04
Reference Design Proposals

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4.1 General

4.1.1 This chapter details the main elements of the Scheme that have defined the Scheme requirements presented in order to apply for the DCO.

4.2 Highways

4.2.1 This chapter should be read in conjunction with Preliminary Maps, Plans and Drawings contained in Appendix A.

Design speeds and stopping sight distance

4.2.2 The speed limit in and around the Blackwall Tunnel is 30mph, rising to 50mph south of Blackwall Lane junction. The Silvertown Tunnel would also be designed to a 30mph speed limit, to provide continuity on the highway network and improve driver safety in the urban environment.

4.2.3 An important element of geometric design is the provision of adequate visibility for drivers to be able to negotiate the carriageway ahead. The level of visibility required is expressed as the stopping sight distance (SSD). The SSD requirements are calculated considering factors for driver perception and reaction time, vehicle speed, the rate of deceleration and the gradient which the design allows for. The resulting SSD determined from the geometric alignment would be compliant with the appropriate design standards.

Highway alignment and junctions - general

4.2.4 The carriageway connections to and from the A102 to the south would be free-flow, grade separated links. To the north, the carriageways would both link independently into the modified Tidal Basin Roundabout. In both directions, the Silvertown Tunnel would have a shared bus/coach and HGV lane.

Highway alignment and junctions – northbound carriageway

4.2.5 The A102 Blackwall Tunnel Approach Northbound alignment would widen from three lanes to four, north of the entry-slip from Blackwall Lane junction. The two left-hand lanes would lead to the Blackwall Tunnel. The two right-hand lanes would form the new approach to the Silvertown Tunnel. They would diverge away from A102 Blackwall Tunnel Approach Northbound, pass underneath the realigned A102 Blackwall Tunnel Approach Southbound carriageway before entering the Silvertown Tunnel southern portal.

4.2.6 The alignment of the highway within the tunnel would be compliant with the appropriate design standards and guidance as it navigates from south to north through the constraints noted above in Chapter 2.

4.2.7 The northbound carriageway of the Silvertown Tunnel would then emerge at the northern portal, north of the existing DLR viaduct, where the alignment returns to existing ground level before joining the modified Tidal Basin Roundabout.

Highway alignment and junctions – southbound carriageway

4.2.8 Southbound traffic approaching the Silvertown Tunnel would use the modified Tidal Basin Roundabout, which would be elongated and signalised to enable the new link to tie-in. The roundabout layout would include a 'hamburger' link for traffic approaching from A1020 Lower Lea Crossing to pass directly across the roundabout. This would improve capacity and journey time. Figure 4.1 shows the hamburger arrangement of the modified Tidal Basin Roundabout.

4.2.9 Upon exiting the southern tunnel portal, the alignment would rise to existing ground level alongside the A102 Blackwall Tunnel Approach to provide access to either the A102 (becoming the A2) or the exit-slip to Blackwall Lane Junction towards Greenwich Peninsula, including The O2.

Figure 4.1 – Illustrative birdseye view of the modified Tidal Basin Roundabout

Highway alignment and junctions – side roads

4.2.10 At the northern end of the Scheme, Dock Road would be realigned to follow the embankment of the DLR and tie into the new Tidal Basin Roundabout.

4.2.11 On Greenwich Peninsula, Dreadnought Street would be totally stopped up to accommodate the widened A102 Blackwall Tunnel Approach carriageway whilst Boord Street would be stopped up at the A102 Blackwall Tunnel Approach, with access provided from Millennium Way only. West of the A102 Blackwall Tunnel Approach, Tunnel Avenue is currently severed close to the location of the existing Boord Street footbridge. Under the Scheme, Tunnel Avenue would be reconnected to provide a two-way local access road along its full length from Blackwall Lane to Ordnance Way.

4.2.12 On the Greenwich Peninsula, a proposed bus-only link on Tunnel Avenue would provide access for buses to join the A102 Blackwall Tunnel Approach northbound into the Blackwall Tunnel. For buses heading southbound along the A102 Blackwall Tunnel Approach from the Blackwall Tunnel, a dedicated bus-only exit-slip is proposed to allow buses to access North Greenwich bus station via Millennium Way. This would replace the existing facility that utilises Dreadnought Street and Boord Street that would be stopped-up. A further link would also provide access for buses and emergency service vehicles from Millennium Way into Silvertown Tunnel, via an access road near the southern portal.

4.2.13 The geometric alignments of all links and junctions will be designed in accordance with the appropriate design standards.

Highway cross section

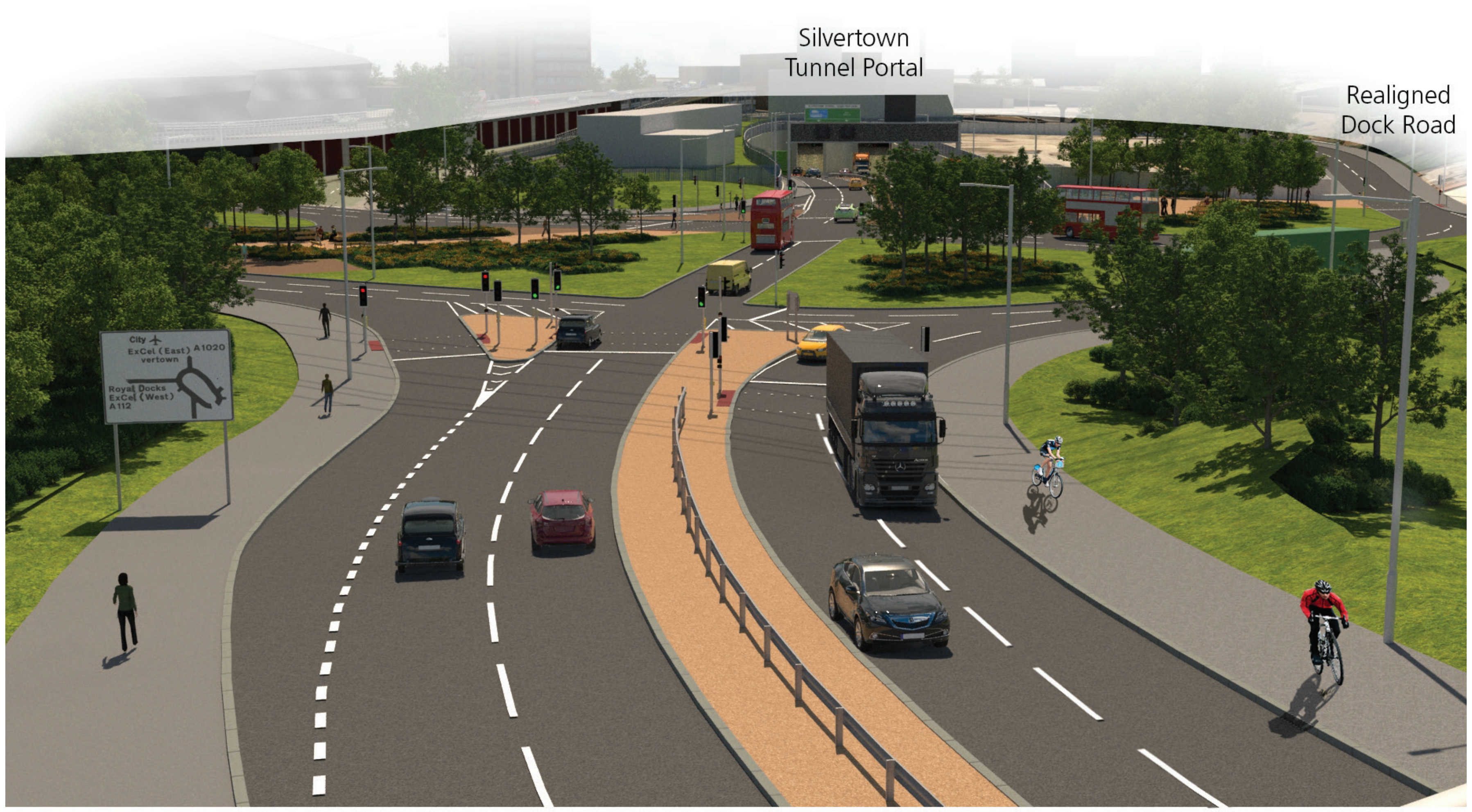
4.2.14 The highway cross section on the Greenwich Peninsula as shown in Figure 4.2 below is generally more dominated by vehicular traffic than at Silvertown due to the existing highway corridor and tunnel access restrictions inherent in the A102 Blackwall Tunnel Approach. At Silvertown there is greater opportunity to enhance the pedestrian and cyclist movements around the northern junction. The Scheme proposals would address this as shown in Figure 4.3.

4.2.15 Carriageway lane widths will be in accordance with the appropriate design standards. Non-motorised users (i.e. cyclists and pedestrians) would be prohibited from the tunnel.

4.2.16 Where possible a highway soft verge could be provided. Headroom to the tunnel, bridges and gantries would be in accordance with the appropriate design standards.

Figure 4.2 – Illustrative view of the southern tie-in from the A102 Blackwall Tunnel Approach near Blackwall Lane Junction looking north towards Blackwall and Silvertown Tunnels

Figure 4.3 – Illustrative view of the modified Tidal Basin Roundabout from the A1020 Lower Lea Crossing looking south towards the Silvertown Tunnel Portal



4.2.17 All earthworks have been designed with a cutting and embankment gradient of 1 vertical to 3 horizontal (1:3). Where conventional earthworks are not possible due to space constraints, alternative retaining solutions would be required to minimise Scheme encroachment and facilitate retention of existing assets in the area.

Drainage

4.2.18 A highway and tunnel drainage strategy has been developed adopting Sustainable Drainage System (SuDS) principles using the appropriate design standards, which requires that the following criteria are met:

- no increase in the current discharge rate from the proposed Scheme to the existing drainage system owned by Thames Water;
- where proposed drainage connects into an existing watercourse, the discharge rates should be limited to greenfield run-off rates and subject to agreement with the owner of the watercourse;
- a 20% capacity allowance is applied for climate change;
- additional paved areas deemed to be new development should not cause flooding in critical 1 in 5 year event, attenuation to be provided for the critical duration 1 in 100 year storm event;
- routine spillage collection and emergency major spillage containment should be provided.

4.2.19 The Reference Design considers two drainage systems: a highway drainage system which would collect and manage water from the road; and a tunnel drainage system which would manage water collected within the tunnel. The basis of the Reference Design is for the highway drainage to use a combined drainage and kerb unit or linear drainage unit system throughout the Scheme. This is largely because it minimises surface water collecting along the carriageway edge, which may result in splashing which is undesirable in an urban environment. A sub-surface filter drain would also be required to intercept sub-surface water and therefore drain the carriageway foundation.

4.2.20 The tunnel drainage system would be designed to collect water that runs-off vehicles entering the tunnel as well as ground water that may seep into the tunnel through the tunnel lining.

4.2.21 The tunnel drainage system would also be designed to collect and pump fire fighting water or that used to wash down a chemical spillage into a large holding tank in the tunnel service building compound from where it can be held and disposed of appropriately.

4.2.22 The Scheme drainage system would ensure a sustainable surface water management system is provided. This would be achieved by minimising the impact of the Scheme on receiving watercourses and the existing foul water drainage network. The Reference Design proposals attenuate the surface water flows utilising underground storage tanks or oversized pipes with flow control devices.

4.2.23 Outfall into the ground e.g. infiltration system has been scoped out due to the presence of contaminated land and high ground water table. A vegetative balancing pond has been investigated, but is not feasible due to the limited open space at the outfall location.

4.2.24 Water quality treatment would also be improved through the use of hydrocarbon separators with manually operated penstock valves and spillage containment to provide a shut-off facility in the event of incident or major spillage.

Safety fencing (road restraint system)

4.2.25 On the Greenwich Peninsula a conventional steel post and rail road restraint system (or safety fence) would be provided along both sides of the A102 Blackwall Tunnel Approach including the links to Blackwall and Silvertown Tunnels, to protect drivers from roadside obstructions. An exception to this is between the northbound A102 Blackwall Tunnel Approach and Tunnel Avenue, where there is insufficient verge width to accommodate this system. In this location a pedestrian guardrail similar to the existing situation would be installed to deter people from uncontrolled crossing of the carriageway.

4.2.26 At the Silvertown end, where a greater level of pedestrian and cyclist interaction is anticipated, provision of conventional post and rail safety fencing would be limited to the sections alongside retaining walls and in the central reserve of the main alignment.

4.2.27 The extent of safety fencing would be developed further during the Detailed Design stage undertaking an appropriate appraisal process suitable for low speed roads.

Road pavement and road surfacing

4.2.28 The design of road pavements would be carried out in accordance with the appropriate design standards and good practice. The road surface would be formed using a suitable material that meets with operational and maintenance requirements whilst also providing noise reduction benefits.

4.2.29 High friction surfacing (HFS) would also be considered where high braking forces would be expected such as on approaches to junctions. Risk assessments would be carried out and the locations where HFS material would be used would be defined during the Detailed Design stage for each junction approach.

Signing

4.2.30 The proposed tunnel and new highway would necessitate the need for substantial new signing in the area. Much of this signing would need to be supported on sign gantries, to provide the greatest visibility to road users as well as making optimum use of the available space.

4.2.31 The road signing strategy for the Scheme would be developed from a consideration of five main elements. These are:

- Directional Signing (including diversion signing);
- Dimensional and other restrictions;
- Dangerous goods;
- Restricted lane access (HGV's and buses);
- Road User Charging (RUC).

4.2.32 Under the Scheme, six sign gantries would be installed at the southern end of the Scheme and one gantry would be installed at the northern end to provide directional signing for strategic and local destinations. The gantry signs would be lit and elevated above the carriageways.

4.2.33 Where possible, existing sign gantries would be used to support the new signing subject to confirmation of their design capacity. A number of new gantries are required however, and certain existing gantries would need modification to support additional signing.

4.2.34 Depending on their location, the proposed new gantries would either be cantilever or portal truss gantries as shown in Figure 4.4 and Figure 4.5 respectively.

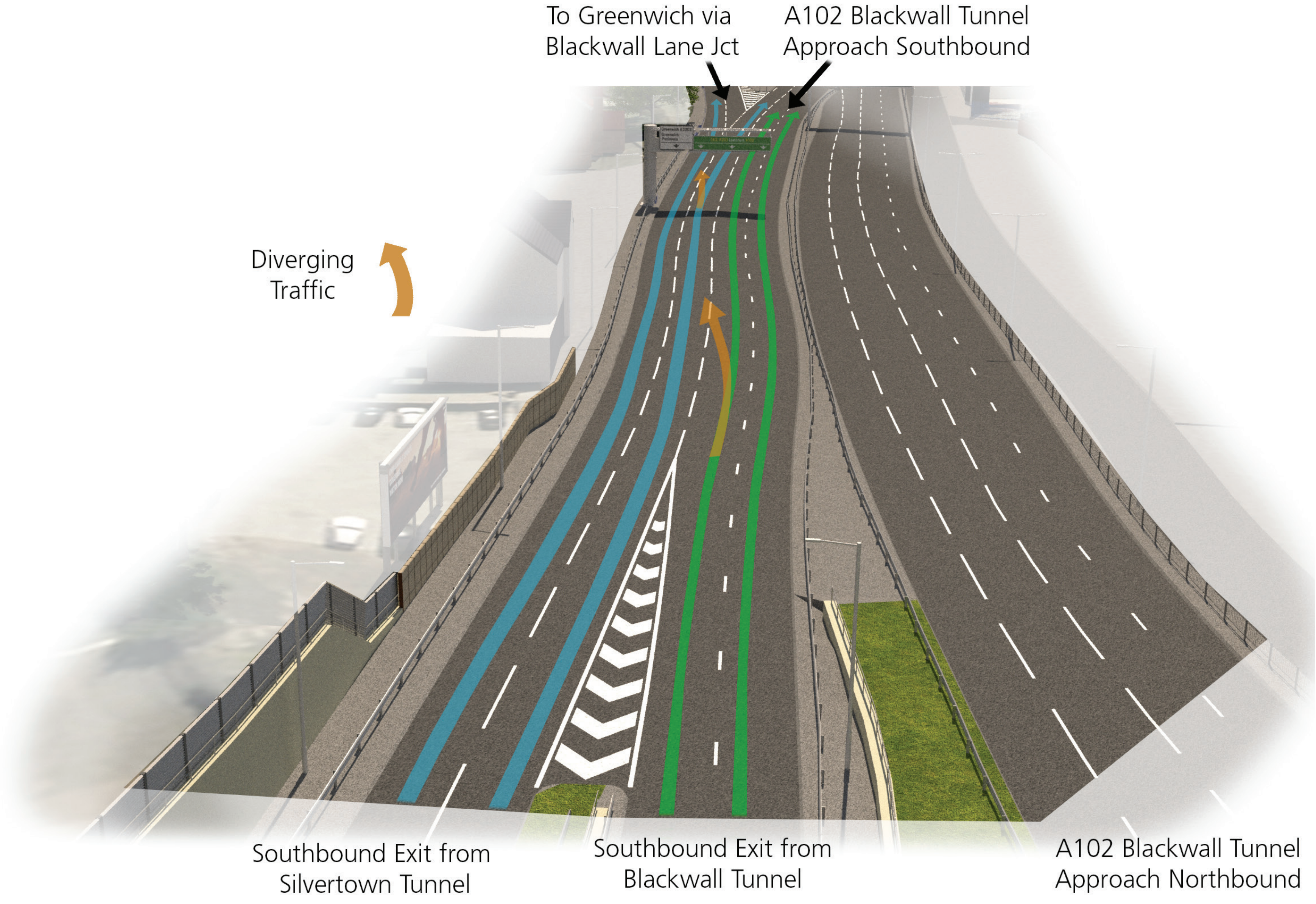
4.2.35 Local signing north of the river would be revised to direct local southbound traffic through Silvertown Tunnel. Strategic traffic would be directed through Blackwall Tunnel as per the existing situation.

4.2.36 Variable Message Signs (VMS) would support the directional signs to indicate lane closures using a red cross over lanes closed for maintenance or incidents and variable speed limits as shown in Figure 4.5.

Figure 4.4 – Typical cantilever gantry

Figure 4.5 – Typical portal truss gantry and VMS signs

Figure 4.6 – Illustrative view of the southbound vehicle manoeurves on the A102 Blackwall Tunnel Approach looking south from the Silvertown Tunnel / Blackwall Tunnel merge



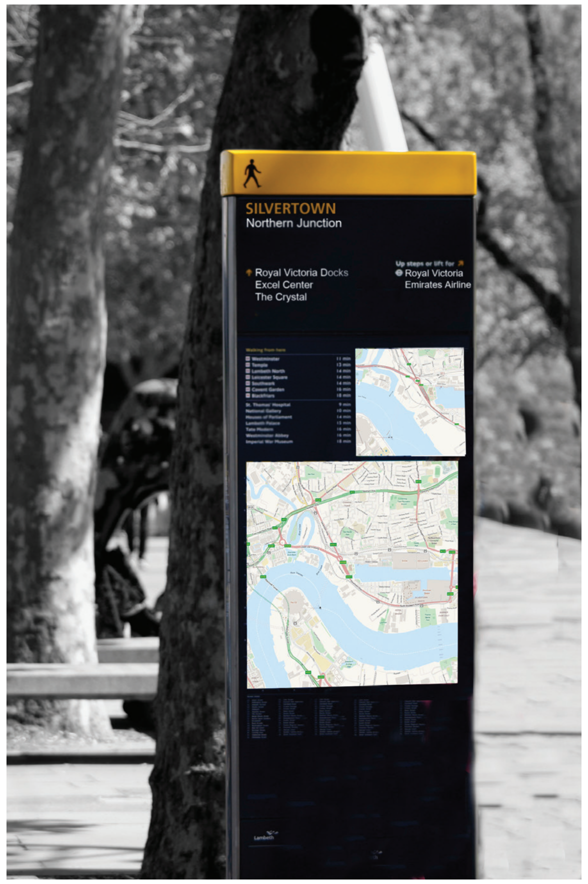
4.2.37 For southbound traffic from the Silvertown and Blackwall Tunnels the destination of each lane is detailed in Figure 4.6. A cantilevered gantry would inform drivers that lane 1 is destined for the Greenwich Peninsula and lanes 2, 3 and 4 towards Lewisham, although lane 2 would have a fork configuration that would allow traffic to either proceed southbound on the A102 Blackwall Tunnel Approach or to exit to Greenwich Peninsula. A final sign at the nosing is currently proposed to reinforce the destinations. On the southbound approach to the Silvertown Tunnel from Lower Lea Crossing, the destination signing would be Lewisham.

4.2.38 The existing Blackwall Tunnel is designated as Category E under the Carriage of Dangerous Goods by Road Regulations[3]. The categorisation of the Silvertown Tunnel would be consistent with this designation. Area wide signage would reflect the consistent categorisation of the two tunnels. This would remain consistent with current information for vehicles carrying dangerous goods.

4.2.39 As both Blackwall and Silvertown Tunnels would be subject to a user charge, the Scheme charging signage would be integrated into the signage design.

4.2.40 Wayfinding signs would be incorporated into the Scheme alongside other pedestrian and cyclist enhancements to improve the movement and accessibility in the Silvertown and Greenwich Peninsula areas as illustrated below in Figure 4.7.

Figure 4.7 – Illustrative wayfinding sign



[3] European Agreement Concerning The International Carriage Of Dangerous Goods By Road (ADR), United Nations Economic Commission For Europe (2015)

Traffic signals

4.2.41 Under the Scheme proposals the modified Tidal Basin Roundabout would be signalised. The traffic signals would be designed to enable safe use of the junction for all road users and to maximise capacity at the junction. Signalisation would enable the roundabout to operate as a 'hamburger' arrangement by which traffic travelling southbound towards the tunnel could pass directly through the roundabout, increasing operational capacity. The key features of the signalisation provision would include the provision of Toucan crossings at all signalised arms to provide shared facilities for both pedestrian and cyclists. With the Dock Road arm not being signalised, a separate Toucan crossing would be located further south along Dock Road.

4.2.42 Junction and crossing controllers would be controlled via TfL's Urban Traffic Control (UTC) system. In the event of a tunnel incident the UTC system could utilise the signals at the roundabout to implement the 'Greenwave' to rapidly clear vehicles from the tunnel.

4.2.43 The existing signalised Blackwall Tunnel height restriction control facility on the A102 Blackwall Tunnel Approach would be modified and retained as part of the Scheme proposals.

Lighting

4.2.44 All highway lighting, including within the tunnel would be in accordance with the appropriate design standards and guidance and use energy efficient illumination throughout. As set out in the Design and Access Statement, lighting would also be used for personal security and to illuminate cycleways and footways.

4.2.45 The tunnel lighting system would be designed to give a level of illumination that would provide tunnel users with adequate visibility throughout and would be designed in three zones to take account of the light level changes experienced by the driver travelling along the tunnel.

4.2.46 In the main body of the tunnel, is the interior zone where a standard level of illumination would be provided. At the entry and exit portals are the entry and exit transition zones respectively, where additional lights would be installed to allow the tunnel control system to 'match' the outside illumination levels.

Pedestrians, cyclists and other non-motorised users

4.2.47 At the northern end of the Scheme, a new footway/cycleway provision would be provided adjacent to the carriageway with signal controlled Toucan crossing facilities proposed at the modified Tidal Basin Roundabout. Non-motorised user (NMU) routes have been designed to achieve the anticipated desire lines through the centre of the roundabout. The footway/cycleway space has been laid-out such that a high quality, open feel could be achieved, especially around the roundabout area. A controlled crossing would also be provided on the realigned Dock Road.

4.2.48 At Greenwich Peninsula, a new footway/cycleway would be provided adjacent to the reconnected Tunnel Avenue. In addition, the existing Boord Street Footbridge would be replaced with a new structure for pedestrians and cyclists with both step and ramp provision on both sides. No on-carriageway cycle facilities would be provided on the A102 Blackwall Tunnel Approach, which leads principally into the Blackwall Tunnel or the proposed Silvertown Tunnel, where NMUs are prohibited. As part of TfL's River Crossings Programme, the EAL has been constructed to improve the opportunities for pedestrians and cyclists to cross the Thames on the same corridor as the Scheme.

4.2.49 To keep the street scene open with minimum street furniture the proposal is that pedestrian guard railing would only be deployed where a clear need exists.

Private means of access

4.2.50 Under the Scheme proposals a number of public highways and or existing private means of accesses to office, industrial and commercial premises would be affected by the Scheme. Where this is necessary, alternative access arrangements would be provided to ensure that a safe access arrangement is maintained for continued use.

4.3 Bridges and retaining walls

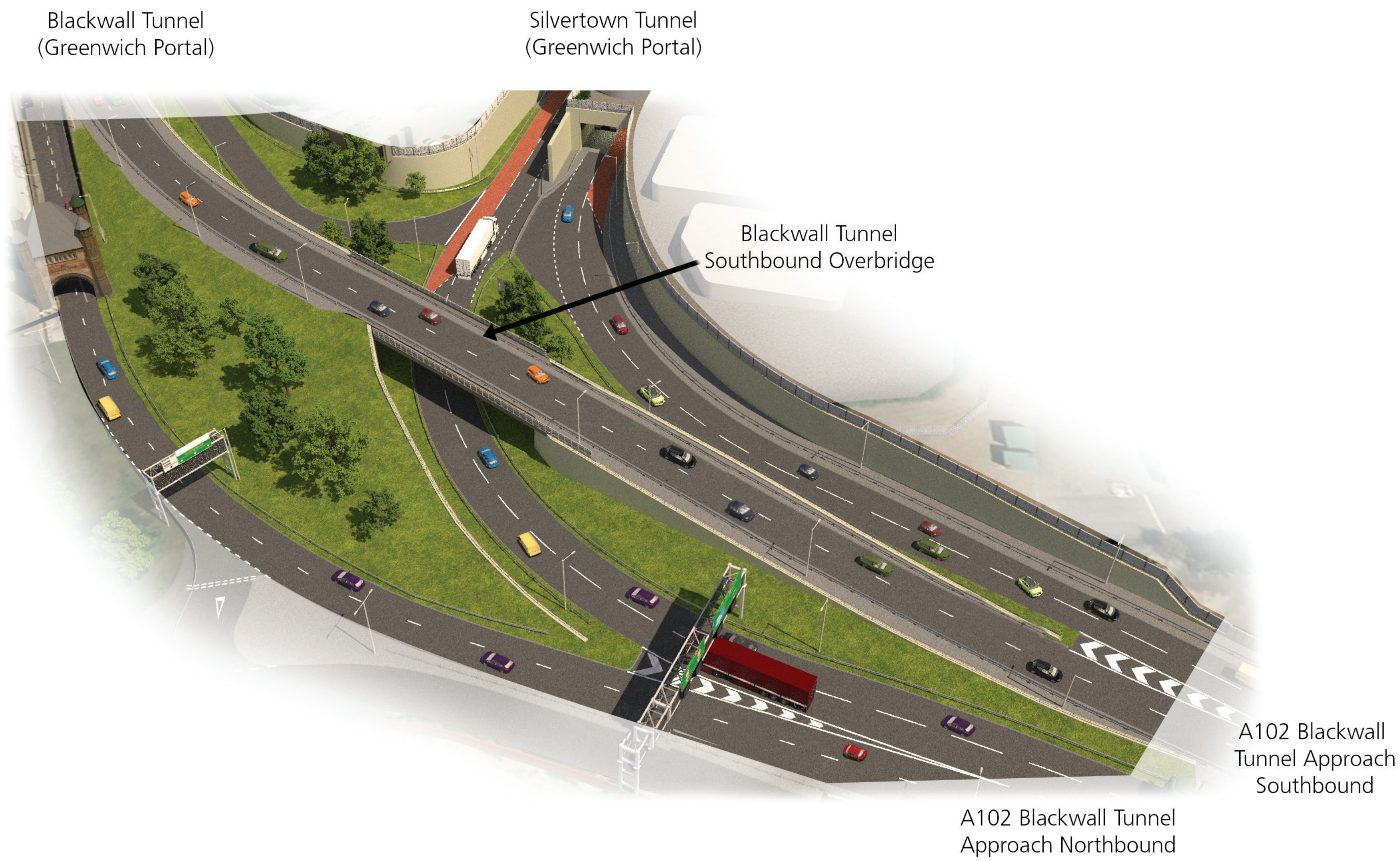
Blackwall Tunnel Approach Southbound Overbridge

4.3.1 The proposed northbound approach to the Silvertown Tunnel would pass beneath a realigned A102 Blackwall Tunnel Approach Southbound carriageway. In the Reference Design, the existing Blackwall Tunnel Approach southbound would be raised onto a new bridge spanning across the new Silvertown Tunnel northbound approach as shown in Figure 4.8 below.

4.3.2 The bridge deck would be supported on abutments at either end which would also serve to retain the earth behind the abutments. The bridge deck would be formed from reinforced concrete or steel girders supporting an in situ concrete deck.

4.3.3 Vehicle parapets would be provided on the bridge edges to ensure any vehicle passing over the bridge is adequately contained in the event of an impact. The bridge abutments would also be designed to withstand similar levels of impact.

Figure 4.8 – Illustrative birdseye view of the southern tie-in on the A102 Blackwall Tunnel Approach showing the proposed new overbridge structure looking north



Retaining walls

4.3.4 An open cut would be required at both Silvertown and Greenwich Peninsula ends of the tunnel, where the approach roads fall from existing ground levels to the tunnel portal. These would be formed by the construction of retaining walls, varying in height, with a maximum retained height of approximately 8m at the tunnel portals as shown in Figure 4.9 below.

4.3.5 Where required, environmental barriers, parapets and guardrails would be provided to the top of the retaining walls. Road restraint systems would be provided in front of the retaining walls to mitigate damage from vehicle impacts.

Boord Street pedestrian and cycle bridge

4.3.6 A safe crossing for NMUs would be maintained near Boord Street on the Greenwich Peninsula, to allow pedestrians and cyclists to cross the widened A102 Blackwall Tunnel Approach. The current footbridge would be demolished to accommodate the realignment of the road and replaced with a wider, shared-use structure.

4.3.7 The location of the replacement pedestrian and cycle bridge would take into consideration outline masterplans for the regeneration of the Greenwich Peninsula. Under the Scheme the replacement footbridge would be relocated south east of the existing footbridge, to make it more visible to users approaching along Boord Street as shown in Figure 4.10 below.

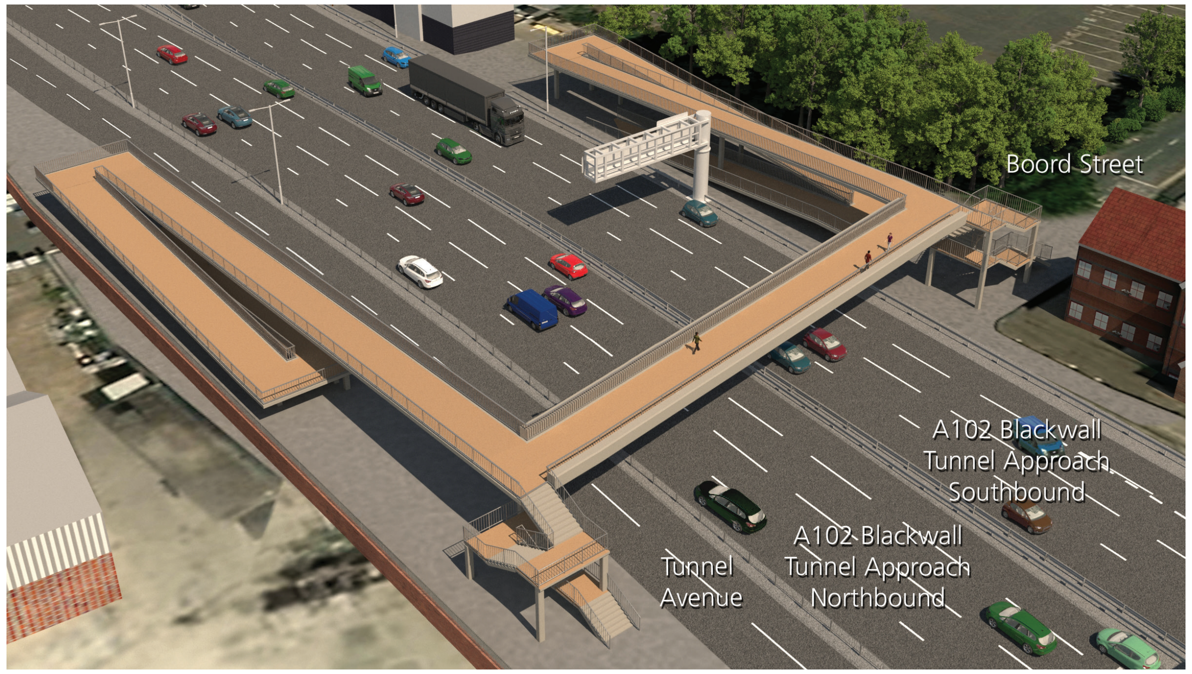
4.3.8 It is desirable to make this new bridge a single span to remove the need for a support column in the central reserve of the A102 Blackwall Tunnel Approach.

4.3.9 Approach ramps and stair access would be provided at each end of the footbridge making the bridge accessible to all in compliance with the Equality Act 2010.

4.3.10 The proposed bridge would have sufficient width to allow safe, un-segregated use by all NMUs and the parapets would be high enough to provide combined cycle and pedestrian containment.

Figure 4.9 – Illustrative view of the Silvertown portal approach ramps and retaining walls from modified Tidal Basin Roundabout looking north

Figure 4.10 – Illustrative birdseye view of the proposed Boord Street pedestrian and cycle bridge looking north



4.4 Tunnels

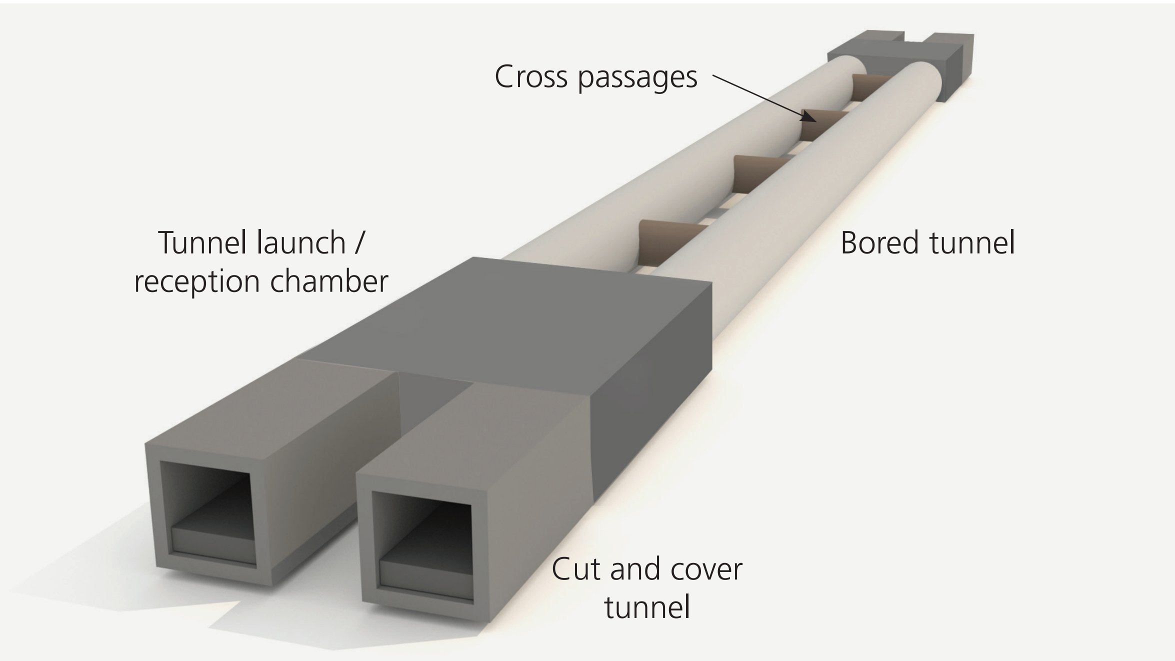
4.4.1 This chapter should be read in conjunction with Preliminary Maps, Plans and Drawings contained in Appendix A.

Tunnel arrangement

4.4.2 The tunnel structure would comprise four distinct elements and shown in Figure 4.11 and described below.

- The main tunnel section under the River Thames would consist of approximately 1,000m of twin bored tunnel, each carrying two lanes of traffic. The bores would be circular in cross section and would satisfy the requirements of the tunnel sizing exercise noted below in 4.4.3;
- The cut and cover tunnel sections would be approximately 200m in length and would provide the transition from the open roads section into the bored tunnels at either end of the tunnel, where the depth of cover is insufficient for bored construction. The cut and cover sections would be rectangular in cross section and would again satisfy the requirements of the tunnel sizing exercise noted below in 4.4.3;
- Cross passages would connect the two tunnel bores at regular intervals to provide safe facilities for self-evacuation and emergency services intervention into the tunnel during an incident.
- Tunnel launch/reception chambers would be used to launch the tunnel boring machines during the construction of the bored tunnel and would form the transition between the cut and cover and bored tunnel sections.
- The option of creating a lit, ventilated voidspace beneath the road deck which could be used as a means for utility services to cross the River Thames.

Figure 4.11 – Tunnel schematic arrangement



Selecting the size of the tunnel

4.4.3 The selection of the diameter of the tunnel bore (‘Space Proofing’), has been developed with due consideration for the appropriate design standards and key operational aspects. The tunnel diameter has been sized to provide adequate space for each of the following:

- Vehicle height clearance envelop with an allowance for construction tolerances;
- Appropriate width of the emergency walkways on either side of the carriageways which would allow evacuation of public and wheelchair users to the nearest cross-passage or tunnel portal;
- Tunnel water-tightness and maintenance issues i.e. allowance for installation of the waterproofing membrane and tunnel lining;
- Space allowance for the ventilation fans installation to optimise operational efficiency;
- Space within the crown of the tunnel for installation of a Fixed Fire Fighting System (FFFS) and miscellaneous Mechanical and Electrical (M&E) equipment.

4.4.4 Anti-recirculation walls are provided at each portal, in advance of the tunnel entry to minimise the potential for polluted air and smoke (in the event of a fire) to re-enter the parallel tunnel. The southern tunnel portal has been staggered to provide the required length of anti-recirculation wall within the specific local constraints.

Tunnel launch/reception chambers

4.4.5 At each end of the bored tunnel would be a large chamber which has two main functions. Firstly they enable the TBM to be launched when starting the first tunnel drive, rotated to launch the second tunnel drive, and removed when the tunnel boring is complete. Secondly they form the connection between the circular bored tunnels and the rectangular cut and cover tunnels.

4.4.6 The TBM required for the Scheme would have a diameter of approximately 12m and, when operational, would be over 100m in length. The TBM would be assembled in the launch chamber using sections of around 20m in length.

Cross passages

4.4.7 Cross passages are proposed along the length of the tunnel at regular spacing for self-evacuation and emergency services' intervention into the tunnel in the event of an incident as detailed in Chapter 4.5.

4.4.8 The cross passage positioned at the tunnel low point would also house the tunnel drainage sump and associated pumps to collect and control drainage flows within the tunnel structure. This sump chamber would be sized to accommodate a large tanker spillage.

Settlement analysis

4.4.9 Tunnelling activities may produce ground movement above and around the tunnelling works. A preliminary analysis has been carried out in order to determine the predicted settlements associated with the tunnel and open cut highway approaches. The analysis has been carried out making assumptions on tunnelling methodologies and control procedures, and takes into consideration the geology in the area.

4.4.10 The preliminary analysis identifies structures and buildings that may require mitigation or protection measures implemented to limit damage during the construction works. This analysis will be refined during the Detailed Design once the construction methods are finalised.

4.4.11 Using this analysis, initial building damage response assessments have been carried out to determine the damage classification. The results indicate that no residential dwellings have been identified that would require further assessment. If mitigation measures were required, a typical example could be the undertaking of ground stabilisation (permeation grouting) in advance of tunnelling works.

4.4.12 Existing transport infrastructure has been designed and constructed with consideration for a potential future tunnel including both the DLR and EAL. This has required the respective foundations to make appropriate allowances for loading and settlement effects from a future tunnel structure.

Over site developments

4.4.13 Silvertown and Greenwich Peninsula areas are subject to major regeneration aspirations that include construction of low and high rise buildings, along with development of public spaces. The new tunnel horizontal alignment has been engineered such that space available for the planned and future proposed developments is maximised.

4.4.14 This is achieved at Greenwich Peninsula by positioning the tunnel under an existing highway (Edmund Halley Way). At Silvertown the tunnel would cross the EAL corridor, then pass under the DLR viaduct and finally continue along the existing Dock Road alignment, all of which are likely to be excluded from the future development plans. The remaining tunnel section at Silvertown crosses under land which offers potential for future development.

4.4.15 Any future developments at Silvertown and Greenwich Peninsula would be subject to TfL's normal asset protection rules, which include restrictions to prevent excessive loads being imposed on the TfL assets and provide adequate horizontal and vertical clearances.

4.5 Tunnel safety systems

Tunnel safety design criteria

4.5.1 Serious incidents in road tunnels (such as vehicle fires) are extremely rare events with very few such occurrences recorded in UK tunnels. Vehicle fires in tunnels in continental Europe and further afield have highlighted the potential consequences of vehicle fires in the enclosed tunnel environment. To mitigate these potential consequences, special safety measures are deployed to firstly safeguard human life and secondly to protect the asset in the unlikely event of a serious vehicle fire.

4.5.2 The risk level in the tunnel required by the appropriate design standards and legislation is required to be As Low As Reasonably Practicable (ALARP). ALARP principles are well established in the UK and are described by the Health and Safety Executive (HSE) as the process of assessing a risk against the effort needed to further reduce it. ALARP assessments are not simply a cost-benefit analysis because ALARP decisions are weighted in favour of health and safety.

4.5.3 The risk approach taken to inform the development of the fire life safety strategy for the Scheme is an overarching qualitative process to define a Scheme that complies with relevant,

Figure 4.12 – Illustrative tunnel cross section detailing key tunnel safety systems

recognised good practice – informed by the integration of the following four key aspects:

- expert judgement and experience;
- quantitative analysis to verify risk levels;
- project requirements and constraints; and
- stakeholder requirements (emergency services and tunnel management).

Tunnel fire safety

4.5.4 The approach to the development of fire safety design for the Scheme has been developed in consultation with the Tunnel Design and Safety Consultation Group (TDSCG) and integrates the four key aspects noted above. The TDSCG provides a forum for specialist knowledge and experience from key stakeholders to define specific requirements in relation to tunnel design, construction and operation through setting of appropriate standards of safety, quality and economy.

4.5.5 A baseline set of proposed tunnel systems is presented below and detailed in Figure 4.12, representing a good practice, standards-compliant tunnel:

- Cross passages at regular intervals for egress to the non-incident tunnel bore and intervention by emergency services as detailed below in Figure 4.13 and Figure 4.14;
- Emergency ventilation for smoke control detailed below;

- Variable Message Signs (VMS) and traffic signals to effectively close the tunnel during an incident. Under normal operating conditions the tunnel traffic management system would remain dormant with the variable message signs in their normal state. When an incident is detected by any of the automatic detection systems (e.g. fire, flooding or traffic abnormality), the traffic signals on the approaches to the tunnel would immediately be used to restrict the amount of traffic entering the tunnel;
- Firefighting facilities (fire main and hydrants with connections between bores) to assist the emergency services;
- Permanent monitoring by closed circuit television (CCTV) from a dedicated control room. The CCTV system would allow the Operators to view real-time events happening in the tunnel. It would be used in conjunction with the automated systems to detect and establish the extent of any incident in the tunnel with the ability to remotely reposition the cameras;
- Greenwave traffic plan operated to prevent and manage congestion and to facilitate preferential management of traffic to clear the tunnel during an incident;
- Automatic incident and fire detection systems linked to automatic system operation (where appropriate) and alerting the operator to the incident location;
- Public Address Voice Alarm (PAVA) system to instigate and manage evacuation. Under emergency conditions, the PAVA system would be used to make voice announcements in the tunnel;
- Radio rebroadcast system providing two way radio service for the emergency services, maintenance teams, mobile telephone networks and repeat domestic radio programmes. Under emergency conditions, the domestic radio broadcasts would be replaced with emergency safety announcements consistent with those being transmitted by the PAVA system;
- Evacuation wayfinding lighting would be provided for use in the event of emergency conditions;
- Tunnel emergency points with fire extinguishers, emergency telephones and alarm call-points to allow road users to make contact with the operators in order to seek assistance;
- Footways for evacuation towards cross passages and portals;
- Passive fire protection;
- Continuous kerb-entry drainage system.

4.5.6 Figures 4.13 and 4.14 demonstrate the function of the cross passages for both self-evacuation and emergency intervention respectively during an incident.

Fixed fire fighting system

4.5.7 In addition to the above baseline tunnel systems, a Fixed Fire Fighting System (FFFS) is proposed for the Scheme. One option is a high pressure mist system, although this is an emerging technology and other systems that provide equivalent performance may be implemented into the final Scheme.

4.5.8 It is now acknowledged that the installation of a FFFS in road tunnels, as part of the overall fire safety provision, is becoming more widespread both in the UK and Internationally. FFFS is considered as a potential fire safety measure that would work in harmony with other tunnel safety systems enhancing self-rescue, supporting emergency services intervention, and limiting the rate of growth of a fire.

Figure 4.13 – Self-evacuation schematic

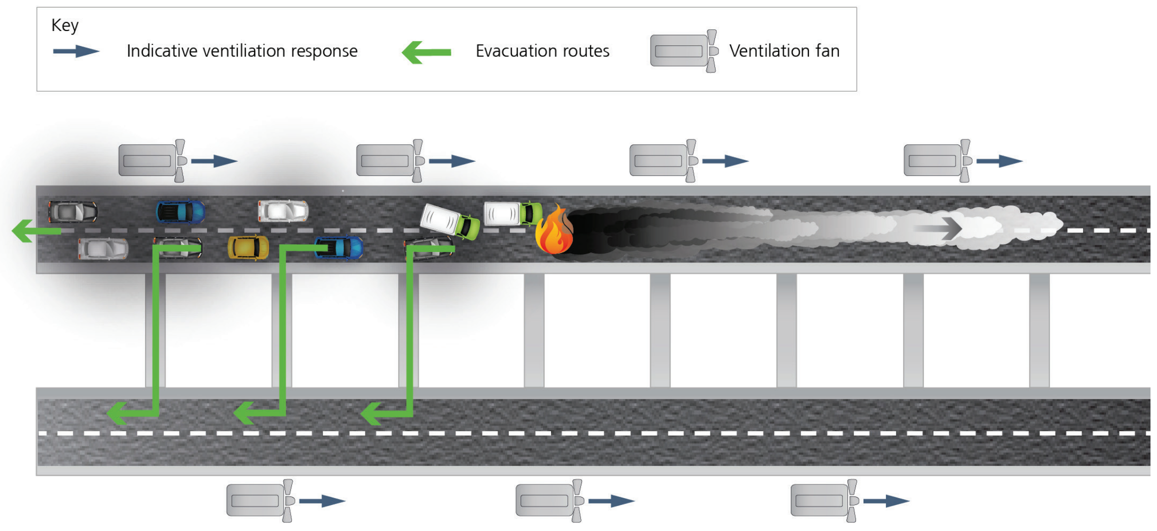
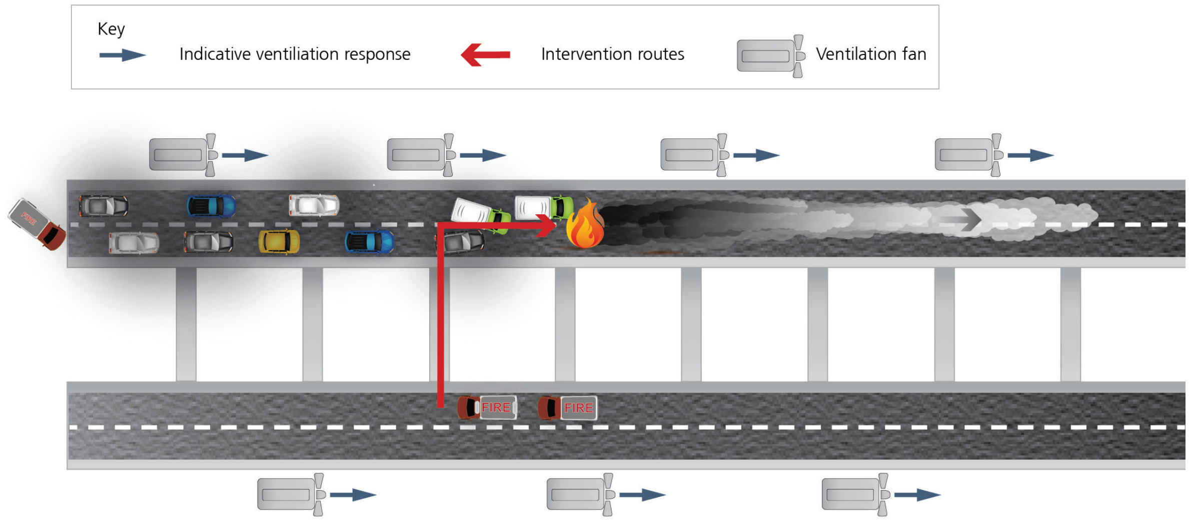


Figure 4.14 – Emergency services intervention schematic



Tunnel ventilation

4.5.9 The tunnel ventilation system proposed for the Scheme comprises two separate functional elements:

- Longitudinal Tunnel Ventilation System (LTVS) for the control of air quality inside the tunnel during normal (non-emergency) operation and for the protection of evacuees during an emergency scenario;
- Portal Extract Ventilation System (PEVS) for the control of the emissions ejected from the exit portals of the tunnel.

4.5.10 During normal operations, the tunnel would be largely self-ventilating due to a ‘piston’ action of moving vehicles under free flow conditions. In the event of congestion occurring within a bore of the tunnel, LTVS fans may be required to be activated to supplement vehicle-induced flow to achieve the required dilution of polluted air. The LTVS is also designed to control smoke from a fire. Jet fans would be reversible.

4.5.11 In order to protect the air quality outside the tunnel the PEVS would divert a percentage of the tunnel emissions to high level ventilation outlets at each portal to limit the extent of road level portal emissions. The effectiveness of the PEVS would vary with the prevailing traffic and wind characteristics.

4.5.12 The operating principles are to be developed at Detailed Design stage to optimise the operation for energy consumption and performance. These would be configured for substantially automatic operation but allowing human intervention from the operator control room.

Electrical power supply and distribution

4.5.13 The tunnel would be connected directly to the national grid high voltage (HV) network via two independent supplies, one at each portal. Under normal conditions, each supply serves half of the tunnel systems. However in the event that one of the supplies fails, the remaining supply would be automatically switched through to power the entire tunnel systems and would be sized accordingly. In the unlikely event that both incoming national grid supplies fail, an emergency uninterruptible power supply would be provided to ensure that the tunnel can be closed and evacuated safely. The uninterruptible power supply is not intended to allow the tunnel to remain operational.

4.5.14 The incoming power feed at each portal would be converted into conventional low voltage supplies in the plant rooms from where low voltage (LV) supplies would be provided to power all the tunnel mechanical and electrical systems. The LV distribution system would be monitored and partially controlled by the plant control system.

4.6 Tunnel service buildings and plant rooms

4.6.1 Under both normal and emergency conditions, the tunnel safety systems would be controlled by pre-approved protocols. The current status and operation of the tunnel safety systems would be visible to the Operator. It would be possible for the Operator to intervene and manually control individual items of equipment in the tunnel if necessary.

4.6.2 Tunnel services buildings would be provided close to the tunnel portals, within a secure compound that provides parking facilities for maintenance vehicles. The tunnel services buildings would contain the electrical and mechanical systems required to operate the tunnel. They would also contain limited welfare facilities to allow their use as a base of operations for tunnel maintenance staff. The tunnel services buildings would also contain facilities for local control of the tunnel facilities.

4.6.3 A ventilation building would be located directly over each tunnel portal within each of the compounds. This would house the PEVS equipment necessary to vent emissions at high level, that would normally be ejected from the exit portal from the tunnel LTVS. The fans in this building would be under fully automatic control under normal operating conditions.

4.6.4 The Tunnel services buildings and plant rooms have been space proofed to determine the necessary footprint required to accommodate the anticipated tunnel safety systems equipment needed to operate a tunnel of this nature as detailed above.

4.7 Utilities

4.7.1 The approximate location of existing utility services and potential diversions has been assessed as part of the Reference Design. The recorded positions of the apparatus are indicative only due to the accuracy of historic records kept by asset owners. It would be necessary to confirm the exact location and depth of all apparatus on site at the Detailed Design stage, prior to finalising detailed proposals for diversions.

Diversion requirements

4.7.2 The utilities assessment has identified that all typical utilities are present and would need to be diverted. These include:

- High voltage and low voltage power;
- Potable water;
- Foul water;
- Gas;
- Telecommunications.

4.7.3 Utility diversion corridors have been proposed to relocate any services that conflict with the construction of the Scheme. The principle of the utility corridor is to have all utilities diverted along the same route in the same trench with the appropriate spacing to the meet with National Joint Utilities Group (NJUG) guidelines as shown in Figure 4.15 below.

4.7.4 Disruption of existing services would be minimised through careful planning and liaison with the utility providers and construction works programme. This would enable the efficient diversion of utilities and prevent excessive outage periods to those fed by the same supply.

Securing future utility demands

4.7.5 Applications for temporary and permanent supplies for the construction and operational phases respectively have been made to the appropriate utility provider. These are the subject of ongoing discussions to ensure that the Scheme demands can be met along with that of other developments in the area and utility network improvements.

Royal Victoria Dock drainage diversion

4.7.6 At present two large 1.4m diameter drainage pipes run across the planned footprint of the northern cut and cover approach to the bored tunnels on the Silvertown work site. These pipes regulate the water levels in the Royal Victoria Docks and discharge via a pumped system into the River Thames intermittently. These pipes would require re-alignment to permit the completion of the cut and cover works as shown in Figure 4.16.

4.7.7 The proposed solution provides a minimal diversion that retains a similar pipe alignment crossing the cut and cover section of the tunnel. The diversion would be undertaken as the piling progresses with a short section of the roof slab constructed parallel to the existing asset spanning the works.

Figure 4.15 – Typical utility diversion trench

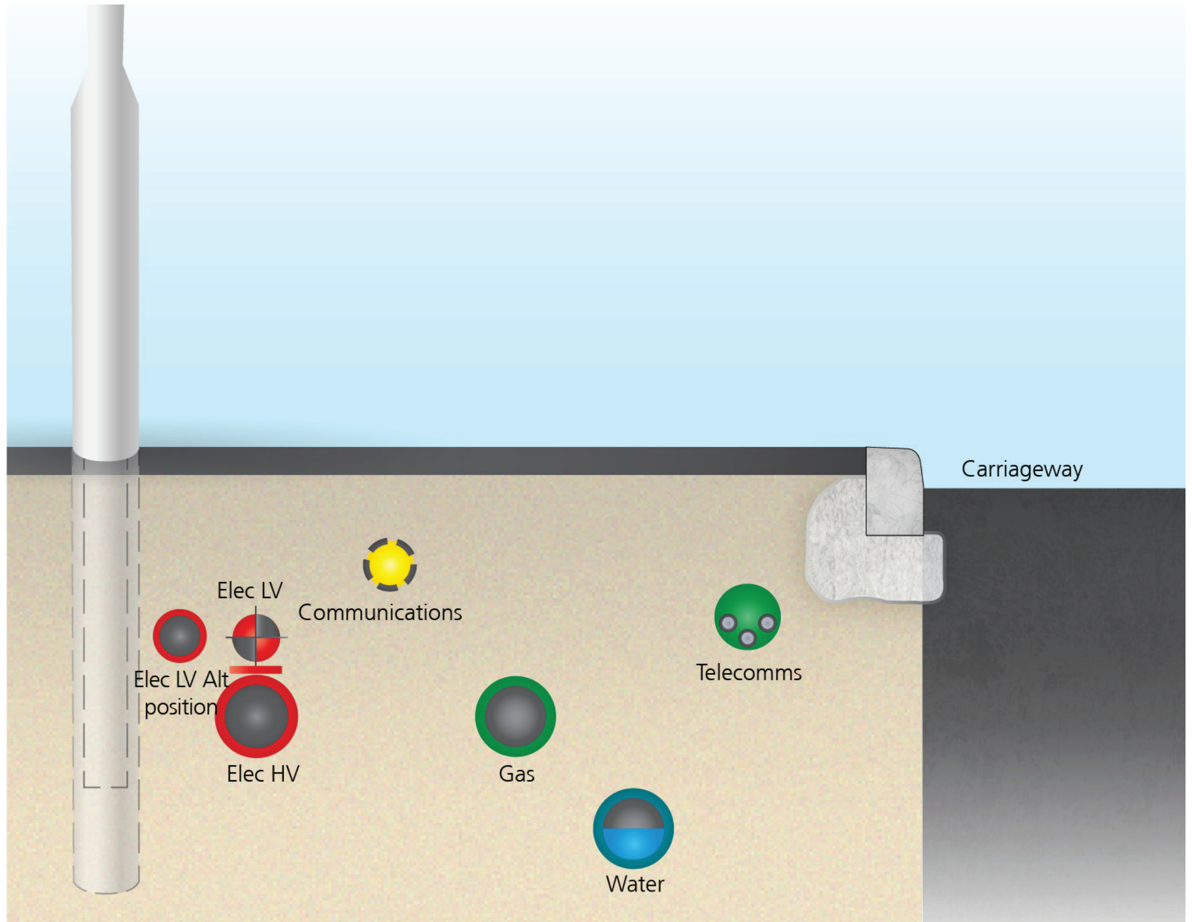
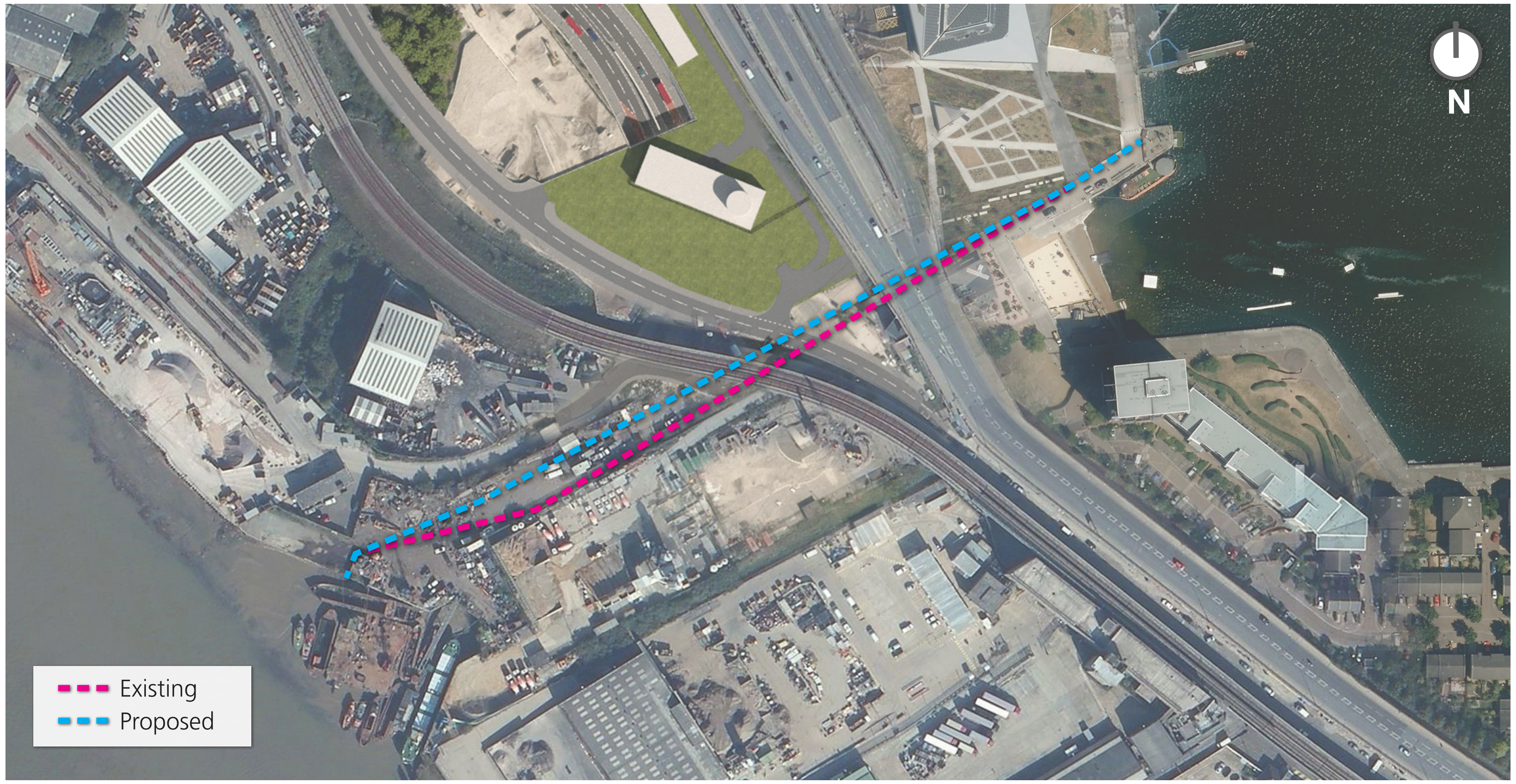


Figure 4.16 – Royal Victoria Dock drainage diversion proposal



05
Construction Methodology

5.1 Introduction

5.1.1 This section describes how the Reference Design solution outlined in Chapter 4 of this report could be constructed.

5.1.2 The methodology ultimately deployed for the construction of the proposed Scheme would be determined by the organisation appointed to undertake these works. The methods adopted may therefore differ from the indicative method presented in this document. However they should not create impacts more adverse than those assessed within the Preliminary Environmental Impact Report (PEIR).

5.1.3 The construction methodology considered under the Reference Design and described within this chapter comprises a comprehensive, practical and achievable approach to the construction of the Scheme. This methodology thereby informs the assessment of the environmental impacts described within the PEIR. It determines the land take required for construction and the potential impacts on the local transport network and users. It has also been used to estimate the cost of constructing the scheme.

5.1.4 The Reference Design construction methodology is based around standard, industry good practice construction methods and techniques that are likely to be used by a competent and experienced contractor. The construction methodology has considered working space requirements to ensure that the Scheme could be built safely and unnecessary constraints are not placed on the construction methods likely to be adopted.

5.1.5 A construction programme has been developed based upon the construction methodology presented here, with construction activity durations and their interdependencies verified to gain confidence in the overall programme duration.

5.1.6 Consideration of existing land use and emerging developments has been taken into account in the construction proposals for both Silvertown and Greenwich Peninsula sites. The proposals aim to minimise adverse impacts or conflicts to existing landowners, residents and businesses. The zonal phasing of these emerging developments would be key to the efficient phasing of the Scheme works to enable the construction works to meet the programme. These phasing and interface aspects are the subject of ongoing liaison with relevant developers and parties with land interests.

5.1.7 Marine transportation has been identified as a viable option for the disposal of excavated material and the delivery of other bulk materials given the logistical constraints, land availability and access to river frontage. To facilitate the marine logistics the Silvertown Site is identified as a key logistics hub and therefore the northern end of the tunnel dictates where the lead in preparatory works would be required to enable tunnelling activities to commence.

5.1.8 Adverse effects of the Scheme construction would be kept to a reasonable minimum through the specification of construction control principles within a Code of Construction Practice (CoCP). The CoCP establishes a framework to control possible environmental, public health and safety impacts arising from the construction of the Scheme that may affect the interests of local residents, businesses, the general public and the surroundings in the vicinity of the Scheme.

5.2 Overall approach

5.2.1 The works necessary to complete the Scheme are complex but can be sub-divided into a number of elements which when planned holistically could be constructed in a logical and safe manner. The main elements of the Scheme are listed below:

- Construction compounds
- Surface works – Silvertown
- Surface works – Greenwich
- Bored tunnel works
- Cut and cover tunnel works
- Testing and commissioning
- Demobilisation

5.2.2 The overall approach to each of these elements is described in the following sections.

5.3 Programme

5.3.1 Subject to receiving confirmation of the DCO and based on the current programme, main construction works could commence in late 2018 following a period for the Detailed Design of the Scheme. The works would last approximately years as shown in Figure 5.1 below. The programme derived is considered realistic at this stage of the design with future opportunity available under the Detailed Design and construction stages to reduce this.

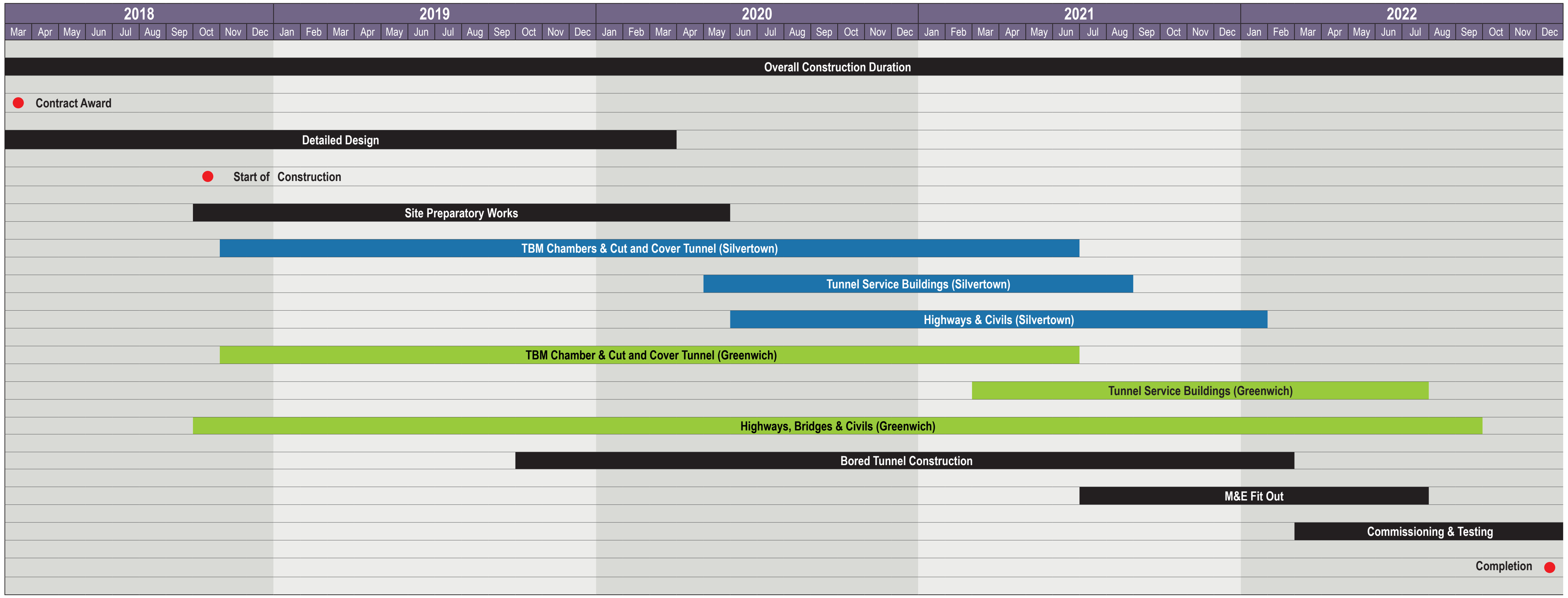
5.3.2 The construction of the TBM chambers would be the critical item to permit the bored tunnel works to progress. Piling activities for the cut and cover tunnel section formation would follow. Once the TBM chambers are completed the TBM could be prepared for launch and the tunnelling activities could commence as detailed in Chapter 5.7.

5.3.3 The necessary reconfiguration of the existing highway networks at Silvertown and Greenwich would progress in parallel with the tunnelling activities. These works would be phased in order to limit any adverse impact on traffic movements in the surrounding areas.

5.3.4 Highway construction through the tunnels and installation of M&E equipment would commence on completion of the tunnelling activities.

5.3.5 The works would culminate in a period for commissioning and testing of the new tunnel safety systems prior to bringing the tunnels into full operation.

Figure 5.1 – Construction overview programme



5.4 Construction compounds

5.4.1 Site compounds would be established at the commencement of the works and would remain throughout the construction phase. The layout of construction compounds needs careful consideration to ensure a safe, secure and efficient base for operation and associated construction activities.

5.4.2 The main site compound would be located at Silvertown as shown in Figure 5.2 and would contain offices, stores, plant maintenance facilities, materials testing laboratory, recycling, medical and welfare facilities. This site has been selected as the best location for utilising Thames Wharf for marine logistics. The Construction Methodology includes for the construction of a temporary jetty which would be necessary to maximise this opportunity. This would enable the efficient management of excavated material removal and material delivery by river and reduce the demand on the local highway network.

5.4.3 The satellite compound at Greenwich as shown in Figure 5.3 would contain sufficient offices and welfare facilities to support the surface works to be undertaken on the peninsula. All of the tunnelling activities would be supported from the Silvertown Site. The only potential exception to this may be a tunnel segmental lining storage area established at this compound to provide segments to the second drive.

Figure 5.2 – Works area Silvertown

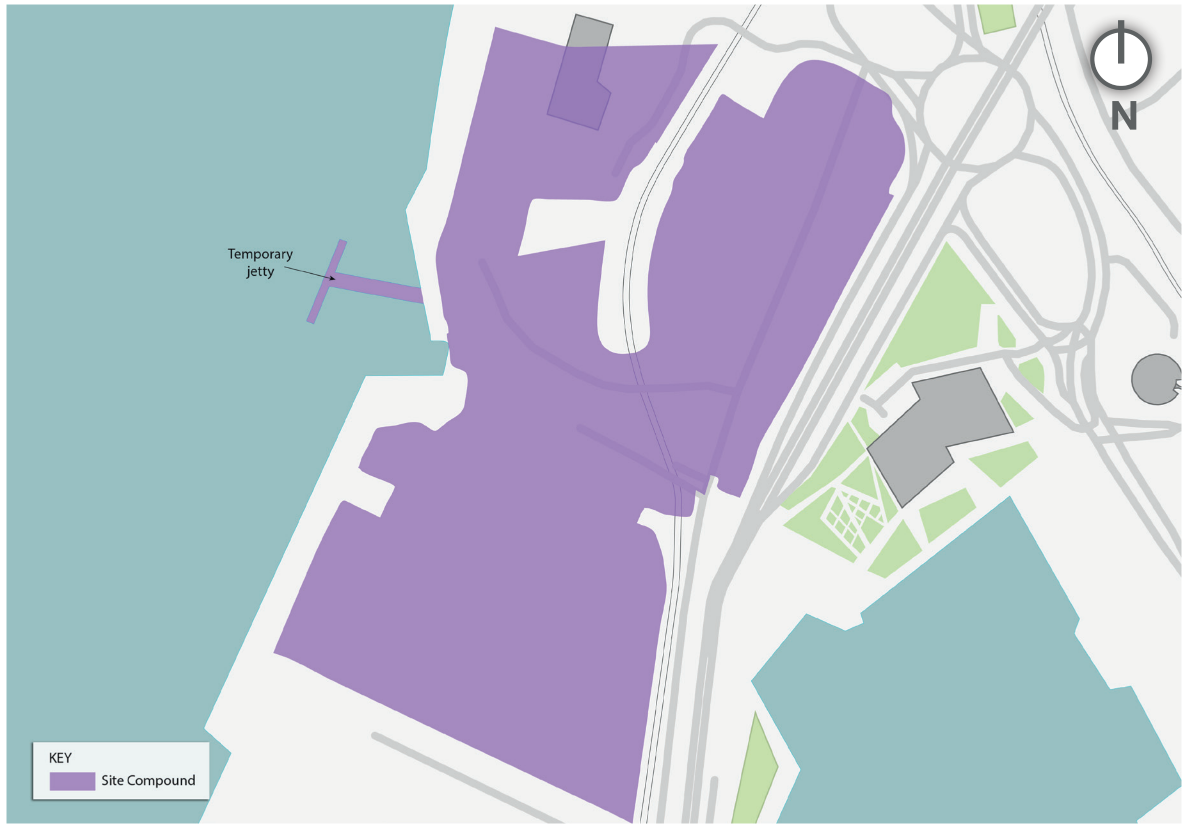
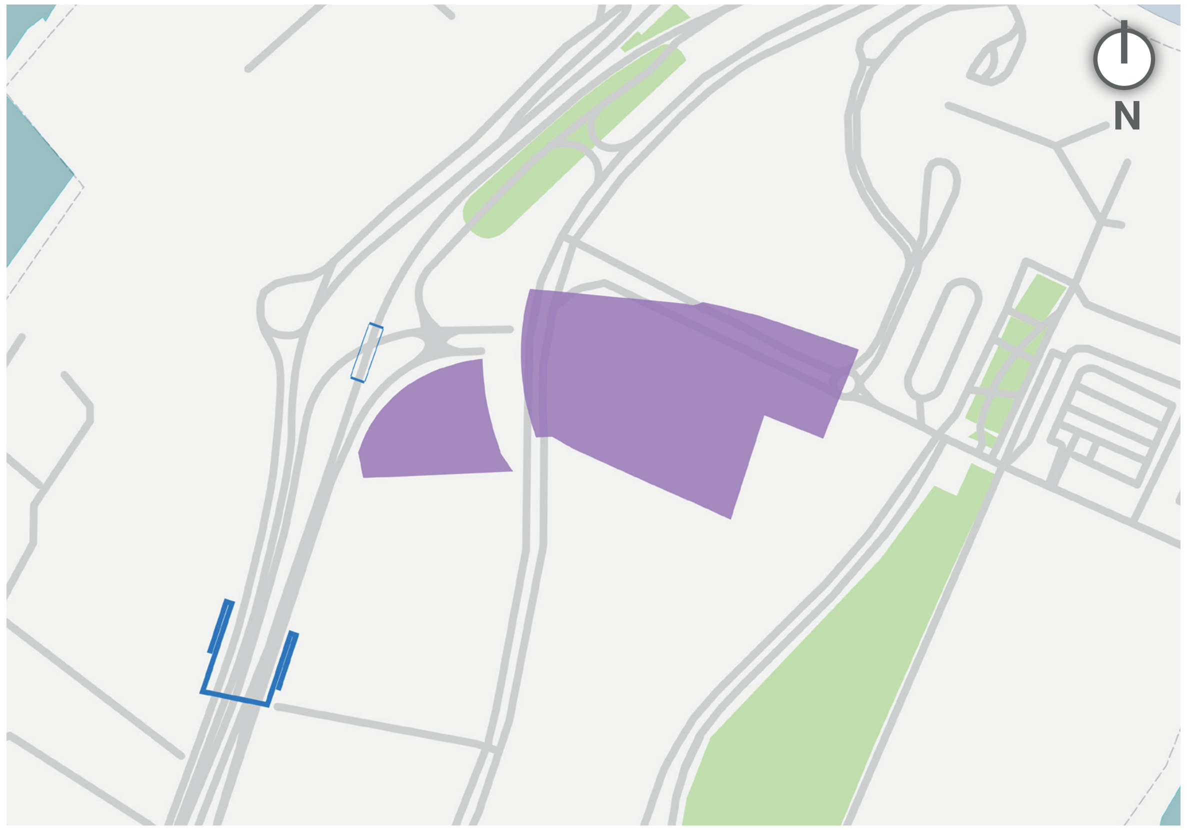


Figure 5.3 – Works area Greenwich



5.5 Surface works – Silvertown

5.5.1 This section describes the works required to construct the approach ramps, retaining walls, highway connections and service compounds at Silvertown. Figure 5.4 below demonstrates the elements of work to be undertaken within the three phases of the surface works at Silvertown as identified in the outline construction programme. Further details are provided in the sections below.

Phase 1

5.5.2 Tunnelling related earthworks would commence during this stage including piling for the retaining walls on the tunnel approaches, for the cut and cover section of the tunnel and for the TBM launch chamber.

5.5.3 The elongated circulatory carriageway extension to the Tidal Basin Roundabout would be constructed along with the realignment of the A1020 Lower Lea Crossing. This would cause minimal disruption to the existing traffic flow with localised temporary traffic management required to facilitate the tie-in to the new construction.

5.5.4 Access from North Woolwich Road would be stopped up at the site boundary and Dock Road would be closed during the works. A turning facility would be constructed at the severed end of North Woolwich Road so that access is maintained.

5.5.5 Tunnel service building construction would commence following the completion of the tunnel launch process and Royal Victoria Dock Drainage diversion.

Phase 2

5.5.6 Traffic would be diverted around the modified Tidal Basin Roundabout which would enable the redundant sections of carriageway to be removed. The southbound link from the A1020 Lower Lea Crossing would be constructed to connect with the hamburger link through the modified Tidal Basin Roundabout.

5.5.7 Drainage attenuation tanks would be constructed and traffic signals would be installed at this stage but these would not be operational until later.

5.5.8 Tunnel ventilation building would be complete with other service building construction ongoing during this phase.

Phase 3

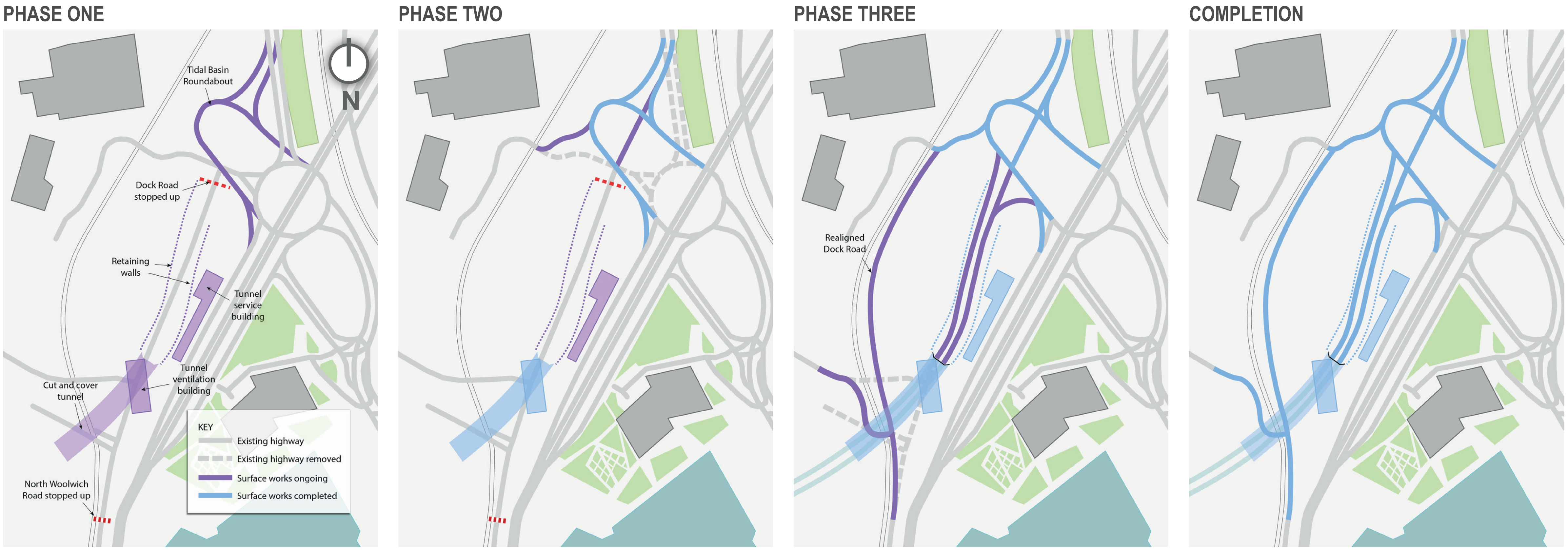
5.5.9 All tunnelling related earthworks would be completed during this stage including the piled retaining walls for the tunnel approaches and the reinforced concrete ground slab beneath the carriageway. These works would enable the construction of the northbound and southbound carriageways from the modified Tidal Basin Roundabout along the tunnel approach ramps down to the tunnel portal.

5.5.10 A gantry would be erected over the carriageway on the tunnel approach and fitted out with signage, CCTV and RUC equipment.

5.5.11 The realigned Dock Road would be constructed across the cut-and-cover structure of the tunnel to tie-in at the modified Tidal Basin Roundabout. The final areas of redundant carriageway would be broken out and all remaining works including drainage, street lighting, and landscaping works would be completed. The traffic signals would become operational once these works were complete and the tunnel had been opened.

5.5.12 Tunnel services buildings including associated compound access roads and landscaping would be completed.

Figure 5.4 – Surface works phasing Silvertown



5.6 Surface works - Greenwich

5.6.1 This section describes the works required to construct the approach ramps, highway connections and service compounds at Greenwich, A102 Blackwall Tunnel Approach overbridge and Boord Street footbridge. Figure 5.5 (below) and Figure 5.6 (next page) demonstrates the elements of work to be undertaken within the four phases of the surface works at Greenwich as identified in the outline construction programme. Further details are provided in the sections below.

Phase 1

5.6.2 Retaining walls for the tunnel approach ramps would be constructed. The A102 Blackwall Tunnel Approach overbridge abutments and bridge deck would also be constructed in this phase to enable the A102 Blackwall Tunnel Approach Southbound diversion in Phase 2. The bulk excavation between the retaining walls would begin at this stage to create the tunnel approach ramps.

5.6.3 Construction of the replacement Boord Street foot and cycle bridge would be completed followed by demolition of the existing footbridge. This would need to be done during night time working with short term road closures with the works over a live carriageway. Disruption to pedestrians and cyclists using the footbridge crossing would be minimised by delaying the demolition of the existing bridge until the new bridge and stepped access had been opened. The ramps for the existing footbridge could then be demolished to allow construction of the new access ramps.

5.6.4 During Phase 1 the new alignment of the southbound A102 could be constructed off-line with minimal disruption to the existing A102 Blackwall Tunnel Approach. The tie-in to the existing carriageway may need to be completed during night time working and with temporary lane closures. Partial construction of the Bus Link to Millennium Way using similar techniques would also occur in this phase.

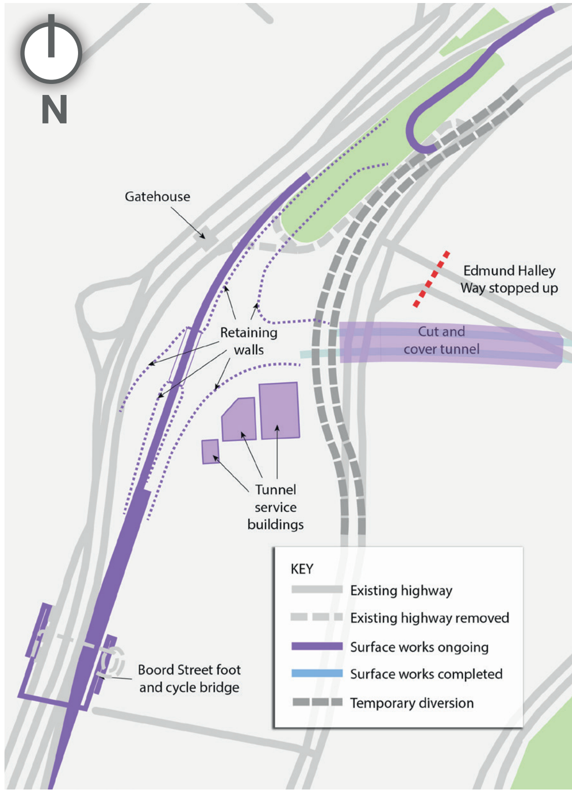
5.6.5 The methodology foresees a temporary diversion of Millennium Way during this phase to allow the construction of the southern tunnel portal. The piling works would be stopped short of the road and the structure completed. Millennium Way would then be diverted over the completed section of the cut and cover structure as the piling works resume. Traffic would be moved back to the original alignment once the cut and cover structure is complete.

5.6.6 Edmund Halley Way would still require temporary closure to permit the construction of the cut and cover tunnel but Millennium Way access would be maintained throughout construction removing the need for a temporary diversion across the area where a multi-story car-park construction is proposed.

5.6.7 Tunnel services buildings construction would commence following the completion of TBM Launch/Reception Chamber.

Figure 5.5 – Surface works phasing Greenwich

PHASE ONE



Phase 2

5.6.8 During Phase 2 the southbound traffic on the A102 Blackwall Tunnel Approach would be diverted over the newly constructed Bridge. This enables the removal of the existing central reserve and construction of the full depth carriageway and temporary safety barrier. An access to this area of works would be necessary from the live carriageway or from beneath the bridge.

5.6.9 Tunnel ventilation building construction would commence with other service building construction ongoing during this phase.

Phase 3

5.6.10 On removal of the central reserve, traffic on the northbound A102 Blackwall tunnel approach would be diverted to the original southbound carriageway and would re-join its original alignment at the Gatehouse structure. This allows construction of the new northbound alignment along with widening of Tunnel Avenue.

5.6.11 The tunnel ventilation building and the remaining tunnel service buildings including associated compound access roads and landscaping would be completed.

Phase 4

5.6.12 During Phase 4 the northbound and southbound traffic would be running in the permanent configuration. A piling rig would be remobilised to complete the retaining walls. The bulk earthworks could be completed for all new alignments. Following completion of the earthworks a reinforced concrete slab could be cast at the base of the secant pile wall. The bus link would then be constructed.

5.6.13 All finishing works remaining including drainage, street lighting and landscaping works would be completed.

Figure 5.6 – Surface works phasing Greenwich

5.7 Bored tunnel works

5.7.1 The bored tunnel section would be excavated through the use of a TBM. The type of TBM selected could be one of two options, either a slurry shield machine or an earth pressure balance machine.

5.7.2 Final TBM selection would be determined by the contractor based on their assessment of the construction risk with consideration for tunnel alignment depth and associated ground pressure, ground cover, anticipated geology and depth of the water table.

5.7.3 These two machines are similar in many ways. However, the condition of the excavated material produced by these two methods is very different. The condition of the material excavated by the slurry shield TBM requires treatment at the surface in order to separate the slurry used in the excavation from the excavated material.

5.7.4 The Reference Design has therefore ensured that sufficient temporary land is available for slurry separation plant if this option is selected.

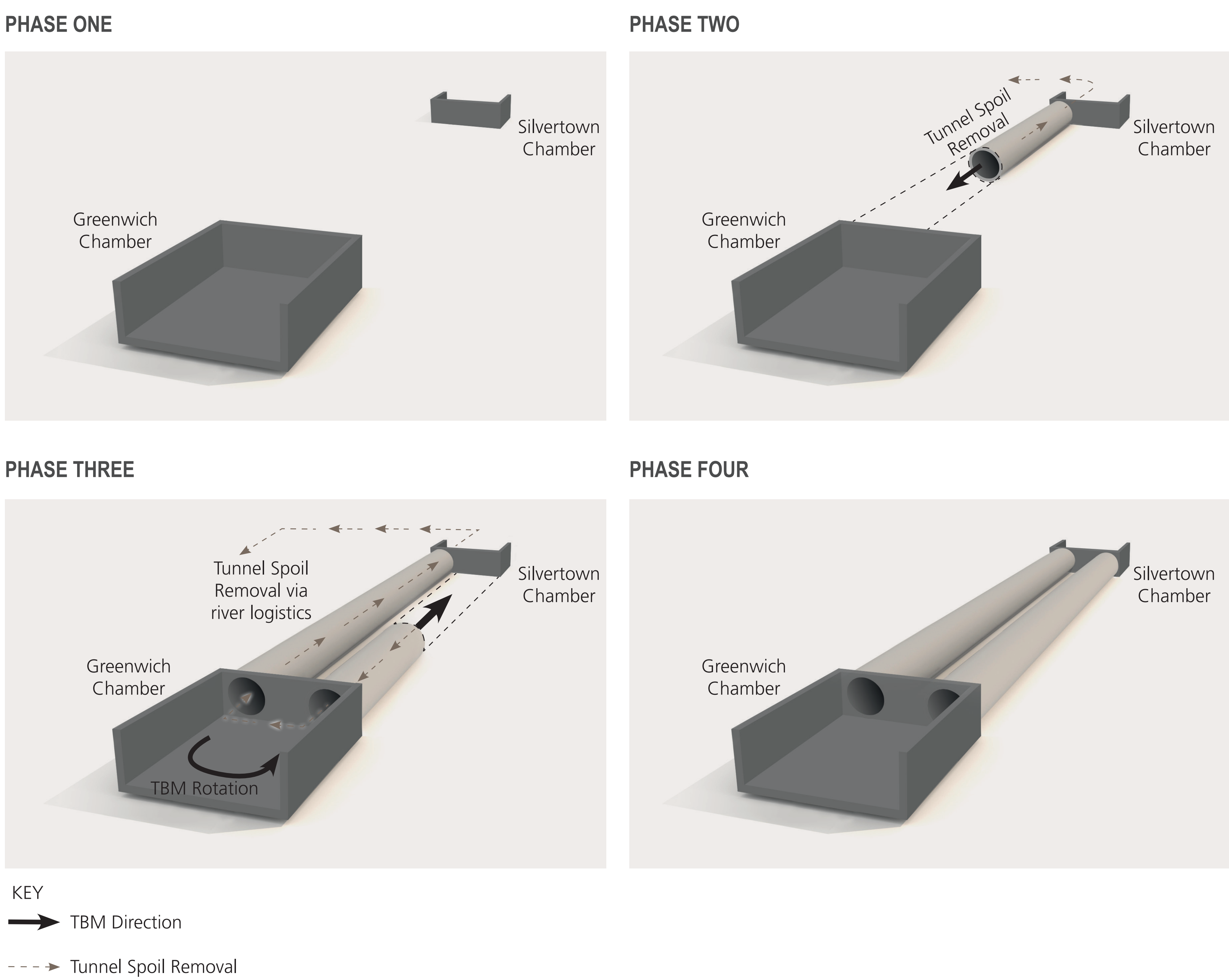
5.7.5 In each case, the excavated tunnel would be lined with a segmental concrete lining formed of precast concrete elements. The Reference Design has assumed that the concrete segments would be cast off site and delivered to site via either river or road.

5.7.6 Large deep chambers – TBM launch chambers – would be required at each end of the tunnel for the launch, reception, and rotation of the TBM. The chambers would be constructed using secant piling or similar techniques as for the retaining walls for the cut and cover tunnel sections. Construction of these chambers is a critical element of the Scheme which must be completed to enable the tunnel works to begin.

5.7.7 The TBM would be delivered to site in sections and assembled in the launch chamber. The size of the TBM means that it would be impractical to transport it to site in one piece or assemble it on the surface.

5.7.8 The Construction Methodology envisages that the TBM would commence from the launch chamber at Silvertown and head southbound beneath the River Thames emerging into the reception chamber at Greenwich Peninsula. Once the TBM has reached the reception chamber it would be rotated before undergoing a period of maintenance to prepare for the next tunnel drive. The launch preparation would then be repeated from the first drive and the TBM would begin tunnelling the second drive northbound beneath the River Thames to create the second bore, finishing up at the Silvertown launch chamber. Refer to Figure 5.7.

Figure 5.7 – Tunnel construction phasing



5.7.9 As the excavation progresses, the TBM advances forward propelled by pistons located to the rear of the TBM structure. Once an excavation advance has been completed the pistons would be sequentially retracted to permit the installation of the segmental lining whilst permitting the face pressure to be maintained. The TBM construction process is detailed further in Figure 5.8.

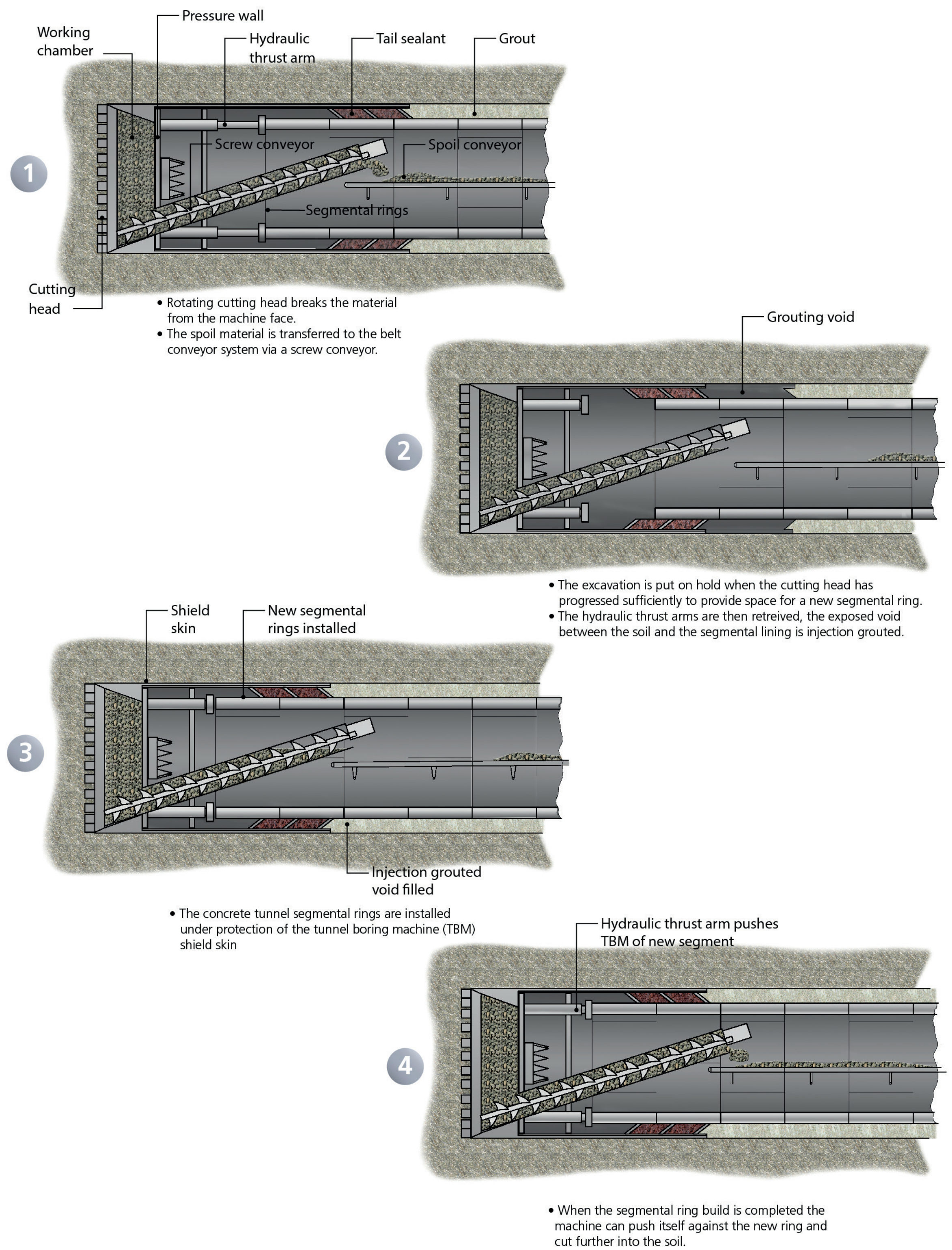
5.7.10 The Reference Design provides for the material from the tunnel excavation to be removed from the site by river. This would be facilitated by constructing a temporary jetty at the Silvertown worksite to enable a conveyor system to be installed from the tunnel to ships via a stockpile area if necessary. It would also be feasible to remove excavated materials from site by road.

5.7.11 This Reference Design proposal adopts a cast in situ secondary lining for the crown of the tunnel. A sprayed or pre-cast concrete secondary lining or cladding are potential alternative solutions. The solution reflected in the Reference Design is the most commonly used and is feasible.

5.7.12 The segmental nature of the primary lining has inherent water paths from the ground through into the tunnel. Gaskets are typical for segmental linings but the long term durability and effectiveness is a maintenance concern. A sheet waterproofing membrane between the primary and secondary linings would give greater certainty of minimising water ingress into the tunnel that would improve durability, tunnel operations and driving conditions.

5.7.13 Noise and vibration monitoring would be undertaken at existing sensitive assets along the tunnel alignment. Initial noise and vibration monitoring would be undertaken following commencement of excavation, and prior to the TBM passing under any existing sensitive assets in order to adjust excavation methods if required, to achieve specified noise and vibration criteria.

Figure 5.8 – TBM construction process



5.8 Cut and cover tunnel works

5.8.1 The approaches to the bored section of tunnel at either end would be constructed by cut and cover techniques to form the sections of the tunnel that are too shallow to be completed using the TBM and are too deep to remain in open cut. This methodology adopts a basic method of forming a wide trench in which the tunnel structures are constructed. The ground above the structure would subsequently be reinstated to permit use in the surrounding area for public spaces, roads or small buildings. If larger structures are required to span the cut and cover tunnel, their foundations must be designed accordingly to allow for the tunnel.

5.8.2 For the purposes of the Reference Design, it is proposed that the walls of the cut and cover structures would be formed using secant piling techniques although other methods exist. Secant piling adopts an overlapping pile configuration to create a continuous wall to support the opening as the cut and cover structure is formed. The piles would form an integral part of the structure.

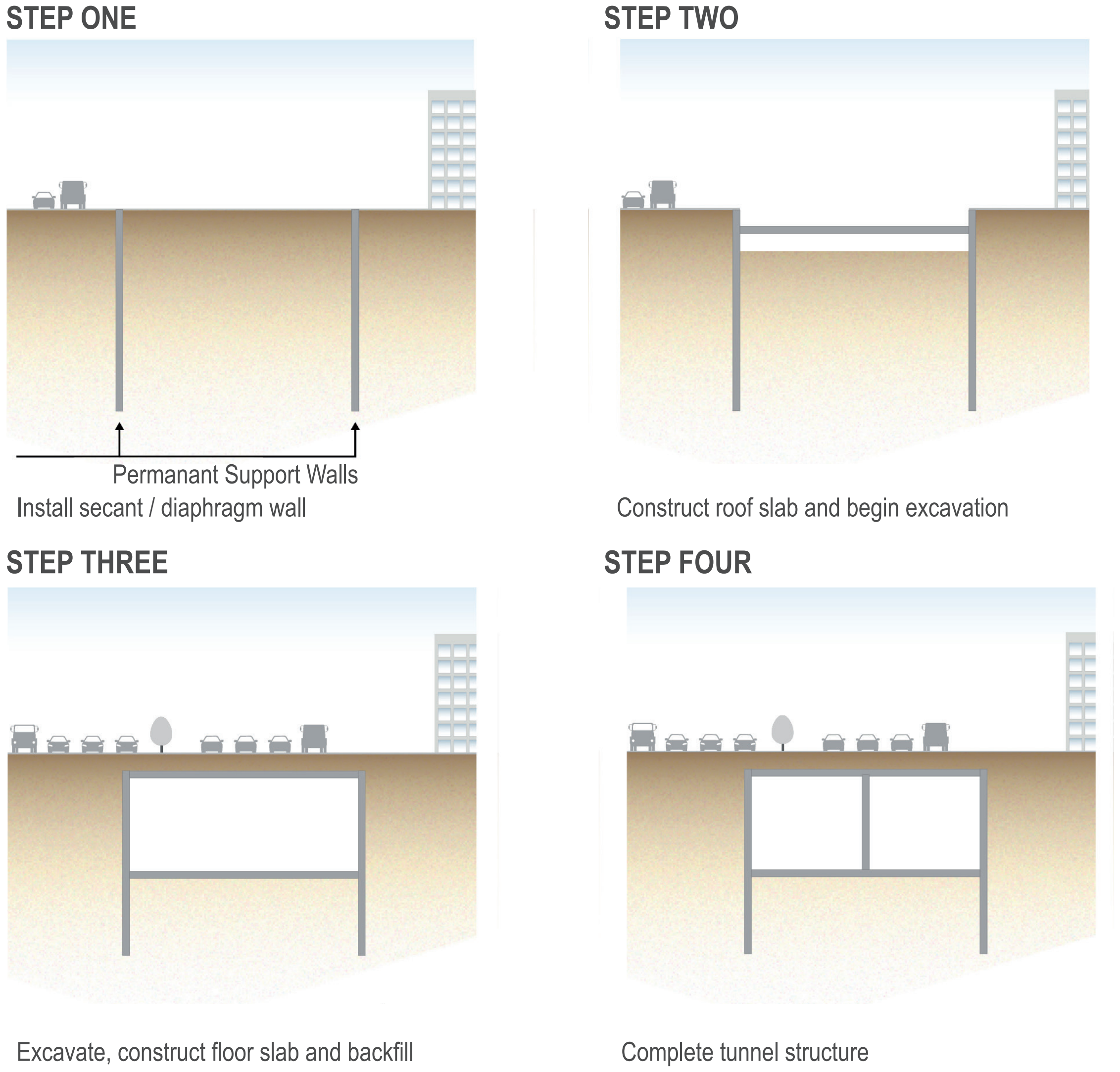
Top down construction

5.8.3 This method is proposed for the majority of the cut and cover areas except for those areas of restricted headroom or known underground obstructions. This method entails excavating down between the piles over where the section of tunnel is to be constructed. When the level for the roof slab is reached the roof would be constructed as shown in Figure 5.8.

5.8.4 Once the roof slab has been formed the overlying ground could be reinstated to permit other activities to progress at the location or free up space for other construction works which is the main benefit of this technique since the roof slab replaces the need for temporary propping.

5.8.5 The works to construct the structure would progress from one of the end faces where there is a means of access. Both ends could be used to gain access for the remainder of the construction process.

Figure 5.8 – Top down construction method

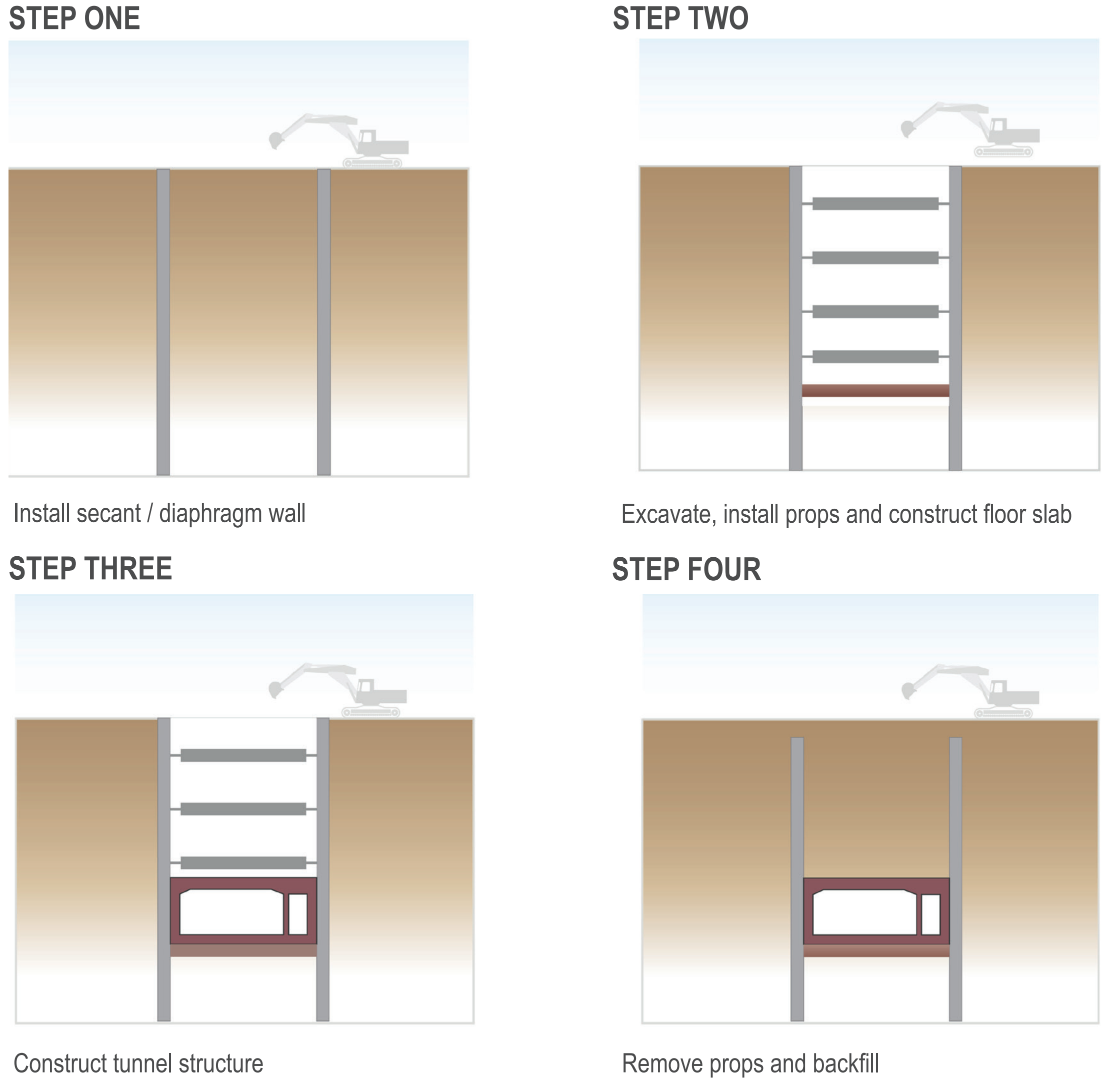


Bottom up construction

5.8.6 As the name suggests, this method forms the permanent structure from the bottom upwards by conventional civil engineering techniques. The trench between the rows of piles is excavated with temporary propping installed as the excavated face progresses down to prevent destabilisation as shown in Figure 5.9.

5.8.7 This method of construction has the benefit of increasing the accessibility of the works without restricting working headroom enabling such activities as excavating through the dock structure to be undertaken with the necessary equipment and not be restricted by working beneath the roof slab.

Figure 5.9 – Bottom up construction method



Cross passages

5.8.8 The tunnel primary lining would be cut to the required opening size for the cross passage and the face sealed with sprayed concrete. Once the face is stable, a permanent supporting frame could be installed within the opening. Excavation for the cross passage would utilise a small excavator able to operate effectively in the close confines of the opening. Once the passage opening has been excavated to the permitted advance length a primary lining of sprayed concrete would be applied using a small robotic application machine. Alternatively a ductile iron lining could be used.

5.8.9 The Reference Design has assumed ground freezing is adopted to address the risks associated with tunnelling with an open face beneath the River Thames with minimal cover and ground conditions expected. Other ground stabilisation techniques are available such as permeation grouting with the final decision made by the contractor.

5.8.10 The cross passage would be excavated using a small excavator able to operate effectively in the close confines of the opening. As the passage opening is excavated a primary lining of sprayed concrete would be applied using a small robotic application machine.

5.9 Testing and commissioning

5.9.1 Upon completion of the main construction and safety systems fit out, the Silvertown tunnel would be subject to a testing and commissioning phase prior to opening. Initially, the individual tunnel safety systems as described in Chapter 4.5 would be installed and tested in isolation. These systems would then be progressively connected and their combined functionality verified through integration testing.

5.9.2 Once all elements of the tunnel safety systems have been installed and integrated, acceptance testing would commence. Acceptance testing would be carried out in a series of increasingly comprehensive tests. This testing and commissioning methodology ensures that the testing is complete and thorough.

5.9.3 The successful completion of the acceptance testing marks the point at which the tunnel safety systems are commissioned and the tunnel could be opened to traffic. It should be noted that the thoroughness of the testing and commissioning phase is vital to the ongoing safety of the tunnel.

5.10 Demobilisation

5.10.1 Following the completion of the construction, testing and commissioning activities the temporary land used to construct the scheme would be handed back to existing land owners. This could be undertaken in a staged process to make land used on a temporary basis available to landowners in order to facilitate original operations or planned future developments.

5.10.2 All construction facilities (offices, workshops, stores, material stockpiling areas waste facilities etc.) would be removed and the land would be reinstated to its previous condition.

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