TRANSPORT FOR LONDON

RIVER CROSSINGS: SILVERTOWN TUNNEL

SUPPORTING TECHNICAL DOCUMENTATION

NEW THAMES RIVER CROSSING:

SILVERTOWN TUNNEL OPTION – ADDENDUM TO VOLUME 1

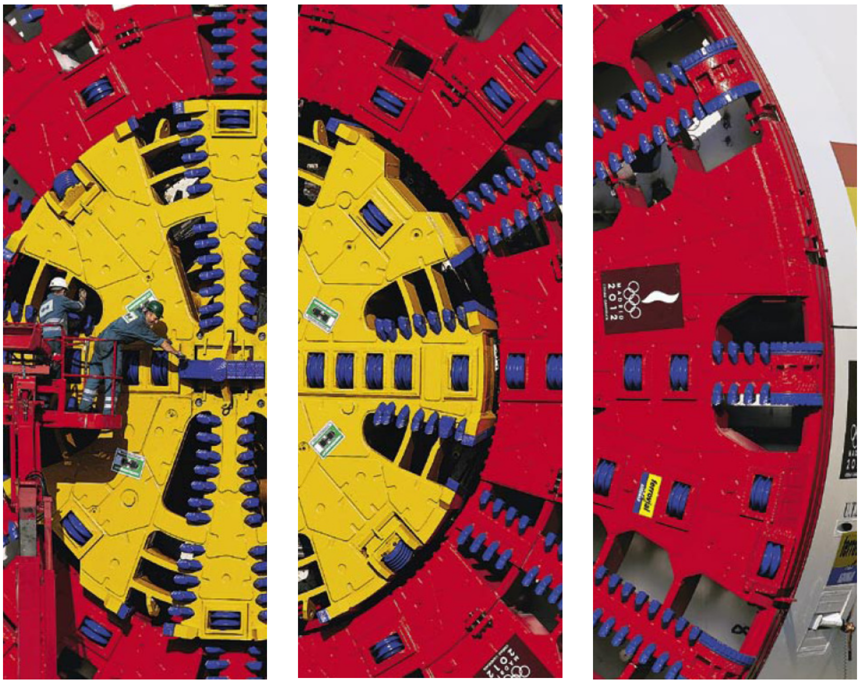
Mott MacDonald

October 2010

This report explores the concept of emergency escape through the tunnel invert and also emergency escape through the tunnel invert with pedestrian access also provided in one of the tunnels.

This report is part of a wider suite of documents which outline our approach to traffic, environmental, optioneering and engineering disciplines, amongst others. We would like to know if you have any comments on our approach to this work. To give us your views, please respond to our consultation at www.tfl.gov.uk/silvertown-tunnel

Please note that consultation on the Silvertown Tunnel is running from October – December 2014.



New Thames River Crossing

Silvertown Tunnel Option - Addendum to Volume 1

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Content

Executive summary

The provision of emergency escape facilities in a road tunnel is an important and significant element in the scheme design. A base case design, known hereafter as Option 1, has been prepared for the New Thames River Crossing, Silvertown Tunnel Option. This Option 1 was based on the provision of twin bore 2 lane uni-directional road tunnels with emergency escape facilities provided through connecting cross passages between the tunnels. The outside diameter of the road tunnels in Option 1 is 12.1m and there are 11 connecting cross passages of 4.55m excavated diameter.

As requested this study examines Options 2 & 3 wherein the emergency escape provisions are provided by escaping into the tunnel invert and along the invert to safety. With these options cross connecting passages are not required; however to accommodate the necessary infrastructure the external bored tunnel diameter is increased to 14.0m. Option 3 includes provision for pedestrian and cycle access in the tunnel invert.

In the course development of Options 2 & 3 four additional sub-options have developed. Options 4 to 7 provide the same level of functionality as Option 2, but at a reduced cost.

- Option 4 involves several small modifications to the traffic envelope to reduce the tunnel diameter down to 12.6m. Escape is via ramps to the invert.
- Option 5 moves the escape passage from the invert to the near side verge similar in principal to the philosophy on the new Tyne Tunnel Crossing now being constructed and results in a small reduction in tunnel diameter and a reduction in the cost of the escape ramp infrastructure.
- Option 6 takes the principle of escape at road level from Option 5 and combines it with the reduced traffic envelop from Option 4 to drive the tunnel diameter down to approximately 12.0m
- Option 7 is similar to Option 1 but with increased cross passage spacing and only cross passages 4 and 9 remaining. The safety case relies on the use of a fire suppression system to control a fire long enough to allow users to escape. Further minor modifications also allow the tunnel diameter to be reduced to 11.3m.

This study finds that while the principal of escape within the tunnel requires an increase in tunnel diameter the extra cost associated with this is at least equal to the savings from not having to construct the cross passages and in the case of Option 5 has a reduced cost. In addition to the direct financial saving there is a significant reduction in risk to be gained from not having to construct 11 cross passages, four of which are directly under the river.

It is considered that escape to invert as shown in Options 2, 3 and 4 offers no benefits over escape at road deck as shown in Options 5 and 6 and the latter require less capital investment and are more suited to disabled users. It should be noted that Options 5, 6 and 7 do not allow for pedestrian use of the tunnel invert.

The inclusion of pedestrians in the invert increases the capital cost by in excess of £10 million. There may also be an increased whole life cost associated with maintenance, and operation.

Option 7 has the potential to be the least expensive of all 7 options. The tunnel diameter can is reduced to 11.3m leading to a saving in excavated volume of 35% compared with Options 2 & 3 whilst at the same time requiring only 2 cross passages, both of which can be constructed under land, albeit on the river bank. However significant investigation into fire suppression systems would be required and a robust safety case needs to be demonstrated. The potential whole life cost of a fire suppression system must be offset against any savings, considering the life of elements of the fire suppression system would be between 15 and 20 years whilst the tunnel will have a design life greater than 120 years.

The study concludes that Option 5 should be the preferred scheme, provided that there is no requirement to provide pedestrian access to the tunnel.

1. Introduction

1.1 Background

A preliminary design for a twin bore 2 lane unidirectional road tunnel crossing of the Thames at Silvertown was developed and reported on in November 2009[1], referred to as Option 1 in this report. The design developed in 2009 was based on the traditional approach of providing emergency escape using inter-connecting passageways between the uni-directional tunnels and identified the merit of exploring the possibility of emergency escape through the tunnel invert. As requested by TfL this report explores the concept of emergency escape through the tunnel invert with two further options:

- Option 2 – Emergency escape through the tunnel invert
- Option 3 – Emergency escape through the tunnel invert with pedestrian access also provided in one of the tunnels

During development of Options 2 & 3 four additional options have been identified:

- Option 4 – Emergency escape through the tunnel invert, but with several challenges to or departures from UK Highways Standards as set forth in BD 78/99 and others.
- Option 5 – Emergency escape at road deck level in fire hardened housing
- Option 6 – Emergency escape at road deck level in fire hardened housing with some challenges to or departures from BD 78/99 and other Highways Standards
- Option 7 – Fire suppression system with two cross passages only

Options 4 to 7 were out of the scope of this study have not been examined in detail, but typical cross sections have been developed for comparison. Section 4 below provides further information on each of these additional concepts.

[1] Mott MacDonald, New Thames River Crossing - Silvertown Tunnel Option – Volume 1, November 2009

2. Option 2

2.1 Emergency escape concept

In the event of an incident in the tunnel leading to traffic stoppage e.g. due to an in tunnel vehicle fire, the escape scenario will be as follows:

1. Users will proceed, prompted by the public address system, to the nearest available emergency tunnel exit and proceed down a ramp into the tunnel invert.
2. Once in the tunnel invert users will proceed along a passageway in the tunnel invert towards the nearest bored tunnel portal as directed by the running man signs.
3. At the bored tunnel portal, i.e. the interface between cut and cover and bored tunnel works, the user will cross into the adjacent bore and climb up a ramp again following illuminated running man signs to reach the cut and cover tunnel roadway in the non-incident tunnel
4. The user will then proceed to walk out of the tunnel along the road in the non-incident bore.

This escape philosophy is shown diagrammatically in Figure B.1 and Figure B.2.

2.2 Design parameters

2.2.1 Alignment and gradient

To maximise in-tunnel sight line lengths escape exits may be located if required or necessary on the outside of curves i.e. on the fast lane side of the northbound tunnel and on the slow lane side of the southbound tunnel. To minimise the lengths of escape ramps a descending gradient of 1:8 is used in the knowledge that these ramps are to be used in descending mode only and the direction of descent is chosen to be opposite to that of the tunnel gradient so that given a tunnel gradient of 1/24 and a ramp gradient of 1/8 a combined effective gradient of 1/6 is achieved.

The under carriageway escape passages terminate at the bored tunnel portal coinciding with the cut and cover to bored tunnel interface where a transverse under-carriageway passageway connects the bores. A ramp then leads up to the carriageway in each bore. The escape passageways up to the carriageway at this point are constructed at a maximum gradient of 1 in 12 to allow for ease of ascending egress. The escaping user will follow the running man signs directing them to the appropriate emergency egress ramp.

2.2.2 Pedestrian passageways – height and width

The escape ramp passageway is of minimum width 850mm locally at the bottom of the ramp and between escape ramps a width of 2m is provided. The 850mm minimum width compares with the general width of 850mm specified for tunnel side walkway and access space as defined in Railway Safety principles and guidance part 2 Section A Guidance on the infrastructure. The Metric Handbook in 'figure 2.26 Passing place for two self propelled wheelchairs' states a required width of 1.8m. A minimum clear height of 2.3m is allowed generally in accord with 'Table 4.5 Minimum Dimensions' of BD 78/99Design of Road Tunnels. Railway Safety principles and guidance part 2 Section A Guidance on the infrastructure specifies a clear height of 2.0m

2.2.3 Permitted design speed

The permitted design speed in the tunnel is 30mph.

2.2.4 Highway parameters

The Design Manual for Roads and Bridges (DMRB) defines highway design parameters and the following parameters have been used to define the traffic envelope:

- Maintained headroom 5.03m (Table 6.1 TD 27/05)
- Flapping tarpaulin clearance 0.25m (Clause 4.25 BD 78/99)
- Carriageway width 7.30m (Figure 4-4a TD 27/05)
- Verge width 1.0m (Clause 4.32 BD 78/99)

2.2.5 In-tunnel equipment-sizing

Ventilation jet fans assumed diameter envelope of 1.1m to be fitted off tunnel crown intrados.

2.2.6 Highway loading

Highway loading is in accord with the UK National Annex to Eurocode 1: Actions on Structures, Part 2: Traffic loads on bridges

2.2.7 Tunnel settlement calculations

The assumed face loss percentage for the calculation of settlement effects due to tunnelling is taken as 1.7% as adopted for the planning phase of the Crossrail project. This leads to ground surface settlement predictions in the order of 150mm, Figure B.3. While arguably 1.7% may be an appropriate assumption in the planning phase a figure between 0.5% and 1% may be more appropriate for a construction contract specification. In this respect it should be remembered that settlement in the river may be important on this project e.g. where required to tunnel beneath in-river structures and settlement control and mitigation in these circumstances may be more challenging.

2.3 In-tunnel infrastructure

2.3.1 Tunnel diameter

The proposed internal tunnel diameter is derived based on the Design Parameters as defined in the previous section. A nominal internal diameter of 12.8m is determined with an outside lining diameter of 14.0m.

2.3.2 Emergency escape infrastructure

Option 2 includes the following escape related tunnel structures;

1. 11 number invert escapes in the North Tunnel, EN1 to EN11 and the same number of escapes to the South tunnel ES1 to ES11, drawing MMD-281586-TUN-1001. All escape exits are located at a nominal spacing of 100m. The invert escapes connect to invert escape passageways, escape passageway north (EPN) in the northbound tunnel and escape passageway south (EPS) in the southbound tunnel
2. At road deck level the cut and cover tunnels have interconnecting doors in their common dividing walls. EE1 to EE3.
3. The invert escape passageways, EPN and EPS are cross connected at the north and south portals in the cut and cover works by gallery GS at the south portal and gallery GN at the north portal.
4. The galleries GS and GN allow escapees to move to the escape passageway in the non incident tunnel. At the bored tunnel portals the escape passageways are connected to the road deck by ramps RN1,

RN2, at the north portal RS1 & RS2 at the south portal. Users exit the sub tunnel into the non-incident tunnel bore via these ramps.

The emergency egress structures in the tunnel invert will be of reinforced concrete precast construction as indicated on drawing MMD-281586-TUN-1201. The precast elements will be dimensioned to match the precast concrete tunnel lining segments, a 2m width is assumed.

2.3.3 Drainage infrastructure

Drawing MMD-281586-TUN-1204 schematically sets out the tunnel drainage philosophy.

Sumps in each tunnel will act to drain the tunnel invert and the granular infill and will have a capacity of around $10m^3$ these sumps will have their own pumps which will discharge to the main drainage sump. The sumps are contained within the tunnel invert and maintenance and inspection access will be through the emergency egress route which will also be the route for replacement of the pumps or alternatively through access manholes in the carriageway. The two tunnel inverts will be connected by directional drilling so that the one main drainage sump is shared between the two tunnels.

The main sump will have a capacity of $30m^3$. It will collect, via gravity, the flows and spills on the carriageway and in particular will be sufficient to cater for a tanker spill, fire hydrant flows and potentially fire suppression system flows. The flows in the bore containing the sump will discharge directly into the sump while flows from the remaining bore will flow under gravity through the directionally drilled connecting pipe. The main pumps will then discharge into a large impounding sump, with a capacity in the region of $250m^3$ at a location outside of the tunnel.

2.3.4 Vehicle Impact Barrier

The emergency exit ramps are protected from errant vehicles using a reinforced concrete vehicle impact barrier constructed integral with the precast concrete road deck units.

2.3.5 Tunnel Finishes

The tunnel lining will be of precast concrete segments bolted and gasketted and designed to be watertight.

Clause 6.28 of BD 78/99 requires that; '*The wall and road surface within the tunnel shall have high reflectance of diffused light. This leads to significant power savings, will reduce the number of luminaries required in the transition zone and provide a high luminance background to silhouette any obstructions'*. Figure 6.2 of BD 78/99 specifies a required tunnel wall reflectance of 0.6 over the 4m wall height above the carriageway. This wall reflectance is commonly achieved by painting the tunnel walls, e.g. Roundhill tunnels on the A20, Southwick tunnels on the A27, Dartford tunnels on the M25 and Hindhead tunnels on the A3.

Alternatively the reflectance may be achieved using high reflectance cladding e.g. Blackwall tunnels London, Clyde tunnel Glasgow and Cuilfail tunnel near Lewis in Surrey (http://www.visualisation.mottmac.com/projects/cuilfailtunnel/).

It is envisaged that the New Thames River Crossing tunnels would be painted, being the cheaper option. The tunnels could however be clad, typically space for a 150mm cladding envelope needs to be reserved however in the present instance the space is available without the need to increase the internal tunnel diameter..

2.4 Emergency escape management

2.4.1 Incident scenarios and infrastructure

A schematic of the invert escape passages layout is presented in Figure B.1. A typical in-tunnel incident or fire location is indicated and the corresponding escape response routes are presented in Figure B.2.

The escape via the invert concept of Option 2 is similar in most respects with the escape via the cross passage concept of the base case i.e. Option 1. In particular the intention is that once a user exits the traffic space he continues to exit the tunnel by the escape route leading to the designated assembly area and does not return to his vehicle until so directed by the emergency services. The location of the emergency escape exit off the nearside or slow lane in Option 2 contrasts with the location of the emergency exit off the off-side or fast lane in Option 1. The Option 1 location of the Offside lane is constrained by the requirement to connect to the adjacent tunnel. The choice for Option 2 is not so constrained and the nearside lane being the natural side on which to locate the emergency exit is chosen, sightlines permitting.

2.4.2 Emergency services access

Emergency services may access an incident in one of two ways:

1. In the event of a fire, tunnel ventilation will direct smoke in the appropriate direction (normally the direction of traffic flow within the incident bore). The emergency services will therefore have vehicular access into the incident bore along the road traffic permitting.
2. Alternatively a road level incident may be accessed from the emergency escape passage in the tunnel invert via the nearest escape ramp. Assuming a fire or incident at the midpoint of the bored tunnel then the emergency services can reach the escape invert in the vicinity of the incident from the non-incident tunnel by walking 500m to 600m from the cross connection gallery.

There is sufficient width in the invert escape passage to propel a wheeled stretcher or wheelchair along the length of the passageway.

It is worthy of note that road tunnels such as Dartford and Blackwall which have high level walkways originally intended to protect operatives from traffic do not have verges in the sense described here.

2.5 Departures from Standards

2.5.1 Ramp gradients

In Option 2 the design intent is that once passengers reach the escape facility they continue along the escape ways and out of the tunnel. The escape ramps have a gradient of 1 in 8 which is steeper than allowed in the Building Regulations which advises 1 in 12 with landings. The ramp guidance in the Building Regulations is for both ascending and descending conditions. The escape ramps are only intended to be used in descending mode. This approach is as used in Queensway Tunnel Liverpool [(2)] and is arguably supported by the research of Sanford in North Carolina State University [(3)].

It is worth noting that according to the Building Regulations for gradients steeper than 1 in 20 landings are required. The standard BD 78/99 allows, but does not recommend gradients steeper than 1 in 20. Clearly as being interpreted here there is a minor disconnect between the Building Regulations and the design standard BD 78/99

[2] Rock T, Arch P, Evers H, Mersey Queensway Road Tunnel Safety Upgrade Additional Emergency Escapes. 5th International Conference on Tunnel Fires October 2004

[3] Sanford J A, A Review of Technical Requirements for Ramps, Final Report January 31, 1996, The Center for Universal Design, North Carolina State University School of Design http://www.access-board.gov/research/Ramps/report.htm

3. Option 3

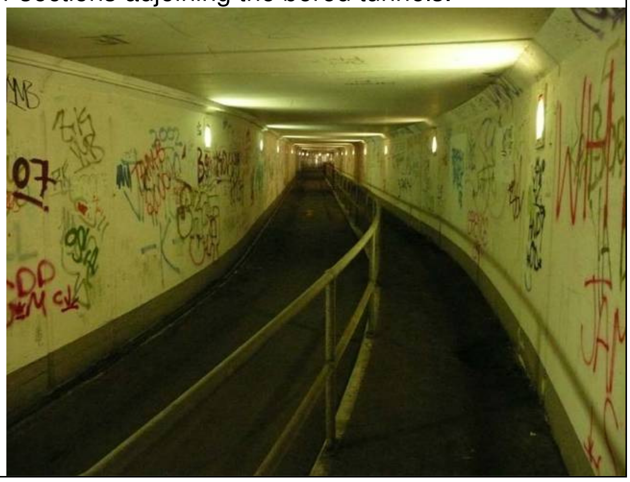
3.1 Introduction

Option 3 is a variant of Option 2 with the addition of pedestrian and cycle access in one of the tunnel inverts. For the purpose of this exercise it is proposed that pedestrian access is provided to the southbound tunnel.

3.1.1 Review of previous practice - pedestrian tunnels in the UK

Within the UK there are a few examples of pedestrian tunnels open to the general public.. The Clyde Tunnels are most similar to that proposed in both its urban location and length. It is recommended that should Option 3 be taken further a study of the operational problems associated with these tunnels be carried out. It should be noted that at approximately 800m it is believed that this would be the longest pedestrian tunnel in the UK.

- Clyde Road Tunnels – Built in the 1950s. Under each road deck is a pedestrian and cycle route approximately 760m long. The tunnels have been recently fitted with security gates to reduce the prevalence of crime. Access is via the cut and cover sections adjoining the bored tunnels.



- Tyne Tunnels – Dedicated twin tunnels opened in 1951 one bore is used for cycles and the other pedestrians. The tunnels are 274m long, and served by two escalators and one lift at each end.

- Greenwich Foot Tunnel – At 370m the Greenwich foot tunnel connects Greenwich and the Isle of Dogs. The tunnel is classed as a public highway and therefore by law is kept open 24 hours a day. Attendant operated lifts are available during the day. The stairs must be used at all other times.

- Woolwich Foot Tunnel – 504m long Thames crossing with attendant operated lifts and stairs. The tunnel has been fitted with a leaky feeder system to permit operation of mobile phones.

- Kelmarsh Tunnel – 294m long disused railway tunnels in Northamptonshire one of which is converted into an unlit pedestrian tunnel

- Oxendon Tunnel – Disused 422m long twin bore railway tunnel in Northamptonshire one of which is now used for pedestrians

- Innocent Tunnel– 320m long disused railway tunnel in Edinburgh, now a pedestrian tunnel

In addition there are or have been the following:

- Boxley Abbey to Detling Tunnel – Pedestrian tunnel in Kent again in a disused railway tunnel
- Rotherhithe Tunnel – Road tunnel with footpaths beside the road
- Tower Subway – disused pedestrian tunnel
- Thames Tunnel – Brunel's original crossing of the Thames, initially used for pedestrians now part of London Overground.

3.1.2 Review of some previous practice for worldwide pedestrian tunnels

Globally there are very few pedestrian tunnels open to the public, with pedestrian tunnels generally located within controlled environments, such as metro stations, airports and stadia. Tunnels of any length are also rare, normally restricted to crossing of roads (subways/underpasses) with lengths of less than 100m.

However despite limited numbers of tunnels there have been at least two high profile incidents:
- In 1990 a stampede during the Hajj inside the Al-Ma'aisim tunnel resulted in the deaths of 1,426 pilgrims.
- During the 2010 Love Parade Festival in Duisburg, Germany, a stampede occurred as the ramp between tunnel/underpasses and festival area became overcrowded resulting in 21 people being crushed to death.

The nature of these incidents highlights a risk associated with proximity of the O2 arena to the proposed tunnel. During an event it may become necessary to control entry to the pedestrian subway to avoid overcrowding.

3.2 Design Requirements

3.2.1 Access to pedestrian sub-tunnel

The pedestrian sub-tunnel is to be accessible to cyclists, pedestrians and persons with restricted mobility (PRMs). To provide maximum benefit the access point for pedestrians and cyclists is different to that of road users. On the southern side the proposed access point is on the river bank, providing immediate access to and from the riverside foot and cycle path. On the northern side access is at the bored tunnel portal, adjacent to a proposed DLR station Resulting in a pedestrian sub-tunnel length of some 800m.

On the southern side it is proposed that a new diaphragm wall box is constructed through which the TBM is taken when constructing the northbound tunnel. Bullflex seals or similar will be used to ensure water tightness during break in and subsequent launch out. The diaphragm wall box eliminates the need for construction of a cross passage in the difficult ground conditions.

At the northern entrance the TBM launch chamber is enlarged on the west side to allow for the provision of lifts and the associated stair.

3.2.2 Lifts

For the purpose of this exercise it is assumed that the principal means of access is lifts. Predictions of pedestrian and cycle user numbers are not currently available, therefore it is assumed that two lifts are provided at each access point, reducing waiting time and ensuring a robust solution in the sense that 1 lift is always available even during maintenance.

It is assumed that each lift requires sufficient room for at least 4 cycles (a family group) and some pedestrians. A typical car size to accommodate these users would be approximately 3m x 3m. The lift car would have two sets of doors, one used for entrance and the other exit, avoiding a clash between those trying to enter and leave the lifts. A dedicated waiting area will also be provided at the surface and in the sub tunnel.

3.2.3 Rejected proposals

At the north and south entrances a stair is also provided for use when the lifts are not available either for normal operation reasons or because of emergency incident. The use of a ramp system for entrance and exit was considered, but discounted due to the required length, in excess of 500m for a 1:20 ramp.

The use of escalators was considered, but they provide no benefit for PRM's or cyclists and it is unlikely that demand would be sufficient to justify the cost of their inclusion.

Potential remains for direct access via a ramp in the cut and cover sections. This would principally be used by cyclists and at this stage is not considered due to the increased cost associated with the widening and deepening of the cut and cover sections.

3.3 Land requirements

Land will be required for the pedestrian access points at the north and south. On the south side it is believed that the Environment Agency own the land adjacent to the river comprising the cycle and footpath. The remainder of the land is owned by the developer of the Greenwich Peninsular. The precise site and orientation will require further study and discussion with relevant land owners.

3.4 Route design

3.4.1 Standards

Principal standards forming the basis of this design are:

- Highways Agency, Design Manual for Roads and Bridges, Volume 6, Section 3, Part 5, TA 90/05, The Geometric Design of Pedestrian, Cycle and Equestrian Routes.
- Highways Agency, Design Manual for Roads and Bridges, Volume 6, Section 3, Part 1, TD 36/90, Subways for Pedestrians and Pedal Cyclists Layout and Dimensions.
- Transport for London, London Cycling Design Standards
- BS 8300-2009 - Design of buildings and their approaches to meet the needs of disabled people - Code of practice

3.4.2 Cycleway and footpath dimensions

It proposed that the width for pedestrians is segregated from the width for cyclists by a level difference as shown in drawing MMD-281586-TUN-2201. Table 3.1 below lists the absolute (preferred) minimum widths for pedestrians and cyclists as stated in the standards.

Table 3.1: Cycle track and footpath widths

	Margin between subway wall and cycle track	Cycle track (two way)	footpath	Margin between subway wall and footpath	Total width between walls	Headroom cycle track /footpath
TD 36/93	0.5	2.5	2.0	0	5.0	2.7/2.6
TA 90/05	0.5	1.5 (3.0)	1.5 (2.0)	0.5	4.0 (6.0)	2.7/2.6
TfL Cycle Standards	0.5	2 (3.0)	2.0	0	4.5 (5.5)	2.4/N/A

For the purpose of this exercise a 2m wide footpath and a 3.0m wide cycle lane have been provided.

3.5 Interaction with road users

It is proposed that pedestrians and cyclists within the tunnel invert are entirely segregated from road users, both in normal and emergency situations. To achieve this, the emergency exits in the northbound tunnel will need to be located on the outside lane, the opposite side to that for option 2.

In an emergency on the road deck the road users will escape in the same manner as for option 2, pedestrian users will be unaware of the emergency.

3.6 Emergency procedures

In the event of an emergency in the pedestrian tunnel escape will be through doors in the wall dividing the pedestrian tunnel from the emergency escape route for road users. Doors will be located every 100m and are atomically locked shut to avoid vandalism, but can be opened remotely by the Tunnel Controller in event of an emergency.

Potential sources of combustion are limited and the greatest risk is from a malicious fire. The use of a fire suppression system should be considered.

3.7 Ventilation

Ventilation of the pedestrian sub tunnel will be provided both to maintain the quality of the air, regulate the temperature and control smoke in the event of a fire.

It is envisaged that ventilation plant and equipment will be housed within the pedestrian access shafts with intake and extract facilities on the surface.

3.8 Security

There will be significant security issues that must be addressed to make the pedestrian sub tunnel safe and inviting to use. Careful use of lighting, finishes and acoustics will make the tunnel more inviting to users. Whilst CCTV will be necessary, it will probably be insufficient to deter crime and it may be necessary to provide additional security measures, such as permanent on-site staffing and controlled access.

3.9 Summary

A 14m diameter tunnel provides sufficient space within the tunnel invert for a segregated pedestrian footpath and cycleway. The additional capital cost associated with the provision of the necessary infrastructure to enable access and safe use is estimated to be in the region of £10m.

No recent precedence for such a tunnel can be found either in the UK or globally and it is considered that such an asset falls outside the scope of current standards and further research and development will be required to define a robust solution.

Careful study of the following issues should be considered:

- Noise – noise from traffic above may adversely affect the environment in the tunnel.

- Lighting and general ambience – to avoid feelings of claustrophobia and general unease the use of lighting and other environmental factors, finishings, paint colour, graffiti resistance and such like will need to be carefully assessed.
- Security – permanent staffing may be required to help improve security within the tunnel and to deter crime. Graffiti, robbery and more serious crimes have all been identified as issues in other tunnels/subways. During a major event at the O2 additional access control measures may be necessary to avoid overcrowding.
- Fire life safety – in the event of a fire or incident, pedestrians may be in excess of 700m from an entrance and discussion and agreement with the local emergency services will be necessary.

4. Options 4, 5, 6 & 7

4.1 Option 4

Option 4 has been developed to explore the financial benefits to be gained through a modification to the traffic gauge.

As described previously a minimum of a 1000mm wide pedestrian height verge is required of which a 600mm width with a full height traffic clearance is required by the DMRB. As shown on drawing MMD-281586-TUN-3201 through removal of the nearside verge at the location of the escape and restriction of the full height (5.03m) maintained headroom over the 600mm of the offside verge it is possible to reduce the tunnel diameter to around 12.6m.

The nearside verge would be lost for the length of the escape ramp, approximately 25m every 100m, or 25% of the length of the tunnel.

This results in a saving of around 25% of excavated volume and an increase in cover of 0.7m with a corresponding reduction in risk.

The risks associated with this approach are as follows:

- Departure(s) not accepted by certifying body.
- Passengers in a broken down vehicle in the slow lane may be forced to exit their vehicle into the fast lane(as for some existing road tunnels in UK. e.g. Dartford, Blackwall)
- Loss of verge and associated edge effect of vehicle impact protection barrier reduces usable highway width.
- Broken down vehicle unable to pull onto nearside verge, thus further restricting highway.
- High vehicles may have an increased risk of striking the offside tunnel lining shoulder.

It should be noted that clause 3.15 of BD 78/99 requires “Unobstructed pedestrian access, at low level, to emergency points shall be provided”.

4.2 Option 5

Option 5 examines placing the escape passage at road level in a fire hardened housing. The escape principle is the same as for the invert escape options. In the event of an incident the users would escape to the housing and travel to the nearest portal where they would cross to the adjacent bore and escape out to the surface. This strategy is similar in principle to that which is being employed on the New Tyne Crossing (4) now under construction.

Option 5 results in a reduction in the tunnel diameter of approximately 1200mm when compared with Option 2. This offers significant savings in both excavation, and through avoiding the need to provide the escape ramp infrastructure.

Option 5 is considered to offer the same level of functionality as Option 2, and therefore is considered more preferable to Option 2.

[4] Tunnels & Tunnelling, Slog on the Tyne, pp 24 -26, March 2010

4.3 Option 6

Option 6 combines the principle of escape at road level from Option 5 with the reduction in the traffic envelope from Option 4. It is likely that in this scenario it will be possible to reduce the tunnel external diameter to around 12.0m

4.4 Option 7

The European Directive 2004/54/EC imposes minimum safety requirements on tunnels belonging to the Trans-European Road Network (TERN). Although the Silvertown Crossing may not be on the TERN these regulations apply to any tunnel over 500m in length as set in clause 3 of The Road Tunnel Safety Regulations 2007.

The EU Directive states that a risk analysis needs to be carried out to establish whether additional safety measures and/or supplementary equipment over and above the minimum stipulated is necessary to ensure a high level of tunnel safety. Clause 2.3.8 also stipulates that *"Where emergency exits are provided, the distance between two emergency exits shall not exceed 500m".*

As stated previously current UK practice is to provide emergency exits every 100m, as is the case with Options 1 to 6. However, it may be possible to increase the spacing of the emergency exits should alternative safety measures and/or equipment be provided which ensure that the level of safety remains high. Fire suppression systems are one such measure that may enable the spacing of cross passages to be increased. Fire suppression systems can reduce the rate of increase of a fire and its corresponding intensity and thereby mitigate the production of smoke within a tunnel. If a risk analysis can show that such a system provides sufficient time to allow users to escape, it may be possible to increase the spacing of emergency exits. Such an exercise was been carried out for the Yas Island Southern Crossing Tunnel. Here a risk analysis was able to show that by including fire suppression system emergency escape spacing could be increased to 588m from the 100mm initially proposed without a reduction in the level of fire life safety (5).

Option 7 explores the opportunity of installing a fire suppression system and then taking advantage of reducing cross passage spacing to 500m nominal. At a spacing of 500m two emergency exits would be required in the bored tunnel section, by placing one under each bank of the river it would be possible to avoid the need to construct a cross passage directly under the river. Thus option 7 is similar to Option 1, but with only two cross passages CP4 and CP9 needing compared with the original 11. The need to work from barges in the river to enable grouting to take place would also be eliminated.

To reduce the diameter of the tunnel further compared to Option 1, the opportunity to remove any cladding or secondary lining should be examined, the required reflectance could be achieved by painting of the segments and infilling of the joints to avoid dust collection. Combined with a 1000mm wide verge (instead of 1200) it may be possible reduce the external diameter of each tunnel to 11.3m, a 35% reduction in excavated volume compared to Option 2 and 13% less than Option 1.

[5] Taradra, Fathi. Emerging tends in tunnel fire suppression, Eurotansport Issue 5, 2009.

5. Option comparison

5.1 Qualitative comparison

The table below provides a qualitative comparison of options 1 to 7, based on a simple ranking of importance. Each option is scored from 1 to 5, where 1 is very poor, 3 neutral and 5 very good. It can be seen that Option 5 is considered to provide the solution that best meets the chosen criteria. A different choice of criteria or weighting may possibly alter the ranking of the options.

	Ranking	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Corridor width (3rd party impact)	3	5	2	2	3	3	4	5
Emergency escape	7	5	4	4	4	4	4	3
Emergency intervention	6	5	4	4	4	4	4	3
Accessibility for disabled persons	2	4	3	3	3	4	4	3
Compliance with highway standards	4	4	4	4	3	4	2	4
Capital cost	1	2	2	1	3	4	5	5
Construction risk	5	1	4	4	4	5	5	4
Score		111	102	101	102	114	110	101
Rank		**2**	**4**	**6**	**4**	**1**	**3**	**6**

6. Risks and Opportunities

6.1 Risks

Table 6.1: High level risks associated with tunnel design and construction

	Hazard	Cause	Mitigation
1	Insufficient cover to tunnel crown	Inadequate survey and soil data	Carry out SI and survey
2		Too large tunnel cross section/diameter	Minimise the tunnel design diameter
3		Too shallow (4%) vertical alignment gradient constraint	Relax constraint on alignment gradient to greater than 4%
4	Contaminated spoil	Pre-existing phenomenon	Detailed advance site investigation
5	Underground obstructions related to Cable Car tower supports	Close proximity of Cable Car alignment	Parallel and collaborative design of both tunnel and cable car systems
6	Sensitivity of cable car tower to differential pile cap vertical movement	Tunnel construction has potential to cause cable car pile cap rotation this movement will be magnified at tower top by factor of 15	Careful design of raking piles a) sleeve piles, b) maximise clearance to tunnel
7	Unknown design constraints on cable car design	Design of Cable Car system in advance of and independent of tunnel design	Advance detailed design of cable car and tunnel systems in parallel
8	Late information from physical model studies of ship impact protection show tunnel protection deficiency	Delay in defining, commissioning and executing model studies	Advance the ship impact analysis and model study and coordinate with tunnel design
9	PLA delay approval of ship impact protection strategy	Complex modelling and 3rd party checking require time to implement	Expedite design and modelling
10	TBM launch chamber on Silvertown side too shallow	Vertical alignment gradient constraints	Relax gradient constraint to greater than 4%
11	Limited constricted road access for transport of TBM to launch site	Local road network	Detailed checking of routes and initiation of improvements if deemed necessary
12	Old Blackwall tunnel cannot accommodate transport of large TBM components for 2nd drive from Silvertown	Insufficient headroom in Blackwall tunnel	Construct TBM turn around chamber at O2
13			Transfer TBM by barge across river from temporary wharves
14			Use QE2 bridge at Dartford, implement a closure and transport TBM northbound over the bridge.
15	Limited consideration of options leads to not best value solutions	Failure to consider advantages associated with Fire Suppression e.g. cross passages at 500m centres.	Consider benefits of fire suppression
16	Failure to challenge Standards leads to more costly solution than necessary	Need to challenge requirement for maintained headroom above footway	Develop relevant cross section and cost
17	Insufficient brainstorming or late peer review means some opportunities missed	Consider enclosed escape corridor above carriageway level	Carry out peer review and risk/opportunity analysis and evaluate the further options proposed in this report
18	Close proximity of Cable Car alignment forces limits of deviation of tunnels to be set too	Breakdown of TBM near Cable Car foundation location with insufficient clearance to Cable Car structure to allow	Increase clearance between Cable Car and tunnel alignments

	Hazard	Cause	Mitigation
	tightly	intervention	
19	Close proximity of Cable Car alignment forces limits of deviation of tunnels to be set too tightly	Unforeseen underground obstacle e.g. buried Victoria dock gates forces impractical re-routing of tunnel alignment	Increase clearance between Cable Car and tunnel alignments
20	Ungrounded obstruction requires change alignment or construction methodology	Desk study and/or geotechnical study results in discovery of underground obstruction	Re align tunnel to avoid obstruction
21			Alter construction technique used
22	Unforeseen ground conditions forces change in alignment of construction methodology	Desk study and/or geotechnical study results in discovery of underground obstruction	Re align tunnel to avoid obstruction
23			Alter construction technique used
24	LFEPA do not approve emergency escape philosophy	Insufficient or untimely co ordination with LFEPA	Proper planning risk assessment and analysis of safety case well presented to LEFPA
25	Traffic backing up in tunnel compromising air quality and safety	Roundabouts on north and south sides inadequate for traffic flows	Carry out traffic modelling
26	Western Entrance to Royal Victoria Dock requires relocation of northern portal	TBM cannot mine through the existing lock structures which remain in-situ	Construct cofferdams and diaphragm wall boxes to enable removal old lock structures

7. Cost estimate

7.1 Summary cost estimate

The cost estimate for Options 2 and 3 have been produced by Mott MacDonald's specialist Construction Economics division. It has been developed using a 'bottom-up' methodology based upon labour, plant, materials and specialist sub-contractor requirements. The estimate is based on the drawings produced by Mott MacDonald as identified in this report.

The cost data is base-lined at 3Q2010 prices. The cost data used for the estimate is based on in-house historical data from tunnelling projects. This data has been supplemented by available published cost data, together with a budget estimate for the tunnel boring machine manufacturer.

Table 7.1: Breakdown cost estimate summary for Options 2 & 3

COST ESTIMATE SUMMARY

Job Title: ***New Thames River Crossing - Tunnel Option***
Job No:
Cost Est. No: ***Feasibility***
Base Date: ***Sep-10***
Area (m^2): ***n/a***

Description		OPTION 2 (Twin 14m dia +Escape) £	OPTION 3 (Twin 14m dia +Escape+ Pedestrian) £
Enabling Works		4,500,000	4,500,000
Roadworks			
Southern End Junction		52,310,121	52,310,121
Northern End Junction		6,518,399	6,518,399
Tunnel			
Bored Tunnel Option 2 and 3		129,424,051	129,424,051
Bored Tunnel Fit-Out Option 2		19,099,789	-
Bored Tunnel Fit-Out Option 3		-	9,550,512
Bored Tunnel Fit-Out Option 3 - Incl. Pedestrian Tunnel		-	14,424,187
Bored Tunnel Fit-Out Option 3 - Access Points		-	4,255,334
Cut & Cover Tunnel - Greenwich		25,967,034	25,967,034
Cut & Cover Tunnel - Silvertown		15,361,068	15,361,068
M&E Systems		27,680,500	27,680,500
Accommodation Works		1,000,000	1,000,000
Services/Statutory Diversions		3,000,000	3,000,000
Toll System		1,500,000	1,500,000
Landscaping/Environmental		1,000,000	1,000,000
Sub-total		287,360,962	296,491,206
Contractors On Costs		Included	Included
Sub-total		287,360,962	296,491,206
Risk/Contingency	15%	43,104,144	44,473,681
TOTAL BUDGET CONSTRUCTION COST		£330,465,106	£340,964,887

The estimate excludes the following items:-

- VAT
- Price escalation beyond base date (3Q2010)
- Client design, preparation and supervision costs
- Planning Approval costs
- Land acquisition and compensation costs
- Fees
- Property Surveys and monitoring
- Demolition costs
- Geotechnical investigations
- Watercourses and Ground Water diversions

The estimate is based on the following key pricing issues applicable to the various estimate components. Included are the potential risk items together with the potential pricing impacts.

Table 7.2: Key pricing risks

[redacted]	
Enabling Works	This has been based on layout drawings for the site establishment on the North side including the riverside materials/spoil handling works.
	Risks: Addt riverside works, contaminated land, planning issues
	Potential Cost Impact : -10% to +30%
Highways	Highways estimate has not been revisited as it is assumed that it is unchanged.
	Potential Cost Impact : -10% to +50%
Bored Tunnel	Estimate based on longitudinal and cross-sections of the tunnels, identifying the size of the tunnel bores now 14.0m dia. The cost of cross passages have been excluded from both Option 2 and 3
	Risks: Detailed site investigation required, aquifer, detailed design incomplete, pricing (productivity)
	Potential Cost Impact : -10% to +30%
Cut & Cover Tunnel	Estimate based on longitudinal and cross-sections of the tunnel
	Risks: Detailed site investigation required, detailed design incomplete, pricing
	Potential Cost Impact : -10% to +30%
M&E Systems	Allowance made based on historical scope and cost data
	Risks: Detailed design incomplete, pricing

	Potential Cost Impact : 0% to +50%
Accommodation Works	Allowance made based on historical scope and cost data
	Risks: Assessment of requirements not fully established
	Potential Cost Impact : -25% to +50%
Services/Stat Diver.	Allowance made based on historical scope and cost data Detailed appraisal required
	Risks: Assessment of requirements not fully established
	Potential Cost Impact : -50% to +75%
Toll System	Allowance made based on historical scope and cost data
	Risks: Assessment of requirements not fully established
	Potential Cost Impact : -10% to +50%
Landscaping/Environment	Allowance made based on historical scope and cost data
	Risks: Assessment of requirements not fully established
	Potential Cost Impact : -10% to +50%

7.2 Alternative Options

The costs of the alternative Options 4 & 5 have been estimated on the same basis as Options 2 & 3. a similar exercise has not been carried out for Options 6 & 7.

- Cost estimate for Option 4 - £306,243,119
- Cost estimate for Option 5 - £323,283,039

7.3 Summary of all Options

The table below summarises the cost estimates for Options 1 to 5. Option 1 is the base case that was developed during the previous phase of this study in late 2009. The estimate for Option 1 was been reassessed to ensure that it provides a suitable comparison with Options 2 to 5.

Table 7.3: Summary cost estimate Options 1 to 5

COST ESTIMATE SUMMARY

Job Title: *New Thames River Crossing - Tunnel Option*
Job No: **Base Date:** *Sep-10*
Cost Est. No: *Feasibility* **Area (m^2):** *n/a*

	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
	(Twin 12.1m dia)	(Twin 14m dia +Escape)	(Twin 14m dia +Escape+ Pedestrian)	(Twin 12.6m dia +Escape)	(Twin 13.8m dia +Escape)
Description	£	£	£	£	£
TOTAL BUDGET CONSTRUCTION COST	£327,865,526	£330,465,106	£340,964,887	£306,243,119	£323,283,039

8. Surface loading

8.1 Woodchip storage facility

It is believed that there are proposals to use a portion of the wharf area above the alignment of the tunnel on the northern bank of the river as a bulk storage area. It has been suggested that this material may be waste wood although no further details are known, constraints will be imposed by the tunnel on the storage of said material.

Typically tunnels are designed for existing ground overburden (depth of ground to surface), hydrostatic loads, plus an additional 50kN/m² imposed at ground level and where appropriate loading from existing structures is also taken into account.

The 50kN/m² imposed load is generally considered to be an appropriate live load and takes account of such items as:

- Minor surface structures (for example dwellings, industrial units and commercial space)
- Vehicular loading
- Minor changes to surface topography
- Accidental loads

Changes in surface loading may result in an increase in axial force and most critically bending moments within the tunnel lining with such effects more pronounced when a tunnel in shallow. An increase in vertical stress will result in a greater bending within the lining and eventually in the case of a segmentally lined bored tunnel, failure of the radial segmental joints.

The use of the site above the tunnel for possible storage of timber would have to be carefully controlled. Cut timber typically has a density of between 300 and 900kg/m³, whilst wood chip is as low as 250kg/m³ and manufactured wood pellets greater than 1000kg/m³. Therefore the height to which the wood may be stockpiled will depend on its nature, with a maximum height of 5m for pellets, but up to 20m for wood chip.

To enable more efficient use of the site a concrete slab or raft could be placed on the ground. This would distribute stockpile loads more uniformly over the tunnel. However without information on ground conditions, depth of the tunnel and designs for the lining it is not possible to provide any further more detailed information on the ability of the lining to take a surcharge load in excess of 50kN/m².

If required the tunnel lining could be designed for a higher imposed loading. This may require strengthening of the lining either through increasing its thickness or the amount of reinforcement used. Obviously such measures would increase the capital cost of the tunnel.

8.2 Accidental ship loading

Cover to the tunnels will potentially be low, at around 10m. There is remote possibility that a large liner or barge could sink onto the river bed above the tunnel, adversely loading the tunnel. Such loading and the possible impacts will have to be considered during design of the tunnel and will have to be the subject of a risk analysis.

9. Construction Management

9.1 Introduction

Within Volume 1, produced in November 2009 key construction issues were addressed. The new options discussed in this report do not require any significant modifications to the construction methodology proposed in that report. However, there has been clarification on several points and this section seeks to build on the previous work with reference to the new options.

9.2 Construction feasibility

The suitability of the local geology for mining was discussed in Volume 1. Proposed in this report are two options which will require an excavated diameter of 14.0m. A diameter of this size is on the larger side of earth pressure balance (EPB) machines, although machines with diameters up to 15.55 are now being built in Germany. As discussed before the geology has been successfully mined on the Jubilee Line Extension and the DLR.

Minor modifications to the alignment have been necessary due to the development of the London Cable Car Crossing, this has necessitated in a reduction of the radius of curvature to 400m, again this is achievable, but tending towards the limits of current practice.

The requirements for a detailed site investigation are being developed as part of this package and this will aid the specifying of the TBM. The geotechnical investigations will also aid the identification of potential underground obstructions along the alignment.

9.3 TBM drive

W the TBM launch chamber for the first drive located on the north side of the DLR viaduct, Volume one stated that there were three options for return drive of the TBM.

1. Transport a 1300+ tonne assembled TBM across the river and crane over the DLR

2. Turn the TBM around at the Greenwich Reception Chamber and drive north back under the river to Silvertown

3. Disassemble the TBM in the Greenwich Reception Chamber transport back across the river, by road or water and reassemble in the Silvertown Launch Chamber.

Discussions with TBM manufacturers has identified that Option 2 would be preferable. This is due to the prolonged period of non-productivity that transport of the TBM back to Silvertown would require, with programme estimates for Option 3 in excess of 4 months. Option 1 would also be very technically challenging particularly with the cable car in place, which will restrict both access to the Thames and headroom for the cranes required to lift the machine.

To avoid transplanting of TBM surface backup services from Silvertown to Greenwich, the first drive could be used for logistics and muck away.

9.4 Construction worksites

Since the completion of Volume 1 of this report in November 2009 additional work has taken place to further understand land ownership in the North Greenwich and Silvertown areas. Using this additional data modifications have taken place to required worksite layouts.

9.4.1 Silvertown worksite

There are no proposed changes to the construction worksite at Silvertown which lies within the safeguarded area. Available information suggests indicates that almost all of the required land is LDA, or DLR Freehold. One possible site layout is shown on drawing MMD-281586-TUN-2603.

9.4.2 Greenwich worksite

Greenwich worksite is not required for tunnelling works, therefore land take is expected to be kept to that required to allow for construction of the cut and cover structures and ancillary buildings. River access is not considered to be essential for the works, although it would reduce traffic movements associated with the muck away operation during excavation of the approaches.

It is anticipated that minor modifications will have to take place to the worksite layout as information or land ownership becomes available. . One possible site layout is shown on drawing MMD-281586-TUN-2602.

9.4.3 Greenwich pedestrian access shaft worksite

Option 3 will require an additional worksite on the corner of Edmund Halley Way and the Thames Path. The location of the worksite will be dictated by precise sighting of the lift access building. The cut and cover diaphragm wall box would be have to be completed before arrival of the TBM and may require temporary diversion of local roads and footpaths. Precise locations would have to be discussed with the local landowners. One possible arrangement is shown on drawing MMD-81586-TUN-2601.

The box itself could be constructed concurrently with Greenwich cut and cover structures taking advantage of the plant and muck away facilities in place for that work.

9.5 Construction programme

Development of the programme is outside the scope of this section. However, through inspection of the programme developed in November 2009, it can be inferred that by elimination of the 11 cross passages there is potential to save up to 6 months on programme.

10. Conclusions and recommendations

10.1 Conclusions

The following conclusions concerning Options 2 & 3 can be reached:

1. Escape via the tunnel as in Options 2 & 3 is feasible, requiring a 14m external diameter tunnel.
2. Option 2 with escape to the tunnel invert attracts considerably less construction risk than is attracted by the base case Option with its cross connecting escape passages
3. The capital cost of invert escape Option 2 is broadly similar to the base case Option 1 at approximately £330 million.
4. A pedestrian footpath and cycleway can be included in the tunnel invert at a capital cost of approximately £10 million.
5. Emergency escape can take place at road level as in Options 5 & 6 at a reduced capital cost of approximately £7 million compared to invert escape.
6. Modifications to the traffic envelope will reduce the tunnel diameter saving approximately £14 million.
7. The inclusion of a fire suppression system may enable the number of cross passages to be reduced to two from eleven. Assuming a cost of £2 million per passage this could save up to £18 million although this would be partially offset by the cost of a fire suppression system.
8. Option 5 appears to offer the best solution, minimising tunnel diameter, cost and risk, while still providing a dedicated emergency escape and full traffic gauge.

10.2 Recommendations

The following recommendations are made;

1. It is recommended that Option 5 is carried forward as the preferred solution.
2. Option 3 appears to the most expensive of the options, estimates of potential pedestrian and cycle usage of Option 3 should be established to assess any potential benefit, particularly in light of the London Cable Car project.
3. Option 2 has a higher capital cost than Option 5 but the benefits appear to be broadly the same. Thus Option 5 should be presented to LFEPA for discussion.
4. A similar system of escape to Option 5 is currently being built on the New Tyne Crossing, discussions with the operator would be beneficial.
5. LFEPA should be contacted at the earliest possible opportunity to discuss the preferred solution(s).
6. Option 7 appears to offer the possibility of further savings, investigation into the potential to increase the spacing of cross passages through the installation of a fire suppression system should be carried out.
7. The views of The Royal Association for Disability Rights (RADAR) should be canvassed.
8. Discussions should take place with the relevant roads authority to assess the potential to reduce the traffic envelope as identified in Options 4 and 6.
9. A full geotechnical investigation in and around the Western Entrance to the Royal Victoria Dock must be carried out to establish the location, condition and presence of the existing structures.

Appendices

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Appendix A. Drawings

Number		Title
MMD-281586-TUN-	1001	Option 2 – Scheme layout - plan
MMD-281586-TUN-	1002	Option 2 – Scheme layout - long section
MMD-281586-TUN-	1201	Option 2 – Bored tunnel - cross sections
MMD-281586-TUN-	1202	Option 2 – Escape ramp - long section
MMD-281586-TUN-	1203	Option 2 – Escape ramp - plan
MMD-281586-TUN-	1204	Options 2 & 3 – Mid tunnel sump
MMD-281586-TUN-	1301	Option 2 – Silvertown approach - plan
MMD-281586-TUN-	1302	Option 2 – Silvertown approach - sections
MMD-281586-TUN-	1303	Option 2 – Silvertown approach - escape access from invert to road deck
MMD-281586-TUN-	1401	Options 2 & 3 – Greenwich approach - plan
MMD-281586-TUN-	1402	Options 2 & 3 – Greenwich approach - sections
MMD-281586-TUN-	1403	Options 2 & 3 – Greenwich approach - escape access from invert to road deck
MMD-281586-TUN-	2001	Option 3 – Scheme layout - plan
MMD-281586-TUN-	2002	Option 3 – Scheme layout - long section
MMD-281586-TUN-	2201	Option 3 – Bored tunnel - cross sections
MMD-281586-TUN-	2202	Option 3 – Escape ramp - long section
MMD-281586-TUN-	2203	Option 3 – Escape ramp - plan
MMD-281586-TUN-	2301	Option 3 – Silvertown approach - plan
MMD-281586-TUN-	2302	Option 3 –Silvertown approach - sections
MMD-281586-TUN-	2303	Option 3 – Silvertown approach - escape access from invert to road deck
MMD-281586-TUN-	2304	Option 3 – Silvertown - pedestrian access shaft - plans
MMD-281586-TUN-	2305	Option 3 – Silvertown - pedestrian access shaft - sections
MMD-281586-TUN-	2404	Option 3 – Greenwich - pedestrian access shaft - plans
MMD-281586-TUN-	2405	Option 3 – Greenwich - pedestrian access shaft - sections
MMD-281586-TUN-	2601	Option 3 - Greenwich - pedestrian access shaft - worksite layout
MMD-281586-TUN-	2602	Options 2 & 3 - Greenwich - worksite layout
MMD-281586-TUN-	2603	Options 2 & 3 - Silvertown - worksite layout
MMD-281586-TUN-	3201	Option 4 – Bored tunnel - cross sections
MMD-281586-TUN-	4201	Option 5 – Bored tunnel - cross sections
MMD-281586-TUN-	5201	Option 6 – Bored tunnel - cross sections
MMD-281586-TUN-	6201	Option 7 – Bored tunnel - cross sections

Appendix B. Figures

Figure B.1: Schematic outline of emergency escape infrastructure

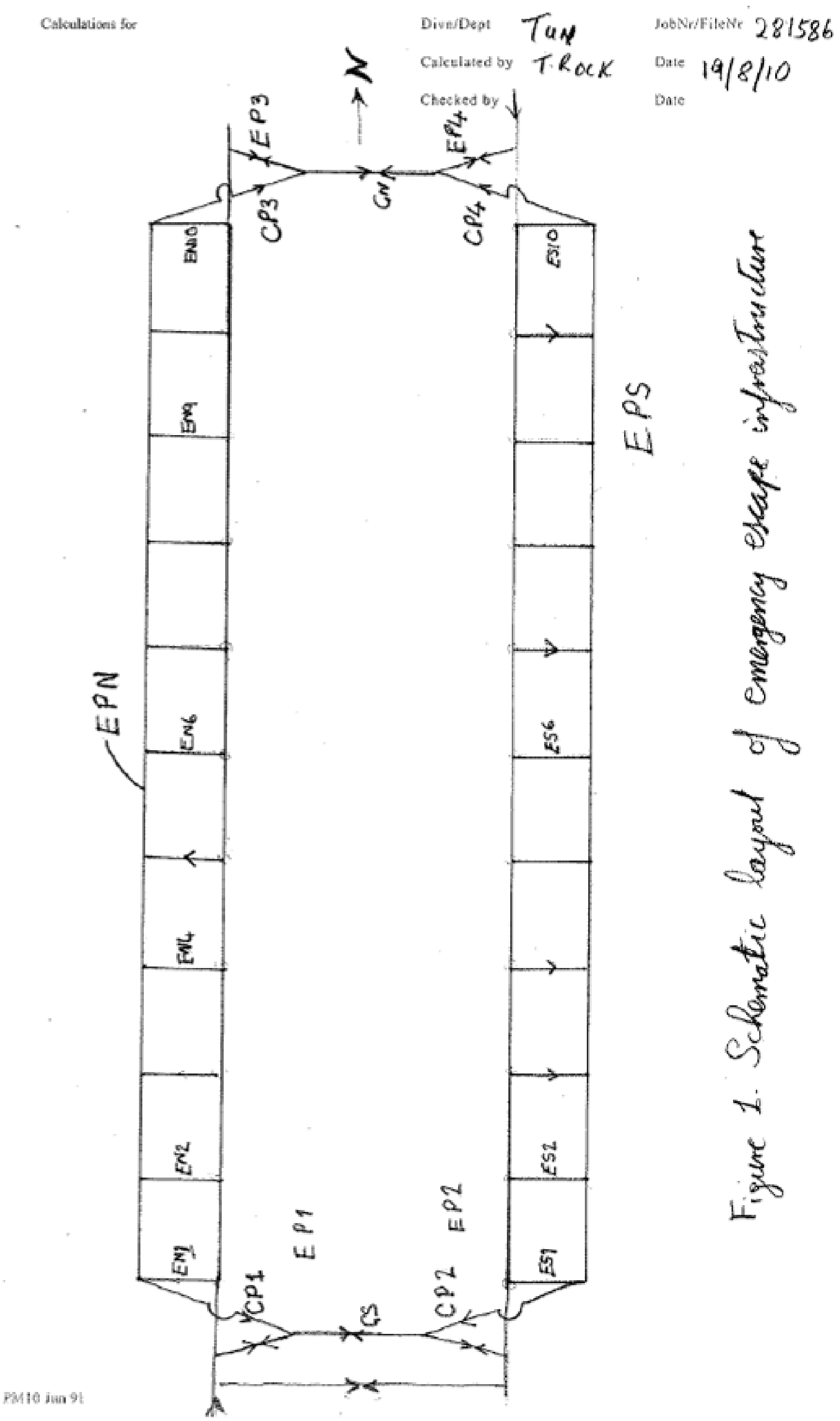


Figure B.2: Schematic of escape routes from emergency incident

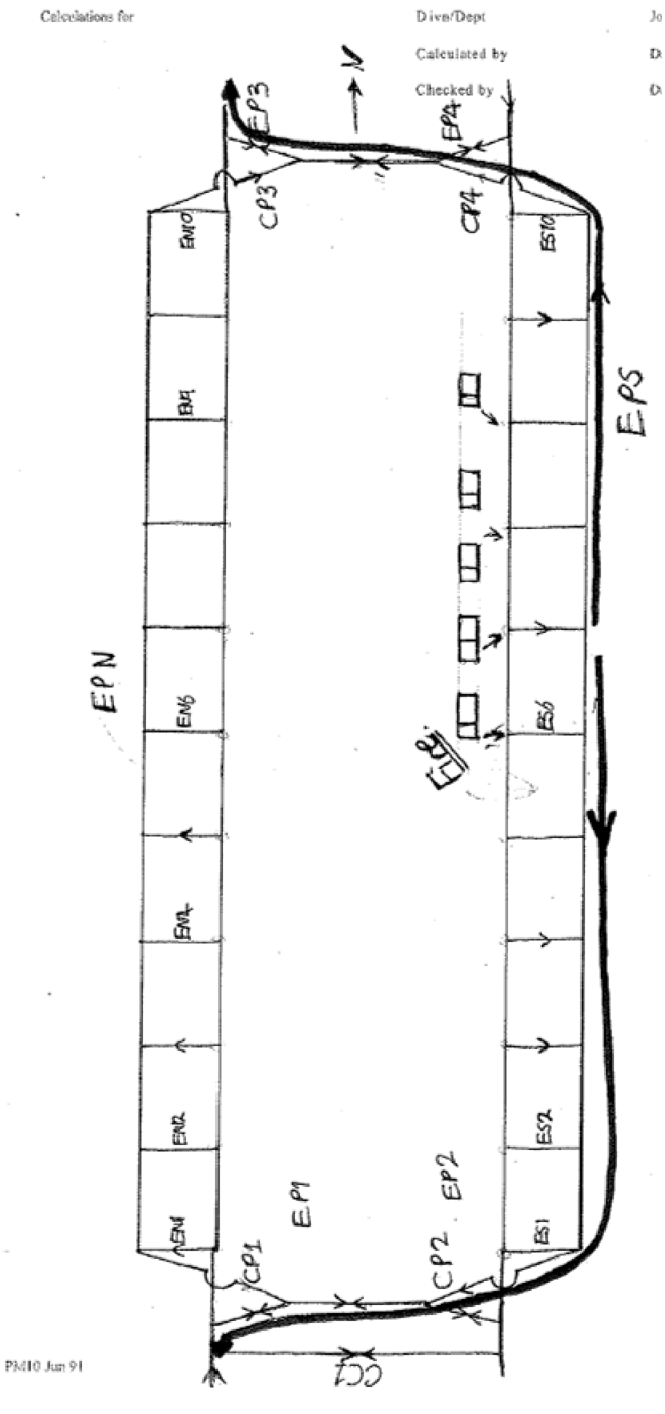
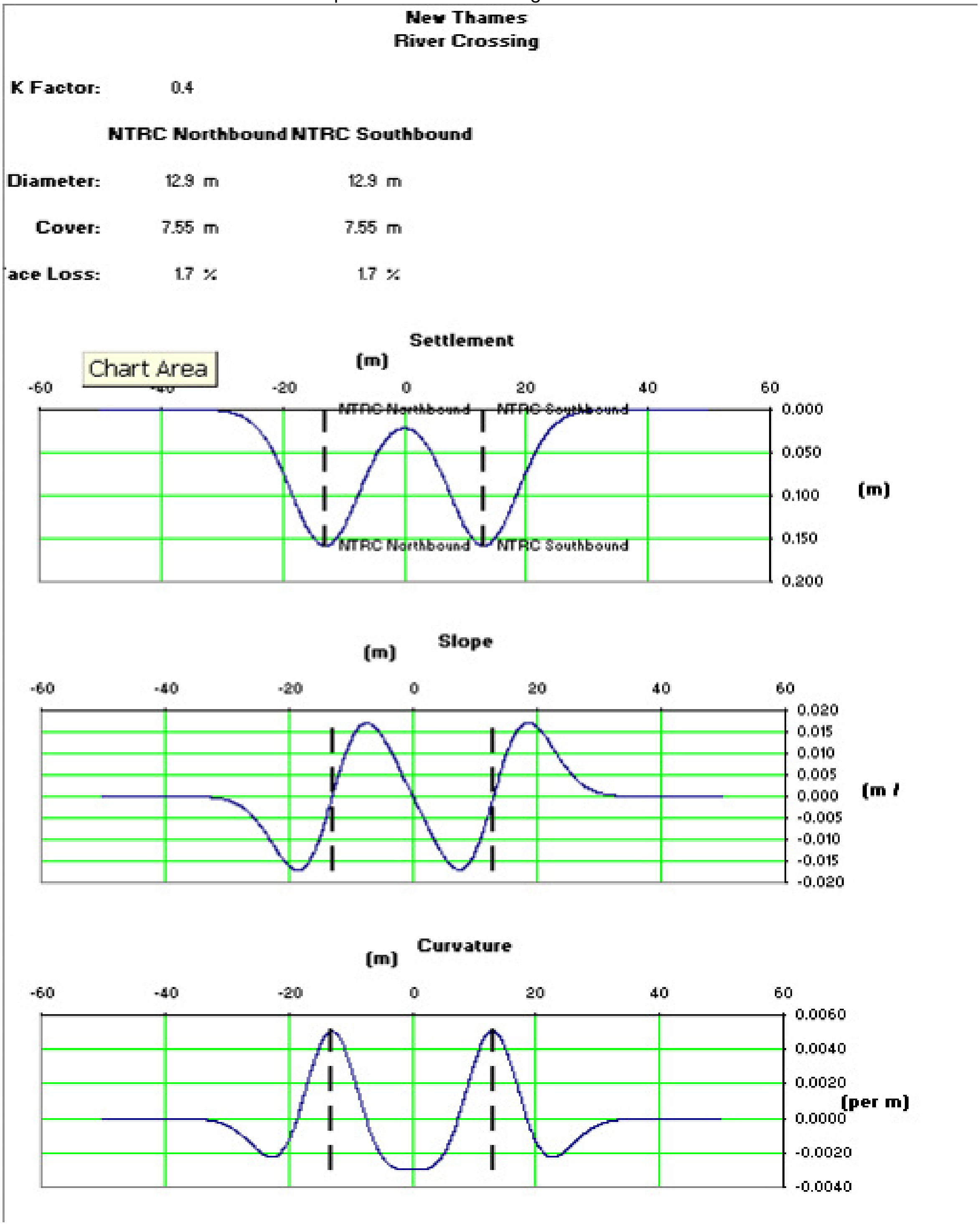


Figure B.3: Indicative surface settlement profile due to tunnelling



Notes

Key to symbols

Reference drawings

CABLE CAR ALIGNMENT FROM **WEA-682-SK-0137**
RECEIVED 08/09/10

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client

Transport for London

Title

New Thames River Crossing
Bored Tunnel Option 2
Scheme Layout Plan

Designed	MAC		Eng check	TAR
Drawn	CAL		Coordination	MAC
Dwg check	MAC		Approved	TAR

Scale at A1	Status	Rev
1:500	PRE	P1

Drawing Number

MMD-281586-TUN-1001

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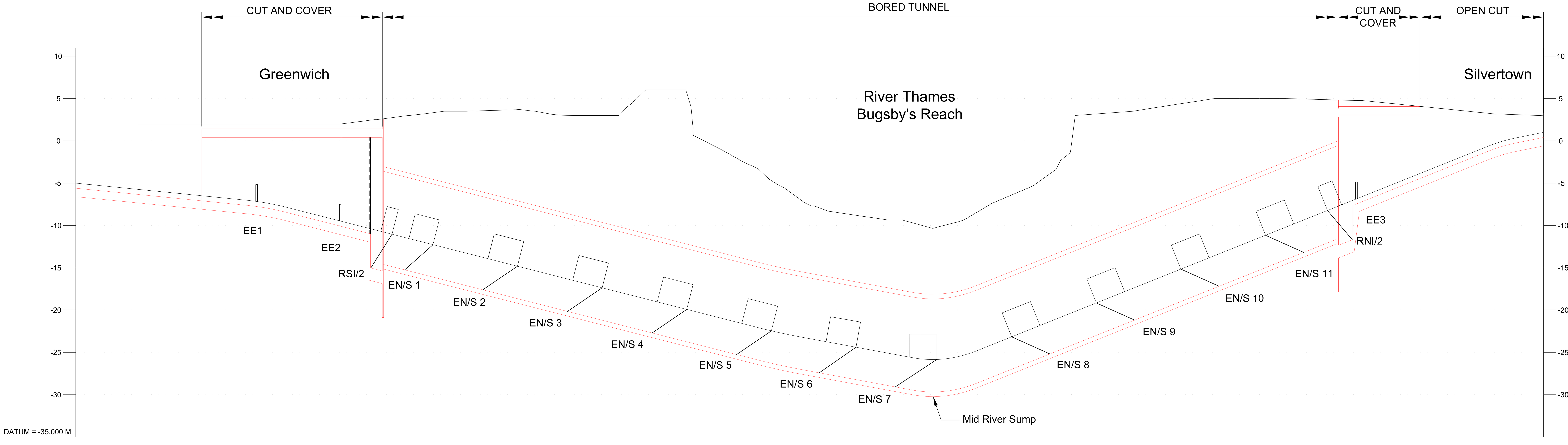

Scheme Layout Long Section

Horizontal Scale 1:2500 Vertical Scale 1:250

1:250 0 12.5m 25m

1:2500 0 125m 250m

Notes

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client

Transport for London

Title

New Thames River Crossing
Bored Tunnel Option 2
Scheme Layout
Long Section

Designed	TAR		Eng check	TAR	
Drawn	CAL		Coordination	MAC	
Dwg check	TAR		Approved	TAR	

Scale at A1: As Shown

Status: PRE

Rev: P1

Drawing Number: MMD-281586-TUN-1002

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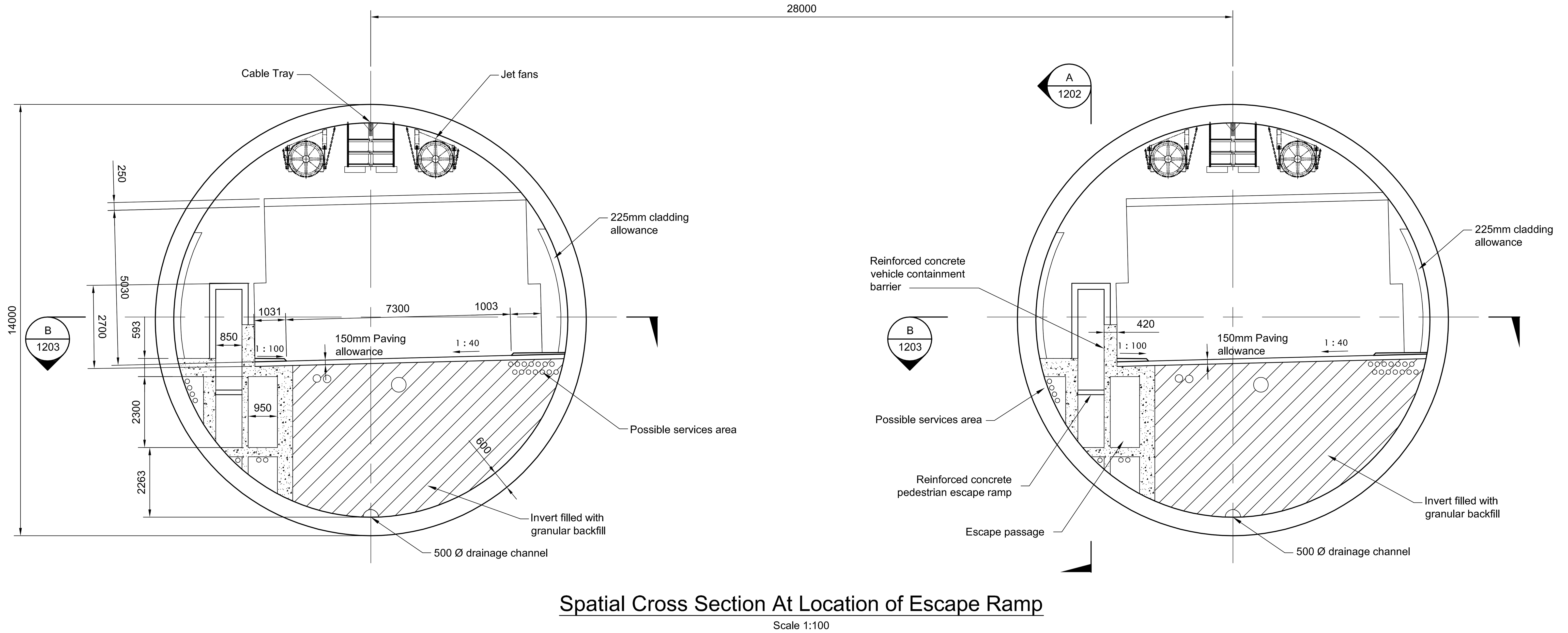
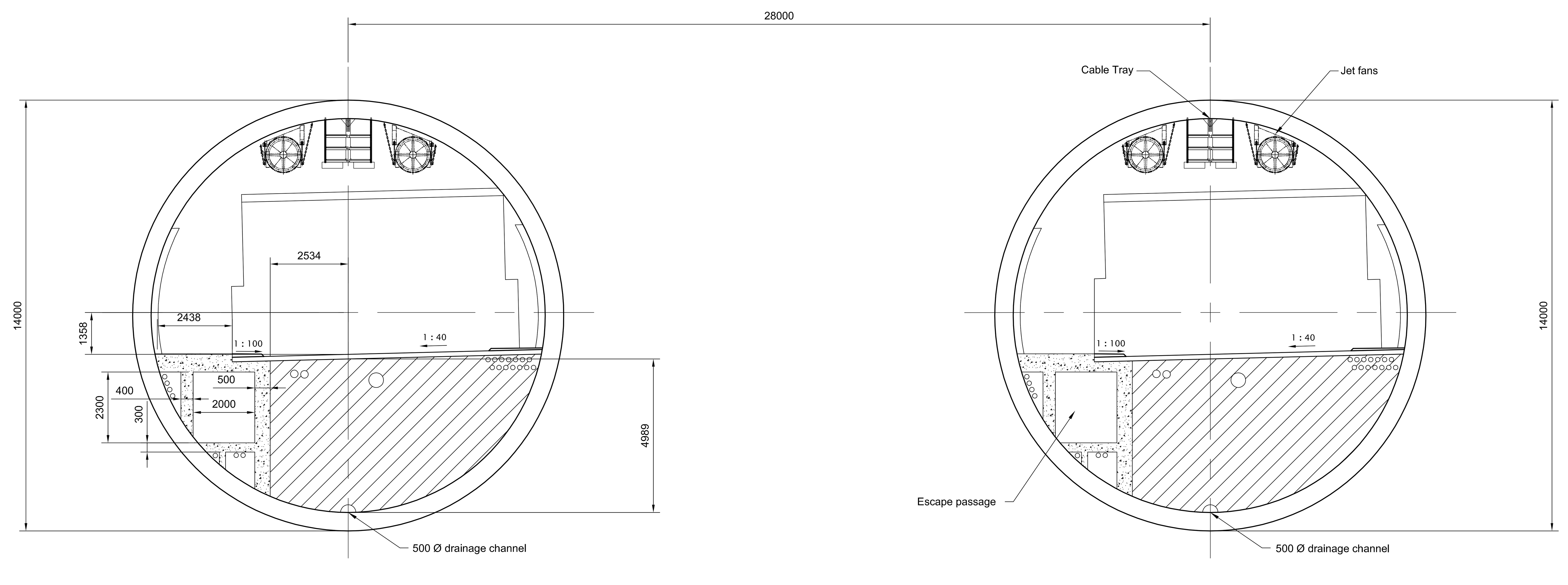


Spatial Cross Section At Location of Escape Ramp

Scale 1:100



Spatial Cross Section Away from Escape Ramp

Scale 1:100

1:100 0 5m 10m

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 2
Bored Tunnel Spatial Cross Sections

Designed	MAC		Eng check	MAC	
Drawn	MAC		Coordination	MAC	
Dwg check	MAC		Approved	TAR	

Scale at A1: 1:100 | Status: PRE | Rev: P1

Drawing Number
MMD-281586-TUN-1201

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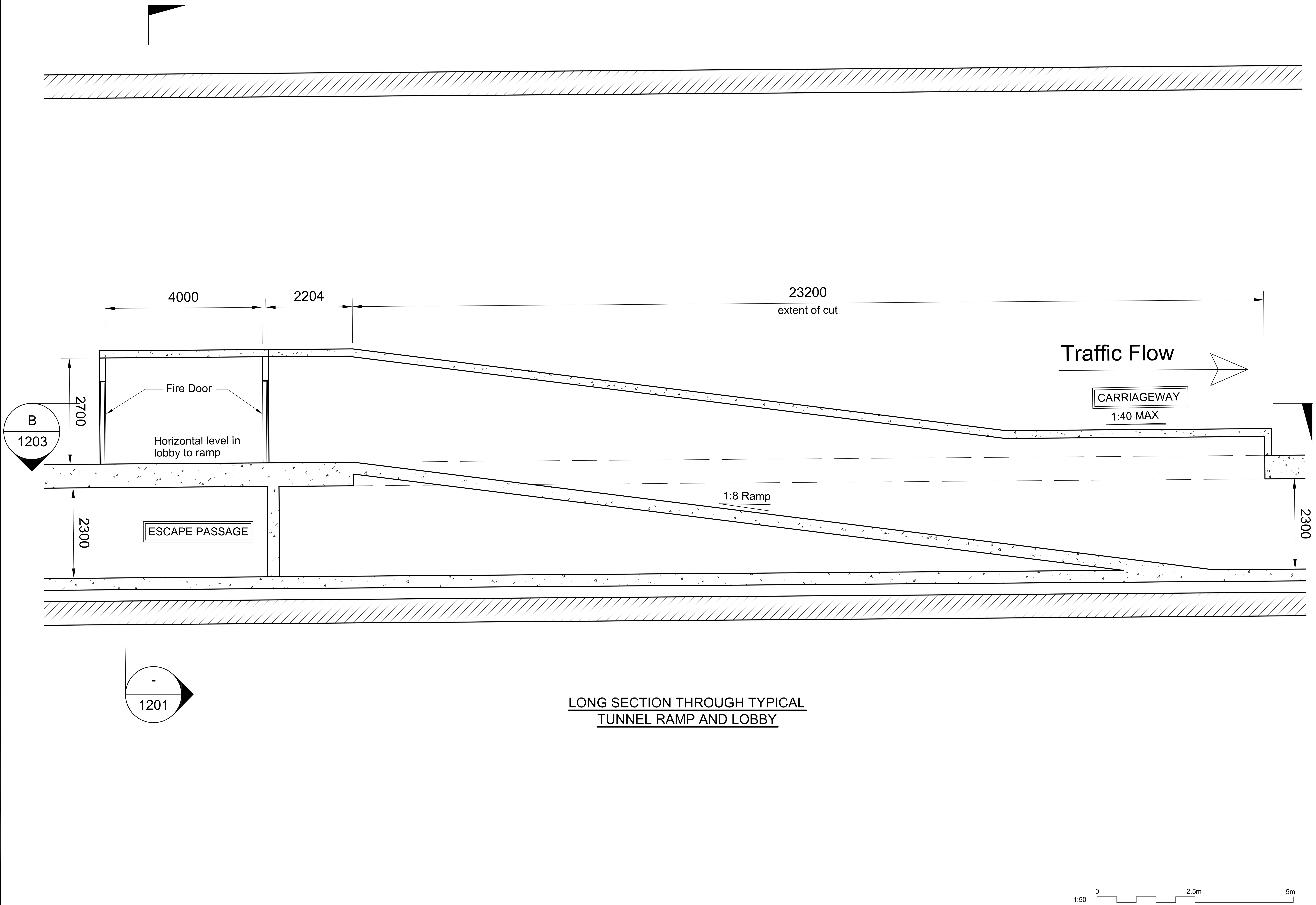

LONG SECTION THROUGH TYPICAL TUNNEL RAMP AND LOBBY

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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W www.mottmac.com

Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 2
Invert Escape Ramp
Long Section

Designed	MAC		Eng check	MAC
Drawn	CAL		Coordination	MAC
Dwg check	MAC		Approved	TAR

Scale at A1	Status	Rev
1:50	PRE	P1

Drawing Number
MMD-281586-TUN-1202

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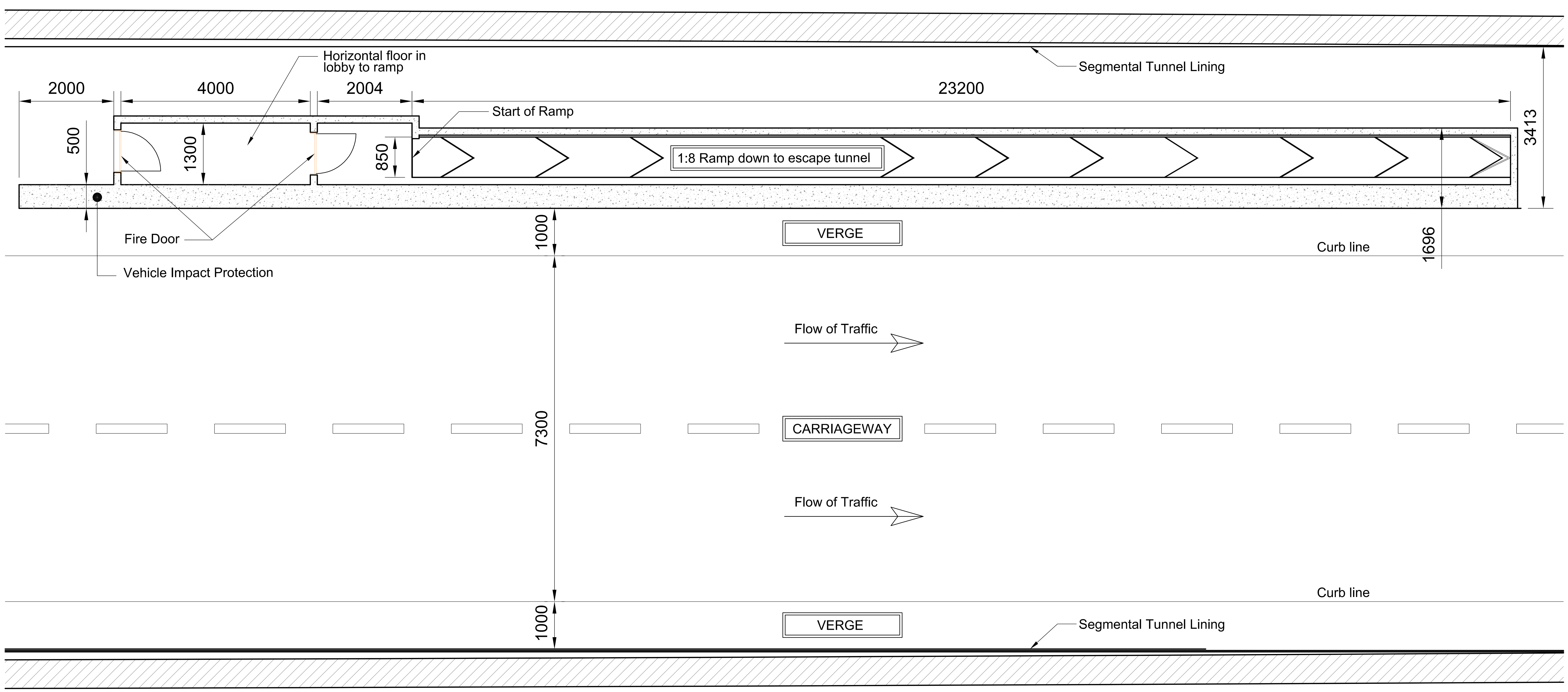

PLAN AT ROAD DECK LEVEL
(B-B)

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 2
Invert Escape Ramp Plan

Designed	MAC		Eng check	MAC	
Drawn	CAL		Coordination	MAC	
Dwg check	MAC		Approved	TAR	

Scale at A1: 1:50 | Status: PRE | Rev: P1

Drawing Number: MMD-281586-TUN-1203

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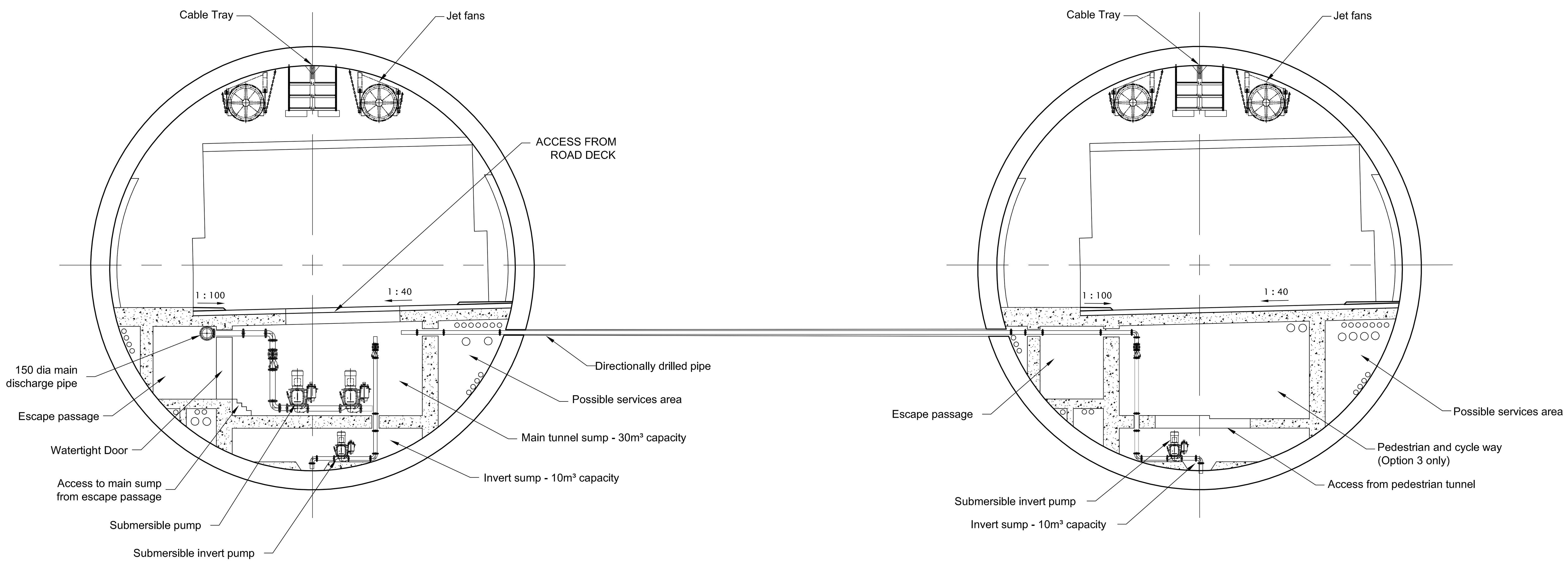

Spatial Cross Section At Mid River Sump - Options 2 & 3

Scale 1:100

1:100 0 5m 10m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Options 2 & 3
Mid River Sump

Designed	MAC		Eng check	TAR
Drawn	MAC		Coordination	MAC
Dwg check	MAC		Approved	TAR
Scale at A1 1:100		Status PRE		Rev P1

Drawing Number
MMD-281586-TUN-1204

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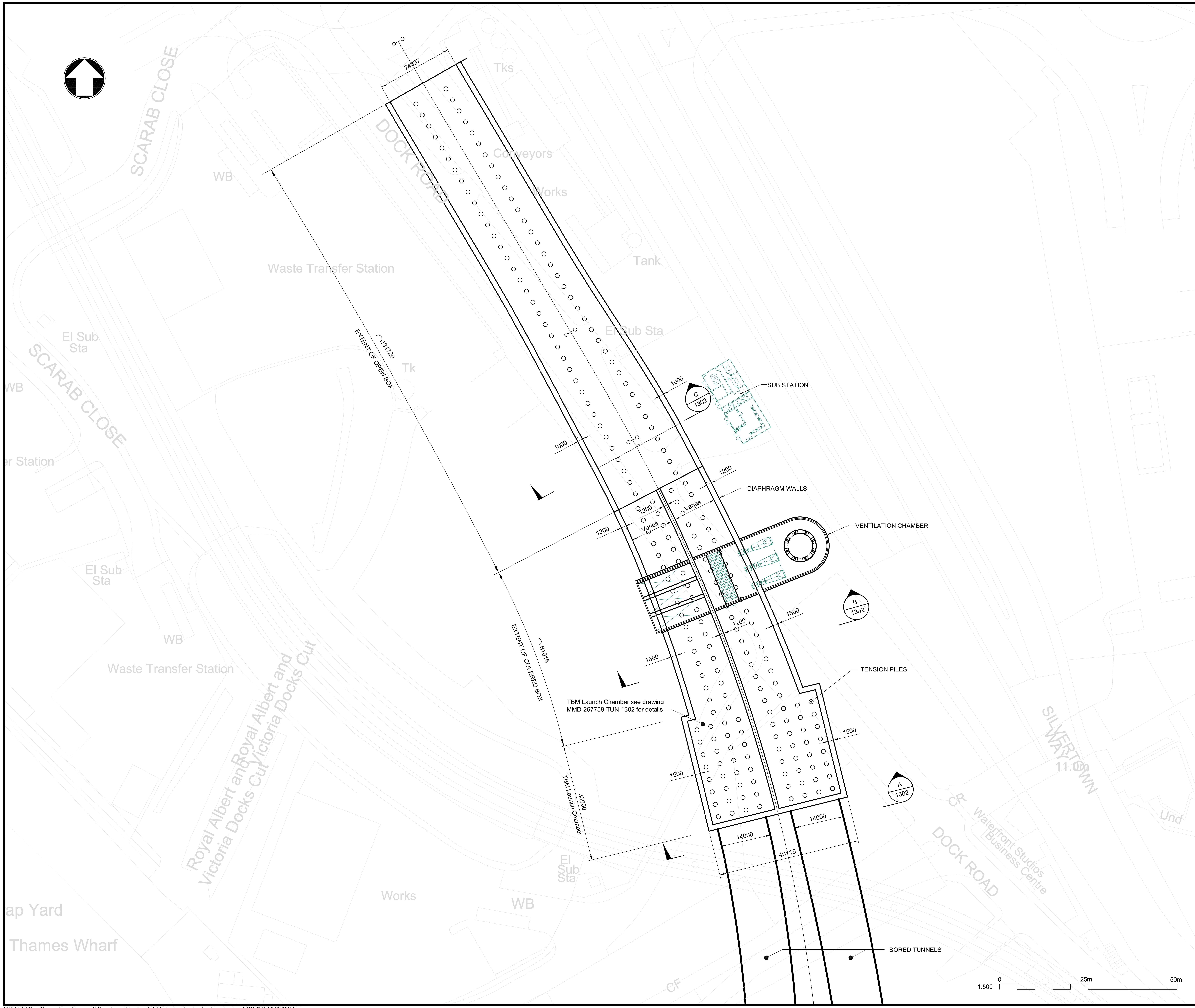

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 2
Silvertown Approach
Structures Plan Layout

Designed	MAC		Eng check	MAC
Drawn	CAL		Coordination	MAC
Dwg check	MAC		Approved	TAR
Scale at A1: 1:500		Status: PRE		Rev: P1

Drawing Number
MMD-281586-TUN-1301

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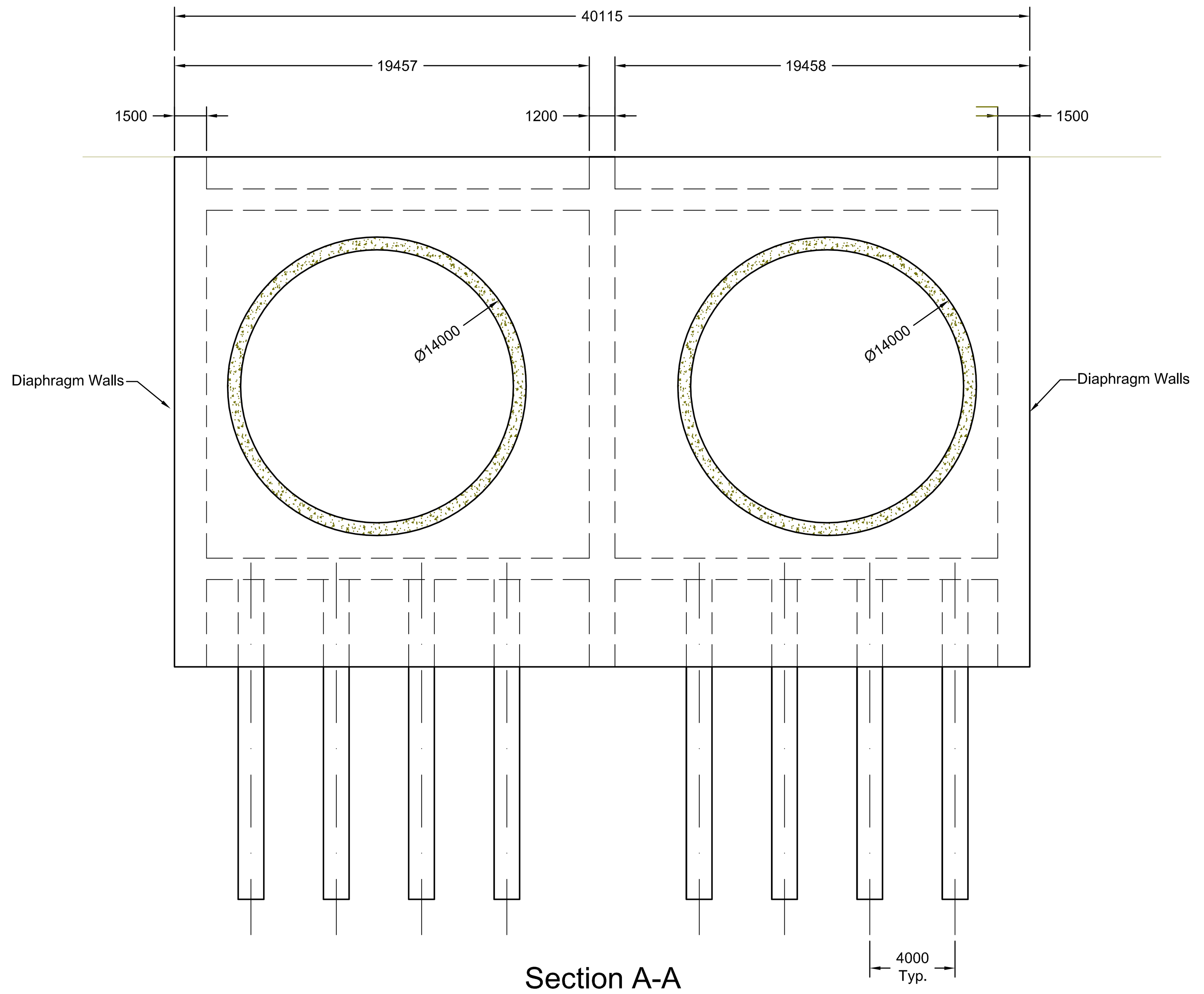
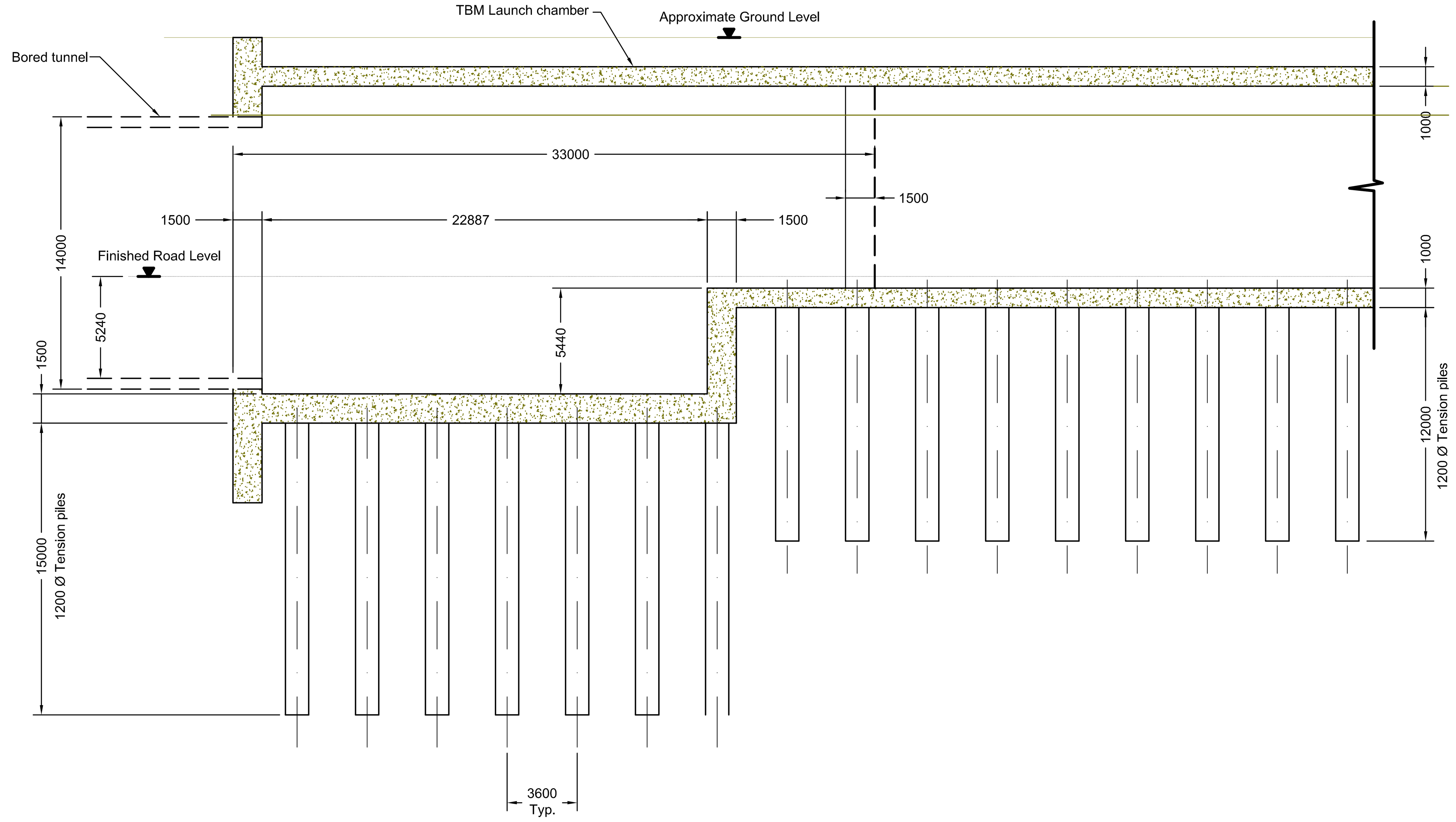
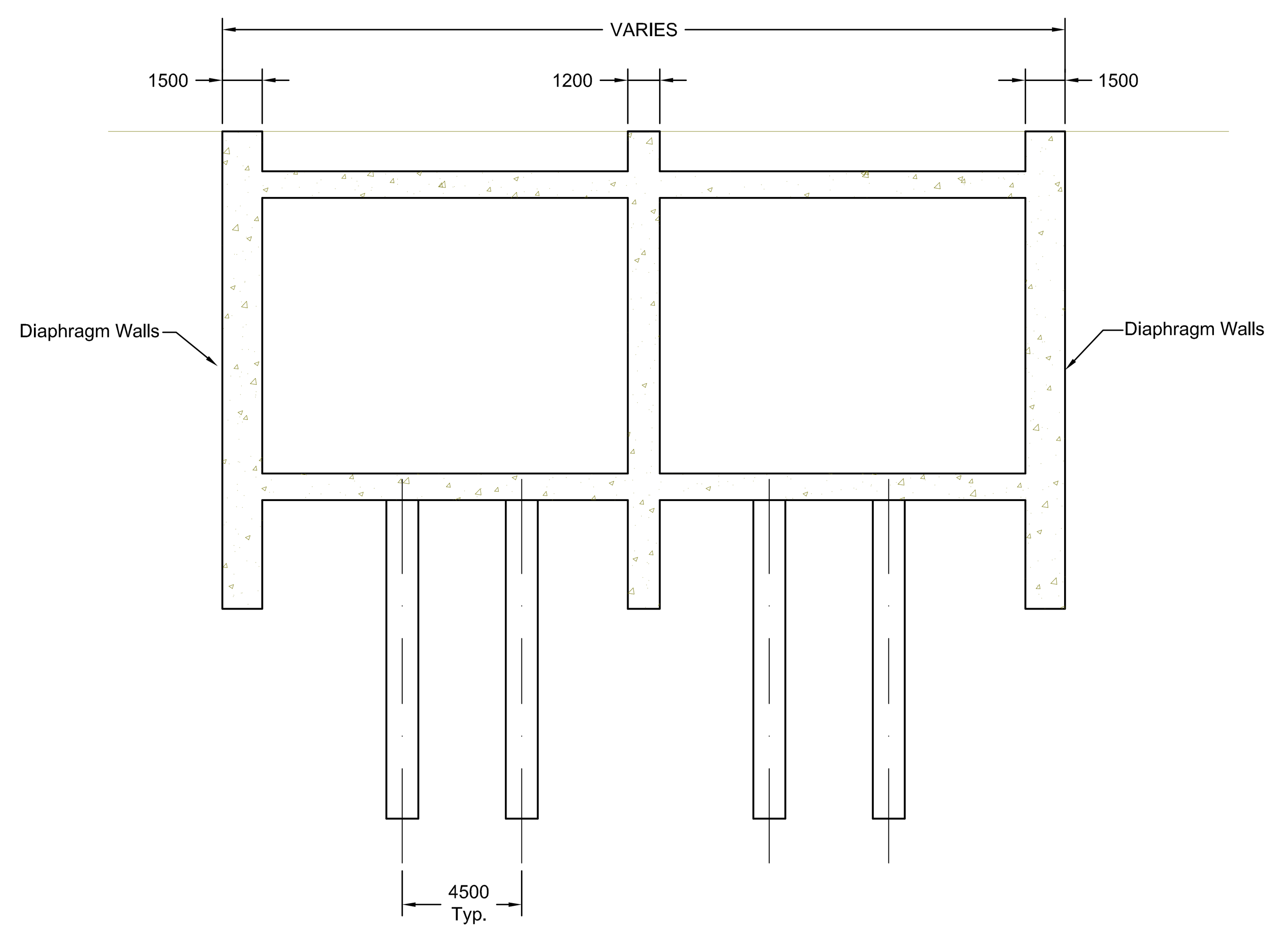


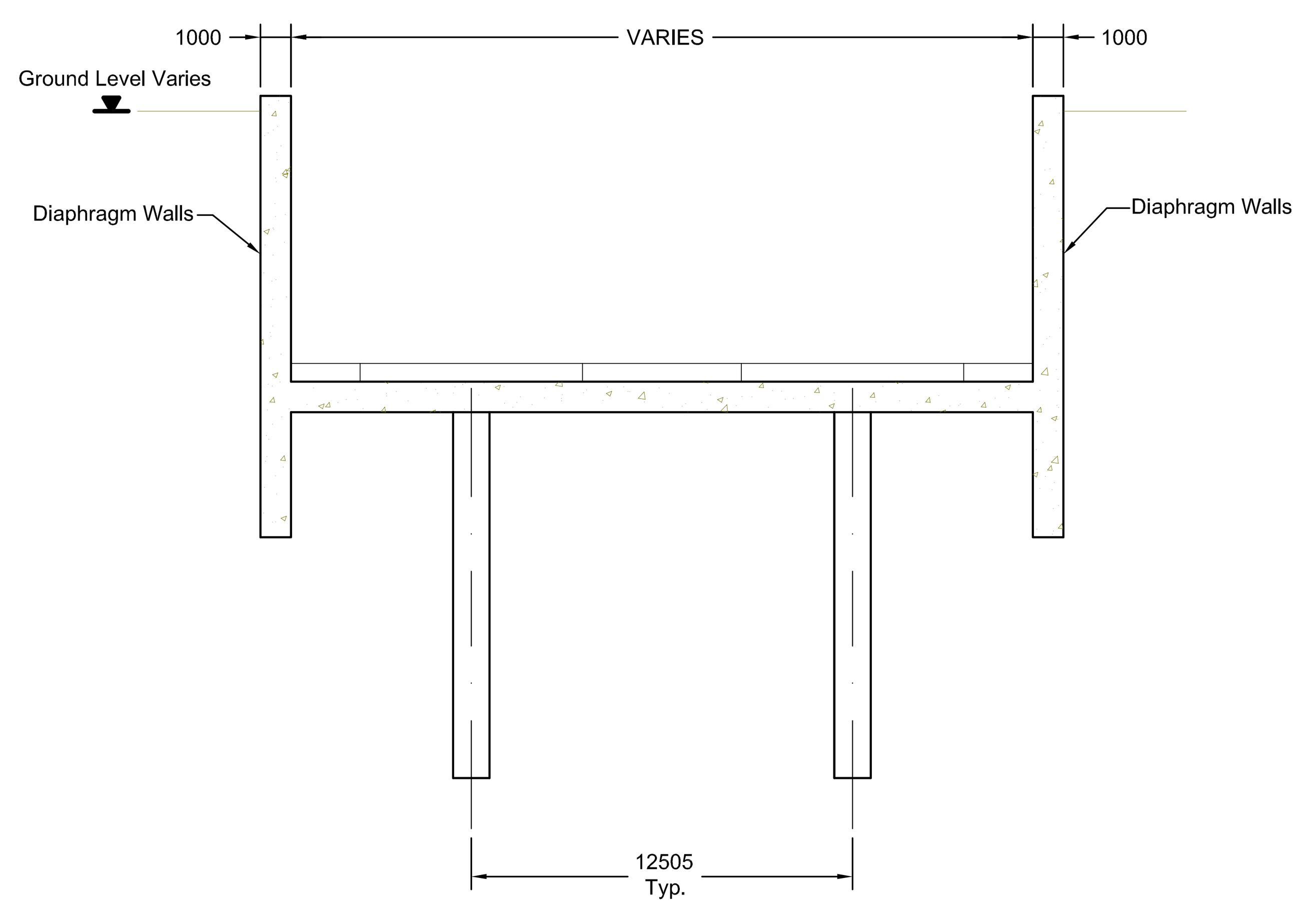
Section A-A
Cut and Cover Twin Tunnels
Spatial Cross Section
Scale 1:100



Section Along ℄ Carriageway
Scale 1:200



Section B-B
Covered box Carriageways
Spatial Cross Section
Scale 1:200



Section C-C
Open box Carriageways
Spatial Cross Section
Scale 1:200

1:200 0 10m 20m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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W www.mottmac.com

Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 2
Silvertown Cut and Cover
TBM Launch Chamber

Designed	TAR	Eng check	TAR
Drawn	CAL	Coordination	MAC
Dwg check	TAR	Approved	TAR
Scale at A1: 1:200	Status: PRE	Rev: P1	

Drawing Number
MMD-281586-TUN-1302

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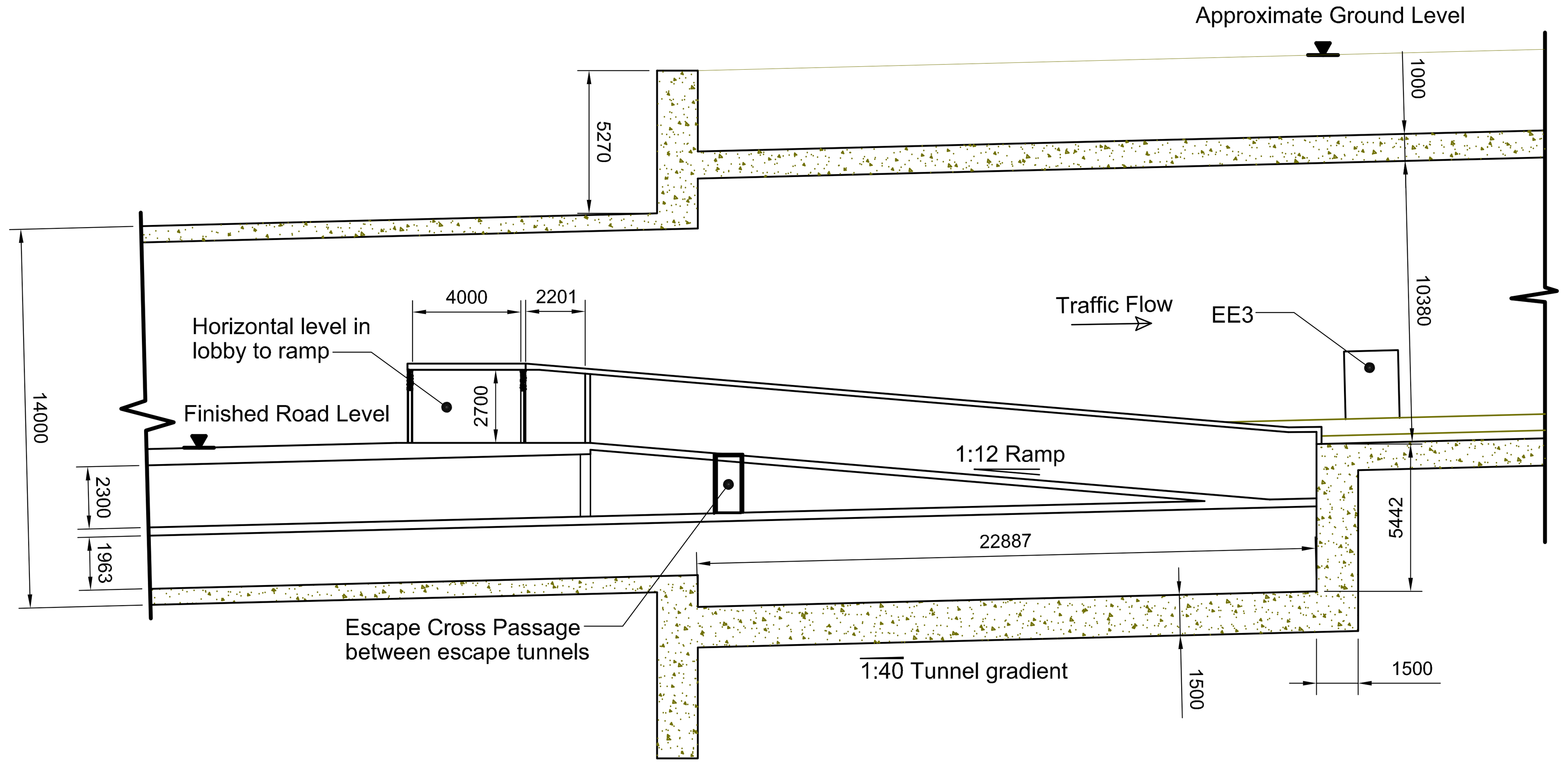
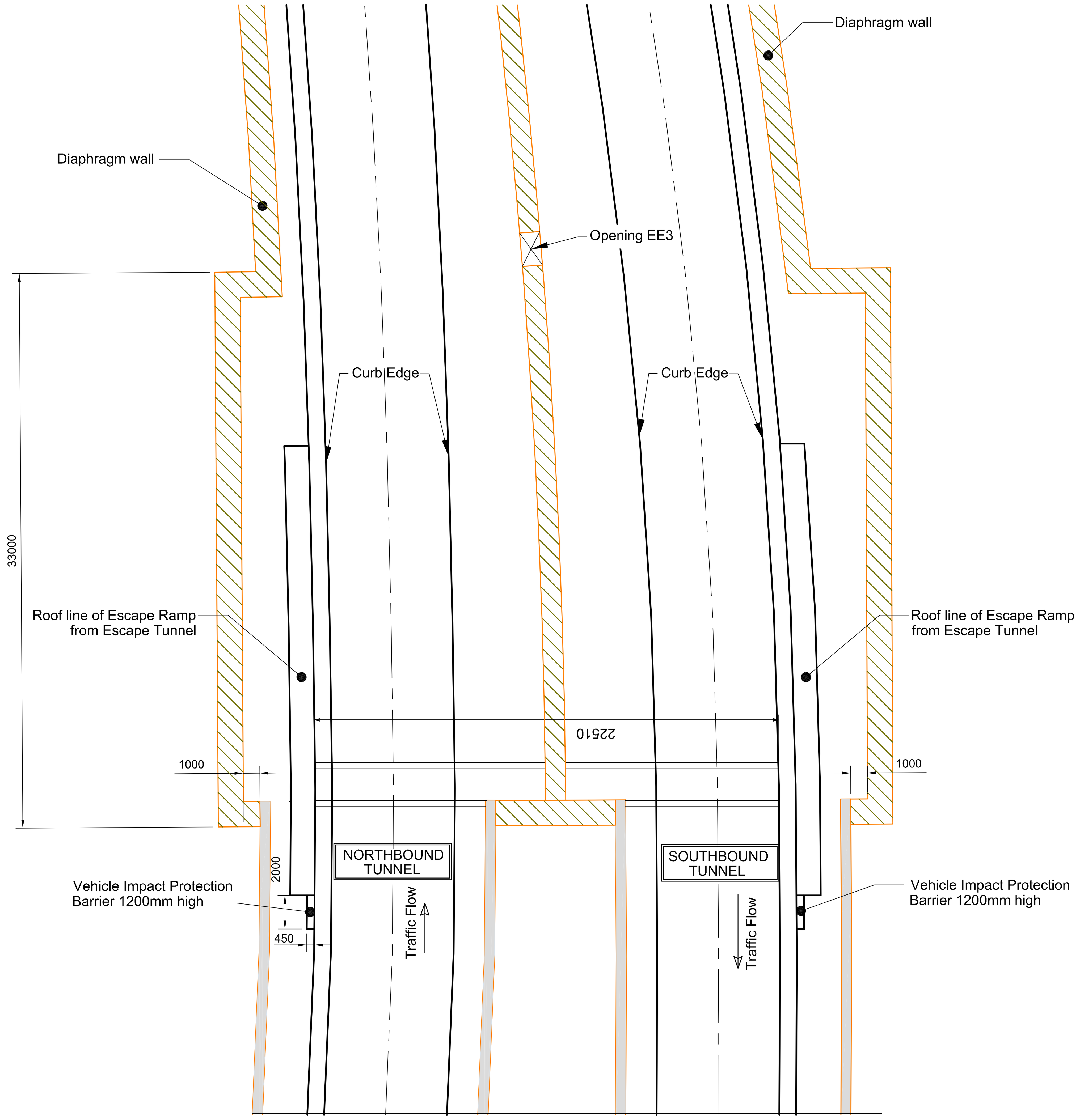
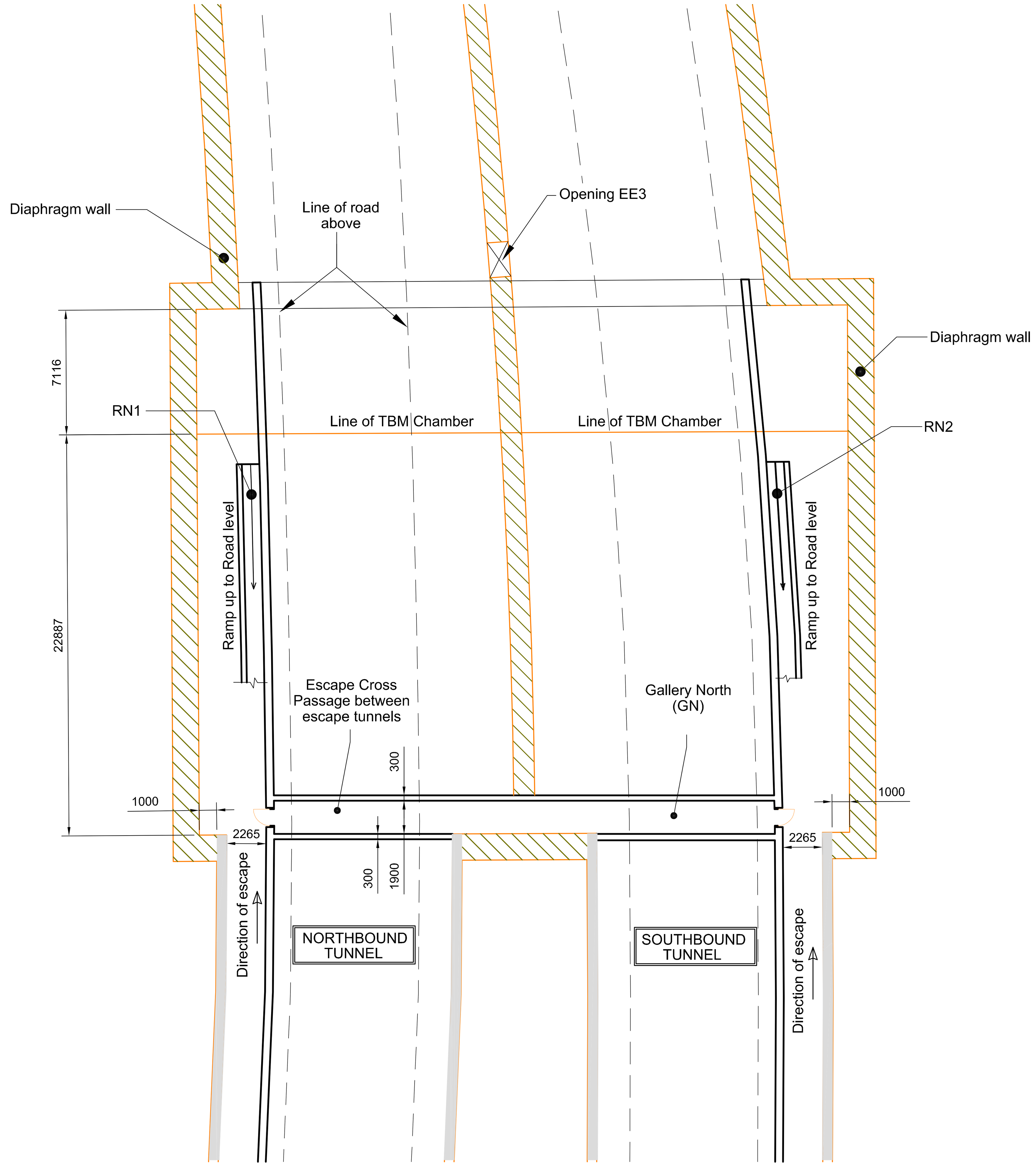


Section A-A



PLAN at SILVERTOWN TUNNEL ENTRANCE ROAD LEVEL



PLAN at SILVERTOWN TUNNEL ENTRANCE EMERGENCY ESCAPE TUNNEL LEVEL

1:200 0 10m 20m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 2
Silvertown Approach Escape Access
Invert to Road Deck

Designed	MAC	Eng check	MAC
Drawn	CAL	Coordination	MAC
Dwg check	MAC	Approved	TAR
Scale at A1: 1:200	Status: PRE	Rev: P1	

Drawing Number
MMD-281586-TUN-1303

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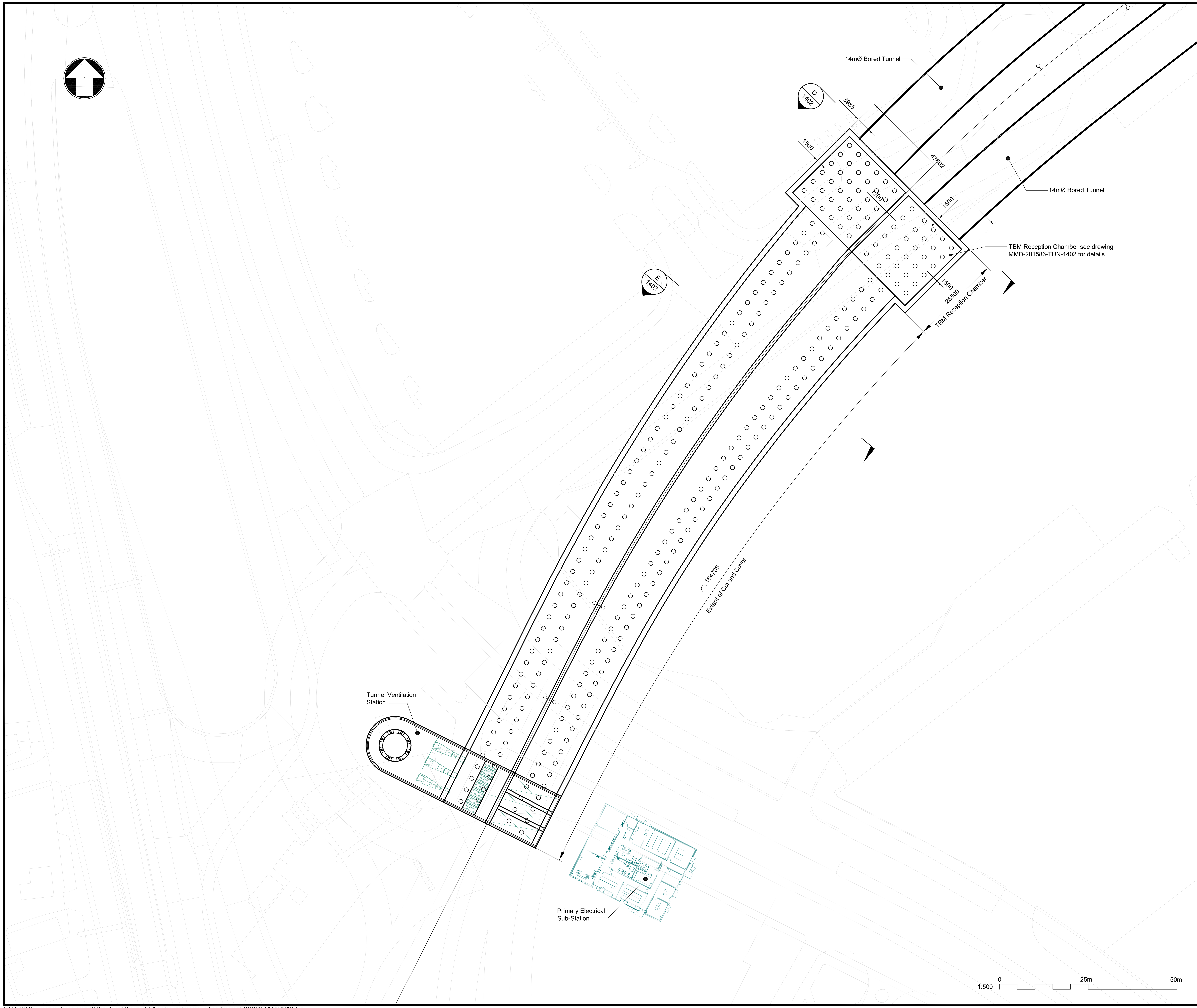

P1	01/10/10	RK	Draft for Comment	MAC	TAR
Rev	Date	Drawn	Description	Ch'k'd	App'd

Notes

Key to symbols

Reference drawings

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 2
Greenwich Approach
Structures Plan Layout

Designed	MAC		Eng check	MAC
Drawn	CAL		Coordination	MAC
Dwg check	MAC		Approved	TAR
Scale at A1: 1:500		Status: PRE		Rev: P1

Drawing Number
MMD-281586-TUN-1401

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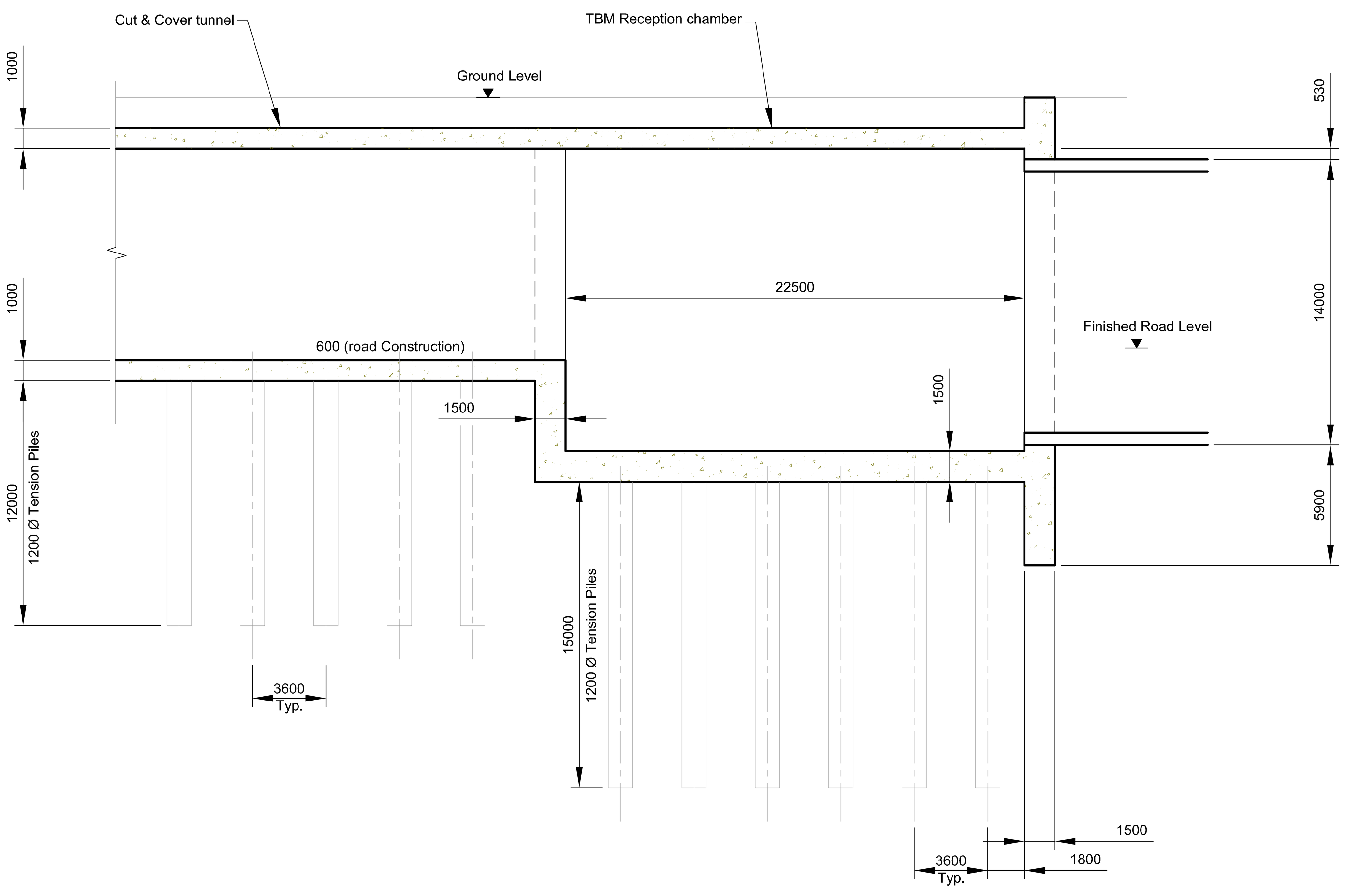
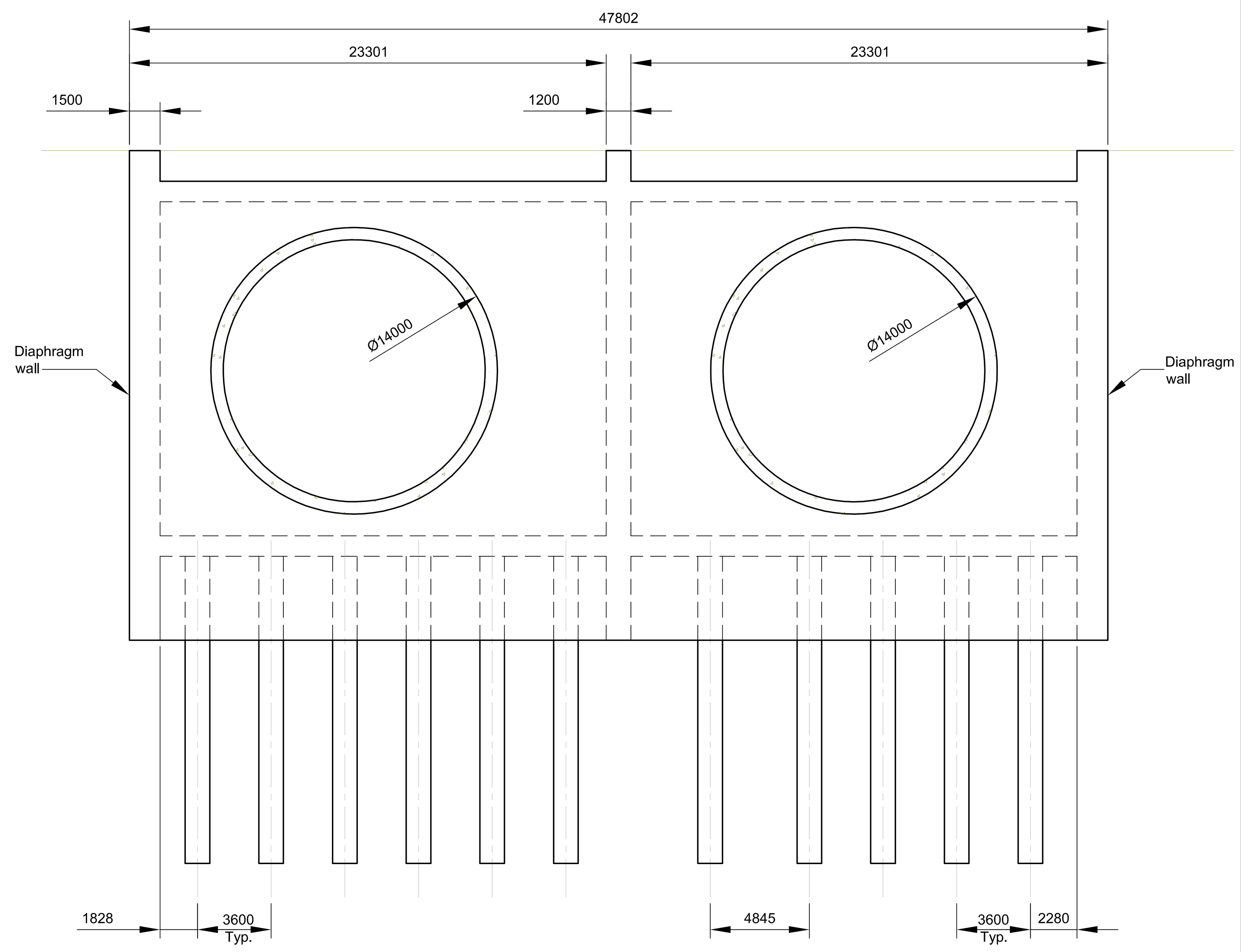
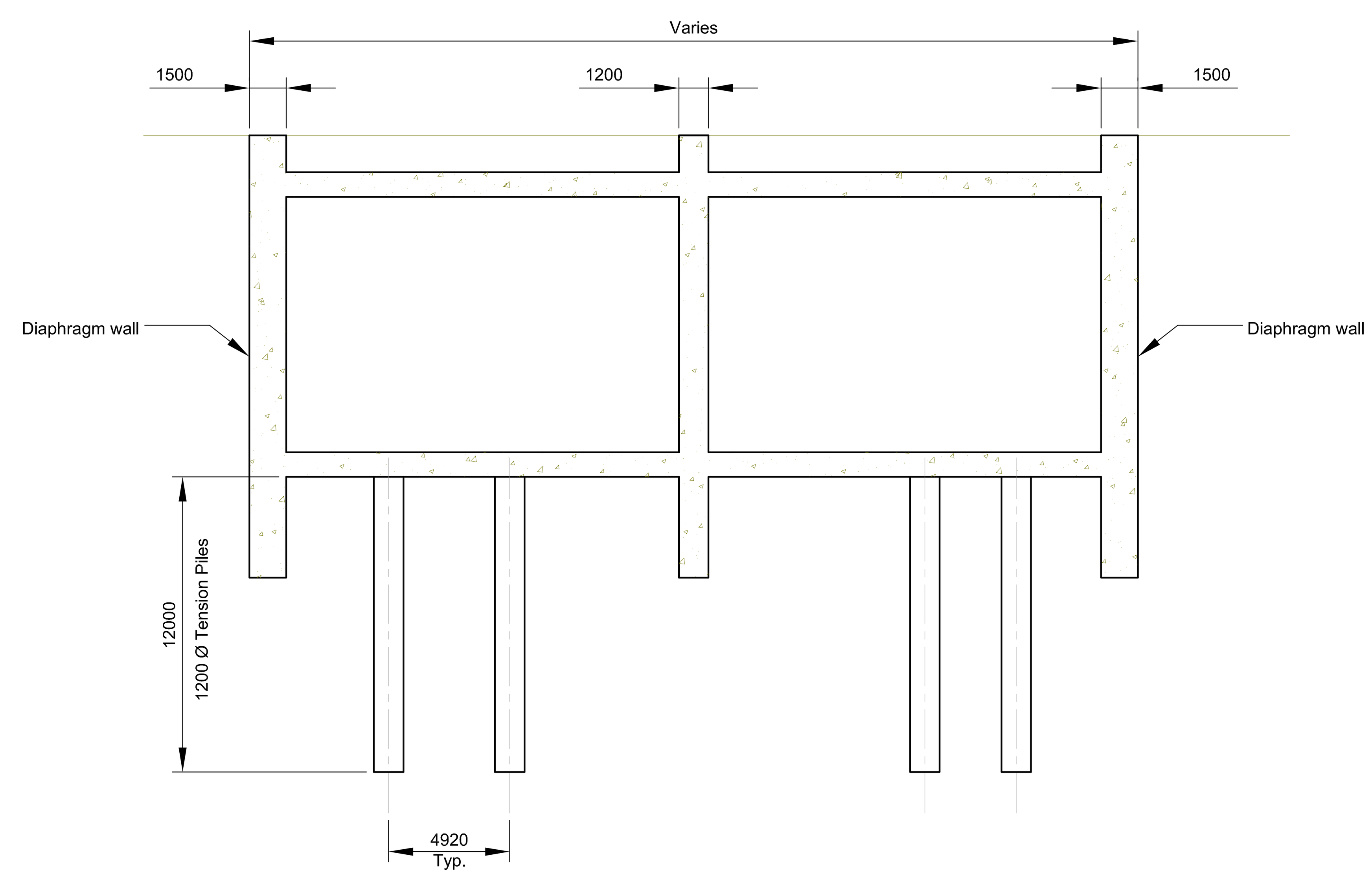


Section A-A
Scale 1:200



Section D-D
Cut and Cover Twin Tunnels
Scale 1:200



Section E-E
Covered box Carriageways
Scale 1:200

1:200 0 10m 20m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 2
Greenwich Approach
Sections

Designed	TAR	Eng check	TAR
Drawn	CAL	Coordination	MAC
Dwg check	TAR	Approved	TAR

Scale at A1	Status	Rev
1:200	PRE	P1

Drawing Number
MMD-281586-TUN-1402

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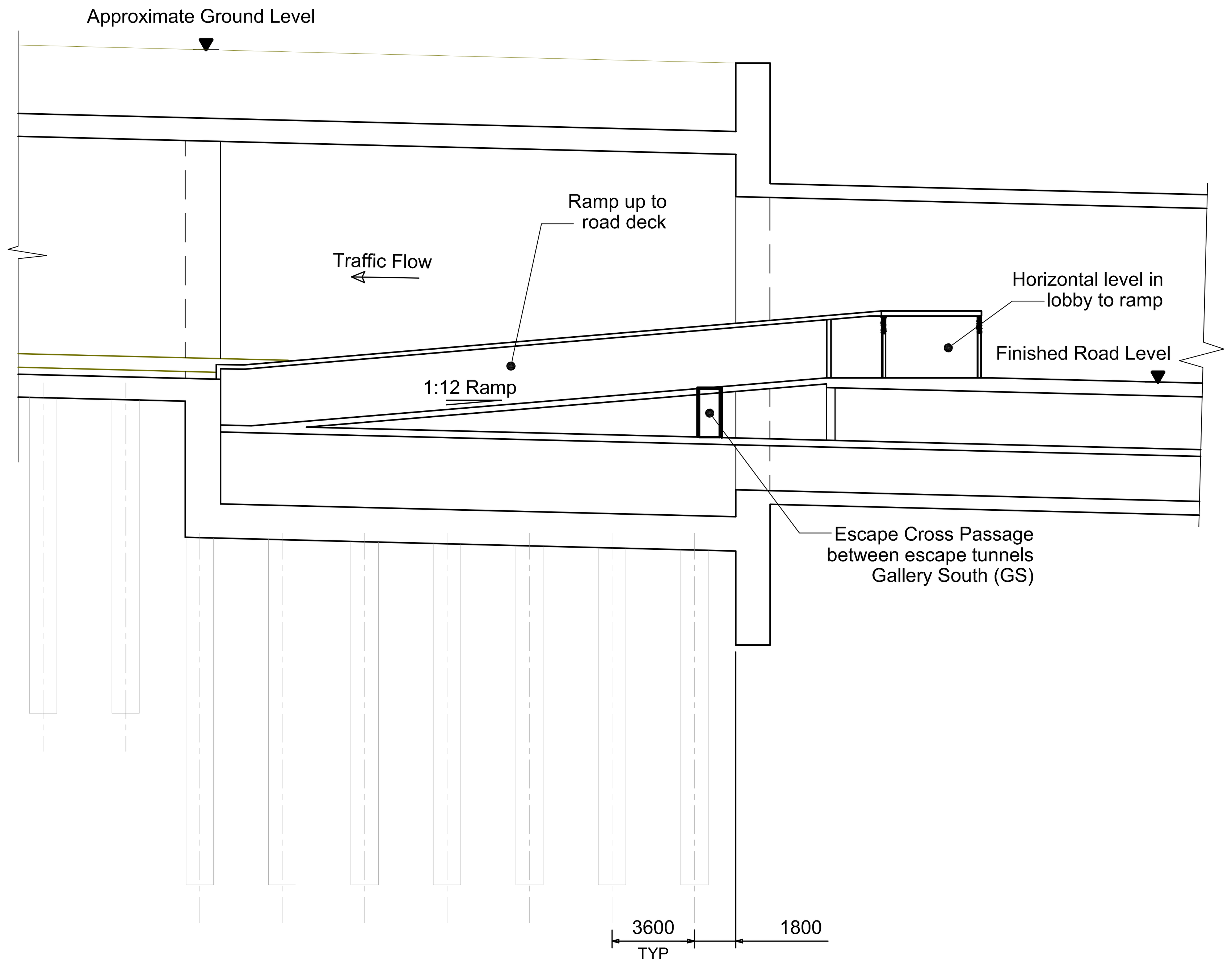
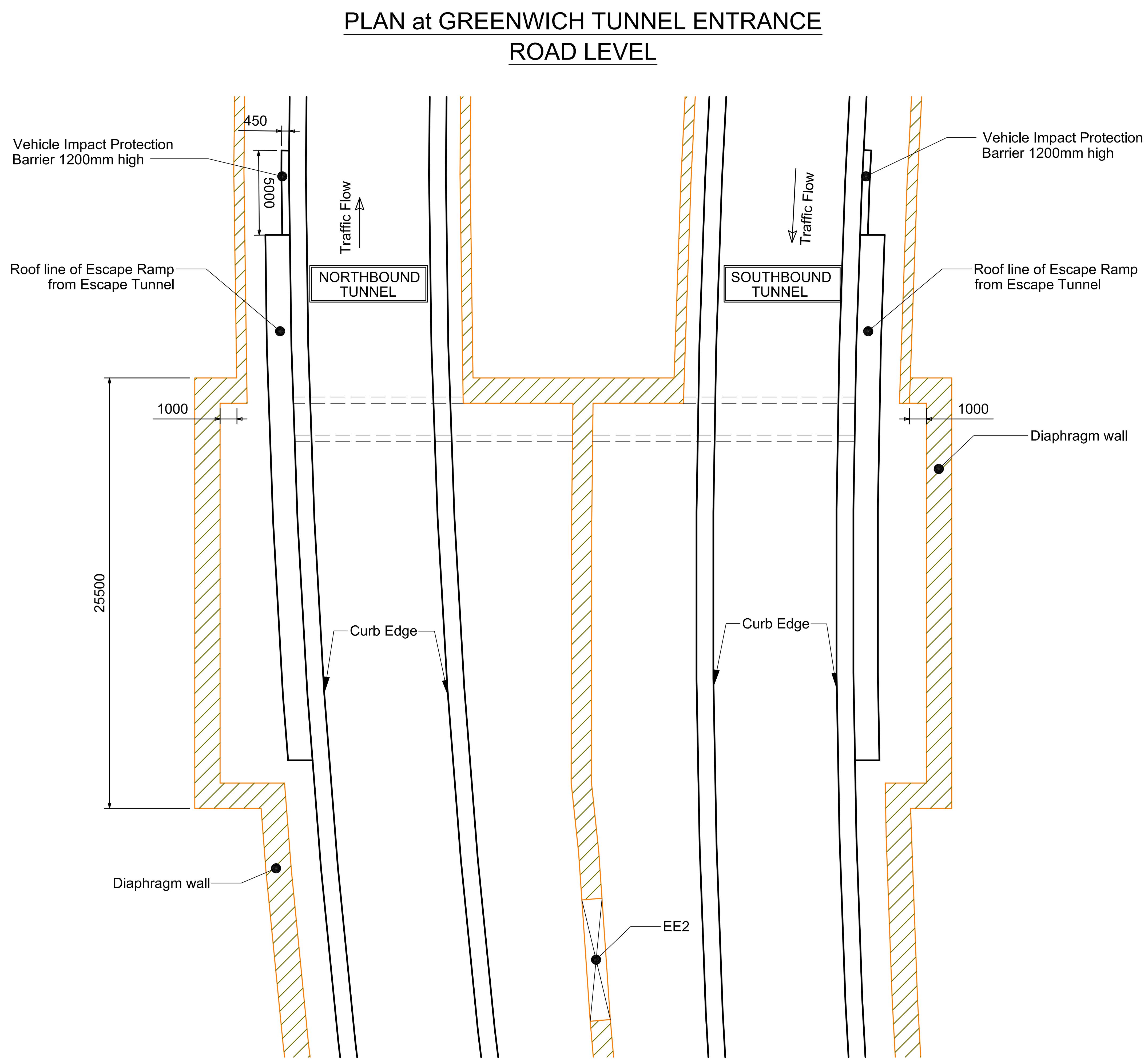
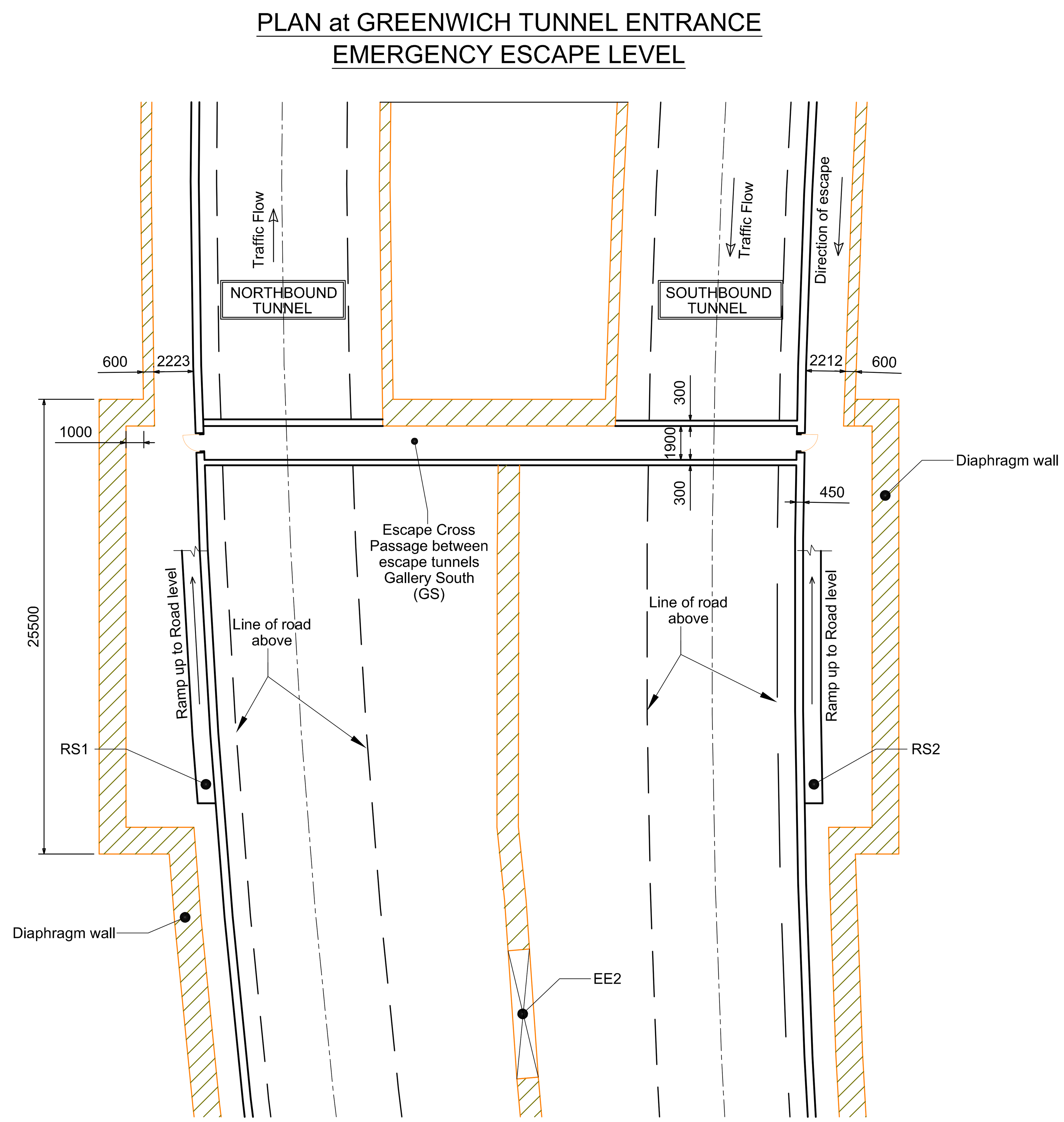


SECTION A-A





Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 2 & 3
Greenwich Approach Escape Access
Invert to Road Deck

Designed	MAC		Eng check	MAC
Drawn	CAL		Coordination	MAC
Dwg check	MAC		Approved	TAR
Scale at A1: 1:200		Status: PRE		Rev: P1

Drawing Number
MMD-281586-TUN-1403

M:\267759 New Thames River Crossing\H Reports and Drawings\H.03 Outgoing Drawings\working drawings\OPTIONS 2 & 3\DWG\Option 2\281586_TUN_1403.dwg — kni56149

Notes

Key to symbols

Reference drawings

CABLE CAR ALIGNMENT FROM **WEA-682-SK-0137**
RECEIVED 08/09/10

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client

Transport for London

Title

New Thames River Crossing
Bored Tunnel Options 3
Scheme Layout Plan

Designed	MAC		Eng check	TAR	
Drawn	CAL		Coordination	MAC	
Dwg check	MAC		Approved	TAR	

Scale at A1	Status	Rev
1:500	PRE	P1

Drawing Number

MMD-281586-TUN-2001

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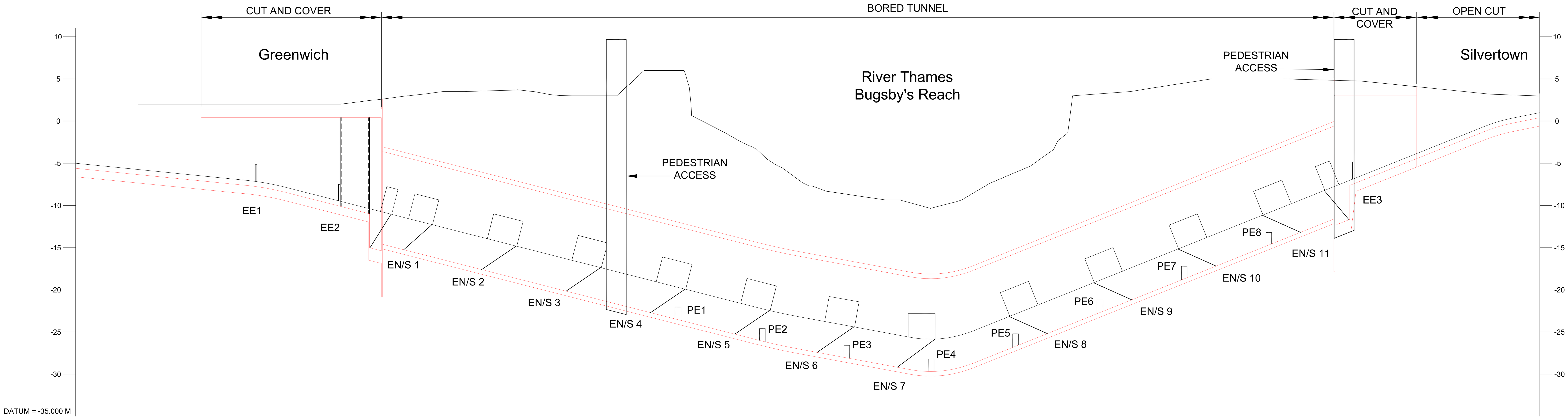

Scheme Layout Long Section

Horizontal Scale 1:2500 Vertical Scale 1:250

Notes

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
NEW THAMES RIVER CROSSING
BORED TUNNEL OPTION 3
SCHEME LAYOUT
LONG SECTION

Designed	TAR		Eng check	TAR	
Drawn	CAL		Coordination	MAC	
Dwg check	TAR		Approved	TAR	

Scale at A1	Status	Rev
As Shown	PRE	P1

Drawing Number
MMD-281586-TUN-2002

1:250 0 12.5m 25m
1:2500 0 125m 250m

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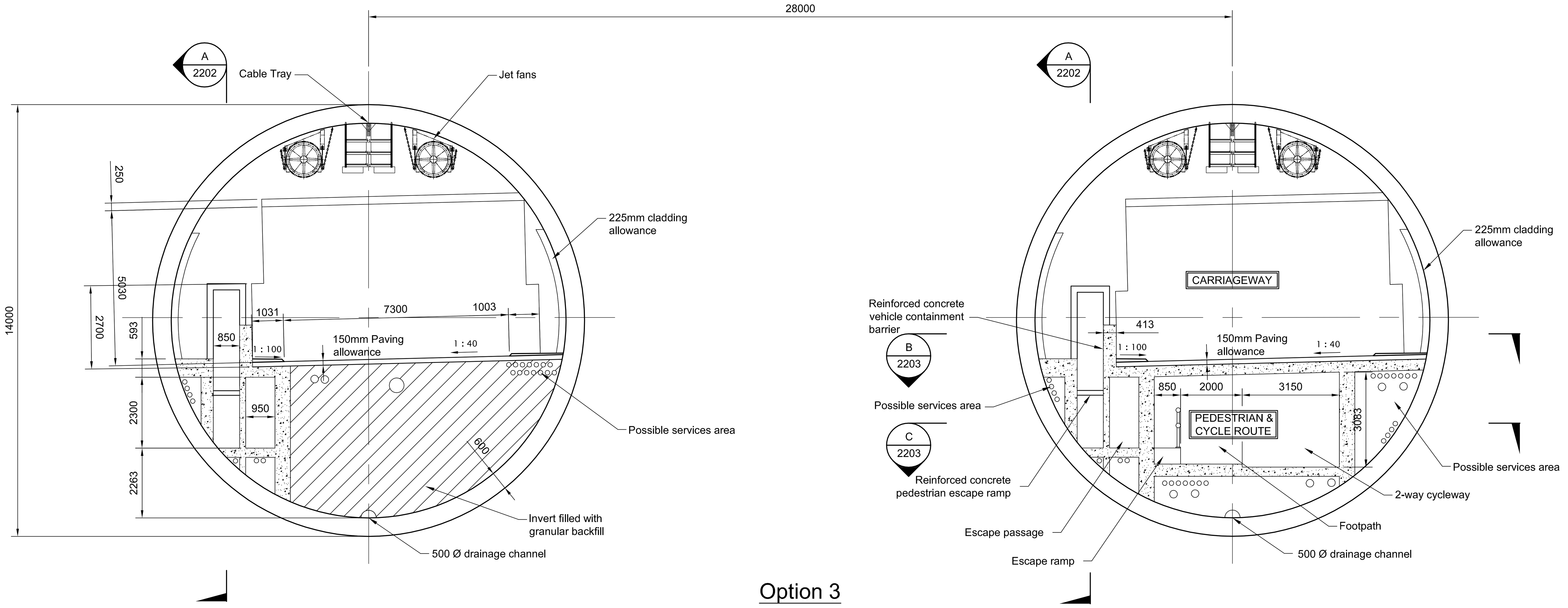
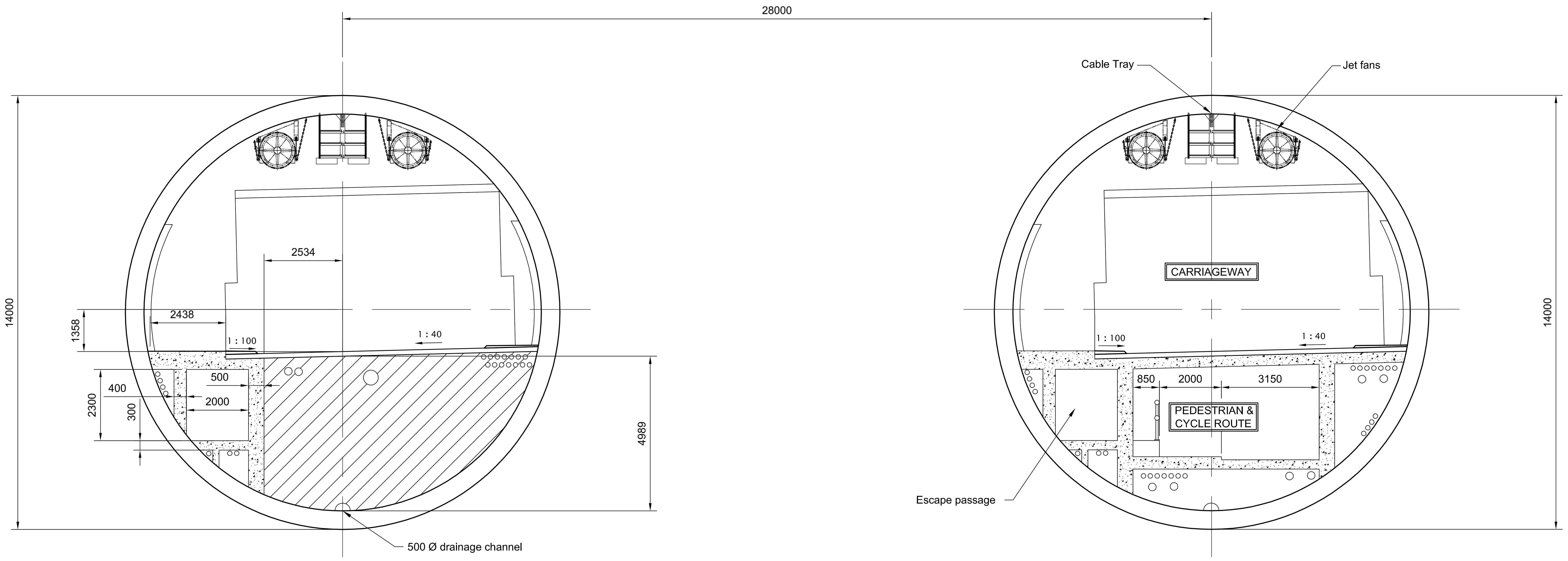


Option 3
Spatial Cross Section At Location of Escape Ramp
Scale 1:100



Option 3
Spatial Cross Section Away from Escape Ramp
Scale 1:100

1:100 0 5m 10m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 3
Bored Tunnel Cross Sections

Designed	MAC		Eng check	TAR
Drawn	MAC		Coordination	MAC
Dwg check	MAC		Approved	TAR
Scale at A1: 1:100		Status: PRE		Rev: P1

Drawing Number
MMD-281586-TUN-2201

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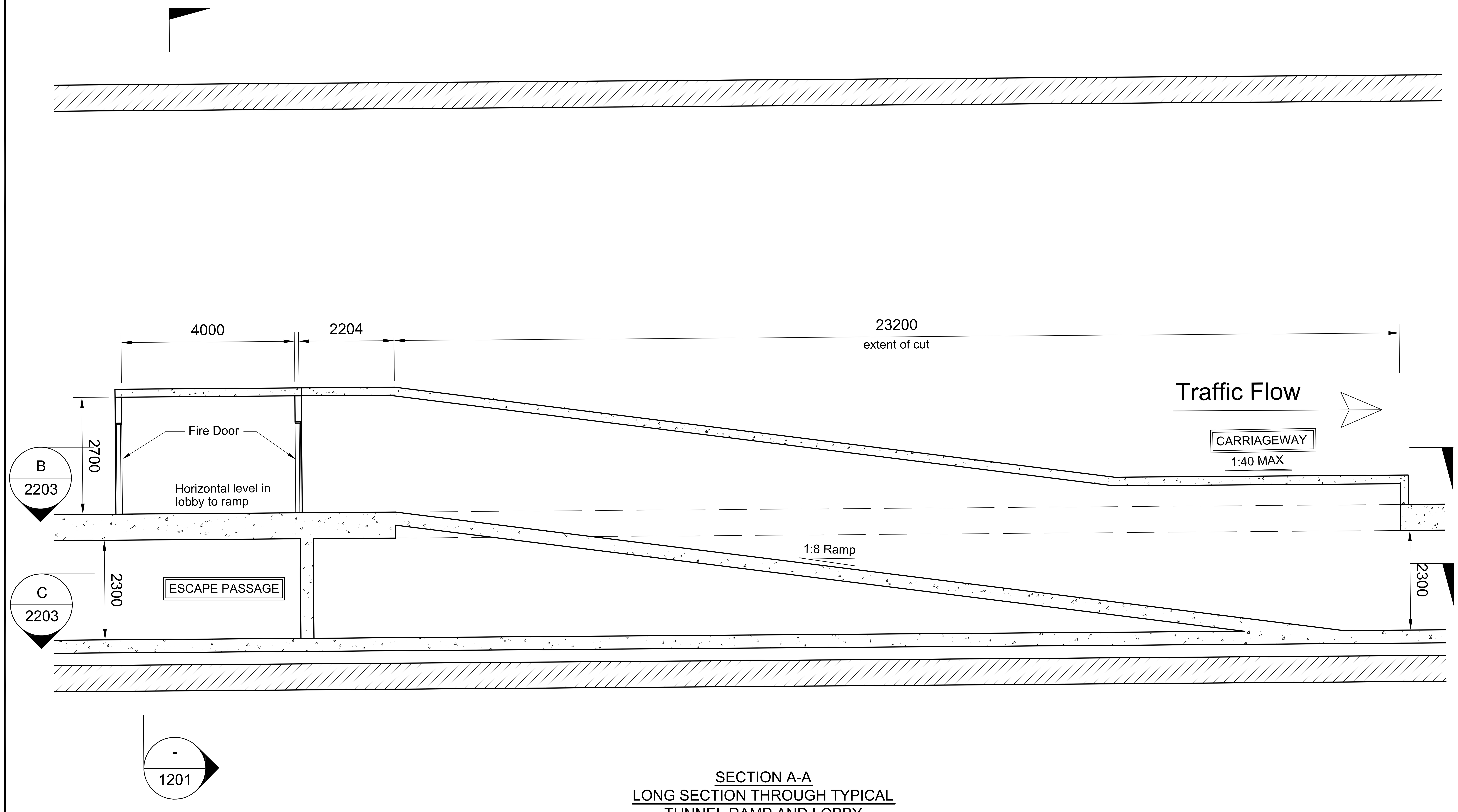

SECTION A-A
LONG SECTION THROUGH TYPICAL
TUNNEL RAMP AND LOBBY

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 3
Invert Escape Ramp
Long Section

Designed	MAC		Eng check	MAC
Drawn	CAL		Coordination	MAC
Dwg check	MAC		Approved	TAR

Scale at A1: 1:50 | Status: PRE | Rev: P1

Drawing Number
MMD-281586-TUN-2202

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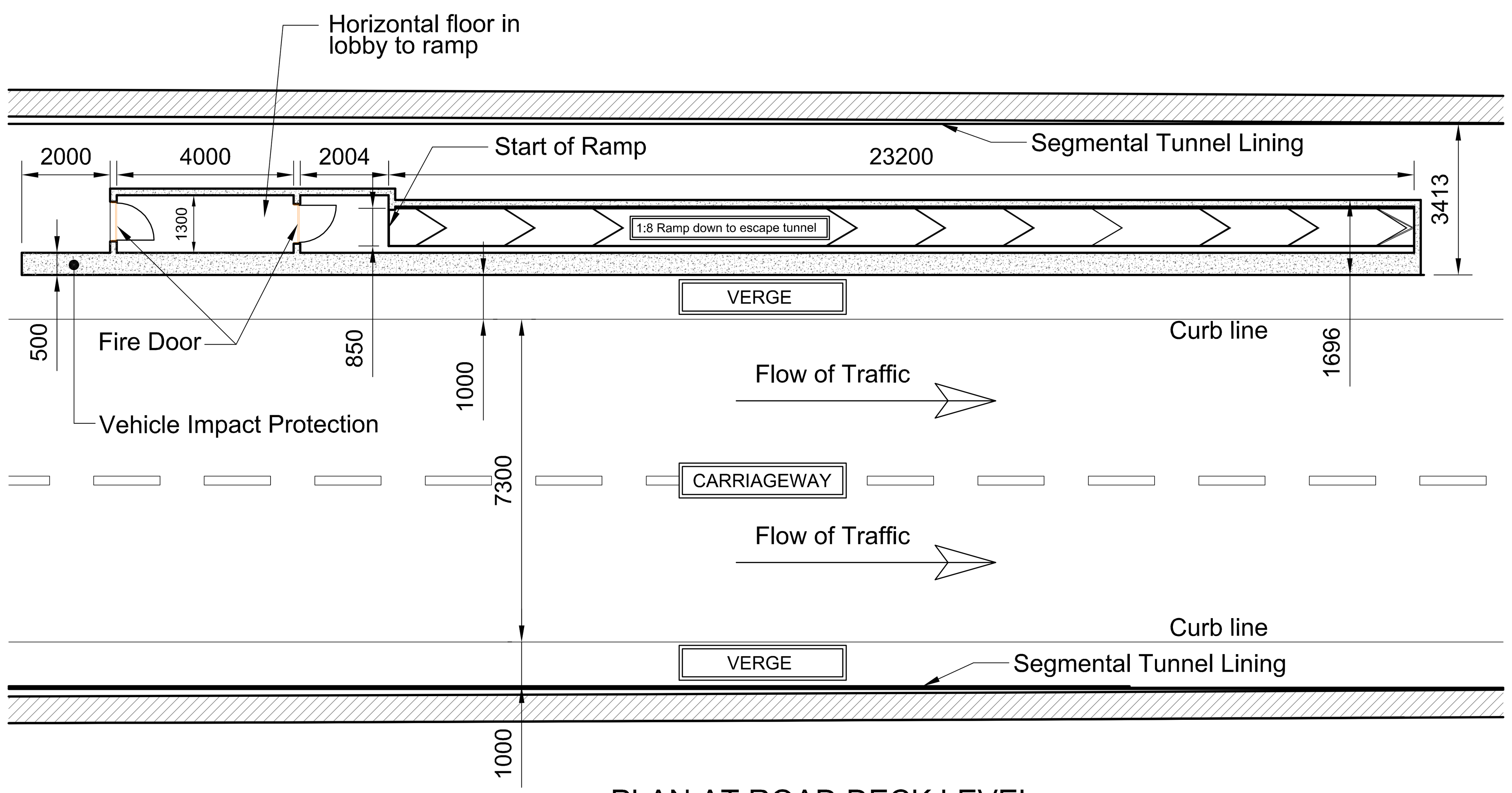
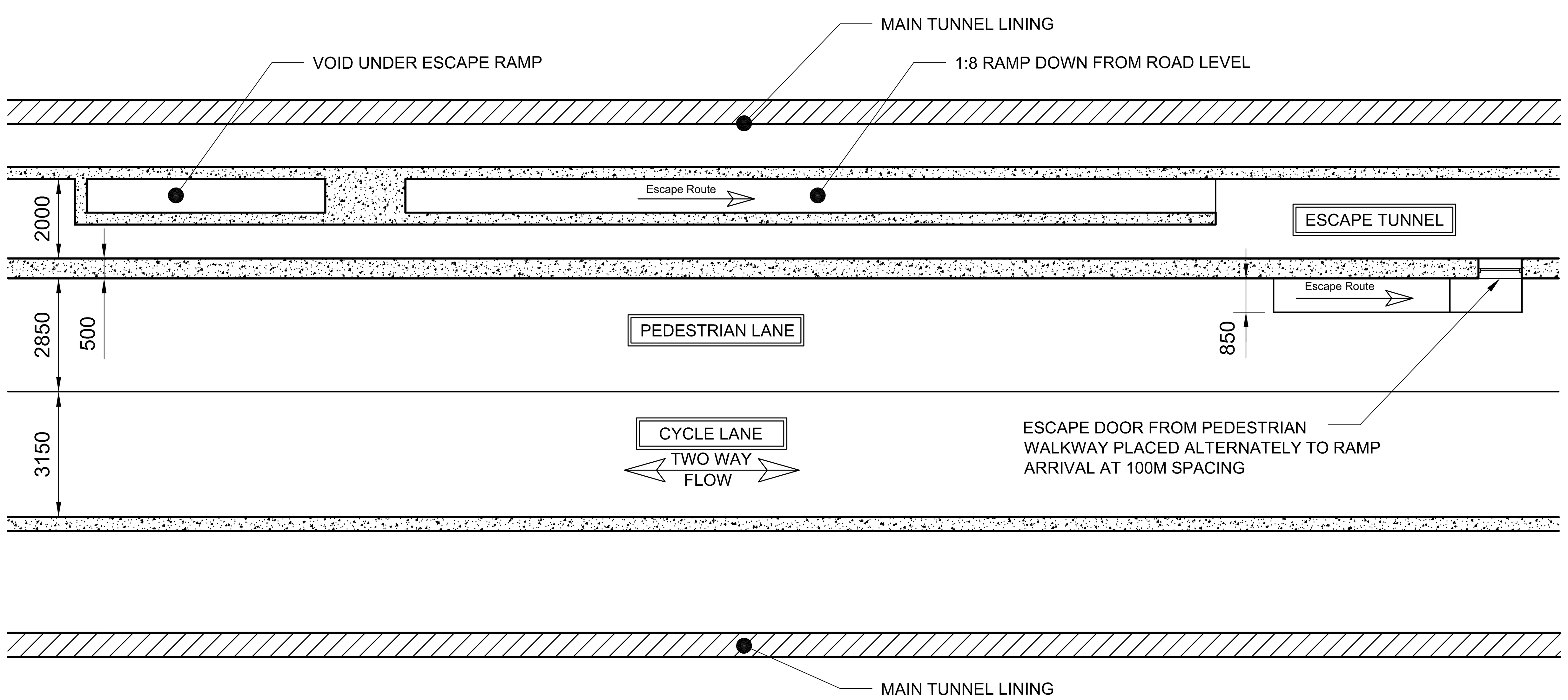


PLAN AT ROAD DECK LEVEL
(B-B)



PLAN AT LOWER DECK LEVEL
(C-C)

1:100 0 5m 10m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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United Kingdom
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W www.mottmac.com

Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 3
Invert Escape Ramp Plan

Designed	MAC		Eng check	MAC
Drawn	CAL		Coordination	MAC
Dwg check	MAC		Approved	TAR
Scale at A1: 1:100		Status: PRE		Rev: P1

Drawing Number
MMD-281586-TUN-2203

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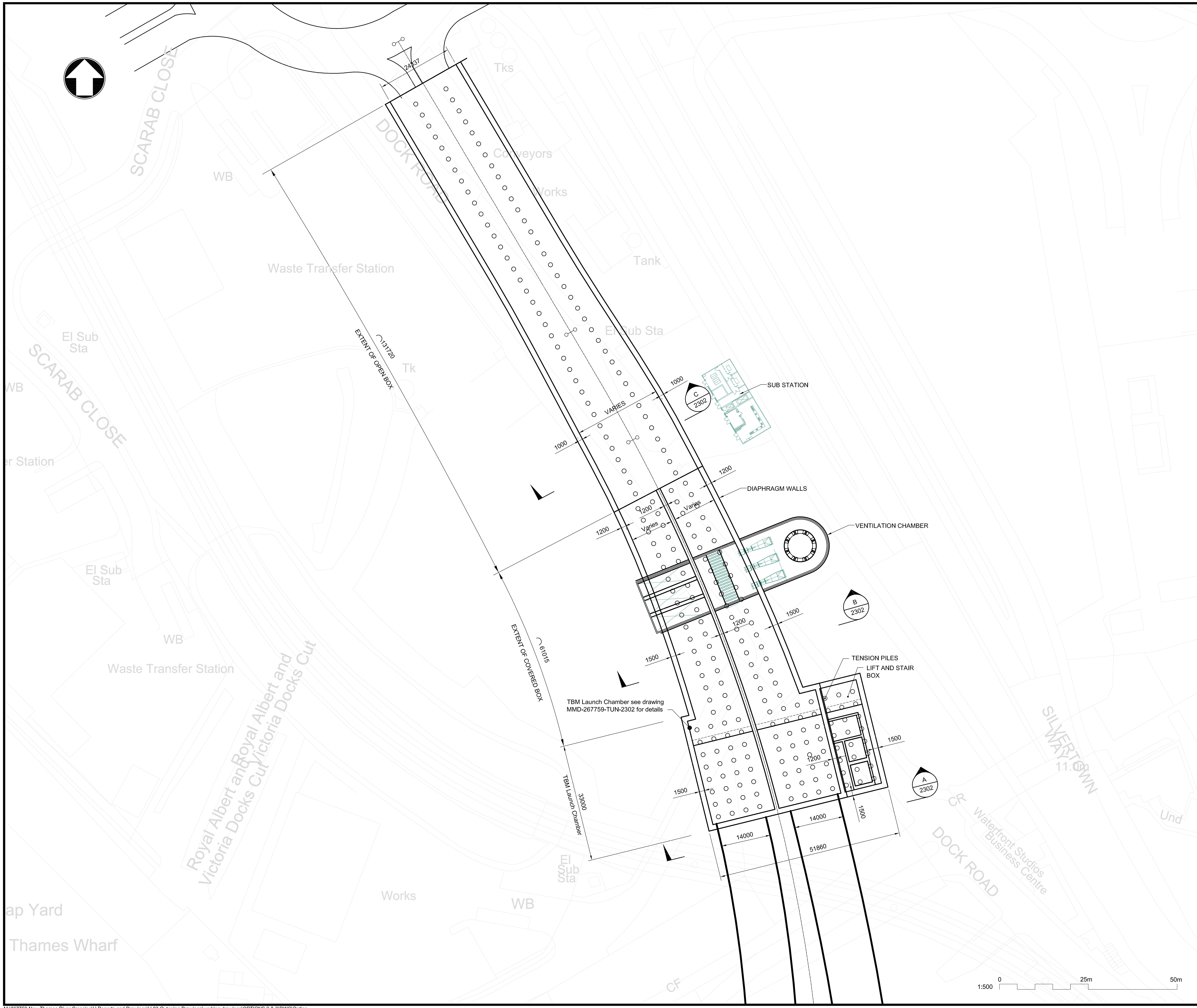

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client

Transport for London

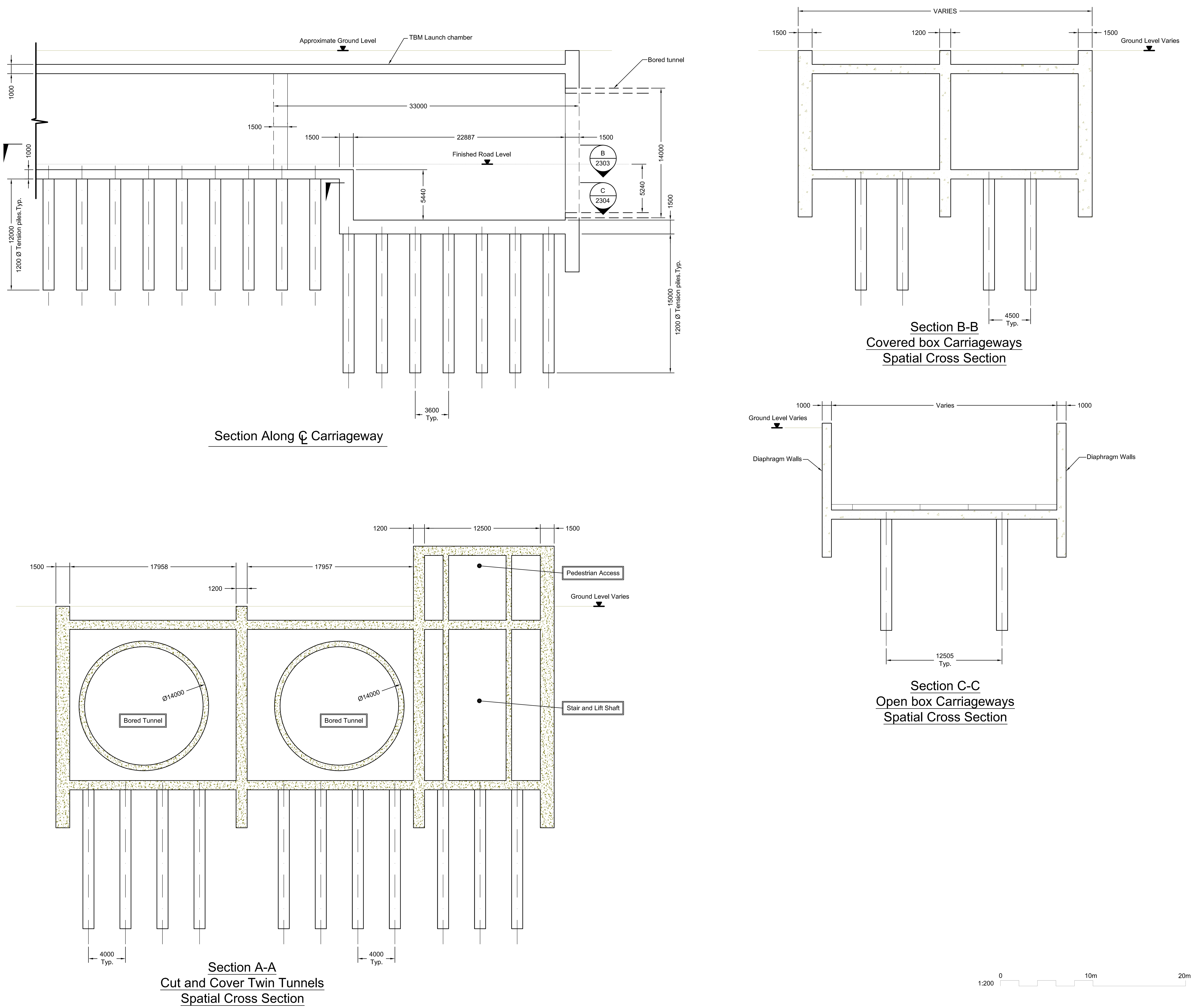
Title

New Thames River Crossing
Bored Tunnel Options 3
Silvertown Approach
Structures Plan Layout

Designed	MAC	Eng check	MAC
Drawn	CAL	Coordination	MAC
Dwg check	MAC	Approved	TAR
Scale at A1: 1:500	Status: PRE	Rev: P1	

Drawing Number

MMD-281586-TUN-2301



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Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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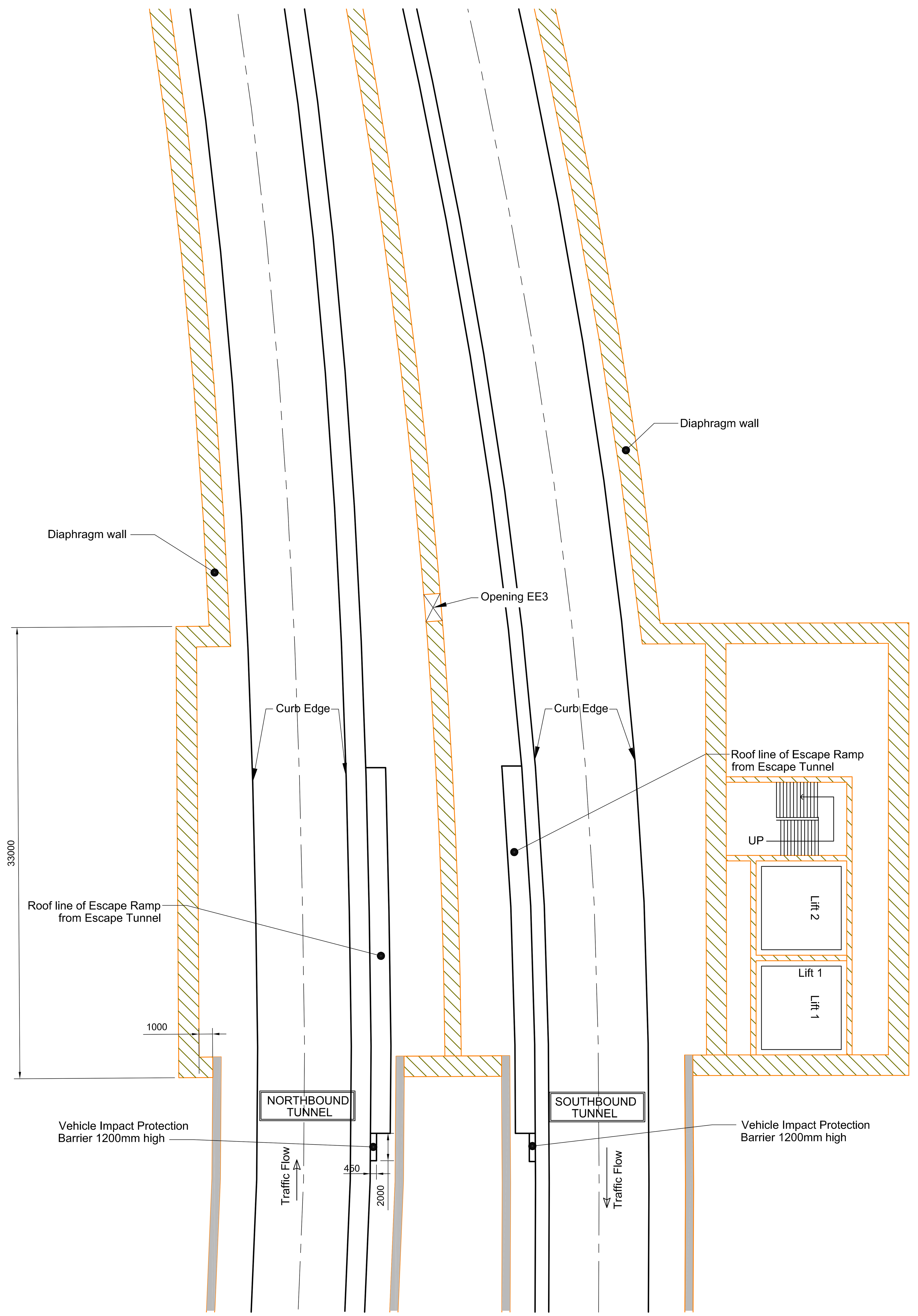
F +44 (0)20 8681 5706
W www.mottmac.com

Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 3
Silvertown Cut and Cover
TBM Launch Chamber

Designed	TAR		Eng check	TAR
Drawn	CAL		Coordination	MAC
Dwg check	TAR		Approved	TAR
Scale at A1 1:200	Status PRE		Rev P1	

Drawing Number
MMD-281586-TUN-2302



PLAN at SILVERTOWN TUNNEL ENTRANCE
ROAD LEVEL

1:200 0 10m 20m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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W www.mottmac.com

Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 3
Silvertown Approach Escape Access
Invert to Road Deck

Designed	MAC		Eng check	MAC
Drawn	CAL		Coordination	MAC
Dwg check	MAC		Approved	TAR

Scale at A1: 1:200 | Status: PRE | Rev: P1

Drawing Number
MMD-281586-TUN-2303

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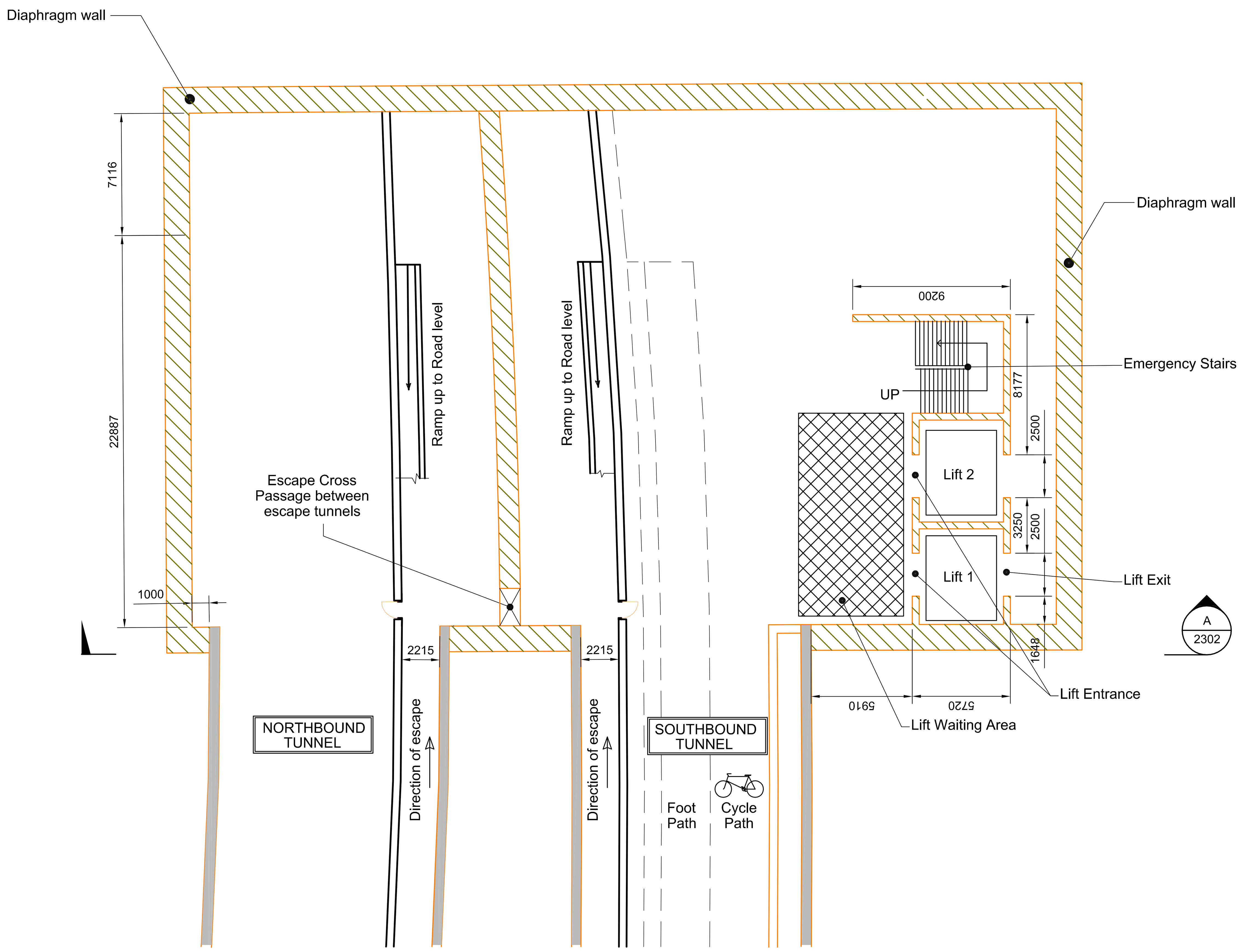

PLAN at SILVERTOWN TUNNEL ENTRANCE
EMERGENCY ESCAPE TUNNEL LEVEL

1:200 0 10m 20m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 3
Silvertown Approach
Pedestrian Access Shaft - Plan

Designed	MAC		Eng check	MAC	
Drawn	CAL		Coordination	MAC	
Dwg check	MAC		Approved	TAR	

Scale at A1: 1:200 | Status: PRE | Rev: P1

Drawing Number
MMD-281586-TUN-2304

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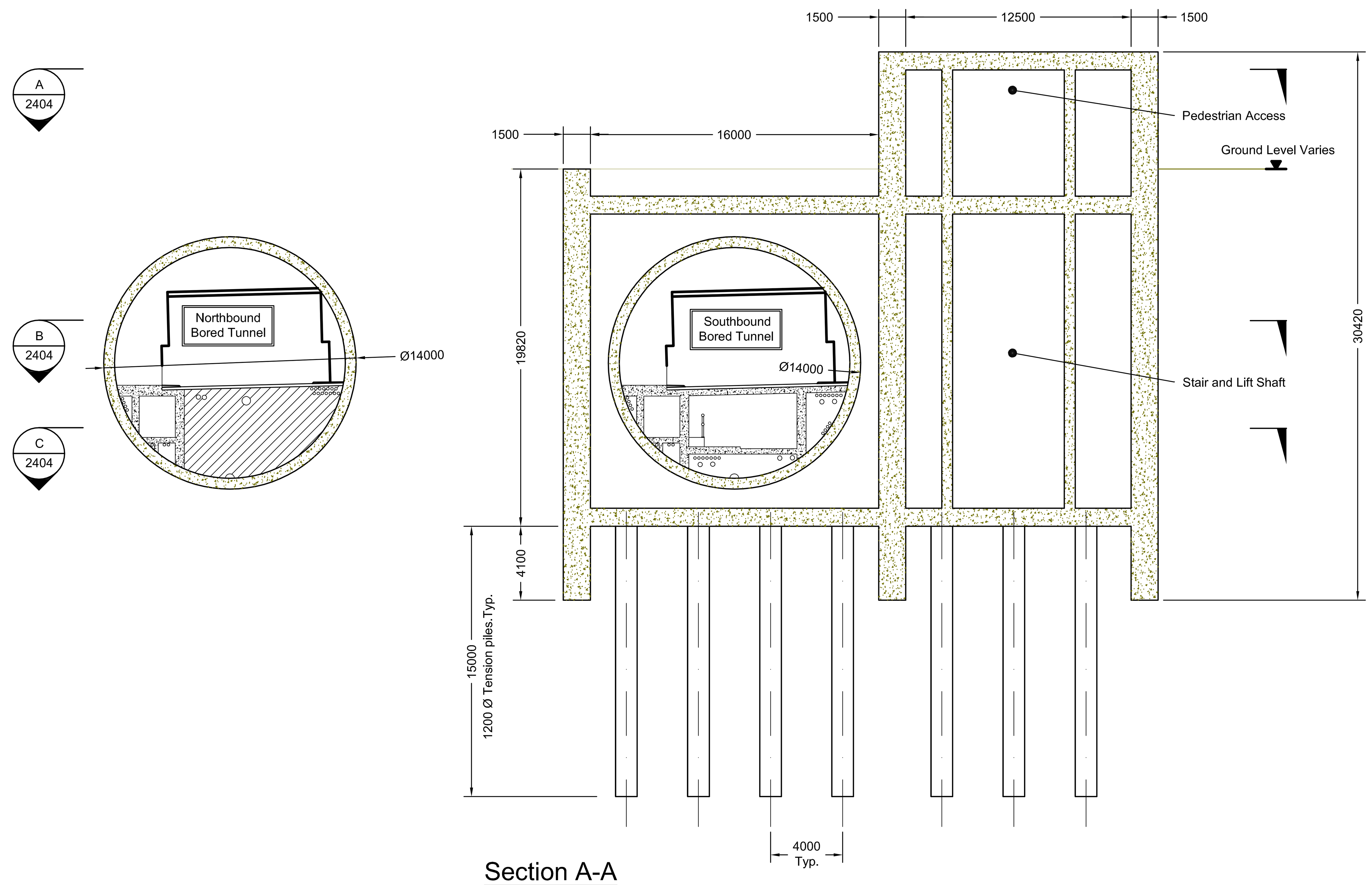
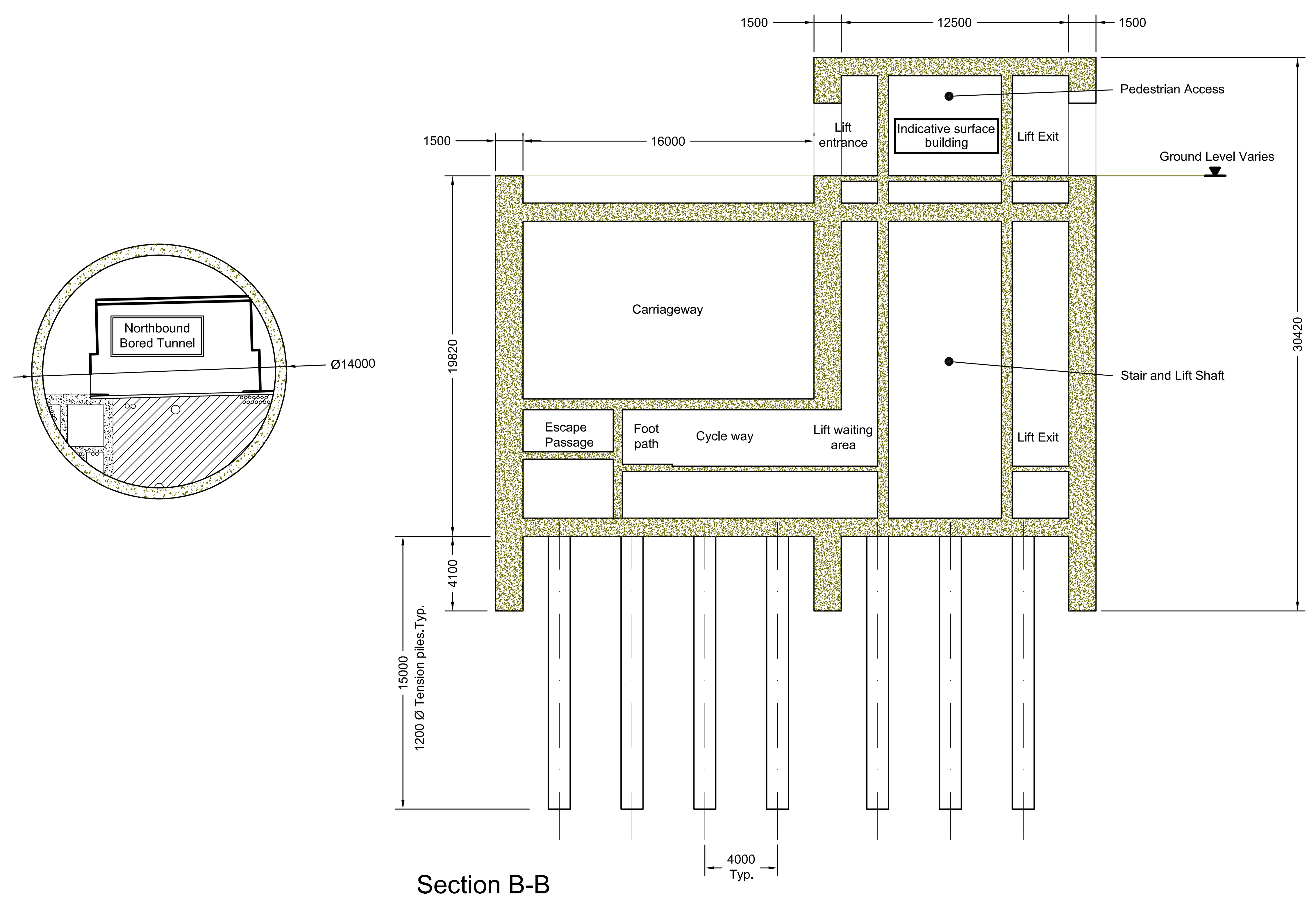


Section A-A
Cut and Cover Twin Tunnels
Spatial Cross Section



Section B-B
Cut and Cover Twin Tunnels
Spatial Cross Section

1:200 0 10m 20m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 3
Greenwich Pedestrian Access Shaft
Sections

Designed	TAR		Eng check	TAR	
Drawn	CAL		Coordination	MAC	
Dwg check	TAR		Approved	TAR	
Scale at A1 1:200		Status PRE		Rev P1	

Drawing Number
MMD-281586-TUN-2305

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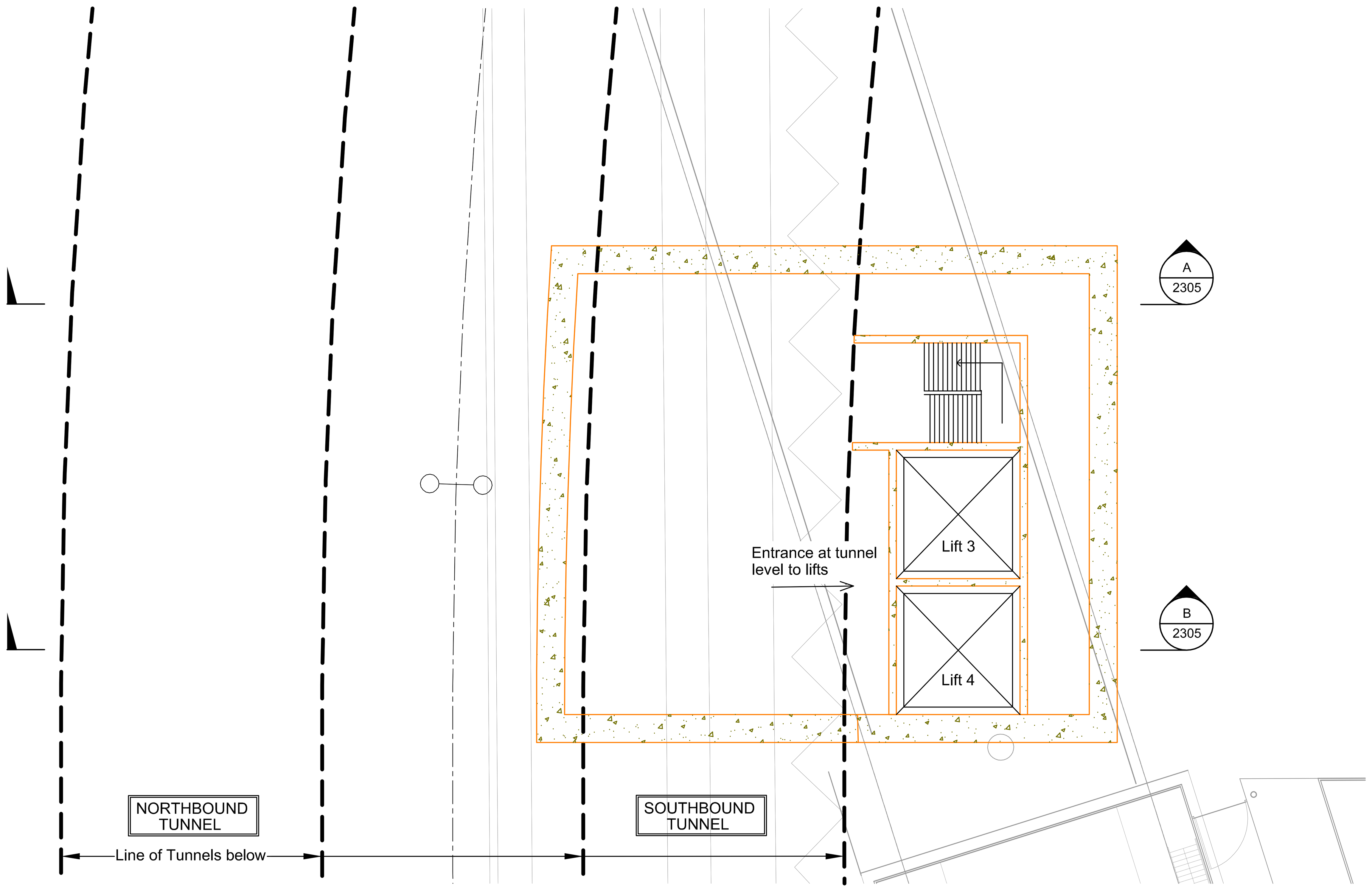
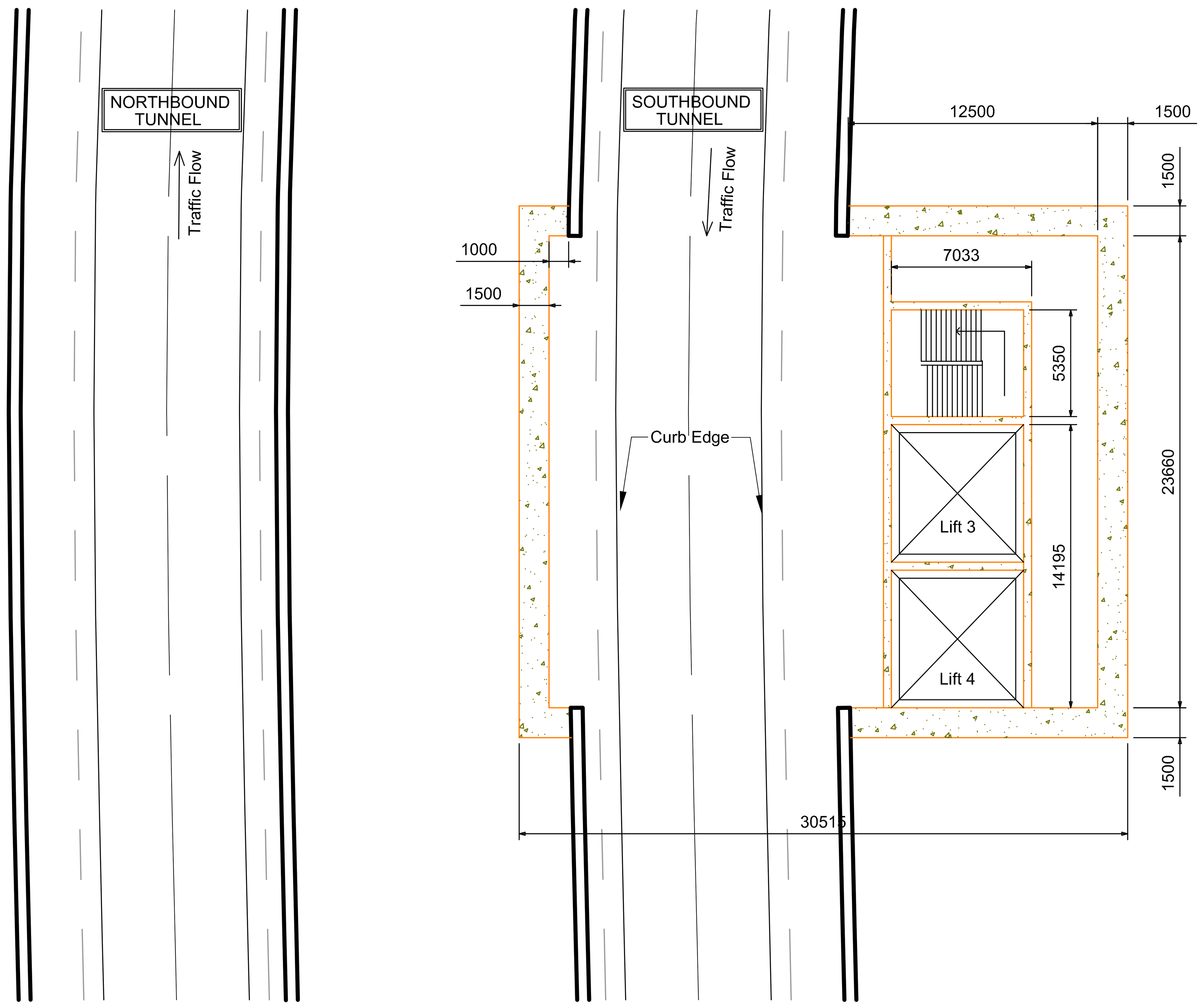
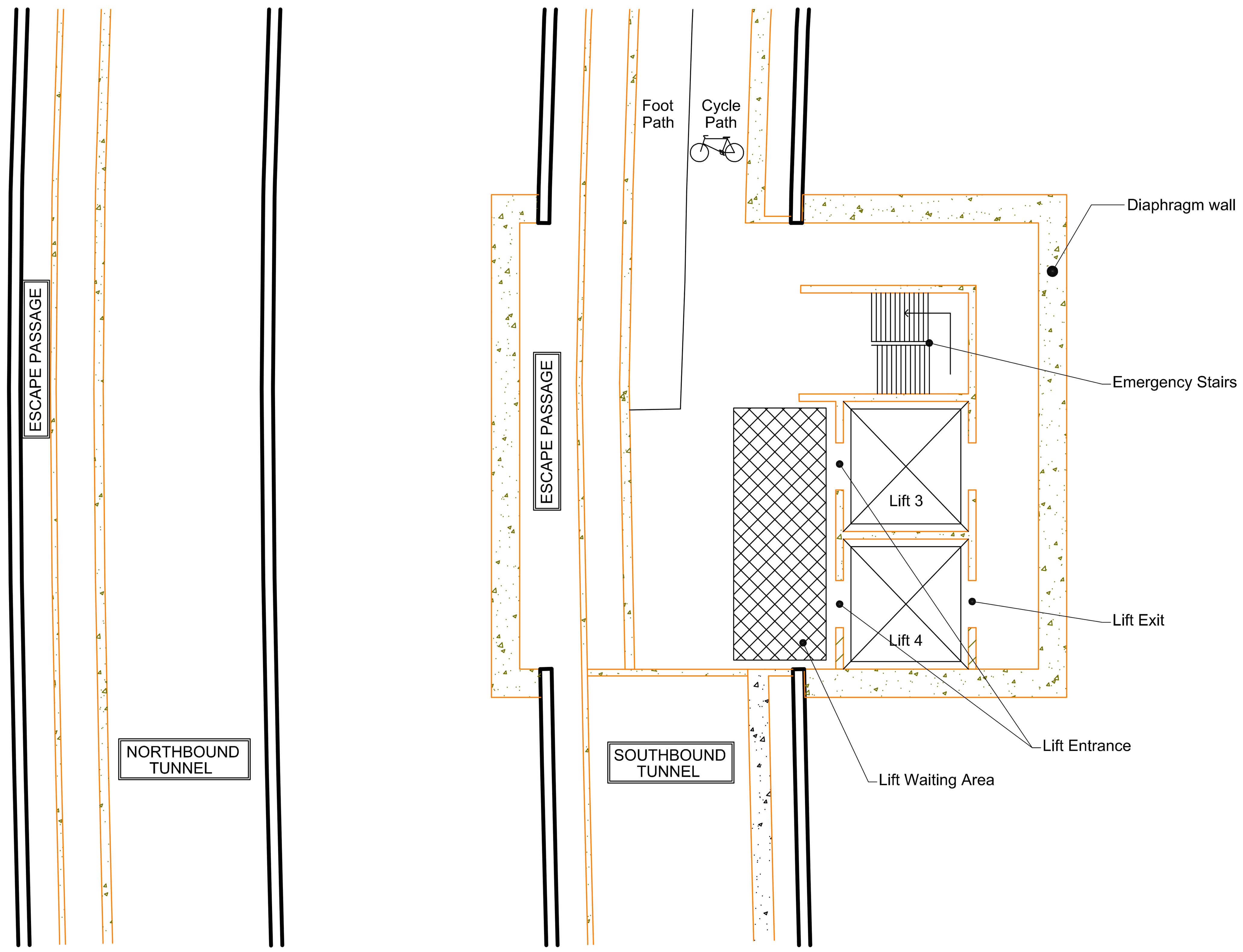


PLAN at GREENWICH TUNNEL ENTRANCE
Section A-A Ground Level



PLAN at GREENWICH TUNNEL ENTRANCE
Section B-B Road Level



PLAN at GREENWICH TUNNEL ENTRANCE
Section C-C Cycle and Pedestrian Level

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 3
Greenwich Approach
Pedestrian Access Plans

Designed	MAC	Eng check	MAC
Drawn	CAL	Coordination	MAC
Dwg check	MAC	Approved	TAR

Scale at A1	Status	Rev
1:200	PRE	P1

Drawing Number
MMD-281586-TUN-2404

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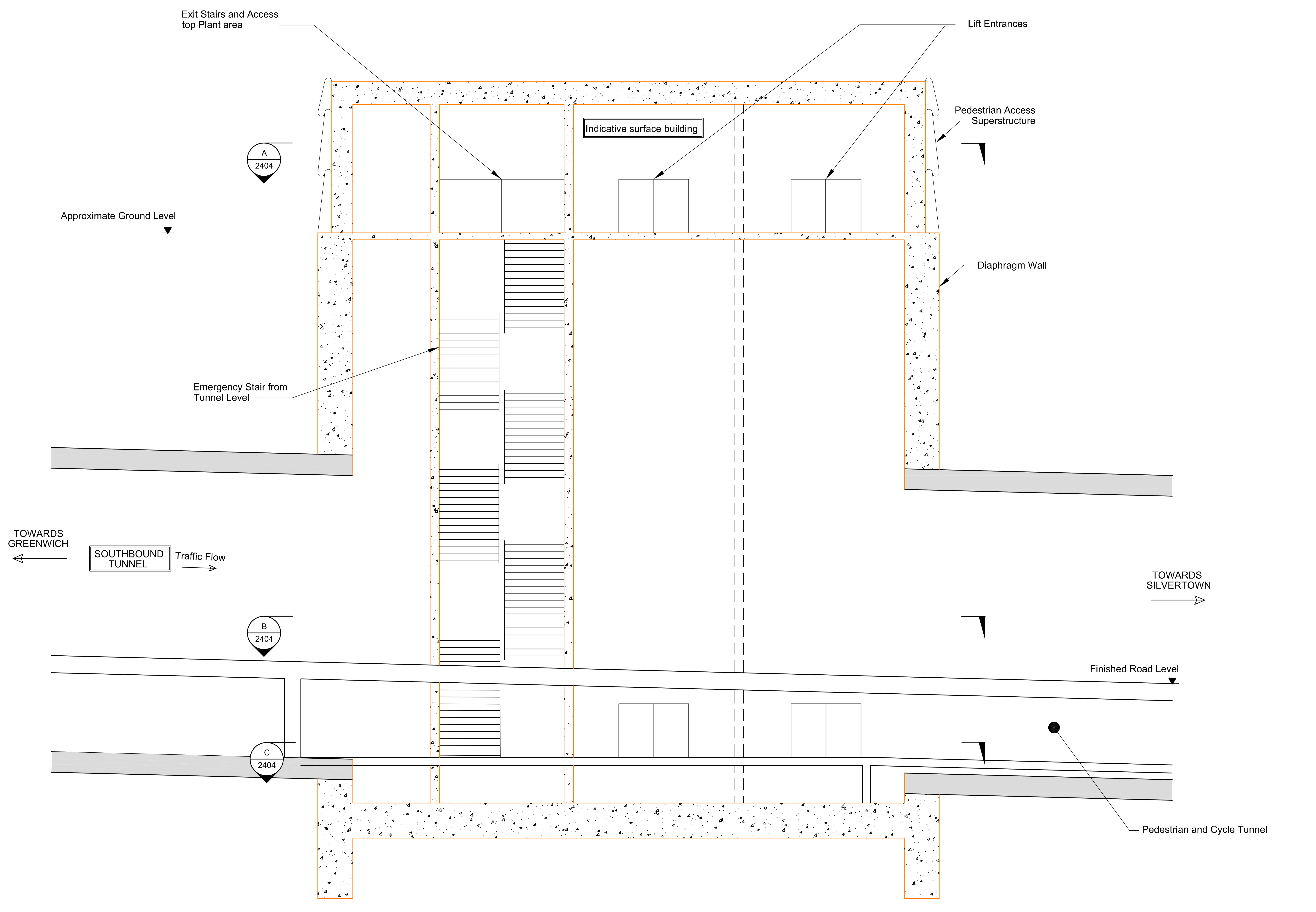

Long section through tunnel showing the lift and Stais Exit

1:100 0 5m 10m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	01/10/10	RK	Draft for Comment	MAC	TAR

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W www.mottmac.com

Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 3
Greenwich Pedestrian Access Plan
& Sections

Designed	TAR		Eng check	MAC	
Drawn	CAL		Coordination	MAC	
Dwg check	TAR		Approved	TAR	
Scale at A1 1:100		Status PRE		Rev P1	

Drawing Number
MMD-281586-TUN-2405

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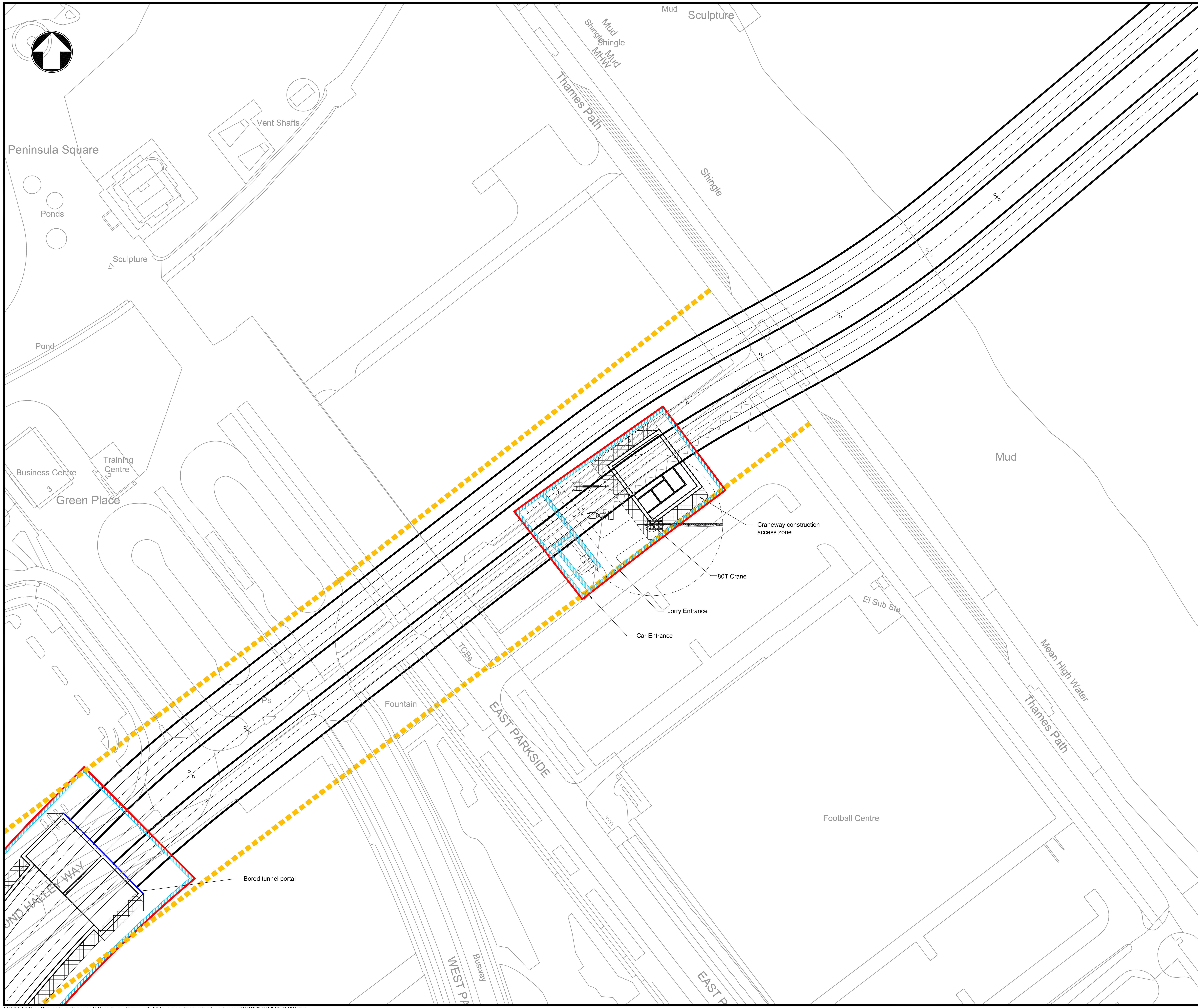

Notes

Key to symbols

- Site Boundaries
- Pedestrian Way (1.5m Wide)
- Cut and Cover Tunnel Portal
- Bored Tunnel Portal

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 3
Pedestrian Access Shaft
Worksite Layout

Designed	TAR		Eng check	TAR
Drawn	SRM		Coordination	MAC
Dwg check	TAR		Approved	TAR

Scale at A1	Status	Rev
N.T.S.	PRE	P1

Drawing Number
MMD-281586-TUN-2601

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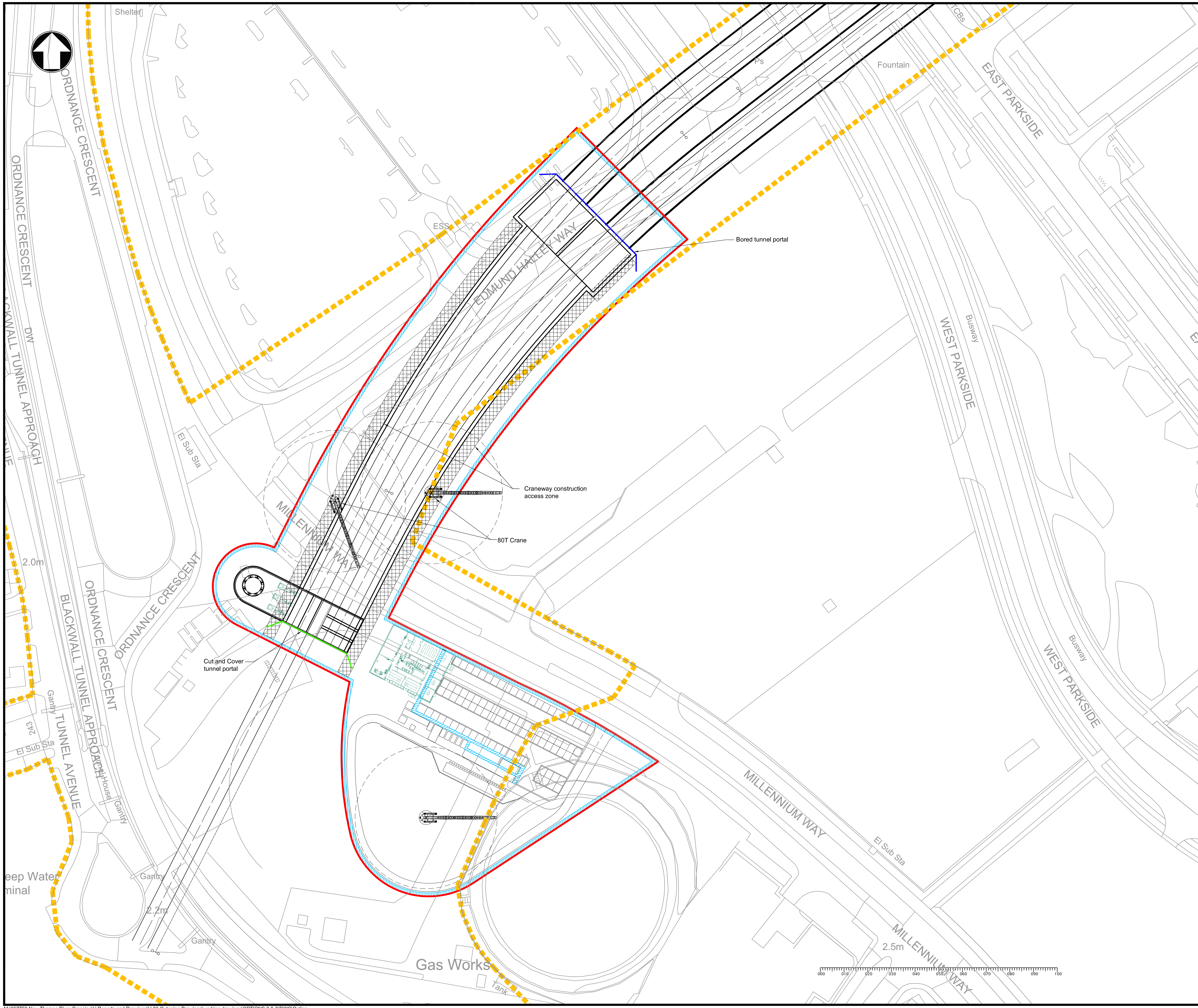

Notes

Key to symbols

- Site Boundaries
- Pedestrian Way (1.5m Wide)
- Cut and Cover Tunnel Portal
- Bored Tunnel Portal

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Options 2 & 3
Greenwich Worksite Layout

Designed	TAR	Eng check	TAR
Drawn	SRM	Coordination	MAC
Dwg check	TAR	Approved	TAR
Scale at A1: N.T.S.	Status: PRE	Rev: P1	

Drawing Number
MMD-281586-TUN-2602

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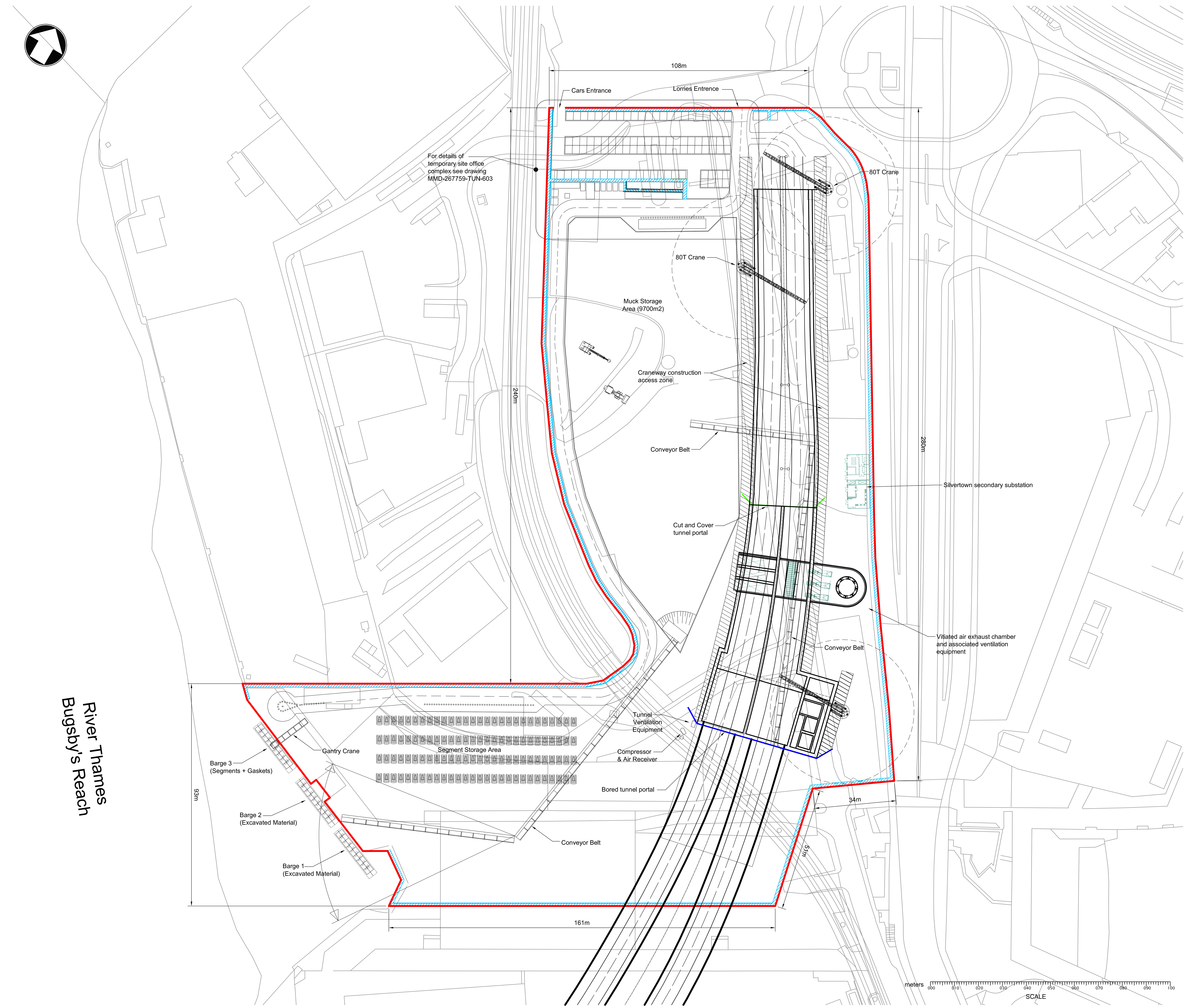

Notes

Key to symbols

- Site Boundaries
- Pedestrian Way (1.5m Wide)
- Cut and Cover Tunnel Portal
- Bored Tunnel Portal

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Options 2 & 3
Silvertown Worksite Layout

Designed	TAR		Eng check	TAR
Drawn	SRM		Coordination	
Dwg check	TAR		Approved	TAR

Scale at A1	Status	Rev
N.T.S.	PRE	P1

Drawing Number
MMD-281586-TUN-2603

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Departures

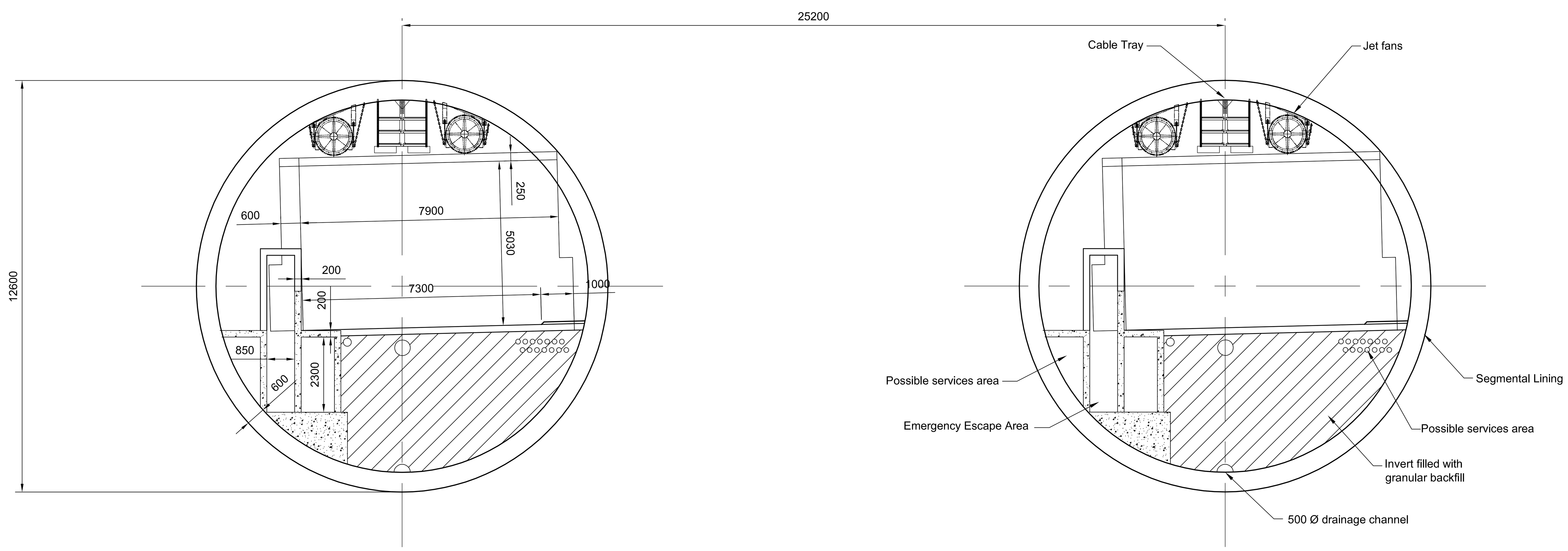
1. No verge on near side adjacent to emergency escape.
2. Far side maintained headroom of 5.03m does not extend into verge
3. Excavate cross section for

   Option 2 = 154m²
   Option 4 = 125m²

   (hence 23% increase)
4. Distance road to crown extrados

   Option 1 = 8.3m
   Option 4 = 7.6m

   (hence 9% increase in tunnel cover)



Spatial Cross Section At Location of Escape Ramp
Option 4
Scale 1:100

1:100 0 5m 10m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	04/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 4
Minimum Diamater Tunnel
Bored Tunnel Spatial Cross Sections

Designed	MAC		Eng check	MAC
Drawn	MAC		Coordination	MAC
Dwg check	MAC		Approved	TAR
Scale at A1 1:100		Status PRE		Rev P1

Drawing Number
MMD-281586-TUN-3201

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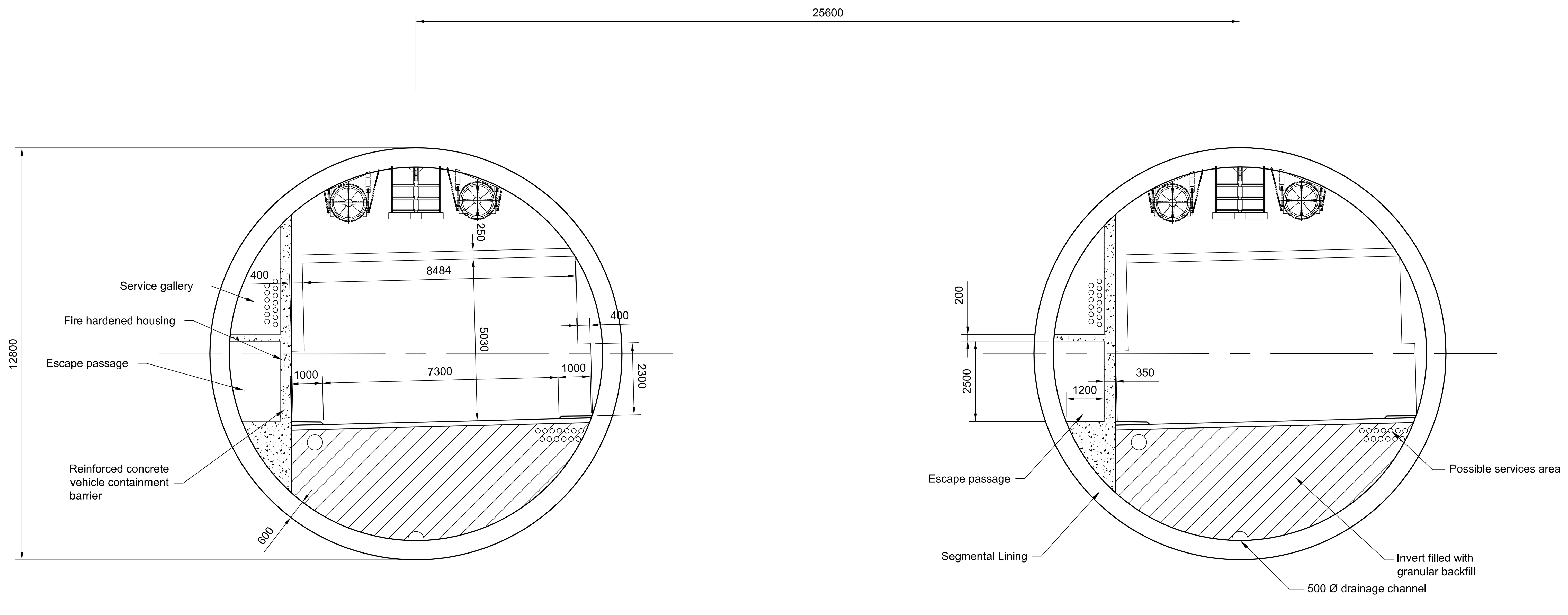

Spatial Cross Section Option 5

Scale 1:100

1:100 0 5m 10m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	04/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 5
Bored Tunnel Cross Sections

Designed	MAC		Eng check	MAC	
Drawn	MAC		Coordination	MAC	
Dwg check	MAC		Approved	TAR	
Scale at A1 1:100		Status PRE		Rev P1	

Drawing Number
MMD-281586-TUN-4201

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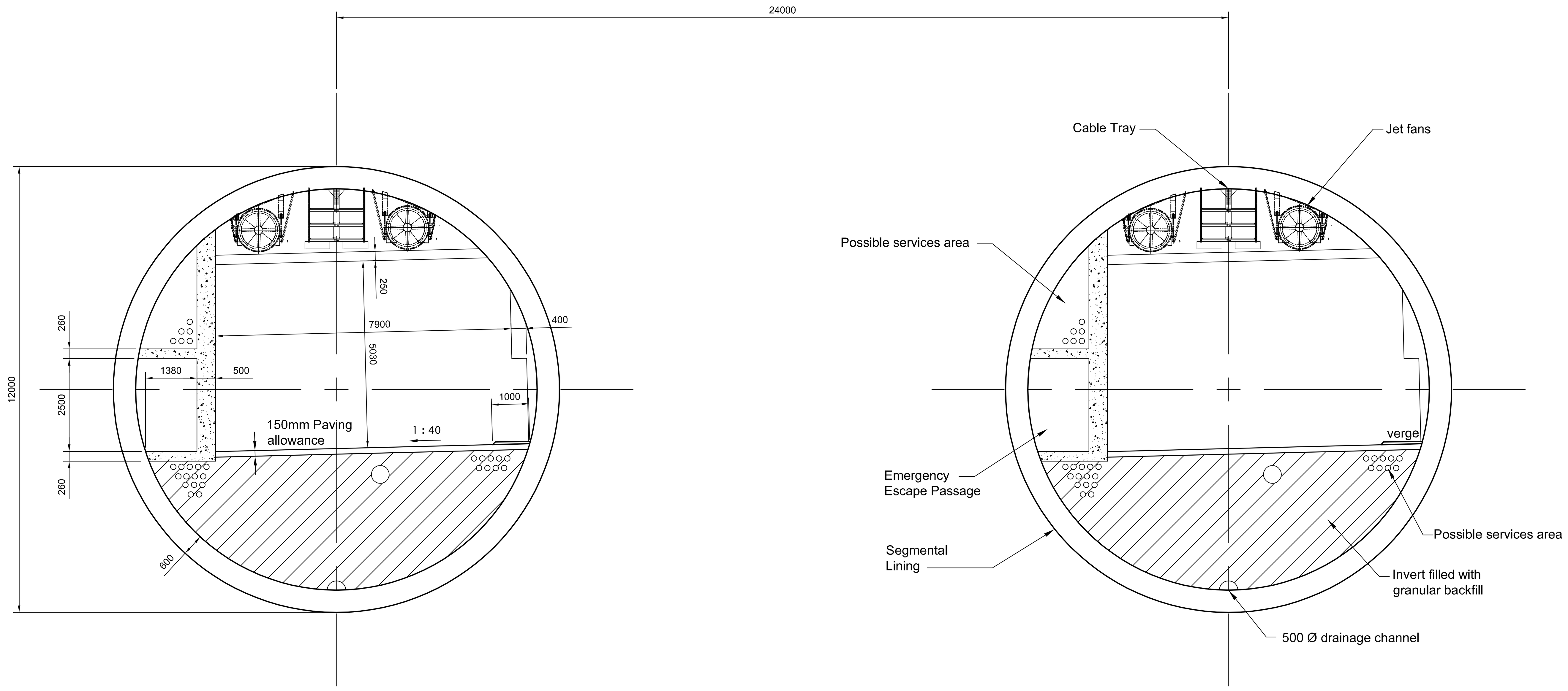

Cross Section Option 6 Restricted Traffic Envelope

Scale 1:100

1:100 0 5m 10m

Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	04/10/10	RK	Draft for Comment	MAC	TAR

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Client
Transport for London

Title
New Thames River Crossing
Bored Tunnel Option 6
Bored Tunnel Cross Section

Designed	MAC		Eng check	MAC	
Drawn	MAC		Coordination	MAC	
Dwg check	MAC		Approved	TAR	
Scale at A1 1:100		Status PRE		Rev P1	

Drawing Number
MMD-281586-TUN-5201

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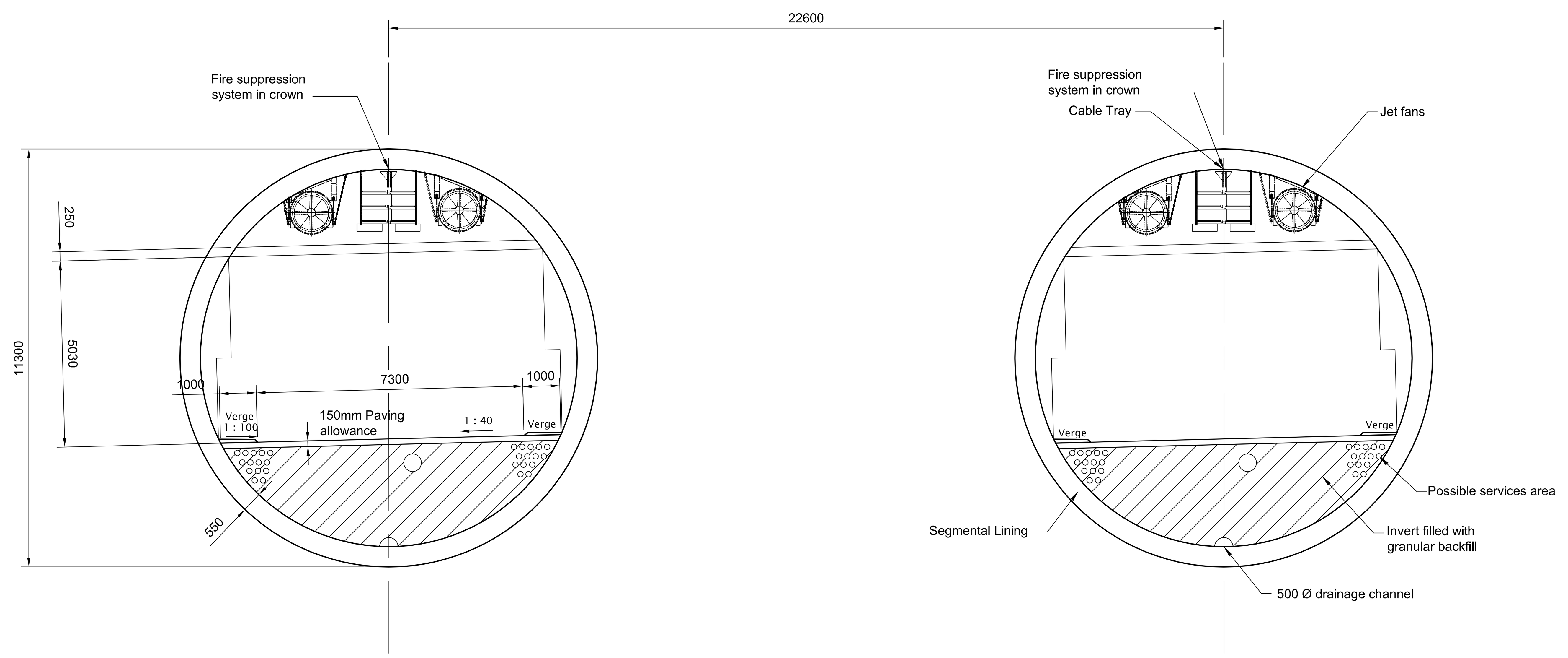
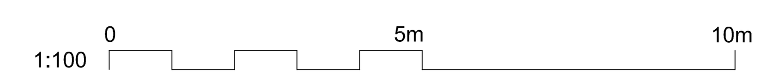


Cross Section Option 7 Fire Supression System

Scale 1:100



Notes

Key to symbols

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	04/10/10	RK	Draft for Comment	MAC	TAR

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Client

Transport for London

Title

New Thames River Crossing
Bored Tunnel Option 7
Bored Tunnel Cross Section

Designed	MAC		Eng check	MAC
Drawn	MAC		Coordination	MAC
Dwg check	MAC		Approved	TAR

Scale at A1: 1:100 | Status: PRE | Rev: P1

Drawing Number: MMD-281586-TUN-6201

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