MONDAY CREEK ECOSYSTEM RESTORATION FEASIBILITY STUDY[1]

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Abstract. The U.S. Army Corps of Engineers, in partnership with the Ohio Department of Natural Resources, Division of Mines and Reclamation, is conducting a Feasibility Study to evaluate the applicability and feasibility of various restoration solutions to the overall degradation of the ecosystem of the Monday Creek Watershed. The watershed encompasses 116 square miles (74,240 acres) of Perry, Athens and Hocking Counties, Ohio. Extensive portions of the watershed have been subjected to underground and surface mining since the mid-1800s and a number of stream reaches are sterile and unable to support diverse, aquatic life due to acid mine drainage (AMD). In addition to the Corps and the ODNR, seven other federal, state and local agencies are actively involved in the project. West Virginia is one of the agencies and its primary role was to develop and use a computer model called the Total Acid Mine Drainage Loading (TAMDL) model simulate the evolution of stream water quality affected by acid mine drainage. The objectives of this paper are to describe the Corps' processes for addressing AMD projects, to presents the results of the model study, and to explain how the stakeholders have worked together to develop a comprehensive plan to address the problems in the Monday Creek Watershed.

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Introduction

Recognizing the concerns of Federal and state agencies, local officials, and individuals about the environmental condition of the Monday Creek watershed, the U.S. House of Representatives Committee on Transportation and Infrastructure adopted a resolution in March 1996, requesting the Chief of Engineers to,

> "*…determine whether modifications are warranted to solve a variety of water and related resource problems in the Hocking River Basin with priority given to Sunday and Monday Creek sub-basins. Special emphasis shall be given to the need for environmental restoration of lands and waters that have been impacted by resource extraction and other land uses. The study is to be conducted in consultation with the Hocking Conservancy District."*

Project Location

Monday Creek watershed, located in the unglaciated portion of the Allegheny Plateau region of southeastern Ohio, is a 116 square mile (74,240 acres) area encompassing Monday Creek and its associated tributaries. The main stem of Monday Creek runs 27 miles before eventually emptying into the Hocking River. The watershed drains roughly 10 percent of the Hocking River system, which itself is part of the Greater Ohio River Watershed. Of the 270 stream miles in the watershed, there are a total of 75.9 miles of perennial streams. The two main tributaries to the 27-mile mainstem of Monday Creek are Little Monday Creek (14.3 mi.) and Snow Fork (10.7 mi.). Located in Athens, Hocking, and Perry counties, the Monday Creek watershed lies in the heart of Ohio's Appalachian coal region.

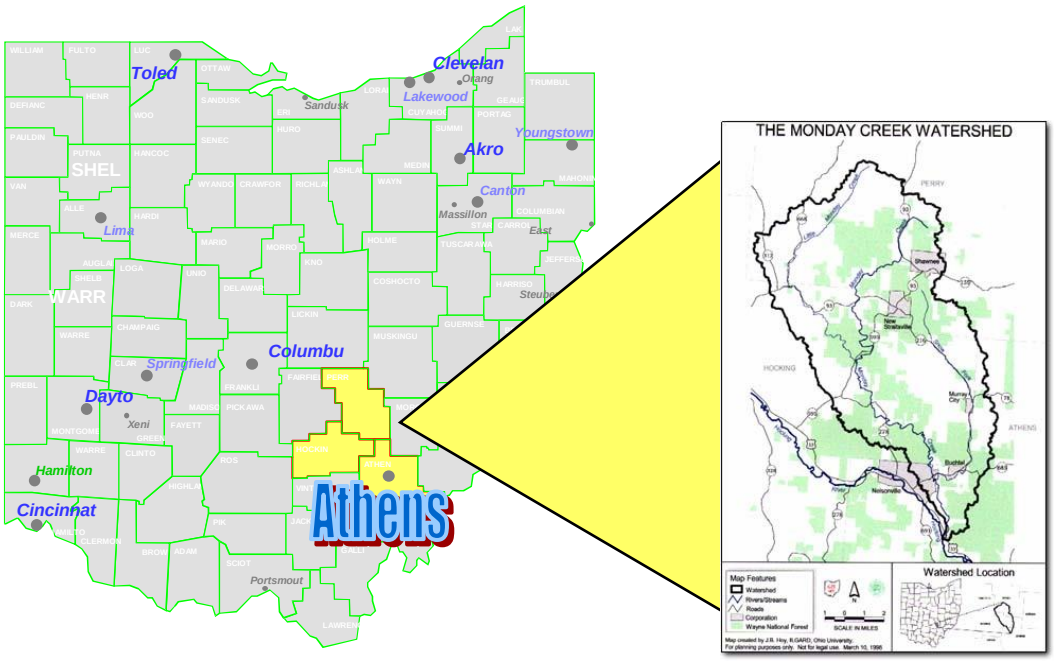

Figure 1. The Monday Creek Watershed is located in southeastern Ohio and covers 116 square miles in Athens, Perry and Hocking Counties.

Reconnaissance Phase

Congress provided funds in 1997 for the U.S. Army Corps of Engineers, Huntington District, to conduct a reconnaissance study on the watershed. The Reconnaissance Report was approved by Corps Headquarters on November 19, 1997 as a basis for proceeding to the feasibility phase. The reconnaissance report identified there were sufficient indications that engineering solutions for resolving the AMD problems could be formulated which would result in ecosystem restoration benefits in excess of project costs.

The reconnaissance phase was formally completed in April 2000 when Congress authorized the Corps to begin the next step – the feasibility phase. The feasibility study began in 2002 following execution of a Feasibility Cost Sharing Agreement between the Corps and the ODNR, the non-federal sponsor, and receipt of a portion of the ODNR's 50/50 cost-share amount for the million dollar study. During the feasibility study, the Corps identified over 4,300 problem areas related to abandoned mine lands within the Monday Creek Watershed including deep mine seeps, gob pile leachate, subsidence features, spoil blocks and stream captures. The U.S. Forest Service (USFS) is also a stakeholder in the project because it owns over 40% of the Monday

Creek Watershed as part of the Wayne National Forest. As shown in Figure 2, in addition to the ODNR and USFS, other agencies involved include the Ohio EPA, Ohio University, the U.S. Department of Energy's National Energy Technology Laboratory, West Virginia University, and the Monday Creek Restoration Project which is a local citizens group dedicated to restoration of the Monday Creek Watershed.

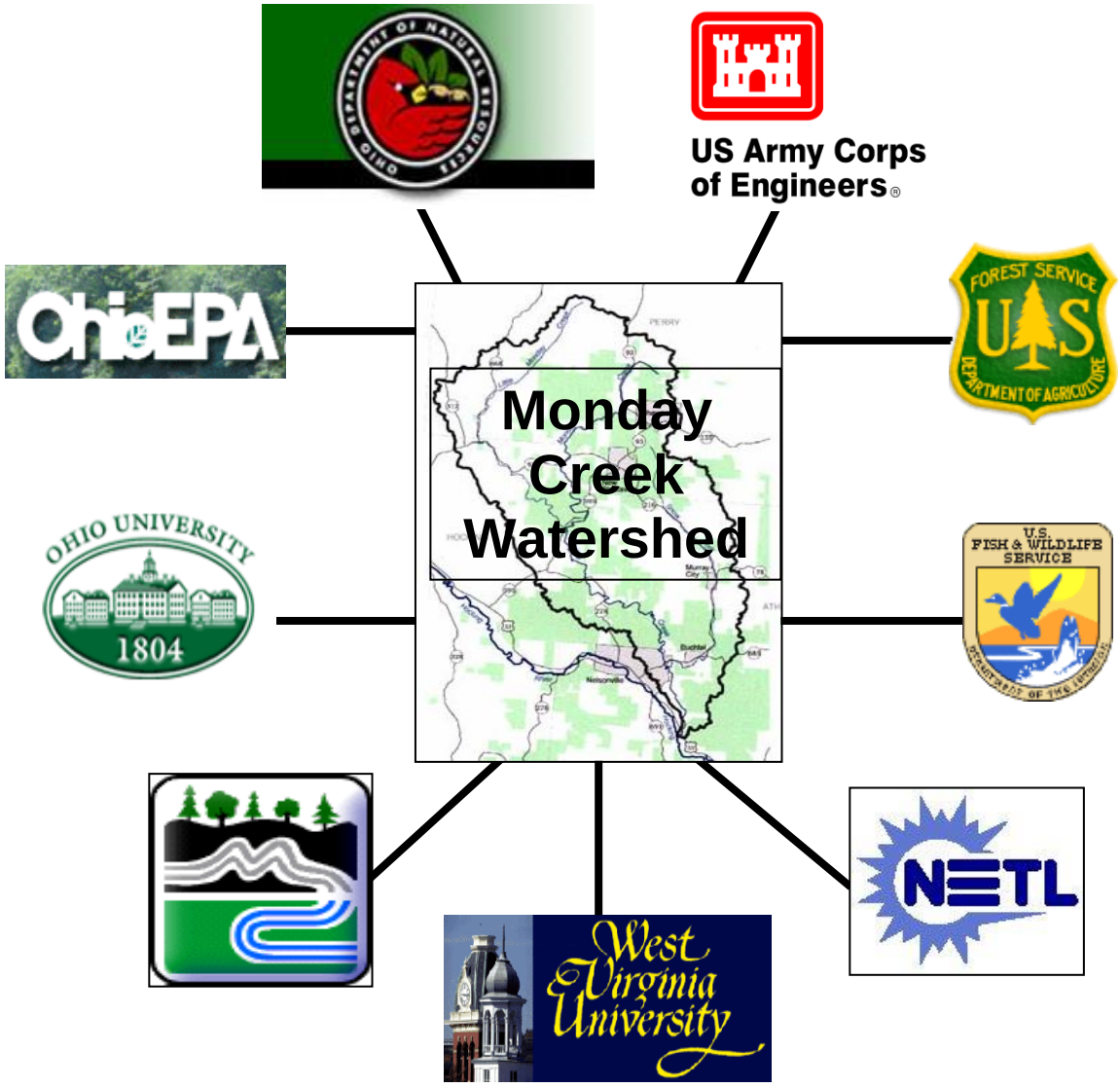

Figure 2. Nine federal, state and local agencies are working together closely to restore the Monday Creek Watershed.

Feasibility Phase

The purpose of the feasibility study is to conduct a thorough investigation of the problems and needs of the area, develop alternative plans to address these problems and needs and to select the optimum plan based on the projected benefits. The feasibility report serves to document the findings of the feasibility study and document the cost of the optimum plan. The results are based upon the analysis of both data collected during the feasibility study and historical data accumulated from previous studies and/or other sources. Technical designs for this study include biological, engineering, and economic evaluations of various alternatives along with required real estate and planning evaluations. In compliance with the National Environmental Policy Act (NEPA), an Environmental Assessment is also being prepared to accompany the feasibility report.

Study Objective

The goal of this project is to sufficiently treat specific discharges to aid in the restoration of both the structural and functional components of the ecosystem of Monday Creek downstream of the discharges. The restoration objective is to restore Monday Creek to conditions generally consistent with the functioning ecosystem designated as Warm Water Habitat by Ohio Environmental Protection Agency.

Under present conditions, AMD has degraded the water quality of Monday Creek and impaired its ecosystem functions to the point that aquatic life has essentially been eliminated along approximately 111 miles of streams within the watershed. Structural degradation of the ecosystem is a result of the pollutant loadings from AMD and metals in the stream. Pollutants such as iron, manganese and aluminum occur at levels that are toxic to aquatic species and pH and acidity levels exist that adversely affect vertebrate and invertebrate life.

Potential measures to achieve ecosystem restoration need to improve water quality to conditions consistent with those in functioning ecosystems. Abatement of AMD which removes adverse pollutant loadings helps to improve water quality from the discharges. The resulting improvement in water quality from abatement of AMD is expected to permit the reestablishment

of fish and macroinvertebrate populations and aquatic vegetation in Monday Creek and its tributaries.

Figure 3. Acid mine drainage seeps from the former Majestic Mine complex.

Plan Formulation

To assist with plan formulation, West Virginia University has recently developed a water quality computer model, the "Total Acid Mine Drainage Loading (TAMDL) Model", for determining the effects of acid mine drainage on streams. The model can simulate the hydrology of the watershed as well as the improvements to water chemistry due to restoration activities. Environmental restoration activities under study include wetland creation, plugging stream captures, filling subsidences, constructing limestone leach beds and open limestone channels and active treatment of acid mine drainage.

TAMDL Model Study

Model Development

The development of the Monday Creek *TAMDL* was a cooperative effort between the U.S. Army Corps of Engineers, Huntington District and West Virginia University (WVU). WVU submitted to the Huntington District a series of locations along Monday Creek and its tributaries. The Huntington District contracted a surveyor to measure the cross section of the stream at those

locations and calculated the drainage area and rating tables for the stream cross sectional area, top width and wetted perimeter at those sites. This information was used by the computer program to calculate the stream hydraulics during the simulation period.

With the hydrologic model results provided by the Huntington District, WVU determined that the mainstem of Monday Creek needed to be divided into seventeen sections and that Snow Fork needed to be divided into three sections. The other Monday Creek subwatersheds needed no further division. When this was completed, the computational domain for the Monday Creek *TAMDL* model was devised.

Because *TAMDL* calculates in-stream pH and metals concentrations by simulating the stream transport process, the net acidity and metals concentrations or loading rates in the water entering the computation domain from the upstream ends must be specified in some manner. Since these concentrations or loading rates must be specified continuously throughout the simulation, regression equations were derived for these locations. It was empirically observed that regression equations of the following form best replicated observed concentrations.

$$C \cong C_{\text{model}} = aQ^b \qquad (1)$$

Where: C = Observed constituent concentrations, mg/L.

C_{model} = Estimated constituent concentrations, mg/L.

Q = Stream discharge flow rate, m^3/s.

a, b = Empirical regression coefficients.

The discharge flow rate, Q, in equation (1) is the same as what was used by the Monday Creek TAMDL model for that stream segment. This data was calculated by adjusting the discharge flow rate measured at the USGS gage at Doanville, Ohio by the drainage area of the stream segment. Stream or seep loading rates can be specified with a formula virtually identical to equation (1).

$$L \cong L_{\text{model}} = 86.4(a)Q^{b+1} \qquad (2)$$

Where: L = Observed constituent loading rates, kg/day.

L_{model} = Estimated constituent loading rates, kg/day.

The empirical coefficients in equations (1) and (2) were calculated for the net acidity, iron, manganese, and aluminum entering the Monday Creek TAMDL model's computational domain.

Model Calibration

Model calibration was accomplished by comparing the model results at water quality sample collection sites against the observed data. The quality of the calibration was judged by calculating the correlation coefficients (R^2) between the observed data and the model's results. All of the correlations are greater than 62%. Given the complexity of AMD chemistry, simplifying assumptions made by the *TAMDL* computer program, and sampling error, these correlations are fairly good.

In order to verify the calibration of the model, a verification model run was executed and the results compared against observed data collected after the end of the calibration model run. Since these coefficients were not less than the coefficients for the calibration model run, we concluded that the quality of the model calibration is accurately reflected in the correlation coefficients for the calibration model run.

Because of the error associated with the Monday Creek *TAMDL* model, margins of safety were specified for the remediation endpoints before the model was used in the design of AMD treatment strategies. Since no water quality model is free of error, this outcome is expected. The margin of safety for pH was 0.25 standard units, which is approximately 25% of the range in the 5^{th} percentile of mainstem stream pH in the treatment model.

Model Study Objective

The basic goal of the TAMDL model study was to design a cost effective AMD treatment strategy for the Monday Creek Watershed. This treatment strategy was designed by first developing a TAMDL model of the watershed which simulates the evolution of stream water quality in watersheds affected by AMD and its treatment. The watershed's *TAMDL* model and the remediation endpoints for the mainstem were used to calculate the level of treatment required in each Monday Creek subwatershed affected by AMD. The level of required AMD treatment was used to design passive and active AMD treatment structures for each affected subwatershed. The feasibility of the designed structures was tested by incorporating them into the Monday Creek model and comparing the simulated stream pH, aluminum and iron concentrations against

the corresponding remediation endpoints. The model was used to calculate the required load reductions from each of the Monday Creek and Snow Fork subwatersheds in order to satisfy the remediation endpoints specified by the Ohio EPA. The required reductions in AMD load were used to develop an AMD treatment strategy that will bring the mainstem of Monday Creek back into compliance with the remediation endpoints. This strategy consists of lime kiln dust dosers, low head dams, limestone leach beds, open limestone channels, slag leach beds and aerobic wetlands. The ultimate feasibility of this treatment strategy was tested by directly simulating the actions of the designed structures in the Monday Creek *TAMDL* model.

Model Study Results

The model was used to calculate the required load reductions from each of the Monday Creek and Snow Fork subwatersheds in order to satisfy the remediation endpoints specified by the Ohio EPA. No water quality model is free from error, and the Monday Creek *TAMDL* model is no exception. To ameliorate the effect of this error on the calculation of the required amount of AMD treatment, margins of safety were adopted for the remediation endpoints. These margins of safety were designed to force the model to over-estimate the amount of AMD treatment needed to satisfy the remediation endpoints to ensure that modeling errors do not result in substandard water quality conditions after the proposed treatment structures have been constructed. These required reductions in AMD load were used to develop an AMD treatment strategy that will bring the mainstem of Monday Creek back into compliance with the remediation endpoints.

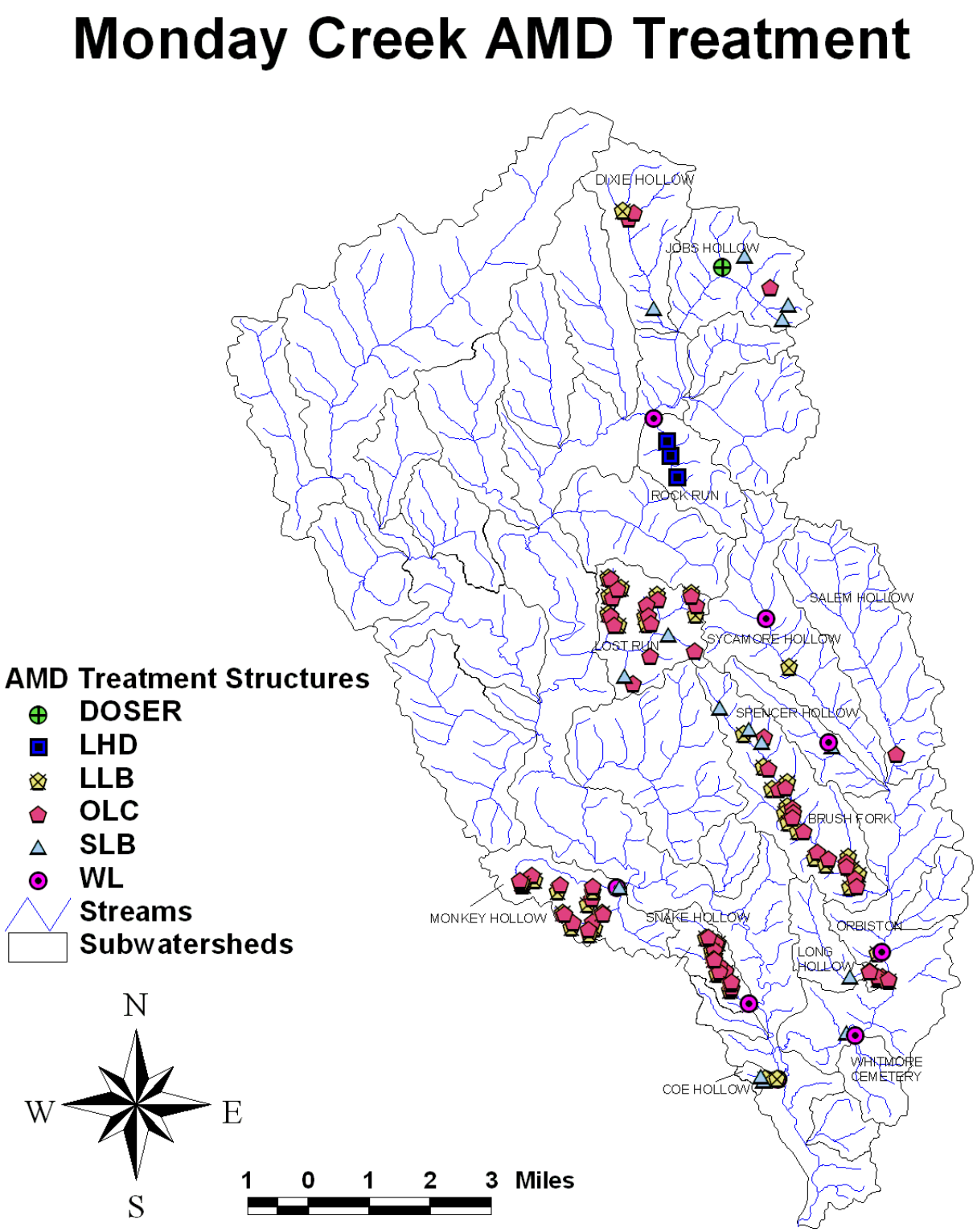

Figure 4. Designed AMD Treatment Structures for the Monday Creek Watershed.

Conclusion

Overall, the strategy provided by this project appears to provide a near optimal set of designs for treating AMD. This strategy consists of the construction of 139 projects as shown on Figure 4 including a lime kiln dust doser, low head dams (LHD), limestone leach beds (LLB) paired with open limestone channels (OLC), slag leach beds (SLB), aerobic wetlands (WL), and stream subsidence closures. The ultimate feasibility of this treatment strategy was then tested by directly simulating the actions of the designed structures in the Monday Creek *TAMDL* model. The results of these simulations showed that the mainstem of Monday Creek would be in compliance with warm water habitat endpoints established by the Ohio EPA. The model indicated that these projects are necessary to treat and remove approximately 76,000 tons of acid and it is estimated that the construction cost to implement the plan will be approximately $10,000,000.