Title: **Lessons Learned from Implementing a Cross Bore Program**

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Abstract: Historical trench-less boring of gas pipelines has increased concerns of inadvertent leaks caused by intersecting foreign utility pipelines. This paper will examine advancements in cross bore program management through the combination of asset data management technology and procedures, including specialized video inspection, records research and real-time GIS analytics, to reduce public risk by proactively identifying leaks before they occur.

Executive Summary:

The detection, repair and prevention of gas cross bores has become a prominent part of Distribution Integrity Management Programs (DIMP) across the industry as replacement and expansion of natural gas facilities has accelerated in recent years. Many operators have updated field procedures to prevent the creation of new cross bores in trenchless gas construction in response to guidance from regulators. The industry has made the shift to "proactive" cross bore discovery programs that address the need to mitigate legacy cross bore risk.

One of the greatest challenges is the secure and complete gathering, organizing and prioritizing of the extensive volumes of interrelated data produced by modern cross bore discovery programs. The "in-house" Cross Bore Safety Programs conducted by many natural gas utility companies rely primarily on job site data and sewer inspection technology to deal with cross bores, whether resulting from service pipe replacement projects or gas main installations. Rigorous management of inspection data has the biggest effect on reaching the goals of a legacy cross bore inspection program; reducing the risk of gas explosion.

Risk reduction comes with control of the variables which cause uncertainty about the evidence that cross bores have been eliminated from your gas distribution system.

- How do you know every property in scope has been thoroughly inspected?
- How do you keep track of workflows delayed for access permissions, cleaning procedures, special permits or repairs?
- How do you ensure inspectors capture data for every in-scope lateral pipe segment and branch, since laterals are not mapped?
- How do you confirm no team is taking shortcuts and producing compromised data?

Successful Cross Bore Safety Programs reduce risks associated with human error by integrating data, technology and verification with a comprehensive solution that provides traceable, verifiably accurate and complete data utilizing the following process:

- Research gas records to identify higher risk asset locations
- Assign controlled data on assets for video inspection by qualified personnel
- Inspect known assets and identify and inspect unmapped assets
- Resolve the disposition of each asset, be it a repair or proof no cross bore exists
- Validate data to increase confidence that all operations run according to plan
- Verifiable Proof of risk reduction is searchable and linked to supporting evidence

An asset-centric assessment process focuses on verifying in real-time that inspections are reliably complete, which maximizes the safety and productivity of an inspection program.

Introduction

Natural Gas Utility operators are well aware of the risks posed by installation or replacement of gas line using trenchless methods, such as horizontal directional drilling (HDD), boring or piercing, which can inadvertently conflict with in-ground utilities. (Figure 1).

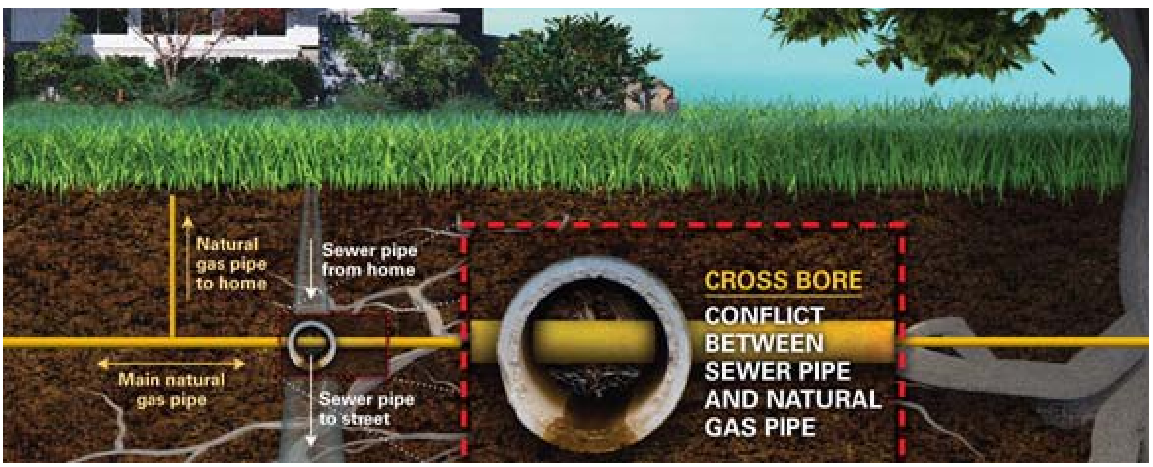

Figure 1. Residential property cross bore depiction
Source: callbeforeyouclear.com

Paraphrasing AGA, for the purposes of this paper we define a gas cross bore as an intersection of a sewer main or lateral by a gas distribution main or supply line, typically resulting from installation by trenchless methods, which compromises the integrity of either utility. Undiscovered cross bores are not self-correcting and will in many cases lead to sewer line blockage, eventually prompting cleaning activity. This presents a risk of the gas line being damaged by sewer cleaning equipment. A dangerous concentration of gas could then accumulate in sewer facilities or in structures.[1]

[1] Natural gas is explosive in concentration between approximately 5% and 15% by volume of air, the lower and upper explosive limits (LEL and UEL) of methane.

Common Elements of a Typical In-House Program

Conscientious operators strive to prevent leaving even one cross bore undetected, to be found later through the release of volatile gas. Safety is the primary driver of the effort, yet with potentially millions of sewer laterals to inspect, schedule cost controls are also important considerations. Building an understanding early on with a variety of stakeholders, including city and county officials, police and utility operators is also very important for efficient operations.[2]

Gas Co. DIMP	Establish goals, coordinate the contracting of work, define deliverables and scope changes
Gas Co. M&C	Determine how to handle potential gas cross bores and conduct repairs
Gas Co. Mapping	Provide access to gas installation and replacement program construction records
Wastewater system operators	Provide sanitary system data, maps, and access to sewer mains, manholes and waste disposal
City, County	Coordinate local operations with transit, police and public, and issue permits to occupy road right-of-way
Plumbers, Homeowners	Notify the gas utility of potential cross bores, as "Call Before You Clear" programs prescribe.[3]
Frontline Energy Services (G2-IS)	Define procedures, hire and manage qualified personnel for research, data analysis, video inspection, GIS and reporting

Table 1. Stakeholder and Collaborator's Roles

Legacy cross bore inspection programs collect evidence of reduced public risk by proactively identifying potential leaks before they occur and jeopardize safety. The evidence is gathered through records research, specialized video inspection and GIS data analytics.

Records Research

Rather than perform costly inspections on every sewer line in proximity to gas services, the more effective programs refine the scope of their efforts by conducting inspections where gas service construction records and "as-built" drawings indicate a potential for conflict with sewer and storm drain systems. Some prioritize inspections further based on structure occupancy, gas main pressure and other risk factors. Typical records show evidence of a trenchless installation or replacement, or a material (plastic, polyethylene) commonly installed without trenching.[4]

Challenges: This valuable data loses relevance when results of records analysis are not securely related to the gas and sewer assets at the location.

[2] "AGA White Paper: Natural Gas Pipelines and Unmarked Sewer Lines – A Damage Prevention Partnership", 2010 American Gas Association, emphasizes communication and education of stakeholders

[3] Public awareness programs such as Call Before You Clear also prevent undetected legacy cross bores from causing incidents by encouraging plumbers and homeowners to call the utility before trying to unclog sewer pipes.

[4] Records lacking installation data do not help with risk decisions and lead to inspections to confirm the absence of cross bores.

Video Inspection

After trenchless gas installation, most programs systematically check inside sewer mains and laterals with CCTV[5] video equipment to identify cross bores High quality video records can demonstrate the absence of cross bores. Sewer system operators generally produce maps of their mains and manholes, but laterals can only be identified by video inspections.

Challenges: Thorough inspection of all mains, laterals and branch laterals in scope must be assured to rule out risk of cross bores. Mains are typically mapped by wastewater agencies, but you cannot know where every sewer lateral and branch is located without using a camera to find them.

It is of utmost importance to enforce standard operating procedures (SOPs) that ensure previously undetected sewer pipe segments will be inspected and their field inspection data added to the GIS map database.

To maximize confidence in the data generated by the inspection process, the responsible camera operators should be trained and qualified in sanitary sewer evaluation protocol. Hire subcontractors with specialized equipment, written SOPs and certifications verifying that their inspectors have over 1000 hours of relevant experience, rather than trying to get gas personnel up to speed in the nuances of CCTV sewer inspection. Quality cross checks have shown that the difference in data quality, particularly in cross bore detection, will be significant.

Figure 2. CCTV sewer inspection with a rugged remote controlled lateral launch camera collects evidence that identifies gas cross bores or verifies their absence.
Source: Frontline Energy Services (cross bore video frame) and Envirosight LLC (lateral launch camera), http://www.envirosight.com/index.php/crawlers/supervisionsat.html

Data Analytics

A Geographic Information System (GIS) is an excellent way to plan and assign work areas for the CCTV video inspection of the interior of sewer pipes. GIS also enables the location-based tracking of inspection, repair status, evaluation of risk factors, and statistical report generation. DIMP should archive the video and other pertinent records, which can be especially valuable in case of incident or audit. Records should be hyperlinked to the GIS data with SSES (Sewer System Evaluation Survey) utility software certified to meet NASSCO (National Association of Sewer Service Companies) criteria.

[5] Closed Circuit Television. In this case, video recording including location and descriptive data.

Challenges: Legacy cross bore inspection programs rely on the quality and completeness of the data they generate. The current common practice, however, does not demonstrate that there are no gaps in the data where a pipe segment identified in the field was overlooked in the video survey. Receiving a report and a video linked to a GIS location is not enough; the length and endpoints of the segments inspected have to be noted and correlate to the video, and every tap or wye observed must result in the video inspection of the segments beyond it.

GIS alone is not sufficient to track each cross bore occurrence through the discovery, reporting and repair process to final re-inspection after repair. Field operators normally transmit data to the office, where GIS technicians update the database, because they do not have access to the GIS in real time. Seamless data connections between field and office using robust data management tools improve the certainty of eliminating cross bore risk.

Unified data management and procedures can help to ensure that field data is validated and that non-compliant data is returned promptly to the field for correction. Without such a direct link between office and field it is too easy to generate misleading data, such as, a duplicate of a single video has been submitted as evidence that separate parcels were complete, or a video that covers a lateral segment from the main tap part way up the pipe to a blockage has been submitted as if it were complete, without video inspection of the segment beyond the blockage.

Most programs are currently limited by their standard GIS database architecture and lack the flexibility to adapt to process changes and scope growth. If you decide in the future to subcontract another portion of the process, or to take previously subcontracted activity in-house, a solution that is designed and built with modular data architecture would allow this kind of flexibility.

Verifiable Proof

As gas operators gain experience in working to reduce cross bore risk, they realize that many steps can be taken to improve data quality and make procedures more efficient, but in the final analysis, safety cannot be assured without verifiable proof that the inspections are thoroughly completed according to project design.

Verifiable proof is the evidence that gives you assurance that each inspection job is verifiably complete. Procedures that do not produce evidence that every subject lateral is finally clear of cross bores end to end, leave the potential for a lateral to become clogged and result in a hazardous gas leak. Whether planning to inspect a targeted high-risk subset or every service address in the system, the decisions operators make about risk tolerance are grounded in reality only when made in light of complete inspection data.

Challenges: Clearly, the procedures and technology currently in use do produce a record of inspections at specific locations. They typically do not give the field operators sufficient real-time feedback to monitor the completeness and accuracy of their work so they can make sure they get it right the first time. They rely on data hand offs to specialists in the office and a fairly long feedback loop, usually with error prone manual data handling or email data transfer built in.

The usual approach to cross bore inspections is based on location data, sending inspectors out to an address and collecting data reported back by them as to whether or not a cross bore exists at that location. GIS is promoted as a data management tool by standard cross bore program best practices, and it is a great tool, but data has to first be entered correctly before it can be managed.

The location-centered process can become confusing because many parcels are served by more than one lateral. These laterals are not mapped, so their number and relative positions cannot be determined beforehand. It is likely that lateral segments will be overlooked, and continue to represent unknown risk, because identifying and accounting for them is not essentially built into the field process.

Asset-Centric Assessment Process

What is needed is a set of processes supported by an integrated data management platform that leads the field operators down the path of least error as they capture real world observations. Managers need to be certain that all inspection observations are acted upon appropriately, whether it's the same day before equipment is moved to the next inspection site, days later after obtaining access permission or a special permit, or after the gas company completes a repair. What the industry needs now is an asset-centric assessment data management system, an integrated solution based on processes and technology that gives each collaborator and management stakeholder an ability to interact with the data and each other in an easy-to-use way, with the right data and level of detail appropriate to their job tasks.

Best results can be achieved by managing each sewer pipe segment as an individual asset, and giving field operators the ability to generate and update status based on their work. Accurate data on each asset is the key to reducing risk. An assessment process centered on the data of each asset is the basis of a set of best practices for running cross bore safety programs that reduce risk to a minimum.

Here is a critical difference between standard practice and a program like this: the status of each asset can always be evaluated and monitored as needed, providing verifiable proof of whether risk of cross bore has been eliminated in each case. A custom software dashboard with a GIS map interface gives all participants a personalized view of the tasks and data relevant to their work at each stage of an asset's lifecycle.

Within the asset-centric assessment data management system, a single parcel record might pass from assignment, to permit queue, to inspector, to access permission, to discovery of a cross bore, to gas company repair crew, and back to the inspector to verify cross bore-free status, all without ever changing hands or unnecessary communication delays. The asset-centric assessment system uses the map database to show involved personnel up to date status information. It eliminates all transfer of data by email and the human error that is prone to, as well as automates many data QC operations.

The process starts in gas record research, progresses to prioritized work assignments, then to gathering inspection data on all known and previously unknown assets, and continuing through the inspection steps until all risk questions have been resolved, automatically and visually validating the results for quality assurance and providing verifiable proof of the asset status to stakeholders on demand. These procedural keys to a successful solution are further described below.

Research –

DIMP gas construction records need to be scanned and analyzed if not already digitized. In either case they can be used in a standard procedure to narrow the scope of inspections to where trenchless technology was used, and other DIMP defined criteria, to focus on those properties at risk for cross bores occurring. Some DIMP leaders additionally choose to prioritize high occupancy properties. A standard operating procedure is used to enforce the research decision making model.

The ID of each parcel is the link between the property location in GIS and the digitized gas construction records, which are visible through the map interface to validate inspection decisions. Once a researcher determines a parcel meets inspection criteria, and the digitized as-built and other records evidence is tied to the parcel asset ID, all subsequent data is also tied to the same record in the database. This makes inspection decisions and results easily traceable to the supporting evidence. The GIS also puts the parcel and its gas records in position relative to manhole locations, digitized mains and storm water drains from the sewer utility.

Assign –

An assembly of parcels and sewer mains are assigned as a map database to a subcontractor camera crew. GIS is used to cluster assignments together where possible to give inspectors a series of addresses to efficiently inspect one after another. Truck ID and camera operator identification is linked to each parcel, and they interact with the GIS map database through an onboard version of the asset-centric data management software interface. Parcels are assigned to responsible parties to perform tasks in sequence within the system until the status is complete or finalized and approved.

Inspect –

After setting up the truck safely at a predetermined manhole and inspecting the sewer main, a camera operator starts each lateral inspection by launching the remote controlled camera into a lateral tap to the main. In the map interface he draws a schematic lateral line between the main and the parcel, linking them. Each lateral drawn represents a new asset with its new ID tied to the parcel ID and tracked in the GIS database. The camera operator connects bothIDs to the video file.

- The data shown in the camera video frame includes the lateral asset ID, the locations of segment endpoints and distances of lateral condition assessment observations along the pipe segment.[6]
- Observation of a wye may indicate a branch lateral connection. A second lateral segment is drawn in the map, forming a second asset ID. The branch must be video inspected.
- Observation of a p-trap or blockage will trigger a procedure that schedules a push-camera crew to collect video of the segment beyond the stop point, where the lateral launch camera cannot proceed. Push-cam footage may complete the length of the lateral, or cleaning may be scheduled before reattempting to clear the lateral asset.

Lateral asset segments on assigned parcels will not be accepted as complete without video and other valid records attached. When the inspection cannot be completed from the sewer main end of the lateral, due to an obstacle the lateral launch camera cannot pass, permission to access a property is often needed. This standard process includes a printed door tag and a toll-free number

[6] NASSCO certified sewer inspectors with specialized lateral assessment qualifications should be employed because their SOPs and experience in the conditions of sewer inspections generate the most accurate data

to schedule an appointment with the property owner. Records of each transaction are tracked with the asset ID in the database, as are traffic permit forms and other pertinent information.

Ultimately, a video for every pipe asset on every assigned parcel will be obtained, or a legitimate reason why it is not possible will be recorded and stored in the GIS system with the asset IDs.

Resolve –

A certified camera operator may collect a video that most observers would say shows a yellow plastic pipe penetrating the wall of a clay sewer pipe, but they don't make the call as to whether it is a gas cross bore. They are not doing the work of gas engineers. Their observations are entered into the database along with the video evidence, so that when they observe a potential cross bore the software will notify the project manager and DIMP stakeholders. A gas engineer will review the images and other evidence to determine when it is appropriate to excavate a cross bore and perform repairs.

Field inspector supervisors oversee camera operators in the inspection process. The supervisors resolve most technical problems in the field, coordinate the permit process, ensure safety compliance, and communicate with stakeholders and property owners as needed. They also compile digital daily reports on all aspects of work, discovery of cross bores or damaged sewers and property access issues. The inspection subcontractor's information populates each report, which is linked in the GIS system to the affected pipe asset ID and the associated parcel ID.

Validate –

A data validation procedure ensures that assigned inspections are completed by automatically crosschecking addresses and parcel IDs in assignment databases against the inspection data returned from contractors. The check includes threshold criteria to filter out inadequate and corrupt data files, such as video file size not up to standards, and questionable results are flagged for closer examination by a technician. Drawn asset lines in the map view change status and color from grey or red to green when video and report data show acceptable evidence of completion.

Randomly sampled videos are viewed by trained technicians in the office to ensure that the video has visibility of the pipe circumference, is unobscured by low light, standing water, debris and other pipe conditions. The technicians confirm that the camera has not been pushed through so fast that the picture is unclear, and carefully look for anything that may have been missed by field operators. Results are tracked in the map interface, either confirming acceptance or returning responsibility to the contractor for remedy. The system compiles stats that show quality trends and prompt management intervention or training as needed. Video QC returns feedback to inspectors that they can use to increase success in the field.

Verifiable Proof –

All the researched gas records, inspection videos and forms are associated in the database, and all notifications of responsibility for the next steps are managed internally without an email or physical hand-off. The asset-centric assessment software profoundly improves transparency, traceability, verification and confidence in each phase of the asset data lifecycle. A unified GIS database provides spatial analytical tools to connect field forms, engineering records, inspection videos, city infrastructure, permit and other data with map locations.

The data collected is used to continually update the GIS database and made available to authorized stakeholders through a web interface. DIMP leaders can find the status and records relevant to any address easily in case of inquiry or audit. They can also query the data to highlight trends to help refine the criteria used in decision making. For example, they may want to analyze all installations by a specific crew in a specific time frame.

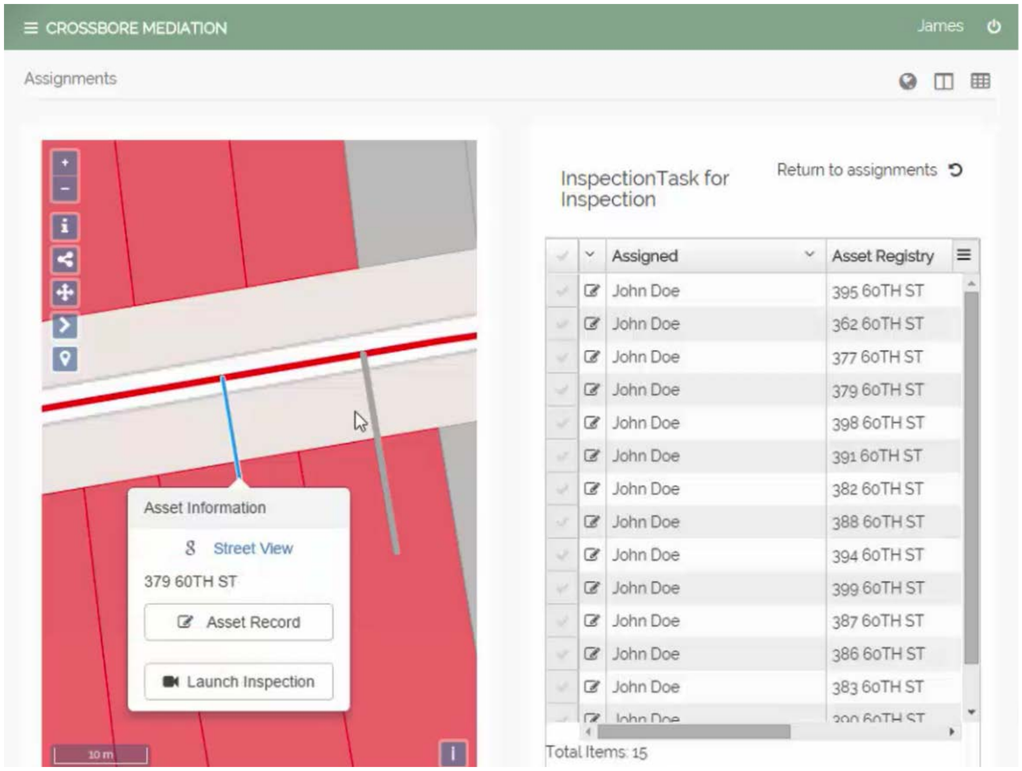

Figure 3. Assignment of parcels for inspection. Color coding indicates inspection status to operators in the field. Red parcel indicates asset "Not resolved"
Source: Frontline Energy Services

Workflow Management Lessons Learned

Communication Issues –

Several problems can arise when email is used as a data transfer method. A cross bore discovery notification form may be emailed to a field supervisor, but this transfer of information is at risk of being misdirected to an unused or incorrect email address, thus postponing follow-up. For example:

- Use of a distribution list is unenforceable. Email may be sent to an obsolete, inactive address which has not been shut down, so no mailer daemon warns of the error.
- Others may not clean up their inbox. Regulations make the utility responsible for positively identifying their gas assets. The responsible gas engineer's email inbox can collect a long list of backlogged requests for positive identification of gas pipe in video stills buried amongst other emails.
- Email remains a weak link in automated processes. One can write software to automatically tabulate forms emailed to a central address, but data may be sent to the wrong address due to a typo or incorrect use of autofill.

Solution: Forms are filled out via a web interface and automatically assigned to the next person in the workflow process. The workflow management system can grant access to people responsible for decisions and prompt them with a task reminder. This moves tasks along, as each responsible party submits their part and the next action in the process is automatically shown to the next person responsible in their task list. An interface gives each participant visibility according to log in permissions, and each decision and transfer of responsibility is traceable. Productivity can increase approximately 20% after replacing email with this system.

Inspection Completeness Issues –

Inspection subcontractors tend to manage their own resources to fulfil assignments. When work is tracked at the parcel level (as opposed to the pipe asset), part of an inspection may be skipped on up to 25% of assigned parcels. This occurs for various reasons; some are postponed to obtain access permission but many lateral segments are bypassed inadvertently. The tendency is to move ahead and complete as many inspections as possible each day, but if they could catch skipped addresses and additional laterals in the field, they would finish while they are there. Coming back to set up again to finish work is a preventable expense.

Video files are so large and numerous that weekly hand delivery of hard drives may be necessary to validate complete assignments. Typically, by the time data is received and the QC team reviews their export files and gives feedback, the inspection crews have moved on to other assignments. Contractors are naturally reluctant to go back out, set up, and re-inspect to complete an assignment without extra compensation.

Solution: Access to an asset-centric assessment database dashboard enables greater situational awareness among subcontractors, resulting in more complete and timely work. Inspectors in their camera trucks have a more immediate view of the inspection status of each assigned asset on a block (Figure 4).

Computer workstations in the inspection trucks are connected by Wi-Fi or wireless cellular, and outside the coverage area, they can still work offline. Subcontractors complete and submit data as they go. It is in their interests to do so, as they are not paid for incomplete laterals.

Every time they identify a lateral tap, that is, the end of a lateral segment, a camera operator will enter a new lateral line in the map interface. The SOP requires that they camera inspect that segment and record the other end point of the segment. This procedure is enforced by the asset-centric data management software as well as by SOP, and overseen by supervisors in the field. A site inspection cannot be counted as "complete" until every lateral and branch lateral discovered has been inspected and its condition resolved.

The dashboard improves promptness of reporting as well. Inspector supervisors, QC personnel and management can monitor work in progress. Authorized stakeholders have the ability to access real time information relevant to their own work through the system as they require it.

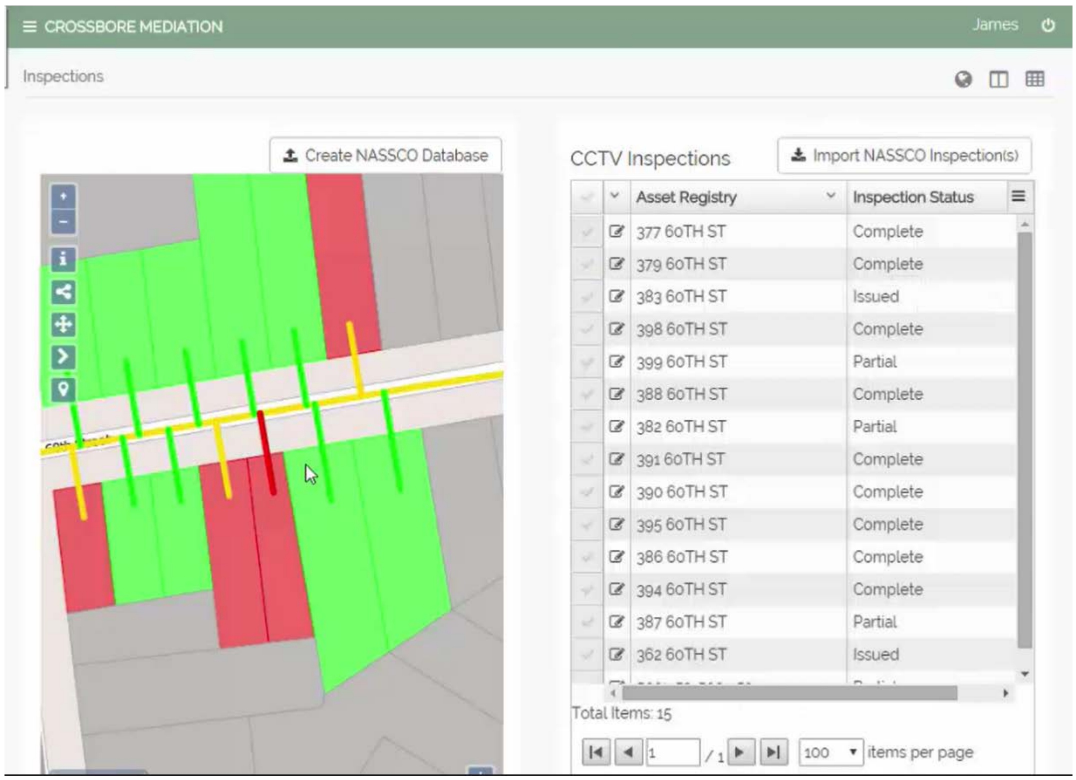

Figure 4. The color of parcels and pipe assets (sewer laterals and main lines) indicates their inspection status at a glance. Green means inspection is complete and status is "resolved". Yellow means "partial inspection", which occurs when the two access points at both ends of the segment have not yet been captured, as may occur when a lateral is blocked with debris. Red means address assignment has been issued but asset status is "unresolved."
Source: Frontline Energy Services

Traceable, Verifiable, and Complete Data

An asset-centric assessment database gives insight to the status for an inspected parcel or sewer lateral at any point in time. GIS holds the data to provide the status at each stage that an address must pass through on its way to being fully cleared. All research, assignments, inspections, resolutions, validation and verifiable proof data is connected through GIS and visible in a customizable dashboard.

Forms of verifiable proof:

- **Engineering Records –** As-built and other construction records showing the basis of decisions, used to determine whether or not to inspect specific sewer mains and laterals.
- **Inspection Videos –** Linked to parcel addresses and providing evidence for decisions regarding repair or clearance, and demonstrating the absence of cross bores in pipe assets.
- **Field Forms and Data –** Cross bore discovery (and repair), pipe damage, building access and cross bores requiring research or a decision by a gas engineer.

Real time database analytics tools validate data and video from the field with GIS assignments and location information. Data outliers, like files that are too small or out of order addresses, are identified for closer examination. Any incomplete segments or gaps are immediately reported to operators in the field for on-site correction, and tracked to prevent unnecessary re-inspection of whole mains and laterals.

Control Cost

Throughput of each analyst increases because numerous analysis hours are saved by automated validation of field work data, reports and videos against the reference GIS and a decision making model incorporating acceptance criteria.

Detailed gas service record review identifies which locations to inspect, reducing the cost of inspection, GPS collection and QC, forms, and results validation, at parcels where sewer lines could not have been impacted due to the relative location of gas installation.

Automatically catching and completing all parts of work assignments while on site saves costs of second or third trips to the site due to incomplete inspections.

Sewer inspection video analysis compliant with industry standards performed by qualified personnel gets the most value out of the video review sampling process.

Traceable and secure systems for managing data, documents and reports to stakeholders save time and frustration searching for evidence of status, because it is all tied to specific assets related to specific locations and addresses.

Verifiably complete records of completed inspections of all potential sewer and natural gas asset conflicts within program scope are readily available to present as evidence that the cross bore safety inspection program is well controlled, and that DIMP leaders are taking prudent precautions to make the gas distribution system safer from cross bore risk.

Conclusion

Asset-centric assessment data management techniques and tools described in this paper help Natural Gas service providers avoid the common pitfalls of a typical manually controlled inspection program and ensure maximum elimination of cross bore risk. Tracking each parcel assigned and each pipe segment observed in an Asset-Centric Assessment System can prevent costly delays and rework by providing field operators with prompt status information for each gas asset. More importantly, natural gas distribution risk management decisions can be made with confidence based on complete and highly accurate inspection data.

G2-Integrated Solutions

G2 Integrated Solutions (G2-IS) delivers expertise to pipeline operators, utility companies and other energy stakeholders in seven specialized service disciplines - Asset Integrity, Engineering, Geospatial Systems and Services, Regulatory, Field Services, Technical Services and Strategic Consulting. G2-IS provides end-to-end solutions that help manage risk, assure compliance and optimize performance. Our commitment is to implement innovative, cost-effective solutions that align specifically with our customers' needs. We are headquartered in Houston, Texas, and we also have offices in Angleton, Texas, Denver, Colorado and Concord, California.

Frontline Energy Services is a G2 Integrated Solutions company based out of Concord, CA. We are Cross Bore, Asset Integrity and GIS experts known for innovative design, software development, asset mapping and verification services. We design and lead cross bore risk management programs, leak and corrosion surveys and other inspection services aligned with PHMSA and API regulatory compliance.

Our clients are major transmission and distribution pipeline utilities. Since 2011, Frontline has designed and run cross bore safety inspection programs. Over 150,000 potential gas and sewer line conflicts have been evaluated so far, and current clients plan to accomplish over 4 million evaluations of customers' and other properties. According to client needs, we manage specific procedures or all daily operations under contract.

References

1. "AGA White Paper: Natural Gas Pipelines and Unmarked Sewer Lines – A Damage Prevention Partnership", American Gas Association, 2010
2. RKI Instruments web page, "What is %LEL and %UEL", http://www.rkiinstruments.com/pages/faq/What_is_LEL_UEL.htm
3. "Call before you clear" web page, http://callbeforeyouclear.com/