The net positive socioeconomic impacts of a rapid transit system in the City of Winnipeg are considerable: increased ridership, reduction of greenhouse gases/air pollutants, improved access to downtown, transit oriented development opportunities and redevelopment of railway lands. The City of Winnipeg included implementation of rapid transit as part of their mandate recognizing that innovative and proactive transportation solutions are fundamental to supporting Winnipeg's current and future prosperity in an economically, socially, and environmentally sustainable manner. Studies examining several alternative rapid transit systems to link the suburbs with the downtown core concluded the most appropriate system for Winnipeg should be developed around grade separated dedicated rapid bus routes that would be on or adjacent to existing railway corridors. In actuality, this meant that a new grade separated transit only road had to be shoehorned into an extensively developed urban setting with pre-existing sewers, utilities, buildings, and most notably, railway tracks.

While the southern portion of the transitway was able to run parallel to CN's railway tracks, there just wasn't enough room to do so for the entire length of the corridor. At some point, the Southwest Transitway had to cross CN's seven rail lines. After an extensive evaluation of alternatives for the City of Winnipeg, including an overpass, Dillon ultimately recommended routing the transit route under the multiple CN Rail tracks due to restricted space within the rail yard, private property constraints, inappropriate site conditions, and cost. This was achieved through the design of a 200 m long cast-in-place concrete, structurally shored dedicated transit-only tunnel. The tunnel design not only works within the aforementioned limitations, but it accommodates the possible future conversion to light rail transit. To assess risk and ensure the most economical and cost effective solutions were provided to the City, Dillon facilitated an independent review in a Value Engineering exercise led by specialists within the engineering and construction community.

Although an open cut excavation for the tunnel required closure of one or more rail tracks at various times throughout construction, a structurally shored open cut alternative with cast-in-place construction was recommended on the basis of simplicity and more robust resistance to water penetration. The client's need for no center supports within the tunnel drove the development of a unique detailed and exclusive reinforcing design at the interface wall, which included using embedded structural steel sections in place of conventional reinforcing. The provision of a closed tunnel was driven by geotechnical issues resulting in the potential for uplift of the base slab. Due to the site constraints mentioned earlier, the tunnel crossed underneath the tracks at a significant skew angle rather than perpendicularly, which complicated design, construction and staging.

Complete closure of all seven tracks for the duration of construction was obviously unacceptable for the railway owners, so construction was sequenced in order to maintain a level of service across the site that was acceptable to CN and VIA Rail. Needless to say, construction staging was extremely intricate. A minimum of four operational tracks were required at any one time: two mainline CN tracks, one track for yard use, and one line for VIA Rail access. During the first stage of construction, CN track diversions were built to the east of the existing rail lines. Once complete and the trains were switched over to the detour, construction of the north half of the tunnel commenced. Following this, a new temporary track detour was built to the west and the rail traffic was switched over again so that the south half of the tunnel could be constructed. In the final stage, the permanent alignment of the rail tracks was finished.

To ensure success during construction of the tunnel structure, the design team had to address and coordinate the installation of gravity sewers, demolition and removals of various encroachments, groundwater depressurization, groundwater dewatering, and most importantly, installation and removal of the shoring system necessary to construct the tunnel. The large skew angle in combination with the depth of excavation required, close proximity of the CN rail tracks, and the tight site constraints presented a challenge for the designers of the temporary shoring that was necessary to build the structure. The contractor, together with Dillon, devised a shoring system that included sheet piling located on three sides of the tunnel structure and struts that spanned between the sheet piles. Sheet piling installations commenced first, with excavation and strut installation staggered at equal intervals throughout the shoring structure to ensure maximum support and containment. The major advantages of this superior structural shoring design were the lack of vertical obstacles, which permitted continuous unobstructed work and increased safety. Dillon's temporary shoring design was essential to completing construction of the tunnel within the City of Winnipeg's allotted schedule.

Aside from the scheduling difficulties that resulted from the constrained construction site, contract administration and coordination was also complicated by other Southwest Transitway contracts, such as the pump station and roadways, that bordered the tunneland were being constructed simultaneously and. The cooperation of all contractors was imperative to meet the tight timeline for the completion of the overall project. Furthermore, dedication from all external stakeholders was required including local businesses and VIA Rail. However, most critical to meeting the project schedule was collaborating with CN.

As a condition of working within the CN right-of-way, the contractor was required to follow stringent protocols and regulations dictated by CN. As the contract administrator, Dillon enforced compliance and was the liaison to CN management to ensure their needs were being met. CN flagging was required for the duration of the project and at times required 24 hour flagging was required to accommodate the contractor's schedule. Construction work near the tracks had to cease whenever a train was passing, therefore work stoppages and the duration of delayed work were significant. Dillon's vigilant re-assessment of schedule and work activities, as well as constant communication with CN to coordinate construction around train movement, was vital to minimizing the impact to CN's operations.

In accordance with Dillon's Quality Management System, a Technical Review Partner was assigned to the project to ensure that wise counsel was available and a senior review was carried out. To accommodate this, the project work was reviewed to confirm that the solutions provided satisfied the City's objectives while meeting professional, regulatory, and societal requirements. Stringent financial controls were maintained by Dillon throughout the project and the City was provided with monthly progress reports for review and discussion. Submitted budget updates included not only contract administration costs, contractor progress payments and change in work orders, but also tracked ancillary costs such as utility relocations and other expenditures. This facilitated frequent evaluation of the overall project budget versus construction progress. The final construction cost of $34 M was within the expected budget estimate and was completed on schedule.

The Southwest Transitway project is a demonstration of the application of pure project management principles with the defined need, critical deadline and solution created in collaboration with the City, Dillon and CN. The implementation of a segregated busway for the southwest area of the City will not only improve the performance of the overall transit system, but will also improve the time savings of transit versus automobile-based travel. By making driving a car an option instead of a necessity, Dillon's design and contract administration for construction of the Southwest Transitway will help reduce the need for vehicle parking lots and extensive road widenings, helping to keep our City green. Attracting transit oriented development along the Southwest Transitway will allow Winnipeg to continue to grow and become more economically prosperous without experiencing the pollution, traffic congestion, reduced land values and other problems typically experienced in auto-oriented communities.

CCE AWARDS OF EXCELLENCE IN CONSULTING ENGINEERING

PROJECT DESCRIPTION

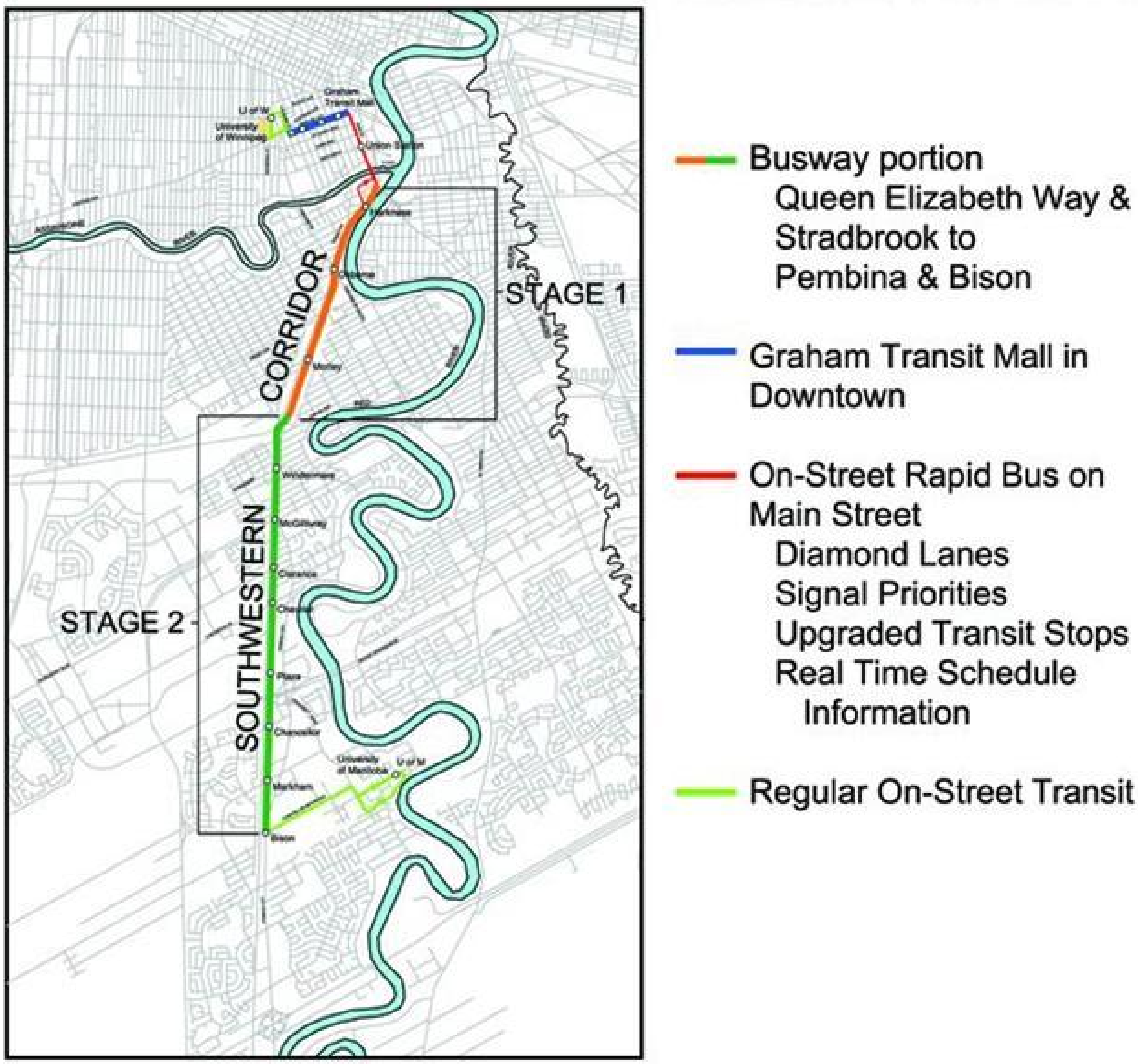
NAME: SOUTHWEST TRANSITWAY TUNNEL
CLIENT: CITY OF WINNIPEG – TRANSIT DEPARTMENT
FIRM: DILLON CONSULTING LIMITED

1 PROJECT BACKGROUND

Home to more than 740,000 people, Winnipeg is growing at a pace we have not seen in several decades. Even as this growth presents challenges, it requires innovative and proactive transportation solutions to support Winnipeg's current and future prosperity in an economically, socially, and environmentally sustainable manner. Rapid transit is needed to ensure that residents are provided with a viable alternative to the automobile, to reduce existing and future road congestion thereby reducing our ecological footprint, and to build a transportation system that is capable of serving future generations.

Mass transit within the City of Winnipeg was initially comprised solely of on-street bus service. To enhance this system, "Transit Quality Corridors" were developed that included features such as diamond lanes, queue jump lanes and transit priority signals, and modern technology was implemented to provide real-time passenger information tools. While this integrated set of improvements improved transit service through speed, reliability, comfort, accessibility, and information, it was simply the forerunner to Winnipeg's first leg of bus rapid transit, the Southwest Transitway. The inclusion of rapid transit in Winnipeg's transit improvement program was necessary since only rapid transit, with its high levels of service frequency and absence of congestion delays, can make public transit fast and convenient enough to compete with the private automobile.

Since the early 1970's, the City of Winnipeg has contemplated a rapid transit system to link the suburbs with the downtown core. Of the alternative systems examined, including subways, monorails, heavy rail vehicles, light rail vehicles, and dedicated rapid bus routes, studies concluded that the most appropriate system for Winnipeg should be developed around dedicated rapid bus routes that would be on or adjacent to existing railway corridors. As a first phase of the Southwest Transitway, Stage 1 links downtown Winnipeg to major destinations in the southwest part of the city on an exclusive right-of-way. For those people familiar with Winnipeg, this corridor starts at Jubilee Avenue at the southern limit and is bounded by Argue Avenue to the east and Fort Rouge Yards to the west. It continues north between the City of Winnipeg Transit Base and VIA Rail maintenance facility, crosses under CN's rail mainline, and parallels the mainline on the west side up to its northern limit at Queen Elizabeth Way.



The alignment along this corridor allows transit buses to bypass traffic congestion on the street system, reducing travel times along the corridor by allowing buses to travel up to 80km/h between stations on an exclusive grade-separated transitway, not only improving the performance of the transit system but also improving the time savings of transit versus automobile-based travel. The latter is of key importance as time savings will more readily encourage mode shift from car drivers to transit users, thus easing congestion and reducing emissions. This initial phase of the Southwest Transitway provides Winnipeggers with fast reliable access to Downtown and University of Winnipeg, as well as opens up areas of land in neighbourhoods in southwest Winnipeg for economic and urban development opportunities. The long-term intention is to continue with Stage 2 of the Southwest Transitway in a southerly direction to provide access to the University of Manitoba and new Winnipeg Blue Bombers football stadium.

2 PROJECT SCOPE

Dillon's initial scope of work for Stage 1 of the Southwest Transitway included the technology review, preliminary design, functional design, detailed design, operational review, and public outreach program. Based on Dillon's design, tri-level funding was secured and construction of Stage 1 of the Southwest Transitway commenced in 2008. Over the following 3.5 years, Dillon provided contract administration and program management services for the construction of this $138 million project, which included the following:

- 3.6 km of roadway
- 2.5 km of land drainage sewer
- A land drainage pump station for the tunnel underpass
- A 350 m designated transit-only tunnel underpass of seven CN tracks
- 100 m overpass crossing Osborne Street
- Three major transit stations
- Overall project aesthetics and landscaping

Of the many challenges posed in this multidisciplinary project, the greatest achievement was designing a two-lane tunnel structure to cross under the seven CN railway tracks that would: have a minimal impact to CN rail traffic operations; work within stringent property constraints; and enable construction to be completed within two years. The resulting design is a 200 m long cast-in-place concrete, structurally shored tunnel including 150 m of retaining/wing walls, complicated by three phases of CN track relocation, two phases of tunnel construction and a 67 degree skew at the construction joint. The tunnel design not only works within the aforementioned limitations, but it accommodates the possible future conversion to light rail transit, taking into consideration vertical clearances/track integration; right-of-way geometry and grades; structural loading; trunk storm sewers; and utility accommodations.

In order to complete the tunnel construction works within two years, CN's railway tracks were relocated in three separate phases and the tunnel itself was constructed over two stages. Construction of the tunnel, which is the focus of this submission, commenced in 2009 and was completed in November 2011. The following sections feature the geometric design constraints encountered by the project team and expounds on the challenges faced during construction. Moreover, it illustrates the innovative solutions applied and highlights the resulting successes.

3 LOCATION CONSTRAINTS

In the simplest of terms, the Southwest Transitway was basically shoe-horned into an extensively developed urban setting with pre-existing sewers, utilities, buildings, and most notably, railway tracks. While the southern portion of the transitway was able to run parallel to CN's railway tracks, there just wasn't enough room to do so for the entire length of the corridor. At some point, the Southwest Transitway had to cross seven rail lines. After an extensive evaluation of alternatives, including an overpass and tunnel boring, routing the transit route under the multiple CN rail tracks at the Fort Rouge Yards was ultimately recommended. This was achieved through a dedicated transit-only tunnel.

The alignment and elevation of the tunnel underpass was determined by several factors including restricted space within the rail yard, private property constraints, inappropriate site conditions, and cost. Some of the site constraints include:

- Proximity to the proposed Osborne Street Overpass.
- The vertical clearance required over Osborne Street and under the rail yard tracks.
- Proximity of the Hydro Substation and adjacent back lane.
- Encroachment onto Pembina Dodge, a local car dealership's private property.
- Proximity of the Quintex building and operational concerns within their property.
- Encroachment onto the MTS Call Centre property.
- Proximity to the Osborne Transit Base as well as access to this facility.
- Existing utilities including a combined sewer line that exists within the tunnel footprint.

4 DETAILED DESIGN

Aside from the obvious impact to CN, many other stakeholders were affected and consequently consulted during the final tunnel design process to ensure a comprehensive solution was reached. This included the Active Transportation Advisory Committee, numerous City Departments, and the multitude of utilities affected by construction. An independent review was also conducted in a Value Engineering exercise led by specialists within the engineering and construction community confirming the most economical and cost effective solutions were applied.

As mentioned previously, several structural alternatives were initially considered but were soon eliminated due to a number of factors. Open cut excavation required closure of one or more rail tracks at various times throughout construction; however, a structurally shored open cut alternative with cast-in-place construction was recommended on the basis of simplicity and more robust resistance to water penetration.

Due to the property constraints mentioned earlier, the tunnel intersects the tracks at a very large skew angle. This skew made avoiding interference with the tracks during construction much more difficult than if the crossing was aligned perpendicular to the tracks. A detailed description of the tunnel design follows.

Foundation – Originally, the foundation was to consist of driven precast piles supporting each side of the tunnel independently, with a simple slab-on-grade forming the roadway surface. However, the geotechnical analysis of this arrangement showed the potential for uplift below the roadway slab caused by the heavy train loads applied behind the tunnel walls on each side. As a result, the structure was revised to be a closed box structure, with the roadway slab becoming structural and forming the bottom of the section.

Roof Slab – The tunnel has an inside width of 10.9 m, providing two lanes of traffic and generous shoulders on each side. A tunnel of this width would often have a line of supports running down the center but for operational and safety reasons, the client requested that the tunnel be kept free of interior supports requiring an innovative structural design. As a result, the roof slab is up to 1500 mm thick, reducing to 900 mm at the portal areas. The roof slab is normally reinforced, with up to three closely-spaced layers of 35M bars required in critical areas of the tunnel. The critical areas are not the deepest parts of the tunnel but the areas to each side; although the deeper sections of the tunnel carry more soil, this extra depth of soil also serves to better distribute the weight of the trains overhead. As a result, the transition areas – where the soil depth is reduced but the train loads remain constant – are the critical locations. To simplify reinforcement detailing, the roof slab is designed as a simple span, with hinges located at the top of each wall.

Floor Slab – The floor slab experiences similar loads to the roof slab, as all the vertical loads transferred down through the walls must be distributed into the soil below. As a result, the floor slab is also very massive, running to 1300 mm thick in some areas. The floor slab is not quite as thick as the roof slab because it has been designed to be continuous with the side walls. This was required due to the difficulty of designing a hinge at the bottom of the walls; a simple span design would have been preferred in order to simplify the reinforcement detailing.

Walls – The walls range from 900 mm to 1000 mm in thickness. Because of the fixity with the bottom slab, most of the reinforcement is required at the bottom of the outside face in order to carry moments transferred around the corner from the bottom slab. The walls were designed with temporary openings to allow the open excavation to be braced across during construction. After the bracing is removed, these openings will be sealed.

Waterproofing – Although the water table is some distance below the underside of the tunnel, a perched water table exists in the area just below the ground surface. As a result, waterproofing of the tunnel is an important consideration. The main waterproofing system is a bituminous waterproofing membrane installed over the top of the roof slab, down both walls, and extending to the outside edge of the bottom slab. The bottom slab inside the tunnel is protected from roadway runoff by a similar membrane. In addition to the membrane, construction joints are protected by two levels of waterstop protection – a continuous polyvinyl strip located at the outside face of the tunnel and a hydrophilic waterstop (bentonite) located within the concrete itself – along the route that water would have to follow from the exterior surface to the interior of the tunnel.

Drainage – The tunnel is built on a sag curve, so the low point in the tunnel clearly requires positive drainage measures. A double catch basin is provided at this point to accept water into the newly constructed land drainage system. As the base of the tunnel is below the elevation of the surrounding land drainage system, a dedicated lift station is required to take storm water from the tunnel and pump it high enough to join into the existing system under gravity flow. This land drainage lift station was constructed prior to the tunnel project.

Corrosion Protection – To minimize future corrosion potential, all reinforcement in the tunnel is hot-dip galvanized after fabrication.

5 CONSTRUCTION STAGING

One of the main challenges of this project was the coordination and phasing between the tunnel structure and CN Rail. Complete closure of all seven tracks for the duration of the construction was obviously unacceptable for CN, so construction was staged in order to maintain the required level of service across the site. Tracks that could not be eliminated entirely for the necessary time were relocated by providing additional switches on each side of the busway disruption in order to shift the rail traffic from the closed track(s) onto adjacent tracks that remained unaffected. A minimum of four operational tracks were required at any one time: two mainline tracks, one line for VIA Rail access, and one track for yard use.

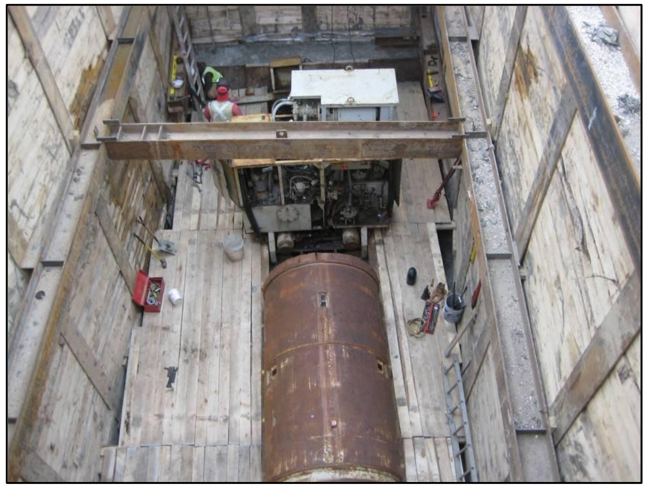
Construction staging was extremely intricate. The main objective was to maintain rail traffic with minimal impact to CN's operations, so construction of the tunnel and the overall staging plan was designed and implemented to best fit CN's and the City of Winnipeg's requirements. The basic overview of the construction sequence is explained below.

- Phase 1 CN Track Detours – CN's tracks were reduced on the mainline and moved eastward towards VIA Rail to allow the Stage 1 Tunnel Structure to be constructed.
- Stage 1 Tunnel Structure – Construction of the first stage of the tunnel structure.
- Phase 2 CN Track Detours – Once Stage 1 Tunnel Structure has been complete, the tracks were relocated westward, running over the recently completed tunnel structure.
- Stage 2 Tunnel Structure – Continuation from Stage 1 Tunnel Structure to the completion of the construction of the tunnel.
- Phase 3 CN Track Relocation – Once Stage 2 Tunnel Structure is complete, CN tracks will be relocated and additional tracks will be added similar to the original CN track alignment. CN tracks will be relocated back to their pre-construction location to run over the completed tunnel structure.

Note that due to the specialized nature of the CN track detours, the three phases of track relocation were tendered separately from the tunnel construction and are, therefore, not described in detail.

6 CONSTRUCTION COMPLEXITY

The tunnel structure had several factors that needed to be addressed and coordinated in order to ensure success during construction. The major components of the overall scope of work are as follows:



Installation of Gravity Sewers – The land drainage sewer system was installed in two stages which were in conjunction with Stage 1 and Stage 2 of the tunnel structure. These gravity sewers tied into a new land drainage pump station, which discharged run-off from the tunnel during rainfall events to an existing sewer outfall. As the tunnel construction was staged, the installation of the sewer system also needed to be staged. This presented a challenge as drainage during construction had to be addressed in rainfall events. As a result, pumping occurred through the course of construction until the connections had been made to the pump station during the final stage of tunnel construction.

Demolition and Removals – Demolitions were required on and off CN property. Existing buildings, partial removal of parking lots, light pole standards, etc. are examples of the overall work that was required for the completion of construction.

Groundwater Depressurization – Prior to the installation of the shoring, the Contractor was required to have the groundwater depressurization system in place. The work consisted of the installation, operation and decommissioning of the groundwater depressurization system. This system was designed to lower the groundwater pressure within the upper carbonate bedrock aquifer. This system protected against hydraulic fracturing, improved stability, and prevented seepage at the base of the excavation and construction of the tunnel structure.

Dewatering – To ensure protection of the shoring and tunnel works during the duration of the contract, the Contractor was required to have the construction of the dewatering system in place prior to construction.

Installation and Removal of the Shoring System – Due to the depth of excavation required, close proximity of the CN rail tracks and the narrow constraints on site, a shoring system was required to be designed and implemented prior to the installation of the tunnel structure. The Contractor, together with Dillon, devised a shoring system that included sheet piling located on three sides of the tunnel structure and struts that spanned between the sheet piles. Sheet piling installations commenced first, with excavation and strut installation staggering at equal intervals throughout the shoring structure to ensure maximum support and containment. The benefits of this design are the lack of vertical obstacles allowing for more continuous unobstructed work and increased safety.

The removal of the shoring system was staggered with the construction of the structural works of the tunnel. The tunnel structure was required to be constructed to a certain elevation and backfill in place prior to the removal of the struts. After the tunnel structure was constructed and backfilled, the majority of the sheet piling was removed.

Excavation – The Contractor was required to perform open and supported excavations throughout the construction of the tunnel structure. This excavation was time consuming and difficult due to the complicated shoring that was required because of the close proximity of CN tracks, as well as Pembina Dodge and Quintex properties. Excavation needed to be carried out in stages and with smaller equipment so that critical shoring struts could remain in place to support the shoring. It was critical that the Contractor was to maintain conditions and protection of the CN railway tracks and ensure that work activities did not at any time jeopardize the stability or impact the performance of the tracks.

Structural Works – This included the placement of the working base, reinforcing steel, structural concrete, waterproofing protection, and installation of subdrain system for maximum drainage.

Architectural and Electrical Works – This included the placement of tile throughout the entrance retaining walls of the tunnel structure, the placement of paint on the ceiling of the tunnel, and the lighting required in the tunnel. The majority of the tile and the ceiling were white in color to maximize light reflectivity therefore reducing the requirements for lighting in the tunnel.

Interface Wall – One of the main concerns during the pre-design was the transition of the construction sequencing between Stage 1 and Stage 2 structures. This area is called the interface wall. As a result, several solutions were incorporated into Stage 1 of the design.

The design included construction of a temporary reinforced concrete wall located inside the tunnel structure at the interface. This temporary wall not only had to meet the design criteria of supporting the tunnel roof structure and train loading for Stage 1, its function was to also connect the shoring of both stages together. Another function of this temporary wall was to keep Stage 1 free of native clay prior to and while Stage 2 excavation commenced. Once the tunnel structure was fully constructed in both Stage 1 and Stage 2 cofferdam area, this temporary wall was removed.

Wing walls were constructed on both sides of the tunnel structure, which functioned to contain backfill from Stage 1 tunnel structure while constructing Stage 2 of the tunnel structure. The design also incorporated a reinforced concrete headwall located on top of the tunnel structure roof slab at the interface wall. The function of the headwall was to contain ballast from Phase 2 CN Track Detour when excavating in Stage 2 of the Tunnel Structure. This headwall was also constructed to be incorporated in the shoring installation in Stage 2.

7 PROJECT CHALLENGES

As typical for most construction projects, this project had challenges that required dedication from all parties to ensure the construction deadline was met and to ultimately ensure success. Challenges encountered and resulting successes include the following:

CN Rail – Working in the CN right-of-way, the Contractor was required to abide by all CN rules and regulations. CN flagging was required for the duration of the project and at times required 24 hour flagging to accommodate the Contractor's schedule. The Contractor and Dillon worked closely with CN to coordinate construction around train movement with minimal impact to CN's operations.

Local Businesses – All efforts were taken to minimize construction activity that could interfere with local business operations. The Contractor periodically scheduled work after business operation hours and on weekends to minimize disturbance. Conversely, the Contractor at times reduced or eliminated night work due to noise concerns.

Overall Construction Limits – The construction limits for each stage was a challenge due to the large footprint of the proposed tunnel and the limited area in which the work could take place. Thus, the Contractor was required to stage construction to minimize congestion of equipment and trades. To gain a further understanding of the structure limits and the overall site, limits were as follows:

- Total Site Area for Stage 1 = 8000 m^2
- Total Construction Area for Stage 1 = 2500 m^2
- Total Site Area for Stage 2 = 13000 m^2
- Total Construction Area for Stage 2 = 4000 m^2

Working with Others – One of the challenges on site was not only the overall constraints of the size of the construction limits, but other related contracts were being constructed consecutively that could potentially impact the tunnel structure. These contracts were the Roadwork, Overpass Structure and the Rail Relocation. The Contractor had to be flexible and at times share the site with other Contractors. The communication and coordination between Dillon's various Contract Administrators was imperative and the cooperation of all Contractors was necessary in order to meet the tight timeline for the completion of the overall project.

Site Conditions – Further complicating the completion of the five construction stages was Winnipeg's harsh winter temperatures, as many construction activities could not be completed during the winter months. Construction schedules had to be managed very carefully with constant re-evaluation of overall construction progress versus target completion dates. This allowed Dillon and the City to anticipate issues and address them before they occurred, rather than reacting after issues arose.

8 PROJECT SUMMARY

Dillon understands that successful transportation projects require more than just good technical solutions – they must be sustainable economically, socially, and environmentally. Winnipeg's first leg of the rapid transit system is expected to have net positive socioeconomic impacts in terms of increased ridership, greenhouse gas reductions, redevelopment of railway lands, improved access to downtown, and development opportunities. Although faced with extraordinary challenges of site, location, hazardous construction conditions, and rapid construction time frame, Dillon's unique mix of design ingenuity, technology and equipment facilitated the successful culmination of the most challenging aspect of Stage 1 of the Southwest Rapid Transit Corridor, the tunnel. The project is a demonstration of the application of pure project management principles with the defined need, critical deadline and solution created in collaboration with the City, Dillon and CN.