

- The positions of the two shafts recorded on the Dicconsons Survey map are unlikely to be sufficiently accurate to precisely locate these shafts. The Coal Authority records should be interpreted that mine openings are present in the area.
- It is uncertain whether there are any shallow workings in the Trencherbone coal seam or at depth in the Cannel Mine coal seam from these shafts. The lack of any mine waste in the CRH site investigation adds to this uncertainty.
- Additional shafts and shallow workings may be present at the location of the conjectured outcrops of the Hell Hole Mine, Five Quarters or Doe coal seams. Records for the thickness of these coal seams are not available. Published information on the Lancashire Coalfield indicates that these seams have, in the area between Bolton and Bury all been worked in the past.
- The potential exists for the mining of two coal seams below the Buckley Wells site, which may present a hazard to the redevelopment of the site.

### 6.3 *Interim Coal Mining Review Recommendations*

The available information indicated that both the Trencherbone and Hell Hole Mine coal seams dip in a southerly to south westerly direction from their conjectured subcrops below the drift geology, therefore drilling should take place to the south/south west of each of these conjectured outcrops to a minimum depth of 30 metres below ground level and in the location where current proposed building foundations may be at risk. Drilling should be undertaken by open-hole rotary methods and backfilled with bentonite.

The above was communicated to Bury MBC and it was agreed to drill two exploratory holes to establish the location and any possible mining of the Trencherbone and Hell Hole Mine seams

### 6.4 *Coal Mining Drilling Works*

Two rotary boreholes, referenced R1 and R2, were drilled on the site on 26<sup>th</sup> April 2006. The locations of each borehole are illustrated on Figure 3-1 and the borehole logs are provided in Appendix G. R1 was located to establish the location of the Trencherbone seam and R2 was located to establish the location of the Hell Hole Mine seam.

A summary of the ground conditions encountered in each borehole is presented below.

R1 encountered made ground (ash, concrete and brick rubble) to a depth of 2.0m. Beneath the made ground, drift deposits comprising interbedded sand and gravels and boulder clay were encountered to 14.5mbgl. The solid geology below the drift comprised interbedded layers of siltstone, mudstone and sandstone, proved to a depth of 30m. No coal seams or voids were encountered.

R2 encountered made ground comprising ash to 8.5mbgl, over drift deposits comprising sand and gravel to 8.50mbgl and boulder clay to 19.0mbgl. Solid geology below the drift comprised red and grey sandstone to 26.0mbgl where a 1.5m thick seam of coal was encountered. Below the coal seam, siltstone was encountered from 27.5 to 30.0mbgl.

### 6.5 *Interpretation of Coal Seam Drilling Works*

The Trencherbone Seam was not encountered in R1, however a black siltstone was recorded between 19.5 and 20.0mbgl which may constitute a pinching out of the coal or a lens of organic-rich material associated with the coal seam. No voids or specifically saturated rock strata were encountered.

A coal seam was encountered from 26 to 27.5m below ground level in R2. As no voids were encountered and the seam was not unduly waterlogged in comparison to surrounding rock strata there is no strong evidence that this seam has been worked below the site.

A schematic cross section of the site and the coal seams taken from the geological mapping and the site data is presented on Figure 6-1. Considering the assumptions highlighted on Figure 6-1, the dip of the possible Trencherbone and Hell Hole seams below the site has been calculated in the order of 4 to 4.4 degrees respectively.

### 6.6 *Coal Mining Conclusions*

The boreholes and cross sections indicate that the coal seams and the regional geology dip at around 4 to 4.4 degrees in the site vicinity.

The presence of the Trencherbone seam was not accurately established in R1, while R2 encountered a 1.5m thick coal seam which was interpreted as the Hell Hole seam.

No voids or selective water logging of the coal seams was encountered, indicating that mining of these seams in the site vicinity has not been undertaken. However, it is noted that R2 may have hit a roof support column of coal.

It is considered the proposed Carriage Shed, Steam Loco Shed Extension, Proposed Car Park and the New Shed near the retaining wall may be at risk from undermining.

### 6.7 *Coal Mining Recommendations*

Specific considerations for each proposed structure considered to be at risk are given in Section 7.

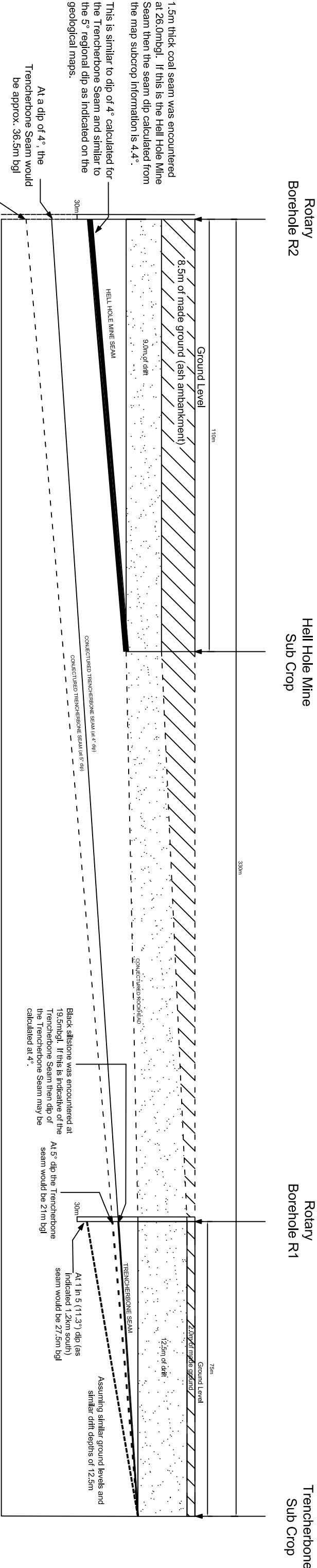
With regards to locating the two possible shafts on site, it may be appropriate to undertake a strip of the site surface down to natural drift deposits and visually inspect the surface for evidence of shafts. Such evidence may comprise mine waste or detritus such as coal and mudstone fragments localised within the surface of the drift.

Exploratory excavations for these shafts should not be undertaken without prior permission from the Coal Authority.

Alternatively, non-invasive geophysical techniques may be appropriate in locating the shafts.

SOUTH

NORTH



## 7 GEOTECHNICAL CONSIDERATIONS

### 7.1 Introduction

The LKA site investigation was designed to target proposed structures and an assessment of the ground conditions for each of these structures is given in the following Sections. For this interim report, factual data is presented pending details on factors such as structure loading characteristics and internal details.

The analytical data indicates that no special precautions for sulphate resistant concrete are required across the site.

The following Sections also include a review of gas monitoring data where appropriate and outline any gas protection measures that may be appropriate.

### 7.2 Proposed Car Parking Area

Trial pits TP6 and TP7 and CRH TP1 were undertaken in this area. Relevant profile logs and geotechnical testing certificates of analysis are provided in Appendix R.

#### 7.2.1 Ground Conditions

The ground conditions encountered were mainly a sandy clayey topsoil over a firm natural clay in TP6 and CRH TP1. In TP7 the topsoil was underlain by a reworked sand to 0.80m over natural sand and gravels.

#### 7.2.2 Laboratory Testing

CBR testing was undertaken in bulk samples collected from between 0 and 0.3mbgl in TP6 and TP7. The CBR results in TP6 were 0.73% (top) and 1.0% (bottom) and in TP7 0.93% (top) and 0.92% (bottom).

#### 7.2.3 Initial Assessment of ground conditions

The CBR results were well below 3% and a capping layer for the car park and access routes should be provided below the finish surface.

Other factors for consideration include the possibility of a potential mine shaft within this area of the site. The creation of a car and coach park in this area of the site may lead to an increase in ground loading and failure of the shaft if it has not been properly capped or treated. Therefore LKA would consider that a search for the mine entry should be undertaken (see Section 6) and once located, treated appropriately.

### 7.3 Carriage / Steam Shed Extension

Boreholes BH3, BH4 and R1 and CRH BH-G1 and TP15 were undertaken in this area. Relevant profile logs and geotechnical testing certificates of analysis are provided in Appendix S.

#### 7.3.1 Ground Conditions

Made ground was encountered in each sampling location and comprised generally ash and clinker with demolition rubble in BH3 and CRH BH-G1 to depths of between 2.5 and 2.7mbgl respectively. R1 encountered concrete between 0.3 and 0.5mbgl. BH4 encountered a clayey topsoil to 0.8m and CRH TP15 encountered ashy made ground to 0.2mbgl.

Natural strata comprised firm to stiff clay to 5.0mbgl in BH3 and interspersed layers of sand and soft wet clay to 5.0mbgl in BH4. Sandy gravel was present to 2.2mbgl over firm to stiff clay to 3.1mbgl in CRH TP15.

In R1 the natural ground succession comprised sand and gravel to 3.0mbgl, clay to 4.5mbgl, sand and gravel to 6.0mbgl and clay to 14.5mbgl where after Coal Measures (siltstone and sandstone) were encountered to 30.0mbgl.

In CRH BH-G1 a stiff clay was encountered from 2.7 to 4.9mbgl over a dense gravel to 6.7m. Stiff to very stiff clay was encountered to 9.3mbgl, silt to 10mbgl, dense sand to 13.8mbgl and very stiff clay or weathered mudstone to 15mbgl.

### 7.3.2 Gas Monitoring

Gas monitoring undertaken in the LKA boreholes in this area of the site indicated no methane, maximum carbon dioxide concentrations of 3.9% and a maximum flow of 1.8litres per hour (l/hr). Monitoring in CRH BH-G1 indicated a maximum methane concentration of 3.8% and a maximum carbon dioxide concentration of 2.3%.

### 7.3.3 Laboratory Testing

PSD tests were undertaken in CRH BH-G1 at 0 to 0.4mbgl (made ground) 3.8mbgl (clay), 8.2mbgl (clay) and 10.2mbgl (sand) and in CRH TP15 at 0.4m (gravel). Triaxial tests were undertaken on clay samples recovered from CRH BH-G1 at 2.8mbgl and 6.8mbgl.

### 7.3.4 In-Situ Geotechnical Testing

SPTs were undertaken in BH3, BH4 and CRH BH-G1. Tests in the made ground returned N values between 10 and 22, characterising these deposits as medium dense. SPTs undertaken in the clay above the gravel ranged between 17 and 23, tentatively characterising these deposits as stiff. A SPT undertaken in the clay below the gravel in CRH BH-G1 returned a value of 33 indicating possible very stiff to hard conditions.

SPTs undertaken in the gravel strata returned values of 35 and 50, indicating dense conditions. Hand shear vanes were undertaken in the natural clay in CRH TP15. The test at 2.6mbgl returned normal values of 42 to 62, indicating firm conditions and remoulded values of 10 to 22. The test at 3.1mbgl returned normal values 48 to 70 indicating firm conditions and remoulded values of 18 to 26.

### 7.3.5 Initial Assessment of ground conditions

Depending on the loading of the proposed structure, it is considered at this stage that the upper clay would be the appropriate founding strata. At depths to the clay of up to 2.7m it may be appropriate to consider trench fill footings.

In accordance with guidance given in Wilson and Card (1999) a Limiting Borehole Gas Volume Flow (LBGVF) may be calculated. As a conservative measure this may include the maximum gas concentration (carbon dioxide or methane) multiplied by the maximum flow rate detected across the monitoring survey. For this area of the site the LBGVF is 0.07l/hr which would equate to Characteristic 2 measures.

Such measures would include a granular vented sub-floor and waterproofing membrane. Given the proposed nature of the structure, LKA would consider that gas protection measures would only be required in small unventilated areas such as offices, toilet blocks or small storage areas.

#### 7.4 *New Roadways and Track Bed*

Trial pits TP-G3 to TP-G6 and CRH TP2 and TP10 to TP14 were undertaken in relevant areas. Relevant profile logs and geotechnical testing certificates of analysis are provided in Appendix T.

##### 7.4.1 *Ground Conditions*

Made ground was encountered in all of the sampling locations and generally comprised ash and clinker with occasional clay inclusions or reworked clay with inclusions of ash, clinker and demolition rubble.

In CRH TP2 ashy made ground was present to 0.2mbgl while in Trial TP-G3 ashy made ground was present to 0.4mbgl.

In TP-G4 to TP-G6 the made ground was observed to extend beyond 0.6mbgl. In CRH TP10, TP12 and TP14 the made ground was observed to be present beyond 3.4mbgl. In CRH TP2, TP11 and TP13 the made ground was present to depths of 2.0mbgl, 1.6mbgl and 1.69mbgl respectively.

Natural strata was encountered in TP-G3 at 0.4mbgl and comprised sand and gravel proved to 0.6mbgl. Natural strata in CRH TP2 and TP13 comprised a soft or firm clay, while in CRH TP11 the natural strata comprised sand to 3.4mkgbl over gravel proved to 3.7mbgl.

##### 7.4.2 *Laboratory Testing*

CBR testing was undertaken in bulk samples collected from between 0 and 0.4mbgl in TPG3 to TP-G6. The CBR results ranged from 2.3% (top TP-G6) to 6.6% (top TP-G5).

Atterberg tests were carried out on CRH TP2 (2.2m), CRH TP12 (1.5m), CRH TP13 (2.1m) and CRH TP15 (2.6m).

PSD tests were carried out on CRH TP2 (1.4m) CRH TP11 (1.7m), CRH TP12 (1.5m) CRH TP13 (2.6m), CRH TP14 (0.6m and 2.1m) and CRH TP15 (0.4m).

Shear box testing was undertaken on samples from the made ground in CRH TP10.

##### 7.4.3 *Initial Assessment of ground conditions*

The CBR tests were mostly undertaken on granular made ground which generally reported values above 3%. Depending on the proposed loading and any localised soft spots this material may be suitable for railway track subject to provision of standard track ballast. A capping layer should be considered for proposed roadways.

#### 7.5 *New Shed on Northern Site Boundary*

BH1 and BH2 and CRH TP4 were undertaken in this area. Relevant profile logs and geotechnical testing certificates of analysis are provided in Appendix U.

##### 7.5.1 *Ground Conditions*

Made ground was encountered in each of the sampling locations at depths between 0.3 and 1.5mbgl (BH2). Topsoil was encountered at all of the sampling locations to 0.1m in CRH TP4, 0.2m in BH1 and 1.0m in BH2. The topsoil was underlain in CRH TP1 by stone setts, and by ash and clinker in BH1.

Natural strata was encountered in each of the sampling locations. In BH1 this comprised sand and gravel to 3.5mbgl over clay to the base of the borehole at 5.0mbgl.

In BH2 natural ground comprised sand and gravel to 2.0mbgl, clay to 2.9mbgl, gravelly sand to 3.5mbgl over clay to the base of the borehole at 5.0mbgl.

In CRH TP4 the natural strata comprised sandy gravel to 2.2mbgl over clay to the base of the pit at 3.1mbgl.

#### 7.5.2 *Gas Monitoring*

Gas monitoring undertaken in BH1 indicated no methane, maximum carbon dioxide concentrations of 4.6% and a maximum flow of 1.8litres per hour (l/hr).

#### 7.5.3 *Laboratory Testing*

PSD testing was undertaken on CRH TP4 (1.0m) and BH1 (1.5m and 2.5m). Please note in the Certificates of Analysis BH1 is labelled as WS-BH1.

#### 7.5.4 *In-Situ Geotechnical Testing*

SPTs were undertaken in the boreholes. The sand and gravel returned N values of 2 and 12 characterising these deposits as very loose to medium dense, and the sand in BH2 returned an N value of 16, characterising this strata as medium dense. SPT tests undertaken in the clay returned values between 9 and 16 characterising these deposits as firm to stiff.

Hand shear vanes were undertaken in the natural clay in CRH TP4. The test at 2.4mbgl returned normal values of 82 to 102, indicating stiff conditions and remoulded values of 18 to 20. The test at 2.9mbgl returned normal values 82 to 94 indicating stiff conditions and remoulded values of 20 to 30.

#### 7.5.5 *Initial Assessment of Ground Conditions*

Depending on the loading of the proposed structure the sand and gravel may comprise suitable founding strata.

The gas monitoring in this area of the site provides a LBGVF of 0.08l/hr which would equate to Characteristic Situation 2 measures. Such measures would include a granular vented sub-floor and waterproofing membrane. Given the proposed nature of the structure, LKA would consider that gas protection measures would only be required in small unventilated areas such as offices, toilet blocks or small storage areas.

### 7.6 *New Station and Platform*

Borehole BH5 and CRH BH-G2 were undertaken in this area of the site. Relevant profile logs and geotechnical testing certificates of analysis are provided in Appendix V.

#### 7.6.1 *Ground Conditions*

Made ground was encountered in each of the sampling locations at depths between 1.85 and 2.0m and comprised ash gravel and reworked clay. Natural ground in CRH BH-G2 comprised clay and silt to 2.4mbgl over a firm to stiff clay which was present to the base of the borehole at 15.0mbgl. Natural ground in BH5 comprised sand and gravel to the base of the borehole at 5.0mbgl.

#### 7.6.2 *Laboratory Testing*

PSD testing was undertaken on CRH BH-G2 (0.5 and 11.45m). Consolidation tests were undertaken on the clay from CRH BH-G2 on samples recovered from 1.9 to 2.35mbgl and 2.6 to 3.05mbgl and triaxial tests were undertaken on samples recovered from CRH BH-G2 at depths of 2.6mbgl, 4.5mbgl, 8.0mbgl and 12.5mbgl.

### 7.6.3 *In-Situ Geotechnical Testing*

SPTs were undertaken in both of the boreholes. The sand and gravel in BH5 returned N values of 25 and 27 characterising these deposits as medium dense. The made ground in CRH BH-G2 returned an N value of 6 characterising these deposits as loose, while SPTs undertaken in the clay (upper 8m) returned values of 20 to 37, tentatively characterising these deposits as very stiff.

### 7.6.4 *Initial Assessment of Ground Conditions*

There would appear to be a strata of sand and gravel above the clay in the vicinity of the proposed structure. The depth of the sand and gravel was not proved in BH5, where as in CRH BH-G2 natural ground comprised clay. Medium dense sands and gravels were encountered in CRH BH-G3 to the south east of BH5 to a depth of 5.8m and were noted to be present above a stiff clay.

LKA would consider that sands and gravels are likely below the station structure and that depending on the proposed loading, foundation into the upper natural strata or compaction of the granular ash deposits may be appropriate.

## 7.7 *Engineering Works Area*

Trial pits TP-G1, TP-G2 and CRH TP6 were undertaken in this area. Relevant profile logs and geotechnical testing certificates of analysis are provided in Appendix W.

### 7.7.1 *Ground Conditions*

The ground conditions encountered in TP-G1 and TP-G2 comprised a sandy topsoil to 0.3 or 0.4mbgl over a soft firm natural clay proved to 0.8mbgl. The ground conditions in CRH TP6 comprised sandy topsoil to 0.3m over sandy gravel to 2.3mbgl.

### 7.7.2 *Laboratory Testing*

CBR testing was undertaken in bulk samples collected from between 0 and 0.3mbgl in TP-G1 and TP-G2. The CBR results ranged from 1.0% (top – both samples) to 1.6% (bottom TP-G1).

### 7.7.3 *Initial Assessment of ground conditions*

The CBR results are well below 3% and a capping layer or sub-base should be provided below the finish surface.

## 7.8 *New Carriage Shed*

Boreholes CP2, CP3, BH7, R2 and CRH TP8, CRH TP9, CRH BH-C2 and CRH BH-C4 were undertaken in this area. Relevant profile logs and geotechnical testing certificates of analysis are provided in Appendix X.

### 7.8.1 *Ground Conditions*

Made ground was encountered at each of the sampling locations. Ash and clinker made ground was present to depths of greater than 8.0mbgl in BH7, to 8.0mbgl in CP2, to 1.5mbgl in CP3, to 8.50mbgl in R1, to 6.5mbgl in CRH BH-C2, to 7.6mbgl in CRH BH-C4, to greater than 3.3mbgl in CRH TP8 and to 3.2mbgl in TP9.

In CP3 the ash was underlain by a reworked soft clay to 7.85mbgl while in CRH BH-C4 the ash was underlain by a reworked sand with a little ash to 11.0mbgl.

Natural ground was encountered in CP2, CP3, CRH BH-C2, CRH BH-C4 and CRH TP9. In CP2 the natural ground comprised a very stiff clay to the base of the borehole at 15.3mbgl,

while in CP3 the natural ground comprised very stiff clay to 12.5mbgl with a layer of sand and gravel from 10.0 to 10.7mbgl. Clay was encountered from 10.0m to 19.0mbgl in R1.

Natural strata in CRH BH-C2 comprised a thin layer of clay / silt to 7.1mbgl over gravel to 9.50m. Stiff clay was then encountered to the base of the borehole at 15.0mbgl. Natural strata in CRH BH-C4 comprised sand and gravel to 12.3mbgl over clay to 14.0mbgl. Natural gravels were encountered in TP9 from 3.2 to the base of the pit at 3.6mbgl.

#### 7.8.2 *Laboratory Testing*

Samples from CP2 (11.0m), CP3 (10.0m and 12.5m), CRH BH-C2 (6.6m, 8.7m, 11.0m and 12.9m), CRH BH-C4 (7.6m, 8.2m and 12.7m) were submitted for Atterberg Limit testing.

CP2 (13.0m) was submitted for hand vane shear testing, CP2 (10.0m and 13.0m) were submitted for bulk density tests, samples from CP3 (9.0m), CRH BH-C2 (6.6m and 9.6m) and CRH BH-C4 (7.7m and 12.5m) were submitted for triaxial tests.

Shear box testing was undertaken on the made ground from 0 to 5.2mbgl from CRH BH-C2.

PSD tests were undertaken on CRH BH-C2 (6.6m and 11.0m), CRH BH-C4 (1.2m and 10.4m) and CRH TP9 (1.0m). A consolidation test was undertaken on CRH BH-C2 (6.6m)

#### 7.8.3 *In-Situ Geotechnical Testing*

SPTs undertaken in the ash made ground ranged from 2 to 8, characterising these deposits as very loose to loose and SPTs undertaken in the reworked sand returned an N values of 12, characterising these deposits as medium dense.

SPTs undertaken in the natural sands and gravels gave N values between 10 and 50, characterising these deposits as medium dense to dense. SPTs undertaken in the natural clays returned N values between 42 and refusal indicating very stiff to hard conditions. The exception was an N value of 8 in the upper clay at 8.0mbgl in CP3.

#### 7.8.4 *Gas Monitoring*

Gas monitoring undertaken in CP2, CP3 and BH7 BH1 indicated no methane, maximum carbon dioxide concentrations of 3.6% and a maximum flow of 1.6litres per hour (l/hr). Gas monitoring in CRH BH-C4 indicated no methane and maximum carbon dioxide concentrations of 1.3%.

#### 7.8.5 *Initial Assessment of ground conditions*

It is likely the foundation strata will be the natural ground which due to its depth will require piled foundations.

Given the proximity of the crest of the ash embankment it is considered that structural loads should be transferred into the deeper ground (see Section 7.11).

The gas monitoring in this area of the site provides a LBGVF of 0.06l/hr which would equate to Characteristic Situation 1 measures where no special precautions are considered necessary.

The presence of the Hell Hole Mine Seam has been identified below the proposed building and it may be prudent to undertake further rotary boreholes to confirm if the seam has not been worked, whether borehole R2 may have encountered a pillar support or if the seam was not worked in the vicinity of borehole R2. If any workings are discovered in this seam, the factor of safety in relation to seam thickness and seam depth should be calculated to establish if any stabilisation works are required.

## 7.9 *Relocation of Turntable*

Borehole BH6 and CRH TP12 were undertaken in this area of the site. Relevant profile logs and geotechnical testing certificates of analysis are provided in Appendix Y.

### 7.9.1 *Ground Conditions*

BH6 encountered made ground comprising ash and clinker interspersed with bands of clay and ash to 2.6mbgl over a loose clayey sand to 3.6mbgl.

CRH TP12 encountered ash and clinker to 0.7mbgl over a sandy ashy clay to the base of the pit at 3.9mbgl.

Natural ground was encountered in BH6 and comprised a soft clay to the base of the borehole at 5.0mbgl.

### 7.9.2 *Laboratory Testing*

Atterberg limits, PSD testing and moisture content – dry density tests were undertaken on the reworked clay from CRH TP12 (1.5mbgl).

### 7.9.3 *In-Situ Geotechnical Testing*

SPTs were undertaken in BH6. The tests in the made ground returned N values of 1 and 2 indicating very loose conditions and an SPT test undertaken in the natural clay returned an N value of 2 indicating very soft conditions.

### 7.9.4 *Initial Assessment of ground conditions*

At this stage we are not aware of the likely loadings associated with the turntable, however given the CBR results for the ash made ground across the site and the historical presence of a turntable on site it may be appropriate to place the turntable on engineered fill.

## 7.10 *New Bridge*

LKA understand the proposed bridge is anchored adjacent to the proposed carriage shed and near to the proposed exhibits area and boreholes CP1 and CP2 and CRH TP14 were undertaken in these areas. Relevant profile logs and geotechnical testing certificates of analysis are provided in Appendix Z.

### 7.10.1 *Ground Conditions*

Made ground was encountered in each of the sampling locations. CP1 undertaken near the proposed exhibits area encountered ash and clinker gravel to 6.3mbgl over a reworked sandy clay to 8.5mbgl. CP2 undertaken near the proposed carriage shed encountered ash and clinker gravel to 8.0mbgl and CRH TP14 encountered ash and clinker to the base of the pit at 3.4mbgl.

Natural ground encountered in CP1 comprised a stiff to very stiff clay to the base of the borehole at 10.45mbgl and CP2 encountered sand and gravel to 9.6mbgl over a very stiff clay to the base of the borehole at 15.3mbgl.

### 7.10.2 *Laboratory Testing*

PSD testing was undertaken on samples of the made ground from CRH TP14 (0.6m and 2.1m). Atterberg Limit testing was undertaken on samples from CP2 (11.0m), hand vane testing was undertaken on a sample from CP2 (13.0m).

#### 7.10.3 *In-Situ Geotechnical Testing*

SPTs were undertaken in the made ground in CP1 and returned N values of 4 to 10 for the ash and clinker and values of 17 and 18 for the reworked clay. This characterises the ash and clinker as loose and the reworked clay as firm to stiff.

An SPT undertaken in the natural clay in CP1 returned an N value of 61 characterising these deposits as hard.

SPTs undertaken in the natural sand and gravel in CP2 returned N values of 10 and 20 characterising these deposits as medium dense and SPTs undertaken in the natural clay in CP2 returned values between 45 and refusal indicating very stiff to hard conditions.

#### 7.10.4 *Initial Assessment of ground conditions*

For the bridge anchor near the proposed exhibits area, the ash and clinker made ground may be the appropriate strata subject to ground improvement techniques.

Near to the proposed carriage shed consideration to potential slope stability impacts should be given and it may be appropriate to transfer loading away from the made ground into the underlying natural strata.

#### 7.11 *Ash Embankment Slope Stability*

Given the development proposals of the proposed carriage shed and extra track near the crest of the slope, slope stability issues must be considered.

At an empirical level, no evidence of failure was noted during the site works; however much of the slope was inaccessible due to thick vegetation.

Site investigation data indicates the embankment mainly comprises ash and clinker and shear box testing has been undertaken on embankment materials. At this stage it may be appropriate to consider qualitative stability measures such as regarding the slope to gradients of 1 in 4 or less, loading the toe with site won spoil or gabions, planting of stabilising low level vegetation such as grasses and ensuring the slope is well drained to reduced failure potential.

## 8 CONCLUSIONS

Based upon the currently available data, LKA conclude the following:

Based on the available information provided by CRH and a review of historical information provided by Bury MBC eight potential pollutant linkages were identified and further assessment was considered necessary.

Potential contaminant sources were considered to include heavy metals, TPH, PAH, asbestos, PCB and herbicides.

The proposed layout provided by Bury MBC indicated that further geotechnical and coal mining information was required to enable the development to proceed. It was considered that a review of archive data and intrusive site works were required.

In order to investigate the potential pollutant linkages, coal mining issues and to provide further geotechnical information, intrusive site investigations comprising 3 cable percussion boreholes, 7 window sample boreholes, 15 trial pits and 14 hand auger holes supplemented with 10 return gas monitoring visits were undertaken. Soil samples were recovered for contamination and geotechnical testing.

Made ground in the eastern part of the site comprised ash and clinker or reworked clay which was present to depths up to 11.0m. Made ground in the lower western site areas generally comprised ash and clinker or re-worked topsoil.

Natural ground comprised stiff boulder clay which was overlain over parts of the site by sands and gravels which are thought to represent river terrace deposits. Lower Coal Measures solid geology comprising interspersed layers of sandstone, mudstone and coal seams were encountered at depths between 14.5 and 19.0m.

Contamination testing indicated elevated levels of heavy metals, PAHs and TPHs however, given the proposed use of the site, comparison with CLEA SGVs for commercial and industrial site use and ATRisk SSVs for parks, playing fields and open spaces indicates that remedial measures are not considered necessary except for alongside the proposed pedestrian walkways. Elevated levels of potentially phytotoxic copper and zinc were encountered across the site and consideration must be given to the nature of areas of proposed landscaping.

Gas monitoring indicated slightly elevated levels of carbon dioxide present across the site. Given the nature of the proposed structures, precautionary gas protection measures may be required in small areas such as offices, toilets and cupboards.

The geotechnical testing is reported factually in the absence of proposed structure loadings, however it is likely that a sub base or capping layer is required for proposed roadways and car parking. An empirical review and assessment of the ash embankment slope indicates that considering measures such as re-grading to 1 in 4, loading the toe, planting stabilising grasses and installing drainage may be suitable. Loading of structures proposed near the slope crest should be transferred to the deeper ground.

A review of coal mining issues and drilling of rotary boreholes did not establish the location of the Trencherbone Seam in the northern part of the site but did encounter the Hell Hole

Mine Seam in the central part of the site. Consideration must be given to further rotary holes to establish if the Hell Hole Mine has been worked elsewhere beneath the site or whether the rotary hole in this investigation encountered an area of roof support.

To allow the site to be safely redeveloped and the risk from contamination at the site appropriately managed, remedial actions are considered necessary. These are outlined in Section 9.

To aid in the design of foundations, gas protection measures and any slope treatment, detailed building designs and loadings may be required.

## 9 RECOMMENDATIONS

The site investigation has identified a number of contamination issues which will require precautionary construction practices or basic remedial measures.

Once detailed proposals for the proposed structures including expected loadings details of internal rooms are available then issues such as foundation design and requirement or specification of gas protection measures may be outlined.

LKA would recommend that a copy of this interim report is forwarded to Environmental Services and Engineering Consultancy for comment.

### 9.1 Contamination Issues

#### 9.1.1 Pollutant Linkage 1 – Alongside Proposed Pedestrian Walkways

The contamination testing has indicated that elevated levels of benzo(a)pyrene with respect to site visitors were encountered alongside the proposed pedestrian walkways.

The main risk from benzo(a)pyrene along the walkways is due mainly to ingestion and dermal contact. To break the relevant pollutant linkage it is considered that restricting contact with the soil would be appropriate. This may include the provision of an engineered surface for the walkways and fencing which will prevent site visitors coming into contact with the soil. Additionally a 200 to 300mm thick clean soil capping layer adjacent to the walkways will be sufficient break the pollutant linkage.

#### 9.1.2 Pollutant Linkage 4 – Proposed Structures

The gas monitoring undertaken at the site has indicated that precautionary gas protection measures up to Characteristic Situation 2 are required in certain buildings across the site. LKA consider that protection measures will be required only in areas of small relatively un-ventilated rooms such as toilet blocks, offices, store cupboards etc. Situation 2 measures generally require a ventilated granular filled sub-floor space.

This should be confirmed following provision of final building design.

#### 9.1.3 Pollutant Linkage 7 – Site Wide

Generally, the contaminant levels in the made ground across the site are above the guidelines given in United Utilities pipeline risk assessment document. United Utilities should be consulted should potable supply pipes be installed in the made ground to any proposed buildings as to any protective measures that may be required.

Given the available data LKA consider it likely that if the pipes are to be installed in the made ground that metallic or protectaline pipes installed in a clean backfilled trench will be required.

#### 9.1.4 Pollutant Linkage 8 – Site Wide

Elevated levels of phytotoxic copper and zinc were encountered across the site which may affect any areas of proposed landscaping

The guideline levels are known to be conservative and for acidic soil conditions. Consultation with the appointed landscape architect should be undertaken to assess if a clean soil capping layer is required for areas of proposed landscaping or whether copper or zinc resistant vegetation should be planted.

## 9.2 *Geotechnical Issues*

It is considered that a capping layer and sub-base is required for the proposed car park and access routes in the north east corner of the site.

A minimal capping layer is required below new proposed track beds and pedestrian walkways where they are to be laid across ashy made ground. A more substantial capping layer or removal of soft spots may be required where they are to be laid over topsoil.

Foundation proposals will be dependant on the proposed structure loadings, however it is considered that generally a piling solution for each structure will be required given the depth and variability of made ground. Depending on the proposed loadings, ground improvement techniques may be suitable to allow the made ground to be the founding strata below the proposed turntable and station.

The embankment slope should be assessed and fully surveyed prior to undertaking an empirical analysis of the potential slope failure. At this stage, qualitative remedial measures and considerations may include re-grading the slope to 1 in 4, loading the toe or placing gabions, planting binding vegetation and ensuring the slope remains well drained.

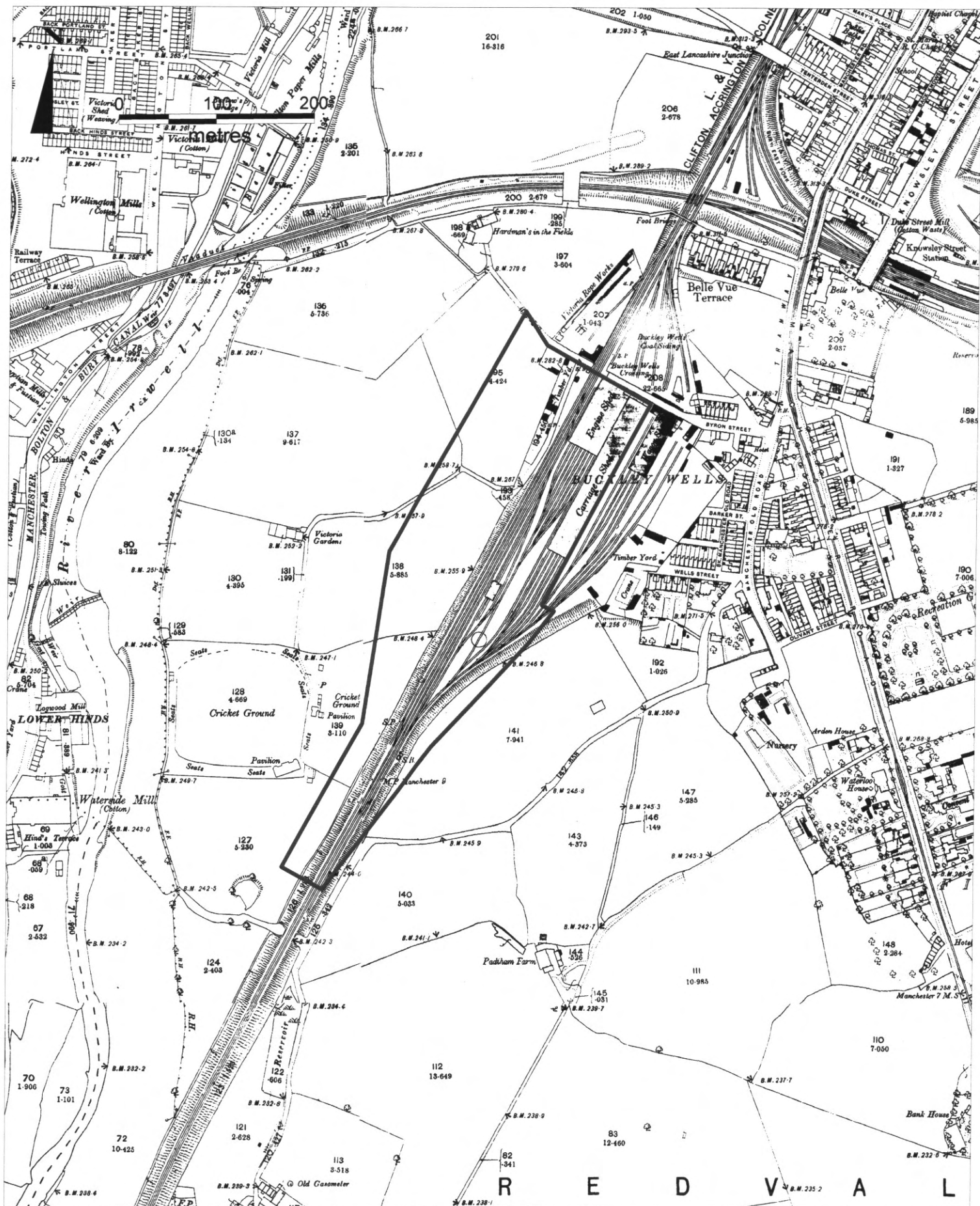
## 10 REFERENCES

- British Standards Institution (2001): Investigation of potentially contaminated sites - Code of practice for foundations. BS10175:2001, London.
- British Standards Institution (1999): Code of practice for site investigations. BS5930, London.
- BRE Special Digest 1 (2003). Concrete in aggressive ground. 2<sup>nd</sup> Edition.
- Card, G.B. (1995). Protecting development from methane. CIRIA Report 149.
- Department for Environment, Food and Rural Affairs and the Environment Agency. 2002 Soil Guideline Value reports for individual soil contaminants, reports CLR10 GV1-10. *WRc plc, Swindon*
- DETR, 2000. Circular 02/2000. Environmental Protection Act 1990: Part IIA, Contaminated Land.
- DETR, 2000. Guidelines for Environmental Risk Assessment and Management. July 2000
- Environment Agency (2001) Environment Agency technical advice to third parties on Pollution of Controlled Waters for Part IIA of the Environment Protection Act 1990, December 2001
- Harries, C.R., Witherington, P.J. and McEntree, J.M. (1995) Interpreting measurements of gas in the ground. CIRIA Report 151
- SNIFFER (2003) Method for Deriving Site-Specific Human Health Assessment Criteria for Contaminants in Soil, Report No LQ01. Prepared by Land Quality Management Ltd, University Park, Nottingham, NG7 2RD
- Terzaghi, K (1943). Theoretical Soil Mechanics. John Wiley, London and New York.
- Terzaghi, K and Peck, R.B (1948). Soil Mechanics in Engineering Practice. Chapman and Hall, London; John Wiley & Sons Inc., London and New York.
- Tomlinson, M.J (1986). Foundation design and construction, 5<sup>th</sup> Edition. Published by John Wiley & Sons, New York
- WRAS (October 2002). The Selection of Materials for Water Supply Pipes to be Laid in Contaminated Land. No 9-04-03, Issue 1.

## **APPENDIX A**

### **DESK STUDY INFORMATION**





KEY:



Site Boundary

TITLE:

Buckley Wells Locomotive Works

1893 Map

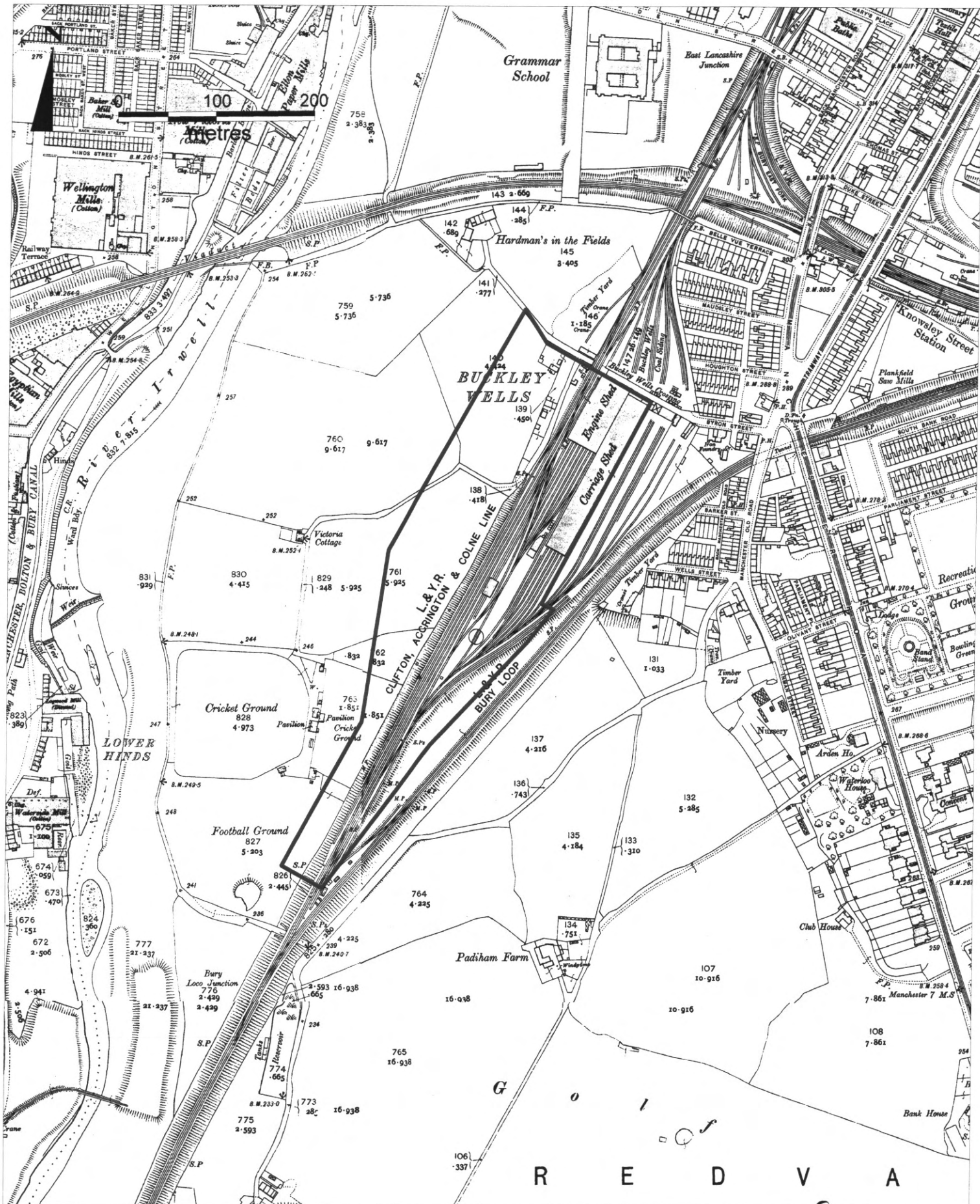
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SCALE (approx): 1:5000 Date: October 2005





KEY:



Site Boundary

TITLE:

Buckley Wells Locomotive Works

1910 Map

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