Through this innovative project, the San Francisco Public Utilities Commission was able to avoid substantial expenses, traffic delays, and economic impacts to local businesses. It involved a compressed schedule, a need for precise data, and eight workdays spent in a tiny, damp, noisy, pipeline, and left our survey staff with stories that will be passed down in their families for many generations to come.

San Francisco Public Utilities Commission San Andreas Pipeline No. 2

The San Francisco Public Utilities Commission (SFPUC), in a proactive move to prepare their water infrastructure for potential seismic activity, planned five water pipeline improvement projects. One of the improvement projects focused on the San Andreas Pipeline No. 2 (SAPL2), part of the Hetch Hetchy regional drinking water system, built in 1929 and owned and operated by the City and County of San Francisco. Two segments of the SAPL2 were replaced, but subsequently, a portion of the pipeline in San Bruno that had not yet been replaced burst. Upon inspection, it was discovered that four additional segments of the original line in San Bruno had deteriorated, and the SAPL2 was taken out of service for repairs.

The SFPUC began to investigate whether a sliplining method could be used to save considerable time, money, road closures, and environmental impacts by inserting a new 48-inch outside-diameter pipeline into the existing 54-inch pipeline rather than excavating and replacing the entire 1,800-foot segment. With only outdated drawings and incomplete information on the dimensions and location of the pipeline, information was needed to determine the exact dimensions of the pipeline's interior and to locate any horizontal and vertical bends.

Towill, Inc. (Towill) was brought on by the design firm, Kennedy/Jenks Consultants (Kennedy/Jenks), to collect and analyze this information using integrated surveying and Static Terrestrial Laser Scanning (STLS) technologies. While this is all in a day's work for Towill's survey staff, this particular project would involve descending into a tiny opening, like the one pictured above, with our instruments for eight days where we would take more than 120 scans of the pipeline's interior in 10-foot segments.

Our project resulted in a spatially accurate as-built survey. We developed plan and profile drawings of the scanned alignment, including a "best fit" alignment of the existing pipe's centerline. This revealed critical differences from the existing as-built plans. Due to the pipe's ovality, which our survey and analysis accurately depicted, the proposed 48-inch outside diameter replacement pipeline would not be able to fit inside of the existing pipeline. We were able to model various pipe diameters and lengths, simulating the installation of the new pipe several times to find the best pipe size to accommodate this project. We ultimately determined that a 42-inch outside diameter replacement pipe would be the best size for the project.

The SFPUC SAPL2 project presented a number of challenges that are not typically encountered on your everyday survey project, including restrictive, sometimes hot, sometimes cold, damp, and noisy conditions that could be very dangerous without appropriate attention to health and safety.

The project's complexity, innovation, uniqueness, value to our profession, perception by the public, successful fulfillment of our client and the owner's needs, and social, economic, and sustainable considerations are presented to you on the following pages of this nomination for a prestigious MAPPS Geospatial Products and Services Excellence Award under Category E: Surveying/Field Data Collection.

Role of Entrant's Firm

Towill, Inc. served as the surveying and scanning consultant to the design firm, Kennedy/Jenks Consultants.

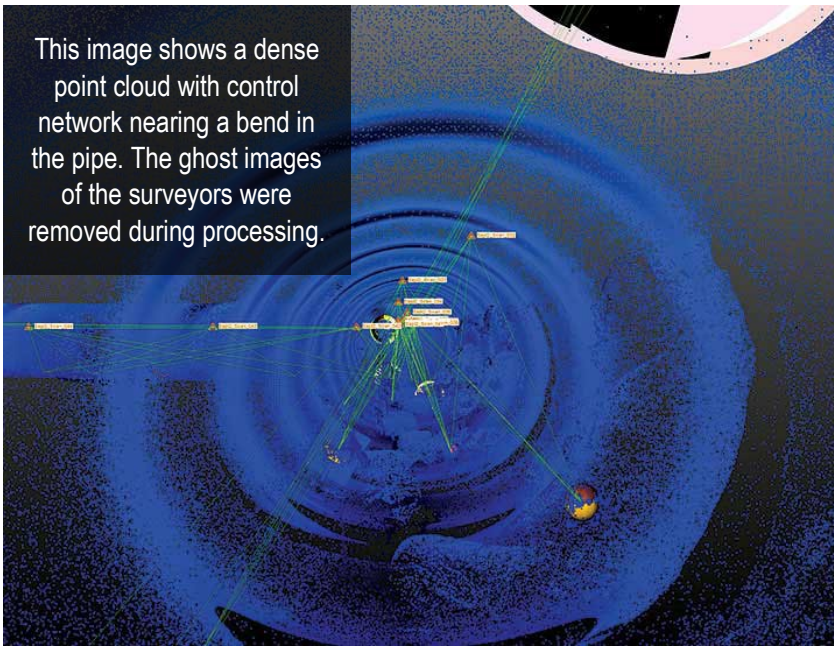
Role of Other Consultants

No other consultants were involved in this study portion of the SFPUC SAPL2 project.

Entrant's Contribution to the Project

Original or Innovative Application of Technologies and Techniques

The SFPUC SAPL2 project was not only technically complex, but it also presented many unique challenges. To determine whether sliplining was a viable option, Towill applied Light Detection and Ranging (LiDAR) technology in a small, confined pipeline and used it to come up with a solution that would result in tremendous benefits to the owner, client, and community.



This image shows a dense point cloud with control network nearing a bend in the pipe. The ghost images of the surveyors were removed during processing.

Our innovative approach involved utilizing STLS technology to create a very dense point cloud to serve as an as-built of the conditions inside of the pipe. From that, we were able to determine some important information in the office, such as the pipeline's horizontal and vertical alignments, ovality and roundness, and unknown horizontal and vertical deflections. Towill staff then modeled various pipe diameters and lengths, simulating the installation of the new pipe.

Unfortunately, the actual alignment of the pipeline did not match the SFPUC's existing plans, and through our data analysis, we discovered several potential issues that could have resulted in very expensive fixes and delays during construction that we were able to help mitigate during design.

The results of Towill's survey helped validate the number of pits that would be needed for the sliplining approach. With each pit coming in at about $100,000, fewer pits would mean substantial cost savings for the SFPUC. The data we gathered in our survey helped us to determine that one of the proposed pits was not needed, saving the owner not only money but time.

Before this project, the typical way of determining the correct pipe sizing for a sliplining project involved building a simple wooden cross of a particular diameter and having a person attempt to "walk" it down the middle of a pipeline to determine whether a new pipe of that size would fit.

When you push a cross of a certain size through a pipe, it is likely that important information will be missed, which can cause costly project impacts. For instance, subtle yet critical issues like an unexpected two or three percent bend in the horizontal alignment of the pipe would be very difficult to notice while hunched over in a dark pipe carrying a

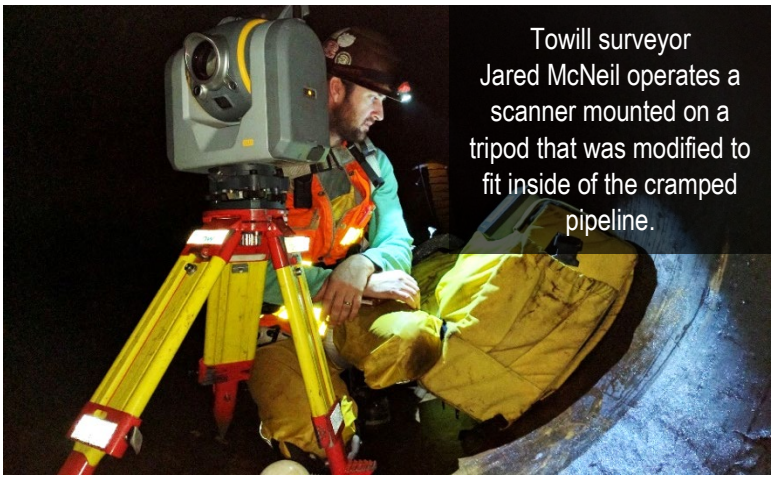
wooden cross. With our approach, we were able to very clearly identify issues on our computer screens from the comfort of the office. Using the STLS data, we were also able to look at multiple options without another site visit. This helped us provide valuable information about the pipeline's interior dimensions and features to the design engineer in a timely, reliable manner.

While technology is great, clients need deliverables that can be easily used and verified. On the SFPUC SAPL2 project, we provided the three-dimensional analysis in AutoCAD on horizontal coordinate and elevation systems that our client could use as part of their project. We added value by providing the deliverables in formats that were not too customized or proprietary, but instead very sharable and user-friendly.

This project demonstrates the use of science and technology as a cost-effective method that helps others in the profession to use sliplining techniques with greater confidence. With such precise data, there is less risk going into a sliplining project. Using this technique, we enable engineers to make better decisions and save time, money, and disruptions for clients and communities.

Future Value to the Geospatial Profession and Perception by the Public

We recently completed a second pipeline scanning project for the SFPUC. The agency is finding value in this efficient, innovative approach, and we anticipate that the SFPUC will continue to use this method in the future due to the SAPL2 project's success.



Towill surveyor Jared McNeil operates a scanner mounted on a tripod that was modified to fit inside of the cramped pipeline.

The work we did was especially challenging because the pipe was small—even smaller than shown on the existing plans. This type of project is much easier and safer in a larger tunnel, but when you get down to a 45-inch interior diameter pipe, it is a physically difficult job to do. Our field staff faced the challenge of maneuvering large, expensive surveying and scanning instruments through the small pipe, all while hunched over on their knees.

Towill's experience, workflow, and delivery of accurate as-built conditions on projects enables engineers and owners to make more informed decisions, reducing risk on projects and redefining geospatial thinking for the better. One of the SAPL2 project's major driving factors was that the SFPUC did not want to close and excavate two major roads. If the sliplining technique had not been possible, the project would have required a very traditional excavation, removal, and replacement of the pipeline, which would have been costly and inconvenient to the public. Our survey helped to confirm that the proposed sliplining technique could be accomplished effectively without road closures.

In terms of public image, many in our profession say that a great survey project is one that you never hear about afterwards. The public might not be aware of what was done here, and that is because they were able to continue using these public streets and major freeway on- and off-ramp while the replacement pipeline construction was in progress.

Many in our profession say that a great survey project is one that you never hear about afterwards. The public might not be aware of what was done here, and that is because they were able to continue using these public streets and major freeway on- and off-ramp while the replacement pipeline construction was in progress.

Social, Economic, and Sustainable

For every project, the SFPUC takes thorough measures to minimize social and economic impacts to the community. For this project, significant social and economic benefits were realized by virtually eliminating impacts on traffic. Our approach allowed the SFPUC to move forward with the project without having to

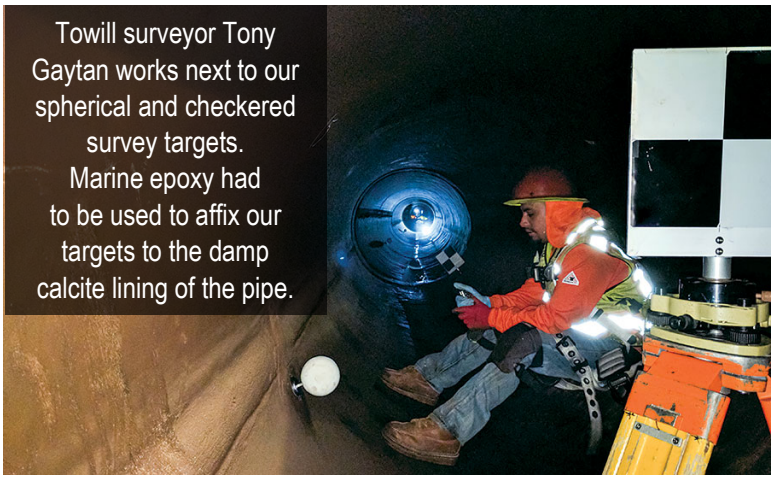
close any streets. This allowed businesses to remain open, enabled commuters to drive unimpeded to their jobs, and minimized inconvenience to the people who use these streets and this part of the highway as a part of their lives.

Eliminating the need to excavate the street also resulted in significant sustainable design benefits, as the client was able to use what already existed as a foundation for installing a new pipe that has better integrity using the very clever and minimally invasive sliplining technique. Going through a street is never a simple job. Streets are much more than a paved surface—they house extensive networks of underground utilities that can be extremely complicated and costly to work around and even more costly to move. Without the sliplining technique, working around these utilities would have added significant costs, delays, and potential complications to the project. Instead, we confirmed a design that would allow construction crews to push the replacement pipe right through the existing pipeline from 300 feet away while traffic continued above, uninterrupted. In addition, anytime excavation can be avoided, risks to the environment are minimized, adding an additional layer of benefits to the project.

As one of the main water transmission lines going into the City of San Francisco, the SAPL2's health and integrity is critical. This project allowed for a more efficiently scheduled, economical approach to restoring the system and plays a major role in the health and welfare of the public and environment.

Complexity

Towill's staff are accustomed to challenging projects, but the SAPL2 project took complexity to a new level.

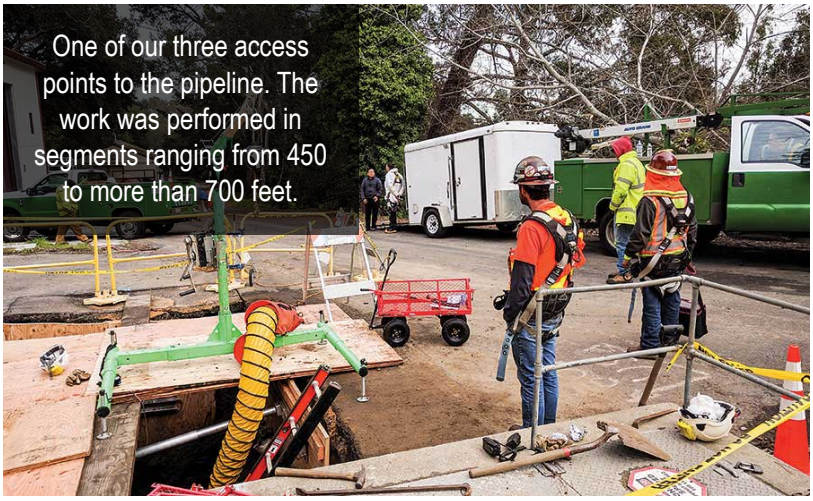


Towill surveyor Tony Gaytan works next to our spherical and checkered survey targets. Marine epoxy had to be used to affix our targets to the damp calcite lining of the pipe.

We first entered the pipe expecting a 48-inch diameter steel interior. Once we were inside, we discovered that the interior was even narrower than predicted, due to it being lined with two inches of calcite. This new information complicated our approach since we had planned to use magnets to affix our STLS control targets to the interior walls of the pipe, and with a calcite interior, that was no longer an option. We had to quickly come up with a different approach to get our magnetic control targets to stick to the sides of the pipes. On top of that, even in an empty water pipeline, conditions are damp, meaning traditional glue was not an option. We came up with an alternate solution to affix steel washers with high-grade marine epoxy to the interior of the pipe. Drying time was impacted by the wet conditions, but ultimately, this method worked to successfully affix the magnetic control targets to the steel washers. In addition, the pipe's interior was not truly circular; it was ovoid, as well as cramped. Furthermore, careful planning, flexibility, and cooperation were required for personnel to avoid being in the path of the scans as much as practical.

Towill's work on the project allowed the SFPUC and the engineer to understand the exact pipe size that could be fit into the existing pipe in such a way that significantly reduced the project's risk. The SFPUC needed this information to determine the existing pipeline's precise size and length.

Imagine, for instance, a trolley. You attach one pipe to the previous pipe and push it through. You discover that there is one place where the pipe was bent horizontally by four degrees. Next, you have to ask whether a series of 10-foot pipes can be maneuvered around this bend in the pipe to the point where it would reach the other pit. By meticulously measuring and analyzing the pipe's precise internal dimensions, we determined that 10-foot long by 42-inch diameter pipe segments would need to be used for construction of the first half of the pipe, as those pipe segments would be capable of making the bend at the angle point. After that, 20-foot sections of pipe would be sufficient to install the remainder of the pipe's length. This was a complex issue to solve and one where a wooden cross template would not have been capable of providing the necessary information. The project ended up working as planned. As the final 20-foot pipe was installed, the first 10-foot pipe reached the pit on the other side.


One of our three access points to the pipeline. The work was performed in segments ranging from 450 to more than 700 feet.

Adding further complexity to the project, there were safety considerations for all field activities. Substantial support from the project owner was provided. We used a four-person survey crew, and the SFPUC provided six safety support crew members. Our staff received confined entry space and lock-out/tag-out training. All safety requirements for a permitted confined space were met, including continuous air monitoring, forced air ventilation, safety monitors/attendants, and a confined-space rescue crew at the surface. Access was also particularly challenging because the entry points to the pipes were often very small, sometimes just a cut-out on the top of a pipe that we had to squeeze ourselves and our equipment through. With careful planning and adherence to the project requirements, all work was accomplished safely and without incident.

Towill is accustomed to clients asking for new and innovative approaches for unique projects. With experienced staff, proper planning, and communication with the client and owner, we were confident that we could meet the project's needs. But even with the most thorough of plans, there were complications as our work progressed. The project initially called for ten days of work inside the pipe, but that was shortened to eight. Ten-hour workdays were initially required due to schedule and access restrictions, which were then reduced to eight and then six due to health and safety precautions. Frequent breaks for our on-site survey personnel were necessary, and the team's hydration was important. The survey data needed to be accurate and complete as the pipeline would resume operation after our survey was complete. The nature and size of the pipeline itself was different than expected, making survey data collection even more challenging.

The project was complex to say the least, but Towill's staff enjoys the thrill of a challenge, and we are proud of the work we accomplished for Kennedy/Jenks and the SFPUC.

Successful Fulfillment of Client/Owner Needs

The success of this project was a direct result of planning and collaboration. We engaged with our client and the project owner to learn as much as we could about the project needs and to gain an understanding of the benefits and constraints of the sliplining system. We took the time to understand what was needed and to develop workflows to suit not only the project needs, but also the unique environment.

Frequent communication with the client and owner was required during our field work for access and safety purposes, and further engagement with our client was required to be sure the deliverables provided the answers they needed. We were able to provide answers to our client's questions regarding not only the diameter of replacement pipe that could be used, but also the segment lengths of the replacement pipe that could be successfully pushed through the existing pipe's bends.

We were successful in meeting our client's and the SFPUC's needs as we were able to provide precise data regarding the conditions inside of the pipe. The plans that were used to build the pipes 90 years ago did not accurately depict the current as-built conditions, and using them to design the project could have resulted in costly surprises during construction. Our dense survey data set showed the exact dimensions and conditions of the pipe and gave the client a solid level of confidence that a sliplining approach would work for this project.

Towill's work was performed in accordance with our $68,000 budget and the client's schedule. The client was very satisfied with Towill's work, and the SFPUC anticipates many future sliplining projects due to this project's success.