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"Using GIS To Analyze The Environmental Impacts of Mining On Water Resources In The State of West Virginia"

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Scope of the Presentation

- Purpose of the Research
- Background Information and Study Area
- Methods Used
- Environmental Analysis of Impacts
- Pollution Analysis
- Factors Fueling the Problems
- Findings
- Remedies and Conclusions

Objectives of the Research

- To make a contribution to the literature
- To develop a decision support tool to guide environmental managers
- To design novel geo-spatial methods for analyzing watershed quality in mining environments
- To examine environmental health issues of mining with GIS technologies
- To analyze factors fuelling the problems
- To identify efforts to remedy impacts of mining in West Virginia

Background Information

- The state of West Virginia has for decades relied on the mining sector as an integral part of its economy
- In that setting, sizeable environmental externalities from mining continue to degrade stream water quality and the surrounding ecosystem
- With much of the mining activities occurring within the vicinity of sensitive watersheds and habitats for rare species
- Very little has been done to spatially identify the frequency and scales of the problems with advances in spatial technology such as Geographic Information Systems (GIS).
- Notwithstanding this void in the literature, there remains widespread growth in the number of mining operations in various areas of the state at the expense of environmental welfare (Figure 1.1).
- The problems of mining hazards and the threats to watersheds do not operate in a vacuum; they emanate from policy defects and socio-economic elements.
- Some of the impacts associated with mining activities in the state range from non-point sources of pollution, impairment of stream and watersheds, loss of vegetation and numerous environmental health threats that impede water quality.

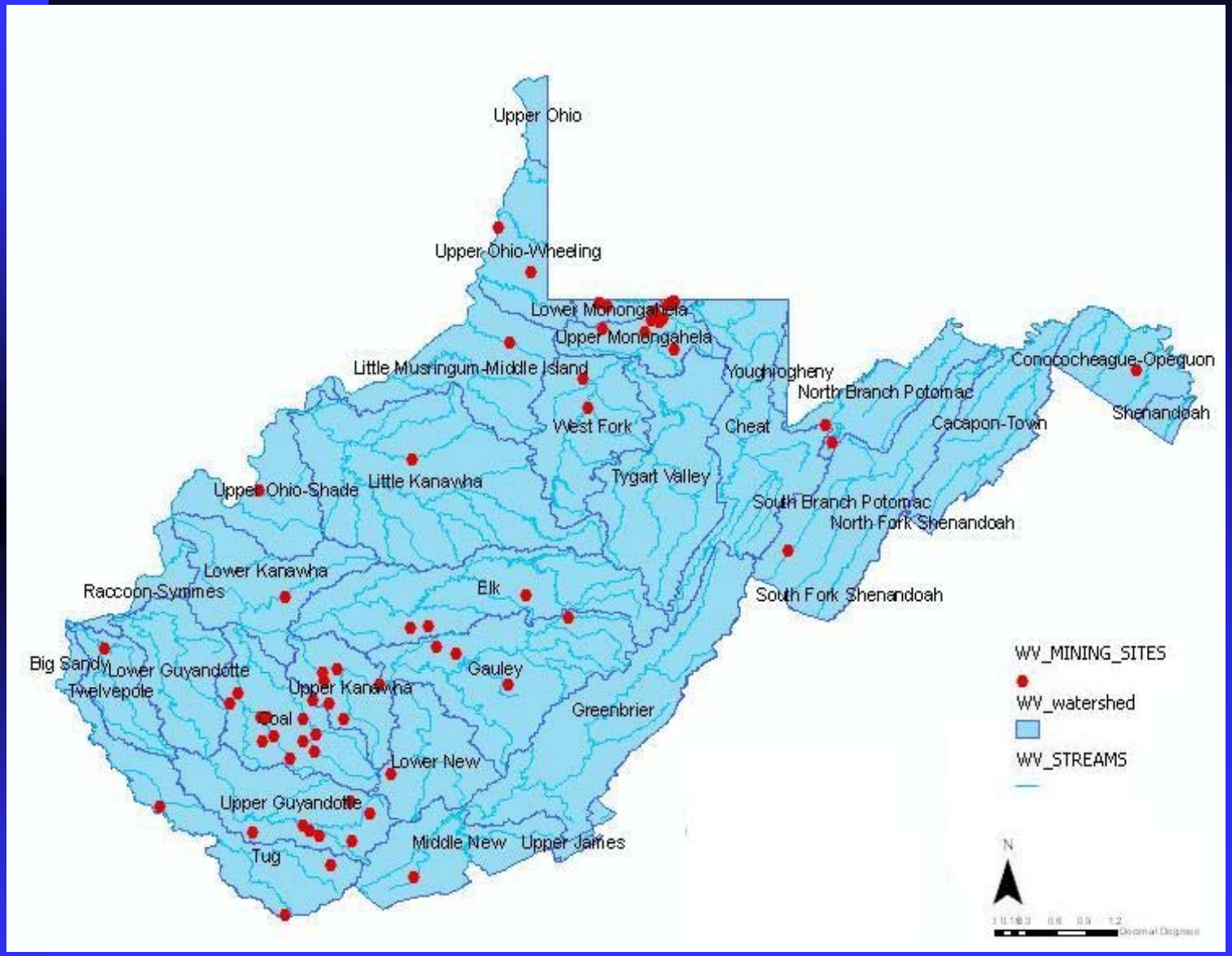

Figure 1.1 : Spatial Location of Mining Sites In The State of West Virginia

Study Area

- The study of West Virginia is located along American Heartland with over 63 counties (Figure 1.2) . It has numerous watersheds and wetlands (Figs 1.3-1.4)
- With a a population of 1.8 million people in 2009, The state has infinite panoramas of sparkling water, fresh air and lush and green mountains
- One of the major resources in West Virginia's economy is coal (Figure 1.5), nearly all of the electricity generated in the area come from coal-fired power plants
- West Virginia produces a surplus of electricity and leads the country in net interstate electricity exports.
- As coal mining and related work became major job sources in the state, there continues to be serious worries about working conditions, and safety issues
- In opening decades of the 21st century, mining safety and ecological concerns pose serious challengies to the state whose coal continues to sustain electrical generating plants in different other states.
- Using GIS provides opportunities to understand the impacts of miming activities on watersheds and the need to use that knowledge to enhance decision making process

Figure 1.2 Map of the Study Area

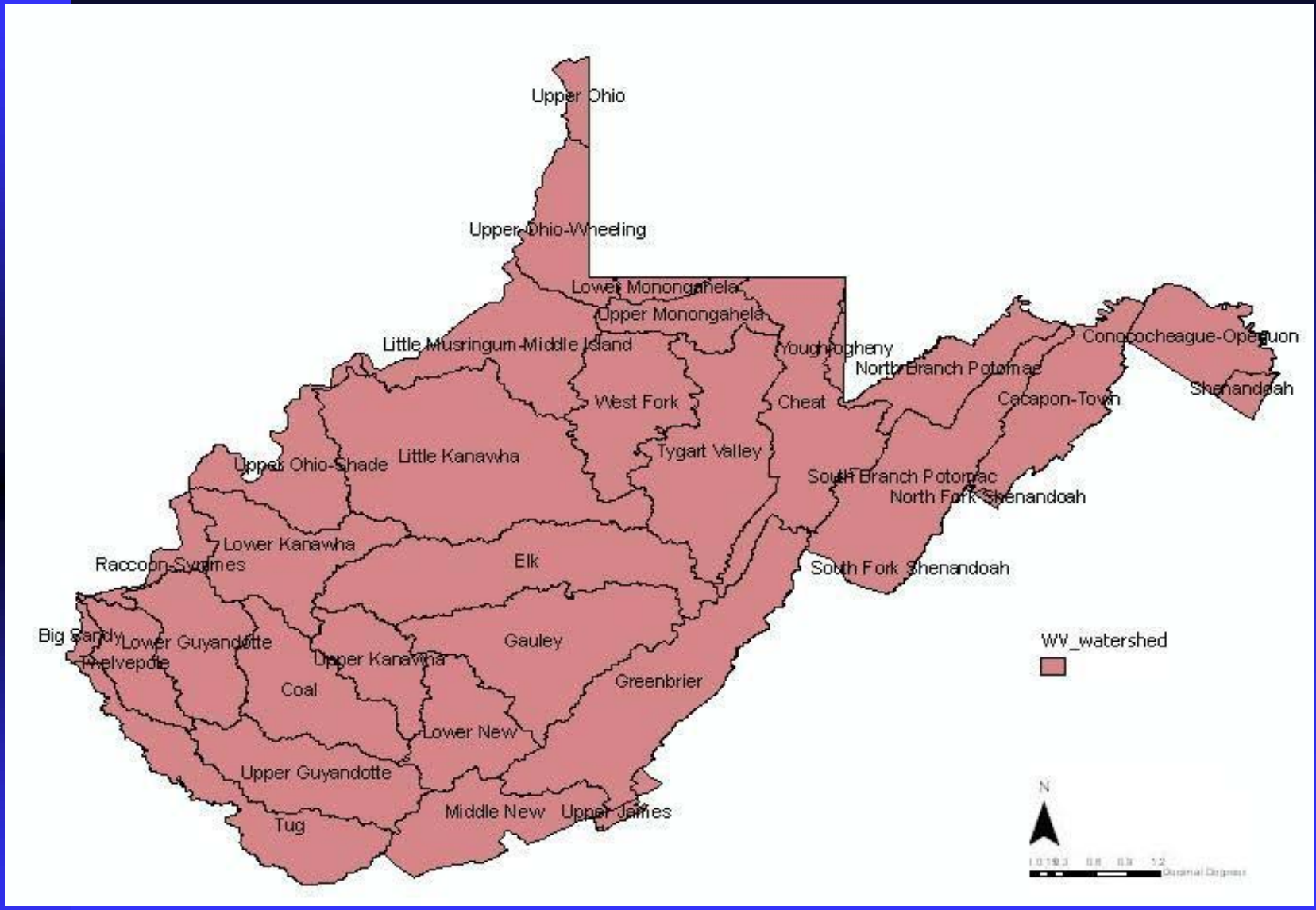

Figure 1.3 : Watershed Boundaries The West Virginia, 2009

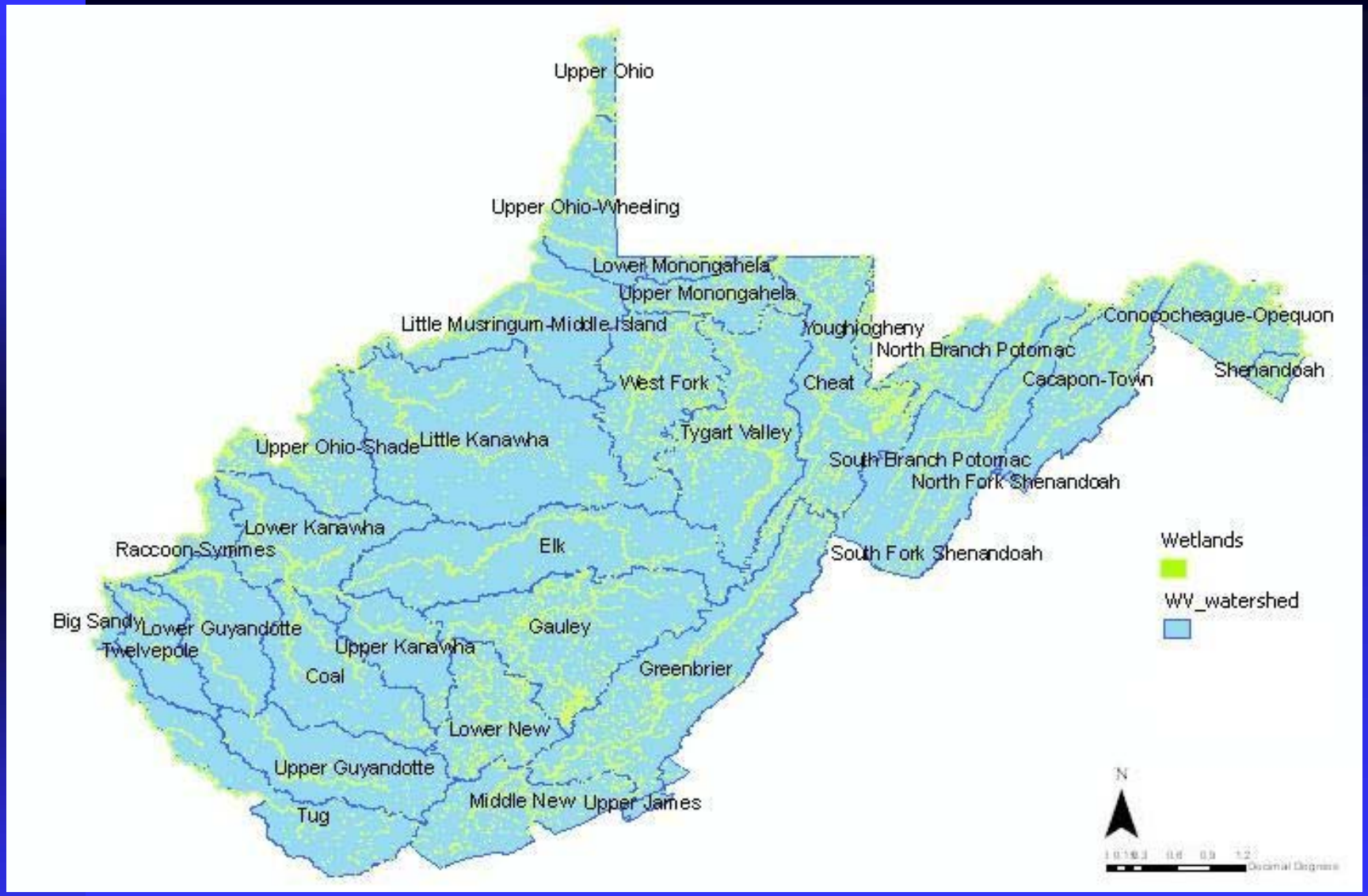

Figure 1.4 Spatial Distribution of Wetlands In The State of West Virginia

Figure 1.5 Images of Coal Mining

Methods

- The paper stresses a mix scale approach involving the use of descriptive statistics analysis and geospatial technologies of GIS in processing data provided through government sources and other organizations

- **Step 1: Data Acquisition**

- The first step involves the identification of the variables needed to assess the state of environmental health involving mining and steam water pollution trends along existing watersheds

- The variables consist of environmental data such as land based elements (of the number of mining sites, number of watersheds, impaired water bodies, categories of pollutants made up of biological elements, PH, and metals) and percentages of pollutants

- In addition to the design stage, access to databases and abstracts that are presently available within the Federal and state archives in the state of West Virginia and the USGS, NASA, and host of other entities quickened the search process.

Step 2: Geospatial Data Acquisition and Processing

- Multi-temporal spatial data made up of shape files and maps using ARCVIEW GIS were obtained for the study

- The data that were assembled for West Virginia watersheds and counties include pollution and ecological data of land cover files of wetlands, watersheds, paper and digital maps from 1996 through 2004.

- The output was visually compared with the trends evidenced in the area to see the extent of spatial dispersion of indicators of mining impacts across time along the boundaries of West Virginia watershed environment.

Environmental Impact Analysis of Mining

- The most common types of pollutants in the area grouped under various classes consist of biological elements, Ph, and metals (Table 1.1)
- Their occurrence in the watersheds as indicated in the table are in the order of 9 for biological pollutants, 7 for PH and 4 for metals
- While the total number of mining sites from which the pollutants originate stood at 65 during the periods of 1996, 1998, 2002 and 2004
- The cases of impaired streams rose from the initial value of 1586, in 1996 to 2676 in 1998, and in 2002 the numbers jumped further to 5389 only to stabilize at 4924 in 2004.
- The breakdown of the trends point to the presence of biological pollutants along the upper Monogahele watershed.
- Being the area with major mining sites estimated at 13, Monogahele watershed saw its number of impaired streams from biological pollutants which stood 56 in 1996 grow to 128 in 1998, 182 in 2002 to 2004 .
- At the same time, metallic pollutants remained quite rampant in four other watersheds most notably the Upper Kanwaha, Coal, Upper Guyandatte and Twelve pole
- The estimated number of mining sites in these watersheds were in the order of 7, 11, 1 and 7 respectively.

Environmental Analysis Continued

- Along the Upper Kanwaha watershed, the number of impaired streams between 1996 -1998 grew from 250 to 319
- In the later periods, it varied from 417 in 2002 to 402 in 2004
- At coal watershed, the number of cases of impaired streams attributed to metal sediments remained in high triple digits
- This is evident between 2002 through 2004 and 1998, but only to drop to upper and lower double digits at Twelve pole watershed.
- The Upper Guyandatte watershed also experienced numerous cases of stream impairment.
- The number of cases were 242 in 1996, 328 in 1998, 427 in 2002 and 286 in 2004 (See Table 1.1)

Table 1.1 Environmental Trends

Watershed	Number of Mining sites	Main pollutant	Impaired streams_2004	Impaired streams_2002	Impaired Streams_1998	Impaired Streams_1996
Conococheague	1	Biological	226	226	30	0
Northbranch	2	Biological	109	115	98	53
South branch	1	PH	191	191	128	27
Lower Monogahele	2	Biological	146	146	37	36
Upper Monogahele	13	Biological	182	182	128	56
West fork	2	PH	333	375	284	258
Upper ohio-wheeling	2	PH	287	287	112	37
Little Musringum middle island	1	Biological	118	118	16	14
Little Kanawaha	1	PH	303	308	235	66
Upper Ohio-shade	1	Biological	274	274	88	11
Elk	3	Biological	358	383	199	96
Gauley	4	PH	162	200	141	112
Upper Kanwaha	7	Metals	402	417	319	250
Coal	11	Metals	671	729	133	80
Twelve pole	1	Metals	67	77	19	10
Tug	3	Biological	222	307	184	148
Upper Guyandatte	7	Metals	286	427	328	242
Middle New	1	Biological	292	310	38	29
Lower new	1	PH	228	228	94	28
Lower Kanawaha	1	Ph	67	89	65	33

Table 1.2 Pollution Analysis

Comparative Pollution Analysis Metal Versus Other Pollutants

Watershed	Sites	Main pollutant	Impaired streams_2004	Impaired streams_2002	Impaired Streams_1998	Impaired Streams_1996
Upper Kanwaha	7	Metals	402	417	319	250
Coal	11	Metals	671	729	133	80
Twelve pole	1	Metals	67	77	19	10
Upper Guyandatte	7	Metals	286	427	328	242
Total	26	Metal pollutants	1426	1650	799	582
Overall Total	65	All pollutants	4924	5389	2676	1536
Total %	40		28.96	30.61	29.85	36.69

Pollution Analysis

- Another dimension to the analysis is that of the 21 watersheds in the study area, metallic elements from 26 mining sites are discharged into sensitive stream habitats (Table 1.2)

- These numbers represent about 40% of all mining activities in the designated watersheds in the area

- In terms of the percentage distribution of steam impairment reported in West Virginia, the four watersheds where metallic effluents are rampant accounted for 36 .69% to 29.85% of impaired stream cases between 1996 through 1998

- In the ensuing years, the percentage of impaired streams attributed to metals discharged from mining sites went from 30.61% in 2002 to 28.96% in 2004

Spatial Analysis

- There seem to be a large incidence of stream impairment along the surrounding ecology of fragile watersheds adjacent to mining sites (Figure 1.1) in the state over the years between 1996 to 2004
- Comparing the 1996 and 1998 maps, one notices the sudden diffusion of impaired elements into adjoining water systems in a manner not seen in the preceding periods (Figure 2.1-2.2)
- Water impairment as a recurrent phenomenon in the state assumed a much bigger scale as the years went by
- Between 2002 through 2004, large scale levels of impairment began to appear extensively in the state (Figure 2.1-2.4)
- Within this period, the magnitude of stream pollution known to threaten water streams reached enormous proportions in the lower and upper part of the state
- The gravity of these impairments, continue to threaten ecosystem quality of the watersheds.

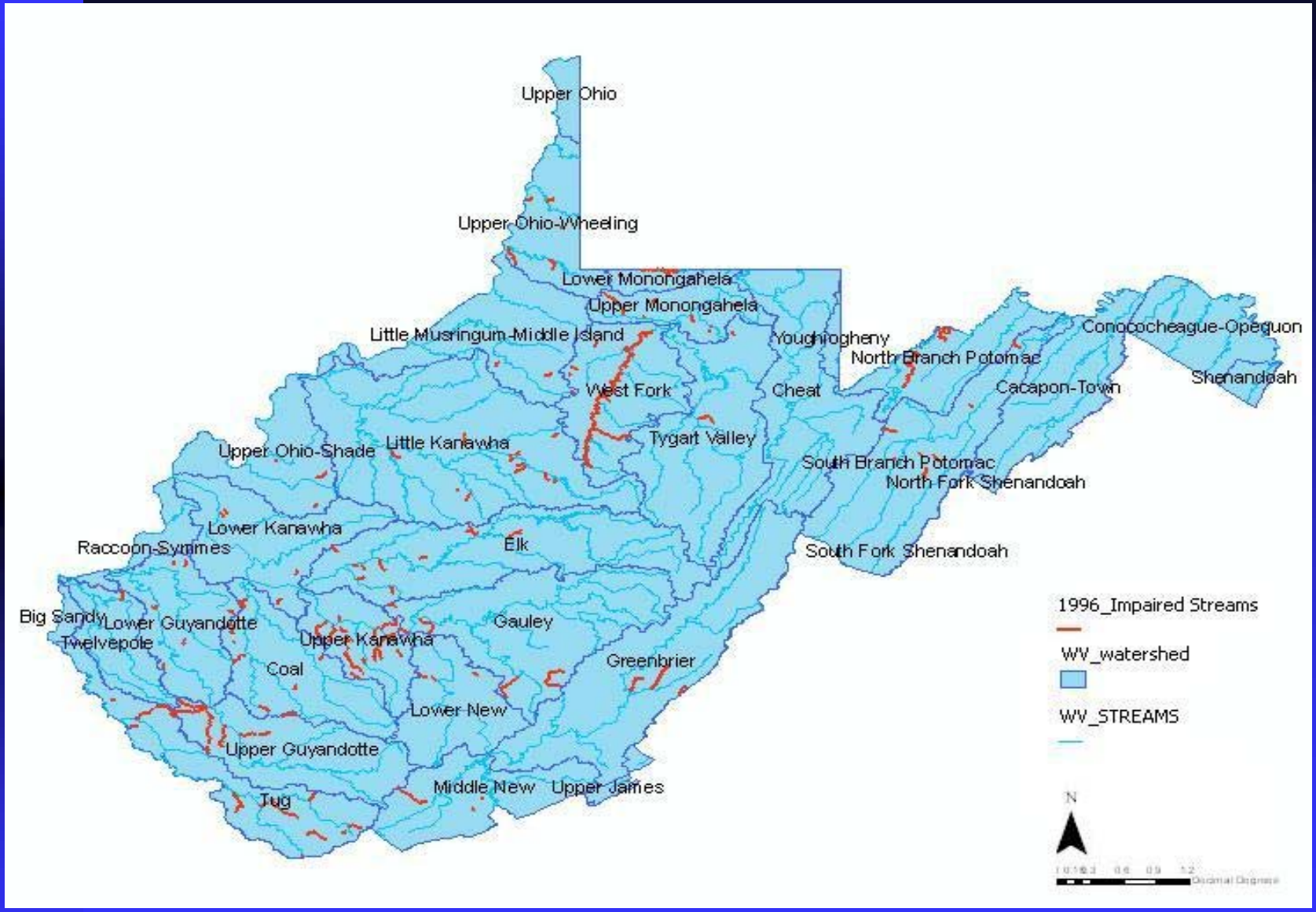

Figure 2.1 Impaired Streams In West Virginia Watersheds In 1996

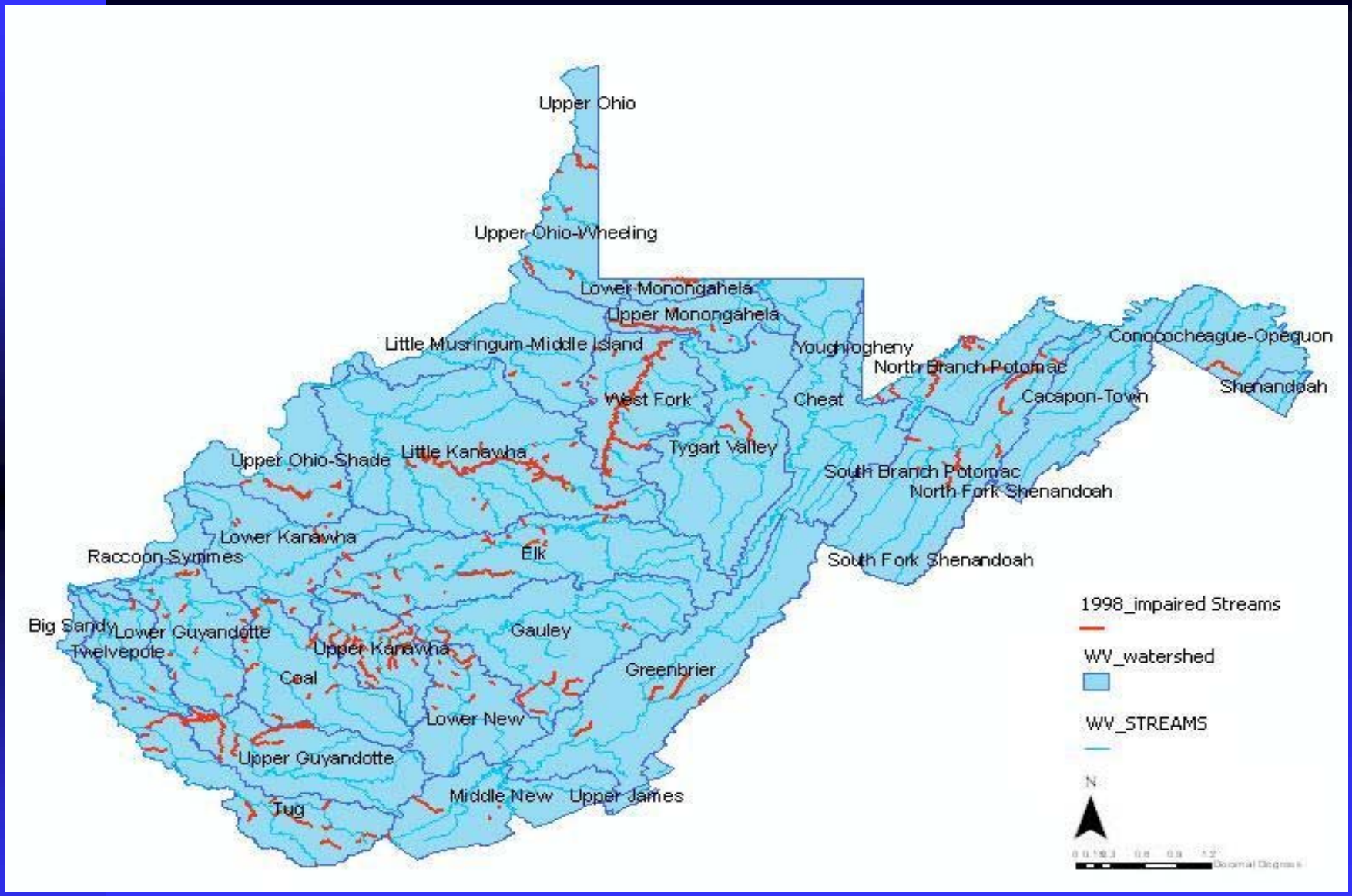

Figure 2.2 Impaired Streams In West Virginia Watersheds In 1998

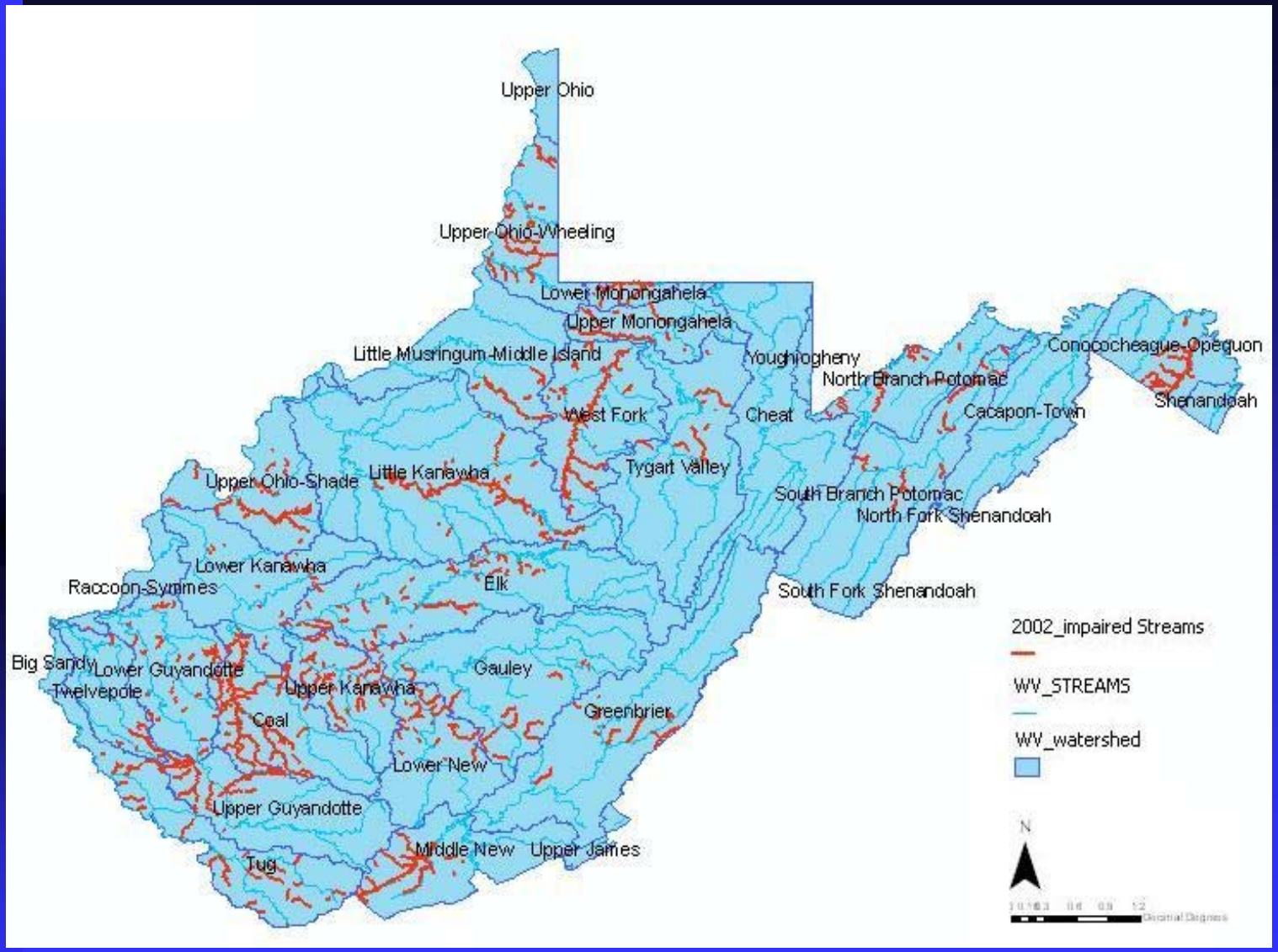

Figure 2.3 Impaired Streams In West Virginia Watershed In 2002

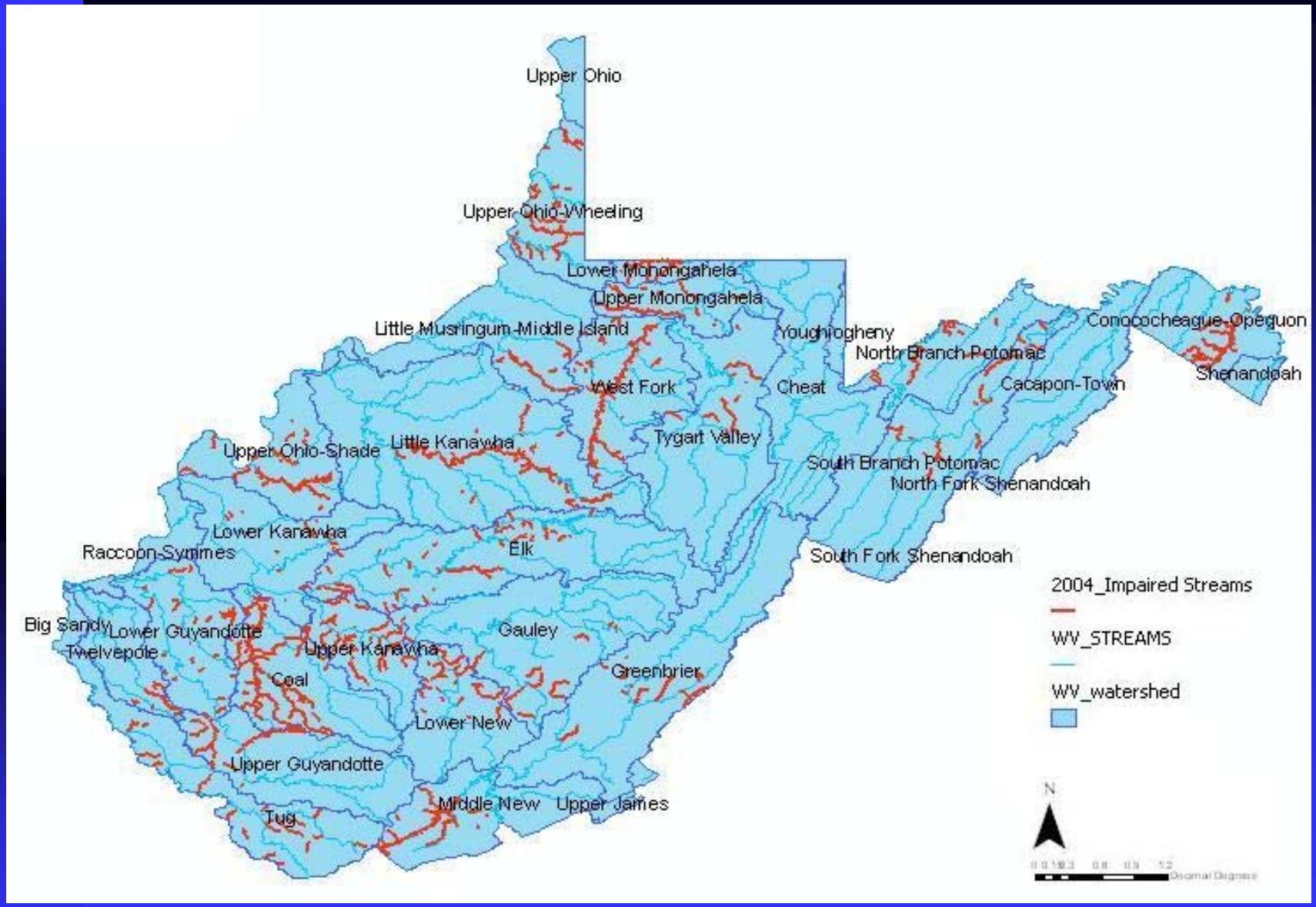

Figure 2.4 Impaired Streams in West Virginia Watersheds In 2004

Miscellaneous Spatial Analysis of Habitats For Vulnerable Life Forms Threatened By Mining Activities

- Regarding the vulnerability of biodiversity, the map in Figure 2.5 shows ample distribution of habitats for diverse species in various areas of the state where mining activities remain quite active
- The data represents the distribution and conservation status of biodiversity in the state of West Virginia
- These areas contain different life forms made up of butterflies, amphibians, reptiles, birds and mammal species.
- Poor environmental and safety management practices during mining activities not only pose enormous threats to ecosystem health in these areas, but sensitive habitats for different life forms are also vulnerable.
- The species richness indicator or index on the high and medium scale in red and yellow colors maintain a large presence in different areas the state adjacent to mining activities

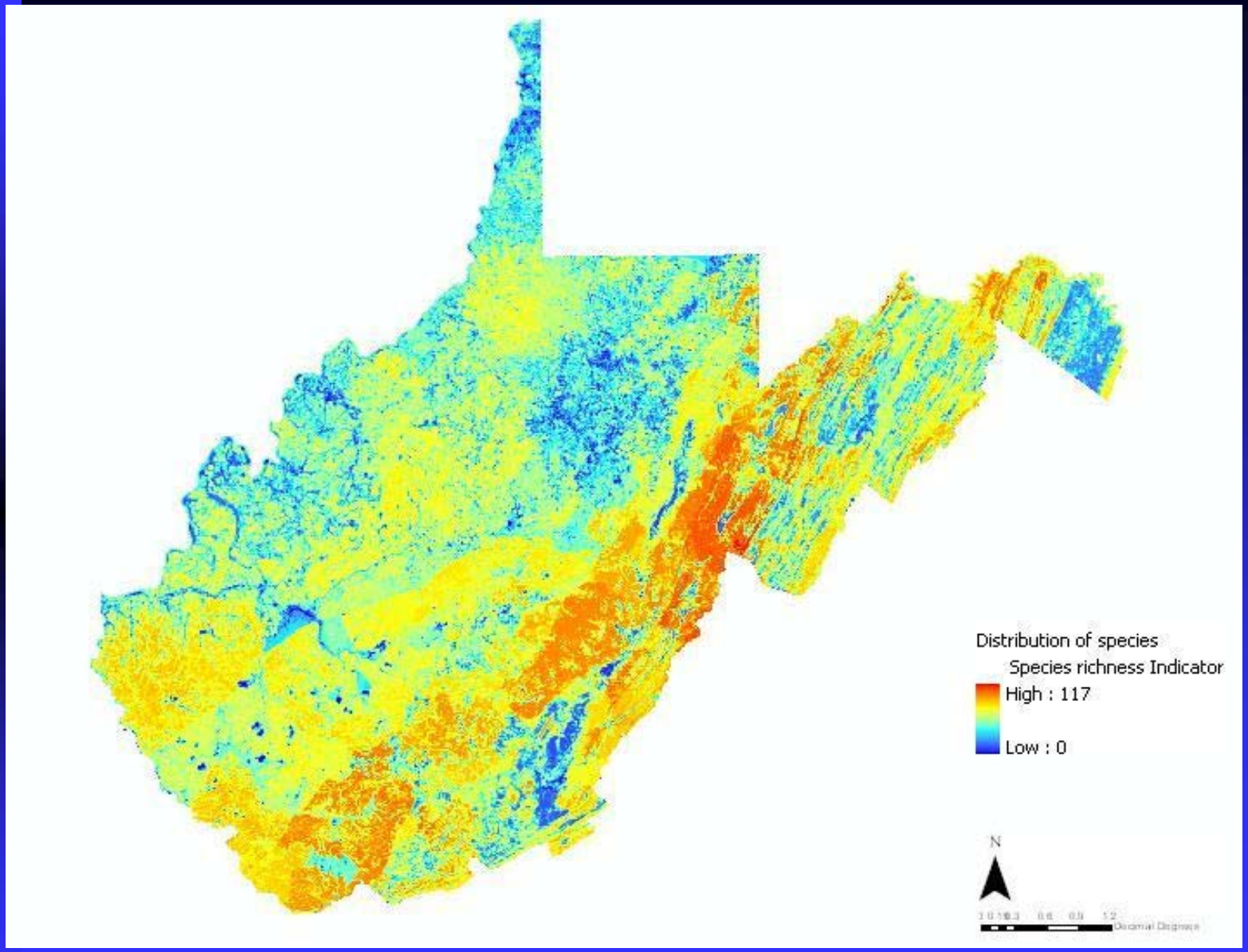

Figure 2.5 The Distribution of The Richness of Species In The State of West Virginia

Factors Responsible For the Problems

- The problems of mining hazards and the threats to watersheds do not operate in a vacuum
- They emanate from policy defects and socio-economic elements.
- These include decades of deregulation, ineffective laws, budget cuts and reduced inspections
- There is also a lack of regulatory oversight in the mining sector coupled with cozy industry and agency relationships
- The over dependence on revenues from mining in a fiscally challenged state such as West Virginia should not be overlooked
- This can be partly buttressed from the map in Figure 3.1 where just a few counties account for the largest concentration of income at a scale much higher than the rest of the state.
- Tougher regulations in those settings, could be interpreted as taking jobs away in economically depressed areas where citizens need jobs in the mining sector for their daily survival

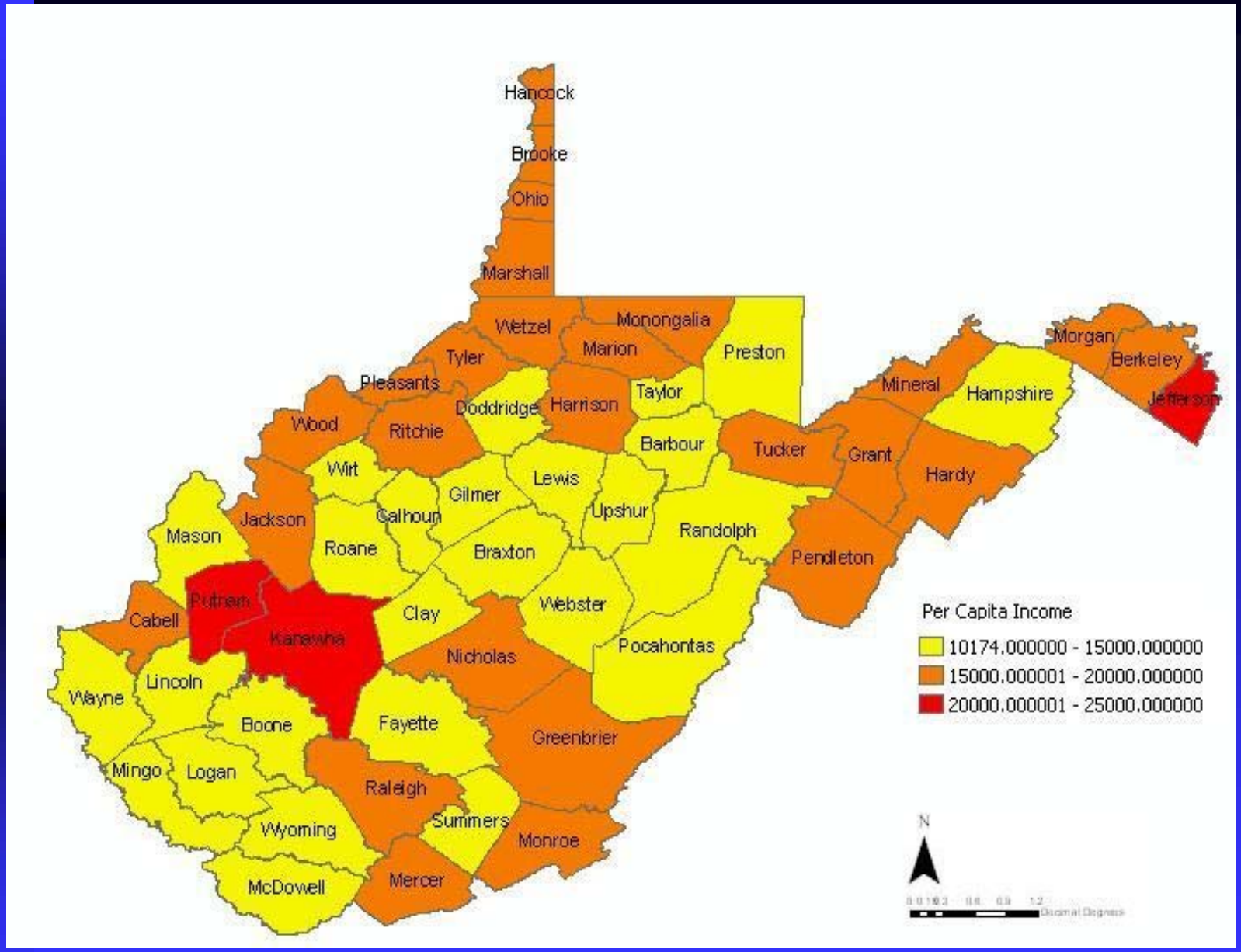

Figure 3.1 Per Capita Income In West Virginia Counties

Findings

- Evidence of large presence of pollutants emanating from mining activities in areas adjacent to sensitive watersheds
- The pollutants threatening the surrounding ecology of the watersheds consists of biological elements, Ph and metals
- The analysis also points to the rising cases of stream watershed impairment as a result of mining
- The study showed the presence of biological pollutants along the upper Monogahele watershed.
- Monogahele watershed saw its number of impaired streams from biological pollutants which stood at 56 in 1996 grow to 128 in 1998, 182 in 2002 to 2004
- Traces of metallic pollutants remained quite rampant in four other watersheds most notably the Upper Kanwaha, Coal, Upper Guyandatte and Twelve pole
- The number of cases of impaired streams attributed to metal sediments remained in high triple digits between 2002 through 2004 and 1998
- Temporal spatial analysis involving GIS mapping of the extent of watershed pollution in West Virginia revealed large concentration of ecosystem quality inhibitors

Remedies

- This section of the paper highlights remedies for dealing with the problems facing the study area of West Virginia

- **Enact Effective Regulations**

  - Authorities can fulfill this by adopting firm legislations to regulate activities prompting pollution and degradation of environmental resources such as stream habitats and others

- **Mining Industry Must Comply With Existing Laws**

  - The mining sector must be required to comply with existing safety guidelines in order to minimize impairment of streams and surrounding ecosystem

- **Improve Existing Data Infrastructure**

  - The authorities in the state of West Virginia should improve existing environmental technologies in order to strengthen public access to data on pollution and the ability to carry out impact assessment

- **Design Regional Ecological Information System**

  - Without access to a spatially referenced system, decision makers and mining operations would not know the location and severity of pollutants for the ecosystem.

Conclusions

- In the geospatial analysis of mining impacts, the paper shows while mining offers various benefits to West Virginia, it continues to impact the environment
- Multiple cases of watershed impairment with greater concentration in different areas of the state
- Temporal-spatial tracking of pollution sources in the state point to activities from mining sites in ecologically sensitive areas
- There were large spatial concentration of biological effluents, PH and metals in streams and the watersheds
- Finally, using GIS to capture the nature of watershed impairment and the dispersion of pollutants in West Virginia improves our knowledge of the scale of exposure to ecosystem stress
- It also provides a framework for improving the health of vulnerable ecosystems through the adoption of effective mitigation measures