London Underground
Capacity Optimisation Programme

Earth Structures Remediation

Feasibility Report

Kingsbury to Wembley Park

B088/EM4

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Prepared by: [redacted] Joseph Kennedy BSc (Hons), FGS Discipline Engineer	Checked by: [redacted] Martyn Tribe Construction Manager
Approved by: Athanasios Papachrysanthou Principle Lead Engineer	[redacted] 22/01/15

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1 Introduction

London Underground - Capacity Optimisation Programme (LU COP) Earth Structures team, have been commissioned to carry out a feasibility study, relating to the planned remediation of embankment B088/EM4. The embankment was re-assessed in 2014 by LU COP [1] and assigned an ACA classification of 76% E2 (Poor), 14% D (Poor) and 10% A (Serviceable). As a result, remedial works are planned to upgrade the whole of the embankment to an ACA classification of '100% A', in accordance with LUL Engineering Standards 1-054 and 1-031.

The purpose of this document is to investigate any constraints and consider all potential options for remediating embankment B088/EM4. Following assessment of each of these remedial options, preferred options will be selected. This feasibility study will take into consideration the following key topics when selecting preferred remedial options:

- Site Description
- Environment
- Access
- Compound
- Potential Remedial Options

Important Note: Both visual evidence and geotechnical monitoring has indicated slope instability between chainages B088/JSB1330 to JSB1370, on embankment B088/EM4. The recorded movements have breached the 'Amber' trigger level defined in the Earth Structure Assessment – Emergency Preparedness Plan [2]. As a result, an engineering review panel meeting has been convened and possible emergency stabilising measures explored. These potential emergency works do not form part of this feasibility study and will be addressed in separate documentation.

1.1 Standards and Documents

The following standards and other documents have been referenced within the text:

- LUL Engineering Standard 1-031 – Asset Condition Assessment and Certification;
- LUL Engineering Standard 1-054 A3 – Civil Engineering – Earth Structures;
- LU Earth Structures Design Guide, Mott MacDonald Report for LUL, July 2012;
- LU Emergency Preparedness Plan (EPP), Earth Structure Assessment – LUL CPD JNP, June 2014. Doc No: TLL-L001-P855-HSE –PLN-00002;

2 Site Description

2.1 Site location

Embankment B088/EM4 is located adjacent to the southbound Jubilee Line track from LU LCS chainages B088/JSB1070 to JSB1615. It has a total length of approximately 545m and is located between Kingsbury and Wembley Park Stations. Asset Location Plans are presented in Appendix A and a 'Site Location Plan' presented in Appendix B.

2.2 Earth Structure Description

The slope form is variable along the embankment length and reaches a maximum height of approximately 7m-8m at chainage JSB1615, before reducing in height to the north until it reaches natural ground level at chainage JSB1070. The embankment slope has an approximate angle of 20° to 25° and generally split into two slopes, by a mid-slope terrace with an approximate slope angle of 2° to 10°. The Wealdstone Brook runs through a culvert (S3) beneath the embankment at chainage JSB1320 and continues to run parallel to the toe of the embankment up to JSB1600. North of the culvert, the toe of the embankment slope is, bounded by residential gardens on Uxendon Hill. The southern end of the embankment terminates at bridge S2.

2.3 Brief History of Embankment

- Constructed between 1930 and 1932, the embankment was described as a feat of engineering and involved moving nearly 500,000m³ of earth and diverting the fast flowing Wealdstone Brook.

- There has been a history of slope instability and poor track performance, dating back to its initial construction.

- Previous remedial works have been undertaken on two occasions with varying degrees of success. This included lime piles, mix in place grout logs and injection grouting.

2.4 Existing Structures

A summary of the existing structures on embankment B088/EM4 are, summarised below:

Earth Structure Asset	Structure Asset Number	Description
B088/EM4	W502	Reinforced concrete open culvert
	W503	Steel sheet piled wall with concrete capping beam. Third Party asset (Environment Agency)
	W518	Reinforced concrete wall
	S3	Reinforced concrete bridged culvert
	W670	Piled, reinforced concrete retaining structure
	S2	Single span, iron girder bridge, supported by brick abutments and wing walls

The location of each of these exiting structures can be found on the Asset Location Plans presented in Appendix A. A detailed description of the structures, along with 'As-Built' and historical drawings are detailed in the LU COP Earth Structure Assessment (ESA) Report (2014) [1].

2.5 Drainage

The remnant of a drainage ditch runs parallel with the toe of the embankment between chainages JSB1070 to JSB1320, with significant ponding recorded in this area during periods of wet weather. At approximate chainage JSB1100, a single catchpit is located at the toe of the embankment, with a single drainage carrier pipe infall and outfall. The pipe runs parallel with the toe of the embankment and is believed to connect to track drainage further north of the embankment. The outfall pipe terminates within the ditch described above, contributing to the ponding at the toe of the embankment.

2.6 Services

A single new (2nd generation) cable run is located at the crest of the embankment and runs parallel with the track.

2.7 Ground Model

The embankment is predominantly constructed from two types of reworked cohesive embankment fill material, defined as reworked London Clay (EFC A) and reworked Alluvium (EFC B). Ballast and ash of varying thickness overlies the EFC A at the crest and across the embankment shoulder. The embankment is founded on cohesive Alluvium of varying thickness, followed by Weathered London Clay and London Clay with depth. Both EFC A and EFC B are high plasticity, with low peak and residual strength.

2.8 Deformation Mechanisms

2.8.1 Deep-seated Instability

Long-term slope stability analysis was carried out in the LU COP ESA Report (2014) [1], using the approach laid out in the LU Earth Structures Design Guide (LU ESDG). The analysis model used clay fill with cautious peak strength and a weakened basal layer with residual strength extending from the toe. By applying this model, this dictates the deformation mechanism encountered, which in the case of embankment B088/EM4, is a deep-seated slip with failure affecting both the track and lineside services, and daylighting at the embankment toe. The global Factor of Safety (FoS) against deep-seated failure ranged between 0.88 to 1.39 (unfactored), which in parts is below the minimum global FoS requirement of >1.10, defined in the LU ESDG.

Inclinometer monitoring at chainages JSB1345 and JSB1360, has identified deep-seated slip surfaces that are in agreement with the worst-case deep-seated slip surfaces calculated in the slope stability analysis. This suggests that this deformation mechanism is already progressively taking place on the embankment and likely to continue until complete failure occurs.

Remedial works are therefore required in order to achieve a global FoS >1.10 against deep-seated slope instability and stop the progressive deformation of the embankment.

2.8.2 Shallow Instability

A combination of relatively shallow slope angles and moderately dense vegetation on the slope surface makes it unlikely that shallow instability will be a dominant deformation mechanism on embankment B088/EM4. Where shallow slips were analysed in the LU COP ESA Report (2014) [1], the FoS against shallow failure ranged between 1.15-1.17, which is above the minimum requirement of 1.15 as detailed in the LU ESDG. Shallow shoulder instability is also unlikely owing to the good condition of the mix in place grout logs stabilising this area of the embankment.

One form of shallow instability that is present on the embankment is downward soil creep deformation, which has been recorded in geotechnical monitoring. This is especially evident downslope of structure W670, where the top of the piles have been exposed.

When designing remedial works to stabilise deep-seated instability discussed in Section 2.7.1, consideration must be given to the affect that removal of vegetation will have on shallow stability. Stabilising works to stop downward soil creep deformations should also be considered.

2.8.3 Serviceability Instability

Serviceability instability in the form of seasonal shrink-swell cycles has been recorded by geotechnical monitoring on embankment B088/EM4, as detailed in the LU COP ESA Report (2014) [1]. Seasonal shrink-swell movements are a result of the seasonal changes in moisture content of the embankment fill. Upward movement (heave) in the winter of 20mm-30mm and downward movement (settlement) in the summer of 30mm-40mm has been recorded.

When designing remedial works to stabilise deep-seated instability discussed in Section 2.7.1, consideration must be given to the affect that removal of vegetation will have on serviceability instability, with consideration given to stabilising works that reduce this seasonal affect.

3 Environment

3.1 Vegetation and Wildlife

The embankment is densely vegetated with a mixture of mature deciduous and evergreen trees and shrubs, with dense brambles on the upper slope. Various tree species are present, including high water demand species such as Sycamore, False Acacia (Rubinia), Willow and English oak. At present, there are no tree preservation orders in place on embankment B088/EM4. No invasive species such as Japanese Knotweed or Giant Hogweed are present on the embankment. It is therefore feasible to remove the vegetation from the embankment without any restrictions.

Wildlife activity in the form of burrowing was observed across the embankment, particularly in the ash at the crest. No protected species have been identified on embankment B088/EM4, although there is a potential for Slow Worms, given the close proximity of Fryent Country Park and the Tube Lines Nature Reserve, both of which host protected species. The presence of protected species could create restrictions that will need to be considered when undertaking the design of any proposed remedial works, therefore, a full ecology survey should be undertaken.

3.2 Noise and Vibration

Noise monitoring may be required depending on the remedial option adopted, due to the vicinity of residential properties on Uxendon Hill. The embankment is inter-station, therefore the LU noise register is not applicable, with the nearest station (Wembley Park) classified as 'Red'. Generally, embankment remedial works are undertaken during daylight sociable hours, therefore noise restrictions will not apply unless particularly noisy. A Section 61 should be considered if works are to be undertaken at night.

Vibration from construction works could pose an issue to third party assets and will need to be considered in any design of remedial works. There are no existing structures on, or near embankment B088/EM4, which are beyond the normal sensitivity to vibration.

3.3 HMU

No hazardous materials have been identified on embankment B088/EM4, with the exception of potential asbestos sheeting fly tipped from residential properties bounding the site. There are no records of any soil contamination above the expected background levels for a railway embankment site. Additional surveys and permits will be required at detailed design and construction stages, however at present, there are no issues that could affect the feasibility of remediating the embankment.

3.4 Unexploded Ordinance (UXO)

UXO is considered to pose a low risk, owing to the fact that the embankment has been remediated in the past and no UXO risk was identified. In addition, historical Desk Study Reports and Design Reports have not revealed any risk of UXO on the embankment. At this stage, UXO should not be considered to affect the feasibility of any potential remedial options. A full survey will be required prior to undertaking the detailed design.

3.5 Third Party and Utility Services

There are no known third party or utility services present on, or beneath embankment B088/EM4. The embankment has been remediated in the past and no services were identified that posed a risk to the construction works. In addition, historical Desk Study Reports and Design Reports have not revealed any evidence of third party or utility services. At this stage, third party or utility services should not be considered to affect the feasibility of any potential remedial options. A full survey will be required prior to undertaking the detailed design.

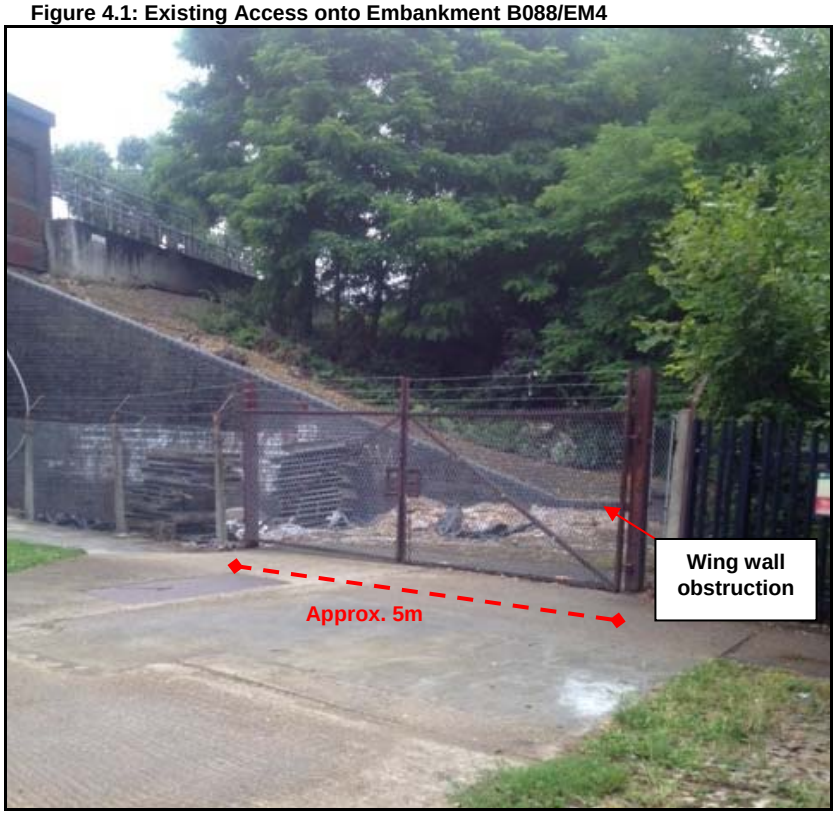
4 Access

4.1 Existing Option

At present, there is one permanent access point onto the embankment, located off The Avenue at approximate chainage B088/JSB1615 (See Site Location Plan – Appendix B). It comprises double access gates of approximately five meters in width, installed into the existing LU boundary fenceline, adjacent to overbridge S2 (Figure 4.1). A concrete crossover was installed between the road and access gate as part of previous remedial works on the embankment. This crossover is in good condition and negates the requirement for additional temporary works to allow plant to access the embankment from the road. The access gates are of a sufficient width to not pose any significant restrictions when considering possible remedial options. It also offers the option of making direct deliveries to the embankment. Other considerations required when using this access point are as follows:

- Suitably designed third party asset protection will be required for a telephone mast and exchange box, located adjacent to access point (Plate 6 Appendix C).
- A full time lorry marshal/banksman will be required at the access point at all times, to ensure public and third parties are segregated from construction traffic attending the site.
- There is a potential to explore segregating an additional area in front of the existing gates, to create a larger space between the road and the embankment, see Section 5.2 for further discussion.
- Access negations with the Local Council, contact details are presented in Appendix D.

Figure 4.1: Existing Access onto Embankment B088/EM4



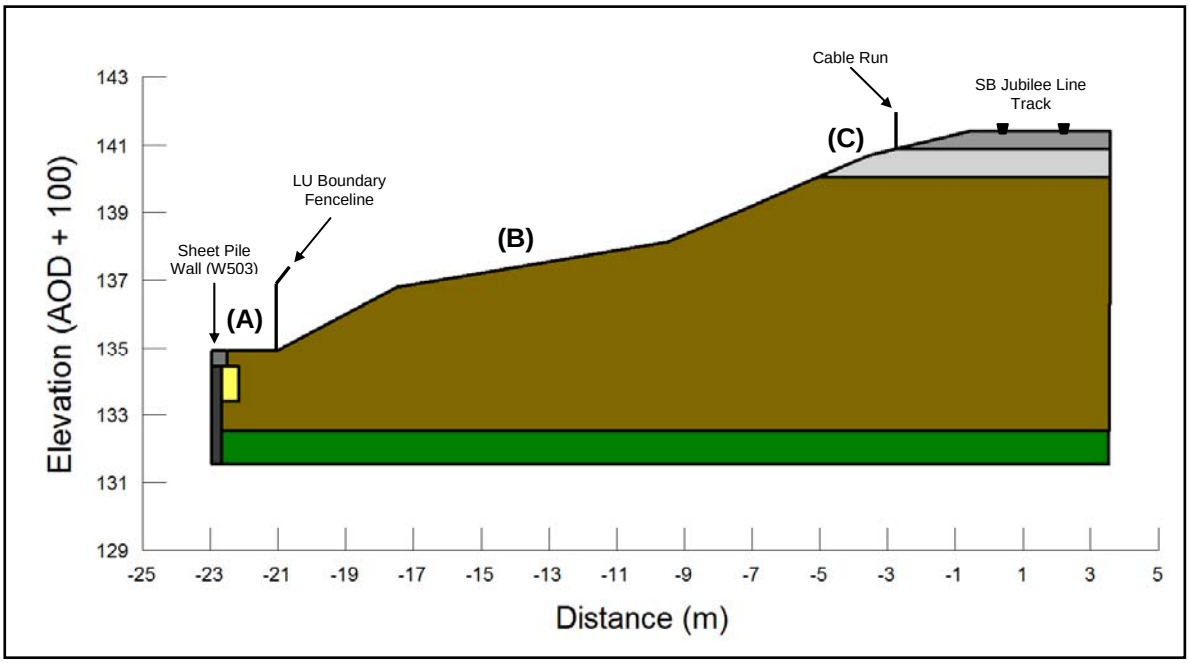
Beyond the access gate, the wing wall of bridge S2 runs perpendicular from the main bridge structure across the area in front of the gates (Figure 4.1), posing an obstruction to any onward access onto the embankment. Suitable temporary works will be required to ramp over this structure and protect it throughout any construction works.

4.2 Embankment Access

Access to areas along the embankment, beyond the access point described in Section 4.1, is extremely limited in its current condition for the following reasons:

- The proximity of the sheet piled wall (W503) restricts the movement of plant and machinery along the toe of the embankment. *(A) - Figure 4.2*
- An existing mid-slope terrace, representing the remnants of an access road constructed for previous remedial works, is not feasible to reuse, owing to its poor construction and the low strength of the embankment fill that supports it. *(B) - Figure 4.2*
- As discussed in Section 3, the embankment is currently densely vegetated with mature trees and shrubs.
- The crest is not of a sufficient width for plant to use to access along the embankment. *(C) - Figure 4.2*
- The presence of the reinforced concrete bridged culvert (S3) at approximate chainage JSB1300, will require suitably designed temporary works to bridge over it without the risk of overloading the structure.

Figure 4.2: Typical Cross Section of Embankment B088/EM4 Showing Access Restrictions



To access the length of the embankment, suitably designed temporary access roads will need to be constructed, taking into consideration the low strength of the embankment fill, along with existing and historical instability of the embankment. Restricted access along the embankment is an issue for any potential remedial option considered.

4.3 Potential New Option

There is a potential to create a new access point onto the embankment at approximate chainage B088/JSB1200 (See Site Location Plan – Appendix B). Access is possible between residential properties 79 and 81 Uxendon Hill (Figure 4.3), where an access lane exists to service an electrical substation, located adjacent to the existing LU boundary fenceline (Plate 8 Appendix C). Considerations required to use this access point are as follows:

- Protection of third party assets will be required, including neighbouring properties, fencing, pathway, walls and areas within Fryent Country Park.
- A full time lorry marshal/banksman will be required at the access point from the lane entrance on Uxendon Hill, to ensure public and third parties are segregated from construction traffic attending the embankment.
- Access negotiations will be required with the Local Council, neighbouring properties and owners of the electrical substation. Contact details are presented in Appendix D.

Figure 4.3: Potential Access onto Embankment B088/EM4

By utilising this additional access point, it will allow the separation of the embankment into two independent working sections, each supplied by separate access points. It will also negate the requirement to construct temporary works over the existing reinforced concrete bridged culvert (S3). This would inevitably reduce the programme length and cost and should be considered in the temporary works design for any permanent remedial works. Further discussion on the benefit of utilising this additional access point can be found in Section 7.4.2.

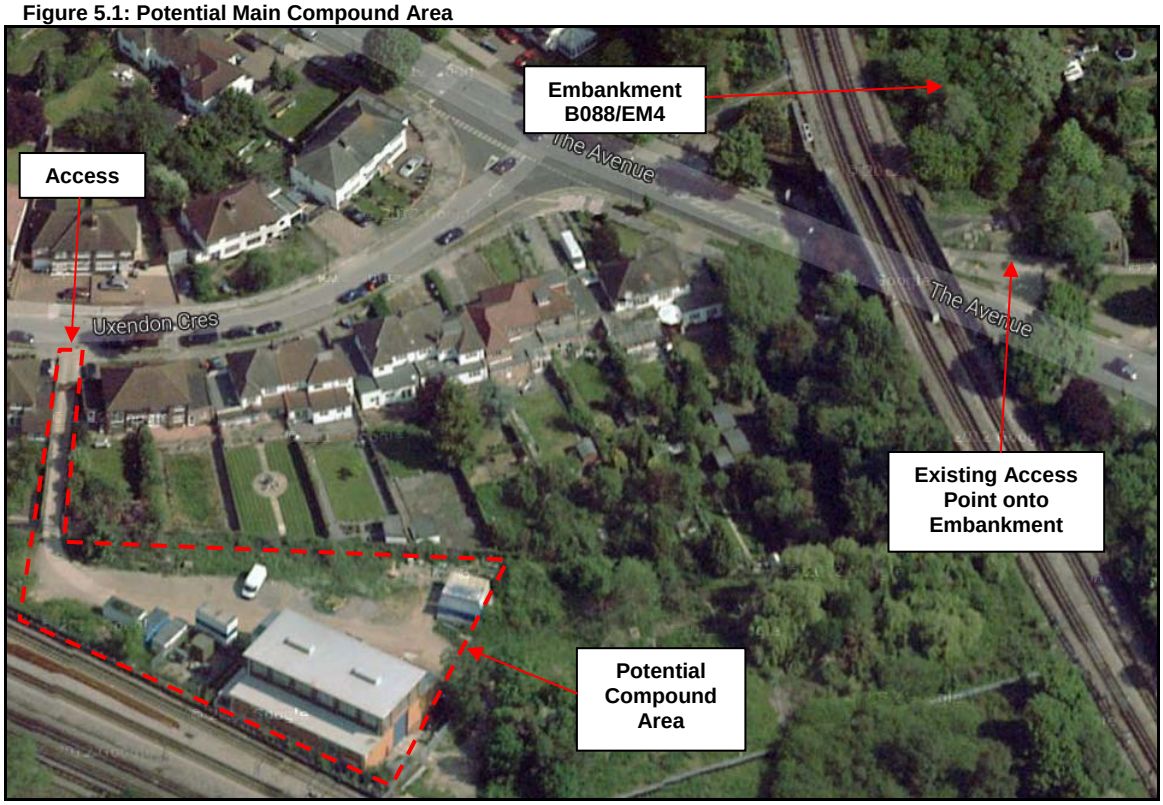
5 Compound

5.1 Main Compound

There is the potential to install a main compound on land adjacent to the Metropolitan Line, in the area of Substation SGS4 (See Site Location Plan – Appendix B). The area is located to the rear of residential properties on Uxendon Crescent, with access possible between residential properties 24 and 26 (Figure 5). Historically, the area has been used as a compound by track maintenance teams, therefore, it already has a suitable working surface and secure gated access (Plates 1-4 Appendix C). The area is of a sufficient size, such that all potential remedial options can be considered, without the compound size posing any restrictions. Considerations required to use this compound area are as follows:

- Access and land use negotiations, along with third party asset protection and parking restrictions to ensure unimpeded access. Contact details are presented in Appendix D.
- Services connections, including Water, Sewerage, Electricity, Communications.
- Security when the compound is in use.
- A full time lorry marshal/banksman will be required at the access point from Uxendon Crescent, to ensure public and third parties are segregated from construction traffic attending the compound.

Figure 5.1: Potential Main Compound Area

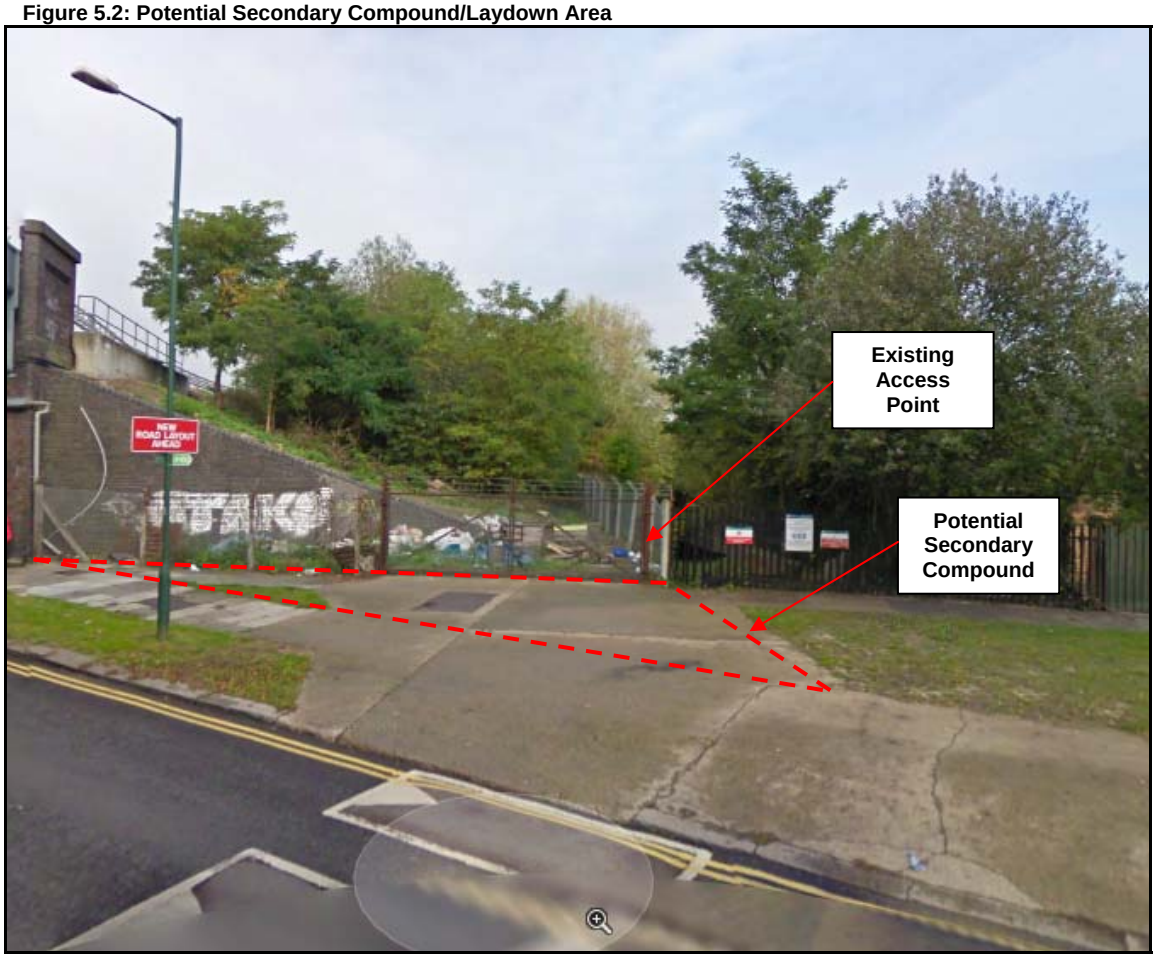


5.2 Potential Secondary Compound/Laydown Area

As discussed in Section 4.1, the area in front of the existing access point offers an opportunity to create a secondary compound/laydown area for deliveries of materials. This could prove more useful for delivering materials used on a daily basis, with longer-term storage of materials and site welfare located in the main compound detailed in Section 5.1. Considerations required to use this compound area are as follows:

- Access and land use negotiations, along with third party asset protection and parking restrictions to ensure unimpeded access. Contact details are presented in Appendix D.
- Security when the secondary compound is in use.
- A full time lorry marshal/banksman will be required to ensure public and third parties are segregated from construction traffic attending the embankment.

Figure 5.2: Potential Secondary Compound/Laydown Area



6 Remedial Options Considered

6.1 Considerations from Section 2 - Section 5

Table 6.1: Summary of Considerations from Section 2 - Section 5

Topic	Consideration
Embankment History	• History of slope instability and poor track performance.
Existing Structures	• There are six existing structures present on, or adjacent to the embankment, that may require protection.
Drainage	• The remnant of a drainage ditch runs parallel with the toe of the embankment between chainages JSB1070 to JSB1320, with significant ponding recorded in this area during periods of wet weather. • At approximate chainage JSB1100, a single catchpit is located at the toe of the embankment, with a single drainage carrier pipe infall and outfall.
Ground Model	• The presence of low/residual strength embankment fill material.
Deformation Mechanisms	• Dominant deformation mechanism is a deep-seated slip affecting both the lineside services and track, and daylighting at the toe of the embankment. • The affects that any potential remedial works will have on shallow and serviceability instability will also need to be considered.
Vegetation and Wildlife	• No restrictions at present, ecology report required to confirm.
Noise and Vibration	• No restrictions at present beyond that normally expected.
HMU	• No restrictions at present, additional surveys required.
UXO	• No restrictions at present, additional survey required.
Third Party/Utility Services	• No restrictions at present, additional survey required.
Access	• Access is sufficient onto the embankment to consider all remedial options.
Access across the Embankment	• At present, there is no suitable access across the embankment for plant or materials.
Compound	• Compound options are sufficient such that all remedial options can be considered.

6.2 Assessment of Remedial Options

Table 6.2: Assessment of Remedial Options

Remedial Option	Advantages	Disadvantages
Granular Replacement	• Well proven technique. • Simple to design. • Suitable for all ground conditions. • No specialist plant required. • Material cost is inexpensive. • No maintenance required post construction.	• May require considerable excavation into an already unstable embankment. • Large quantities of material to remove from site. • Large volumes of engineering fill imported to site. • Large number of lorry movements for import and export of materials in a busy residential area. • Large storage area required for stockpile of materials. • Potential to reduce FoS during construction. • Prohibited/restricted by inclement weather.
Slope Regrade and Toe Berm	• Well proven technique. • Simple to design. • Suitable for all ground conditions. • No specialist plant required. • Material cost is inexpensive. • No maintenance required post construction.	• Large volumes of engineering fill imported to site. • Large number of lorry movements for import and export of materials in a busy residential area. • Large storage area required for stockpile of materials. • Prohibited/restricted by inclement weather. • Requires large amount of space at the toe of the embankment, which B088/EM4 does not have. • Adds weight at the toe, which could affect the stability of W503.
Gabion Toe Wall / Toe Berm	• Well proven technique. • Suitable for all ground conditions. • No specialist plant required. • Allows the construction of toe berms without the need for more space at the toe of the embankment. • Material cost inexpensive.	• Requires excavation at the toe of an already unstable embankment. • Large volumes of engineering fill imported to site. • Large number of lorry movements for import and export of materials in a busy residential area. • Considerable Temporary Works excavation may be required. • FoS potentially reduced during construction. • Gabion foundation may be considerable (mass concrete/shear key needed) and difficult to construct. • Maintenance required post construction. • Adds weight at the toe, which could affect the stability of W503.

Table 6.2: Continued…..

Remedial Option	Advantages	Disadvantages
Discrete Bored Piles	• Well proven technique, recently used on a comparable embankment with success. • Suitable for all ground conditions. • Can provide high lateral support forces. • No maintenance required post construction. • Temporary Works (piling platform) can become part of permanent works on completion. • No significant excavations required.	• Potentially significant Temporary Works required in the form of piling platforms. • Large number of lorry movements for import and export of materials in a busy residential area. • Large storage area required to stockpile material. • Tall Plant concessions required for piling rigs.
Soil Nails	• No significant excavations required. • Cost effective compared to other solutions. • Relatively quick to install. • Temporary Works can become part of permanent works on completion.	• Specialist contractor required. • Trials and testing required prior to full implementation. • Potentially significant Temporary Works. • Increased maintenance. • Does not have a 120-year design life. • Questionable applicability to high plasticity clay slopes.
Electrolysis/Electro-osmosis	• Cost effective compared to other solutions. • Very nonintrusive with minimal access requirements. • Small plant and labour requirements. • Soil nails and slope drainage left in place after treatment. • Very little Temporary Works required. • Quick to install with almost instant stabilising effects.	• Specialist contractor required. • Increased maintenance of soil nails and slope drainage. • Unproven technique, with only a small number of recent case studies available. • Difficult to assure 120-year design life.
Sheet Piles	• Well proven technique. • Can provide high lateral support forces. • Temporary Works (piling platform) can become part of permanent works on completion. • Relatively quick to install.	• Potentially significant Temporary Works required. • Tall Plant concessions required for piling rigs. • Length of sheet pile may require very large plant to install. • Specialist contractor required. • Increased maintenance post construction. • Significant vibrations during installation.

7 Selection of Preferred Remedial Options

7.1 Preferred Remedial Options

Following review of the considerations outlined in Table 6.1 and assessment of potential remedial options detailed in Table 6.2, along with the requirements of LU Standard 1-054, a single preferred remedial option has been chosen, comprising:

- Discrete Bored Piles

Along with:

- Minor Granular Replacement/Granular Capping Layer
- Toe Drainage

This remedial option has been chosen as it provides long-term stability against the deep-seated instability described in Section 2.8.1, without drastically changing the existing slope profile. Discrete bored piles can be constructed in continuous rows where required, depending on the embankment height and width. The piles are designed such that they terminate below the final slope profile and therefore are not visible once the works are complete. They require no maintenance post construction and adhere to the requirement for a 120-year design life, as defined in LU Standard 1-054. There will be no interface or impact with any existing structures or third party assets on the embankment when the final remedial solution has been implemented. At no point throughout the construction of the piles will the embankments FoS be reduced by the works, with no requirement to make large excavations into the slope or import large amounts of materials. This option is feasible to construct within the constraints of the embankment layout. Discrete bored piles have recently been used to successfully stabilise a comparable embankment at Canons Park (B084/EM4), therefore a recent case study can be drawn upon to review the lessons learnt and optimise the design.

The discrete bored piles can be constructed from a piling platform, which is benched into the existing slope profile, negating the requirement for additional space at the toe of the embankment. Whilst the temporary works to construct the piling platform could be significant, it can be left in place to become part of the permanent works and form part of a granular capping layer across the embankment surface. The construction of the piles can be undertaken by a variety of piling rig sizes, depending on the embankment constraints. The access and compound options described in Sections 4-5 are sufficient to not pose any constraints on the constructability of the remedial option.

Any impact of the temporary works on third party assets will be assessed accordingly, i.e. stability of the sheet piled wall (W503), with imposed temporary loading and any risks associated, mitigated through engineering solutions.

The addition of the minor granular replacement/granular capping layer will help to stabilise the slope against shallow instability, that could occur as a result of the removal of vegetation from the slope surface, as discussed in Section 2.8.2. It will also provide a capillary break between the surface and the clay in the embankment core, which in combination with the removal of the mature vegetation, should help to reduce seasonal deformations in the form of shrink swell cycles of the high plasticity clay, contributing to serviceability instability, as discussed in Section 2.8.3.

Toe drainage will reduce the susceptibility of ponding at the toe of the embankment and capture any surface runoff from the relatively impermeable compacted granular capping layer. The drainage could comprise a perforated pipe, installed at the bottom of a filter drain, with potential discharge into the Wealdstone Brook. The existing catchpit at chainage JSB1100 can be used as part of the new drainage system, or ungraded if found to be unsuitable.

7.2 Discounted Remedial Options

Table 7.2: Discounted Remedial Options

Remedial Option	Reasons For Rejection
Granular Replacement	This remedial option requires considerable excavation at the toe of the embankment. This is considered undesirable, owing to the low embankment fill strength and records of historic and current slope instability on the embankment. In addition, this option is considered impractical owing the very large amounts of material required to be removed and replaced with engineering fill.
Slope Regrade and Toe Berm	A lack of space exists between the toe of the embankment and sheet piled wall W503. This makes regrading to a slacker slope angle impractical. Constructing a toe berm that is sufficient to stabilise deep-seated slope instability could risk overloading W503. In addition, it requires the importing of very large amounts of engineering fill material. For both these reasons, this option is considered impractical.
Gabion Toe Wall and Toe Berm	Constructing a gabion wall and toe berm at the toe of the embankment could risk overloading W503. Gabion wall foundations may require deep excavation at the toe of the embankment, possibly requiring significant temporary works to ensure embankment stability. Finally, it requires the importing of very large amounts of engineering fill material. For all these reasons, this option is considered impractical.
Soil Nails	This remedial option has been rejected, as it will require a significantly conservative design/maintenance to provide the 120-year design life required as part of LU Standard 1-054. It is considered undesirable owing to its questionable application to high plasticity clay slopes and the significant and complex maintenance requirements post construction.
Electrolysis/Electro-osmosis	Whilst simple to construct and very nonintrusive, it is an unproven technique with little evidence to justify it meeting the 120-year design life required as part of LU Standard 1-054. Increased maintenance requirements post construction could also make it impractical.
Sheet Piles	The expected depth of embedment for the sheet piled wall would require significant temporary works and very large plant to install. This is considered impractical owing to the embankment space constraints and issues with very tall plant next to an operational railway.

7.3 Potential Temporary Works

To construct the chosen remedial option, it is envisaged that the following temporary works will be required:

- Main and secondary compound setup.
- Protection of LU and third party assets.
- Access ramps and roads.
- Piling platforms.
- Temporary scaffold pole and ply retaining walls.
- Excavations / shoring.
- Protection of lineside services.
- Temporary ramps over bridged culvert S3 and the northeast wing wall of overbridge S2.

Each of the above temporary works is feasible to construct on embankment B088/EM4, taking into account the considerations detailed in Table 6.1.

7.4 Potential Construction Sequence

Based on the chosen remedial option discussed in Section 7.1, the following potential feasible construction sequences could be implemented. 'Option A', is based on utilising only the existing access point onto the embankment, as discussed in Section 4.1, with 'Option B', based on utilising both the existing and potential new access point discussed in Section 4.3.

7.4.1 Potential Construction Sequence - Option A

The following potential high-level construction sequence is based on utilising the existing access point only.

1. Install temporary works at existing access point.
2. Construct ramp over northeast wing wall of overbridge S2.
3. Bench into existing embankment slope and replace with engineering fill material, to construct access road/piling platform between chainages JSB1605 to JSB1320.
4. Construct ramp over bridged culvert S3.
5. Bench into existing embankment slope and replace with engineering fill material, to construct access road/piling platform between chainages JSB1300 to JSB1070. *(Exact extent of piling to be determined at detailed design stage)*
6. Install discrete bored piles along the length of the embankment.
7. Install toe drainage between chainages JSB1070 to JSB1300.
8. Working from chainage JSB1070 back to JSB1605, bench into existing embankment slope up to the crest and replace with engineering fill material, to form a crest path. Cut back to permanent slope profile, place topsoil and spread grass seed to re-vegetate the slope.
9. Working from chainage JSB1320 to JSB1605, install toe drainage.
10. Remove ramp over northeast wing wall of overbridge S2 and temporary works at existing access point.

7.4.2 Potential Construction Sequence - Option B

The following potential high-level construction sequence is based on utilising the existing access point and the potential new access point. By doing so, this allows the embankment to be split into two separate working areas, supplied by independent access points. The embankment can be logically split where the bridged culvert S3 runs beneath the embankment, negating the requirement to ramp over this structure (See Site Location Plan – Appendix B). These two work areas will therefore be referred to as 'South of Culvert' and 'North or Culvert' respectively.

Work Area - South of Culvert

1. Install temporary works at existing access point.
2. Construct ramp over northeast wing wall of overbridge S2.
3. Bench into existing embankment slope and replace with engineering fill material, to construct access road/piling platform between chainages JSB1605 to JSB1320.
4. Install discrete bored piles along the length of the embankment.
5. Working from chainage JSB1320 back to JSB1605, bench into existing embankment slope up to the crest and replace with engineering fill material, to form a crest path. Cut back to permanent slope profile, place topsoil and spread grass seed to re-vegetate the slope.
6. Working from chainage JSB1320 to JSB1605, install toe drainage.
7. Remove ramp over northeast wing wall of overbridge S2 and temporary works at existing access point.

Work Area - North of Culvert

1. Install new access point at chainage JSB1200.
2. Bench into existing embankment slope and replace with engineering fill material, to construct access road/piling platform between chainages JSB1300 to JSB1070.
3. Install discrete bored piles along the length of the embankment.
4. Working from chainage JSB1300 to JSB1070, bench into existing embankment slope up to the crest and replace with engineering fill material, to form a crest path. Cut back to permanent slope profile, place topsoil and spread grass seed to re-vegetate the slope.
5. Working from chainage JSB1300 to JSB1070, install toe drainage.
6. Remove new access point at chainage JSB1200.

7.5 Programme and Estimate

Based on the information contained within this report and the construction sequence assumptions made in Section 7.4, the estimated programme duration is summarised below. The estimate for the project is approximately £3,800,000, based on approximate per-meter costs from a comparable embankment stabilisation project at Canons Park (B084/EM4).

- **Design - 18 weeks; Commencing - TBC**
    - Conceptual Design
    - Detailed Design – Temporary and Permanent Works and Drawings

- **Procurement - 4 weeks; Commencing - TBC**
    - Procurement Strategy
    - Tender Process
    - Contract Award

- **Construction – 60 to 80 weeks; Commencing - TBC**
    - Site Mobilisation
        - Compound
        - Asset Protection
    - De-vegetation
        - Phased
    - Temporary Works
        - Piling Platforms
        - Access Roads and Access Ramps
        - Monitoring
    - Permanent Works
        - Piling
        - Drainage
        - Crest Berms & Crest Walkway
        - Reprofiling, Regrading & Topsoil
    - Site Demobilisation
        - Compound Removal
        - Reinstate Assets
        - Asset Protection Removal

8 References

1) London Underground – Capacity Optimisation Programme, Earth Structures Assessment Programme, Earth Structures Assessment Report, Kingsbury to Wembley Park, B088/EM4, Document No: TLL-B088-P855-CIV-RPT-00006, (October 2014)

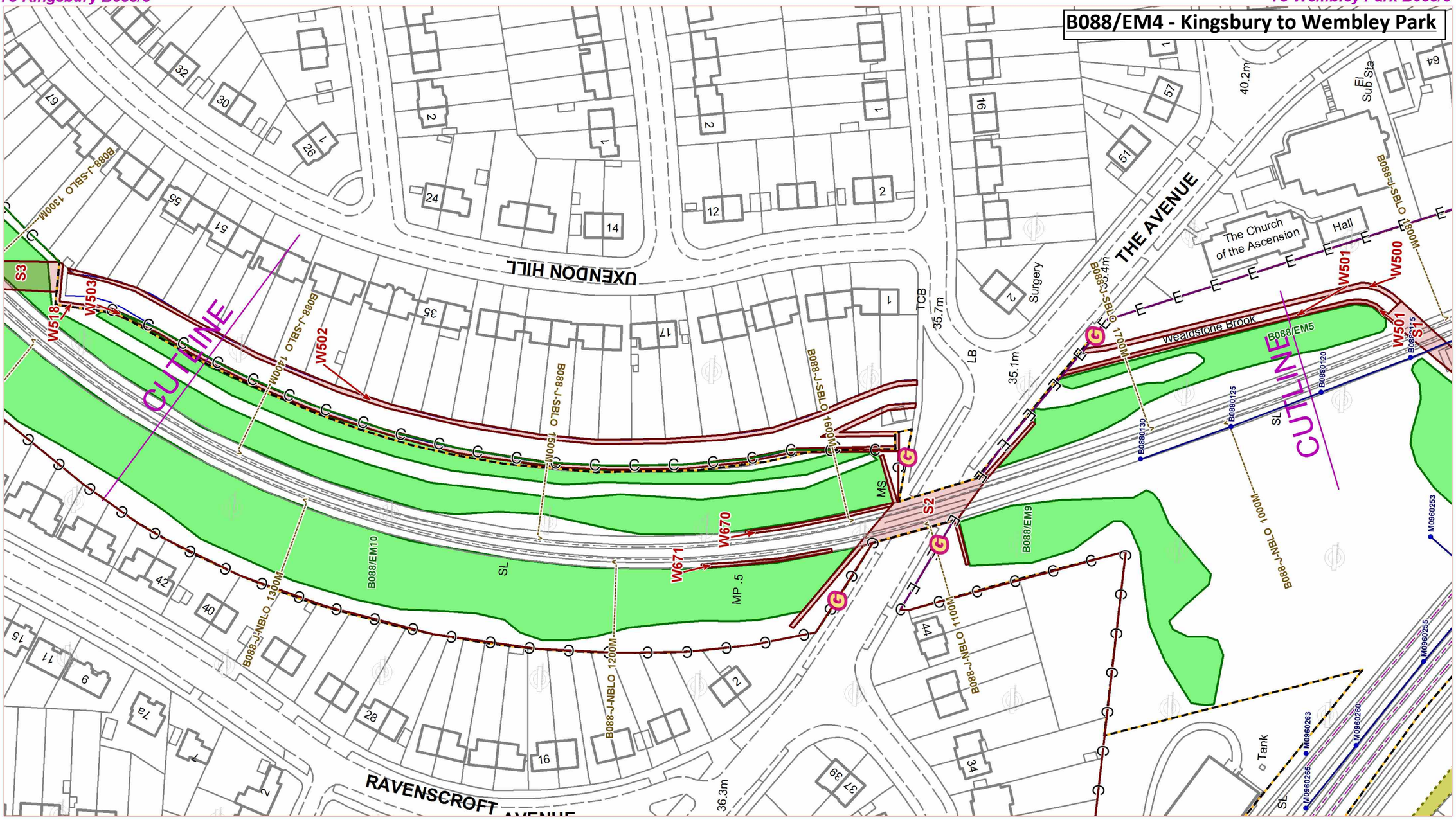
2) LU Emergency Preparedness Plan (EPP), Earth Structure Assessment – LUL CPD JNP, June 2014. Doc No: TLL-L001-P855-HSE –PLN-00002

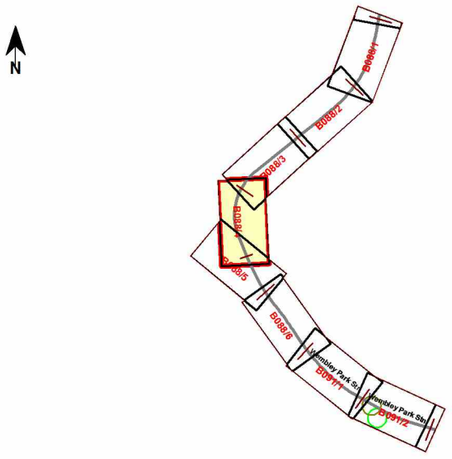
Appendix A Asset Location Plans

To Kingsbury B088/3

To Wembley Park B088/5

B088/EM4 - Kingsbury to Wembley Park





0.00 0.06 0.12 0.18 0.24

Kilometers

OVERVIEW MAP

MR1	Bridges and Structures Asset No.
	Bridges and Structures
N0720470	Track Drainage
N123-N-SLLO 110m	100m Track Markers
23	P and C Number
RD23	Track Siding Road Numbers
	TubeLines Property Boundary
G	Access Gates
B0181/CTS2	Labels of Earth Structures
	Embankments
	Cuttings

Fencing -

H H H	High Security 2.4m
C C	Chainlink 1.2m
C C	Chainlink 1.8m
E E	Expamet 1.8m
W W	Weldmesh 1.8m

Contact email GIS@tubelines.com

Tube Lines
15 Westferry Circus
Canary Wharf
E14 4HD

Tube Lines

ASSET LOCATION PLAN

Kingsbury To Wembley Park

B088/4

PRODUCED 07/12/2012

SCALE 1:1250

To Wembley Park B088/4

To Kingsbury B088/2

B088/EM4 Kingsbury to Wembley Park

RAVENSCROFT AVENUE

WILSON D...

CLOSE

LEDWAY DRIVE

Stone Brook

Posts

B088-J-NBLO 1400M

B088-J-NBLO 1500M

B088-J-NBLO 1600M

B088-J-NBLO 1700M

B088-J-SBLO 1400M

B088-J-SBLO 1300M

B088-J-SBLO 1200M

B088-J-SBLO 1100M

B088-J-SBLO 1000M

W515

W516

W518

W503

W502

S3

B088/EM4

SL

El Sub

Path (um)

CUTLINE

CUTLINE

B0880405

B0880400

B0880395

B0880390

EB0880380

B0880135

B0880136

B0880140

B0880143

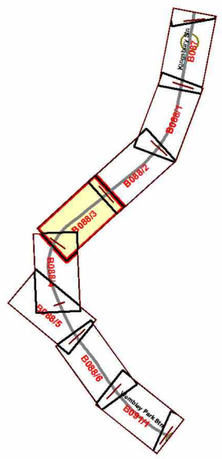
B0880305

B0880306

B0880307

B0880300

B0880297



0.00 0.06 0.12 0.18 0.24

Kilometers

OVERVIEW MAP

MR1 Bridges and Structures Asset No.

Bridges and Structures

N0720470 Track Drainage

N123-N-SLLO 110m 100m Track Markers

23 P and C Number

RD23 Track Siding Road Numbers

TubeLines Property Boundary

G Access Gates

B0181/CTS2 Labels of Earth Structures

Embankments

Cuttings

Fencing -

H H H High Security 2.4m

C C Chainlink 1.2m

C C Chainlink 1.8m

E E Expamet 1.8m

W W Weldmesh 1.8m

Contact email GIS@tubelines.com

Tube Lines
15 Westferry Circus
Canary Wharf
E14 4HD

ASSET LOCATION PLAN

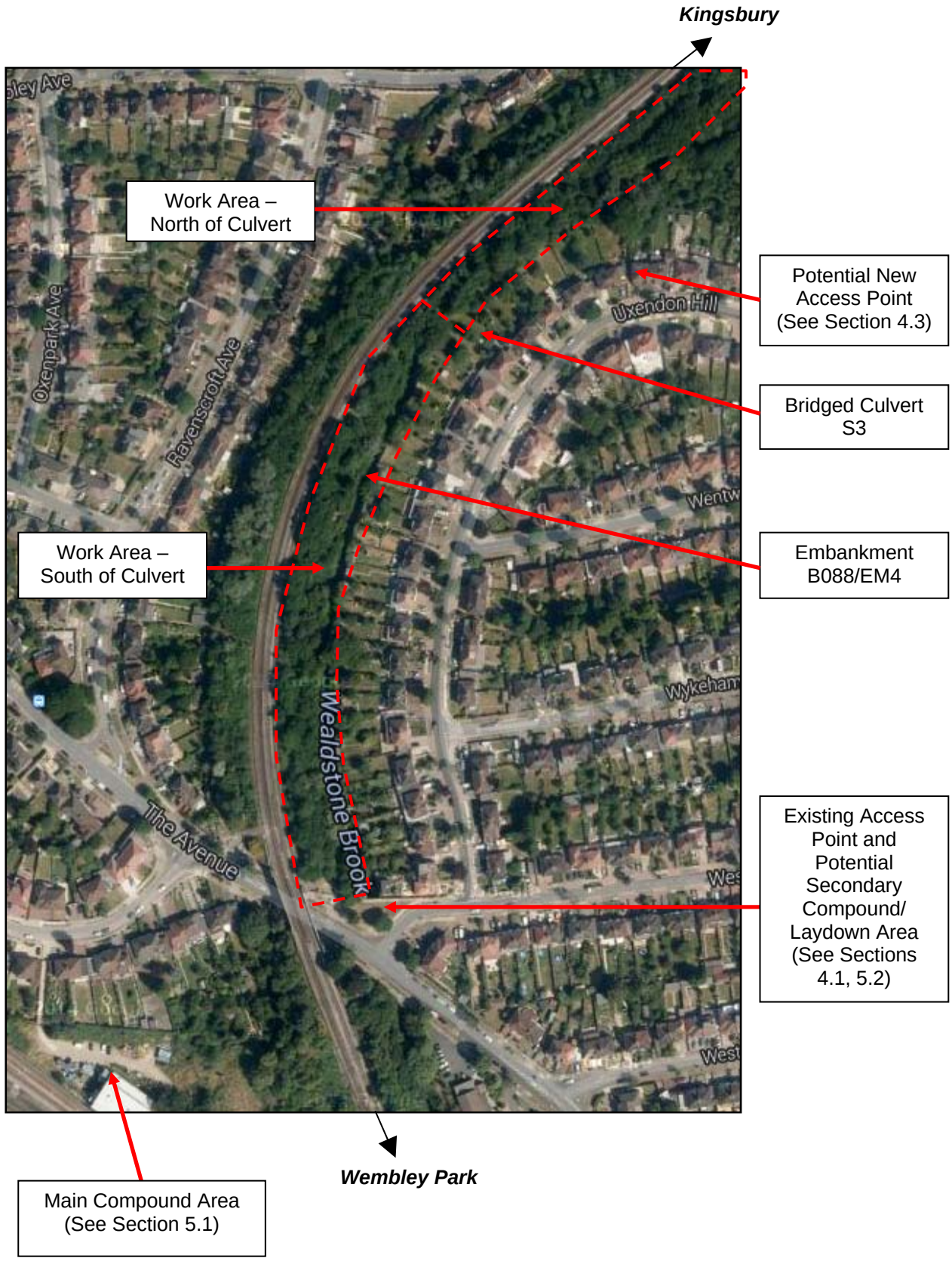
Kingsbury To Wembley Park

B088/3

PRODUCED 07/12/2012

SCALE 1:1250

Appendix B Site Location Plan



Appendix C Photographs

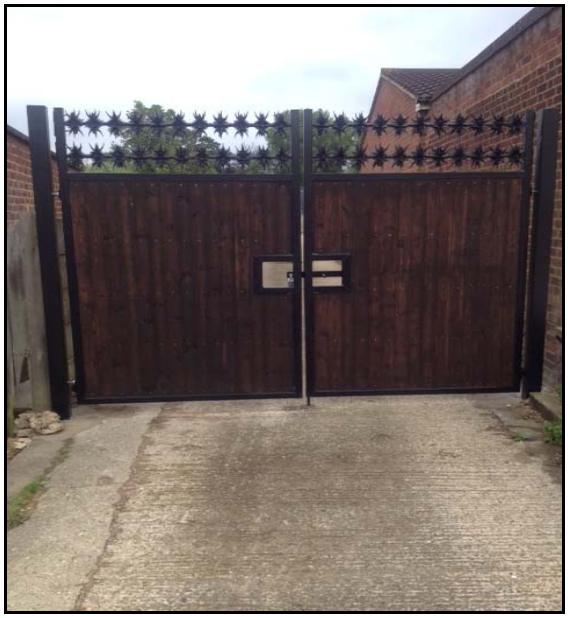


Plate 1 - Proposed Compound Access Gates

Plate 2 - Proposed Compound Access Road

Plate 3 - Proposed Compound

Plate 4 - Proposed Compound

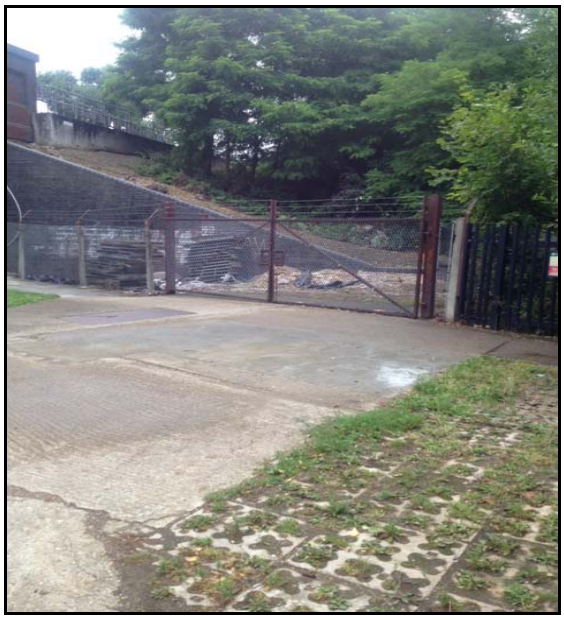


Plate 5 – Existing Access Point

Plate 6 – Telephone Mast and Exchange Box requiring Protection

Plate 7 – Potential New Access Point

Plate 8 – Access Lane to Electrical Substation and LU Boundary Fenceline

Appendix D Third Party Contacts

London Underground
55 Broadway House,
London,
SW1H 0BD

London Borough of Brent
Brent House,
347 - 349 High Road,
Wembley,
HA9 6BZ

Tree Officer
[redacted]

Parks Service (Open & Green Spaces)
[redacted]

Street Works Officer
[redacted]

Environmental Health Officer (EHO)
[redacted]

Environment Agency
National Customer Contact Centre,
PO Box 544,
Rotherham,
S60 1BY

Email: enquiries@environment-agency.gov.uk

Telephone 03708 506 506

Ref:
The Avenue (North) Access Ramp
38WE0101/RA02

National Grid Reference: TQ 18624 87270

Brent Watercourse Inspector
[redacted]

Local Residents
Letter Drop to be completed

- Uxendon Crescent
- Uxendon Hill
- West Hill
- The Avenue