West Virginia Watershed Assessment Pilot Project

Assessment Methodology

Introduction

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. It is also intended to facilitate communication and collaboration regarding watershed protection and restoration among regulatory personnel, decision-makers, and stakeholders; identify data gaps/needs within West Virginia; and suggest possible future projects to generate data that may inform future assessments. The intent of this pilot project was to develop an assessment process that may be applied to all watersheds within the state, given available funding. The initial watersheds chosen for the pilot project (Lower and Upper Monongahela, Elk, Upper Guyandotte, Little Kanawha, and Gauley) are experiencing significant impacts to headwaters and wetlands as a result of development and resource extraction.

We assessed the condition and function of the five pilot watersheds 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 water quality. 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 or private sector with relevant expertise.

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.

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 (Figure 1). 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 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.

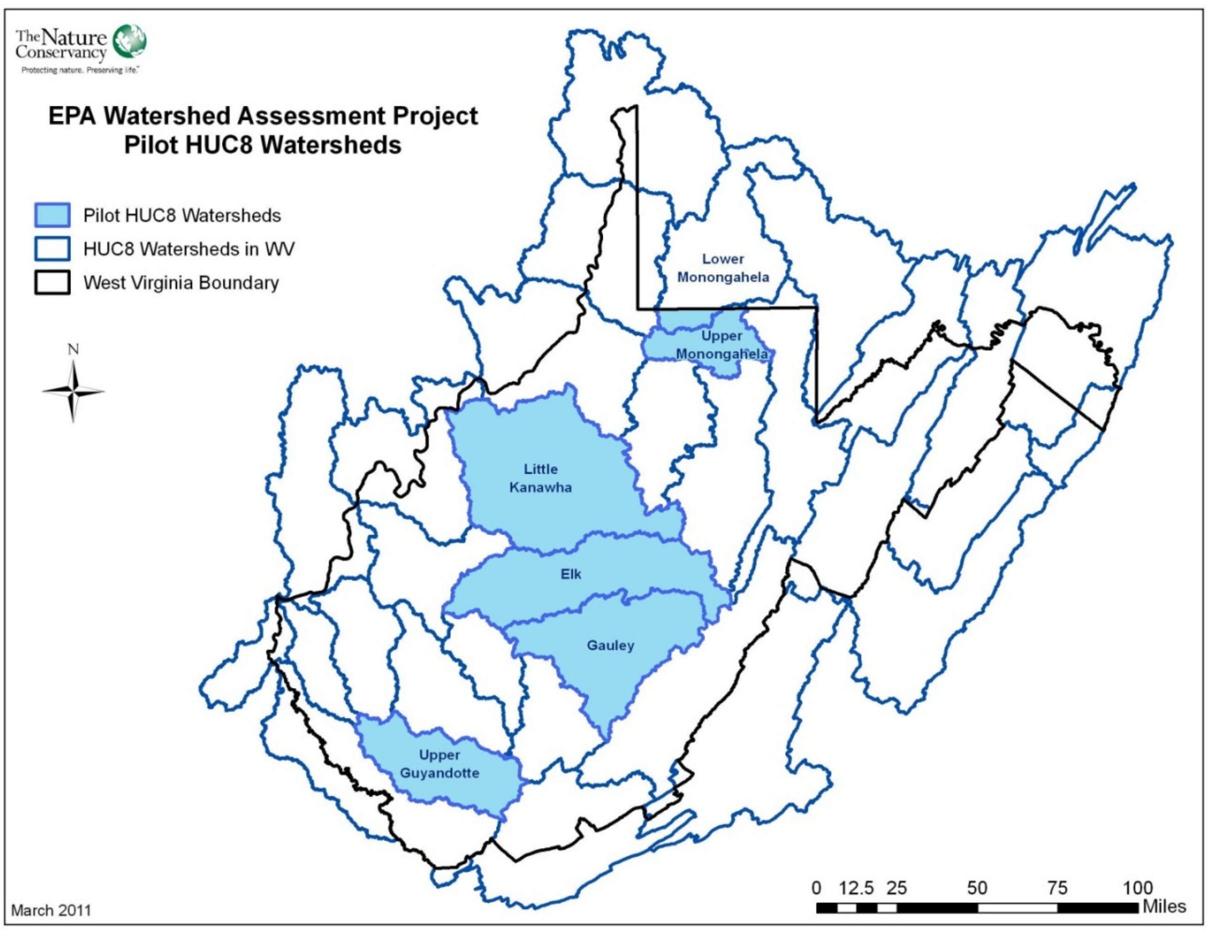

Figure 1. West Virginia Watershed Assessment Pilot Project HUC8 Watersheds

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.

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.

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. Conduct a **decision maker/end user workshop** for Monongahela watershed stakeholders**.**
6. 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 analysis** to indicate where protection or restoration projects might expand upon currently protected lands or priority interest areas.
7. Complete a **draft watershed assessment**. Conduct a **decision maker/end user workshop**.
8. Complete **final assessment**.

Assessment Design

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) within the HUC8. A HUC12 watershed 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. 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.

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 (WBD), primarily to achieve a compatible and hydrologically accurate catchment for each stream segment. 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.

Landscape Classification

Streams/Riparian

Streams considered in the assessment were defined using the USGS National Hydrography Dataset 24K 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, caused the NHD24K dataset to be the most detailed and reliable source of stream line data for the purposes of this project. The riparian buffer was defined using the northeast regional Active River Area (ARA) dataset generated by TNC’s Eastern Regional Office. 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. 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.

Wetlands

Wetlands considered in this assessment were defined using the US Fish and Wildlife Service’s National Wetlands Inventory (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. A 50-meter wetland buffer was generated to include the surrounding wetland habitat in the wetlands analysis. Additionally, some metrics were calculated based on the catchment area for each wetland. These catchments were delineated using NHDPlus catchments and flow direction grids to approximate the total drainage area for each wetland.

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.

Analysis Design

The goal of the project was to prioritize 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 values to one of four quality categories, indicating the degree of deviation from a desirable ecological condition: Very Good, Good, Fair, and Poor (Table 1). These objective, or "categorized," rankings were determined at both the HUC12 and NHDPlus catchment scales of planning units.

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. 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 2). Level I reference streams are the highest quality, while Levels II and III indicate slightly lower quality streams that still meet most criteria for reference stream designation.

Table 1. Definition of Objective Method Categories

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 2. WVDEP Reference Stream Criteria

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 240
No obvious sources of non-point source pollution	
Evaluation of anthropogenic activities and disturbances	
No known point discharges upstream of assessment site	

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 3). For the purpose of defining threshold values for this project, a water quality station site was considered “stressed” if its sampling data and/or RBP scores met at least two of the listed criteria.

Table 3. WVDEP Stressed Stream Criteria

Parameter	Value
Dissolved Oxygen	<4.0 mg/l
pH	< 4.0 or > 9.0
Conductivity	>1,000 µmhos/cm
Fecal coliform	>5,000 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

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 2). Applicable metrics were calculated for the 1084 reference/stressed catchments for all three landscapes (streams/riparian, wetlands, uplands) and threshold values were derived from these calculated results.

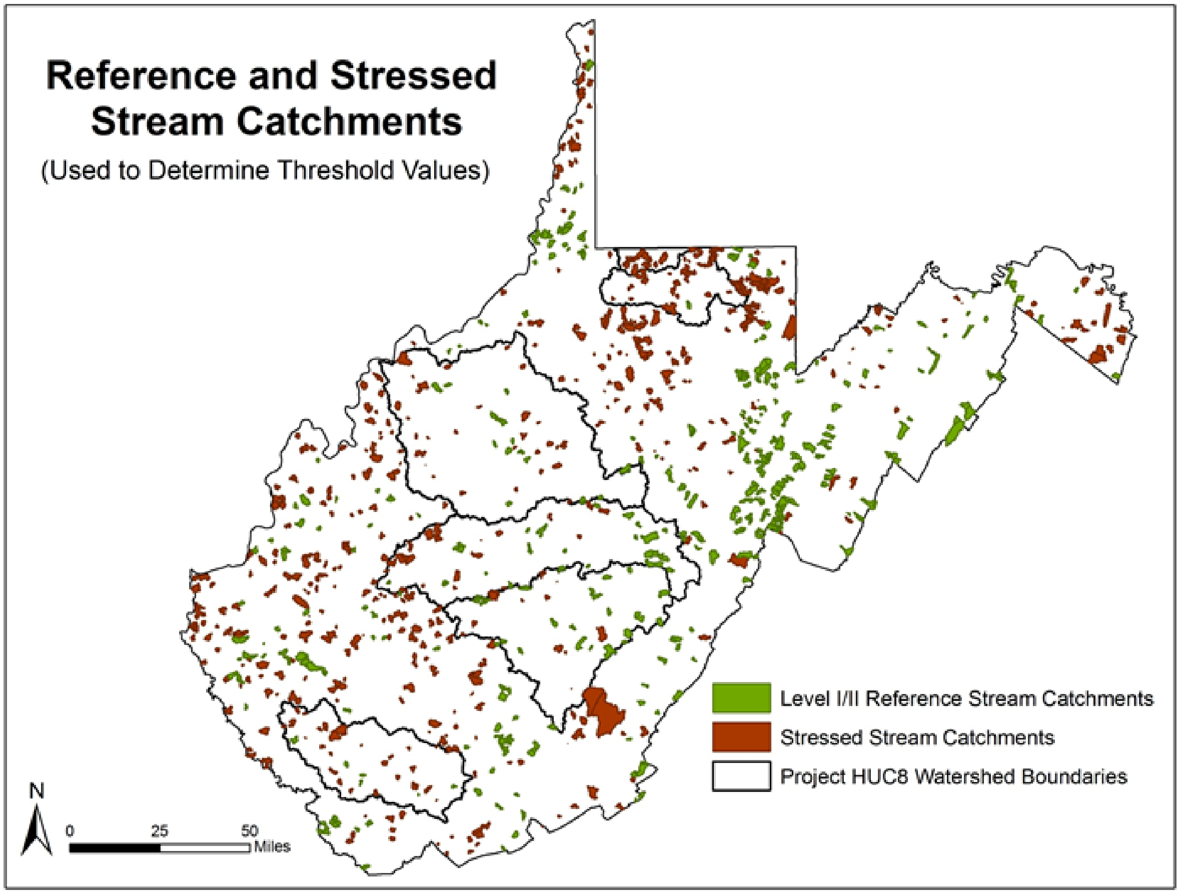

Figure 2. Reference and Stressed Stream Catchments

The distributions of the resulting metric values were examined, and final analysis results were evaluated through an iterative process, using the median and different percentiles as potential threshold values. It was determined that the most consistent results came from using the following values: the Very Good/Good threshold was set as the 35% highest quality of the reference catchment values, the Good/Fair threshold was set as the 75% highest quality of the reference catchment values, and the Fair/Poor threshold was set as the 35% lowest quality of the stressed catchment values (Figure 3).

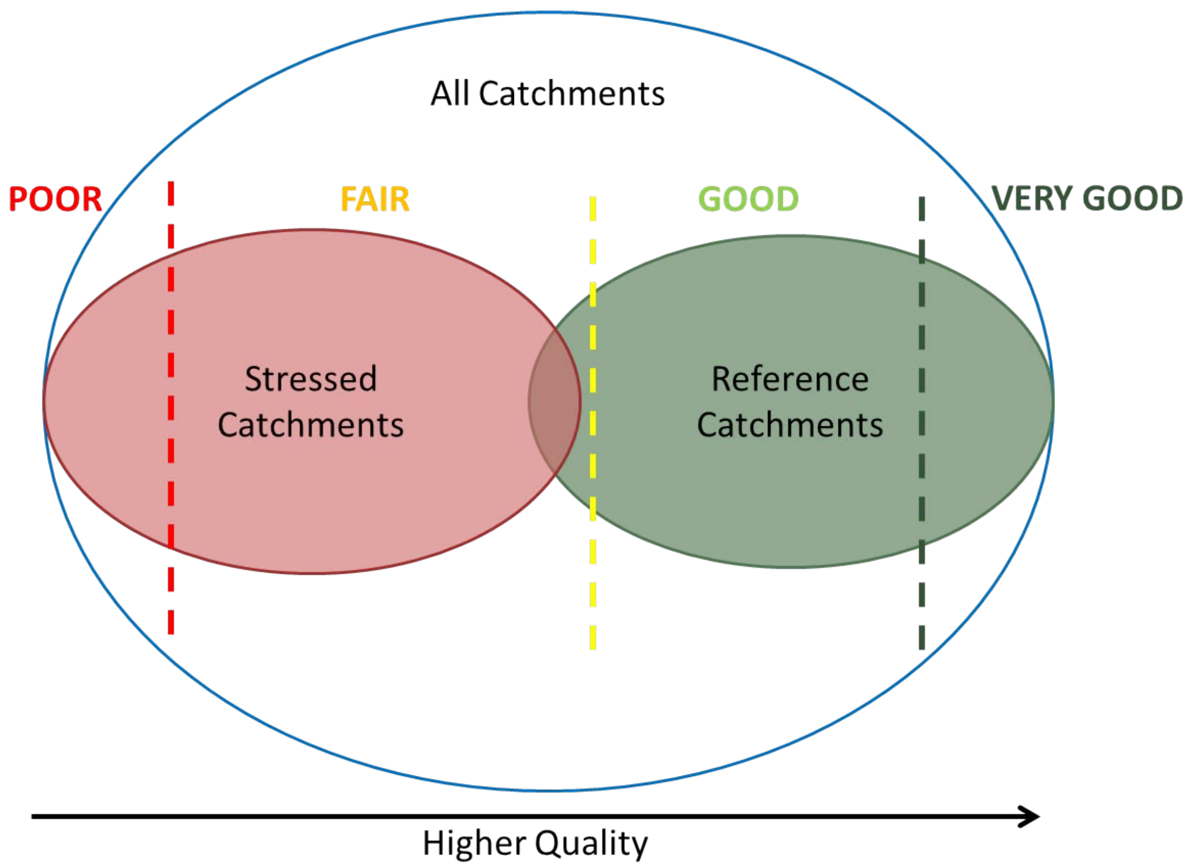

Figure 3. Threshold Definition Model

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 (Table 1). 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 upon the goals of the individual organization or restoration project.

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 the metric was in 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. Only a handful of metrics were considered critical (Table 4).

Table 4. 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

To compare planning units relative to each other within a category, a relative score for each planning unit was also calculated. These scores were standardized 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). For example, to score for 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.

A combined final score was then calculated for every metric for each planning unit, consisting of the objective category score combined with the relative score. The combined score indicates the planning unit's relative ranking within a 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 that can help an end user make decisions about conservation projects. For example, several HUC12 planning units may be in the Fair category for the Streams Overall results, but the combined results indicate which of these planning units rank higher than others, suggesting that restoration work within the higher-quality subset of planning units may have a higher probability of success, all other factors being equal.

Initially, the project team identified 214 metrics to characterize the three landscapes. The values for these metrics at the HUC12 level for all five HUC8 watersheds were subjected to a Pearson's Correlation analysis, 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 5). The most influential component (eigenvalue 18.29, 25% of variation explained) described a gradient of anthropogenic disturbance, from high negative loadings on metrics such as forested riparian area and natural cover in headwater catchments, to high positive loadings on development metrics such as roads/railroads in riparian area. The second component (eigenvalue 9.34, 13% of variation explained) consisted of different mining and coal metrics, while the 3^{rd} component consisted of oil and gas wells (eigenvalue 5.18, 7% of variation explained). Some of the metrics that were identified as important in the PCA were dropped from the assessment due to high correlation with other metrics, lack of data across watersheds, or other reasons. After the correlation and Principal Components analyses, and discussions with experts at the expert workshops, the final current condition analysis dataset was reduced to 94 metrics.

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. These entities provided and refined their recommendations at the technical advisory team meeting, several expert workshops, and/or by private correspondence. Metric and index weights ranged from 0-3, with a weight of "0" assigned to metrics that were eliminated.

The weighted metric scores were aggregated to determine index scores, and index scores were weighted and aggregated to determine overall model scores. The index scores were used in the Priority Models to rank planning units.

Table 5. 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.

Priority Models

The Priority Models used the aggregated index scores produced during the watershed characterization analysis to generate priority rankings for protection and restoration areas and activities. Prioritization occurred at two levels, which were generated independently of each other:

1. a ranking of HUC12 watersheds in terms of their overall and index scores, and
2. a ranking of NHDPlus catchments based on overall and index scores.

Three Priority Models were generated: a Streams/Riparian 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 ranks for each planning unit (HUC12 and NHDPlus catchment), with a high score indicating a higher conservation priority within that Priority Model.

Consolidated Analysis

The Consolidated Analysis consists of two main parts, a Future Threats assessment and an Opportunities analysis. 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
    i. Projected land use change with the potential to negatively impact natural resource value and function (population growth and urban expansion, planned energy projects)
    ii. 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)
    iii. Potential effects of climate change
f. 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. Detailed projections of temperature and precipitation changes are currently being developed for the Ohio River Basin by the USACE 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 to produce Threats Overall Results. 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, TNC aquatic and terrestrial portfolios, West Virginia Division of Forestry priority areas, National Park Service priority areas, and National Forest proclamation boundaries.