Ministry of
Transportation
and Infrastructure

M E M O R A N D U M

January 6, 2020

George Massey Crossing Project
Technical Analysis Summary and Next Steps

Purpose of this cover memo:
This cover memo, prepared by the Ministry of Transportation and Infrastructure's George Massey Crossing Project Team, accompanies and provides context for the technical report prepared by COWI/Stantec: *Technical Services For George Massey Crossing Project* (December 2019).

Purpose of the technical report:
The attached technical report was prepared in support of the consultation with Metro Vancouver's George Massey Project Task Force and as reference material for discussions with other parties.

This report does not make recommendations to the Ministry of Transportation and Infrastructure, nor does it represent the extent of analysis that will be undertaken by the Ministry to complete the business case for the George Massey Crossing Project.

Technical Work Program:
The Ministry retained COWI/Stantec to provide technical services for the George Massey Crossing Project in July 2019. COWI/Stantec's primary task was to provide feasibility level technical services and conceptual designs to support the work with Metro Vancouver Task Forces, and to analyze potential options for the replacement of the existing George Massey Tunnel under the Fraser River. The Ministry also used COWI/Stantec's findings to support discussions with participating First Nations, TransLink, adjacent Fraser River communities, and key stakeholders.

COWI/Stantec developed and refined a range of technical work including traffic modelling and analysis, structural and highway design, geotechnical and hydrotechnical analysis, preliminary environmental review, and high-level cost estimating. COWI/Stantec also compared their findings with the conclusions of the *Independent Technical Review of the George Massey Crossing* (Westmar Advisors 2018).

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The results of COWI/Stantec's work were summarized and compiled between November and December 2019 to document the extent of the work conducted as well as the findings. The Ministry notes the following with respect to the COWI/Stantec technical report:

- The level of traffic modelling and roadway design was sufficient to support a high-level comparison of options and related interchange connections, including proving the feasibility of various crossing options. Additional modelling will be required, including micro-simulations, to develop reference concepts for the business case.
- The scope of the environmental analysis was limited to confirming environmental indicators and a comparative risk assessment. Therefore, the Ministry also commissioned a separate, more detailed environmental review of the options to support the multiple account evaluation. The report, *Environmental Input to GMC Multiple Accounts Evaluation* (Hemmera 2019), is available under a separate cover. The extent of the environmental analysis and mitigation will be prescribed by the Environmental Assessment Office once an application is submitted for an Environmental Assessment Certificate.
- Order of magnitude cost estimates were developed to support the comparative analysis of options. More detailed cost estimates are now being developed to support business case development in 2020.

Summary of Findings:
While the purpose of the technical report was to support the Metro Vancouver Task Force in selecting their preferred option, the Ministry's Project team did draw the following conclusions from the analysis:

- The relative cost, constructability, and environmental risk of a deep bored tunnel renders it unsuitable for consideration as a long-term solution for the George Massey Crossing.
- While the long- and short-term environmental effects of a long span cable bridge and an immersed tube tunnel differ, these effects can be managed through best practice environmental offsets, and enhancements, which will be explored in more depth in the coming months.
- Improving transit services and reliability remains a top priority for the new crossing. Expanding transit lanes on, and leading to, the new crossing will increase people-carrying capacity across the Fraser River. This combined with TransLink's potential support to provide rapid transit service and increase transit frequency should increase ridership, and it will also align with the region's desired shift to sustainable modes.
- Dedicated pedestrian and cyclist facilities provide an important incentive for active transportation, and users are better served if these facilities are in/on the new crossing.

- The benefits of retaining the existing tunnel for traffic over the long term are limited. Additionally, the costs associated with seismic upgrades to retain the existing tunnel for this purpose would be more expensive than the all-new infrastructure options. As such, the existing tunnel should be retained for utilities only.

Actions and Next Steps:
The Metro Vancouver Board's decision to endorse an eight-lane immersed tube tunnel as Metro Vancouver's preferred solution for upcoming public engagement was based on the Metro Vancouver Task Force's discussions with the Ministry's Project Team and the COWI/Stantec analysis.

The Ministry will take the COWI/Stantec analysis and engagement with participating parties into consideration when identifying a preferred option; however, additional technical analysis and ongoing engagement with First Nations, federal, regional and municipal governments, stakeholders, and the public remains to be completed in the coming months. The Ministry is in the process of preparing a full business case by fall 2020.

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TECHNICAL SERVICES FOR GEORGE MASSEY CROSSING PROJECT

FINAL REPORT
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EXECUTIVE SUMMARY

Introduction

The George Massey tunnel, constructed between 1957 and 1959, is a 630-meter long immersed tube tunnel (ITT) crossing the Fraser River (Figure EXEC1). The tunnel design was considered state-of-the-art, and among the first pre-fabricated rectangular concrete tunnels in the world to be installed using immersed tube technology.

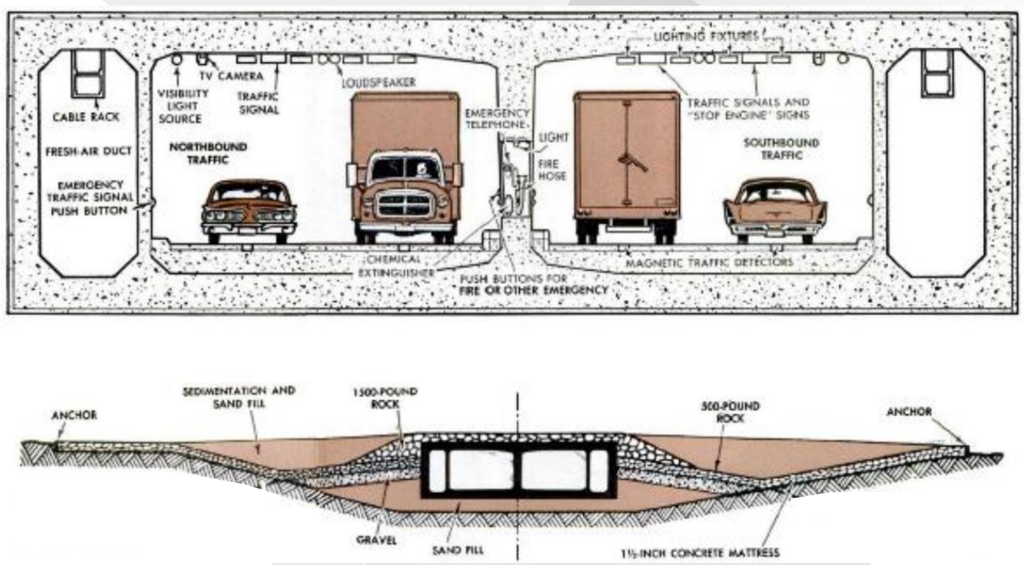

Figure EXEC1: Typical Cross Section of the George Massey Tunnel as originally constructed (extracted from Westmar Advisors, 2018)

Now 60 years old, the existing tunnel does not meet current highway design or seismic standards. Plans to develop a replacement crossing were first announced in 2012, and in 2015 the Province released a project definition report and business case for a 10-lane cable-stayed bridge with interchange and highway improvements to be funded by user tolls.

In response to concerns about the proposed project size and tolling, the Province commissioned an Independent Technical Review (Westmar Advisors, 2018), which concluded that there are other, less costly options for a replacement that would be more in keeping with regional plans. In December 2018, the Minister of Transportation and Infrastructure (the Ministry) committed to work with Indigenous Groups, Metro Vancouver, TransLink, and Fraser River communities to develop a new crossing solution that better aligns with regional plans.

Working with these groups, in May 2019, the Ministry project team reached consensus on principles, goals and objectives, and developed a long-list of 18 potential crossing options for a new crossing. The Metro Vancouver Board also established a Task Force of elected officials to support the Province in identifying and evaluating crossing options.

In early July 2019, the Ministry hired COWI North America Ltd. (COWI) to provide feasibility level technical services and conceptual level design services to define the technical elements of different crossing options, which the Ministry would use to support its work in short-listing options, and ultimately in selecting a preferred option. Stantec is a primary subconsultant to COWI, and the COWI-Stantec Team (CST) is supported by several subconsultants. CST provided the following technical expertise and support to the Ministry:

- Bored tunnel engineering;
- Immersed tube tunnel engineering;
- Long span bridge engineering;
- Highway design engineering;
- Geotechnical engineering;
- Travel demand forecasting;
- High level transportation modeling;
- Multi-modal transportation planning;
- Traffic and safety engineering;
- Review of existing tunnel;
- Hydrotechnical engineering;
- Environmental services;
- Option review/refinement;
- Renderings; and
- Cost estimating.

The COWI-Stantec Team's work was completed between July and December 2019.

Objectives

The primary objectives of the COWI-Stantec Team's assignment were to:

- Provide recognized subject matter expertise for each of the technologies considered (deep bored tunnel, immersed tube tunnel and long span bridge);

- Complete factual and unbiased technical evaluations and conceptual level designs for the various crossing options; and,

- Prepare a detailed summary report of the work completed to support the future business case for a new crossing solution.

Technical Analysis and Design Process

Soon after the COWI-Stantec Team started on the project, the Ministry met with the Metro Vancouver Task Force, and reduced the long-list of eighteen options to a short-list of six options. As a result, CST's efforts primarily focused on the six short-list options which comprised the following:

- **New eight-lane bored tunnel**, plus MUPs in existing tunnel;

- **New six-lane bored tunnel**, plus two traffic lanes and multi-use paths (MUPs) in existing tunnel;
- **New eight-lane immersed tube tunnel**, plus MUPs in new or existing tunnel;
- **New six-lane immersed tube tunnel**, plus two traffic lanes and MUPs in existing tunnel;
- **New eight-lane bridge** with MUPs; and,
- **New six-lane bridge**, plus two traffic lanes and MUPs in existing tunnel.

All six options included allocation of two lanes dedicated for transit (one in each direction).

The Project extent for CST's work included the crossing of the Fraser River, extending from the Steveston Interchange to the Highway 17A interchange. It is also noted that the Ministry is considering interim improvements at the Steveston Highway and Highway 17A interchanges and these improvements were incorporated in the design where applicable.

Given the importance of transit on the Highway 99 corridor, the Ministry asked CST to assess the expected transit travel time for each of the short-listed options. CST found that transit travel time would increase if the existing tunnel was used as a dedicated transit facility, primarily due to the added travel distance. Based on this assessment and discussions with TransLink and the Mayors Task Force, options that use the existing tunnel for vehicle traffic were dropped and the Ministry instructed the COWI-Stantec Team focus on the options with all eight lanes on the new structure.

Eight-Lane Deep Bored Tunnel (DBT)

The need to accommodate up to eight lanes of traffic resulted in a twin bore cross section with a stacked roadway arrangement (there would be two lanes on the top deck and two lanes on the bottom deck in each of the two bores). Given the depth and length of the DBT, pedestrian and cyclist traffic would be accommodated in the existing tunnel.

A cross section of the Eight-Lane DBT, including the existing tunnel use, is shown in Figure EXEC2.

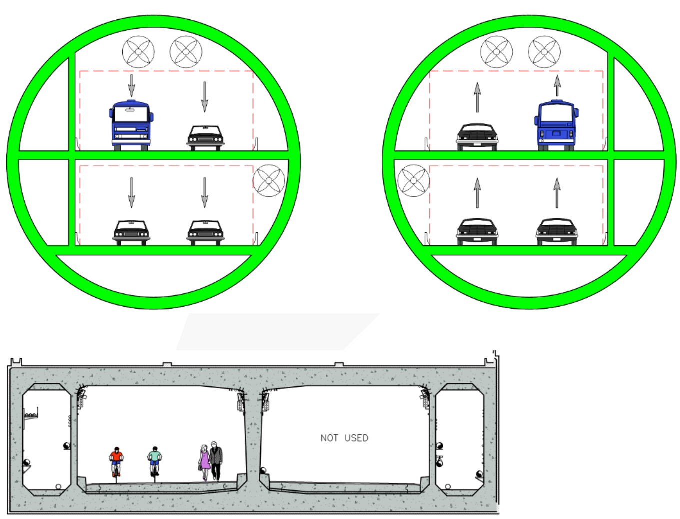

Figure EXEC2: Cross Section of Deep Bored Tunnel Option (Including Existing Tunnel for MUPs)

Based on Ministry lane and shoulder width requirements, CST confirmed that an 18.5 m outside diameter bore would be required to accommodate four lanes of traffic and would be a world record if built (the current largest bored tunnel is the SR99 tunnel in Seattle, WA, which has a 17.5 m outside diameter).

Since the inside of the tunnel would be filled with air and the tunnel structure itself would be quite light, the DBT naturally wants to float. To prevent this, a significant amount of soil would be required on top of the tunnel. Therefore, the crown of the DBT would need to be approximately 60 m below the surface of the river. This results in a tunnel that would be approximately 4.4 km long (3.5 km between portals). Due to the length, the tunnel daylights past the Steveston Highway and Highway 17A interchanges, and therefore both interchanges would need to be replaced.

The entrance portals of the new tunnel were raised to an elevation of +4.38 m (approximately 2 m higher than the existing tunnel portals) to provide flood resiliency to the tunnel. It is possible that the Provincial Dike Authority may require additional height for this flood protection, but this could be accommodated readily if required.

A rendering of the twin bored, stacked roadway arrangement in the portal is shown in Figure EXEC3.

Figure EXEC3: Rendering of the Portal of the Eight-Lane Deep Bored Tunnel Option

There are several significant challenges associated with the DBT, including:

- Construction of the tunnel portals due to the depth needed for the Tunnel Boring Machines (TBM) to start boring.

- The need to un-stack the traffic at each end, as well as the need to direct traffic into the correct lanes to allow vehicles to exit onto Steveston Highway and Highway 17A. Despite best efforts, CST could not identify an easy way to accomplish this; the only viable option identified involved moving the entrances/exits from Steveston and Highway 17A away from the current intersections by approximately 1 km each to allow the traffic to weave into the correct lanes (without this, one level of the bore would be significantly over loaded). This solution is not considered practical, however a better option was not identified.

- The significant impacts to lands in the Agricultural Land Reserve and increased trip times for all users.

- The risk of developing sink holes during construction, especially under the Fraser River. Based on a review of 100 tunneling projects around the world, it was found that, on average, one sink hole occurs for every 1.32 km of tunnel constructed.

- Since the existing tunnel would be used for Pedestrians and Cyclists, the seismic upgrade of the existing tunnel would need to be completed as part of the DBT option.

<u>Eight-Lane Immersed Tube Tunnel (ITT)</u>

In order to accommodate eight lanes and two MUPs, the ITT cross section would need to be approximately 47 m wide. The cross section is shown in Figure EXEC4.

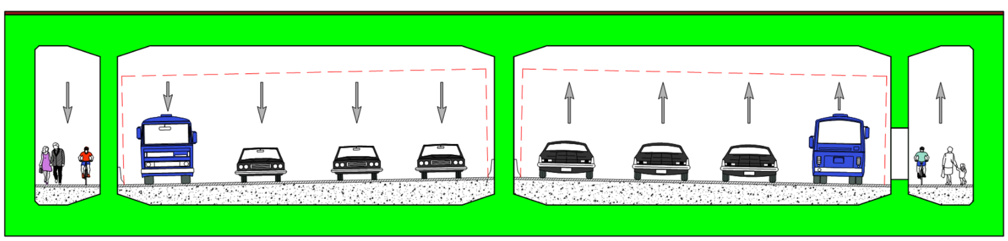

Figure EXEC4: Cross Section of Eight-Lane Immersed Tube Tunnel Option

The significant span of the roof and floor in the eight-lane option would require the use of post-tensioned concrete construction or the use of a double steel sandwich plate construction. CST completed preliminary designs for both and determined that the post-tensioned concrete option would likely be the most economical option, and therefore this option was carried forward.

An upstream alignment for the new ITT was selected for a number of reasons, including: minimizing property impacts; reducing concerns of increasing scour at the existing downstream GVRD water tunnel; and avoiding impacting the location of a future relocation of the BC Hydro transmission line if required (which would be downstream of the existing tunnel).

The new tunnel would be approximately 1 km long and approximately 3 m deeper than the existing tunnel. The distance between the new tunnel and the existing tunnel was chosen to be 42 m to allow a sloped trench to be excavated for the new tunnel without destabilizing the existing tunnel.

The entrance portals of the new tunnel were raised to an elevation of +4.38 m (approximately 2 m higher than the existing tunnel portals) to provide flood resiliency to the tunnel. It is possible that the Provincial Dike Authority may require additional height for this flood protection, but this could be accommodated readily if required.

A rendering of the entrance portal to the new eight-lane ITT is shown in Figure EXEC5.

Figure EXEC5: Rendering of Eight-Lane ITT Option

In addition to the new ITT, the Deas Slough bridge would be replaced with a new bridge. The slough was filled in for the original construction, so the existing bridge is relatively short. CST has assumed that the slough would not be filled in for the new crossing, and this results in a bridge that would be approximately 310 m long. CST has assumed that the vertical clearance under the new Deas Slough bridge would be the same as the clearance under the existing bridge.

Eight-Lane Long Span Bridge

The cross section of the main cable-stayed bridge would be approximately 43 m wide and is shown in Figure EXEC6.

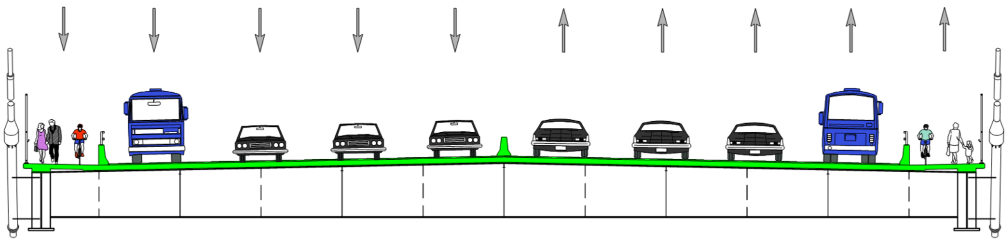

Figure EXEC6: Cross Section of Eight-Lane Bridge Option

Similar to the ITT options, an upstream alignment was selected for the bridge options. Initial designs included a clear-span main section across the Fraser River to avoid in-river impacts, and approach spans with piers on either side including across Deas Slough (Option 1 shown in Figure EXEC7). A subsequent refinement was developed to also avoid piers in Deas Slough by adding a second cable-stayed span (Option 2 shown in Figure EXEC8).

Figure EXEC7: Rendering of Eight-Lane Bridge Option 1

Figure EXEC8: Rendering of Eight-Lane Bridge Option 2

The distance between the edge of the bridge deck and the edge of the existing tunnel would be approximately 25 m. The clear span of the Fraser River crossing would be 650 m and the clear span of the Deas Slough crossing would be 380 m (Option 2).

The required shipping envelope was assumed to be the same as that required for the previous George Massey Tunnel Replacement project.

The Independent Technical Review (Westmar Advisors, December 2018) identified that cost savings could be achieved by shortening the cable-stayed bridge and placing the piers in the river. However, because the river piers would need to resist significant ship impact loads (assumed to be from a 60,000 DWT vessel), CST's analysis determined that there would be little, or no cost savings associated with shortening the cable-stayed bridge.

Traffic Analysis

The COWI-Stantec Team performed macro Regional Traffic Modelling (RTM) to estimate the traffic volumes on the road network around and on the George Massey Crossing. The time horizons investigated were 2017 (the baseline date of the RTM model), 2035, and 2050. All scenarios included recent updates to regional demographic forecasts as well as planned transportation system expansions/improvements for the appropriate time frame.

Today, the George Massey Tunnel carries approximately 85,000 vehicles per day on average, approximately 10% of which are trucks. Additionally, transit represents approximately 1% of the vehicle trips, but carries approximately 10% of the people at the crossing. During the year, daily traffic can vary anywhere from 79,000 vehicles per day during the fall and winter periods to over 92,000 vehicles per day during the summer periods. During the morning and afternoon rush hour periods when the counter-flow lanes are in effect, the tunnel carries approximately 5,000 vehicles per hour in the peak direction and approximately 1,500 vehicles per hour in the off-peak direction. Current demands are between 4,800 and 5,400 vehicles per hour in the peak direction and between 2000 and 2500 vehicles per hour in the off-peak direction. Since the demands are at or above what the tunnel can process, weekday vehicle queues and corresponding delays for cars and commercial vehicles can be significant in both directions during the morning and afternoon three-hour periods.

During weekday midday and evening periods, as well as on weekends, when the tunnel supports two travel lanes in each direction, traffic volumes are slightly below the capacity of the two-lane crossing contributing to some moderate delays, particularly when heavy commercial vehicles are most prominent.

Table EXEC1 shows the forecast 2035 and 2050 demands (veh/hr) assuming an eight-lane crossing with three GP lanes and one dedicated bus lane in each direction, along with current estimated peak hour demand for reference. The forecast volumes are effectively the same for all three technologies (Deep Bored Tunnel, Immersed Tube Tunnel, and Bridge). As illustrated, traffic demand during rush hour is projected to increase over the next 30 years.

Table EXEC1 – Current and expected peak hour demands (veh/hr)

Time Period	**Direction**	**Current Demand (2017 model)**	**2035 GMC Demand**	**2050 GMC Demand**
AM Peak Hour	NB	4880	5300	5570
	SB	2010	3280	3460
PM Peak Hour	NB	2470	3820	4050
	SB	5410	5960	6300

The planned eight-lane George Massey Crossing, including a dedicated bus-only lane in each direction, would support improved mobility for sustainable modes, goods movement as well as vehicular travel through:

- Dedicated bus-only lanes, which would support the existing two minute services in peak directions with increasing service levels and capacity through the introduction of double-decker buses over the next few years. Dedicated lanes would connect with bus-on-shoulder facilities both north and south of the existing crossing and would ultimately support increased ridership to/from South of Fraser communities;

- Dedicated pedestrian and cycling facilities between Richmond and Delta connecting into TransLink's Major Bike Network that serves urban centres across Metro Vancouver;

- Additional capacity serving off-peak directional travel as well as midday and weekend traffic, including commercial vehicles supporting regional, provincial and national trade corridors. The additional capacity for off-peak periods would be particularly important for summer periods when daily traffic is highest; and,

- Improved safety and incident management with active lane-management and improved responses.

The combination of removing buses from general traffic lanes, increased transit service, and moderate improvements in general purpose capacity due to wider travel lanes and improved safety would help improve travel time speed and reliability and reduce congestion. Continued improvement in transit service levels between South of Fraser and Richmond / Bridgeport Station also would be needed to further reduce congestion during these times, as is the case in other parts of the region, to provide attractive alternatives, manage demands and support regional and provincial goals for sustainable modes and climate action.

Additionally, improved utilization for the bus-only lanes could be considered through alternative lane designations (HOV/transit, auxiliary lanes) to avoid or minimize peak period queues in future. In this regard, technical strategies could be considered at subsequent stages of planning and design, to address some of the growth in vehicle queues while maintaining priorities for transit on the new crossing.

Estimated Costs

The COWI-Stantec Team developed estimated order of magnitude, total project costs for the eight-lane DBT, ITT, and Bridge options, which included construction cost, design cost, owner costs, property acquisition costs, environmental offsetting costs, escalation, interest during construction, and an allowance for risk and contingencies.

CST's estimated total project cost for each eight-lane option was as follows:

- **Deep Bored Tunnel:** between $12 and $17 billion.
- **Immersed Tube Tunnel:** between $4 and $5 billion.
- **Bridge:** between $3.5 and $4.5 billion.

The cost ranges allowed for relative comparisons between the various options as the project progressed but are not considered suitable for budgeting purposes.

Following the meeting the Ministry had with the Task Force on October 2, 2019, the Ministry requested that CST develop detailed project cost estimates for the eight-lane ITT option and the eight-lane Bridge option (for the purpose of the Bridge option, the Ministry requested that Option 2 be evaluated). These detailed cost estimates were not complete at the time of writing this report.

Estimated Design and Construction Schedule

The design schedule for all options is expected to be similar – all taking between one and two years. Depending on the procurement strategy, there is a possibility of overlapping the design schedule with the construction schedule (e.g. design-build or forms of early contractor involvement procurement methods).

The construction schedule for the options is expected to be as follows:

- **Deep Bored Tunnel:** approximately seven years (plus an extra year to seismically upgrade the existing tunnel after traffic is transferred to the new facility);
- **Immersed Tube Tunnel:** approximately five years (plus an extra year to close the portals of the existing tunnel and recommission it for utility only use); and,
- **Bridge:** approximately five years (plus an extra year to close the portals of the existing tunnel and recommission it for utility only use).

For the ITT options, work in the river is likely limited to a 6-month or 7-month work window each year. This imposes a schedule risk that would need to be considered since if the construction falls behind, critical path items could be delayed by 6 months, or even potentially a year.