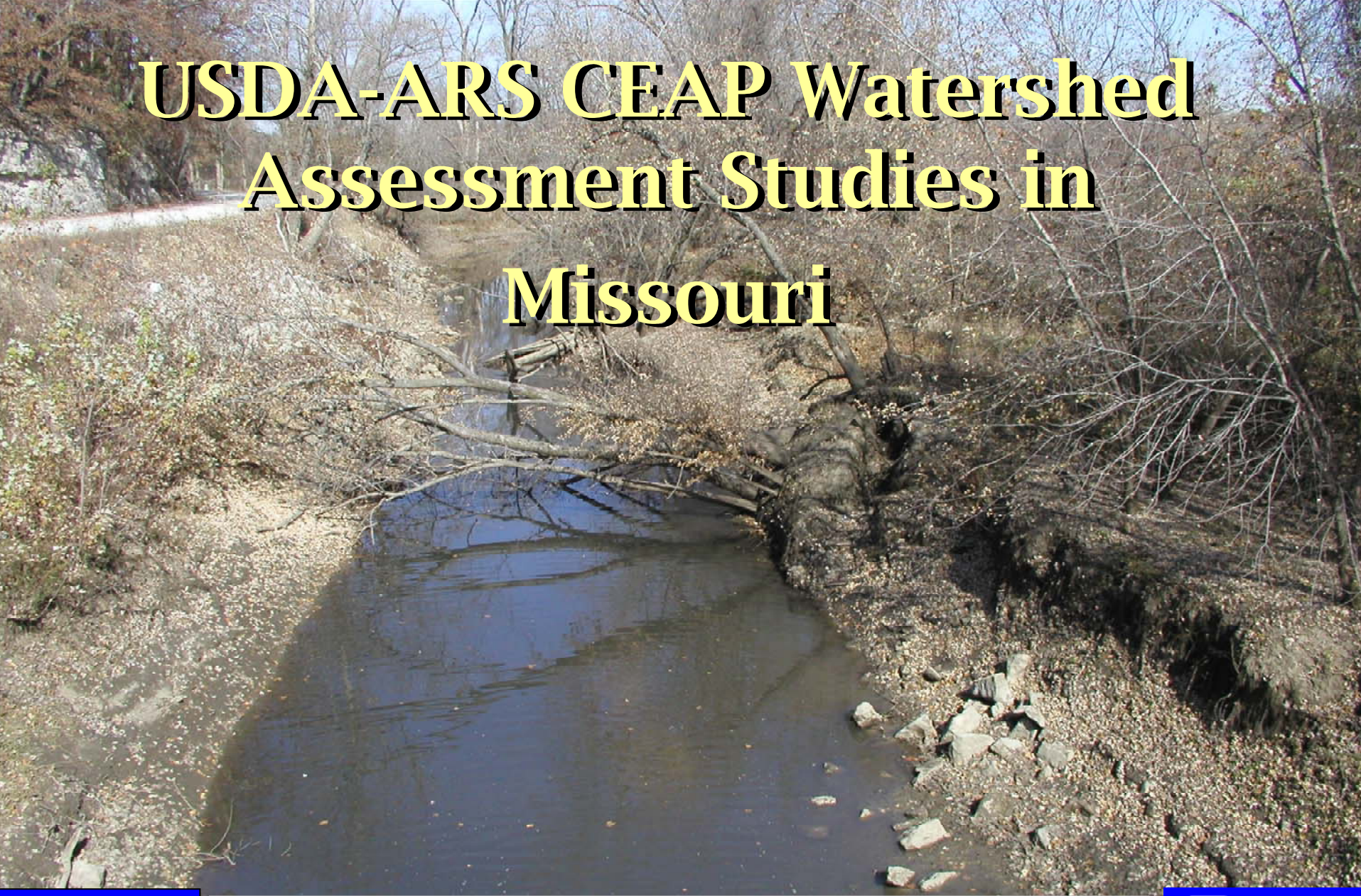
USDA-ARS CEAP Watershed Assessment Studies in Missouri



Robert Lerch, Research Soil Scientist
USDA-ARS, Cropping Systems and Water Quality Research Unit, Columbia, MO

Presentation Overview

- Two types of Water Quality Assessments
  - ✓Long-term Monitoring (15-year dataset) of Goodwater Creek Experimental Watershed (GCEW)
    - ♦Claypan watershed with predominantly agricultural land uses
    - ♦**Trends in Herbicide Transport**
  - ✓Baseline assessment of Bonne Femme Watershed
    - ♦Karst watershed with mixed land use; rapid urbanization occurring
    - ♦Broad-based assessment, including nutrients, herbicides, water-borne pathogens, and other general parameters
    - ♦**Facilitate *watershed planning***

Analysis of Herbicide Transport from Goodwater Creek Experimental Watershed

Robert N. Lerch, E. John Sadler, Kenneth A. Sudduth, and Claire Baffaut

USDA-ARS, Cropping Systems and Water Quality Research Unit, Columbia, MO

Objectives

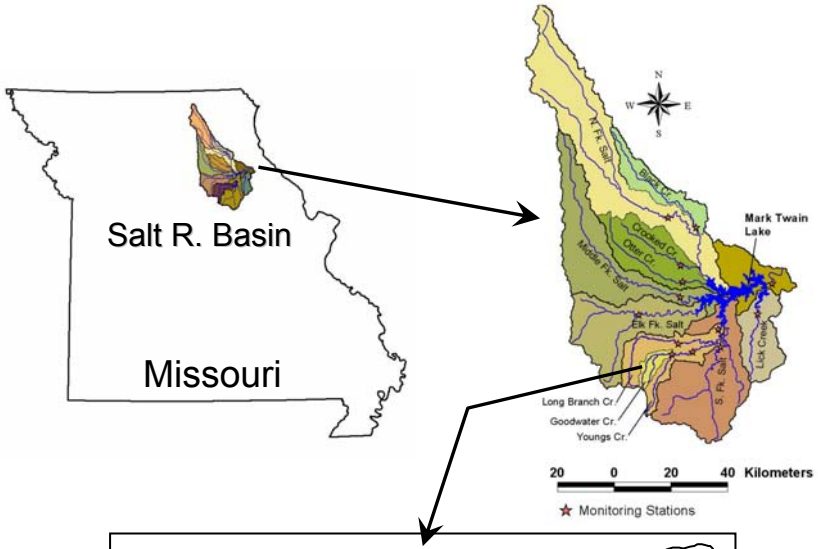
- To document the impact of prevailing farming systems on herbicide contamination and transport in Goodwater Creek Experimental Watershed (GCEW) — original objective.
- To analyze trends in herbicide concentration and load in GCEW from 1992-2006.

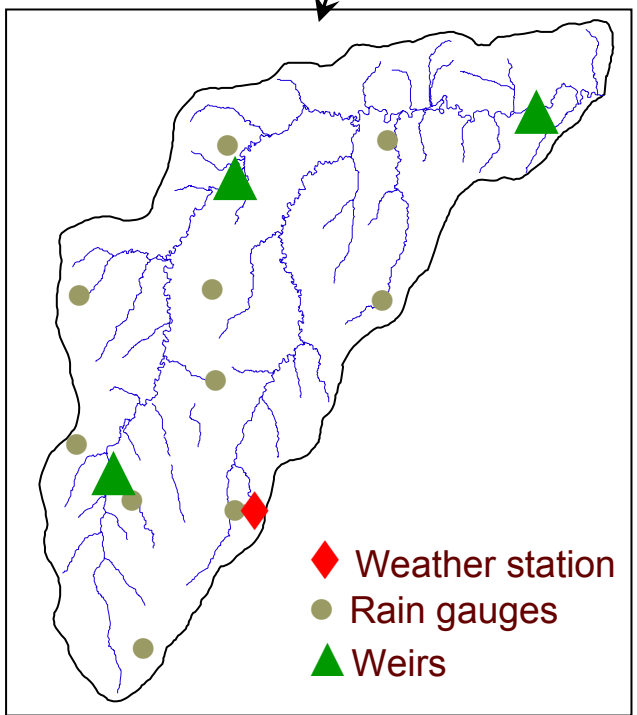
Lessons Learned*

- Herbicide transport is seasonal
  - ✓ Critical loss period from April through June
- Concentrations decline exponentially following field application
  - ✓ General model: $[C] = a(R/Q)e^{-(kt)}$ where C = concentration; R = herbicide application rate; Q = discharge; a,k – coefficients.
- Herbicide concentrations and loads were especially high in GCEW
  - ✓ High runoff potential soils are most vulnerable to herbicide transport.
- **Climate** is the main factor controlling herbicide transport
  - ✓ **Timing is everything** – occurrence of major runoff events relative to spring herbicide application explains annual variation in concentration and loads.

*Lerch et al., 1995, 1998; Donald et al., 1998; Blanchard and Lerch, 2000; Lerch and Blanchard, 2003; Ghidey et al., 2005

Goodwater Creek Experimental Watershed



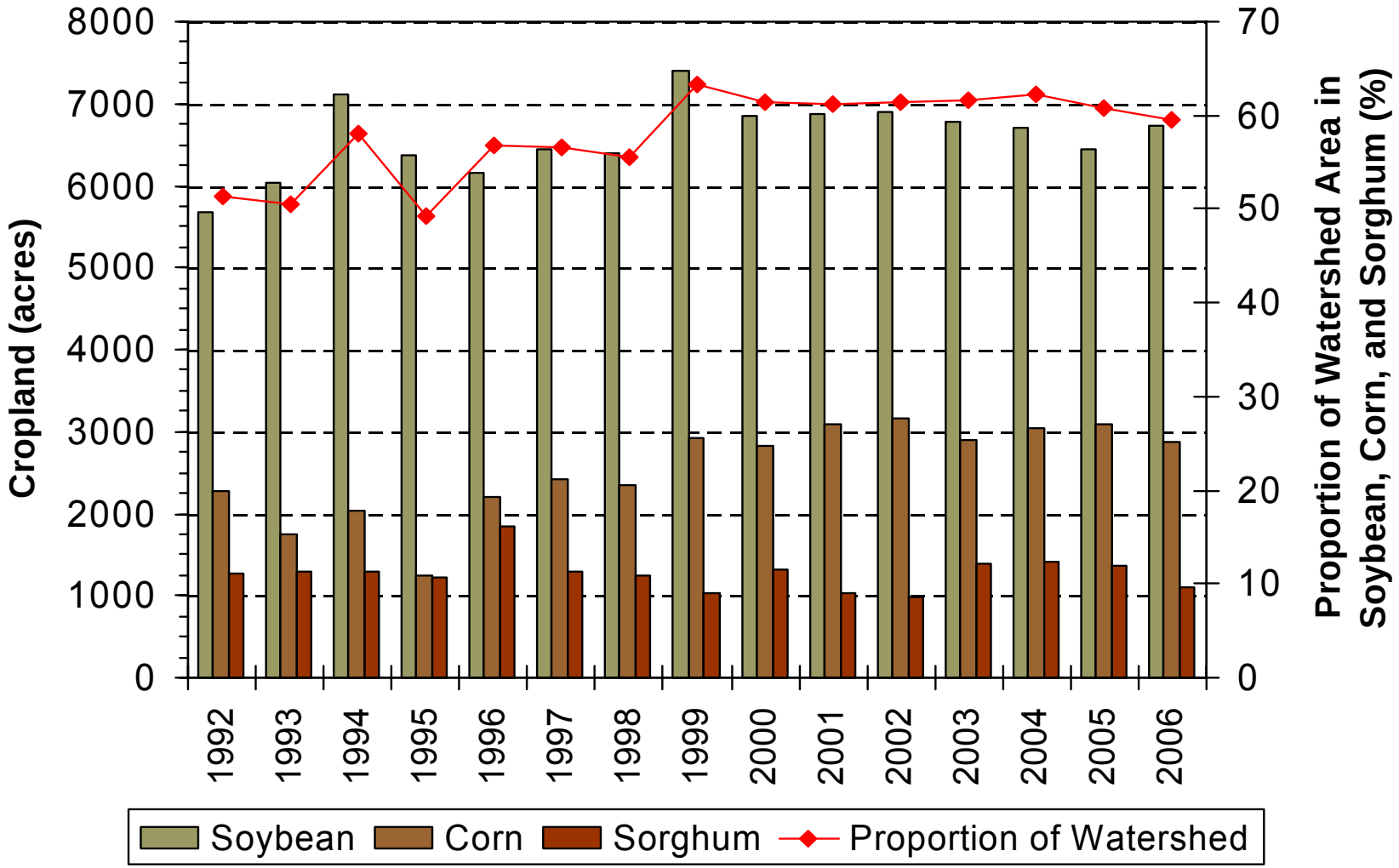


- Drainage area - 72 km^2
  - ✓ 1st – 3rd order streams
- Flat to gently rolling topography (1-3% slopes)
- Claypan soils – high runoff potential
- Surface water hydrology
  - ✓ ~35-yr record
  - ✓ Discharge and Sediment
  - ✓ Weather station and rainfall network
  - ✓ Water table depth
  - ✓ Monitoring stations w/ weirs
- Water quality
  - ✓ ~15-yr record
  - ✓ Nutrients
  - ✓ Pesticides
  - ✓ Surface and Ground water

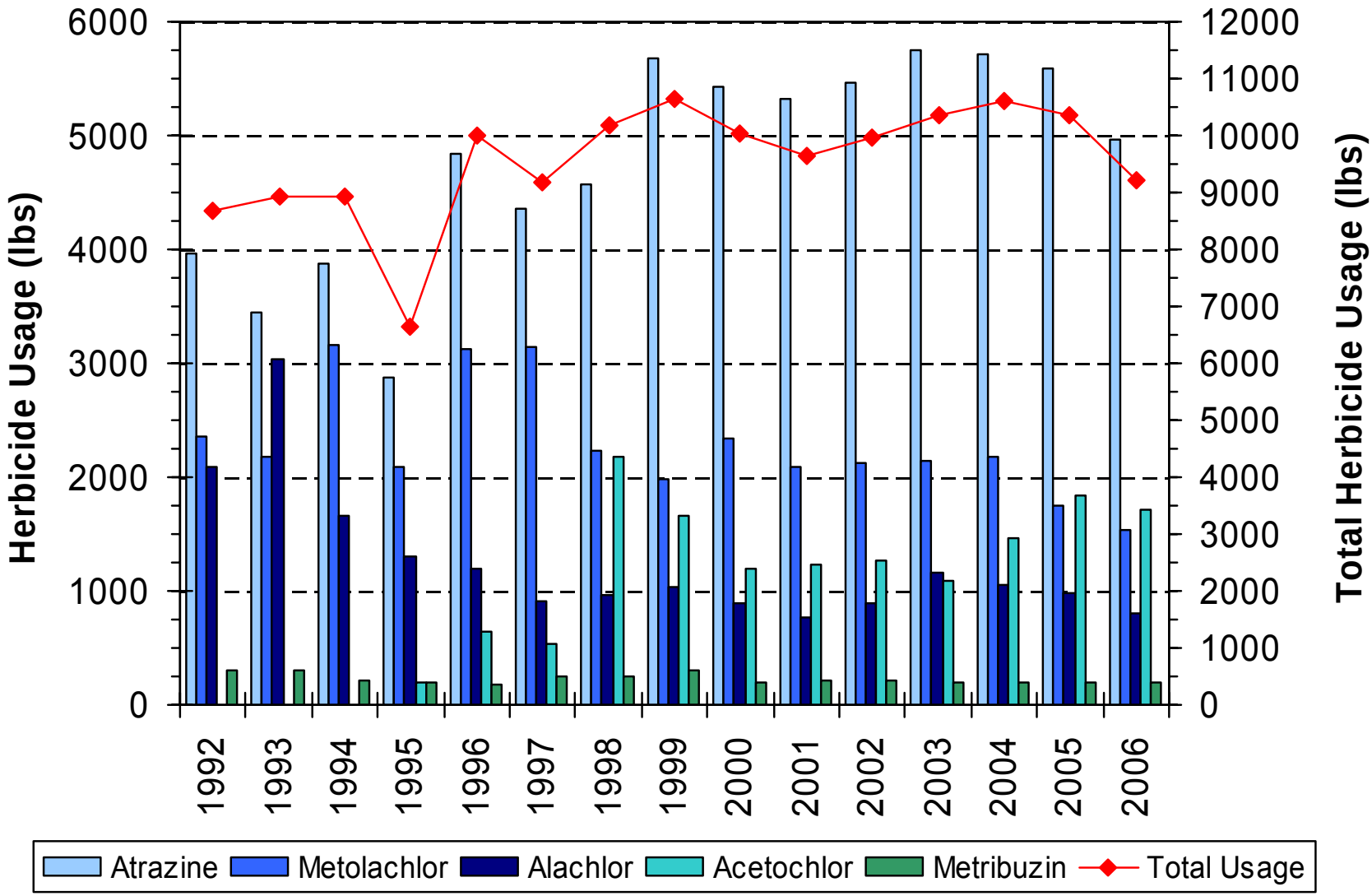
Materials and Methods

- **Data**
  - ✓ Daily stream discharge, precipitation, and herbicide concentration data from 1992-2006 at the GCEW outlet.
  - ✓ Herbicide loads computed using flow-weighted concentrations for days that measurements were made and linear interpolation for un-sampled days.
  - ✓ Cumulative frequency diagrams based on ranked data
- **Herbicides**
  - ✓ Atrazine, alachlor, metolachlor, acetochlor, and metribuzin. Weekly baseflow and flow-proportional runoff sampling.
  - ✓ USDA-NASS data – % crop area treated, application rates, and district planting progress.
- **Land Use**
  - ✓ 1992-93 – initial land use estimates, including crop specific data, were obtained through USDA-FSA records (Heidenreich, 1994).
    - Unreported cropped areas partitioned based on FSA records.
  - ✓ 1994-2005 – NASS Audrain County crop data used to estimate relative annual change in corn, soybean, and, sorghum area within GCEW.
  - ✓ 2006 – ARS windshield survey of GCEW cropped acreage; used to create an annual adjustment of the Audrain County data

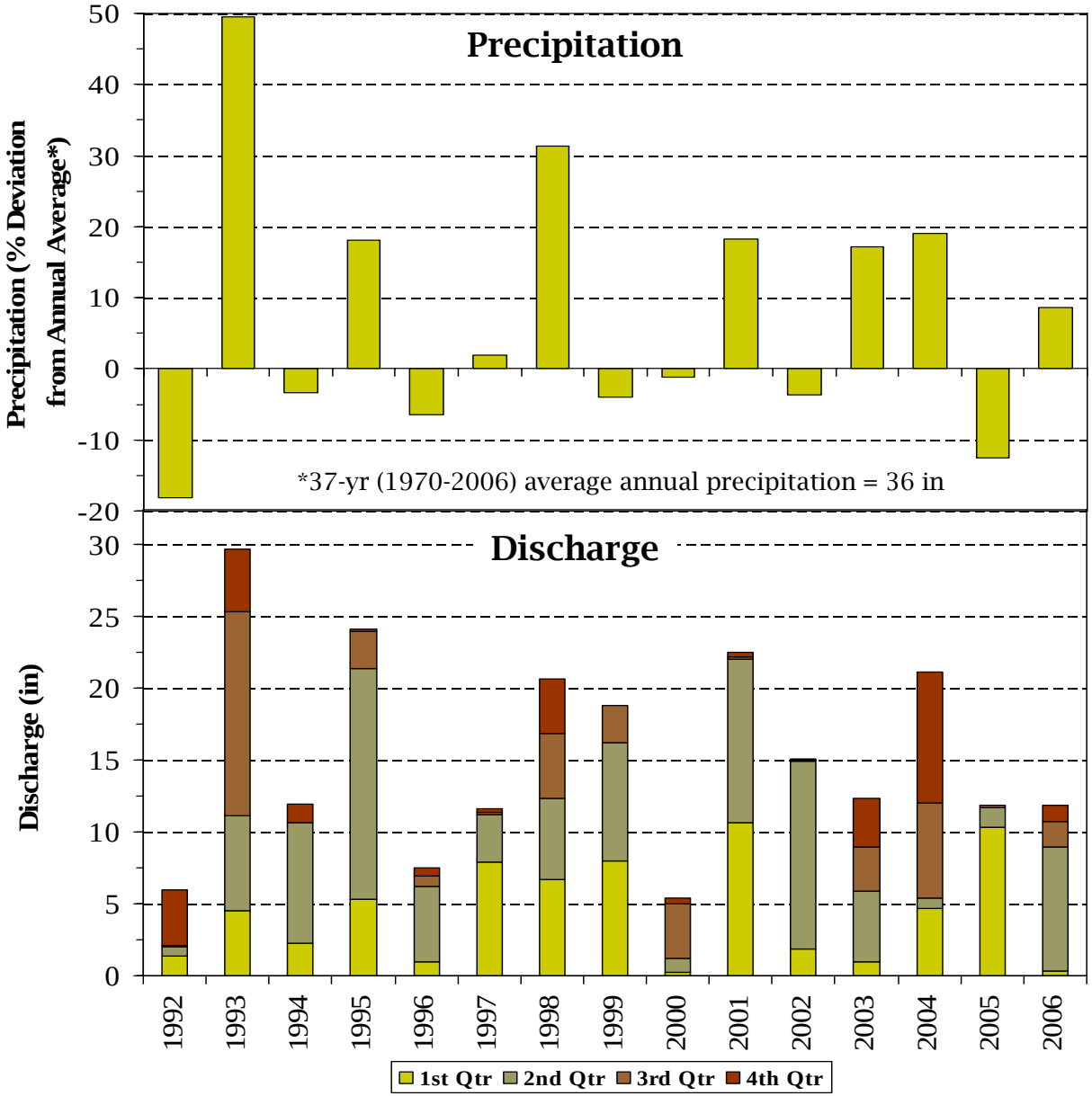
Row Crop Area



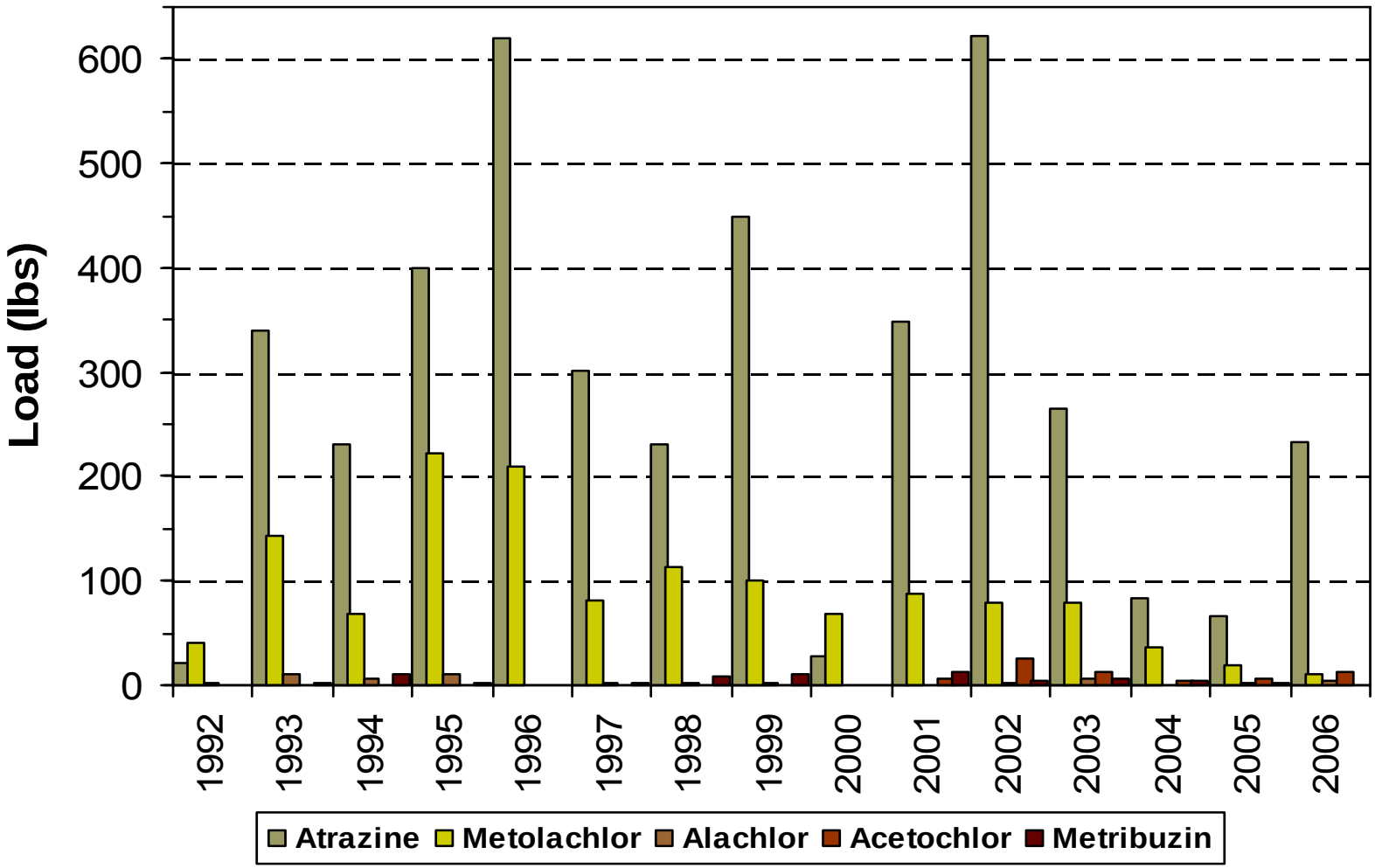
Herbicide Usage



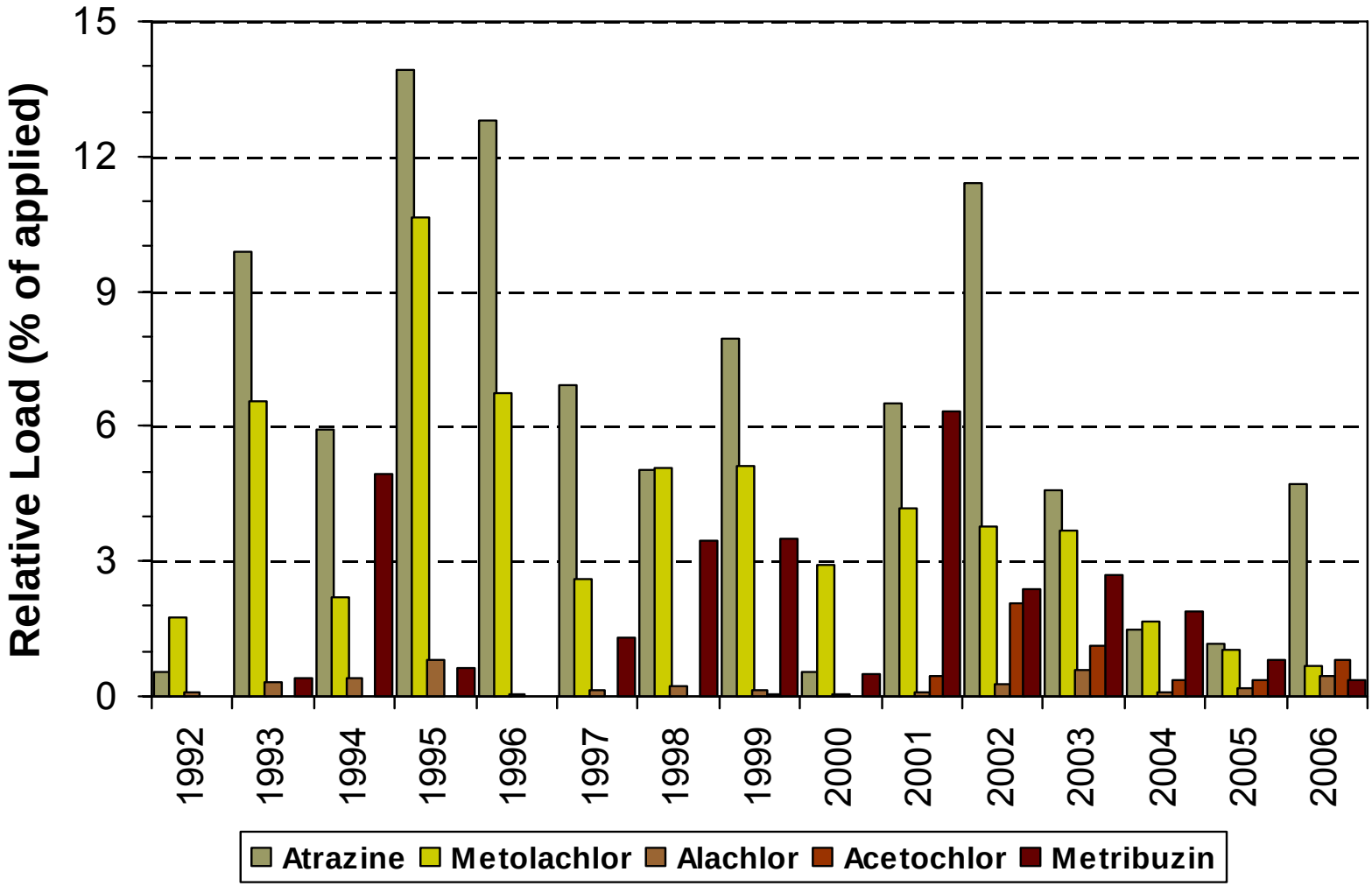
Precipitation and Discharge



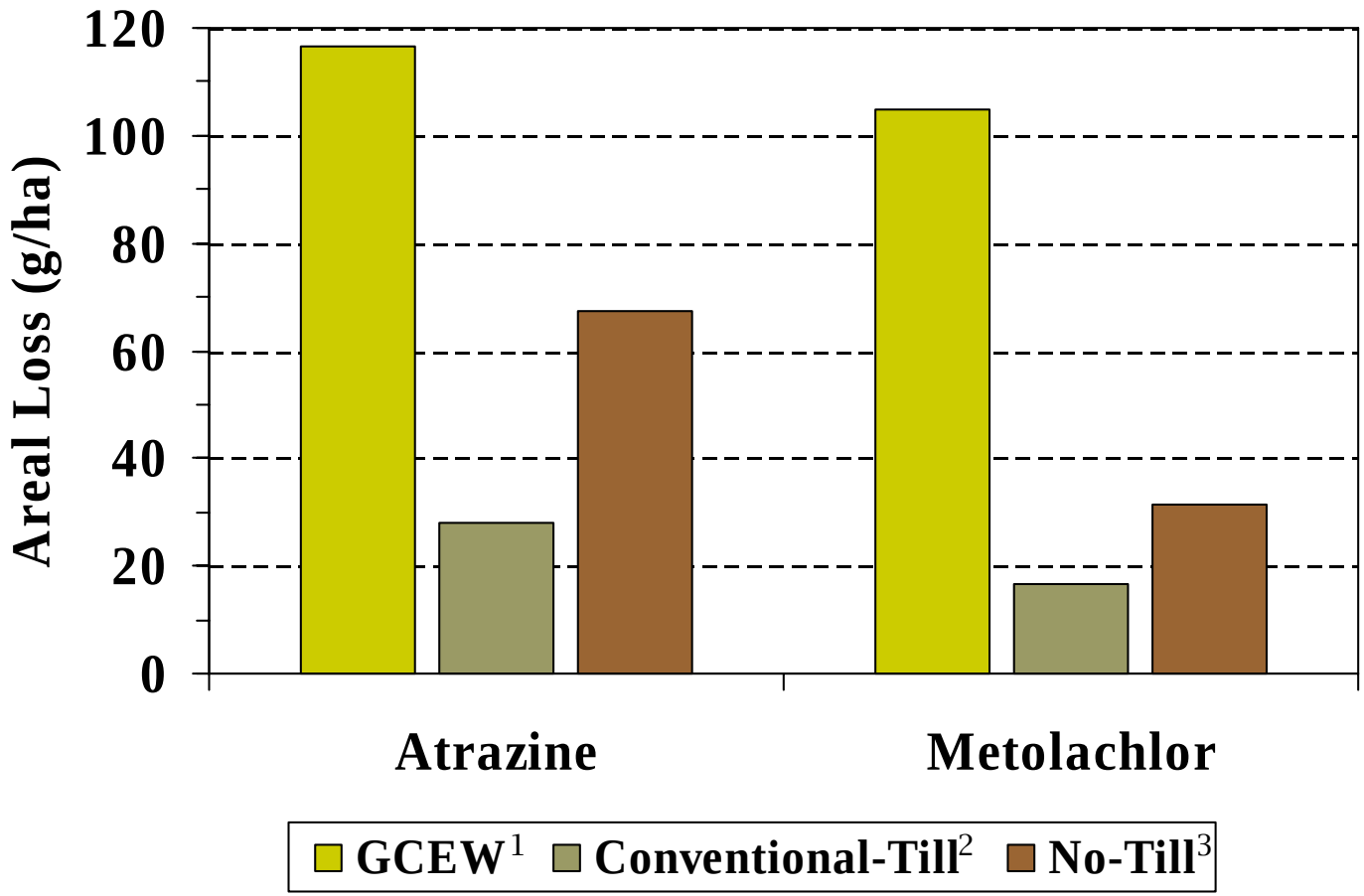
Absolute Herbicide Loads



Relative Herbicide Loads

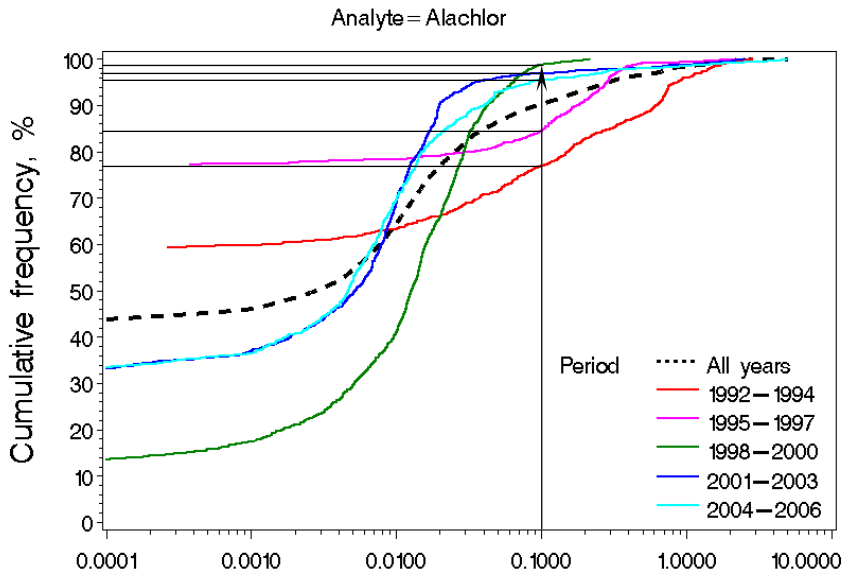


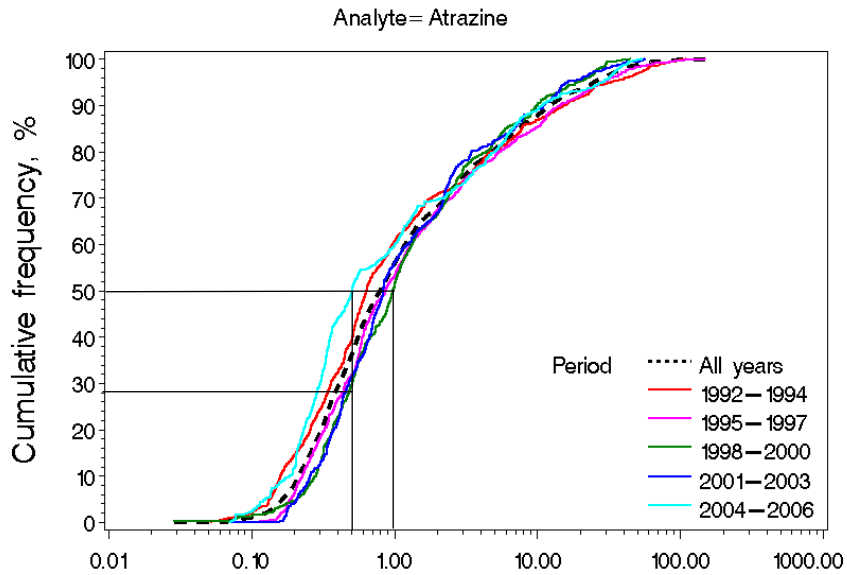
Areal Loss – Watershed and Field Scales

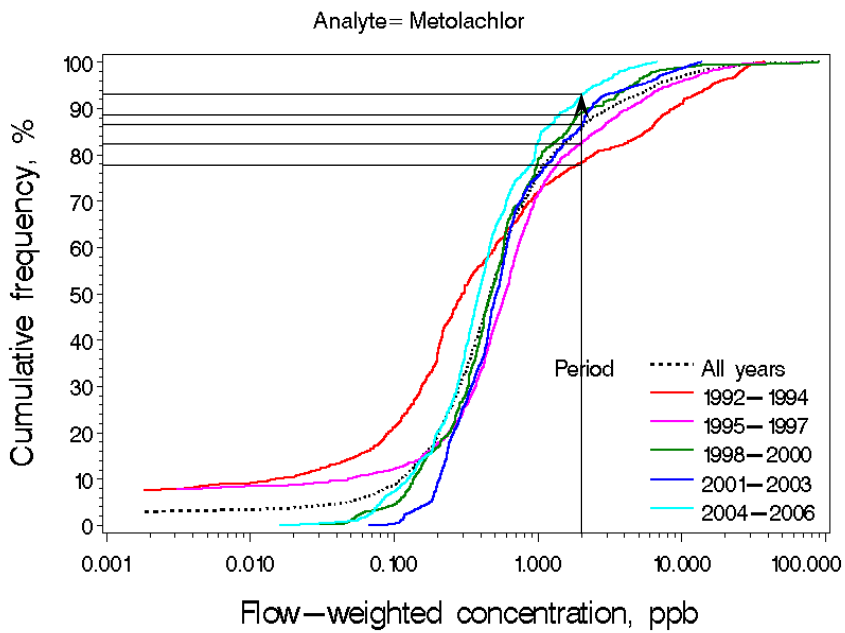


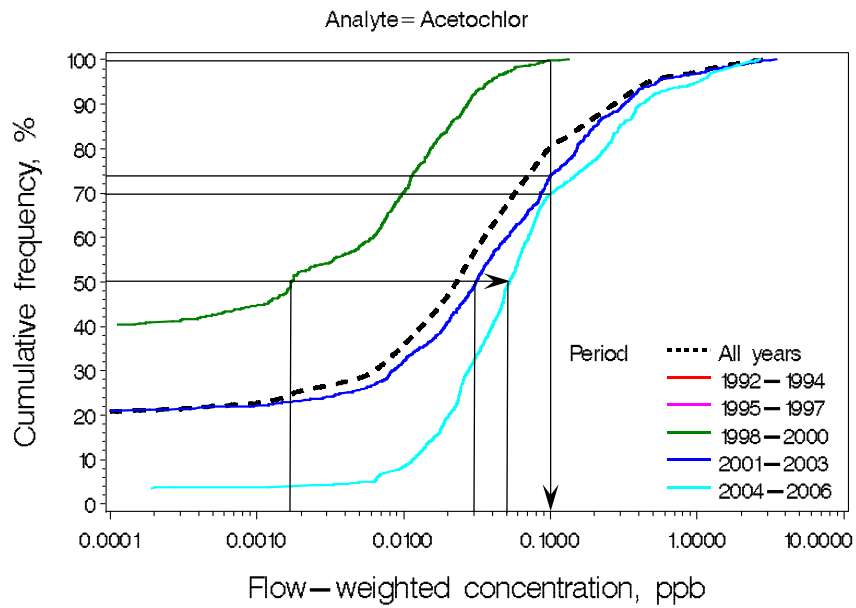
[1]Treated area basis. [2]Herbicides incorporated and applied at maximum label rate. [3]Herbicides not incorporated; application rates varied, but less than maximum label rate.

Trends in Herbicide Concentration, 1992-2006









Trends in Herbicide Concentration, 1992-2006

Correlation Analyses

Herbicide	2nd Quarter Discharge vs. Annual Load		Annual Use vs. Annual Load		Annual Load vs. Time		MCL Exceedance vs. Time	Median Concentration vs. Time	Maximum Concentration vs. Time
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.			
Atrazine	0.68§	0.77	-0.06	-0.41	-0.13	-0.34	-0.01	-0.12	-0.33
Metolachlor	0.48	0.59	0.34	0.09	-0.55	-0.48	_	0.30	-0.36
Alachlor	0.49	0.61	0.58	0.13	-0.36	-0.02	_	-0.26	-0.03
Acetochlor	0.58	0.58	-0.34	-0.44	0.47	0.36	_	0.65	0.63
Metribuzin	0.34	0.35	0.10	-0.02	0.06	0.10	_	0.82	-0.23

§Correlation coefficient, r; For all correlations, n = 15 except Acetochlor, n = 9.

Red = significant at p = 0.01; Blue = significant at p = 0.05; Black = non-significant.

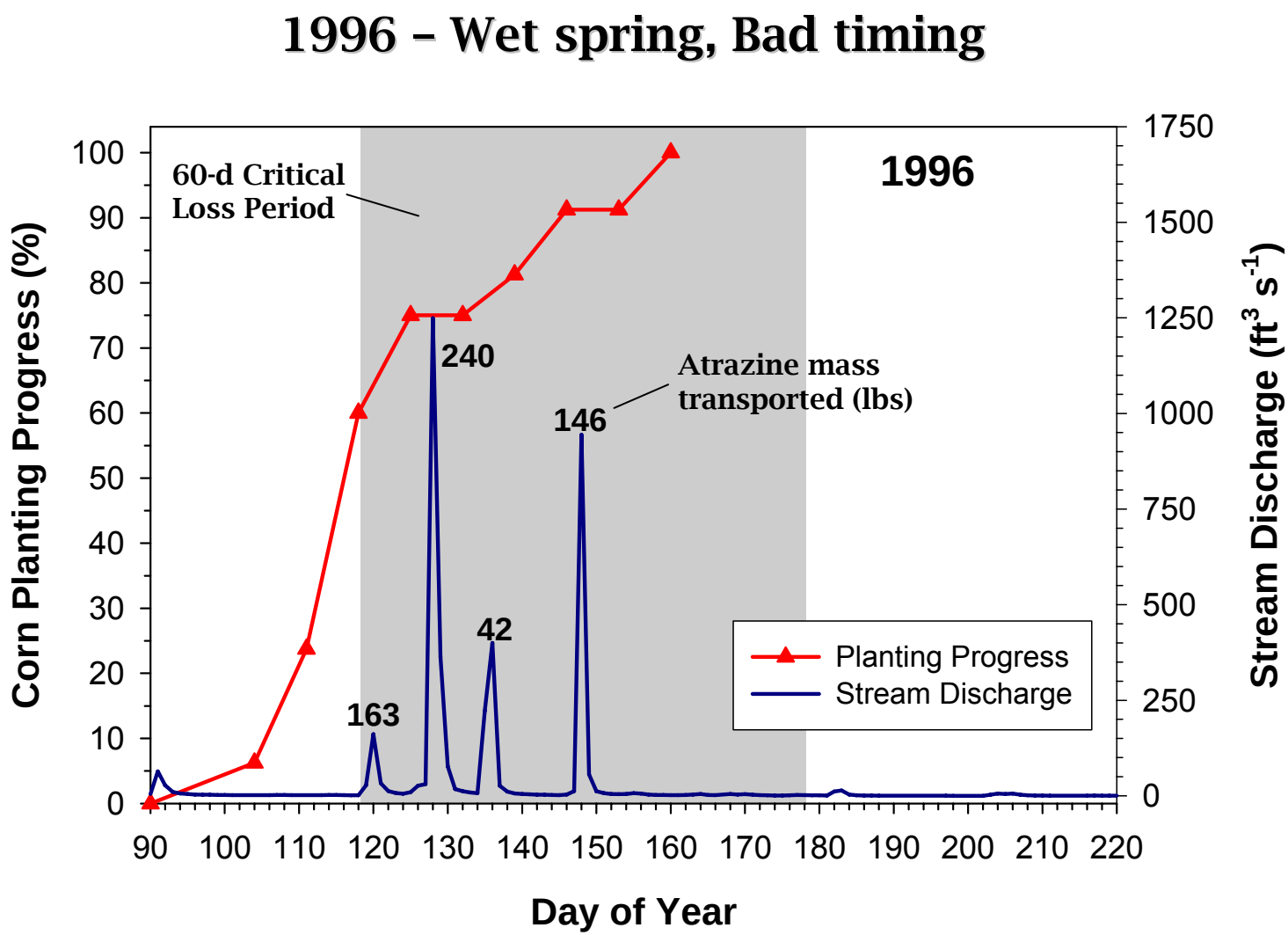
Atrazine Ecological Criteria

Days Per Year Exceeding Levels of Concern§

Year	14-Day	30-Day	60-Day	90-Day
1992	**35** (86.4)	**44** (71.1)	**68** (47.1)	**105** (32.3)
1993	**0**	**6** (29.2)	**34** (23.3)	**66** (16.9)
1994	**0**	**0**	**0**	**0**
1995	**8** (44.9)	**5** (27.6)	**0**	**0**
1996	**14** (62.1)	**25** (38.7)	**44** (26.4)	**93** (23.4)
1997	**18** (65.3)	**30** (47.1)	**56** (30.5)	**89** (22.3)
1998	**0**	**0**	**0**	**0**
1999	**0**	**0**	**0**	**0**
2000	**0**	**0**	**0**	**0**
2001	**5** (43.0)	**2** (27.3)	**0**	**24** (12.9)
2002	**0**	**0**	**0**	**16** (13.1)
2003	**0**	**0**	**0**	**0**
2004	**0**	**9** (29.4)	**7** (18.4)	**40** (13.2)
2005	**0**	**0**	**0**	**59** (13.5)
2006	**2** (38.3)	**15** (34.5)	**35** (19.5)	**69** (14.8)

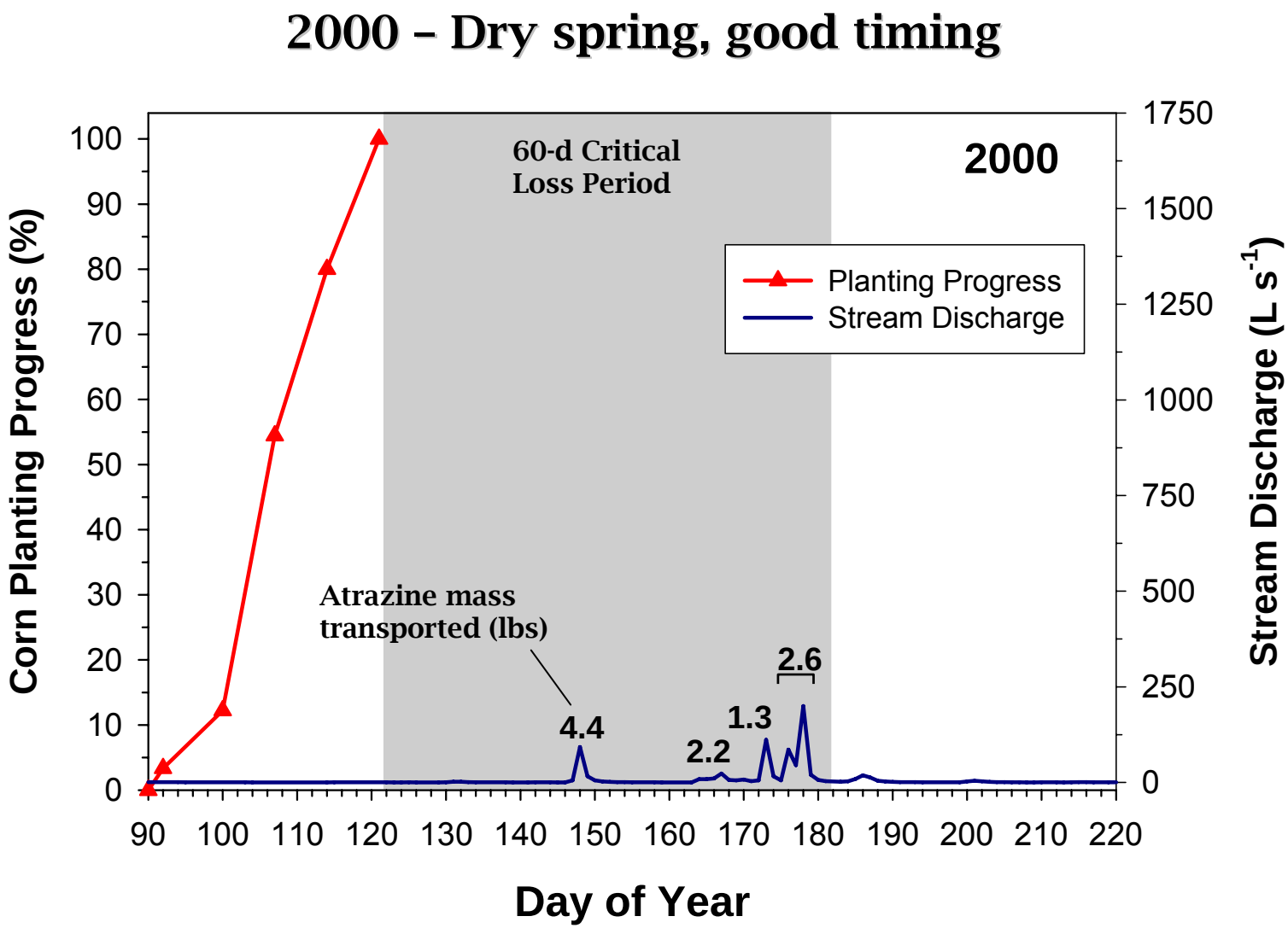
§Levels of concern based on EPA Interim Re-registration Eligibility Agreement (2003); 14-day = 38 ppb; 30-day = 27 ppb; 60-day = 18 ppb; 90 day = 12 ppb. Numbers in parentheses equal maximum running average for the year.

Planting and Runoff Timing



Large runoff events during the critical loss period

Planting and Runoff Timing

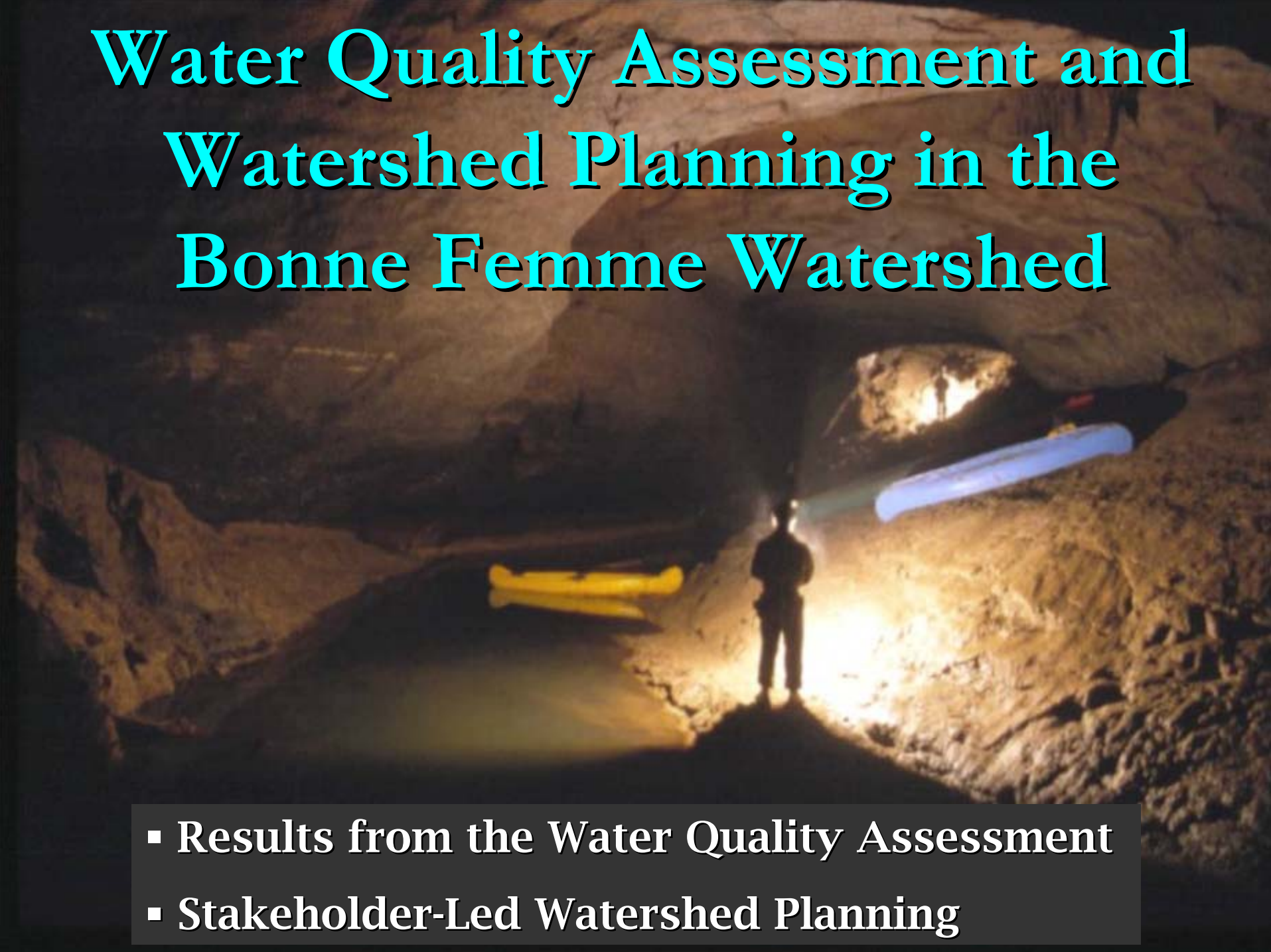


Small runoff events at the end of the critical loss period

Summary and Conclusions

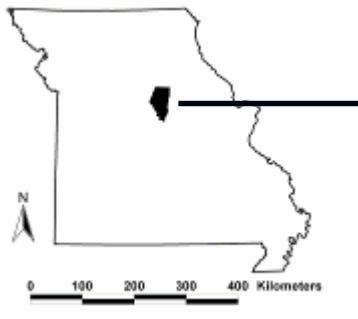
- **Land Use**
  - ✓ Soybean, corn, and sorghum area increased from ~50% of the watershed in 1992 to ~60% in 2006.
  - ✓ Corn acreage more than doubled from 1995 (1255 ac) to 2006 (2886 ac).
- **Herbicide Usage**
  - ✓ Total soil-applied usage has increased from ~8700 lbs/yr to ~10,000 lbs/yr.
  - ✓ Atrazine accounts for more than half the soil-applied herbicide usage.
- **Concentration and Load Trends**
  - ✓ Decreasing alachlor and metolachlor concentrations and loads over time reflect declines in usage.
  - ✓ **No significant trends for atrazine concentration or load**.
- **Factors Controlling Herbicide Transport in GCEW**
  - ✓ Claypan soils – hydrology affects magnitude of transport.
  - ✓ Usage – magnitude and type.
  - ✓ Climate
    - **Interaction of application and runoff events – *Timing is everything!!***

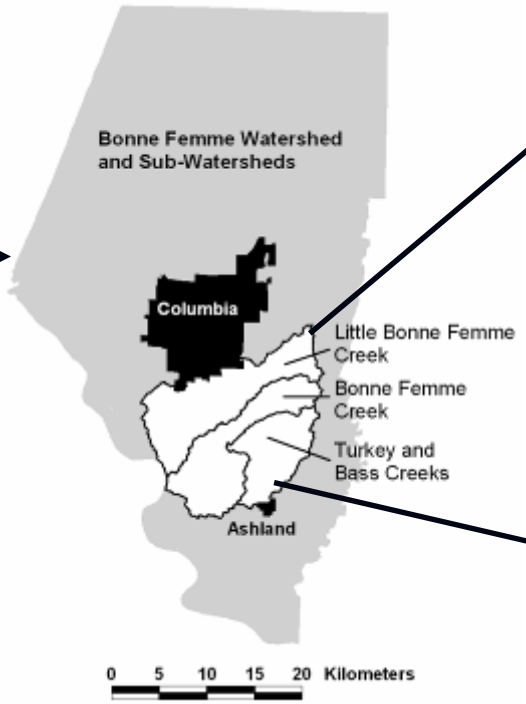
Water Quality Assessment and Watershed Planning in the Bonne Femme Watershed

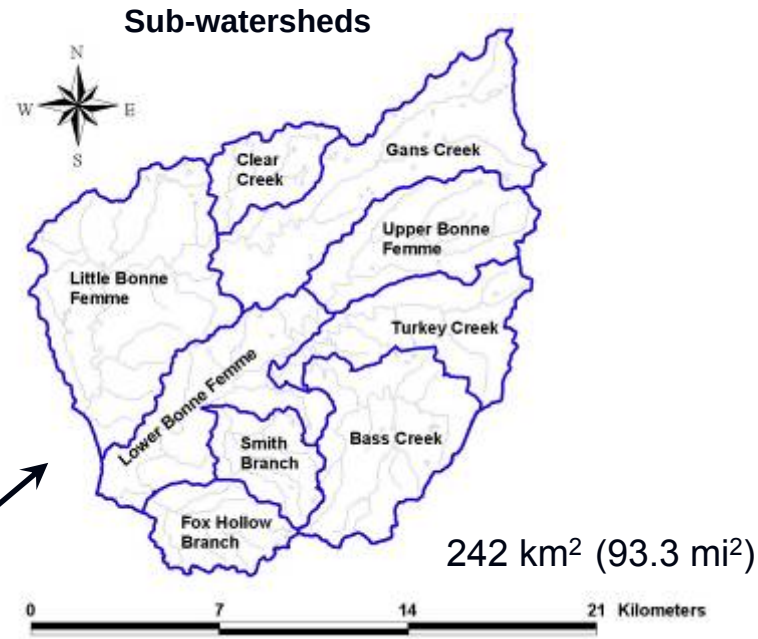


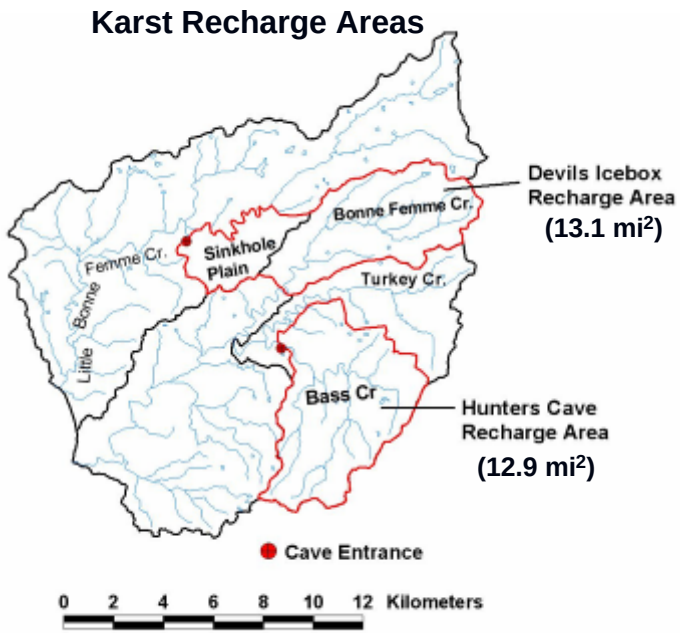
- Results from the Water Quality Assessment
- Stakeholder-Led Watershed Planning

Location of Bonne Femme Watershed, Sub-watersheds, and Karst Recharge Areas.

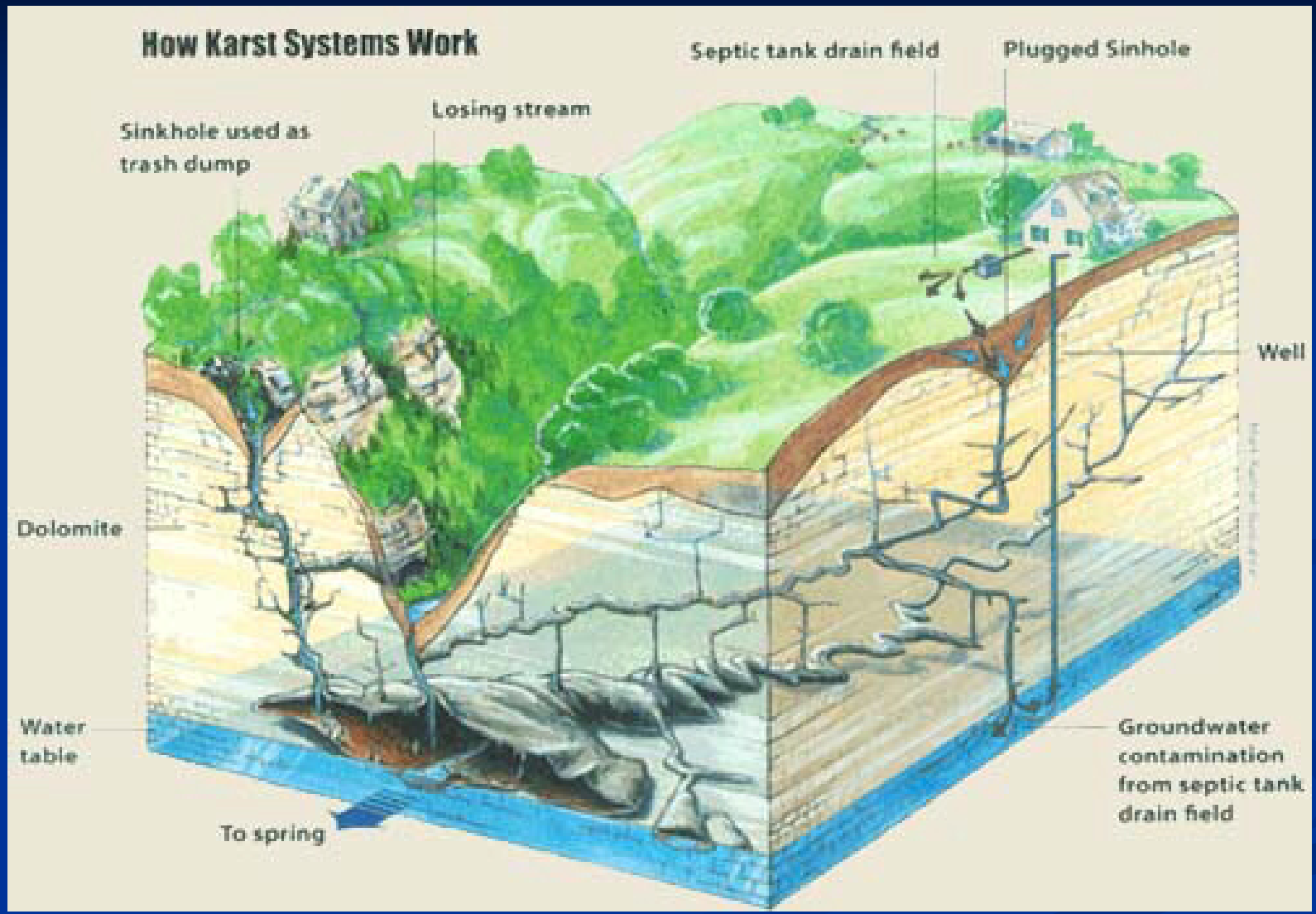






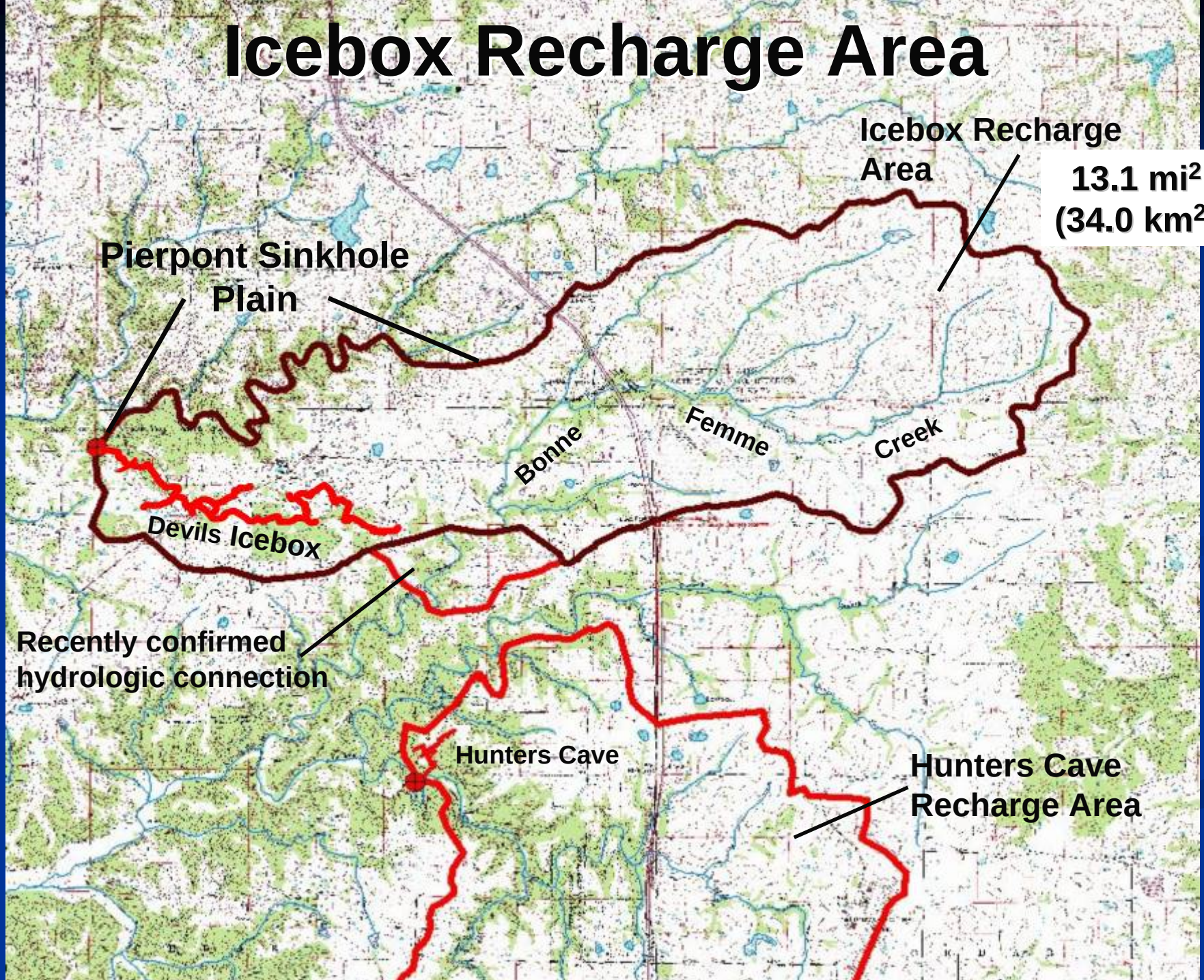


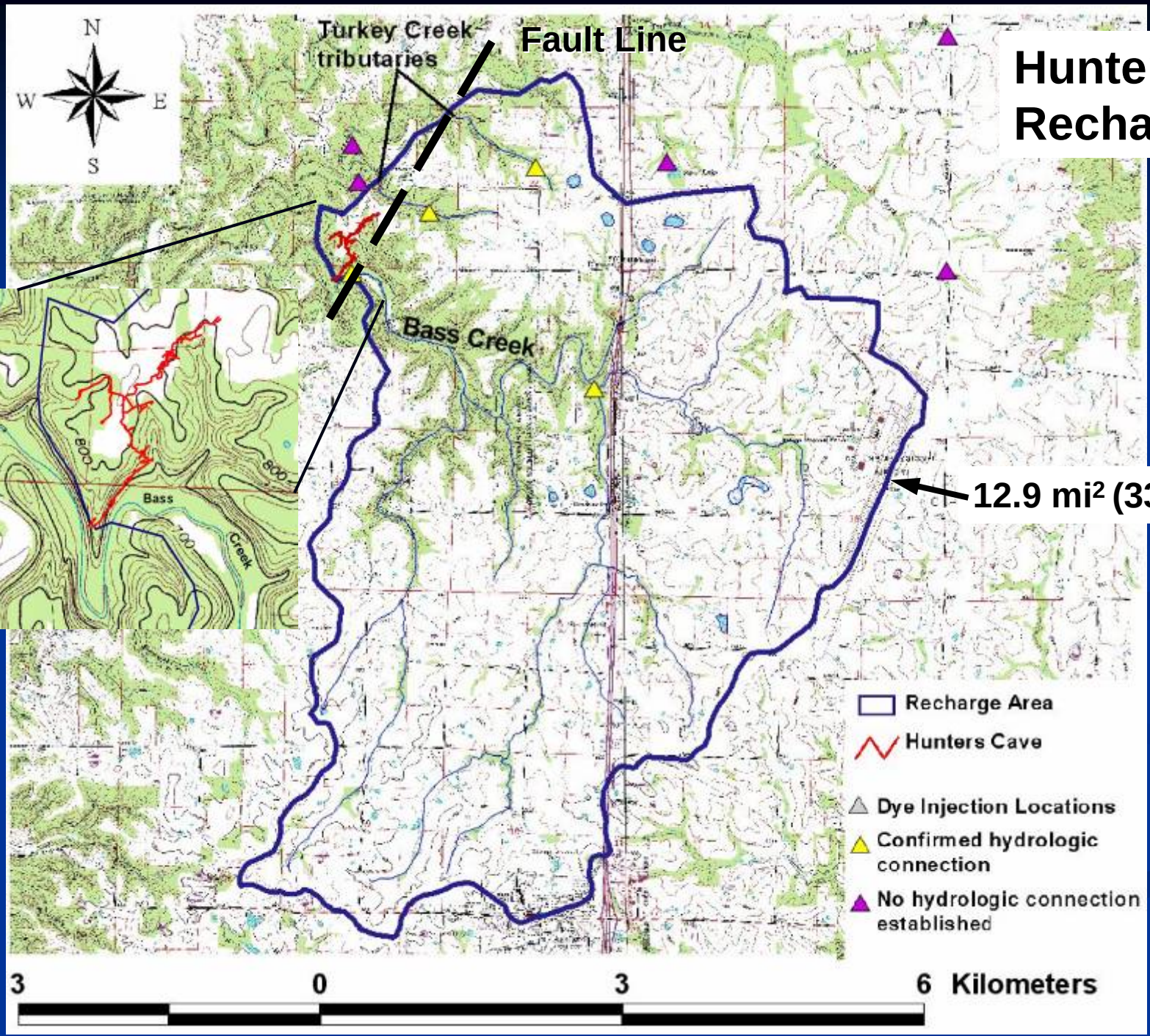
Karst Hydrology



Flow from losing streams or through sinkholes to the groundwater is referred to as conduit flow (i.e., analogous to unimpeded flow through a pipe).

Icebox Recharge Area





Hunters Cave Recharge Area

Overview

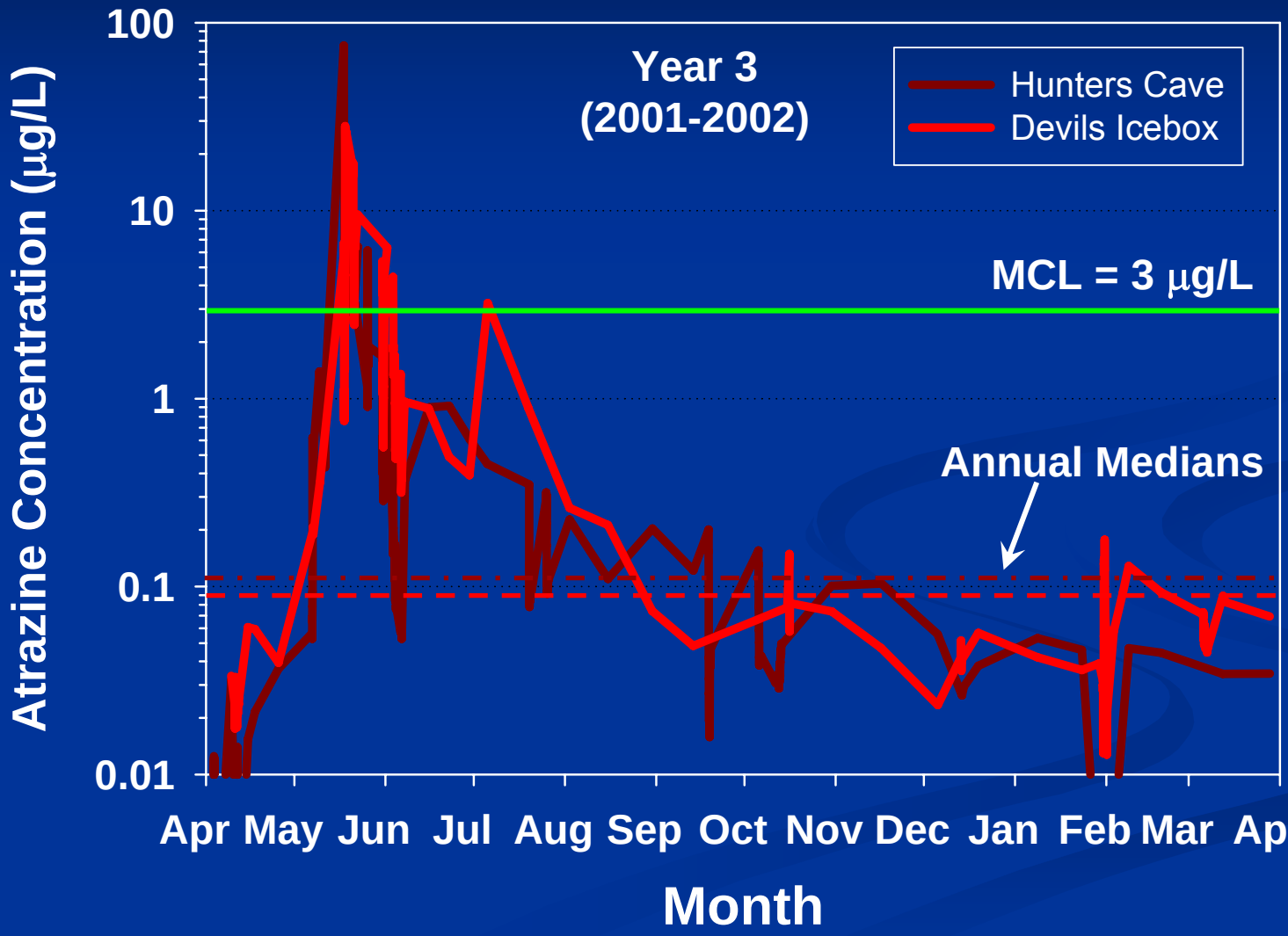
- Summary of Two Studies
  - Intensive water quality monitoring of Hunters Cave and Devils Icebox, 1999-2002
  - Quarterly monitoring of Bonne Femme sub-watersheds, 2001-2007

Water Quality Monitoring

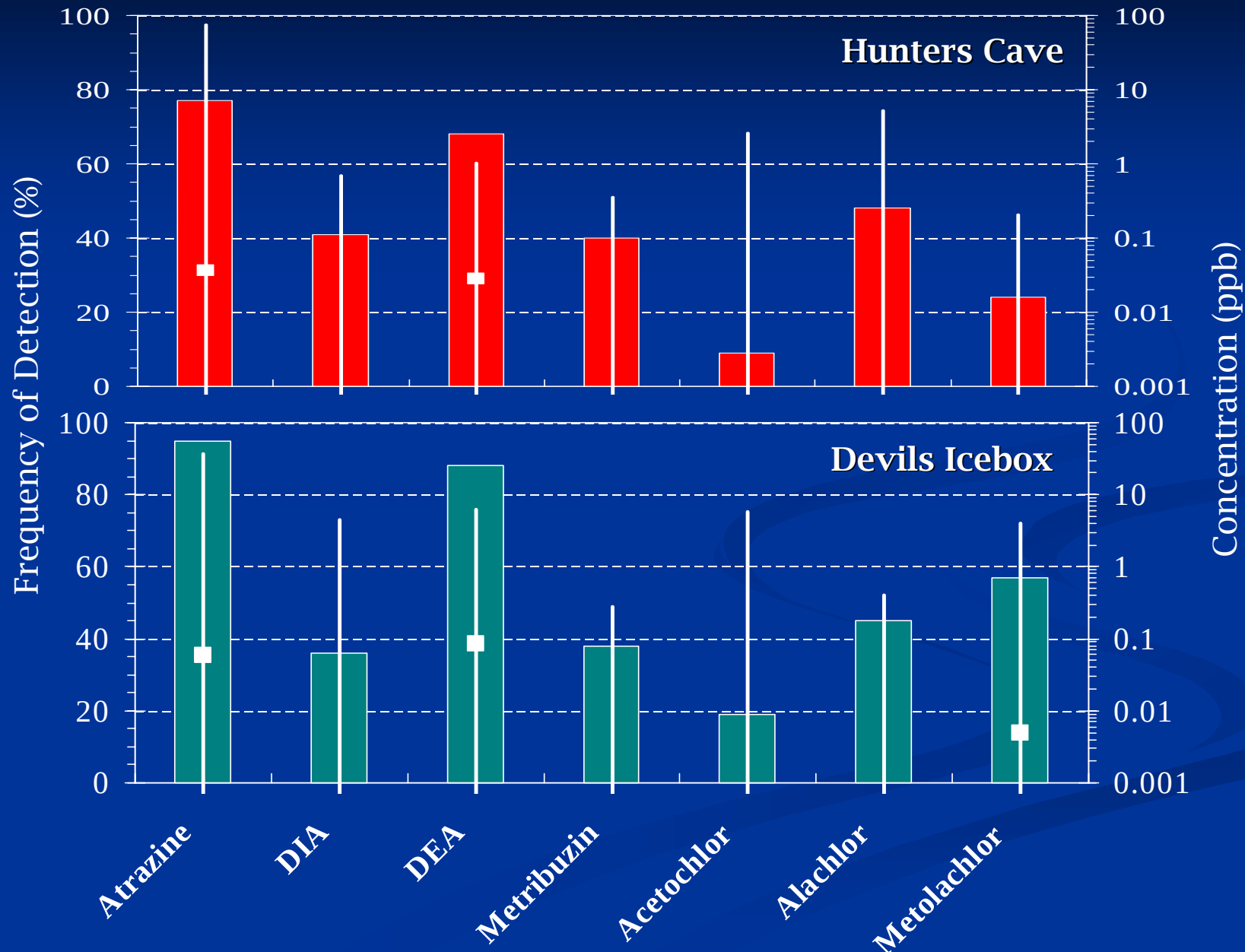
- **Devils Icebox and Hunters Caves**
  - Year-round monitoring at stream resurgence
  - Nutrients and Herbicides
    - Event samples collected w/ automatic samplers
    - Grab samples collected at regular intervals
  - Fecal Coliform Bacteria
    - Quarterly in-cave sampling
      - 2nd Quarter, 1999 to 3rd Quarter, 2000
- **Bonne Femme Sub-watersheds**
  - 8 Bonne Femme sub-watershed streams plus 2 cave streams
  - Fecal Coliforms (FC) and *E. Coli* (EC)
    - Weekly for one month each quarter starting in 2001
  - Nutrients and Herbicides
    - Once per quarter starting in 2003; herbicides 2nd quarter only

Herbicide Contamination

Atrazine

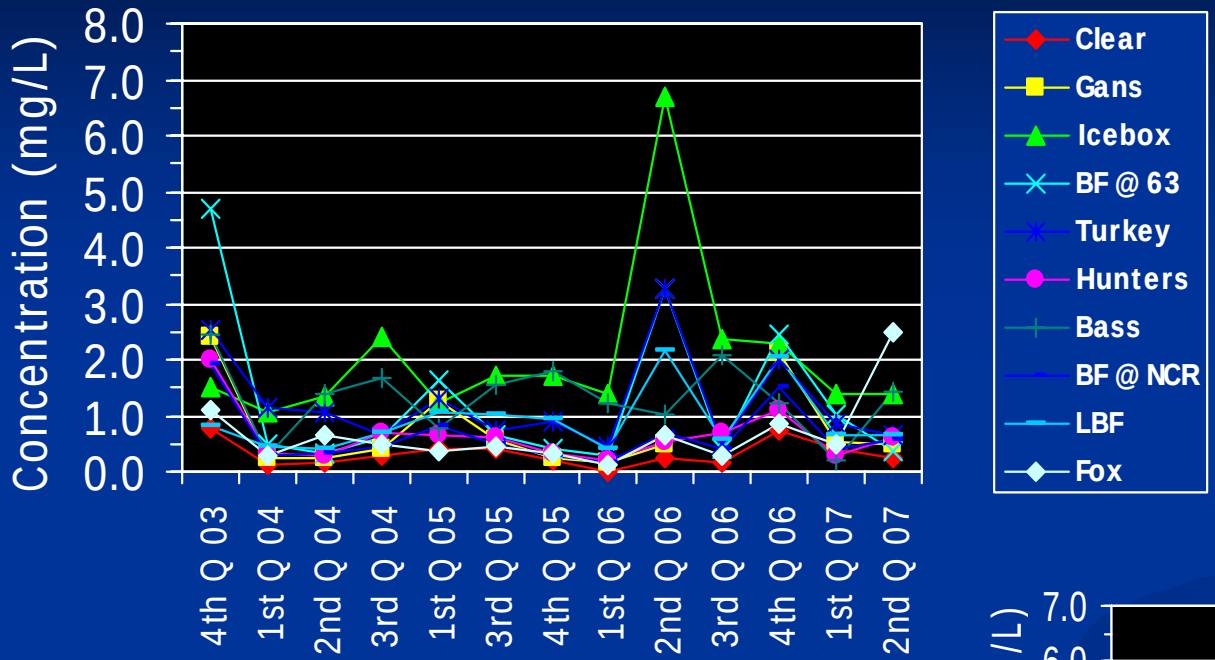


Herbicide Data Summary

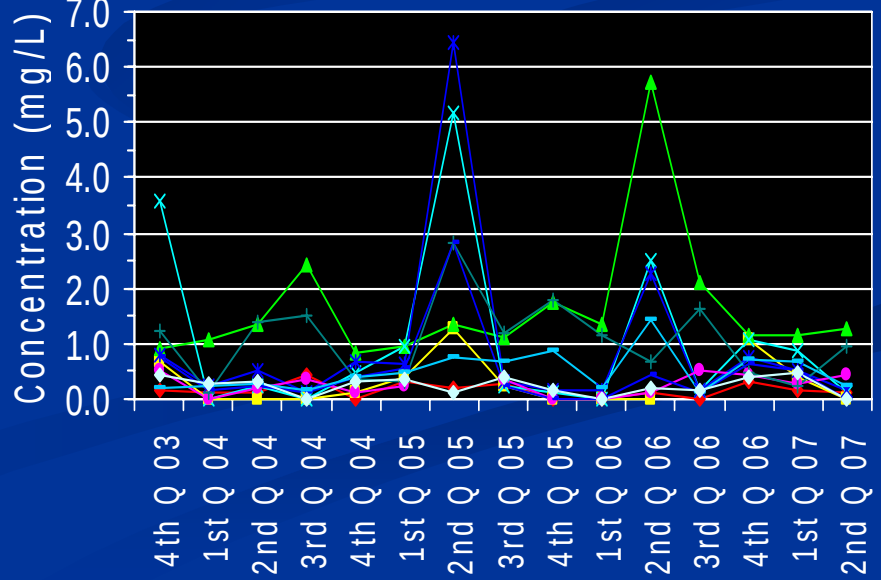


Nitrogen

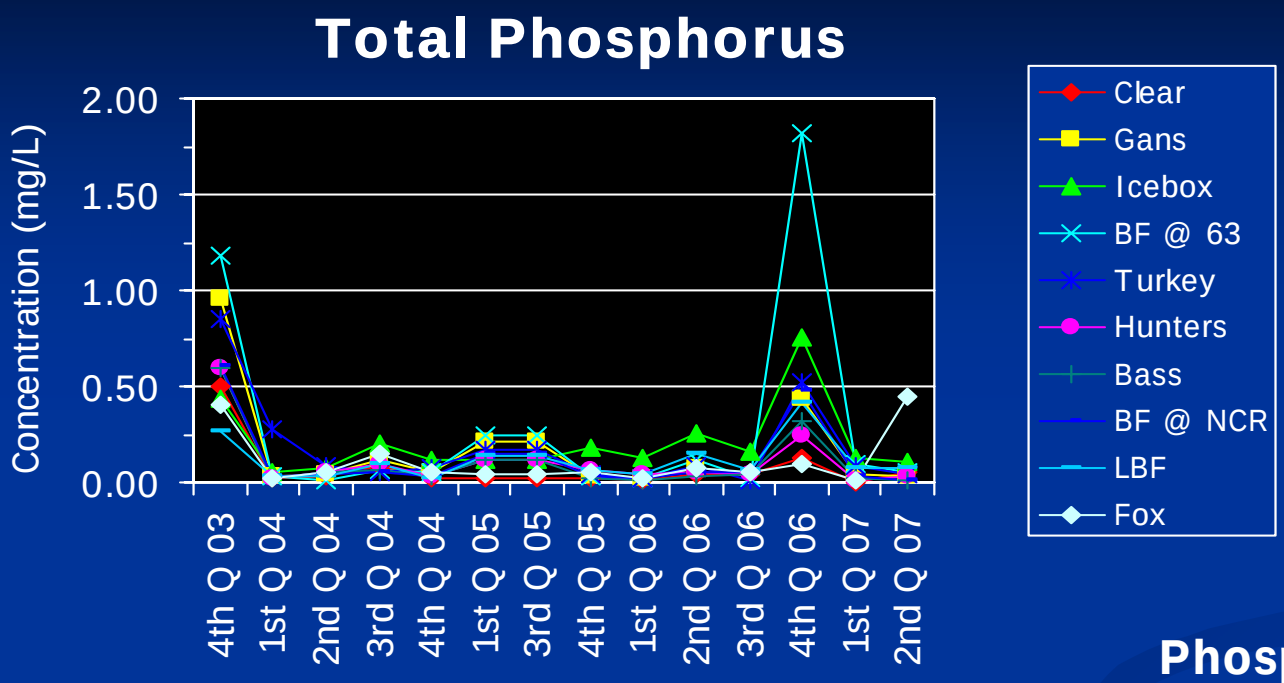
Total Nitrogen

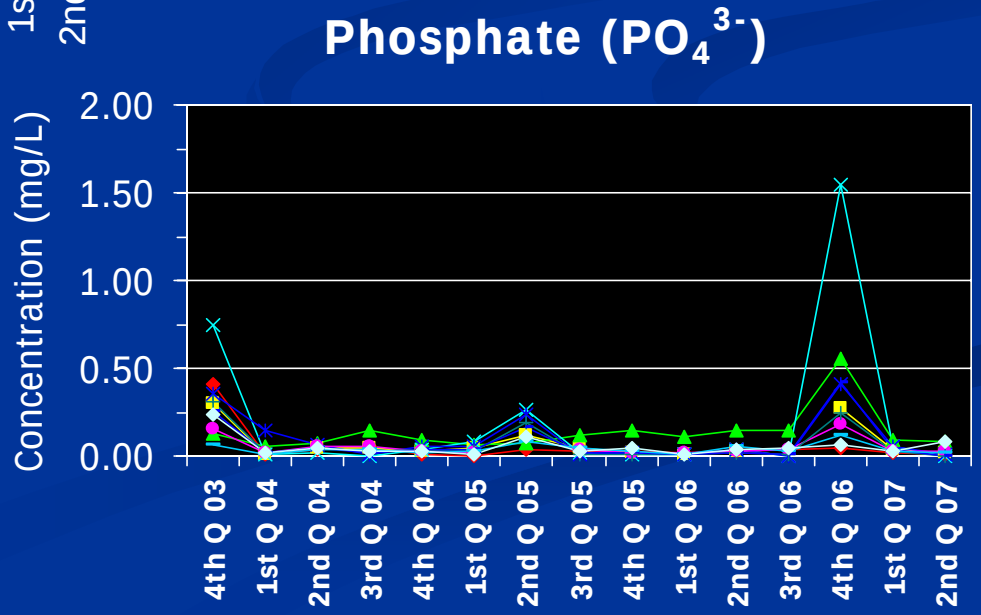


Nitrate (NO_3^-)



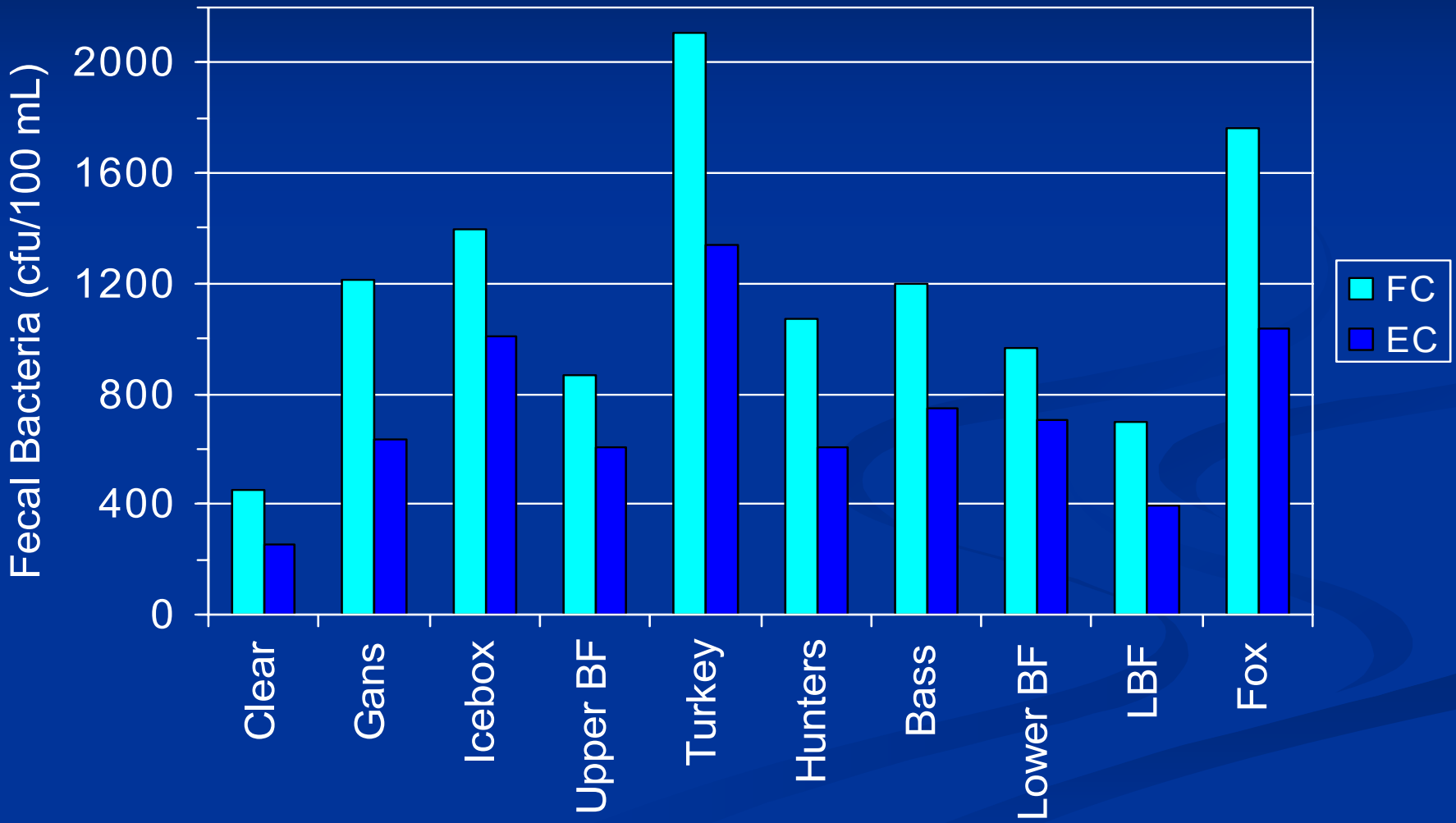
Phosphorus


Total Phosphorus
Concentration (mg/L)
2.00
1.50
1.00
0.50
0.00
4th Q 03
1st Q 04
2nd Q 04
3rd Q 04
4th Q 04
1st Q 05
3rd Q 05
4th Q 05
1st Q 06
2nd Q 06
3rd Q 06
4th Q 06
1st Q 07
2nd Q 07
Clear
Gans
Icebox
BF @ 63
Turkey
Hunters
Bass
BF @ NCR
LBF
Fox


Phosphate (PO_4^{3-})
Concentration (mg/L)
2.00
1.50
1.00
0.50
0.00
4th Q 03
1st Q 04
2nd Q 04
3rd Q 04
4th Q 04
1st Q 05
2nd Q 05
3rd Q 05
4th Q 05
1st Q 06
2nd Q 06
3rd Q 06
4th Q 06
1st Q 07
2nd Q 07

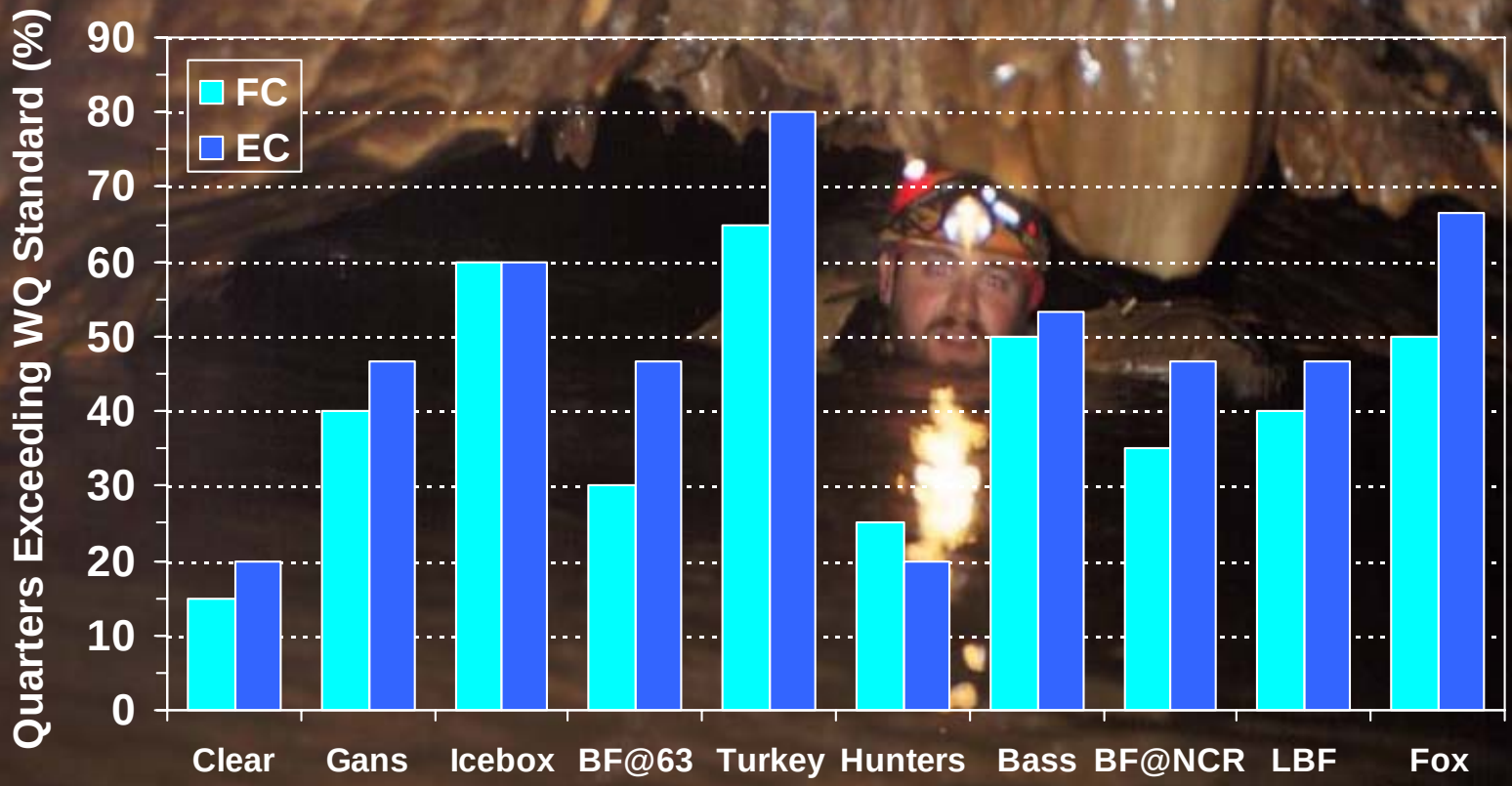
Fecal Coliform and E. Coli Levels

Site Comparisons



Average of all samples, 2001-2007

Coliform Levels and Water Quality Standards



Data are based on computation of geometric mean of 4 samples/quarter and compared against state and federal water quality standards.

Federal Whole Body Contact Standard = 126 cfu/100 mL based on EC
Missouri Whole Body Contact Standard = 200 cfu/100 mL based on FC

First Watercrawl in Hunters Cave

Water Quality Summary*

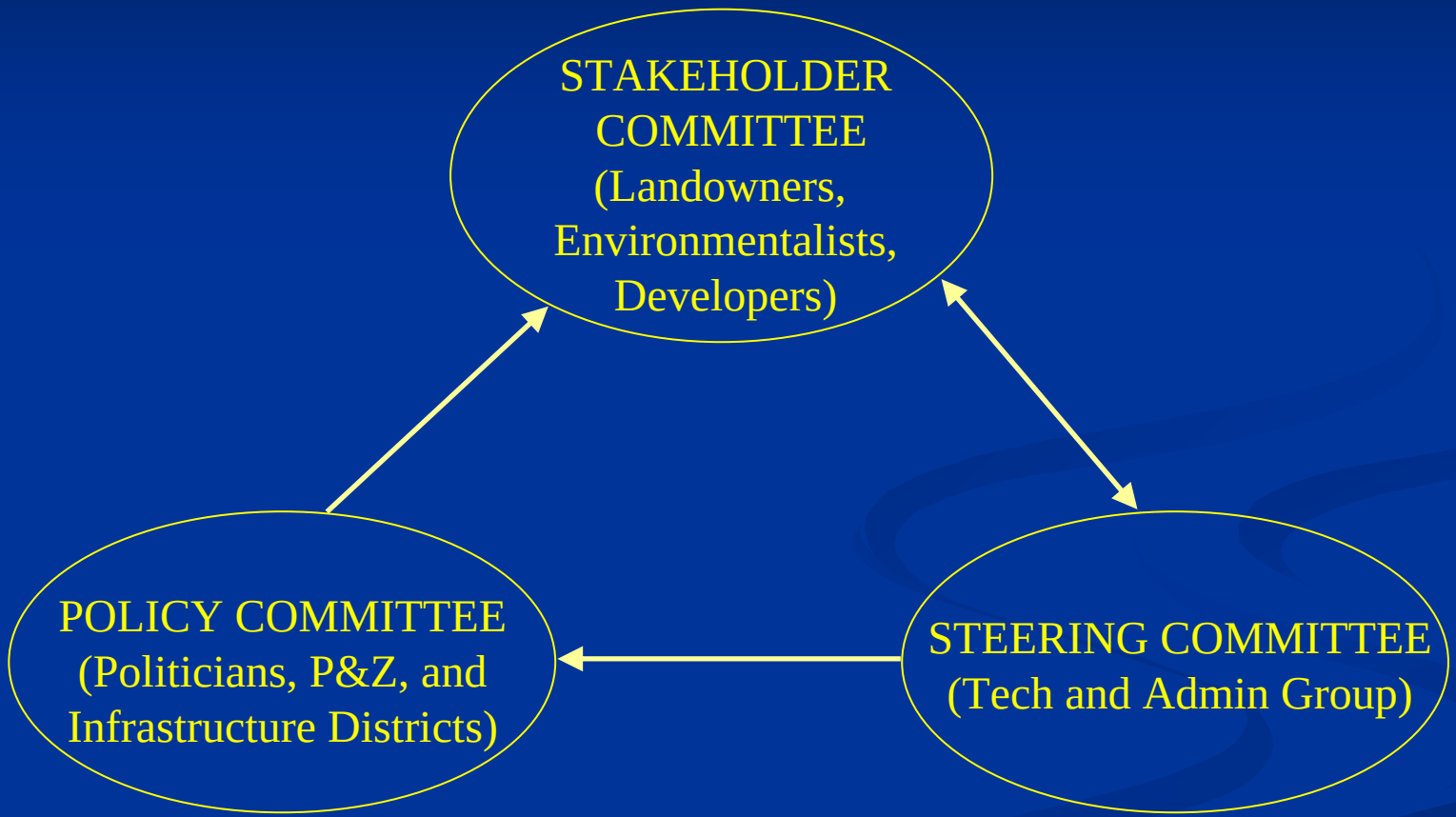
- Nutrient levels were typical for agricultural watersheds in northern Missouri.
  - All sites have some level of nuisance algal growth and presumed loss of macroinvertebrate diversity, but eutrophication conditions have not occurred at any site.
- Herbicides were frequently detected, but usually at very low levels.
  - Atrazine and its metabolites had the highest average concentrations at all sites.
  - Annual spring herbicide spike occurs for a few weeks each year.
- Fecal bacterial contamination was widespread with significant differences observed across sites and over seasons.
  - Concentrations of fecal bacteria were highest in spring and summer.
  - State and Federal whole body contact standards were frequently exceeded; federal standard is more stringent.
  - Land cover did not significantly correlate to fecal bacteria concentrations.

*From the Bonne Femme Watershed Plan, Appendix G.3 (http://www.cavewatershed.org/)

Stakeholder-led Watershed Plan
Project Background

- The Southern Boone County Karst Team was formed in June 2001 at the request of the Directors of the Missouri Departments of Conservation and Natural Resources
  - Team's mandate was to focus on the Bonne Femme Watershed
    - Outstanding State Resource waters
    - Karst topography vulnerable to groundwater pollution
    - Endangered and endemic species present
    - Significant public land holdings
    - Comprehensive urban management needed
  - Members initially represented State and Federal agencies
  - Developed a mission and broad objectives
- Developed the 319 grant as the mechanism for fulfilling our mission
  - Boone County Commission agreed to sponsor the grant

Project Organization



Planning Process

- Identify issues
- Create a vision of the watershed in 2030
  - *Environmental protection must be balanced with economic vitality*
- Transform the vision into achievable goals
- Examine complimentary and conflicting aspects of the goals
- Identify obstacles to achieving the goals
- Develop strategies and policy recommendations

Keys to Success

- Project organization
  - Distinct roles for each committee
- Policy Committee
  - Chose Stakeholder Committee members
  - Created buy-in from politicians upfront
- Steering Committee
  - Organized numerous educational presentations
  - Established a “road-map” for developing the plan
- Stakeholder Committee
  - Members held diverse, even adversarial opinions
  - Hit controversial topics head-on and early in the process to prevent fighting over the finished product
- Stakeholders had full control of the process
  - Plan content
  - Elected Co-Chairs and established voting procedures

Summary – Bonne Femme Watershed

- Monitoring of surface and sub-surface streams demonstrated impact of prevailing land-uses on water quality and established baseline data before major urbanization occurs
  - Fecal bacterial contamination is the major water quality issue in the watershed
    - Sources include on-site sewers, livestock, and wildlife
- Karst recharge areas (i.e., cave streams) are extremely vulnerable to contamination
  - Account for at least 28% of the watershed
- 319 project initiated to protect water quality and manage future urban growth
  - Successful Stakeholder-led watershed plan established
  - **Plan adopted by Boone County and Cities of Ashland and Columbia**