# Watershed Report for Biological Impairment of Licking Creek in Washington County, Maryland Biological Stressor Identification Analysis Results and Interpretation

## FINAL

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## List of Abbreviations

| | |
|---|---|
| ANC | Acid Neutralizing Capacity |
| AR | Attributable Risk |
| BIBI | Benthic Index of Biotic Integrity |
| BSID | Biological Stressor Identification |
| COMAR | Code of Maryland Regulations |
| CWA | Clean Water Act |
| FIBI | Fish Index of Biologic Integrity |
| IBI | Index of Biotic Integrity |
| MDDNR | Maryland Department of Natural Resources |
| MDE | Maryland Department of the Environment |
| MBSS | Maryland Biological Stream Survey |
| mg/L | Milligrams per liter |
| NADP | National Atmospheric Deposition Program |
| NOx | Nitrous Oxide |
| NRCS | Natural Resources Conservation Service |
| $SO_2$ | Sulfur Dioxide |
| SSA | Science Services Administration |
| TMDL | Total Maximum Daily Load |
| USEPA | United States Environmental Protection Agency |
| WQA | Water Quality Analysis |
| WQLS | Water Quality Limited Segment |

## Executive Summary

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met.

The Licking Creek Watershed (basin code 02140506), located in Washington County, was identified on the 2008 *Integrated Report* under Category 5 as biologically impaired. The impairment was first listed in 2002 as a 12-digit watershed (021405060169). A second 12-digit watershed was also listed in 2006 (021405060171) before listing at the 8-digit scale in 2008. All impairments are listed for non-tidal streams. There are no additional Category 5 listings.

In 2002, the State began listing biological impairments on the Integrated Report. The current Maryland Department of the Environment (MDE) biological assessment methodology assesses and lists only at the Maryland 8-digit watershed scale, which maintains consistency with how other listings on the Integrated Report are made, how TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds with multiple impacted sites by measuring the percentage of stream miles that have an Index of Biotic Integrity (IBI) score poor to very poor, and calculating whether this is significantly different from a reference condition watershed (i.e., healthy watershed, less than 10% stream miles degraded).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Licking Creek and all of its tributaries is Use IV-P - *water contact recreation and protection of non-tidal warm water aquatic life, recreational trout waters, and public water supply* (COMAR 2010a,b). The Licking Creek watershed is not attaining its designated use of protection of aquatic life because of biological impairments. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) (Southerland et al. 2005).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause of reduced biological conditions, thus enabling the Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors, sources of stressors and the biological community, and the likely impact this stressor has on the degraded sites in the watershed.

The BSID analysis uses data available from the statewide MDDNR MBSS. Once the BSID analysis is completed, a number of stressors (pollutants) may be identified as probable or unlikely causes of poor biological conditions within the Maryland 8-digit watershed study. BSID analysis results can be used as guidance to refine biological impairment listings in the Integrated Report by specifying the probable stressors and sources linked to biological degradation.

This Licking Creek watershed report presents a brief discussion of the biological stressor identification process, which can be reviewed in more detail in the report titled, *Maryland Biological Stressor Identification Process* (MDE 2009) and provides guidance for category listings in the Integrated Report with regard to specific stressors linked to biological degradation. Data suggest that acidity is the probable cause of biological impairments in Licking Creek watershed. Low pH results from both natural (e.g., low acid neutralizing capacity of geology) and anthropogenic sources (atmospheric deposition).

The results of the BSID process, and the probable causes and sources of the biological impairments in the Licking Creek watershed can be summarized as follows:

- The BSID process has determined that the biological communities in Licking Creek watershed are likely degraded due to acidity related stressors. Acidity is indicated directly by the strong association of low pH and low Acid Neutralizing Capacity (ANC) with biological impairments. Licking Creek watershed experiences localized acidity caused by atmospheric deposition in areas where the geology has little buffering capacity. The BSID results thus support a Category 5 listing of low pH for the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Licking Creek watershed.

## 1.0 Introduction

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met. In 2002, the State began listing biological impairments on the Integrated Report. Maryland Department of the Environment (MDE) has developed a biological assessment methodology to support the determination of proper category placement for 8-digit watershed listings.

The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that guides the assignment of biological condition to Integrated Report categories. In the data quality review step, available relevant data are reviewed to ensure they meet the biological listing methodology criteria of the Integrated Report (MDE 2008). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or black water streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy watershed, <10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report. If a watershed is not determined to differ significantly from the reference condition, the assessment must have an acceptable precision (i.e., margin of error) before the watershed is listed as meeting water quality standards (Category 1 or 2). If the level of precision is not acceptable, the status of the watershed is listed as inconclusive and subsequent monitoring options are considered (Category 3). If a watershed is classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary.

The MDE biological stressor identification (BSID) analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of the biological impairment. Identification of stressors responsible for biological impairments is normally limited to round two of the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) dataset (2000 – 2004) because it provides a broad spectrum of paired data variables (i.e., biological monitoring and stressor information) to best enable a complete stressor analysis. However, round one MDDNR MBSS data was also assessed in the Licking Creek watershed to maximize the number of cases available to facilitate a diagnosis of cause. The BSID analysis then links potential causes/stressors with general causal scenarios and concludes with a review for ecological plausibility by State scientists. Once the BSID analysis is completed, one or several stressors (pollutants) may be identified as probable or unlikely causes of the poor biological conditions within the Maryland 8-digit watershed. BSID analysis results can be used together with a variety of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

The remainder of this report provides a characterization of the Licking Creek watershed, and presents the results and conclusions of a BSID analysis of the watershed.

## 2.0 Licking Creek Watershed Characterization

### 2.1 Location

Licking Creek is a tributary of the Potomac River and is located in Pennsylvania and Maryland. Licking Creek originates on the western slope of Tuscarora Mountain in Pennsylvania, flows directly south then enters Washington County in Maryland, to join the Potomac River. The entire watershed is approximately 119,680 acres. The Maryland portion of the watershed is small (<17,920 acres), and located in the center of Washington County, where Maryland is constricted to about 5 miles between Pennsylvania and West Virginia (see Figure 1). The Licking Creek watershed is part of the Highland eco-region identified in the MDDNR MBSS Index of Biotic Integrity (IBI) metrics (Southerland et al. 2005) (Figure 2).

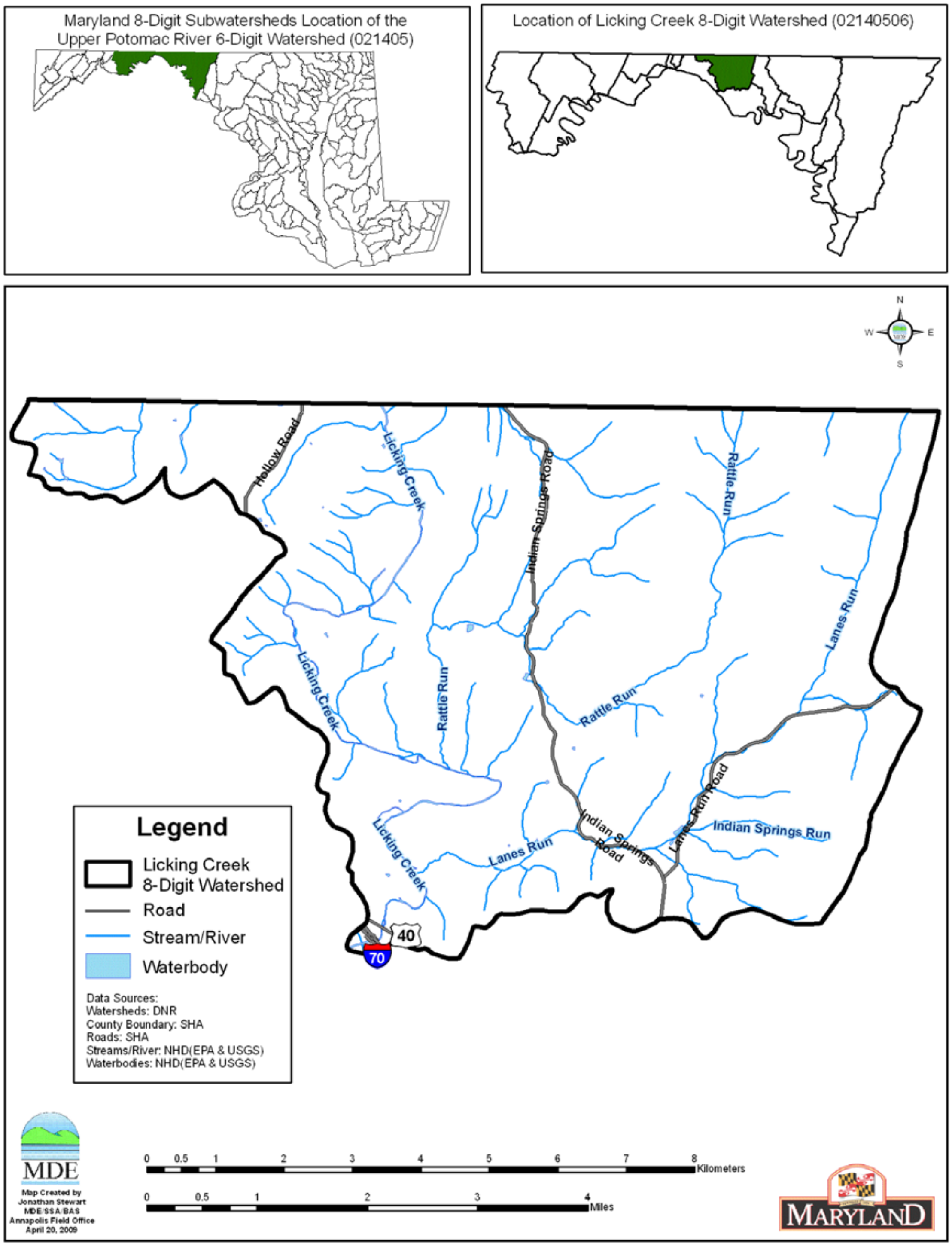


**Figure 1. Location Map of the Licking Creek Watershed**

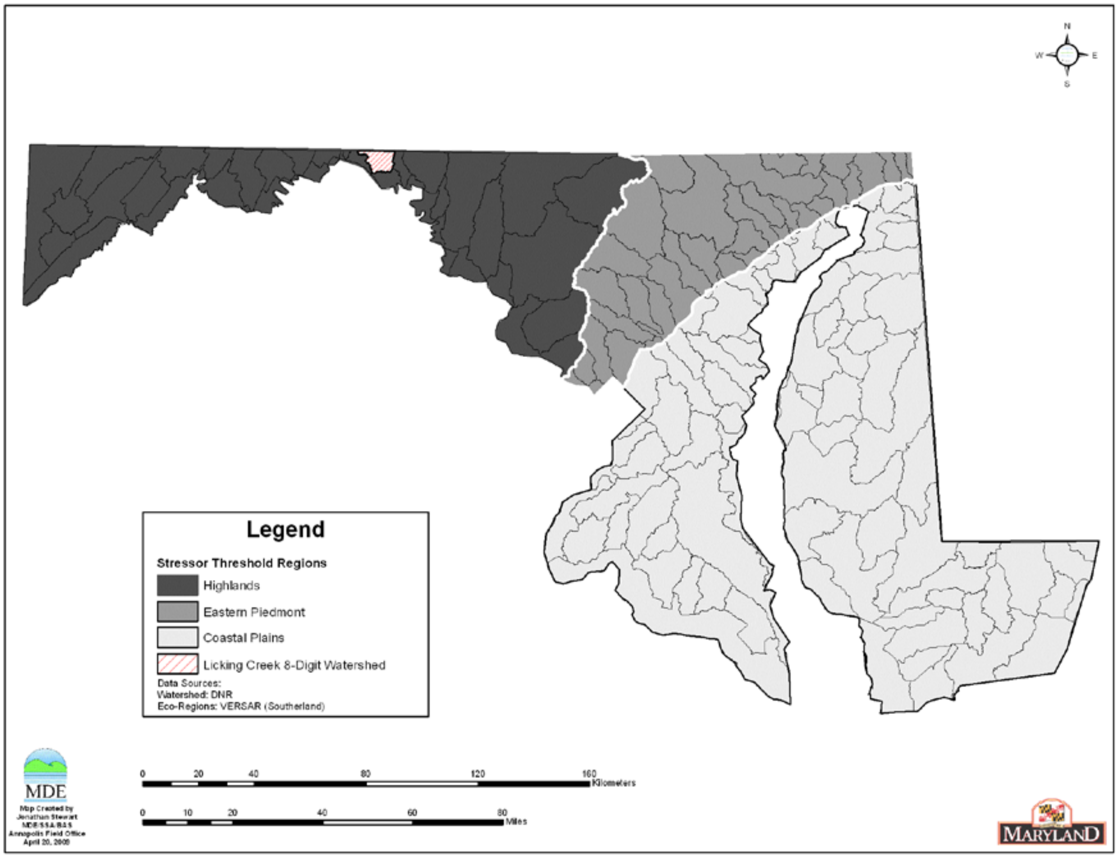


**Figure 2. The Eco-Region Location Map of the Licking Creek Watershed**

## 2.2 Land Use

The Licking Creek basin is largely undeveloped; a large proportion of land area in the watershed is forested, particularly in areas with steep slopes. The basin contains 83% forest, 12% agriculture, and 5% urban land use (Figure 3 and 4) (MDP 2002). Steep, forested areas are located primarily in the northeastern quarter of the basin. Future development of this largely intact forested area is not likely because it contains several publicly owned lands such as the Indian Springs Wildlife Management Area and the Indian Springs Wildlife Demonstration Area, and federal government installations currently occupied by communications services.

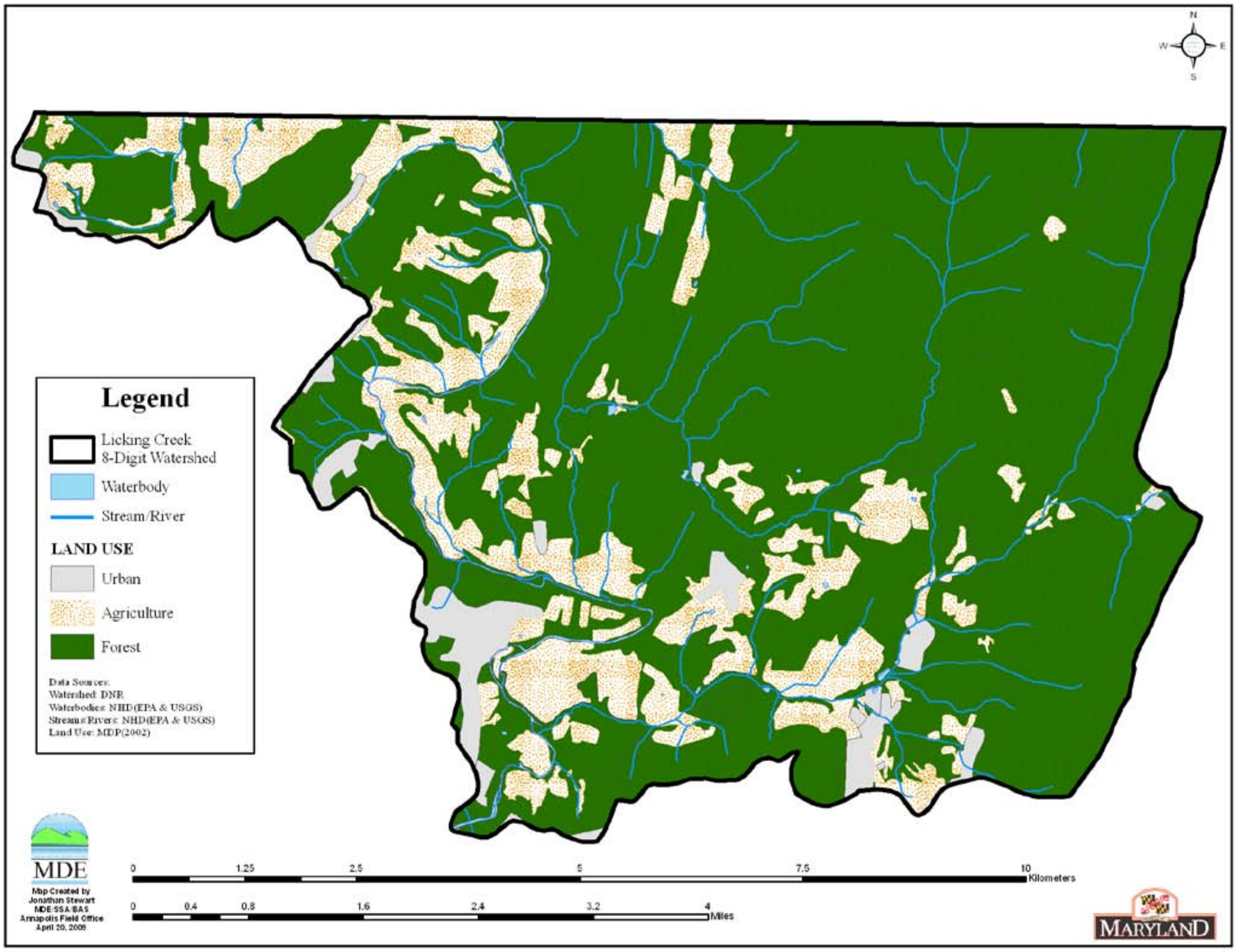


**Figure 3. Land Use Map of the Licking Creek Watershed**

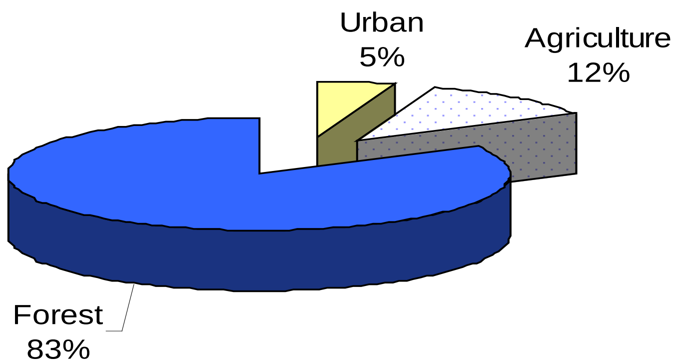


**Figure 4. Proportions of Land Use in the Licking Creek Watershed**

### 2.3 Soils/hydrology

The Licking Creek watershed is situated within the Ridge and Valley Physiographic Province in western Maryland. Licking Creek enters Maryland from Pennsylvania in the western half of the watershed and continues southward primarily through Devonian shales, siltstones, and sandstones before winding through the limestone layers of the Helderburg Formation of the upper Devonian prior to its confluence with the Potomac River. The total length of Licking Creek in Maryland is about 9 miles.

Most Licking Creek tributary stream-miles in Maryland occur in the eastern portion of the watershed. This portion of the basin drains large areas of weather resistant sandstones of the Upper Silurian, including the Tuscarora Sandstone, Rose Hill Formation, and Keefer Sandstone. Siliciclastic bedrock types (such as sandstone), which are found in the watershed have very low buffering capacity (Bulger et al. 1998) partly because it weathers very slowly. Smaller areas of dark shales of the lower Ordovician occur more distally along the northeast and east watershed boundaries. Two relatively large tributaries ($3^{rd}$ order streams) originate in this geology at or near the Pennsylvania border and flow south and southwest for varying distances before encountering limestone containing layers of the lower Silurian and upper Devonian prior to its confluence with Licking Creek. Other tributaries are much smaller (typically $1^{st}$ and $2^{nd}$ order streams around 1 mile in length) and drain similar areas that Licking Creek encounters, or flow northward into Pennsylvania to confluence with Licking Creek.

The Natural Resources Conservation Service (NRCS) has defined four hydrologic soil groups to provide a means for grouping soils by similar infiltration and runoff characteristics during periods of prolonged wetting. Group D soils (clay soils) have very slow infiltration rates thus very high rates of runoff. Group C and Group B soils have increasingly higher infiltration rates and lower runoff potential. Group A soils (sandy soils) have high infiltration rates with little runoff (NRCS 1977).

The distribution of hydrologic soil groups in the Licking Creek watershed are such that mountain tops and stream-side terraces typically have Group A or Group B soils. Group D soils are scattered in very small isolated pockets throughout the watershed and are primarily associated with dual classification soils (C/D) typically located within Licking Creek's broad valley, representing the occurrence of both drained and undrained soil characteristics, respectively. Group B soils are distributed over most other areas of the watershed (NRCS 1977).

# 3.0 Licking Creek Watershed Water Quality Characterization

## 3.1 Integrated Report Impairment Listings

The Licking Creek watershed (watershed code 02140506), located in Washington County, was identified on the 2008 Integrated Report under Category 5 as impaired for impacts to biological communities. The impairment was first listed in 2002 as a 12-digit watershed (021405060169). A second 12-digit watershed was also listed in 2006 (021405060171) before listing at the 8-digit scale in 2008. All impairments are listed for non-tidal streams. There are no additional Category 5 listings.

## 3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Licking Creek and all of its tributaries is Use IV-P - *water contact recreation and protection of non-tidal warm water aquatic life, recreational trout waters, and public water supply* (COMAR 2010a,b). A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

The Licking Creek watershed is listed under Category 5 of the 2008 Integrated Report as impaired for biological impacts. Approximately forty-three percent of stream miles in the Licking Creek basin are estimated as having fish and and/or benthic indices of biological impairment in the very poor to poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data, which include seven monitoring stations. Three out of the seven stations have benthic and/or fish index of biotic integrity (BIBI, FIBI) scores significantly lower than 3.0 (i.e., poor to very poor). The principal dataset, i.e. MBSS round two, has insufficient data (6 sites, including 2 impaired sites) to accommodate BSID analyses, so round one data is also utilized in stressor identification (Figure 5). Only parameters contained in both round one and round two datasets will be used for the BSID results. Many sediment and water chemistry parameters were not collected during the round one sampling.

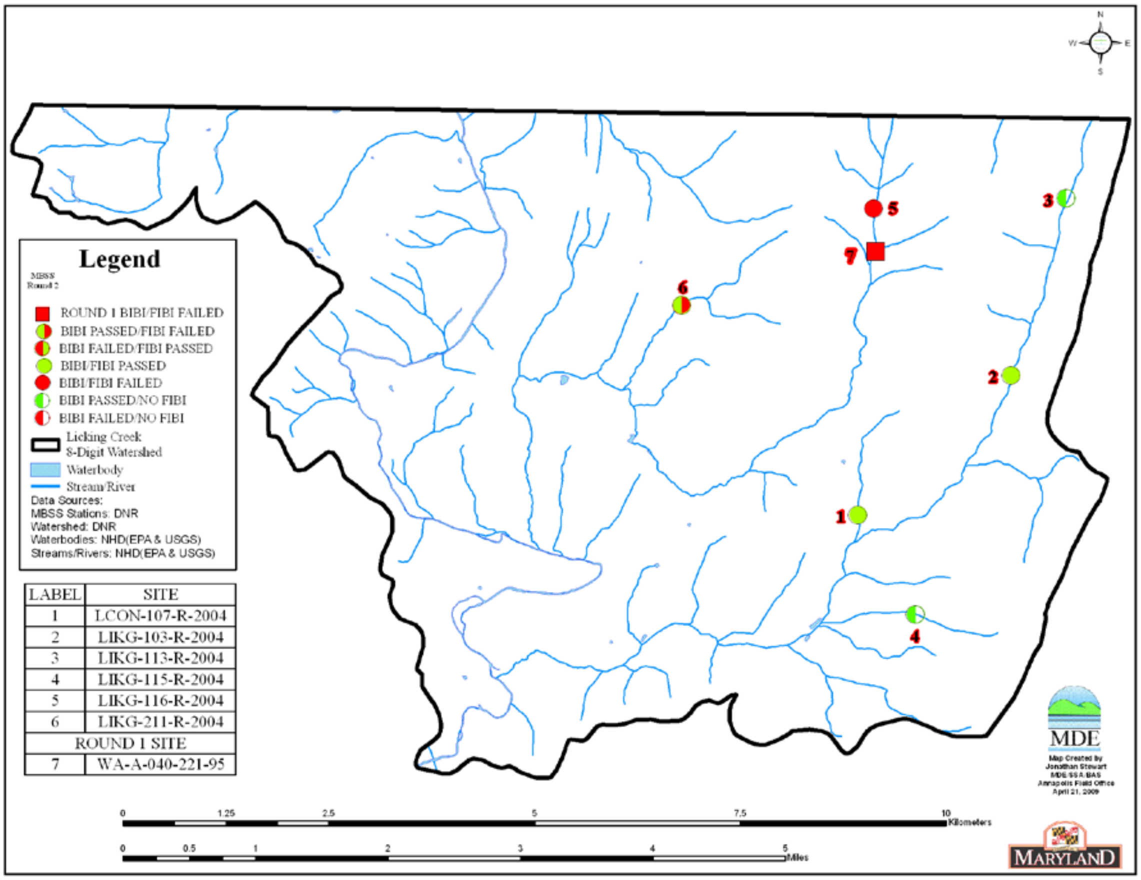

**Figure 5. Principal Dataset Sites for the Licking Creek Watershed**

### 4.0 Stressor Identification Results

The BSID process uses results from the BSID data analysis to evaluate each biologically impaired watershed and determine potential stressors and sources. Interpretation of the BSID data analysis results is based upon components of Hill's Postulates (Hill 1965), which propose a set of standards that could be used to judge when an association might be causal. The components applied are: 1) the strength of association which is assessed using the odds ratio; 2) the specificity of the association for a specific stressor (risk among controls); 3) the presence of a biological gradient; 4) ecological plausibility which is illustrated through final causal models; and 5) experimental evidence gathered through literature reviews to help support the causal linkage.

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores lower than 3.0 (i.e., poor to very poor). The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups; 1st and 2nd through 4th order streams), that have good biological conditions.

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the Mantel-Haenszel (MH 1959) approach and is based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are very poor to poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and very poor to poor biological conditions and is used to identify potential stressors.

Once potential stressors are identified, the risk attributable to each stressor is quantified for all sites with poor to very poor biological conditions within the watershed (i.e., cases). The attributable risk (AR) defined herein is the portion of the cases with poor to very poor biological conditions that are associated with the stressor. The AR is calculated as the difference between the proportion of case sites with the stressor present and the proportion of control sites with the stressor present.

Once the AR is calculated for each possible stressor, the AR for groups of stressors is calculated. Similar to the AR calculation for each stressor, the AR calculation for a group of stressors is also summed over the case sites using the individual site characteristics (i.e., stressors present at that site). The only difference is that the absolute risk for the controls at each site is estimated based on the stressor present at the site that has the lowest absolute risk among the controls.

After determining the AR for each stressor and the AR for groups of stressors, the AR for all potential stressors is calculated. This value represents the proportion of cases, sites in the watershed with poor to very poor biological conditions, which would be improved if the potential stressors were eliminated (Van Sickle and Paulsen 2008). The purpose of this metric is to determine if stressors have been identified for an acceptable proportion of cases (MDE 2009).

Through the BSID analysis, MDE identified three water chemistry parameters significantly associated with degraded fish and/or benthic biological conditions. As shown in Table 1 through Table 3, parameters identified as possible biological stressors in the Licking Creek watershed include *low pH* (lab and field) and *low acid neutralizing capacity (ANC).* One parameter was identified as representing a possible source of impairment, *atmospheric deposition*, as listed in Table 4. A summary of combined AR values for each stressor group is shown in Table 5. A summary of combined AR values for each source group is shown in Table 6.

## Table 1. Sediment Biological Stressor Identification Analysis Results for the Licking Creek Watershed

| Parameter Group | Stressor | Total number of sampling sites in watershed with stressor and biological data | Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI) | Controls (Average number of reference sites with fair to good Fish and Benthic IBI) | % of case sites with stressor present | % of control sites with stressor present | Possible stressor (Odds of stressor in cases significantly higher that odds of stressors in controls using p<0.1) | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor |
|---|---|---|---|---|---|---|---|---|
| Sediment | extensive bar formation present | 6 | 2 | 77 | 0% | 10% | No | ---- |
| | moderate bar formation present | 6 | 2 | 77 | 0% | 46% | No | ---- |
| | bar formation present | 6 | 2 | 77 | 100% | 89% | No | ---- |
| | channel alteration moderate to poor | 7 | 3 | 155 | 0% | 38% | No | ---- |
| | channel alteration poor | 7 | 3 | 155 | 0% | 9% | No | ---- |
| | high embeddedness | 7 | 3 | 154 | 0% | 6% | No | ---- |
| | epifaunal substrate marginal to poor | 7 | 3 | 155 | 0% | 28% | No | ---- |
| | epifaunal substrate poor | 7 | 3 | 155 | 0% | 14% | No | ---- |
| | moderate to severe erosion present | 6 | 2 | 77 | 0% | 25% | No | ---- |
| | severe erosion present | 6 | 2 | 77 | 0% | 3% | No | ---- |
| | poor bank stability index | 6 | 2 | 77 | 0% | 5% | No | ---- |
| | silt clay present | 6 | 2 | 77 | 100% | 99% | No | ---- |

**Table 2. Habitat Biological Stressor Identification Analysis Results for the Licking Creek Watershed**

| Parameter Group | Stressor | Total number of sampling sites in watershed with stressor and biological data | Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI) | Controls (Average number of reference sites with fair to good Fish and Benthic IBI) | % of case sites with stressor present | % of control sites with stressor present | Possible stressor (Odds of stressor in cases significantly higher that odds of stressors in controls using p<0.1) | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor |
|---|---|---|---|---|---|---|---|---|
| In-Stream Habitat | channelization present | 7 | 3 | 157 | 0% | 10% | No | ---- |
| | instream habitat structure marginal to poor | 7 | 3 | 155 | 0% | 20% | No | ---- |
| | instream habitat structure poor | 7 | 3 | 155 | 0% | 2% | No | ---- |
| | pool/glide/eddy quality marginal to poor | 7 | 3 | 155 | 33% | 31% | No | ---- |
| | pool/glide/eddy quality poor | 7 | 3 | 155 | 0% | 5% | No | ---- |
| | riffle/run quality marginal to poor | 7 | 3 | 155 | 0% | 30% | No | ---- |
| | riffle/run quality poor | 7 | 3 | 155 | 0% | 7% | No | ---- |
| | velocity/depth diversity marginal to poor | 7 | 3 | 155 | 33% | 44% | No | ---- |
| | velocity/depth diversity poor | 7 | 3 | 155 | 0% | 5% | No | ---- |
| | concrete/gabion present | 7 | 3 | 157 | 0% | 4% | No | ---- |
| | beaver pond present | 7 | 3 | 153 | 0% | 1% | No | ---- |
| Riparian Habitat | no riparian buffer | 7 | 3 | 157 | 0% | 25% | No | ---- |
| | low shading | 7 | 3 | 155 | 0% | 15% | No | ---- |

## Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Licking Creek Watershed

| Parameter Group | Stressor | Total number of sampling sites in watershed with stressor and biological data | Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI) | Controls (Average number of reference sites with fair to good Fish and Benthic IBI) | % of case sites with stressor present | % of control sites with stressor present | Possible stressor (Odds of stressor in cases significantly higher that odds of stressors in controls using p<0.1) | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor |
|---|---|---|---|---|---|---|---|---|
| Water Chemistry | high total nitrogen | 6 | 2 | 159 | 0% | 8% | No | ---- |
| | high total disolved nitrogen | 0 | 0 | 0 | 0% | 0% | No | ---- |
| | ammonia acute with salmonid present | 6 | 2 | 159 | 0% | 2% | No | ---- |
| | ammonia acute with salmonid absent | 6 | 2 | 159 | 0% | 1% | No | ---- |
| | ammonia chronic with salmonid present | 6 | 2 | 159 | 0% | 4% | No | ---- |
| | ammonia chronic with salmonid absent | 6 | 2 | 159 | 0% | 2% | No | ---- |
| | low lab pH | 7 | 3 | 295 | 67% | 5% | Yes | 61% |
| | high lab pH | 7 | 3 | 295 | 0% | 0% | No | ---- |
| | low field pH | 7 | 3 | 289 | 100% | 11% | Yes | 89% |
| | high field pH | 7 | 3 | 289 | 0% | 0% | No | ---- |
| | high total phosphorus | 6 | 2 | 159 | 0% | 3% | No | ---- |
| | high orthophosphate | 6 | 2 | 159 | 0% | 4% | No | ---- |
| | dissolved oxygen < 5mg/l | 7 | 3 | 290 | 0% | 3% | No | ---- |
| | dissolved oxygen < 6mg/l | 7 | 3 | 290 | 0% | 6% | No | ---- |
| | low dissolved oxygen saturation | 4 | 1 | 205 | 0% | 3% | No | ---- |
| | high dissolved oxygen saturation | 4 | 1 | 205 | 0% | 0% | No | ---- |
| | acid neutralizing capacity below chronic level | 7 | 3 | 295 | 67% | 5% | Yes | 62% |
| | acid neutralizing capacity below episodic level | 7 | 3 | 295 | 100% | 48% | No | ---- |
| | high chlorides | 6 | 2 | 159 | 0% | 7% | No | ---- |
| | high conductivity | 7 | 3 | 295 | 0% | 2% | No | ---- |
| | high sulfates | 7 | 3 | 295 | 0% | 3% | No | ---- |

**Table 4. Stressor Source Identification Analysis Results for the Licking Creek Watershed**

| Parameter Group | Source | Total number of sampling sites in watershed with stressor and biological data | Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI) | Controls (Average number of reference sites with fair to good Fish and Benthic IBI) | % of case sites with source present | % of control sites with source present | Possible stressor (Odds of stressor in cases significantly higher that odds of sources in controls using p<0.1) | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source |
|---|---|---|---|---|---|---|---|---|
| Sources | high impervious surface in watershed | 5 | 2 | 156 | 0% | 1% | No | ---- |
| | high % of high intensity urban in watershed | 7 | 3 | 295 | 0% | 2% | No | ---- |
| | high % of low intensity urban in watershed | 7 | 3 | 295 | 0% | 4% | No | ---- |
| | high % of transportation in watershed | 7 | 3 | 295 | 0% | 5% | No | ---- |
| | high % of high intensity urban in 60m buffer | 7 | 3 | 295 | 0% | 3% | No | ---- |
| | high % of low intensity urban in 60m buffer | 7 | 3 | 295 | 0% | 4% | No | ---- |
| | high % of transportation in 60m buffer | 7 | 3 | 295 | 0% | 5% | No | ---- |
| | high % of agriculture in watershed | 7 | 3 | 295 | 0% | 11% | No | ---- |
| | high % of cropland in watershed | 7 | 3 | 295 | 0% | 3% | No | ---- |
| | high % of pasture/hay in watershed | 7 | 3 | 295 | 0% | 16% | No | ---- |
| | high % of agriculture in 60m buffer | 7 | 3 | 295 | 0% | 10% | No | ---- |
| | high % of cropland in 60m buffer | 7 | 3 | 295 | 0% | 2% | No | ---- |
| | high % of pasture/hay in 60m buffer | 7 | 3 | 295 | 0% | 16% | No | ---- |
| | high % of barren land in watershed | 7 | 3 | 295 | 0% | 4% | No | ---- |
| | high % of barren land in 60m buffer | 7 | 3 | 295 | 0% | 3% | No | ---- |

**Table 4. Stressor Source Identification Analysis Results for the Licking Creek Watershed (Cont.)**

| Parameter Group | Source | Total number of sampling sites in watershed with stressor and biological data | Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI) | Controls (Average number of reference sites with fair to good Fish and Benthic IBI) | % of case sites with source present | % of control sites with source present | Possible stressor (Odds of stressor in cases significantly higher that odds of sources in controls using p<0.1) | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source |
|---|---|---|---|---|---|---|---|---|
| Sources (cont.) | low % of forest in watershed | 7 | 3 | 295 | 0% | 7% | No | ---- |
| | low % of forest in 60m buffer | 7 | 3 | 295 | 0% | 8% | No | ---- |
| | atmospheric deposition present | 7 | 3 | 295 | 100% | 44% | Yes | 56% |
| | AMD acid source present | 7 | 3 | 295 | 0% | 6% | No | ---- |
| | organic acid source present | 7 | 3 | 295 | 0% | 2% | No | ---- |
| | agricultural acid source present | 7 | 3 | 295 | 0% | 2% | No | ---- |

**Table 5. Summary of Combined Attributable Risk Values for Stressor Groups for the Licking Creek Watershed**

| Stressor Group | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk) | |
|---|---|---|
| Sediment | --- | 93% |
| In-Stream Habitat | --- | |
| Riparian Habitat | ---- | |
| Water Chemistry | 93% | |

**Table 6. Summary of Combined Attributable Risk Values for Source Groups for the Licking Creek Watershed**

| Source Group | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk) | |
|---|---|---|
| Urban | ---- | 56% |
| Agriculture | ---- | |
| Barren Land | ---- | |
| Anthropogenic | --- | |
| Acidity | 56% | |

Sediment Parameters

BSID analysis results for Licking Creek did not identify any sediment parameters that have statistically significant association with a poor to very poor stream biological conditions (i.e., removal of stressors would result in improved biological community).

In-stream Habitat Parameters

BSID analysis results for Licking Creek did not identify any in-stream habitat parameters that have statistically significant association with a poor to very poor stream biological conditions (i.e., removal of stressors would result in improved biological community).

Riparian Habitat Parameters

BSID analysis results for Licking Creek did not identify any riparian habitat parameters that have statistically significant association with a poor to very poor stream biological conditions (i.e., removal of stressors would result in improved biological community).

Water Chemistry Parameters

BSID analysis results for Licking identified three water chemistry parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters include *low lab pH, low field pH,* and *low ANC below chronic level.*

*Low pH* was identified as significantly associated with degraded biological conditions in Licking Creek and found to impact approximately 61% (lab pH) and 89% (field pH) of the stream miles with poor to very poor biological conditions. MDDNR MBSS collects pH samples once during the spring, which are analyzed in the laboratory (*pH lab*), and measured once in situ during the summer (*pH field*). pH is a measure of acidity that uses a logarithmic scale ranging from 0 to 14, with 7 being neutral. Most stream organisms prefer a pH range of 6.5 to 8.5. *Low pH* values (less than 6.5) can be damaging to aquatic life. Low pH may allow concentrations of toxic elements (such as ammonia, nitrite, and aluminum) and high amounts of dissolved heavy metals (such as copper and zinc) to be mobilized for uptake by aquatic plants and animals.

*Low ANC below chronic level* was identified as significantly associated with degraded biological conditions in Licking Creek and found to impact approximately 62% of the stream miles with poor to very poor biological conditions. ANC is a measure of the capacity of dissolved constituents in the water to react with and neutralize acids. ANC can be used as an index of the sensitivity of surface waters to acidification. The higher the ANC, the more acid a system can assimilate before experiencing a decrease in pH. Frequent inputs of acidic materials into a system may cause a decrease in ANC. ANC values less than 50µeq/l are considered to demonstrate chronic (highly sensitive to acidification) exposures for aquatic organisms, and values less than 200 are considered to demonstrate episodic (sensitive to acidification) exposures (Kazyak et al. 2005; Southerland et al. 2007).

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the water chemistry stressor group is approximately 93%, suggesting these stressors impact a substantial proportion of the degraded stream miles in the Licking Creek watershed (Table 5).

Sources

The BSID source analysis (Table 4) only identified one potential source (*atmospheric deposition*) for the stressors that may be significantly associated with degraded biological conditions in Licking Creek and found to impact approximately 56% of the stream miles with poor to very poor biological conditions. Acidity is a problematic aspect of atmospheric deposition, with the pH of rain often in the range of 3.5 to 5.0. The typical pH of precipitation in the Licking Creek watershed is around 5.6, resulting from atmospheric deposition (NADP 2009). Acidic deposition is the contribution of material from atmosphere, both as wet precipitation (wet) and particulate (dry) deposition. Atmospheric deposition is generally associated with elevated concentrations of sulfates and nitrates. Acid rain is produced when atmospheric moisture reacts with gases in the atmosphere to form sulfuric and nitric acids. These gases are primarily formed from nitrogen dioxides and sulfur dioxide, which enter the atmosphere through exhaust and smoke from burning fossil fuels such as gas, oil, and coal.

In 1990 the United States Congress enacted Title IV, part of the Clean Air Act Amendments, which required significant decreases in sulfur dioxide ($SO_2$) and nitrous oxides (NOx) emissions, major contributors of acid deposition, from fossil fuel-burning power plants. Implementation of Title IV has substantially reduced emissions of $SO_2$ and NOx, and has also decreased sulfate and inorganic nitrogen deposition in the eastern U.S. Acidity from atmospheric deposition in the eastern United States is demonstrated by National Atmospheric Deposition Program (NADP) monitoring data (NADP 2009). Figure 6 illustrates sulfate deposition over the continental United States over the time period stream data was collected in Maryland to assess biological integrity and diagnose biological impairments (1996-2004). An additional 2008 image is included to illustrate the trend of decreasing atmospheric deposition, presumably caused by more stringent emission controls.

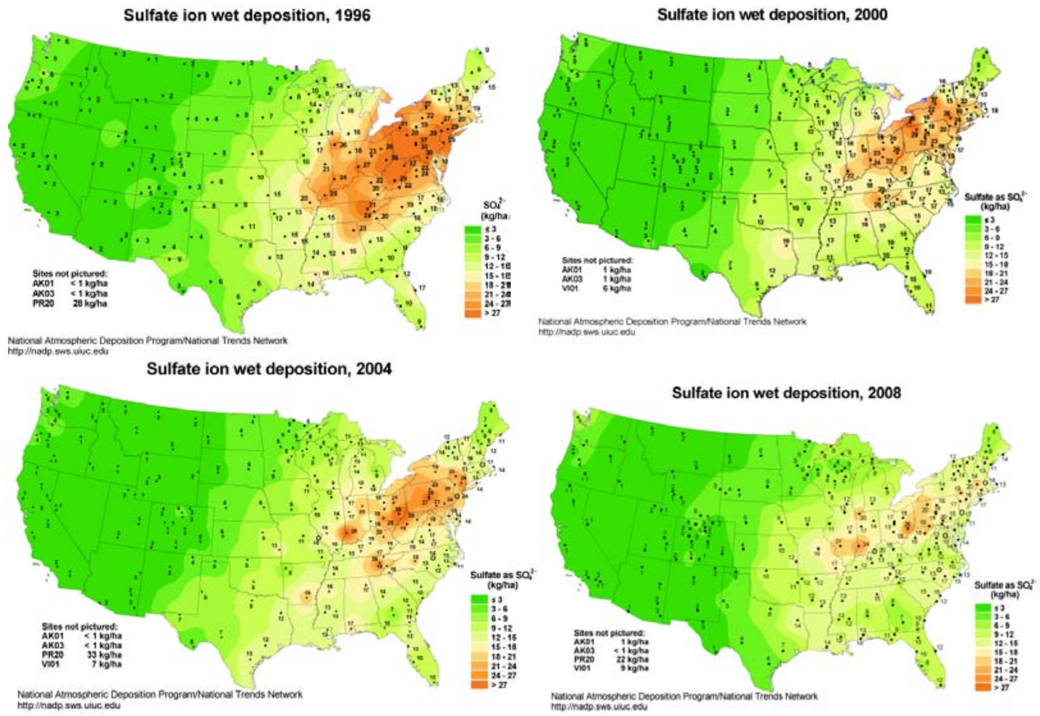


**Figure 6. Sulfate Deposition in the Continental United States 1996-2008.**

In 2007, the State of Maryland passed the Maryland Healthy Air Act. The first phase requires reductions of NOx emissions by almost 70%, and $SO_2$ emissions by 80%. In 2012/ 2013 the second phase of emission controls will reduce NOx and $SO_2$ by another 5%. In 2011, NOx emissions were at approximately 13,000 tons statewide, which represents a decrease of about 60,000 tons (82%) from 2002, prior to the implementation of Maryland's HAA, which were at about 73,000 tons. Maryland's HAA, which imposed stricter emissions standards for electric generating units (EGUs) in Maryland, was supposed to be at full implementation by 2013.

The combined AR is used to measure the improvement of degraded stream miles with poor to very poor biological conditions, if the causal sources were removed. The combined AR for the source group identified in the BSID analysis is approximately 56% suggesting that the presence of atmospheric deposition impacts a considerable proportion of the degraded stream miles in the Licking Creek watershed (Table 6).

Summary

The BSID results suggest that the Licking Creek watershed experiences localized acidity in areas where the geology has little buffering capacity. Regional atmospheric deposition is the probable source of acidity, which exceeds the natural acid neutralizing capacity of local geology. Siliciclastic bedrock types (such as sandstone), which are found in the watershed have very low buffering capacity (Bulger, Cosby, and Webb 1998), partly because it weathers very slowly. All observed impaired stream stations in the Licking Creek watershed (cases) occur on the same unnamed tributary and radiate from an area with weather resistant sandstone.

The Maryland portion of the watershed is largely undeveloped, and the drainage area for impaired stations is nearly 100% forested. Furthermore, this area is largely public land that includes the Indian Spring Wildlife Management Area. There are no other Category 5 listings in the Licking Creek watershed; therefore, there is no evidence of an alternate cause of biological impairment.

The BSID analysis evaluates numerous key stressors using the most comprehensive data sets available that meet the requirements outlined in the methodology report. It is important to recognize that stressors could act independently or act as part of a complex causal scenario (e.g., eutrophication, urbanization, habitat modification). Also, uncertainties in the analysis could arise from the absence of unknown key stressors and other limitations of the principal data set. The results are based on the best available data at the time of evaluation.

Final Causal Model for Licking Creek

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr 1991; USEPA 2007). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 7 illustrates the final causal model for the Licking Creek watershed, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

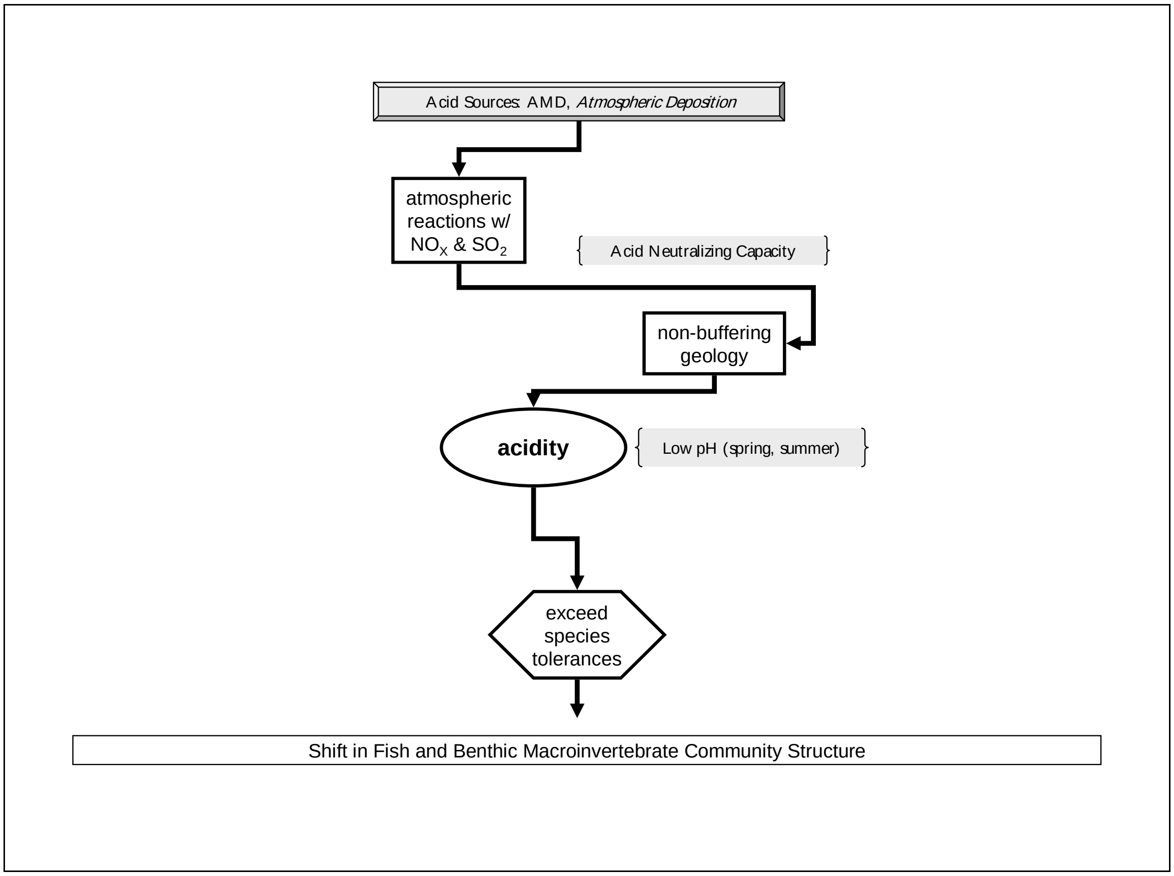


**Figure 7. Final Causal Model for the Licking Creek Watershed**

## 5.0 Conclusions

Data suggest that the degradation of biological communities in the Licking Creek watershed is associated with acidity from atmospheric deposition. Based on the results of the BSID process, the probable causes and sources of the biological impairments in the Licking Creek watershed can be summarized as follows:

- The BSID process has determined that the biological communities in Licking Creek watershed are likely degraded due to acidity related stressors. Acidity is indicated directly by the strong association of low pH and low Acid Neutralizing Capacity (ANC) with biological impairments. Licking Creek watershed experiences localized acidity caused by atmospheric deposition in areas where the geology has little buffering capacity. The BSID results thus support a Category 5 listing of low pH for the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Licking Creek watershed.

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