# Using GIS to Evaluate Relationships between Land Use and Turbidity Loading in Streams within the John Day Watershed of Oregon

**GEOG592 - GIS II - Applications**
**Winter 2012**

Paula Hood
Evelyn Cummings
Jessica Kuonen

# Why Study Sediment Loading?

Negative impacts to designated beneficial uses:

- Water Supply
  - Public domestic water supply
  - Irrigation
  - Livestock watering
  - Hydro power
  - Industrial water supply
- Wildlife
  - Anadromous fish passage
  - Salmonid fish spawning/ rearing
- Stream channel integrity
  - Decreased bank stability
  - Increase in erosion
  - Loss of complex stream structure
- General Water Quality
  - Water contact recreation
  - Aesthetic quality
  - Commercial navigation/transportation

# Background

- High road densities and logging have been implicated in degrading stream water quality by increasing fine sediment production and delivery into streams beyond historically normal levels (Cederholm 1980, McCollough 1999).

- Recently, the 9th circuit court of appeals ruled that sediment inputs from roads into streams could be considered point source pollution (NEDC v. Brown 2010).

# Problem

- Anthropogenic disturbances to the landscape can increase sediment loading in streams
- Modeling sediment loading in streams is complicated by natural variability and by spatial autocorrelation

**Question**: How to certain land use practices influence stream turbidity loading in Western Oregon and to what degree?

# Hypotheses

- Land use will affect stream turbidity
- Geologic factors will overshadow land use relationships with turbidity
- Turbidity values will be spatially autocorrelated

# Objective

- Assess sediment loading of the John Day Watershed by examining values of turbidity in relationship to external factors (i.e., slope, road density, land use, and proximity to dams)
- "A log-linear model showed strong positive correlation between TSS and turbidity ($R2 = 0.96$)…turbidity is a suitable monitoring parameter where water-quality conditions must be evaluated" (Packman, J.J. et al, 2000)

# Identifying Independent Variables for the Model:

- Slope
- Land Cover type
- General rock type (geology)
- Road density
- Dam Density
- Stream order
- Catchment size

# Justification for independent variables

- Slope (Allan et al. 2004, Johnson et al. 2003)
- Land Cover & Land Use (Allan et al. 2004, Belsky et al. 1999, Brett et al. 2005, Pan et al. 2004)
- General rock type (geology) (Johnson et al. 2003)
- Road density (Cederholm et al. 1980)
- Dam Density
- Stream order (Johnson et al. 2003)
- Catchment size (Bolstad et al. 2007)

# Study Area: John Day Watershed


# Study Area: John Day Watershed

- Major watershed located in Central portion of Eastern Oregon.

- John Day River is most biologically diverse river in Columbia Basin: Spring Chinook, Summer Steelhead, Westslope Cutthroat, Redband Trout (Streamnet 2012)

- Over 95% of the lands within the John Day Basin are zoned for agriculture and forestry (OECO 2012).
  - Cattle and sheep ranching
  - Irrigation
  - Timber production
  - Tourism and recreation
  - Designated portions are National Wild and Scenic River

# WEMAP

- Western Environmental Mapping and Assessment Project (EPA Region10)

  "Monitor and assess the status and trends of national ecological resources"

  - Coastal Waters; Rivers and Streams
  - The Wadeable Streams Assessment:
    A Collaborative Survey of the Nation's Streams

    "First-ever statistically-valid survey of the biological condition of small streams throughout the U.S."

# Databases Utilized

- Watershed Boundaries Oregon, BLM
  - John Day Watershed
  - John Day Sub-watersheds – level 5

**The following layers were clipped to John Day Watershed boundary:**

- WEMAP sample points
  - Sampled in summer months from 2000-2003
  - Duplicates removed
- Oregon 10 m DEM
  - PSU:/I/Students/data/GIS/Oregon/DEM
- Land Use
  - National Land Cover Database
- Geology
  - DOGAMI
- Oregon Roads
  - PSU:/I/Students/data/GIS/Oregon/Roads
- Dams
  - Oregon Water Resources Department

Note:
-Not all soil data was available for the study area and therefore geology was utilized to illustrate rock/soil type.

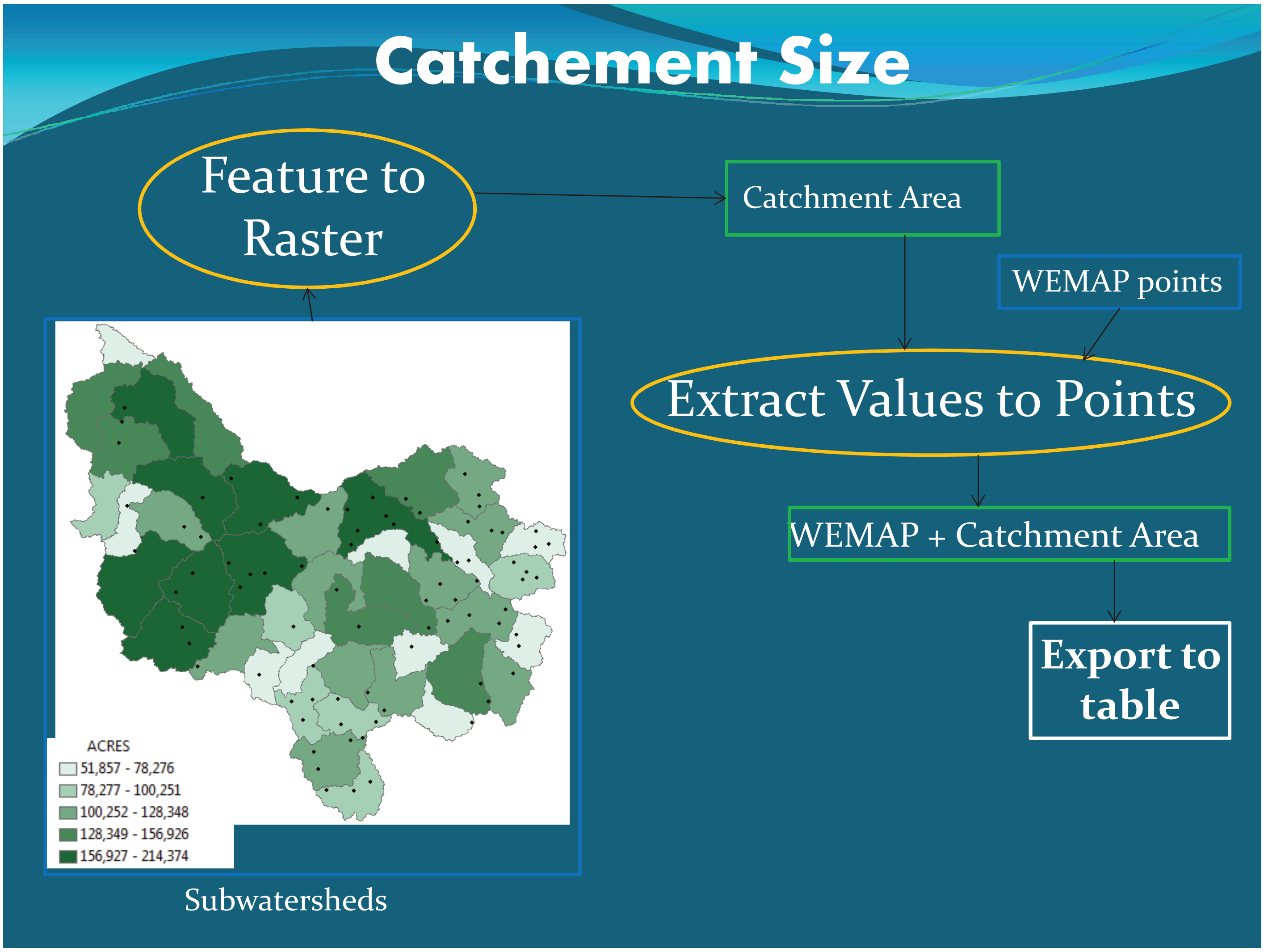
# Methods

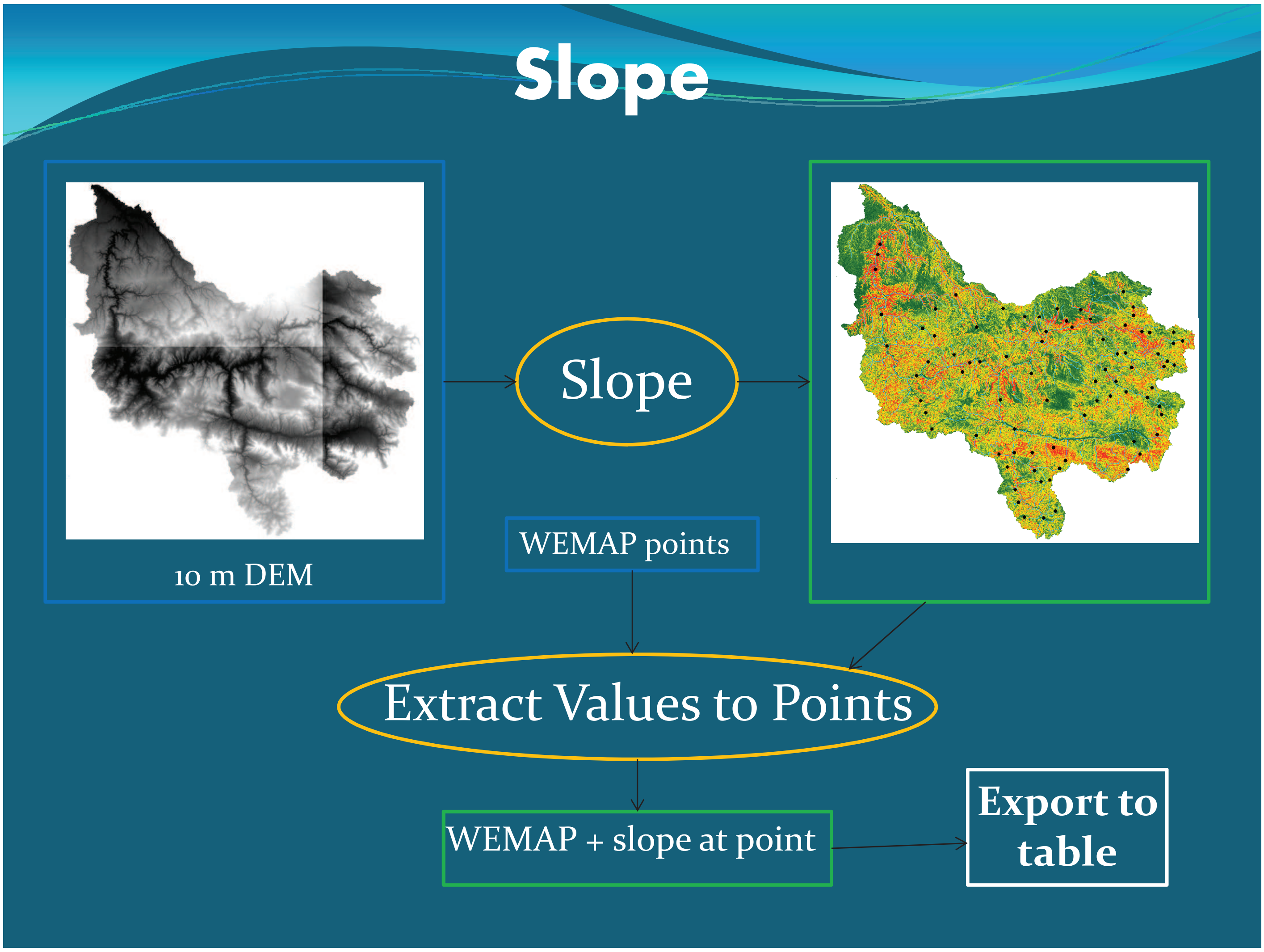
1) Use GIS to extract data on selected attributes at sample point locations.
   - Slope
   - Land Cover
   - General Rock Type
   - Road Density within subwatersheds
   - Dam Density within subwatersheds
   - Stream Order
   - Catchment Size

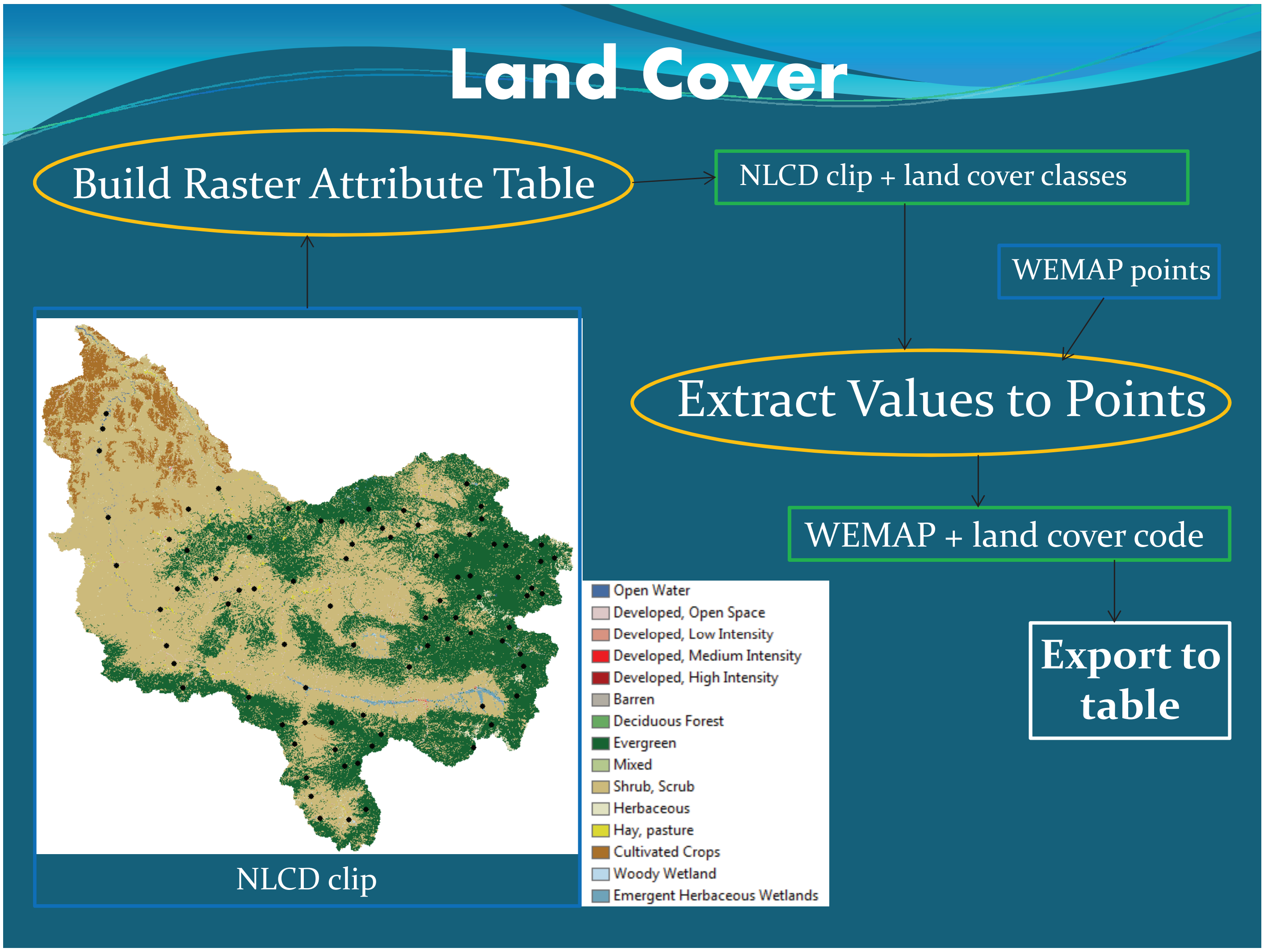
2) Create & Run Model

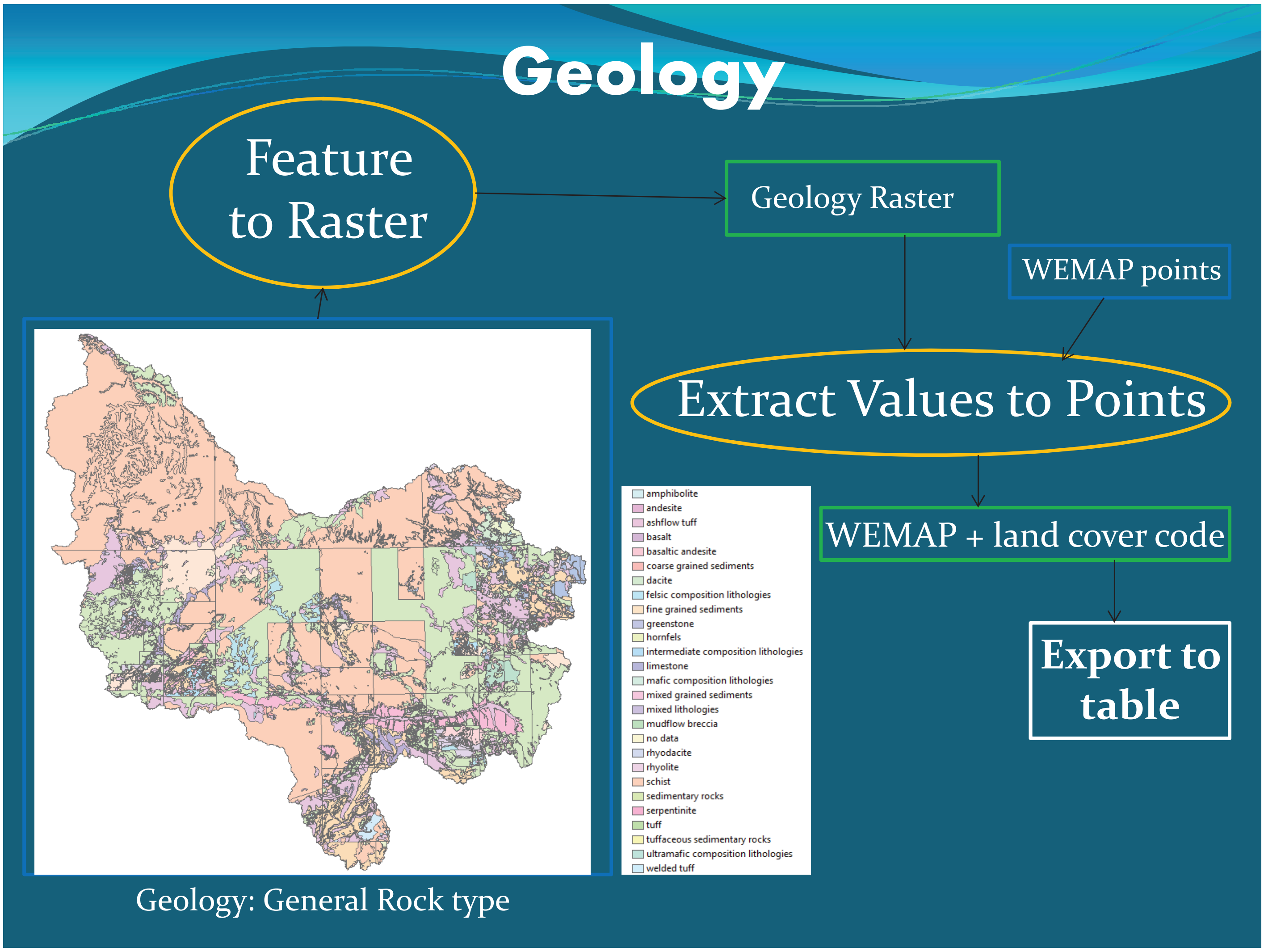
# Pre-Processing of Data

- Most files imported, clipped, converted, and data extracted to John Day WEMAP sample points
  - Slope extrapolated from DEMs
  - Subwatershed boundaries were used for calculating road and dam densities
- Used to format and coalesce data for use in GeoDA

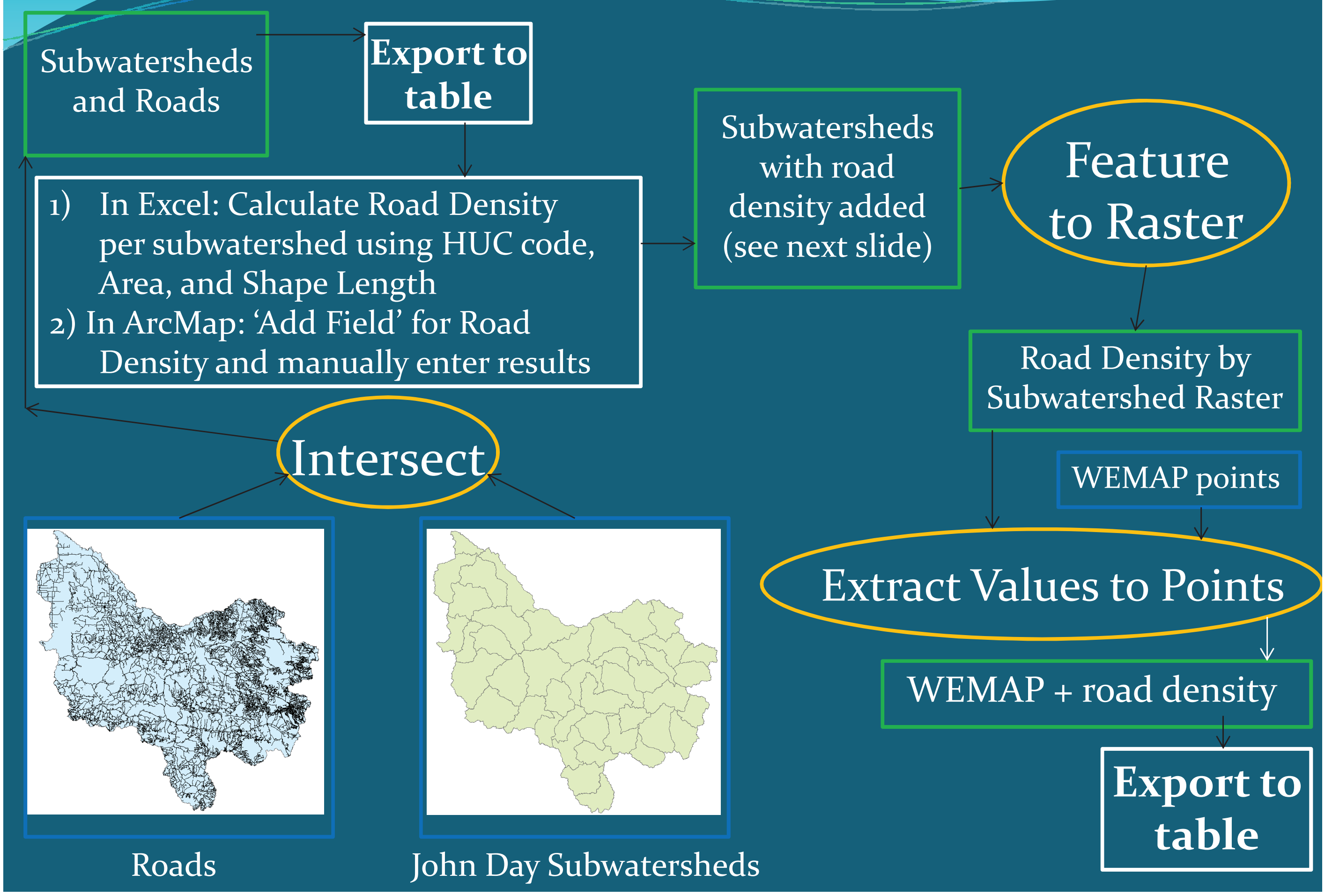

Catchement Size
Feature to Raster
Catchment Area
WEMAP points
Extract Values to Points
WEMAP + Catchment Area
Export to table
ACRES
51,857 - 78,276
78,277 - 100,251
100,252 - 128,348
128,349 - 156,926
156,927 - 214,374
Subwatersheds

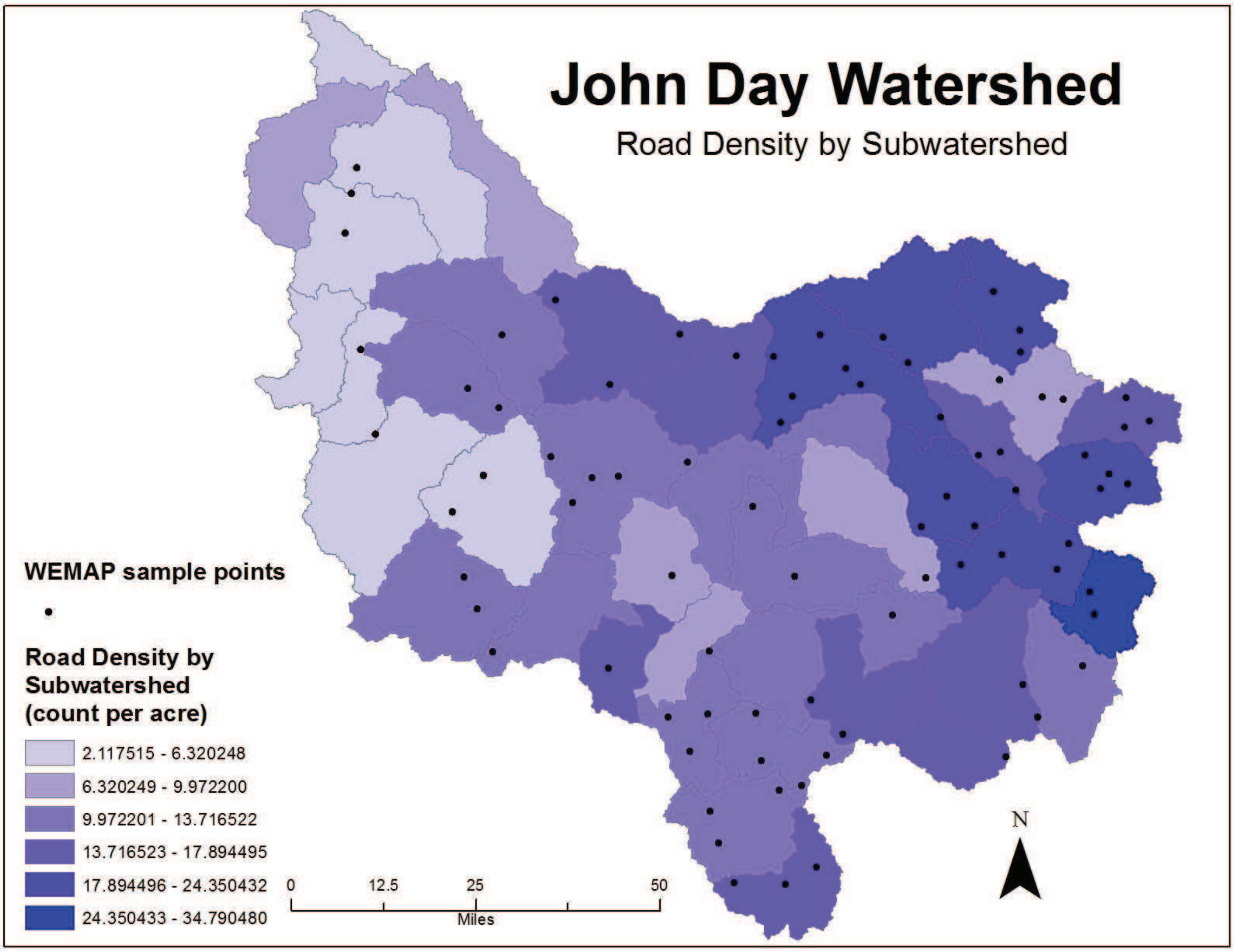

Slope
Slope
10 m DEM
WEMAP points
Extract Values to Points
WEMAP + slope at point
Export to table

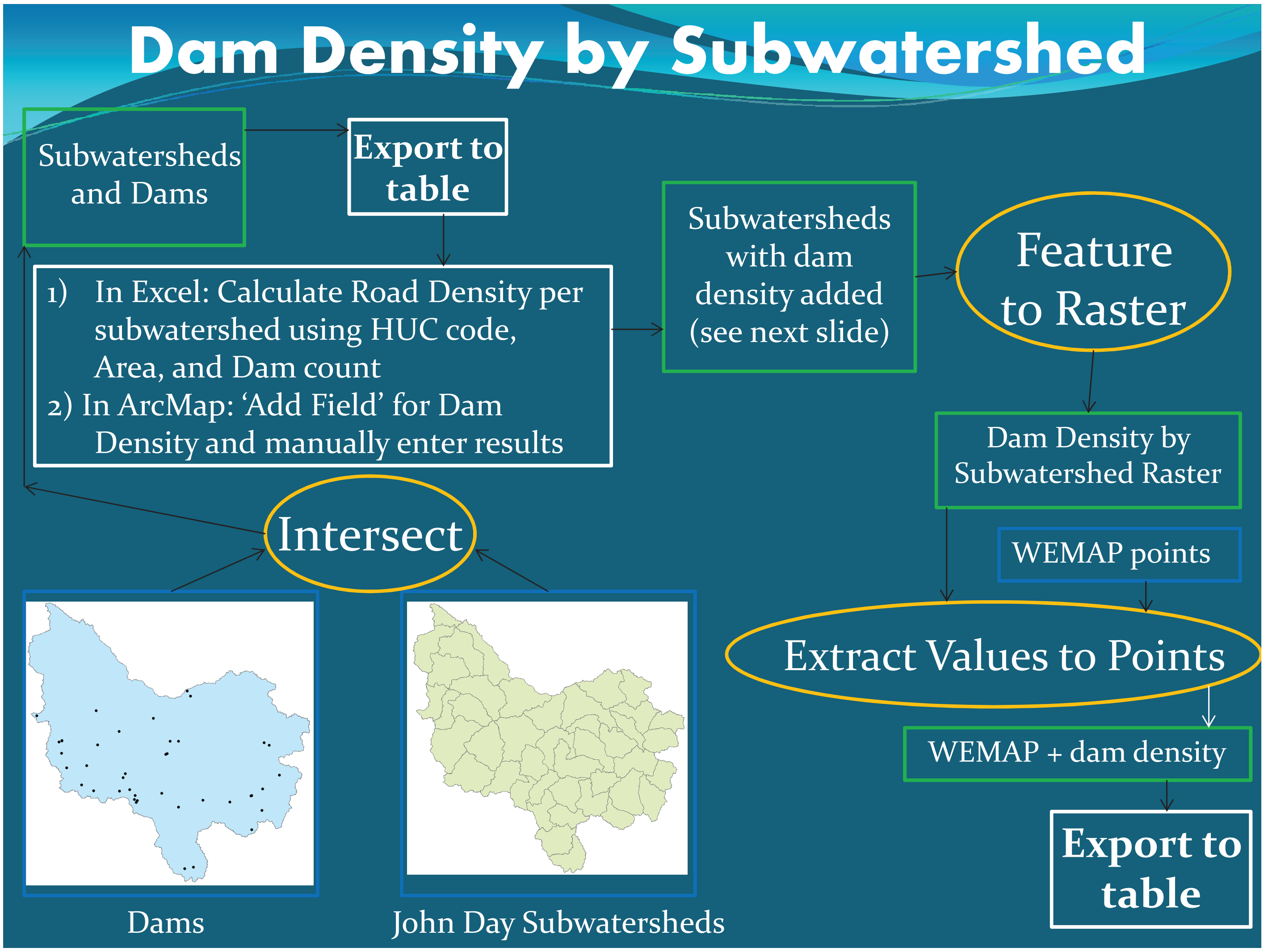

Land Cover
Build Raster Attribute Table
NLCD clip + land cover classes
WEMAP points
Extract Values to Points
WEMAP + land cover code
Export to table
Open Water
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren
Deciduous Forest
Evergreen
Mixed
Shrub, Scrub
Herbaceous
Hay, pasture
Cultivated Crops
Woody Wetland
Emergent Herbaceous Wetlands
NLCD clip

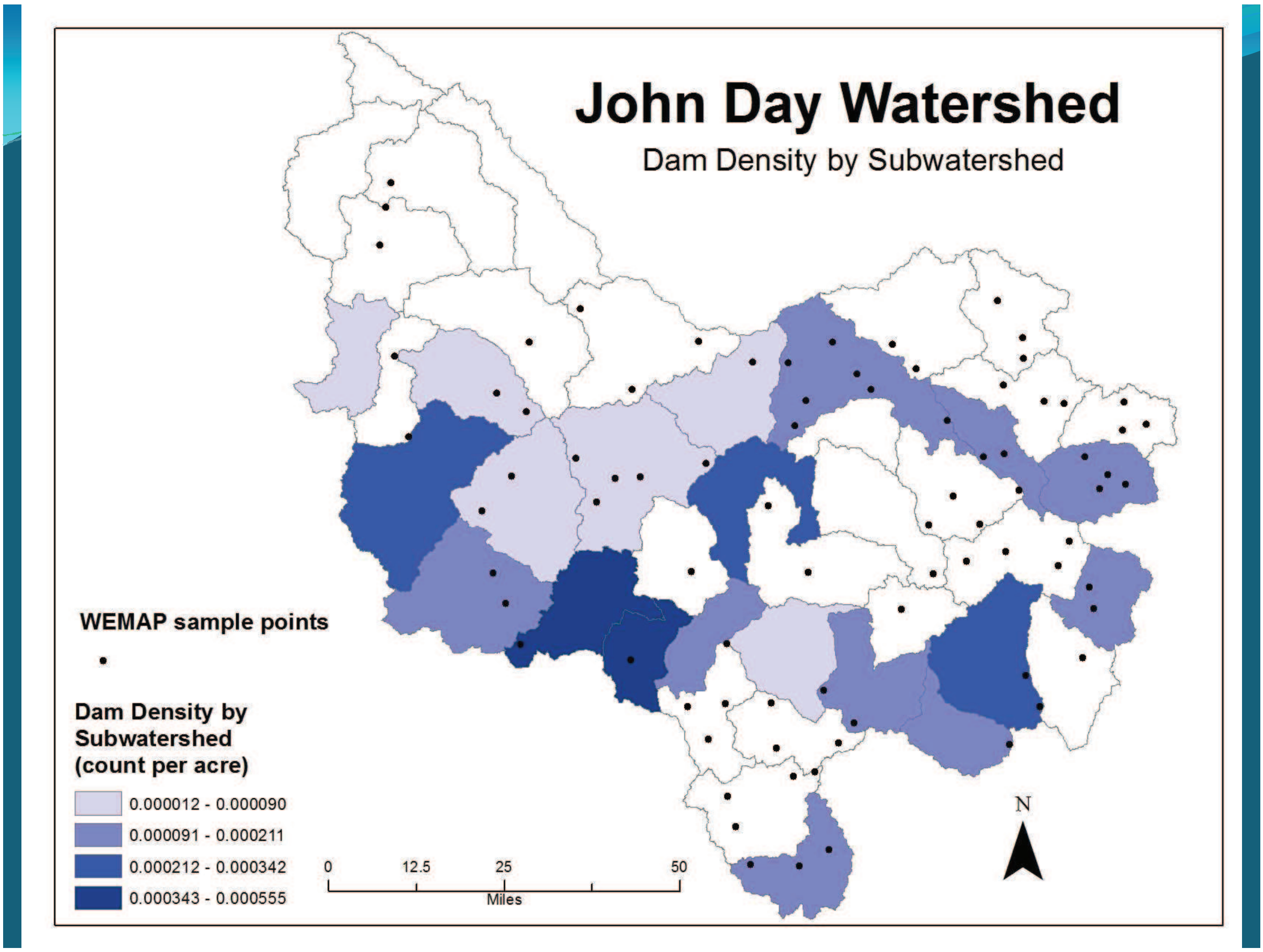

Geology
Feature to Raster
Geology Raster
WEMAP points
Extract Values to Points
WEMAP + land cover code
Export to table
amphibolite
andesite
ashflow tuff
basalt
basaltic andesite
coarse grained sediments
dacite
felsic composition lithologies
fine grained sediments
greenstone
hornfels
intermediate composition lithologies
limestone
mafic composition lithologies
mixed grained sediments
mixed lithologies
mudflow breccia
no data
rhyodacite
rhyolite
schist
sedimentary rocks
serpentinite
tuff
tuffaceous sedimentary rocks
ultramafic composition lithologies
welded tuff
Geology: General Rock type

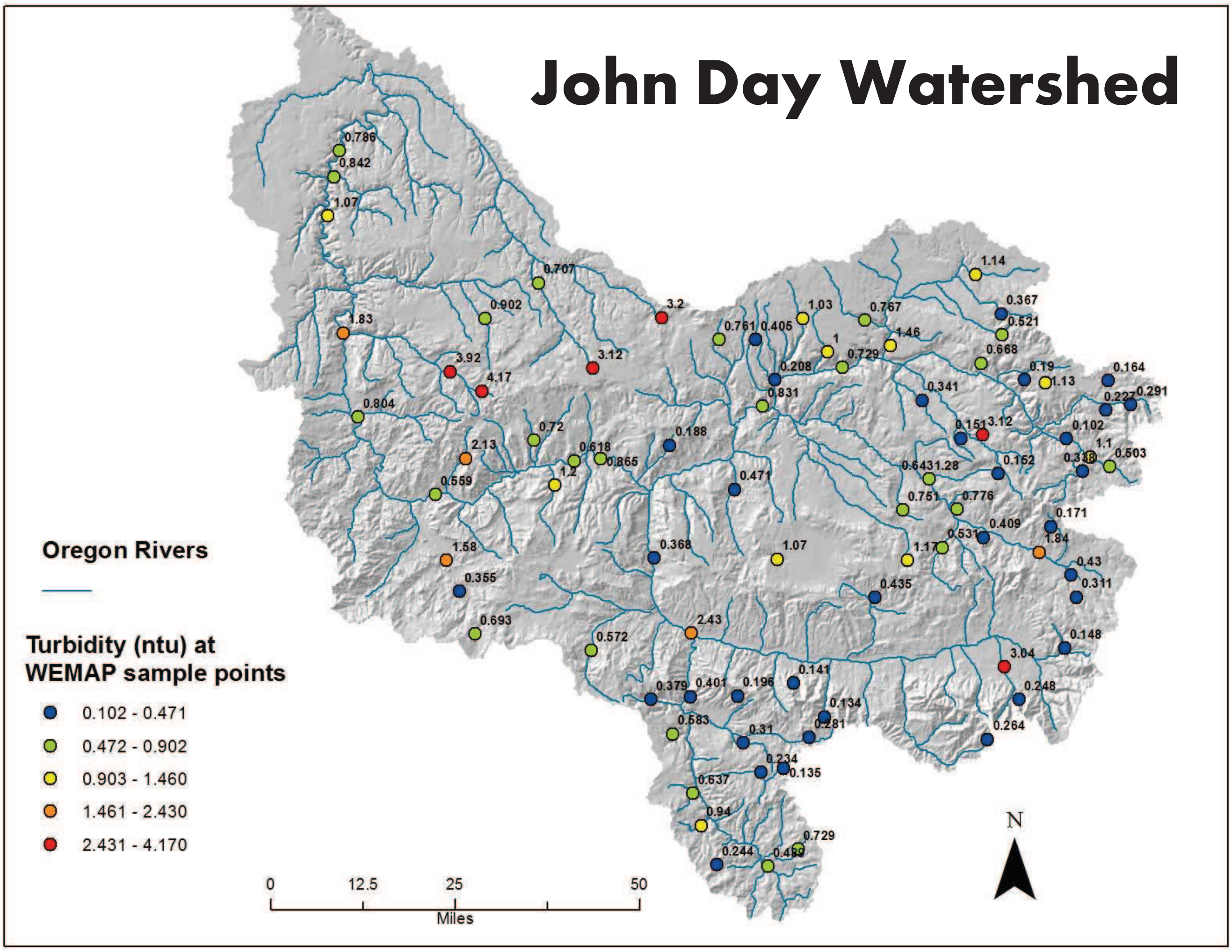
# Road Density by Subwatershed



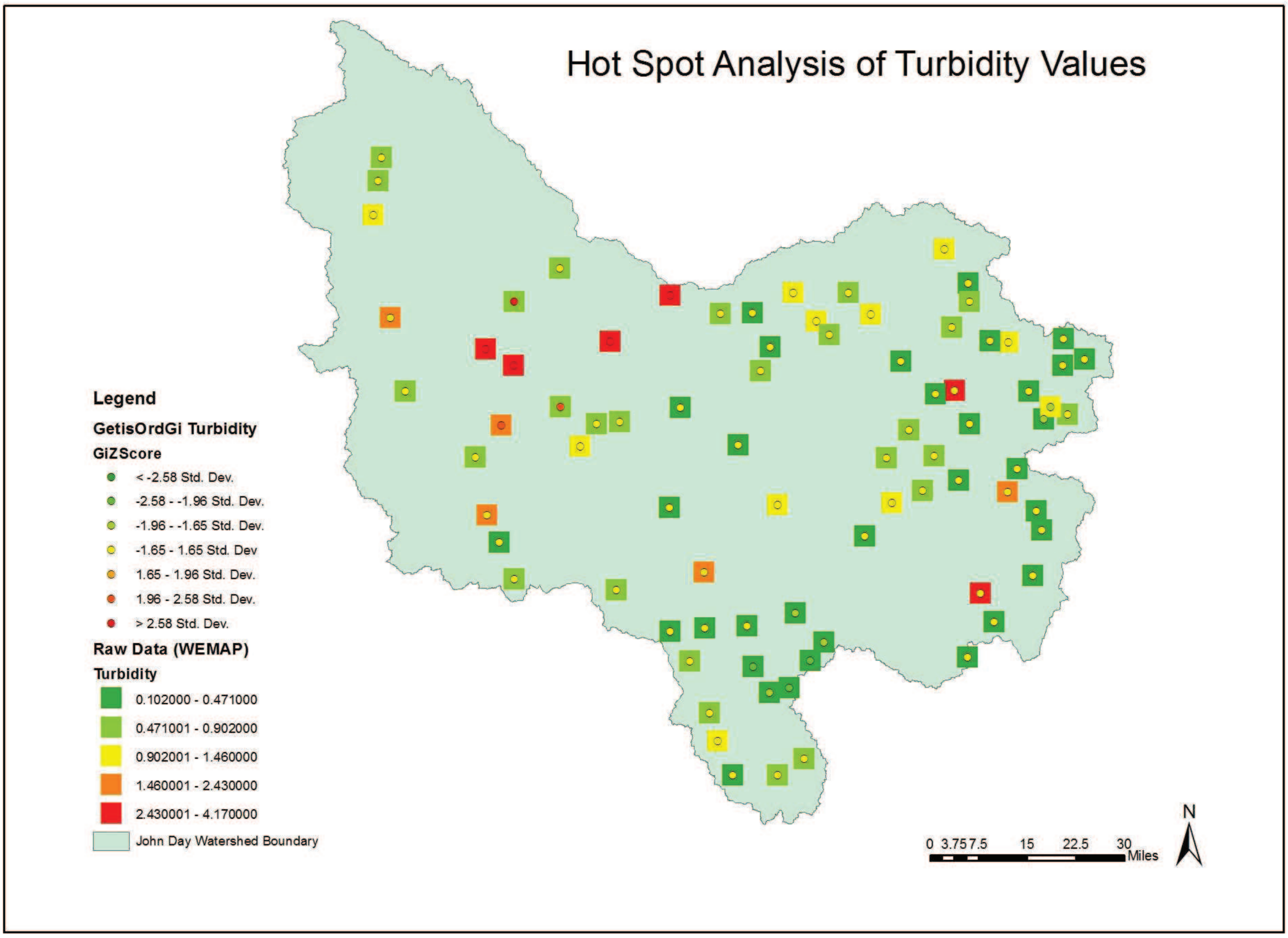

Dam Density by Subwatershed
Subwatersheds and Dams
Export to table
1) In Excel: Calculate Road Density per subwatershed using HUC code, Area, and Dam count
2) In ArcMap: 'Add Field' for Dam Density and manually enter results
Subwatersheds with dam density added (see next slide)
Feature to Raster
Dam Density by Subwatershed Raster
WEMAP points
Intersect
Extract Values to Points
WEMAP + dam density
Export to table
Dams
John Day Subwatersheds


John Day Watershed
Dam Density by Subwatershed
WEMAP sample points
Dam Density by Subwatershed (count per acre)
0.000012 - 0.000090
0.000091 - 0.000211
0.000212 - 0.000342
0.000343 - 0.000555
0
12.5
25
50
Miles
N




# Data Analysis

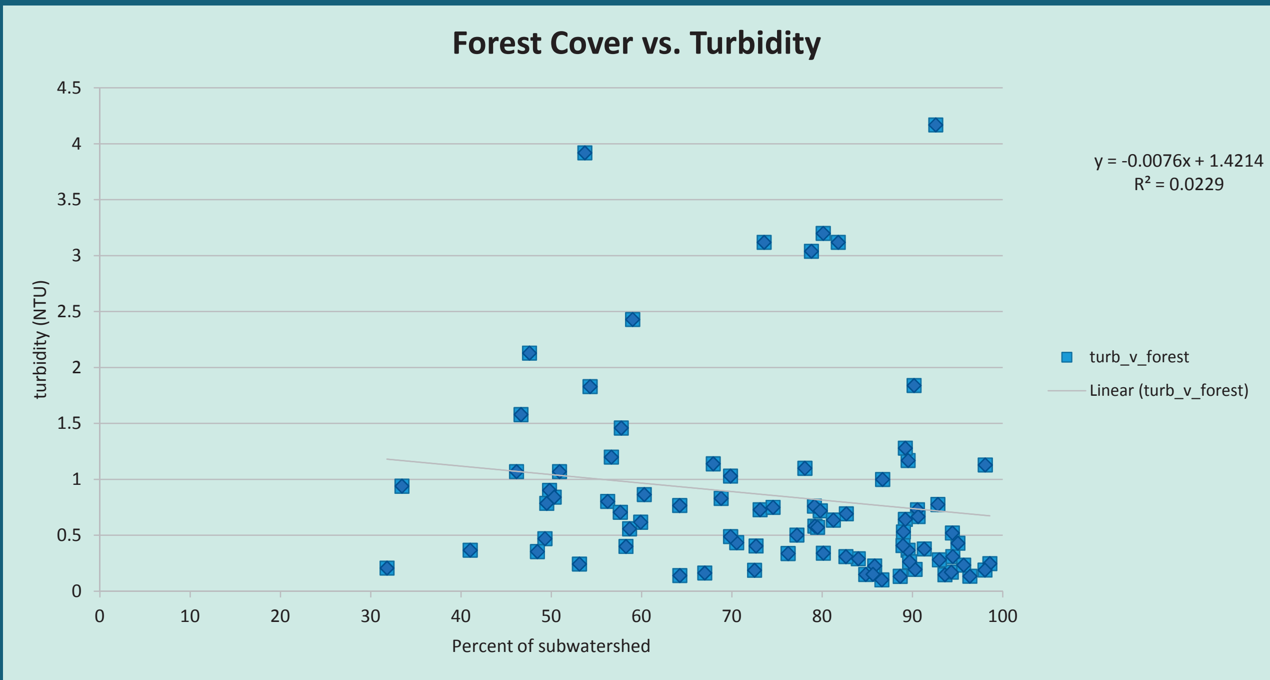
- Getis-Ord Gi employed to identify potential outlier data points
- OLS, Spatial Lag, and Spatial Error Regression Models run in GeoDa
- Geographically Weighted Regression run in ESRI ArcMap 10



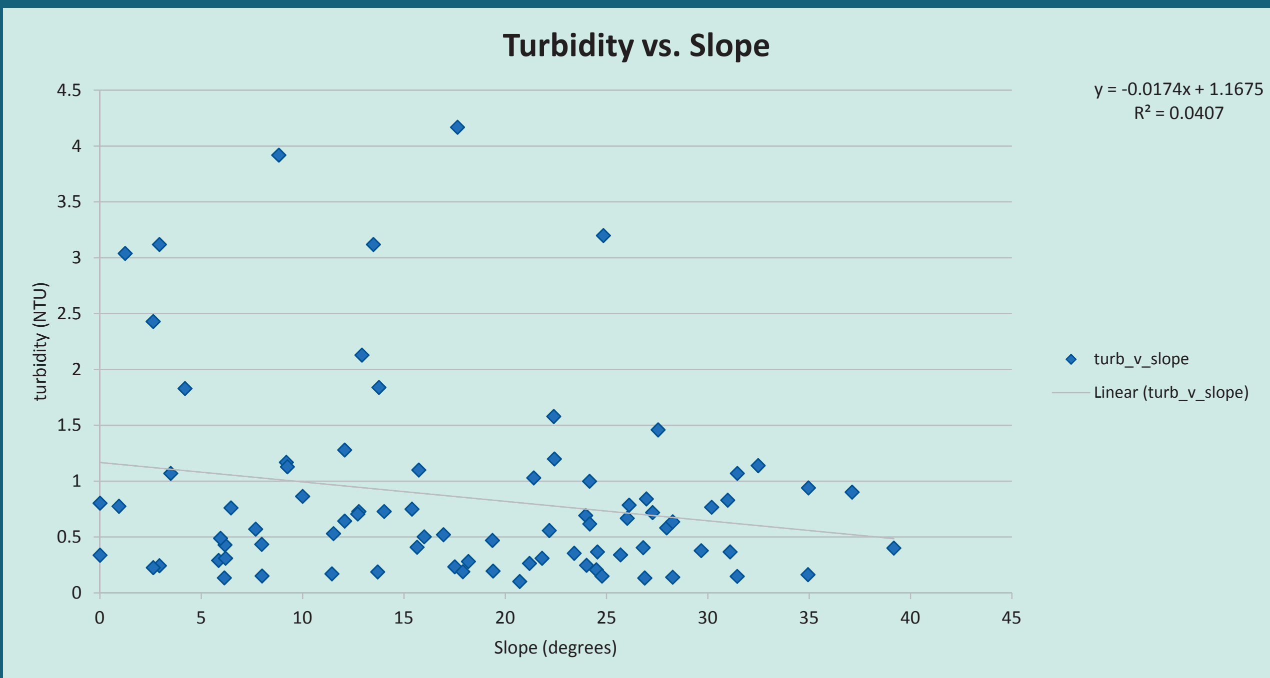

# Results

- Geoda
  - R squared .316
    - Barren Land and Stream Order predicting Turbidity
    - Problems with the model
      - Literature (Peterson et al. 2010)
- ESRI ArcMap 10
  - GWR
    - Independent variables not significant
- Scatter Plots

# Very little correlation




# And another…



# Discussion

- Literature (Allan et al. 2004, Bolstad et al. 2007, Brett et al. 2005, Pan et al. 2003)
- EPA data
- Sample size
- Summer sampling
- Data processing

# What does it mean?

- Do the results support the hypotheses?
  - Is land use a significant predictor for turbidity?
  - Do geologic factors overshadow land use factors?
  - Are turbidity values spatially autocorrelated?

# Next Steps…

- Problems with being confined to stream channel & with considering vertical distance
- Data set strength, excluding outlier data points
- Spatial pattern analysis, semivariogram, kriging

# Data Sources

•Watershed Boundaries Oregon:
http://navigator.state.or.us/sdl/data/mdb/k24/WBD_Oregon.zip
•National Land Use Database
http://www.mrlc.gov/nlcd2001.php
•Geology:
http://spatialdata.oregonexplorer.info/GPT9/catalog/main/home.page
•Road density by Watershed boundary
http://www.fs.fed.us/rm/boise/research/gis/documents/ArcGISRoadDensityStreamCrossing.pdf
•WEMAP dataset info
http://www.epa.gov/emap/west/index.html
•John Day info:
http://www.oeconline.org/our-work/rivers/cleaner-rivers-for-oregon-report/john-day-river

# References


- Allan, J.; 2004. *Landscapes and Riverscapes: the influence of land use on stream ecosystems.* Annual Rev. Ecol. Evol. Syst. Accessed at: arjournals.annualreviews.org
- Anson, R. 2007. Supporting Indicator-Based Management: Using a Geographic Informative System to Assess the Influence of Landscape Characteristics on Stream Turbidity in the Long Island Sound Watershed. Nicholas School of the Environment and Earth Sciences of Duke University. Accessed online 03/01/2012 at: http://dukespace.lib.duke.edu/dspace/handle/10161/299
- Belsky et al. 1999. *Survey of Livestock Influences on Stream and Riparian Ecosystems in the Western United States.* Journal of Soil and Water Conservation . 54.1 p 419. Accessed online 3/12 at: http://go.galegroup.com.proxy.lib.pdx.edu/ps/retrieve.do?sgHitCountType=None&sort=RELEVANCE&inPS=true&prodId=AONE&userGroupName=s1185784&tabID=T002&searchId=R1&resultListType=RESULT_LIST&contentSegment=&searchType=AdvancedSearchForm&currentPosition=1&contentSet=GALE|A182339603&&docId=GALE|A182339603&docType=GALE&role=
- Bolstad, P.; Swank, W.; 2007. *Cumulative Impacts of Landuse on Water Quality in a Southern Appalachian Watershed.* Journal of American Waters Association. 33(3) pp 519-533. Accessed online 3/12 at: http://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.1997.tb03529.x/abstract
- Brett, M.; Arhonditsis, G.; Mueller, S.; Hartley, D.; Frodge, J.; Funke, D. 2005. Environmental Management 35(3) pp. 330-342. Accessed online 3/12 at http://www.springerlink.com.proxy.lib.pdx.edu/content/p06693736q00648o/
- Bryce, S.; Lomnicky, G. Kaufmann, P.; 2010. *Protecting sediment-sensitive aquatic species in mountain streams through the application of biologically based streambed sediment criteria.*Journal of the North American Benthological Society. Accessed online at: http://www.jnabs.org/doi/pdf/10.1899/09-061.1
- Cederholm C.J., Reid L.M., Salo E.O. 1980. Cumulative Effects of Logging Road Sediment on Salmonid Populations in Clearwater River, Jefferson County, Washington. College of Fisheries, University of Seattle, Washington. Accessed online 01/10/2012 at: http://www.fs.fed.us/psw/publications/reid/Cederholm.pdf



# References



- Hecox, E. Water Quality Laws Summary/Oregon. *National Science and Technology Center, Bureau of Land Management.* Accessed online 03/10/2012 from http://www.blm.gov/nstc/WaterLaws/oregon2.html
- Johnson, L.; Richards, C.; Host, G.; Arthur, J.; 2003. *Landscape influences on water chemistry in Midwestern stream ecosystems.* Freshwater Biology 37 (1) pp 193-208. Accessed online 3/12 at: http://onlinelibrary.wiley.com/doi/10.1046/j.1365-2427.1997.d01-539.x
- Kiilsgaard, C., 1999. *Manual and Land Cover Type Descriptions Oregon Gap Analysis 1998 Land Cover for Oregon*. Oregon Natural Heritage Program. Accessed online 03/09/2012 at http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml#D
- Ma, L., Madin, I.P., Olson, K.V., and Watzig, R.J. 2008-2009. *G_MAP_UNIT (vector digital data)*. Oregon Department of Geology and Mineral Industries. Online linkage: \\OGDC_v5 Statewide Coverage\Spatial_data\Geology\shp\G_MAP_UNIT.shp. Accessed online 03/09/2012 at: http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml#D
- McCollough, D. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Fresh Water Life Stages of Salmonids, With Special Reference to Chinook Salmon. Prepared for the EPA.Columbia River Inter-tribal Fish Commission, Portland, Oregon. Accessed online 01/10/2012 at: http://yosemite.epa.gov/R10/ecocomm.nsf/37aa02ee25d11ce188256531000520b3/74476bae1ae7e9fb88256b5f00598b43/$FILE/chinnookrpt.pdf
- NEDC v. Brown 2010. Accessed online 01/10/2012 at: http://crag.org/wp-content/uploads/2010/08/9th-Circuit-Clean-Water-Act-Forest-Roads-Decision1.pdf
- Oregon Water Resources Department, 2010. *Oregon_dams (vector digital data).* Online linkage: \\WPSDCCLR006\K\EISPD\GEO\Home\dmather\Data\OWRD\oregon_dams.shp. Accessed online 03/01/2012 at http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml#D

# References


- Packman, J. J., Comings K.J., and Booth, D. B. 2000. *Using Turbidity to Determine Total Suspended Solids in Urbanizing Streams in the Puget Lowlands.* The Center for Urban Water Resources Management at the University of Washington, Seattle, Washington, 11 pp. Accessed online 03/10/2012 at:
- Pan, Y.; Herlihy, A.; Kaufmann, P.; Wigington, J.; van Sickle, J.; Moser, T. 2004. *Linkages among land-use, water quality, physical habitat conditions and lotic diatom assemblages: A multi-spatial scale assessment.* Hdrobiologia 515(59-73). Accessed online at: http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=ed939086-881c-4004-beab-f3e0c3d953fd%40sessionmgr13&vid=2&hid=112
- Packman, J. J., Comings K.J., and Booth, D. B. 2000. *Using Turbidity to Determine Total Suspended Solids in Urbanizing Streams in the Puget Lowlands.* The Center for Urban Water Resources Management at the University of Washington, Seattle, Washington, 11 pp. Accessed online 03/10/2012 at: https://digital.lib.washington.edu/dspace/bitstream/handle/1773/16333/tssturb.pdf?sequence=1
- Peterson, E.; Merton, A.; Theobald, D.; Urquhart, S.; 2005. *Patterns of Spatial Autocorrelation in StreamWater Chemistry.* Environmental Monitoring and Assessment 121 (1-3) pp. 569-594. Accessed online 3/12 at: http://www.springerlink.com/content/c10p338692646635/
- Scherr, M.; Wooster, D. Rao, S.; 2008. *Interactions between macroinvertebrate taxa and complex environmental gradients influencing abundance and distribution in the Umatilla River, Northeastern Oregon Accessed online 3/12 at:* http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=6cb41554-068d-411b-b759-831bd2bee68d%40sessionmgr13&vid=2&hid=105
- U.S. Department of Agriculture, Natural Resources Conservation Service, last updated 04/25/2011. *Hydrologic Units (digital vector data).* Accessed online 03/09/2012 at http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml#D
- USEPA 2006. SABS *Framework for Developing Suspended and Bedded Sediments (SABS) Water Quality Criteria*
- Walters, D.; Roy, A.; Leigh, D.; 2009. *Environmental indicators of macroinvertebrate and fish assemblage integrity in urbanizing watersheds.* Elsevier d10.1016/j.ecolind.2009.02.011. Accessed online 3/12 at: http://coweeta.uga.edu/publications/10364.pdf