THE BIRKDALE ‘B’ PROJECT: 3,420 LF OF AT-GRADE HDD IN NEW ZEALAND

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ABSTRACT: In 1998, the North Shore City Council, near Auckland, New Zealand launched Project Care with the primary aim of resolving the beach pollution problem caused by an overburdened combined sewer and storm water system. As one of the measures to eliminate overflows, a new pipeline for extra system capacity was needed to carry the increasing loads of everyday sewage flows from the area. The Birkdale Pipeline Project, as an effort to complete this goal, was divided into three separate contracts, Area ‘A’, ‘C’ and the center connecting section, Birkdale ‘B’.

The Birkdale ‘B’ pipeline was an onerous segment of construction, extending 3,380 feet under arterial roads and surrounded by established residential housing. It was installed by at-grade horizontal directional drilling (HDD) methods and has a ~90 foot depth to invert point as it passes through a steep hillside, before weaving through a wetland area and terminating at a newly installed manhole. The initial pilot hole was drilled using a bottom hole assembly configured for drilling through rock, utilizing a down hole mud motor and non-magnetic steering. The pilot drill took six weeks to complete, meeting the requirements for both grade and invert level tolerance. Reaming passes followed with a final diameter of 28-inches attained before final pullback of the 20-inch product pipe.

Fusible Polyvinylchloride Pipe (FPVCP) was chosen for the installation due to the advantages of its smaller outer diameter, thus smaller required bore hole; lighter weight; and greater tensile capacity over other commensurate thermoplastic pipe sections. The FPVCP pipe was joined and staged in three pipe strings, each approximately 1,100 feet long. Upon completion of the borehole, the first FPVCP string was attached to a pull head and pull back commenced. Two intermediate fusion joints were required to connect the three individual pipe strings together during insertion.

1. INTRODUCTION

Birkdale is a suburb in the North Shore area and is located near Auckland, New Zealand and has been prone to wastewater overflow during heavy rain for the last few decades. The old cracked and under-capacity wastewater piping would fill with storm water in times of heavy rain events and flooding of the system would occur throughout the residential properties and streets of Birkdale. To make matters worse, the overflows and discharges of untreated sewerage would end up dumping directly into Eskdale Stream, one of the North Shore’s most environmentally significant streams.
In 1998, North Shore City Council (NSCC) launched Project Care with the primary aim of resolving the beach and stream pollution problem caused by the overburdened combined sewer and storm water system. One of the primary measures used to ease the overburdened system was to install a new pipeline to add extra system capacity. The increased capacity would be critical for the intermittent influxes of storm water, but would also increase the capacity of the system for the normal, diurnal domestic sanitary sewage flow from the catchment area.

This pipeline project, named the Birkdale project, was broken into three sections or phases of work and each phase was tendered as a separate contract. The phases were named Birkdale ‘A’ through ‘C’. The center section of the pipeline, or Birkdale ‘B’, represented the most challenging construction. Specific challenges for the Birkdale ‘B’ segment included:

1. A relatively large pipe diameter required with a 24” (630 mm) nominal pipe (designed with PE pipe sizes and flow areas),
2. A very shallow grade required, as low as 0.5%,
3. Large installation depths, up to 92 feet (28m),
4. A long length of pipe required, at ~3,380 feet (~1,030m),
5. A curved alignment in plan,
6. Difficult soil conditions, including fluctuations between soft clay and sandstone,
7. A large portion of work within an environmentally sensitive area.

The combined geological and environmental conditions of the area dictated that trenchless installation was the only viable installation method. The construction contract was awarded to general contractor, PipeWorks, Ltd. (PipeWorks) in December, 2009, and as an initial action, at the start of the contract, PipeWorks brought together a team of experts to consider new technical solutions and mitigate the significant project risks. The results of this approach included several technical innovations that enabled a successful project. Furthermore, these new approaches and experience gained have resulted in a big step forward in industry knowledge and capability within New Zealand.

When the project was originally bid, two alignments were proposed as suitable to the design of the pipeline. One alignment closely followed the Eskdale Stream (shown in Figure 1 as the black line that veers to the southwest in the middle of the alignment) and the other diverted away from the stream through much harder sandstone and rock material, following under a longer stretch of arterial roadway (shown in Figure 1 as the green line). Final selection of the alignment to be used was left to the construction team. After consultation within the team, it was agreed that
drilling directly under the steam through very soft soils introduced too great a risk to successful completion of the design and it also posed significant risk to the Eskdale Stream environment. The likelihood of an inadvertent drilling fluid return that would delay construction and cause significant surface remediation was too great – this would lead to increased cost and construction time, not to mention the damage to the sensitive ecology in the area. Therefore, even though it would require greater depth drilling through firmer materials, the alternate Option ‘B’ alignment was selected.

The Birkdale ‘B’ pipeline extended approximately 3,380 feet (1030 m) under a major arterial road and surrounded by established residential housing. The pipeline has an approximate maximum depth of 92 feet (28m) to invert point as it passes through a steep hillside and finally weaves through a wetland area before terminating at a newly installed manhole. The ground conditions across the site ranged from Waitemata series sandstone, coupled with short sections of high plasticity clays, silts, sands and organics.

2. TECHNICAL COMPLEXITIES OF THE DESIGN AND INSTALLATION

The HDD installation for Birkdale ‘B’ was extremely challenging with numerous technical complexities woven throughout the design. As a project, it represents a success at the leading edge of current practice. As an “at-grade” installation, not only were contiguous grades mandatory to the success of the pipeline design, they were also very small – starting at only 0.5% for the first ~330 feet (100m) and then averaging only 0.8% over the remainder of the length. These grades are much less than normally achieved by directional drilling as industry best practice generally suggests a minimum grade limitation of 1.0 to 1.5%. The depth of the pipeline presented major challenges to achieving the correct alignment. The minimum depth was ~15 feet (4.5m), but this increased to ~98 feet (30m) over a significant portion of the middle of the alignment. These depths make locating and tracking the pilot drilling equipment difficult. The existing soil in this deep section – largely composed of sandstone and rock – meant that high push forces and torque would be required. Also, the final size of the reamed hole over a length of ~3,380 feet (1,030m) meant that a large volume of drilling fluid would be required during drilling and reaming. Handling and disposing of this drilling fluid within the sensitive reserve property presented a large logistical and environmental challenge, which also translated to all the processes required on the site, including general drilling operations and installing the pipe.

The original scope of work specified the use of conventional 24-inch (630mm) outside diameter HDPE pipe. However, given the large pipe diameter, the pipe length, the small gradient and curve in the alignment, there was a perceived risk that the installation would be unsuitable for the material capabilities of HDPE pipe. The risk of the pipe failing the installation under these conditions was addressed very early on by the PipeWorks team.

The use of fusion welded PVC pipe was considered to provide a way to reduce these risks. Fusible PVC™ pipe (FPVCP) is a stronger plastic material, so not only is the allowable pull force greater with the use of PVC, the wall thickness of the pipe can be reduced when compared to HDPE for the same relative pipe stiffness. This means that with FPVCP the required ~19.7-inch (500mm) internal diameter can be provided with an outside diameter of 21.6-inch (550mm), which is 3-inches (80mm) less than the HDPE required outer diameter. The smaller outside diameter is a significant factor in the amount of excavation required as part of the bore – affecting required drilling fluid, reaming passes, and drill rig size requirements.

The one downside, however, was the fact that FPVCP had not previously been used in a commercial application in New Zealand and its use was a significant unknown to the local industry. There was limited technical knowledge of how the material would behave on site and contracting staff had no previous experience working with it. To evaluate the practical use of FPVCP and application to this project PipeWorks brought together a team of experts to work through the issues. The combined team brought together to consider the use of FPVCP included the Client’s engineers, the consultant design engineer from SKM/Opus, PipeWorks’ site engineers, a technical adviser from Australian drilling firm Ancon Drilling, and PipeWorks’ external technical advisor Dr. Ariaratnam, Professor of Trenchless Technology at Arizona State University. This team considered the technical capabilities of the FPVCP with the pipeline requirements and also considered the practical elements of handling the material during construction. The end result was that FPVCP was determined to be ideal for the intended use and the practical requirements of installing it could be met. In the opinion of the construction team, this first application of FPVCP in New Zealand was a significant innovation of this project and an important contributor to its successful completion.
2. DRILLING PROCESS AND CHALLENGES

Pilot Bore Completion

The difficult nature of the overall HDD project brought about the use of some innovative ideas and methods to assure that the pipeline would be installed at the appropriate grade and alignment. The first major step in this regard was the steering system and methods used to guide the pilot bore. The pilot hole was drilled with a bottom hole assembly configured for drilling through rock, utilizing a down-hole mud motor. In total, the pilot drill required six weeks of work, as the requirements for both grade and invert level tolerance were very stringent. A maximum deviation from alignment was limited to 6-inches (~150 mm) at any location. Various hole enlargement sizes were then employed, with a final ream size of 28-inches (712 mm) rounding out the ream phase before the product pipe installation took place.

A tracking system to allow the drilling crew to accurately monitor the location of the head at any time was going to be essential. Given the presence of hard sandstone and rock, a ‘mud motor’ rotating drill head was the best option to obtain necessary penetration. However, the steel components in the head of these drills posed a major challenge to being able to track and steer the head correctly; the steel components interfere with the local magnetic field and make it very difficult for tracking devices to function. The project team considered all options, and opted for a the Paratrack tracking system. Paratrack is a location system that attaches to a drill head and accurately gives the underground location of drilled pilot holes. In this application, the team had to install the Paratrack unit ~16 feet (5 m) behind the drill head, where it would not be disturbed by the rotating head, and then calibrate the output to account for the 16 foot difference. The drill head was able to be tracked to a very fine degree, and the readings indicated that the deviation in alignment over the 3,380 foot (1,030 m) length was never more than 4-inches (100 mm).

In addition to the conventional tracking mechanisms required for drilling, several unique aspects of this project also aided in the steering and accuracy of the pilot bore operation. A “hard daylight measurement” was required for 4 different points along the route. As one example, at an excavation for an intermediate manhole, ~75 feet (23 m) deep and ~6 feet (1.8 m) in diameter, the bottom of the manhole was intersected well within a tolerance of 3.5 inches (89 mm) from target. This was in rock conditions at 1,800 feet (550 m) away from the drilling rig. These four locations helped to assure the team that the pilot bore was progressing as needed.

![Figure 2. Schematic of ‘picket fence’ drill head alignment check and verification.](image)

Half way along the pipeline length was the most challenging portion of the alignment in terms of steering. At the very deepest point of the line – 98 feet (30 m) below ground – was a horizontal curve in the alignment. Drilling this curved line accurately at this depth was going to be one of the biggest challenges of the job. An innovative solution was created to check the drilled alignment at this location, as a back-up to the Paratrack system. At the deepest point at the middle of the curve, a row of 2-inch (50 mm) diameter tubes were installed into the ground in a line nearly perpendicular to the direction of the drilling deep below. The tubes were drilled 105 feet (32 m) into the ground, and
then they were filled with water. As drilling continued into this line of tubes, one of the tubes would be hit by the drill head, and the water within it would drain. This observation gave the drilling team confirmation of the horizontal alignment the pilot bore was following. The drill head was found to be on the correct alignment, and this physical test was reassuring to the team. This ‘picket fence’ device was a simple and novel way to double check that one of the most difficult sections of the alignment was being performed accurately.

Site conditions prohibited the use of a Maxi HDD Rig and required spread. Instead, a Vermeer D100X120 drill rig was used. This versatile rig was most suitable for the restrictive setup area available, however a job this size, with a required 28-inch diameter final ream, drilled in ~3,380 LF (1030m) of sandstone and clay, is most certainly on the outer limits of its capability.

Figure 3. Vermeer 100x120 drilling rig during the pilot bore excavation. Note the site location within the natural reserve area.

Alignment Details

The drilling rig was set approximately 98 feet (30m) off line and at a distance some 65 feet (20m) back from pipeline start point due to site space requirements around existing roads and houses. The pilot was drilled to intersect the pipeline alignment at 250 feet (76m) and needed to complete a 425 foot (130m) horizontal curve coupled with a 656 feet (200m) vertical curve to achieve this and continue on the designed grade of 0.5%. A drilled grade of 0.5% through the first 985 feet (300m), with the drilled grade from 985 feet (300m) to approximately 2,625 feet (800m) being reduced from 1.1% to 0.8%. This reduced designed grade enabled the upstream pipe alignment grade to be increased and introduced a “safety” aspect for the final 655 feet (200m) in the wetlands portion of the alignment. The contractor was able to change the grade between 1% and 2.5% to reduce likelihood of dips or low points being created in the line. The 0.5% grade in the first ~1,000 foot (300-m) section was required to pass underneath a concrete lined stream channel. Achieving the 0.5% grade ensured that the borehole missed the base of this channel by ~2.5 feet (0.8m).

From ~2,750 feet (840m) through to 3,360 feet (1024m) the required alignment followed under long sections of the streambed in the protected reserve and sensitive ecological area. In this section, a horizontal curvature was introduced with a radius of ~985 feet (300m) that ensured that the pipe alignment only crossed the stream once and remained in firmer, more stable ground. This would help to ensure that the potential for surface fractures within the
streambed were minimized. At the final mark at the “top” of the bore the drill was approximately 4.75-inches (120mm) high from the designed alignment. However, this was needed as the ground conditions in this area are very soft (organics and silts) and the reaming process required to upsize the bore was expected to drop the drill section to the required levels.

In total, three compound curves were required to complete the steering of the pilot bore and this presented its own challenges. In addition to other drilling regimes and parameters, a solid drilling fluid engineering process, coupled with “smooth” and accurate steering was required to keep torque loading on the small 3 ½” drill pipe over such a long distance low. There was groundwater influx into the borehole of up to 13,200 gallons (50m³) per day. Various methods of sediment settling, flocculation and dewatering were employed to enable a disposal of solids free water into the NSCC sewer system. Construction of a 72 foot (22m) deep, 6.5 foot (1980mm) diameter shaft was required at 1,840 feet (560m) in the center of a small cul-de-sac to install a manhole on the alignment. Care was taken to ensure this shaft was installed without disruption to residents and property in close proximity. Construction of a 26 foot (8m) deep access shaft at 250 feet (76m) for drilling slurry return and tooling changes was also created. This shaft was positioned adjacent to the berm and parking lane of the very busy Eskdale Road and was achieved using H piles and timber lagging in the hard sandstone.

At the intersection point at 3,380 feet (1024m) a large “coffer dam” type excavation 13 feet (4m) wide x 33 feet (10m) long x 21 feet (6.5m) deep was installed to capture both the finished pipeline and also to connect to the pipeline that was installed by the previous contract. Excavators installed sheet piles and lagging with vibratory hammers in the very soft, swamp-like conditions. Swamp mats, geotextiles, geo-grids and significant amounts of graded aggregates were required to stabilize the installation. Significant effort went into excavation of the wet, mucky spoils from within the cofferdam enclosure. This excavation was within 20 feet (6m) of Eskdale Stream and approximately 15 feet (4.5m) below the streambed elevation.

**Drilling Fluid Challenges**

One of the major challenges of the project was the volume of drilling fluid that would be required for the proposed borehole. Given the length and diameter required, during pilot drilling and reaming significant volumes of drilling slurry would be extracted. Dealing with this drilling fluid in the best way environmentally and economically would be a key element of project success. It was decided early on to try and recycle as much drilling fluid as possible, rather than simply dumping it at a landfill. The extracted drilling fluid was filtered and re-engineered on site so that it could be re-used. Extensive onsite fluid testing including rheological properties, filtration properties, viscosity, gel strengths, mud weights, sand contents and PH/Hardness were used. To ensure that the maximum volume of cuttings were sufficiently suspended and carried over the long length of the bore, bentonite mixes were used. Polymers and detergents were also employed at times dependent upon soil conditions encountered. This overcame delivery of the drilling mud returns of various viscosities/mud weights through a 3,380 foot (1024m) bore length on relatively “flat” grades.

A specialized de-sanding unit was also on site to process the drilling fluid returns from the borehole and remove all solids. The recycling system consisted of a DFE 2000 de-sander and 40ft container suspension tanks and was able to process 100% of the returning drilling slurry. To enable such efficient recycling required a comprehensive material knowledge of the drilling fluid and how to process it. Before this job, this level of working knowledge simply wasn’t held by anyone in the local industry. PipeWorks had two staff members trained at Drilling Fluids Engineering School in the United States specifically for this project. This expertise was applied during the project and helped ensure efficiencies in operation of the de-sanding machinery and in the recycling operation. Because of the positive and valuable experience, PipeWorks has sent two additional staff to the same program, to gain further knowledge in this important area. The steps taken to increase knowledge about drilling fluid processing will have major benefits for the local industry and this advancement would not have occurred without this project.
Drilling Rig Site Considerations

Within the local area, there is a significant ecological reserve containing native flora and fauna that is very important to the community. The Kaipatiki Ecological Restoration Group spends many weekends on maintenance and preservation activities within this reserve and are passionate about its protection. The primary site used for drilling the excavated hole and feeding the new pipeline was located within this nature reserve, and so the project team had to consult closely with this community group.

To enable the drilling and installation to take place, a temporary access road was formed from the local road, and working platforms were created for the heavy drilling plant to sit on. During the project, there was continual communication between the PipeWorks team and the restoration groups to ensure all construction activities were appropriate. The PipeWorks team got to know the group members well, and a good relationship between the two parties was developed. At the end of the project, the PipeWorks team decided to leave facilities in place simply to improve the area in which the restoration group worked. The access road, that was originally going to be removed and left as bare soil, was left in place in agreement with the group. It now provides them with all-weather access to many more parts of the nature reserve.

At the beginning of the project, the team needed to perform some tree felling and vegetation clearing to create a working space for the drilling plant and machinery. PipeWorks went to the site with an arborist and followed their advice on what trees could and should be removed. No critical native vegetation was removed and to some degree the team had to make adjustments to the site layout and working area to ensure this. Additionally, while on site the team took the opportunity to remove pest and noxious plants in the area for the sole purpose of improving the area where the construction took place.

The site team also built an additional flat platform within the area, at a location beneficial to the group. This will provide the group with a dry working area to help them load or unload vehicles, or attend to vegetation. These two features were provided by the project team purely for the benefit of the Kaipatiki Ecological Restoration Group, and have made the area of even greater value to the people who care for it.
As the project work was located in close proximity to many residential properties, public and stakeholder consultation was a key aspect of the project. The project team implemented practices to ensure local residents and affected parties were informed and involved at all times. At the start of the project, the Stakeholder Manager visited all directly-affected properties and spoke to residents about the project at some length. This initial work helped the residents understand the requirement for the work and the construction activities that needed to take place. This face-to-face consultation helped to ensure the residents’ support for the project and to understand the expected outcomes and what would be required to achieve them. On-going consultation with the neighbors during the course of the work was performed directly by the site team.

When establishing a work site close to Eskdale Stream, the existence of a Maori statue erected at the site to indicate contaminated water and food resources was encountered. Through consultation with the local Iwi, the importance of this statue and what was appropriate in terms of construction operations was determined. Accordingly, the site was set up to ensure it didn’t interfere with the statue and its message. PipeWorks is proud of the relationships that were built with the local community and the work that was delivered for their benefit.

3. OUTCOMES AND RESULTS

Economical Outcomes

The technical complexity of the project meant that a conventional approach would be too risky – there was a high likelihood of errors that would result in significant increased cost and construction time. The project team worked closely with the Client’s engineer and together they found solutions to mitigate cost and time risk. The project budget and timeline was adhered to in the project. The initial budget was expanded during the works by changes that were agreed to with the Client. Works were completed within the programmed timeframe, taking into account the additional variations.

Economically, the use of FPVCP has potential benefits beyond this project. The new FPVCP is compatible with standard fittings and couplers that are used on all other local PVC pipelines. This means that should further connections or installations be necessary in the future, it will be easy to make these connections into the new pipe. HDPE pipe, as originally proposed, would have meant these connections were more difficult and expensive. Keeping consistent with use of FPVCP pipe in this way also reduces the workload of maintenance teams, as they are familiar with this material and are equipped to maintain it.

Social Outcomes

Before the project, the entire community was being severely affected by the undersized wastewater pipe. During high rainfall events the pipe would overflow, and combined wastewater and storm water would seep from the pipe and manholes into the surrounding soil and across residential properties. After successful completion of this project, there will now be no overflow from the wastewater pipe during these rainfall events. This eliminates the potential health hazard of having raw wastewater ponding in backyards, footpaths and roadways in the residential area. Ongoing flooding was taking its toll on buildings and property in the area. Additionally, the time and energy spent on overflow clean-up by residents has been eliminated.

Eskdale Stream and Nature Reserve Environmental Outcomes

Working adjacent to Eskdale Stream carried significant environmental risk, particularly as a manhole was required to be installed within ~6 feet (2m) of the stream. The team identified this as a high-risk operation, with large risk of inadvertent drilling fluid returns. During the work next to the stream, the team placed a line of workers along the creek as ‘spotters’, who in the event of a fluid return at surface could identify it immediately and stop progress before it escalated.

All work was performed according to a project-specific Environmental Management Plan, which detailed the actions and responsibilities for addressing all environmental concerns. The plan directed activity at all times and by following it, the project met all requirements for erosion and sediment controls, accidental spills, vegetation protection, drilling fluid returns, and construction noise and vibration.
Continual overflows had caused contamination of the Eskdale Stream that runs through the neighborhood. This stream has for centuries been an important water resource for local Iwi, and a popular location for catching eel. Contamination had become so bad that local Iwi had placed a traditional carved statue (Pou) next to the creek to warn people of the health hazards of catching eels from the waterway.

Now that the new pipe is in place, it is expected that in a period of time all pollutants will leave the stream and surrounding soil and the restrictions on using the stream for catching eels can be lifted. A ceremony to remove the statue from the site is planned, and this will be a very positive event for the community.

Figure 5: The Eckdale Stream reserve and the Maori statue indicating contamination

*Recycling Drilling Fluid Outcomes*

A major innovation in the project was the team’s ability to recycle a large percentage of excavated drilling fluid, minimizing the amount of drilling fluid that needed to be dumped at landfill. A comprehensive de-sanding unit was established on site to remove the sand and drilling materials from the excavated drilling fluid. This machine allowed recycled drilling fluid to be restored to the right composition so that it could be reused.

Recycling the drilling fluid on this site meant only the excavated solids needed to be disposed of off-site. This created an overall reduced burden on the site, the ecological reserve, and also made drilling work more efficient.

4. **CONCLUSIONS**

In 1998, the North Shore City Council, near Auckland, New Zealand launched Project Care with the primary aim of resolving the beach pollution problem caused by an overburdened sewer and storm water system. The Birkdale Pipeline Project, including all three phases, successfully resolved the issues present with sanitary sewer overflows during wet weather, sensitive ecological contamination and property damage.

The Birkdale ‘B’ pipeline was an onerous segment of construction, extending 3,380 feet under arterial roads and near to established residential housing. It was installed by at-grade horizontal directional drilling (HDD) methods and has a ~90 foot depth to invert point as it passes through a steep hillside, before weaving through a wetland area and terminating at a newly installed manhole. A 20-inch Fusible PVC™ pipe completed the installation, connecting the new pipeline and solving the capacity issues present in the system.
The project not only resulted in an effective design for the flows present in the system, it also rectified long present problems with a sensitive ecological and natural reserve, cultural significance with the use of the Eckdale Stream and the effective use of several newer installation techniques and knowledge for use with HDD technology for the project team and the local industry.