Large Diameter Ductile Iron Pipe Bursting Success Through Collaboration

Mike Paluso, State Utility Contractors, Inc., Monroe, NC
Jeff Greene, KRG Utility, Inc., Lenoir, NC
Brian Hunter, TT Technologies, Inc., Aurora, IL

1. ABSTRACT

To meet the goal of eliminating sewage overflows in its sanitary sewer system, the City of Wilmington in New Hanover County, NC funded the NEI Rehabilitation Phase 2 Project, which included the replacement of approximately 5,140 linear feet (LF) of a 20-inch-diameter ductile iron pipe (DIP) force main. Static pipe bursting was the chosen method for replacing the 20-inch force main due to the high volume of vehicular traffic, a highly restricted work area, and the presence of numerous underground utilities. The successful completion of the project required a number of field adjustments consisting of bypass pumping, additional traffic control measures, intermediate pit locations, and the addition of line stops. The use of line stops providing the ability to isolate sections of the force main, which limited liabilities for both the Contractor and the Owner. The linestops also reduced costs and requirements for pipe drain time and pump station shut downs. The keys to successfully completing this project that has the largest 20-inch DIP bursting job in the United States with the longest single DIP bursting pull were careful construction administration, a skilled contractor, and close teamwork between the owner, contractor, construction observer, and engineering personnel. An indication of the success of this project was that it was submitted by State Utility Contracting with Kimley-Horn as the partner for the 2015 AGC Pinnacle Award for the best construction project of any type with a construction cost of less than 5 million in NC and SC.

2. INTRODUCTION

Per the recommendations of a sewer study by Kimley-Horn, it was recommended to complete particular capital improvement projects to reduce the chances of future overflows that may occur. The last of those capital improvement projects, now completed, included the NEI Rehabilitation Phase 2 Project, requiring cleaning, CCTV inspection, and replacement of approximately 5,140 LF of the existing 20-inch-diameter DIP. The project also included replacement of three air and vacuum/pressure air release valve assemblies, bypass pumping, traffic control, and surface restoration.

The aging 20-inch DIP force main in the NEI Segment 2A was installed in 1977 between the Bradley Creek and Hewlett’s Creek Pump Stations in Wilmington. The presence of sewer gases created a condition causing the force main to deteriorate over time. The areas to be replaced per the sewer study consisted of five different locations along approximately 3 miles of Greenville Loop Road and Oleander Drive (Figure 16). These segments varied from 400 LF to 2,200 LF in length.
Since 1977, the right-of-way in which the new 20-inch DIP force main was installed had become congested with other utilities, making conventional methods of replacement of the force main impractical. In addition, Greenville Loop Road is accessed by 750 to 1,000 residential properties and an elementary school. Any sewage spill in this area would have a disastrous impact on a large number of residents and two tidal creeks, as well as create other adverse environmental concerns.

3. DESIGN CONSIDERATIONS

Understanding that the NEI Rehabilitation Phase 2 Project would be technically challenging, the Owner (Cape Fear Public Utility Authority) and Kimley-Horn considered trenchless technologies for the design solution. The method chosen was an innovative trenchless method known as static pipe bursting. Pipe bursting is a trenchless method used for pipe replacement where the existing pipe is forced and split apart and used as a conduit for the installation of the new pipe. The benefits of pipe bursting are cost savings, less disruptions, and a reduction in the time needed to install new pipe over the more conventional direct bury method. Although pneumatic pipe bursting is more common, it has its limitations for DIP and steel pipe because these type pipes are not made of a brittle material. In addition, sandy soils are prevalent in the City of Wilmington with a potential for high water tables—conditions that are not conducive to using pneumatic pipe bursting. The vibrations created by pneumatic pipe bursting can cause sand to liquefy, which can result in complications with the pipe installation since the work area becomes unstable. CFPUA and Kimley-Horn had experienced success with pipe bursting in the previous Phase 1 of the NEI project that took place in 2008. In this case, much of the existing 20-inch-diameter ductile iron force main was rehabilitated through cured-in-place pipe. However, one particular section of force main failed to maintain pressure under testing and had to be re-lined three times. After attempting to cut out the failed liners from almost 500 feet of force main, another solution had to be determined. Kimley-Horn brainstormed with CFPUA to arrive at more favorable alternatives, and it was decided to attempt pipe bursting. The timing for the force main to be repaired was so critical that equipment for directional drilling was mobilized as a back-up plan. KRG Utility was called in to determine the possibility of replacing the existing main with high-density polyethylene (HDPE) pipe through static pipe bursting. HDPE was used due to its flexibility, which was beneficial due to the area constraints for exit and lunch pits. Crews successfully used a static pipe bursting system with over 200 tons of pulling power to burst the 500 feet of 20-inch-diameter ductile iron force main (with the three high-pressure liners still installed) and replace it with 22-inch-diameter HDPE pipe. The use of pipe bursting on the Phase 1 project provided confidence that the use of static pipe bursting was a justifiable solution for the NEI Rehabilitation Phase 2 Project. Since the project area was in highly traveled section of road and a school it was critical to minimize the construction period.

For the NEI Rehabilitation Phase 2 Project to be successful, the following goals were established by Kimley-Horn and CFPUA:

- Provide CFPUA with a safe new conduit for handling sewer flows,
- Safely bypass sewer flows up to 13.5 million gallons per day,
- Provide a 100% redundant backup bypass system,
- Complete the project within the non-negotiable timeline mandated by the board,
- Safely manage traffic volumes up to 13,600 vehicles per day,
- Zero tolerance for sewage spills.

To achieve these goals, the experience and expertise of the project team during construction would be critical.

4. STATIC PIPE BURSTING PROCEDURE

While pneumatic pipe bursting has become widely used and accepted as a trenchless pipe replacement method, the development of hydraulically operated static bursting systems with bladed rollers has provided a favorable alternative. The static bursting systems are able to burst/split and replace ductile iron and steel pipes (Figure 1).
In the static process, exit and launch pits are used in the same way they are for pneumatic bursting. First, the hydraulic bursting unit is positioned in the exit pit. Then the bursting rods are pushed through the host pipe and into the launch pit. Patented QuickLock bursting rods are linked not screwed together like traditional drill stems or other static systems. This system speeds the installation process as well as the breakdown procedure. The rods can be removed quickly, one at a time, at the exit pit as the bursting operation continues. A flexible guide rod helps the bursting rods navigate through the host pipe as shown in Figure 2 and 3.

![Figure 2. Typical static pipe bursting setup.](image)

This flexible guide rod allows the bursting rods to navigate the typical imperfections found on the inside of the host pipe such as sags, humps, dropped joints, debris, and other obstacles. Based on CCTV the extent of the existing conditions is known to help ensure that the flexible guide rod can be place. At the launch pit, the flexible guide rod is removed. The bladed rollers, bursting head, expander, and new pipe are then attached (Figures 4).

![Figure 3. Flexible guide rod.](image)

![Figure 4. Bursting configuration attached and pullback begins.](image)
Figure 5. Host pipe split and displaced while new pipe is pulled into place.

The entire configuration is pulled back through the host pipe by the hydraulic bursting unit. The specially designed bladed rollers split the existing pipe instead of ripping or tearing it (Figure 5), while the bursting head and expander displace the fragmented host pipe into the surrounding soil. Careful attention needs to be paid to the separation between the pipe to be burst and the existing utilities.

Other pipe materials may be installed in certain situations. Potential pipe materials include restrained joint DIP and restrained joint PVC pipe, among others. The NEI Rehabilitation Phase 2 Project was bid with the alternative of PVC or HDPE to allow for competitive bidding. PVC pipe was more cost effective although it has less flexibility than HDPE, which resulted in larger pits.

5. CONSTRUCTION ADMINISTRATION AND LESSONS LEARNED

State Utility Contractors, Inc. (State Utility) was awarded the bid and subcontracted with KRG Utility, Inc. for the pipe bursting portion of the project.

To meet the project goals, it was critical that there was a clear, established collaboration between the owner, contractor, design engineer, construction observer, pipe supplier, and equipment manufacturer. The Kimley-Horn project manager set up a weekly conference call on Monday morning to maintain this important link between the parties. The typical call included the CFPUA project manager, contractor foreman, contractor office engineer, Kimley-Horn’s project manager, and construction observer. The purpose of these calls was to discuss the key action items identified on the critical path schedule. The sessions also presented a forum for the team to collaboratively resolve construction problems. Although pipe bursting is often referred to as a “no-dig” procedure, it is still a requirement to excavate for pits, and several tasks are required in addition to the pipe bursting procedure. Following are some of these incidental items and project challenges.

Schedule

The milestone date for the award of the NEI Rehabilitation Phase 2 Project was November 30, 2013, and the milestone date for completion of the project was April 30, 2015. Due to issues with permitting and acquiring easements, the project was not awarded until April 2014, reducing the time originally allotted for construction by five months.

During the bidding process, the bidders expressed their concerns to CFPUA and Kimley-Horn about the ability to complete the project in the time allowed. However, it was not acceptable to add time to the contract due to the importance of replacing the pipe prior to the social issues in the area and the goal of limiting possible Sanitary Sewer Overflow (SSO). The project team was aware that proper contractor planning and construction administration would be essential.
Submittal Process
The submittal process began early in the project, before the Notice to Proceed. Kimley-Horn developed a submittal tracking form that was used to log all submittals. This information was discussed at each of the weekly meetings. Kimley-Horn focused on the submittals that State Utility indicated were on the critical path.

The pipe that was approved as the replacement pipe was 20-inch-diameter DR 18 C905 FPVC. This fusible PVC pipe is made by Underground Solutions, Inc from (UGSI), Poway, CA. This pipe came in 45 LF sections that were fused together to make the pipe one continuous run for the lengths that were needed (Figure 6). Underground Solutions provided the pipe and technicians needed to fuse the pipe, with State Utility crews providing support as needed. The pipe sections were fused to the predetermined lengths prior to the bursting operation. These sections could be as long as 900 LF and were staged along the side of the right-of-way.

The Emergency Action Plan was another key submittal. This submittal provided emergency contacts and described how, in the event of a SSO, the environment would be protected and which agencies and individuals would receive notifications. This safeguard was vital to help the team communicate to the public and the City committees.

Subsurface Utility Exploration versus Contractor Locates
CFPUA recently adopted the procedure of not conducting Subsurface Utility Exploration (SUE) during design but instead making SUE a responsibility of the contractor during construction. The advantage of this concept is that, since the contractor will ultimately be performing the work, the contractor can perform this work as part of its mobilization plan and remain responsible for the “means and methods” of the contractor’s work. However, the disadvantage is that there may be substantial field changes that call for design revisions. Although disclaimers are added to the plans to make it clear that the exact location of utilities are unknown, it takes considerable effort to resolve issues if the utilities are not shown correctly and may result in unexpected costs for the contractor.

Prior to the start of construction, locate tickets were called into NC 811 for the pulling and receiving pit locations as originally designed. This step was performed to identify any potential utility conflicts and make adjustments as necessary. State Utility crews performed excavation at every pit site and uncovered all the utilities, including the existing force main, and documented the locations of each. As part of this process, it was found that new utilities had been installed since the design, and some of the as-built information used for the location of the force main was incorrect. This information then was shared with Kimley-Horn prior to construction so that adjustments could be made, which maintained the progress of the project.

Area 1 is a good example of the challenges associated with the unknown utility locations. This area was a 400 LF section of force main at the intersection of Greenville Loop Road and Oleander Drive. The as-built information CFPUA provided for this section was from 1977 and not reliable. Oleander Drive has been widened several times since the as-builts were completed and unfortunately, the point of reference for the as-builts was the centerline of the road, which had changed several times. As a result, the force main was difficult to find and was not reflected accurately on the plans.

Greenville Loop Road is maintained by the City of Wilmington, which has different requirements than North Carolina Department of Transportation (NCDOT.) Oleander Drive is maintained by NCDOT and they require that any excavation that is located within the 1:1 slope of the edge of pavement must use active shoring. Active shoring is different from traditional shoring in that trench
boxes cannot be used; rather, the more expensive and time-consuming method of driving steel sheeting is used. The exploration also uncovered a newly installed AT&T duct bank consisting of several 2-inch PVC conduits carrying fiber-optic lines directly over the pipe to be replaced (Figure 7). The contractor provided the field results to Kimley-Horn and alternatives were discussed during the weekly meetings. To stay on schedule, Kimley-Horn reviewed this information and made recommendations to CFPUA, which resulted in quick approvals and adjustment of the location of the pits.

Due to the location of the existing utilities in the NCDOT right-of-way, it would be necessary to submit for a new NCDOT encroachment, which could take over a month. In addition, NCDOT would require active shoring on these pits, which is a hindrance to the progress of construction. Another complication was that AT&T told CFPUA it would be cost prohibitive for them to relocate their fiber cable. The decision was made to hand dig the entire run of existing fiber ducts in the pit area and temporarily support them at each pit location. This is where the pre-construction planning and team collaboration paid off by eliminating any delays to the project and it was possible to pipe burst in this area with one pull and eliminate a pit and the need for additional excavation.

Based on this project, it was determined by the team that performing some SUE during the design phase is critical. Accurate utility locations can help to reduce the potential for construction delays. However, in the case of the NEI Rehabilitation Phase 2 Project, the collaboration of the team members resolved the problem quickly to keep the project on schedule.

**Bypass Pumping**

The size and duration of the bypassing operation required for this project was large and complex. The bypass system was designed to handle flows of up to 13.5 million gallons per day (MGD) and was to be in place for 7 months. Since the 20-inch-diameter force main in Segment 2A was to be replaced using the pipe bursting method, it was necessary to divert the flow (bypass) of the sewer during construction (Figure 17). This bypass was in operation only during the periods when the rehabilitated segments were not connected to the existing force main. The flow from PS 35 to PS 34 in Segment 2A could be redirected at PS 35 through other segments to go to the Southside Wastewater Treatment Plant, isolating Segment 2A. However, redirecting the flow as stated would create a situation where current head conditions within the NEI would force the pumps at PS 34 and PS 35 to operate outside of the preferred operating range and possibly result in pump shaft failures. This situation required the installation of temporary bypass pumps capable of handling the new head conditions. Xylem Inc. was subcontracted to help design and install the temporary bypass system. Xylem representatives worked closely with Kimley-Horn and CFPUA prior to the bid and after the contract award to design a system that was the best fit as well as a failsafe. This design was critical due to the large flow of sewage encountered at each pump station in a 24-hour period. Because of the expense and liability of running the bypass, a critical goal was to minimize the time that the bypassing had to occur.

**CFPUA Operations and Replacement in Sections**

The CFPUA project manager had the crucial role of coordinating with the CFPUA Operations Department for the period when the bypass of the 20-inch-diameter force main would be in operation as well as for the performance of the 11 smaller pump stations along the route (Figure 17). Per the construction drawings the contractor pipe-bursted in five separate sections, which allowed CFPUA Operations to focus only on the smaller pump stations that would be impacted when the 20-inch-diameter pipe area was taken out of service. The Contractor chose to burst in reverse order 5, 4, 3, 2, 1 that had the benefit of starting with the easiest burst first. As discussed in the following section, the line stops also assisted CFPUA Operations by reducing the shut-down time of some of the smaller pump stations.

**Line Stops (Change Order)**

During the submittal process, the contractor approached CFPUA and Kimley-Horn about inserting temporary valves (line stops) at the ends of each section of force main to be replaced. The team agreed this would be the best option to greatly reduce the risk of a spill, save money, and decrease the impact to the public due to the reduced truck traffic that would be required to drain the line. These line stops were removed as each section was tested and reconnected.
Team Industrial Services, Inc. of Wilmington was subcontracted to install the line stops. A total of nine line stops were used in this project. The use of line stops on a 20-inch-diameter DIP is not a common practice due to the size of pipe. Since these line stops saved the contractor cost in potential pump and haul and traffic control expense as well as helped to reduce risk, State Utility agreed to provide the labor and equipment to dig the pits needed for the line stop subcontractor at no extra charge to CFPUA. CFPUA agreed to pay for the cost of the line stop subcontractor. Sharing the cost in this way provided CFPUA with a savings of $65,000. During the design of a project, the use of line stops should be a consideration. Kimley-Horn has acted on this lessons learned and added line stops / inserta valves to the future NEI ARV project. Another benefit of the line stops is they provide additional sections of pipes (coupounds) that can be analyzed to ensure that the extent of the pipe repair is acceptable.

**Traffic Control**

Lane closures were needed for construction on Greenville Loop Road, one of the most heavily traveled sections of road in Wilmington with an average traffic volume of 13,600 vehicles per day. The work hours were restricted to minimize the impact to traffic during peak periods. Kimley-Horn designed the traffic control plans for the excavation of the pits. Traffic control was required not only for excavating the pits, but also for staging of fusible pipe during the pipe-bursting process (Figure 9).

An unexpected challenge was that a new median was installed in front of a school in Area 4 after the project had been surveyed. Kimley-Horn’s traffic control plans for the area that had been approved would not work because of the median. Although at first it was thought that removing the median was an option, the City decided that the median could not be removed due to public concerns. Therefore, the team worked with the City to revise and adjust the traffic control plans.

In other areas of the project, based on the contractor’s “means and methods,” other adjustments were made to the traffic control plans, which the contractor coordinated with the City. The traffic control plans served their purpose, which is made evident by the fact that there were no reported traffic accidents in the work zone of the NEI Rehabilitation Phase 2 Project.

**Public Coordination**

Staging the fused pipe at these lengths also had its challenges. These sections were made in advance and sometimes had to be staged for longer than one month. One of the significant concerns was maintaining access to driveways and roads. This was addressed by cutting a small trench across the driveway or road for the pipe to set in and placing steel traffic plates over the trench to maintain access. It was critically important to communicate with the businesses and homeowners along the route so they understood the construction schedule (Figure 10). A benefit of pipe bursting is that it can be scheduled to occur when businesses are closed, and the construction time is much faster than open cut to minimize social impacts.

**Ground Water Control and Surface Water (Erosion) Control**

The construction phase took place during the rainy season, so proper erosion control was critical. Due to the presence of ground water, it was necessary to install small well points (whistler pipes) to manage both the ground water and the rainwater that accumulated in the excavation during periods of rain.

The contractor’s “means and methods” resulted in more disturbance than what was originally permitted with the North Carolina Department of Environmental Quality (NCDEQ). Kimley-Horn worked closely with NCDEQ to address their comments during construction and submit a revised permit that was approved on the
first submittal in only eight days! The communication with NCDEQ—both in the office by the Kimley-Horn project manager and in the field by the construction observer kept the project from being shut down and the contractor being fined.

The use of pipe bursting greatly reduces the amount of ground water control and necessary erosion control. However, when considering disturbance areas, it is critical to include locations beyond excavation pits, such as stockpiles and staging areas.

**Pipe Bursting Procedure**

For a typical pipe burst run on the NEI Rehabilitation Phase 2 Project, State Utility prepared the launch and exit pits. The location of the pits were adjusted based on the existing conditions and after the condition of the pipes were verified. KRG Utility crews, after placing the bursting unit in the exit pit, then would rod the host pipe with the QuickLock bursting from the exit pit to the launch pit. At the launch pit, the splitter head configuration was attached to the fusible PVC (Figure 11). The fused PVC was dragged into position at the launch pit. Launch and exit pits were approximately 30 feet long and 8 to 10 feet deep (Figures 12-14). KRG Utility crews divided the job in a way that enabled them to position the bursting unit in the middle of two runs. That way, after the first burst was completed, crews simply lifted the bursting unit, turned it 180 degrees, and set it back in the pit, and it was ready to begin the next bursting run.

As previously discussed, the project was divided into five sections with the largest section being 2,000 feet in length, while the other four sections made up the remaining 3,000 feet (Figure 17). Most of the runs were completed along City roads, along with one section of DOT-maintained road as previously discussed. KRG Utility performed a total of nine bursts, with an average burst length of 450 feet. The longest bursting run for the project was approximately 900 feet. Once the bursting was complete, KRG Utility turned over the project to State Utility to complete the tie-in of the sewer force main.

**Pipe Bursting Adjustments to Save Money**

During the project, State Utility learned from Area 5 (approximately 350 LF) pipe bursting sections and used this information to work with CFPUA, Kimley-Horn, and KRG to lengthen the individual pipe bursts. The pulling pressures remained well below the maximum pressure that the pulling machine could handle. The project design showed there would be a total of 13 sections of pipe to be pulled up to 500 LF in length. Based on information that was collected from the completed sections, the team determined it would be possible to lengthen the pulling length and eliminate some of the pits. As a result of the team’s cooperation and communication, it was possible to reduce the total amount of pulls from 13 to 9, with the longest pull being 900 LF, almost twice as long as the longest pull originally designed. This saved weeks of work and helped to ensure the completion date established by the consent decree would be met.

**Construction Observation**

Kimley-Horns subconsultant Jack Smiley Construction Services, Inc., provided construction observation services. He was at the site between 20% to 40% of the time, depending on the construction activity. Per Kimley-Horn’s
policy, a construction observer is not authorized to make field changes. However, a skilled construction observer can help to anticipate potential problems and make recommendations to the engineer. The engineers quick access to this information can expedite the decision making process. Another important responsibility of the construction observer is to keep track of the quantities on the project. Several of the pay items are paid by units, and the contract documents specify what is to be paid. In some cases, such as pavement damage, a decision has to be made regarding whether the damage was an existing condition, caused by the contractor due to poor construction practices, or a necessary repair due to improper construction procedures. Having an engineer’s representative at the site is beneficial to make recommendations to the engineer based on the site visits.

**Ground Heave**

A concern during design is that there would be some ground heave during the pipe bursting procedure, since the force main only had 3 feet of cover in some areas. The construction observer closely monitored pipe heave, and a section of asphalt did heave as a result of the pipe bursting. Some of the asphalt was not damaged and settled back into the original location once the area was rolled and traffic was reinstated. However, some sections of pavement were damaged and had to be replaced. The contract documents included as bid item for restoration. It is difficult to anticipate the amount of damage caused by pipe heave, and using measured bid items is beneficial.

**Partial Substantial Completion**

To reduce the amount of necessary bypassing to minimize cost and liability, Kimley-Horn worked with CFPUA to have four Partial Substantial Completions so the newly installed pipe could be used as each section was completed. Therefore, CFPUA received use of the new pipe even before the total completion of the project. A pressure test was run to 150 psi on each section, and there was no leakage. The coupons (cut pipe material) from the line stops and the sections of pipe that were cut were carefully observed to verify that the existing DIP was not deteriorated prior to the line being capped. Kimley-Horn wrote a Partial Substantial Completion letter, which allowed the bypass to be turned off.

**6. CONCLUSION**

The NEI Phase 2 Rehabilitation Project was a highly complex pipe bursting project in a densely populated area that included a complicated bypass system, line stops, active shoring, traffic control, and ground water and erosion control. In addition, this project had to be constructed under a tight deadline. The NEI Rehabilitation Phase 2 Project validated the importance of team collaboration, effective project management, and a skilled team consisting of a contractor, owner’s project manager, system operators, equipment suppliers, and construction observer. The use of pipe bursting was the correct trenchless solution for this project. However, it is important to understand that pipe bursting is not a “no-dig” procedure, and there are many incidental items that must be completed for a successful project. A key area of focus is how to both drain the force main and temporarily divert the flow until the new pipe can be tested and placed back into service. An indication of the project’s success can be summarized as follows:

- The contractor successfully accomplished a 20-inch-diameter DIP bursting project that has the longest single DIP bursting pull in the United States.
- There were no sewer spills.
- There were no reported traffic accidents.
- The team worked together for expedited submittal approval and took a collaborative approach to addressing issues in the field to meet the consent decree date.

In recognition of these achievements, State Utility submitted this project to the Carolinas Associated General Contractors Pinnacle Award for Best Utility Project under $5 million and included Kimley-Horn as a Pinnacle partner. The team’s expertise and the ability to collaboratively work together was the key to the success of this challenging and complicated project.