Purdue University Agricultural & Biological Engineering

Energy, Water, and Climate Change

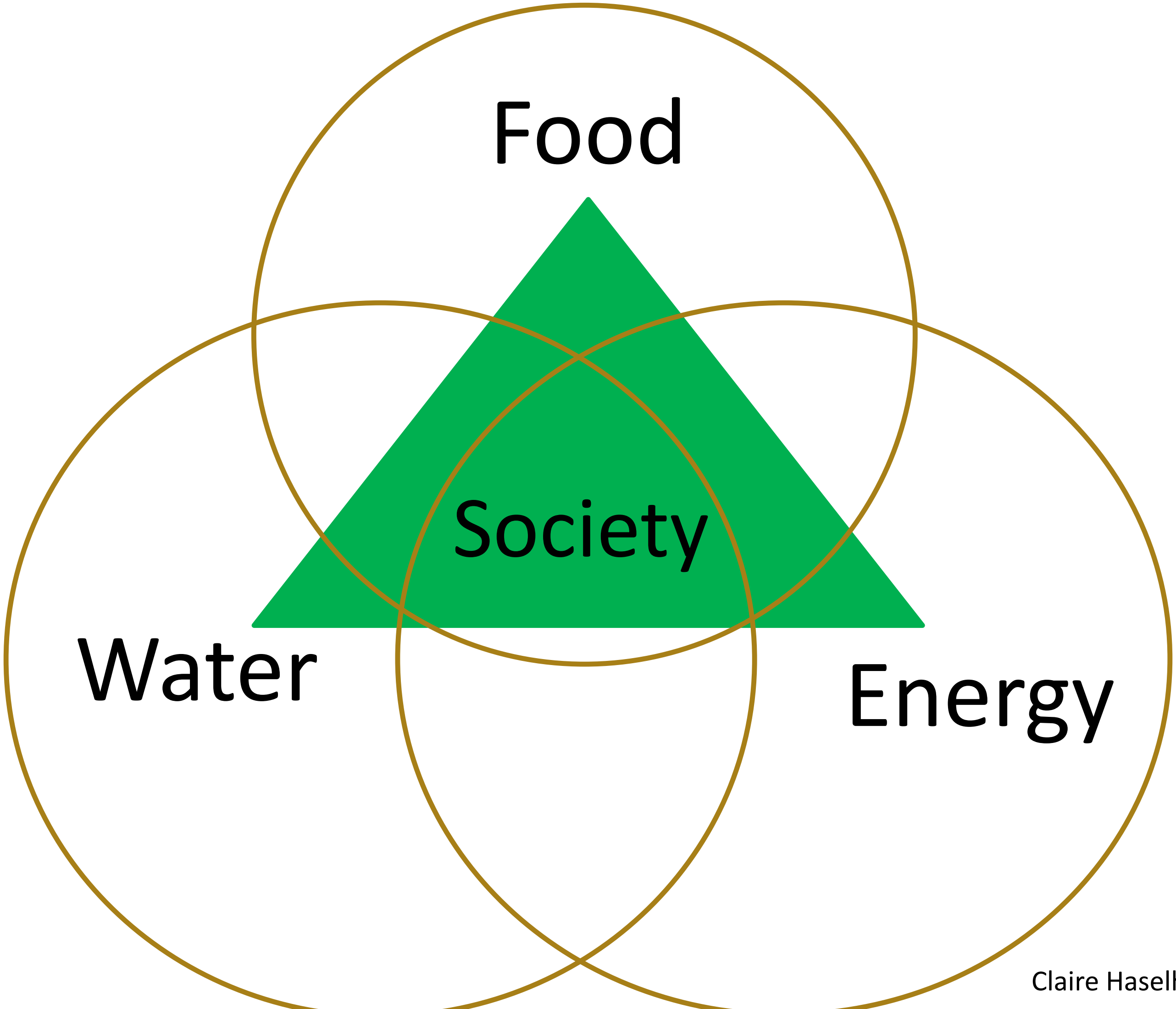
Keith Cherkauer

ABE 290

PURDUE UNIVERSITY

www.purdue.edu/ABE

Grand Challenges



Claire Haselhorst & Vince Bralts, 2014

Agricultural & Biological Engineering

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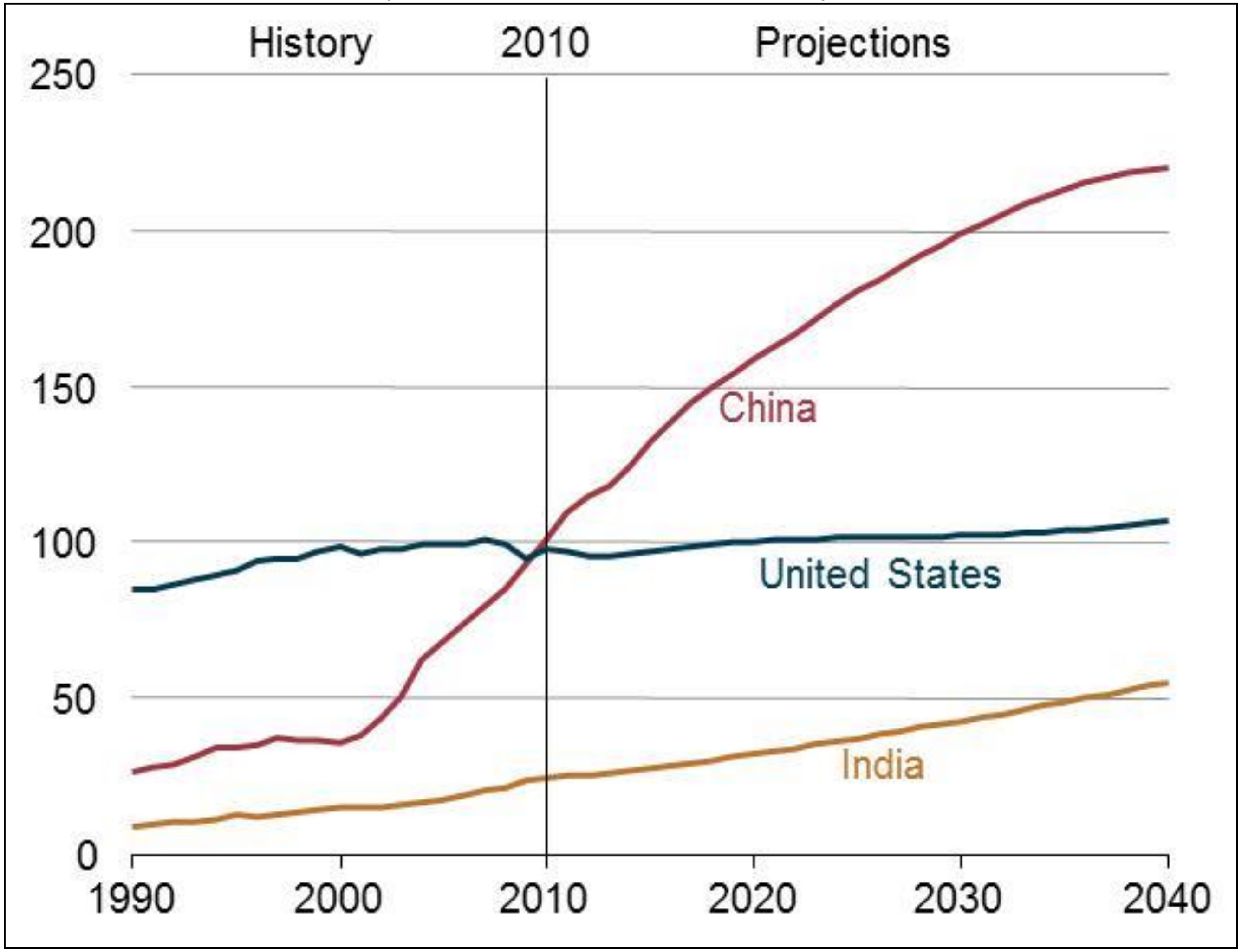
Energy Consumption in other Countries is Increasing

(in Quadrillion Btu)



DOE/EIA-0484(2013) | July 2013

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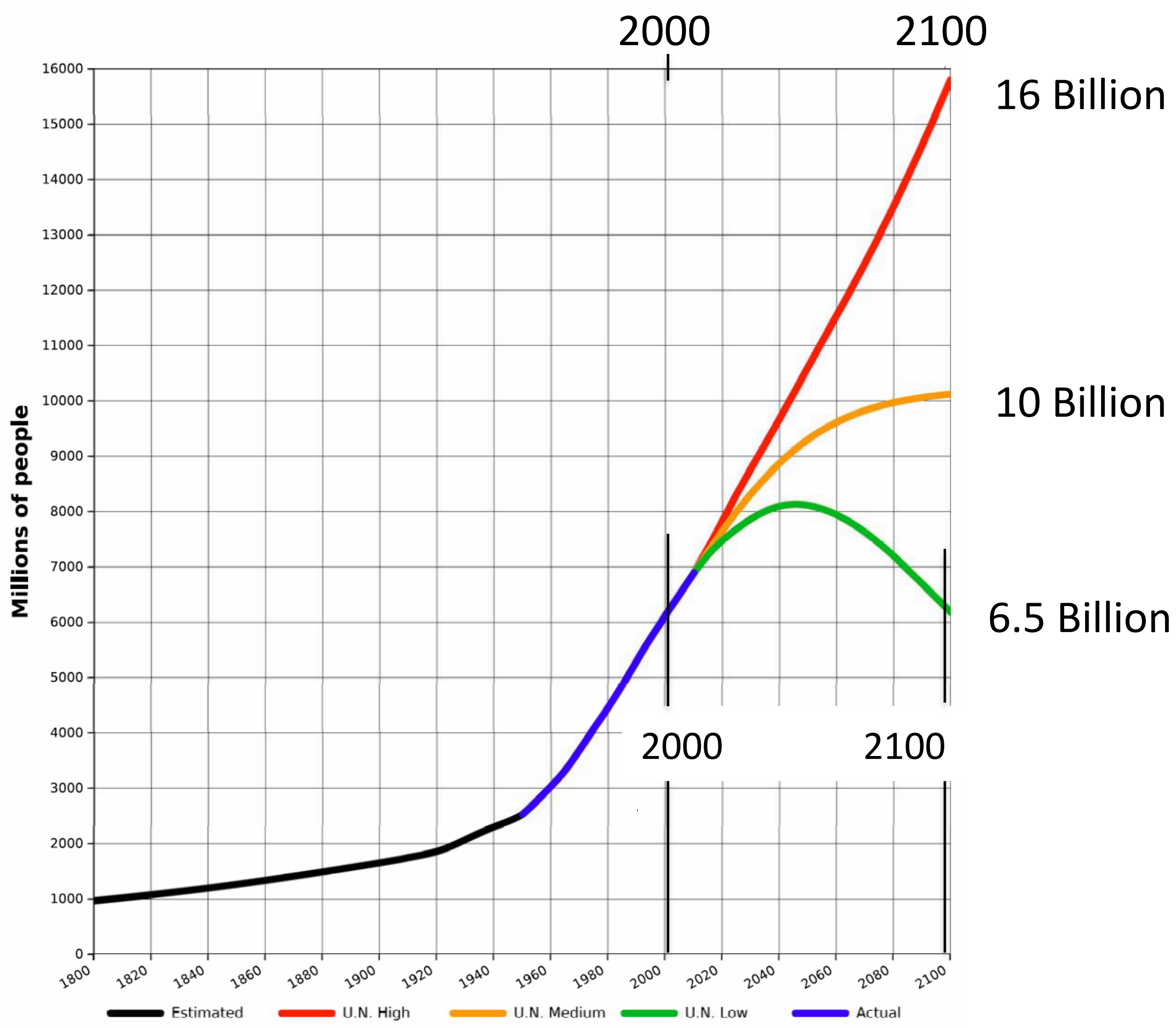
What about population growth?



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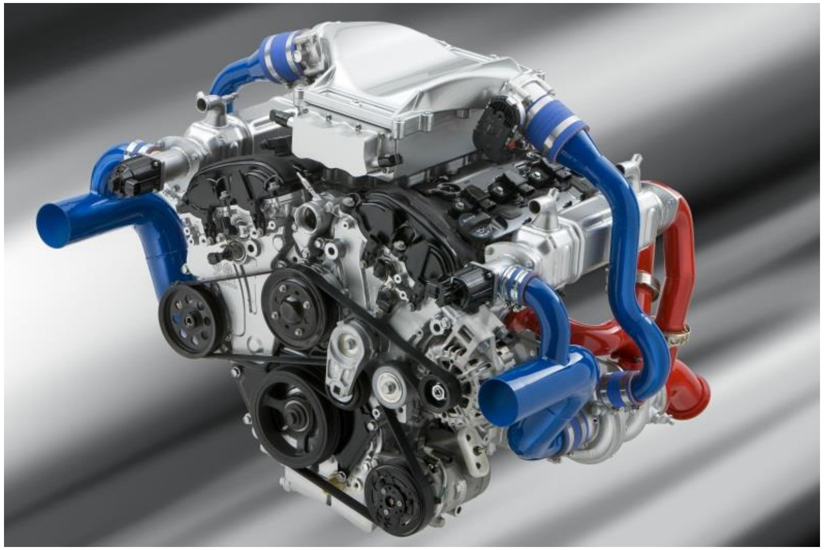
Two Approaches to Reduce Emissions

More fuel with less carbon – advanced low carbon biofuels

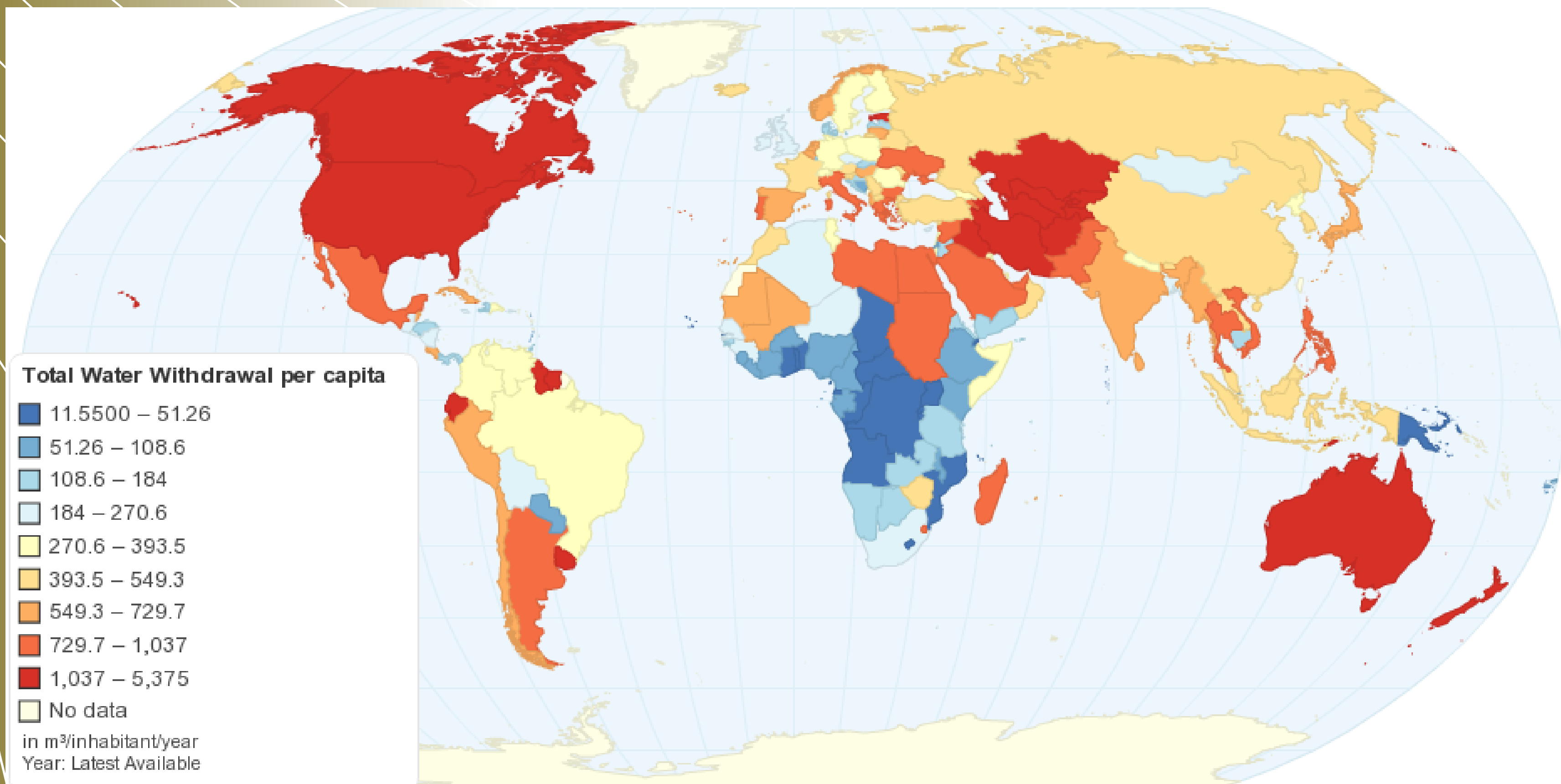
Engine Technology
More miles with less fuel



Cellulosic materials: low carbon and with long term sustainability.
Combined with efficient biofuel engines, emission reductions result.

Shaver, 2014

Total Global Water Use



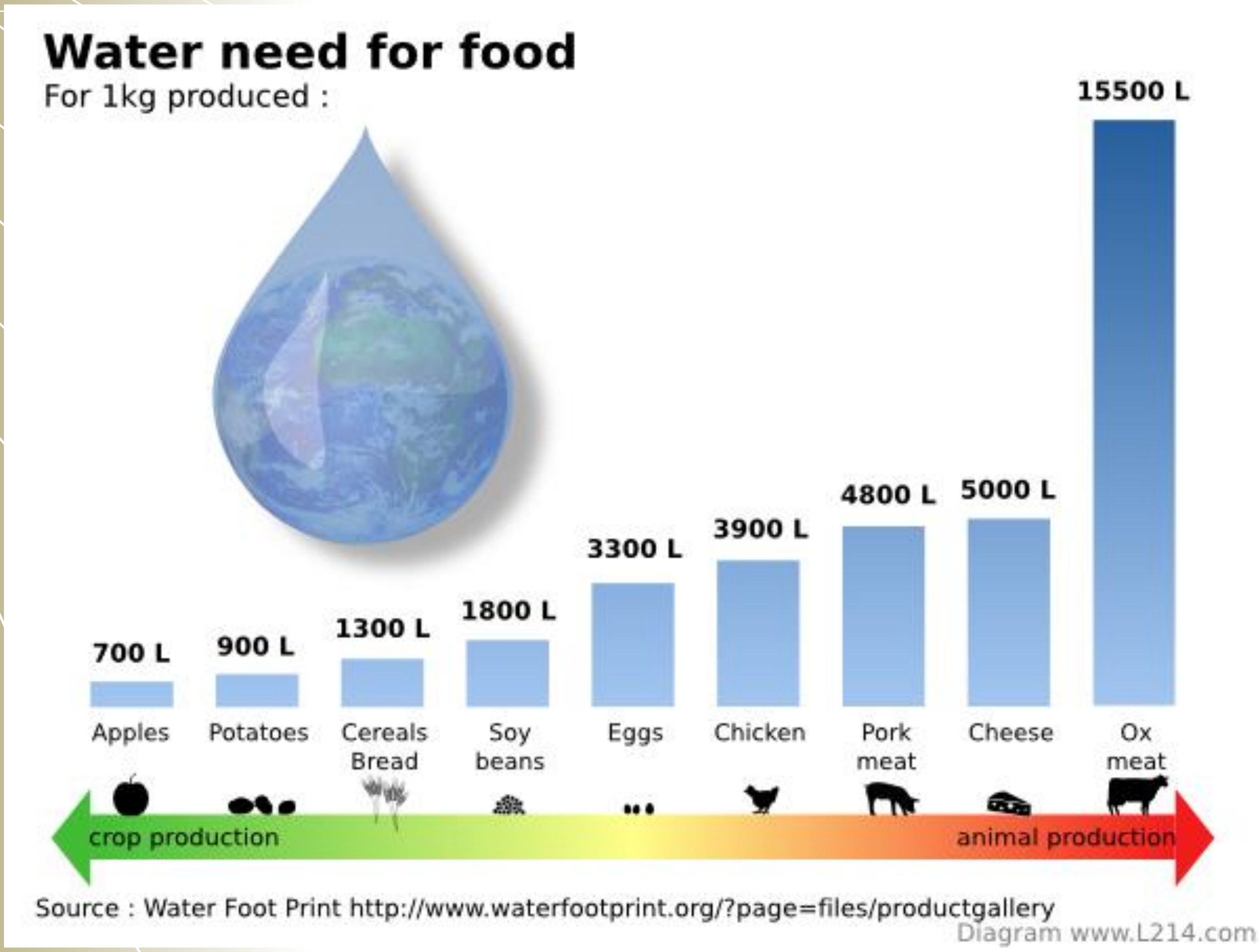
Source: http://chartsbin.com/view/1455

Global Water Usage Statistics

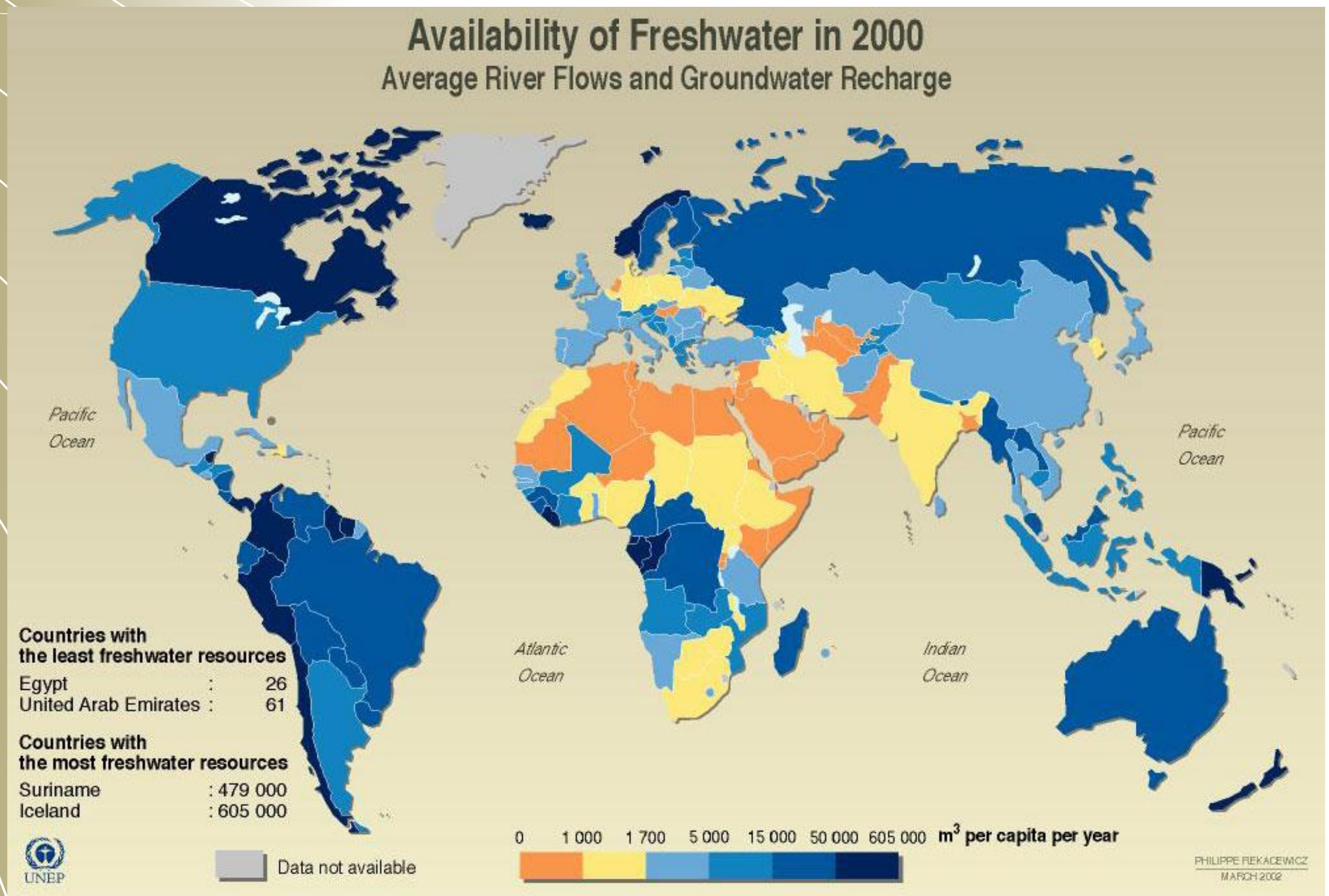
Source: www.worldwatercouncil.org

- 1.1 billion people live without clean drinking water
- 2.6 billion people lack adequate **sanitation** (2002, UNICEF/WHO JMP 2004)
- 1.8 million people die every year from diarrheal diseases.
- 3,900 children die every day from **water borne** diseases (WHO 2004)

Water Used for Food Production

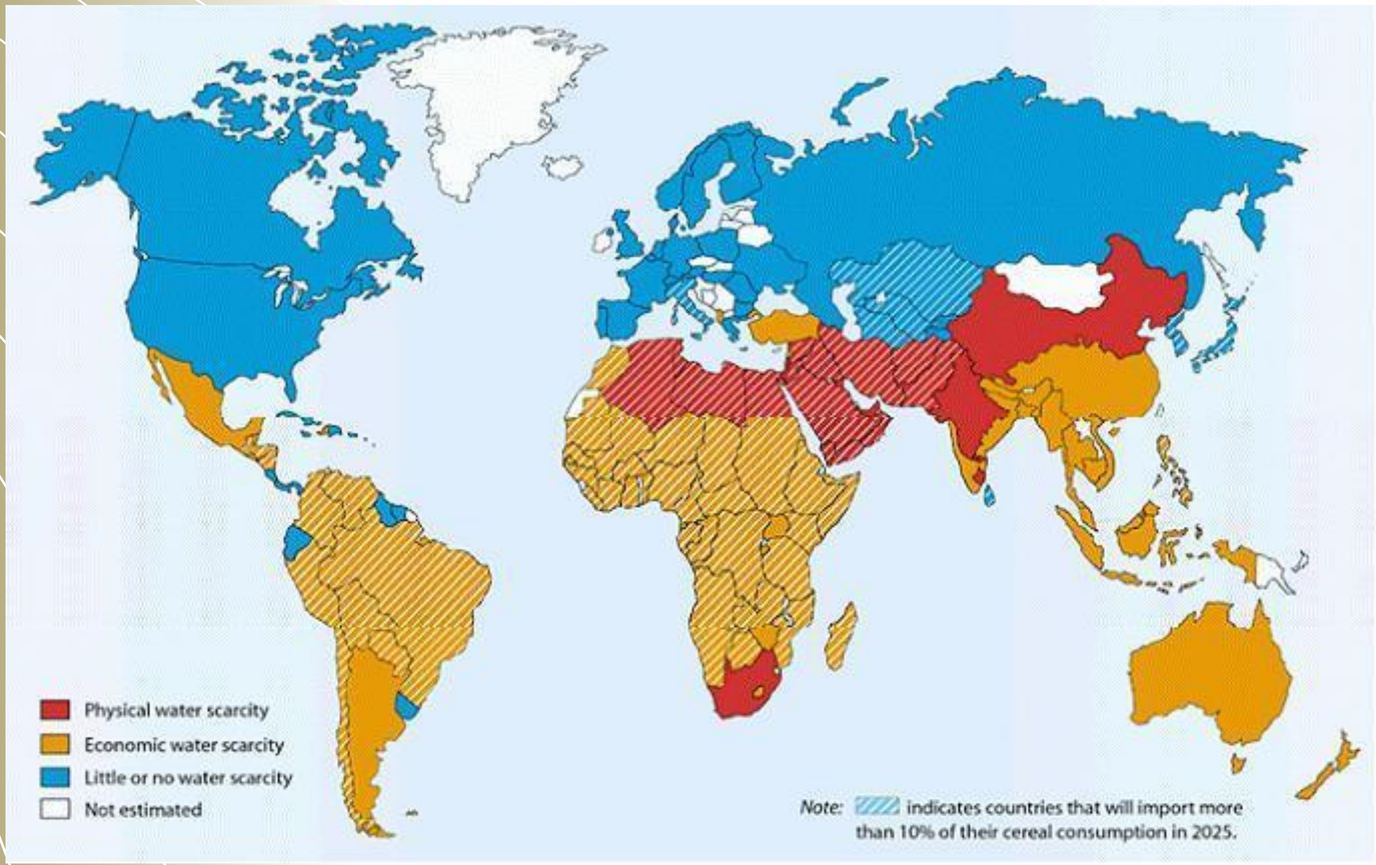


Global Water Distribution

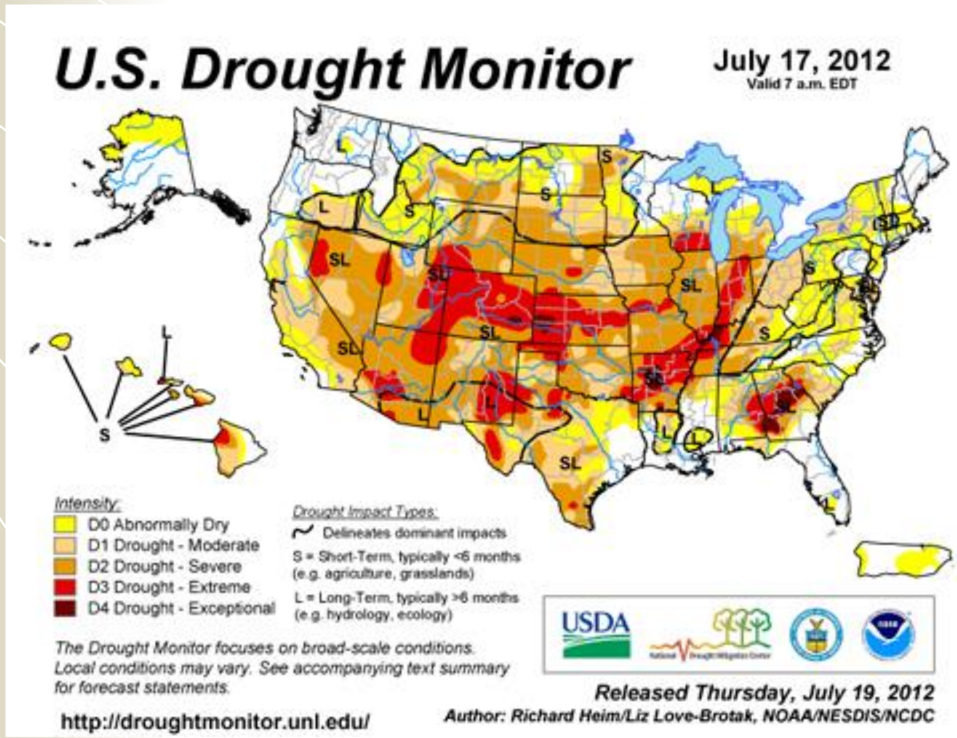


Source: *World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life*, World Resources Institute (WRI), Washington DC, 2000.

Global Water Scarcity



Timing has much to do with scarcity!



Global Water Usage Statistics

Source: www.worldwater.org/conflict

- Water conflicts
  - 24 conflicts from 1950-1974
  - 54 conflicts from 1975-1999
  - 73 conflicts from 2000-2010
  - 35+ conflicts since 2011
- Over 260 river basins are shared by two or more countries mostly without adequate legal or institutional arrangements.
- Major conflicts have been over resources, most recently oil. In the future wars may be over water.

Stationarity

- What is stationarity?
  - It is the idea that natural systems fluctuate within an unchanging envelope of variability
  - Statistical assumption
- Why is stationarity important to engineers?
  - It is a foundational concept that permeates training and practice in water-resource engineering.
  - It implies that any variable (e.g., annual streamflow or annual flood peak) has a time-invariant (or 1-year–periodic) probability density function (pdf), whose properties can be estimated from the instrument record.
- How does this relate to climate change?

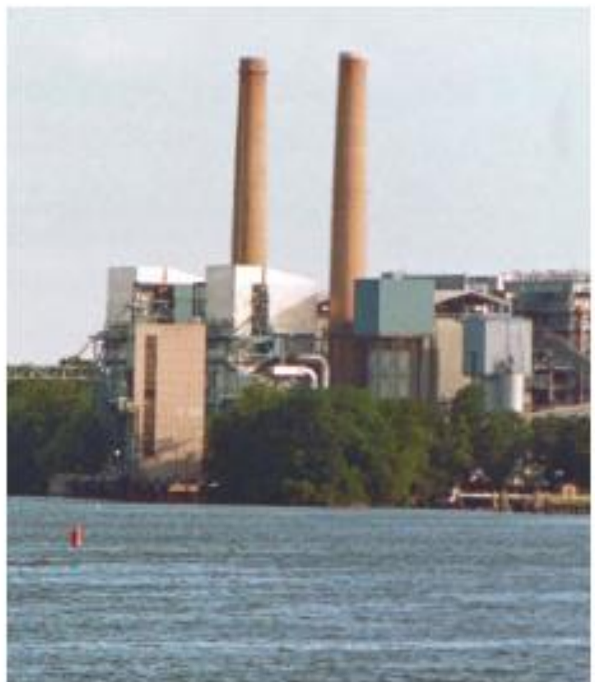
CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,[1*] Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Systems for management of water throughout the developed world have been designed and operated under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a foundational concept that permeates training and practice in water-resource engineering. It implies that any variable (e.g., annual streamflow or annual flood peak) has a time-invariant (or 1-year–periodic) probability density function (pdf), whose properties can be estimated from the instrument record. Under stationarity, pdf estimation errors are acknowledged, but have been assumed to be reducible by additional observations, more efficient estimators, or regional or paleohydrologic data. The pdfs, in turn, are used to evaluate and manage risks to water supplies, waterworks, and floodplains; annual global investment in water infrastructure exceeds U.S.$500 billion (*1*).



An uncertain future challenges water planners.

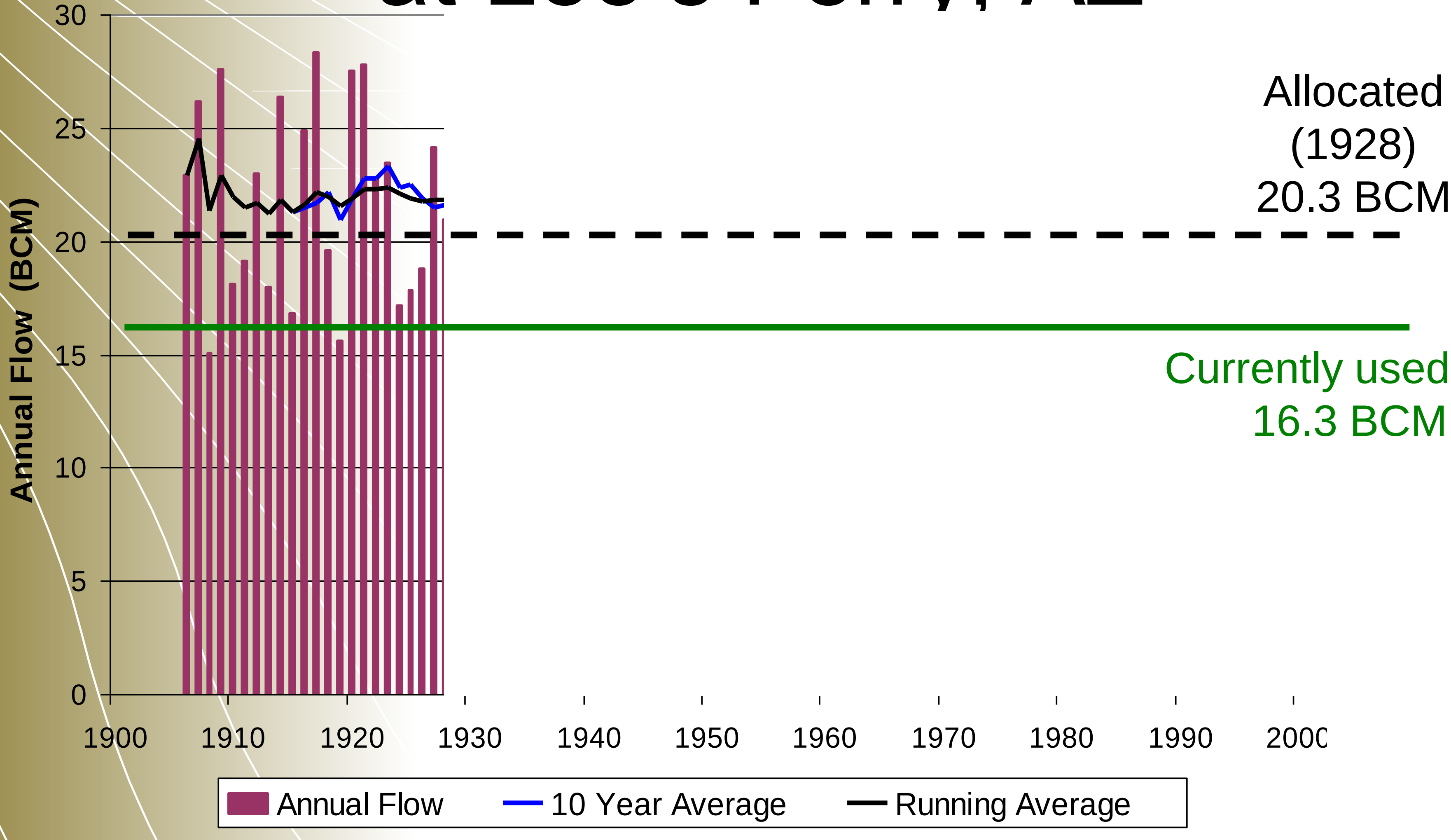
In view of the magnitude and ubiquity of the hydroclimatic change apparently now

that has emerged from climate models (see figure, p. 574).

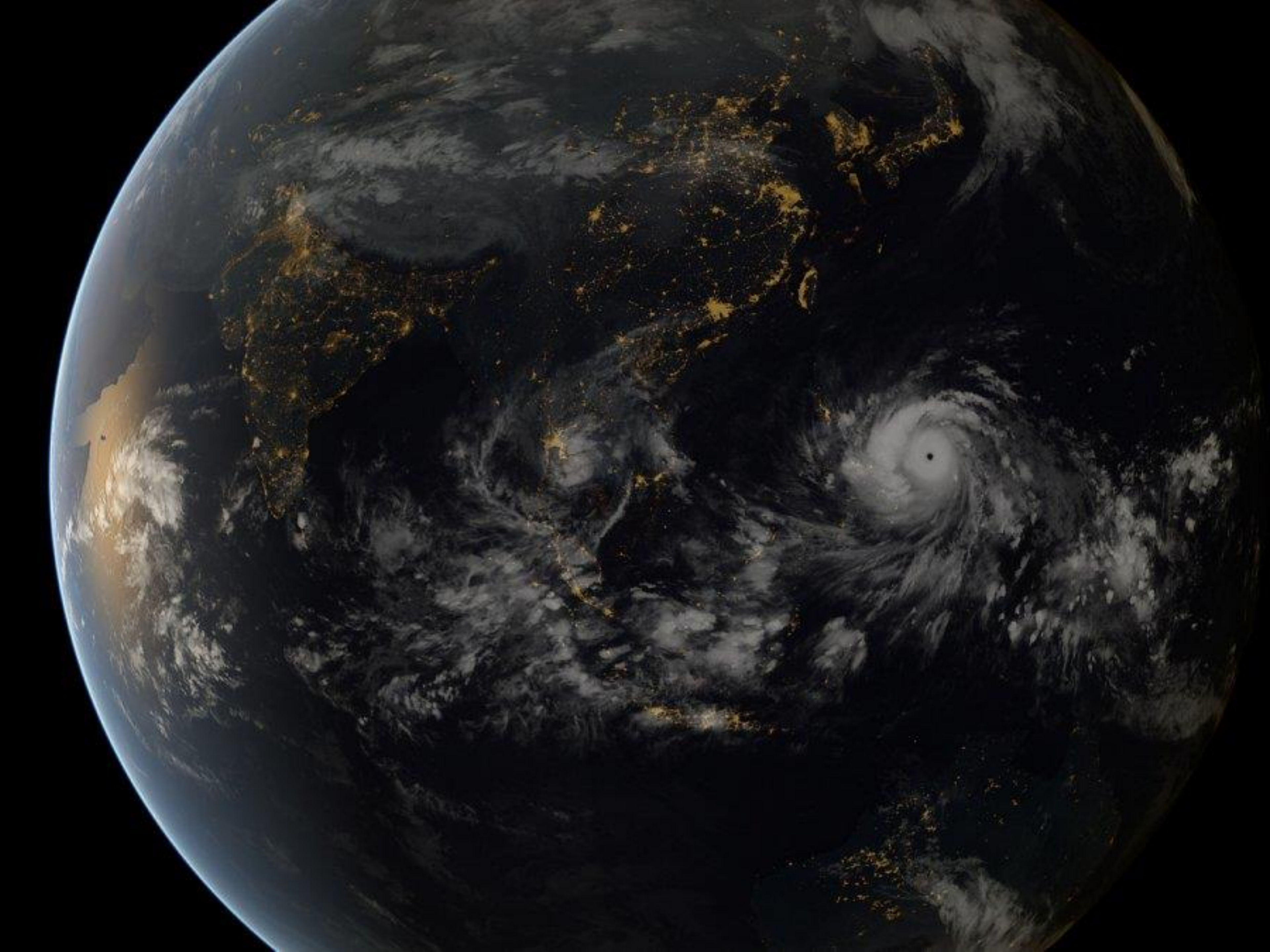
Why now? That anthropogenic climate change affects the water cycle (*9*) and water supply (*10*) is not a new finding. Nevertheless, sensible objections to discarding stationarity have been raised. For a time, hydroclimate had not demonstrably exited the envelope of natural variability and/or the effective range of optimally operated infrastructure (*11*, *12*). Accounting for the substantial uncertainties of climatic parameters estimated from short records (*13*) effectively hedged against small climate changes. Additionally, climate projections were not considered credible (*12*, *14*).

Recent developments have led us to the opinion that the time has come to move beyond the wait-and-see approach. Projections of runoff changes are bolstered by the recently demonstrated retrodictive skill of climate models. The global pattern of observed annual streamflow trends is unlikely to have

Colorado River Natural Flow at Lee's Ferry, AZ




MOST INSURANCE PLANS WELCOME
sigma
Medical Group
$1
BREAKFAST
10 ITEMS STARTING



Is Climate Changing?

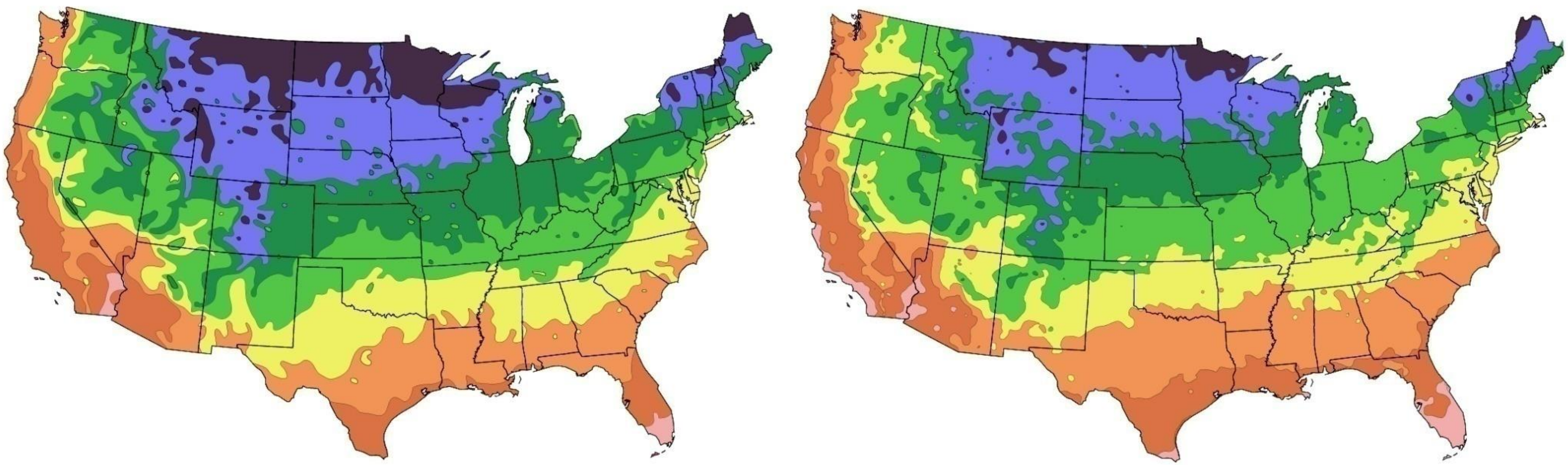
- IPCC Fourth Assessment Report (AR4) - 2007
- The Physical Science Basis
  - "Warming of the climate system is unequivocal"
  - "Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* (> 90%) due to the observed increase in anthropogenic greenhouse gas concentrations."

Local Evidence for Climate Change Here in Indiana

- Temperatures are rising, especially in winter
- Extreme rainfall events (24-hr and 7-day) are becoming more frequent
- Winters have become shorter
- Spring is coming earlier
- Shorter duration of ice cover, especially on smaller lakes

Evidence for Climate Change
Indiana Temperature Increases

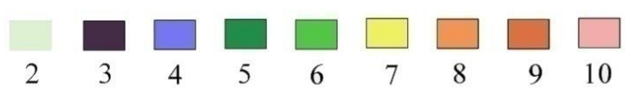
1990 Map | **2006 Map**



After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued Januay 1990

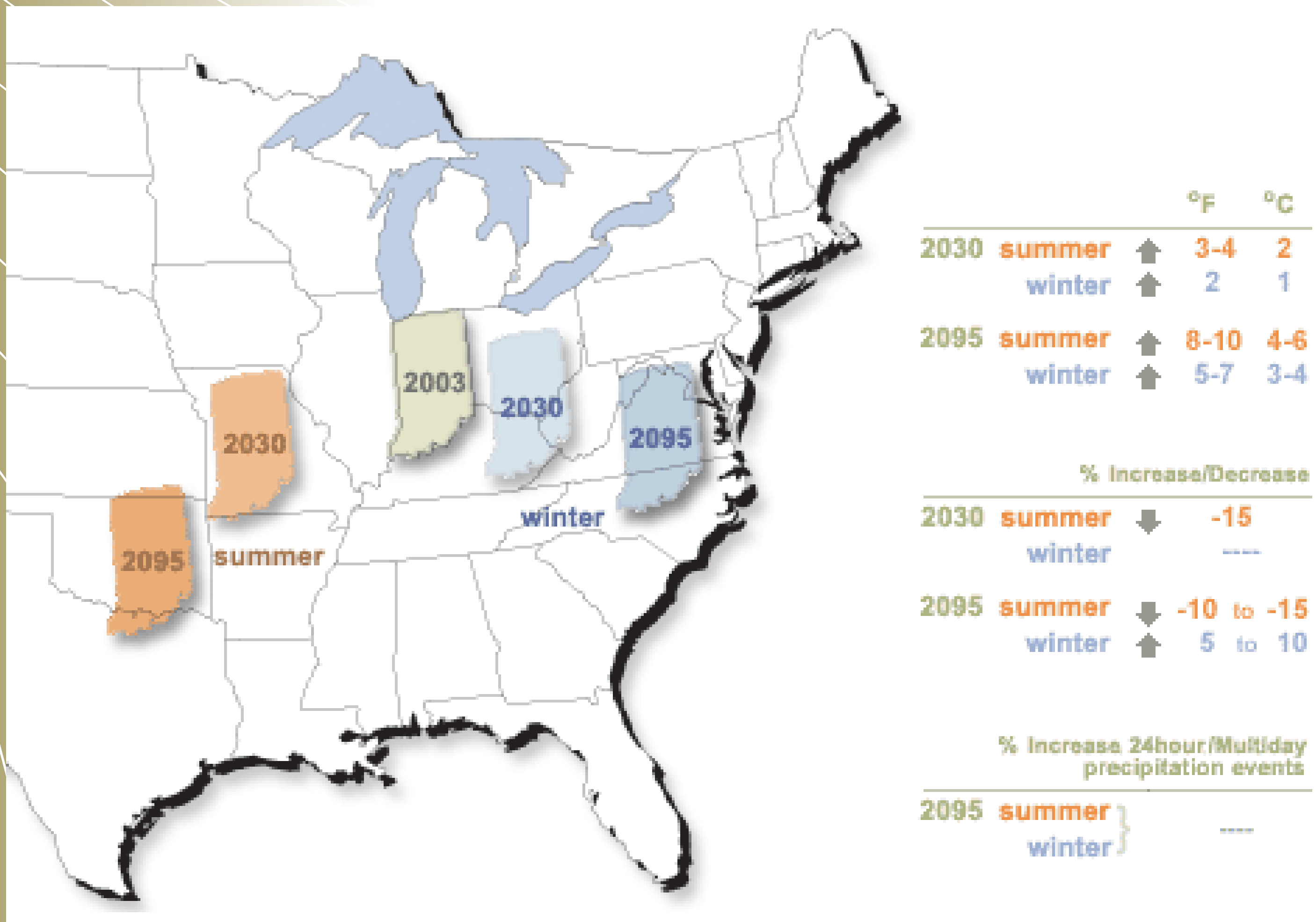
National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.

Zone



The plant hardiness zone for Indiana has *already* shifted to what Kentucky was like just 20 years ago.

How is Climate Changing?



What can you do?

- Designs should take changing climate into consideration
- Climate impacts may be overwhelmed or compensated for locally by land use management and change
- Design with the environment in mind
  - Climate change is in part a result of human activities – pollution
  - Design to minimize waste and pollution

Agricultural and Biological Engineering to address environmental concerns

- **Agricultural:** We address environmental issues and problems faced by rural communities and food producers
- **Biological:** We use biological principles to develop solutions
- **Engineering:** We analyze problems, review options, and design site-specific solutions.

What are the great challenges of the future?

- Eliminate hunger
- Improve quality of life
- Protect the environment
- Develop sustainable energy supplies
- Provide adequate water to meet ecosystem needs

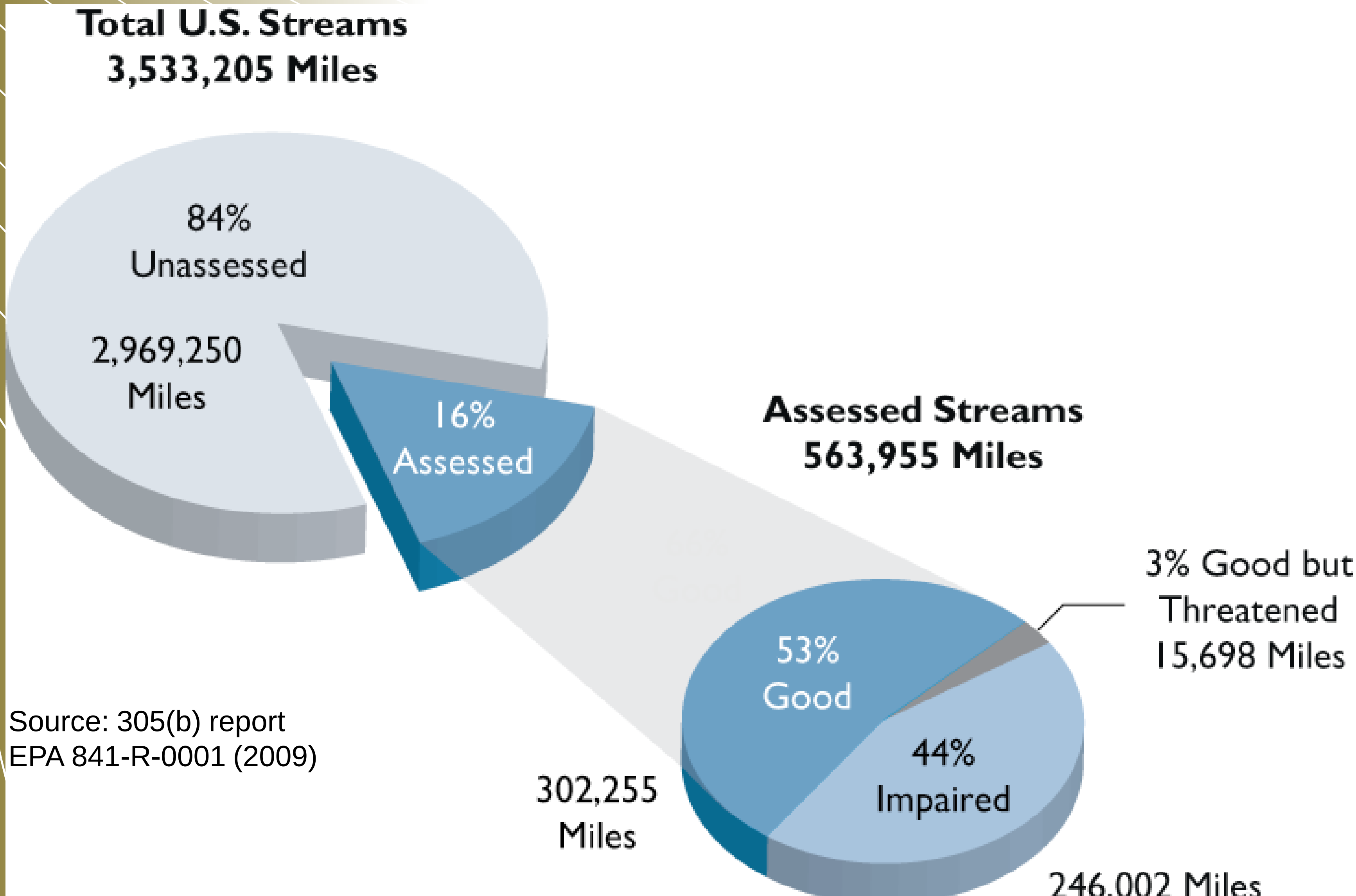
Environmental & Natural Resources Engineering

- Secure clean water for all future generations

safewater for the future

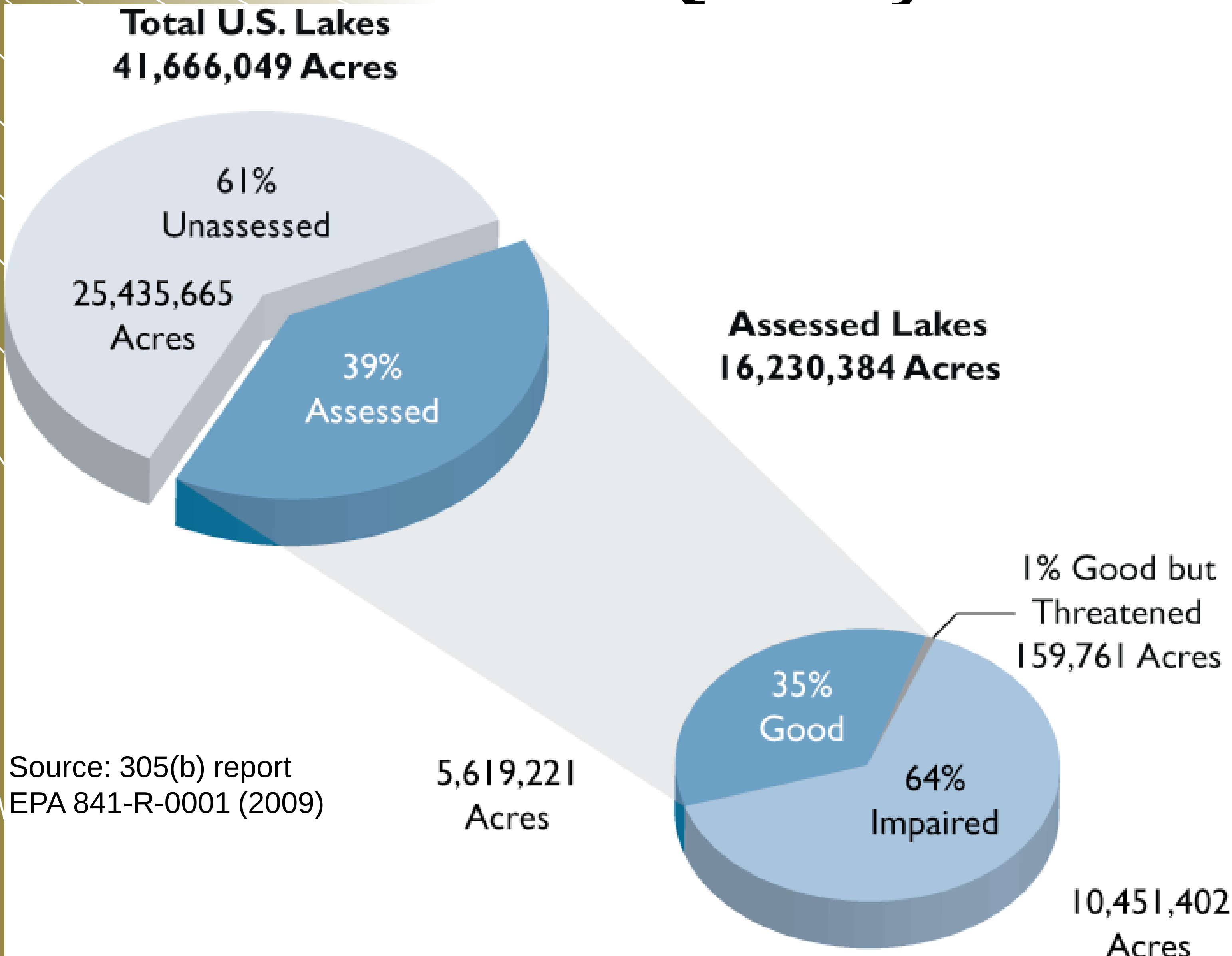
"Helping society protect their drinking water"

Stream Water Quality in USA



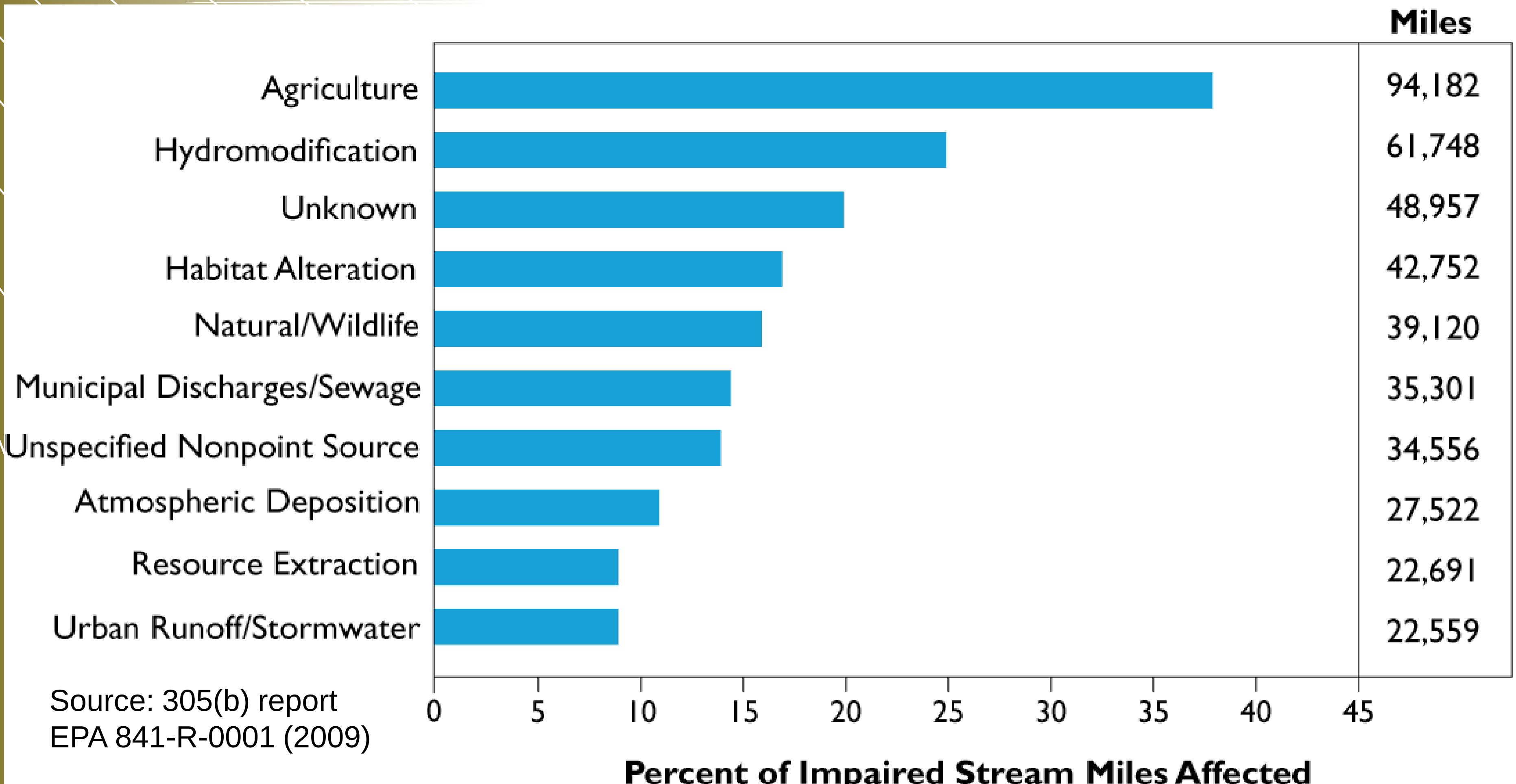
Source: 305(b) report
EPA 841-R-0001 (2009)

Lake Water Quality in USA



Source: 305(b) report
EPA 841-R-0001 (2009)

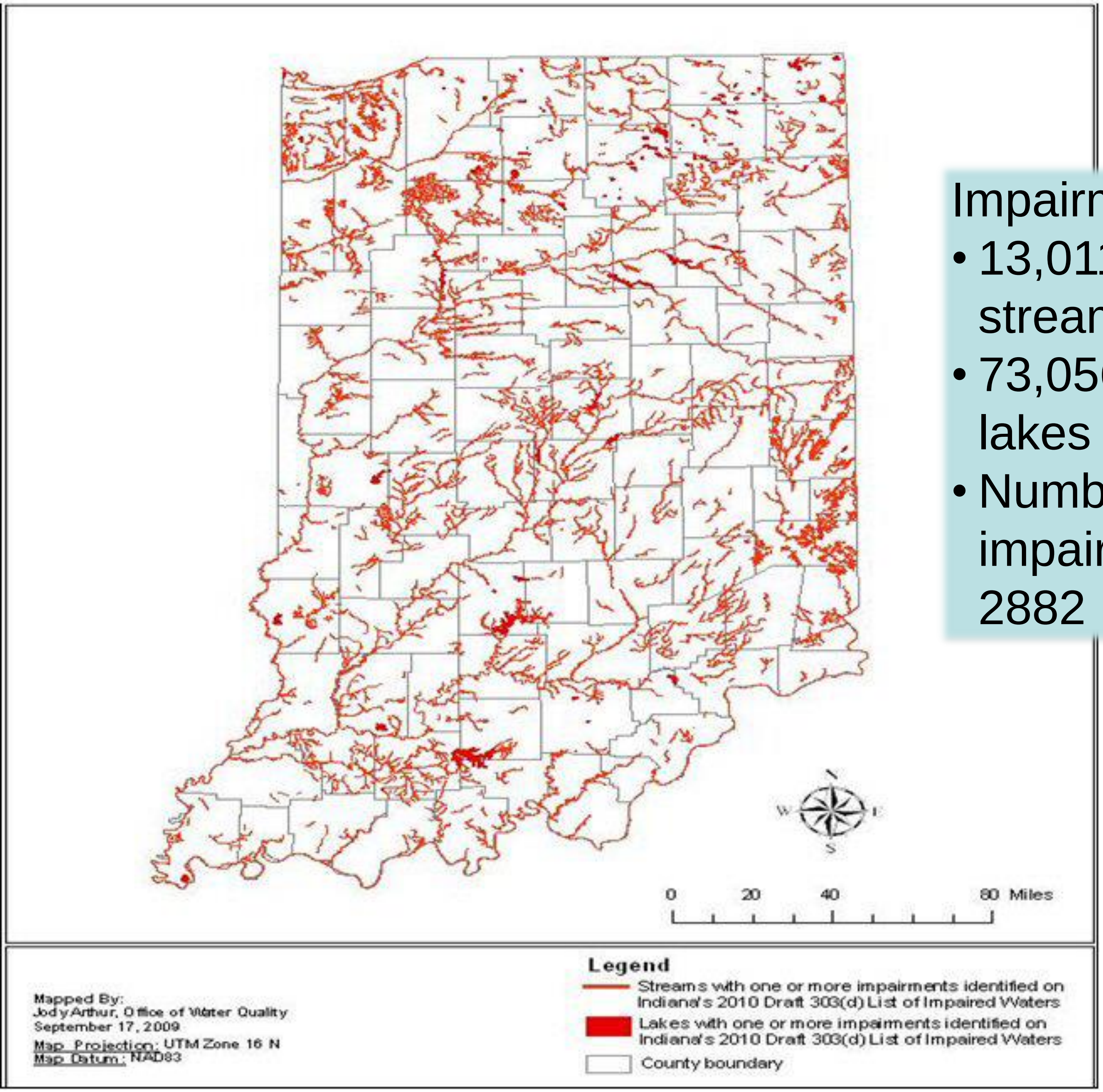
Top 10 Source of Stream Impairments



Source: 305(b) report
EPA 841-R-0001 (2009)

Impairment

- 13,011 miles of streams
- 73,056 acres of lakes
- Number of impairments = 2882

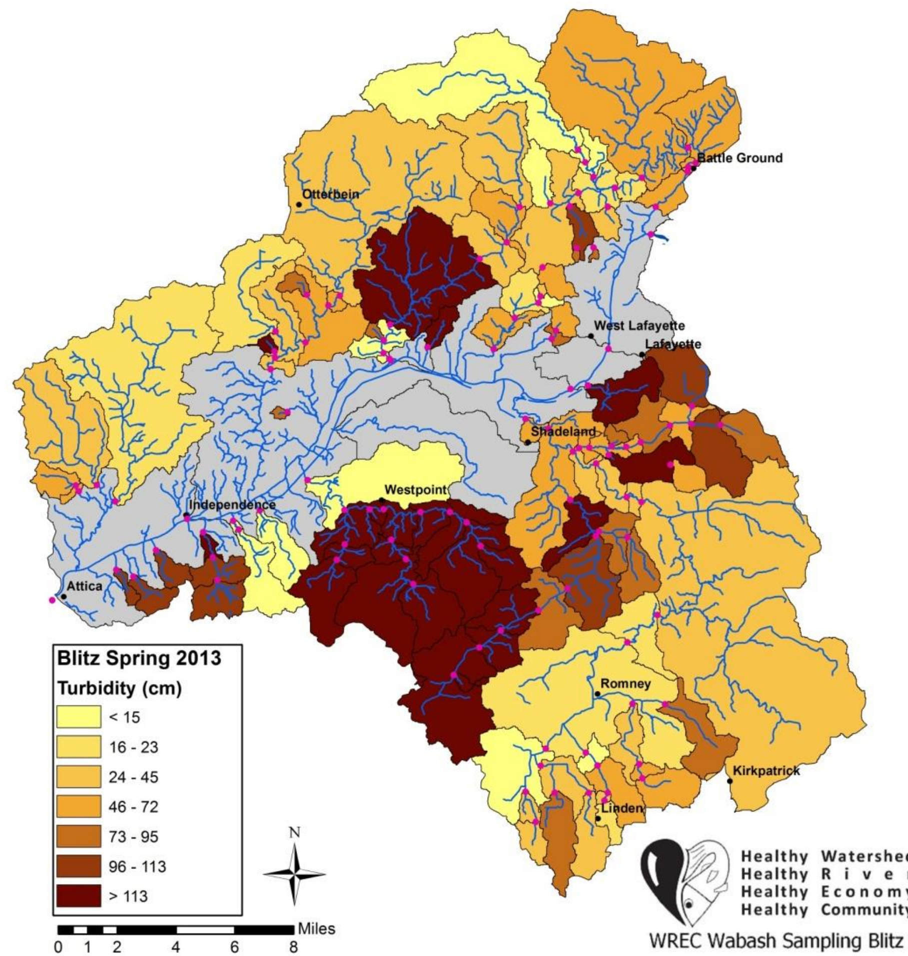


Environmental & Natural Resources Engineering

- Understand basic principles related to water, water, plant, atmosphere interactions
- Use knowledge of math, science and engineering to quantify extent of the problem
- Design components and tools to evaluate impacts on soil, water, air
- Design to mitigate and adapt to problems

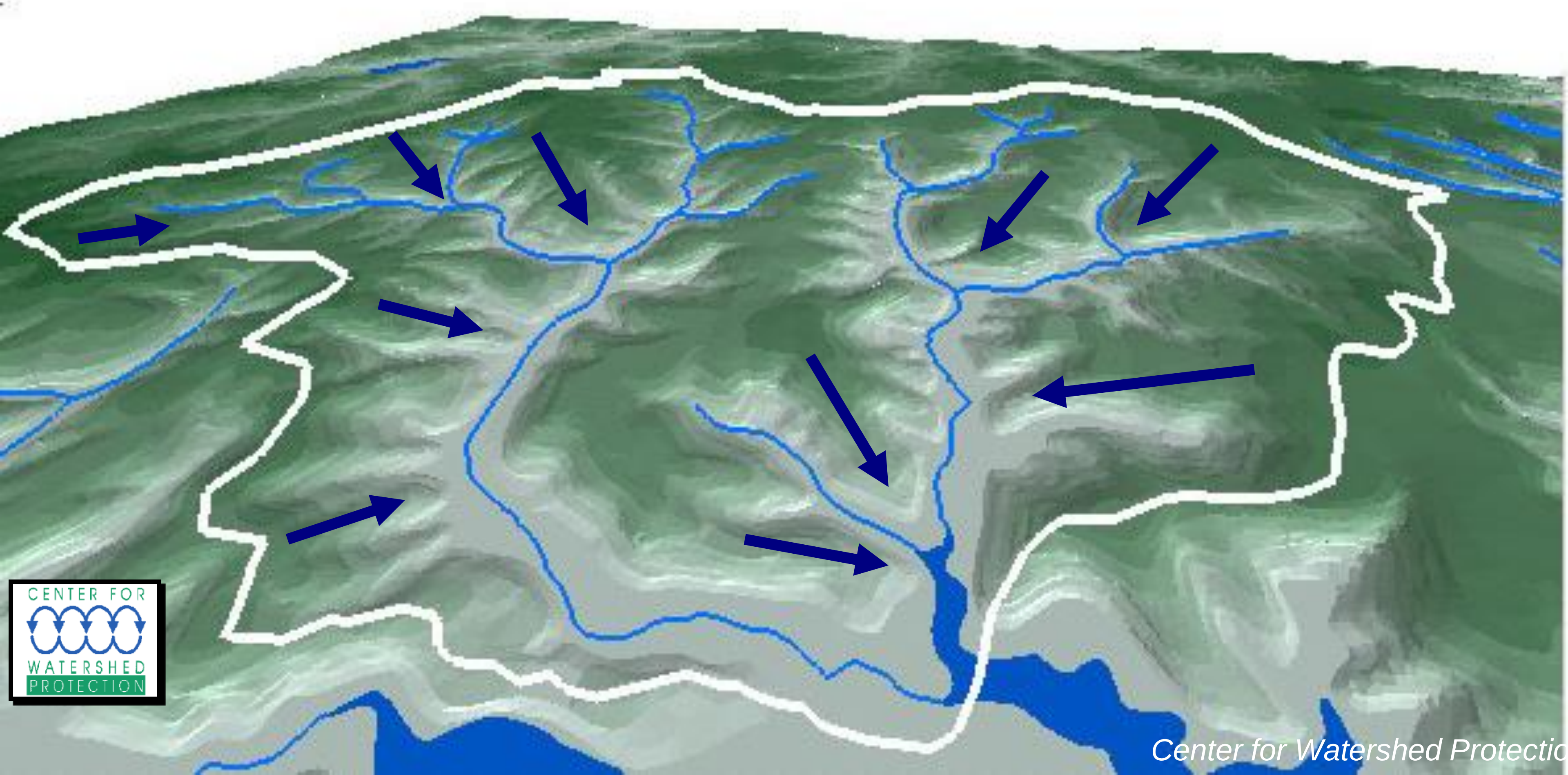
Environmental & Natural Resources Engineering

- **We all live in a watershed that is very likely experiencing water quality problems**



What Is a Watershed?

A watershed is the area of land that drains
to a particular point along a stream



EVERYONE Lives in a Watershed

Water quality issues concern everyone.

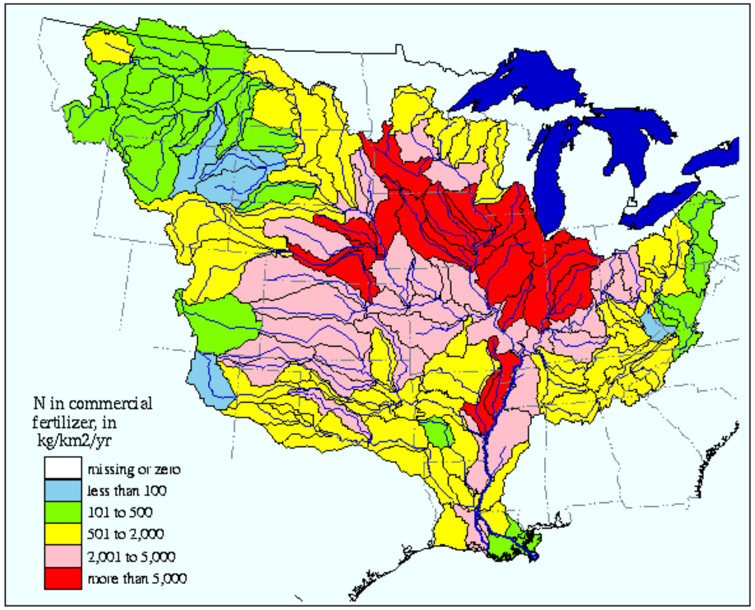
What issues concern you?

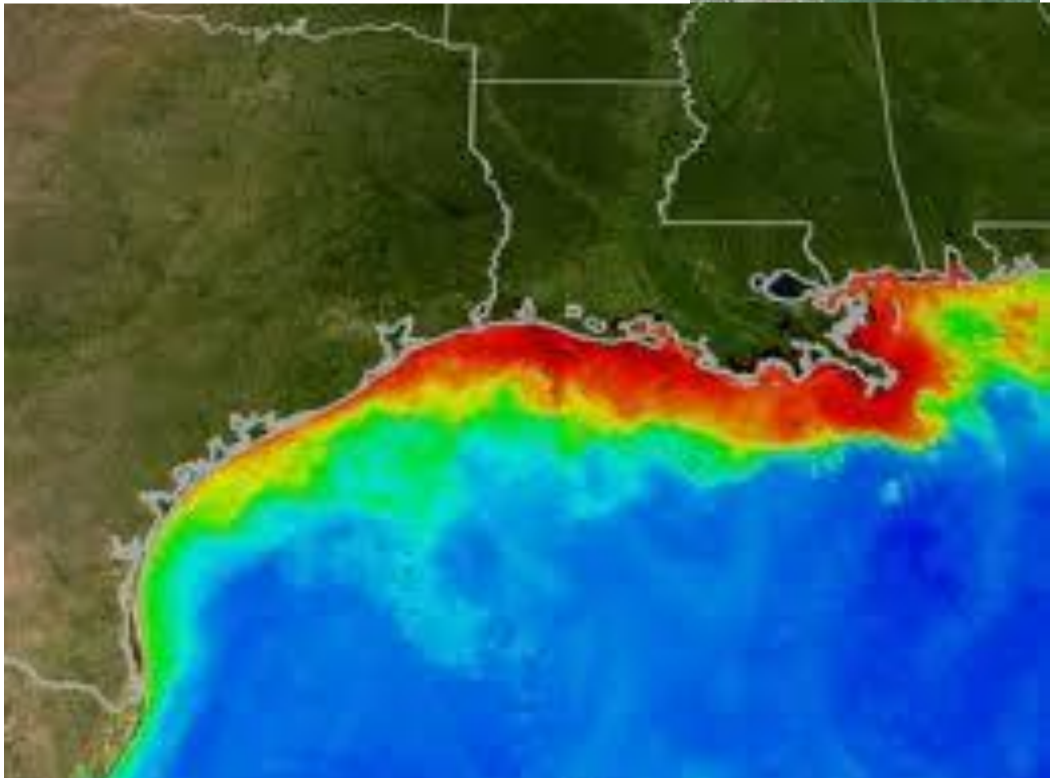
Runoff from streets (salt, leaves, oil)

Runoff from agriculture (fertilizer, pesticides, manure)

Examples of Indiana issues

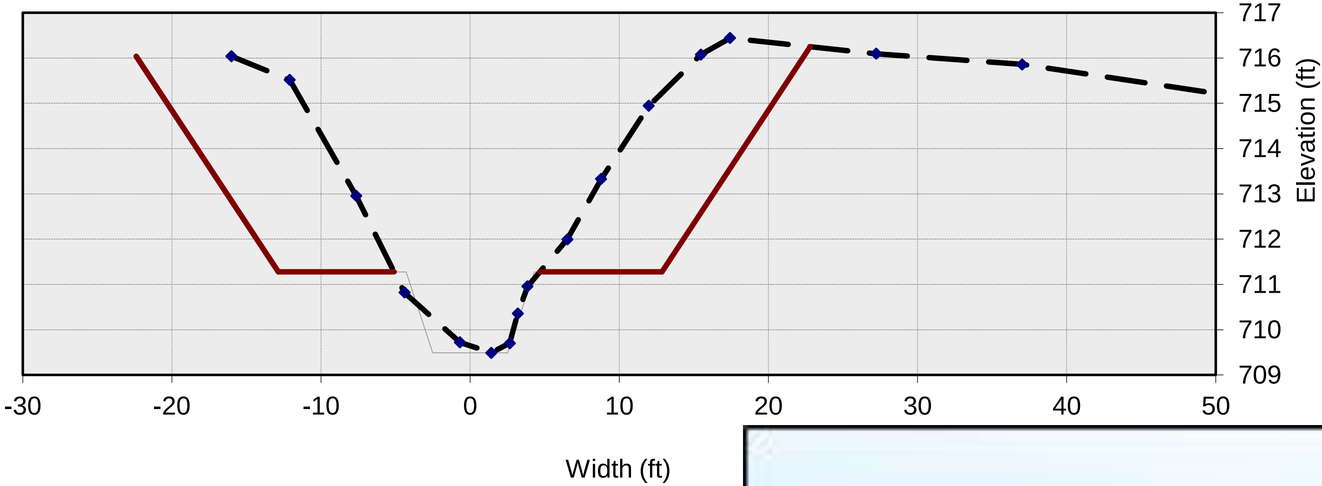
Artificial drainage has greatly changed the landscape





Cross Section 1: Downstream of existing weir
Bench Elevation: 711.3 ft

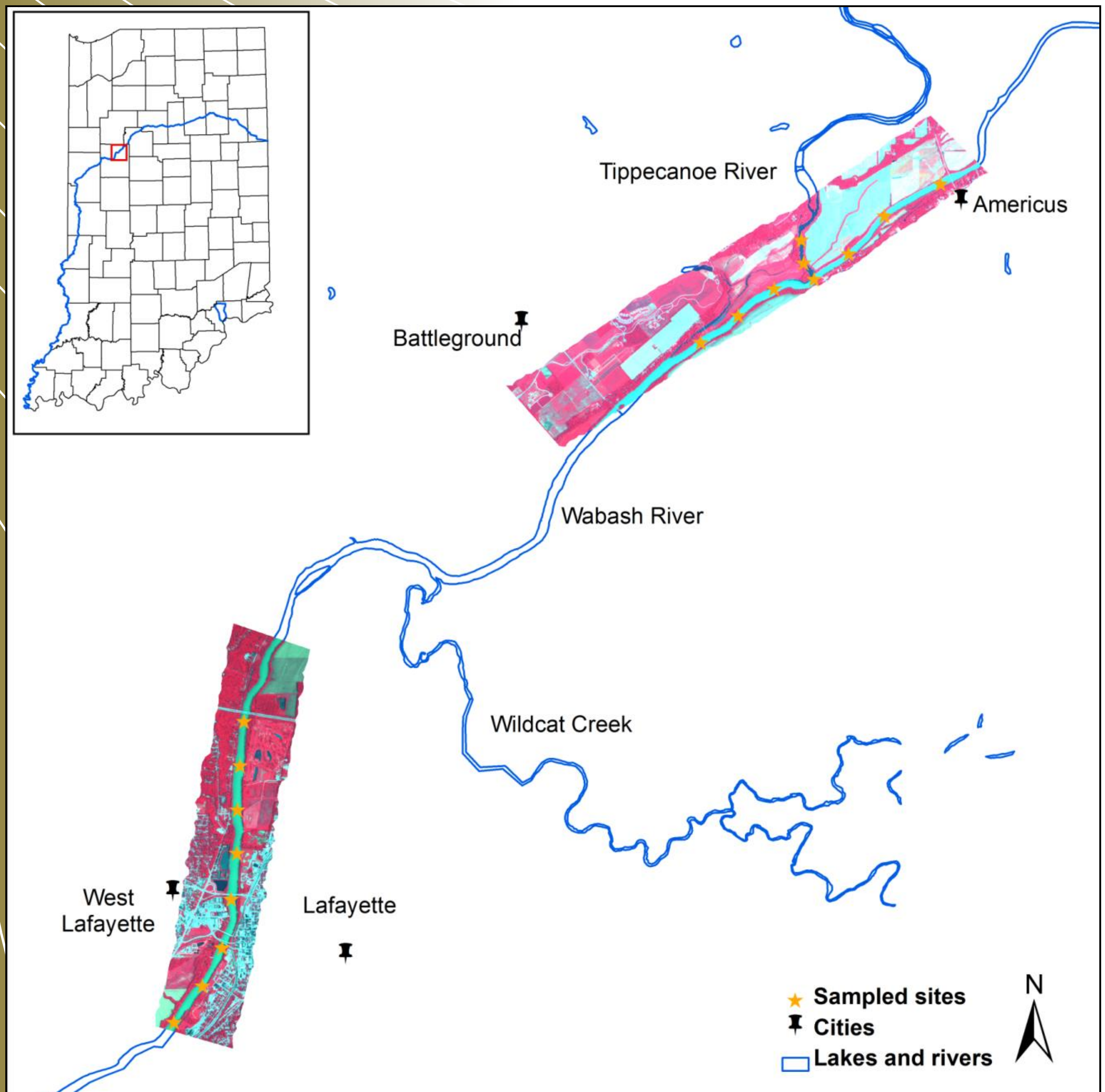
Earthwork Balance: cut 81 sq.ft.
Stream elevation 709.43



Expected Benefits

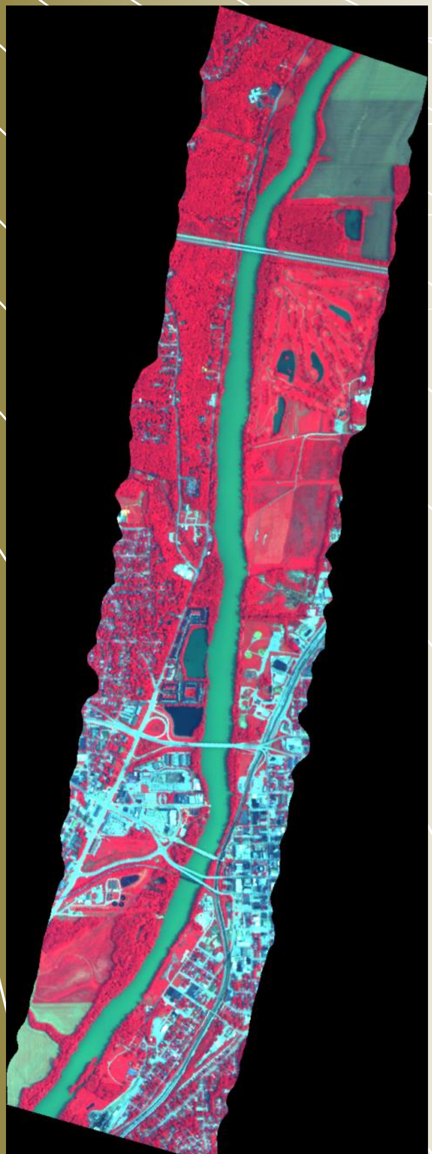
- Improved habitat for fish and microinvertebrates
- Water quality improvements
- Less sediment transported downstream
- Less streambrank erosion because energy is dissipated during high flow events
- Less maintenance

Wabash River

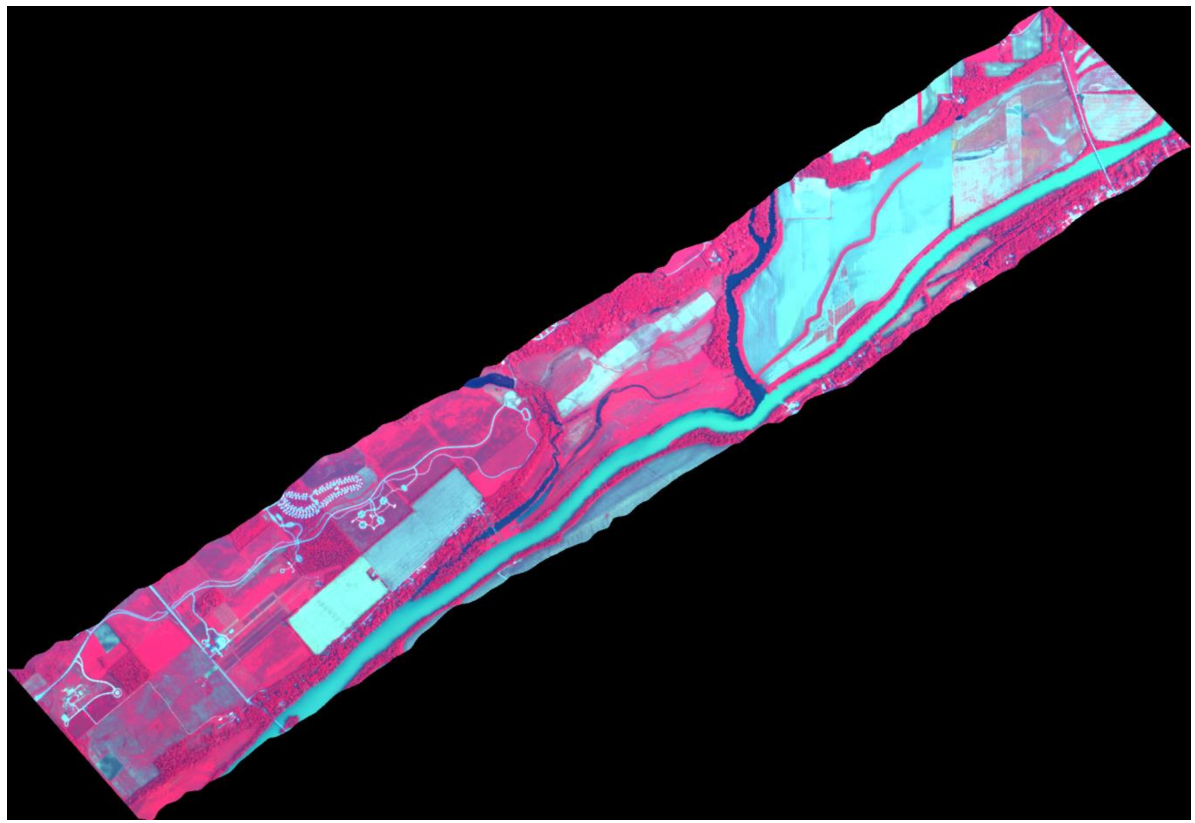


- Chlorophyll a (Chl-a)
- Total Suspended Solids (TSS)
- Colored Dissolved Organic Matter (CDOM)

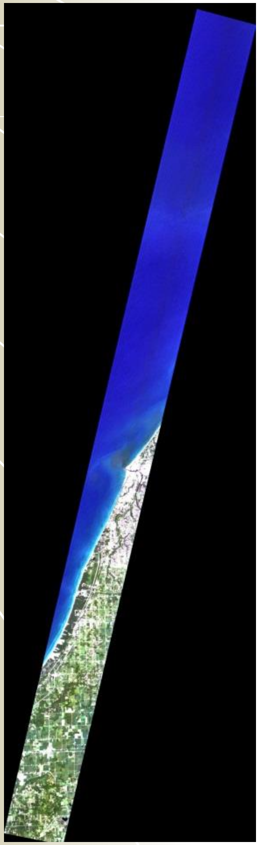
Wabash River through Lafayette, IN

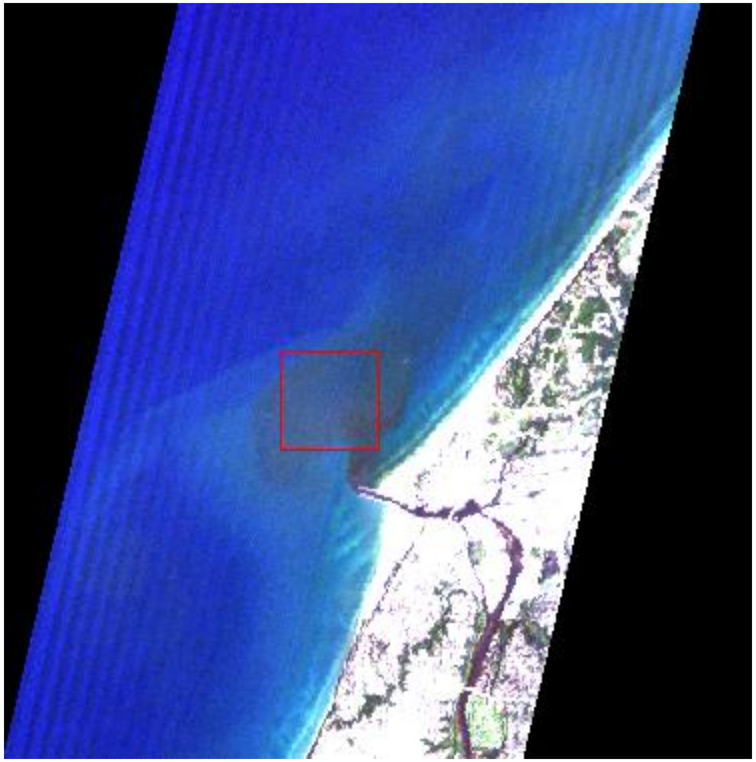


Confluence of the Wabash and Tippecanoe Rivers



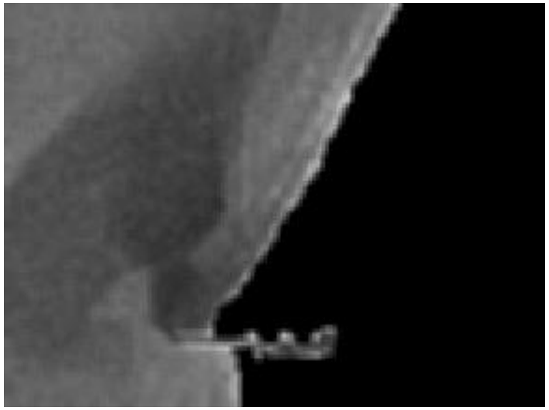
Lake Michigan Plume



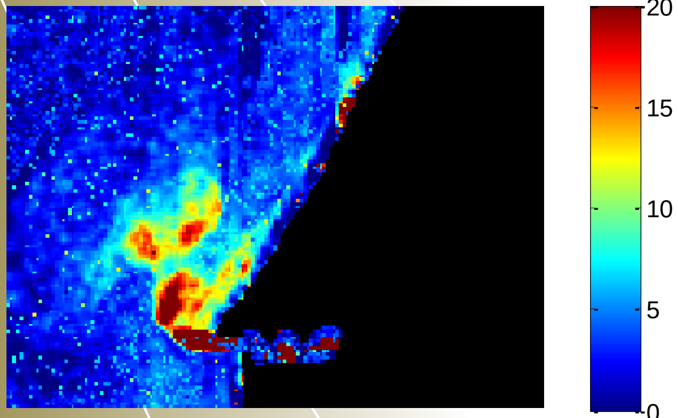


August 7, 2012 at St Joseph River

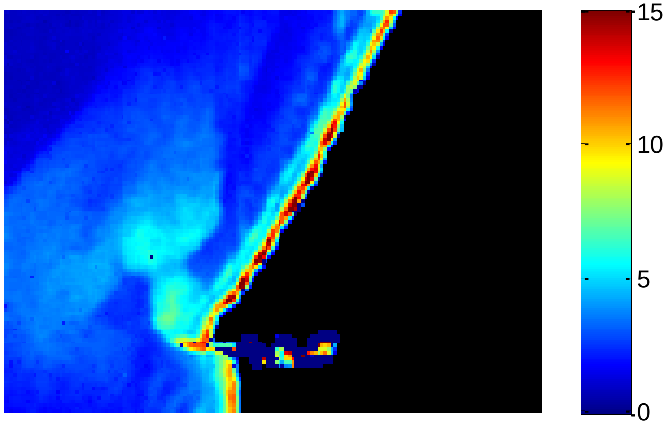
Lake Michigan Plume



chlorophyll-a



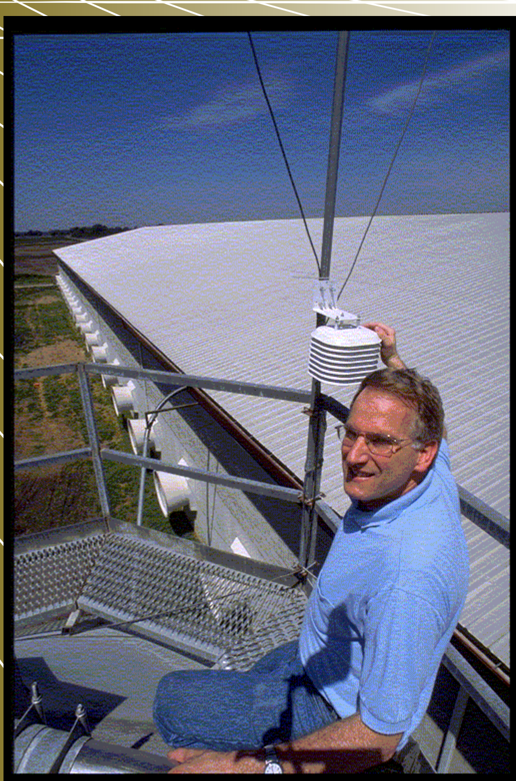
Total Suspended Solids

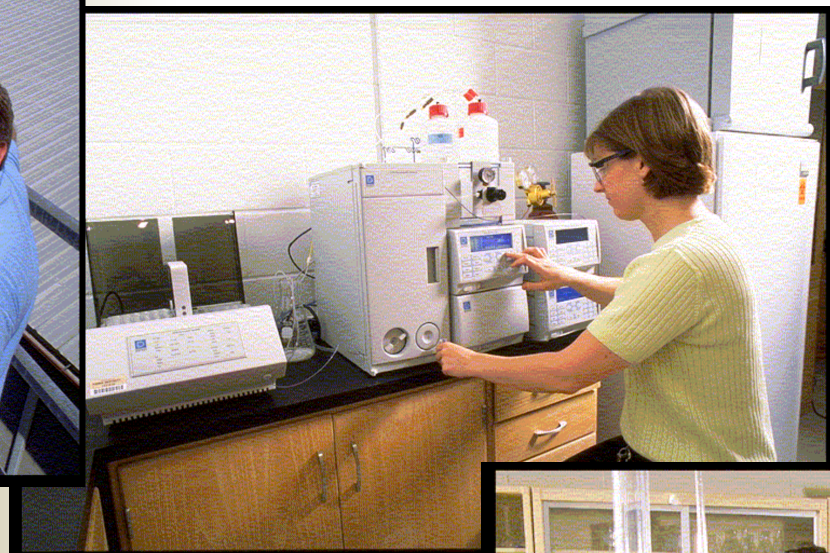


Unmanned Aerial Vehicles (UAVs)

One of many new sensor systems that
Have great potential for helping to manage
And monitor the environment!

Undergraduate Research in ENRE





Air Quality

Water Quality

Contaminant Removal

Environmental & Natural Resources Engineering – where we work

IDEM

Ohio Department of Natural Resources

CATERPILLAR®

United States Environmental Protection Agency

Quest

JFNew

Eco

RAIN BIRD®

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

DNR

NRCS Natural Resources Conservation Service

E·PRO

TETRA TEC

EATON

EARTH TECH

Questions?

Visit the ABE web site for more information about current research.