TOTON UNEARTHED, TOTON, NOTTINGHAMSHIRE

Report on an integrated field survey conducted at Toton Manor Farm Recreation Ground, April-May 2014

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May 2014

TPA Project Code – TOF2

TPA Report No. 047/2014

Hand-survey and laser scanning

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Report Number	047/2014
Status	Report

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Summary

- Trent & Peak Archaeology was commissioned by the Friends of Toton Fields to complete an integrated survey at the site of Toton Manor Farm Recreation Ground in Nottinghamshire, centred on SK501342, as part of the Heritage Lottery-funded community archaeology project *Toton Unearthed*.

- The work included Lidar survey, geophysical (geomagnetic) survey, laser scan topographic survey, and walkover and hand topographic survey. It was carried out during April and May 2014 following the methodology detailed in the WSI (April 2014) approved by the NCC archaeological leader Ursilla Spence.

- The fieldwork was conducted as a community venture with the help of local volunteers. It also coincided with the unveiling of a new blue plaque commemorating the site of the Manor House. The friends of Toton Fields created a display chronicling the progress of the fieldwork and Trent & Peak Archaeology demonstrated the survey techniques to the public.

- The site is situated on deposits of alluvial riverine clays overlying river terrace gravels and the waterstones of the Mercia Mudstone Formation.

- Lidar survey produced a digital terrain model in which several earthworks could be identified. These included:

    - The location of the Manor House
    - the remains of a medieval ridge and furrow field system
    - several previous water courses both to the north and south of the presen-day Erewash
    - possible field boundaries or trackways

- Geophysical survey demonstrated the presence of potential buried archaeological features, some of which will form the basis of further investigation. These comprised:

    - Structural remains belonging to Toton Manor House [7], [18-20], [23-28]
    - Possible structural remains belonging to a mill [44-46]
    - Evidence for previous agricultural land-use, including possible field boundaries or trackways [21-22], [29-36], 38-43]

- The topographic survey, which was composed of walkover and hand offset survey and laser scan survey, identified and recorded in detail a number of earthworks. These were:

    - Medieval ridge and furrow field systems
    - Past water courses (channels 1-4) relating to past water management systems and land division, including probable mill leats or races.

- Map regression and GIS overlays allowed for these results to be integrated into a georeferenced master-plan and compare the results.

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Acknowledgements

The Toton Unearthed project was developed by the Friends of Toton Fields in partnership with Trent & Peak Archaeology, and is managed by Gill Moral and Norman Lewis. The integrated survey was managed by Gareth Davies and the TPA team were Tom Hooley, Paul Flintoft and Pov Cepauskas (geophysics), David Strange-Walker and Rachel Townsend (laser scanning), Steve Malone (Lidar interpretation), Laura Binns and Genevieve Carver (walkover and hand survey). The field survey was completed with the help of volunteers Karen Barker, Dick Brown, Richard Wallis, John Holmes, Mike Riley, Ann Mclennan, Paul Carruthers, Andy Capstick, Gillian Morral, Norman Lewis, Harriet Barker, Margaret Benson, Dave Bullock, Julie Bullock and Hiroko Clark, who are thanked for their efforts. Curatorial monitoring was by Ursilla Spence, Archaeology Leader for Nottinghamshire County Council.

1. Introduction

The integrated survey was the first fieldwork element of *Toton Unearthed*, a Heritage Lottery-funded community project developed by the Friends of Toton Fields in partnership with Trent & Peak Archaeology. The project will also incorporate several other stages including archaeological excavation, educational outreach, public dissemination and on-site interpretation, and its aims are to investigate the development of domestic and industrial activity at the site, including evidence of a medieval and post-medieval Manor House and water mill. The project is designed as a community venture with public engagement and volunteer involvement throughout.

For this stage, Trent & Peak Archaeology were commissioned to apply a series of specialist survey techniques over a 5ha area at the site of Toton Manor Farm Recreation Ground in Nottinghamshire, which is owned and managed by Broxtowe Borough Council and centred on SK501342 (figure 1).

The site is mapped as lying on the waterstones (siltstones, mudstones and sandstones) of the Mercia Mudstone Formation (British Geological Survey 1:50,000 Series, Sheet 125, Derby, Solid and Drift Edition). However, due to the proximity of the of the Erewash river and subsidiary channels, which run through the middle of the recreation ground, the geopmorphology of the site is also characterised by more nuanced alluvium deposits. Geotechnical trial pits revealed a consistent stratigraphical sequence of topsoil overlying alluvial clays of up to 2.6m in depth and river terrace gravels (Webb 2010).

The techniques applied included Lidar survey, geophysical (geomagnetic) survey and topographic survey (using a combination of laser scanning, hand survey and walkover survey). On-site training and supervision was provided for a team of project volunteers whose help was integral to completing the work

Following consultation with the archaeological leader for Nottinghamshire County Council, an approved Written Scheme of Investigation was agreed. The work was completed in April and May 2014.

2. Project Background

2.1 Research context and previous work

Toton Manor was a Medieval township located along the River Erewash and administered by the parish church of Attenborough. The settlement may have Anglo-Saxon origins, but certainly by the time Domesday was written in 1086 a Manor House and two associated water mills were in existence. Since the foundation of the Manor almost a thousand years ago, the agricultural and industrial landscape has changed considerably, but also showed much continuity. By 1271 documentary evidence records only one mill, but it is likely that this can be equated with the ‘flour mill’ that appears on 19th century maps and continued to be used into the 20th century. Management of the water courses has developed over the years, with old leets going out of use and new canal systems being put in place.

The area of interest is now taken up by Toton Manor Farm Recreation Ground, a public space managed by Broxtowe Borough Council and incorporated into Toton Fields, a conservation area managed by Broxtowe Borough Council and Nottinghamshire Wildlife Trust. Neither the Manor House nor either of the mills survive as standing remains, but recent investigations have shed light onto the potential of the underground heritage.

In 2012, amateur historians Gill Morral and Rex Wyatt produced a volume entitled *Toton Revealed* (Wyatt and Morral 2012), which brought together memories and photographs of Toton from the last century alongside documentary historical research stretching further back.

In June 2013 the Friends of Toton Fields learned of a planned play area to be situated on a potential site of one of the ancient water mills. Through the *Connected Communities* scheme funded by the Arts and Humanities Research Council, they were able to commission a geophysical survey of the area, which was conducted by the University of Nottingham in partnership with Trent & Peak Archaeology. Both magnetometry and resistivity methods were employed to reveal reasonably clear anomalies, particularly in the resistance data. High-resistance anomalies in the north-east of the area were interpreted as sub-surface structural remains of a mill building, while low-resistance anomalies were interpreted as the northernmost extent of the in-filled millpond (see *Johnson 2013*). As a result of this work, Broxtowe Borough Council agreed to move the location of the proposed play area to the south-west.

Following on from this, the Friends of Toton Fields prepared an application to the Heritage Lottery Fund for the current project *Toton Unearthed*. The project's main foci are the medieval and post-medieval Manor House and its associated agricultural and industrial landscape, including a mill and water management systems.

2.2 Potential remains

The previous work mentioned has provided a clear indication of the archaeological potential of the site, which can be summarised as the following targets:

- ***Medieval and Post-Medieval Manor House***

Map regression and topographic anomalies give a good indication of the Manor House location, and photographs exist of its latest expression. Geophysical and topographic survey should provide information regarding form and orientation and thereby be able to inform the positioning of trenches on the site.

- ***Medieval and Post-Medieval water mill(s)***

Two mills are mentioned at Toton in the Domesday Book of 1086, and photographic and documentary evidence shows that one mill continued to function into the 20th century. The geophysical survey completed last year (Johnson 2013) located what appeared to be the extent of a mill pond as well as the structural remains of mill buildings. The relationship between the mill known to have existed into the 20th century and its earlier expressions remains unclear, as does the location of the second mill.

- ***Mill leat and other channels***

Site visits, records and plans have determined several topographic anomalies including a very steep extant bank and v-shaped ditch that is thought to be a mill leat. The integrated survey will help locate and characterise these anomalies, providing more detailed information about water management over time.

- ***Medieval and Post- Medieval agricultural landscape***

Ridge and furrow is visible in some parts of the recreation ground, and records document the operation of the Manor House as a farm. The ridge and furrow as well as any sub-surface anomalies such as ditches or hedgerows, are likely targets for the topographic and geophysical surveys.

- ***20th century landscaping***

Manor Farm Recreation ground has undergone much landscaping work in recent time, including the levelling of the Manor House, infilling of the millpond and installation of a cricket pitch. The integrated survey will produce key information regarding the implications of landscaping for sub-surface remains.

2.3 Proposed fieldwork

In order to identify and characterise the specified targets at Manor Farm Recreation Ground, the following stages of archaeological investigation were proposed within the WSI (Davies 2014)

- Production of a digital terrain model through Lidar survey
- Geophysics - magnetometer survey within the 5ha survey area
- Topographic survey – a combination of laser scanning, walkover survey and hand survey (in areas of dense undergrowth)
- Borehole survey, including one pollen sample and one C14 date.
- Five test-pits, each one metre squared and no deeper than 1.20m
- Two ‘evaluation-style’ trenches on the site of the Manor House, measuring 2m x 20m
- The excavation of a 300 square metre open area on the proposed site of the water mill

This report deals with the first three of these elements, which were carried out during April and May 2014

3. Objectives

The research objectives identified for the *Toton Unearthed* project as a whole are as follows:

Objective 1: The location and form of the medieval and post-medieval Manor House

Objective 2: The location and extent of the water mill(s)

Objective 3: The character, function and date of the water mill

Objective 4: The character and development of water management and the industrial landscape over time

Objective 5: The existence of earlier, possibly Anglo-Saxon activity on the site.

The integrated survey was aimed in particular at addressing objectives 1, 2, 4 and 5. In addition to these specific research objectives, the integrated survey aimed to inform the methodology of subsequent stages, i.e. the test-pits, evaluation trenches and open-area excavation. This included the identification of any subsurface archaeological remains and the assessment of their state of preservation. This information could contribute towards a deposit model for the site, particularly with regard to areas that have been landscaped in recent times.

4. Methodologies

4.1 Lidar

4.1.2 Background to the technique

The use of Airborne Laser Altimetry, more often referred to as Lidar (Light Detection and Ranging), for archaeological survey has become increasingly established (Crutchley and Crow 2010). Lidar uses the properties of coherent laser light, coupled with precise spatial positioning (through the use of a Differential GPS) to produce horizontally and vertically accurate elevation measurements. This data has considerable potential for archaeological research in terms of mapping archaeological sites where features survive as upstanding earthworks.

The Environment Agency (EA) has undertaken extensive areas of Lidar survey in coastal zones and river valleys for the purposes of flood risk management. For upland areas coverage is less extensive but full coverage of the area of interest is available in this instance.

4.1.3 Methods

Environment Agency lidar data is provided in two standard formats: processed JPG imagery and gridded ASCII data. The JPG image tiles are pre-processed to a standardised set of colour scales with hill-shading. The flat colour shading provides a more objective representation of the chosen contour intervals (1m-5m-10m-20m-30m) but lacks the more expressive representation of topography possible with a merging colour scale. In high relief landscapes the JPGs can provide a good representation of the landscape and key to areas of more detailed study. In areas of low relief these standardised contour intervals are less informative.

ASCII data is provided in ESRI ASCII grid format. Each .asc file covers an area 1km by 1km. The dataset used in the current study has a resolution of 1m, each tile comprising 1,000,000 elevation data points (higher resolution data is available in some areas of the country). Two different data sets are available for each tile:

i) DSM = Ditigal Surface Model, i.e. the unfiltered elevation data;
ii) DTM = Digital Terrain Model; filtered data, with vegetation and tall buildings removed and ground levels at these points interpolated

The filtering processes used to create the DTM are not always best suited to the sort of fine archaeological or topographical detail of relevance here (Crutchley and Crow 2010, 11) but can provide additional information and both DSM and DTM have been used here. The vertical accuracy of the data is generally quoted as +/-15cm. Relative (point to point) accuracy, more relevant for detailed archaeological mapping, is generally 5-7cm or better (Jones *et al*. 2007, 1576)

The EA lidar data for the study area was read into SAGA GIS 2.0.8 to create a continuous raster grid surface model. Data was first resampled to 0.5m centres enabling a smoother output at larger scales and then further processing and visualisation techniques applied. Standard processing combines constrained colour shading with relief modelling. Additional techniques, in this case sky-view factor and slope severity can also be applied. Unlike conventional relief modelling these are not dependent on a particular direction of illumination and can often be the most informative (Challis *et al.* 2011) but each can emphasise slightly different aspects of the dataset.

Processed data was output as GeoTIFF imagery allowing incorporation into GIS systems or combination with other data sources to produce composite plans. A plot of features was produced as a digitised overlay (see Figures 7 and 8). These are provided in DXF format allowing use with other sources of data.

4.2 Geophysical Survey: *Geomagnetic*

The decision to use magnetic gradiometry to survey the site was based on its efficiency as a survey technique suitable for detecting the buried remains of a range of materials based on differences in their magnetic characteristics as compared to the geological background of the area (Gaffney et al. 1991, 6; 2003).

The results of this method are, however, severely restricted in areas of modern disturbance and by the presence of ferrous material (Scollar et al. 1990, 362ff). Because of the presence of metal within the children's play area, this area was given a wide-berth with an average distance of 3m being allowed to limit its effect on the archaeological data. Other areas could also not be surveyed due to dense undergrowth, and so out of the total 5ha survey area, the geomagnetic survey covered a total of 3.5ha.

The magnetometer survey was undertaken, within the guidelines advocated by English Heritage (David et al. 2008), by a two-person core team using a Bartington Instruments Grad 601-2 fluxgate gradiometer. In addition, up to three volunteers were on hand to help move tapes and set out grids. The equipment allowed the survey to be conducted rapidly as the area was relatively free of obstructions. Readings were taken at 0.25m intervals along traverses of 0.5m spacing walking east. This enabled a sufficiently high density of data for the purposes of archaeological assessment to be collected across the site in the relatively short time allotted for the survey to be completed.

The geophysical survey grids of 30m by 30m were set out using a Leica GS15 GPS with SmartNet directly in the Ordnance Survey National Grid coordinate system. The survey grids were aligned north-east to south-west.

The geophysical survey data were processed in Geoplot 3.0 software to remove any environmental disturbances or variations produced in the course of the survey. Firstly data were manipulated to remove any distorting 'spikes' from the survey results. A high-pass filter was then also used to reduce the effect of geological anomalies in the data-set. Low-pass filtering was then used to improve the resolution of larger archaeologically derived anomalies. Finally the data were interpolated to produce uniform data-densities equivalent to 0.25m x 0.25m.

The results were exported as greyscale, raster images and inserted into the AutoCAD plan of the site, generated from Ordnance Survey data, for georeferencing and production of a descriptive, vector overlay. The anomalies presented here were identified visually and manually digitised to produce the vectorised plans which are discussed in the results section of this report. The final print-versions of these plans were elaborated and prepared for printing in Adobe Illustrator CS4.

4.3 Topographic Survey

4.3.1 Laser scanning

4.3.1.1 On-site methodology

The site was surveyed using a Leica HDS6100 phase-based terrestrial laser scanner, set to 'high' resolution. This produced a point cloud with a point spacing perpendicular to the scanner of 6.3mm at 10m from the scanner. An overall minimum resolution of 100mm (i.e.

one measured 3D survey point in every 100mmx100mm square of ground) was targeted, but the nature of the collection process ensured that much denser data than this was be collected in many areas.

22 overlapping and intervisible survey stations provided coverage of all surveyable areas. These individual scan locations will be linked together by intervisible tilt-and-turn targets.

Survey control was provided by a survey-grade Leica Viva CS15/GS15 RTK-enabled GNSS (GPS) system.

No data was collected within the areas of dense undergrowth, which were targeted using the hand survey method (see 4.2.2 below). The two methods were afterwards integrated by locating the hand-drawn plans within the interpreted laser scan results.

Much of the survey area was covered in long grass, which will result in lower-quality data. The cricket pitch, which has been levelled to be completely flat, was not surveyed due to the lack of topographic information it would provide.

4.3.1.2 Data processing methodology

Surveys were processed, cleaned and linked in software to provide a single georeferenced point cloud for the survey area. This dataset will be processed further using a ground-finding algorithm to produce a simplified point cloud of ground points at a fixed 100mm spacing. This simplified point cloud will be used to produce final deliverable outputs.

The raw point clouds were registered together using the Leica Geosystems Cyclone 8.1 point cloud processing software, and then registered to the Ordnance Survey grid.

The resulting individual but registered point clouds were then unified to a single point cloud of 116 million points, with an overall point spacing in the region of 100mm.

The unified point cloud was cleaned within Cyclone to remove the majority of extraneous and unnecessary points, including trees, buildings, fences and horses. This dataset is referred to in the figures and discussion as ‘rough’ data.

The unified point cloud was further processed in Leica Geosystems’ Cyclone II Topo software package. A ground-finding algorithm was applied to the point cloud. This algorithm interpolates points at ground level based on the lowest points recorded by the laser scanner. It creates new points on a grid of fixed spacing at ground level, thus stripping out almost all unnecessary data. By its nature this process requires large amounts of time and computer power, so the resulting point cloud is simplified to a spacing of c. 1 point/m in the X and Y directions. This dataset is referred to in the figures and discussion as ‘smooth’ data.

Both rough and smooth datasets were imported into the point cloud meshing software 3DReshaper, and meshed to create surface models registered to the OS grid. Copies of the surface mesh were scaled in the Z axis to 3x their original heights, to enhance apparent height differences and topographic features.

All meshes were then viewed and presented in plan with an orthographic projection.

A Minnaert topographic correction shader was applied to highlight topography, earthworks and surface imperfections.

The rough and smooth point clouds were also rendered orthographically using a plane shader, thus colouring points differently according to elevation.

4.3.2 Walkover and hand survey

The walkover survey took the form of a site visit with the aim of identifying and interpreting earthworks and topographic anomalies, particularly in areas of dense vegetation. Where possible, reference photographs were taken with a digital camera and located on the master plan (figure 9).

Where possible, features were drawn by hand using measured off-set survey. Base-lines were set up and located using a survey-grade Leica Viva CS15/GS15 RTK-enabled GNSS (GPS) system, from which points were measured by hand using 30 and 50m tapes. Broad interpretative hachure plans were drawn onto permatrace at a scale of 1:00, showing the principal earthworks identified.

Relative heights were taken using an optical level and converted to O.D. heights against a series of back-sights that were measured using a survey-grade Leica Viva CS15/GS15 RTK-enabled GNSS (GPS) system.

The hand-drawn hachure plans were digitised in DraftSight, georeferenced and integrated with the ordinance survey basemap.

5. Results

5.1 Lidar

Figure 2 shows the lidar plots of the digital surface model and digital terrain model side by side. In the DSM the buildings, roads, etc. of the surrounding built up area are very evident. In the DTM these have been filtered out but still leave a marked effect so that while the general terrain is quite well represented, it adds little detail in the wider area. However, this filtering does also remove areas of vegetation and provides a clearer view of some of the earthwork features. These have been digitised and are shown on Figure 3.

In the western part of the site the parallel ridges (shown in blue) of medieval ridge and furrow can be seen (similar patterns are also evident in the southwest and southeast of the plot beyond the study area). This small survival of the medieval field system is cut across by channels (outlined in green) presumably representing part of the system of leats/races feeding the former mill. The narrow hollow (orange) falling partly into the line of the medieval furrow appears to represent erosion along the line of the footpath that runs on this line. In the east of the site terracing around the northern and eastern edges of the cricket pitch is quite evident as is a mound at the site of the former manor itself. To the south, either side of the River Erewash, a series of fainter marks may indicate the lines of former earthwork boundaries or tracks, but are much less clear than those seen in the north and west of the study area. To the south of the river Erewash at the eastern limit of the study area are further possible previous water courses.

5.2 Geophysical Survey (geomagnetic)

Within the area surveyed, the site exhibited a good response to the geomagnetic survey and buried features, where present, showed clearly against the geological background. As the overall background magnetic response is expected to be low, a result of the nature of the superficial geology, any cut features are likely to show as areas of positive magnetism. In contrast, structural remains are likely to present either positive or negative signals, depending upon the particular materials used and their contrast against the relatively non-magnetic background.

The area surveyed is dominated by the presence of a number of large, extensive areas of strongly dipolar magnetic noise [1], [2], [3], [4], [5], [6], [7], [8], [9] & [10], distributed across the area surveyed and likely to result from the presence of ferrous material on or near the ground-surface. Within this group, anomalies [1], [2] & [3] are associated with the line of the current tarmac path around the edge of the cricket pitch.

A group of 12 further dipolar anomalies [11], describing a 36m x 24m rectangular area are associated with supports for a roped-off area to protect the square of the cricket pitch.

Close to the southwestern extent of the survey is a curvilinear positive anomaly [12], which runs for approximately 32m before appearing to join a linear positive anomaly [13]. The second of these anomalies [13], runs broadly east–west for c. 42m. These two positive anomalies appear to reflect the alignment of a further pathway leading to a small footbridge across the canalised channel of the River Erewash to the south of the recreation ground.

A small amorphous, “kidney-shaped”, strongly positive anomaly [14] lies approximately 12m to the west of [13] but does not appear to be directly related to the previously discussed anomalies. As a result of its location within an area of high, dipolar magnetic noise and its morphology, no interpretation is possible for this feature.

Within the southern extent of the survey area, between the Erewash and the tennis courts, are a group of two negative curvilinear anomalies [15] & [16] which appear to define a sub-rectangular area measuring approximately 27m x 14m. The northern of these, [15], defines the northern extent of this area. While to the south, the c. 12.5m-long anomaly [16] defines the southern extent and a possible re-entrant to the north at the southeastern corner of the defined area. Approximately 9m to the south of [16] are paired positive and negative maculae (not a dipole) [17], which may conform to a similar orientation as the sub-rectangular area.

Approximately 14m to the north of [15] is a small, rectilinear positive anomaly [18], aligned southeast–northwest on its longer axis and measuring 3.5m x 3m. Approximately 8.5m to the northeast of this feature is a group of three positive rectilinear anomalies [19], defining a broadly rectangular area of 11m x 6m and appearing to show some evidence of spatial differentiation within that area. As these anomalies lie close to the known location of the now demolished Manor Farm buildings, these features should be considered to have potential archaeological significance. Immediately to the east of these features is an irregular but linear negative magnetic anomaly [20] which covers an area of 24m2 and extends for c. 11m in a broadly northwest–southeast direction from the edge of the area surveyed. This alignment is picked up to the north of [3] by an irregular, positive anomaly [21] which runs for a further 20m to the northwest and parallel positive/negative anomalies [22], c. 3m further to the north, which extend the alignment a further 11m to the northwest.

Adjacent to the northwestern edge of the tennis courts is a large area (c. 825m2) of dipolar noise, represented by dipolar anomalies [23], [24] & [25], which is consistent with location of the still-extant platform on which the buildings of Manor Farm once stood. Additionally, within this area of the site are a group of small but strong linear and rectilinear positive anomalies [26] which define a series of features 11m x 6m on broadly the same alignment as [18]/[19].

Approximately 10m to the north of this group are a linear series of 7 discrete positive anomalies [27], running northeast–southwest and which appear to define the northwestern extent of the magnetically noisy area. At the northestern terminus of this line of anomalies is a group of six positive maculae which define a sub-rectangular area of approximately 4m x 3m on the same orientation. Approximately 5m to the southeast of this group of anomalies are a pair of linear, positive anomalies [28] which run along the same alignment for c. 8m in a northeast–southwest direction and again, appear to define the extent of the area of dipolar magnetic noise.

Immediately to the north of [3], and adjacent to the line of [20], [21] & [22] is a curvilinear positive anomaly [29]. This feature defines a sub-elliptical area of c.51m2 and is open, or incomplete, to the north. Approximately 8.5m directly to the north of the centre of this previous feature is a 77m-long “L-shaped” curvilinear positive anomaly [30] which intersects with the edge of the area surveyed approximately 30m north of the pavilion. The northeast–southwest alignment of this feature is paralleled approximately 14m to the south by a linear, positive anomaly [31] which runs for c. 27m in a south-west to north-east direction from the edge of the area surveyed. Approximately 15m to the north of [30] are a pair of aligned positive, linear anomalies [32] & [33] which demonstrate a linear alignment over 45m from the eastern edge of the area surveyed.

Within the area of the cricket square (as defined by the dipolar anomalies [11]) the southern end of a curvilinear feature represented by positive anomalies flanked by parallel negative responses [34] can be discerned in the data. This feature runs for a total distance of approximately 20m within the cricket square. To the north of this area it is continued by paired, curvilinear positive and negative anomalies [35] & [36], where the negative anomaly lies to the north of the positive, which extend the alignment for 55m to the northwest towards the edge of the area surveyed. Immediately to the north of the northwestern terminus of [36] is a curvilinear, positive anomaly [37] measuring 8m by 2.5m with the long axis at an approximate 90° angle to the alignment of [36].

To the northeast of [35] are a number of positive anomalies [38] which appear to define a broadly rectilinear area of 5m x 8m, again aligned to the larger linear/curvilinear anomalies crossing the northern part of the survey area. Approximately 11m to the north of these, a group of three positive linear/rectilinear anomalies [39], define a sub-rectangular area of 8m x 14m, on the same alignment as the previously discussed anomalies. Running for c. 33m into the eastern edge of the survey area are a pair of parallel curvilinear positive anomalies [40].

To the west of the cricket square is a group of clear rectilinear positive anomalies [41], these define a series of sub-rectangular divisions, aligned northeast–southwest within a 20m x 17m (at greatest extent) area adjacent to a large area of dipolar noise. Approximately 7m and 20m respectively are a pair of convergent linear, positive anomalies [42] which do not appear to respect the alignments of other anomalies in the area, but could possibly be related to the features in the centre of this part of the site. Approximately 28m to the south of [41] is an "F-shaped" rectilinear positive anomaly [43], measuring 9m x 6.5m and seemingly not aligned with any other features in this part of the site.

To the far west of the area surveyed are three discrete positive anomalies [44], [45] & [46] which although difficult to ascribe any real interpretation at this stage should be seen to be of potential interest in light of the previous geophysical surveys carried out in this part of the site by the University of Nottingham.

5.3 Topographic survey

5.3.1 Laser scan survey

Although the registered point cloud data was processed with the ground-finding algorithm within *Cyclone II Topo*, the length of grass and scrub on the site proved extremely challenging. The software struggled to extract an accurate ground surface from the resultant data, producing a result with a low degree of confidence.

False-colouring the 'rough' point cloud data does however extract the general topography of the site fairly well. Plane shading - colouring by elevation - shows the surviving ridge-and-furrow quite clearly (figures 7&8) and also Channel 1, including the north-western section to the north of the bushes. The mown path and its relationship to the ridge-and-furrow is also visible.

The laser-scanned broadly supports the lidar and hand survey results, but it is clear that less grass and scrub on the site would have produced a more detailed result.

5.3.2 Walkover and hand survey

The walkover survey identified several topographic anomalies, which were recorded using a combination of hand-drawn offset survey and photography. The earthworks and location of photographs are marked in figure 9. Due to dense undergrowth, in certain areas one of more of these techniques was not possible. The earthworks identified are interpreted as follows:

Ridge and furrow

Evenly-spaced undulations in varying states of preservation were identified and photographed in the long-grassed fields to the west of the cricket pitch (figure 10, 11). Because these earthworks were also clearly visible in part in the Lidar and laser-scan data, they were not individually drawn but the general area is annotated on the plan (figure 9). However, the walkover survey was also able to determine that the ridge and furrow continued into areas of vegetation to the immediate south-west and north-east of this open field, where they were surveyed in by hand.

Channel 1

A well-defined curvilinear feature with a u-shaped profile was clearly visible running through the open, long-grassed field containing the ridge and furrow (figure 12, 13). It was possible to draw much of the channel by hand, as well as laser-scan the middle section, and the earthwork is also visible in the Lidar survey (figure 2, 3). The south-western limit of the channel was unclear, as it appeared to terminate in a hollow within some dense undergrowth, but a sloping depression recorded at the far side of this undergrowth may show where it may have once fed into the mill-pond. It is however also possible that the slope relates to the overburden dumped when filling the millpond (figure 14). At its north-western extent the channel appeared to join with channel 3 (see below).

Channel 2

Channel 2 was a very well-defined linear earthwork with a v-shaped profile and tall, steep banks on either side. The eastern part of the feature, which ran from east to west, was clearly visible and can also be discerned in the Lidar survey (figures 2, 3, 15, 16). However its whole length, and particularly the western extent, was covered in dense vegetation. The easternmost limit was truncated by levelling activity and came to an abrupt end just west of the playground. The western extent was problematic as there was some suggestion of it turning either towards the north or the south, but the incredibly dense undergrowth made it difficult to discern which. If the feature was indeed related to water management, it would be unlikely that the feature turned north, away from the river. It is possible that the terminus-like depression to the north-west of the channel is the remains of another truncated feature that once ran north to south and joined the many water courses that appear to take this route down to the river. Alternatively, the lidar interpretation suggests that channel 2 makes a sharp northwards turn before returning back on itself southwards (figure 3). It may be that this apparent kink is in fact the result of pooled water and silting accumulated during the use-life of the channel at the point where it bend, rather than being deliberately constructed.

Channel 3

A linear feature with a shallow, u-shaped profile was identified running east to west alongside the southern limit of the southern bank of channel 2, but could not be photographed due to dense vegetation. Channel 3 was joined by channel 1, at which point it continued westwards before disappearing into extremely think undergrowth. However observation on the ground suggested that it might make a turn towards the south, where it is possible that it joined up with channel 4 (see below).

Channel 4

A shallow but well-defined u-shaped linear feature was identified and photographed running south to north in the area of thick undergrowth to the immediate north of the Erewash (figure 17, 18). The earthwork, which was flanked by small mounds, is likely to be the continuation of one or more of the east-to-west channels (channels 2 and 1/3) after they turn south towards the river.

6. Discussion

6.1 Lidar

The Lidar data was of sufficient quality to show many of the topographic anomalies that were also recorded in the topographic field survey, as well identify further earthworks and characterise the general topography of the wider study area. The main features identified were the dried-up water channels in the north-west part of site, and part of a medieval ridge and furrow field system. The fainter lines marked in green in figure 3 that extend through the cricket pitch and to the south of the Erewash appear to correspond to the negative anomalies picked up by the geomagnetic survey of the cricket pitch, and show that these possible field boundaries or tracks may continue either side of the river.

The features identified provide information regarding the following research objectives:

Objective 2: The location and extent of the water mill(s)

The location of apparent previous water courses as identified by the Lidar survey is in general agreement with the location of the mill as proposed by the previous geophysical survey (Johnson 2013) and by map regression (see below).

Objective 4: The character and development of water management and the industrial landscape over time

The Lidar survey contributes significantly to an understanding of the steeply banked dried-up water channel to the north of the site, whose north-western extent could not be easily detected on the ground. Figure 3 shows an interpretation of the channel curving up slightly to the north before returning southwards to rejoin the river, an interpretation not inconsistent with the hand survey (figure 9) and potentially explained by excessive pooling at the bend during its use-life.

Objective 5: The existence of earlier, possibly Anglo-Saxon activity on the site.

At present it is impossible to give a date to the possible field boundaries or trackways marked in green on figure 3, but they present a potential targets for boreholes or future excavation that would lead to dating evidence.

6.2 Geomagnetic Survey

The majority of the area covered by geo-magnetic survey was disrupted by dipolar noise resulting, probably, from the presence of ferrous material on, or near, the ground-surface. There were, however, potentially a number of archaeologically significant anomalies present within the dataset. The anomalies identified contribute to addressing the following research objectives:

Objective 1: The location and form of the medieval and post-medieval Manor House

The proposed location of the former Toton Manor Farm (Anomalies [26], [27], [28]) demonstrated a good response to the gradiometer survey and although noisy, this area revealed traces of magnetically positive anomalies which might indicate the survival of some parts of the structure in the sub-surface. It is also possible that anomalies to the west of these ([18], [19], [20]) my represent the extension of buildings into this area.

Objective 2: The location and extent of the water mill(s)

The location of the mill as proposed by earlier geophysical survey (Johnson 2013) was identified primarily on the basis of resistivity data, and although the present geomagnetic results were corrupted by a high level of noise, the presence of positive features in this area support this hypothesis.

Objective 4: The character and development of water management and the industrial landscape over time
Objective 5: The existence of earlier, possibly Anglo-Saxon activity on the site.

Clear evidence for a system of former field-boundaries or land-divisions (Anomalies [30], [31], [32], [33]) can be seen within the area now occupied by the cricket pitch. These correlate well with evidence for former trackways or paths which can be detected in the northern part of the survey area (Anomalies [34], [35], [36], [40]), along with what are probably some additional smaller structures (Anomalies [38], [39], [43]). A second trackway alignment may be represented in the results to the west of the field boundaries (Anomalies [21], [22]). Additional evidence for ditches, or other stratigraphically negative features which may be associated with the supposed site of the mills adjacent to the current childrens' playground, can be seen to the west of the main area (Anomalies [41], [42]).

6.3 Topographic Survey

The topographic survey (using a combination of laser-scanning, hand offset survey and walkover survey) was successful in identifying and characterising in significant detail several earthworks, most importantly dried-up water courses and ridge and furrow field systems. The results help to address the following research objectives:

Objective 2: The location and extent of the water mill(s)
Objective 4: The character and development of water management and the industrial landscape over time

The location of apparent previous water courses as identified by the topographical survey is in general agreement with the location of the mill as proposed by the previous geophysical survey (Johnson 2013) and by map regression (see below). Channels 1, 2 and 3 may represent different phases of mill leats or races that made a southwards return (channel 4) back to the main course of the river Erewash.

6.4 Map Regression and Integrated Interpretation

6.4.1 Map regression baseline data

Figures 19 – 22 illustrate several changes in the flow of the Erewash and its channels over the last 250 years. Before today's canalisation, the 1884 and 1847 maps (figures 19 and 20) show two main water courses. The mill and millpond are situated on the northern course, which may be a man-made race, while the meandering second channel to the south may be the natural Erewash course. The 1835 map (figure 21) is markedly different, showing three separate courses, again with the mill situated on the northernmost. The 1789 map (figure 22) is different again, showing the split course with a third channel connecting the two.

The 1782 map also clearly shows that the north to south channel has been used as a field boundary. It is likely that the field boundaries depicted in subsequent maps are also constructed from man-made dykes or re-used old water courses, for example the field boundary running north-east to south-west between the two water courses in the 1884 and 1847 maps (figures 19 and 20) appears to correspond to the easternmost of the water courses shown on the 1835 map (figure 21).

6.4.2 Overlays

Figure 23 shows the water courses from the 1847, 1835 and 1789 maps overlaid onto the Lidar digital terrain model, figure 24 shows the water courses, digital terrain model and offset survey drawings, and figure 25 shows the 1847 map, digital terrain model and geophysics results. It is clear from the digitised water courses that there were some georeferencing problems as apparent by the discrepancy between the location of the channel and mill in the 1847 and 1935 maps. The Lidar and hand survey data is in much better agreement with the 1847 map, as channel 2 seems to correspond well with the northern water course. This mill location is also supported by Johnson’s (2013) geophysical survey. It is possible that channels 1 and 3 correspond to water courses with slightly different trajectories as depicted in the 1835 and 1789 maps, but given the problems with georeferencing it is also possible that they too correspond to channel 2, and that channels 1 and 3 are earlier still.

The map regression also sheds some light on the trajectory of channel 2, which according to the Lidar and hand survey appears to make a turn from east-west to north-south, where it becomes channel 4. The 1847 water course broadly corresponds to another possible channel seen in the Lidar that continues towards the west. Channel 4, on the other hand, corresponds extremely well to a field boundary seen on the same map (figure 26). Given the use of water channels as field boundaries as discussed, it is likely that channel 2 split into two at the point where this field boundary joins the race, one branch continuing west before rejoining the main Erewash course and a second branch (channel 4) flowing south and being used as a field boundary.

Figure 25 shows the geophysical survey results overlain onto the 1884 map and Lidar digital terrain model. The agreement between the historic map and digital terrain model regarding the location of the Manor House confirms the accurate georeferencing of the map, and the geophysical survey results support that there are buried architectural remains at this site. Several of the field boundaries shown on the 1884 map correspond to features detected in the field survey. For example a straight linear boundary running north-east from the northern water course and forming part of the Manor House enclosure complex may correspond to a negative anomaly detected in the geophysical survey (shown in red). In addition, field boundaries running north-east to south-west between the two river branches correspond well to features identified in the Lidar survey.

7. Conclusion

The application of a number of survey techniques has contributed significantly to an understanding of the archaeological features available for further study in Toton Manor Recreation Ground.

The geophysical survey has identified several potential excavation and borehole targets, including structural remains of the Manor House and mill buildings as well as a series of possible field boundaries or trackways. It has also contributed to the general deposit model for the site, showing that archaeological remains are present even underneath the apparently completely landscaped cricket pitch.

The Lidar and topographic survey have identified the remains of a medieval ridge and furrow field system as well as a series of features relating to water management, which when overlaid onto historic maps can be interpreted as previous water courses, mill races and field boundary channels. Bore hole survey in this area would shed light on the phasing of these features.

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Cartographic references

1884 Ordinance Survey map, six inch first edition

1847 tithe map

1835 map from Sanderson's *Twenty Miles around Mansfield*

1789 map of Toton Manor, Sir John Borlase Warren

Appendix A: Details of Survey Strategy

Date of Survey: May 2014
Site: TOF 2 – Toton Unearthed (Nottinghamshire)
Region: Toton, (Nottinghamshire)
Grid Reference: NGR SK501342
Surveyor: Trent and Peak Archaeology
Personnel: Tom Hooley, Pov Cepauskas, Paul Flintoft, David Strange-Walker, Rachel Townsend, Laura Binns, Genevieve Carver
Geology: Mercia Mudstone Formation
Survey Type: Magnetic Gradiometry, laser scanning, walkover and hand survey
Approximate area: 5 hectares
Grid size: 30m
Traverse Interval: 0.5m
Reading Interval: 0.25m
Instruments: Bartington Instruments Grad 601-2, Leica HDS6100, Viva CS15/GS15 RTK-enabled GNSS (GPS)
Resolution: 0.1nT
Traverse mode: Zig-zag

Appendix B: Geophysical Prospection Methods

Magnetic Survey

Magnetic prospection of soils is based on the measurement of differences in magnitudes of the earth's magnetic field at points over a specific area. The iron content of a soil provides the principal basis for its magnetic properties. Presence of magnetite, maghaematite and haematite iron oxides all affect the magnetic properties of soils.

Although variations in the earth's magnetic field which are associated with archaeological features are weak, especially considering the overall strength of the magnetic field of around 48,000 nano-Tesla (nT), they can be detected using specific instruments (Gaffney et al. 1991).

Three basic types of magnetometer are available to the archaeologist; proton magnetometers, fluxgate gradiometers, and alkali vapour magnetometers (also known as caesium magnetometers, or optically pumped magnetometers).

Fluxgate Gradiometer

Fluxgate instruments are based around a highly permeable nickel iron alloy core (Scollar et al. 1990, 456), which is magnetised by the earth's magnetic field, together with an alternating field applied via a primary winding. Due to the fluxgate's directional method of functioning, a single fluxgate cannot be utilised on its own, as it cannot be held at a constant angle to the earth's magnetic field. Gradiometers therefore have two fluxgates positioned vertically to one another on a rigid staff. This reduces the effects of instrument orientation on readings.

Fluxgate gradiometers are sensitive to 0.5nT or below depending on the instrument. However, they can rarely detect features which are located deeper than 1m below the surface of the ground.

Archaeological features such as brick walls, hearths, kilns and disturbed building material will be represented in the results, as well as more ephemeral changes in soil, allowing location of foundation trenches, pits and ditches. The results are however extremely dependent on the geology of the particular area, and whether the archaeological remains are derived from the same materials.