ARCHAEOLOGY IN NEW ZEALAND

High Resolution LiDAR data for Landscape Archaeology in New Zealand

Ben Jones (Clough & Associates Ltd.)
Simon H. Bickler (Bickler Consultants Ltd.)

Introduction

The quality and availability of LiDAR data offers new opportunities for archaeological investigation in New Zealand. These datasets exist for numerous locations across New Zealand, several of which have been captured by local government. Access to these datasets is often available as a by-product of environmental, ecological, civil and survey work which occurs on land developments, and can enhance the quality of archaeological assessments and surveys. We discuss the utility of LiDAR for known archaeological sites, not only emphasising its ability to locate sites by providing a lens into difficult terrain, but also illustrating how the data can generate new maps, update existing site plans, boundaries and locations. Modelling the 3-D component of archaeological locations is also linked to LiDAR's ability to form a high-resolution DEM (digital elevation model). This paper examines case studies to demonstrate LiDAR's capabilities for both new and previously recorded sites, such as the Auckland pa – providing a case study of automatic feature extraction of Maori storage pits through hydrological and machine learning techniques. Where multiple LiDAR coverages exist, DEMs of different time periods can be calculated allowing quantitative measurement of landscape change, useful for developing risk management tools.

LiDAR in New Zealand Archaeology

LiDAR has been used by NZ archaeologists in areas ranging from the micro-recording of erosion and wear of heritage features such as the Antarctic Explorers Hut (e.g., Gibb *et al*. 2011) as well as large–scale recording of both excavated archaeology and built structures using terrestrial laser scanner to generate fine scale LiDAR datasets (Gibb *et al*. 2013; McIvor 2015). The LiDAR used there is specific to the project and collected for the archaeological purposes. This remains out of reach for most consulting archaeological projects as well as impractical for large scale survey work due to cost and time. LiDAR is increasingly being used to create high resolution contour information for land development and this data, often funded by Territorial Local Authorities (TLAs), allows for a standardised quality of topography suitable for many earthwork plans, at least at preliminary stages of development. The resolution of the data has become superior to most land based survey but perhaps one of the most attractive aspects of LiDAR data is that it appears to be almost magical in 'seeing' through vegetation even when it is quite dense - an ideal characteristic for identifying archaeological sites (see also Inomata et al. 2017 for an overseas example).

Site Detection

High resolution contour data is useful for exploring New Zealand archaeology because earthworks are a key part of Maori archaeology in pre-European and contact periods. As a result, aerial photography alongside field survey have been staples of the NZ archaeologists' toolkit since the 1950s (see e.g., Jones 1994) and using contour information has been relevant in describing everything from the large monumental pa sites along through to the smaller pit and terrace sites across the country. Traditional stereoscopic aerial photography provided one method for visually highlighting contour data to find surface archaeological sites such as earthworks, ditches, terraces etc. LiDAR offers ways to complement this toolkit; however, the challenges of the technique should be highlighted to allow a nuanced discussion of how it detects sites.

Technically there are three main challenges associated with LiDAR in New Zealand archaeology. First is the coverage across the country. This is rapidly expanding but many of the regions where it might be most useful for archaeologists such as rural vegetation-covered land have not yet been surveyed.

The second issue relates to the quality of LiDAR data. In New Zealand, horizontal resolution is commonly 1m, which means the elevation is expressed every 1m. In archaeological terms, if a raised rim storage pit is 3 x 3m, then it would be represented as 9 pixels within the DEM, but anything smaller than 2m causes the elevation difference to be omitted and the pit would not to be identified.

The third issue is how the data is processed from the point cloud to DEM. The point cloud consists of xyz information calculated from how long it took the laser to return to the aircraft. There is no discrimination between whether it is hitting a house, a tree or the bare ground. Different returns have to be classified based on the types of returns and correlating them with whether they relate to topography of ground cover. Misclassification leads to a blurry DEM and therefore is not useful for finding archaeological features. Point clouds have to be inspected and DEMs checked to ensure they are suitable. Once the correct set of return points have been identified, the DEM is created by combining the points to create an elevation model mathematically. There are several algorithms to create the DEM, the most commonly used being are IDW (Inverse distance weighting) and Kriging. The different algorithms have different characteristics and determining which algorithm might better represent archaeological information needs to be examined on a case by case basis. Despite these issues, there are good sets of data available and there are rapid improvements in the tools available to assist in using the data for archaeological purposes.

Levin Survey

A survey of 124ha block near Levin (Figure 1) provided an opportunity to test out some of the ideas using LiDAR data where there were no previously recorded archaeological sites. LiDAR data was provided by Horowhenua District Council. This was then used to identify Areas of Interest (AOIs). Defining the AOIs relied on visually inspecting raster-derived surfaces such as slope, hillshades(1) and manipulating the DEM to draw out possible archaeological features (see e.g., Bewley *et al*. 2005; Devereux *et al*. 2008, Harmon *et al*. 2006; Inomata et al. 2017; Jones *et al*. 2015 for further discussion). The results of part of the survey area showing the hillshaded surface and AOIs are shown in Figure 2 with likely pit features in Figure 3.

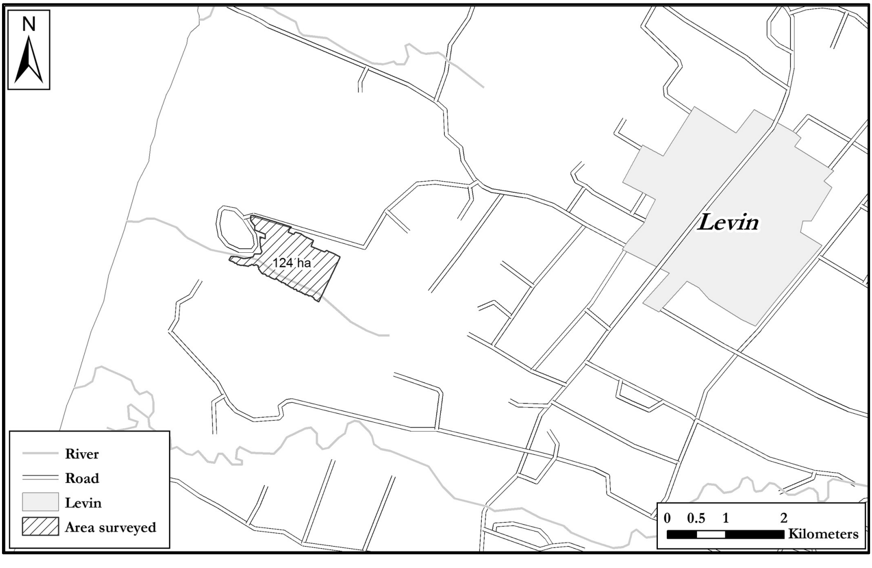


Figure 1. Area of the Levin survey.

Field survey was then undertaken in September 2016 by Ben Jones and Dave Carley. Areas both within and outside the AOIs were inspected thoroughly. The majority of AOIs consisted of rectangular depressions and expected to be Maori food storage pits. This mainly proved to be the case. The storage pits were generally orientated in an N-S direction, between 2-5m long and a width of between 1.7-4m. Terraces were also recorded and followed the natural contour of the ridge or knoll. Eight out of nine AOIs identified through the LiDAR survey did have archaeology located in the general vicinity, while in two cases archaeological features were not identified by the LiDAR data but were evident during field survey. These were a set of terraces and a find spot of oven stones, the latter obviously not visible in the LiDAR. The desktop work proved useful but identification still required manual classification of possible AOIs.

Automated Search

A complementary approach to the GIS based techniques for identifying archaeological features of interest comes from the rapidly emerging field of 'machine learning.' Machine learning algorithms have found a place in variety of applications and most commonly known from areas such as fingerprint matching, facial recognition and other pattern-based identification processes. The GIS based topographic analysis dovetails with machine-learning approaches to identify possible archaeological features within that processed topographic data, rather than just relying on visual recognition alone.

There are a wide range of possible machine learning algorithms and the appropriateness of any one depends on the nature of the archaeological ground surface signature e.g., earthworks and the type of data being examined. The data being analysed ranges from contour information, aerial and satellite imagery, as well as specialised data such as infra-red imagery. All of these have a long history of use in archaeological research. The difference is that there are new ways of processing the information to help pick out features in the landscape rather than relying solely on individual visual recognition as discussed above. To demonstrate this, one technique, 'template matching,' was used on the LiDAR DEM information from the Levin case study.

The DEM for the larger region was processed using hillshading to highlight possible features. A template (see inset in Figure 5) that showed a 'pit' from the series of pits described in the Levin case study discussed earlier was extracted from the shaded DEM. The template matching algorithm was then coded(2) to search for similar looking parts of the DEM and highlight those patterns (see Figure 5).

It is feasible to vary the level of closeness of the matching; the lower the threshold needed for a match the more possibilities that are offered, but the less likely features identified in the area are actually likely to be archaeological. No detailed analysis of the results is presented here, as more detailed work and explanation is required. Nearby pit features of the known sites were identified and a variety of unknown features were also highlighted. These results were then investigated using available imagery and confirmed with field survey. The results did match most of the AOIs identified earlier but could do so rapidly over a much larger region. The current technique only focussed on one 'template' based on pits and does not capture the range of possible archaeological sites, but the example shows how the machine learning approach has potential for archaeological site identification.

Internal Feature Identification and Mapping

LiDAR data also can be useful in mapping previously recorded archaeological sites and contextualising data collected prior to the common use of GPS and GIS technologies. One of the NZAA ArchSite's valuable resources is the large number of sketch, and sometimes, more detailed maps, of archaeological sites. The sketches range from relatively simplistic drawings to works of art and the majority do contain valuable data. Unfortunately, the majority are not geo-referenced, nor necessarily to scale. The high-resolution DEM data now available, however, provides an opportunity to re-evaluate that information and bring it up to date for modern purposes. To illustrate this, a case study of Dacre Point Pa is used to demonstrate the application of site plans and LiDAR data.

Dacre Point Pa, R10/291

Archaeological research at Weiti Station, north of Long Bay between the Okura Bay and Stillwater, has been undertaken since the 1980s (see Bickler *et al*. 2007 for a summary). Many middens have been recorded along sides of the Okura River, but the most prominent site is the pa at the end of the spur. Originally recorded in the Site File in 1981 by Peter Matthews, the site was formally described by Robert Brassey in 1995 and a sketch plan drawn (R10/291 Site Record Form, Figure 6 (left). Then, as now, the site was covered in relatively dense vegetation (Figure 6 middle) but the double transverse ditch across the spur was visible and midden was still detectable at various points along the spur. The dense vegetation makes it difficult to find anything but major features and makes it difficult to accurately map them. The point cloud LiDAR data was processed with the vegetation removed and 1m DEM generated. The ditches were easily identified (Figure 6 bottom) and very accurately plotted.

The DEM also contains additional information that may be less obvious, but no less useful for interpretation of the site. A 3D model of the site was generated with the assistance of Thomas MacDiarmid (Figure 7). The model uses the DEM with an archaeological interpretation of the contour data to identify possible features of the pa site. While the visible evidence identified on the site relates to midden and ditches, in attempting to work out how the area may have been used, it is possible to identify other elements such as potential pathways (Figure 7) that may have been necessary to access the site from the beach. Other topographic elements such as the relatively limited flat areas suitable for housing also become apparent. Finally, areas of erosion were also identifiable, most obviously along the cliff face, but also on the southern end of the outer transverse ditch. This type of information can be used as part of any future management plan. The results require further archaeological investigation, but the DEM offers new avenues to pursue in site interpretation.

Mt Richmond/Ōtāhuhu, R11/13

A more complex example comes from an examination of one of the Auckland volcanic cone pa. Ôtāhuhu/Mt Richmond (R11/13) has been documented for some time but has undergone quite significant alterations over the years. Detailed mapping of most of these volcanic sites was undertaken, often as part of University of Auckland graduate student exercises, but the plans have generally not been updated to modern survey grade. The modern DEM allows for these plans to be upgraded by providing xy coordinates for features detailed in these plans. The DEM (shown in Figure 8) clearly shows a number of archaeological features, and considering that many of these are currently obscured in the satellite and aerial images, the model provides a useful baseline for updating the current archaeological plans by geo-referencing the plans over the new DEM. As in the Dacre Point Pa example, the ability to see what features are present, obscured or have been eroded can be undertaken.

Rather than repeat the ‘mapping’ approach, however, we provide another example as to how the LiDAR-based DEM can be analysed to identify archaeological features. In this case, we use a hydrological ‘sinks’ approach to determine whether pits can be identified. Sinks are defined as land surrounded by areas with higher elevation, which of course is what Maori storage pits are.

The 1m resolution DEM of Mt Richmond and the surrounding area was created and then added into a hydrological sink hole model[3]. The landscape is ‘flooded’ and the water then allowed to flow off the DEM. Features such as ditches which act like drains show up as ‘fast-flowing’ but crucially water into ‘sinks’ cannot flow out as the water reaches the surface. The sinks were then identified as likely pits (if of the appropriate size) in the model (Figure 8).

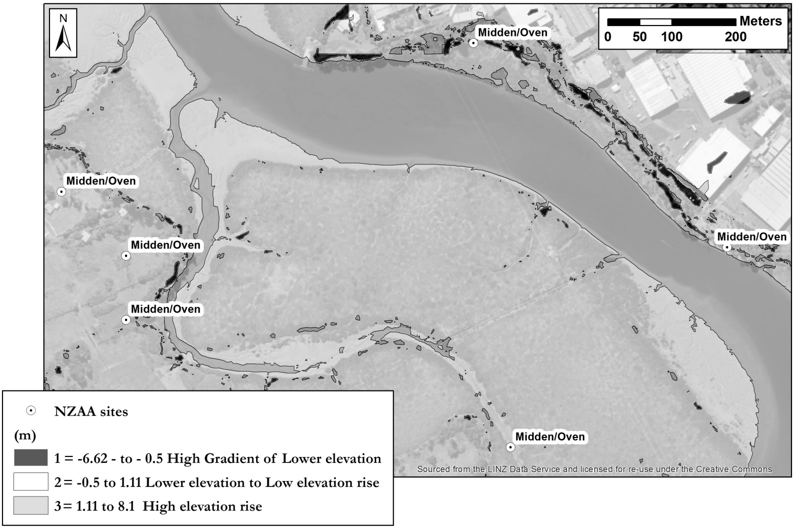
Combining the DEM, hydrological modelling, historical plans, field survey and modern aerial and satellite imagery, it seems possible that re-mapping the large pa sites could be relatively productive in improving the archaeological record.

Site Taphonomy and Risk Assessment

One final example is provided in the paper and uses LiDAR collected in the Auckland Region collected at two different time periods. Analysis of LiDAR data that are 7 years apart covering the area of Whau River in Auckland can be used to illustrate identification of geomorphological processes in coastal and riverine locations. This information is able to highlight how erosion, accretion and sedimentation may be affecting or will affect archaeological sites over time.

The two datasets were from 2006 (ALGGi 2007) and 2013 (NZAM 2015). The most recent survey was more accurate but for this analysis the methodology involved deriving DEMs interpolated from the point cloud (IDW interpolation was used here to the power of 2 using a search radius of 12 points) at the lower shared horizontal resolution, in this case 1m. Comparison was then used to create a differential DEM subtracting the elevation (m) value of the 2006 DEM from the 2013 DEM on a pixel by pixel basis (Figure 9). (3)

The results (Figure 10) suggest the elevations of several sites are lower than they were in 2006, while some are higher, which illustrates the active state of the sediment around the Whau River. Given the short time span, those sites that are clearly vulnerable to changes in 'elevation' are likely to be more vulnerable than those in more stable locations



Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons

Figure 10. Overlay of archaeological sites from ArchSite on resulting differential topographic plan

Discussion

The case studies shown here depict how the quality and availability of LiDAR data coming on stream in New Zealand offers new opportunities for archaeological research and investigation. Typically, the commercially available LiDAR data has simply been used to provide a background of elevation information for sites which is useful, but this represents only a small fraction of its utility. We demonstrate how the data can be used as part of site survey to identify possible locations of unrecorded archaeological sites as well as assisting mapping of known archaeological features.

We have also shown how machine learning techniques can be used on various GIS based data derived from the improving LiDAR data to assist in identifying new archaeological sites and features especially in areas where field survey has not been intensive. There are two significant avenues for further exploration of these techniques. First, finding new ways to find and characterise archaeological sites in the LiDAR data and second, developing new algorithms to search for those elements in LiDAR data.

Potentially, the most useful aspect of the use of LiDAR data will be its ability to provide baseline information for archaeological sites for long term heritage management (see e.g., Jones 2002, 2007). Analysing LiDAR coverage that is 7 years apart covering the area of the Whau River in Auckland shows how rapidly change in the physical landscape in many areas of New Zealand is occurring as the result of land development, sea level rise and climate change. This approach can form the basis of risk assessments relating to the long-term survivability of archaeological record (see e.g., Bickler *et al*. 2013) by highlighting sites in vulnerable zones.

Acknowledgements

The authors would like to thank David Carley, Laura Dawson, Jennifer Low, Thomas MacDiarmid and Dorothy Brown for their assistance in writing this paper. Weiti work funded by Weiti Development Limited Partnership with assistance of Ngati Manuhiri, Te Kawerau a Maki and Ngati Whatua o Kaipara. Levin work funded by the Horowhenua district council.

Endnotes

1 Hillshading refers to the digital lighting of a 3D model to cast shadows at different angles to highlight aspects of the DEM

2 Programmed in python using Open CV (http://docs.opencv.org/3.1.0/d4/dc6/tutorial_py_template_matching.html)

3 Calculation based on ArcGIS flow direction and then sink tool; http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/sink.htm

Bibliography

Auckland Local Government Geospatial Information (ALGGi) (2007) LIDAR DTM and Orthoimagery –Information Sheet – 10th August 2007. Auckland City Council, Auckland.

Bewley, R. H., Crutchley, S. P. and Shell, C. A. (2005) New light on an ancient landscape: LiDAR survey in the Stonehenge world heritage site. *Antiquity* 79: 636-647.

Bickler, S. H., Clough, R. and Macready, S. (2013) *The Impact of Climate Change on the Archaeology of New Zealand's Coastline: A Case Study from Whangarei District*. Science for Conservation No. 322. Wellington, Department of Conservation.

Bickler, S., Harlow, D., Clough, R. and Low, J. (2007) Weiti Station Archaeological Assessment of the Southern Block (Rev. B). Clough & Associates Report prepared for Williams Capital Ltd.

Devereux, B. J., Amable, G. S. and Crow, P. (2008) Visualisation of LiDAR terrain models for archaeological feature detection. *Antiquity* 82: 470.

Gibb, R. and McCurdy, D. (2013) The shore-based whaling stations of South Georgia Island. *Archaeology in New Zealand* 56 (1): 40-52.

Gibb, R., McCurdy, D. and Farrell, R. (2011) The use of laser scanning to record historic huts in Antarctica. *Archaeology in New Zealand* 54 (2): 131-143.

Harmon, J. M., Leone, M. P., Prince, S. D. and Snyder, M. (2006). LiDAR for archaeological landscape analysis: A case study of two eighteenth-century Maryland plantation sites. *American Antiquity* 71 (4): 649-670.

Inomata, T., F. Pinzón, J. L. Ranchos, T. Haraguchi, H. Nasu, J. C. Fernandez-Diaz, K. Aoyama, H. Yonenobu (2017) Archaeological Application of Airborne LiDAR with Object-Based Vegetation Classification and Visualization Techniques at the Lowland Maya Site of Ceibal, Guatemala. *Remote Sensing* 9 (563).

Jones, B. D., Ladefoged, T. N. and Asner, G. (2015) Tracing the resilience and revitalisation of historic taro production in Waipi‘o Valley, Hawai’i. *Journal of the Polynesian Society* 124 (1): 83-109.

Jones, K. (1994) *Nga Tohuwhenua mai Te Rangi: A New Zealand Archaeology in Aerial Photographs*. Wellington, Victoria University Press.

Jones, K. (2002) Condition reporting and monitoring of archaeological sites: The use of large-scale vertical aerial photographs in New Zealand. *Conservation and Management of Archaeological Sites* 5 (3): 131-140.

Jones, K. (2007) *Caring for Archaeological Sites: New Zealand Guidelines*. Wellington, Department of Conservation.

McIvor, Isaac H. (2015).Monumental ideology: A GIS spatial analysis of interior features of Matakawau Pa, Ahuahu (Stingray Point Pa, Great Mercury Island), New Zealand. *Journal of the Polynesian Society* 124 (3): 269.

NZAM (2015) LiDAR Flyover 2013/14 Project Final Report for Auckland Council. NZ Aerial Mapping and Aerial Surveys Limited, Auckland.

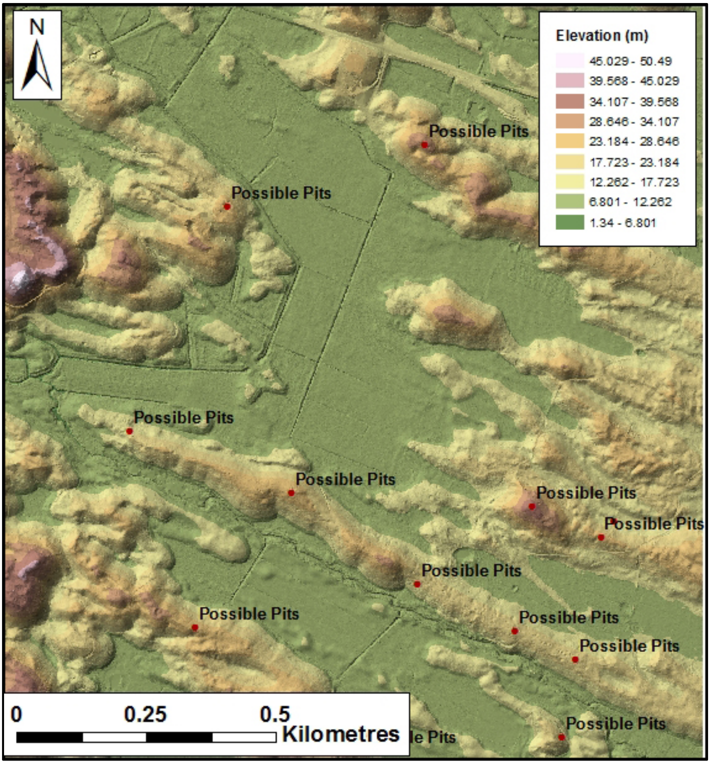


Figure 2. AOIs identified during desktop LiDAR survey.

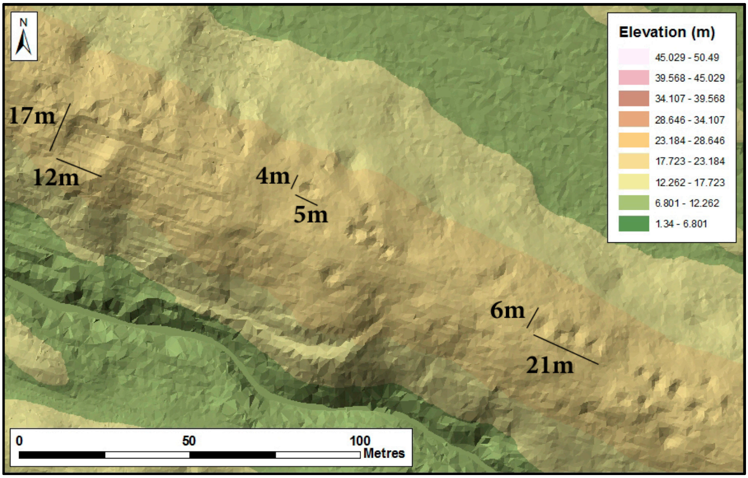


Figure 3. Typical features identified during the LiDAR desktop survey.

Figure 4. Looking west with Dave Carley standing in the middle of a pit.

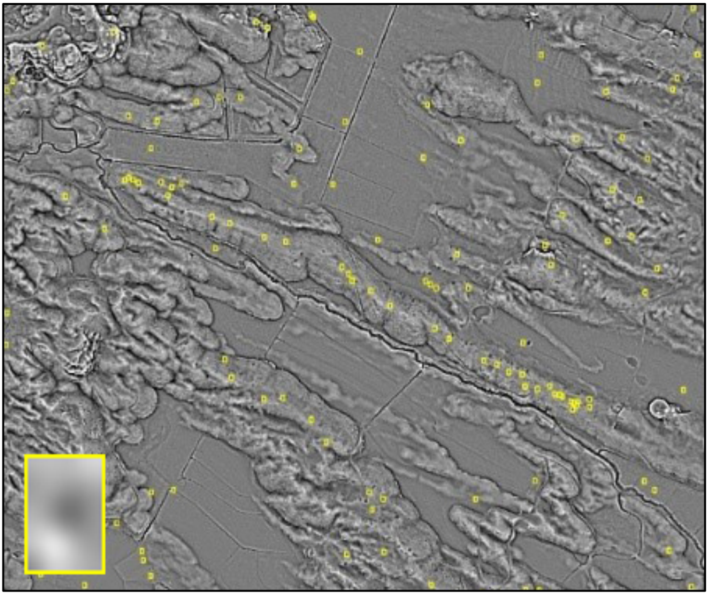


Figure 5. Hill shaded DEM of part of Levin survey area with possible pit features identified with template matching algorithm (threshold value – 0.8). Inset showing template of shaded 'pit' used for matching.

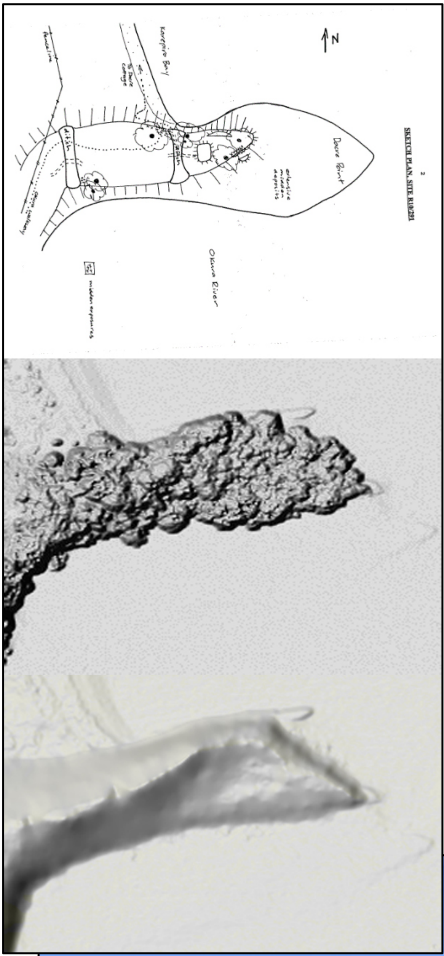


Figure 6 (Left)
Dacre Pt. Pa, R10/291, showing SRF sketch plan (top), LiDAR with vegetation (middle), DEM (bottom).

Figure 7 (Below)
3D model of Dacre Pt. Pa, R10/391 (T. MacDiarmid and S. Bickler).

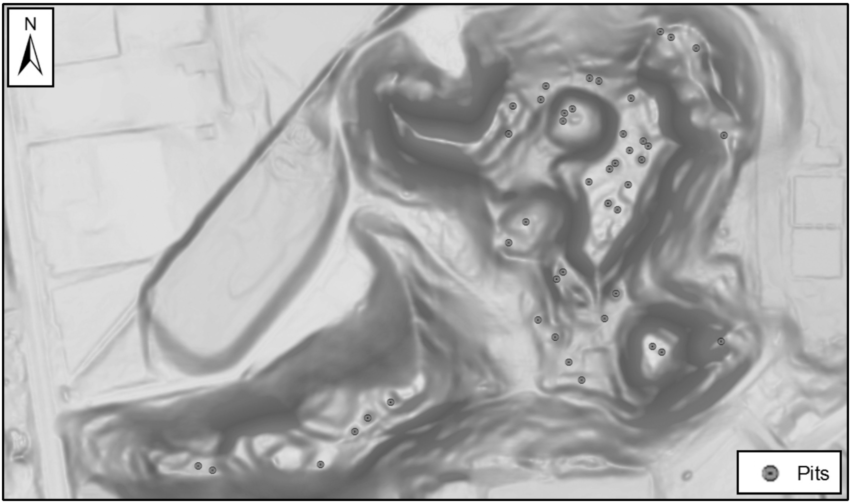


Figure 8. Identified possible pits on R11/13.

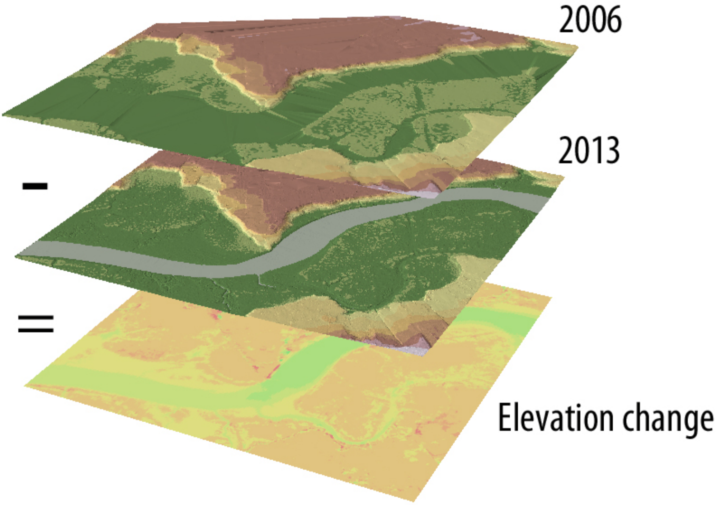


Figure 9. Differential elevation plan of part of the Whau River using the LiDAR data from 2006 and 2013.