Water chemistry and benthic macroinvertebrate response to AMD treatment within a HUC-12 Appalachian watershed

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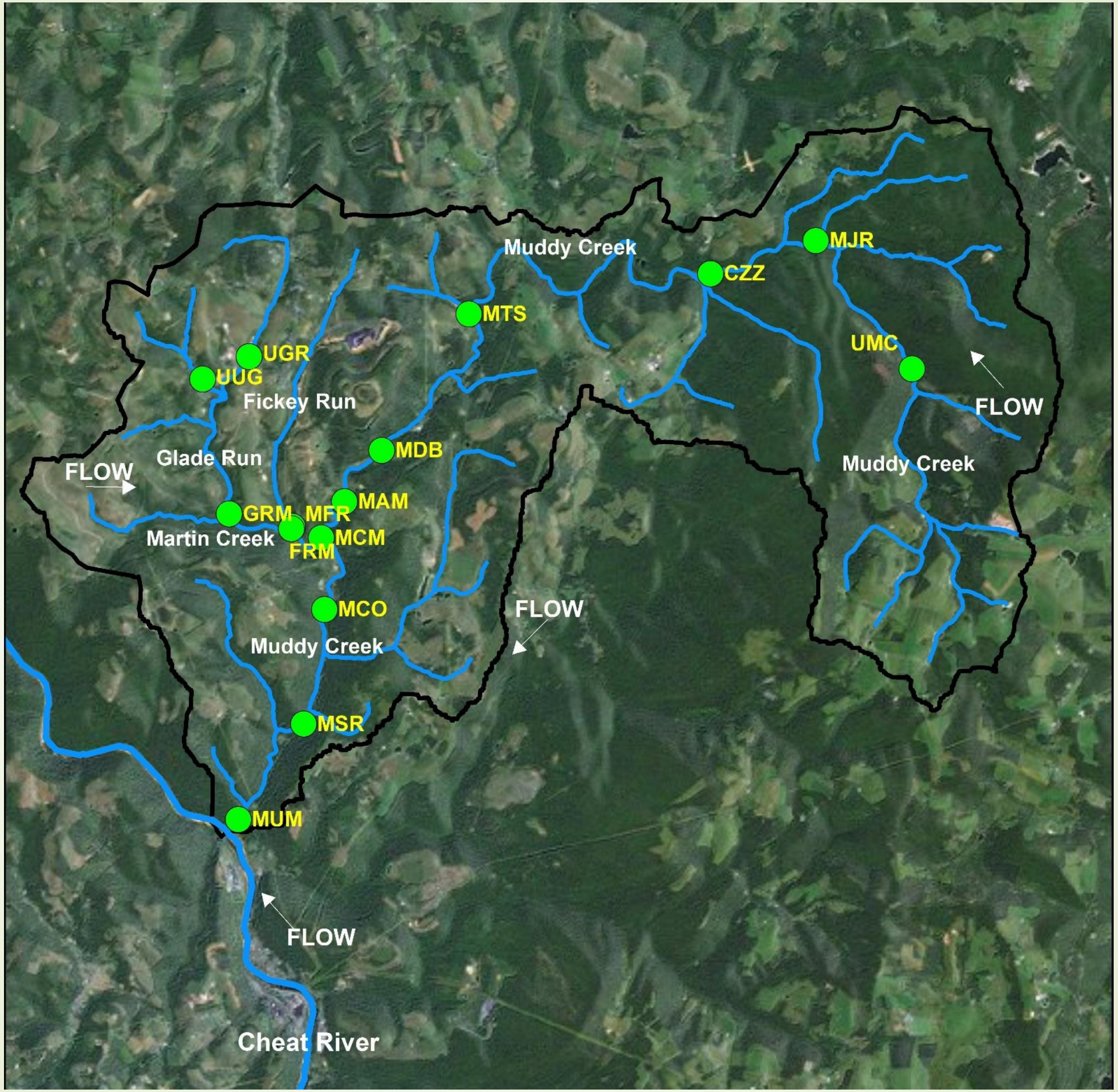
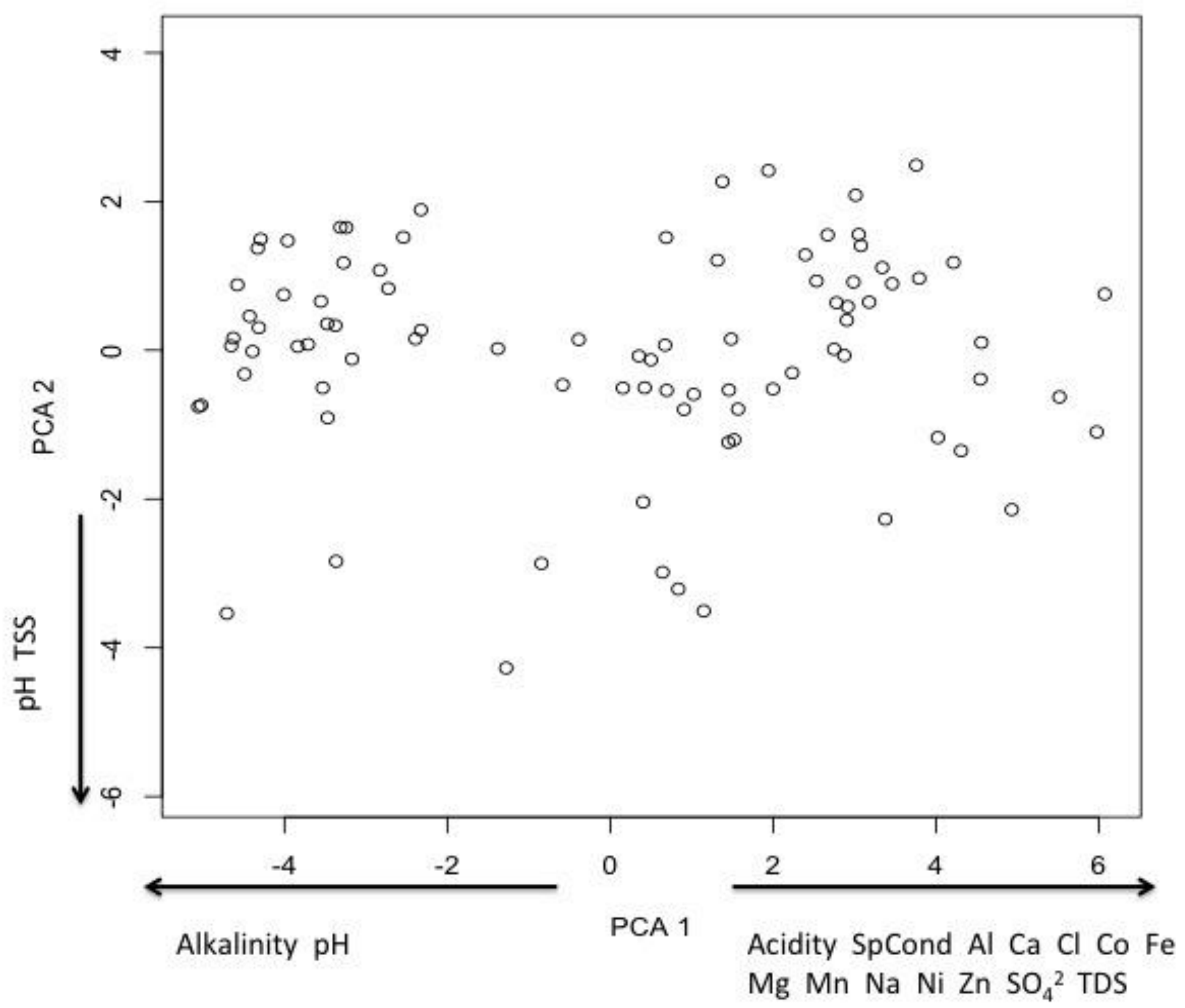

Muddy Creek
MJR
CZZ
MTS
UMC
FLOW
UGR
UUG
Fickey Run
MDB
Muddy Creek
Glade Run
FLOW
MAM
GRM
MFR
Martin Creek
MCM
FRM
MCO
FLOW
Muddy Creek
MSR
MUM
FLOW
Cheat River


PCA 2
pH TSS
PCA 1
Alkalinity pH
Acidity SpCond Al Ca Cl Co Fe
Mg Mn Na Ni Zn SO_4^2 TDS

Acid Mine Drainage in Muddy Creek

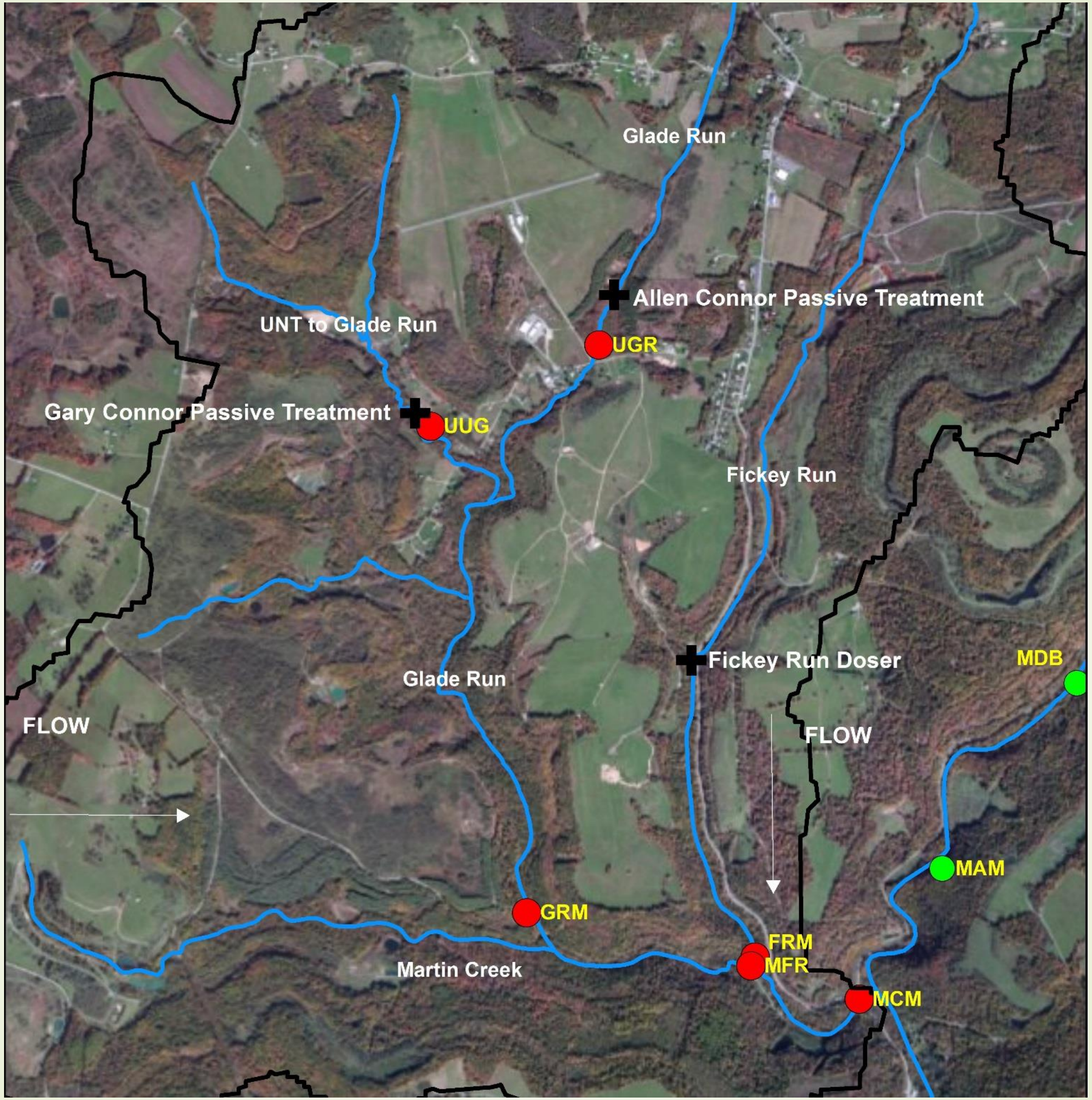
Lower Cheat River Watershed Based Plan

6,000 tons/year Acidity
67 tons/year Fe & Al

22 Sources of AMD from AML and Bond Forfeited Mines

$3.2 million to address 6 of these

3 sources addressed beginning of 2012


Glade Run
Allen Connor Passive Treatment
UNT to Glade Run
UGR
Gary Connor Passive Treatment
UUG
Fickey Run
Fickey Run Doser
MDB
Glade Run
FLOW
FLOW
MAM
GRM
FRM
MFR
Martin Creek
MCM

Response to AMD Treatment

Well documented to address **acidity** and **heavy metals**

(Skousen *et al.* 1996) (Skousen *et al.* 2000)

Expect obvious improvements in water chemistry

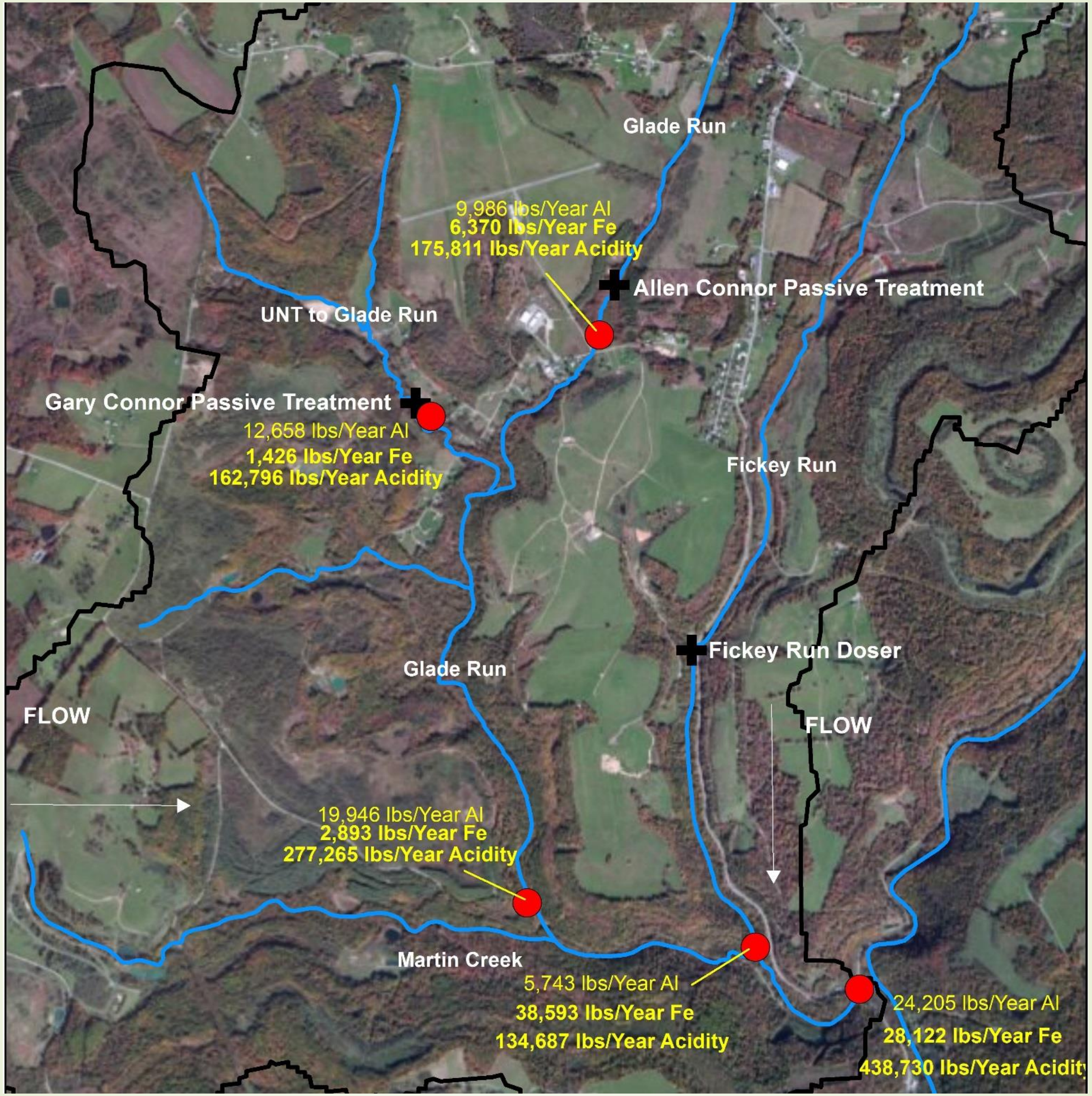
Research shows biological response depends on **time** and **distance**

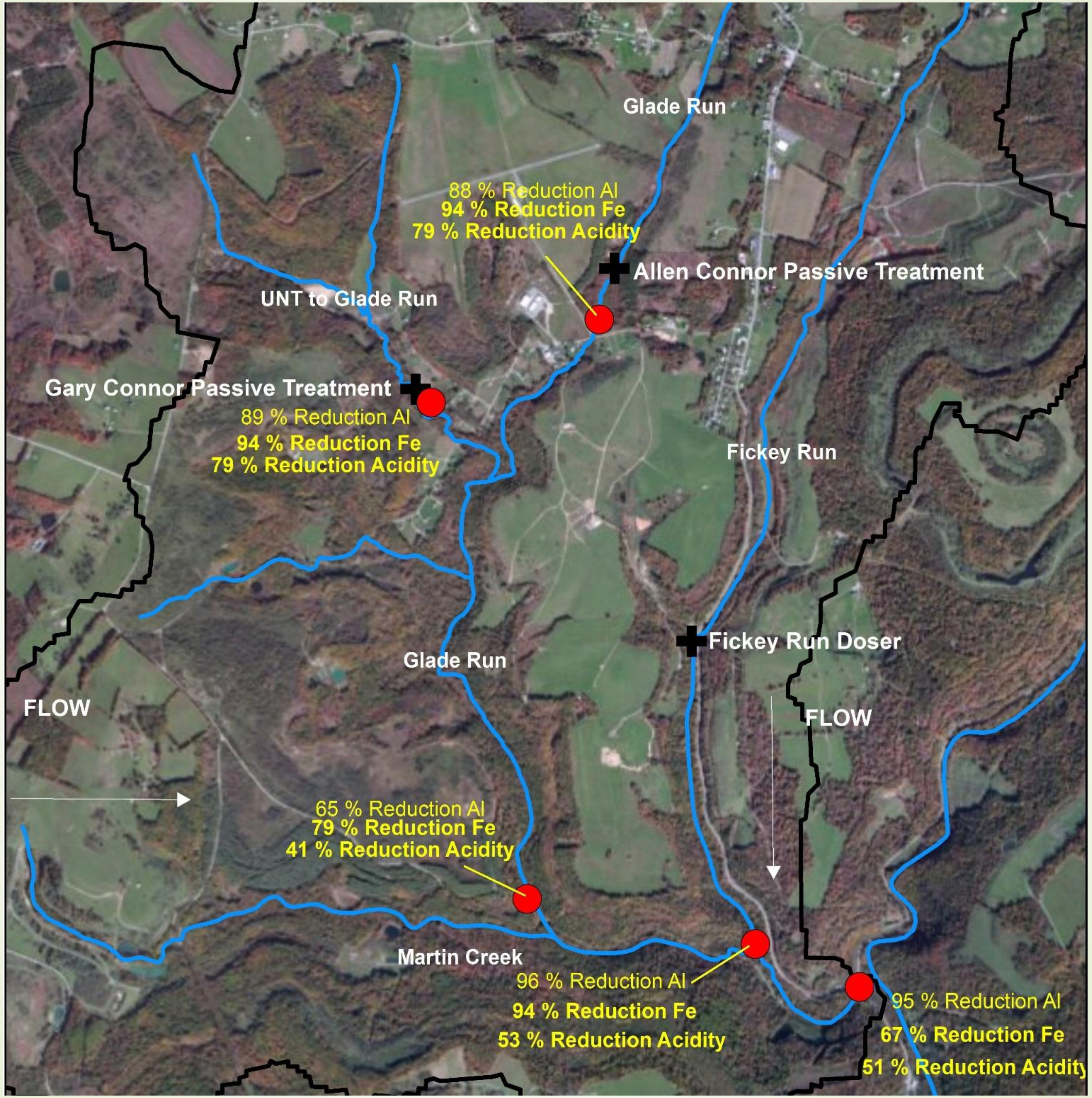
(McClurg *et al.* 2007) (Gunn *et al.* 2010) (Walter *et al.* 2012)

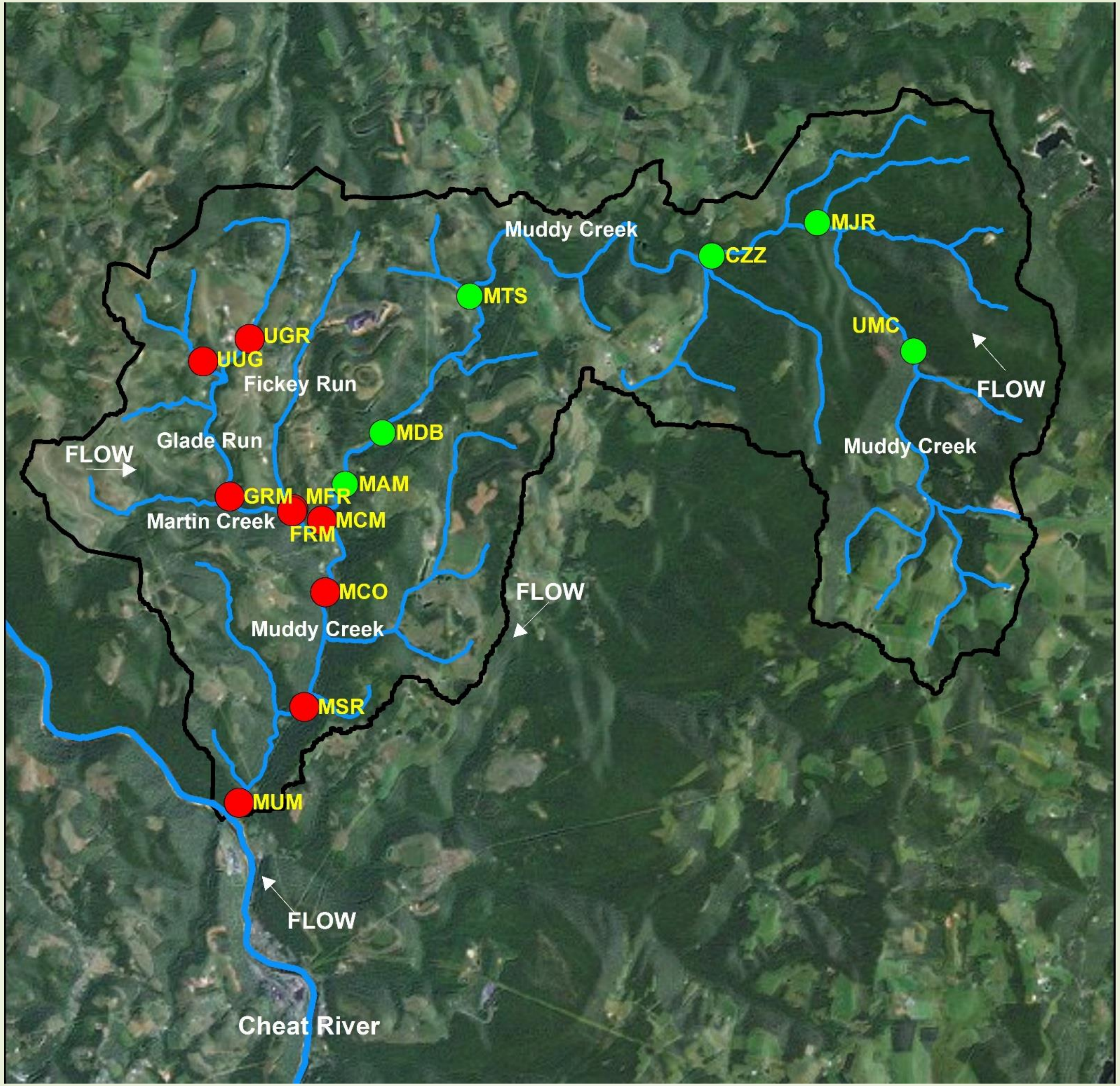
Expect improvements in IBI metrics at downstream most locations

Quantifying Response

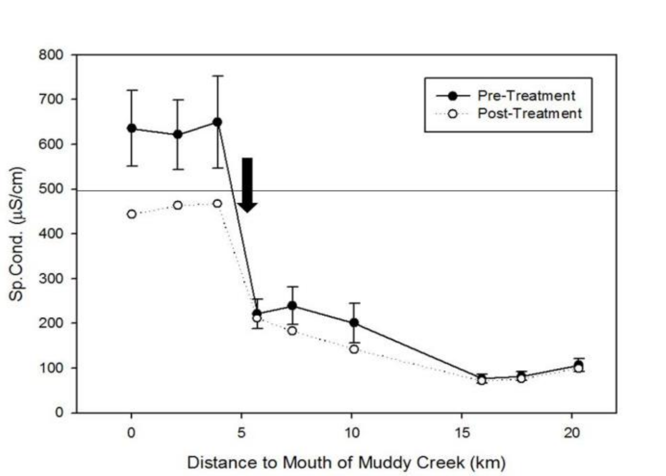
- Water Chemistry
- West Virginia Stream Condition Index (WVSCI) (Gerritsen *et al* 2000)
- Genus-Level Index of Most Probable Stream Status (GLIMPSS) (Pond *et al* 2008)
- Ecological Units (EUs) (Merovich and Petty 2007)

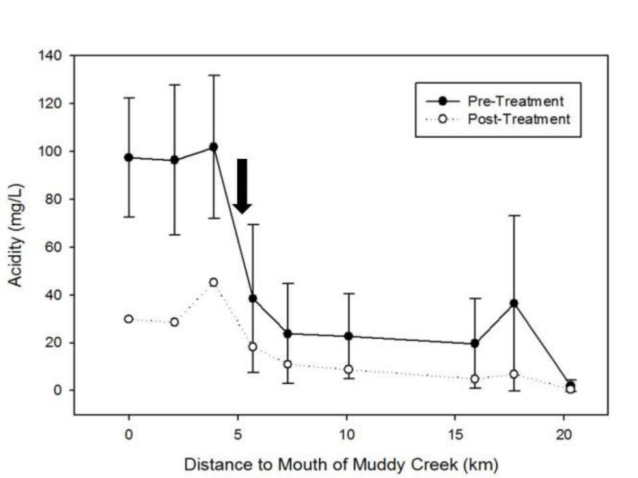

Glade Run
9,986 lbs/Year Al
6,370 lbs/Year Fe
175,811 lbs/Year Acidity
Allen Connor Passive Treatment
UNT to Glade Run
Gary Connor Passive Treatment
12,658 lbs/Year Al
1,426 lbs/Year Fe
162,796 lbs/Year Acidity
Fickey Run
Fickey Run Doser
Glade Run
FLOW
FLOW
19,946 lbs/Year Al
2,893 lbs/Year Fe
277,265 lbs/Year Acidity
Martin Creek
5,743 lbs/Year Al
38,593 lbs/Year Fe
134,687 lbs/Year Acidity
24,205 lbs/Year Al
28,122 lbs/Year Fe
438,730 lbs/Year Acidity

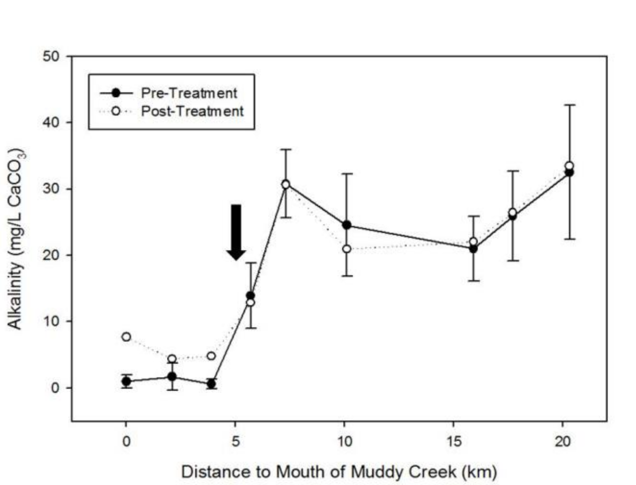

Glade Run
88 % Reduction Al
94 % Reduction Fe
79 % Reduction Acidity
Allen Connor Passive Treatment
UNT to Glade Run
Gary Connor Passive Treatment
89 % Reduction Al
94 % Reduction Fe
79 % Reduction Acidity
Fickey Run
Fickey Run Doser
Glade Run
FLOW
FLOW
65 % Reduction Al
79 % Reduction Fe
41 % Reduction Acidity
Martin Creek
96 % Reduction Al
94 % Reduction Fe
53 % Reduction Acidity
95 % Reduction Al
67 % Reduction Fe
51 % Reduction Acidity

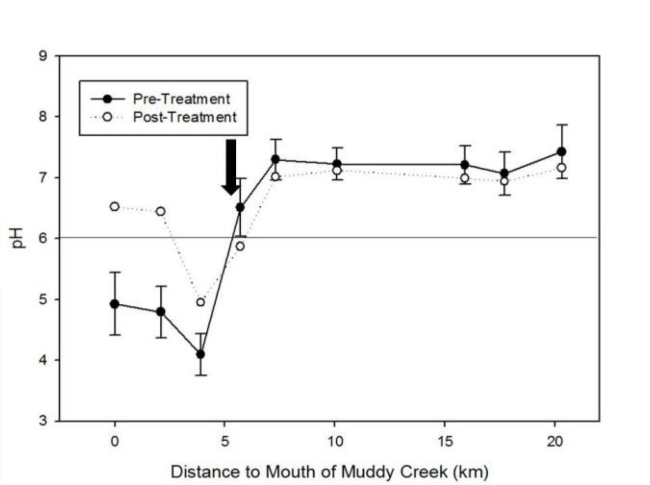

Muddy Creek
MJR
CZZ
MTS
UGR
UUG
Fickey Run
UMC
FLOW
MDB
Glade Run
FLOW
Muddy Creek
MAM
GRM
MFR
MCM
Martin Creek
FRM
MCO
FLOW
Muddy Creek
MSR
MUM
FLOW
Cheat River

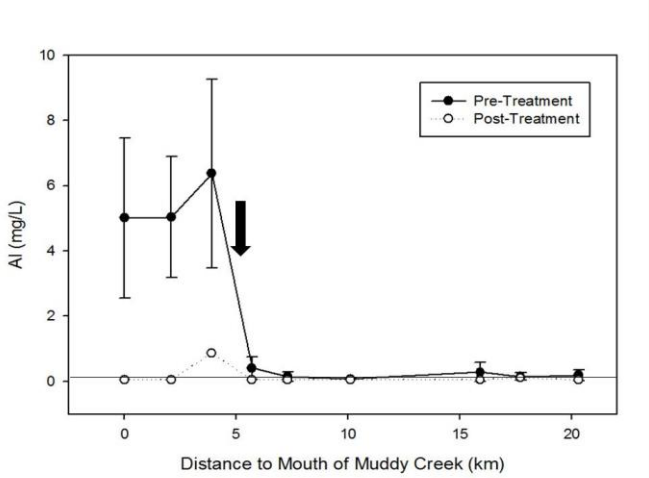
Water Chemistry Response

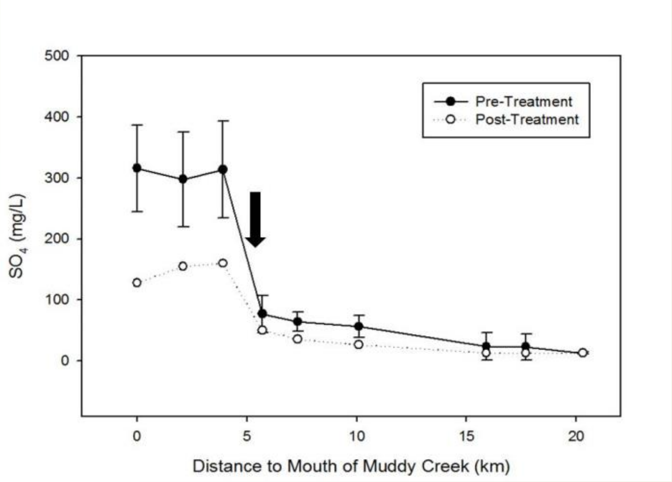


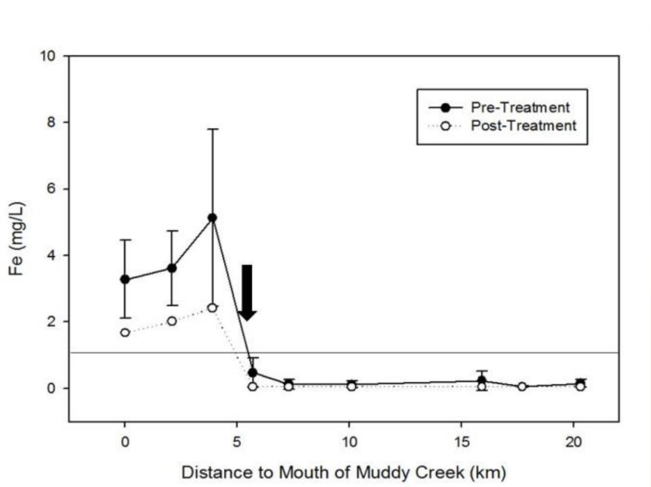


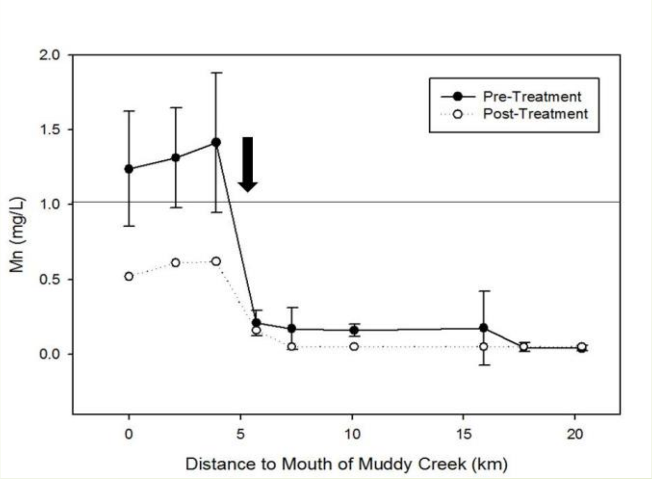


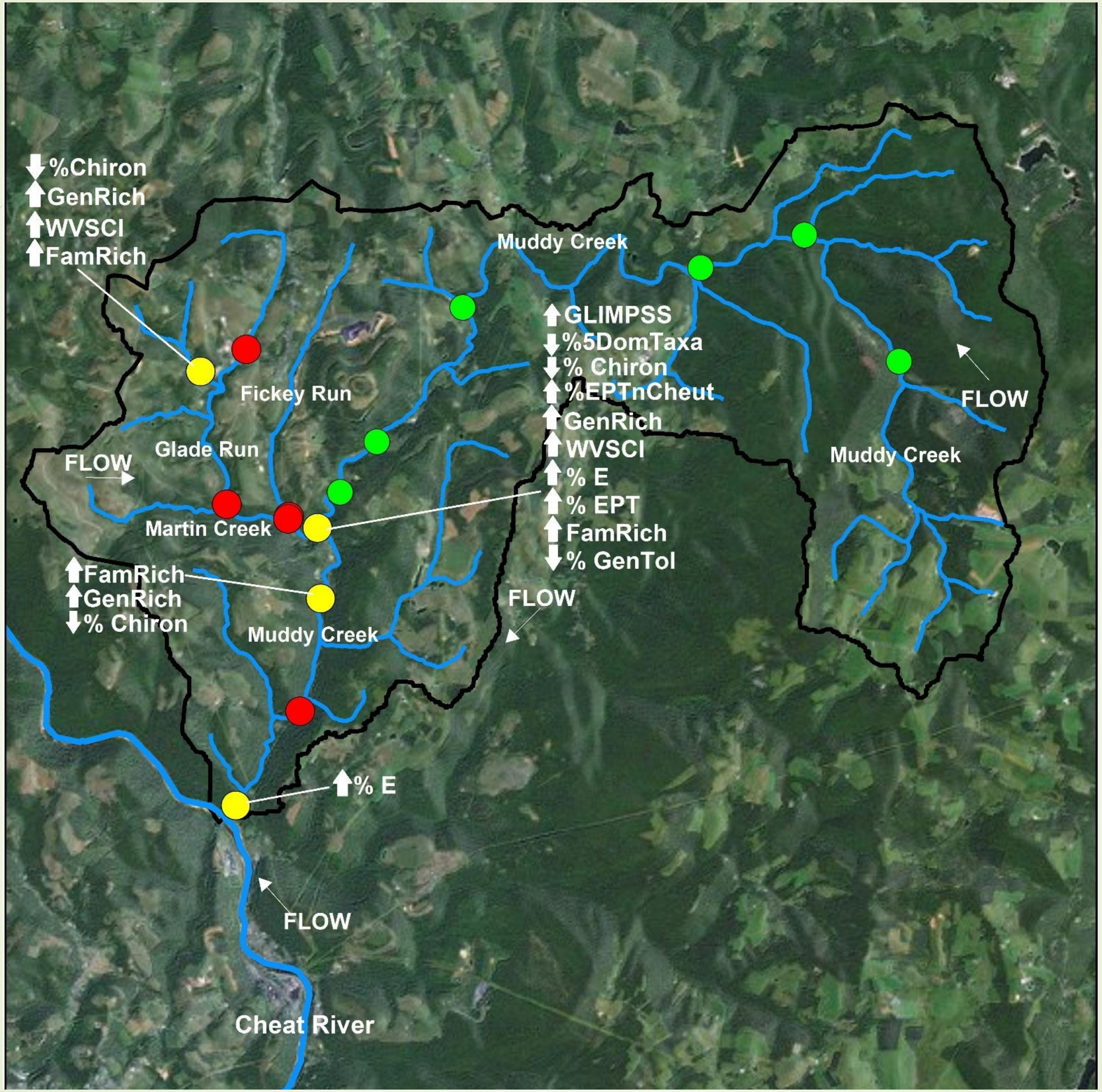



Pre-Treatment
Post-Treatment
Al (mg/L)
Distance to Mouth of Muddy Creek (km)


Pre-Treatment
Post-Treatment
SO4 (mg/L)
Distance to Mouth of Muddy Creek (km)


Pre-Treatment
Post-Treatment
Fe (mg/L)
Distance to Mouth of Muddy Creek (km)

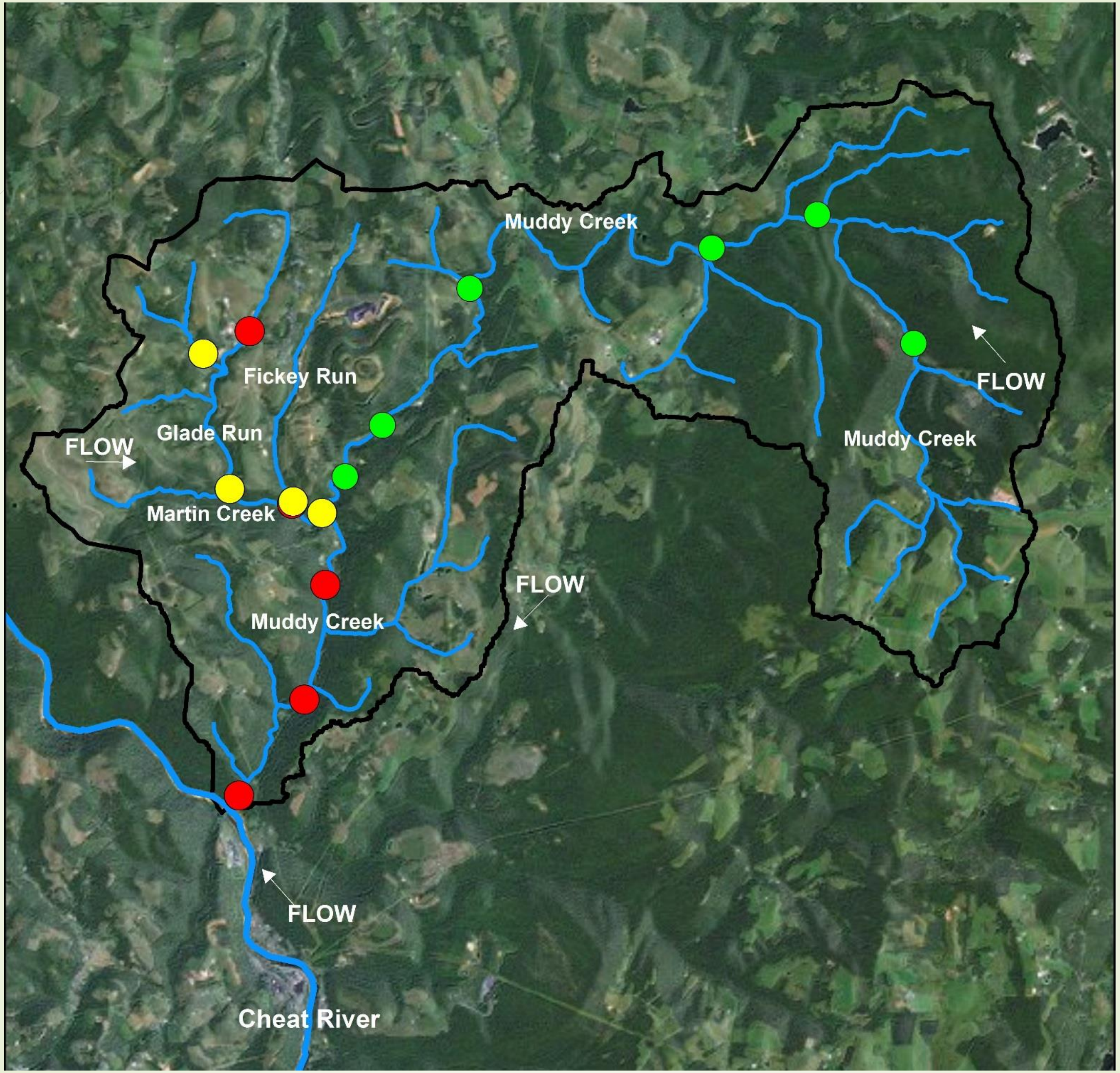

Pre-Treatment
Post-Treatment
Mn (mg/L)
Distance to Mouth of Muddy Creek (km)



⬇%Chiron
⬆GenRich
⬆WVSCI
⬆FamRich
Muddy Creek
⬆GLIMPSS
⬇%5DomTaxa
⬇% Chiron
⬆%EPTnCheut
⬆GenRich
⬆WVSCI
⬆% E
⬆% EPT
⬆FamRich
⬇% GenTol
Fickey Run
Glade Run
FLOW
Martin Creek
FLOW
Muddy Creek
⬆FamRich
⬆GenRich
⬇% Chiron
Muddy Creek
FLOW
⬆% E
FLOW
Cheat River

Ecological Unit Response

- 2012 - Overall Good Year for Benthic Macroinvertebrates
- EUs at all Untreated Sites Increased over pre-treatment mean
- Increases in EUs Immediately Downstream of Treatment
- Further Downstream of Treatment EUs Decreased
- Increases in Martin Creek watershed Greater than Increases Elsewhere
- Average Untreated Increase = 0.9 EUs
- Average Treated Increase = 4.5 EUs


Muddy Creek
Fickey Run
FLOW
Glade Run
FLOW
Muddy Creek
Martin Creek
FLOW
Muddy Creek
FLOW
Cheat River

Statistically Significant Chemistry Improvements ($p \leq 0.05$)

pH	Alkalinity	Acidity	SpCond	Al	Ba	Ca
Co	Mg	Mn	Ni	Zn	SO_4^{2-}	TDS

Near Significant Chemistry Improvements ($p \leq 0.10$)

Fe

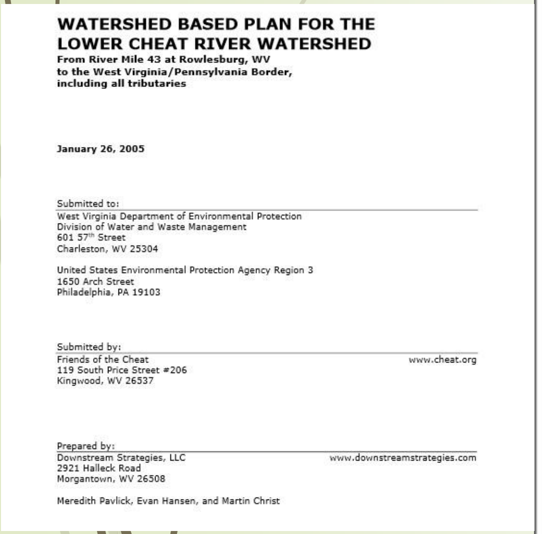
Statistically Significant Invertebrate Improvements ($p \leq 0.05$)

No Indices

Near Significant Invertebrate Improvements ($p \leq 0.10$)

TV4	Clinger Genus Richness

Why didn't invertebrates respond in a similar manner?



WATERSHED BASED PLAN FOR THE LOWER CHEAT RIVER WATERSHED

From River Mile 43 at Rowlesburg, WV to the West Virginia/Pennsylvania Border, including all tributaries

January 26, 2005

Submitted to:

West Virginia Department of Environmental Protection
Division of Water and Waste Management
601 57th Street
Charleston, WV 25304

United States Environmental Protection Agency Region 3
1650 Arch Street
Philadelphia, PA 19103

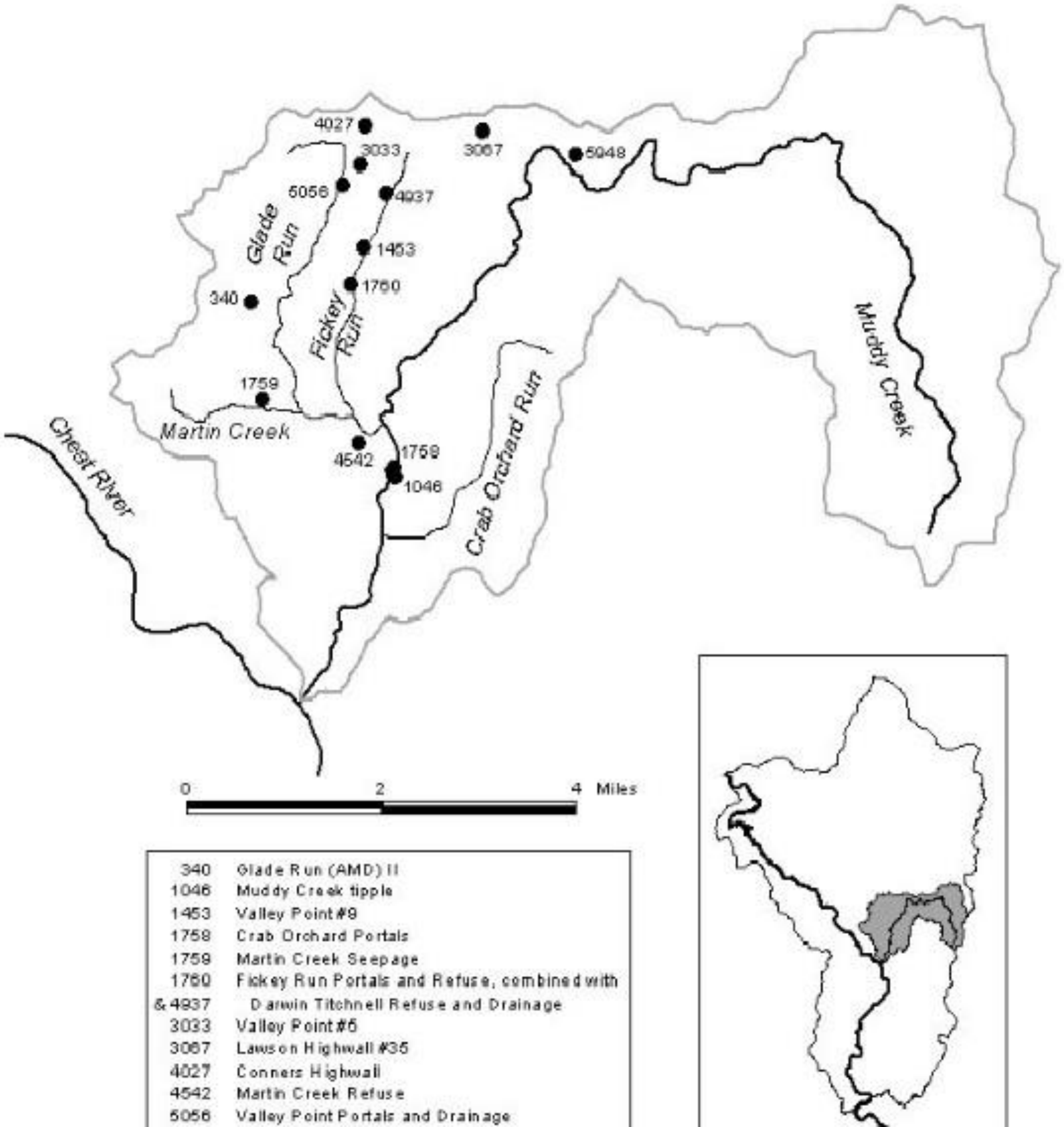
Submitted by:

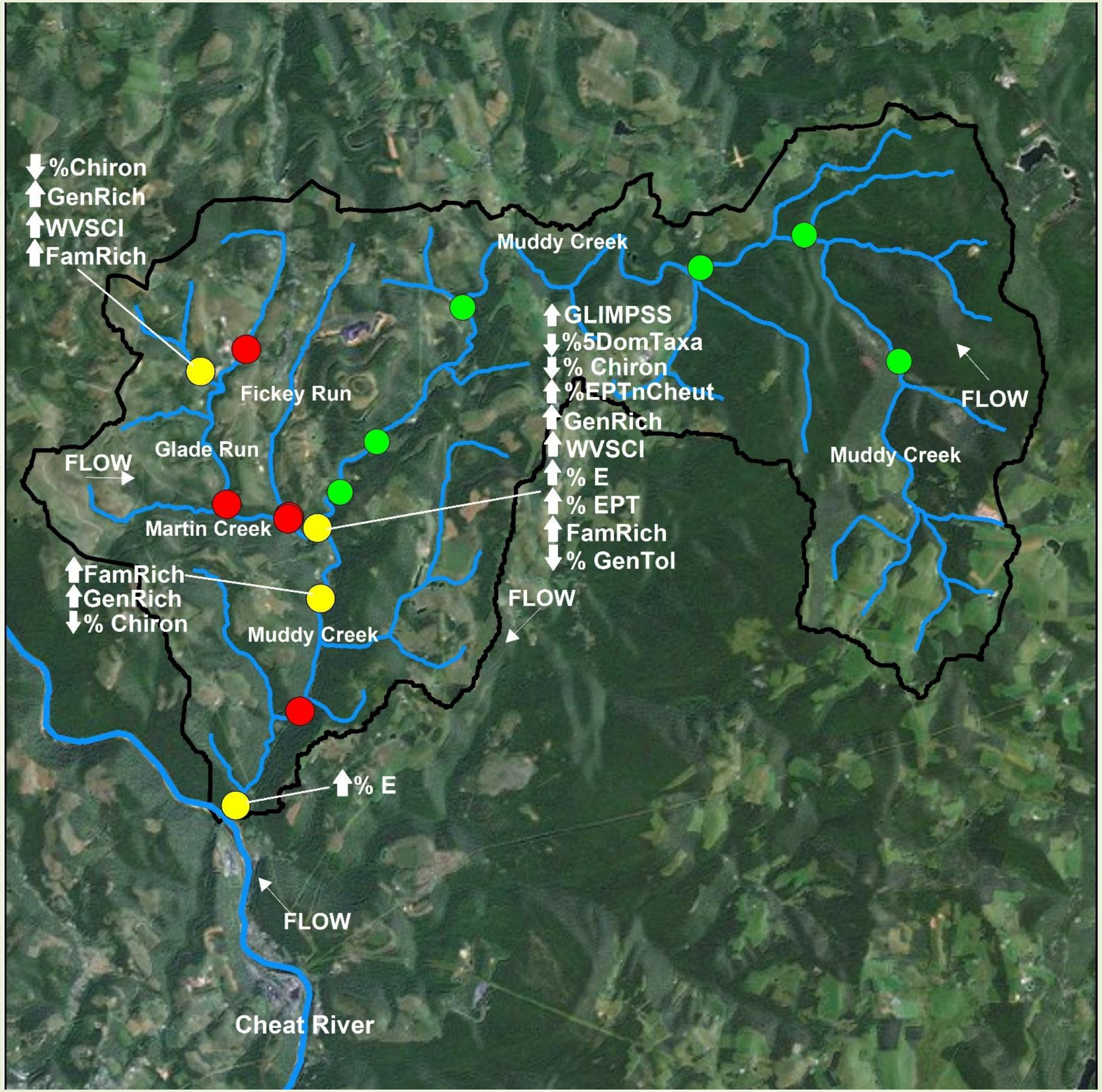
Friends of the Cheat — www.cheat.org
119 South Price Street #206
Kingwood, WV 26537

Prepared by:

Downstream Strategies, LLC — www.downstreamstrategies.com
2921 Halleck Road
Morgantown, WV 26508

Meredith Pavlick, Evan Hansen, and Martin Christ




%Chiron
GenRich
WVSCI
FamRich
Muddy Creek
GLIMPSS
%5DomTaxa
% Chiron
%EPTnCheut
GenRich
WVSCI
% E
% EPT
FamRich
% GenTol
Fickey Run
Glade Run
FLOW
Martin Creek
FamRich
GenRich
% Chiron
Muddy Creek
FLOW
FLOW
Muddy Creek
% E
FLOW
Cheat River

Conclusion

- **Even though we observed significant, immediate improvements in water chemistry throughout the treatment continuum; immediate benthic macroinvertebrate recovery seemed to be dependent on proximity to an unimpaired species pool.**

Stability of Water Chemistry and Benthic Macroinvertebrate Communities along an AMD Impairment Gradient

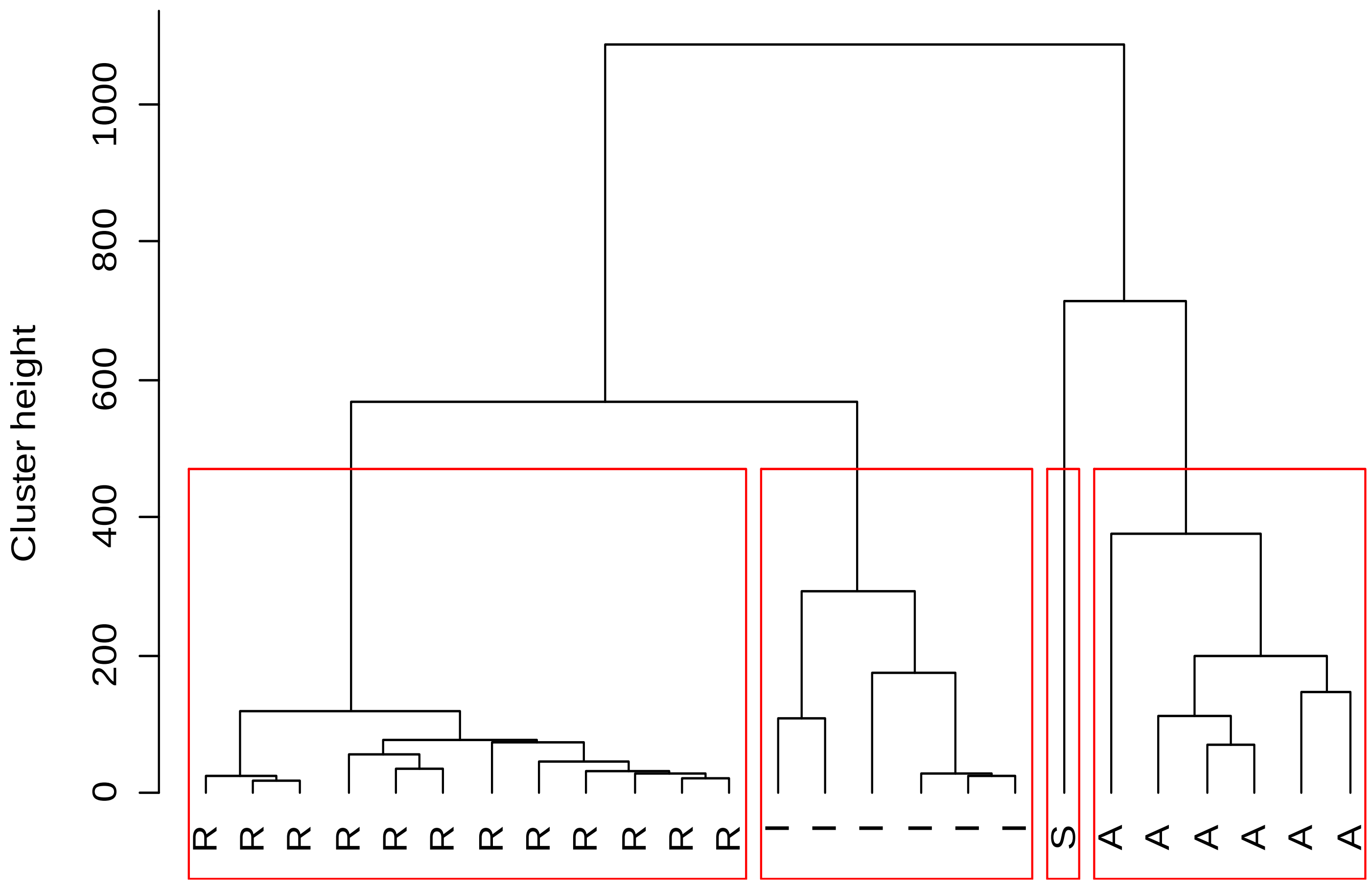
Beta Diversity and Stability

- What is Beta Diversity?
  (Heino 2011)
- How to measure stability (beta diversity)?
  Bray-Curtis and Euclidean Distance Measures
  (Limberger and Wickham 2012)
- Stream reach biotic and abiotic stability over time
- Why measure stability?
  Disturbances effect on communities at various scales (i.e. Long-Term/ Regional)
  (Maloney *et al.* 2011)
  Meta-community research

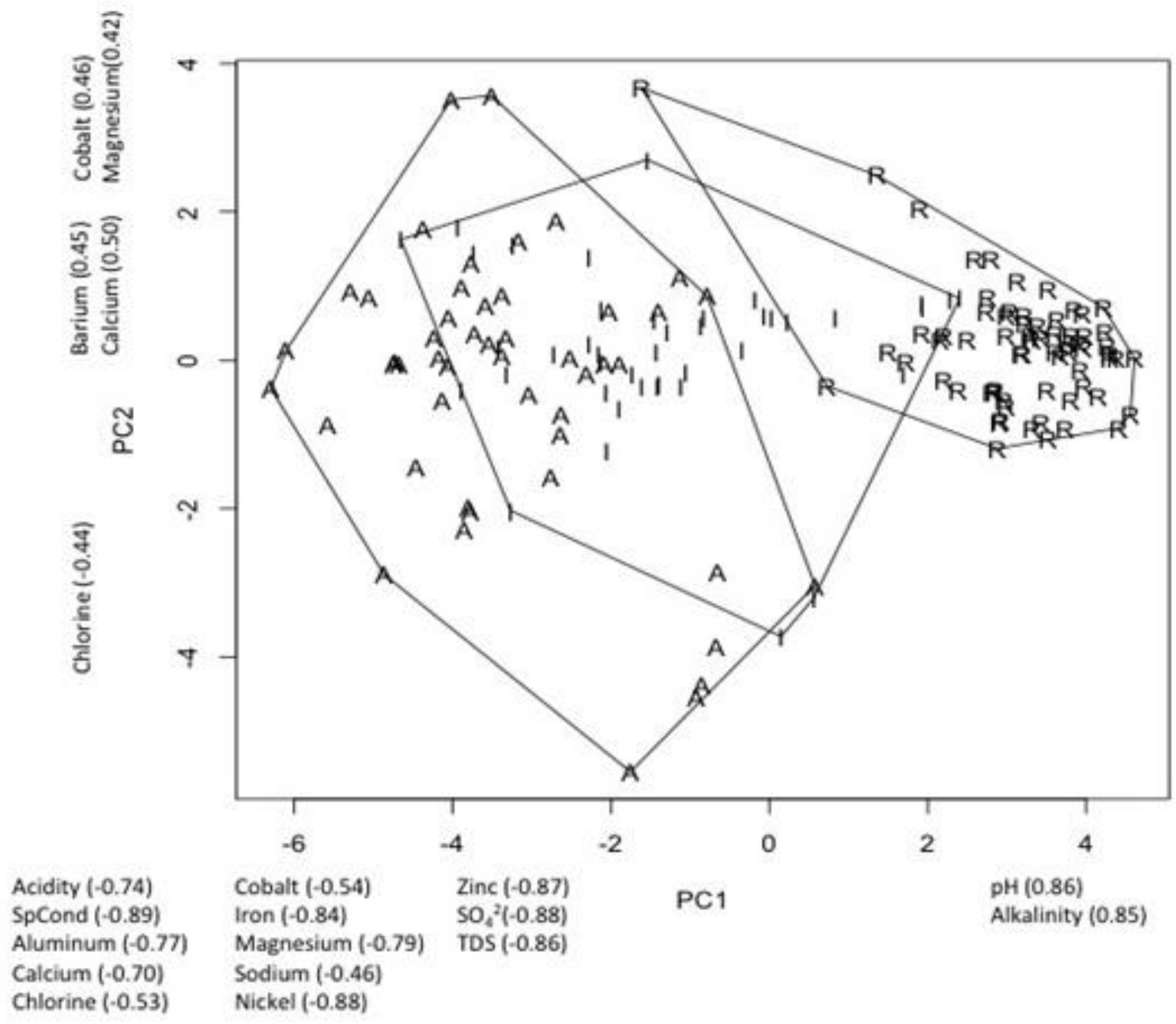
Expected Trends between Disturbance and Stability

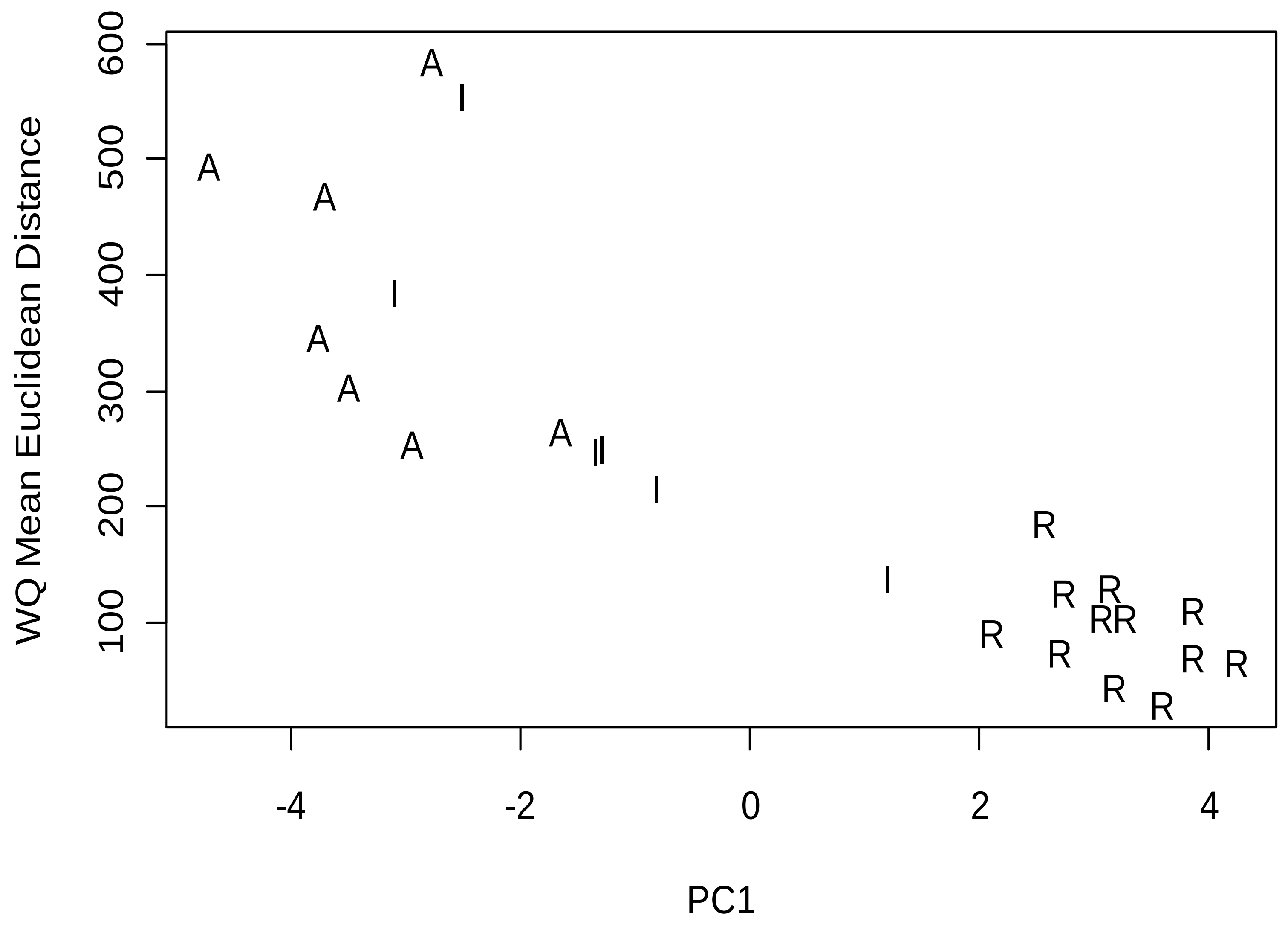
- **Highest Beta Diversity (Unstable) under Disturbance**
  Temporal Checkerboard (Mykra *et al.* 2011)
  Watershed Structure/ Limited Dispersal (Matthiessen *et al.* 2010) (Brown *et al.* 2011)
  Mass Effects/ Source-Sink Metacommunities (Leibold *et al.* 2004)
  Pulse Disturbance vs. Chronic Disturbance (Limberger and Wickham 2012)
  Highly evolved communities in Undisturbed Environments (Relative)
- **Lowest Beta Diversity (Stable) under Disturbance**
  Feeding Specializations (Johnson and Arunachalam 2012)
- We expected: ↑ Beta diversity with ↑ AMD impairment
  Highest Beta diversity under most unstable environmental conditions.
  Lowest Beta diversity under most stable environmental conditions.

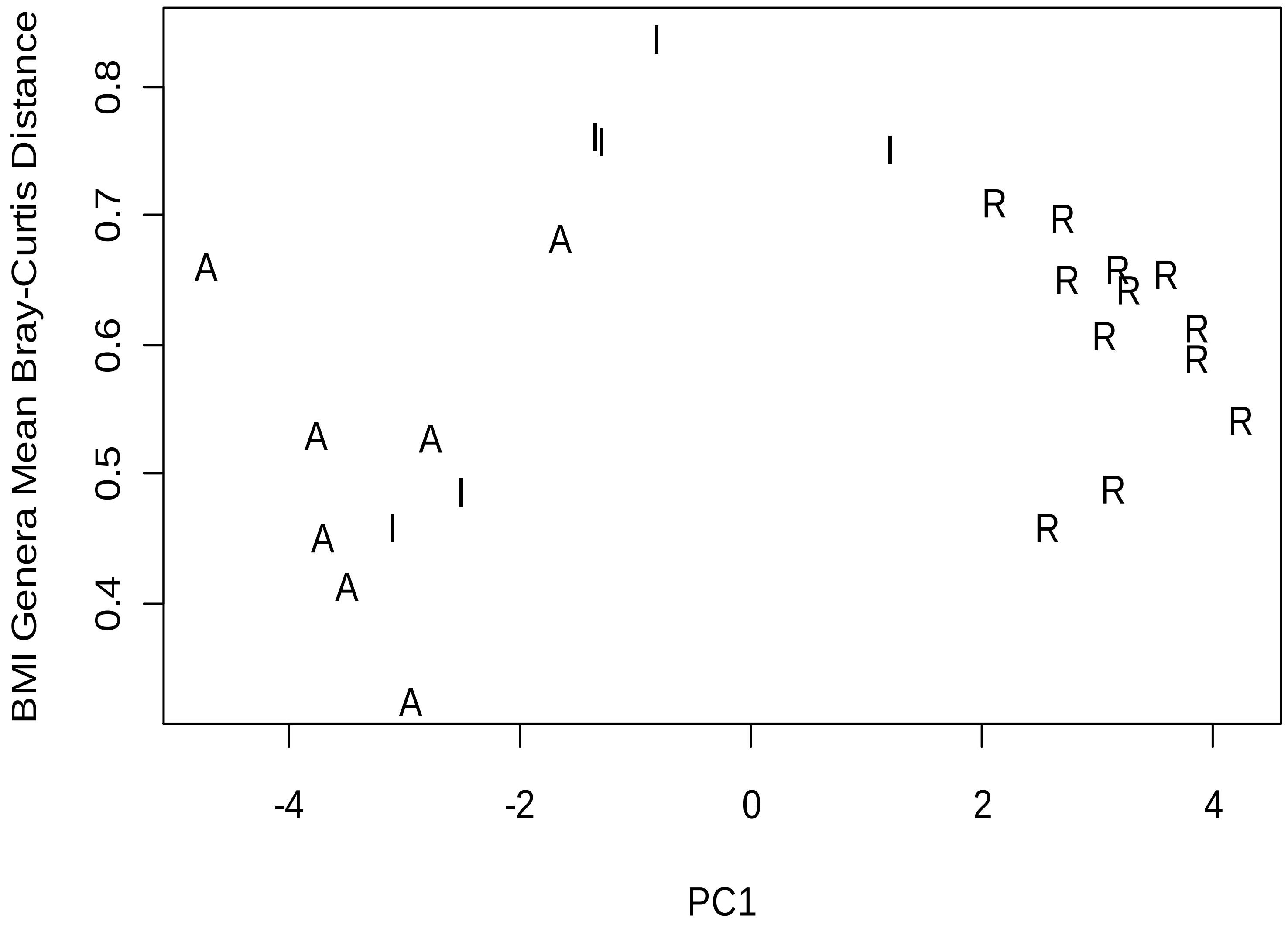

whirligig
saucer bug
water strider
china-mark moth
mosquito pupa
mosquito larvae
water scorpion
water boatman
diving beetle
damselfly larva
mayfly larva
alderfly larva
dragonfly larva
caddis fly larva



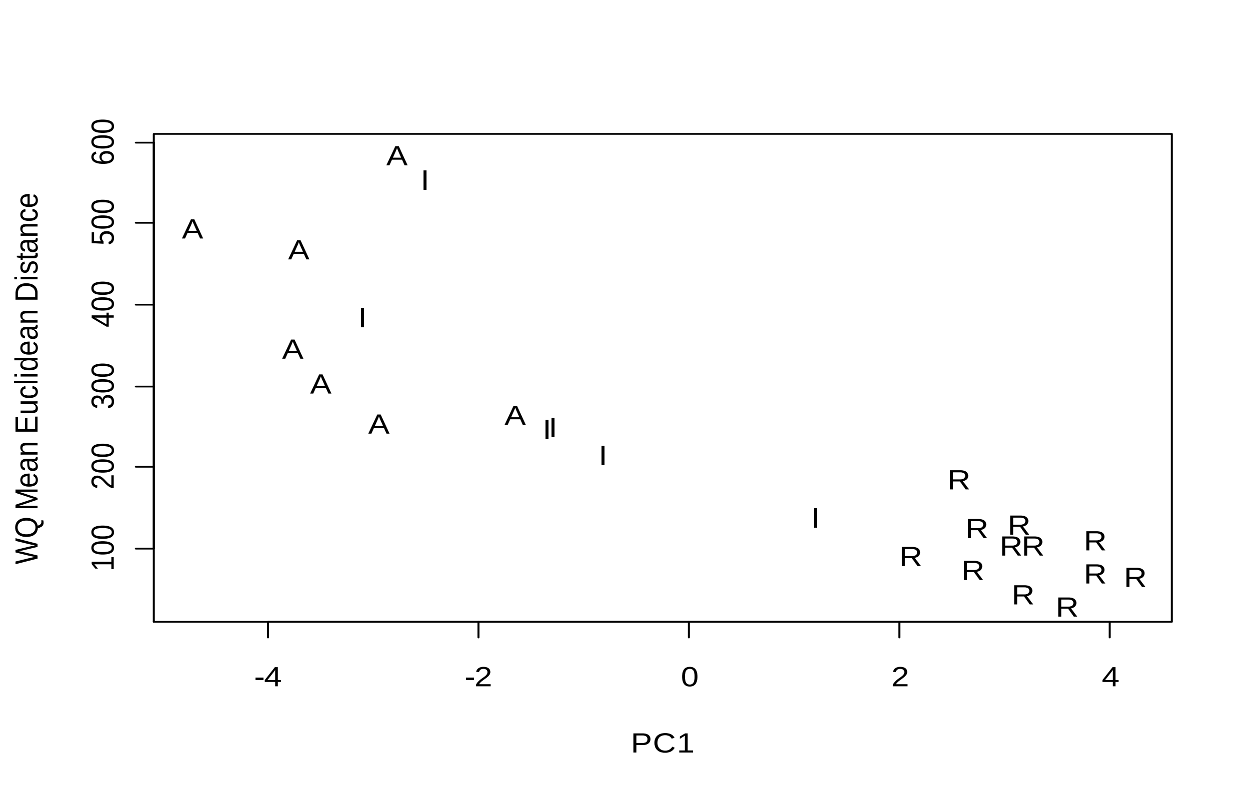
Cluster height
0
200
400
600
800
1000
R R R R R R R R R R R R
— — — — — —
S
A A A A A A

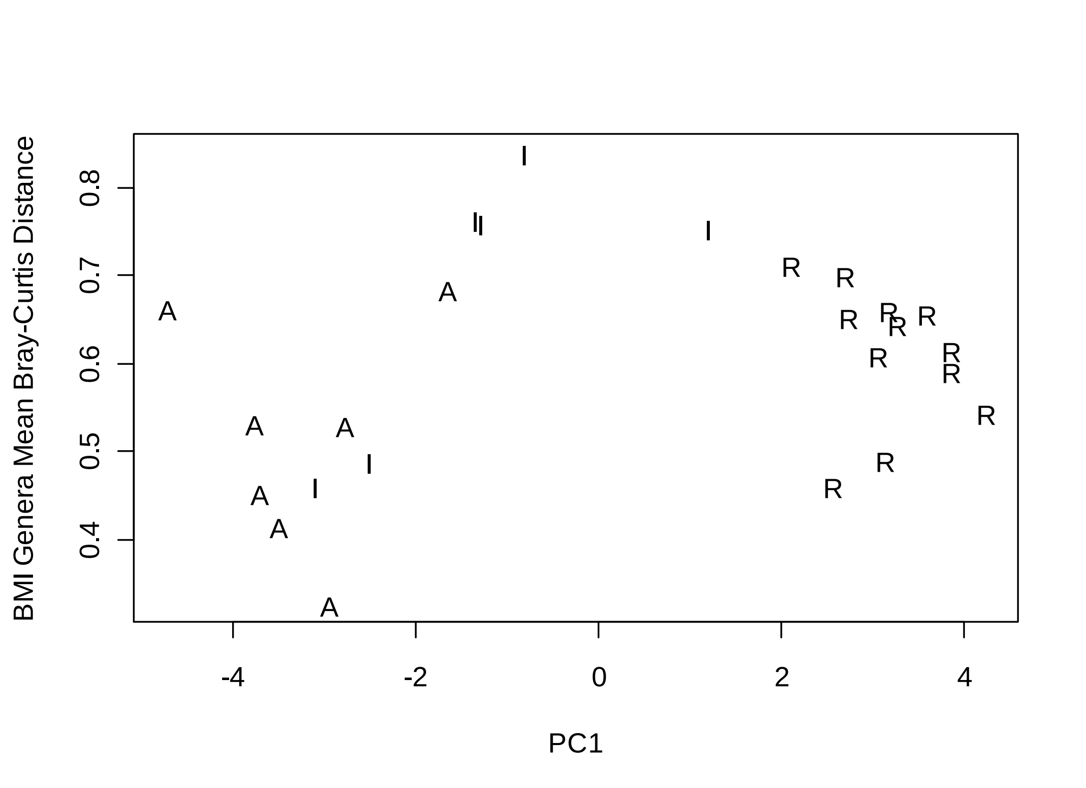

Cobalt (0.46)
Magnesium(0.42)
Barium (0.45)
Calcium (0.50)
PC2
Chlorine (-0.44)
4
2
0
-2
-4
-6
-4
-2
0
2
4
PC1
Acidity (-0.74)
SpCond (-0.89)
Aluminum (-0.77)
Calcium (-0.70)
Chlorine (-0.53)
Cobalt (-0.54)
Iron (-0.84)
Magnesium (-0.79)
Sodium (-0.46)
Nickel (-0.88)
Zinc (-0.87)
SO_4^{2}(-0.88)
TDS (-0.86)
pH (0.86)
Alkalinity (0.85)


WQ Mean Euclidean Distance
PC1
100
200
300
400
500
600
-4
-2
0
2
4
A
I
R



BMI Genera Mean Bray-Curtis Distance
0.4
0.5
0.6
0.7
0.8
-4
-2
0
2
4
PC1


WQ Mean Euclidean Distance
PC1


BMI Genera Mean Bray-Curtis Distance
PC1

Multivariate ANOVA w/ Distance Matrices

ADONIS – Statistical significance of differences in abiotic and biotic dissimilarity values between water chemistry clustered groupings.

H_0: Distance (dissimilarity) values were similar between groups.

Found – Each clustered group had significantly different distances matrices for site specific water chemistry and benthic macroinvertebrate assemblages.

Pairwise Comparison	Water Chem P-Value	Invertebrate P-Value
A – I	0.001	0.006
A – R	0.001	0.001
I – R	0.001	0.001

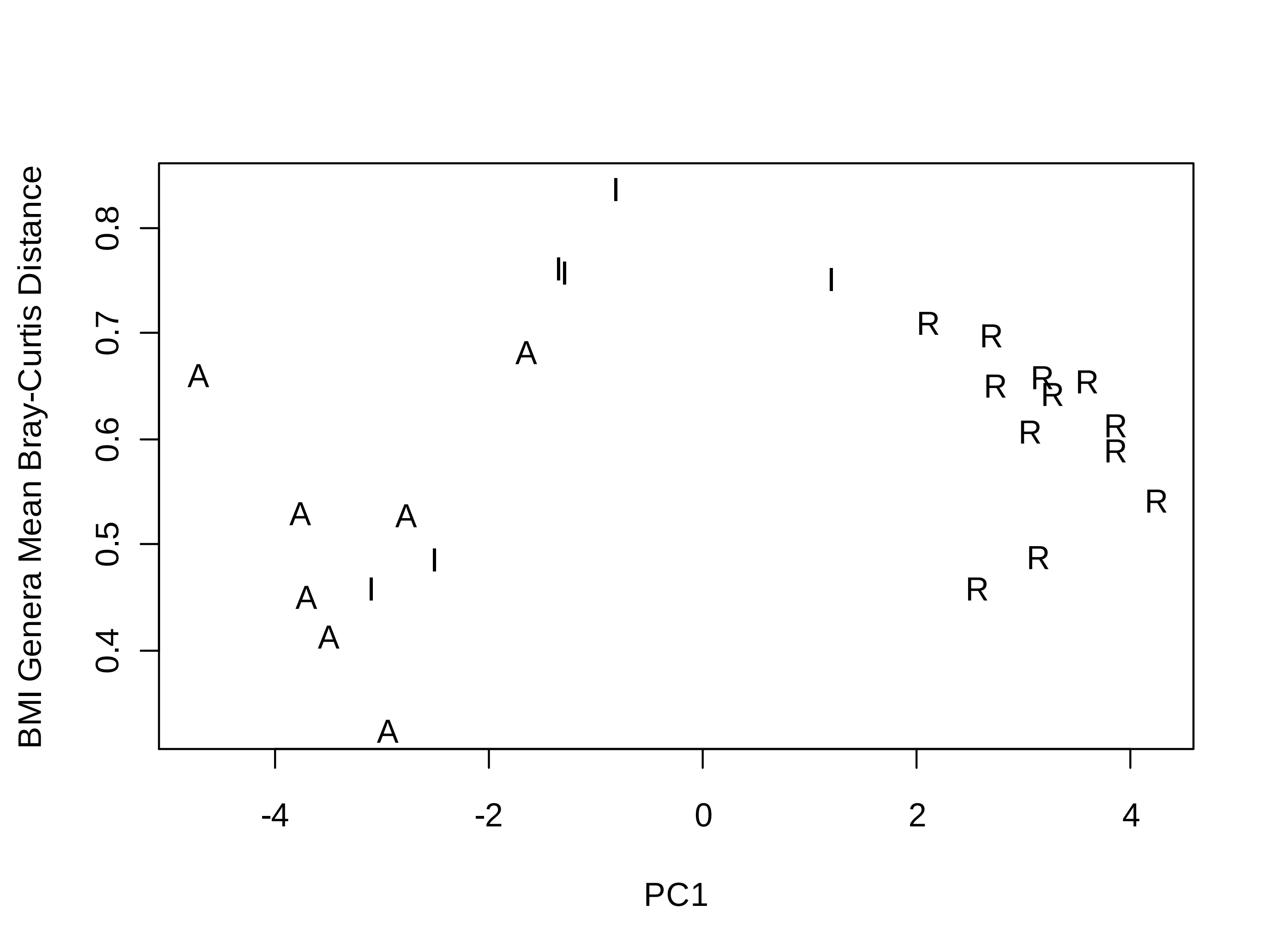
Translated – Significant difference in temporal variation of water chemistry and beta diversities of assemblages over study period.

Expected vs. Observed Results

- **Benthic Macroinvertebrate Community Stability**
- **Expected:** A-type – Most Unstable, R-Type – Most Stable
- **Observed:** I-type – Most Unstable, A-type – Most Stable

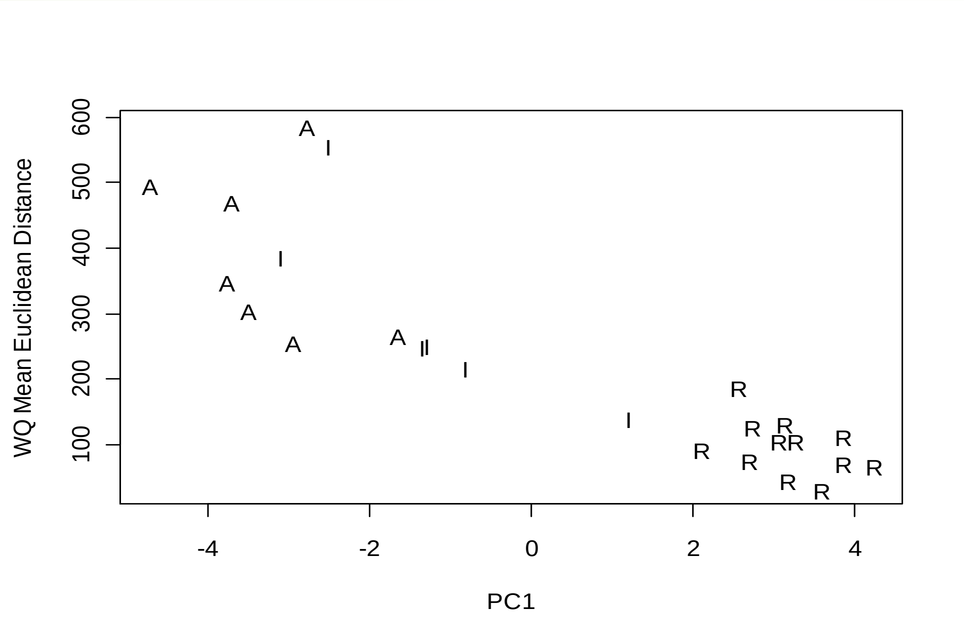
- **Water Chemistry Stability**
- **Expected:** A-type – Most Unstable, R-type – Most Stable
- **Observed:** A-type – Most Unstable, R-type – Most Stable

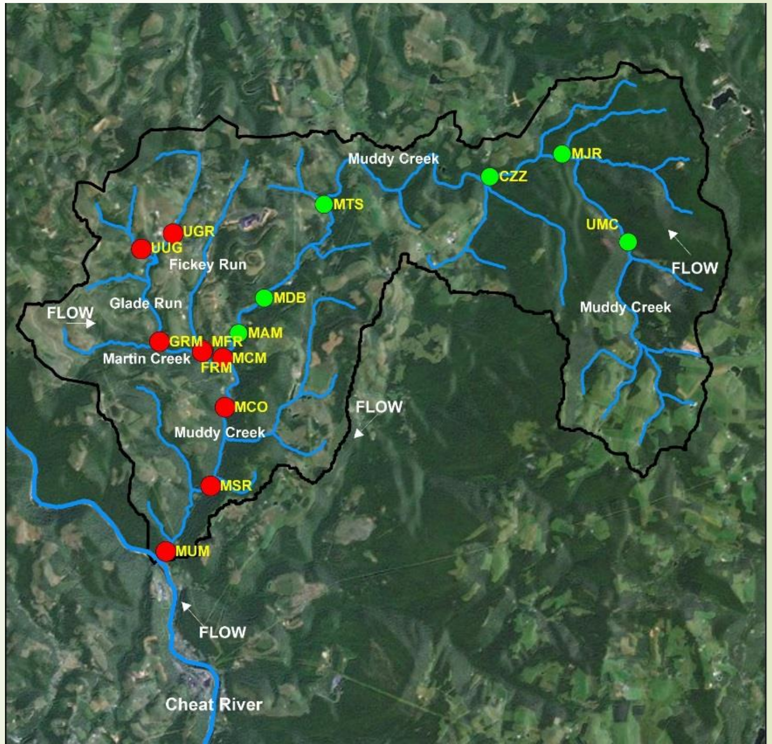
Intermediate Disturbance Hypothesis

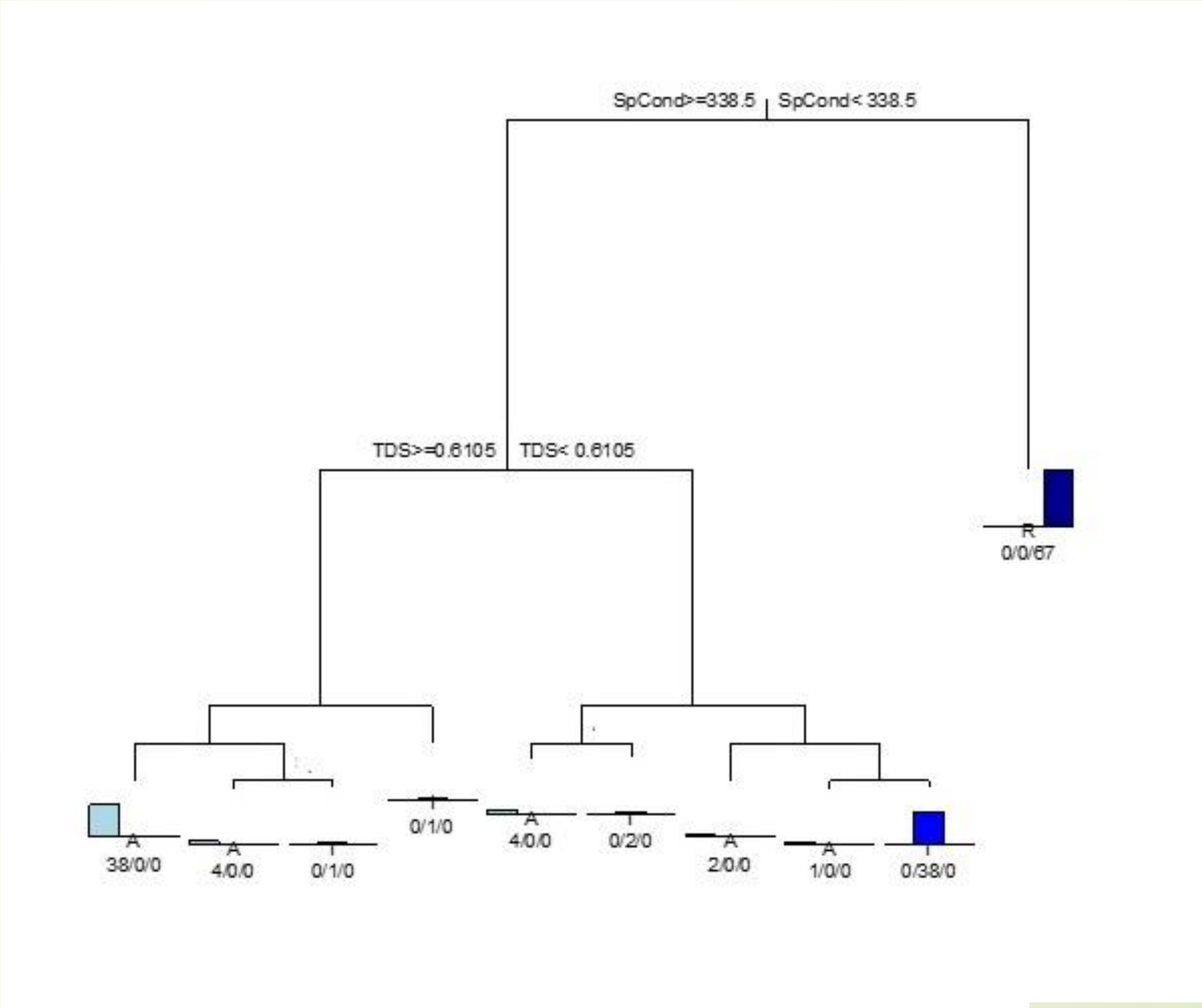


Conclusions

- Intermediate Disturbance Hypothesis?
- Spatial arrangement of I-type sites within watershed
- Richness and Evenness measurements higher at R-type sites
- Maybe valuable for locating potential restoration reaches by examining temporal Beta diversity of impaired areas. Connectedness to Regional Species Pool






SpCond>=338.5
SpCond< 338.5
TDS>=0.6105
TDS< 0.6105
R
0/0/67
A
38/0/0
A
4/0/0
0/1/0
0/1/0
A
4/0/0
0/2/0
A
2/0/0
A
1/0/0
0/38/0

Acknowledgements

- Dr. George Merovich
- Dr. Todd Petty
- Environmental Protection Agency
- West Virginia University