

Geospatial Evaluation of Acid Mine Drainage Potential from Historic Coal Mines in Chattanooga, Tennessee

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Abstract

Chattanooga has undergone a remarkable transformation from a heavily industrialized rail depot and one of the nation's most polluted cities to the first designated National Park City in the United States of America. However, environmental challenges remain, particularly in nearby Soddy Daisy area, where historic coal mining continues to pose potential risks to water quality through acid mine drainage (AMD). This study evaluates the risk of AMD from abandoned coal mines along Walden Ridge using geospatial analysis. Mine locations were identified through mineral surveys, topographic maps, and field knowledge, while hydrologic features were digitized to overcome gaps in existing datasets. A suitability model was developed using a digital elevation model (DEM) and proximity analysis of geospatial data to predict areas most vulnerable to contamination. Among the sixty-eight coal mines evaluated, twenty-four were categorized as high risk, seven as marginal risk, and thirty-seven as low or no risk. Results indicate that although fewer mines than expected pose an immediate threat, high-risk mines tend to occur in clusters, intensifying localized impacts. Northern Big Possum Creek and the confluence of Deep Creek and Carr Branch were identified as priority areas for remediation. These findings highlight the enduring legacy of coal mining in the region and underscore the need for targeted mitigation strategies to protect water resources.

1. Introduction

1.1 Acid Mine Drainage in Chattanooga, TN

The city of Chattanooga (Figure 1) has undergone a remarkable transformation over the past several decades. Once a major rail depot, the city was at one time known as one of the dirtiest in America (Encyclopedia Britannica, 2025). However, decades of intentional investment and environmental restoration have reshaped Chattanooga into the first National Park City in the United States (National Park City Foundation, 2025).

While many of the challenges associated with its heavily industrialized past have been addressed, one significant concern related to coal mining remains relatively neglected. Just outside Chattanooga lies Soddy-Daisy, originally two separate towns, Soddy and Daisy. This small, unassuming community played a crucial role in fueling Chattanooga's early industrial growth, primarily through coal production. The ridges surrounding Soddy-Daisy are rich in coal, leading to the development of numerous mines throughout the area. The scale of this operation was immense, and Soddy-Daisy represented only a small portion of the broader regional mining effort (Bryant, 1966). Walden Ridge and the western portion of the Cumberland Plateau contain more than one hundred coal mines. Many of these mines stretch across Soddy's section of Walden Ridge and extend northward toward Graysville, a town nearly twenty miles away. Although none of these mines are active today, most were never formally closed or sealed, and many have been completely forgotten.

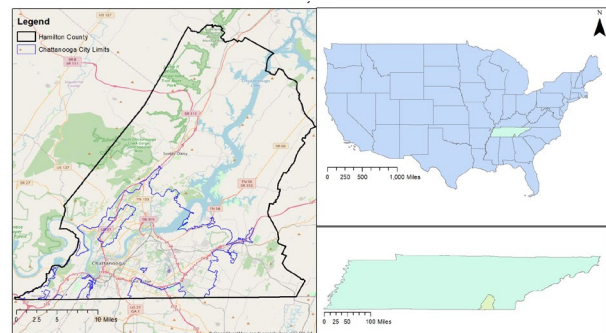


Figure 1. City of Chattanooga, TN.

Coal is naturally rich in sulfur. When sulfur-bearing minerals come into contact with water, they produce sulfuric acid. As a result, abandoned and open coal mines accumulate water that reacts with exposed sulfur minerals, leading to the formation of acid mine drainage (AMD) (Bigham and Cravotta, 2016; USEPA, 1994). This process can continue for decades or even centuries after mining has stopped.

Field observations suggest that none of these mines have truly been closed or reclaimed; rather, they have simply been abandoned. As a result, they remained open to pathways for polluted water to enter surrounding ecosystems.

Protecting the delicate ecosystems in the waterways near these mines requires tracking where AMD is flowing across the landscape. Many organisms, especially amphibians, which are highly sensitive to environmental changes, inhabit the rivers and

streams around Chattanooga. Changes in water chemistry, such as increases in acidity, can significantly disrupt these populations and the broader ecological balance (Norman et. al. 2008; Luis, et. al. 2009).

While completely sealing or reclaiming these abandoned mines is a difficult and resource-intensive process, the movement of drainage from them can and should be monitored. Tracking AMD pathways is an important first step toward effective mitigation and long-term watershed protection.

1.2 GIS to Study AMD

Although acid mine drainage (AMD) has been recognized as a major environmental concern for decades, very few studies have applied Geographic Information Systems (GIS) to investigate AMD patterns, pathways, or environmental impacts. This gap in the literature is notable given GIS's proven ability to integrate spatial, geological, and hydrological data, along with tools ideally suited for tracing contaminant transport and assessing watershed-scale risks.

Among the limited body of research, only two major examples highlight how effectively GIS can be used to map and analyze mine-related pollution in the United States. In one study, Norman et. al. (2008) employed GIS in combination with sediment-delivery models to track the movement of AMD in southeast Arizona. Their work demonstrated the power of GIS to identify pollutant transport routes, estimate sediment contributions, and assess downstream vulnerability. Similarly, Visocky et. al. (2000) conducted a spatial analysis of constructed wetlands in Ohio designed to treat AMD. Their study illustrated how GIS can support remediation planning by mapping treatment efficacy, evaluating landscape position, and characterizing the spatial relationships between abandoned mines and affected waterways.

Together, these studies illustrate the significant potential of GIS-based approaches for AMD monitoring and remediation, while simultaneously revealing a clear research gap, particularly for regions such as the southeastern United States, where abandoned mines are widespread but remain understudied.

2. Objectives of This Study

The primary objective of this study is to evaluate and demonstrate the potential of GIS for identifying, modeling, and predicting areas most at risk for AMD contamination within the Greater Chattanooga region. Specifically, this study aims to:

- Assess spatial relationships between abandoned mine locations, hydrological pathways, and surrounding water bodies.
- Develop GIS-based risk maps to identify mines susceptible to AMD generation and downstream contamination.

3. Study Site

The study took place in the Soddy Quadrangle in the Soddy-Daisy region of southeastern Tennessee, an area well suited for evaluating the long-term effects of legacy coal mining (Figure 2). The landscape contains a high density of abandoned and inactive mines situated close to small streams and tributaries,

creating a natural setting for examining how contaminants from historic mining interact with surface waters.

Approximately sixty-eight abandoned mines have been documented in the quadrangle. Their distribution across ridges, slopes, and low-lying hollows provides a compact yet diverse collection of sites for analysis. Many portals are located where mine drainage can readily enter adjacent waterways, making the region an effective testbed for identifying where and how pollutants are introduced into the hydrologic system.

The environmental importance of the Soddy Quadrangle stems from its potential to reveal pollution hotspots, particularly locations where acidic drainage, metals, or sediment enter streams. Because most of these mines predate modern reclamation practices, their impacts are still poorly characterized. Studying this region will help clarify how contamination varies across the landscape and which areas contribute most to water-quality degradation.

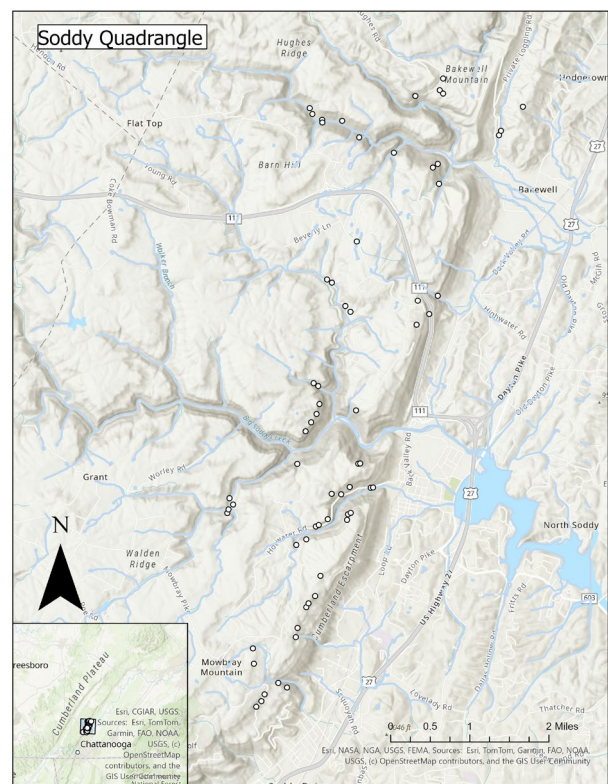


Figure 2. Study site with locations of abandoned coal mines.

This work also supports broader water quality monitoring and restoration efforts in Tennessee. Data from the Soddy Quadrangle will help agencies and watershed groups prioritize remediation sites, understand spatial and seasonal patterns of water-quality change, and assess the persistence of legacy mining impacts. Ultimately, the region provides a focused and meaningful setting for advancing science-based watershed management.

4. Data Collection

This study uses several geospatial datasets to analyze abandoned mines and their relationship to hydrologic features in the Soddy Quadrangle. A key input to the analysis is the GIS drainage network dataset, which provides mapped stream

channels and flow-direction information critical for understanding potential contaminant transport pathways.

Mining activity is represented through a digitized set of mine locations derived from USGS Soddy Quadrangle maps as shown in Figure 2. These spatial features identify known abandoned mines and allow assessment of their proximity to streams and drainage routes.

Topographic information is supplied by a digital elevation model (DEM), offering elevation data used for watershed delineation, terrain characterization, and flow modeling. The DEM helps determine how landscape shape influences water movement and potential transport of pollutants from mine sites.

Together, these datasets generated an integrated geospatial foundation for evaluating mine–water interactions and identifying environmentally sensitive areas within the study region.

5. Methods

5.1 Overview of the Geospatial Approach

The geospatial analysis for this study was designed to identify abandoned coal mines that may pose a risk for acid mine drainage (AMD) based on their spatial relationship to nearby water bodies and steep terrain. By integrating hydrologic, topographic, and mining datasets, the workflow classifies each mine according to its relative environmental risk. Figure 3 presents the flow chart outlining the full AMD geospatial model used in this analysis. All spatial processing and modeling were performed using ESRI's ArcGIS Pro 3.2 software.

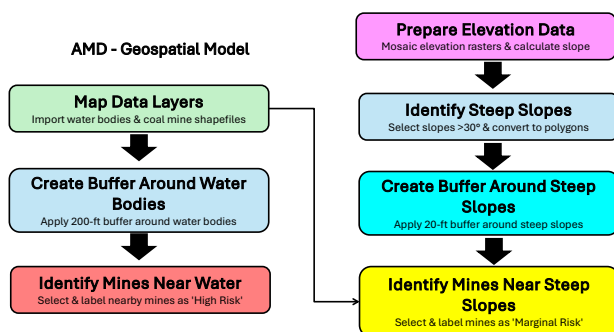


Figure 3. Flow chart of the geospatial model developed to carry out AMD analysis.

5.2 Mapping and Preparing Input Data

The workflow began by importing the key spatial datasets into a GIS environment, including:

- Digitized abandoned coal mine locations.
- The regional waterbody and drainage network dataset.
- A digital elevation model (DEM) and slopes derived from it.

These datasets formed the foundation of the geospatial model. After validating coordinate systems and ensuring alignment of all layers, the analysis proceeded to feature extraction and buffer-based risk assessment.

5.3 Hydrologic Risk Assessment

5.3.1 Buffering Water Bodies

To evaluate potential hydrologic impacts, a 200-ft buffer was created around all mapped streams, creeks, and water bodies. This distance represents a zone in which mine drainage is most likely to reach and influence surface water quality through direct seepage or short-path runoff.

5.3.2 Classification of High-Risk Mines

All mines intersecting the 200-ft water-body buffer were extracted and classified as High Risk. This designation reflects a heightened likelihood that contaminants such as acidic drainage or elevated metals could enter nearby waterways with little opportunity for natural attenuation.

5.4. Topographic Risk Assessment

5.4.1 Slope Derivation from DEM

A parallel screening step evaluated the influence of steep terrain on AMD transport. Elevation rasters were mosaicked into a seamless DEM, and slope was calculated for the entire study area.

5.4.2 Identifying Areas of Steep Terrain

Slopes greater than 30° were selected and converted into polygon features. These areas represent zones where gravity-driven processes such as rapid runoff, erosion, and sediment transport may enhance the movement of contaminants from mine sites.

5.4.3 Buffering Steep Slopes

A 20-ft buffer was then applied around the steep-slope polygons to identify terrain adjacent to high-energy runoff pathways.

5.4.4 Classification of Marginal-Risk Mines

Mines located within the steep-slope buffer were classified as Marginal Risk, reflecting moderate potential for pollutant transport under precipitation-driven or erosion-enhanced conditions.

5.5. Integrated AMD Risk Model

The results from the hydrologic and topographic assessments were combined to form the AMD Geospatial Model, which identifies mine sites requiring different levels of attention. Together, these analyses:

- Highlight mines with direct hydrologic connectivity to streams.
- Capture sites where steep terrain may increase erosion-related transport.
- Enable the rapid screening of dozens of mines across the study area.

This integrated approach supports efficient prioritization for field monitoring, environmental assessment, and potential remediation planning.

6. Results and Analysis

The geospatial model produced a clear classification of abandoned coal mines within the Soddy Quadrangle based on their proximity to surface water and steep terrain. Mines located within 200 feet of a mapped water body were designated as High Risk, reflecting the immediate potential for acid mine drainage or other contaminants to enter nearby streams.

A second group of mines those situated within 20 feet of slopes steeper than 30 degrees and also falling within the 200-foot hydrologic buffer were classified as Marginal Risk, as steep terrain may enhance runoff and erosion, increasing the likelihood of pollutant transport under certain conditions.

Mines that did not fall within either of these zones were considered Safe, indicating no immediate or expected risk of contributing contaminants to adjacent waterways based on spatial criteria alone.

Out of the 68 total mines evaluated:

- 24 mines were classified as High Risk, indicating a strong potential for direct impact on surface-water quality.
- 7 mines were identified as Marginal Risk, suggesting a moderate but spatially significant potential for pollutant transport, especially during high-flow or erosive conditions.
- The remaining 37 mines were categorized as Safe, showing no clear geospatial factors that would place them at elevated risk of contributing to water pollution.

Table 1 presents a summary of the mine-risk classifications derived from the geospatial analysis, showing the number of mines assigned to each risk category based on their proximity to water bodies and steep terrain.

Risk Category	Criteria Used	Number of Mines	Color Code (Map)	Interpretation
High Risk	Within 200 ft of a water body	24	Red	Highest potential for water contamination; priority for field assessment
Marginal Risk	Within 20 ft of slopes $>30^\circ$ and inside the 200-ft buffer	7	Orange	Moderate risk; steep terrain may promote contaminant transport
Safe	Outside both water-body and steep-slope buffers	37	White	No immediate spatial indicators of pollution risk

Table 1. Abandoned mine classification summary.

Figure 4 displays the spatial distribution of all 68 abandoned coal mines within the Soddy Quadrangle, color-coded according to their assigned risk categories. Mines located within 200 feet of a water body are shown in red and classified as High Risk, while those situated within 20 feet of slopes greater than 30 degrees are shown in orange and labeled Marginal Risk. Mines falling outside these zones appear in white and are designated as Safe. The map provides a clear visualization of how proximity to hydrologic features and terrain characteristics influences overall risk assessment.

Figure 5 overlays the assessed mine locations onto a slope raster GIS data derived from the digital elevation model (DEM). Areas with slopes steeper than 30 degrees are highlighted to illustrate terrain conditions that may facilitate runoff or sediment transport. The placement of mines relative to these steep-slope zones demonstrates how topography contributes to the classification of Marginal Risk sites and supports the spatial logic underlying the AMD risk model.

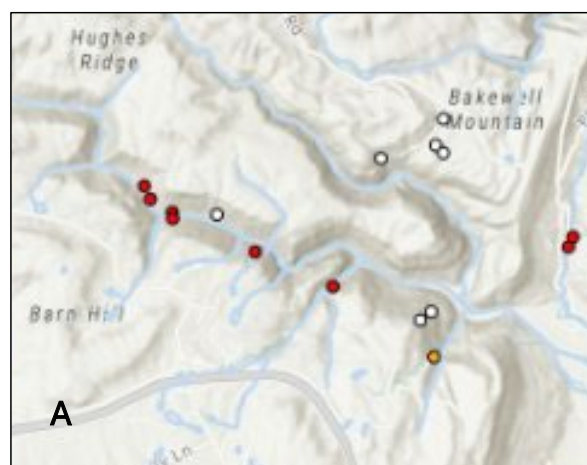
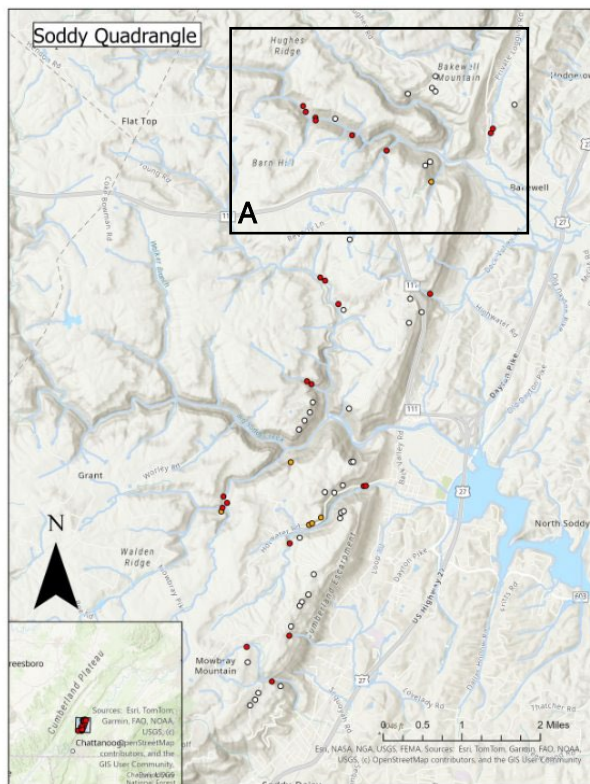


Figure 4. This figure displays the spatial distribution of all 68 abandoned coal mines within the Soddy Quadrangle, color-coded according to their assigned risk categories.

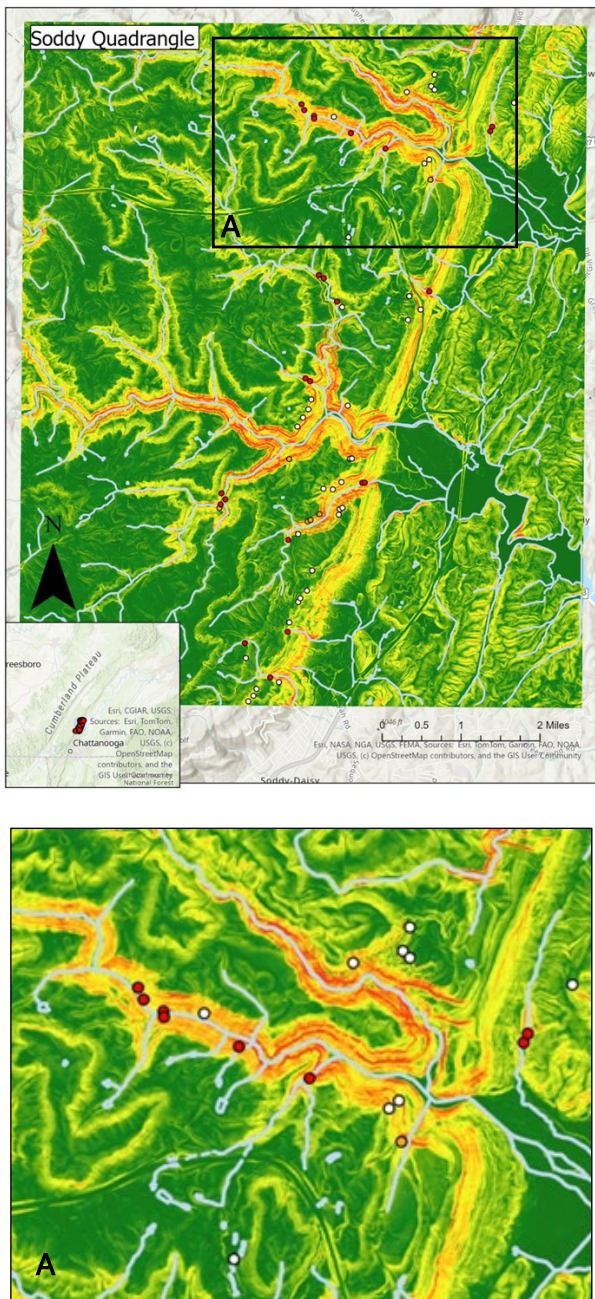


Figure 5. The assessed mine locations shown onto a slope raster GIS data derived from the digital elevation model (DEM).

7. Discussion and Conclusions

The results of this geospatial assessment indicate that most of the abandoned coal mines in the Soddy Quadrangle do not pose an immediate risk to nearby waterways. Most sites fall outside the hydrologic and topographic buffers used to identify elevated acid mine drainage (AMD) potential, suggesting that natural landscape conditions limit the likelihood of contaminant transport for a substantial portion of the mines assessed.

However, the analysis also highlights a cluster of high-risk mines located primarily along upper Big Possum Creek and within the corridor stretching between Carr Branch and Deep Creek. These areas contain multiple abandoned mines situated within close proximity to surface water, and in some cases near steep slopes that may accelerate runoff. As a result, these zones

appear to be the most environmentally vulnerable and should be prioritized for AMD mitigation efforts, targeted field inspections, and long-term monitoring.

More broadly, this study demonstrates that GIS is an effective tool for evaluating the environmental hazards associated with legacy coal mines in the Greater Chattanooga region. By integrating drainage networks, slope data, and mine-location information, the model provides a rapid, spatially explicit method for identifying potential pollution hotspots. While field verification remains essential for confirming site conditions, the GIS-based approach offers an efficient first step for screening large numbers of abandoned mines and guiding resource allocation for environmental management.

Overall, the findings show that spatial analysis can significantly improve understanding of AMD risks and support data-driven decision-making for watershed protection and mine-land restoration across the region.

The study acknowledges several limitations, including uncertainty in historical mine-location data, incomplete stream mapping, and the use of fixed distance and slope thresholds that may not fully capture hydrologic variability. Proximity-based risk also does not guarantee actual AMD discharge, since chemistry and subsurface pathways may differ from surface patterns.

To strengthen confidence in the results, a tiered field-validation approach is recommended. This includes reconnaissance visits to high-priority sites, targeted water-quality sampling, and seasonal storm-event monitoring. Findings from fieldwork should be integrated into a decision matrix to categorize mines as needing remediation, routine monitoring, or reevaluation.

Several low-cost immediate actions such as redirecting surface water, stabilizing erodible slopes, installing vegetative buffers, and securing hazardous sites can help reduce AMD risks while long-term treatment solutions are developed.

Future improvements to the model include incorporating hydrologic connectivity analyses, soil and geological buffering properties, high-resolution elevation data (e.g., LiDAR), and remote-sensing tools to identify mine drainage indicators. Sensitivity testing of thresholds would also refine risk classifications.

Regionally, expanding this workflow across adjacent quadrangles could support the creation of a comprehensive AMD risk atlas for the Greater Chattanooga area. This would help agencies and partners prioritize remediation using an adaptive, data-driven management approach.

Acknowledgements

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