CANADIAN CONSULTING engineer

AECOM

# CCE AWARDS 2016

## Bowness Sanitary Offload Trunk

Site at end of Shouldice Athletic Park near Bow River

## 75 Word Summary

The City of Calgary required additional sewer capacity in the northwest. AECOM provided design and contract administration for the Bowness Sanitary Offload Trunk, constructed via microtunneling rather than open trench. This method allowed the pipeline to be optimized and constructed in a smaller area, covering a shorter distance, with less impact to the community, and was less expensive. Tunneling under the Bow River mitigated environmental concerns and shortened the project construction schedule by one year.

# Introduction

The City of Calgary's Bowness Sanitary Offload Trunk project was constructed to provide additional sanitary sewer capacity for Calgary's northwest to meet existing and future wastewater loads.  A restriction had been placed on upstream land development until the trunk was in service, so schedule was critical from concept to commissioning. AECOM was selected, in a Qualification Based Selection (QBS) process to provide Preliminary Engineering, Detailed Design and Contract Administration services.

The project, as originally proposed, involved construction of approximately 3,700 m of 1,650 mm sewer with a twin 900 mm siphon crossing of the Bow River. The project is located in the mature community of Bowness in northwest Calgary, which is a mix of dense residential and commercial land use. The route of the pipeline required multiple critical infrastructure crossings including major transportation infrastructure (major roads and railways), large diameter storm trunks and a large diameter feedermain, which is a critical piece in the City's water supply system. The original concept proposed construction in Right-of-Ways largely by open cut methods, even in areas where the depth of the excavation would be in the range of 8 - 10 metres in a mature neighbourhood with limited workspace.  AECOM raised concerns over the technical feasibility of open cut construction, its true capital cost, and the social and environmental impact associated with this approach.

# Innovation

AECOM saw that a widespread deployment of trenchless construction technology was well matched to the major technical challenges for the project and would result in successful delivery at a lower cost, in less time and with considerably less impact on the public and the environment. The subsurface conditions along the route were highly variable and complex, which was a major challenge to pipeline construction. Open trench construction in this area had the following ramifications:

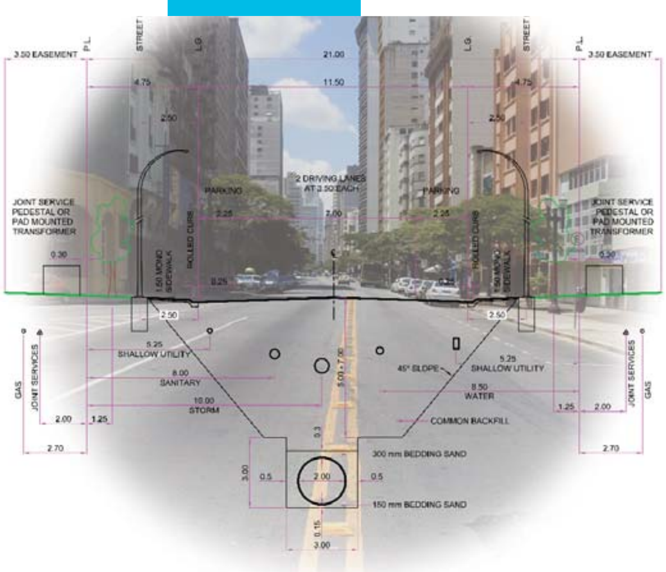
- Complete loss of access to residential and commercial frontage for several weeks at a time.
- Complete loss of conventional access for Emergency Response (Fire Department, EMS, Police) and normal municipal services during the course of construction.
- Extensive requirement for temporary relocation and/ or replacement of both deep and shallow buried infrastructure, and requirement for temporary servicing of residential and commercial properties during construction and / or work in close proximity to these services.
- Limited area to stockpile materials including: trench excavation and construction materials (pipe, bedding, equipment).
- Significant concerns with stability of trench wall and increased potential for damage and encroachment into private lands.


**Route alignment, shows optimized alignments, including two tunnels under the Bow River**

- Limited work area in the public right-of-way unless large construction easements could be obtained.
- Schedule constraints due to both construction logistics (e.g. compaction requirements in cold weather) and regulatory approvals associated with environmental impact.
- Significant loss of amenity to the public from very large equipment with limited noise control features and radically increased large truck volume traffic.

The intelligent use of trenchless technology using a Microtunnelling Boring Machine (MTBM) with properly matched earth pressure balance (EPB) technology solved many critical problems, including:

- Minimized construction footprint which dramatically reduced impact to the public and the environment.
- Increased noise control features on specialty equipment.
- Opening up alternative alignments through corridors that were not technically feasible with open cut techniques, presenting shorter length alignments resulting is a lower cost.
- Minimal relocation of existing utilities and better management of risk for work in close proximity to other infrastructure.
- Tunneling under the Bow River could be completed without impacting the environment which reduced the initial schedule by a year due to an expedited Department of Fisheries and Oceans approval process.




Open cut vs. tunneling, comparing site disturbance

The net result of this approach was the largest MTBM project ever undertaken in Calgary. In addition to the compressed schedule and reduced cost, the reduced impact of disturbance to the public and the environment cannot be overstated. As an example, every 100 m of open cut construction would have resulted in 355 to 500 large truck movements (dependent on depth), whereas the use of a MTBM resulted in only 25 movements per 100 m of pipe, relatively independent of depth.

Innovation was not limited to the construction technique. The hydraulic modelling undertaken determined that an alignment east of the Canadian Pacific Railway (CPR) Right-of-Way provided an opportunity to optimize use of an upstream existing trunk as a parallel conveyance element. This alignment was only viable with trenchless technology and resulted in downsizing approximately one third of the trunk and deferring over $10 million of upgrading construction for approximately 20 years.

Future Tie-In, connection for expansion

The final project configuration involved construction of 900 mm and 1200 mm parallel lines crossing the Bow River; and construction of approximately 2 km of 1500 mm and 1800 mm trunk on the north and south sides of the Bow River. Another unique aspect of route selection design includes a single MTBM drive with two horizontal curves to maximize use of a very narrow right-of-way. The use of curved MTBM alignments is a relatively new technique pioneered by AECOM on a project in Hartford, Connecticut.

Project specifications very carefully matched MTBM technical requirements to site specific conditions and project technical requirements so installation quality and accuracy would not be compromised. MTBMs can now be acquired with sophisticated remote controlled laser guidance systems to meet very stringent horizontal and vertical position control objectives (to within 25 millimeters on very long drives). This was important as the tunnel was excavated in close proximity to a number of critical underground utilities.

Use of MTBM technology greatly minimized surface disturbance. The pipeline was constructed with only eight shafts to launch and receive the MTBM. From a public and environmental perspective, construction was limited to these sites. As a result, there was less impact on public amenities, a radically smaller carbon footprint, and much less noise. The construction sites were approximately 24 m by 70 m for launching shafts, and 20 m by 40 m for receiving shafts in residential areas. The sites were primarily located in Rights-of-Way, public, and CPR lands. This is an incredibly compressed work area to accommodate over 2 km of very large diameter pipe installation.

The use of a more innovative, less disruptive approach resulted in lower overall cost than utilizing open trench construction. Capital and triple bottom line costs were substantially reduced. More flexible route selection reduced the length and less invasive construction methods reduced not only public impact but the environmental footprint to such an extent that regulatory approvals could be greatly expedited. The construction cost for the project was $34.15 million; $6.46 million for two tunnels under the Bow River, and $27.69 million for the remaining work, which was completed one full year ahead of the earliest envisaged completion date.

**MTBM controls, tunneling operator displays**

# Complexity

While the use of MTBM technology met many of the challenges of the project in a more effective manner, it greatly increased the degree of difficulty from the perspective of complexity of design and the degree of construction expertise required.

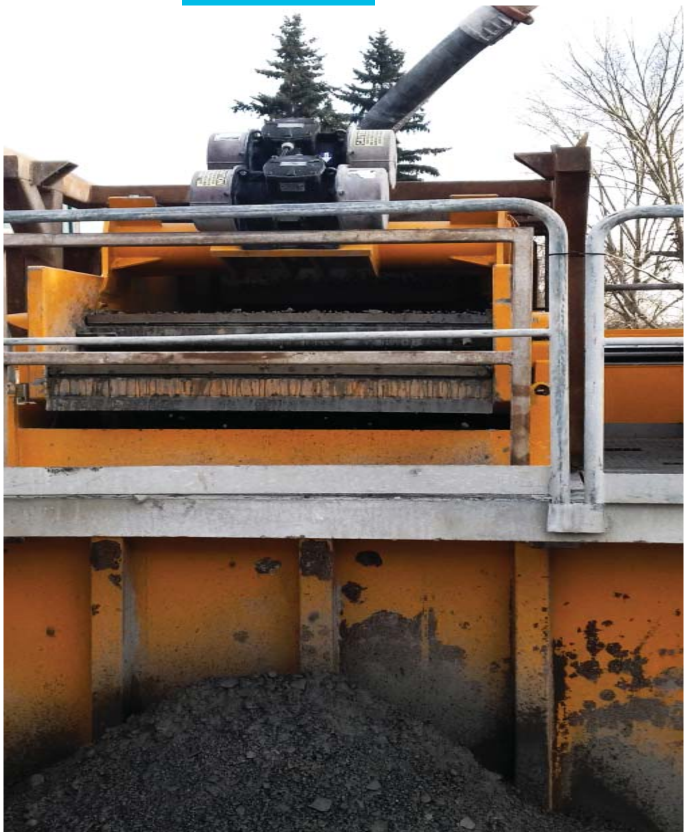
The pipeline design needed to be elevated to consider many forces and design loads not normally considered in conventional pipeline design; axial and asymmetrical loads as opposed conventional earth load designs. Bore hole layout and laydown areas needed to be well developed in the design phase to facilitate utility relocation and the development of traffic management plans in areas where laydown area needed to be accommodated. These items could not simply be "off-loaded" to a contractor and they needed to be implemented in a very short time frame after tendering and award of the contract.

Minimizing extensive loss of ground in tunnelling in complex soils raised the bar for both the contractor and AECOM as the designer. Realistic loss of ground controls were put in place and the necessary monitoring implemented to confirm that what was intended to be built was actually was built. Critical crossings such as the Bearspaw Feedermain, the TransCanada Highway and other critical infrastructure components all elevated the degree of difficulty and need for comprehensive monitoring to deliver the project successfully.

Procurement of a contractor with the appropriate skill level was also essential to success and elevated difficulty level. Intelligent use of a pre-qualification process and equitable distribution of risk through the use of a geotechnical baseline report to understand soil conditions were all good tools to achieve this, but they elevated the difficulty and complexity of the overall project.

## Technical Excellence

Intelligent utilization of MTBM technology allowed optimization of the alignment and overall design of the project without compromising overall technical objectives. The initial concept identified a longer route to be constructed via open trench. The initial route crossed the CPR tracks twice and would have caused major disruptions to residents and emergency services for an extended period of time. The final alignment was only feasible with the innovative use of MTBM techniques. The final alignment has fewer crossings, less environmental impact, reduced risk and a much



Separated Tunneling Waste, soils to be removed

shorter length to construct. This translated into a lower cost to construct this critical piece of infrastructure in much less time over a shortened schedule.

Technical excellence is evident in the design and execution of the project. Detailed shaft layout and safe boring lengths were enabled with staged and detailed geotechnical investigations carried out at the initial stages of the project. A greater understanding of subsurface conditions enabled the development of very precise layout plans at an early stage as well as proper selection of MTBM technical requirements to match the site specific conditions.

As noted above, eight shafts were constructed along the pipeline alignment to launch and receive the MTBM. The shafts are spaced at intervals of 300 to 500 m. To excavate the tunnel, the earth pressure balanced MTBM used bentonite to lubricate the cutterhead. Precise calculations were required to determine how much lubricant to add in front of the cutterhead to maximize boring length at acceptable risk levels due to jacking forces. It was a precise balance between having too much lubricant and not enough. The ground needed to be kept intact enough to prevent the tunnel from collapsing, but still wet enough to facilitate the tunneling process.

As the machine advanced, it excavated a wide range of soils (clay, gravel, boulders, and bedrock - claystone, siltstone, and sandstone) and used EPB technology to maintain a stable tunnel face. The excavated soils/ bedrock went into a separation system in a slurry mixed with the lubricant. The solids were then separated from the liquid. The liquid was recirculated into the operation, and the remaining solids were disposed of at the temporary storage location. The waste was then trucked to a disposal site. While tunneling occurred on a 24/7 basis with minimal disruption to the nearby residences, trucking of the waste only took place during the day. Any debris removed during tunneling overnight was stockpiled at the site then cleared the following day. The decibel levels of evening construction activities was monitored and confirmed to be less than normal background sound levels.

## Advancement of Technology

Technology has advanced to the stage in which MTBM construction is now a feasible option for projects in Calgary. This project demonstrates that it is possible to create a piece of infrastructure in a less conventional and less disruptive way without compromising technical objectives or incurring greater risk. It has the potential to fundamentally change the way we execute projects in built up areas in the future.

The construction contractor, Ward & Burke Microtunneling, used state-of-the-art tunneling machines from Germany to complete the work that were very well matched to the site specific requirements. This has demonstrated what the most recent technology can accomplish even when facing the mixed, complex soil conditions that characterize the Calgary area.

## Management of Risk

Construction of this nature has considerable risk that must be managed well to achieve success. The use of an Active Risk Register was incorporated into project delivery at an early phase to clearly identify and actively mitigate risk over the course of the project.

Specific risks identified at an early stage included:

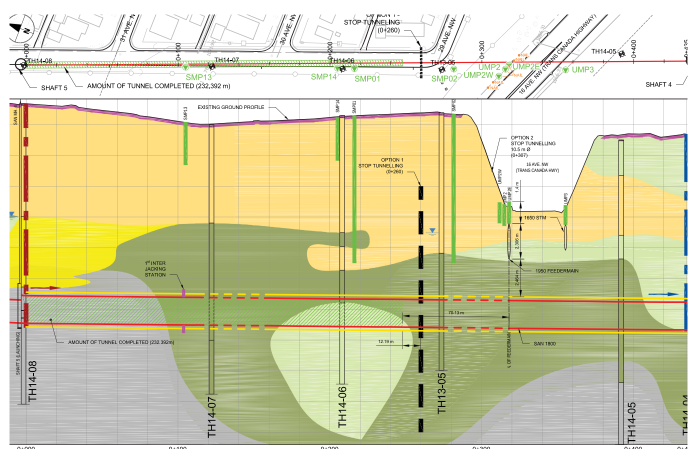
- A minimum of three major infrastructure trunks were in direct conflict with the conceptual design profile, including the 1950 mm Bearspaw Feedermain, the City's largest water supply trunk. These features dictated that the sewer be located at depths of over 15 m for most of the route.
- Ground conditions were complex from a construction perspective and highly variable along the route, including high groundwater levels.
- MTBM construction was not common in the marketplace, and thus there was concern of acceptance in the market.
- There were significant concerns over public acceptance of the project.

To mitigate these risks AECOM proposed several risk mitigation measures:

- Finite Element Analysis (FEA) was conducted at the major utility crossings to predict effects potential geotechnical movements on the infrastructure. Both 2D and 3D FEA models were constructed to assess and mitigate risk.
- An extensive geotechnical program was executed, and a Geotechnical Baseline Report (GBR) was developed to effectively distribute the risk between the Owner and the Contractor. The GBR was based on American Society of Civil Engineers (ASCE) Suggested Guidelines for Geotechnical Baseline Reports for Construction. The purpose of the GBR was to:
  - Provide a realistic, contractual baseline interpretation of the geotechnical aspects of the design and construction of the works.
  - Set clear baselines for subsurface conditions anticipated to be encountered during construction.
  - Provide all bidders with a single contractual interpretation of subsurface conditions in preparing bids.
  - Describe the subsurface conditions along the entire alignment (not just at bore hole locations)
  - Assist in evaluating the requirements for excavation, temporary support, groundwater control, ground movement for shafts, tunnels, and open cut construction.
- A comprehensive contractor prequalification program was developed and tendered, to evaluate the marketplace capability and capacity to execute the project. This was also seen as an opportunity for advanced advertisement of the project to the construction community, which mitigates risk during the normally hectic tender periods. The project also recognized industry guidelines such as the ASCE – Standard Construction Guidelines for Microtunnelling as a fundamental basis for design and delivery.
- A comprehensive Public Communications campaign was initiated at the outset of the project. Two open houses were held to review and discuss the project with the community. The communication campaign was ultimately very successful in removing scepticism from the project.

AECOM conducted a comprehensive site investigation program, with preliminary drilling beginning in August 2013 to determine soil properties and determining groundwater depth and hydraulic conductivity of the soils. Once the soil and rock core samples were analyzed, the team was able to extrapolate the type of soil that would be encountered, and where each soil type begins and ends.

The detailed geotechnical investigation was undertaken following finalization of the alignment and involved excavating two test pits and drilling of 19 test holes along the final alignment in accordance with ASCE guidelines. The detailed geotechnical investigation commenced on March 3, 2014 and was completed on June 3, 2014. The distance between the detailed




**Tunnel alignment under Bearspaw Feedermain, shows subsurgace conditions from Geotechnical Baseline Report**

Installing pipe into tunnel

investigation test holes ranged from 44 m to 260 m, while the overall spacing between all test holes (drilled during the preliminary and detailed geotechnical investigations) varied from approximately 35 m to 142 m. The samples were taken to a depth below the pipeline invert in accordance with ASCE guidelines.

Tunneling has seen limited application in the Calgary area due to the mixed soil types that make it more challenging to excavate. The GBR helped optimize the pipeline alignment and provided measurements and calculations that were necessary for the design of the route as well as the tunneling. The GBR enabled the selection of the appropriate MTBM for the challenging site conditions as well as the appropriate technology for shaft construction.

Excavating mixed soil and bedrock types presents a greater challenge, as the viscosity of the fluid required differs for each soil/bedrock type. The information provided in the GBR allowed the tunneling contractor to much more accurately calculate the fluid requirements, and know when the soil/bedrock type would change to adjust the viscosity.

The greatest construction risk was ground loss or heave. This was critical at locations of utility crossing, especially at the Bearspaw Feedermain Crossing. The additional analytical work up front and monitoring during construction were used to mitigate these risks to acceptable levels. Monitoring was used to confirm that influence zones behaved in their intended manner and within tolerable limits. The influence zone was identified as 10 metres on either side of the tunnel. The monitoring points measured if there was any settlement during construction. If any settlement occurred, the team could anticipate and proactively address issues. This monitoring not only determines soil stability but acts as a quality control measure.

The feedermain from Bearspaw Water Treatment Plant, which provides Calgary with over 50 per cent of its water supply, was unaffected during construction due to careful design and monitoring.

Other techniques were also used to mitigate loss of ground loss including:

- Close schedule control to minimize tunnelling down time (the more continuous the operation the less risk of ground loss)
- Close monitoring of equipment condition and integrity (aside from progress rate monitoring, after each section of tunnel was completed, the machine was taken out, cleaned, inspected, replaced cutters and repaired as needed).

Once the tunnel was excavated and the pipeline was installed, the tie-in to the existing sanitary sewer trunk line was a critical concern. It was necessary to connect the two lines without affecting the existing service or causing sewage backups. This tie-in work was completed successfully.

The bulk of the work was underground, but risks pertaining to overhead powerlines needed to be mitigated when working on the shafts. Prior to the beginning of construction, powerlines were shifted to provide clear access to the site. Signage was also posted at the site to keep construction equipment a safe working distance from the lines.

Maintaining the schedule was critical as development in northwest Calgary was limited by sewer capacity. When the construction schedule was established, AECOM had to keep the project on time during preliminary design, detailed design and tendering as many were eager to begin development. The tunnelling contractor, Ward


Construction site risk mitigation through signage and fencing and Burke, advanced the schedule by constructing shafts and tunnelling simultaneously. During the course of the project, schedule was monitored and closely and variances were managed to expedite completion without compromises to over technical objectives. This proactive approach to both schedule and overall risk management kept the project on time and on budget. The construction was completed one year ahead of the initial schedule.

## Social and/or Economic Benefits

Utilizing a trenchless construction technique in a built-up environment demonstrated social responsibility by completing the project in a fashion that not only benefits the future growth of northwest Calgary but was least disruptive to the directly affected community, businesses and the environment. The project was also fiscally responsible, meeting both short and long term technical objectives for the infrastructure.

The greatest long term benefit to society is the provision of the additional capacity provided by the Bowness Sanitary Offload Trunk to accommodate long term growth as well as increased protection against basement flooding in extreme wet weather periods. The pipeline will serve the citizens of Calgary and surrounding areas for some 50 years or more into the future.

The short term benefits were immense as well, to both the public and the environment. The greatly reduced construction footprint, control of noise and overall minimal amenity disruption as well as completion in a greatly reduced time frame were all of immense benefit to the directly affected residents and businesses.

A high level of public support for this project was achieved through the use of a robust public communications plan. Two open houses were held to inform area residents, business owners and other interested people about the project using language and communication techniques that are readily understood. It was critical to provide technical construction details while focusing on the aspects that impact people directly such as noise levels, access impacts, and traffic control measures. These were all communicated in a manner that made the directly affected public fully aware of the benefits of the project, the direct impact it would have on them, and the means to address any concerns that arose during implementation.

Some key construction mitigation aspects that were beneficial to the public included:

- Noise mitigation to accommodate an increased construction schedule. Mitigation included sound barrier fences, engine silencers and strategic staging to match construction activity noise levels to normal ambient sound and other level of disturbance levels (e.g. halting truck traffic at night; directing lights around shafts to areas away from homes).

**Construction site: powerlines have been moved, shaft built near CPR tracks and homes**

**Construction completed, rehabilitated site**

- The launching site for tunneling across the Bow River was constructed to minimize disruptions to park users. Construction in the park area used means to have the park remain open for users of the athletic park as well as the Bow River pathway system.

The benefits to society were twofold:

- Long term benefits of the improvements
- Considerable attention paid to minimize the impact of implementation.

## Environmental Benefits

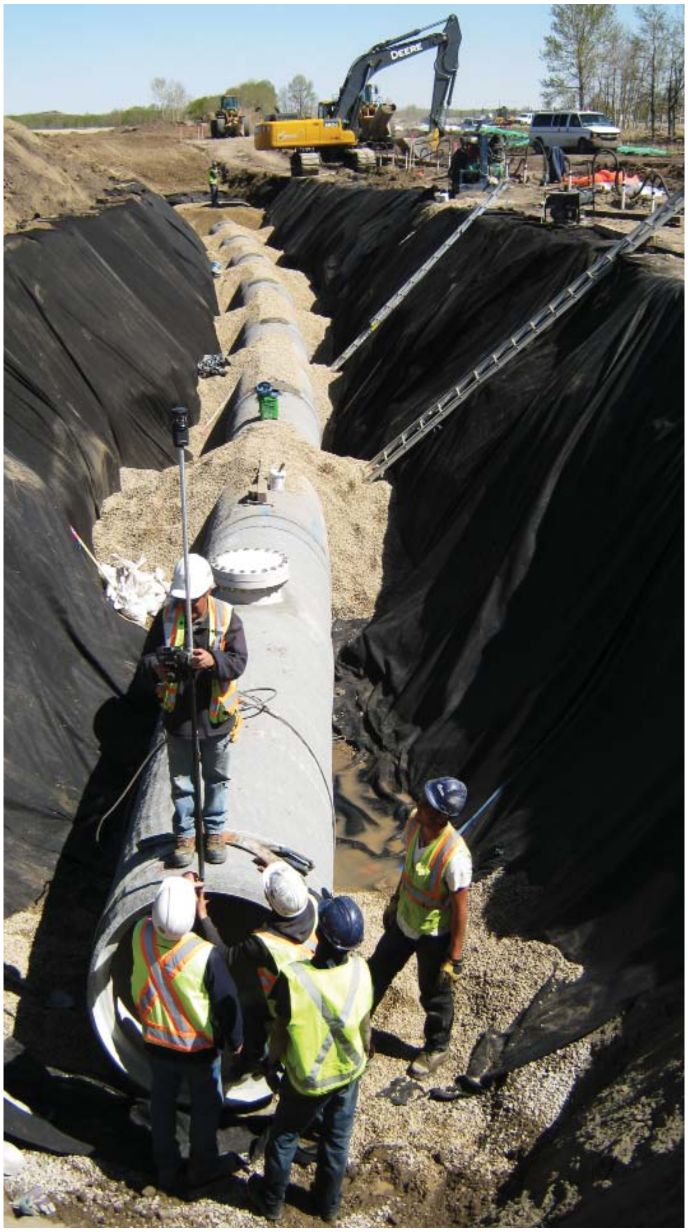
Trenchless construction techniques offered significant environmental value over conventional technologies. For this project, the environmental and triple bottom line cost savings were substantial. Several project features demonstrated environmental responsibility.

The preliminary design considered the implications to the environment of constructing the pipeline across the Bow River using the open trench method. Construction by this method would result in a Harmful Alteration, Disruption or Destruction (HADD) of fish habitat under the Federal Fisheries Act, and would require authorization under the federal fisheries act. Typically, a Department of Fisheries and Oceans authorization has required six months to review construction-ready drawings. This review process, while included in the initial project schedule, would result in construction being deferred until at least the 2015 construction season. Work would have to take place outside of the restricted activity period, as controlled by Alberta Environment. The project is located on the lower Bow River, which is considered a Class C watercourse at the project location. Regulations stipulate two restricted activity periods (RAPs): May 1 to July 15, and September 16 to April 15. These limited windows would require construction to be completed across two seasons. Trenchless construction completely eliminated any in channel work, and thus eliminated any habitat damage.

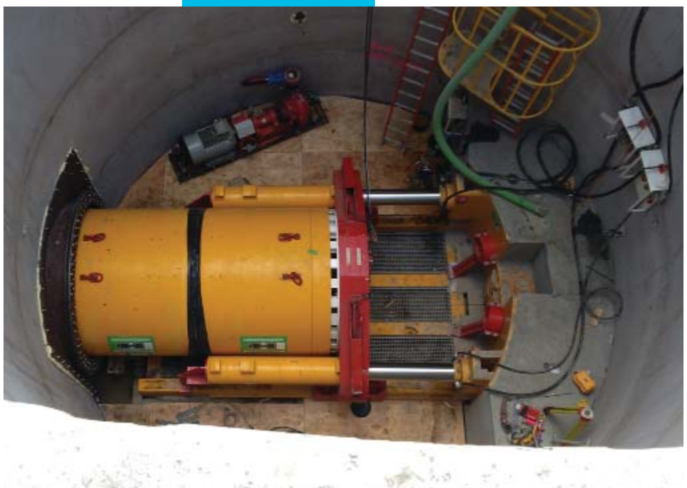
MTBM construction is a minimally invasive technology. In comparison to an 8 - 10 metre trench, eight shafts were built throughout the route to launch and receive the tunneling machine, thus minimizing overall disturbance footprint. As noted previously, every 100 m of open cut construction would have resulted in 355 to 500 large truck movements (dependent on depth), whereas the use of an MTBM resulted in 25 movements per 100 m of pipe relatively independent of depth.

The project required construction through a high water table, but groundwater dewatering and discharge were almost completely eliminated through the use of sealed shaft construction techniques and full face support slurry MTBM systems.

The low impact technology also minimized damages to recreational, natural areas and parks, absolutely minimizing loss of mature trees and disturbances to riverbank areas known to potentially contain archaeological features.



**Open trench construction, photo from previous project shows environmental impact**



**Preparing for tunneling, setting up MTBM**

**13 Avenue upgrades, roadway prior to paving**

# Meeting Client's Needs

The City of Calgary's main goal was to create a vital piece of infrastructure to encourage future development in the city's northwest and create future capacity sewer capacity. AECOM achieved this goal by recommending and designing a solution utilizing microtunneling to advance the project, schedule, and reduce environmental impact. It also minimized disruptions to residents and emergency services.

Successful project completion was achieved through management of risk by incorporating an Active Risk Register into project delivery at an early phase to clearly identify and actively mitigate risk over the course of the project. Risks requiring mitigation included:

- A minimum of three major infrastructure trunks were in direct conflict with the conceptual design profile, including the 1950 mm Bearspaw Feedermain, the City's largest water supply trunk. These features dictated that the sewer be located at depths of over 15 m for most of the route. Monitoring was required while drilling to confirm that the nearby utilities were not affected.
- Ground conditions were complex from a construction perspective and highly variable along the route, including high groundwater levels.
- MTBM construction was not common in the marketplace, and thus there was concern of acceptance in the market. A qualified contractor was selected through a prequalification process.

Additional added value was provided as the project was seen as an opportunity to partner with area stakeholders to enhance community services upon completion of construction. This included assisting in upgrading of 13th Avenue through Shouldice Athletic Park and re-establishment of park areas adjacent to the worksites.

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