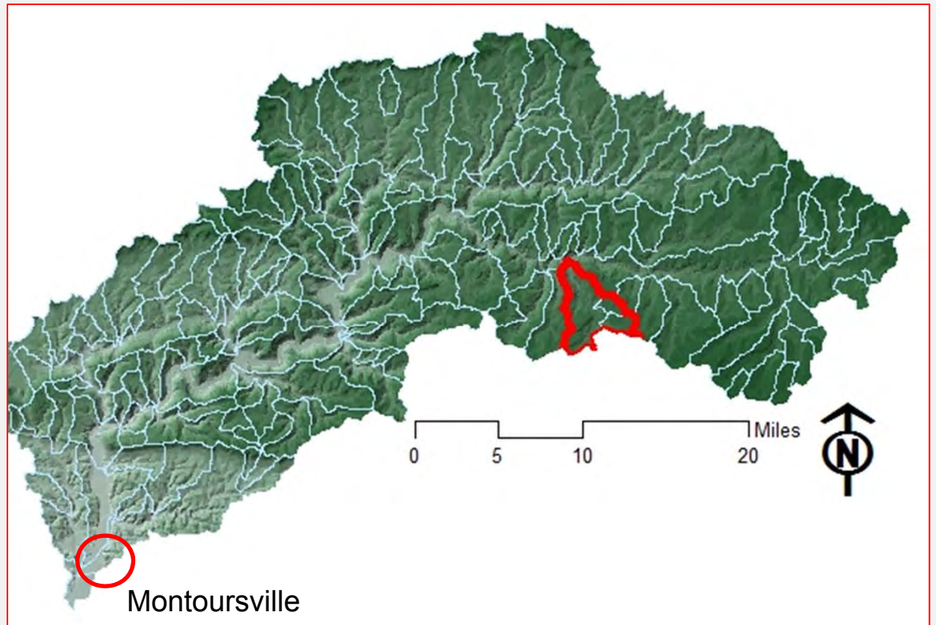
FLOODING RISKS OF GAS DEVELOPMENT

A study of the Loyalsock Creek Watershed and a focused study of Lake Mokoma Watershed

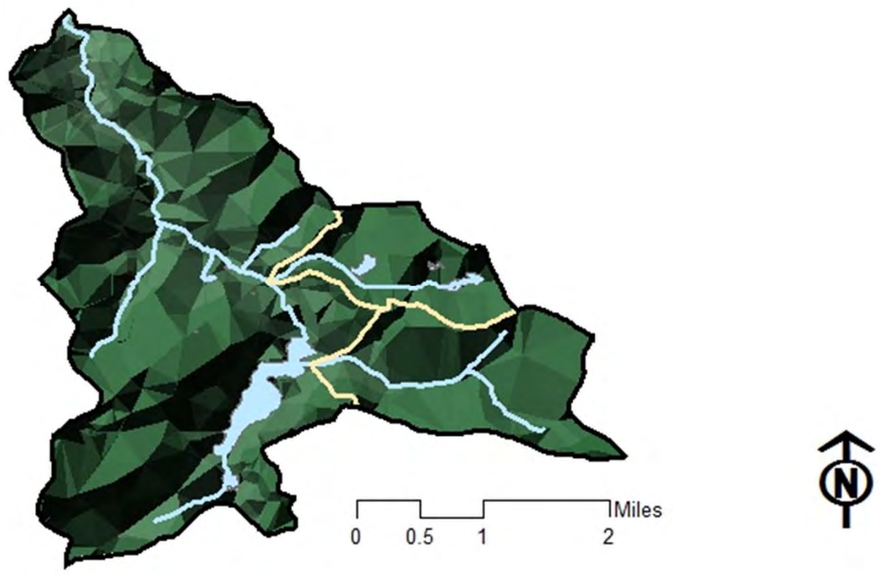
By Elliot Shibley and Emily Carlson

IMPACTS OF LAND-USE ON FLOODING

Loyalsock Creek Watershed



Lake Mokoma Watershed



What does land-use have to do with flooding?

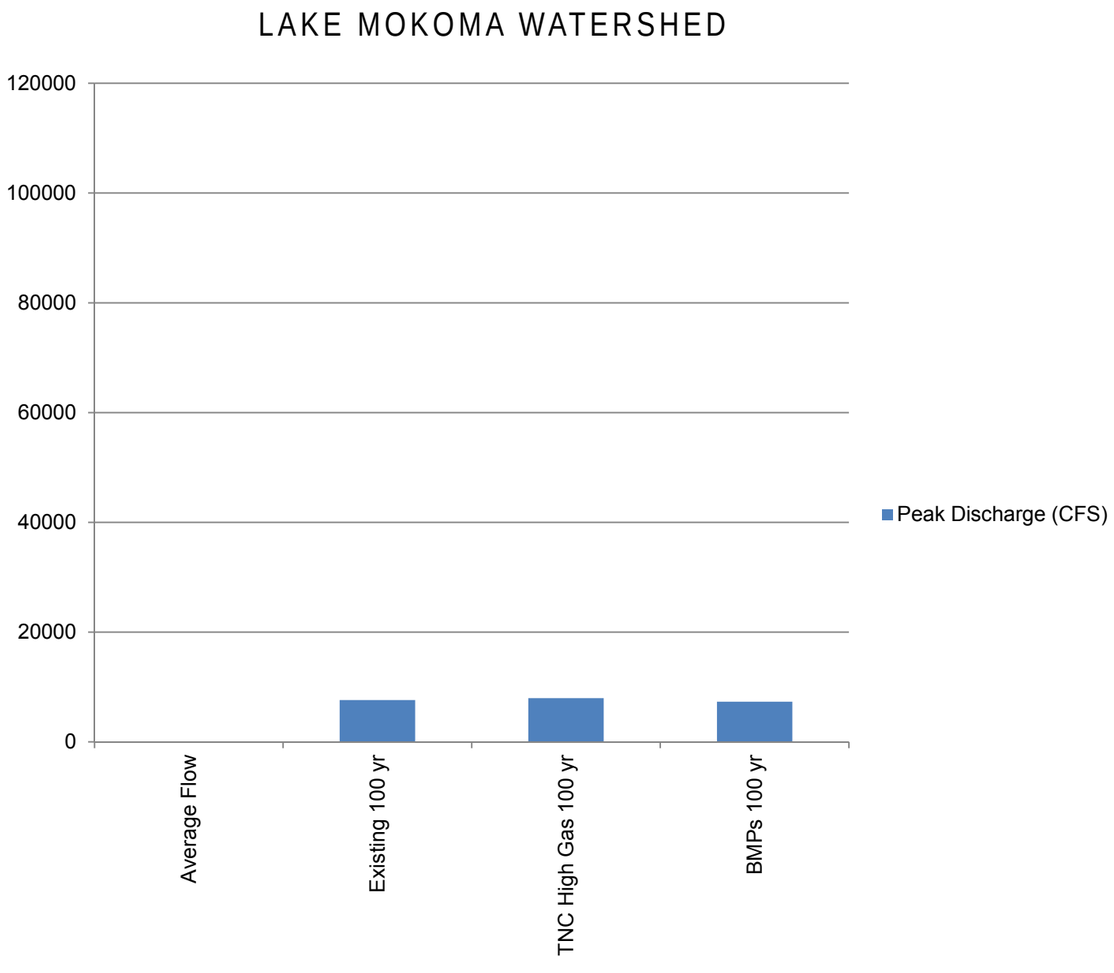
As impervious surfaces increase in a watershed, the land has less ability to slow and absorb stormwater, which protects downstream areas from flooding. Unconventional gas drilling is drastically changing the land-use of rural areas, with drill pads, soil compaction of roads and pipelines, as well as increased urban development. Increase in impervious surfaces has a more drastic impact on flooding than even global climate change (Feyen et. al. 2009).

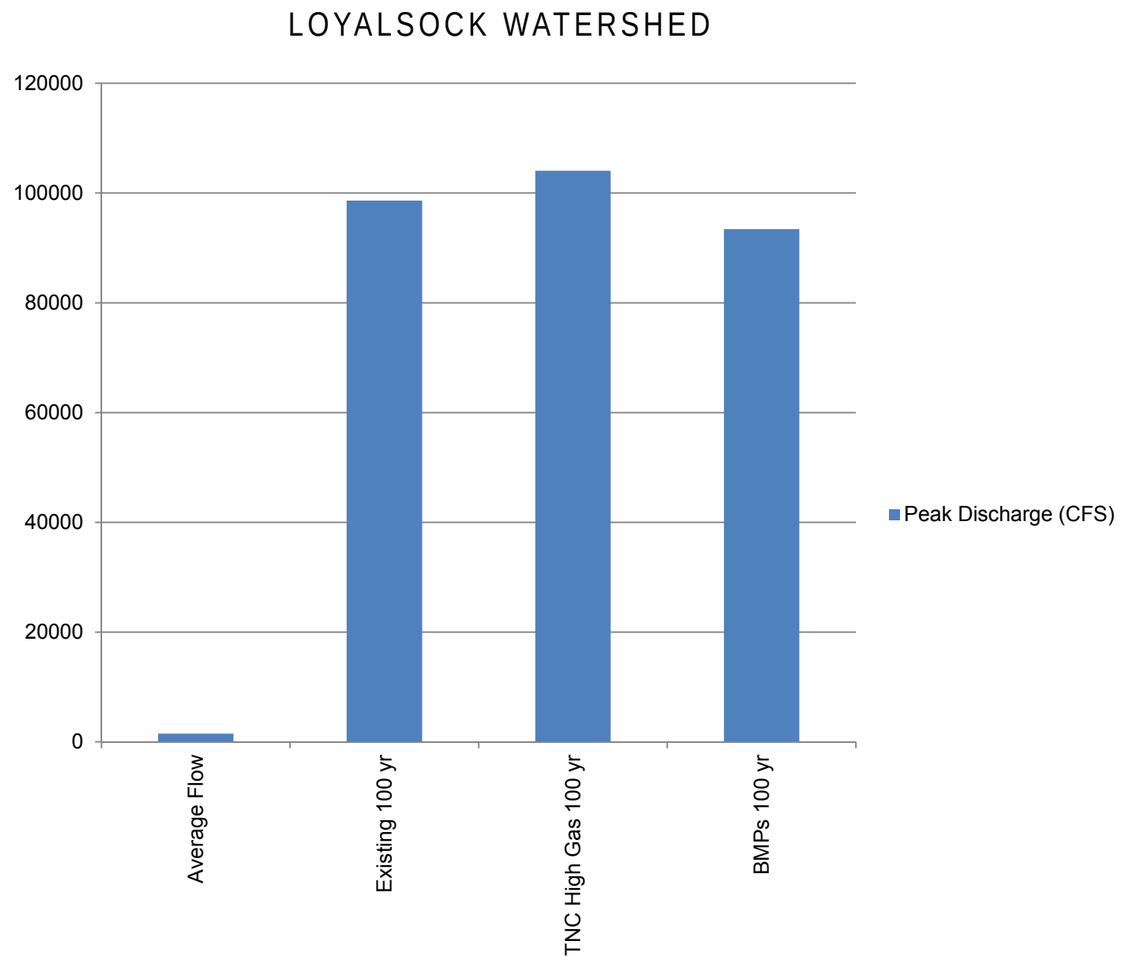
The goal of this project is to develop an interactive set of graphics rendered from sound research and surface water modeling projections, which will engage landowners, decision-makers, and even gas industry representatives in the implications of gas development on water quantity and floodplains. The audience will be able to understand how surface water quantity will change with varying intensities of gas development, as well as how suggested interventions might ameliorate potentially tragic outcomes.

Small scale watershed management is necessary for flooding mitigation downstream.

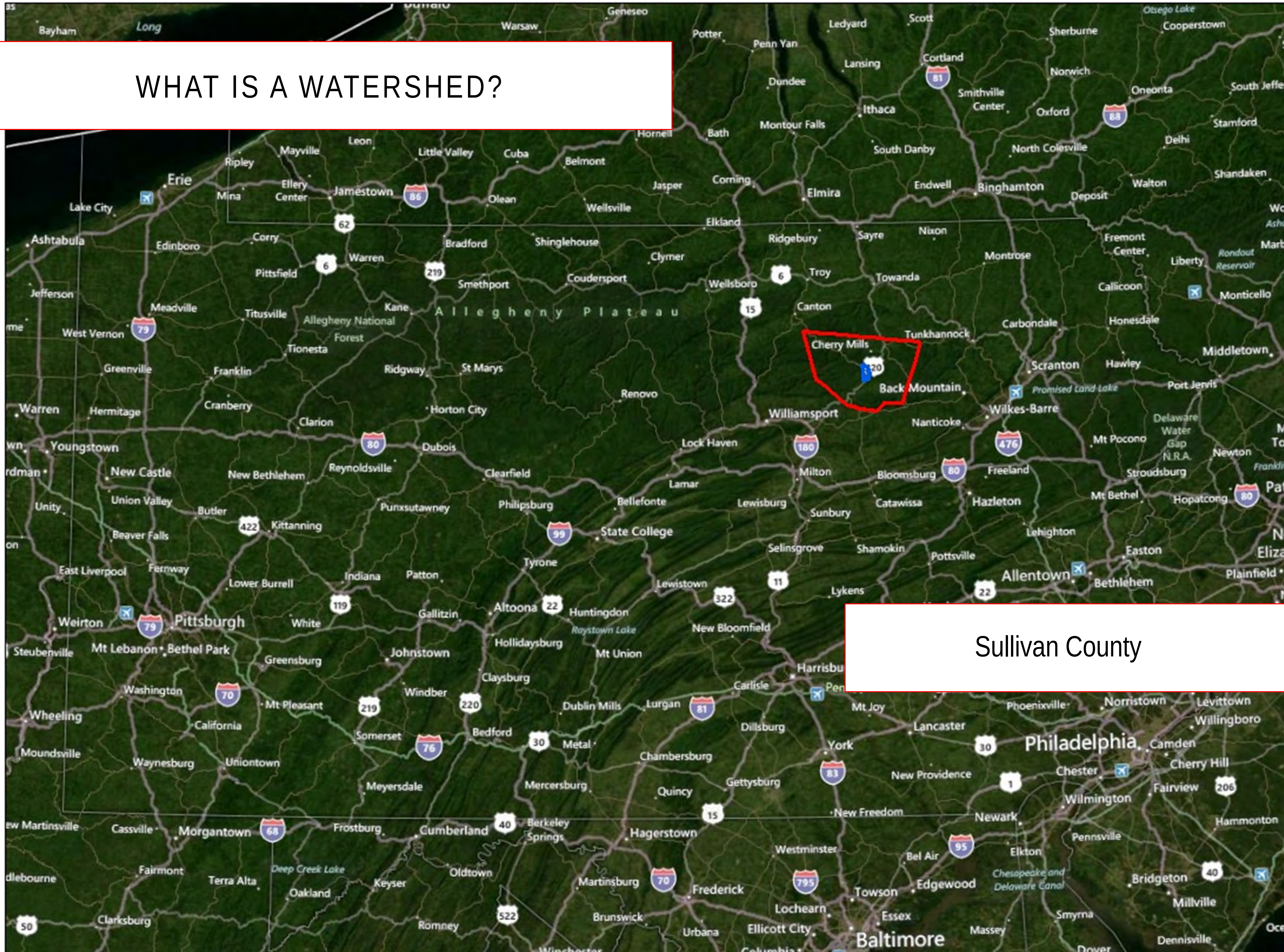
Lake Mokoma watershed is nested within the Loyalsock Creek watershed. After looking at Lake Mokoma watershed's change in flow, we realized that the larger effects downstream would require a larger watershed approach. By focusing on the Loyalsock Creek Watershed, where gas development is accelerating in the heavily-forested headwaters and the downstream area is well-populated and already experiencing flooding issues, a projected flood study can serve to guide decisions on how gas development proceeds.

FLOW DATA BY WATERSHED





WHAT IS A WATERSHED?



Sullivan County

WHAT IS A WATERSHED?

wa·ter·shed

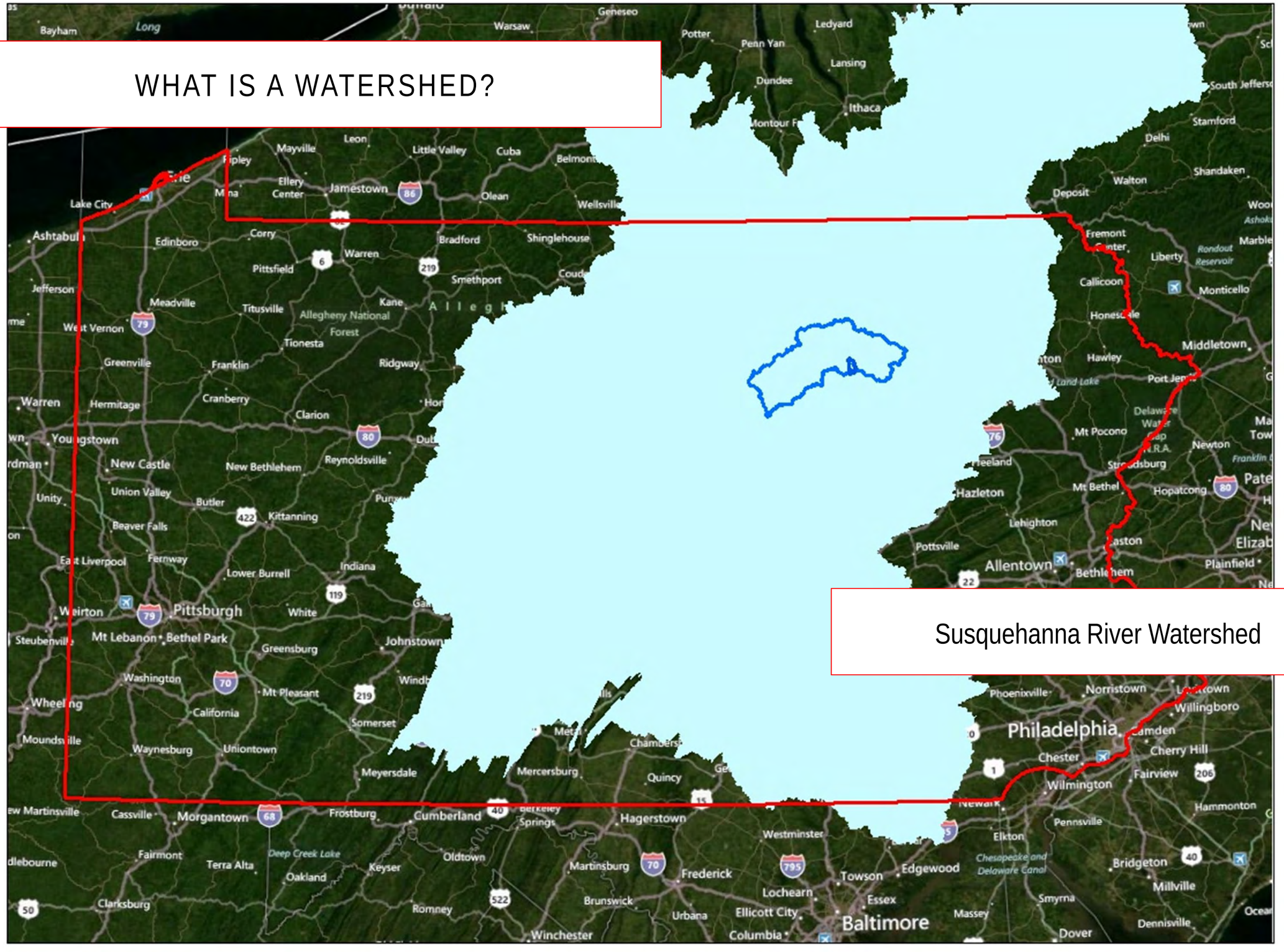
/ˈwôtərˌSHed/

Noun

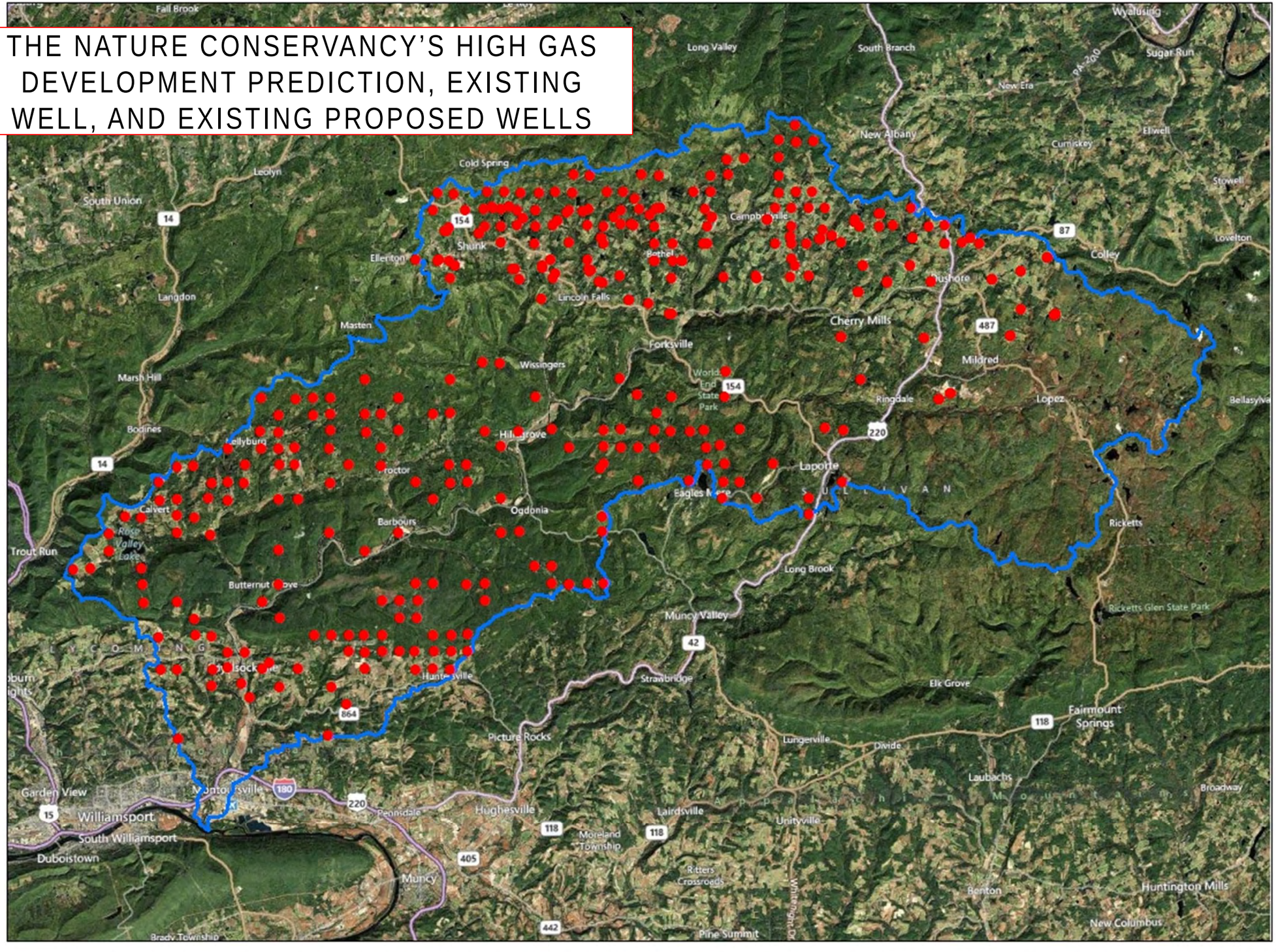
1. An area or ridge of land that separates waters flowing to different rivers, basins, or seas.
1. An area or region drained by a river, river system, or other body of water.

Loyalsock Creek Watershed

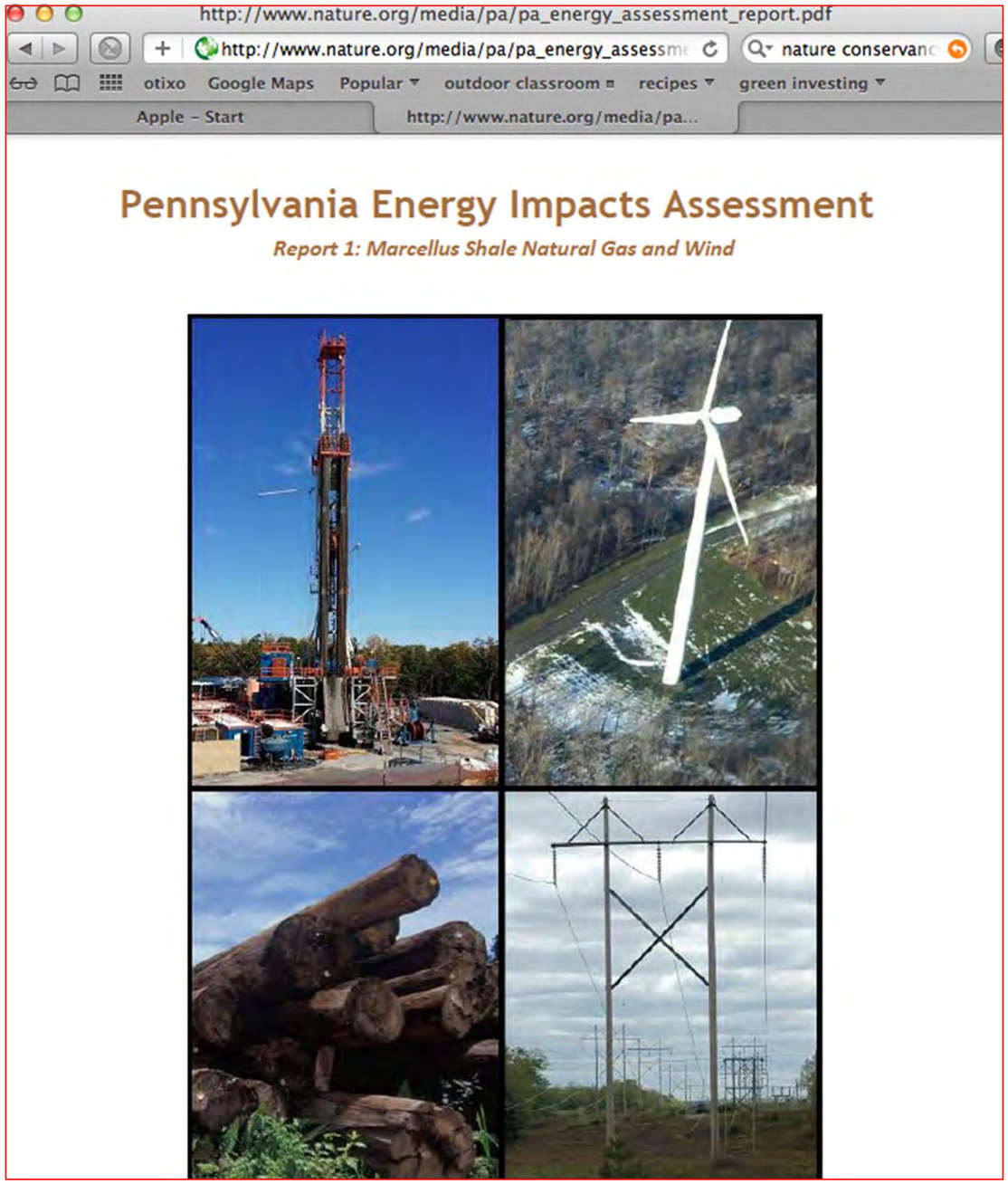
WHAT IS A WATERSHED?

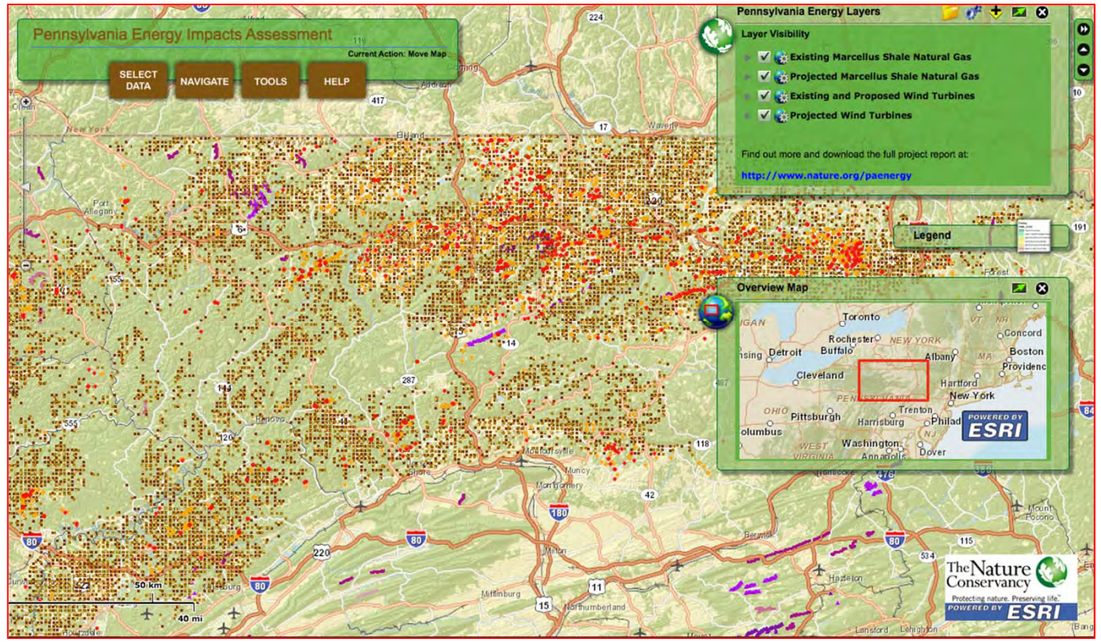


THE NATURE CONSERVANCY'S HIGH GAS DEVELOPMENT PREDICTION, EXISTING WELL, AND EXISTING PROPOSED WELLS



THE NATURE CONSERVANCY



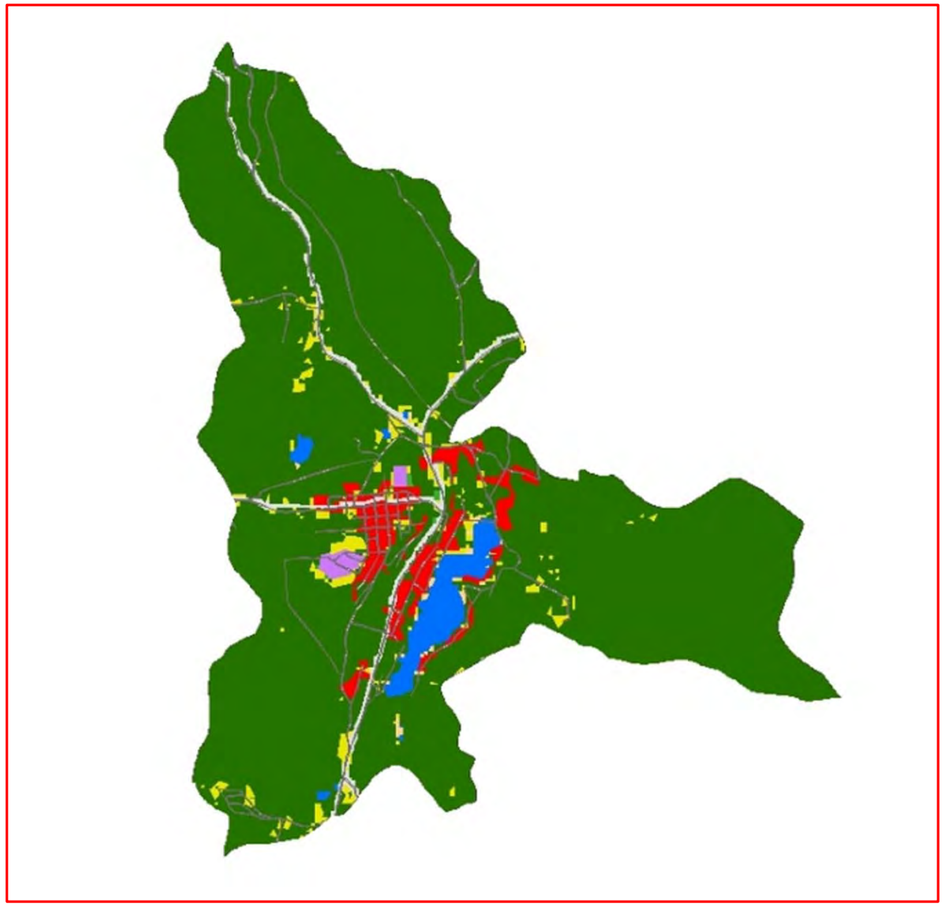


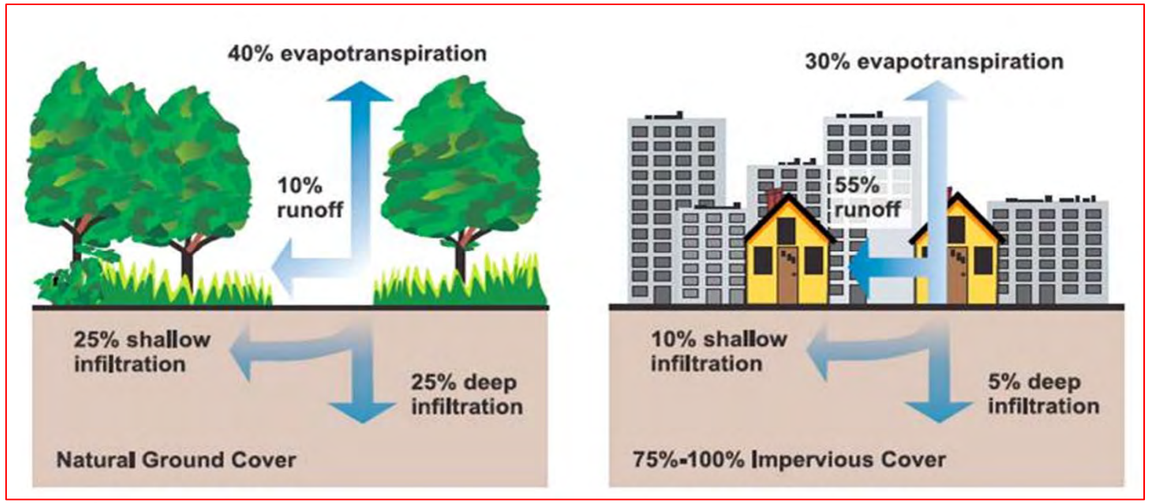
The Nature Conservancy conducted the Pennsylvania Energy Assessment in order to track the impacts of Marcellus gas development on sensitive habitats, so that better planning could be implemented to protect ecologically precious tracts of land.

They produced scale projections for low, medium, and high Marcellus gas, wind, and wood biomass as well as the location of the transmission line development might occur based on existing projections and data from credible sources.

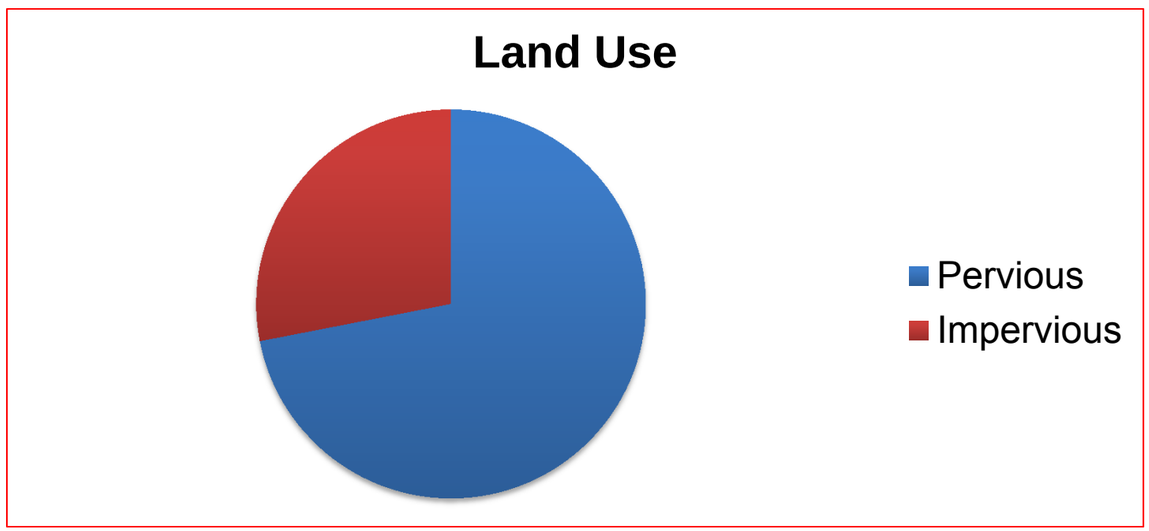
http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/pennsylvania/explore/the-energy-equation.xml

LAKE MOKOMA WATERSHED EXISTING LAND USE

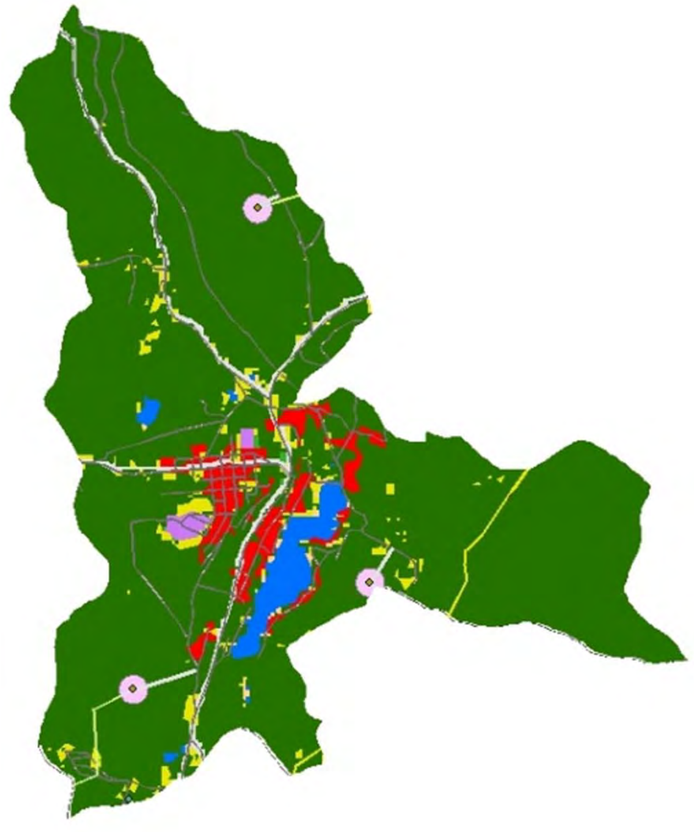


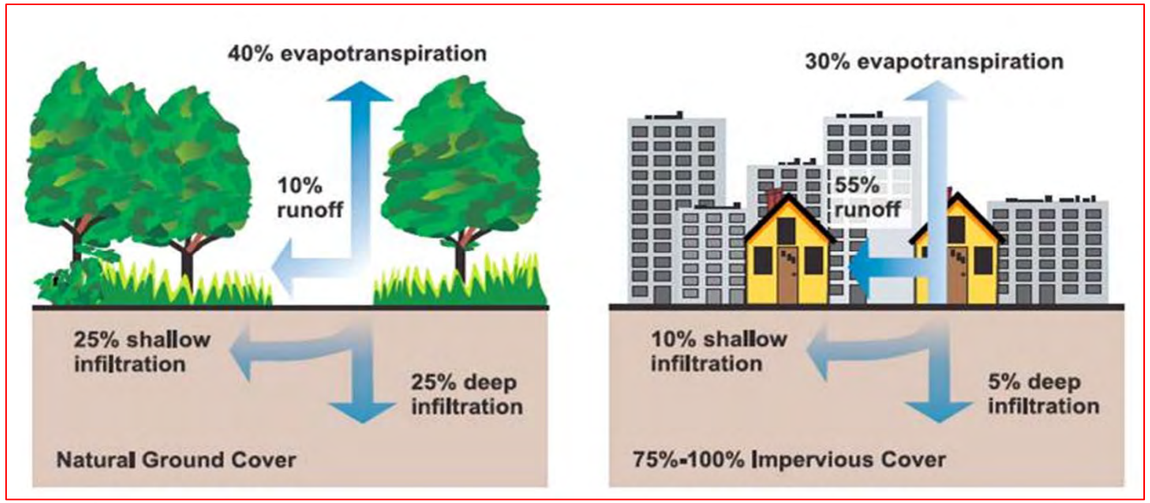


More natural than urban

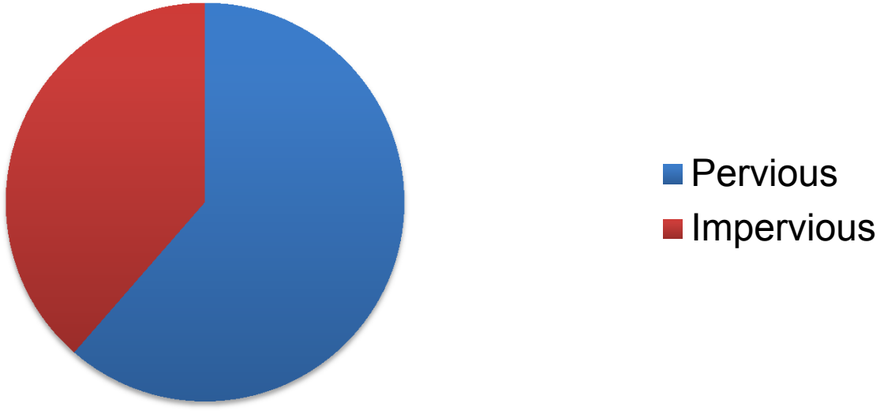


LAKE MOKOMA WATERSHED WITH HIGH GAS DEVELOPMENT



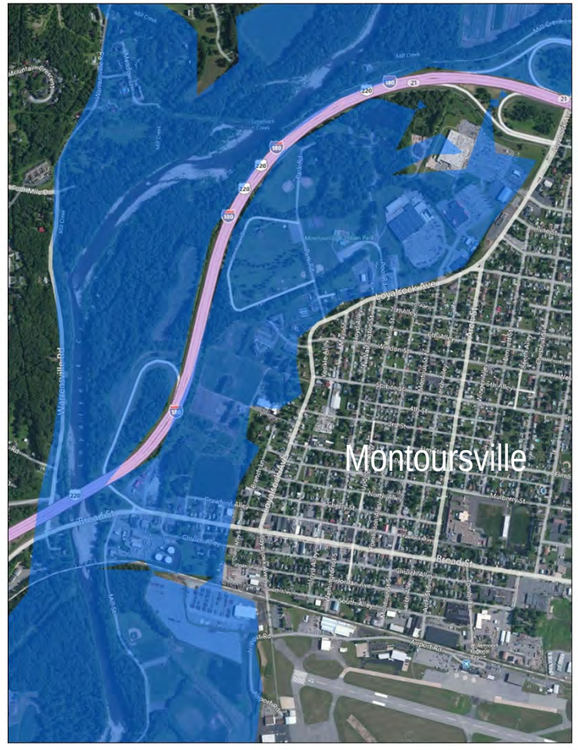


Moving towards urban

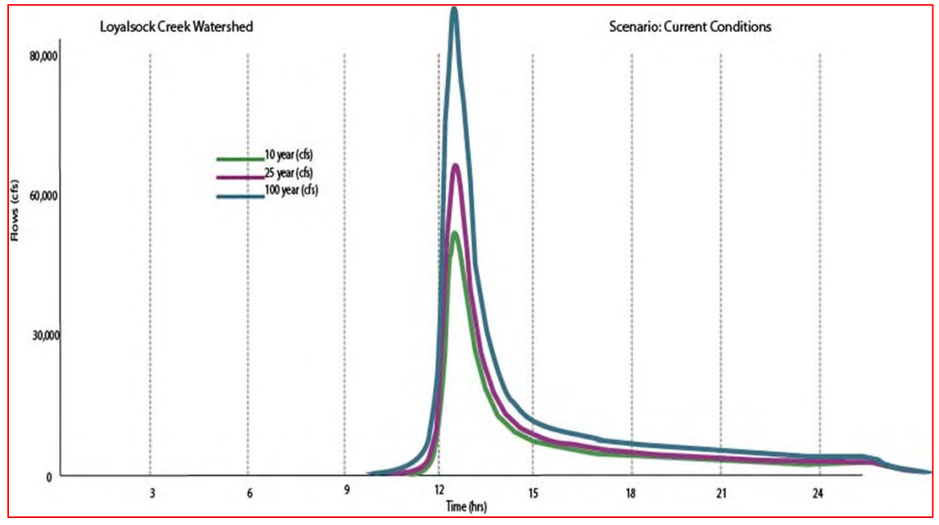


FLOODING ANALYSIS

LAND-USE: Existing (NO GAS)



Floodplain

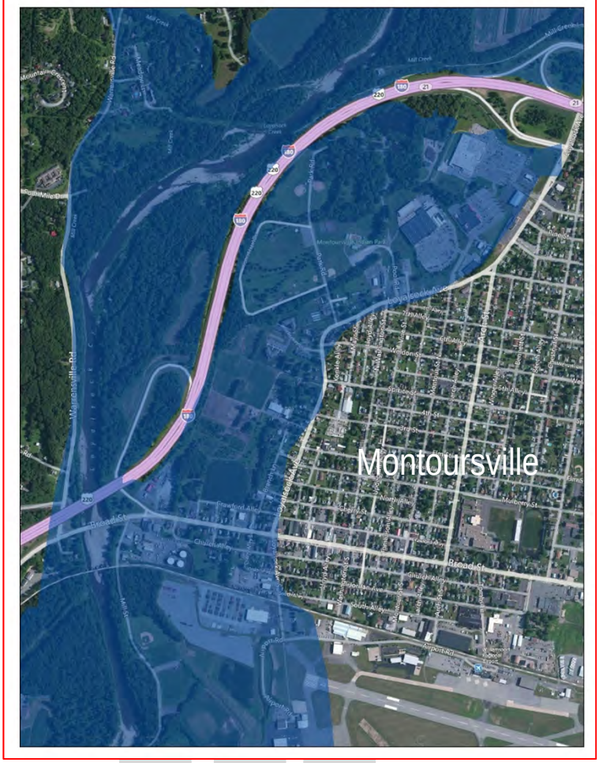


Hydrograph

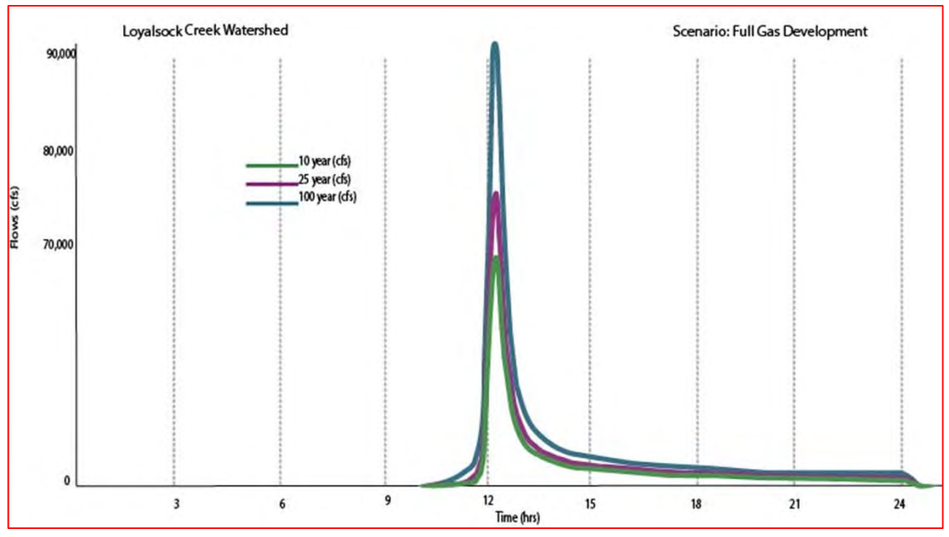
Perspective

FLOODING ANALYSIS

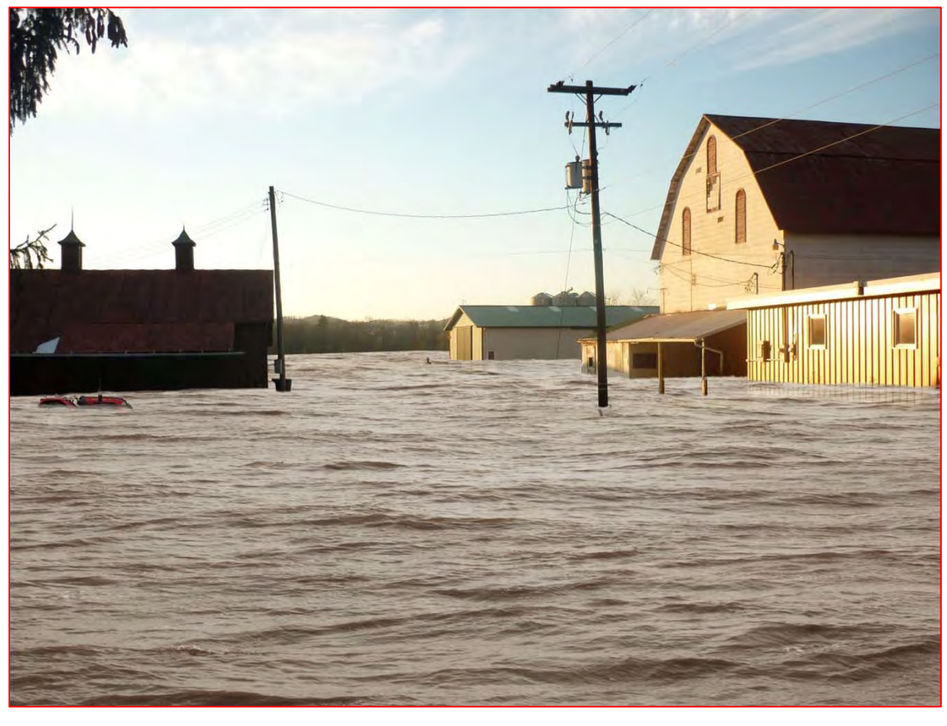
LAND-USE: TNC High Gas



Floodplain



Hydrograph

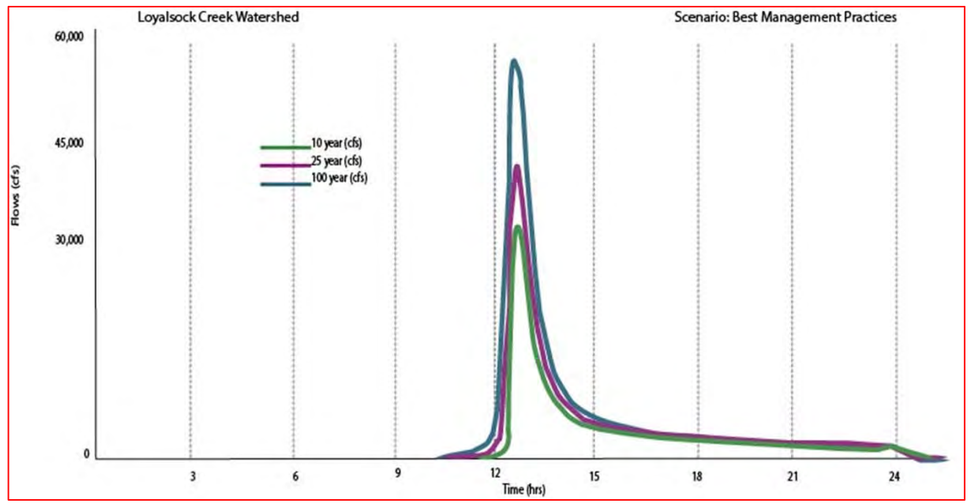


Perspective

FLOODING ANALYSIS

LAND-USE: BMPs Implemented

Floodplain

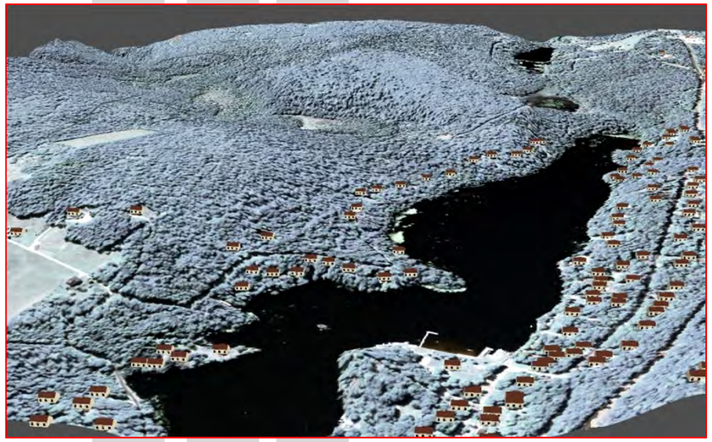


Hydrograph

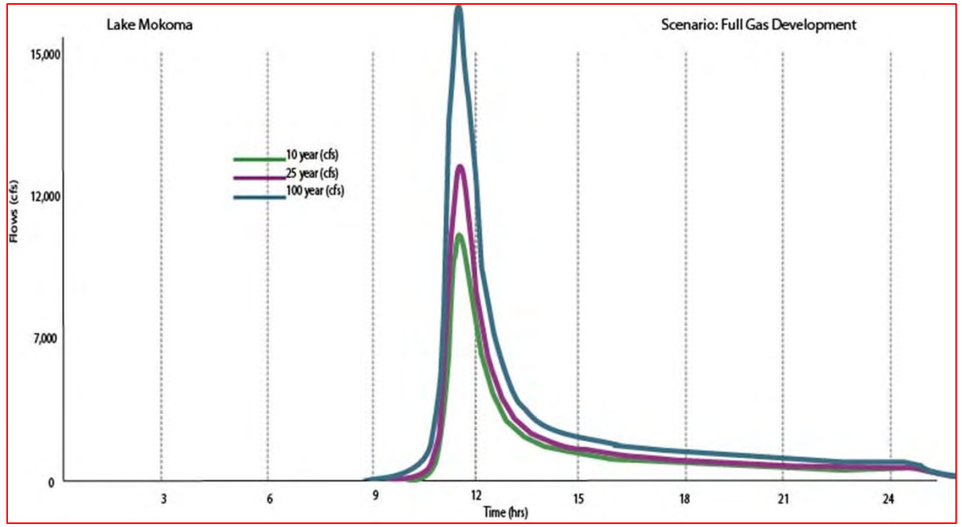
Perspective

FLOODING ANALYSIS

LAND-USE: Lake Mokoma Scale
No prominent changes



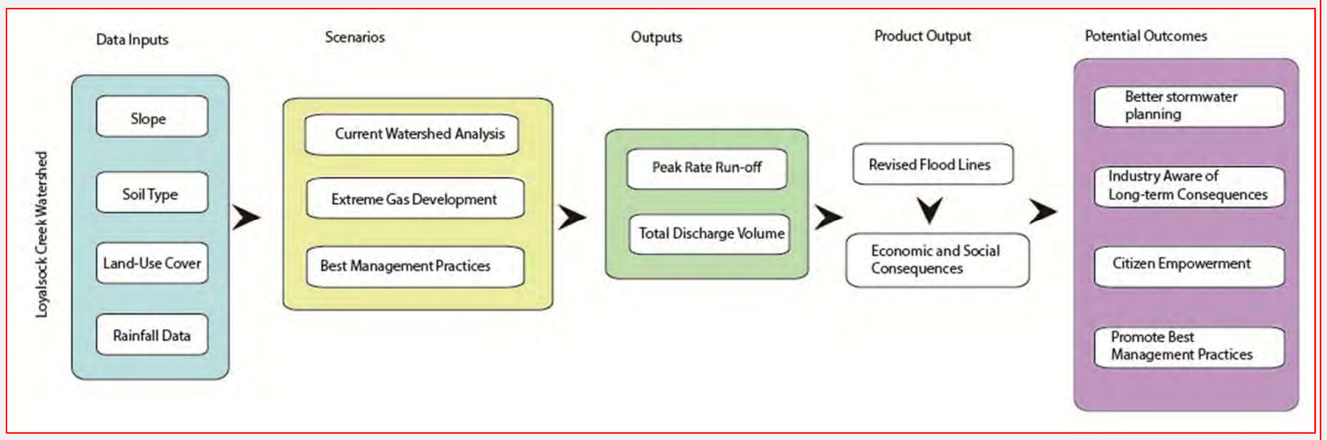
Floodplain



Hydrograph

Perspective

FLOODING ANALYSIS



Scenario Break-down:

1) Existing Conditions

   Curve Number of 66 : accounts for current land-cover and flow

2) Full Gas Development: 738 wells.

   Curve number of 67: accounts for decrease in pervious acreage due to new access roads, well-pads, deforested pipeline area

3) Full Gas Development with watershed-wide Best Management Practices

   Curve Number of 65, accounts for:

   1) new access roads gravel, 18' wide right of way, with crown, and swales on each side

   2) Pipelines planted with dense grass to reduce run-off (rate and amount)

   3) Bio-Retention Ponds: reduce flow, increase evaporation

   4) No-mow fields and Riparian Buffers: implemented on farm edges and riparian zones to increase absorption, decrease run-off rate.

   5) Retro-fit existing local roads with curb-cuts into swales

   6)French drains installed in residential areas

Supporting Materials:

Analyzing Data: Work Flow

1) Compiling GIS layers (Land use, Hydrography, Soils, Slopes, Buildings, Streams, Small Watersheds)

2) Code soils, land-use, and stream slope/length, according to TR-55 criteria

3) Input data into WINTR-55 for each watershed hierarchy and for a 10yr, 25yr, and 100yr storm

   Scenario 1) existing conditions

   Scenario 2) full gas development according to Nature Conservancy's projections plus pipeline projections (from Megan and Danielle) and Ryan's road width and length projections.

   Scenario 3) Best Management Practices: full gas development + smart planning

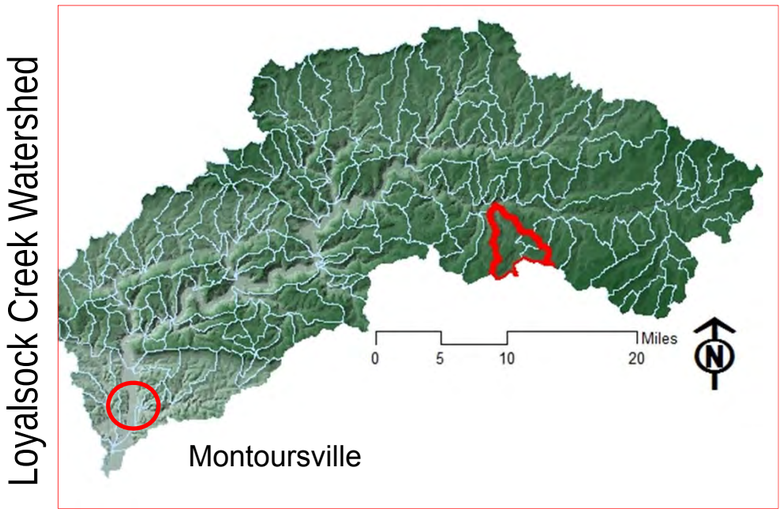
4) Run watershed level 3 (Loyalsock core watershed) calculations manually due to WINTR-55 acreage limitations and compare to existing USGS flow data as a control.

5) Derive final peak discharge for mouth of Loyalsock Creek by interpolating differences between 80-year storm found in the Sullivan County Flood Study and current conditions

6) In ArcMap, designate new floodplains according to stream elevations perpendicular to contours.

7) Analyze possible damage (inundated buildings) and calculate economic impact.

FLOODING ANALYSIS



Supporting Materials:

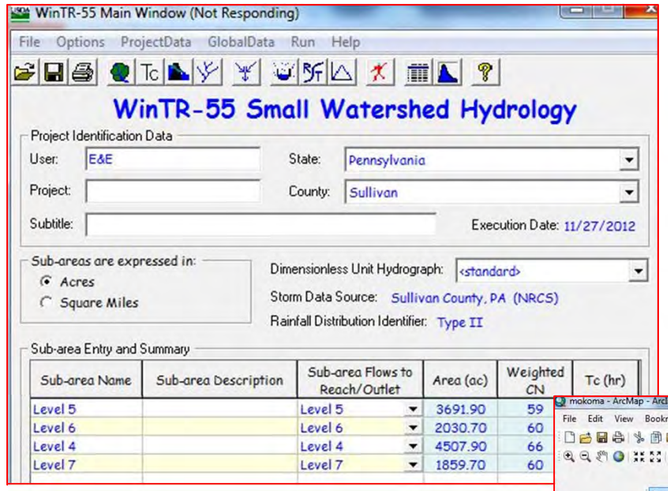
Background

The land of the “Endless Mountains” holds an important cultural and economic place in the Mid-Atlantic region. An area rich in natural and cultural resources, this rural landscape is positioned to reap the economic benefits of a booming industry, but the vulnerability of social and landscape change needs deliberate consideration.

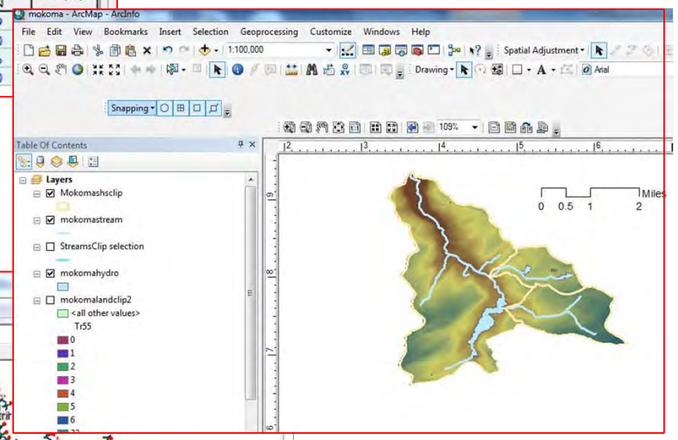
The local issues seem endless: health impacts, viewshed and noise pollution, existing road damage, new road construction impacts, increased income disparity, fragmented habitat, increased flooding potential, rapid economic development, boom & bust phenomena… The list could go on for pages, that examining the larger scale impacts like greenhouse emissions and inhibiting the alternative energy market seems behold the scope of feasibility (Jiang et al. 2011). Preventing and remediating the potential impacts on water resources are of utmost importance (Rahm et al. 2012). Possible vehicles for water contamination are drilling and fracturing, transporting liquids, drilling site leaks and spills, and the especially precarious, wastewater treatment (Rozell et al. 2012). The drilling infrastructure itself has the potential to drastically alter the ability of the watershed to provide core forest habitat and protect human settlements from increased flooding (Droham et al. 2012). Although the environmental impacts draw the most immediate attention, the less obvious, community and cultural impacts deserve thorough consideration as well.

The need to look closely at surface-water quantity arises from the latent threats of flooding as well as the increased surface water run-off that attributes to sedimentation and water contamination. In light of last year’s hurricane Lee that resulted in devastating flooding of the Loyalsock Creek in central Pennsylvania, understanding the processes that govern water quantity in quickly changing watersheds is imperative. Not only does flooding wreak economical havoc on a community, but the long-term health impacts of moisture and mold in buildings pose economic threats as well (Mudarri et. al 2007). By decreasing forest cover and increasing impervious (and less pervious) surfaces in small sub-watersheds, increases to the surface water flow are inevitable. In a resource extraction industry that has yet to be thoroughly studied, expertise must be pulled from other land-use area changes and hydrologic models in order to develop new, engaging models which will inform the decisions of those most impacted by these drastic changes.

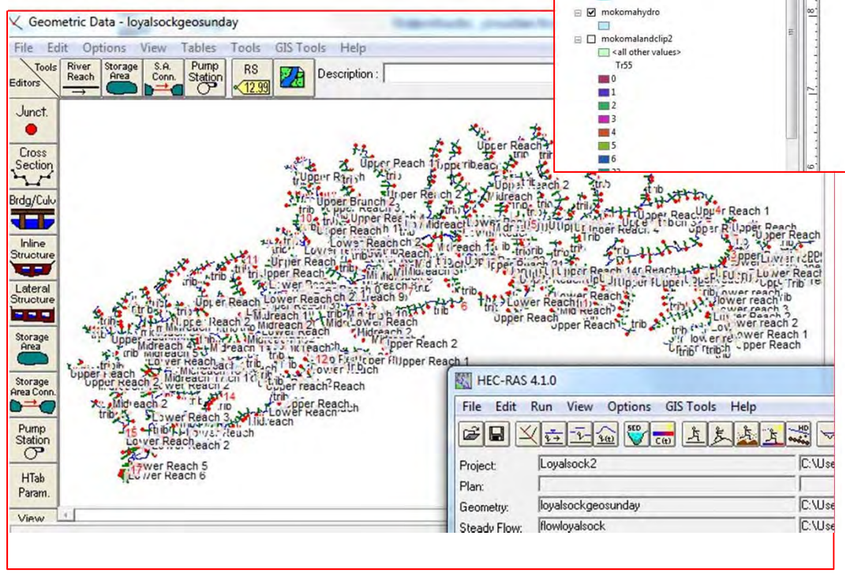
FLOODING ANALYSIS



WinTR55



ArcMap GIS



Hec-Ras

Supporting Materials:
Tools

ArcMap GIS: allows us to compile, sort, and analyze geographic data within the watershed

TR-55: The Natural Resource Conservation Service (NRCS) TR-55 method is one of the most widely used model for small watershed analysis (ODOT manual 2007). The manual for the TR-55 method (USDA's Urban Hydrology for Small Watersheds), provides thorough and clear instruction on the parameters and specific inputs necessary for using the method. Numerous watershed studies have tested this method through the years (Reilley et. Al 2004, Cesur 2007, Harbor 2003). Although the method was developed with small urban watersheds in mind, it is equally applicable to small rural watersheds and has been utilized many times as such.

WINTR55: Free software available from the NRCS website which processes data inputs and calculates hydrographs and flow data according to TR-55 method. Once its limitations were known, 10 sub-watershed max, and 16,000 acre max), averages of landcover and soils were made about the sub-watersheds (131) according to their watershed hierarchy in order to work within TR-55's parameters. TR-20 was thoroughly considered since it is intended for analyzing larger watersheds, but critical data inputs are missing (seasonal flow).

Hec-Ras & HEC-GeoRas: HEC-Ras is a free software program available on the US Army Corps of Engineer's website, as well as the HEC-GeoRas plug-in, which allows for GIS interface collaboration. In theory, Hec-Ras would allow us to project new floodplain lines according to the flow data from TR-55 along with the 3D cross-sections produced from ArcMap's Digital Elevation Model (DEM or TIN). Although much progress was made in preparing the data for HEC-Ras input, complex errors and general unfamiliarity with the software prohibited progress.

FLOODING ANALYSIS

Supporting Materials:

Historic Flooding in Montoursville

Located at the mouth of the Loyalsock Creek, Montoursville is especially vulnerable to surface water quantity changes in the watershed. On September 8th,2011, the town experienced its worse flood even from Hurricane Lee; the creek rose almost 20 feet, inflicting much economic damage on the area. The landcover changes upstream will have the most impact on this town, which is why we chose it as our focus.

Historical Floods: Loyalsock Creek at Loyalsockville

Period of Record: 1926-Present

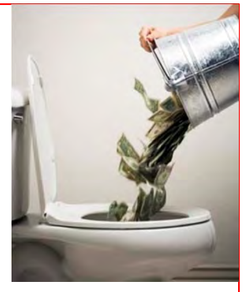
Last Flood: 9/8/2011

Date of Flood	Crest (ft)	Streamflow (cfs)	Category	Code
11/16/1926	12.30	30,500	Minor	none
8/24/1933	12.20	29,800	Minor	none
5/28/1946	12.20	29,800	Minor	none
11/26/1950	12.32	30,500	Minor	none
6/23/1972	14.74	47,900	Major	none
9/26/1975	14.50	46,000	Major	none
2/1/1982	12.45	-9,999	Minor	(1)
12/14/1983	12.18	29,700	Minor	none
8/29/1988	12.41	28,600	Minor	none
1/19/1996	17.93	55,800	Major	none
1/27/1996	12.18	20,000	Minor	none
9/18/2004	15.24	40,400	Major	none
1/25/2010	14.18	34,800	Major	none
3/11/2011	12.34	25,900	Minor	none
9/8/2011	19.78	69,100	Major	none

http://www.erh.noaa.gov/marfc/Rivers/FloodClimo/Pointfloods/Wbs/Loyalsockville-WBS-%20PointFloods-Table.pdf

FLOODING ANALYSIS

Expenses of Flood Damage



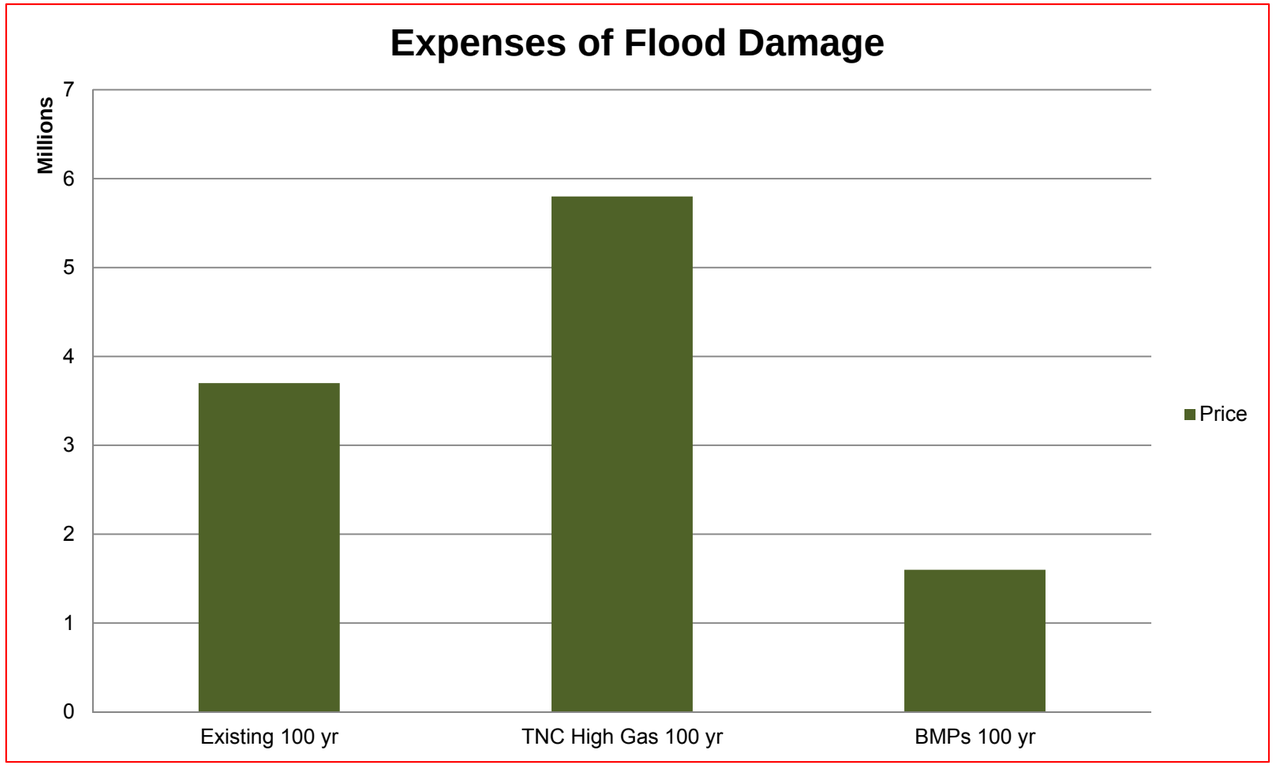
EXISTING: ~$3.7 Million

HIGH GAS DEVELOPMENT: ~$5.8 Million

BMP: ~$1.6 Million

ANNUAL REVENUE PRODUCED BY ALL OF THE WELLS IN LOYALSOCK WATERSHED: ~$16.5 Million

http://www.floodsmart.gov/floodsmart/pages/flooding_flood_risks/the_cost_of_flooding.jsp



Supporting Materials:

Tallying the damages of flooding

Once the new floodplains were projected, we could look at where the different levels intersected with existing buildings. By using the flood-smart calculator, we were able to estimate economic damages for each gas development scenario.

We based our damage estimates on: a 100-year flood, in a 2,000 square foot house, with 6inches of flooding (of course this would be higher in houses closer to the creek, multiplied by number of buildings intersecting with projected flood plains.

Expenses of Flood Damage

These numbers are produced from the National Flood Insurance Program and represent the damage done to houses assuming 2,000 sq ft, and assuming that all buildings are residential homes. This number does not factor in damage done to infrastructure, shops, or vehicular damage.

LOCAL STORIES

"According to Kathy, her husband coped with the loss of the house by going there every day to clean it up. On one occasion, while work was being done on the house, it began to shift and cracks appeared in the walls.

"We were actually in the house when they yelled for us to get out," Kathy said.

http://www.sungazette.com/page/content.detail/id/583056/A-trying-year-for-1-family-who-returned.html

"Trapped and helpless inside their own home, the Rungs spent the night upstairs with the sound of floodwaters wreaking havoc downstairs.

"The refrigerator and freezer - everything on the first floor was upset," Robert Rung said. "You could hear dishes breaking. There were sounds that you didn't know what it was."

Asked if he was frightened, Rung said, "You'd better believe it."

http://www.sungazette.com/page/content.detail/id/582986/Trapped-in-home--couple-spent-harrowing-night-riding-out-storm.html

"We started to put things up because we thought it would be like 1996," Carey said. "We put things on high shelves. Never in my wildest dreams did I expect the water to reach the ceiling."

It did reach the ceiling, however, and ripped away an addition the Careys built to accommodate a master bedroom, hot tub and bathroom. An enclosed porch facing the creek was washed away and a section of roof was torn off the house.

http://www.sungazette.com/page/content.detail/id/583057/Woman-calls-it-quits-after-living-30-years-along-the-Loyalsock.html

LOCAL STORIES

Video Collage of Montoursville Flood Damage 2011

http://youtu.be/2BIkdRkBJ80

FLOODING ANALYSIS

- Cesur, Durmus. "GIS as an information technology for water modeling." *Journal for Hydroinformatics*. 9. no. 2 (2007): 123-133.
- Susanna T.Y. Tong, Wenli Chen, Modeling the relationship between land use and surface water quality, Journal of Environmental Management, Volume 66, Issue 4, December 2002, Pages 377-393, ISSN 0301-4797, 10.1006/jema.2002.0593. (http://www.sciencedirect.com/science/article/pii/S0301479702905931)
- Mudarri, D., and W.J. Fisk. "Public health and economic impact of dampness and mold." *Indoor Air*. 17. (2007): 226-235.
- Reilly, James, Patricia Maggo, and Steven Karp. "A model to predict impervious surface for regional and municipal land use planning purposes." *Environmental Impact Assessment Review*. 24. (2004): 363-382.
- *Oregon Department of Transportation Hydraulics Manual*. Portland, OR: 2005. http://library.state.or.us/repository/2010/201008091625501/part1.pdf (accessed September 25, 2012).
- *Urban Hydrology for Small Watersheds: TR-55*. United States Department of Agriculture, 1986.

Supporting Materials:

Bibliography

- Rozell, Daniel J., and Sheldon J. Reaven. "Water Pollution Risk Associated with Natural Gas Extraction from the Marcellus Shale." *Risk Analysis*. 32. no. 8 (2012): 1382-1393.
- Drohan , P.J, M. Brittingham, J. Bishop, and K. Yoder. "Early Trends in Landcover Change and Forest Fragmentation Due to Shale-Gas Development in Pennsylvania: A Potential Outcome for the Northcentral Appalachians." *Environmental Management*. 49. (2012): 1061-1075.
- Kinchy, Abby J., and Simona Perry. "Can Volunteers Pick up the Slack? Efforts to Remedy Knowledge Gaps About the Watershed Impacts of Marcellus Shale Gas Development." (2012): 303-339.
- Rahm, Brian G., and Susan Riha. "Toward strategic management of shale gas development: Regional, collective impacts on water resources." *environmental science & policy*. 17. (2012): 12-23
- Harbor, Jonathan. "A practical method for estimating the impact of land-use change on surface runoff, groundwater recharge and wetland hydrology". *Journal of the American Planning Association*. 60. No. 1 (2003): 95-108.
- Park, S.W., S. Mostaghimi, R.A. Cooke, and P.W. McLellan. "BMP IMPACTS ON WATERSHED RUNOFF, SEDIMENT AND NUTRIENT YIELDS." *WATER RESOURCES BULLETIN*. 30. no. 6 (1998): 1011-1023.