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# CONTINGENCY PLANNING for HIGH-RISK HDD CONSTRUCTION

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**ABSTRACT:** The Middlesex Water Company (MWC) is a 113-year-old, publically traded company providing water, wastewater and related utility services to a population of nearly 400,000 in central New Jersey and Delaware. Recently, MWC completed the planning, design and construction of a new 24-inch, 5,800-foot-long water main to replace an existing 24-inch cast iron water main more than 100 years old. The existing water main conveys water from MWC's northern distribution system near the city of Perth Amboy, across the Raritan River, and into MWC's South River Basin system in Southern Middlesex County, New Jersey. Due to the age, corrosivity and unstable nature of the surrounding environment, the existing main experienced several breaks, requiring costly emergency repairs on an increasing frequency. These outages caused major operations disruptions and repairs were costly due to access impediments associated with the river, soft sediments adjacent to and under the river and regulatory considerations associated with adjacent wetlands and river navigation.

Alternative construction methods for crossing the 4,800-foot-wide Raritan River were evaluated. Studied options included open-cut trenching, microtunneling, pipe jacking, conventional tunneling, and horizontal direction drilling (HDD). Factoring in construction schedule, cost, sustainability, impacts to the environment and marine traffic, and permitting requirements, HDD using fusible polyvinylchloride (FPVC) pipe was recommended for the river crossing. The final design consisted of a HDD crossing approximately 5,365 feet in length using 24-inch FPVC pipe.

The length and diameter of the crossing, as well as subsurface conditions encountered during construction, classifies this project as high-risk. One key element of the successful execution of any high-risk project is contingency planning. This paper describes various contingency planning elements that were considered during the project's planning, design and construction phases. These include those associated with the geotechnical investigation, preparation of construction drawings and specifications, HDD construction techniques, staging and fusing of the FPVC pipe, and contingency planning meetings with the owner, contractor and engineer at each stage during startup and construction to anticipate and mitigate major potential risks.

## 1. INTRODUCTION

The Middlesex Water Company (MWC) is a 113-year-old, NASDAQ-listed company providing water, wastewater and related utility services to a population of nearly 400,000 in central New Jersey and Delaware. The water company currently owns and operates a 24-inch cast iron potable water main that conveys water from Perth Amboy, through the banks of the Raritan Bay, across the Raritan River and into the borough of Sayreville, New Jersey. This existing pipeline was originally installed in approximately 1904 by Perth Amboy. Within MWC's distribution

system, this pipeline conveys potable water across the Raritan River from the township of Woodbridge to the city of South Amboy. In the 1980s, this 24-inch water main was leased by the MWC from Perth Amboy and was ultimately purchased by the MWC from Perth Amboy. The location of this existing water main and the surrounding area is shown in Figure 1.

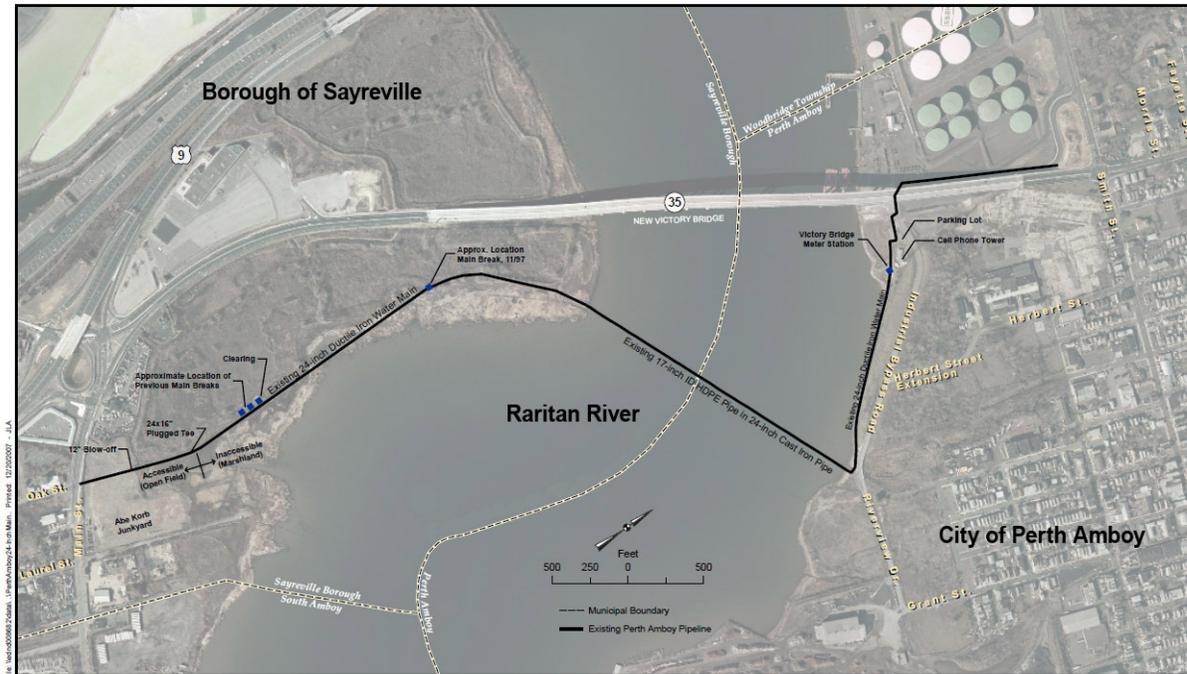


Figure 1. Location Map

## 2. BACKGROUND

The existing 24-inch water main crosses the Raritan River in an easterly direction, with a total linear footage of approximately 1,700 feet. This section of water main was slip-lined with a high density polyethylene (HDPE) pipe with an internal diameter of 17-inches in 1987 by the MWC. Approximately 300 feet prior to reaching the south bank of the Raritan River within the City of Sayreville, there is a concrete thrust block collar that is part of this existing 24-inch water main, which served as the start/end point of this 17-inch slip lining. The section of water main located along the south bank of the Raritan Bay/Raritan River (approximately 3,700 linear feet) between the intersection of Oak and Main Streets in Sayreville and the concrete collars located on the south bank Raritan River, was cleaned and cement-lined in 1987 by MWC.

The majority of this section of existing water main is located within marshlands/wetlands and is covered with 0 to 2 feet of muck and reeds. Due to the age, corrositivity and unstable nature of the surrounding environment, the existing main experienced several breaks, requiring costly emergency repairs on an increasing frequency. These outages caused major operations disruptions and repairs were costly due to access impediments associated with the river, soft sediments adjacent to and under the river, and the many regulatory considerations associated with adjacent wetlands and river navigation. Because of this, MWC determined that this existing 24-inch water main had to be replaced in order to continue to provide a reliable source of drinking water to its customers south of the Raritan River. As such, MWC proceeded with the planning, design and construction of a new 24-inch water main from Perth Amboy across the Raritan Bay/Raritan River and into Sayreville, New Jersey. CDM, an engineering consulting firm in Edison, New Jersey, was retained by MWC for the planning, design and construction phases of this project.

After evaluating different methods of construction and pipe materials, the final design consisted of:

- 410 linear feet (LF) of 24-inch ductile iron pipe installed in cross-country conditions in new easements obtained from private entities located within Sayreville

- 5,365 LF of 24-inch fusible polyvinyl chloride (FPVC) pipe installed via horizontal directional drilling (HDD) within the Raritan Bay and Raritan River, a tidally influenced body of water
- 105 LF of 24-inch ductile iron pipe installed in cross-country conditions in new easements obtained from Perth Amboy

Other appurtenances and features of the new water main included:

- New meter chamber located within Sayreville
- Air/vacuum valve chambers located within Sayreville and Perth Amboy
- Blow-off assembly located within Perth Amboy
- Isolation valves located on the new water main located within Sayreville and Perth Amboy

During preliminary design phase of the project, eight geotechnical borings were taken on the Raritan River and three additional borings were taken on the banks of the river. The borings in the Raritan River were performed by using barge-mounted, mud-rotary drilling methods. The marine borings extended to depths varying from 48 to 115 feet below the existing mud line. The land borings were advanced using conventional truck-mounted hollow stem auger drilling equipment, extending between 25 and 50 feet deep. The geotechnical investigation of the site revealed various zones of extremely soft silty clay overlying stiff silty clay, sand, gravel that is underlain by a bedrock shelf on the north side of the crossing. Considering the above characteristics and the technical analysis performed during the design of the project, an alignment with the deepest part of the pipe (the central section) located at an elevation of -60 feet below the mud line was recommended with radii of curvature along the entry and exit locations in the alignment set to 5,107 feet and 3,310 feet respectively, as shown in Figure 2.

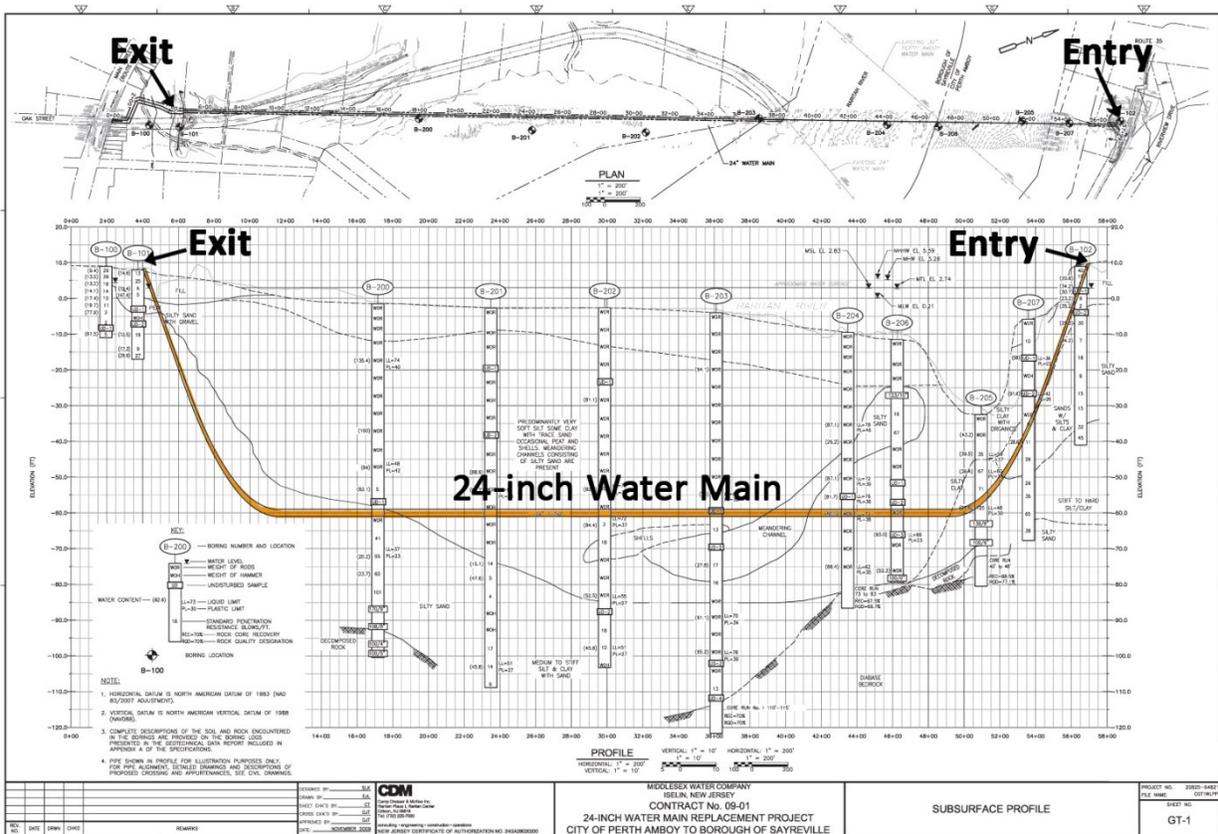


Figure 2. Horizontal and Vertical Profile

A geotechnical data report (GDR) was prepared for the project. This GDR included:

- Background, site history and description of the project
- Description of the soil classification system that was used for the geotechnical exploration
- Description of the drilling and sampling procedures that were used
- Project datum
- Description of the geotechnical and environmental laboratory testing procedures
- Boring logs
- Geotechnical laboratory data
- Environmental laboratory data

Although a formal geotechnical baseline report (GBR) was not prepared for this project, geotechnical baseline statements were included in the project specifications. These included:

- The drilling equipment used for the project was required to be capable of advancing through the geological conditions to be encountered at the site, as presented in the GDR.
- The drilling fluid was required to be designed for the geological conditions to be encountered at the site, as presented in the GDR.
- The drilling system was required to include a fluid pump and separation plant that can achieve the rates of drilling fluid pumping, soil separation, and slurry cleaning required by the contractor to achieve planned production rates for the soils described in the GDR, and as anticipated by the contractor.
- The Contractor was required to immediately notify the engineer, in writing, when any significant problems are encountered or if ground conditions are considered by the contractor to be materially different than those represented in the GDR.
- All calculations prepared by the contractor were required to use the following soil properties for determination of loads and methods of construction of the HDD:

Soil	Unit Weight (pcf)	$\phi$	Cohesion (psf)	Poisson Ratio, $\nu$	Modulus of Elasticity (psf)
Silty Sand	110	34	0	0.3	3,000,000
Very Soft Silt Some Clay	105	0	300	0.45	180,000

### 3. CONTRACTOR PRE-QUALIFICATION PROCESS

The delivery of this project was traditional design-bid-build; however, the owner and engineer undertook a pre-qualification process to select contractors capable of performing the work. A list of potential contractors was developed and pre-qualification packages were sent to 22 potential general contractors and HDD specialty subcontractors. Eleven pre-qualification packages were received by the owner and eight contractors (four general and four HDD subcontractors) were deemed prequalified to submit a bid for the project.

Even though general contractors and HDD subcontractor were prequalified prior to formal bidding of the project, the contractor was still required to submit, as part of the shop drawing review process, information showing that the HDD subcontractor, HDD superintendent and key personnel met the following minimum qualifications:

1. Contractor must be licensed in the state of New Jersey as an underground utility contractor for a minimum of 5 years.
2. The contractor must have at least 5 years of demonstrated successful experience installing pipelines by the means of HDD.
3. The contractor must have successfully completed three water or sewer projects where the carrier pipe was installed with HDD techniques, each (unless otherwise noted) meeting the following criteria:
  - Minimum carrier pipe nominal diameter of at least 16-inches
  - Minimum length of 2,750 linear feet in a single pull through soil

4. The contractor must have successfully completed one water or sewer projects where the carrier pipe was installed with HDD techniques, meeting the following criteria:
  - The carrier pipe must be FPVC pipe
  - Minimum carrier pipe nominal diameter of at least 16-inches
5. The Contractor was required to employ skilled, experienced superintendent(s), equipment operator(s) and personnel throughout the project. The superintendent for this project was required to have at least 10 years of successful experience using the HDD process and the HDD equipment operator for this project was required to have at least 5 years of successful experience using the HDD process, and each of these individuals must have completed one project that utilized HDD meeting the following criteria:
  - Minimum carrier pipe nominal diameter of at least 16-inches
  - Minimum length of 2,750 linear feet in a single pull through soil

It should be noted that the contract documents required that the superintendent proposed for the project be on site during all construction related activities required for the HDD installation for this project.

#### **4. CONTINGENCY PLANNING AND CONSTRUCTION PHASE**

Given the high-risk nature of the project's HDD operations, the contract documents (i.e., drawings and specifications) were structured to require the general contractor and HDD subcontractor to develop and submit to the engineer for review and approval a number of plans for dealing with a number of potential obstacles that could be encountered during construction. All of these plans were required to be reviewed and approved by the engineer and owner prior to allowing the general contractor to mobilize to the project site. In order to expedite the shop drawing review process, the engineer, owner, general contractor and HDD subcontractor met either in person or by conference call to discuss these plans. The cost for this was included in the cost for the HDD portion of this project.

##### **4.1 Contingency Plans for Remediation of Potential Problems**

Various contingency plans were developed to remediate a number of potential drilling operation problems. These contingency plans outlined observations that would lead to the discovery of the problem and the methods to mitigate them. The following plans were prepared and agreed to during the shop drawing review phase of the project.

###### **4.1.1 Loss of Returns/Circulation Contingency Plan**

In the event that a loss of circulation was experienced, it was agreed that the following steps would be taken:

1. Immediately stop all drilling operations.
2. Notify the drilling superintendent and the general contractor's onsite representative.
3. Inspect the surface path of the crossing for inadvertent returns of drilling fluid.
4. If considered safe to do so without damage to the existing structures and environment, the drill string would be rotated slowly and swabbed back and forth, and the drilling fluid would be pumped at a reduced rate in an attempt to regain circulation.
5. If circulation was not restored in a timely manner, consideration would be given to tripping back the drill string until circulation was regained. The drill string would then be slowly advanced, monitoring the quality of the returns.
6. If circulation is again lost, a loss control material (LCM) pill, which is a mixture of polymer additives and swelling agents, would be set.
7. If circulation was lost again, further action would be determined after consultation between the general contractor, HDD subcontractor, engineer and owner.

###### **4.1.2 Inadvertent Returns/Hydrofracture or Surface Spill Contingency Plan**

It is generally acknowledged that with construction via HDD techniques, it is possible that some drilling fluids will be lost in fractures within the formation. In cases where the fracture is horizontal, these lost fluids will likely not surface. In other cases, drilling fluids may reach the surface (e.g., the fracture comes close enough to the surface that the pressure causes the release of drilling fluid above ground). Such a release is termed an inadvertent return.

The contract documents required the general contractor maintain mobile spoil removal equipment onsite during all drilling, pre-reaming, reaming and pullback operations to quickly remove spoils. As part of the shop drawing review process, an inadvertent return plan for drilling fluids was required to be submitted. This plan identified the activities to be monitored and appropriate response actions to be taken to ensure that any release of drilling fluid was minimized. It also outlined a process of monitoring the drilling fluid in order to identify a loss-of-returns situation and to determine if there was a release to the surface.

#### **Ground Release**

If a release occurred in an upland area (outside of the entry and exit points), appropriate reasonable actions to reduce, eliminate or control the release were required to be taken by the HDD subcontractor. The actions to be taken would depend on the location of the release point and the amount of fluid being released. Actions include:

- Construction of a small pit or sand bag coffer around the release point, installation of a section of geotextile filter fabric (“silt fence”) and / or hay bales to trap as much sediment as possible, and placement of a pump hose in the pit to pump the drilling fluid back to the bore site.
- Use of a vacuum truck to clean up and return the drilling fluids to the bore site to be recycled or if drill fluids are deemed unrecyclable taking them to a pre-approved disposal site.
- Reducing drilling fluid pressures.
- Thickening drilling fluid mixture.
- Adding pre-approved loss circulation materials (LCM’s) to the fluid mixture.
- Ceasing pumping operations.

#### **Underwater Release**

If an underwater release occurred, the HDD subcontractor was required to take appropriate reasonable actions to reduce, eliminate or control the release. The actions to be taken would depend on the location of the release point and the amount of fluid being released. Actions included:

- Reducing drilling fluid pressures
- Thickening drilling fluid mixture
- Adding pre-approved LCMs to the fluid mixture
- Ceasing pumping operations

Which actions would be implemented would depend on the specific conditions at the time of the release and the volume of the release. It was agreed that the HDD subcontractor, in consultation with the engineer and owner, would determine what methods were the most appropriate to eliminate, reduce or control the release. It was agreed that drilling fluids that were recovered would be recycled and reused to the extent that was practical. The HDD subcontractor was required to document the nature of the release including physical characteristics of the fluid, the location and extent (e.g., area, estimated volume, duration), the modified procedures used to reduce the rate of leakage, and the extent to which these measures are successful in controlling or eliminating the release.

#### **4.1.3 Obstruction in Drill Path Contingency Plan**

If an obstruction was encountered during the pilot hole or reaming phases of construction, it was agreed that the HDD subcontractor would attempt either to drill through the obstruction or drill around the obstruction. If the obstruction was determined to be composed of drillable materials, such as rock, drilling through the obstruction would be attempted. It was acknowledged that this may require tripping out of the hole to change the bottom hole assembly (BHA) to attach the appropriate tools to penetrate the obstruction.

If it was determined that the obstruction could not be drilled through, such as a utility or extremely hard rock, the drill string would be pulled back. An attempt would be undertaken to side track from the original drill path and adjust the plan and profile of the drill to avoid the obstruction.

#### **4.1.4 Non-advancement of Drill Pipe or Product Pipe Contingency Plan**

It was agreed that in the event that the drill pipe becomes stuck during drilling, pre-reaming or reaming activities, one or more of the following options would be undertaken:

- Attempt to force the pipe free with the drill rig

- Connect an air hammer to the drill string to loosen the pipe
- Abandon the pipe and restart the crossing

It was agreed that in the event the 24-inch FPVC host pipe becomes stuck during pullback operations, one or more of the following options would be undertaken:

- Attempt to push the pipe back to the surface on exit with mechanical assistance on exit side
- Allow the pipe to sit to allow any hydrolock to subside and then attempt to continue pullback

Once the pipe was back on exit, the drill string would be disconnected from the pipe and another ream and swab pass would be performed. Further, the properties of the drilling fluid used would be evaluated for suspension and hole cleaning.

#### **4.1.5 Break of Drill Pipe or Product Pipe Contingency Plan**

It was agreed that in the event that the drill string broke, the following steps would be performed:

1. Drilling operations would cease.
2. The HDD subcontractor would advise and consult with the general contractor's onsite representative and engineer.
3. If the drill string failure occurred within a reasonable proximity of the entry/exit work sites, the drill string would attempt to be recovered by open excavation.
4. If it was determined that it would not be possible to excavate the drill string, the drill string would attempt to be recovered.

#### **4.1.6 Product Pipe Collapse or Excessive Deformation Contingency Plan**

In the event that the 24-inch FPVC pipe comes to surface collapsed or excessively deformed, it was agreed that the following steps would be performed:

1. Continue to pull the pipeline out of the hole, adding more sections of 24-inch FPVC pipe on exit if necessary, until pipe of the proper diameter was exposed.
2. If deemed necessary by the engineer, the entire length of pipe may be required to be removed.

#### **4.1.7 Hydrolock Contingency Plan**

In the event that hydrolock occurs during pullback, it was agreed that the following steps would be performed:

1. Pullback operations would be paused to allow any hydrolock to subside. Once hydrolock subsides, pullback would continue.
2. The buoyancy control program would be reviewed to ensure that it was being followed and that the product pipe was full of water.
3. Should hydrolock not subside, an attempt would be made to remove the product pipe through the exit point of the drill.
4. Once the product pipe has been removed, the borehole would be reswabbed and reaming to a larger diameter would be considered. Further, an evaluation of the drilling fluid properties to ensure they are acceptable for pullback installation would be undertaken.

#### **4.1.8 Exceedance of Allowable Tolerances from Design Line and Grade Contingency Plan**

It was agreed that in the event the pilot hole deviated from the tolerances set forth in the contract documents, the following steps would be performed:

1. Drilling operations would cease.
2. The HDD subcontractor would advise and consult with the general contractor's onsite representative and engineer.
3. If the deviation was within acceptable limits according to the engineer, drilling would continue and the deviation would be corrected as the pilot hole was extended.
4. If the deviation was not within acceptable limits according to the engineer, the hole would be tripped back to a point where exiting the original pilot hole would most likely be achieved.

5. Once the original point was reached, the pilot hole would continue to be drilled as close to the original design as possible.

#### **4.1.9 Excessive Ground Settlement Contingency Plan**

If excessive ground settlement was encountered during drilling operations, it was agreed that the following steps would be performed:

1. Drilling operations would cease.
2. The HDD subcontractor would advise and consult with the general contractor's onsite representative and engineer.
3. The drilling fluid flow rate may be reduced, or the profile of the drill may need to be adjusted.
4. The surrounding area will then be restored.

#### **4.1.10 Utility Strike Contingency Plan**

In the event that a utility was contacted during any point in the drilling operations it was agreed that the following steps would be performed:

1. Drilling operations would cease.
2. The HDD subcontractor would advise and consult with the general contractor's onsite representative and engineer.
3. Utility companies with structures in the vicinity would be contacted.
4. The area in the vicinity of the strike would be re-located.
5. The general contractor and HDD subcontractor would perform an incident investigation into the cause of the utility strike.

#### **4.2 Equipment Layout Plan**

In order to confirm that all operations would be completely contained within the permanent and temporary construction easements shown in the contract documents, the general contractor was required to submit an equipment layout plan, which provided drawings depicting the layout and locations of equipment on the entry and exit sides of the crossing including:

- Staging area
- Pipe (drill string) storage
- Control cab
- Drilling rigs
- Mud cleaning facilities
- Frac tanks
- Liquid storage
- Spoil storage
- Temporary power facilities
- Storage trailers
- Construction vehicles

#### **4.3 Rig Capacity Plan**

The contractor was required to submit a plan that provided details on the capacity of the drill rig and verifying that the pull back capacity was greater than the required pullback that was calculated.

#### **4.4 Surveying Equipment and Procedure Plan**

As part of the shop drawing review process, the contractor was required to submit records of equipment calibrations and certifications for all equipment used for downhole surveys and tracking of the drill head. Procedures for operating the downhole survey tools were required to be provided, including measures that would be implemented to verify the accuracy of the equipment readings.

#### **4.5 Protection of Adjacent Structures and Facilities Plan**

A plan that provides details on measures to be taken to monitor and protect adjacent utilities, structures, roadways and sidewalks was required to be prepared. To protect against adjacent structures and utilities, it was agreed that the following practices would be implemented for this project:

1. Prior to moving equipment onsite, the entire worksite and surrounding areas would be photographed and special attention would be given to structures and utilities that appear to already have been damaged prior to mobilization to the project site.
2. Utility mark outs would be performed as required by local regulations. All existing utilities would be located prior to commencement of work.
3. The general contractor or HDD subcontractor would survey these utilities and structures to ensure that the drill profile avoids these utilities.
4. Any utilities that are exposed on the worksite would be protected by either being covered or barricaded to prevent accidental damage to the utilities.
5. Excavation near a known utility will be done by hand and not by mechanical equipment.
6. After pullback of the product pipe has been completed and all drilling equipment has been demobilized from the project site, the jobsite will be photographed again to confirm that no utilities or structures were damaged during construction activities.

#### **4.6 Contact Grouting Plan**

A contact grouting plan was required to be prepared that would describe the methods, equipment and materials to be used for contact grouting any areas where over-excavation, aborted bores, voids, or cavities were created or encountered during construction. Because of the length of the crossing, it was acknowledged that grouting during the pullback could negatively affect the installation of the pipe. It was therefore agreed that any voids and cavities would be filled with grout after the installation of the product pipe was complete.

#### **4.7 Soil Separation Plan**

The contractor was required to submit a soil separation plan which included details on the pump(s) and soil separation plant. Details that were required to be submitted as part of this plan included:

- Dimensions of all equipment
- Manufacturer's specifications
- Pump capacity
- Noise rating
- Soundproofing details, including confirmation that the generator and other onsite equipment can be operated without exceeding the maximum allowable noise tolerances specified in the contract documents

For this project, two soil separation plants were mobilized to the project site. An 880 Rig Cleaning System was mobilized to the exit pit on the Sayreville side of the crossing. The combination mud mixing-pumping-cleaning system that was used with the 880 rig was a trailer-mounted Tulsa Rig Iron MCS-1000, which was capable of pumping up to 612 gallons per minute (gpm) using an onboard triplex positive displacement mud pump. The MCS-1000 used centrifugal cleaning elements with 10 5-inch desilter cones, two 10-inch desander cones, and primary and secondary screen shakers to separate solids from the mud, and was capable of holding 6,000 gallons of fluids. It had a sustained cleaning volume of up to 800 gpm.

A 140 Rig Cleaning System was mobilized to the entry pit on the Perth Amboy side of the crossing. The combination mud mixing-pumping-cleaning system that was used with the 140 rig was a trailer-mounted Tulsa Rig Iron MCS-500, which was capable of pumping up to 612 gpm using an onboard triplex positive displacement mud pump. The MCS-500 used centrifugal cleaning elements with eight 5-inch desilter cones, one 10-inch desander cone, and primary and secondary screen shakers to separate solids from the mud, and was capable of holding 5,000 gallons of fluids. It had a sustained cleaning volume of up to 400 gpm.

Prior to mobilization both mud cleaning systems had hospital grade mufflers installed. Upon arrival to the jobsite, noise levels were monitored in order to determine if additional measures needed to be taken to bring the noise level within the acceptable levels.

#### **4.8 Disposal of Spoils and Drilling Fluids Plan**

A disposal of spoils and drilling fluids plan was required to be prepared which would describe the plan for the disposal of waste materials resulting from the pipeline construction, including drilling fluids, cuttings, waste, oil, fuel, discharge water, etc. As part of the shop drawing review process, the general contractor was required to identify a disposal site and provide documentation that indicated the willingness and legal authority to accept any anticipated waste products that may be encountered during construction operations.

During all construction activities, a private waste hauling and disposal service was retained to be onsite to assist with any cleanups that would be required. Fluids (i.e., bentonite slurry) that were processed as part of construction activities were classified as ID-72 waste and were temporarily stored in 21,000 gallon epoxy-coated frac tanks that were then transported via 5,000 gallon vacuum-trucks to the certified disposal facility. Spoils (i.e., drill cuttings) that were collected as part of construction activities were classified as ID-27 waste and stored in 20-yard roll-off containers for future transport to the certified disposal facility.

#### **4.9 Pipe Filling Plan**

In order to reduce pullback loads and to ensure that adequate internal pressure was maintained at all points to counter balance external pressures, the carrier pipe was required to be filled with water as it entered the bore hole. To provide the most effective pull force for installation of the host pipe, the pipe that entered the bore and was below ground level was required to be maintained full of water during the entire pullback process. The above grade portion of the host pipe was kept empty during pullback. As part of the shop drawing review process, the Contractor was required to submit a plan showing the methods and procedures for filling the 24-inch FPVC pipe with water during pullback and testing. The following methods for filling the pipe with water during pullback were agreed to:

1. After the pipeline section had been made-up and tested, a 6-inch diameter HDPE line would be made up and inserted into the FPVC pipeline at the end opposite the pulling head.
2. The HDPE line would be long enough to reach the deepest elevation along the drill path as measured from the exit side elevation.
3. As the FPVC pipeline was pulled into the hole it would carry the HDPE pipe inside.
4. When the leading end of the FPVC pipeline has passed through the curved portion of the drill path and has become horizontal, from the exit side, water would then be pumped through the HDPE pipe to the inside of the FPVC pipeline.
5. The ballast water must be metered to insure that only enough water was pumped into the pipeline to fill the portion below the exit grade elevation.
6. As the pipeline continues to enter the drilled hole, water would be simultaneously metered into the HDPE pipe to keep the pipeline filled with a water level no higher than the exit grade elevation.
7. This process would be repeated on each of the segments of FPVC to be pulled into the borehole.

24-inch FPVC pipe has an internal diameter of 22.76 inches, which equates to an internal volume of 2.76 cubic feet (accounting for a deduction for the 6-inch HDPE fill line) per linear foot, or 20.6 gallons per linear foot. Based on this, during pullback, the portion of the pipeline that was below the natural water level was filled at a rate of approximately 640 gallons per average 31-foot extracted drill joint. A total volume of approximately 112,000 gallons of water was used during pullback in order to ballast the host pipe. Water for ballasting of the pipeline was provided by the owner.

#### **4.10 Calculations**

The following calculations were required to be submitted during the shop drawing review phase of the project.

##### **4.10.1 Maximum Allowable Drilling Fluid Calculations**

The contractor was required to submit calculations that identified the critical downhole pressure that would cause hydrofracture or inadvertent return of drilling fluids.

##### **4.10.2 Pullback Calculations**

The contractor was required to calculate pipe stresses expected to result from the pullback, bending, fluid buckling loads, earth loads, groundwater loads, and any other installation and service loads to be exerted on the pipe.

#### **4.01.3 Radius of Curvature Calculations**

The contractor was required to confirm that the bore could be completed using the radius of curvature and geometry shown on the contract drawings, as well as provide calculations showing that installation stresses do not exceed the allowable pipe stresses.

#### **4.11 Safety Plan**

The contractor was required to submit a safety plan that included:

- Name of contractor's site safety representative
- Emergency telephone numbers for medical facilities and emergency personnel
- Precautions for handling and disposal of any hazardous or flammable materials
- Material safety data sheets (MSDS)
- Code of safety practices and emergency response plan in accordance with OSHA requirements
- HDD subcontractor health, safety and environmental program

#### **4.12 Required Reporting During Construction**

The following documents were required to be submitted as construction progressed and at the completion of construction:

1. Daily logs and records: The contractor was required to submit complete, legible, written daily logs and records, by noon of the following day to which the records correspond. The following was required to be reported:
  - Drilling lengths
  - Location of drill head
  - Drilling fluid pressures and flow rates
  - Drilling fluid losses
  - Inadvertent returns
  - Drilling times required for each pipe joint
  - Any instances of retraction and re-drilling of the pilot bore or segments thereof, and
  - any other relevant observations, including any observed settlement, heave, frac-outs, or surface spills.
2. Drilling and reaming rates: The contractor was required to submit maximum drilling speeds and reaming rates for pilot bore and each reaming pass. Measurements were required to be taken every 30 feet or 30 minutes, whichever was more frequent.
3. Drilling fluid pressures and flow rates: The contractor was required to continuously monitor and record the drilling fluid pressures and flow rates during the pilot bore drilling, reaming, and pullback operations.
4. Drilling fluid viscosity and density (mud weight): The contractor was required to submit measured mud and/or drilling fluid weights used during pilot boring and reaming of the bore hole measured at a minimum of three times per shift or at least once per 200 feet of drilled or reamed length, whichever was more frequent, with at least 2 hours between readings. Modifications to the drilling fluids, types and quantities of drilling fluid additives and the dates and times when introduced were required to be included in these daily logs.
5. Pilot bore as-built profile: The contractor was required to submit an as-built profile of the pilot bore within 24 hours of completion of the pilot bore. In addition, during drilling of the pilot hole, any deviations between the recorded and design bore path was to be calculated and reported on the daily log.
6. Pressure test records: The contractor was required to submit all pressure test records for both the pre-installation and post-installation tests. These were required to be submitted within 24 hours of completion of such tests.

7. Variations in plan and profile: The contractor was required to document any variations between the actual contract drawings and profile of the bore path and the location shown on the contract drawings. The contractor was required to notify in writing and by telephone the engineer immediately upon discovery of any deviations.

## **5. RISK MITIGATION MEETINGS**

Prior to the start of and during the course of construction, the engineer, owner, general contractor, HDD subcontractor and FPVC pipe supplier held workshops prior to commencement of key phases of the project. These workshops included:

- Pre-contract award meeting
- Pre-pilot drill meeting
- Pre-reaming meeting
- Pre-pull meeting
- Pre-hydrostatic test meeting

## **6. IMPLEMENTATION**

A contract was awarded to Northeast Remsco Construction, Inc. (Remsco), Farmingdale, New Jersey, in December 2009. Mears Group, Inc. served as the HDD subcontractor to Remsco. Underground Solutions Inc. (UGSI) supplied the FPVC pipe and was responsible for fusing operations of the pipe. Mobilization to the project site took place in early March 2010. For this installation, Mears used two drilling rigs. A 140,000 lb. rig was used for drilling the pilot hole, incorporating a Drillguide GST (gyro) System for the holes first portion due to the presence of ferrous debris in and along the river edge. An 880,000 lb rig was used for the reaming and pullback of the FPVC pipeline. A 140 LF, 42-inch casing pipe was installed at the entry due to the proximity at the river's edge and the shallow depth of cover. This casing was installed through rubble and concrete debris in order to stabilize the start of the pilot hole. Once completed, the casing was cleared and centralizers were installed to initiate drilling of the pilot hole.

A 10-inch jet assembly was used to drill the pilot hole. This drilling commenced on March 11, 2010, and was completed by the end of March 2010. When the pilot hole reached approximately 700 feet, Mears switched from the GST system to a Para-Track II wireline system that was equipped with a pressure probe. This was necessary because of overburden pressure concerns, and the need for monitoring annular pressures to minimize inadvertent returns of drilling fluid escaping into the river. The final exit location of the pilot hole was within 5 feet of the originally intended target. Used in tandem were 26-inch and 36-inch reamers to prepare the hole for the 24-inch product FPVC pipe. Reaming and reswabbing of the hole was completed in late April 2010.

The pipe lay down area limited pipe strings to be fabricated up to a maximum length of 1,500 feet; therefore, four pipe strings and three tie-in fusion welds were required to be made by UGSI during pullback operations. To reach the HDD bore hole from the pipe lay-down area, the pipeline was suspended over a major roadway and supported as it traversed a steep hillside with numerous elevation changes. Staging of the product pipe between the lay down area and the entry pit commenced early the morning of April 29, 2010. Due to difficulties in terrain and the need to span across a roadway, this work was completed in the early afternoon at which time the connection between the host pipe and the drill rod was made and pulling of the host pipe commenced.

Pulling of all four strings of pipe was completed on April 30, 2010; approximately 23-hours after pulling of the host pipe commenced. After completion of pullback and demobilization of all drilling equipment, the 24-inch water main was swabbed with a 24-inch diameter flexible polyurethane foam pig. After all land connections were made and after successful disinfection and hydrostatic testing of the water main, it was formally placed into service in late May 2010.

## **7. CONCLUSION**

The successful completion of this high-risk project was accomplished through the skills and cooperative efforts of all of the participants working together throughout the project. The level of contingency planning that went into the design and construction phases of the project provided a continual assurance and confidence to the project team that the original designed plan was attainable and the risks were manageable, thereby assuring the ultimate success of the project.