NORTH-EAST LINK PROJECT
BANYULE CITY COUNCIL, VICTORIA

Options for Extension of the Underground Alignment

BabEng

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Index	Description of Revision	Date

Available Documents:

[1] "North East Link Authority, North East Link Environmental Effects Statement, Groundwater Technical Report", Draft version, December 2018.

[2] "Environmental Effects Statement, Chapter 8 – Project Description" Draft version prepared by GHD, Revision B, 31. July 2018.

[3] "Environmental Effects Statement, Chapter 6 – Project Development for TRG review" Draft version prepared by GHD, 12. July 2018.

[4] "North East Link Project Update", Banyule City Council – Presentation, June 2018

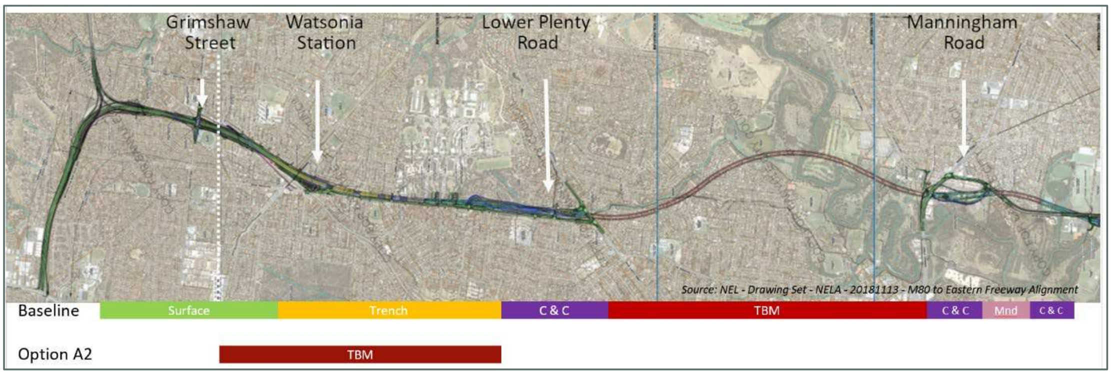
EXECUTIVE SUMMARY

The North East Link Project (NELP) is developing its design of the North East Link (NEL) based on the State Government decision to adopt corridor Option A, which is a new freeway connection between the M80 Ring Road and the Eastern Freeway through Banyule municipality.

Banyule Council asked BabEng to elaborate on the following questions in connection with the North-East Link Project, as designed and presented by NELP on behalf of the State Government:

- Explore technical options for extending the underground portion of the proposed alignment,
- Assess the costs of any viable option, and
- Evaluate the alignment options as suggested from community stakeholders.

Taking into account the identified constraints like existing railway lines, bridges, the underground main gas line, limits in permissible road inclination, and maintaining existing interchanges, one of four theoretical tunnelling options appeared to be the most viable alternative.



Option A2 consists of the replacement of the open trench section by continuing the TBM excavations for another 2,500 metres of twin tunnels. This option would stand for the following key reasons:

- It reduces the surface roads by approximately 40 %;
- The open trench is replaced by a fully covered structure;
- All through is traffic below surface for the major part of the alignment; and
- All major connections and intersections are maintained.

BabEng undertook a costing assessment for the extended tunnel component. A detailed cost estimate would have been beyond the possibilities of this study in the set time frame and budget. Instead, the construction volumes of the different main structures, for example “open trench” or “bridges”, were compared between the reference design and Option A2. Option A2 shows a substantial reduction of all works on surface, while the further utilisation of the TBMs from the southern alignment section permits the continuation of TBM tunnelling at comparably reduced costs for the additional tunnelling component. Classifying all TBM tunnelling related machinery costs as “anyway-costs” for the project, the Option A2 should be on a comparable level cost-wise with the reference design.

Furthermore, it is noted that the BabEng assessment of a longer tunnel option as suggested by community stakeholders was consistent with the proposed Option A2.

A INTRODUCTION

The North East Link Project (NELP) is developing its design of the North East Link (NEL) based on the State Government decision to adopt corridor Option A, which is a new freeway connection between the M80 Ring Road and the Eastern Freeway through Banyule municipality.

The North East Link reference design for Option A indicates that the new freeway will be in tunnel from north of the Eastern Freeway (southern portal) to just north of Lower Plenty Road (northern portal). The section between northern portal and M80 Ring Road will be constructed in trench and at grade.

Banyule City Council (BCC) has identified a number of issues such as impacts to local businesses, local access and local environment, due to the extensive surface works proposed between northern portal and M80 Ring Road.

Extending the NEL tunnel has been proposed as an option to reduce these impacts on the Banyule community and BCC has engaged to BabEng to:

- Explore options for extending the tunnelled section of NEL;
- Assess the costs of any viable option; and
- Evaluate the viability of a longer tunnel option suggested by Banyule community stakeholders.

For this purpose, BabEng received publicly available documents as listed under "Available Documents". To further support the study, BabEng had to rely mainly on information gathered from the internet, here especially Google Maps, as well as assessments derived from own photos. Consequently, the findings in this report need to be verified in future design phases.
This study focuses on optimising the tunnelled section while maintaining the fundamental project parameters.

B REFERENCE DESIGN

The current North-East Link Project alignment has been divided into the three project elements, which are 1) connection of the M80 / Road 46 to the Northern tunnel portal, 2) Northern tunnel portal to Southern tunnel portal, and 3) connection structures to the M3 Eastern Freeway.

The second element includes approximately 5.2 km of twin three-lane tunnels. Both parallel tunnels extend from Lower Plenty Road in the North to the proximity of the Veneto Club in Bulleen in the South.

According to the available documents, the tunnels would be constructed using three different tunnelling methods: Cut & Cover, conventionally mined tunnels, and utilising tunnel boring machines (TBMs) (see Figure 1).

The baseline design incorporates about 3.1 km bored tunnels, excavated in parallel by two TBMs. The excavation diameter of 15.6 m would allow for three traffic lanes in the tunnels. The maximum overburden above the tunnel alignment is found to be 40 metres. Cross Passages (XPs) between the tunnels for safety purposes are planned to be excavated every 120 m.

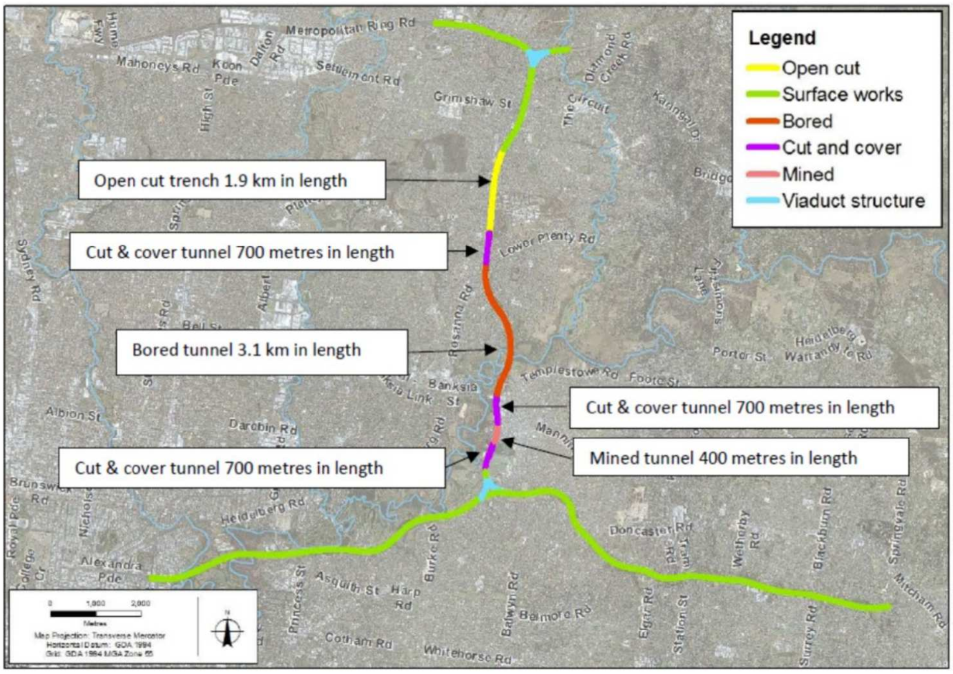


Figure 1 North-East Link Project alignment – Northern portal to Southern portal [2]

Cut & Cover

The standard earth moving equipment are implemented for opening a space for construction of the tunnel structure using C&C method. After building of the main structural elements, the tunnel can be covered again with the excavated material, then the created space on surface is available for reuse. It is comparable to the construction of basements.

This technique especially applies for shallow alignments above the ground water table. With water drainage, this technology can be applied as well below the ground water table. This technology does not require any overburden and permits flexibility in the tunnel profile. Figure 2 shows an open trench excavated below the ground water table just before construction of the main structural elements of the tunnel.

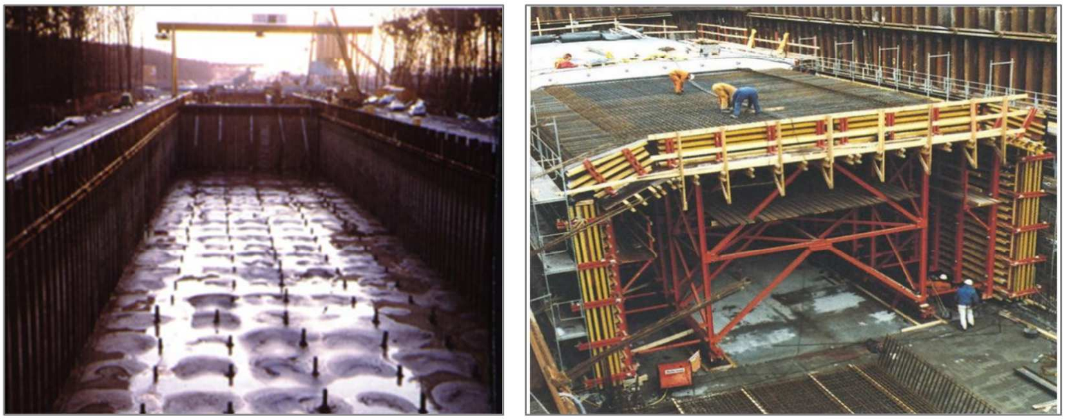


Figure 2: Construction of Cut & Cover tunnelling

The current project documents show the following cross-section for this method (See Figure 3):

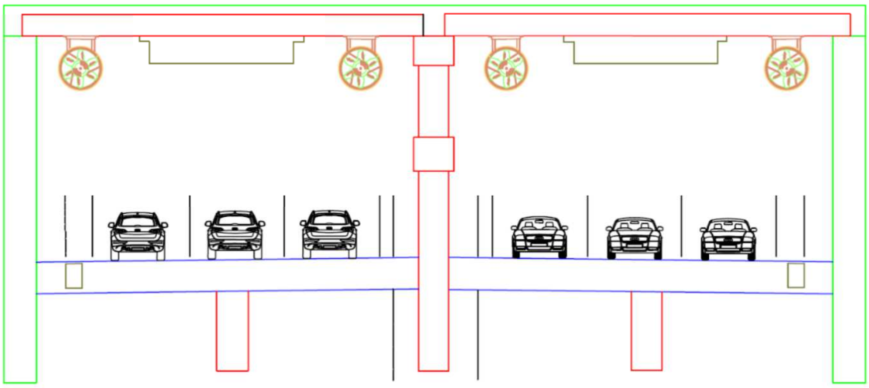


Figure 3: Tunnel cross-section of the Cut & Cover section [2]

Mined Tunnelling

Mining or Conventional Tunnelling is the excavation of cavities below ground with immediate support of the profile, e.g. by shotcrete. Typical machinery for excavation are excavators or roadheader, depending on the ground conditions. The technology requires a certain overburden above the tunnel. Applying temporary water drainage, it can be applied as well below the groundwater table. It offers as well, in certain boundaries, flexibility in the excavated profiles. The mobilisation time for an excavation is rather short due to standard equipment.

Figure 4 shows an excavator that is mining the tunnel face at the crown part of a tunnel profile. In the front of the excavator is the tunnel face consisting in this case of soft rock. The tunnel invert and the side walls are already stabilised by steel wire mesh, shotcrete and rock bolts.

The cross section for a mined road tunnel using an excavator or road header is depicted in Figure 5 and has an excavation area for this project of about 173 m².

Figure 4: Excavator working at the tunnel face

Figure 5: Tunnel cross-section of the mined tunnels. [2]

Bored Tunnelling by Tunnel Boring Machine (TBM)

A TBM, simplified, is a steel can with a full-face cutterhead on the front side to excavate the ground at once. The steel can give initial support to the ground and protects the workers. In the rear of the can the final round concrete structure is built out of precast elements. With hydraulic jacks the TBM is pushing itself off from the last concrete ring and further excavating the space for the next ring. The TBM can be equipped to work in ground water and in different geologies. TBMs require as well certain ground overburden. Changes in the excavation profile are rather difficult. TBMs require long mobilisation time, but are faster in the tunnelling process, surpassing the other technologies.

Figure 6 shows a TBM ready to advance in an underground cavern. On the left-hand side, the rotating cutterhead. The steel casing gives immediate support to the ground. On the right-hand side would be the concrete lining.

Figure 6: TBM in underground cavern

Figure 7 shows the cross section for the bored tunnel using TBM. The calculated excavation area is 193 m2, 20 m2 larger than the tunnel area of a mined tunnel.

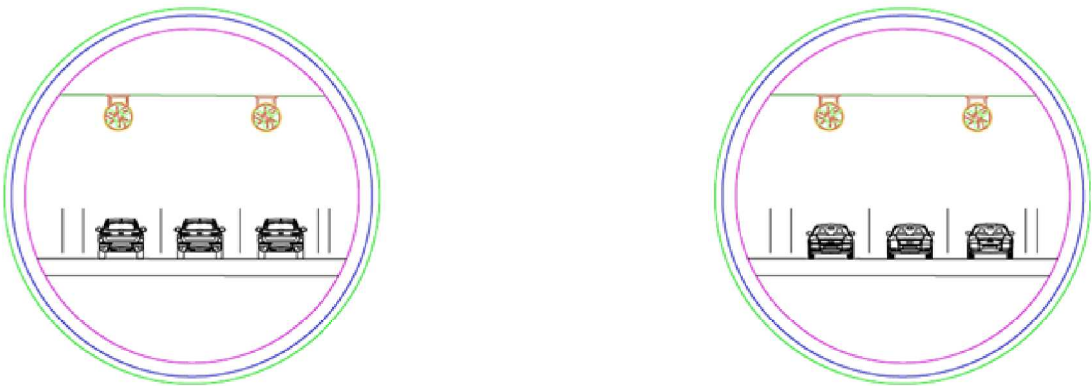


Figure 7: Tunnel cross-section of the bored tunnels [2]

Geology

The geology in the project area mainly consists of folded and faulted Palaeozoic marine sedimentary rocks. The Silurian Anderson Creek Formation and the Melbourne Formation form the bedrock. These sedimentary rocks are mainly siltstones, mudstones and sandstones. According to the "Groundwater Technical Report", the massive siltstones layers are described as fractured rock aquifers and underlie the entire study area. Therefore, the geological subsurface in the project area is characterized by weathered siltstone and alluvial deposits associated to Yarra River floodplain (See Figure 8 below). Further information on the geological situation north of Greensborough Road have not been available.

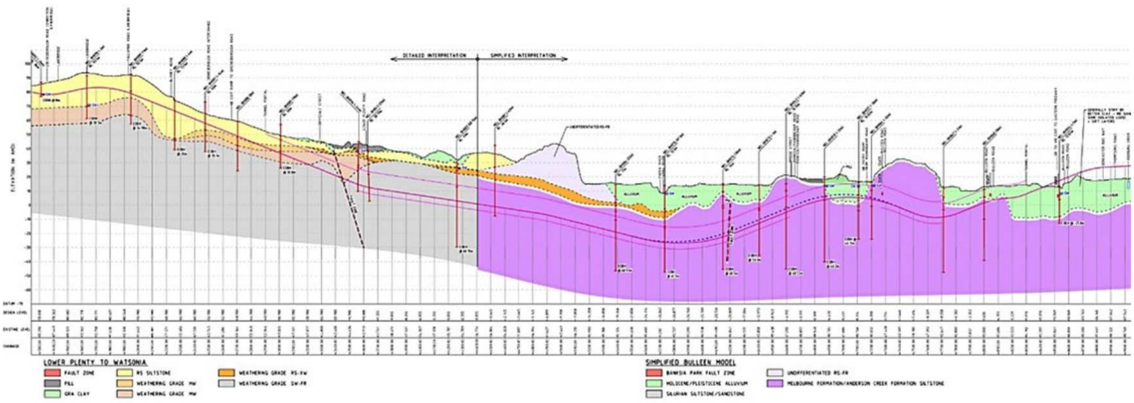


Figure 8: Geological profile through the project area from the southern portal to Greensborough Road.

Alignment Constraints

The vertical alignment of the tunnel route needs to fulfil certain constraints due to the infrastructure. The Hurstbridge rail line underpassing Greensborough Road is located north of Watsonia Station and is a limiting factor influencing the position of the tunnel portal. According to [4], the acute angle of the Hurtsbridge rail line causes the TBM to be under the rail line for at least 150 m.

The 450 mm transmission gas main crosses the alignment at Elder Street just opposite of Watsonia Station at a depth of approximately 8 m and drops to 12 m on the northbound Greensborough Road. Hence the gas main is another limiting factor influencing the tunnel length.

Another constraint is the maximum tunnel gradient of 4 %. The grades for entry and exit ramps at Grimshaw were adjusted to a maximum value of 6 % by Banyule City Council in order to achieve constructability of the Grimshaw Street interchange. The southbound entry ramp of the interchange at Grimshaw Street incorporates a "weave" section to cross over lanes. This specification relocates the start of the entry ramp 150 m south of Grimshaw Street. Further, the land acquisition should be optimised by reducing the usage of private and public land along the roads.

Summarising the above, the vertical alignment needs to take the rail line and the position of the gas main into account by maintaining a necessary vertical clearance for safe passage of the TBMs. At the same time, the alignment shall retain the functionality of the current interchanges and not to exceed the maximum gradient.

C EXTENSION OPTIONS

BabEng investigated possible options that can be employed for extending the tunnel. At first, four options were identified and examined, aside of the reference design (NELP alignment). These are identified and described in Table 1 and Figure 9.
In order to draw the vertical alignment of these extensions, the elevation model was extended further north, generated from elevation data provided by Google Earth Pro. The vertical alignment shall retain the functionality of the existing interchanges.

Table 1: Selected options at the first stage

Options	Total length [m]	Extension [m]	Description
Reference	3,100	0	3.1 km twin tunnels with TBM
Option A1	4,000	900	Approx. 900 m in addition excavated by roadheader
Option A2	5,600	2,500	Approx. 2.5 km additional TBM excavation
Option A3	5,800	2,700	Approx. 2.7 km of additional TBM excavation
Option A4	6,500	3,400	Approx. 3.4 km of additional roadheader excavation

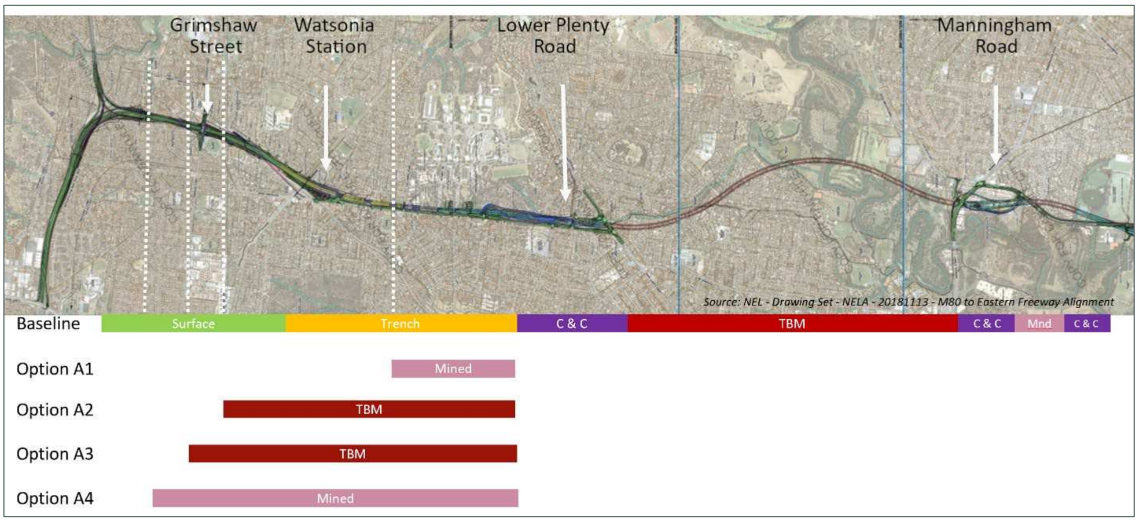


Figure 9: Preliminary options for extending the North East Link Tunnel.

An extension of the tunnel northwards is achieved in Option A1 by a 900 m long roadheader section. The tunnel portal is located near Yallambie Road. Option A2 extends the tunnel by 2,500 m TBM drive until north of Doris Street. The tunnel portal of the TBM drive of Option A3 is located northwards of Grimshaw Street near Kempston Street. In Option A4 a roadheader is used to extend the tunnel by 3,400 m, directly linking to the M80.

Since the geological conditions at this end of the alignment can be described as weak, with shallow overburden and at least partly below ground water table, the risk for unstable tunnel face conditions might be increased applying mined tunnelling options. For this reason and with the current information, BabEng does not consider mined tunnelling as a viable option for this section and Option A1 and A4 are dismissed.

Options A2 and A3 were selected for further investigations. The proposed extension options were selected in this report for cost estimations as shown in Table 3 and in Figure 10. These options could be described as follows.

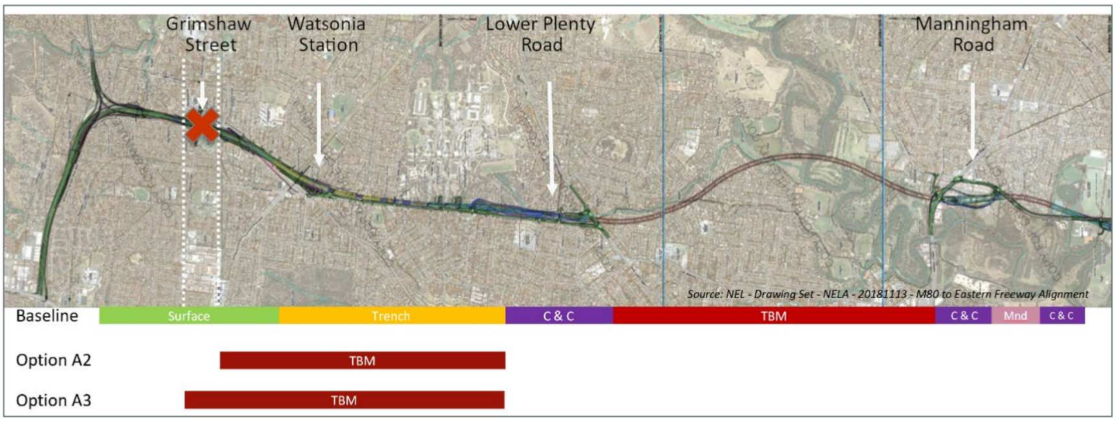


Figure 10: North East Link Project alignment for the reference design and extension Options A2 and A3

OPTION A2

Option A2 as mentioned in Table 3 considers the extension of tunnel for further 2,500 m from Lower Plenty Road to north of Watsonia Station by continuing the TBM operations from the southern alignment part. The northern tunnel portal and ramp lie within the 600 m long open cut trench section, that is extending from the rail line to just north of Grimshaw Street (Station 7+950 m).

The maintained minimum clearance to the rail line was calculated to 15 m. The vertical alignment of Option A2 shows the position of the tunnel portal and the gradient of tunnel route. The gradient does not exceed the limitation of 4 % and remains within a range of 1 to 1.7 %. Furthermore, both the interchange Grimshaw Street and the underpass Kempston Street could be maintained.
Enhanced available space at Watsonia Station might be used for an intermediate ventilation and access shaft. Due to the increased tunnel length, additional ventilation shafts are necessary. The baseline concept suggests ventilation shafts at the vicinity of the southern

portal and Lower Plenty Road. An additional ventilation shaft is required at the northern portal. Considering the smoke exhaust shafts, an additional shat is required at the northern portal.

3D Model

BabEng elaborated a 3D model of Option A2 to depict the complexity of the northern portal at Grimshaw Street. It includes google map information of the wider Grimshaw Street area and the traffic proposal from community stakeholder input, since these are well in line with the investigated portal position of Option A2. The southbound merging lane from Grimshaw Street is the most critical lane, as the eastern tunnel tube is the closest to the Hurstbridge Rail line. Further, the southbound entry ramp incorporates a "weave" section, that is considered in the design. The 3D model depicts the different height levels for crucial points given by the alignment constraints. The cross section at the northern portal (see Figure 11) displays a 23 m difference in height between lanes and ground level. The space at the north

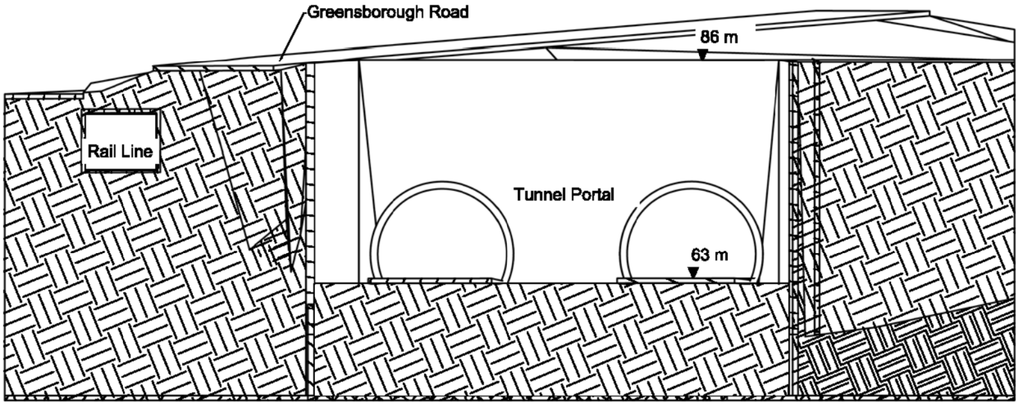


Figure 11: Cross section of the northern tunnel portal displaying the different height levels

ramp could be used for the ventilation and operation centre.

With the vertical alignment of the tunnel route, the difference in height between lanes and the Grimshaw Street bridge amounts to 10 m (see Figure 12).

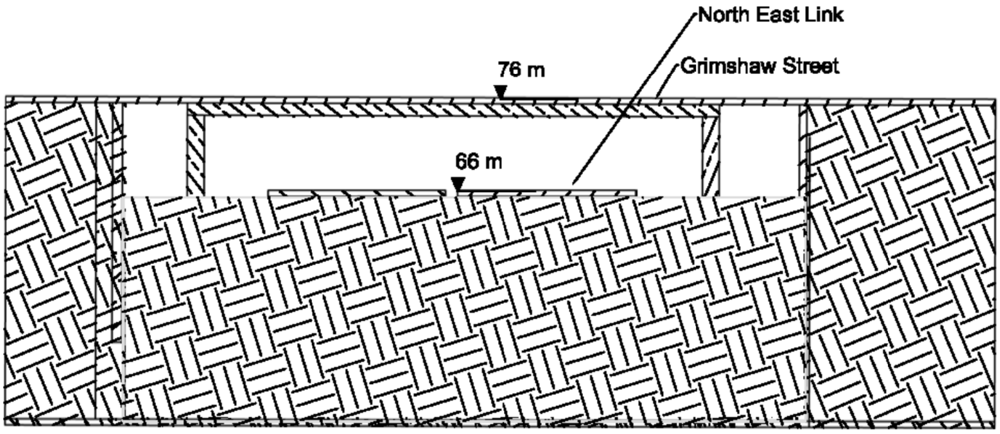


Figure 12: Cross-section at the Grimshaw Street Bridge displaying the different height levels

The rail line tunnel crosses the tunnel alignment with a shortest distance of 7 m at the southbound tunnel (see Figure 13). This small distance might require additional protection measures for the rail line, like compensation grouting. This needs to be further investigated.

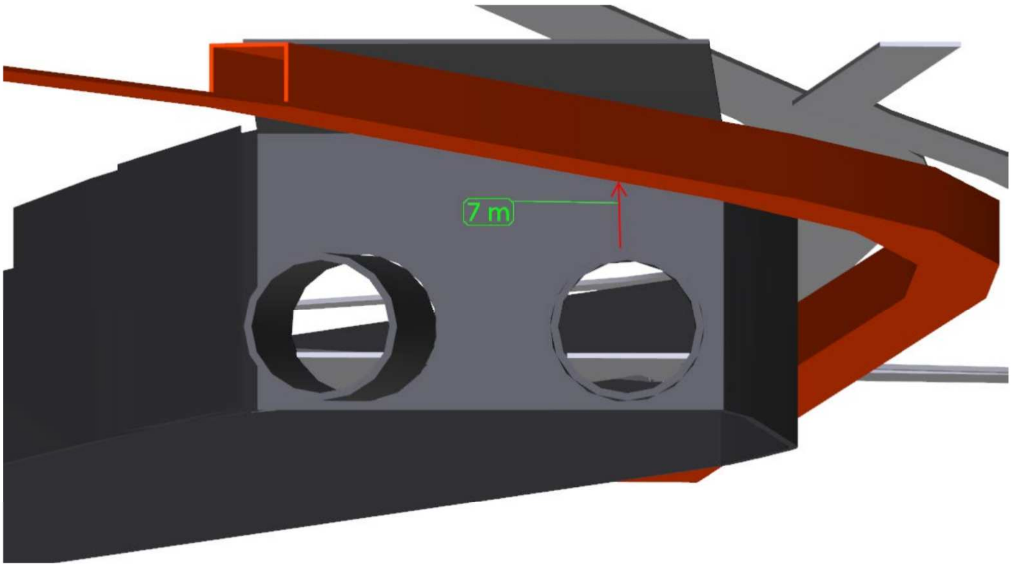


Figure 13: 3D - model displaying the distance between the southbound tunnel and the rail tunnel (in red) - position: south looking north to the portal

OPTION A3

Option A3, as mentioned in Table 3, considers the extension of tunnel for further 2,700 m from Lower Plenty Road to Grimshaw Street and using TBM. The tunnel portal would also be located between Watsonia station and Grimshaw Street, but 200 m further north. The tunnel portal has a length of 900 m. The minimum overburden was found to be 22 m below the rail line. The gradient of the tunnel route is reduced to a maximum value of 1.6 %. Option A3 does not allow an interchange Grimshaw Street to the North East Link. In addition, the open cut trench cut offs Kempston Street.

SUMMARY

In consideration of the given alignment constraints, Option A3 does not meet the requirement of maintaining the interchange at Grimshaw Street. Further, Option A3 cuts off Kempston Street, which functions as a local road connection between east and west. Therefore, Option A3 is not considered a viable option.

However, Option A2 does meet the requirements. All alignment constraints are fulfilled. Especially the interchange at Grimshaw Street retains its functionality and the maximum-possible tunnel length is achieved. Further, the 3D model shows that a crossing of the rail line is possible. Hence, Option A2 is recommended as a concept of extending the North-East Link tunnel.

DESIGN FROM COMMUNITY STAKEHOLDERS

In addition, a long tunnel proposal from community stakeholders was provided by the Banyule City Council assess its viability. This design shows a surface design for the interchanges at Lower Plenty Road and Grimshaw Street with a potential tunnel portal near Doris Street. The design of the interchange at Lower Plenty Road is adapted and the southern entry ramps towards the North-East Link are placed on the eastern and western side of the tunnel route.

The comparison of the design from community stakeholders with Option A2 indicates that the tunnel alignment is similar to the Option A2.

D TIME SCHEDULE

To display both the location and time-base dimension of extension options A2 and A3, a time schedule was created covering the entire length of the North East Link.

The construction of the cut and cover sections located at the interchanges at Eastern Freeway, Manningham Road and Lower Plenty Road will start successively. Further, they are needed as start shafts for the mining and TBM sections. The site mobilisation of the Cut & Cover section is assumed to take 45 days and 60 days at the main construction site, followed by the excavation of these sections. The work on the final structures of the sections Manningham Road and Eastern Freeway interchange are assessed to be completed after two years. Since the TBM must pass through the cut and cover section at Lower Plenty Road, the final structures are completed after 2.5 years.

The construction of the mining section south of Manningham Road starts after the excavation of the cut and cover section is finished. The mining takes approximately 213 days.

Roughly one-year delivery and assembly time is needed for the TBM section. The final performance of the tunnel excavation is achieved after five months, assuming a learning curve with a 10 % advance rate within the first month, 30 % within the second, 60 % within the third and a 90 % advance rate within the fourth month. The second TBM will follow eight weeks after the first one started. The time required for the TBMs to pass through the Cut & Cover section is presumed with 50 days. The TBMs will need approximately 167 days for the 2,500 m long extension of Option A2. The construction of culverts starts with a 21-week time offset to the TBM start. The construction of the kerbs starts 10 weeks later.

The construction time of the cross passages is expected to take 8 weeks and could commence after the completion of TBM drive 1 and could be finished after 22 months. There is also the possibility to split the construction of the cross passages into a mining part, that can run parallel to the TBM drive, and a finishing part, that follows up TBM drive. The works on tunnel equipment and M & E can commence while installing culverts and kerbs.

In Addition, BabEng investigated the temporal impact of varying the amount of TBMs and the location of the start shaft. It should be noted, that the main construction site is not constraint to the cut and cover section at Manningham Road.
Another possible location is Lower Plenty Road.
Table 2 lists the variations of Option A2. The concept suggests a northwards tunnel driving direction. Therefore Version 1 of Option A2, with two TBMs, needs in total 20 month for tunnelling. A change in direction and an unchanging amount of TBMs leads to an increase in time required for tunnelling. While the duration until completion is reduced by one month due to a more effective processing. Undoubtedly, more TBMs would reduce both the time required for tunnelling and for completion.

Table 2: Time required using different amount of TBMs and varying the start direction

	Option A2 V1	Option A2 V2	Option A2 V3	Option A2 V4
Amount of TBMs	2	4	2	3
Direction	North to south	Centre to shaft	Centre to shaft	Centre to shaft
Duration Tunnelling	20 months	12 months	21 months	16 months
Duration Completion	37 months	29 months	36 months	32 months

E COST ESTIMATION

The cost estimation of the extension option is influenced by the limited market expertise of BabEng in Australia. Due to that reason and unavailable cost information of the current North East Link Project design, the cost evaluation of Option A2 is compared relatively to the reference design. Hence absolute numbers are not provided in the context of this study. Further, the costs include direct tunnelling costs only. Costs of road construction and tunnel fit-out are not assessed in this study. Cost savings are only shown in relation to the reduction of the length.

The main tunnel and machine parameters which are used for preliminary estimation of costs for extension options are summarized in Table 3.

Table 3: Main TBM and tunnel parameters used in the preliminary cost estimation

TBM diameter [m]	Segmental ring internal diameter [m]	Segment thickness [m]	Overcut [m]	Boring diameter [m]	Ring length [m]
15.30 m	14.40	0.50	0.20	15.70	2.00

For the assessment of the costs for the proposed options, both the construction of bored tunnels and Cross Passages are taken into considerations. The following items are considered in order to perform a cost estimation for construction of the bored tunnels:

- Cost of TBMs: Two EPB TBMs with diameter of 15.7 m are considered according to the bored tunnel diameter and geological conditions. Special installations such as the air locks (person and material) are assumed inclusive in TBM. The cost for the medical locks, oxygen, tunnel ventilation and compressed air plant are taken into consideration under this section.
- Precast concrete segment: cost of precast concrete segments inclusive reinforcement bars and the accessories like sealing gaskets, dowels etc. is estimated. The production cost is included.
- Tail void grout and plants: the material cost for the grout volume required to fill the ring gap and the cost of grout mixing plant and silos.
- Personnel: the numbers of working staffs are taken as per the specified task like operation of TBM, erectors, locomotives, cranes etc. The amount to be allocated is then assessed as per the number of working shifts and tunnel construction period with mobilization and demobilization period. It also comprises the cost for the management staffs.
- Tunnel transportation system: the transportation system for tunnel muck disposal within the job site, supply of segments, grout etc. Cranes, conveyer belt, track and walkway locomotives with segment cars, muck cars, person transport, flat bed cars etc. are assessed.
- Pipelines: cost of pipelines to supply industrial water, industrial air, cooling water, tunnel drainage is estimated.
- Consumables: cost of consumables like conditioning agent, electricity, diesel, hydraulic oil, tail skin grease etc. are estimated.

- Muck disposal: cost of tunnel muck disposal from the job site is estimated assuming a fixed price per cubic meter of tunnel muck.
- Site set up: as a parts of site installation fixed cost are adopted for driveways, site offices, workshop etc.
- Rescue tunnels: the lump sum price was considered in the cost estimation. The tunnels are assumed with diameter of 10 m.

The summary of the conducted cost assessments is presented in Table 4. An extended tunnel option reduces the cost per meter of bored tunnel by approx. 16 %. Further, these cost savings are also related to the original tunnel length, since the costs for the TBMs are evenly distributed over the entire tunnel length. Material and personnel are time-dependent costs and do not affect the costs per tunnel meter.

It should be noted that the estimated costs here are an approximate estimation and for comparison purpose only. Furthermore, the estimated costs are covering the primary lining structure and are only tunnel related cost. Costs for temporary structures, road construction, M&E and other items are not considered. Further, costs affecting the interchanges and all related cost are not considered. Additionally, the risks and uncertainties associated with an estimate are not calculated within the cost estimations.

Table 4: Summary of estimated costs for baseline option and proposed extension option

Option		Reference 3,100 m	Option A2 5,600 m
Item	**Item Description**	**Budget (AUD)**	**Budget (AUD)**
Tunnel Boring Machine	TBM with back-up system and Transport	46,695,000	46,695,000
Personnel	For operation of TBM, Tunnel transportation, Segment erection, Management staffs	8,698,000	12,628,000
Materials	Installations, Supply of Segments, Grouting, Plants, Tunnel Transportation System, Pipelines, Consumables, Muck Disposal, Site set up, Rescue Tunnels and Launching Thrust	112,966,000	196,087,000
Total Estimated Cost		**168,359,000**	**255,410,000**
Estimated Cost per Metre of Bored Tunnel		**54,400**	**45,700**

In lack of resilient costing data, BabEng prefer to compare changes in volume of the different structures and options and potential savings are considered relatively by comparing the construction volume.

Table 5 summarises the construction volume estimation for Option A2 in comparison to the current North East Link Project design. Only for the TBM operation, costs have been assessed. The other tunnelling methods and surface works are compared by using the changes in volume. The TBM-Operation shows that an increase in volume of about 80 % (2,500 m extension of the bored tunnels) does generate a cost increase of only 53 %. This is mainly due to the already available TBMs on site. Of course, this does not apply to the final structures, road works, M&E, etc. and which are listed under "Mined Tunnel". The construction volume for Cut & Cover tunnelling is not affected by an extended tunnel on the grounds that the amount and length of the Cut & Cover sections remain unchanged. The volume of Open cut trenches is reduced by 70 %, if the Grimshaw Street Interchange is included in the consideration. The amount of surface roads is reduced by 40 %.

Table 5 Evaluation of volume estimation for Option A2

Construction work	Reference Design	Option A2
Mined Tunnel	100 %	188 %
Cut & Cover Tunnel	100 %	100 %
Surface Roads	100 %	60 %
Open Cut Trench	100 %	30 %
TBM Operation	100 %	153 %

By selecting the Option A2, the cost for trenching and the surface use for the project would be reduced considerably. Further, the construction volume of trenches and bridges and the land use decrease (see Table 6). The construction volume of the concrete retaining walls was calculated by assuming a bored pile wall with 1,20 m of diameter and 0,3 m overlap and a 0,5 m thick concrete wall. It includes both the trench section and the Grimshaw Street interchange and is reduced by 66 %. The point "trench" considers the trench section area between Lower Plenty Road and Watsonia Station and neglects the trenched Grimshaw Street interchange, resulting in a 100 % decrease. With the extended tunnel option the area used for bridges is reduced by 82 %. In order to provided public open space and a connection of the trenched area, the North East Project Alignment encompasses land bridges between Lower Plenty Road and Watsonia Station. The extended tunnel Option A2 does not require land bridges. The land use was approximated by using the section and interchange length. The extended tunnel Option A2 causes a decrease of land use by 73 %.

Table 6 Evaluation of construction volumes

Construction volume	Reference Design	Option A2	Reduction
Trench	57,000 m^2	0 m^2	100 %
Concrete retaining wall	172,200 m^3	58,000 m^3	66 %
Bridges	11,735 m^2	2,135 m^2	82 %
Land use	80,310 m^2	21,900 m^2	73 %

The surface utilization of the extended tunnel Option A2 (see Figure 14) is reduced due to the tunnel section between the Lower Plenty Road and the northern portal at Doris Street. Within this area land and buildings remain intact.

Figure 14: Land utilization of the extended tunnel alignment

F CONCLUSION

Considering the geological and groundwater conditions through the tunnel alignment within the project area from the southern portal to Greensborough Road, two extension Options A2 and A3 were selected by BabEng to create a vertical alignment that fulfils the given alignment constraints. Option A3 does not comply with the constraints since the connection to Grimshaw Street would not be possible. However, in combination with the proposal by community stakeholders, it seems that the Option A2 is the best choice for extending the North-East Link Project using bored tunnelling. The extended tunnel Option A2 fulfils all alignment constraints.

A cost estimation was performed for Option A2, keeping in mind the limited market expertise of BabEng in Australia and unavailable cost information of the current North East Link Project. The cost per tunnel metre are reduced by approx. 16 %. Due to the extended utilisation of the existing equipment, this cost reduction would not be limited to the extended tunnel but applies as well to the already planned tunnel section.

In lack of resilient costing data for the project's structural elements, BabEng compared changes in volume of the different structures and options. Effectively, Option A2 would reduce the trench section by 100 %, resulting in a decrease of land use by 73 % and less bridges.

These evaluations were made by comparing volumes and areas of the current North East Link Project alignment with the extended tunnel Option A2. The values were derived from the available documents. BabEng had to rely mainly on information gathered from the internet, here especially Google Maps, as well as assessments derived from own photos. Consequently, the findings in this report need to be verified in the next design phases.

The whole BabEng team hopes that Banyule City Council find this report helpful in their considerations. We would be pleased to answer any questions which may arise.

Lübeck, April 25th 2019

Lars Babendererde

G TBM DISASSEMBLY

In an addendum BabEng was asked to give opinion on the required space for a TBM disassembly at the northern end of the tunnel drive.
Figure 18 indicates a possible scenario to disassemble the TBMs within the ramp area of the future road alignment. The largest part of the TBM is the cutterhead which is typically lift off the TBM in one piece. The size and weight of it does not allow for transport in one piece. A 1,200 t crawler crane with additional counterweight will lift the cutterhead, rotate 180° and place it on the ramp utilizing a second crane for assistance. Once lying flat on the ramp, the cutterhead will be cut into segments and lifted by the assistance crane on trucks for transport off-site.

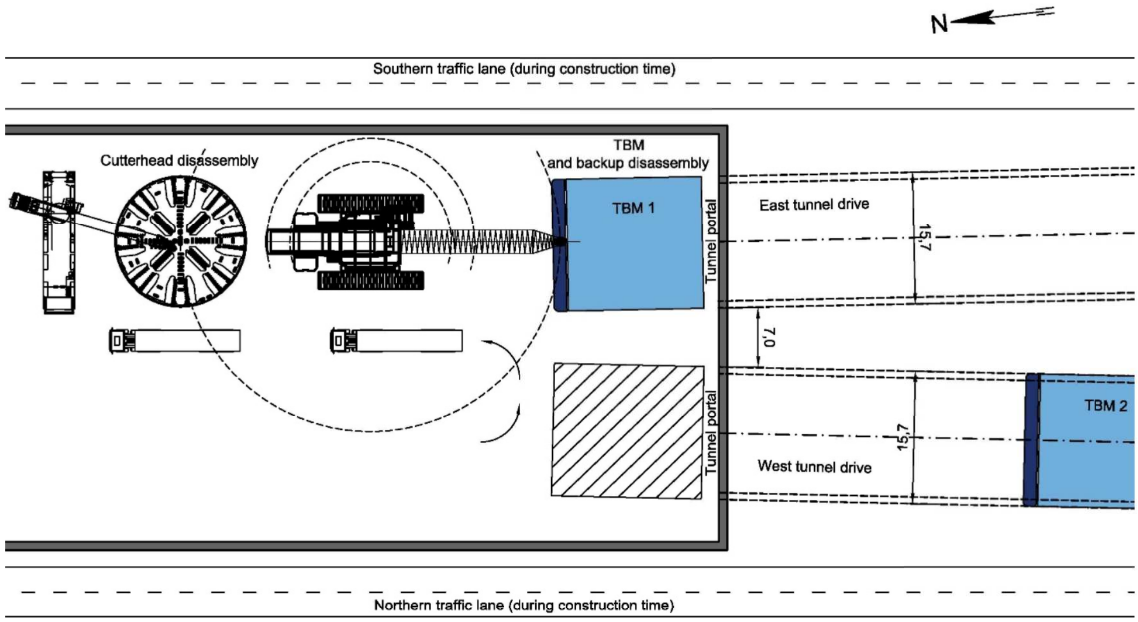


Figure 18: Construction site plan TBM dismantling.

The main drive unit of the TBM is typically the heaviest single part of the TBM. The same crawler crane will lift the piece out of the TBM and will place it on special brackets for transport. This unit goes onto oversize trucks. Once these parts are off site, the crawler crane leaves the project and is replaced by standard mobile cranes for the remaining machineries.
The approximate duration for this work is about 2 months per TBM.
Figure 19 shows an example of a TBM disassembly in a more congested situation. For the disassembly in Melbourne a width of twice the TBM diameter plus half the TBM diameter is suggested.

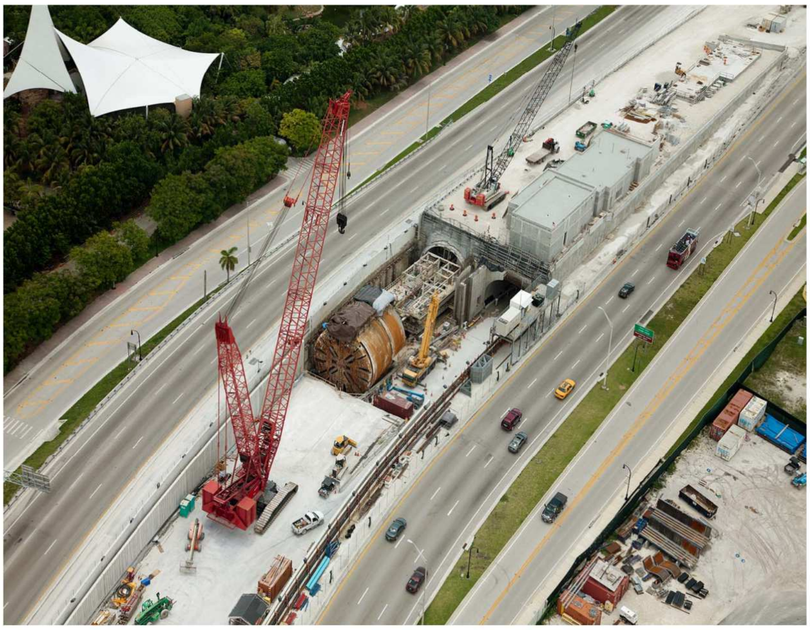
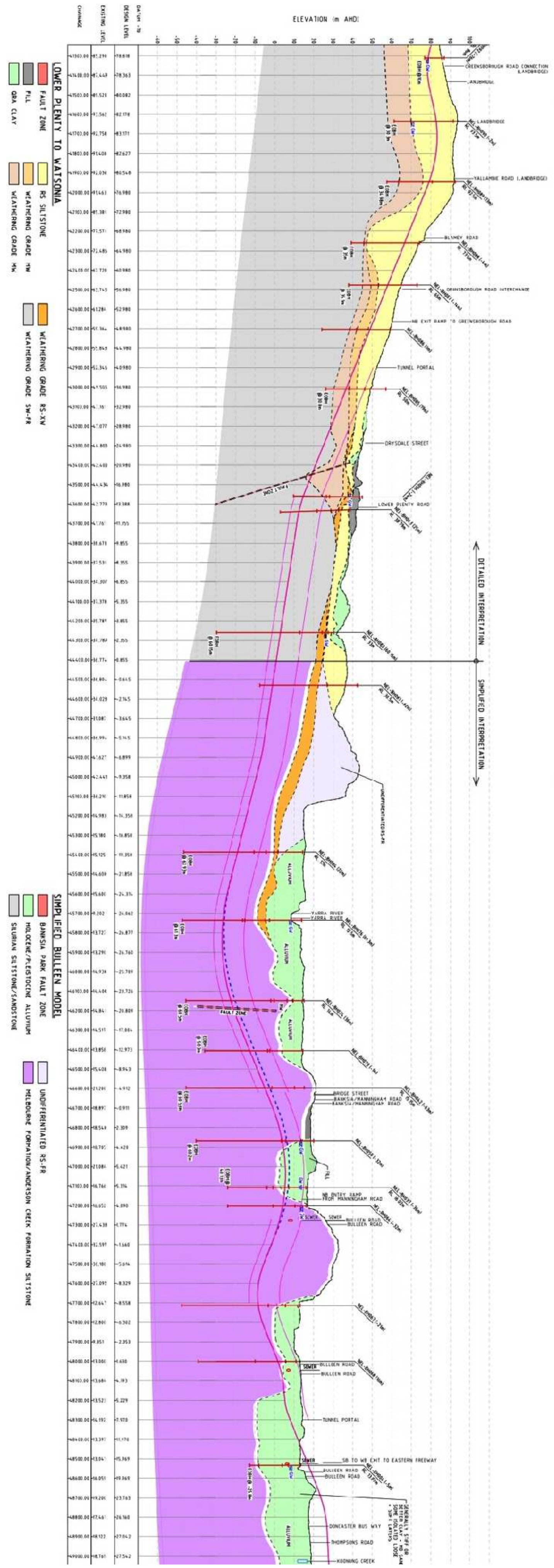
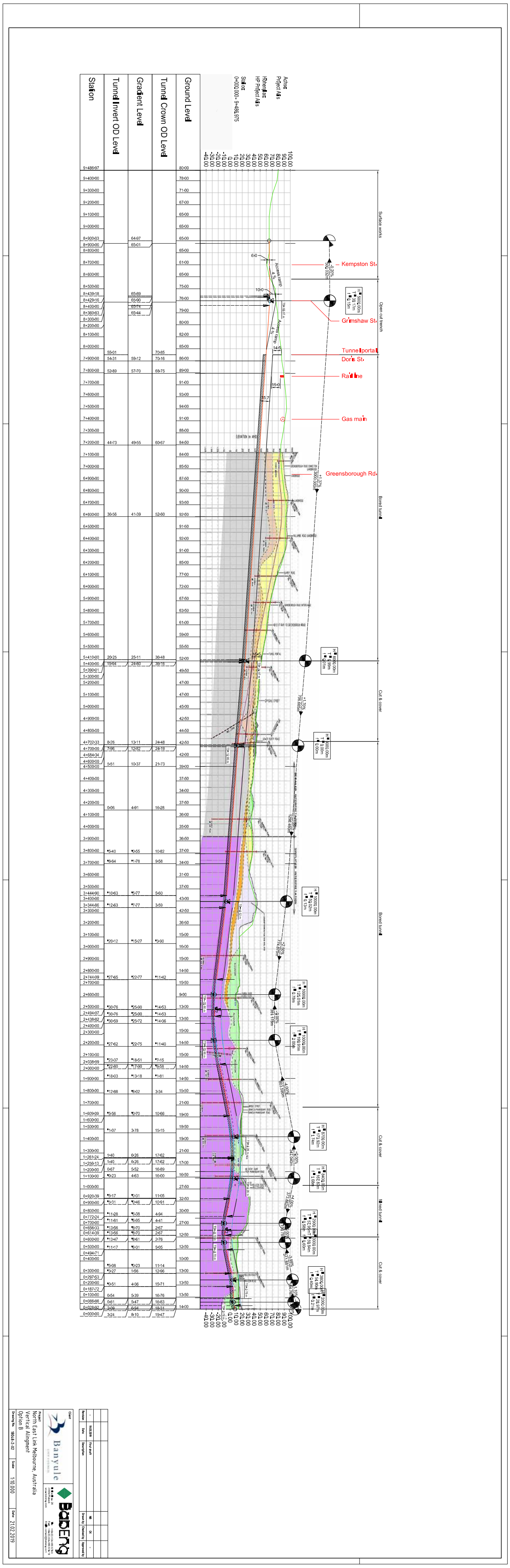


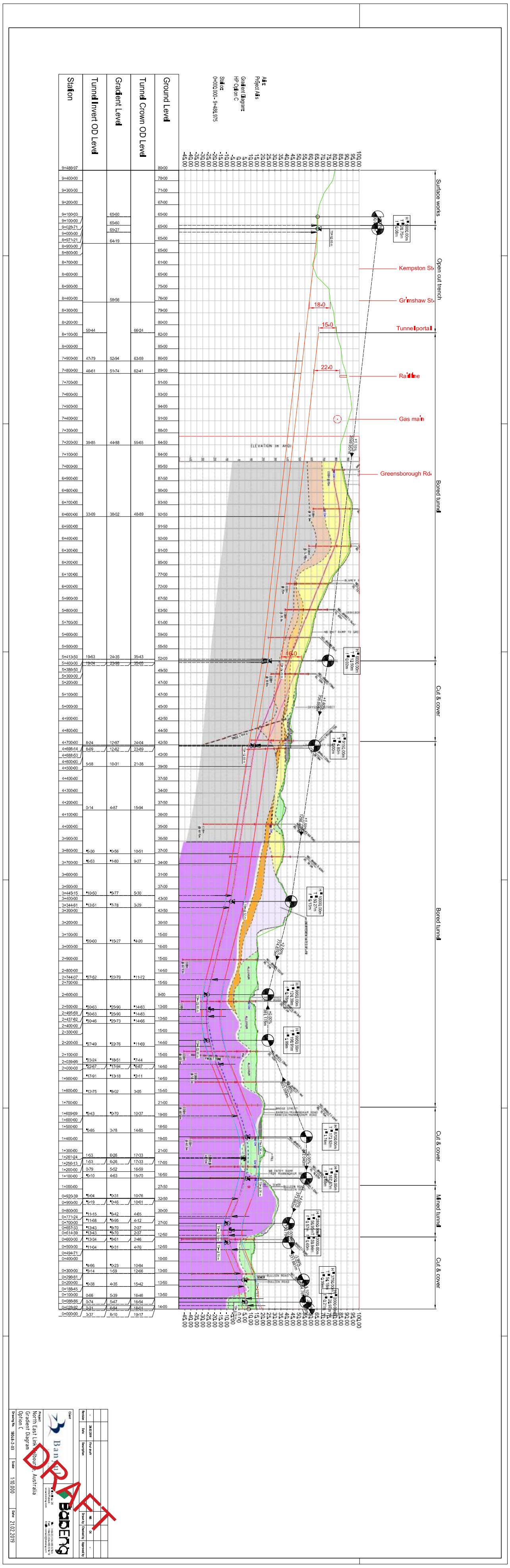
Figure 19: Example of a TBM disassembly in a congested situation

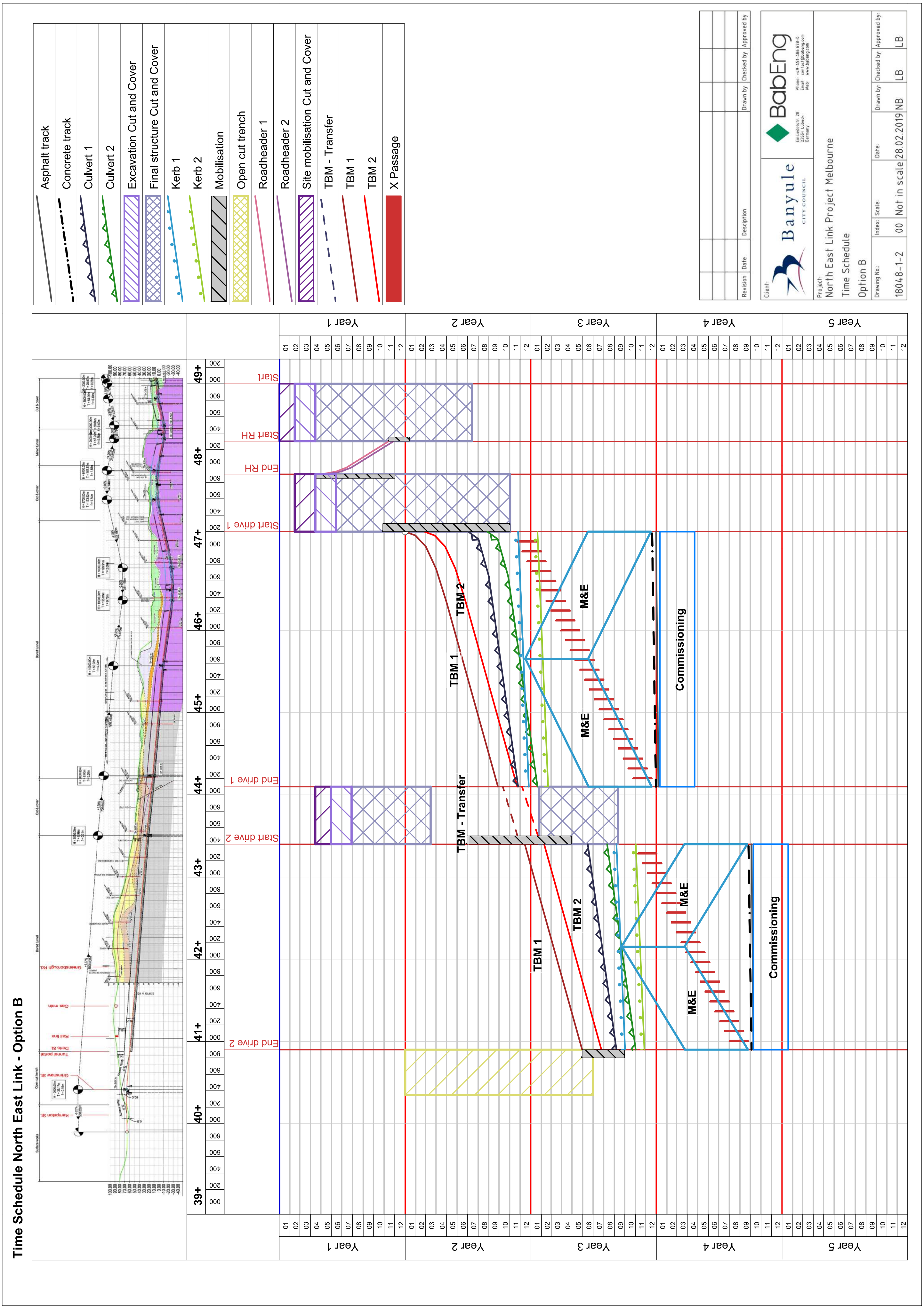
During construction and dismantling, the new Greensborough Road can be used as the southbound temporary diversion road with three lanes. While, the three-lane northbound diversion road will be located on the western side of North East Link, minimizing the impact on the North Primary School and the AK Lines Reserve (see Figure 20).

Figure 20: Possible temporary diversion road at the northern portal


LOWER PLENTY TO WATSONIA
FAULT ZONE
FILL
QRA CLAY
RS SILTSTONE
WEATHERING GRADE HW
WEATHERING GRADE MW
WEATHERING GRADE RS-XW
WEATHERING GRADE SW-FR
SIMPLIFIED BULLEEN MODEL
BANKSIA PARK FAULT ZONE
HOLOCENE/PLEISTOCENE ALLUVIUM
SILURIAN SILTSTONE/SANDSTONE
UNDIFFERENTIATED RS-FR
MELBOURNE FORMATION/ANDERSON CREEK FORMATION SILTSTONE
ELEVATION (m AHD)
DETAILED INTERPRETATION
SIMPLIFIED INTERPRETATION
TUNNEL PORTAL
DRYSDALE STREET
LOWER PLENTY ROAD
YARRA RIVER
BRIDGE STREET
BULLEEN ROAD
TUNNEL PORTAL
DONCASTER BUS WAY
THOMPSONS ROAD
KOONUNG CREEK


Station
Tunnel Invert OD Level
Gradient Level
Tunnel Crown OD Level
Ground Level
Kempston St
Grimshaw St
Gas main
Greensborough Rd
Banyule


Station
Tunnel Invert OD Level
Gradient Level
Tunnel Crown OD Level
Ground Level
Surface works
Open cut trench
Bored tunnel
Cut & cover
Mined tunnel
Kempston St
Grimshaw St
Tunnel portal
Rail line
Gas main
Greensborough Rd
DRAFT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Asphalt track
Concrete track
Culvert 1
Culvert 2
Excavation Cut and Cover
Final structure Cut and Cover
Kerb 1
Kerb 2
Mobilisation
Open cut trench
Roadheader 1
Roadheader 2
Site mobilisation Cut and Cover
TBM - Transfer
TBM 1
TBM 2
X Passage
Start
Start RH
End RH
Start drive 1
End drive 1
Start drive 2
End drive 2
TBM 1
TBM 2
TBM - Transfer
M&E
Commissioning
Year 1
Year 2
Year 3
Year 4
Year 5
Banyule City Council
BabEng
Project: North East Link Project Melbourne
Time Schedule
Option B
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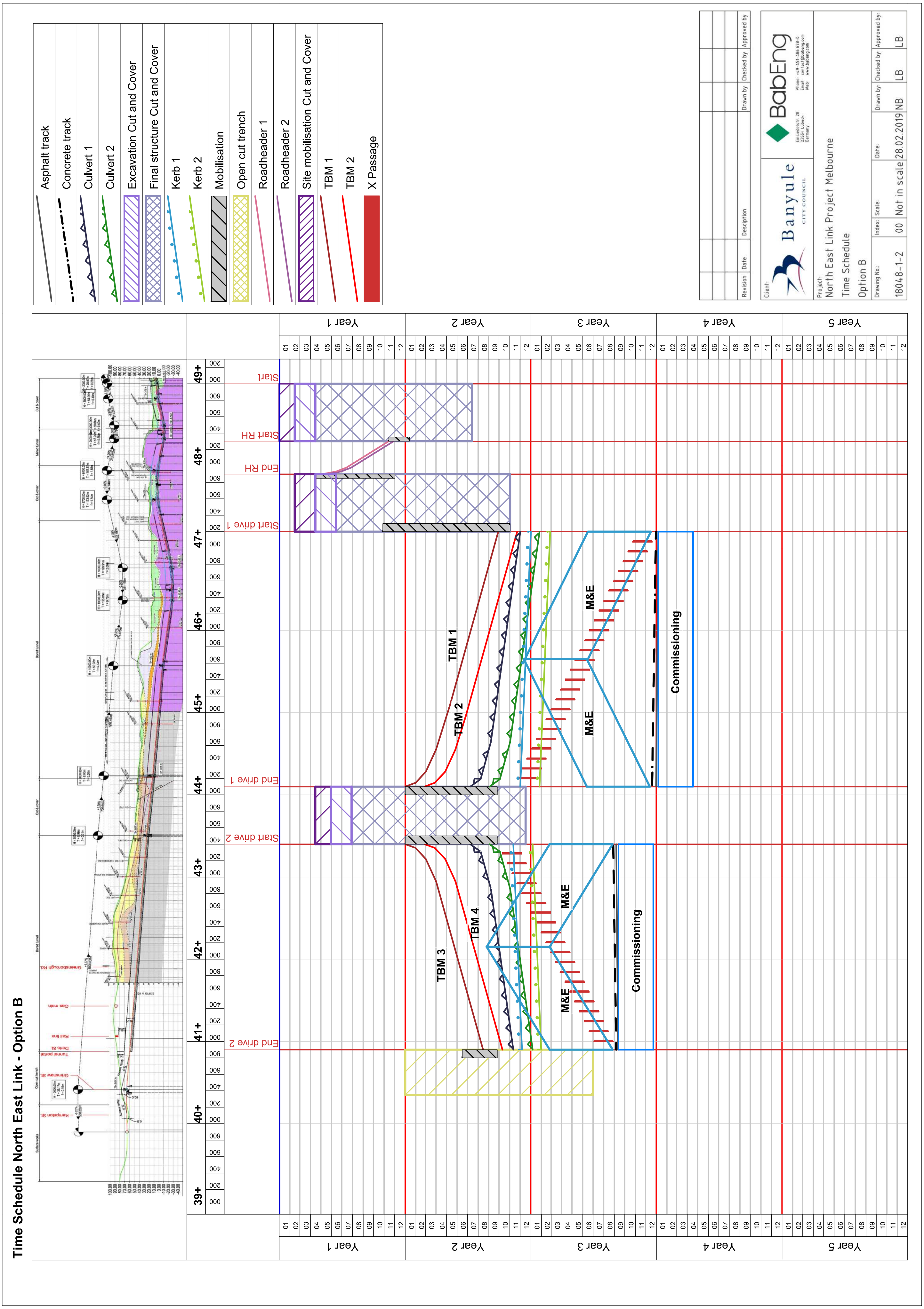
Index: 00
Scale: Not in scale
Date: 28.02.2019
Drawn by: NB
Checked by: LB
Approved by: LB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Kerb 2
Mobilisation
Open cut trench
Roadheader 1
Roadheader 2
Site mobilisation Cut and Cover
TBM 1
TBM 2
X Passage
Year 1
Year 2
Year 3
Year 4
Year 5
Start
Start RH
End RH
Start drive 1
End drive 1
Start drive 2
End drive 2
TBM 1
TBM 2
TBM 3
TBM 4
M&E
Commissioning
Banyule City Council
BabEng
Project: North East Link Project Melbourne
Time Schedule
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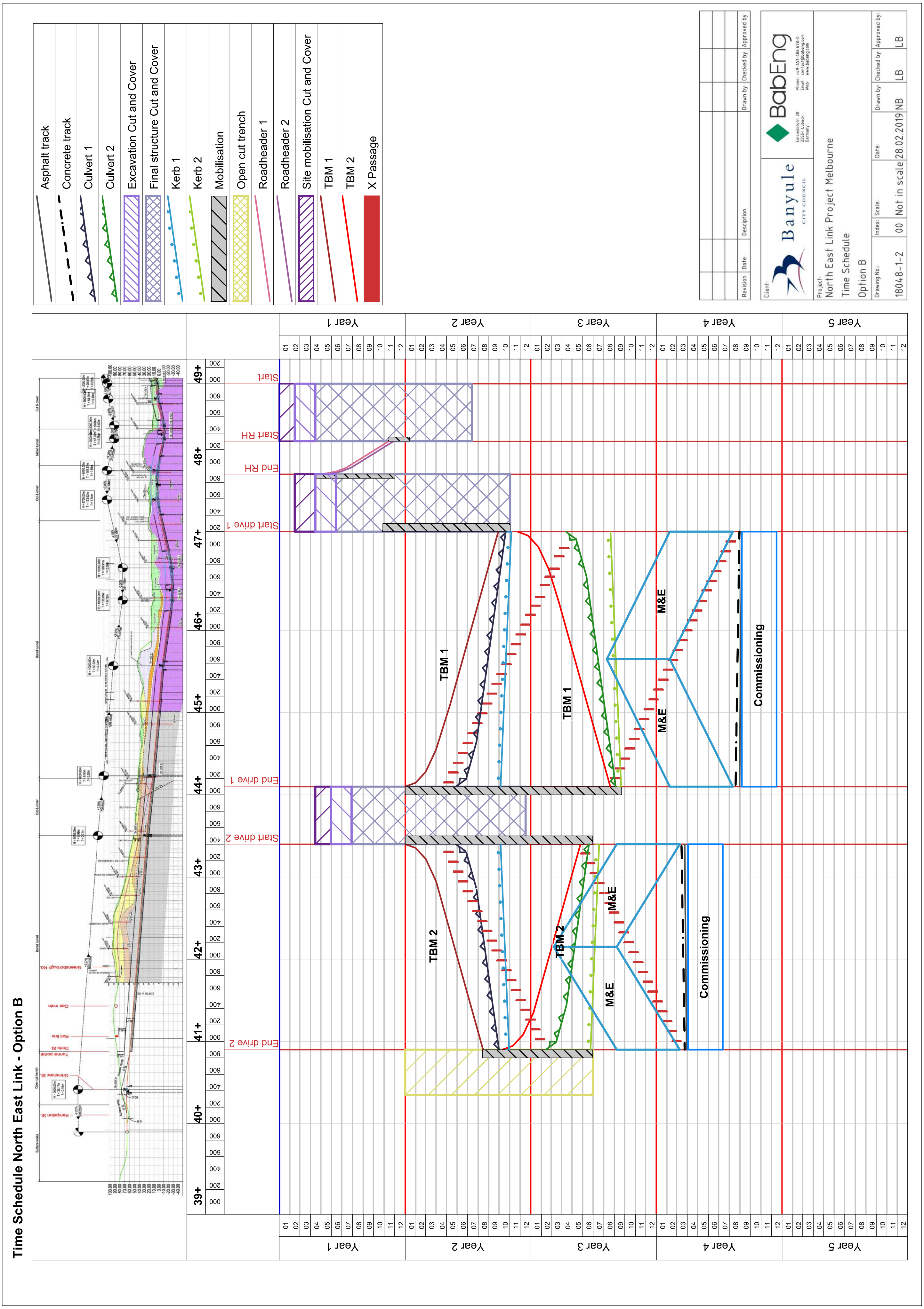
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Excavation Cut and Cover
Final structure Cut and Cover
Kerb 1
Kerb 2
Mobilisation
Open cut trench
Roadheader 1
Roadheader 2
Site mobilisation Cut and Cover
TBM 1
TBM 2
X Passage
Year 1
Year 2
Year 3
Year 4
Year 5
Start
Start RH
End RH
Start drive 1
End drive 1
Start drive 2
End drive 2
TBM 1
TBM 2
M&E
Commissioning
Client:
Banyule CITY COUNCIL
BabEng
Project:
North East Link Project Melbourne
Time Schedule
Option B
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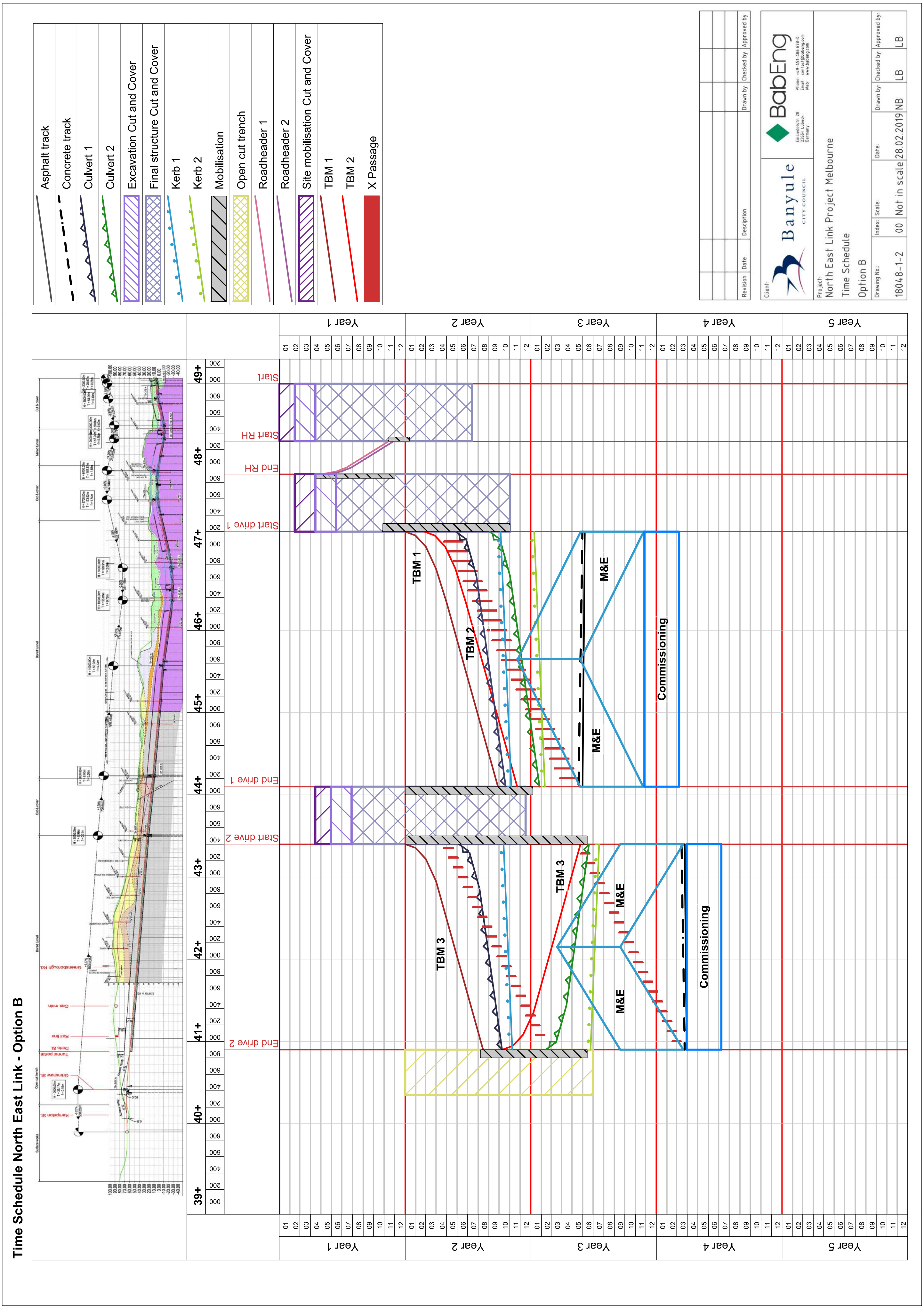
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Concrete track
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Culvert 2
Excavation Cut and Cover
Final structure Cut and Cover
Kerb 1
Kerb 2
Mobilisation
Open cut trench
Roadheader 1
Roadheader 2
Site mobilisation Cut and Cover
TBM 1
TBM 2
X Passage
Year 1
Year 2
Year 3
Year 4
Year 5
Start
Start RH
End RH
Start drive 1
End drive 1
Start drive 2
End drive 2
TBM 1
TBM 2
TBM 3
M&E
Commissioning
Banyule CITY COUNCIL
BabEng
Project: North East Link Project Melbourne
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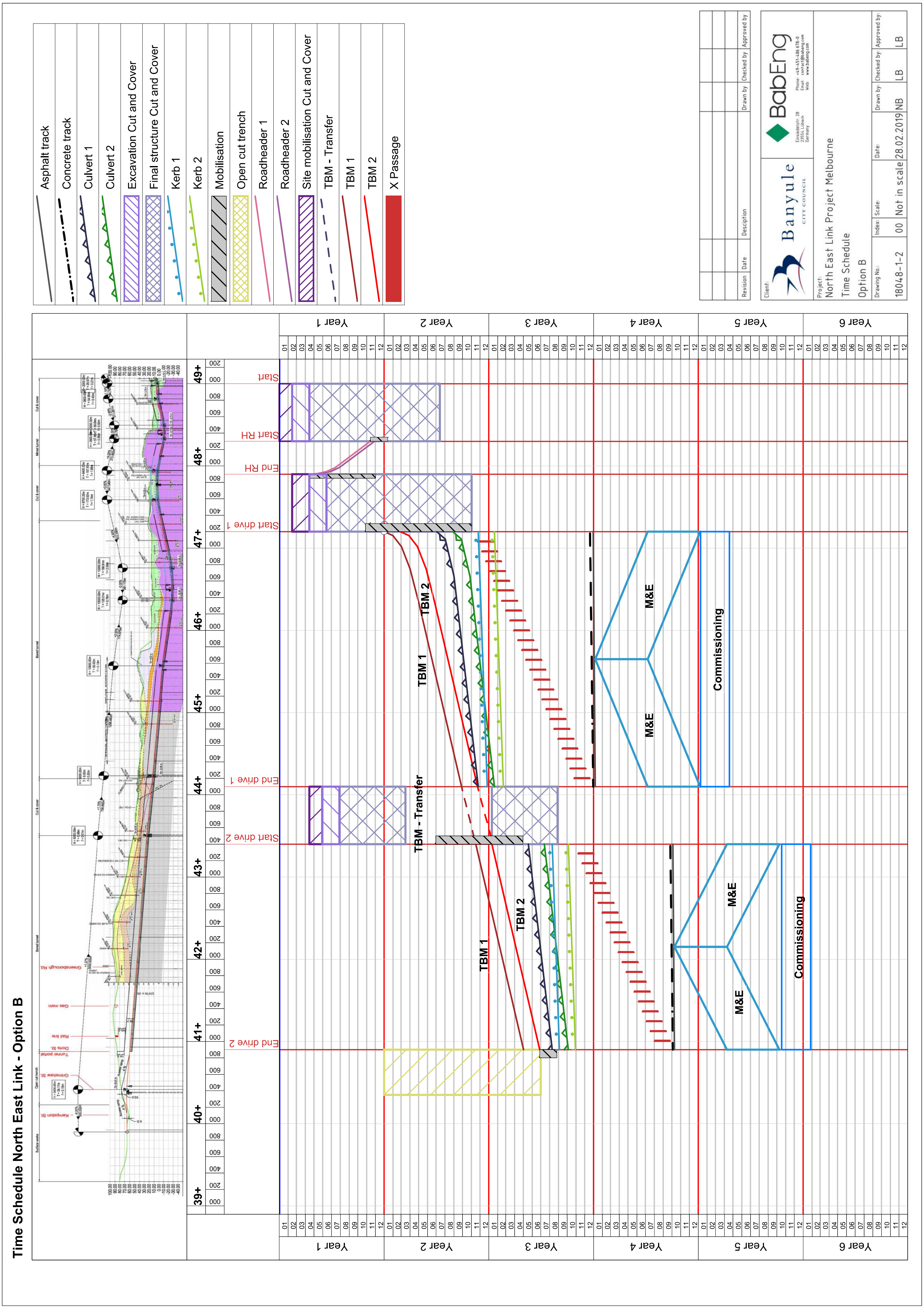
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Concrete track
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Culvert 2
Excavation Cut and Cover
Final structure Cut and Cover
Kerb 1
Kerb 2
Mobilisation
Open cut trench
Roadheader 1
Roadheader 2
Site mobilisation Cut and Cover
TBM - Transfer
TBM 1
TBM 2
X Passage
Year 1
Year 2
Year 3
Year 4
Year 5
Year 6
Start
Start RH
End RH
Start drive 1
End drive 1
Start drive 2
End drive 2
TBM 1
TBM 2
TBM - Transfer
M&E
Commissioning
Client: Banyule City Council
BabEng
Project: North East Link Project Melbourne
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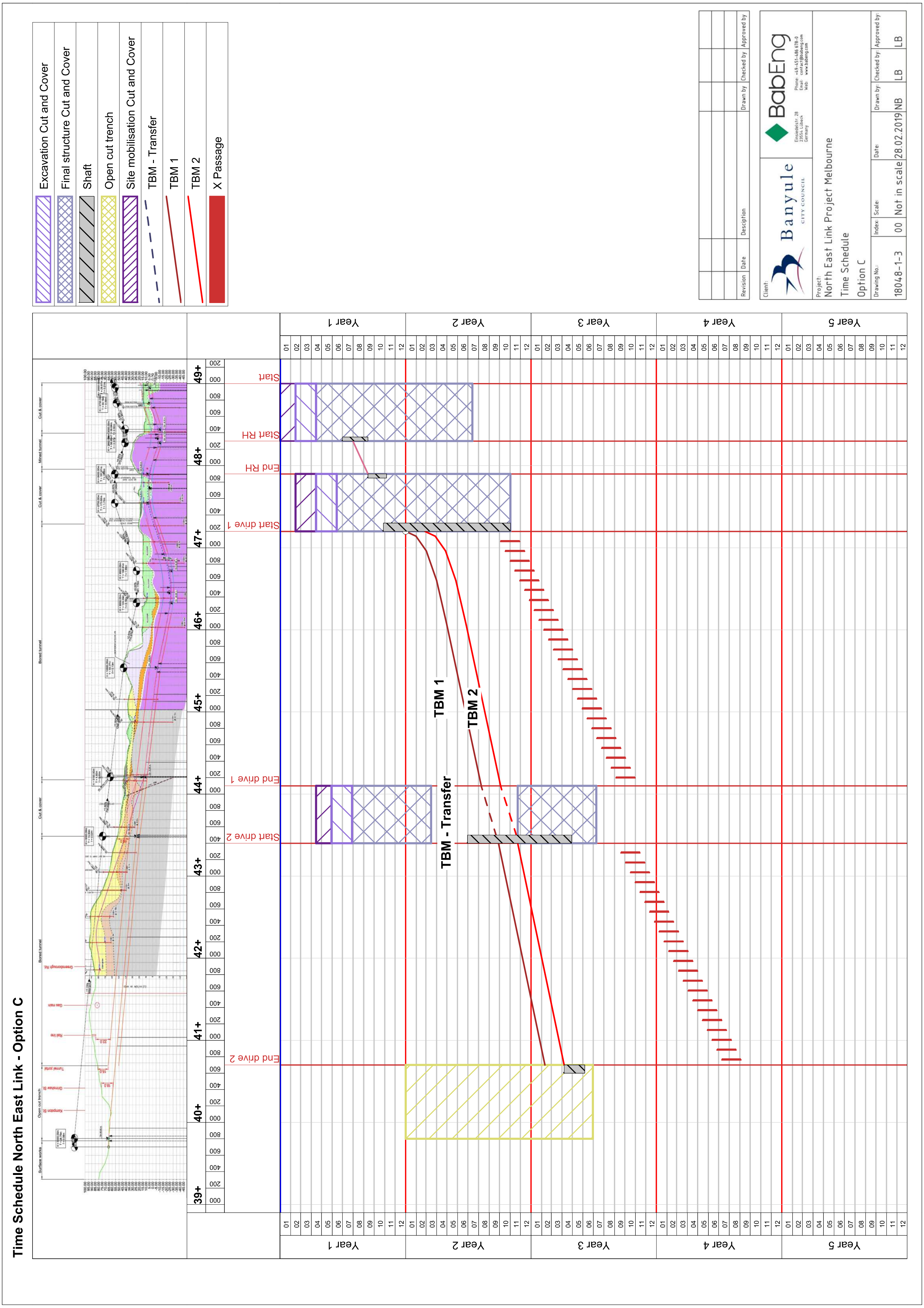
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Final structure Cut and Cover
Shaft
Open cut trench
Site mobilisation Cut and Cover
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TBM 2
X Passage
Start
Start RH
End RH
Start drive 1
End drive 1
Start drive 2
End drive 2
TBM 1
TBM 2
TBM - Transfer
39+
40+
41+
42+
43+
44+
45+
46+
47+
48+
49+
Year 1
Year 2
Year 3
Year 4
Year 5
Revision
Date
Description
Drawn by
Checked by
Approved by
Client:
Banyule
CITY COUNCIL
BabEng
Project:
North East Link Project Melbourne
Time Schedule
Option C
Drawing No.: 18048-1-3
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Date: 28.02.2019
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