

# Technical Note 112 – Principal Worksites

<b>Subject:</b>	Principal worksites option review	<b>Originator:</b>	██████████ (Costain) • ██████████ (LIS)
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<b>Date:</b>	23/03/18	<b>Issue no.:</b>	1

## 1. Purpose

This technical briefing note has been developed to assess from a constructability perspective, the relative merits and concerns for the various principal worksites for this project.

### 1.1. Work so far

Following a comprehensive, multidisciplinary desktop study, an original list of seven potential locations for principal worksites were proposed. These included on route and off route options and were:

- Old Kent Road 2
- New Cross Gate
- Lewisham
- Wearside Estate
- Ladywell Fields
- Hither Green
- Catford

A sifting process was then carried out which eliminated all but two options. These were New Cross Gate and Wearside Road Industrial estate. The other five proposed locations were eliminated for the following key reasons:

Old Kent Road 2	<ul style="list-style-type: none"> <li>• No rail access – all deliveries and muckaway by road</li> <li>• Heavily residential</li> <li>• No clear constructionability benefit over any other site proposed</li> <li>• Congested road access</li> </ul>
Lewisham	<ul style="list-style-type: none"> <li>• Very small site. Viability of use as a principal worksite is low.</li> <li>• No rail access</li> <li>• Heavily congested road access</li> <li>• Significant residential developments nearby</li> </ul>
Ladywell Fields	<ul style="list-style-type: none"> <li>• Greenfield site – significant opposition would be anticipated</li> <li>• Would preclude all but extension to Hayes as a phase 2 route without significant additional tunnelling</li> <li>• Significant additional tunnelling required to reach Lewisham (not currently necessary)</li> </ul>
Hither Green	<ul style="list-style-type: none"> <li>• Extensive additional excavation would be required to reach tunnel invert level due to existing height above GL</li> <li>• Would potentially preclude certain Phase 2 extensions without very significant additional tunnelling</li> <li>• Significant additional tunnelling would be required to reach start of line (not currently necessary)</li> </ul>
Catford	<ul style="list-style-type: none"> <li>• Would preclude certain Phase 2 extensions without very significant additional tunnelling</li> <li>• Significant additional tunnelling would be required to reach start of line (not currently necessary)</li> </ul>

After further design development and sifting workshops were carried out, a number of constraints were identified for both main options (New Cross Gate and Wearside Road). Hither Green also became more advantageous in terms of rail systems as it offered stabling facilities. Therefore, Hither Green was brought back in to consideration as a principal worksite and is included in this technical note.

## 2. Tunnelling methodology

### 2.1. Type of Tunnel Boring Machine (TBM)

Due to the space constraints of the principal worksites proposed, the tunnelling methodology significantly influences the decision making process. A thorough review of the methodology has been carried out by Costain, using experts within the business and trusted suppliers.

The geological strata across the route is primarily chalk, with a section of sands and clays between proposed Old Kent Road 1 and Lambeth North (see below).

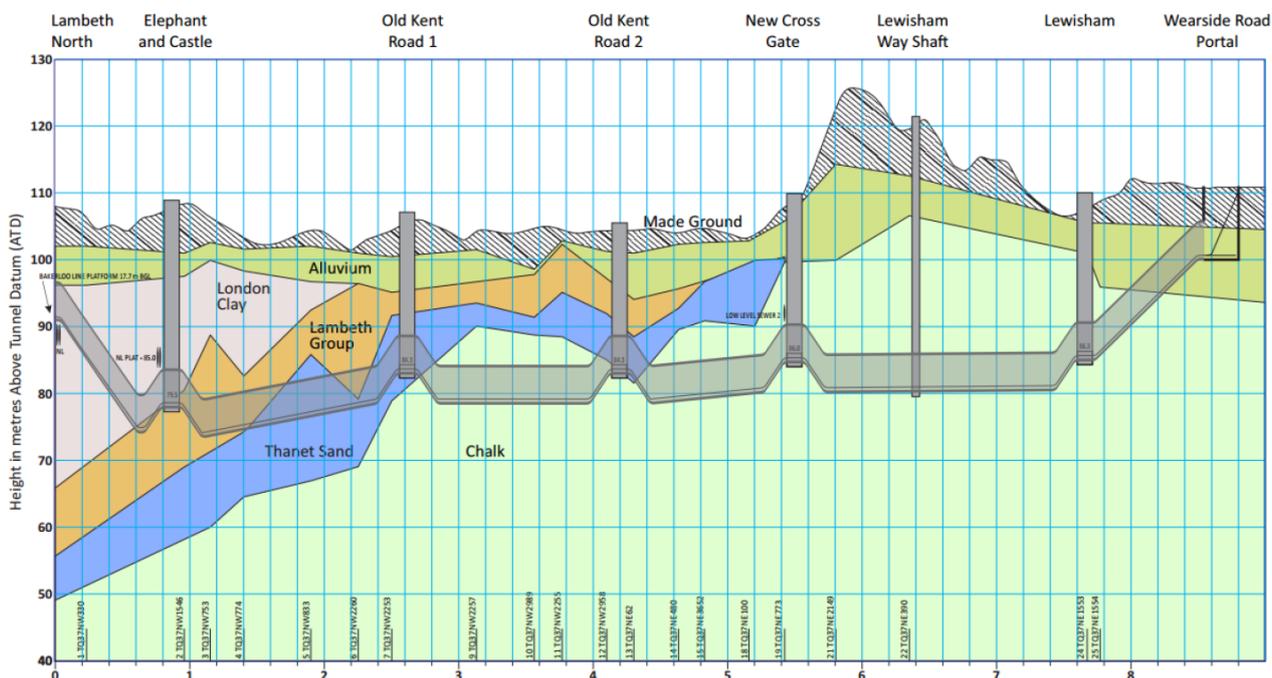


Figure 1 - Proposed tunnel alignment

Three main types of TBM are being considered:

- Earth Pressure Balance (EPB) machine
- Slurry machine
- Multi-mode types (more expensive but can switch configuration)

Historically, all types of TBM have been used in these conditions. The type will usually be determined by the contractor, once the ground and groundwater conditions are understood in more detail. The depth of the drive and risk of settlement are also key factors to consider when making this decision.

An EPB TBM works using a screw conveyor system to balance the face of the TBM without the use of bentonite slurry. The material excavated by the cutter head is transported via conveyor system to an above ground storage area.

A slurry TBM works on the principle that the ground being tunnelled through is supported by bentonite slurry. The slurry is mixed with material excavated by the cutter head and removed from the tunnel via a pipeline. The excavated material is transported above ground, where it is separated from the slurry using a slurry treatment plant (STP), an example is shown in Figure 2.

There is a significant change in geology around the proposed Old Kent Road 1 area (from chalk to sands/clays), so there may be a requirement to swap TBM's, or reconfigure the existing ones (if using multi-mode types) at this point. Facilities for this should be allowed for in the proposed Old Kent Road 1 site, although the primary logistics route will still be from the principal worksite.

At Elephant & Castle/Lambeth North, the TBMs would either be recovered in a reception shaft or part of it sacrificed, depending on the final tie-in detail at the north end of the extension.

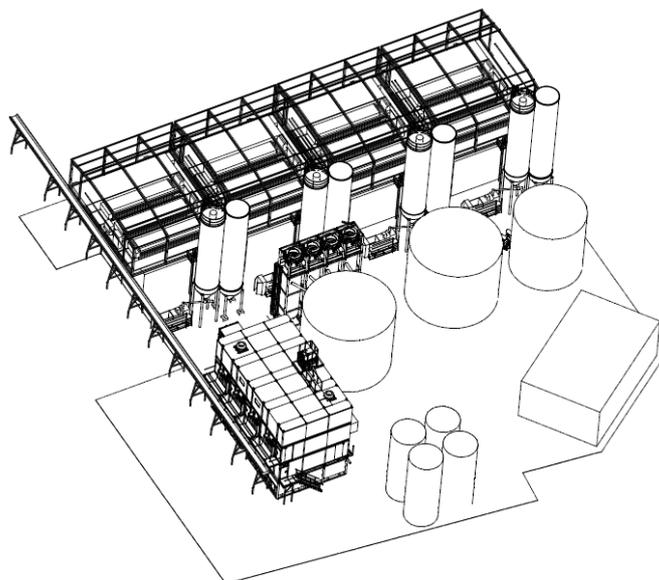


Figure 2 - Typical example of a slurry treatment plant

The overall area required for the principal worksite is normally higher for a slurry TBM because of the additional treatment facilities required. At this stage of the project, it is assumed that a slurry TBM will be used for at least part of the drive as this is the most likely option from a desktop study of the geological strata and gives a worst case in terms of land area required.

## 2.2. Area required

A desktop study of other sites with similar ground conditions has been undertaken to determine the likely area required:

Project	Geology	Type of TBM	No. of drives	Diameter	Area of STP required	Comments
Shieldhall Tunnel	Soft clays to strong rock	Slurry TBM	1	5.50m	3000m <sup>2</sup>	
Thames Tideway	Chalk	Slurry TBM	1	8.00m	5040m <sup>2</sup>	
Lee Tunnel	Chalk	Slurry TBM	1	8.90m	4300m <sup>2</sup>	
Crossrail (Plumstead to North Woolwich)	Chalk	Slurry TBM	2	6.20m	4750m <sup>2</sup>	Only 1no. drive at a time due to power restrictions

The Thames Tideway project is the best comparison, as a single bore of 8.0m diameter will produce approximately the same amount of spoil as the BLE project (two 5.8m diameter bores).

Based on this study and guidance from tunnelling specialists, an estimated 6,000m<sup>2</sup> has been allowed for slurry treatment plant facilities at the principal worksite.

The estimated minimum land area required for a principal worksite is shown in the following table:

<b>Construction Area</b>	<b>Storage Area Required</b>
General (haul roads, pedestrian footpaths, containers, loading areas, ventilation, pipe storage etc.)	5,000m <sup>2</sup>
Segment Laydown Area (3 days storage plus buffer)	1,400m <sup>2</sup>
Spoil storage area (3 days storage plus buffer)	2,140m <sup>2</sup>
Welfare and Parking	2,000m <sup>2</sup>
Shaft	500m <sup>2</sup>
M&E Stores and Workshop	1,000m <sup>2</sup>
Grout Plant	500m <sup>2</sup>
Rail sidings	4,500m <sup>2</sup>
HV Substation	600m <sup>2</sup>
Slurry Treatment Plant	6,000m <sup>2</sup>
<b>Total:</b>	<b>23,640m<sup>2</sup></b>

# 3. Baseline Option (Wearside Road)

## 3.1. Construction lay out



Figure 3 - Wearside Road Site Layout

## 3.2. Tunnelling strategy

A portal (100m long x 25m wide) will be constructed at the northern end of the site for launching two TBM's concurrently towards Elephant & Castle/Lambeth North. The portal will consist of diaphragm/contiguous pile walls, with the intention that part of the walls can be used in the permanent case, for reducing the ground to allow for turnback facilities.

Once the portal has been constructed a roof slab will be installed to allow the area above it to be utilised, leaving an open section on the northern end for segment deliveries/spoil removal. Once the TBM's have been launched, the portal area can be used for segment storage.

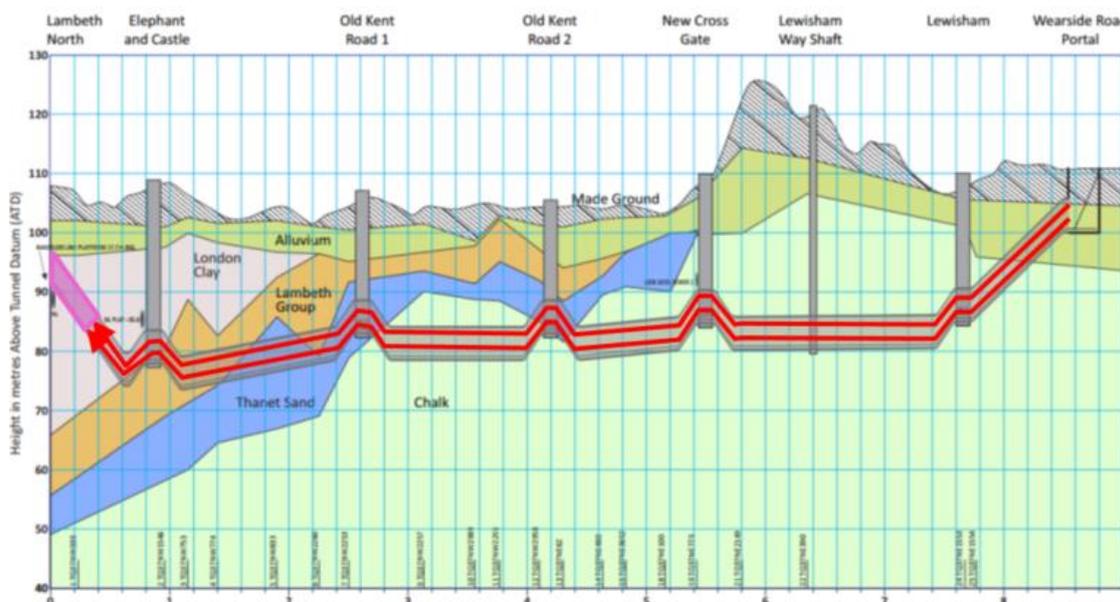


Figure 4 - TBM Drive

At this stage it is assumed that slurry TBM's will be required, as the majority of the drive is in chalk and it reduces the possibility of ground settlement.

Spoil would be conveyed back to the principal worksite for treatment and loaded onto freight trains for removal from site (see logistics section). However, starting from Wearside and continuing with one drive to Lambeth North/Elephant & Castle also means that none of the tunnel fit-out can commence until the tunnelling has finished and pipes/conveyors etc. have been removed.

The advantage of using Wearside Road as a principal worksite is it can be used to launch and service TBM's independently of station construction. The enabling works required for launching the TBM's can commence at the start of the programme and the only interface will be when the TBM's drive through the stations i.e. station box first or TBM first. The interface will be detailed in the construction programme and used to develop the design.

The main constraint of Wearside Road from a tunnelling strategy perspective is the size. Based on similar projects an area of approximately 23,640m<sup>2</sup> would be required for this scale of project, which is substantially lower than the space available (16,000m<sup>2</sup>). The slurry treatment facilities take up a significant amount of this space (6,000m<sup>2</sup>), but there is a high likelihood that they will be required based on a desktop study of the geological profile. Reducing the area required for this plant is challenging due to the size of equipment required (the sand filters are likely to be 20m high). Using EPB machines instead of slurry machines would reduce the land area required, but would pose a significant risk to the programme as the ground and groundwater conditions aren't known in enough detail at this stage. Alternatively one TBM could run at a time, which also have significant programme implications.

There are opportunities to maximise use of the space, for example by using the underground portal to store segments, however it is likely that additional land would have to be acquired. For example, areas have been identified to the south of the site as well as parcels of rail locked land to the north which could potentially be used.

### 3.3. Construction strategy

A phased approach to the construction and site set up of Wearside will be required to enable it to operate as a principal worksite, given the size constraints:

#### Phase 1:

- Site setup
- Construction of portal (diaphragm/contiguous pile walls) and TBM erection
- Construction of temporary siding along the western edge of the site (on the Hayes Line)
- Installation of plant/equipment to support tunnelling operations (slurry treatment plant, HV substation, grout plant etc.)

#### Phase 2:

- Roof slab to be installed above section of portal to allow for additional spoil storage at ground level
- TBMs to commence drives concurrently towards Elephant & Castle/Lambeth North.
- Slurry to be pumped back to the STP, pressed and the slurry cake is loaded onto freight trains for removal from site.
- Portal to be used for segment storage during tunnelling operations

#### Phase 3:

- Once tunnelling is complete and all spoil has been removed, the site can be cleared and all plant/equipment dismantled and removed from site.
- A diaphragm wall will be constructed in a section of the site. The ground level will be reduced to c.8m BGL as required for permanent turnback/stabling facilities (note: temporary sidings to be maintained as long as possible here to maintain as much spoil removal by rail as possible).
- Permanent stabling and turnback facilities to be completed and commissioned with the rest of the extension

### 3.4. Logistics strategy

#### 3.4.1. Rail access onto the recognised freight network

Wearside Road is a council owned utilities hub which currently has no access to the railway network, however it is adjacent to the down line travelling from Lewisham to Hayes. The site is positioned between Lewisham station and Ladywell Station on the Courthill Loop.

##### Sidings

To remove spoil via rail, a new siding (classified as an internal loading line) would be required on the west side of the Wearside Road site and linked into the existing signalling network. Due to the space restrictions of Wearside Road, it is likely that the maximum length of sidings which can be achieved is in the region of 150m. There is also only enough room for one siding.

A shorter siding makes the spoil removal process a lot less efficient. A full freight train would typically require 320m for a siding. This allows for a loco and twenty wagons, each capable of carrying approximately 80T of spoil. If only 150m of sidings is available, approximately three times the number of train movements would be required for spoil removal on an already congested network.

##### Rail Capacity

The down line from Lewisham terminates at Hayes, therefore when a freight train leaves the proposed siding, it must travel across the Down Line on to the Up Line towards Lewisham. Currently, there are four trains per hour (outside of peak times) travelling on the Up Line, towards either Lewisham or New Cross Gate via Courthill Junction.

At this stage the end destination for spoil is unclear, so the assumption is that trains will join the nearest recognised freight path for transport to disposal points that have been used by previous projects (Crossrail, Thames Tideway etc.). Once on the Up line, trains will travel on a recognised freight path through the Courthill Junction area, and on towards a recognised disposal point.

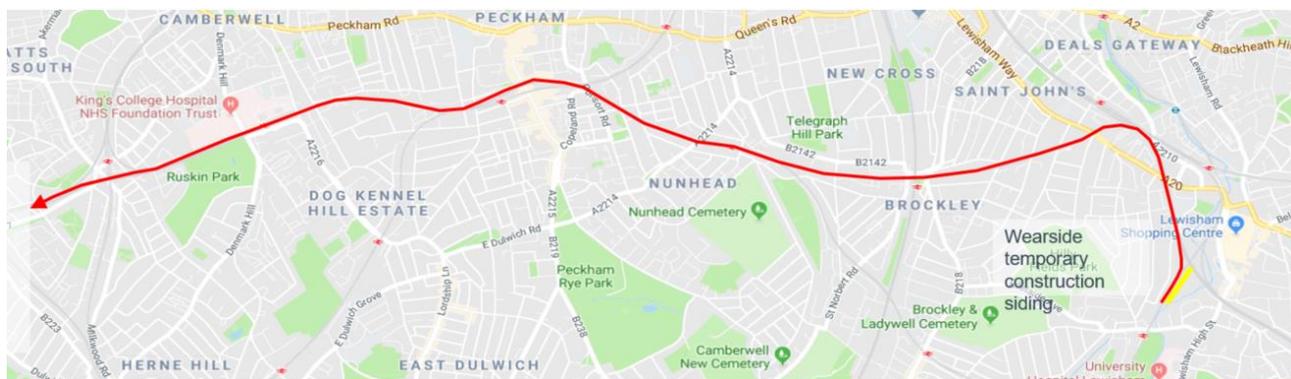


Figure 5 - Proposed freight route

### 3.4.2. Access onto the strategic road network:

Wearside lies approximately 1.5km from the closest point at which to access onto the strategic road network.

This route would involve travelling approximately 300m along a narrow residential street (Wearside Road) with parking on both sides. This is likely to require part suspension for periods of, if not all, the tunnelling duration.

Vehicles would then turn right and head south along Lewisham High street (A21) for 1.2km. This is a very busy high street, with pedestrian crossings, shops and residential premises along the entire length. It is also a key route on the south-east London bus network, and as such, has a bus lane.

Once vehicles have reached Catford, the South Circular (A205) is accessed via the Catford Gyratory.

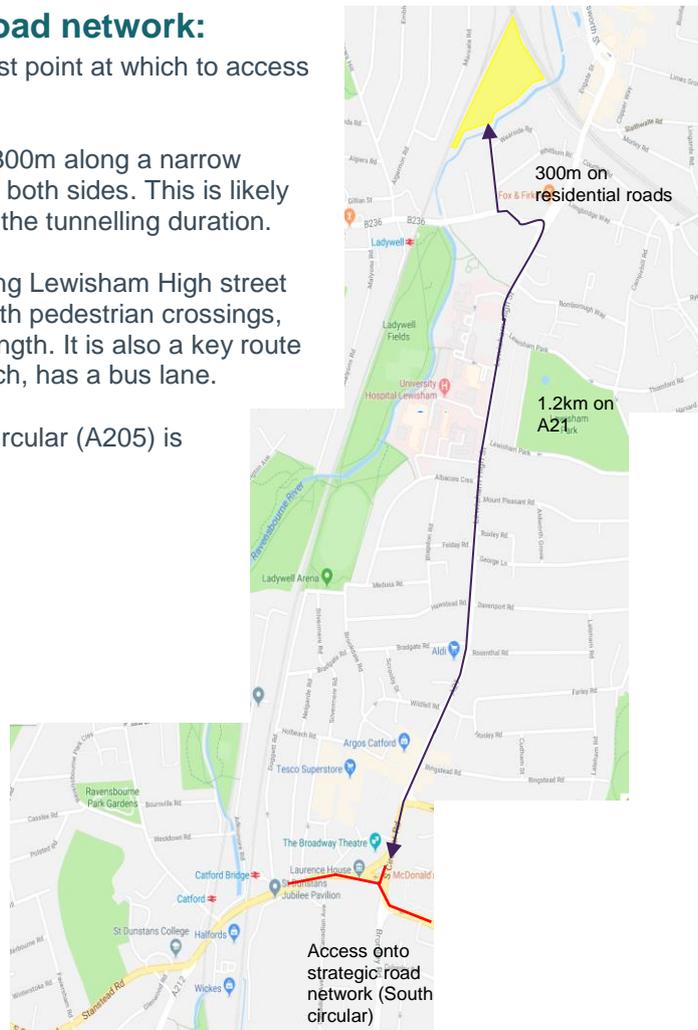


Figure 6 - Proposed road access onto strategic network

### 3.5. Summary

Advantages	Disadvantages
Good location – no additional tunnelling required	Smaller, more congested site means less efficient site – double handling.
Could be used as a turnback and stabling facility in permanent condition – no additional worksite required	Programme penalties incurred due to construction sequencing needs (site size)
Independent of station construction – programme advantages	Will potentially need to acquire additional land to facilitate tunnelling works
Single twin bore drive possible	Road access through residential streets (final 300m)
Direct access onto an established freight path	Must wait until TBMs reach E&C before tunnel fit out can commence
	More technically complicated temporary works required to enable tunnelling works
	Smaller length siding within site means shorter trains and therefore more train movements - less economical

# 4. Alternative Option (New Cross Gate)

## 4.1. Construction lay out

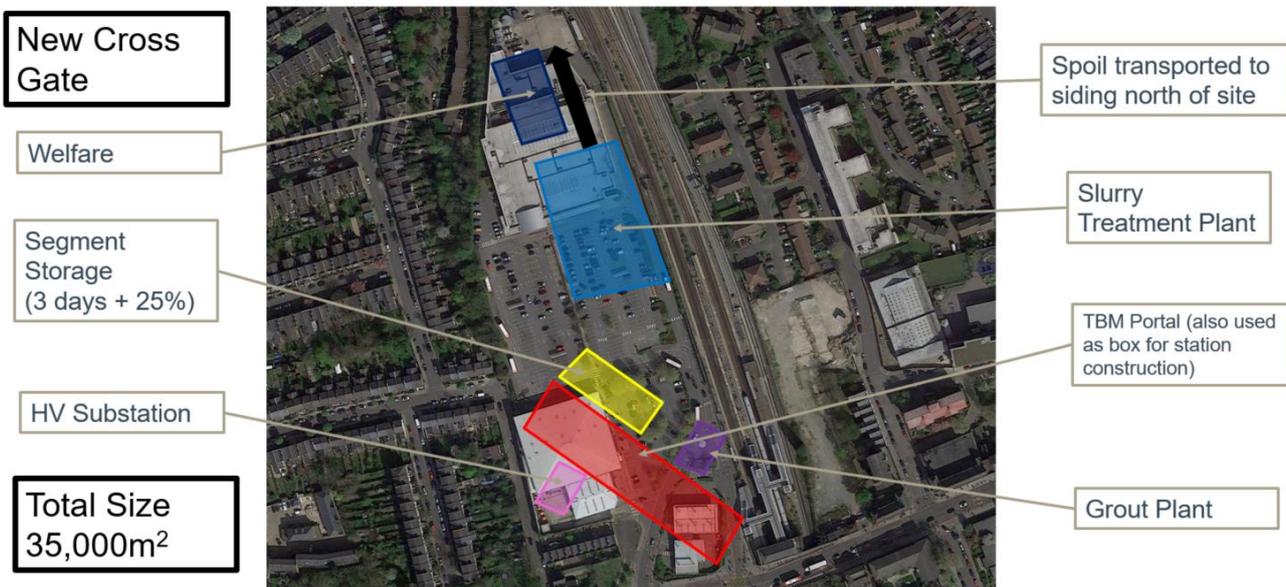


Figure 7 – New Cross Gate Site Layout

## 4.2. Tunnelling strategy

The second option for a principal worksite is at New Cross Gate, where a new underground station as part of the Bakerloo Line Extension is already proposed.

A station box (130m long x 30m wide) is currently the preferred design for the new station, rather than a mined solution, which is likely to be formed using contiguous piles or diaphragm walls. The box will be used as a launch portal for two TBM's concurrently, travelling south towards Wearside Road where they will be extracted from a reception shaft, stripped and transported back to New Cross Gate, for the final drive towards Elephant & Castle/Lambeth North.

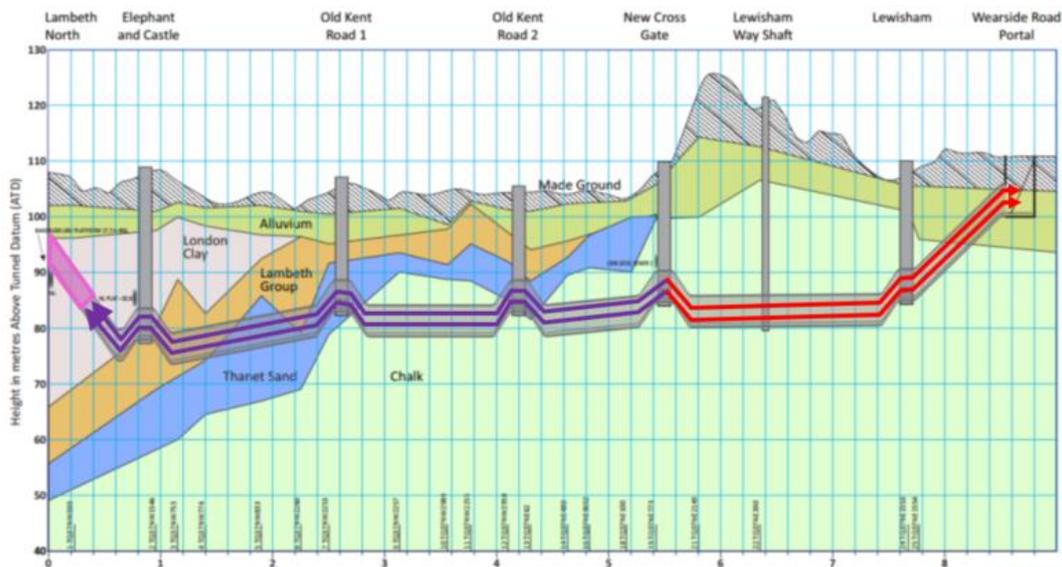


Figure 8 - TBM Drive

All spoil will be transported back to New Cross Gate, where it will be treated and disposed of via rail. A new siding is proposed on an area of land approximately 650m north of New Cross Gate (next to Mercury

Way/Cold Blow Lane). A conveyor will be used to transport treated spoil to a storage area adjacent to the sidings, where it will be loaded onto freight trains.

The advantage of using New Cross Gate as a principal worksite is there is a significant amount of space for the equipment required to service the TBM's - regardless of the chosen machine type. The station box can also be used as a launch portal, reducing the need for temporary works and provides cost efficiencies.

Once the first drive towards Wearside Road has finished, tunnel fit-out can begin between Wearside and New Cross Gate, whilst the tunnelling is continuing north towards Elephant & Castle/Lambeth North.

The main disadvantage is the tunnelling works will interface with the underground station works at New Cross Gate. The equipment required for servicing the TBM's (segment delivery/spoil removal) will prevent certain parts of the station from being constructed until the tunnelling works are finished. This will have to be factored into the construction programme and measures implemented to mitigate this programme risk.

There will also be a time/cost impact associated with stripping the TBM's down at Wearside Road, transporting them back to New Cross Gate and re-launching them at New Cross Gate towards Elephant & Castle/Lambeth North.

### 4.3. Construction strategy

New Cross Gate (NXG) is a significantly larger site, therefore there is more flexibility in site set up.

If the site to the east of the existing station is taken, it is suitable for welfare, offices and long-term storage. However with station construction on the west of the station, the need to shuttle materials via road regularly from east to west is inefficient and introduces risk to operatives and the general public.

#### Phase 1:

- Demolition of existing buildings on site
- Site setup (including plant/equipment to support tunnelling operations)
- Construct the temporary sidings north of the site (Mercury Way/Cold Blow Lane)

#### Phase 2:

- Construction of box (diaphragm wall/contiguous piles) and excavation - all spoil to be removed from site using freight trains on the temporary sidings
- Ensure soft eyes built into the sides of the box to enable TBM launch
- Launch TBMs and drive south towards Wearside Road
- At this point, the assumption is that certain enabling works to the north of the station box can take place, whilst still providing access for tunnelling operations (segment delivery/spoil removal etc.)

#### Phase 3:

- Once the drive to Wearside is complete, the TBM's will be dismantled, transported back to New Cross Gate and re-launched back towards Lambeth North/Elephant & Castle.
- At this point, the assumption is that the main works to the station structure to the south of the station box can commence. Access for servicing the tunnel drive at the north of the box will be maintained throughout.

#### Phase 4:

- Once tunnelling operations have finished and all spoil has been removed, work can continue on New Cross Gate station to complete civils, station fit-out etc.
- Temporary sidings can be removed
- Site demobilisation

## 4.4. Logistics Strategy

### 4.4.1. Rail access onto the recognised freight network

The proposed New Cross Gate principal worksite is next to the existing station, therefore a siding within the worksite isn't feasible as it is within platform limits. However, there is an industrial area 650m north of New Cross Gate station (adjacent to Cold Blow Lane/Mercury Way) which is being proposed.

#### Sidings

The site currently has a 340m long piece of track on the Up Main to London Bridge called the Up Sussex Loop, which is currently used for reversing trains or regulating the network. The proposal is to add new sidings to this line for use as loading lines, utilising the existing industrial area as necessary for additional space. The advantage of this site is it allows full length trains to be loaded, which minimises the number of train movements required. It also gives the opportunity to load more than one train at any one time as there is enough space to install additional new sidings.

Tunnelling spoil would be transferred from the principal worksite to the industrial area using conveyors and stored in a stockpile, for loading onto trains using an excavating grab or front-loading shovel.

#### Rail Capacity

All trains would have to depart southwards towards New Cross Gate station and onwards to Sydenham. This section is a four track railway, currently used extensively by passenger services without any freight paths except some rail treatment and stock moves. Pathing would be challenging and liaison between Network Rail and the TOC would be required to ensure movements can be accommodated.

From Sydenham, it travels onwards to Tulse Hill and Latchmere Junction, which currently has freight use. Capacity at this point is unlikely to be an issue, based on the current timetable.

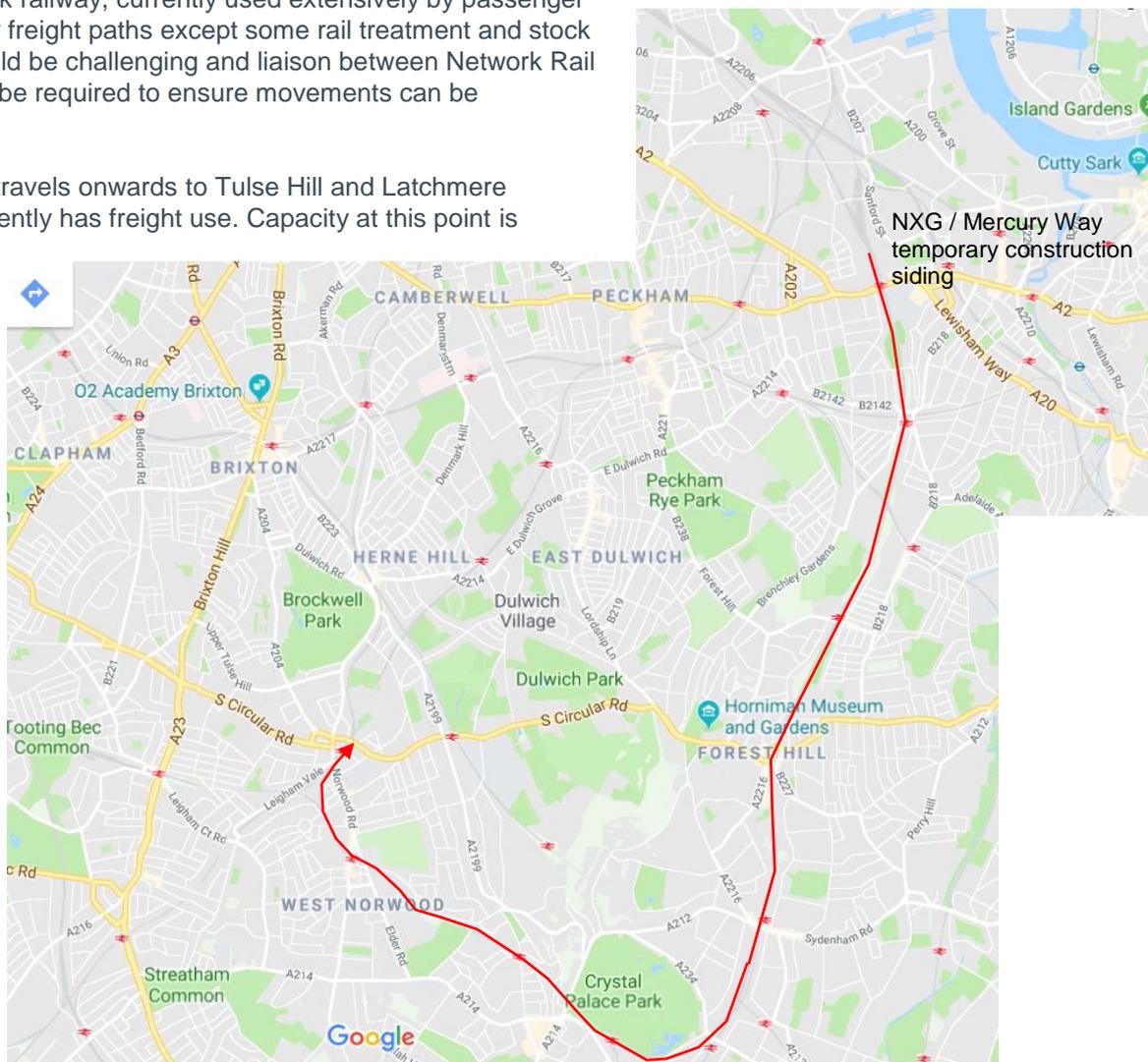


Figure 9 – Proposed freight route

#### 4.4.2. Access onto the strategic road network:

Access onto the strategic road network is simplest from New Cross Gate. The site lies directly on the A2 which is both part of the strategic road network and also a key freight route out to Kent.

It is assumed that vehicle access to the site would be at the same point as the existing access for store delivery wagons currently.

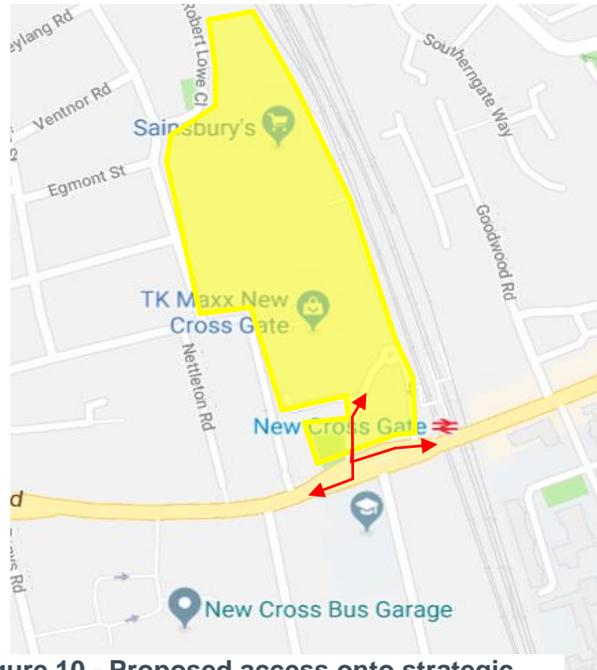


Figure 10 - Proposed access onto strategic network

#### 4.5. Summary

Advantages	Disadvantages
Large site allows for more efficient site operation	Multiple tunnel drives
Direct access onto strategic road network	Places New Cross Gate station on the critical path due to TBM servicing requirements
Potentially space for multiple sidings available north of site	Sidings are 650m away and will require permission from NR to go through their Maintenance depot
On route - No additional tunnelling required	Programme penalty incurred for relaunch
Road access is less impactful on local community	Additional demolition required at sidings location
NXG – WEA becomes independent of rest of tunnel – fit out and stabling works can commence as soon as TBMs taken out for relaunch at NXG	Train paths onto recognised freight route will be difficult

# 5. Hither Green

## 5.1. Construction lay out

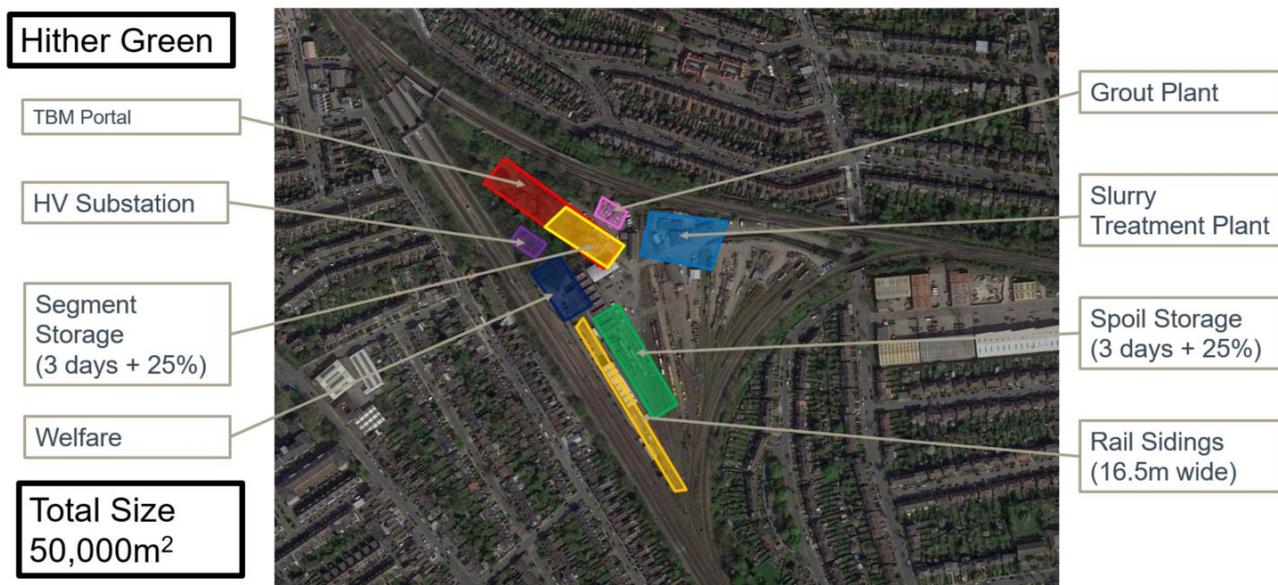


Figure 11 - Site Layout

## 5.2. Tunnelling strategy

The proposed site layout for Hither Green is very similar to Wearside Road, except that there is significantly more space available.

A portal (100m long x 25m wide) will be constructed at the northern end of the site for launching two TBM's towards Elephant & Castle/Lambeth North. The portal will consist of diaphragm/contiguous pile walls, with the intention that part of the walls can be used in the permanent case.

Once the TBM's have been launched, the portal area can be used for segment storage (similar to Wearside Road). However, as there is more space available the portal can be left open which allows segments to be transported more efficiently.

The main advantage of Hither Green is the size (50,000m<sup>2</sup>) as it gives sufficient space for plant required to service the TBM's and allows operations to be carried out more efficiently. There is also an existing sidings on the site which could potentially be used for the removal of spoil using freight trains (see logistics section).

It also allows tunnelling to continue independently of station construction with minimum interfaces (tunnel first or station first approach to be factored into the programme – similar to Wearside).

The main disadvantage is the additional tunnelling that would be required. 1.5km of twin bore tunnel would be required between Hither Green and Wearside, which would have cost and programme implications.

The system wide fit-out works cannot commence until the main drive has been completed. Slurry pumping/conveyors and segment delivery equipment will be required for spoil removal throughout the duration of the tunnel drive.

### 5.3. Construction strategy

A phased approach to the construction and site set up of Hither Green as a principal worksite:

#### Phase 1:

- Site setup
- Construction of portal (diaphragm/contiguous pile walls) and TBM erection
- Work on existing siding to ensure it is suitable for spoil removal using freight trains
- Installation of plant/equipment to support tunnelling operations (slurry treatment plant, HV substation, grout plant etc.)

#### Phase 2:

- TBMs to commence drives concurrently towards Elephant & Castle/Lambeth North.
- Slurry to be pumped back to the STP, pressed and the slurry cake is loaded onto freight trains for removal from site.
- Portal to be used for segment storage during tunnelling operations

#### Phase 3:

- Once tunnelling is complete and all spoil has been removed, the site can be cleared and all plant/equipment dismantled and removed from site.
- A diaphragm wall will be constructed in a section of the site. The ground level will then be reduced as required for permanent stabling facilities
- Permanent stabling facilities to be constructed and commissioned once systemwide works are complete

## 5.4. Logistics strategy

### 5.4.1. Rail access onto the recognised freight network

The proposed worksite is situated just south of Hither Green Station, between the lines running east to Lee and south to Grove Park. It is currently being used as a maintenance depot for freight trains.

#### Sidings

As the site is currently being used as a maintenance depot there are several existing sidings which could be utilised during construction, with signalled connections onto the national network. The length of the existing sidings means that a full freight train could be loaded, which reduces the number of additional train movements required on the rail network. It also means that multiple trains could be loaded/unloaded at any one time.

#### Rail Capacity

The site does not connect to main passenger running lines at Lee Spur Junction, but to the Up and Down Goods Loops. In turn, these are connected to several freight sidings to the east of Grove Park Carriage Siding.

Once wagons have been moved into the freight sidings, trains are formed and departed to the North via Lewisham and Nunhead; east via Lee and onto North Kent; or to the south east via Orpington. As this site is on routes used regularly by freight services there are numerous opportunities to access freight paths within the timetable in all three directions. The assumption at this stage is that they will take either of these routes to a recognised disposal point.

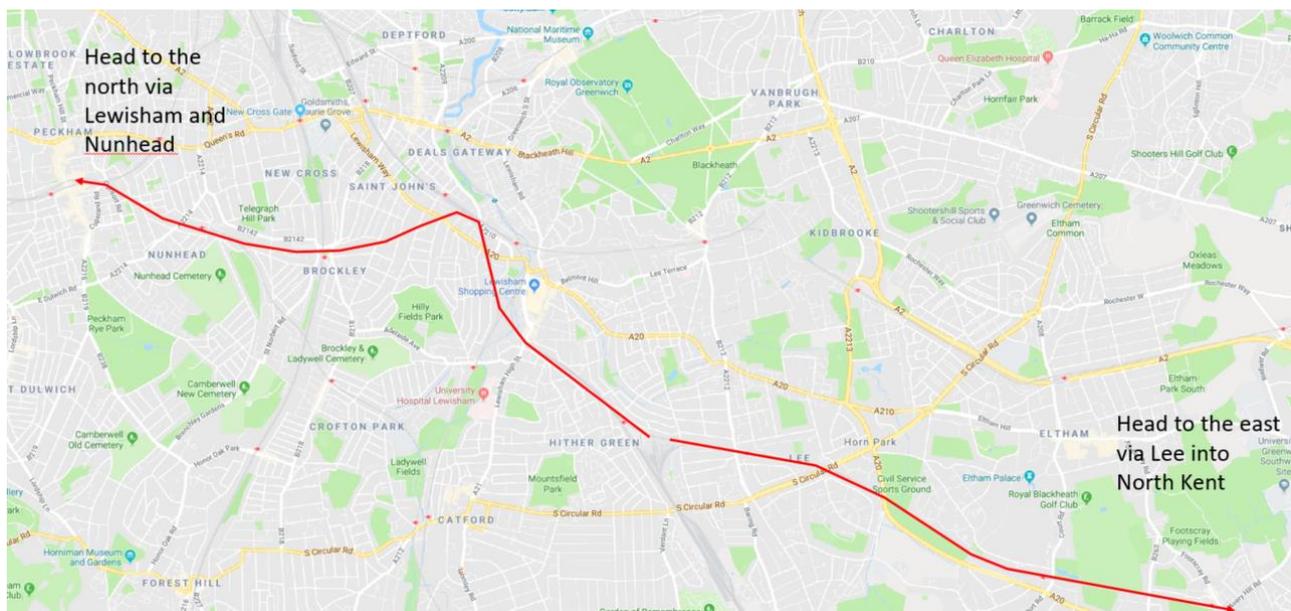


Figure 12 - Proposed access onto freight routes

### 5.4.2. Access onto the strategic road network:

Hither Green sidings yard lies approximately 550m from the closest point at which to access onto the strategic road network.

This route would involve travelling along a narrow residential street (Manor Lane) with parking on both sides, road humps and a 20mph speed limit. The parking may require part suspension for periods of, if not all, the tunnelling duration at least on one side of the road.

By turning left or right at the end of the road, vehicles would then have reached the South Circular road. This is part of the strategic road network but the junction is not managed by traffic lights.

To prevent a back up of traffic turning into a very busy main A-road, it is anticipated that the junction may need to be altered to install temporary traffic signals or traffic marshals as a minimum to manage the influx of heavy vehicles onto the road.



Figure 13 - Proposed access to strategic network

## 5.5. Summary

Advantages	Disadvantages
Large site – allows for more efficient site operations	1.5km additional tunnelling required - additional tunnelling costs and programme duration
Existing access to sidings and rail network	Extensive additional excavation required – HG currently several metres higher AOD
Additional stabling achieved	

## 6. Comparison

	Baseline Option	Wearside Road	New Cross Gate	Hither Green
<b>Size of available site</b>	23,640 m <sup>2</sup>	16000m <sup>2</sup>	34,000m <sup>2</sup>	50,000m <sup>2</sup>
<b>Methods of delivery / muckaway available</b>	Road and rail	Road and rail	Road and Rail	Road and Rail
<b>Impact on programme?</b>	Shortest programme	Loss of productivity and site becomes less efficient due to congestion	NXG station fit out on critical path. Additional 2 months required to relaunch TBMs	Additional 1.5km of tunnelling required
<b>Residents?</b>	No	Yes – along the entrance route and one side of site	Yes - On the east of the tracks and west of site	Yes – along the entrance route and one side of site
<b>Already required for extension construction?</b>	Yes	Yes – turnback at Lewisham	Yes – station location	Yes – stabling facilities
<b>Effect on network capacity</b>	Minimal	Mainline train every 15 mins	Mainline train every 6 minutes	Directly onto recognised freight path
<b>Sufficient space for sidings available</b>	Yes – to suit both muck away and segment deliveries	Single siding not full length	Capacity for multiple full length sidings	Existing multiple full length sidings available
<b>Distance to sidings / method of conveying</b>	- On site	- Sidings right next to shaft	650m Method of conveying muck required to reach optimised sidings at Cold Blow Lane	- Sidings right next to portal
<b>Quality of road network</b>	Direct access onto strategic road network	Main road accessible via residential street	Main artery road through to Kent (A2)	Main road accessible via residential street
<b>Where will TBMs end up?</b>		2x TBMs at E&C	2x TBM at E&C	2x TBM at E&C