WV R-EMAP Study: Multiple Objective Sampling Design Framework

Dan Cincotta[1], Naomi Detenbeck[2],
Florence Fulk[3] and Frank McCormick[3]

[1]WV Division of Natural Resources, Wildlife Resources Section;
[2]US EPA National Health and Environmental Effects Research Laboratory
[3]US EPA National Exposure and Research Laboratory

WV R-EMAP PROJECT

COLLABORATORS	ROLES
• WV DNR WRS	• Field collections & IBI development
• US EPA-NERL (Cincinnati) and TetraTech	• Water quality data and IBI development
• US EPA-NHEERL (Duluth)	• Watershed characterization and classification
• US EPA-NHEERL (Corvallis) and WV DEP	• WV “State-of-the-Streams” Report (305b data)
• US EPA Reg III (Wheeling)	• Advisement
• Canaan Valley Institute	• Tech transfer/watershed studies
• God (Tom DeMoss alternate)	• Sanity and safety advisement

BACKGROUND

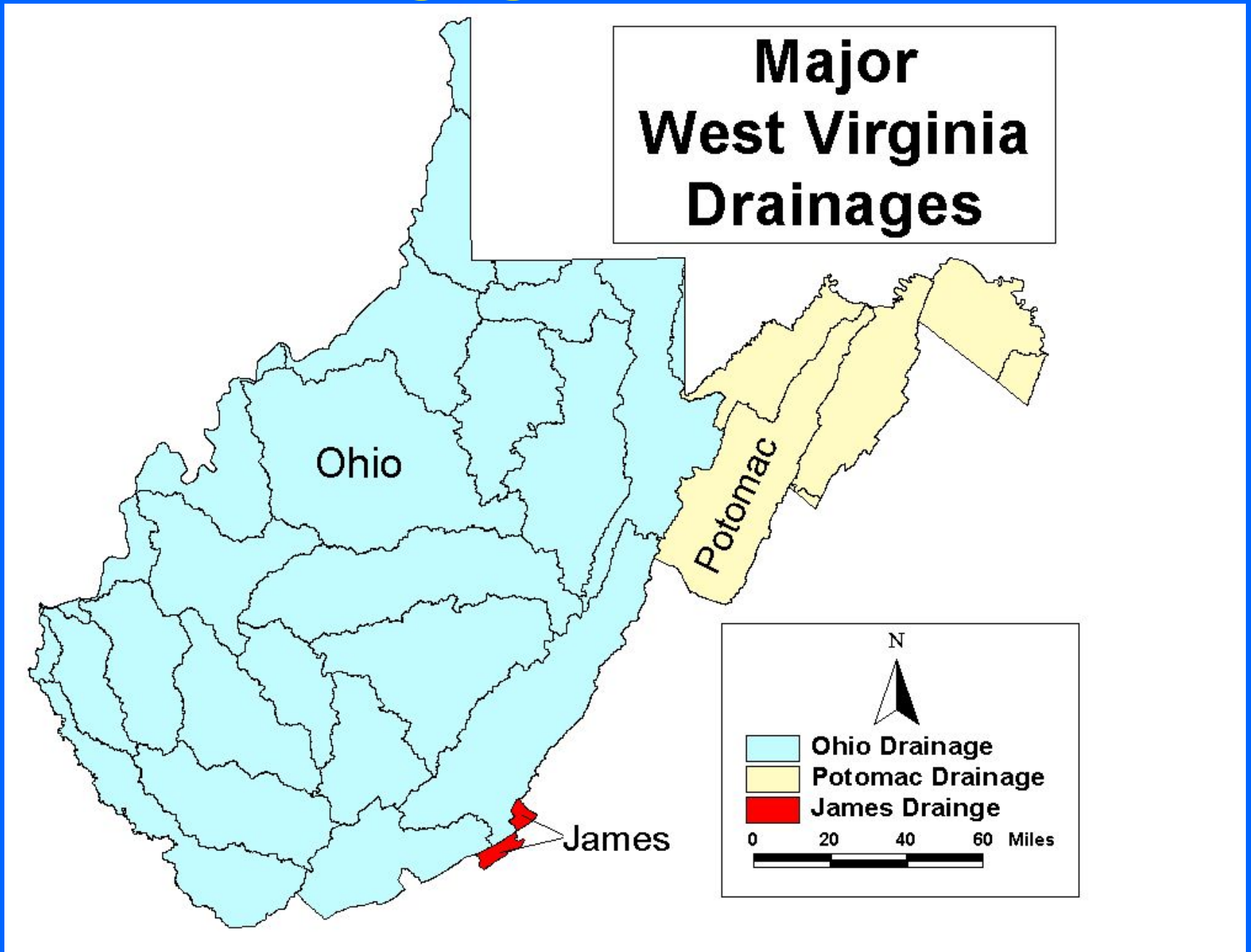
Year and/or Event	Action
• 1972-FWPCA	• "…restore and maintain chemical, physical and biological integrity of the Nation's waters."
• 1977-CWA	• State Programs implement and emphasize chemical and invertebrate analysis
• 1981-Karr's IBI	• Water Quality Assessment using fishes
• 1989-Plafkin *et al*. 1989	• Encourage State Agency Use of RBPs
• 1992-Law Suits	• EPA and States upgrade monitoring programs
• 1993-98 EMAP	• Mid-Atlantic Highland Collections (WV participates in 1998)
• 2001-2003	• R-EMAP funding for WV

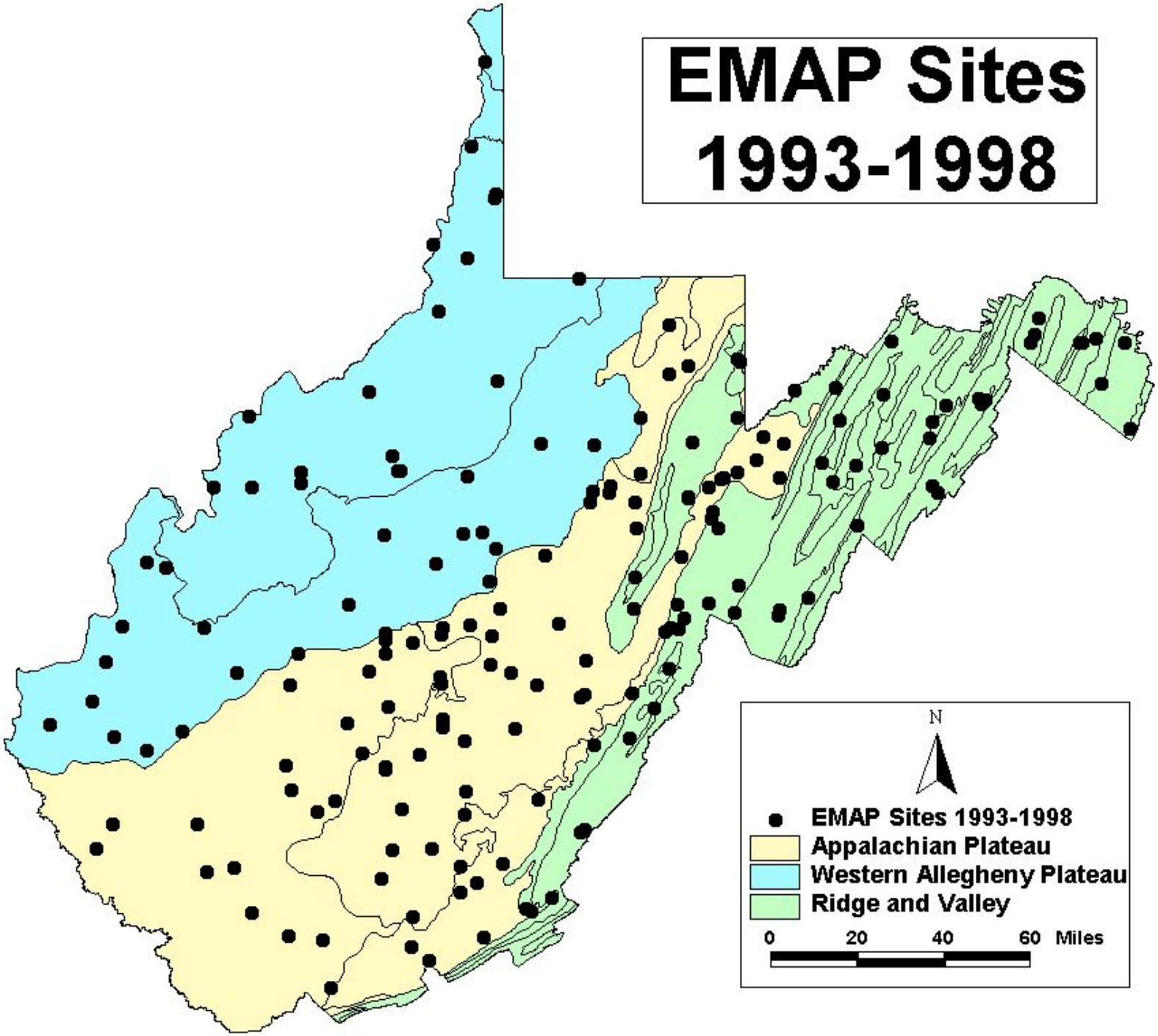
OBJECTIVES

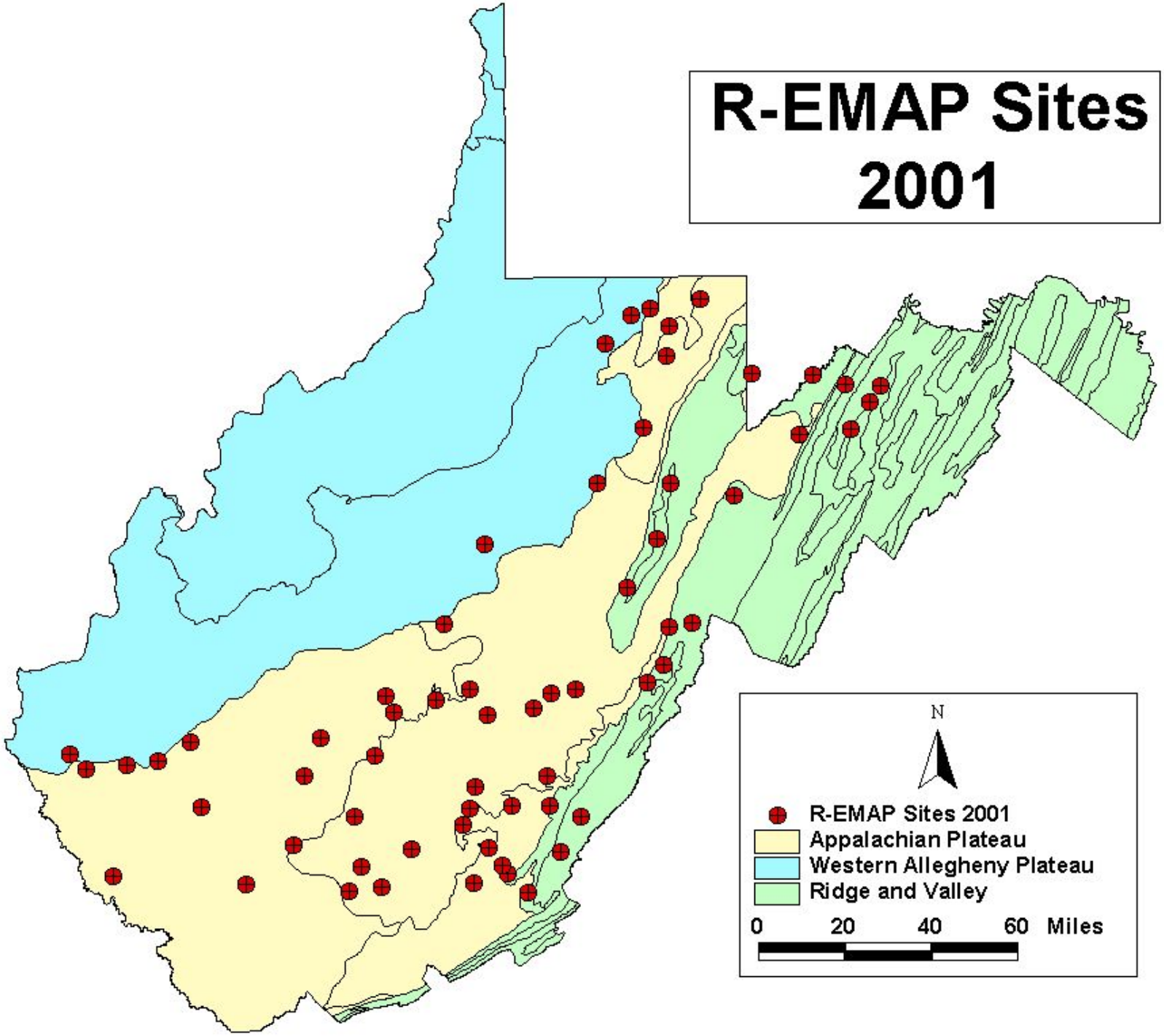
"A Small Watershed Characterization, Classification, and Assessment for West Virginia utilizing EMAP Design and Tools"

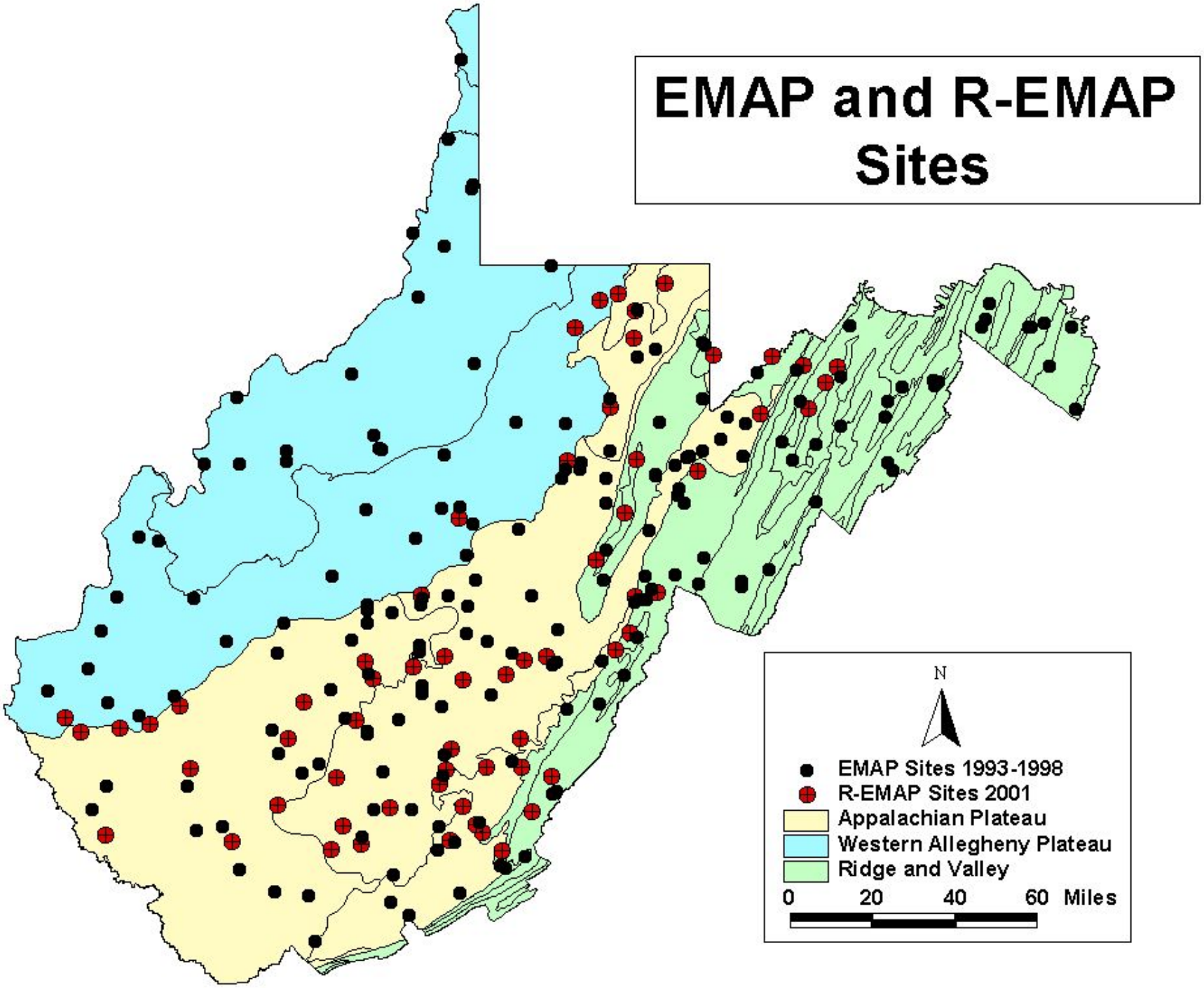
- Develop IBI specific to WV's wadeable streams and small watersheds utilizing a probability based design
  - Coldwater vs warmwater
  - Landscape-based prediction of thermal regime
- Develop and test a small watershed characterization and classification system to explain variation in reference condition (400-40000 ha watersheds)
- Establish baseline for assessing biological impairments by identifying stressor impacts and small watershed vulnerability
- Produce a "State-of-Streams" report (based on 5 years of statewide 305b data)

STUDY AREA

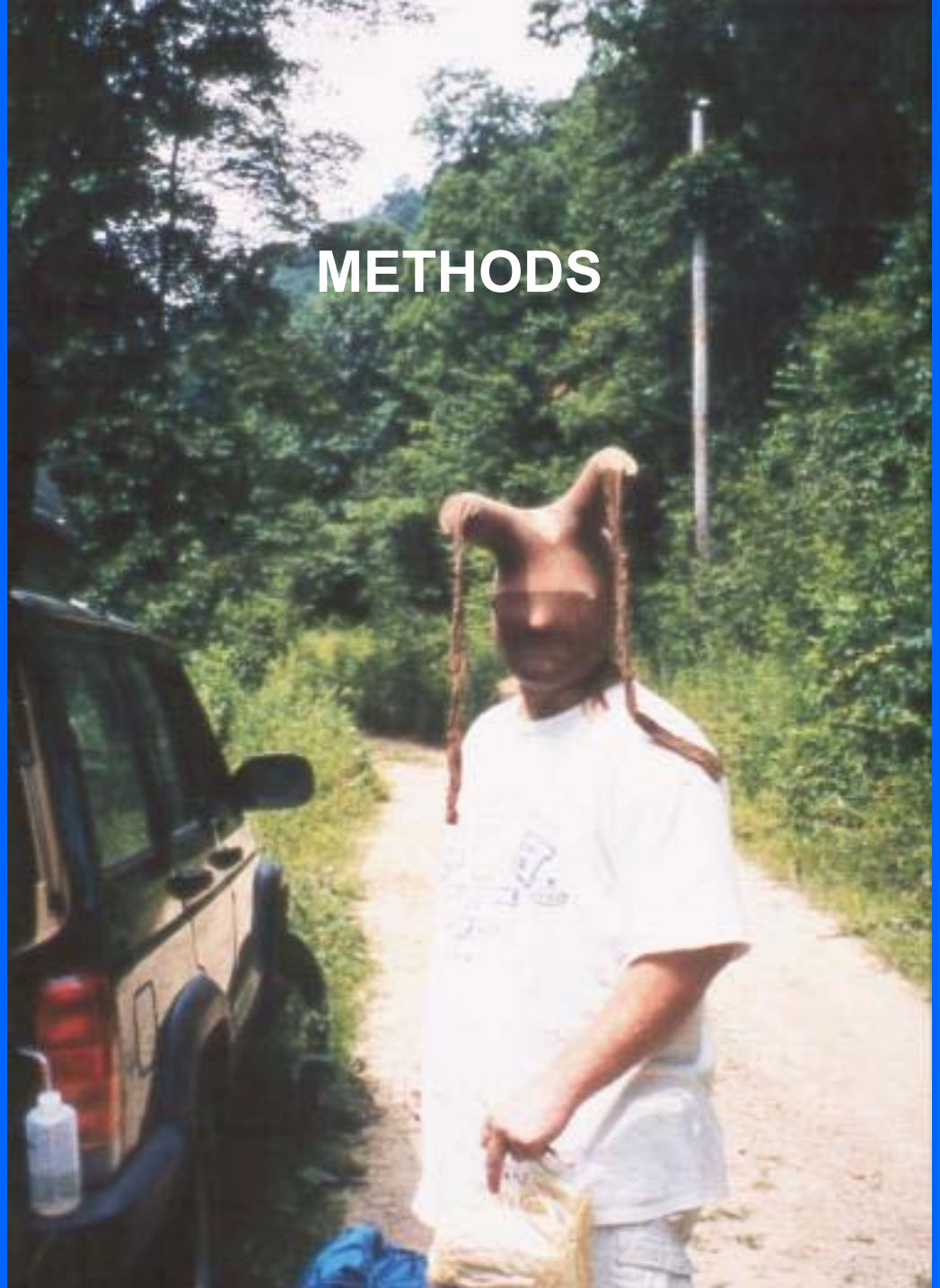

Major
West Virginia
Drainages
Ohio
Potomac
James
N
Ohio Drainage
Potomac Drainage
James Drainge
0
20
40
60
Miles


EMAP Sites
1993-1998
N
EMAP Sites 1993-1998
Appalachian Plateau
Western Allegheny Plateau
Ridge and Valley
0
20
40
60
Miles


R-EMAP Sites
2001
N
R-EMAP Sites 2001
Appalachian Plateau
Western Allegheny Plateau
Ridge and Valley
0
20
40
60
Miles

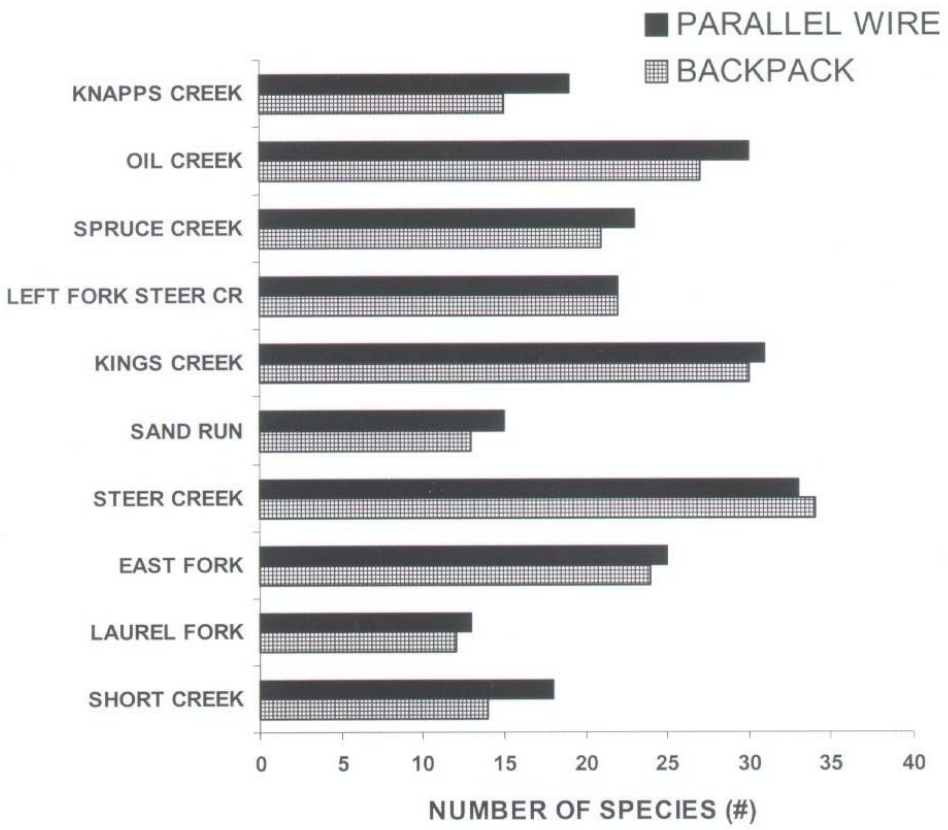

EMAP and R-EMAP Sites
N
EMAP Sites 1993-1998
R-EMAP Sites 2001
Appalachian Plateau
Western Allegheny Plateau
Ridge and Valley
0 20 40 60 Miles

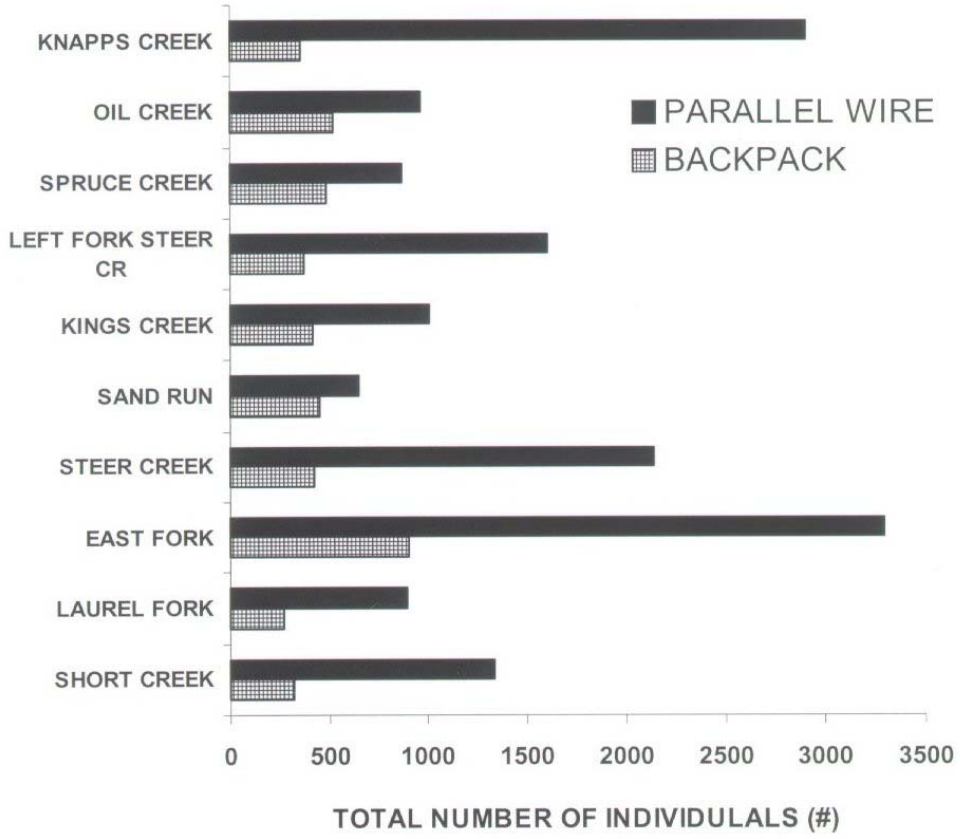
METHODS

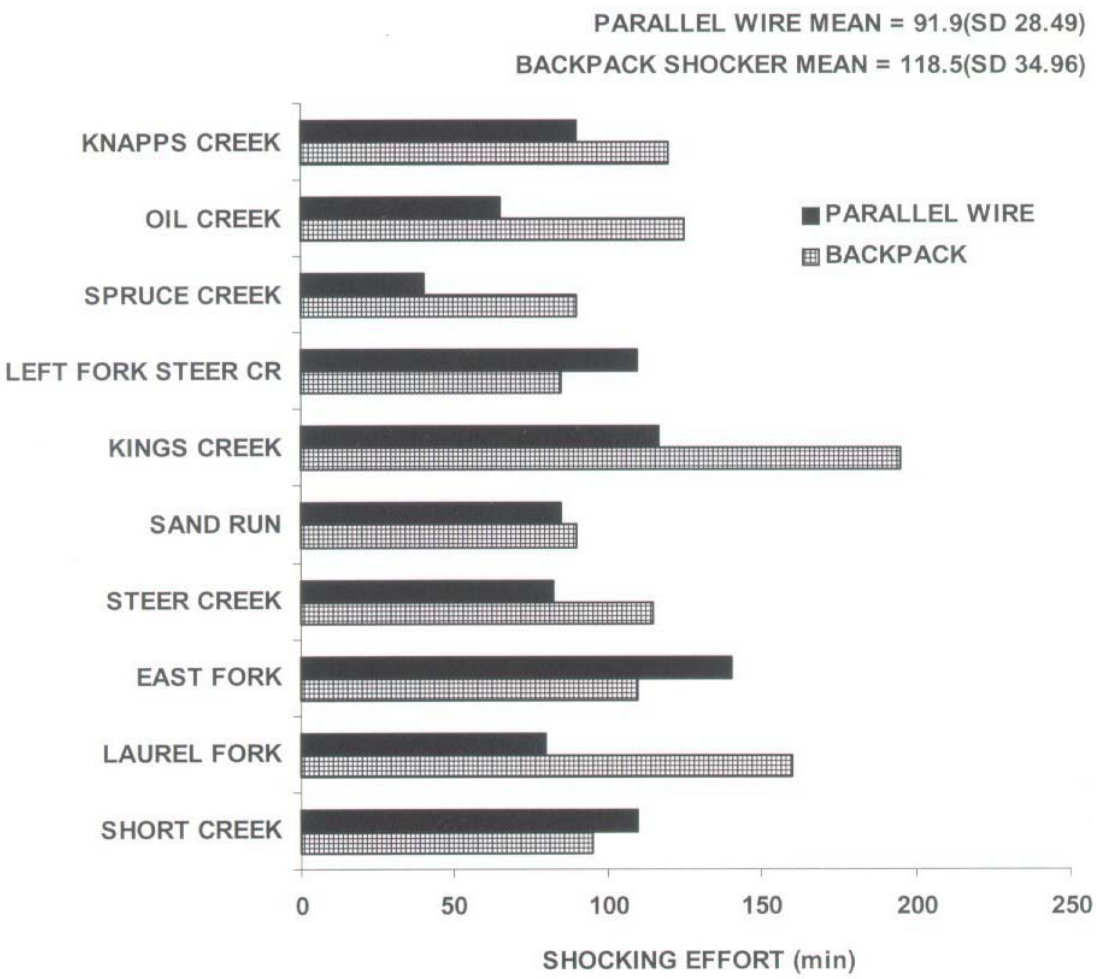


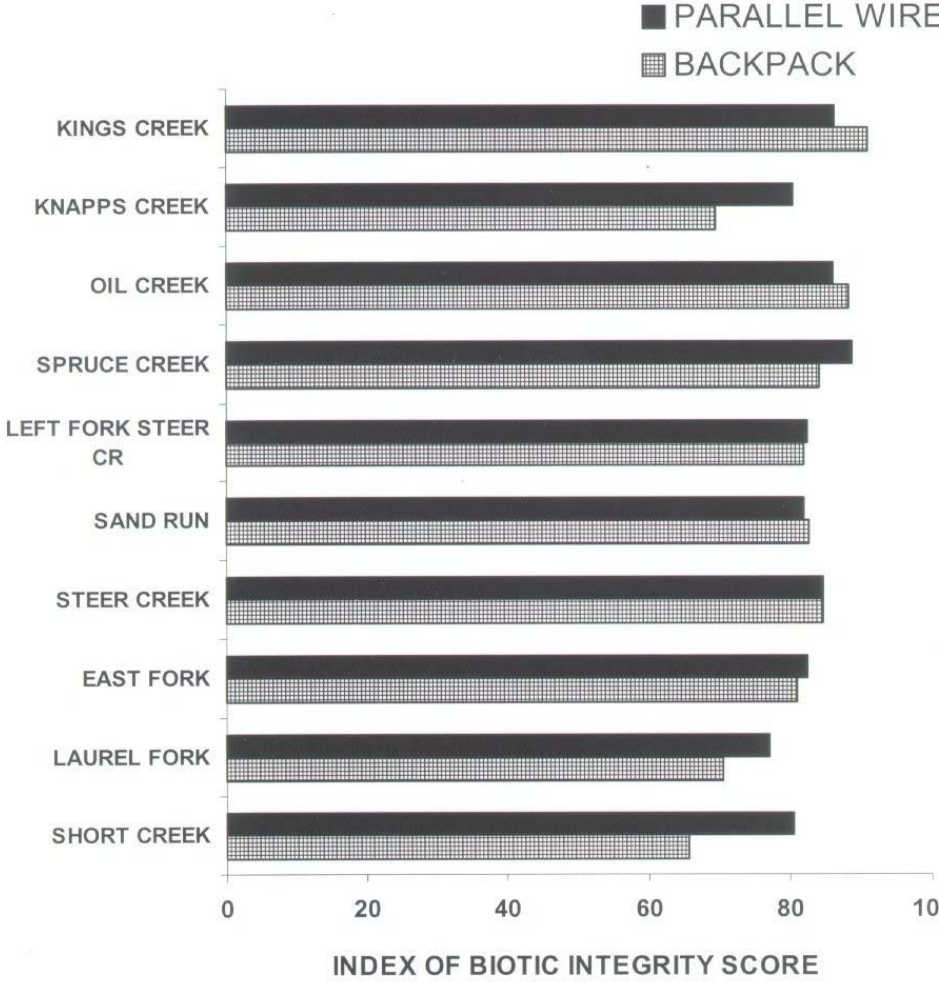
FISH COLLECTION METHODS

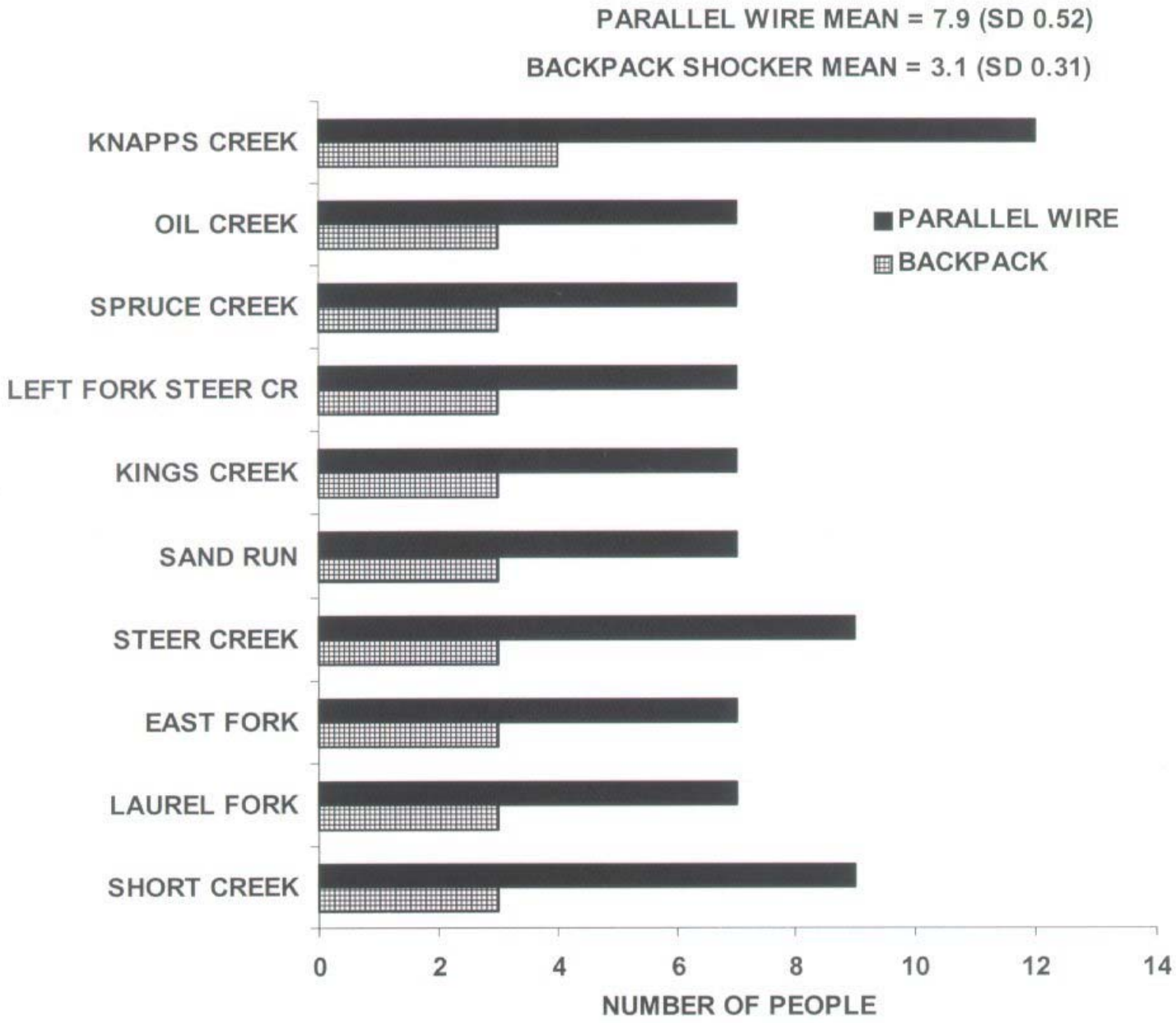
9 16


PARALLEL WIRE
BACKPACK
KNAPPS CREEK
OIL CREEK
SPRUCE CREEK
LEFT FORK STEER CR
KINGS CREEK
SAND RUN
STEER CREEK
EAST FORK
LAUREL FORK
SHORT CREEK
0
5
10
15
20
25
30
35
40
NUMBER OF SPECIES (#)


KNAPPS CREEK
OIL CREEK
SPRUCE CREEK
LEFT FORK STEER CR
KINGS CREEK
SAND RUN
STEER CREEK
EAST FORK
LAUREL FORK
SHORT CREEK
PARALLEL WIRE
BACKPACK
0
500
1000
1500
2000
2500
3000
3500
TOTAL NUMBER OF INDIVIDULALS (#)


PARALLEL WIRE MEAN = 91.9(SD 28.49)
BACKPACK SHOCKER MEAN = 118.5(SD 34.96)
KNAPPS CREEK
OIL CREEK
SPRUCE CREEK
LEFT FORK STEER CR
KINGS CREEK
SAND RUN
STEER CREEK
EAST FORK
LAUREL FORK
SHORT CREEK
PARALLEL WIRE
BACKPACK
0
50
100
150
200
250
SHOCKING EFFORT (min)


PARALLEL WIRE
BACKPACK
KINGS CREEK
KNAPPS CREEK
OIL CREEK
SPRUCE CREEK
LEFT FORK STEER CR
SAND RUN
STEER CREEK
EAST FORK
LAUREL FORK
SHORT CREEK
0
20
40
60
80
INDEX OF BIOTIC INTEGRITY SCORE


PARALLEL WIRE MEAN = 7.9 (SD 0.52)
BACKPACK SHOCKER MEAN = 3.1 (SD 0.31)
KNAPPS CREEK
OIL CREEK
SPRUCE CREEK
LEFT FORK STEER CR
KINGS CREEK
SAND RUN
STEER CREEK
EAST FORK
LAUREL FORK
SHORT CREEK
PARALLEL WIRE
BACKPACK
0
2
4
6
8
10
12
14
NUMBER OF PEOPLE

HABITAT MEASUREMENTS

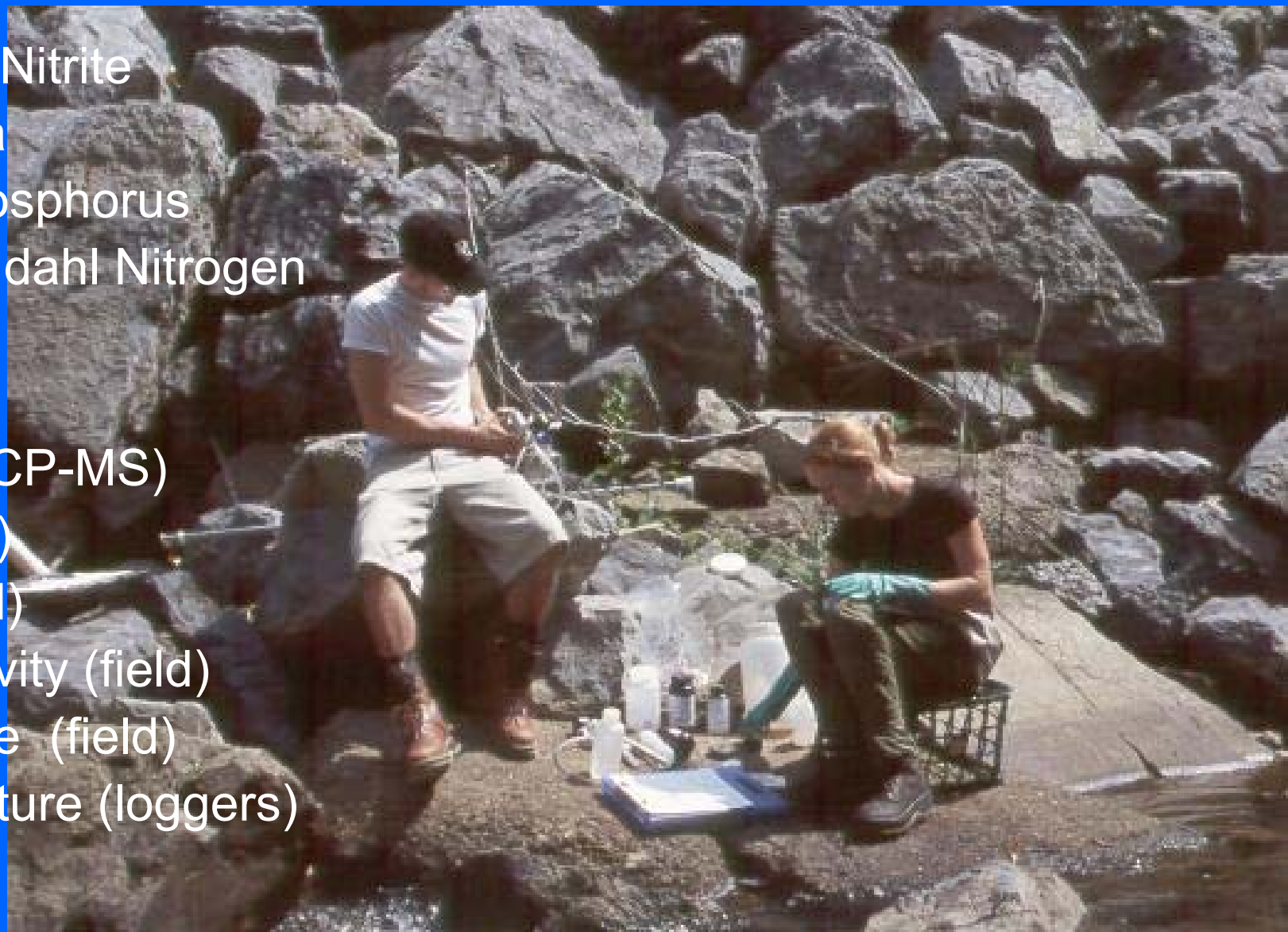
(EMAP Protocols = Kaufman + Robinson 1998)

- Channel dimensions
- Gradient
- Substrate size and type
- Habitat complexity and cover
- Riparian vegetation and structure
- Anthropogenic alterations
- Channel-riparian interaction

WATER QUALITY MEASUREMENTS

(EMAP protocols = Herlihy 1998)

- Nitrate + Nitrite
- Ammonia
- Total Phosphorus
- Total Kjeldahl Nitrogen
- Anions
- ANC
- Metals (ICP-MS)
- pH (field)
- DO (field)
- Conductivity (field)
- Discharge (field)
- Temperature (loggers)



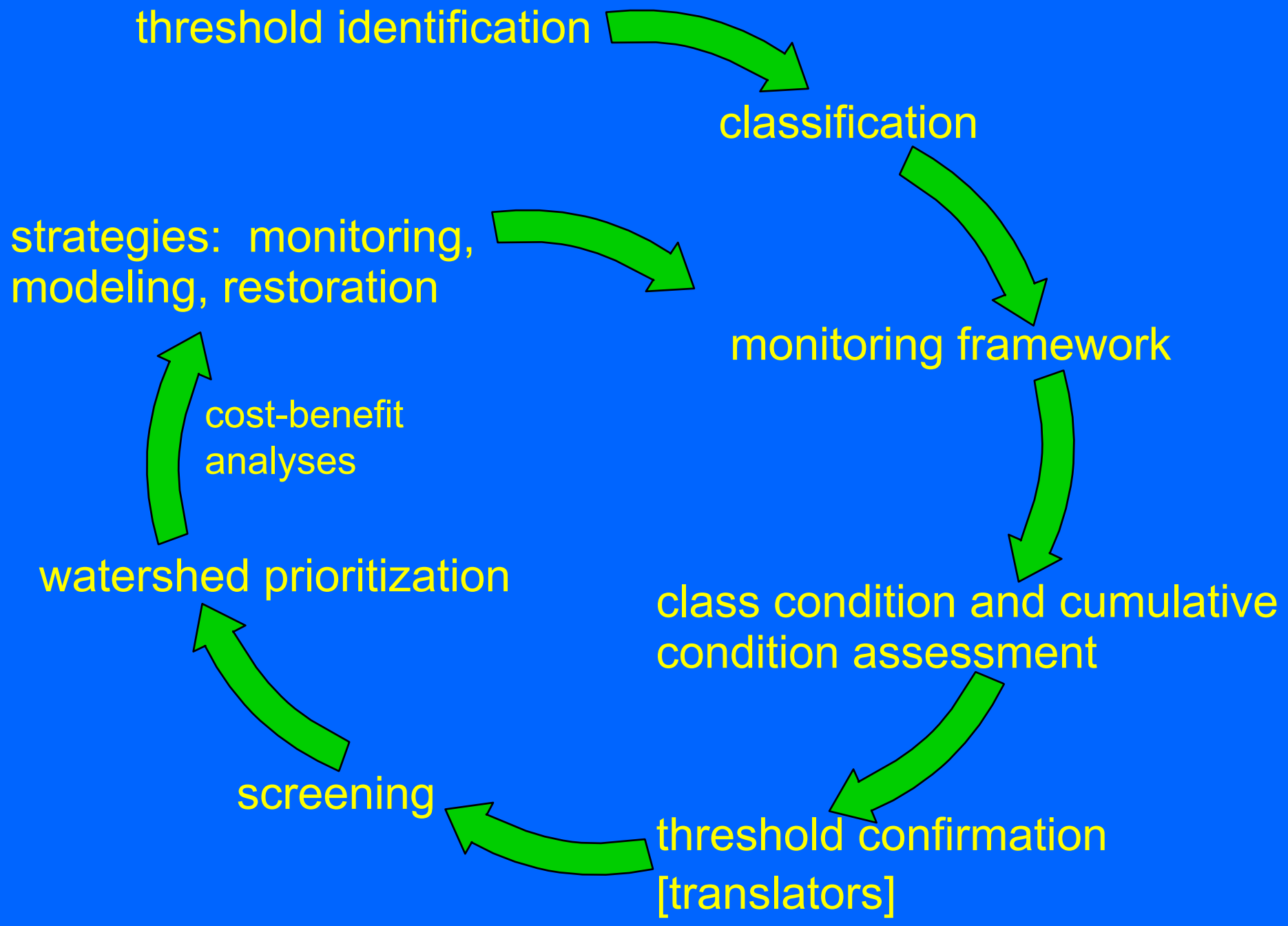
TEMPERATURE LOGGERS

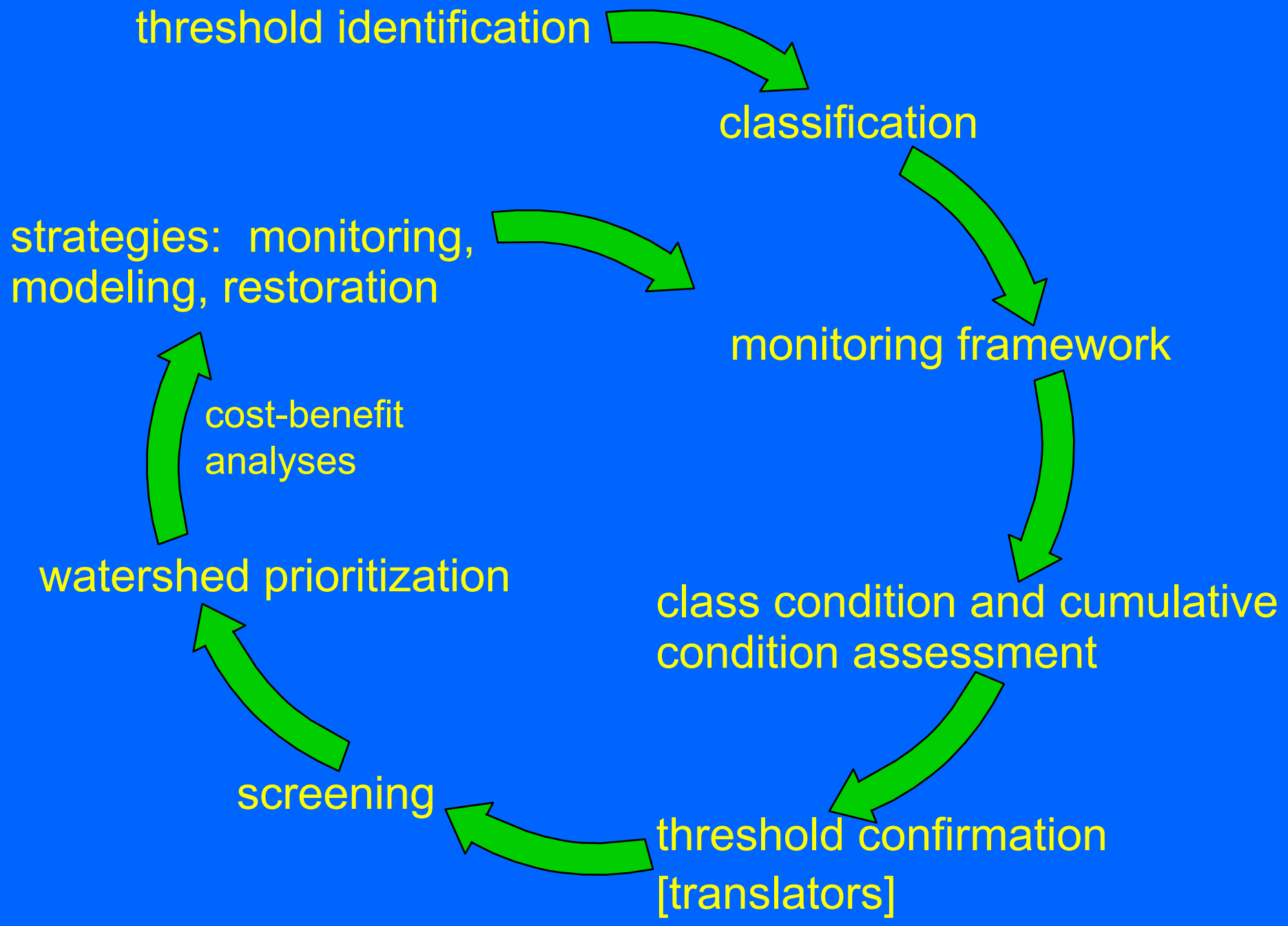
Questions of interest for 305b vs 303d programs

- 305b assessments
  - % impaired water bodies by region
  - temporal trends in impairment by region
- 303d listings
  - site-specific identification of all impaired water bodies
  - probability of impairment by watershed class to facilitate extrapolation

Combined approaches for consolidated assessment and listing methods

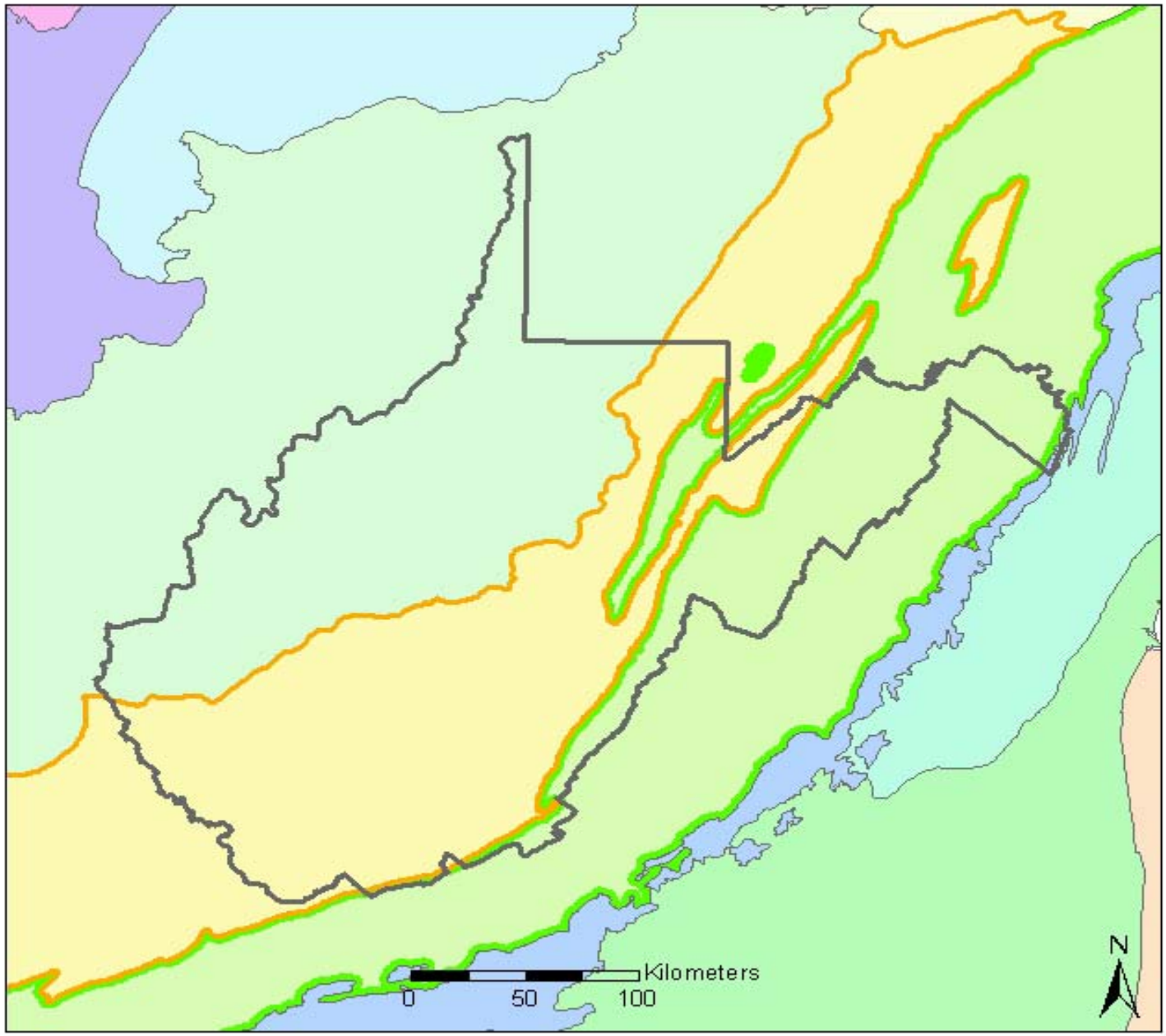
- Monitor all water bodies - prob not feasible
- Probability sample w RTS (EMAP) design to spatially distribute sample points
- Random-stratified design using watershed units (12-digit HUCs)


threshold identification
classification
monitoring framework
class condition and cumulative condition assessment
threshold confirmation [translators]
screening
watershed prioritization
cost-benefit analyses
strategies: monitoring, modeling, restoration


threshold identification
classification
monitoring framework
class condition and cumulative condition assessment
threshold confirmation [translators]
screening
watershed prioritization
cost-benefit analyses
strategies: monitoring, modeling, restoration

West Virginia Ecoregions

Central Appalachian Ridges and Valleys and Central Appalachian Plateau



Legend

- West Virginia

Ecoregions

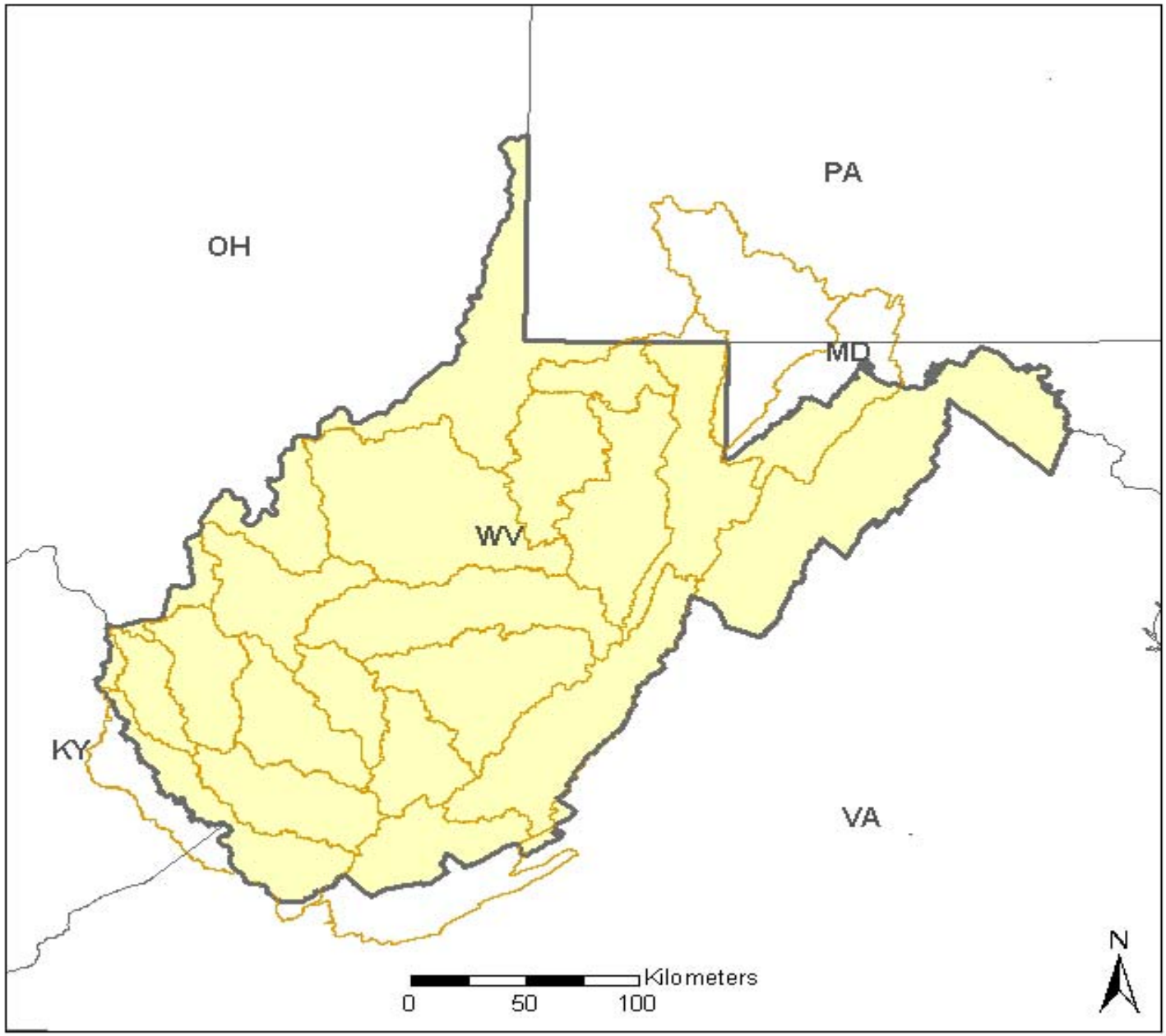
- Blue Ridge Mountains
- Central Appalachian Ridges and Valleys
- Central Appalachians
- Eastern Corn Belt Plains
- Erie/Ontario Lake Hills and Plain
- Huron/Erie Lake Plains
- Interior Plateau
- Middle Atlantic Coastal Plain
- North Central Appalachians
- Northern Piedmont
- Piedmont
- Southeastern Plains
- Western Allegheny Plateau

EPA
Mid-Continent Ecology Division (MED
Duluth, Minnesota 55804-2595
(218)529-5000 / Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

West Virginia with 8-Digit HUC Boundaries

(With 10 and 12-Digit Data Available



Legend

- West Virginia
- State Boundaries
- 8-digit HUCs

Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 : Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

West Virginia with 8 and 10-Digit HUC Boundaries

(Clipped to State Boundary)

Kilometers

0 50 100

N

Legend

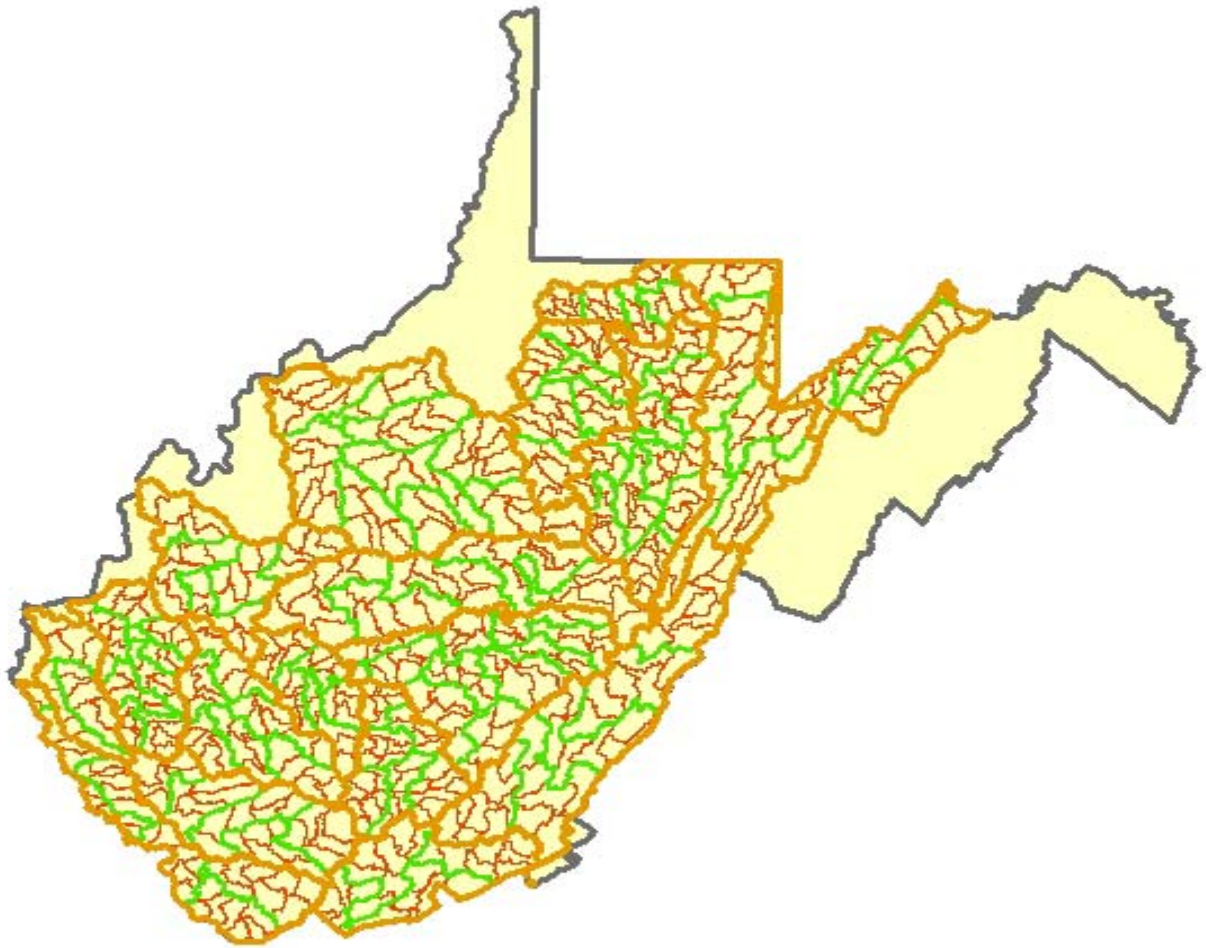
- West Virginia
- 8-digit HUC boundaries
- 10-digit HUC boundaries

EPA
Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 · Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

West Virginia with 8, 10, and 12-Digit HUC Boundaries

(Clipped to State Boundary)

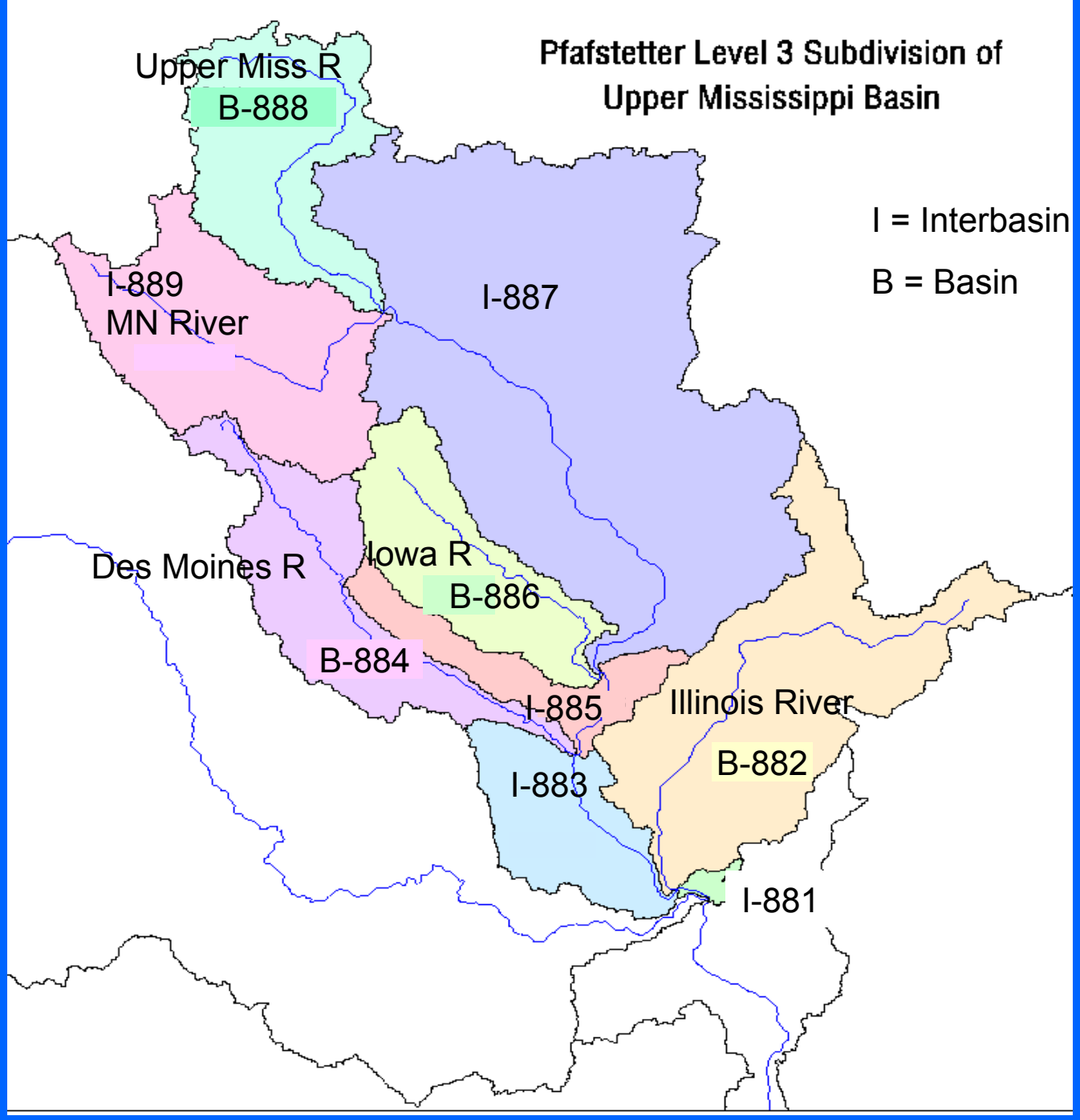


Legend

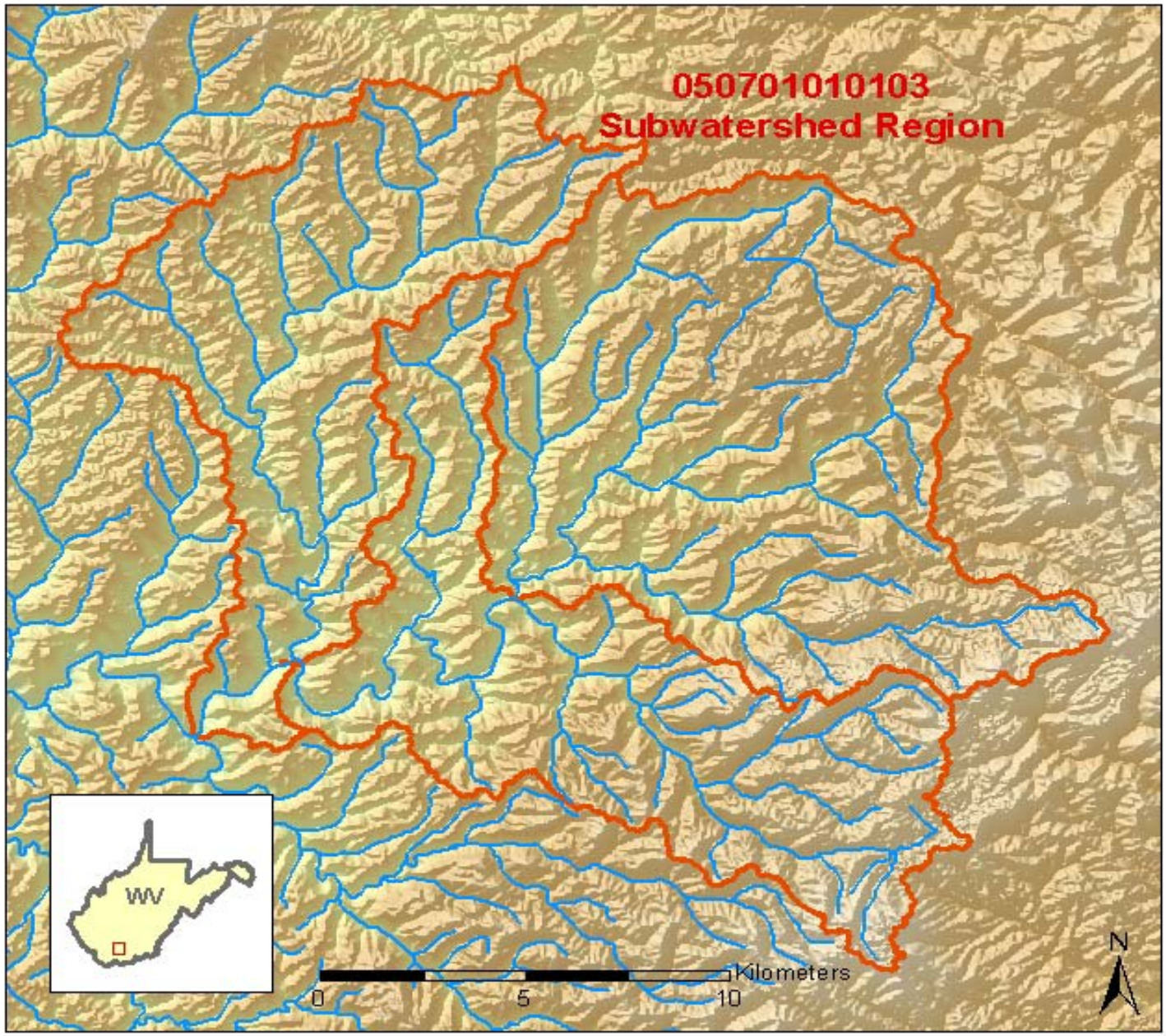
- West Virginia
- 8-digit HUC boundaries
- 10-digit HUC boundaries
- 12-digit HUC boundaries

Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 ; Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024


Pfafstetter Level 3 Subdivision of
Upper Mississippi Basin
I = Interbasin
B = Basin
Upper Miss R
B-888
I-889
MN River
I-887
Des Moines R
Iowa R
B-886
B-884
I-885
Illinois River
B-882
I-883
I-881

HUC 050701010103 Region with NHD and Shaded NED



Legend

NED Value (meters)

High : 1481

Low : 68

NHD stream reaches

050701010103 Region

EPA Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 : Fax (218)529-5003

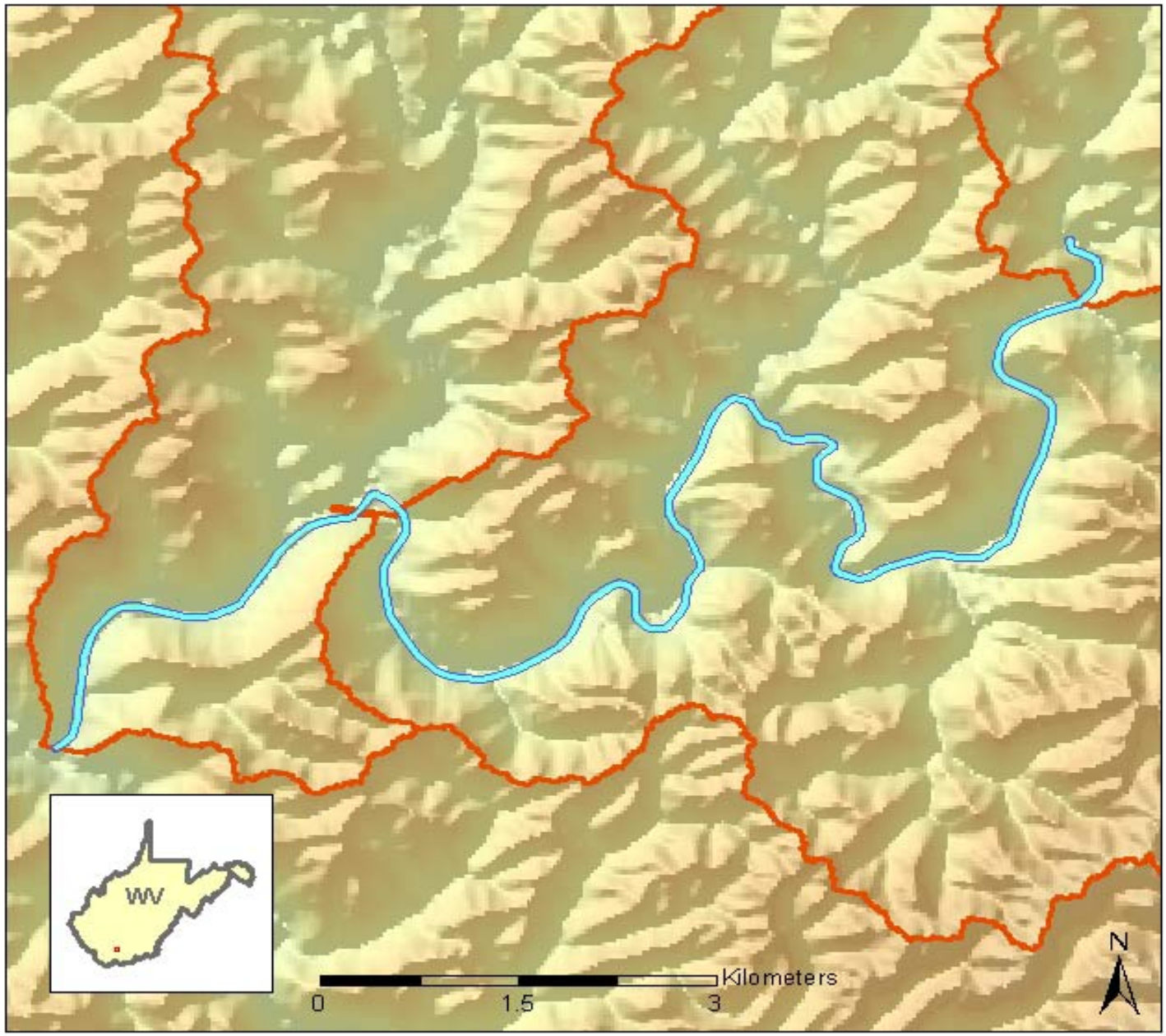
Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

Potential variables[1] affecting peak flow for West Virginia streams

- watershed area
- channel slope
- watershed storage
- percent forest
- main channel length
- elevation
- snowfall
- average annual precipitation
- soil infiltration rate
- average minimum January temperature
- [1] from Frye, P.M. and G.S. Runner. 1970. A proposed streamflow data program for West Virginia. US Dept. of the Interior Geological Survey Water Resources Division, Open-file report, Charleston, WV.

HUC 050701010103 Region with NHD and Shaded NED

Main Channel Buffer



Legend

NED Value (meters)

High : 1481

Low : 68

050701010103 Region

Main channel

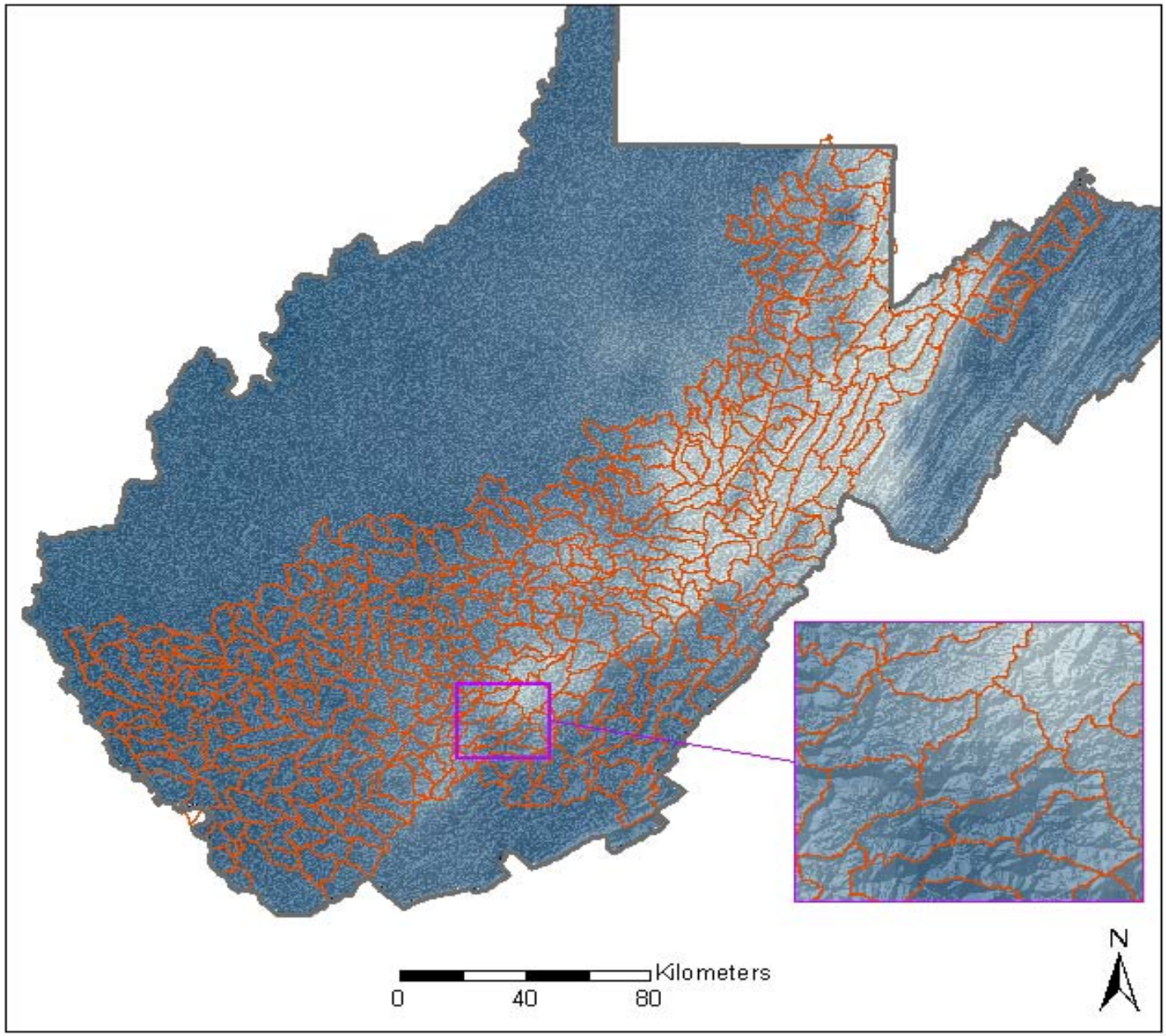
Main channel buffer

Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 - Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

Derivation of Watershed Attributes

(PRISM Average Annual Snowfall)



Legend

West Virginia

12-digit HUCs (joined)

PRISM Value (mm)

High : 4588

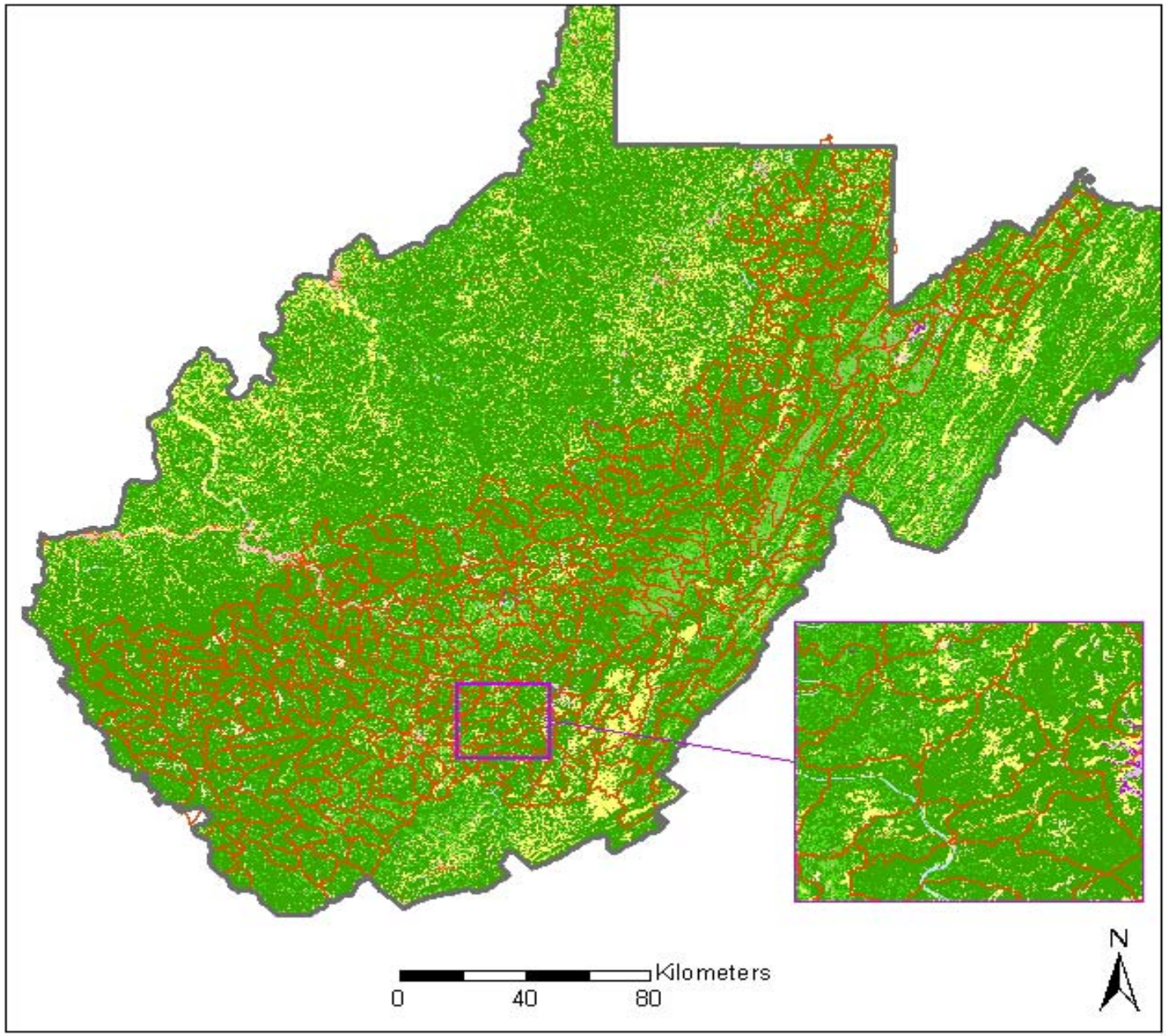
Low : 286

Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 : Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

Derivation of Watershed Attributes

(Mining-Modified NLCD)



Legend

- West Virginia
- 12-digit HUCs (joined)

Mining-Modified NLCD

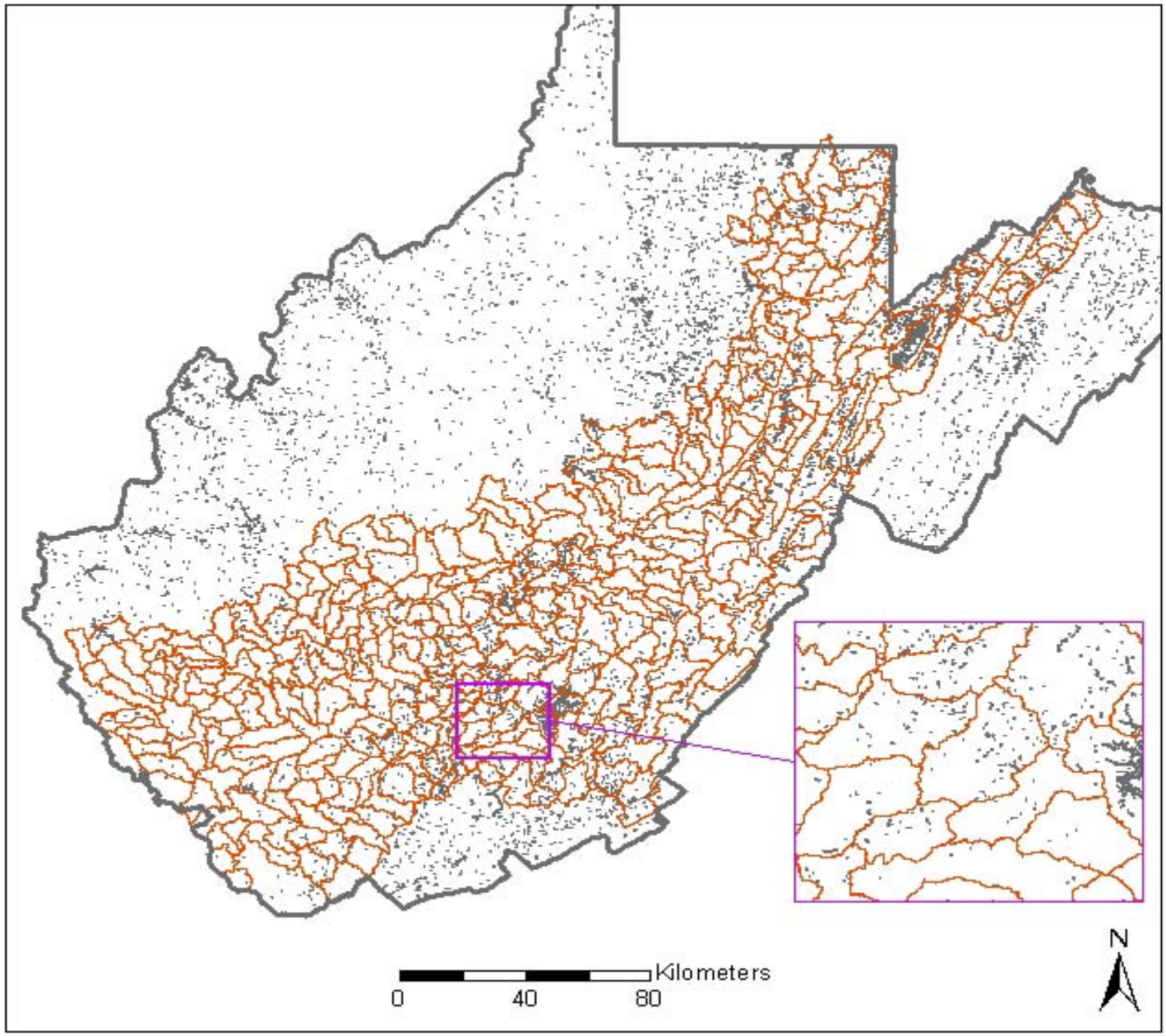
- Open Water
- Low Intensity Residential
- High Intensity Residential
- Commercial/Industrial/Transportation
- Bare Rock/Sand/Clay
- Quarries/Strip Mines/Gravel Pits
- Transitional
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Pasture/Hay
- Row Crops
- Urban/Recreational Grasses
- Woody Wetlands
- Emergent Herbaceous Wetlands

ORD
EPA
Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 / Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

Derivation of Watershed Attributes

(NWI)



Legend

- West Virginia
- 12-digit HUCs (joined)

NWI SYSTEM

- Lacustrine
- Palustrine

ORD
EPA
Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 · Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

Analysis of factors affecting peak flow for West Virginia streams in Central Appalachian Plateau and Ridge and Valley Province[1]

Potential variables: watershed area, channel slope, watershed storage, percent forest, main channel length, elevation, snowfall, average annual precipitation, soil infiltration rate, and average minimum January temperature

Results of regression analysis (Mallow's Cp statistic)

$$Q_2 = A^a \; P^p \; T^t \; Sn^{sn} \; St^{st}$$

where Q2 = 2-year peak flow

A = watershed area

P = average annual precipitation

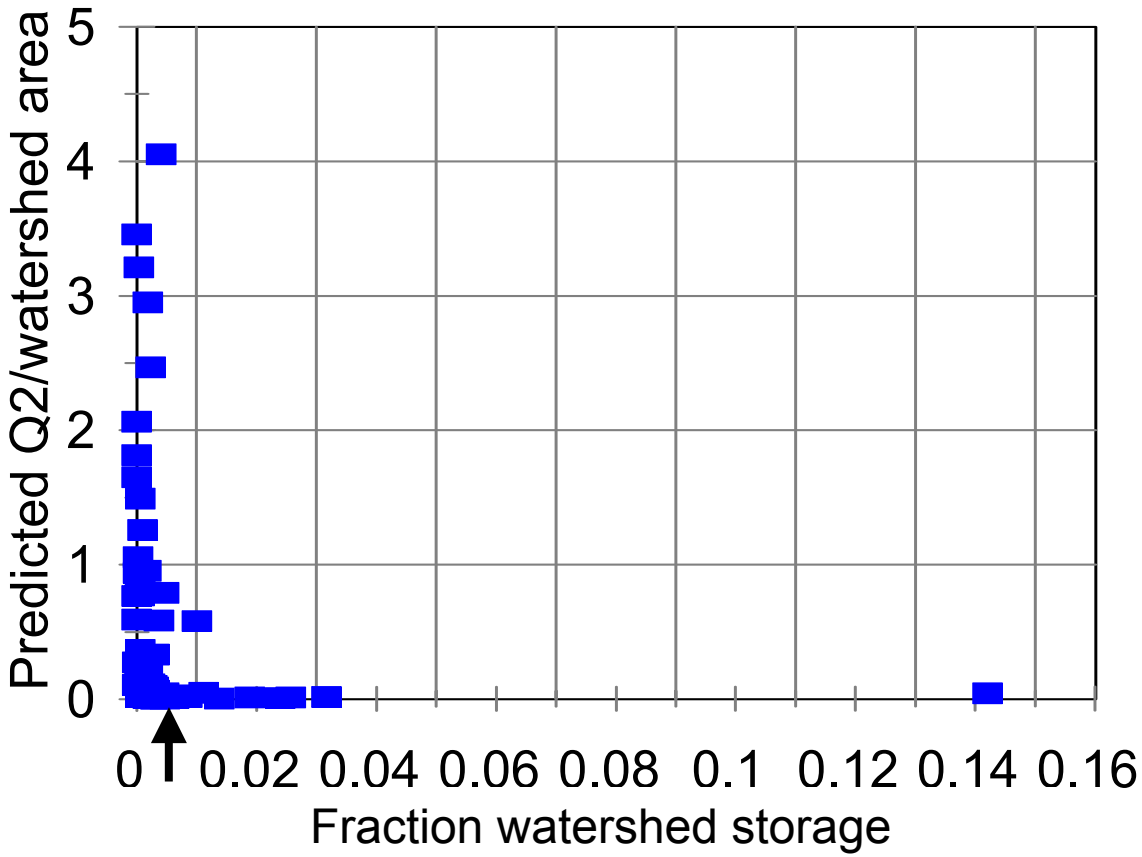
T = average minimum January temperature

Sn = snowfall

St = watershed storage

1 (Data from Frye and Runner 1970, Runner 1980)

Graphical analysis of WV hydrologic threshold



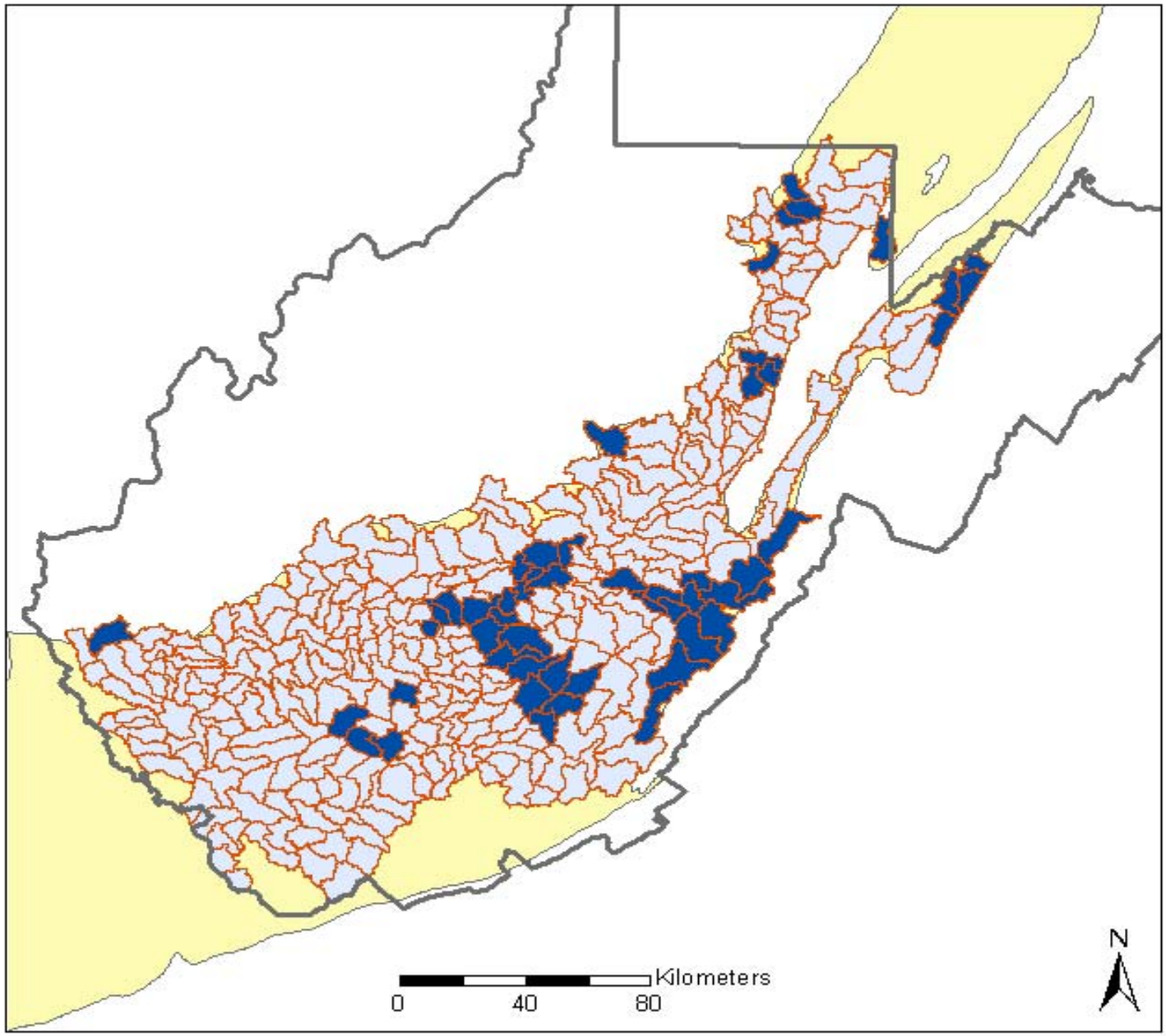
(lake + wetland area/watershed area)

Potential Land-Use Threshold Values for WV

- Peak flow equations (Q_5, Q_{10}) for full state
  - % forest alone showed no threshold effect
  - forest * (snowfall * Jan min temp) : “noisy” threshold
- Agriculture
  - MD Biological Stream Survey Data
  - water quality threshold at > 25% (Berrigan et al, unpubl.)
- Impervious surface area
  - >10-15% (most literature sources)
  - species shifts at > 2% (MD BSS Data)
- Mining
  - Peak flow model results: >30% disturbed area (Scott 1984)
  - Disturbed area analogous to impervious area: > 10%

Derivation of Watershed Attributes

Low vs. High Storage



Legend

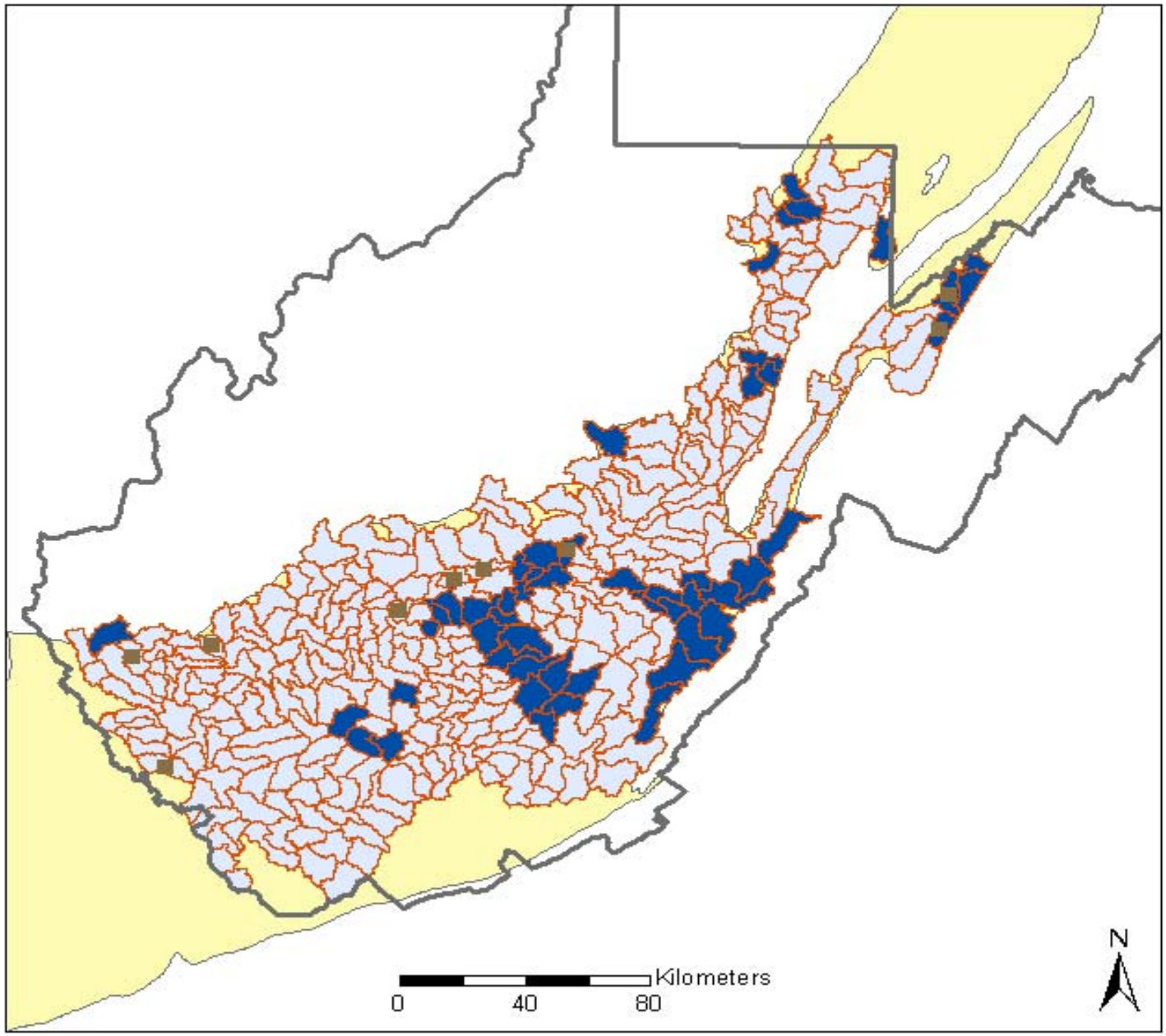
- West Virginia
- Central Appalachians
- Low storage
- High storage

EPA
Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 ; Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

Derivation of Watershed Attributes

Low vs. High Storage with High Mining



Legend

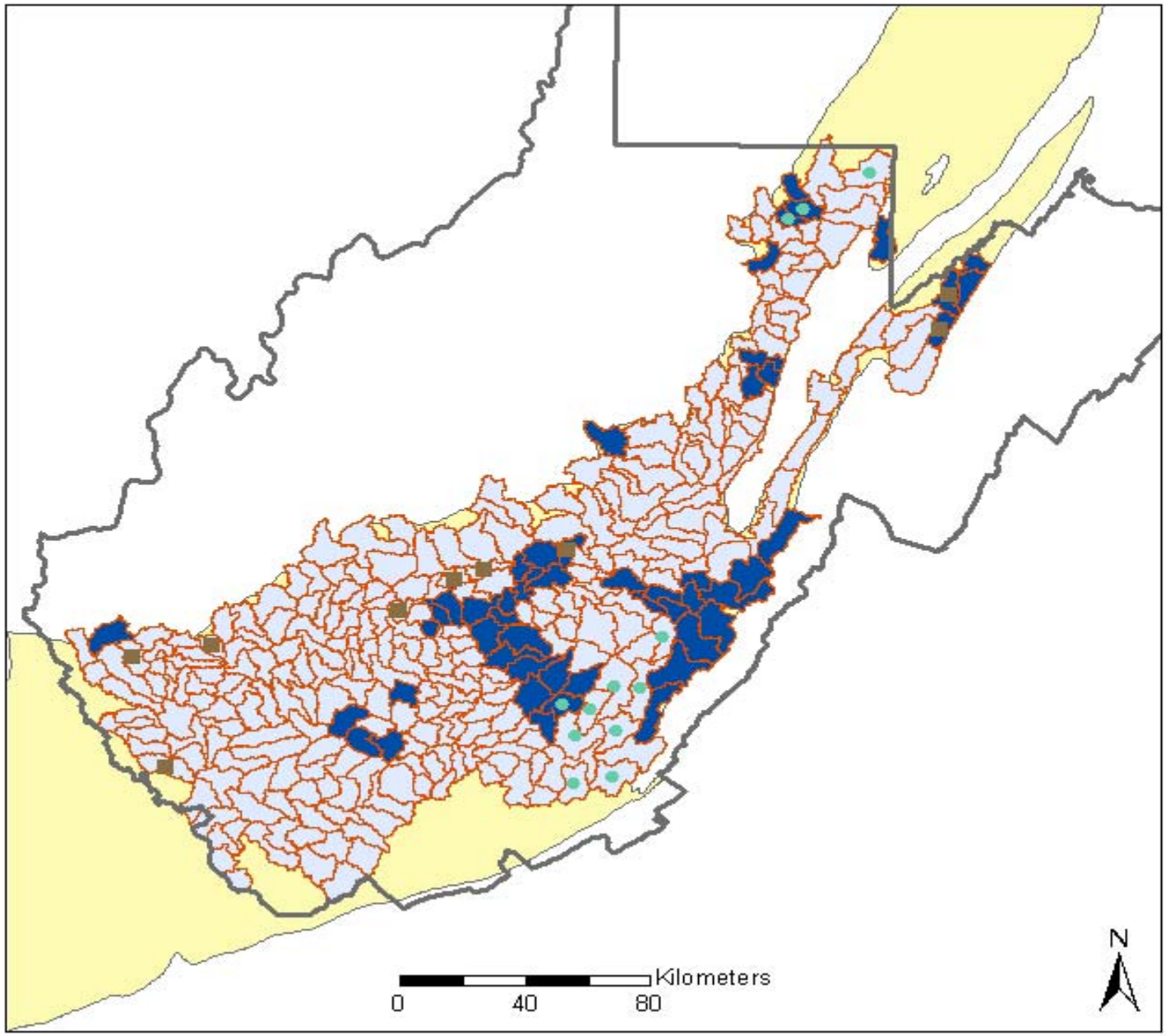
- West Virginia
- Central Appalachians
- Low storage
- High storage
- High mining

EPA
Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 : Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

Derivation of Watershed Attributes

Low vs. High Storage with
High Mining
High Agriculture



Legend

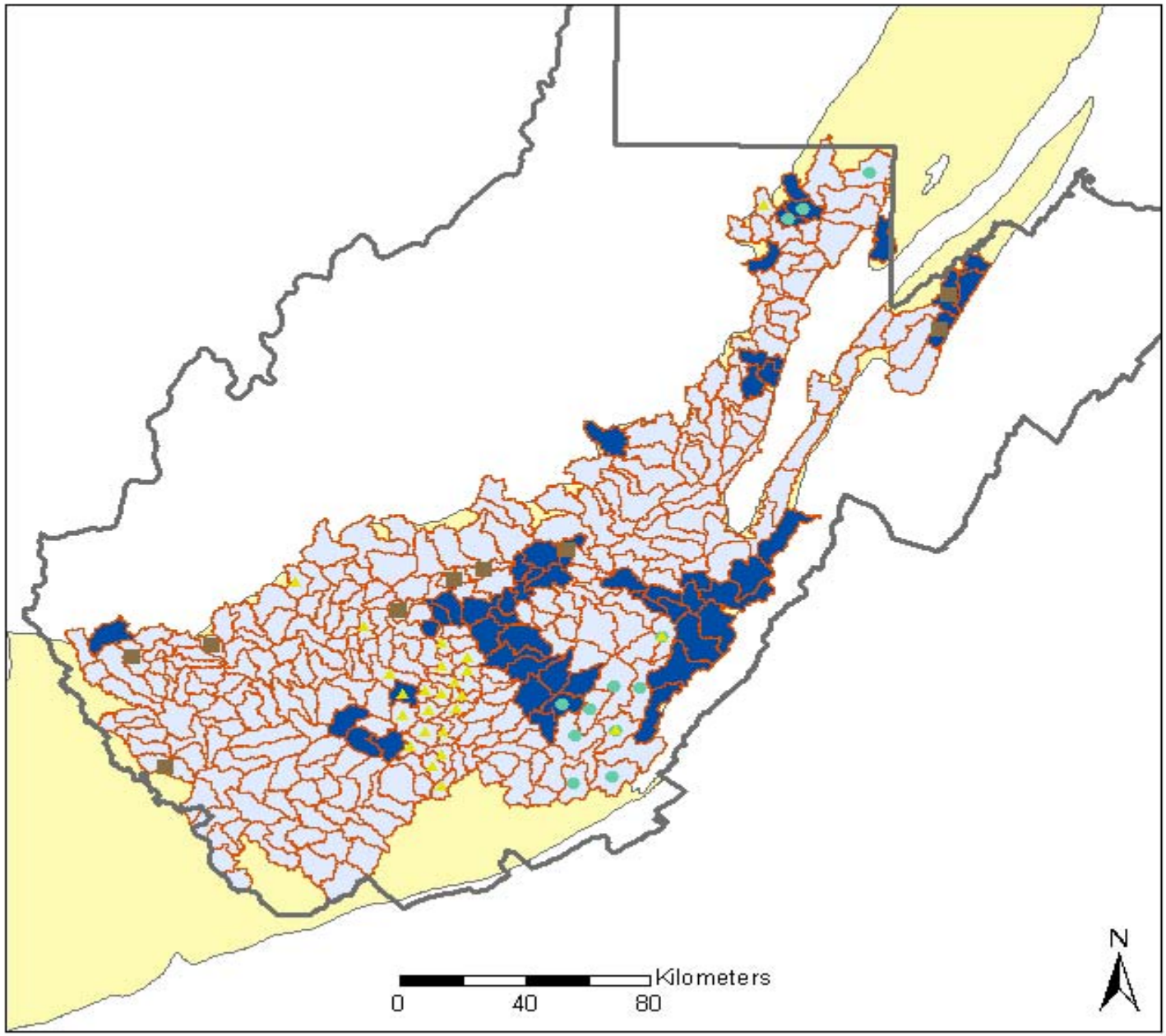
- West Virginia
- Central Appalachians
- Low storage
- High storage
- High mining
- High agriculture

ORD
EPA
Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 · Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

Derivation of Watershed Attributes

Low vs. High Storage with
High Mining
High Agriculture
High Impervious Surface



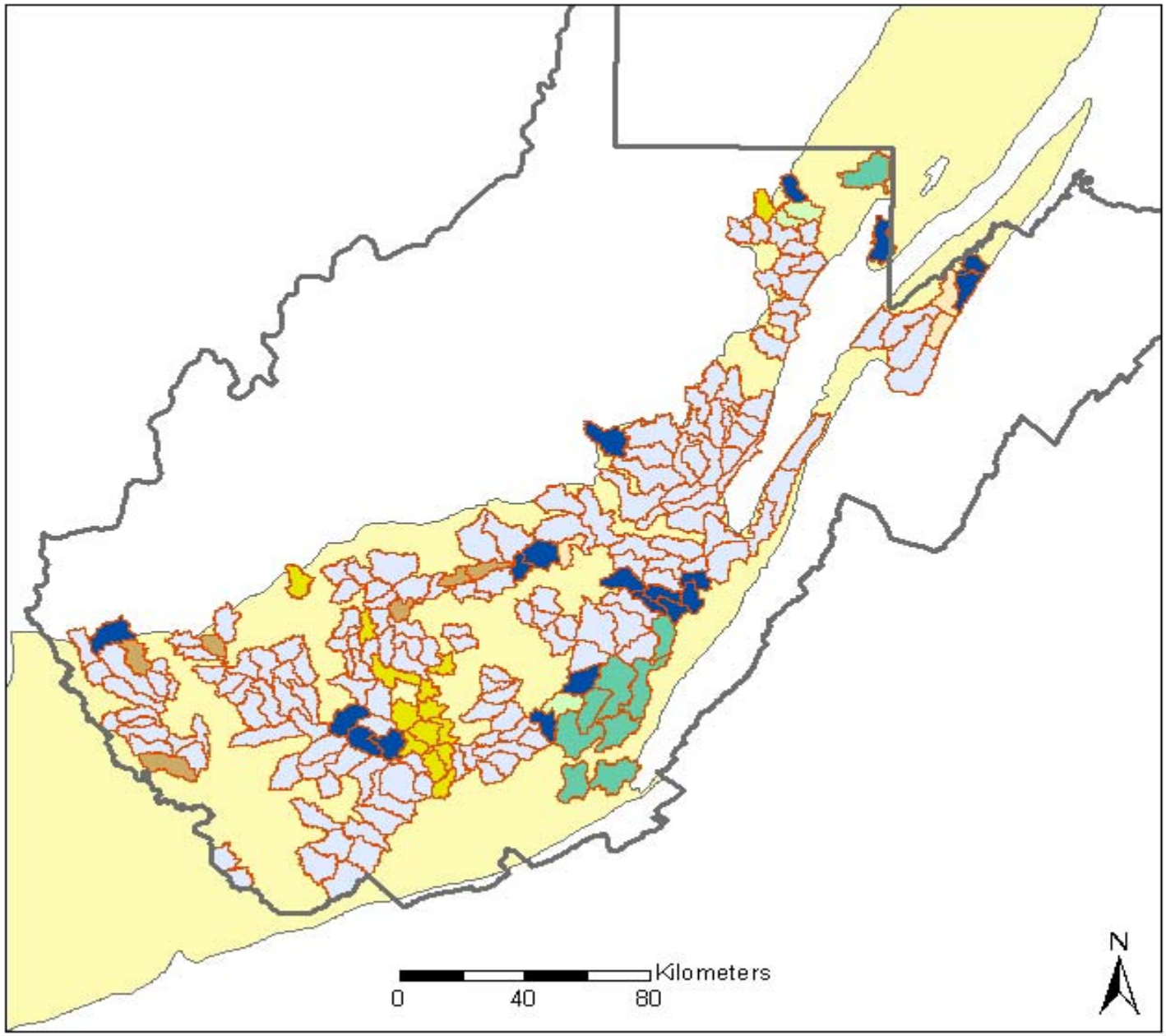
Legend

- West Virginia
- Central Appalachians
- Low storage
- High storage
- High mining
- High agriculture
- High impervious

ORD
EPA
Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 · Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

Final Watershed Classes

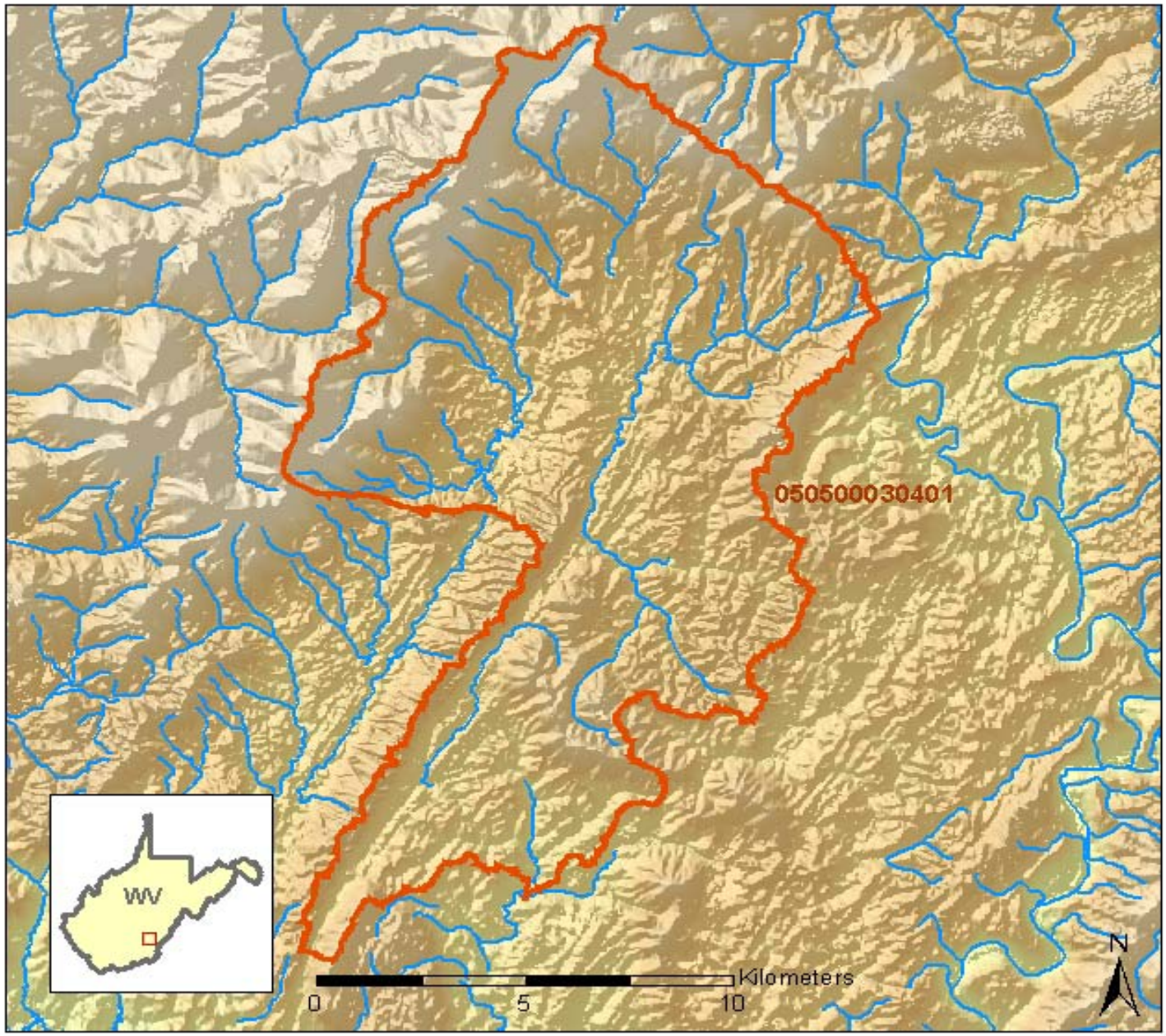


Legend

- West Virginia
- Central Appalachians
- Reference, low storage
- Reference, high storage
- High mining, low storage
- High mining, high storage
- High agriculture, low storage
- High agriculture, high storage
- High impervious, low storage
- High impervious, high storage

ORD
EPA
Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 / Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024



Random-Stratified Selection Process

Example of HUC Removed From Sampling Process

(Internal Drainage)

Legend

NED Value (meters)

High : 1481

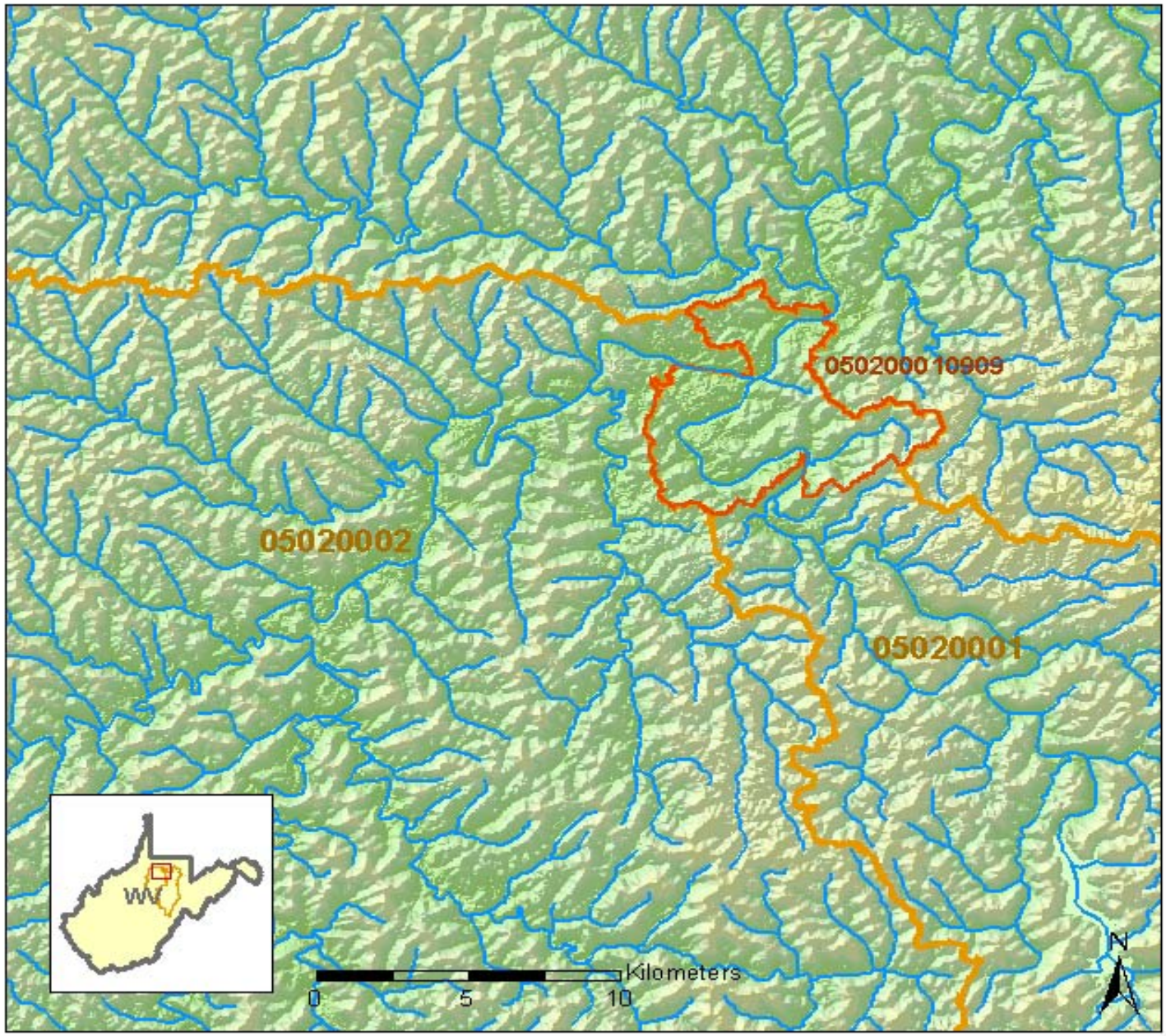
Low : 68

NHD

HUC 050500030401

EPA
Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 ; Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024



Random-Stratified Selection Process

Example of HUC Removed From Sampling Process

(12-Digit HUC with Upstream 8-Digit HUC)

Legend

NED Value (meters)

High : 1481

Low : 68

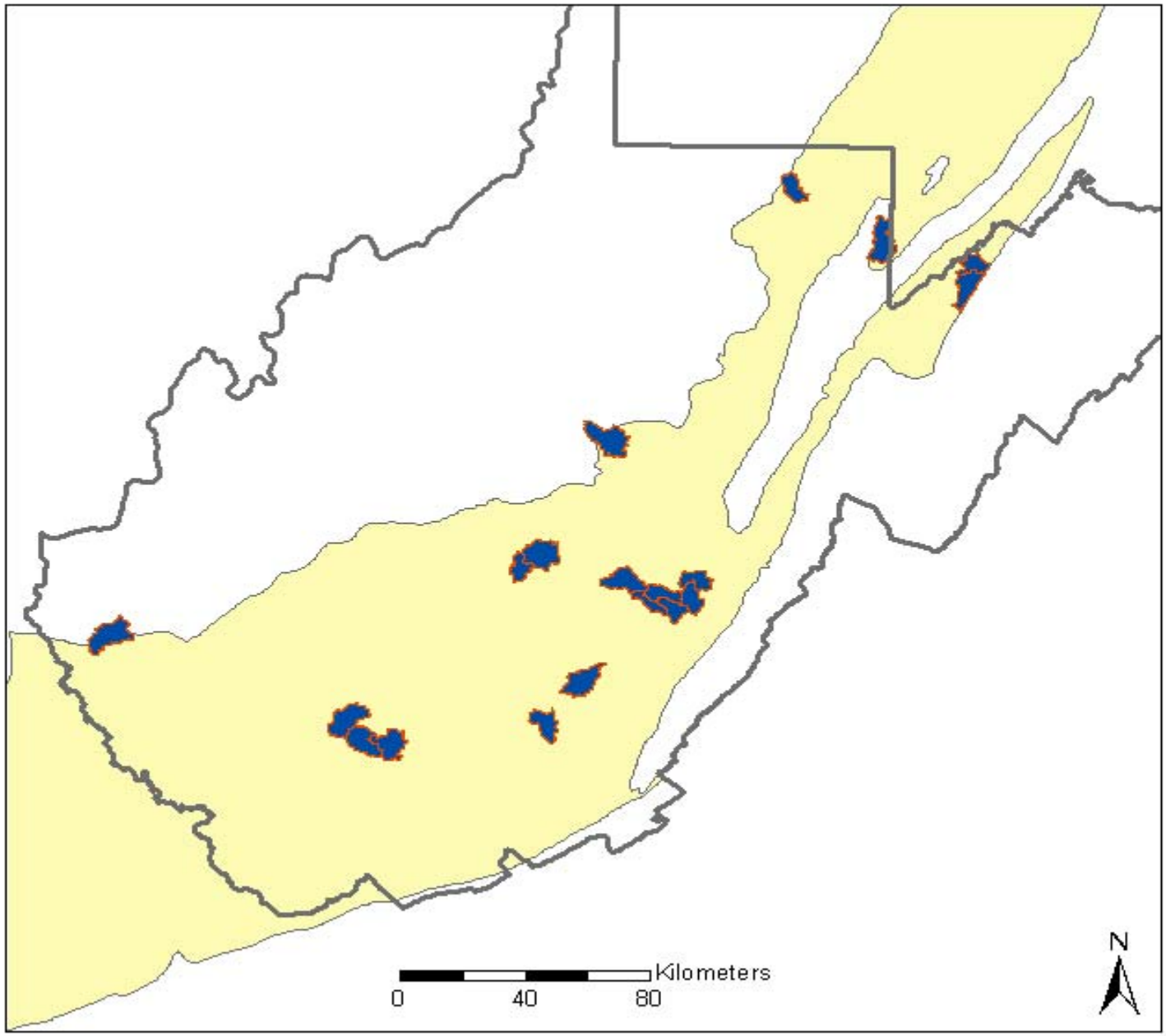
NHD

HUC 050200010909

8-digit HUCs

ORD
EPA
Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 · Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024



Random-Stratified Selection Process

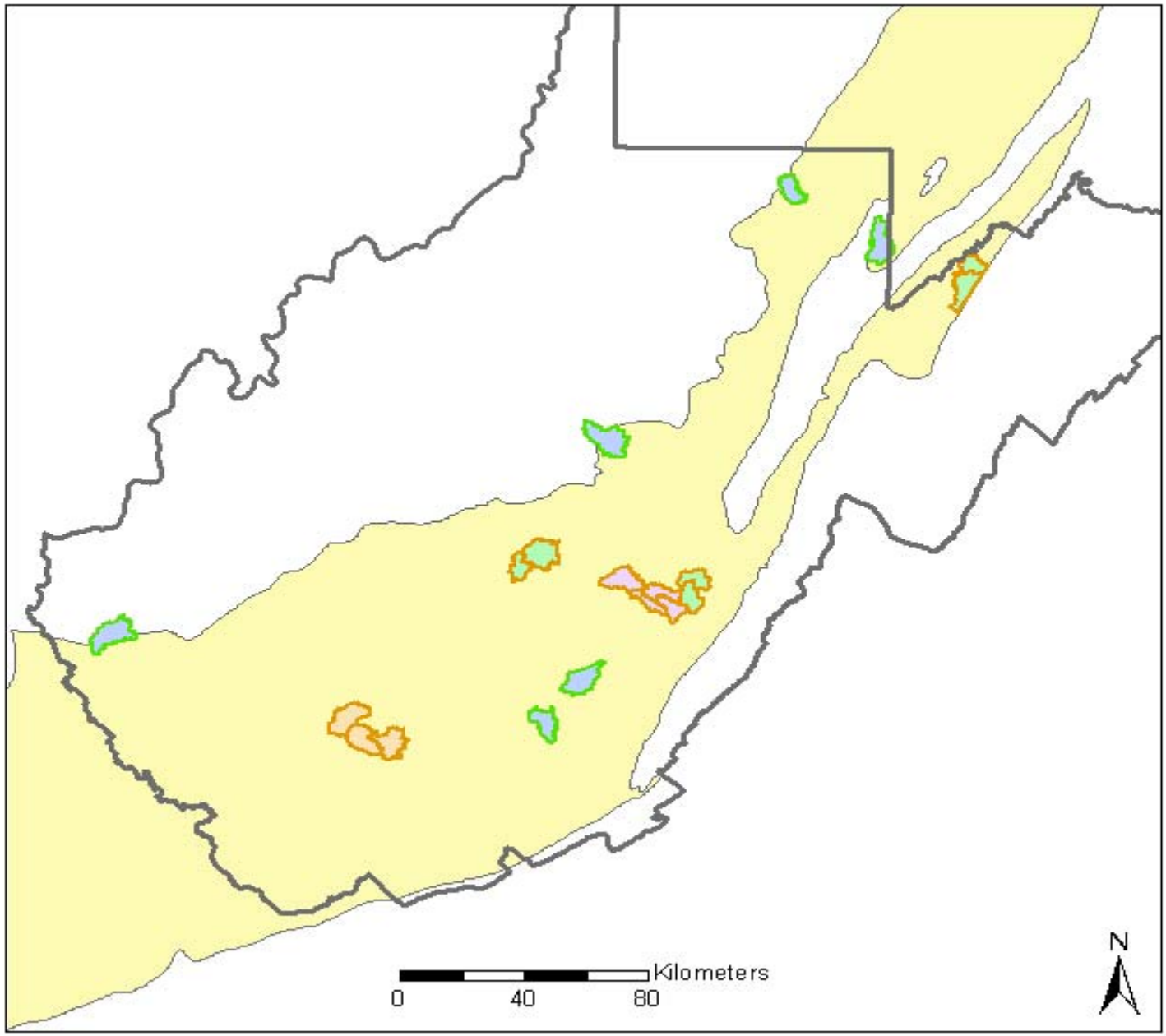
Weighting Procedure

Legend

- West Virginia
- Central Appalachians
- Reference, high storage

Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 ; Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024



Random-Stratified Selection Process

Weighting Procedure

Legend

- West Virginia
- Central Appalachians
- Independent 12-digit HUCs
- Dependent 12-digit HUCs

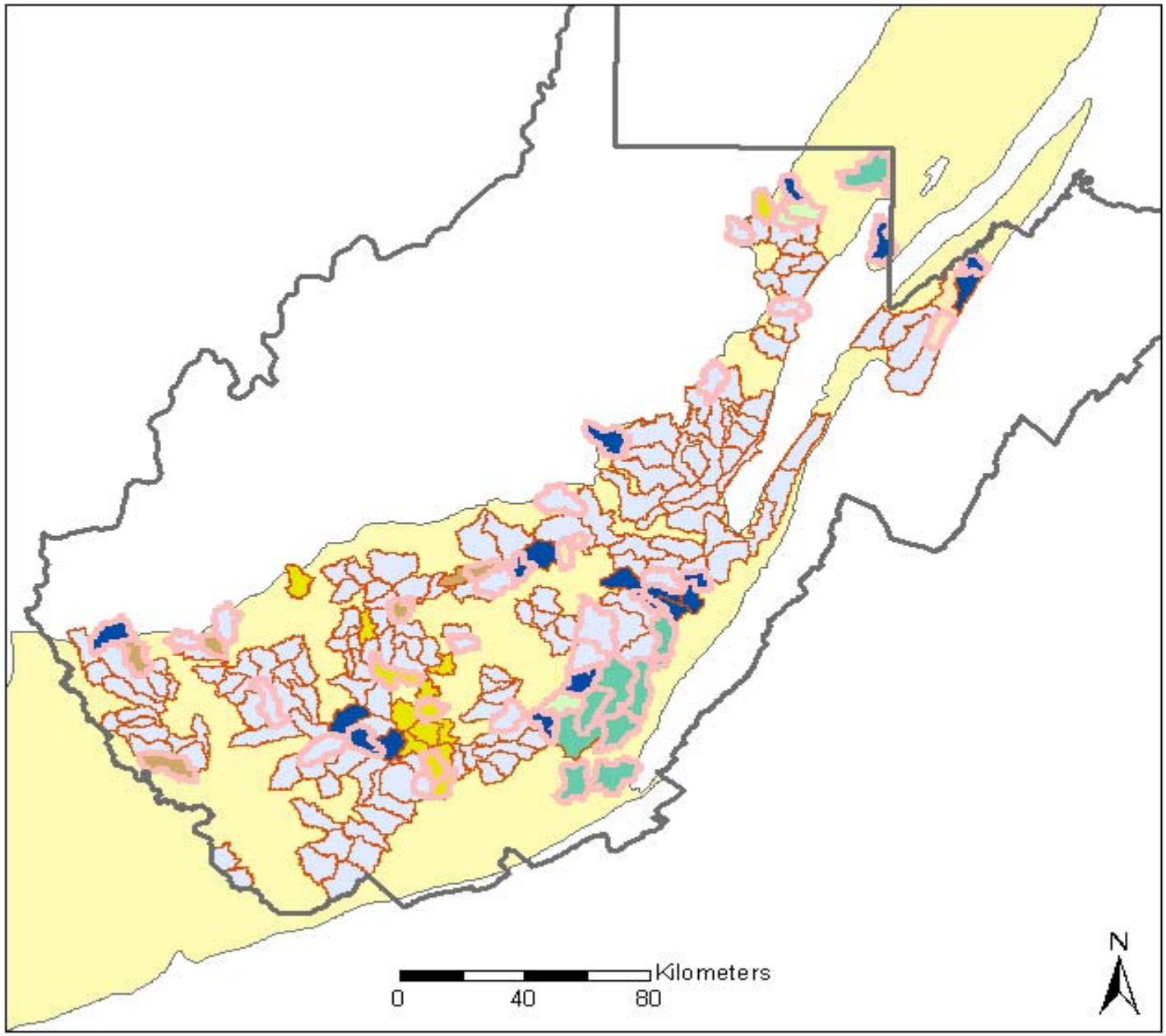
Inclusion Probabilities

- 0.013
- 0.018
- 0.026
- 0.053

Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 / Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

Random-Stratified Selection of HUCs for Sampling



Legend

- West Virginia
- Central Appalachians
- HUCs selected for sampling
- Reference, low storage
- Reference, high storage
- High mining, low storage
- High mining, high storage
- High agriculture, low storage
- High agriculture, high storage
- High impervious, low storage
- High impervious, high storage

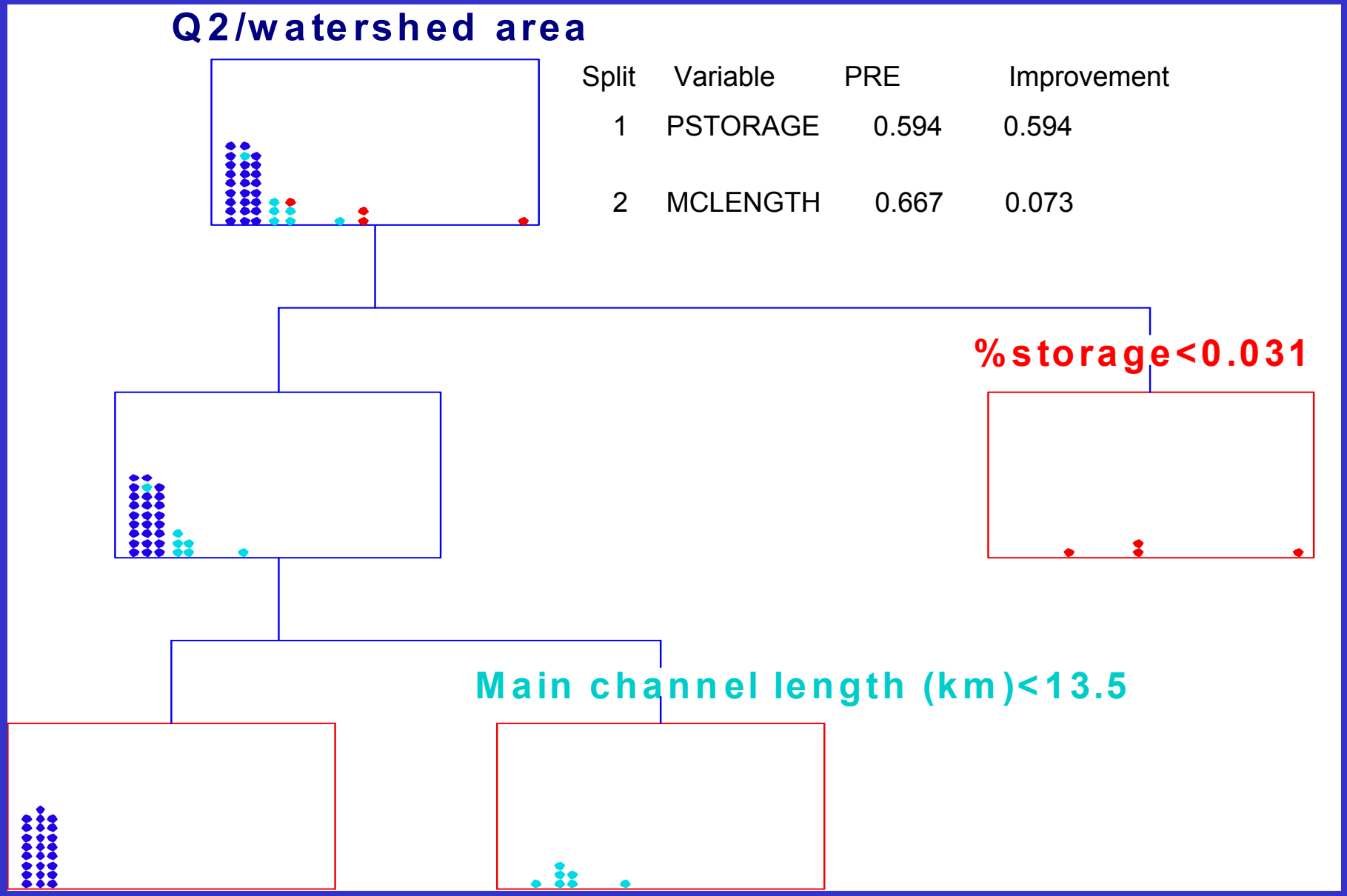
ORD
EPA
Mid-Continent Ecology Division (MED)
Duluth, Minnesota 55804-2595
(218)529-5000 · Fax (218)529-5003

Map layout produced by CSC under the FAIR II Contract 68-W01-023 Task Order #024

Next steps

- Site selection for 2002 within W Alleghany Plateau
- Preliminary data analysis
  - Confirm thresholds
  - Compare fish community, habitat condition across watershed classes
  - Evaluate probability of impairment
  - Multivariate analysis to confirm main driving factors
  - Methods for predicting thermal regime and associated fish community reference condition
  - IBI development

Use of Classification and Regression Tree (CART) Analysis to Identify Hydrologic Thresholds for W Alleghany Plateau



Split	Variable	PRE	Improvement
1	PSTORAGE	0.594	0.594
2	MCLENGTH	0.667	0.073