## 5.3 The GPR surveys on terrace 2

The GPR investigations on terrace 2 consisted of one transect survey and one grid survey.

### *5.3.1 Terrace 2 transect 1 (T2T1)*

The T2T1 transect ran for 335m from east to west (Fig. 5.43), using a 200MHz antenna. Data processing used a variable migration model. A gouge core transect ran along the GPR transect, sampling at a 10m interval. The LiDAR last pulse DTM does not identify any significant topographic variation within the survey area. Aerial photography of terrace 2 reveals a wealth of archaeological monuments and also a section palaeochannel, T2C1 (Fig. 5.44). Calibration of the GPR transect was made through using data from the gouge core transect and the dielectric constant was set at 24.

The T2T1 transect interpretation classifies the alluvium overlying the terrace 2 gravels (Fig. 5.45). The gravels of terrace 2 are apparent as a strongly reflecting unit (T2B1). Some limited variation is seen in the gravel structure and three sub units are labelled as T2D1, T2D2, T1D3 and T1D4. The transect does not identify any palaeochannels such as T2C1, identified through aerial photography. The transect does show topographic variation between 175m – 230m and this may relate to an older palaeochannel. The deposits identified as unit 3 on the gouge core transect may represent the base of a palaeochannel fill but they are shallow and are considered to have a low palaeoenvironmental potential. The contact with the bedrock is seen at circa 4m below ground surface. Overall the GPR interpretation and the gouge core data provide a good correlation. The level of alluvium overlying the gravels deposits on terrace 2 is shallow, generally between 30cm – 40cm.

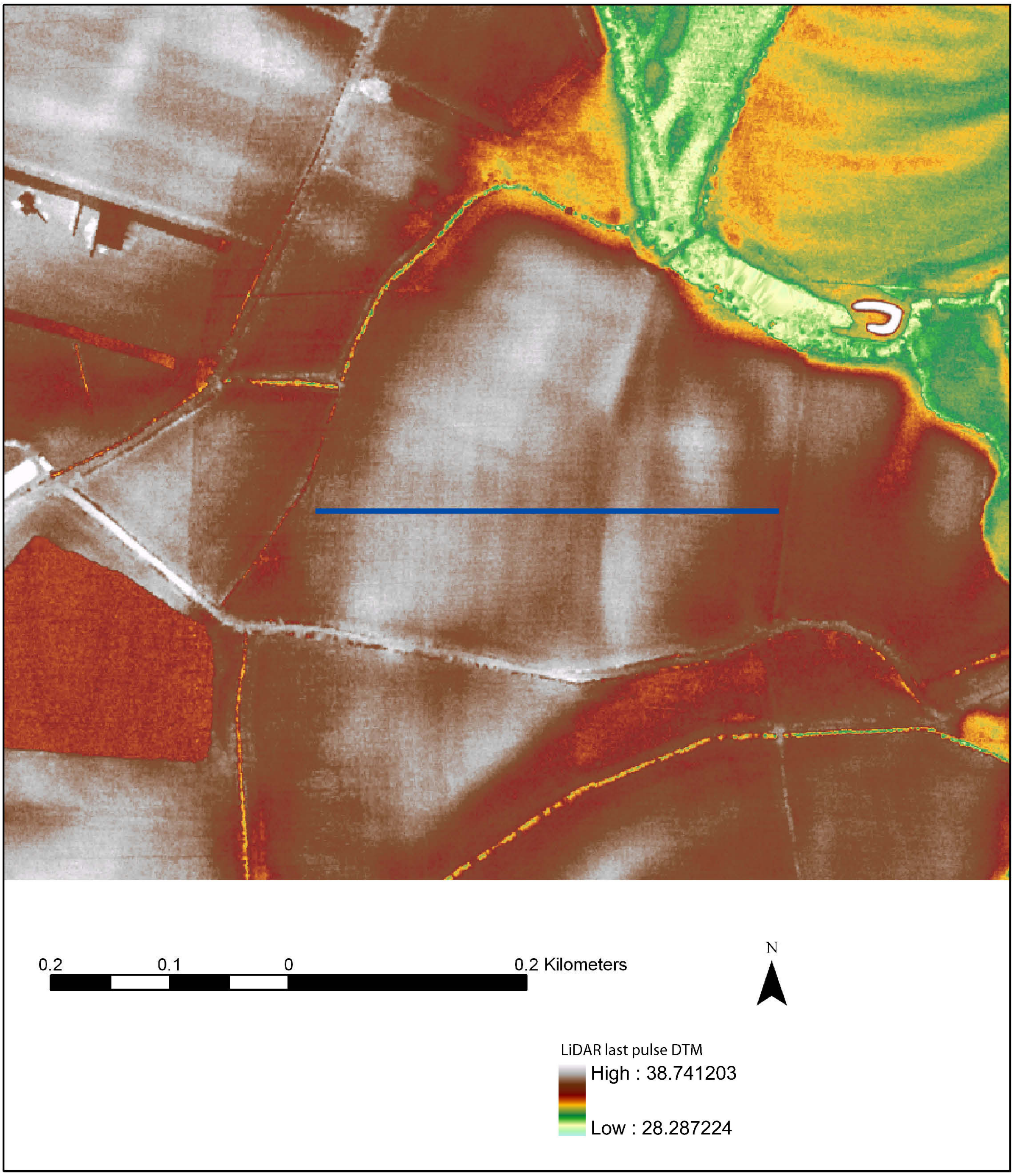

**Fig 5.43:** The location of the T2T1 transect, shown on the LiDAR last pulse DTM. There is no major topographic variation seen in the survey area.

**Fig 5.44:** A rectified aerial photograph of the T2T1 survey area, showing a possible palaeochannel, T2C1.

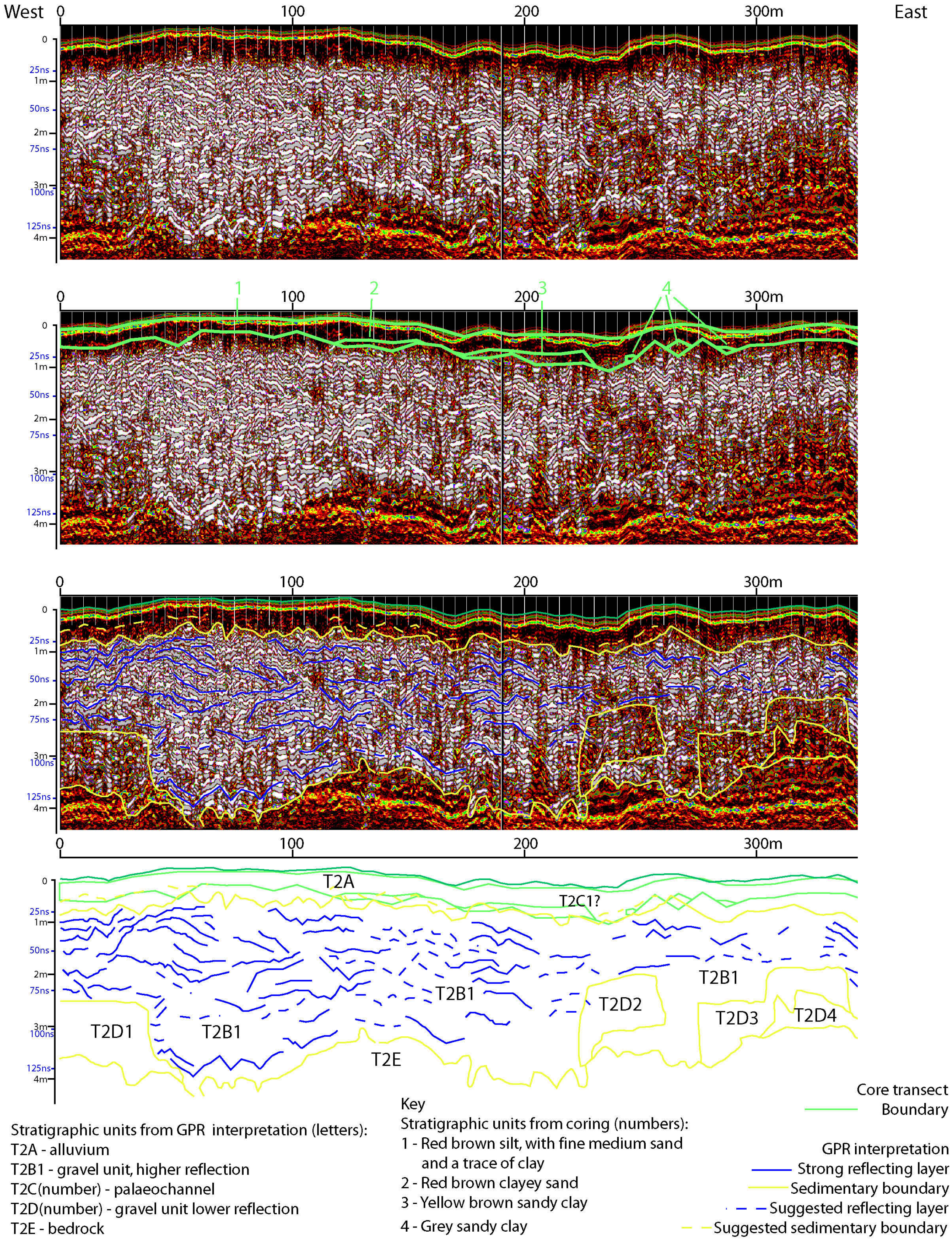

**Fig 5.45:** The T2T1 GPR transect shown with interpretation and against the gouge core transect.

### *5.3.2 Terrace 2 grid 1 survey (T2G1)*

This survey utilised a 200MHz antenna collecting twenty transects of data using a 5m transect interval. No coring work was undertaken within this field but the same dielectric constant is applied from the T2T1 calibration in the adjacent field. The GPR reflectance values ranged from –112 to +128. The data was processed through a variable velocity migration. The T2T1 survey is depth sliced at 0.5m intervals using a 0.2m depth slice, shown with the LiDAR intensity at 70% transparency. The LiDAR last pulse DTM identifies this area as terrace 2 but reveals little topographic variation within the field (Fig. 5.46). The LiDAR intensity values depict some subtle variation between the northern and southern end of the survey area (Fig. 5.47).

The time slicing of the GPR survey adds further evidence to the interpretation of the LiDAR intensity results. The 0.4m – 0.6m time slice gives a high reflectance value across most of the survey area being at the edge of the gravel alluvium interface (Fig. 5.48). The 0.9m – 1.1m time slice displays more marked variation within the survey area, with lower reflectance/higher absorbance values at the southern end of the survey (T2A1) and high reflectance lower absorbance values at the northern end (T2A2) (Fig. 5.49). This pattern is repeated in the 1.4m – 1.6m time slice and the 1.9m – 2.1m time slice (Figs. 5.50 and 5.51). The 2.4m – 2.6m and 2.9m – 3.1m time slices reveal less variation and generally show the higher reflecting gravels (Figs. 5.52 and 5.53). Penetration is not achieved below the 2.9m - 3.1m depth slice and the gravel/bedrock contact is not seen.

From the depth of 0.9m - 2.1m variation is seen in the structure of the gravels. The reason for the variation in the gravel structure is not clear but it potentially relates to the structure of the gravel affecting the moisture content. Alternatively, T2A1 could possibly be relating to a palaeochannel on terrace 2, although this is speculative. Such an example highlights the importance of using integrated remote and ground based sensing methods for investigation of sedimentary units.

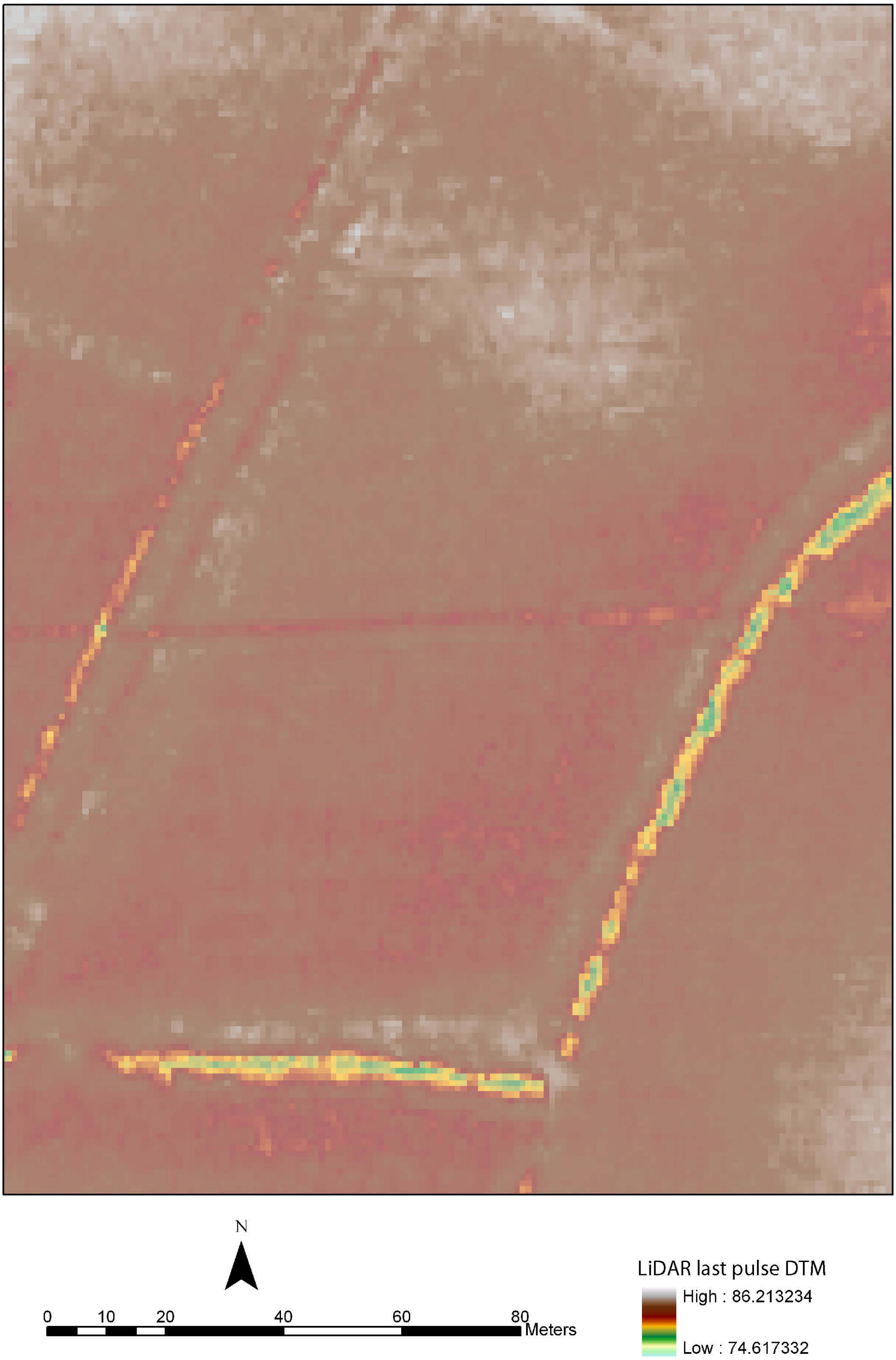

**Fig 5.46:** LiDAR last pulse DTM over the T2G1 survey area. No significant topographic variation is seen.

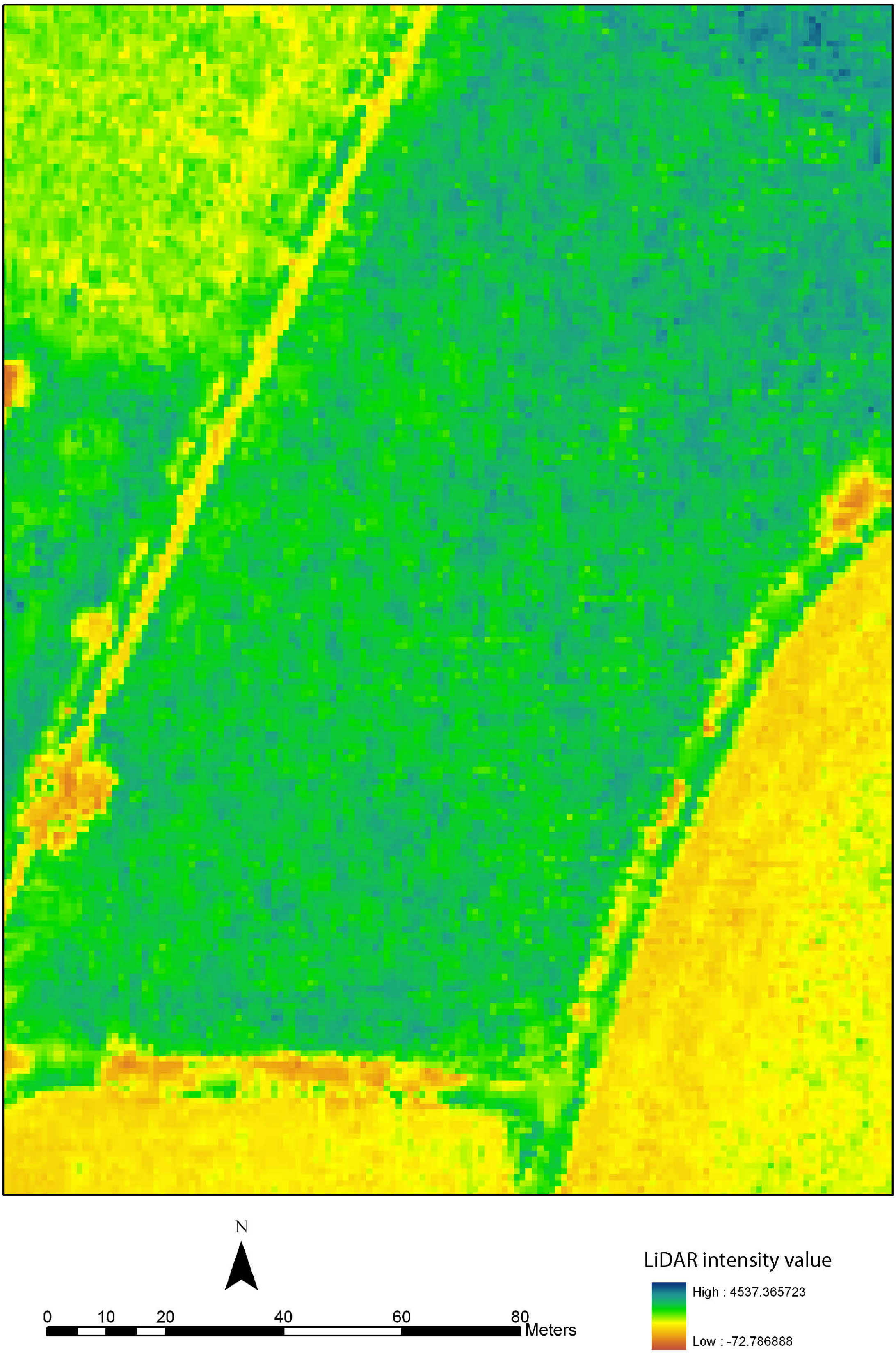

**Fig 5.47:** The LiDAR intensity values across the T2G1 survey area. Some subtle variation is discernable between the north and south of the survey area.

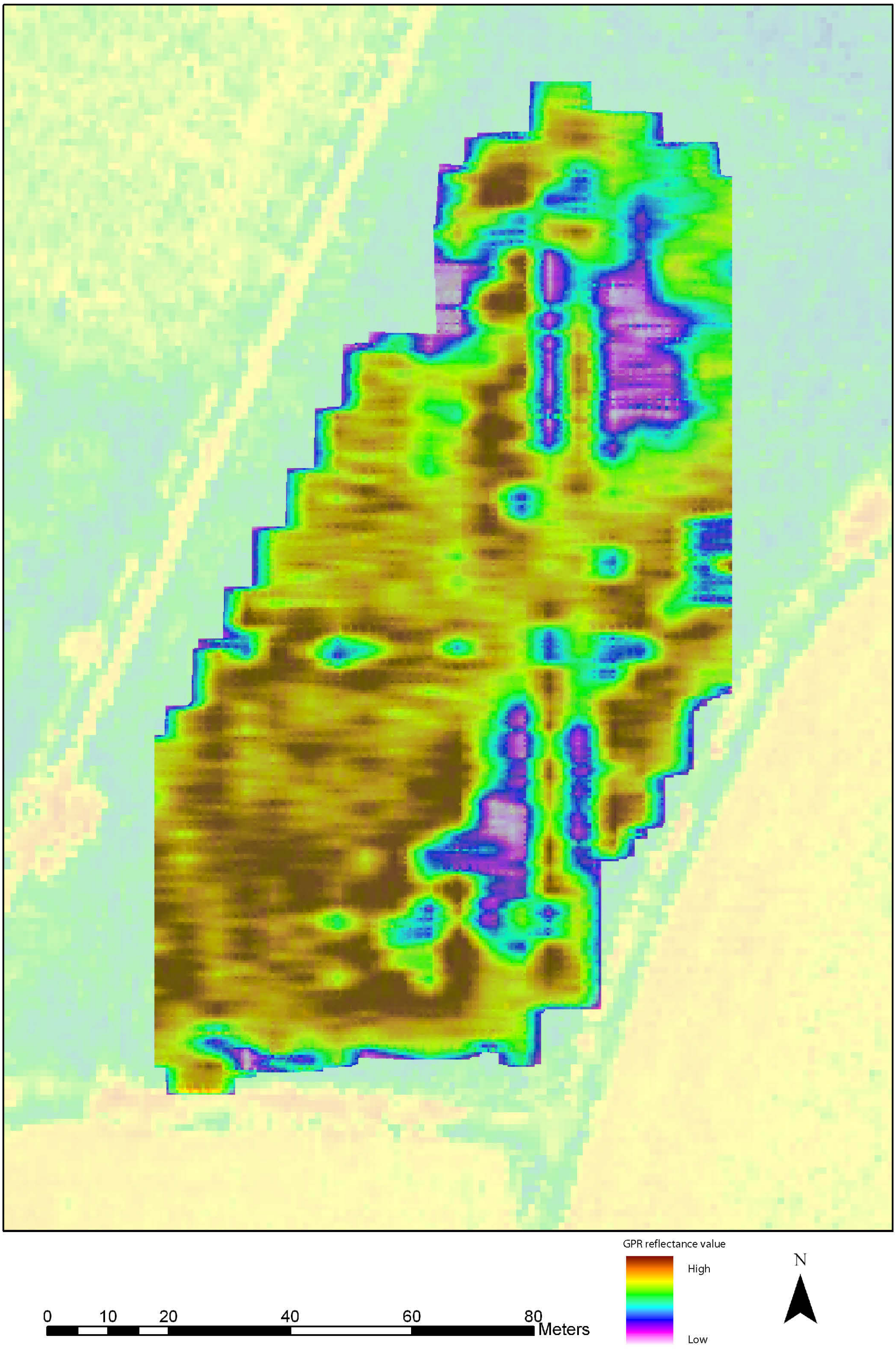

**Fig 5.48:** The T2G1 survey, 0.4m – 0.6m depth slice. A general area of high reflectance is seen across the survey area.

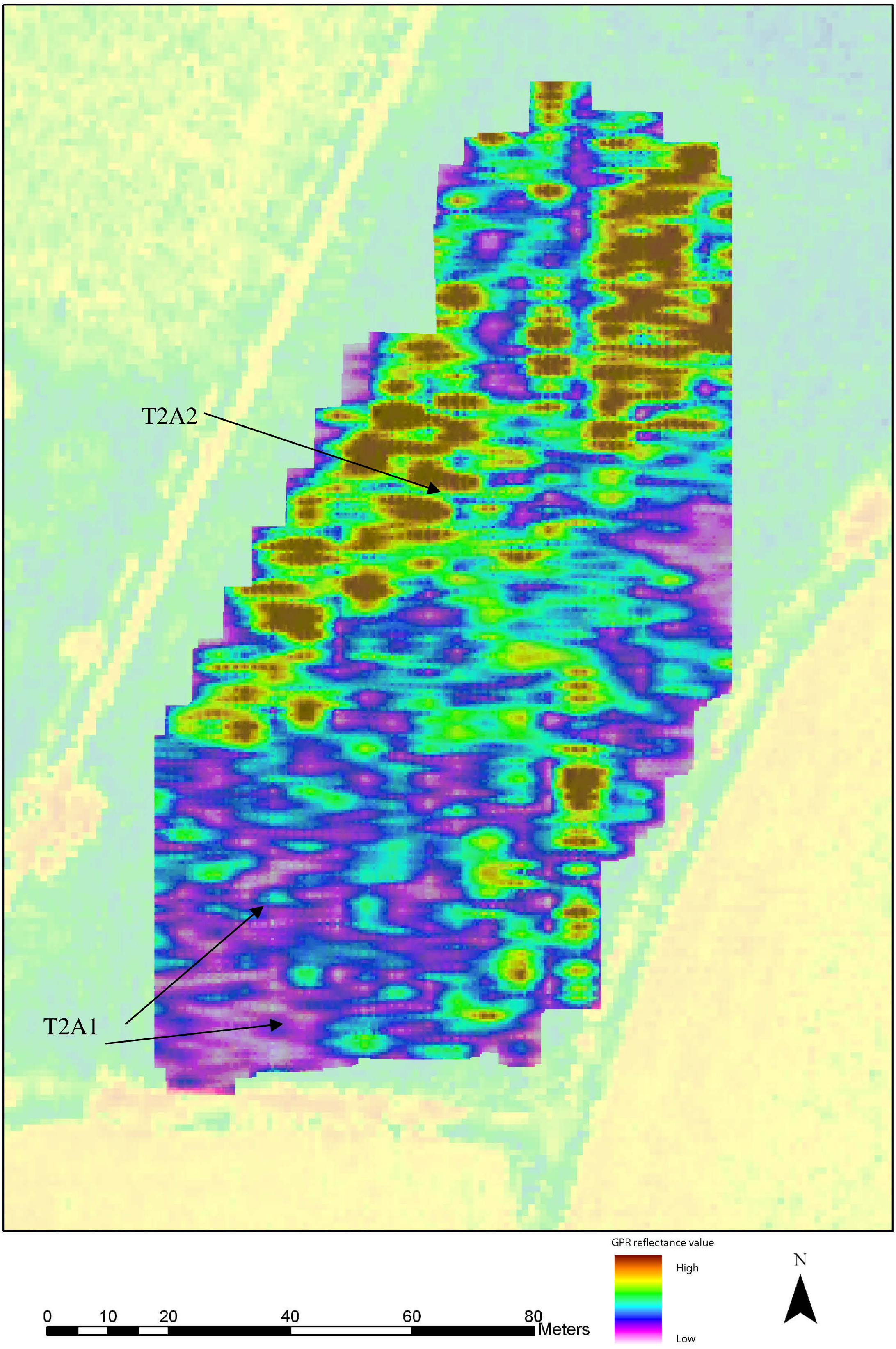

**Fig 5.49:** The T2G1 survey, 0.9m to 1.1m depth slice. Some variation is evident in the structure of the gravel deposits. Two distinct areas are visible, being T2A1 and T2A2.

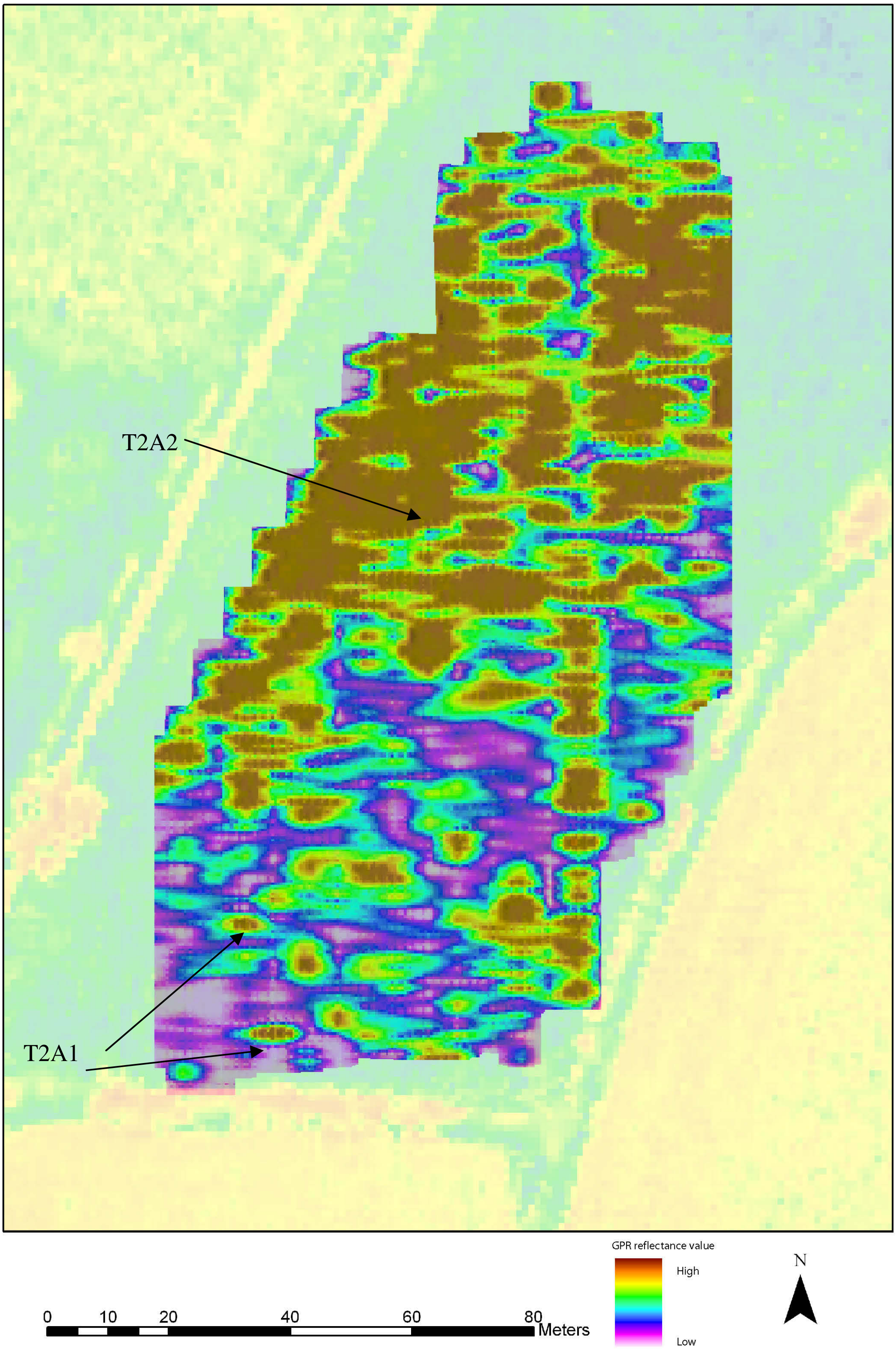

**Fig 5.50:** The T2G1 survey, 1.4m – 1.6m depth slice.  Variation is still evident between T2A1 and T2A2.

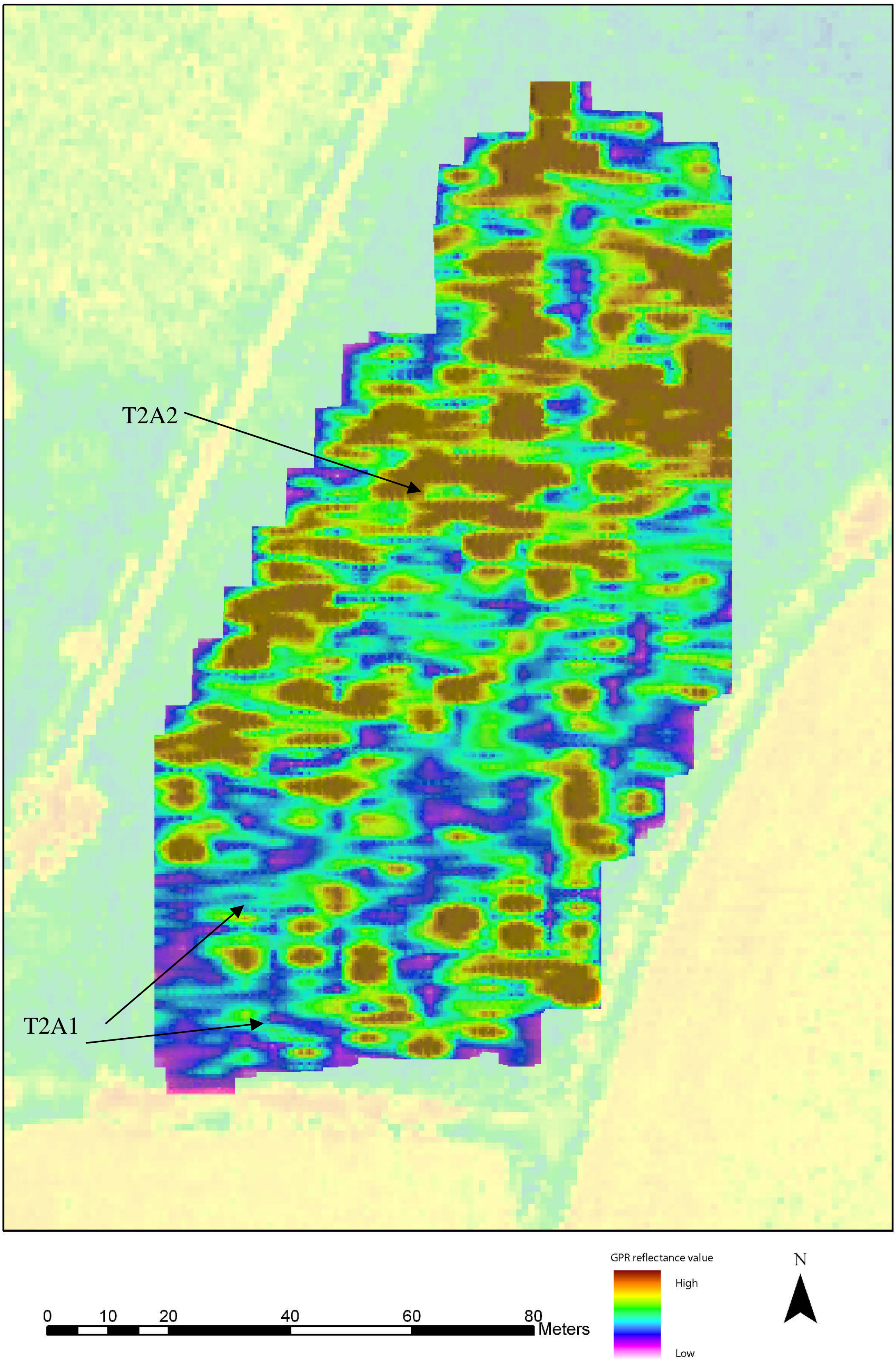

**Fig 5.51:** The T2G1 survey, 1.9m – 2.1m depth slice. There is still some variation in the gravel deposits, with T1A1 and T1A2 visible.

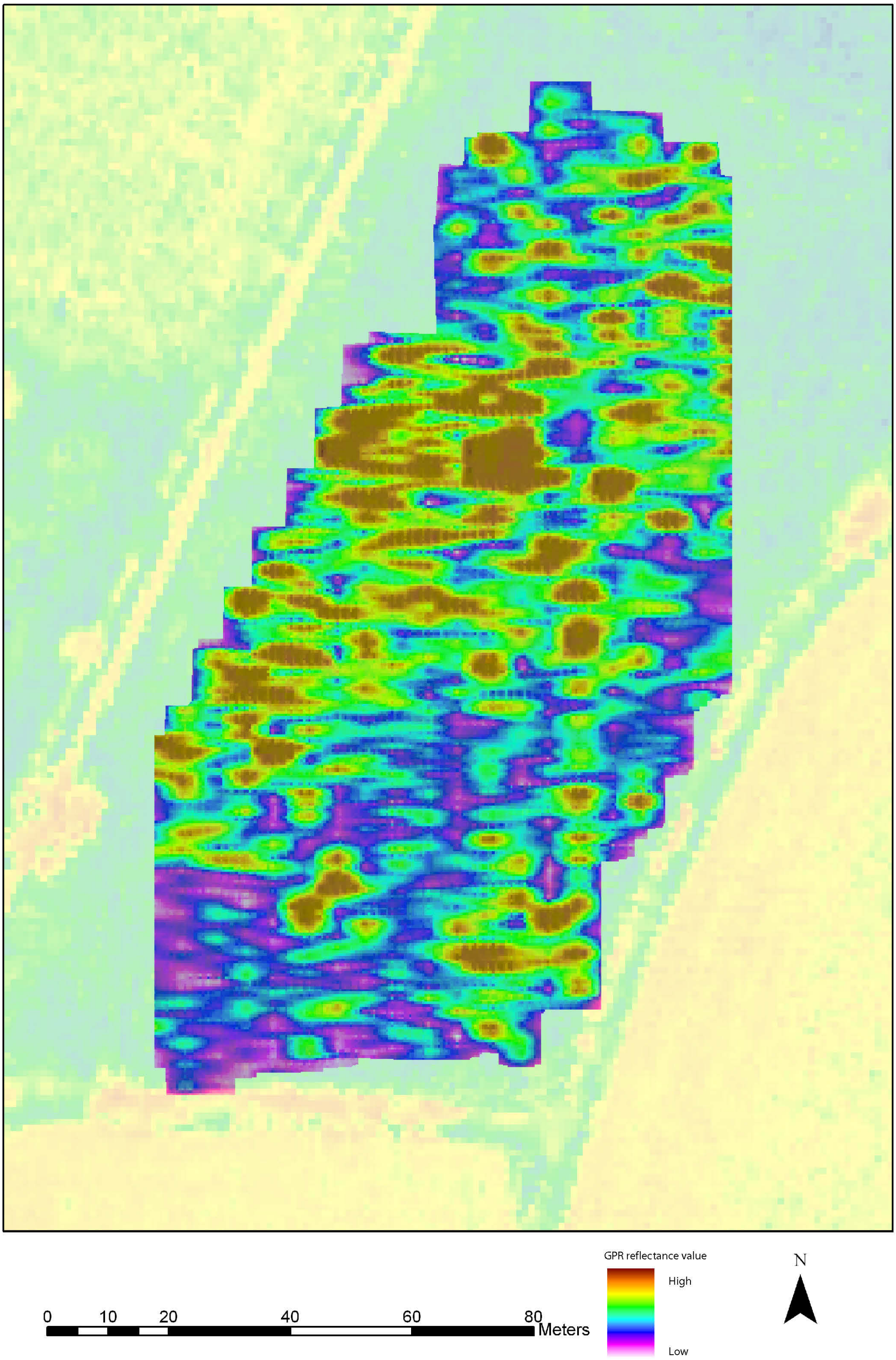

**Fig 5.52:** The T2G1 survey, 2.4m – 2.6m depth slice.

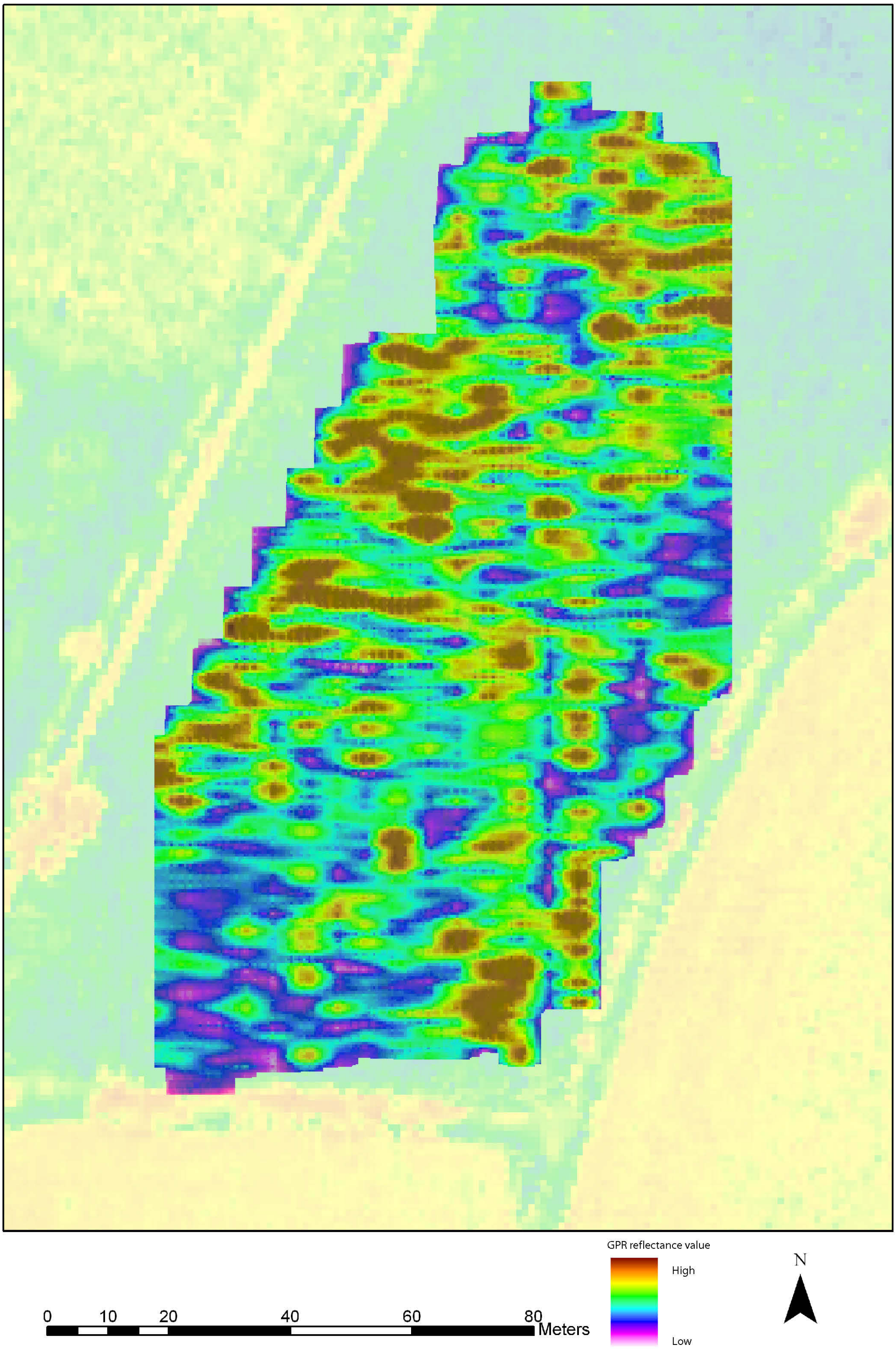

**Fig 5.53:** The T2G1 survey, 2.9m – 3.1m depth slice.

### *5.5.3 Summary of the GPR surveys on the upper unit*

From the two GPR surveys undertaken on terrace 2 the main points can be summarised as:

- In the areas of the T2T1 and T2G1 surveys Terrace 2 had a thin layer of alluvium overlying substantial gravel deposits.
- The gravel deposits have a contact with bedrock at circa 4m thick.
- The relatively deep GPR penetration on terrace 2 is a product of a lower water table and lower overall substrate water content.
- Within the terrace 2 survey areas no well-preserved palaeochannels were identified.
- The palaeoenvironmental potential within the survey areas on terrace 2 is considered to be low.
- Variation was seen in the T2G1 grid gravels, which may possibly relate to a palaeochannel, although this is a speculative interpretation.

## 5.4 Comparison of the GPR surveys with bore hole data

Data was made available by Lafarge quarries on a series of boreholes recorded across the study area from water table monitoring. Five boreholes have spatial proximity to the GPR surveys (Fig. 5.54). Of these bore holes LKN90/78b is located on terrace 2, LKN89/20 and LKN90/57 are located in palaeochannels on terrace 1 and LKN90/61 and LKN90/16 and located on terrace 1. These bore holes provide complimentary data for comparison with the stratigraphy recorded from the GPR surveys (Fig. 5.55).

The GPR survey T2T1 is interpreted as reaching the gravel bedrock interface. The depth of gravels, although not constant, varies between 3m and 4.1m although it becomes shallower on the eastern edge of the transect. In comparison the core LKN90/78b produces a depth to bedrock of 4.4m. The borehole produces a depth to bedrock of circa 50cm below the level seen from the GPR interpretation. The borehole LKN90/78b is not adjacent to T2T1 and therefore variations in terrace 2 may account for some of the difference. It is also possible that the GPR profile is slightly too shallow, calibrated through the alluvial depth, which has had the effect of compressing the gravel depth.

The LKN89/20 and LKN90/57 bore holes both sample palaeochannels associated with terrace 1. In LKN89/20 the depth to pebbly sand is 4.0m and to bedrock 4.7m. In LKN90/57 the depth to a silt below the sand and gravel is 3.5m, with a pebbly sand to 3.9m, with bedrock being encountered at 5.8m. Located on the gravels of terrace 1 LKN90/61 reveals a depth to bedrock of 6.0m, whilst LKN90/16 reveals a depth to bedrock of 5.3m. The GPR surveys on terrace 1 struggled to penetrate to the depth of the interpreted bedrock/gravel interface. On the T1T1 survey high gains were used that attempted to penetrate to this depth. A major junction is seen at circa 3.5m across the transect. The borehole data strongly suggests this is not the gravel/bedrock interface. There are two possibilities: either a pebbly/sand layer below the gravel has been reached (analogous to LKN89/20) or a silt layer below gravel, (analogous to LKN90/57). In either situation the GPR has not penetrated through this layer and the contact with bedrock is not seen.

The borehole data also produces data on the level of alluvium on terraces 1 and 2 and the nature of the palaeochannel fills. LKN90/78b shows this area of terrace 2 to have 1.4m of combined topsoil and red brown silty clay. This compares with the 0.4m covering seen in T2T1. This bore has importance in showing that some areas of terrace 2 have substantial coverings of alluvium over the terrace gravels. It also highlights that substantial differences exist in the floodplain stratigraphy between the bore LKN90/78b and survey T2T1.

The two boreholes on terrace 1 have alluvial depths of 1.8m (LKN90/61) and 1.1m (LKN 90/16). Both of these figures are in good agreement with some of the surveys conducted on terrace 1, such as T1G1 and T1QT, which both showed circa 1.4m of alluvium overlying terrace gravels. Notably, LKN90/16 I located within part of the potential palaeochannel identified in T1G3 and this may explain the depth of 1.1m of alluvium at this point.

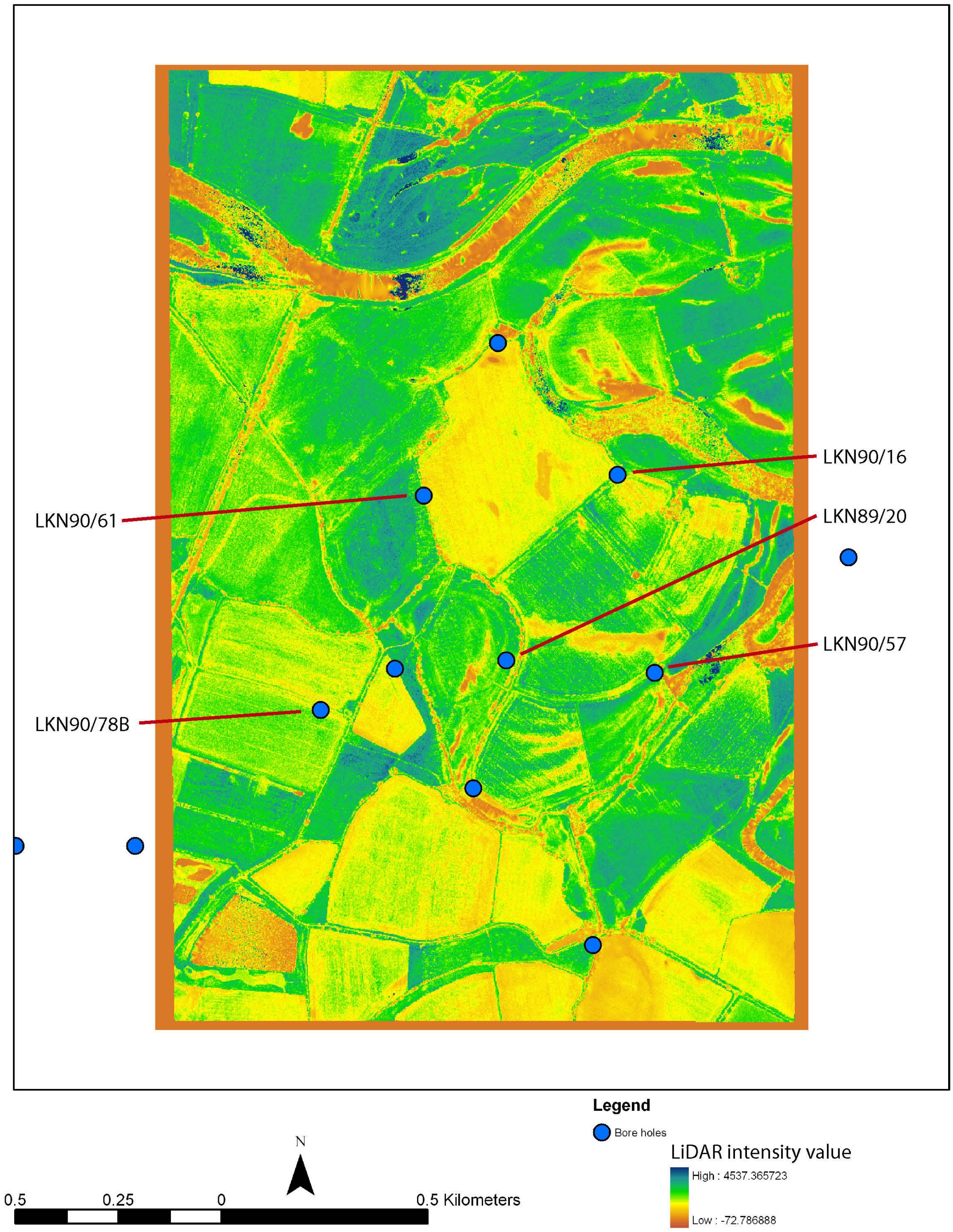

**Fig 5.54:** The location of five bore holes within the survey area.

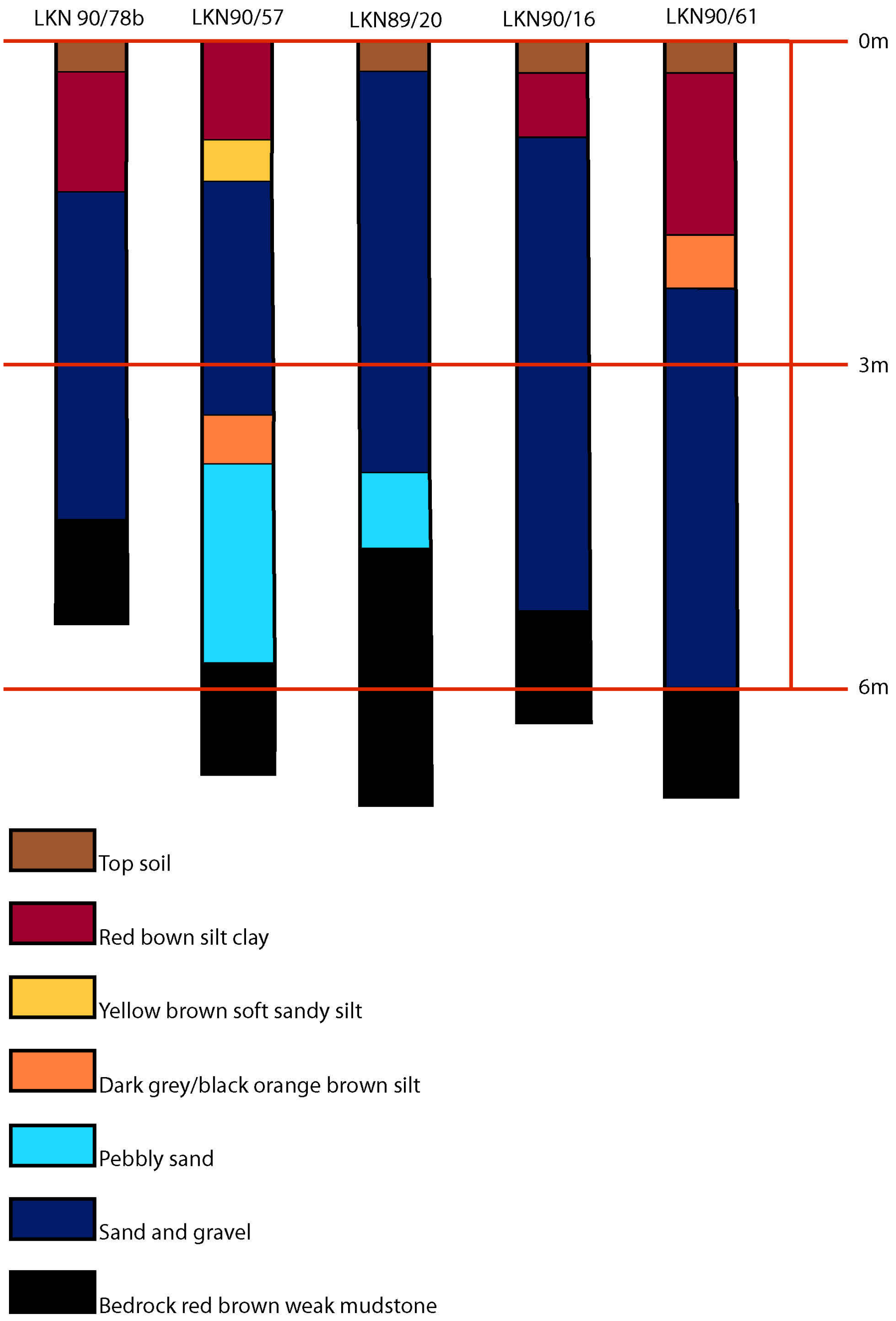

**Fig 5.55:** The stratigraphy of the boreholes.

## 5.5 A summary of ground penetrating radar survey within alluvial environments

The application of Ground Penetrating Radar to map the subsurface stratigraphy of an alluvial environment has produced mixed results. Primarily, the GPR has been effective in mapping the depth of alluvium above the gravels, the composition of the upper gravel deposits and identifying boundaries and variation between gravels and palaeochannels on the modern floodplain, terrace 1 and terrace 2. Conversely, the GPR penetration into the palaeochannels was generally poor. Where the channels had high water/clay contents, GPR penetration was particularly weak. Therefore, GPR cannot be used to investigate the structure of high water/clay content palaeochannel fills, which are the palaeochannels that have high palaeoenvironmental potential. However, by using this criteria, palaeochannels that cause rapid attenuation of the radar signal should be earmarked for palaeoenvironmental sampling, due to the nature of the fill causing the loss of signal. It was possible to see the cross section of some palaeochannels and variation in their fill. Such palaeochannels are suggested to have a low palaeoenvironmental potential, due to the lack of highly conductive material within their fill such as clay, which would cause rapid attenuation of the GPR signal. Through looking at the patterns of deposition within the GPR transect it is possible to build simple chronological models of deposition of the sedimentary units.

The two and three dimensional GPR surveys recognised distinct sedimentary structures in the heterogeneous alluvium deposits. Sedimentary units were interpreted according to their reflection pattern and interpreted shape. The reflection amplitudes that were recorded related to differences in the sedimentary architecture of different geomorphological units. However, it was not possible to unambiguously predict the physical properties of a geomorphological unit from GPR reflection data. In general it was possible to differentiate between alluvium, palaeochannels, gravel and variations within the gravel, through changes in their relative RDP and hence reflectance pattern. However, in some cases different sedimentary units gave similar patterns of reflectance, e.g. gravels were generally seen as units of high reflectance but some clay layers (e.g. QT5 on the T1QT survey) produced a very similar reflectance pattern.

The integration with the remote sensed LiDAR data has been excellent. It has allowed an assessment to be made of the ability of LiDAR to map surface sediment deposits. The LiDAR intensity values in particular seemed to reflect changes in subsurface sediments. Through using the 200MHz antenna the contact between the gravels and the bedrock was not seen, except for on the T2T1 survey. The 200MHz antenna was effective in mapping the stratigraphy and composition of the upper gravel deposits. These are shown to be heterogeneous in their structure. The correlation between the LiDAR results and the GPR surveys highlights the potential for integration between remote sensing and ground based prospection.

In methodological terms of the GPR data quality and penetration the results were best on terrace 2, and worst on the modern floodplain, with terrace 1 intermediate between them. This difference in data quality is interpreted as a function of the water content, with the modern floodplain having the highest water content of sediments. The presence of the high water table within surveys was a key factor in reducing penetration of the GPR signal. The use of a 5m transect interval is suggested as a maximum for all grid surveys, collecting a minimum of twenty transects of data per grid. In the future, it is suggested that GPR surveys on alluvial environments used to assess geoarchaeological potential should follow the sequence:

1. Consult remote sensed data (e.g. IFSAR, LiDAR, aerial photography) for areas in which to undertake GPR surveys, targeting different areas of the modern floodplain and terrace sequence.
2. Undertake a series of single evaluative GPR transects, combined with topographic modelling and gouge core survey.

3. Evaluate results from 2.
4. Undertake grid plan GPR surveys on areas identified through 3.
5. Integrate remote sensed and ground based prospection data.