The locational characteristics of the existing conditions with respect to traffic conditions and access to property and environmental requirements for each area and location are highlighted in Table 2.

Table 2: Existing conditions summary for YDSS sewer section locations

Affected Areas (A) and Locations (L)	Existing Conditions
A1:L1, A1:L2, A4:L8	High Traffic Area
A2:L3	Tributary of the East Don River which provides habitat for species at risk, Toronto and Region Conservation Authority (TRCA) and Ministry of Natural Resources and Forestry (MNRF) approval required
A3:L4, A3:L5	Tributary of the Rouge River including species at risk habitat, TRCA and MNRF approval required
A3:L6	No traffic, area not regulated
A4:L7	Tributary of the West Don River, TRCA approval required
A4:L9	Private property, area not regulated by the TRCA
A5:L10, A5:L11, A5:L12	Tributary of the West Don River, TRCA approval required, Ecologically Significant Forest
A6:L13, A6:L14, A6:L15, A6:L16	Tributary of the West Don River, TRCA approval required. Railway corridor, Metrolinx Approval required.

REHABILITATION TECHNOLOGY SELECTION

Spray Applied Lining to Maintenance Holes

The Region issued a performance-based tender for the YDSS rehabilitation and the awarded contractor chose the SprayShield product to rehabilitate the maintenance holes. Rehabilitation with the SprayShield spray applied lining offered York Region a solution to address the groundwater infiltration at the two identified locations. The SprayShield product is a two-part polyurethane liner that is spray-applied to the entire internal surface of the maintenance hole, and typically has quick cure times of 10 seconds to gel, 60-minute return to service and full cure within 72 hours. The minimum recommended thickness is 240 mil or 0.24 inches (6.0 mm); however, with multiple passes thicknesses of up to 1 inch (25 mm) can be achieved. The polyurethane is 100% Volatile Organic Compound (VOC) free, is resistant to attack from hydrogen sulphide, sulphuric acid, chlorine and road salts and has a service life of approximately 50 years.

Surface preparation of the maintenance hole has a significant impact on the performance and longevity of the protective lining. Standard practice for the preparation of the maintenance hole prior to installation includes a high-pressure wash to remove loose material and application of heat to the maintenance hole to remove humidity and residual moisture. The primary restriction

with polyurethane linings is that they are challenging to apply in the presence of any moisture or water. Polyurethane liners are very sensitive to moisture and the heat generated during the curing process is capable of drawing moisture through the maintenance hole wall at installation. A thin polyurethane coating is applied to seal the surface of the maintenance hole from any further moisture before the second coat is applied, minutes after the first coat. The moisture concentration within the maintenance hole is essential for the product to adhere to the prepared surface and all surfaces must be completely dry that come into contact with the polyurethane.

Figure 2: Inflatable grout packer before (left) and in service (right)

Chemical Grouting to Sewer Sections

Several sewer rehabilitation options were considered for the YDSS project that included chemical grouting, full length Cured-In-Place Pipe (CIPP) and CIPP spot repair. Chemical grouting was selected as most cost effective for York Region. Chemical grouting is a non-structural solution involving the injection of grout into pipe defects such as leaking joints and minor cracks. The grout is typically a two-part grout that when mixed forms a gel-like structure. Some grouts have similar viscosity to water which allows them to penetrate the defect and any voids behind the pipe wall. This rehabilitation method can be used to significantly reduce, or even eliminate infiltration and exfiltration in sewers. When properly used, chemical grouting can stabilize and seal the defect in the pipe, as well as stabilize the adjacent soil or fill voids outside the pipe. Grout volume and back pressure is monitored to determine when a sufficient amount of grout has been injected. For this project chemical grouting utilized inflatable packers (Figure 2) for all sewer diameters 20 to 54 inches (525 to 1,350 mm), to isolate the section of pipe to be grouted and prevent grout from entering the rest of the sewer, while the sewer is in service. Generally, the grout will cure within minutes while the packer remains in place over the defect. Required pressures used to install chemical grout are typically 0.5 psi per vertical foot of pipe depth below grade plus 2 psi; however, installation pressure shall not exceed 10 psi. In small diameter applications the packer can be easily lowered through the manhole or assembled at its base for deployment. The entire sewer section is recommended to be cleaned prior to grout installation for the packer to form a seal with the sewer wall. The flow becomes the largest factor when installing chemical grout and is generally accomplished during low flow periods, typically at night.

Grouts often consist of acrylamide, acrylic or urethanes (hydrophilic and hydrophobic) and inhibitors can also be added to deter root growth. The specific type used should be based on pipe

materials and surrounding soil conditions. The use of chemical grouting to seal pipe defects and leaks is an effective rehabilitation option, for most circumstances and operational environments, and was used as a stand-alone rehabilitation method for the identified sewer sections for this project.

ISSUES AND RESOLUTION

Metrolinx railway

Metrolinx is a Province of Ontario regional transportation agency that operates GO Transit and UP Express that aims to increase accessibility of the Toronto Pearson International Airport from the downtown Toronto core through public transit via bus and rail. A portion of Location 14 on the Maple Collector Relief sewer resides within the boundary of a Metrolinx railway. Extensive discussions took place during the design phase and there was no permitting requirement at that time. However, boundaries had been altered from the design phase to the construction phase and an approved Metrolinx Work Permit Application was required to access MH 9937-114 of the Maple Collector Relief Sewer to conduct inspection and rehabilitation activities within this boundary.

This involved a significant adjustment to the construction schedule as the original date for cleaning and rehabilitation of Location 14 were slated for June 2018. The work permit application package to conduct the work was submitted to Metrolinx which involved the review of shop drawings, work plans, record drawings and submission of other associated documentation by the Metrolinx reviewing agent. The process started in June 2018 with a draft work plan and comments and official submission took place in July 2018. Through effective communication between all stakeholders involved (LiquiForce, Hatch, York Region and Metrolinx) the work permit was approved on October 1, 2018 and work commenced shortly after and was completed on October 25, 2018 within the timeline required by Metrolinx (before October 31, 2018).

Environmental Sensitivity

The Redside Dace (*Clinostomus elongatus*) is a small fish in the minnow family which can grow up to 4.5 inches (12 cm) in length. This species has been designated as endangered both federally and provincially and is protected by the *Species at Risk Act* and *Endangered Species Act* respectively. This species is highly dependent on naturally vegetated riparian areas in the floodplain adjacent to the creek, as these areas provide the primary source of food (terrestrial inspects) as well as cover and other critical habitat functions. A primary threat to Redside Dace is habitat loss due to urban and agricultural development, and due to the YDSS being constructed within river valleys several of the sewer rehabilitation sites are adjacent to the East Branch of the Don River (Area 2, Location 3) and the Rouge River (Area 4, Locations 4 and 5), which are watercourses known to support Redside Dace amongst various other species. The specific timing (construction) window of July 1 to September 15 is typically applied to works within the regulated habitat of this species to protect them during sensitive spawning and rearing periods; however, the Region worked collaboratively with the MNRF and demonstrated an ability to minimize disturbance and employ various mitigation measures to extend the timing window to October 15, 2018.

The maintenance holes were located near the tributary and were required for sewer cleaning, CCTV inspection and installation of chemical grout. Access to these sensitive areas utilized

existing trail infrastructure where available and minimized disturbance to vegetation to the fullest extent possible by utilizing temporary wooden mats to extend access roads where trail networks did not exist. Erosion and sediment control measures were employed prior to construction, including heavy duty silt fences and filter socks, in order to prevent any migration of sediment into the creek. Tree protection measures (Figure 3) were implemented throughout the project to provide protection zones around the trees and eliminate the potential for impact of any rehabilitation operations. Given that Area 5 is identified as an Ecologically Significant Forest, measures were implemented to minimize or eliminate disturbance altogether on the trees.

Figure 3: Examples of temporary tree protection measures

Figure 4: Typical equipment mobilizations on municipal walking tails

The project also considered mitigative measures to prevent the spread of invasive species. A highly invasive plant, European Common Reed (*Phragmites australis*) exists within the floodplain at Area 4 Location 7, and Area 6 Location 16. This species is so aggressive that one of these maintenance holes now exists within a thick stand of this reed which can grow up to 16 feet (5-metres) in height. The area required for rehabilitation works was minimized to the fullest extent possible, and the invasive reeds were matted down and covered with geotextile and wooden swamp mats (Figure 5) to provide access and a temporary barrier between the plant matter and equipment. As an additional precaution, clean equipment protocols were implemented before leaving these sites to ensure that no seeds or other plant matter migrated to other habitation areas.

Accessing Maintenance Holes

Several of the sewer sections that required rehabilitation were located within forested areas and flood plains, where the only access to the maintenance hole was by way of municipal trails and pathways, shown in Figure 4.

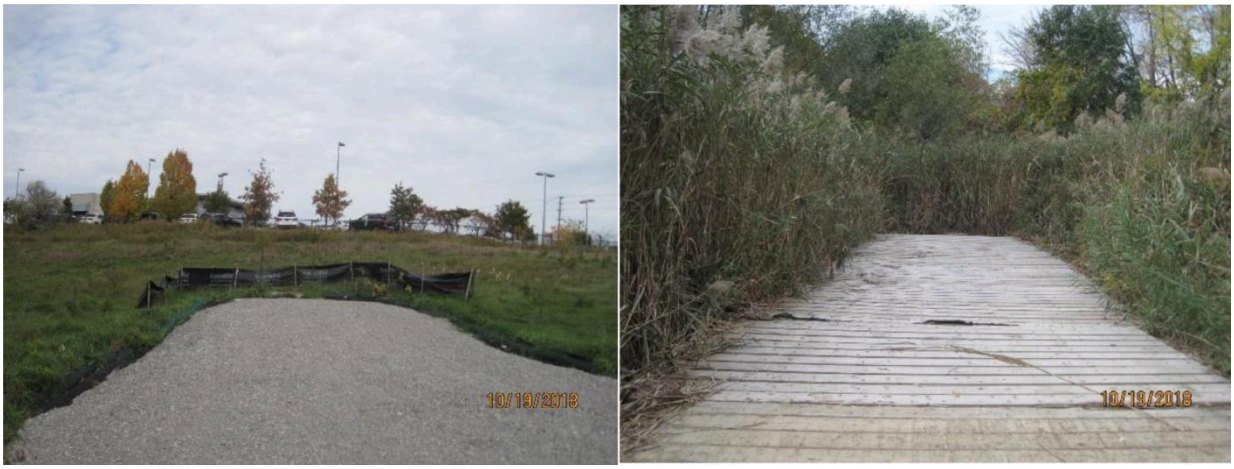

Figure 5: Temporary gravel access road (left) and swap mat installation (right)

In the case where the maintenance holes were located within forested areas, Contractors had to be mindful not to damage the trails and install tree protection measures where necessary in all forested areas to prevent damage during access for rehabilitation operations. For sewers located within flood plains, where the Contractor mobilized equipment off the pathways to access the maintenance hole, the contractor installed temporary access roads to reach the maintenance hole.

Two methods of temporary access road construction were utilized, depending on conditions: i) gravel access roads were used for manicured grassy areas, and ii) wooden swamp mats were used for natural meadow areas and areas with wet soil conditions (Figure 5). The temporary construction access roads consisted of laying a non-woven geotextile fabric, minimum 12 inches (300 mm) depth of 2 inches (50 mm) limestone at 13 feet (4 m) width, lined with the installation of sediment control logs and heavy-duty silt fence barriers. Following the removal of the access road, the affected areas were restored with compost seeding in accordance with York Region requirements and restoration occurred immediately following removal of the road. If the time of year did not allow for sufficient germination prior to or during winter months, all disturbed areas are required to be covered with erosion control blankets until such time when vegetation can be established (i.e., following spring). The wooden swamp mats used for this project were 8 feet (2.5 m) length by 14 feet (4.3 m) wide, by 5 inches (0.13 m) thick and provided zero ground disturbance where the ground vegetation or marsh-like areas were not suitable for the installation of an access road. Temporary access roads and swamp mats were used to preserve the ground from access by heavy vehicles that enabled sewer cleaning and sewer rehabilitation installation crews and associated heavy equipment to reach their destination safely and reliably with minimal impact to the natural environment.

Maintenance Hole Rehabilitation

The two maintenance holes on Islington Avenue present a set of unique challenges due to the forcemain at the Pine Valley Pumping Station further upstream. The typical solution in this

situation is to bypass the flow from the forcemain altogether to allow the maintenance hole preparation and provide rehabilitation crews the opportunity to complete their tasks. Islington Avenue is a five-lane major arterial road lined by residential and commercial properties that made flow bypass an unfeasible option due to limitations of space and access requirements.

York Region and the Consultant conducted flow monitoring during detailed design phase. Based on the flow rate during construction phase all parties came up with a solution to control the flow from upstream of Pine Valley Sewage Pumping Station. York Region requested an Operator during the trials which took place during the night time hours to assist with pumping down the Pine Valley pumping station so that Operations can monitor the duration required to fill the wet well. They also performed a test to see if one of the variable speed pumps can operate at a lower consistent speed. The Contractor was onsite at the maintenance hole locations to monitor the field conditions during this test.

Pump curves were evaluated to determine alternatives to reduce the flow or pump cycles without impacting pump performance and it was determined that the following arrangement was most suitable:

- Reduction of the cycles from 60 hz to 40 hz to lower the pumping rate. This was able to be accomplished without vibration issues at the lower speed. This would entail the manual operation of variable speed pumps for the entire duration of the maintenance hole rehabilitation.
- Installation of a temporary weir wall in MH 22A to further increase the time for the workers within the maintenance hole.

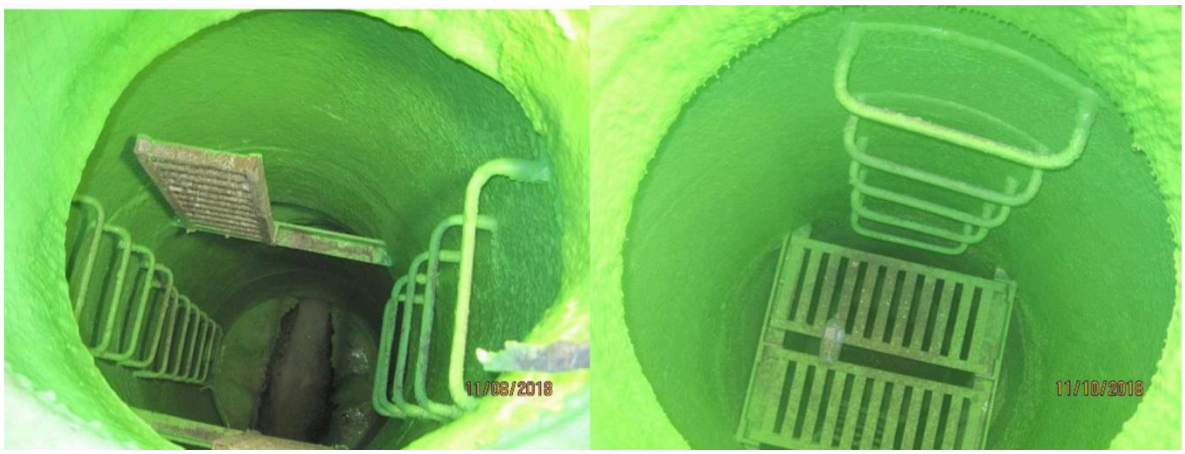

Figure 6: Maintenance holes after rehabilitation: 22A (left) and 31A(right)

The rehabilitation effort required support from several project stakeholders to complete the rehabilitation in an efficient manner and to avoid disruption to the public during night time operations. The Consultant project team evaluated the operational requirements of the pumping station with the pump manufacturer to ensure the pumps could be reliably operated at the reduced speeds. Hatch also reviewed communication and rehabilitation plans. York Region's Operations Maintenance and Monitoring staff were onsite at the upstream pumping station during all rehabilitation activities. The Contractor implemented the traffic control which included lane reduction at two locations along Islington Avenue during the maintenance hole rehabilitation. The Sub-contractor managed the maintenance hole cleaning/surface preparation and installation of the spray applied liner. Robinson Consultants Inc. (Sub-consultant) provided QA/QC inspections and testing of the prepared surface finish of the maintenance hole prior to

rehabilitation and adhesion testing during the maintenance hole rehabilitation (Figure 6).

Notifications for Noise

The maintenance hole rehabilitation for Areas 1 and 2 took place within residential areas and measures were taken to address the potential for noise related issues during construction. Rehabilitation took place during the night hours when sewer flows are at their lowest, so all parties took necessary precautions such as using equipment with muffling devices to address any noise related concerns before the work took place. Notification letters for area residents that were within the affected areas and notified them a week prior to the start of work.

Local businesses were identified, and proactive engagement took place, which included on-site meetings, informing local residents/businesses of the potential impacts. It was necessary to provide reassurance that their concerns were being addressed and that additional mitigation measures such as the use of barrier tarps or equipment noise barriers were available as a further precaution.

Schedule Challenges

The project was arranged with a construction window of 250 days for the Contractor to complete the identified maintenance holes and sewer rehabilitations and conduct specific work within the contract mandated timing windows. The construction schedule was frequently updated to balance timing and availability due to conflicting schedules with the Sub-Contractors which often resulted in durations where no work was performed. Frequent communication between LiquiForce, Hatch and York Region were required with each schedule update and at every project meeting to maintain resource efficiency and progress the project to substantial completion.

CONCLUSION

The Region went forward and rehabilitated the sewers to reduce infiltration and restore the capacity and condition of the sanitary sewer system. The rehabilitation of the maintenance holes on Islington Avenue in the City of Vaughan were completed within the prescribed timeframe and measures taken to reduce the flow at the Pine Valley pumping station were successful. Through effective communication between York Region, LiquiForce and Hatch, all identified areas and locations were rehabilitated with spray applied liners for maintenance holes and chemical grout for sewer sections without undue disruption to the public. The rehabilitation works were conducted under live sewer conditions and night work was scheduled as required to take advantage of low flow conditions. The environmental measures put in place to protect the environment reduced the impact to near zero when contractors were required to access the maintenance holes located on municipal trails and flood plains for rehabilitation operations.

The capacity of the sewers was improved two-fold: i) through cleaning, the removal of encrustation and debris build up, and ii) active infiltration was eliminated through rehabilitation with chemical grout. The benefit becomes the increase in capacity of the sewer, especially during periods of high flow and the reduction in treatment costs at the associated water treatment plant. The savings as a result from the rehabilitation can allow the local municipalities to grow without the cost of new sewage infrastructure.

A new sewer section that requires priority repair was added to the contract to extend the timeline for construction with substantial performance in May 2019.

Narragansett Bay Commission Rehabilitation of Large Diameter Brick Sewer with Geopolymer Mortar

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1. ABSTRACT

The summer of 2018, the Narraganset Bay Commission (NBC) undertook their first large scale geopolymer mortar pipe rehab project as part of the Route 6 and 10 Interchange reconstruction in Providence, RI. This is part of a Rhode Island Department of Transportation (RI DOT) project to fully reconstruct the Route 6 and 10 approach ramps and elevated superstructure by 2020. The trenchless subcontractor rehabilitated 2,430 linear feet (LF) of brick pipe up to 60” diameter round and including vertical ellipses ranging 30”×45” to 38”×57”. This was done using spin cast geopolymer lining (SCGL) utilizing GeoSpray geopolymer mortar. SCGL provides a structurally independent, corrosion resistant new pipe in a pipe. Because many of the manholes were located in the middle of a 4-lane highway, maintenance and protection of traffic (MPT) played a critical part in the success of this project. Fortunately, SCGL requires a very small construction footprint, beneficial in dense traffic areas, and it does not require excavated insertion pits. The contractor completed all the rehabilitation in August 2018. This presentation will focus on the trenchless options considered, why NBC selected geopolymer mortar, construction challenges in the middle of a highway, and lessons learned.

2. INTRODUCTION AND SITE ASSESSMENT

In 1893, a large brick interceptor sewer was built in the outskirts of downtown Providence, RI in an area that housed multiplex units and was divided by railroad tracks. 125 years later this sewer is located in the middle of a 4-lane highway at the interchange of Route 6 and10 and includes many lateral connections. See **Figure 1**. When RI DOT awarded a $350 million heavy highway project to Barletta Construction to completely reconstruct this interchange, this provided the perfect opportunity to upgrade the sewer infrastructure.

Narraganset Bay Commission (NBC) reviewed the CCTV inspection videos, and although the vertical ellipse and 60” diameter round brick pipe seemed to be in fairly good shape, NBC was aware that brick pipe can be deceiving and hard to evaluate just from visual inspection. Even though there was not a lot of deformed ovality, the pipe had significant infiltration due to missing mortar. Due to the advanced age of the pipe, limited access to monitor and maintain, and concerns about the 6 and 10 construction impact load, NBC asked RI DOT to include rehabilitation of the pipe structure as part of the interchange reconstruction. Since most of the manholes were in the middle of the median or highway travel lane, access to the site was very difficult. NBC wanted an upgrade to their system so that they could avoid maintenance in this high traffic area for the next 50 years. It made sense to take advantage of this window of opportunity to reconstruct the pipe and MH Structures and RI DOT agreed to pay for it.

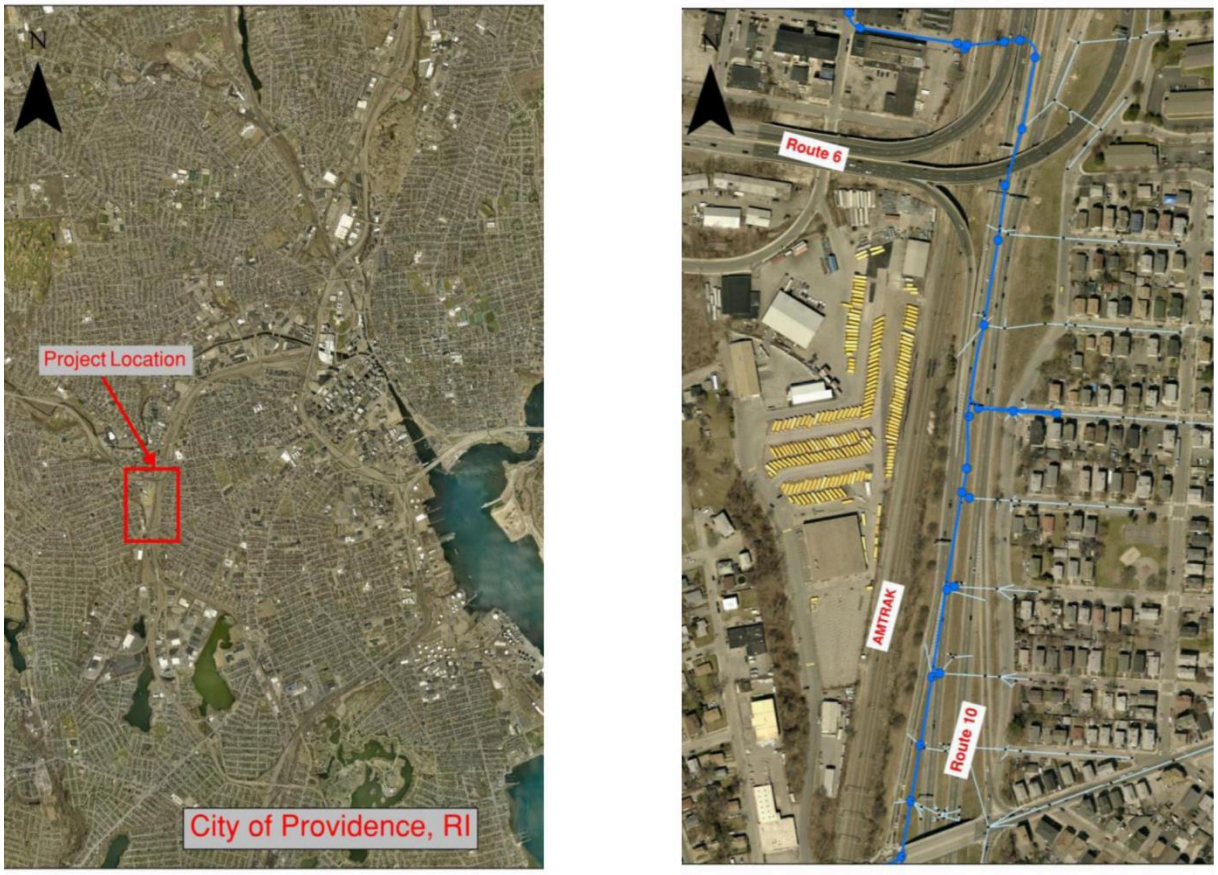

Figure 1 Project location (left); manhole and pipe location in blue (right)

3. FOUR LINING OPTIONS CONSIDERED BY NBC

A. Cured-in-place-pipe (CIPP): This was considered a less desirable option for the following reasons:

1. The brick pipe was made up of irregular shapes ranging from vertical ellipse 30” x 45” and 38” x 57” to 60” round. It was determined that matching these shapes and the transitions from one size and/or shape to another would be difficult and lead to fins and folds of the liner during construction. A fin in the flow line could cause a hydraulic blockage with rags, and NBC wanted to avoid having to clear future blockages in the middle of a highway. In addition, a fold or fin on the crown would compromise the structural repair.
2. The 10 to 20’ deep access manholes were irregular in shape (See **Figure 2**) and shared a second 12” pipe at a higher elevation. Use of CIPP would have required excavation down to the pipe and replacing the manhole structure.
3. Since manhole structures were either in the median, on the edge of the road, or in the middle of the highway, excavation for an insertion pit would have required expensive sheeting and shoring and would have extended into the highway, necessitating closing down a traffic lane.
4. Over the hole, wet out would have required a much larger construction footprint extending outside of the median and into the roadway.

B. Slip line: NBC ruled this out for many of the same reasons as CIPP, wanting to avoid insertion pits and lane closures. In addition, the flow capacity would be greatly reduced.

C. Centrifugally Cast Concrete Pipe (CCCP): This is a spray on lining using Portland cement. NBC did not select this trenchless technology due to concerns about water intrusion, less corrosion resistance and shorter longevity.

D. Spin Cast Geopolymer Lining (SCGL): NBC selected this technology because it prevents water intrusion with a thin, fully structural liner that does not require removal of the manhole frame and cover. It provides excellent corrosion protection and is environmentally friendly. It is also economical since installation has a small construction footprint and did not require excavation or extra lane closures.

Figure 2 Irregular brick manhole with parallel 12" collector at a higher elevation

4. GEOSPRAY GEOPOLYMER MORTAR LINING SOLUTION

GeoSpray geopolymer mortar is a corrosion resistant trenchless rehabilitation technology for pipes (30" or greater), manholes, wet wells, pump stations, and clarifiers.

Application of geopolymer mortar is typically done by centrifugally casting the material or hand spraying. According to a 2014 evaluation done by the EPA, GeoSpray geopolymer was found to be a "viable structural alternative to traditional means and methods" (EPA 2014). The U.S. Army Engineer Research and Development Center (ERDC)'s Construction Engineering Research Laboratory (CERL) concluded, "This is a process that should be seriously considered by all Army organizations when planning to repair or rehabilitate deteriorated storm culverts, and storm or sanitary pipes" (Wilson and Mathis 2016). To date, over 135,000 LF have been completed across the USA and in 10 countries, internationally. It is a proven effective economical tool in the right location.

In the early 1970s, a French scientist, Joseph Davidovits, discovered that under the right set of conditions, pozzolanic materials such as fly ash and slag could fully react with one another to form an extended polymeric network primarily made up of aluminosilicate bonds (Al-O-Si), see