Trenchless TECHNOLOGY

SPECIAL REPORT
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CONDITION ASSESSMENT

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PROMOTING TECHNOLOGY IN THE UTILITY CONSTRUCTION INDUSTRY

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BY MIKE KEZDI

THE ART OF PLANNING

How Condition Assessment Improves Our Underground Infrastructure

There are millions of miles of underground pipelines in place throughout North America and much of that aging infrastructure needs repair or replacement.

Unfortunately, for many years, systems owners had an out-of-sight, out-of-mindmentality for these structures. Only addressing issues as they arose rather than taking a proactive approach. What this means is that the amount of repair and replacement that should be taking place is nowhere near what is taking place. Much of this has to do with lack of funding and a lack of people to do the work.

One of the steps that system owners are now taking as they change from reactive to proactive, is setting funding aside to start and maintain condition assessment programs. Through these programs, systems owners can precisely target dollars at the spots that need it the most.

To help readers get a better understanding of this important part of an overall system maintenance program, we've built this special report focusing on the condition assessment sector. I'd be remiss if I didn't thank our sponsors – Xylem, SewerAI, NASSCO and CUES – for making the report possible.

Contributing editor Bradley Kramer leads things off with a look at how the collapse of a 66-in. sanitary sewer was the impetus for Arlington, Texas's pivot to a proactive condition assessment and sewer maintenance program. Read more starting on Pg. 4.

John Higginbotham, P.E., PLS, with the Sangamon County Water Reclamation District in Springfield, Illinois, offers readers an overview of the district's proactive, map-driven approach to managing its collection system using GraniteNet, an asset management and decision support software. Read more starting on Pg. 8.

In the world of condition assessment of pipelines, standards are paramount to ensuring inspections are completed with a high level of confidence and in a consistent manner. In North America, the foremost standard for condition assessment of pipelines is NASSCO's Pipeline Assessment Certification Program (PACP). The primary purpose of PACP training and certification is to assure that all pipe system data is collected and coded in a consistent and reliable manner. It is the standard in North America. Find out more about NASSCO's PACP standards starting on Pg. 24.

Large-diameter pipelines have long service lives that can be greatly extended with data-driven management. Starting on Pg. 12, Alan Bair explores how pipeline owners can leverage data to reduce risk, manage costs, and maintain reliability across the asset lifecycle.

Over the last few years, many in the trenchless industry have taken note of the emergence of Artificial Intelligence-based (AI) computer vision tools for automatic identification of conditions in sewer inspection videos, and how this technology continues to be implemented on projects throughout North America. Eric Sullivan gives readers a look at how AI is being leveraged by the City of Houston, as well as the benefits of AI in creating more robust data sets for systems owners. Turn to Pg. 16 to read more.

Giving a more over-arching look at the trenchless industry's view of AI including for condition assessment of pipelines, Editor Sharon M. Bueno chatted with several companies either incorporating AI today or looking at its potential for the future. Her story starts on Pg. 20.

All-in-all, this report offers glimpse at what condition assessment is, how system owners are incorporating it into their everyday practices and what the future holds as we head more and more into the world of AI and machine learning.

CLOSING THOUGHTS

Trenchless Technology is the go-to resource for the North American trenchless industry. We rely on our readers to make this possible. To that end, whether you are a distributor, contractor, engineer or manufacturer, my door (well in this case email inbox) is always open. Feel free to reach out to me with news and story ideas or other ways in which we can improve the magazine.

I'd love to hear what you have in store for next year. Let's connect virtually whether it be Microsoft Teams, Google Meet or any of the other video conferencing applications. I am always available to chat about this growing, and ever-changing industry.

Cheers!

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REACTIVE TO PROACTIVE

How Arlington, Texas, Built a Condition Assessment Program One Piece at a Time

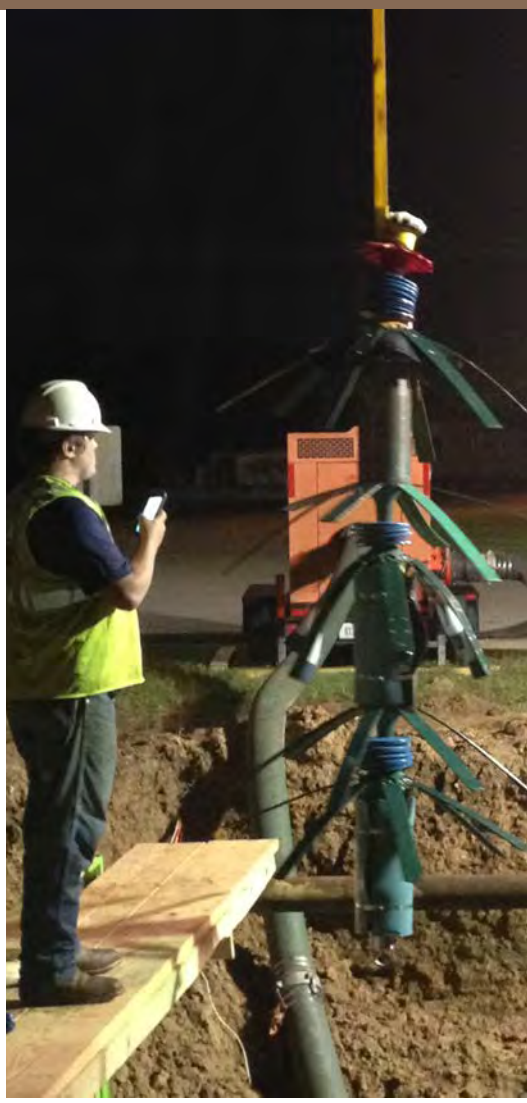
By Bradley Kramer, Contributing Staff Editor, *Trenchless Technology*

Sometimes a negative can turn into a positive. The City of Arlington, Texas, had a 33-year-old, 66-in. sanitary sewer main collapse in the spring of 2015. For civil engineers at the City, it illustrated what they'd been discussing for years — a need for thinking more proactively and data oriented about condition assessment then something as simple as the assets age.

"We had never really had a comprehensive condition assessment program," according to Robert Stanley, senior engineer, planning and asset management for Arlington Water Utilities, the city's water and sewer department. "That's what we're trying to do now."

In the past, Arlington field operations crews used technology such as CCTV and a scoring system to keep tabs on where problems existed. Then, engineers examined age, material or break history to determine where to focus replacement dollars in the city of about 400,000 residents. The push for a department-wide asset management program would require adjustments in both areas of the utility, and an appreciation of how the data could fuel better funding decisions.

Arlington was not alone. In the 2021 Report Card for America's Infrastructure, the ASCE said that in 2016, just 20 percent of all utilities had a robust asset management program in place to help prioritize their capital and operations/maintenance investments. That number increased somewhat in 2019 to about a third of



utilities, according to the ASCE.

Arlington Water Utilities began its current condition assessment program in 2016 with 1,250 miles of the sanitary sewer system, said Stanley, who has worked at Arlington Water Utilities for 18 years. Specifically, Arlington Water Utilities employed a RedZone multi-sensor inspection float to inspect 48 miles of large-diameter sanitary sewer.

Soon, its technology-based initiatives moved to the smaller sanitary sewer mains and water infrastructure as well, according to Michael Mosier, modeling engineer, planning and asset management for Arlington Water Utilities.

The ultimate goal is identifying the compromised pipe segments and replacing only those segments to maximize the useful life of the majority of the pipe still in good condition. The department employs a variety of tools to assess its system.

"The biggest one on the sewer side is CCTV. That's our bread and butter," Mosier says. "It gives us the best and clearest picture of our assets. We use a traditional pan/tilt/zoom (PTZ) camera, and lately we've had a lot of success with the panoramic cameras such as Envirosight Digisewer."

The panoramic view helps cut down on operator error and time in the field because it's not dependent on the operator to pan and zoom in on each defect.

"The operator in the field can just run the sewer, and the camera collects all the footage, showing the full circumference of the sewer, and then we can stitch it all together later in a laydown view," Mosier says. "Then we can take the footage back to the office and score it. It's faster in the field and allows for more consistent scoring in the office."

When Arlington started its condition assessment program, Mosier began scoring the CCTV in adherence to the NASSCO Pipeline Assessment Certification Program (PACP) standard. Following a standardized system helps the department better assess its infrastructure.

Stanley adds that training has eliminated subjectivity among the department's camera operators.

"Now, we have four people on staff

who are NASSCO PACP certified," Stanley says. "Our scoring is more consistent than it ever was."

The Utility has also began performing systemic assessments of all water distribution system prestressed concrete cylinder pipe using Pure Technologies electromagnetic tools.

"We're always looking around to what technology other people are adopting," Stanley says. "In Denton, Texas they have a successful program, and they shared with us using a jetter camera ensures an accurate clean and assessment. After the pipe is cleaned, you run the jetter camera through to make sure it was done thoroughly, and from the video collected we can also get a look at the condition of the pipe. You can't fully code it as you can with traditional CCTV inspection, but you get a general assessment."

That collaborative spirit has helped Arlington Water Utilities find success in other ways too, such as with managing its database.

SO MUCH DATA

One of the biggest challenges Arlington Water Utilities faces is managing the huge amount of data collected through its condition assessment program.

"We have a lot of data, and a lot of inspection tools use their own proprietary software," Stanley says.

The department found that different tools required different databases.

"We sometimes outsource inspection projects because we only have two CCTV trucks," Mosier says. "We bid a job using panoramic camera technology, but we ran into a barrier regarding contractors needing to purchase propriety software. Ultimately, we had to remove most of the panoramic scope from the project and fall back to traditional pan/tilt/zoom inspection. How we integrate the contactor's data with our own was another challenge.

The solution to compiling all the data the department was collecting into a one place was developing its own in-house database to avoid all the proprietary roadblocks that were causing an issue. The data was then pushed back to various other programs as needed.

Concerning viewing and storing the various sanitary sewer inspection data, the Arlington Water Utilities team visited with its counterpart in Fort Worth, Texas, and settled on the ITPipes software package.

"Of all the systems we looked at five or six years ago, that was the one that allowed us

to configure our database the way we wanted it," Stanley says.

PEOPLE AND FUNDING

The average age of Arlington's water and sewer system is about 33 years, Stanley says. The challenge Arlington Water Utilities faces is securing sufficient funding to rehabilitate or replace all the deficient water and sanitary sewer mains identified through the condition assessment program. The department is only able to renew about 1 percent of the system each year.

"Since we don't have the resources to get everything fixed at once, we have to triage. We have to figure out which areas are the worst because we only have funding for so many projects per year," Mosier said.

The condition assessment program helps the department pinpoint where renewal is needed most, Mosier adds.

Having a successful and proactive condition assessment program allows Arlington Water Utilities to narrow its focus, but also to show municipal leaders the value in providing funding for the department.

"By showing the importance of being proactive, we're tying that back into the level of service customers expect," Stanley says. "We hope to reduce that reactive mindset."

The more CCTV data the department can collect, the better Stanley and his team can focus its efforts and optimize their limited renewal dollars. With a more proactive approach to condition assessment, Arlington Water Utilities is showing the importance of providing funding to the department.

"What we're trying to build with our condition assessment program is present a clearer picture of what renewals are needed," Stanley says. "If we're going after more funding, we want hard data to back up our case. We have to show that we're not just going after more funding, but that we have these failing assets that we have to renew. We can't keep kicking the can down the road."

Bradley Kramer is a contributing editor to *Trenchless Technology*.

STREAMLINING ASSET INSPECTION IN THE CLOUD:

Improving Productivity and Leveraging Critical Data

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The Sangamon County Water Reclamation District (SCWRD) provides wastewater treatment for the City of Springfield, Illinois and surrounding communities.

As the Illinois State Capital, Springfield is known for a popular dish called a "horseshoe" consisting of an open face sandwich thoroughly smothered with fries and cheese sauce. A close second to the horseshoe, Springfield is also President Abraham Lincoln's hometown and the place of his burial at Lincoln's Tomb. Located approximately 190 miles southwest of Chicago in central Illinois, the District was organized in 1924 and provides wastewater treatment and disposal services to approximately 150,000 residents of Springfield and the surrounding area.

The District maintains approximately 280 miles of gravity sewer mains consisting of typical small 8-in. diameter mains to 16-ft diameter CSO lines and everything in between. The District also operates and maintains 37 pump stations within the collection system and low pressure sewer systems around Lake Springfield.

Since 2015, the District has taken a proactive, map-driven approach to managing its collection system using an asset management and decision support software platform from CUES, Inc. called GraniteNet.

"Over the years tracking collection system maintenance activities such as cleaning and CCTV had become inefficient due to the number of different paper forms, software solutions, and "in-house" applications we were using. We decided to find a data management solution that could transform our processes by being tightly integrated with our other strategic systems. We evaluated and selected GraniteNet from CUES."

The first step was integrating maps with our wastewater collection system asset layers between ESRI ArcGIS and GraniteNet so our inspection crew could easily orientate themselves and verify field data with our master data to ensure correct information was being collected on the proper assets. The bidirectional data exchange between ESRI and GraniteNet went live a few weeks after we purchased the modules from CUES and provided the CCTV crew with up-to-date information and helped to eliminate repetitive data entry, reducing errors and increasing efficiency in the field.

After several years of leveraging the benefits of GraniteNet integrated with ESRI, several things came together to push the District to take its investment in GraniteNet to the next level. A need for a robust and integrated CMMS, the ability to enable field, office, and remote workers, and a significant security breach directed focus toward upgrades and functionality improvements in several systems, included GraniteNet. The District desired to use web or "browser-based" applications to enable field, office, and remote workers to view, collect, share, run reports, create tasks and much more from virtually any device with a browser. The District imple-

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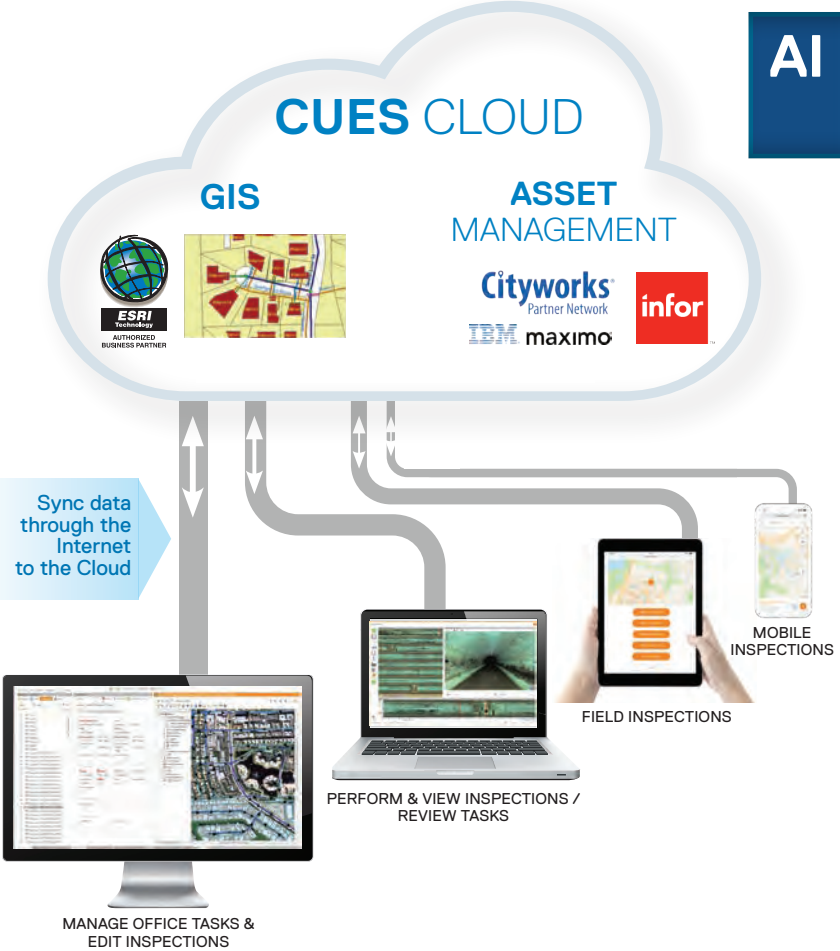

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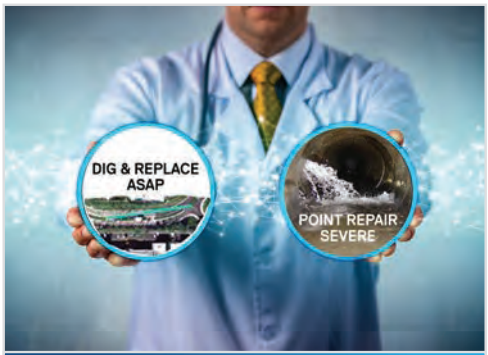

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CHALLENGE

STREAMLINE MULTIPLE ASSET INSPECTION PROCESSES – PAPER, SOFTWARE, "IN-HOUSE" APPLICATIONS

John Higginbotham, PE, PLS
Assistant District Engineer

"Over the years tracking collection system maintenance activities such as cleaning and CCTV had become inefficient due to the number of different paper forms, software solutions, and "in-house" applications we were using. We decided to find a data management solution that could transform our processes by being tightly integrated with our other strategic systems. We evaluated and selected GraniteNet from CUES."

mented Trimble's Cityworks Asset Management platform to create and track Work Orders. GraniteNet has certified integration modules with Cityworks so that each software product has bidirectional integration. Thus the District is completely synchronized with its ESRI maps, its Cityworks asset management software and its GraniteNet inspection and decision support applications.

With challenges from the pandemic necessitating remote workers to support critical infrastructure, the District evaluated and decided to extend its GraniteNet platform by acquiring a suite of tools called "GraniteNet Web". The solution is completely web-based and allows the District's users to easily access infrastructure data and maps from devices such as iPads, iPhones, Android devices, tablets, etc. The core application is called "WebOffice" and as the name indicates, it empowers managers, engineers, reviewers, etc. to log in from wherever they are to review statuses, watch video, create new projects, assign tasks and much more.

Included in the suite of applications is a tool called "WebSync" which uses internet connectivity to transmit encrypted inspection data and video wirelessly to the office or the Cloud. "It truly synchronizes our data instead of merely making a copy of it in a location such as Drop Box or Google Docs which requires a two-step process susceptible to human error." Whether synching new, incomplete inspection tasks out to the field trucks from the office or synching from the field back to the office, WebSync happens at the database level to ensure precise, up-to-the-hour statuses that do not require human intervention. If data transmission is interrupted due to connectivity issues, WebSync will re-initiate its session from where it left off and resume the transfer from that point when a suitable connection is obtained. "There's no need for lugging hard drives or carrying media. The guys simply finish their CCTV inspection, and the transfer begins automatically while they start a new inspection or pack up to move to the next location."

And the third tool that the District uses within GraniteNet Web is called "WebInspect" which is a browser-based SAAS inspection application that provides the District with out-of-the-box capability to perform inspections, collect information and track maintenance tasks on District assets. Using this out-of-the-box functionality, the District has expanded its collection system inspections to include manhole inspections in MACP format. Sewer mainline cleaning, root foaming, root cutting and tap cutting are also all tasked within WebInspect and can be completed by field workers from any internet connected device. "There's no software to install or maintain on any user devices to use GraniteNet WebInspect". Additionally, the CCTV inspections and the various mainline cleaning tasks are all stored in the GraniteNet system making CCTV inspection observations and videos available to maintenance crews and vice versa. This access to information enables workers, speeds data collection, provides insight to maintenance activities, and improves decision making.

CUES implementation specialists worked closely with the District to configure the Web solutions as the District required; and because Web applications can be located on-premise at the utility or up in the GraniteNet Cloud, the District decided to "lift and shift" the management of its Web infrastructure and secure storage to the GraniteNet Cloud, powered by AWS, as an annual service contract. There, up in the Cloud, all of the GraniteNet Web applications are secured using Amazon Security Groups with an Amazon Web Application Firewall (WAF). All data is backed up and server maintenance is included within the turnkey annual service from CUES.

SCWRD has implemented a truly forward-thinking Asset Management program that takes full advantage of automation technologies, security and real time, map-driven, task-oriented workflows for greater efficiency and productivity.

Forward thinking adoption of contemporary technologies have incrementally helped the District achieve an 'A' rated IDR bond rating which is supported by a growing, diverse and primarily residential customer base surrounding Sangamon County. Its operating cost burden is low yet the District has invested in information technology to maintain service levels and address both its combined sewer overflows (CSO) and its long-term control plan (LTCP) as required by the Illinois Environmental Protection Agency (IEPA).

GraniteNet Web, ESRI ArcGIS and Cityworks -all working seamlessly together- are all helping Sangamon County Water Reclamation District achieve its goals.

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HOW DATA IS CHANGING THE WAY UTILITIES MANAGE BURIED INFRASTRUCTURE

Alan Bair, Practice Lead, Xylem

The water industry is increasingly adopting proactive management strategies for buried infrastructure. This shift is possible due to assessment technology and data analytics that deliver short- and long-term insights into asset performance. Large-diameter pipelines have long service lives that can be greatly extended with data-driven management. This article explores how pipeline owners can leverage data to reduce risk, manage costs, and maintain reliability across the asset lifecycle.

CHANGING PERCEPTIONS OF AGE

Average industry service life expectations for large-diameter pipelines are about 50 years. In some cases, this has proven to be a gross underestimate. There are cast iron pipelines and even reinforced concrete pipes that have been in the ground close to 100 years.

Using general service life estimates to guide replacement decisions has proven infeasible due to the cost and critical nature of these assets. New pipelines are typically buried, prioritized at the end of a long queue of assets, and not addressed until there is a problem. Pipeline owners are struggling against a headwind of diminished or unchanging funding and increasing service demand.

However, the way pipeline owners perceive service life and manage large-diameter pipes is shifting due to advances in condition assessment.

Failure of Prestressed Concrete Cylinder Pipe, a 2008 study by the Water Research Foundation, says the life expectancy of this pipe type varies from 50 years to 100 years to indefinite depending on the perception of the pipeline owner. This claim is supported by condition data Xylem has collected over two decades and thousands of miles of pipeline inspection. The data shows that most large-diameter pipelines have low, manageable distress rates.

Achieving an extended service life requires a certain level of manufacturing quality control and proper installation, operation, and maintenance.

Effective maintenance depends on a solid understanding of asset condition. Advances in technology have changed the game for buried infrastructure. Pipeline owners can identify distressed pipe segments, make targeted repairs, and return pipelines to like-new status for a fraction of the cost of holistic replacement.

SHIFTING RISK MITIGATION STRATEGIES

High-profile pipeline failures have shone a spotlight on the challenges of managing aging infrastructure. These failures can cause significant damage, erode community trust, and leave utilities unsure about next steps.

Past replacement decisions were often reactive, driven by failure avoidance, and based on limited information — such as pipeline age and failure history, visual inspection data, and asset criticality.

However, data shows that pipeline failures are usually the result of localized deterioration. Often, the rest of the pipeline is still in serviceable condition. Knowing this, it is difficult to justify the cost and disruption of full-scale replacement in response to failure.

Today, pipeline inspection and structural analysis can guide short-term repair decisions that improve infrastructure reliability and bring utilities peace of mind. Advanced data analytics that predict future pipe performance inform long-term asset management strategies. This information helps utilities mitigate risk and allocate resources in the most cost-effective way.

AUGMENTING A CHANGING WORKFORCE

An aging water workforce is a top challenge for utilities, threatening an industry that relies on the intuition and expertise of long-time engineers. A wave of retirements could leave a huge gap in institutional knowledge about managing buried assets.

Data-driven insights can help fill this gap as the industry evolves. Utilities that leverage a growing volume of available data to aid human decision-making will achieve the greatest benefits.

PRIORITIZING PIPELINE ASSESSMENT

Pipeline owners often procure assessment services in response to leaks and breaks. However, the most economic approach is to look holistically at a system and take a long-term, programmatic approach.

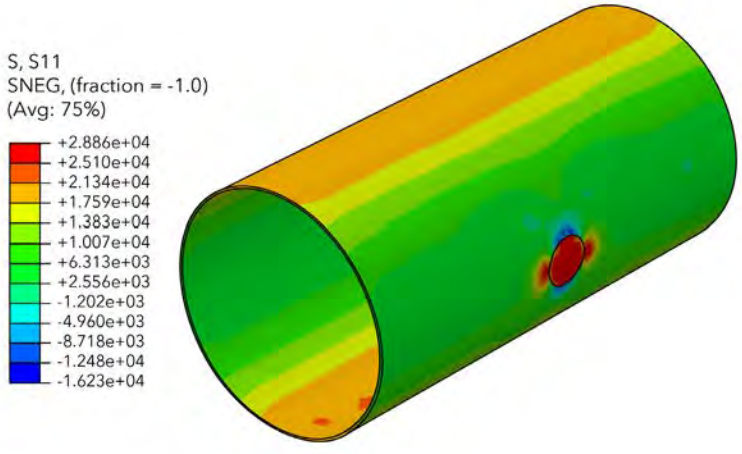
North American utilities operate thousands of miles of buried transmission mains and force mains. A proactive condition assessment program starts by identifying which of these pipes warrant the most attention. This means prioritizing assets for inspection and determining the appropriate level of assessment.

Gaining an initial understanding of risk is key to maximizing the value of a condition assessment program.

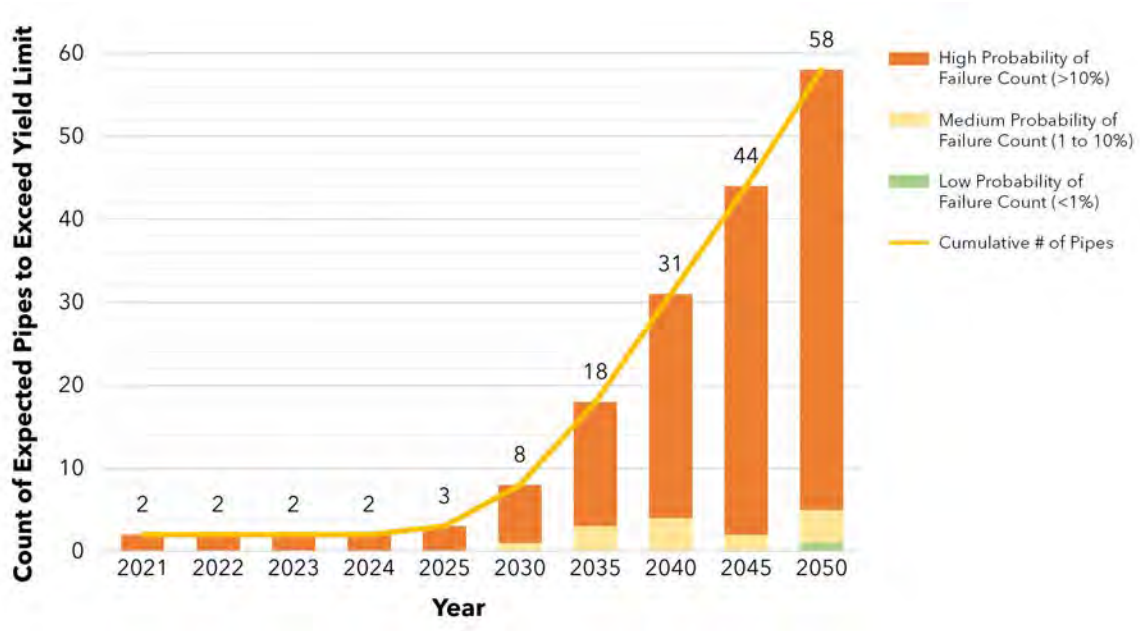
Xylem starts by collecting and reviewing information specific to the utility's assets, such as past failures and soil corrosivity. Combining this information with condition data from similar pipelines around the world offers a valuable benchmarking tool. We can see how pipes of the same material, size, age, and design responded to distress under similar operational and environmental conditions. Layering this information with pipeline criticality and consequence of failure provides a broad measure of risk.

This initial risk analysis provides insight into suspected pipe condition before utilities invest in an assessment approach. As risk increases, so does the value of gathering more data using high-resolution inspection methods and engineering services. A phased approach may be more appropriate for low-priority pipelines where we use less expensive methods to identify red flags and guide next steps.

A successful pipeline management program balances level of service, lifecycle costs, and acceptable risk. For example, a utility that cannot tolerate any failures on a critical transmission main may need to invest more in condition assessment and ongoing maintenance.



Finite element simulations show how a pipe responds to degradation with increasing pressure and defect size.



Statistical models predict how long a pipe can operate until it is likely to fail or exceed certain structural thresholds.

BUILDING A DEFENSIBLE PIPELINE MANAGEMENT STRATEGY

Inspection data gives some insight into at-risk pipes and helps utilities avoid imminent failures. However, engineering analysis unlocks further value from the data. It contextualizes the information and provides a measuring stick for determining the severity of findings and the urgency of management actions.

Xylem engineers use inspection data to build three-dimensional models that show how a pipe responds to degradation with increasing pressure and defect size. The result is a pipe performance curve that shows when a pipe is expected to reach its yield limit. This actionable threshold can vary depending on the utility's risk tolerance and level of service. For example, it could be defined as the point when the pipe develops a through-wall leak or when it exceeds its design structural capacity.

When a structural performance evaluation is not feasible, large condition datasets are again helpful for guiding management actions. We can aggregate a range of expected structural responses using a database of existing performance curves for similar pipes. Inspection data is measured against the defined yield limit, and the utility may choose to repair any pipes exceeding that threshold.

Inspections provide a snapshot of pipeline integrity in time. Reinspection is important for identifying new areas of distress and determining whether existing problem areas are worsening over time. With each reinspection, utilities can better understand a pipe's deterioration rate.

Understanding the deterioration rate is critical for calculating a pipe's remaining useful life. However, it is not reliable to build a predictive model with only one or two data points from the baseline inspection and reinspection.

Here, a large condition dataset is a huge advantage. Engineers can supplement and tighten deterioration estimates using a database of similar pipelines. Using statistical models, we can predict how long a pipe can operate until it is likely to fail or exceed structural thresholds.

Xylem's condition assessment database is built on more than two decades of inspection data. Drawing on this large dataset means better predictive performance and higher confidence in the results.

TRANSITIONING FROM REACTIVE TO PROACTIVE

Pipeline inspection and structural performance evaluation help utilities understand current pipeline condition and address short-term risk. Advanced degradation analyses provide insight into how pipes will behave in the future. This empowers defensible long-term planning and budgeting for reinspection and repairs.

Replacing pipelines based on generalized service life estimates is not feasible. It is costly and inefficient given the low distress rates found in large-diameter pipelines. Utilities can manage these assets for the lowest lifecycle cost with incremental investment in condition assessment and rehabilitation. This approach typically costs 5 to 10 percent of capital replacement, and the investment is spread over many years. With proactive, data-driven management, utilities can greatly extend the life of transmission mains and force mains.

Where extending pipeline life is not feasible, condition data is still valuable for managing risk while planning for replacement within a favorable window, such as in coordination with larger municipal capital improvement plans.

Leaks and breaks have been the catalyst for many condition assessment programs in place today. Condition assessment is often touted as a solution for preventing failures and managing aging infrastructure. While these are important drivers, data-based pipeline management plans deliver benefits across the asset lifecycle. Current and future condition insights help utilities prioritize and justify risk mitigation actions to optimize spending and asset reliability.

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AFTER ASSESSING THOUSANDS OF MILES OF SEWERS, A LOOK AT AI COMPUTER VISION'S CURRENT & FUTURE IMPACTS WITHIN THE TRENCHLESS SPACE

By Eric Sullivan, NASSCO PLMACP Trainer, Director of Business Development, SewerAI

More than one third of U.S. wastewater utilities are unable to engage in proactive asset management, according to the American Society of Civil Engineers. As aging underground infrastructure continues to deteriorate, too many wastewater utilities continue to operate in a reactive mode as sewer overflows, sinkholes, pipe collapses, and storm events increase in frequency and severity.

Relatedly, CCTV condition assessment programs have long provided the foundation for long-term asset management and maintenance strategies for sewer collection systems. CCTV-based condition assessments noting defects and features throughout pipelines provide essential information engineers and utilities rely on for capital planning. Unfortunately, traditional assessment methods have long been constrained by sewer professionals having to manually review and annotate inspection videos in real-time, contributing to a major portion of the total cost to inspect and assess collection systems.

Over the last few years, many in the trenchless industry have taken note of the emergence of Artificial Intelligence-based (AI) computer vision tools for automatic identification of conditions in sewer inspection videos, and how this technology continues to be implemented on projects throughout North America. These AI tools and methods, also known as Automated Defect Recognition (ADR), have proven to be effective in reducing field inspection costs, accelerating workflows for data collection and analysis, and, importantly, contributing to an elevation in the quality, accuracy, and consistency of condition assessment data.

One area in the U.S. where AI is regarded as mission-critical is in the City of Houston. Since late 2021, the same year it began a Consent Decree agreement with the EPA requiring an estimated total expenditure over 15 years of $6 billion to conduct the necessary improvements to avert future sewer overflow events in the region, the City has integrated AI into its assessment and capital planning workflow. The Consent Decree includes, at a minimum, the inspection of the entirety of its 6,200-mile sewer collection system within the Consent Decree's first several years (and on an additional 10-year cycle following that), with the same applying to the more than 129,000 maintenance hole (MH) structures in the City.

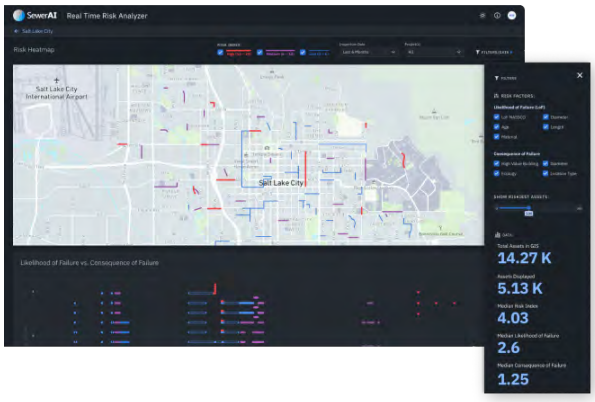
After evaluating a total of six different software and AI vendors from around the world, the City of Houston selected SewerAI, a California-based company which leverages computer vision tools for sewer inspection in a process called AutoCode, running inside of its cloud-based platform called PIONEER, enabling remote, secure, and real-time sewer data management and collaboration. According to Ayobamidele Bello, PE, from HR Green, who helped conduct a third-party QC analysis of the outputs from SewerAI, reviewing over 1,500 AutoCode surveys performed in the first several months of SewerAI's involvement, found that, in terms of precision, "AutoCode has a high accuracy rate [with an] average of 97 percent at properly coding identified defects." A similar comparison involving approximately 150 surveys coded by four different CCTV inspection contractors also found "AutoCode has a significantly higher [8x greater] accuracy rate compared to [outputs from] contractors," according to Bello.

In addition to computer vision

and cloud technologies there's an opportunity presented when these tools are paired with emerging photogrammetry methods for utilizing digital images to automatically render 3D geometric models of sewers. In case the term photogrammetry is a new one to you, it's basically the science of using advanced math and computing processes to rapidly calculate points in 3D space from the pixels in digital images. Specifically in this case, rendering 3D models from 360 videos captured by "action cameras" such as those made by GoPro, Insta360, and others, so that components of MHs and dimensions of connecting pipes can be easily and accurately measured.

According to Billy Gilmartin, SewerAI's Cofounder, "We believe that with the right software tools we can help our customers simplify the hardware used in the field, saving them a ton of time and money. Furthermore, we reduce the stress experienced by operators by making their jobs easier to perform, so they can focus on what's most important; which is safety."

Looking at the MH inspection



space, the increased usefulness of affordable 360 action cameras with retail prices in the range of hundreds of dollars, as opposed to the $80k to $180k capital outlays needed to acquire legacy MH scanning systems, has been a positive disruption in the industry, welcomed by contractors, utilities, and engineering firms alike.

According to Felix Ladoucer-Belanger, General Manager at RinnoVision, a Quebec-based SewerAI technology partner that manufactures a MH camera inspection system utilizing 360 action cameras, "the democratization of a simple and affordable MH camera combined with powerful AI-assisted software has proven to allow cities and contractors to greatly improve assessment capabilities at a fraction of the cost, while also making it easy to implement for their workforce."

Solutions that address workforce concerns are badly needed. A 2021 report from the Associated General Contractors of America found the construction industry is facing a shortage of skilled workers, in part due to an aging workforce where 40% of construction workers are older than 45. The wastewater industry is facing its own shortage of skilled workers, creating challenges such as project delays, increased costs, and potential safety concerns. It's worth noting that leveraging AI and cloud technologies to offload the burden of analysis and annotation of data collected in the field means operators are no longer required to be experts at sewer condition assessment, making these roles more accessible to those who are new to the industry, or who may not have had the prior education needed to put together inspection deliverables by themselves.

What might these technologies mean relative to existing sewer assessment standards?

SewerAI has now been performing condition assessments in North America for over three years, having completed hundreds of thousands of mainline, lateral, and MH surveys, involving the analysis and annotation of conditions in several thousand miles of sewer and stormwater pipes, while generating and leveraging hundreds of thousands of AI training images in the process. During this time, SewerAI has also been able to harvest countless insights about pipe deterioration and failure mechanisms, the efficacy of certain trenchless rehab methods, the prevalence and risk of utility conflicts such as gas-sewer cross bores, and how this relates to historical trends and past construction practices throughout North America.

Looking ahead, there's even more opportunity for the industry to evolve. Since 2001, Pipeline Assessment Certification Program (PACP) guidelines, created by the National Association of Sewer Service Companies (NASSCO), have been widely used in condition assessment in all types of buried drainage infrastructure. After over two decades of use, there now exists an abundance of PACP, LACP (laterals), and MACP (MH) data on infrastructure throughout North America. Now, increasingly, this data is being stored and streamed on cloud-based applications so the people who need it can review it and collaborate securely, remotely, and in real-time.

This increased access to large amounts of PACP data, combined with AI/ADR computer vision tools such as AutoCode means condition assessments are more consistent, more rigorous, and conducted more efficiently and expeditiously. Data assessed within industry standards, managed in NASSCO-certified software platforms, becomes even more valuable for two reasons:

First, the ability to analyze PACP data at scale enables rehabilitation of sewers with trenchless technologies before they reach a critical state of failure, avoiding disruptive emergency open-cut methods. That being said, gaining these kinds of useful insights from the massive amounts of both archival and recently collected sewer data, and doing this as cost-effectively as possible, has historically been one of the biggest challenges our industry has faced.

Second, large datasets aggregated and accessible in a cloud computing environment means that now utilities and engineers can finally benefit from the "crowd-sourcing" of the tens of millions of feet of anonymized data from other participants within this cloud platform. This type of "big data" is what allows for national benchmarking comparisons, offering levels of insight that have simply not been possible in the past.

This is an exciting time in our industry as asset owners, consulting engineers, and services contractors all stand to continue to benefit from advancements in AI software and cloud connectivity. The stage has now been set for an even more positive shift as we all collectively do our various parts to take on the daunting task of renewing our deteriorated underground infrastructure.

SewerAI

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SewerAI's unique in-house photogrammetry technology leverages GoPro MAX (360) videos to render detailed textured 3D models of manhole (MH) structures, in addition to providing advanced tools in PIONEER for 360 video playback, enabling virtual pan, tilt, zoom, vertical distance, and clock position orientation.

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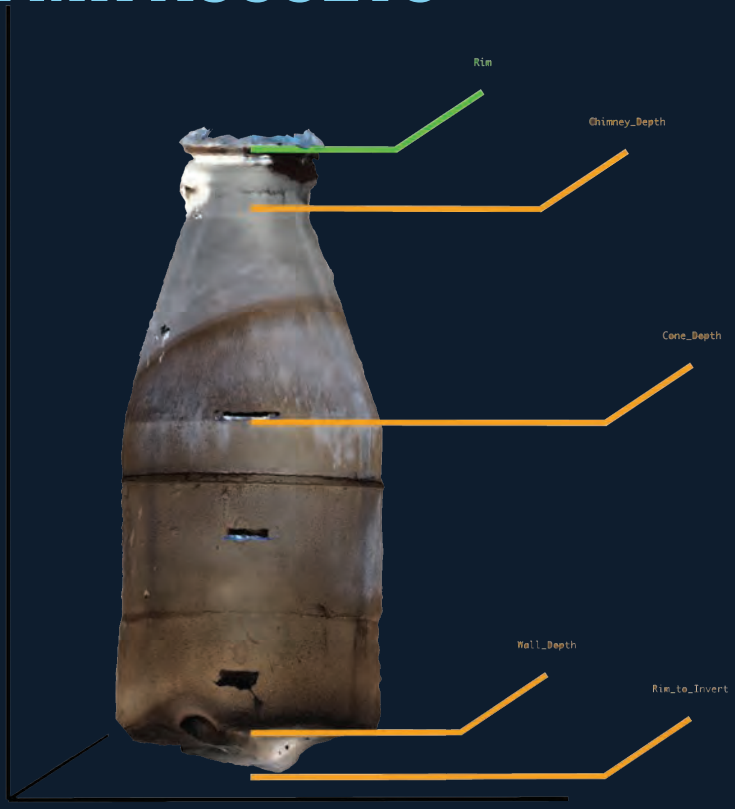

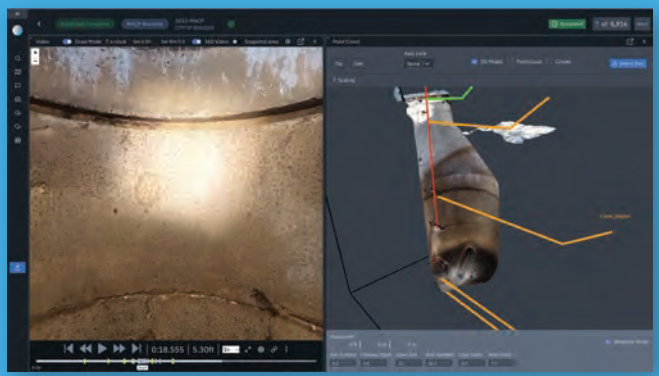

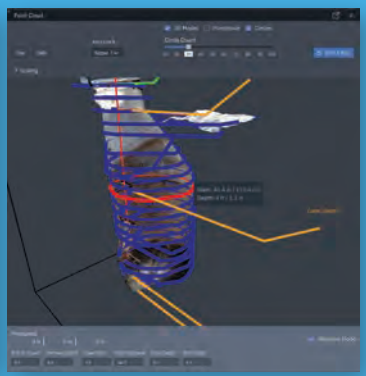

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THE FUTURE IS NOW

How Artificial Intelligence Is Impacting Trenchless Technology

By Sharon M. Bueno, Editor, *Trenchless Technology*

Artificial intelligence (AI) is deeply woven into the fabric of our daily lives in so many ways that we can take for granted that it's there. Spam filters. Smart phones with their personal assistants Alexa and Siri. Autonomously-powered vehicles with predictive capabilities. The cloud — and not those fluffy, cumulous ones floating above us.

Hollywood has glorified AI in films and television for years, dating back as far as 1927 and the film Metropolis, in which AI takes the form of a humanoid robot intent on taking over a mega-city by inciting chaos; on the TV side we had The Jetsons. In these instances, they offered exaggerated, make-believe glimpses of how the technology can be used. In everyday life, AI technology may not be as exciting and epic; however, its impact on the construction industry has been exactly that as it has brought an added level of efficiency, accuracy and safety to the construction landscape.

For the world of trenchless technology, we used to speak of AI technology in the future tense. No more. The future is now for AI use in the trenchless market, as it continues to integrate into several trenchless application segments.

Most notably, AI has had an immediate and visible impact in CCTV pipe inspection and has quickly gained traction as an important technology tool in the software toolbox in the last few years. Pipe inspection software companies have been in the research and development stages for AI for many years, working to perfect its inclusion in the inspection process through images and accurate coding. Companies such as WinCan, SewerAI, and Fracta, to name a few, have rolled out AI software packages to enhance technol-

ogy already utilized to more accurately gather and assess the condition of the underground pipes.

"AI is the ability to learn and solve problems the way the human mind does," says WinCan general manager Mike Russin. "In relation to condition assessment, AI is already improving the speed and accuracy as to which data is collected and reviewed. Now as AI evolves into work management and financial planning on the data, we see tremendous benefits for years to come in the trenchless industry."

AI technology for pipe inspection has garnered the most attention but AI has been incorporated in other trenchless applications including new installation segments such as microtunneling, horizontal directional drilling (HDD), pipe jacking and auger boring, to name a few. AI use here has provided for more accurate data reporting and logging, safety features and guidance/steering.

"AI definitely has a place in new installation projects and aid in the production of doing an auger bore, microtunnel or HDD bore," says Scott Fisher, international sales manager and technical advisor at Barbco, a worldwide maker of auger boring machines, directional drills, guided boring machines and advanced tunneling equipment. "AI is not going to do the job for you but it will make it easier, safer, more efficient and cost-effective. It's there to assist us in completing jobs and keep our operators safe."

HOW AI WORKS IN TRENCHLESS

Let's take a look at how AI is being used on jobsites today, starting with CCTV pipe inspection. In general terms, AI will offer the ability to auto-recognize defects from CCTV inspections and produce an accurate grade for the condition of said pipe. Its proponents say AI has the potential to produce this data more quickly and accurately than the human eye does right now.

And part of that efficiency and accuracy is having NASSCO certification of the process. NASSCO's Pipeline Assessment Certification Program — better

known as PACP — has been an integral part of the pipe inspection process for more than 15 years. Using its 1-5 coding system (with 5 being the most severe condition), PACP has given a universal voice to identifying and recording pipe defects, deformities, deterioration and other issues. Any use of AI technology will need to be able to replicate this very specific coding system.

"Opportunities right now [for AI] are in the visual aspects of the data," Russin says.

There is a gamut of different equipment available to collect data from the pipes — CCTV to drones, push cameras, 360 cameras, HD scanning. As cities become inundated with the amount of data they are collecting and the time it takes to assess said data, AI can help them get out from underneath it.

"Cities are getting inundated with data causing choke points that delay condition assessment workflows," Russin says. "The opportunity for AI right now is to lessen the choke points and start processing data more efficiently. With these efficiency gains, end users are able quickly build accurate data models for efficient review of their overall wastewater network"

WinCan launched its Sewermatics program in 2021 leveraging AI to provides users with AI assisted defect coding ,data conversion, data visualization all hosted in an intuitive cloud platform. All of these functions give users a more accurate condition assessment of the infrastructure, strengthening decision-makers information on which to select and budget for the appropriate rehab/repair program.

SewerAI was founded three years ago in Walnut Creek, California, and provides professional services that use AI tools — a cloud-based platform built for data management. Customers upload the data and SewerAI executes the AutoCode process for pipe assessment. SewerAI director of business development Eric Sullivan sees the impact AI technology is having today and is excited for what lies ahead.

"AI tools generate information for three categories: descriptive, predictive and prescriptive," Sullivan says. "Ours focuses on descriptive and using AI to identify and describe the conditions that are in the pipe. We are starting to leverage that data through other AI processes where they can yield predictions that humans would not be able to calculate.

"We're not relying on the AI tools to tell us to do or not to anything," he says. "We're using the tool to help us more reliably and efficiently identify what is or is not in the pipe, manhole or sewer."

Sullivan also sees AI impacting the

workforce of operators — in a good way. He says the CCTV industry is also struggling find good operators who can film and analyze the pipe data. "While they still need NASSCO training, operators [with AI] do not themselves need to be experts in analyzing the condition of a pipe," he says. "AI is a pretty powerful tool to all of our industry to be more inclusive of newer people who might not otherwise be suited for the role.

"We're seeing a pretty major impact on contractors being able to complete projects much quicker and more efficiently and at a higher level of consistency in terms of the final product," he says. "The benefit to the lining companies is that they are better able to get the information they need to plan for various types of installs, especially identifying problematic conditions that might pose issues for certain CIPP lining installs."

NEW INSTALLATION AI OPPORTUNITIES

While AI may be more visible on the pipe inspection side, the technology is being used in new installation applications, primarily in areas of data logging, crew safety and guidance. In smaller ways, AI technology has been incorporated into applications such as microtunneling, pilot-tube guided boring, HDD, pipe jacking and auger boring.

"AI is a way to enhance quality, productivity and provide a level on internal inspection," says Akkerman vice president and chief revenue officer Jason Holden. "AI has been used longer than we have been thinking that it was 'a thing.' Right now, the parameters are contained within the guidance system and just does the reporting," he says. "Nothing is linked to machine control because the geotechnical and ground conditions that the machines go through can't be fully known. That's always the underlying factor.

"We see AI in the control systems, behind the scenes for warnings and safety checks and data reporting," Holden says.

One area Akkerman is testing AI on is with autonomous muck hauling, with the end-game being able to drive the hauling system between the launch shaft and the TBM system to retrieve the processed muck from the reception shaft. "We're testing this in-house to see other ways we can use the AI technology in other systems," Holden says.

Fisher is a proponent of AI technology and its use in making the boring operations safer, even though some old-school thinking contractors have been slow to come around to that way of thinking. He sees technology being able reduce labor costs vs. getting rid of labor costs. "The efficiency and accuracy are where it's going to pay off," he says. "The straighter you can put in a pilot hole and follow that pilot hole, the more accurate your job will be."

One area that Fisher says AI is used is in Tilt Anticipation Shutdowns for Barbco auger boring machines. In general terms, if the machine senses it will exceed previously set parameters of grade, the machine will shut down and disengage the clutch to aid in prevention of the machine flipping over. But this AI-aided safety enhancement isn't a favorite for all operators, as the machine would be stopped multiple times as sensors react to how the machine is moving.

"Getting older contractors on board with this was a challenge," Fisher says. "They didn't like the stoppage and they didn't trust the buttons to be fast enough for a human reaction [, if needed]. They just wanted to run the machines. I was used to running the old machines too, but I could see the benefit [of the technology] because if I'm on a tough job I don't want to put my life in danger. If there is something available, I want to use it."

HUMAN VS. MACHINE

Will AI ever reach the point of replacing humans performing the work? Not likely. No matter how much or how little AI becomes integrated into a trenchless application/system, it won't take the place of a human, our panelists say.

"It's impossible to replace the experience of an operator," says Holden. "I don't think AI will ever be in a position to replace them."

Holden says for installation applications there is a safety factor to consider. "In the confined spaces we work in, it can be dangerous and require reactions and quick thinking. That's built on years of experience. Fully autonomous tunneling is years and years away. There is the brain power and it can be done but the cost is high, as are the risk and exposure."

Fisher agrees that operator-less boring and drilling is not a consideration at this point, primarily due to safety considerations. "If you're thinking that you want to put a machine without humans operating on the job and said do this bore, there are so many factors against it," he says. "Auger boring, for example, may seem very simple on the outside but it's very complex on the inside. There are so many variations in ground conditions, weather, groundwater, soil hardness and to have a machine that's able to deal with all those factors isn't possible. I could take all the people I've been associated with in the last 35 years and take all their knowledge and it's still not enough. How could you program a machine to do all that?

Regarding pipe inspection, Russin and Sullivan say AI technology enhances what is already available. "AI will not eliminate jobs," Russin says. "It will produce accurate results more quickly while supporting field and office personnel, not replace them. The AI models still rely on human supervision so as training continues the models will improve and become more beneficial."

"It's not replacing anything right now, other than traditional workflows," Sullivan notes. "In the next few years, you'll see AI more commonly used than not. The technology has progressed very quickly. The market adoption is more a question of educating the stakeholders."

In the future, AI will be used in more ways as the technology gets better and smarter. But that doesn't mean humans will not be needed. "Machines aren't smart because they are machines," Fisher says. "They are smart because humans made them smart and there will still be humans involved in AI use."

Sharon M. Bueno is editor of *Trenchless Technology*.

Trenchless TECHNOLOGY

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NASSCO's PIPELINE ASSESSMENT CERTIFICATION PROGRAM

PACP™ Standards, History, and Application to Artificial Intelligence

By NASSCO Staff

PACP – THE NATIONAL STANDARD

NASSCO's Pipeline Assessment Certification Program (PACP), which serves as a prerequisite for Lateral and Manhole Assessment Certifications (LACP™ and MACP™, respectively), has become the national standard for the proper assessment and identification of sewer conditions.

The primary purpose of PACP training and certification is to assure that all pipe system data are collected and coded in a consistent and reliable manner. PACP uses a unique and proprietary language and it is important for users of PACP to understand how proper PACP coding fits into the overall picture of pipeline assessment. PACP also assigns a condition grade number to every defect that is coded during a pipe inspection:

5 = Most significant defect grade
4 = Significant defect grade
3 = Moderate defect grade
2 = Minor to moderate defect grade
1 = Minor defect grade

The PACP Condition Grading System provides a framework within which to calculate several pipe rating numbers, which is useful for ranking line segments based on severity of observed defects and conditions. The ultimate benefit is to properly manage assets based on the ability to predict the most significant risk of failure.

Standardization is important because it allows pipe conditions to be benchmarked within a single utility as well as from one utility to another; provides the ability to detect changes in pipe condition due to deterioration over time; avoids redundant effort of developing utility-specific or project-specific standards; creates options to integrate data from different asset management software programs; improves pipe condition grade quality and consistency, which improves ability to identify priorities for pipe system rehabilitation; and advances professionalism of the CCTV inspection industry.

HOW PACP CAME TO BE

The idea for NASSCO's PACP came from NASSCO Past-President (2007-2008) Rod Thornhill, who continues to be one of NASSCO's most knowledgeable and well-respected PACP Trainers.

Rod saw great value in the condition assessment program developed by WRc for use in the United Kingdom and knew that with some modifications it could serve the U.S. market well. Rod brought the idea to NASSCO's then-Executive Director, Mike Burkhard, around the year 2000. Shortly thereafter, a partnership with WRc was formed and a small group of industry professionals came together to make PACP a reality. Through years of hard work, many hours and commitment in the modification of WRc's Manual of Sewer Condition Classification (MSCC) for conditions and materials specific to North America, PACP was launched in 2002.

"My vision for PACP came from the lack of any standardization of CCTV data," shared Rod. "This lack of standardization meant several things:

- The data collected was limited to single project use;

2001 NASSCO/WRc Workgroup. Back row (left-right): Marilyn Shepard, John Jurgens, Jeff Tinlin, Rod Thornhill, Gerry Muenchmeyer, Lynn Osborn and Greg Anderson. Front row (left-right): Phil Wildbore, Andy Drinkwater, Mike Burkhard.

- Data between CCTV software vendors could not be exchanged;
- Data quality was poor because there was no way to independently confirm coding of data was correct; and
- Since no standard existed, the shelf life of the CCTV data was often only a few months, or until a project was completed, or when CCTV software was retired. With PACP the industry now has the ability to accumulate mass quantities of data in perpetuity.

"Since PACP's launch in 2002, NASSCO coding standards have become the de facto standard for condition assessment of gravity pipe assets nationwide, with growing influence in other countries throughout our territories. While this level of success if phenomenal, I still have a vision for the future of condition assessment, specifically that data quality will greatly improve and there will be a nationwide approach to consolidate PACP from hundreds of utilities nationwide into a virtual model of the entire country. This could be used for countless applications starting with providing a data-driven estimate of the actual cost needed to bring sewer condition to an acceptable level. This wealth of data could also be used to develop better estimates of various rehab technology markets."

Today, PACP has grown to become the industry standard throughout North America and through its partnership with LAMSTT (Latin American Society for Trenchless Technology), PACP standards are gaining a significant foothold in South and Central America.

With nearly 40,000 professionals certified to date, we do not see the growth of PACP-Certified Professionals slowing down. While Covid was extremely disruptive to many industries, it accelerated NASSCO's development of virtual sessions to offer PACP and NASSCO's Inspector Training Certification Programs (ITCP™) to an even wider audience.

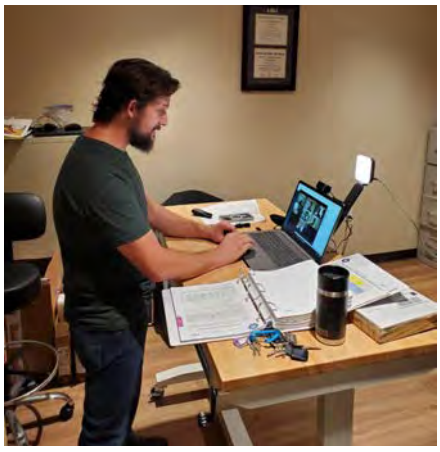
Heather Myers, NASSCO's Program Director, was there at the inception of PACP and has watched it evolve over the years. "I have seen PACP grow from the hope of a standard to the North American standard it has become. I never imagined it would reach beyond that, but it has. Thousands of people are certified and recertified each year as we strive to provide quality data for decision-makers to properly allocate their limited budgets to rehabilitate the most appropriate assets in their system. With each version of the Program, we make every effort to address the changing needs of the industry by adding new codes - including pressure pipe codes in PACP version 8 to be released in late 2023, for example, or by making adjustments based on industry input to codes that already exist.

"In addition to Program content, NASSCO-certified PACP Trainers are held to higher standards than ever before which can only improve the data that is collected in the field. My hope for PACP is that it continues to grow and evolve based on the industry's needs and that it will extend its reach even further, allowing for unprecedented collaboration and benchmarking across the world as our underground infrastructure ages."

PACP AND AI TECHNOLOGY

Artificial Intelligence (AI) is the theory and development of computer systems that can perform tasks that normally require human intelligence (such as an operator coding pipe defects), visual perception, speech recognition, decision-making, and translation between languages. AI techniques lend themselves to solving complex problems involving large volumes of data. Data, by virtue of its magnitude, can challenge problem solving initiatives. Data, regardless of size or level of complexity, require organization to promote clarity and consistency to make informed decisions. With an estimated 800,000 miles of wastewater sewers and 500,000 miles of lateral sewers in the US alone, pipe inspections and the ability to perform condition assessments have become an attractive candidate for AI processes.

As it relates to condition assessments, the success of AI in sewers requires what is referred to as machine learning (ML), automated defect recognition (ADR) and advanced analytical processes (AAP). ML is an algorithmic process that helps software improve,



NASSCO-Certified PACP Trainer Nick Spano conducting a virtual PACP/LACP/MACP session.

like humans do, through iterative trial and error experiences using mass amounts of training data (such as photographs or video of known defects/features), to make better decisions or choices. ADR is the software output, that uses ML techniques, to progressively identify defects "observed" within individual images of video. And finally, AAP refers to the broad spectrum of processes uniquely focused on the analysis and leveraging of information in large data compilations. In sewer networks, this can embrace a wide range of studies from deterioration analysis of specific cohorts or eras of pipes, sustainable funding assessments, optimization techniques, among others.

PACP was built on sound engineering practices focused on consistency, clarity, and science in terms of classifying visual observations to provide both qualitative and quantitative condition assessment definitions, such as:

- the ability to make observations that are readily replicable. They do not have to be perfect but do need to be replicable enough such that a diverse group of reasonable individuals applying the same visual standard should arrive at the substantially same conclusion, and
- the ability to make observations that are relevant in terms of understanding the structural and operational significance. Many successful engineering studies have been completed by the ability to look at combinations of PACP observations, the pipe materials involved and the ground conditions around the pipe to make informed decisions on how much to spend, when to spend it and what to spend it on.

Merging the PACP condition assessment standard with other data sources that influence pipe remaining useful life requires significant organizational and data management skills, which is where AI comes in. Using the PACP standard, many of the concepts that are evolving through AI can apply to sewer condition assessments by providing increased automation and data processing, however this also increases the importance of data verification by trained operators assigned to performing the work of coding defects/features in pipelines to reduce errors that can result on a larger scale during ML and ADR. AI and advanced analytics can support the work by improving productivity, accuracy, and the ability to solve increasingly complex problems facing the aging infrastructure industry.

NASSCO recognizes the use and growth of AI and ML within the sewer inspection and rehabilitation industry and is actively providing leadership on the subject, including the development of a workgroup and collaboration with software and hardware developers. Presently there are no AI systems that are certified by NASSCO for recognizing every PACP/LACP/MACP observation; however, end-users may not need this level of functionality if the observations that are recognized and captured are consistent with their individual goals for CCTV inspection. Regardless, the present advantage of AI for CCTV pipe inspection is its efficiency to code large volumes of legacy and new inspection data in a cost-efficient manner that is consistent with the quality standards per the "Guidelines for Quality Control (QC) of NASSCO's PACP, LACP and MACP Surveys," April 2022. The NASSCO AI workgroup additionally recognizes the following uses for AI-collected inspection data:

- Training aid to supplement and improve PACP coding for novice inspection personnel or operators becoming familiar with code classification for pipe types that they do not have experience coding
- QC of inspections to identify missing or inaccurately coded defects/features
- Quick coding of legacy inspection video for benchmarking purposes
- Cross bore identification
- Embedment of NASSCO QC guidelines for automated quality validation
- Simplified operator workflows (less time coding with potential for improved inspection rates)

As the market evolves, NASSCO's Software Committee, Infrastructure Condition Assessment Committee, Technical Advisory Council and other industry professionals will determine the best approach for assessing and rating ADR software products and their level of accuracy as they pertain to NASSCO's PACP, LACP and MACP codes. While that process has not yet been defined, NASSCO will ensure that it presents a fair picture of AI/ADR technological capabilities and how they are applied in the field, knowing that it will evolve as the technology becomes more developed, advanced, and accepted in the future. NASSCO is committed to providing similar written updates on the subject to inform the industry, our users, and our membership on the advancement of AI in the PACP-environment.

As a reminder, NASSCO requires license agreements for all software products that utilize NASSCO's intellectual property relating to PACP, LACP and MACP codes, including ADR and import/export functions using existing PACP-inspection databases. To learn more or to become a NASSCO-certified PACP professional please visit *NASSCO.org/education-and-training*.

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