



**North American Society for Trenchless Technology (NASTT)
NASTT's 2014 No-Dig Show**



**Orlando, Florida
April 13-17, 2014**

Paper # MA-T5-02

**Pilot Tube Microtunneling Chosen in Omaha Nebraska
for 585', Single Drive with Depths Reaching 50'
to Preserve Sensitive Garden Area**

David Gill, The Logan Clay Products Company, Blair, Nebraska
Chris Koenig, HDR Engineering, Omaha, Nebraska
Chris Cain, HDR Engineering, Omaha, Nebraska
Kenton Moore, Horizontal Boring & Tunneling Co., Exeter, Nebraska
Tim Papstein, City Of Omaha, Nebraska

1. ABSTRACT

Case Study: Pilot Tube Microtunneling project: 30" Diameter Storm Sewer
Project: Lauritzen Gardens Sanitary and Storm Sewer Separation Project
Owner: City of Omaha, Nebraska
Engineer: HDR; Omaha, Nebraska
Contractor: Horizontal Boring & Tunneling Co.; Exeter, Nebraska

Omaha, NE, stretching along the Missouri River for 7 miles, is currently under a consent order with the Nebraska Department of Environmental Quality to improve the water quality in the Missouri River. The estimated construction cost of the program, including sewer separation is \$1.7 billion dollars. One project defined by the program was a sewer separation project, which took place in a very sensitive setting, Omaha's Lauritzen Gardens.

A portion of the project consisted of one 587' drive of 30" gravity storm sewer, installed through a hillside at depths up to 50 ft. The contractor elected to utilize a 12 ft. x 40 ft. rectangular shaft and a three-pass installation process. Hard clays caused the insertion of the pilot tubes to halt 280' short of the reception shaft. A decision was made to retract the pilot rods and relocate the pilot tube frame to the reception shaft and install pilot tubes from the opposite direction to intersect the first pilot tube hole.

After successfully intersecting the first pilot tube, it was determined that alignment was slightly off causing issues with the planned three-pass installation process. To resolve the alignment issues, an additional temporary casing pass was added to the installation process. The additional pass consisted of installing a 24" temporary steel casing for the entire crossing, followed by installation of the planned 38.5" OD temporary casing. Difficulty maintaining alignment of both temporary casings through the area of the pilot tube intersect, presented challenges which were overcome in the field. The final step was to jack out the 38.5" OD temporary casing using 30" ID (36" OD) vitrified clay jacking pipe. The 30" product pipe was on grade and 3' off alignment at the completion of this drive.

2. INTRODUCTION

One part of the Lauritzen Gardens Sanitary and Storm Sewer Separation Project was a single pilot tube microtunnel drive, 587' in length, through a hillside at depths of up to 50'. The designer needed to avoid a landfill area on one side and a large apartment complex on the other, or this path would not have been chosen.

Soil borings were taken at either end of the line indicating clay geotechnical conditions consisting of Peorian Loess of medium stiff to stiff consistency. The entire crossing was above groundwater. Conditions outside those described in the Defined Subsurface Conditions were encountered 260' into the crossing during the initial pilot tube pass preventing further advancement. The conditions encountered were hard clays, later determined to be in excess of 4.5 tons per square foot upon testing with a soil pocket penetrometer.

The contractor, Horizontal Boring & Tunneling Co., had the experience onsite to adjust the installation plan to create solutions based on the conditions and problems encountered during the crossing. In order to complete a pilot tube pass through the entire crossing, the crew opted to attempt an intersect of the first attempt. Moving their jacking frame from their original jacking pit, located at the upstream end of the crossing to the planned receiving pit location on the downstream end of the crossing was just the first step. The foreman, superintendent and project manager were aware of the potential for alignment issues when attempting an intersect and proceeded with caution.

3. BACKGROUND & DESIGN CONSTRAINTS

The City of Omaha is entering the fifth year of an eighteen-year program to address the combined sewer overflows in the City. A component of the work is to separate sanitary and storm sewers in selected areas of the combined sewer system area. One project within this program is the Lauritzen Gardens Sanitary and Storm Sewer Separation Project.

The site consists of 100 acres, approximately 70 of which are owned by the City with the remaining 30 acres owned by the Omaha Botanical Center, Inc. A portion of the Gardens site is referred to as the Balefill. The city operated a municipal solid waste landfill on the site between 1976 and 1982. Solid municipal waste was compacted and bound into bales and then placed at the site. The city completed closure of the site in May of 1983.

The Gardens were established in 1993 and are the result of a unique public-private partnership. Construction of the rose garden began in 1995, with other gardens following in short order. Today the site includes a shade garden, herb garden, Victorian Garden, Japanese Garden, children's garden and a spring flowering walk. Since opening, new garden areas have been added each year. Lauritzen Gardens has also created several exhibits including a multilevel model train that is maintained by the Union Pacific Railroad, memory garden, Japanese gate, the Song of the Lark Meadow that is reminiscent of Nebraska's prairies and is filled with native wildflowers and a stream. Lauritzen Gardens is a privately funded enterprise with several industry leaders on the Board of Directors. The Gardens are open year round and hosts over 150,000 visitors each year.

The improvements envisioned involved the construction of a new sanitary sewer within the Gardens and conversion of the existing combined sewer to a storm sewer system. However, the condition assessment of the existing sanitary, storm, and combined sewer systems found numerous defects that could not be easily repaired. The existing sewers, leachate collection, and sub-drain piping were located in the center of the valley under baled waste with manhole depths ranging up to 60-feet.

Abandonment of the existing sewers was recommended and approved. The new design called for only one crossing of the Balefill and that was a bridge crossing so the integrity of the Balefill would not be disturbed. (See Figure 1 for the site conditions and plan.) The 30" storm sewer alignment chosen was the only good option to avoid the Balefill on one side and a large apartment complex on the other. The design engineer specified a guided technology to ensure accuracy. (Koenig, 2013)

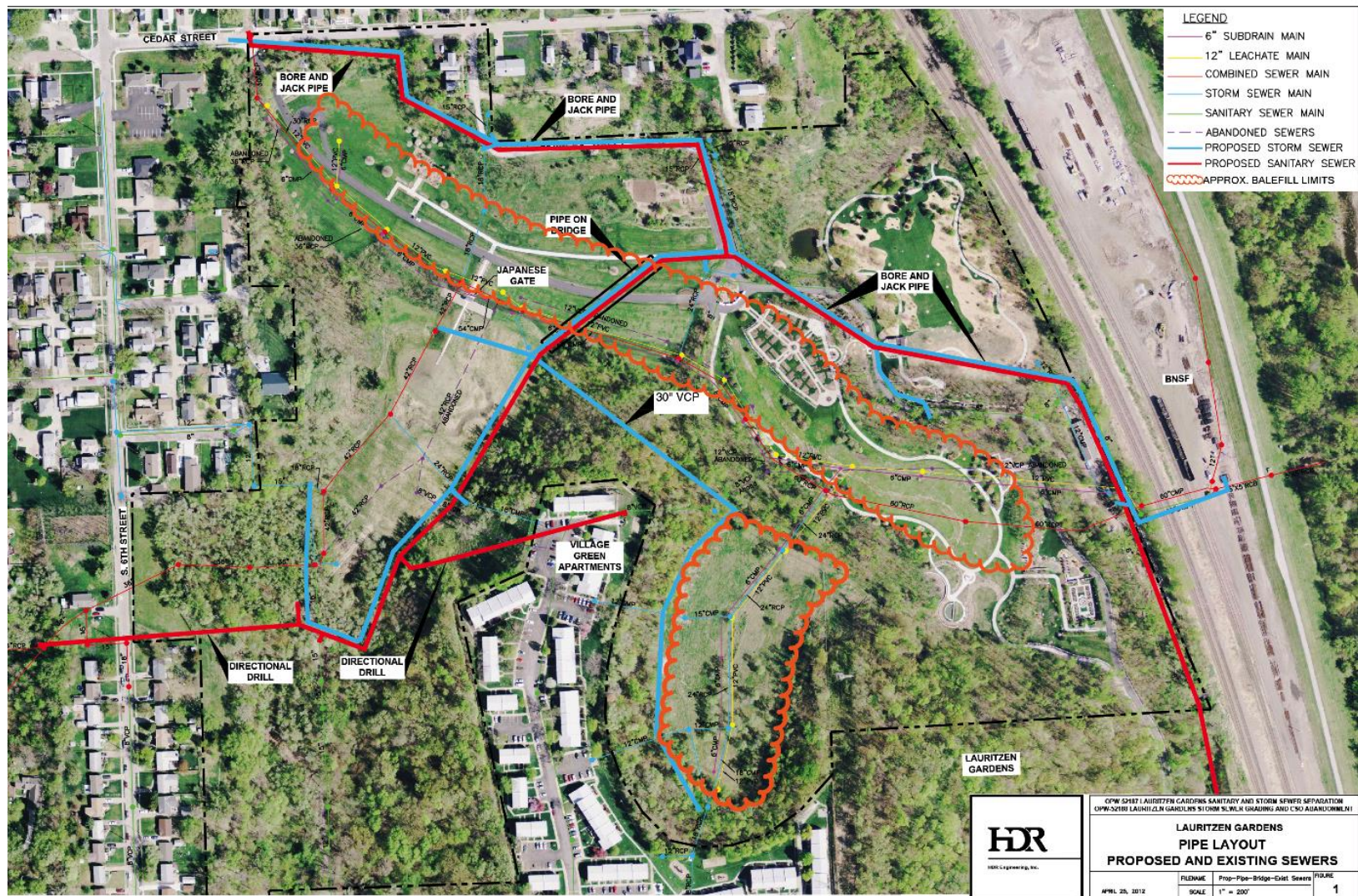


FIGURE 1: Site condition and plan

4. CONSTRUCTION PLAN

The subject project was designed as a 587' long pilot tube microtunnel installation of a 30" ID storm sewer at a 2.47% grade with depths of up to 50'. Although typically utilized for its corrosion resistance in sanitary applications, vitrified clay jacking pipe was selected for this installation for its axial compressive strength.

The 587' design length included a section on the downstream end that exited the ground, thus the trenchless crossing length was shortened to 540'. Based on previous experience, the contractor felt comfortable proceeding in the expected clay soils throughout the crossing.

A 17' deep, 12' x 40' jacking pit was constructed at the upstream end of the line. Because of pit depth, the adjacent hill, and the close proximity to the access road, the pit was constructed by stacking two 24' trench boxes at the front of the pit and two 16' trench boxes at the back of the pit. Both ends of the jacking pit were supported by custom-designed I-beam whalers, sheet piling, and steel plates. The receiving pit area was just a few feet below grade and a sloped excavation was utilized. A steep, tree-covered hillside obscured any line of sight between the jacking and receiving pits so survey control points were established, by a sub-contracted surveyor, using GPS. (See figures 2, 3 and 4 for elevation and site conditions.)

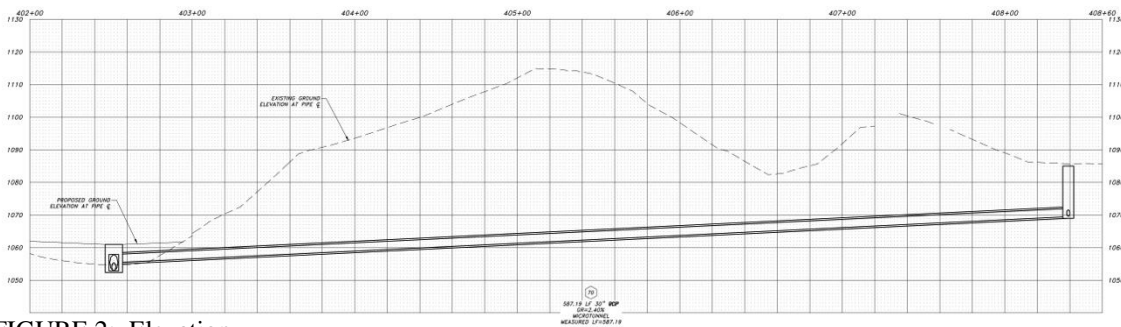


FIGURE 2: Elevation



FIGURE 3: Tree-covered hill obstructed line of sight



FIGURE 4: 12' x 40' upstream jacking pit

Soil bores had been taken at each end of the crossing near what became the pit locations. Due to the sensitive setting within the Lauritzen Gardens, the inability to access the steep hillside and the depth of cover in this area, no additional bores were taken along the length of the planned drive.

Once shaft construction was complete, an Akkerman 240A Guided Boring Machine jacking frame was set to the desired height, grade and alignment from the established survey control points. This machine provides 10,500 ft.-lbs. of rotational torque, 100 tons of jacking force and 50 tons of pull back force.

As in all pilot tube installations, the guidance system consisted of a digital theodolite with an integrated camera (mounted independent of the jacking frame), a battery powered LED illuminated target housed in the slant-faced steering head and a computer monitor screen. This guidance system provides the operator with a “real time” view of the position and orientation of the pilot tubes during installation (see figure 5).

The anticipated construction plan was to utilize a three-pass installation, which includes installation of a 4-inch pilot tube using the guided boring machine (first pass). The second pass was installation of a temporary casing followed by jacking the temporary casing out with concurrent installation of the product pipe (third pass). Horizontal Boring & Tunneling Co. elected to use an auger boring machine to install the temporary casing and product pipe because of its torque and thrust capabilities as well as the ability to install longer joints of steel casing pipe.

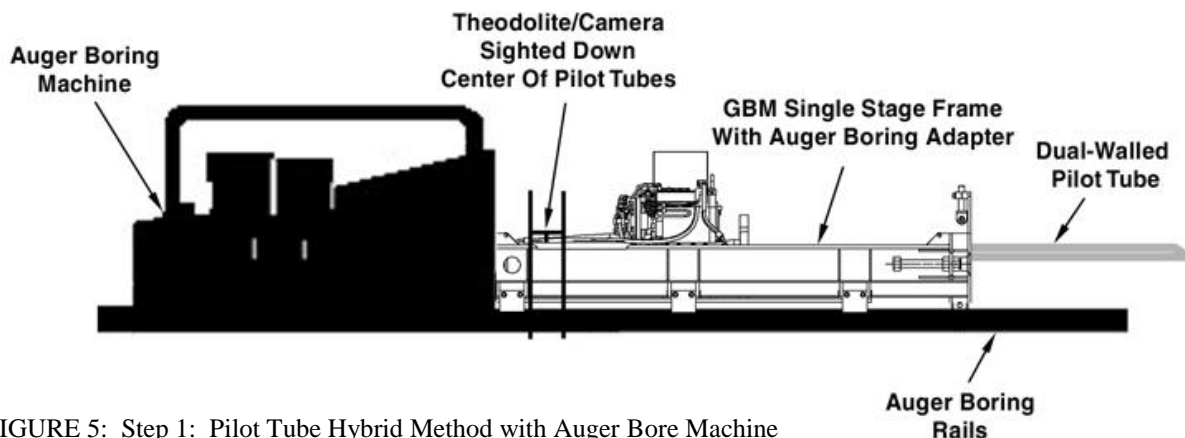


FIGURE 5: Step 1: Pilot Tube Hybrid Method with Auger Bore Machine

The planned first phase of construction involved pushing the pilot tube through the entire length of the drive. When all goes well, the completed pilot tube is upsized by a steel adapter attached directly to the pilot tube rod on one end and temporary steel casing on the opposite end. The auger boring machine turns an auger inside the adapter to remove the spoil as it enlarges the tunnel path created by the pilot tube. On this project, the initial plan was to upsize to 24" temporary casing for a distance of 60-80' and then utilize another upsize adapter to transition from 24" temporary casing to 38.5" OD temporary casing. . This intermediate step between the pilot tube and the finished size of the tunnel was planned and necessary because of the hardness of the soil. (See figure 6.)

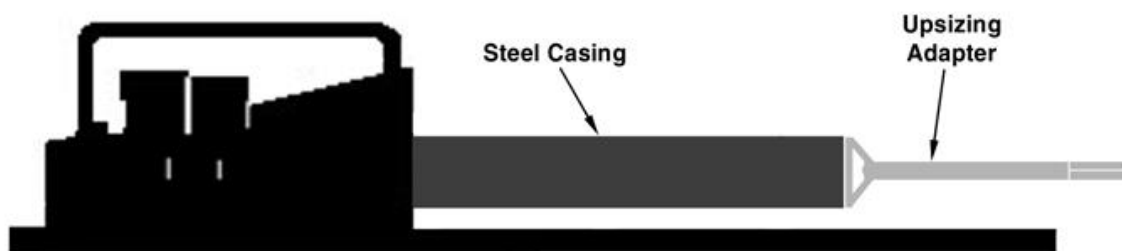


FIGURE 6: Step 2: Installation of the 24" casing

The initial 260' of the pilot tube drive proceeded as expected, but approximately 280' short of the receiving shaft pilot tube advancement halted after encountering hard clays. The pilot tube equipment did not reach its maximum thrust capability, but the jacking pressure applied to the pilot tube was sufficient to cause the pilot tube to flex in a serpentine motion in the slight overcut surrounding the pilot tube, making it difficult for the operator to see the target. The crew on site removed the pilot tube and attempted to reinsert it one time using a 5" O.D. and once, using a 4½" OD head, including a bullet shaped head for hard soils. The goal of using the reduced size head was to prevent overcut and reduce the serpentine motion created by the excessive stress. It was later discovered that this region included soils with an unconfined compressive strength in excess of 4.5 tons per square foot, well outside the manufacturers' recommendations.

Hard clays caused the insertion of the pilot tubes to halt 280' short of the reception shaft. A decision was made to retract the pilot rods and relocate the jacking frame to the reception shaft and install pilot tubes from the opposite direction to intersect the first pilot tube hole.

5. THE REALITY

The intersect pilot tube drive started from the downhill jacking site. At approximately 180' into this drive, 100' from successful intersection, the hard clays were encountered from the opposite direction. The operator was able to stay on target, until the point of intersection where the target shifted and the thrust pressure decreased suddenly and dramatically. As the operator continued to push the pilot tube string, it transitioned into the previous path and the visual on the target was lost. Despite the inability to see the target, the contractor chose to continue the advance until it exited on the uphill side of the crossing.

That inability to see the target and the ease of advancement once the pilot found the previous bore indicated to the experienced crew that the two holes were not perfectly aligned. Because of the imperfect alignment, adjustments to the initial plan were made in an effort to mitigate the bend or kink in the pilot tube bore. Because of the hard clay soil conditions, a 24" diameter auger was attached to the pilot tube via a swivel. This represented a change because the initial plan called for an adapter head to connect the 24" temporary casing to the pilot tube rod. In addition, instead of attaching a 24" to 38½" reaming head after installing 60' - 80' of 24" temporary casing per the original plan, the new plan called for pushing 24" temporary casings through the entire length, essentially adding a fourth pass to the three-pass method.

A Barbco 48/60-950 Auger Boring Machine was utilized to drive this process. This unit, which produces over a million pounds of thrust and up to 199,481 ft. lbs. of torque was selected because it produces enough torque to comfortably turn a long string (540 ft.) of large diameter (up to 36" in this case) auger.

The harder than expected soils and stiffness of the welded casing string made the attempt to smooth the alignment at the intersect point problematic. When the 24" temporary casing reached the intersect point in the original pilot tube path, the auger began to bind against the casing, indicating the auger was following the pilot tube through the slight bend, while the casing was continuing in a straight line. In order to alleviate some of the pressure, a bit was inserted to provide greater overcut in an attempt to get the casing to follow the pilot tube alignment. Use of a rock bit did not alleviate the bind, and when the rock bit was removed, it was apparent the swivel between the auger and pilot tube had been destroyed. In order to get a 24" casing through the entire crossing, the augers were removed from this casing and moved to the other pit (on the downhill side) where a second auger boring machine was set up to drive the remaining length in the opposite direction. The casings didn't meet up as desired, so the 24" temporary casing string could not be tied together. The crew began to remove casing from the downhill shaft by pulling it out while the other string of casing was augered and pushed down through from the uphill shaft. The crew was able to periodically inspect the behavior of the 24" casing being pushed downward from inside of the 24" casing being pulled out. Using this push-pull technique, the crew was able to achieve a continuous 24" temporary casing through the entire run, although the bend was still present, daylight could be seen through the 24" casing (See Figure 7).



FIGURE 7: View through the 24" temporary casing

After careful consideration of the current conditions and goals for the project, the decision was made to push the 38½" casing with 36" auger from the uphill shaft downward, while pushing out the 24" temporary casing. In order to connect and center the 38 ½" casing on the 24" casing, Horizontal Boring & Tunneling Co.'s fabrication shop produced an inverted top hat that would go inside the 24" casing and accommodate a swivel that attached to the hex on the 36" auger. This resulted in a similar configuration as before, where the 36" auger was connected directly to the 24" temporary casing. A rock bit was used and the crew began to push casing. Again, the crew encountered grinding near the point of intersect and the swivel connection was destroyed. The crew entered the casing and removed the top hat connection allowing visual inspection of the alignment. The 38 ½" casing was having trouble making the slight bend. The crew resumed the push-pull technique by pulling 24" temporary casing out from the downhill side with one boring machine while pushing 38 ½" casing downhill from the topside. Periodic visual inspection indicated the 38½" casing was on grade, but deviated from alignment. This deviation worsened in the softer soils towards the end of the crossing, but since grade was holding true, the crew continued to push. Once the casing emerged, the result was that the downstream end of the drive was out of alignment by approximately 3', with most of the alignment deviation occurring on the downhill end of the crossing in the softer soils.

With the path established by the 38.5" temporary casing, VCP was used to jack the casings out of the tunnel. The crew attached a 2" PVC line on top of the VCP in order to convey CLSM (Controlled Low-Strength Material) or flowable fill to fill the annular space at the completion of the installation (See figures 8 and 9). Some bentonite lubrication was used during VCP installation, but with an established alignment and hard clay soils, this became the smoothest portion of the project and was completed in just two days.



FIGURE 8: Jacking the 30" VCP in the final step became the smoothest part of the installation



FIGURE 9: Pumping CLSM to fill the annular overcut

6. CONCLUSIONS

Final connection at the misaligned downstream end was completed into the concrete structure, which was large enough to accommodate the alignment error. The line was air tested and visually inspected via CCTV to absolutely ensure the quality of the completed project.

Unexpected geotechnical conditions are a frequent hazard of trenchless installations, especially where long drives are needed. At Lauritzen Gardens, a 100' section of hard clays with a measured compressive strength of 4.5 tons per square foot created an obstacle in the middle of a 540' drive. This obstacle made an intercept both necessary and challenging. A tree-covered hill blocked line of sight between the jacking and receiving pits, so all line and grade calculations were made based solely on established control points. A very minor variance in those control points resulted in an intercept that was misaligned.

The misalignment created a kink in the line that made establishing a complete line through the crossing a problem. After attempting to establish that line using a 24" casing and again using a 38½" casing, the larger casing was pushed in a straight line from the intercept point to establish a new, but complete crossing.

Important lessons are frequently learned on more challenging projects. In this case, the primary lesson learned is the critical nature of the survey control points. A very small misalignment created a cascading series of challenges.

7. REFERENCES

Koenig, Chris J. (2013) – *Accomplishing Sewer Separation through a Landfill and Botanical Garden with Trenchless Technology*, North American Society for Trenchless Technology (NASTT)