

THE American Surveyor

A FOOT IN THE PAST... AN EYE TO THE FUTURE

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DESCENDING TO THE CHALLENGING

Spatial Imaging proves to be
the **right tool** for a **mine survey**

In one sense, it was an exceptionally straightforward job: all that Illinois' V3 Companies was being asked to do was survey a mostly straight, 1,600-foot long, limestone quarry tunnel. Miners call it the decline, and it drops 350 feet to "the bench," a vast mined space with a 65-foot tall ceiling supported by pillars of stone with 25-foot by 50-foot footprints.

The challenging details added up, however, and Mining International's POWC limestone mine in Joliet, Illinois, turned into one of the more difficult and rewarding projects in the firm's portfolio. Overcoming darkness, Mine Safety and Health Administration (MSHA) permits, and transport issues, V3 Project Manager Grant Van Bortel and crew chiefs Steve Arnold and Harry Sulek successfully completed a project that easily could have gone wrong.

By highway or train standards, the tunnel's cross section is larger than normal. To accommodate 40-ton dump trucks, the

tunnel is approximately 25 feet high and 20 feet wide, and the crushed limestone floor is scraped daily to keep things smooth.

As originally conceived, the decline was intended solely for trucks bringing rock rubble to the surface for crushing. But as underground levels and galleries were rapidly expanded by blasting, it made more economic sense to build a crushing plant *in* the mine and use a conveyor to haul crushed rock to the surface. While huge by most standards, the tunnel was just wide enough for existing traffic. So the conveyor system—which would normally be supported by tower legs—would have to hang from the ceiling to be out of the way. In addition, since truck traffic is the quarry's economic pipeline—at least until the conveyor is up and running—disruptions had to be kept to a minimum. To accomplish this, conveyor sections would be fabricated offsite and quickly bolted into place, which meant an accurate survey of the entire decline was needed, since gentle undulations in the tunnel's course had to be accommodated by conveyor designers.

>> By Craig R. Dylan



Steve Arnold, V3 Crew Chief, sets up a Trimble VX Spatial Station near the middle of the decline to establish primary control for use in scanning and layout.



Ramp looking towards the “Limelight” or decline entrance.

On the decline looking down towards the sump (halfway point to the “bench”). Steve Arnold continues setting control.

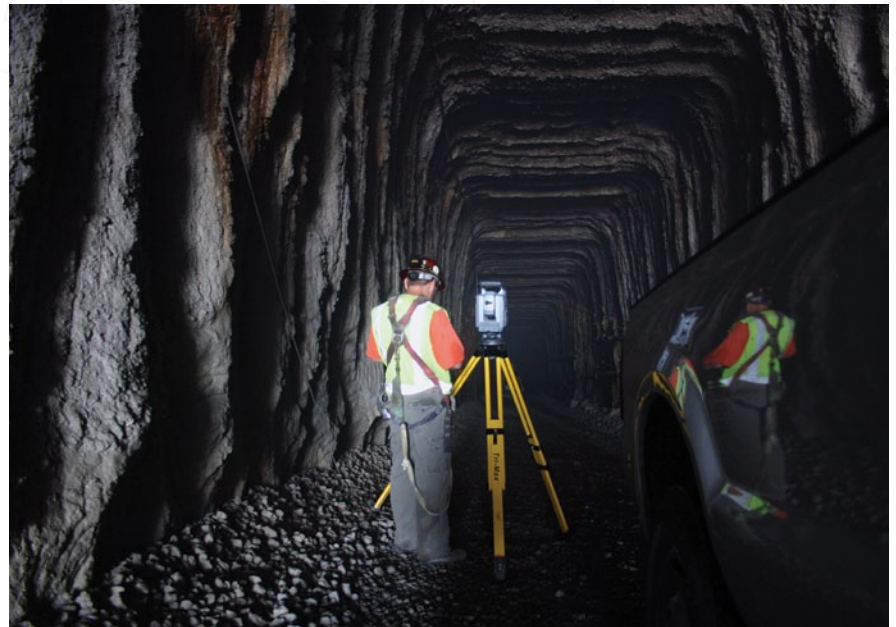
“If the decline was like conduit with straight edges, surveying wouldn’t be necessary,” explains Van Bortel, V3’s Survey Technology Manager. “But Mother Earth has soft and hard spots, so the tunnel bows in and out, and the owners couldn’t afford having the steel in the decline come to a point where the wall bulged out or the ceiling dipped, causing installation delays.”

V3 was hired to provide an accurate 3D model, cross sections and a profile of the tunnel and bench area where the crusher would ultimately be positioned and to lay out bolt holes for the conveyor system after design. Ultimately, the project involved two 3D scanners, GNSS equipment, homemade control monuments, a man lift, miners’ lamps, upside-down prism poles, and a variety of other equipment that turned out to be essential for working underground.

Control

To set up a topside control network, V3 used Trimble R8 GNSS receivers and Precision Midwest’s VRS Network. “It’s a property we’d never been on before,” explains Van Bortel, “and we always make sure we’re tied into the property accurately. So, using VRS, we collected property corners, local bench marks, and we got on State Plane coordinates.”

V3 took advantage of Trimble’s Connected Site™ solutions by using the same Trimble TSC2™ controllers to run the R8 receivers and the Trimble VX™ Spatial Station; the VX was used to extend control and layout bolt holes underground. “It’s simpler to have all these tools connected,” says Van Bortel, “using the same controller on our scanners, total stations and receivers makes life easier and lessens the need to move



“...this is what surveyors do— they master the intricacies of a particular piece of ground and describe it for others.”

control files and linked layout information between multiple controllers.”

After the control network was established on the surface, it was extended to the “ramp area,” a carved-out entryway with limestone walls about 55 feet high, and then to the decline entrance, known onsite as the “limelight.”

Control in the actual tunnel required additional planning for use by the scanners. To quickly get established and locate a few key locations, V3 first tried setting spikes in the decline’s crushed-

gravel floor, but that control didn’t survive—truck traffic and back dragging (to smooth the roadway) moved or pulled out spikes.

Crews then tried setting spikes in the tunnel walls. Tunnel walls were covered with three to six inches of shotcrete (mortar or concrete that is conveyed through a hose and pneumatically projected at high velocity onto a surface) and a hammer drill was used to make holes in which steel spikes were set and epoxied into place. “Some areas in shale



Grant Van Bortel, V3 Technology Manager, aboard a manlift, using an inverted prism pole staking out bolt locations on the ceiling of the decline in preparation for the conveyor installation.

Even with spikes in the wall, there was one unpleasant surprise; while working in the “bench” area, crews had been using control set at head height, only to return the next week and discover that the floor level had changed—and that the previous week’s control was now 35 feet up the wall! It seems that this part of the bench was being prepped for installation of the crusher, and miners thought nothing of filling a 500-foot by 75-foot space with 40-feet of crushed limestone in order to get ceiling access for a vertical drilling and bolting rig—that’s a half of a million cubic feet of rock being used as a temporary step ladder.

Spatial Imaging

Conventional total station topographic surveying was quickly ruled out due to 25-foot tunnel heights. Even reflectorless total station work would have been difficult since the tunnel was completely dark, since using lights to locate the shots that would accurately convey the tunnel’s gentle undulations would have been laborious. Clearly, the tunnel survey was a job for a scanner. Two scanners, in fact.

The tunnel isn’t simply a long tube. It descends 800 feet away from the entrance to a sump—basically a large carved-out basin where water collects before pumping—levels out for 20 feet, and then descends another 800 feet further in and down to the “bench” and takes a hard right to a mined area that is 65 feet high, with 75-foot-wide travel lanes running between rock pillars with a 25-foot by 50-foot footprint. A Trimble VX Spatial Station, run by the same TSC2 controllers as the GNSS receivers, was used for control work and to scan in tight areas, and a Trimble GX™ 3D Scanner, controlled by laptop and Trimble’s PointScape™ software, was used for the bulk of the tunnel and pillars.

For a change, large data files were not an issue on this scanning job. The GX was set to scan at half-foot intervals—“We’re scanning rock, after all,” Van Bortel points out—and data gathered for the shaft came to a relatively modest 45 megabytes. And rather than worrying about registration, V3 uses the GX’s survey workflow methodology, setting



Spike set in wall with epoxy glue and adhesive target used for control. This method was later replaced with threaded bolts and spin- on prisms.

seams were like butter, and in other areas we had to work the drill for a longer time,” says Van Bortel, but eventually adequate control was in place. He looked at manufactured marker systems but, believing they were too expensive, ended up just putting adhesive reflective targets on the head of the spikes during the initial survey. Since there was never a physical point to occupy on the tunnel floor, the points were used for resections

and to confirm scan registration on the otherwise featureless tunnel walls.

Later, during layout, V3 had a more flexible control solution that entailed the same process of drilling into the tunnel walls. Instead of spikes, however, threaded rods were installed so that prisms could be screwed on and turned as needed to face the instruments. That way, “the focal point of the prism became our control point,” he says.



Point Cloud of decline and bench area in background created with Trimble GX 3D Scanner and Trimble RealWorks Survey software.

up and getting on basis as with a total station, and then scanning.

“We *always* set up our control network first, and occupy points,” says Van Bortel. This way, crews trained in conventional field techniques can leave the site with strong confidence that they have accurate data gathered.

V3 turned over the point cloud to designers, but also provided a profile of the decline showing ceiling undula-

tions, and cross sections showing wall locations at regular intervals. The client was very happy with the product, and there have been no problems with conveyor installation with respect to the survey data. In fact, the scanning was exceptionally smooth from start to finish, and rather unremarkable as such work goes. It was getting the scanners in place, and ready to work, that proved to be a challenge.

Challenges

Working underground in total darkness is an unsettling experience, and Van Bortel says it occasionally “gets to you,” which was confirmed by the rest of the crew. “We were on the site for ten days or so and a third of the way through the project I was okay with being in the dark and below ground all day, but on the first trip down I kind of clung to the truck’s door handle. We were in areas with no lights at all, just our miners’ hats, and if the hat lamps go out it’s like being in a closet with the door closed—pitch black and your eyes don’t adjust.”

Curiously, height and exposure were also issues. The mine’s high ceilings required the use of a man lift (boom truck), and we were sometimes 45 feet or more above the ground, in dark caverns, when marking out bolt holes in the ceiling, according to Van Bortel.

V3 Companies is MSHA Part 48 certified, meaning onsite crew members have completed 40-hour courses qualifying them to work underground. In addition, every V3 employee working on the project went through site-specific orientation, and there were daily reminders that mines can be dangerous places. For a



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day's work, crew members were required to don miners' hats with five-pound battery packs, and personal carbon monoxide ventilators. The ventilators, which are like snorkels with silicone mouthpieces, have the reputation of heating up when pressed into service, so much so that the mouthpieces have melted onto people's lips, a welcomed inconvenience over not making it back to the surface.

"Strong boxes," which store telephones and food for use by anyone trapped in cave-ins, are deployed around the site. MSHA regulations also forbid the use of non-diesel engines in mines, which ruled out the use of generators, one method V3 uses to power their scanners. Instead, the company rented a diesel truck to carry around a set of large batteries and other equipment—the truck's headlights also provided supplemental light at times.

Layout

Marking out bolt holes in the decline ceiling posed a final challenge—how does one mark holes in the dark, 25 feet overhead? V3's team decided to "reverse" the usual order of things.

"We fashioned an inverted rod: we flipped the bubble over and replumbed

the rod, then strapped a flashlight on the rod so we could see the bubble—and since the bubble motion was reversed we had to relearn years of experience," said Van Bortel. "We also attached the TSC2 bracket on upside down." Using the VX and a reversed rod, one man would locate the bolt location on the ceiling and a second man would drill a pilot hole and spray it with paint—"regular spray paint, not upside down marking paint that surveyors typically use," Van Bortel notes with amusement—since, for a change, the can needed to spray right side up.

Once the points were marked, mine crews drilled deeper holes and installed octagonal bolts in solid rock often up to ten feet in length, which would ultimately support the conveyor being installed. Time pressure was intense throughout, since daily blasts below meant the mine had to be cleared, and 40-ton dump trucks were on hold during every locate and drill.

Descending to the Challenge

V3 has been scanning for almost two years, and just *using* scanners is no longer an issue: clients are getting used to the data, and the company has long

since worked out field and office issues. Still, it's new technology and using new technology in new situations is bound to be a learning experience. Every survey job looks easy from the office; but field conditions are often surprising, and actually extracting useful data from a highly variable world is the skill in which V3 Companies' surveyors excel.

On paper, accurately describing a long tunnel must not have looked *too* hard, but when confronting the actual difficulties presented by mine work—darkness, shifting rock floors, height and safety issues, and a bit of claustrophobia—a lot of assumptions made in the office had to be abandoned. But this is what surveyors *do*—they master the intricacies of a particular piece of ground and describe it for others. In the case of the Joliet limestone mine, V3 Companies had to take aboveground expertise and apply it *below* the surface. With the help of good tools and experienced field personnel, the firm was able to rise—or *descend?*—to the challenge. **A**

Craig Dylan is a freelancer with a land surveying background who specializes in writing for the AEC industry.

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