A GIS Model
To Support Cumulative Hydrological Impact Assessments

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Abstract

We have developed a GIS modeling approach and system to aid in performing cumulative hydrological impact assessments (CHIA). The model was developed as an ESRI ArcView extension that provides many hydrological modeling and overland flow analysis tools for the permit writer. It is a combination of capabilities built within the Watershed Characterization and Modeling System (WCMS) version 2.8 and additional tools for completing cumulative hydrological impact assessments. Some of the main capabilities of the modeling approach include the ability to delineate the cumulative impacted area, provide baseline conditions for water quality and quantity, identify hydrological concerns in the downstream flow paths, and assessing the impacts of the proposed mine on indicator parameters.

Introduction

One requirement for a mining permit in West Virginia is an analysis of all cumulative hydrological impacts from the proposed activity. This analysis is currently being done by permit writers from the West Virginia Department of Environmental Protection. Their procedure includes a number of related phases of analysis. The first two phases include defining maximum upstream and downstream extent of impact, comparing the prevailing water data that reflects impacts from mining, identifying a receiving stream common to an anticipated operation, and finding watershed drainage boundaries. The next two phases include determining baseline conditions through water quality sample data and stream flow information as well as characterizing the surface water system in relation to runoff.

These four phases are the main components that our modeling system was designed to address. While never intended to take the place of very specific and large scale information that requires field or site inspection, our modeling system allows for easy calculation of many landscape driven calculations that can reduce the burden of the permit writer. The remaining sections of this document describe in more detail the components and functionality in meeting the requirements of the CHIA.

Components of the CHIA GIS Model

STUDY AREA SELECTION. Because the CHIA extension is not tied to specific datasets, the selected study area component allows users to find a County, watershed, stream, and quad name easily. From this selection, available GIS datasets such as permit boundaries or images can be integrated and displayed. Any vector dataset (point, line, or polygon) that the user adds into a view can be queried, selected, and then the resulting selected features form the new extent. With a dataset such as permits or water quality samples, which may be updated very regularly, the user is assured of viewing the most current available data at that time.

DELINEATE DRANAGE PATHS. Drainage paths are defined as locations on the landscape where water is likely to flow during a precipitation event. They identify areas of accumulated flow based on the drainage area. Higher drainage areas will more likely have water flow longer during the year. Lower drainage areas are more likely to be dry during summer low flow months but do help track where the landscape funnels water. The results are affected by land cover change, construction projects, rerouting of water direction, etc. The CHIA extension allows the user to delineate drainage paths based on a specified area. Drainage divides or "wet weather streams" which represented all drainage paths can be tracked and identified as they flow across the landscape. The user can specify the drainage area interactively, and paths are delineated for the current view extent.

WATERSHED DELINEATION. The watershed delineation tool allows users to type in the drainage area or delineate based on a location the user clicks in the display. For many watershed areas, the pour point may be a point not mapped as a perennial or intermittent stream.

AMD TREATMENT COSTS. Two acid mine drainage treatment cost spreadsheets have been added to the CHIA extension to allow for quick calculation of the differences in costs treating acidic water. These spreadsheets are activated from the analysis window and require the user to type in values for acidity and stream flow. The calculations are based on work completed by published work by the National Mine Land Reclamation Center at West Virginia University. Cost estimates for active treatment of acid mine drainage are based upon February 1999 unit costs. The calculations were based from the 1996 publication: 'Acid Mine Drainage Control & Treatment' published by the National Mine Land Reclamation Center, compiled by Jeff Skousen and Paul Ziemkiewicz.

The cost estimates for anoxic limestone drains (ALDs) were based on the work done by Jeff Skousen and Ben Faulkner in their published 1996 article 'AMD Treatment Costs', published in Greenlands. The calculation of chemicals were used to obtain neutralization of acidity to a pH of 8.3. The results were compared and calibrated against the Royal Prep Plant and Refuse Area at Claremont OLC, West Virginia and the Alton AMD treatment site.

The efficiency percentages are associated with labor costs, chemical handling and sludge removal. Reagent expense is calculated by chemically titrating to a pH of 8.3. The estimated efficiency of system is factored into reagent costs. Total expense includes factor for labor and repair (but not capital expenditure) at a large-scale site. Actual expense at smaller sites would be much higher. Actual expense to meet effluent limits for metals could be higher. The calculated wetland size is based on iron load. A surface drain size is based on the dimensions and weight. The addition of limestone fines will reduce the size requirements.

POTENTIALLY-AFFECTED STREAMS. This tool was designed to help identify streams potentially affected from pollution sources. The potential pollution sources can be digitized into

the view display or they can be selected from the categorical grid land cover dataset. The advantage of this tool is to allow the user to add new permit boundaries or potential boundaries to determine affected streams.

EXPECTED MEAN CONCENTRATION MODELING. Water quality can be estimated for total nitrogen, phosphorus, suspended solids, zinc, biological oxygen demand, copper, lead, cadmium, chromium, and nickel. The approach uses a defined runoff grid based on rainfall and runoff relationships specific for the watershed. The estimates are driven from area weighted load allocations tied to the location and size of different land cover. A parameter file is used to link pollutant loads to land cover type. The user can access the parameter file of the database to change/alter pollutant loading coefficients. The user also has the ability to use any land cover dataset to take advantage of the best available spatial and temporal scaled data.

STREAM FLOW ESTIMATION. The stream flow estimation model in the CHIA extension was designed to query any stream location in WV and report a value based on three methods for 7Q10 (seven day, 10-year average low flow). The first method uses an empirical equation from the Water Resources Investigations Report 88-4072 "Low Flow Characteristics of Streams in West Virginia," which is referred to as the graphed method. The second method of 7Q10 flow estimation includes using a percentage of drainage area to gauged 7Q10 values. The third method of 7Q10 flow estimation includes an override 7Q10 location in the state that are primarily downstream of dams, locks, or impoundments. The values associated with all three of these methods are reported back to the user. It is their responsibility to determine which of the three best represents the value they require. These values may also be affected by potential springs in the display.

7Q10 is a low flow stream flow measure. In addition to 7Q10, our stream flow approach can also report 30-year annual and monthly averages. The technique is a weighted average approach that incorporates gauged information downstream of the point clicked as a drainage area ratio. Stream flow was modeled for the state by watershed using the annual and monthly averages for 88 gauges in the state. For each gauging station the 30-year monthly and annual average flow was found and used as a percentage of the drainage area upstream of the gauge. In this way, we can quickly find a stream flow based on drainage area for all locations upstream of the gauge throughout the watershed.

ADDITIONAL CAPABILITES

The following features are also available to the user as tools for the permit writer. Many of the tools were originally developed as part of the Watershed Characterization and Modeling System Version 2.8.

- Tabulate the percentage of land use and cover for a polygon
- Land use and cover histogram for a polygon
- Map points from X and Y input
- Drainage area query
- Find the distance of a drawn line in feet, meters and miles
- Find the area of a drawn polygon
- Slope analysis tool
- Identify the coordinates of a point clicked in UTM, Latitude Longitude, and stateplane
- Return the elevation in feet and meters of point clicked