Cumulative-effects assessment and implementation of multi-stressor mitigation approaches in an intensively mined central Appalachian watershed

Eric Merriam

Todd Petty

WVU Division of Forestry and Natural Resources

Major stressors

Coal mining

- Consistently results in increased TDS and conductivity
- Consistently produces change in invertebrate communities
- Inconsistently increases Se

Residential development

Current state of understanding

- Local impacts interact across space and time to produce unique patterns of degradation
- Current mine permitting and mitigation strategies do not account for cumulative impacts across the landscape
- Ability to quantify cumulative effects is critical for successful restoration and sustainability of aquatic resources

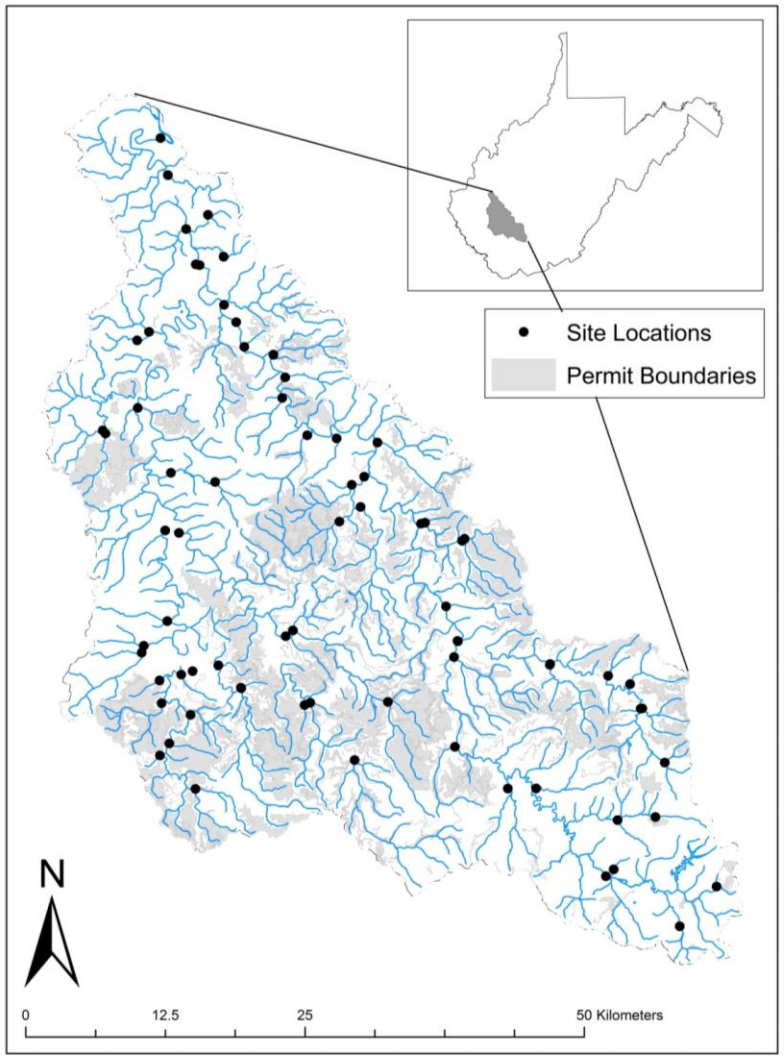
Research objectives

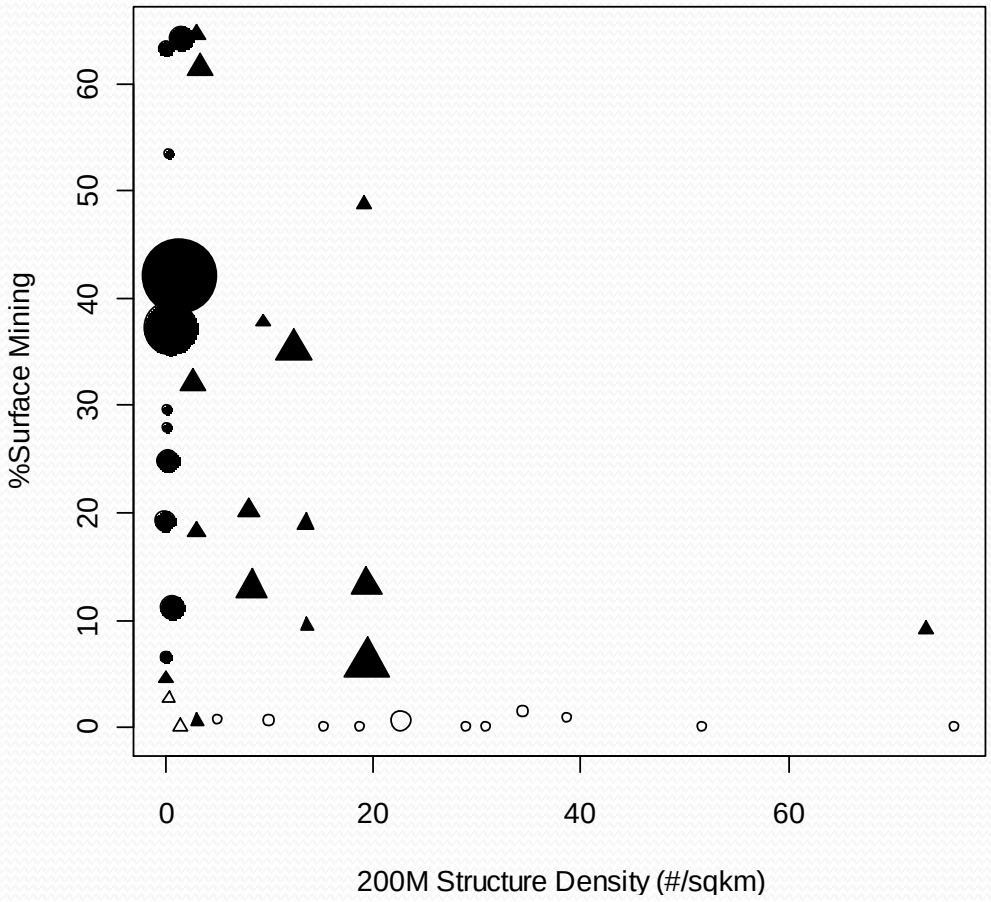
1. Quantify cumulative effects of current land use practices and predict associated in-stream condition

2. Integrate models within a spatially-explicit framework to predict cumulative effects and current conditions at the watershed scale

3. Predict future conditions under a series of multi-stressor mitigation approaches (“alternative futures”)

Site selection

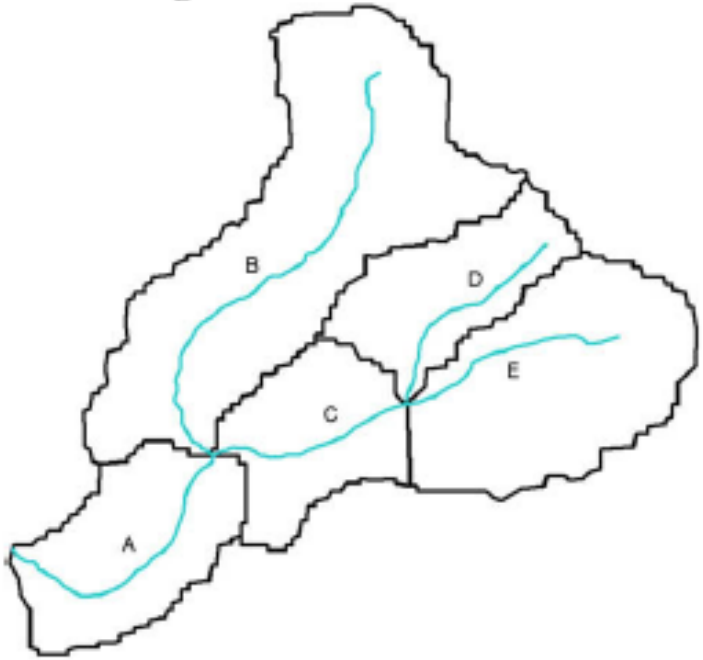




Methods: landscape data

M.P. Strager et al. / Journal of Environmental Management 90 (2009) 1854–1861

Segment-level watersheds



Flow table linking watersheds

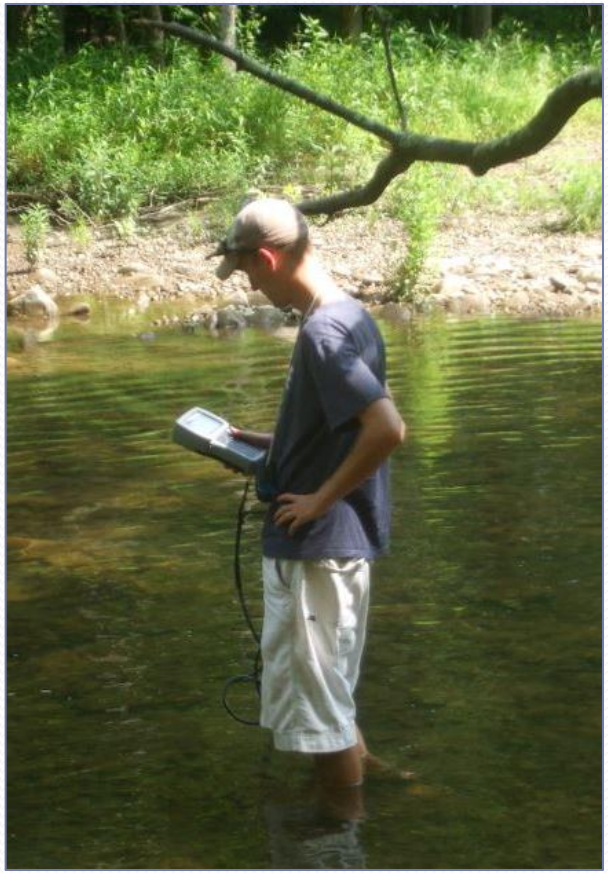
Up	Watershed	Type
none	B	start
none	D	start
none	E	start
D	C	in
E	C	in
C	A	in
B	A	in

Fig. 3. Example of flow table for linking watersheds.

Methods: landscape data

Coal Mining	Development	Natural Variables	Other
% Reclaimed	Serviced SD	% Forest	All NPDES Permits
% Active	Unserviced SD	% Allegheny Coal	Road Density
% Valley Fill	% Barren/Developed	% Kanawha Coal	
% AML	% Grass/Pasture	% Open Water	
% Slurry Ponds			
UM NPDES Permits			

Methods: field sampling

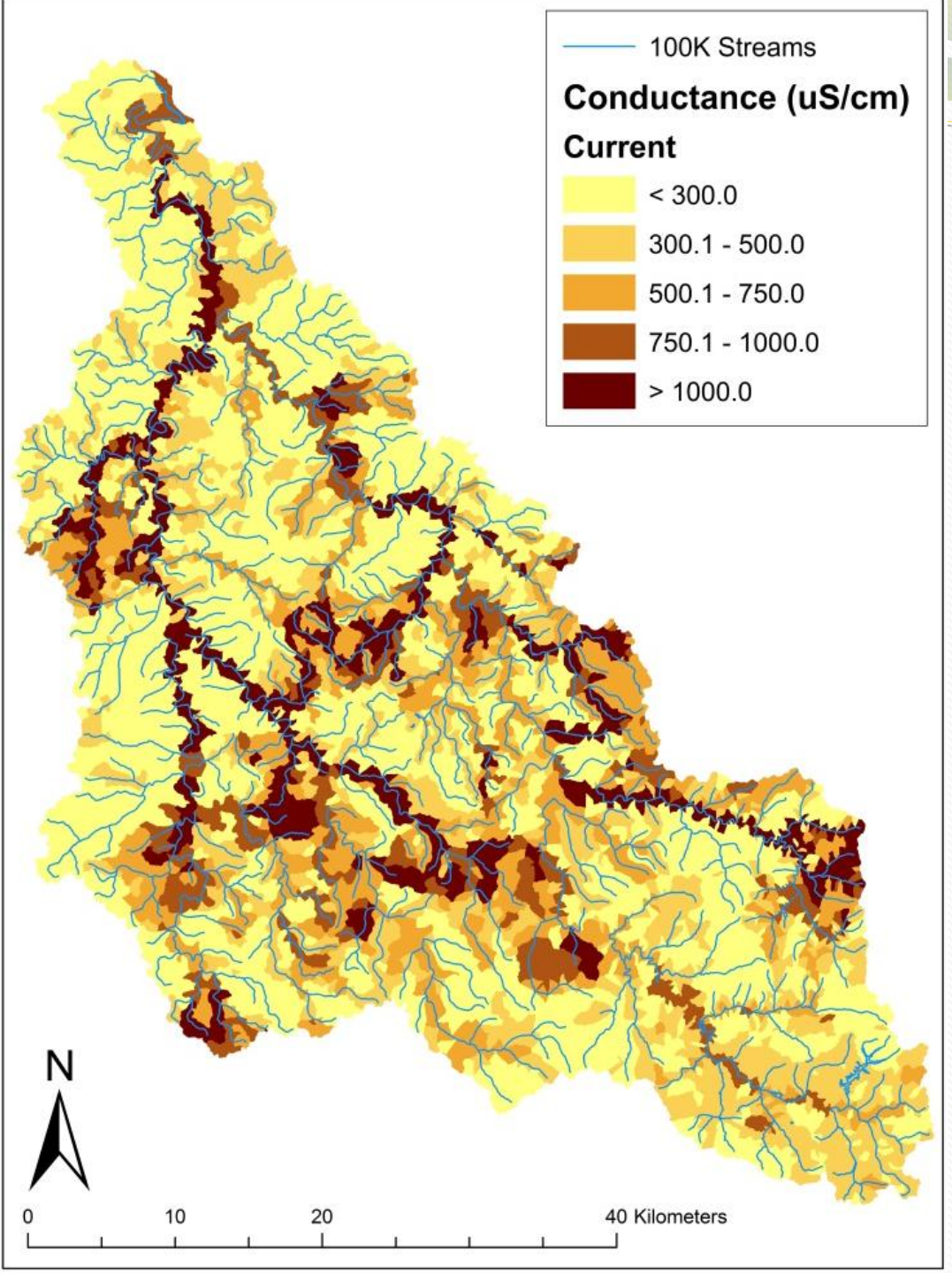


Boosted Regression Trees (BRT)

- Combines individual classification or regression trees
- Successive trees focus on explaining residual variance

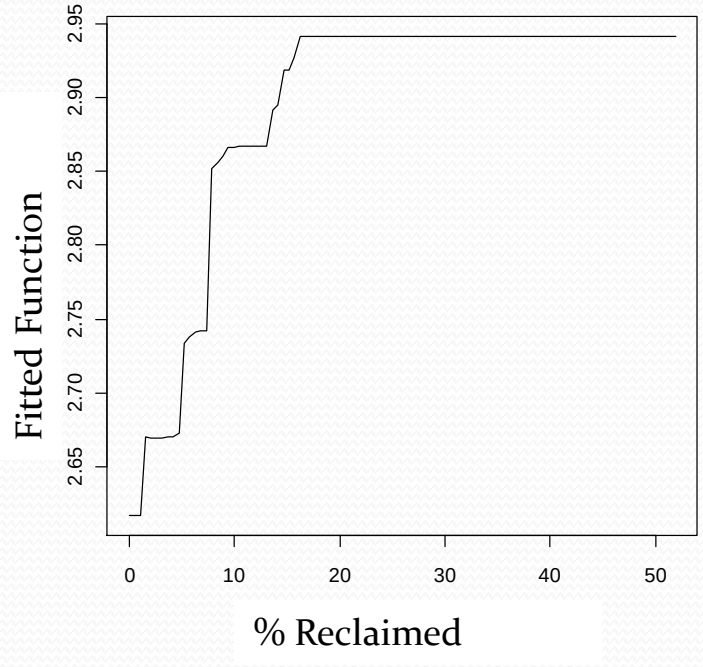
- Benefits over conventional regression techniques:
  - Accommodates multiple predictor types and missing data
  - Unaffected by outliers and irrelevant predictors
  - Models interactions between predictor variables
  - Internal CV for model development and evaluation
  - Typically outperforms conventional techniques

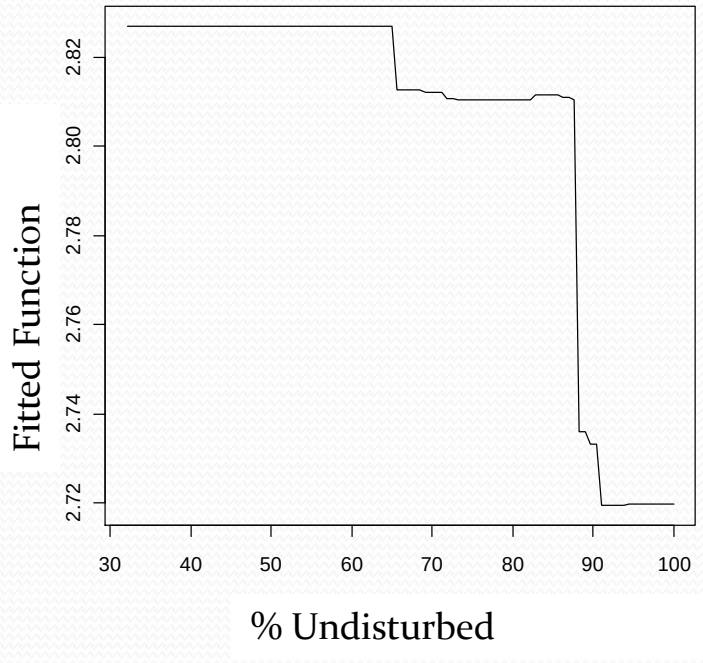
Current Conditions: Conductivity



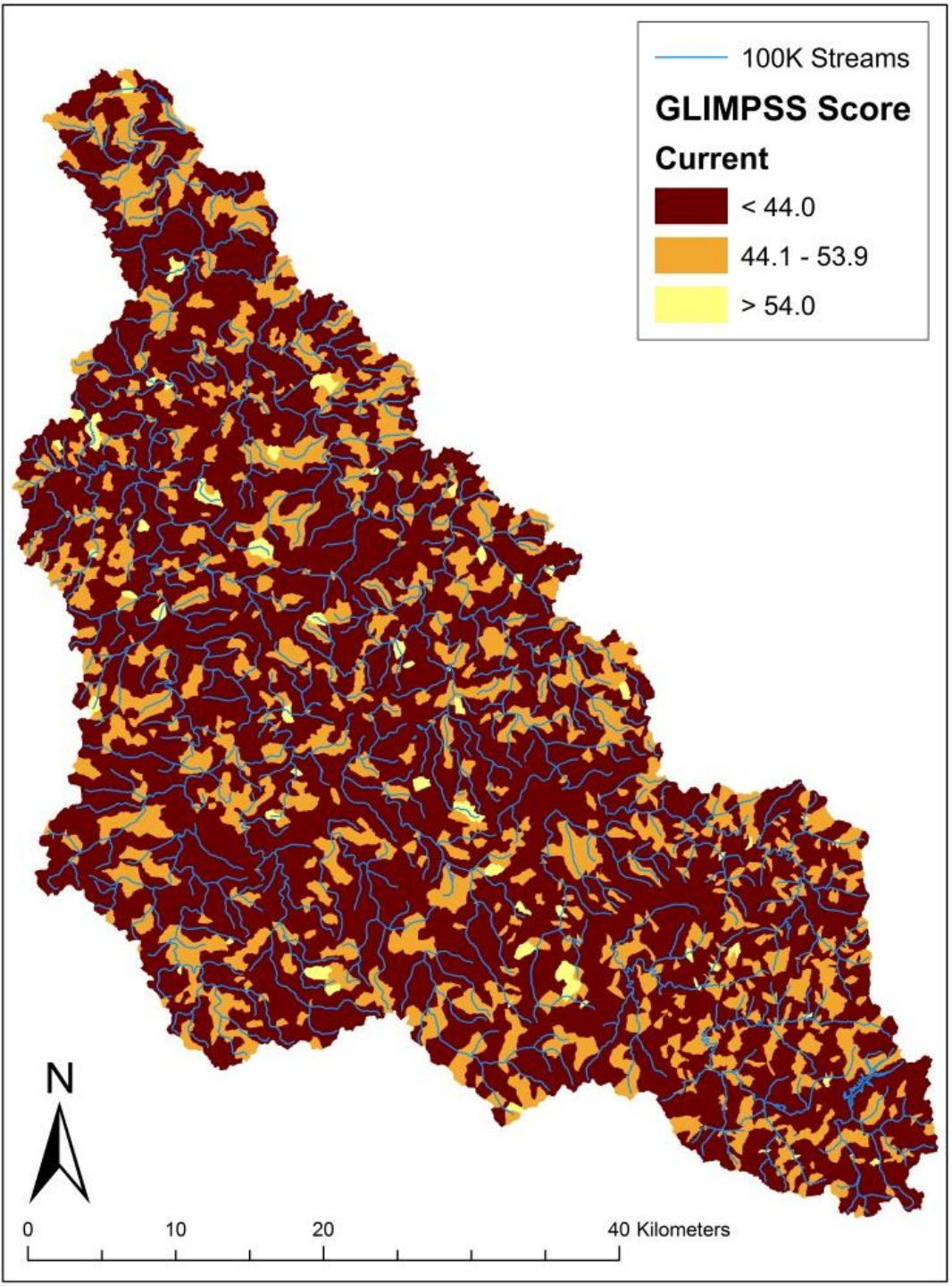
Variable	Rel. Influence
No. Trees	3300
Var. Explained	92%
CV Var. Explained	75%

Variable	Rel. Influence
CUM % Reclaimed	31.7%
CUM % Forest	18.8%
CUM % Grass/Pasture	14.8%
CUM UM NPDES	13.0%
CUM % Valley Fills	12.6%
CUM % Active Mining	9.1%


Fitted Function
2.65
2.70
2.75
2.80
2.85
2.90
2.95
0
10
20
30
40
50
% Reclaimed


Fitted Function
2.72
2.74
2.76
2.78
2.80
2.82
30
40
50
60
70
80
90
100
% Undisturbed

Current Conditions: GLIMPSS

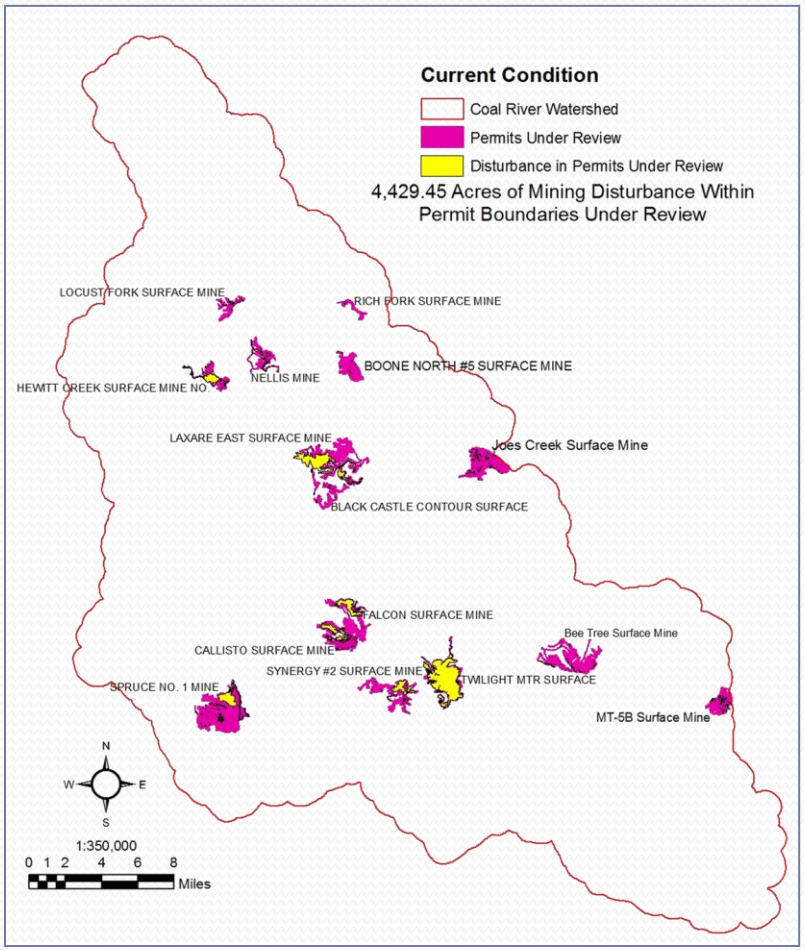


Variable	Rel. Influence
No. Trees	2800
% Dev. Explained	86%
% CV Dev. Explained	54%

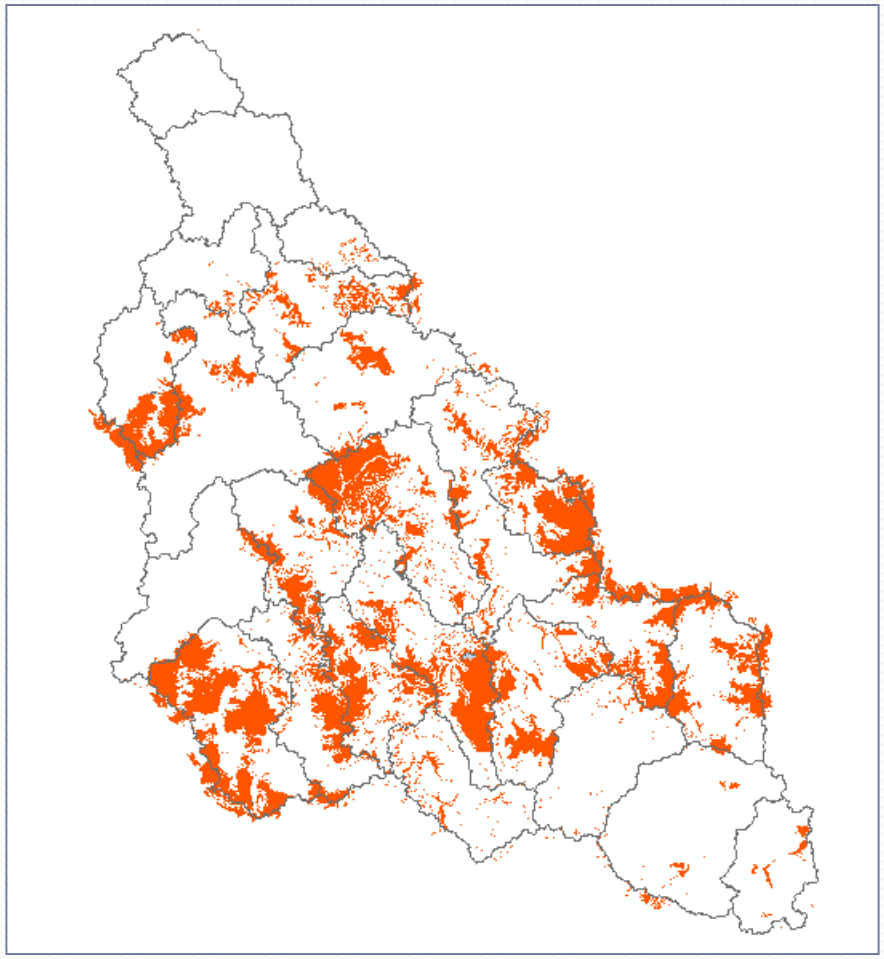
Variable	Rel. Influence
CUM % Forest	31.0%
CUM % Grass/Pasture	21.2%
Local % Grass/Pasture	10.8%
CUM Serviced SD	9.4%
Local % Barren/Dev	9.2%
CUM All NPDES	8.2%
CUM Road Density	5.6%
Local Serviced SD	4.6%

Alternative future scenarios

15 Additional Permits

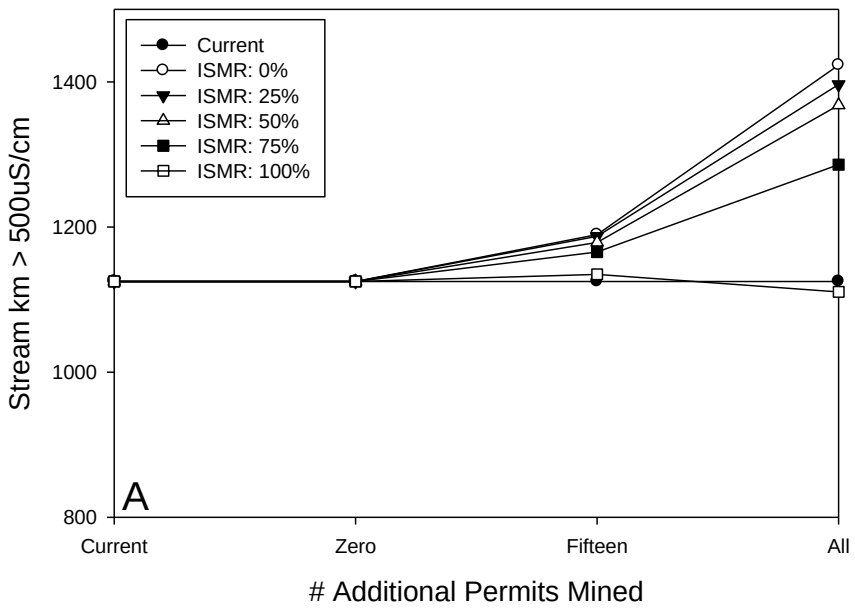


All Permits

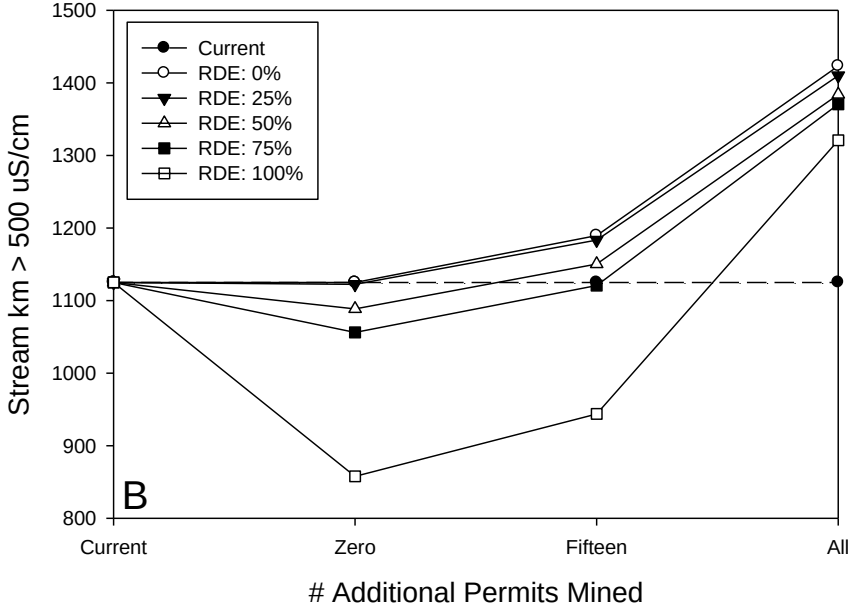


Alternative future scenarios: conductivity

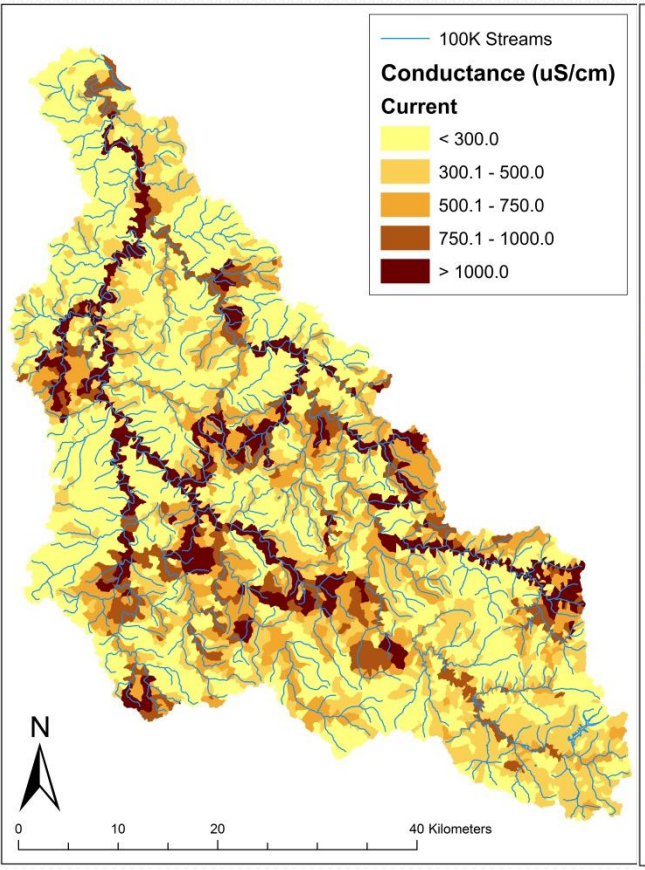
Increased Surface Mine Reclamation

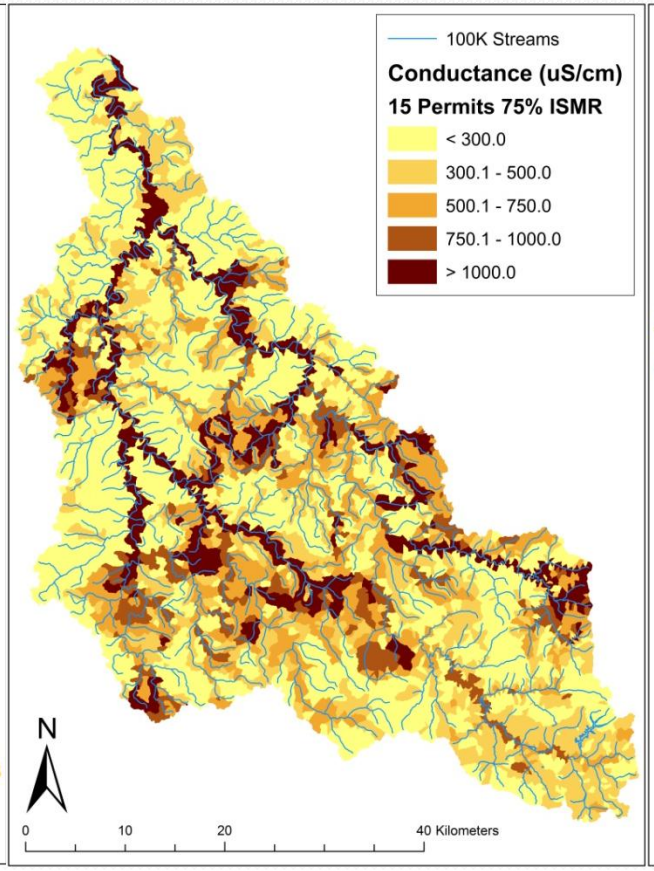


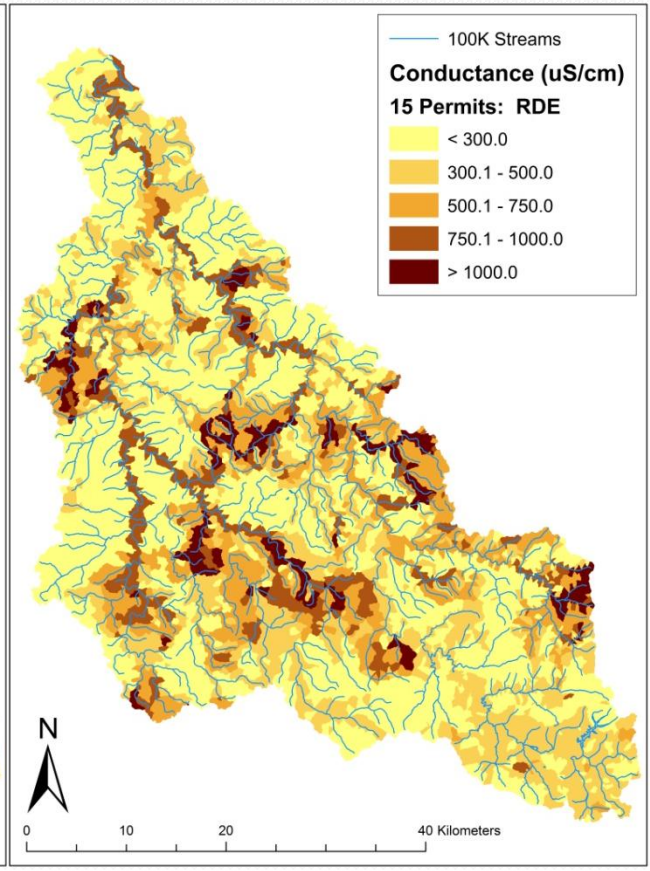
Decreased Deep Mine Influence



Alternative future scenarios: conductivity

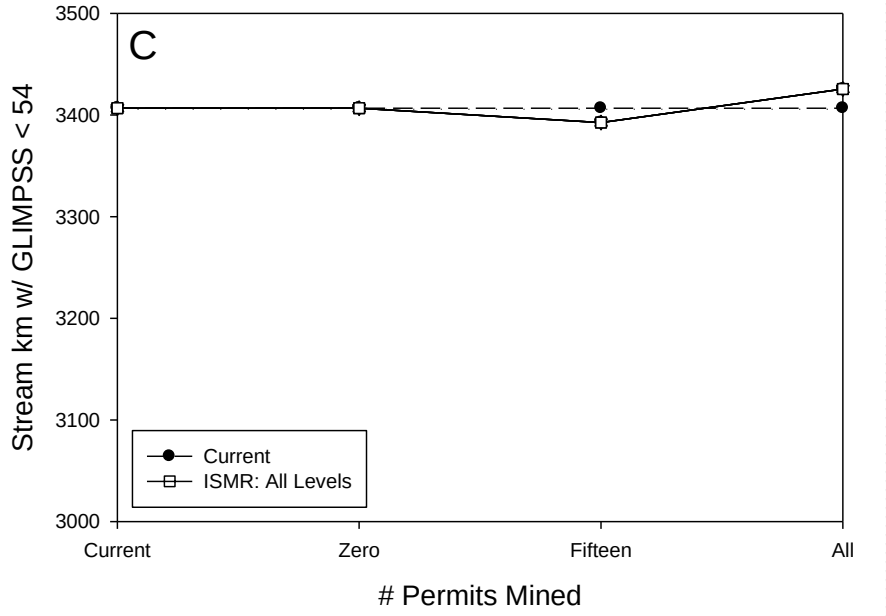




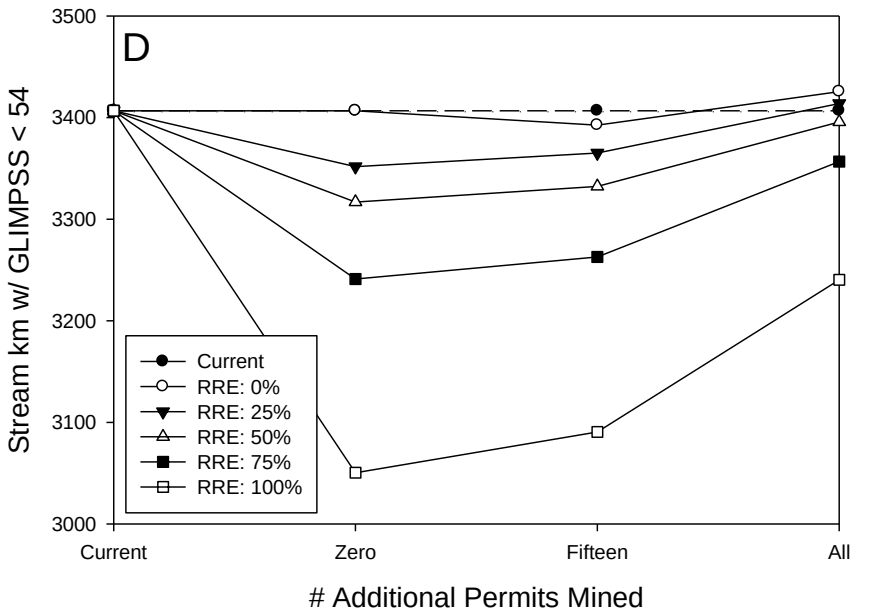


Alternative future scenarios: GLIMPSS

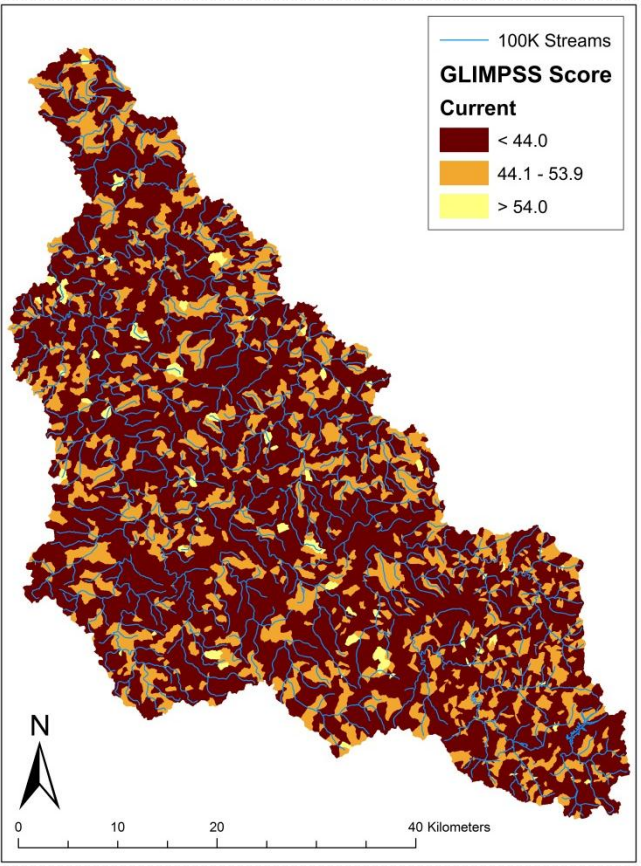
Increased Surface Mine Reclamation

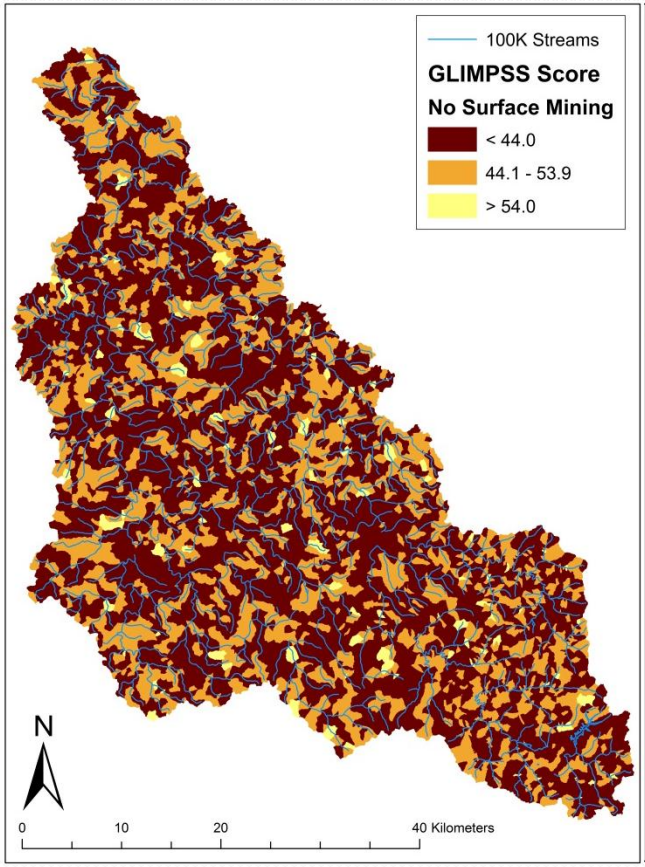


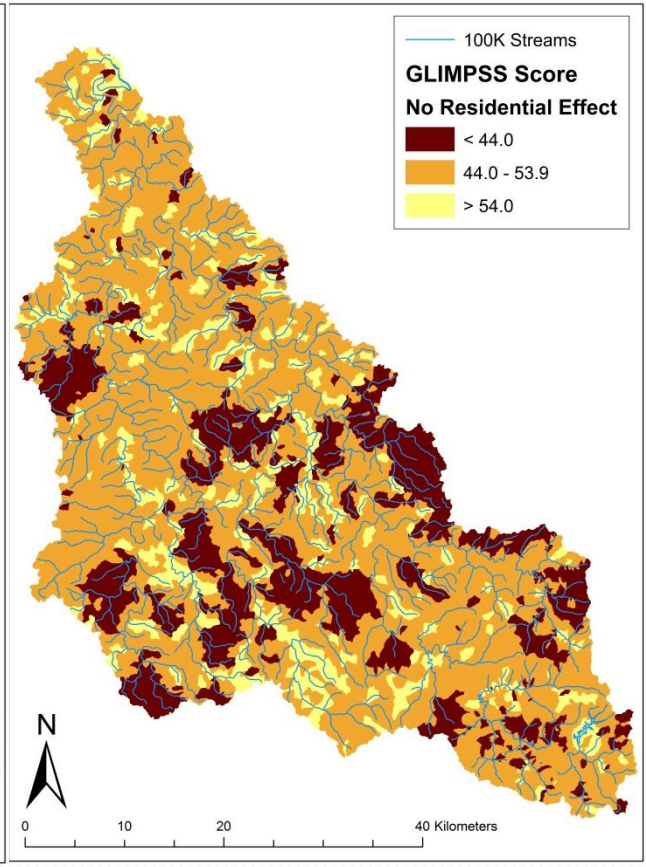
Decreased Residential Influence



Alternative future scenarios: GLIMPSS







Management Implications

- The Coal River watershed is highly impaired given cumulative impacts from surface mining, deep mining, and residential development

- Our results can be used to facilitate regulatory decisions regarding mine permitting and mitigation, as well as targeted restoration activities

Management Implications

- Restoration efforts targeted at reducing effects of deep mine effluent and impacts from residential land use will be most beneficial at the watershed scale

- Our modeling framework provides a necessary next step in the science and practice of cumulative effects assessment

Acknowledgments

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