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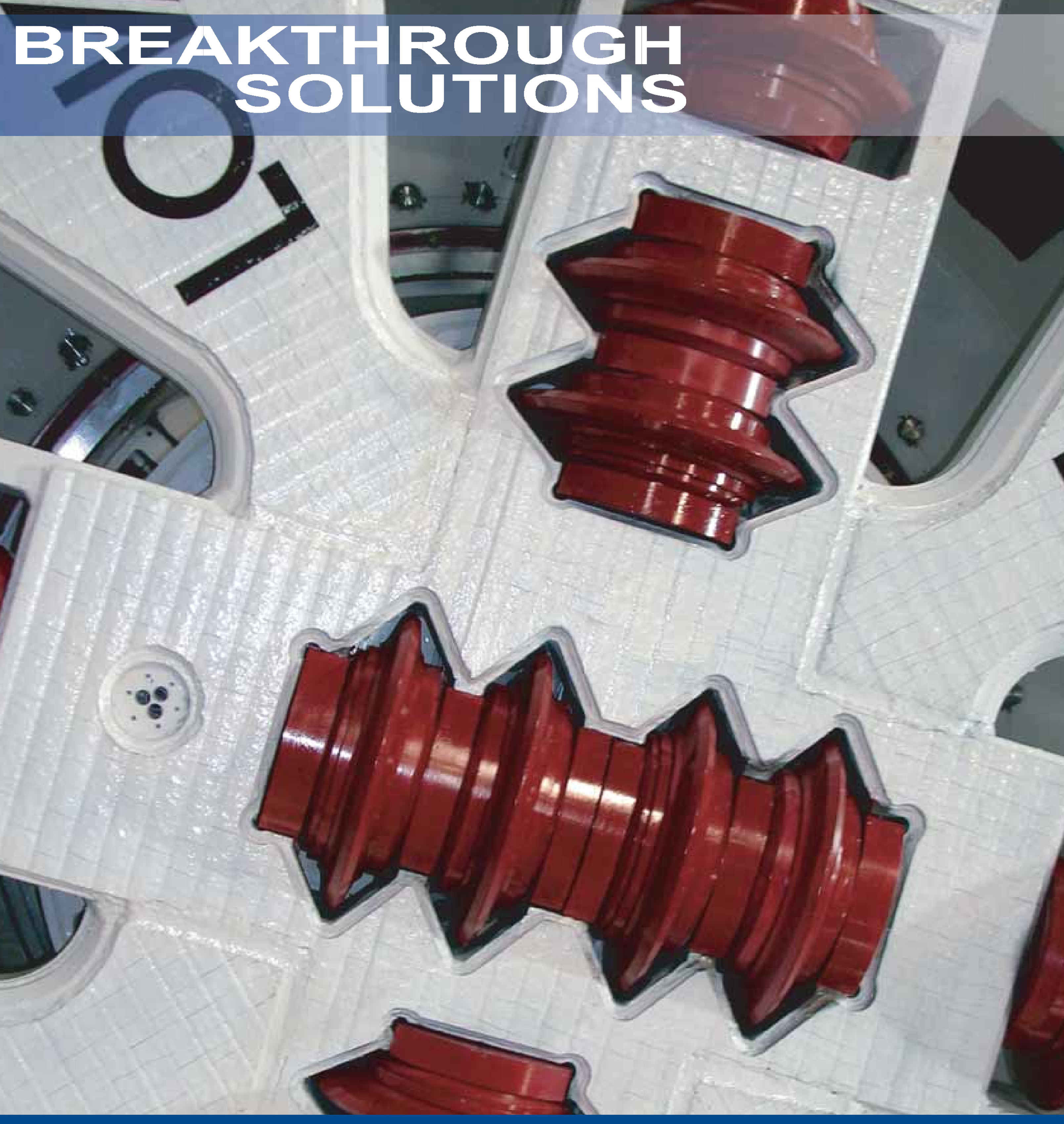
Official publication of the Tunnelling Association of Canada

# CANADIAN TUNNELLING MAGAZINE

2008

Vancouver Canada Line Breakthrough

# BREAKTHROUGH SOLUTIONS



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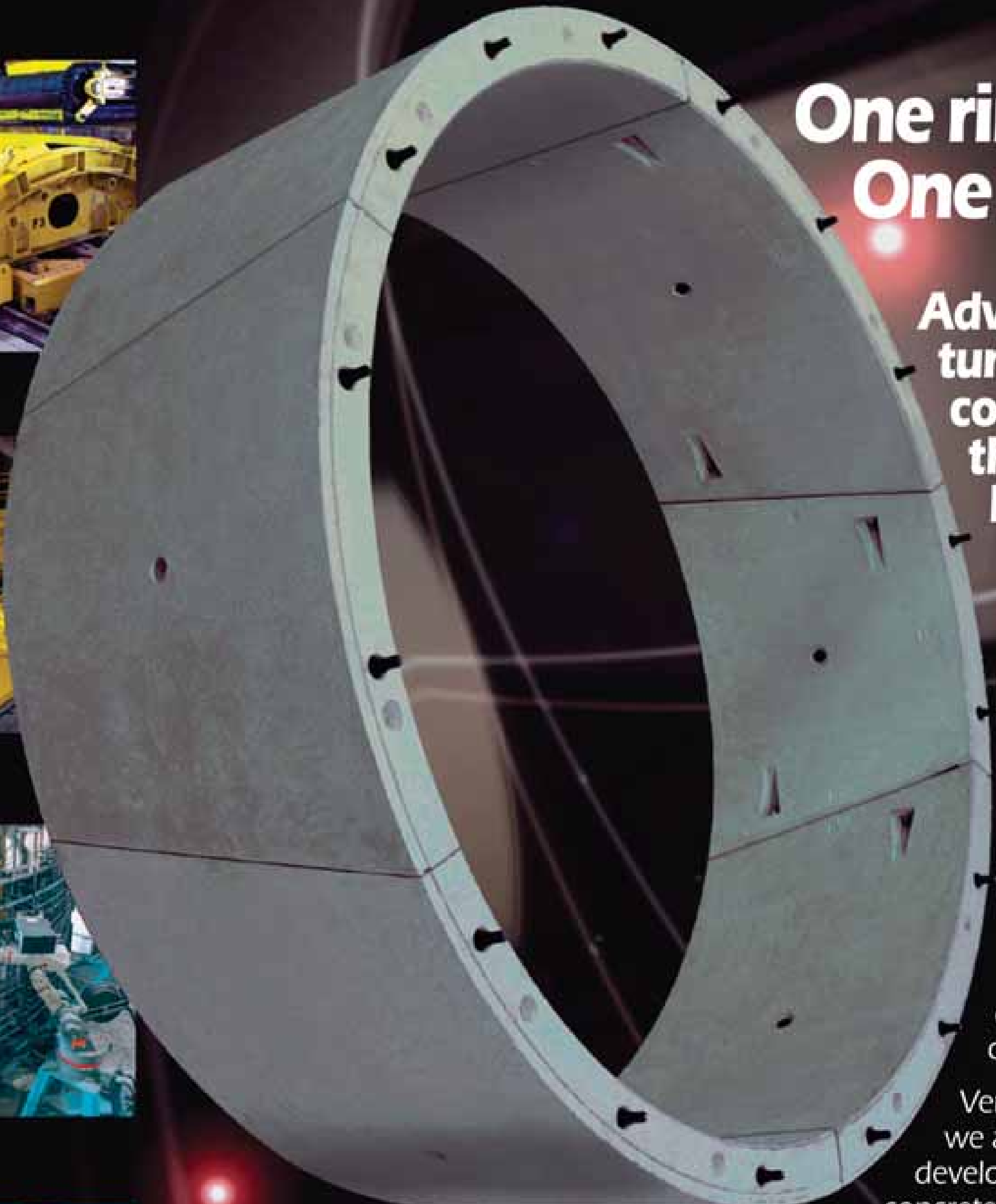

York Region


# YORK REGION'S SOUTHEAST COLLECTOR TRUNK SEWER

## *$500 million capital sewage project for planned tendering in 2009*

The York Durham Sewage System (YDSS) is a state-of-the-art wastewater collection system within the Great Lakes basin. Initial phases of the YDSS were constructed by the Province of Ontario in the late 1970s and early 1980s in response to a 1965 decision that no additional sewage treatment plants could be built on the Humber, Don and Rouge Rivers.

The YDSS complements the Canada-Ontario Agreement respecting the Great Lakes Basic Ecosystem. What evolved was one of, if not the most environmentally respectful sewage systems in the entire Great Lakes basin. York Region is justifiably proud of its reputation as a leader of providing quality infrastructure to our growing communities and protecting our environment.

Southeast Collector Trunk Sewer ($500 million infrastructure project) | Scheduled Completion – December 2012

The proposed (SeC) Trunk Sewer is an integral component of the overall YDSS trunk sewer system. It moves wastewater from communities throughout York Region, as well as the communities of Pickering and Ajax in Durham Region to the Duffin Creek Water Pollution Control Plant (WPCP) in Pickering, Ontario. The portion of the SeC within Durham Region is co-owned by the Regions of York and Durham, who are co-proponents on this project. The SeC Trunk Sewer is a critical component of servicing approved future growth in York Region, up to 1.5 million and beyond, and must be completed on time in December 2012.

Key aspects of this critical project now being considered by York Region include early procurement of up to four tunnel boring machines and project materials including the supply of segmental liners.

**PROJECT DETAILS**

- 15 kilometres of 3 m (inside) diameter sewer • Depth of sewer ranges between 10 and 40 metres • Virtually all of the route is in Newmarket Till
- 13 shafts including maintenance and working shafts • Odour control and metering facility
- Corrosion control through technology may include one (or a combination) of the following: PE Liners, polymer concrete
- Baffle drop shafts for up to 30 m or chemical feed facilities
- SCADA controlled flow control gates

**PROJECT TIMELINES** (Subject to change)

- Fall 2008 - Individual Environmental Assessment (IEA) filing with Ministry of the Environment
- Fall 2008 – Initiation of early procurement of equipment and materials
- Fall 2009 - Expected Approval of IEA
- Winter 2009 - Detailed Design
- Winter 2009 – Four construction tender packages to run concurrently
- 2010 – 2012 – Construction of Southeast Collector Trunk Sewer


*For further information on this project, please contact Wayne Green, Senior Project Manager at (905) 830-4444, ext. 5049 or mail to: wayne.green@york.ca*

You can also visit

http://www.york.ca

for more details.

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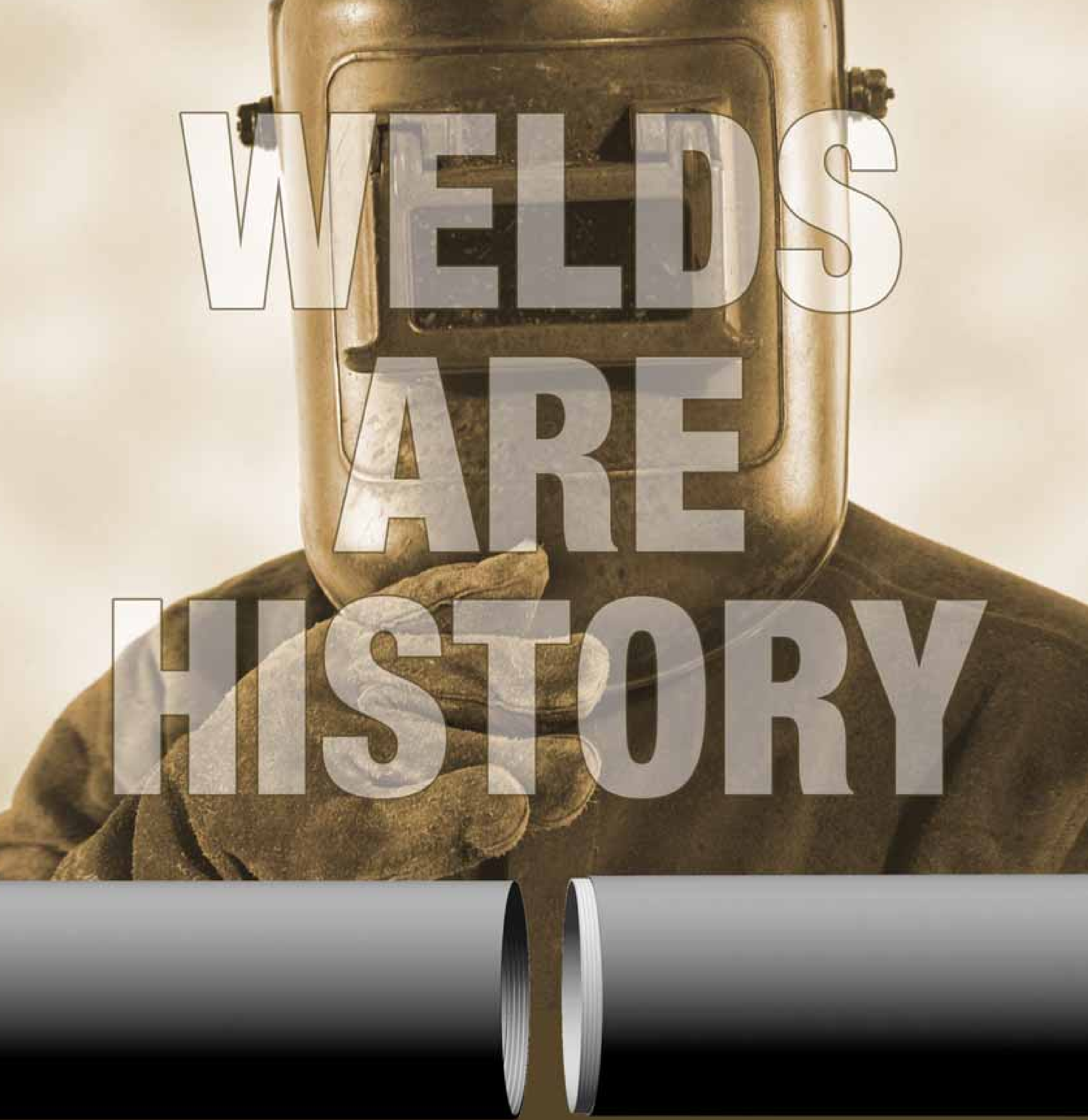
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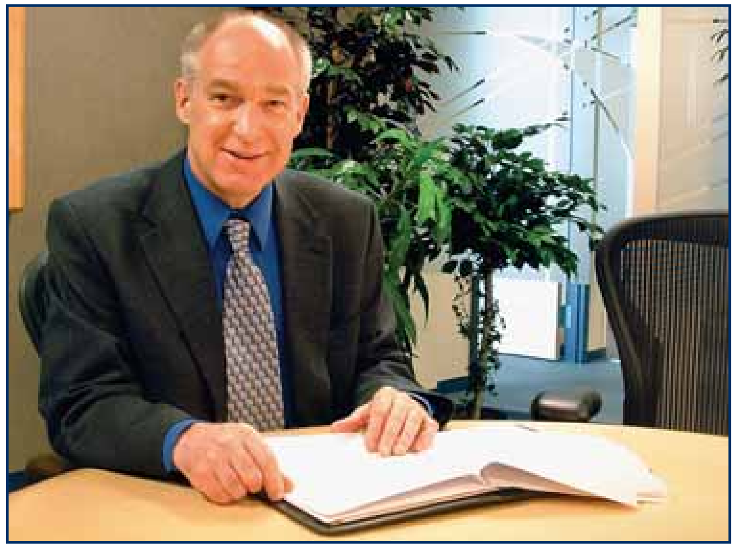
# *From the president*

## GARRY STEVENSON



Welcome to our first TAC Magazine of 2008. The tunnelling industry remains vibrant across Canada, with civil tunnelling works under way in nearly every province for water supply, wastewater control, hydroelectric development and transportation.

We continue our countdown to the World Tunnelling Congress in Vancouver in May 2010, with planning well under way. Volunteers are required for the several committees necessary for a successful congress. Contact Dean Brox, organizing committee chairman, for more information on the committees. His contact information is in the list of TAC Directors on page 12. Dean, who has also taken over the position of Canada's representative to the International Tunnelling Association, will be attending an International Tunnelling Association meeting later this year to present Canada's reports; one on activities in Canada and a second on progress in preparations for the 2010 WTC.

Rick Lovat served for many years as Canada's representative to ITA. His strong support of both TAC and ITA was recognized by ITA's directors. I have no doubt that Rick's work was a major reason for the support we received for our proposal for the 2010 congress in Vancouver. Thanks to Rick for your ceaseless efforts over those many years.

Later this year, the Ontario chapter of TAC will host our 20th Canadian Tunnelling Congress in Niagara Falls, currently home to the world's largest hard rock TBM. This is an excellent reason to see one of the world's great natural features, as well as the TBM, and the venue is within striking distance of several tunnelling projects in the northeast USA and eastern Canada. I hope you will consider submitting a paper to the conference, as well as attending.

Mes chers collègues du Québec, j'aimerais étendre mes remerciments aux membres qui se sont chargés de régénérer les activités de TAC dans votre province. Le Québec a une longue histoire d'innovation dans le domaine du tunnelling en ce qui a trait aux projets hydroélectriques et de transports. En ce sens, j'anticipe votre participation continue dans l'association.

On page 12 of this magazine is a list of TAC's directors. Please make a point of contacting the director in your vicinity and getting involved in the local activities.

See you in Niagara!

*Garry Stevenson*
*gstevenson@klohn.com*

# INTERNATIONAL TUNNELLING ASSOCIATION (ITA)

*By Martin Knights ITA President*

Since becoming President of the International Tunnelling and Underground Space Association, I have been struck by two impressions of our industry:

- That there is a lot of work out there in the market place
- That there isn't the resources to take on that work

A major factor in my observation that we have a shortage of resources is that many "baby boomer" children born just after WWII in the late 1940's and early 1950's will be retiring in the next 5-10 years. This would remove at least 20% of the current professional engineering resource from the engineering profession – and tunnelling is no exception. Look at the average age of tunnellers attending conferences and gatherings, and it will quickly be evident who will not be actively practicing their tunnelling career by 2017! If there is going to be an Energy Gap in 10 years time, it will happen at the same time as the gap in resources for engineering, and most likely when we will see intense requirements for underground/tunnelling professionals if current projections of urban underground infrastructure projects are to be believed. In London, 2 large tunnelling construction projects will be starting in the next 5 years – a major London east/west railway under the capital (Euro 15bn) and a major 35km tunnel under the River Thames to remove intense storm water/effluent overflows during extreme rainfall. Right now, it is almost impossible to recruit more experienced tunnel engineers in the UK, and I know this is also true in the USA (now experiencing many tunnel projects in cities such as New York, Detroit, Miami, Los Angeles etc). I suspect it is so in Western Europe (most of the conversations I have at ITA conferences are about – "where will the resources come from?")

What is the solution to the human resource problem in tunnel engineering? It has always been a unique industry attracting a specialist and enthusiastic following. Well, we are going to have to use better ways to use the scarce engineering talent in Europe and the USA. We need to increase our tunnelling supply chain of talent from developed nations that are currently building their own underground infrastructure (the very nations who are currently requesting ITA participation in tunnelling training courses such as China, India, Eastern Europe, Asia and South America). We would need to use better ways of delivering projects by reducing complex procurement that demands more people participating in projects with overlapping duties reporting to the various contracting participants. More collegiate team working would be necessary. Owners should be educated on the need to use efficient integrated teams to ensure good quality projects, and ensure that the limited resource is harnessed more effectively and efficiently to deliver projects. Why should there be so much reporting or Engineering Audits on behalf of the different parties to a Contract to achieve a common aim?

We must give more responsibility to young engineers and keep them focused and inspired. Procedures and Contracts will have to reflect the need for tighter, more co-operative and effective management effort using fewer engineers. In return, we will have to train this scarce resource and ensure that there is no 'drought' of talent or any more migration of engineers to other industries. By this means, our tunnelling industry can encourage and keep those who have chosen to be in underground engineering and reward them appropriately. We could attract the good talent, and thereafter it can be a self-fulfilling prophesy for a successful and well-rewarded industry and we can compete for talent, young or not so young! ●

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Organizing for the ITA 2010 World Tunnel Congress (WTC) to be held in Vancouver is well underway. An organizing committee comprised of members from the Tunnelling Association of Canada (TAC) is now meeting quarterly with our Congress Organizer, Laurier Forget, and Marie Lanouette from the National Research Council of Canada (NRC) to discuss and decide upon the various issues to be addressed as part of the overall organizational requirements. The theme for the ITA 2010 WTC is "Tunnel Vision Towards 2020" which is expected to attract technical articles relating to innovation in the tunnelling industry for the next decade to 2020. Over 1000 participants are expected to attend ITA 2010 WTC in Vancouver following the 2010 Winter Olympics and Paralympics.

The ITA 2010 WTC will be held in the new west wing of the Vancouver Conference and Exhibition Centre (VCEC) that is currently under construction. The Marriott Pinnacle Hotel located near the VCEC has been selected as the designated conference hotel. Local and internationally recognized keynote speakers are being considered to be a part of the congress. The planning for social events is also well underway to showcase the scenic sights of Vancouver.

NRC is progressing well with the creation of the website that will contain all the necessary information for registration and hotel reservations as well as for submission of abstracts. A very attractive splash page has been created which will hopefully entice many visitors to come to Vancouver in 2010. The proceedings for the ITA 2010 WTC will be produced only in

digital form (CD) with a hard copy of the abstracts for viewing during the congress. Our scientific committee chaired by Dr. Derek Martin of U of A with Dr. Erik Eberhardt of UBC are establishing the topic themes for the congress along with a sub-committee for review of all abstracts.

Organization updates for WTC 2010 have and will continue to be provided to the ITA Executive council at annual ITA events and other conferences (ITA 2008, 2009, NAT 2008, RETC 2009). ●

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Tunnelling Association of Canada

**VANCOUVER TO HOST 2010 WORLD TUNNEL CONGRESS**

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## October 26-28, 2008
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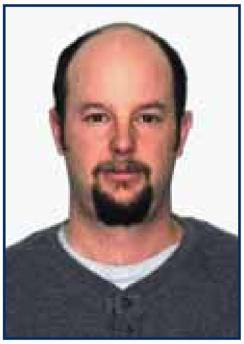


# ROCK STRENGTH IN SUDBURY REQUIRES ALTERNATE APPROACH

*By Dan McNally*
*McNally Construction Inc.*

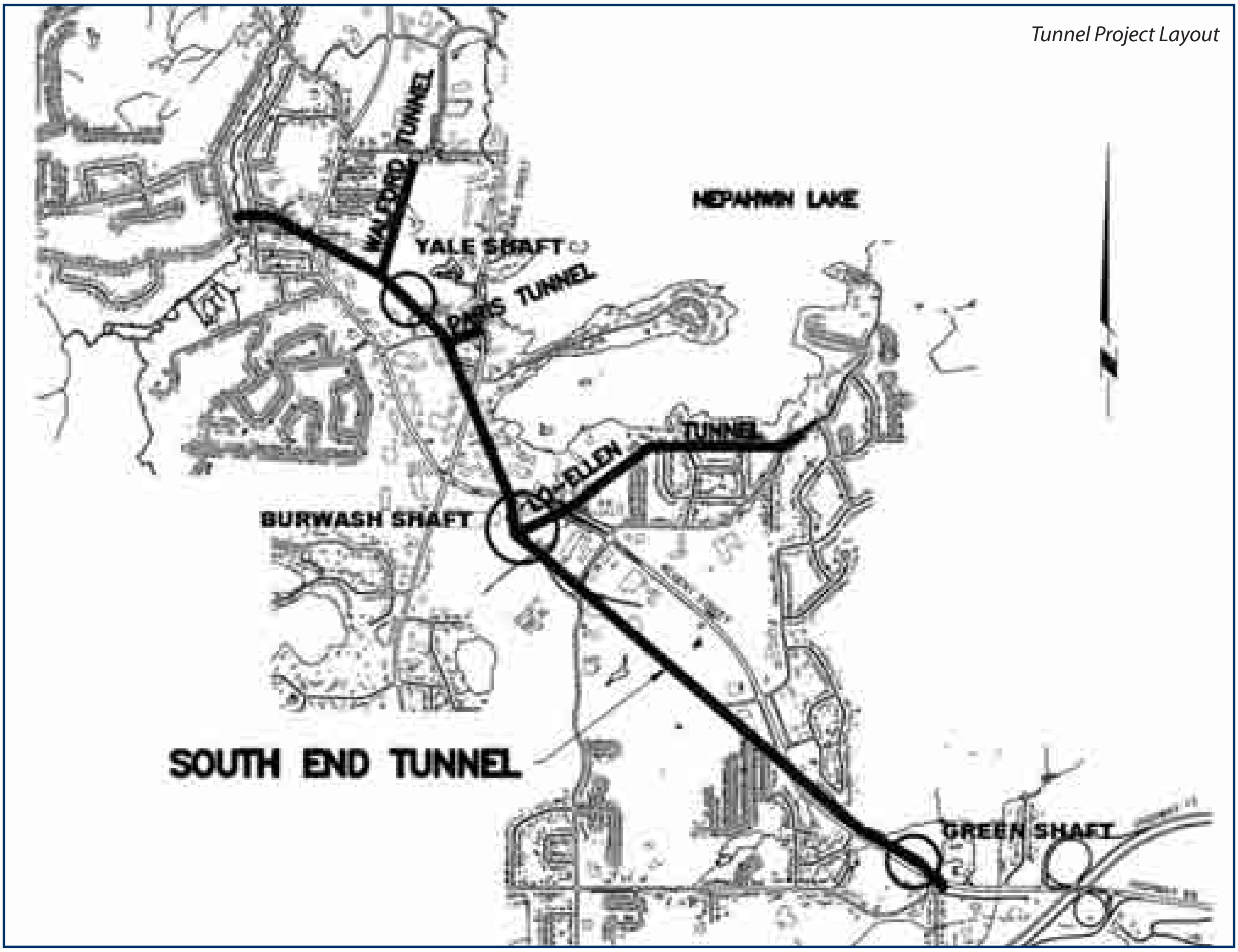
With the growth of population in the South End of the City of Sudbury, and the existing sewer system operating at capacity, a 6.5km tunnel was designed to replace the existing force main system.

## Geology

The tunnel lies in Metamorphosed Precambrian Sedimentary Rocks, with the majority of the tunnel falling in the Mississauga formation which consists of quartzite, arkose and greywacke. Generally the uniaxial compressive strength of the rock ranges from 100 to 250 MPa, with the majority of the rock falling in the higher range of UCS values. The tunnel typically runs about 25m below ground surface, with the least cover at 12m. Minimum rock cover for the tunnel is anticipated to be approximately 5m. Rock quality assessments based on GBR show about 50 percent of the tunnel having a Q value of greater than 40 (requiring little support), 40 percent having a Q value between 4 and 40 (requiring pattern bolting), and about 10 percent having a Q rating of less than 4 (requiring pattern bolting, mesh and shotcrete).

## Contract Overview

McNally construction was awarded the contract in August of 2005,




*Tunnel Project Layout*


*First Blast at the beginning of the project*

with an approved contract value of $26.4 million. It was determined during the bid stage that the contract could not be completed with a tunnel boring machine, due to the strength of the rock, subsequently traditional drill and blast methods were chosen. The project consists of four interconnected lengths of tunnel, three working shafts, six drop structures and three retrofitted lift stations, with corresponding underground chambers. The tunnel alignments are such that they are driven below existing pump stations. The tunnels are being driven from all three working shafts, with one site utilizing a ramp for access and muck haulage. Typically the tunnels are 2.2 meters wide and 2.1 meters high and driven at a 0.11 percent grade. The tunnel will receive a concrete invert upon completion to improve flow characteristics.

### Shaft Construction

Two different construction methodologies were used for shaft construction. The Burwash Shaft site is located in the middle of the project at the intersection of the two main tunnel sections. A ramp was driven on an 18% decline to the tunnel depth. The ramp was driven utilizing a 2.5 yd scoop for mucking and primarily jacklegs for drilling. The ramp has a dimension of 2.4m high and 3m wide. A shaft was then excavated off of the tunnel alignment to provide permanent access to the tunnel when the ramp is abandoned upon completion of the project. At both the Yale (27m deep) and Green (29m deep) sites at the north and south ends respectively of the project, 5.4m by 3.8m shafts were sunk over the tunnel alignment for access. For both locations .1 m diameter holes were drilled on .45m spacing around the perimeter of the shaft and four .15m holes were drilled in the center from top to bottom utilizing down the hole hammer drills prior to shaft excavation. Approximately fifty 0.05m production holes were drilled for each

*Beginning of ramp excavation at Burwash Site*

3m blast utilizing the center holes for relief, and blasting perimeter holes on the same delay. The shafts were pattern bolted and shotcreted from the muck pile. Upon completion of the tunnelling operation the shafts will receive a permanent concrete collar with removable caps which will provide for access for future tunnel inspections.

### Tunnel Construction

**Yale site:** Headings were developed in both directions from the shaft at a width of 4m to allow for a staging/switching area for the tunnel operations. This section of tunnel was driven utilizing jacklegs, an Eimco 630 overshot mucker, and a 1.25 yd scoop. Upon completion of this section, rail was laid in preparation for mining of three separate headings. The shaft was separated into two compartments, one for mucking and the other containing the man way and utilities. All three headings are being driven utilizing jacklegs, Eimco 12b overshot muckers, 5.5 ton Clayton battery


Ground
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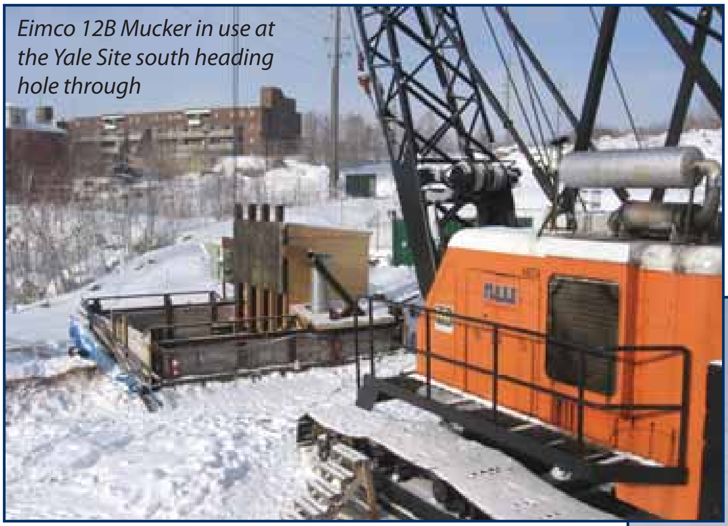
Solutions!


*Typical Drift*


*Typical Concrete dropshaft structure*

locomotives, and 77 cf side dump muck cars. In the shaft a 30 cubic meter box was installed below grade to receive muck. An air cylinder is mounted in the wall of the shaft that is utilized for dumping the cars. A 9570 Northwest Crane equipped with a 2.5 yd clam is then used to hoist the muck to surface. All mucking is performed with a camera system which allows the operator to clam without a signalman. Shaft access is controlled by a light system operated by the crane operator. Typical tunnel rounds are 1.8 m in length and require thirty eight 32mm production holes and three 64mm “reamed” relief holes. Holes are loaded with anfo, and perimeter holes are loaded and traced with primer cord to produce a smooth walled “half barrel”. Nonel “easy drifters” are used for caps, and the round is initiated electrically from the station area. All headings are running an exhaust system which allows the headings to operate independently. Ventilation is exhausted from each heading to surface utilizing 7.5 hp fans. Utilizing an exhaust system allows each heading to blast



*Eimco 12B Mucker in use at the Yale Site south heading hole through*

headings are mined using jacklegs, Eimco 12b muckers, 5.5 ton Clayton battery locomotives and 11 yd Haaglund cars. Haaglund cars are discharged into the remuck area, where the 2.5 yd scoop loads and hauls the shot rock to surface. Typical tunnel rounds are the same as the Yale site, although mining from this location has encountered more water which has necessitated the use of packaged emulsion products in place of the anfo. All air for ventilation independently, as all contaminated air is sucked thru the vent line and discharged on surface. Two 750 cfm compressors coupled to a receiver tank, located on surface, are used to supply air to the tunnel.

*9570 Northwest Crane and Yale Shaft*

**Burwash site:** From the bottom of the ramp, all three headings were developed utilizing the 2.5 yd scoop and jacklegs, to sufficient length to allow for rail installation. A sump and remuck area was also excavated at this time. All

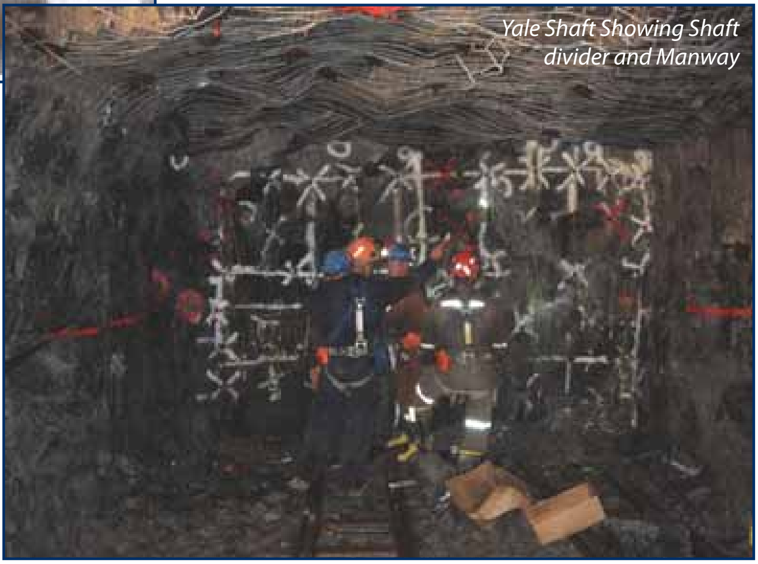
*9570 Northwest Crane set-up at Yale site*

is blown down the shaft. From the shaft about two thirds of the air volume flows directly up the ramp. Each heading is equipped with an exhaust fan setup that draws fresh air from the station area to each heading and deposits it back into the ramp. This setup ensures that the station area is not contaminated when blasting occurs, allowing the headings to work independently. Compressed air is provided on surface utilizing two 750 cfm and one 600 cfm compressors coupled to a receiver tank.

**Green site:** Both headings were developed from the bottom of the ramp utilizing a .5 yd scoop and jacklegs at a width of 4m to allow for a staging/switching area. Upon completion, rail and switches were installed, along with the sump/remuck box and dump cylinder. The shaft is divided and a camera system has been set up. A 108 Link Belt equipped with a .75 yd bucket is being used to muck. Fans are set up exhausting from each heading, and a 600 cfm compressor coupled to a receiver is supplying air.

## Drop Structures

There are six drop shaft structures and three retrofitted lift stations that will connect along the tunnel alignment. Currently Terra North Construction has completed five structures, with the final structure scheduled to be completed this spring. At the structures with a foundation on soil, Marathon Drilling placed casings to rock which were then sealed with cement at the base. A small raise bore unit was then used to drill a 200 mm pilot hole down to a cut out on the side of the tunnel



*Yale Shaft Showing Shaft divider and Manway*

where a .6 m reaming head was then attached. Holes were then reamed back to the casing. A 400 mm, or 550 mm stainless steel liner has then inserted and grouted in place (depending on location). Each structure has two holes, one for venting and one for flow. The structures that are located on rock were constructed prior to drilling. Holes at these locations will be drilled when the tunnel below is completed. The three lift stations will be retrofitted when the tunnel is completed.

*Haaglund Car*

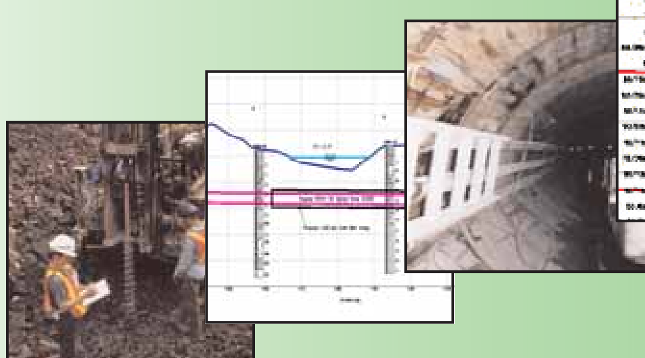

*Final development round prior to rail switches being installed*

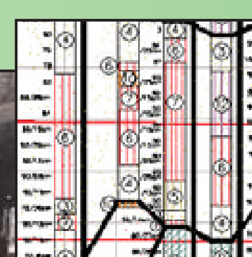
### Schedule

As of February 2008 4.2 km of tunnel have been completed. Lining of the tunnel invert will start in April. Work at the Yale site will be complete by the end of September, and flow from two pump stations will be diverted in the sections of tunnel accessed from the Yale.

*Dan McNally is currently working as a Project Manager for McNally Construction Inc. He has also worked in a supervisory capacity on both hard rock and soft ground tunnels since graduating from the Colorado School of Mines in 2001.* ●







# Ground Freezing for Deep Shafts in Soils

*B. Lukajic, R. Pintabona, and M. Schafer, Montgomery Watson Harza, Cleveland, Ohio, USA*
*M. Kritzer and R. Switalski, Northeast Ohio Regional Sewer District, Cleveland, Ohio USA*

Ground freezing was chosen as an initial support method during construction of two deep shafts at the Mill Creek Phase 2 project in Cleveland, Ohio. The 13,000 feet long Mill Creek tunnel is utilized to convey and store combined storm and sanitary sewage collected from the member communities in the greater Cleveland area. The main objective of ground freezing was to provide a strong shaft support structure to resist soil and groundwater pressures during excavation. Both shafts (Shaft 11 and 13) are located in a buried ancient glacial valley, ranging in depth from 145 feet to 170 feet. This article provides an overview of how ground freezing techniques were applied at this site.

## GROUND FREEZING CONCEPT

In frozen ground, the ice becomes a bonding agent, which makes the soil impervious to water seepage. The large increase in soil strength makes it possible to perform deep excavations in soil safely and efficiently. The concept of ground freezing procedure consists of installing a series of freeze-pipes in which the cooling medium is circulated. The coolant is provided by a refrigeration plant, which is usually located on the ground surface. Typically, the coolant circuit includes a brine tank, a pump, and an insulated manifold for the supply of coolant to the freeze pipes and return to the refrigeration plant.

Soil thermal parameters are used for calculation of the energy to be extracted for freezing, the time required for formation of the freeze wall, and for selection of the refrigeration plant capacity.

## WHY GROUND FREEZING

Constructing deep shafts in soils at this project presented a few technical challenges, such as ground settlement and safety. Considering this, four alternative methods were evaluated for construction of two deep shaft structures. They included slurry wall construction, jet grouting, deep soil mixing, and ground freezing. Key parameters in the evaluation were the depth of the proposed construction and presence of boulders in the valley deposits. To minimize risks, ground freezing was determined to be the most practical method to excavate the shafts.

## SOIL CONDITIONS AND GROUND FREEZING REQUIREMENTS

The depth of soil to be frozen at Shaft 11 was 170 feet, while at Shaft 13 the depth of soil was 145 feet. The soils at the site were cohesionless, predominantly dense fine sand and silty sand, which can be classified as being moderate or high frost-susceptible. The groundwater table was at 7 feet below the ground surface at Shaft 13 and 60 feet for Shaft 11. Groundwater velocities in the vicinity of both shafts were estimated to be generally 1.5 feet per day or less, which had no significant impact on ground freezing process.

In order to successfully perform a ground freezing operation, soils are required to have adequate saturation for ground freezing. Usually, soils below the groundwater table have a degree of saturation greater than the 90 percent that is required for ground freezing work. Such a condition was encountered at Shaft 13 and the contractor was able to perform freezing at this shaft along the entire 145 feet soil section depth.

As the work progressed at Shaft 11, an attempt was made by the contractor to freeze a soil section located immediately above the groundwater table. This was proposed in lieu of liner plate/rib installation. It was found that the moisture content within the section in question was less than 7 percent, which is well below the required value of 10 percent (-70 percent of degree of saturation). Therefore, the proposed alternative was rejected on the basis that a reduced water saturation condition, such as the above, would lead to low stiffness and low ultimate strength of frozen soil. Because of these conditions, ground freezing at Shaft 11 was applied only to a section below the ground water table.

## REQUIRED FROZEN WALL THICKNESS

The wall of frozen soil structure must be thick enough to provide adequate support to the shaft excavation. The design of the frozen wall should also consider the expected delay between the initial excavation and the permanent lining installation. Applying these criteria, the resulting freeze-wall thicknesses, for a 44-ft diameter Shaft 11 and a 32-ft diameter Shaft 13, were 7.5 and 8.5 feet, respectively. In order to achieve this thickness, freeze pipes had to be set back 4.5 feet from the shaft perimeter line. Observations made during construction indicate that these assumptions were reasonably accurate. The maximum encroachment of the frozen structure towards center of the shaft was within a few feet.

## FREEZING METHOD

The ground freezing was performed by use of a brine coolant circulating through a series of vertical freeze-pipes installed at four feet centers around the shaft perimeter. The coolant circuit included a brine chiller, down freeze pipes and two manifolds. The system consisted of four and a half-inch outside diameter steel pipes placed inside 6-inch boreholes, drilled on a 4-ft center. A rotary-percussion system was used to install freeze pipes, primarily for its ability to penetrate large boulders. Deviation of the pipes was verified using borehole inclinometer.

A surface distribution system consisted of a supply header and a return header. A center-well was drilled inside the shaft to verify closure of the ice-wall. A polyurethane material was used to maintain the integrity of the exposed walls during shaft excavation. Temperature monitoring wells were installed to verify the freeze-wall thickness. Schematics of freezing method and site layout are shown in Figures 1 and 2, respectively.

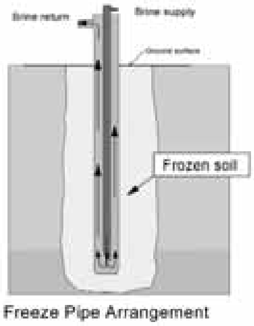



*Figure 1 – Schematics of Ground Freezing*

*Figure 2 – Freeze-wall Site Layout*

## FREEZING SCHEDULE

The length of time necessary for creating an ice-wall depends on the required thickness and strength. Initial calculations showed that between 40 and 55 days would be required for scheduling purposes. As evidenced in Table 1, these estimates were within the actual schedule.

Table 1. Typical Freezing Schedule

| Work Items | Duration (days) | % of total period |
|---|---|---|
| Drill and install freeze pipes | 43 | 29 |
| Freeze ground | 53 | 35 |
| Excavate soft core | 24 | 16 |
| Install final concrete liner | 30 | 20 |
| Total works | 150 | 100 |

## GROUND TEMPERATURE VERIFICATIONS

A positive method for determining ground temperatures consisted of installation of full depth temperature monitors, each consisting of individual thermocouples, around each shaft. By utilizing the data from the monitors, the field staff was able to monitor the temperature trends as well as the rate of growth of the frozen soil. The temperature readings were taken on a daily basis from the start of the freezing process until completion of the final concrete liner. Following this period, monitoring was reduced to once a week. The excavation of shafts was commenced once the temperatures reached -10 degrees C.

## SHAFT EXCAVATION AND LINING

Excavation of the soft core was accomplished by the use of a backhoe equipped with a 2-yard bucket. Mucking was completed utilizing a crane to hoist a skip box. A typical frozen ground encroachment ranged between 1 foot and 3 feet. Chipping, by means of hand tools and mechanical breakers was used to reduce any over frozen areas of the shaft. The frozen earth walls exposed to ambient temperatures were continuously insulated with polyurethane material. A view of insulation along the shaft wall is shown in Figures 3 and 4.

*Figure 3 – View of Shaft Excavation*

*Figure 4 – View of Insulating Material and Frozen Soil*

## CONCLUSIONS

Ground freezing method was effective in providing temporary support while constructing two deep shafts in sandy soil formations at the Mill Creek Project. Its success can be attributed to sound construction strategies taken jointly by the Owner (NEORSD), Engineer (MWH) and Contractor (KMM&K). It is also emphasized that any freezing program should have the full benefit of a thorough understanding of underground conditions.

## ACKNOWLEDGEMENT

The authors would like to thank Northeast Ohio Regional Sewer District for approving the publication of this article. The authors wish to acknowledge the contribution of MWH staff, namely Carol Chavis for support during preparation of this paper.

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# An Introduction to Mining Equipment Ltd.

*Durango, Colorado, USA*

**Introduction:**

Mining Equipment is a supplier of new and quality remanufactured rolling stock and tunnelling equipment – based in the United States our products are exported to countries on 6 continents.

Examples of equipment that we have recently fabricated/supplied are as follows:

- California Switches and Moveable Passing Switches
- Muck Wagons – Lift off, Side Dump, 5th Wheel, Roll Over, etc.
- Flat Cars, Segment Cars, Grout Cars and Mantrips
- Locomotives, Battery and Diesel units from 1.5 to 35 tons
- Ventilation Fans 18" to 84" Diameter (up to 500hp)

Mining Equipment has been in business for more than 25 years, and during that time, we have worked on more than 200 projects on 6 continents.

**History:**

During its first 15 years, Mining Equipment concentrated on remanufacturing equipment and its sale and rental to the mining and tunnelling industries world wide, but this all changed almost 10 years ago. At that time, Mining Equipment purchased C.S Card, a US based producer of rolling stock to the mining industry since the 1900's and by default, Moran, a major supplier of rolling stock in North America. This purchase provided Mining Equipment with an extensive library (approximately 2000 drawings) of proven designs ranging from Telluride "no loss" muck cars to concrete/grout cars. Our design team uses these drawings as a base that they can adapt to meet the specific requirements of almost any project.

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Another step in the development of Mining Equipment was the decision in 2001 to start production and fabrication of our new rolling stock in China. Now with over 5 years experience of producing equipment in China, Mining Equipment has staff permanently in country, and this is augmented by regular inspection visits from head office to our production facilities.

**International Focus:**

Due to expansion and investment, Mining Equipment over the last few years has been able to respond to market demand and apply increasing resources to the international market place that has (we feel) traditionally been dominated by too few suppliers in custom built rolling stock for tunnelling applications.

**Contractor References:**

Mining Equipment has worked on projects in North America, South America, Europe, Asia, and Australasia. References can be provided on request by Senior Personnel from any of the projects/companies listed below:

**International Contractor References:**

- Traylor Bros – San Vicente Project
- Kiewit – Portland

- Kenny Construction – NECIS, ECIS (LA), Seattle (Brightwater)
- Frontier Kemper – Seattle (Brightwater),
- Shea – Arrowhead (San Bernardino),
- CSM BESSAC – Choully, France
- CIFT – Bogotá, Colombia
- Impregilo S.p.A – Portland CSO, Portland, USA
- Bilfinger Berger – Portland CSO, Portland, USA
- Dragados – East Side Access, New York, USA.
- Bouygues Construction – CLP Cable Tunnel, Hong Kong

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Mining Equipment has supplied our Chinese fabricated rolling stock to companies with very strict quality tolerances such as the US Government.

*For further information on Mining Equipment Inc and their products, call 970.259.0412 or visit their website at www.miningequipment.com.* ●

# TBM Tunnelling at the Ashlu Hydropower Project, Squamish, BC

*By Serge Moalli, Project Manager, Frontier Kemper Constructors*

TBM tunnelling of the 4.02 m diameter, 4.4 km power tunnel at the Ashlu Hydropower project near Squamish, BC continues on pace. The 49 MW run-of-river hydropower project is being developed by Innergex and Ledcor under Ashlu Creek Investments Limited as one of many private hydropower projects currently underway in BC. Ledcor is the prime contractor and the power tunnel is being constructed by Frontier Kemper ULC under a design-build arrangement. This TBM tunnel project represents the first TBM application in BC for the hydropower industry since the mid-1990's and the future looks bright for several more TBM excavated power tunnels for privately developed power projects to meet the growing energy demand of BC.

The 1400 kW Wirth TBE III – 400/450E open gripper type TBM has completed 1.5 km (35%) of the total tunnel drive through mixed rock conditions requiring various levels of rock support and has successfully

*This TBM tunnel project represents the first TBM application in BC for the hydropower industry since the mid-1990's and the future looks bright for several more TBM excavated power tunnels for privately developed power projects to meet the growing energy demand of BC.*

excavated through two of the anticipated six major fault zones with minor impact to overall progress. Geology along the tunnel alignment generally comprises very strong (> 200 MPa) granitic bedrock that is typical within the coastal mountains of BC. Maximum daily progress rates of 28 m have been achieved to date. Groundwater inflows of less than six litres/second (90 gpm) have been measured.

Rock support installed to date has included spot bolting in good quality sections, C100 channels in conjunction with pattern rock bolts in blocky sections, and W100 steel ribs at one of the major fault zones. Steel rib supports were selected to be installed over the 15 m wide F1 fault near chainage 650 m and C100 channel support was installed over the 85 m wide F2 fault near chainage 1150 m. Rock conditions at both encountered fault zones has comprised closely fractured and altered granitic rock.

TBM tunnelling is being carried out on a 24/7 basis with three crews. TBM cuttings are being removed via a locomotive muck train comprising five – 6 m3 cars that discharge over a tipping wall outside the portal for pick up and road transport to the designated spoil site within the project area by the prime contractor.

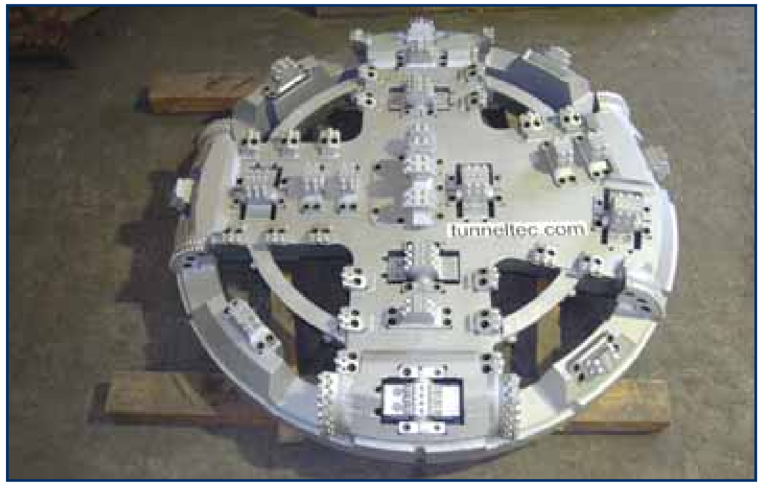
TBM tunnelling is scheduled to be completed in late 2008. A 135 m deep drop shaft of 4.35 m diameter is planned to be excavated by conventional drill and blast methods at the end of the TBM power tunnel as part of the conduit to the intake constructed on Ashlu Creek and be completed to facilitate disassembly and removal of the TBM.

# DIBCO UNDERGROUND LTD.
## WORKING ON 15TH STREET SANITARY SEWER PROJECT CALGARY

Ribs and lagging behind a full face tunnelling shield has been selected as the best approach to the 15th Street Sanitary Sewer Project for the City of Calgary. Microtunnelling and pipejacking alternatives came in at a higher price than Dibco's $ 14 million bid. Dibco will be using an open TBM to excavate the two 300m long tunnels through the claystone, siltstone, sandstone bedrock beneath the Bow River riverbed between two 35m deep access shafts. This presents a challenging task for the Toronto-based company.

*Subcontractor at North Shaft (working shaft)*

The 15th Street SE siphon project is needed by the City to increase flow capacity across the Bow River to the treatment plant. The siphon consists of two separate 1.5m diameter pipelines, one for current use, and the second to meet anticipated demand increases for the next 35 – 50 years. The siphons are Hobas pipelines backfilled into the primary ribs and lagging support of the tunnels and will connect to the existing sewer


*TBM Cutterhead arrangements*

network via short sections of open cut work. The open cut work will be completed under a separate contract.

Project Manager for Dibco, Gary Lukez, comments on the project's progress. " In mid-April, we have just completed fabrication of a new cutterhead for our existing 2.44 m diameter American Augers TBM. The cutterhead was fabricated by TunnelTec, a German company, in association with American Commercial, a US company. The cutterhead has been designed to excavate the tunnel on this project based on the conditions outlined in the GBR of the Contract. The TBM cutterhead has two arrangements, one consisting of disk cutters for hard rock applications, and one cutterhead arrangement of ripper teeth for soft rock conditions. The TBM is equipped with both types of tooling/cutters, which are interchangeable from within the TBM itself. All of the tooling/cutters are front end loaded. As it stands today, the TBM will be launched in "disk cutter" mode, based on the conditions reported in the GBR. The plan to use the TBM in this mode will be finalized during shaft excavation, based on the insitu conditions of the excavated rock encountered." ●

# MULTIURETHANES (MME) IS ALWAYS ON CALL

Multiurethanes (MME) has been assisting tunneling companies, shoring companies and excavating companies overcome difficult water and sand infiltration issues since 1988.

As a supplier of grouting materials, grouting equipment, and grouting expertise, we have provided the support that contractors require when encountering unforeseen ground issues. MME engineers and technicians are on standby to assist with emergency, unplanned for conditions.

MME has teams of experienced grouting technicians who will work onsite with your crew in order to get control of flows and regain the productivity of your project. Our expertise lies in the application of fast setting cement grouts, microfine cements, polyurethanes, and silicates that will cut off water or stabilize sand.

*MME Grouting Technicians travel across North America and the world providing equipment, materials, and technical support to a wide variety of tunneling and underground applications.*

In addition to grouting materials, which are always in stock, Multiurethanes supplies a variety of rental grouting equipment. Whether you require chemical pumps to deliver large volumes of polyurethane or cement pumps and colloidal mixers to place microfine cement, the right piece of equipment is always available at MME.

MME Grouting Technicians travel across North America and the world providing equipment, materials, and technical support to a wide variety of tunneling and underground applications.

A recent project where MME was able to successfully assist a tunneling contractor, occurred at the collar of a tunnel in the base of the launch shaft, where a high volume infiltration of sand and water suddenly and unexpectedly started. Chemical grouts were

initially used by the experienced tunneling crew to get the flows under control. At first, the tunneling crew was successful in cutting off the in-flows. However after several hours a new leak began in a different location around the tunnel collar. This leak was stronger and at an increased pressure than the original flow. At this point, the tunneling contractor contacted Multiurethanes for an alternative solution to the chemical grouting to get the high volume flows under control.

Multiurethanes Technicians mobilized a cement grout plant and immediately proceeded to the jobsite. Onsite it was agreed that the grout plant would stay 50′ up at the top of the tunnel shaft while the grout injection proceeded at the tunnel collar below. Drillers located the source of water and sand through the tunnel segments within the tunnel and the grouting work proceeded. After successfully pumping grout into the stream of sand and water, a "flashing" additive was injected into the grout stream. In seconds, the heavy flows were cut off by the thickening of the cement grout in the stream of flowing sand and water.

The prompt and effective support of the Multiurethanes Technicians allowed the tunneling job to resume immediately as the grouting equipment was demobilized from site.

Multiurethanes will work with your team – supplying grouting materials, equipment or technical support – to resolve the most difficult ground control issues. Call us anytime at 800-663-6633 or in an emergency call 416-254-5212 – we're here to help. ●

# EPB T[illegible] R[illegible] A[illegible]

By Laura McNally and Steve Skelhorn - McNally Construction Inc

In 2006 McNally International Inc. in a Joint Venture partnership with Aecon Constructors was the successful bidder on two York Region Tunnel Projects: Bathurst Collector / Langstaff Trunk Sewers; and YDSS Interceptor Sewer 19th Avenue Project. These projects comprise a total of 13 kilometres of 2.74 meter finished diameter tunnels and are both part of the York Durham Sewer System (YDSS).


YDSS General Layout

Both contracts require the use of EPB tunnel boring machines with a precast concrete segmental liner. A paper was published in the April 2007 TAC magazine outlining the project scope and construction approach for the two projects. The following provides an update on the tunnelling on these projects. Although these are two separate contracts, construction management for both contracts was combined by McNally / Aecon; consequently, this article discusses the project as one.

### P[illegible]

The projects include construction of 12,600 m of 2744 mm internal diameter tunnel, including 11 access shafts. The tunnels range from 9 m to 30 m in depth, and are being constructed through till, sand and silty clay deposits with water heads up to 1.5 bar.

The tunnels are split into five distinctive drives: Bathurst South Tunnel (2500 m); Bathurst North Tunnel (2500 m); 19th South Tunnel (500 m); 19th West Tunnel (3600 m); and, Langstaff Tunnel (3500 m). Three new Lovat EPB TBMs were purchased for use on the projects.

For the Bathurst tunnels, a main mining shaft, located at the mid-point of the Bathurst Sewer, was used to launch the first TBM for the south drive in January 2007. The TBM successfully completed the 2500 m drive in early December 2007, was removed from the reception shaft at Bathurst & Steeles. The TBM was re-launched for the north drive in January 2008 and as February, 220 rings (265 m) have been completed.

Installing first TBM Bathurst

The 19th Avenue tunnels are being completed from a single mining shaft, from which two TBMs were used to mine the west and south tunnels concurrently. The second TBM was launched from this shaft for the west drive in February 2007. As of February 2008 this TBM has completed 2100 rings (2540 m) and has reached the S3 intermediate shaft where the TBM was turned and re-launched. To expedite completion of the west tunnel, it was decided to move the mining operation up to the S3 shaft. This effectively split the drive, allowing finished works at the main mining shaft and within the tunnel to proceed concurrent with the mining of the remainder of the drive, as well as reducing the travel time in the tunnel during mining operations.

In April 2007 the third TBM was launched from the main mining shaft on 19th Avenue for the south drive. The drive was successfully completed in June 2007 and the TBM was removed, delivered to the Langstaff, and re-launched there in July 2007.

As of February 2008, 1000 rings (1210 m) have been completed on the Langstaff drive.

### E[illegible]

The 19th Avenue tunnel alignment crosses through the Oak Ridges Moraine Aquifer (a significant water resource for Ontario), as well as other highly sensitive environmental features. Environmental requirements on the project include: daily checks of siltation and ground water disposal facilities; regular liaison with the regulatory agencies; and, strict monitoring of ground

*Launching third TBM Langstaff*

water, site run of water and process water discharge. Additionally, the tunnel passes between two highly sensitive creeks which are classified as provincially significant wetlands and include cold water fish habitats. During the mining beneath these features, the monitoring regime was stepped up and regulatory agency presence was continuous.

The first of the creeks was crossed without incident; however, the second location presented some challenges during tunnelling. The creek is located at 19th Ave and Bayview Ave and comprises two tributaries, one on each side of Bayview Ave. The tunnel through this zone is located entirely within the Oak Ridges Moraine sand formation at a depth of approximately 12m. Above the sand is a relative thin (6 m) till cap. Ground water at this location is artesian with a head of water at 6 m above ground level. During previous construction of a CN bridge spanning 19th Avenue, piling for the bridge breached the till cap and resulted in a flowing condition, which in turn created a cold water fish habitat. Throughout the planning and design stages of the project, concern was raised about potential to breach the till cap.

During tunnelling below the Bayview creeks, air bubbles were noticed in the creek bed. This disturbed sediments in the creek and raised concern about water quality impacts on spawning Brook Trout. Mining procedures were adjusted to mitigate the concern. The ground conditioning system was run without air and EPB pressures were closely monitored. Environmental controls were installed to contain sediment, and a vacuum truck was on site continually to clean up the area. It took approximately 1 week to pass through the 50 m sensitive zone. Close cooperation with regulatory agencies and the owner throughout this process resulted in a successful outcome with no detrimental effects to the creek.

### B[illegible] C 1[illegible]: 1 9[illegible] A [illegible]. [illegible]

To date, on all projects, environmental feedback from the Agencies has been positive. Working with the agencies in a proactive manner has greatly assisted in achieving this.

### TBMP [illegible] 1[illegible] 1- [illegible]. [illegible]

As discussed above, three new Lovat TBMs were purchased for these tunnels. The TBMs are 3.25 m in diameter and incorporate mixed face cutter heads. Face dressing includes ripper teeth across the full face, scraper teeth on the outer two thirds of the circle and disc cutters on each blind to provide protection to the gauge. The face is protected with Trimay wear plates and incorporates grizzly bars to limit cobble and boulder ingress to 225 mm. The head incorporates five ground conditioning injection ports, four on the face and one on the outer wrap.

As of February 2008, over 50% of the tunnel drives have been completed, with 5,800 of 10,400 total rings completed. An analysis of all the tunnels reveals similar performance for all three TBMs. Average tunnel progress is approximately 6 m a day for each drive. This average includes the launch and start-up periods. At peak performance, daily production of 20 m a day has been achieved with high of 29 m a day and 116 m in a week

*TBM and tunnel – 19th Avenue*

Some of the ground conditions encountered along the individual tunnel drives have created challenges for the project team. As the project proceeds, new methods are being tested and developed to address these challenges and improve productivity in specific ground conditions. These are summarised below.

### B [illegible] 1[illegible]

Approximately 30% of the Bathurst tunnel is through highly plastic clay (sticky clay). Despite high concentrations of ground conditioning agents (up to 80% foam injection ratios), mine times were slower than originally anticipated in this material. On the south drive, mine times through the sticky clay averaged between 20 and 25 minutes for a 1.2 m push. Typical mine times of 10 to 15 minutes are generally achieved through the sand and till deposits. The main problems encountered were caused by limited ability to break down the clay into small enough pieces to pass effectively through the screw and remoulding of the clay in the head and screw. The first 900 m of the north drive are through sticky clay. Trials of different ground conditioning formulas are currently underway on the north drive. In addition, the air volume available to generate foam on the TBM has been increased for the north drive.

*Screw Discharge – Bathurst*

### [illegible]

The 19th Avenue tunnels are generally though homogenous ground with approximately 3 km through well graded sand and the remainder in a competent over-consolidated till deposits. Ground conditioning consists of foams in the till and polymer in the sand.

The till deposits contained a substantial amount of cobbles and boulders, which the TBMs were designed to accommodate. Oversize cutter teeth, grizzly bars for boulder exclusion and Trimay hard facing were provided with the TBM as some of the enhancements. In practice, both TBMs passed through the tills with little incident. Occasional jamming of the screw caused some minor delays when irregular shaped cobbles entered the chamber, but these delays were minimal. Mine times through the tills were generally around 15 minutes, with ground conditioning consisting of foam with an injection ratio of around 60%.

The sand deposits proved easier to mine once the polymer conditioning was perfected. Mine times of 8 minutes were routine; however, there were some issues with ingress of fine sand and water through the screw and the tail can. By maintaining sufficiently high pressures, combined with polymer injection, the screw discharge was easily controlled. However, the tail seal leaks proved to be more problematic on the west drive and it was necessary to inject polyurethane grout through the segments, into the annulus around the tail brushes, to seal the leaks until the TBM reached the intermediate shaft and brushes could be changed.

### L[illegible]

Langstaff mining has to date been the most difficult of all the drives. The ground conditions to date have been highly variable, changing frequently from competent silty clays or tills to running sands, silts, or gravels, sometimes in the space of one shove. To accommodate this, ground conditioning needs to be adjusted frequently to suit the conditions. A combination of foam and polymer has been used to date and has proved successful.

In general terms, the TBMs have performed well. Tool changes were carried out at approximately 500 ring intervals with normal wear patterns observed. Some wear to the blinds of the TBM head was apparent on the removal of the first two machines, requiring significant repair work prior to re-launching both the Bathurst & 19th TBMs.

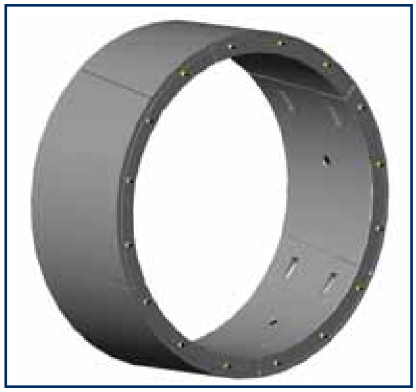

*Typical TBM Head Dressing*

Tail brush leaks have proved problematic on all three TBMs, while the use of polyurethane grout stops the leaks, it does introduce other problems with the ring build, reducing the tolerances for steering the TBM.

### S[illegible]T[illegible]

The tunnels are being constructed using a precast reinforced concrete segmental liner. The liners are manufactured in Ottawa by Boucher Precast and the Joint Venture team with Chris Smith of CRS Consultants retained by the Joint Venture to provide management and quality assurance. Tunnel liner design was by Halcrow Group Ltd.(UK).

The configuration is a tapered 6 piece segmental ring, consisting of four 67.5 degree rhomboid plates, one 67.5 counter key and one 22.5 degree key. A 20mm taper is provided to the ring for purpose of steering. Left and right rings are used to limit the start of ring building above spring line.



*Segmental ring*

To date segment casting has been very successful. Boucher's quality control has been outstanding with very few reject casts, with most weeks achieving 100% in usable rings. Transportation of the rings was identified as a potential problem at the start of the project. With the plant 380 km from site and the packers and gaskets installed at the plant, there was concern that some of these items would have become dislodged during transport. Different systems such as shrink wrap and custom formed tarpaulins were considered but not adopted. Overall, this has not been a problem, even with segments stored uncovered outside.

Using a 1.2m wide segment on a 2.744 internal diameter tunnel has generated some issues. The width of the rings determined the width of the TBM gantry, which resulted in the running skids of the gantry riding high up on the completed rings, in turn increasing the tendency for the gantry to roll. Also the ring geometry allows less movement within the tail can, due to its length, which in turn provides less flexibility in the steering of the TBM. The end result is that good control of line and grade on the TBM is essential to ensure perfect ring build. On the whole, however, the rings have performed well with very little installation damage. Control of steps and lips has also been good to date, with lipping only apparent in a few areas where TBM alignment control was a problem.

### S[illegible]

With restrictions on groundwater seepage volumes at shafts, sealed shaft construction was required at locations with non competent ground conditions. Slurry wall and secant piles construction methods were used for shaft sinking in these locations. In areas where the geology consists of stable clays and tills, liner plate and rib bracing or soldier pile and lagging shoring structures were suitable.

*Slurry Wall Shaft – 19th Avenue*

All shafts were completed by the end of 2007, ahead of the tunnelling works, with the exception of the final TBM removal shaft on the Bathurst north drive. Soldier piles have been installed for this shaft and excavation is schedule for spring 2008.

All the shafts are required as part of the permanent design, either for access to the tunnel for maintenance purposes or to facilitate connections and drop pipes. Traditionally, shaft structures would be constructed after completion of the tunnelling. To accommodate scheduled constraints, it was advantageous to construct some of the structures concurrent with tunnelling. One innovative redesign proposed by the construction team, involved constructing a box out within the structure to allow the TBM to pass through the intermediate shaft. This allowed the entire structure, less the box, to be completed ahead of time. Once the TBM passed the shaft, the tunnel segments were broken out from within the tunnel and the benching was finished.

Two of the structures at intermediate shafts on the Bathurst & Langstaff tunnels will be constructed once the tunnel has passed, prior to completion of the overall drive. In these locations, the shafts have been backfilled with low strength (5 MPa) concrete, to 1 m above the top of tunnel. The TBM will mine through the shaft and segments will be constructed within the 5 MPa concrete. The concrete is then removed to spring line of the tunnel for construction of a base structure for the manhole.

Other structures within the current mining shafts cannot be started until mining is completed, however, options for improving constructability such as the inclusion of precast elements, etc are being considered at these locations.

### T[illegible]

With over 50% of the tunnelling completed and all crews and system fully up to speed, mining is expected to be complete by late summer of this year. A great deal has been learned over the course of tunnelling. Modifications to systems and procedures are constantly being updated. For example, within the sticky clay on the northern drive, different foam formulations are to be tried, to maximise the production through this ground.

*Tunnelling set-up – Langstaff*

TBM performance has also been monitored, and adapting each machine to the individual ground conditions has enabled all tunnels to maintain similar progress, despite the varied geology. We have also been in the unique position, with three machines continuously mining, to gain a wide range of experience, not only as a company, but also for our individual crews who have worked on different tunnel drives through the course of the project. ●

# Electrical Protection for Tunnel Boring Applications

*By Jeff Glenney, P.Eng.*


Many electricians and users are not familiar with the benefits and requirement for high-resistance grounding. The ground-potential rise on portable equipment is equal to the product of the fault current and the ground-return resistance. High-resistance grounding limits the amount of current that flows when one of the phase conductors contacts ground. Controlling the fault current therefore reduces the risk of hazardous touch or step voltage on equipment. In addition, the neutral-grounding resistor (NGR) limits the possibility of arc flash exposure during a ground fault. In confined spaces, such as a TBM, limiting arc flash exposure is extremely important.

Where a utility supplies power to a TBM from an existing substation, high-resistance grounding is achieved with an isolation transformer. When a dedicated power transformer with a wye-connected secondary is used, an NGR can be connected to the neutral bushing of the transformer, presuming the neutral is accessible. High-resistance grounding can be achieved on a delta system or a wye-connected transformer where there is no access to the neutral, without replacing the power transformer by adding a zigzag transformer to derive a neutral. The zigzag transformer should have the same or better time and current rating, as the neutral-grounding resistor, and a voltage rating equal to the system voltage. Resistance ground the derived neutral as normally done for a wye-connected transformer secondary.

In Canada, the electrical standard that covers tunnelling is CSA-M421 Use of Electricity in Mines, which has been adopted into law in many jurisdictions. To meet CSA-M421 Section 3.6.2 (b), the supply must be de-energized in less than 60 ms if the neutral-grounding device opens. An SE-325 or SE-330 NGR Monitor can be used to provide this protection and ground-fault protection.

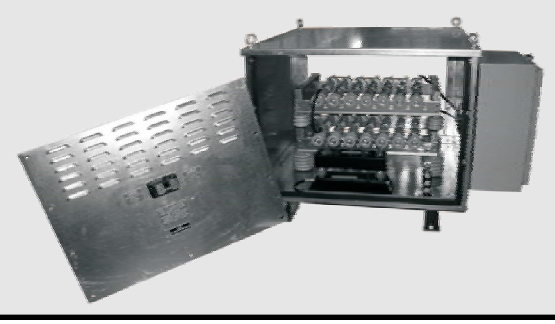
Under M421, a portable load such as a boring machine or a submersible pump must be powered by a trailing cable that includes a pilot wire. The cable must have ground-check and ground-fault protection. In addition to offering sensitive ground-fault protection, with pickup levels down to 0.5 A, a Startco SE-134C provides ground-check-loop-resistance monitoring. A low-resistance ground-return path must be present to allow ground-fault current to flow during a phase-to-ground fault on the equipment. The fault current can then be detected and the load de-energized by the interruption device.

Cables in tunnelling applications suffer the same stress seen in other portable-equipment applications including bending, abrasion, overheating, and occasionally stretching. The pilot wire is by design the smallest conductor in the trailing cable and most susceptible to failure. The SE-134C monitors the ground-check loop and a relay such as an FPU-32 Feeder Protection Unit can monitor the cable for overloads. Any load that is connected with pin and sleeve connectors must include a ground-check relay to help protect workers who inadvertently disconnect energized cables and to meet CSA-M421 Section 3.4.4.1 (f).

Startco Engineering Ltd. has over three decades of experience in underground electrical applications.

*Jeff Glenney, P.Eng., has thirteen years in the industry, all with Startco Engineering. Jeff graduated with a BSc.E.E. from the University of Saskatchewan. His current position is Sales Engineer, with responsibility for the U.S. and parts of South America.*



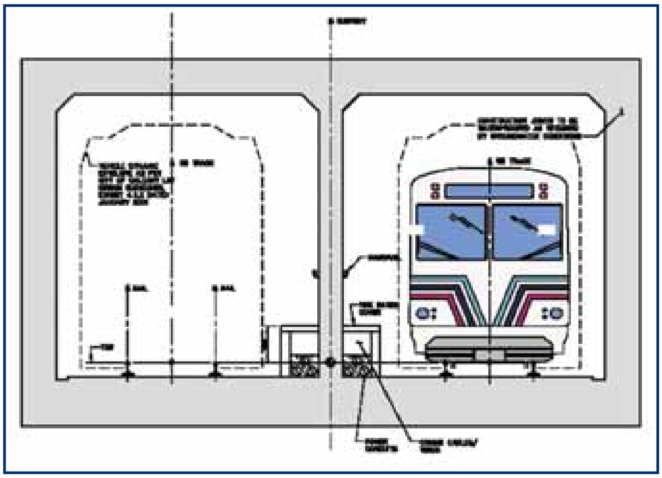


# Preliminary Design Underway for Calgary West Light Rapid Transit (LRT) Tunnels

Preliminary design is underway for Calgary's 700 Million Dollar West Light Rapid Transit (LRT) Line. This 8km alignment represents an extension of Calgary Transit's LRT System routing from 11th Street Southwest in downtown to 69th Street Southwest and is to include 3.5 km of track at grade, 2.4 km of elevated track and 1.3 km in tunnel with a total of six stations – one along Bow Trail and the other five along 17th Avenue S.W.

The 1.3 km tunnel component of the West LRT line alignment passes below Bow Trail at 33rd Street and cuts through a portion of Westbrook Mall and a high school playfield. An underground station is planned at this location and therefore the high school will be relocated. Construction of the 1.3 km tunnel section is envisaged to be constructed using cut and cover methods.

The preliminary design is expected to be completed in late 2008 and to allow a design-build approach for construction in



2009. The preliminary design is being completed by Hatch Mott Macdonald and Focus Corporation. Klohn Crippen Berger is the geotechnical consultant.

# Credit Valley Trunk Sanitary Sewer

*By Brian Barber, Genivar Consultants*

Expansion of the Region of Peel's west sanitary sewer system was required in order to accommodate future population growth within the Region. The Credit Valley Trunk Sanitary Sewer will extend from Highway 401, in the City of Mississauga, to Queen Street, in the City of Brampton, and is being completed under four separate construction contracts. GENIVAR of Markham, Ontario was retained by the Region of Peel to complete the detailed design and contract administration for the project.

Contract 1A of the project is being constructed by Technicore Underground Inc. of Newmarket, Ontario. This portion of the trunk sewer is being completed in tunnel outside of the river valley to minimize potential environmental impacts. The approximately 3100m long tunnel follows existing road allowances and easements through a mixture of industrial, commercial and residential areas. Contract documents and drawings were prepared by GENIVAR and were accompanied by Geotechnical Reports prepared by GeoTerre Ltd. of Brampton, Ontario.

*Tunnel Digging Machine (TDM) manufactured by Technicore, that was used to complete the back tunnel around a sharp curve south towards the Credit River*

The tunnel depth ranged from approximately 10m to 20m and was completed through a variety of soil and groundwater conditions. Technicore, who is a manufacturer of tunnelling equipment as well as a tunnelling contractor, manufactured a 2400mm diameter TBM to complete the tunnel. The TBM was equipped with disc cutters, rippers, a screw auger and also had EPB capabilities. Each of the three northbound drives and one southerly drive presented different challenges.

A 110m back tunnel was constructed from the main mining shaft around a sharp curve towards the Credit River. Technicore used a TDM to complete this dead-end section of tunnel. Steel mesh, rock bolts and shotcrete was used for the primary lining system for the horseshoe shaped tunnel within the shale bedrock and transitioned to ribs and lagging as the tunnel approached the Credit River and shale elevations dropped. The downstream connection of the trunk sewer required a crossing of the Credit River from the limit of the south tunnel to the existing trunk sewer. GENIVAR obtained the required approvals from regulatory agencies to complete an open-cut crossing of the river using a two-stage cofferdam method. The cover between the river bed and the trunk sewer was approximately 1.2m, which prohibited tunnelling this crossing.

*Primary tunnel liner, which was constructed of steel ribs and hardwood lagging*

The first northbound drive was approximately 1285m long extending from Highway 401 to Derry Road. The mining shaft was approximately 15m deep and was constructed using ribs and lagging as well as shotcrete below the bedrock elevation. This portion of the tunnel included crossings of the CP Railway, Levi Creek, and Derry Road and also passed immediately adjacent to a large stormwater management pond. A detailed settlement monitoring program was implemented by GeoTerre for the CP Rail crossing, which was successfully completed with no recorded settlements. The ground conditions through this section ranged from shale bedrock to clayey silt till to sand and silt till. In the area of Levi Creek and the storm pond the tunnel elevation coincided with the bedrock-till interface. This mixed face mining condition was complicated by the presence of several cobbles and boulders within the till unit above the weathered shale. A rib and lagging primary liner was used for this drive as well as the other two northbound drives. Filter cloth was placed behind the lagging in areas with significant groundwater.

The second drive was approximately 950m long through a residential neighbourhood in northern Mississauga. A 10m deep rib and lagging intermediate mining shaft was constructed within an easement obtained from the City of Mississauga for this drive. This section of the tunnel alignment passed between two schools, across a park block and directly underneath a semi-detached house. Approximately the first half of this drive was completed within the shale bedrock, however, as the tunnel crossed the park block and approached the houses at Samuelson Circle the shale elevation dropped significantly. The crossing of Samuelson Circle involved tunnelling directly underneath a house, which was previously purchased by the Region, on the south side of the street and through a 3m wide easement between two other houses on the north side of the street.

Prior to proceeding through this section, GENIVAR and Technicore agreed that precautionary ground treatment should be conducted to protect the existing homes. The lack of surface access was a significant factor when considering various ground treatment techniques. A single line of eductor dewatering wells was installed by Atlas Dewatering along the alignment to lower the groundwater table and stabilize the sand and silt material that was present at the tunnel elevation. Above this sand and silt material, a clayey silt till capping layer was present that ranged in thickness. Advanced Construction Techniques Ltd. (ACT) installed a compensation grouting system across the entire right-of-way. This system consisted of vertical grouting tubes, settlement monitoring points and a grouting plant that was set up within the Hydro Corridor north of the houses. Technicore completed the tunnel under the house and across Samuelson Circle using EPB mode. Several cobbles and boulders were encountered through this section and had to be broken into pieces and removed from the TBM head. As the tunnel advanced, the ground beneath the till capping layer was stabilized by injecting grout as required.

The third and final northbound drive was approximately 740m long and included a crossing of Highway 407. A 20m deep rib and lagging shaft was constructed within the Hydro Corridor adjacent to Highway 407. The tunnel grade was increased from 0.2% to 0.5% for this section in order to avoid much of the mixed face condition at the bedrock-till interface. Technicore elected to complete this drive using a 2660mm diameter EPB TBM while the 2400mm diameter TBM was simultaneously completing another drive. The major challenge for this section was the

*Tunnel Boring Machine (TBM) that was used to complete 2 of the 3 northerly tunnel drives. The first section of the TBM is being lowered into Shaft #1*

*TBM jacking can and screw auger*

abundance of cobbles and boulders present in the till unit. Technicore modified the auger and conveyor systems several times throughout the drive to accommodate boulder and cobble removal. Specially designed carbide-tipped teeth were also required for the TBM face and were replaced regularly due to both wear and damage from boulders.

The trunk sanitary sewer has an inside diameter of 1500mm. Precast reinforced concrete pipe supplied by Munro Concrete Products Ltd. of Barrie, Ontario was used for the secondary liner. Technicore manufactured a pipe carrier that was used to place the precast concrete pipe in the tunnel using the locomotive rail system. The pipe was blocked in place and the annular space was filled with cellular grout.

Manholes are currently being constructed at the four shaft locations along the alignment. At Shaft #2, an existing 525mm diameter sanitary sewer on Derry Road will be intercepted, which will allow the Region to eliminate a siphon under Levi Creek. Since designing the Credit Valley Trunk Sanitary Sewer, GENIVAR was retained by the Region of Peel to complete a Schedule 'C' Class Environmental Assessment for the twinning of the West Trunk Sewer approximately 13km from Highway 401 to the QEW. This proposed sewer will connect to the Credit Valley Trunk Sanitary Sewer on the north side of Highway 401. The manhole design at this location (Shaft #1) was modified in order to accommodate this future connection and also provide the option to divert flow to the new sewer in the future.

Contract 1A of the Credit Valley Trunk Sewer is expected to be completed by April 2008 and the entire trunk sewer from Highway 401 to Queen Street is scheduled to be in service by late 2009. GENIVAR is currently preparing designs for Contract 2B of the project, which is also to be completed by tunnelling. This tunnel will be almost entirely within bedrock and will reach depths of 40m.

●

*Looking south from within the horseshoe-shaped starter tunnel at Shaft #1, which was over-excavated in order to accommodate a switch*

# The Niagara Tunnel Project

*Hatch Mott MacDonald*

## PROJECT UPDATE

### Project Background

Ontario Power Generation (OPG) awarded the Design/Build Contract for construction of the 10.4-km long, 12.7-m internal diameter Niagara Diversion Tunnel to Strabag AG from Austria in August 2005. Strabag AG is being supported by a number of subcontractors, including Dufferin Construction for surface works construction and tunnel spoil handling, Dufferin Concrete for supply of concrete and shotcrete, McNally Construction, Bermingham and Geo Foundations for marine works, cofferdam construction and curtain grouting at the intake end of the project. Designers for the project are ILF Consulting Engineers from Austria for tunnel design, and local consultant Morrison Hershfield for surface works design. Hatch Mott MacDonald in association with Hatch Energy are engaged on the project as Owner's Representative to OPG.

### Tunnel Construction Methodology

Strabag AG adopted a two-pass tunnelling system for construction of the Diversion Tunnel using a Robbins open gripper hard rock Tunnel Boring Machine (TBM), mining from the outlet end to the intake.

A primary lining consisting of rockbolts, wire mesh, steel channels or steel ring beams, and varying thicknesses of shotcrete is installed behind the advancing TBM.

Once TBM tunnelling has progressed a suitable distance, concurrent installation of the 600 mm thick final lining will commence, including placement of a waterproof membrane against the shotcrete primary liner, construction of the cast-in-place concrete final liner and grouting of the lining. This will be done in four distinct phases as follows:

- Phase 1 – invert membrane placement and concrete invert
- Phase 2 – arch membrane placement and concrete arch poured above the invert
- Phase 3 – contact grouting of voids between concrete final liner and membrane
- Phase 4 – high pressure interface grouting between the waterproof membrane and primary liner shotcrete to develop sufficient prestress in the tunnel final liner to resist internal hydrostatic pressures under operational conditions.

### Tunnel Alignment and Route Geology

The horizontal alignment for the Niagara Diversion Tunnel runs in a westerly direction from an intake located in the Niagara River approximately 2 km upstream from the Horseshoe Falls, and then turns northward parallel to Stanley Avenue below the City of Niagara Falls, Ontario, before swinging north-eastward to connect to an outlet structure located close to the existing Sir Adam Beck Generating Stations just south of Queenston.

Approximately 80% of the tunnel length will lie within the Queenston Formation (Figure 1), a siltsone/mudstone with an unconfined compressive strength ranging from 19 to 45 MPa.

The St. Davids Gorge forms the principal vertical constraint to the tunnel alignment at the north end of the route, with a 7.8 % downgrade being required from the outlet structure to pass beneath the buried gorge with a minimum rock cover of approximately 25 m. At the south end of the route, the vertical alignment is constrained by the requirement to pass at a suitable distance from two existing OPG power tunnels, constructed in the 1950's, and the turbine pit of the decommissioned Toronto Power Generating Station. An upgrade of 7.2% completes the tunnel to the intake structure in the Niagara River.

### Tunnel Construction Update

Strabag AG is currently boring the diversion tunnel from the outlet end (Figure 2) using a Robbins14.4 m diameter open, main beam type hard rock boring machine. The 'L1' forward 'build area' (Figure 3) of the TBM includes three rock drill units (two radial and one forward

*Figure 1: Tunnel Sidewall in the Queenston Formation*

Figure 2: Aerial View of Outlet Site

Figure 3: Rock Support Installation in the 'L1 Build Area'

probing), two telescopic manlift baskets, a scissor lift assembly for installation of steel channels, and shotcreting equipment.

A system of four conveyors and three intermediate transfer points capable of handling 1600 tonnes/hour is being used for removal of excavated material from the face to the surface disposal area. The TBM and backup system (BUS) were assembled in the previously excavated outlet excavation from June to August 2006, and commenced tunnelling on the scheduled date of September 1, 2006.

On the decline reach of the tunnel in rock formations above the Queenston Formation TBM production peaked at 18 m/d. The tunnel crown entered the Queenston Formation at approximately CH 810 m and challenging rock conditions were soon encountered. In response, Strabag AG installed a series of overlapping pipe spile umbrellas as a method of 'pre-support' in the tunnel crown. As rock conditions improved deeper in the Queenston Formation pipe spile umbrella installation was stopped and production rates increased reaching as high as 13 m/d.

At approximately CH 1400 m the TBM completed the 7.8% decline, reaching the low point of the alignment and commencing the 0.1% inclined reach of tunnel. Concurrent construction of the five dewatering shafts at the tunnel low point is currently underway (Figure 4).

At approximately CH 1600 m from the tunnel outlet structure, the tunnel passed beneath the eastern rim of the buried St. Davids Gorge, an earlier river course infilled with glacial outwash material. Challenging rock conditions were encountered beneath the gorge and Strabag resumed installation of the overlapping pipe spile umbrellas. It is expected that as the TBM moves beyond the zone of influence of the St. Davids Gorge production rates will improve. At the time of writing, the TBM has advanced

*Figure 4: Dewatering Shaft Access Platform at Tunnel Low Point*

approximately 1800 m, and continues to progress through the zone of influence of the buried St. Davids Gorge.

*Figure 5: Aerial View of Intake Site with Cofferdam, Ice Groyne and New Accelerating Wall in Place*

## Tunnel Intake

The tunnel intake (Figure 5) consists of a submerged reinforced concrete bell-mouth intake structure in the Niagara River beneath Bay 1 of the existing International Niagara Control Works (INCW) structure, and a 170-m long underwater approach channel in the river bed. The intake structure accommodates sectional gates installed from the shore for closure of the tunnel when required for dewatering. The approach channel was kept relatively short and steep to ensure that ice will pass through the INCW gates rather than be entrained into the tunnel. The design of the intake must accommodate local rock squeeze conditions and allow for dewatering of the tunnel.

To ensure a minimum of three INCW operational gates were available during winter months to flush ice from the SAB (Sir Adam Beck) Intake Tunnels No. 1 and No. 2 during construction, the existing Accelerating Wall, extending upriver from Pier 4 of the INCW structure, was removed and a new parallel Accelerating Wall was constructed from Pier 5.

In-water blasting and excavation of the Intake Channel upstream of the temporary cofferdam was completed during the summer of 2006 and presently, the dry blasting required to excavate a 6 to 40 m deep channel within the dewatered cofferdam at the bottom of the Niagara River is nearing completion (Figure 6). Prior to commencing dry blasting, to reduce water seepage into the cofferdam work area, a perimeter grout curtain was installed in the rock. The approximately 340 m long x 50 m deep grout curtain (from existing riverbed) tied into several other previously installed

*Figure 6: Intake Channel Excavation*

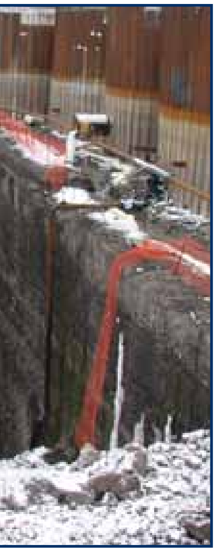
water retaining structures including a temporary caisson wall and INCW structure piers. The completed Intake Structure and Channel will be approximately 200 m long by 20 m wide and up to 40 m deep. In the coming months an 8 m x 7 m x 400 m long grout tunnel will be excavated below the Niagara River bed by drill and blast from the Intake Channel. The TBM will intersect the terminus of this grout tunnel and then continue mining the remaining 400 m of the alignment to the Intake Channel.

**Cast-In-Place Concrete Tunnel Lining**

To meet schedule milestones in the design/build contract, the contractor is in the advanced planning stages of the second pass cast-in-place concrete tunnel lining operations that are to be carried out concurrent with TBM tunnelling. Progressing from the tunnel portal at the Outlet, concrete lining of the tunnel will be carried out as two separate and distinct linear operations, namely, an invert concreting operation, following behind the TBM, and an arch concreting operation following behind the invert operation.

**Invert concreting operation**

The invert concreting operation will be carried out from an approximately 190 m long 'bridging' type gantry structure (Figure 7) that will include raised vehicle parking/passing platforms at either end.



The equipment 'train' will allow for surface profiling and preparation, membrane installation and staggered two 12.5-m long invert concrete pours per day while allowing vehicle traffic to/from the TBM to pass by way of the overhead bridge. Peak advance rates of 25 m/d are expected. The invert forms are currently being assembled on site and concreting is expected to begin in the summer of 2008.

**Arch concreting operation**

Similar to the invert, the arch concreting operation will be carried out from a 350 m long gantry structure. This equipment 'train' is designed to achieve advances of up to 25 m/d (two 12.5 m pours) while allowing for vehicle access to/from the invert concreting and TBM operations.

Strabag is currently forecasting project substantial completion in 2011.

*Figure 7: Invert Concreting Gantry Structure*

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Photographs courtesy Ontario Power Generation Inc.

# Galore Creek Mine Project – Construction Halted on 4.5 km Mine Access Tunnel

*By Dean Brox, Hatch Mott MacDonald*

In November 2007 construction was halted on the entire Galore Creek Mine Project due to escalating construction costs. This included suspending the works on the 4.5 km mine access tunnel that commenced in June 2007.

The Galore Creek Mine project is one of the newest major mining projects in Canada located in a remote area of northwestern British Columbia that is virtually surrounded by glacier covered mountains. The mine project comprises one of the largest and highest grade undeveloped porphyry-related gold-silver-copper deposits in North America that is being developed by NovaGold Resources and Teck-Cominco of Vancouver.

The mine access tunnel was to provide access to the mine property and was located at the end of a 120 km access road to the site. The mine access tunnel was designed to allow the transport of large mining equipment during mine construction and operations. The mine access tunnel started construction in June 2007 by a joint venture of EBC and Neilsen of Montreal and works completed before the project shutdown was announced included portal excavation, driving of the 30 m starter tunnel segment of the 8 m wide main tunnel, and the installation and backfilling of the 65 m long, 9 m diameter avalanche protection canopy at the North Portal. No works were started at the South Portal.

All other construction contracts of the mine development including two major road contracts were also terminated. Most of the project construction was underway with helicopter support due to the remote location of the site and costs associated with air support using the world's largest helicopter, the Mi26 from Russia, contributed significantly to escalating cost overruns of the project.

Further studies are now underway to look at reducing project costs and include one option that contemplates a 12 km conveyor and transport tunnel.


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