Chapter 1.
Landscape Visualisation: A LiDAR Topographic Model

SURVEY AREA

One of the key project elements involved in the '*Where Rivers Meet*' project design was the creation of a LiDAR (**L**ight **D**istance **A**nd **R**anging) based DEM/DTM (Digital Elevation Model/Digital Terrain Model) of the complete survey area. DEM's/DTM's can be established by other means, for example Orthphotography, Ordnance Survey Panorama data or Aster Satellite imagery. However, the benefits of a LiDAR survey, large point density, the intensity readings (see below), the capture of the landscape as current as possible, and the flexibility of output makes for a highly appropriate method. The coverage of LiDAR in the case of *Where Rivers Meet* approximated to 72km^2 of South Staffordshire, from just north of Tamworth in the south to just below Burton upon Trent in the North.

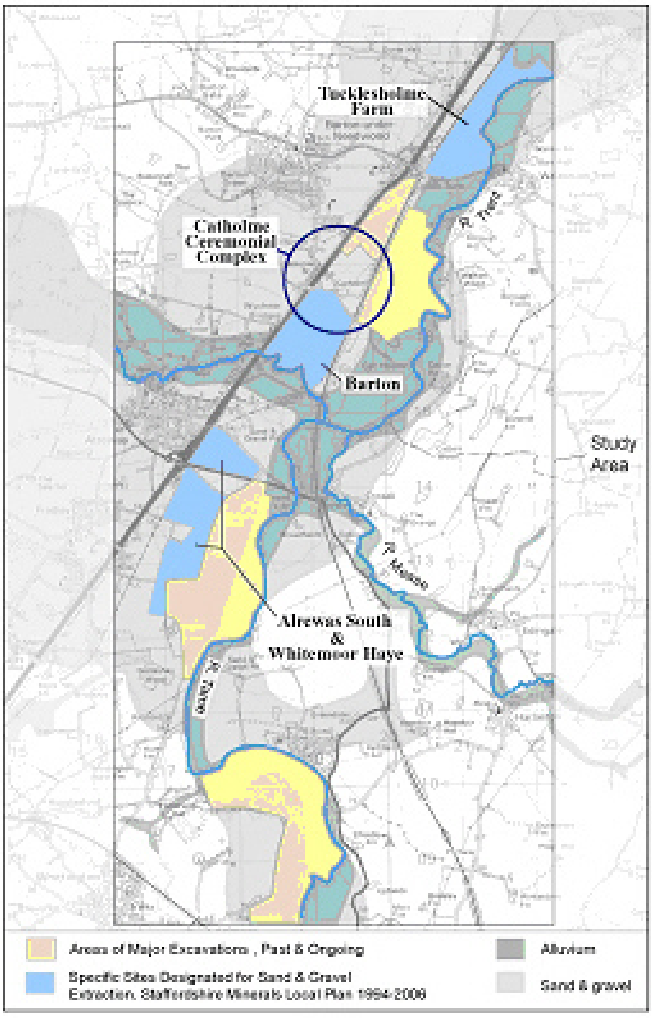

Figure 1: Where Rivers Meet LiDAR survey area

DATA COLLECTION

The LiDAR survey was commissioned in February 2002 to be flown by Infoterra Ltd using their Optech ALTM 2033 (Airborne Laser Terrain Mappers) system, as operated by NERC and the Environment Agency. The survey was scheduled to take place as soon as an open weather window became available. Undertaking the survey at this time of year takes full advantage of the lack of vegetation cover from crop growth and foliage. Care has to be taken not to fly directly after heavy rain as large areas of standing water may adversely effect the resulting data. The system is mounted in a light aircraft or helicopter with the laser at 90 degrees to the base of the plane. The aircraft will then follow a predetermined flight plan of transects over the survey area with the pilot attempting to keep the aircraft at a set altitude and consistent angle relative to the landscape surface. The laser beam then scans the ground surface in 20-degree swaths. LiDAR lasers are not eye safe and will shut off if an object passes under the beam close to the plane. Therefore air traffic clearance and laser cut off buffer zones around large towers/obstacle are important issues.

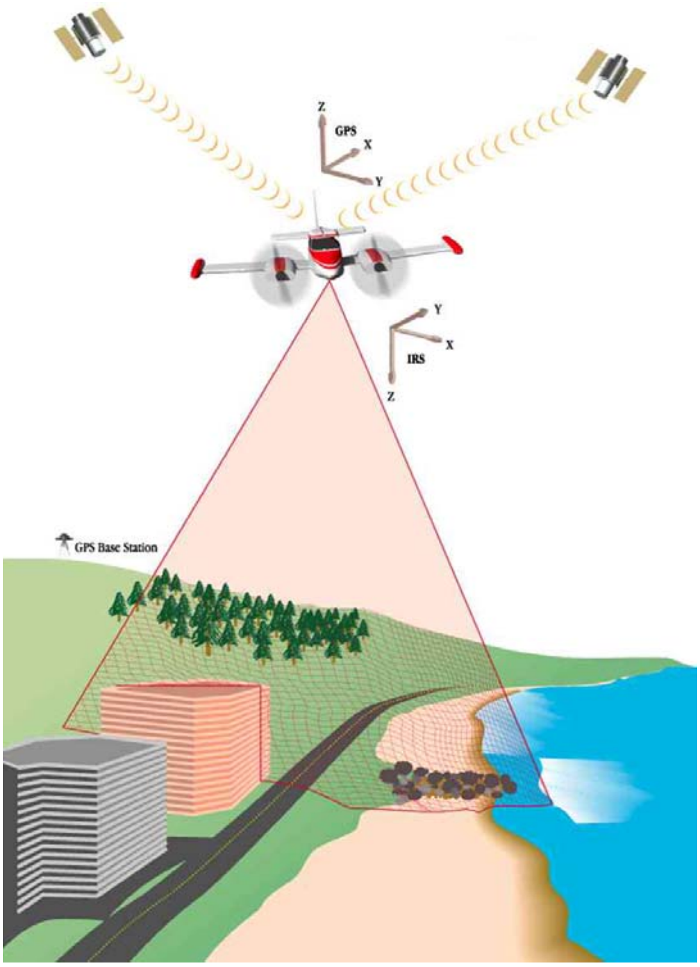

Figure 2: LiDAR survey positioning information (Optech ALTM www.optech.on.ca/prodaltm.htm)

Unlike the majority of other airborne survey techniques LiDAR is not effect by lighting levels, with the ability to operate at night or to be calibrated for extremely bright environments. Reflectivity does not generally cause a problem for LiDAR units, with the exception of water, however, different reflective elements do effect the returning signal strength, a property that can be utilised by imaging the resulting return intensity (see below).

LiDAR surveys produce highly accurate topographical information, but still based around basic survey principles. LiDAR surveys generate x, y, z point information but collect millions of these during the flight, the ALTM 2033, using a time of flight format, generating 33,000 points per second. The density of the point spacing can be varied by flight speed, by the number of passes made over the target area, and by narrowing the band swath the laser collects. For the '*Where Rivers Meet'* (WRM) survey an effective minimum spacing of 1 point per metre (ppm) was specified. A further reading, known as intensity, was also collected (see below). The LiDAR system records not only the data coming back from the laser but also the GPS (Global Positioning System) and INS (Inertial Navigation System, the role, pitch, and yaw, or 'attitude' of the plane). By combining the two onboard measurements the LiDAR system can produce a relatively accurate positional fix. However to reach to desired positional accuracy of the point data, stated as +/-15cm for the ALTM 2033, this navigational information has to be related to a positional fix on the ground. As the LiDAR survey takes place a GPS base station on the ground collects observations from a fixed point for the duration of the flight. The observations gathered from this base station are then merged with the GPS/INS from the LiDAR sensor in the initial stage of post-processing to provide the very accurate positional fix (Figure 1).

Initial Data Processing

There are two levels of point data collected by the LiDAR survey along with the intensity measurement mentioned above. Data from first pulse and last pulse are elements of the same survey referring to different stages in the measuring process. First pulse refers to the fastest return signal to the LiDAR sensor and can be thought of as the 'first return' of the laser. As the laser beam can penetrate vegetation cover and some man made materials a last pulse is also received; this refers to the final return of the pulse. These differences in return time produce varying end products. Point clouds generated from first pulse data will normally have a far greater emphasis on vegetation cover and fine objects (e.g. power lines from electricity pylons).

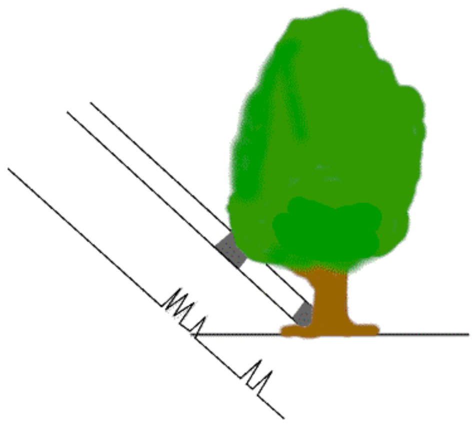

Figure 3: First pulse/last pulse return. Surfaces under vegitation can often be picked up by a last pulse measuement (www.optech.on.ca/aboutlaser.htm)

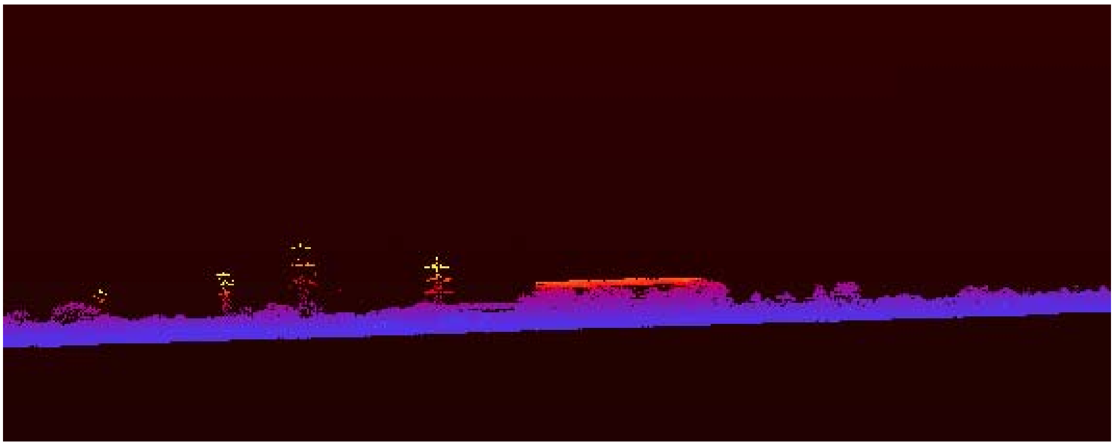

Figure 4: Profile view of raw first pulse points file. vegitation & pylons are clearly visable

Point clouds generated from the last pulse return will often have passed through some of the vegetation and will more accurately represent surface or ground features. Therefore first pulse data is best used in the creation of a Digital Elevation Models (DEM) where the highest point of every surface is required and so will include vegetation, buildings, vehicles and groups of people. Last Pulse point clouds will pick up thicker vegetation but will also have more points relating to the actual landscape surface. As such last pulse point clouds are closer to a Digital Terrain Model (DTM) but while still requiring further processing. This initial separation of points into first and last pulse clouds can be performed as a first output straight after the ground and airborne navigation integration and correction. The output of this will be an ascii (see glossary) text file with x, y, z and intensity (int) columns for first and last pulse. Although the first pulse data can be taken and used for a DEM the last pulse data requires a further stage of separation to filter out more points.

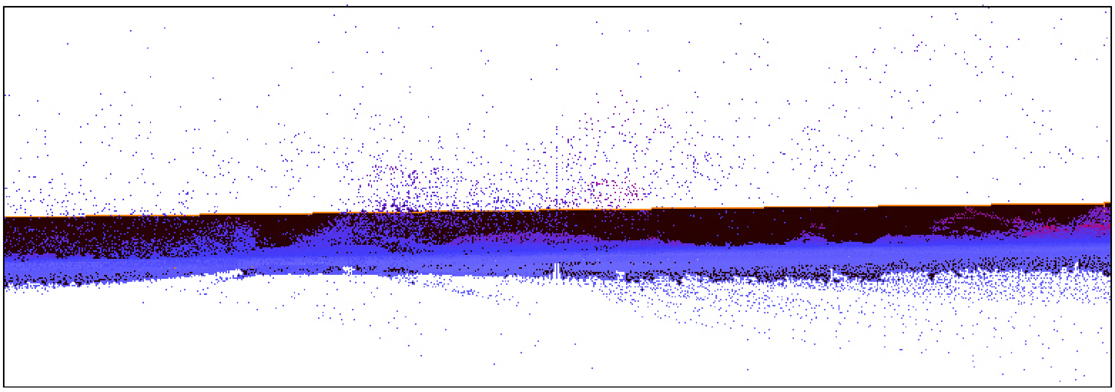

Figure 5: Raw point cloud showing out-liers (above surface normal) and erroneous points (below surface normal)

Although some vegetation will be missing from the last pulse information it will still contain hard vegetation (tree trunks, thick canopy), buildings, and vehicles. To create a useful DTM these points need to be filtered out to achieve last pulse ground file, just the points relating to the ground surface. This can be performed in a number of software packages, REALM (www.optech.on.ca/altmsys.htm), TerraScan (www.terrasolid.fi), Amira (www.tgs.com), using varying techniques. Most have mathematical algorithms that trace a path from point to point in the data looking for changes in the height value. By scanning surrounding points and referring to a configurable tolerance they can detect points that are unlikely to be the natural ground surface. These points can then be separated off and a more realistic ground surface generated. This process is not always completely accurate and some manual editing is often necessary. Very large one to two story warehouses, aircraft hangers (especially old domed military hangers) and open shaft mines can all occasionally be interpreted incorrectly and require reassigning. Packages such as TerraScan allow multiple levels of grouping and targeting algorithms to allow much finer segregation. This allows for producing files containing ground points and intermittent larger vegetation but not buildings and scrub. However these will often require more user intervention.

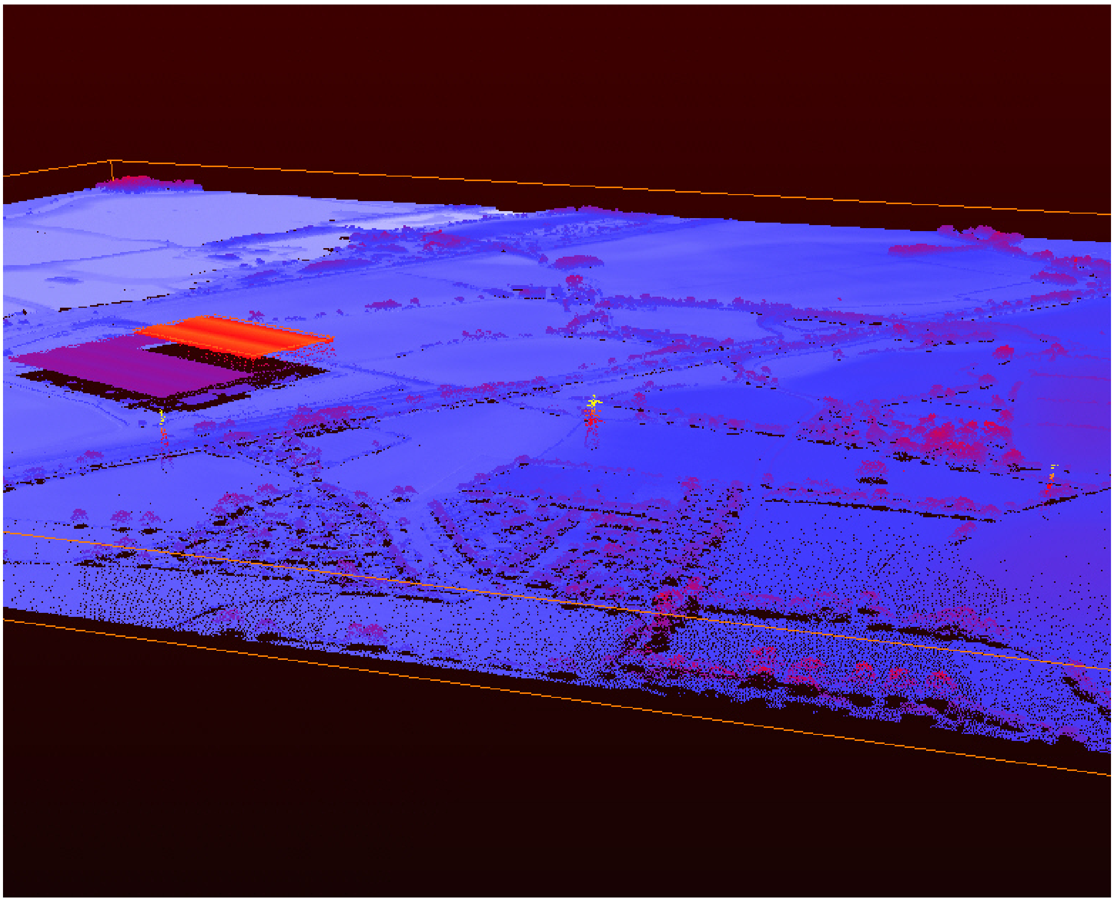

Figure 6: Overview of WRM focus area generated from raw first pulse points

LiDAR Data Surfacing

The above processes and imaging have been performed on the raw point data with some modifications. However, LiDAR surveys are generally collected in WGS84 co-ordinate framework, which for the purposes of integration with all the other datasets would require reprojection to OSGB36 ('02). Also the millions of individual points involved makes manipulation difficult unless high-end workstations and high level software are employed. The combined ascii text files produced for the WRM project area amounted two nearly 3500MB (3.5GB), a relatively small amount in LiDAR terms.

To be able to work with a more manageable complete data set a process known as 'surfacing' can be undertaken. In the case of the WRM project this was performed in ERDAS Imagine 8.6. The surfacing process takes the individual scatter points and imposes a regular surface grid upon their geographical position. Then a raster image is generated with either the z or intensity rating used as the pixel value. This image can then be used to view the LiDAR surface in relief as quick psuedo-3D image.

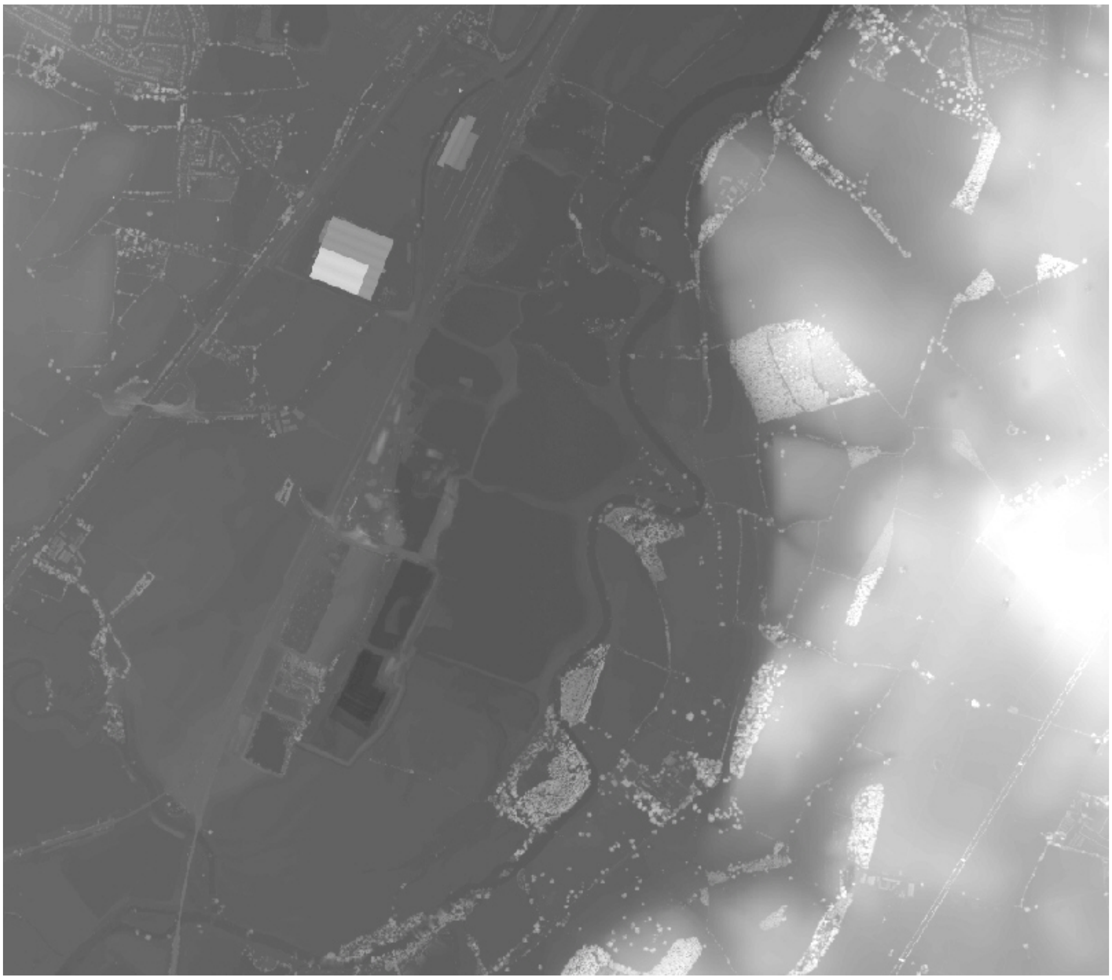

Figure 7: Surfaced first pulse data of WRM focus area and surrounds

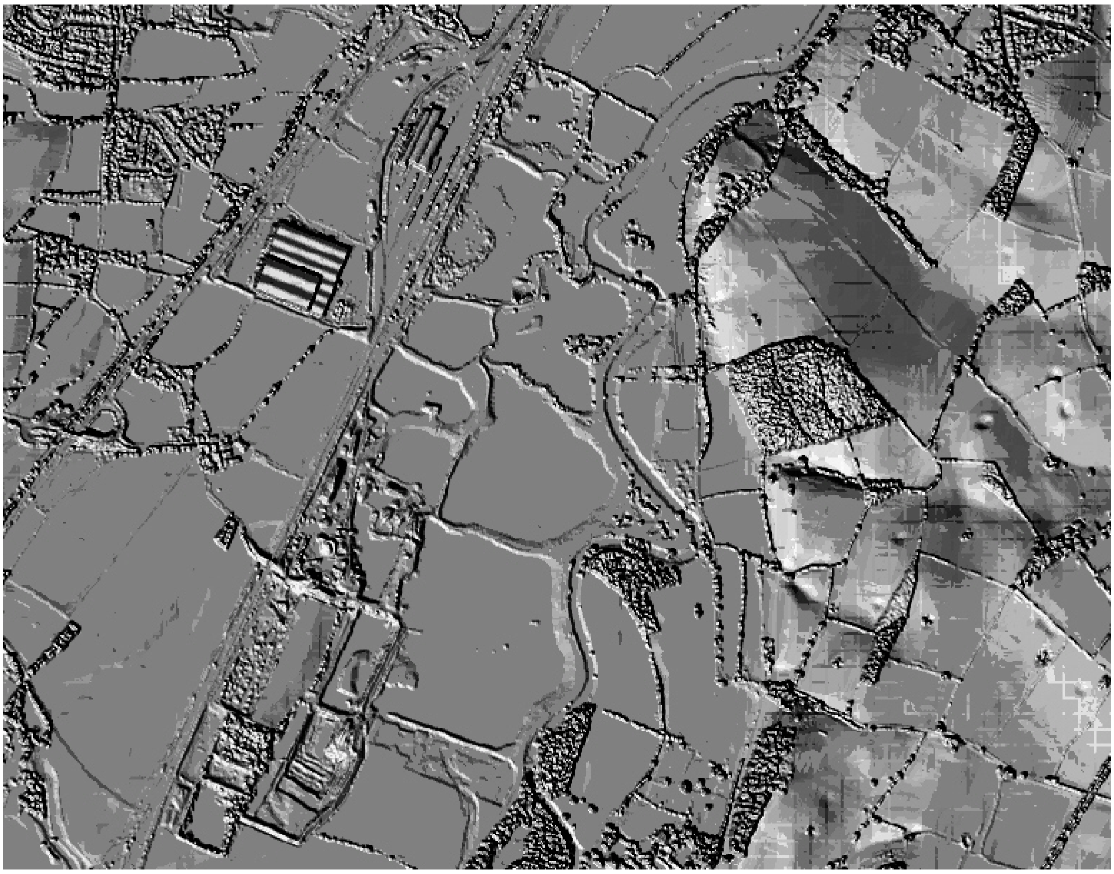

Figure 8: Surface first pulse .img file as a relief view

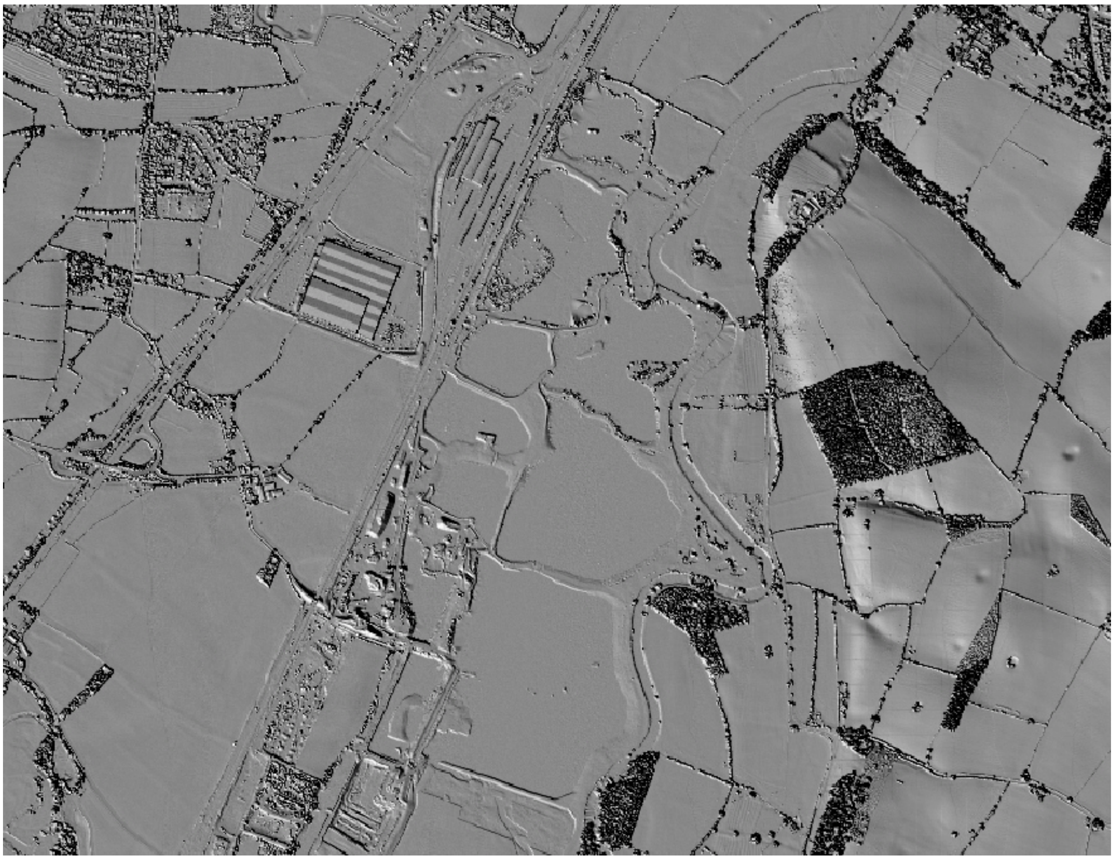

Figure 9: Refined relief view of first pulse DEM

Sections of the overall LiDAR survey are surfaced individually, in the case of WRM approximately 100MB files at a time. Running on a P4 2.2Ghz processor with 1GB of RAM, a 100MB section would normally be left overnight. Once this section is surfaced (for each data type, first pulse, last pulse, last pulse ground, and intensity there are 22 sections, 88 in total) then the individual tiles can then be pulled together as one image.

Before any further processing takes place the ERDAS Imagine images (.imgs) are reprojected from UTM Zone 30 WGS84 to Transverse Mercator OSGB36 ’02 (see glossary & appendix B). This is performed in Imagine’s Reprojection facility using the provided stock datum’s and spheroid’s (see glossary & appendix B). This places the LiDAR data in the correct georeferenced framework for the British Isles. This is an absolute necessity as it enables the DEM’s/DTM’s to match up with all the other data in the GIS (see below).

Figure 10: Refined relief view of last pulse ground DTM

LANDSCAPE VISUALISATION & PALAEOCHANNEL MODELLING

The LiDAR DEM/DTM for the WRM project forms a key element in all the methods of landscape analysis (see Paleofluvial/Hydrogeological modelling, Geophysical Survey at Catholme, and Field GIS Assessment: Wychnor Pilot Project reports), and also serves as the basis for the GIS (see below). It was also used as the source for mapping palaeochannels outside of the focus area (the focus area and immediate surrounding landscape also making use of multiple years' orthophotgraphs for identification). Due to the high density of points small changes in the landscape, or micro contours, can be visualised very effectively. This enables subtle changes, often not viable with the naked eye or in aerial photographs, to be brought to light. Height changes and channels that may have been obscured by vegetation can also be picked up in the DTM due to LiDAR's ability to penetrate vegetation cover.

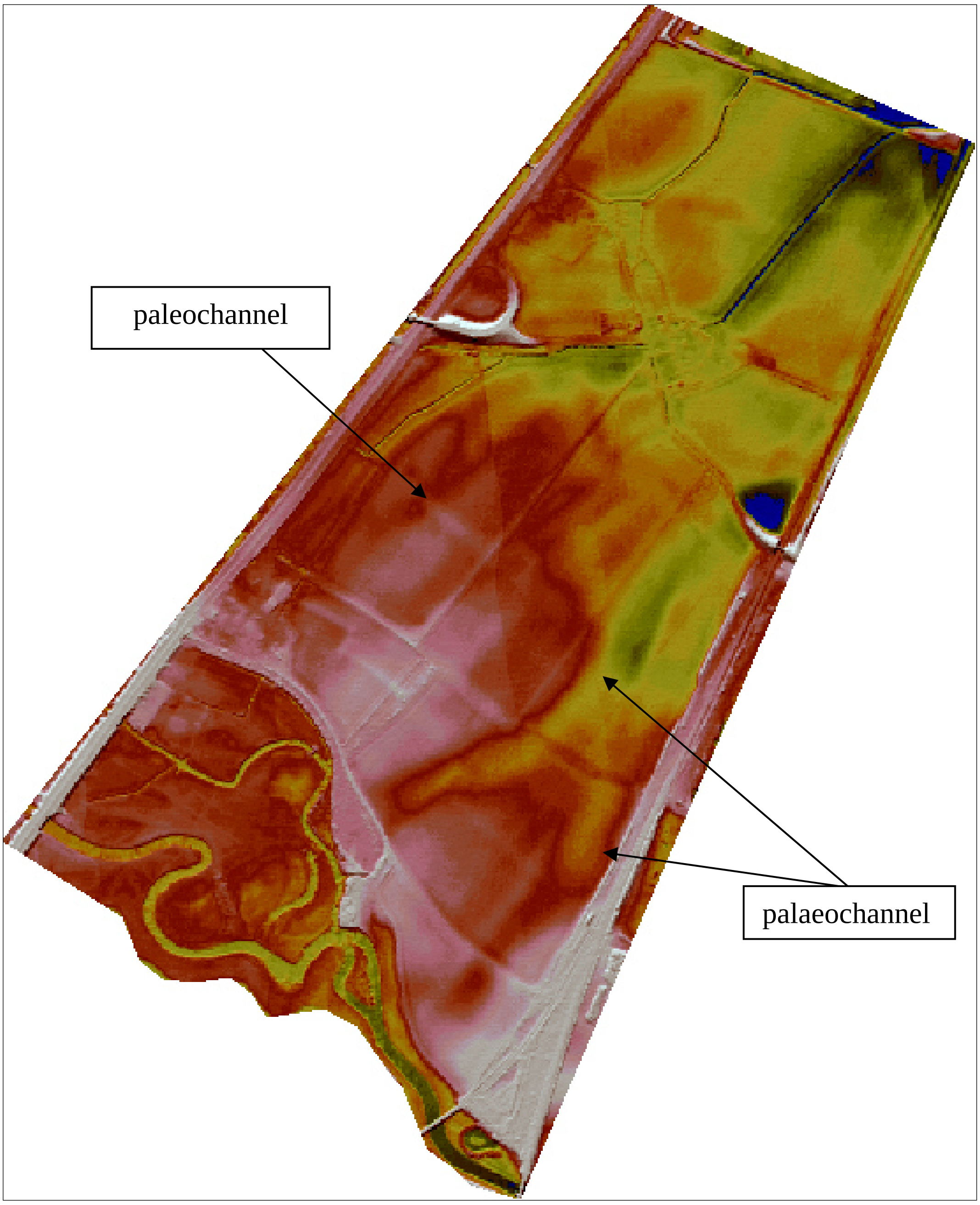

Figure 11: False coloured DTM of focus area showing previously undetected palaeochannels

In figure 11 the focus area, a very flat surface to the eye, has been false coloured with 32 different classes. As the landscape dips ever so slightly where the palaeochannels occur the classification differs from the surrounding area.

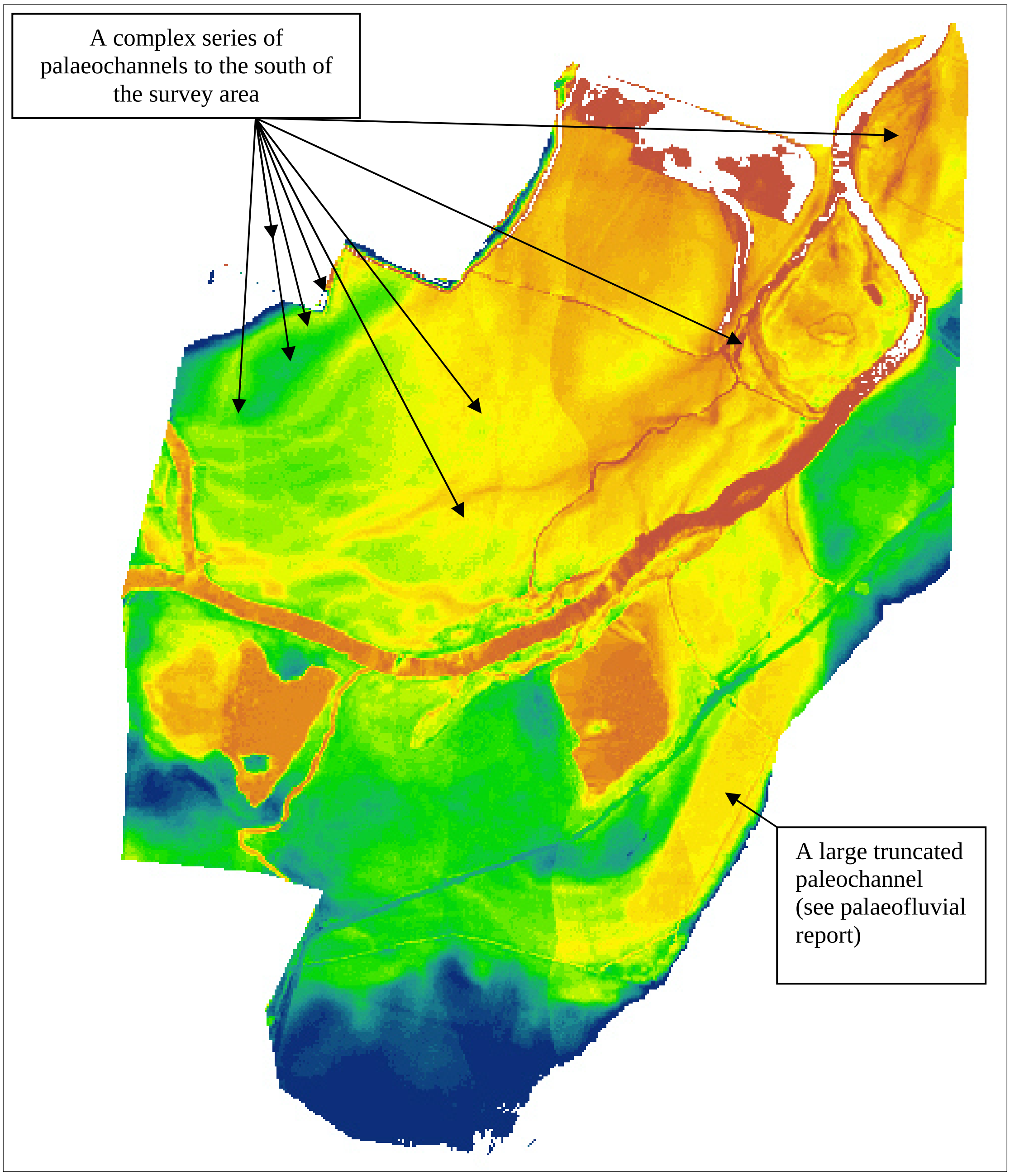

Figure 12: A complex series of palaeochannels to the south of the focus area

The investigation of the palaeochannels in the focus area specifically is dealt in more detail in the Palaeofluvial/Hydrogeological report. However the LiDAR has been used to identify main palaeochannels in the project area as a whole. The following are some examples showing the build up of possible palaeochannels in the project area and gravel islands. A full image catalogue of the river valley from the whole project area is to be found in appendix A.

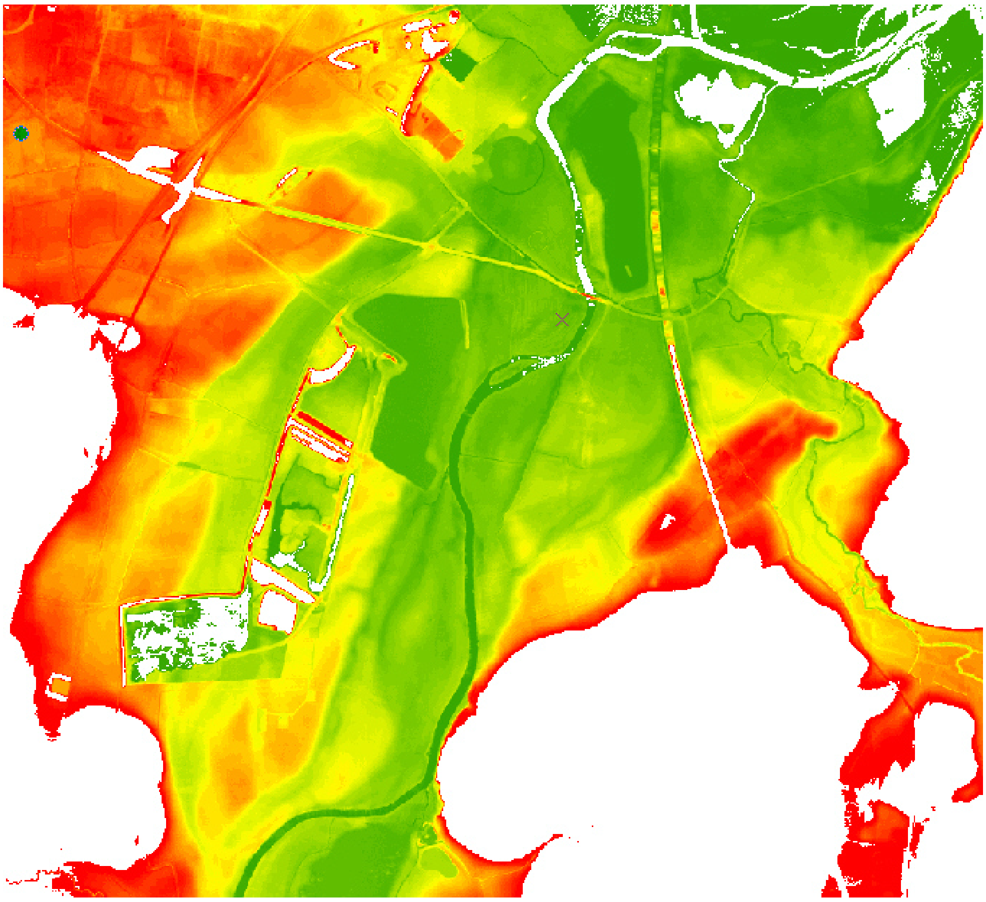

Figure 13: False colour DTM of part of the river valley showing palaeochannels

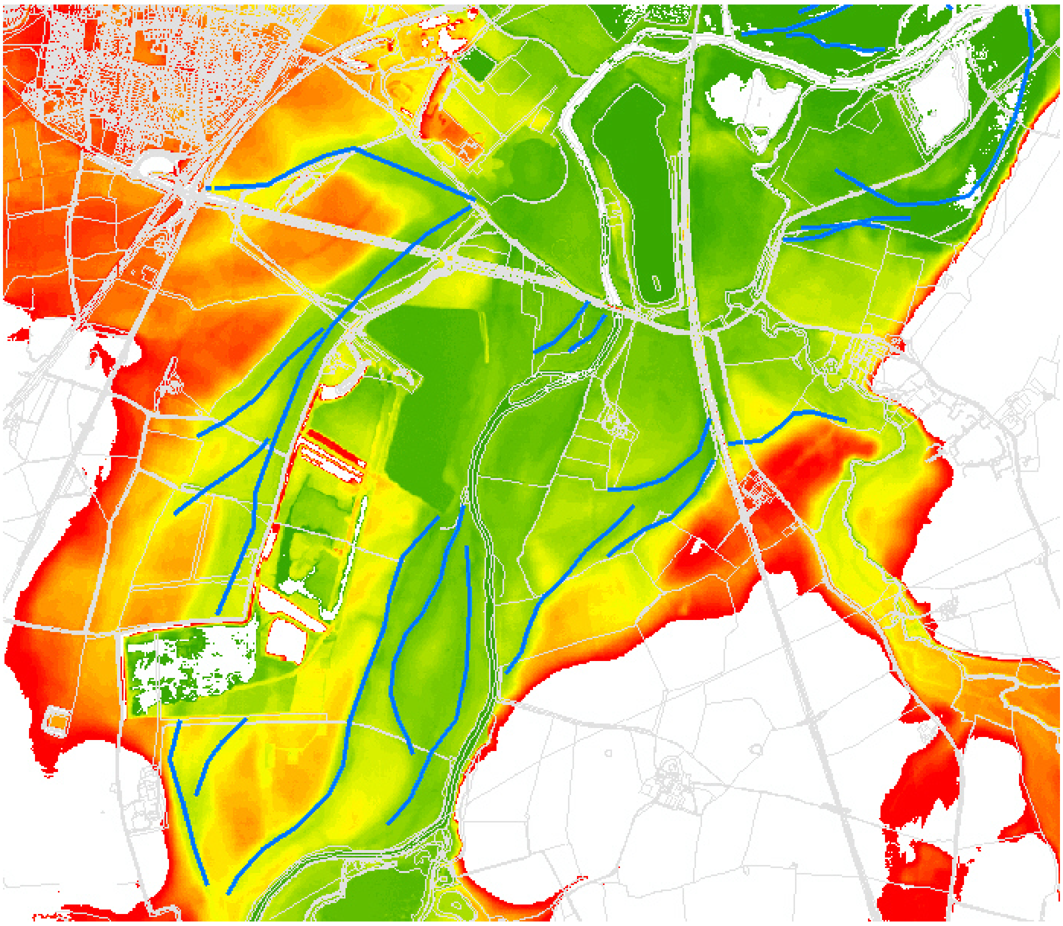

Figure 14: Vector lines digitised over possible channels in ArcGIS

Figure 15: Intensity image of the area featured above (for intensity see below)

Figure 16: Intensity image with overlying vector lines

3D MODELLING & FLY THROUGHS

Although the LiDAR survey produces a fully 3D dataset a lot of the analysis performed is still looking from a traditional vertical (planar) view point, similar to looking at aerial photographs. Certainly in the case of paleochannel studies and in the case of the Palaeofluvial analysis this is the best way to readily identify features of interest. However, the fully 3D nature of the data must not be over looked. 3D visualisation of the WRM focus data had already been performed as a part of the earlier stage of point processing (TGS Amira) looking for trends, errors and structures in the raw point data that may be lost in the later surfacing. However in both the main software packages now being employed by the WRM project (ESRI's ArcGIS 8.3 3D Scene & ERDAS Imagine 8.6) 3D visualisation can be renewed.

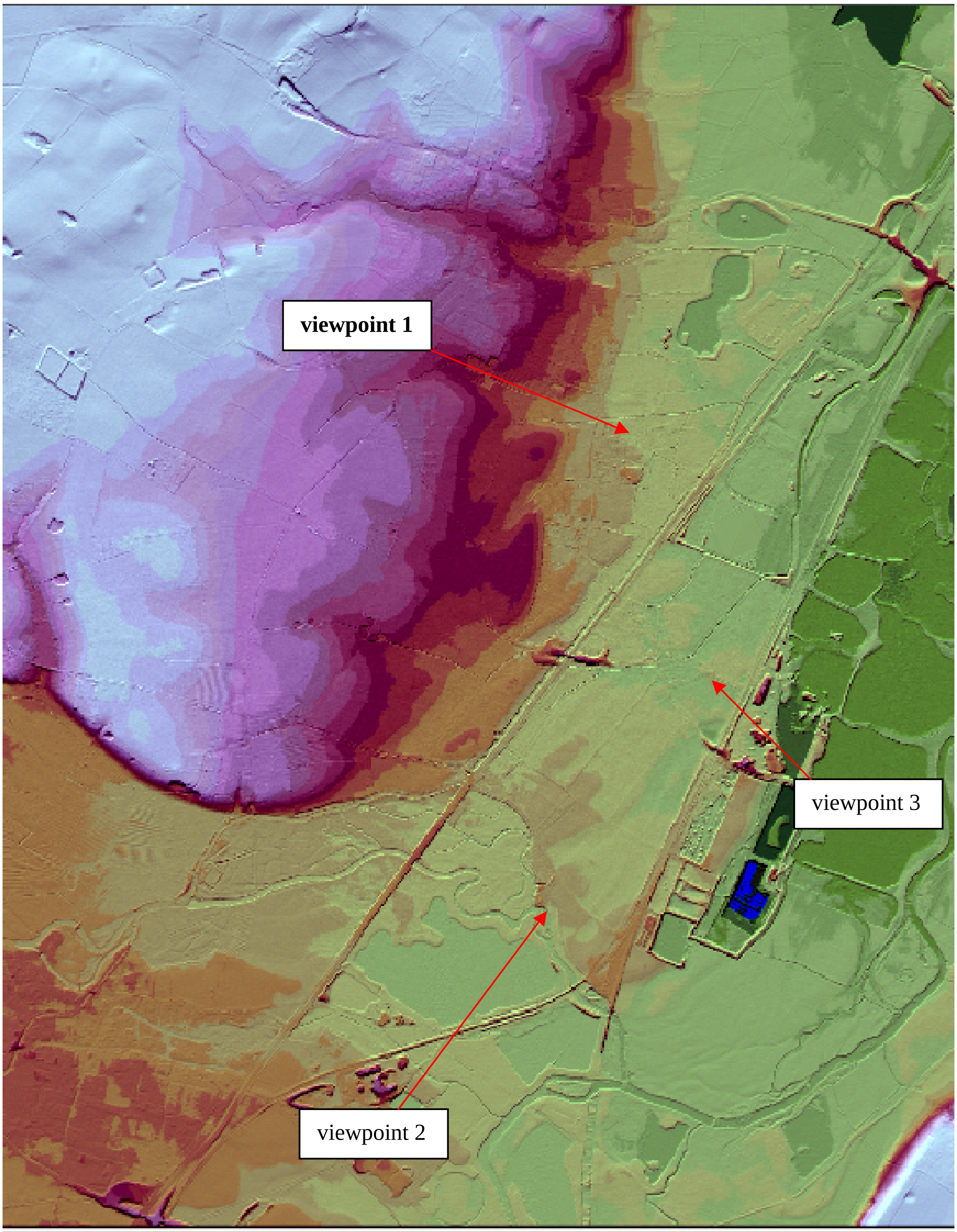

Figure 17: Overhead coloured DTM from ERDAS Imagine. Numbers related to 3D viewpoints below

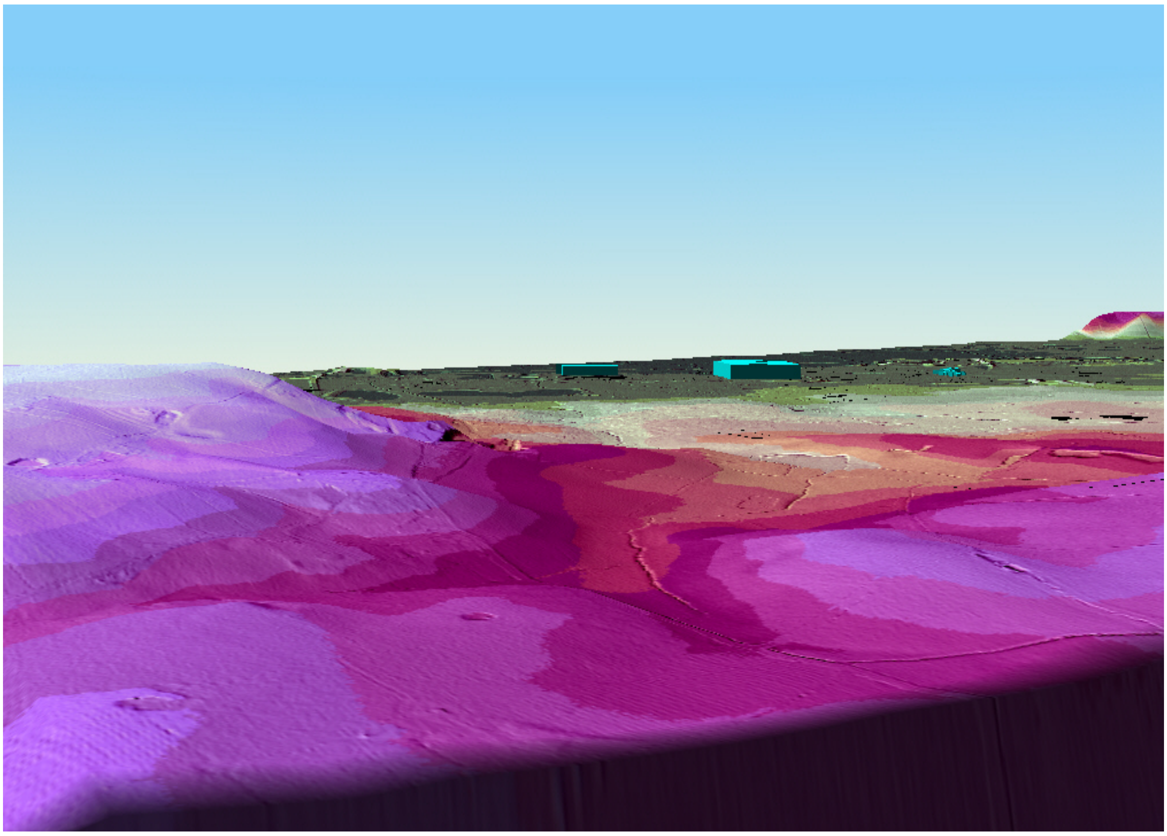

Figure 18: Viewpoint 1, a low-level first person perspective from a valley leading down to the focus area from the north-west

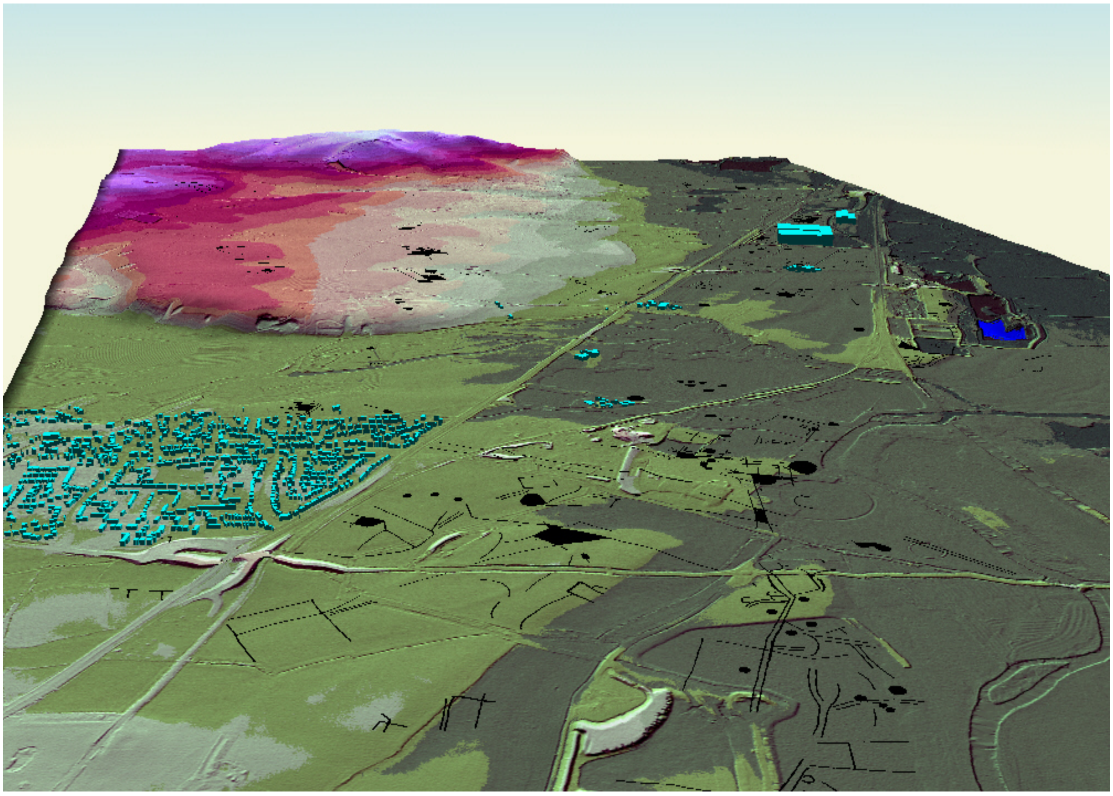

Figure 19: Viewpoint2, a high level oblique flying view of the project area from the south. Cropmark plots can be made out in black

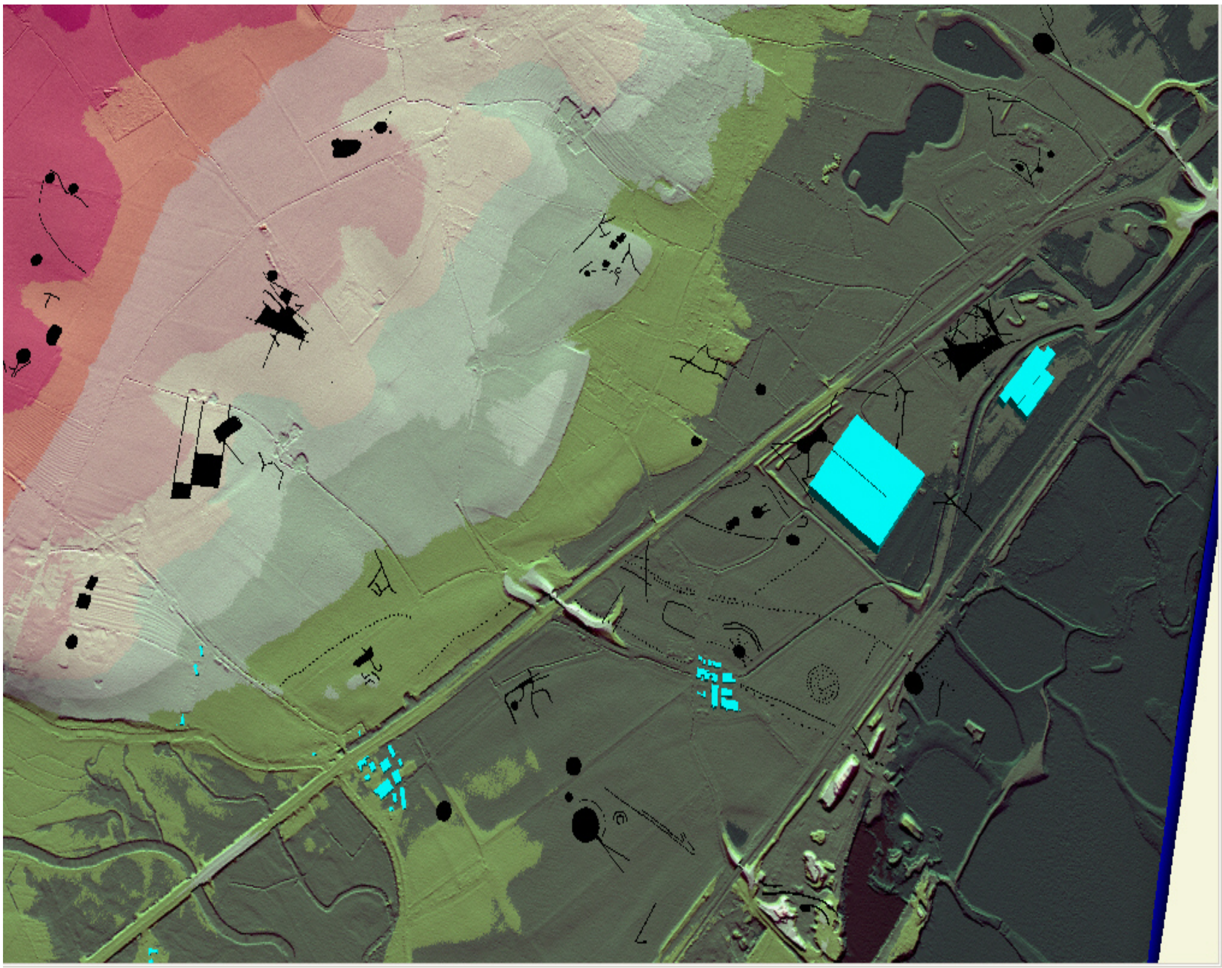

Figure 20: High level near plan view, directly over the focus area

The above figures are taken from a fly through (see attached CD, alsf_wrm1) around the WRM project area, generated in ERDAS Imagine's VGIS module. However, rather than just keeping to the LiDAR DTM extra dataset can be added, due to every dataset being correctly georeferenced to OSGB36. In the larger of the two fly throughs (as above) a false coloured DTM has been combined with the cropmark shapefiles (see GIS below) and building models developed from Ordnance Survey landline polygons. The large building to the north is the new Argos depot with Catholme farm featuring in the centre of figure 16.

To create a fly through a 2D path is digitised over the subject area (figure 17) this gives the initial path and camera fixed points, but is set by default at a specific view direction, altitude, speed, and attitude. These first camera positions can then be added to, and the viewpoints, speed etc. customised to create the desired perspectives and focal points (figure 18). The small of the two fly throughs in this report having over 50 individual camera fix points. The VGIS module then tracks from one point to the next swinging the view to hit the following camera position in as smooth a transition as possible. Once these position have been determined additional datasets can be added to the VGIS world, layering the view, just like the GIS (see below) to create dataset focused flight paths.

Figure 21: 3D building models generated from OS landline polygons

Figure 22: 3D building models with combined OS landline data

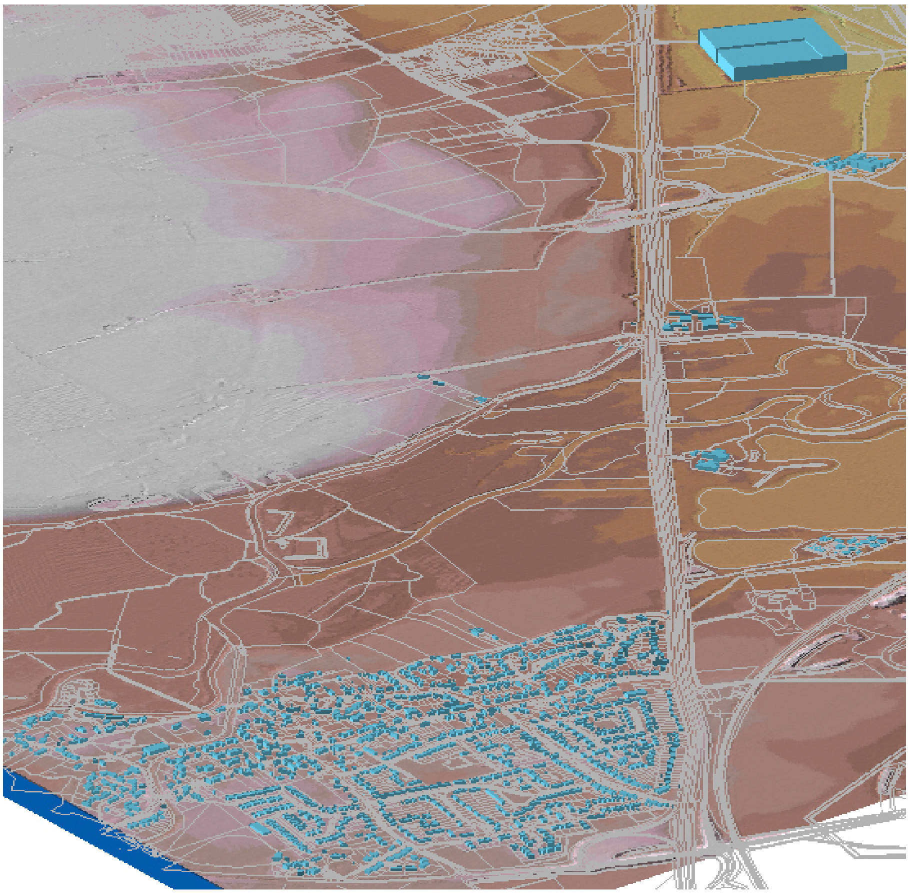

Figure 23: LiDAR DTM underlay with 3D models & OS data

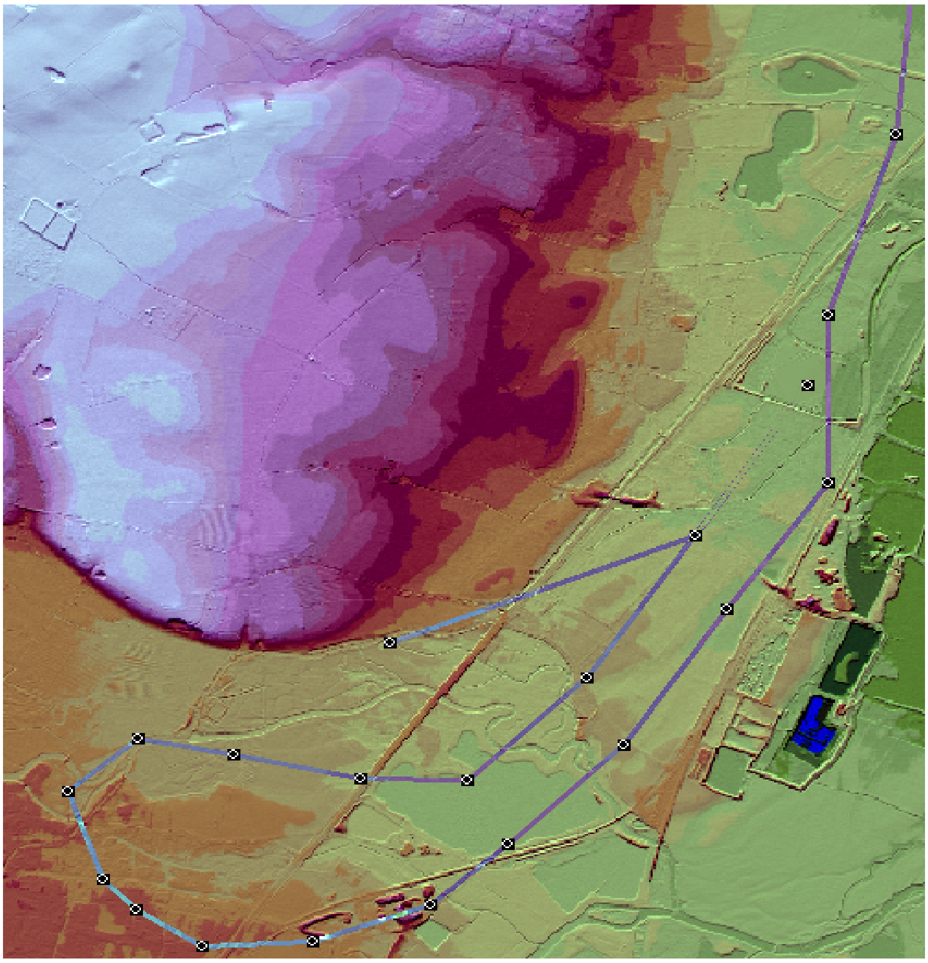

Figure 24: 2D digitised flight path

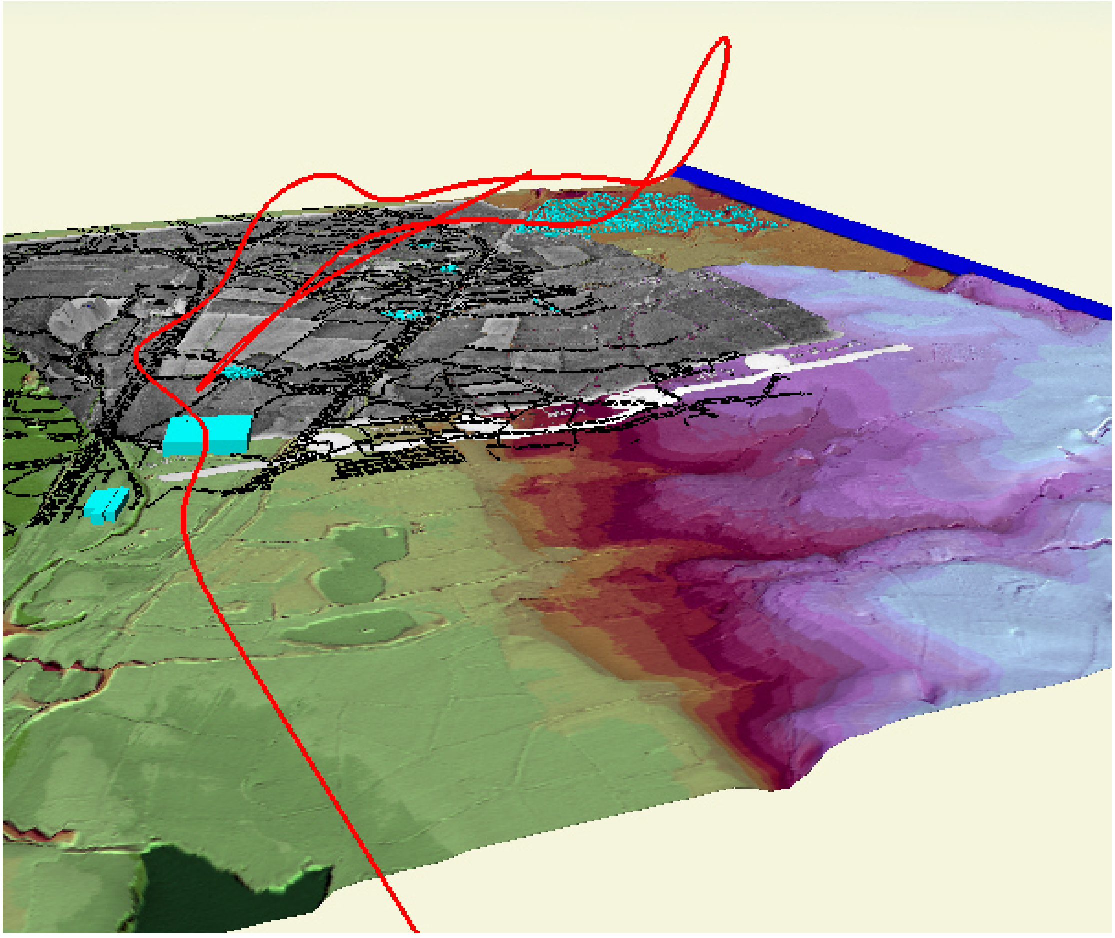

Figure 25: Final 3D flight path, georeferenced aerial photographs, OS Landline data, and LiDAR DTM

The final results of two of the Where Rivers Meet fly throughs can be viewed as AVI's on the attached CD. However, it should be pointed out that these are compressed formats of the original ERDAS Imagine versions. The uncompressed versions are approximately twice as large as those are on the CD. The main noticeable difference between the two is the change in colouring of the LiDAR DTM to accommodate the limited availability in the Intel compressed AVI format.

LiDAR Intensity Data

The LiDAR system not only records the geographical position and height of the points in any given survey; it also records the intensity of the resulting signal. This extra property can provide an added level of information about the landscape of the survey area. The intensity reading can be substituted for the z value of the survey and surfaced just like the DEM/DTM's above. The results of this look similar to a greyscale aerial photograph but with some notable characteristics.

Figure 26: Intensity data surfaced at 25cm intervals to produce a near photographic image

By clipping the extreme values of the intensity data and surfacing at four times the density of the actual data points a near photographic image can be produced. This provides a good image of the landscape on the day the LiDAR survey took place and adding to the 'photographic' record in the GIS. However by surfacing the same data at different intervals weight can be given to predominant values in the data to enhance other properties within the landscape (figure 23).

Figure 27: Adjusted intensity image of Barton Under Needwood, showing ridge and furrow and moisture heavy areas in the north

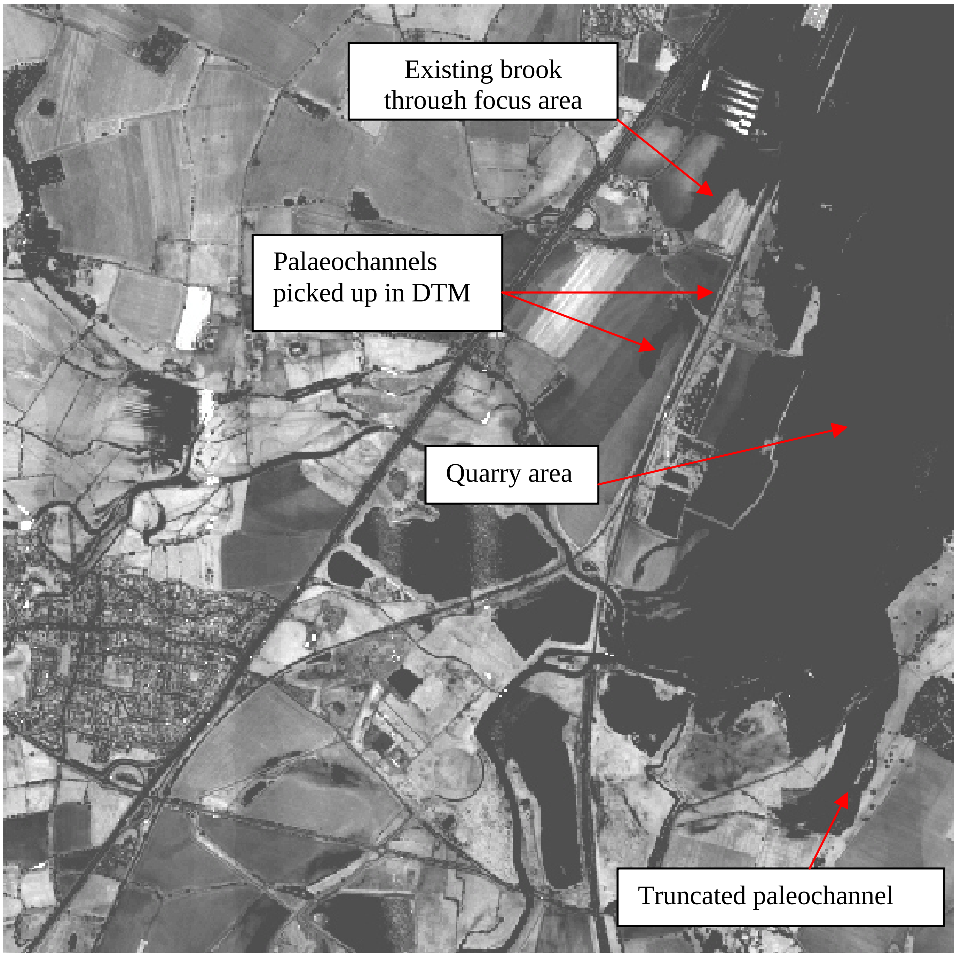

Figure 28: Adjusted intensity image showing a large concentration of weak signals over the quarry areas and in some larger palaeochannels

Although it seems likely that by analysing the intensity data and surfacing with different ranges it is possible to bring out areas of increased moisture content within the landscape. If this is the property being highlighted in the intensity images as seems to be the case then the area around the quarry works is of particular interest due to the high concentrations of moisture in that area compared to the surrounds. Similar levels only appear in some palaeochannels, existing brooks and rivers but certainly without the general impact of the quarry area. Further processing and ground truthing of targets in the intensity data would be required before definite conclusions could be drawn as to the exact elements being brought to light.

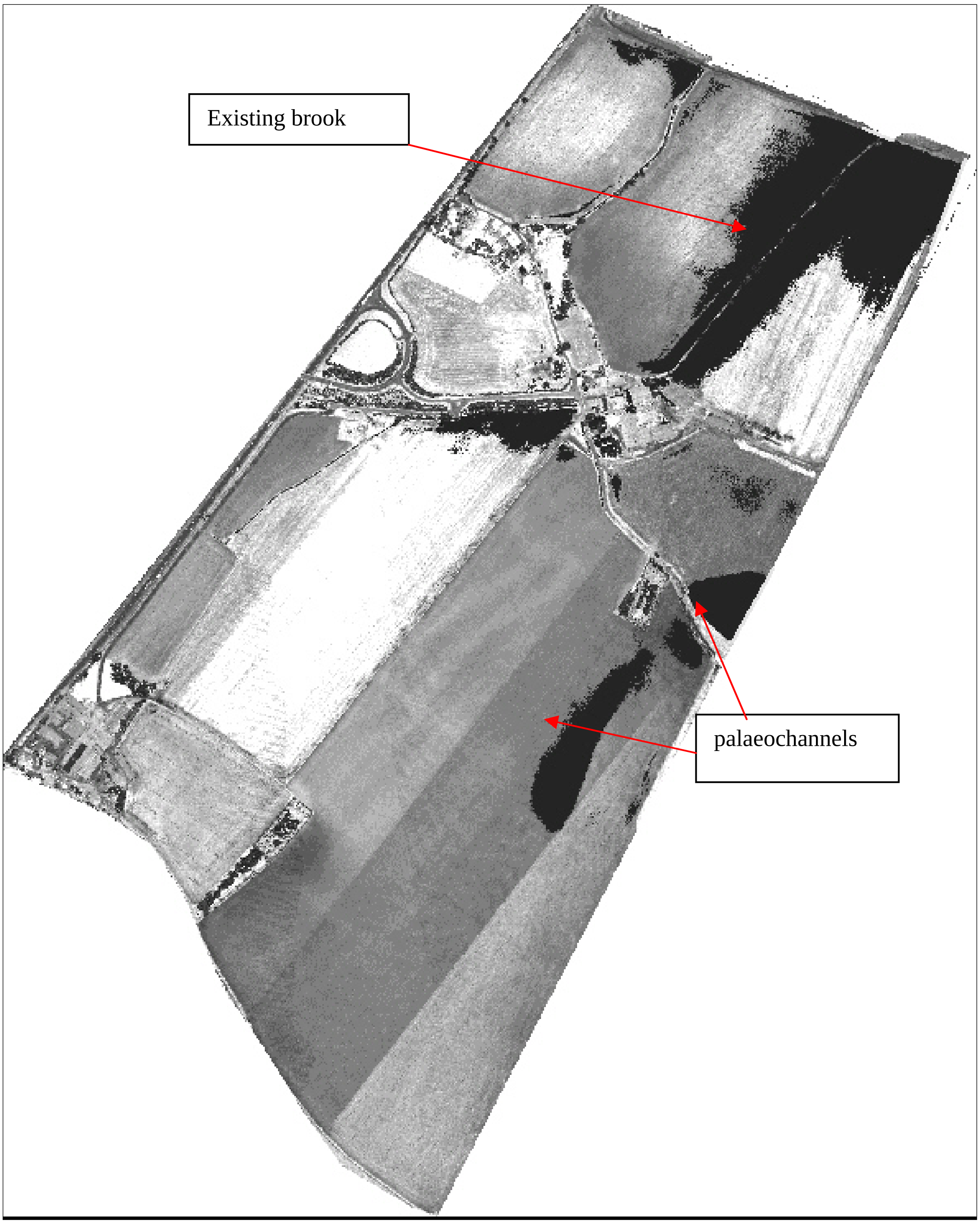

Figure 29: Intensity image of the focus area highlighting the effect of the existing brook and palaeochannels

LiDAR DATA & LANDSCAPE ANALYSIS

LiDAR is no longer a new technology, yet its potential in landscape archaeological terms has yet to be realised. The importance and use of accurate high precision terrain models for environmental modelling, geophysical analysis and landscape survey is great. This is added to with the growing availability of data from LiDAR surveys leading to less individual commissions as data is archived as a resource. The WRM surveys main aim was to provide a base terrain model for all the combined areas of analysis but with specific targeting of the palaeofluvial and hydrological research groups. The proven ability to accurately identify and model palaeochannels and water systems is a key factor. The dataset itself, realistically being collected at 1 point per metre would not be sufficient to pick up very faint archaeological remains in the focus area. However, it did succeed in bringing to light the medieval landscape quite effectively and further processing and recording of this will continue (see the Wychnor report below). Larger more robust landscape features, such as surviving round barrows and henges, which still have a presence in the landscape could also be picked up. Newer LiDAR systems, like the ALTM 2077, collect over twice as many points as the system used for WRM, and by flying the same survey area more than once a far greater point density can be achieved, enabling the modelling of far subtler features.

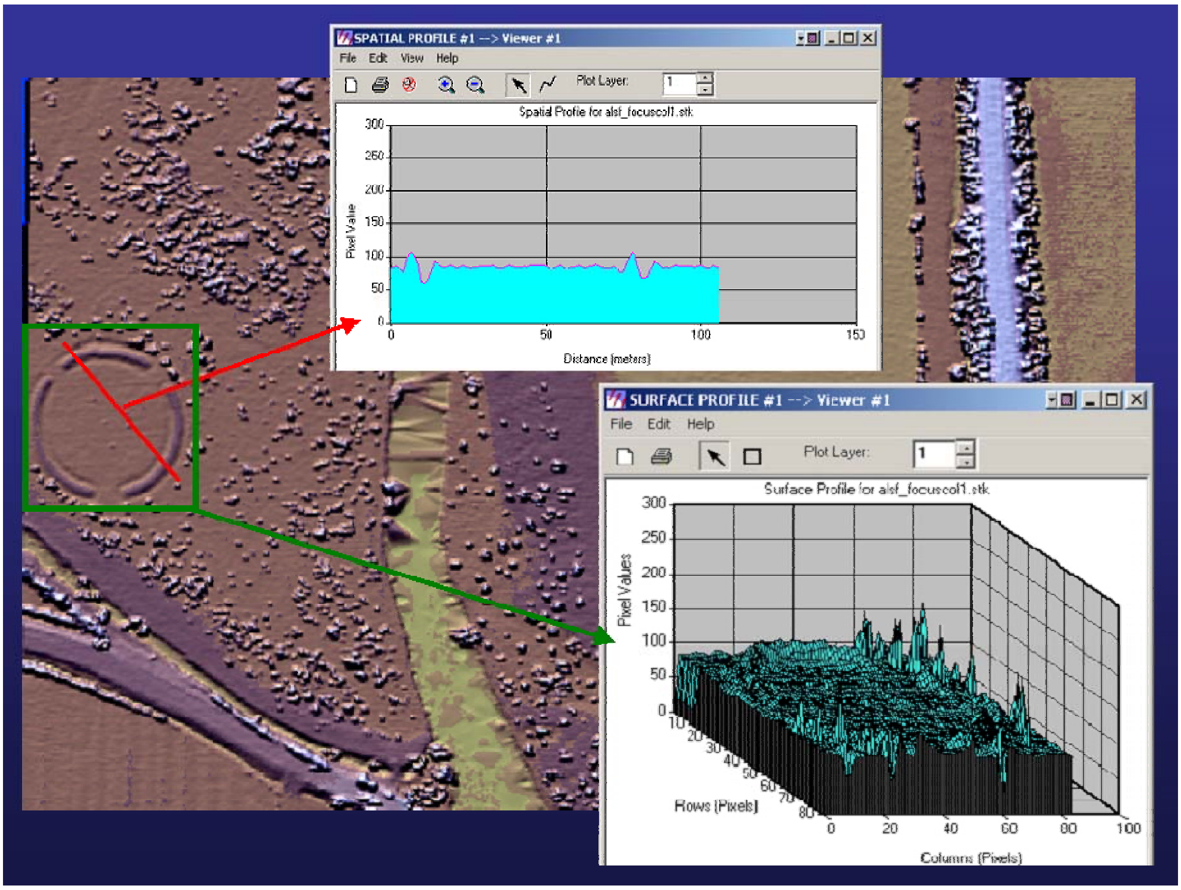

Figure 30: Henge-like landscape feature in the National Arboretum, profiled and surfaced graphed from LiDAR DEM in Imagine. Banks and ditches can easily be picked out.

Further investigation of intensity images and the development of software handling surfaces and point models with great speed and flexibility will also aid in the analysis of LiDAR based landscapes. Also the ability to create high quality 3D fly throughs of areas of interest can provide a great out reach tool, generating interest within local communities and companies alike. Integration of such datasets and remote/mobile access to this (see below) can only aid the growing appreciation of the historic landscape.