Mitigation in artesian conditions;

Abandoned coal mine presents unique challenges

by William Gleason, Editor

Figure 1

The town of Glenrock, WY was built on top of 87 ha (217 acres) of underground coal mines.

Mining roots run deep in Glenrock, WY, a town that was founded in part, because of the coal mining that began in the late 1800s. But that rich history also now threatens large parts of the town that were built over the top of the mines.

Like many towns in the Western United States, mining is a proud part of the historical fabric and heritage of the town, but the legacy issues from past mining activities continue to present challenges to modern-day engineers.

In the case of Glenrock, a small town about 40 km (25 miles) east of Casper, it is flooding from a century of water that has accumulated in the down geologic dip of the furthest northeastern extent of 87 ha (217 acres) of mine workings that has made the town susceptible to sinkholes and other issues (Fig. 1).

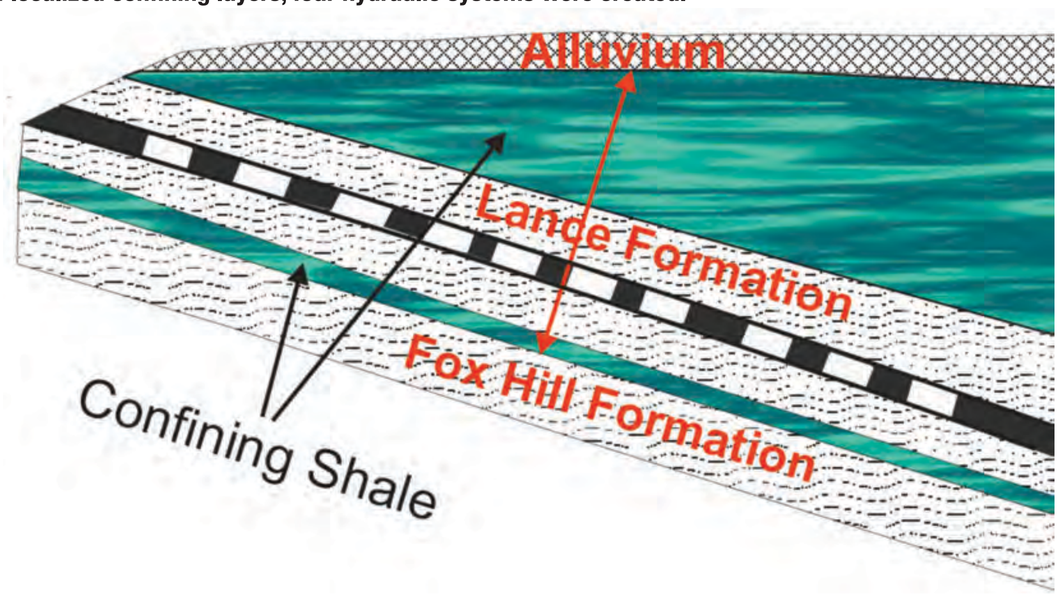
Full commercial coal mining production began in Glenrock in 1887 during the development of the Fremont, Elkhorn and Missouri Valley railway. Due to poor overlying roof rock and continuous flooding within Glenrock, Mines No. 1 and 2 were fully closed in 1909. During its history, an estimated 87 ha (217 acres) were mined with 50 to 60 percent extraction ratio within the eastern town limits through room-and-pillar mining. It is estimated that the mines produced 22 kt/a (25,000 stpy) during their lifetime. A century later, the water pressure built up in the northeastern most portion of the mine has created serious concerns for residents.

In 2016, the Wyoming Department of Environmental Quality's Abandoned Mine Lands Divisions (AML) investigated a number of subsidence events in the town including sinkholes following heavy precipitation. The AML investigations confirmed that most events were related to the previous mining in the area.

Mitigation efforts on the mines were done in the 1980s and 1990s, but the problems in the town and in a nearby subdivision persisted,

Figure 2

Because of localized confining layers, four hydraulic systems were created.



leading the AML to search for alternative solutions.

The AML hired Denver, CO-based Brierley Associates to investigate the area and to conduct a pilot program. David Hibbard, an engineering geologist, and Mohamed Gamal, Ph.D. professional engineer with Brierley Associates led the pilot program.

The purpose of the program was to test the feasibility of mitigation under artesian conditions within a heavily developed suburb of the town.

Hibbard explained that the mines had originally shut down because of flooding and roof-stability issues. And it didn't take long for Hibbard and Gamal to realize that the project would be unlike any other they had encountered during their careers.

The team from Brierley and Associates drilled its first exploration holes in the fall of 2018 and found that there were a lot of voids and rubblized material in the mine despite the previous mitigation efforts that used a viscous grout. The Brierley team devised an alternative plan for the reclamation project.

Brierley Associates planned to utilize a high-mobility, multistaged grouting technique to penetrate into the often rubblized mined interval. The multistaged technique entailed not just backfilling the voids within the mine interval with grout but also filling all voids and cracks in the overburden rock. In the past, the mitigation was limited to only the mine interval leaving void space in the overburden unmitigated. Over time, these voids continue to propagate up, causing subsidence due to continuous degradation of the weakly cemented rock by flowing ground water and downward percolation, Hibbard said.

In June 2019, the first unique problem arose when the team tested grouting techniques in artesian conditions by injecting grout at about 200 lbs/in. About 200 m (650 ft) from the injection point water was expelled through a crack in the asphalt.

The town's director of public works was the first to see the water in the street and quickly notified the team.

"We found that water extended far beyond the point of injection," said Hibbard. "We expected to have water displacement within the formation and the mine interval, but we did not expect it to be that far away."

Gamal said that was a clear indication of the communication of the water that was in the mines. Upon further exploration, the team determined that it was working with three aquifers in the mine, each with different transmissive conditions. (Fig. 2)

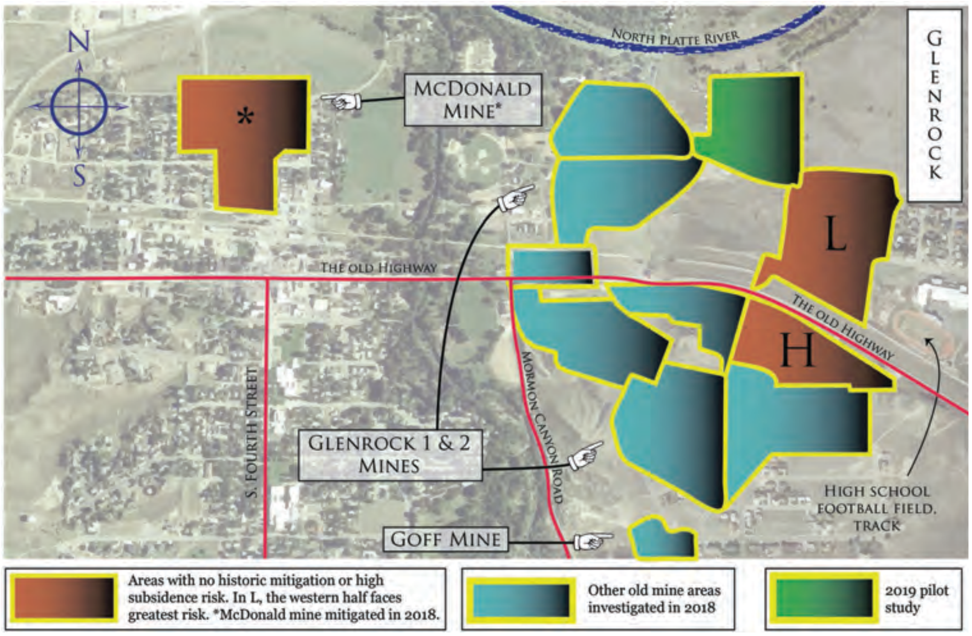
"We had to figure out how to create an equilibrium underground, because any time we injected grout, we were displacing water and leaving a void. It was definitely not a normal situation," Hibbard said.

Gamal explained that the confined aquifer was artifically created. The water acts as ground support and therefore, it could not be pushed out without having something else to take its place. Dewatering of the mine could have lead to serious subsidence issues.

"This area is in a valley and it is surrounded by relatively high hills, so what happened is eventually the mine began to act as a man-made aquifer," explained Gamal. "The water would collect into that mine at the lowest spot and eventually you will get the head of the water. Once you punch a hole, the water will come all the way up, 61 m (200 ft) to the ground surface.

Figure 3

Areas L and H will be mitigated using the same techniques used in the pilot program.



the head pressure has been seen as high as 1,135 L/m (300 gpm). Eventually what happens, because the water is under high pressure, it will find its way through joints, cracks and abandoned exploratory boreholes..."

"We had to get a handle on the hydrogeology, and what we found was that each aquifer had radically different hydrogeologic values," Hibbard said. "Our primary focus was on the one in the mine."

To alleviate the head water pressure the team installed a series of discharge wells that would help create an equilibrium within the mine. The team installed eight monitoring wells in the pilot area and a total of 23 across the town. About 100 proposed injections for boring were drilled, and a PVC pipe was trenched to an existing retaining pond to collect water. Two wells were equipped with a valve to release pressure when needed.

"The wells were key for us, we were able to monitor them 24/7. We trenched a 17.8 cm (7 in.) PVC pipe underground to the pond and had a valve on that so we open and close any time we wanted.

"One of the many challenges faced with historic underground coal mining is locally altered groundwater regimes creating preferred flow paths for water to move between the upper and lower portions of the Lance Formation (a water-bearing rock formation, averaging 2.1 m (7 ft) of mined coal thickness). Within this extracted seam, man-made confined aquifer conditions were inadvertently created by mining the coal and have acted as an underground reservoir for water to freely transmit down-gradient," Hibbard said. "In addition, it was hypothesized that permeation rates within the vadose zone have been accelerated by mine collapse and degradation of the overbearing rock loosening and the existing weakly cemented rock fabric. This, in addition to localized seasonal run-off and precipitation, has produced springs down-gradient as well as artesian conditions measuring up to 1,324 L/m (300 gpm) within the confined artificial aquifer."

To create the proper equilibrium, the team went with three different mixes of grout. The condition of the mine dicated the type of grout viscosity. To contain the grout or create a barrier grout, a low-mobility grout was used. In highly rubbelized areas a high-mobility grout that has the potential to permeate into the soft rock was used. Importantly, the grout is heavier than the water and can replace the water.

The grout that was used filled the rubblized voids and performed as it was designed.

In all, the team was on site for 100 days and grouted 4,975 yd^3 (134,325 cu ft) in the pilot program. The pilot program was considered a success and the Brierley team .expects to return to Glenrock in 2020 to mitigate the adjacent sub-division affected by the artesian conditions (Fig. 3)."

Among the challenges will be obtaining permission to work from property owners. According to the *Glenrock Independent*, AML has also changed the way it gains consent from property owners prior to investigation and grouting. In the past, AML had a 30 m (100-ft) rule, where they wouldn't do anything within 30 m (100 ft) of a nonconsenting party. That causes problems though, because it can lead to blind spots in AML's knowledge when the nonconsenting property owner's land overlaps with a consenter's land. The new approach will allow AML to operate closer to nonconsenters' property boundaries.

Hibbard explained that in order for mitigation to be successful, it is important that homeowners give consent. Without consent, Brierley will only be able to mitigate isolated pockets of voids, which could potentially increase risk to the adjacent homes. ■