Four predictive models to describe Aboriginal lithic artefact site patterning on the Cumberland Plain

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Aboriginal archaeological predictive modelling is a necessary and fundamental requirement for all investigations and studies in Aboriginal heritage. In New South Wales, the application of predictive modelling is commonly based on White and McDonald’s 2010 Stream Order Model. This provides a sound basis for archaeological investigation; but can be supplemented by other models, which engage different investigations associated with social and economic theory. This paper presents four different and complementary models which can be used to underpin consequent archaeological survey and excavation methodologies. The application of the models may also provide a basis for interpreting the data collected. A case study demonstrates the application, but also the clear limitations of any archaeological model.

Introduction

Located within the Sydney Basin, New South Wales, the Cumberland Plain extends from Windsor in the north to Picton in the south, bounded in the north and west by the Nepean-Hawkesbury River (Figure 1). Physiographically described as the Cumberland Lowlands, the region comprises low lying, gently undulating plains and low rolling hills on Wianamatta Group shales and sandstones, with a dense drainage network of low order creek channels, predominantly draining north (Bannerman & Hazelton 1990). Soil landscapes are predominantly residual Blacktown soils and the erosional Luddenham soils, incised by the fluvial South Creek soils found along most major water courses.

The Cumberland Plain is an intensively investigated archaeological landscape due to the extensive nature of development associated with Sydney’s expansion. This area is dominated by lithic artefacts that comprise the dominant cultural evidence (Attenbrow 2010: Plate 12) relating to the past 30,000 years of Aboriginal occupation (McDonald 2008: 36).

Figure 1 Location map of the Cumberland Plain and case study site, East Leppington.

Land use pressures have focused archaeological attention on the spatial distribution of lithic artefacts within this landscape. In such an open landscape the locations where Aboriginal people camped and undertook other traditional activities, which provide an enduring archaeological record,
are not readily apparent (Wandsnider & Camilli 1992; Fanning and Holdaway 2001; McDonald et al. 1994; Owen 2015a). Large-scale assessments, such as those for the Growth Centres (growthcentres.planning.nsw.gov.au), tend to direct heritage management towards the identification of sites with a high density of artefacts in an attempt to conserve places with higher scientific and social value (OEH 2011). Thereby, intergenerational equity is sustained during the release of greenfield land (DECCW 2009; Owen 2015b), and an objective of the National Parks and Wildlife Act 1974 (NSW) is met.

**Archaeological Predictive Modelling**

All Cumberland Plain archaeology makes extensive use of predictive modelling as a primary investigative tool. This is because there is a general absence of surface based archaeology and the observable surface expressions of archaeology do not correspond with subsurface extents of material (White and McDonald 2010: 29-30). In NSW all archaeological assessments have, since 2010, been required to develop predictive models in line with the Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales (2010: 10):

- consider the distribution of natural resources, and the probable land-use strategies employed by Aboriginal people in the specific landscape context
- consider the spatial and temporal relationships of sites
- identify what sorts of material traces are predicted to be present, and in what densities
- make inferences about past Aboriginal occupation of the landscape based on the evidence collected and presented.

The first Cumberland Plain archaeological predictive models were developed during the 1980s and 1990s (Fletcher-Jones 1985; Kohen 1986a; Smith 1989). During archaeological surveys, observations were made relating to the type and distribution of archaeological sites, notably the ubiquitous presence of lithic artefacts. Key observations included that artefacts were present as an almost continuous scatter across the landscape, site distribution centred on the availability of water, and other factors—proximity to a diverse range of animal, plant and lithic resources, and elevation above water courses—were also correlated to site location (Kohen 1986b; Brayshaw 1993: 9). Smith (1989) developed a model stating that while Aboriginal sites would be found across all landforms, half would be positioned primarily within 50 metres of water. Applying the distance-decay theory, Smith suggested that sites would be densest near lithic material sources within sedge communities, more often in open forests than in woodlands, and associated with good visibility.

In this landscape context, the generation of specific predictive lithic artefact based models requires significant quantities of data derived from archaeological excavation. Key to the development of any new model is the intensive investigation of a landscape with a range of archaeological sites across a range of landforms. The ability to archaeologically sample and test a wide range of landforms is instrumental in
developing models capable of differentiating locations with high lithic artefact densities from an almost continuous background scatter that is present across the landscape. The best area for providing sufficient data for the creation of a model was the Rouse Hill Development Area (RHDA). This landscape was subject to numerous test and salvage excavations between 1999 and 2014 (McDonald & Mitchell 1994; Jo McDonald Cultural Heritage Management Pty Ltd 2001, 2002, 2007; GML Heritage + Jo McDonald CHM 2014) that culminated in a detailed archaeological record pertaining to lithic artefact based sites across numerous landforms. The outcome was the development of the Stream Order Model (White & McDonald 2010) which has become the standard applied to archaeological investigations on the Cumberland Plain, particularly since 2010.

Four Predictive Models

Large landscape-scale archaeological sampling is an appropriate means to detect, determine and assess the specific locations of archaeological remains, and contribute to suitable land-use planning. However, many studies on the Cumberland Plain are constrained by their coverage and cannot undertake large sampling programs. Whilst the Stream Order Model provides a predictive model for large areas with multiple landforms, it cannot by its very nature consider intra-landform variation, or provide predictions for unusual circumstances or the occurrence of unusual landforms. The complementary application of an additional predictive model(s), which may account for smaller-scale intra-landform variation, is therefore useful.

We present four predictive models developed on the Cumberland Plains largely as a result of the extensive archaeological investigations occurring over the past two decades. These models are complementary and, when used in conjunction, can describe archaeological patterning at both the large and small landscape scales. The four models are:

- Stream Order Model
- Economic Resource Model
- Activity Overprinting Model
- Domiciliary Spacing Model.

Stream Order Model

The Stream Order Model is a large-scale landscape model which identifies landforms by standardised descriptions (McDonald et al. 1998) and applies a series of predictive statements about landforms in relation to watercourse category, landform, aspect and distance to water. Simply, stream order identifies the smallest tributary as first order, two first order streams join and form a second order stream, two second order streams join to form a third order and so on (Strahler 1952; White & McDonald 2010: 32). During RHDA excavations the Stream Order Model was refined, tested and critically analysed. This culminated in White and McDonald’s publication of the excavated data along with a series of predictive statements (2010: 36):

- stream order—higher order streams tend to have higher densities and more continuous distributions of artefacts associated with them than lower order streams
- landform—higher artefact densities occur on terraces and lower slopes, with sparse discontinuous lithic artefact scatters on upper slopes
- aspect—higher artefact densities occur on landforms facing north and northeast, on lower slopes associated with larger streams
- distance from water—higher artefact densities occur 51–100 metres from fourth order streams, and within 50 metres of second order streams.

Further considerations under the model include a landform’s proximity to the sandstone-shale interface. It was thought that the distance to known silcrete sources did not influence lithic artefact distribution.

The Stream Order Model provides an assessment of general trends in Aboriginal landscape use, but does not determine the use of any specific
location or the subtle variations in landform on the small scale. Also, the model does not account for aspects of Aboriginal tradition, or the bounded nature of Aboriginal sites. The model does, however, offer additional points for consideration in that:

slightly elevated, well-drained locations in the lower parts of valleys would have been favoured because they received winter sun and were sheltered from southerly and southwesterly winds. Locations away from immediate creek banks may have been preferred because they were elevated and well-drained, to avoid mosquitoes, to allow animals to drink, and/or to accommodate the spatial requirements of residential groups allowing all members access to water (McDonald & White 2010: 36).

These conjectures permit smaller scale landform analysis, and commence the process of understanding how specific areas may have been used by Aboriginal people. The following three models expand on the Stream Order Model and provide refinement to account for specific location occupation, tradition and long-term landform use.

**Economic Resource Model**

The Economic Resource Model focuses on locations with high value food and/or economic resources, as well as their connection to landscape texture change (Evans 2003; refer below) and ecotones.

Economic zones are areas rich in resources that Aboriginal people regularly accessed—e.g. creeks, yam beds and seed collection localities, as well as regular grazing/feeding areas for animals regularly hunted. An economic zone ranges in size from a single tree, to a large yam bed, and up to the length of a creek. The habitat represented by the economic zone can be either an unmodified landform (such as a particular ecological habitat), or one which has been created or modified by a specific Aboriginal subsistence strategy (through firing, vegetation clearance, replanting of tubers/seeds, creation of traps etc.). Certain economic zones, such as fish traps or lithic quarries, are simply and readily identified economic zones.

Landscape texture refers to the land’s living surface and is defined by an area’s landform, ecology, geology, soils and climate etc. (Evans 2003). Texture is fine-grained and expresses the interpretation of how everyday activities were practiced. This requires an examination and recording of subtle changes in landform, soils and vegetation within a larger system of landforms. Landscape texture can be a component of the Aboriginal cultural landscape, and may require formal management to maintain the aesthetic and physical attributes.

Ecotones are junctions between different ecosystems, and these provide a rich diversity of natural resources (Evans & O’Connor 1999: 53). Ecotones are frequently defined by vegetation communities, where a boundary defines clear changes in soils, water and frequently landform. These locations may represent significant resource areas for Aboriginal people due to an increased abundance of natural resources.

The Economic Resource Model suggests that evidence of Aboriginal activities (artefacts, hearths, ground ovens etc.) is most likely to be located on a suitable landform (defined by the texture changes and ecotone) within, adjacent to and around the economic zone (Figure 2).

![Figure 2 Relationship between an economic zone and archaeological evidence.](image)

The likelihood for sites occurring adjacent to an economic zone, and the distance one could expect...
their positioning away from the economic zone, are dependent upon two factors (based on the archaeological and ethnographic observations of the authors):

- the potential of the economic zone to yield resources
- the ‘texture’ and ‘ecotone’ of the landforms adjacent to the zone.

If an economic zone is small (such as a single tree), in general, it is unlikely a physical archaeological site would be located within or adjacent to the economic zone. Identified site features could include isolate finds or low artefact density. Conversely, larger economic zones (areas with a high potential for resources) have a higher potential for continued and long-term use. It is likely that dense and/or varied archaeological deposits would be formed within and/or adjacent to the zone.

Texture changes may be either permanent or temporary. Permanent texture changes include variations in landform (e.g. a flat abutting a simple slope), an area adjacent to water sources, a natural shelter from the elements (wind, sun, rain, etc.), a deliberately created element (e.g. a mound), or an area with a prominent view (such as a ridge or cliff). Temporary texture changes may be impossible to detect among the cultural remains and consist of social or traditional aspects (possibly identifiable to Aboriginal people), wooden bark shelters, heavy vegetation, trees and smaller artificial earthen banks.

Competing texture changes (e.g. a ridge, overlooking a simple flat and open depression) can be ranked to determine which element would present the most suitable location for repeated visits, and thereby likely occurrence of archaeological evidence. Once the economic zones and the texture changes are identified and ranked, a cross reference between the two will suggest where, within any given landscape, archaeological sites are most likely (Figure 4), as well as some idea about their potential density.
resources and the nature of the texture change. The local landscape, long-term environmental factors, and the social, economic and demographic forces influencing a particular society are factors that also must be taken into account.

Analysing landscape texture continues the process of examining landforms using the Stream Order Model. The Stream Order Model predicts that a terraced flat should contain an archaeological deposit. An examination of landscape texture indicates specific locations where archaeological remains are most likely, based on ecotone occurrences and associated economic resources. The Economic Resource Model does not provide further interpretation of intra-landform use, which is where the Activity Overprinting and Domiciliary Spacing models begin to be useful.

**Activity Overprinting Model**

The Activity Overprinting Model (Baker 2000) aims to explain the presence and absence of artefact densities/complexity at increasing distance from a creek. This is achieved through understanding the nature of repeated long-term activities on a landform. The spatial analysis from a large-scale open excavation may identify areas related to such occurrences through evidence of re-tooling (where Aboriginal people had replaced old implements with newly manufactured ones), and the long-term re-use of knapping localities. The model provides insight into complex human behaviour and site patterning, particularly the long-term re-use of a place, where stratigraphic separation of long term re-use could be difficult or impossible.

The model accounts for intra-site archaeological spatial variability through the identification of discrete artefact concentrations at roughly two-metre spacing (Baker 2000: 53-54), a result of repeated site use (identified through detailed analysis of knapping assemblages). The model requires examination of local environmental resources; achieved through use of the Economic Resource Model, to distinguish zones of ‘complexity’, the locations of which were related to distance from the environmental focus. The zones of complexity were defined as varying ‘activity overprint zones’ (Figure 5):

- **complex zone**—near an environmental focus. In this zone, overlapping knapping and other activity concentrations are present due to repeated occupation and use of the area;
- **dispersed zone**—where knapping concentrations and activity areas are spatially discrete. This is the product of less frequent activity areas some distance from an environmental focus, or the positioning of activities that had to be conducted away from the primary residence or other activities;
- **sparse zone**—a consistently low-density distribution of artefacts likely resulting from discard in the context of use or loss, rather than manufacture;
- beyond the sparse zone—archaeological evidence found in low density scatters that may not be consistently identified by subsurface testing.

**Figure 5 Model of Activity Overprint Zones (after Baker 2000).**

This model focuses on intra-site variability in artefact densities and assemblage characteristics. Cultural materials recovered from one site/place may not be typical of an assemblage from another nearby location.
Domiciliary Spacing Model

The Domiciliary Spacing Model uses an anthropological perspective about Aboriginal camp arrangements describing the layout and features of a habitation site. An understanding of the layout and space between camp features can be translated into an idea about where and how archaeological evidence may be found.

A traditional Aboriginal campsites included several distinct camping locations termed ‘domiciliary’ spaces or areas. Each consisted of shelters, hearths, activity and storage areas (Memmott 2007: 33). The number of domiciliary areas was determined by the composition of the Aboriginal group camping. A small group may require two or three areas, whereas larger groups established multiple areas, including areas for nuclear families, men, women, initiates and so forth. The arrangement of domiciliary areas was governed by the social laws, with spaces allocated for day-time activities; in other words, places where men and women may have been apart, and late afternoon and night-time activities, when families came together (Clark 2012: 67).

The division of the family unit into six to ten sub-groups is an important consideration when understanding the social structure and habitation requirements for a camping area. RH Mathews (2007) suggested that occupation of any landscape area was governed by a strict set of traditions and societal rules.

The location of the huts or roofs in the camp is regulated by certain laws. When a camp is chosen at the shores of a waterhole or river, the older people begin taking up land for their dwellings at the water, while the others put up camp a bit further back. The entrances to the dwellings are situated to the north or northeast, so as to admit the rays of the morning sun, unless the wind comes from that direction. If there is a meeting of the community for a corroboree, or for an initiation ceremony, the local people set up camp first, and the visiting tribes take that side of the general camp for themselves which lies in the direction in which their home is situated. As far as the condition of the ground allows, they take exactly the same position to each other as in their own land, in a kind of miniature depiction of their home camps (p. 59).

In general, the six to ten groups occupying a camp location would each require their own space, separated from other groups by a distance of 30 to 100 metres (Memmott 2007: 121). These gaps separated individuals and provided for intra-camp patterning (Figure 6). When establishing a camping location, each group would erect a shelter (gunyahs) for adults, children and, possibly, dingoes. Heating fires would be placed at the entrance of each shelter, and cooking fires and food preparation areas, as well as knapping zones would be constructed in the domiciliary space (Figure 7). These camps could be occupied until shifting to a new zone was necessary due to...
tradition, ceremony or other economic and/or environmental drivers.

The archaeological investigation of a landform used in such a way would yield discrete spacing of archaeological evidence across the landform, corresponding to the locations of each camp. Between the camping areas, an absence of archaeological evidence could be expected (Owen 2015a: 75-76; Owen et al. 2016). The key to interpreting domiciliary spacing is an understanding of local site formation, soil conditions and site stratigraphy (with temporal and spatially discrete deposits).

The interpretation of the archaeological evidence must consider the consequence of such time-space-action models (Darvill 1999), the memory of place and how long-term site re-use would vary over millennia (Silliman 2009: 211-230). These matters can be addressed through stratigraphically controlled excavation and an examination of activity overprinting among artefact scatters. An understanding of the reasons for a site’s presence in a landscape must also take into account the textural landscape, which may have influenced long-term site selection and thus continuity in use. Interpretative frameworks should consider the importance of not only the archaeological deposits, but also the spaces between these deposits (Owen 2015a: 75-76).

**Case Study**

East Leppington is in the Sydney region, in the southwest Cumberland Plain 10 kilometres north of Campbelltown (Figure 1). Archaeological heritage assessment and test and salvage excavations were undertaken prior to residential development between 2011 and 2013, on behalf of the NSW Department of Planning and Stockland Development. Central to the process of Aboriginal heritage assessment and management was the development, application and consequential testing of a precinct-wide predictive model (Owen 2012, 2015b; Owen et al. 2016).

The test excavations (Owen 2012) included extensive landscape testing of a range of soil landscapes and landforms, with the aim of identifying those locations with and without an archaeological signature (533 Test Units following the OEH’s Code of Practice (Department of Environment, Climate Change and Water 2010) were excavated). The outcome was the identification of 12 spatially distinct locations that became the focus for open area salvage excavation (Owen et al. 2016). Open excavation involved hand excavating in several zones (a total area of 487 square metres), with the recovery of 7533 lithic artefacts. Twenty-one archaeological features were identified in association with lithic artefacts, including ground ovens, hearths and heat treatment pits—site types rarely recorded on the Cumberland Plain. The theoretical interpretation of the excavations is the occurrence of discrete temporal and spatial use of the landscape (Owen 2015a; Owen et al. 2016). Of particular relevance are the outcomes arising from applying the four predictive models to the East Leppington Aboriginal cultural and archaeological landscape.

The Stream Order Model and the Economic Resource Model were applied to the study area to evaluate the effectiveness of each alone and in combination. Both models were used to designate the three areas with highest archaeological potential. Applying the models at a more detailed level was possible. However, testing each model sought to provide a basic indication of whether or not an area exhibited a particular archaeological signature, and not whether every potential site location revealed a detectable archaeological deposit. Once a clear understanding of archaeological potential was demonstrated, then a detailed application of the other two models was possible.

The Stream Order Model (Figure 8) pointed to two discontinuous zones with high potential along the western alluvial terraces and lower slopes above Bonds Creek at 51 to 100 metres from the creek channel. Both corresponded with
three of the model’s characteristics—large streams, type of landform and north/north-easterly aspect. The western bank of Bonds Creek South formed a third zone with its terraced alluvial landforms and north-east aspect.

![Diagram](image)

**Figure 8** Application of the Stream Order Model to East Leppington, showing the three primary zones designated with archaeological potential. (Basemap source: Nearmaps 2016)

The Economic Resource Model indicated major texture changes within the landscape (indicated by red in Figure 9). These were present at Error! Reference source not found., the slope base and tops, and changes associated with the major creeks and hilltops. Economic zones were allocated along the major and minor watercourses, and the junction of the ecotone between the Cumberland Plain Woodland and Alluvial Woodland (Ecological Australia 2012). Assessment of the proximity between the two economic zones and major landform texture changes predicted highest probability for archaeological remains to occur on the western alluvial terraces along Bonds Creek. The same potential was assigned to the low terraced landforms on the southern inner banks of Bonds Creek and Bonds Creek South. These locations exhibited landform texture changes and economic zones converged and crossed several times, thus resulting in a long thin, U-shaped zone with archaeological potential (Figure 9). The third zone with two distinct texture changes and two economic zones occurred along the base of the Luddenham Hills, on the eastern alluvial banks of Bonds Creek South.

Comparing the Stream Order and Economic Resource models and their identification of areas with archaeological potential (Figure 10) showed considerable overlap along the north-western bank of Bonds Creek. The Stream Order Model covered a narrower, but longer area while the Economic Resource Model covered a wider, but shorter expanse. Both models designated that there was archaeological potential associated with the eastern bank of Bonds Creek South, although
the Economic Resource Model indicated some potential along the eastern bank of Bonds Creek. Each model designated some distinctly different zones with archaeological potential. The Economic Resource Model identified landforms at the base of the Luddenham Hills, while the Stream Order Model identified a long length of terraced banks upstream along Bonds Creek. Neither model pointed toward archaeological potential being found away from the major water channels.

Figure 9 Application of the Economic Resource Model to East Leppington, the green areas indicate the zones designated with highest archaeological potential. (Basemap source: Nearmaps 2016)

The results of the archaeological excavations (both testing and salvage) are shown in Figure 10. Those locations with varied and dense archaeological evidence are indicated by yellow circles; the areas with less dense archaeological evidence by orange circles (after Owen et al. 2016). The ability of the two predictive models (Stream Order and Economic Resource) in identifying the major archaeological deposits is also shown in Figure 10. An amalgamation of the two models resulted in a designation of archaeological potential at eleven of the twelve areas, which, through excavation, were confirmed to have dense archaeological evidence. The identification of smaller, less dense deposits was far less successful. Only 14 of the 28 zones (50%) fell within areas designated as having potential.
through geomorphological analysis of soil strata, and a combination of optically stimulated luminescence (OSL), thermoluminescence (TL) and radiocarbon dating (Owen et al. 2016: Table 5.3). The transition to the ‘dispersed’ zone was apparent from the abrupt decrease of artefacts beyond the boundary of each site. The background artefact scatter in dispersed test units reflected a sparse zone, notably among landforms extending away from the primary economic zones.

The Domiciliary Spacing Model described the potential patterning within landforms where dense cultural evidence occurred (Owen 2015a: 77-80). The discrete patterning of archaeological material, particularly on the alluvial terraces of Bonds Creek and Bonds Creek South, was separated by distances of between 20m and 150m (Figure 10). Given the longevity of continuous Aboriginal occupation and the evidence for repeat visitation to the same places, the application of the model indicates that Aboriginal people retained detailed knowledge of a social landscape where memory of place, law and tradition defined

![Figure 10](application-of-the-two-predictive-models-contrasted-with-the-outcome-of-archaeological-excavations-dense-archaeological-evidence-was-present-inside-the-yellow-circles-less-dense-inside-the-orange-circles-areas-with-no-archaeological-evidence-or-a-background-scatter-are-all-other-areas-after-owen-et-al-2016-domiciliary-spacing-of-evidence-is-apparent-within-the-core-archaeological-zone-basemap-source-nearmaps-2016)
how and when sites were established and occupied (Owen 2015a: 77-80; Silliman 2009).

Conclusions

The combined application of the Stream Order and Economic Resource models provided a good understanding of the over-arching archaeological potential associated with this landscape. This resulted in the allocation of potential to the majority of landforms with major archaeological sites (Figure 9). Therefore, as the basis for initial research into Aboriginal cultural landscape use, the Stream Order and Economic Resource models provide a sound basis, from which more detailed study commenced. However, these models did not provide a description of those locations with less dense occupation deposit. Nor did either model describe aspects of social or intangible use of landscape.

Further application of other more specific models, such as the Activity Overprinting and Domiciliary Spacing models provide an understanding of Aboriginal time-space-action representations of landscape use. Data generated from these four models may be used to interpret the cultural landscape, including application of more complex entanglement models (Tilley 2004: 73-75), proving a means of assessing intangible values and reconnecting Aboriginal people to their former traditions and places (Australia ICOMOS Inc. 2013).

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ISSN 2202-7890