West Virginia Watershed Assessment Pilot Project:

Tug Fork 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 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

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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.

We assessed the condition and function of the Tug Fork River watershed at two different 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 Tug Fork River watershed exhibited higher quality in the northwestern portions at the mouth of the river as well as along the southwestern river valley. Mining was the major cause of lower quality within central and southeastern portions of the watershed; overall, the Tug Fork is significantly impacted by resource extraction.

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 Tug Fork watershed stakeholders**.**
7. Complete final assessment.

1.5 Tug Fork Watershed Timeline

Table 1. Tug Fork River Watershed Timeline

Date	Activity
April 1, 2011	Award date, project initiation
June 13, 2011	First Technical Advisory Team meeting
November 13, 2013	Final End User Workshop and demonstration of prototype interactive web tool
December 31, 2013	Final Tug Fork 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 seven 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), **Gauley** (05050005), **Tug Fork** (05070201), and **Tygart Valley** (05020001). Draft watershed assessments were completed in two of the seven watersheds (the Lower/Upper Monongahela and the Elk) in the first year of the project, and during the second year an additional three (Upper Guyandotte, Little Kanawha, and Gauley) were completed and the assessment methodology 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 final two watersheds (Tug Fork and Tygart Valley) were completed during an extension of the pilot project, using the methodology defined during the first two years. The assessment results from the seven watersheds were incorporated into an interactive web tool that is accessible to a wide variety of stakeholders.

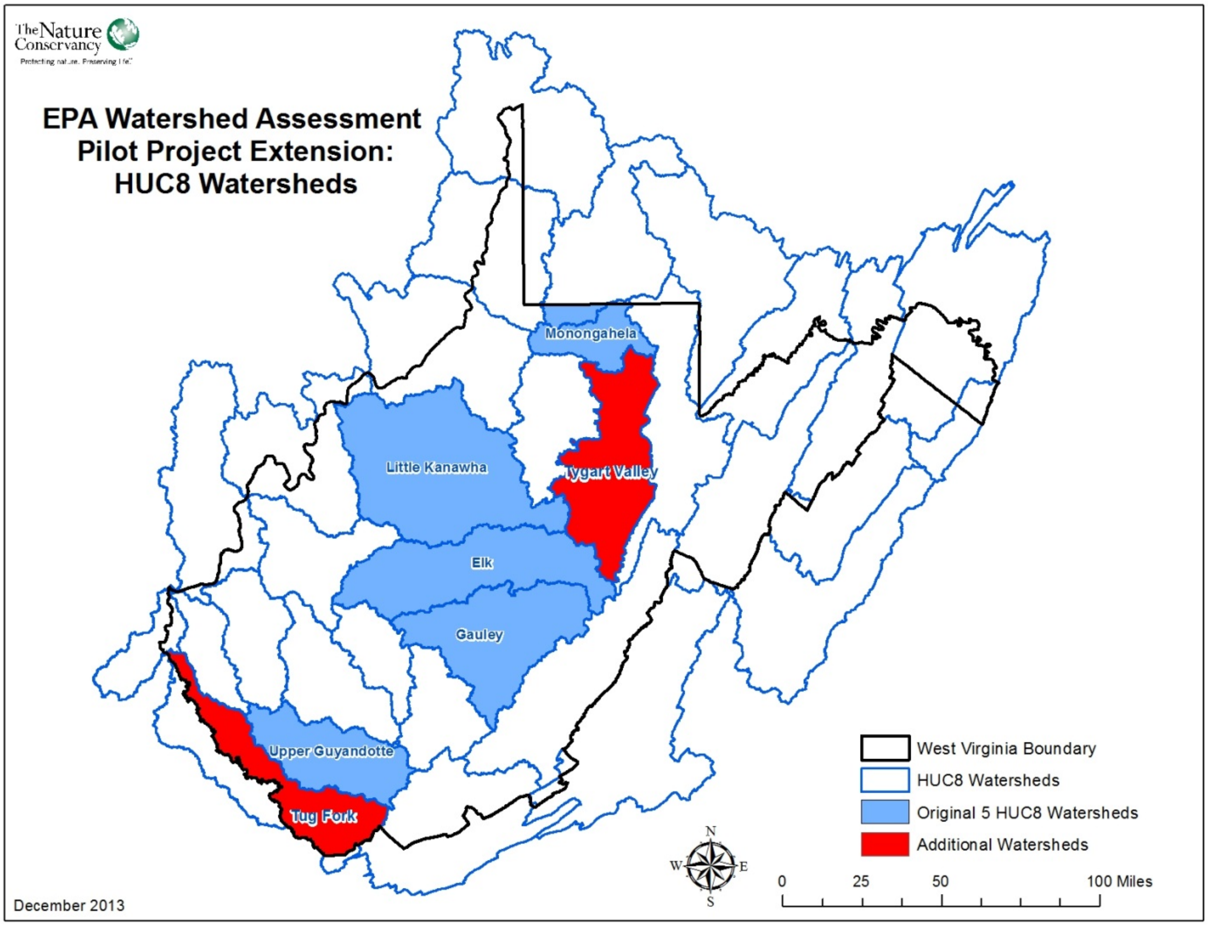

Figure 1. West Virginia Watershed Assessment Pilot Project HUC8 Watersheds (NRCS 2009)

1.6.2 Tug Fork River Watershed Study Area

The study area considered in this report is the portion of the Tug Fork River watershed, or drainage area, within West Virginia, which covers approximately 935 square miles along the southern border of the state (Figure 2). A significant portion of the watershed drains lands from the neighboring mountains of Kentucky and Virginia; the entire Tug Fork watershed area covers approximately 1,555 square miles within the three states. The Tug Fork River is a major tributary of the Big Sandy River and flows northwest for about 159 miles from its source in McDowell County, West Virginia at an elevation of 2,450 feet, to its confluence with Levisa Fork at the state line, at an elevation of 600 feet. The two forks join at Louisa, Kentucky to form the Big Sandy River. Major tributaries to the Tug Fork include Pigeon Creek, Dry Fork, and Elkhorn Creek. The Tug Fork flows through the West Virginia counties of McDowell, Mingo, and Wayne and drains a small portion of Mercer County. No major urban centers exist in the very rural watershed, and the largest town, Williamson, which sits along the river, had a population of 3,191 at the 2010 census. Other small towns within the watershed include Welch, Gary, Chattaroy, and War.

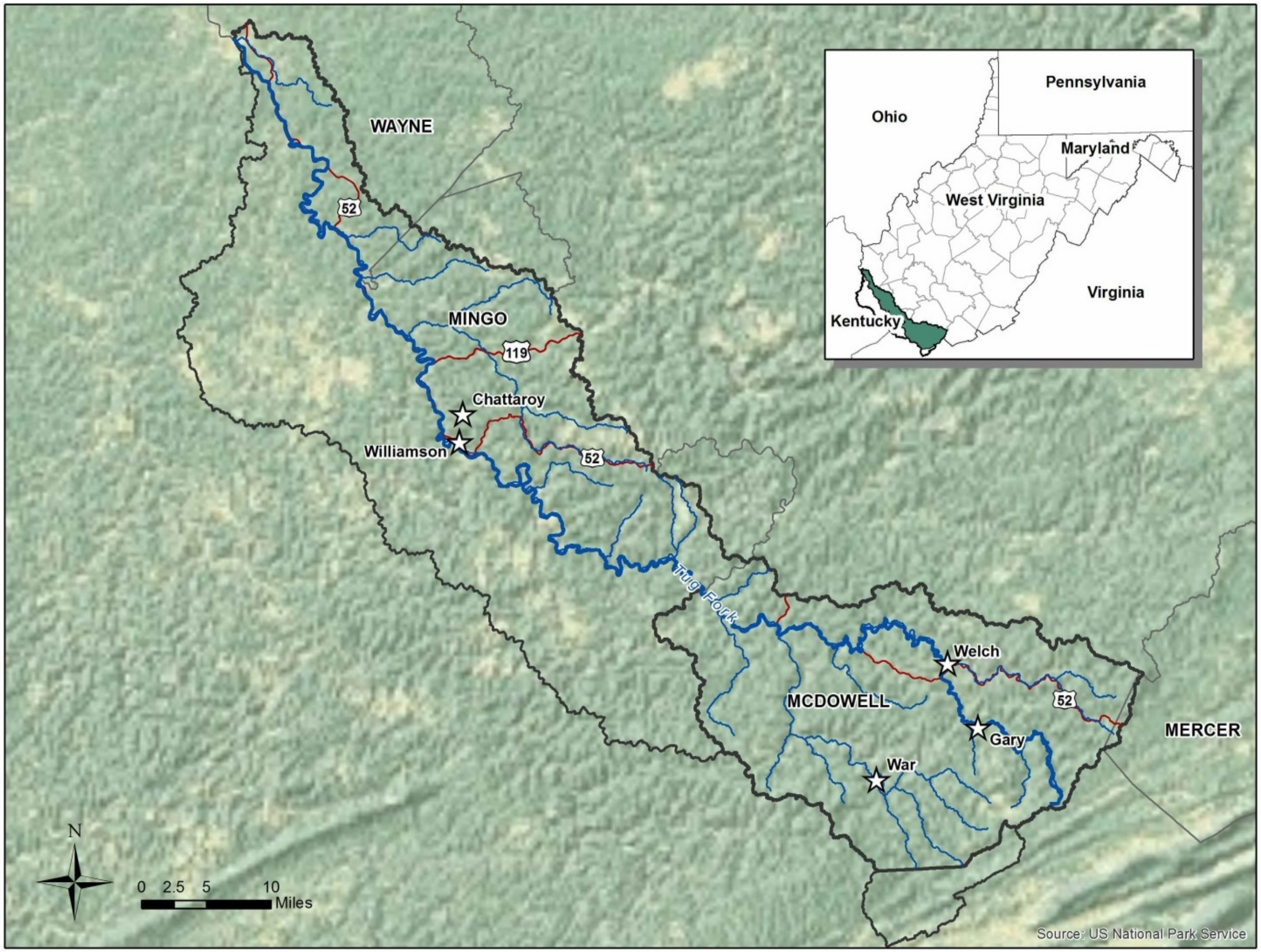

Figure 2. Tug Fork River Watershed Study Area (USGS 2005)

Section 2: Tug Fork Watershed Description

2.1 History/Economics

The Tug River valley is one of the most remote areas of West Virginia, and was one of the last places to be settled, with Mingo County being the last county created in the state in 1895. However remote, the region still played an active role throughout its history, and was the geographic setting for events of the French and Indian War, the West Virginia Mine Wars and the Hatfield-McCoy feud.

The river valley was occupied by various Native American tribes, such as the Cherokee, Shawnee, and Mingo, before the arrival of Europeans in the 18th century. Indeed, the naming of the river has its own place in history, as it is attributed to soldiers fighting during the French and Indian War in 1756. An expedition was led up Sandy Creek (the Big Sandy) against the Shawnee Indians of Ohio, and in the descent from the headwaters of a major tributary (the Tug Fork), the troop of Virginians and Cherokee Indians leading the expedition lost their canoes and supplies, and were forced to boil buffalo hides, or "tugs," to eat for food (Gillenwater 2010). It has also been noted that the Cherokee word "tugulu" refers to the forks of a stream, so this may have also been a reinforcing source of the name Tug Fork (Stewart 1967).

The Tug Fork watershed lies mostly within the southern coalfields of West Virginia and is underlain by extensive coal deposits; mining has been a dominant and continuous industry in the region since the Norfolk and Western Railroad was built there in the late 1800's. The booming mining industry made the area notable for being unusually diverse, as immigrants came in on trains seeking work. However, increased mechanization within the industry during the 20th century caused a steady reduction in staff, and the region currently has many abandoned mines and mining towns. Through the 1970s, the high quality metallurgical coal from the area was accessed primarily by underground mining, but surface mining has steadily increased since then with the growing demand for low sulfur coal (USEPA 2002b).

Coal mining was historically a dangerous and poorly compensated source of employment, with mining companies keeping wages low, forcing workers to shop in company-owned stores, and work under unsafe conditions. The creation of the United Mine Workers of America, a mining union, in 1890 sought to correct some of these wrongs, but the union was difficult to establish in West Virginia. Coal miners in Mingo County sought to join the union in 1920, and a standoff between locals and coal company employees resulted in twelve men being killed. This event also set in motion a course of events that later resulted in the death of the chief of police Sid Hatfield, a local hero (West Virginia State Archives 2013). This episode of West Virginia's history was dubbed the "Matewan Massacre" (Matewan being a small mining town at the confluence of the Tug Fork and Mate Creek).

In 1996, the National Coal Heritage Act recognized a 13-county region in the Appalachian Mountains of West Virginia as a National Coal Heritage Area, a unique cultural region where coal mining has made "a significant contribution to the national story of industrialization," and designated 187 miles of trails throughout the region, which includes the Tug Fork basin (NCHA 2013). Mining is still a significant part of the local economy, but is even more notable for its cultural legacy. The Tug Valley

Chamber of Commerce is housed in the Coal House, built in 1933 in Williamson, and is constructed of 65 tons of locally mined coal. Many festivals and activities, as well as most tourism in the Tug Fork watershed, are themed around the cultural heritage of coal mining.

The region is famous for the legendary Hatfield-McCoy feud, which lasted from 1865-1890, with the Hatfields in what would eventually be Mingo County, and the McCoys across the Tug Fork River in Kentucky. An extensive trail system for all-terrain vehicles (ATVs) was created to promote tourism in the area, and now supports more than 500 miles of off-road recreational routes.

The Tug Valley is also known for its significant historical flooding events, which have occurred several times since the area was first settled in the 1800s. A major flood in 1977, during which the river rose 25 feet above flood stage, caused eleven counties to be declared disaster areas (Gillenwater 2010). The flooding of the river was often used to transport logs from timber harvesting/logging, the first historical, and currently second major, industry in the region. Currently more than 2,000 acres of the West Virginia portion of the Tug Fork basin are held in corporate timber industry ownership (USEPA 2002b).

2.2 Climate

The Tug Fork River watershed experiences a humid continental climate with variable weather patterns (warm to hot summers and cold winters) and a fairly mild seasonal and geographic temperature range (Figure 3). Temperatures are generally lowest (average 49-51 degrees Fahrenheit) in the mountainous areas in the far eastern arm of the watershed, with the warmest temperatures in the western, lower river valley (average 55 degrees Fahrenheit), which coincides with an 1,850 foot increase in elevation from west to east. The mean annual precipitation shows a slightly different pattern, with the highest amounts of precipitation in the central portion of the watershed (average 47-49 inches) and noticeably less annual precipitation in the eastern portion (average 41-43 inches, Figure 4).

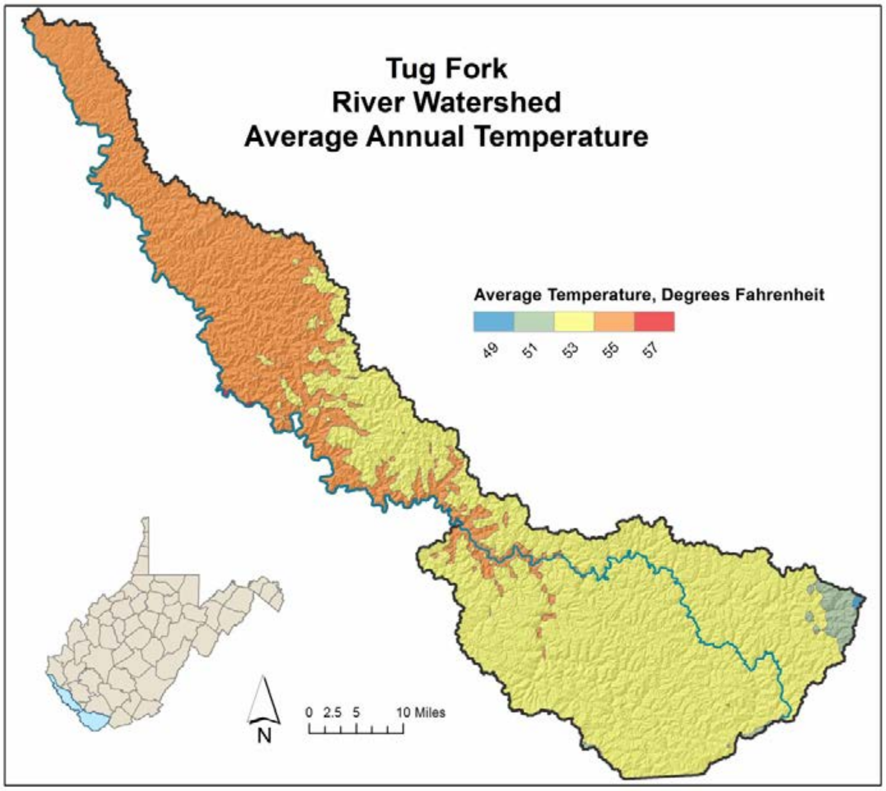

Figure 3. Average Annual Temperature in the Tug Fork River Watershed (USDA/NRCS 2006a)

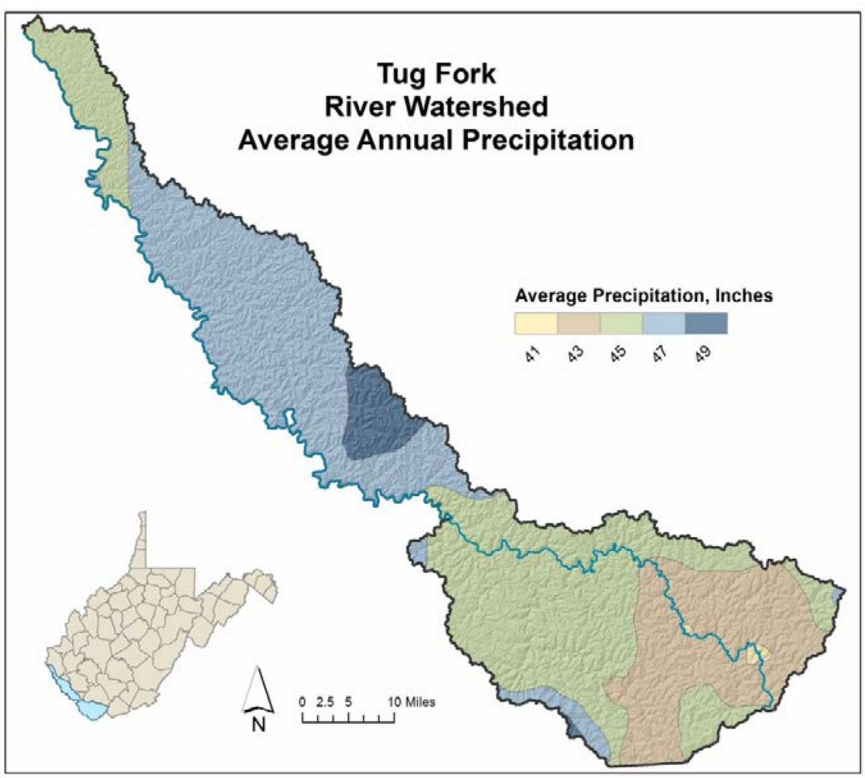

Figure 4. Average Annual Precipitation in the Tug Fork River Watershed (USDA/NRCS 2006b)

2.3 Natural Resources

2.3.1 Ecoregions/Geology

The Tug Fork River watershed lies within two TNC ecoregions (Figure 5). The eastern portion of the watershed is within the Cumberlands and Southern Ridge & Valley Ecoregion (CSRV), an incredibly varied topographic landscape with a complex geologic history and rich biodiversity. The Cumberlands portion of the ecoregion is composed of a high plateau and low mountains, while the Southern Ridge & Valley is characterized by a series of narrow valleys bounded by high ridges (TNC 2003). The area is notable for its steep hills and rock cliffs and the land is generally very rugged; this topography also makes the region prone to severe flooding events. The CSRV contains some of the largest blocks of intact hardwood forests in the eastern United States. The very western portion of the watershed is within the TNC Western Allegheny Plateau Ecoregion, an unglaciated plateau of horizontal layers of sedimentary rock.

The Tug Fork River watershed is primarily within USEPA Level III Ecoregion 69, the Central Appalachians (Figure 6, Omernik et al. 1992), with only the very mouth of the river within EPA Ecoregion 70, the Western Allegheny Plateau (WAP). The Central Appalachians Ecoregion is a “high, dissected and rugged plateau made up of sandstone, shale, conglomerate, and coal of Pennsylvanian and Mississippian age” (Woods et al. 1999). Elevations generally increase toward the east, and can be high enough to ensure a short growing season and a substantial amount of rainfall, resulting in extensive forest cover. The Western Allegheny Plateau is a dissected plateau with some rugged hills, underlain by horizontally

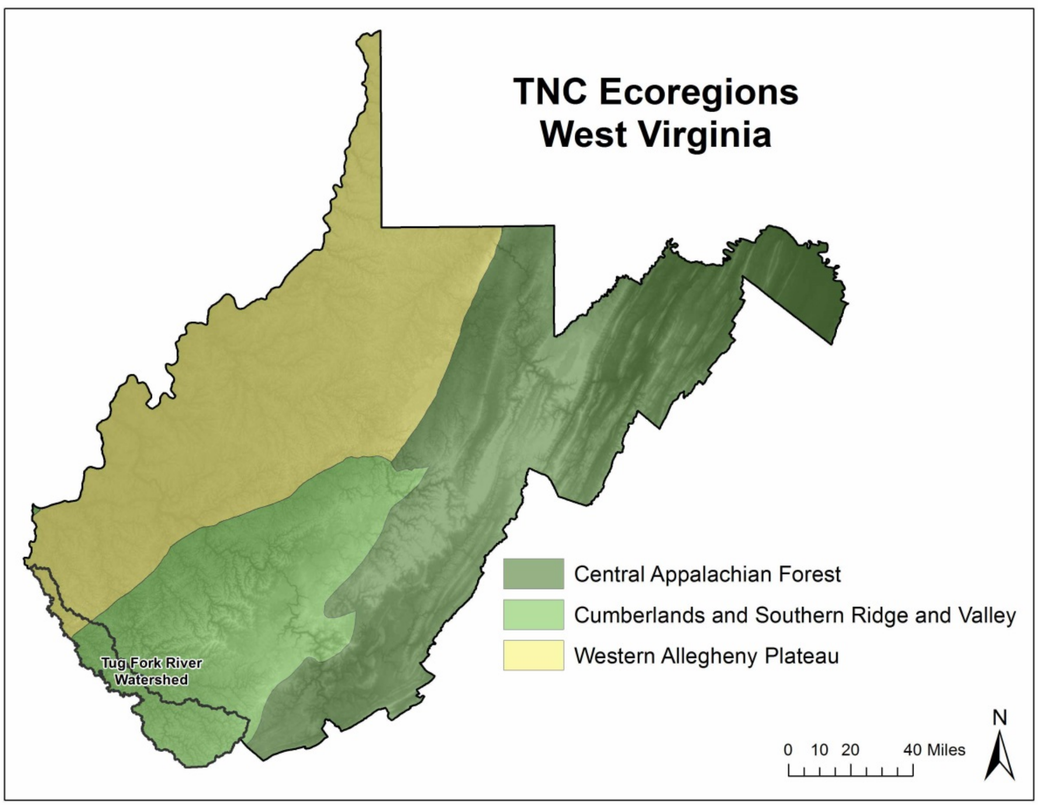

Figure 5. The Nature Conservancy Ecoregions – West Virginia (TNC 2009)

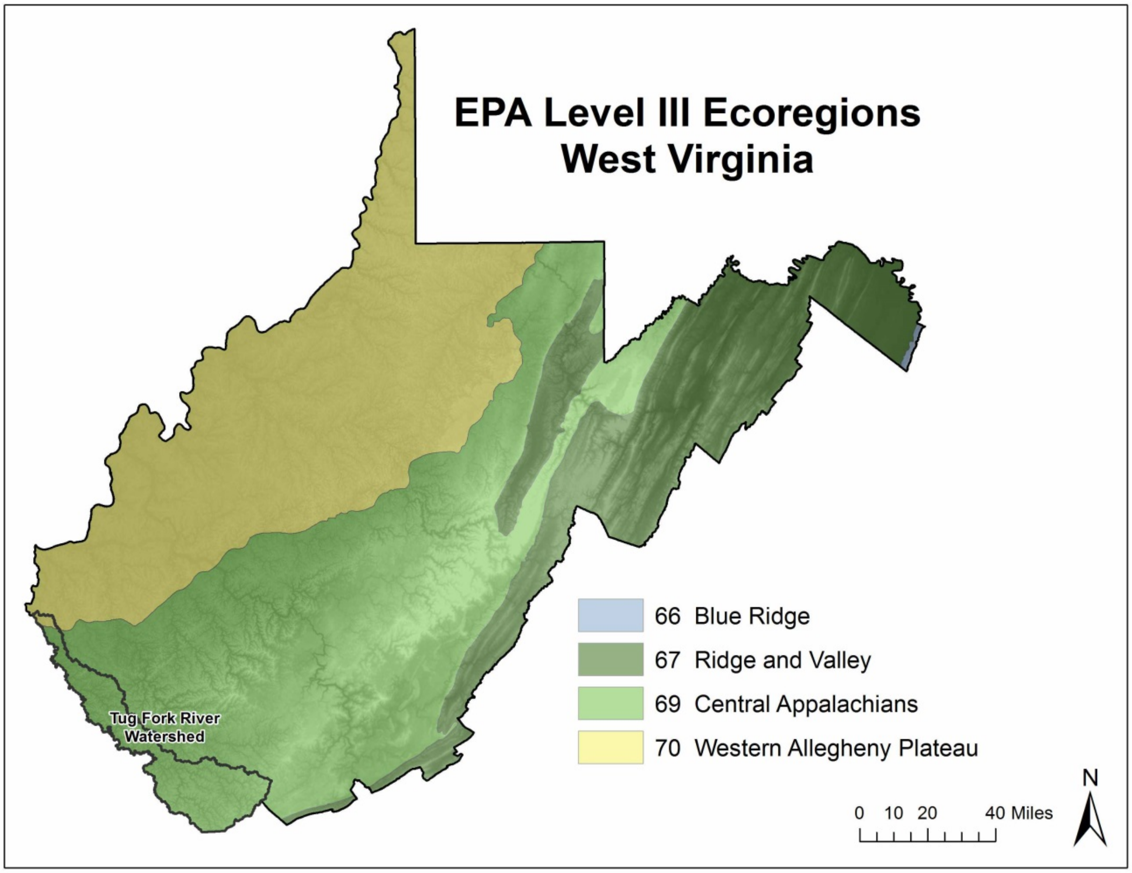

Figure 6. USEPA Level III Ecoregions – West Virginia (USEPA 2011)

bedded sedimentary rock, with generally lower elevations and less local relief than the Central Appalachians; it is also generally warmer and less densely forested.

Most of the rock strata within the Tug Fork basin are Pennsylvanian age, with coal-bearing formations of the upper part of the Kanawha and Allegheny formations exposed at the surface in Mingo County (WVGES 1998).

2.3.2 Land Use/Land Cover

According to a 2009-2010 land cover analysis (Maxwell et al. 2011, Figure 7), the Tug Fork River watershed consists predominately of deciduous, evergreen, and mixed forest (Table 2). Mining disturbance is the predominant anthropogenic land use, covering approximately 4% of the watershed, and grazing/agricultural land use types cover less than 1% of the watershed. Only about 1% of the watershed is developed; there are only a few small towns and the area is generally very rural. There are very few wetlands in the Tug Fork watershed, with a combined cover of less than one square mile.

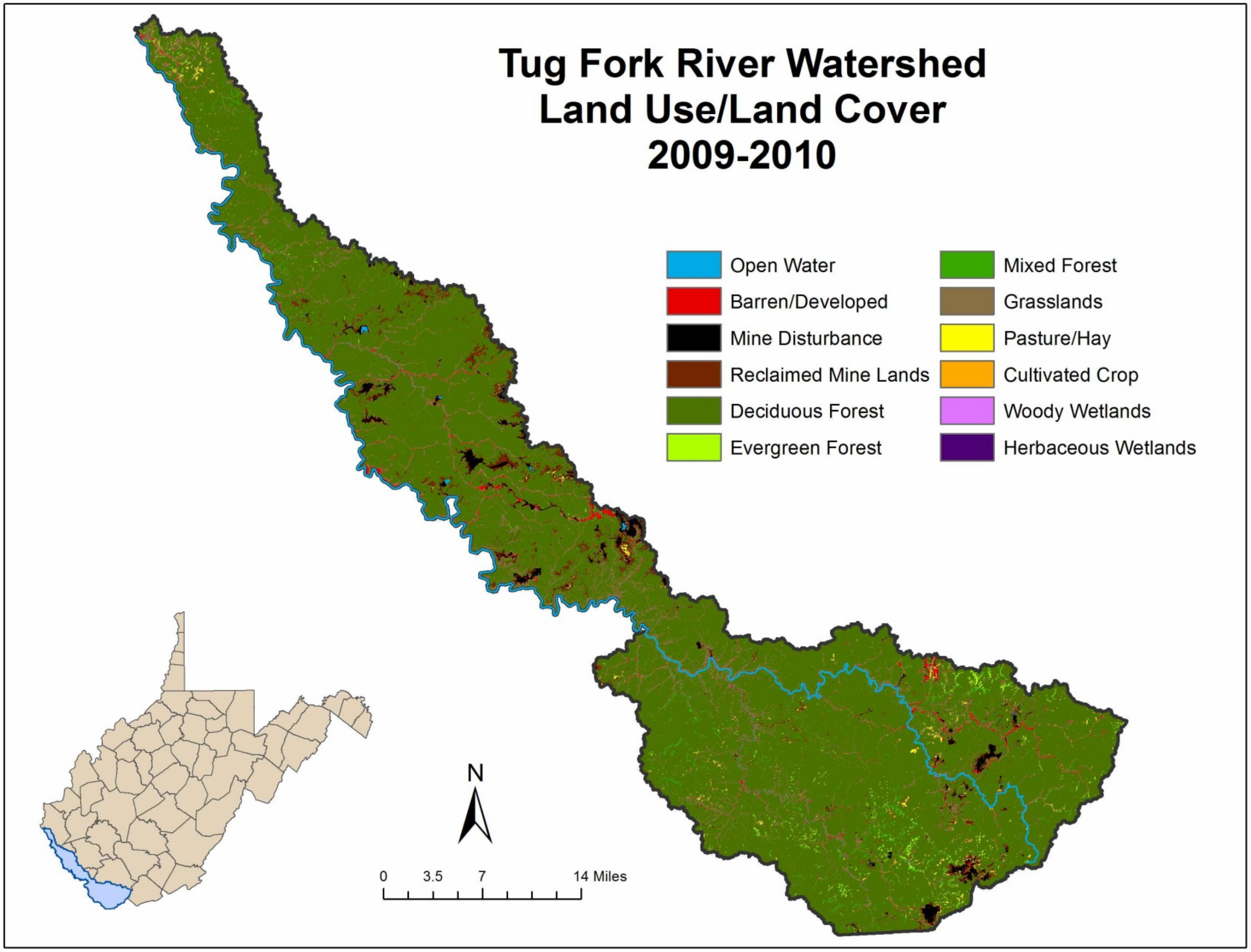

Figure 7. Tug Fork River Watershed – Land Use/Land Cover 2009-2010 (Maxwell et al. 2011)

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

Land Cover Type	Square Miles	Percent Area
Forest	793	85
Grassland	80	9
Mining Disturbance	42	4
Development	12	1
Pasture/Hay	5	<1
Open Water	4	<1
Wetlands	<1	<1
Agriculture	< 1	<1

2.3.3 Biodiversity

The West Virginia Natural Heritage Program has recorded 49 Species in Greatest Need of Conservation (SGNCs) in the Tug Fork River watershed (Table 3). No federally endangered species occur in the Tug Fork watershed, and many of the included species are imperiled or vulnerable only at the sub-national level, while they are considered more secure globally. Information about the species ranking definitions can be found in Table 4. A new species of stream-dwelling crayfish (Tug Valley Crayfish, *Cambarus hatfieldi*) endemic to the Tug Fork River system was identified by West Liberty University scientists in 2013; it is prevalent in the main stem of the river and all of the major tributaries of the Tug (Loughman et al. 2013). The scientific name of the Tug Valley crayfish is in honor of the legendary Hatfield and McCoy feud which occurred in the region in the late 1800s (see Section 2.1 History/Economics).

Thirty-four species of non-native invasive plants have been recorded in the Tug Fork River watershed (Table 5), with the most commonly reported being Japanese knotweed (*Polygonum cuspidatum*), mimosa/silk tree (*Albizia julibrissin*), tree-of-heaven (*Ailanthus altissima*), kudzu vine (*Pueraria montana*), and purple loosestrife (*Lythrum salicaria*).

Table 3. Rare Species in the Tug Fork Watershed (WVDNR 2005)

Scientific Name	Common Name	Sub-National Rank	Global Rank
Ambystoma jeffersonianum	Jefferson Salamander	S2	G4
Aneides aeneus	Green Salamander	S3	G3G4
Desmognathus welteri	Black Mountain Salamander	S2	G4
Pseudotriton montanus diastictus	Midland Mud Salamander	S1	G5
Pseudotriton ruber	Northern Red Salamander	S3	G5
Aimophila aestivalis	Bachman's Sparrow	S2S3	G3
Ichthyomyzon bdellium	Ohio lamprey	S2	
Lampetra aepyptera	Least brook lamprey	S2S3	
Lampetra appendix	American brook lamprey	S2	
Phoxinus erythrogaster	Southern redbelly dace	S2S3	
Pimephales vigilax	Bullhead minnow	S2	
Macrhybopsis hyostoma	Shoal chub	S3	

Scientific Name	Common Name	Sub-National Rank	Global Rank
Carpiodes carpio	River carpsucker	S2S3	
Carpiodes velifer	Highfin carpsucker	S1	
Moxostoma carinatum	River redhorse	S3	
Noturus eleutherus	Mountain madtom	S1	
Percina copelandi	Channel darter	S1	G3
Percina evides	Gilt darter	S2S3	
Percina sciera	Dusky darter	S2	
Neotoma magister	Allegheny Woodrat	S3	
Synaptomys cooperi	Southern Bog Lemming	S3	G3G4
Cicindela ancocisconensis	A Tiger Beetle	S3	G5
Cicindela unipunctata	A Tiger Beetle	S3	G3
Speyeria Diana	Diana Fritillary	S3	G4G5
Tritogonia verrucosa	Pistolgrip	S2S3	G3G4
Liatris scariosa var. nieuwlandii	Northern Blazing-star	S2	G4G5
Liatris turgida	Turgid Gay-feather	S1	G5
Solidago faucibus	Gorge Goldenrod	S2	G3
Silene rotundifolia	Roundleaf Catchfly	S1	G2G4
Calycanthus floridus var. glaucus	Sweet Shrub	S1	G4
Leucothoe recurva	Recurved Fetterbush	SH	G5
Juglans cinerea	Butternut	S1	G4G5
Stachys nuttallii	Nuttall's Hedge-nettle	S3	G4
Synandra hispidula	Guyandotte Beauty	S3	G5
Polygala curtissii	Curtiss' Milkwort	S2	G4
Anemone quinquefolia var. minima	Dwarf Anemone	S2	G5
Ranunculus pusillus var. pusillus	Low Spearwort	S2	G5
Heuchera longiflora	Long-flowered Alumroot	S1	G5
Saxifraga caroliniana	Carolina Saxifrage	S2	G4
Scleria oligantha	Little-headed Nutrush	S1	G3
Prosartes maculate	Nodding Mandarin	S1	G5
Lilium michauxii	Carolina Lily	S1	G3G4
Cleistes bifaria	Spreading Pogonia	S1	G4G5
Listera smallii	Kidney-leaf Twayblade	S1	G4
Arundinaria gigantea ssp. Gigantean	Giant Cane	S2	G4
Trichomanes boschianum	Filmy Fern	S2	G5
Botrychium oneidense	Blunt-lobe Grape-fern	S1	G4
Lygodium palmatum	Climbing Fern	S3	G4
Scleria oligantha	Little-headed Nutrush	S3	G4

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 the Tug Fork River Watershed (WVDA 2011)

Taxon	**Scientific Name**	**Common Name**
Plant	*Celastrus orbiculatus*	Asiatic bittersweet
Plant	*Elaeagnus umbellata*	Autumn olive
Plant	*Buddleja davidii*	Butterfly Bush (Orange-eyed)
Plant	*Cirsium arvense*	Canada thistle
Plant	*Miscanthus sinensis*	Chinese silvergrass
Plant	*Verbascum thapsus*	Common mullein
Plant	*Dipsacus fullonum*	Common teasel
Plant	*Holcus lanatus*	Common velvetgrass
Plant	*Echium vulgare*	Common viper's bugloss
Plant	*Dipsacus laciniatus*	Cutleaf teasel
Plant	*Cuscuta sp.*	Dodders
Plant	*Hedera helix*	English ivy
Plant	*Alliaria petiolata*	Garlic mustard
Plant	*Glechoma hederacea*	Ground Ivy
Plant	*Lonicera japonica*	Japanese honeysuckle
Plant	*Humulus japonicus*	Japanese hop
Plant	*Polygonum cuspidatum*	Japanese knotweed
Plant	*Microstegium vimineum*	Japanese stiltgrass
Plant	*Sorghum halepense*	Johnson grass
Plant	*Arthraxon hispidus*	Jointhead arthraxon
Plant	*Pueraria montana*	Kudzu vine
Plant	*Albizia julibrissin*	Mimosa, Silk Tree
Plant	*Lonicera morrowii*	Morrow’s honeysuckle
Plant	*Rosa multiflora*	Multiflora rose
Plant	*Carduus nutans*	Nodding thistle
Plant	*Conium maculatum*	Poison hemlock
Plant	*Ampelopsis brevipedunculata*	Porcelain Berry
Plant	*Paulownia tomentosa*	Princess tree
Plant	*Lythrum salicaria*	Purple loosestrife
Plant	*Daucus carrota*	Queen Anne's lace
Plant	*Lespedeza cuneata*	Sericea
Plant	*Ailanthus altissima*	Tree-of-heaven
Plant	*Rubus phoenicolasius*	Wineberry
Plant	*Iris pseudacorus*	Yellow iris

2.3.4 Impaired Streams

The WVDEP identified the key stressors to water quality in the Tug Fork watershed as: alkaline and acid mine drainage, inadequately treated sewage, excess sediment deposition, inadequate riparian buffer zone, and dredging and channelization (WVDEP 2006, Figure 8). Ecological assessments conducted in 1998 and 2003 showed that a significant portion of streams in the Tug Fork basin were suffering negative impacts to biological communities, particularly from coal mining activities. Results from the study corroborated other similar studies in the coalfields region, which found that dissolved solids caused biological impairment, as indicated by specific conductance and sulfate values.

Total Maximum Daily Loads (TMDLs) were developed for the main stem of the Tug Fork and 63 tributaries listed on West Virginia's 303(d) list in 1996 and 1998, primarily for metals and pH impairments, caused by both nonpoint and point sources of pollution. Most of the point sources are from permitted mining-related activity, while nonpoint sources include abandoned mine lands, timber harvesting, oil and gas wells and development/roads. Over 90 stream segments were listed in 2010 for metals, pH, biological, and fecal impairments, including the entire length of the Tug Fork main stem.

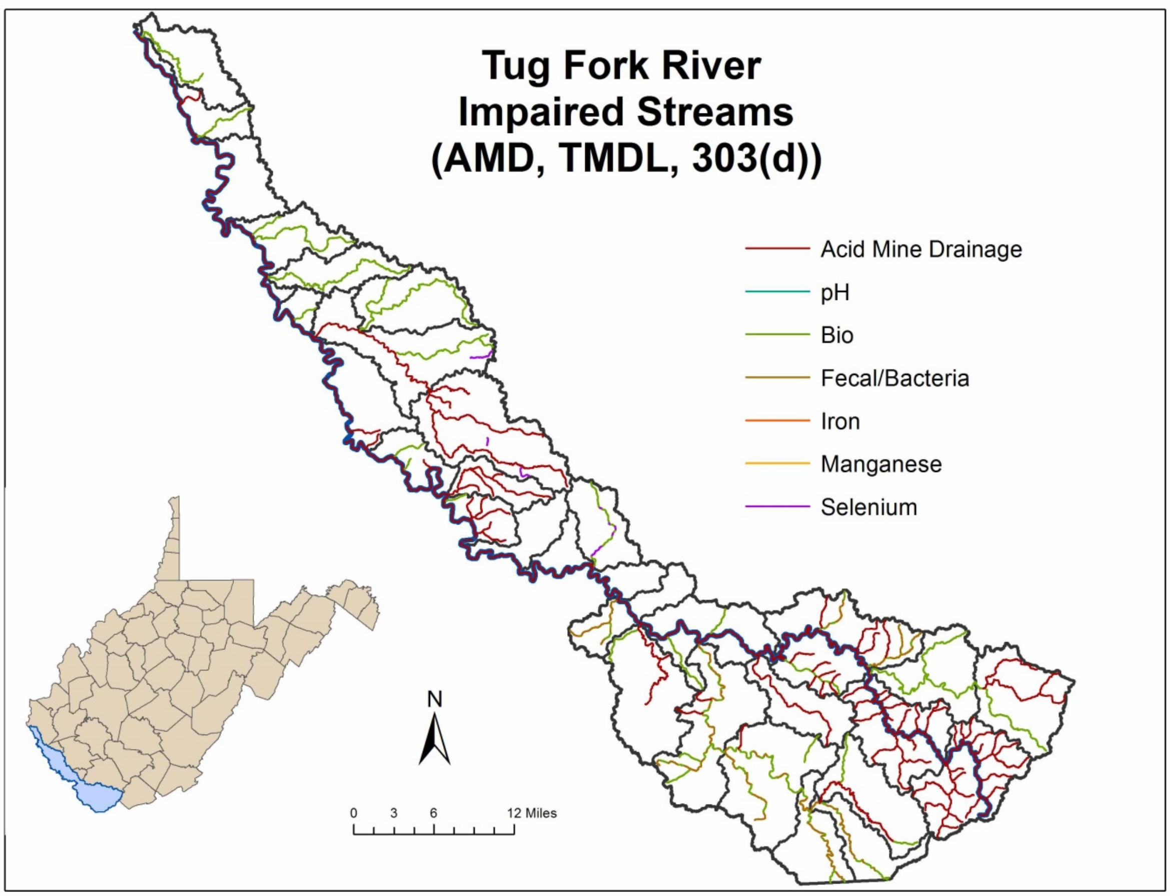

Figure 8. Tug Fork River Watershed – Impaired Streams

2.3.5 Wetlands

The Tug Fork River watershed has very little area of wetlands, with only 78 acres of mapped National Wetland Inventory (NWI) wetlands (Table 6, Figure 9. See also Section 3.1.2.2 for a discussion of NWI wetlands).

Table 6. National Wetland Inventory (NWI) Wetland Types - Tug Fork River Watershed (USFWS 2010)

NWI Code Prefix	NWI Wetland Type	Total Acres
PSS	Palustrine Shrub-Scrub Wetland	31
PFO	Palustrine Forested Wetland	25
PEM	Palustrine Emergent Wetland	22

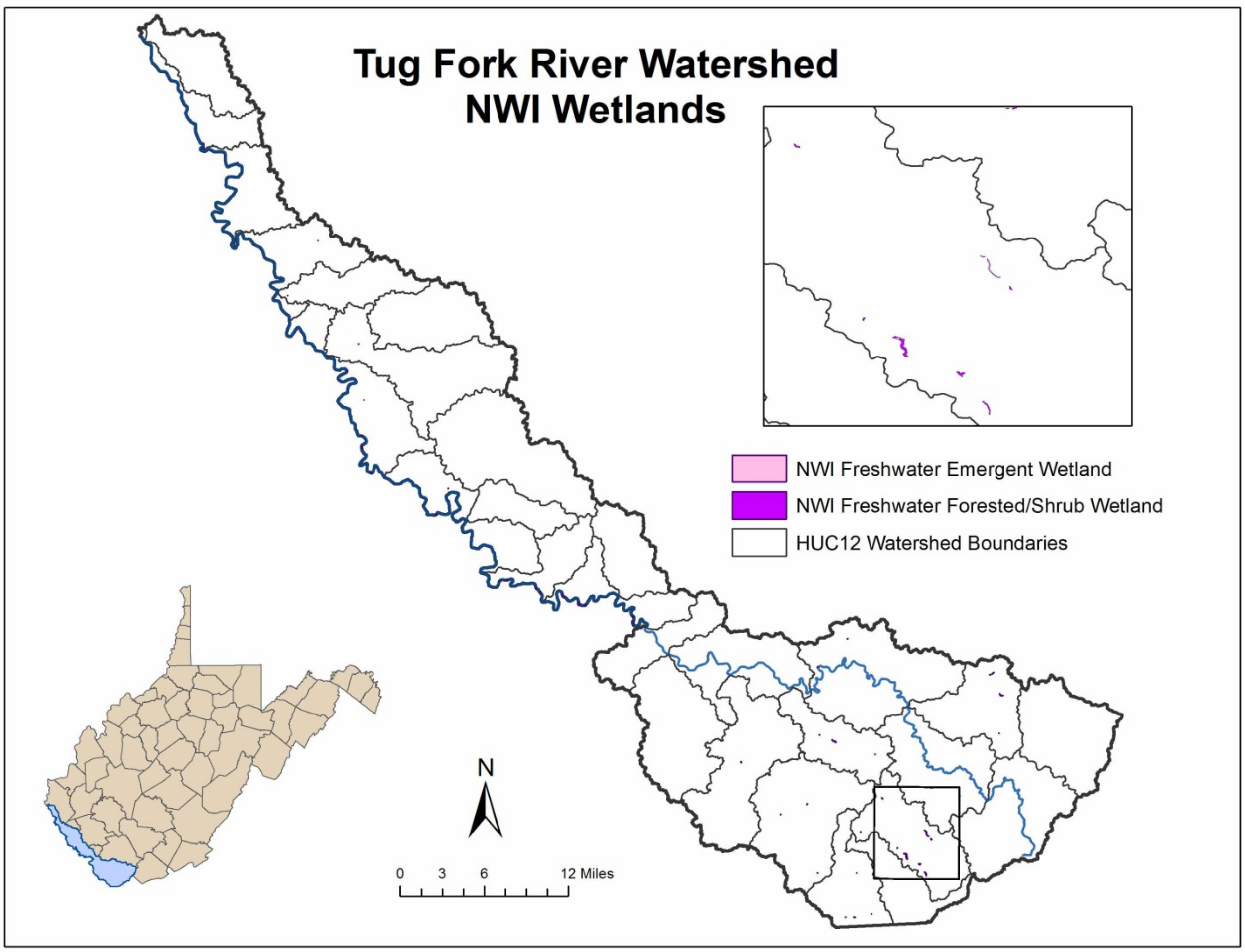

Figure 9. Tug Fork River Watershed – NWI Wetlands (USFWS 2010)

2.3.6 Vegetation Types

According to the Northeast Terrestrial Habitat Classification System (Gawler 2008), the upland habitat of the Tug Fork River watershed is dominated by southern Appalachian oak forest and south-central interior mesophytic forest, with significant cover of Allegheny-Cumberland dry oak forest and woodland (Table 7). For the purposes of this analysis, however, we used a 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). It is notable that developed habitats cover about 75 square miles of the watershed; it is likely that this classification includes the relatively extensive amounts of surface mining across the Tug Fork drainage.

Table 7. Northeast Terrestrial Habitat Types – Tug Fork River Watershed (TNC 2011c)

Ecological System Code	Habitat Type	Acres	Square Miles	Percent Area
202.886	Southern Appalachian Oak Forest	181,516	284	30
202.887	South-Central Interior Mesophytic Forest	167,085	261	28
202.359	Allegheny-Cumberland Dry Oak Forest and Woodland	121,780	190	20
20	Developed	47,939	75	8
202.373	Southern and Central Appalachian Cove Forest	30,444	48	5
5271	Grassland/Shrubland/Herbaceous	20,423	32	3
202.309	Cumberland Acidic Cliff and Rockhouse	15,311	24	3
80	Agriculture	10,374	16	2
11	Open Water	1,876	3	<1
202.600	Central Appalachian Pine-Oak Rocky Woodland	685	1	<1
202.591	Central Appalachian Dry Oak-Pine Forest	400	<1	<1
202.596	Central and Southern Appalachian Montane Oak Forest	346	<1	<1
202.593	Appalachian (Hemlock)-Northern Hardwood Forest	202	<1	<1
202.601	North-Central Appalachian Acidic Cliff and Talus	185	<1	<1
201.582	Laurentian-Acadian Wet Meadow-Shrub Swamp	27	<1	<1
202.604	North-Central Appalachian Acidic Swamp	20	<1	<1
201.594	Laurentian-Acadian Freshwater Marsh	16	<1	<1
202.332	Southern Appalachian Low Elevation Pine Forest	3	<1	<1

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 10). 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 Tug Fork River basin is presented in Table 8.

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 Tug Fork River watershed has 2,408 miles of NHD24K streams, of which approximately 2,028 miles, or 84%, are headwater 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).

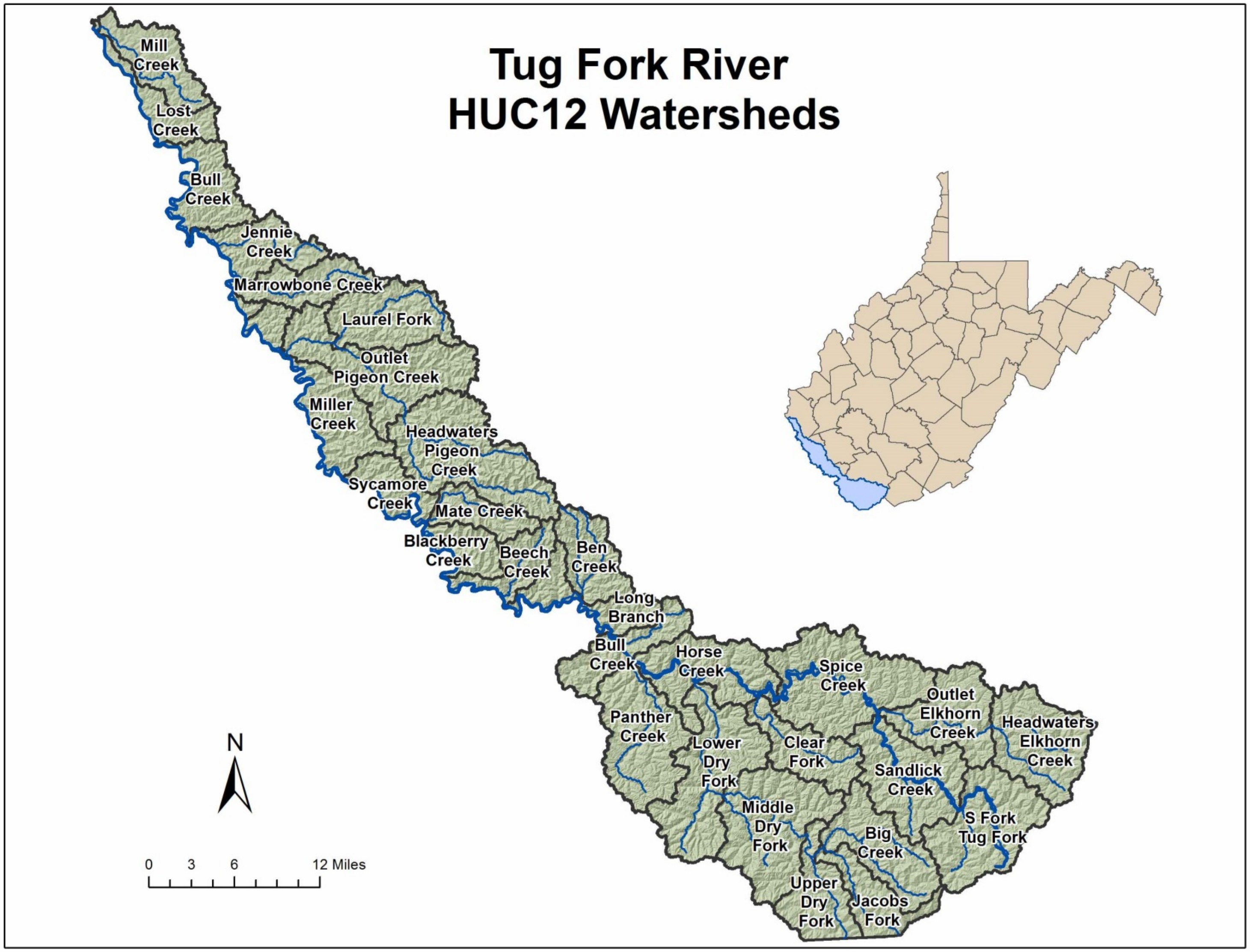

Figure 10. Tug Fork River HUC12 Watersheds (NRCS 2009)

Table 8. Tug Fork River Watershed – HUC12 Watershed Information (NRCS 2009, USGS 2011)

HUC12	HUC12 Name	Acres	Square Miles	Stream Miles (100K)	Stream Miles (24K)
050702010101	Big Creek	21740	34	46	87
050702010102	Jacobs Fork	13389	21	25	52
050702010103	Upper Dry Fork	16235	25	35	67
050702010104	Middle Dry Fork	33130	52	70	137
050702010105	Lower Dry Fork	32819	51	72	141
050702010201	South Fork Tug Fork-Tug Fork	29255	46	59	97
050702010202	Headwaters Elkhorn Creek	25669	40	60	93
050702010203	Outlet Elkhorn Creek	21142	33	39	78
050702010204	Sandlick Creek-Tug Fork	27454	43	55	100
050702010205	Spice Creek-Tug Fork	37519	59	81	157
050702010206	Clear Fork	16172	25	33	68
050702010207	Panther Creek	28745	45	63	115
050702010208	Horse Creek-Tug Fork	24392	38	46	91
050702010301	Bull Creek-Tug Fork	14602	23	26	53
050702010302	Ben Creek	14907	23	25	51
050702010303	Long Branch-Tug Fork	13120	20	32	53
050702010308	Beech Creek-Tug Fork	11168	17	25	38
050702010310	Blackberry Creek-Tug Fork	9244	14	20	32
050702010311	Mate Creek	10467	16	17	35
050702010312	Sycamore Creek-Tug Fork	10053	16	20	33
050702010401	Headwaters Pigeon Creek	36981	58	74	120
050702010402	Laurel Fork	21185	33	46	70
050702010403	Outlet Pigeon Creek	32723	51	69	112
050702010506	Miller Creek-Tug Fork	22971	36	56	83
050702010601	Marrowbone Creek	14612	23	33	50
050702010602	Jennie Creek-Tug Fork	16406	26	39	59
050702010607	Bull Creek-Tug Fork	15631	24	36	70
050702010608	Mill Creek	15965	25	28	68
050702010609	Lost Creek-Tug Fork	10752	17	27	50

The ARA 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 4. 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.

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

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

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) 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 Tug Fork 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 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

Table 10. 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.

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	

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 11). 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 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

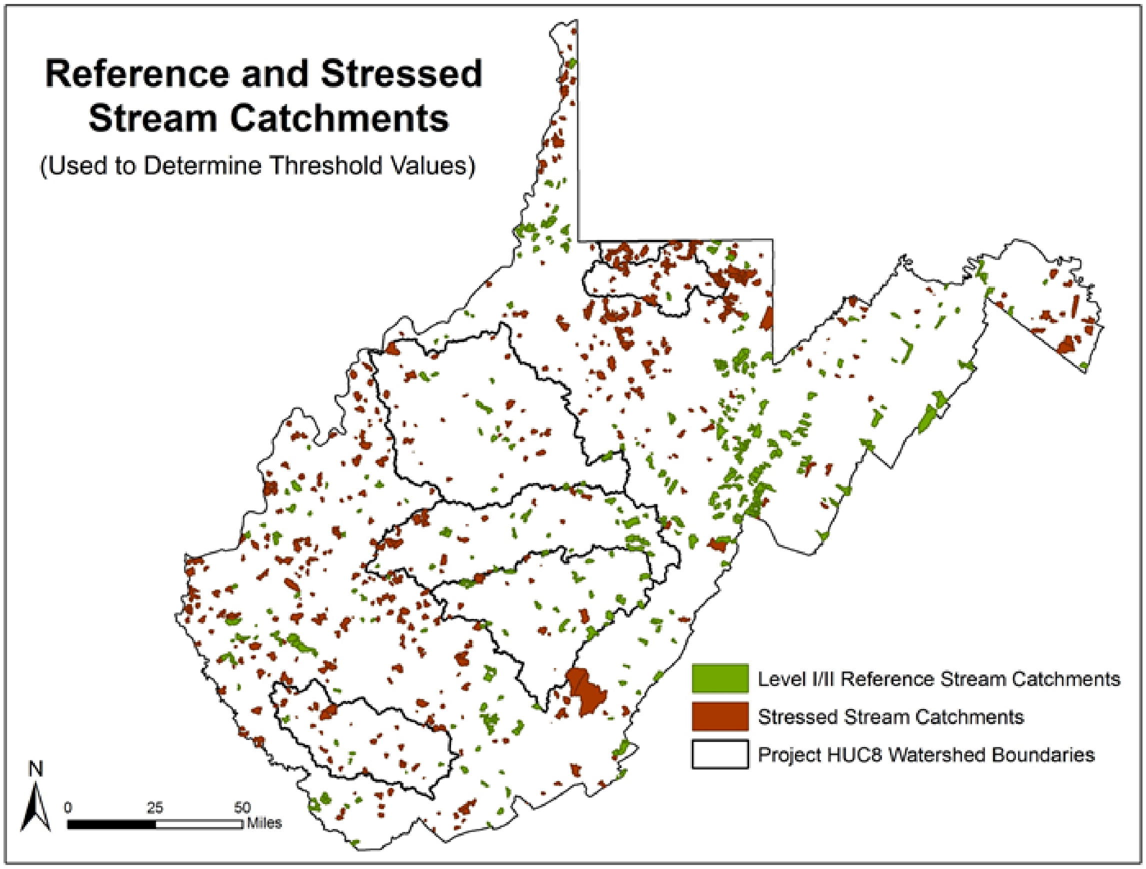

Figure 11. Reference and Stressed Stream Catchments

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 12). This methodology did not work well for some metrics with extremely skewed distributions, for example where both the 35th percentile and the median and 75th 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.

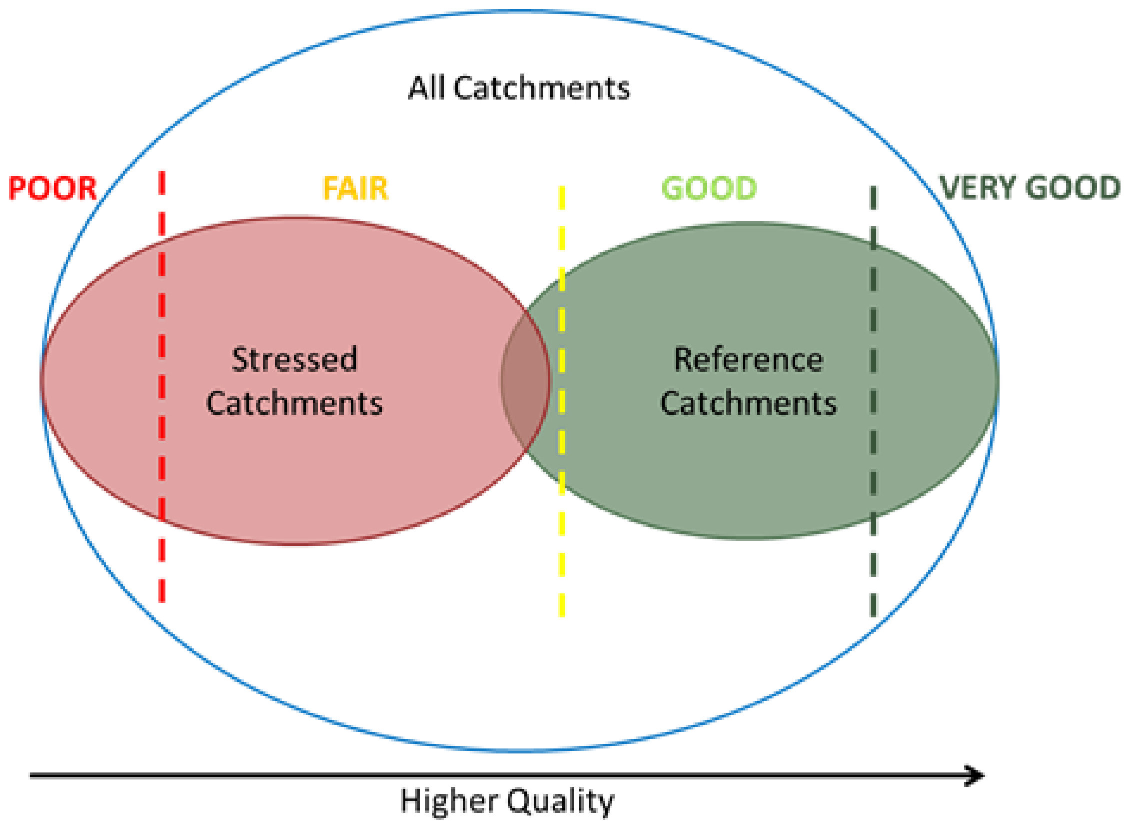

Figure 12. Threshold Definition Model

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 3rd 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:

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

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:

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

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 18, 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:

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

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 13 - 15): 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.

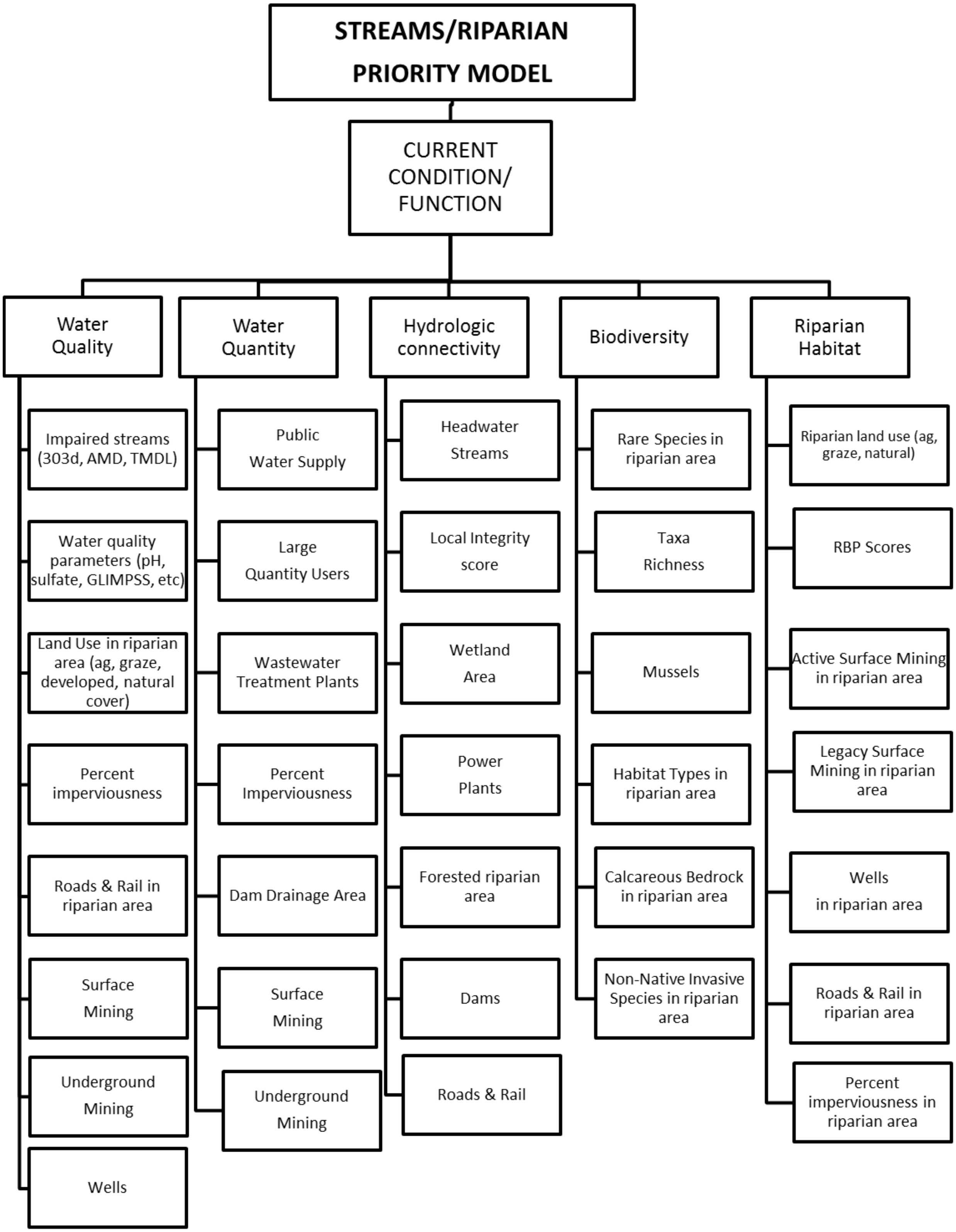

Figure 13. Streams/Riparian Areas Priority Model Flowchart

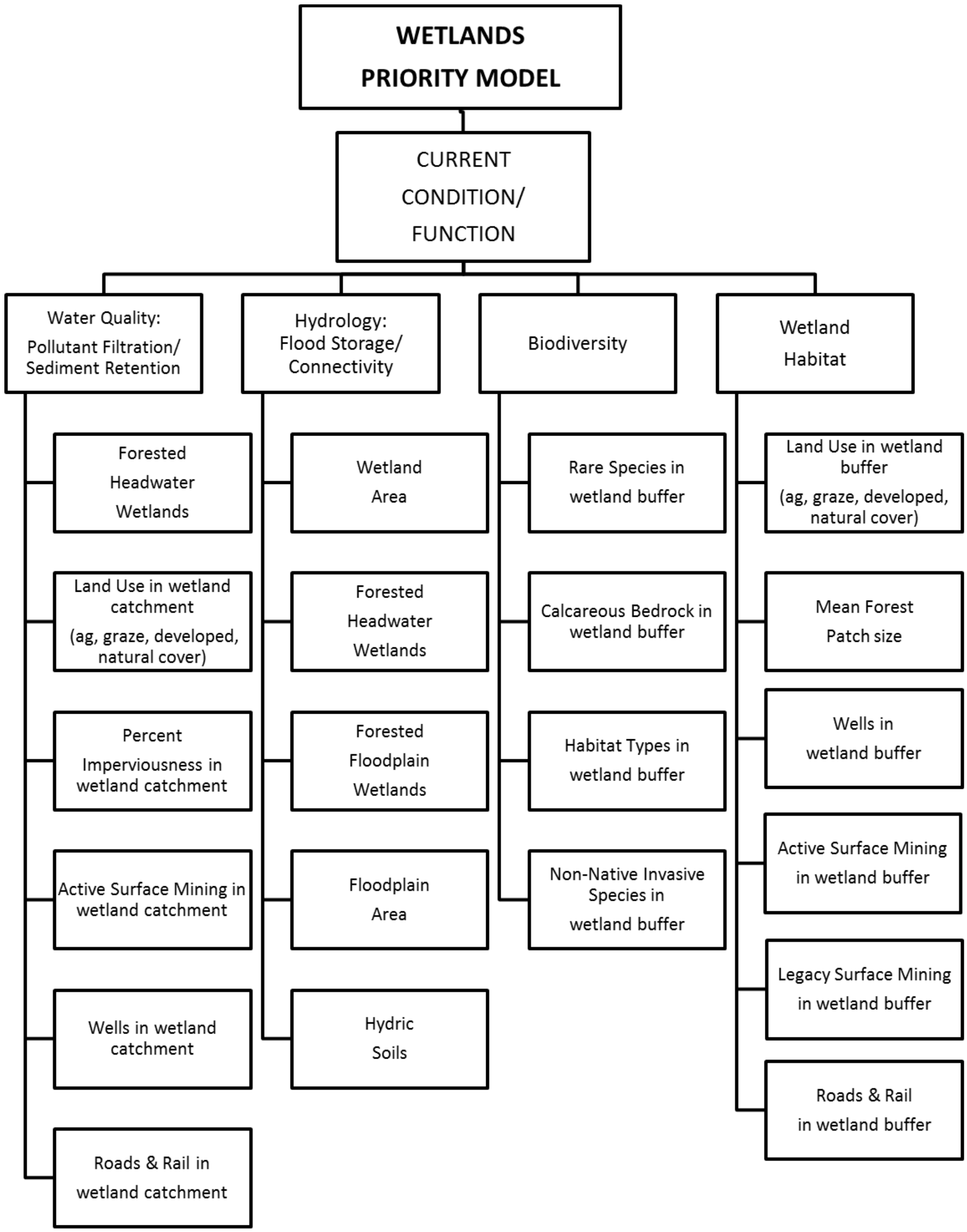

Figure 14. Wetlands Priority Model Flowchart

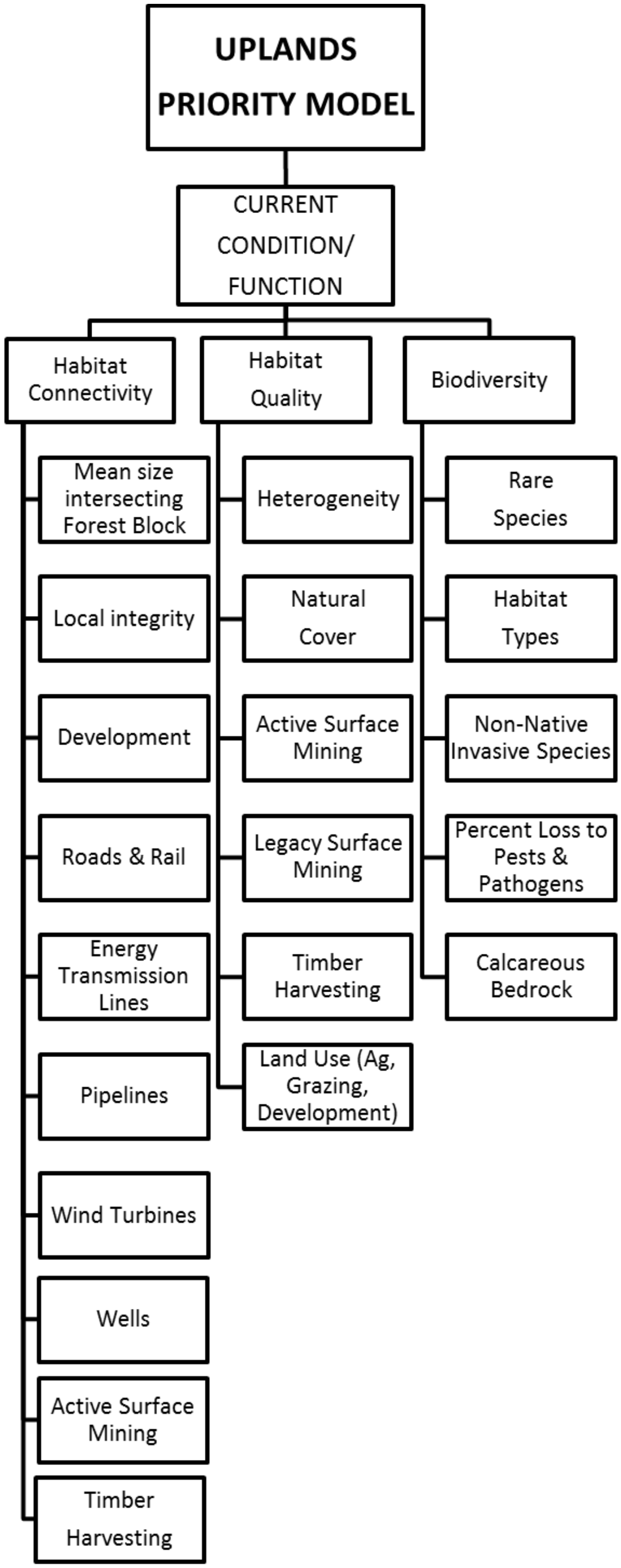

Figure 15. Uplands Priority Model Flowchart

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 19, 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 16). 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:

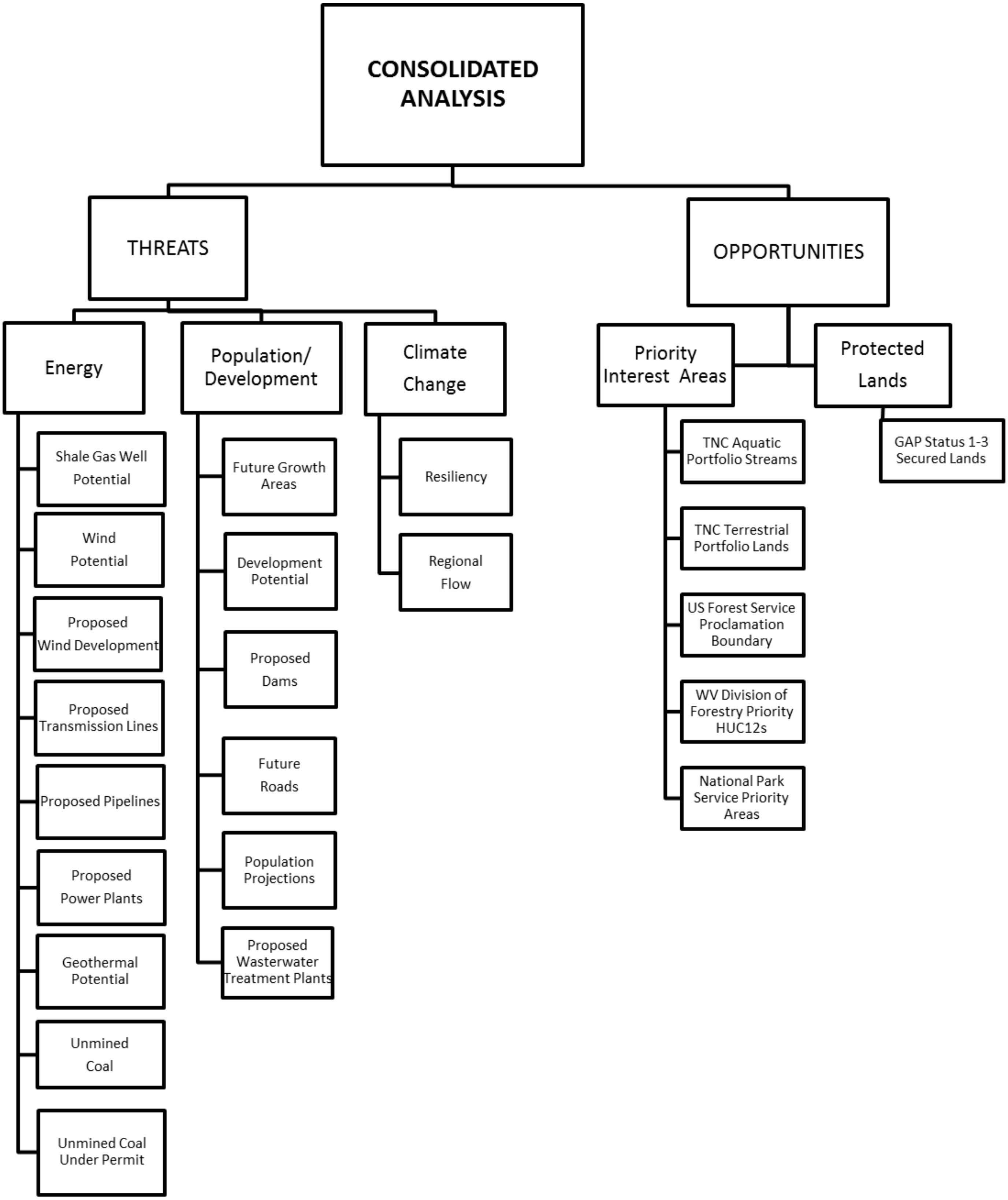

Figure 16. Consolidated Analysis Flowchart

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.

4.1 Current Condition Results and Discussion

4.1.1 Streams/Riparian Areas

Figures 17a and 17b 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 most notable trends, which are evident in all models and most indices, are the higher quality scores in the northwestern section of the watershed at the mouth of the river and along the southwestern river valley, likely due to the high percentages of natural cover and some protected lands in these areas, and the lower quality scores in the central and southeastern portions of the watershed, where resource extraction, particularly mining activity, is more concentrated (Figure 18). The Tug Fork has mostly Fair Streams Overall scores, though several HUC12s are in the Good category, those with the relative highest quality including Panther Creek, Clear Fork, and Big Creek. The catchment level analysis results follow the same pattern, with the addition of a few Very Good catchments throughout the watershed, primarily in headwaters catchments. At the catchment level, the Fair planning units are generally in areas with extensive mining activity. Mining activity is a strong determinant of scores in most models and indices within the Tug Fork basin.

Similar patterns emerge, with slightly lower overall quality, in the Streams Water Quality (SWQ) index results (Figures 19a and 19b). Ben Creek is the only HUC12 scoring in the Poor category, likely due to the extent of mining in this watershed (Figure 18), which caused a Poor score in two critical metrics, surface mining and median specific conductivity values (it also scored a Poor in median sulfate values, indicating that this HUC12 has a mining-related water quality issue). A combination of factors caused the many Fair HUC12 scores, including low scores for stream water quality parameters that are mostly mining-related (sulfate and specific conductance), high percentages of underground mining, a higher density of wells, and increased development in the riparian area. Among the Good HUC12 scores, the primary drivers were lack of surface and underground mining and oil and gas wells, and more natural cover in the riparian area. Some areas, however, did still have development, grazing, or agriculture in the riparian area, keeping those HUC12s in the lower quality Good category. SWQ results at the catchment level agree with the patterns of the HUC12 analysis, with several Poor catchments in areas of mining activity, and mostly Good and Very Good catchments around the mouth of the river and within the southwestern river valley. Generally, the catchments around Panther State Forest/WMA and Laurel Lake WMA are in the Good to Very Good category throughout most indices and including the SWQ index. The general patterns seen within both the Overall scores and the Streams Water Quality scores repeat throughout most of the index results.

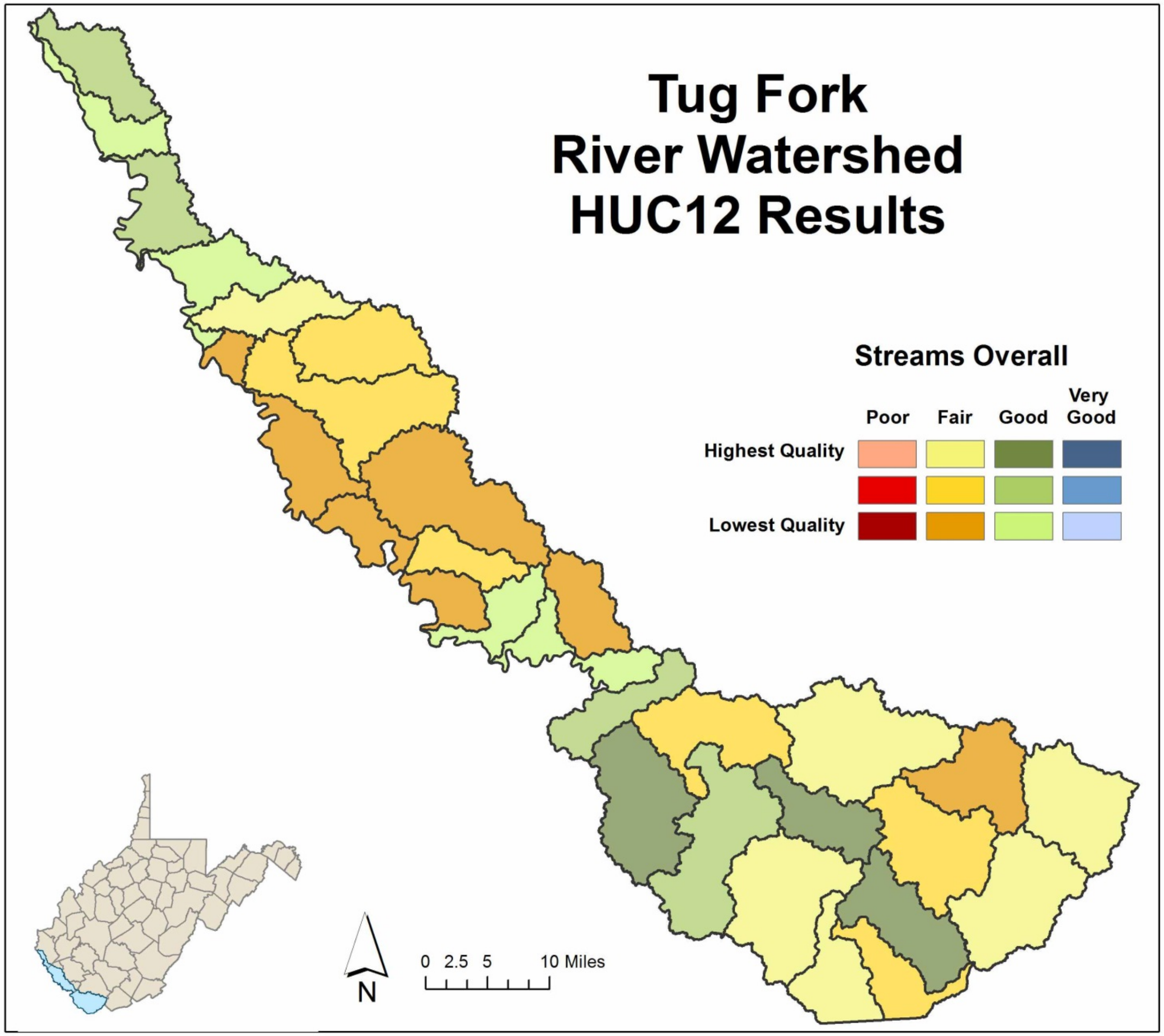

Figure 17a. Streams Overall Results – HUC12 Level

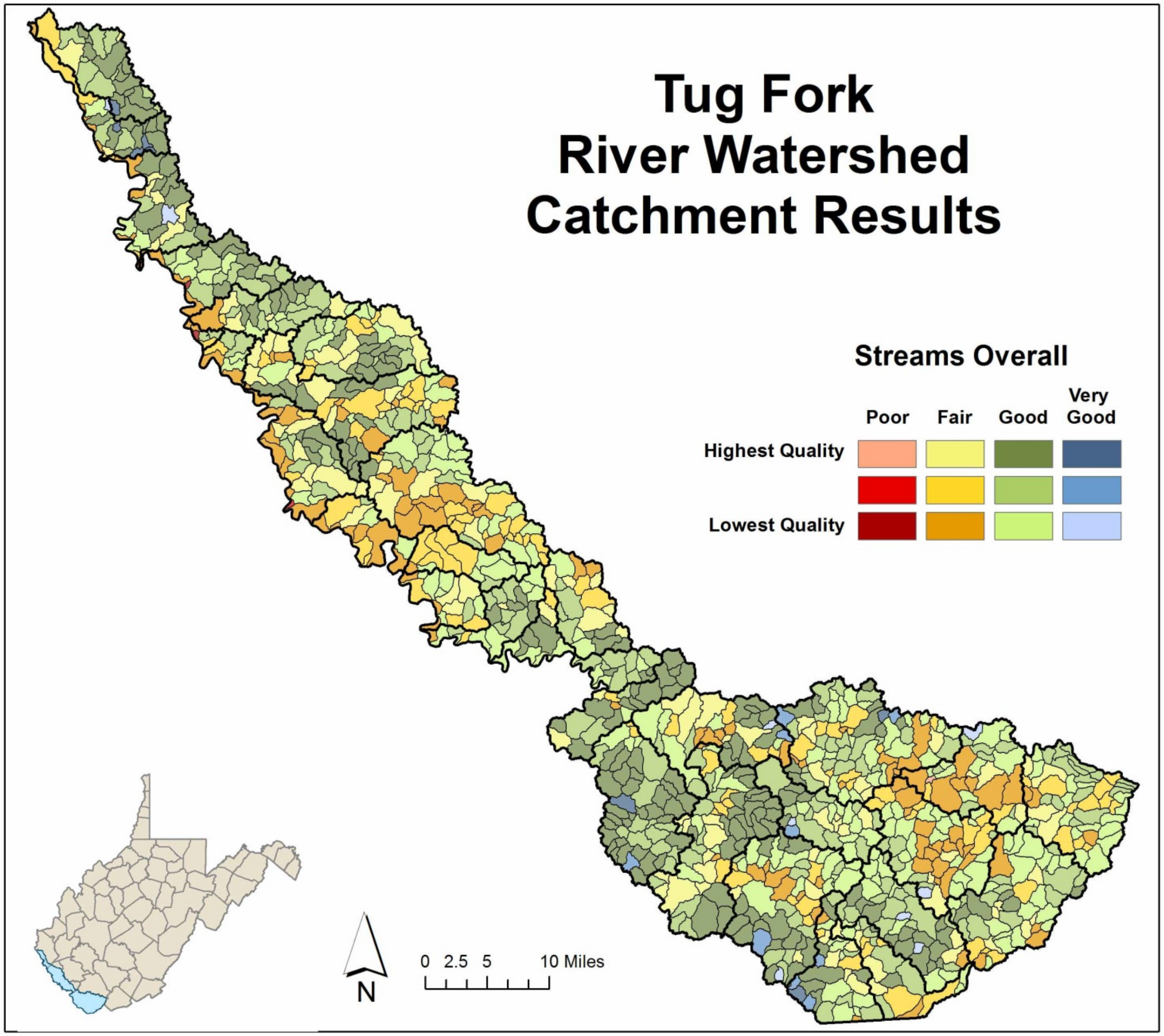

Figure 17b. Streams Overall Results – Catchment Level

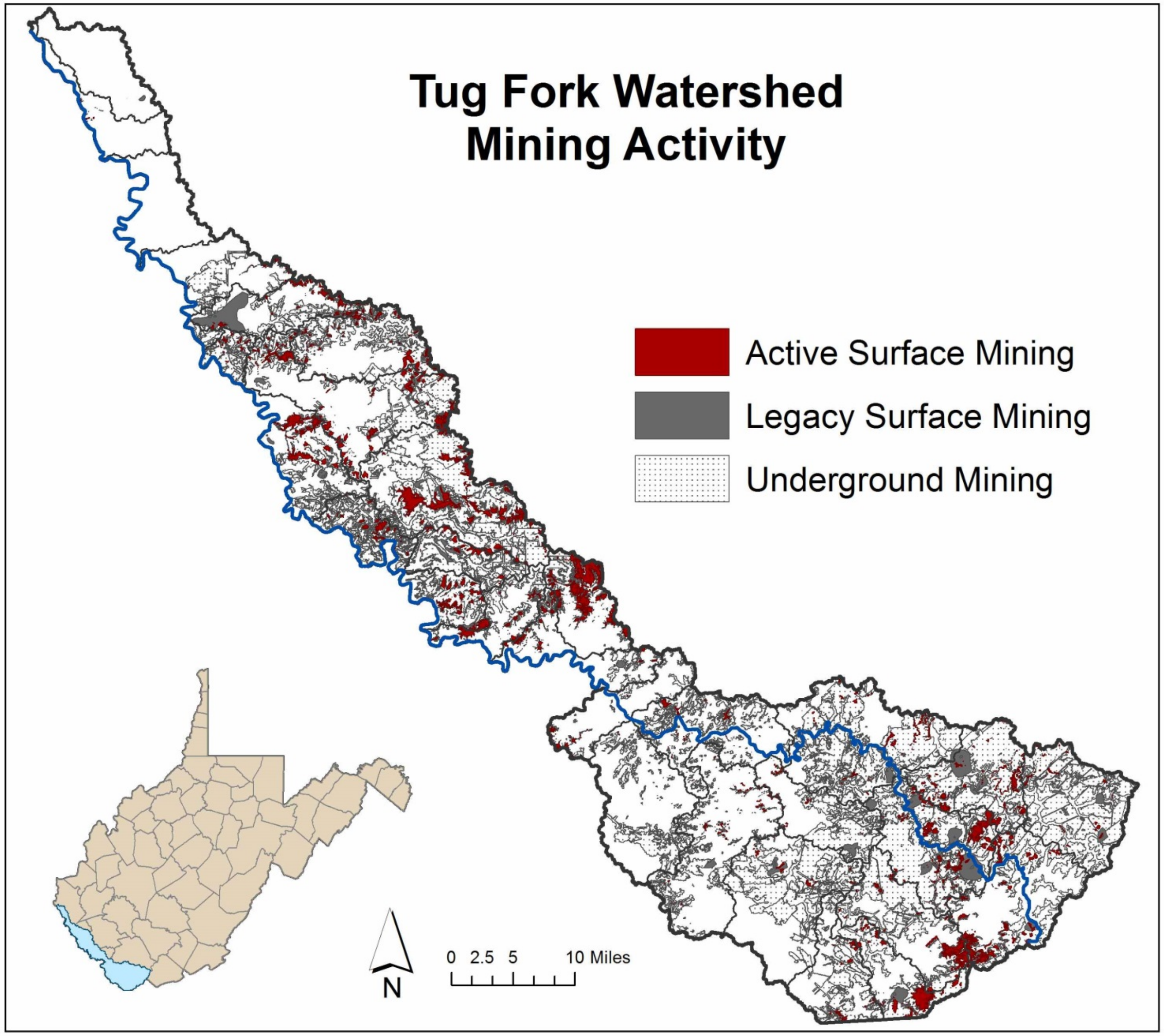

Figure 18. Tug Fork River Watershed - Mining Activity (Maxwell et al. 2011, WVDEP 1996, WVDEP 2011b, WVGES 2010)

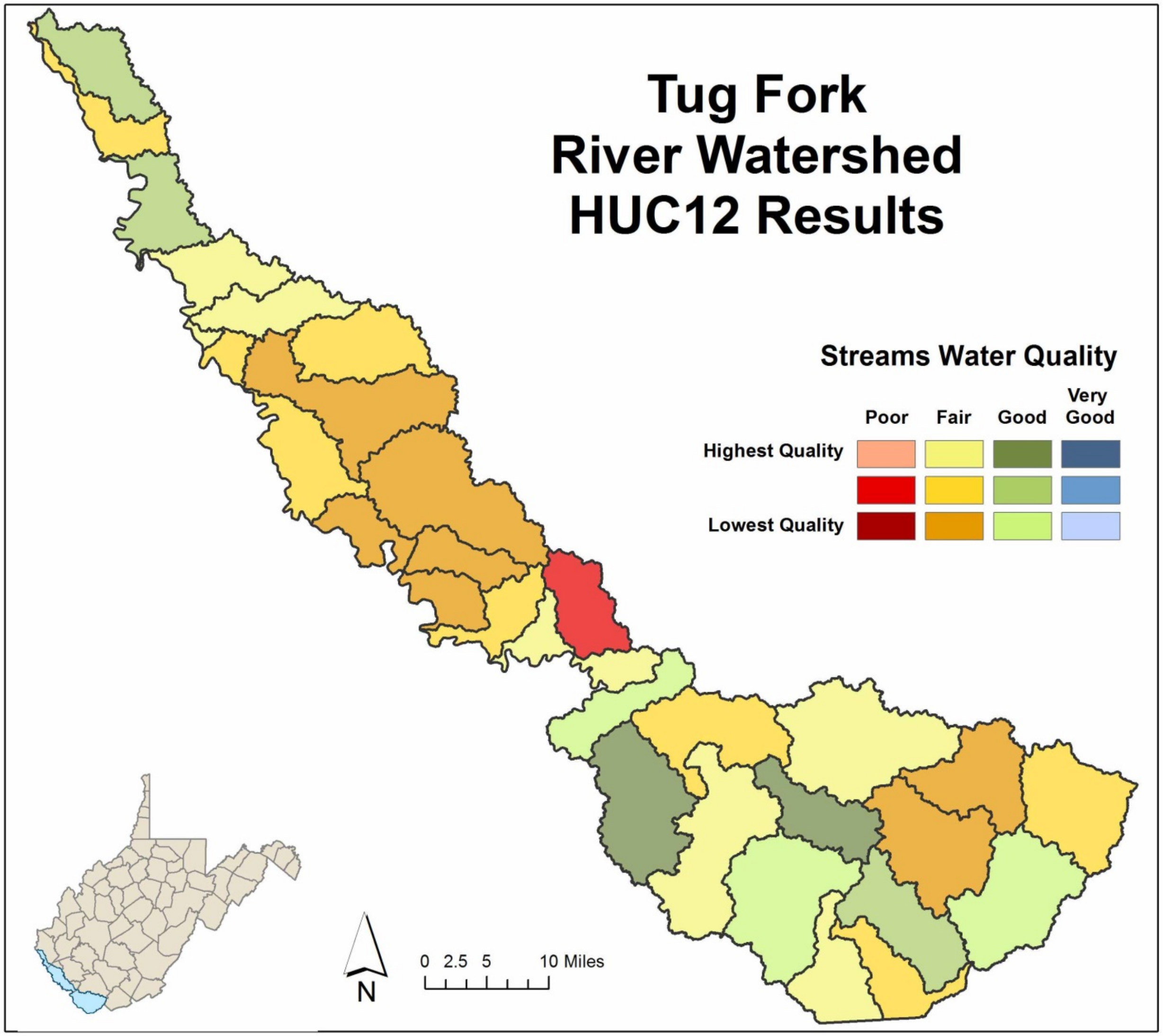

Figure 19a. Streams Water Quality Index Results – HUC12 Level

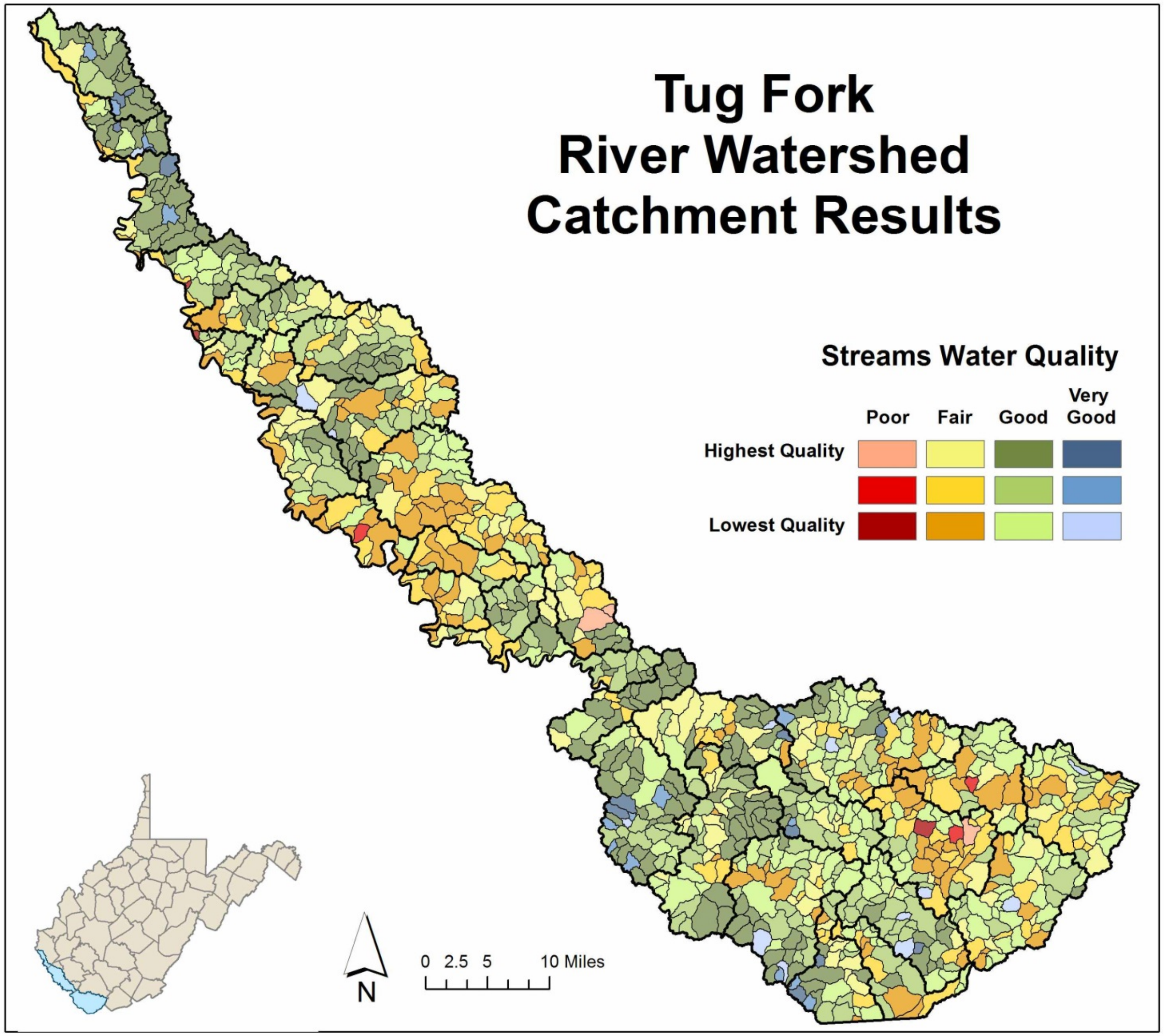

Figure 19b. Streams Water Quality Index Results – Catchment Level

The Streams Water Quantity (SWN) index results are higher than the previous index, with more HUC12s scoring in the Good category and even one Very Good HUC12, Bull Creek (Figure 20a). This high score is due to a lack of negative metrics associated with this index in the Bull Creek HUC12, except for a very low impervious cover score (1.26%). Those HUC12s in the Good category often have a significant amount of underground mining or dam drainage area, which keeps their scores slightly lower. The same overall pattern is maintained at the catchment level, though this level shows greater variation of scores with more planning units falling into either the Poor or Very Good category (Figure 20b). Poor catchments all had impervious cover scores in the Poor category, which is the critical metric in this index. Fair catchments often had very high percentages of either surface or underground mining, and many were also influenced by the impervious cover critical metric. Those catchments scoring in the Very Good category had good scores in the negative metrics. There are some instances where a Good HUC12 includes mostly Very Good catchments. This is generally caused by point-scale metrics that are located in small numbers in each catchment, but are additive over the larger HUC12 scale and will therefore impact the scores of the HUC12 planning units more than the catchment planning units.

The Streams Hydrologic Connectivity (SHC) index results follow the same geographic trends as the SWN, but include more Good and fewer Fair HUC12s (Figure 21a). The catchment level results are also slightly higher quality than the SWN index, with more catchments in the Very Good category and none in the Poor (Figure 21b). There are no critical metrics in the SHC index, and several of the highest weighted metrics reflect riparian conditions, such as roads and railroads or forested riparian area. Therefore, many of the Good or Very Good HUC12s and catchments also scored highly in the Streams Riparian Habitat index. Factors that tended to bring a score down included mining or development instead of forested cover in the riparian area, and the existence of dams, as most of the watershed contains headwater streams and there are few wetlands and no power plants. Local integrity metric scores reflect the same geographic patterns as the other metrics, with lower scores in mined or developed areas. Overall, the watershed still includes consistent patches of good hydrologic connectivity, which correspond consistently with higher scores in other indices.

The Streams Biodiversity (SBD) index results showed little variation at both the HUC12 and catchment levels (Figures 22a and 22b), with most planning units scoring in the Good category. In planning units without rare or invasive species the results in this index depend on the values of only two or three other metrics. In planning units with invasive species present this metric tended to be the determining factor between a Good versus a Fair score. There is a noticeable trend in the Tug Fork that non-native invasive species sampling occurred primarily along highway roadsides, resulting in the patterns of lower scoring catchments generally following the major US highways, particularly highway 52. More than any other index, the Biodiversity index in each landscape should be reviewed in greater detail 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.

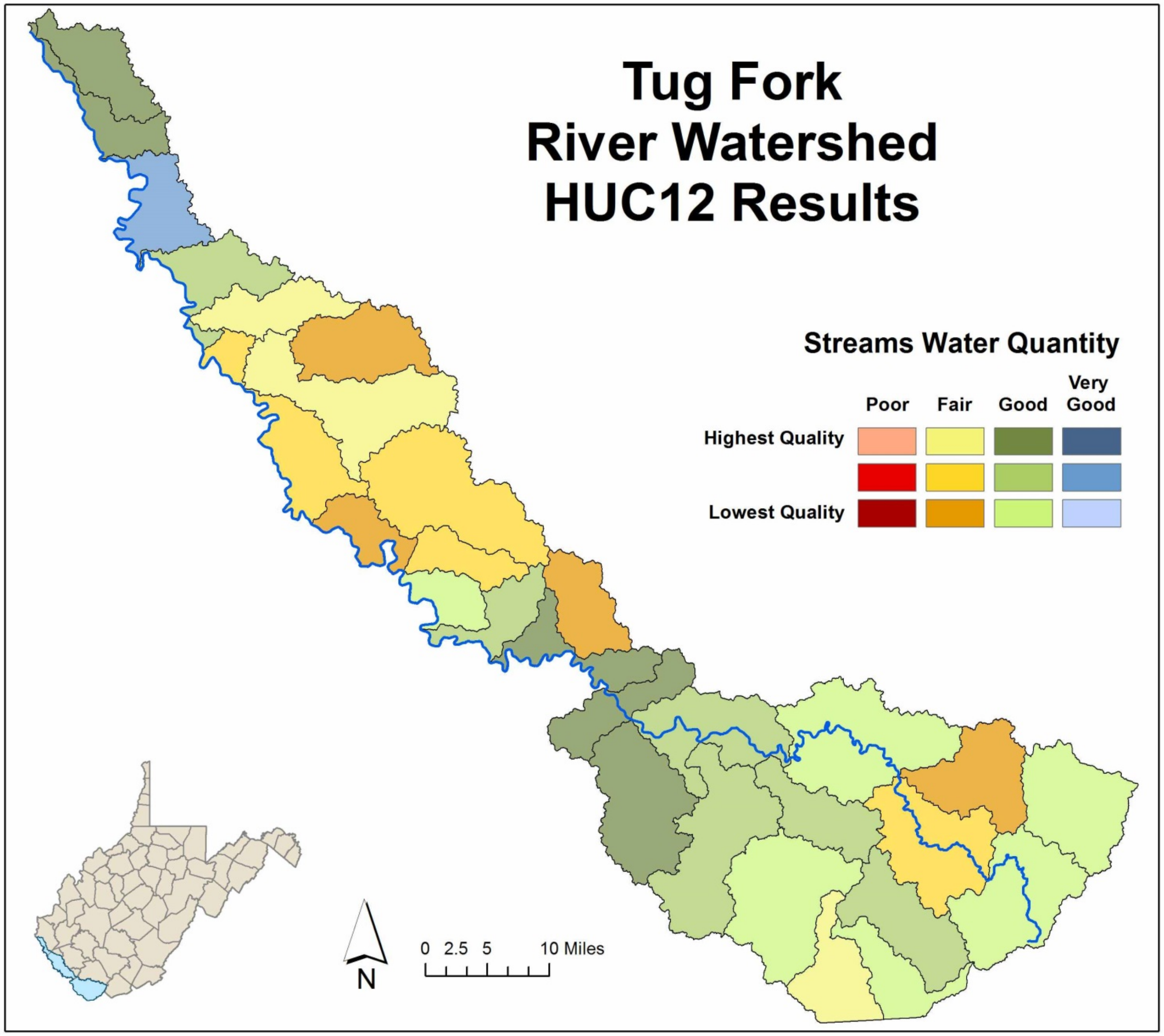

Figure 20a. Streams Water Quantity Index Results – HUC12 Level

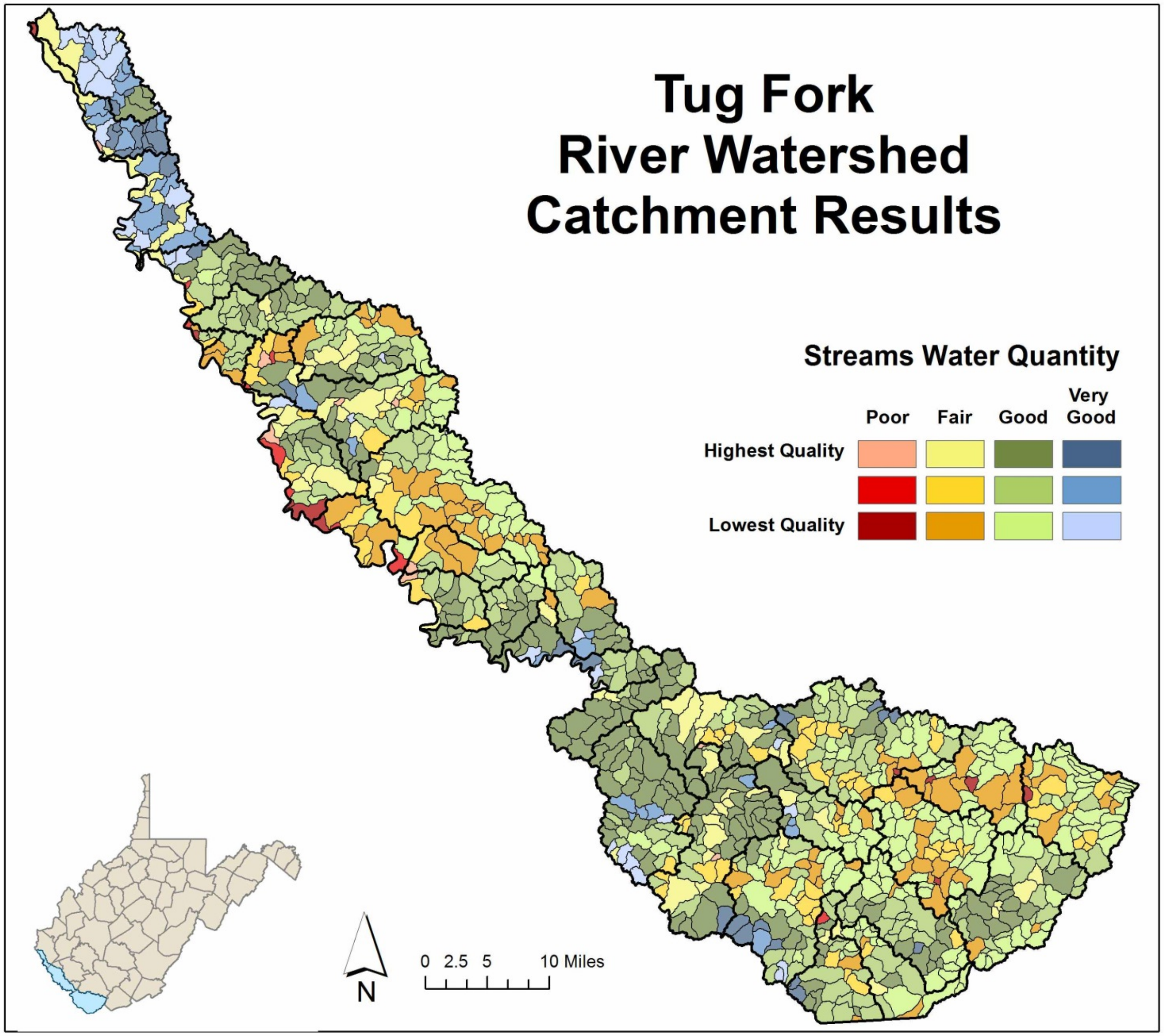

Figure 20b. Streams Water Quantity Index Results – Catchment Level

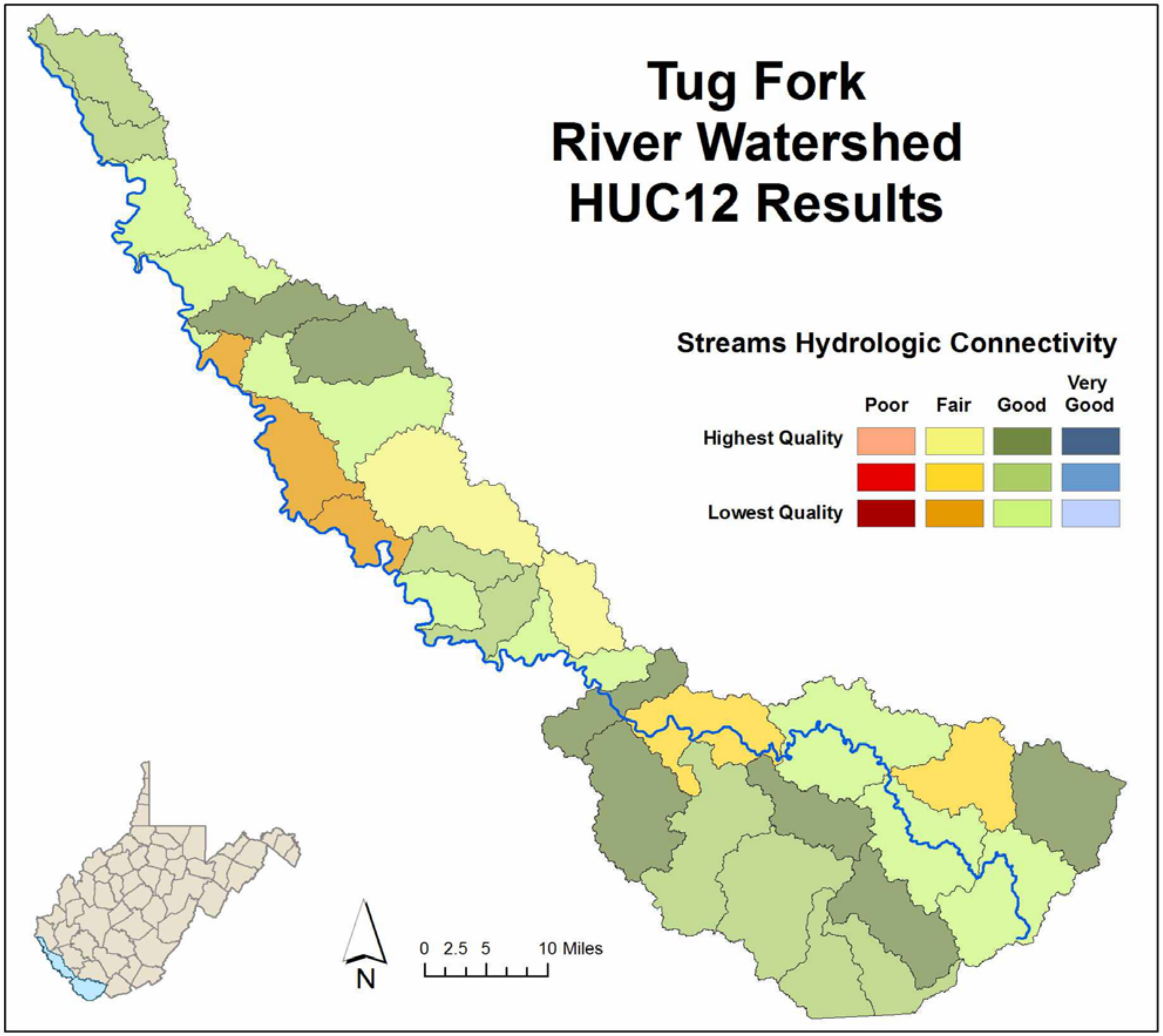

Figure 21a. Streams Hydrologic Connectivity Index Results – HUC12 Level

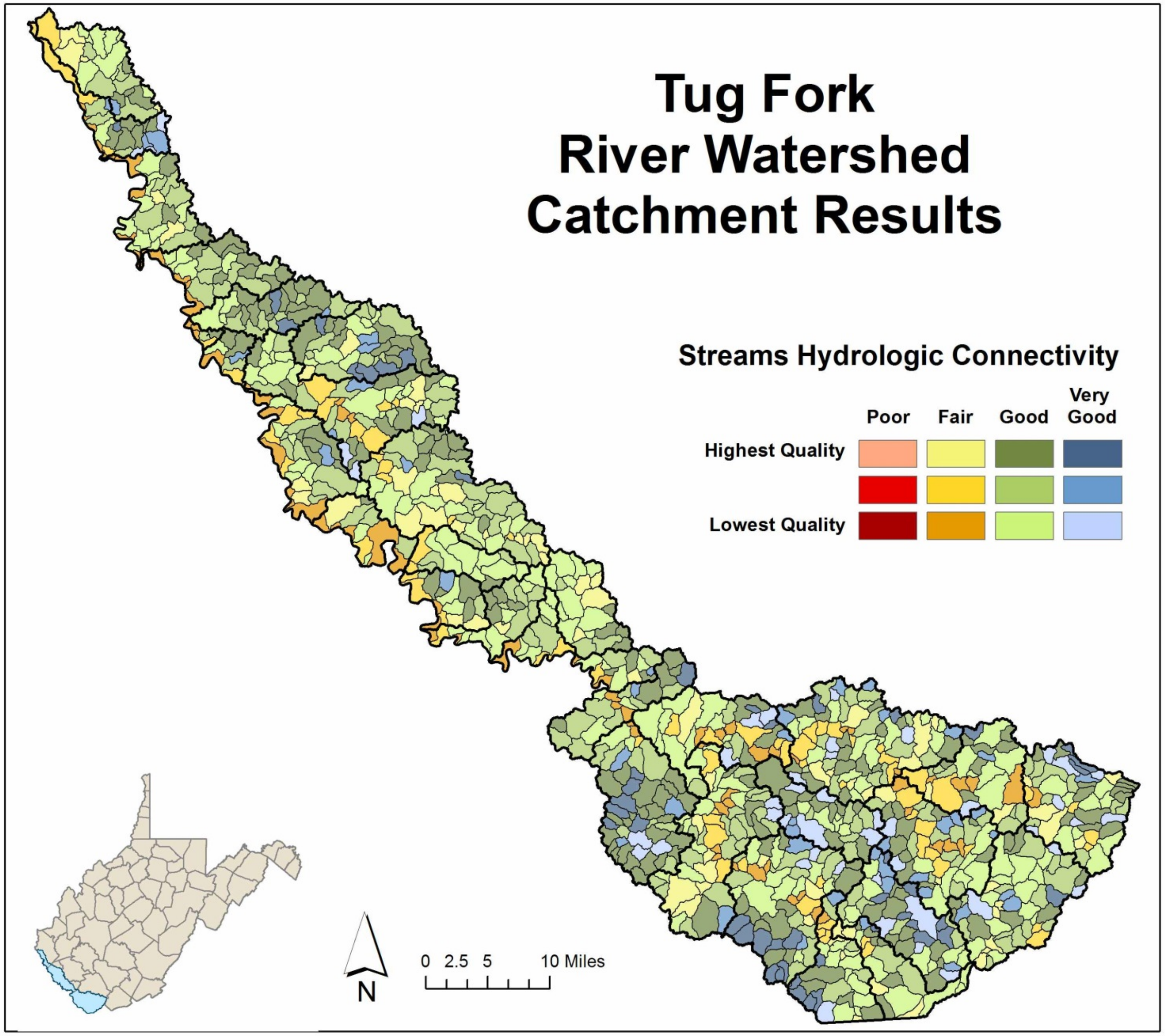

Figure 21b. Streams Hydrologic Connectivity Index Results – Catchment Level

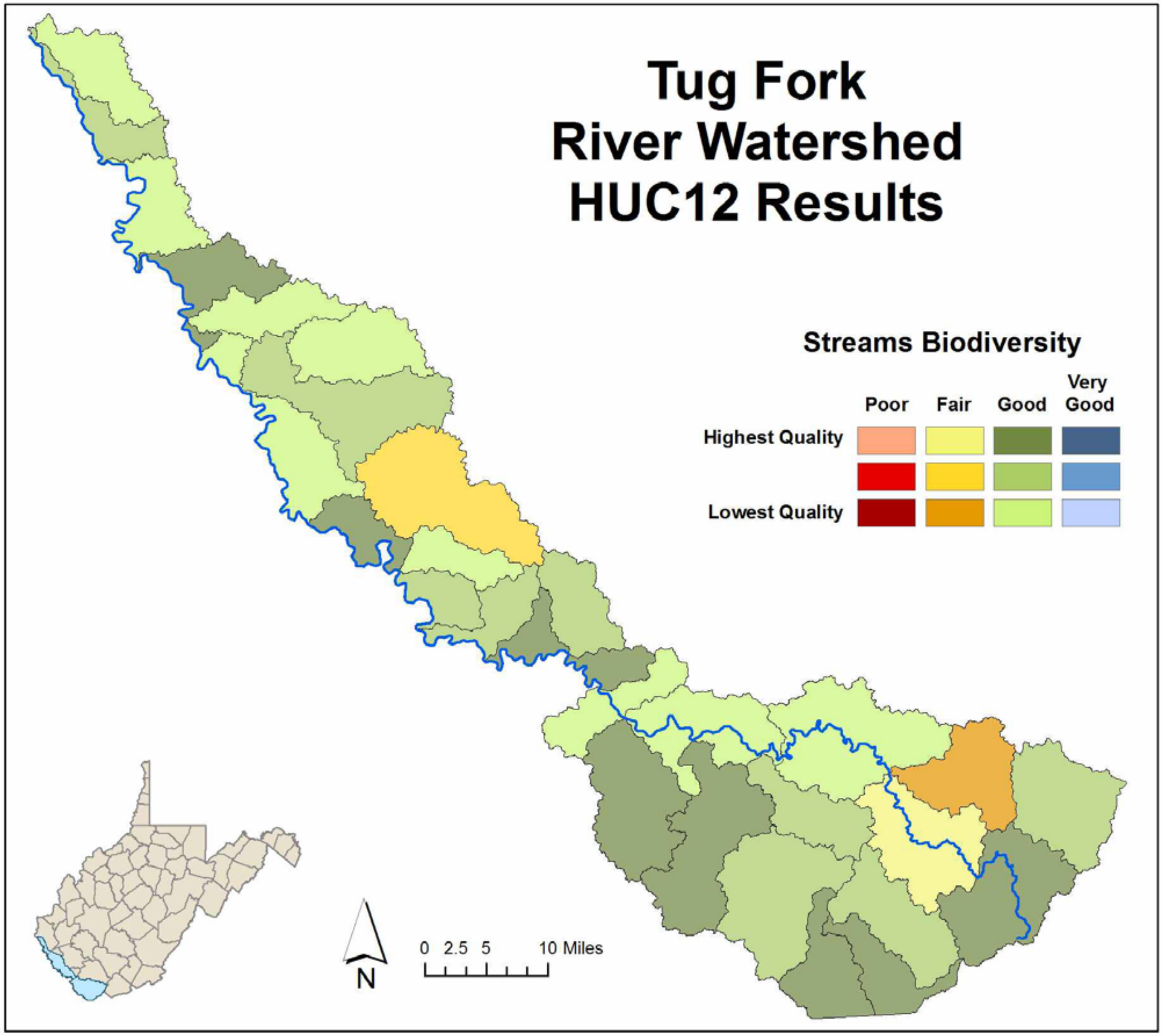

Figure 22a. Streams Biodiversity Index Results – HUC12 Level

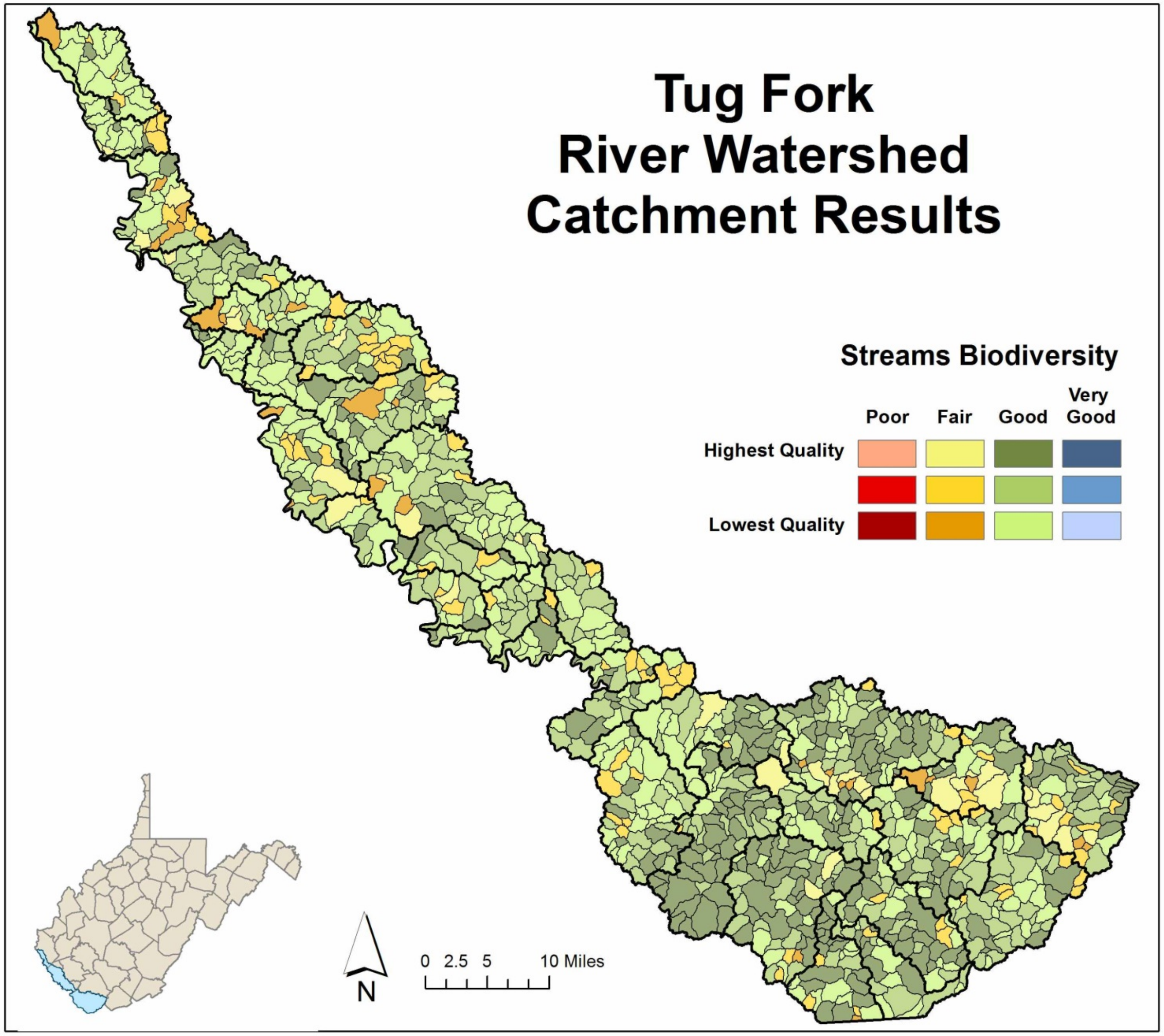

Figure 22b. Streams Biodiversity Index Results – Catchment Level

The Streams Riparian Habitat (SRH) index results exhibit more variability than the other Streams indices, particularly at the catchment level (Figures 23a and 23b). Only a few HUC12s scored in the Good category, generally having riparian areas that are predominantly natural cover with minimal or no anthropogenic land uses. There is, however, extensive mining activity in the watershed, and with the steep terrain forcing most development, grazing, and agriculture into the riparian area, the SRH scores are generally lower than other indices. The SRH index includes two critical metrics, percent imperviousness and active surface mining in the riparian area. These metrics are the main drivers of index results in HUC12s and catchments that score Poor or Fair. Other metrics that affected the Fair HUC12s and catchments are indicators of fragmentation in the riparian area, including roads and railroads and wells. The amount of natural cover in the riparian area is a highly weighted metric in this index and affects the score of each planning unit significantly, particularly influencing the Very Good scores at the catchment level. Due to the intense level of resource extraction and significantly impacted nature of the watershed, any catchments scoring in the Very Good category in this index should be considered high priorities for protection activities, particularly if those catchments also score highly in other Streams indices, such as Water Quality.

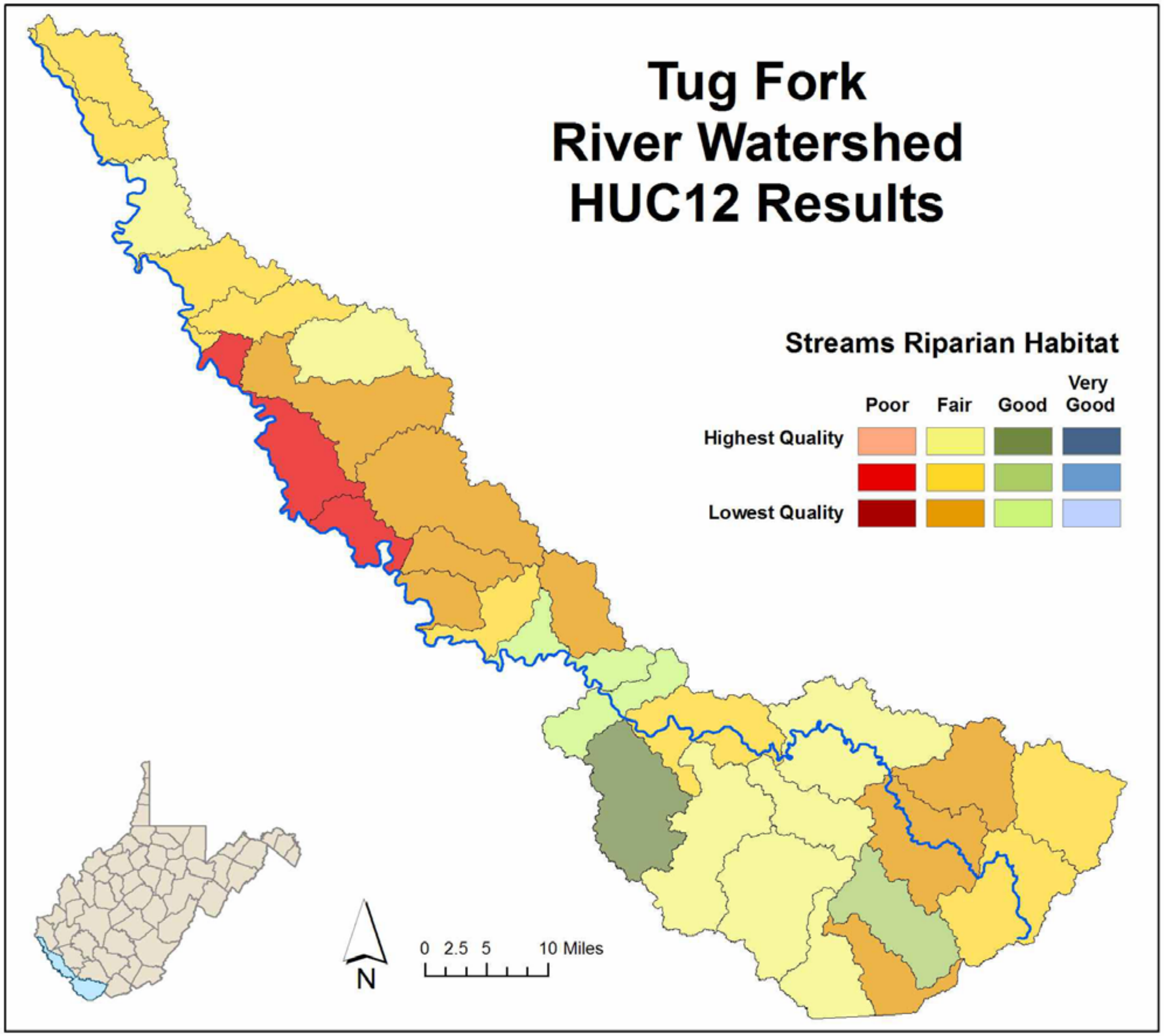

Figure 23a. Streams Riparian Habitat Index Results – HUC12 Level

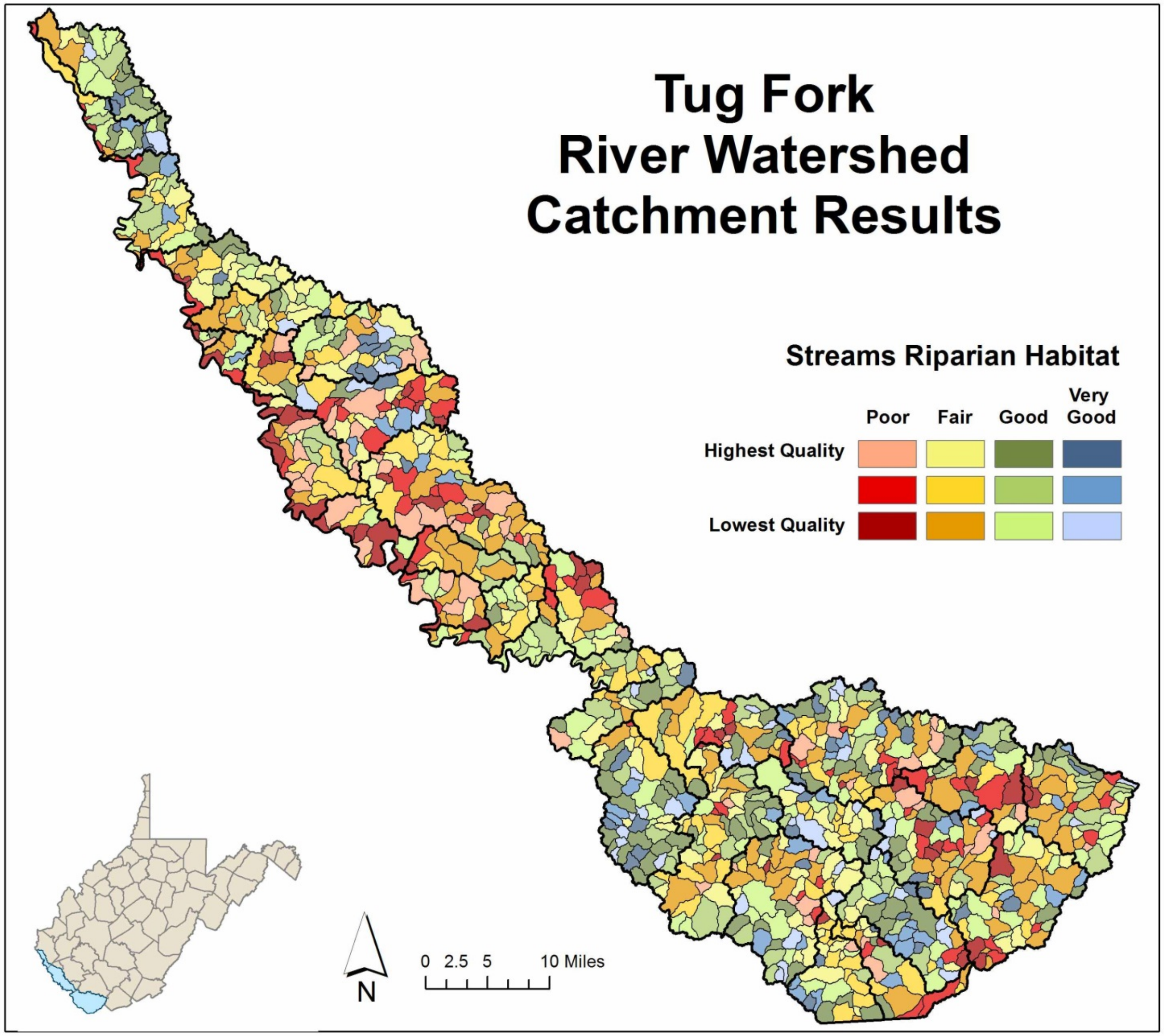

Figure 23b. Streams Riparian Habitat Index Results – Catchment Level

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 index (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 where 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 have 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 and/or floodplain area will automatically receive a Fair score due to the presence of wetlands hydrology, indicating that the potential for wetland restoration exists.

The Tug Fork watershed has a very limited amount of wetlands, even for West Virginia, with almost half of the HUC12s not containing any mapped wetlands (Figure 9). Of those HUC12s with wetlands, most scored within the Good category, with Fair HUC12s being mostly areas with wetland hydrology potential but no currently existing wetlands (Figure 24a). At the catchment level, results are mostly in the Fair category (Figure 24b), primarily due to a lack of mapped wetlands but the presence of hydric soils or floodplain area. The few Good catchments contain mapped wetlands in overall good condition without too much alternate land use or resource extraction within the wetland catchment or wetland buffer. Those catchments in the Good category likely have significant functional and ecological value and should be a priority for conservation, particularly in a watershed with so few wetland features.

The Wetlands Water Quality (WWQ) index results follow the same basic pattern as the Overall results, with most HUC12s and catchments scoring in the Good category and a few in the Fair (Figures 25a and 25b). This change in quality is mostly due to variations in land use and land cover, as the WWQ metrics are based on land uses in the wetland catchment. The Good planning units at both scales of analysis generally had higher percentages of natural cover (forests and grasslands) in the wetland catchment, and no or minimal other land use types or fragmenting features, while those in the Fair category had higher percentages of development or mining, particularly in the central-southwest river valley. Fair catchments may be good candidates for restoration or mitigation activities, as the incompatible land uses could be converted or reclaimed to natural cover, or BMPs could be implemented to minimize the effects of adjacent land use on existing wetlands.

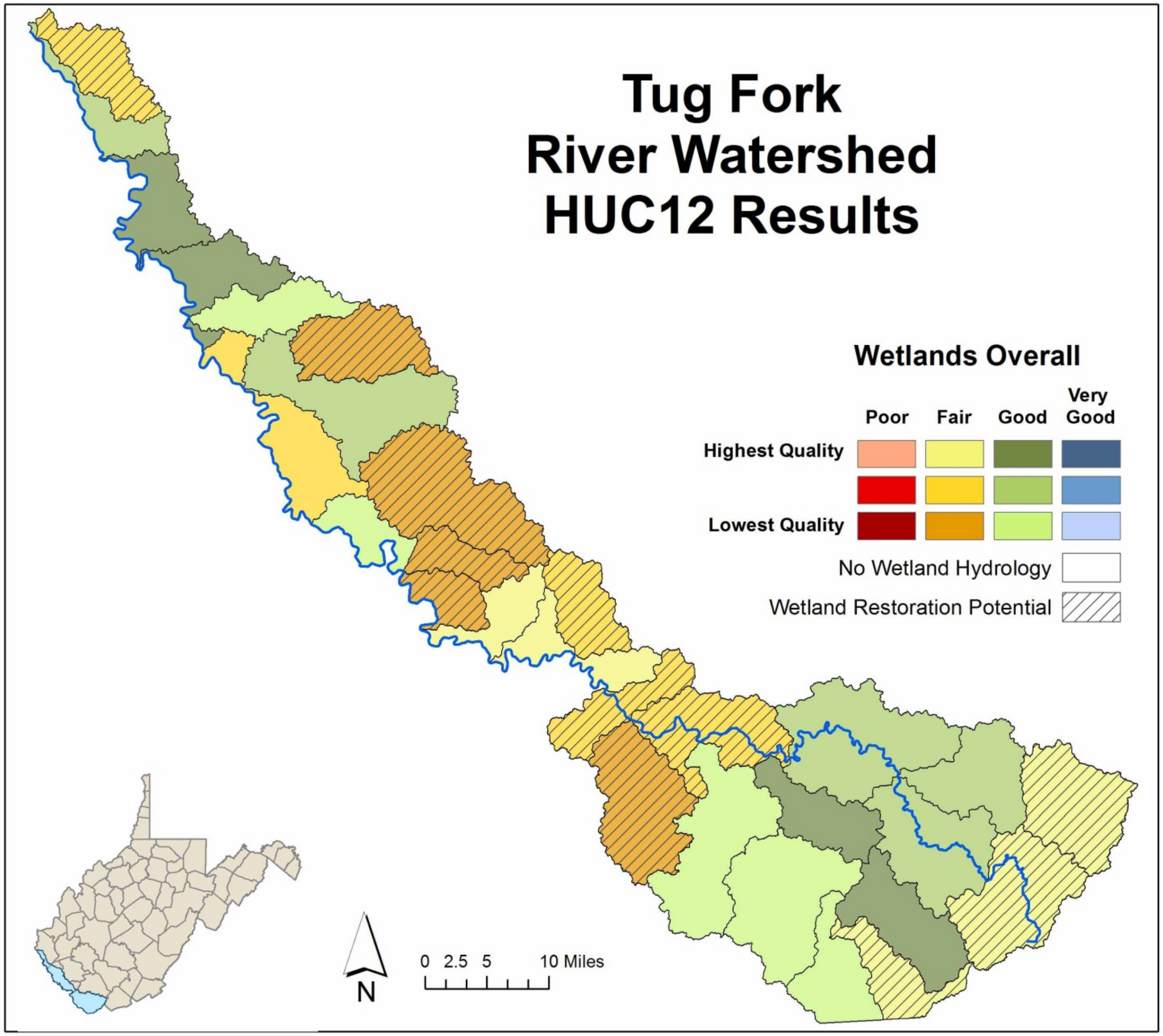

Figure 24a. Wetlands Overall Results – HUC12 Level

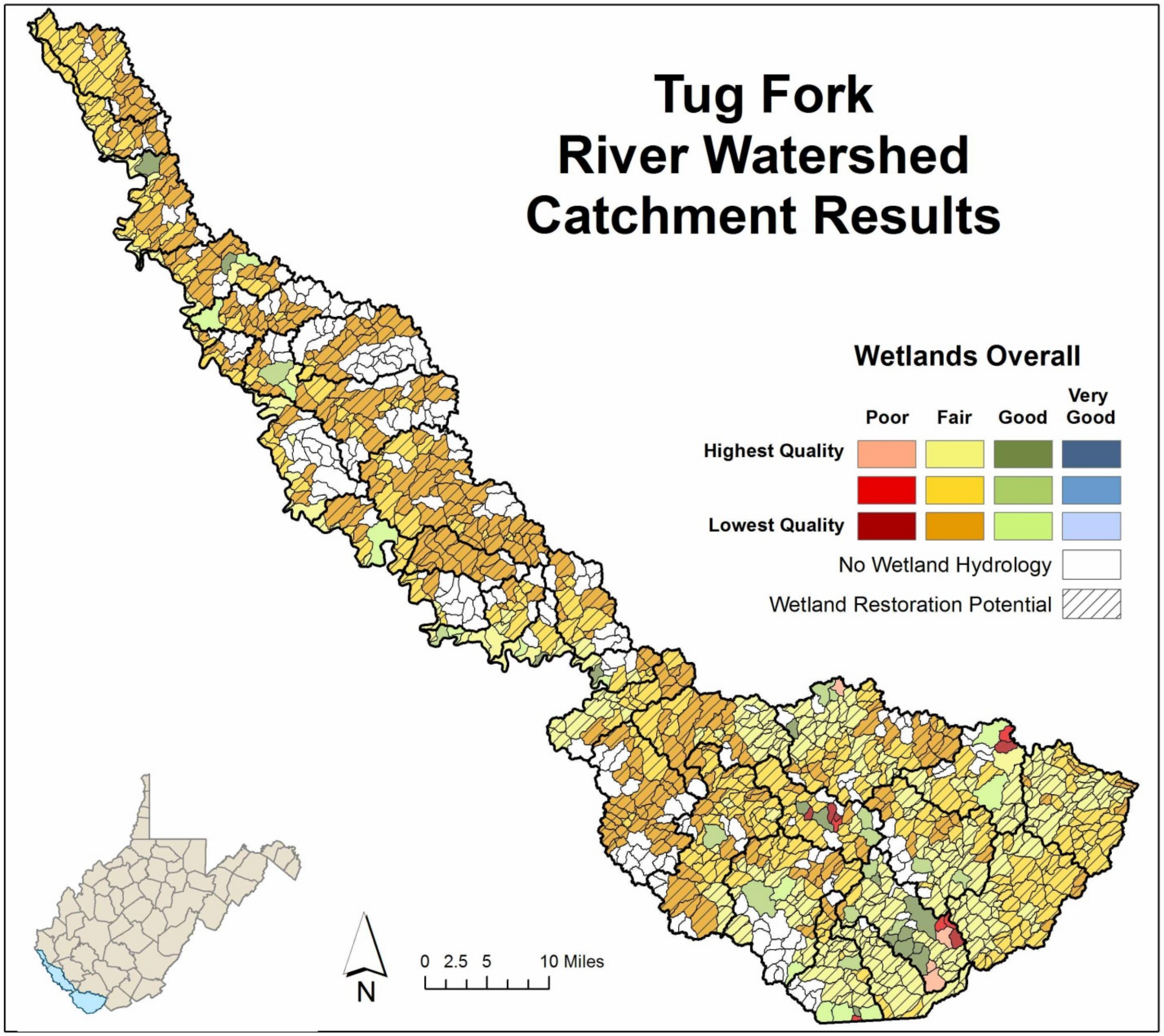

Figure 24b. Wetlands Overall Results – Catchment Level

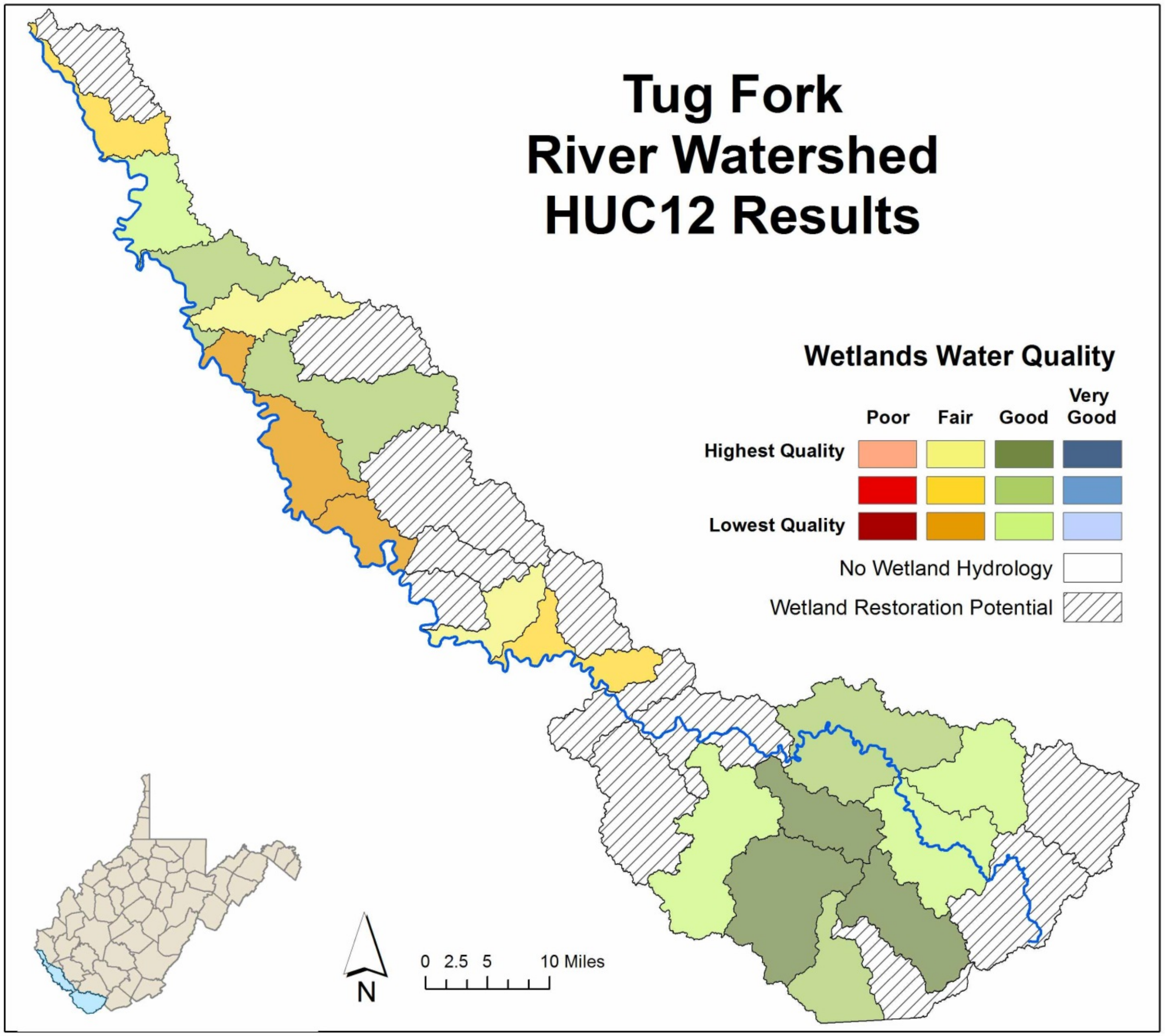

Figure 25a. Wetlands Water Quality Index Results – HUC12 Level

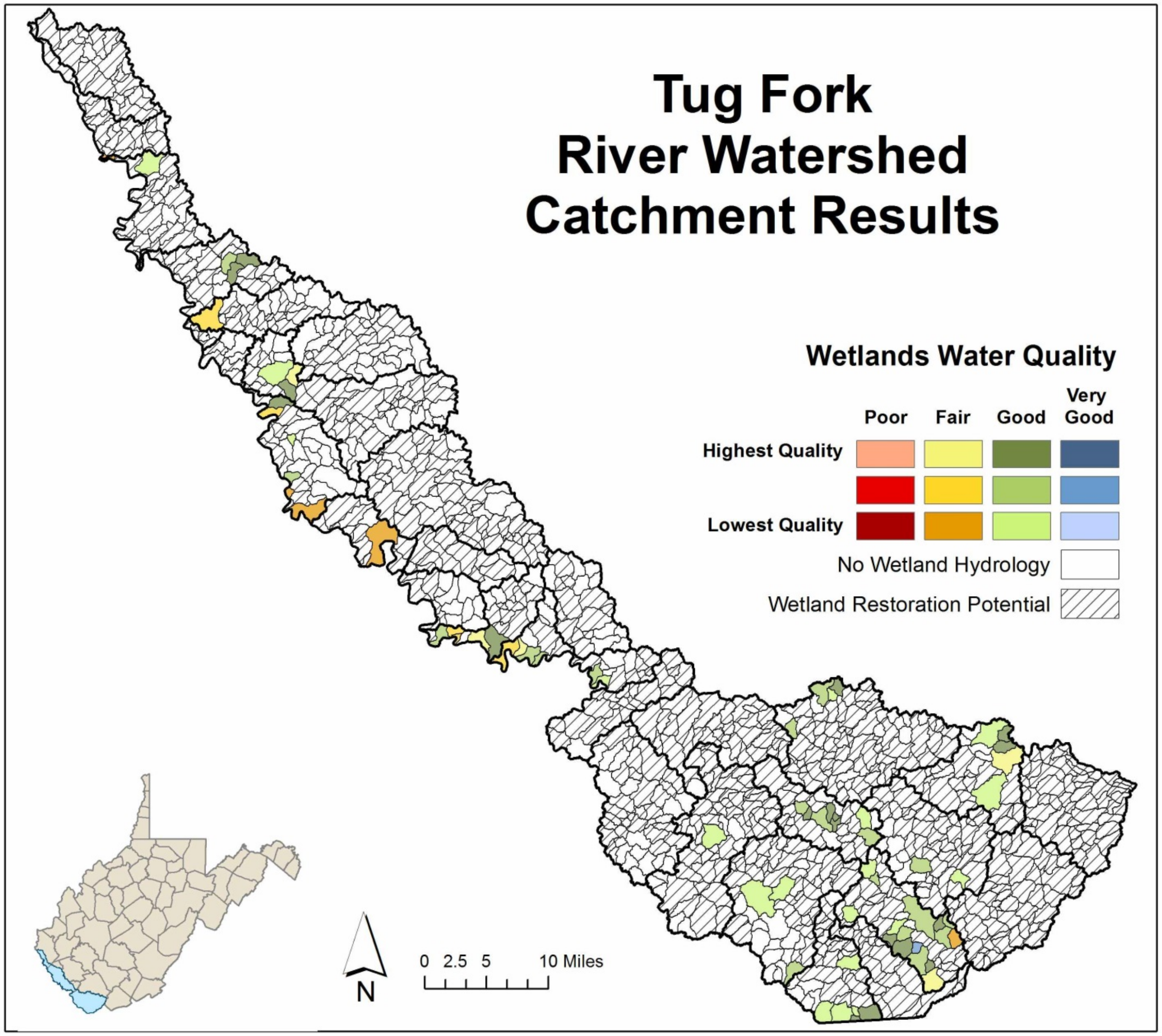

Figure 25b. Wetlands Water Quality Index Results – Catchment Level

There is a general increase in quality in the Wetlands Hydrology (WHY) index results compared to the WWQ index (Figures 26a and 26b), with different geographic patterns and a clustering of Good planning units in the far west and far east of the watershed. This index is designed primarily to identify areas with extensive and well-connected existing wetlands, or areas that have no mapped wetlands but have the potential for restoration of lost wetlands due to the presence of hydric soils. All of the WHY metrics are presence/absence, meaning the metric will receive a Good score if it has a value, and a Fair if it does not. The Tug Fork watershed has very few mapped wetlands, and mapping of the hydric soils seems more complete and extensive within the eastern counties of the watershed, which explains the higher quality Good scores planning units in this area. The same patterns are maintained at the catchment level, indicating that the presence or absence of mapped wetlands drive the WHY results very strongly in the Tug Fork watershed.

The Wetlands Biodiversity (WBD) index has only four metrics, three of which are presence/absence. The few Fair HUC12s either have fewer terrestrial habitat types or more recorded non-native invasive species occurrences than higher-scoring HUC12s (Figure 27a). The Good HUC12s are generally the result of the presence of more rare species, or occasionally the absence of invasive species. The same situation applies to the catchment level results (Figure 27b). 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 have more variability than other Wetlands indices (Figures 28a and 28b). WWH is based on wetland buffer metrics, which means that results are dependent upon the existence of mapped wetlands, and restricted to features or land uses that fall within 50 meters of a mapped wetland. At the HUC12 level, Very Good and Good planning units all had high percentages of natural cover within the wetland buffer and minimal other land uses, with only some instances of grazing and a few roads and railroads. The WWH index includes two critical metrics, development and active surface mining, which determined many of the Fair results. Similarly, at the catchment level results were often driven by the critical metrics, with about half of the catchments scoring Fair in the critical metric active surface mining. Many of the Very Good catchments have high percentages of natural cover in the wetland buffer, and may be good candidates for protection, particularly in conjunction with other high-scoring Wetlands index results, like Water Quality or Biodiversity.

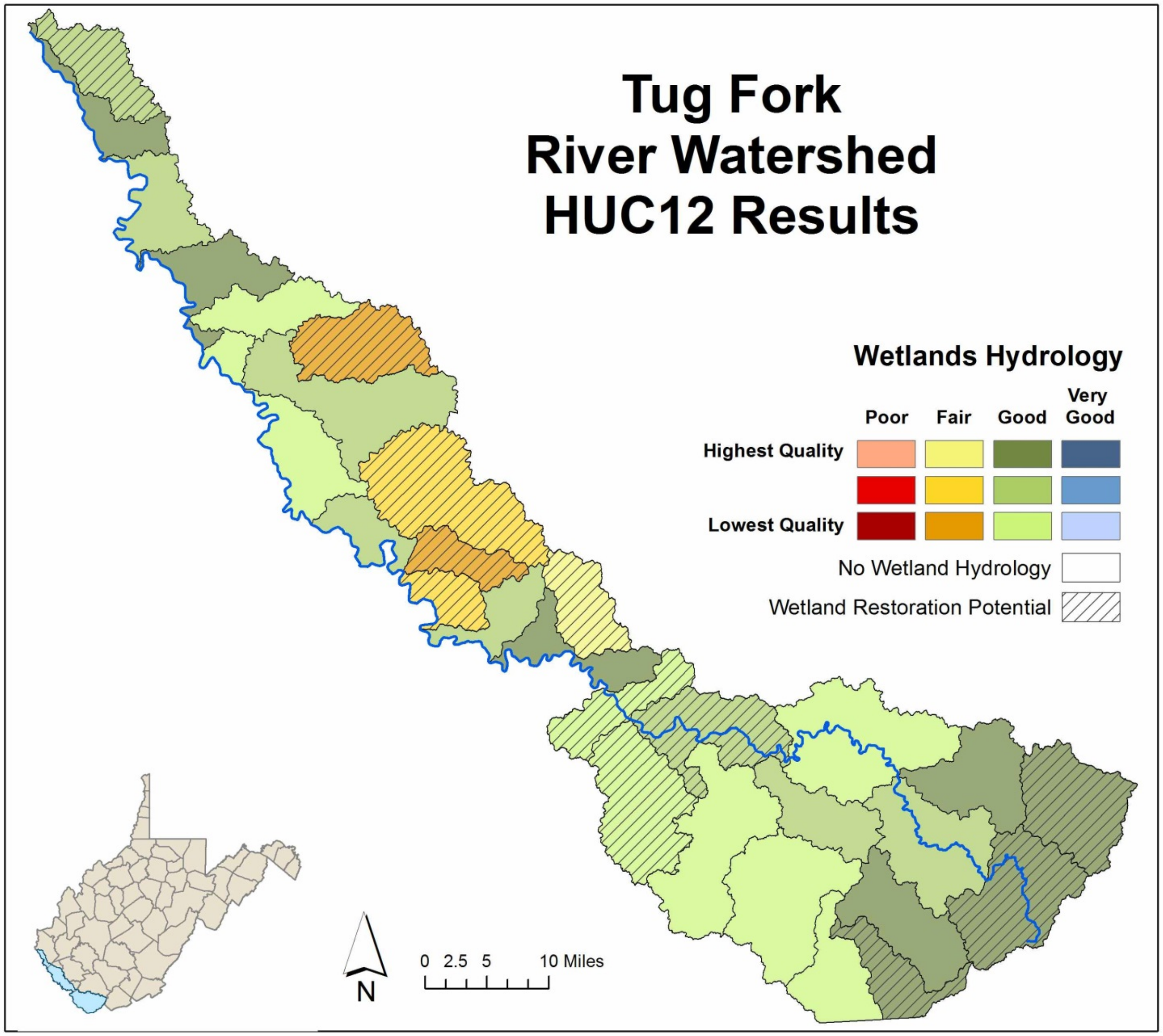

Figure 26a. Wetlands Hydrology Index Results – HUC12 Level

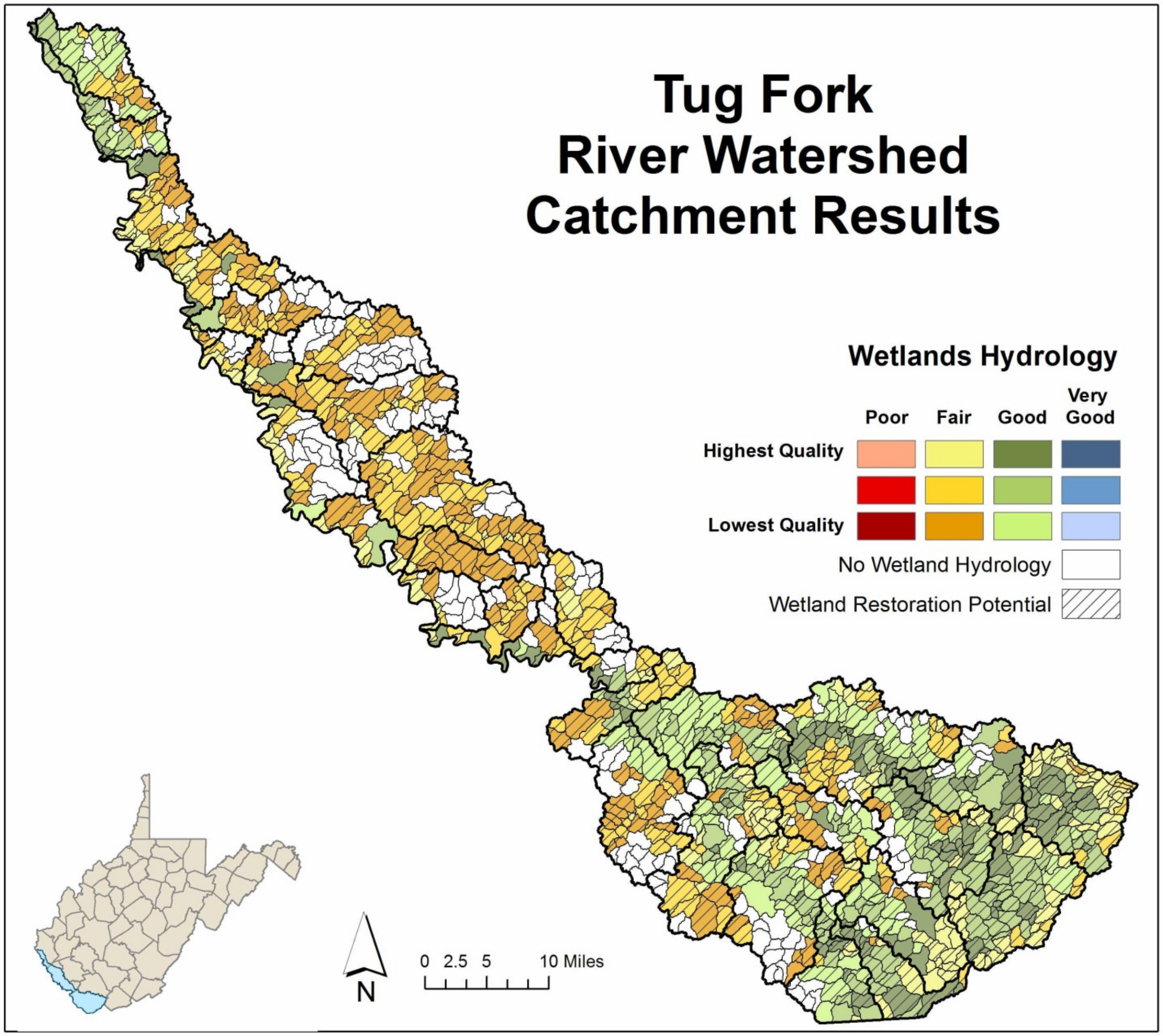

Figure 26b. Wetlands Hydrology Index Results – Catchment Level

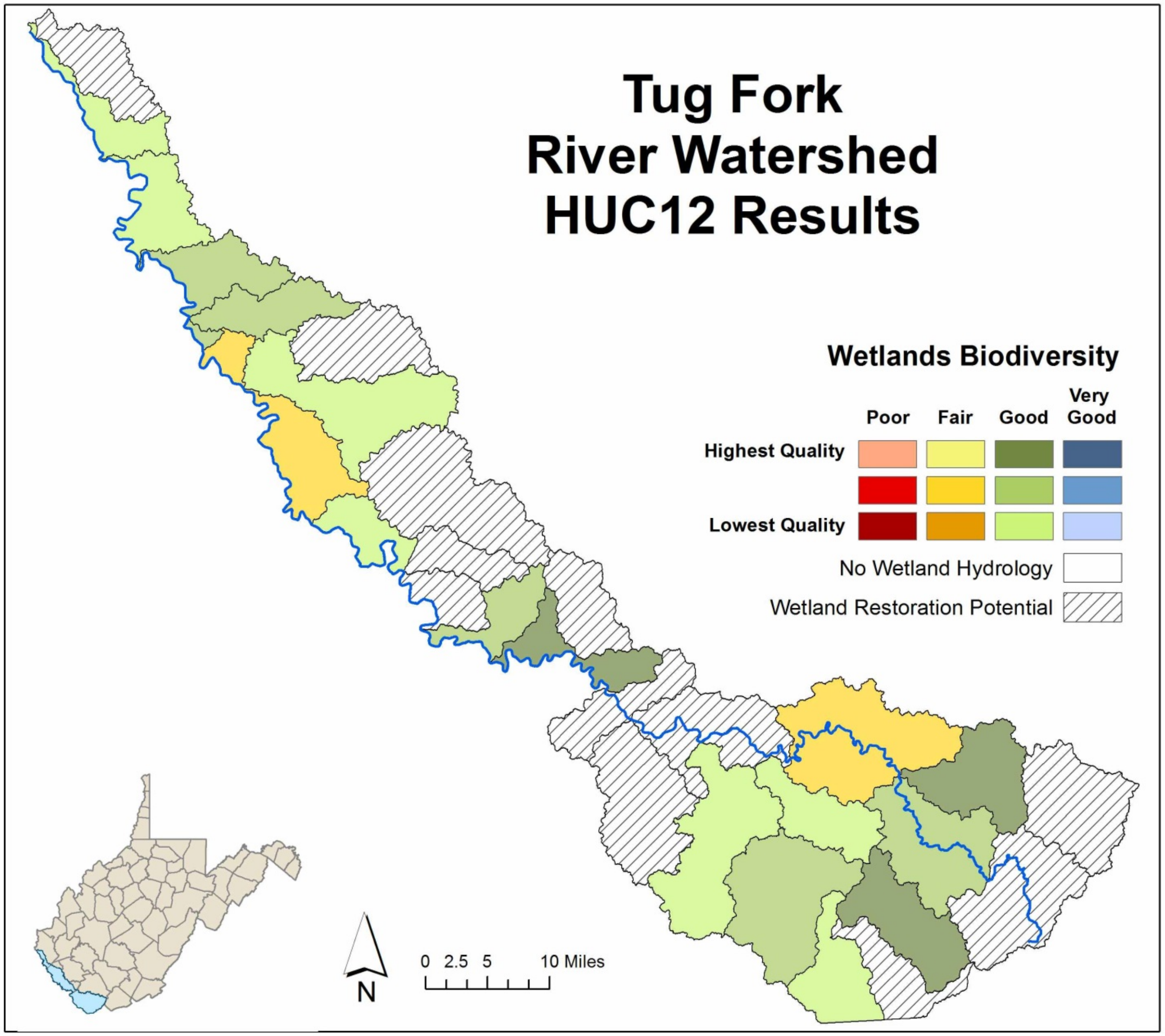

Figure 27a. Wetlands Biodiversity Index Results – HUC12 Level

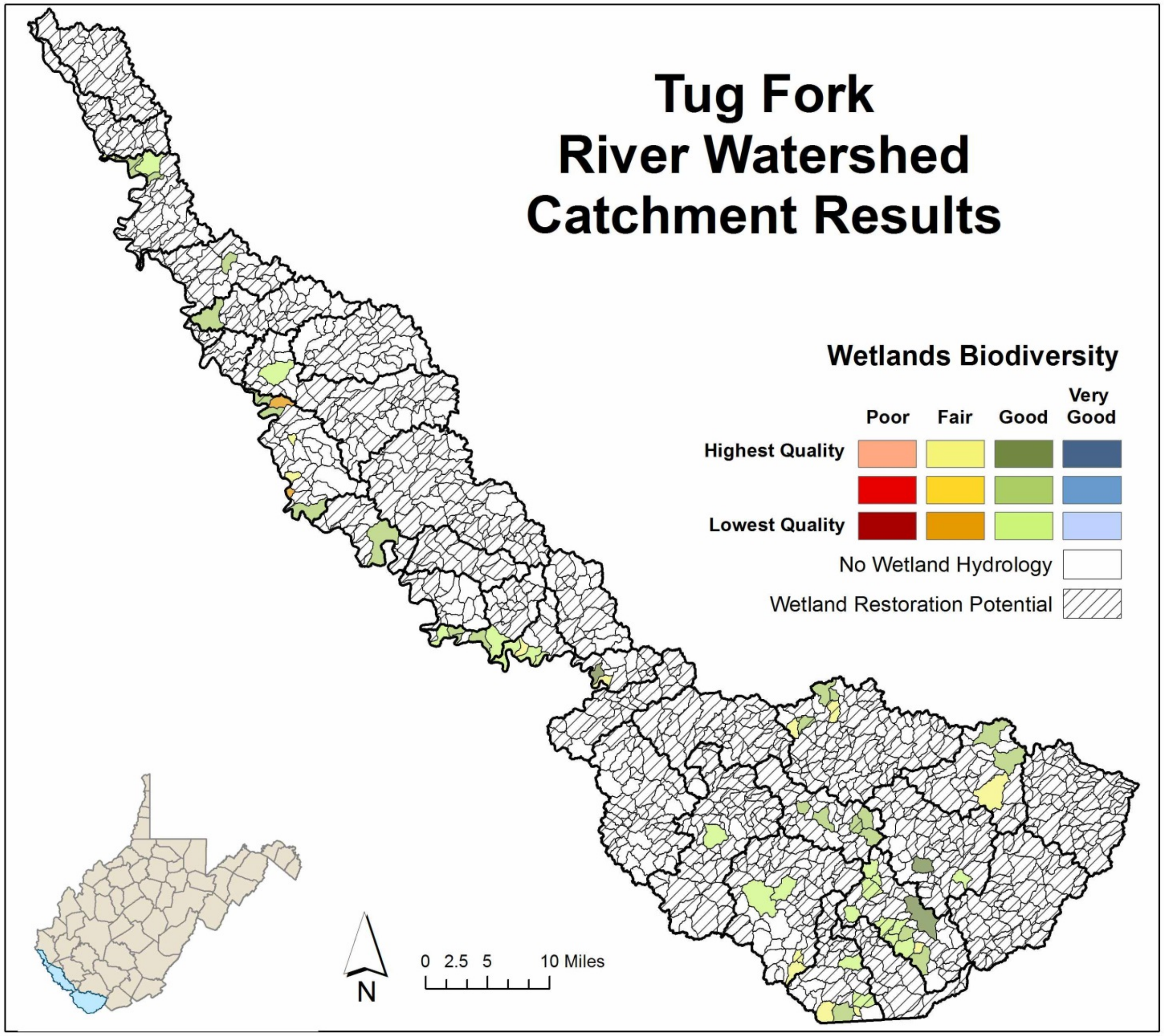

Figure 27b. Wetlands Biodiversity Index Results – Catchment Level

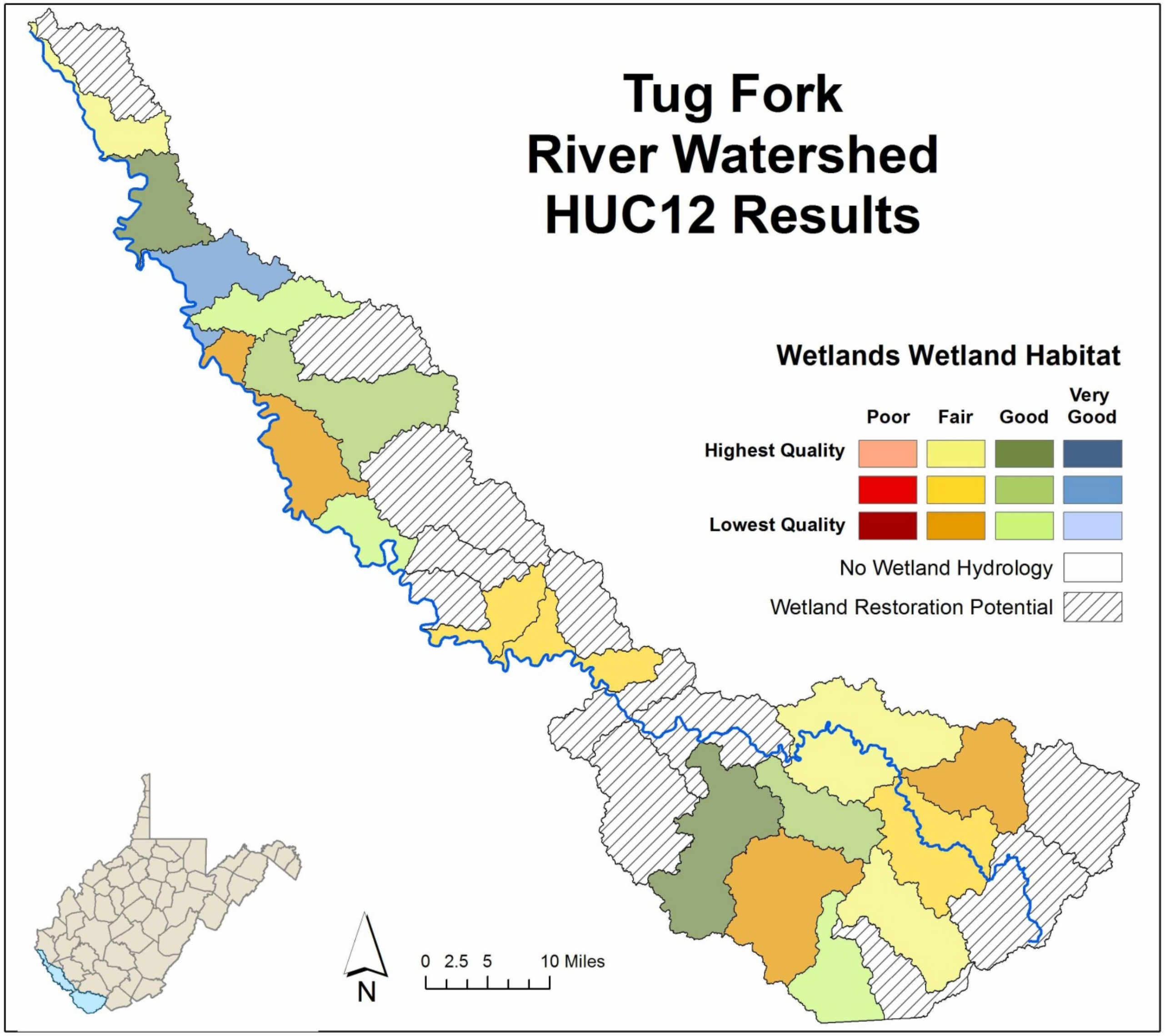

Figure 28a. Wetlands Wetland Habitat Index Results – HUC12 Level

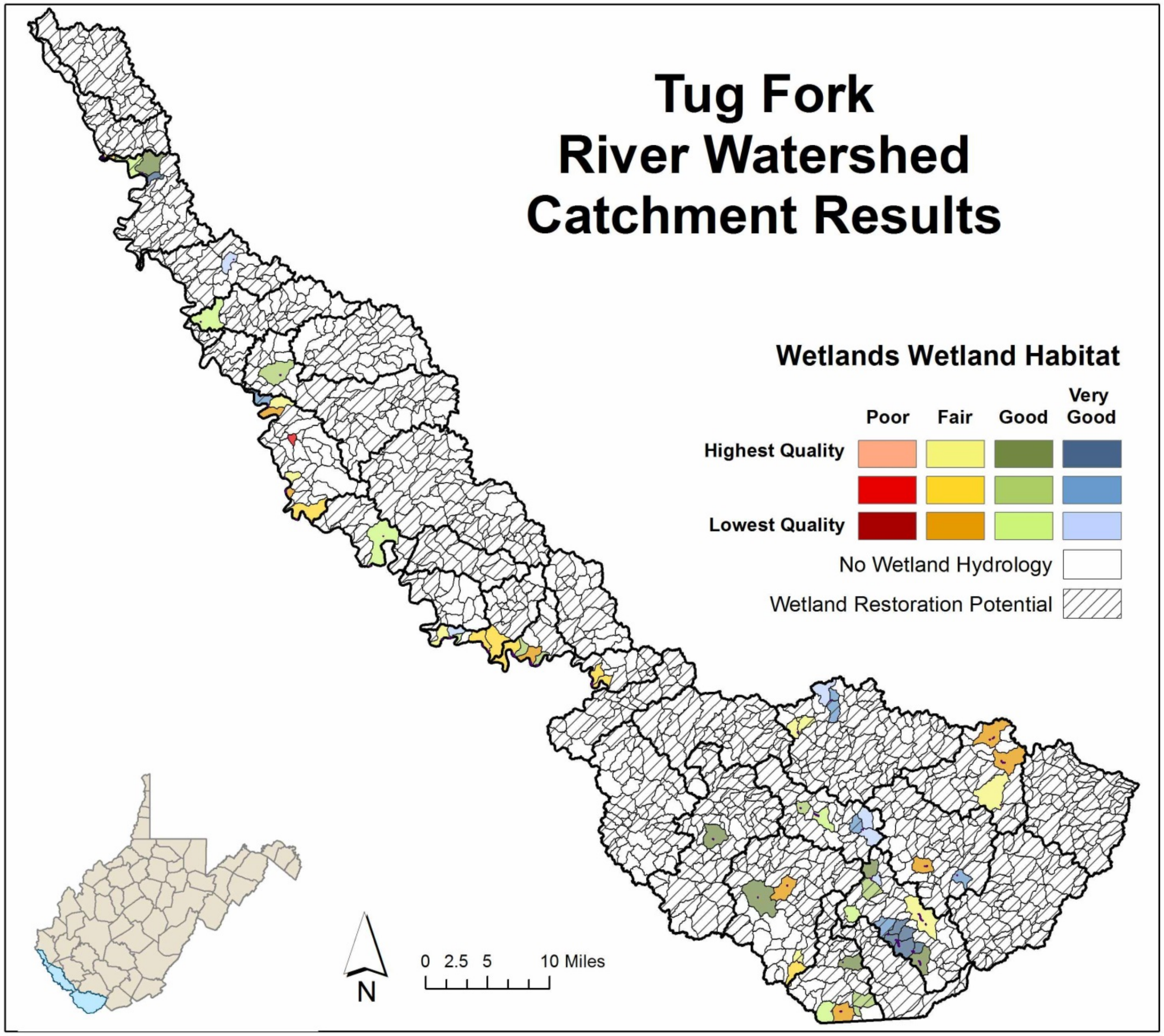

Figure 28b. Wetlands Wetland Habitat Index Results – Catchment Level

4.1.3 Uplands

The Uplands Priority Model Overall results are generally much lower than other models and indices, though the geographic patterns maintain throughout all of the results, with the lowest quality planning units in the southeast and central portions of the watershed, and relatively higher quality particularly in the southeast (Figures 29a and 29b). The minimally impacted areas are highlighted most distinctly at the catchment level, where Very Good catchments indicate a comparatively pristine uplands environment: often there are only a few roads or oil and gas wells in otherwise heavily forested headwaters catchments. Panther Creek catchments have noticeably higher quality in the Uplands Overall model compared to the other catchments, likely due to the presence of a large state forest in that HUC12. Otherwise, the overall uplands results stayed within the Fair-Poor range, particularly at the HUC12 level. This is due to the fairly extensive habitat fragmentation throughout the watershed, from resource extraction activities like mining, timber harvesting and oil and gas wells, and infrastructure such as roads, railroads, energy transmission lines, and natural gas pipelines (Figure 30).

The Uplands Habitat Connectivity (UHC) index results are very similar to the Overall model results, particularly at the HUC12 level, with most planning units staying within the same category and just shifting in relative quality (Figure 31a). UHC has two critical metrics, development and active surface mining, which often drive the index results, as Poor HUC12s and catchments are all within the more heavily mined areas of the watershed. The UHC index is largely driven by the presence of intact forests and lack of anthropogenic stressors, therefore the higher quality areas are generally in the protected and higher elevation areas in the headwaters regions, which are characterized by large forest patches and little development or industrial activity. This trend is most noticeable at the catchment level of results (Figure 31b). Additionally, several UHC metrics have presence/absence thresholds only (energy transmission lines, pipelines, and timber harvesting), which means that if that feature is absent the metric receives a Good score, and if the feature is present, a Fair. Therefore, many of the Very Good catchments include minimal amounts of fragmenting features, and are therefore good candidates for protection activities.

The Uplands Habitat Quality (UHQ) index results are also very similar to the Uplands overall model, with slightly higher quality than the UHC results (Figures 32a and 32b). The UHQ also has two critical metrics, development and active surface mining, which are the driving metrics for most of the Fair to Poor planning units at both scales. The UHQ is almost completely based on the inherent quality of existing land use in the watershed, so Very Good areas at the catchment level, which cluster primarily in the southwestern portion of the watershed and to a lesser extent near the mouth of the river, have very high percentages of natural cover and high heterogeneity scores, both of which are heavily weighted in this index. Besides the critical metrics, the most significant land use that tends to lower scores in the Tug Fork is development, even though it is a mostly rural watershed. At the catchment level, Good scores tend to result from the roll-up of a variety of different individual metrics scores, and depending on the nature of work intended within candidate sites, any Good catchments chosen should be carefully reviewed for their underlying land use characteristics.

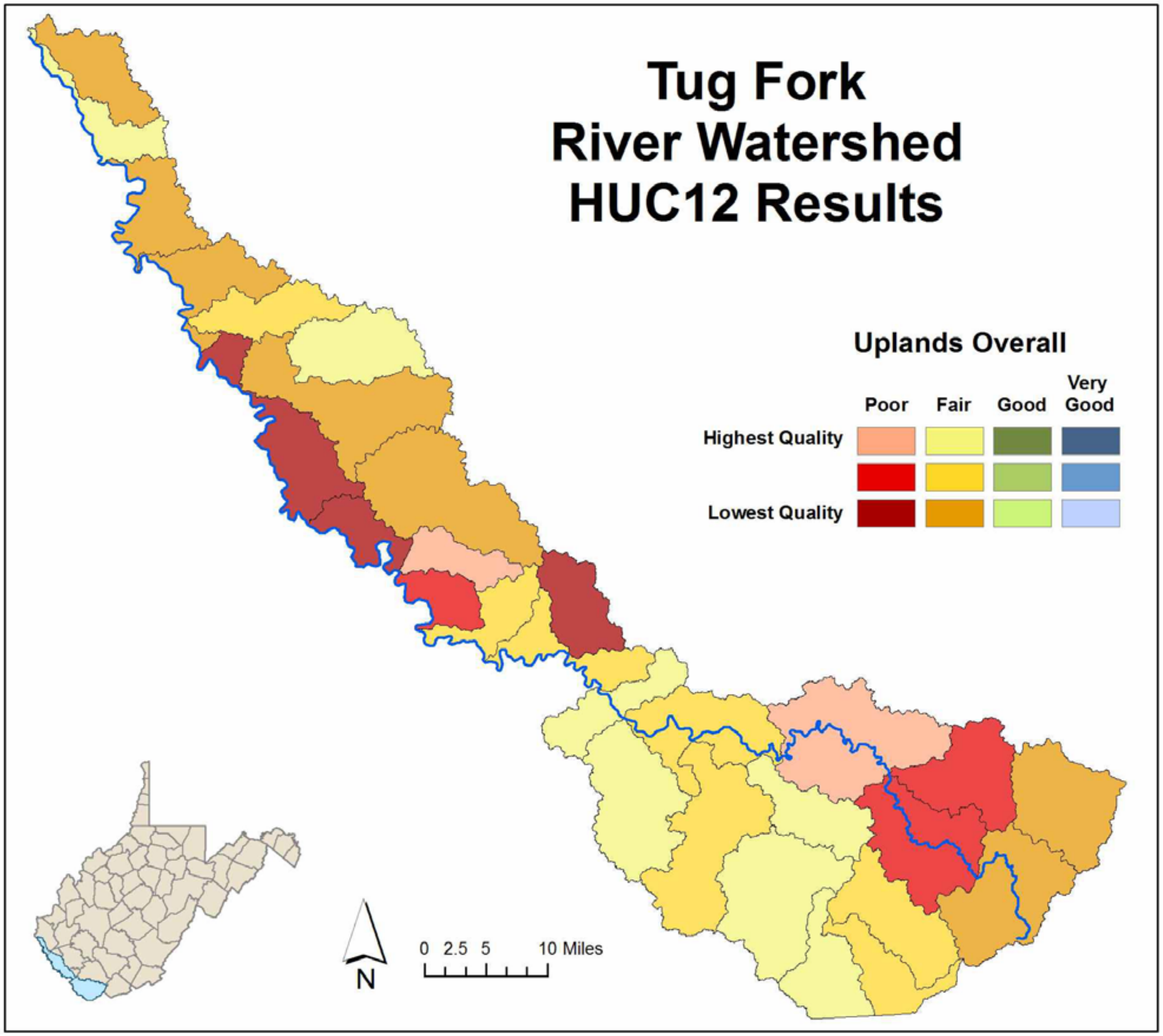

Figure 29a. Uplands Overall Results – HUC12 Level

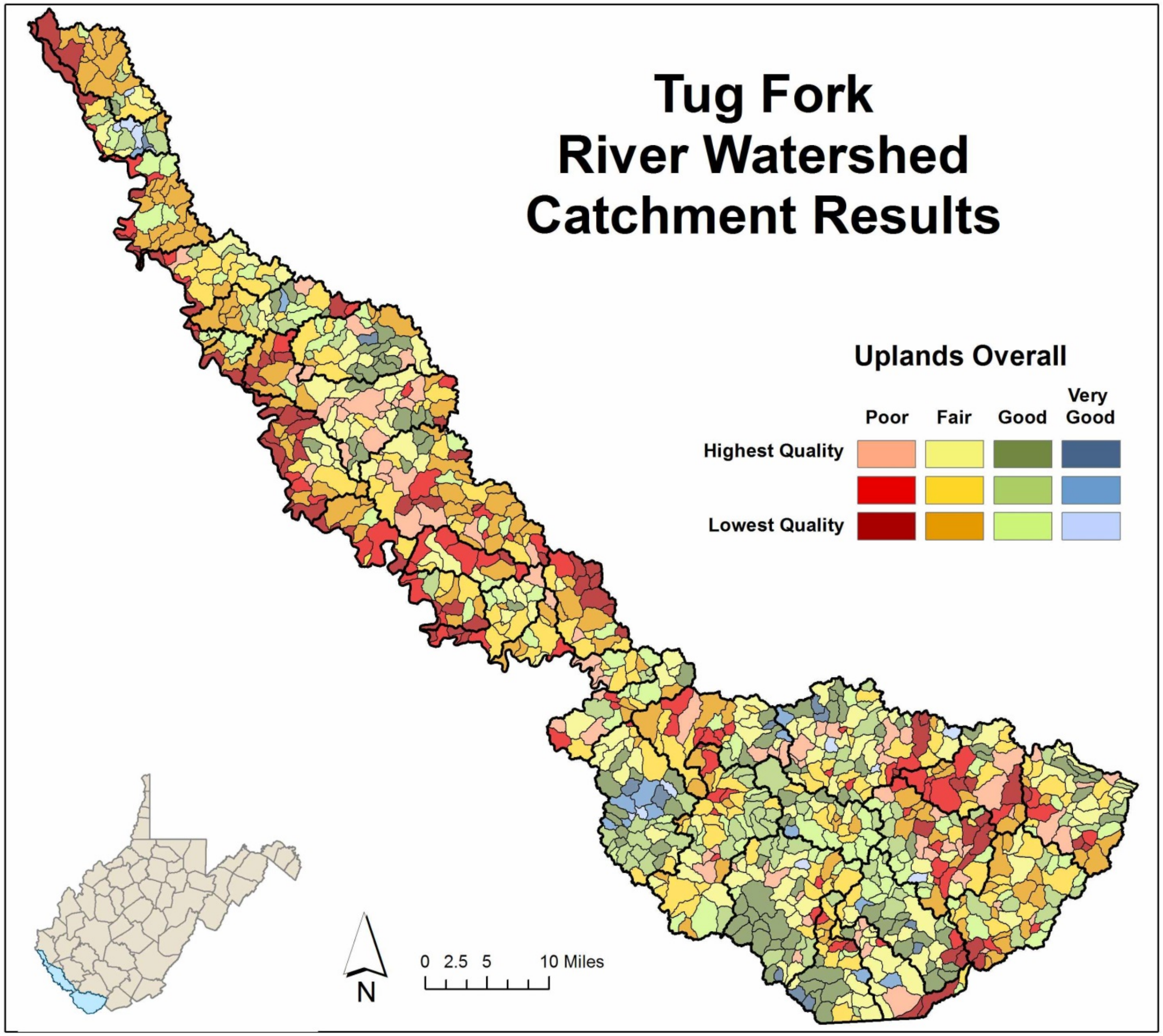

Figure 29b. Uplands Overall Results – Catchment Level

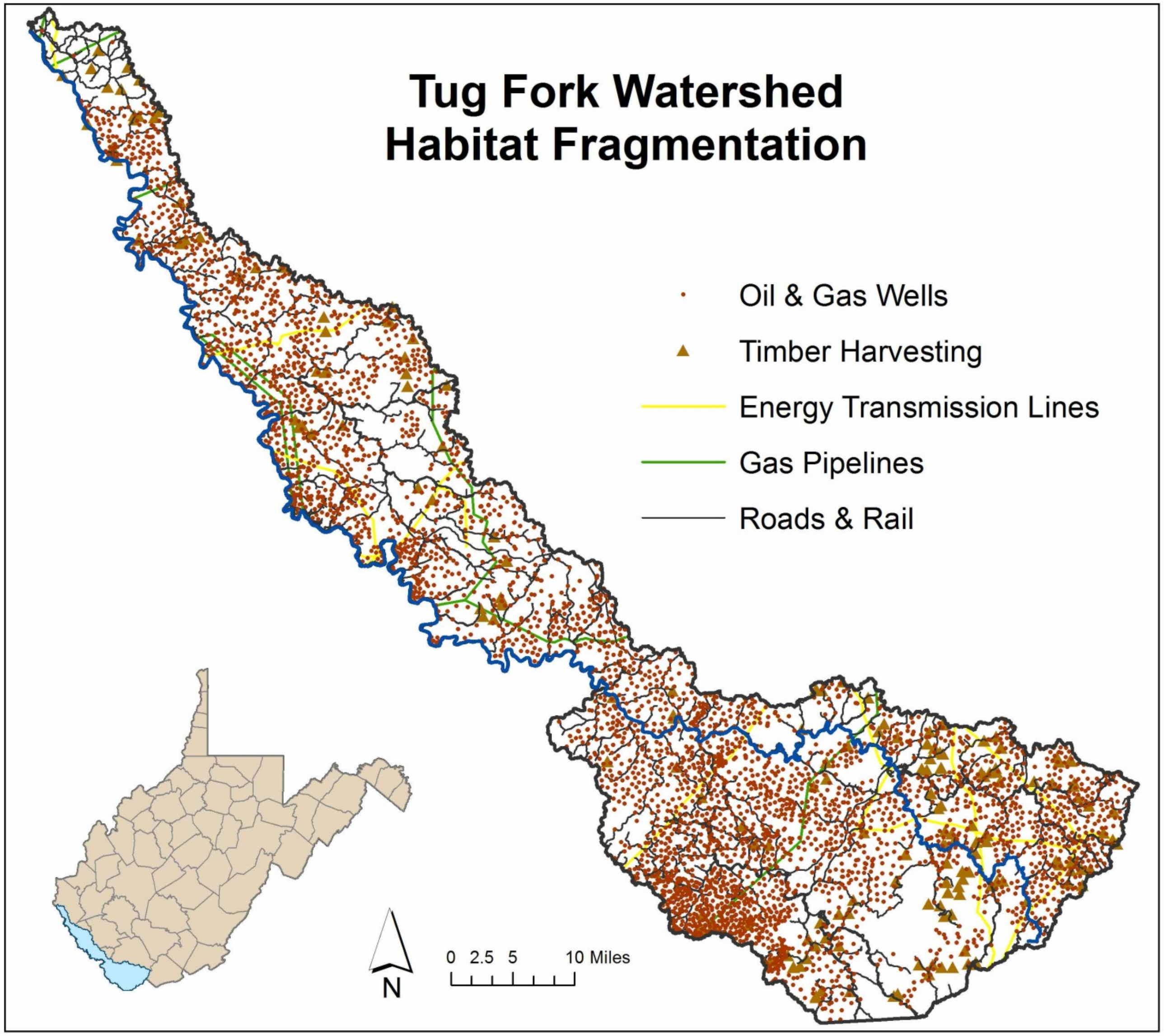

Figure 30. Tug Fork River Watershed – Habitat Fragmentation

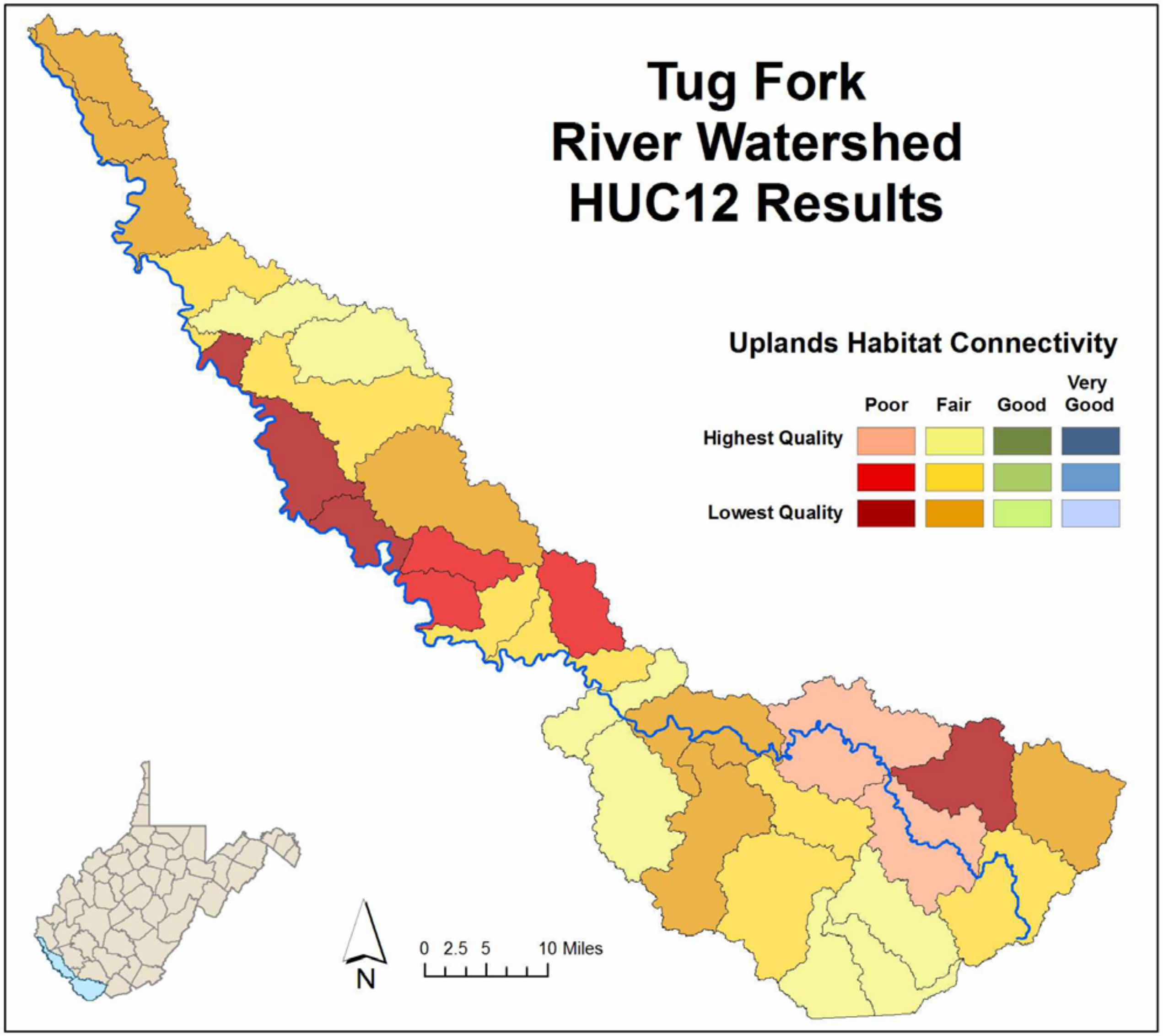

Figure 31a. Uplands Habitat Connectivity Index Results – HUC12 Level

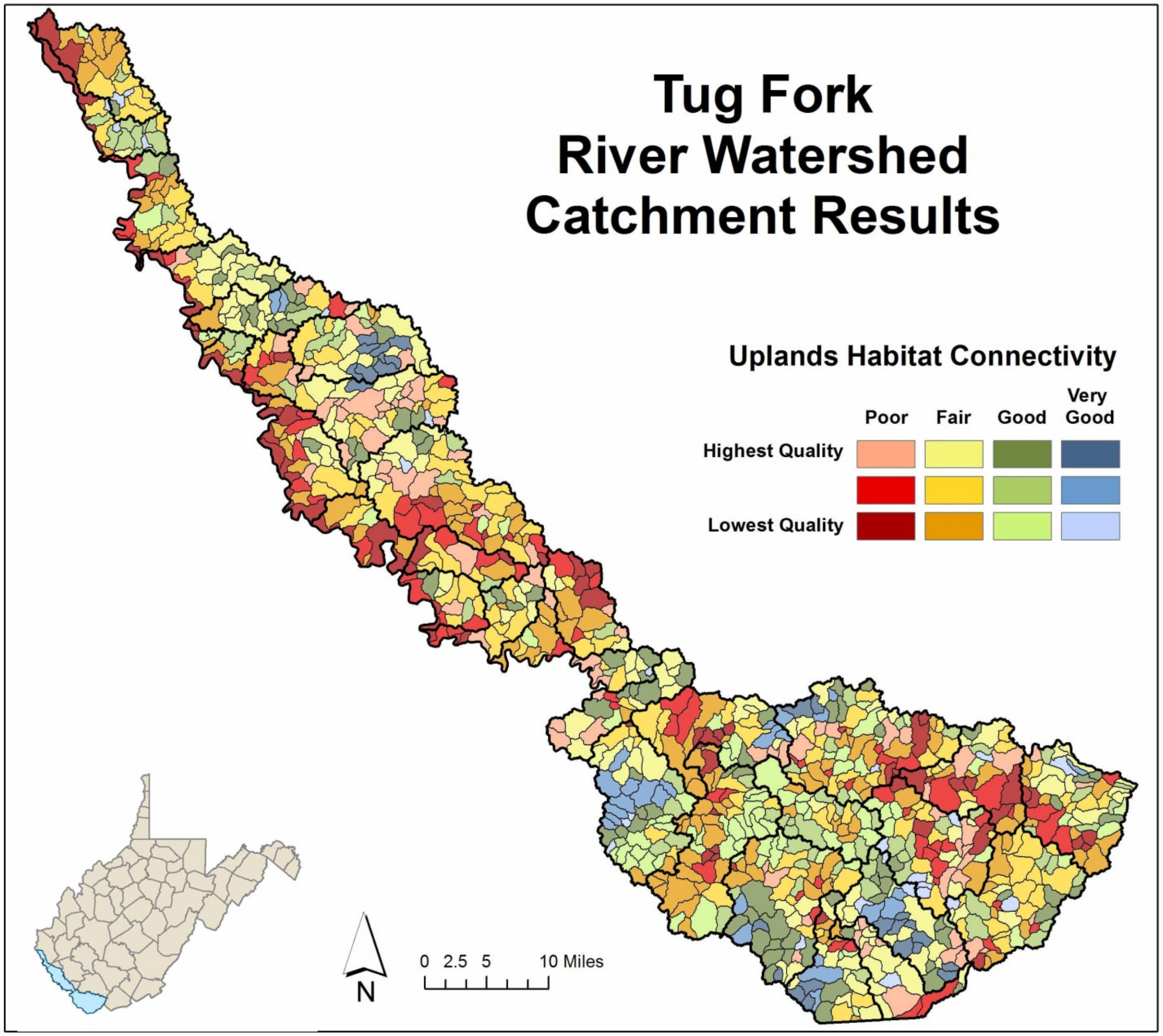

Figure 31b. Uplands Habitat Connectivity Index Results – Catchment Level

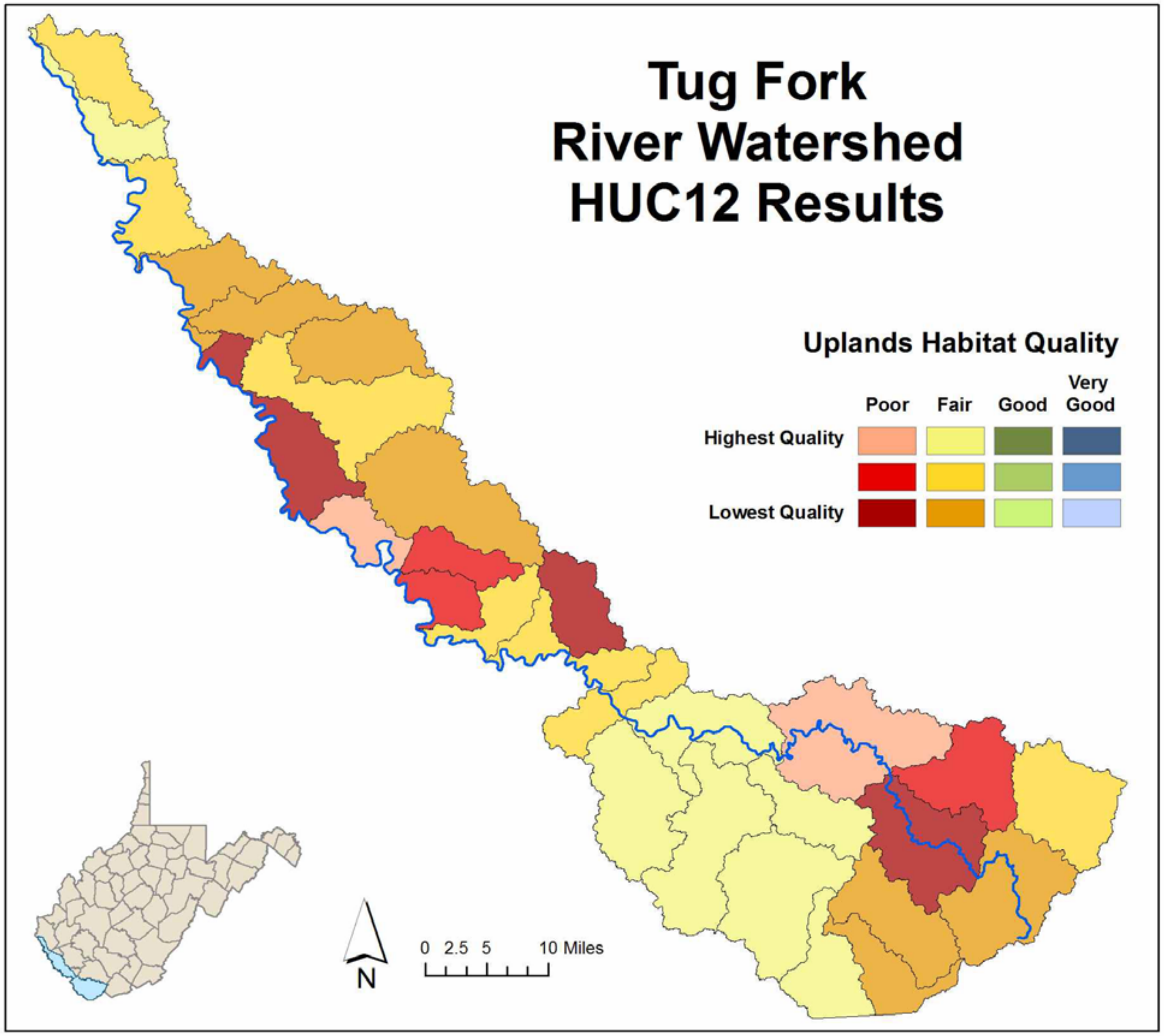

Figure 32a. Uplands Habitat Quality Index Results – HUC12 Level

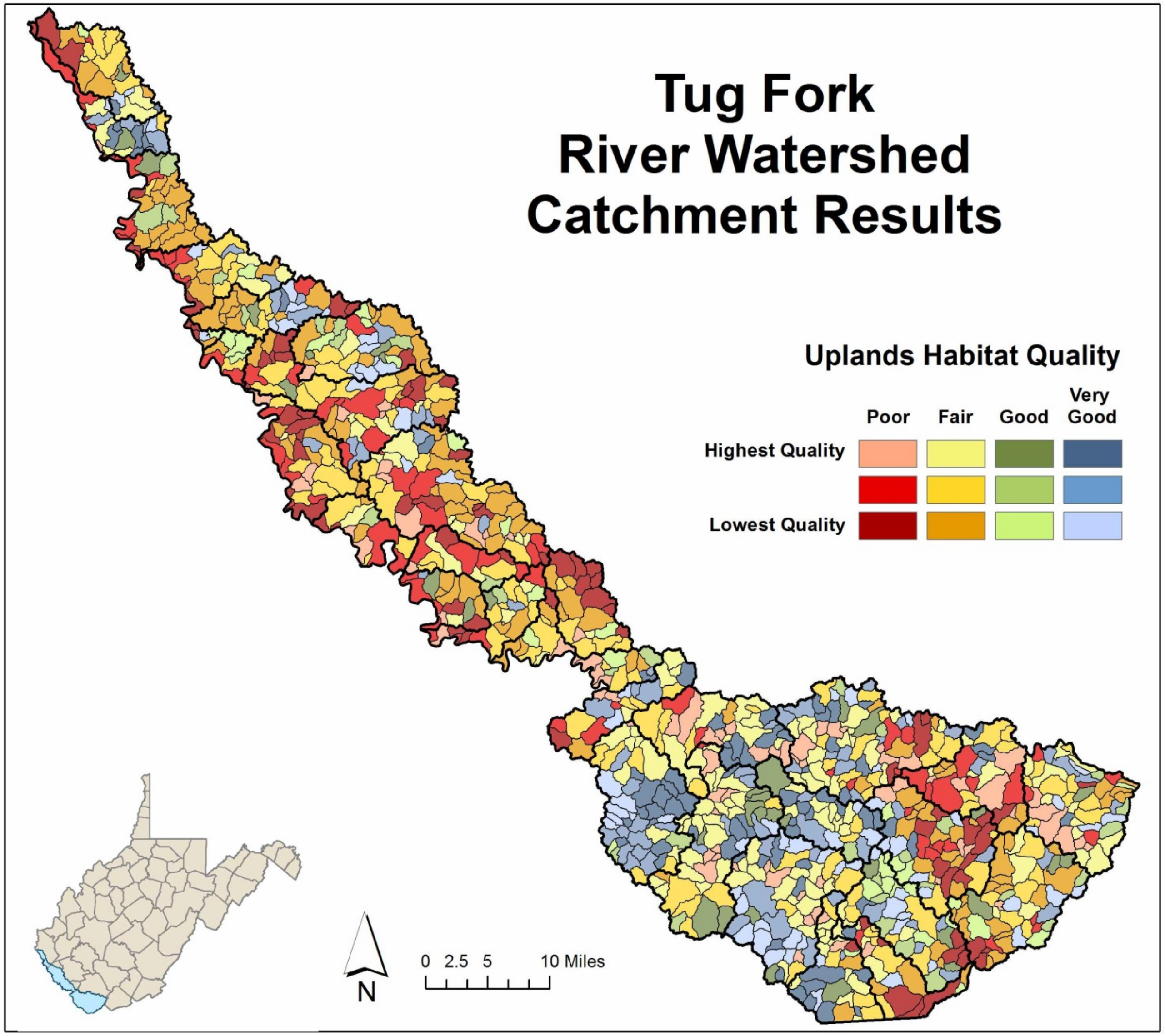

Figure 32b. Uplands Habitat Quality Index Results – Catchment Level

The Uplands Biodiversity (UBD) index results (Figures 33a and 33b) generally agree with the trends seen in the Streams and Wetlands Biodiversity indices, though the UBD results do have a few more concentrated areas of Fair planning units. This is likely due to an additional metric in the UBD index for uplands compared to streams or wetlands, the predicted percent tree basal area loss due to pests and pathogens. Fair-scoring HUC12s and catchments are generally in the areas where the percent loss metric is the highest, indicating a greater threat to forest loss from pests and pathogens. Otherwise, many of the watershed's planning units at both scales are in the Good category.

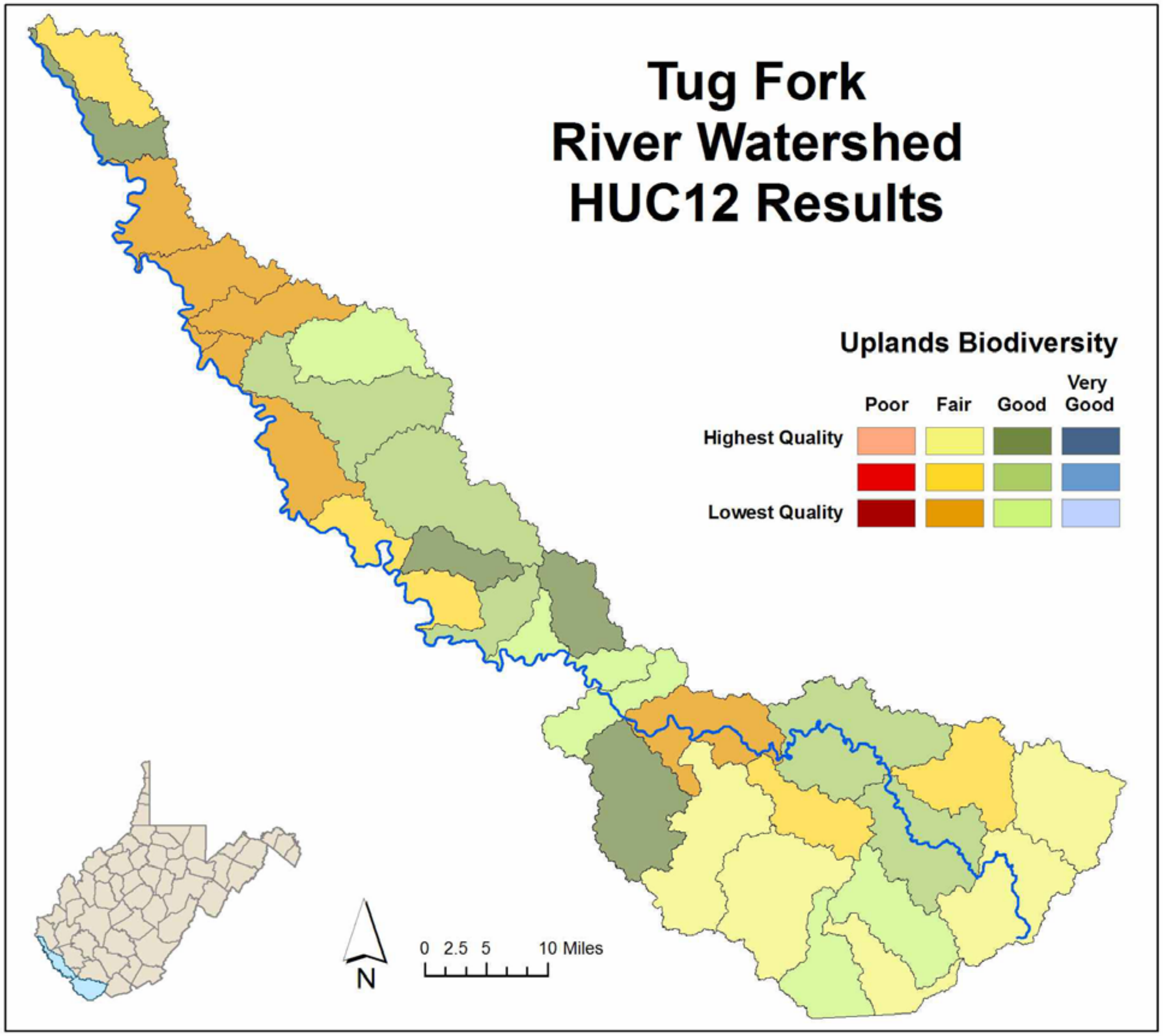

Figure 33a. Uplands Biodiversity Index Results – HUC12 Level

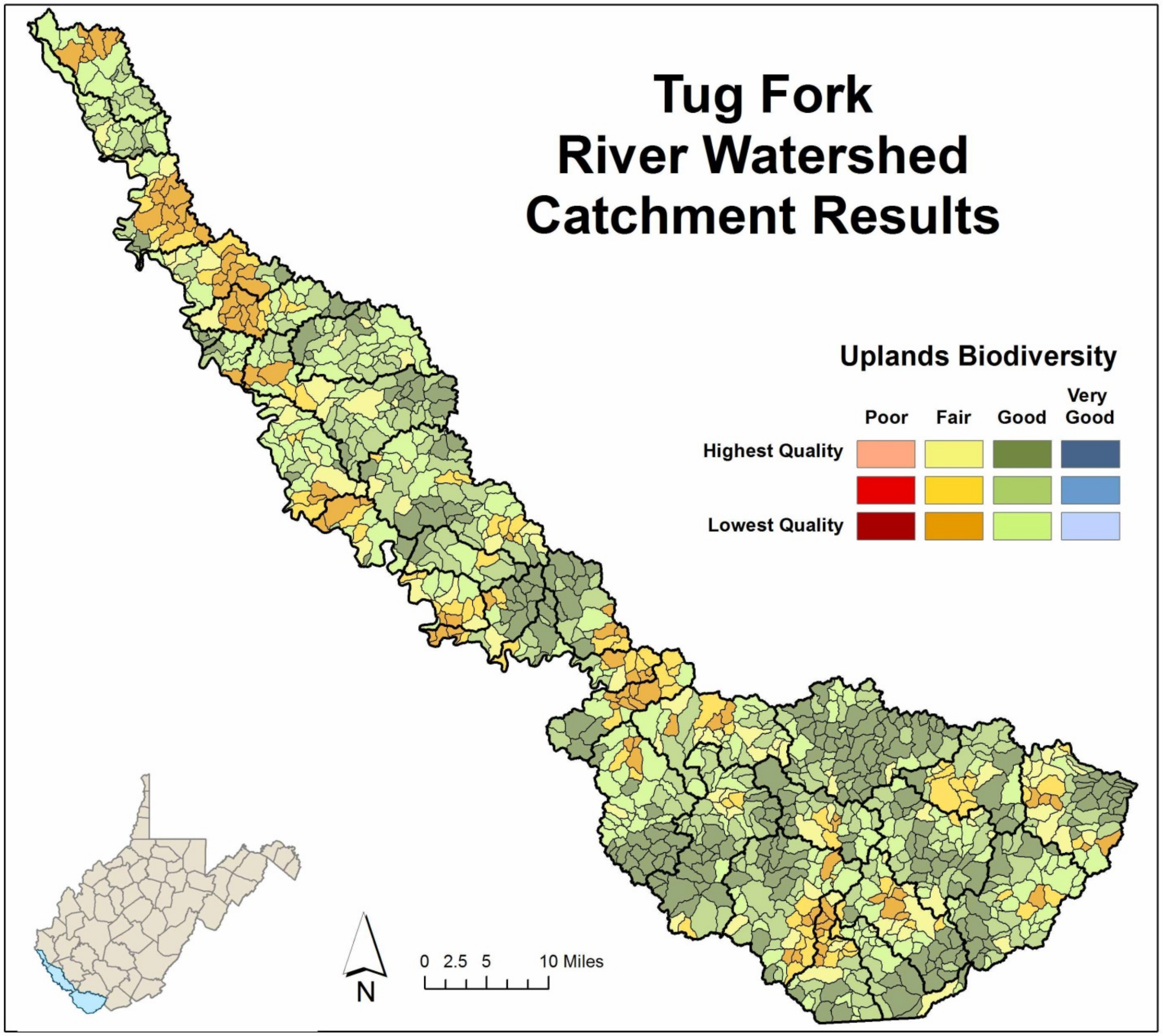

Figure 33b. Uplands Biodiversity Index Results – Catchment Level

4.2 Consolidated Analysis Results and Discussion

The Consolidated Analysis Overall results for the Tug Fork watershed show varying levels of future threats dispersed across the watershed (Figure 34). These results are primarily influenced by future threats from energy development, particularly future coal mining activity, as data for other types of threat were scarce for this geographic area. The general trend is for higher threats in the northern areas and minimal threats throughout the rest of the watershed. The small areas of highest threat are all related to potential for further future coal extraction activities. All other types of future threat are very low within the Tug Fork watershed.

The Consolidated Analysis Energy results are variable as the different threats are unevenly distributed across the landscape (Figure 35). The highest threat areas are likely to be mined in the future for coal resources, as many layers of unmined coal beds remain and are in unmined portions of existing mining permit boundaries. The Marcellus Shale thickness is also greatest in the southeastern portion of the watershed, though overall the Marcellus is not very thick in this region and extensive future oil and gas well development is likely not a significant threat in the watershed. There is some potential for wind development on a few of the ridges in the southeast of the watershed, but again development of this energy source is unlikely as there are other areas of West Virginia with much higher wind development potential values.

Two indices, Population and Development and Climate Change, had data available for only one or two metrics each and are therefore not very robust. It should be noted, however, that county-level population projections for the Tug Fork watershed show a decrease in population for all counties, with Mercer having the lowest projected decrease in population (at -3.5%) and McDowell having the highest (-18.3%, Christiadi 2011). Projected development is therefore not a likely threat in the watershed, except possibly along major highways. The Climate Change metrics Resiliency and Regional Flow data indicate lower threat levels (more resilient to the impacts of climate change and with enough connectivity to allow species to adapt within the landscape) generally in the higher elevation headwaters areas, with the highest levels of resiliency within and adjacent to existing protected lands (Figures 36 and 37). Lowest values generally follow the road and railroad infrastructure in the watershed. 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 3.4 Consolidated Analysis. Some of these highly resilient and connected areas, particularly along the northern border of the watershed, are also threatened by potential energy development. These areas of the watershed may therefore be good candidates for protection activities, if planning units also have high scores in the current condition analysis and lower threat levels in other indices of the Consolidated Analysis.

The Opportunities analysis is not a quantitative analysis, but rather an overlay intended as an aid to conservation action planning, incorporating areas of potential conservation priorities for different agencies as well as lands currently under various degrees of protection by state, federal, and private

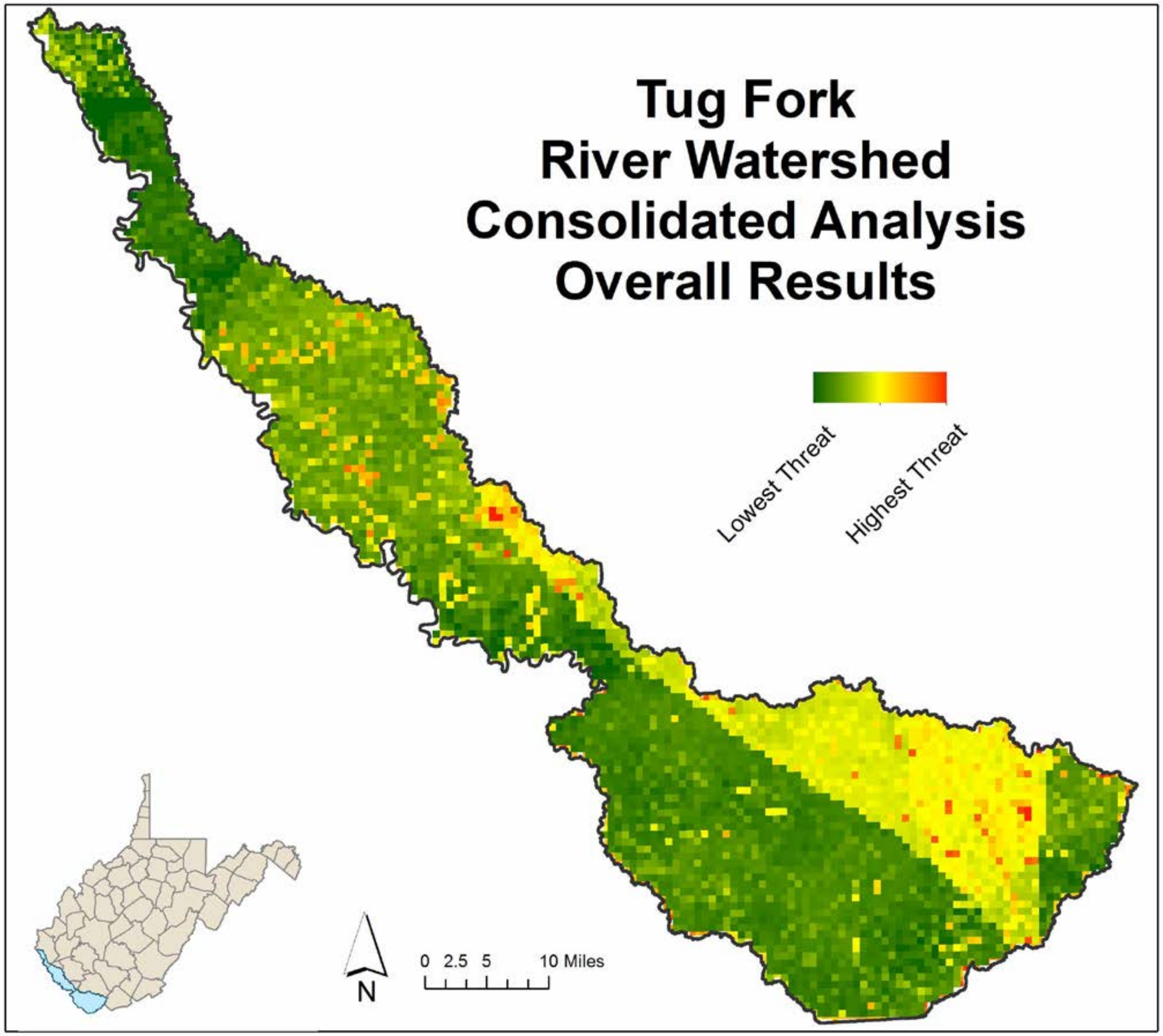

Figure 34. Consolidated Analysis Overall Results

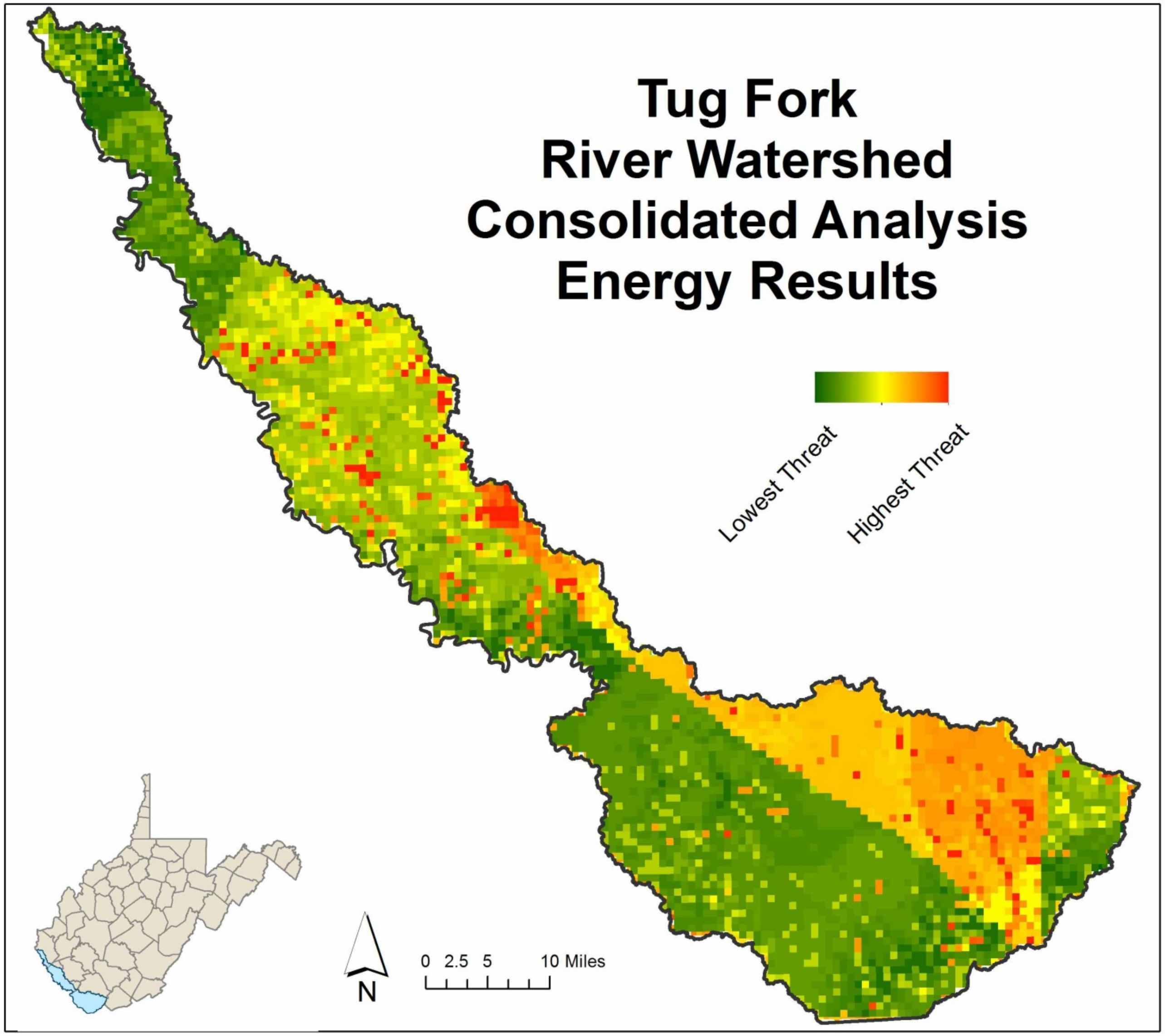

Figure 35. Consolidated Analysis Energy Results

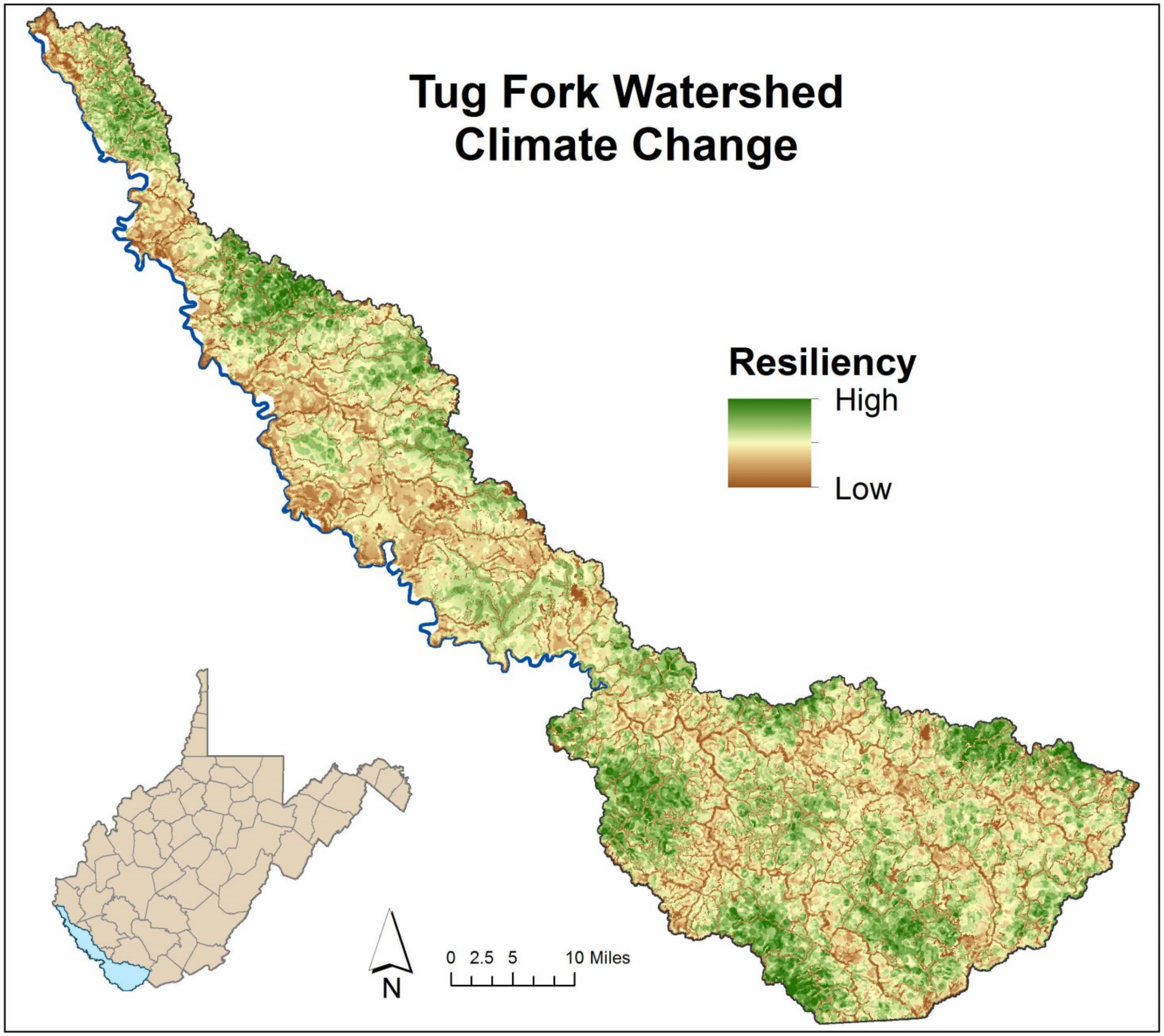

Figure 36. Consolidated Analysis Climate Change – Resiliency (TNC 2012)

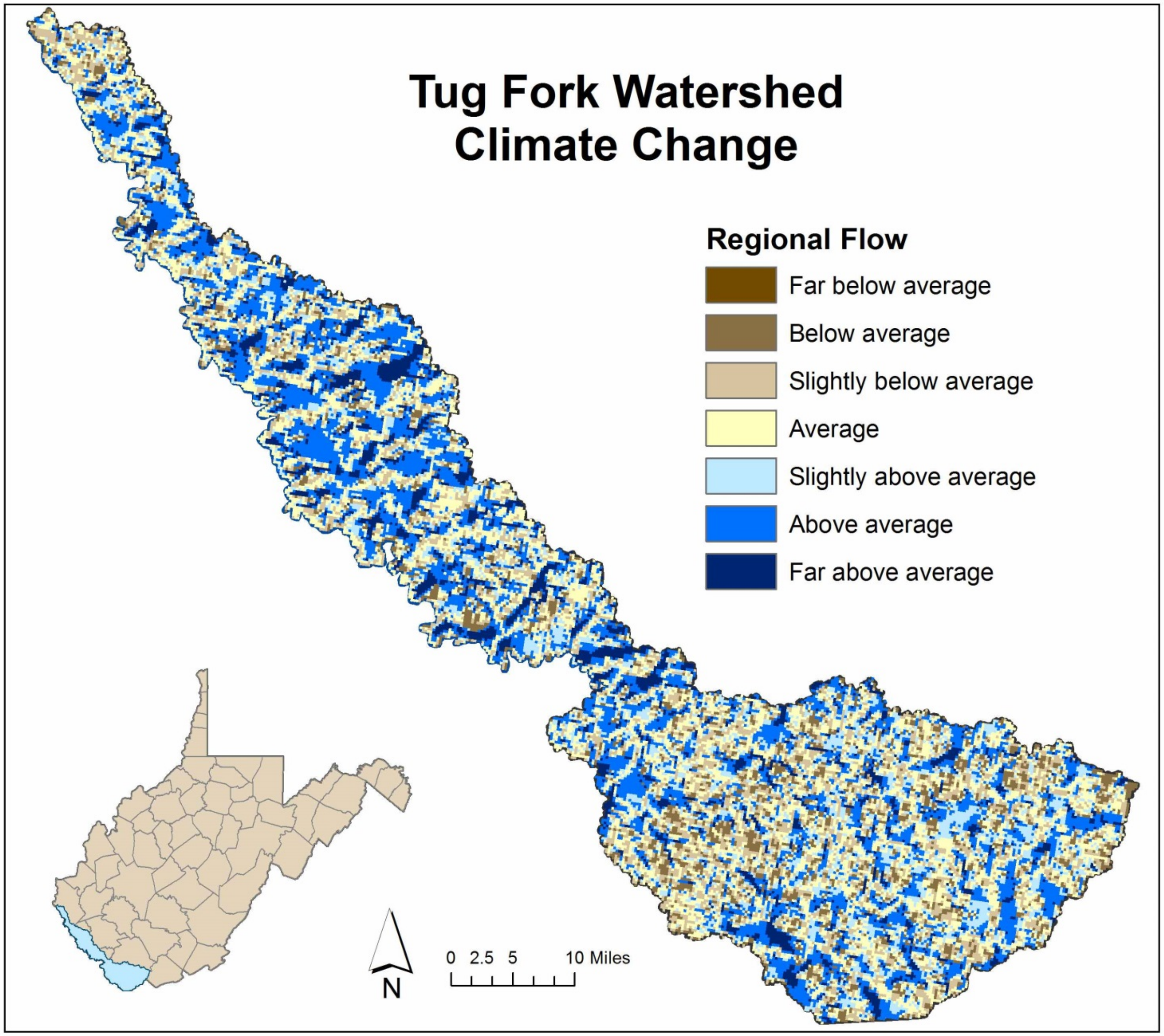

Figure 37. Consolidated Analysis Climate Change – Regional Flow (TNC 2012)

agencies, which could be expanded on or connected in the future. Approximately 28,000 acres of public land occur in the Tug Fork River watershed , most of which are Wildlife Management Areas (Figure 38). The watershed also contains Panther State Forest, with about 7,700 acres.

Several agency priority interest areas occur within the Tug Fork River watershed (Figure 39). The Nature Conservancy has included the lower portion of the Tug Fork main stem and the entire Dry Fork in their aquatic portfolio. TNC's terrestrial portfolio also spans much of the watershed, including the areas surrounding Panther Creek and Laurel Lake WMA. Several HUC12s were identified as priorities by the West Virginia Division of Forestry water quality analysis.

These Opportunities datasets are included to encourage collaboration and partnership between agencies and organizations that may have overlapping goals and priorities within the watershed.

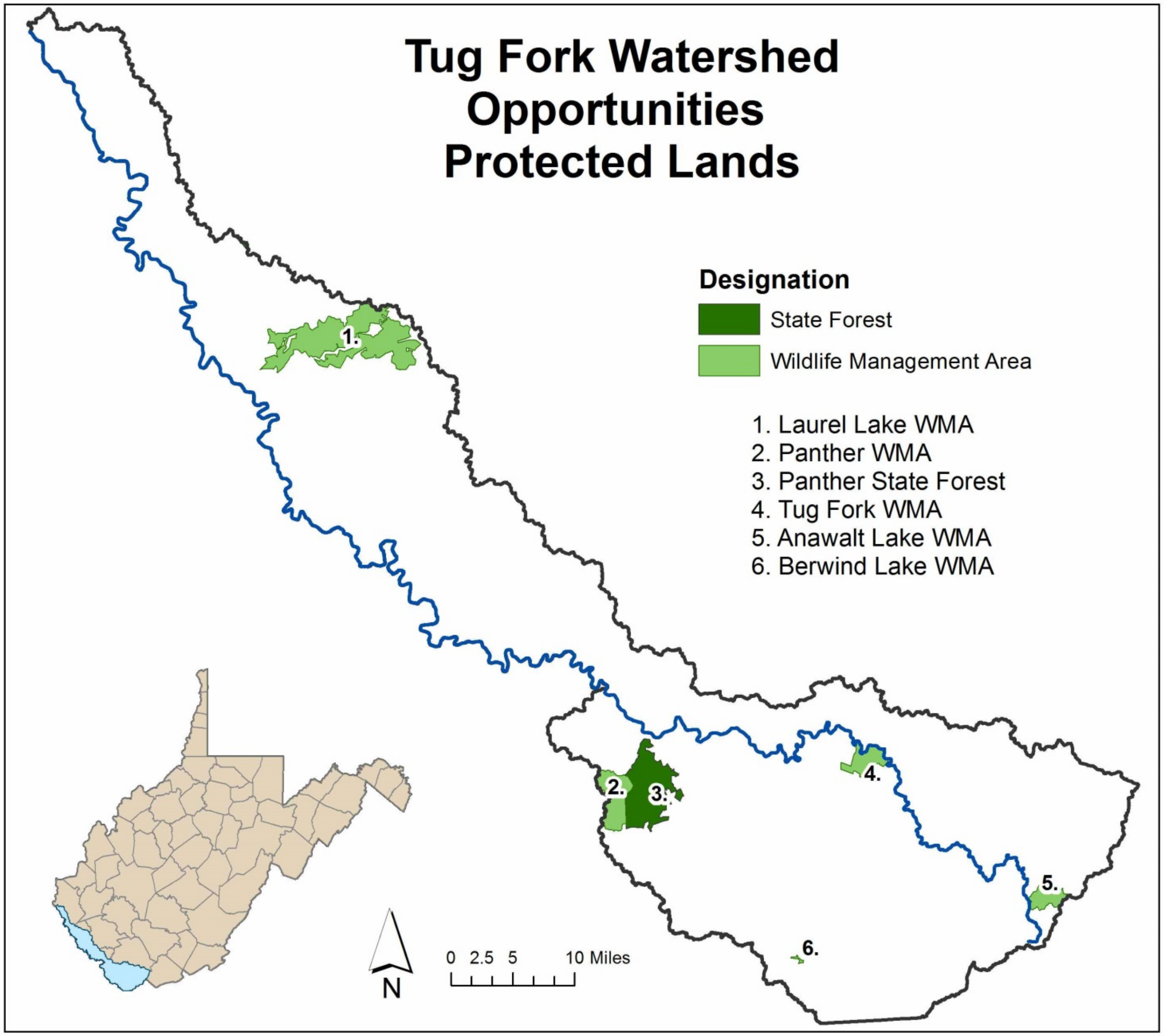

Figure 38. Tug Fork River Watershed Opportunities – Protected Lands

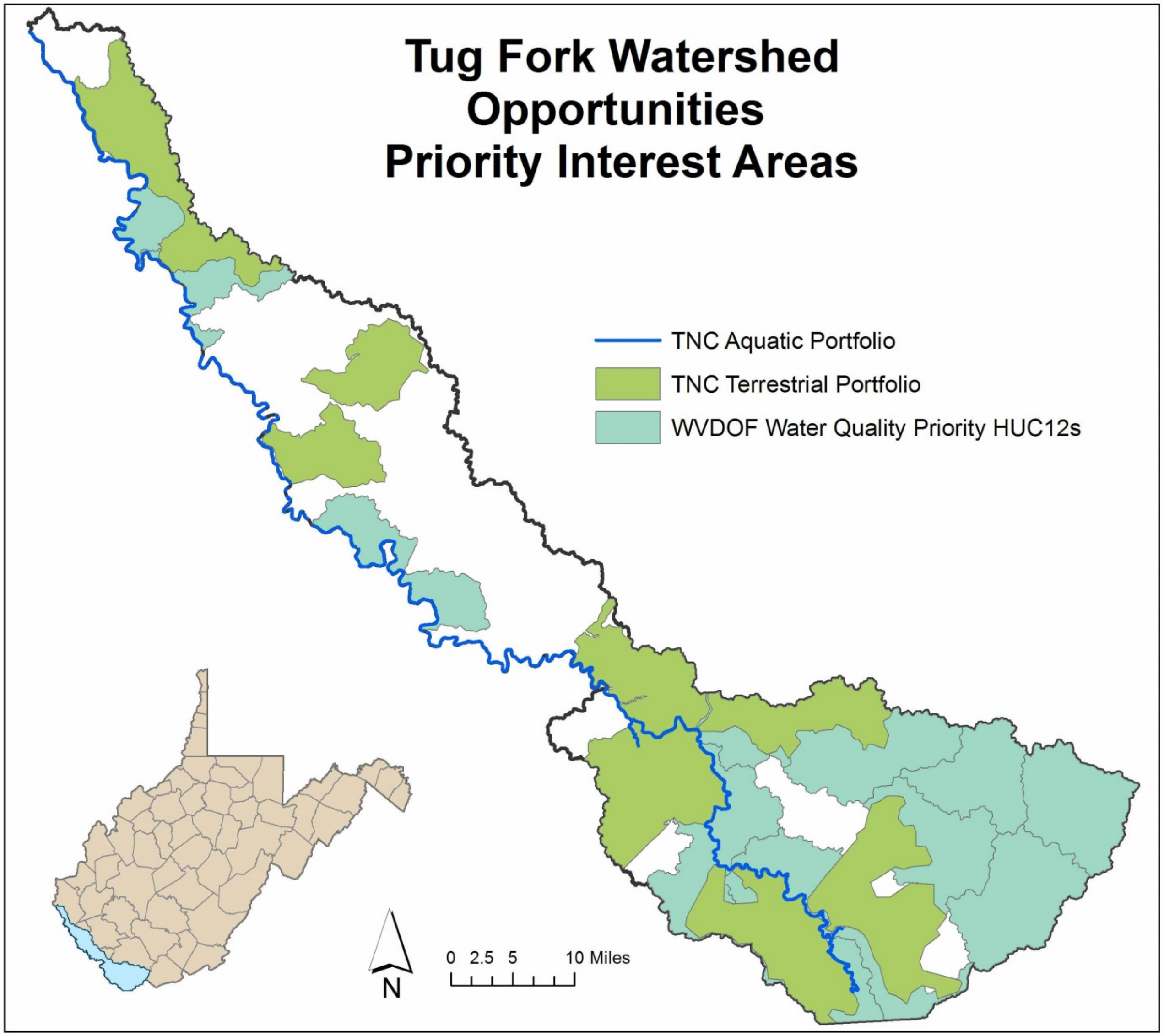

Figure 39. Tug Fork River Watershed Opportunities – Priority Interest Areas (TNC 2012)

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 40). 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:

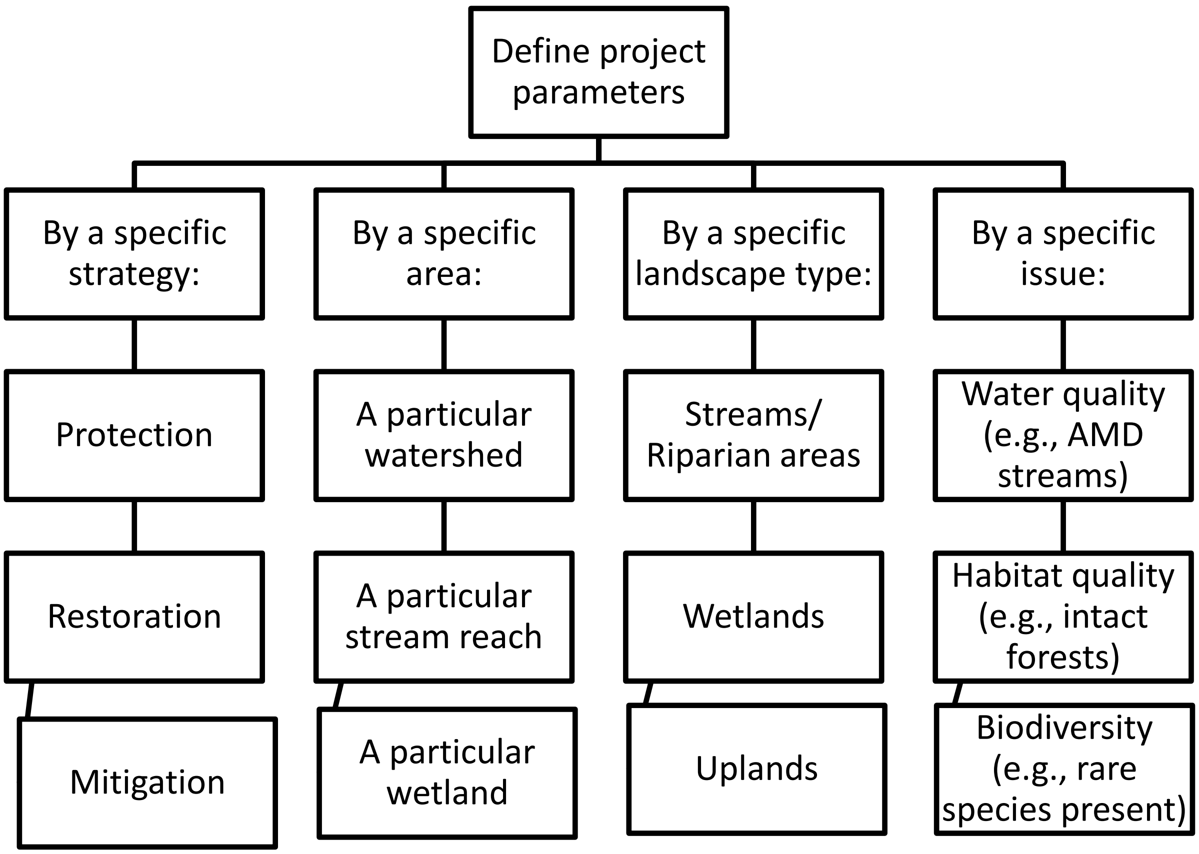

Figure 40. Possible End User Project Parameters

Step 2: Identify candidate areas for conservation action:

<u>a)</u> Protection Sample Process (Figure 41)

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

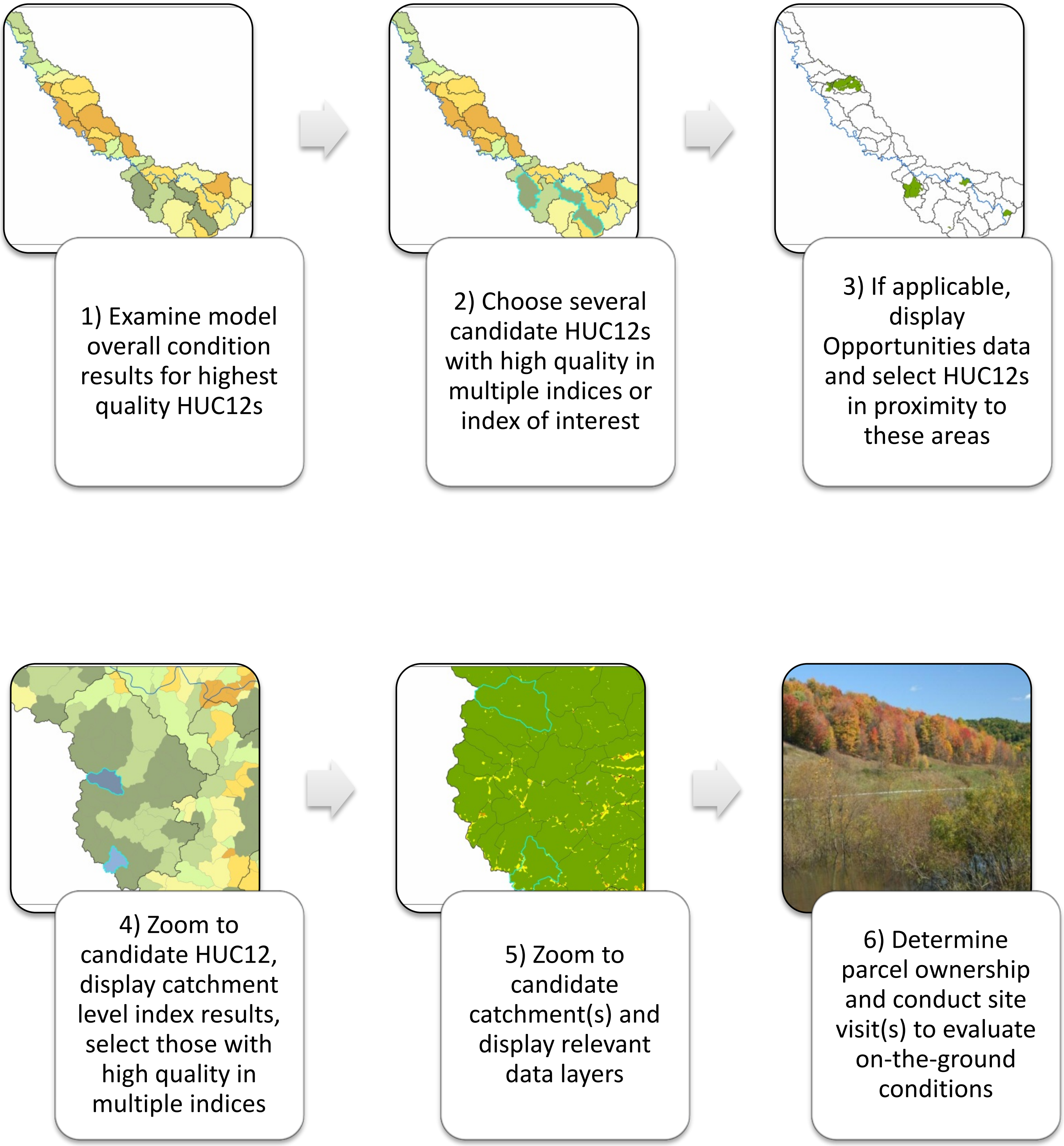

Figure 41. Protection Sample Process Flowchart

b) Restoration Sample Process (Figure 42)

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

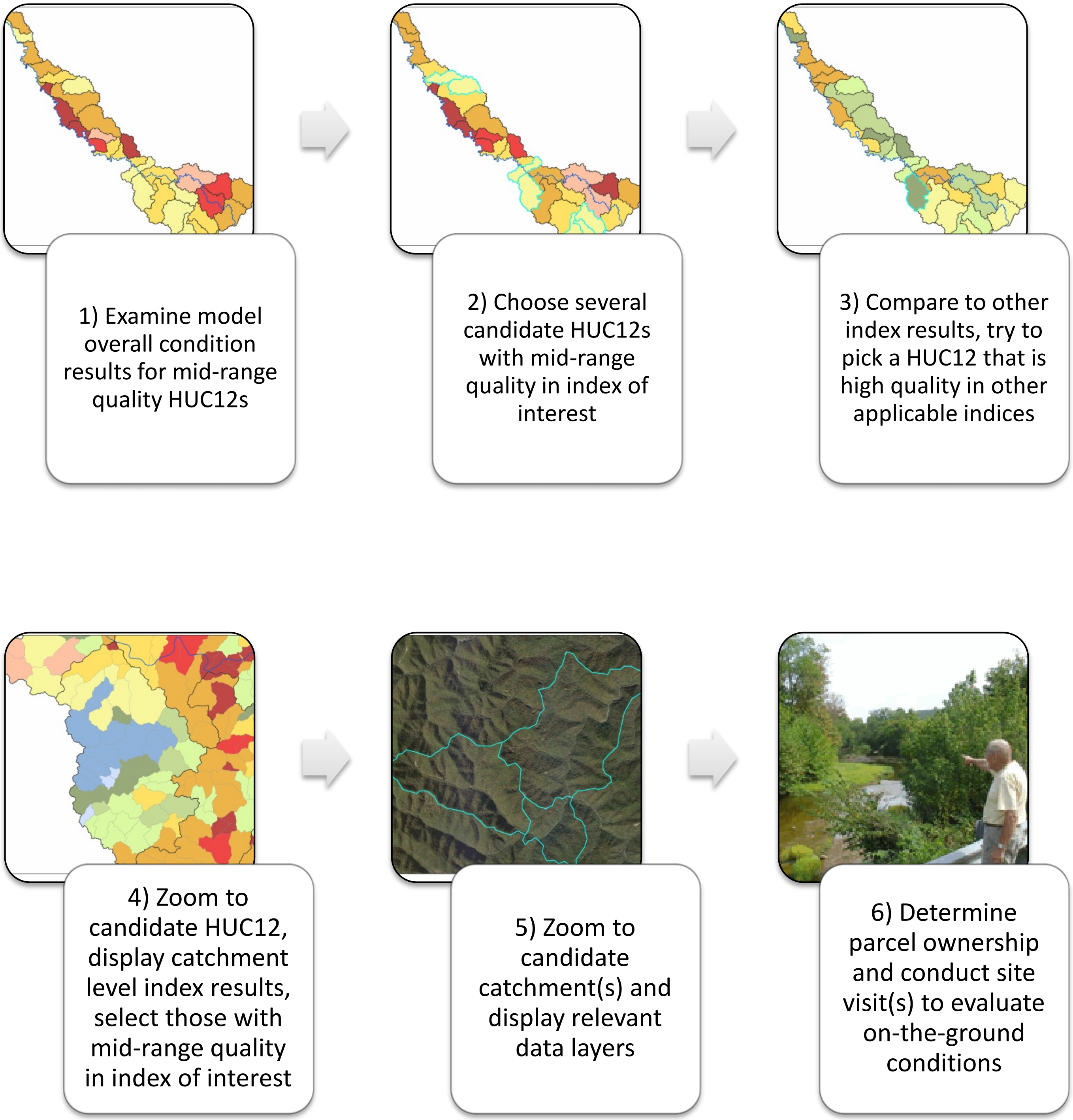

Figure 42. Restoration Sample Process Flowchart

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
July 1, 2013	Extension of project to include 2 additional watersheds due to unspent funds
Nov 13, 2013	Decision maker and end user workshop held on final 2 watersheds. Final revisions made
Dec 31, 2013	Final assessment reports on all 7 watersheds completed, assessment methodology report revisions made. Final report and all completed deliverables, including interactive first version of web tool, submitted

West Virginia Watershed Assessment Pilot Project
Tug Fork and Tygart Valley Watersheds
Stakeholder Workshop Summary
November 13, 2013
Flatwoods, West Virginia

Workshop Objectives

The goals of this workshop were to:

1) present the current condition and consolidated analysis results for the final two watersheds and obtain stakeholder feedback; and
2) 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.

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. This was followed by a presentation of the latest version of the current condition and consolidated analysis results for the Tug Fork and Tygart Valley 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 two 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 feedback on desired functionality and possible user workflows for the interactive web tool.

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. An initial question dealt with whether or not there would be a way for individuals to get ground-truthed data into the system to update the analysis results. The response from the project team was that this process would likely be too complex to incorporate into the web tool automatically, but that the project does plan to provide a list of data providers and links to relevant contacts so that users can get in touch with the right people to help update the data. Another question was whether there was a consideration of land costs in the final results and/or web tool. The project team acknowledged that this was valuable information, but that there are many technical and proprietary issues around providing those data publicly and keeping them current, and suggested that users compare the watershed assessment results and data with tax map parcels to determine ownership and appraisal values.

Overview of Tug Fork Watershed Results

Misty Downing, TNC

A large amount of resource extraction activity occurs in this watershed, particularly surface and underground mining and oil and gas well development. There is very little urban development, but significant amount of roads and railroads. There are a few areas of protected lands, including several wildlife management areas and one state forest. Overall, streams suffered from a variety of mining-related water quality impairments in certain areas, and there are areas of degraded riparian habitat and fragmented hydrological features. The watershed has few wetlands, and most of the existing mapped wetlands were in decent condition, with generally minimal habitat fragmentation in the wetland buffer or anthropogenic land use in the wetland catchments. The watershed has a significant amount of fragmenting features and recorded invasive species (which are likely roadside based surveys, based on the spatial distribution of the data).

Comments: It was noted that water from underground mining pools in McDowell County is used as a public water supply and is generally very high quality water. Thus, underground mining should not be considered an impairment of water quality in that area. Underground mining water regulation has also reduced flashiness in streams. The project team acknowledged this reality, which has been discussed multiple times in various expert and stakeholder workshops; however, due to the fact that the assessment methodology is designed to be applicable across the state and in various geographies, it is difficult to modify results based on just one county or several HUC12s. Additionally, underground mining is a polygon dataset, and does not include point features where mining pool discharges exist. Therefore, the contribution of high quality underground mining water cannot be spatially identified; also, this water is stored in aquifers/subsurface waters, and groundwater is not a consideration in this analysis, also due to data limitations. WVDEP stakeholders shared that more information about underground mining water may be available in mining permit data or well sampling data, but this will only cover newer permits, and wouldn't apply to older mines (the mines discussed in the Tug Fork are older mines with existing permits). Stakeholders also noted that there is a water quality assessment report for the Pigeon Creek HUC12, conducted by the Natural Resource Conservation Service (NRCS).

Overview of Tygart Valley Watershed Results

Misty Downing, TNC

The Tygart Valley River watershed has distinct land use/land cover trends, and results for all models and indices tend to reflect these patterns, with higher quality areas in the south and east along headwater mountain ridges, and lower quality areas in the northwest and around developed areas of the watershed. There are significant amounts of oil and gas wells and some surface and underground mining in the western parts of the watershed. There are several large towns in the watershed, and this land use and associated fragmenting features are concentrated in these areas. The Tygart has some significant wetlands complexes, particularly in the southeastern river valley; these areas also have higher concentrations of agriculture and grazing pasture land uses. Several protected lands occur in the watershed, particularly in the south and east, with Kumbrabow State Forest and a portion of the Monongahela National Forest in these areas of the watershed.

Comments: It was noted that within this watershed development of Marcellus shale in the eastern mountainous regions would be limited regardless of shale thickness values, due to tectonic shifting in this area which releases gas and makes drilling geologically and economically infeasible.

Interactive Web Mapping Tool

Ruth Thornton, TNC

The stakeholder group was presented with the demonstration/draft version of the future web mapping tool currently under development by Casey Schneebeck and Paul Angelino 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 a prototype of the attribute table design. Current layers include hydrology and mining, various land use and land cover layers, and the assessment analysis 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.

Desired functionality/features of the web tool suggested by participants:

- Make a YouTube video as a how-to manual to guide users in using the web tool
- Link to other economic/social websites to get further data or information/contacts
- Be able to export data as a .kmz (Google Earth) file
- Search function, and identify function, print function, export as Excel function
- Label or the ability to identify USGS stream names
- Provide a link to WVDEP alerts
- Ability to bookmark certain areas or by a list of catchments
- Ability to download data from a user-specified AOI (area of interest) into GIS – primarily results from the analysis, since other datasets are already publicly available from various sources
- May be useful to open multiple attribute tables to compare different results between planning units (for example, if you were determining where best to work on water quality issues for the drainage area of a lake, you may want to be able to compare several of the contributing catchments to see where your work may be most effective)
- Find water quality sampling stations by latitude/longitude and/or stream name

The project team will work with the developers of the web tool to incorporate as many of these suggestions as is practically feasible within the project scope.

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