Watershed Classification: Description of classes, and vulnerability, as a function of physiographic characteristics throughout the MAHA

The purpose of this section is to provide a narrative description of the watershed cluster types, identify the prominent areas of their distribution, and to discuss their potential vulnerability to a variety of stressors throughout the study area (MAHA), whereas the preceding analyses focused on the vulnerabilities of watersheds in West Virginia. Here, we extend our understanding of those relationships to a broader, regional context. This information should be useful to managers who are using this classification approach to prioritize their watersheds of concern and to locate them on the conceptual diagram that follows. It is anticipated the additional local knowledge will be used to further refine any prioritized order.

Cluster 1 – Cold Wet Flats (black, Figure 13)

Characterization:
Clusters of watersheds throughout the region of this type appear to have little in common, however, there are a few common themes. The climate tends to be relatively cold and wet. Landforms are flat, with low rates of soil infiltration. Glacial and periglacial influences are evident. Watersheds are relatively compact in shape. Clusters appear to occur in physiographical transition zones between ecoregions and geologic features that have moderate slopes (e.g., Allegheny Front, Pocono Plateau slopes into the Delaware River valley, etc. The northern clusters fall primarily in the A and B Climate Zones, which are cold, and possibly moist or at least has discharges of groundwater into streams. The compact shape in northeastern PA can be explained by the glaciated landscape of the northern Pocono Plateau, with relatively flat terrain (not rugged), and wet, but with a poorly developed stream network. In contrast, the cluster along the Venango/Clarion counties border in PA may have some periglacial effects as it is close to the glacial boundary. Also, this area lies between two parallel rivers, the Allegheny and the Clarion, which may restrict the extent of the watersheds, producing a compact shape. Other clusters of this type occur in the Wilkes-Barre/Scranton valley, as well as the Allegheny Front in central PA (Centre and Blair counties). Other clusters appear sporadically in the Allegheny Plateau, which has relatively flat terrain.

Vulnerability to Stressors:
Given the lack of common features of this type, impacts will become apparent at more local scales. For example, the Pocono and Allegheny Front regions may be susceptible to high acidity, whereas, the Venango/Clarion cluster is probably buffered to some extent by calcareous glacial till. Soils tend to moist or wet, which may have reduced historic land conversions, and these conditions appear to have forced human uses away from the riparian corridor toward the base of hills. Farming is present in glaciated northwestern PA, where fertility of glacial tills is fairly high. When land conversion do occur, however, impacts to aquatic resources in watersheds of this type are likely to be substantial and potentially harmful, thus, vulnerability tends to be high.

Cluster 2 – Dry Glaciated Northeast (red, Figure 13)

Characterization:
Watersheds in this cluster have been influenced by glacial and periglacial effects. The climate is cold and relatively dry, although streams can have high accumulation of flow, and wetlands can

be relatively abundant. Rapid responses of streams to precipitation events or spring runoff can result in severe flooding (e.g., Tioga County, PA). Wetlands are less abundant than glaciated regions to the east or west, primarily due to more rugged topography, but are more common than in most unglaciated areas of the Mid-Atlantic region.

Vulnerability to stressors:
Soils have high silt content, and thus, can be vulnerable to erosion. Broader areas of valleys are farmed. There is some mining of gravels of glacial origin in the streams. Acidification is less of a threat here than to watersheds to the east that contain more peat wetlands and coniferous forests.

Cluster 3 – Floodplains (light green, Figure 13)

Characterization:
Watersheds of this cluster are characterized as pass-through types. That is, they represent higher order streams with broad floodplains. When we tried to maintain watershed units of comparable size during the classification process, they were delineated necessarily without their contributing headwaters. Thus, their distribution is scattered throughout the region. Many of these watersheds have been substantially altered through farming in the floodplains, construction of dams, and in some cases, industrialization. Wetter portions of the floodplains may have escaped these conversions.

Vulnerability to stressors:
The river channels in some watersheds of this type served as transportation corridors, which in turn attracted commerce and industry. These areas tend to have the highest concentration of urban lands uses in the region studied (e.g., Pittsburgh, Williamsport). Issues related to management will be tied to concerns about flooding of economic property, brownfield development, and transportation infrastructure (e.g., highways, bridges). Some opportunities for restoration of forested floodplains may occur.

Clusters 4 & 8 - Moderate Mountains and Clay Hills Plateau (dark blue and brown, respectively – Figure 13)

Characterization:
Although these two regions are distinct, they have similar topographic, watershed, and use characteristics, and thus, are discussed together. These features tend to be moderate is many respects, relative to other watershed types – moderately large, moderately rugged, and with moderate flow accumulation in streams. The plateaus of western WV/southwestern PA (Cluster 8 – rust) are associated with Climate Zones C and E, where mining is not prevalent, but these have low to moderate levels of agricultural use (Detenbeck et al. 2004). The plateau is probably eroding toward the Ohio River resulting in a high drainage density. This condition may presuppose these watersheds to relatively high rates of erosion and sedimentation. In the PA Ridge and Valley (Cluster 4 – blue), associated with Climate Zone C, the watersheds encompass farmlands in the narrow valleys and lower slopes, but are forested on the ridges. In VA, there is a linear cluster located on the southeastern slopes of the Blue Ridge. Relief is moderate, but less steep than the higher elevation mountains to the west.

Vunerability to stressors:
For these watersheds in Clusters 4 and 8, there are no major obstacles to use by humans, so all kinds of uses are present; agriculture, land development, road building, etc. Thus, both the likelihood of stressor occurrence and the resultant degradation from all stressors, except acidification, are likely to be moderate to high. For these same reasons, riparian corridors are subject to the same stressors. Stressors can be proximal to streambanks. Disturbed vegetation is likely to proliferate in these areas. Natural vegetation is expected to be fragmented due to the wide distribution of uses. The base of these ridges may consist of colluvium from eroded slopes producing soils of moderate agricultural value. There also may be sources of water produced along topographic breaks in slope and geologic contacts. Given that this type of watershed is common and widely-distributed, and because it is fairly vulnerable to a variety of stressors, implementation of a generic array of BMPs is probably warranted.

Cluster 5 – Canyon Lands (turquoise, Figure 13)

Characterization:
The Deep Valleys of PA and Southern Coal Counties of WV characterize these watersheds. In the south the land tends to be in private ownership, contrasting with north which is primarily in public ownership (state forest and state game lands). This type subsumes the Appalachian Plateau portion of western Virginia. These lands are not conducive to past or current agricultural uses, and thus, agriculturally generated nutrients and sediments are not a threat. Some of these valleys collect and store water for municipal water authorities and private water companies, so extra caution should be taken when evaluating potential impacts by stressors in these areas.

Vulnerability to Stressors:
Rock strata are generally oriented horizontally, which may restrict movement and infiltration. Oil and gas deposits are present in both north and south, with an emphasis on coal in the south. These energy extraction activities can lead to fragmentation by access roads, and potential contamination of headwaters, which ultimately discharge into the larger valley rivers, with inherent impacts. Drilling and excavation can potentially lead to aquifer contamination. Hillslopes are vulnerable to erosion from land clearing activities (e.g., logging, land development) leading to high sediment loads. Creation of impervious surfaces exacerbates runoff into streams. Linear invasion of disturbed vegetation along transportation and river corridors is likely, although less so for smaller streams. Land development activities are proportionally low, so it may be less likely to see disturbed vegetation encroaching outside riparian and transportation corridors. With the steep terrain, the tendency will be to locate development proximal to rivers out of necessity, with inherent impacts. This also intensifies the vulnerability of human settlements to unstable slopes and severe flooding. Plateaus could potentially support development, but encroachment and addition of impervious surfaces could lead to impacts. The mountain top mining activities of southern West Virginia present a unique challenge to protect and/or restore vital headwater systems. In general, aquatic resources in this watershed type show high vulnerability to stressors. The cumulative impacts of large-scale land clearing and topographic alterations will be significant in this sub-region.

Cluster 6 – Fertile Plains (pink, Figure 13)

Characterization:

This cluster is concentrated in the eastern Ridge and Valley region and into the western portion of the Piedmont region, but can occur sporadically throughout as the pass-through portions of other watersheds. Thus, they are not superimposed on any particular physiographic province. Elongated, trellis drainage patterns with short stream segments, that are mostly first order, are common. With regard to climate zones, there is some concentration of this watershed type in D and E zones; both feature mild, moist, mesic and hilly, but not steep conditions. Soils are fertile, which has supported agricultural uses for hundreds of years.

Vulnerability to Stressors:

Valley locations will tend to neutralize any acidity. Concentrations of this watershed cluster occur in the Great Valley of PA (Allentown, Reading, Lancaster), Fredrick and Hagerstown in MD, Fairmont and Clarksburg in WV, Lexington and Stanton portions of the Great Valley along I-81 corridor in VA. Another linear group lies in the valleys along Laurel and Chestnut ridges in southwestern PA, extending to the Fairmont/Clarksburg cluster. Along the northcentral PA-NY border, there are farmland valleys associated with the glaciated Genessee River basin with similar characteristics. Similar watersheds can be found scattered throughout the region in smaller, narrower valleys, such as the Allegheny River in western PA, and valleys in the northern reaches of the Ridge and Valley in PA. A few are present in western WV presumably small farmland valleys entering the Ohio River along the state border.

Floodplains are broad due to high sinuosity, allowing for extensive human uses along the mainstems, less so for the tributaries. This type of watershed supports significant agriculture, the highest proportion in the study area, and has suitable sites for industrial development, railroad yards, and storage facilities. These floodplains will be dominated by alluvial soils, which can unstable, subject to erosion, incision, undercutting and slumping of streambanks. When coupled with crops or livestock, these soils will be vulnerable to nutrient and sediment loads that degrade water quality. Activities tend to be proximal to streambanks, and within the riparian corridor. There are potential opportunities for establishing BMPs for riparian corridor protection and fencing.

The headwater stream portions of these watersheds are short, of moderate gradient, and of low sinuosity reaches. A good example would be the hollows along the Allegheny Front in central PA. These hollows may provide water supplies from spring and groundwater discharges, and could be vulnerable to poor logging practices (e.g., sedimentation, streambank erosion, channel destabilization). There may be secondary roads, old railroad beds, and sparse to moderate residential development in these areas. Impacts could include flashy runoff into these streams, which in turn could alter the structure of larger rivers at confluences. These confluences might be characterized by a transition in stream bed load and materials from cobbles to alluvial sediments. These headwaters are potential vectors for disturbed vegetation and invasives, but the problem is assumed to be moderate. Acid impacts may occur selectively in the higher elevations of these headwaters, but are unlikely to severely affect the mainstems.

Cluster 7 – Steep Dry Mountains (yellow, Figure 13)

Characterization:

Watersheds in this cluster tend to have a large elevational range. Stream densities are high, with headwaters emanating from the hills. Their steepness tends to preclude many land uses. These watersheds tend to be drier than those found further west, so flow rates from streams are modest.

Vulnerability to stressors:
Land cover conversions have been modest, constrained by steep slopes. Agriculture is generally confined to the narrow valleys, placing it proximal to riparian corridors. Watersheds in this type appear to tolerate land use conversions. The relative steepness and lower fertility may have discouraged development of intensive land-altering activities. Vulnerability is ranked relatively low, and mining is not a major threat. BMPs should be given high priority, especially along streams to minimize potential impacts.

Cluster 9 – High Wet Mountains (dark green, Figure 13)

Characterization:
Concentrated in eastern WV and western VA, these watersheds are associated with the ridges of the eastern Allegheny Plateau, Ridge and Valley, and Blue Ridge. They originate in the highest elevations of the region, often accumulating significant flow through a high drainage density. Due to past land uses, they are primarily forested today. These watersheds appear to be dominated by Climate Zones C and D, which can produce drought prone or mesic conditions, respectively, but in general, watersheds of this type receive high rates of precipitation and contain moist soils. High degrees of soil saturation and wetland occurrence can occur in some watersheds.

Vulnerability to Stressors:
Acid sensitivity is expected to be significant due to high elevations, and with a likelihood of poorly buffered geology (e.g., sandstone and shale). If forested, stress associated with high nutrient concentrations is not anticipated, unless it comes from concentrated land development (e.g., stormwater and septic systems). Erosion and sedimentation problems are expected due to land clearing, especially with clear-cutting and any road development. It is expected that small amounts of impervious cover (<5%) will contribute to flashy hydrologic regimes, with resultant stream incision.

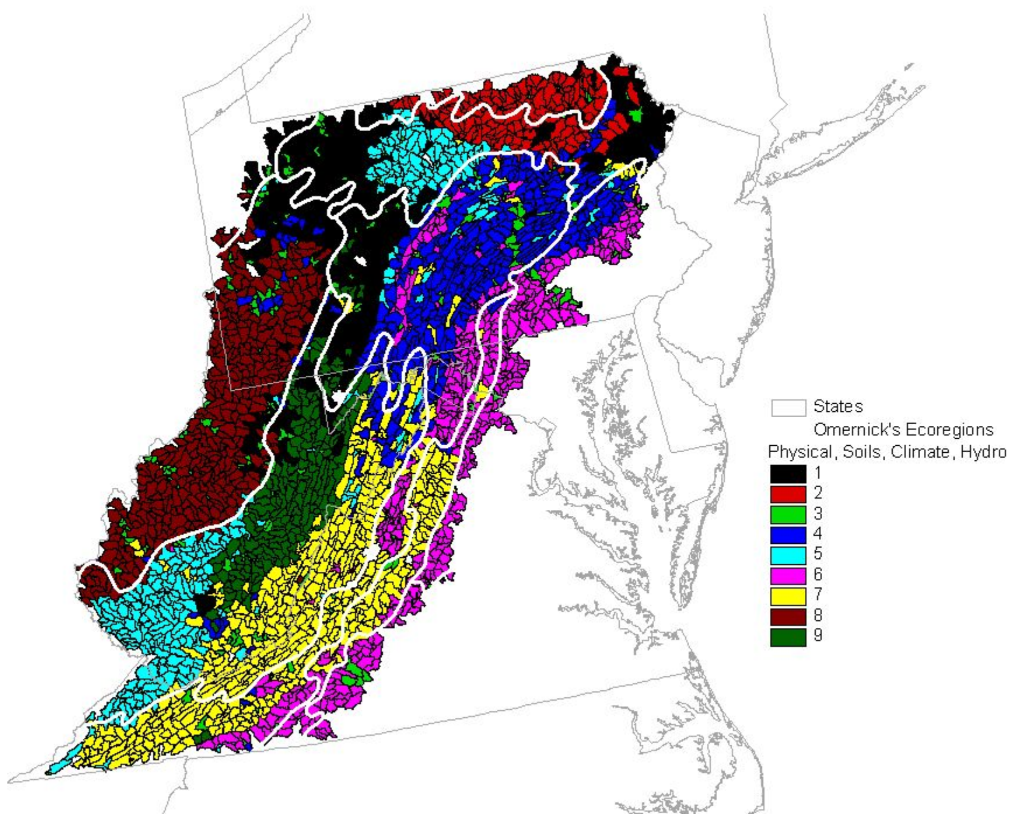
Where non-forested cover types are predominant, there may be an increased risk of flooding damage along the larger rivers (e.g., Tioga and Bradford counties in northeastern PA). Based on Detenbeck et al. (2004), the impervious coverage in the WV and VA portions tends to be less than 1%, however, development of second homes may be increasing in this region, which could be a cause for concern. Also, according to Detenbeck et al. (2004), agriculture does occur with some frequency in some of these WV and VA watersheds. It is suspected that agricultural land uses would occur on the lower slopes and in the associated hollows of these watersheds, and thus, there is potential for runoff of excess nitrogen, phosphorus and sediment from these fields into receiving streams.

Many of these watersheds, both in public and private holdings, currently have mature deciduous forests as the primary cover. If managed sustainably, they should remain fairly resilient to most stressors. Use of Best Management Practices for forestry and land development would provide substantial protection for aquatic ecosystems in these watersheds.

Areas of non-forest cover, and particularly along larger rivers and small streams, could serve as sources and vectors for spread of invasive plants. Riparian corridors without natural vegetation may be threatened by invasives and exotics. We predict that impervious cover is less associated with riparian corridors in this type than in others, because there are more options for land development in these larger watersheds.

By way of comparing our classification system to others, during the characterization process we found that the geographic dispersion of watershed types matched, to some extent, the available ecoregional classification, although we found recognizable subclusters of watersheds within those delineated ecoregions. We found that the nine-cluster classification system based on inherent, natural, physical features, developed for this project, aligned best with biological measures of stream integrity.

Figure 13. Our nine-cluster classification is shown below for reference (repeated from Fig. 3)



Recommendations for Applying Watershed Classification Approach

Our recommendations to potential users are to locate watersheds of interest, determine their cluster membership, and then consider their vulnerability to expected stressors. By understanding the inherent characteristic that compose each cluster, and considering its probable response to specific stressors, one can conceptually locate a watershed in the two dimensional space portrayed in Figure 14 presented below. When it is necessary to prioritize among multiple watersheds, then the relative location of a watershed in that space will suggest which is most vulnerable and in need of attention first. Although not developed during this project, a third axis to the diagram could incorporate aspects of technological and economic feasibility. Sometimes, even after a problem is properly assessed and diagnosed, its solution may be outside the realm of known technological treatments and available funds. At this point, perhaps other watersheds considered to be in a high priority category can be addressed. Based on our collective experience and interaction with stakeholders, we recognize that some of the more intangible, subjective aspects of professional judgment should definitely remain as part of any prioritization scheme. In this manner, a collaborative decision informed by science, policy, and local knowledge, can be made with resultant solutions implemented with an increased probability of success.

We recommend a prioritization approach that incorporates summary measures of condition and overall assessments of human disturbance (Figure 14). The x-axis of this conceptual model is a composite index of overall anthropogenic disturbance. That is, what is the current, assessed condition of the watershed(s) under consideration? The human disturbance gradient should combine landscape metrics (e.g., proportional land cover, LDI, riparian corridor) and site-specific data on stressors as available (e.g., fragmentation, acidification, influence of mining, etc.; Adamus and Brandt 1990, Karr and Chu 1998, USEPA 2000a). Best professional judgment or a quantitative measure of condition (e.g., Brooks et al. 2006a) should be used to place a watershed along this gradient from reference (least impaired) to severely impaired. The y-axis is used to assess how vulnerable a watershed is to observed or expected stressors. This axis can be regarded as "vulnerability to impairment." As was found in this study, most watershed cluster types that are already impacted by land cover conversions, often have high ecological resistance or tolerance of future disturbance (e.g., cluster types: Moderate Mountains (4), Fertile Plains (6)), whereas cluster types demonstrating high vulnerability may show less conversion and impairment to date (e.g., Canyon Lands (5), Cold Wet Flats (1)). The high vulnerability of these latter watershed types implies that when landscape conversion or other types of stressors are present, then ecological condition declines rapidly.

We believe this approach is simple for, adaptable to, and useful by managers, because it combines the best available information from scientific investigations with the knowledge and intentions of local stakeholders. Whether comparing among watersheds or varying condition within the same cluster type or across cluster types, this approach should generate a relevant list of prioritized watersheds. The contemplative process used to locate multiple watersheds in this conceptual space should be most helpful in deciding upon a course of action with regard to prioritizing watershed protection and restoration.

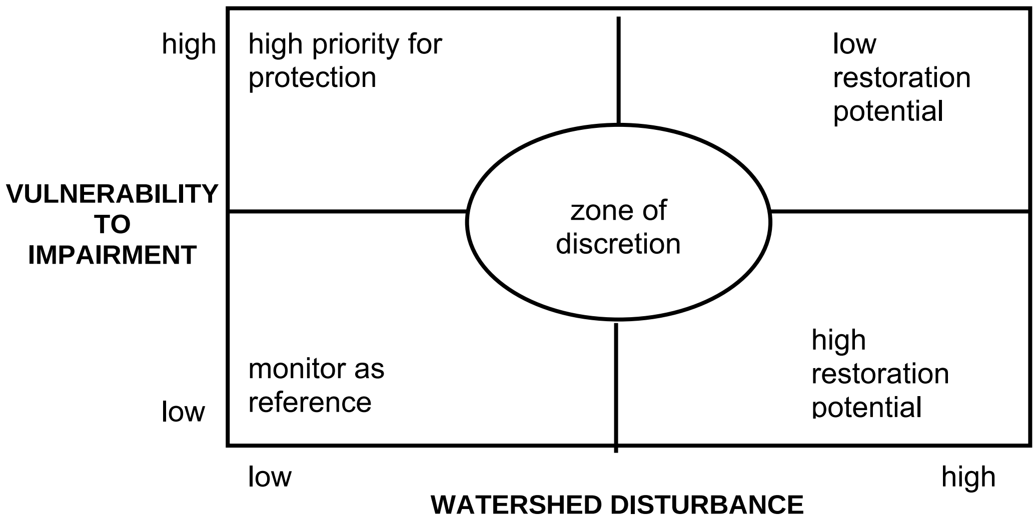


Figure 14. Conceptual framework for considering a watershed's vulnerability and potential for restoration given it's inherent characteristics and current condition. Users of this classification system are encouraged to consider where in this two-dimensional space they would place the watersheds of interest.

STAKEHOLDER COMMUNICATION

Meetings with Stakeholders

As part of this project, CVI coordinated three meetings with stakeholders. These included:

- On 12 Oct 2005, in State College PA, the PSU-CVI team met with representatives of Trout Unlimited, the Coldwater Heritage Partnership, and the PA Fish & Boat Commission to present an outline of our project.
- On 19 Jan 06, in Harrisburg PA, the research team met with fisheries biologists and program managers of the several resource agencies and conservation organizations in the Mid-Atlantic to present an overview of the project, alternate classifications based on inherent characteristics and stressors, and examples of watersheds prioritized for restoration. Feedback was solicited in a structured session.
- On 14 Jul 06 in Pleasant Gap PA, the CVI members presented a more advanced version of our watershed classification to members of the PA Fish & Boat Commission.

At these meetings, we solicited two general kinds of comments: (1) critical evaluations of our watershed classification scheme and (2) a conjecture of whether they might use it in their natural resources management programs. After each stakeholder meeting, all comments were discussed during the following all-hands team work sessions, and recommendations were implemented where feasible. Some additional details of these meetings are provided in Appendix C. Overall, the stakeholders' collective comments have placed us in a stronger position for applying and advocating the uses of our watershed classification system.

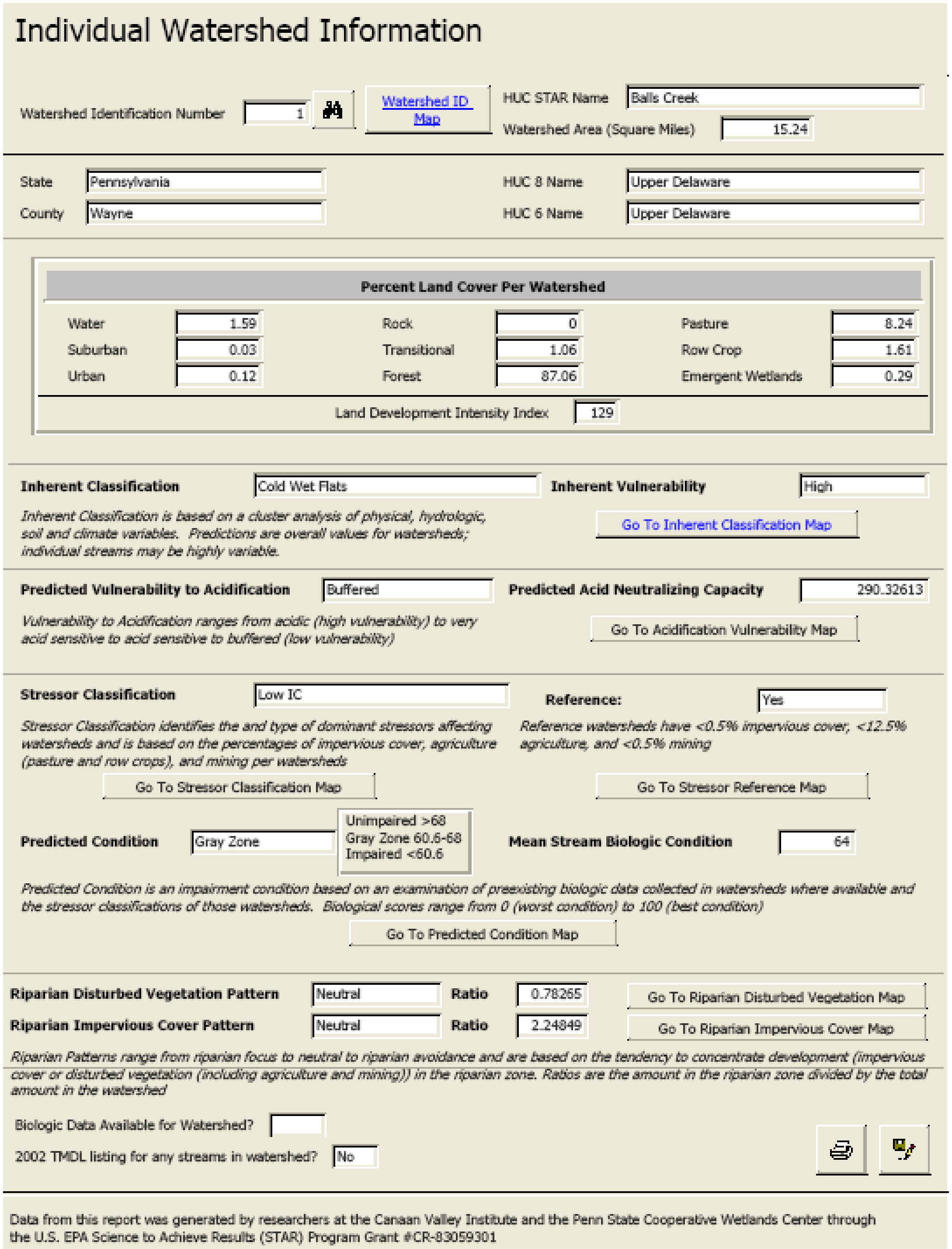
STAKEHOLDER TOOL

A prototype of a watershed visualization tool was developed as part of this project. This tool is referenced in Appendix B and can be found on the CD included with this report. In its current form, it consists of:

(1) a "zoom-able" JPG-format map of the study area, showing HUC-14 watersheds (including a reference number), streams, and county boundaries, and

(2) a database in Microsoft Access, referenced by watershed number, that provides a formatted version of much of the information generated by this project. An example watershed record is shown in Figure 15.

The database is searchable and can be linked to the watershed cluster map, providing easy assess to this information. Users can locate their watersheds to graphically zooming on the watershed map provided until the ones of interest are identified (one at a time). Once selected, the database is queried and produces a form listing the characteristics and predicted vulnerability of those watersheds according to the nine cluster types developed during this project. Then, stakeholders can locate their watersheds of interest in the two-dimensional prioritization space shown in Figure 13. At this point, best professional judgment should be used to further understand the vulnerabilities of the watersheds of interest and to devise an appropriate management, restoration, or protection approach to conserve the aquatic resources observed or predicted to occur in those watersheds. As stated previously, management decisions should be tied to the spatial scale of concern (e.g., several watersheds vs. an entire state or ecoregion) and the intended use of the information (e.g., planning development projects, targeting restoration areas, etc.).



Individual Watershed Information

Watershed Identification Number: 1 | Watershed ID Map

HUC STAR Name: Balls Creek

Watershed Area (Square Miles): 15.24

State: Pennsylvania

County: Wayne

HUC 8 Name: Upper Delaware

HUC 6 Name: Upper Delaware

Percent Land Cover Per Watershed

Water	1.59	Rock	0	Pasture	8.24
Suburban	0.03	Transitional	1.06	Row Crop	1.61
Urban	0.12	Forest	87.06	Emergent Wetlands	0.29

Land Development Intensity Index: 129

Inherent Classification: Cold Wet Flats

Inherent Vulnerability: High

Inherent Classification is based on a cluster analysis of physical, hydrologic, soil and climate variables. Predictions are overall values for watersheds; individual streams may be highly variable.

Go To Inherent Classification Map

Predicted Vulnerability to Acidification: Buffered

Predicted Acid Neutralizing Capacity: 290.32613

Vulnerability to Acidification ranges from acidic (high vulnerability) to very acid sensitive to acid sensitive to buffered (low vulnerability)

Go To Acidification Vulnerability Map

Stressor Classification: Low IC

Reference: Yes

Stressor Classification identifies the and type of dominant stressors affecting watersheds and is based on the percentages of impervious cover, agriculture (pasture and row crops), and mining per watersheds

Reference watersheds have <0.5% impervious cover, <12.5% agriculture, and <0.5% mining

Go To Stressor Classification Map

Go To Stressor Reference Map

Predicted Condition: Gray Zone

Unimpaired >68
Gray Zone 60.6-68
Impaired <60.6

Mean Stream Biologic Condition: 64

Predicted Condition is an impairment condition based on an examination of preexisting biologic data collected in watersheds where available and the stressor classifications of those watersheds. Biological scores range from 0 (worst condition) to 100 (best condition)

Go To Predicted Condition Map

Riparian Disturbed Vegetation Pattern: Neutral **Ratio**: 0.78265 | Go To Riparian Disturbed Vegetation Map

Riparian Impervious Cover Pattern: Neutral **Ratio**: 2.24849 | Go To Riparian Impervious Cover Map

Riparian Patterns range from riparian focus to neutral to riparian avoidance and are based on the tendency to concentrate development (impervious cover or disturbed vegetation (including agriculture and mining)) in the riparian zone. Ratios are the amount in the riparian zone divided by the total amount in the watershed

Biologic Data Available for Watershed?

2002 TMDL listing for any streams in watershed? No

Data from this report was generated by researchers at the Canaan Valley Institute and the Penn State Cooperative Wetlands Center through the U.S. EPA Science to Achieve Results (STAR) Program Grant #CR-83059301

Figure 15. Example information page available for each watershed in the study area, using a Microsoft Access database developed specifically for this project.

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