# West Virginia Watershed Assessment Pilot Project:

## Little Kanawha River Watershed Assessment

Final Report

December 31, 2013

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Report Prepared by The Nature Conservancy for the West Virginia Department of Environmental Protection and the United States Environmental Protection Agency

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## *List of Tables*

Table 1. Little Kanawha River Watershed Timeline ........ 2
Table 2. Little Kanawha River Watershed - Land Use/Land Cover 2009-2010 (Maxwell et al. 2011) ........ 8
Table 3. Rare Species in Little Kanawha River Watershed (WVDNR 2005) ........ 8
Table 4. Species Rankings Definitions (NatureServe 2012) ........ 10
Table 5. Invasive Species in Little Kanawha River Watershed (WVDA 2011) ........ 10
Table 6. Northeast Terrestrial Habitat Types – Little Kanawha River Watershed (TNC 2011c) ........ 13
Table 7. HUC12 Watershed Information (NRCS 2009, USGS 2011) ........ 16
Table 8. NWI Wetland Types - Little Kanawha River Watershed (USFWS 2010) ........ 18
Table 9. Watershed Characterization Priority Models and Indices ........ 19
Table10. Definition of Objective Method Categories (Foundations of Success 2009) ........ 23
Table 11. WVDEP Reference Stream Criteria (Pond et al. 2012) ........ 24
Table 12. WVDEP Stressed Stream Criteria (Pond et al. 2012) ........ 25
Table 13. Reference and Stressed Distribution Examples for Three Types of Metrics ........ 27
Table 14. Critical Metrics for Priority Model Analysis ........ 28
Table 15. Principal Components Analysis of Streams Condition Metrics ........ 30
Table 16. Metrics Included in the Current Condition Analysis ........ 31
Table 17. Example Values, Relative Scores, Objective Categories, and Objective Scores for Selected Catchments and Metrics ........ 37
Table 18. Example Index Objective, Relative, and Combined Results for Selected Catchments for the Streams/Riparian Areas Model ........ 38
Table 19. Example Model Objective, Relative, and Combined Results for Selected Catchments for the Streams/Riparian Areas Model ........ 40
Table 20. Example Streams Water Quality Metrics for Catchment C1235 with Value, Objective Category, Objective Score, and Relative Score for Each Metric ........ 45
Table 21. Metrics Included in the Consolidated Analysis ........ 49

## *List of Figures*

Figure 1. West Virginia Watershed Assessment Pilot Project HUC8 Watersheds (NRCS 2009) .................. 3
Figure 2. Little Kanawha River Watershed Study Area (USGS 2005) ........................................................ 1
Figure 3. Average Annual Temperature in the Little Kanawha River Watershed (USDA/NRCS 2006a) ....... 3
Figure 4. Average Annual Precipitation in the Little Kanawha River Watershed (USDA/NRCS 2006b)........ 3
Figure 5. The Nature Conservancy Ecoregions – West Virginia (TNC 2009) .............................................. 5
Figure 6. USEPA Level III Ecoregions – West Virginia (USEPA 2011)......................................................... 5
Figure 7. Little Kanawha River Watershed – Land Use/Land Cover 2009-2010 (Maxwell et al. 2011) ........ 7
Figure 8. Little Kanawha River HUC12 Watersheds (NRCS 2009) ............................................................ 15
Figure 9. Reference and Stressed Stream Catchments............................................................................. 25
Figure 10. Threshold Definition Model ..................................................................................................... 27
Figure 11. Streams/Riparian Areas Priority Model Flowchart ................................................................. 42
Figure 12. Wetlands Priority Model Flowchart......................................................................................... 43
Figure 13. Uplands Priority Model Flowchart .......................................................................................... 44
Figure 14. Consolidated Analysis Flowchart ............................................................................................ 47
Figure 15a. Streams Overall Results – HUC12 Level ................................................................................ 53
Figure 15b. Streams Overall Results – Catchment Level .......................................................................... 54
Figure 16a. Streams Water Quality Index Results – HUC12 Level ............................................................ 55
Figure 16b. Streams Water Quality Index Results – Catchment Level ...................................................... 56
Figure 17. Little Kanawha Watershed – Wells and Roads/Railroads (WVGES 2012, WVDOT 2011).......... 57
Figure 18a. Streams Water Quantity Index Results – HUC12 Level.......................................................... 59
Figure 18b. Streams Water Quantity Index Results – Catchment Level ................................................... 60
Figure 19a. Streams Hydrologic Connectivity Index Results – HUC12 Level ............................................ 61
Figure 19b. Streams Hydrologic Connectivity Index Results – Catchment Level...................................... 62
Figure 20a. Streams Biodiversity Index Results – HUC12 Level ............................................................... 63
Figure 20b. Streams Biodiversity Index Results – Catchment Level ......................................................... 64
Figure 21a. Streams Riparian Habitat Index Results – HUC12 Level......................................................... 66
Figure 21b. Streams Riparian Habitat Index Results – Catchment Level4.1.2 Wetlands........................... 67
Figure 22a. Wetlands Overall Results – HUC12 Level ............................................................................... 69
Figure 22b. Wetlands Overall Results – Catchment Level ........................................................................ 70
Figure 23a. Wetlands Water Quality Index Results – HUC12 Level .......................................................... 71
Figure 23b. Wetlands Water Quality Index Results – Catchment Level .................................................... 72
Figure 24a. Wetlands Hydrology Index Results – HUC12 Level ................................................................ 74
Figure 24b. Wetlands Hydrology Index Results – Catchment Level .......................................................... 75
Figure 25a. Wetlands Biodiversity Index Results – HUC12 Level.............................................................. 76
Figure 25b. Wetlands Biodiversity Index Results – Catchment Level ....................................................... 77
Figure 26a. Wetlands Wetland Habitat Index Results – HUC12 Level ...................................................... 78
Figure 26b. Wetlands Wetland Habitat Index Results – Catchment Level ................................................ 79
Figure 27a. Uplands Overall Results – HUC12 Level ................................................................................. 81
Figure 27b. Uplands Overall Results – Catchment Level .......................................................................... 82

Figure 28a. Uplands Habitat Connectivity Index Results – HUC12 Level ... 83
Figure 28b. Uplands Habitat Connectivity Index Results – Catchment Level ... 84
Figure 29a. Uplands Habitat Quality Index Results – HUC12 Level ... 85
Figure 29b. Uplands Habitat Quality Index Results – Catchment Level ... 86
Figure 30a. Uplands Biodiversity Index Results – HUC12 Level ... 87
Figure 30b. Uplands Biodiversity Index Results – Catchment Level ... 88
Figure 31. Consolidated Analysis Overall Results ... 90
Figure 32. Consolidated Analysis Energy Results ... 91
Figure 33. Consolidated Analysis Climate Change – Resiliency (TNC 2012) ... 92
Figure 34. Consolidated Analysis Climate Change – Regional Flow (TNC 2012) ... 93
Figure 35. Little Kanawha River Watershed Opportunities – Protected Lands ... 94
Figure 36. Little Kanawha River Watershed Opportunities – Priority Interest Areas (TNC 2012, WVDOF 2011) ... 95
Figure 37. Possible End User Project Parameters ... 97
Figure 38. Protection Sample Process Flowchart ... 99
Figure 39. Restoration Sample Process Flowchart ... 101

## *List of Abbreviations*

| | |
|---|---|
| AMD | Acid Mine Drainage |
| ARA | Active River Area |
| BMP | Best Management Practice |
| CRP | Conservation Reserve Program |
| CSRV | Cumberlands and Southern Ridge and Valley Ecoregion |
| DEM | Digital Elevation Model |
| ERO | Eastern Regional Office (TNC) |
| ESRI | Environmental Systems Research Institute, Inc. |
| FEMA | Federal Emergency Management Agency |
| FRA | Forest Reclamation Approach |
| GIS | Geographic Information Systems |
| GLIMPSS | Genus Level Index of Most Probable Stream Status |
| NED | National Elevation Dataset |
| NHD | National Hydrography Dataset |
| NLCD | National Land Cover Dataset |
| NPDES | National Pollutant Discharge Elimination System |
| NRAC | Natural Resource Analysis Center (WVU) |
| NRCS | Natural Resource Conservation Service |
| NWI | National Wetlands Inventory |
| PAFO | Pennsylvania Field Office (TNC) |
| PCS | Permit Compliance System |
| RBP | Rapid Bioassessment Protocol |
| SGNC | Species in Greatest Need of Conservation |
| SMCRA | Surface Mining Control and Reclamation Act |
| TMDL | Total Maximum Daily Load |
| TNC | The Nature Conservancy |
| USEPA | United States Environmental Protection Agency |
| USFS | United States Forest Service |
| USGS | United States Geological Survey |
| WAB | Watershed Assessment Branch (WVDEP) |
| WRP | Wetland Reserve Program |
| WVDA | West Virginia Department of Agriculture |
| WVDEP | West Virginia Department of Environmental Protection |
| WVDNR | West Virginia Division of Natural Resources |
| WVDOF | West Virginia Division of Forestry |
| WVFO | West Virginia Field Office (TNC) |
| WVGES | West Virginia Geological and Economic Survey |
| WVGISTC | West Virginia Geographic Information Systems Technical Center |
| WVSAMB | West Virginia Statewide Addressing and Mapping Board |
| WVU | West Virginia University |

## *Table of Contents*

Acknowledgments ..... iii
List of Tables ..... iv
List of Figures ..... v
List of Abbreviations ..... vii
Table of Contents ..... viii
Executive Summary ..... x
Section 1: Introduction ..... 1
1.1 Project Description ..... 1
1.2 Project Goals ..... 1
1.3 Project Objectives ..... 1
1.4 Project Process ..... 2
1.5 Little Kanawha Watershed Timeline ..... 2
1.6 Project Study Area ..... 2
1.6.1 Pilot HUC8 Watersheds ..... 2
1.6.2 Little Kanawha River Watershed Study Area ..... 3
Section 2: Little Kanawha Watershed Description ..... 1
2.1 History/Economics ..... 1
2.2 Climate ..... 2
2.3 Natural Resources ..... 4
2.3.1 Ecoregions/Geology ..... 4
2.3.2 Land Use/Land Cover ..... 6
2.3.3 Biodiversity ..... 6
2.3.4 Streams ..... 12
2.3.5 Vegetation Types ..... 12
Section 3: Assessment Methodology ..... 14
3.1 Assessment Design ..... 14
3.1.1 Planning Units ..... 14
3.1.2 Landscape Classification ..... 14
3.1.2.1 Streams/Riparian Areas ..... 14
3.1.2.2 Wetlands ..... 18
3.1.2.3 Uplands ..... 18
3.2 Priority Models ..... 19
3.2.1 Streams/Riparian Areas Model ..... 20
3.2.2 Wetlands Model ..... 21
3.2.3 Uplands Model ..... 22
3.3 Ranking Procedure ..... 23
3.3.1 Objective Classification ..... 23
3.3.2 Objective Thresholds ..... 25
3.3.3 Critical Metrics ..... 28
3.3.4 Metrics Final Selection ..... 29
3.3.5 Metric Weights ..... 29
3.3.6 Metric Scores ..... 36
3.3.7 Index Scores ..... 36
3.3.8 Model Scores ..... 39
3.3.9 Example Index and Model Scores Calculation ..... 41

3.4 Consolidated Analysis ... 46
3.5 Data ... 50
3.5.1 Data Sources ... 50
3.5.2 Data Quality ... 51
Section 4: Results and Discussion ... 52
4.1 Current Condition Results and Discussion ... 52
4.1.1 Streams/Riparian Areas ... 52
4.1.2 Wetlands ... 68
4.1.3 Uplands ... 80
4.2 Consolidated Analysis Results and Discussion ... 89
Section 5: Recommendations and Conclusions ... 96
5.1 Recommendations for Use ... 96
5.2 Potential Strategies ... 102
5.2.1 Streams/Riparian Areas ... 102
5.2.2 Wetlands ... 103
5.2.3 Uplands ... 104
5.3 Data Needed and Next Steps ... 105
References ... 107
Appendix A: Detailed Data Source Information ... 112
Appendix B: Metrics Description and GIS Process ... 121
Appendix C: Detailed Full Project Timeline ... 145
Appendix D: Workshop Notes and Attendees ... 146

## *Executive Summary*

Accurate, current, and scientifically defensible watershed assessments are invaluable in a variety of decision-making processes, such as regulatory decisions concerning permitting impacts to aquatic and terrestrial resources, and the suitability and placement of mitigation and restoration projects to offset these impacts. The West Virginia Watershed Assessment Pilot Project was initiated to address the lack of comprehensive watershed assessments in the state, which has likely contributed to a loss in area and function of critical aquatic resources, particularly in watersheds where mining, oil and gas development, or other significant land use changes are occurring. Its purpose was to advance knowledge about aquatic and terrestrial resources within the state, inform regulatory decisions, and establish priorities for protection and restoration activities. It was also intended to facilitate communication and collaboration regarding watershed protection and restoration among regulatory personnel, decision-makers, and stakeholders; to identify data gaps/needs within West Virginia; and to suggest possible future projects to generate data that may inform future assessments. The intent of this pilot project was to develop an assessment process that may be applied to all watersheds within the state, given available funding. The initial watersheds chosen for the pilot project (Lower and Upper Monongahela, Elk, Upper Guyandotte, Little Kanawha, and Gauley) are experiencing significant impacts to headwaters and wetlands as a result of development and resource extraction.

We assessed the condition and function of the Little Kanawha River watershed at two spatial scales—HUC12 watersheds and NHDPlus catchments—using a hierarchical approach that individually modeled three landscapes that characterize a watershed: streams, wetlands, and uplands. For each landscape, we defined several indices that contributed to its condition and function, e.g., water quality, habitat connectivity, and biodiversity. Each index consisted of multiple metrics, e.g., impaired streams, number of wells, and percent natural cover. Metric values were normalized and assigned to one of four categories to assess each planning unit objectively in terms of its deviation from an ideal ecological condition. Metrics were weighted and aggregated to provide index scores, which were weighted and aggregated into overall scores for each landscape. To ensure scientific validity of the assessment process, a Technical Advisory Team and an Expert Panel were assembled to provide peer review of the assessment methodology and review preliminary results throughout the project process. The two groups consisted of agency personnel, academic researchers, and individuals from the non-profit and private sectors with relevant expertise.

Results of the assessment show that all landscapes in the Little Kanawha River watershed exhibited higher quality throughout the center of the watershed, with lesser quality areas around the major urban center of Parkersburg in the far west. Development and alternative land uses such as grazing were the most influential metrics determining stream quality, with most of these impacts in the northwest. The central and southeast part of the watershed both emerged as higher quality.

Two products were developed to disseminate the assessment results to interested parties and potential users: individual watershed reports and an interactive web tool that displays the results of the analysis and selected spatial data with attribute information. The ranking of planning units generated in the assessment may be used to identify and prioritize areas within the watershed for conservation, restoration, or mitigation activities, depending upon stakeholders' goals and resources.

## *Section 1: Introduction*

### 1.1 Project Description

The West Virginia Department of Environmental Protection (WVDEP) was awarded a US Environmental Protection Agency (USEPA) Region III Wetland Program Development Grant to complete a Watershed Assessment Pilot Project for five HUC8 watersheds in West Virginia. This was matched with funding from WVDEP and sub-awarded to The Nature Conservancy of West Virginia (TNC). The West Virginia Watershed Assessment Pilot Project (WVWAPP) was initiated to develop a watershed assessment process to inform conservation and management actions within the state. The project defined the methodology and data necessary to generate a peer-reviewed watershed assessment procedure and a decision support tool that can potentially be implemented for all watersheds throughout West Virginia. The information presented in these assessment reports will provide guidance to regulatory agencies, non-governmental organizations (NGOs), and other partners and decision-makers on potential strategies and locations for protection and restoration of critical aquatic and terrestrial resources within each watershed. Examples of intended uses include: identifying areas of high conservation value for protection by state and federal government agencies or NGOs, identifying high priority sites for conducting restoration activities, and assessing cumulative watershed effects contributing to the degradation of aquatic resources.

### 1.2 Project Goals

1. Provide a rigorous assessment process that leads to the advancement of the science and protection of aquatic headwater resources within watersheds in West Virginia.
2. Achieve a net increase in the quantity and quality of wetlands and other aquatic resources, and their resource function, within the watershed by providing support and information to state and federal agencies, private organizations, and stakeholders.
3. Protect, sustain, and restore the health of people, communities, and ecosystems by supporting integrated and comprehensive approaches and partnerships.

### 1.3 Project Objectives

1. Design and test a watershed assessment process that includes analysis of cumulative watershed effects.
2. Suggest priorities for protection and restoration of aquatic and terrestrial resources and evaluate/rank areas within watersheds accordingly.
3. Provide relevant information, strategies/actions, and a decision support tool to assist partners, stakeholders, and regulatory staff with decisions affecting watershed resources.
4. Increase communication and collaboration regarding watershed protection and restoration among decision-makers and stakeholders.
5. Identify data gaps/needs within West Virginia.

### 1.4 Project Process

1. Define the watershed **assessment methodology**.
2. Complete a **Baseline analysis** that describes watershed resources, impacts, and condition.
3. Conduct **expert workshop 1** to review the assessment process, evaluate the data collected, obtain local information on watershed specific resources, issues, and other relevant information, and define appropriate metrics for parameters used to evaluate the importance or value/contribution of potential actions.
4. Conduct **expert workshop 2** to review the data collected, evaluate the conclusions of the prioritization process, and develop strategies designed to address issues within the watershed.
5. Complete a **future threats analysis** using results from the expert workshop to incorporate local data and apply prioritization metrics to rank potential actions and sites within the watershed; create an **opportunities layer** to indicate where protection or restoration projects might expand upon currently protected lands or priority interest areas.
6. Complete a draft watershed assessment. Conduct a **decision maker/end user workshop** for Little Kanawha watershed stakeholders**.**
7. Complete final assessment.

### 1.5 Little Kanawha Watershed Timeline

Table 1. Little Kanawha River Watershed Timeline

| Date | Activity |
|---|---|
| April 1, 2011 | Award date, project initiation |
| June 13, 2011 | First Technical Advisory Team meeting |
| Oct 10-11, 2012 | Expert Workshop 1 |
| Jan 8-9, 2013 | Expert Workshop 2 |
| May 8, 2013 | Final End User Workshop and demonstration of prototype interactive web tool |
| Dec 31, 2013 | Final Little Kanawha River watershed assessment report and interactive web tool complete |

For a detailed timeline of the entire project, please see Appendix C: Detailed Full Project Timeline.

### 1.6 Project Study Area

#### 1.6.1 Pilot HUC8 Watersheds

The Project Study Area includes five 8-digit HUC watersheds (referred to as HUC8 watersheds) within West Virginia (Figure 1), including: **Lower and Upper Monongahela** (05020005 and 05020003, respectively), **Elk** (05050007), **Upper Guyandotte** (05070101), **Little Kanawha** (05030203), and **Gauley** (05050005). Draft watershed assessments were completed in two of the five identified watersheds (the Lower/Upper Monongahela and the Elk) in the first year of the project. During the second project year, the remaining three watershed assessments were completed and the assessment methodology was refined by incorporating new data, suggestions from the technical advisory team and other experts and stakeholders, and lessons learned during the first project year. The assessment results from the five watersheds were incorporated into an interactive web tool to be accessible to a wide variety of stakeholders.

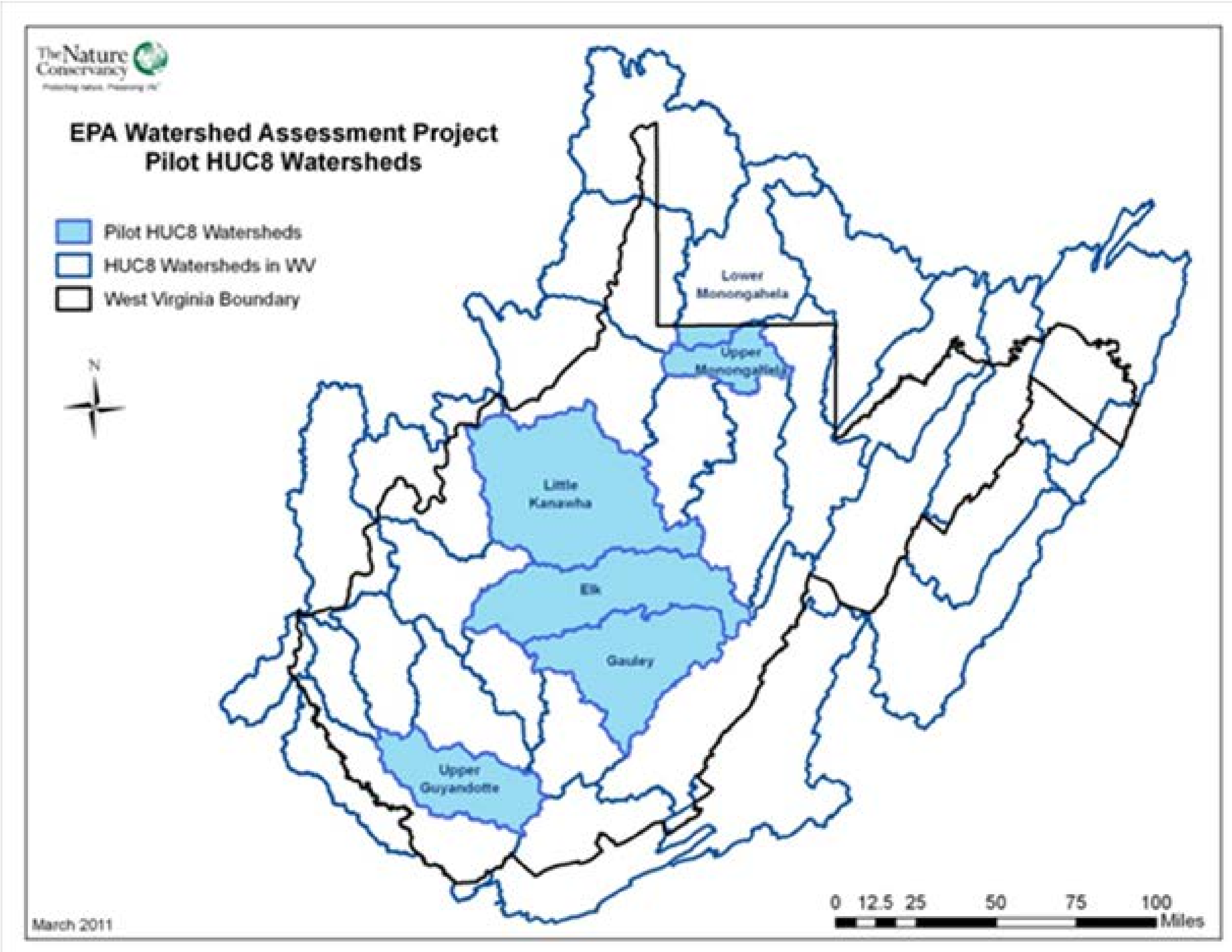


Figure 1. West Virginia Watershed Assessment Pilot Project HUC8 Watersheds (NRCS 2009)

### 1.6.2 Little Kanawha River Watershed Study Area

The study area considered in this report is the Little Kanawha River watershed (Figure 2). The watershed, or drainage area, covers approximately 2,308 square miles in northwest West Virginia, making it the largest of the pilot HUC8 watersheds. From its origin at Kanawha Head in Upshur County, the Little Kanawha River flows northwest for 171 miles to its confluence with the Ohio River at Parkersburg. It passes through Upshur, Lewis, Braxton, Gilmer, Calhoun, Wirt, and Wood counties, although the watershed also comprises portions of Ritchie, Doddridge, Roane, Webster, and Clay counties. The major population center is Parkersburg, and the larger towns include Blennerhassett, Spencer, Glenville, Harrisville, and Mineral Wells. A U.S. Army Corps of Engineers Dam on the river near Burnsville created Burnsville Lake as a recreational and flood control reservoir in 1976 (Gilchrist-Stalnaker 2010).

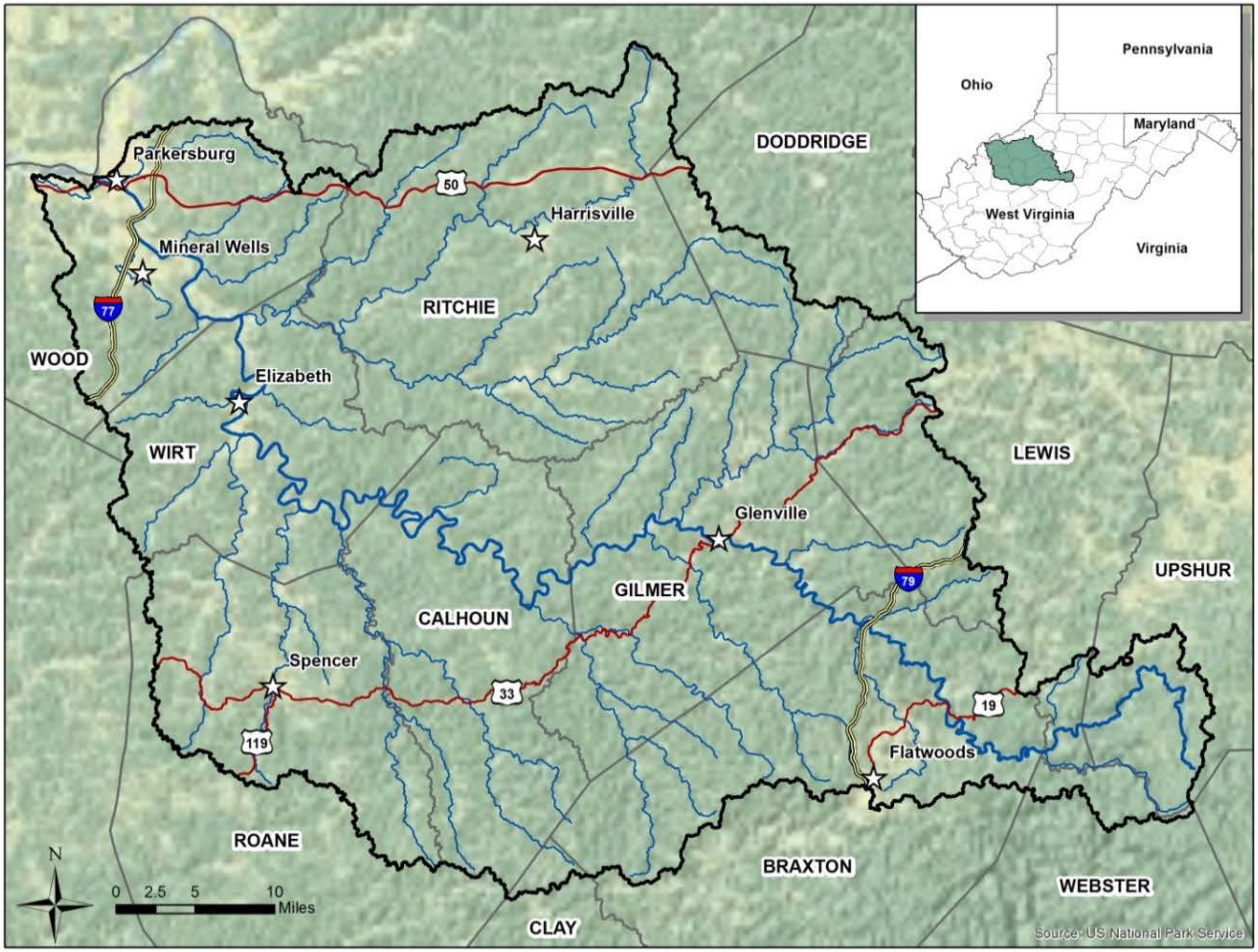


Figure 2. Little Kanawha River Watershed Study Area (USGS 2005)

## *Section 2: Little Kanawha Watershed Description*

### 2.1 History/Economics

Named for the Native Americans who settled along its banks, the Little Kanawha River was, before European settlement, a route between the Ohio Valley and the hunting grounds of central West Virginia (Bonar 2012). The upper watershed was first explored by European settlers in the 1770s; the first settlement was called Bulltown, after the settlers massacred the Indians settled there under Chief Bull (Gilchrist-Stalnaker 2010). In the late 1700s Parkersburg (originally known as Newport) was settled, followed soon after by Burnsville, Gilmer Station, Glenville, Elizabeth, Grantsville, and Creston along the Little Kanawha River (Gilchrist-Stalnaker 2010, Hendricks 2010).

The Little Kanawha watershed was the center of some of the most important events in the state's political, economic, and ecological history. During the civil war, its residents fought under both flags; Calhoun County was named for John C. Calhoun, a proponent of the Southern states-rights philosophy, while its county seat was named for Union general Ulysses S. Grant (Bonar 2012). Parkersburg resident Arthur Ingraham Boremann was one of the founders of the Unionist Reorganized Government of Virginia, which led to the creation of the state of West Virginia with Boremann as its first governor (Hendricks 2010). The first school for African-American children in West Virginia was established in Parkersburg in 1862, and became part of the segregated public school system in 1866 (Hendricks 2010). Most importantly, however, the Little Kanawha watershed was the birthplace of West Virginia's oil and gas industry.

Petroleum and natural gas production started as an outgrowth of the salt industry, because oil and gas are often associated with brine deposits. Salt manufacture began in the Kanawha Valley in the late 1700s, and gas was first struck in a well drilled for salt at Charleston in 1815 (Thoenen 1964, WVGES 2013). In the Little Kanawha watershed, natural gas famously escaped along with the salt water from brine springs along the Little Kanawha near the Hughes River, resulting in the stream being named Burning Springs Run (WVGES 2013). Petroleum seepages were also found along the Little Kanawha, Big Sandy, and Hughes rivers (a colloquial name for the Little Kanawha was "Old Greasy"), and oil was struck while drilling for salt in the Burning Springs area in 1859 (Thoenen 1964). The resulting oil boom created the town of Burning Springs, lit by natural gas. Oil from the Burning Springs oil field—one of only two oil fields in the world-- was floated down the Little Kanawha River to Parkersburg (WVGES 2013) and in 1861 charters were granted for a railroad and a turnpike into the area (Thoenen 1964). In 1863, in what was arguably West Virginia's first ecological disaster, the Confederate army set fire to the oil fields and oil that was stockpiled along the river, burning an estimated 150,000 barrels (WVGES 2013). Oil production then shifted to other areas, such as the boomtown of Volcano, with hundreds of wells being drilled. As the industry expanded, to facilitate transportation of oil to Parkersburg, locks and dams were constructed along the Little Kanawha River for steamboats and barges, roads were constructed to link the new oilfields to the established roads, and small railroad companies constructed spur lines to the Northwestern Virginia Railroad. One of the country's first oil refineries was constructed at Parkersburg in 1866 (Hendricks 2010), and the first oil pipeline from Volcano to Parkersburg was constructed in

1879. By 1900, West Virginia had reached peak oil production at 16 million barrels, second only to the state of Ohio (Thoenen 1964).

Large quantities of natural gas were often found along with oil in exploratory wells, and Burning Springs oil field observers noted that the wells placed along the Burning Springs-Volcano anticline, then called the “oil break,” were gas-bearing. In 1867, a dry oil well in Burning Springs produced a large quantity of gas at greater depths, and the West Virginia natural gas industry was born. Population and employment increased in the watershed as the oil and gas industries, and the infrastructures that supported them, expanded. By 1907 there were 22 gas pipelines crossing the state’s boundaries, and in 1910 West Virginia was the leading producer of natural gas in the nation, accounting for 39% of total production (Thoenen 1964).

As in the rest of West Virginia, timbering had also become an important economic activity after the Civil War, and logs were floated down the Little Kanawha River to Parkersburg (Bonar 2012), but it did not achieve the importance of petroleum and natural gas. All three industries remain in the watershed today, but most important is probably Marcellus Shale gas development, which takes advantage of the new hydrofracturing and horizontal drilling technologies. Other industries in the watershed include tourism and recreation, aided by the construction of the dam on the Little Kanawha River that created Burnsville Lake in 1976 (Gilchrist-Stalnaker 2010), and small-scale agriculture such as livestock farming.

**2.2 Climate**

The Little Kanawha River watershed experiences a humid continental climate with variable weather patterns and a large seasonal temperature range. Prevailing winds are from the west during most of the year, but in the summer low pressure cyclonic systems often bring southerly winds and heavy precipitation (USACE 2011). As shown in Figures 3 and 4, average annual precipitation and especially temperature do not vary greatly over most of the watershed. As the elevation change becomes more pronounced at the eastern end of the watershed in the Little Kanawha headwaters area, average temperatures decrease from 53 to 49 degrees and precipitation increases from 51 to 63 inches within a distance of 10 miles.

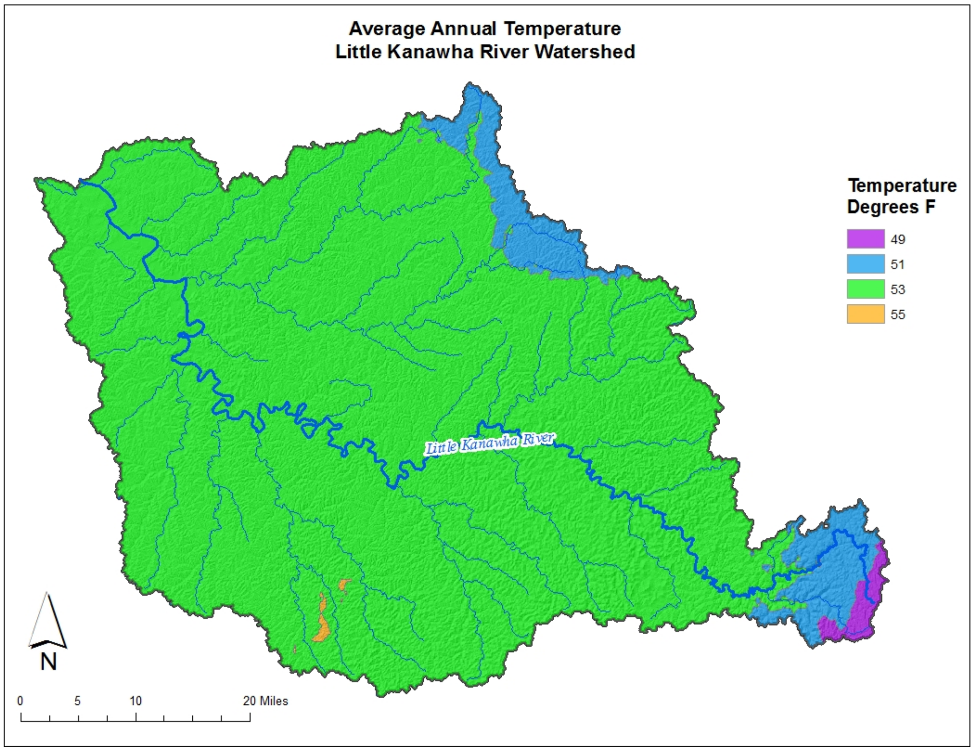


Figure 3. Average Annual Temperature in the Little Kanawha River Watershed (USDA/NRCS 2006a)

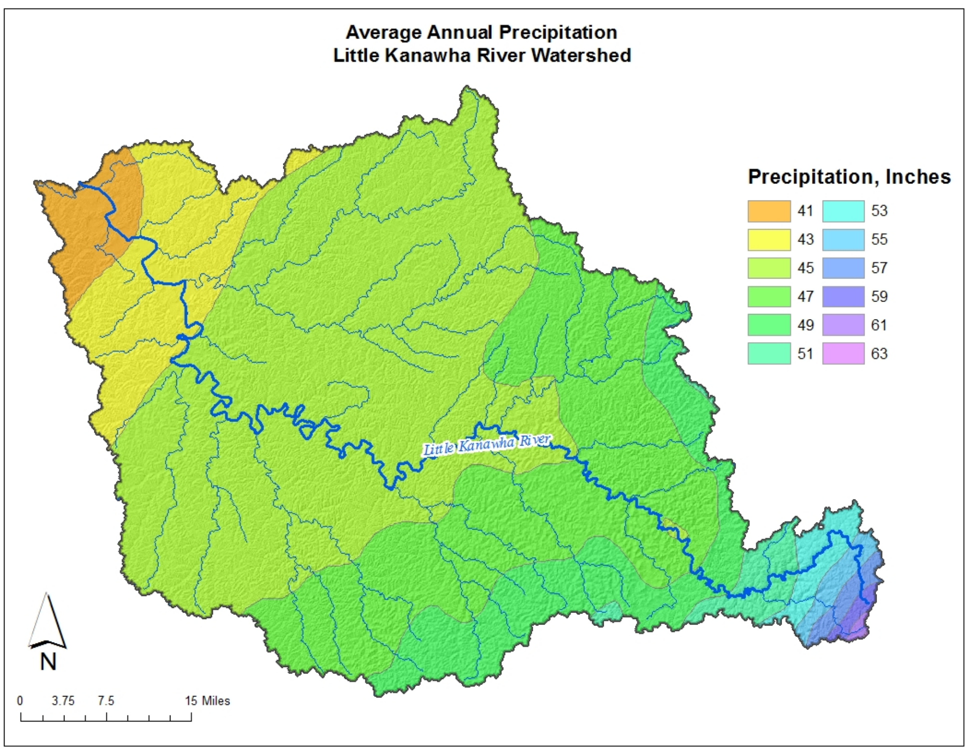


Figure 4. Average Annual Precipitation in the Little Kanawha River Watershed (USDA/NRCS 2006b)

## 2.3 Natural Resources

### 2.3.1 Ecoregions/Geology

The Little Kanawha watershed lies almost entirely within the TNC Western Allegheny Plateau Ecoregion (USEPA Level III ecoregion 70), an unglaciated plateau of horizontal layers of sedimentary rock, Figure 5 (Bailey 1995, Omernik et al. 1992, Woods et al. 1999). The northwestern portion of the Little Kanawha is part of USEPA level IV ecoregion 70a, Permian Hills, a hilly region dominated by Appalachian Oak Forest with soils derived from shale, siltstone, limestone, sandstone, and coal (Woods et al. 1999). The south-central portion lies within ecoregion 70b, the Monongahela Transition Zone, an area of low hills and entrenched rivers that is less rugged and warmer than the Permian Hills. Though its soils and underlying rock strata are similar to that of the Permian Hills, it is dominated by Mixed Mesophytic Forest. The headwaters area of the Little Kanawha in the southeast extends into the Central Appalachians (USEPA ecoregion 69), subregion 69a, Forested Hills and Mountains (Figure 6). Ecoregion 69 is more densely forested, and higher, cooler, and steeper than the Western Allegheny Plateau (Woods et al. 1999).

There are no known coal resources in the western half of the Little Kanawha watershed. The West Virginia Coal Bed Mapping project has completed mapping in Gilmer County and in parts of Braxton and Lewis counties, and the only appreciable mapped coal resources are part of the Redstone and Pittsburgh formations of the Monongahela group (WVGES 2012a). The Little Kanawha is the only one of the five pilot HUC8 watersheds to have very little mining activity, which is confined to the Sand Fork watershed (EPA 2000). There are, however, extensive deposits of oil and natural gas, which were first produced as by products from salt mining and later became the locus of West Virginia’s oil and gas industry.

The Marcellus Shale play, a large deposit of black sedimentary rock containing natural gas, underlies nearly the entire watershed at a depth of 4,000-8,500 feet (USACE 2011). The thickness of the Marcellus shale increases from west-east across the watershed, ranging from 20-40 feet in the western portion to 80-100 feet in the extreme eastern end (WVGES 2012b). Production from the Marcellus play has grown rapidly since 2008, due to advancements in hydraulic fracturing technology making extraction more economically feasible. Several thousand feet below the Marcellus, the Utica shale also extends under the entire watershed and most of West Virginia. The potential of this shale play is only beginning to be developed.

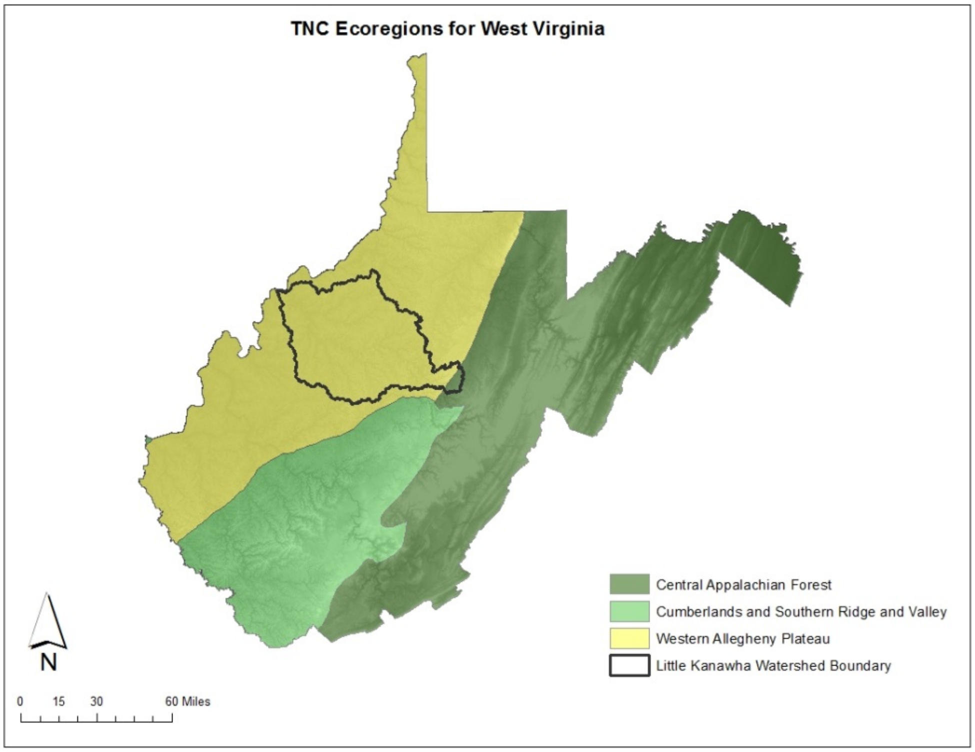


Figure 5. The Nature Conservancy Ecoregions – West Virginia (TNC 2009)

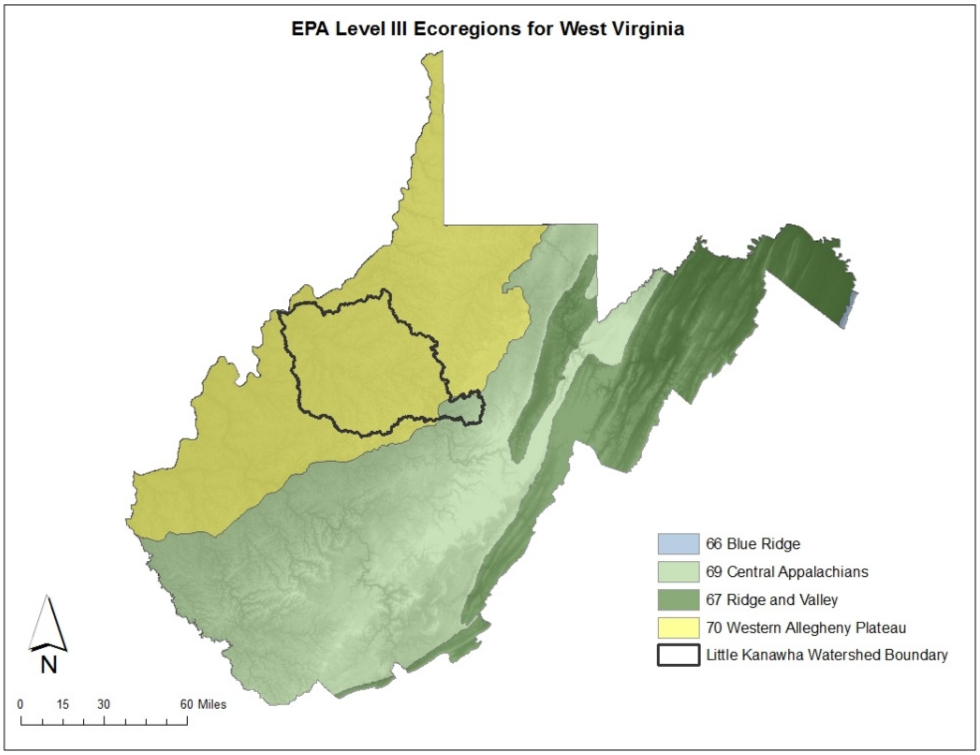


Figure 6. USEPA Level III Ecoregions – West Virginia (USEPA 2011)

### 2.3.2 Land Use/Land Cover

According to a 2009-2010 land cover analysis (Maxwell et al. 2011, Figure 7), the Little Kanawha River watershed consists predominately of deciduous, evergreen, and mixed forest (Table 2), dominated by dry oak forest (TNC 2011a). Grazing pasture is the predominant anthropogenic land use, followed by urban development and cultivated crops. Unique among the five pilot HUC8 watersheds, the Little Kanawha has very little active mining (surface or underground) or reclaimed mine lands.

### 2.3.3 Biodiversity

The West Virginia Natural Heritage Program has recorded 56 Species in Greatest Need of Conservation (SGNCs) in the Little Kanawha watershed since 1990 (WVDNR 2005, Table 3). Two are federally endangered species, the mussels snuffbox (*Epioblasma triquetra*) and clubshell (*Pleurobema clava)*. Aside from these, the majority are vulnerable to critically imperiled statewide (NatureServe ranks S1-S3, Table 4, NatureServe 2012), but are apparently secure globally (G5). Three species have G3 rank signifying globally vulnerable status: a dragonfly (the green-faced clubtail, *Gomphus viridifrons)*, a fish (the Eastern sand darter, *Ammocrypta pellucida)*, and a mussel (the long-solid, *Fusconaia subrotunda)*. A limitation of this element occurrence dataset is that it is apparently biased toward riparian and wetland areas. In addition, it is not known where points were sampled and no rare species were found. A full listing of rare species and their conservation status is given in Table 3, and an explanation of the rankings is given in Table 4 (NatureServe 2012).

Thirty-nine species of non-native invasive plants have been recorded in the Little Kanawha watershed (Table 5), the five most common being multiflora rose (*Rosa multiflora*), Japanese honeysuckle (*Lonicera japonica*), common teasel (*Dipsacus fullonum*), Japanese stiltgrass (*Microstegium vimineum*), and autumn olive (*Elaegnus umbellata*). The USGS has recorded 12 species of non-indigenous fishes; some, like the common carp (*Cyprinus carpio*) and brown trout (*Salmo trutta*), are exotic, while others are natives, often stocked for sport. Rainbow trout (*Onchorhyncus mykiss*) and brown trout, which are stocked in the Little Kanawha River, have been shown to negatively impact native brook trout and darters in other states, although similar studies have not been carried out in West Virginia (NPS 2011, Wood 2012). The Asian clam *(Corbicula fluminea)* has become established in the Little Kanawha River and several tributaries (USGS 2013), but zebra mussels have not been recorded. The freshwater jellyfish (*Craspedacusta sowerbyi*), which can be transported on the legs of waterfowl or in aquatic plants, and has been found over most of the eastern U.S., also has several records from the watershed (USGS 2013).

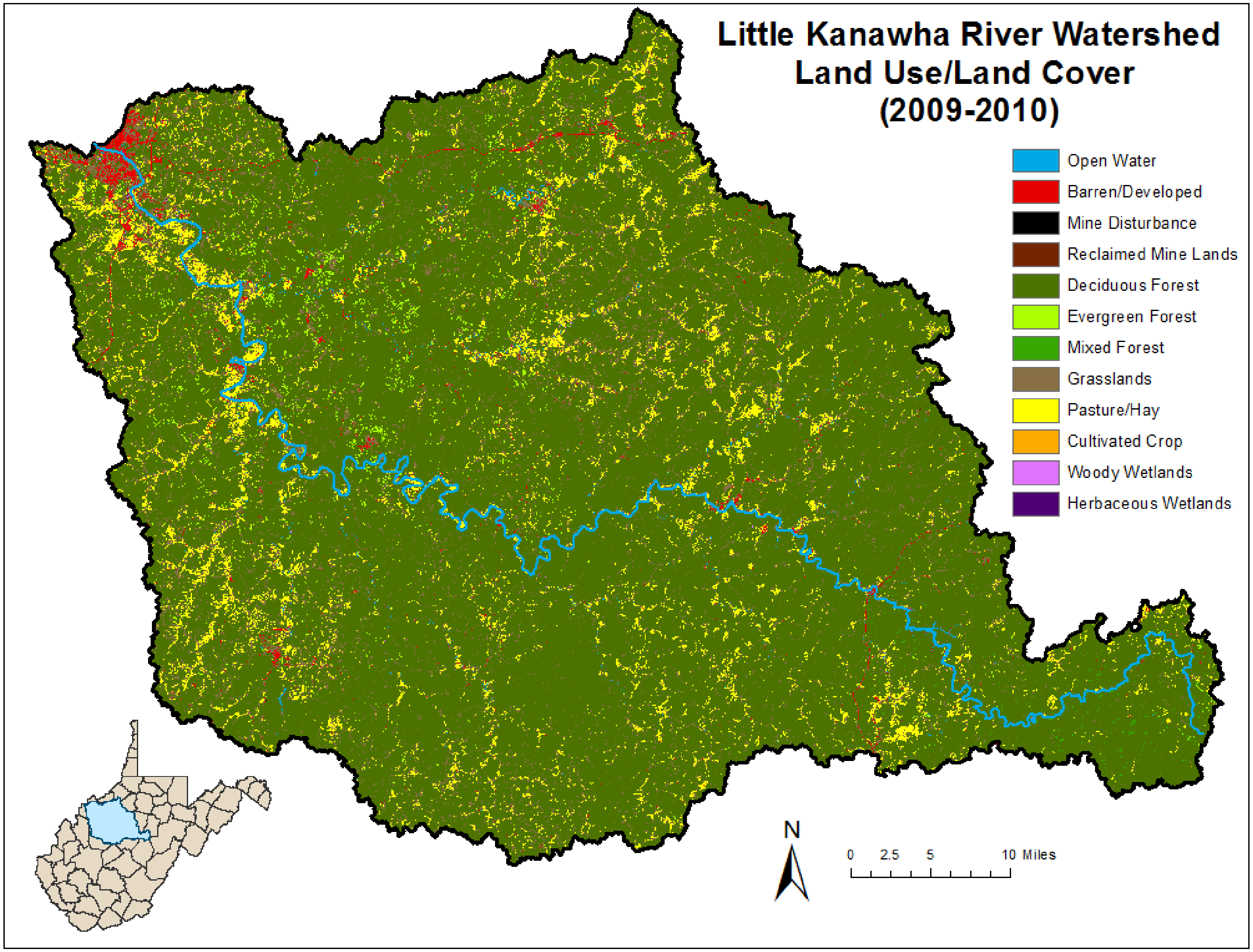


Figure 7. Little Kanawha River Watershed – Land Use/Land Cover 2009-2010 (Maxwell et al. 2011)

Table 2. Little Kanawha River Watershed - Land Use/Land Cover 2009-2010 (Maxwell et al. 2011)

| Land Cover Type | Square Miles | Percent Area |
|---|---|---|
| Forest | 1984 | 86 |
| Grasslands | 161 | 7 |
| Pasture/Hay | 132 | 6 |
| Development | 20 | 1 |
| Open water | 9 | < 1 |
| Agriculture | 1 | < 1 |
| Wetlands | <1 | < 1 |
| Mine disturbance | < 1 | < 1 |

Table 3. Rare Species in Little Kanawha River Watershed (WVDNR 2005)

| Taxon | Scientific Name | Common Name | Global Rank | Sub-National Rank | Federal Rank |
|---|---|---|---|---|---|
| Insect | *Dromogomphus spoliatus* | Flag-tailed spinyleg | G4G5 | S2S3 | |
| Insect | *Gomphus vastus* | Cobra clubtail | G5 | S2 | |
| Insect | *Gomphus descriptus* | Harpoon clubtail | G4 | S3 | |
| Insect | *Gomphus quadricolor* | Rapids clubtail | G3G4 | S2S3 | |
| Insect | *Gomphus viridifrons* | Green-faced clubtail | G3 | S2 | |
| Insect | *Aeshna tuberculifera* | Black-tipped darner | G4 | S2 | |
| Insect | *Anax longipes* | Comet darner | G5 | S1 | |
| Insect | *Epiaeschna heros* | Swamp darner | G5 | S3 | |
| Insect | *Macromia alleghaniensis* | Allegheny river cruiser | G4 | S3 | |
| Insect | *Cordulia shurtleffii* | American Emerald | G5 | S4 | |
| Insect | *Neurocordulia yamaskanensis* | Stygian shadowdragon | G5 | S2 | |
| Insect | *Somatochlora linearis* | Mocha emerald | G5 | S1 | |
| Insect | *Celithemis fasciata* | Banded pennant | G5 | S3 | |
| Insect | *Sympetrum ambiguum* | Blue-faced meadowhawk | G5 | S1 | |
| Insect | *Sympetrum obtrusum* | White-faced meadowhawk | G5 | S2 | |
| Insect | *Lestes dryas* | Emerald spreadwing | G5 | S1 | |
| Insect | *Enallagma vesperum* | Vesper bluet | G5 | S1 | |
| Insect | *Stylurus spiniceps* | Arrow clubtail | G5 | S1 | |
| Insect | *Cyllopsis gemma* | Gemmed satyr | G5 | S2S3 | |
| Mussel | *Epioblasma triquetra* | Snuffbox | G3 | S2 | LE |
| Mussel | *Fusconaia subrotunda* | Long-solid | G3 | S2 | |
| Mussel | *Pleurobema clava* | Clubshell | G2 | S1 | LE |
| Mussel | *Pleurobema sintoxia* | Round pigtoe | G4 | S2 | |
| Mussel | *Toxolasma parvus* | Lilliput | G5 | S2 | |
| Crustacean | *Cambarus monongalensis* | A crayfish | G5 | S3 | |

| Taxon | Scientific Name | Common Name | Global Rank | Sub-National Rank | Federal Rank |
|---|---|---|---|---|---|
| Amphibian | *Ambystoma jeffersonianum* | Jefferson salamander | G4 | S3 | |
| Amphibian | *Cryptobranchus alleganiensis* | Eastern hellbender | G3G4 | S2 | |
| Amphibian | *Aneides aeneus* | Green salamander | G3G4 | S3 | |
| Amphibian | *Pseudotriton montanus diastictus* | Midland mud salamander | G5T5 | S1 | |
| Amphibian | *Pseudotriton ruber* | Northern red salamander | G5 | S3 | |
| Reptile | *Graptemys geographica* | Northern map turtle | G5 | S2 | |
| Reptile | *Eumeces laticeps* | Broad-headed skink | G5 | S2 | |
| Reptile | *Heterodon platirhinos* | Eastern hog-nosed snake | G5 | S3 | |
| Fish | *Ichthyomyzon bdellium* | Ohio lamprey | G3G4 | S2 | |
| Fish | *Ichthyomyzon greeleyi* | Mountain brook lamprey | G3G4 | S1 | |
| Fish | *Lampetra aepyptera* | Least brook lamprey | G5 | S2S3 | |
| Fish | *Lampetra appendix* | American brook lamprey | G4 | S2 | |
| Fish | *Polyodon spathula* | Paddlefish | G4 | S1 | |
| Fish | *Notropis blennius* | River shiner | G5 | S2 | |
| Fish | *Notropis procne* | Swallowtail shiner | G5 | S2 | |
| Fish | *Phoxinus erythrogaster* | Southern redbelly dace | G5 | S2S3 | |
| Fish | *Pimephales vigilax* | Bullhead minnow | G5 | S2 | |
| Fish | *Luxilus cornutus* | Common shiner | G5 | S3 | |
| Fish | *Lythrurus umbratilis* | Redfin shiner | G5 | S3 | |
| Fish | *Carpiodes velifer* | Highfin carpsucker | G4G5 | S1 | |
| Fish | *Ameiurus melas* | Black bullhead | G5 | S3S4 | |
| Fish | *Ammocrypta pellucida* | Eastern sand darter | G3 | S2S3 | |
| Fish | *Etheostoma camurum* | Bluebreast darter | G4 | S3 | |
| Fish | *Etheostoma tippecanoe* | Tippecanoe darter | G3G4 | S2 | |
| Fish | *Percina copelandi* | Channel darter | G4 | S2S3 | |
| Fish | *Percina phoxocephala* | Slenderhead darter | G5 | S1 | |
| Fish | *Percina sciera* | Dusky darter | G5 | S3 | |
| Fish | *Percina shumardi* | River darter | G5 | S1 | |
| Bird | *Ardea herodias* | Great blue heron | G5 | S3B,S4N | |
| Bird | *Circus cyaneus* | Northern harrier | G5 | S1B,S3N | |
| Bird | *Petrochelidon pyrrhonota* | Cliff swallow | G5 | S3B | |

Table 4. Species Rankings Definitions (NatureServe 2012)

| | |
|---|---|
| **G1** | Critically Imperiled—At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors. |
| **G2** | Imperiled—At high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors. |
| **G3** | Vulnerable—At moderate risk of extinction or elimination due to a restricted range, relatively few populations, recent and widespread declines, or other factors. |
| **G4** | Apparently Secure—Uncommon but not rare; some cause for long-term concern due to declines or other factors. |
| **G5** | Secure—Common; widespread and abundant. |
| **LE** | Listed Endangered (Federal) under the US Endangered Species Act of 1973 |
| **LT** | Listed Threatened (Federal) under the US Endangered Species Act of 1973 |
| **S1** | Critically Imperiled—Critically imperiled in the jurisdiction because of extreme rarity or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the jurisdiction. |
| **S2** | Imperiled—Imperiled in the jurisdiction because of rarity due to very restricted range, very few populations, steep declines, or other factors making it very vulnerable to extirpation from jurisdiction. |
| **S3** | Vulnerable—Vulnerable in the jurisdiction due to a restricted range, relatively few populations, recent and widespread declines, or other factors making it vulnerable to extirpation. |
| **S4** | Apparently Secure—Uncommon but not rare; some cause for long-term concern due to declines or other factors. |
| **S5** | Secure—Common, widespread, and abundant in the jurisdiction. |

Table 5. Invasive Species in Little Kanawha River Watershed (WVDA 2011)

| Taxon | Scientific Name | Common Name |
|---|---|---|
| Plant | *Ailanthus altissima* | Tree-of-heaven |
| Plant | *Albizia julibrissin* | Mimosa, Silk Tree |
| Plant | *Alliaria petiolata* | Garlic mustard |
| Plant | *Arthraxon hispidus* | Jointhead arthraxon |
| Plant | *Barbarea vulgaris* | Yellow rocket |
| Plant | *Berberis thunbergii* | Japanese barberry |
| Plant | *Carduus acanthoides* | Plumeless thistle |
| Plant | *Centaurea biebersteinii* | Spotted knapweed |
| Plant | *Cirsium arvense* | Canada thistle |
| Plant | *Conium maculatum* | Poison hemlock |
| Plant | *Cuscuta campestris* | Prairie dodder |
| Plant | *Daucus carrota* | Queen Anne's lace |
| Plant | *Dipsacus fullonum* | Common teasel |
| Plant | *Dipsacus laciniatus* | Cutleaf teasel |
| Plant | *Elaeagnus umbellata* | Autumn olive |
| Plant | *Glechoma hederacea* | Ground Ivy |
| Plant | *Hedera helix* | English ivy |
| Plant | *Holcus lanatus* | Common velvetgrass |

| Taxon | Scientific Name | Common Name |
|---|---|---|
| Plant | *Humulus japonicus* | Japanese hop |
| Plant | *Iris pseudacorus* | Yellow iris |
| Plant | *Lespedeza cuneata* | Sericea |
| Plant | *Creeping Jenny* | Lysimachia nummularia |
| Plant | *Lonicera japonica* | Japanese honeysuckle |
| Plant | *Lonicera maackii* | Amur honeysuckle |
| Plant | *Lonicera morrowii* | Morrow's honeysuckle |
| Plant | *Lysimachia nummularia* | Moneywort |
| Plant | *Lythrum salicaria* | Purple loosestrife |
| Plant | *Microstegium vimineum* | Japanese stiltgrass |
| Plant | *Miscanthus sinensis* | Chinese silvergrass |
| Plant | *Phalaris arundinacea L.* | Reed Canarygrass |
| Plant | *Phragmites australis* | Common reed |
| Plant | *Polygonum cuspidatum* | Japanese knotweed |
| Plant | *Polygonum perfoliatum* | Mile-a-minute weed |
| Plant | *Pueraria montana* | Kudzu vine |
| Plant | *Rhamnus cathartica* | Common buckthorn |
| Plant | *Rosa multiflora* | Multiflora rose |
| Plant | *Rubus phoenicolasius* | Wineberry |
| Plant | *Rumex acetosella* | Sheep sorrel |
| Plant | *Sorghum halepense* | Johnson grass |
| Coelenterate | *Crespedacusta sowerbyi* | Freshwater jellyfish |
| Mollusk | *Corbicula fluminea* | Asian clam |
| Fish | *Lepomus gibbosus* | Pumpkinseed |
| Fish | *Lepomis humilis* | Orangespotted sunfish |
| Fish | *Carassius auratus* | Goldfish |
| Fish | *Cyprinus carpio* | Common carp |
| Fish | *Pimephales promelas* | Fathead minnow |
| Fish | *Esox lucius* | Northern pike |
| Fish | *Morone chrysops* | White bass |
| Fish | *Morone chrysops x M. saxatilis* | Wiper |
| Fish | *Sander Canadensis x vitreus* | Saugeye |
| Fish | *Onchorhynchus mykiss* | Rainbow trout |
| Fish | *Salmo trutta* | Brown trutta |
| Fish | *Salmo x Salvelinus trutta x fontinalis* | Tiger trout |

### 2.3.4 Streams

In 2010, 728 stream miles in the Little Kanawha watershed, including the main stem of the river, were classified by WVDEP as 303(d) impaired streams. The most common impairment was biological (533 miles), followed by metals (primarily iron, 236 miles) and fecal coliform (144 miles). The sources for fecal and biological impairments are non-point sources such as inadequate sewage treatment and agricultural runoff; sedimentation from wells, timber harvest, agriculture, and roads can also contribute to biological impairments. The same land disturbances can contribute to metals impairment, as can abandoned mine lands (TetraTech 2008). Fourteen stream miles impaired by PCBs are found in the Hughes River HUC12. Thirty-one miles of pH impaired streams are in the Little Kanawha headwaters areas in the Glady Creek and Right Fork Little Kanawha River HUC12s; these streams are in the Forested Hills and Mountains region of the Central Appalachians, and as such are susceptible to acid deposition impacts due the nature of the soils and bedrock (WVDEP 2010). In 2008 TMDLs were generated for six impaired streams in the Little Kanawha Watershed (TetraTech 2008) and the DEP plans to submit TMDLs for 26 streams in the watershed in 2017 or 2022, depending on the stream (WVDEP 2010).

Forty-eight miles of streams in the Glady Creek and Right Fork Little Kanawha River HUC12s in the southeast portion of the watershed are designated as trout streams. Approximately 979 miles of streams in the Little Kanawha watershed have been judged by WVDNR to be high quality with potential for mussels, including 688 with potential for endangered species occurrence.

### 2.3.5 Vegetation Types

According to the Northeast Terrestrial Habitat Classification System (Gawler 2008), the upland habitat of the Little Kanawha River watershed is dominated by dry-mesic oak forests and mesophytic forest, with smaller pockets of specialized habitats such as oak-pine forest and areas of cliff and talus (Table 6). For the purposes of this analysis, however, we used the more general concept of “forested cover” and combined the three forest landcover classifications (deciduous, evergreen, mixed) defined by the landcover dataset of Maxwell et al. (2011).

Table 6. Northeast Terrestrial Habitat Types – Little Kanawha River Watershed (TNC 2011c)

| Ecological System Code | Total Acres | Percent area | Habitat Type | Wetland Type |
|---|---|---|---|---|
| 5920 | 510,298 | 35 | Northeastern interior dry-mesic oak forest:typic | |
| 887 | 450,812 | 30 | South-central interior mesophytic forest | |
| 359 | 295,876 | 20 | Allegheny-Cumberland dry oak forest and woodland | |
| 80 | 108,657 | 7 | NLCD Agricultural classes 81 & 82 | |
| 20 | 87,474 | 6 | NLCD developed classes 21-24 & 31 | |
| 3731 | 9,821 | <1 | Southern and central Appalachian cove forest | |
| 5271 | 6,467 | <1 | NLCD 52/71 Shrubland/grassland | |
| 11 | 5,193 | <1 | NLCD-NHD open water | |
| 5930 | 1,741 | <1 | Appalachian (Hemlock) northern hardwood forest: typic | |
| 690 | 578 | <1 | Central interior calcareous cliff and talus | |
| 601 | 442 | <1 | North-central Appalachian acid cliff and talus | |
| 591 | 315 | <1 | Central Appalachian dry oak-pine forest | |
| 16049 | 103 | <1 | North-central Appalachian acidic swamp | Larger river floodplain |
| 5939 | 86 | <1 | Appalachian (Hemlock) northern hardwood forest:moist-cool | |
| 15949 | 48 | <1 | Laurentian-Acadian freshwater marsh | Larger river floodplain |
| 15947 | 36 | <1 | Laurentian-Acadian freshwater marsh | Smaller river riparian |
| 16059 | 32 | <1 | North-central interior and Appalachian rich swamp | Larger river floodplain |
| 16047 | 31 | <1 | North-central Appalachian acidic swamp | Smaller river riparian |
| 15827 | 28 | <1 | Laurentian-Acadian wet meadow-shrub swamp | Smaller river floodplain |
| 15829 | 26 | <1 | Laurentian-Acadian wet meadow-shrub swamp | Larger river floodplain |
| 16057 | 12 | <1 | North-central interior and Appalachian rich swamp | Smaller river riparian |
| 5929 | 8 | <1 | Laurentian-Acadian wet meadow-shrub swamp | Larger river floodplain |
| 16044 | 6 | <1 | North-central Appalachian acidic swamp | Large lake |

## *Section 3: Assessment Methodology*

### 3.1 Assessment Design

#### 3.1.1 Planning Units

The assessment analysis was conducted at two spatial scales, beginning with planning units at the coarser scale of 12-digit USGS Hydrologic Unit Code (HUC) watersheds (referred to as HUC12 watersheds) nested within the HUC8 watershed (Figure 8). A HUC12 is a drainage area delineated by a spatial modeling technique using 24K scale hydrographic and topographic maps and data, to represent a 10,000-40,000 acre area that contributes source water to a single outlet point on a river or stream. It is identified by a 12-digit code indicating its position in the larger landscape, as well as a name corresponding to a significant hydrographic, cultural, or political feature within its boundaries (USGS 2009, NRCS 2012). A HUC12 may be composed of headwater streams, in which case it is self-contained, or it may include streams that originate in an upstream HUC12, in which case its water quality may be influenced by attributes of the upstream watershed. Detailed information about the HUC12 watersheds within the Little Kanawha River basin is presented in Table 7.

A finer level of planning units consisted of NHDPlus catchments within the HUC8 watershed, a scale at which protection or restoration activities are more likely to take place. The NHDPlus catchments are elevation-derived drainage areas of individual stream segments produced by Horizon Systems Corporation, using a drainage enforcement technique that involved "burning-in" the 100K NHD flowlines and, when available, building "walls" using the national Watershed Boundary Dataset, primarily to achieve a compatible and hydrologically accurate catchment for each stream segment (USEPA and USGS 2005). Some NHDPlus catchments were modified to provide a more uniform planning unit size, by dividing very large catchments into smaller units or merging very small catchments with the larger adjacent catchment.

#### 3.1.2 Landscape Classification

Watersheds were divided into three separate landscapes that were analyzed independently of each other, and for which separate sets of results at both levels of planning units (HUC12 watersheds and NHDPlus catchments) were calculated:

##### 3.1.2.1 Streams/Riparian Areas

Streams considered in the assessment were defined using the USGS National Hydrography Dataset 24K (NHD24K) flowlines, plus an approximately 90-125 meter riparian buffer. The NHD24K dataset is known to be missing some headwater stream reaches, particularly intermittent streams, but several constraining factors, such as compatibility between datasets and amount of manual processing time required to generate auxiliary data for certain metrics, resulted in the NHD24K being the most detailed and reliable source of stream line data for the purposes of this project.

The Little Kanawha watershed has 5,388 miles of NHD24K streams, of which approximately 3,985 miles are headwaters streams. A riparian buffer was delineated using the northeast regional Active River Area (ARA) dataset generated by TNC's Eastern Regional Office (Smith et al. 2008). The ARA


Figure 8. Little Kanawha River HUC12 Watersheds (NRCS 2009)

Table 7. HUC12 Watershed Information (NRCS 2009, USGS 2011)

| HUC12 | HUC12 Name | Acres | Square Miles | Stream Miles (24K) | Stream Miles (100k) |
|---|---|---|---|---|---|
| 050302030101 | Headwaters Sand Fork | 24,950 | 39 | 90 | 58 |
| 050302030102 | Indian Fork | 15,202 | 24 | 53 | 37 |
| 050302030103 | Outlet Sand Fork | 11,152 | 17 | 42 | 28 |
| 050302030201 | Fink Creek | 27,193 | 42 | 99 | 63 |
| 050302030202 | Headwaters Leading Creek | 19,049 | 30 | 69 | 39 |
| 050302030203 | Cove Creek | 20,449 | 32 | 74 | 46 |
| 050302030204 | Horn Creek | 12,806 | 20 | 48 | 30 |
| 050302030205 | Outlet Leading Creek | 13,742 | 21 | 55 | 36 |
| 050302030301 | Right Fork Little Kanawha River | 24,095 | 38 | 93 | 62 |
| 050302030302 | Glady Creek-Little Kanawha River | 38,861 | 61 | 138 | 93 |
| 050302030303 | Falls Run-Little Kanawha River | 21,082 | 33 | 74 | 51 |
| 050302030304 | Saltlick Creek | 31,461 | 49 | 103 | 62 |
| 050302030305 | Burnsville Lake-Little Kanawha River | 22,735 | 36 | 70 | 54 |
| 050302030306 | Oil Creek | 20,163 | 32 | 64 | 43 |
| 050302030307 | Copen Run-Little Kanawha River | 21,451 | 34 | 65 | 45 |
| 050302030308 | Stewart Creek-Little Kanawha River | 19,994 | 31 | 71 | 49 |
| 050302030401 | Headwaters Cedar Creek | 30,405 | 48 | 102 | 69 |
| 050302030402 | Outlet Cedar Creek | 21,451 | 34 | 78 | 50 |
| 050302030501 | Headwaters Right Fork Steer Creek | 19,607 | 31 | 73 | 44 |
| 050302030502 | Crooked Fork | 10,288 | 16 | 34 | 24 |
| 050302030503 | Outlet Right Fork Steer Creek | 25,687 | 40 | 87 | 53 |
| 050302030504 | Left Fork Steer Creek | 32,120 | 50 | 108 | 73 |
| 050302030505 | Steer Creek | 30,290 | 47 | 119 | 77 |
| 050302030601 | Left Fork West Fork Little Kanawha River | 18,415 | 29 | 68 | 43 |
| 050302030602 | Upper West Fork Little Kanawha River | 24,999 | 39 | 83 | 55 |
| 050302030603 | Headwaters Henry Fork | 15,054 | 24 | 53 | 36 |
| 050302030604 | Beech Fork | 15,823 | 25 | 61 | 36 |
| 050302030605 | Outlet Henry Fork | 27,329 | 43 | 95 | 64 |
| 050302030606 | Middle West Fork Little Kanawha River | 29,403 | 46 | 119 | 80 |
| 050302030607 | Lower West Fork Little Kanawha River | 26,557 | 41 | 94 | 67 |
| 050302030701 | Right Fork Spring Creek | 25,209 | 39 | 74 | 51 |
| 050302030702 | Spring Creek | 32,137 | 50 | 104 | 76 |
| 050302030801 | Left Fork Reedy Creek | 39,553 | 62 | 139 | 88 |
| 050302030802 | Right Reedy Creek | 27,308 | 43 | 89 | 67 |
| 050302030803 | Reedy Creek | 18,349 | 29 | 56 | 46 |
| 050302030901 | Cabin Run-North Fork Hughes River | 25,269 | 39 | 98 | 48 |

| HUC12 | HUC12 Name | Acres | Square Miles | Stream Miles (24K) | Stream Miles (100k) |
|---|---|---|---|---|---|
| 050302030902 | Bunnell Run-North Fork Hughes River | 18,461 | 29 | 79 | 41 |
| 050302030903 | Bonds Creek | 27,878 | 44 | 131 | 80 |
| 050302030904 | Stewart Run-North Fork Hughes River | 17,016 | 27 | 74 | 46 |
| 050302030905 | Addis Run-North Fork Hughes River | 15,133 | 24 | 59 | 39 |
| 050302030906 | Devilhole Creek-North Fork Hughes River | 14,927 | 23 | 61 | 39 |
| 050302030907 | Gillespie Run-North Fork Hughes River | 10,770 | 17 | 36 | 22 |
| 050302031001 | Middle Fork | 14,876 | 23 | 60 | 37 |
| 050302031002 | White Oak Creek-South Fork Hughes | 18,081 | 28 | 70 | 40 |
| 050302031003 | Bone Creek | 12,242 | 19 | 47 | 23 |
| 050302031004 | Slab Creek-South Fork Hughes River | 16,534 | 26 | 74 | 42 |
| 050302031005 | Spruce Creek | 15,166 | 24 | 63 | 38 |
| 050302031006 | Leatherbark Creek | 11,523 | 18 | 49 | 25 |
| 050302031007 | Indian Creek | 21,861 | 34 | 101 | 60 |
| 050302031008 | Grass Run-South Fork Hughes River | 21,797 | 34 | 94 | 58 |
| 050302031009 | Macfarlan Creek-South Fork Hughes River | 27,893 | 44 | 107 | 71 |
| 050302031101 | Headwaters Goose Creek | 14,808 | 23 | 73 | 33 |
| 050302031102 | Outlet Goose Creek | 21,464 | 34 | 65 | 45 |
| 050302031103 | Hughes River | 12,382 | 19 | 36 | 30 |
| 050302031201 | Tanner Creek | 23,430 | 37 | 97 | 55 |
| 050302031202 | Sinking Creek-Little Kanawha River | 22,035 | 34 | 83 | 55 |
| 050302031203 | Laurel Creek-Little Kanawha River | 17,037 | 27 | 74 | 41 |
| 050302031204 | Yellow Creek | 9,848 | 15 | 42 | 28 |
| 050302031205 | Pine Creek-Little Kanawha River | 25,234 | 39 | 108 | 67 |
| 050302031206 | Cole Run-Leading Creek | 10,943 | 17 | 46 | 31 |
| 050302031207 | Straight Creek-Little Kanawha River | 27,302 | 43 | 103 | 72 |
| 050302031208 | Tucker Creek | 12,018 | 19 | 44 | 31 |
| 050302031209 | Standingstone Creek | 13,471 | 21 | 35 | 27 |
| 050302031210 | Lee Creek-Little Kanawha River | 30,511 | 48 | 81 | 68 |
| 050302031301 | Slate Creek | 13,416 | 21 | 50 | 33 |
| 050302031302 | Walker Creek | 20,148 | 31 | 53 | 40 |
| 050302031303 | Stillwell Creek | 15,565 | 24 | 46 | 35 |
| 050302031304 | Tygart Creek | 32,713 | 51 | 153 | 81 |
| 050302031305 | Worthington Creek | 22,430 | 35 | 62 | 32 |
| 050302031306 | Neal Run-Little Kanawha River | 28,365 | 44 | 90 | 61 |

is based on the concept that river health depends on a dynamic interaction between the water and the land through which it flows, thus incorporating both aquatic and riparian habitats. The ARA explicitly considers processes such as system hydrologic connectivity, floodplain hydrology, and sediment movement along the river corridor and delineates areas along a stream where such processes are likely to occur (Smith et al 2008). However, the ARA for this region was generated based on the NHD 100K flowlines dataset, a coarser-level dataset than the NHD24K dataset. Since a primary goal of the project was to analyze headwater streams within each HUC8, the greater detail of the NHD24K dataset was needed. Therefore, a 120-meter buffer was generated for any headwater streams that occurred within the 24K dataset, but were not covered within the Active River Area.

#### 3.1.2.2 Wetlands

Wetlands considered in this assessment were defined using the US Fish and Wildlife Service's NWI dataset. The West Virginia NWI contains data collected over a large time period, from February 1971 to December 1992, and the statewide coverage was published in 1996. Therefore, the quality and accuracy of the wetland locations within the watershed are questionable, as the dataset is both old and largely based on interpretation of aerial photography and a variety of field survey techniques. The general NWI palustrine wetland types are listed in Table 8. To include the immediately surrounding wetland habitat into the analysis, a 50-meter wetland buffer was generated. A width of 50 meters was chosen based on a literature review and discussions with experts during workshops. Additionally, some metrics were calculated based on the catchment area for each wetland. These catchments were delineated by NHDPlus catchments, using flow direction grids to determine which NHDPlus catchments drained to a particular wetland, and manually selecting those catchments to create a wetland catchment layer that approximated the total drainage area for all mapped wetlands within a watershed.

Table 8. NWI Wetland Types - Little Kanawha River Watershed (USFWS 2010)

| NWI Code Prefix | NWI Wetland Type | Total Acres |
|---|---|---|
| PEM | Palustrine Emergent Wetland | 128 |
| PFO | Palustrine Forested Wetland | 239 |
| PSS | Palustrine Shrub-Scrub Wetland | 71 |

#### 3.1.2.3 Uplands

The purpose of including uplands as a separate landscape was two-fold: to characterize areas that are important for terrestrial species, and to quantify the potential impacts of upland habitat disturbance on water quality. We defined uplands as any areas not included in the riparian or wetland buffers; however, the material contribution zone of the Active River Area extended into the uplands. For the majority of metrics, we used the spatial datasets for the entire watershed instead of limiting the analysis to the riparian or wetland buffer as with the analysis of the previous two landscapes.

### 3.2 Priority Models

Three Priority Models were defined based on the three landscapes defined in the assessment:

- Streams/Riparian Areas
- Wetlands
- Uplands

Priority models were further divided into several indices to assess both the condition and function of the watershed (Table 9). Each index was defined by numerous metrics, derived from various datasets that were processed and analyzed for each planning unit (HUC12 and NHDPlus catchment). Condition and function include both *quality indicators* of the inherent physical features of the landscape (e.g., total miles of headwater streams), as well as any *stressors*, or anthropogenic/natural factors that may have a negative impact on the landscape (e.g., active surface mining). In many instances, a direct measurement or data source for a particular metric was unavailable or unreliable. In such cases, surrogate data were identified and used to estimate quality or stress (e.g., dam drainage area used to approximate the impacts of flow alteration from impoundments).

The objective was to identify and utilize datasets that characterize the following aspects of the watershed:

a. Riparian, wetland, and upland natural resources in the watershed
b. Functional values and ecological services provided by the natural resources in the watershed (surface water use, flood storage/abatement, groundwater use, sediment retention, pollutant assimilation, recreational benefits, etc.)
c. Freshwater connectivity within the watershed, and hydrologic connections upstream and downstream of the watershed (where appropriate), to determine how these affect watershed condition
d. Water quality impairments (including 303(d) stream listings, acid mine drainage (AMD)

Table 9. Watershed Characterization Priority Models and Indices

| Priority Model | Index |
|---|---|
| Streams | Water Quality |
| | Water Quantity |
| | Hydrologic Connectivity |
| | Biodiversity |
| | Riparian Habitat |
| | |
| Wetlands | Water Quality |
| | Hydrology |
| | Biodiversity |
| | Wetland Habitat |
| | |
| Uplands | Habitat Connectivity |
| | Habitat Quality |
| | Biodiversity |

impaired, and TMDL streams) within the watershed, and issues affecting hydrology and environmental flows

e. The contribution of consumptive water use on aquatic resource quantity and function
f. Rare, unique and/or sensitive species (and their habitat requirements) and vegetative communities within the watershed
g. Existing conservation investments on the ground (local, state, federal, and private conservation lands; conservation easements; mitigation sites)
h. Identified government and private conservation priorities within the watershed (protection and/or restoration priorities identified by conservation organizations and government agencies)
i. Natural physical vulnerability of the watershed as indicated by factors such as slope, highly erodible soils, etc.
j. Land use practices in the watershed with the potential to negatively impact natural resource value and function (resource extraction activities such as mining, oil and gas well drilling, mineral operations; development, road construction, etc.)
k. Land use practices in the watershed with the potential to cause pollution of aquatic resources (point sources such as facilities that discharge to water, non-point sources such as impervious cover runoff, agriculture, landfills, etc.)
l. Sources of natural resource and/or function loss due to fragmentation (dams, transportation infrastructure, energy transmission, etc.)

### 3.2.1 Streams/Riparian Areas Model

The *Streams Water Quality* (SWQ) index attempted to evaluate the overall water quality of all streams within the watershed. Metrics for impaired streams included those that have been 303(d) listed, covered by a Total Maximum Daily Load (TMDL) requirement, or are known to be impacted by acid mine drainage (AMD). Many streams were monitored and sampled by the WVDEP Watershed Assessment Branch (WAB) for a variety of standard water quality parameters (e.g., pH, sulfates, heavy metals, specific conductivity), as well as biological and habitat indices, such as GLIMPSS (Genus Level Index of Most Probable Stream Status, a measure of macroinvertebrates) and RBP (Rapid Bioassessment Protocol, a measure of habitat quality) scores. However, as other factors may affect the water quality in a stream, and many stream segments lack a WAB sampling station, several surrogate metrics were added to this index. These included percent imperviousness and various anthropogenic land uses and potential stressors (e.g., surface and underground mining, roads and railroads, well locations, etc.).

The *Streams Water Quantity* (SWN) index attempted to evaluate the overall degree of flow alteration within a given planning unit. However, very little data were available as direct measurements of stream flow or of stream withdrawals or discharges, with the few known points of such activities (such as public water supply intakes or sewer treatment plants) having incomplete or possibly inaccurate attribute data regarding water volume. The USGS stream-gauging network, a principal source of streamflow data in West Virginia, is concentrated on large streams. Since flow characteristics of large and small streams are different, flow data from the main stem of the Little Kanawha River could not be used to distinguish among the various HUC12s in the watershed (Messinger 2012). Therefore, surrogate metrics were developed to approximate the impact of water use within a planning unit and its potential alteration of flow, such as area of mining activities (surface and underground), percent of impervious surface, and dam drainage area (the total catchment area above a dam).

The *Streams Hydrologic Connectivity* (SHC) index attempted to evaluate the aquatic connectivity of the watershed in terms of network complexity and overall system integrity, with accompanying metrics such as miles of headwater streams, the mean local integrity of the planning unit, and total wetland area. The SHC index also addressed the more functional elements of hydrologic connectivity, focusing primarily on unimpeded flow and the ability of a stream segment to allow passage for aquatic species. Metrics generated for this purpose included the number of any potential structural impediments such as dams, roads/railroads in the riparian area (a surrogate for culverts and bridges), and conditions that may cause temperature changes that would affect passage of organisms (such as power plants whose discharges may raise overall stream temperatures or forested riparian area where the canopy may help maintain cooler temperatures).

The *Streams Biodiversity* (SBD) index attempted to capture the species diversity within the stream and riparian area, including metrics for the presence of rare or endangered species, the maximum number of invertebrate taxa found in stream samples, and known locations of non-native invasive species. Since species data for West Virginia do not distinguish between areas sampled with no species found and areas not sampled, additional metrics were included as an estimate of potential species presence (such as calcareous bedrock and number of terrestrial habitat types in the riparian area). Because of the lack of robust biodiversity data, this index received a weight of half compared to the other indices, and results should be used with caution.

The *Streams Riparian Habitat* (SRH) index attempted to characterize the habitat within the approximately 90-125 meter riparian buffer (the Active River Area), assuming that intact natural cover within this buffer will be most effective at stabilizing stream banks, moderating stream temperature, and providing habitat (such as native aquatic vegetation, rocks, and logs) for aquatic species. Corresponding metrics included various land uses and land cover within the riparian buffer (natural cover, mining, agriculture, grazing), percent impervious cover within the riparian area, RBP scores, and fragmenting features such as roads and wells.

### 3.2.2 Wetlands Model

The *Wetlands Water Quality* (WWQ) index attempted to identify the current water quality condition of existing wetlands, as well as approximate the functional value of each wetland in terms of pollutant filtration and sediment retention, two major functions related to wetland water quality. Thus, wetlands were evaluated based on their inherent ability to serve a designated function, as well as their potential for serving such function based on surrounding land uses and potential pollutants. WWQ metrics included type of wetland (e.g., forested headwater wetland) and stressors located within the wetland catchment (i.e., the drainage area of the wetland; with metrics including the amount of agriculture, grazing, or development; percent imperviousness; active surface mining; and wells). Since the WWQ metrics are dependent on the existence of a wetland, those planning units without an existing NWI wetland were excluded from this index.

The *Wetlands Hydrology* (WHY) index attempted to quantify the wetland extent within an area as well as assess the functional aspect of potential flood storage. Wetland extent was represented by total wetland area, while potential flood storage capacity metrics included the area of forested floodplain wetlands, total floodplain area, and hydric soils. These metrics also identified areas in the watershed with a greater potential for wetlands to develop under wet conditions, and which may have been areas of wetland loss in the past. It is due to these "potential wetlands" metrics (hydric soils and floodplain area) that the WHY index was calculated for all planning units (at both the HUC12 and NHDPlus catchment level), and not just those containing existing NWI wetlands. Any planning units with the potential wetlands metrics but no mapped NWI wetlands may be considered potential sites for wetland restoration.

The *Wetlands Biodiversity* (WBD) index attempted to capture the species diversity within the wetland buffer area, including metrics for the presence of rare or endangered species and known locations of non-native invasive species. Since species data for West Virginia do not distinguish between areas sampled with no species found and areas not sampled, additional metrics were included as an estimate of potential species presence (such as calcareous bedrock and number of terrestrial habitat types within the wetland buffer). Because of the lack of robust biodiversity data, this index received a weight of half compared to the other indices, and results should be used with caution.

The *Wetlands Wetland Habitat* (WWH) index attempted to quantify the habitat condition within the wetland buffer area. Habitat quality metrics included percent of natural cover and the mean size of unfragmented forest patches that intersected a given wetland buffer (connection with a larger forest patch is likely to create more desirable habitat within a wetland area). Habitat stressors included metrics that may indicate the amount of fragmentation within the wetland buffer, such as surface mining, wells, and road/railroad density.

### 3.2.3 Uplands Model

The *Uplands Habitat Connectivity* (UHC) index attempted to assess the ability of terrestrial organisms to reside and move within the landscape. It is generally agreed that blocks or corridors of native vegetation are most conducive to hosting native animal species. In West Virginia the natural cover is primarily forest. The amount of habitat required varies by taxon and species, but large forest blocks and blocks that are connected provide the optimal habitat for a variety of species to disperse, establish breeding territories, and migrate (Anderson et al. 2004). Habitat connectivity is positively affected by forest block size and local integrity, a metric developed by Compton et al. (2007) that quantifies the structural connections between ecosystems in a landscape. Fragmenting features (e.g., roads, energy transmission lines, and resource extraction) negatively affect habitat connectivity.

The *Uplands Habitat Quality* (UHQ) index attempted to quantify the degree to which a landscape has been altered from its original condition. Metrics included heterogeneity (a measure of landform variety) and the percent of the planning unit in natural cover (forest, grassland, wetlands). Conversion of forest to agriculture or pastureland is an example of degraded habitat quality. Some metrics that impact habitat connectivity also impact habitat quality, such as development and resource extraction.

The *Uplands Biodiversity* (UBD) index attempted to capture the species diversity within the uplands area, including metrics for the presence of rare or endangered species and known locations of non-native invasive species. Since species data for West Virginia do not distinguish between areas sampled with no species found and areas not sampled, additional metrics were included as an estimate of potential species presence (such as calcareous bedrock and number of terrestrial habitat types). Additional datasets were available from the US Forest Service (USFS) that provided information about predicted tree basal area loss to pests and pathogens within upland forests. Because of the lack of robust biodiversity data, this index received a weight of half compared to the other indices, and results should be used with caution.

### 3.3 Ranking Procedure

#### 3.3.1 Objective Classification

The goal of the project was to prioritize the planning units for protection and restoration opportunities. To achieve this, it was necessary to develop a method of ranking planning units based on their current ecological condition and inherent overall quality. Therefore, individual metrics were evaluated using thresholds that assigned metric results to one of four quality categories, indicating the degree of deviation from a desirable ecological condition: Very Good, Good, Fair, and Poor (Table 10). These objective, or "categorized," rankings were determined at both the HUC12 and NHDPlus catchment scales of planning units.

The Good/Fair threshold is also referred to as the "restoration threshold," with any planning units in the Fair category requiring restoration to bring the planning unit into an acceptable ecological condition. Planning units in the Good category may require some restoration to increase the quality to ideal conditions and move the score into the Very Good category, and any planning units in the Very Good category should be considered as potential candidates for protection activities. Planning units in the Poor category may also be potential candidates for restoration, depending on the goals of the individual organization or restoration project.

Thresholds were used to define quantitatively, for each metric, the divisions among the four quality categories. Initially, research focused on identifying sources for threshold values from literature and previous studies (e.g., the percentage of surface mining that places the corresponding metric into a Poor category, or a specific conductivity level that places the metric into a Fair category). However, beyond a few land use classifications and impervious cover percentages, very few thresholds have been established in the scientific literature for landscapes comparable to those in West Virginia. Additional threshold values were solicited from experts, but there was still a notable lack of reliable, defensible

Table10. Definition of Objective Method Categories (Foundations of Success 2009)

| Category | Definition |
|---|---|
| Very Good | Planning unit is in ecologically desirable status; requires little intervention or maintenance. |
| Good | Planning unit is within acceptable range of variation; some intervention is required for maintenance. |
| Fair | Planning unit is outside of an acceptable range of variation; requires human intervention. |
| Poor | Restoration of the planning unit is increasingly difficult; may result in extirpation of target. |

threshold values for most metrics. Therefore, an alternative approach was developed using WVDEP's reference and stressed streams to define the thresholds. The WVDEP has defined three levels (I, II, III) of reference (i.e., high quality) streams, which categorize a stream based on both water quality sampling data and field survey/visual inspections, such as Rapid Bioassessment Protocol (RBP) scores (Table 11). Level I reference streams are the highest quality, while Level II indicates slightly lower quality streams that still meet most criteria for reference stream designation, and Level III are considered the best representatives in geographic areas lacking true reference streams (WVDEP 2013). To ensure that only the highest quality streams were included in the analysis, the project used only Level I and II reference streams to determine threshold values.

The WVDEP has also identified criteria for water quality sampling and field survey data that indicate whether or not a particular stream reach is significantly impaired (Table 12). While the WVDEP defines stressed sites as meeting at least one of these criteria, this project used at least two criteria to minimize the potential for false positives.

To establish thresholds, the contributing NHDPlus catchments for both reference and stressed streams were identified, resulting in 501 reference catchments and 583 stressed catchments statewide, with a relatively broad and inclusive geographic distribution (Figure 9). Applicable metrics were calculated for the 1,084 reference/stressed catchments for all three landscapes (Streams/Riparian, Wetlands, Uplands) and threshold values were derived from these calculated results.

Table 11. WVDEP Reference Stream Criteria (Pond et al. 2012)

| Parameter | Value |
|---|---|
| Dissolved Oxygen | ≥ 6.0 mg/l |
| pH | ≥ 6.0 and ≤ 9.0 |
| Conductivity | <500 µmhos/cm |
| Fecal coliform | <800 colonies/100 ml |
| RBP Epifaunal Substrate score | ≥11 |
| RBP Channel Alteration score | ≥11 |
| RBP Sediment Deposition score | ≥11 |
| RBP Bank Disruptive score | ≥11 |
| RBP Riparian Vegetation Zone Width score | ≥6 |
| RBP Total Habitat score | 65% of maximum 200 |
| No obvious sources of non-point source pollution | |
| Evaluation of anthropogenic activities and disturbances | |
| No known point discharges upstream of assessment site | |

Table 12. WVDEP Stressed Stream Criteria (Pond et al. 2012)

| Parameter | Value |
|---|---|
| Dissolved Oxygen | <4.0 mg/l |
| pH | < 4.0 or > 9.0 |
| Conductivity | >1,000 µmhos/cm |
| Fecal coliform | >4,000 colonies/100 ml |
| RBP Epifaunal Substrate score | <7 |
| RBP Channel Alteration score | <7 |
| RBP Sediment Deposition score | <7 |
| RBP Bank Disruptive score | <7 |
| RBP Riparian Vegetation Zone Width score | <4 |
| RBP Total Habitat score | <120 |

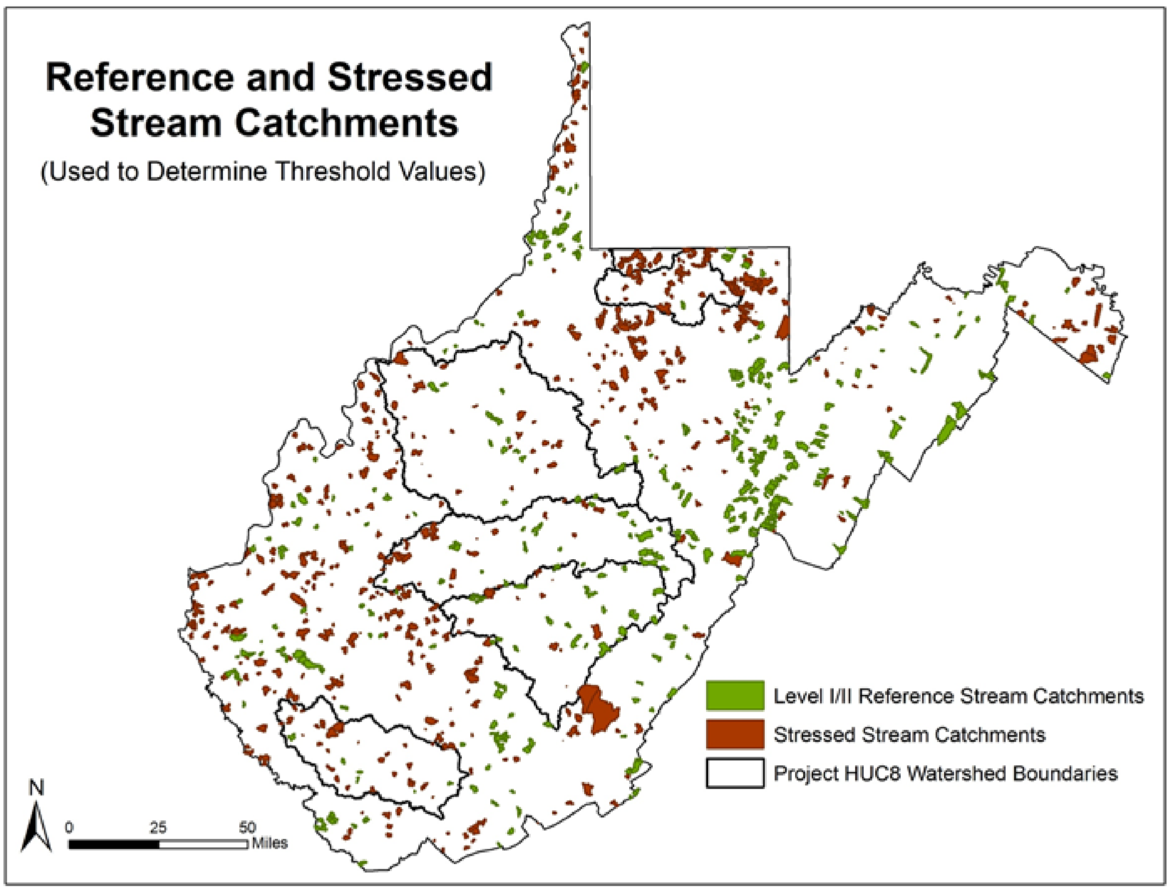


Figure 9. Reference and Stressed Stream Catchments

### 3.3.2 Objective Thresholds

To determine threshold values for each category, the distributions of the reference and stressed metric values were examined individually, and final analysis results were evaluated through an iterative process, using different percentiles as potential threshold values for all metrics. Different scenarios were run using different percentiles of the individual metrics as thresholds for all five pilot watersheds. Results were examined for consistency and validated by comparing the results of the various scenarios with known high-quality and impacted areas and by presenting the results to experts familiar with the condition of these areas at the expert workshops. For example, planning units in wilderness areas were expected to be in the Very Good category across most indices for all three models (Streams/Riparian Areas, Wetlands, and Uplands). Similarly, planning units with significant mining or development were expected to score predominantly in the Poor to Fair categories across most indices. It was determined during the expert workshops and project team discussions that the most consistent and reliable results were achieved when using the following percentiles: the Very Good/Good threshold was set as the 35% highest quality of reference catchment values, the Good/Fair threshold was set as the 75% highest quality of reference catchment values, and the Fair/Poor threshold was set as the 35% lowest quality of stressed catchment values (Figure 10). This methodology did not work well for some metrics with extremely skewed distributions, for example where both the 35$^{th}$ percentile and the median and 75$^{th}$ percentile were zero. Table 13 lists the percentiles for three different types of metrics: roads and railroads in the riparian area (a negative metric, with higher values indicating lower quality); percent forested riparian area (a positive metric, with higher values indicating higher quality); and percent surface mining (a metric for which this method of threshold selection did not work) in 5% increments for both stressed and reference catchments. Metrics for which the reference/stressed threshold determination were not suitable were either set as presence/absence metrics, resulting in a Good score if the metric was present for positive metrics or absent for negative metrics, or a Fair score if the metric was absent for positive metrics or present for negative metrics. A small subset of metrics (e.g., impervious cover and percent mining) had reliable threshold values in the literature, in which cases the values from the literature were used after consultation with and validation from experts at expert workshops. As water quality parameters were used by the WVDEP to define reference and stressed catchments, thresholds for water quality parameters were defined using the WVDEP's water quality standards.

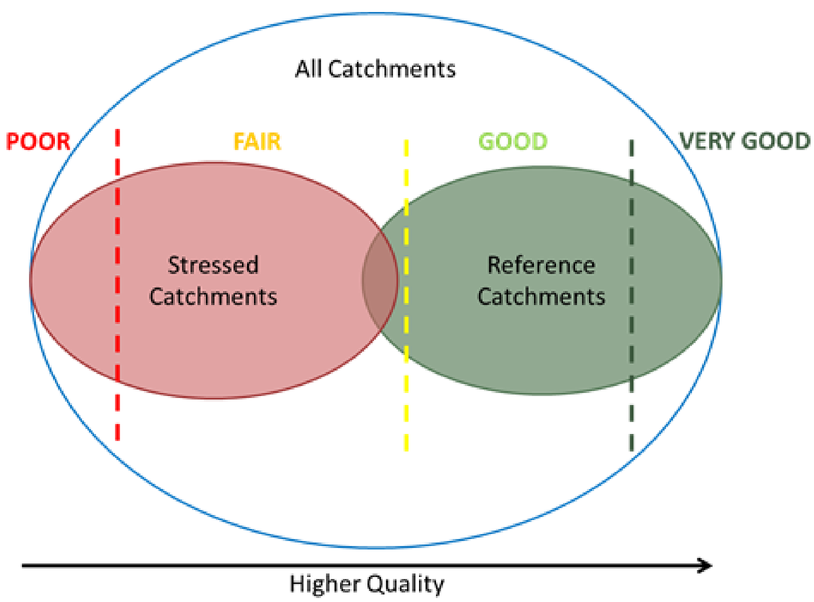

Figure 10. Threshold Definition Model

Table 13. Reference and Stressed Distribution Examples for Three Types of Metrics

| Percentile[a] | Reference Catchments | | | Stressed Catchments | | |
|---|---|---|---|---|---|---|
| | Negative Metric: Roads and Railroads in the Riparian Area (mi roads/sq mi planning unit) | Positive Metric: Percent Forested Riparian Area | Alternate Method[b]: Percent of Planning Unit with Surface Mines | Negative Metric: Roads and Railroads in the Riparian Area (mi roads/sq mi planning unit) | Positive Metric: Percent Forested Riparian Area | Alternate Method: Percent of Planning Unit with Surface Mines |
| Min/Max | 0.00 | 102.7[c] | 0.00 | 0.0 | 99.8 | 0.00 |
| 5th/95th | 0.00 | 100.6 | 0.00 | 0.20 | 94.7 | 0.00 |
| 10th/90th | 0.00 | 100.2 | 0.00 | 1.22 | 91.5 | 0.00 |
| 15th/85th | 0.00 | 100.0 | 0.00 | 1.98 | 87.8 | 0.00 |
| 20th/80th | 0.00 | 99.7 | 0.00 | 2.46 | 84.5 | 0.00 |
| 25th/75th | 0.00 | 99.5 | 0.00 | 2.86 | 82.2 | 0.00 |
| 30th/70th | 0.00 | 99.2 | 0.00 | 3.25 | 80.7 | 0.00 |
| 35th/65th | 0.00 | 98.7[d] | 0.00 | 3.62 | 78.0 | 0.00 |
| 40th/60th | 0.00 | 98.5 | 0.00 | 3.93 | 75.2 | 0.00 |
| 45th/55th | 0.13 | 98.0 | 0.00 | 4.29 | 63.8 | 0.00 |
| Median | 0.29 | 97.6 | 0.00 | 4.63 | 67.1 | 0.00 |
| 55th/45th | 0.51 | 96.7 | 0.00 | 5.10 | 63.8 | 0.00 |
| 60th/40th | 0.87 | 95.8 | 0.00 | 5.47 | 61.0 | 0.00 |
| 65th/35th | 1.14 | 94.5 | 0.00 | 5.97 | 57.0[f] | 0.24 |
| 70th/30th | 1.69 | 93.2 | 0.00 | 6.34 | 53.4 | 0.80 |
| 75th/25th | 2.46 | 91.6[e] | 0.00 | 7.02 | 49.9 | 1.51 |
| 80th/20th | 3.10 | 90.1 | 0.00 | 7.93 | 44.9 | 2.99 |
| 85th/15th | 3.72 | 88.0 | 0.00 | 9.07 | 40.3 | 5.47 |
| 90th/10th | 4.57 | 83.5 | 0.00 | 10.97 | 33.3 | 9.78 |
| 95th/5th | 5.83 | 75.9 | 0.06 | 14.43 | 20.6 | 20.11 |
| 96th/4th | 6.26 | 74.6 | 0.21 | 15.94 | 17.0 | 24.84 |
| 97th/3rd | 6.49 | 72.3 | 0.54 | 16.87 | 14.5 | 27.72 |
| 98th/2nd | 6.81 | 69.8 | 1.59 | 18.29 | 10.7 | 38.96 |
| 99th/1st | 9.74 | 59.1 | 7.68 | 23.93 | 6.4 | 51.02 |
| Max/Min | 34.6 | 1.28 | 29.28 | 35.27 | 2.9 | 84.93 |

[a] Negative metrics used the first percentile (i.e., Minimum value if row is “Min/Max”), positive metrics used the second percentile (i.e., Maximum value if row is “Min/Max)

[b] Alternate method used for threshold selection

[c] Values are higher than 100% because of differences in the spatial properties of the geographic information system (GIS) datasets between the landcover dataset used for this metric and the planning units

[d] Selected as percentile for Very Good/Good threshold

[e] Selected as percentile for Good/Fair threshold

[f] Selected as percentile for Fair/Poor threshold

### 3.3.3 Critical Metrics

Discussions held during expert workshops suggested that some metrics, subsequently referred to as “critical metrics,” indicated an impairment or land use alteration of enough significance that these metrics should limit the final index category value, regardless of other metric values in that index. For instance, if a planning unit had a high enough percentage of impervious cover that placed the metric into the Fair category, the final index score for that planning unit could not be higher than Fair, regardless if other metrics ranked Good or Very Good. Since the Water Quality index in the Streams model had more critical metrics than the other indices, two of the critical metrics had to be Fair or Poor to cap the index at that category. Only a handful of metrics were considered critical (Table 14).

Table 14. Critical Metrics for Priority Model Analysis

| Model | Index | Critical Metrics |
|---|---|---|
| Streams | Water Quality | Percent imperviousness |
| | | Surface mining (active & legacy) |
| | | Median pH values |
| | | Median specific conductivity values |
| | Water Quantity | Percent imperviousness |
| | Hydrologic Connectivity | None |
| | Biodiversity | None |
| | Riparian Habitat | Percent imperviousness in riparian area |
| | | Active surface mining in riparian area |
| | | |
| Wetlands | Water Quality | None |
| | Hydrology | None |
| | Biodiversity | None |
| | Wetland Habitat | Development in wetland buffer |
| | | Active surface mining in wetland buffer |
| | | |
| Uplands | Habitat Connectivity | Development |
| | | Active surface mining |
| | Habitat Quality | Development |
| | | Active surface mining |
| | Biodiversity | None |

### 3.3.4 Metrics Final Selection

Initially, the project team identified 214 metrics to characterize the three landscapes (listed in Appendix B: Metrics Description and GIS Process). The values for these metrics at the HUC12 level for all five HUC8 watersheds were subjected to a Pearson's Correlation analysis separately for each model, and if two metrics were highly correlated (R > 0.90), one of the metrics was eliminated. For metric pairs with correlation coefficients between 0.75-0.90, one of the metrics was eliminated if they were judged to be truly redundant. The full set of HUC12 metric values for the Streams priority model (which had the greatest number of metrics) was subjected to a Principal Components Analysis (PCA) to identify the most important metrics to retain in the assessment, i.e., those metrics that accounted for the greatest variation among the HUC12s. Three principal components together accounted for 45% of the variation among HUC12s (Table 15). The most influential component (eigenvalue 18.29, 25% of variation explained) described a gradient of anthropogenic disturbance, from high negative loadings on metrics such as forested riparian area and natural cover in headwater catchments, to high positive loadings on development metrics such as roads/railroads in riparian area. The second component (eigenvalue 9.34, 13% of variation explained) consisted of different mining and coal metrics, while the 3$^{rd}$ component consisted of oil and gas wells (eigenvalue 5.18, 7% of variation explained). Some of the metrics that were identified as important in the PCA were dropped from the assessment due to high correlation with other metrics, lack of data across watersheds, or other reasons. After the correlation and Principal Components Analyses, and discussions with experts at the expert workshops, the final current condition analysis dataset was reduced to 94 metrics.

Table 16 lists all metrics that were used in the final analysis with details on grouping of metrics into individual indices, thresholds, method of determining the thresholds, weight of the metrics in the final analysis, critical metrics, and if a metric was considered a positive or negative metric in the final analysis.

### 3.3.5 Metric Weights

Metrics were weighted to ensure that each metric contributed a value in its corresponding index relative to its significance in terms of affecting watershed condition. The weights were assigned to each metric based on literature where available, but more often on a synthesis of current knowledge provided by experts from TNC, state and federal agencies, universities, non-profit organizations, and local experts. Recommendations were provided and subsequently refined at several expert workshops and/or by follow-up correspondence with experts. Metric and index weights ranged from 0 to 3, with a weight of 0 assigned to those metrics initially considered but later removed from the analysis (see Appendix B for a full list of metrics originally considered in the analysis). Metrics with weights greater than 0 and considered in the final analysis are listed in Table 16.

Table 15. Principal Components Analysis of Streams Condition Metrics

| Metric | Factor Loading* |
|---|---|
| **Component 1** | |
| Forested riparian area | -0.8252 |
| Natural cover in headwater catchments | -0.6871 |
| Median GLIMPSS scores | -0.6836 |
| Local integrity in headwater catchments | -0.6786 |
| Median taxa richness | -0.6210 |
| Large quantity users | 0.5107 |
| Wastewater treatment plants | 0.5166 |
| Biologically impaired streams | 0.5272 |
| Septic systems in riparian area | 0.5464 |
| Power plants | 0.5780 |
| Energy transmission lines in riparian area | 0.6117 |
| Bridges | 0.6600 |
| Septic systems | 0.6730 |
| Roads and railroad density in riparian area | 0.7385 |
| Percent imperviousness | 0.7659 |
| Buildings in riparian area | 0.7799 |
| NPDES permits | 0.7866 |
| Development in riparian area | 0.8049 |
| Road and railroad density | 0.8056 |
| **Component 2** | |
| Total coal production | 0.6804 |
| Legacy surface mining in riparian area | 0.7279 |
| Active surface mining in riparian area | 0.7395 |
| Active surface mining | 0.7514 |
| Legacy surface mining | 0.7641 |
| Coal NPDES permits | 0.7889 |
| **Component 3** | |
| Oil and gas wells in riparian area | -0.6943 |

*Only factors with loadings > |0.5| and loading on only one component are presented here.

Table 16. Metrics Included in the Current Condition Analysis

| Model | Index | Metric Description (* "Critical Metric") | Weight | Units | Positive/ Negative Metric[a] | Threshold Method | Threshold: Very Good – Good | Threshold: Good – Fair | Threshold: Fair – Poor |
|---|---|---|---|---|---|---|---|---|---|
| STREAMS | *Water Quality* *(Weight: 1)* | AMD, TMDL, 303(d) impaired streams | 2 | % of total stream miles in planning unit | N | Reference/stressed | 0 | 11.32 | 78.09 |
| | | Median pH values*[c] | 2 | Index[b] | P | Literature | 350[b] | 250 | 150 |
| | | Median sulfate values[d] | 1 | Index | P | Literature | 350 | 250 | 150 |
| | | Median specific conductivity values*[e] | 1.5 | Index | P | Literature | 350 | 250 | 150 |
| | | Median GLIMPSS scores[f] | 2 | Index | P | Literature | 350 | 250 | 150 |
| | | Median sedimentation & embeddedness[g] | 1 | Index | P | Literature | 350 | 250 | 150 |
| | | Percent imperviousness* | 2 | mean % imperviousness per planning unit | N | Literature | 0 | 2 | 8 |
| | | All wells | 1.5 | #/sq mi planning unit | N | Reference/stressed | 0 | 2.28 | 5.47 |
| | | Surface mining (active & legacy)* | 2 | % of planning unit | N | Literature/Expert opinion | 2 | 10 | 20 |
| | | Underground mining | 2 | % of planning unit | N | Reference/ stressed | 0 | 3.82 | 18.30 |
| | | Agriculture in riparian area | 1 | % of riparian area | N | Reference/ stressed | 0 | 0.07 | 0.12 |
| | | Grazing/pasture in riparian area | 1 | % of planning unit | N | Reference/ stressed | 0 | 1.67 | 10.31 |
| | | Development in riparian area | 1 | % of planning unit | N | Reference/ stressed | 0 | 0.02 | 2.44 |
| | | Natural cover in riparian area | 2 | % of planning unit | P | Reference/ stressed | 99.88 | 97.01 | 75.48 |
| | | All roads & rail | 1.5 | miles/sq mi planning unit | N | Reference/ stressed | 0.13 | 1.66 | 2.79 |
| | *Water Quantity* *(Weight: 1)* | Public water supply intakes | 0.5 | #/stream mi | N | Presence/ absence | - | 0 | - |
| | | Large quantity users | 2 | #/stream mi | N | Presence/ absence | - | 0 | - |
| | | Wastewater treatment plants | 0.5 | # customers served/sq mi planning unit | N | Presence/ absence | - | 0 | - |
| | | Dam drainage area | 1 | % of planning unit | N | Presence/absence | - | 0 | - |
| | | Percent imperviousness* | 1.5 | mean % imperviousness per planning unit | N | Literature | 0 | 2 | 8 |
| | | Surface mining (active & legacy) | 1 | % of planning unit | N | Literature/Expert opinion | 2 | 10 | 20 |
| | | Underground mining | 1.5 | % of planning unit | N | Reference/ stressed | 0 | 3.82 | 18.30 |
| | *Hydrologic Connectivity* | Headwater streams (size class 1a) | 1.5 | % of total stream miles in planning unit | P | Presence/ absence | - | 0 | - |
| | | Local integrity score | 1 | mean score/planning unit | P | Reference/ stressed | 44.43 | 30.35 | 20.72 |

| Model | Index | Metric Description (* "Critical Metric") | Weight | Units | Positive/ Negative Metric[a] | Threshold Method | Threshold: Very Good – Good | Threshold: Good – Fair | Threshold: Fair – Poor |
|---|---|---|---|---|---|---|---|---|---|
| STREAMS | *Hydrologic Connectivity (Weight: 1)* | Total wetland area | 1 | % of planning unit | P | Presence/ absence | - | 0 | - |
| | | Power plants | 0.5 | # / stream mi | N | Presence/ absence | - | 0 | - |
| | | Forested riparian area | 1.5 | % of riparian area | P | Reference/ stressed | 98.73 | 91.60 | 57.00 |
| | | Dams | 1.5 | #/ stream mi | N | Presence/absence | - | 0 | - |
| | | All roads & rail in riparian area | 2 | mi/sq mi planning unit | N | Reference/ stressed | 0 | 2.46 | 5.97 |
| | *Biodiversity (Weight: 0.5)* | Rare species in riparian area | 1.5 | # species/riparian area | P | Presence/ absence | - | 0 | - |
| | | Maximum taxa | 1 | maximum # taxa | P | Reference/ stressed | 27 | 21 | 13 |
| | | Mussel streams | 1 | % of total stream miles in planning unit | P | Presence/ absence | - | 0 | - |
| | | Northeast habitat types in riparian area | 1 | #/riparian area | P | Reference/ stressed | 6 | 5 | - |
| | | Calcareous bedrock in riparian area | 1 | % of riparian area | P | Presence/ absence | - | 0 | - |
| | | Non-native invasive species in riparian area | 1.5 | # species/riparian area | N | Presence/ absence | - | 0 | - |
| | *Riparian Habitat (Weight: 1)* | Median Rapid Bioassessment Protocol score[h] | 1 | Index | P | Literature | 350 | 250 | 150 |
| | | Natural cover in riparian area | 2 | % of riparian area | P | Reference/ stressed | 99.88 | 97.01 | 75.48 |
| | | Agriculture in riparian area | 1 | % of riparian area | N | Reference/ stressed | 0 | 0.07 | 0.12 |
| | | Grazing/pasture in riparian area | 1 | % of riparian area | N | Reference/ stressed | 0 | 1.67 | 10.31 |
| | | Percent imperviousness in riparian area* | 2 | % of riparian area | N | Reference/stressed | 0 | 2 | 8 |
| | | Active surface mining in riparian area* | 2 | % of riparian area | N | Literature/Expert opinion | 2 | 10 | 20 |
| | | Legacy surface mining in riparian area | 1 | % of riparian area | N | Literature/Expert opinion | 2 | 10 | 20 |
| | | All wells in riparian area | 1 | #/sq mi riparian area | N | Reference/stressed | 0 | 3.22 | 5.00 |
| | | All roads & rail in riparian area | 1.5 | miles/sq mi riparian area | N | Reference/stressed | 0 | 2.46 | 5.97 |
| WETLANDS | *Water Quality* | Forested headwater wetlands | 2 | % of planning unit | P | Presence/absence | - | 0 | - |
| | | Agriculture in wetland catchment | 1 | % wetland catchment | N | Reference/stressed | 0 | 0.01 | 0.37 |
| | | Grazing/pasture in wetland catchment | 1 | % wetland catchment | N | Presence/absence | - | 0 | - |
| | | Development in wetland catchment | 1 | % wetland catchment | N | Reference/stressed | 0 | 0.04 | 2.17 |

| Model | Index | Metric Description (* "Critical Metric") | Weight | Units | Positive/ Negative Metric[a] | Threshold Method | Threshold: Very Good – Good | Threshold: Good – Fair | Threshold: Fair – Poor |
|---|---|---|---|---|---|---|---|---|---|
| WETLANDS | *Water Quality (Weight: 1)* | Natural cover in wetland catchment | 3 | % wetland catchment | P | Reference/stressed | 98.78 | 92.97 | 72.82 |
| | | Percent imperviousness in wetland catchment | 1 | mean % imperviousness wetland catchment | N | Literature | 0 | 2 | 8 |
| | | All roads & rail in wetland catchment | 1 | # miles/sq mi wetland catchment | N | Presence/absence | - | 0 | - |
| | | Active surface mining in wetland catchment | 2 | % wetland catchment | N | Literature/Expert opinion | 2 | 10 | 20 |
| | | All wells in wetland catchment | 1 | #/sq mi wetland catchment | N | Reference/stressed | 0 | 0.60 | 3.90 |
| | *Hydrology (Weight: 1)* | Total wetland area | 2 | % of planning unit | P | Presence/absence | - | 0 | - |
| | | Forested headwater wetlands | 1 | % of planning unit | P | Presence/absence | - | 0 | - |
| | | Floodplain, forested wetlands | 1 | sq mi/wetland buffer | P | Reference/stressed | - | 0 | - |
| | | Floodplain area | 1 | % of planning unit | P | Presence/absence | - | 0 | - |
| | | Hydric soils | 1.5 | % of planning unit with hydric soils | P | Presence/absence | - | 0 | - |
| | *Biodiversity (Weight: 0.5)* | Rare species in wetland buffer | 1.5 | # species/sq mi wetland buffer | P | Presence/absence | - | 0 | - |
| | | Calcareous bedrock in wetland buffer | 1 | % of wetland buffer | P | Presence/absence | - | 0 | - |
| | | Northeast habitat types in wetland buffer | 1 | # types in wet buffer/planning unit | P | Reference/stressed | 5 | 3 | - |
| | | Non-native invasive species in wetland buffer | 1.5 | # species/sq mi wetland buffer | N | Presence/absence | - | 0 | - |
| | *Wetland Habitat (Weight:1)* | Natural cover in wetland buffer | 2 | % of wetland buffer | P | Reference/stressed | 92.76 | 82.63 | 58.95 |
| | | Agriculture in wetland buffer | 1 | % of wetland buffer | N | Presence/absence | - | 0 | - |
| | | Grazing/pasture in wetland buffer | 1 | % of wetland buffer | N | Reference/stressed | 0 | 1.16 | 26.55 |
| | | Development in wetland buffer* | 2 | % of wetland buffer | N | Presence/absence | - | 0 | - |
| | | Mean forest patch size within wetland buffer | 1 | mean sq mi forest block size in wetland buffer/planning unit | P | Reference/stressed | 14.37 | 3.23 | - |
| | | All wells in wetland buffer | 1.5 | #/wetland buffer | N | Presence/absence | - | 0 | - |
| | | Active surface mining in wetland buffer* | 2 | % of wetland buffer | N | Reference/stressed | 2 | 10 | 20 |
| | | Legacy surface mining in wetland buffer | 1 | % of wetland buffer | N | Reference/stressed | 2 | 10 | 20 |
| | | All roads & rail in wetland buffer | 1 | miles/sq mi in wetland buffer | N | Reference/stressed | 0 | 0.93 | 5.99 |

| Model | Index | Metric Description (* "Critical Metric") | Weight | Units | Positive/ Negative Metric[a] | Threshold Method | Threshold: Very Good – Good | Threshold: Good – Fair | Threshold: Fair – Poor |
|---|---|---|---|---|---|---|---|---|---|
| **UPLANDS** | *Habitat Connectivity (Weight: 1)* | Mean forest patch size | 2 | mean forest block size/planning unit | P | Reference/stressed | 10.43 | 2.40 | 0.77 |
| | | Local integrity score | 1.5 | avg score/planning unit | P | Reference/stressed | 44.43 | 30.35 | 20.72 |
| | | Development* | 1.5 | % of planning unit | N | Reference/stressed | 0 | 0.11 | 1.55 |
| | | All roads & rail | 1 | miles/sq mi planning unit | N | Reference/stressed | 0.13 | 1.66 | 2.79 |
| | | Energy transmission lines | 0.5 | miles/sq mi planning unit | N | Presence/absence | - | 0 | - |
| | | Gas pipelines | 0.5 | miles/sq mi planning unit | N | Presence/absence | - | 0 | - |
| | | Wind turbines | 0.5 | #/sq mi planning unit | N | Presence/absence | - | 0 | - |
| | | All wells | 1 | #/sq mi planning unit | N | Reference/stressed | 0 | 2.28 | 5.47 |
| | | Active surface mining* | 1.5 | % of planning unit | N | Literature/Expert opinion | 2 | 10 | 20 |
| | | Timber harvesting operations | 0.5 | sq mi/planning unit | N | Presence/absence | - | 0 | - |
| | *Habitat Quality (Weight:1)* | Heterogeneity score | 2 | avg score/planning unit | P | Reference/stressed | 38 | 36 | 33 |
| | | Natural cover (forest, grassland, wetland) | 2 | % of planning unit | P | Reference/stressed | 98.59 | 94.00 | 79.96 |
| | | Active surface mining* | 1.5 | % of planning unit | N | Literature/Expert opinion | 2 | 10 | 20 |
| | | Legacy surface mining | 1 | % of planning unit | N | Literature/Expert opinion | 2 | 10 | 20 |
| | | Timber harvesting operations | 1 | sq mi/sq mi planning unit | N | Presence/absence | - | 0 | - |
| | | Agriculture | 1 | % of planning unit | N | Reference/stressed | 0 | 0.01 | 0.1 |
| | | Grazing/pasture | 1 | % of planning unit | N | Reference/stressed | 0.06 | 4.14 | 9.76 |
| | | Development* | 1.5 | % of planning unit | N | Reference/ stressed | 0 | 0.11 | 1.55 |
| | *Biodiversity (Weight: 0.5)* | Rare species | 1.5 | #/sq mi planning unit | P | Presence/ absence | - | 0 | - |
| | | Northeast habitat types | 1 | #/planning unit | P | Reference/ stressed | 7 | 5 | - |
| | | Calcareous bedrock | 1 | % of planning unit | P | Presence/ absence | - | 0 | - |
| | | Non-native invasive species | 1.5 | #/sq mi planning unit | N | Presence/ absence | - | 0 | - |
| | | Percent tree basal area loss | 2 | % of planning unit | N | Reference/ stressed | 3 | 15 | 30 |

[a] Positive metrics are characterized by higher values indicating higher quality, negative metrics are characterized by lower values indicating higher quality

[b] To enable comparison among different water quality parameters and among planning units, an index was calculated based on the WVDEP's water quality standards. Highest quality values were assigned the value 400, values higher than impairment level but not in the highest category were assigned the value 300, values considered impaired were assigned the value 200, and values considered severely impaired were assigned the value 100. The values 400, 300, 200, and 100 are analogous to the categories Very Good, Good, Fair, and Poor, respectively.

[c] Index values for pH values were assigned as follows: >10 or <5: 100, >9 or <6: 200, >8 or <6.5: 300, between 6.5 and 8 (inclusive): 400.

[d] Index values for sulfate values were assigned as follows: >250 mg/l: 100, >50 mg/l and <=250 mg/l: 200, >25 mg/l and <=50: 300, <=25 mg/l: 400.

[e] Index values for specific conductivity values were assigned as follows: >835 µmhos/cm: 100, >500 µmhos/cm and <=835 µmhos/cm : 200, >200 and <=500 µmhos/cm: 300, <=200 µmhos/cm: 400.

[f] Index values for GLIMPSS values were assigned as follows: <50: 100, <100 and >=50: 200, <125 and >=100: 300, >=125: 400. Based on percent threshold values of the modified GLIMPSS (CF), which excludes genus-level Chironimidae.

[g] Index values for an added Sedimentation/Embededdness score, two components of the RBP, assigned as follows: <11: 100, <21 and >=11: 200, <31 and >=21: 300, >=31: 400.

[h] Index values for the Total RBP score, assigned as follows: <60: 100, <110 and >=60: 200, <160 and >=110: 300, >=160: 400.

### 3.3.6 Metric Scores

Each metric received an objective score according to the thresholds developed in the objective classification, placing the metric into one of the four quality categories: Very Good, Good, Fair, or Poor. To be able to aggregate the metric scores to index scores and ultimately to model scores, objective categories were translated to a numerical rating for each metric, where the categories Very Good, Good, Fair, and Poor were assigned the values 4, 3, 2, and 1, respectively.

To compare planning units relative to each other, a relative score for each planning unit was calculated in addition to the objective score. Relative scores were defined by scaling the results for each metric on a scale from 0 to 1 (0 being defined as the lowest quality value and 1 being defined as the highest quality value for a particular metric over all planning units in the watershed). For example, to rank according to the amount of forested riparian area, a positive metric where a high value indicated a higher quality, the highest scoring planning unit's metric was set to a value of 1 and the lowest scoring planning unit was set to a value of 0, with all remaining scores distributed between 0 and 1. Conversely, to score for the amount of mining in a planning unit, a negative metric where a higher value indicated lower quality, the highest scoring planning unit's metric was set to a value of 0 and the lowest scoring planning unit was set to a value of 1. These scores were determined for both HUC12 and NHDPlus catchments.

Table 17 illustrates the value, relative score, objective category, and objective score for several catchments for three metrics: percent forested riparian area, percent of planning unit with surface mines, and roads and railroads in the riparian area.

### 3.3.7 Index Scores

Metric scores were aggregated, according to their assigned weights, to produce index scores. To compute the individual index scores (for example, Streams Water Quality) the following formula was used for each index:

**Index objective score:**

$$IOS = \frac{MOS_1 * MW_1 + MOS_2 * MW_2 + \cdots + MOS_n * MW_n}{MW_1 + MW_2 + \cdots + MW_n}$$

**Where:** IOS = index objective score
$MOS_i$ = metric i objective score, where Very Good = 4, Good = 3, Fair = 2, Poor = 1
$MW_i$ = metric i weight

These results were standardized by assigning them to the four objective categories according to the following definitions:

$$IOS > 3.5 \rightarrow 4\ (Very\ Good)$$
$$2.5 < IOS \leq 3.5 \rightarrow 3\ (Good)$$
$$1.5 < IOS \leq 2.5 \rightarrow 2\ (Fair)$$
$$IOS \leq 1.5 \rightarrow 1\ (Poor)$$

Table 17. Example Values, Relative Scores, Objective Categories, and Objective Scores for Selected Catchments and Metrics

| Metric | Catchment ID | Value | Relative Score | Objective Category | Objective Score |
|---|---|---|---|---|---|
| *Percent Forested Riparian Area* | C1167 | 100 | 1 | Very Good | 4 |
| | C1277 | 98.79 | 0.9872 | Very Good | 4 |
| | C932 | 98.50 | 0.9843 | Good | 3 |
| | C622 | 91.88 | 0.9178 | Good | 3 |
| | C995 | 82.71 | 0.8259 | Fair | 2 |
| | C1336 | 61.43 | 0.6124 | Fair | 2 |
| | C592 | 44.35 | 0.4409 | Poor | 1 |
| | C662 | 10.17 | 0.0981 | Poor | 1 |
| | | | | | |
| *Percent of Planning Unit with Surface Mines* | C998 | 0 | 1 | Very Good | 4 |
| | C1018 | 1.71 | 0.9828 | Very Good | 4 |
| | C874 | 3.12 | 0.9686 | Good | 3 |
| | C359 | 6.93 | 0.9303 | Good | 3 |
| | C999 | 10.51 | 0.8942 | Fair | 2 |
| | C184 | 16.77 | 0.8313 | Fair | 2 |
| | C210 | 23.61 | 0.7625 | Poor | 1 |
| | C873 | 92.65 | 0.0680 | Poor | 1 |
| | | | | | |
| *Roads and Railroads in Riparian Area (mi roads/sq mi planning unit)* | C998 | 0 | 1 | Very Good | 4 |
| | C647 | 0 | 1 | Very Good | 4 |
| | C1065 | 1.05 | 0.9514 | Good | 3 |
| | C582 | 2.03 | 0.9061 | Good | 3 |
| | C1055 | 2.56 | 0.8820 | Fair | 2 |
| | C815 | 4.47 | 0.7936 | Fair | 2 |
| | C387 | 6.41 | 0.7042 | Poor | 1 |
| | C62 | 21.67 | 0.2422 | Poor | 1 |

**Index relative score:**

$$IRS = \frac{MRS_1 * MW_1 + MRS_2 * MW_2 + \cdots + MRS_n * MW_n}{MW_1 + MW_2 + \cdots + MW_n}$$

**Where:** IRS = index relative score
$MRS_i$ = metric i relative score (between 0 and 1)
$MW_i$ = metric i weight

A combined score was then calculated for every index for each planning unit, consisting of the objective category score added to the relative score, resulting in the possible values for each index ranging from the lowest possible score of 1 (a Poor catchment that also has the lowest possible value relative to the other catchments) to the highest possible score of 5 (a Very Good catchment that is also the highest relative quality compared to the other catchments). Table 18 gives examples of the Streams/Riparian Areas model indices and their corresponding objective, relative, and combined scores.

Table 18. Example Index Objective, Relative, and Combined Results for Selected Catchments for the Streams/Riparian Areas Model

| | **Index Objective Scores** | | | | | **Index Objective Scores, standardized** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Index** | **Water Quality** | **Water Quantity** | **Habitat Connectivity** | **Biodiversity** | **Riparian Habitat** | **Water Quality** | **Water Quantity** | **Habitat Connectivity** | **Biodiversity** | **Riparian Habitat** |
| **Index Weight** | **1** | **1** | **1** | **0.5** | **1** | **1** | **1** | **1** | **0.5** | **1** |
| C1235 | 3.81 | 3.75 | 3.59 | 3.50 | 3.74 | 4 | 4 | 4 | 3 | 4 |
| C721 | 3.78 | 3.56 | 3.53 | 2.93 | 3.70 | 4 | 4 | 4 | 3 | 4 |
| C191 | 3.36 | 3.56 | 3.53 | 2.76 | 3.48 | 3 | 4 | 4 | 3 | 3 |
| C920 | 3.25 | 3.44 | 3.34 | 2.26 | 3.30 | 3 | 3 | 3 | 2 | 3 |
| C519 | 2.00 | 3.31 | 3.59 | 2.67 | 3.65 | 2 | 3 | 4 | 3 | 4 |
| C954 | 3.11 | 2.00 | 2.75 | 2.50 | 2.00 | 3 | 2 | 3 | 3 | 2 |
| C765 | 2.53 | 2.53 | 2.88 | 1.51 | 2.00 | 3 | 3 | 3 | 2 | 2 |
| C27 | 2.00 | 2.00 | 1.85 | 2.67 | 1.00 | 2 | 2 | 2 | 3 | 1 |
| C872 | 1.00 | 1.00 | 2.97 | 1.51 | 1.00 | 1 | 1 | 3 | 2 | 1 |
| | | | | | | | | | | |
| | **Index Relative Scores** | | | | | **Index Combined Scores** | | | | |
| **Index** | **Water Quality** | **Water Quantity** | **Habitat Connectivity** | **Biodiversity** | **Riparian Habitat** | **Water Quality** | **Water Quantity** | **Habitat Connectivity** | **Biodiversity** | **Riparian Habitat** |
| **Index Weight** | **1** | **1** | **1** | **0.5** | **1** | **1** | **1** | **1** | **0.5** | **1** |
| C1235 | 1.00 | 1.00 | 0.94 | 0.91 | 1.00 | 5.00 | 5.00 | 4.94 | 3.91 | 5.00 |
| C721 | 0.99 | 0.99 | 0.82 | 0.17 | 0.99 | 4.99 | 4.99 | 4.82 | 3.17 | 4.99 |
| C191 | 0.90 | 1.00 | 0.93 | 0.50 | 0.97 | 3.90 | 5.00 | 4.93 | 3.50 | 3.97 |
| C920 | 0.98 | 1.00 | 0.89 | 0.06 | 0.97 | 3.98 | 4.00 | 3.89 | 2.06 | 3.97 |
| C519 | 0.76 | 0.98 | 0.89 | 0.13 | 0.99 | 2.76 | 3.98 | 4.89 | 3.13 | 4.99 |
| C954 | 0.88 | 0.98 | 0.63 | 0.37 | 0.93 | 3.88 | 2.98 | 3.63 | 3.37 | 2.93 |
| C765 | 0.88 | 0.90 | 0.78 | 0.00 | 0.92 | 3.88 | 3.90 | 3.78 | 2.00 | 2.92 |
| C27 | 0.65 | 0.95 | 0.31 | 0.38 | 0.67 | 2.65 | 2.95 | 2.31 | 3.38 | 1.67 |
| C872 | 0.71 | 0.78 | 0.74 | 0.00 | 0.66 | 1.71 | 1.78 | 3.74 | 2.00 | 1.66 |

**Index combined score:**

$$ICS = IOS + IRS$$

**Where:** ICS = index combined score

These results were again standardized to the four objective categories according to the following definitions:

$$\begin{aligned} ICS \geq 4 &\rightarrow 4\ (Very\ Good) \\ 3 \leq ICS < 4 &\rightarrow 3\ (Good) \\ 2 \leq ICS < 3 &\rightarrow 2\ (Fair) \\ ICS < 2 &\rightarrow 1\ (Poor) \end{aligned}$$

The combined score indicates the planning unit's relative ranking within the respective category compared to all other planning units in that HUC8 watershed. The objective and relative ranking methods convey different information about the planning unit, and provide an additional level of analysis to help an end user make decisions about conservation projects. For example, in Table 16, while both C1235 and C721 catchments are in the Very Good category for Water Quality, C1235 is slightly higher quality than C721 and may be considered a slightly higher priority for conservation, all other factors being equal. However, both are considered to be in the ideal ecological condition for water quality.

### 3.3.8 Model Scores

Index scores were aggregated to produce a score for each model: Streams/Riparian Areas, Wetlands, and Uplands. The aggregated model scores are referred to as "overall scores" to differentiate them from the individual index scores.

**Model objective score:**

$$ModOS = \frac{IOS_1 * IW_1 + IOS_2 * IW_2 + \cdots + IOS_n * IW_n}{IW_1 + IW_2 + \cdots + IW_n}$$

**Where:** $IOS_i$ = index i objective score
$IW_i$ = index i weight
ModOS = model objective score

These results were once again grouped into the four categories according to the same standardization as the index objective scores:

$$\begin{aligned} ModOS > 3.5 &\rightarrow 4\ (Very\ Good) \\ 2.5 < ModOS \leq 3.5 &\rightarrow 3\ (Good) \\ 1.5 < ModOS \leq 2.5 &\rightarrow 2\ (Fair) \\ ModOS \leq 1.5 &\rightarrow 1\ (Poor) \end{aligned}$$

**Model relative score:**

$$ModRS = \frac{IRS_1 * IW_1 + IRS_2 * IW_2 + \cdots + IRS_n * IW_n}{IW_1 + IW_2 + \cdots + IW_n}$$

**Where:** $IRS_i$ = index i relative score
$IW_i$ = index i weight
ModRS = model relative score

A combined overall model score was then calculated using the same method as for individual indices above, to produce an overall combined score for each model (Streams/Riparian Areas, Wetlands, and Uplands). Table 19 lists examples of the Streams/Riparian Areas model objective, relative, and combined results aggregated from the results for all Streams indices (Water Quality, Water Quantity, Hydrologic Connectivity, Biodiversity, and Riparian Habitat indices) selected catchments. For example, both C1235 and C721 catchments are in the Very Good category and are therefore considered to be in an ideal ecological condition and priorities for conservation, though C1235 is slightly higher quality than C721, and may be considered a slightly higher priority, all other factors being equal.

**Model combined score:**

$$ModCS = ModOS + ModRS$$

**Where:** ModCS = model combined score

The combined results were standardized to the four quality categories as follows:

$$\begin{aligned} ModCS \geq 4 &\quad \rightarrow 4\ (Very\ Good) \\ 3 \leq ModCS < 4 &\quad \rightarrow 3\ (Good) \\ 2 \leq ModCS < 3 &\quad \rightarrow 2\ (Fair) \\ ModCS < 2 &\quad \rightarrow 1\ (Poor) \end{aligned}$$

Table 19. Example Model Objective, Relative, and Combined Results for Selected Catchments for the Streams/Riparian Areas Model

| Catchment ID | Objective Score | Standardized Objective Score | Objective Category | Relative Score | Combined Score |
|---|---|---|---|---|---|
| C1235 | 3.70 | 4 | Very Good | 0.98 | 4.98 |
| C721 | 3.56 | 4 | Very Good | 0.86 | 4.86 |
| C191 | 3.40 | 3 | Good | 0.90 | 3.90 |
| C920 | 3.21 | 3 | Good | 0.86 | 3.86 |
| C519 | 3.09 | 3 | Good | 0.82 | 3.82 |
| C954 | 2.47 | 2 | Fair | 0.80 | 2.80 |
| C765 | 2.38 | 2 | Fair | 0.77 | 2.77 |
| C27 | 1.82 | 2 | Fair | 0.62 | 2.62 |
| C872 | 1.49 | 1 | Poor | 0.64 | 1.64 |

The calculation of scores occurred at both planning unit levels, generated independently of each other:

1. a ranking of HUC12 watersheds in terms of their overall model combined scores for each priority model (Streams/Riparian Areas, Wetlands, and Uplands) and each index combined score (e.g., Water Quality, Biodiversity, Habitat Connectivity, etc.), and
2. a ranking of NHDPlus catchments based on overall model and index combined scores.

Through this process, three Priority Models were generated (Figures 11 - 13): a Streams/Riparian Areas Priority Model, a Wetlands Priority Model, and an Uplands Priority Model. These models remain separate, as they each identify a key landscape that was independently ranked. The analysis presents the final combined scores for each planning unit (HUC12 and NHDPlus catchment), with a high score indicating a higher conservation priority within that Priority Model.

### 3.3.9 Example Index and Model Scores Calculation

To illustrate the methodology outlined above, an example is presented to clarify how the relative, objective, and combined scores were produced for the Streams Water Quality index and Streams/Riparian Area model for one particular catchment, C1235. Table 20 shows the metric results for this catchment for the Streams Water Quality index. Applying the formulas from Section 3.3.6 and the metric values from Table 20, the Streams Water Quality (SWQ) index objective score was calculated as:

$$IOS = \frac{4*2+4*2+4*1.5+4*2+4*2+4*1+3*1+4+1+3*2+4*1.5}{2+2+1.5+2+2+1+1+1+2+1.5} = \frac{61}{16} = 3.81$$

which corresponds to the index objective score in Table 18. No water quality data were available for this planning unit and are therefore excluded from the analysis.

Similarly, the SWQ index relative score is:

$$IRS = \frac{1*2+0.985*2+1*1.5+1*2+1*2+1*1+1*1+1*1+0.988*2+1*1.5}{2+2+1.5+2+2+1+1+1+2+1.5}$$
$$= \frac{15.946}{16} = 0.997\ (rounded\ to\ 1.00)$$

which corresponds to the index relative score in Table 18.

To calculate the ICS, the IOS is standardized to 4 (as it is greater than 3.5), and the IRS added to it:

$$ICS = 4 + 1.00 = 5.00$$

which corresponds to the index combined score in Table 18, and is considered to be in the Very Good category.

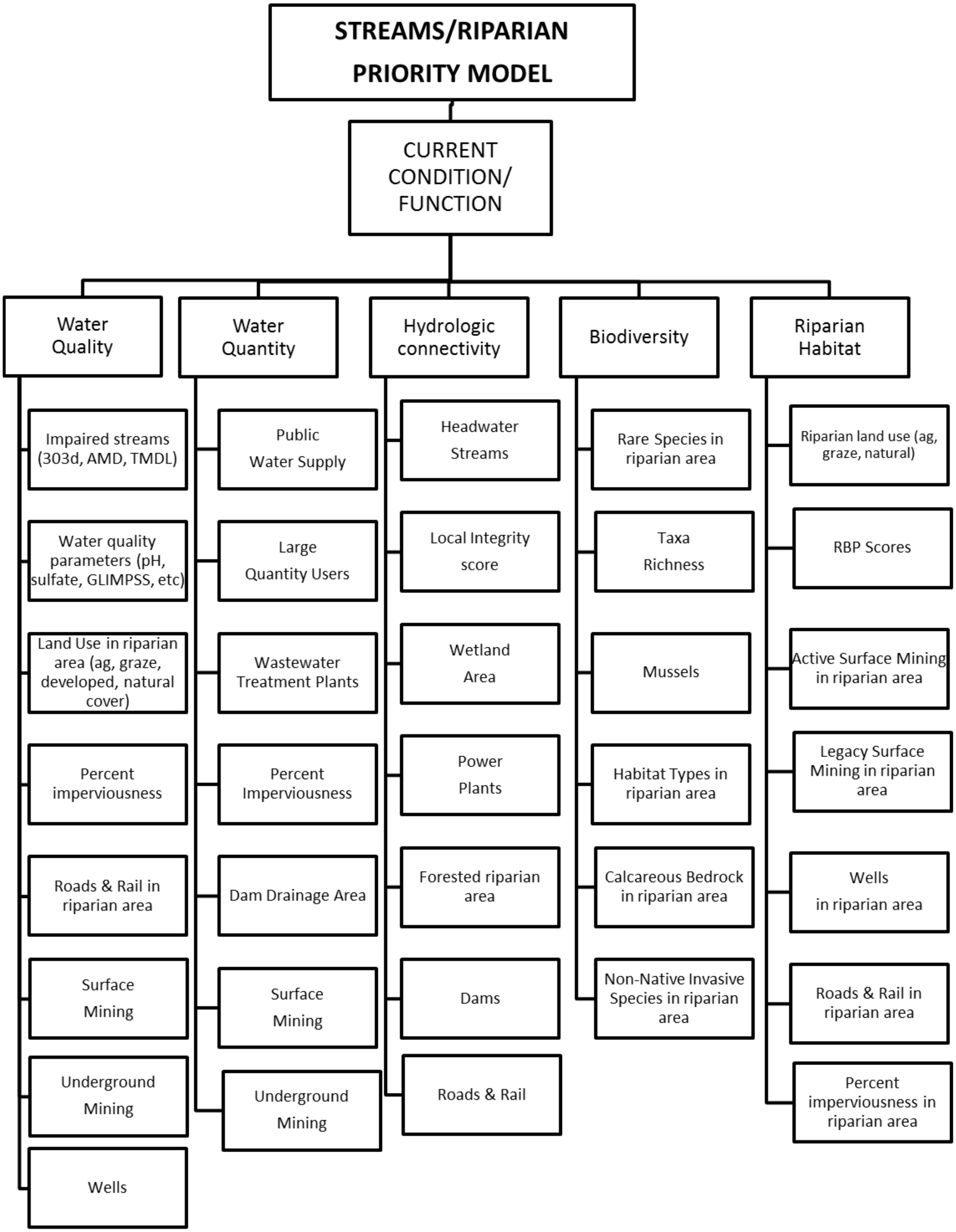


Figure 11. Streams/Riparian Areas Priority Model Flowchart

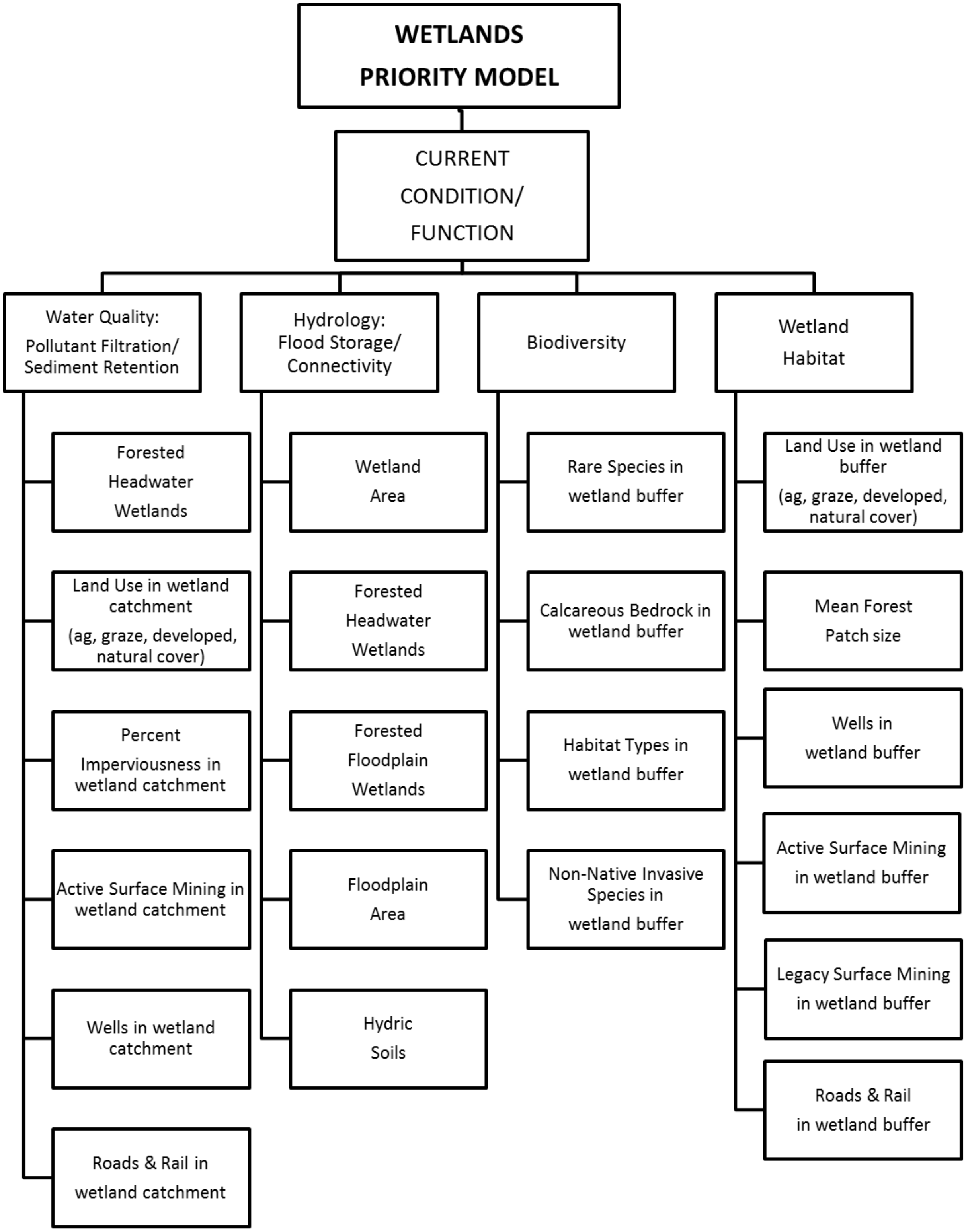


Figure 12. Wetlands Priority Model Flowchart

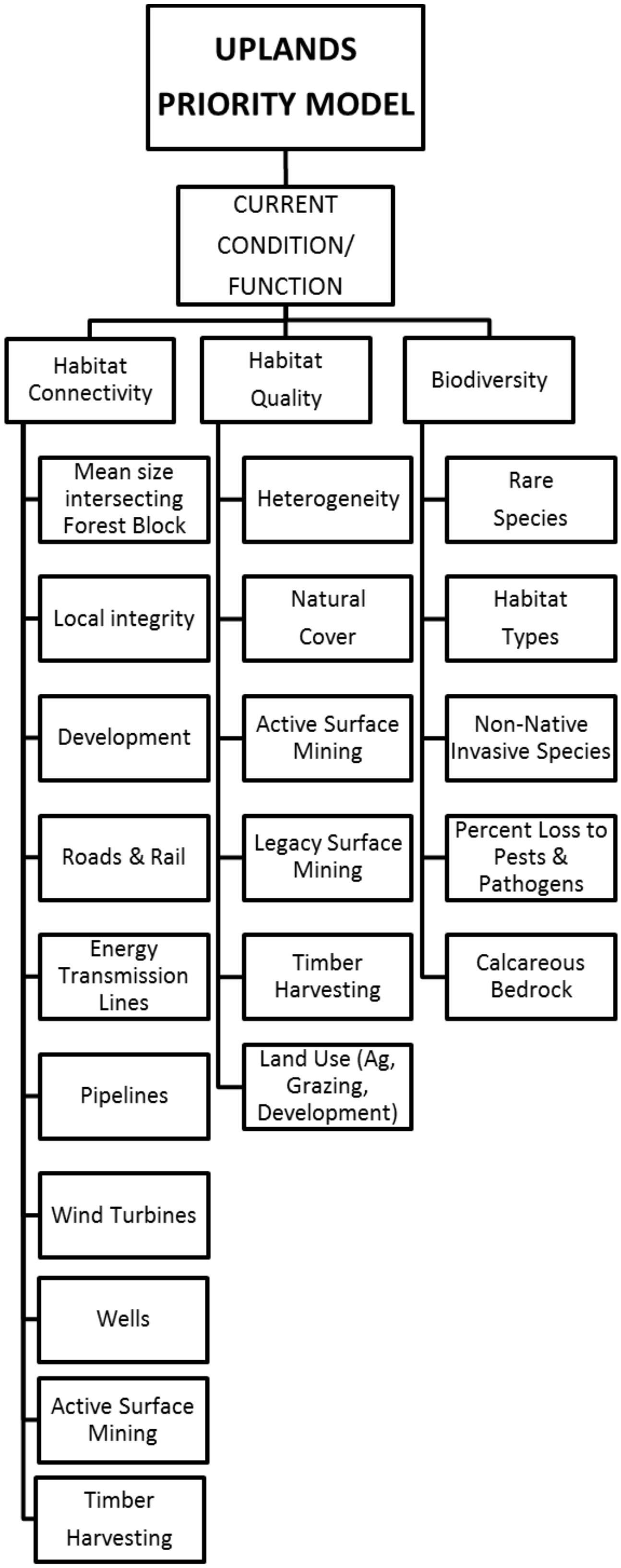


Figure 13. Uplands Priority Model Flowchart

To calculate the Streams/Riparian Areas Model objective and relative scores, all index scores in Table 18 are used:

$$ModOS = \frac{3.81 * 1 + 3.75 * 1 + 3.59 * 1 + 3.50 * 0.5 + 3.74 * 1}{1 + 1 + 1 + 0.5 + 1} = \frac{16.64}{4.5} = 3.70$$

which corresponds to the model objective score in Table 17, and places the index in the Very Good category.

$$ModRS = \frac{1.00 * 1 + 1.00 * 1 + 0.94 * 1 + 0.91 * 0.5 + 1.00 * 1}{1 + 1 + 1 + 0.5 + 1} = \frac{4.395}{4.5} = 0.98$$

which corresponds to the model relative score in Table 19.

The ModOS score is then standardized to 4 (as it is greater than 3.5), and the ModRS is added to it to produce the overall Streams/Riparian Area model combined score:

$$ModCS = 4 + 0.98 = 4.98$$

which corresponds to the model combined score in Table 19, and places the model into the Very Good category.

Table 20. Example Streams Water Quality Metrics for Catchment C1235 with Value, Objective Category, Objective Score, and Relative Score for Each Metric

| **Metric** (* critical metrics) | **Weight** | **Value** | **Objective Category** | **Objective Score** | **Relative Score** |
|---|---|---|---|---|---|
| AMD, TMDL, 303(d) impaired streams | 2 | 0 % | Very Good | 4 | 1 |
| Median pH* | 2 | [a] | [a] | [a] | [a] |
| Median sulfate | 1 | [a] | [a] | [a] | [a] |
| Median specific conductivity* | 1.5 | [a] | [a] | [a] | [a] |
| Median GLIMPSS | 2 | [a] | [a] | [a] | [a] |
| Median sedimentation & embeddedness | 1 | [a] | [a] | [a] | [a] |
| Percent imperviousness* | 2 | 0 % | Very Good | 4 | 0.985 |
| All wells | 1.5 | 0 % | Very Good | 4 | 1 |
| Surface mining (active & legacy)* | 2 | 0 % | Very Good | 4 | 1 |
| Underground mining | 2 | 0 % | Very Good | 4 | 1 |
| Agriculture in riparian area | 1 | 0 % | Very Good | 4 | 1 |
| Grazing/pasture in riparian area | 1 | 1.13 % | Good | 3 | 1 |
| Development in riparian area | 1 | 0 % | Very Good | 4 | 1 |
| Natural cover in riparian area | 2 | 98.80 % | Good | 3 | 0.988 |
| All roads & rail | 1.5 | 0 % | Very Good | 4 | 1 |

[a] null value due to the absence of a WVDEP WAB water quality station in this catchment

### 3.4 Consolidated Analysis

The Consolidated Analysis consists of two main parts, a Future Threats assessment and an Opportunities assessment (Figure 14). It was originally envisioned to evaluate cumulative watershed effects, to analyze historical and possible future conditions where applicable data were available, to assess the impacts of past changes on the watershed, and to project future trends that might significantly impact the planning units over time (such as climate change or population growth). The objective was to incorporate the following into the consolidated analysis:

a. Impacts and stresses to natural resources, functions, and sensitive species (and their habitats) and vegetative communities in the watershed
b. Current and past land use changes in the watershed, evaluating their cumulative watershed effects on natural resource condition and function
c. The extent and location of riparian, wetland, and upland loss compared to historic conditions, including the loss of any species or vegetative communities
d. Natural resources, functions, and/or services that have been lost or degraded, where they are, and how significantly they have been impacted
e. Future threats analysis
f. Projected land use change with the potential to negatively impact natural resource value and function (population growth and urban expansion, planned energy projects)
g. Potential for increased resource extraction activities due to the presence of undeveloped natural resources (unmined coal, high wind or geothermal energy potential, Marcellus shale gas play)
h. Potential effects of climate change
i. Priority interest areas identifying portions of the landscape that are known priorities for protection by various federal, state, or non-governmental organizations

However, much of the data necessary for a comprehensive and thorough Consolidated Analysis was not consistently available for the five pilot HUC8 watersheds, and these datasets are listed in Section 5.3 as data gaps/needs identified for the state. For example, potential Marcellus shale development projections are not yet available from partner agencies, so the Marcellus shale thickness was used as a surrogate to estimate the probability of Marcellus shale development. Urban development projections were surprisingly lacking in West Virginia, except for the Morgantown area in the Monongahela watershed, and population projections were only available on a county-wide level. In contrast, the modeled resiliency and regional flow data, indicating potential response to climate change, are at a relatively fine scale. The latter two datasets are part of a larger analysis of the Northeast and Mid-Atlantic region conducted by The Nature Conservancy's Eastern Conservation Science program to identify geographic areas that are resilient in terms of providing species on the landscape the opportunity to adapt to a changing climate (Anderson et al. 2012). The concept of "resiliency" in this sense indicates that some areas may be able to buffer the effects of climate change by "offering a connected array of microclimates that allow species to persist." The analysis is based on two factors:

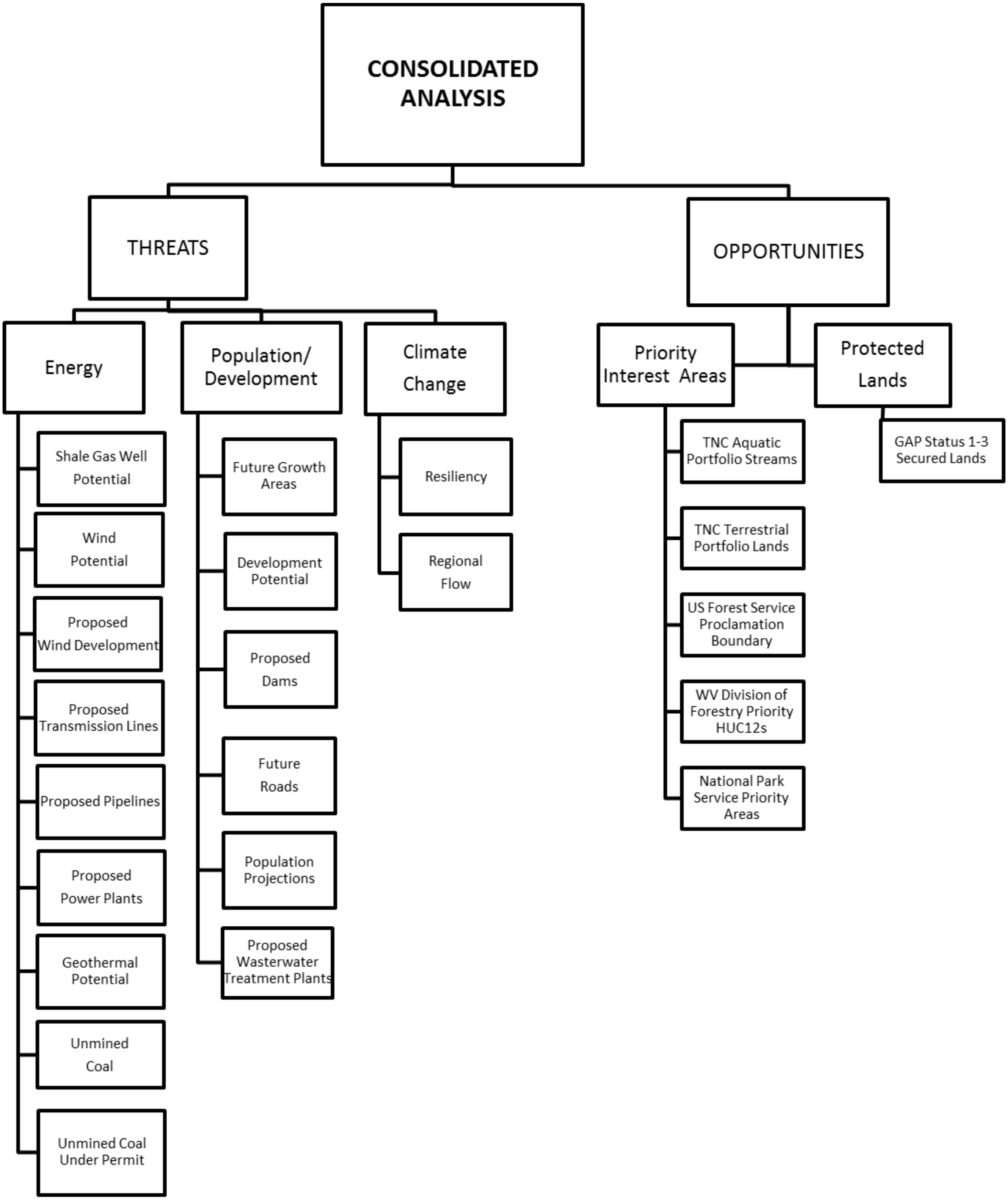


Figure 14. Consolidated Analysis Flowchart

landscape complexity (topography, elevation range, and wetland density) and landscape permeability (local connectedness and regional flow patterns, which are measures of landscape structure in terms of barriers, connected natural cover and land use patterns; Anderson et al. 2012). Detailed projections of temperature and precipitation changes are currently being developed for the Ohio River Basin by the USACE (Drum 2013) and may be incorporated into the Climate Change threats analysis when they become available.

Because of the inconsistent nature and variable scales of the different datasets, the Consolidated Analysis results were not calculated for the HUC12 or catchment-level planning units, but were instead calculated as gradients over the entire HUC8 watershed and are displayed as an informational layer rather than included in the model analysis results.

To display the cumulative known Future Threats to areas within the watershed, each metric was standardized from 0 to 100, with 100 indicating the lowest threat level for the metric in the HUC8 watershed, and 0 indicating the highest threat level. Metrics were weighted according to their significance in terms of affecting the overall future threat level of the watershed and summed to produce an overall index score. The indices were then combined using Esri's ArcGIS Spatial Analyst Raster Calculator tool to produce Threats Overall Results (a full list of metrics and assigned weights can be found in Table 21). This information was not included in the analysis results for each planning unit, but is meant to provide an additional set of information once the current condition of a planning unit has been determined.

The purpose of the second part of the Consolidated Analysis, the Opportunities assessment, was to provide information about currently protected areas, or areas that have been identified as priorities for protection by other organizations or regulatory agencies. This information may be helpful to entities planning protection or restoration activities in a given area by identifying potential partners or funding sources. Datasets included in the Opportunities assessment include permanently protected areas, The Nature Conservancy aquatic and terrestrial portfolios, West Virginia Division of Forestry priority areas, National Park Service priority areas, and National Forest proclamation boundaries.

Table 21. Metrics Included in the Consolidated Analysis

| Model | Index | Metric Description | Weight | Units |
|---|---|---|---|---|
| FUTURE THREATS | Energy | Currently unmined area within permit boundary | 2 | % of planning unit |
| | | Unmined area of mineable coal seams | 2 | % of planning unit |
| | | Marcellus well potential, based on shale thickness | 2 | mean thickness/planning unit |
| | | Modeled wind potential | 2 | % of planning unit |
| | | Proposed wind turbine locations | 1 | #/sq mi planning unit |
| | | Proposed energy transmission lines | 1 | mi/sq mi planning unit |
| | | Proposed gas pipelines | 1 | mi/sq mi planning unit |
| | | Proposed power plants | 1 | #/sq mi planning unit |
| | | High geothermal potential (temp>150 degrees) | 1 | % of planning unit |
| | Population/ Development | Population projections | 1 | percent change, by county |
| | | Areas designated for future development | 1 | % of planning unit |
| | | Proposed dam locations | 1 | #/stream mile |
| | | Proposed future roads | 1 | mi/sq mi planning unit |
| | | Proposed wastewater treatment plants | 1 | #/planning unit |
| | Climate Change | Resiliency score | 1 | avg score/planning unit |
| | | Current density score | 1 | avg score/planning unit |
| OPPORTUNITIES* | Priority Interest Areas | TNC aquatic portfolio streams | - | - |
| | | TNC terrestrial portfolio lands | - | - |
| | | US Forest Service proclamation boundary | - | - |
| | | WV Division of Forestry priority areas | - | - |
| | | National Park Service priority areas | - | - |
| | Protected Lands | GAP Status 1-3 secured lands | - | - |

*The “Opportunities” metrics/datasets are considered informational and were not part of an analysis, but are presented to aid decision-making. Therefore, these datasets do not have assigned weights or normalized units of measurement.

## 3.5 Data

### 3.5.1 Data Sources

Spatial data acquired for this study included:

- Surface water quality monitoring data
- Impaired streams (303(d), TMDL, AMD)
- Land use and land cover (LULC) data
- Surface and subsurface geology
- Soils
- Elevation (DEM)
- Stream network and drainage areas
- Wetlands location and type
- Species and habitat data
- Protected lands
- Infrastructure (roads, railroads, dams, energy transmission lines, pipelines)
- Mining, mineral extraction, oil and gas wells data
- Regulated sites (permitted discharge, landfills, toxic waste disposal, etc.)
- Demographics/population data
- Climate change models
- Political boundaries

Data were obtained from many sources including, but not limited to:

Federal agencies

- US Environmental Protection Agency
- US Geological Survey
- US Forest Service
- US Fish and Wildlife Service
- US Department of Agriculture
- US Department of Transportation
- US Census Bureau

State agencies

- WV Department of Environmental Protection
- WV Division of Natural Resources
- WV Division of Forestry
- WV Geological and Economic Survey
- WV Statewide Addressing and Mapping Board

Local agencies

- City/county/regional governments
- River or Watershed Associations

Non-profit organizations

- The Nature Conservancy

Universities

- West Virginia University
- WV GIS Technical Center

For a thorough reference to all data sources and intended uses please see Appendix A: Detailed Data Source Information.

### 3.5.2 Data Quality

Data were selected or rejected based on their relevance, completeness, accuracy, quality, and age. The most current data available were used, except in cases where using historical data for comparison or trend prediction was desirable. For example, species occurrence data older than 20 years were not used since they are unlikely to reflect current conditions. Particular factors that caused data to be rejected included: lack of appropriate or complete metadata; data that do not accurately reflect the current status of the watershed; data that appear incomplete or significantly conflict with known quality-assured data (thus casting doubt on data quality); and data that were deemed irrelevant or redundant during the analysis.

*Section 4: Results and Discussion*

### 4.1 Current Condition Results and Discussion

#### 4.1.1 Streams/Riparian Areas

Figures 15a and 15b show the overall results for the Streams/Riparian Areas landscape at the HUC12 and NHDPlus catchment scales, respectively, incorporating the scores for all the Streams/Riparian Priority Model indices. The Little Kanawha watershed has relatively high Streams scores compared to other watersheds assessed during the pilot project, most likely due to the mostly rural nature of the basin (which limits negative metrics like impervious cover and development) and the lack of significant mining activity. Additionally, the Little Kanawha is known to be currently under-represented for water quality sampling, which may keep some issues from emerging in the analysis (Whitman 2013). Consequently, the Streams Overall results were mostly Good, with just a few planning units scoring in the Fair category. The two Fair HUC12s, Neal Run and Worthington Creek, contain the urban area of Parkersburg, and therefore have more development and related metrics that bring down scores in most indices. Many of the Fair-scoring catchments are also in this area in the northwest corner of the watershed, and other Fair catchments are near the smaller towns within the watershed (around Harrisville, Spencer, Glenville, Flatwoods, etc.). The Overall results therefore clearly show the influence of development and infrastructure on Streams scores. The south-central part of the watershed, with a density of high quality Good and even some Very Good catchments, emerges throughout the Streams indices as a high quality area, and these catchments should be considered as potential candidates for protection within the Little Kanawha watershed.

Similar patterns emerge in the Streams Water Quality (SWQ) index results (Figures 16a and 16b), with the Fair planning units mostly in the northwest of the watershed around Parkersburg, and the higher scores in the central corridor and southeast of the watershed. While the SWQ index does have four critical metrics, they are not a primary driver of the Fair results in this watershed – generally, planning units received Fair scores due to lack of natural cover (the Little Kanawha watershed has a comparatively significant amount of grazing and agriculture) and wells and/or roads and railroads. These Fair catchments would therefore be potential candidates for restoration activities. Most of the Very Good scoring planning units have no stream impairments, a minimal amount of impervious surface, and a high percentage of natural cover, and would be good candidates for protection activities. It is important to note, however, that the Little Kanawha watershed has a high density of oil and gas wells (Figure 17). Most of the catchments that scored Good did so for a variety of reasons and any candidate planning units chosen for protection purposes should be reviewed for all metrics scores to ensure they are compatible with the project's goals.

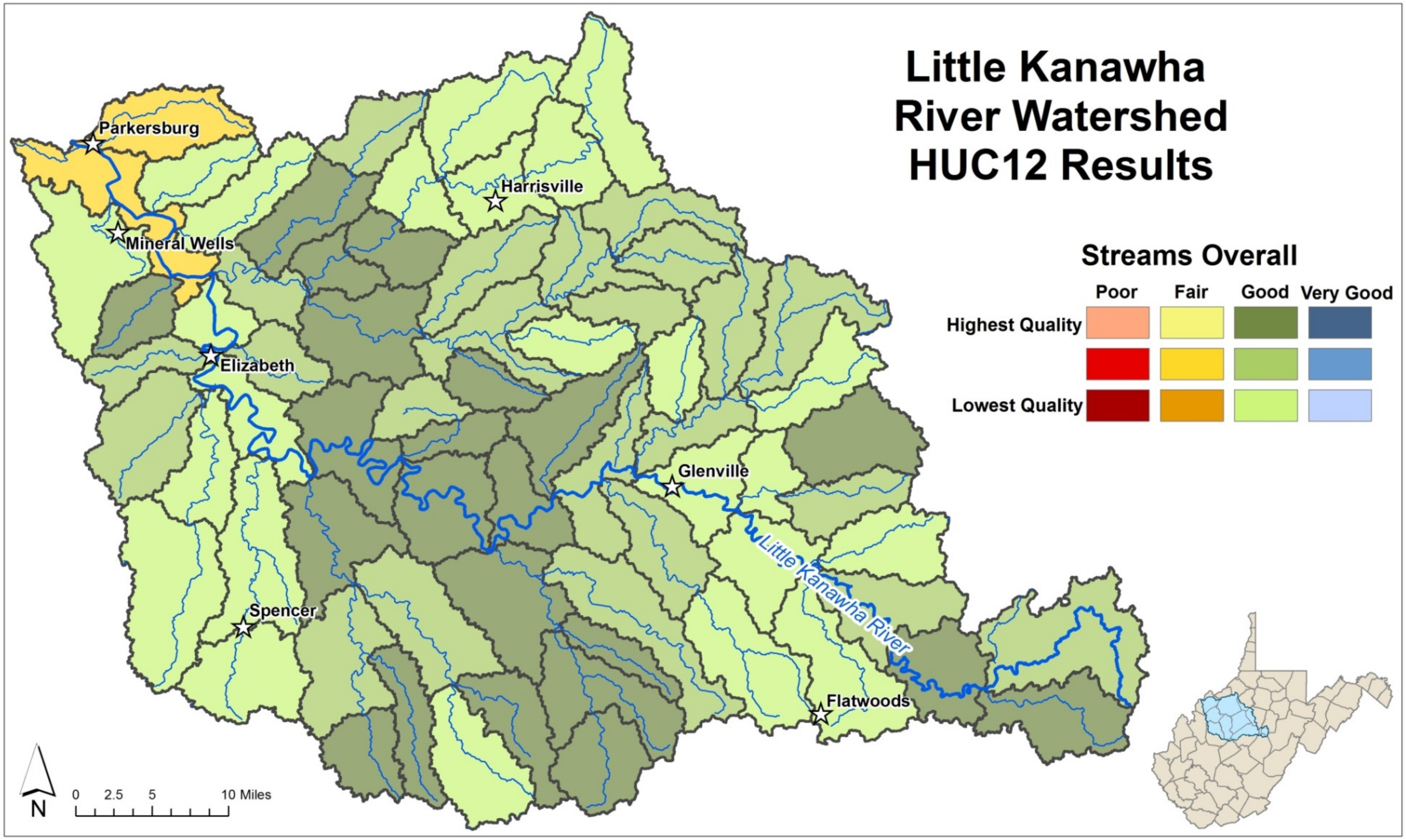


Figure 15a. Streams Overall Results – HUC12 Level

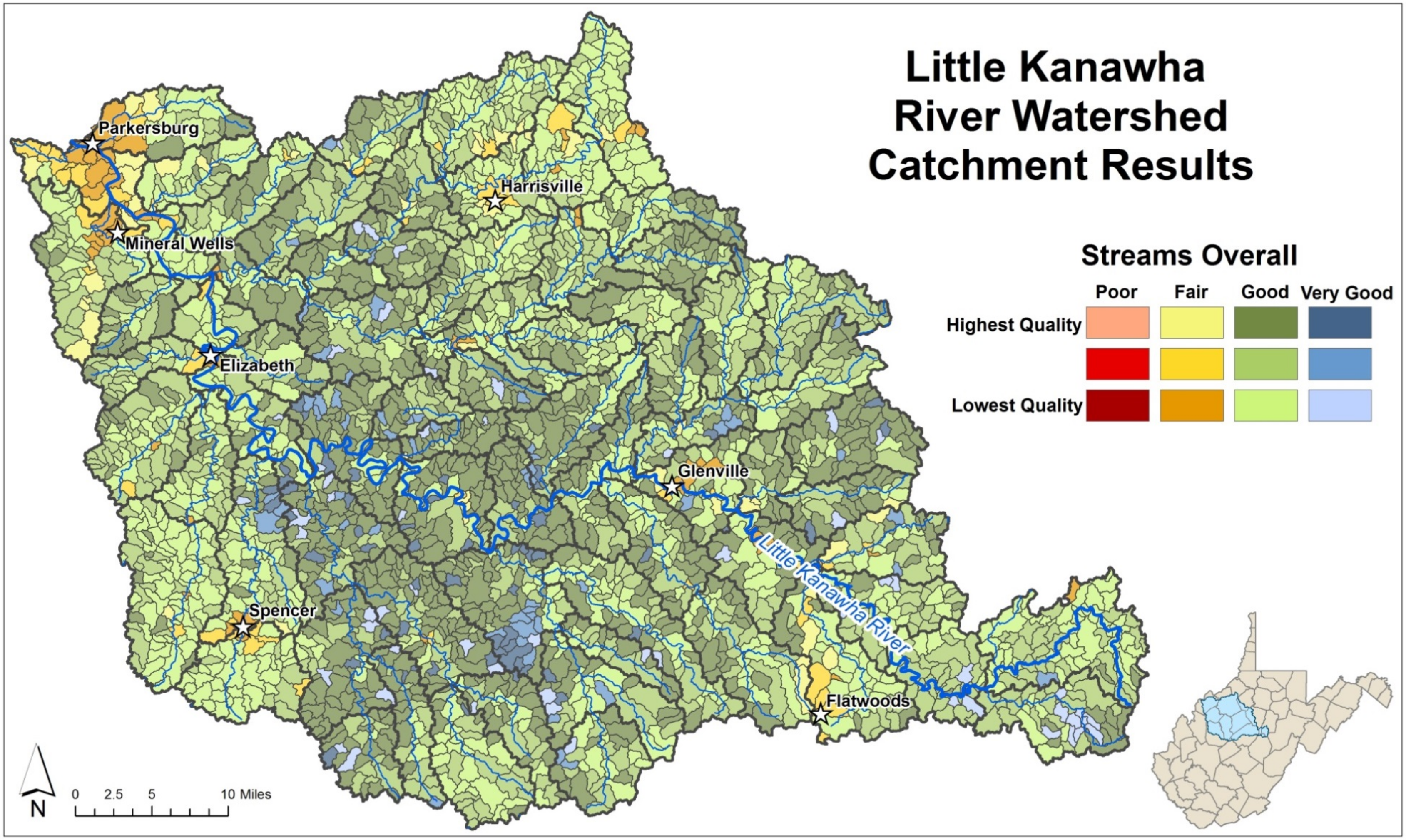


Figure 15b. Streams Overall Results – Catchment Level

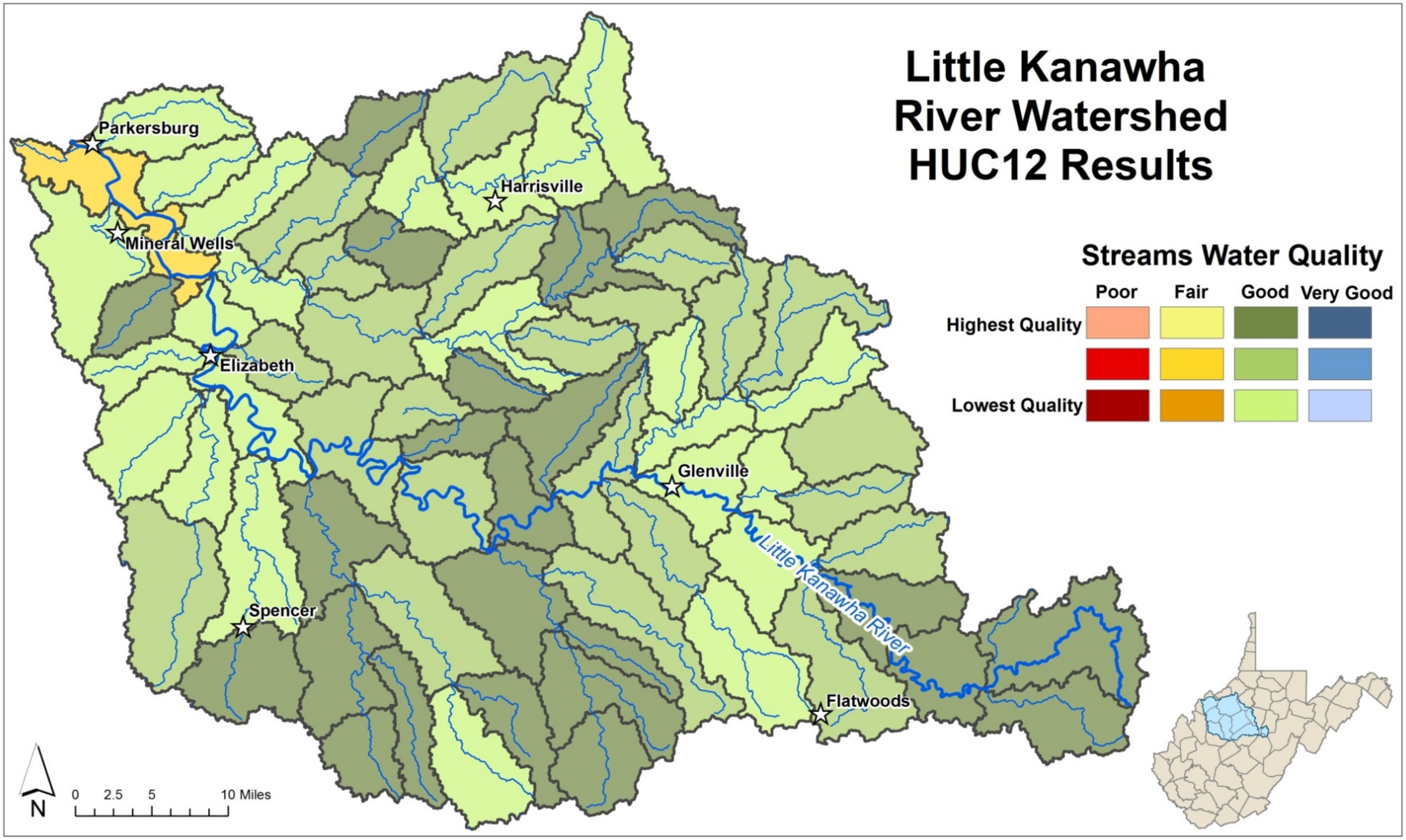


Figure 16a. Streams Water Quality Index Results – HUC12 Level

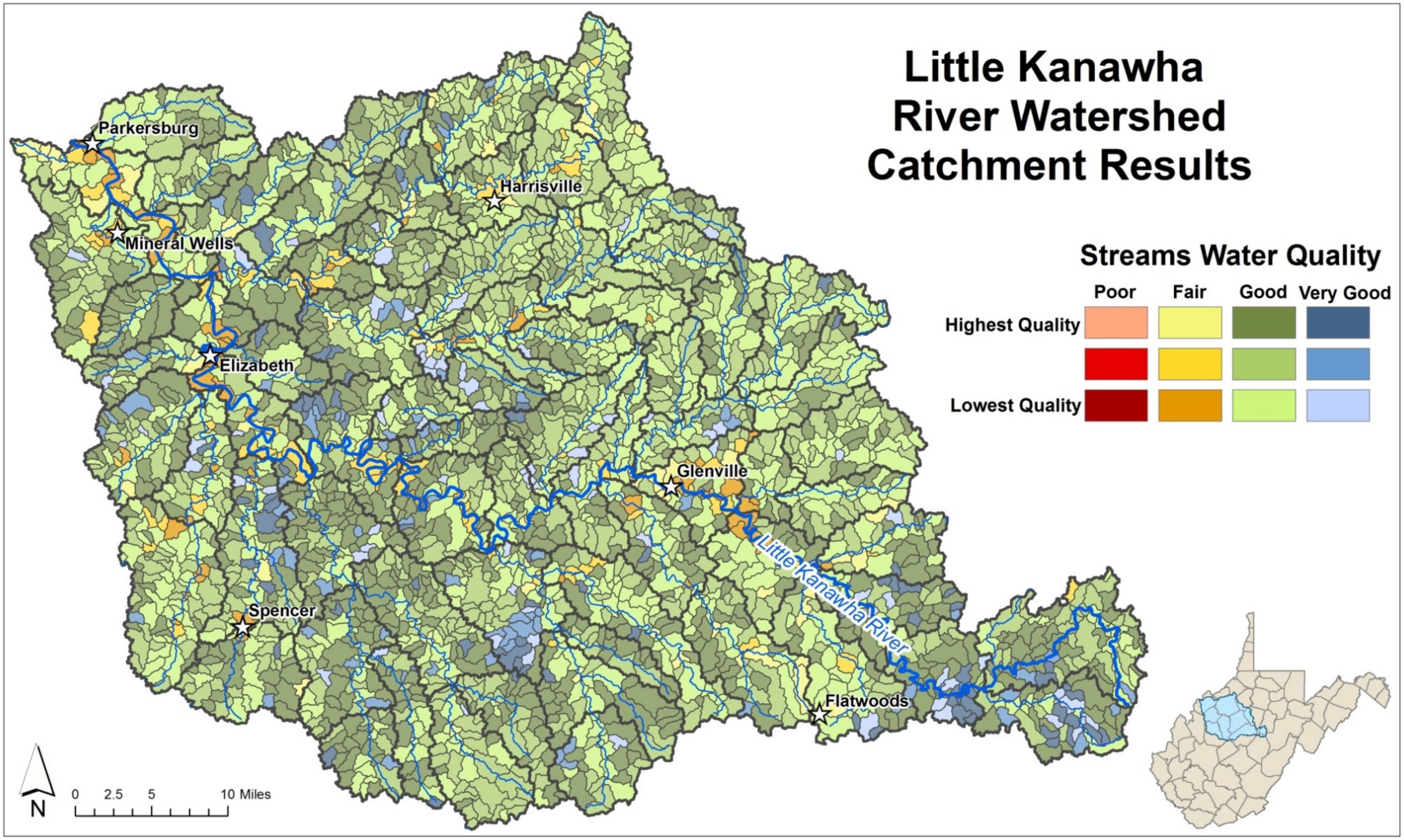


Figure 16b. Streams Water Quality Index Results – Catchment Level

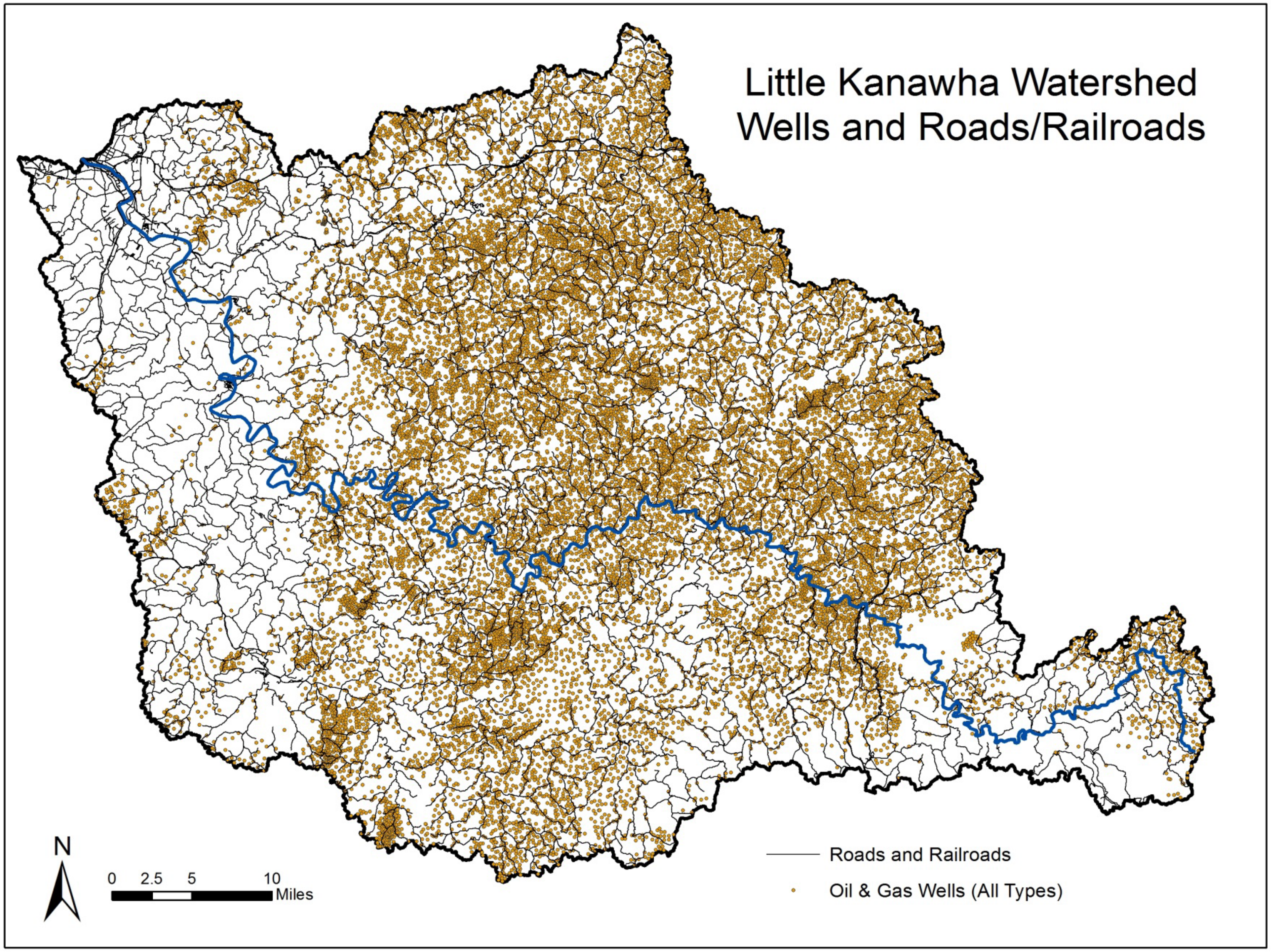


Figure 17. Little Kanawha Watershed – Wells and Roads/Railroads (WVGES 2012, WVDOT 2011)

Greater variability is evident across the watershed in the Streams Water Quantity (SWN) HUC12 results (Figure 18a). The Neal Run HUC12 scored a Poor, due to primarily to the critical metric of percent imperviousness, which is expected as this HUC12 contains the Parkersburg urban area; the same issue caused the Worthington Creek HUC12 to score a Fair. All of the Very Good HUC12s scored Good in all metrics and have no mining activity, raising their scores to the highest category as mining is relatively heavily weighted in this index. Those HUC12s scoring in the Good category were generally negatively impacted by features such as the presence of dams, public water supply intakes, or wastewater treatment plants. The locations of these features can often be distinguished on the catchment level results map (Figure 18b) by the lower scores around small towns with these features surrounded by Very Good catchments. Overall, the Little Kanawha watershed has very high SWN scores.

A few new trends emerge in the Streams Hydrologic Connectivity (SHC) index HUC12 results (Figure 19a). While the HUC12s around the Parkersburg area are in the Fair category, a few HUC12s around Harrisville were also Fair, mostly due to roads and railroads in the riparian area, lack of forested riparian area, the presence of dams, and low local integrity scores. Otherwise, most planning units scored Good in the SHC index, with some catchments scoring Very Good, particularly in the headwaters areas of Steer Creek and the Right Fork Little Kanawha in the southeast corner of the watershed (Figure 19b). Very Good catchments often have many headwaters streams, a high percentage of forested riparian area, and no roads or railroads, making them potentially good candidates for protection activities. Good catchments also have many headwaters, but often more infrastructure and less forested cover.

The Streams Biodiversity (SBD) index results show little variation at the HUC12 level (with mostly Very Good and Good scores), and a bit more variation at the catchment level, which may seem an apparent contradiction (Figures 20a and 20b). While a HUC12 may have many rare species or invasive species that collectively lower or raise its SBD index score, at the catchment level there are often none, or only one or two occurrences recorded within each planning unit. In planning units without recorded rare or invasive species the index results depend on the values of only two or three other metrics. Unfortunately, it is not known if no recorded occurrences are due to a lack of surveys in that area or an actual lack of occurrences. Catchments with Very Good scores all had Very Good northeast terrestrial habitat scores with the presence of calcareous bedrock. More than any other index, the Biodiversity index in each landscape should be reviewed in greater detail by potential users, by investigating which metrics are driving the final score. Biodiversity results are best viewed as informational, and should not be consulted as a primary or guiding index within the model without further evaluation of other index results and the individual Biodiversity metrics scores.

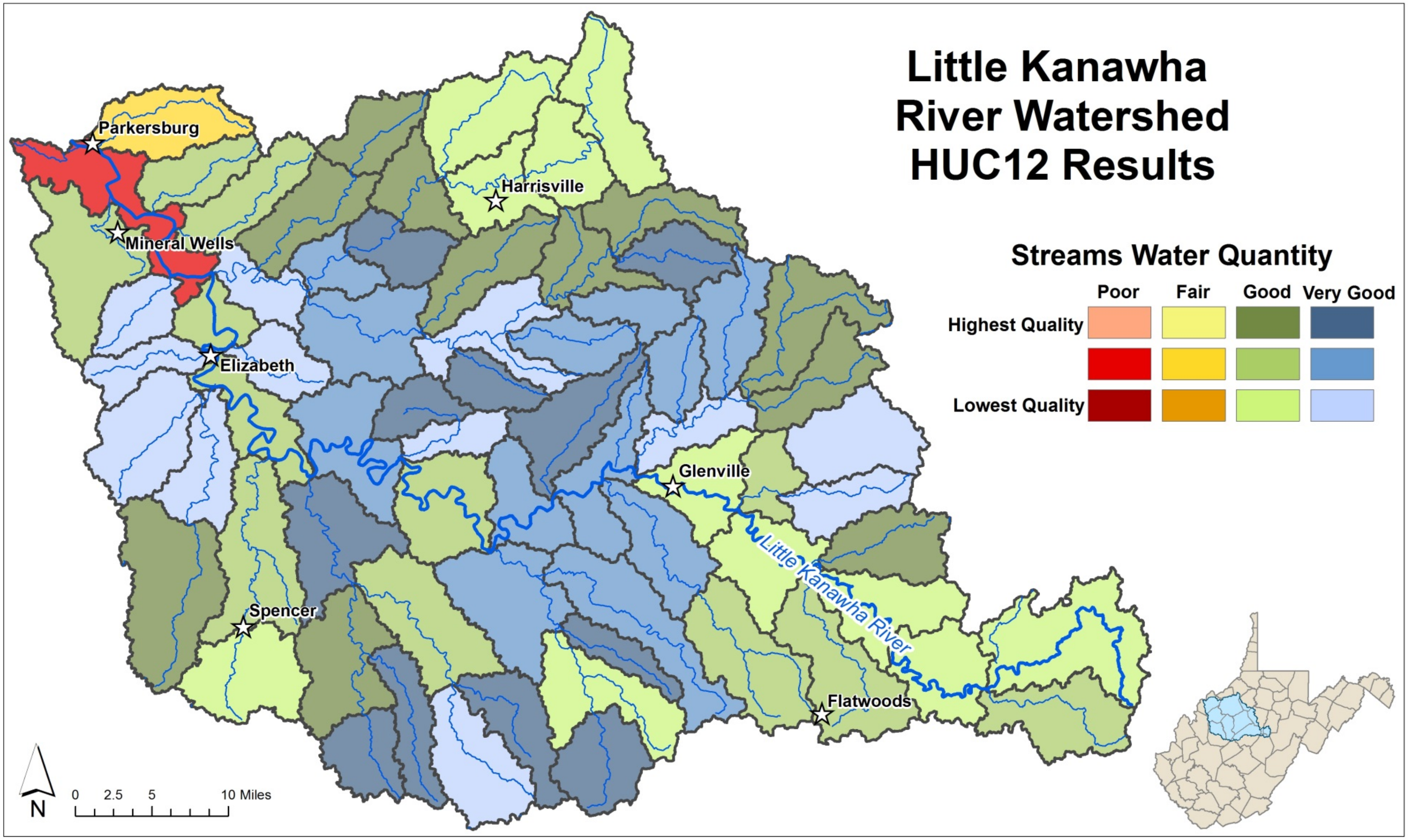


Figure 18a. Streams Water Quantity Index Results – HUC12 Level

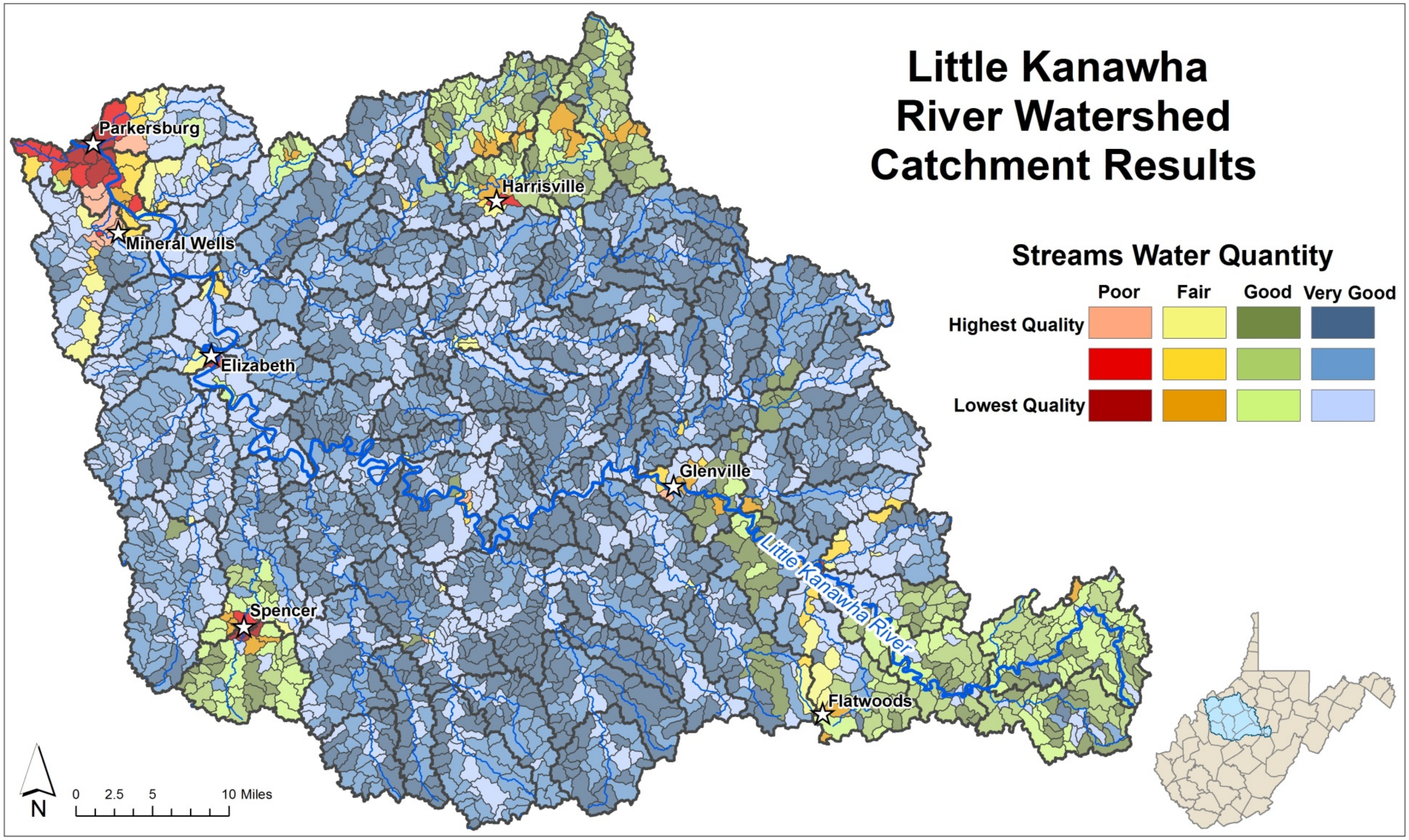


Figure 18b. Streams Water Quantity Index Results – Catchment Level

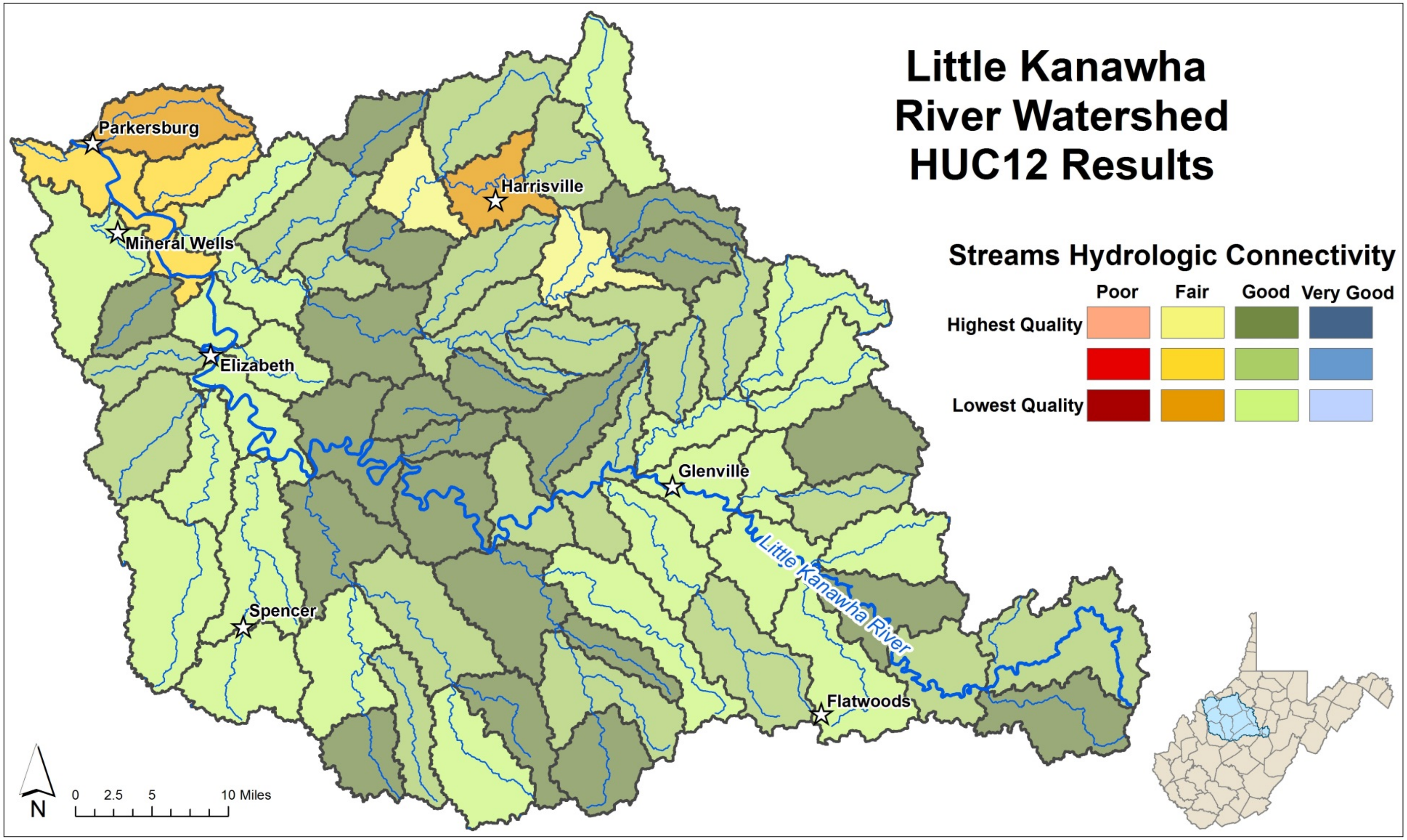


Figure 19a. Streams Hydrologic Connectivity Index Results – HUC12 Level

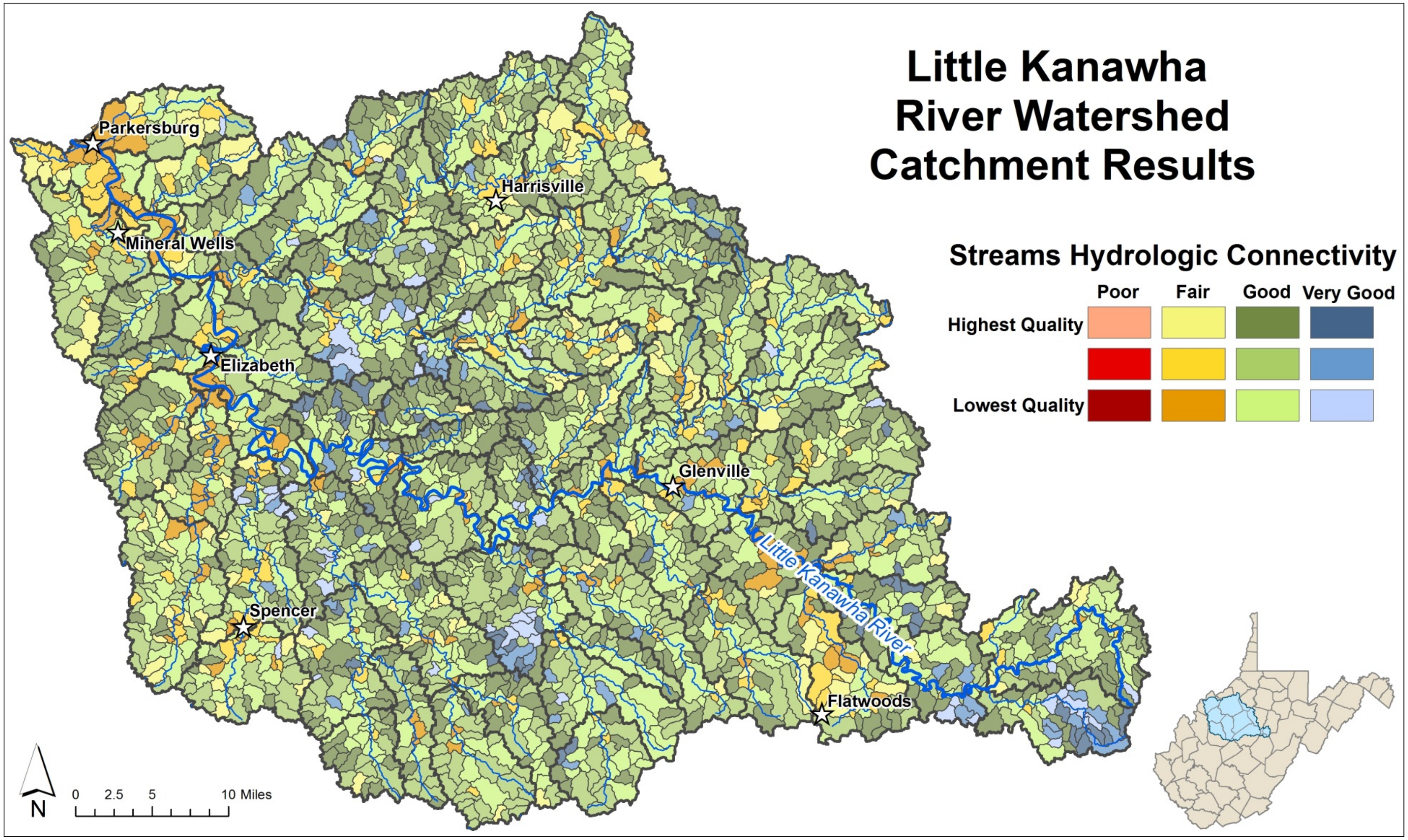


Figure 19b. Streams Hydrologic Connectivity Index Results – Catchment Level

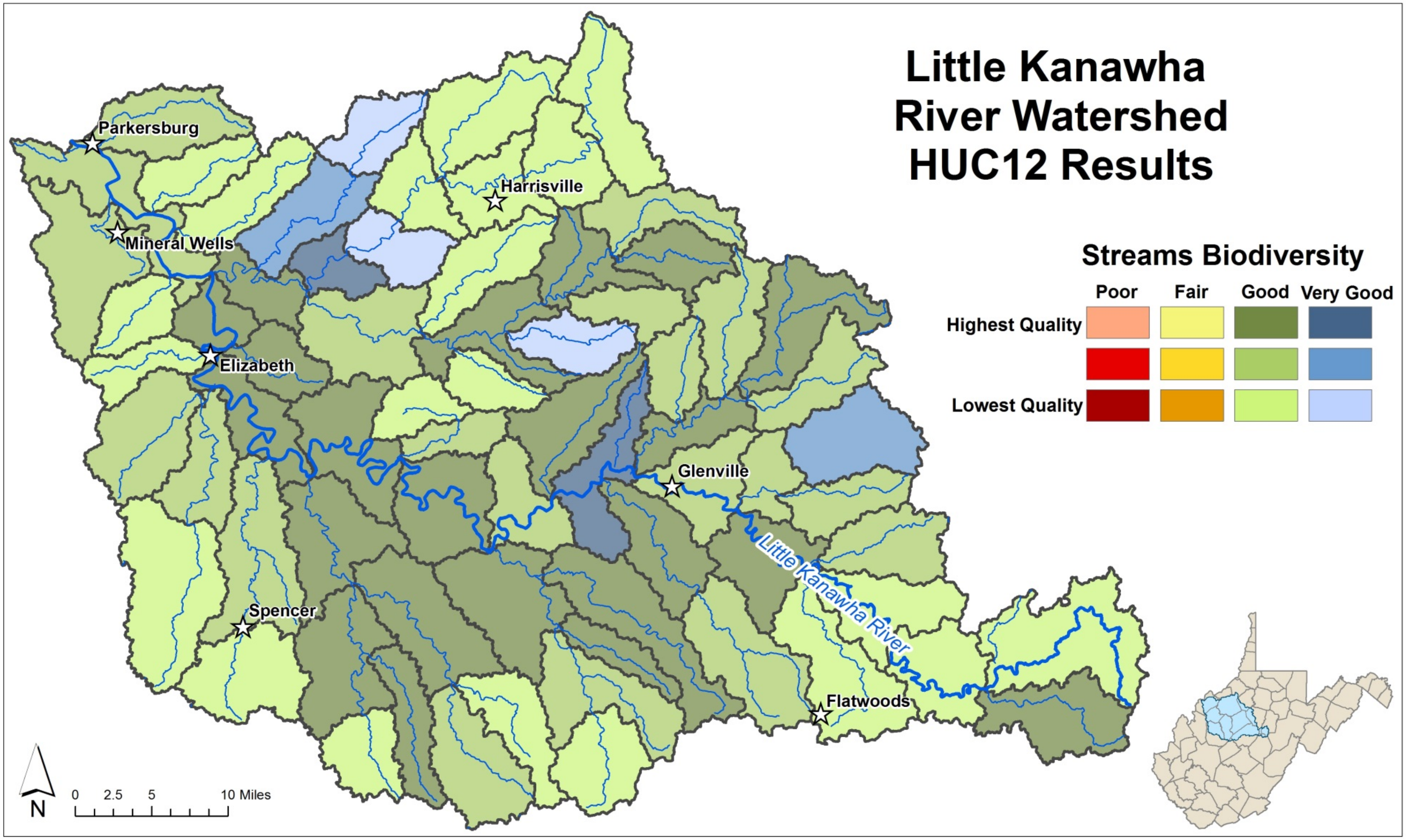


Figure 20a. Streams Biodiversity Index Results – HUC12 Level

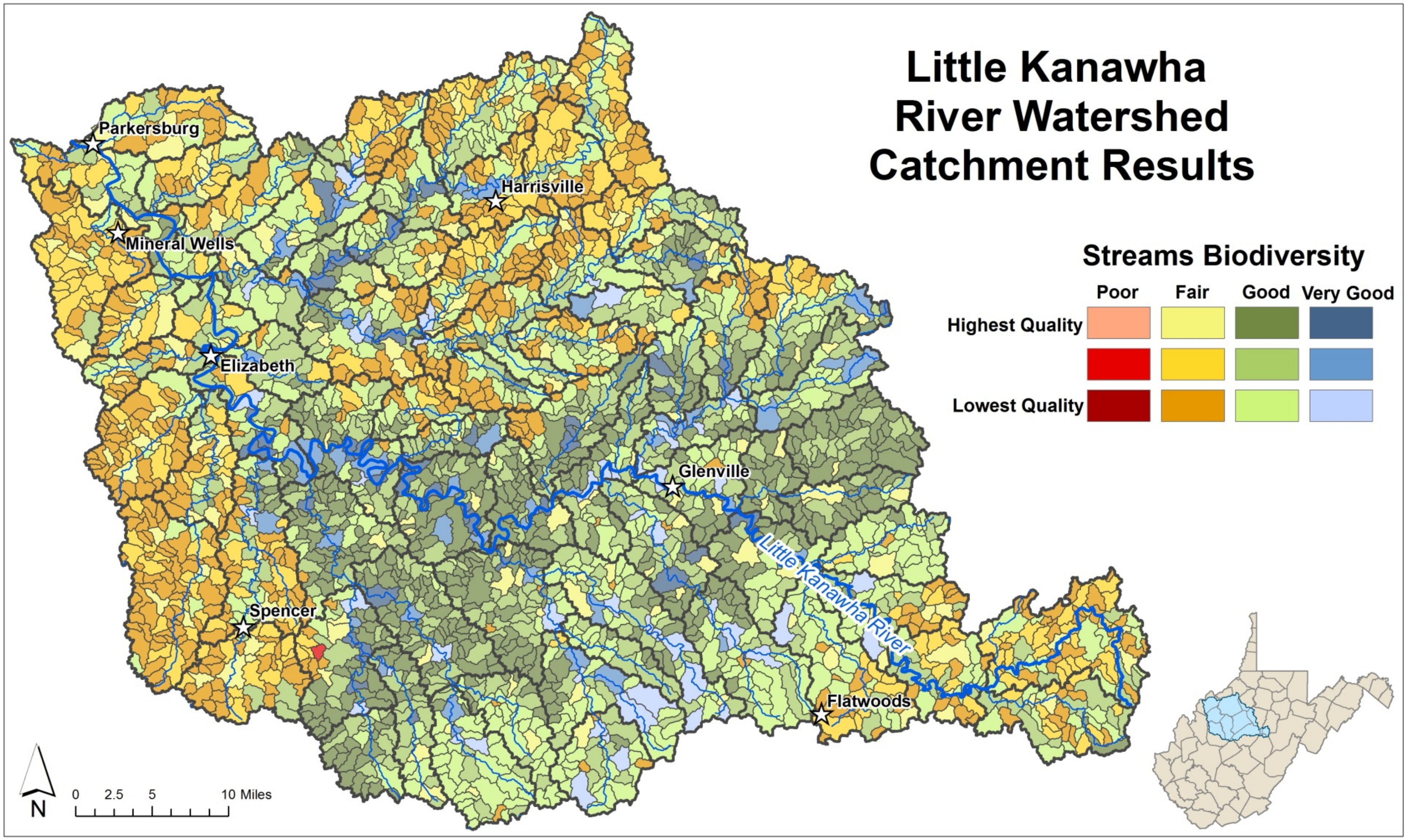


Figure 20b. Streams Biodiversity Index Results – Catchment Level

The Streams Riparian Habitat (SRH) index results are interesting to interpret. At the HUC12 level the scores were all Good or Fair, with some of the Fair scores caused by the critical metric of percent imperviousness in the riparian area (Figure 21a). Otherwise, Fair HUC12 scores were generally a result of higher amounts of agriculture or grazing land cover. At the catchment level, this trend mostly disappears, with a vast majority of the catchments scoring Very Good (Figure 21b). This is largely due to the intact nature of the natural cover in the riparian area in the Little Kanawha watershed, with only an occasional higher density of roads and railroads and wells, but otherwise mostly undisturbed forested riparian area. All of the Poor catchments were caused by the percent imperviousness in the riparian area critical metric. Main metrics that resulted in a Fair or Good score at the catchment level included natural cover in the riparian area, percent imperviousness in the riparian area, and wells in the riparian area.

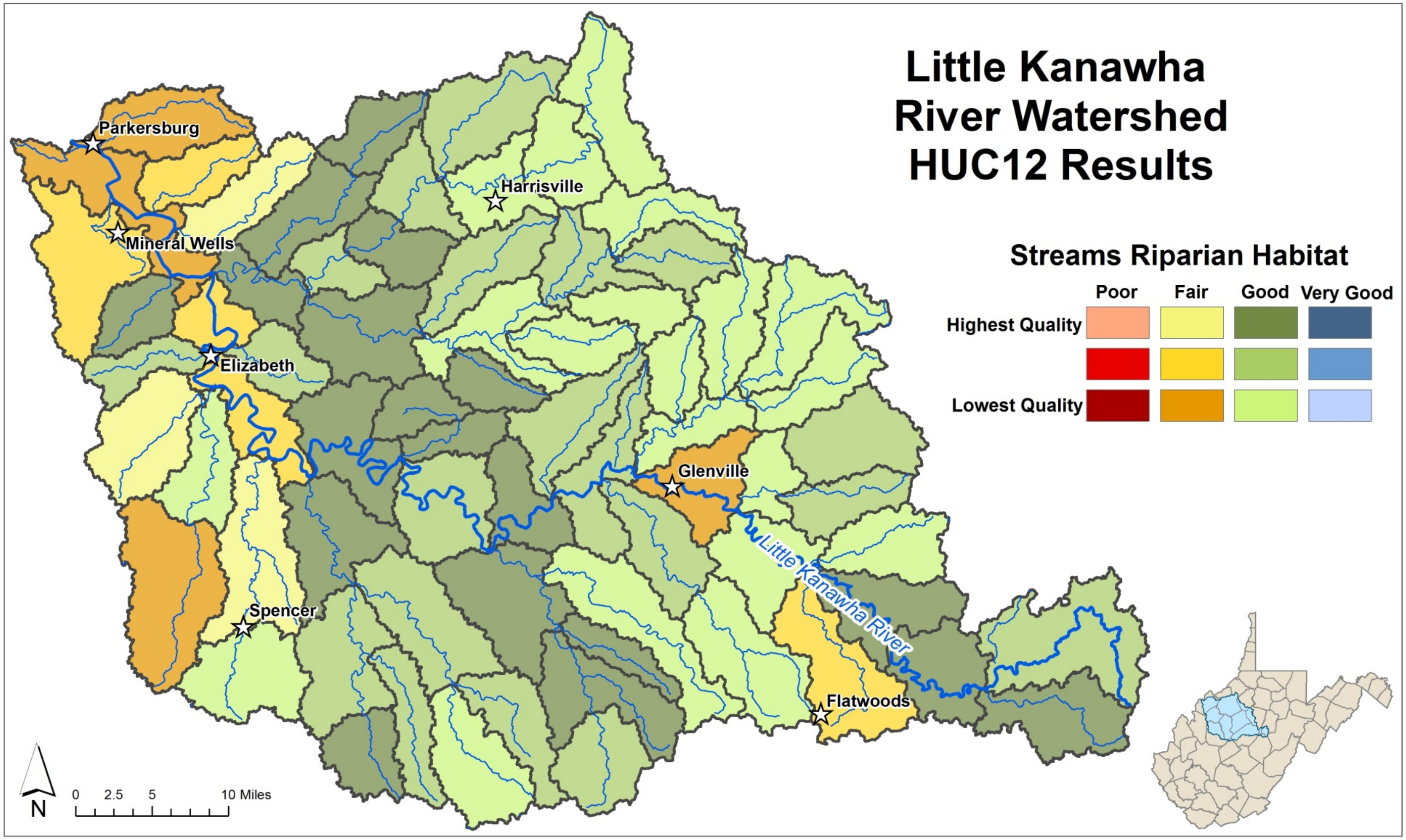


Figure 21a. Streams Riparian Habitat Index Results – HUC12 Level

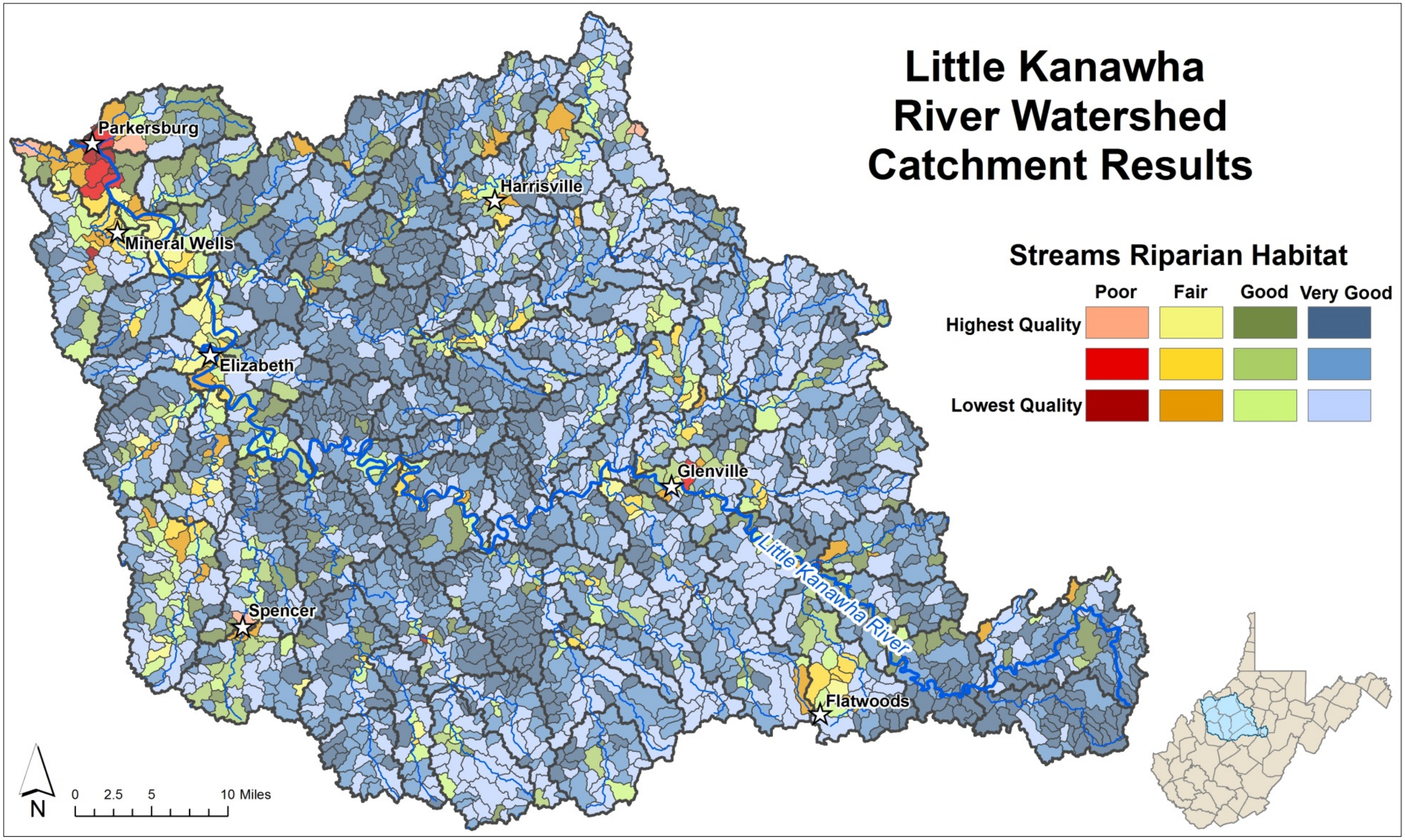


Figure 21b. Streams Riparian Habitat Index Results – Catchment Level4.1.2 Wetlands

### 4.1.2 Wetlands

As previously stated, the wetlands NWI dataset was compiled over many years and published almost two decades ago, based on data from the 1970s and 1980s. Therefore, it is likely that wetlands locations and sizes have changed, some wetlands may no longer exist, or some wetlands may have been drained or converted to other land uses since they were mapped. New wetlands may also have been constructed or developed over time. Additionally, though most Wetlands metrics rely on data derived using existing wetland buffers or wetland catchments, the Wetlands Hydrology (WHY) includes two metrics that do not depend on the current existence of wetlands: hydric soils and floodplain area. These metrics represent the potential for wetland hydrology and the possible historic presence of wetlands that have been drained, and therefore a potential for wetland restoration activities exists. All planning units have values for the WHY index, but planning units that contain no NWI wetlands include null values for the WWQ, WBD and WWH indices. This can affect the Wetlands Overall results, as planning units without mapped wetlands but with hydric soils will automatically receive a Fair score due to the presence of wetlands hydrology, indicating that the potential for wetland restoration exists.

The Little Kanawha watershed has very few wetlands overall, with about 24% of the HUC12s and about 91% of the catchments having no mapped wetlands. Therefore, results at the HUC12 level should be interpreted with caution, as many HUC12s contain only one or just a few mapped wetlands. This is the case with the Beech Fork HUC12, the only HUC12 to receive a Very Good score, but has only one mapped wetland. Many of the Fair scores at the HUC12 level in the Overall results do not have mapped wetlands; their scores are based on the Wetlands Hydrology (WHY) index and the potential for wetland hydrology. Otherwise, the Little Kanawha had mostly Good scores for Overall Wetlands results, with concentrations of the relatively higher quality Good HUC12s in the northern and southern portions of the western half of the watershed (Figure 22a). The catchment level results had many Fair scores, largely due to the lack of mapped wetlands, indicating the potential for wetland restoration in these areas (Figure 22b).

Wetlands Water Quality (WWQ) results show the same trends as the Wetlands Overall results, with slightly lower quality overall. The Beech Fork HUC12 scored Very Good, as the wetland catchment for the mapped wetland within Beech Fork has 100% natural cover and no roads, though it does have some oil and gas wells. The Good and Fair HUC12s generally have more development and roads in the wetland catchment area, and occasionally more grazing and agriculture, with the main difference between Good and Fair HUC12s being the percentage of natural cover. Seventeen HUC12s have no mapped wetlands and did not receive a score for this index (Figure 23a). The catchment level WWQ results are similar to the HUC12 results, with Fair catchments largely in the vicinity of Parkersburg and smaller towns, with their associated development and infrastructure (Figure 23b). The Very Good catchments have 100% natural cover in the wetland catchment area, and would be potential candidates for protection activities.

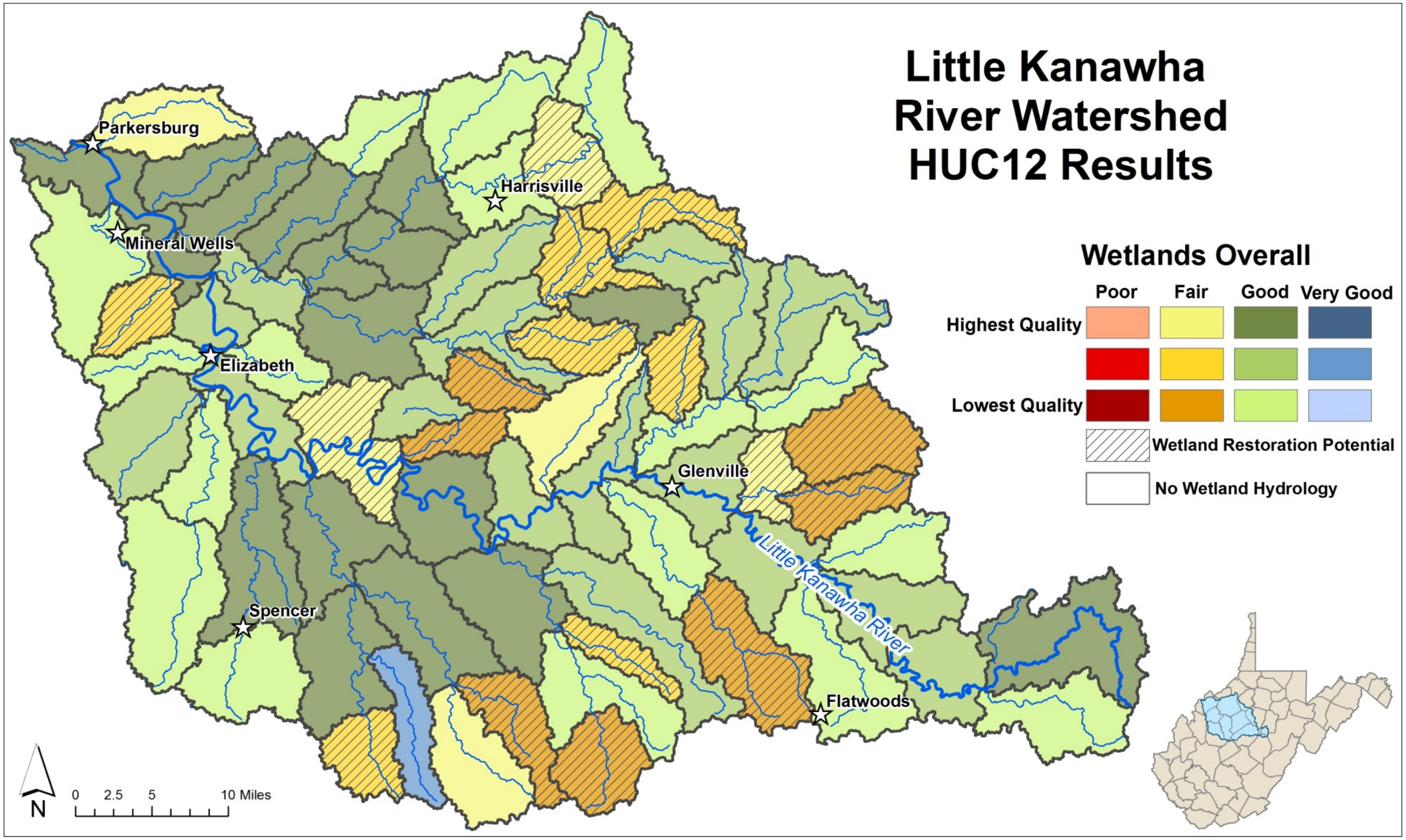


Figure 22a. Wetlands Overall Results – HUC12 Level

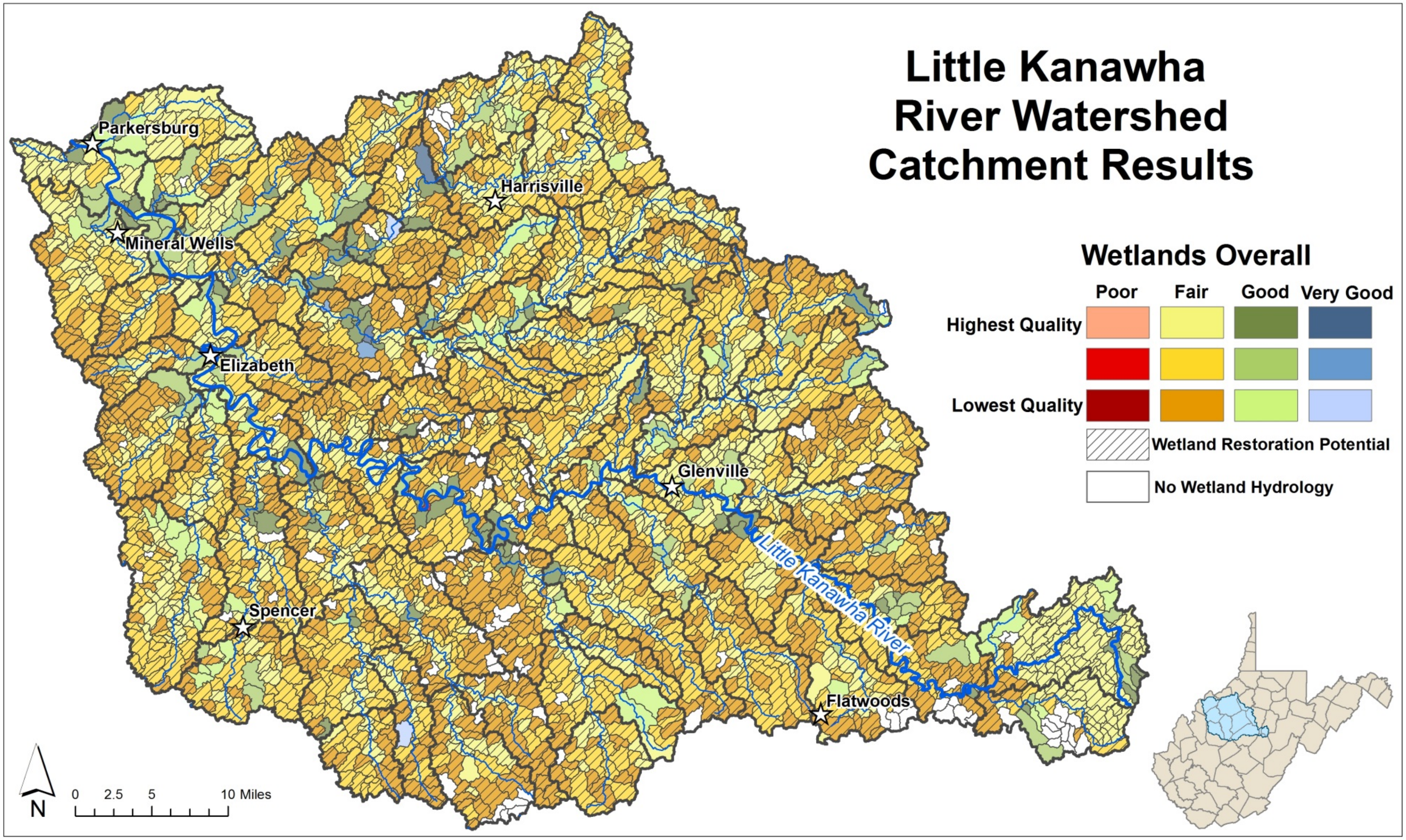


Figure 22b. Wetlands Overall Results – Catchment Level

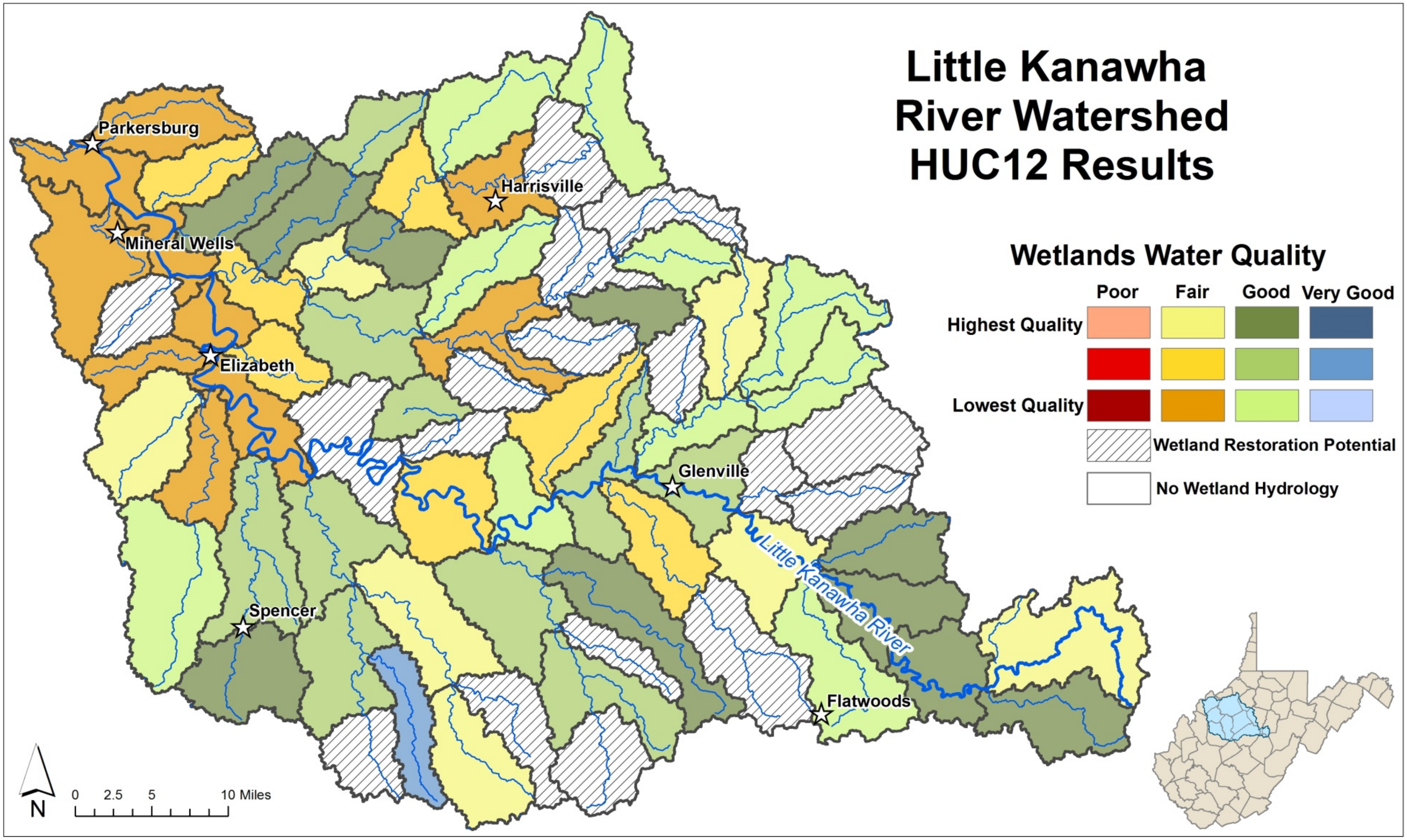


Figure 23a. Wetlands Water Quality Index Results – HUC12 Level

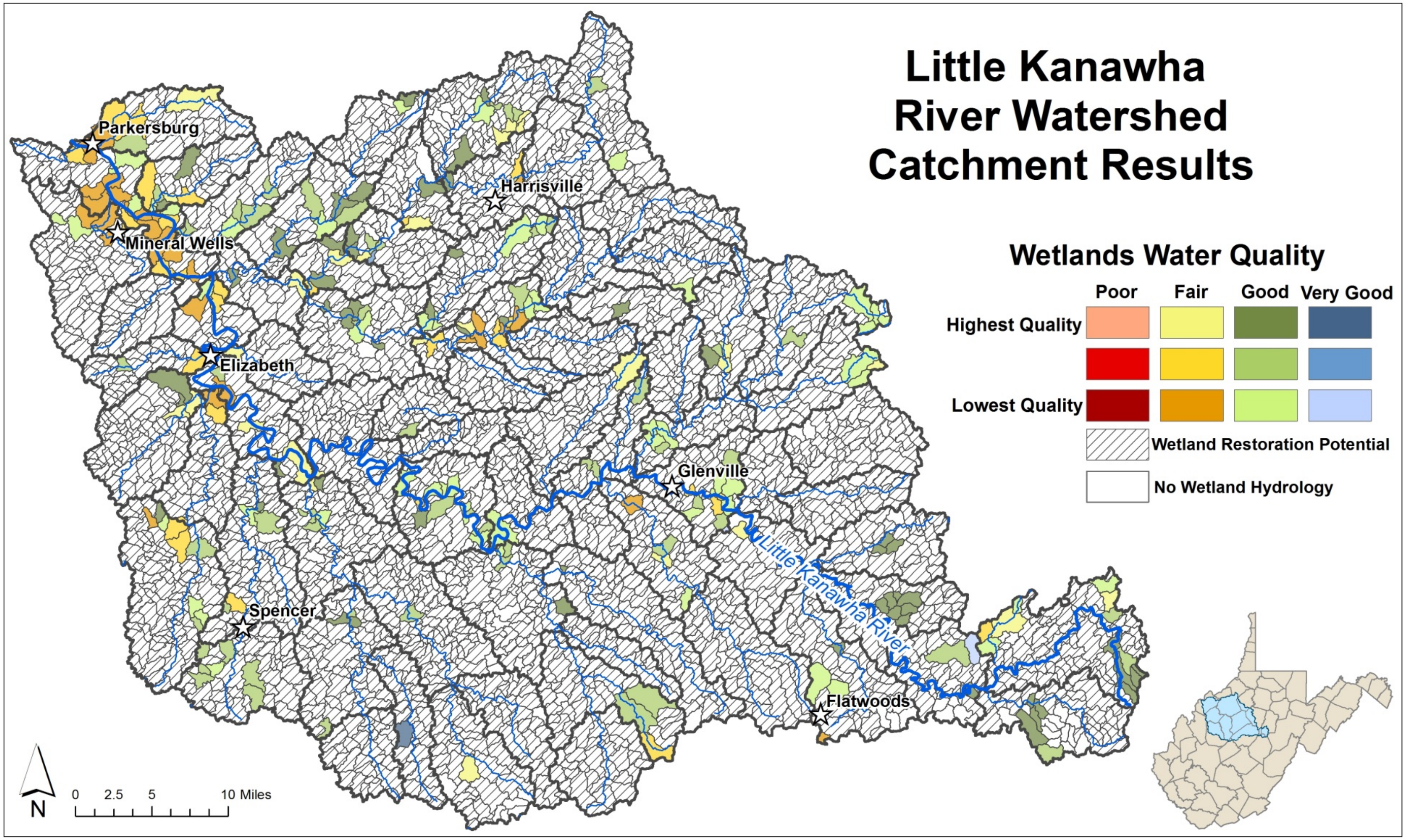


Figure 23b. Wetlands Water Quality Index Results – Catchment Level

There is a general lack of variability in the Wetlands Hydrology (WHY) index results, which is expected (Figures 24a and 24b). This index is designed primarily to identify areas with extensive and well-connected existing wetlands, or areas that have no mapped wetlands but contain hydric soils and therefore have the potential to restore lost wetlands. All of the WHY metrics are presence/absence, meaning the metric will receive a Good if it has a value, and a Fair if it does not. The Little Kanawha watershed has hydric soils and floodplain area in every HUC12, therefore all HUC12s received a Good WHY score. The catchment level results are similar, with only a few catchments without wetlands hydrology. The few Fair WHY results at the catchment level are mostly planning units without floodplain area but some mapped wetlands.

The Wetlands Biodiversity (WBD) index only has four metrics, three of which are presence/absence. Fair HUC12s therefore either have fewer terrestrial habitat types, or recorded non-native invasive species occurrences than higher-scoring HUC12s (Figure 25a). The Very Good and Good HUC12s usually include calcareous bedrock, which provides the lift into the higher quality categories. The same situation applies to the catchment level results (Figure 25b). As mentioned previously, it is recommended that individual metrics within the WBD index are evaluated closely to determine which metric(s) most influenced the index score.

The Wetlands Wetland Habitat (WWH) index results are generally lower than other Wetlands indices, with several more Fair planning units at the HUC12 level (Figure 26a). The WWH index contains metrics based on the 50-meter wetland buffer around each mapped wetland, so factors like increased non-natural land use and increased infrastructure will bring down a score. Additionally, the WWH index includes two critical metrics, development and surface mining in the wetland buffer. While the Little Kanawha HUC8 has minimal mining, all of the Fair HUC12s also scored a Fair for development in the wetland buffer. The Beech Fork HUC12 emerged again as the only Very Good HUC12, again because of 100% natural cover in the wetland buffer. The same trends continue at the catchment level, with several Very Good catchments due to the high percentages of natural cover within the wetland buffer (Figure 26b).

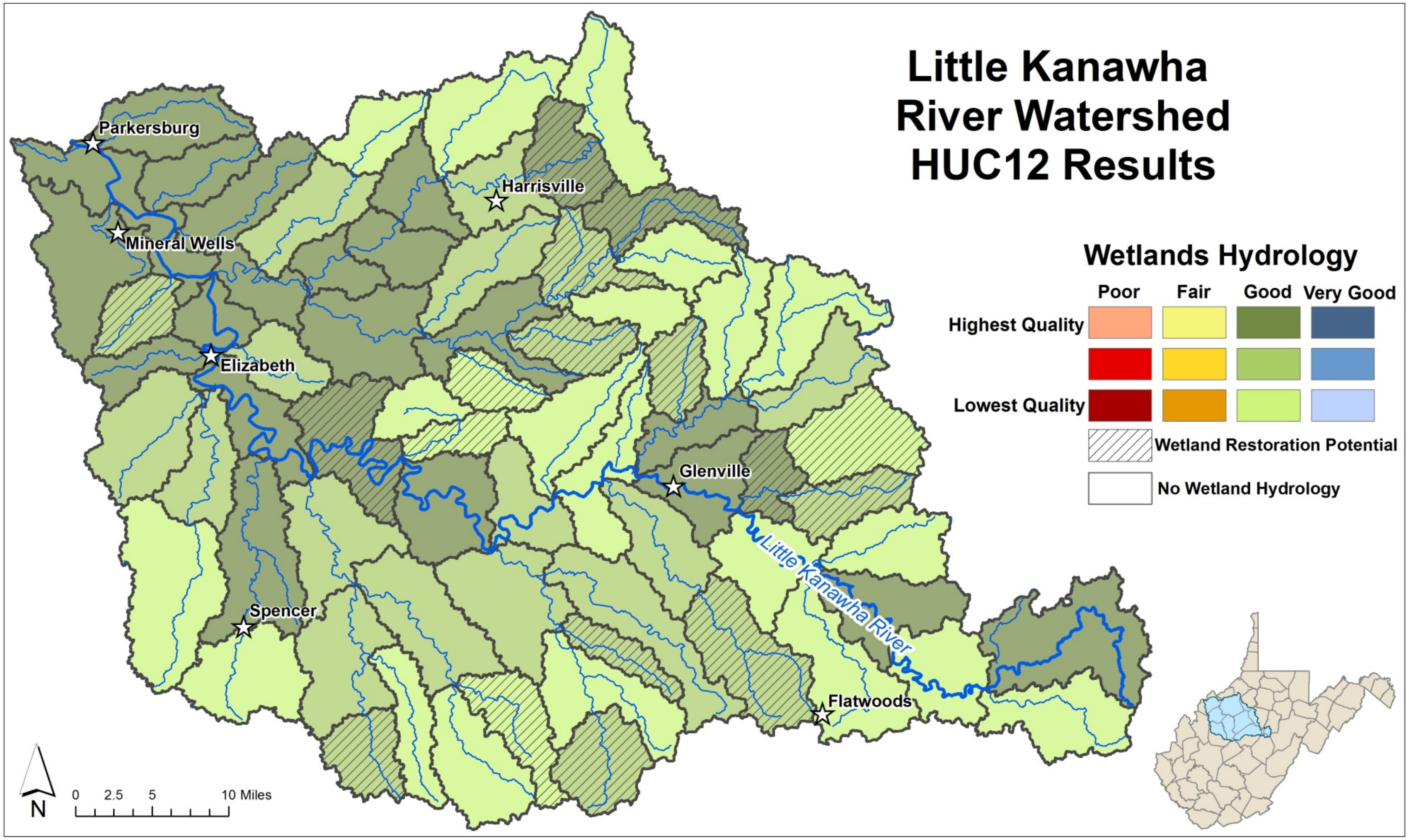


Figure 24a. Wetlands Hydrology Index Results – HUC12 Level

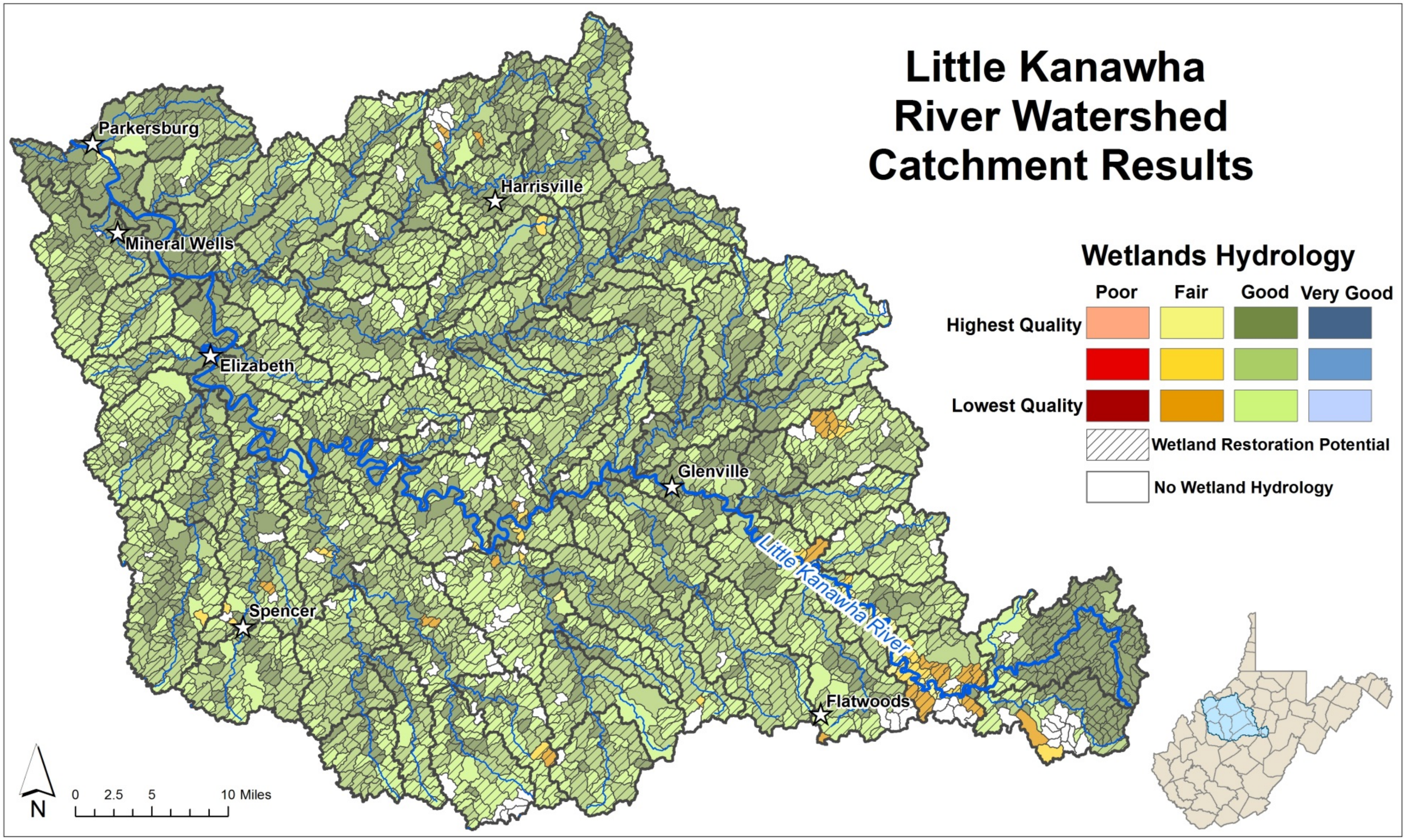


Figure 24b. Wetlands Hydrology Index Results – Catchment Level

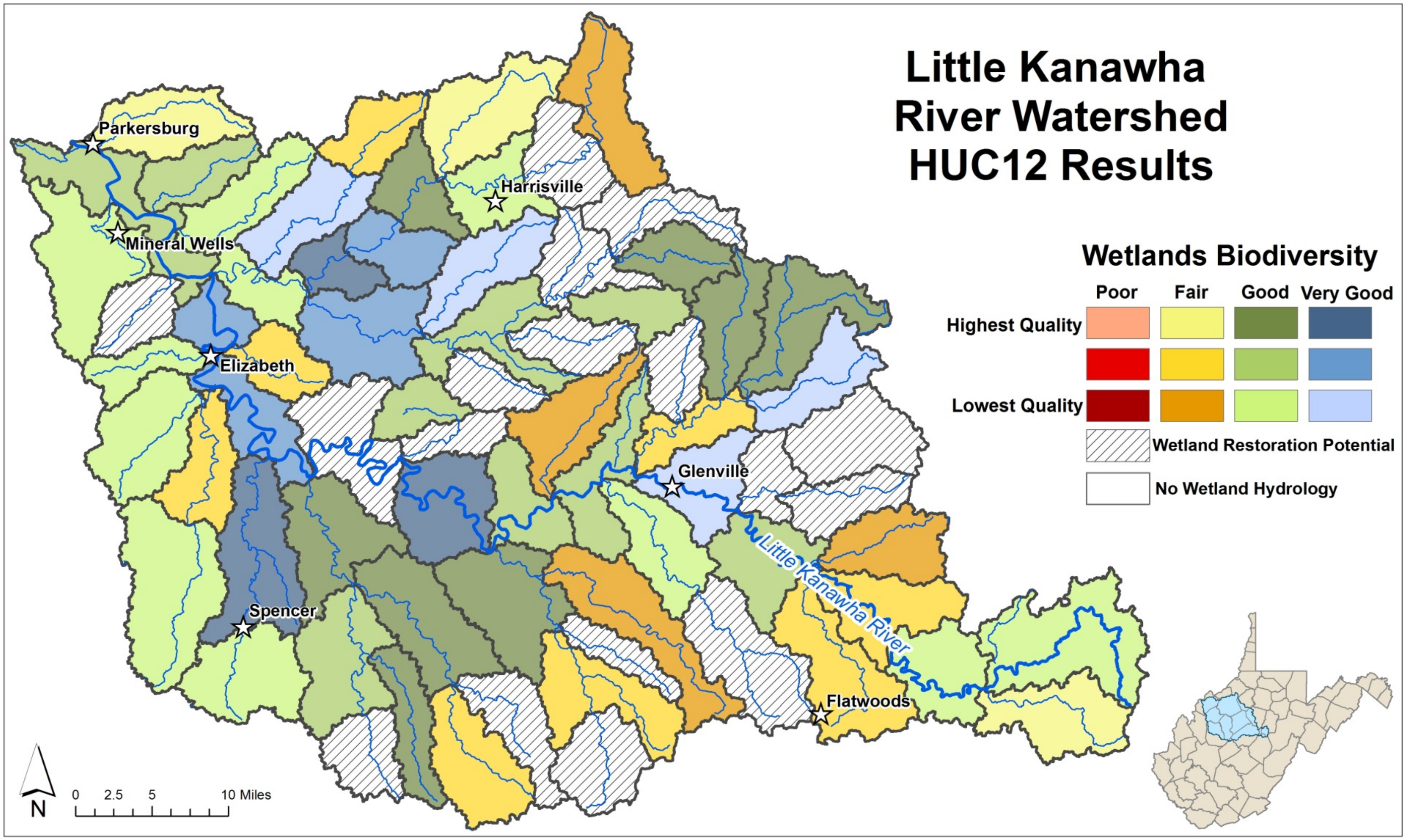


Figure 25a. Wetlands Biodiversity Index Results – HUC12 Level

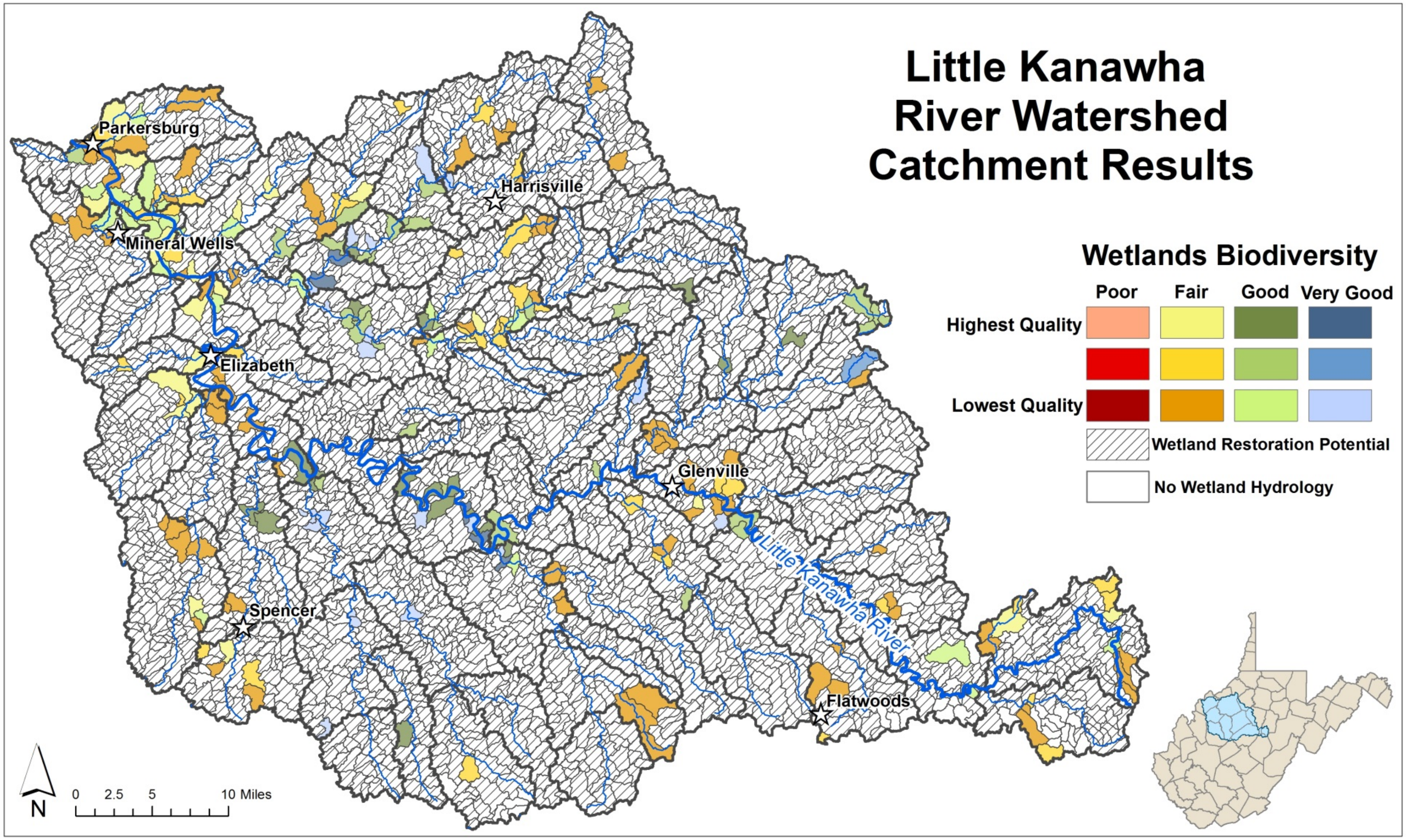


Figure 25b. Wetlands Biodiversity Index Results – Catchment Level

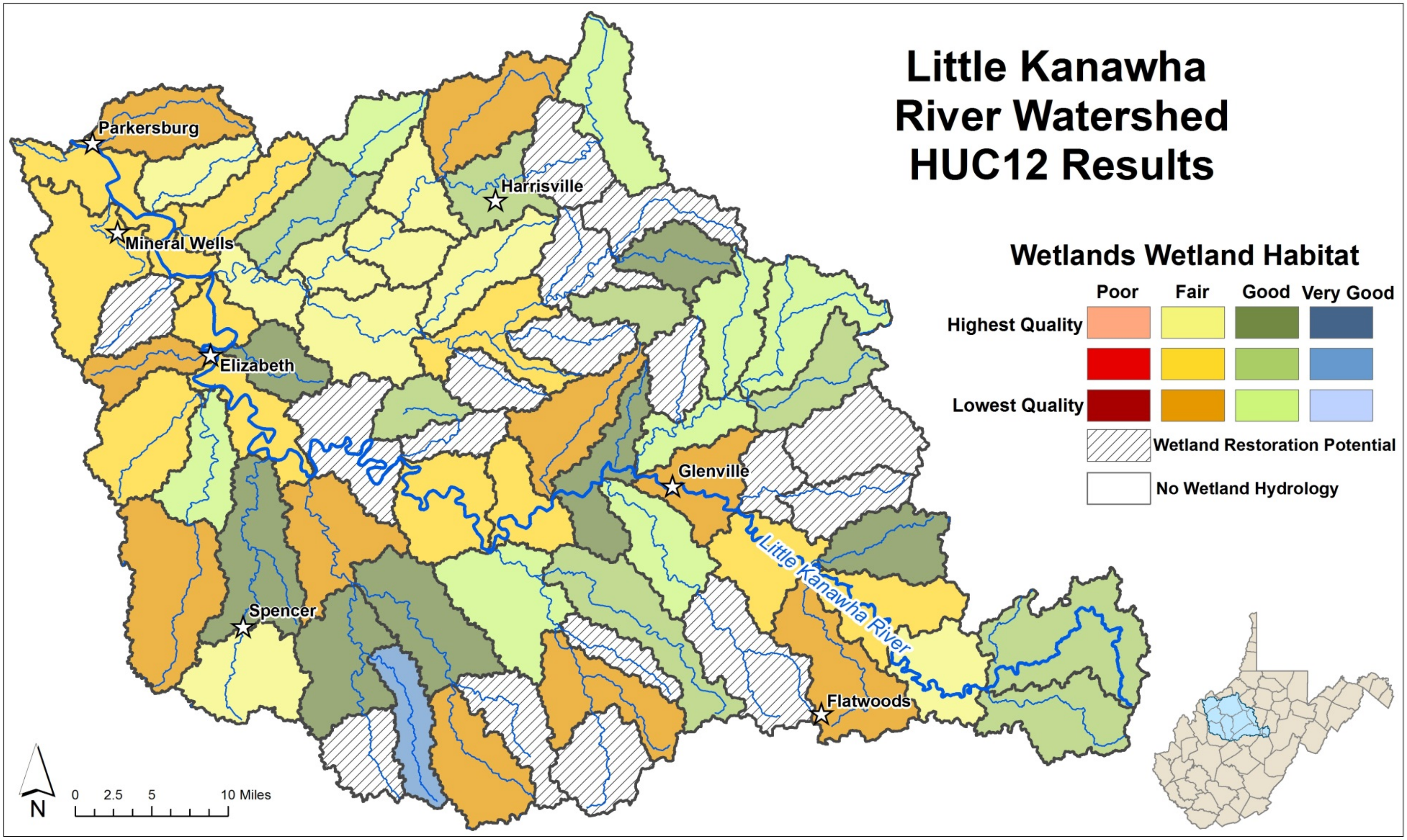


Figure 26a. Wetlands Wetland Habitat Index Results – HUC12 Level

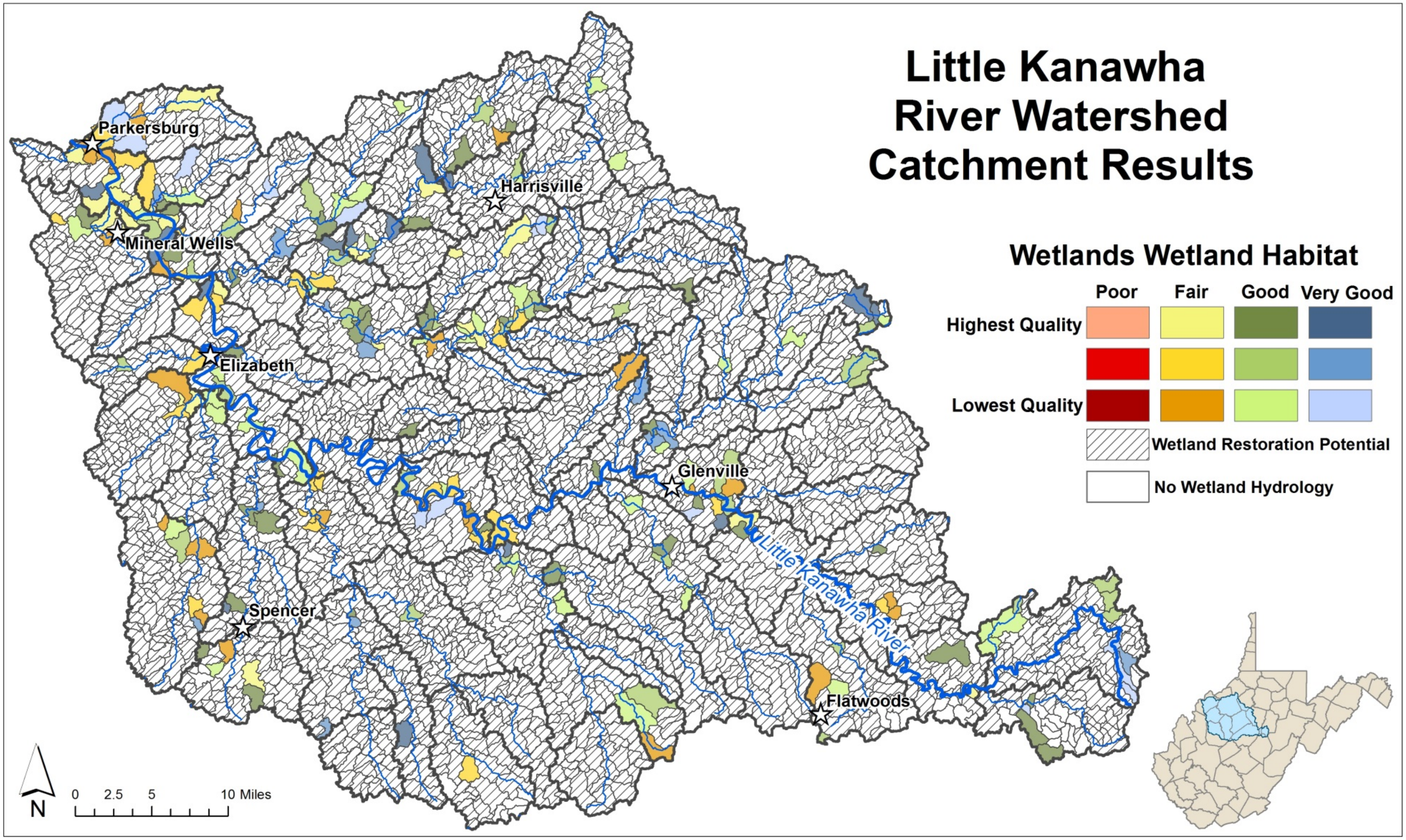


Figure 26b. Wetlands Wetland Habitat Index Results – Catchment Level

### 4.1.3 Uplands

The Uplands Overall results for the Little Kanawha watershed are generally lower than the Streams and Wetlands, though the same patterns emerge, with lowest quality around the Parkersburg urban area and other developed areas like Harrisville and Glenville, and highest quality in the south and southeast (Figure 27a). Some of the results, particularly at the catchment level, are caused by infrastructure such as major highways dissecting the watershed. Development, a critical metric in two uplands indices, often accompanies such features (Figure 27b).

The Uplands Habitat Connectivity (UHC) index results are very similar to the Overall model results, with many of the same patterns (Figures 28a and 28b). The UHC index is largely driven by the presence of intact forests and lack of anthropogenic stressors, so the higher scoring areas are generally in the higher elevations in the headwaters regions and have large forest patches and little development or industrial activity. Development is a critical metric in the UHC index, so all of the Poor and many Fair planning units generally have high percentages of developed land use. Many of the Good catchments have no development and high local integrity scores. The Very Good catchments have high scores in most metrics, particularly the average size of intersecting forest patch, indicating that they may have unfragmented forests with a high percentage of natural cover, and making these areas potential candidates for protection activities.

The Uplands Habitat Quality (UHQ) index results are very similar to the UHC results, with a general slight increase in quality (Figures 29a and 29b). Development is also a critical metric in this index, so Fair and Poor scores for planning are often driven by the development metric. Good planning units generally have Good scores in heterogeneity, natural cover, and development, indicating that there is minimal anthropogenic disturbance.  Very Good catchments often had Very Good natural cover scores, with most of them averaging about 99% natural cover.

The Uplands Biodiversity (UBD) index results (Figures 30a and 30b) generally agree with the trends seen in the Streams and Wetlands Biodiversity indices, though the UBD results include a few more concentrated areas of Fair and Poor catchments. This is likely due to an additional metric in the UBD index, the percent predicted tree basal area loss to pests and pathogens. The isolated pockets of Fair and Poor catchments are in areas with the highest predicted potential for tree basal area loss. Otherwise, most of the watershed’s planning units scored Very Good or Good, at both scales of analysis

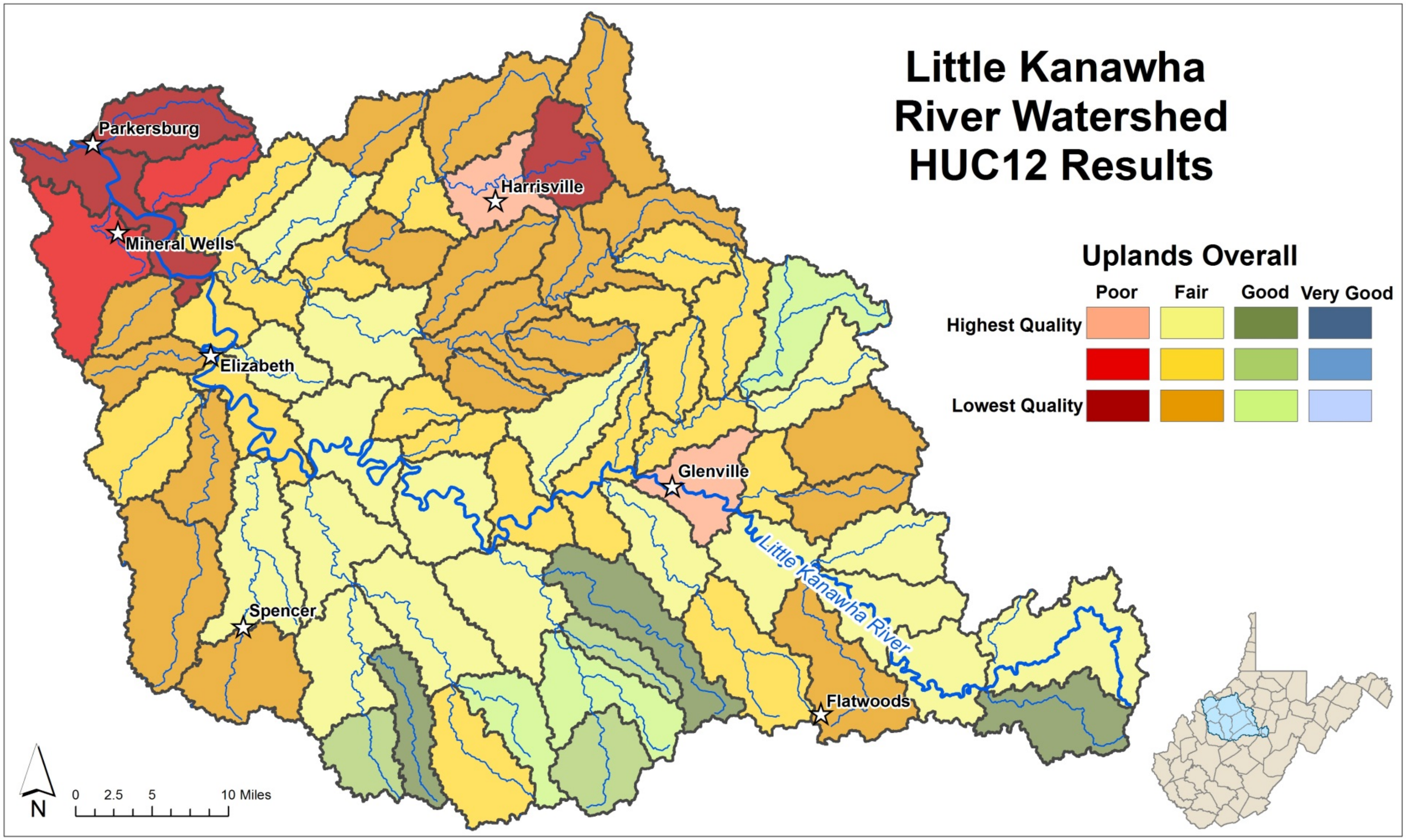


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Figure 27a. Uplands Overall Results – HUC12 Level

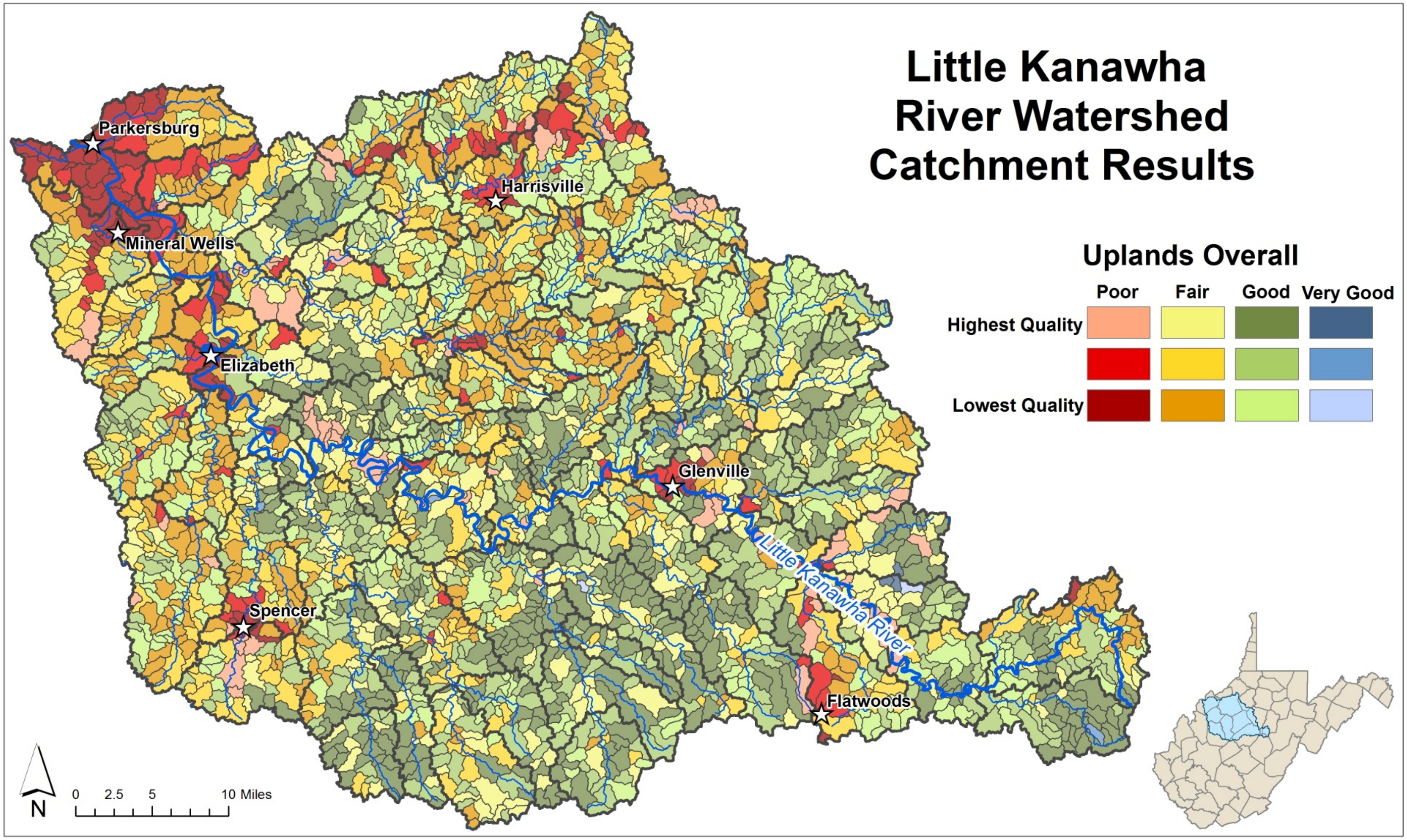


Figure 27b. Uplands Overall Results – Catchment Level

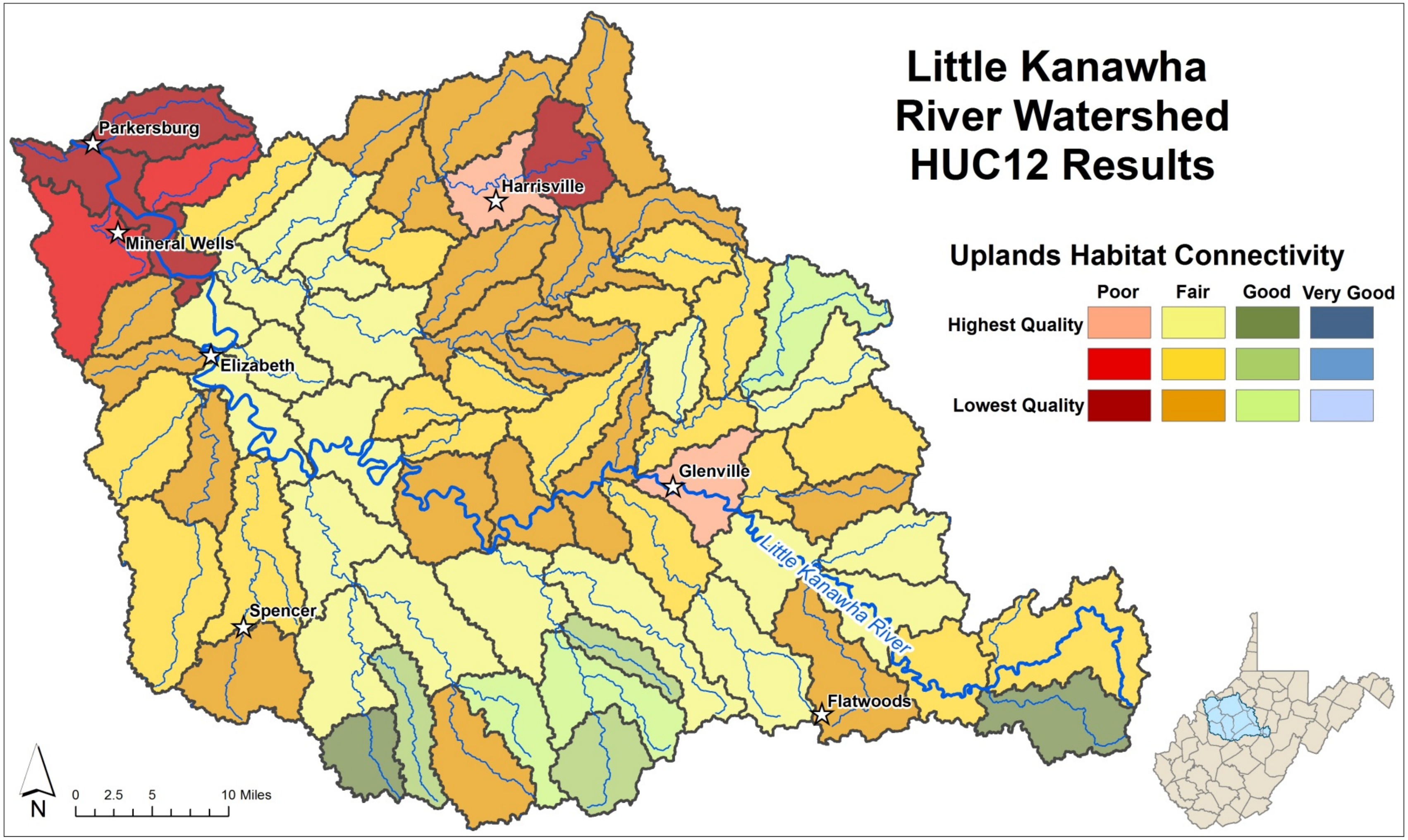


Figure 28a. Uplands Habitat Connectivity Index Results – HUC12 Level

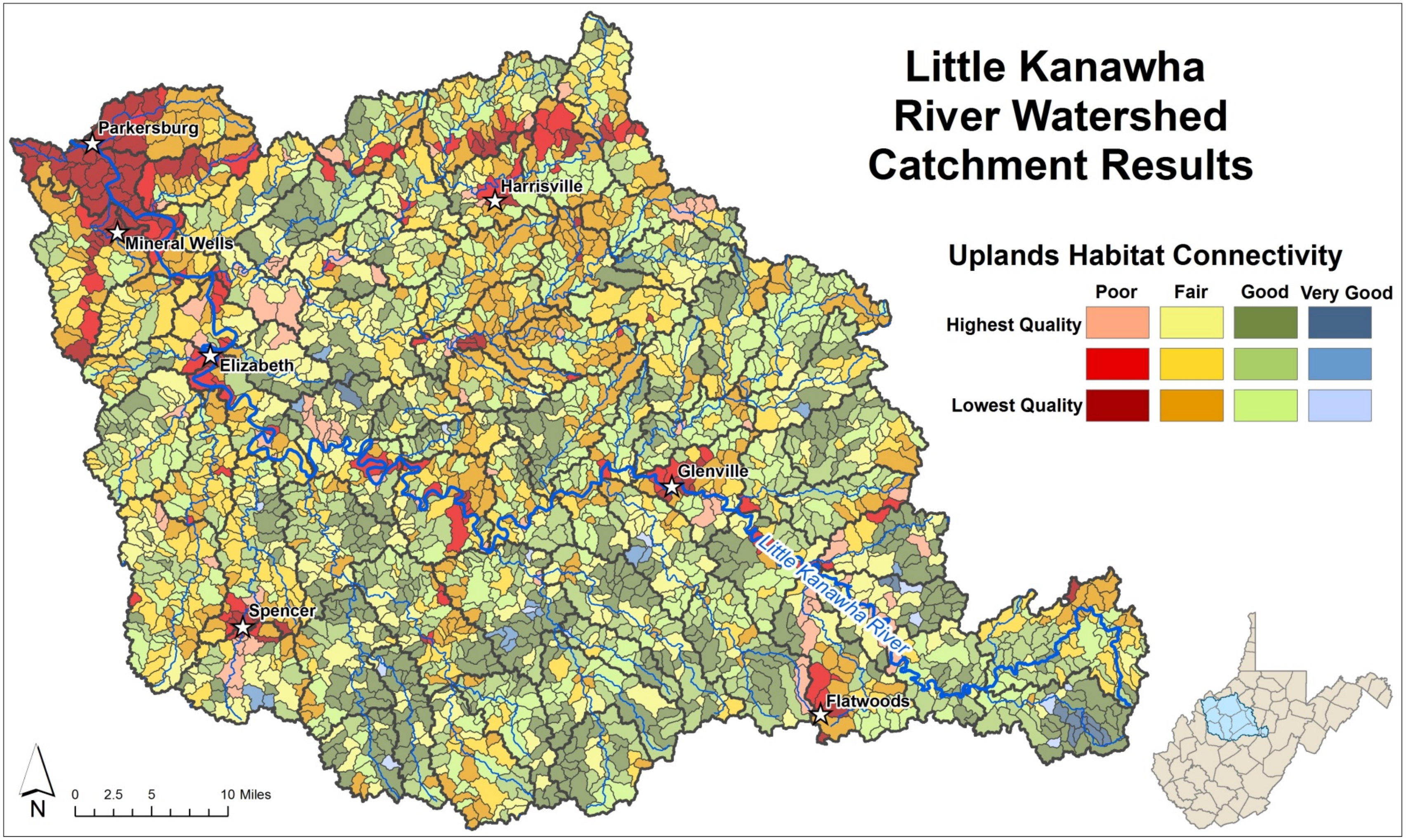


Figure 28b. Uplands Habitat Connectivity Index Results – Catchment Level

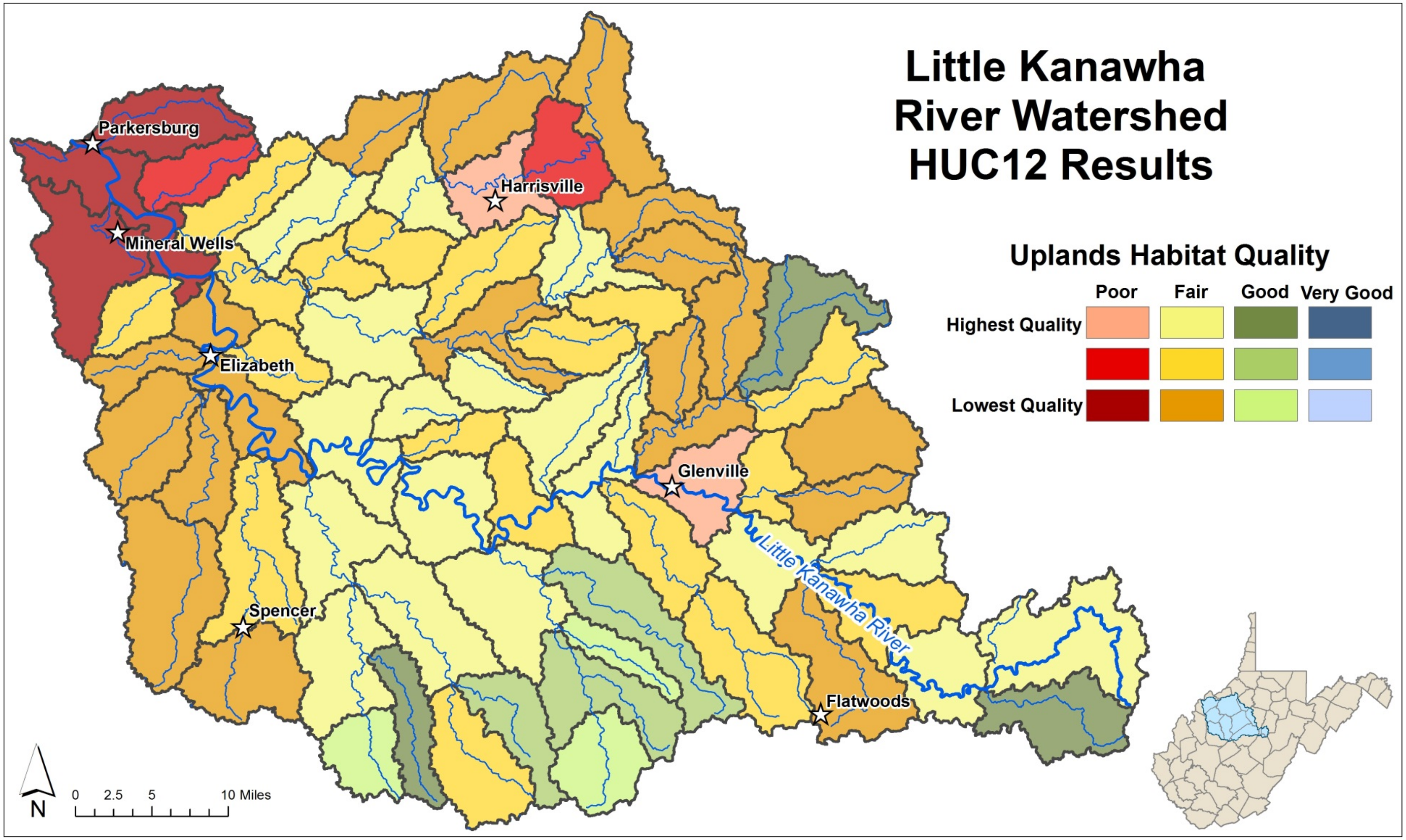


Figure 29a. Uplands Habitat Quality Index Results – HUC12 Level

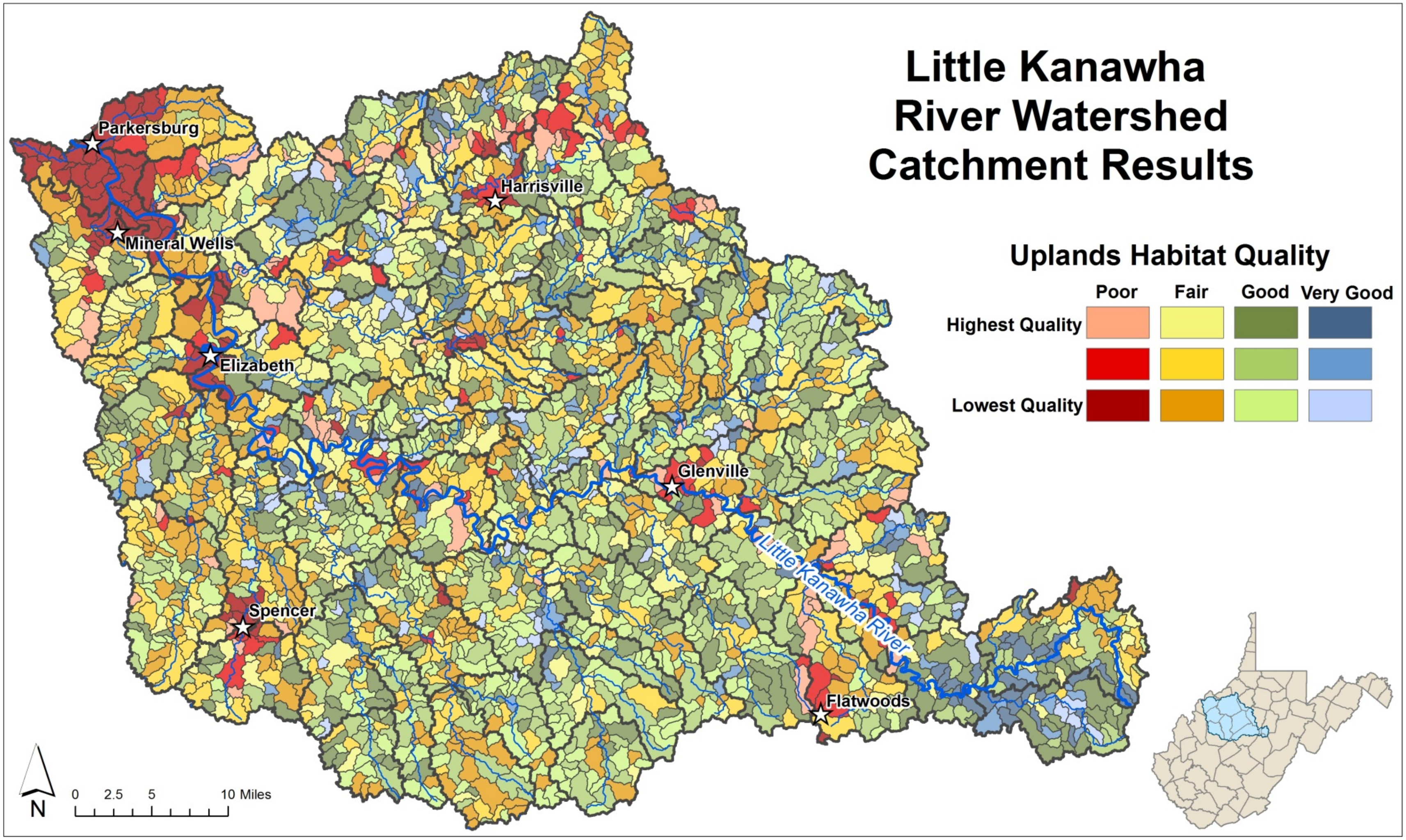


Figure 29b. Uplands Habitat Quality Index Results – Catchment Level

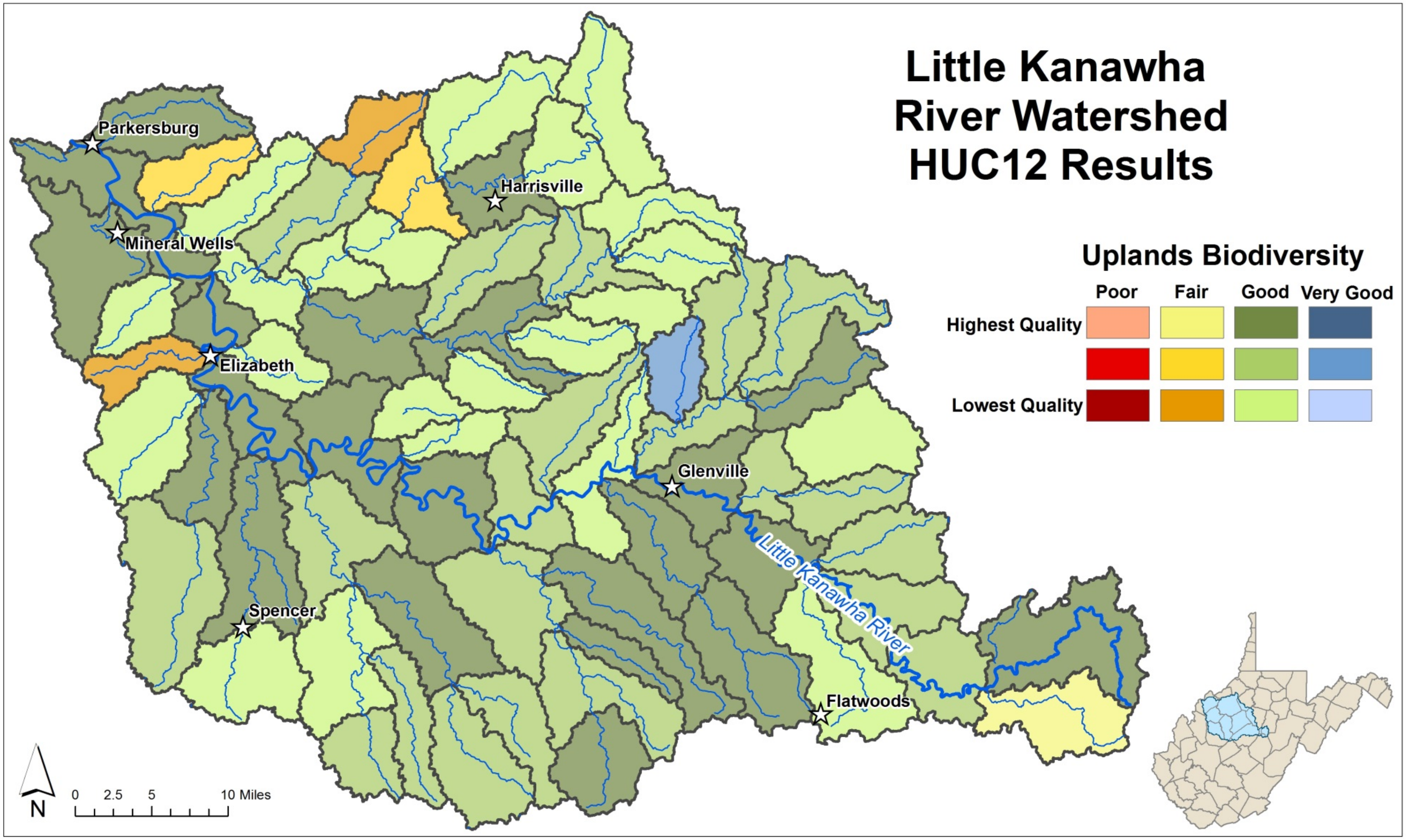


Figure 30a. Uplands Biodiversity Index Results – HUC12 Level

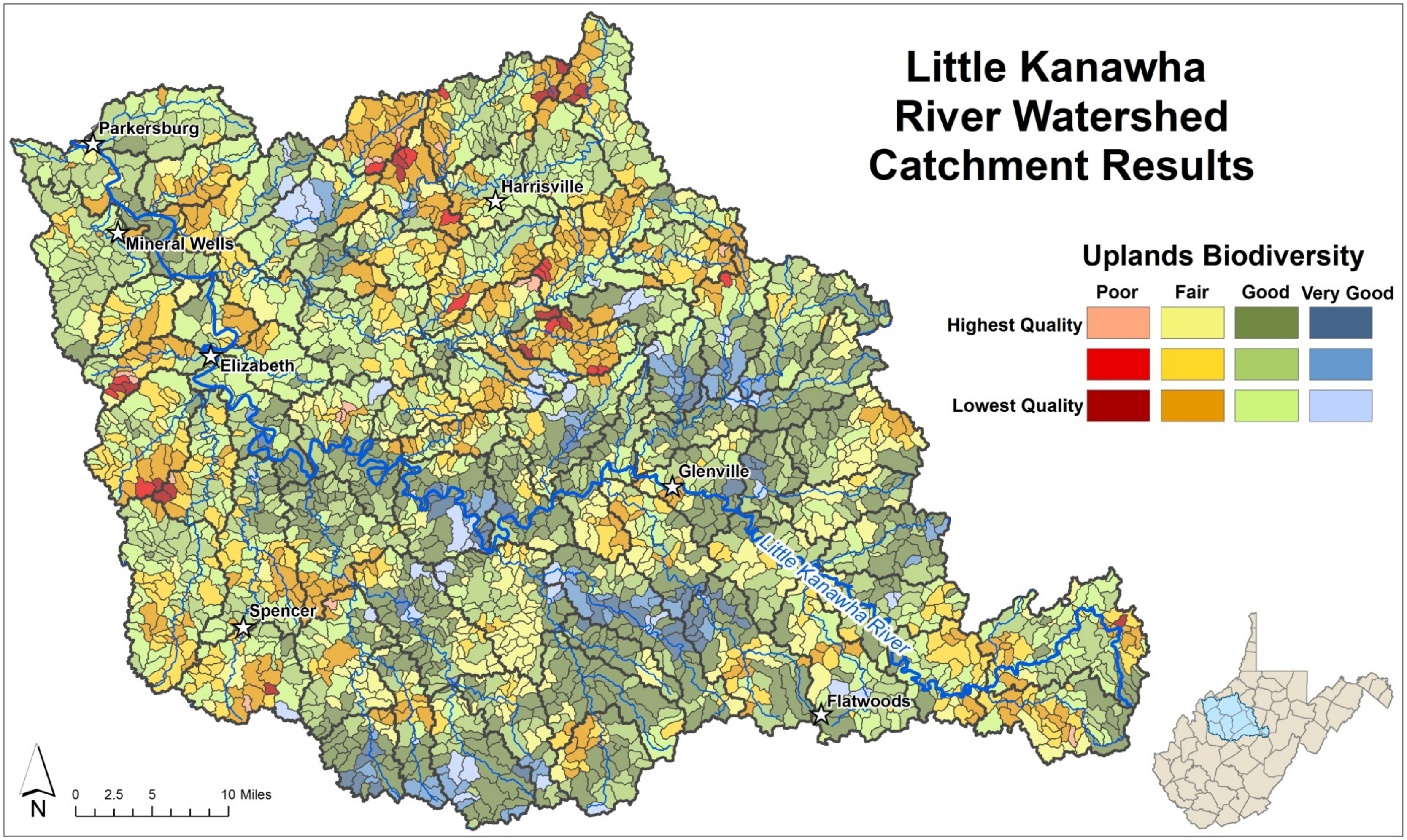


Figure 30b. Uplands Biodiversity Index Results – Catchment Level

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## 4.2 Consolidated Analysis Results and Discussion

The Consolidated Analysis Overall results for the Little Kanawha watershed indicate varying levels of future threat dispersed across the watershed (Figure 31). A general east-west trend is apparent across the watershed, with lower threat levels in the west and increased threat levels in the east. This trend may be misleading however, since there is a lack of potential development data for any developed areas of the watershed, including the Parkersburg area.

The Consolidated Analysis Energy results for the Little Kanawha watershed consider only three metrics (due to data limitations or lack of a particular threat, such as mining, in the watershed): potential Marcellus shale gas well development, wind energy development potential, and geothermal potential. All of these threats are highest in the east and decrease toward the west, due to topography and geology (Figure 32). It is likely that the most significant future energy threat is gas well development, which is already a significant industry in this watershed.

The Population and Development index had data available for only one metric, population projections at the county level, and is therefore not very robust. In general, the population projections for counties in the Little Kanawha watershed indicate expected growth only in the far eastern arm, with a projected population decrease by 2030 in all counties except Upshur County (increase of 3.4%) and Ritchie County (no change; Christiadi 2011).

The Climate Change index also had data limitations, with data available only for Resiliency and Regional Flow (surrogates for the predicted effects of climate change on organisms' ability to adapt as a result of climate change). These datasets are from a greater regional analysis conducted by The Nature Conservancy's Eastern Conservation Science division. Resiliency is a measure of landscape complexity and landscape permeability, while Regional Flow data more specifically identifies "larger-scale directional movements and…areas where they are likely to become concentrated, diffused, or rerouted, due to the structure of landscape" (Anderson et al. 2012). More details about the resiliency data can be found in Section 3.1.6 Consolidated Analysis. The Resiliency data has the lowest scores (indicating less resiliency to the impacts of climate change) in the northwest around the Parkersburg urban area, with pockets of high resiliency throughout the watershed and particularly in the southeast (Figure 33). The Regional Flow data shows less pronounced trends, though Parkersburg again had the higher threat scores, and many of the lowest threat areas of the watershed are in areas with the highest Resiliency scores (Figure 34).

The Little Kanawha watershed has approximately 35,500 acres of protected lands (Figure 35), with six Wildlife Management Areas (WMAs), three State Parks, one TNC preserve, one Wetlands Reserve Program (WRP) easement, and one fairly large (~2,100 acres) community park. Several overlapping priority areas occur within the Little Kanawha watershed (Figure 36). The Nature Conservancy has included several major tributaries in their aquatic portfolio and their terrestrial portfolio also highlights different areas of the watershed. Nineteen HUC12s were identified as priorities by the West Virginia Division of Forestry water quality analysis report.

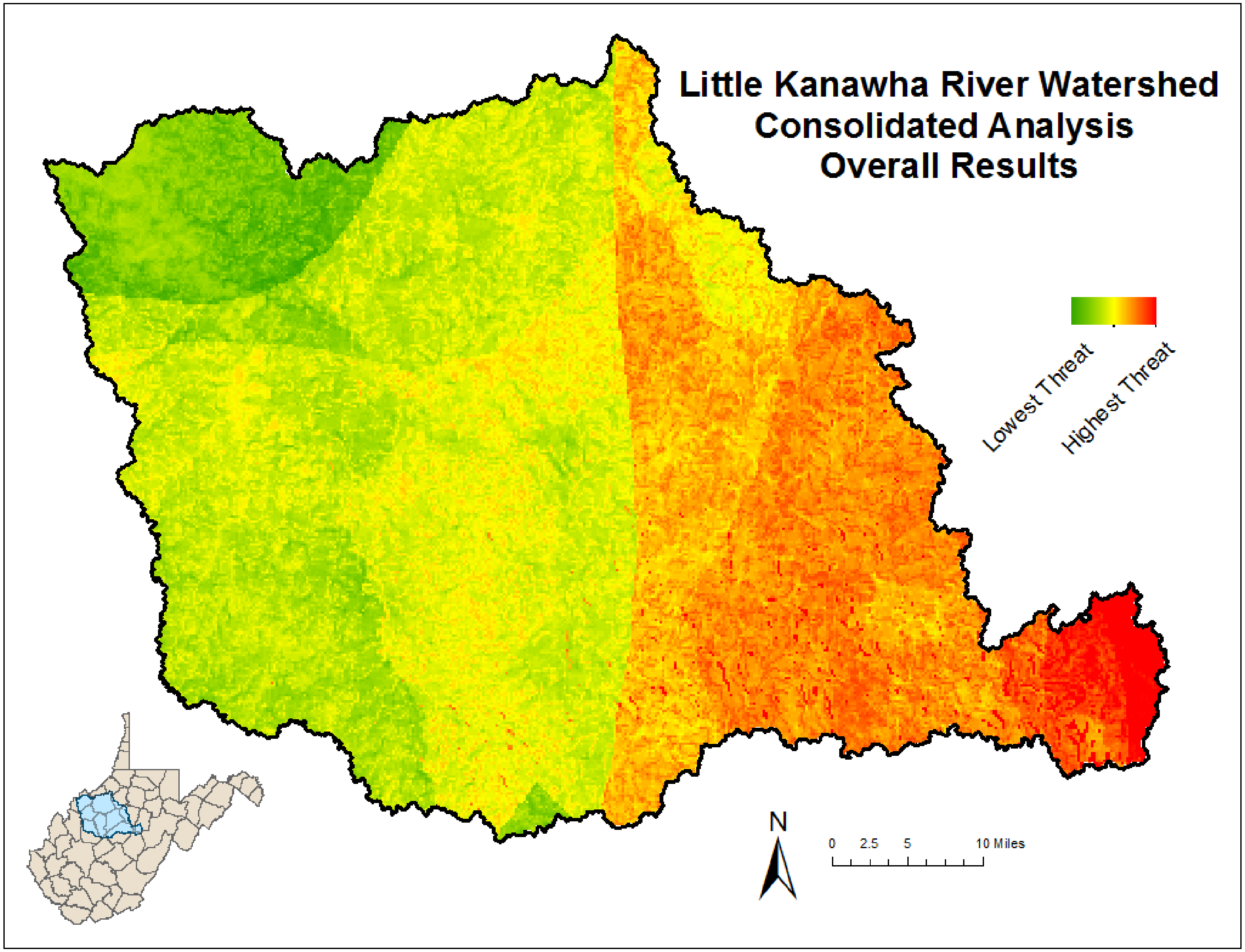


Figure 31. Consolidated Analysis Overall Results

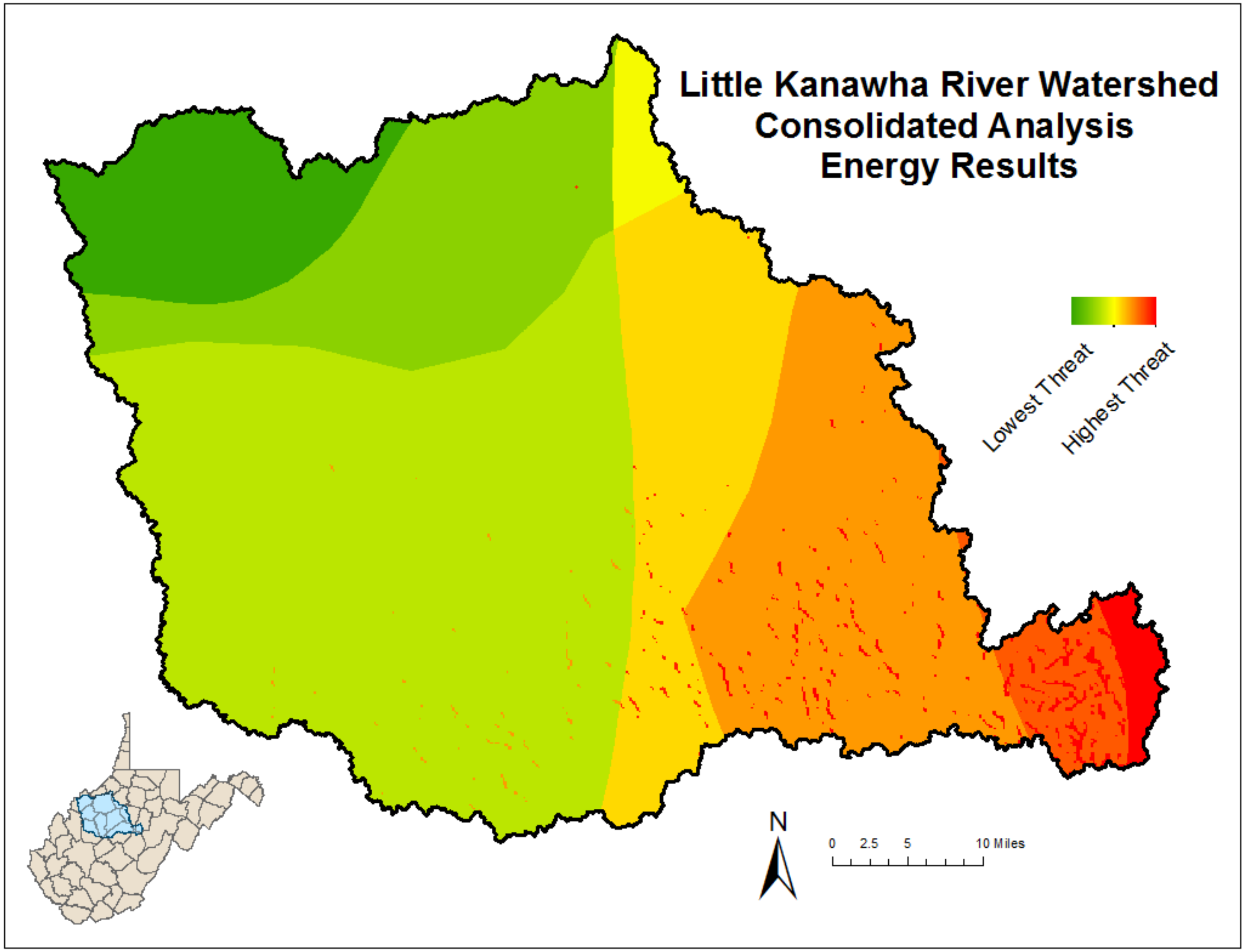


Figure 32. Consolidated Analysis Energy Results

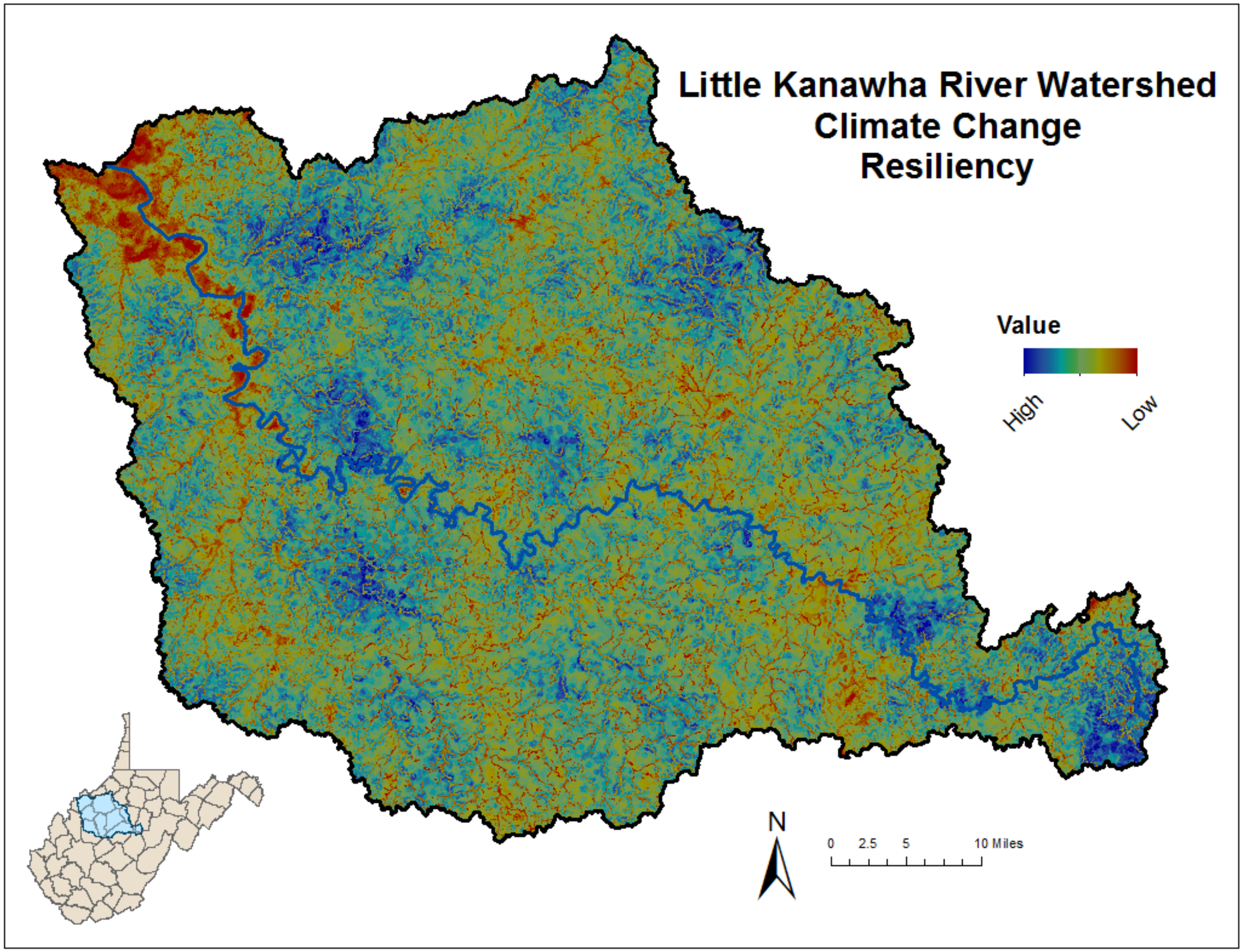


Figure 33. Consolidated Analysis Climate Change – Resiliency (TNC 2012)

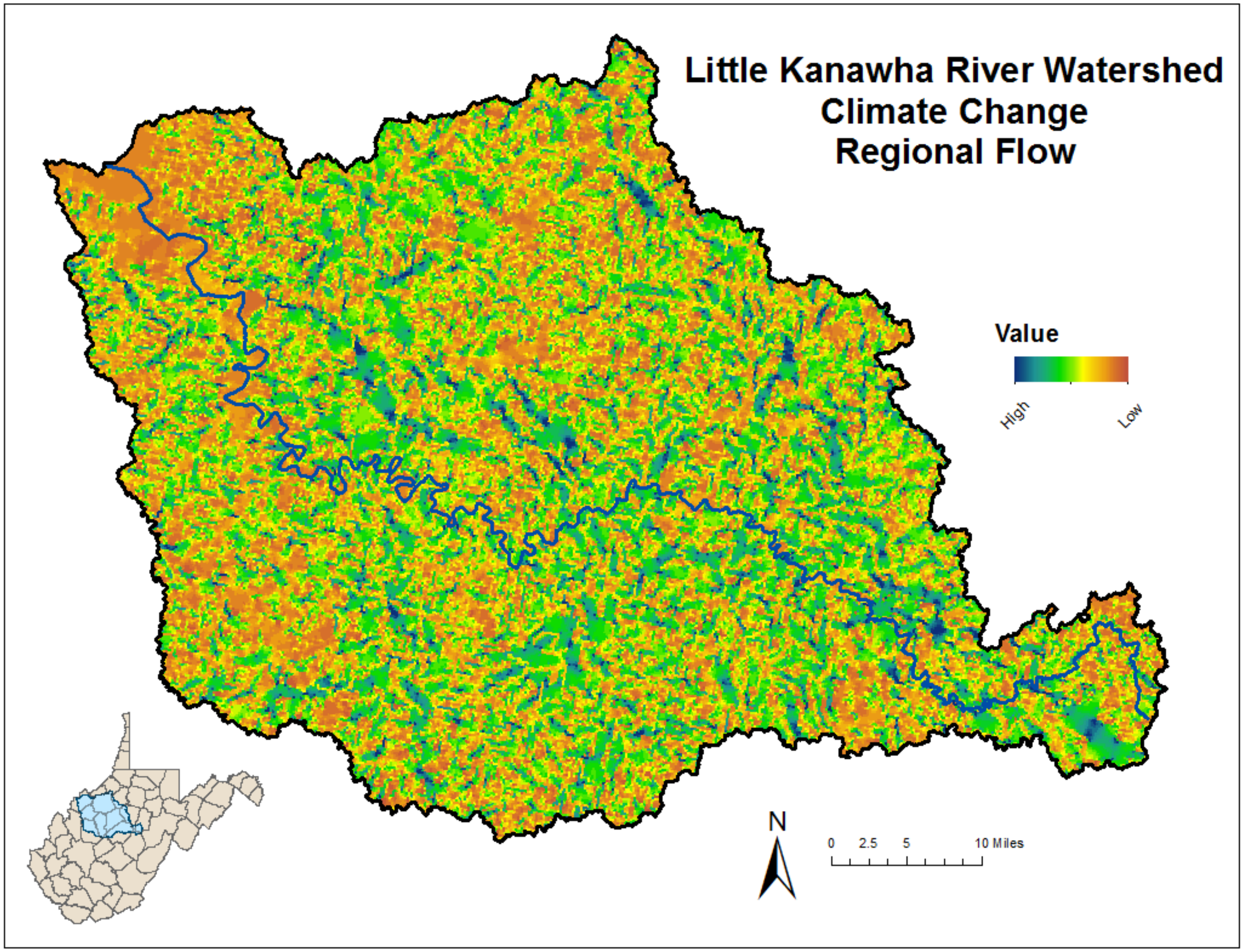


Figure 34. Consolidated Analysis Climate Change – Regional Flow (TNC 2012)

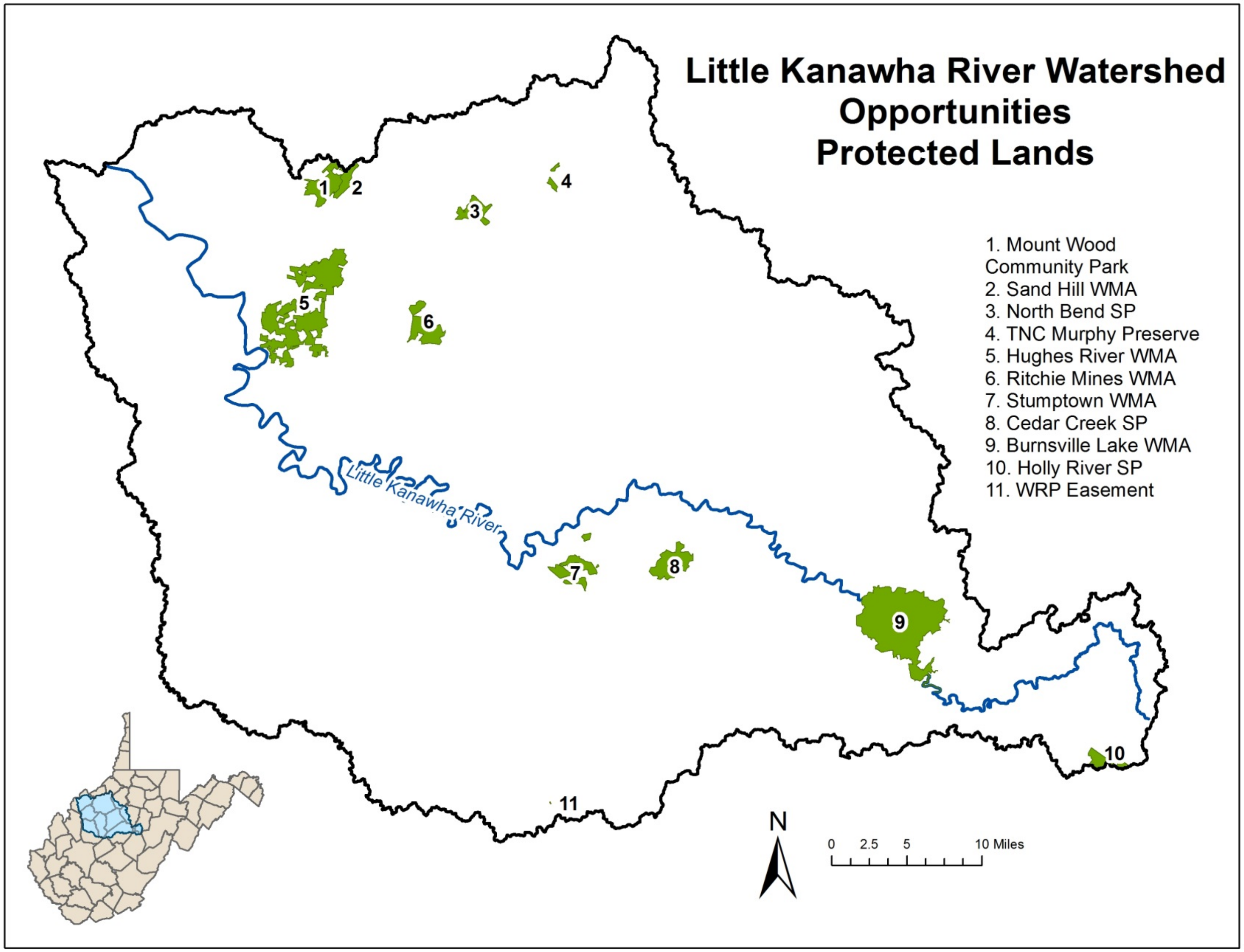


Figure 35. Little Kanawha River Watershed Opportunities – Protected Lands

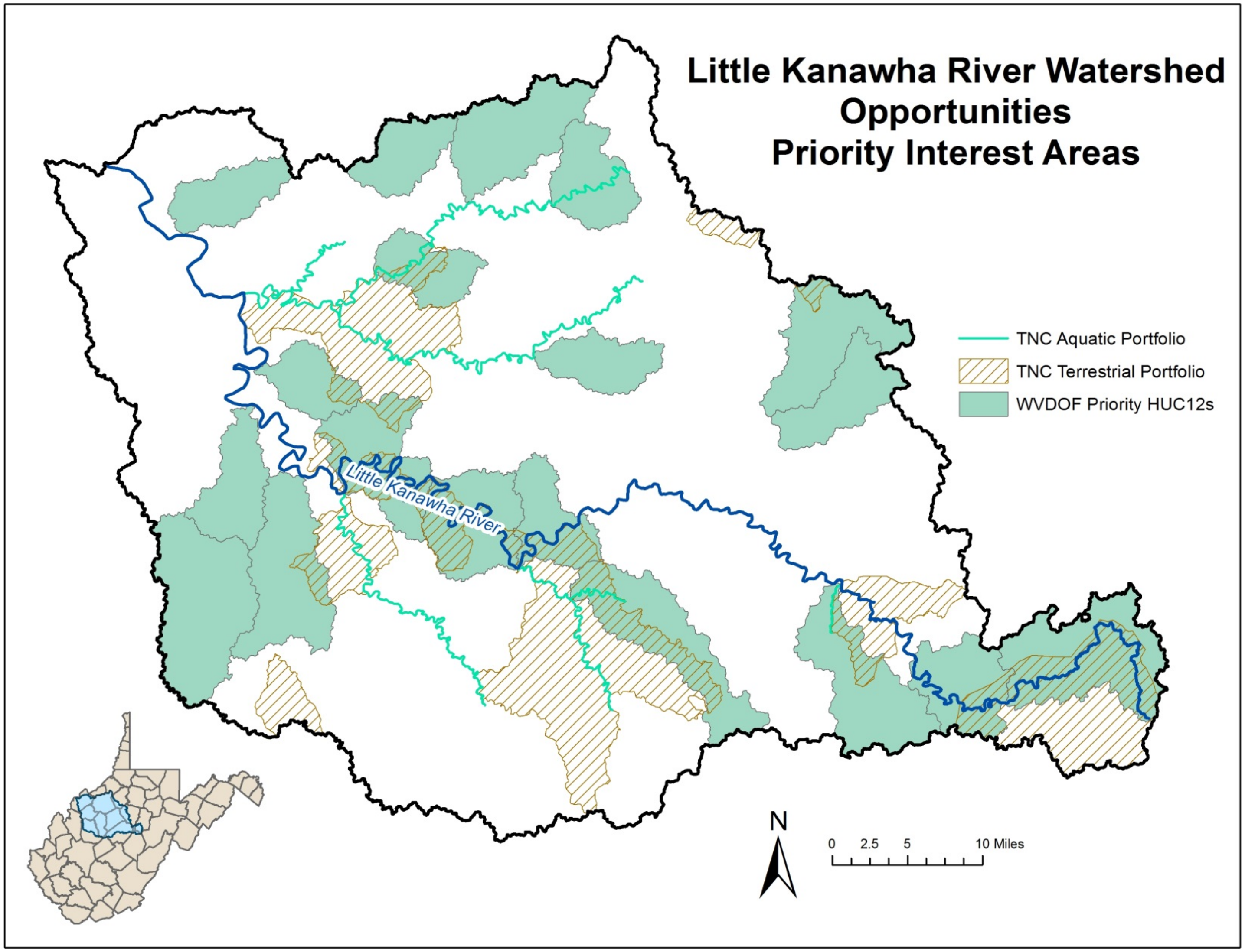


Figure 36. Little Kanawha River Watershed Opportunities – Priority Interest Areas (TNC 2012, WVDOF 2011)

## *Section 5: Recommendations and Conclusions*

### 5.1 Recommendations for Use

The goal of the watershed assessment pilot project was to be comprehensive and flexible enough to be applicable for a wide variety of potential end uses by regulatory staff, stakeholders, or any interested parties. We recognize that different users will likely have different goals, questions, and uses of the project results in mind. Regulatory staff may target a particular HUC12 watershed or stream reach, or have funds available for a particular strategy (e.g., to use funds targeted specifically for protection or restoration activities). Regulators may also use this information for cumulative impacts analyses to make permitting decisions. A watershed association may be interested in working only on streams, or may have a very specific issue they are interested in addressing within a watershed (e.g., treating acid mine drainage streams, or restoring wetland habitat to promote biodiversity). Alternately, an end user may not have any preconceived ideas of where they would like to work or what type of work they would like to pursue, and may just be interested in perusing the data collected and developing a comprehensive view of the watershed as a whole. And inevitably there will be additional uses and applications of the assessment results that the project team has not foreseen.

Considering the great variety of potential uses, it is necessary to not be too specific or prescriptive in suggesting different strategies on applying the assessment results on the ground or on using the interactive web tool. We have therefore developed two sample procedures for potential uses based on the strategies of protection and restoration. These examples are intended to walk users through a potential process for assessing the results, familiarizing themselves with underlying datasets, and choosing candidate sites for applying potential restoration or protection strategies on the ground.

As there are many decisions and factors involved in deciding where and how to work, the project team highly recommends as the initial step to determine the goals and objectives of a potential project, before approaching the assessment results and data (Figure 37). With the specifics and limitations of their own unique project(s) in mind, users can approach the results and web map in much the same way as the process described in the examples, by viewing and becoming familiar with overall and index results for each landscape model, and then viewing relevant data at whatever scale seems appropriate considering their unique goals.

The project makes some key assumptions: that protection priorities are most likely areas of Good or Very Good quality, possibly adjacent to or near existing public lands; and that restoration priorities are most likely areas with Fair scores, implying that they are in need of human intervention to repair function or restore quality, but are not so impacted by stressors that work in the area seems unfeasible or impractical. Within the results maps, blue areas indicate planning units with scores in the Very Good category, green areas indicate planning units in the Good category, yellow-orange planning units are in the Fair category, and red planning units have scores in the Poor category. Depending on the index, a Fair score may indicate an imbalance between quality metrics and anthropogenic stressors. A Fair planning unit may be of poor quality, but also have relatively few stressors, implying that restoration of the area may greatly benefit its overall quality and potentially changes its score from Fair to Good. Conversely, a Fair planning unit may have very high quality metrics, but also a high number of anthropogenic stressors, indicating that strategies designed to counteract the effects of the stressors may successfully increase the score from Fair to Good or even Very Good.

However, it is important to note that these are only a few of the possible uses for the project results. It is possible that the priorities and goals of different end users will suggest a different protection or restoration threshold to focus on.

Suggested process for using the results of the pilot project to determine project strategies:

Step 1: Define Project goals and objectives:

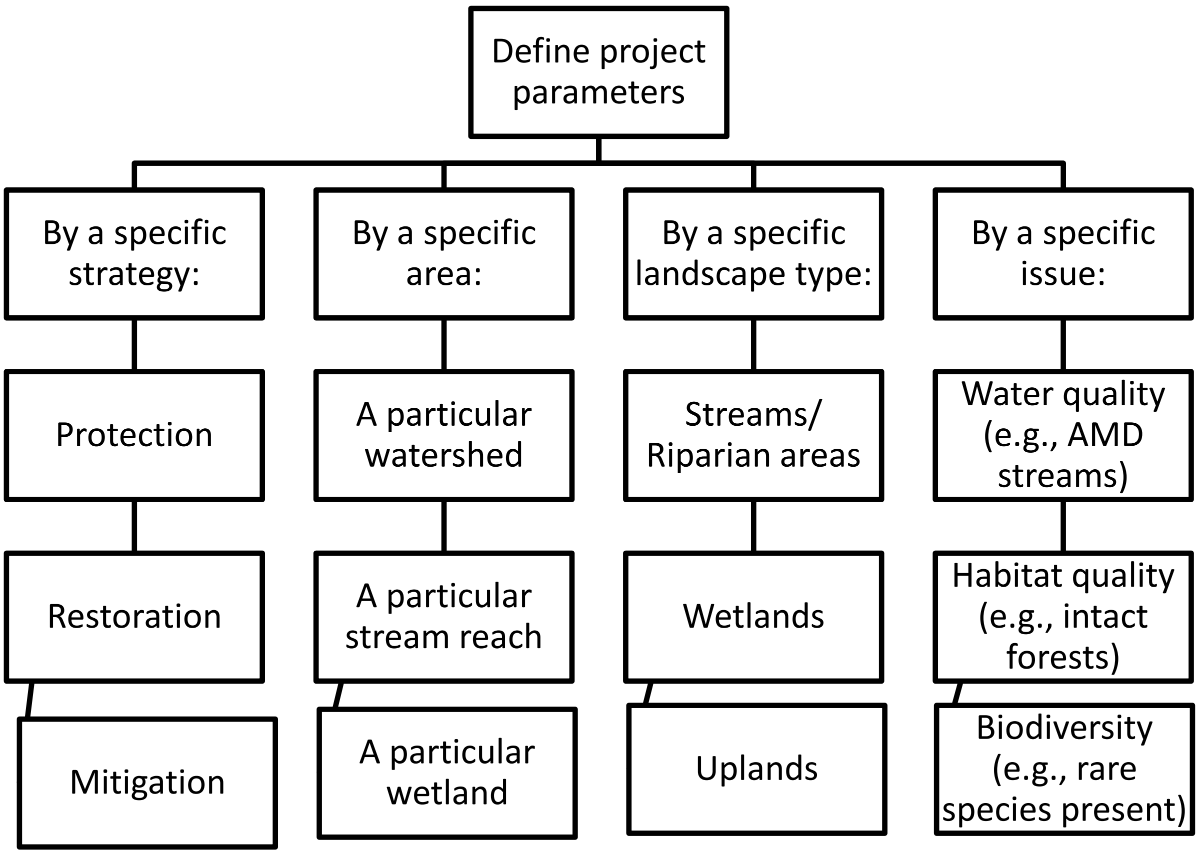


Figure 37. Possible End User Project Parameters

Step 2: Identify candidate areas for conservation action:

**a)** Protection Sample Process (Figure 38)

1) Select a Priority Model (Streams, Wetlands, or Uplands) according to specific project goals, and examine model's overall condition results for highest scoring HUC12s (green - blue areas)
2) Choose several candidate HUC12s with high scores (green - blue) in index or indices of interest
    a. Example: A HUC12 with high Streams Water Quality and/or Riparian Habitat ranking
    b. Example: A HUC12 with a high Wetlands Hydrology ranking, indicating extensive wetlands
    c. Example: A HUC12 with a high Uplands Habitat Connectivity ranking, indicating a low level of fragmentation
3) If applicable, display the Opportunities layer and select HUC12s in proximity to protected lands or priority interest areas to evaluate the potential for collaboration with other agencies
4) If applicable, display the Future Threats layer to evaluate each candidate HUC12's potential for future energy development, population projections, and resiliency to climate change
5) Zoom to each candidate HUC12, display catchment level index results, select those with high scores (green-blue areas) in multiple indices
    a. Example: For Streams catchments, consult the Water Quality, Riparian Habitat, and/or Biodiversity indices
    b. Example: For Wetlands catchments, consult the Wetlands Hydrology and Wetland Habitat indices
    c. Example: For Uplands catchments, consult the Habitat Connectivity and Habitat Quality indices
6) Zoom to candidate catchment(s) and display relevant data layers (imagery, land use, roads, resource extraction, etc.) to evaluate individual factors and datasets that may have contributed to a particular index score
    a. Example: For a high-ranking Streams catchment, display impervious surface, roads, NPDES outlets, mining, and wells to indicate potential water quality threats in the area
    b. Example: For a high-ranking Wetlands catchment, display any nearby WAB station data to indicate water quality of contributing streams
    c. Example: For a high-ranking Uplands catchment, display the land use data layers and aerial imagery
7) Determine parcel ownership and conduct site visit(s) to evaluate on-the-ground conditions and formulate specific strategies and action steps

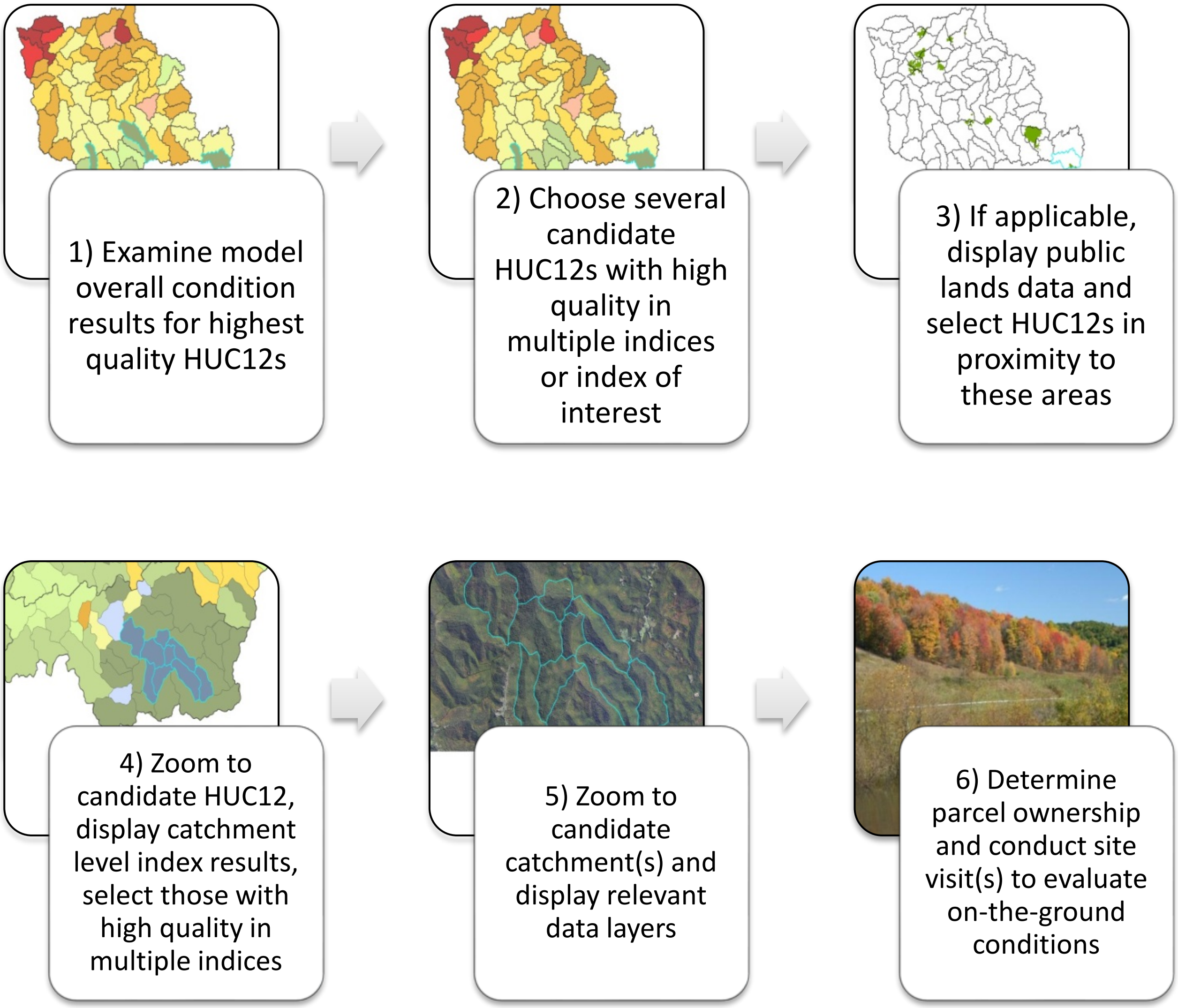


Figure 38. Protection Sample Process Flowchart

**b)** Restoration Sample Process (Figure 39)

1) Select a Priority Model (Streams, Wetlands, or Uplands) according to specific project goals, and examine model's overall condition results for Fair-scoring HUC12s (yellow-orange areas); or, if desired, select Poor-scoring HUC12s (red areas)
2) Choose several candidate HUC12s with Fair or Poor scores in index or indices of interest
    a. Example: A HUC12 with Fair or Poor Streams Water Quality
    b. Example: A HUC12 with Fair or Poor Wetlands Wetland Habitat
    c. Example: A HUC12 with Fair or Poor Uplands Habitat Connectivity
3) Compare to other index results. It may be advisable to select a candidate HUC12 with Good or Very Good scores (green-blue) in additional indices, depending on specific project goals
    a. Example: A HUC12 with Fair or Poor Streams Water Quality and Good or Very Good Riparian Habitat rankings, such as an AMD stream that could be chemically treated.
    b. Example: A HUC12 with Fair or Poor Wetlands Water Quality and Good or Very Good Wetlands Hydrology rankings, such as a wetland that could be expanded or revegetated
    c. Example: A HUC12 with Fair or Poor Uplands Habitat Connectivity and Good or Very Good Uplands Habitat Quality rankings, such as a grazed area that could be reforested
4) If applicable, display the Opportunities layer and select HUC12s in proximity to protected lands or priority interest areas to evaluate the potential for collaboration with other agencies
5) If applicable, display the Future Threats layer to evaluate each candidate HUC12's potential for future energy development, population projections, and resiliency to climate change
6) Zoom to each candidate HUC12, display catchment level index results, select those with Fair or Poor scores (yellow-red) in index of interest and Good or Very Good (green-blue) in additional applicable indices as in steps 2 and 3
7) Zoom to candidate catchment(s) and display relevant data layers (imagery, land use, roads, resource extraction, water quality impairments, wetlands, etc.) to evaluate individual factors and datasets that may have contributed to a particular index score
    a. Example: For Streams catchments, display nearby WAB station results to evaluate specific stream conditions, and land use/land cover and aerial imagery to visualize riparian habitat
    b. Example: For Wetlands catchments, display aerial imagery to determine if the wetland still exists, and hydric soils and floodplain layers to determine possible extent for wetland expansion/construction
    c. Example: For Uplands catchments, display roads, energy transmission lines and wells to locate permanent forest fragmenting features
8) Determine parcel ownership and conduct site visit(s) to evaluate on-the- ground conditions and formulate specific strategies and action steps
    a. Example: Restore natural vegetation along stream banks, improve streambed structure, restrict stream bank access, and/or treat chemical imbalances
    b. Example: Create/expand wetland basin structure, address quality issues of contributing streams, restrict access, and/or restore native vegetation
    c. Example: Restore native vegetation to upland forests and/or remove invasive species

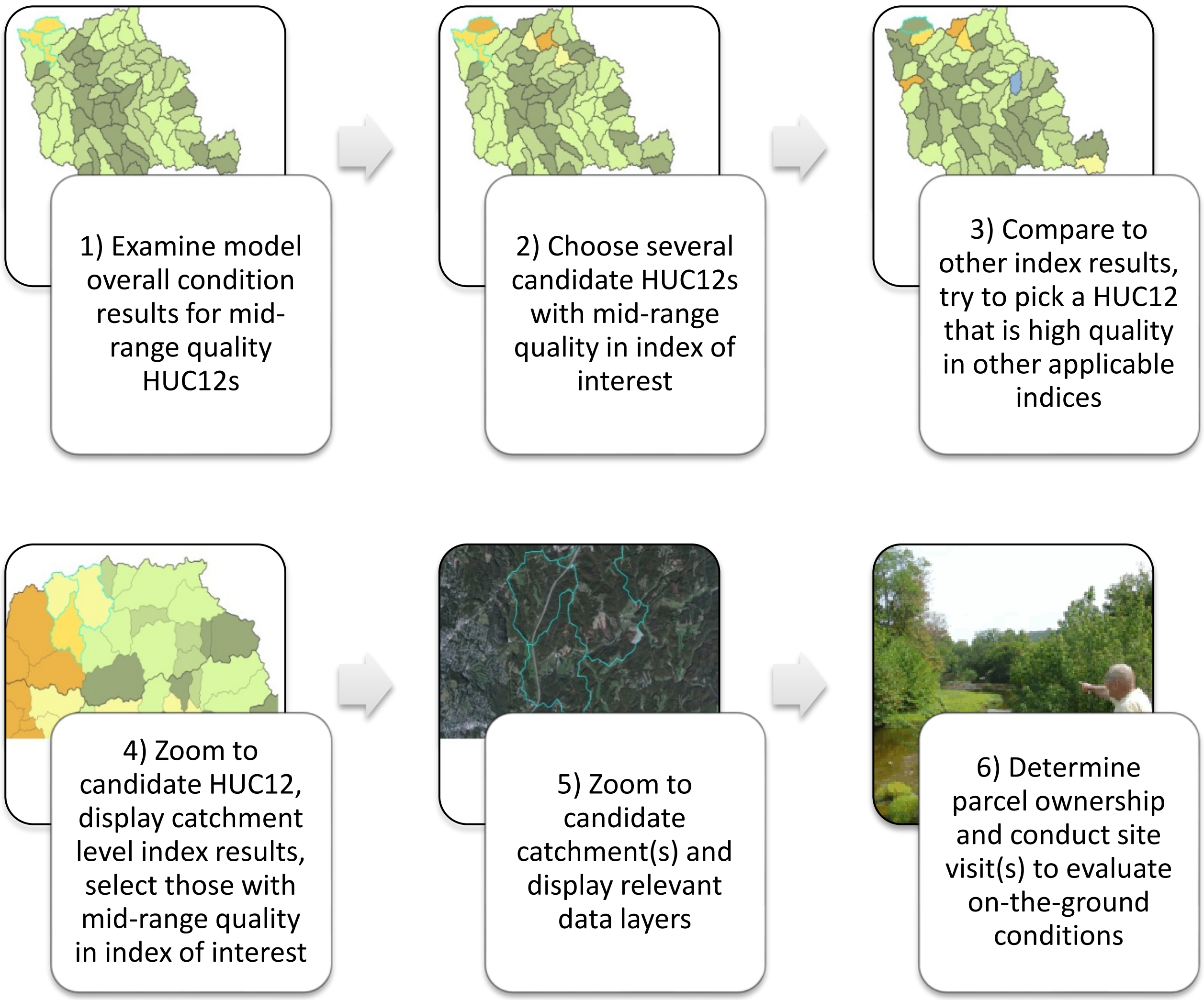


Figure 39. Restoration Sample Process Flowchart

## 5.2 Potential Strategies

As with the recommendations for use of the model results and selection of project sites, when suggesting potential strategies to address observed trends in selected project sites it is necessary to be aware of potential users' many different project goals and missions. The project team has therefore defined a set of broad potential strategies for various observed trends that are outlined in the results section. The user is encouraged to modify these strategies as appropriate for their particular project.

### 5.2.1 Streams/Riparian Areas

For Streams Water Quality results, observed trends that lowered index scores can be grouped into mining-related water quality impairments (AMD, pH, and heavy metals impairments, high specific conductivity values, low GLIMPSS scores), development (inadequate sewage treatment, high impervious surface, etc.), and riparian habitat stresses (grazing in riparian areas, high road/railroad densities, etc., which result in high fecal coliform and sedimentation issues). Potential strategies to address mining impacts may include treating and disposing of contaminated water appropriately before it leaves the mine site, controlling runoff and sedimentation from active mine sites, installing settling ponds to allow contaminants to settle out before reaching impacted streams, and installing lime treatment stations. Treatment for issues such as acid mine drainage requires a long-term investment of time, money, and equipment, and may be beyond some stakeholders' capabilities. Watershed associations may apply for funds through the Abandoned Mine Lands program for remediation of sites that were established before the Surface Mine Control and Reclamation Act (SMCRA) went into effect. In areas with inadequate septic systems, two potential strategies are to encourage installation/appropriate maintenance of functioning septic systems, and expansion of sewage treatment service areas. Urban areas also contribute to impaired water quality through runoff due to high imperviousness. A number of urban planning educational programs are available for interested parties to learn about how to minimize effects of impervious surfaces. Disturbance in riparian areas can be addressed by installing buffer areas along streams where activities such as grazing, timber harvesting, or road and railroad construction are limited, and adherence to Best Management Practices (BMPs) for any activities that do occur in riparian areas. Federal programs exist through the NRCS and Conservation Reserve Program (CRP) to assist private landowners with protecting watercourses from livestock.

Streams Water Quantity results indicated that index scores were often lowered by underground and active surface mining and high imperviousness. This index was dependent on surrogate measurements of flows altered from natural conditions, as no direct measurements were available to reliably rank individual planning units. Potential strategies include maintaining maximum natural cover in affected catchments to minimize imperviousness. High imperviousness in urban areas not only contributes to water quality impairments as noted above, but also alters natural flow conditions. Strategies designed to minimize effects of imperviousness on water quality will also help mitigate for any effects on water quantity. Mining effects on water quantity can be minimized by adhering to BMPs in actively mined areas, minimizing impervious surfaces in mined areas, controlling runoff and sedimentation from active mine sites, and controlling releases of mine pool water from underground surface mines.

Streams Hydrologic Connectivity issues included a lack of forested riparian area (which may impede the movement of organisms throughout the length of a stream due to temperature changes, potentially limiting their ability to complete their life cycles), and direct flow impediments such as bridges and culverts. Riparian areas that are lacking forested cover are prime candidates for forest restoration and installation of riparian buffers to minimize fragmenting activities along the stream. Culverts are often incorrectly installed and impede stream flow, and bridges can be impediments to organism movement and stream flow if not installed and maintained properly. Potential strategies would be to install and maintain appropriate culverts and bridges where they have been found to be negatively affecting stream flow and/or organism movement.

Streams Biodiversity index trends observed included invasive plants and lack of mussel streams identified in lower-scoring planning units. Strategies may include restoration of impacted areas by removing invasive species. Potential strategies to increase the mussel score of a planning unit may include direct relocation of mussels to an area, maintenance of an adequate flow regime where low flow conditions have impacted mussel populations, and improvement of water quality in potential mussel streams. Rare species data are hampered by the absence of information about where species were sampled but no rare species found versus where species were not sampled. Results in this index should therefore be regarded with caution and only used to design strategies in conjunction with other index results.

For the Streams Riparian Habitat index, results indicated that factors negatively affecting planning units' scores included a lack of natural cover in the riparian area and the presence of fragmenting features such as impervious surface, roads and railroads, oil and gas wells, and active surface mining. Trends also included low RBP scores (which may indicate problems with the stream bank itself). Potential strategies to address these issues include restoration of natural cover in riparian areas (including invasive species removal), and establishment of buffers in riparian areas designed to minimize fragmenting features by restricting incompatible activities. Any development that does occur in riparian areas should adhere to BMPs to minimize adverse effects from these activities. Areas with low overall RBP and bank stability scores may benefit from stream bank restoration, such as creating woody and vegetative riparian buffers and building bankfull benches, and other restoration activities depending on particular issues identified by the RBP assessment.

### 5.2.2 Wetlands

For the Wetlands Water Quality index, observed trends included a lack of forested headwater wetlands, presence of stressors in the wetland catchment area (including high impervious surface and low natural cover), and incompatible land uses in the wetland buffer (including fragmenting features and grazing). A lack of forested wetlands can be addressed by restoration of forested wetlands in headwater areas of the watershed. Restoration of natural cover in the wetland catchment area may mitigate for high impervious cover. In wetland catchments that include urban areas, urban planning programs mentioned above for streams water quality are also potential strategies for this index. Construction of additional impervious surfaces in impacted wetland catchments should be avoided. Incompatible land uses in wetland buffers may be minimized by adhering to BMPs on any construction activities in buffer areas, fencing out livestock from wetland buffers, and assigning appropriate permitted discharges to NPDES outlets.

Observed trends for the Wetlands Hydrology index included small or no wetlands in planning units and a lack of floodplain area and hydric soils. A potential issue for this index is inconsistent soil mapping among different counties. Some counties did not map hydric soils to the same extent as neighboring counties did, resulting in a likely bias in the index results. One potential strategy to improve index results in the future is to implement a statewide project to consistently map hydric soils; work is currently in progress across the state updating soils maps in certain counties. Any planning units with hydric soils but no wetlands, or without existing floodplain areas, are potential candidates for wetland restoration.

Wetlands Wetland Habitat index results indicated that small forest patch sizes, low natural cover, and roads in wetland buffers were stressors in some areas. Potential strategies to address these issues include restoration of unfragmented forest areas that extend into wetland buffers, and restoration of natural cover in wetland buffers. Landowners may be able to take advantage of federal or state programs for wetland protection or conservation easements, such as the Wetland Reserve Program (WRP). Roads in wetland buffers should be minimized, and any road construction or maintenance projects should adhere to accepted BMPs to minimize any adverse impacts on wetlands.

For a discussion of Wetlands Biodiversity index, please see discussion of the corresponding index under Streams above.

### 5.2.3 Uplands

Uplands Habitat Connectivity results indicated that fragmentation was the main trend across planning units (small unfragmented forest blocks and presence of fragmenting features such as transmission lines, pipelines, roads, railroads, timber harvesting, oil and gas wells, active surface mining, and development). One key potential strategy would be to utilize this watershed assessment as a tool to identify less fragmented areas within the watersheds; then utilize direct corporate, regulatory, and/or stakeholder/public engagement to avoid, minimize, or mitigate fragmenting effects to these areas through appropriate siting of infrastructure, development, and application of BMPs, retiring and restoring infrastructure no longer needed, and protection of irreplaceable sites.

Observed trends for Uplands Habitat Quality included low natural cover in upland areas, low heterogeneity, and incompatible land uses such as timber harvesting and grazing. Potential strategies include restoration of natural cover in affected areas and establishing compatible grazing regimes in areas affected by livestock grazing. Logging BMPs should be adhered to in all instances, and timber companies should be encouraged to utilize the Forest Reclamation Approach (FRA) of cultivating multi-species stands of hardwoods instead of managing for only one species.

For a discussion of the Uplands Biodiversity index, please see discussion of the corresponding index under Streams above.

### 5.3 Data Needed and Next Steps

An objective of this pilot project was to identify data gaps and needs in West Virginia: datasets that would be useful to include in the analysis to improve the models developed, but that were not available to include in the assessment. These include:

- Updated NWI wetlands data such as NWIPlus. At this writing, the WVDNR is in the process of ground-truthing NWI wetlands. This dataset will be incorporated once available.
- Reference wetlands or wetlands analyzed for function.
- More information on rare species sampling; i.e., information on areas that were sampled and no rare species were found.
- More comprehensive rare species sampling, especially in upland areas.
- Common plant and animal species diversity data.
- Forest Inventory Analysis data that can be accessed for GIS analysis at planning unit scales, i.e., locations that are not blurred, along with type and extent of harvest.
- More randomly sampled water quality data, particularly reference index values.
- Additional long-term USGS stream gauge data.
- Current and projected Marcellus and Utica shale gas well development, including sources and quantity of water use.
- Data on underground mine discharge points, and mine pools locations, extent, and water quality.
- Updated status information on wells, e.g., inactive vs. plugged, Marcellus well status.
- Soils data that are consistently mapped and coded across county boundaries.

The consolidated analysis of future impacts for the five pilot HUC8 watersheds was hampered by lack of data on population and development projections (except for the Morgantown metropolitan area), incomplete coal mapping, and uncertainty in the direction and degree of Marcellus shale development, but projected declines in population in some counties and likely stagnation in development may slow any development-related declines in water and habitat quality. Since a consolidated analysis was one of the original goals of this project, the methods will continue to be refined as more data become available and more assessments inform our understanding of the influence of different metrics on index results. As more sophisticated climate projections become available, such as a predictive model for the Ohio River Basin currently being developed by the USACE (Drum 2013), they may be incorporated into the analysis to indicate areas that are especially vulnerable to temperature and precipitation changes and where landscape resilience is especially important.

This watershed assessment combines several features that make it unique:

- It addresses watershed condition not only in terms of species and habitat, but also in terms of functions, such as water purification, sediment retention, and flood storage.
- It allows for quantitative assessment at two spatial scales: the HUC12 scale, which is of interest to state agencies for regulatory purposes, and the NHDPlus catchment scale, which is more useful for site-specific conservation planning.

- It performs an in-depth analysis of three landscapes— streams, wetlands, and uplands—yet recognizes that they are not independent, but mutually influence condition and function; in particular it quantifies the contribution of upland habitat to stream and wetland function by incorporating both aquatic and terrestrial metrics in these models.
- It aggregates a wide variety of disparate spatial datasets from many sources, such as land use, water quality, and resource extraction, in one location.
- The assessment methods are transferable to all HUC8 watersheds across the state.

The West Virginia Watershed Assessment Pilot Project recognizes that conservation actions are not uniform: protection, restoration, and mitigation projects are undertaken by a variety of entities with a variety of goals and resources. It provides a tool and a framework for users to obtain information about a watershed and use the assessment analysis to inform their decisions or create their own strategies appropriate to their needs. The development and improvement of the interactive web map will be ongoing, with the goal of making the data as dynamic and the assessment procedure as automatic as possible. Potential users have expressed interest in predictive aspects of the tool and the desire for functionality that allows users to create “what-if” scenarios to evaluate the effects of conservation actions. When the web tool becomes available, continued involvement by users and experts throughout the development process may result in further efforts to develop this functionality.

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# APPENDICES

## Appendix A: Detailed Data Source Information

| Type | Description | Format | Source (Date Published) | Downloaded | Intended Use | Limitations | QA/QC* |
|---|---|---|---|---|---|---|---|
| BASE LAYERS | | | | | | | |
| NHDPlus (100K) | Catchments, flowline, flow direction grid | polygon, line, raster | USGS (2005) | 5/2011 | Planning unit delineation, base stream network, wetland distance to nearest surface water | 100K (not consistent scale among various stream datasets) | Moderate |
| NHD24K with stream codes | Flowlines with additional attributes including DEP stream code | line shp | WVU Natural Resource Analysis Center (2010) | 11/2010 | Join with mussel stream survey data Excel file | | None |
| Land Use/Land Cover 2009-2010 | WV land use/land cover data; updated using Landsat 5 imagery | raster | WVU Natural Resource Analysis Center | 11/14/2011 | Recent land cover dataset, to determine percent forested, developed, mining, etc | Not all roads included as developed land | None |
| City boundaries | Outline of city boundaries | polygon | US Census (1990) | 5/2010 | Spatial reference | | None |
| County boundaries | Outline of county boundaries | polygon | USGS/WVDEP (2002) | 2/2010 | Spatial reference | | None |
| Ecoregions | TNC defined ecoregions | polygon | TNC - ERO (2008) | 2/2010 | Join with ecoregional targets Excel file | | None |
| Ecological Land Units | TNC defined ecological land units | polygon | TNC-ERO(2008) | 2/2010 | Determine calcareous bedrock; predict rare species occurrence based on landscape and geology | | None |
| Topographic maps | Relief maps of WV, by quad | image | USGS (varies) | Varies | Spatial reference, data verification, mining | Dated (mostly from 1970's) | None |
| Aerial imagery | Satellite imagery of WV | image | USDA (2007, 2009); ESRI online imagery (2009, 2010) | Online access; 6/2010 | Spatial reference, data verification | | None |
| WATER QUANTITY | | | | | | | |
| Public water supply (PWS) | Surface water intakes | points shp | WVDHHR (2011) | 8/2011 | Measure of water withdrawal along stream | Point locations required verification (not all outtakes along streams) | Limited |

| Type | Description | Format | Source (Date Published) | Downloaded | Intended Use | Limitations | QA/QC* |
|---|---|---|---|---|---|---|---|
| Large quantity users (LQU) | Withdrawal over 750,000 gal | points shp | WVDEP (2011) | 8/2011 | Measure of water withdrawal along stream | Self-reporting; table listed coordinates as "fuzzy", required verification | Limited |
| Wastewater treatment plants (WWTP) | Locations of municipal sewage treatment plants | points shp | WVDEP (2002) | 5/18/2011 | Identify points where streamflow may be altered due to plant discharges | | None |
| USGS stream gages | Stream gage locations | points shp; Excel table | USGS (2003) | 8/2011 | Measure of flow variation along stream | | None |
| WETLAND QUANTITY | | | | | | | |
| National Wetlands Inventory (NWI) | Locations of wetland features | polygon shp | FWS (2011) | 4/2011 | Identify locations of wetland features | Data derived from dated aerial imagery | Limited |
| Historical topo maps | Topo maps (from 1900-1930) | image | USGS/WVDEP (varies) | 8/2011 | Identify areas labeled as wetlands in the past | | None |
| Floodplain area | FEMA 100-year floodplain area | | WVGISTC (11/01/2010 | | Identify areas with potential wetland hydrology based on presence of floodplain | | None |
| WATER QUALITY | | | | | | | |
| Impaired streams (303(d), TMDL) | 2010 303(d) and TMDL listed streams | line shp | WVDEP (1/11/2011) | 2/2011 | Identify streams with known impairments | Combined with AMD impaired streams | Limited |
| Impaired streams (AMD) | Acid mine drainage streams | line shp | WVDEP (2/11/2009) | 3/2010 | Identify streams with known impairments | Combined with 303(d), TMDL impaired streams | Limited |
| WAB database samples | Water quality samples (includes water chemistry parameters, GLIMPSS, taxa richness, RBP scores, etc) | points shp | WVDEP (10/2011) | 12/14/2011 | Measure of water quality parameters, biotic index and riparian habitat, etc | Point locations required some verification due to NHD24k accuracy issues | Limited |
| NLCD impervious cover (2006) | Impervious surfaces | raster | USGS (2/16/2011) | 2/2011 | Measure of contributing area of impervious cover | Data based on 2006 aerial images, low resolution | None |

| Type | Description | Format | Source (Date Published) | Downloaded | Intended Use | Limitations | QA/QC* |
|---|---|---|---|---|---|---|---|
| BIODIVERSITY | | | | | | | |
| Element occurrences | Natural Heritage Program rare species | points shp | WVDNR (2/14/2011) | 2/2011 | Identify areas with known rare species | Some geographic coordinate errors (outside WV boundaries); some data prior to 1991 | Moderate |
| SGNCs | Species in greatest need of conservation | Excel table | WVDNR (2005) | 8/2011 | Join with element occurrences | | None |
| Odonates | Additional odonate occurrences | Excel table | WVDNR (8/2011) | 8/2011 | Join with element occurrences | Some element codes missing | Moderate |
| Hellbenders | Hellbender occurrences | Excel table | The Good Zoo, Wheeling, WV (11/2010) | 11/2010 | Join with element occurrences | Locations required verification. | Limited |
| Crayfish | Crayfish occurrences | Excel table | Researcher at West Liberty University (12/2010) | 12/2010 | Join with element occurrences | Locations required verification, some geographic coordinate errors (outside WV boundaries) | Limited |
| Fish | Fish occurrences | Excel table | WVDNR (10/2010) | 10/2010 | Join with element occurrences | | None |
| Ecoregional targets | TNC target species for 3 ecoregions of WV | Excel table | TNC - ERO (2007) | 8/2011 | Join with element occurrences | Some data prior to 1991 | Moderate |
| Mussel streams | Stream reaches containing endangered mussels | Excel table | WVDNR (09/2011) | 9/2011 | Join with NHD 24K streams shapefile; prioritize streams with endangered mussel species or high quality habitat | No specific information beyond presence/absence of unspecified endangered species in stream reach; some stream codes outdated | Moderate |
| Trout streams | Naturally reproducing trout streams | line shp | WVDEP (2010) | 8/2011 | Identify DEP priorities for trout streams | | None |
| Northeast terrestrial habitat types | Terrestrial habitat types based on shared characteristics across region | raster | TNC – ERO (7/14/2011) | 8/8/2011 | Surrogate measure of potential species diversity based on variety of available habitats | | None |

| Type | Description | Format | Source (Date Published) | Downloaded | Intended Use | Limitations | QA/QC* |
|---|---|---|---|---|---|---|---|
| PHYSICAL INTEGRITY | | | | | | | |
| Soils | Soils data by county | polygon shp | SSURGO (varies by county) | Varies | Determine hydric soils; highly erodible soils; high infiltration rate soils; soil buffering capacity | Varying resolution between county; generalized data; incomplete coding | None |
| Fire regime condition class (FRCC) | Degree of departure from reference condition vegetation | raster | USFS LANDFIRE (2007) | 7/2011 | Estimate of change in vegetation conditions | Low resolution | None |
| Heterogeneity | Landscape heterogeneity metric reflecting elevation change and landform variety | raster | TNC - ERO (03/2011) | 3/2011 | Indicate variation in landscape topography and landforms | | None |
| HYDROLOGIC CONNECTIVITY | | | | | | | |
| Active River Area (ARA) | Riparian and material contribution zones along streams | raster | TNC - ERO (2009) | 2/2011 | Define riparian area | | Moderate |
| Northeast Association of Fish and Wildlife Association (NEAFWA) streams | Stream classifications and stream order/size | line shp | TNC - ERO (2008) | 8/2010 | Determine headwaters streams | | None |
| Power plants | Locations of power plants on small (size class 1a) streams | points shp | Ventyx | 12/5/2011 | Identify locations where plant discharge may change water temperature and disrupt aquatic connectivity for species | | None |
| HABITAT CONNECTIVITY | | | | | | | |
| Forest blocks | Unfragmented forest blocks larger than 100 acres | polygon shp | TNC - PAFO (07/2011) | 8/2011 | Prioritize areas of unfragmented forest | | None |
| Local integrity | Local integrity metric reflecting unfragmented natural habitat | raster | TNC - ERO (03/2011) | 3/2011 | Prioritize areas of unfragmented natural habitat (forest, grassland, wetland, stream) | | None |
| PROTECTION PRIORITIES | | | | | | | |
| Aquatic portfolio | TNC priority streams | line shp | TNC - ERO (2/25/2011) | 3/2011 | Identify TNC priority streams | | None |
| Terrestrial portfolio | TNC priority lands | polygon shp | TNC - ERO (07/2011) | 8/2011 | Identify TNC priority lands | | None |

| Type | Description | Format | Source (Date Published) | Downloaded | Intended Use | Limitations | QA/QC* |
|---|---|---|---|---|---|---|---|
| Secured lands | Preserves and publicly owned lands | polygon shp | TNC – ERO/WVFO (6/27/2011) | NA | Identify lands already under protection or in public trust | | None |
| National Forest proclamation boundary | USFS target area for land acquisition | polygon shp | USFS (2004) | 2/2011 | Identify USFS priority lands | | None |
| Watershed assessment results | Division of Forestry analysis results for Water Quality and Forest Resource Areas | polygon shp | WVDOF (2010) | 8/2011 | Identify WVDOF priority lands | By HUC12 | None |
| National Park Service priority areas | Priority interest areas identified by the NPS | polygon shp | NPS | 2/152013 | Identify NPS priority lands | No metadata for attributes | None |
| RESOURCE EXTRACTION | | | | | | | |
| Oil and gas wells | Locations of oil and gas wells | points shp | WVDEP (8/15/2011) | 8/2011 | Identify locations of active oil and gas wells | Point locations required verification | Limited |
| Marcellus Shale gas wells | Locations of Marcellus shale gas wells | points shp | WVGES (4/14/2011) | 8/2011 | Identify new and existing Marcellus wells | Point locations required verification | Limited |
| Surface mines (Appalachian Voices) | Digitized mining footprint for watersheds based on aerial imagery | polygon shp | Appalachian Voices (2007) | 9/2011 | Identify areas with active surface mines as of 2007 | | None |
| Abandoned mine lands | Outline of abandoned mine areas | polygon shp | WVDEP (1996) | 2/2010 | Identify areas with possible residual effects from mining activity | Accuracy issues | Limited |
| Mining footprint | Outline of current mining activity | polygon shp | WVGES (3/10/2011) | 3/2011 | Identify areas with current surface and underground mining activity | Some conflicts with aerial imagery (mining land possibly already overgrown/ reclaimed) | Extensive |
| Valley fills | Valley fill locations from SMCRA permit maps | polygon shp | WVDEP (8/23/2011) | 8/2011 | Identify areas with surface mining refuse | Some overlap with other mining datasets | Limited |
| Coal refuse structures | Coal refuse (disposal area) locations | polygon shp | WVDEP (8/23/2011) | 8/2011 | Identify areas with surface mining refuse | Some overlap with other mining datasets | Limited |
| Coal production data | Measure of coal production per facility, by year | Excel table | US EIA (2007, 2008) | 7/2011 | | No MSHA ID in state data; production data distributed by county/mine site | None |

| Type | Description | Format | Source (Date Published) | Downloaded | Intended Use | Limitations | QA/QC* |
|---|---|---|---|---|---|---|---|
| Mineral operations | Quarries, mineral extraction facilities | points shp | USGS (2002) | 3/2010 | Identify surface mineral extraction activities | Some duplicate data; not polygon data so unable to calculate area | Limited |
| Timber harvesting | Locations of timber permits and acreage | points shp | WVDOF (2010) | 6/2011 | Identify timber extraction activities | Not polygon data so unable to determine exact spatial location | Limited |
| DEVELOPMENT & AGRICULTURE | | | | | | | |
| National Pollutant Discharge Elimination System (NPDES) | Locations of permitted discharges to surface water | points shp | WVDEP (2011) | 8/2011 | Identify possible point source pollution along streams | Point locations required verification | Limited |
| NLCD 2006 | National Landcover dataset | raster | USGS (2/16/2011) | 2/2011 | ID development/agriculture/ pasture landcover types | Data based on 2006 aerial images, low resolution | None |
| Buildings | Locations of structures | points shp | WVSAMB (2003) | 8/2011 | Used to identify land disturbance and generate septic systems points for structures outside of city boundaries | | None |
| Solid waste facilities | Locations of landfills | points shp | WVDEP (2002) | 5/2010 | Identify possible source of pollution | | None |
| HABITAT FRAGMENTATION | | | | | | | |
| Roads | Interstate, US and state highways, county road networks | line shp | WVDOT (2011) | 9/2011 | Roads as potential source of runoff/sedimentation pollution and as forest habitat and stream fragmenting features (road/stream crossings) | | None |
| Railroads | Railroad networks | line shp | WVDNR (2010) | 5/2010 | Railroads as potential source of runoff/sedimentation pollution and as forest and stream fragmenting features (RR/stream crossings) | | None |
| Energy transmission lines | Locations of energy lines, by voltage class | line shp | Ventyx (08/2011) | 9/2011 | Lines as habitat fragmenting features | | None |
| Natural gas pipelines | Locations of pipelines, by diameter | line shp | Ventyx (08/2011) | 9/2011 | Lines as habitat fragmenting features | | None |

| Type | Description | Format | Source (Date Published) | Downloaded | Intended Use | Limitations | QA/QC* |
|---|---|---|---|---|---|---|---|
| Wind turbines | Locations of wind turbines and wind farms | points shp | TNC - PAFO (12/25/2010) | 5/2011 | Points as habitat fragmenting features, source of pollution (sedimentation) | | None |
| Bridges | Locations of bridges and culverts | polygon shp | WVDOT (2008) | 8/2011 | Structures as habitat fragmenting features | Locations required verification | Limited |
| Dams | Locations of impoundments | points shp | TNC - ERO (2/10/2011) | 2/2011 | Points as habitat fragmenting features; surface water capture & storage capacity | Point locations required verification | Limited |
| ECOLOGICAL THREATS | | | | | | | |
| Non-native invasive species | Locations of invasive species sitings | Excel table | WVDA (8/2011) | 8/2011 | Estimate of invasive species location and coverage | Data table contains entries/formats not compatible with import into GIS; some geographic coordinate errors | Moderate |
| Basal area loss, by species | National Insect and Disease Risk Maps | rasters | USFS (2006) | 8/2011 | Estimate of timber pests and pathogens | | None |
| Quarantined counties | Infested/infected/ quarantined counties | polygon shp | WVDA (2011) | 8/2011 | Used to estimate pests & pathogens threats | Resolution by county | Limited |
| FUTURE THREATS | | | | | | | |
| Mining permit boundary | Existing mining permit boundaries | polygon shp | WVDEP (8/23/2011) | 8/24/2011 | Used to estimate high potential threat of future mining activity | | None |
| Unmined coal | Unmined coal formations | polygon shp | WVGES (6/30/2011) | | Used to estimate potential threat of future mining activity | Some areas not mapped yet | None |
| Marcellus Shale thickness | Thickness of Marcellus shale geology | polygon shp | WVGES (11/16/2011) | 11/22/2011 | Used as surrogate for potential of gas well development | | None |
| Wind development potential | Areas with high potential for wind energy development | polygon shp | National Renewable Energy Lab (2003) | 5/10/2010 | Used to estimate potential threat from wind development | | None |
| Proposed wind turbines | Known locations of proposed wind turbines | points shp | TNC – PAFO (12/2010) | | Used to estimate potential threat from wind development | Some locations are existing wind turbines | Limited |
| Proposed energy transmission lines | Known locations of proposed energy lines | line shp | Ventyx (01/2012) | 01/2012 | Used to estimate potential fragmentation threat from energy lines | Some large projects have been cancelled (e.g., PATH) | Limited |
| Proposed natural gas pipelines | Known locations of proposed gas lines | line shp | Ventyx (01/2012) | 01/2012 | Used to estimate potential fragmentation threat from energy lines | Some large projects may be missing from data | Limited |

| Type | Description | Format | Source (Date Published) | Downloaded | Intended Use | Limitations | QA/QC* |
|---|---|---|---|---|---|---|---|
| Proposed power plants | Known locations of proposed power plants | points shp | Ventyx (01/2012) | 01/2012 | Used to estimate potential threat from power plants | Some projects have been cancelled | Limited |
| Geothermal potential | Estimate of geothermal temperature ranges | kmz | SMU Geothermal Lab (2011) | 10/27/2011 | Used to estimate potential threat from geothermal energy | | None |
| Population projections | Population projection to 2030, by county | PDF | WVU (08/2011) | 2011 | Used to estimate potential threat from development | County-level scale; only percentage estimates | None |
| Development potential | Potential for expansion of development, based on watershed | varies | varies | | Used to estimate potential threat from development | Only data found was for Morgantown area in Monongahela | None |
| Future roads | Known locations of proposed new routes | line shp | WVDOT (2003) | 9/28/2011 | Used to estimate potential fragmentation threat from road construction | Some roads in dataset have already been constructed | Limited |
| Resiliency | From TNC resiliency dataset | raster | TNC – ERO/PAFO (3/06/2012) | 3/14/2012 | Used to estimate potential resiliency to climate change | Regional level analysis, not specific to WV | None |
| Regional flow (current density) | From TNC resiliency dataset | raster | TNC – ERO/PAFO (3/06/2012) | 3/14/2012 | Used to estimate potential resiliency to climate change | Regional level analysis, not specific to WV | None |

* In the initial stages of data collection, datasets requiring varying degrees of Quality Assurance/Quality Control (QA/QC) were identified, the levels of which are explained below. All of the following descriptions refer to QA/QC activities conducted by the watershed assessment project team and do not refer to any QA/QC conducted by the generator of the data. (Many of the agencies that collected or generated the data adhere to more or less rigorous and extensive QA/QC protocols.)

- Little or no QA/QC required: National or state agency data such as the National Land Cover Dataset or WVDEP water quality data, and data generated by lead scientists at TNC Eastern Regional Office and published in the open literature, such as landscape connectivity and resiliency data. Generally these data need only to be clipped to the desired geographic extent or possibly converted between vector and raster data types.
- Limited amount of QA/QC required: Data that may have been received as “fuzzy” or with point locations requiring verification, such as large quantity water withdrawals, public water supply data and wells locations. Generally, verification involves comparing against 2010 aerial imagery or address information to ensure that points are accurately located. Limited QA/QC often results in data being filtered by attributes to only those features that are most reliable (e.g., taking only active well locations).
- Moderate amount of QA/QC required: Data generated by TNC partners and maintained in internal databases, such as locations of rare species (“element occurrences”) collected by West Virginia Natural Heritage Program. Such data may include blank, duplicate, or erroneous records, or data earlier than the time frame during which it can be reasonably expected that a species or environmental condition persists. In these cases, removal, addition, or correction of records renders the data acceptable. Moderate QA/QC may also be conducted on datasets

to ensure compatibility with the formatting or resolution needs of the project, such as manual amendment of datasets generated from models.

- Extensive QA/QC required: Data that are found to be deficient for this analysis, irrespective of the data source, but that are necessary for a complete watershed assessment and for which no alternative exists. Such data may need extensive additions or deletions of geographic features or attributes, often based on manual verification from other data sources, such as the most recent aerial imagery (TNC 2011a). The only dataset that required extensive QA/QC for this project (mining footprint data from WVDEP) was later removed as a metric and replaced by more recent and complete datasets.

## *Appendix B: Metrics Description and GIS Process*

### Streams

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| **WATER QUALITY** | | | | | |
| Impaired | Impaired Streams | Impaired Streams: 303(d), TMDL, AMD (WVDEP) | Identify streams with known water quality impairment | Merge 303(d), TMDL , AMD impaired streams, Identity to planning unit and Dissolve to get miles per planning unit | 2 |
| Bio | Biologically impaired streams | Impaired Streams: 303(d), TMDL, AMD (WVDEP) | Not considered in final analysis | Select features where Cause: Bio, Identity to planning unit and calculate miles per planning unit | 0[f] |
| DioxPCB | Dioxin/PCB impaired streams | Impaired Streams: 303(d), TMDL, AMD (WVDEP) | Not considered in final analysis | Select features where Cause: PCBs, Identity to planning unit and calculate miles per planning unit | 0[f] |
| Fecal | Fecal coliform impaired streams | Impaired Streams: 303(d), TMDL, AMD (WVDEP) | Not considered in final analysis | Select features where Cause: Fecal/Bacteria, Identity to planning unit and calculate miles per planning unit | 0[f] |
| pHImp | pH  impaired streams | Impaired Streams: 303(d), TMDL, AMD (WVDEP) | Not considered in final analysis | Select features where Cause: pH, Identity to planning unit and calculate miles per planning unit | 0[f] |
| MetalsImp | Metals impaired streams | Impaired Streams: 303(d), TMDL, AMD (WVDEP) | Not considered in final analysis | Select features where Cause: Aluminum, Iron, Lead, Manganese, Identity to planning unit and calculate miles per planning unit | 0[f] |
| ChlorideImp | Chloride impaired streams | Impaired Streams: 303(d), TMDL, AMD (WVDEP) | Not considered in final analysis | Select features where Cause: Chloride, Identity to planning unit and calculate miles per planning unit | 0[f] |
| MedpH* | Median pH sample values | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Represent pH values for sampled streams | pH index, calculated on median values among samples per station: 100: >10 or <5, 200: >9 or <6, 300: >8 or <6.5, 400: 6.5 - 8 | 2 |
| MedRefIndex | Median reference index values | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Weighted Percentage of points that are DEP reference points (median among samples per station) | 0[a] |
| MedSulfate | Median sulfates | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Represent sulfates values for sampled streams (possible indicator of impairment due to mining) | Sulfate index, calculated on median values among samples per station: 100: >250 mg/l, 200: >50, 300: >25, 400: <=25 | 1 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| MedNitro | Median nitrogen | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Total Kjeldahl Nitrogen index, calculated on median vallues among samples per station: 100: >=0.5 mg/l, 200: >0.4, 300: >0.25, 400: <=0.25 | 0[a] |
| MedStressed | Median stressed | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Median percent of stations fitting DEP's Stressed Category (GLIMPSS calculation) | 0[a] |
| MedMetal | Median metals | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Median % of measured metals (Al, Fe, Mn, Se, Cu, Zn) not attaining DEP's water quality standards per station, calculated on median values among samples | 0[f] |
| MedChloride | Median chloride | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Median chloride index: 100: >860mg/l, 200:>230, 300:>115, 400: <=115 | 0[f] |
| MedSpecCond* | Median specific conductivity | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Represent specific conductivity values for sampled streams (possible indicator of impairment due to mining) | Specific Conductance index, calculated on median values of samples per station: 100: >835 umhos/cm, 200: >500, 300: >200, 400: <=200 | 1.5 |
| MedGLIMPSS | Median GLIMPSS scores | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Represent benthic macroinvertebrate communities in sampled streams | GLIMPSS_CF index of Percent Threshold, calculated on median values: 100: <50, 200: <100, 300: <125, 400: >=125 | 2 |
| MedS&E | Median sedimentation & embeddedness | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Represent RBP habitat score of streambank condition | Median sum of individual indices for Embeddedness and Sedimentation scores: 100: <11, 200: <21, 300: <31, 400: >=31 | 1 |
| MaxMinpH | Maximum/minimum pH | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | pH index calculated on extreme values among samples for each station (maximum or minimum): 100: >10 or <5, 200: >9 or <6, 300: >8 or <6.5, 400: 6.5 - 8 | 0[a] |
| MinRefIndex | Minimum reference index value | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Weighted Percentage of points that are DEP reference points (minimum among samples per station) | 0[a] |
| MaxSulfate | Maximum sulfates | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Sulfate index, calculated on maximum values among samples per station: 100: >250 mg/l, 200: >50, 300: >25, 400: <=25 | 0[a] |
| MaxNitro | Maximum nitrogen | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Total Kjeldahl Nitrogen index, calculated on extreme values among samples per station: 100: >=0.5 mg/l, 200: >0.4, 300: >0.25, 400: <=0.25 | 0[a] |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| MaxStressed | Maximum stressed | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Maximum percent of stations fitting DEP's Stressed Category (GLIMPSS calculation) | 0[a] |
| MaxMetal | Maximum metals | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Median % of measured metals (Al, Fe, Mn, Se, Cu, Zn) not attaining DEP's water quality standards per station, calculated on extreme values | 0[a] |
| MaxChloride | Maximum chloride | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Chloride index, calculated on extreme values among samples per station (maximum or minimum): 100: >860mg/l, 200:>230, 300:>115, 400: <=115 | 0[a] |
| MaxSpecCond | Maximum specific conductivity | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Specific Conductance index, calculated on extreme vallues among samples per station: 100: >835 umhos/cm, 200: >500, 300: >200, 400: <=200 | 0[a] |
| MinGLIMPSS | Minimum GLIMPSS score | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | GLIMPSS_CF index of Percent Threshold, calculated on extreme values among samples per station (maximum or minimum): 100: <50, 200: <100, 300: <125, 400: >=125 | 0[a] |
| MinRBP | Minimum Rapid Bioassessment Protocol score | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Total RBP Score index, calculated on extreme values among samples per station: 100: <60, 200: <110, 300: <160, 400: >=160 | 0[a] |
| MinBSS | Minimum Bank Stability Score | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Bank Stability Score index, calculated on extreme values among samples per station (maximum or minimum): 100: <6, 200: <16, 300: <17, 400: >=16 | 0[a] |
| MinS&E | Minimum sedimentation and embeddedness score | Water Assessment Branch (WAB) water quality sample data (WVDEP) | Not considered in final analysis | Sum of individual indices for Embeddedness and Sedimentation scores, calculated on extreme values among samples per station: 100: <11, 200: <21, 300: <31, 400: >=31 | 0[a] |
| VolRem | Voluntary remediation sites in riparian area | Voluntary Remediation Sites (WVDEP) | Not considered in final analysis | Spatial join to get number per planning unit | 0[d] |
| KarstRip | Karst features in riparian area | Karst geology (WVDNR) | Not considered in final analysis | Identity to planning unit and calculate square miles per planning unit | 0[f] |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| HES | Highly erodible soils | Soils by county (SSURGO) | Not considered in final analysis | Generate erosion hazard dataset from Soil Data Viewer, select all values of EroHzdORT = severe, very severe, identity to planning unit, calculate square miles per planning unit | 0[g] |
| Imperv1* | Percent imperviousness | NLCD Impervious surface (USGS) | Generates increased run off as potential non-point source of pollution to streams | Convert raster to polgyon, Identity to planning unit, Dissolve to get mean percent imperviousness per planning unit | 2[b] |
| AllWells | Wells in riparian area | All Wells (WVDEP) | Source of sedimentation | Spatial join to get number per planning unit | 1.5[b] |
| CBMTWellProd | Coal bed methane and Trenton well production | Coal bed methane and Trenton well production (WVGES) | Not considered in final analysis | Join Excel table by well ID, dissolve to get mean production per HUC12 | 0[d] |
| ActiveSurface1 | Active surface mining | LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP) | Not considered in final analysis | Merge mining polygons, Identity to planning unit and calculate to get square miles per planning unit | 0[a,c] |
| ActiveSurfaceRip1 | Active surface mining in riparian area | | Not considered in final analysis | | 0[f] |
| SurfaceMine1* | Surface mining (active and legacy) | LULC 2009 Mined and reclaimed mine lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP); Abandoned mine lands (WVDEP) | Source of pollutants and sedimentation | Merge all mining polygons, Identity to planning unit and calculate to get square miles per planning unit | 2 |
| UndrgrndMine1 | Underground mining | Underground mining (WVGES) | Potential impacts to water quality from acid mine drainage | Identity to planning and calculate to get square miles per planning unit | 2[b] |
| TotalCoalProd | Total coal production | Coal production: 2000-2010 (US EIA) | Not considered in final analysis | Calculate cumulative mine production totals in Excel, Join table, distribute by percent area active mining per county, calculate per planning unit | 0[a] |
| MinOps | Mineral operations | Mineral operations (USGS) | Not considered in final analysis | Spatial join to get number per planning unit | 0[d] |
| Timber | Timber harvesting | Timber operations (WVDOF) | Not considered in final analysis | Identity to planning unit and Dissolve to get total square miles per planning unit | 0[f] |
| NPDES | National Pollutant Discharge Elimination System permit sites | NPDES permit sites (WVDEP) | Not considered in final analysis | Select features where perm_type: Industrial, Sewage; iut_code: OUTLT, CSO, Spatial Join to get number per planning unit, normalize by stream miles per planning unit | 0[a] |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| CoalNPDES | Coal-related NPDES permit sites | Coal NPDES (WVDEP) | Not considered in final analysis | Spatial Join to get number per planning unit | 0[a] |
| Ag | Agriculture | LULC 2009 (WVU NRAC) | Not considered in final analysis | Convert raster to polygon, Select features where Value: 82, Identity to planning unit and calculate square miles per planning unit | 0[a,c] |
| Graze | Grazing | LULC 2009 (WVU NRAC) | Not considered in final analysis | Convert raster to polygon, Select features where Value: 81, Identity to planning unit and calculate square miles per planning unit | 0[a,c] |
| Developed | Development | LULC 2009 (WVU NRAC) | Not considered in final analysis | Convert raster to polygon, Select features where Value: 20, Identity to planning unit and calculate square miles per planning unit | 0[a,c] |
| AgRip1 | Agriculture in riparian area | LULC 2009 (WVU NRAC) | Potential source of pollutants and sedimentation in stream | Convert raster to polygon, Select features where Value: 82, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit | 1 |
| GrazeRip1 | Grazing in riparian area | LULC 2009 (WVU NRAC) | Potential source of sedimentation in stream | Convert raster to polygon, Select features where Value: 81, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit | 1 |
| DevelopedRip1 | Development in riparian area | LULC 2009 (WVU NRAC) | Potential source of pollutants and sedimentation in stream (from run off and construction) | Convert raster to polygon, Select features where Value: 20, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit | 1 |
| NatCoverRip1 | Natural cover in riparian area | LULC 2009 (WVU NRAC) | Can identify natural conditions of resiliency and riparian health in watershed | Convert raster to polygon, Clip to riparian area, Select features with values: 41, 42, 43, 71, 91, 92, Identity to planning unit and Dissolve to get square miles per planning unit | 2 |
| NatcoverHdwtr | Natural cover in headwater stream catchments | LULC 2009 (WVU NRAC) | Not considered in final analysis | Convert raster to polygon, Select features with values: 41, 42, 43, 71, 91, 92, Select catchments containing headwater streams, Clip Natural Cover to headwater catchments, Identity to planning unit and Dissolve to get square miles per planning unit | 0[a] |
| AllRdRail | Road/railroad density | Roads (WVDOT); Railroads (WVDNR) | Potential source of sedimentation in stream | Merge shapefiles, Identity to planning unit and calculate miles per planning unit | 1.5 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| AllRdRailRip1 | Road/railroad density in riparian area | | Not considered in final analysis | Merge shapefiles, Clip to riparian area, Identity to planning unit and calculate miles per planning unit | 0[a] |
| Superfund | Superfund sites | Superfund sites (USEPA Envirofacts) | Not considered in final analysis | Select values where CERC1_INT = superfund NPL, Spatial Join to get number per planning unit | 0[d] |
| TSD | Toxic waste storage and disposal | Hazardous waste disposal sites (USEPA Envirofacts) | Not considered in final analysis | Select features where value RCRA1_INT, RCRA2_INT, or RCRA3_INT = TSD, Spatial Join to get number per planning unit | 0[d] |
| BoatLaunch | Recreational boat launches | Boat launches (WVDNR) | Not considered in final analysis | Spatial Join to get number per planning unit | 0[d] |
| Septic | Potential septic systems | Septic systems (WVFO generated) | Not considered in final analysis | Digitize sewer areas from WV IJDC GIS Data Portal, Erase structure points that fall within these areas, Clip to riparian area, Spatial Join to get number per planning unit | 0[a,c] |
| SepticRip | Potential septic systems in riparian area | | Not considered in final analysis | | 0[b] |
| Landfill | Landfills | Landfills (WVDEP) | Not considered in final analysis | Spatial Join to get number per planning unit | 0[b,d] |
| **WATER QUANTITY** | | | | | |
| PWS | Public water supply intakes | Public water supply intakes (DHHR) | Points of water withdrawal from stream | Select any features except wells, Spatial Join to get number per planning unit, normalize by stream mile | 0.5 |
| LQU | Large quantity users | Large quantity users (WVDEP) | Potential flow alteration from large quantity water withdrawals | Select features where Size class 1(a,b) and 2, find LQU along those stream reaches | 2 |
| LQU3yr | Large quantity users 3 Year Average water use | | Not considered in final analysis | | 0[f] |
| PWSTrib | Tributaries draining to a public water supply reservoir | Public water supply (DHHR) tributaries (NHD 24K) | Not considered in final analysis | stream segments draining to PWS reservoir; FAC_TYPE: IN, RS | 0[d] |
| WWTP | Wastewater treatment plants | Sewer treatment plants (WVDEP) | Potential flow alteration from treated water discharges | Select features where sub_desc: Ind POTW, Spatial Join to get number per planning unit, normalize by stream miles | 0.5[e] |
| DamDrainage | Dam drainage areas (catchment above dam sites) | Dam drainage area (WVFO generated) | Surrogate for potential flow alteration and dam storage capacity | Select NHDPlus catchments that drain to dam point along stream, Identity to planning unit and Dissolve to get square miles per planning unit | 1[b] |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| Imperv2* | Percent imperviousness | NLCD Impervious surface (USGS) | Surrogate for potential flow alteration from stormwater run off | Convert raster to polgyon, Identity to planning unit, Dissolve to get mean percent imperviousness per planning unit | 1.5[b] |
| ActiveSurface2 | Active surface mining | LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP) | Not considered in final analysis | Merge mining polygons, identity to planning unit and calculate square miles per planning unit | 0[f] |
| LegacySurfaceRip1 | Legacy surface mining in riparian area | LULC 2009 reclaimed mine lands (WVU NRAC); Abandoned mine lands (WVDEP) | Not considered in final analysis | Merge mining polygons, identity to planning unit and calculate square miles per planning unit | 0[f] |
| SurfaceMine2 | Surface mining (active and legacy) | LULC 2009 Mined and reclaimed mine lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP); Abandoned mine lands (WVDEP) | Source of pollutants and sedimentation | Merge all mining polygons, Identity to planning unit and calculate to get square miles per planning unit | 1 |
| UndrgrndMine2 | Underground mining | Underground mining (WVGES) | Surrogate for potential flow alteration from mining discharge | Identity to planning and calculate to get square miles per planning unit | 1.5[b] |
| LowFlow | Low flow impaired streams | Low flow impaired streams (WVDEP) | Not considered in final analysis | Select features where Cause: Low Flow, Identity to planning unit and calculate miles per planning unit | 0[d] |
| Consum | Consumptive water use | Consumptive use data (USGS) | Not considered in final analysis | Sum of consumptive and non-comsumptive water usage by county | 0[g] |
| NonConsum | Non-consumptive water use | | Not considered in final analysis | | 0[g] |
| **HYDROLOGIC CONNECTIVITY** | | | | | |
| Unimpeded | Unimpeded streams | Functional river network (TNC - ERO) | Not considered in final analysis | Select features where value N_SZCL > = 4, Identity to planning and Dissolve to get miles per planning unit | 0[e] |
| TempImp | Temperature impaired streams | 303(d) Listed Impaired Streams - Temperature (WVDEP) | Not considered in final analysis | Select features where Cause: Temp Identity to planning unit and calculate miles per planning unit | 0[d] |
| Hdwtrs | Headwater streams | Headwaters (NHD 24K) | Prioritize headwaters streams | Select features where Stream Order = 1,2, Identity to planning unit and Dissolve to get stream miles per planning unit | 1.5[b] |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| LocInt | Mean local integrity score | Local integrity (TNC - ERO/PAFO) | Measure of local connectedness of landscape | Convert raster to polygon; Identity to planning unit, dissolve to mean gridcode | 1 |
| LocIntHdwtr | Local integrity of headwater stream catchments | Local integrity/Headwater catchments (TNC - ERO/PAFO) | Not considered in final analysis | local integrity score (grid_code); Headwater catchments | 0[a] |
| WetArea | Wetland area | NWI Wetlands (FWS) | Prioritize planning units with greater wetland areas | Type: Freshwater emergent wetland, Freshwater forested/shrub wetland | 1 |
| PowPlants | Power plants | Power plants (Ventyx) | Identify potential temperature increase from power plant discharges in entire stream segments as a potential fragmenting feature | Select streams features where size class = 1(a,b) and 2 streams, Select by location any power plant points along stream, Spatial join to get number per planning unit | 0.5 |
| Forestriparea | Forested riparian area | LULC 2009 (WVU NRAC) | Identify potential temperature maintenance from canopy cover of stream segments | Convert raster to polygon, Select features where Value: 41, 42, 43, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit | 1.5[b] |
| Dams | Dams | Dams (TNC - ERO) | Fragmenting features that inhibit fish passage and natural flow levels within stream networks | Select features where Use = 1,2, spatial join to get number per planning unit | 1.5[b] |
| Culverts | Potential culverts | Culverts (WVFO generated) | Not considered in final analysis | Headwater streams/roadRR crossings; Bridges over headwater streams | 0[a] |
| Bridges | Bridges | Bridges (WVDOT) | Not considered in final analysis | Bridges over non-headwater streams | 0[a] |
| AllRdRailRip2 | Road/railroad density in riparian area | Roads (WVDOT); Railroads (WVDNR) | Potential source of sedimentation in stream | Merge shapefiles, Identity to planning unit and calculate miles per planning unit | 2 |
| **BIODIVERSITY** | | | | | |
| AllSGNCRip | Species in Greatest Need of Conservation in riparian area | SGCNs (WVDNR) | Identify and prioritize known locations of rare, endangered or threatened species | Select features that are G1-G3, S1-S3, Federally listed, Clip to riparian area, Spatial Join to get number per planning unit | 1.5 |
| Muss | Mussel streams | Mussel streams (WVFO generated) | Stream quality indicator | Identity to planning unit and Dissolve to get miles per planning unit | 1 |
| Trout | Trout streams | Trout streams (WVDEP) | Not considered in final analysis | Identity to planning unit and Dissolve to get miles per planning unit | 0[d] |
| MedTaxa | Median taxa richness | Taxa richness (WVDEP) | Not considered in final analysis | GLIMPSS_CF taxa | 0[f] |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| MaxTaxa | Maximum taxa richness | Taxa richness (WVDEP) | Indicator of habitat quality | GLIMPSS_CF taxa | 1[b] |
| NEHabRip | Northeast terrestrial habitat types | NE terrestrial habitat types (TNC - ERO) | Higher diversity of habitat types leads to greater species diversity | Convert raster to polygon, Clip to riparian area, Identity to planning unit and Dissolve to get count per planning unit | 1 |
| SpeciesPredict | Species diversity prediction index | Ecological Land Units (TNC - ERO) | Considers landform variability measures as possible indicators of resilient sites for presence of rare species, both currently and in the future | Export tables to Excel, calculate # geology classes/elevation range/hectares calcareous bedrock per planning unit, normalize data, roll up into index by planning unit | 0[g] |
| CalcBedRip | Calcareous bedrock in riparian area | Ecological land units (TNC - ERO) | Contributes to soil structure and topography that support a variety of vegetative and animal species; partial predictor of rare species | Select features where GEOL_DESC = Calcareous sed/metased; Mod calcareous sed/metased, Clip to riparian area, Identity to planning unit, Dissolve to get square miles per planning unit | 1 |
| NNISRip | Non-native invasive species in riparian area | Non-native invasive species (WVDA/WVDNR) | Non-native invasive species displace natives; alter food webs | Spatial Join to get number per planning unit | 1.5 |
| Corbicula | Corbicula | Corbicula mussels (WVDEP) | Not considered in final analysis | None: Access database by planning unit | 0 |
| Carp | Carp | Carp (WVDEP) | Not considered in final analysis | None: Access database by planning unit | 0 |
| Zebras | Zebra mussel streams | Zebra Mussels (WVDNR) | Not considered in final analysis | Identity to planning unit, Dissolve to get stream miles per planning unit | 0 |
| Infected | Quarantined/Infested/Infected counties | Quarantined/Infested/Infected counties (WVDA) | Not considered in final analysis | Sum number per county, Identity to planning unit and Dissolve to get mean per planning unit | 0[a] |
| **RIPARIAN HABITAT** | | | | | |
| NatcoverRip2 | Natural cover in riparian area | LULC 2009 (WVU NRAC) | Functional contribution in terms of water storage and filtration | Convert raster to polygon, Select Codes 41, 42, 43, 52, 71, 90, 95, Clip to riparian area, Identity to planning unit, Dissolve to get square miles per planning unit | 2[b] |
| AgRip2 | Agriculture in riparian area | LULC 2009 (WVU NRAC) | Source of sediments and other pollutants | Convert raster to polygon, Select Code 82, Clip to riparian area, Identity to planning unit, Dissolve to get square miles per planning unit | 1 |
| GrazeRip2 | Grazing in riparian area | LULC 2009 (WVU NRAC) | Source of sedimentation | Convert raster to polygon, Select Code 81, Clip to riparian area, Identity to planning unit, Dissolve to get square miles per planning unit | 1 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| DevelopedRip2 | Development in riparian area | LULC 2009 (WVU NRAC) | Source of sedimentation and other pollutants | Convert raster to polygon, Select Code 20, Clip to riparian area, Identity to planning unit, Dissolve to get square miles per planning unit | 0[f] |
| ImpervRip* | Percent imperviousness in riparian area | NLCD Impervious surface (USGS) | Generates increased run off as potential non-point source of pollution to streams | Convert raster to polgyon, Clip to riparian area, Identity to planning unit, Dissolve to get mean percent imperviousness per planning unit | 2 |
| MedRBP | Median Rapid Bioassessment Protocol score | WAB database (WVDEP) | Indicator of stream physical habitat quality | Median total RBP index: 100: <60, 200: <110, 300: <160, 400: >=160 | 1 |
| MedBSS | Median Bank Stability score | | Not considered in final analysis | Median RBP Bank Stability Score index: 100: <6, 200: <16, 300: <17, 400: >=16 | 0 |
| ActiveSurfaceRip2* | Active surface mining in riparian area | LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP) | Source of sediments and other pollutants | Merge mining polygons, Identity to planning unit and calculate square miles per planning unit | 2 |
| LegacySurfaceRip | Legacy surface mining in riparian area | LULC 2009 reclaimed mine lands (WVU NRAC); Abandoned mine lands (WVDEP) | Source of sediments and other pollutants | Merge mining polygons, Identity to planning unit and calculate square miles per planning unit | 1 |
| AllWellsRip | Wells in riparian area | Wells (WVDEP) | Source of sediments and other pollutants | Spatial Join to get number per planning unit | 1 |
| AllRdRailRip3 | Roal/railroads in riparian area | Roads (WVDOT); Railroads (WVDNR) | Source of sediments and other pollutants | Merge shapefiles, Clip to riparian area, Identity to planning unit and calculate miles per planning unit | 1.5 |
| EnergyRip | Energy transmission lines in riparian area | Energy transmission lines (Ventyx) | Not considered in final analysis | Clip to riparian area, Identity to planning unit and calculate miles per planning unit | 0[f] |
| PipeRip | Pipelines in riparian area | Pipelines (Ventyx) | Not considered in final analysis | Clip to riparian area, Identity to planning unit and calculate miles per planning unit | 0 |
| WindRip | Wind turbines in riparian area | Wind turbines (TNC - PAFO) | Not considered in final analysis | Spatial join to get number per planning unit | 0[b,d] |
| BldgsRip | Buildings in riparian area | Structure points (WVSAMB) | Not considered in final analysis | Spatial join to get number per planning unit | 0[a,b] |
| **PROTECTED LANDS** | | | | | |
| GAP1Rip | GAP Status 1 in riparian area | Secured lands (TNC) | Not considered in final analysis | Select features where value GAP_STATUS: 1, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit | 0[f] |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| GAP2Rip | GAP Status 2 in riparian area | Secured lands (TNC) | Not considered in final analysis | Select features where value GAP_STATUS: 2, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit | 0[f] |
| GAP3Rip | GAP Status 3 in riparian area | Secured lands (TNC) | Not considered in final analysis | Select features where value GAP_STATUS: 3, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit | 0[f] |

## Wetlands

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| **WATER QUALITY: POLLUTANT FILTRATION/SEDIMENT RETENTION** | | | | | |
| ForestHdwtrWet1 | Forested headwater wetlands | 2009 LULC (WVU NRAC); Wetlands (NWI); Headwater streams (NHD 24K) | Functional contribution in terms of water storage and filtration | Select wetland buffers within 50 m of headwater stream, Clip forested landcover to wetland buffer, Identity to planning unit and Dissolve to get square miles per planning unit | 2 |
| AgWet1 | Agriculture in wetland buffer | 2009 LULC (WVU NRAC) | Not considered in final analysis | Convert raster to polygon, Select features where Value: 82, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit | 0[c] |
| GrazeWet1 | Grazing in wetland buffer | 2009 LULC (WVU NRAC) | Source of sedimentation | Convert raster to polygon, Select features where Value: 81, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit | 0[f] |
| DevelopedWet1 | Development in wetland buffer | 2009 LULC (WVU NRAC) | Not considered in final analysis | Convert raster to polygon, Select features where Value: 20, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit | 0[c] |
| AgCatch | Agriculture in wetland catchment | 2009 LULC (WVU NRAC) | Source of sediments and other pollutants | Convert raster to polygon, Select features where Value: 82, Clip to wetland catchment, Identity to planning unit and calculate square miles per planning unit | 1 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| GrazeCatch | Grazing in wetland catchment | 2009 LULC (WVU NRAC) | Not considered in final analysis | Convert raster to polygon, Select features where Value: 81, Clip to wetland catchment, Identity to planning unit and calculate square miles per planning unit | 1 |
| DevelopedCatch | Developed in wetland catchment | | Source of sediments and other pollutants | Convert raster to polygon, Select features where Value: 20, Clip to wetland catchment, Identity to planning unit and calculate square miles per planning unit | 1 |
| ForestCatch | Forest Cover in wetland catchment | | Not considered in final analysis | Convert raster to polygon, Select features where Value: 41, 42, 43, Clip to wetland catchment, Identity to planning unit and calculate square miles per planning unit | 0[a] |
| NatCoverCatch | Natural Cover in wetland catchment | | Functional contribution in terms of water storage and filtration | Convert raster to polygon, Select Codes 41, 42, 43, 52, 71, 90, 95, Clip to wetland catchment, Identity to planning unit, Dissolve to get square miles per planning unit | 3[b] |
| ImpervWet | Percent imperviousness of wetland buffer | NLCD 2006 Impervious surface (USGS) | Not considered in final analysis | Convert raster to polgyon, Identity to planning unit, Dissolve to get mean percent imperviousness per planning unit | 0[c] |
| ImpervCatch | Percent imperviousness of wetland catchment | | Source of sediments and other pollutants | | 1[b] |
| RoadsRRCatch | Roads/railroads in wetland catchment | Roads/rail | Not considered in final analysis | Merge shapefiles, Clip to wetland catchment, Identity to planning unit and calculate miles per planning unit | 1 |
| NPDESCatch | NPDES permits in wetland catchment | NPDES sites (WVDEP) | Not considered in final analysis | Spatial join to get number per planning unit | 0 |
| ActiveSurfaceWet1 | Active surface mining in wetland buffer | LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP) | Not considered in final analysis | Merge mining polygons, Clip to wetland buffer, Identity to planning unit and calculate to get square miles per planning unit | 0[c] |
| ActiveSurfaceCatch | Active surface mining in wetland catchment | | Source of sediments and other pollutants | Merge mining polygons, Clip to wetland catchment, Identity to planning unit and calculate to get square miles per planning unit | 2 |
| SurfaceCoalProd | Surface coal production | Coal production 2000-2010 (US EIA) | Not considered in final analysis | Calculate cumulative mine production totals in Excel, Join table, distribute by percent area active mining per county, calculate per planning unit | 0 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| DistAllWells | Distance to wells | Oil and gas wells (WVDEP) | Not considered in final analysis | Distance tool to get distance from wetland to well; Dissolve to get average distance | 0[d] |
| AllWellsCatch | Wells within wetland catchment | | Source of sediments and other pollutants | Clip shapefile to wetland catchment; Spatial join to get number per planning unit | 1 |
| SepticWet | Septic systems in wetland buffer | Septic systems as structure points which fall outside of sewer area boundaries (digitized from WV IJDC GIS Data Portal) | Not considered in final analysis | Spatial join to get number per planning unit | 0[f] |
| SepticCatch | Septic systems in wetland catchment | | Not considered in final analysis | Clip to wetland catchment; Spatial join to get number per planning unit | 0[f] |
| LandfillCatch | Landfills in wetland catchment | Landfills (WVDEP) | Not considered in final analysis | Clip to wetland catchment; Spatial join to get number per planning unit | 0[b,d] |
| MinOpsCatch | Mineral operations in wetland catchment | Mineral operations (USGS) | Not considered in final analysis | Clip to wetland catchment; Spatial join to get number per planning unit | 0[d] |
| TimberCatch | Timber harvesting in wetland catchment | Timber operations (WVDOF) | Not considered in final analysis | Clip to wetland catchment; Spatial join to get number per planning unit | 0[f] |
| **HYDROLOGY: FLOOD STORAGE/CONNECTIVITY** | | | | | |
| WetSize | Mean wetland size | Wetlands (NWI) | Not considered in final analysis | Select features where type: Freshwater emergent wetland, Freshwater forested/shrub wetland, Identity to planning unit, Dissolve to get mean size per planning unit | 0[a] |
| WetArea | Total wetland area | | Prioritize planning units with greater wetland areas | Select features where type: Freshwater emergent wetland, Freshwater forested/shrub wetland, Identity to planning unit, calculate square miles per planning unit | 2[b] |
| ForestHdwtrWet2 | Forested headwater wetlands | 2009 LULC (WVU NRAC); Wetlands (NWI); Headwater streams (NHD 24K) | Functional contribution in terms of water storage and filtration | Select wetland buffers within 50 m of headwater stream, Clip forested landcover to wetland buffer, Identity to planning unit and Dissolve to get square miles per planning unit | 1 |
| RatioCatchWet | Ratio of wetland area to wetland catchment area | Wetlands (NWI); Wetland catchments (based on NHDPlus) | Not considered in final analysis | Export Excel tables of wetland area and wetland catchment values, sum per planning unit, divide area by catchment | 0[c] |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| DistNearWtr | Distance to nearest surface water feature | Surface water features (NWI Wetlands, NHD24K Hydrography) | Not considered in final analysis | Distance tool to get distance from wetland to streams layer; Dissolve to get average distance | 0[d] |
| HdwtrWet | Headwater wetlands | Wetlands (NWI); Headwater streams (NHD 24K) | Not considered in final analysis | Select wetland buffers within 50 m of headwater stream, Identity to planning unit and Dissolve to get square miles per planning unit | 0[a] |
| FldForestWet | Forested wetlands within the floodplain | Floodplain (FEMA); Wetlands (NWI) | Functional role for flood storage capacity, indicates areas of potential wetland development | Clip forest cover to wetland buffer; Clip to floodplain; Identity to planning unit and Dissolve to square miles per planning unit. | 1[b] |
| FloodArea | Floodplain area | | | Identity to planning unit; Dissolve to get square miles per planning unit | 1[b] |
| Hydricsoils | Hydric soils | Hydric soils (SSURGO) | Indicator of conditions suitable for potential wetland development | Use Soil Data Viewer to generate Hydric Rating by Map Unit, Select hydric, partially hydric soils, Identity to planning unit and calculate square miles per planning unit | 1.5[b] |
| **BIODIVERSITY** | | | | | |
| AllSGNCWet | Species in Greatest Need of Conservation in wetland buffer | SGCNs (WVDNR) | Identify and prioritize known locations of rare, endangered or threatened species | Select features that are G1-G3, S1-S3, Federally listed, Clip to wetland buffer, Spatial Join to get number per planning unit | 1.5 |
| SpeciesPredict | Species diversity prediction index | Ecological Land Units (TNC - ERO) | Not considered in final analysis | Export tables to Excel, calculate # geology classes/elevation range/hectares calcareous bedrock per planning unit, normalize data, roll up into index by planning unit | 0 |
| CalcBedWet | Calcareous bedrock in wetland buffer | Ecological land units (TNC - ERO) | Contributes to soil structure and topography that support a variety of vegetative and animal species; partial predictor of rare species | Select polygons where GEOL_DESC = Calcareous sed/metased; Mod calcareous sed/metased, Clip to wetland buffer, Identity to planning unit and Dissolve to get square miles per planning unit | 1 |
| KarstWet | Karst in wetland buffer | Karst features (WVGES) | Not considered in final analysis | Clip to wetland buffer, Identity to planning unit and Dissolve to get square miles per planning unit | 0[d] |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| NEHabWet | NE terrestrial habitat types in wetland buffer | NE terrestrial habitat types (TNC - ERO) | Higher diversity of habitat types leads to greater species diversity | Convert raster to polygon, Clip to wetland buffer, Identity to planning unit and Dissolve to get count per planning unit | 1 |
| NNISWet | Non-native invasive species in wetland buffer | Non-native invasive species (WVDA/WVDNR) | Non-native invasive species displace natives; alter food webs | Clip to wetland buffer, Spatial Join to get number per planning unit | 1.5 |
| Infected | Pest/pathogen infected counties | Quarantined/Infested/ Infected counties (WVDA) | Not considered in final analysis | Sum number per county, Identity to planning unit and Dissolve to get mean per planning unit | 0[d] |
| **WETLAND HABITAT** | | | | | |
| NatcoverWet | Natural Cover in wetland buffer | LULC 2009 (WVU NRAC) | Functional contribution in terms of water storage and filtration | Convert raster to polygon, Select Codes 41, 42, 43, 52, 71, 90, 95, Clip to wetland buffer, Identity to planning unit, Dissolve to get square miles per planning unit | 2 |
| AgWet2 | Agriculture in wetland buffer | 2009 LULC (WVU NRAC) | Not considered in final analysis | Convert raster to polygon, Select features where Value: 82, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit | 1 |
| GrazeWet2 | Grazing in wetland buffer | 2009 LULC (WVU NRAC) | Source of sedimentation | Convert raster to polygon, Select features where Value: 81, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit | 1 |
| DevelopedWet2 | Development in wetland buffer | 2009 LULC (WVU NRAC) | Not considered in final analysis | Convert raster to polygon, Select features where Value: 20, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit | 1 |
| WetForestPatchMax | Largest forest patch in wetland buffer | Forest Patches (TNC) | Not considered in final analysis | Select patches >100 acres, Clip to wetland buffer, Identity to planning unit and Dissolve to get maximum (in square miles) forest patch per planning unit | 0[a] |
| WetForestPatchMean | Mean forest patch in wetland buffer | Forest Patches (TNC) | Larger forest patches provide more habitat for wetland organisms, greater sediment retention and pollutant filtration | Select patches >100 acres, Clip to wetland buffer, Identity to planning unit and Dissolve to get mean (in square miles) forest patch per planning unit | 1 |
| AllWellsWet | Wells within wetland buffer | Oil and gas wells (WVDEP) | Fragmenting features within the landscape | Spatial join to get number per planning unit | 1.5 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| ActiveSurfaceWet2* | Active surface mining in wetland buffer | LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP) | Source of sediments and other pollutants | Merge mining polygons, identity to planning unit and calculate square miles per planning unit | 2 |
| LegacySurfaceWet | Legacy surface mining in wetland buffer | LULC 2009 reclaimed mine lands (WVU NRAC); Abandoned mine lands (WVDEP) | Source of sediments and other pollutants | Merge mining polygons, identity to planning unit and calculate square miles per planning unit | 1 |
| RoadsRRWet | Roads/railroads in wetland buffer | Roads (WVDOT); Railroads (WVDNR) | Fragmenting features within the landscape | Merge shapefiles, Clip to wetland buffer, Identity to planning unit and calculate miles per planning unit | 1 |
| CulvertsWet | Culverts in wetland buffer | Road/railroad crossings (WVFO generated) | Not considered in final analysis | Select streams size class 1a and 1b, generate points for intersection of streams and roads/railroads, spatial join to get number per planning unit | 0 |
| EnergyWet | Energy lines in wetland buffer | Energy transmission lines (Ventyx) | Not considered in final analysis | Identity to planning unit and calculate miles per planning unit | 0 |
| PipeWet | Pipelines in wetland buffer | Pipelines (Ventyx) | Not considered in final analysis | Identity to planning unit and calculate miles per planning unit | 0 |
| BldgsWet | Buildings in wetland buffer | Structure points (WVSAMB) | Not considered in final analysis | Spatial join to get number per planning unit | 0[b] |
| **PROTECTED LANDS** | | | | | |
| UnsecnatcoverWet | Natural cover in wetland buffer within unsecured lands | LULC 2009 (WVU NRAC) | Not considered in final analysis | Convert raster to polygon, select codes 41, 42, 43, 52, 71, 90, 95, erase by secured lands, identity to planning unit and calculate square miles per planning unit | 0 |
| GAP1Wet | GAP Status 1 in wetland buffer | Secured lands (TNC) | Not considered in final analysis | Select features where value GAP_STATUS: 1, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit | 0[f] |
| GAP2Wet | GAP Status 2 in wetland buffer | Secured lands (TNC) | Not considered in final analysis | Select features where value GAP_STATUS: 2, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit | 0[f] |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| GAP3Wet | GAP Status 3 in wetland buffer | Secured lands (TNC) | Not considered in final analysis | Select features where value GAP_STATUS: 3, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit | 0[f] |

## Uplands

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| **HABITAT CONNECTIVITY** | | | | | |
| LgstForest | Largest intersecting forest block | Forest patches (TNC) | Not considered in final analysis | Select forest patches >100 acres; Create shapefile from forest patches layer crossed by/within watershed outline; calculate geometry, identity to planning unit, dissolve to max forest patch size | 0 |
| ForestSize | Mean intersecting forest block | Forest patches (TNC) | Large forest blocks provide more habitat for greater species diversity | Select forest patches >100 acres; Create shapefile from forest patches layer crossed by/within watershed outline; calculate geometry, identity to planning unit, dissolve to mean forest patch size | 2 |
| LocInt | Mean local integrity score | Local integrity (TNC - ERO/PAFO) | Measure of local connectedness of landscape | Convert raster to polygon; Identity to planning unit, dissolve to mean gridcode | 1.5 |
| Developed1* | Development | LULC 2009 (WVU NRAC) | Structures and roads eliminate and fragment habitat | Identity to planning unit and Dissolve to get total square miles per planning unit | 1.5 |
| AllRdRail | Roads/railroads | Roads (WVDOT); Railroads (WVDNR) | Potential fragmenting feature | Identity to planning unit and Dissolve to get total miles per planning unit | 1 |
| Energy | Energy transmission lines | Energy transmission lines (Ventyx) | Potential fragmenting feature | Identity to planning unit and Dissolve to get total miles per planning unit | 0.5 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| Pipe | Pipelines | Pipelines (Ventyx) | Potential fragmenting feature | Identity to planning unit and Dissolve to get total miles per planning unit | 0.5 |
| Wind | Wind turbines | Wind turbines (TNC - PAFO) | Potential fragmenting feature | Spatial Join to get number per planning unit | 0.5 |
| Bldgs | Buildings | Structure points (WVSAMB) | Not considered in final analysis | Spatial Join to get number per planning unit | 0[a,b] |
| Towers | FCC Towers | Towers (WVGISTC) | Not considered in final analysis | Spatial Join to get number per planning unit | 0[a] |
| AllWells | Wells | Oil and gas wells (WVDEP) | Potential fragmenting feature | Spatial Join to get number per planning unit | 1 |
| ActiveSurface1* | Active surface mining | LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP) | Eliminates and fragments habitat | Merge mining polygons, Identity to planning unit and calculate to get square miles per planning unit | 1.5 |
| SurfaceCoalProd | Coal production (2000-2010) | US EIA | Not considered in final analysis | Calculate cumulative mine production totals in Excel, Join table, distribute by percent area active mining per county, calculate per planning unit | 0[a] |
| MinOps | Mineral operations | USGS | Not considered in final analysis | Spatial Join to get number per planning unit | 0 |
| Timber1 | Timber harvesting | Timber operations (WVDOF) | Temporarily fragments and reduces quality of forest habitat | Identity to planning unit and Dissolve to get total square miles per planning unit | 0.5 |
| Landfill | Landfills | Landfills (WVDEP) | Not considered in final analysis | Spatial Join to get number per planning unit | 0[b,d] |
| **HABITAT QUALITY** | | | | | |
| Hetero | Heterogeneity | ERO/PAFO | Heterogeneous landscapes have high potential for species diversity | Convert raster to polygon; Identity to planning unit, dissolve to mean grid code | 2 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| FRCC | Vegetation altered from reference condition | Fire Regime Condition Class (LANDFIRE) | Not considered in final analysis | Convert raster to polygon; Create new layer from gridcode =1; Identity to planning unit, dissolve to get total square miles per planning unit | 0[g] |
| NatCover | Natural cover | LULC 2009 (WVU NRAC) | Natural cover indicates less disturbance, higher quality habitat for native species | Convert raster to polygon; Select features where Value: 41,42,43,71,92; Identity to planning unit and calculate sqare miles per planning unit | 2 |
| Karst | Karst features | Karst geology (WVDNR) | Not considered in final analysis | Identity to planning unit and Dissolve to get total square miles per planning unit | 0[d] |
| ActiveSurface2* | Active Surface mining | LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP) | Eliminates and fragments habitat | Merge mining polygons, Identity to planning unit and calculate to get square miles per planning unit | 1.5 |
| LegacySurface | Legacy Surface mining | Appalachian Voices/TNC digitized shapefile | Mine sites represent poor to sub-optimal quality habitat due to altered topography, soil structure, and vegetation | Merge mining polygons: non-active WVFO generated mining from aerials/topo; abandoned mine lands | 1 |
| Timber2 | Timber harvest | Timber operations (WVDOF) | Temporarily fragments and reduces quality of forest habitat | Identity to planning unit and Dissolve to get total square miles per planning unit | 1 |
| Ag | Agriculture | LULC 2009 (WVU NRAC) | Eliminates native species and original vegetation structure; alters soil structure and contributes to soil loss; not as destructive as development | Convert raster to polygon, Select features where Value: 82, Identity to planning unit and calculate square miles per planning unit | 1 |
| Graze | Grazing | LULC 2009 (WVU NRAC) | Eliminates native species and original vegetation structure/habitat; not as destructive as row-crop agriculture or development | Convert raster to polygon, Select features where Value: 81, Identity to planning unit and calculate square miles per planning unit | 1 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| Developed2* | Development | LULC 2009 (WVU NRAC) | Structures and roads eliminate and fragment habitat | Convert raster to polygon, Select features where Value: 20, Identity to planning unit and calculate square miles per planning unit | 1.5 |
| **BIODIVERSITY** | | | | | |
| AllSGNCUp | Species in Greatest Need of Conservation | SGCNs (WVDNR) | Identify and prioritize known locations of rare, endangered or threatened species | Select features that are G1-G3, S1-S3, Federally listed, Spatial Join to get number per planning unit | 1.5 |
| NEHab | Northeast terrestrial habitat types | NE terrestrial habitat types (TNC - ERO) | Higher diversity of habitat types leads to greater species diversity | Convert raster to polygon, Identity to planning unit and Dissolve to get count per planning unit | 1 |
| SpeciesPredict | Species diversity prediction index | Ecological Land Units (TNC - ERO) | Not considered in final analysis | Export tables to Excel, calculate # geology classes/elevation range/hectares calcareous bedrock per planning unit, normalize data, roll up into index by planning unit | 0 |
| CalcBed | Calcareous bedrock | Ecological land units (TNC - ERO) | Contributes to soil structure and topography that support a variety of vegetative and animal species; partial predictor of rare species | Select features where GEOL_DESC = Calcareous sed/metased; Mod calcareous sed/metased, Identity to planning unit, Dissolve to get square miles per planning unit | 1 |
| NNIS | Non-native invasive species | Non-native invasive species (WVDA/WVDNR) | Non-native invasive species replace natives in the landscape; alter food webs for animals that depend upon native plants for food and habitat | Spatial Join to get number per planning unit | 1.5 |
| PctLoss | Pests and Pathogens | Percent basal area loss (USFS) | Reduces native plant populations and the animal species that depend on them | Convert raster to polygon, clip to watershed; Identity to planning unit, calculate geometry; Add field Pct_PU, calculate (area of fragment)/(area of planning unit); Add field Wtd_Value, calculate pct_PU*gridcode for weighted value per planning unit. Dissolve by planning unit to sum Wtd_Value | 2 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| GypsyMoth | Pests and Pathogens | Percent basal area loss (USFS) | Not considered in final analysis | Convert raster to polygon, clip to watershed; Identity to planning unit, calculate geometry | 0[a] |
| HrdDecline | Pests and Pathogens | Percent basal area loss (USFS) | Not considered in final analysis | Convert raster to polygon, clip to watershed; Identity to planning unit, calculate geometry; Add field Pct_PU, calculate (area of fragment)/(area of planning unit); Add field Wtd_Value, calculate pct_PU*gridcode for weighted value per planning unit. Dissolve by planning unit to sum Wtd_Value | 0[a] |
| RdOakDecline | Pests and Pathogens | Percent basal area loss (USFS) | Not considered in final analysis | Convert raster to polygon, clip to watershed; Identity to planning unit, calculate geometry; Add field Pct_PU, calculate (area of fragment)/(area of planning unit); Add field Wtd_Value, calculate pct_PU*gridcode for weighted value per planning unit. Dissolve by planning unit to sum Wtd_Value | 0[a] |
| Infected | Quarantined/Infested/Infected counties | Quarantined/Infested/Infected counties (WVDA) | Not considered in final analysis | Sum number per county, Identity to planning unit and Dissolve to get mean per planning unit | 0[d] |
| EcoSubunits | Ecoregional subsections | Ecoregional subsections (TNC) | Not considered in final analysis | Identity to planning unit, dissolve to get count per planning unit | 0[g] |
| **PROTECTED LANDS** | | | | | |
| GAP1 | Secured lands | TNC | Not considered in final analysis | Select features where value GAP_STATUS: 1, Identity to planning unit and calculate square miles per planning unit | 0[f] |
| GAP2 | Secured lands | TNC | Not considered in final analysis | Select features where value GAP_STATUS: 2, Identity to planning unit and calculate square miles per planning unit | 0[f] |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| GAP3 | Secured lands | TNC | Not considered in final analysis | Select features where value GAP_STATUS: 3, Identity to planning unit and calculate square miles per planning unit | 0[f] |

## Consolidated Analysis

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| **ENERGY** | | | | | |
| UnminedPerbd | Potential coal mining activity | Unmined coal beds (WVGES); Mining permit boundary (WVDEP) | Assumed that unmined coal within existing permits would have high potential to be mined in the future | Normalize raster 0-100, reclass based on data, sum with relevant data layers | 2 |
| UnminedCoal | Potential coal mining activity within active mine permit boundary | Unmined coal beds (WVGES) | Used to estimate potential for future coal mining activity, assuming all coal beds are mineable | Normalize raster 0-100, reclass based on data, sum with relevant data layers | 2 |
| MSWellPot | Potential Marcellus Shale gas well development | Marcellus Shale thickness (WVGES) | Used to estimate potential for future gas well development, assuming greater thickness indicates greater potential | Normalize raster 0-100, reclass based on data, sum with relevant data layers | 2 |
| WindPot | Potential wind energy development | Wind energy potential (NREL) | Used to estimate potential for wind development | Select polygons with values > 3, Normalize raster 0-100, reclass based on data, sum with relevant data layers | 2 |
| PropWind | Proposed wind turbines | | Known locations of proposed future wind turbines | Spatial join to get number per HUC12 | 1 |
| PropEnergy | Proposed energy transmission lines | Ventyx | Known locations of proposed future energy lines | Identity to HUC12, calculate length in miles per HUC12 | 1 |
| PropPipe | Proposed gas pipelines | Ventyx | Known locations of proposed future energy lines | Identity to HUC12, calculate length in miles per HUC12 | 1 |
| PropPower | Proposed power plants | Ventyx | Known locations of proposed power plants | Spatial join to get number per HUC12 | 1 |
| Geothermal | Potential geothermal energy development | Geothermal energy potential (SMU Geothermal Lab/Google Earth) | Used to estimate potential for geothermal energy development | Select polygons with Temp (at depth 7.5 km) values > 150 degrees, Normalize raster 0-100, reclass based on data, sum with relevant data layers | 1 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| **POPULATION/ DEVELOPMENT** | | | | | |
| PopProject | Projected future population | County population estimates to 2030 (Christiadi 2011) | Estimates of future population growth as indicator of possible future land use scenarios (surrogate for potential increase in developed lands and infrastructure) | Join Excel table of data by county name, Convert to raster based on percent change, Normalize raster 0-100, reclass based on data, sum with relevant data layers | 1 |
| FutureGrowthArea | Potential future growth scenarios | Socioeconomic Data Forecasts - 2030 | Zoned areas of future development at various intensities | Digitize polygon of projected growth, Normalize raster 0-100, reclass based on data, sum with relevant data layers | 1 |
| DevelopPot | Potential development areas | Primary and Secondary Growth Areas (WVRPDC Region VI) | Projected economic development growth corridor | Digitize polygons of zoned future development, Normalize raster 0-100, reclass based on data, sum with relevant data layers | 1 |
| **CLIMATE CHANGE** | | | | | |
| Resiliency | Resiliency | Resiliency (TNC - ERO/PAFO) | Resilient landscapes have greater potential to preserve species diversity in the face of climate change due to landscape heterogeneity and permeability | Normalize raster 0-100, reclass based on data, sum with relevant data layers | 1 |
| CurrDens | Regional flow | Current density/Regional flow (TNC - ERO/PAFO) | Identify areas with high permeability and concentrated key linkages for species movement/adaptation to climate change | Normalize raster 0-100, reclass based on data, sum with relevant data layers | 0 |
| ClimateWizPrec | Potential future precipitation changes | Climate Wizard (TNC) | Estimates of future increases in precipitation, which will affect species and vegetation distribution | Generate map from Climate Wizard for: Medium Emissions, 2050s, precipitation change, annual, digitize, identity to HUC12 and dissolve for mean precipitation change | 0[g] |
| ClimateWizTemp | Potential future temperature changes | Climate Wizard (TNC) | Estimates of future increases in temperature, which will affect species and vegetation distribution | Medium Emissions, 2050s, temperature change, annual | 0[g] |
| **PRIORITY INTEREST AREAS** | | | | | |
| AquaPort | TNC aquatic portfolio streams | Aquatic portfolio (TNC) | Identify streams of known high value | Data intended as informational overlay, no analysis conducted | 1 |

| Metric Name | Metric Description | Data (Source) | Rationale | GIS Process | Weight |
|---|---|---|---|---|---|
| TerrPort | TNC terrestrial portfolio sites | Terrestrial portfolio (TNC) | Identify land of known high value | Data intended as informational overlay, no analysis conducted | 1 |
| USFSProBndy | USFS priority areas | National Forest proclamation boundary (USFS) | Identify land that the Forest Service has deemed a priority to acquire | Data intended as informational overlay, no analysis conducted | 1 |
| NPS | National Park Service priority areas | NPS priority areas (NPS) | Identify land that NPS has deemed a priority in future planning | Data intended as informational overlay, no analysis conducted | 1 |
| DOFPrior | WV Division of Forestry priority areas | WVDOF | Identify HUC12s that WV Division of Forestry has analyzed as high priority for water quality | Select poygons where layScr11 > 20. Data intended as informational overlay, no analysis conducted | 1 |

*Metrics that are identified as "critical metrics" within an index (see Section 3.3.3 for detailed explanation)

[a] Highly correlated (r = 0.75- 1.00) with one or more other metrics
[b] Expert opinion/Literature
[c] Metric with different spatial extent considered more appropriate; e.g., grazing in riparian buffer instead of grazing in entire planning unit
[d] Metric insufficiently represented among planning units
[e] Project team decision
[f] Data effectively represented by or captured within other metric or index
[g] Data at insufficient resolution for scale of analysis (e.g. county or regional level data)

## *Appendix C: Detailed Full Project Timeline*

| Month | Activity |
|---|---|
| March 18, 2011 | Grant award signed by DEP |
| April 1, 2011 | Sub-award agreement between DEP and TNC, project timeline starts |
| April 15, 2011 | Quarterly report (1) for January, February, March due |
| June 1, 2011 | Draft assessment methodology completed, Baseline data set identification and compilation begins for 2 watersheds, QAP Plan developed and submitted for review |
| June 13, 2011 | Technical Advisory Team 1st meeting |
| July 15, 2011 | Quarterly report (2) for April, May, June due |
| **Oct 1, 2011** | QAP Plan completed, Baseline data collection completed |
| Oct 15, 2011 | Quarterly Report (3) for July, August, September submitted |
| Oct 26, 2011 | 1st Expert Workshop on 2 watersheds completed, Consolidated analysis data development and revisions begin |
| Jan 15, 2012 | Quarterly Report (4) for October, November, December submitted |
| Jan 31, 2012 | Consolidated analysis data development and revisions completed, 2nd expert workshop held, strategy development completed in 2 watersheds |
| March 1, 2012 | Draft assessments completed in 2 watersheds |
| April 5, 2012 | Decision maker and end user workshops held. Final revisions made and sent out for peer review. |
| April 15, 2012 | Quarterly Report (5) for January, February, March submitted |
| June 15, 2012 | Quarterly Report (6) for April, May, June submitted |
| **June 29, 2012** | Peer review completed. Final assessment reports on 2 watersheds completed, assessment methodology report completed. Begin Baseline data collection on remaining 3 watersheds. |
| Sept 1, 2012 | Baseline data collection completed on remaining 3 watersheds |
| Oct 11, 2012 | 1st expert workshops on remaining watersheds |
| Oct 15, 2012 | Quarterly Report (7) for July, August, September submitted |
| Jan 1, 2013 | Draft assessments completed in remaining 3 watersheds |
| Jan 8, 2013 | Revisions completed in remaining 3 watersheds, draft web tool demonstrated, 2nd expert workshops held |
| Jan 15, 2013 | Quarterly Report (8) for October, November, December submitted |
| April 15, 2013 | Quarterly Report (9) for January, February, March submitted |
| May 8, 2013 | Decision maker and end user workshops held. Final revisions made on 3 watersheds |
| **Dec 31, 2013** | Final assessment reports on all 5 watersheds completed, assessment methodology report revisions made. Final report and all completed deliverables, including interactive first version of web tool, submitted |

*Appendix D: Workshop Notes and Attendees*

**West Virginia Watershed Assessment Pilot Project**
**Gauley, Upper Guyandotte, and Little Kanawha Watersheds**
**First Expert Workshop Summary**
**October 10-11, 2012**
**Bridgeport, West Virginia**

## Workshop Objectives

The goals of this workshop were to:
1) present the recently developed objective method of watershed classification and obtain experts' opinions and suggestions;
2) present the results of the condition assessments for the final three of five pilot watersheds: the Gauley, Upper Guyandotte, and Little Kanawha, and request feedback from the experts on any knowledge of issues in these watersheds; and
3) request expert feedback on desirable features for the interactive web tool that will be developed for the assessment.

**Workshop Day 1**
**October 10, 2012**

## Presentation Summary

The workshop began with a review of the project goals and timeline, as well as a brief review of the watershed assessment structure: landscapes, indices, and metrics. The team then presented the new objective method of classifying the results, followed by reports on the assessment results for the Upper Guyandotte and Gauley watersheds. An open discussion followed each presentation, during which experts who had not attended previous workshops requested further information, and experts familiar with the project offered suggestions and additional questions. Overview maps of the Upper Guyandotte and Gauley watersheds were displayed for reference. After the watershed presentations, the Team's final list of metrics and weights was reviewed with the experts.

## Objective Methodology

*Ruth Thornton, TNC*

Ruth presented the project background and a summary of the methodology. A particular emphasis was the presentation of the objective ranking of planning units, for which the Team used the DEP's Reference and Stressed catchments to determine the values for all metrics in the three models. This resulted in the establishment of thresholds to place planning units into four objective categories: Very Good, Good, Fair, and Poor.

A list of metrics and the objective thresholds used was provided to the experts. Handouts showing results maps for the Little Kanawha watershed illustrated the differences between the objective and relative methods of classification, which ranks each HUC12 or NHDPlus catchment relative to the others within the HUC8 watershed.

## Overview of Upper Guyandotte Watershed Results

*Diane Packett, TNC*

There is a large amount of active and legacy surface mining, as well as underground mining, in the Upper Guyandotte watershed, especially in the northwest and southeast areas. There are many wells, but little concentrated development except in the Logan area. Most of the major tributaries of the Guyandotte River are impaired. There are GAP 2 & 3 Protected Lands, including several WMAs and one state park.

Comments: Experts noted that the Coal Field Expressway and King Coal Highways are currently under construction and can be added to the Consolidated Analysis. An expert also suggested the possibility of including the Hatfield – McCoy ATV trails.

## Overview of Gauley Watershed Results

*Misty Downing, TNC*

The Gauley watershed is notable for a large area of undeveloped Wilderness Area, and the large Meadow River wetland complex in the southern portion. There is some surface and underground mining, and gas development occurs in the northwestern portion of the watershed. Experts noted that acid precipitation is a current and future threat to the unbuffered soils, especially in the Cranberry Wilderness.

## Metrics and Weighting: Discussion Summary

*Ruth Thornton, TNC*

After introducing the first two watersheds, the team reviewed with the experts the final list of metrics used for each condition index for each of the three landscape models (Streams, Wetlands, and Uplands) along with their weights in the assessment. Experts were provided with a list of metrics that were dropped from, and retained in, the analysis (based on expert opinion, correlation, regression, and Principal Components Analysis).

TNC then facilitated a breakout session with two groups to discuss the metrics, thresholds, weighting, and categorization methods. Specific questions that participants were asked to consider were:

- Are thresholds defined appropriately?
    - Is the Very Good/Good threshold too stringent? Very difficult to attain.
    - Is the Poor/Fair threshold too stringent?
    - Should an alternate definition (i.e., quantiles, other?) be used where thresholds don't work?
- How should metrics with missing thresholds be handled?
    - Keep as presence/absence
    - Assign intermediate very good/good and poor/fair categories instead of forcing into good and fair only
    - Assign arbitrary/"best guess" thresholds for all thresholds

The feedback and recommendations from the experts during the roundtable discussion and breakout session are summarized by topic in the following sections.

## Landscapes and Indices

**Streams Water Quality Index.** The experts had a number of opinions on the weighting of the land cover metrics used in the calculation of the Streams indices.

- The “positive” and “negative” landscape metrics do not necessarily have to be weighted equally; for example, 1 acre of urban development has a far more negative impact on stream quality and function than 1 acre of natural cover has a positive impact.
- Much of the land conversion in West Virginia occurs in the riparian zone, so the weight of the riparian metrics should reflect that in some indices they are more important to stream quality than land cover in the catchment.
- Upland conversion affects streams only within 300’ of stream so that the riparian buffer captures all of the upland area that is necessary for stream health.
- Riparian land condition is always the driving factor in stream health except in the cases of mining and urbanization.
- Perhaps weight the riparian land cover higher than the catchment-scale land cover (i.e. 0.75/0.25).

The Team’s interest in retaining information at both riparian and catchment scales led to the following compromises:

- Use the riparian area metrics for SWQ land cover, instead of full planning unit, although they are highly correlated;
- Retain wells, surface and underground mining, and impervious surface for the entire catchment.

Suggestions from the experts:

- Create a “Riparian Area” metric in the Streams Water Quality Index (SWQ), because the amount of riparian area is an important water quality indicator. Response: The Team has essentially captured this with the NatCoverRip (Riparian Natural Cover) metric since most of the riparian area is forested.
- Redefine the headwaters metric, since most of the catchments currently contain headwaters, which the Team has defined as size class 1a and 1b streams. They should be ephemeral or intermittent streams of first order or lower, with a drainage area of ~2000 acres. Response: The Team checked the streams dataset, and agreed that only size class 1a should be used to define headwaters.

Questions from the experts:

- How were the impervious surface scores computed? Response: The Team used Mike Strager’s 2009 land cover data, and the NLCD 2006 impervious cover data. Experts suggested looking at impervious scores of different land uses, and assigning impervious equivalencies to the Strager data to see how they look. Response: the Team researched impervious surface calculation methodologies and determined that using the NLCD 2006 impervious cover data was the most accurate method for determining average percent imperviousness.

- Is WV's impaired streams data based on more than one dataset? Response: The Team used the DEP's 303(d), TMDL, and AMD streams data.

Other recommendations and summary points:

- Several of the metrics are, in the Experts' opinion, important enough that they should determine the entire index: pH, imperviousness, surface mines, and specific conductivity for the SWQ index. If any two of them are poor, the SWQ index should be poor; if any two of them are fair, the entire index should be fair. This idea is further elaborated in the Categorization section below.
- Perhaps the GLIMPSS score should not be the metric used to indicate good water quality in regression models. The team should determine whether there are high GLIMPSS scores in poor quality areas to ensure that GLIMPSS scores do correspond to water quality parameters measured in these watersheds.
- Double check the impervious thresholds because they are very low. Check the Potomac ELOHA study for their treatment of impervious surface. Response: the Team checked the imperviousness threshold numbers, and they are correct, as determined by the method of using reference and stressed catchments.
- If the impervious surface thresholds come from the Reference Streams catchments, then use the Tier 1 streams to determine the Very Good threshold, and the Tier 2 streams to determine the Good threshold. Response: to keep the imperviousness metric consistent with other metrics, this suggestion was not incorporated. Since reference and stressed results were so low, thresholds from the literature were used instead.
- Some of the experts believed that urban development has the same effective impact as surface mining, and so perhaps should have the same thresholds. Response: the objective method of threshold calculation based on stressed and reference catchments worked well for the development metric, and was therefore used. Thresholds for surface mining were adopted from expert's suggestions during the workshop and a review of available literature.

**Streams Water Quantity Index.** Experts recommended that the Large Quantity Users (LQU) on small streams metric should be weighted as high as 2, since water is often consumed and not returned. Response: The Team increased the weight of this metric to 2.

Only large quantity users with permits are captured by the LQU metric, and gas drilling is not. This is because the water is often withdrawn in planning units other than where the well is located. The Team and Experts are not aware of any data for discharge to show what is coming in to the streams, to balance what is withdrawn.

**Streams Hydrologic Connectivity Index.** There was a question from the experts regarding the purpose of the Power Plants metric. Response: It indicates a temperature barrier to aquatic life. One expert observed that, technically, the water should be cooled before being released into the stream, but some plants like Mt. Storm are discharging 98 degree water. Another commented that the high temperature is getting dissipated quickly with the rest of the stream and it doesn't seem like a thermal barrier should last long.

The experts recommended increasing the weight of road/rail and culverts metrics. Response: the Team incorporated this recommendation.

**Streams Biodiversity Index.** The Team requested expert opinion on whether a planning unit with a large number of rare species should automatically be put into a higher category as a priority for protection, even if its score is “Fair” or “Good.” The Experts did not venture an opinion on this.

The Experts recommended using the maximum number of taxa vs. median number taxa to indicate macroinvertebrate diversity. Response: the Team incorporated this recommendation.

**Streams Riparian Habitat Index.** The Experts asked for a definition of riparian area. Response: It is based on TNC’s Active River Area, with a 120-m buffer on the NHD 24k streams, and encompasses the floodplain and riparian wetlands.

There was extensive discussion if the Team should use Emily Bernhardt’s published thresholds for surface/legacy mining. It was agreed that they are conservative numbers determined in the southern coalfields. In contrast, data from Todd Petty covers the entire state, and is likely more relevant to this project.

Other recommendations:

- Increase the weights of road/rail and active surface mining in the riparian area. Response: The Team increased the weight of surface mining to 2 and road/rail to 1.5.
- One expert suggested that development and active surface mining are of greater importance in the riparian area than roads, so their weights should be higher. Response: the Team incorporated these recommendations.

**Wetlands Water Quality Index.** Question from the Experts: Should the wetland water quality metrics be the same as those for streams? Response: The Team is trying to capture more of the wetland functions: a wetland may be of “poor” quality but still serve to moderate flood events. Likewise, poor quality of water entering a wetland may make its functions even more valuable for water purification. It was agreed that the presence of any wetlands is good, and that even poor quality may be worth protection and/or restoration.

**Uplands Landscape**. The major issue the Team and the Experts noted with the Uplands model results was that there are few if any HUC12 planning units that fall into the “Poor” or “Very Good” categories.

The Experts had several observations:

- It is possible that these three watersheds really do have little variation among the planning units. It would be interesting to analyze a watershed containing a heavily impacted area, such as Wheeling, as well as a watershed expected to be pristine, to see if some of those planning units are ranked as Poor or Very Good by the objective method. Response: The Team analyzed the Monongahela watershed and presented the results on Day 2.
- Depending on whether the goal is to assess current watershed condition or restoration potential, land uses could be weighted differently. From a hydrology perspective, grazed lands are better than cropped areas, and both are better than development because they are restorable. Response: Since the SWQ index assesses the current condition of the watershed,

weights for grazed, agricultural, and developed areas in the riparian area were kept at 1. The web tool will include these land uses as overlays so users can evaluate restoration potential based on local conditions.

- Habitat fragmentation by roads is potentially a more complicated issue than represented by road presence/absence, and road buffer acreage (i.e. road classes) instead of mileage could be used to represent this. Response: The Team considered this during the assessment methodology development. It is already captured in the Forest Size metric, which uses hierarchical road buffers as forest fragmentors. Another factor is that road size effects are often taxon-specific: birds, mammals, and seeds may travel across highways, where amphibians and insects may not.
- Gravel roads have different impacts depending on their purpose, location, and level of use, so their incorporation into the analysis is potentially very complex. Response: Roads are not separated by surface type because of the complexity of the issue and uncertainty of effects on the metrics.
- Gas wells or surface mines are often located on legacy mine lands: should this be reflected in the analysis? Re-mining often creates fresh impacts, and revegetated mines may no longer impact streams directly. Response: The Team has addressed this by separating surface and legacy mining in the habitat metrics, and combining them in the water quality metrics.
- Experts noted that GAP 3 lands may still be subject to resource extraction, and GAP 2 lands may still experience the effects of previous land uses.

**Uplands Habitat Connectivity and Uplands Habitat Quality Indices.** Because land conversion is such a large driver in these indices, the Team and Experts discussed the idea of “killer metrics”: the situation in which a catchment contains so much development or surface mining that it is inappropriate for either conservation or restoration, regardless of its other attributes. This idea is further elaborated in the discussion of Categorization and Thresholds below.

**Uplands Biodiversity Index.** Concerns with the Biodiversity Index were reiterated: it emphasizes rare species, and the available data on rare and invasive species are spatially biased and do not indicate areas that were sampled but no targets were found. Response: Unfortunately, there are no available alternatives.

The Percent Basal Area Loss metric is weighted very high, and in some cases appears to drive the results of the biodiversity index. Positive attributes of this metric are that the results cover a wide range of values and are appropriate for the watershed scale (unlike some datasets that are county-wide). The predicted basal area loss metric might also be useful in deciding where to undertake treatment or restoration. The experts suggested retaining this metric if the Team is confident in the models used to generate the predictions. Response: The team will review the literature on the National Insect and Disease Risk Maps.

**Protected Lands Index**. The Team requested expert opinion on how to deal with the Protected Lands Index for each landscape. Most planning units contain no protected lands in categories GAP 1, 2 and 3, bringing down the overall model scores. Should this index be removed from the analysis?

Opinions varied regarding retention of the Protected Lands Index, but it was generally agreed that this information is most important for establishing priorities for conservation and restoration, so it depends upon whether the web tool will be used for condition assessment or for prioritization. Areas adjacent to protected lands are especially important in this context. Ideally a metric might be a cost-weighted distance from the planning unit to the nearest protected land, but this would be very complex because many different types of obstacles might lie between them; i.e., an interstate highway vs. a gravel road. Response: Because of the complexity and uncertainty of distance effects from different land uses, this suggestion has not been incorporated into the model.

One suggestion was to use the Protected Lands layer as an overlay to the analysis, rather than incorporating it. This would allow identification of adjacent areas to be targeted for protection or restoration. The condition of the protected lands, especially GAP 1 or 2, would also be an indication of the potential quality to which newly acquired lands could be restored. Response: The web tool will include protected lands as an overlay to allow users to evaluate this factor for their uses.

Another suggestion was to incorporate a presence/absence type metric to indicate protected lands and those immediately adjacent so that they receive a slightly higher condition score. Response: this is how the model is currently set up.

## Metric and Index Categorization and Thresholds

The objective results for the three watersheds show little variation; most of the HUC12s or catchments were in the "Fair" or "Good" categories. An expert agreed that seeing only two categories displayed on a map suggests that the analysis is not sufficiently refined. It was also suggested that the many metrics/indices were cancelling each other out, especially in the case of the HUC12s. Another possibility is that the planning units in these three watersheds really are "Fair" and "Good" compared with all the others in the state. Experts suggested looking at a watershed that is expected to be highly impacted, such as in the Wheeling area, to see if any of the planning units fall into the "Poor" category. Response: As summarized below, the Team re-analyzed the more heavily impacted Monongahela watershed with the objective method and found more variability in this watershed.

It was suggested that the "Poor" results category should be renamed to impartially reflect the low numerical results, without implying that an area is unsuitable for restoration, since some organizations may specifically target highly impacted areas such as AMD-impaired streams for restoration. Suggestions for renaming the category included:

- Changing Fair and Poor to Impaired and Severely Impaired or Degraded and Severely Degraded
- Changing Poor to Restorable at Cost
- Adding a "Not Recoverable" category for the lowest-scoring planning units, which would include intensely urban areas, to distinguish from those areas that could be lifted from Poor to Fair for ecological mitigation credits

Experts did not recommend adding any additional categories, although there may be a way to flag individual metrics (or otherwise make data available to users) that either indicate that a planning unit is not recoverable, or that if improved might make it a target for restoration. Any terminology should be explicitly and prominently defined in the documentation of the interactive web tool or in the watershed assessments. Response: the Team decided to keep the terminology as is with explicit definitions in any documentation.

As an extension to the discussion of relative metric weights, the Team and Experts began developing the idea of “killer metrics:” those metrics that either alone or in combination may have sufficient negative impacts on a planning unit that their value determines the value of the entire index. As an example, the Streams Water Quality index contained four metrics that the Experts believed were sufficiently indicative of stream health that if two or more had “Fair” or “Poor” scores, the entire water quality index should be rated as Poor, overriding other factors: Median pH, Median Specific Conductivity, Impervious Surface, and Surface Mining. Metrics for other indices the Experts identified as “killer metrics” included:

Streams Water Quantity: Impervious surface
Streams Riparian Habitat: Development and Active surface mining
Wetlands Wetland Habitat: Development and Active surface mining
Uplands Habitat Connectivity: Development and Active surface mining
Uplands Habitat Quality: Development and Active surface mining

## Workshop Day 2
## October 11, 2012

### Presentation Summary

The second day of the workshop opened with an overview of the Little Kanawha watershed results and a preliminary analysis of the Monongahela watershed to give an example of results obtained in a more impacted watershed. This was followed by more general discussion of the Wetlands and Uplands landscapes. The floor was then opened to the experts to give their opinions on the features and content of the interactive web tool that will be constructed to present the watershed assessments to various users.

### Overview of Little Kanawha Watershed

*Diane Packett, TNC*

Habitat fragmentation by grazing, development, and roads is more prominent than in the other watersheds. There is very little surface or underground mining, although there are many wells. Most of the major tributaries of the Little Kanawha River are impaired, and biological contaminants/fecal coliform and iron are the predominant impairments. There are GAP 1, 2, and 3 protected lands in the watershed, including several WMAs, two state parks, and one TNC preserve. There was one irregularity on the display map: the absence of the Wells locks & dam; this was a data processing error and has been corrected.

Comments: Experts noted that there are several pollution issues in the Little Kanawha River, and DEP will be starting TMDLs in 2014. Sedimentation from well pads and access roads is an issue due to a shortage of well inspectors and lack of training in sedimentation. They also noted the presence of federally endangered mussels in the Little Kanawha, and speculated on the location of a new DNR wetland conservation area, managed by Ducks Unlimited, next to a Wal-Mart.

### Preliminary Analysis, Monongahela Watershed

*Misty Downing, TNC*

In the previous day’s session, it was speculated that the reason that the objective method shows little variability among HUC12 watersheds is that in fact these particular watersheds contain little variability. Experts had suggested running the analysis on a watershed containing an area that is likely to be heavily impacted to determine if appropriate HUC12 watersheds are categorized as poor. Accordingly, Misty Downing subjected the Monongahela watershed to the objective analysis, and found that there is, in fact, greater variability among planning units (from Poor to Very Good) in this more heavily impacted watershed, at both the HUC12 and catchment levels.

### Wetlands and Landscape

*Ruth Thornton, TNC*

The Team requested expert advice on dealing with a troublesome issue in the Wetlands model: currently, having no mapped wetlands in a planning unit places it in the “Poor” category, although there may be hydric soils indicative of past or potential future wetlands. The Wetlands Hydrology index, an indicator of wetland “potential,” incorporates the presence of floodplain and hydric soils. However, hydric soils are inconsistently mapped across the state, and where they are not mapped, the “null” values skew the results.

Recommendations:

- The Team and the Experts were most comfortable with the idea of removing from the wetlands analysis those catchments that do not have an NWI wetland, floodplain, or hydric soils, which indicates that no restoration potential exists. For the HUC12 analysis, it may be advisable to set a “minimum area requirement” so that HUC12s with very few wetland indicators are classified as “null” instead of “poor”. Response: The Team incorporated this suggestion by removing planning units without wetlands, floodplains, or hydric soils from the wetlands analysis.
- It may also be possible to “extrapolate” the presence of hydric soils: depending on the stream gradient, there will be a certain percentage of the floodplain that will be hydric. Response: This would likely be very time intensive, and is impractical since soil map units are often inconsistent between counties. There is a DNR project in progress to develop a tool to predict wetland potential; this and other datasets could be incorporated into the model in the future as improved data become available.

**Interactive Web Mapping Tool**
*Ruth Thornton, TNC*
It was agreed that the web tool will be used by a variety of groups for different purposes, and it would be desirable to provide a User’s Guide with tutorials for different scenarios and levels of information needed: a watershed group writing a grant, in lieu fee mitigation projects, USACE projects, etc. It will be important for users to identify their priorities, and the User’s Guide could direct users to the Objective or Relative ranking system that would most suit their purposes. Response: the Team agrees with this recommendation and will develop appropriate tutorials.

Types of maps/processes that could be included in the web tool:

- A step-by-step process for those seeking a protection or restoration site with varying criteria;
- A place-based results map similar to the EPA’s Surf Your Watershed tool, in which a user might click on a place in a state map to view HUC12 or catchment results and attributes. This may keep less technically-oriented users engaged;
- A ‘hot spots’ issues map that someone with funding for particular projects can use to locate sites.

Suggestions for features to include in the tool:

- An example of a use scenario, taking the user from large scale to small – HUC12 to catchment
- The ability to save the current search/place within the tool so that the user can resume later
- An ID tool to display the attributes of selected features
- The ability to select desired layers to view and features displayed for the base layer
- Data that was dropped from the analysis but which users could display as overlays if desired.

Response: the Team will work with the web tool developer to incorporate as many of these suggestions as can be accommodated.

**Next Steps**

Prior to the second expert workshop, the Team will incorporate the metric thresholds and weighting recommendations, including the "killer metrics" and wetland hydrology, into the objective method and re-run the analyses for the Gauley, Little Kanawha, and Upper Guyandotte watersheds. These results will be presented at the second expert workshop with the preliminary Consolidated Analysis results. The Team will also seek expert input on potential strategies for addressing issues identified in the watersheds.

**Meeting Attendees**

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**West Virginia Watershed Assessment Pilot Project**
**Upper Guyandotte, Gauley, and Little Kanawha Watersheds**
**Second Expert Workshop Summary**
**January 8-9, 2013**
**Charleston, West Virginia**

## Workshop Objectives

The goals of this workshop were to:

4) present and compare updated relative and objective method current condition results for the Upper Guyandotte, Gauley, and Little Kanawha watersheds and get expert feedback;
5) present overall trends from current condition results for all five project watersheds and discuss potential strategies to address them; and
6) present preliminary Consolidated Analysis results for all three watersheds and get expert feedback on the results, methodology, and data recommendations.

**Workshop Day 1**
**January 8, 2013**

## Presentation Summary

The workshop began with a review of the project objectives and timeline, as well as a brief review of the watershed assessment structure: units of analysis, model structure, landscapes, indices, and metrics. The Consolidated Analysis was introduced, followed by a description of its indices and metrics. The Team presented the updated current condition results for both the relative and objective methods of analysis, with maps of assessment results for all three watersheds. An open discussion around each watershed map followed each presentation, during which experts provided feedback and asked additional questions. Overview maps of the three watersheds were displayed for reference. After the watershed results presentations, the Team presented overall trends that emerged from the initial assessment results, and discussed potential strategies for addressing the identified trends with the experts.

## Project Background and Objective Methodology

*Ruth Thornton, TNC*

Ruth presented the project background and a review of the methodology, including an introduction to the Consolidated Analysis model structure, with a detailed description of the indices and metrics used to determine potential future threats. A detailed review of both the relative and objective methods of analysis was presented, including reference and stressed catchment criteria, how objective thresholds were determined, and the concept of critical metrics (defined as metrics that are crucial enough to cap the overall score of a planning unit regardless of other metrics: the highest score of an index with critical metrics defined is capped by the highest score of the critical metrics, regardless of other metric values). Ruth also introduced the idea of combining the objective and relative ranking methods into a combined results method, which starts with the objective score and then uses the relative ranking results to rank planning units relative to each other within an objective category. Benefits of the combined score include greater ease of use by presenting only one set of results, while a potential disadvantage would be that some of the detail of the objective and relative rankings would be lost.

A list of metrics, weights, and objective thresholds for the objective analysis was provided to the experts. Results maps for all three watersheds at both the HUC12 and NHDPlus catchment scales for both the objective and relative analyses were provided.

### Overview of Upper Guyandotte Watershed Current Condition Results

*Diane Packett, TNC*

There is a large amount of active and legacy surface mining, as well as underground mining, in the Upper Guyandotte watershed, especially in the northwest and southeast areas. There are many oil and gas wells, but little concentrated development, except in the Logan area. Most of the major tributaries of the Guyandotte River are impaired. There are GAP 2 & 3 Protected Lands, including several WMAs and one state park. A seeming anomaly was presented for feedback by the experts: the overall results in the Wetlands model can differ greatly between the relative and objective methods of analysis. This is a result of the Wetlands Hydrology index, which is the only scored index for planning units without any mapped National Wetlands Inventory (NWI) wetlands but with underlying hydrology such as floodplain or hydric soils, a situation which can produce a low relative quality score but a Very Good objective quality score.

Comments: Experts mentioned that a large scale mitigation bank is being proposed on Pinnacle Creek and is worth noting.

### Overview of Gauley Watershed Current Condition Results

*Misty Downing, TNC*

The Gauley watershed is notable for a large area of undeveloped protected lands in the east (Cranberry Wilderness, Cranberry Glades, etc.) and the large Meadow River wetland complex in the south. Surface mining occurs along the northern and some southeastern ridges of the watershed, and gas well development occurs in the northwest. Urban development is confined to the western part of the watershed, and is most dense along infrastructure such as US Hwy 19 in the northwest and US Hwy 60 and Interstate 64 across the south.

Comments: It was noted that a road along the Cranberry River that divides the backcountry from wilderness is missing from the maps. Experts noted that the underground mining in Nicholas County is not showing up as causing impairments in Streams Water Quality (SWQ). This was explained by the Team as Underground Mining not being a critical metric, and while there are stream impairments for metals in this area, the overall SWQ score was not brought down significantly by these two metrics. Experts noted that some water treatment is happening in this area as well, which may help impairments. Acid deposition and low buffering capacity are probably driving the existing impairments within the headwaters/wilderness areas. Some active mining occurs south of Richwood, and legacy mining along the Williams and Gauley Rivers in the east.

## Overview of Little Kanawha Watershed Current Condition Results

*Diane Packett, TNC*

Threats from habitat fragmentation by grazing and roads are more prominent than in the other watersheds. There is very little surface or underground mining, although there are many oil and gas wells in the center of the watershed. Most of the major tributaries of the Little Kanawha River are impaired, with biological contaminants/fecal coliform and iron being the predominant impairments. GAP 1, 2, and 3 protected lands exist in the watershed, including several WMAs, two state parks, and one TNC preserve. The watershed is largely rural with very small towns, with the most significant urban development occurring in the northwest corner of the watershed, around Parkersburg. Higher quality areas for potential protection tend to occur in the south-central section of the watershed.
Comments: No comments related to presented results.

## Results Discussion Summary

*Ruth Thornton, TNC*

After presenting the results for the three watersheds, the Team reviewed the final list of metrics and their corresponding weights for each current condition index. Experts provided input on changing metric weights, as needed. The experts were also questioned regarding objective ranking thresholds, the idea of presenting combined results, and how best to handle the Wetlands overall model issue.

Specific questions that participants were asked to consider were:

- Are metrics weighted appropriately?
- Are thresholds in objective ranking defined appropriately?
- Should we use the combined objective/relative ranking results?
    - Is this an appropriate method to compare the two rankings?
    - Will this make presentation of analysis results easier or more confusing for end users?
    - Are there alternate ways to combine the two rankings?
- How should results be presented in the interactive web tool?
    - Use of the combined ranking versus objective and relative separately?
    - Is there a suggested alternate work flow for end users?

The feedback and recommendations from the experts during the roundtable discussion and maps discussion sessions are summarized by topic in the following sections.

## Individual Model and Index Discussions

### Streams Water Quality Index

Resource extraction (underground and surface mining, oil and gas well drilling):

- Underground mining may be worse than surface mining in some cases (because of discharges of polluted mine water, dewatering of streams, high specific conductivity values, and mine pool discharges). Water returns to mines and gets “remineralized” over and over, so that dewatering is a water quality as well as a water quantity threat.

Therefore Underground Mining should be weighted at least as high as Surface Mining. Response: Underground Mining weight was raised to 2, equal to Surface Mining.

- The effects of underground mining are already at least partially accounted for in the assessment, as the in-stream water quality (such as median pH, etc.) is affected by surface and deep mine discharges. The lack of exact locations of where mine discharges enter streams as a result of underground mining and resulting uncertainty of which planning units may be most affected preclude increasing the weighting of underground mining beyond 2.
- The temperature of deep mines is constant, so mine water temperature doesn't fluctuate with the seasons.
- Experts suggested using pre- and post- SMCRA (Surface Mine Control and Reclamation Act) mining categories and using the SMCRA dataset for field data from the last 20 years.
- New data are being compiled by the EPA and OSM on how valley fill construction methods affect water quality. It was noted that valley fills would never reproduce the original water quality.
- OSM noted that water quality depends on the geochemistry of the enclosing rock. While valley fills affect the water quality for decades, the effects of underground mining persist for centuries.
- OSM noted that mining water crosses state lines. Gas drilling discharges also make their way into mine complexes and are discharged to streams (this sort of information is very difficult to capture as geospatial data).

Suggestions from the experts:

- Combine Surface and Underground Mining into one Mining metric, and let the web tool user drill down into what type of mining/discharges they are interested in. Response: the Team kept both surface and underground mining in the analysis for ease of use.
- Increase weight of oil and gas wells in relation to sedimentation issues. Response: The AllWells weight was increased from 1 to 1.5.
- Suggestion to include NPDES water quality data into the analysis. Response: The Team will look into the feasibility of including these data.

Questions from the experts:

- Did the Team consider the age of surface mines (assuming older mines like Barton Bench would have fewer detrimental effects)? Response: The Team does not know of a reliable data source for this information.
- Why is Sulfate weighted so low (at 0.5)? It should be higher, since sulfates could come in with mine water seepage. Response: There was a high correlation between Sulfate and Specific Conductivity. The Team decided to increase the weight of Sulfate to 1.
- Should Agriculture and Grazing be weighted higher in watersheds where they are more significant stressors on the landscape? Response: The goal of the project is to develop a

methodology consistent across all the watersheds of the state, it is therefore desirable to weight metrics the same across all watersheds for ease of use. Additionally, effects from these metrics are captured by the metric Natural Cover in Riparian Area.

**Streams Water Quantity Index**

Suggestions from the experts:

- Increase Underground Mining to a higher weight than Surface Mining. Response: Underground Mining weight was increased to 1.5.
- Impervious Surface is the main agent of flow alteration in this index. Response: No change, since this is already a critical metric in this index.
- Dams that actively regulate flow have managers that you can work with to shift flow releases, so dams are regulated and should not be a critical metric. Response: No change is needed because this was not a critical metric.
- The Team should consider modifying the Dam Drainage metric (meant as a proxy for volume of dam water storage relative to catchment volume) to include only the part below the dam. Response: This suggestion was not incorporated.

**Streams Biodiversity Index**

Experts questioned if the non-native invasive species (NNIS) data was robust enough to be weighted a 1.5. Response: All of the biodiversity data are weak, so the Biodiversity index weight was lowered to 0.5.

**Streams Riparian Habitat Index**

Experts noted that active surface mines seem more of a problem than legacy surface mines, which are now mostly re-vegetated. In the future, active mines will become legacy mines.Response: No change; Active Surface Mining is already weighted at 2 and Legacy Surface Mining at 1, which addresses this issue.

**Wetlands Overall Results**

The major issue the Team presented regarding Wetlands results was the apparent lack of agreement between the Wetlands Overall model results between the relative and objective methods. This is an artifact of the methodology: the relative method gives a low score to planning units that have no wetlands, while the objective method assigns the score of underlying hydrology (if present) to the entire index for planning units without mapped NWI wetlands.

Suggestions from the experts:

- Include a legend that shows planning units symbolized as white = no existing or potential wetlands (no wetlands hydrology present), gray = potential wetlands (wetlands hydrology present but currently no mapped NWI wetlands). Label planning units with existing hydrology and no mapped wetlands as having “restoration potential” and flag them as restoration priorities (which would place them in the Fair category).

- Create a special category for planning units with hydrology and no wetlands, since this is an important consideration for planning restoration projects.
- Regardless of how the issue is handled, make sure it is discussed in the executive summary and in the wetlands discussion of the final reports. Response: The Team agreed to implement these suggestions in some form, and plans to document the issue in the final reports.

Questions from the experts:

- OSM questioned the reason for having Overall Model scores at all, as they found it confusing and thought it was losing detail. Response: Watershed associations and private citizens are likely to use the overall results, which should therefore be retained in the analysis. Two different types of users are expected: those who are graphically-oriented and those who are text-oriented. This should be considered in designing the map symbology, map navigation tools, and attribute information tables of the web tool.

**Wetlands Hydrology**

Experts suggested an increase in the weight of Hydric Soils. Response: The metric weight was relatively low because of the inconsistency of the soils data among counties, but was increased from 1 to 1.5.

**Wetlands Wetland Habitat**

Experts suggested an increase in the weight of the metric Development in Wetland Buffers. It is a critical metric and should therefore be weighted higher than it currently is. Development is permanent while other land conversions like agriculture have the potential to be reversed. Response: The Team increased the weight of Development in the Wetland Buffer from 1 to 2.

**Uplands Habitat Connectivity**

Experts mentioned that the fragmentation from wind turbines and energy transmission lines is more long-term than timber harvesting operations. Timbering is not necessarily equivalent to deforestation or habitat fragmentation, and does not permanently convert land. However, the impacts of unpaved roads from timber harvesting and energy development on water quality may be similar. Response: The nature of the timber harvesting data was not spatially precise enough to increase the weight of the Timber Harvest metric in the analysis.

**Uplands Biodiversity**

Experts asked what species were represented in these data. Response: Only terrestrial plants and animals (no aquatic species were included for the Uplands Model).

**Protected Lands Index**

The Team requested expert opinion on how to deal with the Protected Lands Index for each landscape. Most planning units contain no permanently protected lands, thus potentially artificially lowering the overall model scores. Should this index be moved to another category or removed from the analysis?

Experts felt that this information was valuable, as agencies and organizations often seek to expand upon existing protected lands. It may also be valuable to include a metric that indicates adjacency or proximity to protected lands. Response: The Team has considered this but has not found a practical way to accomplish this, since the presence of roads or other fragmenting features may negate the value of the adjacency. An option would be to buffer protected lands by an arbitrary distance and increasing the ranking of areas within the buffer, but this would not take into consideration parcel ownership or size, development, etc.

It was decided that a new category should be created, such as “opportunity” or “feasibility,” that would include protected lands and priority interest areas. The Protected Lands index would be removed from the current condition models, and the Priority Interest Areas would be removed from the Consolidated Analysis, incorporating both into the new category.

### Combined Results Maps Discussion Summary

Experts were asked to provide feedback regarding the presentation of Combined Results in the web tool. Sample draft maps of combined results for the Gauley watershed were presented. Excel spreadsheets of numerical results were presented to illustrate some of the differences between the relative and objective methods, and corresponding results of the combined method.

Response from the experts:

- Some experts thought having one set of results was useful, but were wary of the combination technique. They thought users may stop there and not dig deeper into the details of the results and potentially missing important nuances of the results.
- Some experts preferred having only one results map, particularly if users can start with the combined results and then view the objective categories and relative rankings as attributes of planning units to dig deeper into the analysis.

Suggestions from the experts:

- Modify the colors to more clearly distinguish between shades (they found it hard to distinguish High Quality Very Good and Low Quality Poor, for example). Response: The presented results were an initial draft to get expert feedback on the concept, more time will be spent refining the final symbology before the final web tool and reports are completed.
- One monochromatic color ramp could be used for the combined results instead of using four different hues for the four categories: a continuous scale may provide a “quick assessment” of the entire watershed.
- In the final reports, highlight a few of the instances where relative and objective results seem to contradict each other and explain why this happened in terms of the methodology. Response: The Team plans to incorporate such examples in the final reports.
- Experts suggested including maps of objective and relative results in addition to the combined results, enabling users to turn these layers on and off. Response: The Team is concerned this may require too many data layers and create capacity issues in the web tool, but will look into it.
- Consult social science research how to best represent the quality of different areas using colors and/or symbology. Response: The Team will research colors and conduct an informal office survey to ensure the final symbology is intuitive and comprehensible.

### Interactive Web Tool Discussion Summary

Experts were asked to provide feedback on optimal features and symbology to include in the interactive web tool. They were also asked about what sort of work flow they might use in the tool, and what a good sample work flow may be for potential end users.

Suggestions from the experts:

- Include a mechanism for users to submit data to the web tool, or at least include contact information on the website guiding users on whom they should contact with new data. Response: The Team plans to compile a list of contacts and links for the website to contact for more information.
- Consider adding mitigation bank and In Lieu Fee projects as a new layer. Response: The Team will try to obtain this data layer, but it may not be available in a spatial form, at least for the first iteration of the web tool.
- Include an “identify” tool that would display attribute information for a planning unit. Response: The Team plans to incorporate this feature into the final tool.
- Create a User Guide or provide alternate work flows for each type of user and project type. Response: The Team plans to provide a User Guide that would address a wide range of work flows.
- Include the ability to search for sites that meet specific criteria (e.g., wetland soils with no wetlands, fecal coliform impairments, future threats, etc.).
- Add congressional districts as an additional informational overlay layer.
- Use language such as “a purely GIS-based analysis suggests…” rather than explicitly stating that an area is the best to work in (for both reports and the web tool).

### Potential Strategies Discussion Summary

Project objectives were reviewed with an emphasis on the goal of developing strategies to address watershed trends identified by the assessment. The purpose of the final tool is to inform a wide variety of end users, including federal and state agency personnel, watershed associations, and non-profit organizations. Thus, the project should suggest strategies that are broad and widely applicable, and avoid prescribing specific stream reaches or wetlands as conservation action targets. The goal is to identify general trends of stressors within a watershed and potential strategies to abate them. A summary of recurring trends from all five watersheds was presented. Experts were divided into two breakout groups and asked to consider the following questions:

- What are potential strategies that could be developed to address these stressor trends?
- Is this level of detail a useful part of the watershed assessment? Is it too detailed?
- What can we do to improve the usefulness of the strategies section for the end user?

Suggestions from the experts:

- Create a drop-down box with a list of strategies and actions that a user could consider to address identified issues.

- Provide links to other resources such as online manuals, websites, and organizations active in a watershed. Response: The Team will provide a page of useful links, including the West Virginia Watershed Network list of watershed associations within the state and their contact information.
- Consider questions such as: "What can I do as a landowner?", "Who should I call?", and "What can we do as a watershed association?"
- Provide examples of specific strategies that have been used successfully.
- Be sure to note that these are suggestions and not a comprehensive list, and are not necessarily endorsed by the Project Team. Add a disclaimer statement that relieves TNC, DEP, EPA, and any other partners of liability for listed recommendations.
- Note that regulatory and enforcement actions are often needed to effect certain changes, which may be outside the users' scope of influence.

Potential strategies suggested by the experts:

Overall

- Develop a statewide green infrastructure plan.
- Work with local governments to integrate the watershed assessment findings with zoning or comprehensive plans.
- Develop resources and/or points of contact for each watershed (e.g., basin-wide coordinators or county floodplain coordinators).
- Include information for lay users on subjects such as mineral rights, deed restrictions, enforcement of conservation easements.

Streams

- Create and enforce stormwater management regulations or implement new techniques (rain gardens, semi-pervious surfaces, protection/restoration/construction of small urban wetlands).
- Conduct education and outreach for owners of small businesses that may discharge to streams (e.g., dry cleaners, car washes).
- Build special handling plants for toxic materials affecting streams.
- Protest issuance of new permits.
- Add culvert sizing requirements for nation-wide permits.
- Have citizen groups assist DEP/EPA with water quality monitoring.
- Suggest Federal programs that provide funds to fence off water sources from livestock: Conservation Reserve Program (CRP) or Natural Resources Conservation Service (NRCS) for private landowners.
- Sediment control.
- Invasive species control.

Wetlands

- Develop new or influence existing floodplain management plans

- Conduct education and outreach to the public and local government officials on the value of wetlands and floodplains and the ecosystem services they provide.
- Invest resources in the mapping and inventory of wetlands, including identifying important wetlands/floodplains. Characterize wetlands (by chemistry, structure, biology) and determine their history.
- Take advantage of state tax credits for wetland protection or conservation easements.

Uplands

- Streamline procedures for constructing access roads (the BMPs for farmers, wind turbines, timber harvesting, and mining are all different).
- “Checkerboard” surface mine complexes (like timber harvest is often done) to leave habitat islands and corridors.
- Forest Reclamation Approach (FRA): cultivate multi-species stands of hardwoods instead of managing for one species.
- Forest Stewardship Council (FSC) certification for timberlands.
- Develop a system of carbon credits.

Suggestions and comments from the experts:

- Ensure that the project’s basic instructions should be sufficient for a watershed group to use.
- Strategies for handling current and legacy mining work are already available in SMCRA.
- Treatment for issues like acid mine drainage requires a mechanism that is permanent and long term (e.g., an endowment) and requires substantial investment and equipment. This may be beyond some users’ capability. However, the abandoned mine lands program has money for pre-SMCRA sites, which established watershed associations can apply for.

Questions from the experts:

- Will the user not already know which strategies are needed? It is more important to spell out the problems, not the solutions. Users might be looking for places to implement strategies they have already developed. Response: Because the tool is intended for different types of users, and because it is a project deliverable for the grant, strategies need to be included in the assessment.

## Workshop Day 2
## January 9, 2013

### Presentation Summary

The second day of the workshop consisted of presentations of Consolidated Analysis results for the three watersheds. Experts were asked to provide feedback and suggestions for improvement of the overall methodology and model structure, as well as suggestions for any additional data sources that may help make the product more robust.

A significant suggestion regarding the Consolidated Analysis model methodology was to change from a discrete, vector-based analysis to a continuous, raster-based analysis that would present a gradient of potential threat across the entire HUC8 watershed. This would address some of the shortcomings of the current, HUC12 planning unit-based analysis, including the coarse scale of many of the individual metrics. The Team plans to try this new methodology to determine if it provides a better representation of the Consolidated Analysis results. Another significant suggestion was to add an additional category that would capture the idea of “opportunity” or feasibility, and would include the Protected Lands and Priority Interest Areas metrics, since they do not fit well within the current condition analysis.

### Overview of Upper Guyandotte Watershed Consolidated Analysis Results

*Diane Packett, TNC*

The overall Consolidated Analysis results suggest that the greatest potential future threats lie in the eastern portion of the watershed. Within the Energy index results, the northwestern portion of the watershed also emerged as highly threatened, largely due to the extensive future coal mining potential in that area. Within the Population/Development index, a few major roads are proposed to run along the southern ridge of the watershed (King Coal Highway) and across the eastern section (Coalfields Expressway and Shawnee Parkway). Priority Interest Areas are restricted primarily to the southern and eastern portions of the watershed.

Suggestions from the experts:

- Coal could be separated into metallurgical versus steam coal, since metallurgical has a much higher probability of development, which may affect the threat potential. Response: Attribute information that distinguishes between the different types of coal is not available.
- Provide coal seam layer names in the attribute information of the dataset.
- The 2002 Environmental Impact Statement (EIS) report has maps and data for each coal seam volumetrically. Response: The Team will research these to determine if the data can be used.
- The analysis seems to be missing Route 10. Response: Some of the Route 10 construction has been completed but the proposals for other parts are not done yet.

Questions from the experts:

- Is the project tapped into TNC's Energy Development/Development by Design work? Response: Yes, we have included the data that are completed, but many of the results will not be ready for another 6-12 months. The Team plans to incorporate the newly released TNC Aquatic Resiliency data.
- What is the definition of good vs. bad for the future energy threat? Response: Red corresponds to higher ecological threat to stay consisted with other color symbologies used in the assessment, where red indicated lower quality.
- What is the time frame considered in the Consolidated Analysis? Response: This varied by metric, but the Team tried to stay as consistent as possible given different sources of data, and generally projected threats for the next 50 – 100 years.

## Overview of Gauley Watershed Consolidated Analysis Results

*Misty Downing, TNC*

Results suggest that the greatest potential future threats are in the north-central portion of the watershed. Within the Energy index results, the northern portion and part of the northeast also emerged as highly threatened, largely due to the extensive future coal mining potential in the north, and wind and shale gas development potential in the east, though this is an area largely within existing protected lands. Priority Interest Areas are restricted primarily to the eastern portion of the watershed, around the existing protected lands areas.

Suggestions from the experts:

- The power plant proposed for Rupert/Rainelle appears to be off the books and will not be constructed. Response: The Team will remove it from the analysis.
- Wind development and natural gas development within the Monongahela National Forest is a policy and mineral ownership issue. While some forms of development are unlikely in the Forest, they are not strictly prohibited, and there is no guarantee that energy development will not occur on national forest lands. Response: Mineral ownership on federal lands is included in the analysis, and only the portions in the National Forest where mineral rights are owned by other entities are included in the analysis.

## Overview of Little Kanawha Watershed Consolidated Analysis Results

*Diane Packett, TNC*

The overall Consolidated Analysis results suggest that the greatest potential future threats are in the eastern portion of the watershed. Within the Energy index results, the eastern portion of the watershed emerged again as highly threatened, due to potential shale gas development and a proposed energy transmission line, though it is believed that the PATH line has been cancelled. The watershed has a few scattered pockets of high resiliency and current density (indicating relatively low fragmentation of habitat), mostly away from existing development and infrastructure. Priority Interest Areas are found throughout the watershed, mostly around major tributaries to the Little Kanawha River.

Comments from the experts:

- The PATH transmission line is officially off the books. Response: The Team will remove it from the analysis.
- Potential future Marcellus Shale gas development is influenced not only by the shale bed thickness, but also by proximity to existing transmission lines. Areas close to existing lines are more likely to be developed first, which should be included in the analysis. Natural gas is compressed and transported by rail from North Dakota, suggesting that rail availability may also influence the likelihood of gas well development while pipelines are being constructed. Response: The Team will investigate the feasibility of including these factors in the analysis.

### Consolidated Analysis Discussion Summary

After the presentation of the Consolidated Analysis results, experts were divided into two breakout groups to discuss the following questions:

- What is your comfort level with the Consolidated Analysis model given the data limitations?
- How do we best integrate the Consolidated Analysis model with the web tool?
  - First select candidate conservation sites using Current Condition analysis results,
  - Then use Consolidated Analysis results to provide more information and make final selection of sites to explore further.
- Should Protected Lands be moved to this category instead of being in Current Condition?
  - Though Protected Lands are a reflection of the current state of the watershed, they are not an ecological factor, and inform the feasibility or priority for projects more than ecological quality.

Suggestions from the experts:

- USACE Institute of Water Resources is completing the Ohio River Basin climate change study, which will have basin-specific 30-year modeled precipitation and temperature changes due to climate change. The dataset should be available within a few weeks. Response: The Team plans to incorporate these data if they become available in time.
- Check the Department of Education for new schools data or school consolidation data. Response: The Team researched but found no spatial data for proposed schools in the five watersheds.
- The final reports and web tool should state clearly that the Consolidated Analysis is a broad generalization and the available data are coarse-scale, modeled, or vague.
- Include the Consolidated Analysis results in the final reports but not the web tool.
- Include sources and dates for the data and thoroughly explain any limitations.
- Experts liked the idea of having three categories: Current Condition/Function, Future Threats, and a third category that indicates conservation opportunities and includes protected lands and priority interest areas.
- Include FEMA mitigation lands, if available.

- Demonstrate the web application to the experts before presenting it at the partner/stakeholder workshops or releasing it to the public to get experts' feedback on the functionality and included datasets.
- Check the geothermal study quality assessments; the experts suspect it may have been "debunked".

Questions from the experts:

- Why are there no National Park Service data in Priority Interest Areas? Response: The Team has tried repeatedly to obtain these data and has not received it. We will continue to try to get these data.

**Next Steps**

Prior to the final partner/stakeholder workshop, the Team will incorporate suggested changes to the metric thresholds and weighting, symbology for wetland hydrology and combined results, and strategies. Final results will be presented at the stakeholder workshop in addition to a demonstration of a preliminary version of the interactive web tool.

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**West Virginia Watershed Assessment Pilot Project**
**Gauley, Upper Guyandotte, and Little Kanawha Watersheds**
**Stakeholder Workshop Summary**
**May 8, 2013**
**Flatwoods, West Virginia**

## Workshop Objectives

The goals of this workshop were to:

7) present the final assessment methodology, current condition, and consolidated analysis results for all three watersheds and obtain stakeholder feedback;
8) demonstrate a preliminary version of the interactive web tool and present potential use scenarios. Get stakeholder input on desired web tool design, functionality, and possible uses/workflows; and
9) present and discuss the development of strategies that should be applied according to the analysis results.

## Presentation Summary

The workshop began with a review of the project background, including project goals and timeline, and a brief review of the watershed assessment methodology: landscapes, indices, metrics, and objective thresholds and categorizations. The Team then presented the latest version of the current condition and consolidated analysis results for the Upper Guyandotte, Gauley, and Little Kanawha watersheds. An open discussion followed each presentation, during which experts who had not attended previous workshops requested further information, and experts familiar with the project offered suggestions and additional questions. Overview and results maps for the three watersheds were displayed for reference. After the watershed presentations, the demo version of the web map tool was presented, and potential workflows for use of the tool were discussed. The Team reviewed trends emerging from the analysis results with stakeholders, and solicited advice on the best way to present potential strategies to end users.

## Review of Project Background

*Ruth Thornton, TNC*

Ruth presented the project background and a review of the methodology, including a detailed review of analysis indices and metrics, and how the thresholds used for the analysis were determined from reference and stressed catchments. She also presented the concept of “critical” metrics, those metrics significant enough to cap their corresponding index score, regardless of other metrics within that index.

Following the review of the project, stakeholders were given the opportunity to ask questions about the assessment methodology and results. Many of the questions involved the nature of the data used in the project. A brief discussion ensued about wetlands data, and whether or not non-natural wetlands (such as stormwater catchments) were included, or other sources of wetlands data (such as DNR) were used. The Project Team explained that only National Wetlands Inventory (NWI) data were used, as other sources were less reliable or currently incomplete or unpublished. A recurring question was whether or not the project results in the web tool would be updated as conditions changed, and if users could contact the Project Team with information to update either the data or analysis. The Team explained that as the results are calculated through a complex analysis they will remain static, but as many of the data layers as possible will be dynamic and updated regularly. Further funding for the project is being pursued, and if successful, the results may be updated in the future, perhaps on a 3-5 year cycle by interns at the DEP, or through a similar process.

### Overview of Upper Guyandotte Watershed Results

*Diane Packett, TNC*

A large amount of active and legacy surface mining occurs in this watershed, as well as underground mining, especially in the northwest and southeast areas. There are many wells, but little concentrated development except in the Logan area. Most of the major tributaries of the Guyandotte River are impaired. There are GAP 2 & 3 Protected Lands, including several WMAs and one state park. Consolidated Analysis results revealed higher potential future threats in the northwest and east of the watershed, with the central and southern portions having relatively lower future threats.

Comments: It was noted that separation of mineral rights is a big problem, particularly in the Upper Guyandotte. Incompatible land ownership patterns can be considered a threat much like energy development is a threat; for example, even if DNR owns the surface rights they may not own the mineral rights in a WMA. The project team should check with the GIS Analyst at the WV DNR, Alicia Mein, to see if she has spatial information on state mineral ownership to supplement the federal mineral rights data from USFS.

### Overview of Gauley Watershed Results

*Misty Downing, TNC*

The Gauley watershed is notable for a large area of undeveloped Wilderness Area, and the large Meadow River wetland complex in the southern portion. There is some surface and underground mining, and gas development occurs in the northwestern portion of the watershed. Development trends are clearly reflected in the results; the impacts of roads and urban areas are particularly evident in the uplands analysis. Streams water quality impairments are concentrated in the northwest part of the watershed, near mining activity, though there are impairments even within the protected areas. General trends consisted of Very Good-Good quality planning units in much of the eastern part of the watershed, and lower quality in the west and south, particularly around the major highways and small urban areas. There is also a significant amount of alternative land use, such as grazing, in the southern Meadow River portion of the watershed.

Comments: It was noted that DNR considers the Meadow River watershed a top priority, although there are no spatial data available on their priority areas at this time. It was questioned whether or not natural cover included pasture/hay, which it does not (this explains some of the lower scores in the Meadow River area, due to increased grazing activity). A stakeholder inquired about how TNC handles prioritization of potential conservation projects – do we use the results from this project, or would TNC send out a team to collect data in the field, particularly regarding biodiversity. The Project Team explained that field work is generally outside the scope of TNC protection projects, though we do consult DNR and other agencies/experts to assess the biodiversity of a particular site and conduct site visits to determine an area's suitability for conservation. Explanations of the various agency priority areas was requested (WV Division of Forestry, TNC, etc.), suggesting that it may be useful to provide documentation/background information about priority areas on the project's ConserveOnline webpage.

### Overview of Little Kanawha Watershed Results

*Misty Downing, TNC*

The Little Kanawha watershed has very little mining activity, but a great of oil and gas well development, both current and historic. It is largely a rural watershed, except for the urban area around Parkersburg, where the river drains into the Ohio. The water quality results were generally good, as there are few impaired streams, with the major issue being sedimentation. It was noted that the Streams Riparian Habitat ranks were relatively low in all three watersheds, and there appears to be a discrepancy in results between the HUC12 and catchment levels. This is believed to be a result of the methodology, i.e., the thresholds for critical metrics being the same for both HUC12s and NHDPlus catchments, and the fact that HUC12 and catchment-level results are determined independently of each other, but the Project Team plans to investigate this issue more closely. The Little Kanawha has comparatively few wetlands, but those existing provide decent opportunities for restoration. Uplands results were dominated by the effect of development/infrastructure around the urban areas. Consolidated Analysis results revealed a general trend of increasing potential future threats from west to east across the watershed.

Comments: Representatives from DEP mentioned that the Little Kanawha was known to be under-sampled and under-represented, and this was in the process of being rectified, which may explain the fewer impaired streams.

### Interactive Web Mapping Tool

The stakeholder group was presented with the demonstration/draft version of the future web mapping tool currently under development by Paul Angelino and Graham Emde of TNC's Colorado office. Currently, the demonstration version is a basic map with data layers that can be turned off and on in a table of contents, with little advanced functionality or formatting. Current layers include hydrology and mining, various land use and land cover layers, and the assessment results. To provide a clearer example of how the final web tool would function and what potential work flows would be, a potential use scenario was presented for each watershed and landscape. These scenarios were based on many of the project team's assumptions about how users would mainly use the web tool, for example that Very Good areas would be considered priorities primarily for protection and Fair areas mainly for restoration. Stakeholders were encouraged to provide their own examples of how they anticipated using the tool, their possible workflow(s), and what data and attribute information may be most useful in project planning.

Potential uses/alternative workflows suggested by stakeholders:

- DNR may use the tool to assess the potential success of a project, for example for mitigation proposals.
- Some agencies, such as USACE, may work at a regional or HUC8 level, and use the tool to get a general idea of trends within a larger watershed, before focusing on individual HUC12- based watershed planning.

- Some stakeholders envisioned using the tool for planning future projects: for example, determining accessibility, extent of surface mining, and if there is a watershed group operating in the area.
- A potential application of the tool would identify HUC12s that are ranked Very Good or Good, and look at the catchments within those HUC12s to identify areas ranked Fair or Poor, and which may indicate higher priorities for restoration action as they are pockets of poorer quality within higher-quality areas.
- A Poor rating was not considered necessarily a deterrent, as some end users may specifically look for those places to work, so that their efforts provide significant enough "lift" for regulatory purposes.
- Some stakeholders anticipated using the tool for project prioritization.
- Analysis results could help support other conservation activities by objectively rating the quality of different areas (for instance, WV Rivers Coalition demonstrating the importance of the eastern portions of the Gauley HUC8 watershed being designated a Birthplace of Rivers, supported by the Very Good-Good scores across multiple models and indices).

Stakeholders requested a Resources page for the web tool and suggested potential contacts or webpages to list that users can consult with further questions:

- Any existing best management practices (BMPs), how-to manuals and/or potential funding sources.
- USDA-NRCS (Natural Resources Conservation Service; www.nrcs.usda.gov).
- WV Division of Forestry.
- Chesapeake Bay Program (www.chesapeakebay.net).
- US EPA.
- Non-point pollution source webpage at WVDEP.
- Arbor Day Foundation.
- Nurseries/tree farms.
- WV Conservation Agency (www.wvca.us): Has 14 conservation districts across the state, with cooperative working agreements between different agencies and organizations, making it a good clearinghouse to reach multiple partners.

Stakeholders suggested additional datasets or changes to the data for the web map:

- Link map to Web Soil Surveys, which are updated 4-5 times a year, to bring in soils data if desired.
- Add the Wetland Reserve Program (WRP) national dataset.
- Add all modeled future energy threats data, if available (shale gas/well development potential, wind potential).
- Retain the impervious cover layer, which stakeholders considered an important dataset.
- Separate the protected lands into several layers that can be turned on/off (state, federal, etc.) as some users would be limited on which type of public lands they can work on or with.
- Add local watershed groups as potential contacts for more information or collaboration.

- Add data about which streams have current or pending watershed-based plans or TMDLs.
- Find or create spatial data to reflect all other restoration work happening within the watersheds, so end users know what projects exist or are pending in places they may be interested in working (this could help to identify gaps between existing projects and increase connectivity).
- Add a layer for activities carried out under Nationwide Permit 27 (general federal permit for stream/wetland restoration).
- Add layers for In Lieu Fee (ILF) projects, mitigation banks, and compensatory mitigation sites.
- Regularly update the Water Quality data (perhaps include a version of the trends tool from the DEP mining data application if feasible). Project Team intends to publish median Water Quality data for each station in the web tool.
- Add volunteer water quality monitoring data (which should be kept separate from agency data, with its rigorous quality control procedures). Trout Unlimited is initiating a water quality study, data may be available in about one year.

Desired functionality/features of the web tool:

- Search by town, county, HUC12, latitude/longitude coordinates.
- Print attribute tables.
- Manipulate the transparency and order of layers.
- Access contact information and publication dates (particularly for water quality data) for datasets in web tool
- Hover mouse over planning units to get their names.
- Hover mouse over a feature to get the lat/long coordinates.
- Import/export shapefiles.
- Save a map to pdf or jpg format.
- Export to .kmz format (for use in Google Earth).
- Get a well's API number, perhaps by hovering mouse over point feature.
- Click on map feature and open hyperlink to more info about data, a web page with a data source or ability to download that data.
- Streams labeled with DNR stream reach codes.
- A user guide to help users who aren't familiar with prioritization procedures or how to choose the best project for their goals.
- An embedded glossary of some of the more scientific or agency-related terms (particularly acronyms).

## Strategies and Trends

Ruth presented the concept of strategy development for the pilot project watersheds and solicited input on how end users may perceive the usefulness or necessity of including a list of potential strategies, and how detailed the strategies should be. Stakeholders were reminded that the goal of the project was to conduct watershed assessments and not provide watershed-based plans, so that the tool remains useful to the widest variety of potential stakeholders. Stakeholders were given a list of trends that emerged from the initial analysis results and asked to consider the following questions:

- How useful are potential strategies to you?
- How do you anticipate using the web tool and supplied strategies?
- What can we do to improve the usefulness of the strategies section for the end user?
- What datasets would help you develop useful strategies?

The stakeholders provided a variety of feedback to these issues. It was believed that a strategies section would be most useful to groups other than regulatory agencies. It was suggested that it would be beneficial to distinguish between regulatory/enforcement related strategies versus voluntary or optional strategies (which often also differentiates between more expensive and complex strategies versus what would be feasible for a watershed group or private landowner). One suggestion was to relate results seen in particular indices or metrics to trends in the watershed and potential resulting strategies to abate those threats. Another suggestion was to provide a sample workflow of this process so end users can learn how to associate analysis results in certain models and indices with possible conservation or remediation projects. As trends are anticipated to be different with different causes in each watershed, a general trends section may not be applicable, but a guide for identifying trends from analysis results may be more useful. There was an overall sentiment that a specific strategies section would likely not be very useful, but a detailed guide to potential resources for determining strategies (links to BMPs, manuals, etc.) would be more helpful.

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