

Proposed Carriage Shed
Buckley Wells Locomotive Works
Bury

Slope Stability Assessment Report

Job Number: LKC 23 1449

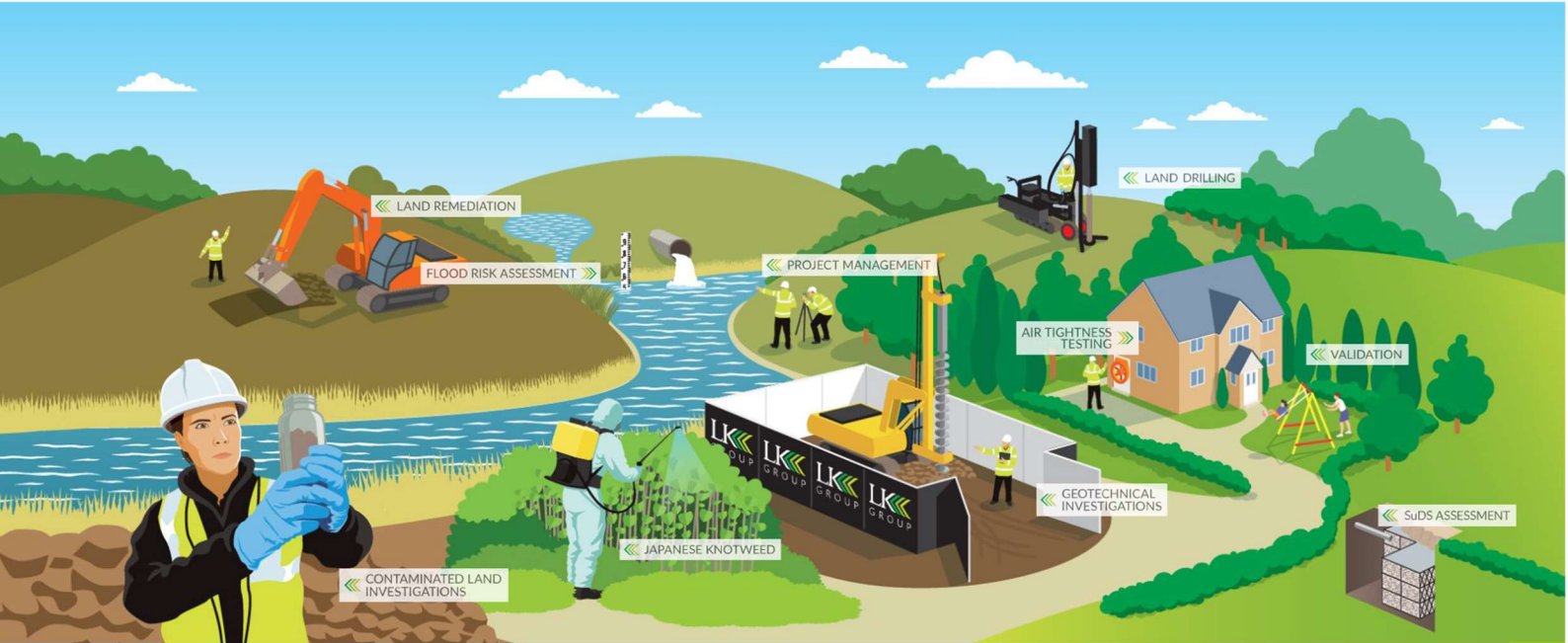
Date: July 2024

Client: East Lancashire Light Railway Ltd



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Client	East Lancashire Light Railway Ltd

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1. Introduction

1.1. Background

LK Consult Ltd (LKC) has been commissioned to carry out a Slope Stability Risk Assessment relating to the proposed new carriage shed at Buckley Wells Locomotive Works, Bury. This assessment is in relation to the embankment slope located to the northwestern side of the proposed building and where associated car parking is proposed. It is understood the new building will be piled and is therefore assessed to be not significant in terms of the long-term slope stability.

1.2. Scope of this Report

The scope of this report follows the guidelines for carrying out a stability risk assessment as recommended on the official website <https://www.gov.uk/guidance/land-stability> with the purpose of assessing the proposed redevelopment for the risk of instability from the embankment slope only. The potential from ground instability from shallow mining and for new running lines into the shed is addressed by others.

1.3. Site Details

The following work previously undertaken has been reviewed as part of the current stability assessment:

- Site Investigation, undertaken by Campbell Reith Hill (ref. PR1k6955-100699Rep/Buckley Wells, Bury, dated June 1999).
- Ground Investigation and Risk Assessment Report, undertaken by LKC (Ref: JB578-02, dated 25th October 2006).
- Embankment Intrusive Works Letter Report, undertaken by LKC (Ref: JB578-04, dated 26th March 2007).
- Ground Investigation Letter Report, undertaken by LKC (Ref: JB578, dated 9th October 2009).
- Supplementary Site Investigation and Coal Mining Risk Assessment, undertaken by NXConsulting (Ref: NX397, dated April 2020).

The above reports should be referred to alongside this report.

Site Location and proposed development plans are provided in Appendix A.

1.4. Site Reconnaissance

As part of the current assessment the study site was revisited on 19th February 2024 and the following relevant notes recorded in relation to the slope.

The site comprises railway siding near to slope approximately 8-10m in height. It is proposed to construct a new carriage shed to cover existing and additional sidings with the shed being located approximately 8m from the crest of the existing slope. Car parking will be built up to and adjacent to the crest of the slope.

The ground on the upper plateau where the sidings are located is flat, surfaced predominantly with coarse gravel hardstanding. The crest of the slope falls steeply, c. 40° down to a level which undulates with small embankments. The slope and lower

level are heavily vegetated by self-seeded trees and invasive plant species (Japanese knotweed, buddleia identified).

The slope appears constructed of ash material and includes much end tipped detritus (ceramic insulators from electric power lines, Yorkshire flags, concrete sleepers etc.).

The vegetation on the slope, and at the base of the slope, shows some movement and geotropism, leaning down slope. This may also be an indication that the trees have shallow root systems and could also be prone to being blown over by wind.

At the base of the slope is a drainage channel which was not noted during previous walkover surveys. There is an area of ponding and marshy ground at the base of the slope which the drainage channel feeds, anecdotal information indicates that this area is always wet and that the fields further south of the pond are prone to flooding.

Lighting masts along the crest of the slope appear to be piled whereas a mast located further west on the lower level appear to have a gravity base.

2. Ground Conditions

2.1. Site Investigation and Borehole Locations

Several historic intrusive ground investigations have been undertaken during previous phases of reporting as referenced in Section 1.3, the findings of the exploratory holes have been used to assess the likely ground conditions of the slope. A summary of these reports is provided in the following sections:

2.1.1. *Campbell Reith Hill (CRH) – Site Wide Investigation (1999)*

This report included a Preliminary Risk Assessment (PRA) of the full Buckley Wells site and intrusive ground investigation.

Sampling positions within the proposed carriage shed area comprised TP8, TP9, TP14, BH C2 and BH C4.

2.1.2. *LKC – Site Wide Investigation (2006)*

Sampling positions within the proposed carriage shed area comprised R2 (open hole rotary), CP2, CP3 (cable percussion) and BH7 (window sample) with HA1-HA5 (hand dug) adjacent. Made ground found at variable depths, at least 8m in some locations.

2.1.3. *LKC – Embankment (2007)*

The investigation comprised window sample boreholes from the higher plateau and at the base of the embankment. In the area adjacent to the proposed new carriage shed boreholes WS101-WS103 were undertaken on the higher plateau at the top of the embankment and WS106-WS108 undertaken at the base of the embankment.

2.1.4. *Proposed Diesel Shed Ground Investigation Letter Report (2009)*

Hand dug trial pits close to the base of the slope completed during this investigation suggest that the extent of the slope is the extent of the Made Ground.

2.1.5. *NXC – Proposed Carriage Shed (2020)*

The investigation comprised the drilling of 3no. rotary boreholes ref. NXRBH01, NXRBH01b and NXRBH02. They were located in a NE-SW direction, down dip of the conjectured outcrop position of the Hell Hole Mine coal seam (as encountered LKC borehole R2) within the footprint of the proposed carriage shed. Made ground was indicated to depths of 7.50mbgl to 9.50mbgl.

2.2. Ground Conditions

2.2.1. *Made Ground*

Made Ground (MG) was present across the entire site and is likely to make up the entirety of the slope.

BH C2 proved the Made Ground to 6.5m comprising black ash Sand. BH C4 was completed to 10m and had not proven the base of the Made Ground, which generally comprised black ash Sand with clinker and burnt shale.

SPT 'N' values for the Made Ground were in the range 2-15 with an average of 5.

2.2.2. Superficial

BH C2 proved a thin band of clay alluvium, underlain by Glacial Gravels. These were very dense with SPT 'N' values in excess of 50. From 9.5mbgl to the base of the borehole at 15mbgl was stiff Glacial Till with SPT 'N' values in the range 35-50.

2.2.3. Bedrock

The bedrock beneath the Glacial Till has not been encountered in BH C2 and BH C4 and is not modelled in this assessment.

2.2.4. Groundwater

Based on the recent site visit it is assumed that there is a perched groundwater table close to the base of the Made Ground.

For this assessment it has been assumed that as a worst case the entirety of the slope comprises Made Ground underlain by Alluvium and these ground conditions, represented on Section A-A', will underlie the proposed car parking area.

3. Stability Modelling and Results

3.1. Methodology

This assessment addresses the current profile and the proposed profile along a single section, A-A'. The aim of the slope stability assessment is to understand the current and future profile stability of the slope in order to address any remediation/strengthening/re-profiling of the slope to create a stable development.

Available geotechnical information including borehole logs, geological maps, findings of site reconnaissance and findings of the laboratory testing results were used for the slope stability modelling.

The assessment has been undertaken using the Limitstate:GEO software package. Limitstate:GEO is designed to analyse the ultimate limit state (or 'collapse state') for a wide variety of geotechnical problems by directly determining the ultimate limit state (ULS) using the computational limit analysis technique Discontinuity Layout Optimization (DLO), and is designed to work with modern design codes such as Eurocode 7 by providing full support for partial factors and the ability to solve multiple scenarios.

In a conventional slip circle analysis, a pre-determined slip surface is assumed and the stability of the soil mass and retaining structure is evaluated by comparing resisting and disturbing moments/forces. Usually many trial slip surfaces are investigated and the most critical one identified. This typically requires specification of a search zone and entry and exit points, and can be very sensitive to the shape of slip surfaces used (e.g. circular or non-circular). In contrast the general purpose limit analysis procedure used by Limitstate:GEO does not require the form of the collapse mechanism to be pre-specified. The software analyses all collapse states and mechanisms and reports an adequacy factor (AF) of the most pertinent failure mechanism; if the AF is greater than 1.0 then the model is in a stable condition.

3.2. Ground Model and Geometry

Two sets of analysis have been undertaken, Section A-A' Current and Section A-A' Proposed. The geometry and ground model for the modelling of the slope stability are presented in Appendix B. The slope geometry was based on GIS modelling, with confirmation that the profile is realistic following the site walkover. The ground model and geology were based on exploratory hole logs as referenced in Section 2.

3.3. Parameters Used in Stability Calculations

Long term stability was modelled along the profiles A-A' in both the existing and proposed profiles. It was considered that the Made ground and natural strata behaved as drained.

The drained and undrained design parameters and unit weight density of the individual soil units used in the ground model are presented in Table 3-1 overleaf:

Soil Unit	Bulk Density (kN/m ³)	Saturated Density (kN/m ³)	Drained Shear Strength Values		Cu (kN/m ²)
			ϕ' (°)	c' (kN/m ²)	
Made Ground – Ash (granular)	19	19	30	1	20
Superficial Deposits – Soft Clay	19	19	18	2	30
Superficial Deposits – Medium dense Sand and Gravel	16	20	37.5	0	-

Table 3-1: Parameters Used in Stability Modelling

Geotechnical parameters for design have been derived from the in-situ and laboratory testing results and assumed where no data are available.

A case study for “physical, chemical and geotechnical properties of coal fly ash: A global review”(Case studies in construction materials, Volume 11, December 2019, e00263 puts the angle of friction of fly ash to vary between 25° to 40° which would put the slope at its highest angle.

Values for unit weight for most of the encountered soils were based on the conservative characteristic unit weight density values presented in British Standard BS 8004:2015 (BS8004:2015) Code of practice for foundations.

The drained angle of shearing resistance for the granular soils was derived from the SPT testing results using the correlation of Peck et al. (1974), while for the cohesive soils it was derived from BS8004:2015, based on the Plasticity Index from laboratory testing results.

In granular soils of the Superficial Deposits, the SPT ‘N’ value (uncorrected) was recorded as value of 2-15 in the Made Ground (BH C2 and BH C4). Using the relationship between SPT ‘N’ values and angle of shearing resistance (Peck et al, 1974) the SPT ‘N’ value of 2-15 correlates to an angle of shearing resistance of 28-31°. An average value of 30° is used in the slope stability assessment.

The effective cohesion values were assumed for all soil types.

3.4. Findings of Slope Stability Modelling

The summary of modelling results is presented in Table 3-2 with the results of the slope stability modelling are presented in Appendix B.

The two sections have been assessed in their current profile along with their proposed profile.

Section	EC7 DA1/1 Short Term	EC7 DA1/1 Long Term	EC7 DA1/2 Short Term	EC7 DA1/2 Long Term	Acceptability
A-A' Existing	2.432	1.551	1.737	1.241	Safe
A-A' Proposed	2.361	1.54	1.686	1.232	Safe

Table 3-2: Results of Slope Stability Modelling.

The modelling results, shows an AF of >1 (safe), for both the existing and proposed scenarios.

As the site observations show the slope angles are close to where they would be predicted to be stable based on their properties and locally where the slope angle is 35-40° there are likely to be localised failures and long-term creep.

The loading from the car parking has not been modelled as permanent as this would not be realistic, however, the imposition of a load to the top of the slope, reduces the factor of safety marginally as would be expected.

It is not considered that any significant reprofile of the slope is required but the designers should take into account long term creep of the slope which will occur. This can be mitigated in the long term by incorporating a geogrid within the pavement and storm water storage should not be incorporated in that area such as to increase the load.

The long-term stability of the slope is helped by the presence of the vegetation and significant de-vegetation of areas is not recommended. It is recommended that long term maintenance should ensure that the drainage at the toe of the slope continues. Any increases in the porewater pressures within the slopes would potentially cause localised failures.

4. Conclusions and Recommendations

4.1. Ground Conditions

Ground conditions were found to comprise:

- The ground profile is assumed to comprised granular Made ground, overlying a layer of cohesive Alluvium, underlain to depth by granular Glacial Till. The bedrock depth is not significant to the current assessment.
- Groundwater is encountered at the base of the slope and is modelled as being at the base of the Made Ground and perched on the Alluvium.

4.2. Slope and Site Stability

The slope located on the western side of the development will not be redeveloped but car parking will be created at the top. The slope was assessed along a single theoretical section, both in its current profile and its proposed end use where a loading will be imposed. The risk assessment was based on the findings of the previous intrusive investigations and a more recent site reconnaissance.

From the slope stability risk assessment, the conclusions are:

- The preliminary slope stability assessment shows the slope appears stable.
- The slope angle is not constant along the slope and some local steeper area may be marginally safe or unstable.
- The proposed loadings marginally decrease the factor of safety, however, the long-term stability is considered safe.

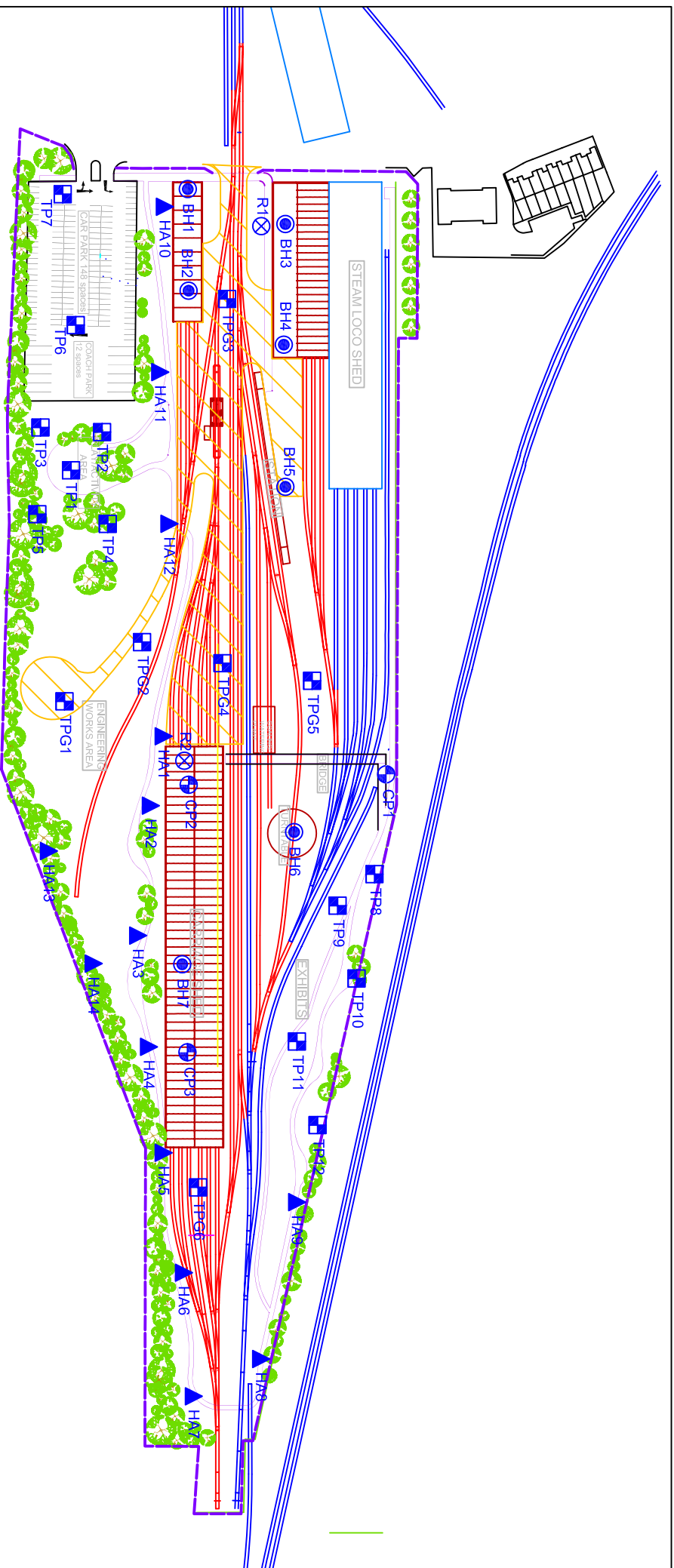
During the development of the site, the following measures should be incorporated to mitigate against long term creep:

- Incorporation of the geogrid within carpark construction formation
- Maintenance of drainage at base of slope.
- The existing vegetation and trees generally provide support to the slope as such the development plan should not include removal.

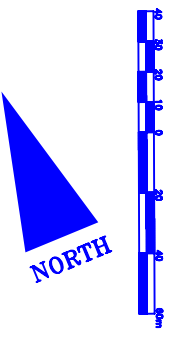
Appendix A: Site Plans



Client: East Lancashire Light Railway Ltd				Title: Site Location & Boundary Plan		
Site: Buckley Wells Loco Works, Bury				Scale (see scale bar): 1:25,000 & 1:5000 @ A4		
Job No.: LKC 23 1449	Drawn By: CC	Checked By: PQ	Drawn: July 2024	Figure: 1	Revision:	



- Key to LKA Sampling Locations**
- Window Sample Borehole
 - ▲ Hand Auger
 - Trial Pit
 - ⊗ Rotary Borehole
 - ⊕ Cable Percussion Borehole



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Title:

Figure 3-1 LKA Sampling Locations

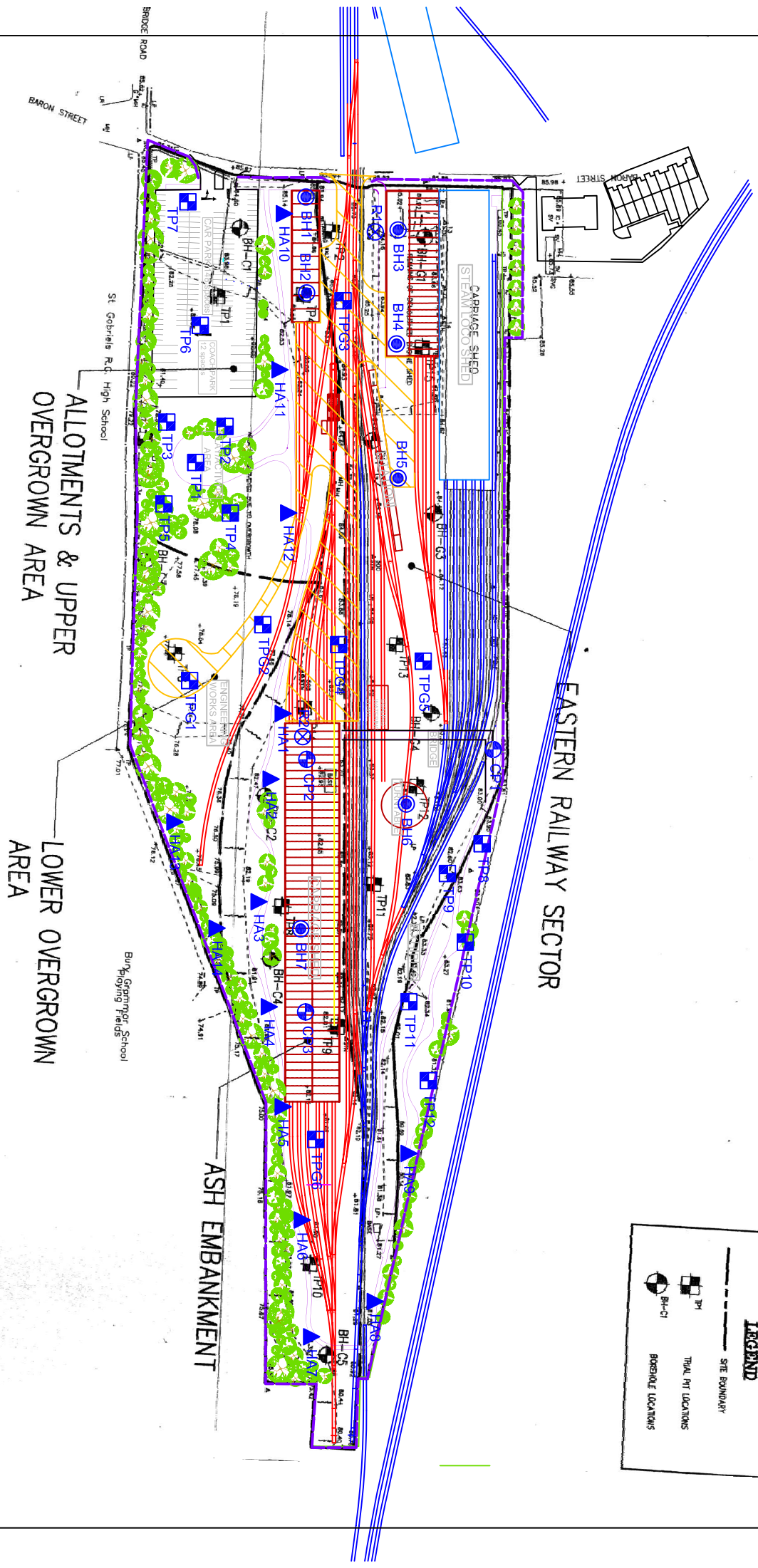
Date: September 2006 | Scale: ~1:2500 @ A4

LEGEND

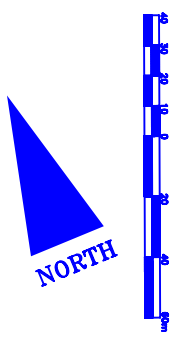
--- SITE BOUNDARY

TP1 TRIAL PIT LOCATIONS

BH-C1 BORING LOCATIONS



- Key to LKA Sampling Locations**
- Window Sample Borehole
 - ▲ Hand Auger
 - Trial Pit
 - ⊗ Rotary Borehole
 - ⊕ Cable Percussion Borehole



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Title:

Figure 3-2 LKA & CRH Sampling Locations

Date: September 2006 Scale: ~1:2500 @ A4

