Seeing the water through the valley fill: Emerging hydrologic controls in a

Nicolas Zègre & Andrew Miller

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Mountain Hydrology Lab

Division of FORESTRY and NATURAL RESOURCES

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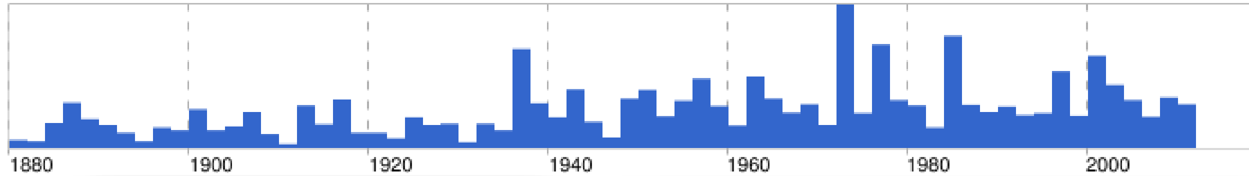
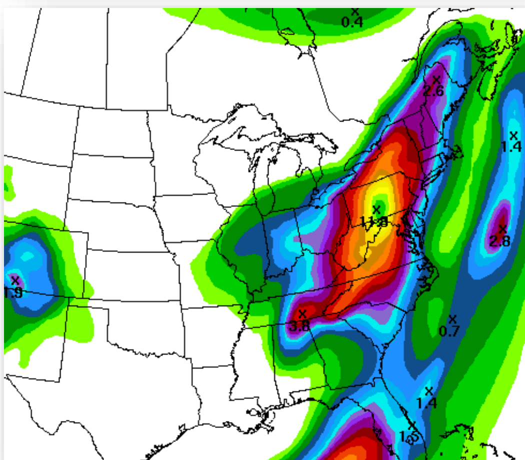
MTM Impacts - Implicated in Flooding

WV flood counts – 1880 - 2011






Parkersburg, 1884

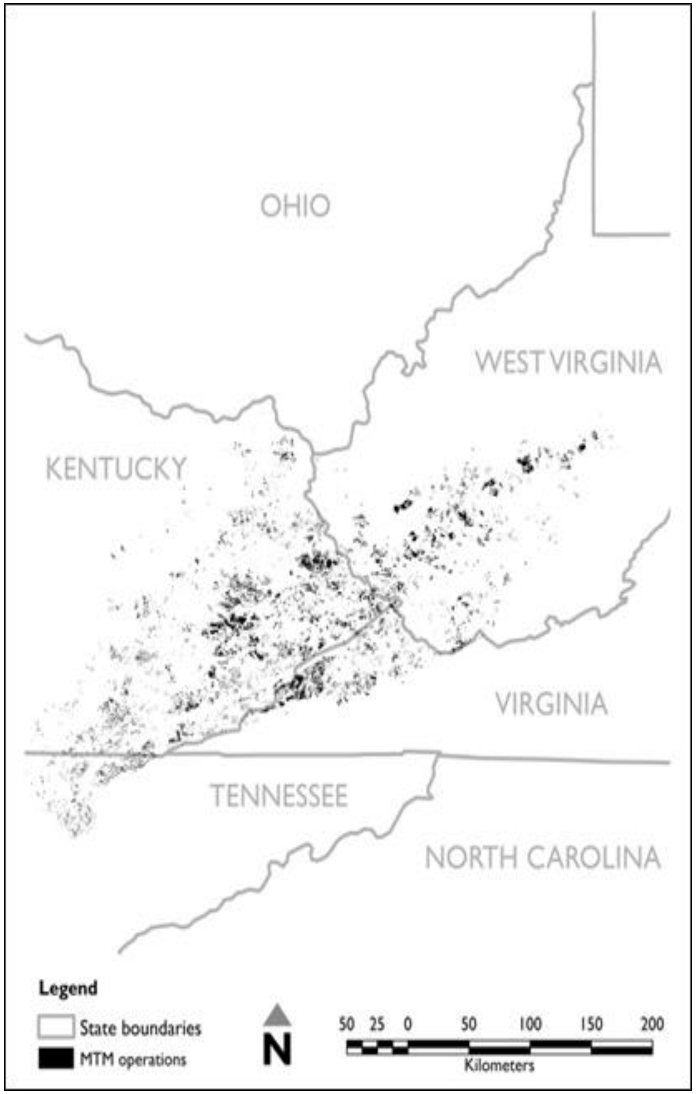

West Union, 1939

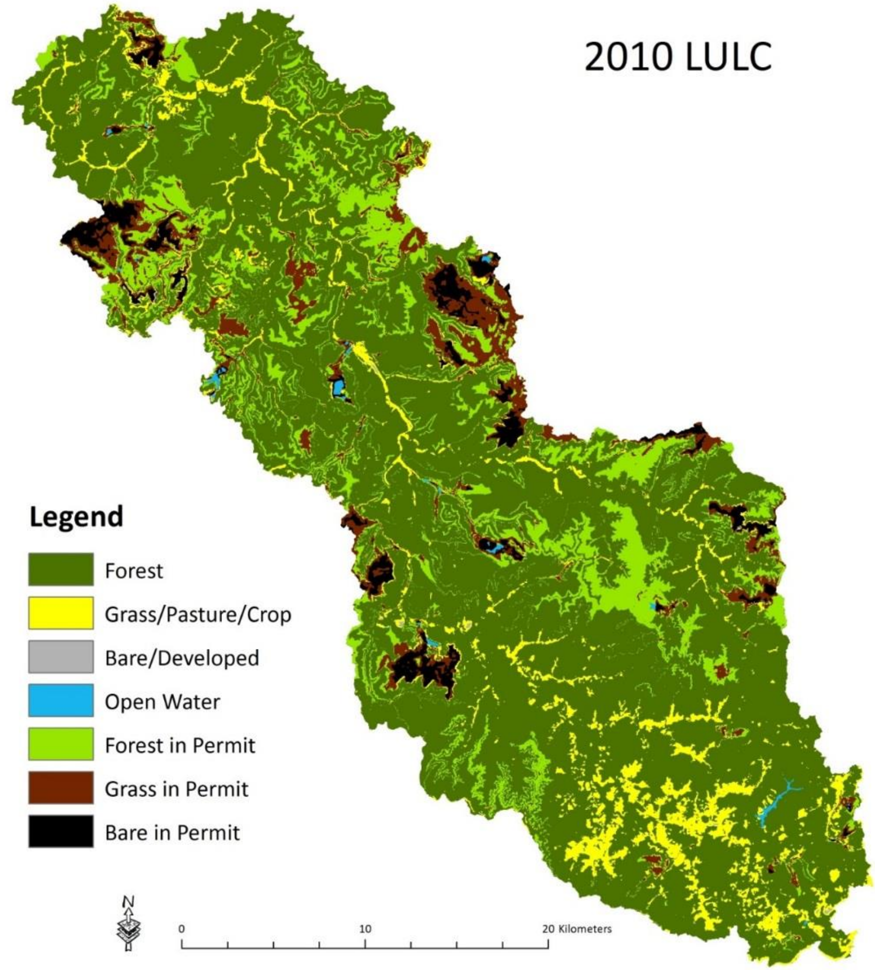

Cheat River, 1985


Mullens, 2001


Gilbert, 2009

Land cover changes over time & space





Hydrology is poorly understood

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Review

Mountaintop Removal Mining and Catchment Hydrology

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Abstract: Mountaintop mining and valley fill (MTM/VF) coal extraction, practiced in the Central Appalachian region, represents a dramatic landscape-scale disturbance. MTM operations remove as much as 300 m of rock, soil, and vegetation from ridge tops to access deep coal seams and much of this material is placed in adjacent headwater streams altering landcover, drainage network, and topography. In spite of its scale, extent, and potential for continued use, the effects MTM/VF on catchment hydrology is poorly understood. Previous reviews focus on water quality and ecosystem health impacts, but little is known about how MTM/VF affects hydrology, particularly the movement and storage of water, hence the hydrologic processes that ultimately control flood generation, water chemistry, and biology. This paper aggregates the existing knowledge about the hydrologic impacts of MTM/VF to identify areas where further scientific investigation is needed. While contemporary surface mining generally increases peak and total runoff, the limited MTM/VF studies reveal significant variability in hydrologic response. Significant knowledge gaps relate to limited understanding of hydrologic processes in these systems. Until the hydrologic impact of this practice is better understood, efforts to reduce water quantity and quality problems and ecosystem degradation will be difficult to achieve.

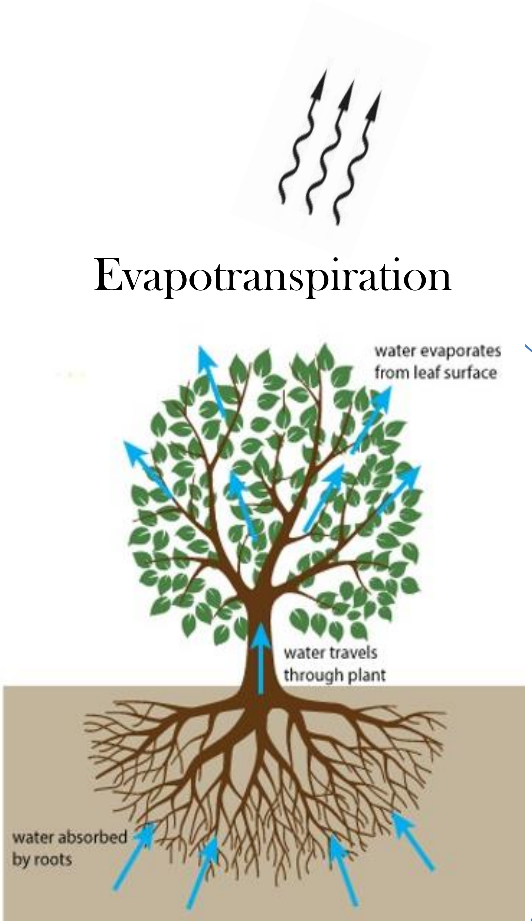
Keywords: mountaintop removal mining; valley fills; streamflow; hydrology; Appalachians; surface coal mining

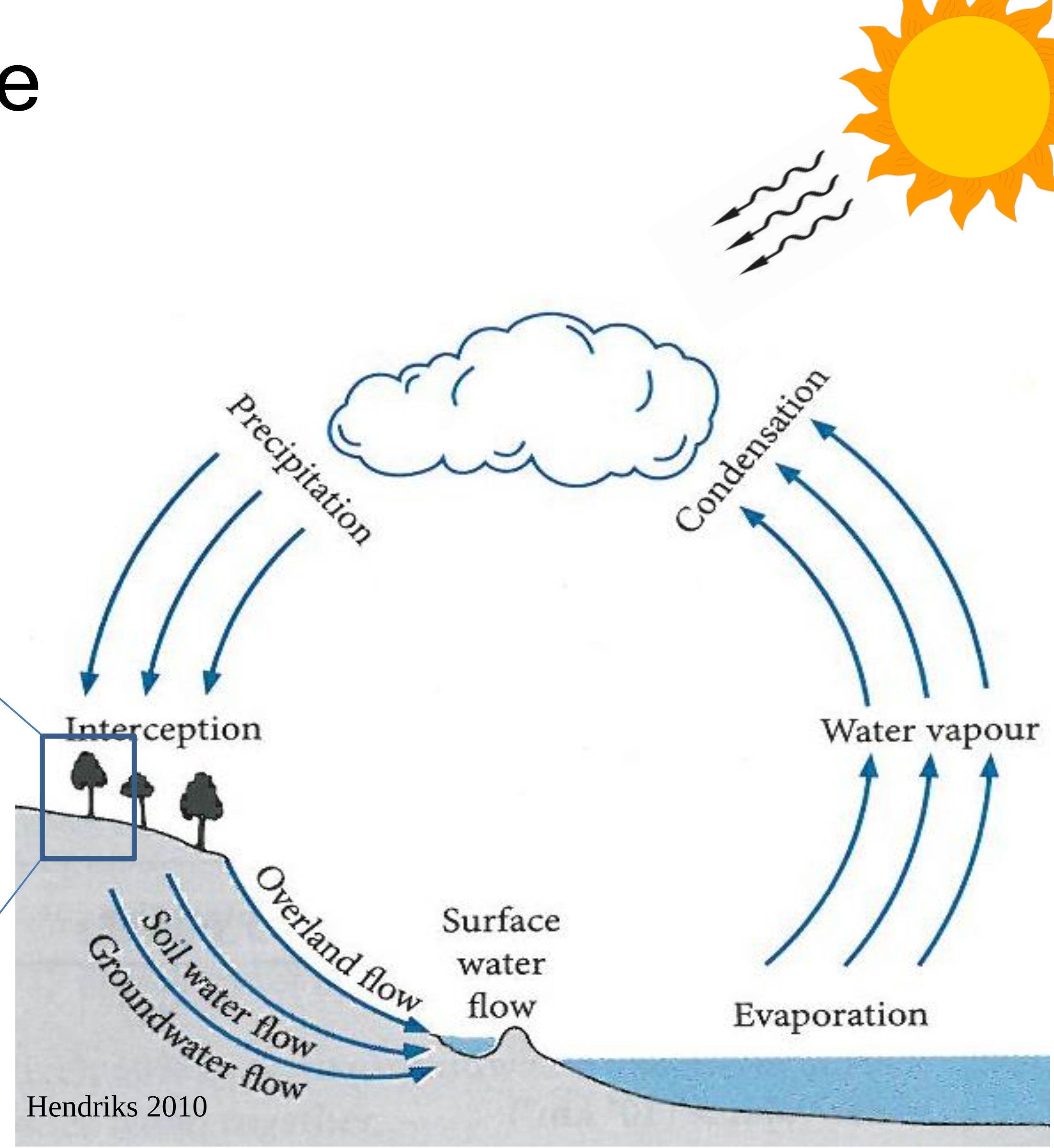
- Increases, decreases or no change in peakflows;
- Baseflow generally increases;
- Changes related to Et & soil compaction.

Knowledge Gaps –

- Large spatial scales;
- Valley fill hydrology;
- Reclamation;
- Thresholds;
- Altered topography;
- Streamflow processes in MTM & legacy disturbed catchments.

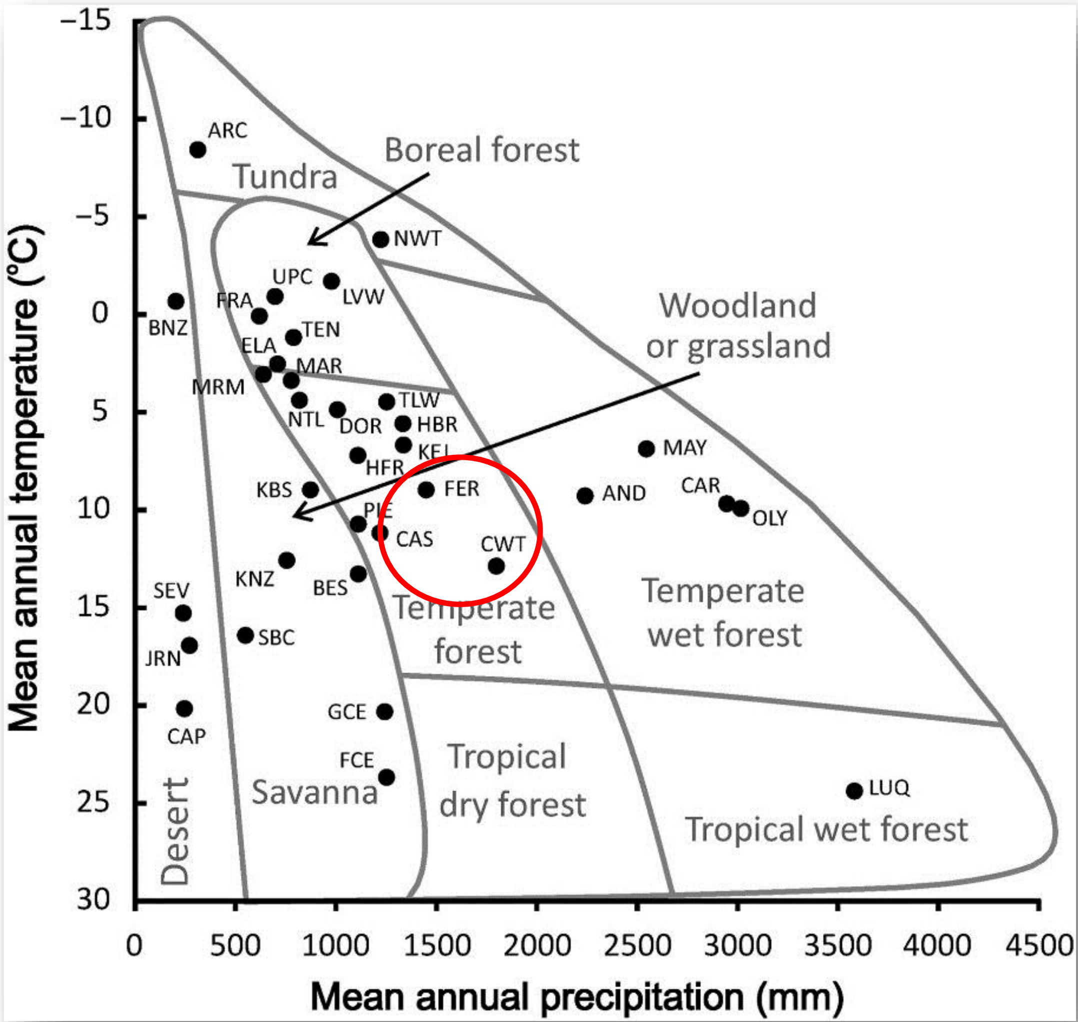
The Water Cycle





Controls on hydrology

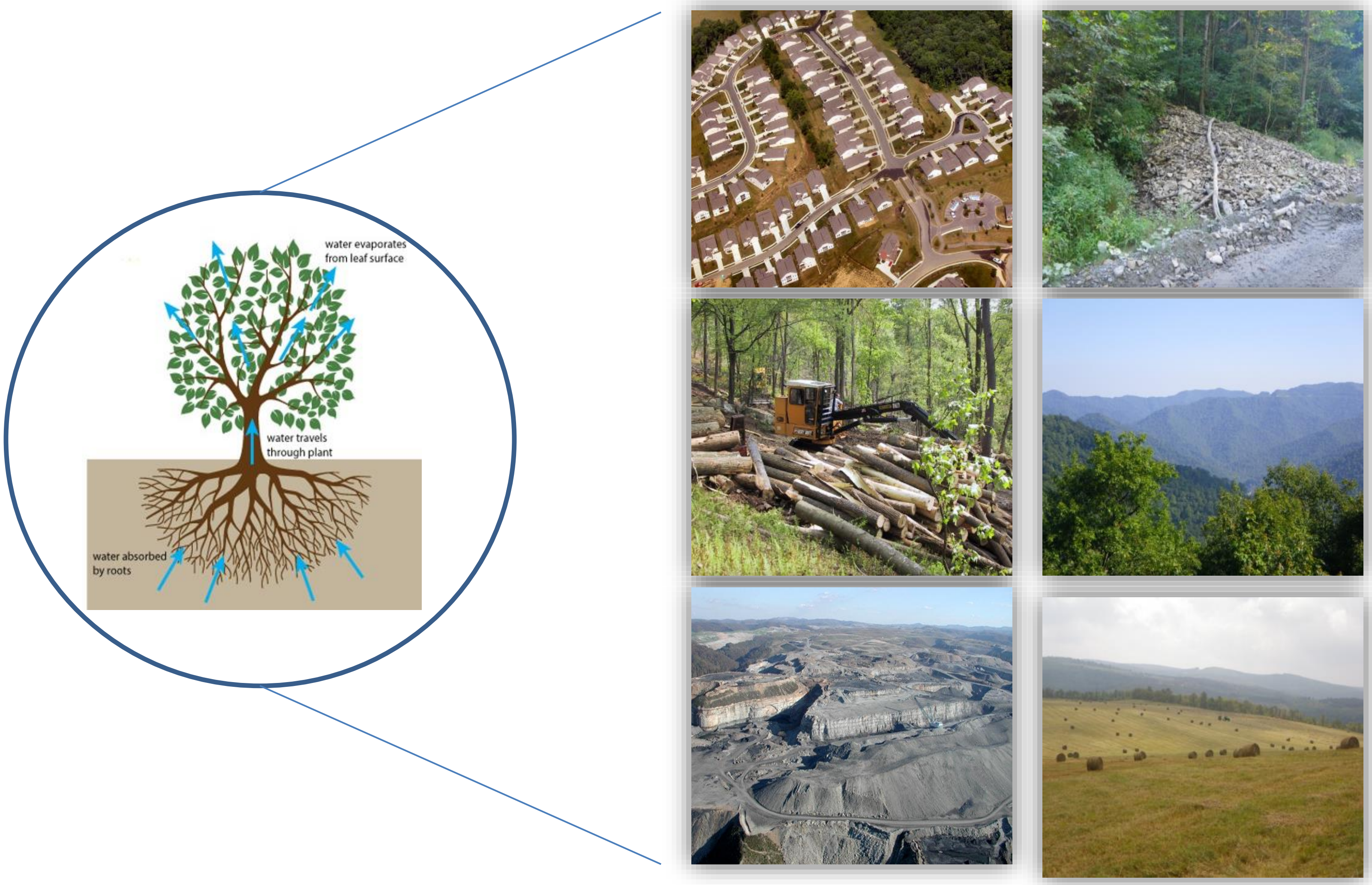
Climate, Landcover, & Morphology



Jones et al, 2012

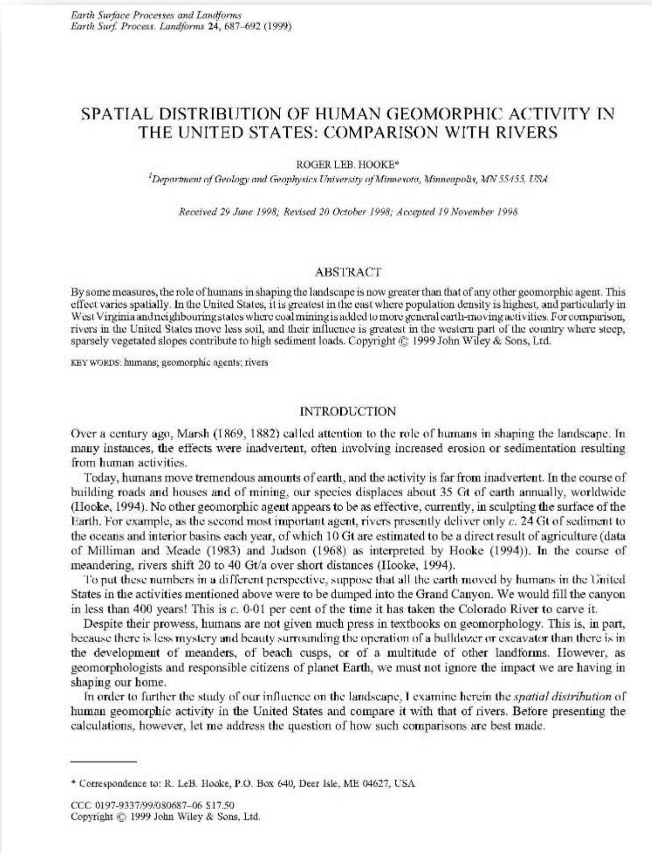
Controls on hydrology

Climate, **Landcover**, & Morphology



Controls on hydrology

Climate, Landcover, & **Morphology**



Earth Surface Processes and Landforms
Earth Surf. Process. Landforms **24**, 687–692 (1999)

SPATIAL DISTRIBUTION OF HUMAN GEOMORPHIC ACTIVITY IN THE UNITED STATES: COMPARISON WITH RIVERS

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Received 29 June 1998; Revised 20 October 1998; Accepted 19 November 1998

ABSTRACT

By some measures, the role of humans in shaping the landscape is now greater than that of any other geomorphic agent. This effect varies spatially. In the United States, it is greatest in the east where population density is highest, and particularly in West Virginia and neighbouring states where coal mining is added to more general earth-moving activities. For comparison, rivers in the United States move less soil, and their influence is greatest in the western part of the country where steep, sparsely vegetated slopes contribute to high sediment loads. Copyright © 1999 John Wiley & Sons, Ltd.

KEY WORDS: humans; geomorphic agents; rivers

INTRODUCTION

Over a century ago, Marsh (1869, 1882) called attention to the role of humans in shaping the landscape. In many instances, the effects were inadvertent, often involving increased erosion or sedimentation resulting from human activities.

Today, humans move tremendous amounts of earth, and the activity is far from inadvertent. In the course of building roads and houses and of mining, our species displaces about 35 Gt of earth annually, worldwide (Hooke, 1994). No other geomorphic agent appears to be as effective, currently, in sculpting the surface of the Earth. For example, as the second most important agent, rivers presently deliver only *c.* 24 Gt of sediment to the oceans and interior basins each year, of which 10 Gt are estimated to be a direct result of agriculture (data of Milliman and Meade (1983) and Judson (1968) as interpreted by Hooke (1994)). In the course of meandering, rivers shift 20 to 40 Gt/a over short distances (Hooke, 1994).

To put these numbers in a different perspective, suppose that all the earth moved by humans in the United States in the activities mentioned above were to be dumped into the Grand Canyon. We would fill the canyon in less than 400 years! This is *c.* 0·01 per cent of the time it has taken the Colorado River to carve it.

Despite their prowess, humans are not given much press in textbooks on geomorphology. This is, in part, because there is less mystery and beauty surrounding the operation of a bulldozer or excavator than there is in the development of meanders, of beach cusps, or of a multitude of other landforms. However, as geomorphologists and responsible citizens of planet Earth, we must not ignore the impact we are having in shaping our home.

In order to further the study of our influence on the landscape, I examine herein the *spatial distribution* of human geomorphic activity in the United States and compare it with that of rivers. Before presenting the calculations, however, let me address the question of how such comparisons are best made.

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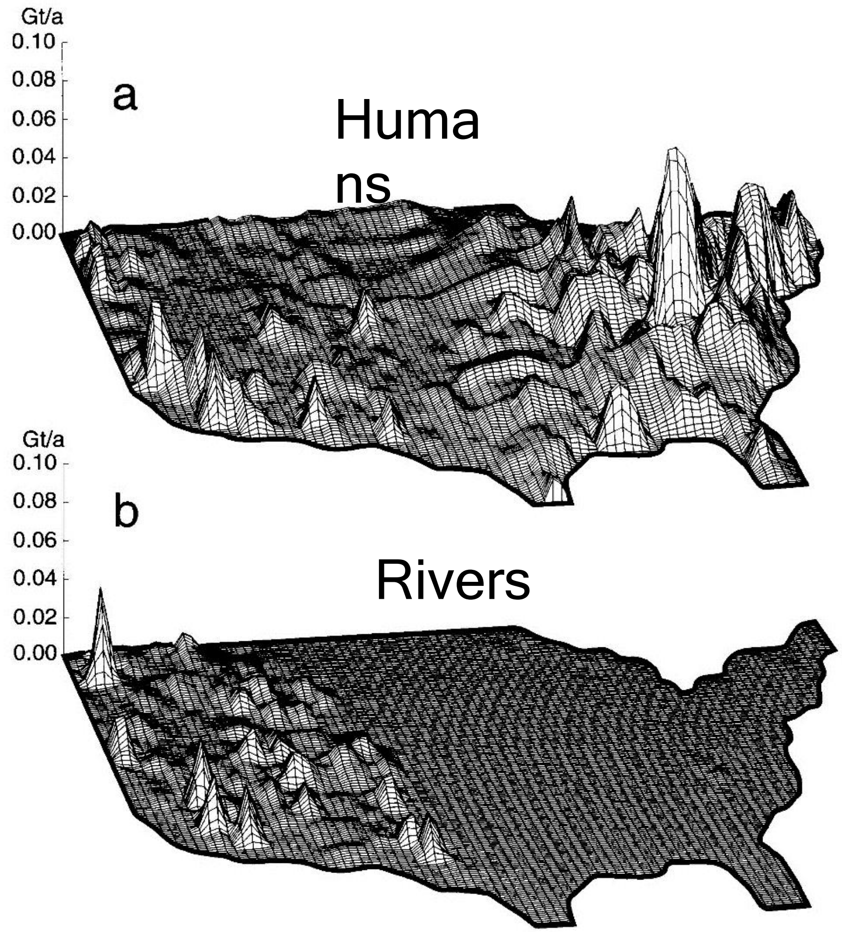
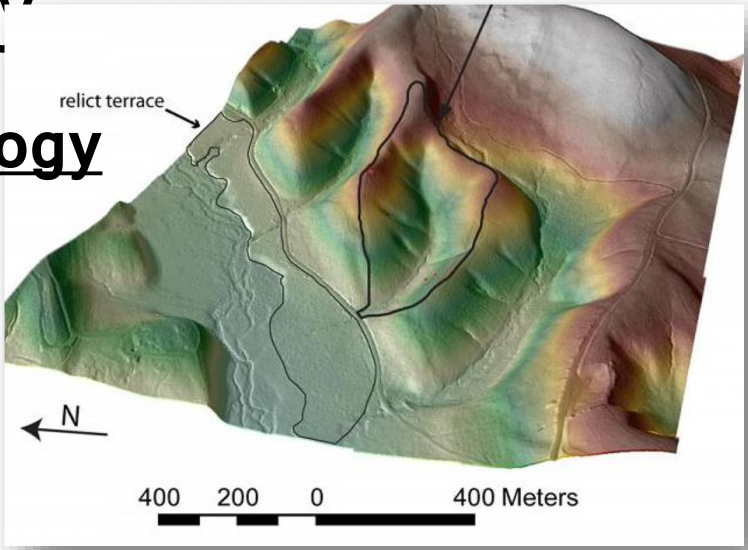
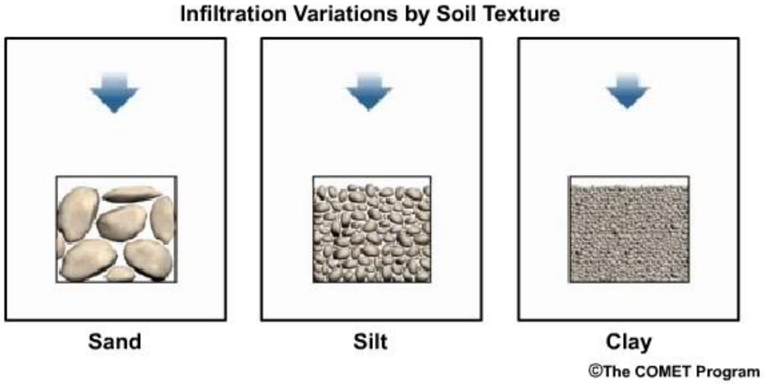
CCC 0197-9337/99/080687–06 $17.50

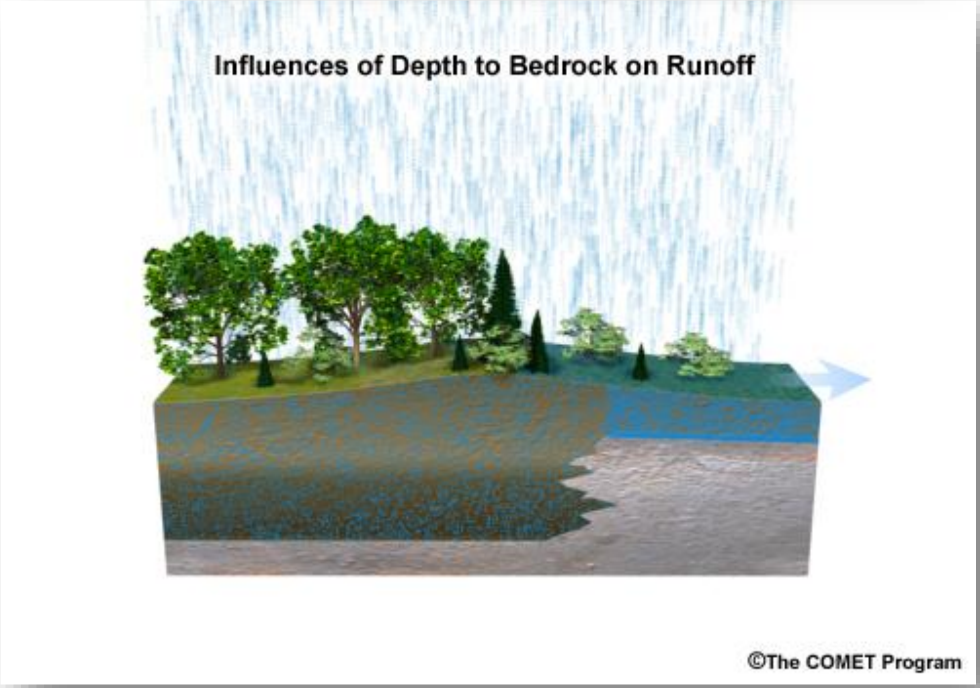


Controls on hydrology

Climate, Landcover, & **Morphology**







Mountaintop-removal mining

Surface mining

- Removes forest (Et) - increase wate volume;
- Removes soil – changes storage;
- Changes catchment structure – flow paths;

Valley fills

- Modifies original channel geometry;
- Increases storage capacity;
- Forces contact time b/w runoff & spoil – runoff chemistry & water quality;

Need to recognize it as a two-part system

1) Surface mine
2) Valley fill

Basin scale - Over the lifetime of MTM (1969-2010)

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
AMERICAN WATER RESOURCES ASSOCIATION

MULTISCALE ANALYSIS OF HYDROLOGY IN A MOUNTAINTOP MINE-IMPACTED WATERSHED[1]

Nicolas P. Zegre, Andrew J. Miller, Aaron Maxwell, and Samuel J. Lamont[2]

ABSTRACT: In the Appalachian region of the eastern United States, mountaintop removal mining (MTM) is a dominant driver of land-cover change, impacting 6.8% of the largely forested 4.86 million ha coal fields region. Recent catastrophic flooding and documented biological impairment downstream of MTM has drawn sharp criticism to this practice. Despite its extent, scale, and use since the 1970s, the impact of MTM on hydrology is poorly understood. Therefore, the goal of this study was a multiscale evaluation to establish the nature of hydrologic impacts associated with MTM. To quantify the extent of MTM, land-cover change over the lifetime of this practice is estimated for a mesoscale watershed in southern West Virginia. To assess hydrologic impacts, we conducted long-term trend analyses to evaluate for systematic changes in hydrology at the mesoscale, and conducted hydrometric and response time modeling to characterize storm-scale responses of a MTM-impacted headwater catchment. Results show a general trend in the conversion of forests to mines, and significant decreases in maximum streamflow and variability, and increases in base-flow ratio attributed to valley fills and deep mine drainage. Decreases in variability are shown across spatial and temporal scales having important implications for water quantity and quality. However, considerable research is necessary to understand how MTM impacts hydrology. In an effort to inform future research, we identify existing knowledge gaps and limitations of our study.

(KEY TERMS: mountaintop removal mining; land-cover change; change detection; streamflow; trend analysis; transfer functions; rainfall-runoff modeling.)

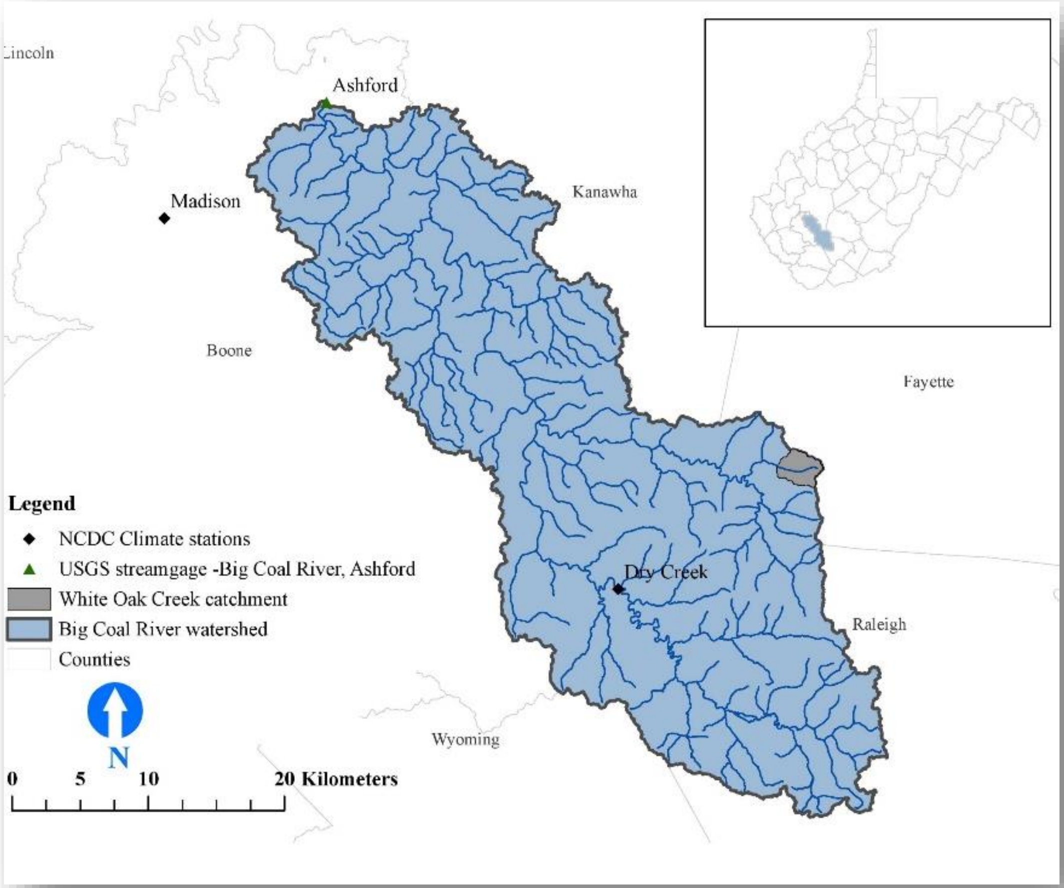
Zegre, Nicolas P., Andrew J. Miller, Aaron Maxwell, and Samuel J. Lamont, 2014. Multiscale Analysis of Hydrology in a Mountaintop Mine-Impacted Watershed. *Journal of the American Water Resources Association* (JAWRA) 1-16. DOI: 10.1111/jawr.12184

INTRODUCTION

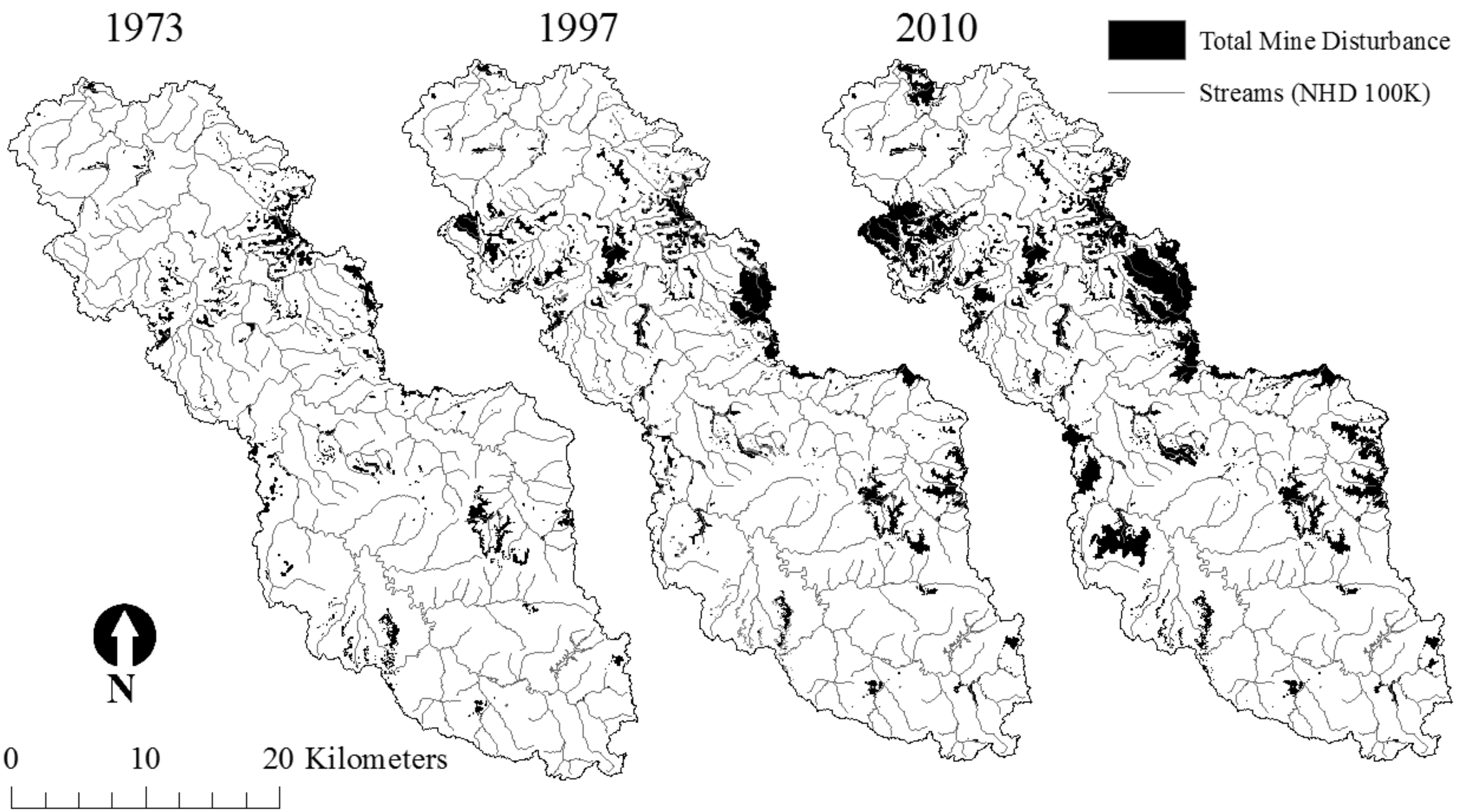
Surface mining for coal, including mountaintop removal mining (MTM), is a dominant driver of land-cover changes in the Appalachian region of the eastern United States (U.S.) (Sayler, 2008) and is expected to increase in scale in the coming decades (Townsend *et al.*, 2009). The U.S. Environmental Protection Agency (USEPA) estimates that, by 2012, MTM will have impacted 6.8% of the largely forested 4.86 million hectares of the Appalachian coal field region within West Virginia (WV), Kentucky, Virginia, and Tennessee (EPA, 2011). Between 1992 and 2002, ~1,994 km of headwater streams have been buried, and this number is expected to double to

[1]Paper No. JAWRA-13-0162-P of the *Journal of the American Water Resources Association* (JAWRA). Received July 17, 2013; accepted January 24, 2014. © 2014 American Water Resources Association. **Discussions are open until six months from print publication.**

[2]Assistant Professor of Forest Hydrology (Zegre) and Graduate Student (Miller), Forestry & Natural Resources, West Virginia University (WVU), Campus Box 6125, Morgantown, West Virginia 26506; Assistant Professor (Maxwell), Division of Natural Sciences, Alderson Broaddus College, Philippi, West Virginia; and Assistant Professor (Lamont), Natural Resources Analysis Center, WVU, Morgantown, West Virginia (E-Mail/Zegre: nicolas.zegre@mail.wvu.edu).



Basin scale - Over the lifetime of MTM (1969-2010)



In 2010, MTM covered 9% and 84 VFs cover less than one-half percent of

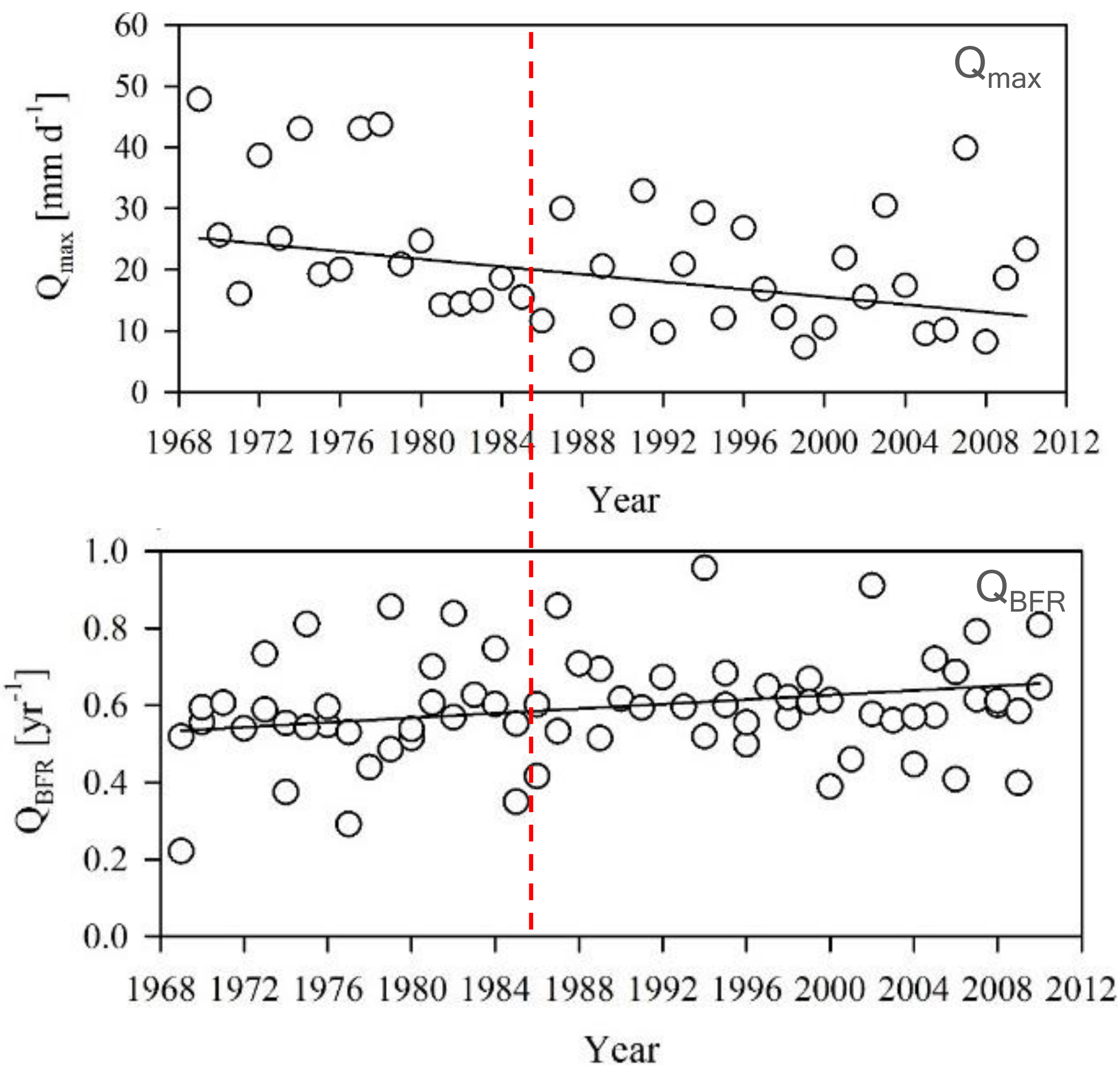
Study overview

Characterize hydrologic regime of the Big Coal River watershed

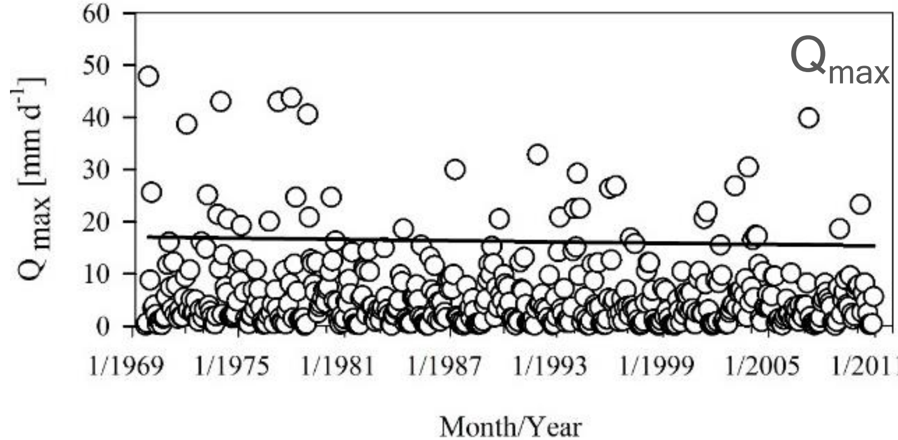
- 390 $mile^2$(1,011 km^2);
- rich history of coal, timber, & gas development;
- mixed hardwood forest with steep topography & shallow soils;

- Daily USGS streamflow from 1969-2010;
- Calculated metrics that describe hydrologic regime:
    - min, 25^{th}, median, 75^{th}, max, IQR, IQR/median, & average streamflows;
    - baseflow & baseflow ratio;
- Daily precipitation & air temperature from 1969-2010;

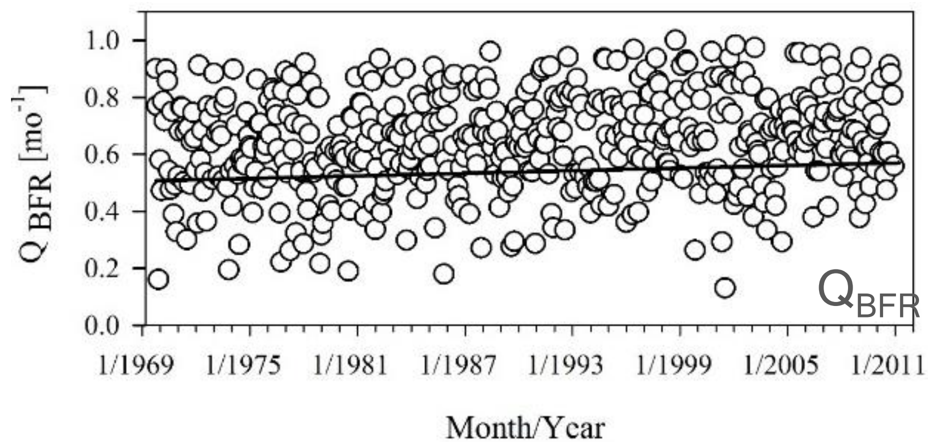
Results - Annual scale

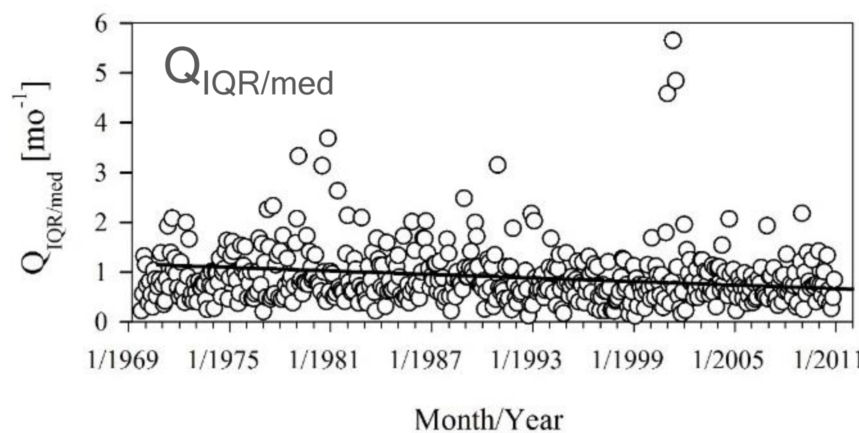


Results - Monthly scale



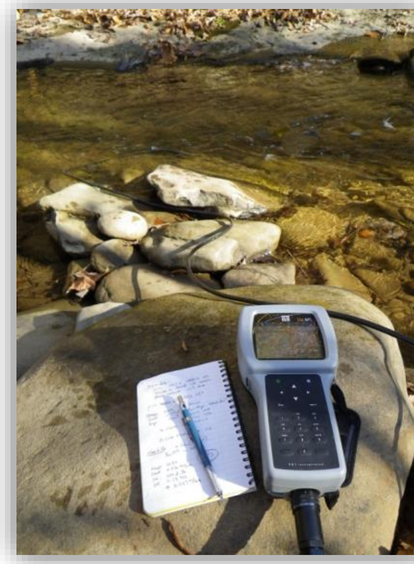
Decreasing max flows; decreasing variability; & increasing baseflow.





Discussion

We were surprised by decreases in Q_{max} given propensity, based on the literature, for peakflow increases downstream;



Also surprised by the decreases in $Q_{IQR/med}$ & increases in Q_{BFR};

- No significant changes in climate;
- Streamflow variability is dampened over time;
- Proportion of streamflow from baseflow increasing overtime;

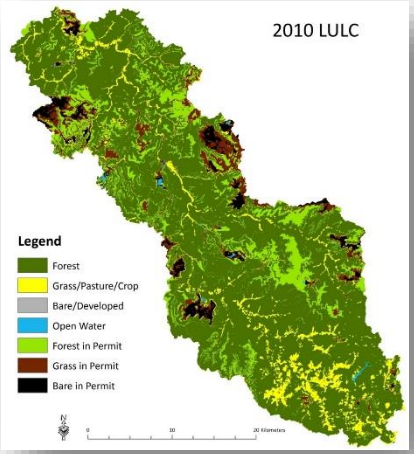
Implicates valley fills in controlling hydrology

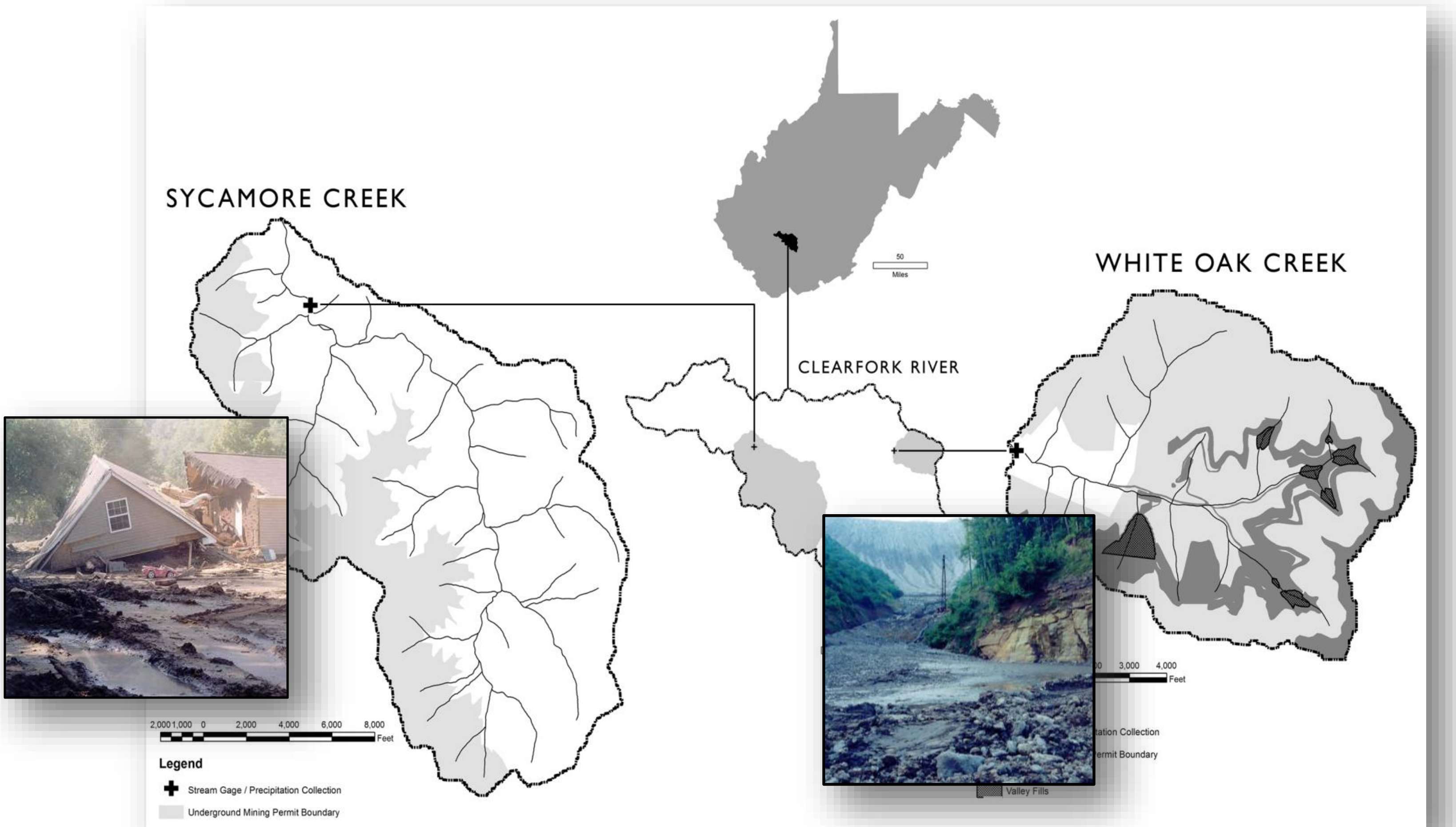
Discussion

- Forest harvesting thresholds: 20% of watersheds harvested for detectable changes in hydrology;

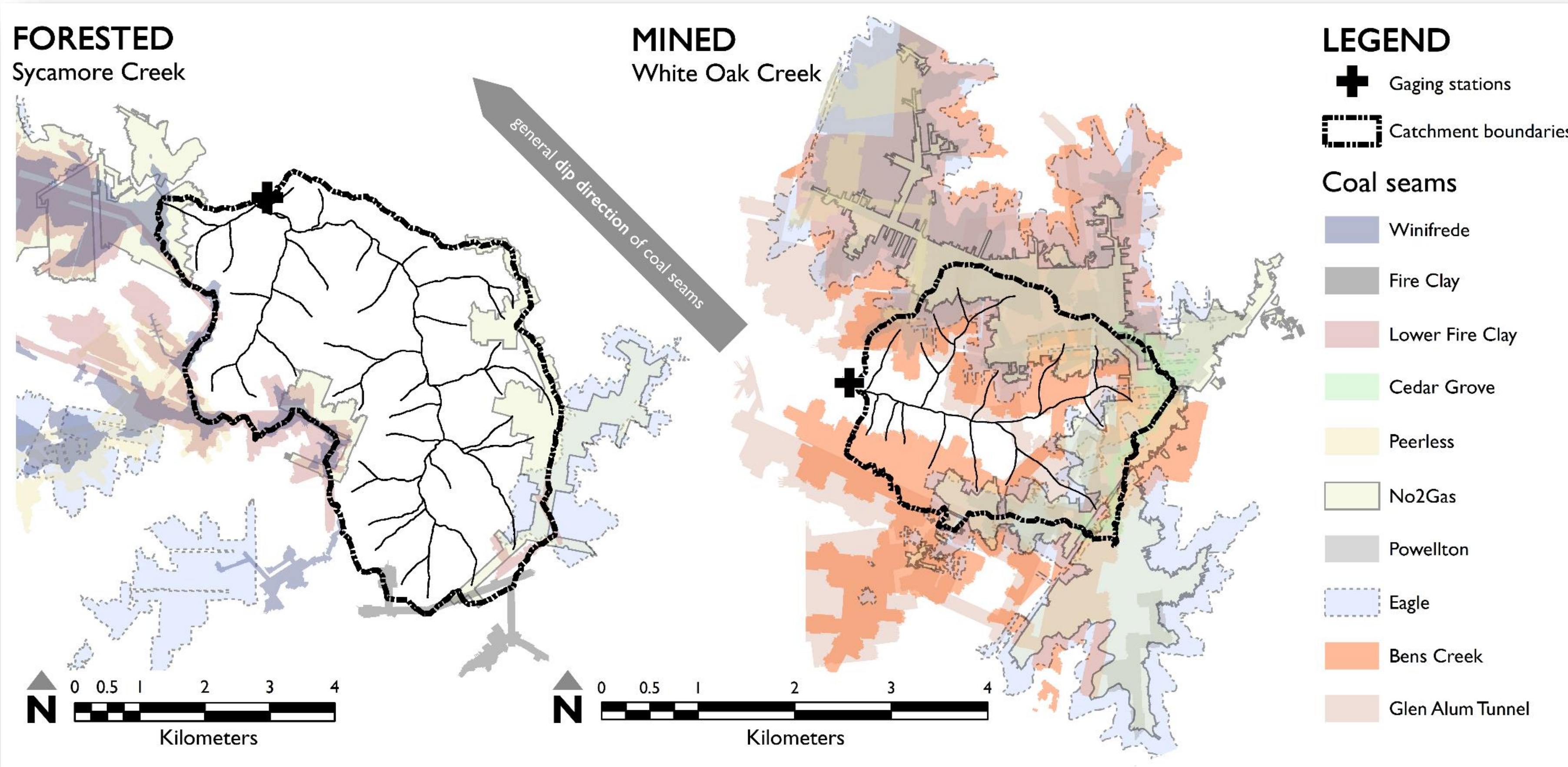
- MTM occupy ~9% of the Big Coal River watershed; 84 VF's occupy less than one-half percent (~6 km^2) of basin;

- Decreases in variability and increases in baseflows were similar to a study conducted at the headwater-scale;





SYCAMORE CREEK
WHITE OAK CREEK
CLEARFORK RIVER
50
Miles
2,000 1,000 0 2,000 4,000 6,000 8,000
Feet
Legend
Stream Gage / Precipitation Collection
Underground Mining Permit Boundary
3,000 4,000
Feet
Valley Fills


FORESTED
Sycamore Creek
MINED
White Oak Creek
general dip direction of coal seams
LEGEND
Gaging stations
Catchment boundaries
Coal seams
Winifrede
Fire Clay
Lower Fire Clay
Cedar Grove
Peerless
No2Gas
Powellton
Eagle
Bens Creek
Glen Alum Tunnel
N
0 0.5 1 2 3 4
Kilometers
N
0 0.5 1 2 3 4
Kilometers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Review

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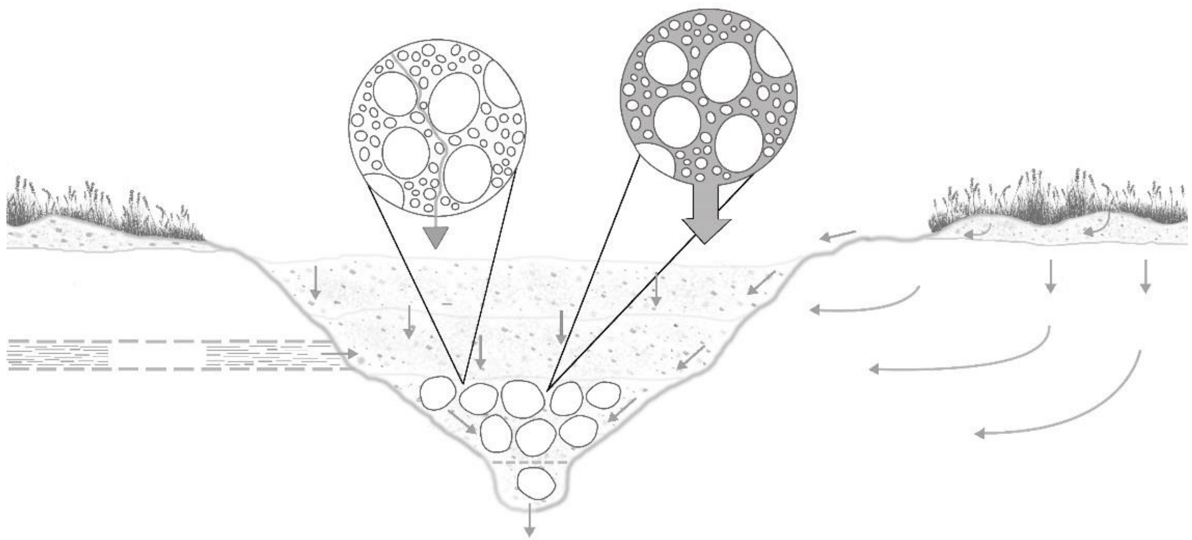
Keywords: mountaintop removal mining; valley fills; streamflow; hydrology; Appalachians; surface coal mining

Final thoughts

Valley fill hydrology still uncertain but results suggest VF's potentially regulate hydrology across spatial & temporal scales;



Final thoughts

- Potential benefits of flood dampening at larger scales;
- VF storage implies forced contact time with coal bearing chemistry; implications for water quality at local & downstream scales;
- Multiple long-term watershed studies to understand hydrologic variability & influence of mine and VF structure, age, and stage of reclamation; & legacy disturbances;
- Process studies using geochemistry & isotopes at VF & watershed scales would be helpful to understand hydrologic processes and to inform reclamation and function.