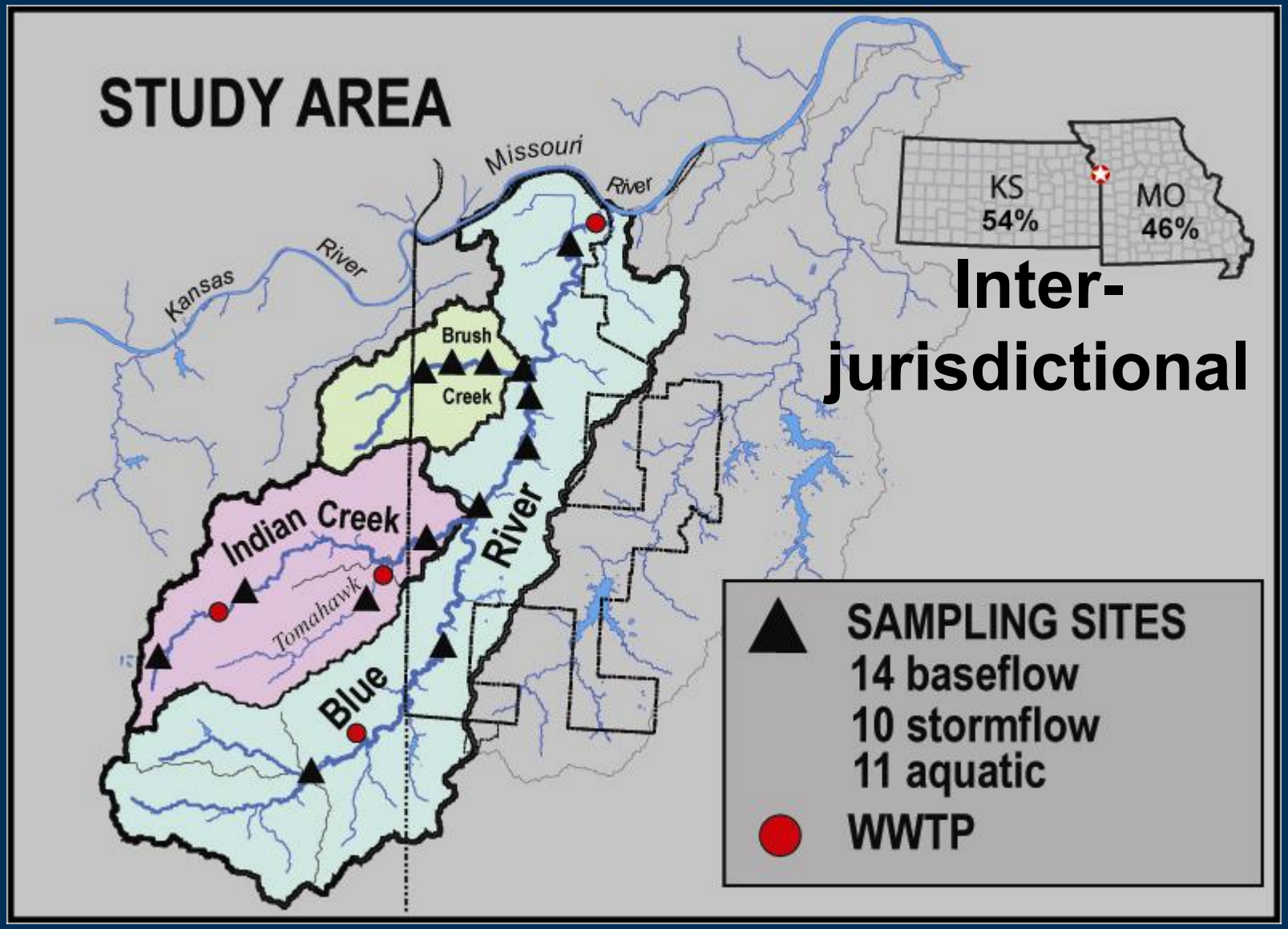
Study area



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Study area

Commercial, Industrial, or Residential
-Brush Creek 83%
-Indian Creek 61%
-Blue River 43 %

Upper Blue River
67% Grass/Forested

Brush Creek
43% Impervious

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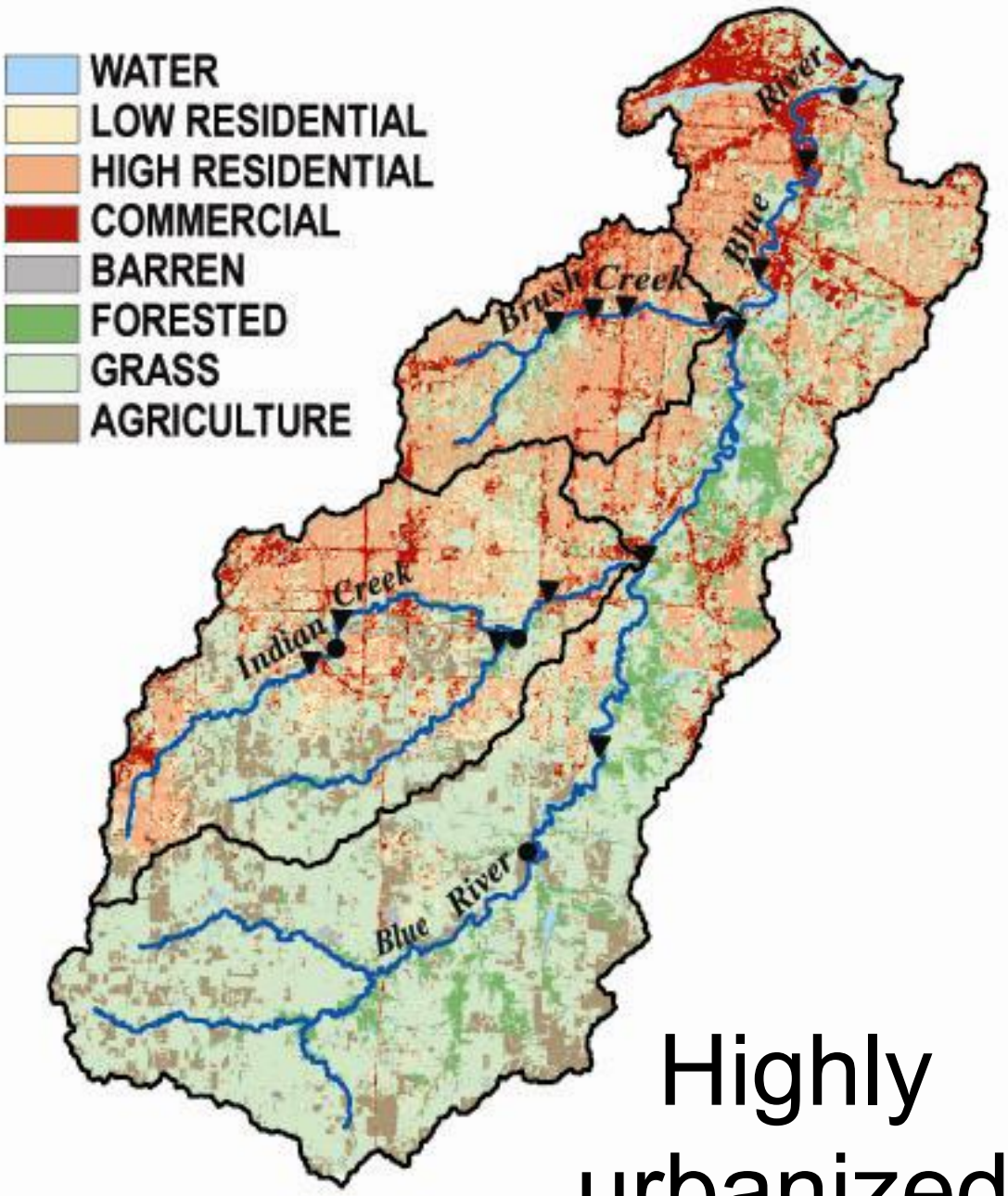


Highly urbanized

Study area

Mrs.Sam Ray Postcard collection www.kcpl.org

History of channel modifications in the basin

USGS

Study area

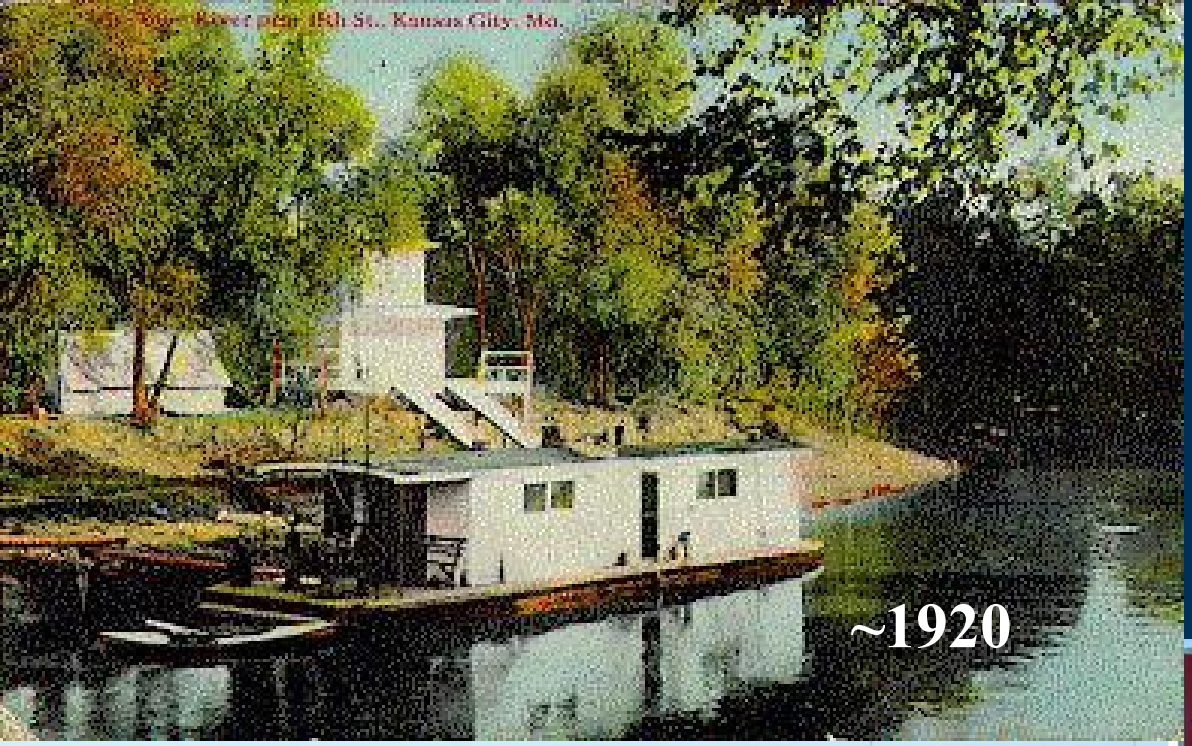

urbanization
Site 12
Site 11
Site 10
Site 9


Site 12
1930


Site 10
1932
www.kcpl.org


Site 9

Flood protection projects on lower Blue River



Study area

Most basin stream reaches basin affected by channelization or modification

areas upstream from site 9

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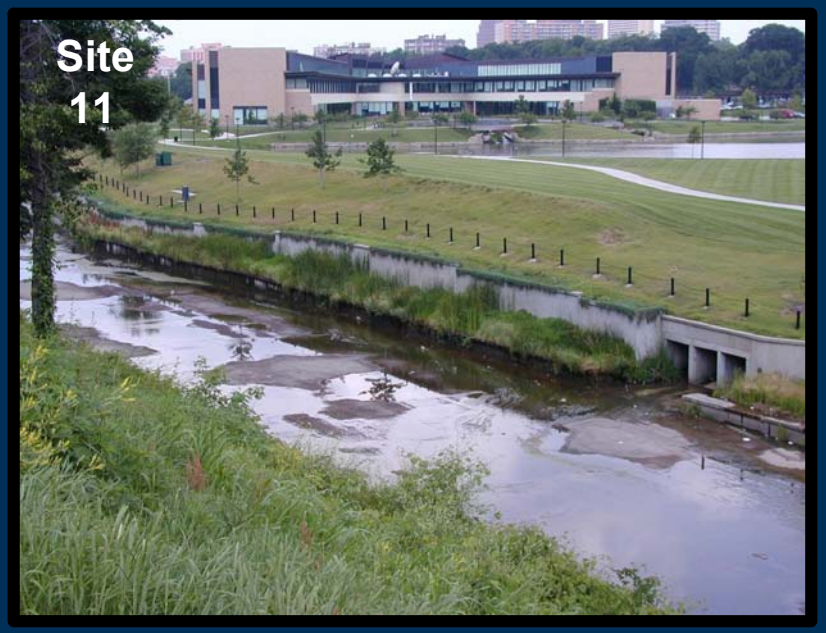
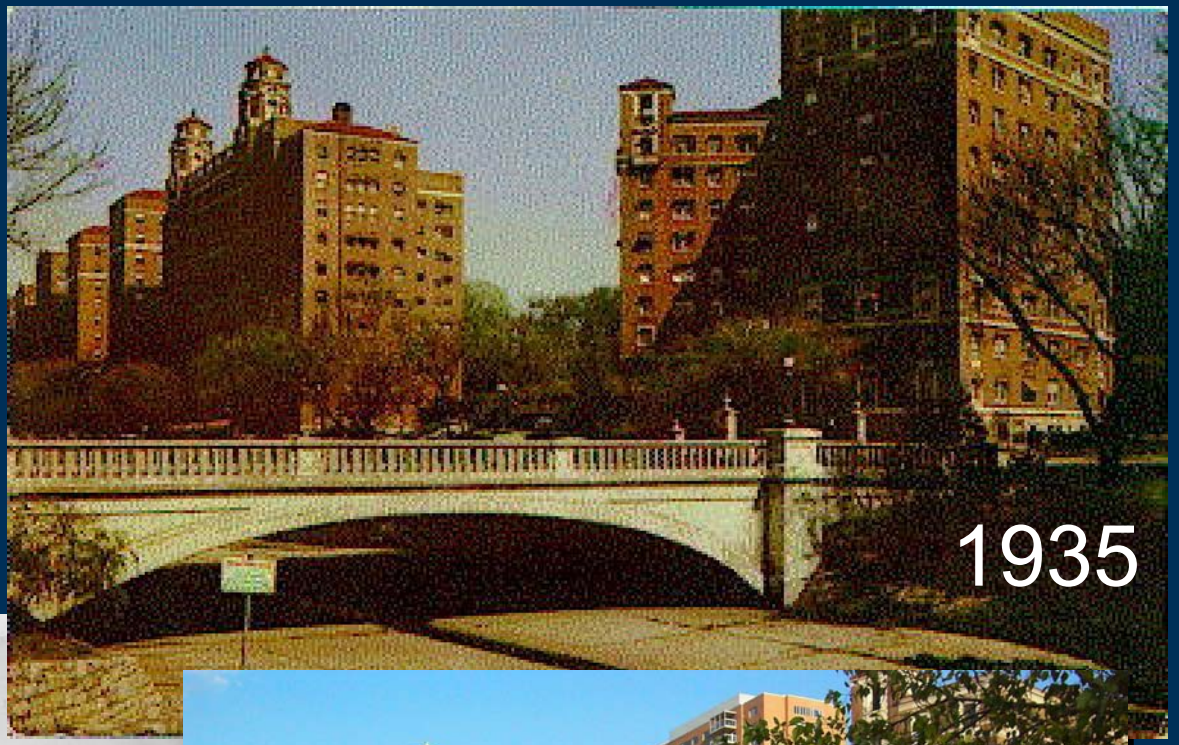
Study area

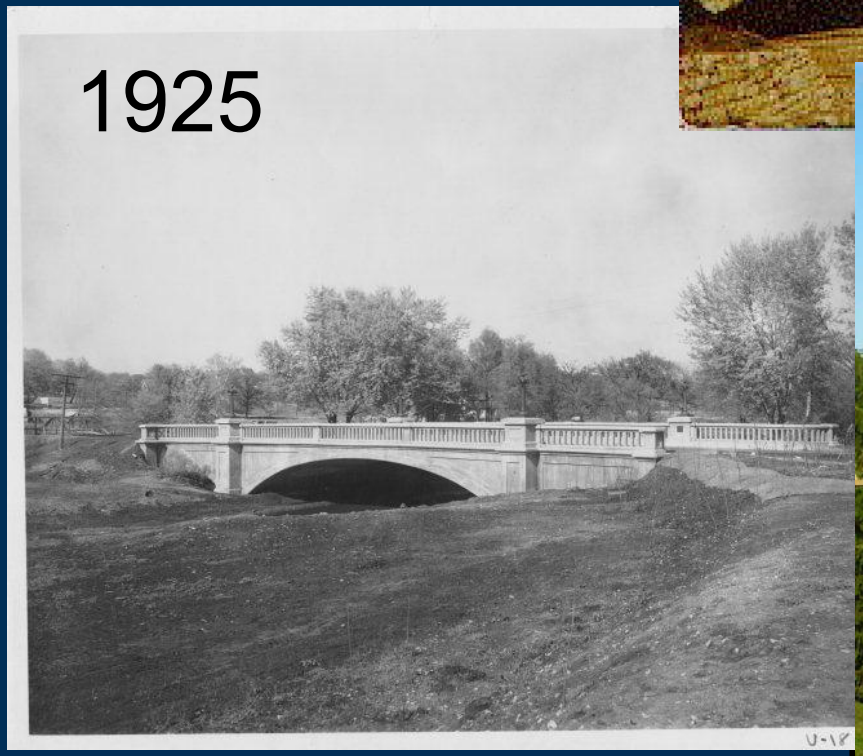


Channel modifications/habitat loss increase downstream

Study area

Brush Creek channelization for flood protection alters hydrology






BrushCreek
Upper (Plaza) Pool
BrushCreek
Middle (Volker) Pool

Methods

- Site selection based on proximity to:
  - -CSS area
  - -WWTPs
  - -tributaries
  - -hydrologic alterations
- 6 sites main stem Blue R.
- 4 sites on Brush Creek
- -3 BC impoundments
- 3 sites on Indian Creek
- 2 control sites
- 4 Wastewater treatment plants

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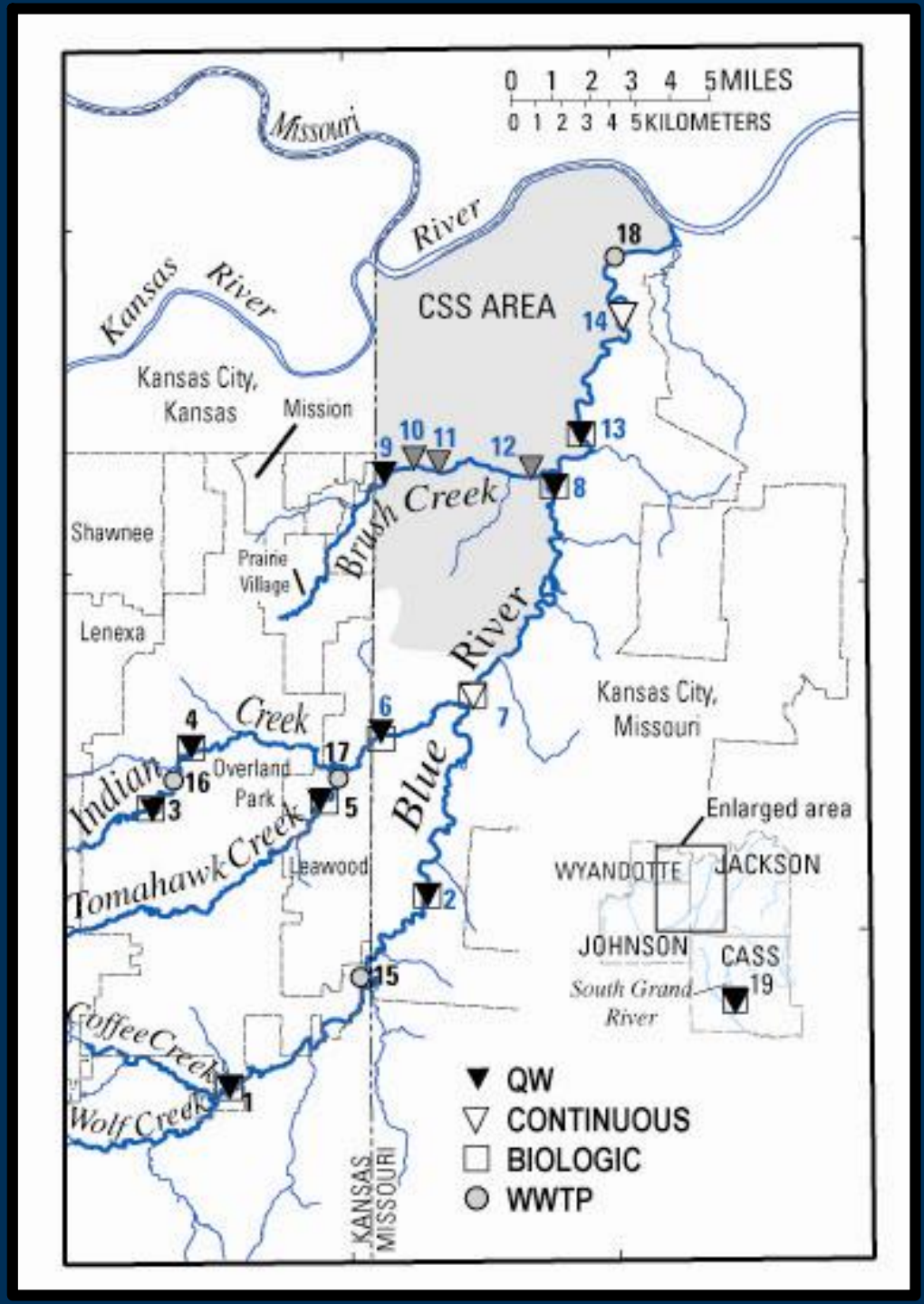


Methods-sampling protocol

Streams

- Streamflow
- Physical properties
  - pH, specific conductance, dissolved oxygen, turbidity
- Nutrients, sediment, ions
- Steroids, household and industrial chemicals
- Prescription and over-the-counter medications
- Fecal indicator bacteria and sources using local library

Standard methods

- Real-time data on web
- Publish streamflow and water-quality annually
- Minimize contamination
- Field replicates and blanks
- Lab replicates and blanks

(Wilkison and others; 2002, 2005)

Methods-sampling protocol

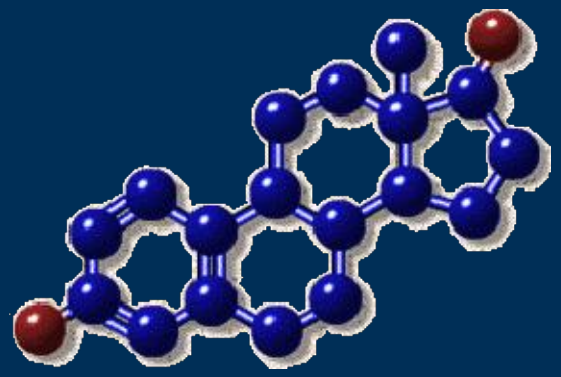
Impoundments

- Pool volumes
  - Bathymetry
  - Turnover rates
- Vertical profiles
  - Physical properties
  - Water chemistry
- Bottom sediments

Aquatic community assessments

- Macroinvertebrates
- Standardized protocols
  - Missouri (2002)
  - Kansas (2003, 2004)
- Identified to lowest level
- Standard metrics
- Proportional scaling

Methods-data analysis

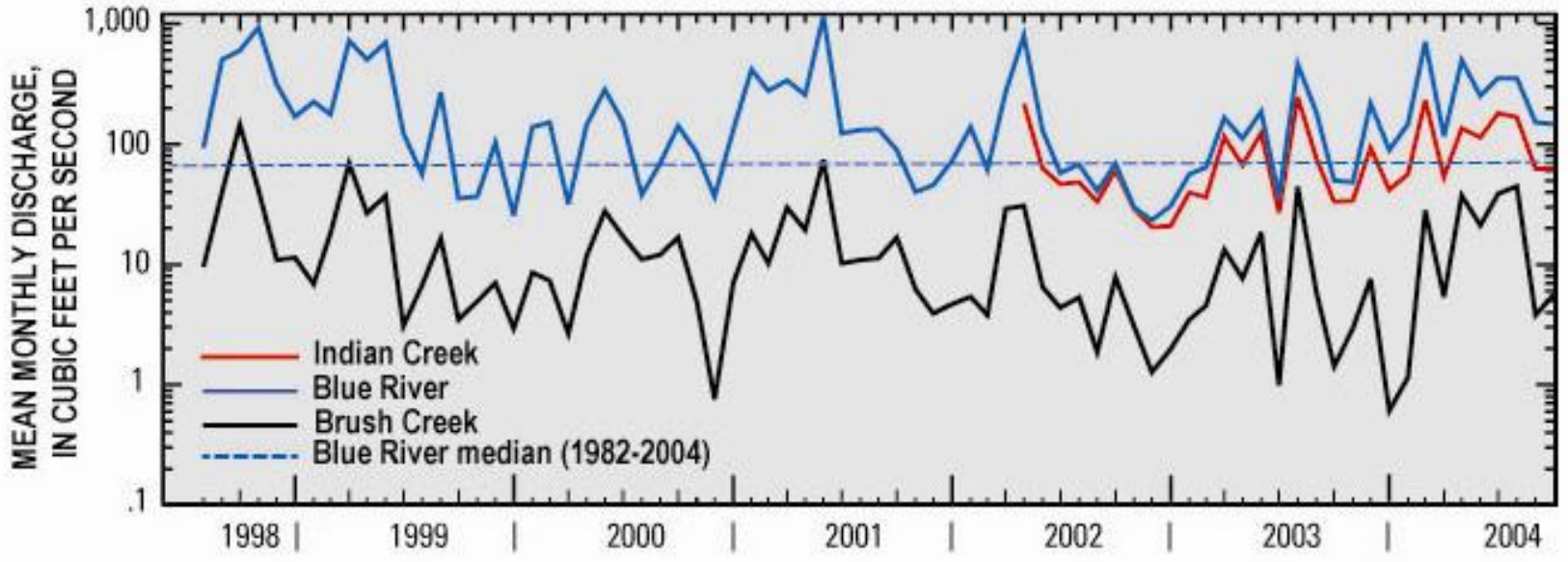


- Hydrologic condition: Baseflow, stormflow, or continuous
- Concentrations and loads
- Load models using minimum variance unbiased estimation procedures
- Stream reach
- Potential wastewater sources

Data analysis

- Non-parametric statistical techniques
- Total (sum of all compounds) and
- General use categories
  - Ex. Detergents, plastics, sterols,…
  - Ex., antibiotics, cardiac, stimulants,…

Basin water quality-Hydrologic effects on concentrations



- Indian Creek major contributor of flow to Blue River
- Large percent of Blue River flow is treated effluent
- Effluent percent increases during droughts
- Brush Creek typically about 10% of flow to Blue River

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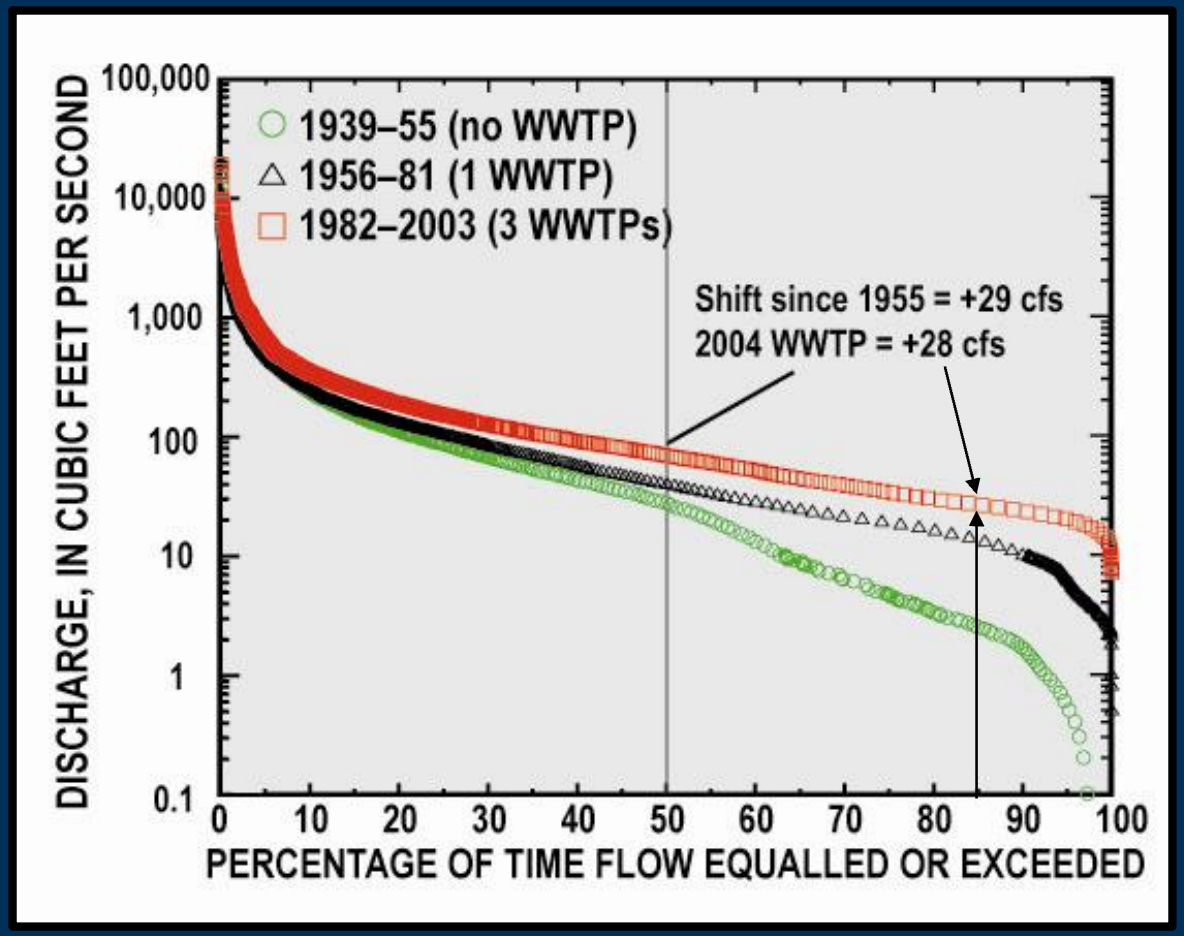
Basin water quality-Hydrologic effects on concentrations



- Treated effluent alters stream hydrology
- About 85% of the time treated effluent is most of the flow in middle and lower Blue River

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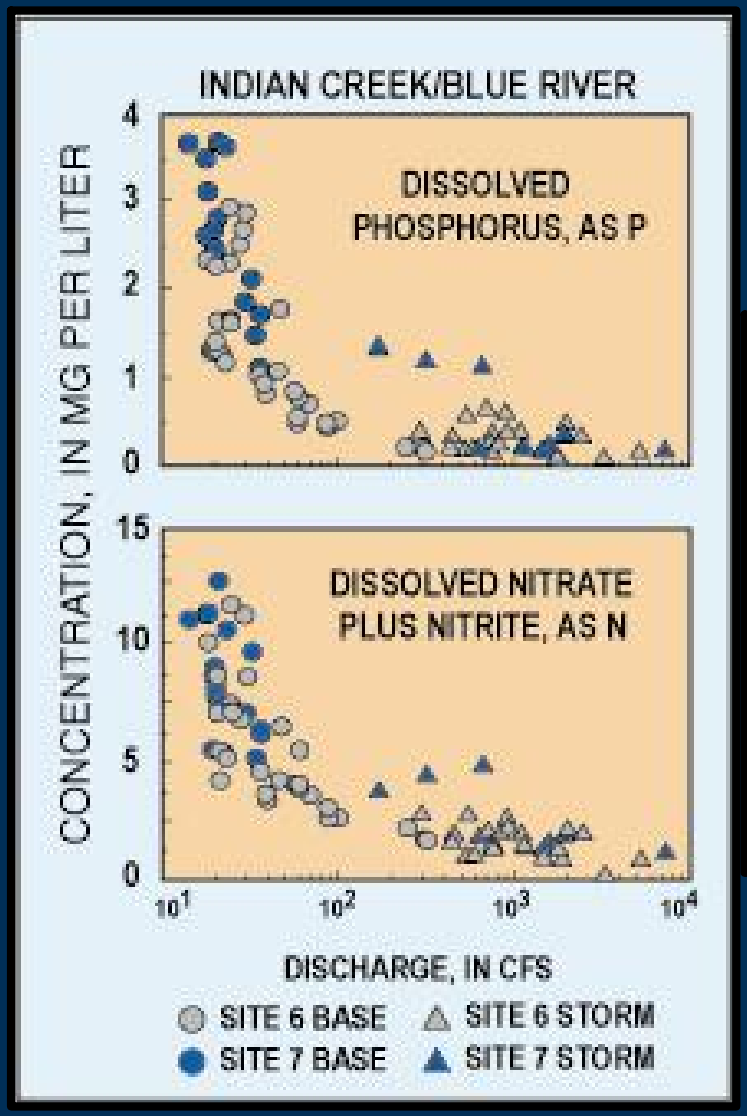
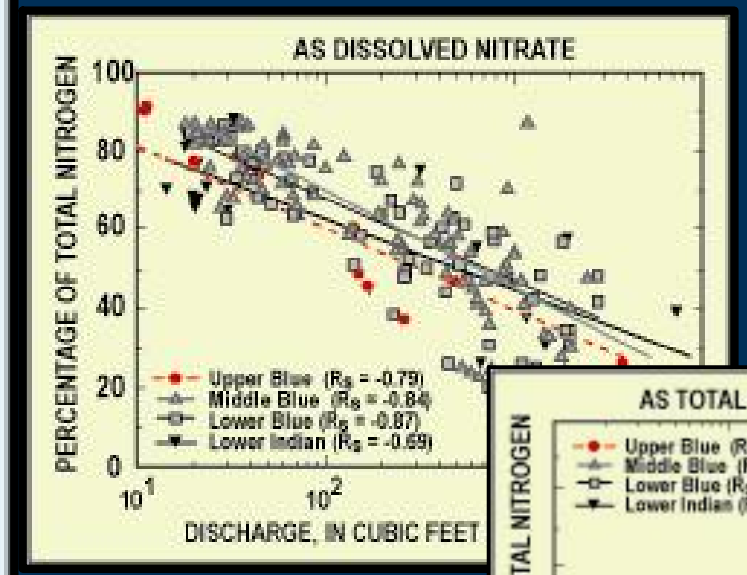
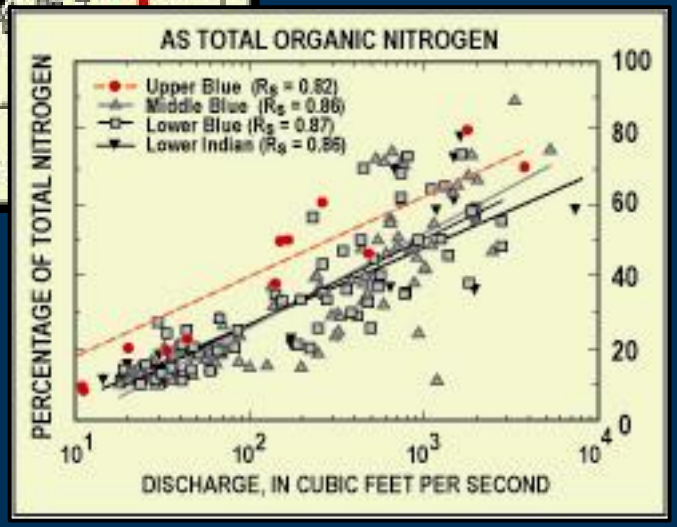
Basin water quality-Hydrologic effects on concentrations

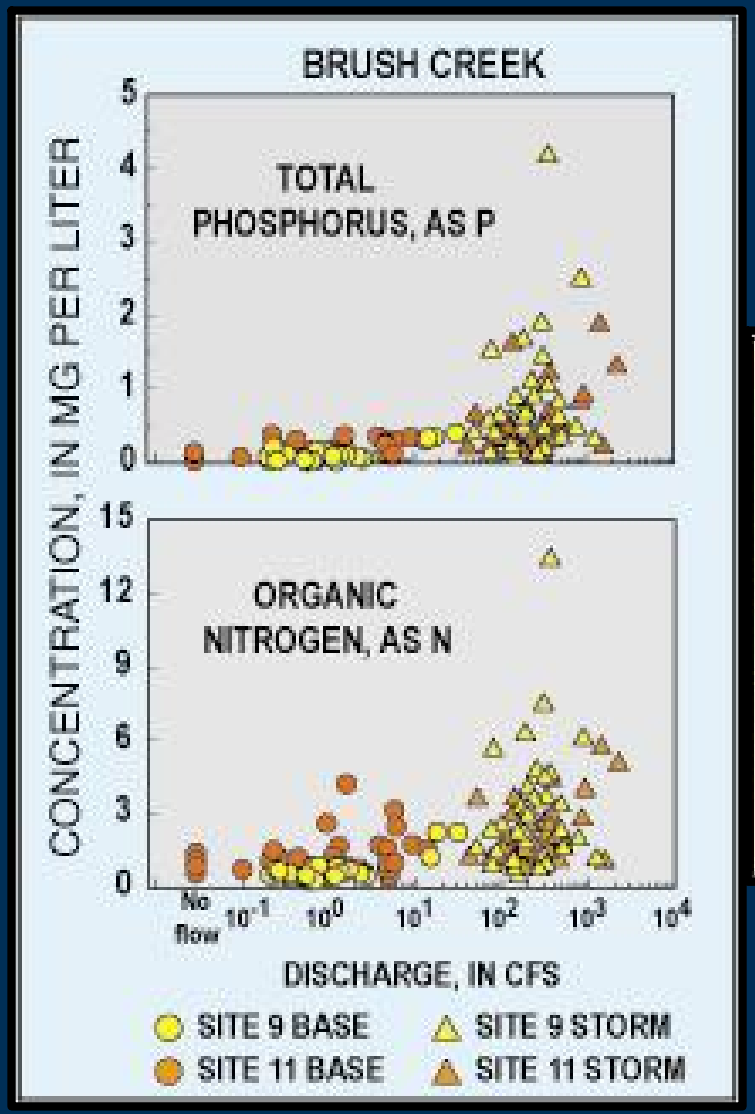
- As stream flow increases, point-source contributions effectively diminish because most WWTP nutrients are in the dissolved phase
- Offset by increases in non-point sources



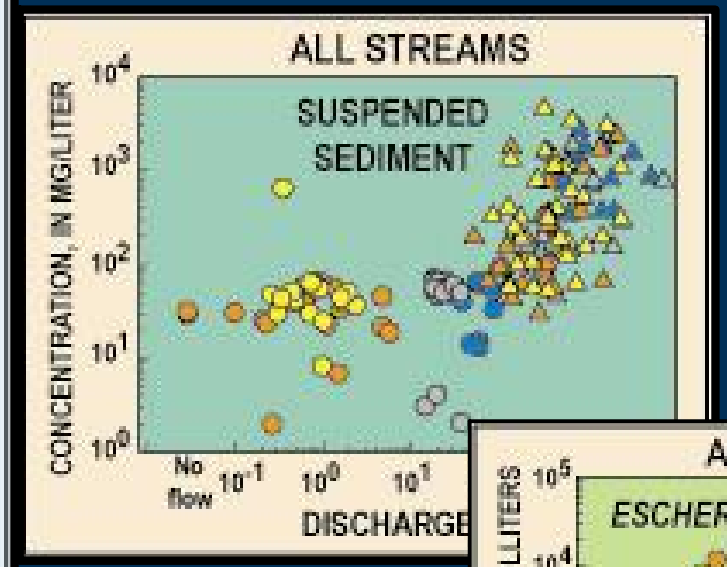


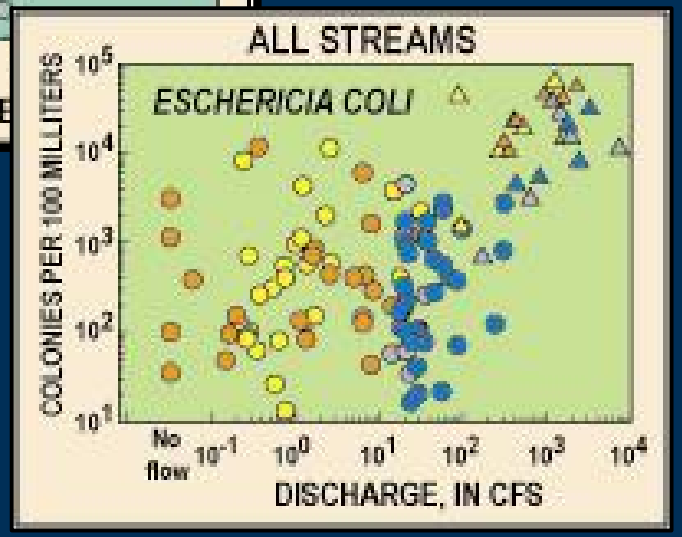


Basin water quality-Hydrologic effects on concentrations



- As stream flow increases, particulate nutrients increase
- Suspended sediment increases
- Bacteria densities increase





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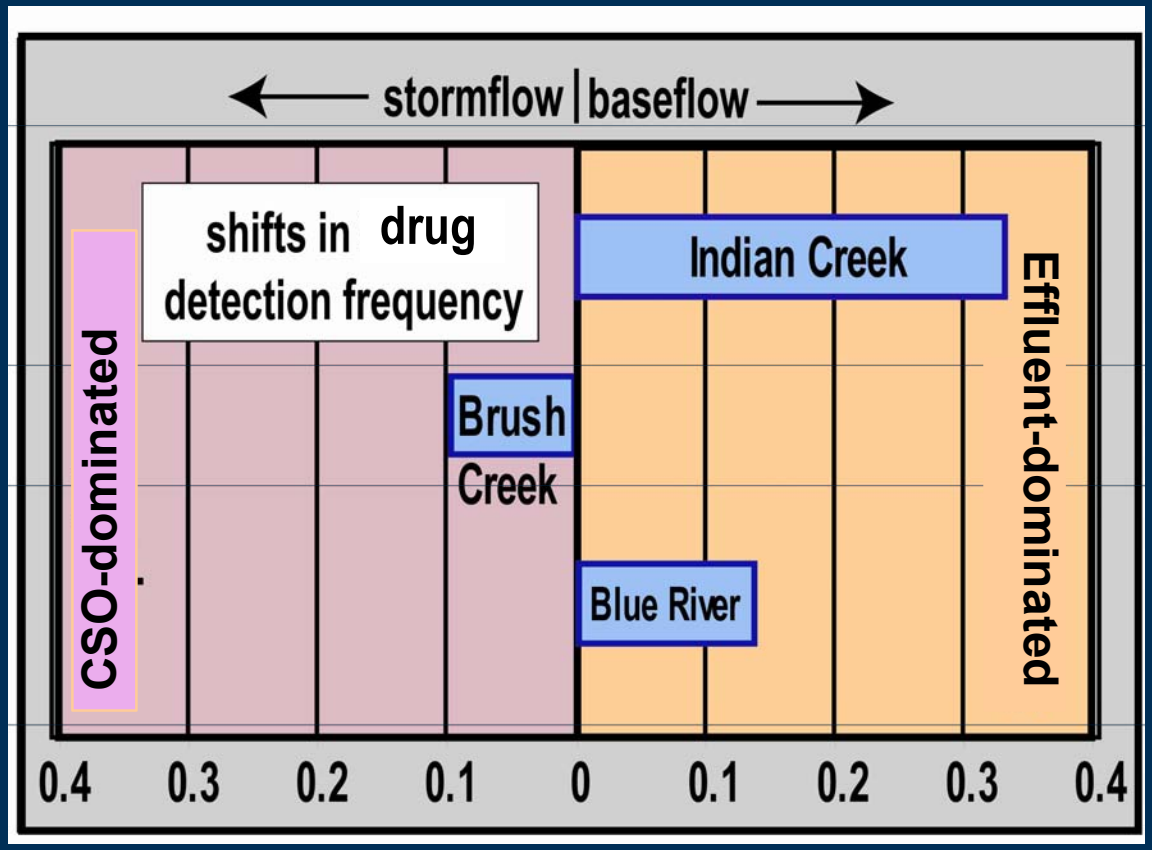
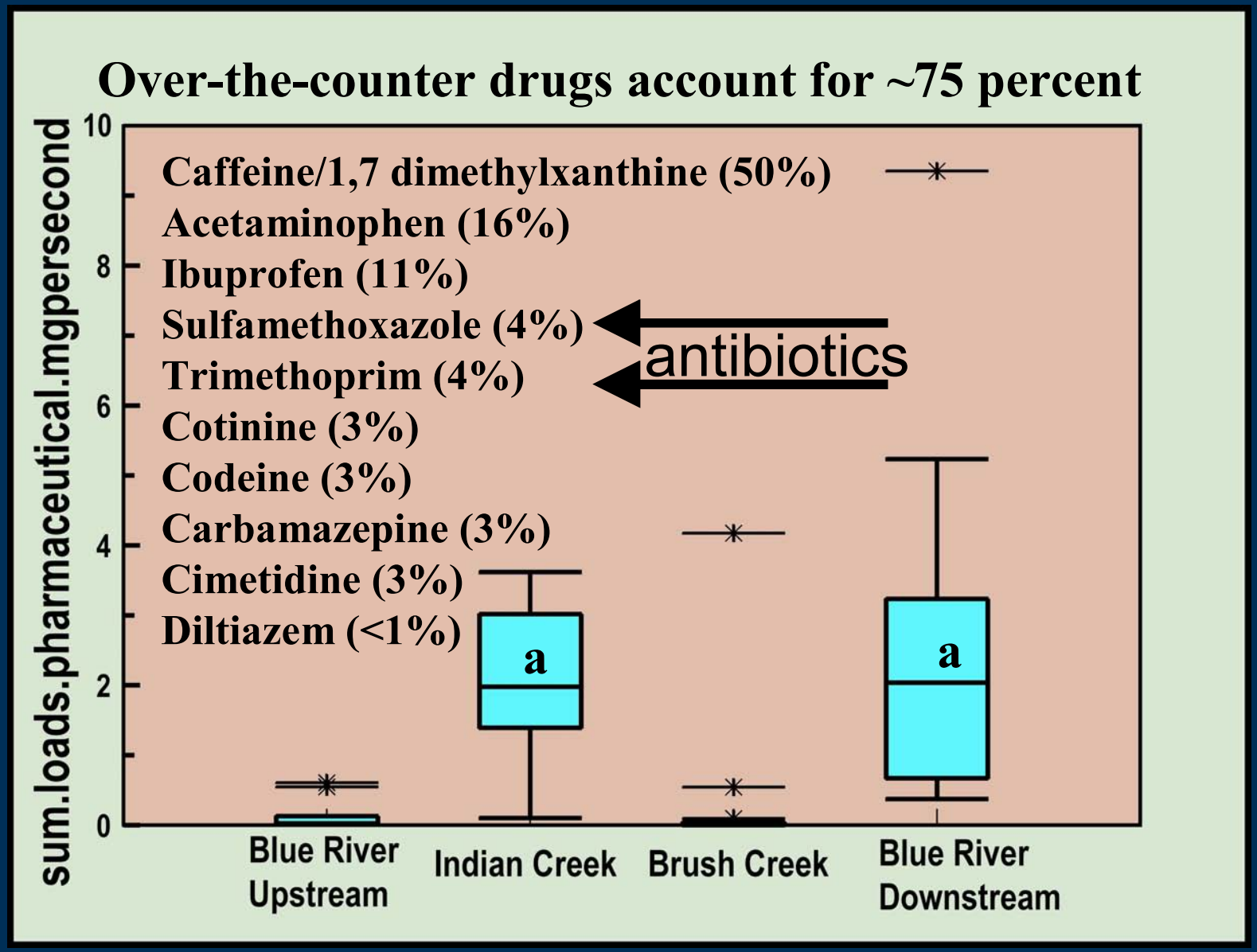


- Baseflow - More frequent detections of pharmaceuticals in Indian Creek and Blue River

- Stormflow – More frequent detections in Brush Creek

Basin water quality



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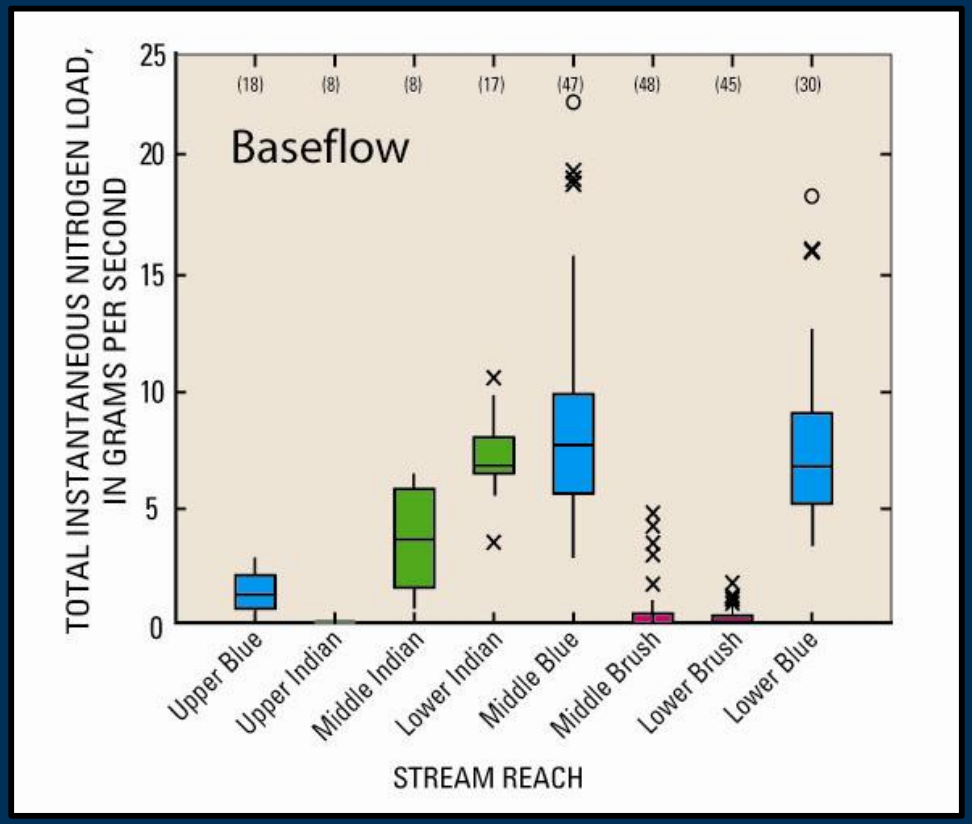
- Very low concentrations
- Not regulated

- Environmental understanding is just beginning

Basin water quality

- Multiple lines of evidence
- Large data sets
- Concentration patterns
- Load (conc. X flow) patterns
- Multiple tools for tracing



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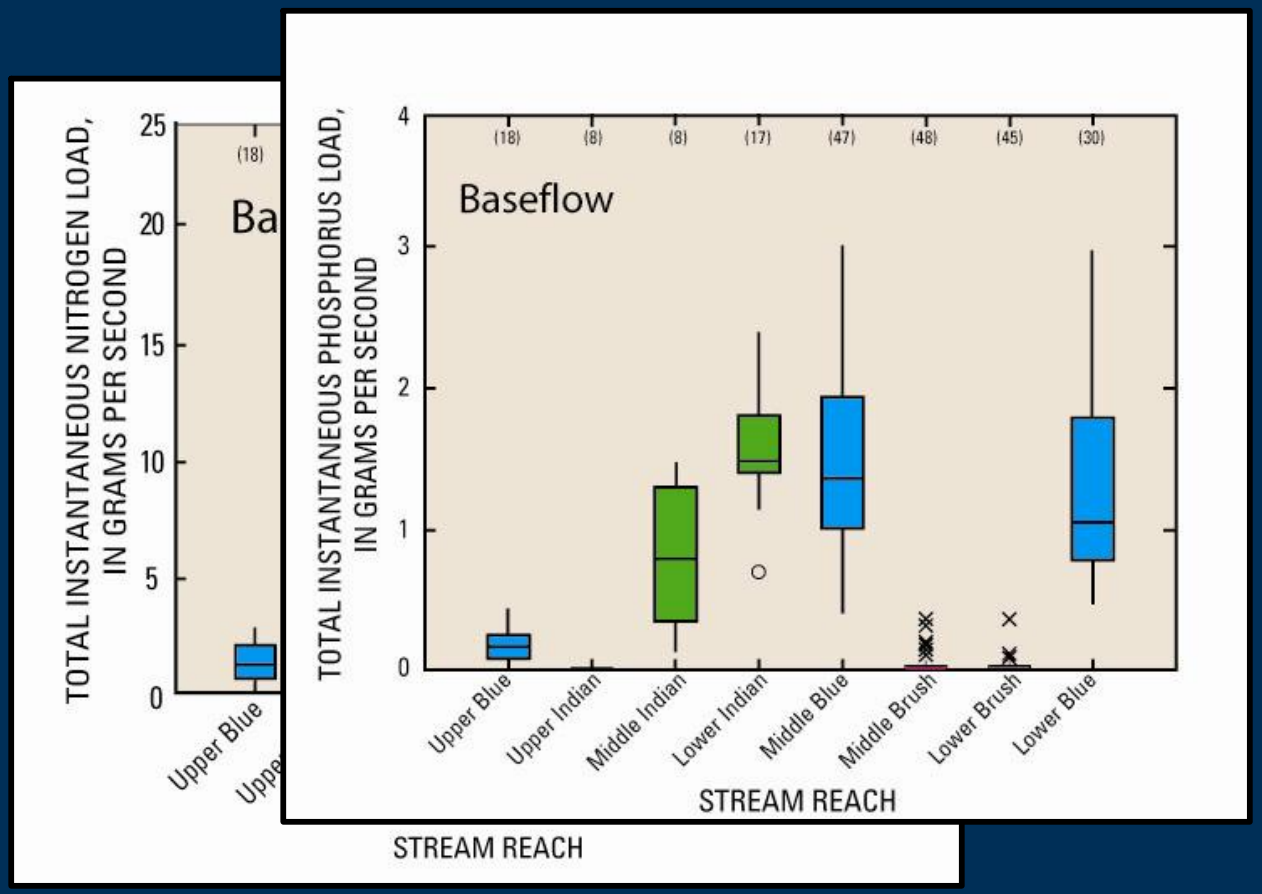

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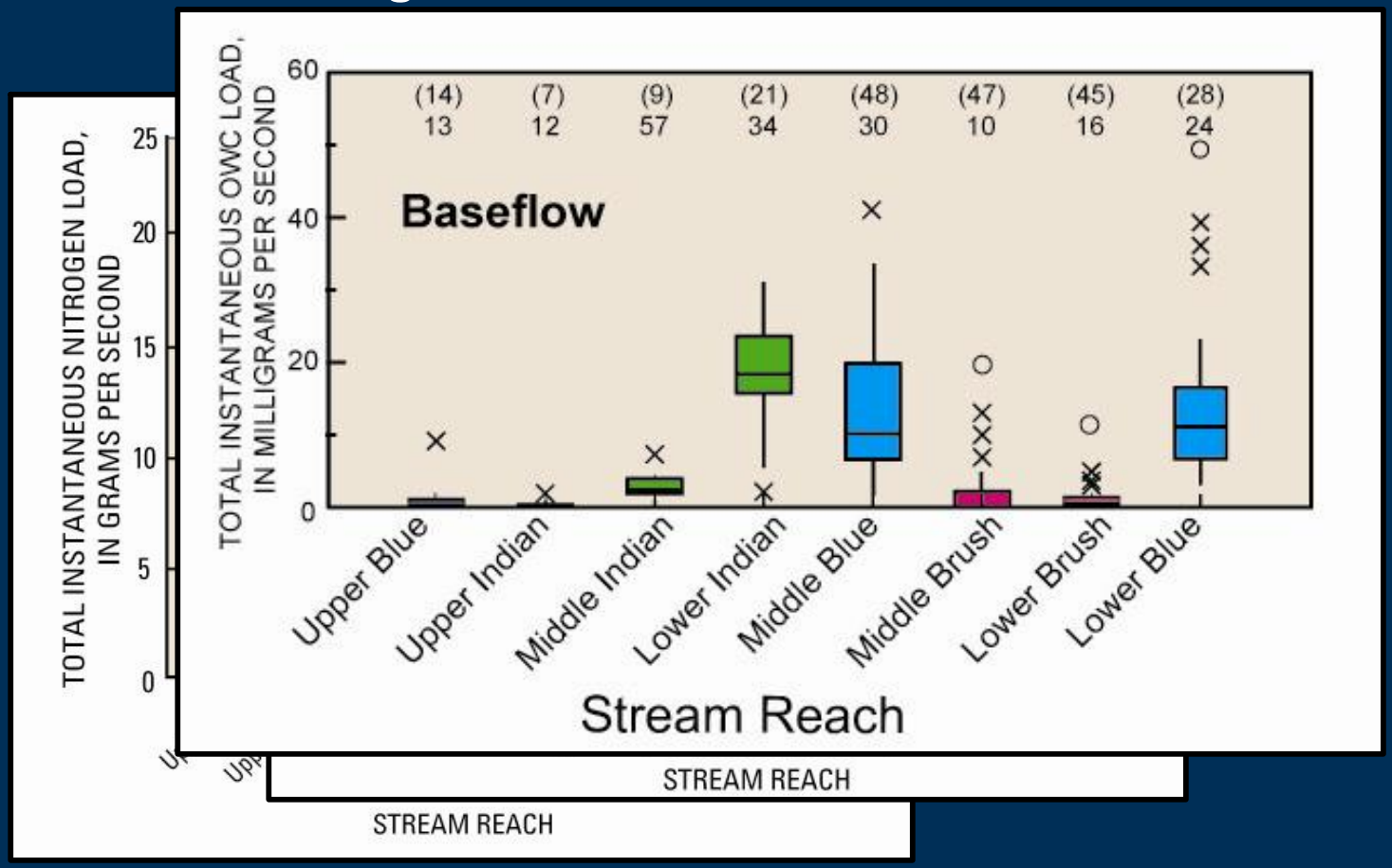

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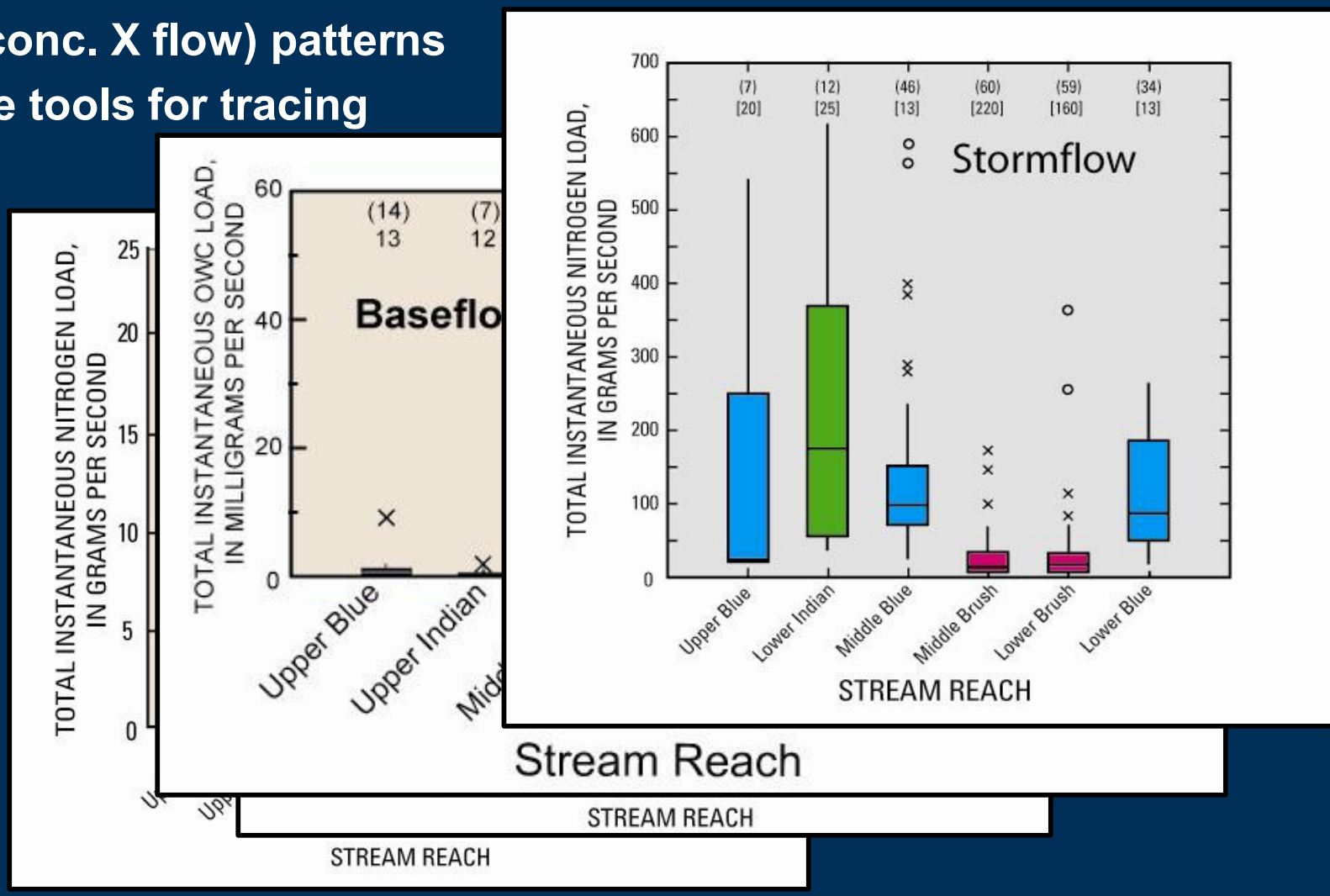

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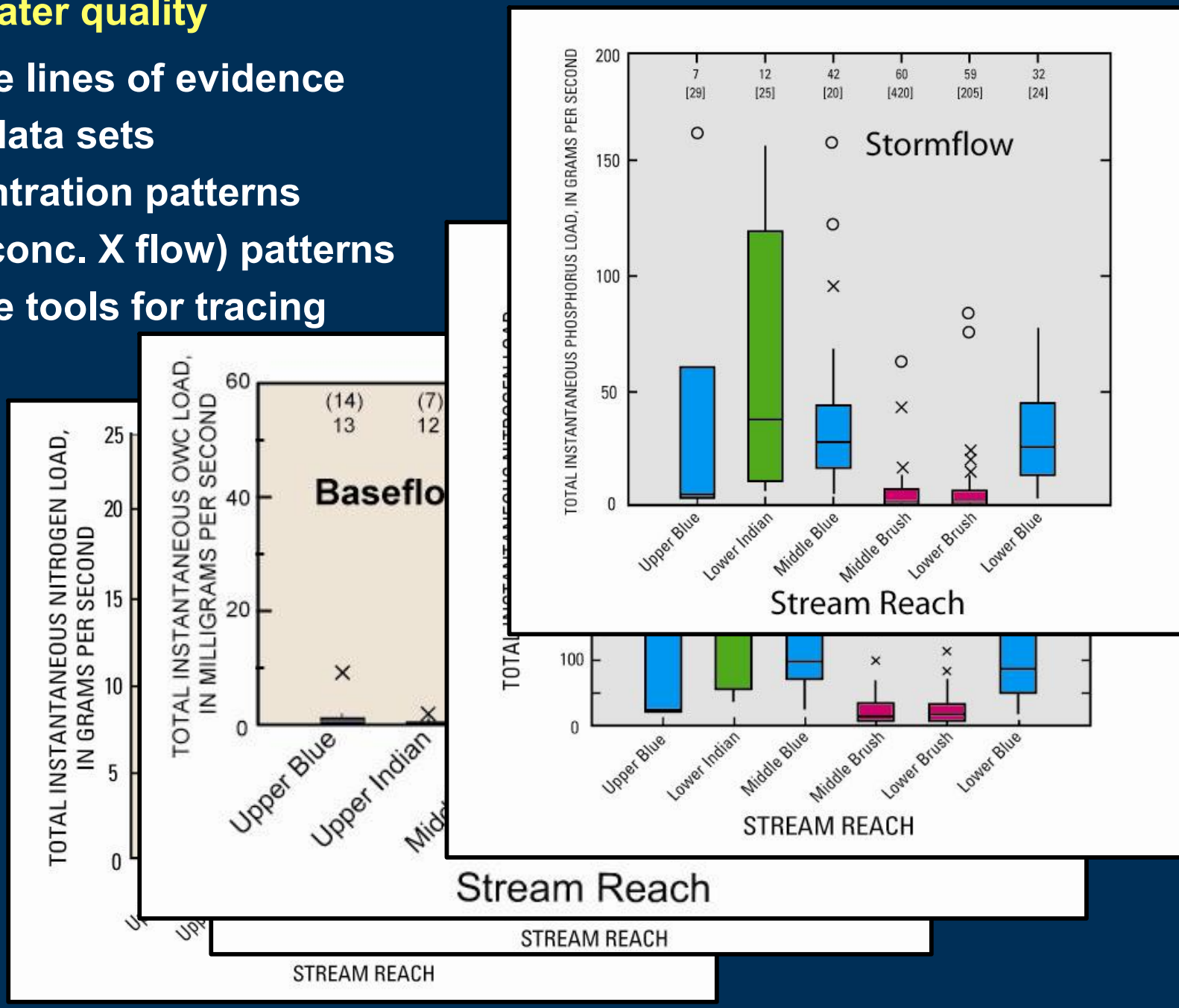
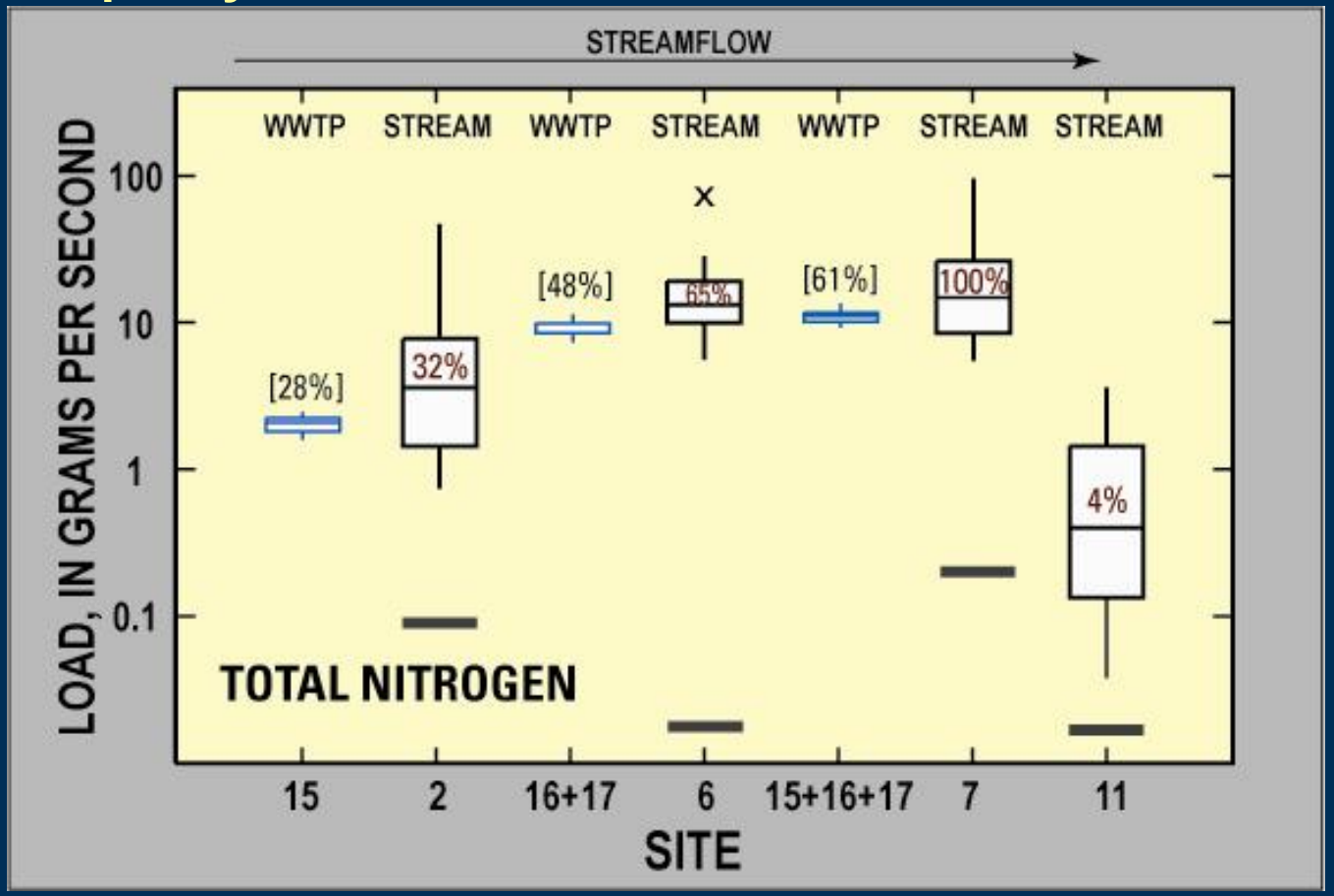
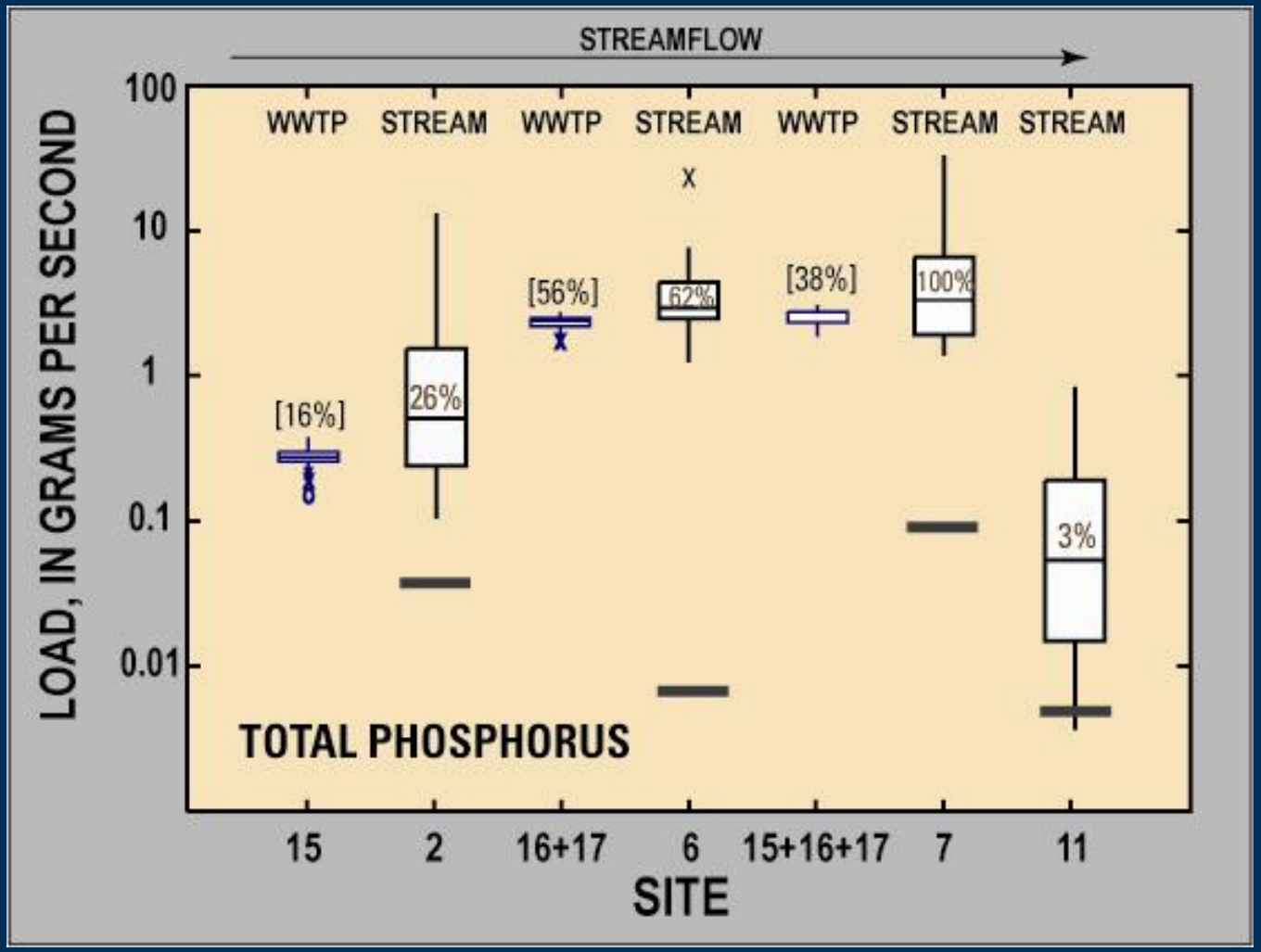


Basin water quality-nutrient loads



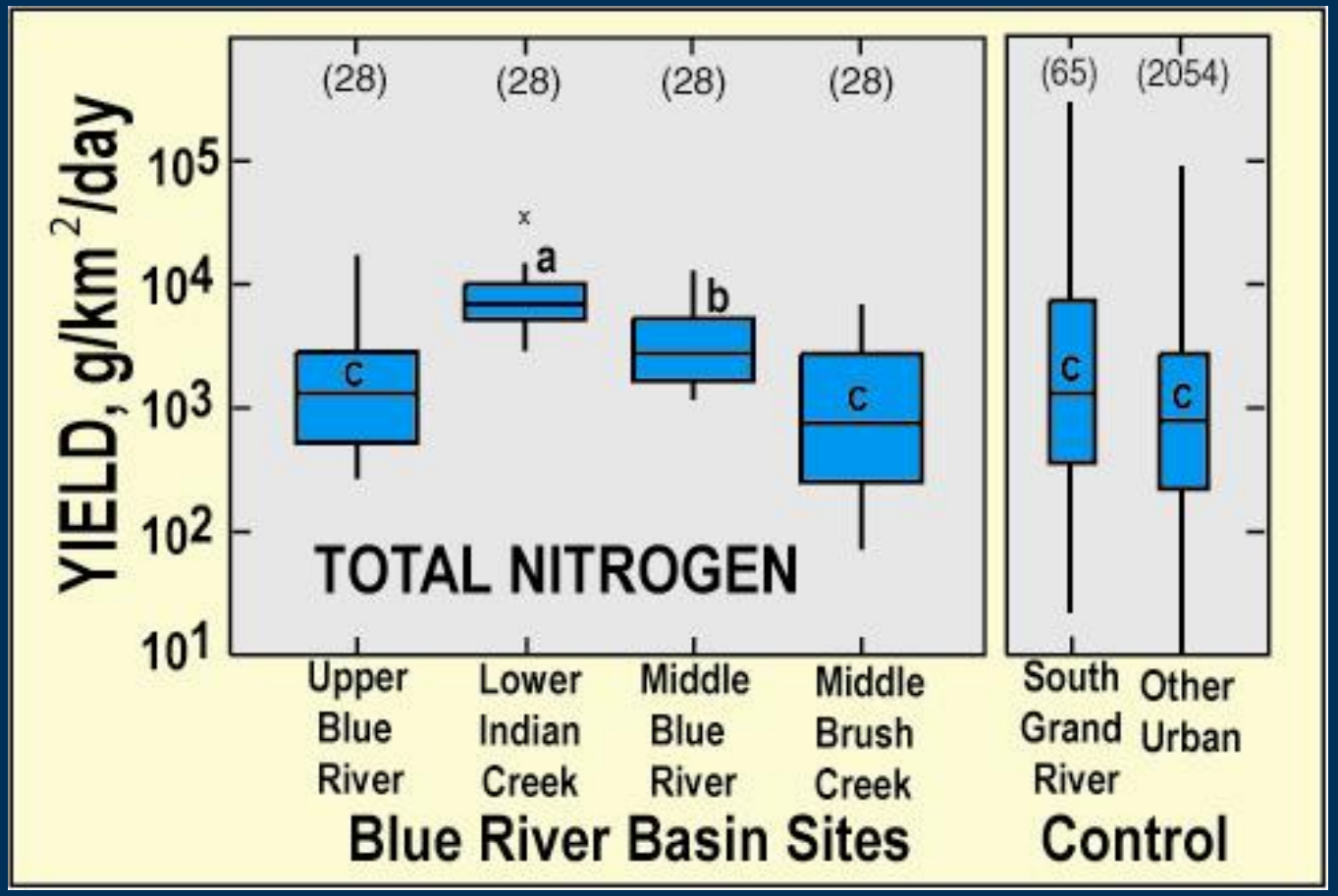
- Loads integrate all events, account for time variations
- Provide estimate of uncertainty
- Predominate source of N in Blue River from Indian Creek (>60%)
- Non-point sources substantial
- Effluent sources substantial in some reaches
- Brush Creek <5 percent to Blue River

Basin water quality-nutrient loads



- Predominate source of P in Blue River from Indian Creek (>60%)
- Non-point sources substantial
- Effluent sources substantial in some reaches
- Brush Creek <5 percent to Blue River

Basin water quality-nutrient yields



- Yields allow reach comparisons by normalizing drainage areas
- Highest in lower Indian Creek and middle Blue River
- Upper Blue River/Brush Creek not significantly different from control sites

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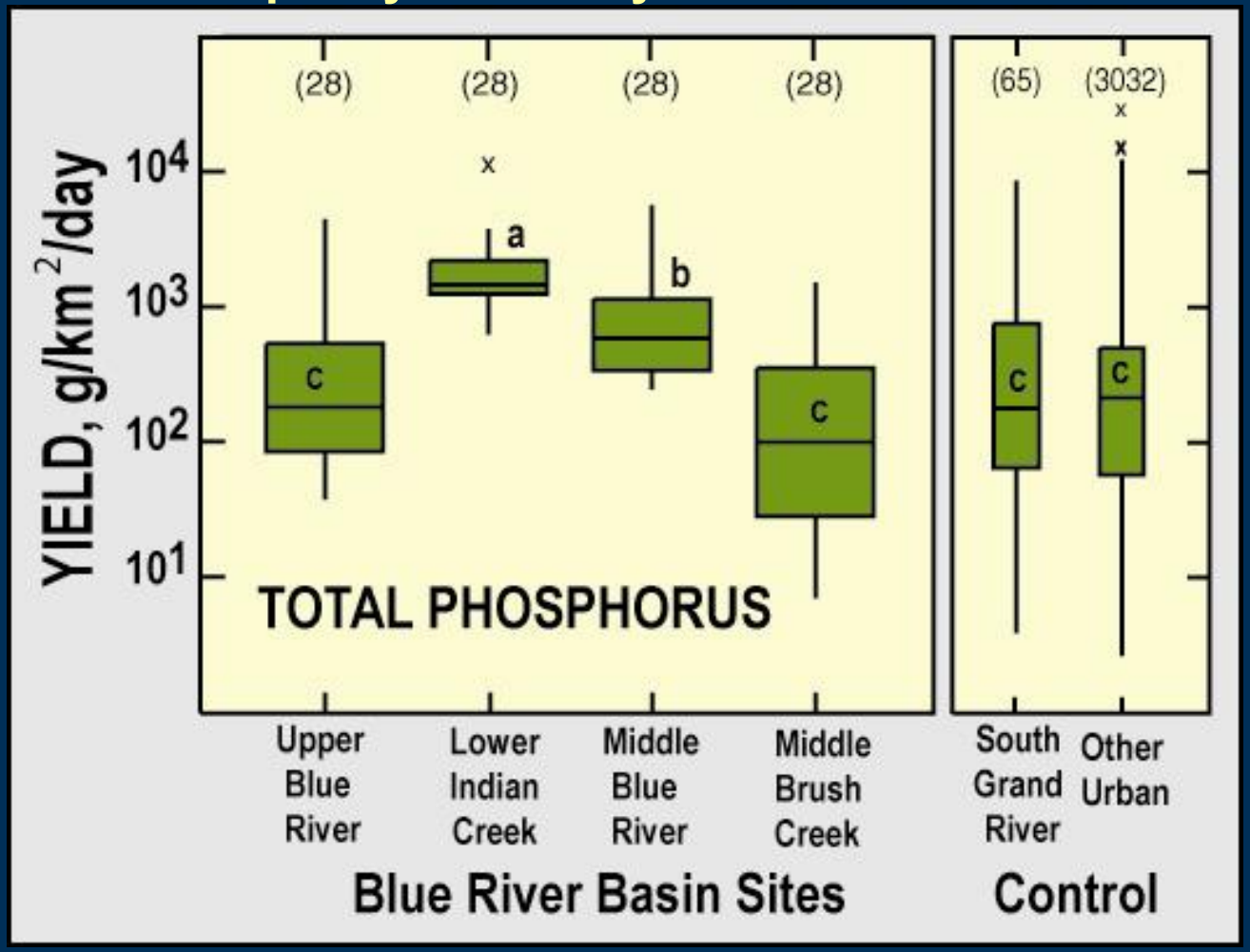
Basin water quality-nutrient yields



- Highest in lower Indian Creek and middle Blue River
- Upper Blue River/Brush Creek not significantly different from control sites

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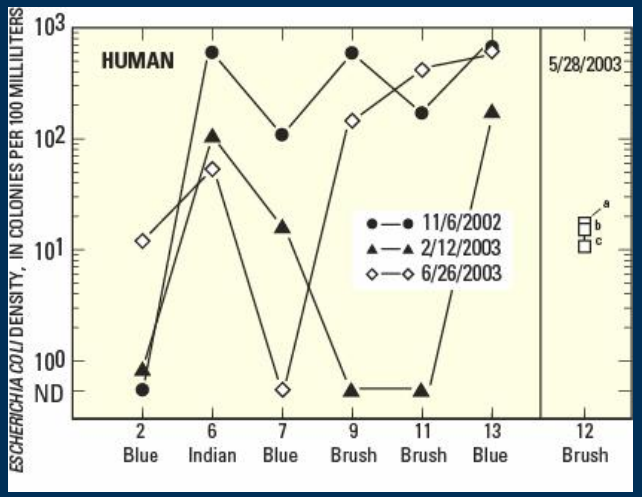
Basin water quality-bacteria

- *E. coli* sources (densities) vary spatially and temporally in the basn



Basin ranges (2002-2004)

Dog = 28 - 32%

Geese = 8 - 22%

Human = 23- 42%

Unknown or unclassified = 18 - 26%

- WQ standards are based on total numbers
- Sources are subset of total bacteria
- Represent a small percent of all bacteria

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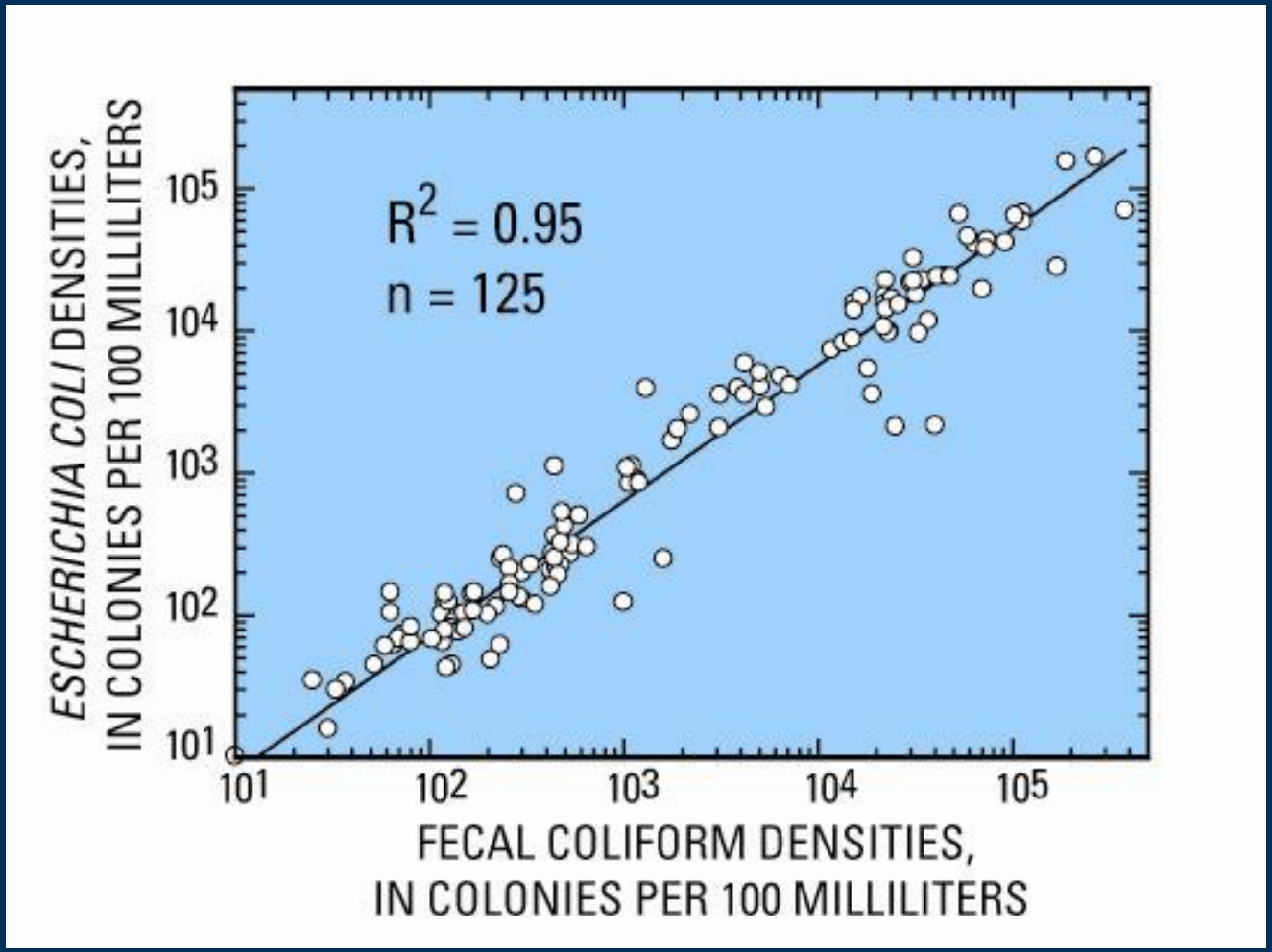
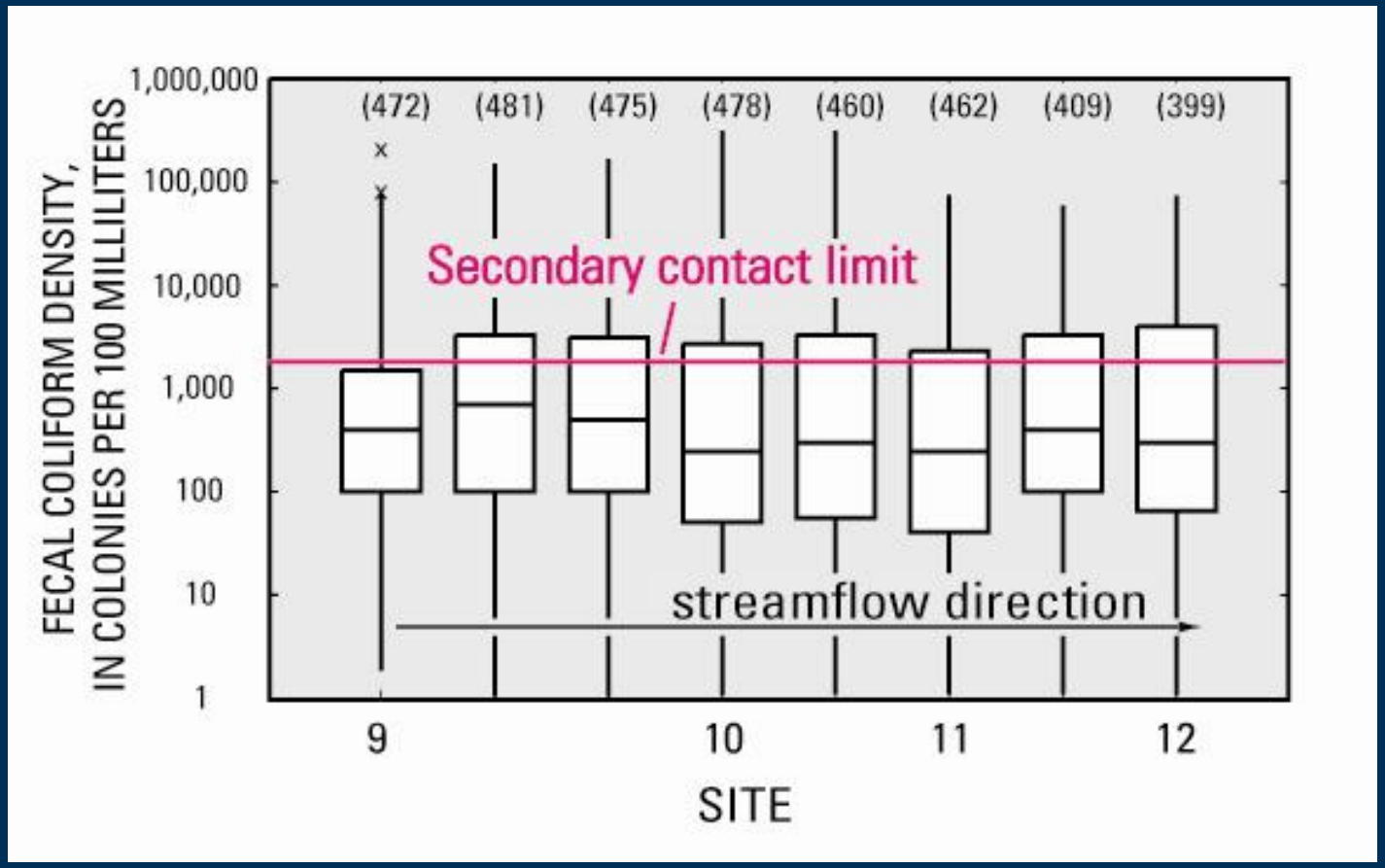
Basin water quality-bacteria



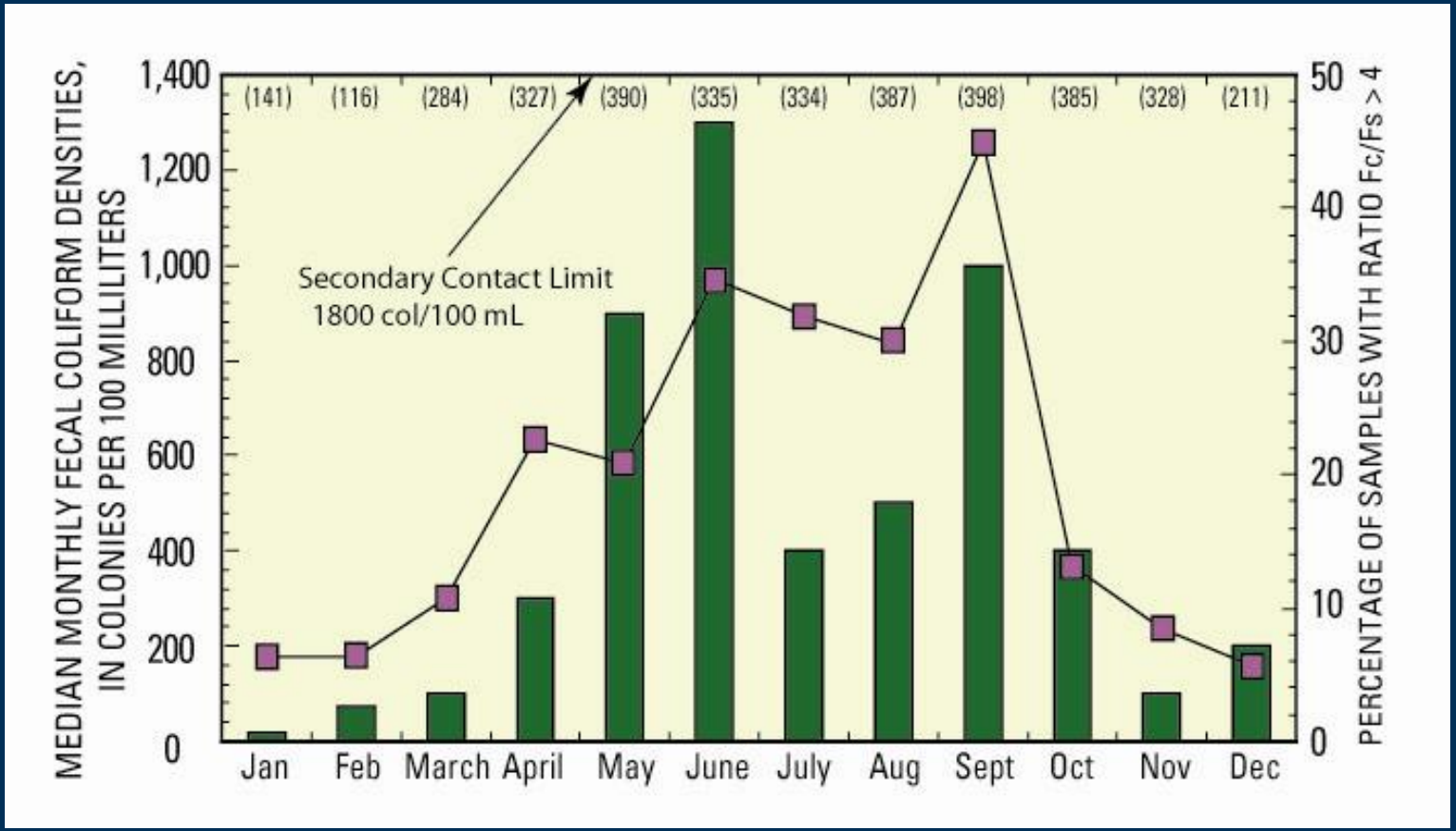
- **Strong relationship between *E.coli and* Fecal coliform**
- **Looking at Fecal coliform provides better understanding of *E.coli***

Basin water quality-bacteria



- Weekly sampling (1998-2004) Fecal coliform at 8 Brush Creek sites
- Captures a variety of hydrologic conditions
- Little variance in densities along Brush Creek
- Densities not related to CSO diversion density
- 70 percent of samples less than secondary contact limit of 1800

Basin water quality-bacteria



- Seasonal component
- Correlated with days >0.5 inch precipitation
- Median densities < secondary contact limit

Basin water quality-bacteria

- How *E. coli* much from non-point sources?
- Compare median loads @:
  - Brush Creek @ Ward Parkway (outside CSS area)
  - Brush Creek @ Rockhill Road (in CSS area)
- Baseflow; n =
  - outside CSS : inside CSS = 66 percent
- Stormflow loads; n = 6
  - outside CSS : inside CSS = 59 percent
- Drainage area ratio 72

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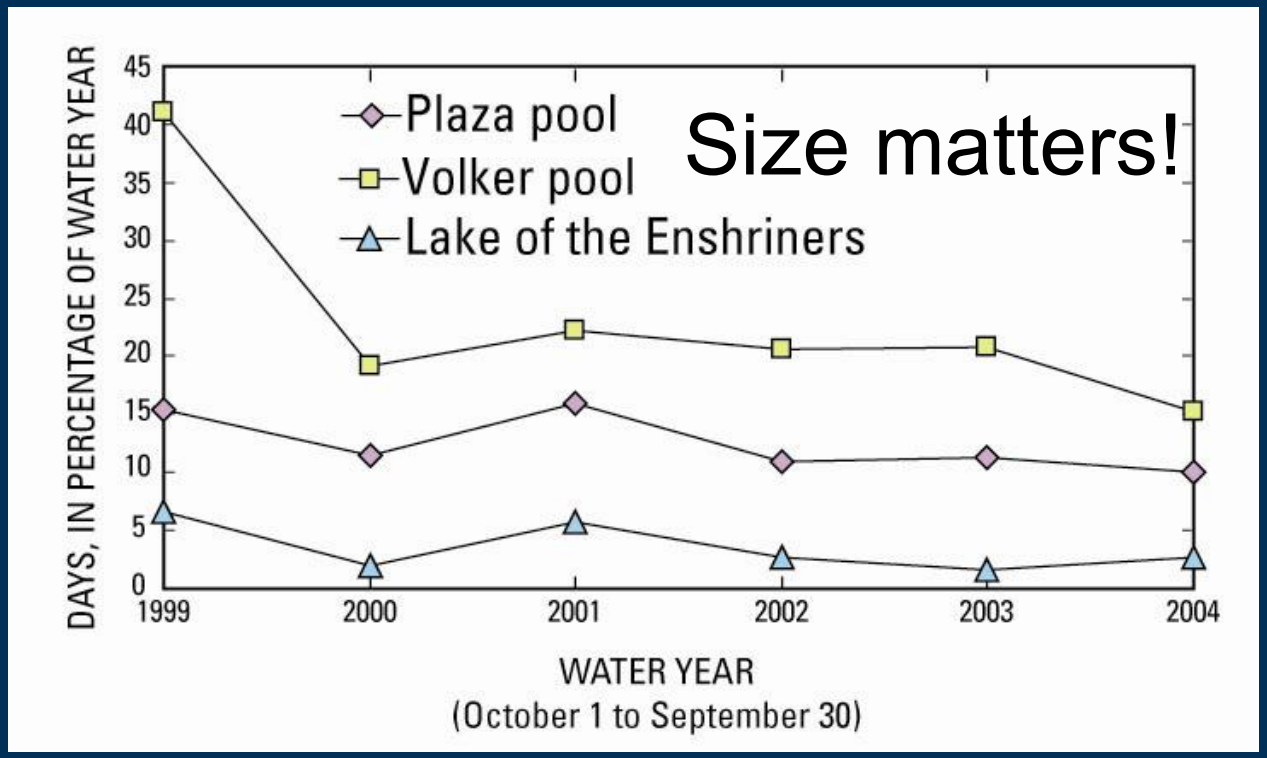
Basin water quality-Brush Creek impoundments



- Storm runoff can quickly replace pool volume
- Lake of the Enshriners has lowest turnover frequency
- Only Lake of the Enshriners deep enough to strongly stratify
- Droughts effect water quality by reducing turnover

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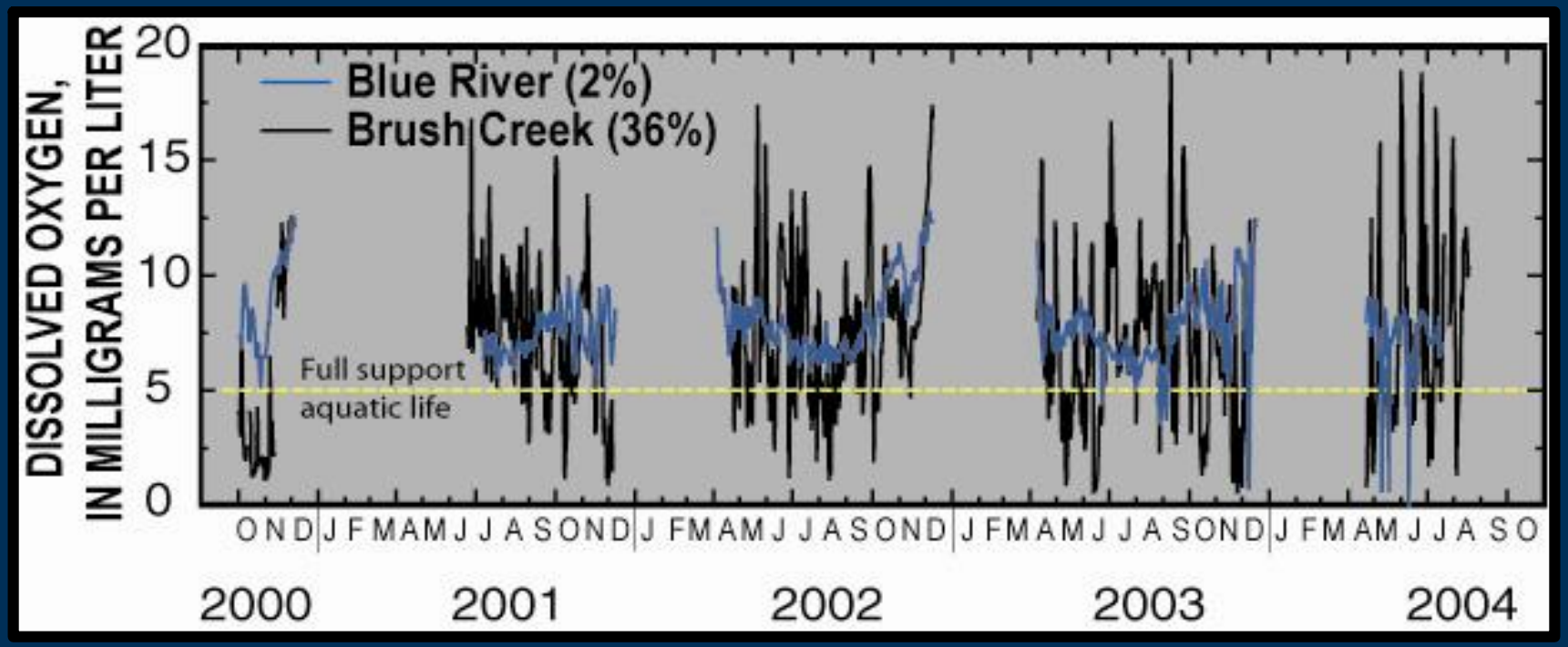
Basin water quality-Brush Creek impoundments

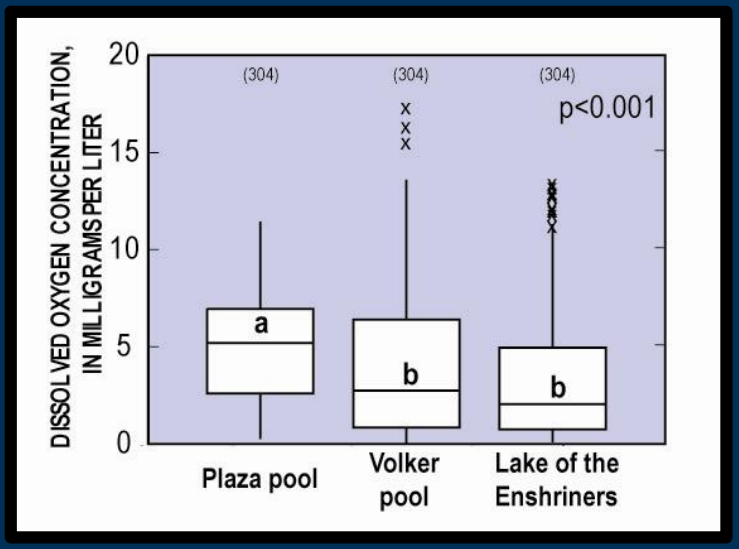
Storm bring organic matter and sediments which are trapped in impoundments

USGS

Basin water quality-Brush Creek impoundments



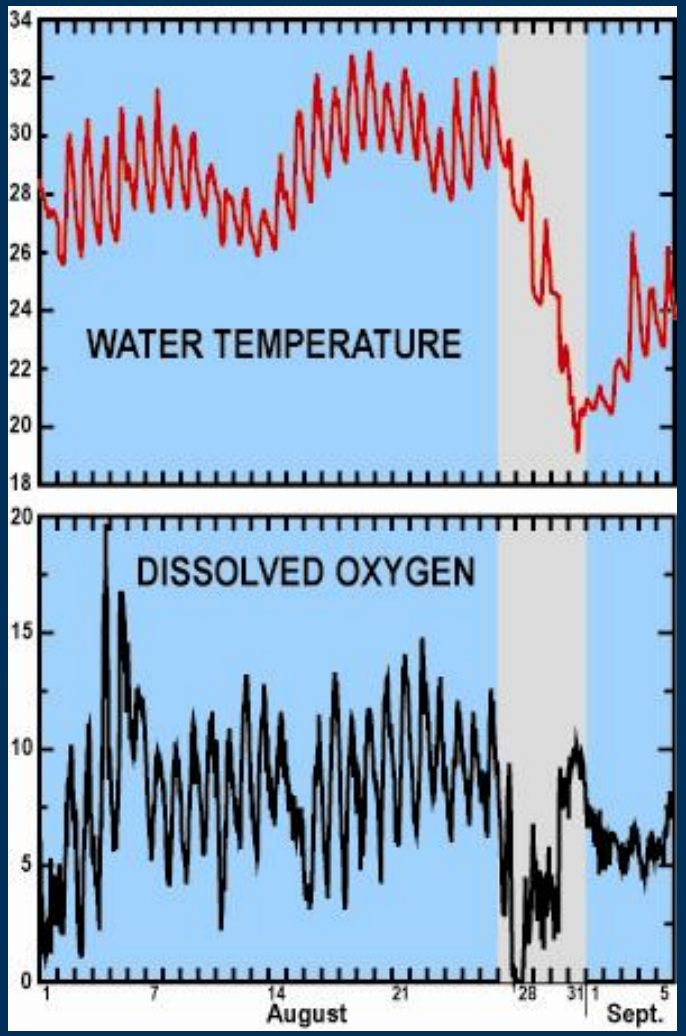
- DO conc. in Brush Creek significantly less than in the Blue River
- DO conc. in Plaza Pool greater than in other pools
- 1/3 time Volker Pool DO conc. less than full-support for aquatic life threshold

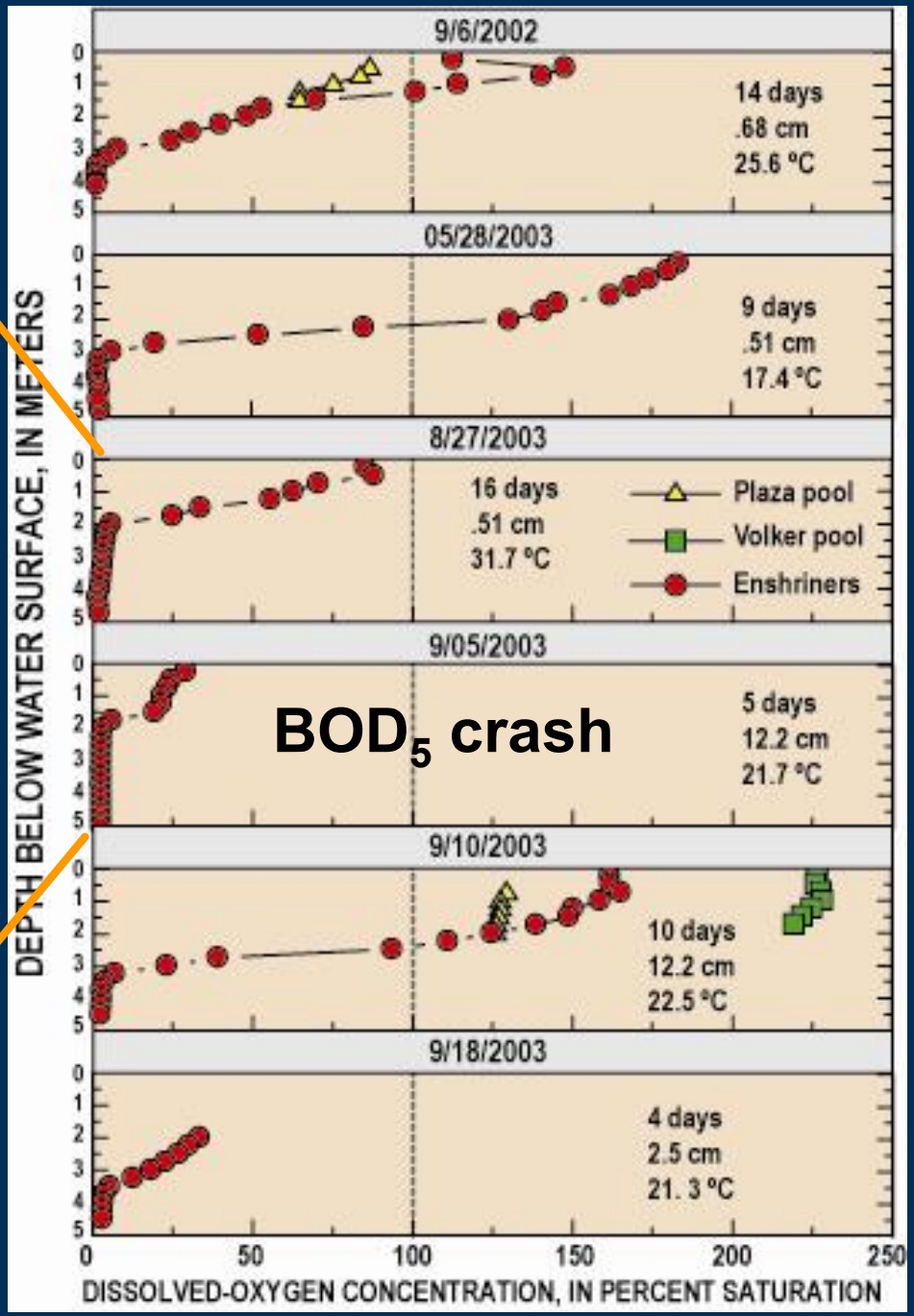


Basin water quality-Brush Creek impoundments

Range of productivities

Basin water quality- Brush Creek impoundments





BOD_5 crash

Cycles interrupted by precip events

Basin water quality-Brush Creek bottom sediments

- Include contributions from nonpoint source runoff and CSOs

- Lake of the Enshriners
  - Denitrification (N removal) in anoxic sediments
  - Release orthophosphate into water to supply algae growth
  - Drought periods can produce very reducing conditions (methanogenesis)

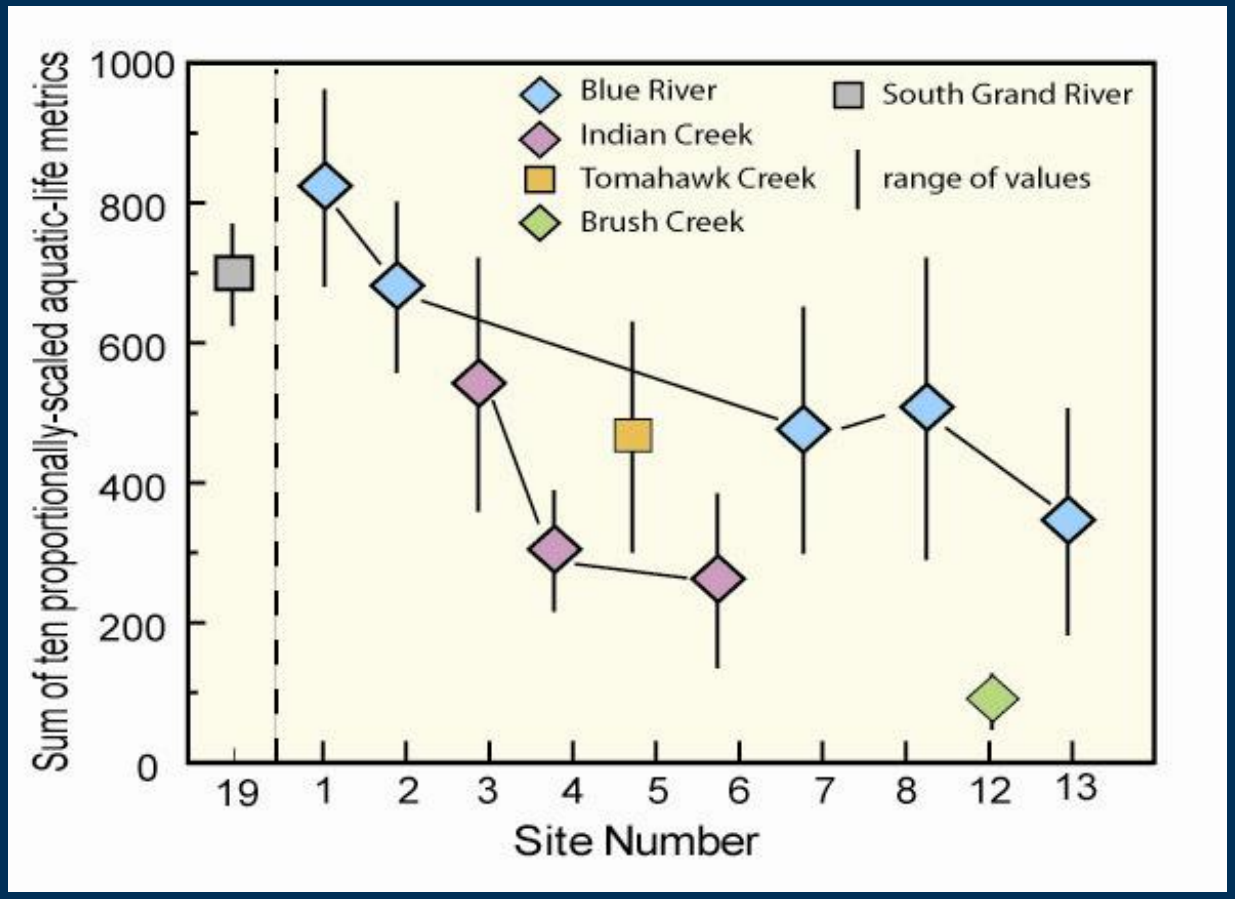
- Sterols, PAHS, plastics, and detergents had largest concentrations in bottom sediments

- Concentrations increased with impoundment size

- Decreased with time indicating some decompostion

- Concentrations of wastewater compounds in Brush Creek sediments were equivalent to, or greater than stream sediments near WWTP discharges

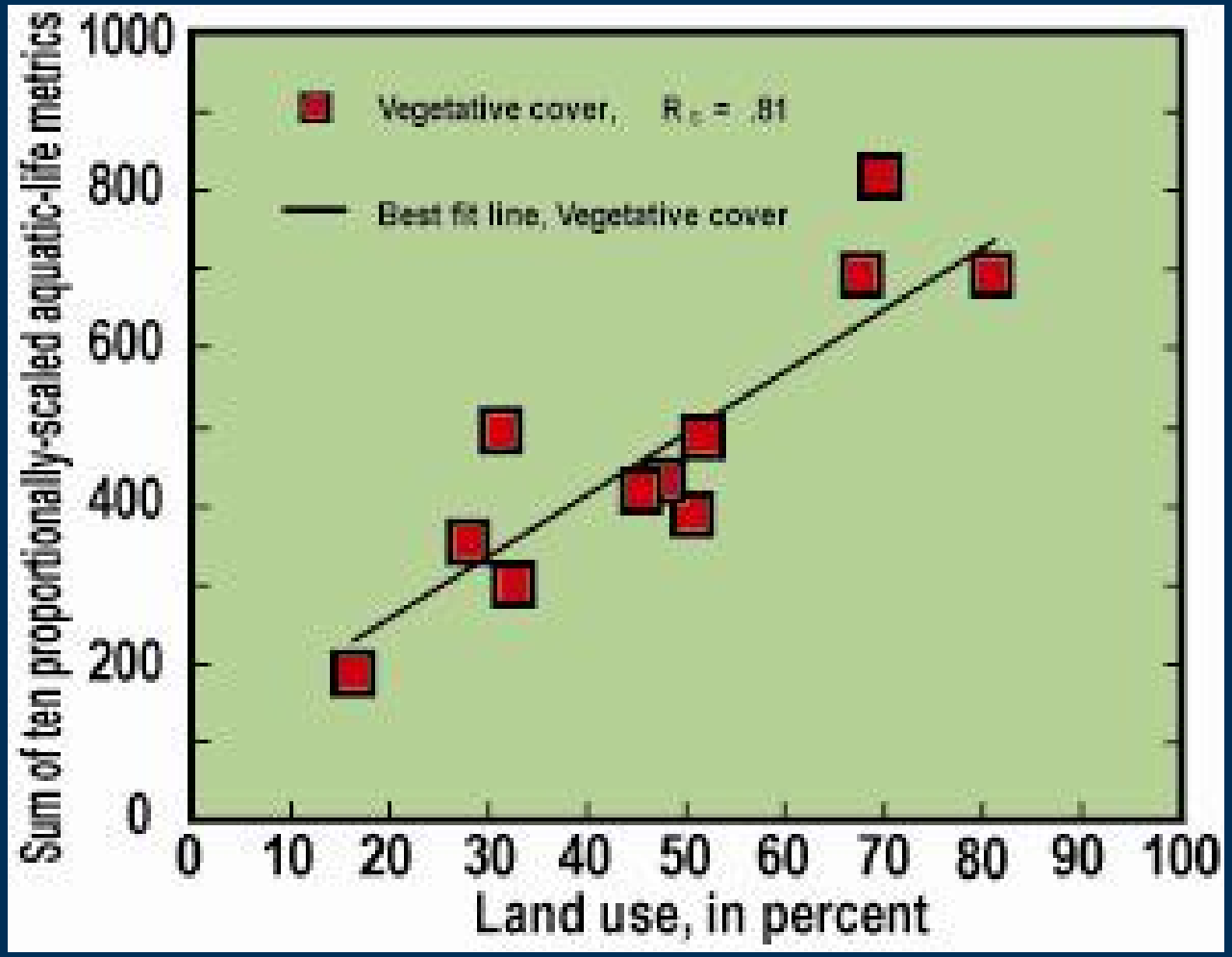
Basin water quality-biological assessments



- Aquatic health and diversity declines downstream in the basin
- Upper basin sites have higher scores than control sites

USGS

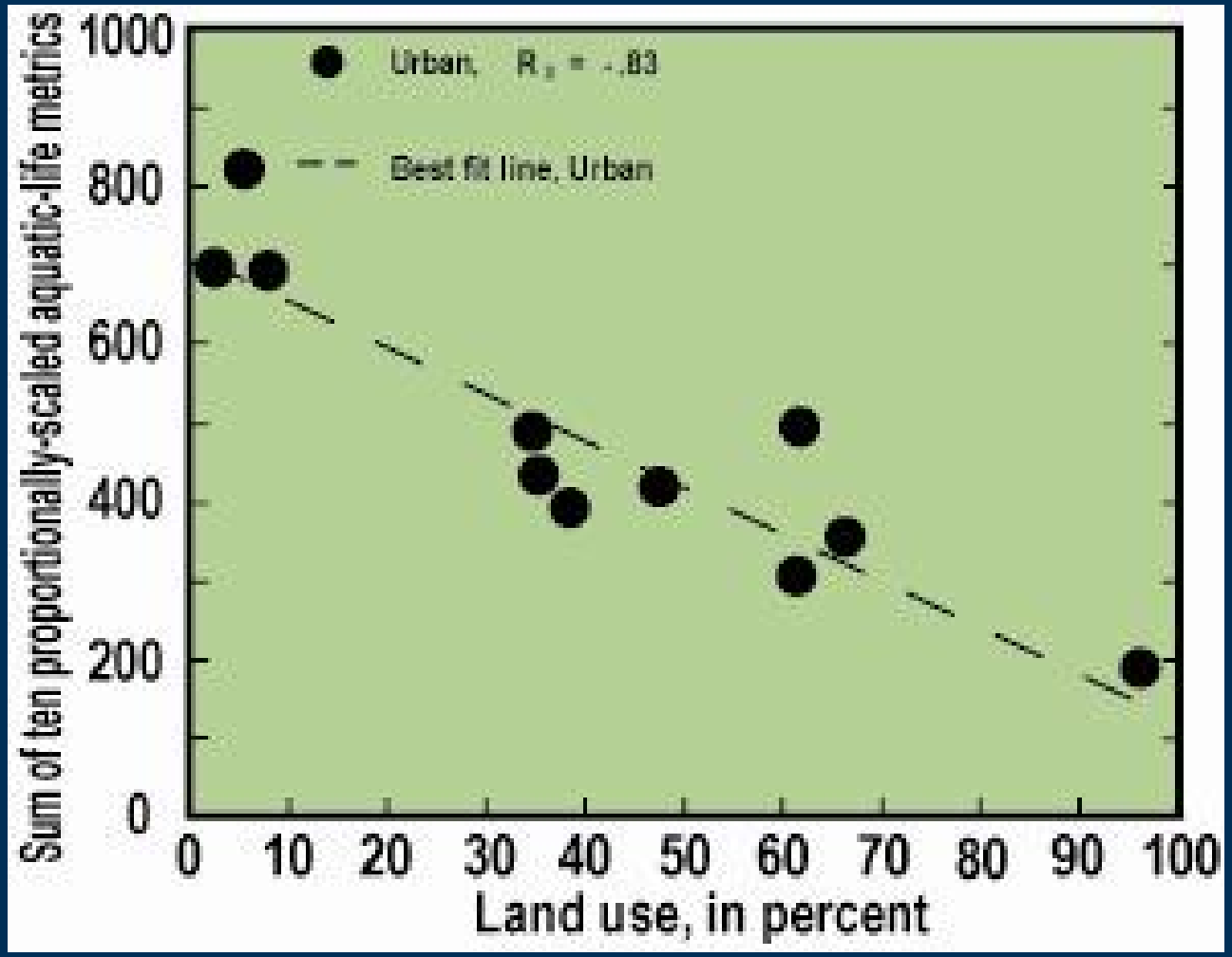
Basin water quality-biological assessments



- Aquatic health strongly correlated with greater amount of vegetation: forests + grasslands + parks

USGS

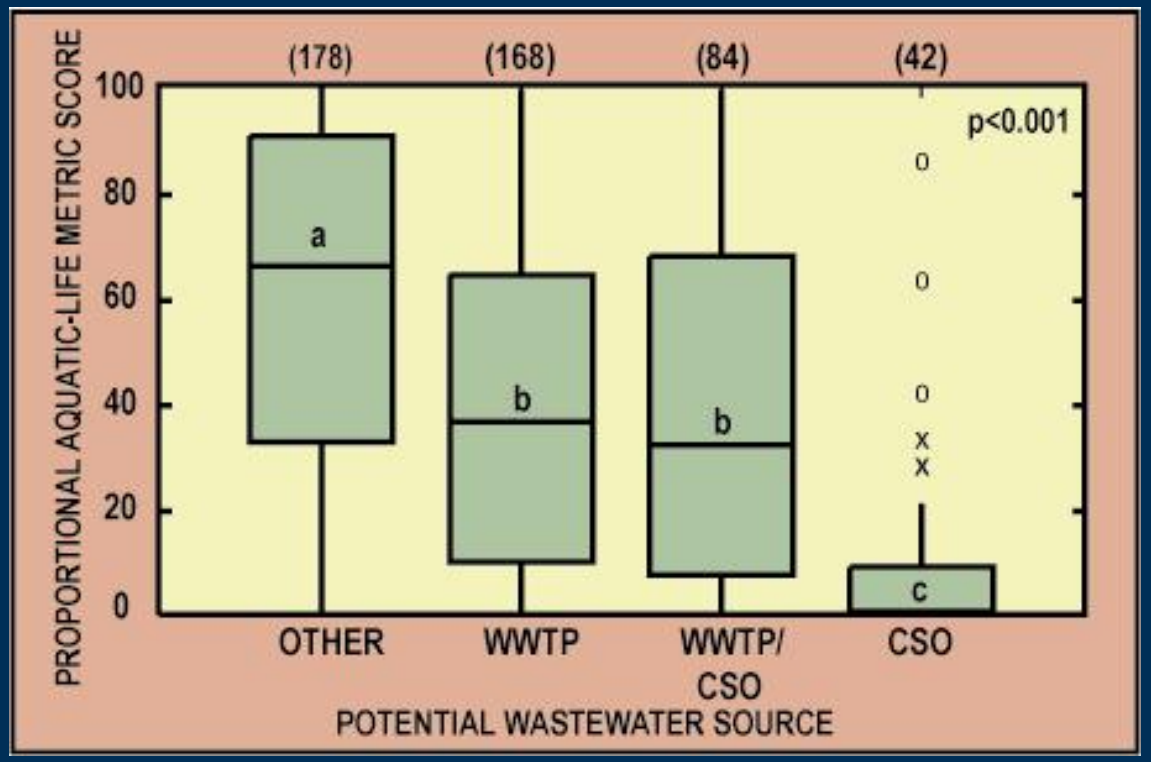
Basin water quality-biological assessments



- Declines correlated with increasing urbanization: sum of commercial + residential development + roads

USGS

Basin water quality-biological assessments



- Aquatic diversity highest at sites without apparent wastewater sources
- Difficult to separate urbanization from wastewater sources, increase simultaneously

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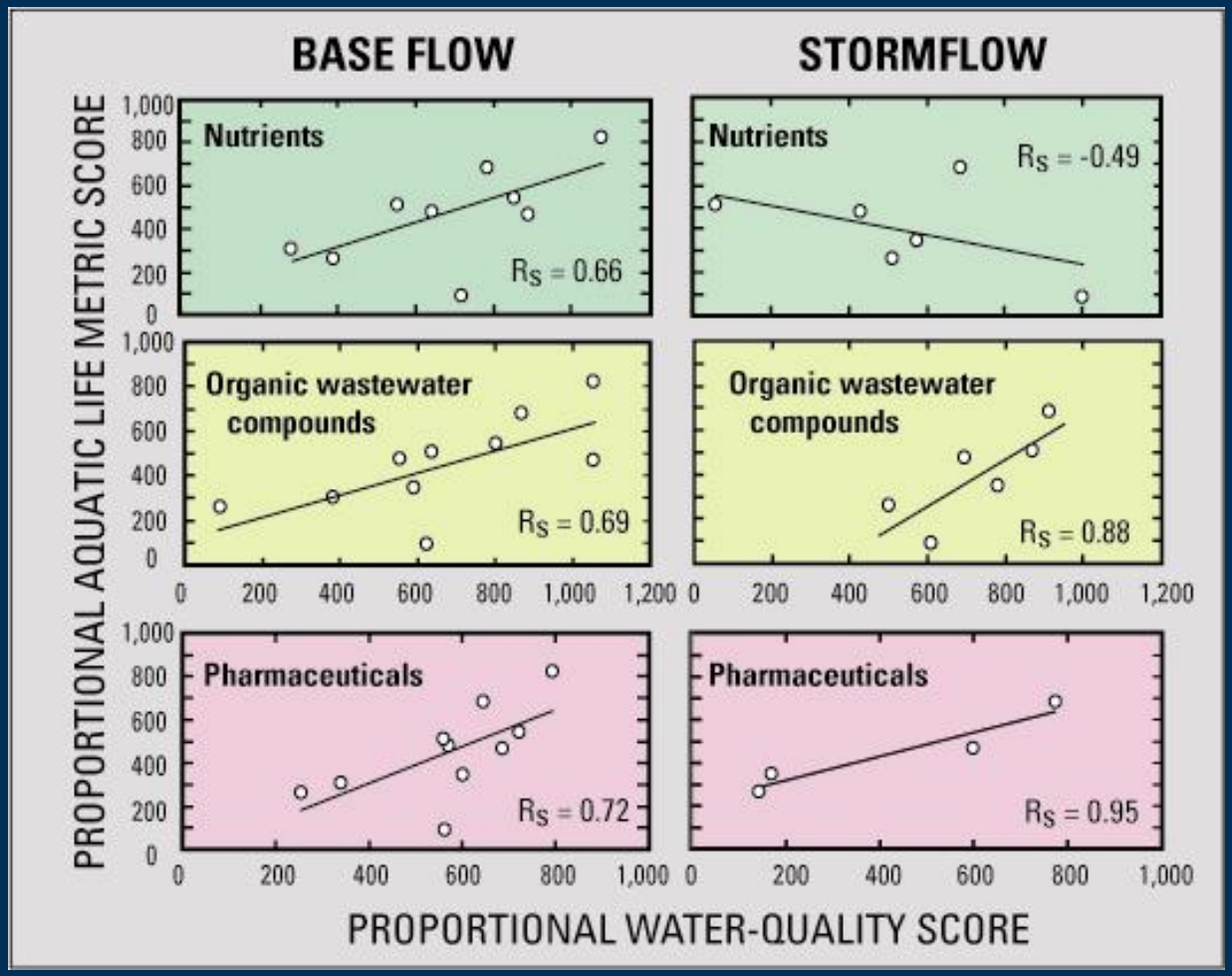
- **Basin water quality-biological assessments**



- **Lower aquatic life scores correlated with higher concentrations of: Nutrients, organic wastewater compounds, pharmaceuticals**
- **Exception-stormflow (nonpoint) nutrients**

Water quality in the Blue River Basin-Conclusions

- Basin approach
- Numerous, over-lapping, urban-related factors have adversely affected water quality and ecology in the basin
  - Channelization and flood control projects result in substantial loss of riparian vegetation, degraded stream habitat, altered stream hydrology
  - Significant urban nonpoint source contributions
  - Discharges of treated and untreated wastewater effect hydrology and water quality
- Nutrient enrichment is common at many sites
- Effects most pronounced in lower Indian Creek, the middle and lower Blue River, and lower Brush Creek

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Water quality in the Blue River Basin-Conclusions

- WWTPs provided dominant source of streamflow, nutrients, OWCs, and pharmaceuticals to middle and lower Indian Creek and Blue River during base flow
- Ecological capacity of receiving waters frequently exceeded; only a small part nutrients removed by in-stream processes
- During storms predominant sources shifted from point to nonpoint sources
- Suspended sediment and bacteria loads increased substantially during storms at all sites

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Water quality in the Blue River Basin-Conclusions

- In Brush Creek, wet weather events provided the dominant source of contaminants
- Wet weather contaminants are a combination of non-point and CSO sources
- Nutrient yields in lower Brush Creek are similar to those in the upper Blue River; not different from other US urban areas
- Hydrologic alterations to Brush Creek trapped nutrients, facilitated algal growth and eutrophication

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Water quality in the Blue River Basin-Conclusions

- Bacteria densities greatest in stormwater
- Significant nonpoint source contributions
- Sources vary temporarily and spatially
- Average presumptive sources in baseflow samples ranged from:
  - 26-32% Dog
  - 8-19% Geese
  - 28-42% Human
  - 18-28% Unknown or unclassified

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Water quality in the Blue River Basin-Conclusions

- Stream water quality in upper Blue River supports diverse biological component
- Aquatic integrity declines downstream in the basin
- Declines correlated to inter-related urbanization factors:
  - Declines in vegetative cover
  - Increases in development and
  - percent impervious cover
  - Increases in nutrient enrichment
  - Increases in wastewater inputs

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thank you

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