Predicting the Natural Flow Regime: Assessing Hydrologic Alteration in Stre

U.S. Geological Survey
National Water-Quality Assessment Program

Hydrologic Alteration

- Metrics of frequency, duration, magnitude, timing, rate of change
- Calculated over record (20+yrs) of mean daily values
- Extent to which observed metric (O) deviates from the value expected (E) under "natural" conditions
- O/E >>1 OR <<1 =Alteration

The Questions

- Can we estimate natural flow characteristics (E) for rivers across a region / the Nation?
- Can we quantify hydrologic alteration in a consistent way across a region / the Nation?
- What degree of hydrologic alteration causes ecological impairment?

How can we determine E, i.e. quantitative estimates of natural flow regime?

- Pre-disturbance period of record
  - Generally unavailable
  - How to generalize/apply to "nearby" sites
- "Mechanistic" models
  - Resource-intensive
  - Limited geographic scope
- Statistical models
  - Widely used
  - Inconsistently applied

Study Objectives

1. Evaluate alternative statistical approaches for predicting E at regional & national scales

2. Relate hydrologic alteration to health of biological communities

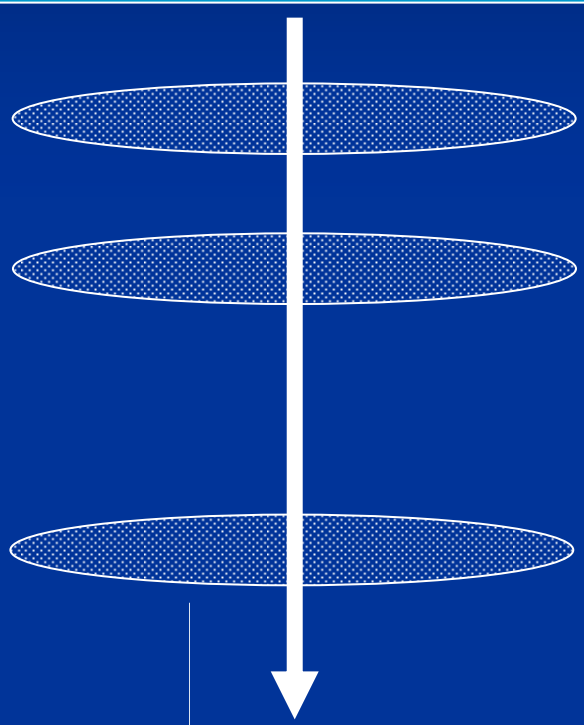
Assessment Philosophy: Reference Condition Concept
(Bailey et al. 2004)

- Expected "natural" conditions (E) are derived from a *population* of environmentally relevant reference sites

- Develop, among reference sites, statistical models that predict site-specific E from natural environmental features

Selecting Hydrologic Reference Sites

~20,000 gages = U.S. total



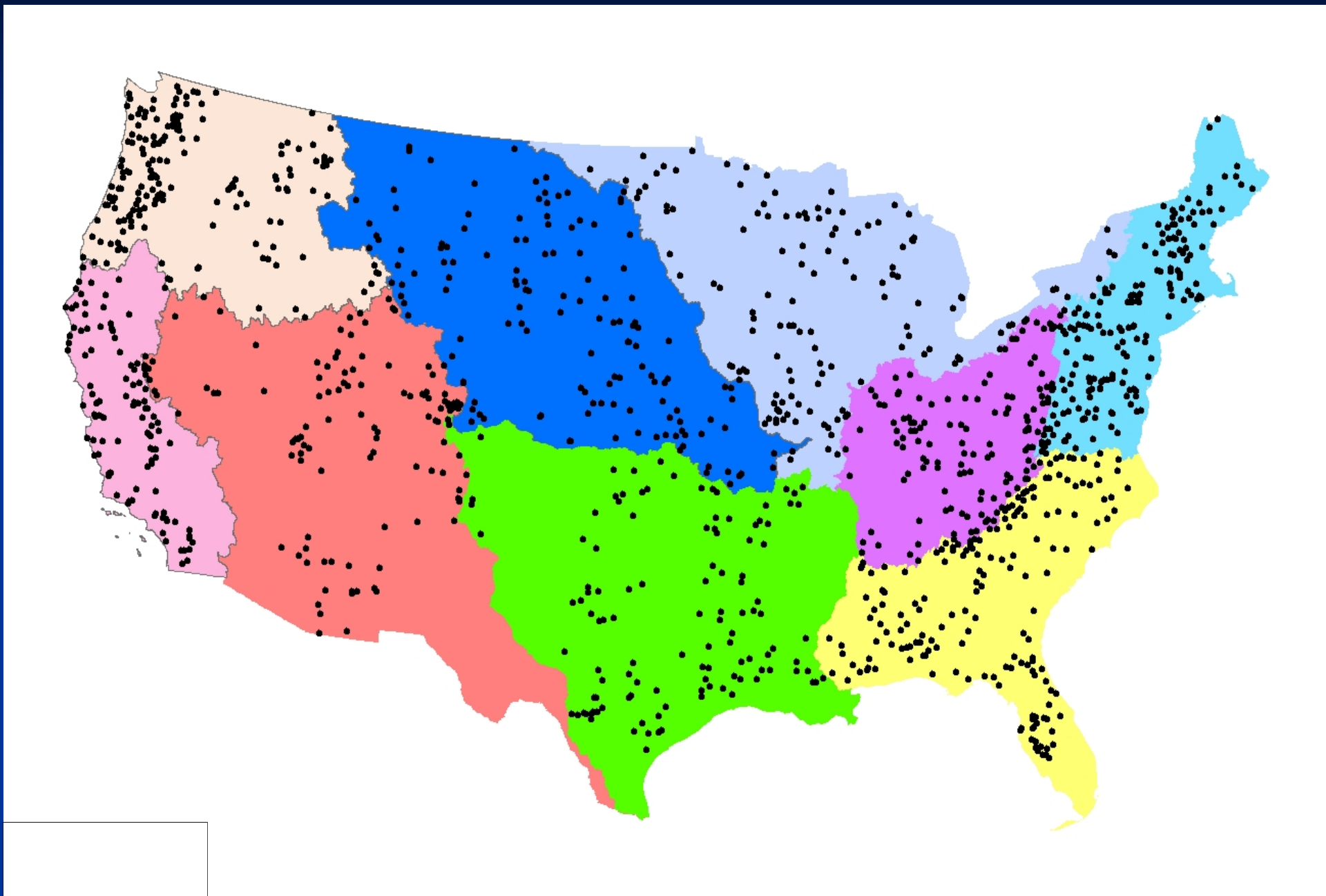
20+ yrs PoR since 1950

Basin size < 50K km^2

* GIS indicators of hydrologic modification
* Local judgment
* Water withdrawal estimates
* Imagery and topo map examination

~1200 "reference" sites

Reference Sites & Major Hydrologic Units (HUC 2)



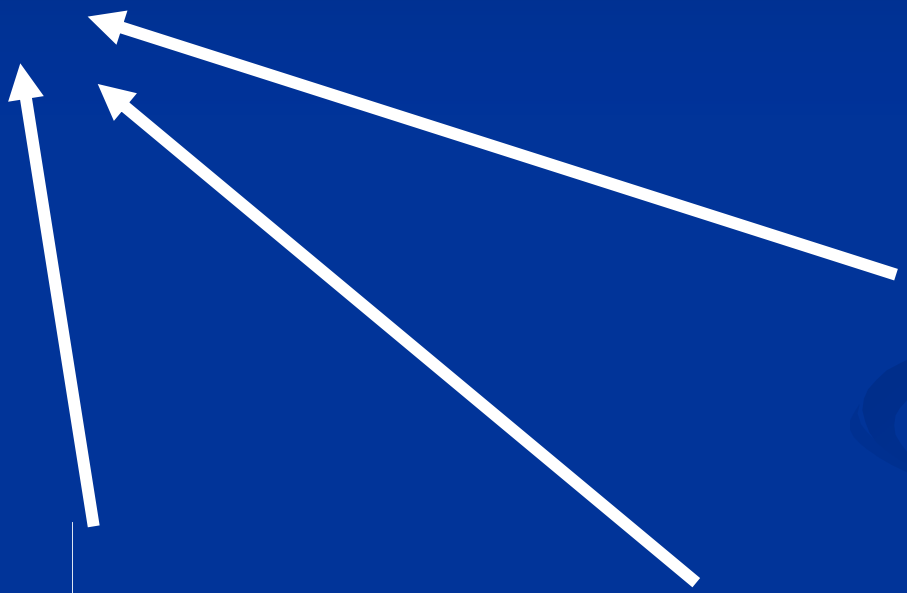
Selected Hydrologic Metrics

- Daily flow variability
- Mean annual skewness
- Median annual runoff
- Baseflow index
- Median annual max. flow
- Low flow pulse count
- High flow pulse count
- Low flow pulse duration
- High flow pulse duration
- Flood interval
- Flood-free days
- Predictability
- Number of reversals

Alternative "Models" for Deriving E

O_i = observed metric value at site i

E_i = expected metric value at site i from:



Predictive models

~ Site-specific E from:

1. Nationwide Model
2. HUC 2 Model

NULL model

~ Fixed E nationwide

Stratification models

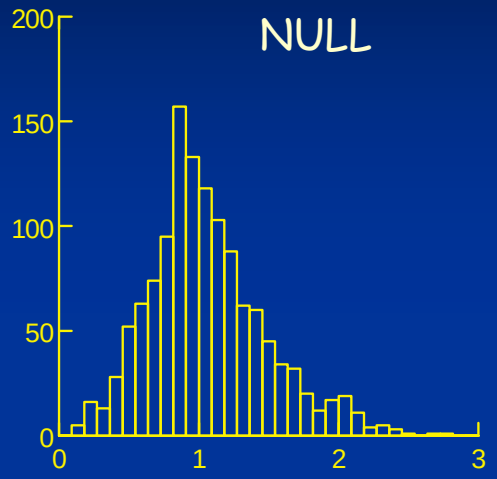
~ Fixed E for:

1. HUC 2
2. Ecoregion Level 3
3. Hydrologic Landscape Region

80+ Predictor Variables

- Basin size & location
- Topography
  - Mean slope
  - Mean elevation
- Climate
  - Precipitation
  - Air temperature
- Soils
  - Hydrologic characteristics
  - Soil properties
- Geology
  - Dominant surficial geology
  - Pct of various geology

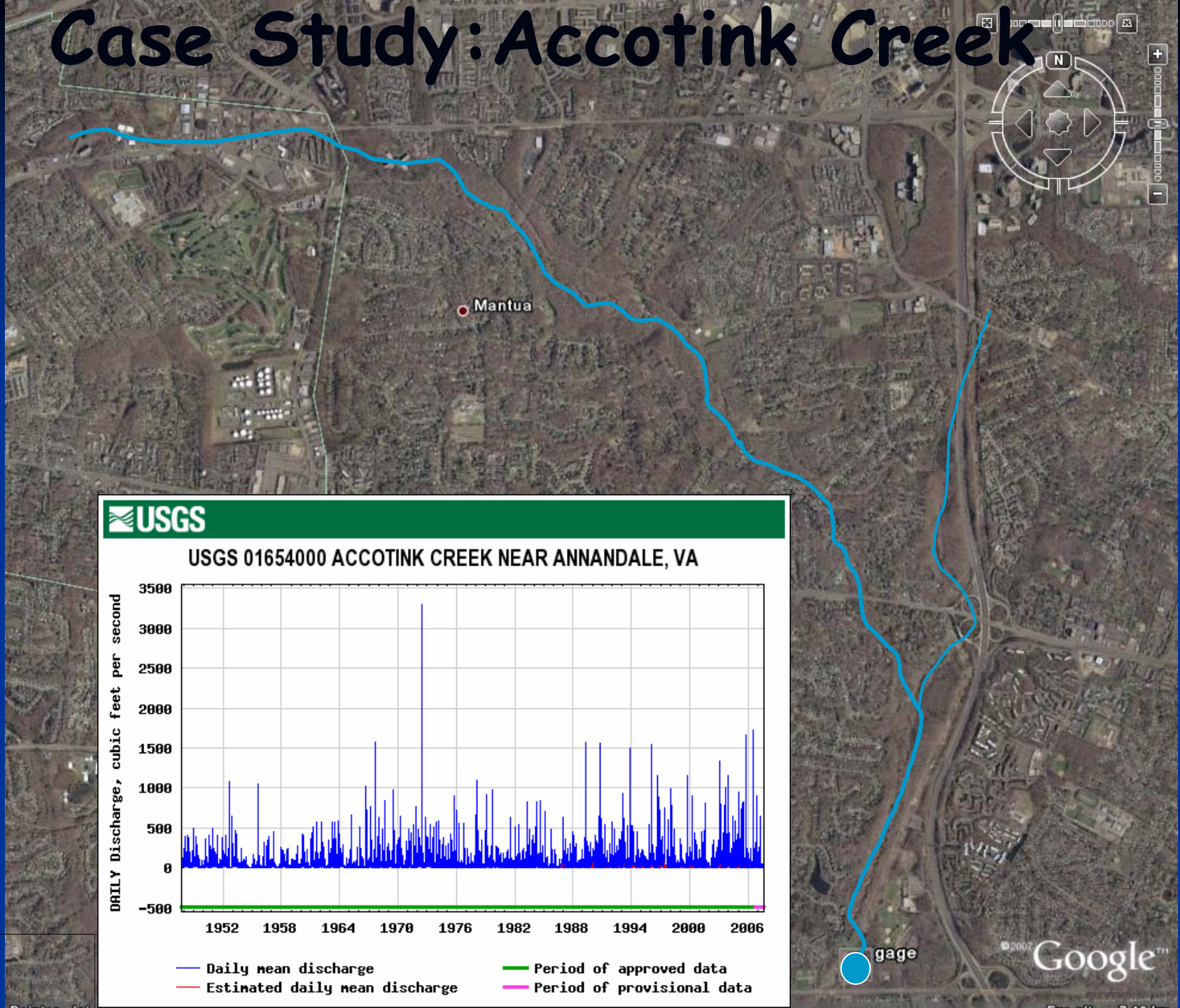
Results: daily variability



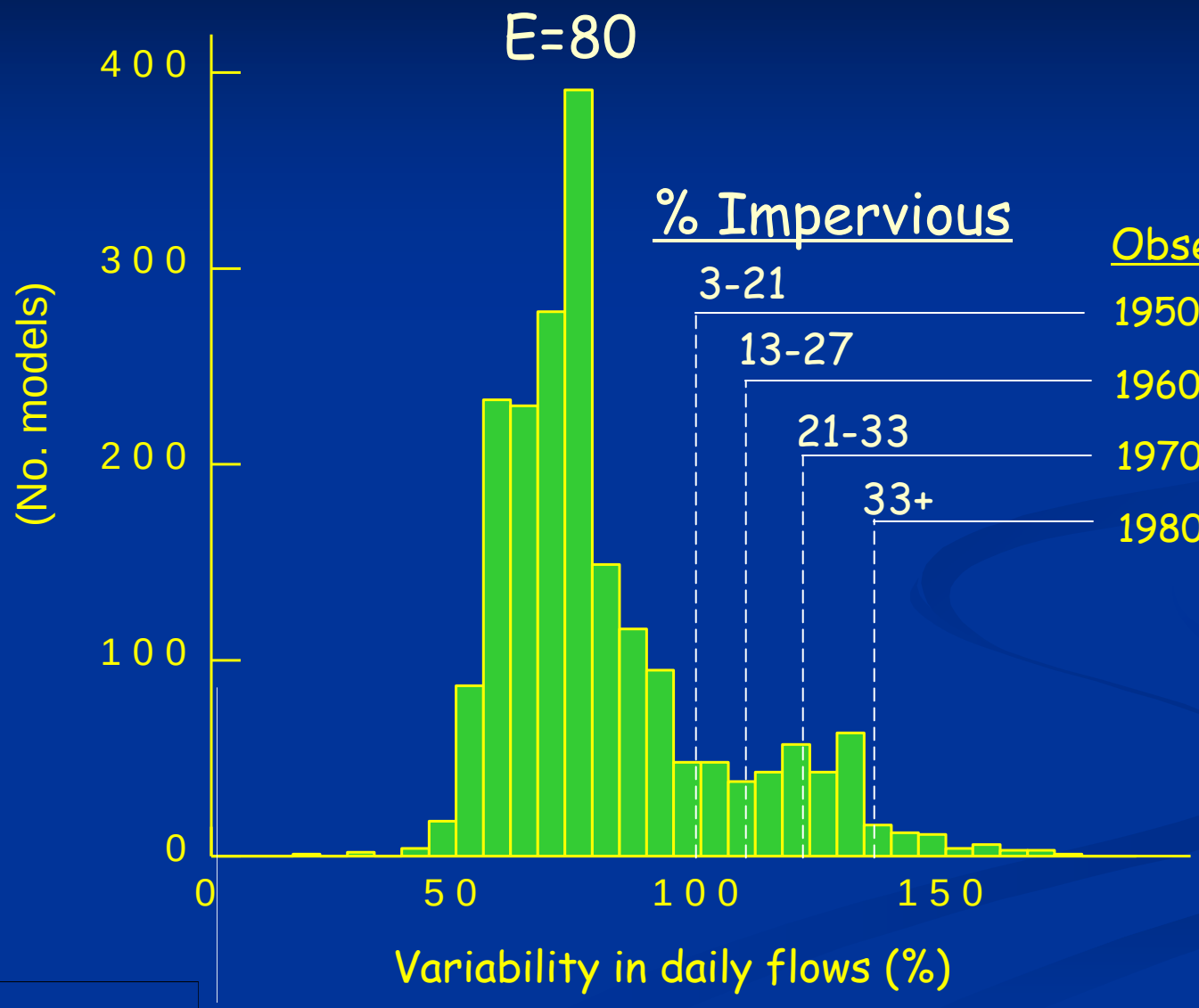
Summary of Model Performance

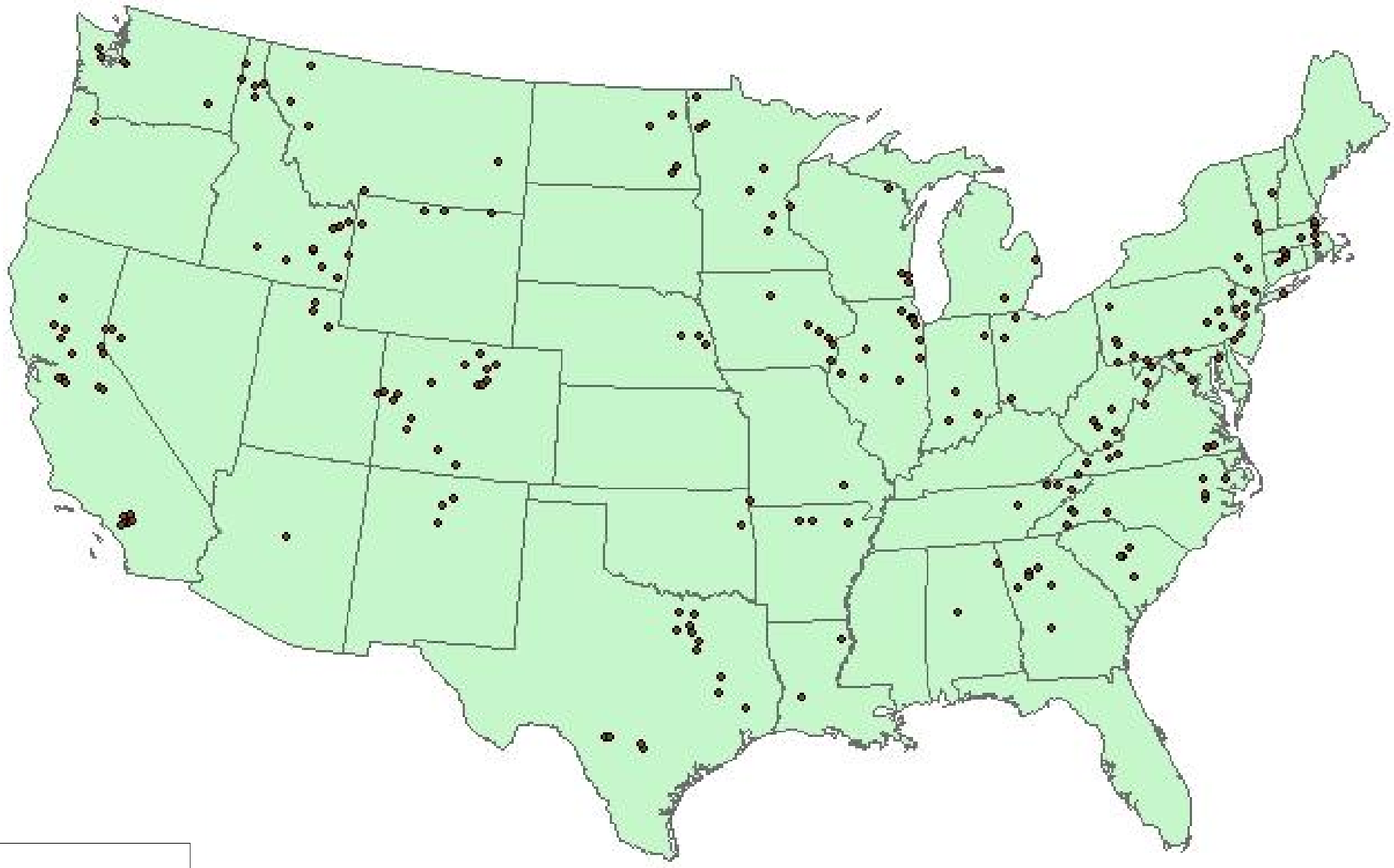
- Predictive models performed best for ALL metrics
  - 29-81% improvement over NULL
  - 18-80% improvement over HUC 2 stratification
  - 9-61% improvement over Ecoregion stratification
- The national predictive model for each metric performed as well as regional predictive models
- 12 of 13 metrics predicted with relatively low (<30%) error

Case Study: Accotink Creek



Model Predictions for Accotink Creek





Biolo

Summary

- Metrics of natural flow regime (e.g., "ecological flows") can be modeled for large percentage of US streams
- hydrologic alteration can be QUANTIFIED as O/E…
- for a standardized & consistent assessment across regions & the Nation…
- Broad-scale losses of biological integrity are evident in hydrologically altered streams
- Ecological effects of hydrologic alteration may be cumulative

Authors & Acknowledgements

- U.S. Geological Survey, National Water-Quality Assessment (NAWQA) Program
  - D. M. Carlisle
  - D. M. Wolock
  - J. Falcone
  - M. R. Meador
  - L. Weber
  - Marty Gurtz
- Water Cooperative Research Centre and Institute for Applied Ecology, University of Canberra, Canberra, Australian Capital Territory
  - R. H. Norris