

OCT 4 – 6, 2015 • Queens University • Kingston, ON Canada

*Challenges and Innovations in Tunnelling*

# Ottawa LRT Tunnel Construction Update

Tom Middlebrook, Humberto Ferrer  
DRAGADOS CANADA

Oct 5<sup>th</sup>, 2015

Tunnelling Association of Canada  
Association Canadienne Des Tunnels



# Agenda

Self Introduction

Dragados

Ottawa LRT Tunnel

Station Construction Techniques



Tom Middlebrook

Sr. Vice President, Business Development – Eastern Canada  
Dragados Canada

Previously...

MMM Group – Urban Mobility

MRC – Transit Consultant

Toronto Transit Commission – Chief Engineer

Smaller Construction Companies



# 2006

**Top Spanish contractor  
with sales over € 14 bn**

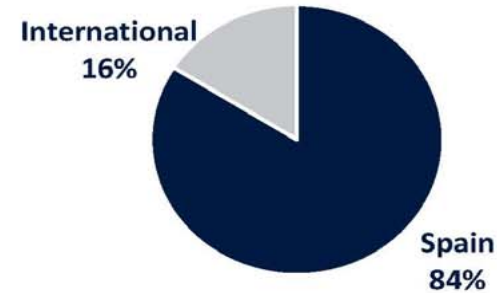
**Holding a portfolio of listed stakes in  
capital intensive industries**



**EBIT € 1.0 bn (margin 6.9%)**

**Net Debt € 8.7 bn**

**123,652 employees**



## The Top 225 International Contractors

(Based on Contracting Revenue from Projects Outside Home Country)

RANK	FIRM	2006 REVENUE (\$ MIL.)	
2007	2006	INTERNATIONAL	TOTAL
1	1 HOCHTIEF AG, Essen, Germany <sup>†</sup>	17,598.9	19,795.0
2	2 SKANSKA AB, Solna, Sweden <sup>†</sup>	12,347.1	15,722.2
3	3 VINCI, Rueil-Malmaison, France <sup>†</sup>	11,065.0	32,699.0
4	4 STRABAG SE, Vienna, Austria <sup>†</sup>	10,799.0	13,502.0
5	5 BOUYGUES, Paris, France <sup>†</sup>	9,576.0	24,960.0
6	7 BECHTEL, San Francisco, Calif., U.S.A. <sup>†</sup>	8,931.0	15,367.0
7	9 TECHNIP, Paris La Defense, France <sup>†</sup>	8,084.0	8,245.0
8	6 KBR, Houston, Texas, U.S.A. <sup>†</sup>	7,426.4	8,150.2
9	10 BILFINGER BERGER AG, Mannheim, Germany <sup>†</sup>	6,553.0	9,967.0
10	8 FLUOR CORP., Irving, Texas, U.S.A. <sup>†</sup>	6,338.5	11,273.7
11	11 ROYAL BAM GROUP NV, Bunnik, The Netherlands <sup>†</sup>	5,892.0	10,844.0
12	13 BOVIS LEND LEASE, Harrow, Middlesex, U.K. <sup>†</sup>	5,680.0	8,353.0
13	17 CONSOLIDATED CONTRACTORS INT'L CO., Athens, Greece <sup>†</sup>	3,941.2	3,941.2
14	45 CHINA COMMUNICATIONS CONSTRUCTION GROUP, Beijing, China <sup>†</sup>	3,380.7	14,734.4
15	15 JGC CORP., Yokohama, Japan	3,159.0	3,804.0
17 <sup>th</sup>	CHIYODA CORP., Yokohama, Japan <sup>†</sup>	3,053.0	3,517.0
	<b>GRUPO ACS, Madrid, Spain<sup>†</sup></b>	<b>3,004.0</b>	<b>18,526.6</b>
	CHINA STATE CONSTRUCTION ENG'G CORP., Beijing, China <sup>†</sup>	2,956.1	16,146.9
19	22 PCL CONSTRUCTION ENTERPRISES, Denver, Colo., U.S.A. <sup>†</sup>	2,527.0	4,110.0
20	19 BALFOUR BEATTY PLC, London, U.K. <sup>†</sup>	2,380.0	9,073.0

August 20, 2007 **enr.com**

2

→ **Today**

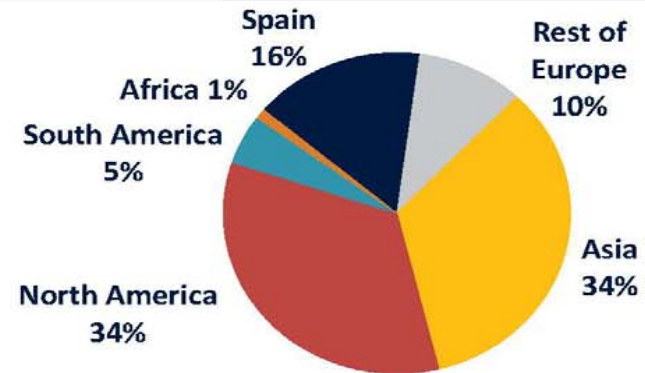
**#1 global contractor with sales reaching € 35 bn**

Leading international contractor, highly diversified in terms of geographies and contracting activities

**EBIT 14 € 1.6 bn (margin 4.6%)**

**Net Debt 1H15 € 3.5 bn**

**210,000 employees**



**ENR THE TOP 250 INTERNATIONAL CONTRACTORS**

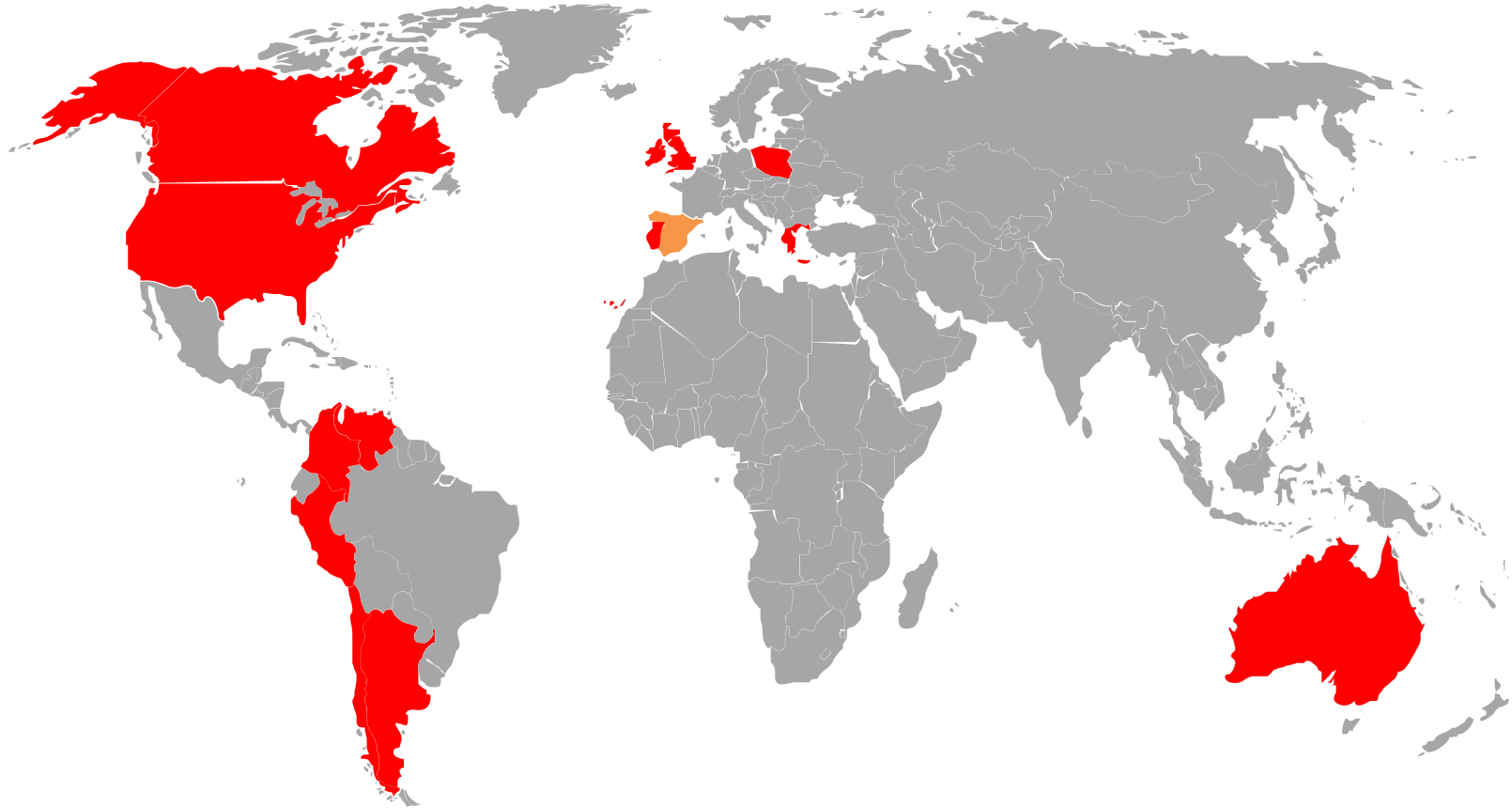
RANK	2015	2014	FIRM	2014 REVENUE \$ MIL.	
				INT'L	TOTAL
1	1	1	ACS, ACTIVIDADES DE CONSTRUCCION Y SERVICIOS SA, Madrid, Spain†	38,707.5	46,081.1
2	2	2	HOCHTIEF AKTIENGESELLSCHAFT, Essen, Germany†	29,299.3	31,118.8
3	3	3	BECHTEL, San Francisco, Calif, U.S.A.†	21,414.0	28,302.0
4	4	4	VINCI, Rueil-Malmaison, France†	19,679.9	51,868.8
5	9	9	CHINA COMMUNICATIONS CONSTRUCTION GRP. LTD., Beijing, China†	15,827.0	60,314.6
6	10	10	TECHNIP, Paris, France†	14,223.6	14,343.6
7	7	7	BOUYGUES SA, Paris, France†	14,201.0	32,335.0
8	8	8	SKANSKA AB, Stockholm, Sweden†	14,024.9	17,687.2
9	6	6	STRABAG SE, Vienna, Austria†	13,972.0	16,470.0
10	11	11	SAIPEM, San Donato Milanese, Italy†	13,623.4	13,831.9
11	23	23	POWER CONSTRUCTION CORP. OF CHINA, Beijing, China†	11,653.4	38,689.6
12	5	5	FLUOR CORP., Irving, Texas, U.S.A.†	11,524.1	16,924.9
13	12	12	CONSTRUTORA NORBERTO ODEBRECHT SA, Sao Paulo, SP, Brazil†	10,199.7	14,042.9
14	13	13	HYUNDAI ENGINEERING & CONSTRUCTION CO. LTD., Seoul, S. Korea	9,687.4	16,366.4
15	14	14	FERROVIAL, Madrid, Spain†	8,365.6	11,618.6

enr.com August 24/31, 2015



**DRAGADOS**

# Dragados - Global Presence



- Argentina
- Australia
- Canada
- Chile
- Colombia
- Ireland
- Greece
- Peru
- Poland
- Portugal
- Spain
- United States
- United Kingdom
- Venezuela



# Dragados in North America

December 2005

**DRAGADOS USA**

- ✓ In December 2005, **Dragados USA** began operating in the United States.

January 2008

**DRAGADOS CANADA**

- ✓ **Dragados Canada** opened its headquarters office in Toronto

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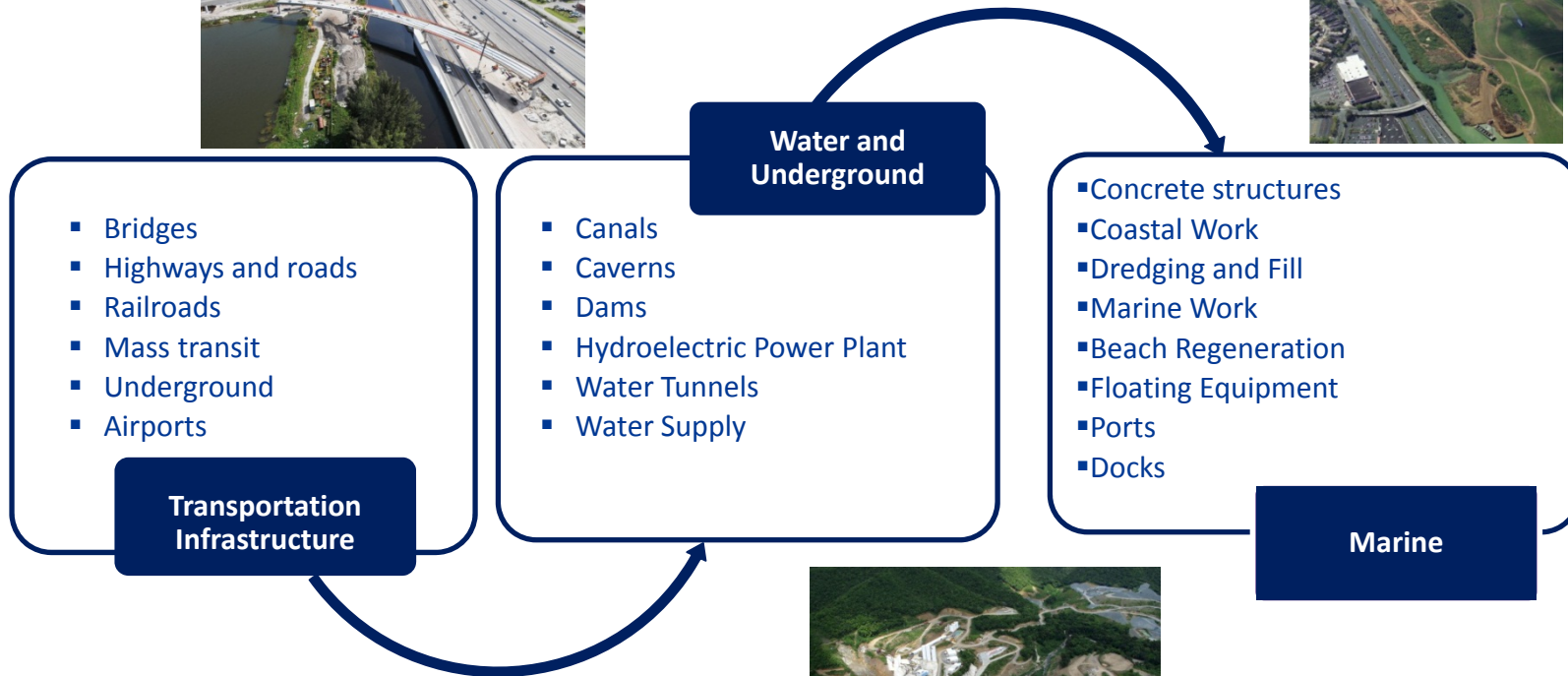
## North American Companies Acquired





# Services and Areas of Expertise

- ✓ Major Projects
- ✓ Alternative Project Delivery
- ✓ Design-Build
- ✓ Public Private Partnership (P3)



# CITY BELOW THE CITY



Create new urban spaces in congested areas

Increase the quality of life  
Sustainable growth

Free surface for citizens  
Underground infrastructures



**NEW INFRASTRUCTURE  
IS BUILT FOR THE USER'S BENEFIT  
HOWEVER DURING CONSTRUCTION  
THE NEIGHBOURHOOD IS DISTURBED**

**AMONG THE MULTIPLE TECHNOLOGIES  
WE ARE OBLIGED TO LOOK FOR  
THE LESS DISRUPTIVE ONES**



# Traffic management



## Social cost

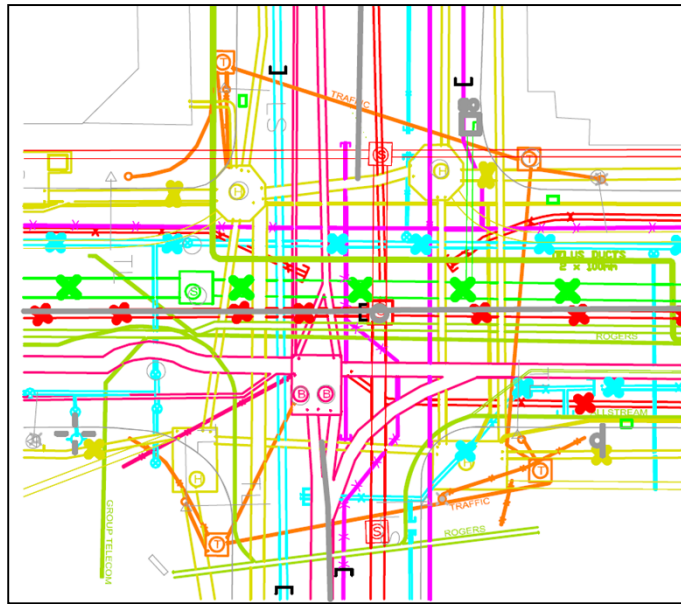
Fuel consumption

Longer journeys

Higher carbon footprint

Higher risk of accident



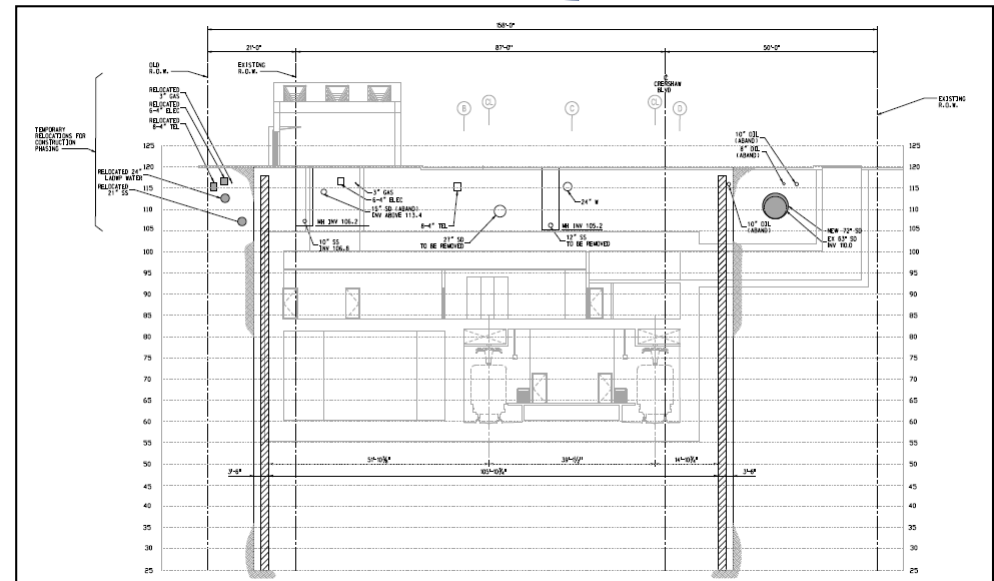


# Utilities relocation

- Water
- Gas
- Sewage
- Phone
- TV
- Communications
- Traffic control
- Confidential org.
- Unknown

Request  
Permits  
Approvals  
Relocation by others  
Final green light

Project  
schedule and  
cost  
(Lack of  
control)



## Business loss –SOCIAL COST



# Confederation Line, Ottawa

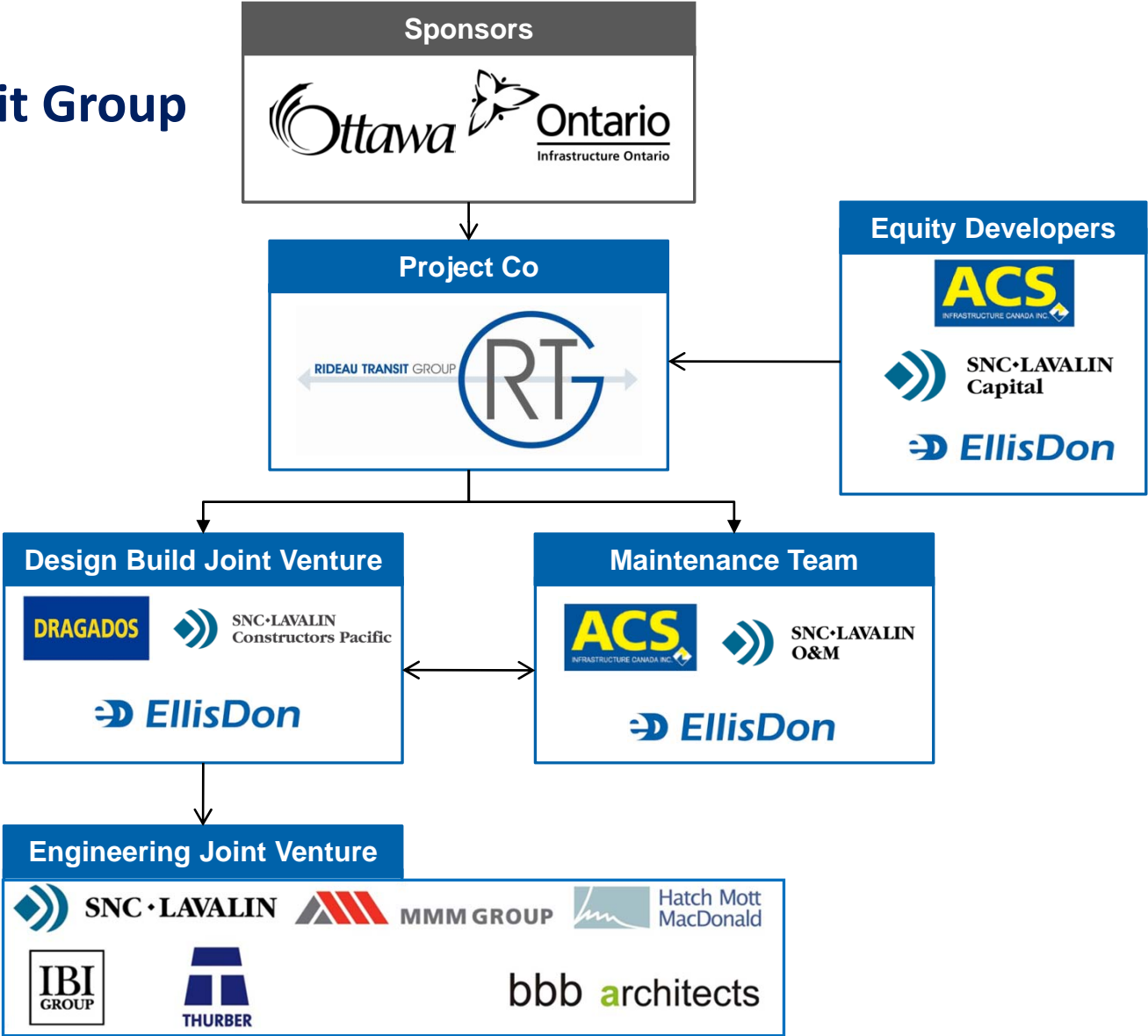


# OTTAWA LRT TUNNEL Confederation Line



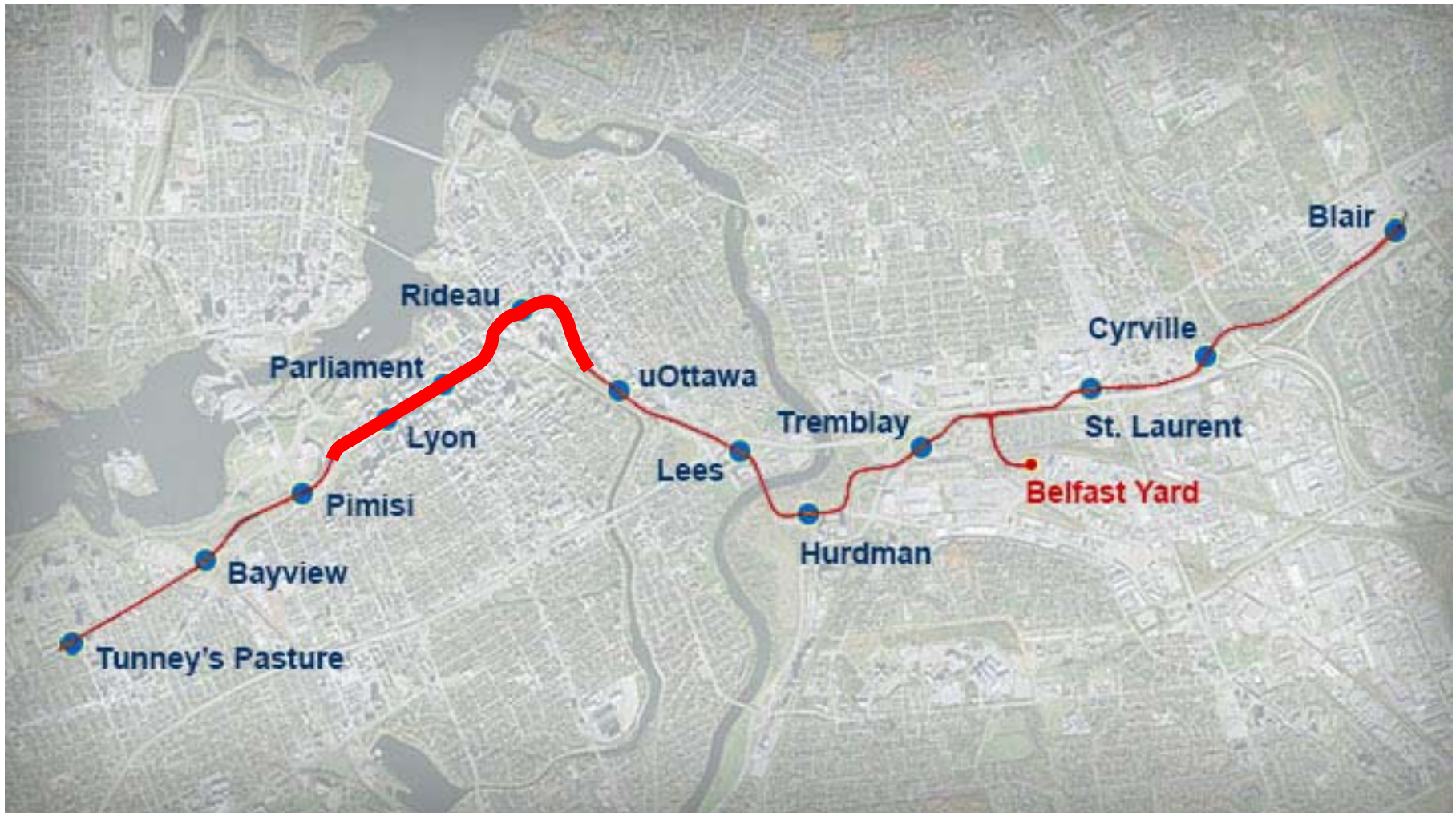


# Rideau Transit Group



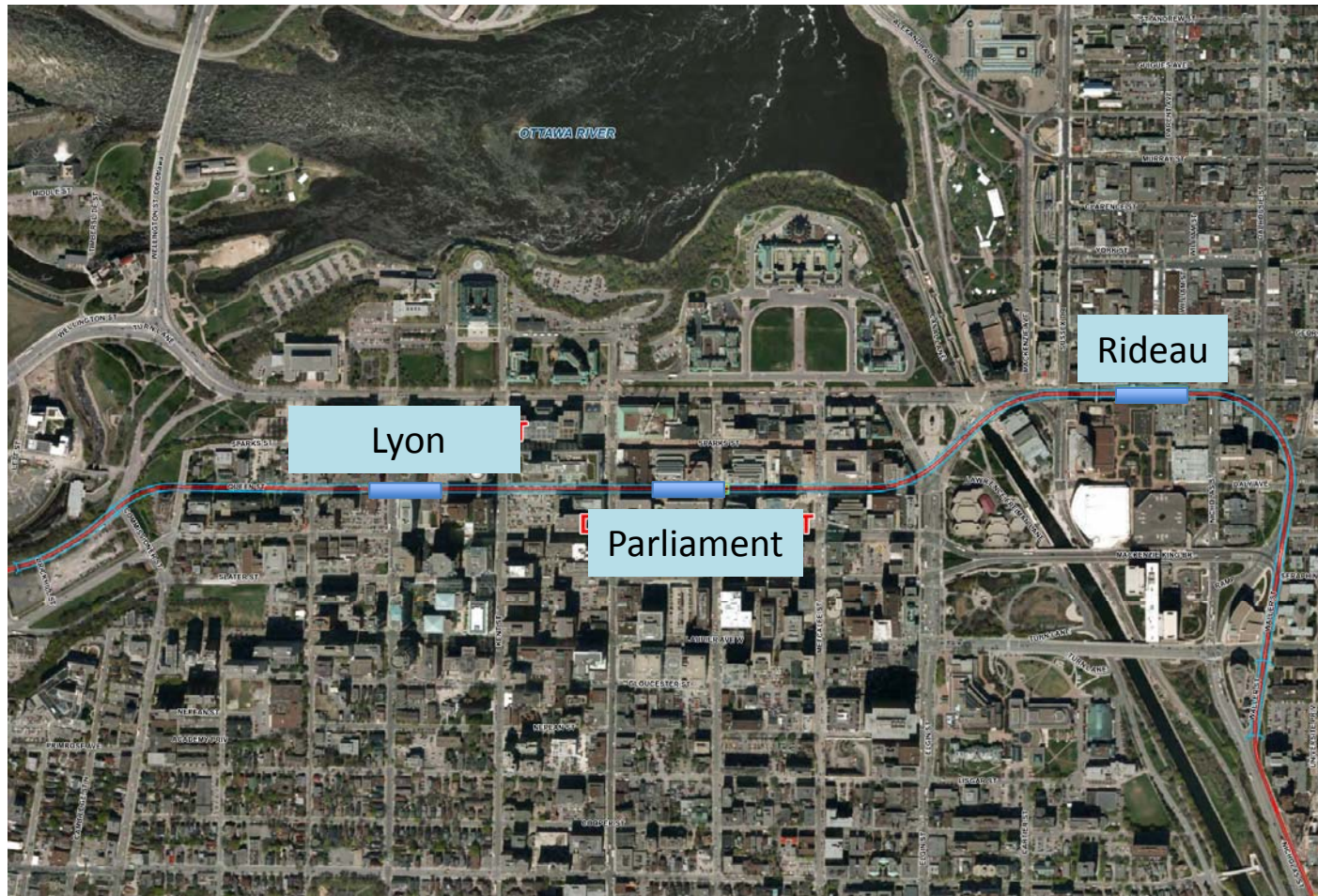
## Confederation Line LRT

12.5 km project with 10km at grade in existing BRT Right-of-Way.  
Biggest problem for the BRT was downtown – this has been solved by a  
2.5 km tunnel from between uOttawa and Pimisi



## Underground works

2.530 m running tunnel twin track  
3 mined stations: Lyon, Parliament and Rideau

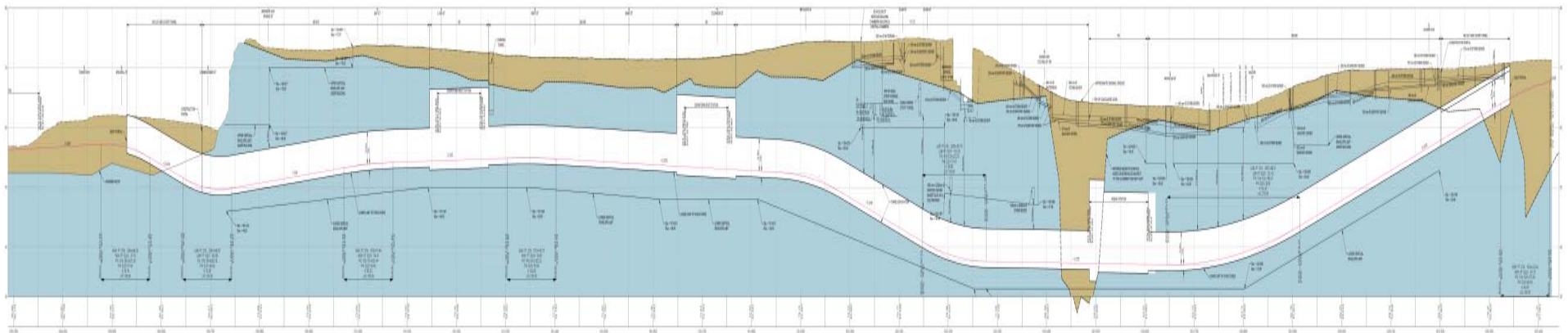


# OTTAWA Geology

Sound limestone interbedded with shale from the Lindsay and Verulam formations

Compress strength varies from 50 to 90 MPa and its RQD from 30 to 90

Overlaying this sedimentary ground, glacial deposits of clay and fines including a paleovalley at Rideau



## DESIGN SCHEME

	Pros	Cons
SINGLE TUNNEL	Lower Cost Flexibility in operation	Higher risk of settlement minimize by rock quality
TWIN TUNNEL	Multiple faces Overlapping of construction activities	Higher cost and schedule Potential impact on building basement

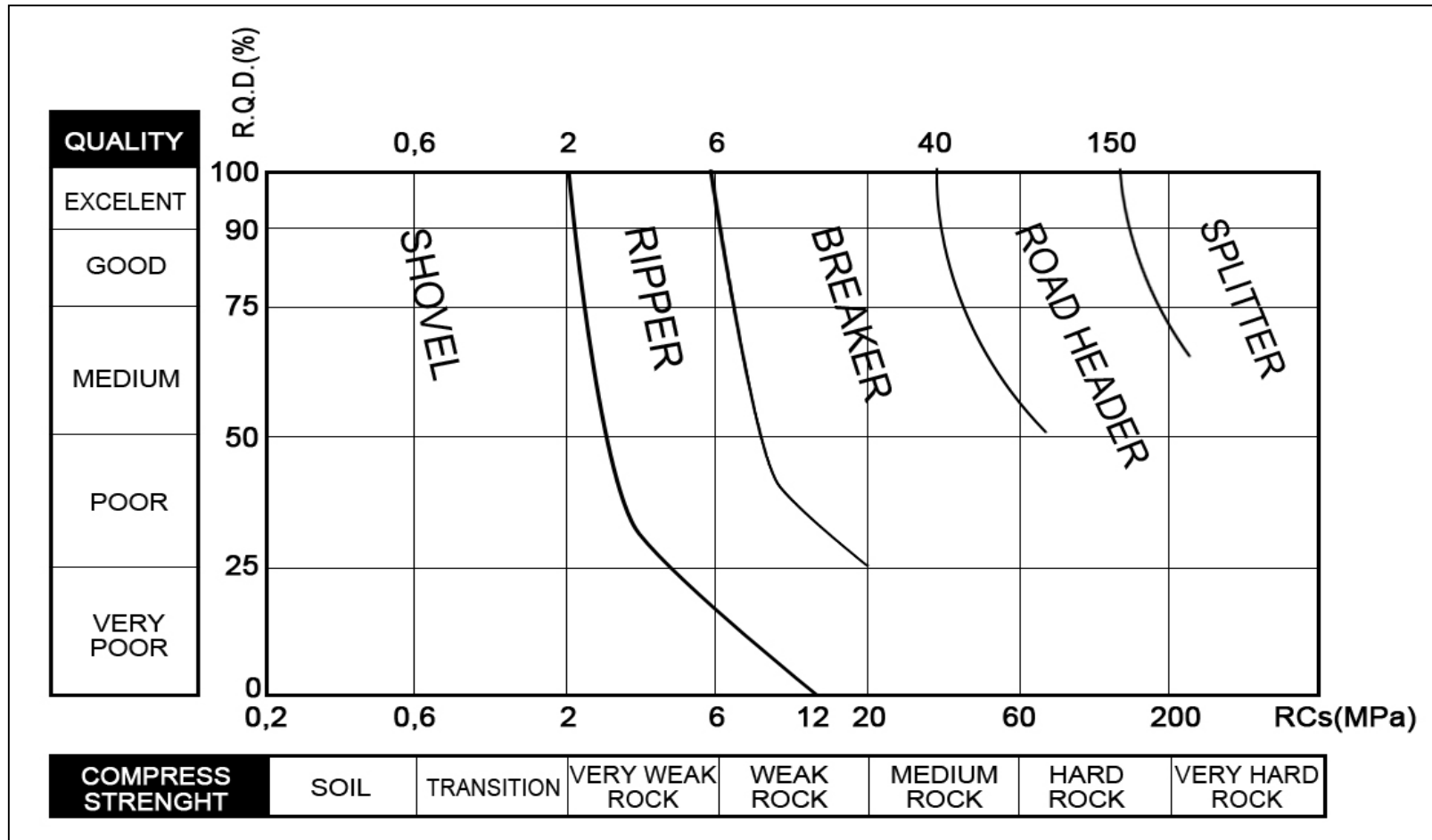


## EXCAVATION PROCEDURES

	<b>Pros</b>	<b>Cons</b>
<b>TBM</b>	Speed Open mode One pass lining	Paleovalley Possible damage to building basement Coordination with stations 1.5-2 years TBM procurement
<b>Drill &amp; Blast</b>	Speed Economy Multi face	Urban restrictions Noise Vibrations
<b>Mechanical</b>	Flexibility, Geometry Multiple faces Mobilize quickly	Lower speed / face

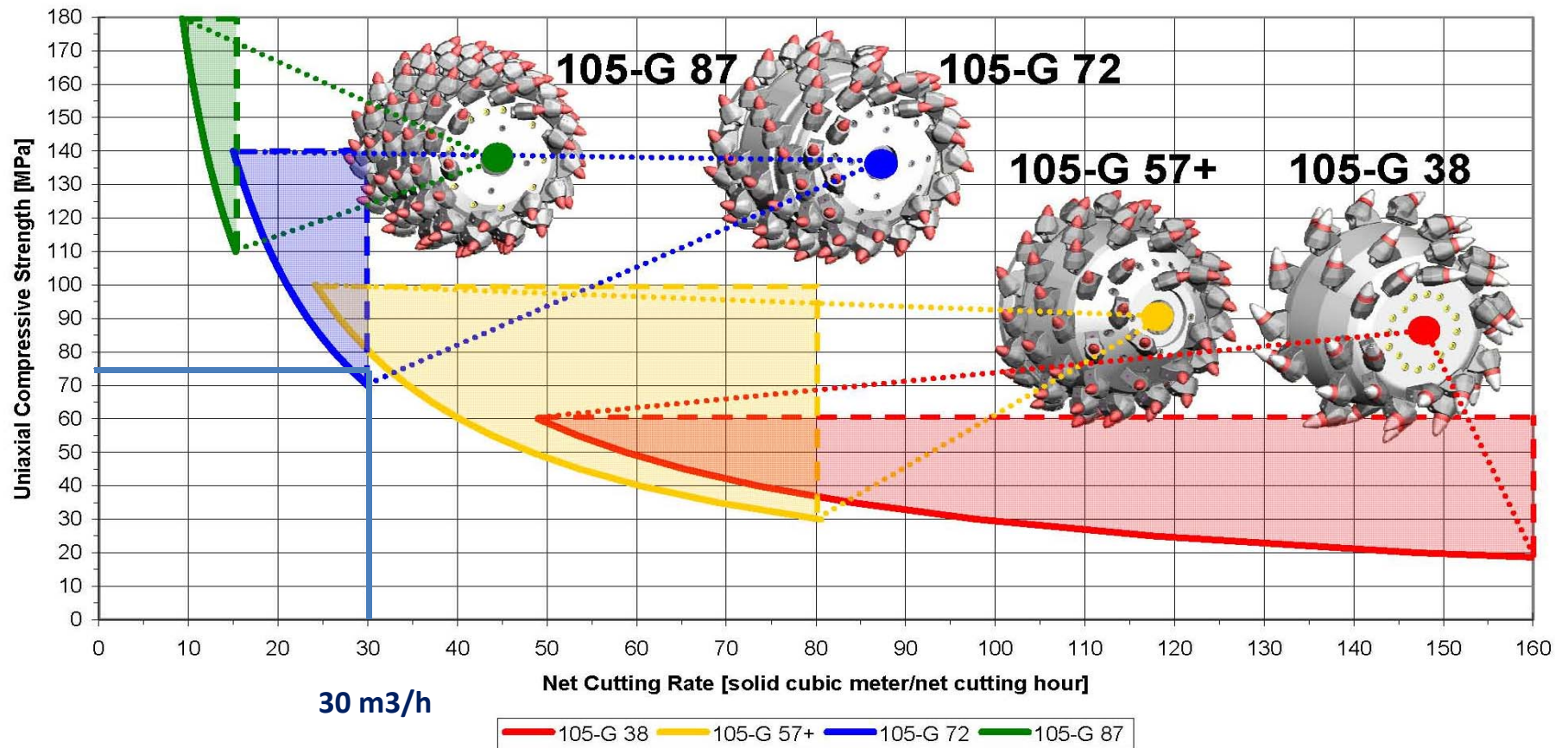


## MECHANICAL EXCAVATION



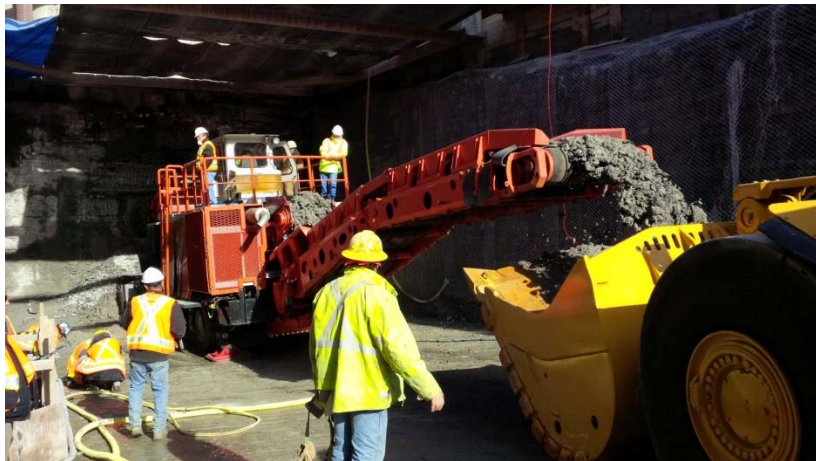
## MECHANICAL EXCAVATION

Net Cutting Rate for ATM 105-IC (300 kW installed cutter head power)  
 equipped with Cutter Head 105-G 38 or 105-G 57+ or 105-G 72 or 105-G 87 and 22 mm TC Insert  
 Picks according to Uniaxial Compressive Strength for Intact to Moderately Fractured Rock Mass





### 3 ROADHEADER SANDVIK MT-720



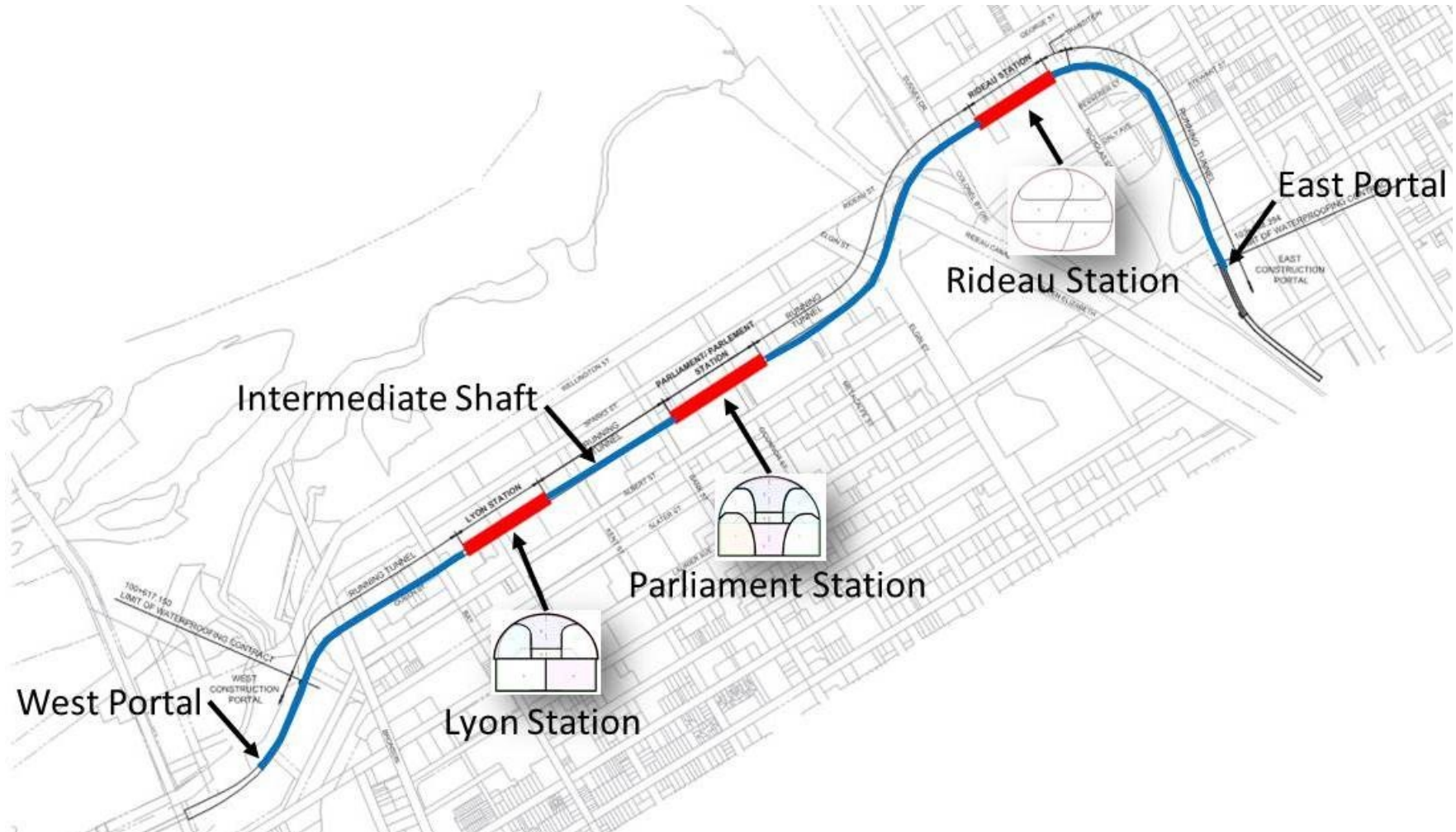
### 6 SCOOPTRAM CAT R1600G

*Challenges and Innovations in Tunnelling*



Tunnelling Association of Canada (TAC) – Ontario Chapter

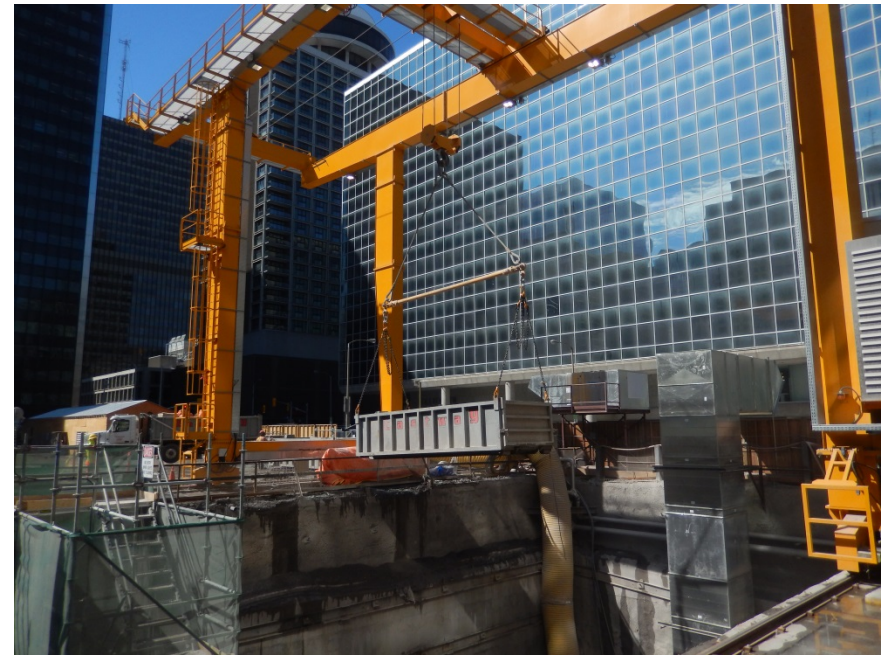
# SITE ORGANISATION





## WEST PORTAL





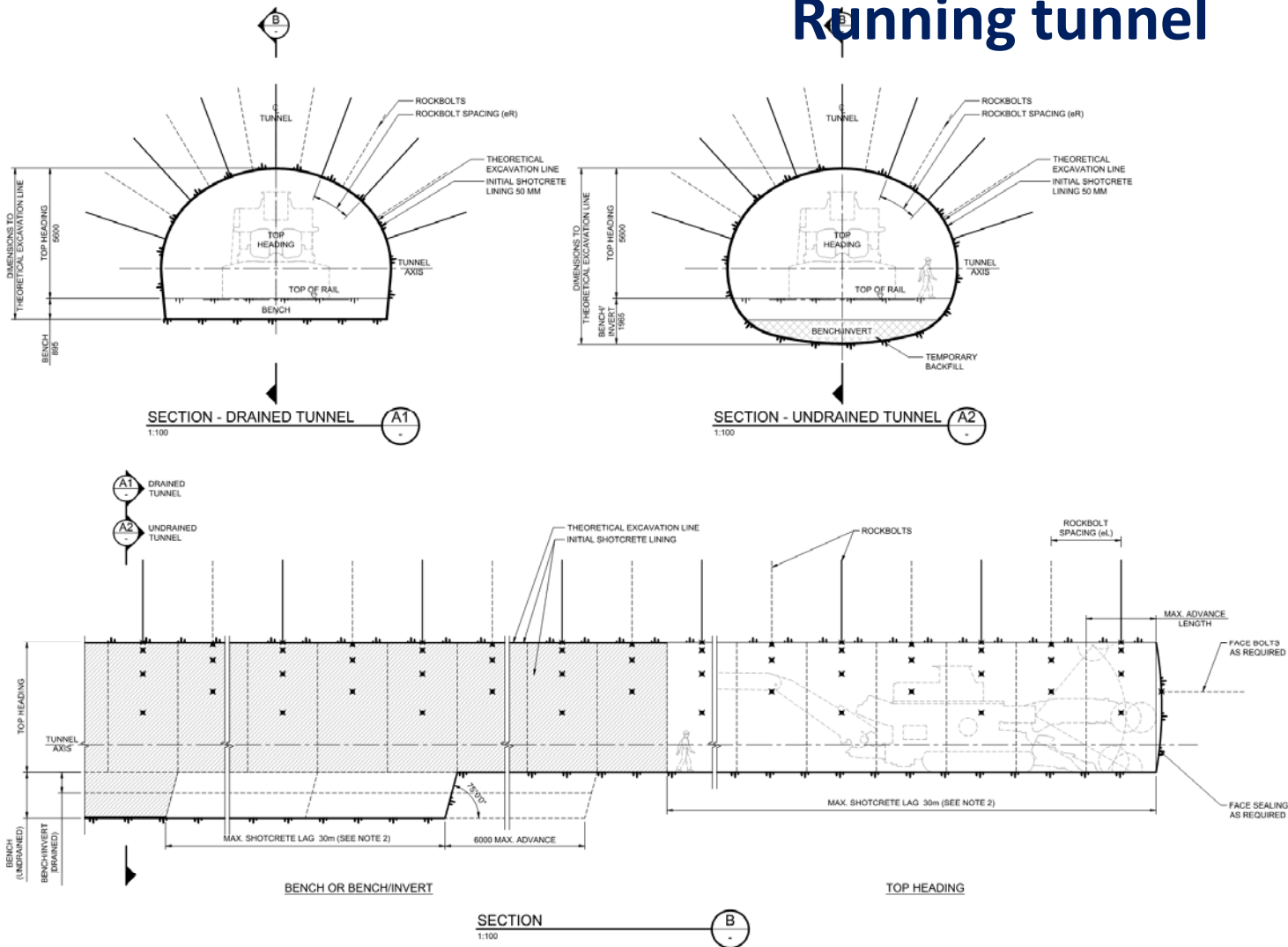
## Intermediate shaft



# EAST PORTAL



# Running tunnel

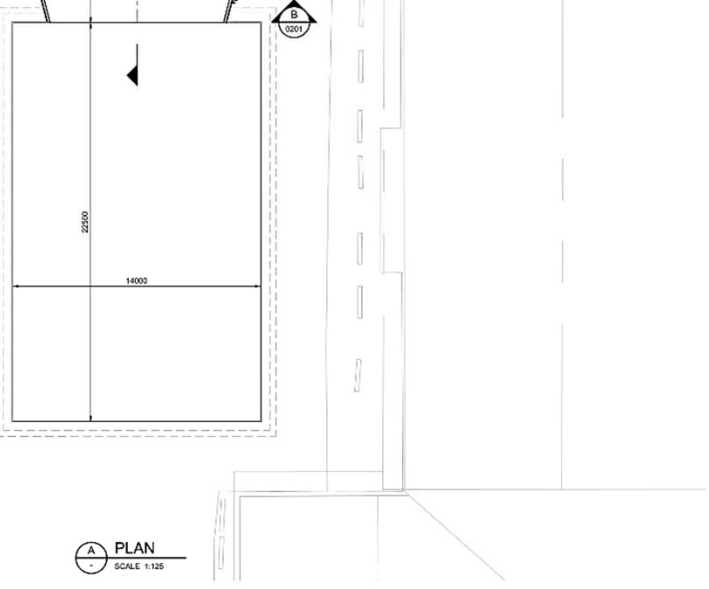
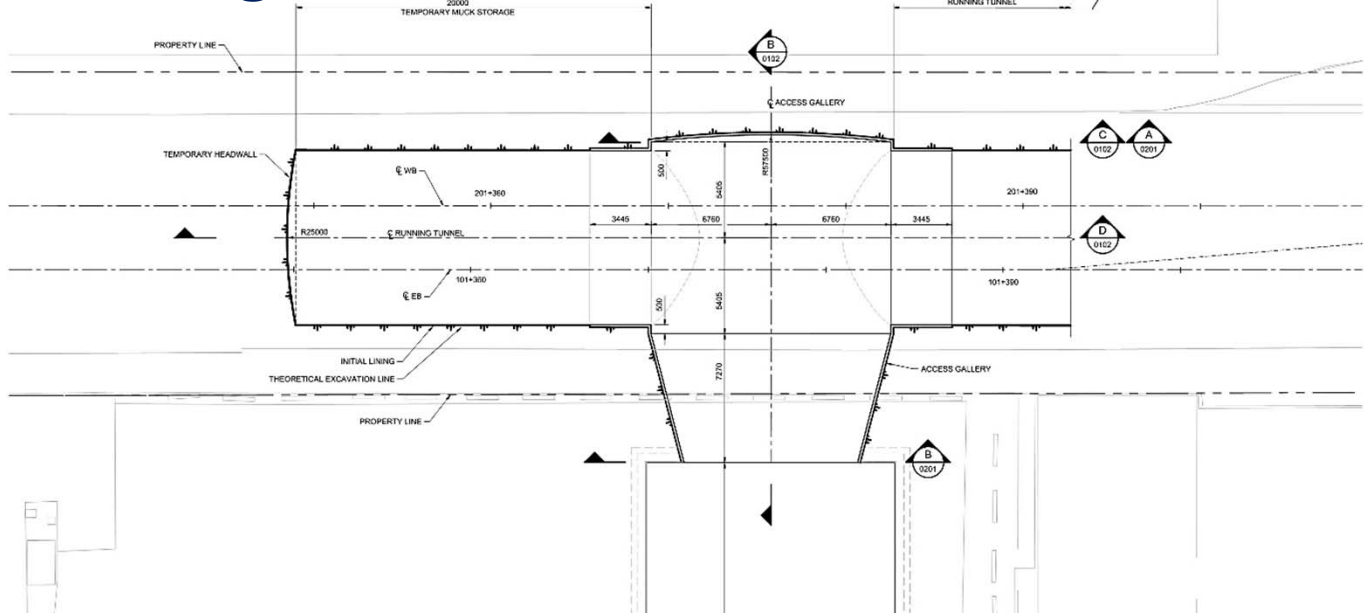


THEORETICAL QUANTITIES - DRAINED (SEE NOTE 3)			
INITIAL SHOTCRETE LINING THICKNESS [mm]	EXCAVATION AREA TOP HEADING [m <sup>2</sup> ]	EXCAVATION AREA BENCH/INVERT [m <sup>2</sup> ]	EXCAVATION AREA TOTAL [m <sup>2</sup> ]
50	46.37	8.59	54.95

THEORETICAL QUANTITIES - UNDRAINED (SEE NOTE 3)			
INITIAL SHOTCRETE LINING THICKNESS [mm]	EXCAVATION AREA TOP HEADING [m <sup>2</sup> ]	EXCAVATION AREA BENCH/INVERT [m <sup>2</sup> ]	EXCAVATION AREA TOTAL [m <sup>2</sup> ]
50	46.29	14.71	61.00



# Running tunnel



**A PLAN**  
SCALE 1:125

CONFEDERATION LINE			
RUNNING TUNNEL ACCESS GALLERY GENERAL ARRANGEMENT SHAFT & GALLERY			
CONTRACT NO. OILC-11-00-P006		DESIGNER DESIGNED APR	
CHECKER SHE		DRAWN BY MVM	
DATE 12-12-12		PROJECT NO. DSP-86-2-ISTU-DRD-0101	
ENGINEERING BY Dr. Sauer & Partners		SECONDARY SEAL (F. IN CHARGE)	
SCALE 1:125 PLAN 1:100 SECTION			
ALL PARTS OF THIS DRAWING MAY BE REPRODUCED AND/OR TRANSMITTED IN ANY FORM OR BY ANY MEANS, ELECTRONIC OR MECHANICAL, INCLUDING PHOTOCOPYING, RECORDING, OR BY ANY INFORMATION STORAGE AND RETRIEVAL SYSTEM, WITHOUT THE WRITTEN PERMISSION OF THE PROJECT ENGINEER.			
REV	DESCRIPTION	BY	DATE
0	IFC SUBMISSION	ES	2013-12-12
KEY MAP N.T.S.			
ISSUED FOR CONSTRUCTION			

**NOTES:**

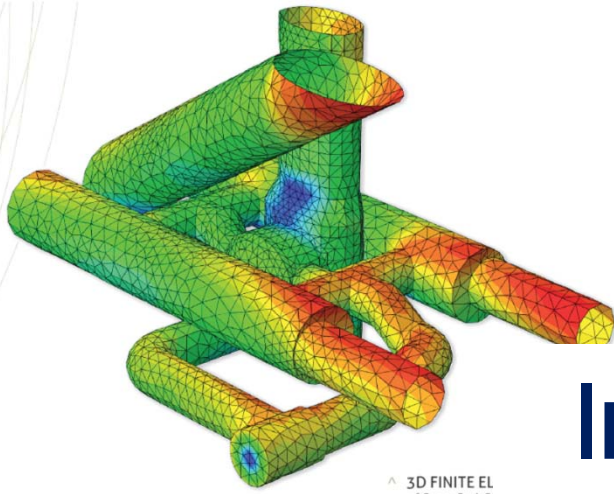
- INTERMEDIATE SHAFT - DESIGN REFERENCE: SOFT GROUND SHORING DESIGN AND ROCK SUPPORT DESIGN BY: RWI ENGINEERING INC. AS CONSULTANT TO HCM DRAWINGS NO. SH1, SH2, SH3, SH4, SH5, SH6, SH6.1, SH7



# Running tunnel

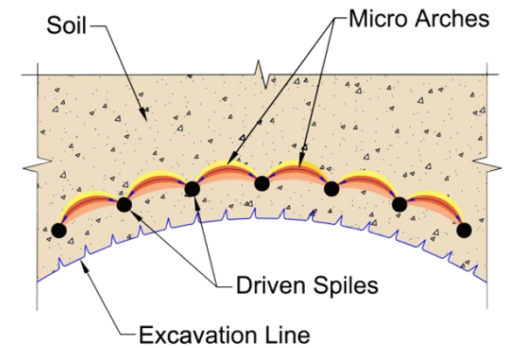
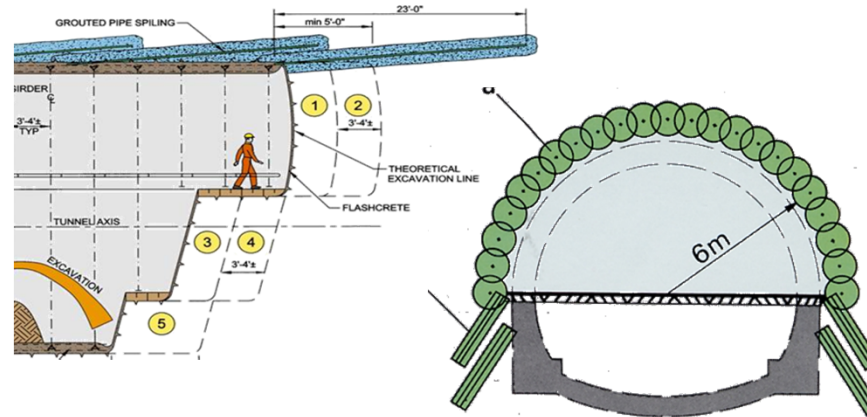
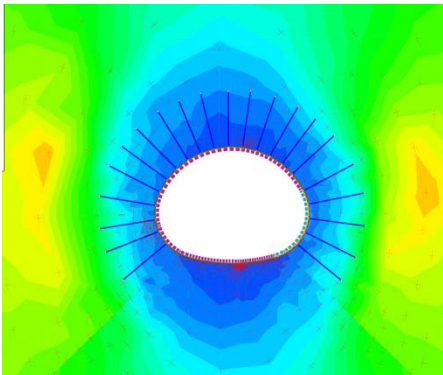
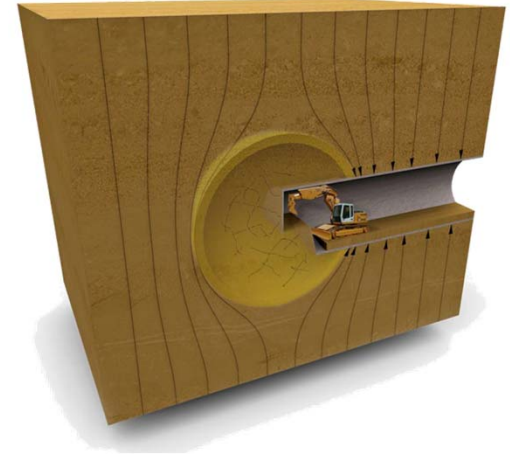






3D FINITE EL  
of Green Park St

# Innovations in Tunneling

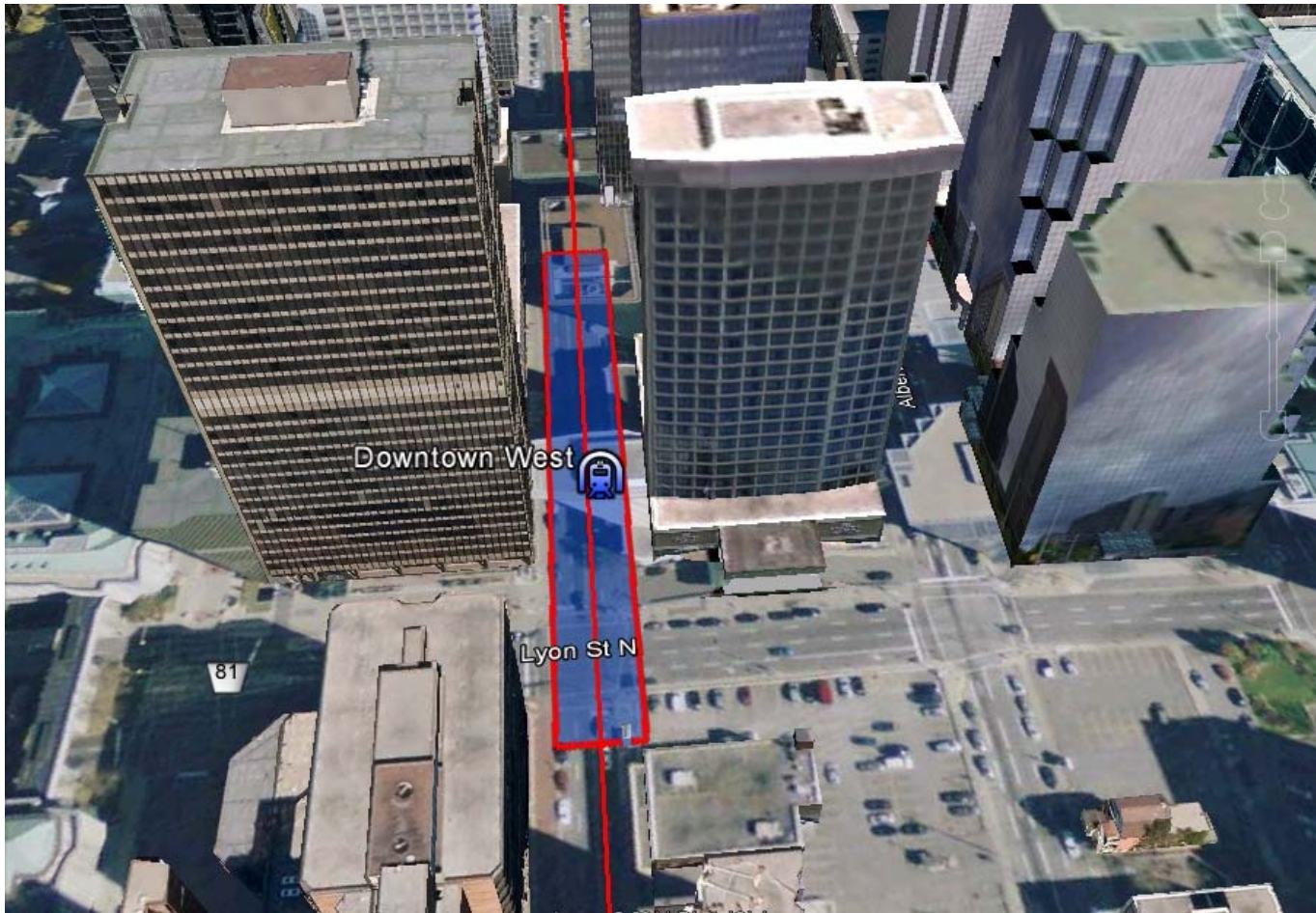
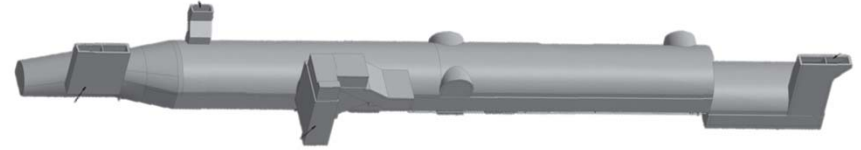


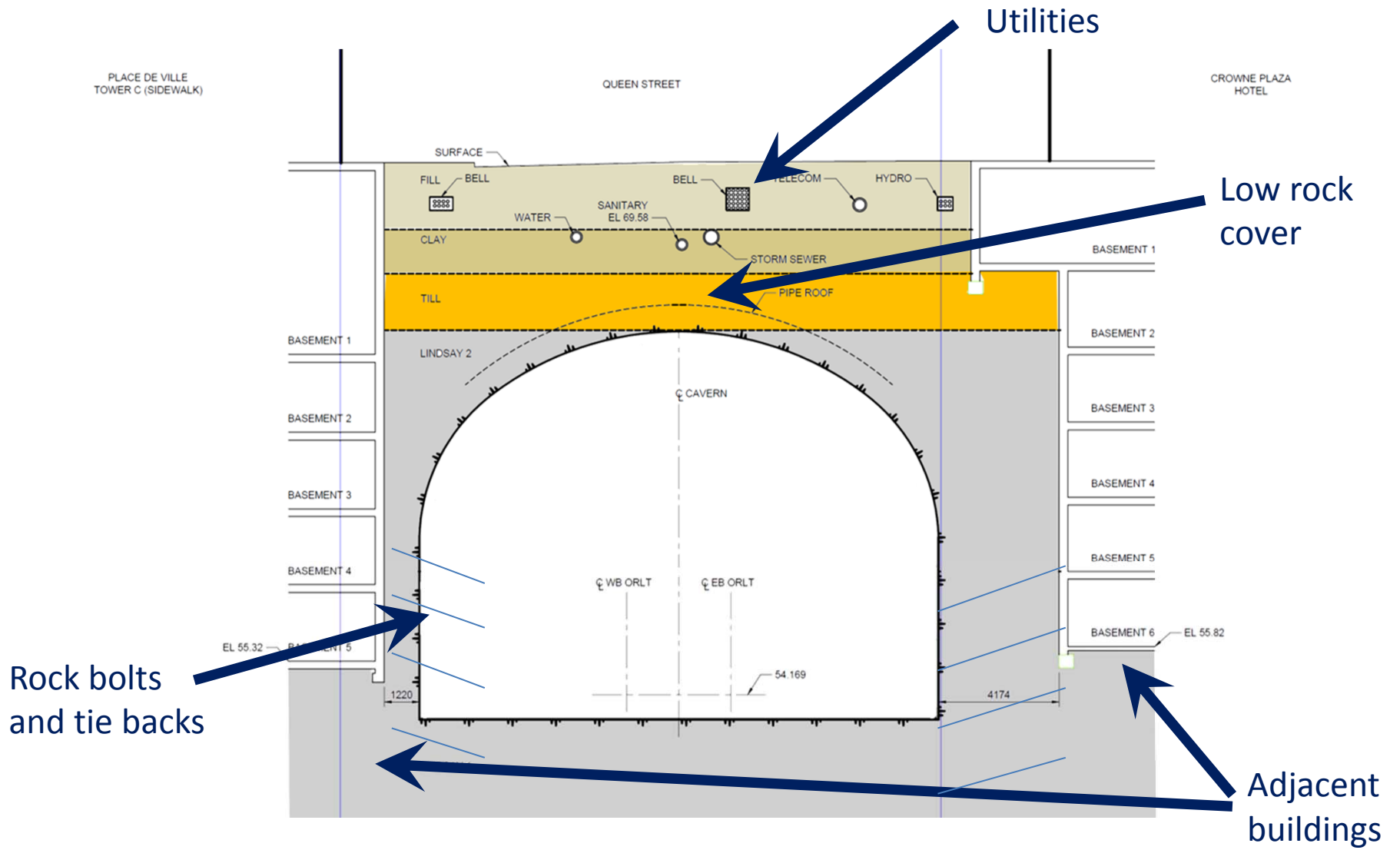
# Station Construction Challenges

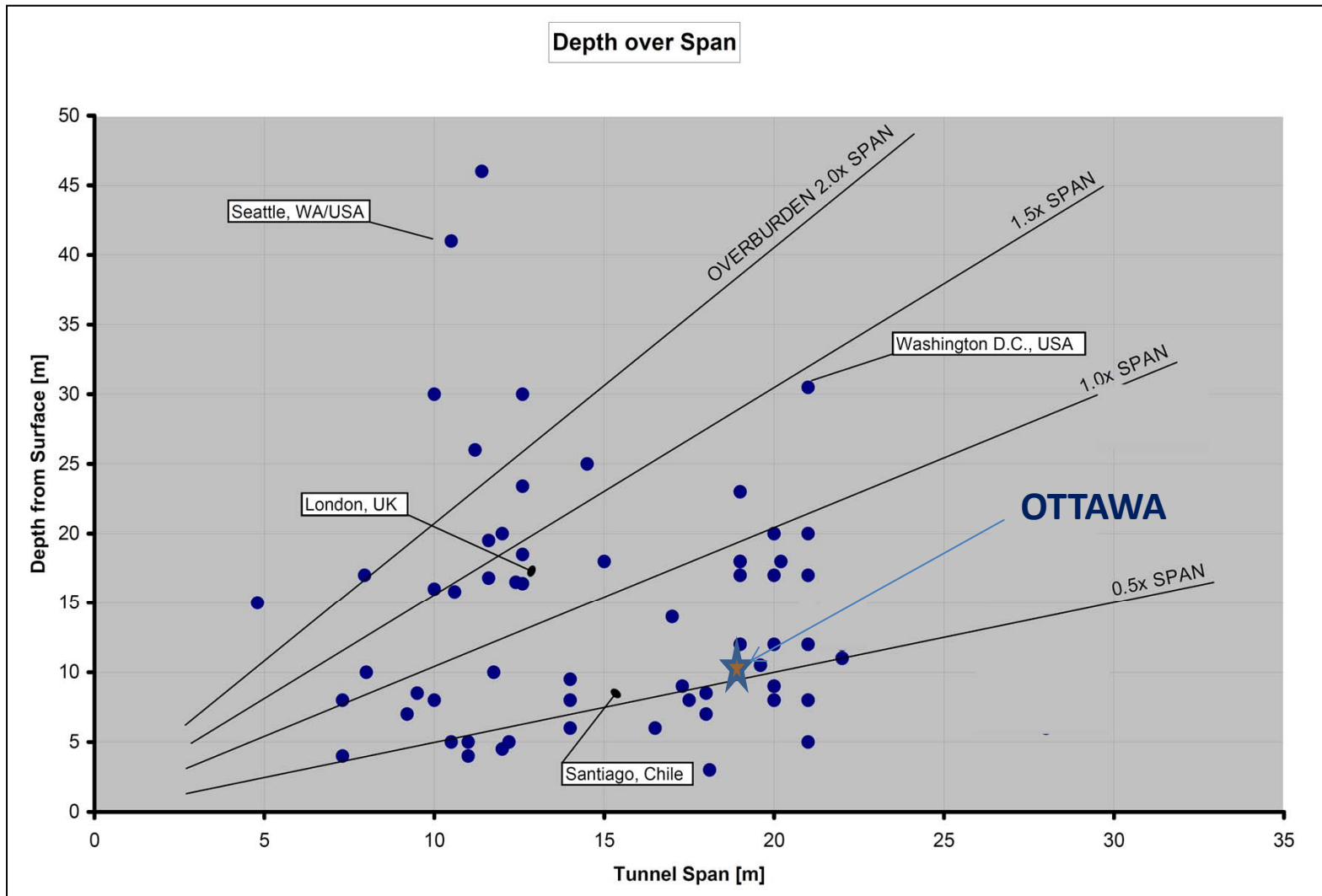
- Large Span ~18 m
- Low Overburden ~10 m
- Significant Potential for impact on buildings
- Obstructions: rock dowels & tie backs
- Mixed Ground Conditions



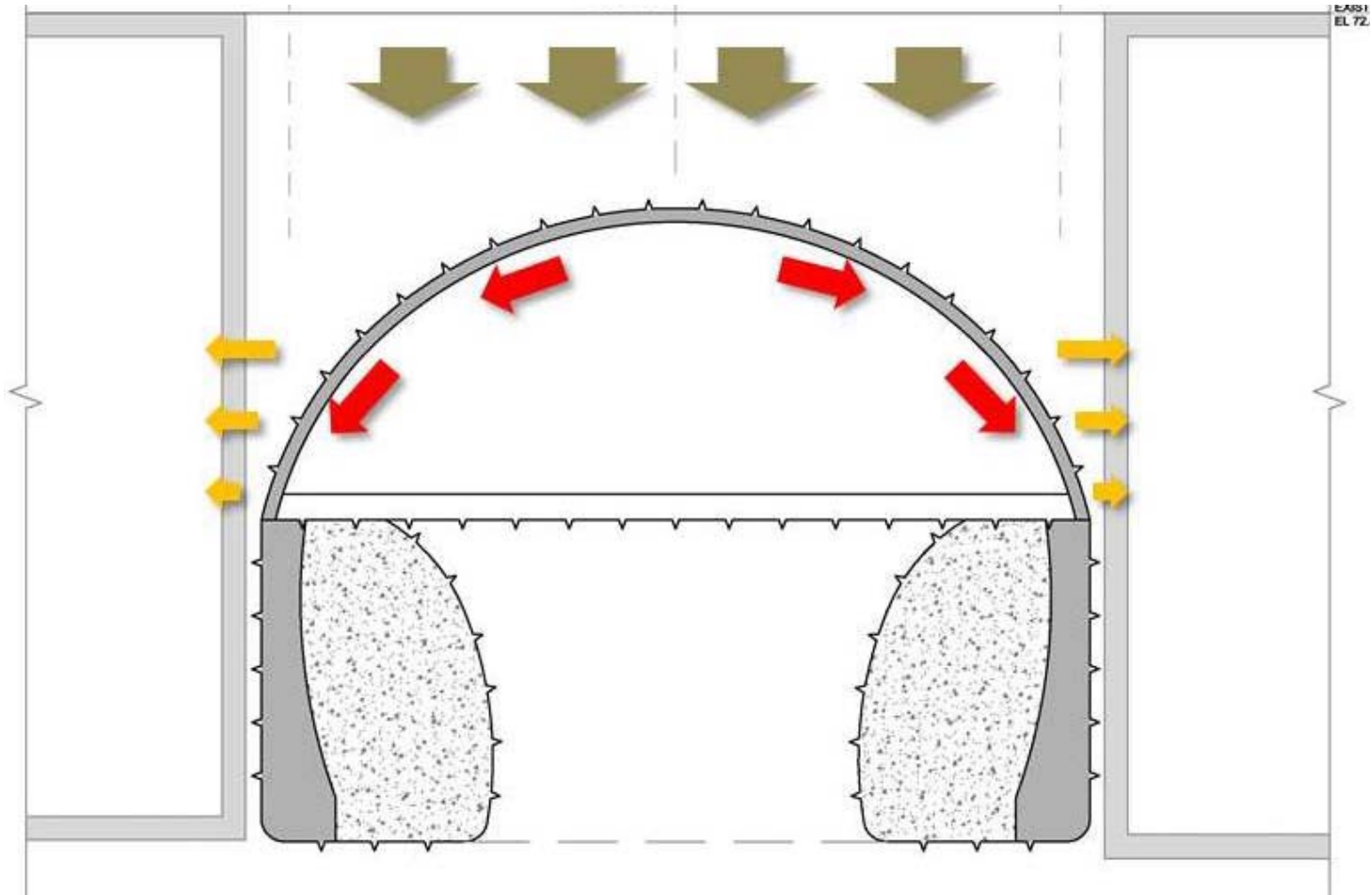
# LYON Station







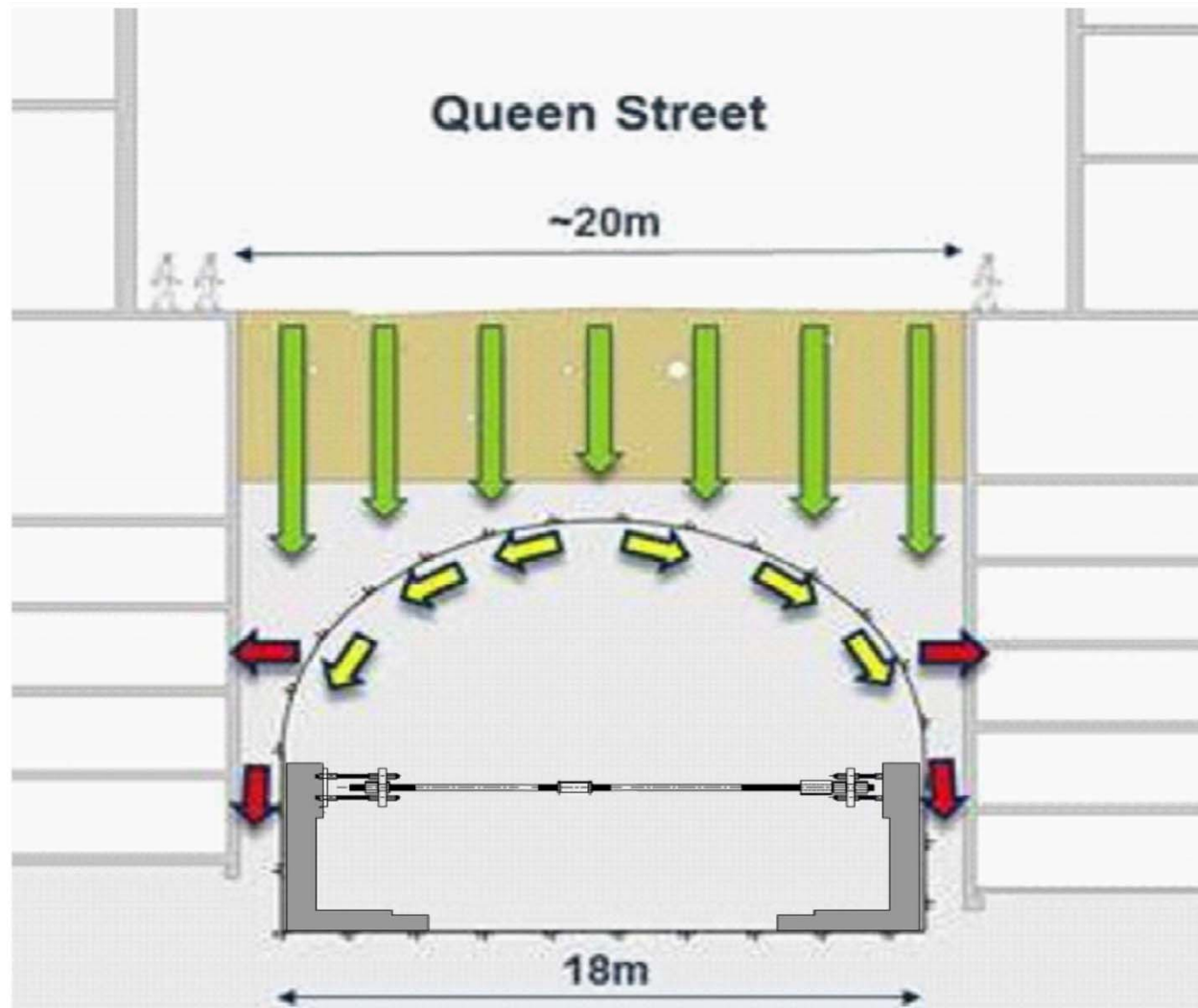
## Key Design Issue



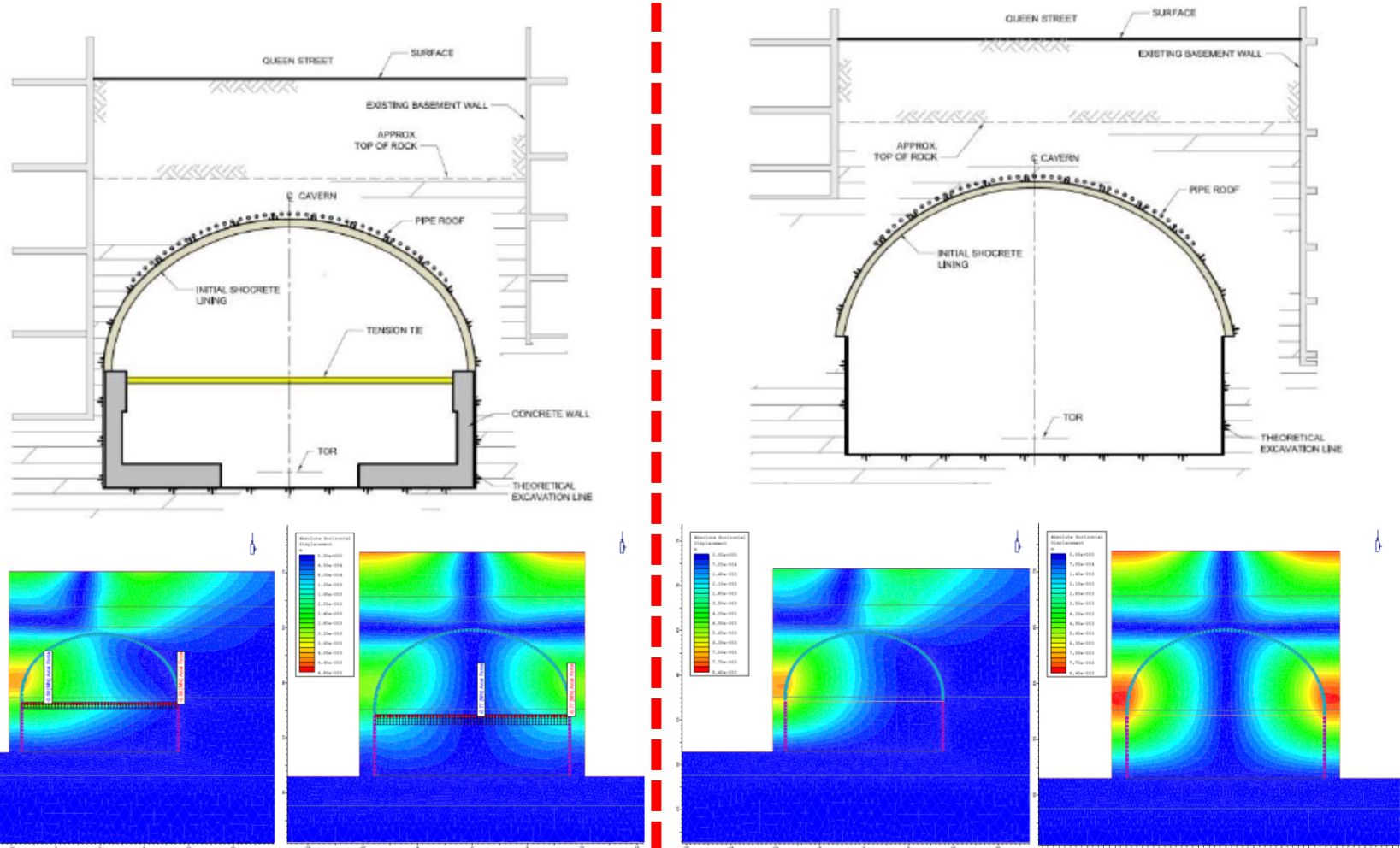
Potential Load transfer onto the buildings



# Solution – Tension Ties



# Confirmation – FE Analysis

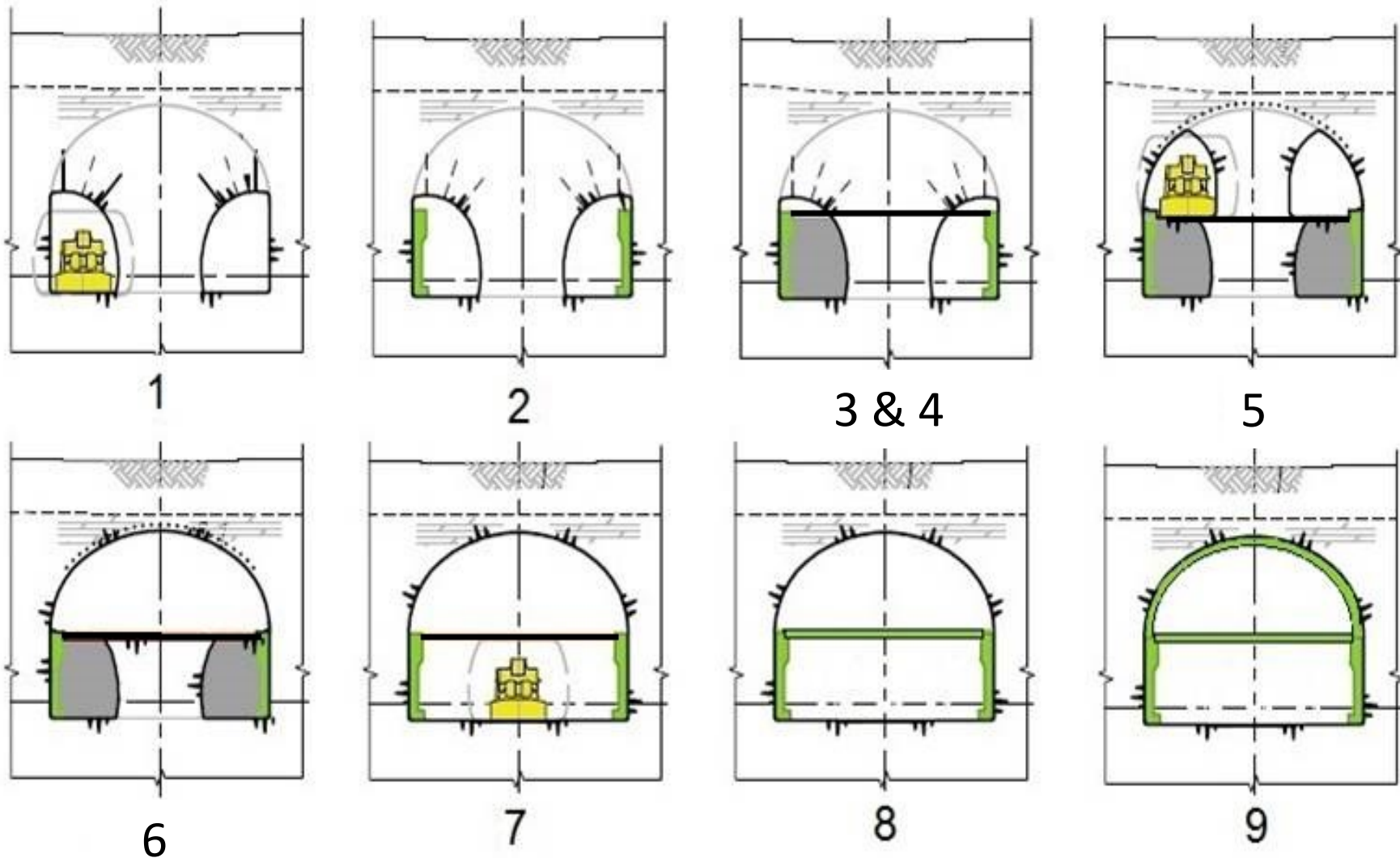


## Tension ties / No ties

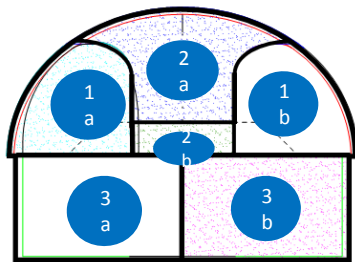
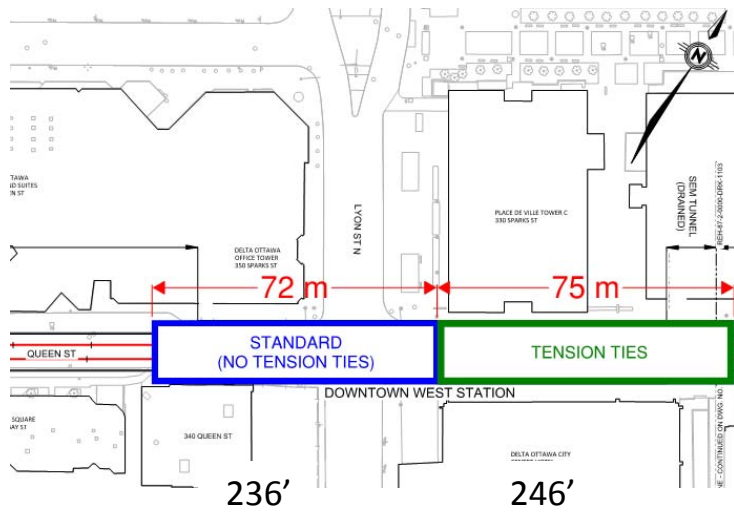




# Sequencing



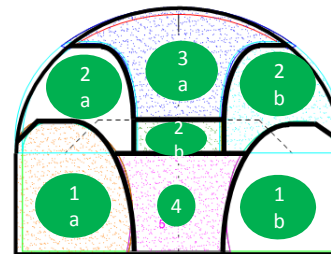
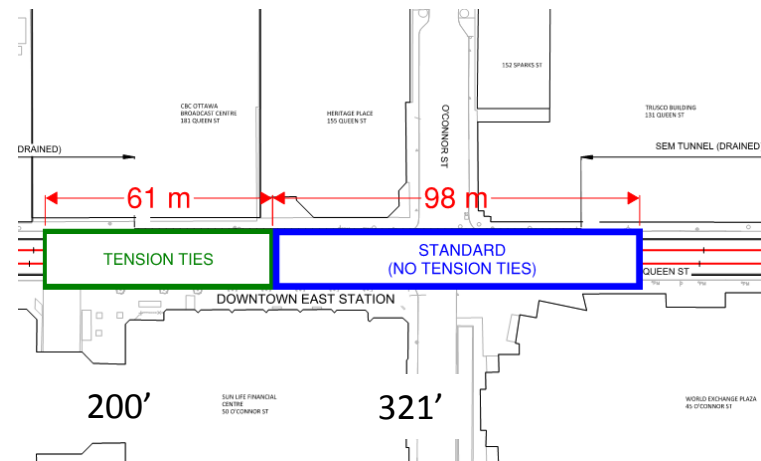
# LYON Station



No Ties

Excavation stages

# PARLIAMENT Station

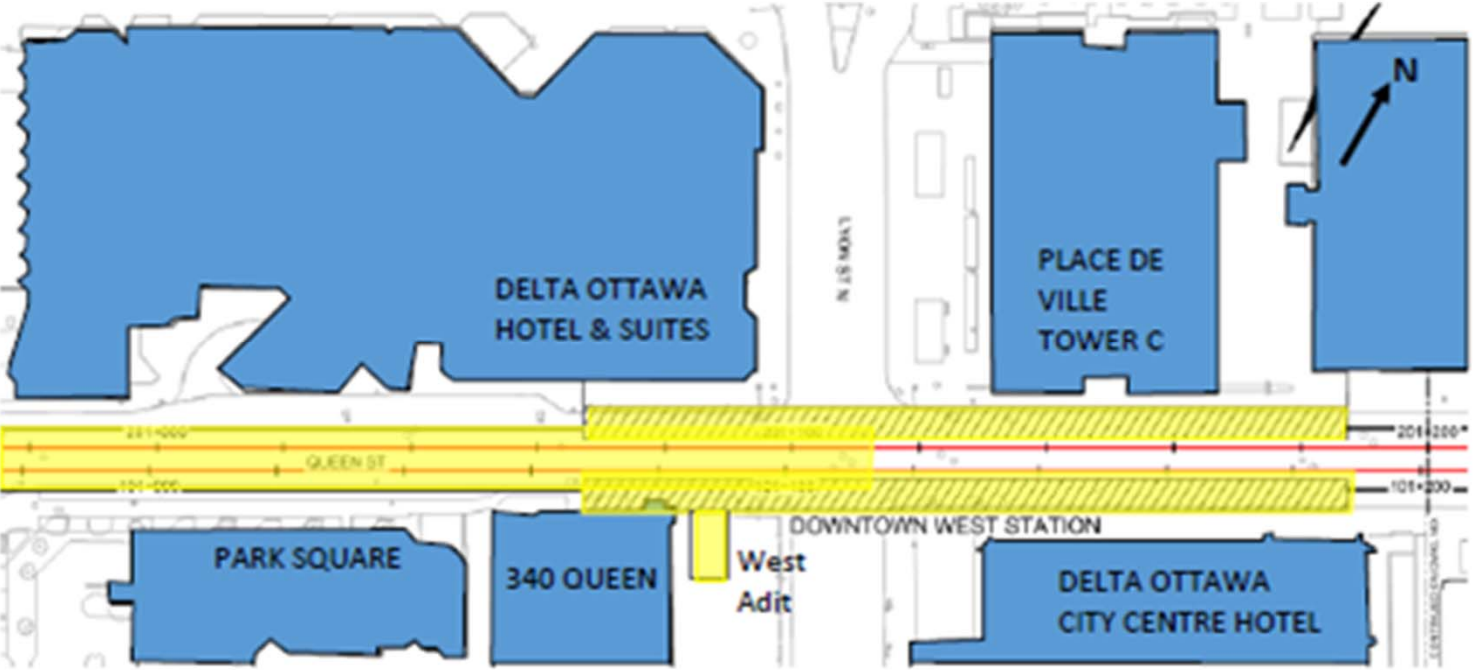
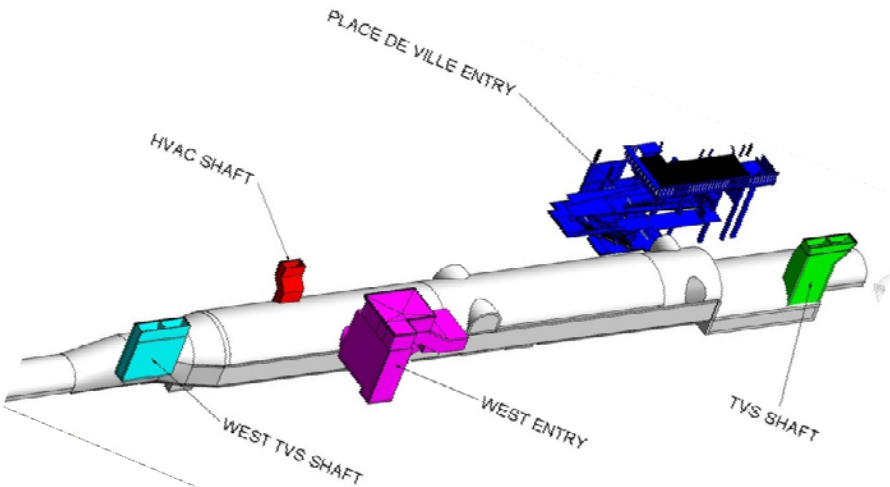


Ties



# Building assessment

## LYON Station



# Building assessment

## PARLIAMENT Station

