



A U S T R A L I A

WestConnex3A

—
AGS (HK) Technical Seminar

24/08/2023



Acknowledgment to country

We would like to acknowledge the traditional custodians of this land and pay our respects to the Elders past, present and emerging.

Presenters



Mathieu Gonzalez, MSc, FICE, CEng, PMP

Senior Technical Manager Dragages HK
17 years experience in the construction industry
Senior Method Manager on WCX



Leo Paul Calbrix, MSc, CPEng

Bid Manager BYCA
14 years experience in the construction industry
Design Manager on WCX



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design

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Questions ?



01

The WestConnex Project

Key figures

The whole scheme

33 km of new highway
22 km tunnels (linear) divided in 3 contracts
Constructed between 2015 and 2023

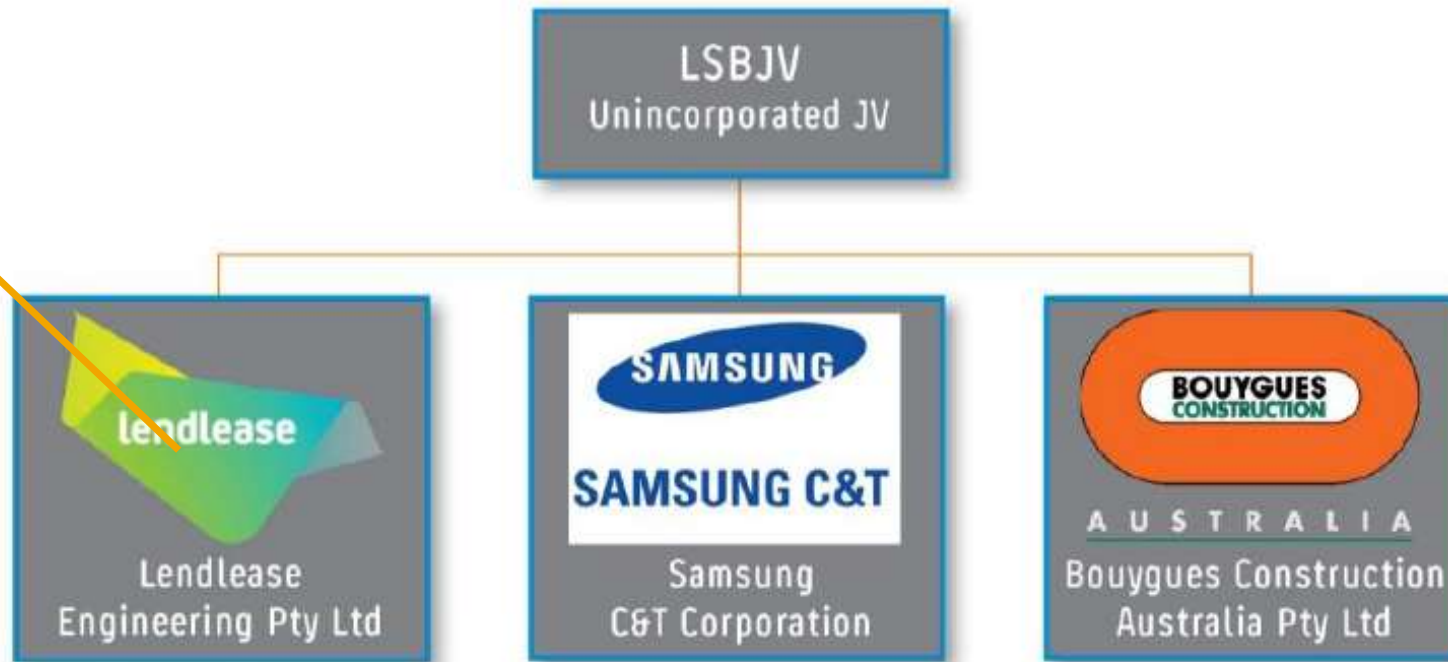
An interchange at Rozelle under construction

WCX3A

7.4 km of twin tunnels + ramps
> 21 km of tunnel excavation including ramps and ventilation tunnels.
Project cost : AU\$3.9 bn



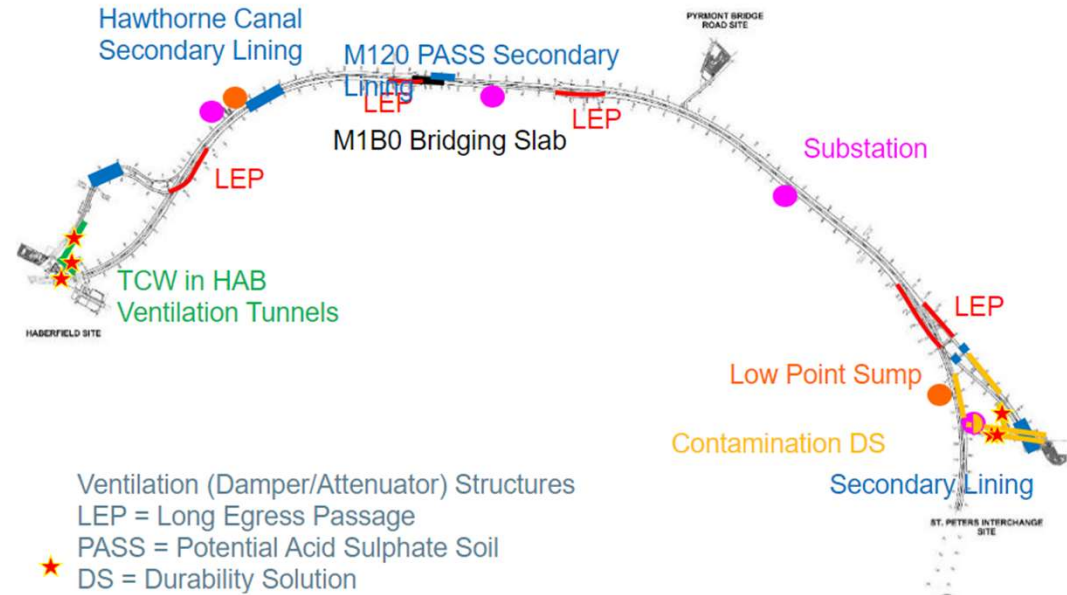
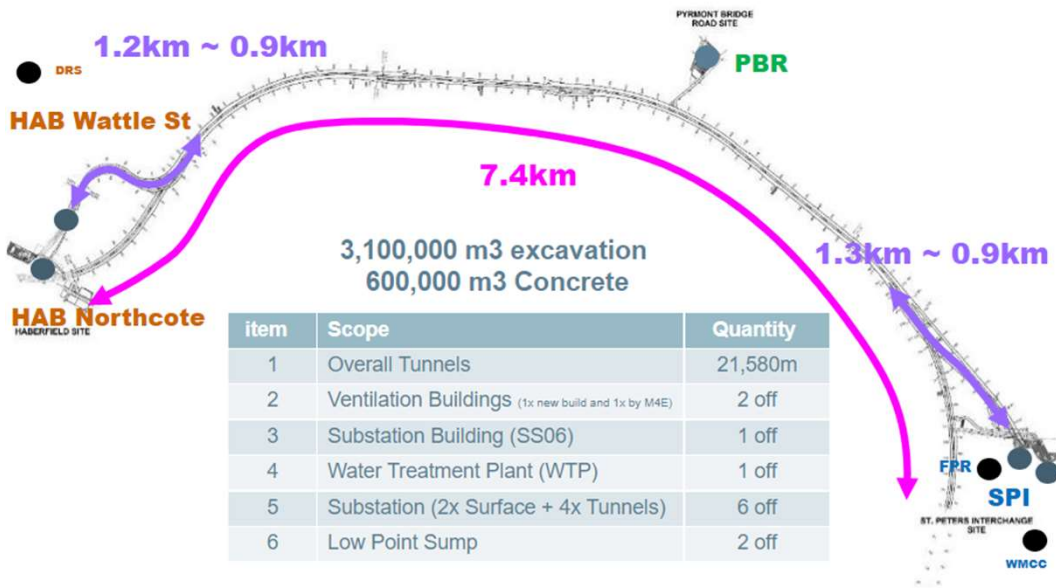
Project Structure: ASBJV Unincorporated JV



Participating Interest of each party in the **JV is 33.3% each.**

Overview

M4-M5 Link Tunnels



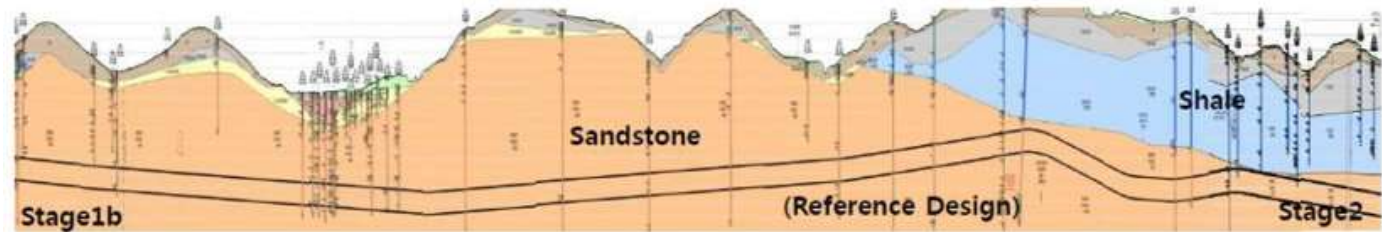
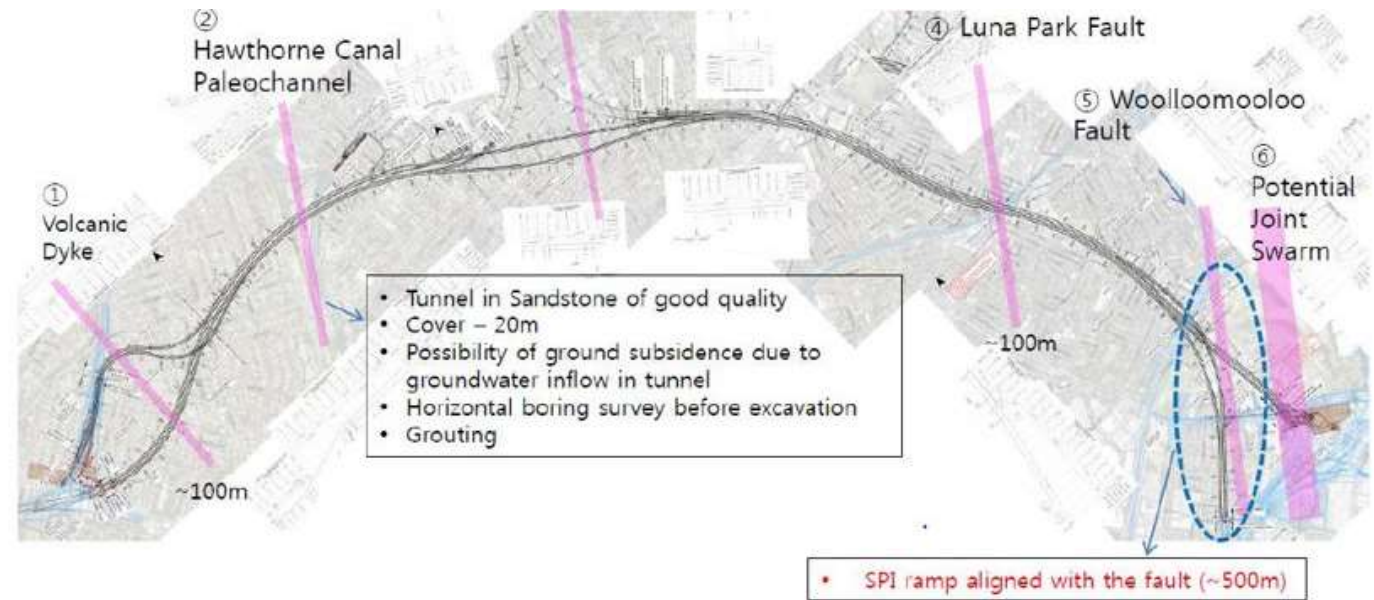
Overview

Geological Map

87% Hawkesbury Sandstone

10% Ashfield shale

3% Soft Ground





02

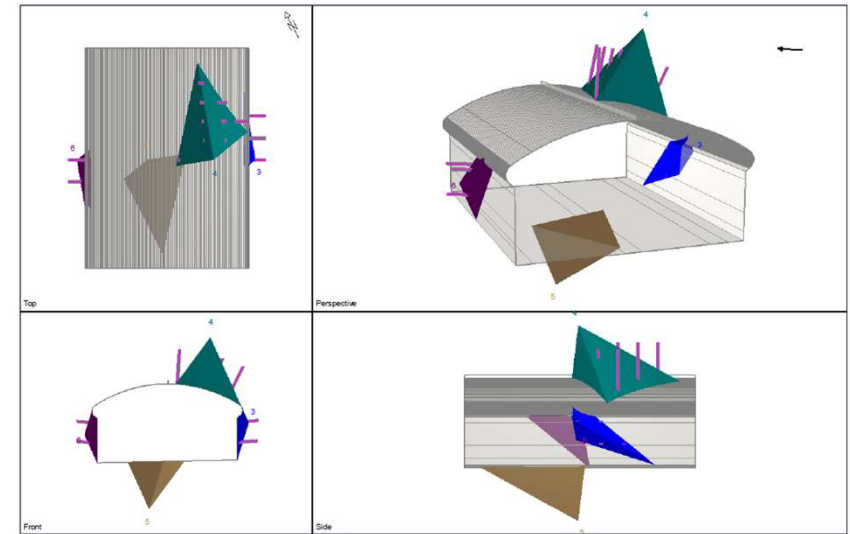
Tunnel and Geotechnical Design

Tunnel Design

Support design

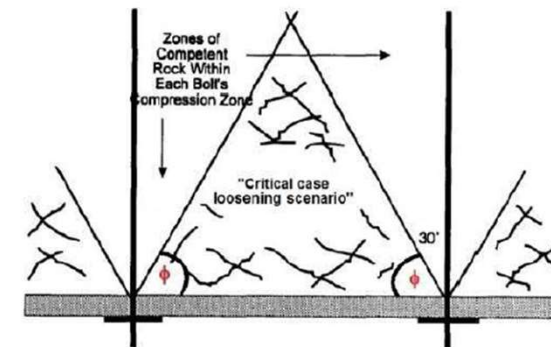
Rockbolt design :

Rock wedge analysis with Unwedge
Pattern bolting with bolt spacing between 1.2 and 2 meters



Shotcrete design :

Barrett and McCreath (1995) complemented by Christine et al (2017)
Shotcrete thickness of 100 mm



Tunnel Design

Sequence constraints

Supported ground

- No access under unsupported ground
- Sequential excavation
- Supported ground completed with rockbolts and shotcrete

Sequence depending of production needs

HEADING EXCAVATION SEQUENCE - OPTION 2 (TWO HEADINGS)
TYPICAL PLAN

HEADING EXCAVATION SEQUENCE - OPTION 3 (THREE HEADINGS)
TYPICAL PLAN

HEADING CONSTRUCTION SEQUENCE
TYPICAL ELEVATION

TABLE 1

HEADING CONSTRUCTION SEQUENCE - SANDSTONE	GROUND SUPPORT TYPE									
	OPTION 2 (TWO HEADINGS) (SEE NOTES 1 & 2)					OPTION 3 (THREE HEADINGS) (SEE NOTES 1 & 2)				
	TW-SS-ST1	TW-SS-ST2	TW-SS-ST3	TW-SS-ST4	TW-SS-ST5	TH-SS-ST1	TH-SS-ST2	TH-SS-ST3	TH-SS-ST4	TH-SS-ST5
① MINIMUM ADVANCE FACE 'Y' FROM HEAD OF SHIPING RULES IS FORBIDDEN AREA OF 10 x 45 SQUARE	30	5750	4500	3010	2510	2000	1550 (4000*)	1500 (4000*)	1150	2100
② INSTALL ROCK BOLTS (RIP AND USE WALLS) AT 100 TYP SHALL THE FACE IN ADVANCE OF 'Y' OF COMPLETED BOLT.	10	5750	5100	3700	3200	2700	1950 (4000*)	1900 (4000*)	1450	2700
③ DECREASE SHOTCRE AND JETLY PRIMARY SHOTCRE BOMB TO MINIMUM THICKNESS 'T' IN LAYERS IF GREATER THAN OR EQUAL TO 150MM THICK - AT 100 TYP SHALL THE FACE BE IN ADVANCE 'Y' OF THE FINAL LAYER OF SHOTCRE BOMB OR FACE LAYER IF MORE THAN 1 LAYER.	10	5750	5100	3700	3200	2700	1950 (4000*)	1900 (4000*)	1450	2700
④ INSTALL PRIMARY SHOTCRE ON USE WALLS AT A MINIMUM ADVANCE OF 'Z' AT 100 TYP SHALL THE FACE BE IN ADVANCE OF 'Z' OF THE FINAL LAYER OF SHOTCRE BOMB	10	40	40	40	40	90	40	40	40	90
⑤ THE LENGTH SHOWN IN BRACKET IS ONLY APPLICABLE IF GROUND SUPPORT TYPE IS T1/T2/T3/T4/T5/T6/T7/T8/T9/T10/T11/T12/T13/T14/T15/T16/T17/T18/T19/T20/T21/T22/T23/T24/T25/T26/T27/T28/T29/T30/T31/T32/T33/T34/T35/T36/T37/T38/T39/T40/T41/T42/T43/T44/T45/T46/T47/T48/T49/T50/T51/T52/T53/T54/T55/T56/T57/T58/T59/T60/T61/T62/T63/T64/T65/T66/T67/T68/T69/T70/T71/T72/T73/T74/T75/T76/T77/T78/T79/T80/T81/T82/T83/T84/T85/T86/T87/T88/T89/T90/T91/T92/T93/T94/T95/T96/T97/T98/T99/T100	20	10200	9700	4700	5700	4700	10200	9700	4700	4700

TABLE 2

MINIMUM SHOTCRE STRENGTH	GROUND SUPPORT TYPE			
	TW-SS-ST1	TW-SS-ST2	TH-SS-ST1	TH-SS-ST2
FOR UNSUPPORTED GROUND	L10Pa	L10Pa	L10Pa	L10Pa

NOTES

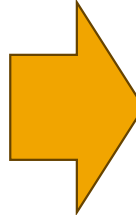
- FOR GENERAL NOTES REFER TO DRAWING POINT: JAL-10N-10C-10C-200-10A.
- NO REINFORCEMENT SHALL BE REQUIRED UNDER UNSUPPORTED TUNNEL UNLESS APPROPRIATE PROTECTIVE MEASURES FOR THE PURPOSE OF THE REQUIREMENT A TUNNEL IS DESIGNED TO BE SUPPORTED. SHIELD ROCK REINFORCEMENT HAS BEEN INSTALLED AND THE LAYER OF SHOTCRE APPLIED WITHIN A DISTANCE OF 'Y' FROM EXCAVATION FACE AND SHOTCRE BUILT UP TO A MINIMUM ADVANCE OF 'Z' FROM EXCAVATION FACE.
- FOR PRIMARY SHOTCRE LAP DETAILS FOR MULTIPLE HEADINGS EXCAVATION REFER TO DRAWING POINT: JAL-10N-10C-10C-200-10A.
- TRAILING HEADINGS WITHIN THE MINIMUM SHALL BE IN.
- OPTION 2 TYPICAL FACE EXCAVATION IS ONLY APPLICABLE TO GROUND SUPPORT TYPES TW-SS-ST1/ST2/ST3 TO TW-SS-ST4/ST5/ST6/ST7/ST8/ST9/ST10/ST11/ST12/ST13/ST14/ST15/ST16/ST17/ST18/ST19/ST20/ST21/ST22/ST23/ST24/ST25/ST26/ST27/ST28/ST29/ST30/ST31/ST32/ST33/ST34/ST35/ST36/ST37/ST38/ST39/ST40/ST41/ST42/ST43/ST44/ST45/ST46/ST47/ST48/ST49/ST50/ST51/ST52/ST53/ST54/ST55/ST56/ST57/ST58/ST59/ST60/ST61/ST62/ST63/ST64/ST65/ST66/ST67/ST68/ST69/ST70/ST71/ST72/ST73/ST74/ST75/ST76/ST77/ST78/ST79/ST80/ST81/ST82/ST83/ST84/ST85/ST86/ST87/ST88/ST89/ST90/ST91/ST92/ST93/ST94/ST95/ST96/ST97/ST98/ST99/ST100.

ACCEPTED FOR CONSTRUCTION

Geotechnical Design

Ground categorization and specification

GROUND TYPE	TYPICAL CORE	TYPICAL ROCK FACE	ROCK MASS CLASSIFICATION - HAWKESBURY SANDSTONE			SYDNEY ROCK MASS CLASSIFICATION (RSL ET AL 1998)	GROUND BEHAVIOUR	SYSTEM BEHAVIOUR	
			ROCK TYPE	STRENGTH	DISCONTINUITIES				ADDITIONAL CRITERIA WITHIN GROUND SUPPORT ZONE
GT-SS-1			<ul style="list-style-type: none"> MASSIVE UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	<ul style="list-style-type: none"> UC1 - 55 MPa 100 - 120 MPa 	<ul style="list-style-type: none"> FRAC/MEAN: P1 01 UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	<ul style="list-style-type: none"> NO SEAMS - 25mm or 40mm THICK UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	CLASS I	<ul style="list-style-type: none"> OVERALL STABLE LOCALISED ROCK FALLOUT SMALL ROCK DEBRIS POSSIBLE FLOORING POSSIBLE WALL PROBLEMS POSSIBLE TUNNELLING 	<ul style="list-style-type: none"> NEAR INCIDENT ON BEARING - 2000 NEAR INCIDENT ON BEARING - 1000 NEAR INCIDENT ON BEARING - 1000 NEAR INCIDENT ON BEARING - 1000
GT-SS-2			<ul style="list-style-type: none"> MASSIVE UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	<ul style="list-style-type: none"> UC1 - 55 MPa 100 - 120 MPa 	<ul style="list-style-type: none"> FRAC/MEAN: P1 01 UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	<ul style="list-style-type: none"> NO SEAMS - 25mm or 40mm THICK UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	CLASS I	<ul style="list-style-type: none"> OVERALL STABLE LOCALISED ROCK FALLOUT SMALL ROCK DEBRIS POSSIBLE FLOORING POSSIBLE WALL PROBLEMS POSSIBLE TUNNELLING 	<ul style="list-style-type: none"> NEAR INCIDENT ON BEARING - 2000 NEAR INCIDENT ON BEARING - 1000 NEAR INCIDENT ON BEARING - 1000 NEAR INCIDENT ON BEARING - 1000
GT-SS-3			<ul style="list-style-type: none"> MASSIVE UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	<ul style="list-style-type: none"> UC1 - 55 MPa 100 - 120 MPa 	<ul style="list-style-type: none"> FRAC/MEAN: P1 01 UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	<ul style="list-style-type: none"> NO SEAMS - 25mm or 40mm THICK UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	CLASS I	<ul style="list-style-type: none"> OVERALL STABLE LOCALISED ROCK FALLOUT SMALL ROCK DEBRIS POSSIBLE FLOORING POSSIBLE WALL PROBLEMS POSSIBLE TUNNELLING 	<ul style="list-style-type: none"> NEAR INCIDENT ON BEARING - 2000 NEAR INCIDENT ON BEARING - 1000 NEAR INCIDENT ON BEARING - 1000 NEAR INCIDENT ON BEARING - 1000
GT-SS-4			<ul style="list-style-type: none"> MASSIVE UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	<ul style="list-style-type: none"> UC1 - 55 MPa 100 - 120 MPa 	<ul style="list-style-type: none"> FRAC/MEAN: P1 01 UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	<ul style="list-style-type: none"> NO SEAMS - 25mm or 40mm THICK UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	CLASS I	<ul style="list-style-type: none"> OVERALL STABLE LOCALISED ROCK FALLOUT SMALL ROCK DEBRIS POSSIBLE FLOORING POSSIBLE WALL PROBLEMS POSSIBLE TUNNELLING 	<ul style="list-style-type: none"> NEAR INCIDENT ON BEARING - 2000 NEAR INCIDENT ON BEARING - 1000 NEAR INCIDENT ON BEARING - 1000 NEAR INCIDENT ON BEARING - 1000
GT-SS-5			<ul style="list-style-type: none"> MASSIVE UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	<ul style="list-style-type: none"> UC1 - 55 MPa 100 - 120 MPa 	<ul style="list-style-type: none"> FRAC/MEAN: P1 01 UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	<ul style="list-style-type: none"> NO SEAMS - 25mm or 40mm THICK UNFOLDED UNFRACTURED UNFOLDED UNFRACTURED 	CLASS I	<ul style="list-style-type: none"> OVERALL STABLE LOCALISED ROCK FALLOUT SMALL ROCK DEBRIS POSSIBLE FLOORING POSSIBLE WALL PROBLEMS POSSIBLE TUNNELLING 	<ul style="list-style-type: none"> NEAR INCIDENT ON BEARING - 2000 NEAR INCIDENT ON BEARING - 1000 NEAR INCIDENT ON BEARING - 1000 NEAR INCIDENT ON BEARING - 1000



TUNNEL MAPPING RECORD
MAP-MTD-TM-1700.00 to 1713.65 LHS

- Unique record ID
- Digital format and Signature
- Ipad Sketch Markup of map overlaid on photograph of tunnel face
- Record of additional support required
- Automated Calculation of GSI and Q rating



Geotechnical Design

Drained tunnel mainly in Hawkesbury Sandstone

“observational” approach for the implementation of the groundwater control measures

Ingress limited by the client to 1 L/s/km

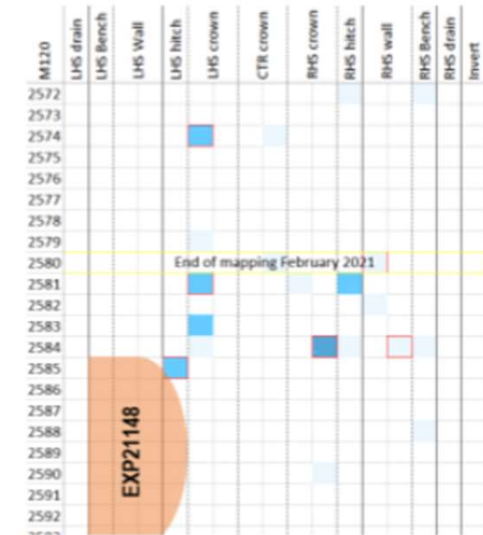
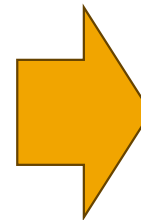
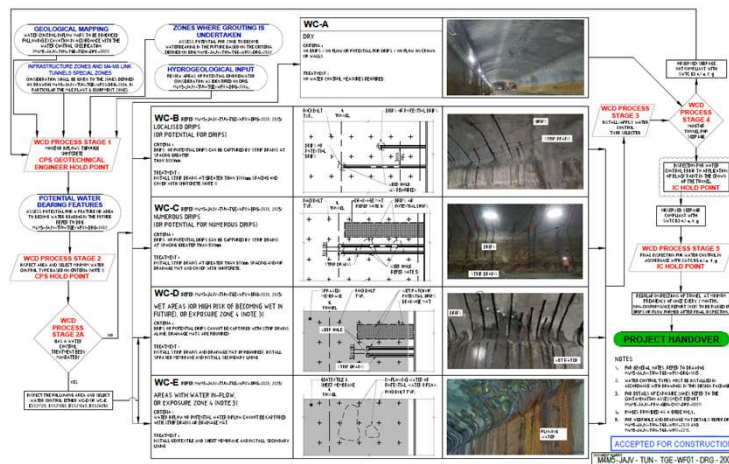
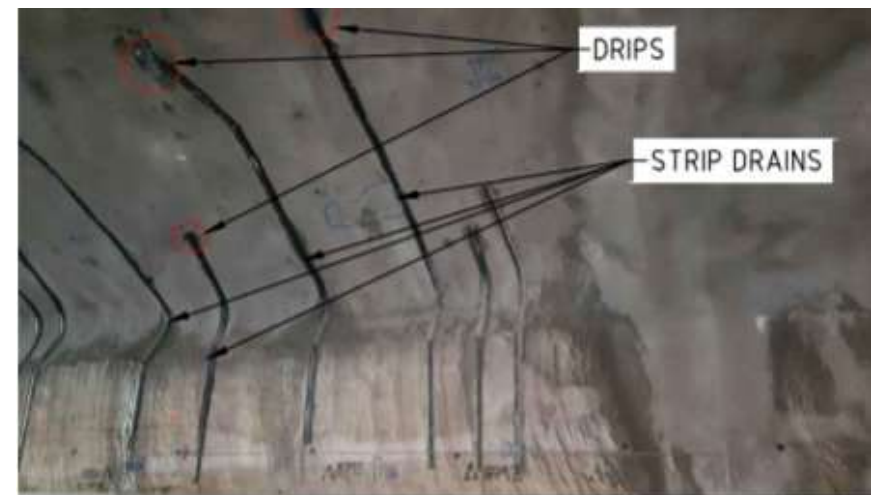
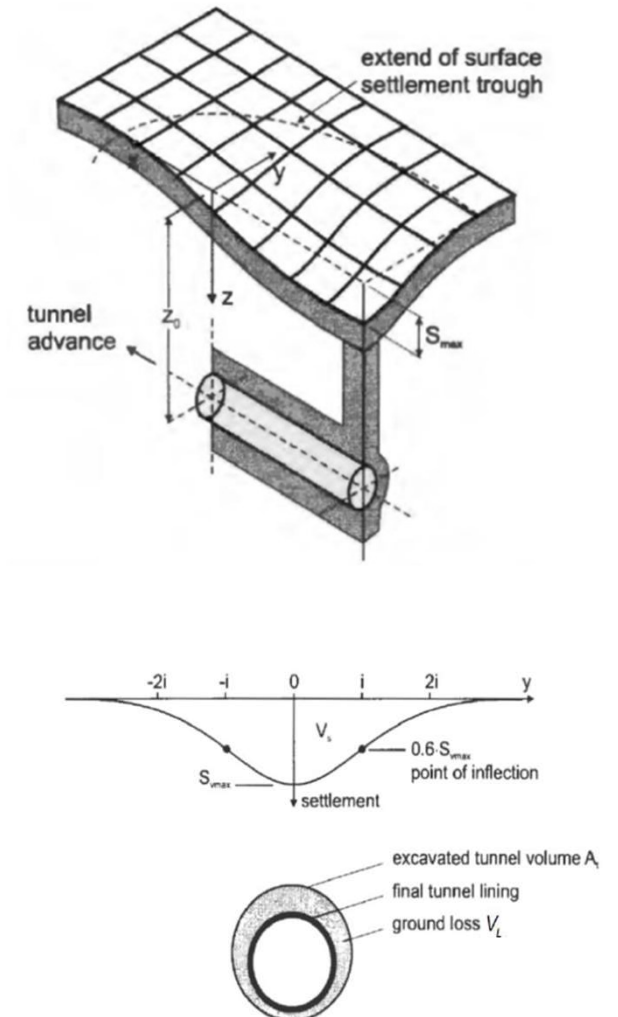


Figure 22 Groundwater mapping record sheet



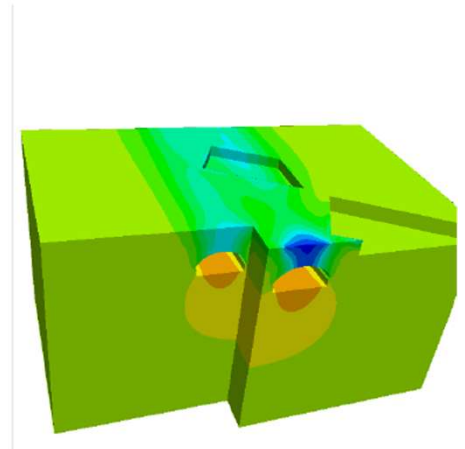
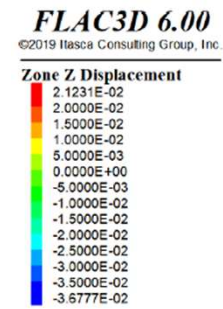
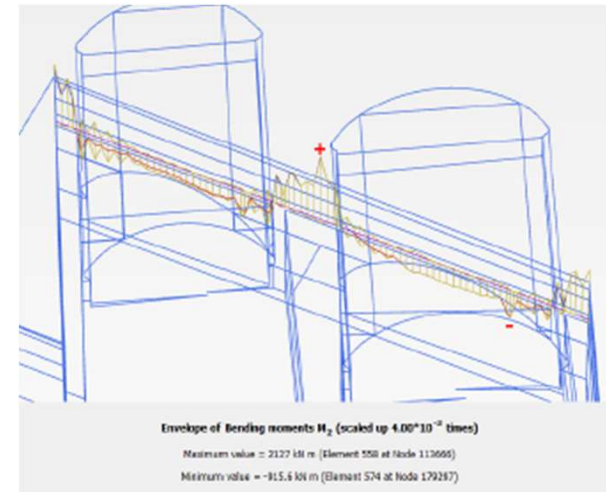
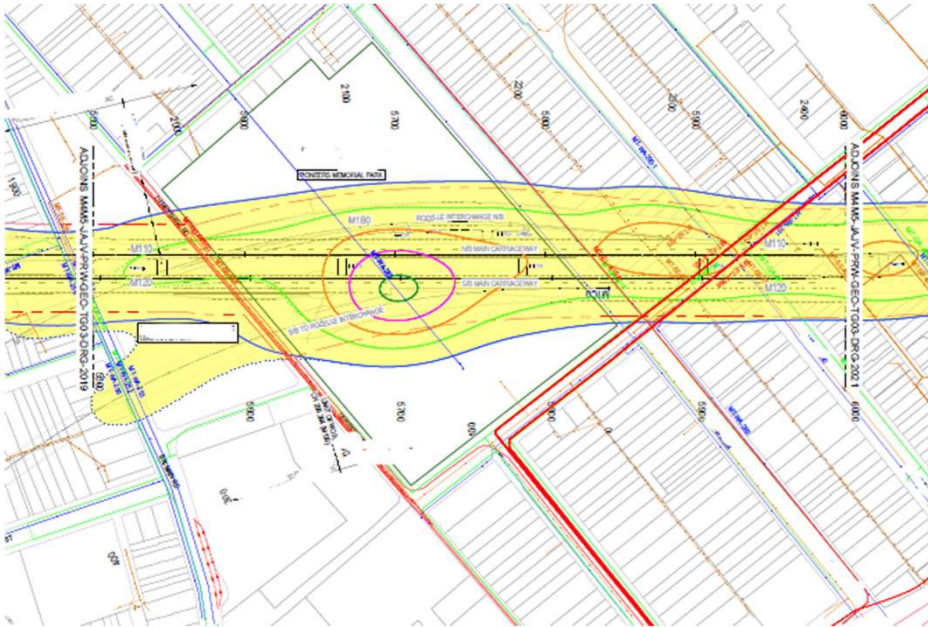
Geotechnical Design

Third parties' impact



Geotechnical Design

Third parties' impact



Design

And much more geotechnical / structural

Shallow cover tunnel design

Grouting

Groundwater model and contamination transportation

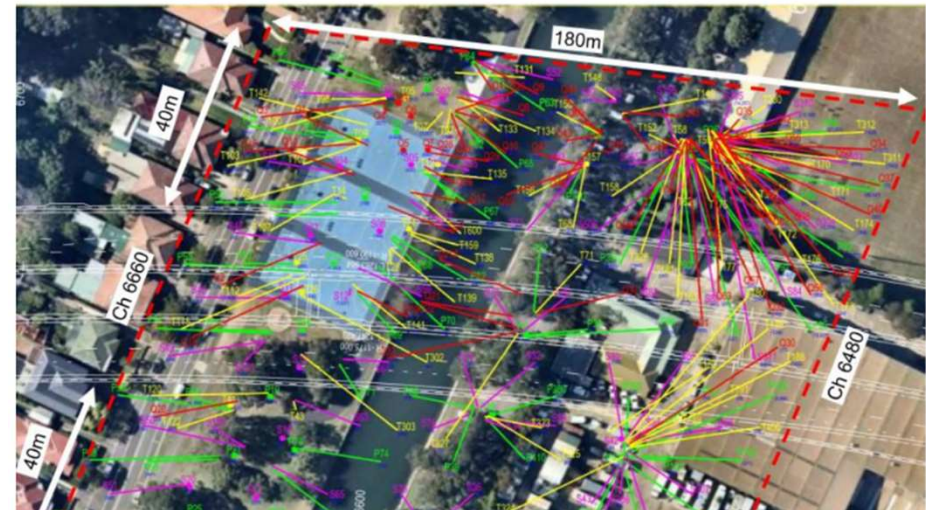
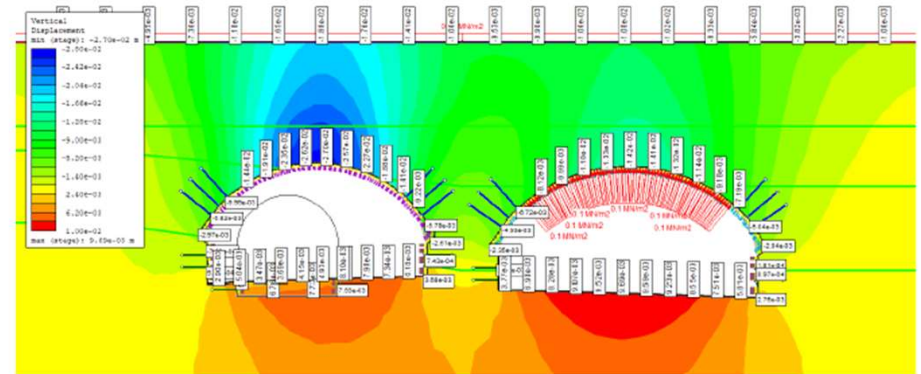
Shafts design

Structural design

Durability design

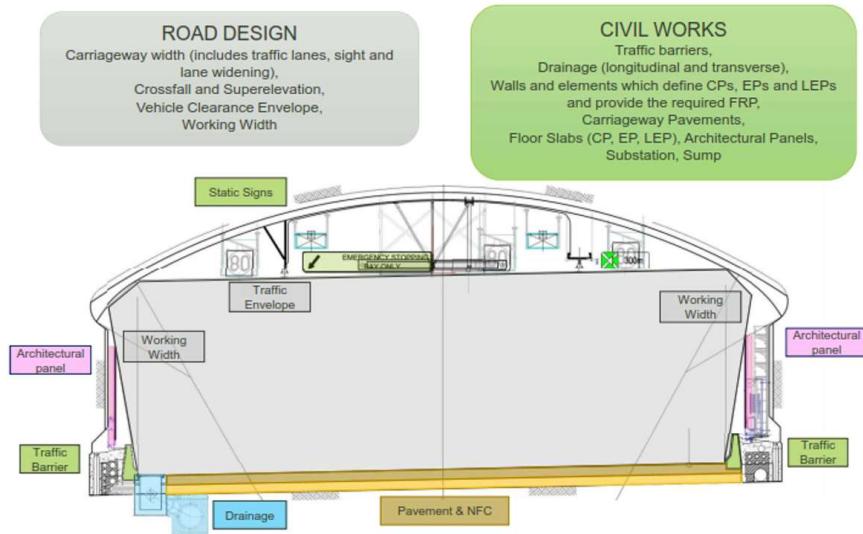
Bridging slab

Etc.

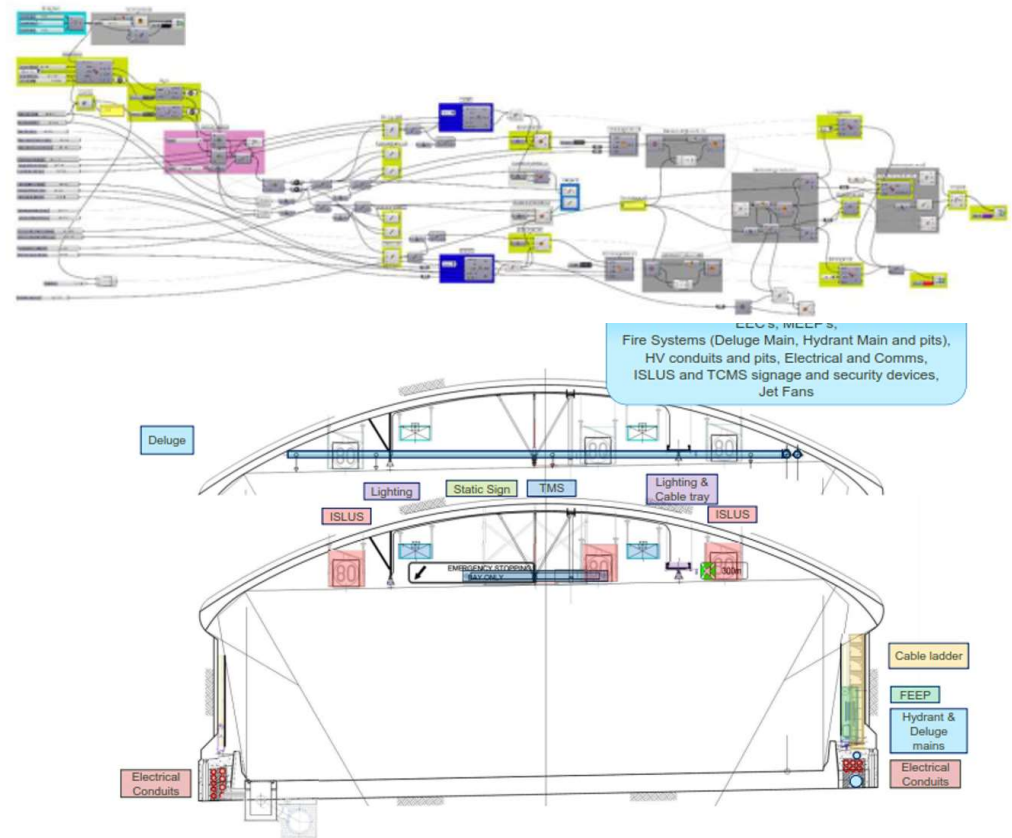


Design coordination / integration – Digital Engineering

Spaceproofing



Rhino/Grasshopper
Tunnel, Civil, M&E constraints





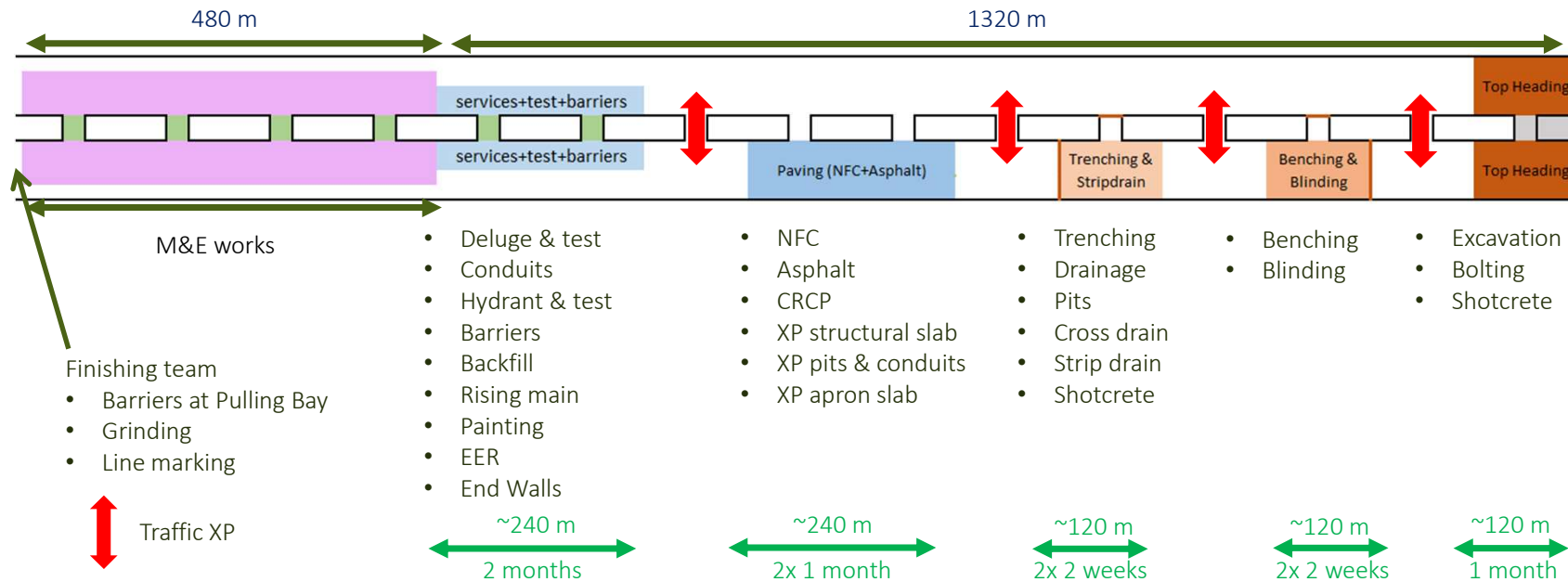
03

Delivery strategy

WCX3A scope - delivery phase strategy: 4 main challenges

1. Spoil management
2. Concrete and Supply for Civil Fit-Out works during tunnel excavation
3. Integrated M&E works during tunnel excavation & fit-out works
4. Interface of other existing assets e.g. the City and Pressures Tunnels from Sydney Water, the proximity of properties – especially at the portals and Rozelle Stub Tunnels, the Sydney Metro, the assets at Hawthorne Canal

Tunnel Production Line principle



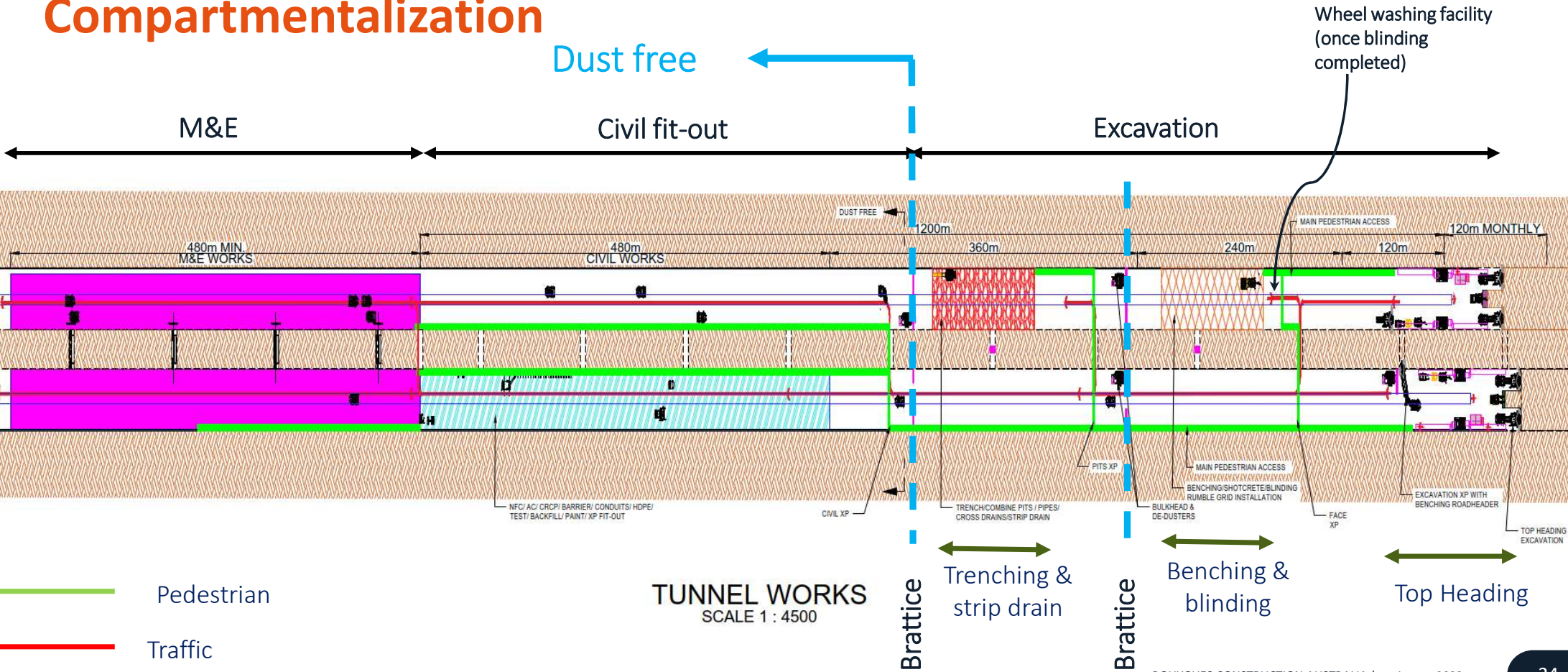
Tunnel Production Line principle



Tunnel Production Line principle



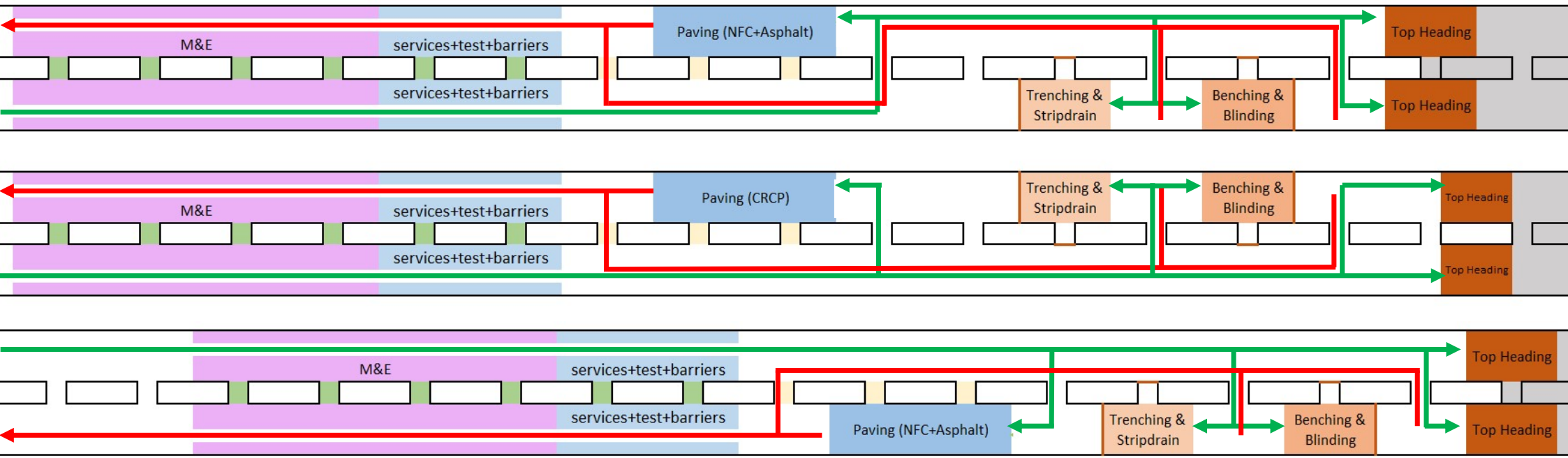
Tunnel Production Line: dust management / Tunnel Compartmentalization



Dust Management – Product development



Tunnel Production Line: tunnel logistic / traffic

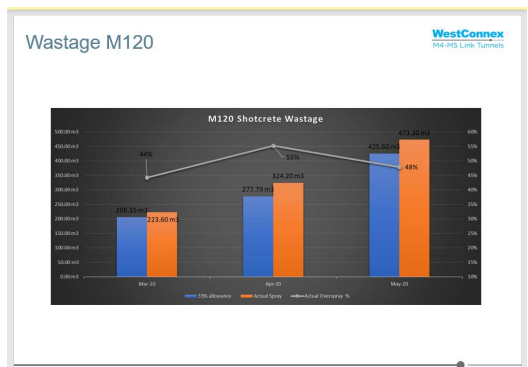
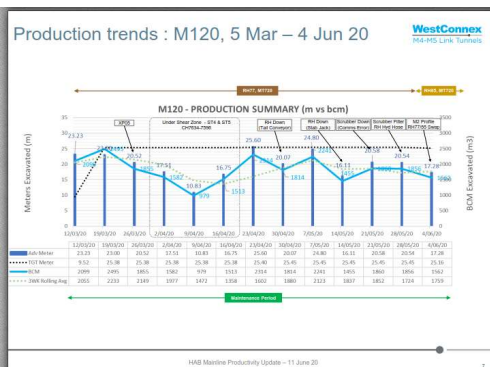
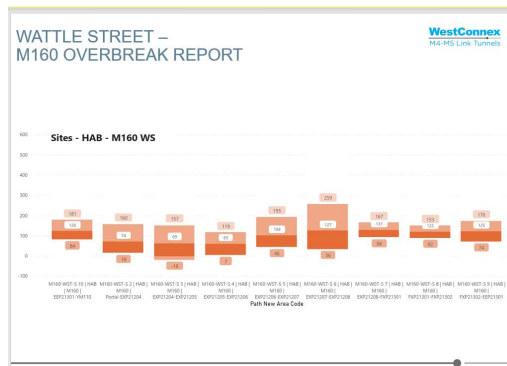
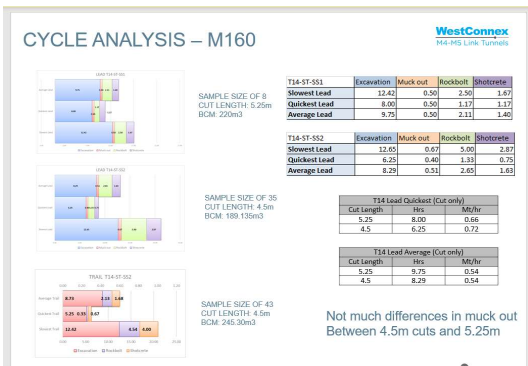
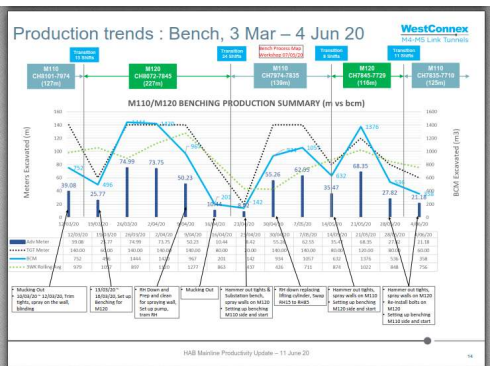


→ Traffic towards the excavation face
← Traffic leaving the tunnel

03 Delivery strategy

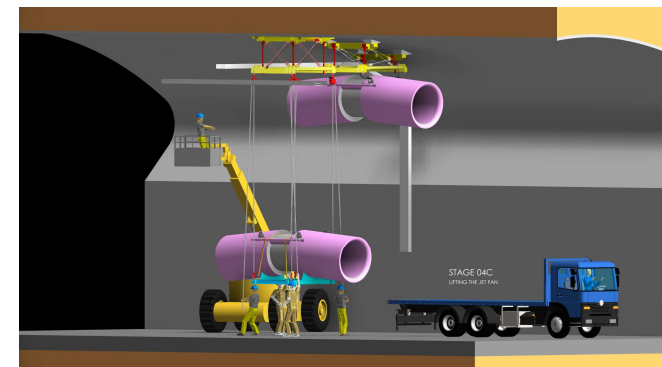
Lean – Continuous Improvement - Anticipation

LEAN HAS GIVEN US
THE CULTURAL
CURIOSITY TO WANT
TO IMPROVE
... AND THE DATA TO
SHOW US WHERE TO
IMPROVE

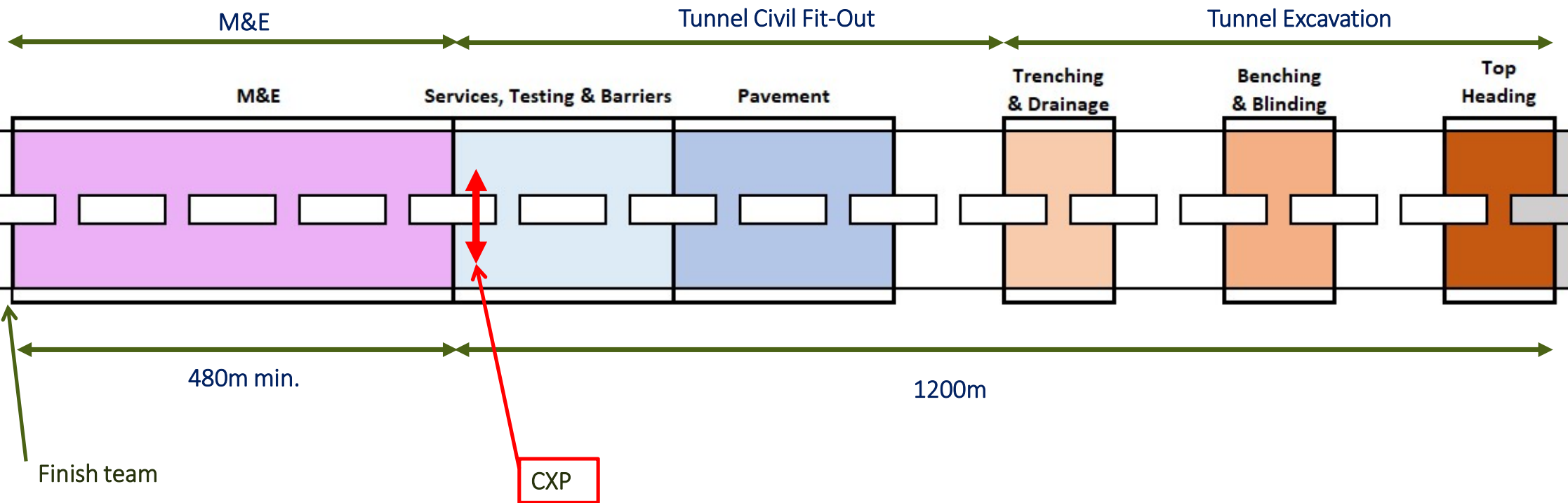


M160/M110 - DATA

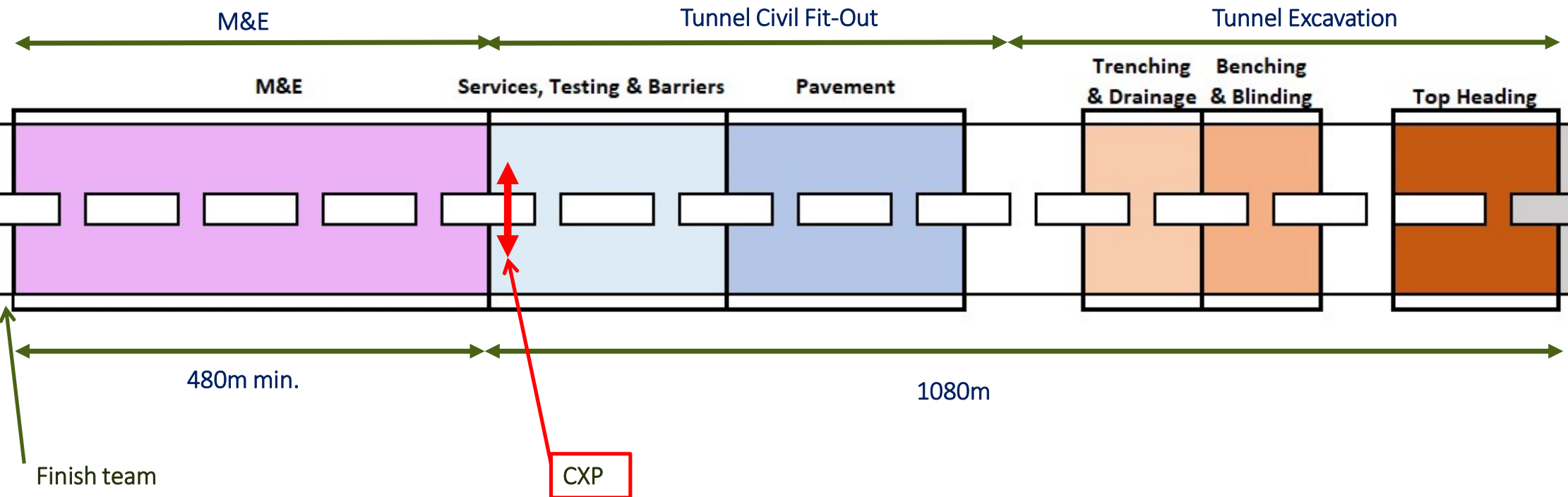
TOP 5 DELAYS MAY				
Delays	Total Time	%	Hrs/Abft	Rank
03. Mucking out digger/loader	32:40	24%	00:31	1
06. Ventilation works/extension	19:20	14%	00:18	2
06. Scraper move	11:10	8%	00:10	3
43. RH-Electrical failure	08:30	6%	00:08	4
29. RH-Pick change	08:20	6%	00:08	5
Total Delay Hours	138:08		Total Hours Worked	620:00
22.37%				
TOP 5 DELAYS APR				
Delays	Total Time	%	Hrs/Abft	Rank
03. Mucking out digger/loader	31:40	25%	00:31	1
35. RH-Belt conveyor	18:30	15%	00:18	2
06. Ventilation works/extension	13:20	11%	00:13	3
43. RH-Electrical failure	09:55	8%	00:09	4
39. RH-Electric motor	06:30	5%	00:06	5
Total Delay Hours	128:30		Total Hours Worked	600:00
21%				
TOP 5 DELAYS MAR				
Delays	Total Time	%	Hrs/Abft	Rank
03. Mucking out digger/loader	27:00	20%	00:26	1
43. RH-Electrical failure	26:30	19%	00:25	2
06. Ventilation works/extension	13:15	9%	00:13	3
35. RH-Chain conveyor	10:50	8%	00:10	4
29. RH-Pick change	08:25	6%	00:08	5
Total Delay Hours	138:40		Total Hours Worked	620:00
22.37%				



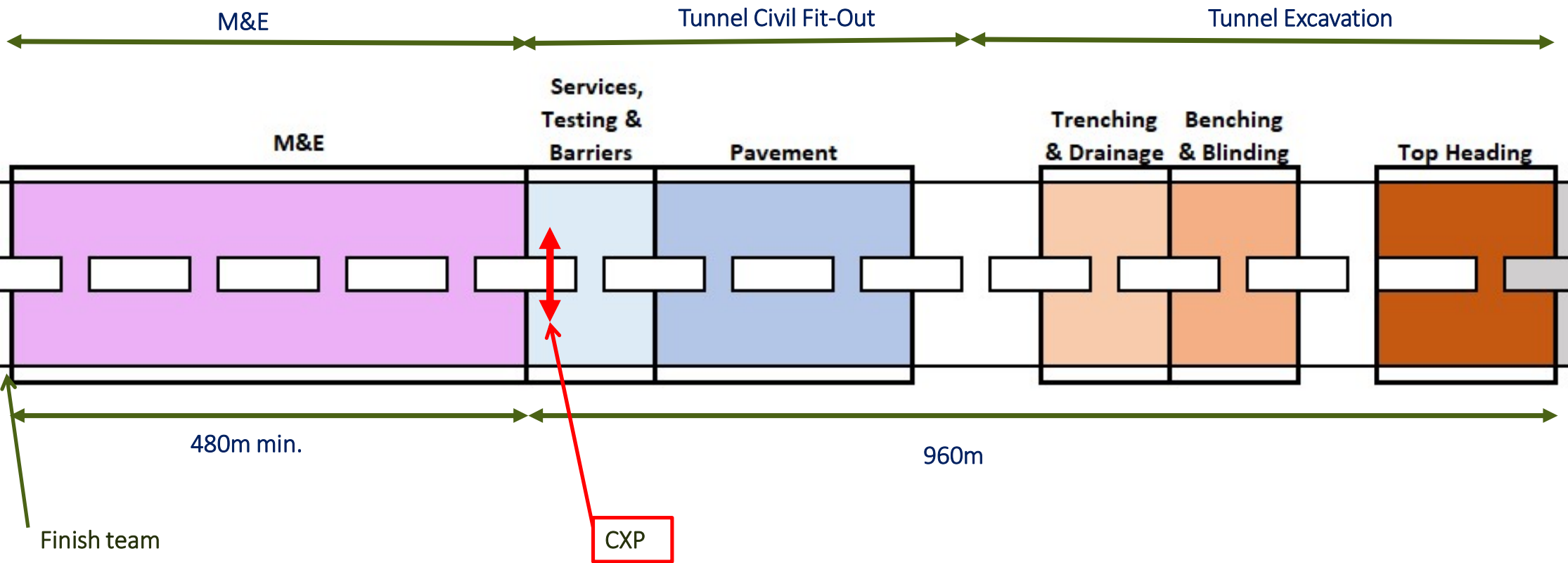
Tunnel Production Line Improvement #1



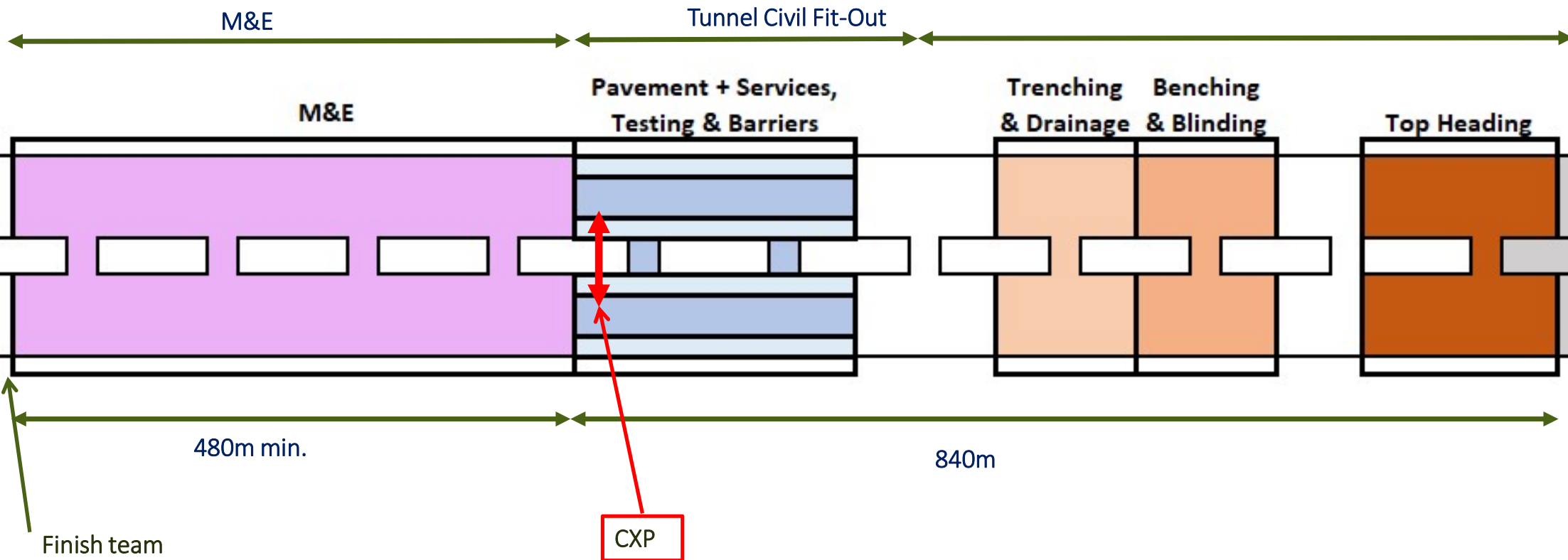
Tunnel Production Line Improvement #2



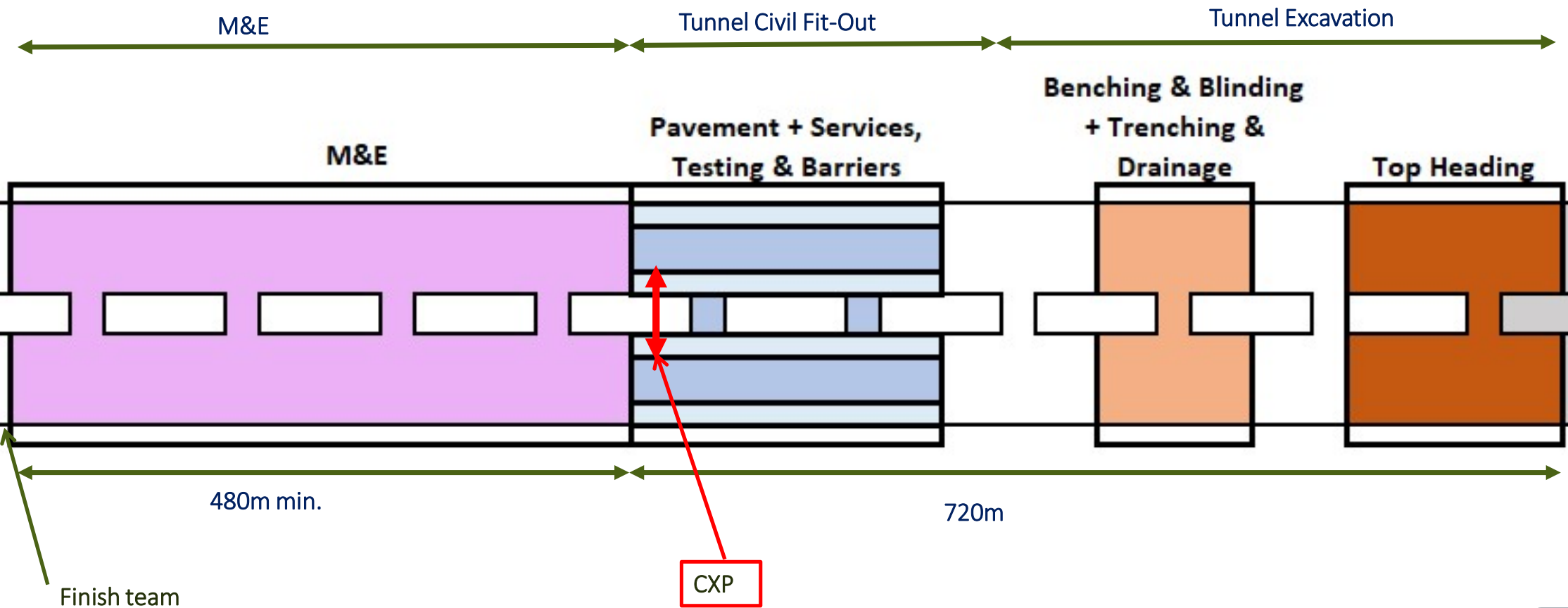
Tunnel Production Line Improvement #3



Tunnel Production Line Improvement #4

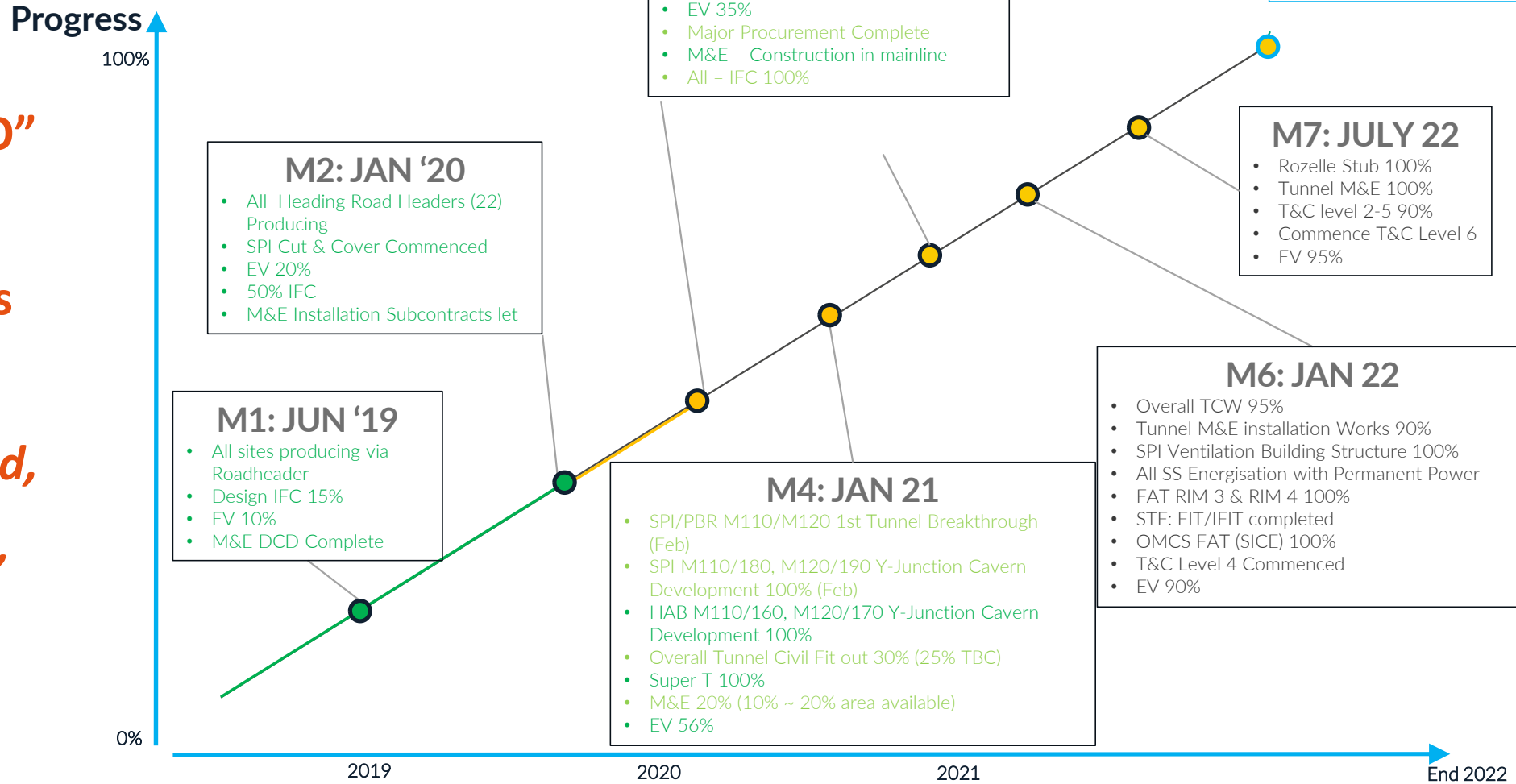


Tunnel Production Line Improvement #5



A "CAN DO" Culture: Vision & Milestones

"Integrated, Inclusive, Improved"

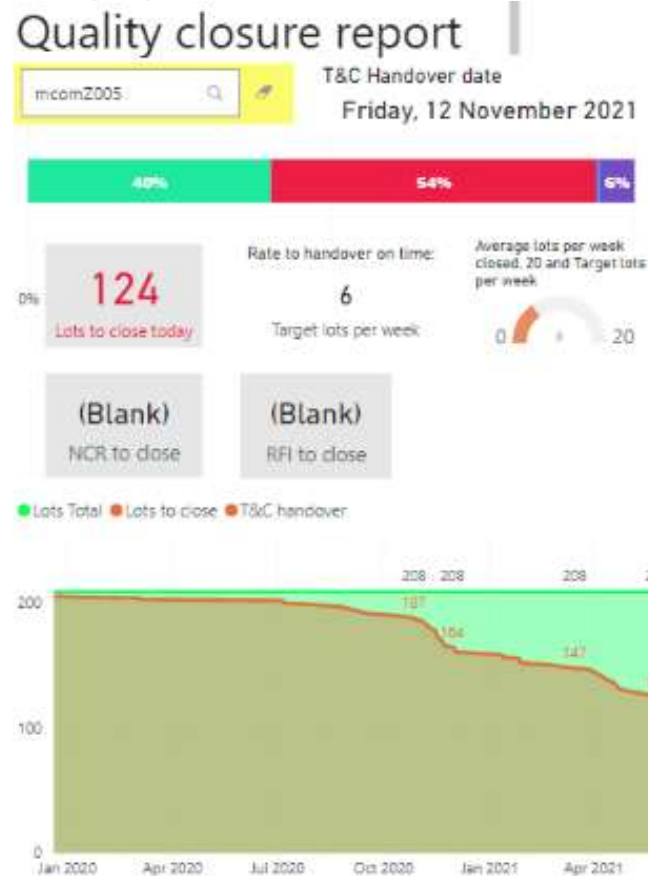


Integrated quality process control and validation

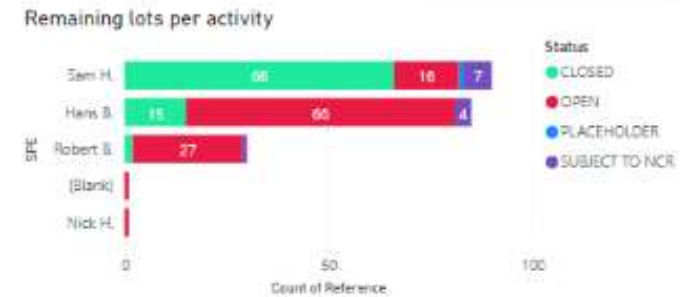
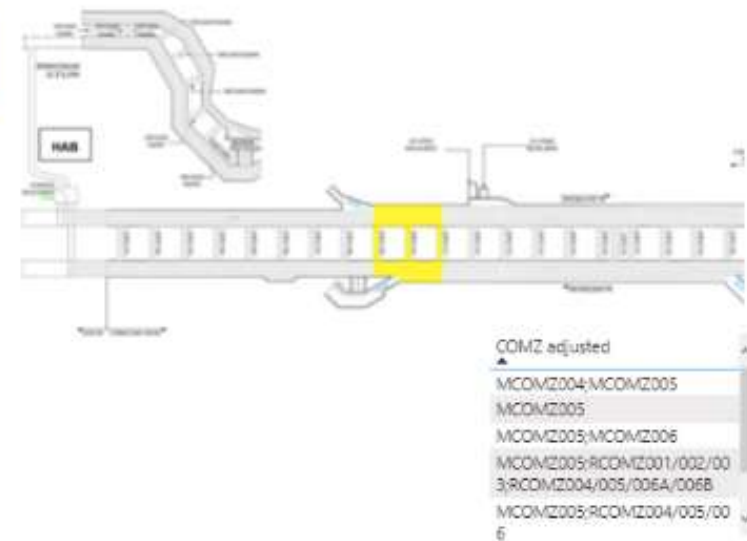
Lot management & monitoring

Punch lists Tunnel / Civil / M&E / T&C for quality at first

As-built documentation populated during construction



152 Days Left



WHAT NEXT?

- Focus on T&C from the start of the project (and integrate T&C into the design)
- Multi perspective thinking (with multidisciplinary trades and engineers)
- Reduce the number of people in the tunnel → remote control

Conclusion: “*Integrated, Inclusive, Improved*”

WE PLANNED WHAT WE DID, and WE DID WHAT WE PLANNED

AND WE DID EVEN BETTER

Awards and publication



Publications :

A Case Study- Tunnelling adjacent to major water transfer tunnels

MARK SHEFFIELD¹, DAVID OLIVEIRA², SIVANATHAN THIRUKUMARAN³, DINESH DINESHARAN⁴ AND LEO-PAUL CALBRIX⁵

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Permanent rock bolts with 100-year design life in contaminated ground

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Application of the Socratic Method to: Permit-to-Tunnel (PTT) meetings

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Building a tunnel starting with the end (Opening Completion) in mind - The Tunnel Production Line at the WestConnex M4-M5 Link Tunnels (WCX Stage 3A) Project

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Thank you

