Landscape/Predictive Tools Manual Development

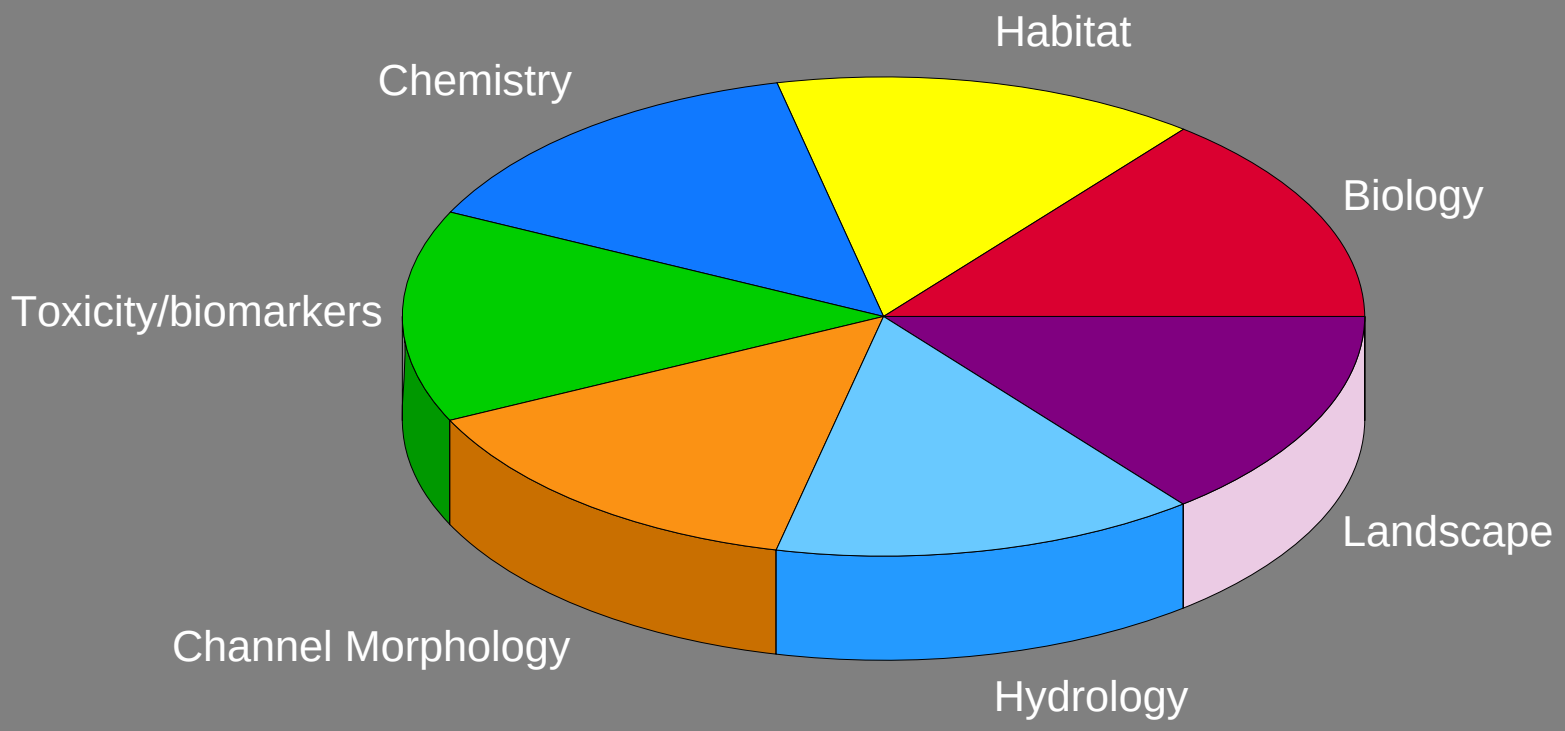
NWQMC Conference

May 2008

Atlantic City, NJ USA

Jim Harrison
Environmental Scientist – Region 4
Co-Chair – Landscape/Predictive Tools Steering Committee

Dividing the monitoring pie by technique



Steering Committee

Begins work July 2006 through meetings and conference calls

Approximately 30 Members Representing:

- **EPA Headquarters (OWOW & OST)**
- **EPA Regions (1, 4, 5, 6, 8 &10)**
- **EPA ORD (Las Vegas, Corvallis, Cincinnati, Narragansett, RTP)**
- **States (AL, FL, OR and others)**
- **Other Agencies (USGS)**

Committee Co-Chairs:

- **Jim Harrison – EPA Region 4**
- **Ellen Tarquinio – EPA HQ/OWOW**
- **Don Ebert – EPA ORD/Las Vegas**

Mission:

Strengthen and support incorporation of geographic frameworks, and landscape information and tools into Clean Water Act programs

Objectives:

1. Collaboratively produce a state-of-the-art national methods document to aid state/tribal development and application of stressor/pressure/disturbance gradients and predictive tools relating stress(es) to response(s).

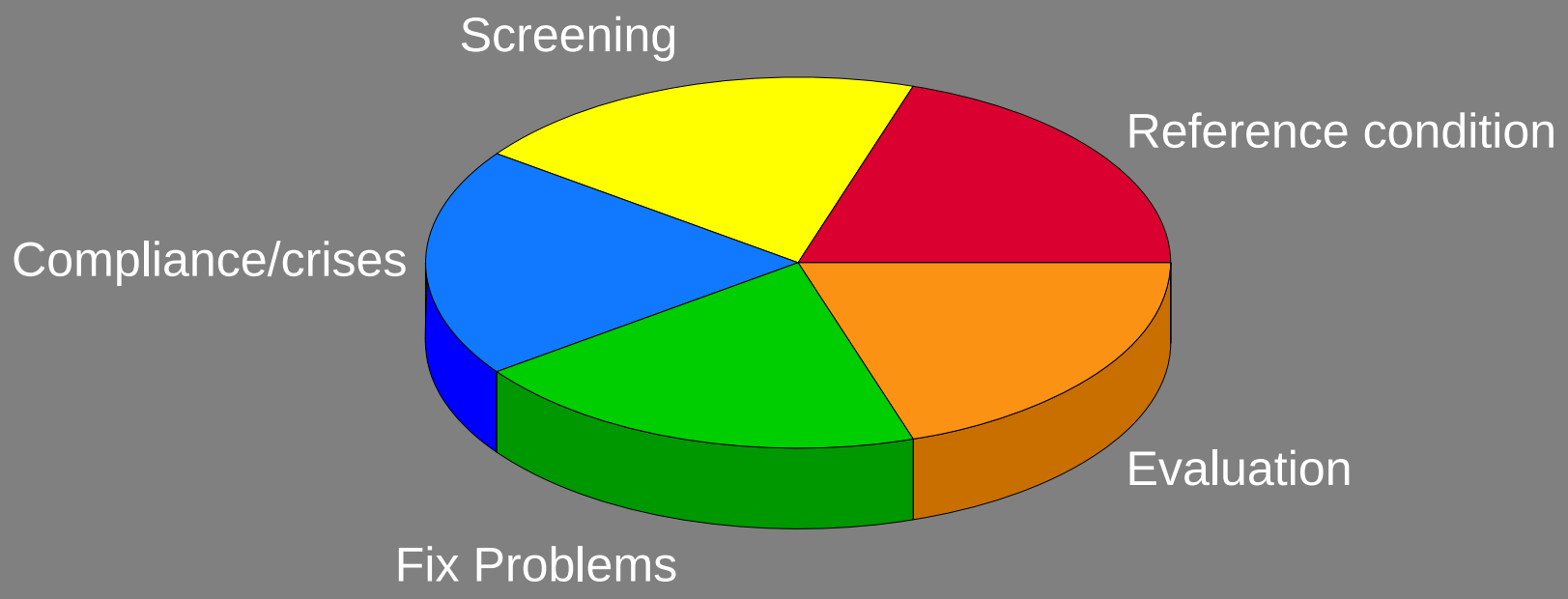
Objectives:

2. Support a wide variety of water quality monitoring needs by disseminating tools and methods to extrapolate aquatic condition estimates to areas & waters lacking in-situ monitoring.

Objectives:

3. Illustrate actual and potential applications including: identifying potentially impaired, high quality and reference waters, identifying potential stressors, calibrating biological and other indices, and planning, and targeting and prioritizing monitoring activities, prevention and restoration efforts.

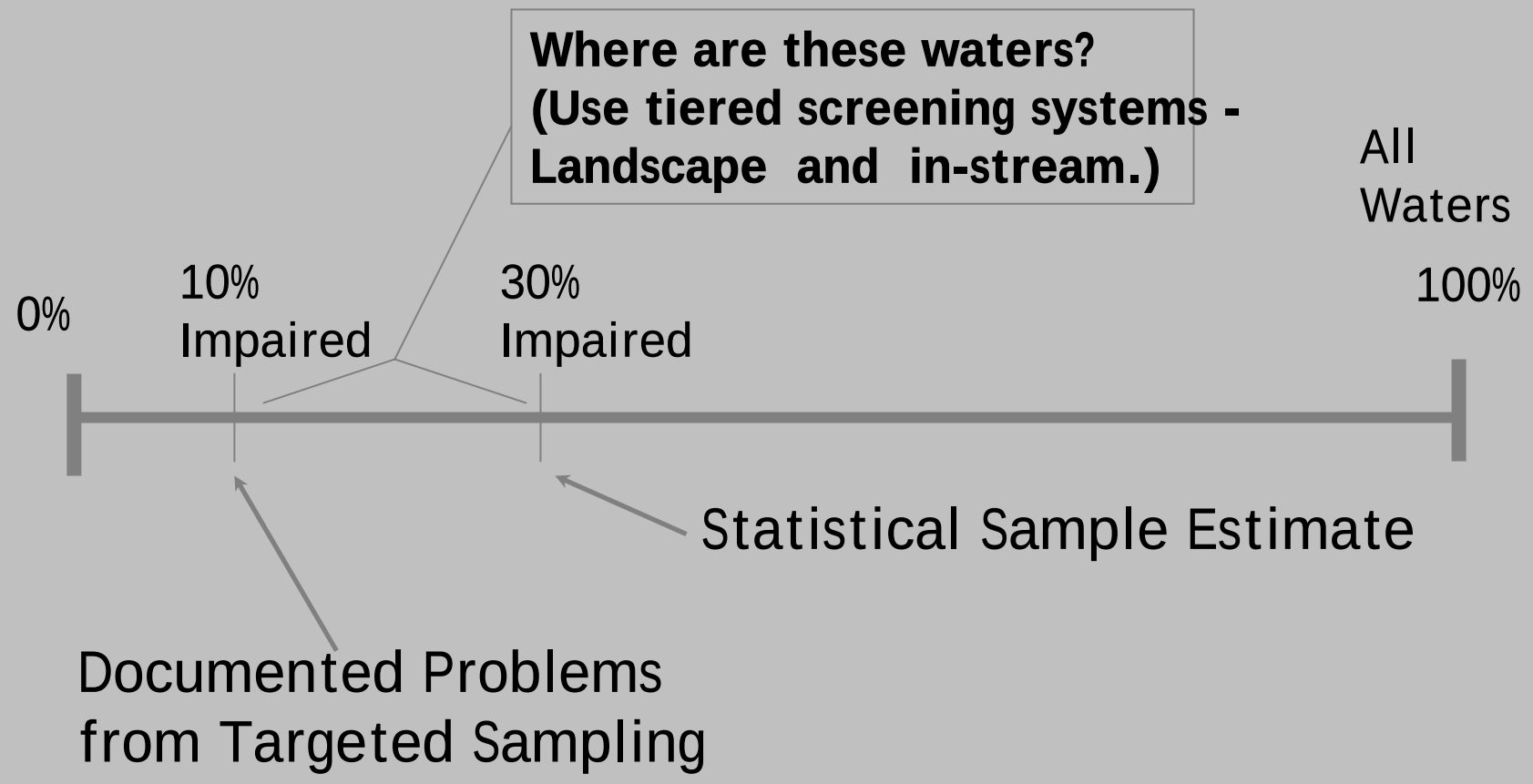
Dividing the pie by key questions



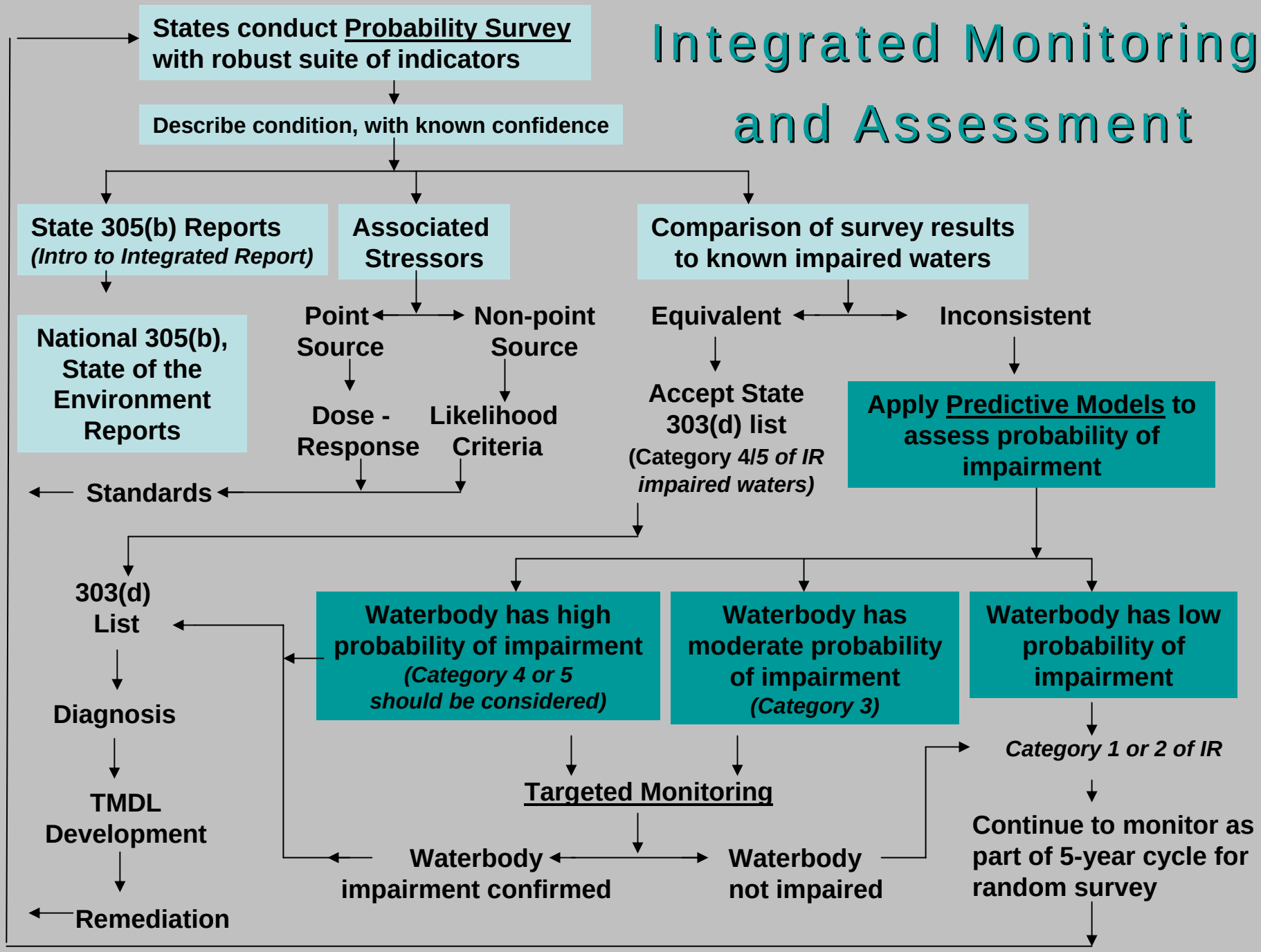
Combination of Tools Serve Water Quality Decisions

Statistically-valid survey	• Predict proportion of all waters in good or poor condition, with documented confidence • Measure trends in water resource condition and CWA program effectiveness • Support development of new WQS • Prioritize targeted monitoring to specific parameters/stresses
Modeling and landscape analysis	• Determine where water quality is likely impaired • Predict localized water quality • Prioritize targeted monitoring to specific areas and stresses
Targeted monitoring	• Assess WQS attainment for specific segments • Measure trends at specific sites • Identify sources of pollutants to specific waters • Support development of local management measures (TMDL, NPDES permits, NPS BMPs, WQS) • Assess performance of individual measures

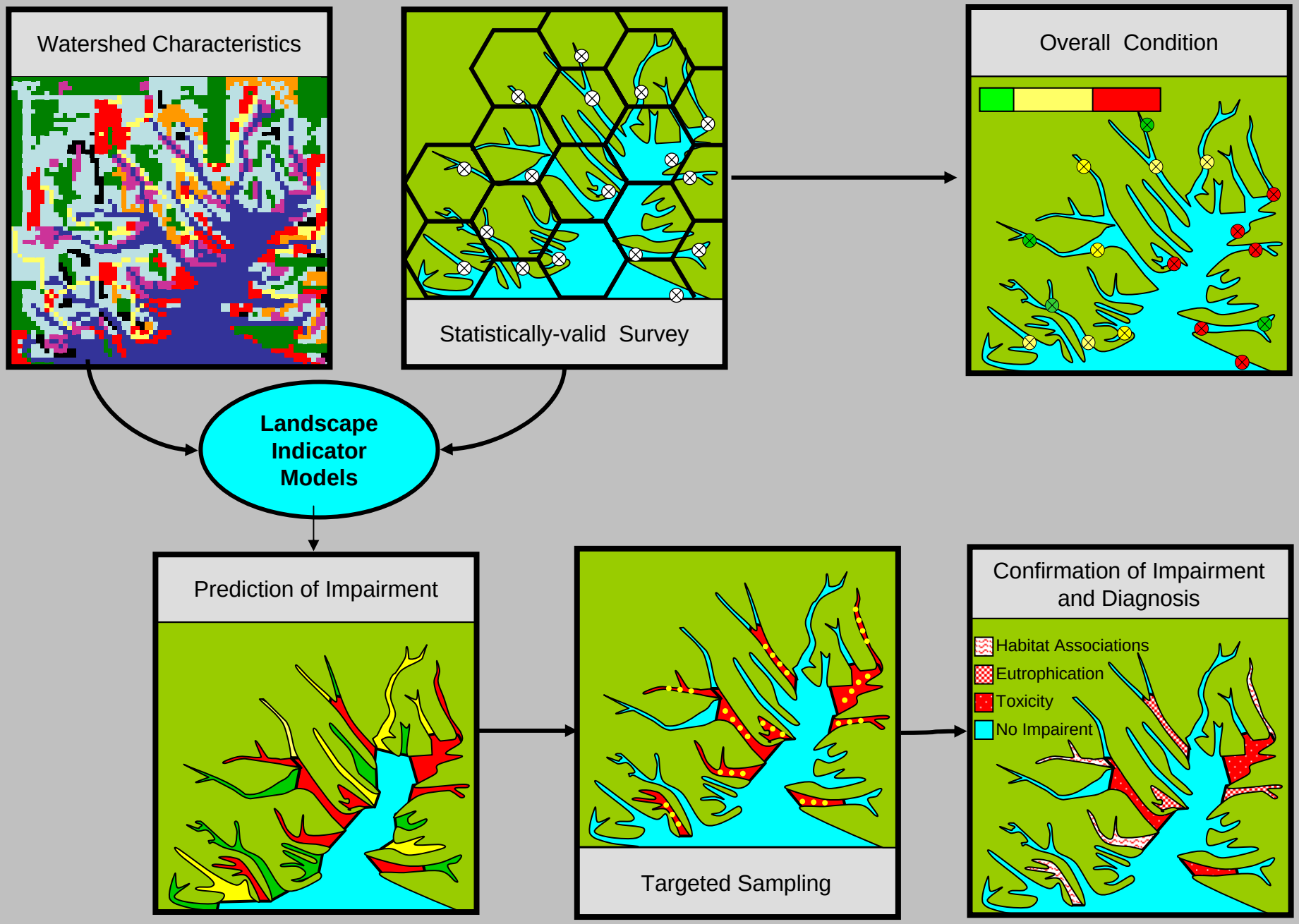
Need for Predictive Screening Systems to Identify Problems



Integrated Monitoring and Assessment



Streamlined Monitoring – Using the Tools Together



Spectrum of Uses for Landscape and Predictive Tools

Purpose	***Uses***
Criteria and Standards Development	Identify candidate reference (minimally disturbed, least disturbed) areas Calibrate reference condition at state, multi-state, and national scales Calibrate biological and other condition measures Develop more protective predictive models of biota & biocriteria Define & document human disturbance gradients for Tiered Aquatic Life Uses (TALU) and other purposes
Problem Identification and Prevention	Extrapolate condition estimates to waters lacking in-situ data Identify suspected problem areas Target monitoring to assess likely problems Estimate vulnerability to stress(es) Target areas for prevention or protection
Prioritization and Targeting of Rehabilitation	Assist stressor identification & diagnosis Identify causes and sources Prioritize TMDL and rehabilitation or regulatory efforts Prioritize waters for delisting efforts Estimate recovery potential and target rehabilitation actions
Science, Education and Management	Evaluate landscape stresses and problem causes (pressures) for large areas Assess relative influence of different stresses/pressures and scales (site, watershed/catchment) Relate human disturbance to effects occurring in water bodies (rivers, lakes, wetlands, estuaries) Raise awareness of consequences of local land decisions

Preliminary Analysis Steps and Factors

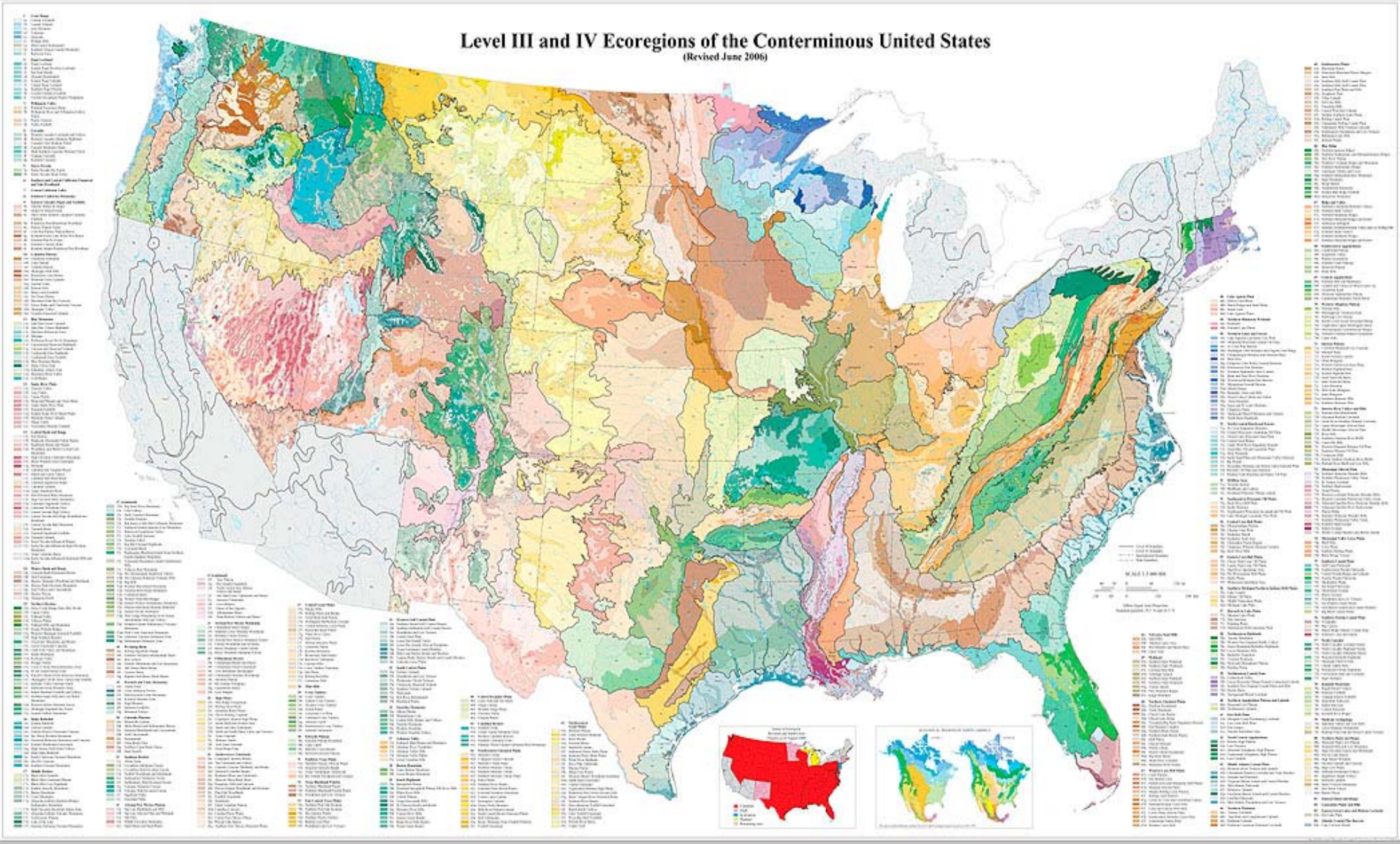
Preliminary Analysis Steps	*Factors to Consider*
Problems/questions (See Slide 17: Spectrum of Uses for Landscape and Predictive Tools)	Criteria and Standards Development Problem Identification and Prevention Prioritization and Targeting of Rehabilitation Science, Education and Management
Areas of interest	Scales Geographic Frameworks Appropriate areas for analysis and extrapolation
Pressure/stress/response parameters of interest	Landscape Habitat/channel/geomorphology Chemistry Hydrology Biology Others
Available data	Geographic Frameworks/Classifications Landscape Ambient stress/response - Gradient of sites covering full range of stress(es) - Probability survey data: biological response and stressors - Before/After and Control/Impact (BACI) designs
Data quality objectives	Are existing data sufficient to answer questions with required power?
Exploratory analysis	Simple GIS & statistical approaches Describe stress and response gradients Derive simple stress/response relationships (if needed/possible)
Evaluate results	Identify gaps Plan next steps

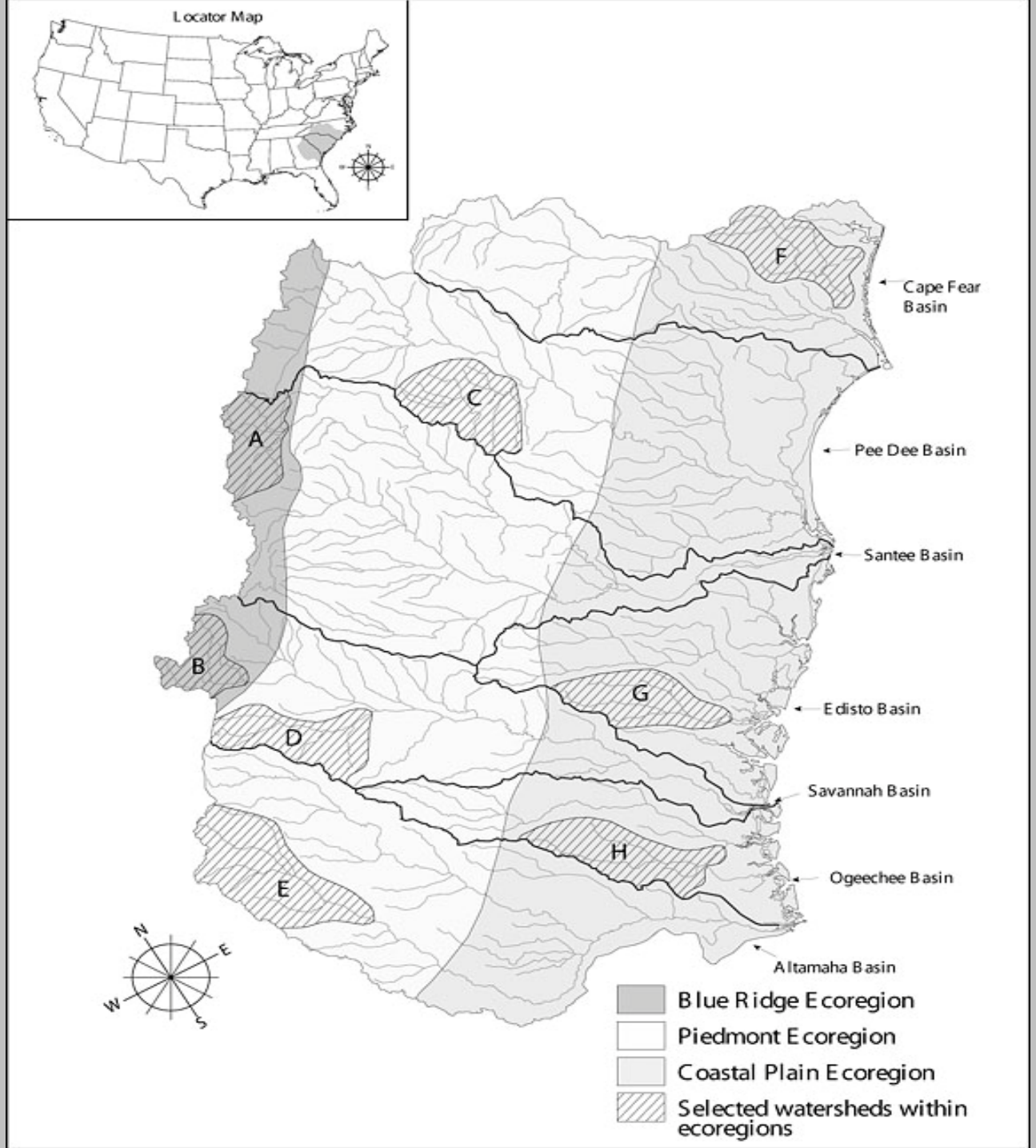
Spatial Scales
and
Geographic Frameworks

- Ecoregions (levels 4, 3 and 2)
- Watersheds (catchments, 14, 12, 11, 10 & 8 digit HUC's)
- Hydrologic Landscapes
- Political and other boundaries (city, county, regions, state, EPA region, nation)

Level III and IV Ecoregions of the Conterminous United States

(Revised June 2006)




Locator Map
A
B
C
D
E
F
G
H
Cape Fear Basin
Pee Dee Basin
Santee Basin
Edisto Basin
Savannah Basin
Ogeechee Basin
Altamaha Basin
N
E
S
W
Blue Ridge Ecoregion
Piedmont Ecoregion
Coastal Plain Ecoregion
Selected watersheds within ecoregions

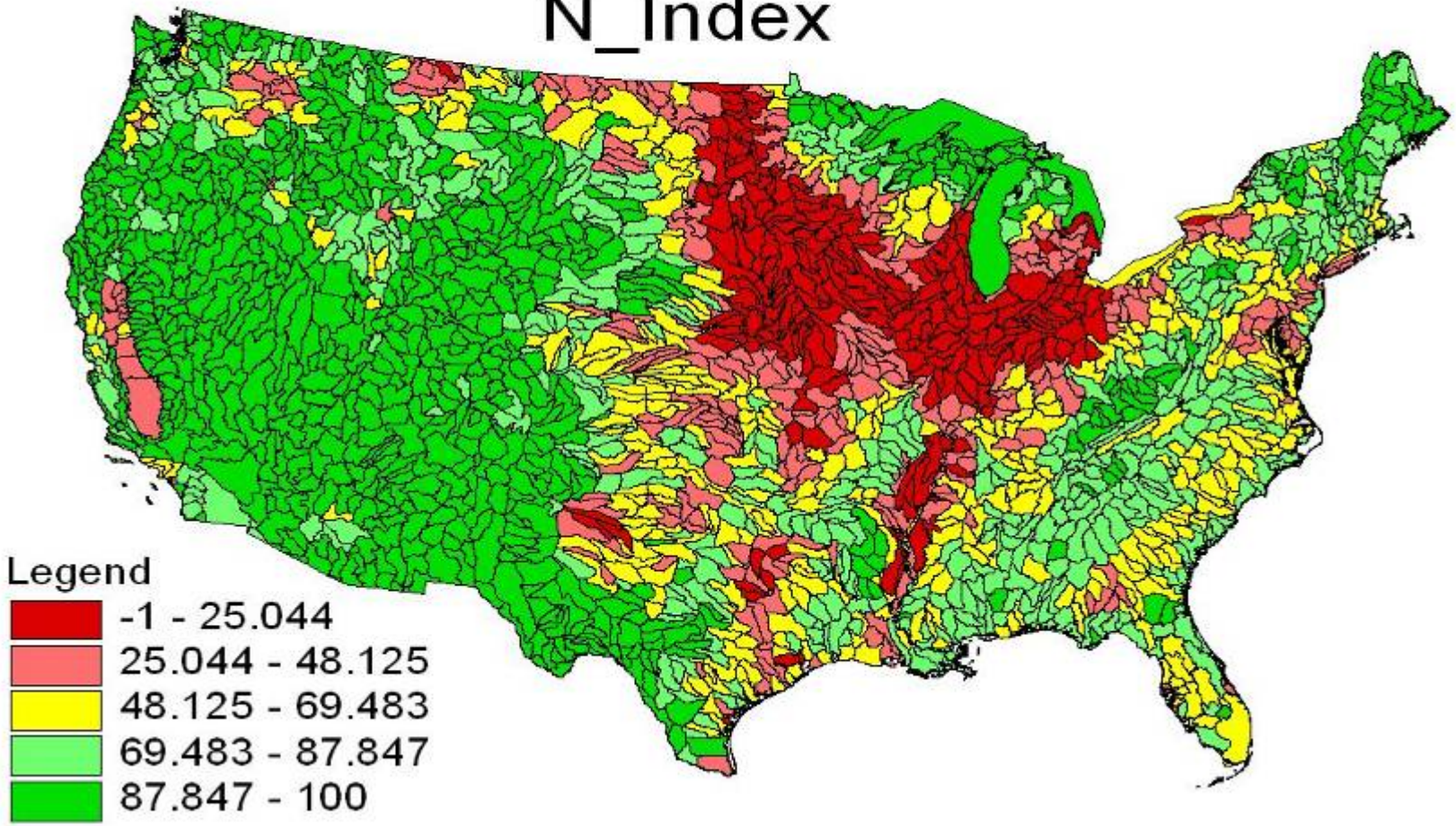
Resolutions of data (examples)

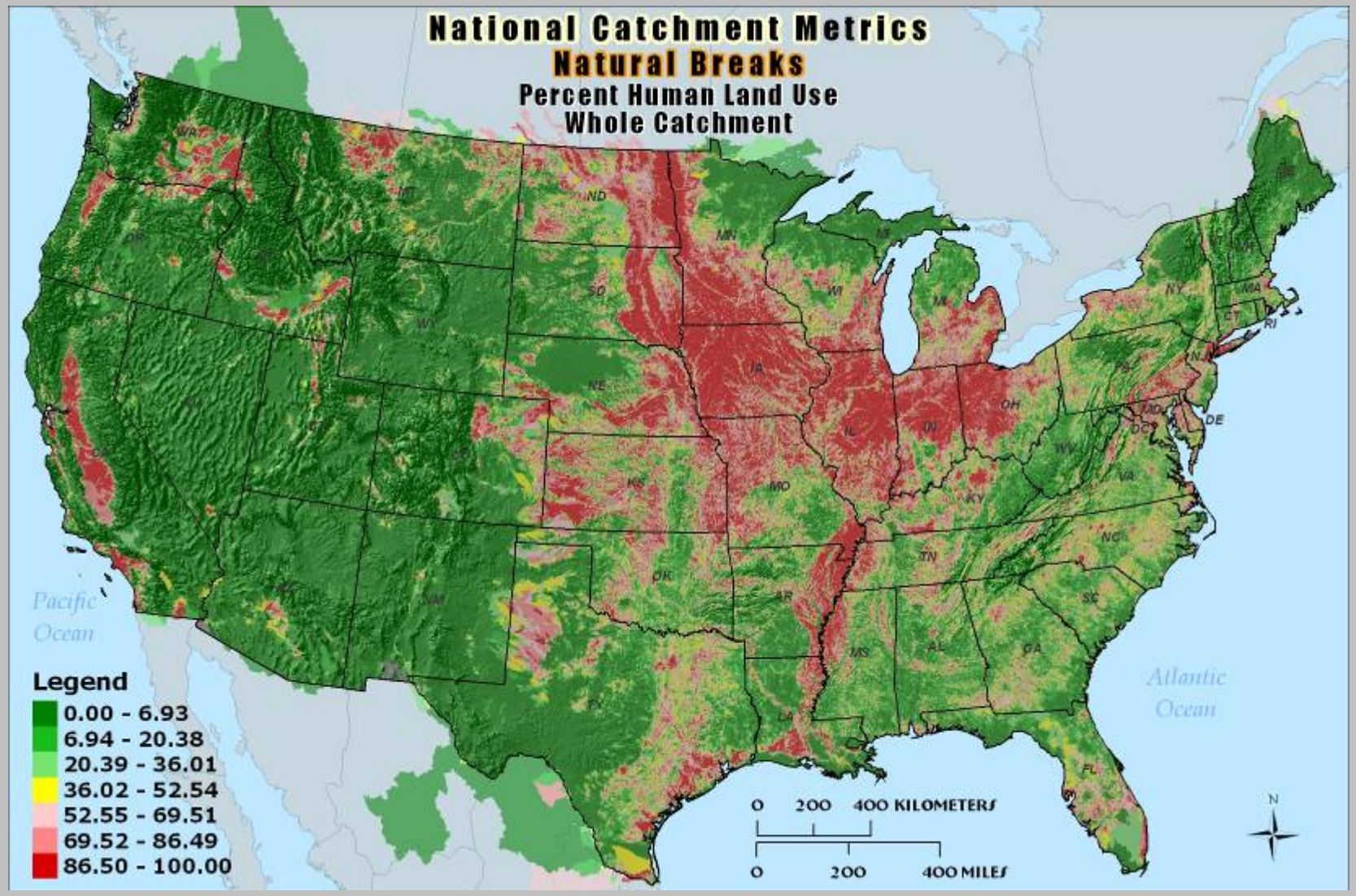
- MODIS ~ 1 hectare
- Landsat ~ 30 meters (NLCD 1993 & 2000)
- SPOT ~ <10 meters
- Air Photo ~ <3 meters
- In-situ measurements such as channel, riparian and habitat factors
- Classifications, continuous and “direct” remote sensed data (chl a, temp, lidar, etc.)

National 8-digit HUC Metrics

Natural Breaks

N_Index




National Catchment Metrics
Natural Breaks
Percent Human Land Use
Whole Catchment
Legend
0.00 - 6.93
6.94 - 20.38
20.39 - 36.01
36.02 - 52.54
52.55 - 69.51
69.52 - 86.49
86.50 - 100.00
Pacific Ocean
Atlantic Ocean
0 200 400 KILOMETERS
0 200 400 MILES
N
WA
OR
CA
NV
ID
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MI
IN
OH
KY
TN
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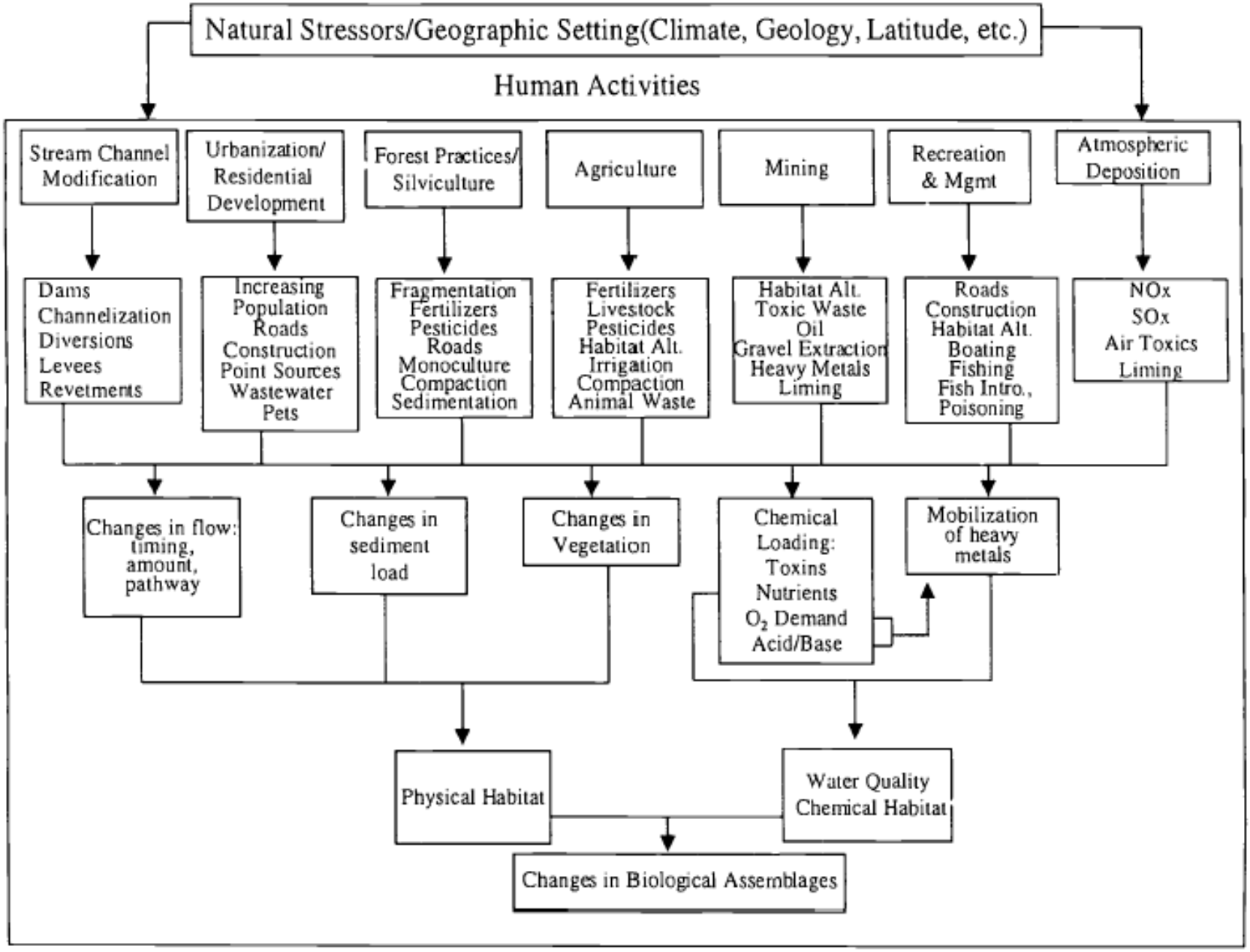
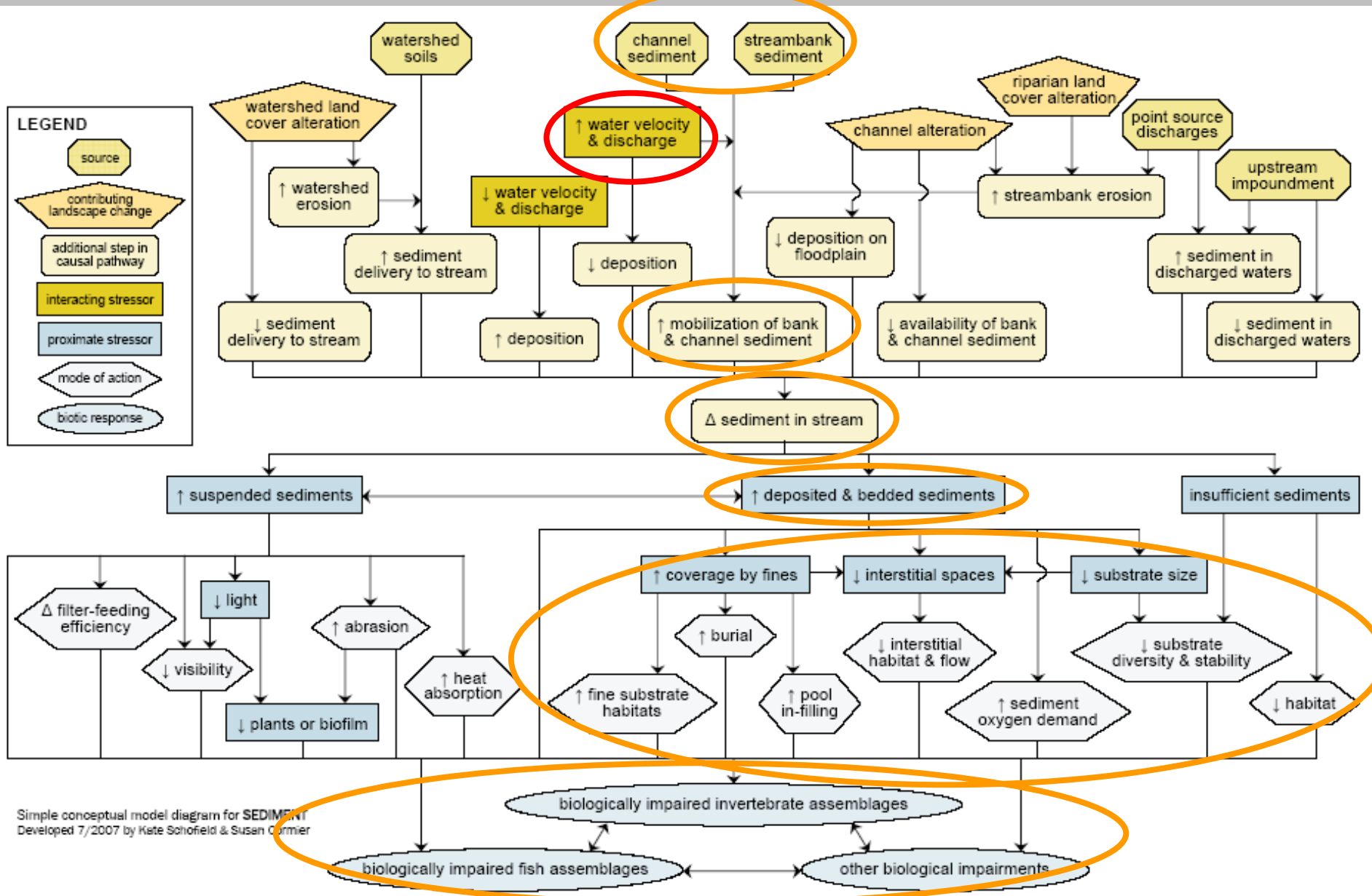

Natural Stressors/Geographic Setting(Climate, Geology, Latitude, etc.)
Human Activities
Stream Channel Modification
Urbanization/ Residential Development
Forest Practices/ Silviculture
Agriculture
Mining
Recreation & Mgmt
Atmospheric Deposition
Dams Channelization Diversions Levees Revetments
Increasing Population Roads Construction Point Sources Wastewater Pets
Fragmentation Fertilizers Pesticides Roads Monoculture Compaction Sedimentation
Fertilizers Livestock Pesticides Habitat Alt. Irrigation Compaction Animal Waste
Habitat Alt. Toxic Waste Oil Gravel Extraction Heavy Metals Liming
Roads Construction Habitat Alt. Boating Fishing Fish Intro., Poisoning
NOx SOx Air Toxics Liming
Changes in flow: timing, amount, pathway
Changes in sediment load
Changes in Vegetation
Chemical Loading: Toxins Nutrients O_2 Demand Acid/Base
Mobilization of heavy metals
Physical Habitat
Water Quality Chemical Habitat
Changes in Biological Assemblages

Parameters/stresses

- Nutrients
- Sediment
- Bacteria
- Imperviousness/hydrology
- Riparian/habitat/large wood/channel
- Chemicals/biocides/etc
- Others

Sediment Conceptual Model



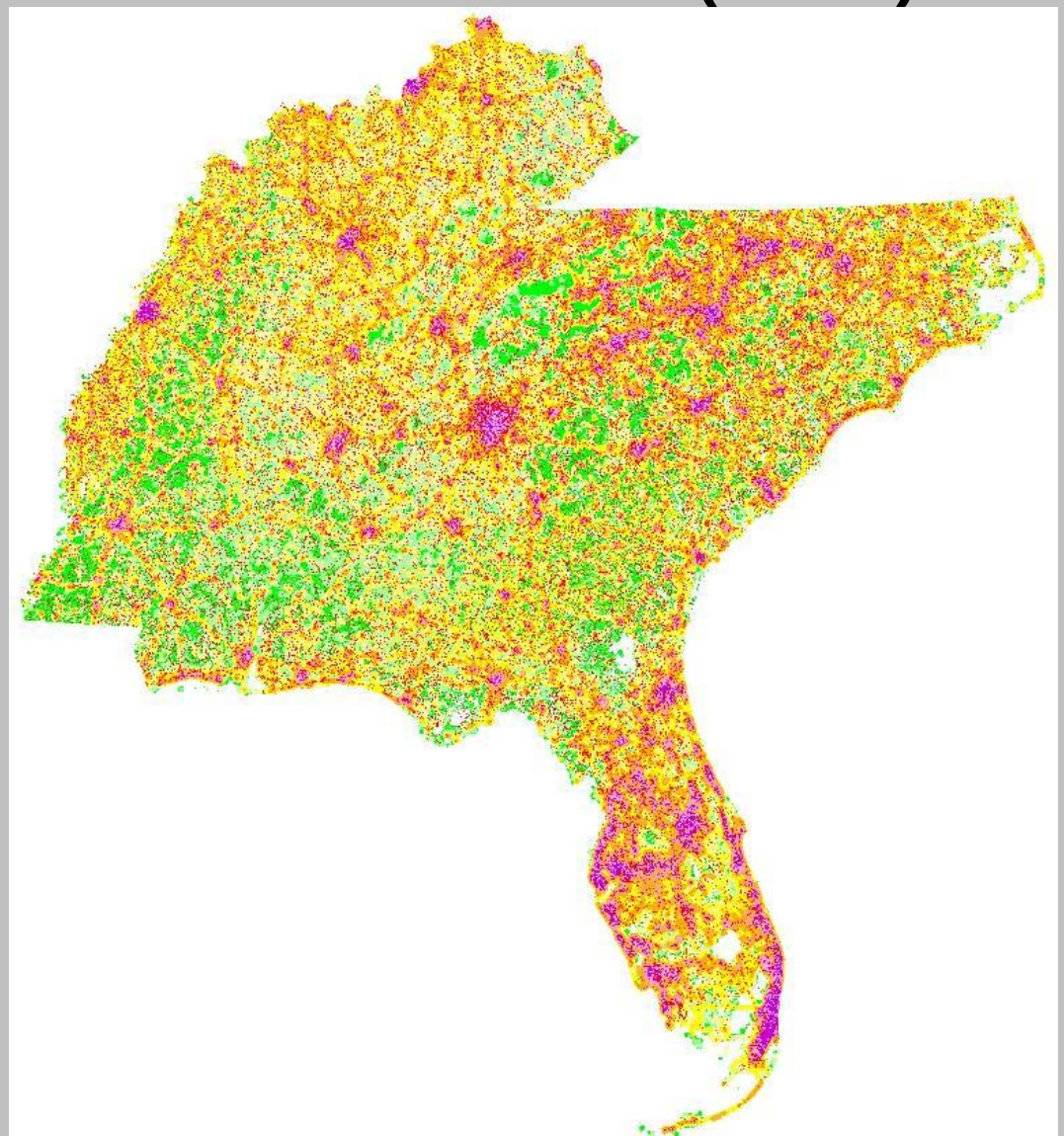
One, many and “all” stresses

- Single predominant stress (descriptive/relative risk, simple regression)
- Multiple factors (empirical/multiple regression)
- Multiple factors (multivariate/process models)
- “Universal” stress measures (LDI, U-Index, N-Index, etc.)

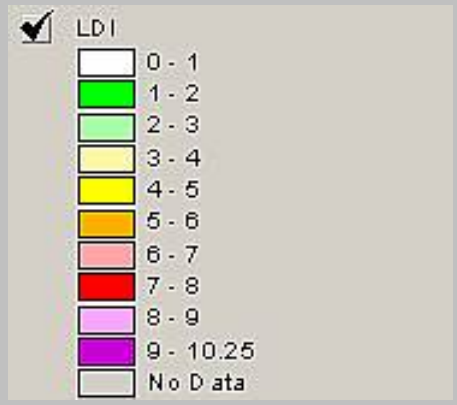
Simple to complex statistical relationship & predictive modeling techniques

- Descriptive
- Empirical
- Multivariate & multi step statistics
- Process models

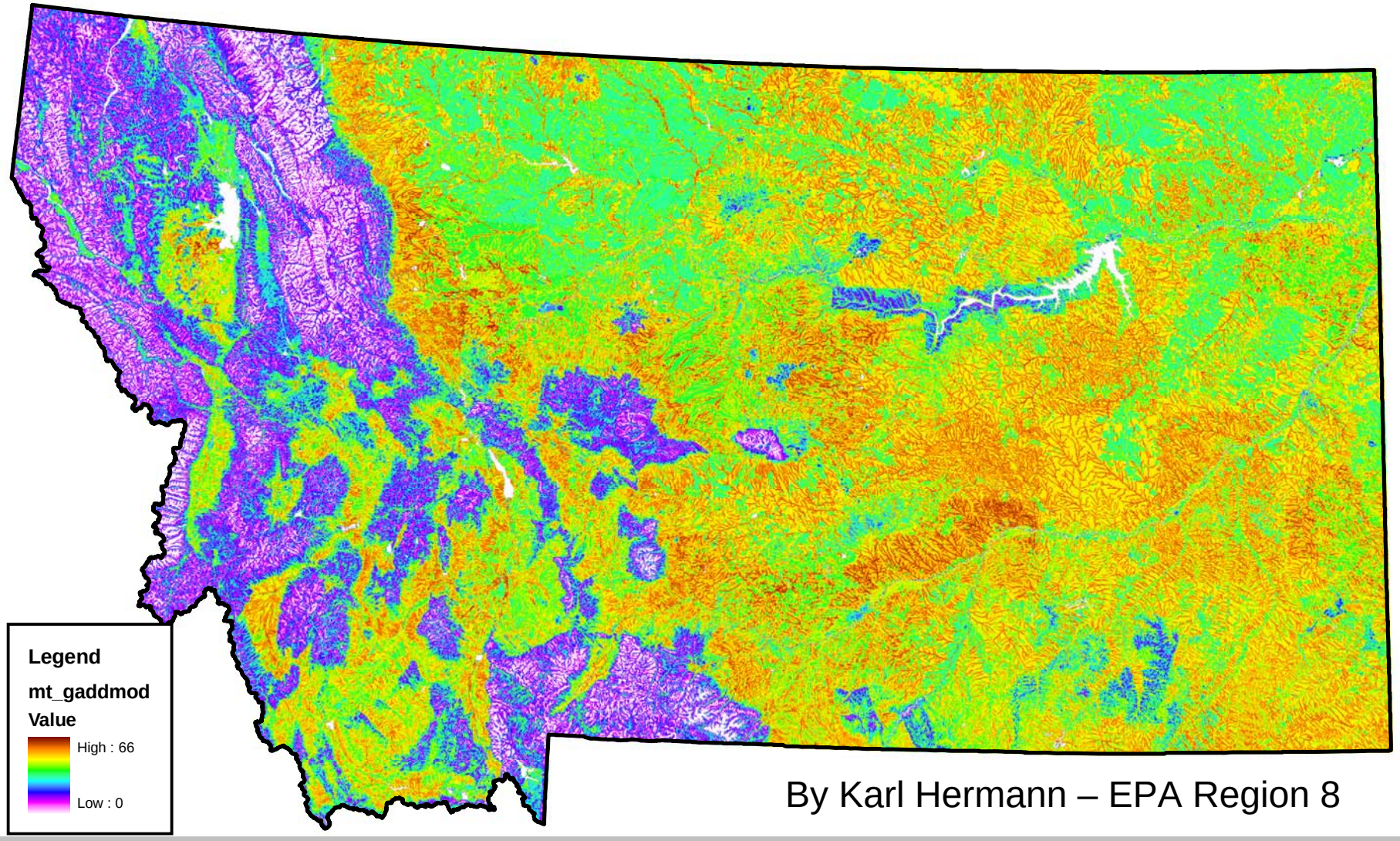
Landscape Development Index (LDI)



- Based on embodied energy (emergy)
- Regional and national scale
- Being developed by Dr. John Richardson (EPA Region 4)



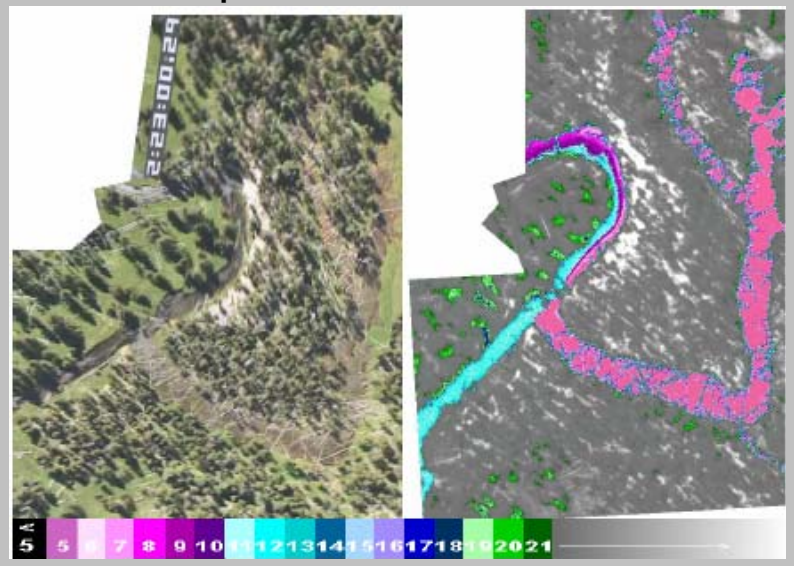
Montana – Potential Grazing Impact (additive) Model

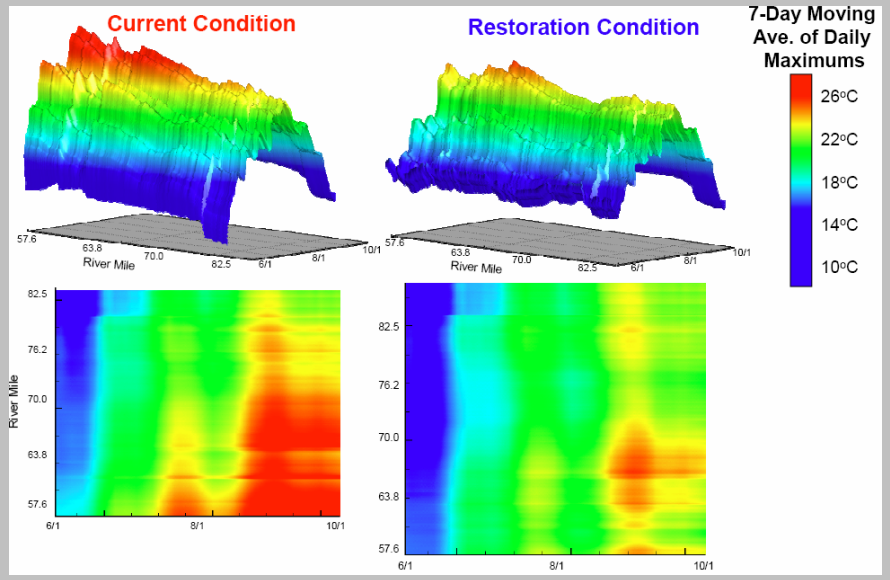


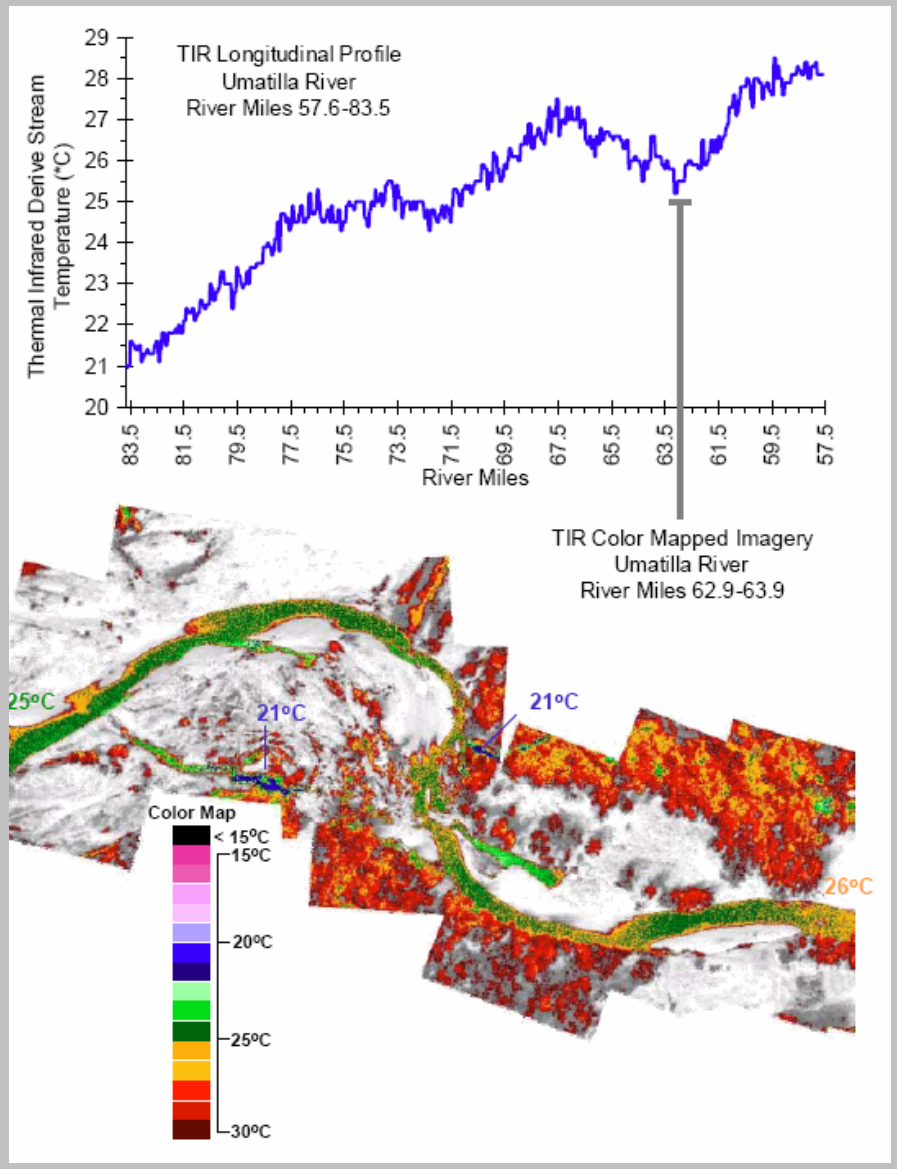
By Karl Hermann – EPA Region 8

Temperature

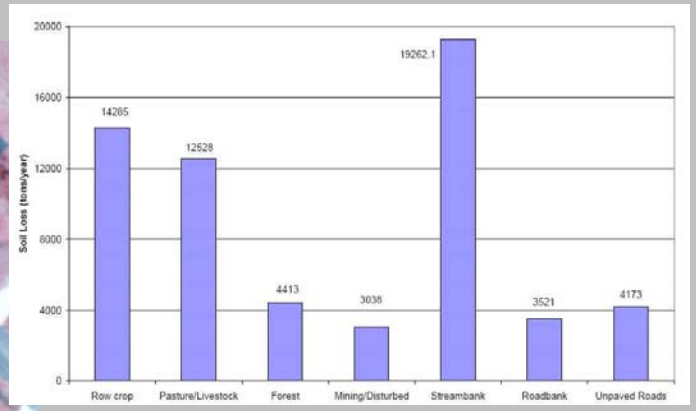
Thermal Infrared Derived Temperatures

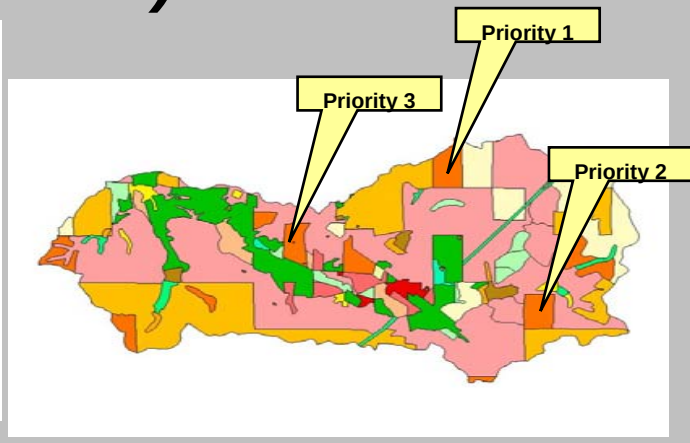


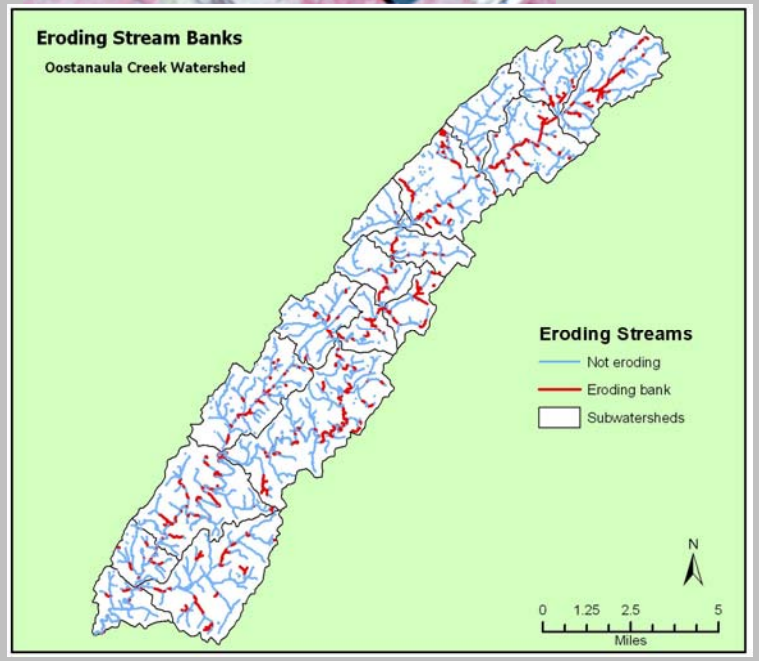


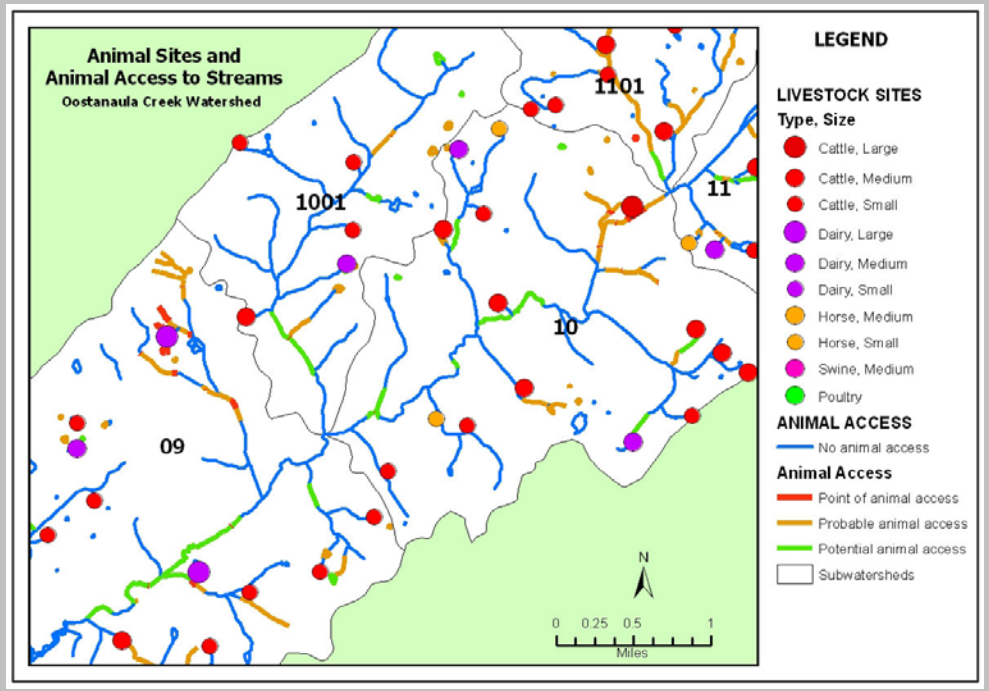


TVA's Integrated Pollutant Source Identification (IPSI)

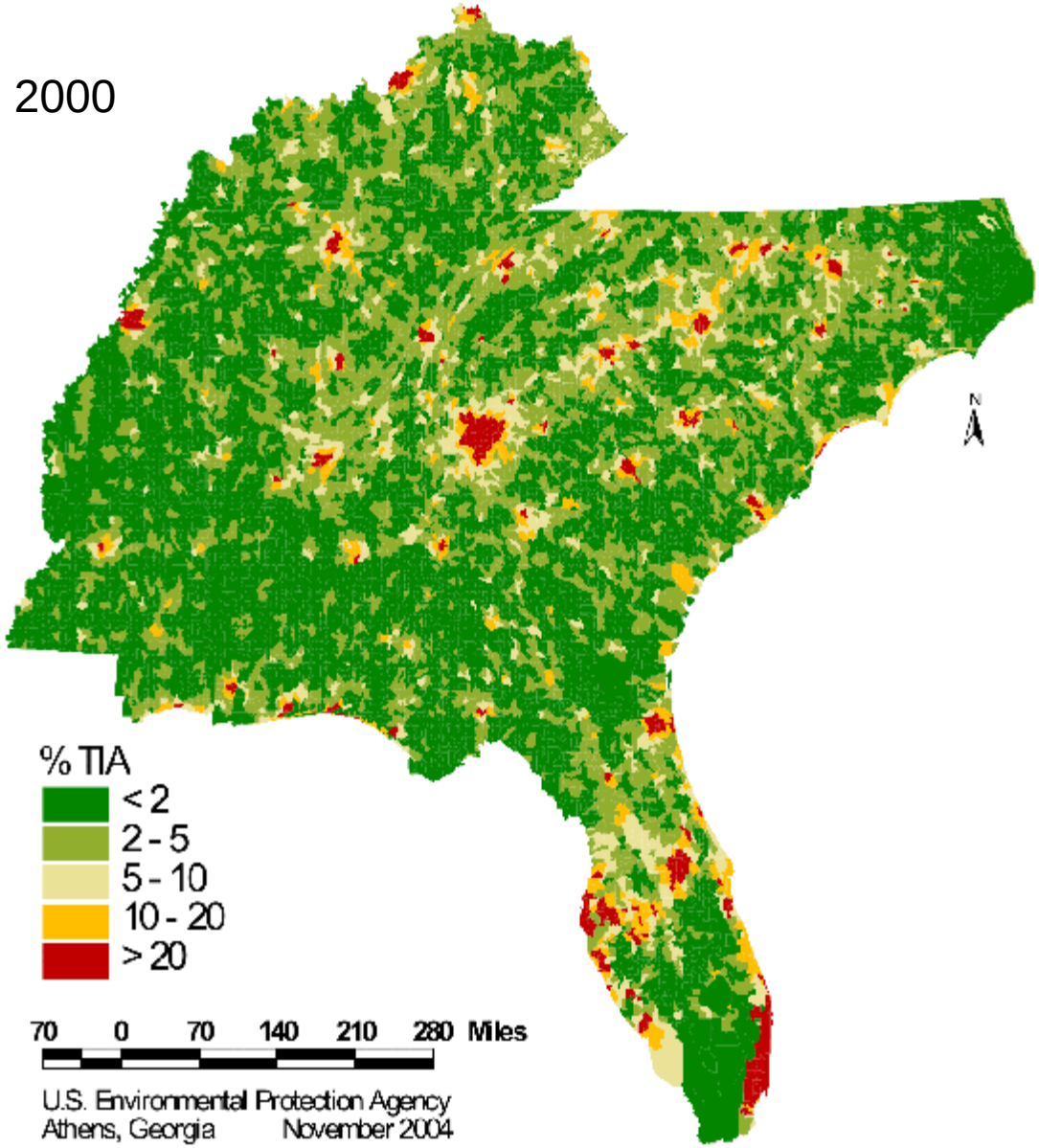


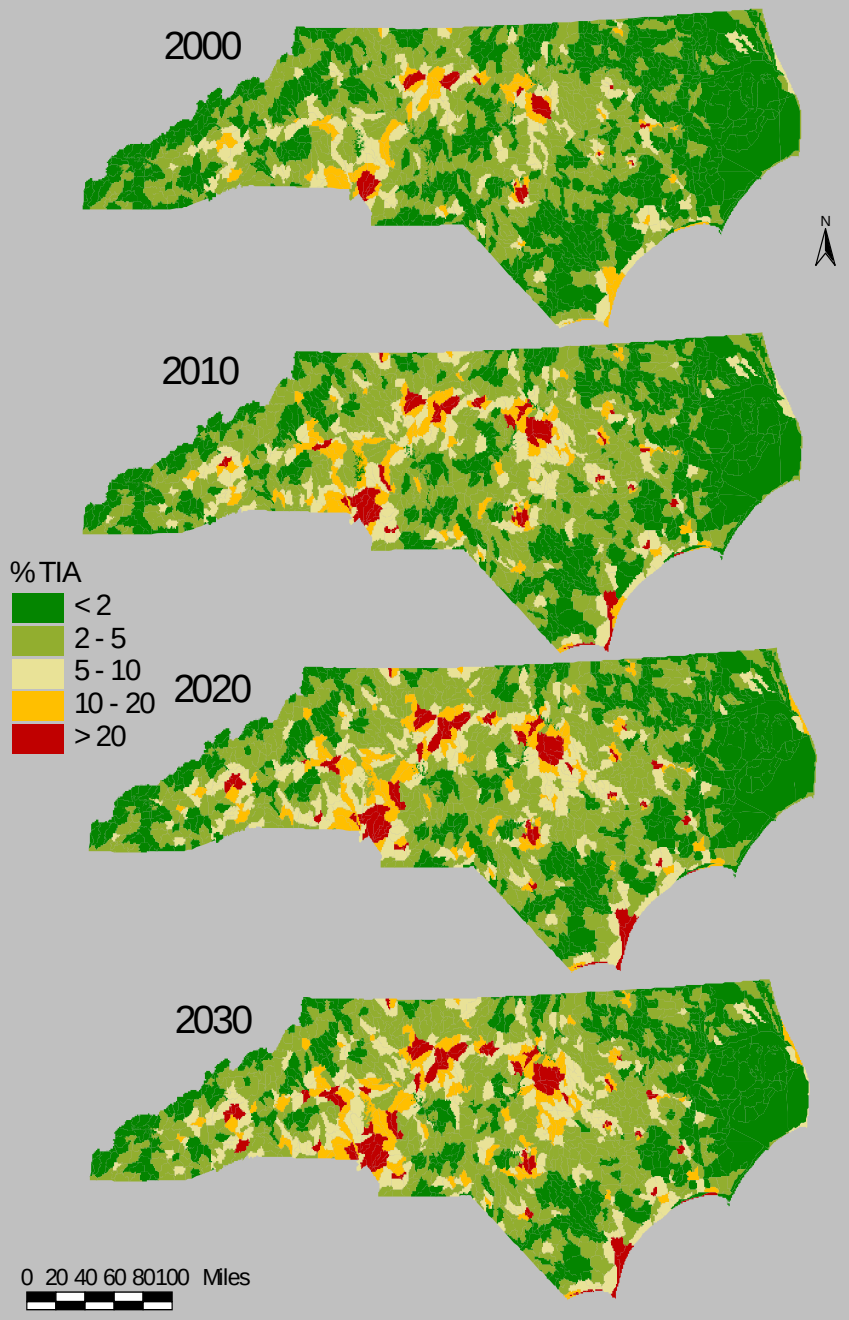




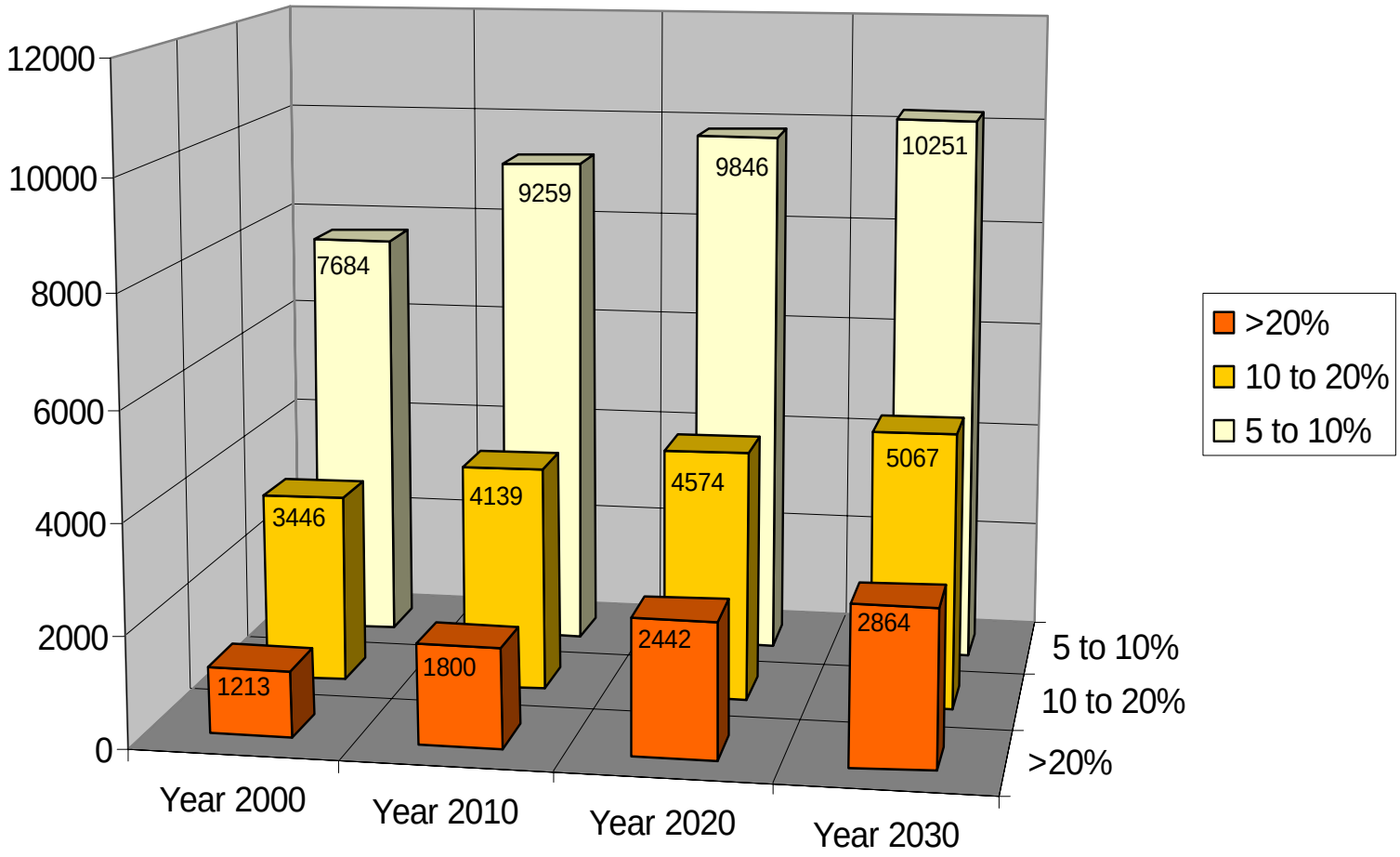


Map 2: The Megapolitans

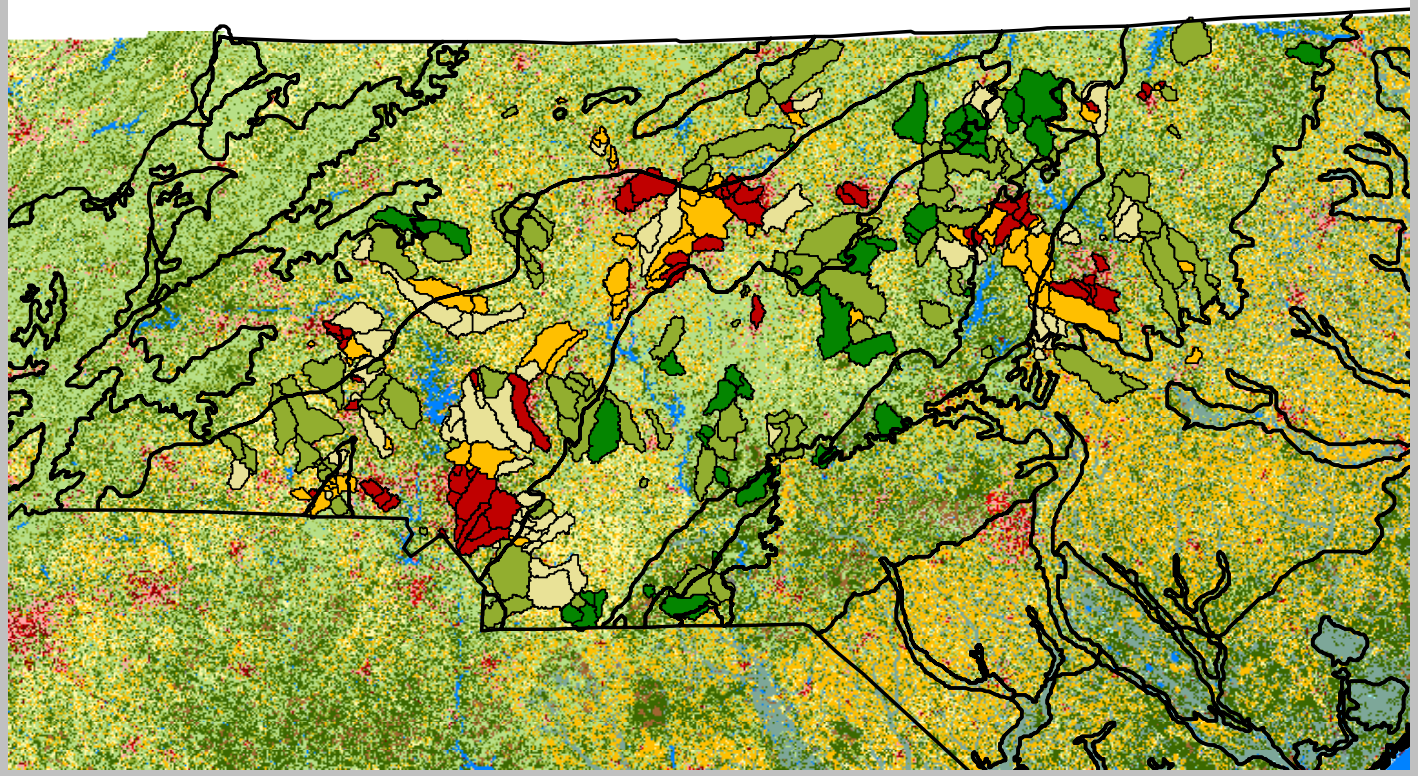

2000
% TIA
< 2
2 - 5
5 - 10
10 - 20
> 20
70 0 70 140 210 280 Miles
U.S. Environmental Protection Agency
Athens, Georgia November 2004
N



U.S. Environmental Protection Agency Athens, Georgia November 2004


North Carolina Stream Miles
by
HUC Impervious Area Class
2000 - 2030
12000
10000
8000
6000
4000
2000
0
7684
9259
9846
10251
3446
4139
4574
5067
1213
1800
2442
2864
Year 2000
Year 2010
Year 2020
Year 2030
5 to 10%
10 to 20%
>20%
>20%
10 to 20%
5 to 10%

Impervious Area Percent
Multiple Data Source (MDS) Method
North Carolina Piedmont
Benthic Site Watersheds
(317 sites - some watersheds overlap)



North Carolina Level 4 Ecoreigons (Omernik)
Impervious Area Percent: Benthic Site Watersheds
- 0 - 1.999
- 2 - 4.999
- 5 - 9.999
- 10 - 19.999
- 20 - 100

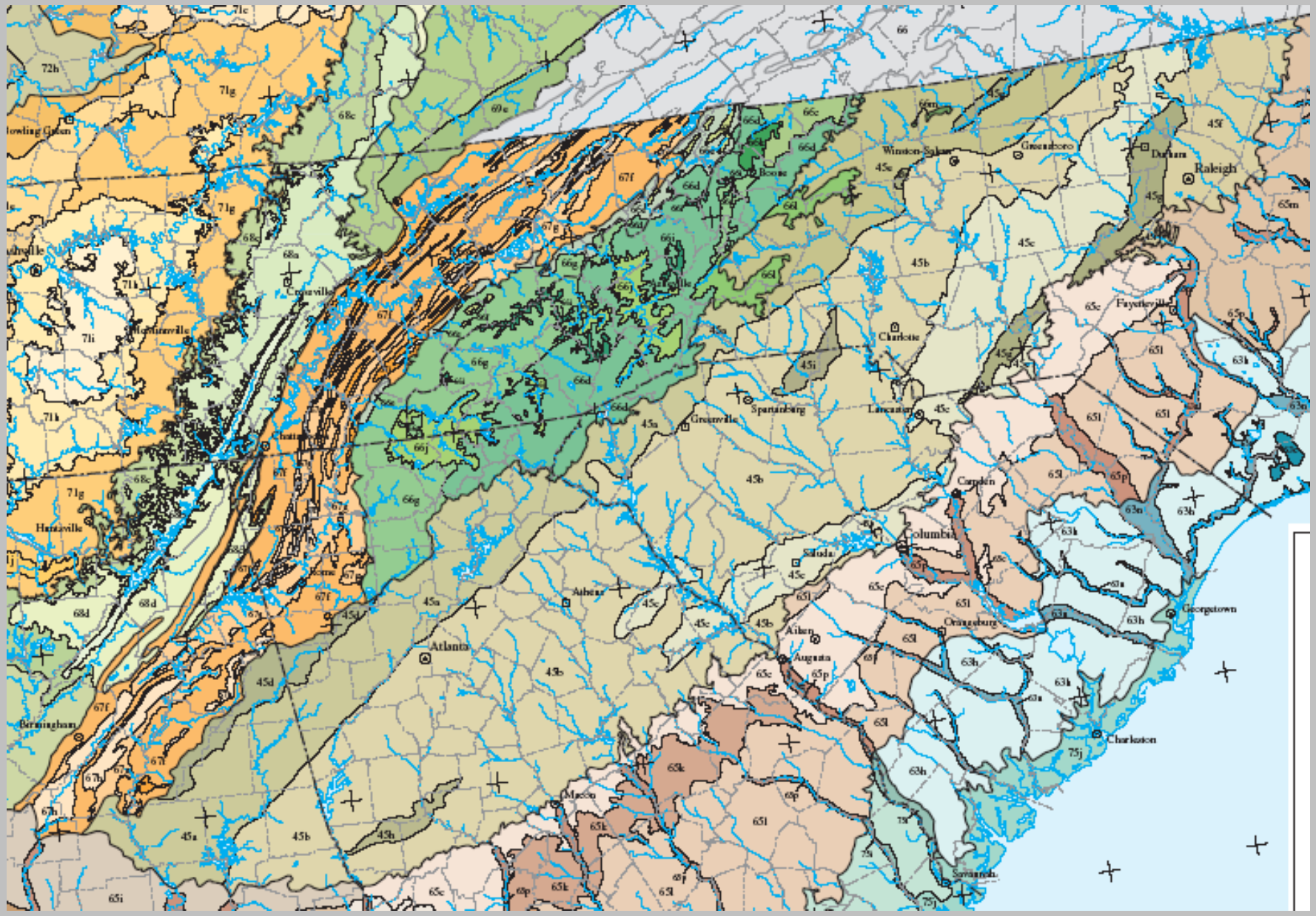
NLCD Land Use/Land Cover (~1993)
- Water
- Low Density Residential
- High Density Residential
- High Intensity Commercial/Industrial
- Bare Rock/Sand
- Quarries/Mines/Gravel
- Transitional
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Pasture/Hay
- Row Crops
- Other Grasses
- Woody Wetlands
- Emergent Wetlands
- No Data

30 0 30 60 Kilometers

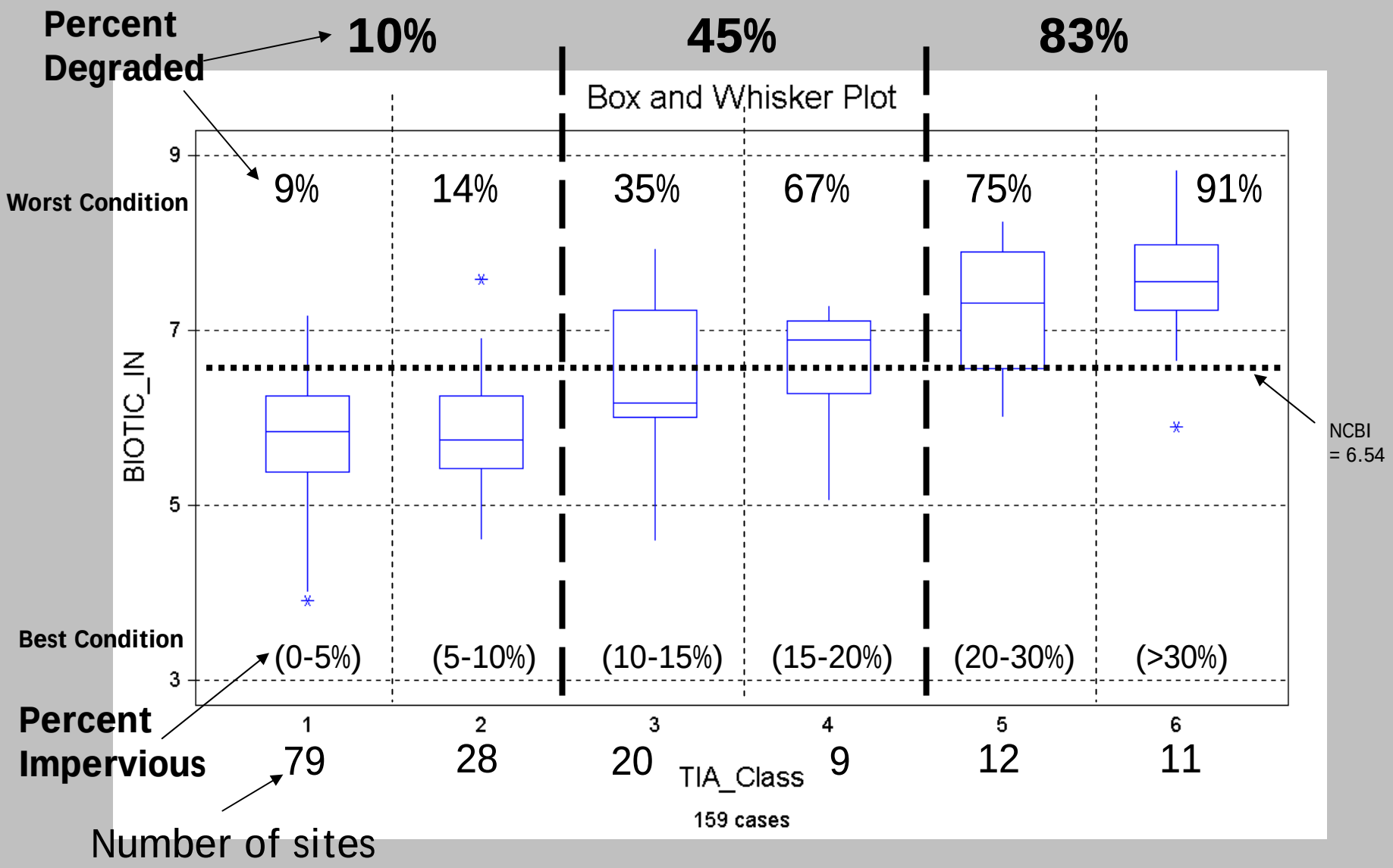
N W E S

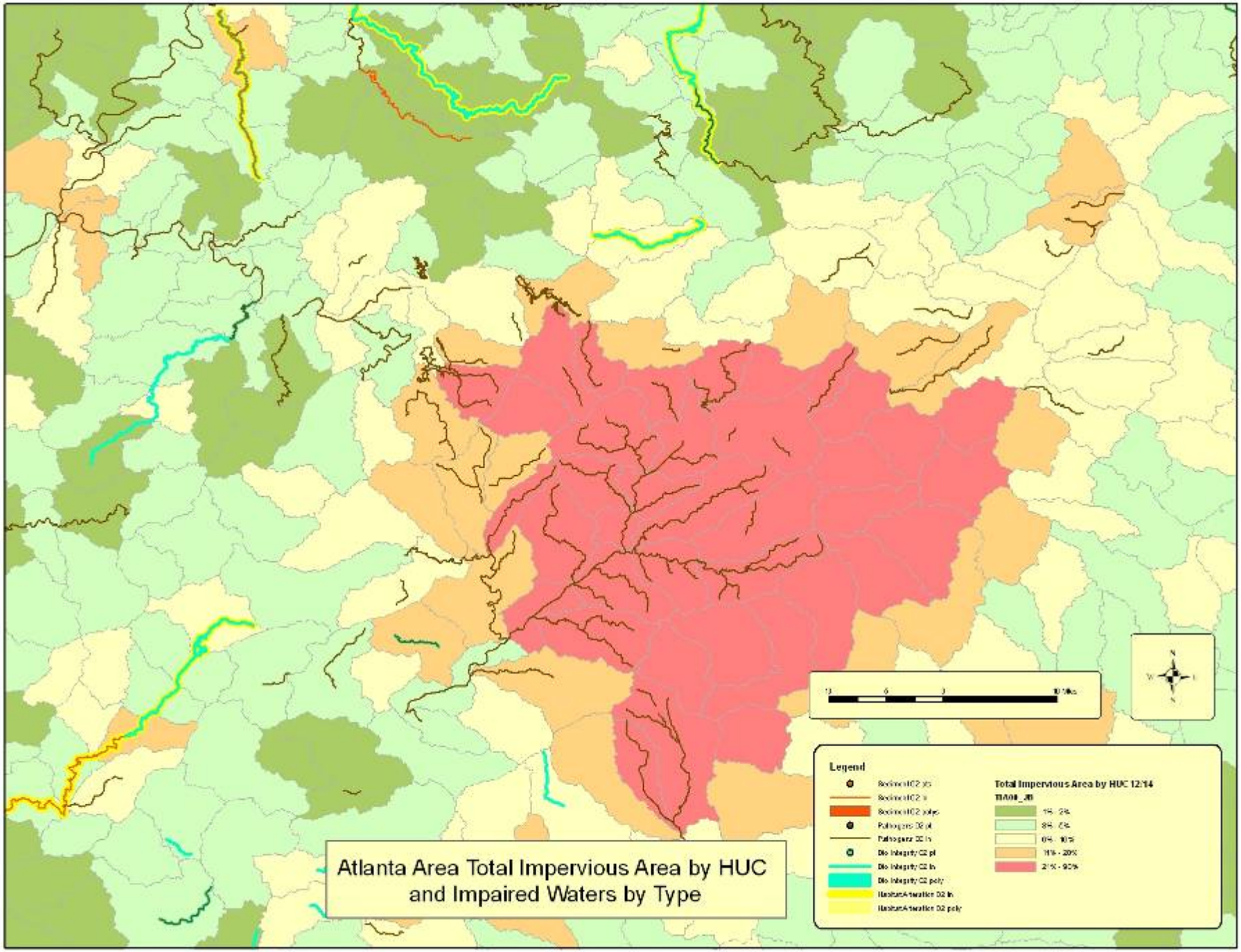
Jim Harrison
US EPA
11/23/2004

Piedmont


Bowling Green
Knoxville
Cookeville
Nashville
Huntsville
Birmingham
Atlanta
Auburn
Aiken
Augusta
Macon
Columbia
Saluda
Camden
Orangeburg
Charleston
Georgetown
Savannah
Lancaster
Charlotte
Spartanburg
Greenville
Boone
Winston-Salem
Greensboro
Durham
Raleigh
Fayetteville

Percent Degraded (NCBI > 6.54: < fair) vs. Total Impervious Area





*Based on 2002 Section 303(d) Impaired Waters lists. Map by Jon Becker

Why Use Landscape and Predictive Tools?

- Systematic priority setting
- Comprehensive targeting of problems and monitoring efforts
- Improve efficiency of limited monitoring resources
- Monitor smart – from ad hoc/BPJ to scientifically sound basis
- Focus on measuring results – keep score on what’s really important

End

- Thank you !
- Contact Information
  - Jim Harrison
  - Harrison.jim@epa.gov
  - 404-562-9271
- Questions/comments?

According to “Dilbert” Slightly Modified

Statutory Clean Water Act Monitoring Objectives

- Establish, review and revise WQS, TMDL, and establish appropriate monitoring methods. (CWA 303(c), 303(d))
- Conduct analyses of the extent to which all navigable waters attain water quality standards. (CWA 305(b))
- Identify impaired waters. (CWA 303(d)
- Determine Abatement and control priorities (CWA 402)
- Support implementation of water management programs (CWA 319, 402, 303, 314)
- Evaluate effectiveness of water management programs. (CWA 319, 314, 303, 305, 402) bracket

Goals

- Illustrate a variety of methods to document stress/pressure/disturbance gradients at multiple scales
- Cover a spectrum of methods to build predictive tools relating stress(es) to response(s) including simple to complex statistics, etc.,
- And approaches to target and prioritize monitoring, and restoration and prevention actions
- Provide a useful array of examples/case studies/applications

Goals

- Describe actual and potential applications for Clean Water Act Programs
- Define appropriate roles for and integration of predictive modeling tools and monitoring
- Use as a basis for training and application development for states, regions and others

Timeline

2006

July	Steering Committee formed
	Bi-monthly calls
Oct	Meeting – Annapolis
	Draft Outline developed

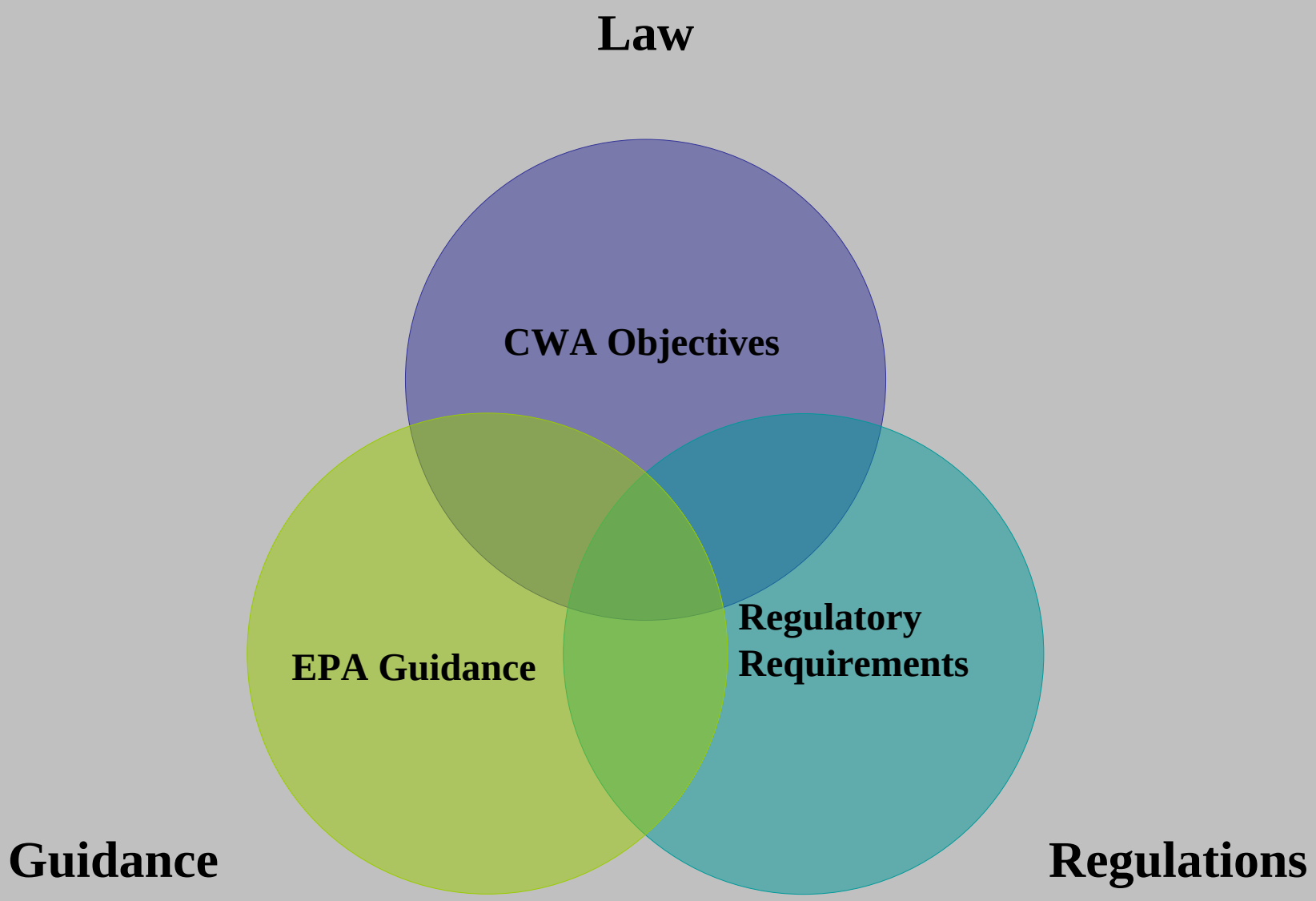
2007

Jan	Bi-monthly calls continue
	Chapter Leads established
Aug	1st draft of most Chapters

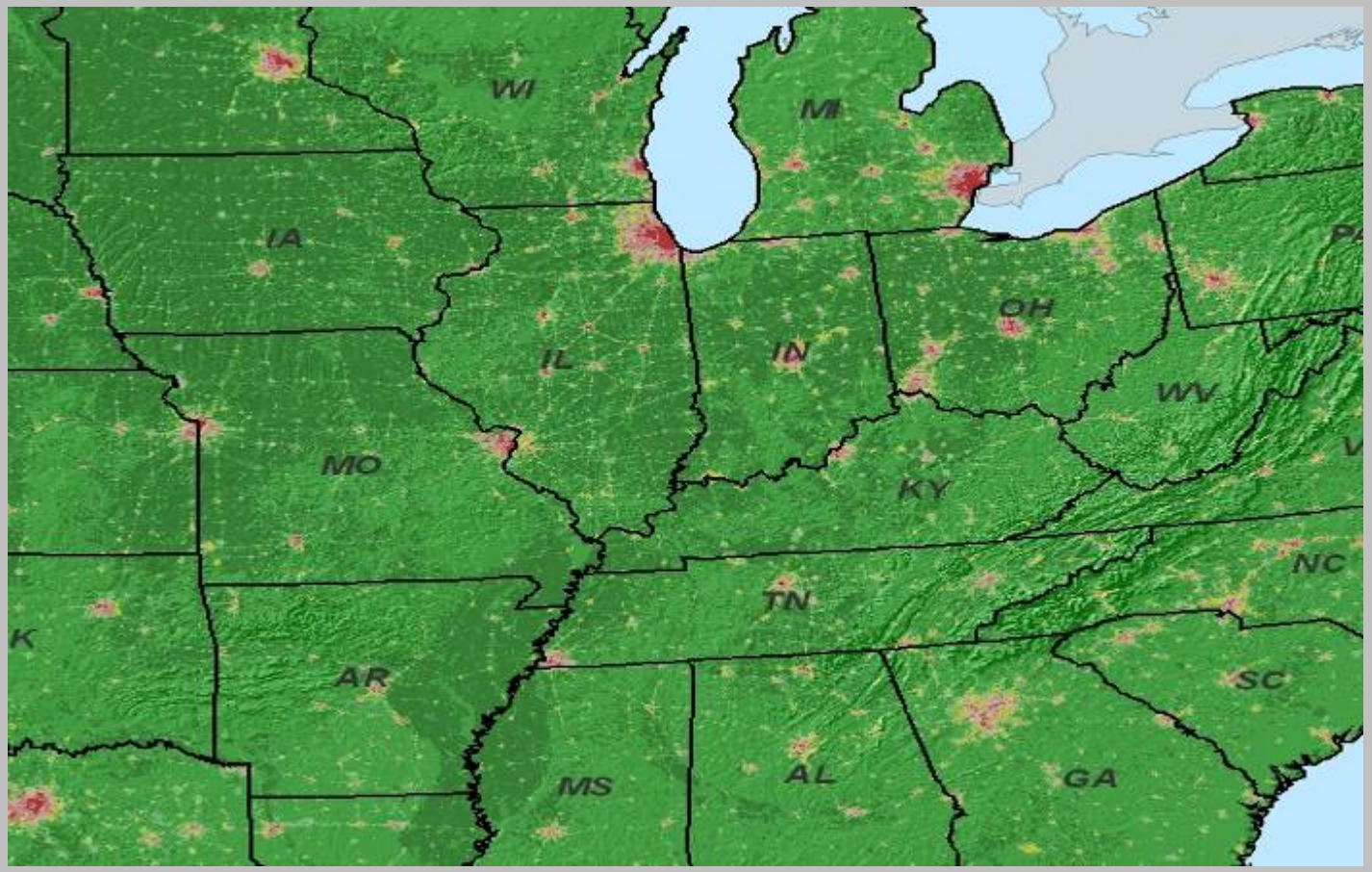
2008

Jan	1st draft of all Chapters
	Internal committee review
Mar	Meeting – DC area
Apr	Internal EPA review
May	Revise for peer review
June	Peer Review - begin
Aug	Revise per peer review comments

Finalize - by end of FY2008?


Law
CWA Objectives
EPA Guidance
Regulatory Requirements
Guidance
Regulations

Percent Impervious Surface



Scales of Responses

- Biological Scales
  - Gene, cell, organ, organism, population, community, ecosystem, ecoregion (other)
- Examples
  - Biological community integrity for periphyton, benthics and fish
  - Species population
- Spatial: site, reach, segment, watershed, basin, ecoregion, etc.

Clean Water Act
Monitoring Objectives

Establish, review and revise **WQS, TMDL**, and establish **appropriate monitoring methods**. (CWA 303(c), 303(d))

Conduct analyses of the **extent to which all navigable waters attain water quality standards**. (CWA 305(b))

Identify impaired waters. (CWA 303(d)

Determine Abatement and control **priorities** (CWA 402)

Support **implementation of water management programs** (CWA 319, 402, 303, 314)

Evaluate effectiveness of water management programs. (CWA 319, 314, 303, 305, 402) bracket

Regulatory Requirements

40 CFR 130.4

Establish **appropriate methods and procedures** to **monitor the quality of navigable waters and ground waters**

Devices, methods, systems, procedures

- Biological monitoring
- Eutrophic conditions

Compile and analyze data on navigable waters and ground waters

Devices, methods, systems, procedures

- Classification of eutrophic conditions
- Physical, chemical, biological data

Guidance: Elements Document

A. Develop strategy for all water resource types: streams, rivers, lakes, & reservoirs, coastal areas (estuaries), wetlands, groundwater

B. **Monitoring objectives**

C. Monitoring design

D. Core and supplemental water quality indicators

E. Quality assurance

F. Data management

G. Data analysis & assessment

H. Reporting

I. Programmatic evaluation

J. General support & infrastructure planning

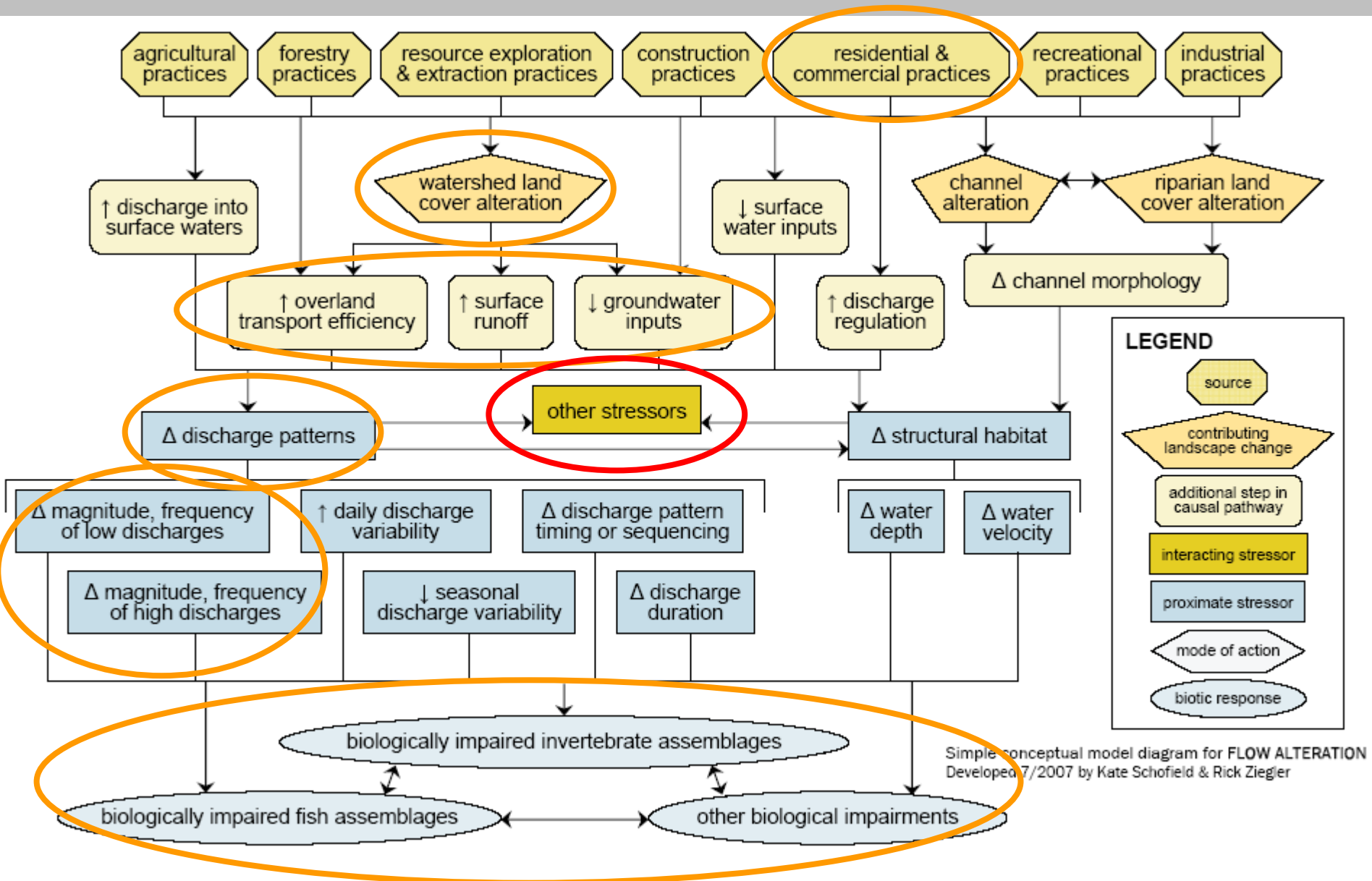
CADDIS Analysis Methods

Method	Evidence
Percentile	SABS Level for a Proportion of Sites
Linear Regression	Response Commonly Achieved for a Given SABS Level
Quantile Regression	Best Response Achievable Given SABS Level
Conditional Probability	Probability of Achieving Use
Species Sensitivity Distribution	Proportion of Species Protected

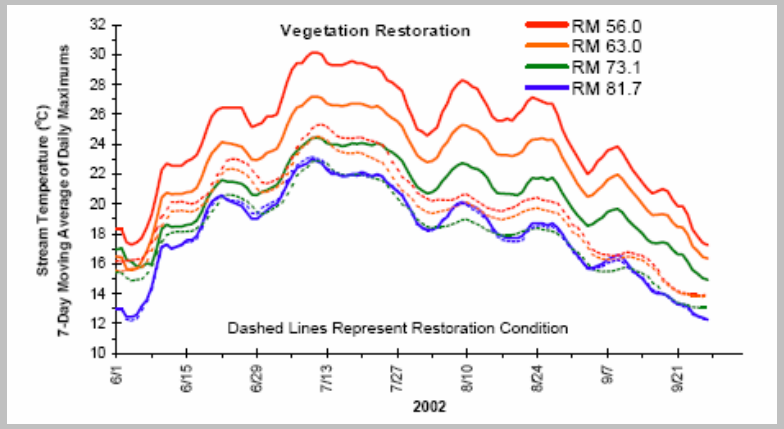
Detailed Analysis Steps and Factors

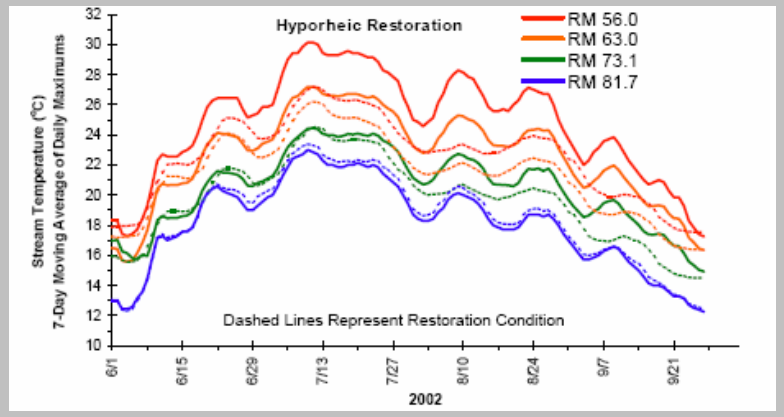
Detailed Analysis Steps	Factors to Consider
Refine Basis of Analysis	Problems/questions Areas/scales of interest Geographic frameworks Pressure/stress/response parameters of interest
Identify analysis methods and data requirements	GIS analyses Statistical approaches
Refine data quality objectives	Develop QAPP/SOP/Study Plan Peer review (if desired/needed)
Gather additional site and landscape data to fill gaps	Gradient of sites covering full range of stress(es) Probability Survey data
Derive landscape stress/disturbance factors	Delineate watershed boundaries and buffers for sites Watershed Riparian Buffer Proximity Buffer Other appropriate landscape factors
Apply analysis methods	Describe stress and response gradients Reduce number of variables (if needed) Derive robust stress/response relationships
Extrapolate stress/response models to area of interest	Estimate response for areas lacking in-situ data
Evaluate power of results	Balance false negative vs. false positive
Refine analyses if needed	Go back to Refine Basis of Analysis
Report results	Peer review (if needed or desired) Other reviews Publish results
Utilize analyses to make decisions	Targeting and Priorities Other critical water quality monitoring/management decisions

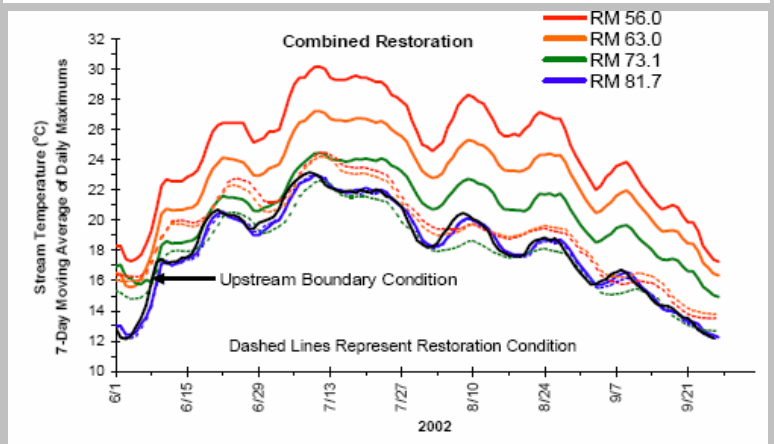
Flow Conceptual Model

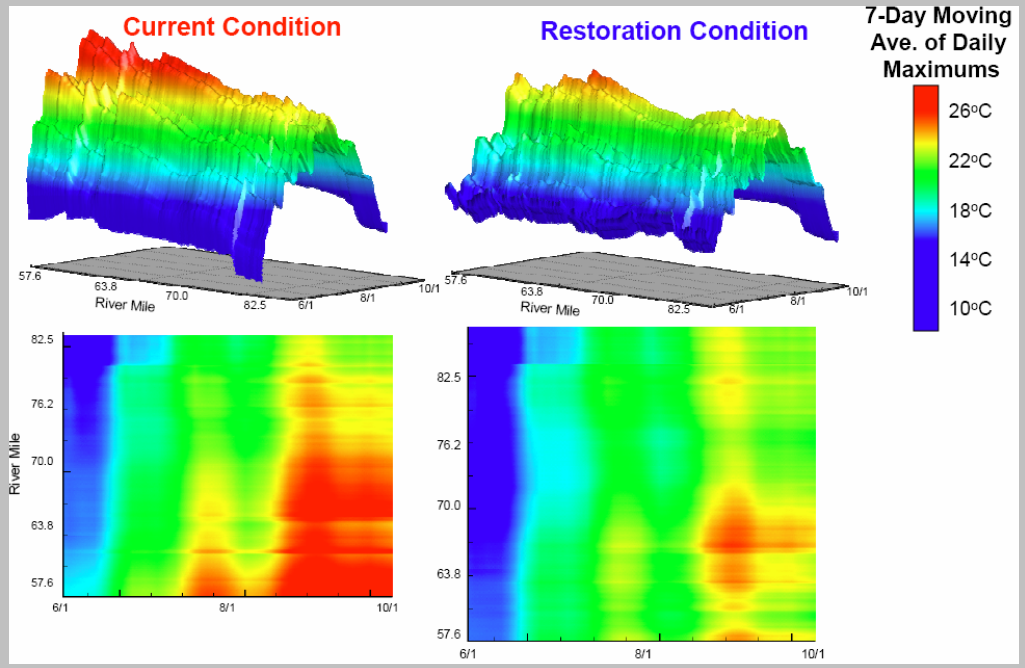


Temperature Restoration Modeling

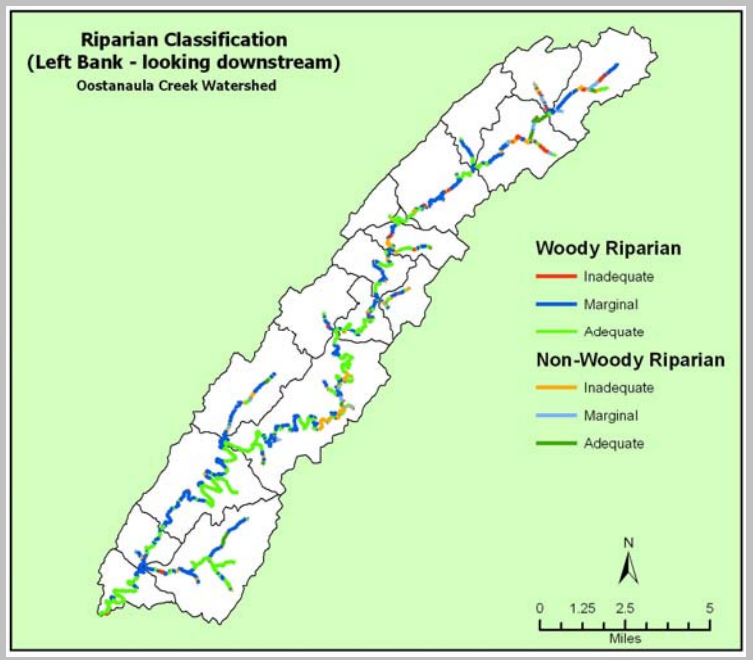


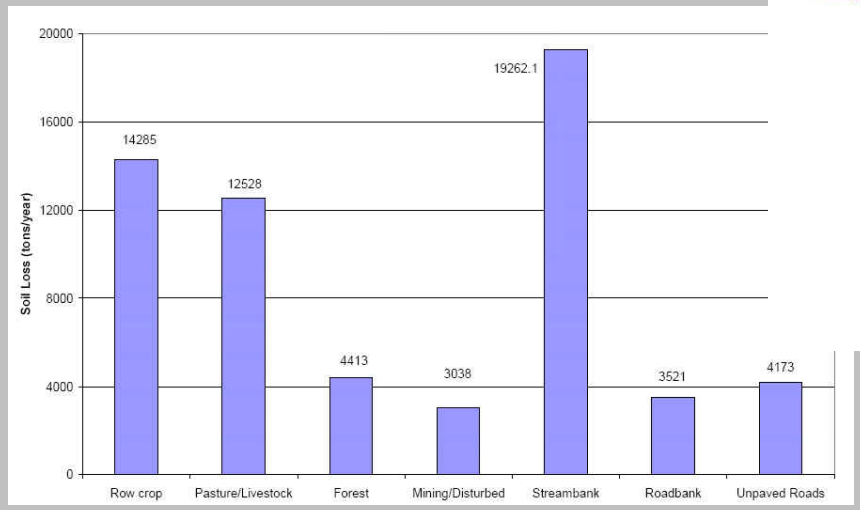


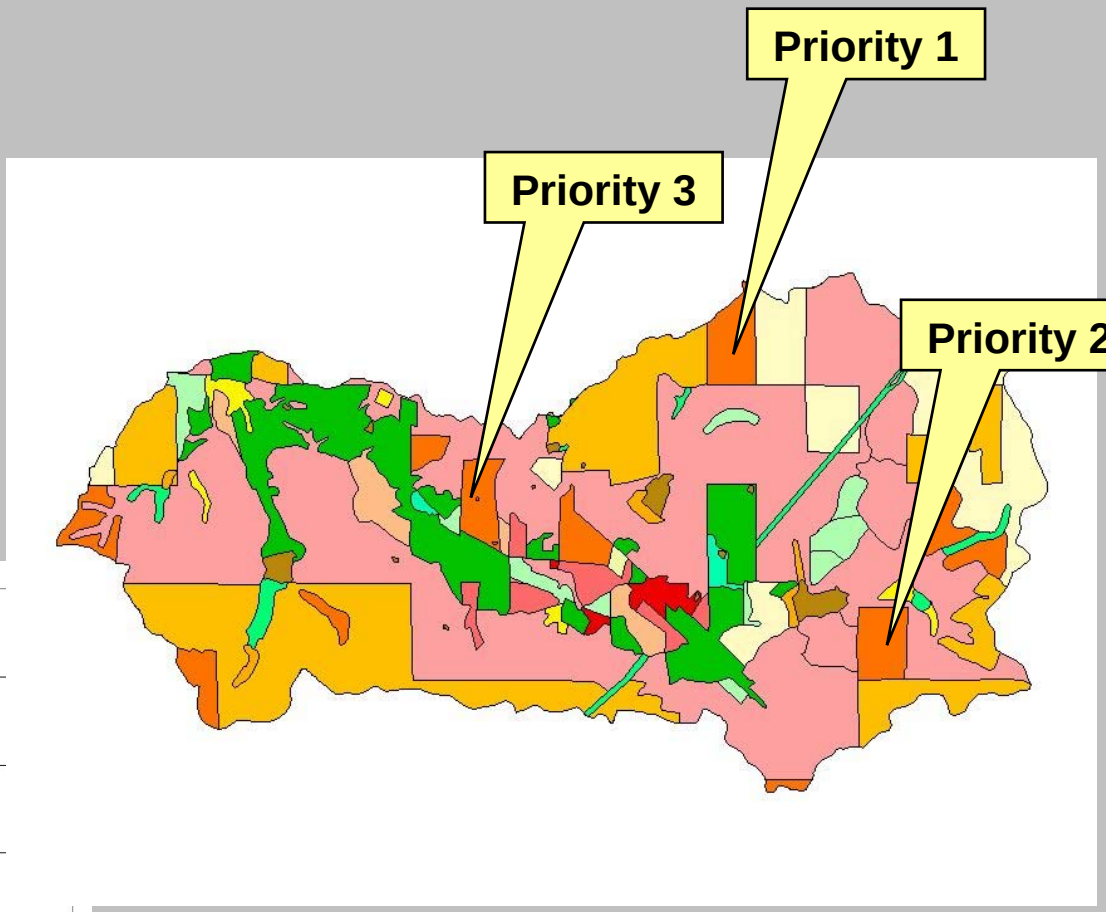


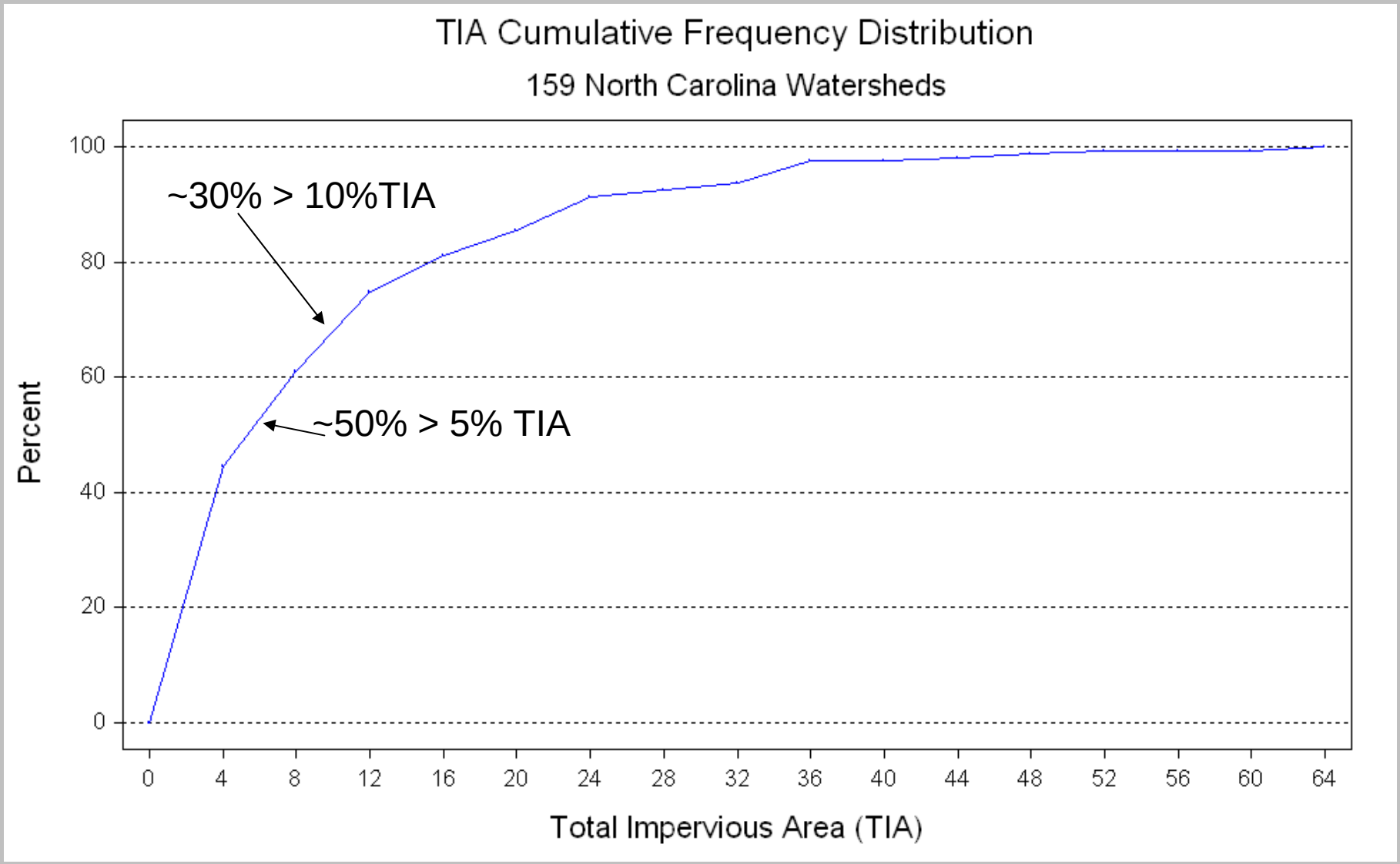


IPSI (cont.)

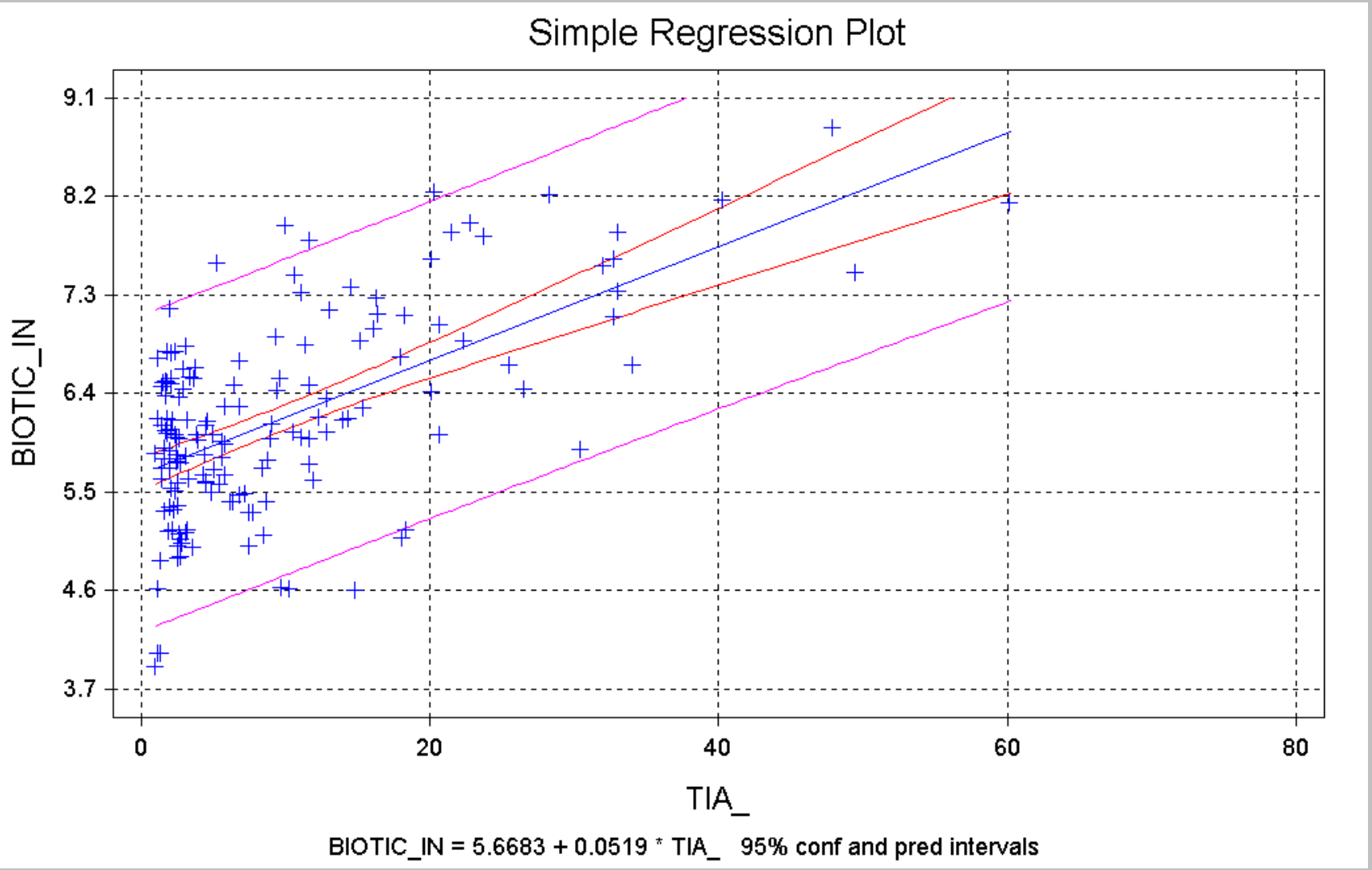

Riparian Classification
(Left Bank - looking downstream)
Oostanaula Creek Watershed
Woody Riparian
Inadequate
Marginal
Adequate
Non-Woody Riparian
Inadequate
Marginal
Adequate
N
0 1.25 2.5 5
Miles


Soil Loss (tons/year)
20000
16000
12000
8000
4000
0
14285
12528
4413
3038
19262.1
3521
4173
Row crop
Pasture/Livestock
Forest
Mining/Disturbed
Streambank
Roadbank
Unpaved Roads


Priority 1
Priority 3
Priority 2


TIA Cumulative Frequency Distribution
159 North Carolina Watersheds
~30% > 10%TIA
~50% > 5% TIA
Percent
100
80
60
40
20
0
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
Total Impervious Area (TIA)

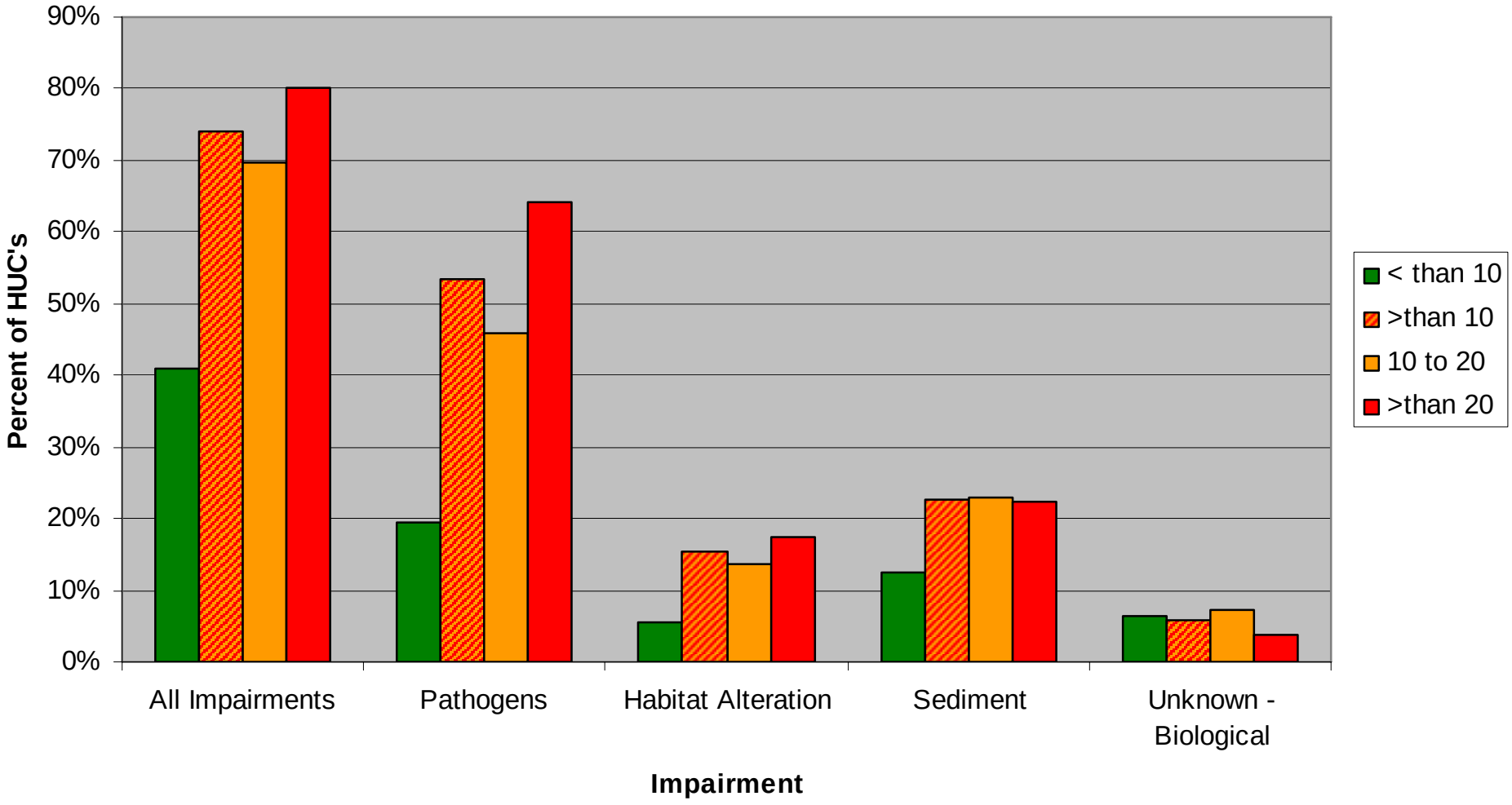
159 Piedmont Sites



Relative Risk

%TIA Range	% Degraded	Relative Risk
<5	9	1.0
5-10	14	1.5
10-15	35	3.9
15-20	67	7.4
20-30	75	8.3
>30	91	10.1

Percent of Region 4 HUCs Within Impervious Area Ranges Having Specific Impairments



*Based on 2002 Section 303(d) Impaired Waters lists and year 2000 estimated impervious area.
Analysis by Jon Becker and Jim Harrison