

Scanning the Impossible: Turkey Creek Diversion Tunnel

“How do we get in there?” This was the first question usually asked by the field personnel upon their first visit to the mouth of the Turkey Creek Diversion Tunnel. The standard response was generally recited to the rookie with a smirk: “You have to strap this equipment to your back, grab on to the rope, and repel down the rocky cliff to the ledge at the edge of the water. If you fall, try not to break the equipment or get it wet, because it’s very expensive.” Never mind personal injury.

The Turkey Creek Diversion Tunnel is very impressively constructed circa 1920 at 28 feet in diameter and 1,400 feet long, concrete-lined, and in desperate need of repair. Turkey Creek runs under Interstate 35 in Kansas and into

ser scanner, the answer was very simple: perform a 3D terrestrial lidar scan of the entire length of the tunnel. For underground, tunneling-type applications, there is currently no more accurate way to document the existing conditions of a tunnel. The laser scanner allows you to map the entire circumference of a tunnel at a very high accuracy and speed, producing a 3D cloud of point data. This data can then be used to study and produce cross sections at any point in the tunnel.

The Scanner

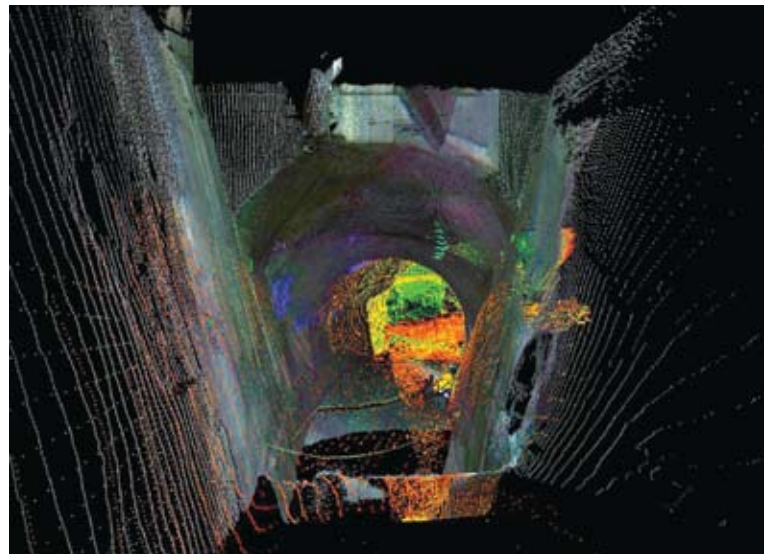
At first glance to a regular surveyor, a laser scanner seems to be more like magic than hardcore surveying equipment. But quite the contrary. Lidar (light intensity distance and ranging) technology

tor, it has the ability to acquire this data at a 6mm positional accuracy of each individual point, making it a very accurate piece of equipment for the current task at hand.

Additionally, the scanner has an on-board digital camera that captures low resolution digital photos. The photos are output, through a program inside the software, into a 360° x 270° panoramic digital photograph. This allows the technician the ability to look at photos when drafting as well as the point cloud. Also, the pixels from the photos can be mapped to the corresponding point in the point cloud, creating a photo realistic 3D model. This feature has been very helpful in minimizing questions about the site between the draftsman and the field personnel.



▲ This photo of the creek invert before construction shows the enormous amount of water the tunnel receives, as well as the difficulty crews faced getting equipment down the sides of the creek.



▲ This 3D point cloud was captured at the mouth of the tunnel, pre-construction.

New parcel creation using the COGO workflow with radial lines

the Kansas River. The nearly 100 years of diverting massive amounts of water from it (and several notable natural disasters) had taken its toll on the tunnel. As surveyors, our task was to document the existing conditions of the tunnel for determining the extent of damage and designing the much-needed repairs. But how?

Because BHC RHODES owned a la-

captures 3D survey-grade data points at a rate of up to 50,000 points per second and a range of up to 300 meters to a 90 percent reflective surface. The medium the scanner uses is a pulsed or time-of-flight laser. It uses two mirrors to direct the laser throughout its 360° x 270° field of view. And because the scanner we used, a Leica Scanstation, also possesses a survey-grade dual axis tilt compensa-

Scan Plan

First we needed to transfer our survey control from the surface of the tunnel to the invert. This was easier said than done. The terrain was treacherous and virtually untouched by anyone other than Mother Nature for nearly 100 years. We deployed global positioning systems (GPS) and robotic total stations to transfer control information into the invert of the tunnel. Concurrently a dewatering

effort was taking place by a contractor in the way of a coffer dam and installation of a 48" pipe to slow the flow and carry the water out of the invert in order to establish a working environment.

Once the invert had been dewatered, we sent our laser scanning team into the tunnel. Our plan was to traverse through the tunnel, making a setup approximately every 200 to 400 feet. We set our scanning resolution at 0.30 feet in the horizontal and 0.10 feet in the vertical at a range of 300 feet from the scanner. This made our scan time approximately 30 minutes per setup. Because of the terrain, the pre- and post-setup and moving to the next position took significantly longer than the actual scan time. The entire tunnel was scanned from six locations and required two field days to complete.

Office Processing

Because of the amount of data a scanner collects, you have to determine

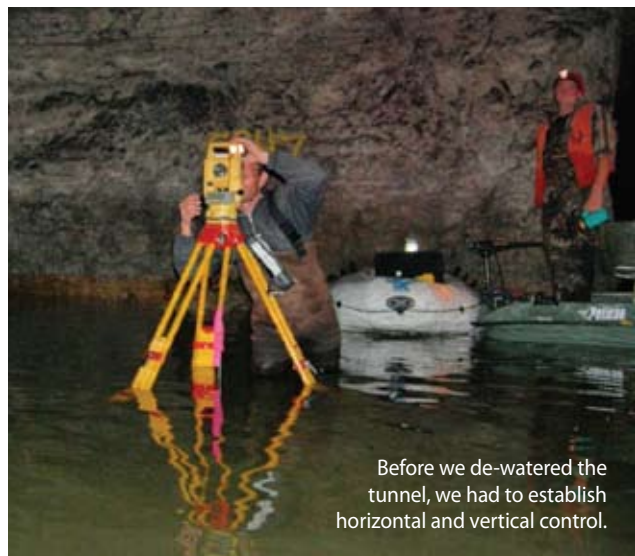
what information is important to the client and in what format. For the Turkey Creek Tunnel we provided the engineer two things: a 3D wireframe mesh of the tunnel in AutoCAD and 2D cross sections of the tunnel at regular intervals and at critical areas as specified by the engineer.

Using Leica Cyclone software we were able to produce 2D cross sections at a rate of approximately one cross section per hour. We produced between 40 and 50 cross sections. Because the entire tunnel had been scanned, it was very simple for us to create more cross sections at the request of the engineer. We did not have to make a field trip to acquire the data for the additional cross section; we simply mined the point cloud for the additional information right from our computer.

Once we produced the cross sections, the software made creating the 3D wireframe very simple. We then exported the wireframe to a CAD-compatible format

to the surveyor, designer, and client. A benefit to the project manager is that the field data collection is no longer up for interpretation among the engineer, surveyor, and client. I now have all of the data, whether I need it all or not. This allows me to later extract data from the point cloud from my office, rather than sending a field crew back to the field to collect more data. This has proven to be invaluable in the current climate as a method of reducing field costs through additional field visits.

As I look back on this project, it is sort of like looking back to the future. A once very difficult if not impossible surveying task is now being made not only possible, but very fast and accurate by way of 3D lidar technology. I believe that this technology can provide the tunneling industry with a new tool to document a project during all three phases of construction: preconstruction to determine existing conditions, during construction to document progress, and post-con-



Before we de-watered the tunnel, we had to establish horizontal and vertical control.



▲ Years of excess water events damaged the invert, as we saw when the tunnel was de-watered.



The scanner capturing 3D points inside the tunnel

and sent it to the engineer. This gave the engineer a to-scale, 3D wireframe to use in his design, allowing him to virtually put himself inside the tunnel.

As you can see, the scanner collects so much point data that we are able to produce multiple delivery types from the same data. We call this "data mining" for delivery. This is a huge ben-

efit to the surveyor, designer, and client. This can all be done with a laser scanner, which now allows us to measure the once unmeasurable aspects of a tunnel in the third dimension. ▼

ADAM HORN, L.S. is a project manager for BHC RHODES, a civil engineering and surveying firm based in Overland Park, Kansas.