Teaching hydrogeology in a mined site: A case study on West Run, Morgantown, WV

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Abstract

West Run is an impaired stream that flows through Morgantown, WV and discharges into the Monongahela River. Direct-point coal mine discharges, non-point mine seeps, agriculture run-off, urban run-off, and road salt pollution are all issues in West Run and its associated watershed. A portion of the watershed is located on West Virginia University (WVU) research farms and is close to the main campus; this area was chosen to use as a case study for students enrolled in Fall 2023 hydrogeology course in the Department of Geology and Geography at WVU.

The students went weekly to the field to build small spatial and temporal data sets by completing tasks that included redevelopment of piezometers, installation of new piezometers, slug tests, 3-point flow problems, stream monitoring, and the collection of field data. Students worked in small groups that divided the research area into three distinct zones, then they converged data to study the findings through problem sets and field reports. Additionally, GIS maps and Google Earth .kmz files were created to allow for historic spatial analysis of overall landcover/land use to be evaluated.

The students concluded that the main influx of impaired water to the study area is from a discharge pipe from a historic mine. Additional input from underlying flooded mines is upwelling directly into the stream and/or natural stream bank wetlands, further increasing the amount of coal mine discharge entering the stream. The natural wetlands in the area have anerobic/slow flow conditions and alter the pH, alkalinity and redox conditions in the subsurface, possibly reducing some of the negative mining effects. Extensive urban development and an overall reduction of natural groundcover like grasses and wetlands has occurred over the last 25 years in this watershed region, suggesting that overall surface water flow has been affected. Students recommended further investigations and remediation of the area.

Using West Run as a classroom case-study has demonstrated that student's natural curiosities about "real-life" negative mining effects and hydrogeology improve overall learning in a class. The data that was collected and analyzed will be shared with other classes and departments within WVU. Also, a poster will be presented by students at the 2024 Pittsburgh Geological Society's annual student research night.

Keywords: Mining, hydrogeology, education

Introduction

The pedagogy of hydrogeology remains steadfast amidst a rapidly changing world marked by climate shifts, political and social pressures, and escalating human effects on hydrological systems. While discussions about the demise of the traditional "Darcy" approach echo in agencies and corporations outside controlled pipe environments, the adaptation of teaching methods within classrooms lags (Kreamer 2021).

Simultaneously, the demand for skilled professionals in hydrogeology is surging. Paradoxically, student interest in geology and science fields is plummeting, primarily due to the perceived challenges of math and science (Stephens 2009). Urgency surrounds the need to confront these issues head-on and revolutionize how hydrogeology is taught. The solution may lie in incorporating hands-on, real-world scenarios into the curriculum.

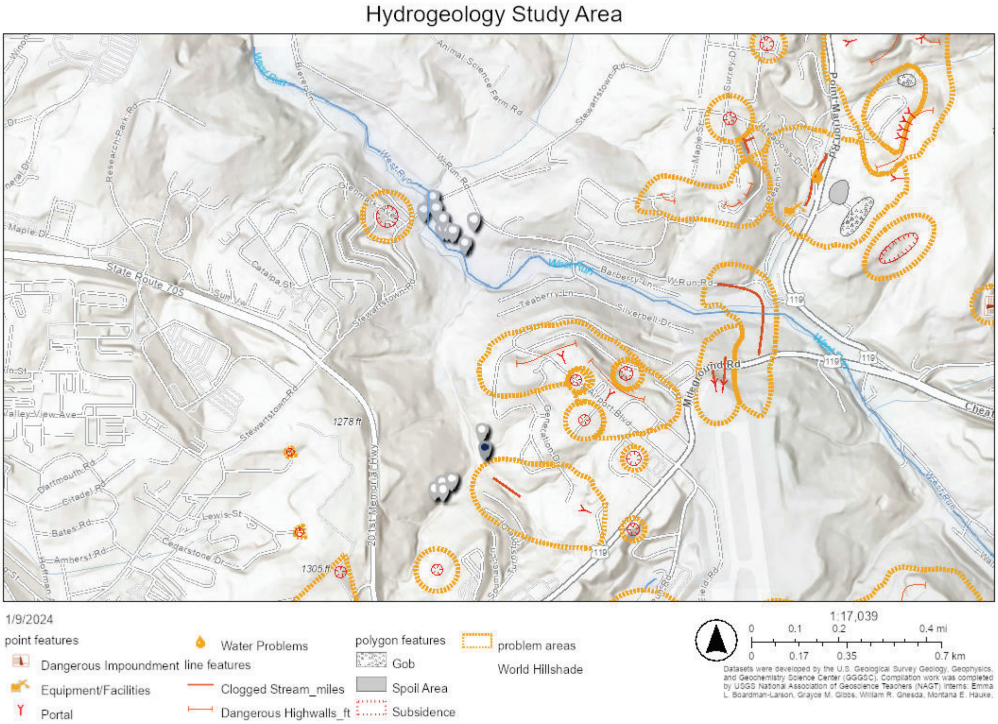

Figure 1 Topographic Map of Study Area with Historic Coal Mine Activity and Class Piezometer Locations

Due to the proximity to the main campus of WVU, West Run, a stream flowing through Morgantown, WV, was chosen to be case study area for the Fall 2023 undergraduate section of hydrogeology offered by the Department of Geology and Geography. Of particular interest is a section of the watershed situated on the West Virginia University (WVU) research farms (fig. 1). West Run is characterized as an impaired stream by the DEP and EPA's definition for exceeding The Daily Maximum Limit (TDML) for iron, fecal coliform and CNA biologicals that ultimately empties into the Monongahela River (Protection W. D.). The associated watershed faces a spectrum of challenges, including direct-point coal mine discharges, non-point mine seeps, agricultural run-off, urban run-off, and road salt pollution.

Methods

Students were divided into three groups, self-named S.T.E.M, D.A. and CJ's, to investigate different zones within the West Run Watershed region, specifically focusing on an area around a discharge pipe and the region adjacent to urban development discharge zones.

Each week, topics aligned with the course text, "Hydrogeology 101: An Introduction to Groundwater Science and Engineering" (Kresic 2023), were introduced in the classroom. This text, designed to support a 16-week semester course, formed the basis for theoretical instruction. Classical classroom instruction on concepts such as confined/unconfined aquifers, permeability/porosity, hydraulic conductivity, water quality/contaminants, mine chemistry and hydrology occurred twice a week.

Fridays were dedicated to field visits for data collection, designed to reinforce theoretical concepts through practical applications. These field excursions culminated in a final data collection, where each group covered the entire study area. Notably, this 3-credit class had no mandatory field component. In a unanimous decision during the first day of class, students voted to engage in this immersive learning format.

Each group assumed responsibilities, including collecting and packing the necessary equipment, meeting at designated sites, completing sampling tasks, labeling data, and sharing findings with the class. Additionally, groups were responsible for cleaning and returning all equipment to designated storage areas.

Supplemental reading materials covering hydrologic conditions, wetland classifications, negative effects on water quality from wetlands, mining, environmental impacts, and climatic shifts affecting groundwater demand and recharge were incorporated. Computational resources such as 3PE (Beljin 2015) and Bouwer-Rice slug USGS Excel workbooks (USGS 2004) were utilized to analyze data. Soil characteristics and classification were determined through samples collected from auguring, using the USDA Munsell soil color comparisons and the USDA Excel soil calculator (Vanlear 2023).

Results

At the end of the semester, each group prepared a final report. Utilizing an academic journal-like template, groups were given discussion topics and questions, such as descriptions of soil composition, observed parameter changes, and analyses of the overall hydraulic flow within the study area, to guide their reports. The following are excerpts from the student's final reports, accompanied by relevant supporting graphs and images.

Discussion of Soil Composition of West Run from Team D.A.:

The variety in terrain and environmental factors within the West Run site caused differences in the observed soil composition, dependent on where the soil samples for analysis were taken. Two new wells were augured during this semester, CJ04 and DA03. CJ04 is in the agricultural farmland area while DA03 is located next to the West Run Stream near the road. Bags of soil were collected as the auger filled until a satisfactory depth was reached to perform further hydrologic tests such as slugging.

The DA03 well's proximity to the road and lower elevation, adjacent to the West Run Stream, caused it to experience a combination of AMD and urban runoff environmental factors. The soil analysis of the DA03 followed a typical pattern of the environmental factors experienced in the area. The soil samples taken at ground level were made of silt clay, at 2–3 ft (0.6–0.9 m) depth were sand, and at deeper depths (3–5 ft: 0.9–1.5 m) of the well became a combination of silty sand to sand. …

The CJ04 well was on an incline within a corn field. Overturning of topsoil prevents the formation of clay unlike what was observed in the DA03 well. All the soil analyzed within the construction of CJ04 was sand both at the top and the bottom of the well with one sample in the middle showing as clay, seen in Fig. 3 shows the overall soil compositions for DA03 and

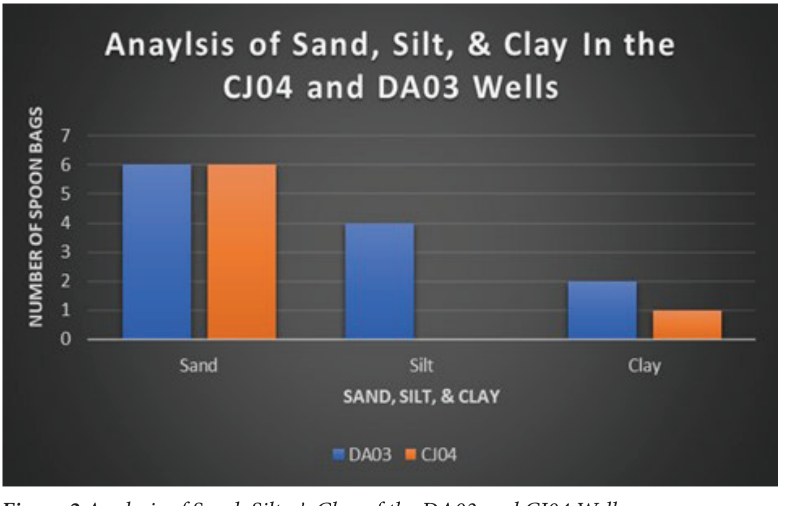

***Figure 2** Analysis of Sand, Silt, & Clay of the DA03 and CJ04 Wells*

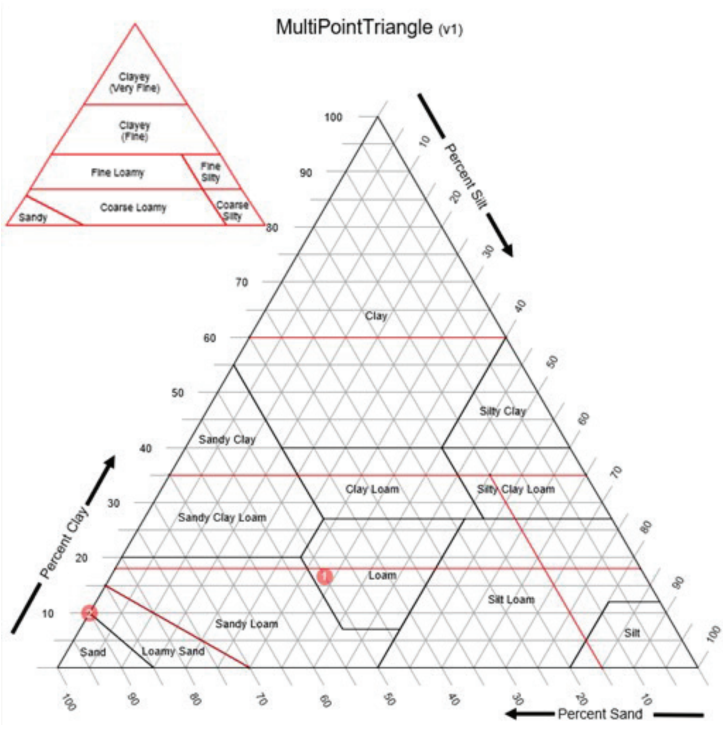

Figure 3 Soil Composition of the DA03 and CJ04 Wells

CJ04, comprising their estimated percentages of sand, silt, and clay. DA03 has more clay and silt than CJ04 and its soil texture is calculated to be Loam. CJ04 has no silt and almost all sand, with some clay present, and is assessed as Loamy Sand.

Portion of Discussion of Ecology from Final Report in West Run by Team CJ:

Moving downstream to the next area of interest is a line of wells adjacent to the stream in a wetland area. This wetland area is in stark contrast to the before-mentioned wetland area that resembled a bog. While the prior area had shrubby grasses and sphagnum moss, this area contains an abundance of cattails and tall grasses along with blackberry vines albeit the populations are sparse. This area is much better suited to support a wide variety of flora. The pH in this area is much closer to neutral than in the other. There are still contaminants present in the water, but they are much lower. The abundance of foliage can trap sediments funneled towards it from the surrounding hillsides. It also traps sediments during times that the stream overflows its banks. This is confirmed by the presence of foliage? found deep in the ground during the process of drilling new wells. This area works as a filter and sediment absorber for the west run stream.

The final area for flora examination is the river and banks adjacent to the wells and wetlands. This area is experiencing a large amount of erosion in its banks partly due to the lack of root structure in the banks to hold them in place. Tall grasses and trees can be found growing above the stream banks, but they terminate at the bank. The water still lacks algae or any other aquatic plant life. Though the conditions are less acidic by this point along the stream they are still outside of what is needed for plants to take hold. The lack of these plants prevents the slowdown of the water and causes it to become faster-flowing than it should be. This is another reason for the excessive erosion along this section.

Discussion of local clay types and hydrologic flow condition of West Run by Team S.T.E.M.:

The lithology of the given areas also plays a pivotal role in determining hydraulic flow. Clay is consistently found in all 3 Zones. Both vermiculite and bentonite reside in West Run which both expand as silicas in the presence of water. An alternating pattern of clay and sand contributes to the flow in both Zones 1 and 2, which subsequently affects the poor drainage basin of Zone 3. One differing factor from Zone 1 to Zone 2 is the presence of copious amounts of Mica found in Zone 2.

Zone 1 has consistently drier soil and subsequently has a slow hydraulic conductivity. Zone 2 has varied results depending on which well is being observed. Well C.J.01 which is located closer to Zone 1 has a fast hydraulic flow, which varies from C.J.02, located closer to Zone 3, which is evidently slower.

As for Zone 3, the hydraulic flow is much more complex to view due to the overlying environment factor of the creek located adjacent to our well systems. This area is oversaturated resulting in a wetland. The mere fact of water seeping up from the ground with any given pressure further complicates data derived from our wells. The hydraulic flow in Zone 3 is slow as there is no unoccupied room for the water to flow out of our wells.

Discussion from S.T.E.M. of overall waterflow in the West Run Study Area:

It's important to grasp hydraulic conductivity, hydraulic gradient, and groundwater velocity, as all three play a key role in understanding the movement of water, its flow patterns and water quality over time. Take West Run again as an example, with its surrounding farms and empty mines. Groundwater velocity is a critical parameter for following the pace of contaminants such as pesticides and AMD in groundwater, and how quickly they can spread downstream. Hydraulic conductivity, and the availability of optimal pore size and distribution help us understand how pollutants will be transmitted underground, through what materials, in our case most likely sandstone. And lastly, hydraulic gradient determines the path of least resistance for our flow and its possible contaminants, through cracks, fissures, and conduits. All these factors play a role in how pollutants flow from our wetland area to the West Run stream and the eventual Mon River. As proven in our Fig. 4, we have a Vector Inspector Graph to visually show flow initially moving down towards the West Run.

This direction of the flow in the area represents the importance of which AMD follows surface flow water of the West Run running westward, while groundwater pollutants flow south towards the stream itself (fig 4).

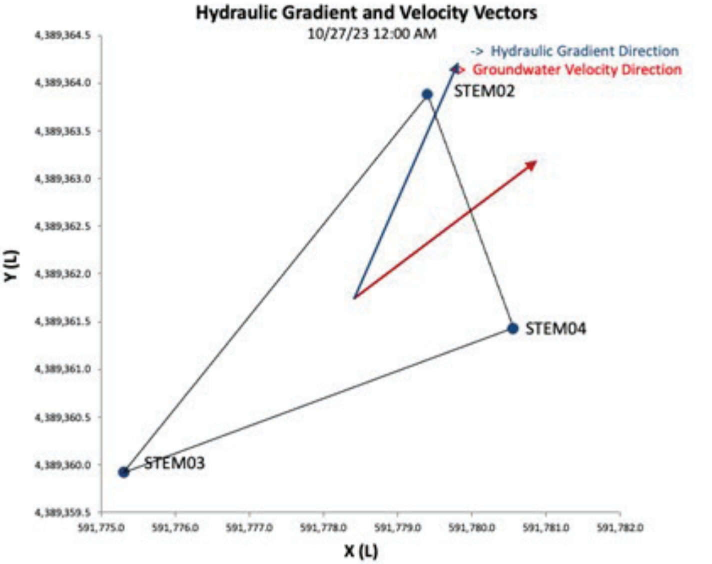

Figure 4 *Hydraulic Gradient and Velocity Vectors indicating direction of flow*

Conclusion and Future Recommendations

Class engagement, morale and quality of work submitted were well above expectations for this course. Each group experienced uncomfortable weather conditions in the field, being exposed to hot and humid bug filled days to the shift of icy rain at the end, and a true field camaraderie was developed amongst the class. This bond seemed to enhance the learning environment and extended into their efforts to help each other in other aspects of the course. Course evaluations showed that fieldwork was the highlight of the course, with it being the top ranked component of the course.

Future efforts to develop this course include more speakers to meet us in the field to discuss their areas of expertise, to allow students to interact more with professionals and understand the job opportunities available to them.

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