

Just Add Water:
**Transformations in a peopled riverscape in the
Riverland region of South Australia**

By

Craig Stuart Westell

BSc, GradCertAppSc, GradDipHum

*Thesis
Submitted to Flinders University
for the degree of*

Doctor of Philosophy

College of Humanities, Arts and Social Sciences

29 September 2022

Abstract

This thesis examines a record of Aboriginal occupation in the upper Riverland region of South Australia against a backdrop of an evolving riverscape. The development of the River Murray floodplains is explored through a geomorphological interpretation of two anabranch systems; the Calperum and Pike floodplains. The structural changes evident in the Riverland floodplains are assessed against a history of shifting hydroclimate identified elsewhere in the broader Murray-Darling Basin (MDB). Some peculiarities in the local evidence are attributed to the nature of flow transmission in the MDB and the configuration of the River Murray valley in the Riverland.

The history of Aboriginal occupation in the Riverland has manifest in a staggering array of archaeological sites and materials. The geomorphological interpretation provides a basis in which to interpret and contextualise this record. The archaeology preserved across the Calperum and Pike floodplains is cast amongst a time-series in landscape development as a means of value-adding, and validating, a set of radiocarbon ages returned on exposures of shell midden and other occupation materials. In combination, the survey and dating results indicate that Aboriginal lifeways in the Riverland existed at the periphery of more sustained occupation in the MDB over a long period of time following the initial Aboriginal settlement in the basin c. 50–45 ka. Short-lived pulses in occupation, or strategies embedded in high mobility, seem to have persisted in the Riverland until a major, albeit short-lived, phase in site development c. 15 ka. This parallels evidence from the broader south-western MDB and illustrates a major reconfiguration of regional settlement patterns following the nadir of the Last Glacial Maximum (LGM). This reconfiguration was defined, in large part, by an expanded use of riverine corridors beyond major lacustrine settings.

The initial phase of site development appears to have been short-lived. A staggered development of middens across the terminal Pleistocene is likely to reveal tipping points in riverine ecology where the viability of freshwater mussel as an economic staple may have periodically collapsed. It is not until the early Holocene, that the extant evidence suggests a more persistent Aboriginal occupation incorporating the broader habitat mosaic into economic strategies. Subsequent periods of climatic variability and ecological stress across the Holocene were accommodated

through an expanded use and emphasis on plant resources. The diversified riverine economy observed in historical observations reflects an essential template to accommodate the high level of variability inherent in this riverscape.

Existing narratives and conceptual frameworks around Aboriginal demographic and economic changes in the MDB are assessed against the Riverland evidence. The role of population increase as the instigator of change in past Aboriginal society has been fundamental to a common narrative, though little support for this is found in the Riverland evidence. Instead, economic strategies and technologies employed in various MDB regions were applied in unique combination in the Riverland and honed to suit local circumstance independent of population changes. These solutions may, however, have provided a platform for a substantial increase in economic capacity and Aboriginal populations with improved hydrological conditions in the very late Holocene.

Statement of Authorship

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and that to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Craig Stuart Westell

22 July 2022

Word Count 94,000

Co-authorship Statements

A. STUDENT'S DETAILS (to be completed by the Student)	
Name: Craig Westell	Student ID: 2070496
Degree: PhD	College: Humanities, Arts and Social Sciences
Title of Thesis: Transformations in the peopled landscapes of the River Murray corridor, Riverland region of South Australia	

B. CO-AUTHORSHIP APPROVALS (To be completed by the student and co-authors)							
If there are more than four co-authors (student plus 3 others), only the three co-authors with the most significant contributions are required to sign below. <i>Please note: A copy of this page will be provided to the Examiners.</i>							
1.	Full publication Details <u>Australian Archaeology Volume 86 Number 2 August 2020</u> Section of the thesis where the publication is referred to <u>Results and Discussion</u> Student's Contribution to the publication: <table><tbody><tr><td>Research Design</td><td><u>95%</u></td></tr><tr><td>Data Collection and analysis</td><td><u>60%</u></td></tr><tr><td>Writing and editing</td><td><u>90%</u></td></tr></tbody></table> Outline your (the student's) contribution to the publication: <u>The article provides an initial presentation and discussion of research data (radiocarbon dating) collected by myself and co-author AR. All laboratory processing was done by co-author GJ. I planned and implemented the overall research design, provided much of the text, all the figures, graphs and tables, and the synthesis of the data presented in the results, discussion and conclusion sections of the article. Editing was done by all authors.</u> ☐ I confirm that the details above are an accurate record of the student's contribution to the work. Name of Co-Author 1: <u>Amy Roberts</u> Signed: <u>[Signature]</u> Date: <u>20/12/21</u> ☒ I confirm that the details above are an accurate record of the student's contribution to the work Name of Co-Author 2: <u>Mick Morrison</u> Signed: <u>[Signature]</u> Date: <u>28/01/2021</u> ☐ I confirm that the details above are an accurate record of the student's contribution to the work Name of Co-Author 3: <u>Geraldine Jacobsen</u> Signed: <u>[Signature]</u> Date: <u>10/02/2022</u>	Research Design	<u>95%</u>	Data Collection and analysis	<u>60%</u>	Writing and editing	<u>90%</u>
Research Design	<u>95%</u>						
Data Collection and analysis	<u>60%</u>						
Writing and editing	<u>90%</u>						

Acknowledgements

First and foremost, I would like to thank the River Murray and Mallee Aboriginal Corporation for allowing me to undertake this research, and the broader First Peoples community for their long and continuing friendship and guidance. I also thank the RMMAC Directors for they help in facilitating the field work and consenting to publications stemming from the research, and the various RMMAC members who have assisted in the field work. Special thanks to Angus Giles, Heidi Zielke, Ena Turner, Timothy Johnson, Jason Johnson, Philip Johnson, Julie Cook and William Cook.

I would like to thank my supervisors Prof. Amy Roberts, Assoc. Prof. Mick Morrison and Assoc. Prof. Mike Morley for helping me steer a course through this. I would especially like to thank Prof. Roberts for her tireless efforts in coordinating the Calperum research project and for pursuing funding options in support of this work. Amy's reputation as an ethical researcher precedes her and was a major factor in my decision to undertake this research through Flinders University.

The research has been supported in various ways by various people. Chantal Wight (Terrestrial Archaeology Technical Officer) has provided critical logistical support to the project and offered invaluable technical advice. Field studies have been assisted by Robert Jones, Marc Fairhead, Chantal Wight, Amy Roberts, Catherine Morton, Matthew Boulden and Alex Watson. Dr Alice Gorman's feedback on my candidature document got me thinking outside the box. Mark Carroll, Alan Lance, Vanessa Edmonds, Peter Hill, Vivienne Wood, Quentin Fogg, Donald Pate, Brad Hollis, Daniel McCullough, Colin Pardoe and Richard Fullagar have provided comments, data and/or references along the way.

Professor Nigel Spooner and Kathryn McDonnell undertook the collection and analysis of OSL sampling and have offered a wealth of invaluable advice. I am also extremely grateful to Dr Fiona Petchey for her advice on the results of radiocarbon dating undertaken through the Waikato Radiocarbon Laboratory. Assoc. Prof. Ian Moffat exposed me to the dark art of geophysics and undertook geophysical survey and analyses for me. Rachel Rudd undertook the analyses of sediment samples collected from the Pike hearth. Alice Beale (Collections Manager South Australian Museum [SAM]) facilitated access to the SAM collections store. Loretta Braunack (DEW) and Peter Cale (ALT) assisted in AAR permits and various Calperum staff have helped coordinated

accommodation and access to the Calperum property.

Financial support for this research has been provided by the Australian Government through the Australian Research Council (ARC Linkage Project LP170100479), the Australian National Collaborative Research Infrastructure Strategy (NCRIS) (funding for radiocarbon dating conducted at the ANSTO Lucas Heights facility), and the National Landcare Programme (administered by the SAMDB NRM Board). Additional financial support has been provided by Vivienne Wood Heritage Consultant Pty Ltd, the Flinders University College of Humanities, Arts and Social Sciences Research Assistance Grant and the Australian Archaeological Association Student Research Grant scheme.

I would finally like to thank my partner, Viv, for her support and advice throughout this research and for setting me on this path over 30 years ago.

Table of Contents

Abstract.....	1
Statement of Authorship.....	iii
Co-authorship Statements	iv
Acknowledgements.....	v
Table of Contents.....	vii
Glossary and Abbreviations.....	xxvi
CHAPTER ONE: INTRODUCTION.....	1
1.1 Background.....	1
1.2 Research questions.....	5
1.3 The research area	6
1.4 Aims and methodological approaches.....	11
1.5 Research significance.....	13
1.6 Ethics, approvals and traditional owner engagement.....	15
1.7 Reporting age determinations	15
1.8 Contested terms: Contact and Sedentism	16
1.9 Thesis structure	17
1.10 Supplementary material.....	19
CHAPTER TWO: TOWARD A TIMELINE IN MURRAY-DARLING BASIN ARCHAEOLOGY	20
2.1 Introduction.....	20
2.2 Intensification explained through the lens of Human Behavioural Ecology.....	20
2.2.1 Optimal Foraging Theory.....	22
2.2.2 Niche Construction Theory.....	24
2.2.3 Low Level Food Production	26
2.2.4 The Broad Spectrum Revolution and Intensification in Australia	27
2.3 The early Murray-Darling Basin record	29
2.4 The early River Murray record	35
2.5 The Holocene.....	39
2.5.1 Distributions in ¹⁴ C	39
2.5.2 Oven mounds in the debate	41
2.5.3 Plant use.....	43

2.5.4	Burial practices and ancestral remains	46
2.6	An emphasis on change or a change in emphasis?	50
2.7	Chapter summary	53
CHAPTER THREE: RIVERINE LANDSCAPES OF THE WESTERN MURRAY-DARLING BASIN		57
3.1	Introduction.....	57
3.2	Processes and common landforms	58
3.3	Indicators of change	61
3.3.1	Terracing and channel planform.....	61
3.3.2	Lunettes.....	63
3.3.3	Terrestrial dunes	64
3.4	A palaeoenvironmental narrative from 50 ka	66
3.4.1	The early glacial (late MIS 3).....	69
3.4.2	Toward the LGM nadir (MIS 2)	70
3.4.3	MIS 2–MIS 1 transition	74
3.4.4	The Holocene	75
3.5	Insights gained through archaeofauna	78
CHAPTER FOUR: THE RIVERLAND		81
4.1	Introduction.....	81
4.2	Aboriginal people of the Riverland	81
4.2.1	Introduction	81
4.2.2	Demography.....	83
4.2.3	Foods and materials	86
4.2.4	Floodplain management.....	89
4.3	The archaeological evidence.....	90
4.3.1	Introduction	90
4.3.2	Common site types and their content	91
4.3.2.1	Open scatters	91
4.3.2.2	Oven mounds	95
4.3.2.3	Burials and cemeteries	98
4.3.3	The grinding assemblage	99
4.3.4	Site distribution & chronology.....	108
4.3.5	Chronology	110

4.4	The modern Riverland floodplains	110
4.4.1	Hydrology	110
4.4.2	Riverine ecology and some insights from the Millennium Drought.....	114
4.5	Chapter summary	121
CHAPTER FIVE: METHODS AND MATERIALS		126
5.1	Introduction.....	126
5.2	Literature review	126
5.3	Data management	127
5.4	Permits obtained under the <i>South Australian Aboriginal Heritage Act 1988</i>	127
5.5	Field studies.....	128
5.5.1	Geomorphological mapping	128
5.5.2	Archaeological Survey	129
5.5.3	Site recording	131
5.5.3.1	Distinguishing natural from anthropogenic deposits.....	131
5.5.3.2	Site recording, definitions and attributes	131
5.5.3.3	Stone artefact identification and nomenclature.....	136
5.5.3.4	Identification of shell species	137
5.5.4	Excavation	137
5.5.5	Geophysical prospecting in CAPR18_S41	139
5.6	Chronological methods.....	140
5.6.1	¹⁴ C Dating	140
5.6.1.1	Site and sample selection	140
5.6.1.2	Sample collection	141
5.6.1.3	Laboratory techniques and calibration.....	142
5.6.2	Typological dating	142
5.6.3	OSL dating	143
5.6.3.1	Sample selection.....	143
5.6.3.2	Field and laboratory methods	143
5.7	South Australian Museum Collections	147
5.8	Other laboratory methods.....	148
5.8.1	Sorting of excavated material.....	148
5.8.2	PXRF (Portable X-ray Fluorescence Spectroscopy)	148
5.8.3	Acid test	149

5.8.4	Geoarchaeological methods applied in Pike_SP16_05	149
CHAPTER SIX: RESULTS		151
6.1	Introduction.....	151
6.2	Floodplain geomorphology.....	151
6.2.1	Landscape chronology.....	151
6.2.2	Terrace T1.....	161
6.2.3	Lunette lakes and Woorinen dune-fields.....	162
6.2.3.1	The outer lunette lakes.....	167
6.2.3.2	The inner lunette lakes	177
6.2.4	The sequence of bedload channels	193
6.2.5	Nooreela’s intervention: a floodplain transformed.....	199
6.2.6	The Pike floodplain	200
6.2.7	Auger excavations at Clover Lake and Big Huncree Creek	209
6.2.8	Revisiting the Monoman–Coonambidgal distinction.....	215
6.3	Archaeology.....	216
6.3.1	Survey coverage and conditions	216
6.3.2	Sites recorded	220
6.3.3	Surface sampling	228
6.3.4	Excavation	232
6.3.4.1	CAPR18_S37	232
6.3.4.2	CAPR17_14	237
6.3.4.3	CAPR18_S41	241
6.3.4.4	PikeSP16_05	247
6.3.5	The PikeAWE15_10 irrigation trench and other exposures.....	266
6.3.6	¹⁴ C chronology	267
6.3.7	Chronology based on typology.....	272
6.3.8	The grinding assemblage	273
6.3.9	Evidence of earthworks in CAPR17_08.....	278
6.3.10	A taphonomic profile.....	281
CHAPTER SEVEN: DISCUSSION		289
7.1	Introduction: A landscape defined by change.....	289
7.2	Rivers die from the bottom up.....	294

7.3	An age-old problem: palimpsests and the considered use of ¹⁴ C ages.....	297
7.4	Linking landscapes and archaeology	300
7.4.1	The outer lakes	302
7.4.2	The inner lakes	306
7.4.3	The T2 bedload channels.....	313
7.4.3.1	Hunchee Lagoon and the T1 backplain	313
7.4.3.2	The Ral Ral–Hunchee anabranch and T2b scrolls.....	318
7.4.3.3	T2c scrolls centred on the Ral Ral Wide Water oxbow	323
7.4.4	T3 scroll	329
7.4.5	River Murray.....	330
7.4.6	The Pike record.....	331
7.4.7	Other Riverland settings.....	332
7.5	A proposed timeline in Riverland occupation	338
7.5.1	A lag to River Murray settlement?.....	341
7.5.2	The 15 ka ‘event’	344
7.5.3	Holocene change?	348
7.6	Chapter Summary: The relevance of HBE and population models	356
CHAPTER EIGHT: CONCLUSIONS		362
8.1	Revisiting the research questions	362
8.2	Further directions in research.....	371
8.3	A summation: Transformations in a Peopled Riverscape.....	373
REFERENCES		376
APPENDICES		441
Appendix I: A selection of ethnohistoric observations of food staples in the Central Murray region (including the Riverland) and adjoining regions		442
Appendix II: A summary of grinding material held in the SAM archaeological collections and provenanced to the upper Riverland		452
Appendix III: An example of a sediment recording log.....		456
Appendix IV: An example of a Site Recording Sheet		458
Appendix V: Examples of Excavation Recording Sheets		461
Appendix VI: Example of a ¹⁴ C sample collection sheet		468
Appendix VII: Descriptions of the OSL sampling locations		470

Appendix VIII: Archaeological sites identified during the research	479
Appendix IX: Content summaries from gridded and C14 sampling locations.....	501
Appendix X: OSL results	514
Appendix XI: ¹⁴ C results.....	517

LIST OF FIGURES

Figure 1-1: The locations of the Calperum and Pike floodplains and the Calperum Station boundary in relation to the MDB.	3
Figure 1-2: The upper Riverland in SA showing the major anabranch floodplains overlain with the 'tribal' boundaries proposed by Tindale (1974). Tindale's boundaries are not the only rendering of Aboriginal land tenures in the region and are used here as guide only. A full exegesis of cultural geographies is beyond the scope of this thesis.	4
Figure 1-3: The location and major features of the Calperum floodplain.	7
Figure 1-4: The location and major features of the Pike floodplain.	10
Figure 2-1: The general locations of ¹⁴ C determinations recorded in the south-western MDB prior to this research.....	30
Figure 2-2: The distribution of mean calibrated age estimates returned on occupation related materials in the south-western section of the MDB assigned to major hydrological phases (see Table 3-4).	32
Figure 2-3: Calibrated median age determinations from lake and channel-based occupation sites (see Figure 1-1 for location of MDB regions).	36
Figure 3-1: Common floodplain elements. A sequence of meander scrolls that developed under different flow regimes are marked as A (older) and B (younger) in each slide.	59
Figure 3-2: Schematic representation of the cut-and-fill process in respect to the terracing in the Riverland floodplains.	59
Figure 3-3: Classification of Riverland channel morphologies based on Schumm (1981). Examples shown here are from the Pike floodplain with Bookmark Creek shown on the far right.	62
Figure 3-4: Lunettes located within the Central Murray corridor between Lake Bonney and Lake Victoria. Inset shows the Calperum lunettes.	65
Figure 3-5: Major sedimentary and morphological phases identified in fluvial/alluvial systems in the MDB.	68

Figure 3-6: The approximate boundary of the expanded Pleistocene arid zone overlain on the modern climatic zones in south-eastern Australia.....	72
Figure 3-7: The median ages of shell and other derived ¹⁴ C estimates from subregions of the MDB in relation to major hydrological phases, glacial advances, dune cycles and soil development. Paleoenvironmental stages are adapted from Barrows et al. (2001), Fitzsimmons et al. (2014: Figures 6, 7 & 8); Kemp and Rhodes (2010: Figure 1); Lomax et al. (2011:Figure 6).....	80
Figure 4-1: The distribution of documented grinding materials in the Riverland.....	94
Figure 4-2: Locations of documented oven mounds in the upper Riverland.....	96
Figure 4-4: Homogenous mound structure exposed in rabbit warren excavated into site PFBS14_01, Pike floodplain (Photograph C. Westell, 2014).....	97
Figure 4-3: Site PFBS14_50, a typical example of a Riverland mound. The gravelly texture seen in the image is baked clay heat retainer (Photograph C. Westell, 2014).	97
Figure 4-5: Examples of Type I Grinding Bases (mortars) held in the SAM collection.	102
Figure 4-6: Examples of Type II Grinding Bases (mortars) held in the SAM collection.	103
Figure 4-7: Examples of Type III Grinding Bases (millstones) held in the SAM collection.....	104
Figure 4-8: Examples of Type I Grinding Topstones (mullers) held in the SAM collection.....	105
Figure 4-9: Examples of Type II Grinding Topstones (pestles) held in the SAM collection.	106
Figure 4-10: Examples of Type III Grinding Topstones (pestles) held in the SAM collection.	107
Figure 4-11: Examples of edge ground axes held in the SAM collection.	107
Figure 4-12: Regional topography and main physiographic elements including the incised Murray River valley, the linear (EW) dune-fields of the Woorinen Formation, major lunettes and individual floodplains within the valley, the Millewa Ridge and the valley-gorge transition coinciding with the Hamley fault line.	111
Figure 4-13: Massive seams and blocks of silicified and ferruginous sandstone within the Karoonda Surface exposed in the confining cliff-line at Murtho (Photograph C. Westell, May 2016).	112
Figure 4-14: Geological cross section of the Pike Floodplain adapted from Australian Water Environments (AWE) and CMC (2012:Figure 6.6).	112
Figure 4-15: Vegetation communities on the Calperum floodplain (source: SA Vegetation GIS dataset).	120
Figure 5-1: The locations of sediment logs and auger excavations conducted at Calperum.	130
Figure 5-2: Amy Roberts, Marc Fairhead and Catherine Morton using a 1x1 m drawing grid to	

scrutinise midden content in site CAPR17_19.	136
Figure 5-3: The location of OSL sampling at Calperum.	145
Figure 5-4: Insect tubules straddling the contact between sedimentary units at OSL sampling location WOL-10/11 and recovered during the excavation of the hearth feature at Pike near OSL sample Pike-02. Fine, light coloured sand can be seen incorporated into tubules that intersect the hearth feature.	146
Figure 5-5: The combustion feature identified in site PikeSP16_05. Shown are the locations of the micromorphology section, the sediment column and magnetic susceptibility traverse, OSL and ¹⁴ C sampling locations, and the inferred base of the original pit feature. ...	150
Figure 6-1: The locations of OSL and ¹⁴ C dating at Calperum.	152
Figure 6-2: The locations of OSL and ¹⁴ C dating at Pike.	153
Figure 6-3: Abanico plots for OSL ages at Calperum (12 age estimates) and Pike (3 age estimates).	154
Figure 6-4: An interpretation of the Calperum floodplain geomorphology.	156
Figure 6-5: Topography across the Pike floodplain (surface based on Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid, Geoscience Australia).	157
Figure 6-6: An interpretation of the Pike floodplain geomorphology.	158
Figure 6-7: Topography across the Pike floodplain (surface based on Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid, Geoscience Australia).	159
Figure 6-8: Generalised meander forms in each of the terraces on the Calperum floodplain.	160
Figure 6-9: Eroded T1 surface at Calperum under chenopod shrub community. A Woorinen Formation dune is visible in the background.	161
Figure 6-10: Topographic features associated with the Calperum lakes and assigned to the terrace sequence. Features include the various lunette ridges (Phases I–III), beach-ridges and strandlines.	163
Figure 6-11: Surface profiles across a selection of the Calperum lakes showing topographic features and the terrace sequence. The height differences have required the meshing of three elevation datasets; RTK data, Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid, Geoscience Australia and the ALOS Global Digital Surface Model (AW3D30), Japanese Aerospace Exploration Agency (JAXA). Appendix XIV shows the height differences between these.	164
Figure 6-12: View looking south along the notch etched into the outer lunette at Lake Woolpoolool.	165

Figure 6-13: The elevations of etched lines visible on the Calperum floodplain compared to the height of the 1956 megaflood. Elevations are derived from the JSA DEM and based on a 10 m sampling of the traced lines.....	165
Figure 6-14: Examples of etched lines at Calperum in comparison to the extent of the 1956 megaflood: A - northern margin of Lake Woolpoolool and Woolpoolool Swamp, B - southern section of the Woolpoolool lunette and C - northern margin of Clover Lake.	166
Figure 6-15: Surface sediments in the area of Outer Lake B and C.	167
Figure 6-16: Schematic profile across Outer Lake C.	168
Figure 6-17: View looking east to OSL sampling location WOL-05/06 on the Outer Lake A lunette (left) and the exposed section showing the OSL component ages (right).....	170
Figure 6-18: View looking southwest along the gypsum lunette at Rotten Lake.....	171
Figure 6-19: Context images of OSL sample WOL-07. The landscape view is looking south from the bed of Outer Lake C to the lunette. OSL component ages are shown in the section image.....	171
Figure 6-20: The complex HSGD stratigraphy exposed in the Rotten lake lunette (scale = 2 m). Unit D dated to c. 27 ka at Outer Lake C in OSL sample WOL-07 is equivalent to the buff sand seen adjacent to the range pole in the Rotten Lake lunette.	172
Figure 6-21: Dune phases exposed around the northern margin of Outer Lake A.	173
Figure 6-22: A dune transgressing the bed of Outer Lake A. The dotted line separates pre and post-LGM phases.	174
Figure 6-23: Stratigraphy exposed in gully erosion on the north-western margin of Rotten Lake.	175
Figure 6-24: Sediment logs and schematic profile across the north-western margin of Rotten Lake.	176
Figure 6-25: Lakes Merreti and Clover in respect to the original T2a meander scroll (left) and an equivalent T2a scroll centred on Coppermine Waterhole (Chowilla floodplain) with interior point bars and SBDs preserved (right).	178
Figure 6-26: OSL samples WOL-01 and WOL-02.....	178
Figure 6-27: Schematic interpretation through the southern section of the Lake Woolpoolool lunette.	180
Figure 6-28: PXRF assays of sedimentary units from various locations around Lake Woolpoolool including OSL sampling locations WOL-01/02, WOL-04 and WOL-12.....	181
Figure 6-29: Saline (gypsiferous) clay exposed in a borrow pit west of Lake Woolpoolool (left) and	

shallow gully erosion on the south-eastern margin of the lake (right).	182
Figure 6-30: Schematic interpretation through the north-eastern lunette (Phase III) at Lake Woolpoolool.	183
Figure 6-31: Exposure across the Phase III lunette at Lake Woolpoolool in the area of archaeological site CAPR17_16 showing the weakly developed soils partitioning the lunette sediments.	184
Figure 6-32: The exposed section at OSL samples WOL-03 and WOL-04 (the range pole increments are 20 cm).	184
Figure 6-33: Beach-ridges preserved around the inner lakes.	186
Figure 6-34: Schematic profile across north-western margin of Lake Woolpoolool.	187
Figure 6-35: The gypsum ridge exposed along the northern margin of Lake Woolpoolool including the WOL-12 sampling location.	188
Figure 6-36: Calibrated ages on freshwater mussel shell midden and charcoal at Calperum in relation to various palaeoenvironmental data.	190
Figure 6-37: Schematic interpretation of the inner lake stages based on the dating results and unit elevations.	192
Figure 6-38: A high SBD developed through reworking of point bar sands in T2c.	194
Figure 6-39: A deep palaeosol exposed across the crest of an eroded T2b SBD.	194
Figure 6-40: Schematic interpretation through a T2b cut-bank exposed along Hunchee Creek. ..	195
Figure 6-41: OSL sample location WOL-09.	196
Figure 6-42: Two palaeosols preserved in T2b SBD topography within archaeological site CAPR18_S29; a younger thin carbonate soil (left) and older, deeper deep red soil overprinting the original T2b feature.	197
Figure 6-43: (A) The structure of T2c scrolls at Calperum, (B) context image of WOL-08 looking north, (C) the WOL-08 profile and (D) view looking south across a deep deflation in a SBD in T2c (scroll 2) and exposure of the angle bedded Unit G (dashed lines shows the trend of the bedding) (see A for location).	198
Figure 6-44: River red gum (<i>E. camaldulensis</i>) / black box (<i>E. largiflorens</i>) woodland, and lignum and chenopod shrubland on the undulating ridge and swale topography typical of T3 and T4.	199
Figure 6-45: The geological context of the Pike cliff-line showing (top) an example of a climbing sand sheet at the Cobdogla floodplain, (middle) the geology truncated along the eastern side of the floodplain in the area of site PikeSP16_05, and (bottom) Woorinen	

Formation sediments exposed in an artificial cutting in the area of site PikeSP16_05.	201
Figure 6-46: A characteristic bench formed in the Karoonda Surface around the eastern side of the Pike floodplain.	202
Figure 6-47: View looking east along the southern cliff-line at the Pike floodplain with the coarse calcrete boulder surface capping the Blanchetwon Clay and underlying Woorinen Formation sediments.	202
Figure 6-48: The development of the south-eastern section of the Pike floodplain.	203
Figure 6-49: Geochronological framework for the palaeosol PS-Ic and hearth feature in PikeSP16_05 based on OSL and ¹⁴ C age estimates.	204
Figure 6-50: (Top) Calibrated ¹⁴ C ages returned on archaeological materials along the Pike cliff-line colour coded by site) and OSL Fmix components at PikeSP16_05. (Bottom) ¹⁴ C and OSL ages are arranged as stacked plots below the main graph and related to Woorinen Formation phases and the dated shell species. The clear blocks in the shell species plot relate to undiagnostic materials. 2-sigma ranges are shown below each PDF in the main plot.	205
Figure 6-51: Sediment logs recorded at various locations around the Pike cliff-line.	206
Figure 6-52: Examples of major channel avulsions in the Pike floodplain. Also shown are the locations of the open scatters subject to dating.	208
Figure 6-53: Age depth plot for the auger sediments. The dashed lines link reliable ¹⁴ C ages and provide generalised trends for the Clover and Hunchee sites. Sediment characteristics are presented below the graph with solid blocks able to be related to ¹⁴ C age estimates and dashed lines requiring interpolation. Time brackets with no reliable data are indicated by question marks.	210
Figure 6-54: Sediment logs and pXRF assays for the Clover Lake auger excavations.	212
Figure 6-55: Schematic interpretation of the Clover Lake sedimentary record (also see Figure 6-56).	213
Figure 6-56: Sediment logs and pXRF assay for the Hunchee auger excavation.	214
Figure 6-57: The archaeological survey coverage at Calperum.	218
Figure 6-58: The archaeological survey coverage at the Pike floodplain showing the locations of archaeological sites specifically assessed during this research.	219
Figure 6-59: Archaeological sites and isolated finds recorded at Calperum.	221
Figure 6-60: The size characteristics of all sites recorded at Calperum and Pike.	223

Figure 6-61: Exterior (left) and interior (right) images of the bone point located in site PikeSP16_05.	227
Figure 6-62: Interior (left) and exterior (right) images of the serrated shell located in site CAPR17_23.	227
Figure 6-63: Exterior (left) and interior (right) images of the perforated shell recovered from excavation trench TP-01 in site CAPR17_14.	227
Figure 6-64: A comparison of consistent <i>A. jacksoni</i> sizes noted in CAPR19_O01 (left) and PikeSP16_01 (right). The CAPR19_O01 sample includes valves that are significantly smaller than the growth potential in natural populations illustrated in the PikeSP16_01 sample.	231
Figure 6-65: The breakage pattern in <i>V. ambiguus</i> collected from CAPR17_14 trench TP01.	231
Figure 6-66: The size range of <i>N. sublineata</i> from excavation trench PikeSP16_05 TP03.	232
Figure 6-67: CAPR18_S37 site plan showing ¹⁴ C sampling results and the location of TP01.	234
Figure 6-68: North and east sections drawings of TP01 (CAPR18_S37) together with context images.	235
Figure 6-69: The weight of shell expressed as a percentage of the total bucket weights in each XU in excavation trench CAPR18_S37 TP01.	235
Figure 6-70: CAPR17_14 site plan showing ¹⁴ C sampling results and the location of TP01.	238
Figure 6-71: Section drawing and context images of TP01 (CAPR17_14).	239
Figure 6-72: The weight of shell as a percentage of the total bucket weights in each XU in excavation trench CAPR17_14 TP01.	239
Figure 6-73: CAPR18_S41 site plan showing ¹⁴ C sampling results and the locations of TP01, TP02 and the magsus survey and targets (TGT).	242
Figure 6-74: North and east section drawings of TP01 (CAPR18_S41) together with context images.	243
Figure 6-75: East section drawing of TP02 (CAPR18_S41) together with context images.	245
Figure 6-76: PikeSP16_05 site plan showing the locations of 14C sampling on surface exposures and the test pits.	248
Figure 6-77: View looking north along the Pike cliff with TP02 (hearth) adjacent to the range pole. The Pike River anabranch is visible in the left of the image.	249
Figure 6-78: View looking north along the Pike cliff showing the relationship between the loose aeolian cover and underlying hardpan. Also shown are tilted sediment blocks suggestive of undercut erosion.	249

Figure 6-79: View looking east to the cliff with stratigraphy extrapolated from TP01. Also shown is a possible hearth feature.....	250
Figure 6-80: Section drawing and context images of TP01 (PikeSP16_05).....	251
Figure 6-81: A comparison between the ash/charcoal-rich hearth feature assessed in TP02 (left) and a nearby feature located higher in the aeolian sand cover (right).....	253
Figure 6-82: Section drawing and context image of TP02 (PikeSP16_05).....	254
Figure 6-83: The dating results from the PikeSP16_05 hearth including the ¹⁴ C sampling (red) and main components in OSL sample Pike-02 (AD20013).	256
Figure 6-84: View looking to the midden lens exposed in the eastern wall of the trench.....	258
Figure 6-85: View looking west to TP03 with the Pike River in the background.....	259
Figure 6-86: View of the eastern wall of the shallow excavation in TP03 showing in situ <i>N. sublineata</i>	259
Figure 6-87: Section drawing and context images for PikeSP16_05 TP04A.....	262
Figure 6-88: The typical presentation of bivalve in PikeSP16_05 TP04A.	265
Figure 6-89: Distribution of shell expressed as a weight percentage of the total excavated sediment from each XU together with the number of charcoal fragments per kg of sediment excavated in PikeSp16_05 TP04A.	265
Figure 6-90: A midden lens c. 15.4 ka exposed at the top of a thin cover of Woorinen Formation sediments.	266
Figure 6-91: Schematic of the stratigraphy sectioned by an irrigation trench in site PikeAWE15_10.	267
Figure 6-92: A summary of the counts and ranking of ¹⁴ C ages younger than 16 ka. The bar graph on the left shows the counts of median calibrated ages within 200-year bins (green), together with counts corrected for taphonomic loss (orange) and a 600-year moving average (green line) of the corrected values following the methods established by Williams (2012). The graph on the right includes minimum, maximum and median calibrated age values (yellow-orange-blue lines) based on the 95.4% probability range together with the minimum gap between successive ranked calibrated ranges (dashed green line) and a 2-point moving average of the minimum gap (solid green line). ...	270
Figure 6-93: Interpreted phases and phase boundaries represented in the full set of ¹⁴ C age estimates. The lower and upper boundaries for each phase from Phase 3 onward were determined using the 'Boundary' function in OxCal 4.4. The three ¹⁴ C ages in Phase 1-2 relate to a hearth in PikeSP16_05 and a midden lens in PikeAWE15_10, as annotated.	

.....	271
Figure 6-94: The spans of ¹⁴ C age clusters.....	272
Figure 6-95: Examples of Type I (A, B), Type II (C, D, E) and Type III (F, G, H) grinding bases identified at Calperum together with a possible 'Quandong stone' (I).....	274
Figure 6-96: Various Type II (A, B, C) and Type III (D) grinding topstones (pestles) recorded at Calperum.	275
Figure 6-97: The distribution of extant grinding material in the area of the Calperum floodplain.	276
Figure 6-98: View looking south along the excavated channel in site CAPR17_08 with the gravel spoil seen to the left of the range pole	279
Figure 6-99: (Top) Flood inundation modelling showing the diversion of rising waters to the west and north of the basin and (bottom) the topography in the area of earthworks in site CAPR17_08.	280
Figure 6-100: A stratigraphic interpretation of CAPR17_14 TP01.	283
Figure 6-101: Archaeological sites at Calperum in relation to the extent of flooding associated with 1 in 2, 3, 10 and 100-year flows.....	284
Figure 7-1: Topography in the southern section of the Calperum floodplain showing the late Holocene avulsion.	292
Figure 7-2: The timing of the Willandra Creek and Darling River avulsions.....	295
Figure 7-3: The extent of salt interception scheme borefields developed in the Riverland.	297
Figure 7-4: All reported calibrated 14C ranges grouped to habitat zones. The 95.4% probability range is shown as lines under the individual PDFs.....	301
Figure 7-5: Context images of hearth features in site CAPR19_J02 (left) and CAPR19_M12 (right). WfM-V sediments date to 8–5 ka.....	302
Figure 7-6: The distribution of archaeological sites and isolated finds in the area of Rotten Lake and Outer Lakes A and C.....	303
Figure 7-7: The grey beach sand exposed in shallow gully erosion on the north-western shoreline of Rotten Lake. OSL sample WOL-10 (left) was collected from the southern wall of the gully and dislodged a broken, retouched chert point. Two additional flakes (middle and right images) were identified in the northern wall of the gully immediately downstream, and slightly below the level of WOL-10. ¹⁴ C sample Wk-52353 (7940– 7740 cal BP) comprised a fragment of freshwater mussel shell recovered from the top of the beach sand upstream of WOL-10.	305
Figure 7-8: A core (left) and reduction floor (right) developed in telegraph insulator in site	

CAPR18_S44.	306
Figure 7-9: Sites and survey coverage associated with the inner lakes.	307
Figure 7-10: ¹⁴ C dating results and other locations associated with Lake Woolpoolool.	309
Figure 7-11: ¹⁴ C sampling and other locations in the area of Lakes Merreti and Clover.	310
Figure 7-12: A hearth feature eroding from Unit B2 sediments in the phase III lunette at Lake Woolpoolool. Images show the extrapolation of OSL sample WOL-03 and 04 results across the surface of the lunette and the extent of exposure across the lunette slope.	312
Figure 7-13: Sites, survey and dating results in the area of Hunchee lagoon.	314
Figure 7-14: The relationship between ¹⁴ C ages and stratigraphy in the area of CAPR18_S10 & S11.	316
Figure 7-15: An interpretation of the stratigraphy and context of the midden exposed across the southern section of CAPR18_S41.	317
Figure 7-16: Sites, survey and ¹⁴ C results in the area of the T2b scrolls centred on the Ral Ral - Hunchee Creek anabranch. The dashed white lines indicate the position of the final channel in each scroll.	320
Figure 7-17: Plan of CAPR17_19 showing the dating locations and major features. The dashed white lines indicate the position of the final channel in each scroll.	321
Figure 7-18: Stratigraphic interpretation of a T2b SBD in site CAPR17_19.	322
Figure 7-19: The typical extent of deflation and examples of pedestalled sediment in site CAPR18_S29.	323
Figure 7-20: The sequential development of T2c scrolls in the south-western section of the Calperum floodplain.	325
Figure 7-21: Profiles across SBDs in CAPR17_10 (top) and CAPR17_09 (bottom).	327
Figure 7-22: Sites, survey and ¹⁴ C dating results in the T2c scrolls at Calperum.	328
Figure 7-23: Archaeology associated with a T3 scroll and Horseshoe Lagoon in the south-eastern section of the Calperum floodplain.	330
Figure 7-24: Open scatters, mounds and burials (all shown in red) recorded in the area of Lake Bonney. The dashed blue lines indicate palaeochannel traces. Yellow shading indicates the extent of survey coverage. The label MD indicates the locations of late Holocene oven mounds. See text for descriptions of the -x- annotations.	333
Figure 7-25: Open scatters, mounds and burials (all shown in red) recorded in the area of the lunette-fringed lakes on the Chowilla floodplain. The dashed blue lines indicate	

palaeochannel traces. Yellow shading indicates the extent of reported survey coverage. The label MD indicates the locations of late Holocene	334
Figure 7-26: (Top) The stratigraphy and Pleistocene context of burials exposed along the crest of the Lake Limbra lunette. (Bottom) View looking south along the lunette with the modern shoreline of Lake Limbra seen in the right of the image.	335
Figure 7-27: Open scatters, mounds and burials (all shown in red) recorded in the area of major oxbows in the Riverland. The dashed blue lines indicate palaeochannel traces. Yellow shading indicates the extent of survey coverage. The label MD indicates the locations of late Holocene oven mounds. See text for descriptions of the -x- labels.....	337
Figure 7-28: The Riverland ^{14}C age results and terrace boundaries in relation to the MDB dataset and major environmental phases. The dataset established in this research is based on the two species of freshwater mussel (<i>A. jacksoni</i> and <i>V. ambiguus</i>), the freshwater snail (<i>N. sublineata</i>) and a small number of charcoal samples.	339
Figure 7-29: (Top) Stacked plots of the calibrated ^{14}C ages from 16 ka and in each habitat zone at Calperum with median ages are shown as vertical lines above each PDF. (Bottom) Context of the Holocene record and introduction of grinding and oven mounds.	340
Figure 7-30: The calibrated ^{14}C ages returned on midden shell at Calperum younger than 6 ka and the age ranges from oven mounds reported by (Jones et al. 2022). Mean ages are shown as circles under the individual PDFs.	351
Figure 7-31: Locations and scale of burial sites in the upper Riverland. Also shown are the language boundaries identified by Tindale (1974) and ^{14}C ages returned on skeletal remains from the Katarapko floodplain, the Lindsay Island area (Pardoe 1993a; Polach et al. 1978) and Keera Station (Blackwood and Simpson 1973; Pardoe 1993a). Median ages are shown as vertical lines above the ^{14}C age PDFs.	355
Figure 7-32: Estimated maximum number of individual burials recorded in each burial site on the Calperum floodplain during this research.....	356
Figure 7-33: A comparison between summed ^{14}C ages derived from archaeological materials in the Riverland and the modelling proposed by Smith et al. (2008) of the MDB data (base graph is adapted from Smith et al. 2008Figure 3).....	360

LIST OF TABLES

Table 1-1: Previous accounts of archaeology in the Calperum research area.	9
Table 1-2: A summary of the Supplementary Materials.....	19
Table 3-1: A summary of floodplain inundation based on Lock 5 data and modelled for the Pike floodplain.	60
Table 3-2: Sedimentary facies and related hydrological conditions identified in lunette lakes (after Bowler et al. 2012).	64
Table 3-3: Wfm members based on Churchward (1961) and Lawrence (1966) in comparison to the activation phases identified by Lomax et al. (2011). The phase codes adopted in this thesis (Phases I-VI) are also shown.	66
Table 3-4: Broadly defined hydrological stages recognised in the MDB.....	67
Table 4-1: Seasonal distribution, collection and cooking methods of key staple foods identified in ethnohistoric observations as summarised in Appendix I (darker green represents the main collection times).	88
Table 4-2: Site types and numbers reported in the Riverland.....	91
Table 4-3: Summary of artefacts collected and recorded from the proposed Chowilla Dam Impact Area (Casey 1973:209).....	95
Table 4-4: Grindstone morphologies recognised in the Riverland sites and in the SAM collections.	101
Table 4-5: Comparison of natural and regulated flows in the Murray River (source: Bloss et al. 2015; Ecological Associates and Australian Water Environments 2008). The 341 GL/day relates to the 1956 flood.	113
Table 4-6: The main terrestrial vegetation communities and aquatic habitats found in the Riverland floodplains.	119
Table 4-7: The influence of flow conditions on riverine ecology (summarised from Gippel and Blackman 2002; Poff et al. 1997; Purczel et al. 2016; Thoms et al. 2000; Walker et al. 1995; Ye et al. 2014).	124
Table 4-8: The survival and recruitment requirements of vegetation on the Riverland floodplains (adapted from Newall et al. 2008:Tables E1 & E2; Swirepik et al. 2015).	125
Table 5-1: GIS data layers generated through this research.	127
Table 5-2: GIS data used in the mapping of the floodplain geomorphology.	129
Table 5-3: Criteria used to distinguish between natural and cultural deposits of shell.....	132
Table 5-4: Characteristics of cultural and natural burning.	133

Table 5-5: Physical and chemical pre-treatments used on C14 samples.	142
Table 6-1: Palaeolandscapes captured in the survey coverage.	217
Table 6-2: A breakdown of site types and site components recorded at Calperum.	222
Table 6-3: The number of sites and sampling locations containing various fauna.	226
Table 6-4: A summary of archaeological materials identified in surface samples and at additional ¹⁴ C sampling locations in each site.	230
Table 6-5: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴ C samples in CAPR18_S37 TP01.	236
Table 6-6: Summary of fauna, combustion material and lithics recovered from CAPR18_S37 TP01.	236
Table 6-7: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴ C samples in CAPR17_14 TP01.	240
Table 6-8: Summary of fauna, combustion material and lithics recovered from CAPR17_14 TP01.	240
Table 6-9: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴ C samples in CAPR18_S41 TP01.	244
Table 6-10: Summary of fauna, combustion material and lithics recovered from CAPR18_S37 TP01.	244
Table 6-11: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴ C samples in CAPR18_S41 TP02.	246
Table 6-12: Summary of fauna, combustion material and lithics recovered from CAPR18_S37 TP02.	246
Table 6-13: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴ C samples in PikeSPS16_05 TP01.	252
Table 6-14: Summary of fauna, combustion material and lithics recovered from in PikeSPS16_05 TP01.	252
Table 6-15: Summary of the stratigraphic (SU) and excavation (XU) units and ¹⁴ C/OSL sampling in PikeSP16_05 TP02.	255
Table 6-16: Summary of fauna, combustion material and lithics recovered from PikeSp16_05 TP02.	255
Table 6-17: Key features in the sediment analyses at TP02.	258
Table 6-18: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴ C samples in PikeSP16_05 TP03.	260

Table 6-19: Summary of fauna, combustion material and lithics recovered from PikeSP16_05 TP03.	260
Table 6-20: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴ C samples in PikeSP16_05 TP04A.	263
Table 6-21: Summary of fauna, combustion material and lithics recovered from PikeSP16_05 TP04A.	264
Table 6-22: Minimum and maximum age ranges within each habitat zone at Calperum and Pike.	268
Table 6-23: Phase types and spans based on modelled boundaries represented in the full set of ¹⁴ C results (ages are shown at a 95.4% probability range).	272
Table 6-24: A summary of grinding materials identified in the survey coverage (see Table 4-6 for Type descriptions).	273
Table 6-25: Numbers of sites and ¹⁴ C sampling locations impacted at various FIM extents at Calperum.	283
Table 6-26: Key natural taphonomic components to consider in the research area (after Baxter 2004; Karkanas 2010; Kibblewhite et al. 2015).....	285

Glossary and Abbreviations

¹⁴ C	Radiocarbon age
AHA	<i>South Australian Aboriginal Heritage Act 1988</i>
ALT	Australian Landscape Trust
BSR	Broad spectrum revolution
cal BP	Calibrated radiocarbon years before present (present is identified as 1950)
CE	Common era
FIM	Flood inundation model
Fmix	Finite Mixture Model (as applied to OSL dating)
HBE	Human behavioural ecology
HS GD	High salinity gypsum dune (in reference to lunettes)
ka	1,000 years before present
LGM	Last glacial maximum
LLFP	Low level food production
Magsus	Magnetic susceptibility
MDB	Murray-Darling Basin
MHP	Murray High Plain
NCT	Niche construction theory
OFT	Optimal foraging theory
OSL	Optically stimulated luminescence
QSD	Quartz sand dune (in reference to lunettes)
RMMAC	River Murray and Mallee Aboriginal Corporation
SAM	South Australian Museum
SBD	Source bordering dune
SLSA	State library of South Australia
WFm	Woorinen Formation

CHAPTER ONE: INTRODUCTION

'... the blind Nooreela, starting out from near Lake Victoria, made, by her magic, a new territory for her people. The erratic course she followed much increased the length of the river, to the great benefit of her people in the matter of their hunting grounds. At a later time came Wurranderra, who, leading forth so many tribes from the north, gave each of them an inheritance in the new territory, providing instruction for their guidance.'

(Charles Nattoon in Bellchambers 1931:104-105).

1.1 Background

A common image of the River Murray in South Australia (SA) is of a verdant shoestring oasis meandering its way gracefully to the coast. It would be easy to imagine this river, flush with seemingly bountiful resources, as having been a constant in a long history of Aboriginal occupation. The river corridor is, after all, draped with a remarkable array of archaeological sites that, together with ethnohistorical observations, seem to portray a long and persistent record of riverine specialists. Yet, this image belies a system that can be more accurately defined by its dynamism and fragility, traits brought into sharp relief during the Millennium Drought (1997–2009). This event, which is regarded as the most severe drought since instrumental records began (Barr et al. 2014), triggered a dramatic collapse in floodplain ecology and provided a poignant reminder of the potential scale and pace of change in this riverscape, and the challenges faced by the Aboriginal economic and social systems that had been embedded in it.

In Charles Nattoon's account of Nooreela, one of the great creation-ancestors of the River Murray, change is recognised as a defining aspect of the river. An older, larger and relatively depauperate river is transformed into a more sinuous and productive system. This grand transfiguration in landscape led to shifts in economic opportunity, demographic change and governance. On the basis of the geomorphological aspects assessed in this research, Nooreela's benevolent intervention can be related to a period of profound change in the riverine corridor around 13,000 years ago. At this time, a hydrological regime more akin to the modern system was established as the Murray-Darling Basin (MDB) emerged from the

nadir of the Last Glacial Maximum (LGM)¹. The parallels between Nooreela's story and the evidence presented in this thesis are, to say the least, captivating.

Between the South Australian border and Overland Corner (Figures 1-1, 1-2), long term transformations in the riverine corridor are captured in a remarkably detailed landscape architecture, providing an opportunity to delve into the dynamic nature of the river in fine resolution and cast the human story amongst it. This, in essence, is the aim of this thesis—to capitalise on the configuration of the Murray River floodplains in the Riverland region of SA in order to expose, analyse and contextualise the dynamic of Aboriginal engagements with this river system. In doing so, the research aims to integrate the archaeology of this region into current knowledge regarding the broader MDB and address the extent to which the Riverland evidence can contribute to a regional narrative. This thesis is framed around three themes:

The **first** is the apparent lag of 20,000 years between early MDB settlement and evidence of occupation along the River Murray itself. This lag has been noted by various researchers (Balme 1995; Garvey 2013; Hope 1993; Luebbbers and Ellender 1991; Prendergast et al. 2009; Richards et al. 2007), though interpretations, to date, have stopped frustratingly short. The Riverland evidence suggests that this lag may have been a real phenomenon and not simply an artefact of preservation. Rather, this thesis proposes that the lag reflects the nature of flow transmission to the Murray floodplains prior to and during the LGM, the sensitivity of this down-basin location to changes in inflow conditions, and the mechanisms and consequences of salinisation in the Murray valley. In effect, the environmental responses recognised in upstream locations to changing inflows are naturally amplified as one progresses downstream. The 'lag', and a subsequent pulse-like trend in early occupation, reflects upon this sensitivity.

¹ Based on records of glaciation, Barrows et al. (2002) suggest that the LGM in Australia straddled the period of approximately 20.1–17.3 ka.

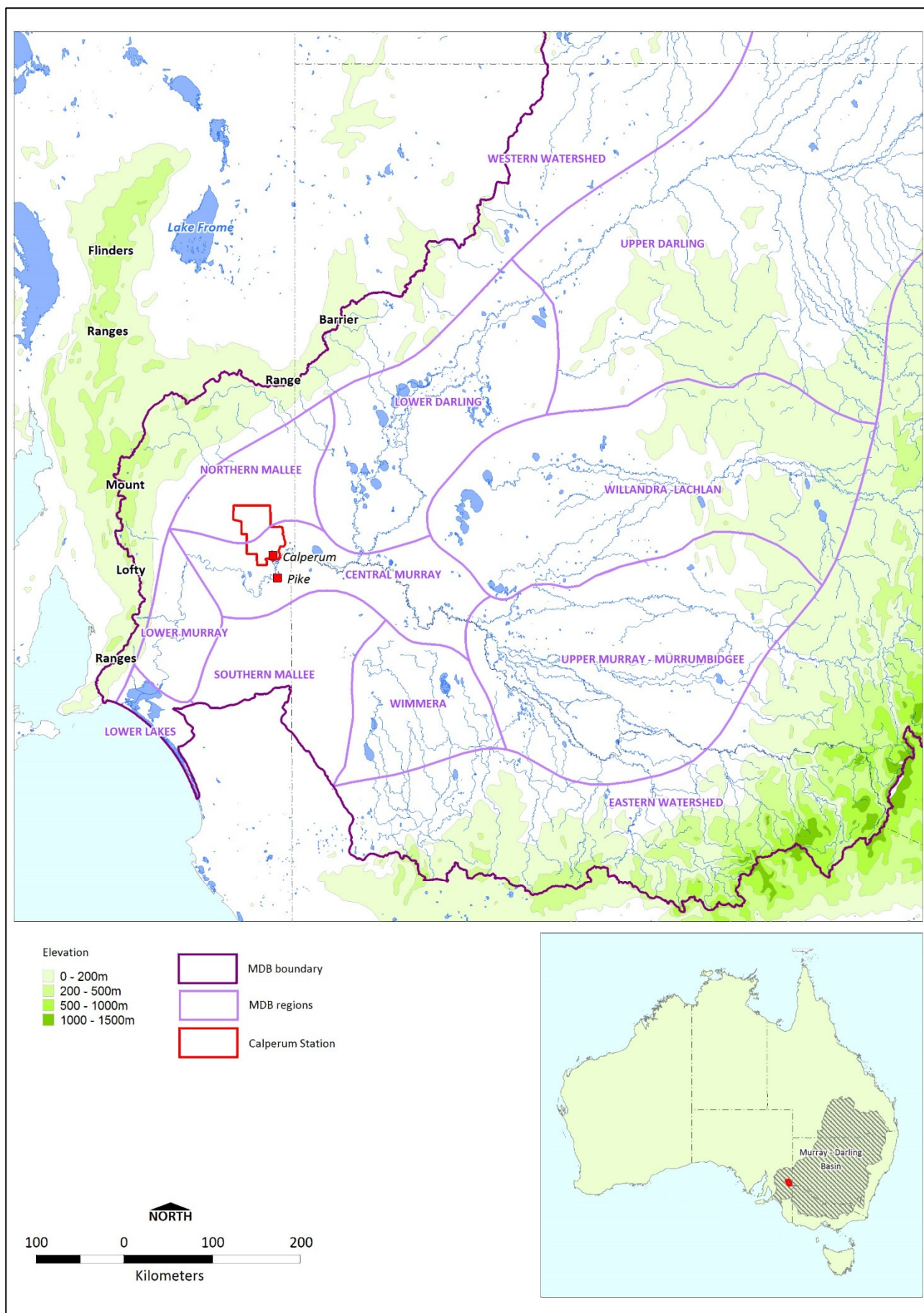


Figure 1-1: The locations of the Calperum and Pike floodplains and the Calperum Station boundary in relation to the MDB.

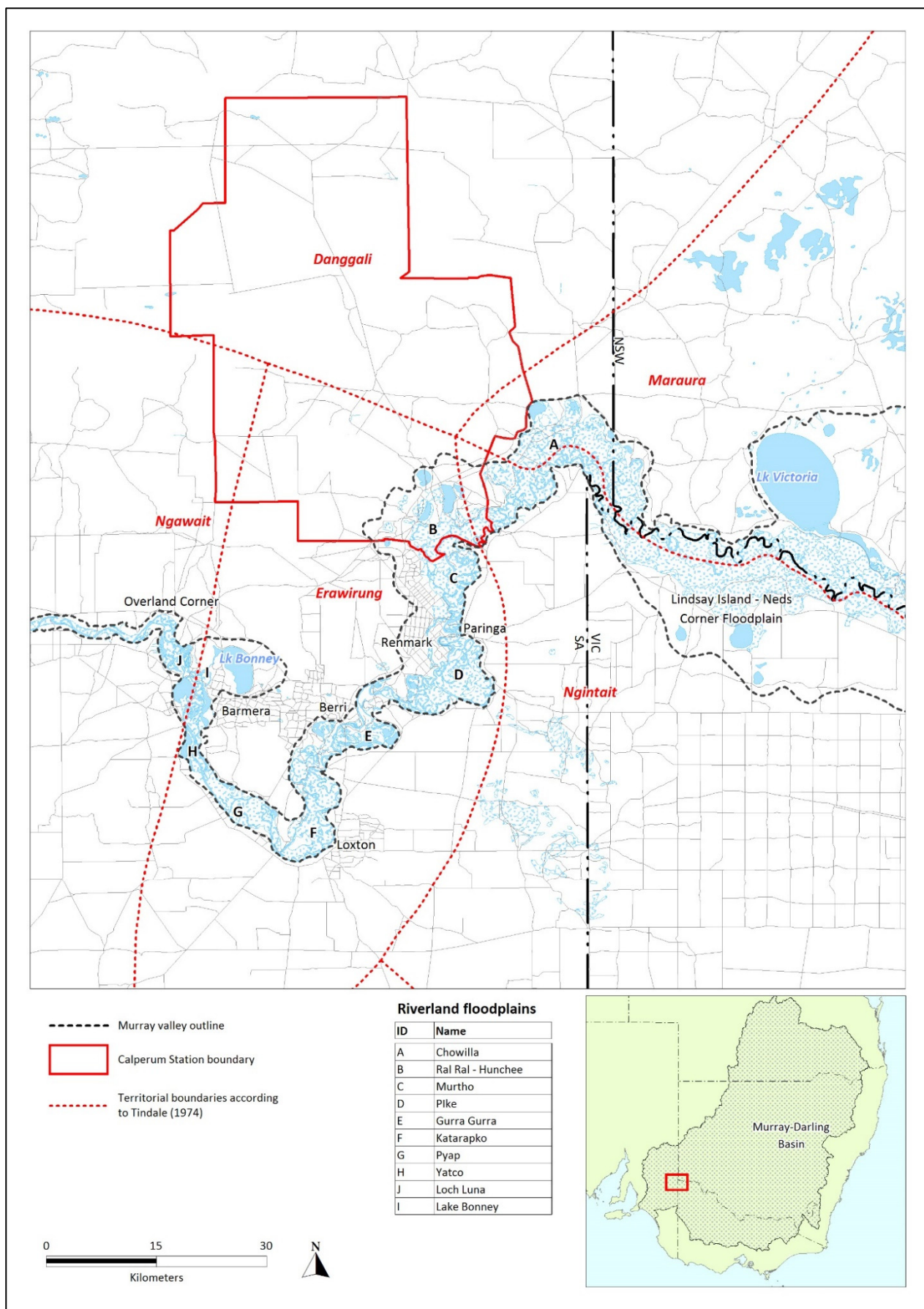


Figure 1-2: The upper Riverland in SA showing the major anabranch floodplains overlain with the 'tribal' boundaries proposed by Tindale (1974). Tindale's boundaries are not the only rendering of Aboriginal land tenures in the region and are used here as guide only. A full exegesis of cultural geographies is beyond the scope of this thesis.

Second, this thesis examines the context and timing of a distinctive change in the character of Aboriginal occupation in the central River Murray corridor at the close of the LGM. This manifest as an abrupt, large-scale development of middens comprised principally of freshwater mussel shell at locations throughout this region. It also saw settlement extend beyond lacustrine settings and into the broader riverine corridors. In some respects, this period mimics the perceived socio-economic intensification of the late Holocene and seems to challenge the view that the dynamism manifest in late Holocene archaeology was somehow distinct from the preceding record of human occupation. On the basis of this research, it is apparent that similar large-scale middens had developed in the Riverland by c. 15 ka.

The **third** theme is essentially a critique of the intensification narrative. Whilst this narrative has attained a level of 'orthodoxy' in Australia (Brian 2006), the timing, mechanisms and manifestations of change have been the basis of continuing and largely unresolved debates over the course of four decades (see Ulm 2013 for summary). Criticisms have been mounted on the grounds of both evidence and concept. The intensification narrative in Australia has drawn heavily upon studies of diversification and intensification amongst 'hunter-gatherer' economies the world over, and there has been an underlying assumption that the Australian record could be framed around the same fundamental pathways. As elsewhere, economic intensification in the MDB has been attributed to either an increase in population (demographic packing) or climate-forced environmental change, and a range of archaeological and other societal evidence has been attributed to this. The Riverland archaeology bears all the hallmarks of supposed intensified systems, though this research argues that the local evidence, and that of the MDB more generally, describes a far longer and continual change in emphasis in socio-economic strategies.

1.2 Research questions

This research is founded in the premise that riverine processes can aid in the interpretation of archaeological records rather than be seen solely as taphonomic agents. To this end, this dissertation examines a record of Aboriginal occupation against a backdrop of landscape development in the Calperum and Pike anabranch floodplains, located in the upper Riverland region of SA. The research strategy seeks to exploit the detail preserved in this riverscape in identifying and interpreting an occupation chronology. The principle questions addressed by this

thesis are:

- How has the riverine corridor in the Riverland region of SA evolved over the period from the initial Aboriginal peopling and through subsequent occupation?
- How has change in the riverine environment been accommodated in Aboriginal socio-economic pathways?
- Can the explanatory models applied within and beyond the Australian context adequately address these pathways?
- How can the local pathways inform a broader regional narrative?

1.3 The research area

The Riverland incorporates the downstream portion of the Central Murray region (Figure 1-1) in the south-western portion of the MDB, a vast drainage system encompassing much of south-eastern Australia. The basin straddles semi-arid, subtropical, temperate and cool temperate climate zones, includes 22 major sub-basins and approximately 77,000 kilometres of tributary, distributary and main-stem river courses (MDBA 2020). The research area relates specifically to the section of river corridor between the SA border and Overland Corner (Figure 1-2) with field studies having focused on the Ral Ral–Hunchee (Calperum) and Pike River (Pike) anabranch floodplains.

The Calperum floodplain is located 15 km upstream of the regional centre of Renmark (Figure 1-3) and is contained within Calperum Station, a former pastoral station that has been a dedicated conservation and research reserve managed by the Australian Landscape Trust (ALT) for the past several decades. The floodplain is representative of a series of anabranch systems that characterise this section of river corridor, occupying an area of approximately 145 km² on the northern side of the River Murray and forming a contiguous, downstream extension to the Chowilla anabranch floodplain. A network of flow paths include the main anabranch channels of Hunchee and Ral Ral Creeks, minor flood runners (e.g. Little Hunchee, Amazon and Nelbuck Creeks) and a range of smaller ephemeral channels. These flow paths partition the southern section of the floodplain into three islands; namely Little Hunchee, Hunchee and Reny Islands, with Bulyong Island lying immediately outside the Calperum Station boundary on the southern side of Nelbuck Creek.

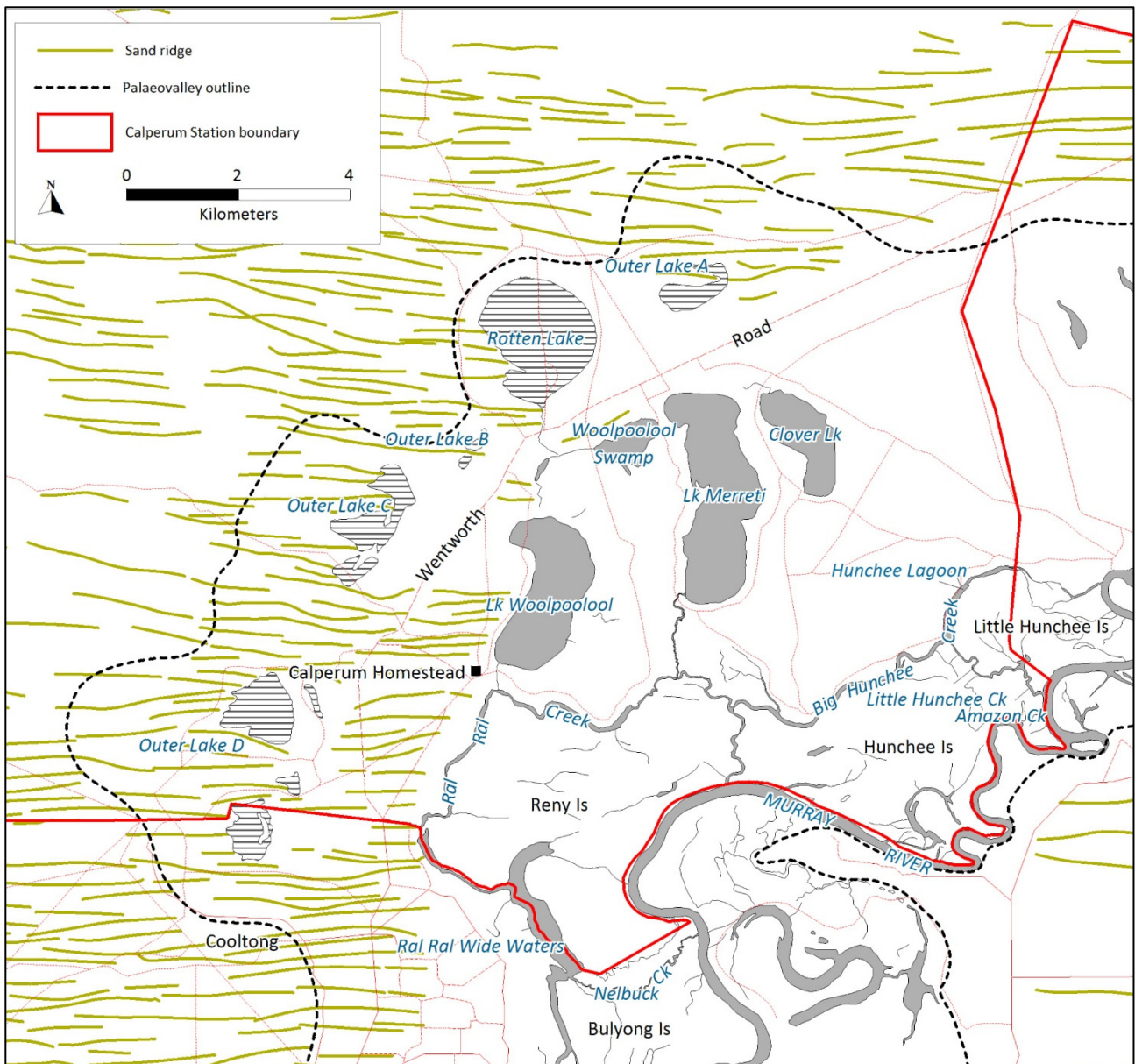


Figure 1-3: The location and major features of the Calperum floodplain.

Lakes at Calperum occur as an outer belt of salina (including Rotten Lake and Outer Lakes A to D) and an inner belt of intermittent waterbodies that include Lakes Woolpoolool, Merreti and Clover. The two major oxbow lagoons of Ral Ral Wide Water and Hunchee Lagoon occupy palaeochannel traces along the anabranch creeks. Major topography is developed across a series of four inset alluvial terraces, the swale and ridge terrain in the meander scrolls, and across lunettes and source bordering dunes (SBD). Typical of the Riverland floodplains, vegetation communities can be broadly grouped as dense eucalypt woodland (river red gum and black box) across the lower,

more regularly inundated sections of the floodplain, narrow belts of woodland along the streams and lagoon margins, lignum shrubland and herbfield across the lower floodouts and backplain areas, and chenopod shrubland across the higher, sandier terraces. Dense mallee woodland extends across vast dunefields of the Murray High Plains (MHP) beyond the valley margins.

Very few archaeological studies had been undertaken at Calperum prior to this research, though historic newspaper articles describe extensive sites around the northern and southern margins of Lake Merreti and the western side of Ral Ral Creek (see also Linn 1995:9). These articles are noteworthy in respect to the frequency of grinding implements, with most referring to 'nardoo-stones' and pounders (i.e. mortar and pestles). Whilst restrictions placed on public access have mitigated the wholesale impacts to Aboriginal archaeology seen elsewhere in the Riverland, these references indicate that a bias brought about by collectors should be considered when interpreting the extant archaeology.

Historical records also suggest that the Calperum–Chowilla area had served as one of several major occupation centres for Aboriginal people in this region at the time of European contact (Burke et al. 2016). Captain Charles Sturt described the area as 'one of the most celebrated localities on the Murray' with 'flats [that] are very extensive and are intersected by numerous creeks and lagoons' and that 'consequently, the [Aboriginal] population has always been greater than elsewhere on the Murray' (Sturt 1849).

The Pike floodplain is located immediately downstream of Renmark and Paringa (Figure 1-4) and occupies an area of approximately 65 km² between the River Murray and a high valley cliff-line. The floodplain is developed around the Pike River anabranch and is characterised by a series of extensive seasonal wetlands formed in palaeochannel traces, including the Mundic Creek, Pike River and Tanyaca Creek wetlands. In comparison to the Calperum floodplain, older terraces have largely been stripped out of the Pike floodplain with relatively smaller remnants occurring as an isolated feature in the south-eastern section of the floodplain (Sandy Island). The modern floodplain contains no lakes or lunettes.

Table 1-1: Previous accounts of archaeology in the Calperum research area.

Reference	Summary
Anon (1887)	Water Commissioner tour of Murray from Morgan upstream to Wentworth. Reports on a large campground (1/2-mile x 200 yards) and cemetery in high sandy ground along the northern side of Lake Merreti (possibly a reference to CAPR17_24). Large quantity of mussel shell as well as animal bone in midden. Collected flint, quartzite - no local sources.
Anon (1904)	Image of bough structure over grave at the Chowilla Orangerie
Anon (1921a)	Refers to large groups of Aboriginal people in Chowilla area (many hundreds) around 1870, with a big camp located between the woolshed and station homestead, big camps in sandhills back from river. Refers to the Chowilla Orangerie cemetery as containing graves crowned with bough structures, clay mourning caps, nardoo stones.
Anon (1921b)	Refers to 'numerous' camps, cemeteries and nardoo stones upstream of Renmark, cemeteries. Also suggests that the nardoo stones must have been carried significant distance as no local sources.
Anon (1942)	Describes 'largest mortar ever found' measuring 45 inches in diameter x 23 inches in white quartzite 400 yards north of Hunchee Creek, nardoo stone nearby, also large burial ground near 'battle ground' according to story told to Robert Robertson by local people (bones almost dust, adults and children), large middens; collectors had been fossicking 'over the whole of this area recently people from Adelaide interested in the stone age people have been digging small holes and searching for axes for which few remain'.
Archer Russell (1921a)	Walking club excursion to Ral Ral describes large sites in dunes - hearths, stone artefacts (including spear-shaped point retouched on dorsal face – pirri?); though the bank of Ral Ral creek contained few sites - a midden; also found a bifacially flaked axe made on a flinty sandstone.
Archer Russell (1921b)	Murray Tramps walking club excursion to Ral Ral. Describes a mortar and pestle used to pound small pods of nardoo into flour, as well as diverse assemblages including flakes, cores, scrapers, cutters, pounders, hammerstones, red and white ochre, and rare stone axes, middens and mounds of dark ashy earth thickly impregnated with broken mussel shell and bones.
Archer Russell (1921c)	Murray Tramps walking club excursion along Ral Ral Creek between Chaffey No. 1 Survey Camp and Lake Woolpoolool. Describes a large burial ground, multiple skeletons (mostly weathered and eroded) in deflated dune halfway to Ral Ral Creek. Skulls missing - presumed to be from earlier fossickers, but post-cranial remains intact. All lying on back and orientated west (head) - east. This is 'common mode' of disposal seen throughout region. Positioned in dune above all but extreme flood levels. Associated hearths, midden and artefacts across intervening claypans and parallel ridges for a mile or more. Artefacts include nardoo stones (millstones), grinding stones (topstones/grinders/hammerstones - developed on water worn cobbles), knives, scrapers, points.
Archer Russell (1923)	Describes extensive burial and sites on Ral Ral Creek with spear points, scraper and grindstones.
Archer Russell (1924)	G. E. Archer Russell, a self-described collector, states 'there are few places on the Murray - indeed I know of none - where the archaeologist may gather a richer harvest'. Goes on to describe: ... on tree sheltered mounds above the shores, are camp sites and kitchen middens out of number, ... within certain limits of the shores there is scarcely a square yard of earth that does not contain some relic of the land's old time inhabitant, a heap of hearth stones, flint flaking, little mound of bleached mussel shells, nardoo, grinding and hammerstones. Flints in thousands, occasional well worked pick head, or flaked axe head, spear shaped point, scraper, gouge. ... most significant find was a stone pick head 4 inch length, 1 inch thick, hard desert mudstone, flaked and secondarily worked grooves suggesting it was hafted. Pick heads seem to have been in great use amongst the middle and upper Murray Aborigines. ... hollow in dune was strewn with mussel shells, countless flints (worked and unworked), two nardoo stones, one with a pounder. Another symmetrical nardoo stone with grinding hollows on both upper and lower sides. Flints include points, thumbnail scraper, gouge, knife. Have previously found many oval-shaped hammerstones in the region'
Wood (2002)	This assessment of a proposed power corridor traversing the northern edge of the Calperum floodplain identified a low density scatter of artefacts, midden and hearth material in dunes fringing an outer lunette lake, together with a background scatter of hearths and stone artefacts exposed in scalded areas across the T1 and Wfm surfaces.
Wood and Westell (2008b)	This study comprised a small-scale assessment of hydrological scout wells and identified a large open scatter of midden and hearth material together with single burial in an SBD south of Ral Ral Creek.
Wood and Westell (2008c)	Small-scale assessment of scout wells identified a mound adjacent to Hunchee Lagoon.
Wood and Westell (2012)	Small-scale assessment of regulator structures at Lake Merreti and Woolpoolool inlet creeks reported a scarred tree and an isolated quartzite cobble hammerstone.

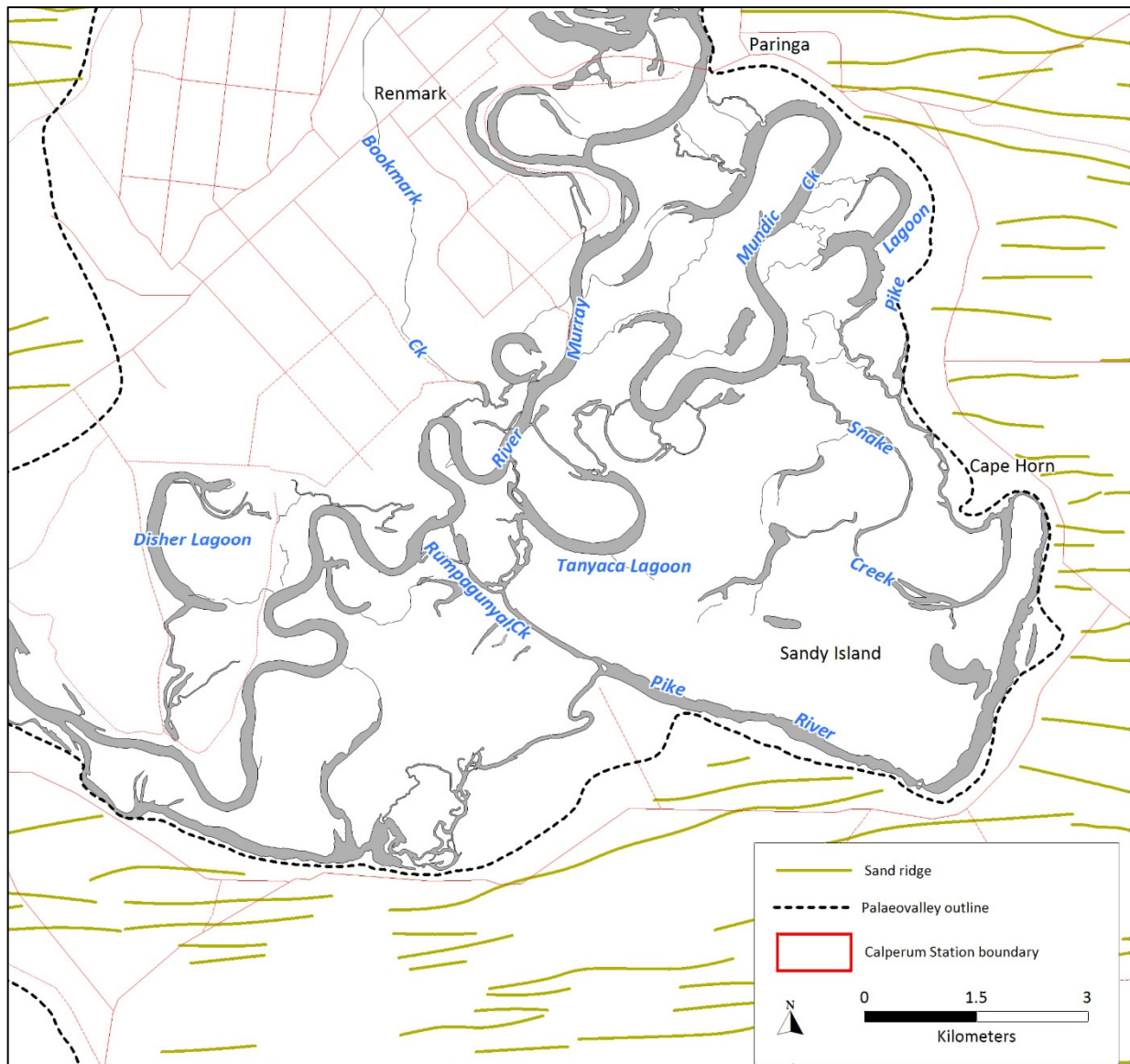


Figure 1-4: The location and major features of the Pike floodplain.

An extensive amount of archaeological survey has been conducted on the Pike floodplain and along the bounding cliffs, including a major baseline study conducted by Wood and Westell (2014b). A key feature of this floodplain is Cape Horn, a prominent headland extending from the eastern cliff-line and the location of one of several major Aboriginal chert/silcrete quarries found in the Riverland. Tindale (1940-1956) describes a number of sites at Pike, including the quarry, where he interpreted the weathering in several ‘cuttings’ as indicative of a long period of quarry use. According to Tarby Mason, one of Tindale’s Aboriginal ‘informants’, trade parties travelling downstream from the Darling River were permitted to camp on a dedicated island opposite Renmark during missions to obtain chert from Erawirung controlled quarries in this area, potentially including the Cape Horn site. Beyond the Cape Horn quarry, the archaeology preserved

across the floodplain is essentially replicated at Calperum. This research has focused specifically on a series of open scatters of shell midden and heat retainer hearths exposed along the cliff line overlooking the south-eastern corner of the floodplain. An equivalent valley margin is concealed by Woorinen Formation (WFm) sand sheets and dunes at Calperum.

An extensive amount of archaeological data has been amassed in the Riverland region beyond the Calperum and Pike floodplains, though the bulk of this is contained in unpublished grey literature. Baseline archaeological surveys conducted on the Chowilla (Wood et al. 2005), Katarapko (Wood and Westell 2009, 2010) and Pike (Wood and Westell 2014b) floodplains provide the most comprehensive synthesis of this material, to date, though this work has tended to focus on the spatial arrangement of the archaeology rather than considering any chronological or paleoenvironmental frameworks. A deeper narrative remains elusive. This thesis aims to fill this knowledge gap.

1.4 Aims and methodological approaches

The broad objective of this thesis is to provide insights into the long term nature and context of Aboriginal interactions with the habitat mosaics of Riverland floodplains. This objective is framed around themes that integrate the Riverland with a broader MDB narrative; the apparent lag between initial MDB occupation and intensive settlement along the River Murray corridor, the context and implications of a widespread development of freshwater mussel middens from around 15 ka and evidence of late Holocene socio-economic change. Given this broad temporal and geographic scope, **the** main challenge in this thesis is one of scale—meshing various scales of cultural and environmental data into a meaningful interpretation of human-environment interactions (Holdaway et al. 2010; Rowland 1999:15). This interpretation is framed around a set of ^{14}C ages that ultimately relate to a series of events interspersed throughout a longer period of contextual change. The guiding principle in this research has been to remain focused on scale, to consider the limitations imposed by it, to value-add the data where possible through exposing relationships between landscapes and archaeology, and build connections between data only to the point where these connections can be reasonably supported.

An additional set of issues arises from the open site and palimpsest nature of Riverland

archaeology. It is inevitable, given the scope of this thesis that interpretation is geared toward what Bailey (2007:210) has referred to as a 'macroscopic tendency', accepting palimpsests for what they are and basing argument on the general tendencies represented by them. The methods applied in this research have sought to identify and respond to these qualities in the Riverland archaeology and exercise extreme caution when building connections both within and between places.

The research strategy is based around the following aims and methodological approaches:

- *Establishing a geomorphological model.* A combination of GIS analysis and remote and field observations have been employed to refine geomorphological frameworks established in the broader MDB to more accurately reflect the Riverland landscapes. A program of OSL dating keys-in a relative landscape chronology to something of an absolute timeline and provides further integration with regional schema. Ecological data amassed during the Millennium Drought is used as proxy evidence for the environmental shocks and environmental transitions indicated in the geomorphological evidence.
- *Assessing the archaeology of the Calperum floodplain.* A program of archaeological site surveys, site analysis and excavation were informed by the geomorphological model. Site recording has focused on midden content, habitat association and the typology of grinding material. Excavation was used sparingly, consistent with the overriding research principles negotiated with the River Murray and Mallee Aboriginal Corporation (RMMAC).
- *Characterising the broader Riverland archaeology.* Various archival, published and unpublished literature resources have been compiled in a dataset of over 1,000 individual sites that can be provenanced with a high degree of certainty in the Riverland. The Calperum results are compared to this database, ostensibly to identify any conflicting evidence.
- *Establishing a chronological framework in the Riverland archaeology.* This aim has been approached using a program of direct dating via ^{14}C and OSL methods, assessing relative chronologies based on geomorphic context, typological dating in respect to the late Holocene oven mounds and adzes, and inferences made on additional site content.
- *Identifying taphonomic influences on floodplain archaeology.* The Riverland floodplains represent a complex taphonomic environment. The natural migration of the river, regular flooding and more extreme catastrophic events, post-contact land use and modifications to

natural inundation regimes are all destructive and/or modifying processes. A taphonomic profile is presented based on flood inundation modelling (FIM) and other observations, and the survey and dating results are canvassed against this. Excavation was used to develop a commentary around the potential loss of archaeological residues following exposure.

1.5 Research significance

The multi-disciplinary investigations carried out in the Willandra Lakes have captivated the archaeological community for decades. These investigations have documented a record of Aboriginal occupation extending over at least 45,000 years. The patchwork nature of investigations in the MDB, however, limits the ability to contextualise this and other disparate records. The Riverland represents a notable research ‘gap’ with a limited integration of this region into the broader MDB narrative with the exception of Aboriginal burial sites located on Katarapko Island (Dowling 1990; Littleton 2007; Littleton and Allen 2007), the Riverland oven mounds (Jones 2016b; Jones et al. 2017; Ross 2018; Ross et al. 2019; Thredgold 2017; Westell and Wood 2014), scarred trees (Dardengo 2019) and some artefact studies (Incerti 2018; Munt 2022; Roberts et al. 2020). This thesis aims to provide a basis for building pan-basin narratives.

The processes that form and transform riverscapes impose obvious biases in archaeological records. This is countered to some degree in the Riverland by the development of terraced floodplains which have acted to preserve and partition an extended time-series of alluvial and fluvial landscapes. The high bounding cliff-lines of the Murray valley also provide a baseline, of sorts, to compare and contrast with the floodplain record. This configuration of the valley offers a degree of preservation in both the physical and cultural landscapes that is not universally shared across the basin.

The geomorphological component of the thesis is the first major assessment of this down-basin setting since the 1970s, and importantly, offers a more reliable chronological framework based around a set of OSL and ¹⁴C ages. This provides an opportunity to assess how hydrological phases studied exhaustively in the upper and central MDB have translated to the lower end of the system.

Elements of the archaeological landscape key to the arguments of societal change are represented in this region, notably middens, mounds and cemeteries, though despite an extensive body of site data contained in grey literature, this resource remains largely outside of the research space. This thesis incorporates this largely untapped resource into a narrative that is accessible to broader research and scrutiny. The research also represents the sort of detailed, local-level sampling that Ulm (2013) argued is required in building robust insights into regional trajectories and counter the generalisations built into continent-wide narratives.

Importantly, the radiocarbon dating program conducted as part of this research has sought to address what could aptly be described as a data-void in the MDB in relation to the geographic and temporal spread of ^{14}C determinations. The Riverland lies between the intensively studied areas of the greater Darling region and the lower Murray Lakes and Coorong, represented by deep Pleistocene and Holocene records, respectively. In recent years, continental narratives have been framed around ever more sophisticated statistical analyses of radiocarbon ages (Williams 2013; Williams et al. 2013; Williams et al. 2015b; Williams et al. 2015c) pooled from vast sets of regional data. This thesis assesses these outcomes against an intensive and localised sampling of radiocarbon ages.

The investigation of Aboriginal archaeology in the MDB has produced an extensive body of literature on a wide range of topics and has continued to shape both theory and practice in the broader discipline. Early and ongoing investigations conducted in the Willandra Lakes and broader Darling region, in particular, have exemplified the value of multi-disciplinary approaches to archaeological interpretation (Hiscock 2008:5). This thesis integrates a range of ecological, geomorphological and archaeological aspects, building on a multi-disciplinary synergy that has been the hallmark of studies in the MDB.

Ultimately, this thesis has developed around a research project embedded in the expectations of RMMAC, the representative body corporate for the First Peoples of the River Murray and Mallee native title group (consent determination was recognised in *Turner vs State of South Australia* 2011; FCA 1313). RMMAC are currently engaged in a variety of projects designed around the rehabilitation and restoration of the Murray floodplains. The research provides context to the long-term interactions of river peoples and their floodplains, builds upon the inventory of

documented cultural heritage sites, and contributes to the strategic planning of infrastructure within these highly sensitive cultural landscapes. The research also provides a basis for interpretative and educational materials.

1.6 Ethics, approvals and traditional owner engagement

The thesis has been conducted as part of the broader Calperum Station Research Project, a multi-faceted investigation into the long-term interactions of Aboriginal peoples with the central River Murray floodplains. The project is a collaborative endeavour between Flinders University and RMMAC. Research protocols have been approved by RMMAC in relation to the access and use of archival and other records from the South Australian Museum (SAM), State Records, Aboriginal Affairs and Reconciliation (AAR) and other libraries and institutions, and the conduct of field-based studies. RMMAC have approved the collection of dating samples and excavations. The progress, results and ongoing planning of the research, have been routinely discussed at RMMAC Directors meetings and with RMMAC community members engaged in the fieldwork. Cultural protocols, as required by RMMAC, have been respected and followed.

Ethics approval was undertaken by the Flinders University, Social and Behavioural Research Ethics Committee Project Number 6618.

Approvals under Sections 21, 23 and 29 of the South Australian *Aboriginal Heritage Act 1988* (AHA) were obtained for the collection and submission of ^{14}C dating samples (shell and charcoal), and the excavation of archaeological sites. Approval was obtained to conduct research-based activities on Crown Lands administered by the South Australian Department for Environment and Water (DEW) under Section 61 of the *Crown Land Management Act 2009* (DEW Document reference 11/5984).

1.7 Reporting age determinations

Archaeological dating conducted in the MDB has relied on various methods and reporting standards. The majority of ages are reported in the literature as conventional ^{14}C determinations,

i.e. years BP. This includes the current AustArch dataset (Williams et al. 2014). Age estimates presented in this thesis have been converted to calibrated years BP using the OxCal 4.4 program and applying the SHCal 20 atmospheric curve as described by Hogg et al. (2020). For ease of comparison, the original uncalibrated formats are used in relation to cited age determinations, followed by an equivalent calibrated age range presented in square brackets and labelled as cal BP. Where generalised timelines are described, the abbreviation ka can be taken as meaning 1,000 years before present. The suffix CE is applied where 'Common Era' ages are cited. The interpretation of geomorphological timelines has relied largely on luminescence techniques (e.g. Kemp and Spooner 2007) and can therefore be considered comparable to calendar years BP. Following Telford et al. (2004) and Millard (2014), calibrated ages are presented as a 95.4% probability range except where stated otherwise.

1.8 Contested terms: Contact and Sedentism

Captain Charles Sturt's expedition along the River Murray in 1830 is thought to have represented the initial direct engagement between Aboriginal peoples and European colonists in the Riverland. This heralded a period of profound impact on Riverland Aboriginal communities (Burke et al. 2016), though the interactions throughout and beyond this period were complex. Tutchener and Claudie (2022) have argued that the term 'contact' risks biasing an understanding and appreciation of these early cross-cultural encounters and the ongoing ramifications of them. It is, however, the application and intent of words that ultimately reveal meaning. In lieu of any formal consensus, any alternate term could equally be used to bias, diminish or distort an appreciation of this period and its lasting impacts. Importantly, I would argue that any consensus must be driven by, and accepted by First Nations peoples, and to this point, I am unaware of this having been achieved. The term 'contact' is used in this thesis to specifically describe the period c. 1830–1850 during which Aboriginal socio-economic systems responded to, and were modified by, the processes of cross-cultural encounter. It does not seek to prejudice any one aspect of this complex engagement over another, or diminish or fail to 'recognise and respect the persistence of Indigenous culture' (Tutchener and Claudie 2022:89) and ongoing effects of colonisation.

The use of the term 'sedentism' is also contentious. If we take sedentism to include those systems that make continual use of settlements across at least part of the year, there are clearly degrees of

sedentism, as this description aptly describes the vast majority of societies where structured seasonal movements employed the use of semi-permanent camps. Dow and Reid (2015:57) defined sedentary systems as those capable of transcending environmental shocks over periods of decades or centuries. Architecture, investment in earthworks and infrastructure, ground stone tools, food processing and storage facilities, the remains of plants and animals relating to multiple seasons, the presence of organisms that benefit from human activity, and mortuary practices that include an increase in burial numbers; are commonly referred to as material indicators of sedentism (e.g. Dow and Reid 2015; Kent 1989; Marshall 2006). There is also an inevitable coevolution of sedentism and socio-political structures, including systems of resource ownership and land-tenure at scales from the individual to the collective. Mobility patterns are, after all, governed in large part by complex social, political and ritual factors as much as utilitarian necessities (Kent 1989:3). These attributes are, in part, replicated in both the historical accounts and archaeology of the Riverland, where Aboriginal people were engaged in a diversified economy that seems to have operated within a context of exceptionally low residential and logistical mobility governed by clearly demarcated tenure (see Chapter 4.2).

Sedentism is a concept easily lost in semantics though it could be argued that Riverland occupation at the time of contact was, in any definition of the word, sedentary. In this case, however, the archaeology tends to describe a meshwork of locations within a closely integrated 'taskscape' (sensu Ingold 1993) in which individual floodplains seem to have acted as the unit of occupation. A network of closely located, task-specific sites fulfilled a range of social and economic roles within this landscape; weir fish traps strategically placed on flood-runners, processing sites (mounds) located at stands of *Typha* spp., sand dunes dedicated for burial use, for instance. Residential areas were undoubtedly relocated in response to flooding cycles, though these small-scale relocations, in and of themselves, do not detract from a broader image of sedentism (contra Klaver 1998).

1.9 Thesis structure

The scope, context and aims of this thesis are summarised in this first chapter.

Chapter 2 has two elements. First, it reviews the origins of the intensification debate in Australia. This narrative has borrowed heavily on interpretive frameworks developed outside of this continent and the chapter outlines some of the explanatory models used to describe the phenomenon. This thesis addresses the efficacy of these models in respect to the Riverland evidence. Second, the chapter presents an occupation timeline within the MDB, focusing on several themes used to integrate the Riverland and broader MDB evidence.

Chapter 3 presents a palaeoenvironmental narrative for the western MDB by drawing on a wealth of regional data.

Chapter 4 provides an overview of Riverland archaeology, with descriptions of the common site types, their content and distribution. Key features of the archaeology are highlighted, including the character of faunal assemblages and the distribution and typology of grinding materials. The ecology and hydrology of the modern Riverland floodplains is canvassed and provides context to an interpretation of palaeoenvironmental settings presented in subsequent chapters.

Geomorphological and archaeological field and laboratory methods and materials used in this research are described in Chapter 5.

The research results are outlined in Chapter 6. This includes an assessment of the survey coverage, the sites recorded, dating results and other analyses. A more thorough discussion is presented in Chapter 7, in which the survey results are compared to data previously amassed within the Riverland and broader MDB. The discussion assesses the efficacy of the study methods and approaches in addressing the research questions. A taphonomic profile is presented as context to the extant archaeology. The applicability of HBE models is then canvassed.

Chapter 8 revisits the research themes and questions and offers some concluding remarks. Some further directions for research in the areas related to this thesis are also suggested.

1.10 Supplementary material

A range of data has been generated during this research and may be provided on request, subject to approval by RMMAC. Precise locations have been redacted from this material to allow open access. The material and its formats are summarised in Table 1-2.

Table 1-2: A summary of the Supplementary Materials.

Material	Detail	Formats
Riverland Site Listing_Redacted	This includes summary details for previously reported sites in the upper Riverland (excluding scarred trees). This detail has been used to characterise the Riverland archaeology, to identify the locations of oven mounds and grinding materials, and to compare and contrast the Calperum and Pike results to the broader Riverland data. A bibliography is also provided.	MS Word
Site Records	The materials includes folders containing site recording sheets and photographic images generated during the Calperum and Pike fieldwork.	Jpeg, pdf
Calperum Sites	Summary details and context for the archaeological sites recorded during the current research.	MS Word
OSL reports	The two OSL reports provided by Prescott Environmental Luminescence Laboratory are supplied here.	Pdf
¹⁴ C reports	Various radiocarbon dating reports issued by the Waikato, ANSTO and Beta Analytic facilities.	Pdf
Excavation_SurfSampling_MasterList	A spreadsheet including summary details of the excavation and surface sampling results.	MS Excel
Sediment Logs_FieldSheets	Scanned copies of the sediment logs compiled during this research.	Pdf
SAM Grinding Materials	Summary details for the various grinding material held in the South Australian Museum (SAM) collections and provenanced to the upper Riverland.	MS Excel, jpeg
Excavation Recording Sheets	Scanned copies of all excavation recording sheets and section drawings.	Pdf

CHAPTER TWO: TOWARD A TIMELINE IN MURRAY-DARLING BASIN

ARCHAEOLOGY

2.1 Introduction

This chapter has two elements. First, it reviews the origins of the intensification debate in Australia, a debate that has framed a grand narrative of Aboriginal occupation in the MDB. This narrative has borrowed heavily on interpretive frameworks developed outside of this continent and the chapter outlines some of the explanatory models used to describe the phenomenon. This thesis also addresses the efficacy of these models in respect to the Riverland evidence. Second, the chapter sketches out a timeline of Aboriginal occupation within the MDB, focusing on the themes used in this thesis to integrate the Riverland evidence with the broader MDB:

- An initial MDB colonisation focused around lacustrine environments and lag to the broader use of riverine environments, including the River Murray corridor itself;
- A change in the nature of occupation evidence c. 15 ka; and
- Evidence of change in socio-economic systems across the Holocene.

2.2 Intensification explained through the lens of Human Behavioural Ecology

Diversification and intensification in ‘hunter-gatherer’ economies around the Pleistocene–Holocene boundary is recognised as a major transformation in human economic behaviour in various settings the world over. In an interpretation of the Near East record, Kent Flannery (Flannery 1969) labelled this phenomenon the ‘Broad Spectrum Revolution’ (BSR) and viewed it as a precursor to the development of domesticated economies in the region. Innovations in social systems (notably increased sedentism and socio-political hierarchies), technologies (e.g. seed grinding), a shift in emphasis to r-selected prey (i.e. with high reproductive rates), an increased use of plants and the expansion into marginal resource zones, are considered manifestations of the BSR in various regional settings (Bellwood 2011; Binford 1968; Broughton et al. 2010; Flannery 1969, 1986; Jones 2016a; Munro 2003, 2004, 2009; Phoca-Cosmetatou 2003; Prendergast et al. 2009; Rillardon and Brugal 2014; Stiner 2001, 2004; Stutz et al. 2009; Yeshurun et al. 2014; Zeder 2012).

The BSR is inextricably linked with the concept of intensification and explained through the lens of Human Behavioural Ecology (HBE), a conceptual framework which recognises the capacity of humans to apply 'predictable, short-term, often real-time adaptive responses to social and ecological features of their environment' (Bird and O'Connell 2006). Intensification, as recognised in the BSR, relates to increased levels of food production achieved through greater labour effort though at the expense of declining foraging efficiency (Morgan 2015:165). Optimal Foraging Theory (OFT) and its variants of prey-choice, patch-choice and diet breadth models, together with Niche Construction Theory (NCT) and Low-Level Food Production (LLFP), are examples of HBE frameworks applied in the interpretation of intensified hunter-gatherer economies.

Whilst the timing, impetus and universality of the BSR continues to be debated (see Morgan 2015 and Zeder 2012 for exhaustive reviews), diet diversification and intensification has commonly been attributed to some environmental, economic or population crisis. In high-latitude Europe, for instance, Binford (1968) attributed it to an effect of population pressure reducing the availability and increasing the search costs of high ranked species, thereby shifting the reliance onto a wider array of lower return items (Jones 2016a:12-13; see also Stiner 2001; Stiner et al. 2000; Stutz et al. 2009).

There is also broad agreement that socio-economic change occurred in Australian Indigenous societies during the Holocene with similar evidence used to frame the BSR narrative recognised in some combination in regional records (see Ulm 2013 for summary). Given these similarities, there has been a tendency to draw direct parallels and relate the changes seen on this continent to the processes considered fundamental to patterns observed elsewhere. This presumption of sameness has been criticised by Holdaway et al. (2008:411), who argued that the engagement of Indigenous societies with Australian environments is likely to have described a unique set of pathways that need to be canvassed within their own 'theoretical framework built upon the [local] evidence'. With few exceptions, the debates around intensification in Australia have tended to focus on fitting evidence to concept rather than the relevance or fitness of the conceptual frameworks themselves. As outlined below, various HBE models have their strengths and weaknesses in respect to the MDB.

2.2.1 Optimal Foraging Theory

OFT encompasses a range of models including prey-choice, patch-choice and diet breadth, though the underlying premise of all is that food resources have inherent costs associated with their collection and handling. Resources can therefore be ranked in terms of the energy returns given these costs, and there is a natural tendency toward greater foraging efficiency with the addition or removal of items in an optimally ranked set (Bird and O'Connell 2006, 2012; Stiner 2001). Within OFT, modifications in economic behaviour, e.g. the BSR, reflect trade-offs in resource ranking in response to changes in ecological, social or technological contexts.

Some of the main criticisms of the simple cost/gain approach in OFT have focused on integrating the complexities of demography and intergroup relationships on subsistence strategies (Morgan 2015; Stiner and Kuhn 2016; Zeder 2012). Mobility, for instance, is the 'fundamental adaptive feature' within OFT (Zeder 2012:253), though there will inevitably be some limits imposed on it, for example through territorial constraints or degrees of sedentism. In effect, the option to pursue optimal foraging strategies may never exist in the real world simply because people have never been able to make decisions based on boundless options for encounter with the highest ranked resources (Kelly 1995).

Collection strategies would also be heavily influenced by the age, sex, responsibilities and signalling behaviour of individuals and complex groups of people (Hawkes and O'Connell 1992; Hill et al. 1987; Jochim 1988, 1998). Reliability and more consistent access to protein might be favoured over high profitability, for instance, where the needs and capabilities of children are factored into a workable strategy (Bird and Bliege-Bird 2000; Coddling et al. 2011; Hawkes and O'Connell 1992; Jochim 1988; Stiner and Kuhn 2016; Stiner et al. 2000). The simple OFT equations are further complicated by investments in mass-capture strategies where an initial outlay of effort generates pay-offs that skew the cost-benefit outcomes for individual resources (Jones 2006:286). This has relevance to the MDB where netting and weir fish traps were used extensively (Allen 1972, 1974; Eyre 1845; Finniss 1966; Robinson and Clark 2000). Netting, in particular, has a long history of use in this region (Balme 1990, 1995), and seems to have been the hallmark of MDB economies at the time of European contact where it was applied to a broad range of prey items including birds, fish and small and large land animals (see for example Eyre 1845). Of course, the ability to collect these items *en masse* is only one part of the equation—processing has associated costs and to realise the pay-offs requires a minimum level of production that may not be

guaranteed over the long or short term (Ugan 2005).

The notion that small-prey equates to low-rank is also context specific and very much dictated by prey habits that might include speed, agility, reproductive behaviour and a range of other species characteristics. In assessing the terminal Pleistocene record of Picareiro Cave, Portugal, Hockett and Bicho (2000:721), for instance, suggested the availability and ease in which rabbits were caught could account for their prevalence in the assemblage rather than the need to consider resource stress and depletion of larger game. Similarly, within the MDB, various 'low value' staples are likely to have been procured with relatively low collection costs given their growing conditions. The freshwater mussel *A. jacksoni*, for instance, can occur in densities of up to 300 individuals/m² (Walker 1981:22–3, 28, 61, 65) providing a substantial and easily obtainable volume of protein despite the small return from individual shells. Historical accounts identify freshwater mussel as a daily staple in the MDB (e.g. Mitchell 1839) with shells able to be collected throughout much of the year though with some difficulty during winter when they tend to burrow (Allen 1974:311; Berndt and Berndt 1993:563; Walker et al. 2001:17). Garvey (2017:89–98) has argued that despite the low meat mass obtained from individual shells (28–45 gms), their widespread availability and low collection costs made them a reliable protein source, particularly for women and children. Similarly, dense stands of *Typha* spp. represent concentrated and easily accessible sources of carbohydrate-rich plant food. The MDB economies at the time of European contact seem to have been underpinned in large part by foraging strategies developed around these abundant and predictable 'high yield tertiary taxa' (sensu Atici 2009:9), despite their low per-unit returns. This might also be considered for the archaeofauna assemblages throughout the deeper MDB timeline, a point developed further in this chapter.

Within OFT, economic intensification (and diversification) has been considered a consequence of higher and/or more sedentary populations having to extract more resources from smaller territories and expanding a diet to rely more heavily on lesser ranked items. Greater labour costs with declining foraging efficiency are required to sustain this increased production (Morgan 2015:165). A feedback loop develops, wherein higher periods of residency cause further depletion of core staples and place an ever-greater dependence on a broader range of food options. Given the lower returns from these lesser-ranked items, intensification is typically coupled with innovation or expansion of technologies that reduce collection and/or handling costs (Coddington and Bird 2015; Hawkes and O'Connell 1992; Stiner and Kuhn 2016). This take on OFT has been a key

element in the interpretations of the MDB record where 'demographic packing' has been cited as the key impetus of economic change manifest in the introduction or proliferation of technologies such as seed grinding, the use of oven mounds and movement into the semi-arid mallee plains beyond the riverine corridors (Allen 1972; Balme 1990; Edwards and O'Connell 1995; Pardoe 1995; Ross 1985; Williams et al. 2015b).

2.2.2 Niche Construction Theory

The capacity of humans to manipulate natural systems in order to improve the ranking (return) of food resources lies at the heart of Niche Construction Theory (NCT) (Laland and O'Brien 2010; Odling-Smee et al. 2003; Smith 2015a). Rather than a reaction to resource depression or demographic stress, active manipulation of the environment, what Zeder (2012) refers to as 'ecosystem engineering', is used to optimise a selection of resources (Bird et al. 2016a). Procurement strategies that are best suited to benefit existing social structures and those inheriting that environment are naturally preferenced over others (Broughton et al. 2010; Zeder 2012). Zeder (2012) has argued that within NCT, diversification and reduced logistical mobility would tend to occur in mosaic habitats where abundant, varied and predictable resources could be exploited throughout the year. Furthermore, the investment in these locations and related subsistence strategies would promote change in inter-communal relationships with territories established and defended around a bounded or territorially conscripted set of invested resources (Smith 2011a). One outcome of this investment may be increased sedentism. This scenario resonates with the image of Riverland society at contact (see Chapter 4.2).

An interpretation by Zeder and Spitzer (2016:156) of the intensified use of birds in the early Holocene record at Hallan Çemi, Turkey, provides an example of NCT as an interpretive framework. They argued that rather than a consequence of resource depression brought about by demographic packing, an economic repertoire may have simply been honed through an expanding ecological knowledge and an ability to manipulate biotic communities that had emerged through the early Holocene. Increased sedentism was supported by these reliable and durable strategies that secured a resource base over the long term. In effect, social systems in this region coevolved with an increasing investment in key habitats and resources, leading ultimately to domesticate economies and the development of village communities (Zeder and Spitzer 2016:157).

Importantly, this example, as with the study of Picareiro Cave described above, illustrates how an increase in the number of small prey items in archaeofauna assemblages can occur through the enhancement of resources within the realm of niche construction and beyond the influence of resource depression—a counter to the underlying premise of the OFT-diet breadth scenarios (Smith 2011a).

One potential consequence of niche construction is that it may act to embed a level of reliance in strategies that may become increasingly difficult to retreat from (Stiner and Kuhn 2016). Having committed to a strategic pathway, there would be a tendency to continue to invest in its related technologies, facilities and specialisation, and the social systems built around these. Flexibility may ultimately be jettisoned as the cost of changing economic course increases (Freeman et al. 2015). In this respect, the domestication of plant and animal resources is perhaps the exemplar of niche construction in practice, and followed a long period of ‘auditioning’ of wild species that would ultimately ‘reshape local biotic communities and ecosystems’ (Smith 2007, 2011b:836). Domestication arose as co-evolutionary relationships developed with increasing investments in the management of a small sub-set of economically important species (Zeder and Spitzer 2016).

The use of fire is an obvious example of niche construction in the Australian context. Here, mosaic burning acted to modify vegetation communities, increased heterogeneity in habitats and changed the trophic composition of these curated landscapes to benefit hunting productivity (Bird et al. 2016a; Bliege-Bird et al. 2008; Bliege-Bird et al. 2013; Gammage 2011; Smith 2011b; Zeanah et al. 2017). The larger, denser and territorially bounded late Holocene populations theorised by Williams (2013) in Australia, at least those in the arid zone, may have capitalised on, and were ultimately supported by these landscape modifications (Bliege-Bird et al. 2008; Williams et al. 2015a). Fire was also used in the MDB to manage stands of *Typha* spp. and promote rhizome growth (Eyre 1845:269). Oven mounds, a distinctly late Holocene site type, seem to have been developed around the large-scale processing of this material resource. It could be argued that an increased investment in *Typha* spp. had manifest in a distinctive form of processing site (oven mounds) and was supported by the modification (burning) of wetland vegetation with the realm of niche construction. Further landscape modification within the MDB can be seen in the construction of weirs and diversion channels which directly manipulated hydrological systems (e.g. Finniss 1966; Robinson and Clark 2000).

2.2.3 Low Level Food Production

The BSR is commonly viewed as the precursor to the development of agriculture-based societies—an initial transformation along an envisaged developmental pathway, linear or otherwise, from hunter-gather economies reliant solely on ‘wild’ resources to economies formed around the management of domesticate plant and animal resources. It is recognised, however, that long periods of time commonly separate the appearance of early domesticates and the development of fully engaged agricultural economies (Smith 2001). Lying between these two ‘distinct evolutionary transitions’ (Smith 2015a:217) is what Smith (2001) refers to as this ‘middle-ground’, a period in which elements are progressively added to, or removed from, an economic repertoire. While there has been a tendency to equate this period to an extension of one or the other systems, e.g. ‘complex hunter gatherers’ (Williams 1988) or ‘incipient agriculturalists’ (Mulvaney 1999:238–248), there is ethnohistorical and archaeological evidence from various regions to suggest that viable and enduring socio-economic systems had successfully integrated elements of both adaptive solutions (Smith 2001). It is a period of ‘complex shifts in subsistence behaviour’ that are likely to have manifested in unique scenarios in various contexts (Bogucki 1995:105), though with a common defining element that food **production** occurred in combination with food **collection**.

The Jomon cultures of Japan, for instance, were characterised by foraging lifeways that persisted over much of the Holocene though incorporated aspects of active landscape manipulation that systematically influenced the ‘reproduction and productivity of plant communities’ (Bleed and Matsui 2010:364). Smith (2001) outlines several additional case studies of subsistence economies built around low-level food production without domesticates. These include the Paiute peoples of the Owens Valley in eastern California, where meadows of aquatic plants (hyacinth [*Hyacinthus spp.*], nutgrass [*Cyperus rotundus*] and spikerush [*Eleocharis palustris*]) were expanded through the construction of irrigation ditches to enhance a major dietary component (Bettinger 1977). Permanent camps were often located near these floodplain meadows with the management of diversion dams on the tributary creeks of the Owens River a focus of communal effort. Smith (2001) equates this scenario with the eel-trap systems of south-western Victoria. The mound-scapes and fish weirs of the Central Murray corridor provide another obvious analogue (Finniss 1966; Robinson and Clark 2000; Westell and Wood 2014). Both are examples of food production built around non-domesticated resources though undoubtedly relate to resources enhanced through the curation of landscapes.

2.2.4 The Broad Spectrum Revolution and Intensification in Australia

Debate around the timing, implications and archaeological manifestation of Holocene change in Australia has raged since the 1970s when Harry Lourandos proposed a reframing of the pathways traced by Indigenous societies on this continent (Lourandos 1988, 2016; Lourandos and Ross 1994). In an interpretation of the Holocene archaeological record and ethnographies of southwest Victoria, Lourandos (1983, 1985) argued that intensification had occurred in the regional economy; that this could be recognised archaeologically, and that it could be broadly ascribed to increasing demands placed upon food production. The prevailing paradigm of the time viewed Aboriginal society as having been in a state of homeostasis, controlled fundamentally by external (environmental) forces, though as the transformations had arrived independent of what Lourandos regarded as major environmental change, he argued that a simple environmental deterministic explanation could be dismissed as inadequate (see also Lourandos 1985:403; Ross 1985; Williams et al. 2015b:8). Instead, Lourandos viewed the late Holocene archaeological evidence and ethnographic record as manifest of a distinctive period of change shaped by internal (social) forces placing demands on the environment rather than being shaped or constrained by external (environmental) agents (David and Denham 2006:62; Lourandos 1983, 1985, 1988:149; McNiven et al. 2006). This ‘decoupling’ from environment set the late Holocene record apart from the preceding history of Aboriginal occupation (David and Lourandos 1997).

At the heart of the intensification debate has been a tussle, perceived or otherwise (see Lilley 2008), between environmental and cultural deterministic standpoints, which, at a basic level, recognise environment as either constraint or opportunity (Fekadu 2014; Hardin 2009). While it is undeniable, as Hiscock (2008:10) has contended, that ‘fundamental connections between environments and the organisation of human societies’ have always existed, the key departure from an environment-driven model was an insistence that Aboriginal society had participated in a dynamic and non-passive relationship with natural and sociocultural environments over both the long and short-term (Lourandos and Ross 1994:60). This is, after all, a truism of all societies, at all times and in all places, to paraphrase Allen (2015:192). Specifically, Lourandos (1983, 1985; 1988:149) viewed economic change as having been stimulated by increasingly complex and competitive social networks, in which the ability to generate surpluses through more intensive and innovative resource capture methods allowed the freedom to host ritual gatherings and formalised exchange, acting to ‘validate, maintain and enhance local groups within larger social

systems' (Pate 2006:229). It was the 'arena' of intergroup relations rather than the domestic level of production that provided the context of change (Lourandos 1988:150). As Bender (1978:205) had argued, to understand why particular technologies and economies are applied, the focus must be on understanding social relations and the demands that these alliance networks generate.

Lourandos viewed economic change as being pulled along by social imperatives and reflected in the use of marginal environments, the introduction of new resources and increased economic complexity (e.g. diet breadth, production methods) (Lourandos 1983:81–82, 1985:391; Lourandos and Ross 1994:56), a thesis with clear parallels to the BSR narrative. Alliance formation was supported by higher labour investments in food production strategies which 'tethered' foragers to key resource areas and 'facilities' such as the water management systems at Tooloondo (Lourandos 1983) and the eel traps at Mt Eccles (Builth et al. 2008; Coutts et al. 1978), both examples of niche construction in practice. Lourandos (1983:87; 1985) recognised similar trends across the broader southeast of the continent, including in the Darling River and semi-arid Murray mallee records interpreted by Allen (1972) and Ross (1981), respectively, as evidence of a pan-regional transformation in Aboriginal societies and economies during the late Holocene.

Various researchers, however, remained critical. An early retort by Beaton (1983:95) questioned whether economy and society can ever be disentangled, and instead saw the two constantly adjusting to each other in a gradual and subtle fashion. Lourandos' thesis, Beaton suggested, was more an ideological counter to the deterministic materialists and he questioned whether new resources or capture methods necessarily translated as evidence of intensification. Instead, Beaton (1983) favoured the dominant paradigm of the time that emphasised stability and conservatism in an Australian 'domiculture', i.e. where 'selective environmental knowledge and resource strategies' are applied within specific temporal and geographic contexts (Hynes and Chase 1982:38). Beaton (1983:96) argued that the various aspects attributed to intensification, such as an increase in site numbers, could be explained by simply adjusting the population growth model proposed by Birdsell (1957) without the necessity of radical social transformation.

Hiscock (2008:250), too, argued against a uni-directional trajectory from 'simple' to 'complex' (read here intensified) society, suggesting that similar territorial systems, specialised labour-

intensive economies and relatively higher population densities may have existed at various times in the past. The MDB evidence may lend support to this stance, as it is evident that a wide diet breadth has been a hallmark of MDB economies from the get-go (Allen 1974, 1998; Balme 1990, 1991, 1995; Balme and Hope 1990; Walshe 1998), so much so that it is hard to argue that profound directional change had in fact occurred, at least in respect to the diversity recognised in archaeofauna. A similar range of taxa is reported in assemblages from across an extended timeline, with small mammals, freshwater shellfish, birds and fish having remained embedded (nested) parts of MDB economies. The same might be said for the use of plant resources, a key component of the BSR discussion. The context and application of grinding technologies may have adjusted through time, though a long tradition of its use exists in the MDB (Field and Fullagar 1998; Fullagar et al. 2015).

One key element missing in Lourandos' original thesis is the influence of El Niño Southern Oscillation (ENSO) in the Holocene record. Lourandos viewed the socio-economic trend as independent of major environmental change though the regionally significant impacts of ENSO in archaeological landscapes have been explored more fully since Lourandos' original thesis (Asmussen and McInnes 2013; Ferrier and Cosgrove 2012; Holdaway et al. 2010; Rowland 1999; Turney and Hobbs 2006).

2.3 The early Murray-Darling Basin record

The current AustArch dataset (Williams et al. 2014) and other published sources (e.g. Wilson et al. 2012) list $n=772$ radiocarbon age determinations that can be reliably attributed to Aboriginal occupation in the MDB². Figure 2-1 shows the locations of the combined set in the south-western portion of the MDB. The majority of the age determinations and dated sites occur within New South Wales with data concentrations associated with the Willandra Lakes, the Darling Anabranch and the River Murray between Euston and Lake Victoria. When viewed collectively, the paucity of ages within SA, particularly between the border and Roonka, is striking. Age determinations obtained in SA come from relatively few locations (Fromm's Landing [Tungawa], Devon Downs

² Age determinations have been derived predominantly from charcoal ($n=381$), freshwater mussel ($n=257$) and human bone ($n=86$) with lesser sampling of fish otoliths, mammal bone, wood and emu egg shell.

[Ngaut Ngaut], Katarapko, Pompoota to Swanport, Roonka, Tartanga) compared to a broader spread of sampled sites, and an almost fourfold number of published dates upstream of the border.

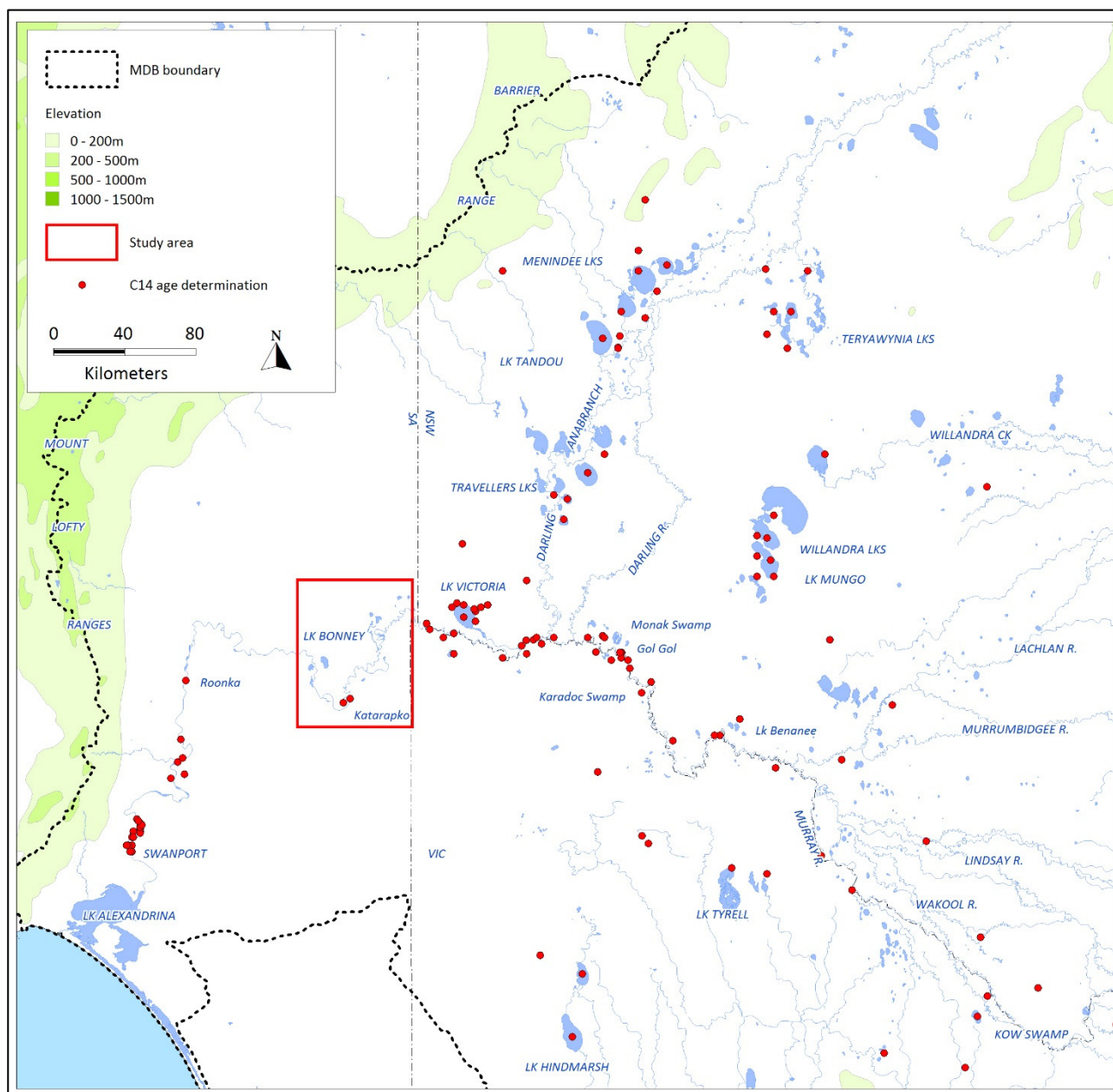


Figure 2-1: The general locations of ^{14}C determinations recorded in the south-western MDB prior to this research.

Evidence of initial occupation within the MDB currently extends to approximately 46 ka in the Menindee Lakes region (Cupper and Duncan 2006) and possibly as early as 50 ka in the Willandra Lakes (Bowler et al. 2003)³. Regardless of current debates around the timing of human arrival in

³ Bowler et al. (2003) obtained an OSL range of 50.1 ± 2.4 and 45.7 ± 2.3 ka on a sand deposit containing 11 silcrete flakes located above a sterile layer dated to 52.4 ± 3.1 ka in the Mungo B trench.

Sahul (see Clarkson et al. 2017; Clarkson et al. 2018; Clarkson et al. 2015; O'Connell and Allen 2004; O'Connell and Allen 2015; O'Connell et al. 2018; Williams et al. 2021), the early MDB evidence falls within the same narrow timeline of several thousand years from c. 50 ka that, based on current dating evidence, saw a rapid dispersal of humans across much of the continent from the initial point(s) of settlement (Bradshaw et al. 2021; Hamm et al. 2016)⁴. This dispersal may have been sustained by a climate that provided far greater water reliability, availability and connectivity (Bird et al. 2016b) and more biologically productive habitats than current conditions (see for instance Hiscock and Wallis 2005; Hughes et al. 2017). Higher local rainfall generated by mid-latitude westerlies coupled with significant inflows from the northern monsoon-sourced rivers had, for instance, maintained vast permanent waterbodies through what is now the modern arid zone. A highstand shoreline around Megalake Frome, located on the north-eastern margin of the Flinders Ranges, is dated to 48–45 ka, for instance (Cohen et al. 2012:97).

People may have arrived in the MDB via any number of theorised routes (see for example Bradshaw et al. 2021; Hamm et al. 2016; O'Connell and Allen 2015) though subsequent occupation in the basin appears to have centred initially on large capacity lake systems to both the north and south of the modern River Murray corridor, including the Willandra Lakes (Allen and Holdaway 2009; Bowler et al. 2003; Fitzsimmons et al. 2014; Gillespie 1998, 2002; O'Connell and Allen 2004), the Menindee Lakes (Balme and Hope 1990; Cupper and Duncan 2006; Hope et al. 1983) and Lake Tyrell (Richards et al. 2007; Richards and Weber 2004) (Figure 2-2). Based on the data available at the commencement of this research, these lake systems appear to have defined the limits of early expansion into the southwestern MDB. No equivalent ages had been returned on archaeological material over a vast swathe of the basin downstream of these systems until around 29 ka when the earliest evidence is recorded at Lake Victoria in the form of a thin lens of shell midden (Abdulla et al. 2019). Importantly, Balme and Hope (1990:96) observed that the first evidence of human occupation in the Menindee Lakes can be related to the activation of Lake Tandou and its lunette, and there is no evidence that occupation occurred along the river system pre-dating the development of this lacustrine habitat.

⁴ The c. 65 ka age for the Madjedbebe site in northern Australia reported by Clarkson et al. (2017) remains an outlier by as much as ~15,000 years to the period of dispersal.

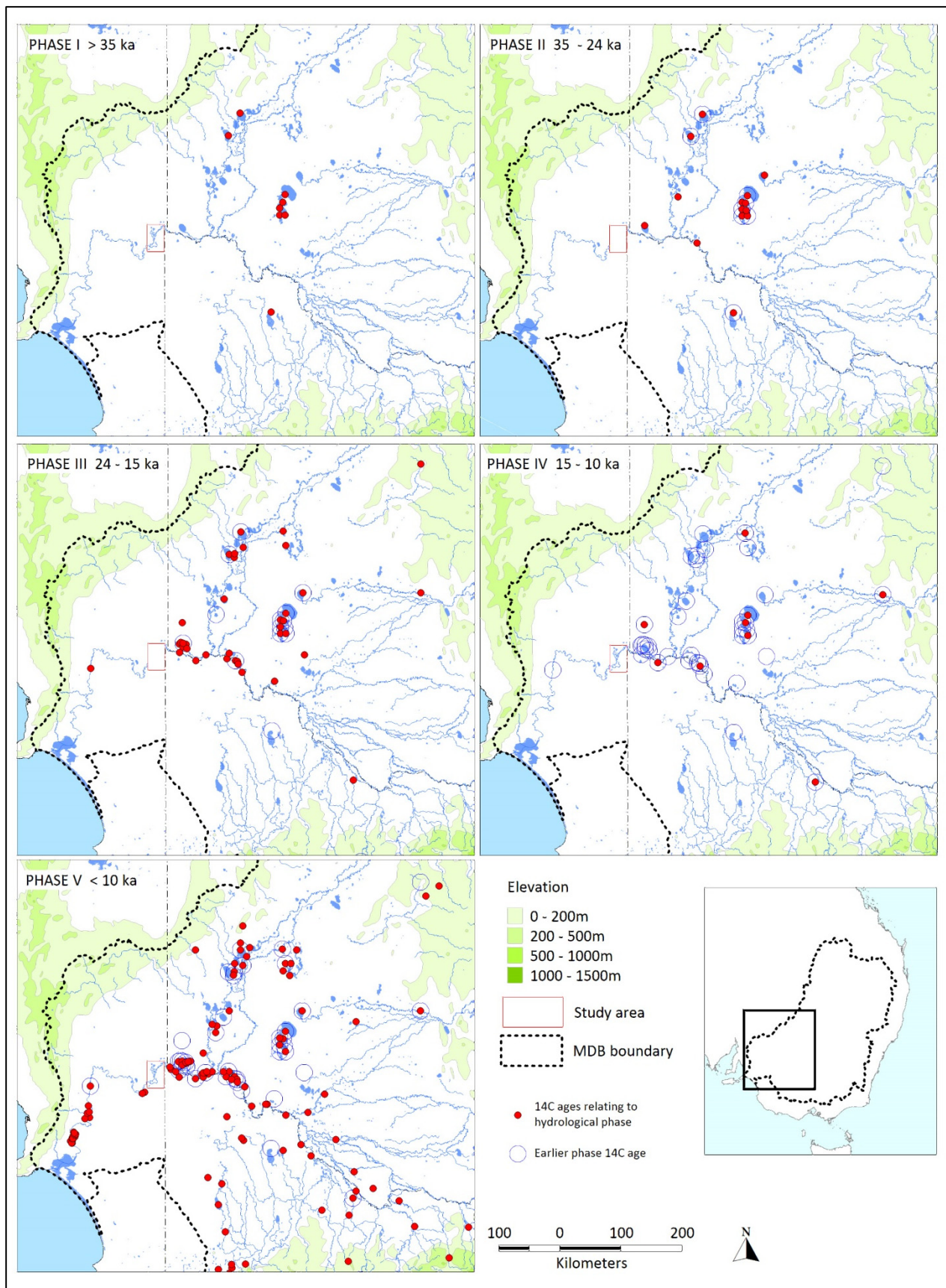


Figure 2-2: The distribution of mean calibrated age estimates returned on occupation related materials in the south-western section of the MDB assigned to major hydrological phases (see Table 3-4).

With few exceptions, there is evidence of occupation of these lake systems across subsequent hydrological regimes, though levels of occupation have varied. In the Willandra system, for instance, a progressive upstream focus of occupation may have occurred as reduced inflows approaching the LGM saw the gradual abandonment of the lower parts of the overflow system of lakes (Barrows et al. 2020; Bowler et al. 2012:292–293). This scenario may provide a useful analogue to the broader MDB, a theme developed further in Chapter 3. Fitzsimmons et al. (2014, 2019) have suggested that occupation at Lake Mungo had continued throughout the full range of lake regimes from about 50 ka, including the period following the lake’s final drying. Furthermore, settlement may have been most intensive during the regime of fluctuating lake levels (see also Smith 2019). At this time, flood pulses are likely to have enhanced the biological productivity of the lake system, food was able to be caught more efficiently during lower or oscillating lake levels, and the decline of water in the surrounding country (Fitzsimmons et al. 2014:361–362) made the lakes attractive aggregation centres—‘oases within a mobile sandy desert’ (Allen 1998:215).

In all of these early lacustrine settings, initial occupation appears to have been defined by short-term foraging sites focusing on the capture of a single or small range of species (Allen 1972, 1998; Allen et al. 2008:15; Balme 1995; Bowler et al. 1970:55; Richards et al. 2007; Richards and Weber 2004:Table 24; Stern et al. 2013). An early focus on small to medium sized mammals including hair wallaby (*Lagorchestes* sp.) and bettong (*Bettongia* spp.) was probably supplemented with an array of lesser foods items including freshwater mussel (*Velesunio ambiguus*, *A. jacksoni*), fish (golden perch (*Macquaria ambigua*), Murray cod (*Maccullochella peelii*), lizards, snakes, birds and bird egg (Allen 1972, 1974, 1998; Allen and Holdaway 2009; Balme 1990, 1995; Bowler et al. 1970; Clark 1987; Johnston 1993; Richards et al. 2007; Walshe 1998:205). Sites containing both lacustrine and terrestrial resources dominate. According to Walshe (1998:201, 204), this pattern reflected a regime of central place foraging from these lake-based sites and year-round procurement of resources from both the ‘lacustrine environment and forested hinterlands’.

The differential decay of organic material is obviously a factor in shaping extant assemblages given the timeframes being considered here. Balme (1990; 1995:1–3), for instance, identified a rapid decay of middens along the Darling River following their exposure, while Johnston (1993:199) observed that over a ten year period, shell had disappeared from 23 Willandra sites. Despite this, Balme and Hope (1990:99) have argued that the surviving evidence indicates an ‘almost

continuous use of aquatic resources in the MDB since about 36,000 years BP [41 cal kBP]'. The colonising peoples either imported or quickly adapted a lacustrine component into their subsistence enterprise (see Balme 1990). According to Allen (1998:213), freshwater mussel, golden perch and yabby (*Cherax destructor*) have remained constants throughout the Willandra and Darling River sequences. Despite its availability, freshwater mussel forms a minor albeit ubiquitous component of the early assemblages, and most likely served as a dietary supplement rather than staple (Allen and Holdaway 2009; Bowler 1998; Clark 1987:45; Johnston 1993:200-202). The earliest direct evidence of riverine or lacustrine fauna in occupation assemblages in the MDB is in the form of relatively small middens of freshwater mussel dated to between 41.5 cal kBP at Lake Arumpo in the Willandra system⁵ (Clark 1987; Hope 1993; Johnston 1993) and from 39.5 cal kBP on the Darling Anabranh (Balme 1990; Balme and Hope 1990).

Along the River Murray corridor, Barkindji Maraura Elders Council and Dillon (2020; see also Abdulla 2019) reported an age of 29.5–28.8 cal kBP (Wk50137) on freshwater mussel from a midden at Lake Victoria. Edmonds (1998:Table 5.1) reported an age estimate of 27.3–22.4 cal kBP (CS159) on freshwater mussel shell midden at Monak Swamp. Prior to this thesis, these two age estimates represented the outer limits of lakeside and channel situated sites within the River Murray corridor, respectively.

Fish, notably Murray cod and golden perch, is also commonly reported in the early record (Kalish et al. 1997). Balme (1990, 1995) interpreted the large number and consistent size range of golden perch otoliths recovered from site TNL 36 on Lake Tandou, as evidence of the use of fibre gill nets by around 27 ka. Allen (1998) reached the same conclusion of an early establishment of netting in Willandra system. That specialised technologies tailored to aquatic resources have a long-standing tradition in the western MDB, is significant (Allen 1998; Balme 1995:17; Hiscock 2008:123; Pardoe 1995). A slightly different take on a similar fish-dominated assemblage at Lake Mungo is provided by Long et al. (2014) based on isotopic and trace element analyses of golden perch otoliths. These analyses indicated that fish had entered the lake sometime between 19.5–19.2 cal kBP, and as lake levels fell, the stranded and potentially oxygen-starved fish had been caught *en masse* in what could be described as an 'easy prey' scenario, similar to that proposed by Bowler (1998:147) and

⁵ It is also possible that a small amount of golden perch and mussel shell dates to around 44 ka (Bowler 1998:146).

Bowler et al. (2012:234).

The apparent lag between initial MDB and evidence of occupation along the River Murray corridor is despite the presence of large intermittent lakes such as Lake Victoria, Karadoc Swamp, Hattah Lakes and Lake Bonney, that would have functioned contemporaneously with the Willandra and other systems (e.g. Chen 1995; Kotsonis et al. 1999). Early development of the Lake Victoria lunette, for instance, extends to at least 40 ka (Chen 1995) though the earliest middens only developed here from around 29 ka (Abdulla et al. 2019). The Lake Victoria record suggests an absence, or at least a low (undetectable) level of occupation along the Central Murray corridor and its associated lake systems until this time (Hope 1993; Luebbers 1995:9). Again, there is no evidence that lacustrine environments attached to the River Murray were exploited on a similar scale during the early occupation of the Willandra, Tyrell and Menindee systems (Hope 1993:191), a point worth reiterating, and as Lance (1993:30) suggested, a 'conundrum'.

2.4 The early River Murray record

Across the western MDB, an expanded pattern of occupation was established from around 24 ka (Hope 1986, 1993:187–189, 191)⁶ (Figure 2-2 and Figure 2-3). This included a cluster of early channel and lake-based sites along the River Murray upstream of the Darling River junction at locations including Monak and Karadoc Swamps (Edmonds 1997; Luebbers 1995: see also Edmonds 1998:Table 5.1). Excluding an earlier (26 ka) inferred limit at Kow Swamp⁷, very few other pre-LGM sites had been identified along the River Murray corridor. The earliest occupation evidence within both the Karadoc Swamp (Luebbers 1995) and Lake Victoria (Abdulla et al. 2019; Kefous 1983:97, 107, 113) lunettes take the form small, discrete, single lens features. In the case of Karadoc Swamp, the middens also included a diverse range of species included freshwater mussel (*V. ambiguus*), yabby, fish, lizard, bird and small mammals, including hair wallaby and

⁶ Age estimates obtained along the ancestral and modern Darling River systems describe a staggered development of middens at approximately 39, 28, 15.5 and 7.7 cal kBP, attributed by Balme and Hope (1990:99) to variation in water inflows and aquatic resource availability. The ¹⁴C ages also indicate the major avulsion between the ancestral (anabranch) and modern Darling systems occurred around 10–7.5 cal kBP (Balme and Hope 1990).

⁷ The 26 ka age represents the lower limit of the Cohuna Silt, the unit containing all skeletal material at Kow Swamp, though Stone and Cupper (2003:110) suggest the remains may be constrained more narrowly within this unit.

betting (Luebbers 1995:21). The Monak Swamp middens are interpreted by Edmonds (1997:17–19) as having formed during short, small-scale events specifically targeting colonies of *A. jacksoni*. On the Darling Anabranch, i.e. the ancestral Darling River, the earliest reported channel-based middens occur from around 18.4 ka (site KGE 1 reported in Balme and Hope 1990:Table 1).

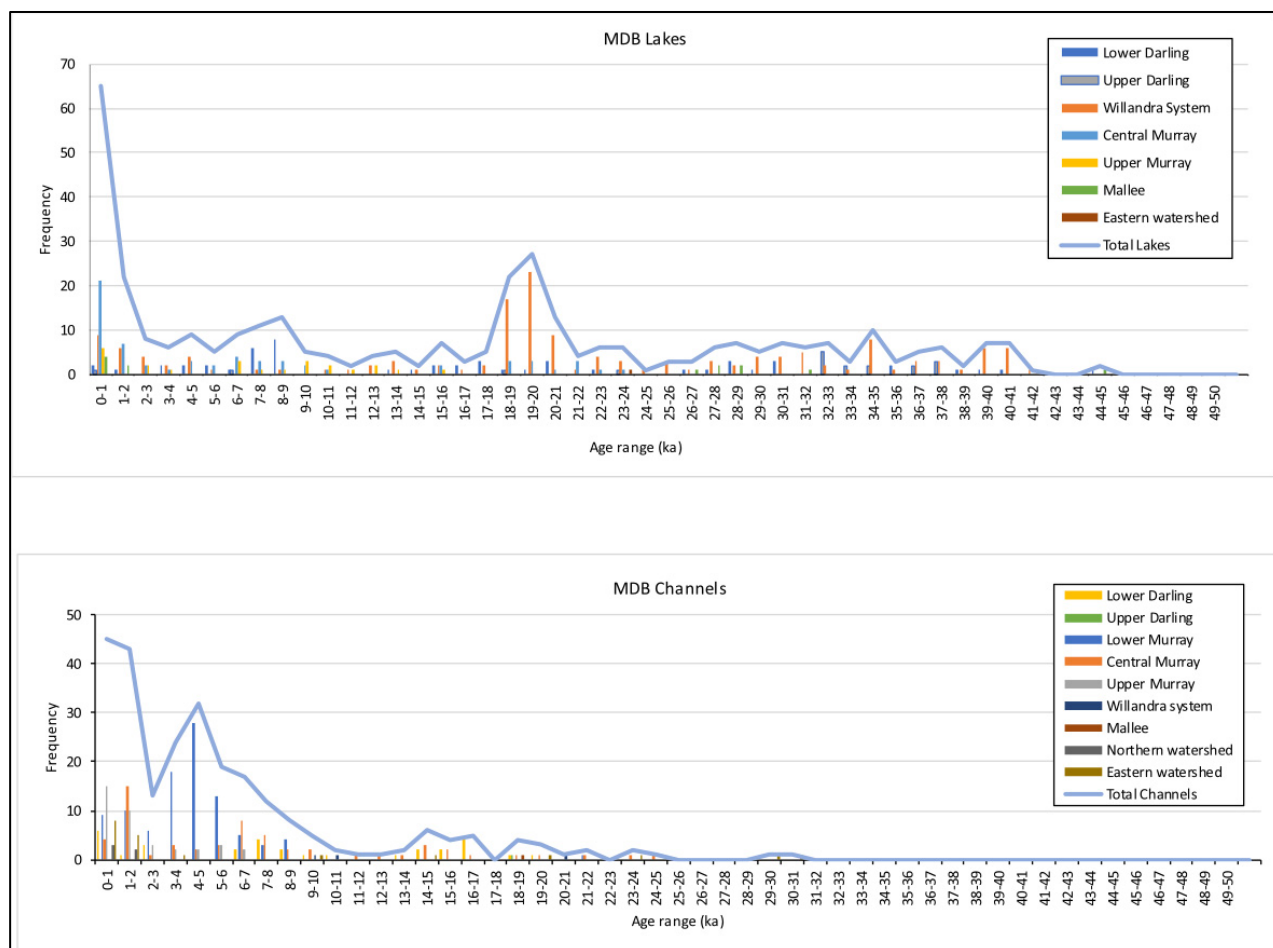


Figure 2-3: Calibrated median age determinations from lake and channel-based occupation sites (see Figure 1-1 for location of MDB regions).

The lag to channel-based sites along the River Murray is pronounced in SA where the majority of age estimates relate to Holocene occupation (Bourman et al. 2022; Mulvaney 1960; Mulvaney et al. 1964; Pate et al. 1998; Pretty 1977a; Smith 1982; Tindale 1957; Wilson et al. 2012; Wilson 2017). The two exceptions are a 20–16 ka OSL range for a series of three burials at Roonka East Bank (Robertson and Prescott 2006) and a disputed Pleistocene age on possible hearth features at Roonka Flat⁸ (see Figure 2-2). Ages reported on the River Murray in SA have ranged between

⁸ Determining chronologies within dune-fields is fraught given the complex deflationary and depositional nature of these landscapes. Paton (1983:320) suggests a date of 6910 ± 450 BP (ANU-1408) [9321–6408 cal BP] is probably a

8,390–8,190 cal BP (ANU-3119) ka at Glen Lossie on the Lower Murray (Wilson et al. 2012) to 350 ± 200 BP (ANU-6899) (793 cal BP) returned on ancestral remains in the Katarapko Island burial ground in the Riverland (Dowling 1990).

A significant change in the nature of middens along both the Murray and Darling River corridors occurred c. 15 ka as the typically small, discrete features gave way to often sprawling and stratified deposits. Within the greater Darling region, this timing includes the first large-scale harvesting of freshwater mussel from Tandou Creek (Allen 1972:235–244) and coincides with the introduction of larger numbers of fish and bird remains into other Darling corridor middens (Balme 1990:187, 1995). Similarly, Prendergast et al. (2009) have suggested that a series of large freshwater mussel shell middens exposed across SBDs at Neds Corner⁹ demonstrate that the earliest ‘substantial’ occupation of the Central Murray corridor had occurred c. 15 ka (see also Luebbbers 1995). This timing is contemporaneous with the development of similar scale middens at locations such as Merbein, Dareton, Red Cliffs, Gol Gol and Lake Benanee (Clark and Hope 1985; Coutts and Victoria Archaeological Survey 1977; Edmonds 1998:Table 5.1; 2007; Johnston 1990; Lance 1993; Luebbbers 1995; Luebbbers and Ellender 1991). In several cases, the development of these middens was evidently abrupt. The Dareton midden investigated by Johnston (1990 cited in Lance 1993), for instance, extends for 3 km along a cliff top, forming a semi-continuous lens up to 14 cm thick. Two near identical ¹⁴C determinations of 12,450±80 BP [Beta-38416] and 12,420±80 BP [Beta-38418] (c. 14,600 cal BP) obtained on shell samples separated by 1 km, suggests an abrupt though possibly short-lived and large-scale collection of freshwater mussel in this location (Lance 1993:28).

The proliferation of channel-located middens also coincides with the development of large-scale, superimposed and thicker middens at Lake Victoria found throughout the upper Talgarry Sand (Kefous 1983:118, 121). Within the western MDB, the staggering array and extent of

more reliable age estimate for the ‘well defined [Pleistocene] living floor’ identified by Pretty (1977a) at Roonka Flat. A series of hearth-like features on this floor had no associated cultural material. No direct ¹⁴C ages have been determined for the East Bank burials which were originally described as ‘little more than shadows in the sand’ (Robertson and Prescott 2006:2592).

⁹ This included the Homestead Midden which was dated to between 15,000 ± 88 cal BP (Wk-15,263) and 15,262 ± 720 cal BP (Wk-15262). These age estimates were later confirmed by Garvey (2017).

archaeological material deposited around this lake is a standout feature (Hope 1998). Estimates of between 6,000–16,000 individual burials around the lake shoreline reflect upon its regional significance as a continuing and ‘central focus’ of Aboriginal occupation (Luebbers 1995:8). Numerous and often laterally extensive middens continue throughout the lunette (Hope 1998:121-122) with the volume of shell in individual deposits estimated to be as much as 3,750 m³ (Djekic 1980 cited in Kefous 1983). As above, the bulk of this material occurs through the upper section of the Talgarry Sand and dates to within the last 15,000 years, with potential clusters occurring 18–12 ka, 7–4 ka and 2 ka (Hope 1998:216).

As Garvey (2013:120; see also Hope 1993:190–191; Lance 1993:30) contended, the constrained occupation timeline along the River Murray is difficult to reconcile given that the river corridor would have provided ‘a constant source of water and other significant resources’ and an obvious fall-back for people during the LGM. Prendergast et al. (2009; see also Pardoe 1995 and Pate 2017:130) have argued that initial occupation in the Murray corridor was tied to an increase in the ecological productivity of riverine environments, in part through the creation of high resource value billabong habitats in the increasingly sinuous deglacial riverine system. Clark and Hope (1985:83) proposed a similar explanation for the rapid development of river middens from 15 ka, suggesting that an ecology more favoured to the growth of freshwater mussel made them more accessible and/or abundant than other foodstuffs, supporting a period of specialisation, possibly by larger numbers of people. Neither of these explanations, however, provide a comparison between the relative productivity of the pre-LGM phase riverine systems of the Central Murray and the lacustrine habitats of the Willandra/Menindee/Tyrell systems, i.e. was the Murray corridor so depauperate in comparison so as to deter large-scale occupation for a period of 20,000 years? Hope (1993:193; see also Luebbers 1995) has also offered a number of possible explanations for the absence of older River Murray sites that include a differential exposure of sites, the burial of sites on floodplains, hydrologic regimes that did not support the large-scale collection of shell, and the erosion of older surfaces (and sites). These are all valid arguments, though may be downplayed to some extent in terms of the Riverland record, as discussed in later chapters.

The widespread development of often large, diverse and stratified middens c. 15 ka represents a significant juncture in the MDB record. On the face of it, this evidence may indicate a refocusing of regional economies and/or demographic change. Importantly, parallels might also be drawn to the

intensified use of resources observed in the late Holocene. Indeed, Kefous (1982) argued that these middens point to relatively high late Pleistocene Aboriginal populations along the Murray system, and the notion, therefore, that ‘demographic packing’ had been the underlying impetus for late Holocene change should be reconsidered (see also Balme 1991). What needs to be determined in these arguments is what intent and context do these characteristic middens actually represent and whether direct comparison with the preceding or subsequent record is necessarily valid. Can we be certain that large middens necessarily equate to large groups of people given the specific context and intent of freshwater mussel collection at that time? As Morgan (2015:195–196) has argued, there are many potential ‘pathways to increases in economic output and the development of complexity in hunter-gather economies’ and many factors unrelated to population levels that could potentially mimic population-mediated change in assemblages: foraging goals, prey habitat preference and behaviour, environmental change or technological innovations, for instance. Klaver (1998) has similarly argued that change observed in settlement evidence cannot, in and of itself, be used as evidence of population change.

2.5 The Holocene

Debate around perceived intensification in socio-economic systems looms large over interpretations of the Holocene record in the MDB. In outline, the common narrative proposes that relatively conservative and stable economic and social systems had persisted until a period of rapid change during the mid to late Holocene ushered in a distinctive suite of economic and social strategies. An expanded use of marginal resource areas (the mallee hinterland), an increase in site numbers, the emergence of site types suggestive of more intensive resource use (oven mounds, expansive middens), an increased emphasis on foods requiring significant processing effort (seed grinding) and forms of place making related to increased territoriality (cemeteries), have all been cited as evidence of change that was ultimately stimulated by population pressure. The following sections describe some of the key elements used in support of an intensification narrative in the MDB.

2.5.1 Distributions in ^{14}C

The use of time-series analyses of radiocarbon ages to model population trends have come to the

fore in recent years (Johnson and Brook 2011; Smith et al. 2008; Williams et al. 2008; Williams 2013; Williams and Smith 2013; Williams et al. 2010; Williams et al. 2015b; Williams et al. 2015c). These sophisticated statistical analyses rely on an underlying assumption that ^{14}C age frequency is a valid proxy for population size, though caveats such as the taphonomic loss of older ages are openly acknowledged and accommodated on some level (see for example Williams 2012). The analyses have stimulated the debate around the use of ‘dates as data’ (see Carleton and Groucutt 2021) and the generalisations and assumptions inherent in the intensification narrative (Ulm 2013). In outline, these analyses propose a series of pulses in continental scale population growth culminating in an exponential increase during the late Holocene (Williams et al. 2015c). This gross trend is punctuated by periods of sharp population decline coinciding with phases of major climatic and ecological instability, including the most significant collapses during the LGM and the period of heightened ENSO variability during the mid to late Holocene. Shorter period trends have also been resolved in the data. The construction of hearths (used as a proxy for occupation intensity) in the Paroo River region of the north-western MBD, for example, track a close correlation with wetter ENSO-forced events through the late Holocene (Holdaway et al. 2012). Similarly, Williams et al. (2008:255) found a strong correlation between modelled Holocene populations and variability in ENSO, with population peaks interpreted at 8 ka and 1.5 ka punctuated by a ‘sharp decline’ between 3–2 ka concomitant with a peak in ENSO cycling. This modelled decline, they argued, was of such ‘disproportionate amplitude’ that it may have represented a ‘critical human-environment threshold’ initiating a major restructuring of socio-economic systems (Williams et al. 2008:255).

Smith et al. (2008) contend that the spread of radiocarbon age estimates for the western MDB also reflect upon high frequency boom-bust variability in populations through time, rather than smooth transitions. Within this ‘saw-tooth’ pattern, however, the MDB appears to have remained a ‘persistent node’ and potential refugia throughout the LGM desertification (Williams et al. 2013). Importantly, the late Holocene trend also forms part of a longer-term growth in population initiated prior to late Holocene intensification (Williams 2013:8). On this basis, Williams et al. (2015b) and Williams et al. (2015c), have argued that the foundations of intensified systems may have been laid in an earlier move to low-level food production during the ameliorated interglacial environments of the early Holocene in which ‘demographic packing’ placed constraints on mobility and demanded a broadening of diets and increased control over resources—a repeat of the BSR narrative. Their argument was that the strategies developed in the early Holocene buffered later

Aboriginal populations against the peak in ENSO cycling (4–2 ka) and allowed a rapid, six-fold rebound in populations over the last 2,000 years (Williams et al. 2015b: see also Williams et al. 2010).

Similar conclusions based around ^{14}C frequencies continue to be scrutinised and debated. Studies conducted by Fanning et al. (2009b:142) in the western plains of New South Wales, for instance, concluded that the apparent late Holocene increase in the quantity of archaeological material in this region could be accounted for by geomorphic processes and the ‘cumulative action of chance erosion events’ without the need for inferring intensified landuse patterns. Furthermore, Holdaway et al. (2008) concluded that arguments in favour of intensification based on dating evidence may be fatally compromised through a lack of consideration of site formation processes, and specifically geomorphic context. Beyond trends in ^{14}C , however, there exists a range of complementary evidence used to support arguments in favour of intensified late Holocene systems in the MDB, as described in the following sections.

2.5.2 Oven mounds in the debate

Oven mounds are a distinctly late Holocene feature in the archaeological landscape (based on current dating) and are heavily implicated in the intensification debate (Hiscock 2008:188–189; Klaver 1998; Lourandos 1983; Martin 2006; Williams 1988). Historical descriptions of mound use are both detailed and widely distributed across the MDB (see exhaustive summaries in Edmonds and Long 1998:Table 5.1; Martin 2006, 2010:101–106). These descriptions invariably relate mounds to the large-scale processing of vegetation, with bulrush (*Typha* spp.) and yam daisy (*Microceris lanceolata*) featuring prominently. One of the earliest observations of mound use in the MDB observed ‘lofty mounds of ashes’ resembling small hills in the Lachlan-Murrumbidgee region formed by cooking food, principally bulrush root, in ‘kilns’ built from layers of heated stones or calcined clay where no stone was available (Mitchell 1839:80–81). Beveridge (1883:36–38) described mounds upstream of Wentworth as combined cooking places and kitchen middens, positioned with ready access to game and other food stuffs. Individual ovens were excavated into a mound, with clay heat retainer recycled or added to the structure over multiple firings (Beveridge 1865:17, 1883:37–38; see also Crawford cited in Pike 1965). Mounds are also invariably located in seasonal floodplains or wetlands. Lourandos (1983, 1997) viewed mounds as an engineered solution to allow semi-sedentary occupation of these highly productive though

regularly inaccessible environments (see also Beveridge 1883:39; Coutts and Victoria Archaeological Survey 1977; Kenyon 1912:89).

Historical observations also relate mound use to the production of plant-based fibre used for netting (Beveridge 1899: cited in Gott 1999; Mitchell 1839), a critical supporting technology in regional subsistence economies. The emergence of mounds broadly corresponds with an increase in the chewing of plant fibre as evidenced in the heavily scalloped dental wear observed on late Holocene Aboriginal remains (Pardoe 1995:710). No such evidence exists in the Pleistocene record (Pardoe 1993a:90). A prevalence of temporomandibular arthritis in the Central Murray remains examined by Webb (1989:117–118, 160) is also consistent with mechanical stress on the jaw related to the preparation of fibre (see also Littleton et al. 2013). Given the large yields of fish, waterbirds and land animals attributed to netting activities, the implications of intensive fibre production are significant in terms of economic capacity and the organisation of communal effort.

Mounds are a common feature within several disparate regions of the MDB including the Wakool River and Central Murray (including the Riverland), the Murrumbidgee/Lachlan Rivers, Hay Plains and Macquarie Marshes (Jones 2016b; Westell and Wood 2014). While their function(s) and societal role(s) are widely debated (Balme and Beck 1996:39; Westell and Wood 2014), in all regions, mound structures are comprised principally of oven debris (ash, charcoal and heat retainer) and the repeat firing of inground ovens seems to be a consistent aspect of mound use and construction (Martin 2011; Westell and Wood 2014:50). This is certainly the impression gained from historical observations (Beveridge 1883:37–40; Krefft 1865; Pike 1965).

Luebbers and Ellender (1991:31) have estimated that 3,000 mounds could be present within the floodplains of the Murray in northwest Victoria alone, representing the most frequent site type in the region, if not the whole of Victoria. Approximately 78% of the 64 radiocarbon dates attributed to mounds within the MDB relate to the last 2,000 years (Jones 2016b:16). Given these numbers and the apparent age distribution, it is evident that mounds had redefined various MDB landscapes over a relatively short period of time. Their rapid proliferation, and the scale of processing they represent, marks a refocusing of regional economies during the late Holocene defined by a greater reliance on aquatic vegetation treated in repeat-use inground ovens.

The use of oven mounds from the mid Holocene undoubtedly marks a key juncture in the MDB timeline and has provided some justification in the intensification narrative. Mounds embody the various themes of intensification in a single site type; representing a new extractive technology, a new and widely established site type and a more intensive use of resources (in this case predominantly aquatic vegetation) supporting the highly territorialised system depicted in historical accounts (Lourandos 1983; Lourandos and Ross 1994; Martin 2006:195–196, 254; Williams 1988). Whilst acknowledging the inherent risk in extending historical analogy to archaeological interpretation (Allen and Holdaway 2009; Hiscock 2008:5–6; Mulvaney 1999), it could be reasonably argued that the subsistence economies observed historically, or at least one significant component of them, have a timeline defined by the mid to late Holocene emergence of mounds. As such, the introduction of mounds necessarily defines a limit to the extrapolation of at least some strands in the historical record.

Mounds are a highly visual element of the cultural landscape, though as with the palimpsest nature of open scatters, it is important to recognise mounds as cumulative assemblages developed through repeat episodes of use (Klaver 1998). The refurbishing of ovens with clay heat retainers would have added large volumes of material to a mound structure during individual firings or over relatively short periods of sustained use. Beveridge (1883:38) estimated that a 'barrow load' of fresh material was required for each use, providing a rough correlate between mound volume and oven construction. A large mound would undoubtedly reflect repeat, though not necessarily long term or continuous use, and unless individual site histories can be determined (see for example Jones et al. 2022), some caution is required when interpreting the economic contribution of mounds.

2.5.3 Plant use

Plant foods represented a significant component of regional economies at the time of European contact, accounting for an estimated third of the total diet of Darling River groups (Allen 1972:75) and half the Lower Murray diet (Pate 1995a, 2000; Paton 1983:92). *Typha* spp., perhaps more than any other species, is referred to as a mainstay in terms of both its food and material contributions (Gott 1999). Angas (1847:89) referred to it as 'the staff of their existence' in relation to the Lower

Murray peoples and similar impressions are described across large parts of the MDB (Beveridge 1883:36; Clarke 1985; Gott 1982, 1983; 1999: Appendix I; Krefft 1865:65; Mitchell 1839:81; Wrangham et al. 2009).

Plant residues are seldom preserved in archaeological contexts (Denham et al. 2009:2) and instead, grinding material is commonly used as proxy evidence. Given the open site context of much of the MDB archaeology, establishing a reliable chronology for the use of grinding technology is also difficult, though seed processing, supported by residue, usewear and morphological traits, has been confidently dated to beyond 35 ka at Cuddie Springs (Dodson et al. 1993; Field and Fullagar 1998; Fullagar and Field 1997; Hiscock 2008:121; contra Gillespie and Brook 2006) and in Pleistocene contexts at Lake Mungo (Allen 1972:232–235, 1974:314; Fullagar et al. 2015; Hayes 2015) and the Menindee Lakes (Allen 1972; Pardoe 2003). The evidence, however scant, illustrates a wide geographic and temporal spread, though perhaps an early ‘incidental’ use of grinding technologies during the Pleistocene (Zeanah et al. 2017:3). Given the paucity of the Pleistocene sample, interpretation hangs heavily on interpolation. Two plausible scenarios are that grinding had been a continuing and embedded component of regional economies since its introduction sometime prior to 30 ka, or alternatively, that grinding was what Chatters (2009) refers to as a ‘sleepers technology’, applied in specific geographic areas within clearly defined temporal brackets with its use in disparate regions of the MDB unrelated until its proliferation during the Holocene (Smith 2015b).

Despite a long established timeline of use, Balme (1991:6–7) draws upon several compelling lines of evidence to suggest that seed grinding proliferated in the greater Darling region around the terminal Pleistocene and most likely during the early Holocene. Specifically, grinding material is seldom found in sites located on defunct Pleistocene waterbodies though is widespread in sites situated along the modern (Holocene age) Darling River course. It occurs in association with Pleistocene age deposits in lunettes and source bordering dunes only where these are positioned near waterbodies that maintain some flow under the modern hydrological regime. In these circumstances, grinding activity is likely to have occurred during the more recent phases of occupation and is simply superimposed on the older exposed Pleistocene land surfaces.

Allen (1974:311–312) attributed the extensive grinding assemblages in the greater Darling River

region to the large-scale uptake of cereal gathering, such as native millet (*Panicum* sp.), around the terminal Pleistocene as riverine species became either harder to capture/collect or declined in availability during a period of lower inflows. This interpretation was questioned by Balme (1991) (and has since been reassessed by Allen 1998), who argued that the introduction of grinding technologies and the broadening of diets in the Darling system around the terminal Pleistocene corresponded with increased rather than reduced water availability and productivity in riverine habitats. Instead, Balme viewed the introduction of grinding technologies as having been related to some social stimuli, specifically population increase, rather than an adaptation to environmental stress. Pardoe (2003:51) cited population pressure, climate change and concomitant species availability in the Menindee Lakes region as contributing factors in a move to a broader diet breadth and a heavier reliance on seed grinding, though places this change within the mid Holocene. This scenario more closely aligns to the late Holocene diversification in diets proposed by Edwards and O'Connell's (1995).

In describing the Darling River peoples as 'cereal gatherers', Allen (1974) also drew a distinction between what he saw as a seed-based economy in the Darling region and a tuber-based economy along the River Murray (see also Pardoe 2003:51). Seed use along the Darling is described by Smyth (1876: Vol I) as occurring on an 'industrial scale', an impression perhaps best illustrated in Thomas Mitchell's evocative description of hay-ricks of native millet extending for miles along the Darling River (Mitchell 1839:238–239). This image certainly contrasts with the observations of Berndt and Berndt (1993:76) that ground seed was a standby and not an item of preference or regular consumption along the Lower Murray where aquatic plants were the primary food items. Similarly, Paton (1983:92), in noting an absence of grinding material downstream of Morgan, suggested that terrestrial seed resources had represented a minor contribution in the Lower Murray economies, a region where Sturt (1849:100) observed that herbs and roots were the 'principal food'.

Grinding material identified within and upstream of the Riverland region, however, suggests that a simple seed-tuber distinction may not hold true here. Large numbers of 'grinders' manufactured on sandstone similar to that sourced from the Broken Hill region occur around Lake Victoria (Luebbers and Ellender 1991:15) and Casey (1973) collected large numbers of upper and lower millstones, mortars, pestles and pounders during the Chowilla Dam studies. Similarly diverse and

extensive grinding assemblages have been described in the Riverland (contra Clarke 2009:151) and include examples of the formal millstones generally attributed to the wet milling of soft seed.

In addition to bulrush and native millet, two other plant resources feature prominently in accounts of the MDB; namely yam daisy (*M. lanceolata*) and nardoo (*Marsilea drummondii*). Gott's (1983) exhaustive list of ethnohistorical references to yam daisy are concerned principally with the south-eastern and eastern highland margin of the basin (see also Frankel 1982), though Bellchambers (1931:132) considered that of all the tubers 'the yam [daisy] held first place in the estimation of the River Murray Aborigines'. Nardoo (*M. drummondii*) has also been generally dismissed as a dietary standby (e.g. Allen 1972: contra Curr 1886:193), though the form of grinding material and prevalence of 'nardoo-stones' in the Central Murray assemblages suggests a more significant role. It is worth noting that nardoo is specifically mentioned in the Eagle and Crow narrative (Tindale 1939) in which the two female protagonists collected it on 'a daily basis', along with other vegetable foods. The broad range of growing conditions, and importantly the salinity tolerances of this species (see Newall et al. 2008), would have potentially elevated its significance in the context of seasonal and longer-term variability in the riverine environment. Other grass and hard seed resources, such as *Acacia* spp., are similarly regarded as a 'hard time' fall back (Clarke 2018) and not commonly related to the River Murray corridor. Again, however, the Riverland grinding assemblages present some contradictory evidence.

In discussing the use of grinding, it is also important to note that the expansion and contraction of the arid zone across the last glacial cycle saw the application of grinding activities within the MDB transition between distinct climatic and ecological contexts.

2.5.4 Burial practices and ancestral remains

The association with dunes and sandy soils is a consistent aspect of burial distribution in this region. The most striking, and perhaps overlooked aspect of burial practice in the Riverland is, however, the almost exclusive locating of burial sites in sandy landforms within the confines of the valley itself rather than the fringing mallee plain. Perhaps this was the ultimate expression of a spiritual affinity with the river; people were buried where they were born and lived their entire lives, on the river that had nurtured them. RMMAC's profound connection to these places and

their ancestors is reflected in their continuing efforts to protect and maintain these places. The following discussion acknowledges this connection.

The nature, chronology and geographic distribution of burial grounds in the MDB, together with the morphology, palaeopathology and isotopic traits of human skeletal remains, have provided comparative datasets to the intensification debate. In an analysis of the Murray Black collection (Robertson 2007; Sunderland and Ray 1959) and investigations in the central and lower Murray regions (Pardoe 1988a, 1988b), Colin Pardoe theorised that formal 'cemeteries', as opposed to random burials, arose along the River Murray as poignant signifiers of ancestral ties to, and control over, land (Pardoe 1988a:14, 1988c). This occurred in the context of increased population densities from the terminal Pleistocene where the exclusive economic use of high resource value areas became increasingly important in the maintenance of social groups (Pardoe 1988a:9). Pardoe (1988a:7–8) observed that cemeteries were unevenly distributed, standing out above the background of single internments, and thereby suggesting that non-random factors had been in play in the selection of cemetery locations, i.e. cemeteries were strategically located to serve as territorial markers.

Cemeteries, as opposed to random burials, were defined by Pardoe (1988a) on the number of burials (more than 20 on average), contiguity, boundedness by landform or the distribution of graves and exclusivity of site use, i.e. cemeteries were not used contemporaneously as occupation spaces. Based on these criteria, Pardoe (1988a:6; 1995) suggested that cemeteries were a unique feature of the River Murray corridor. Furthermore, Pardoe (1993a:88) noted that 'virtually no skeletal evidence' is found on the River Murray prior to 13 ka, a striking comparison to a Holocene record defined in large part by its burial record. While cemeteries date from 13 ka in the Upper Murray (Kow Swamp), they become more widespread by 6 ka and become 'well defined and numerous in the last 4 ka' (Pardoe 1988a:9, 14, 1988c). The burials recorded during the Chowilla Dam project, for instance, date from 7–4 ka (Gill 1973a), the earliest Karadoc Swamp burials occur from 9 ka (Luebbers 1995), while a recent re-evaluation of the Roonka Flat site indicates that initial burials occurred around 7 ka with an episodic use since this time (Littleton et al. 2017). Furthermore, Pardoe (1993b:229–230) argued that long-standing regularity in mortuary practices (orientation, form, continuing cemetery use, variation in internment method based on age and sex) had reflected consistent defining aspects of society.

The legitimacy of Pardoe's criteria and inferences relating to territoriality have been questioned by others, notably Littleton (1999, 2002) and Littleton and Allen (2007) in respect to the Hay Plains record (see also Hiscock 2008:226–227). A pattern of a larger group of burials surrounded by dense clusters of graves is a common feature in this area (Littleton 2002:112). While this depicts a patterned behaviour indicative of place maintenance, only four locations fulfilled Pardoe's criteria relating to the number and density of burials. This is despite a similar formalism as that identified by Pardoe in the Central Murray cemeteries, i.e. the deliberate positioning of burials under consistent mortuary rules, together with an exclusivity of site use being replicated within small burial groupings (Littleton 2002:114–115; Littleton and Allen 2007). Littleton and Allen (2007) concluded that cemeteries had been used non-exclusively by small foraging groups and evolved more as 'persistent places' with their repeat use stimulated by memory and custom in the short term and by monuments (huts, mounded sediments, grave markers, carved trees), associated materials (mourning caps, kopi eggs, exposed burials) or a familiarity with landform use in the longer term. The wide variation in disposal method in the Hay Plains argued for a 'flexible, more fluid and less bounded system' of tenure in which 'cemetery behaviour was not necessarily associated with increased territorialism' (Littleton and Allen 2007:296).

The arguments around burial mode and cultural affinity assume that mortuary practices amongst individual groups would necessarily follow a clear set of rules over time, negating the possibility that sex, age, hierarchy, status, cause of death or any number of factors, may have played out in the style and methods of internment over the short term (Robertson 2007:127). The notion of highly territorialised social systems is, however, supported by other skeletal evidence. Skeletal morphology within the late Holocene River Murray population exhibit 'some of the greatest diversity in the continent while still maintaining a regional similarity' that is distinct from the Darling and Willandra systems, indicating a limited gene flow between neighbouring groups (Pardoe 1988a:12, 1988b:58, 1994:185, 1995). Furthermore, the morphological similarities between Pleistocene and Holocene populations in discrete geographically-bounded areas, i.e. related ancestor and descendant groups, indicate that stable patterns of gene flow had persisted over thousands of years (Pardoe 1993a:89, 2010:14–15). This proposition is supported by isotopic comparisons between skeletal material from the Lower Lakes and the Roorka Flat cemetery, which imply long-term and consistent dietary intake and limited movement of people across food-

defined territorial boundaries, at least during the late Holocene (Cockburn 2003; Pate 1995a, 1995b, 1997, 1998; Pate et al. 2002; Pate and Owen 2014). In essence, the isotopic data suggests that people had been buried in the same area they were born into and led their entire lives in, and according to Pate (2006:299, 231), lends support to the notion of increased late Holocene sedentism and territorial maintenance.

Similar conclusions have been made on other skeletal evidence. Webb (1984; see also Prokopec 1979) viewed the high level of violence related trauma, chronic and acute stress, infectious disease and osteoarthritis in the Holocene Central Murray skeletal record, as indicative of large, sedentary populations engaged in high workload. The high rates of cribra orbitalia¹⁰, a condition related to iron deficiency and anaemia, were considered by Webb (1984:169; 1989) to be far larger than would have expected in a 'hunter-gatherer' community, and instead, resembled rates expected amongst more sedentary populations where crowded environments raise the exposure to gastrointestinal parasites and infectious disease (see Latham 2013; Suby 2014). Webb (1984:170; 1989:148) saw periodic nutritional stress as a significant contributory factor in this phenomenon, possibly related to the seasonal reduction in riverine biomass being incapable of fully supporting the demands of high resident populations (see also Hope 1986; Paton 1983). It is also worth considering that this condition is commonly reported in early agriculture-based societies that became increasingly reliant on high carbohydrate diets with low protein, iron and Vitamin B12 intake—the maize-based diet of the Americas, for instance (Eshed et al. 2010:122; Larsen 2006; Papathanasiou 2005:388; Suby 2014; Walker et al. 2009).

Hill et al. (2016) attributed change in the symmetry and robustness of the femora of the post-ENSO skeletal material at Roonka to increased levels of mobility, primarily among the female component (see also Hill 2014). Their assertion that increased mobility was a response to a reduction in the predictability of the ENSO-influenced river runs counter to the overwhelming archaeological and ethnohistorical evidence of late Holocene sedentism in this region. The conclusions reached by Hill et al. (2016:97) are consistent with various behavioural

¹⁰ This condition is expressed as pitting and porosity in the orbital roof caused by an increase [hypertrophy] in red blood cell production and marrow expansion. Webb (1989) noted this condition in almost 34% of the skeletal material he examined from the Central Murray.

reconstructions, including mobility studies, that argue for a causative relationship between increased logistical mobility and anterior-posterior femoral rigidity expressed as asymmetry in the diaphyseal cross section (and conversely, increased circularity in less mobile populations) (Brock and Ruff 1988; Holt 2003; Maggiano et al. 2008; Nikita et al. 2011; Ruff 1987; Sladek et al. 2006; Stock and McIntosh 2016; Worne 2002). Bone is a self-organising tissue (Mittag et al. 2015:223) and the morphology of the arm and leg bones are known to be highly responsive to the levels of mechanical loading (Larsen 2006:16). Change in bone geometry is one adaptation to stresses brought about by habitual activity (Ruff 1987:392). However, Carlson et al. (2007:18–19) has cautioned against a simple bone geometry to distance travelled correlate, as factors such as terrain, habitat type and the nature of motion would also affect bone morphology. Attributing asymmetry to specific activities is difficult (Maggiano et al. 2008:475; Westcott 2014:113, 116). Furthermore, Carlson et al. (2007:20) suggested that ‘burden-carrying may be relevant to loading regimes of lower limbs’ and ‘may have equalised distance discrepancies between females and males in terms of loading conditions for the lower limb’ (see also Hilton and Greaves 1995: cited in Carlson et al. 2007). Westcott (2014:121) asserted that ‘copious non-ambulatory habitual activities apply loads to the lower limbs that clearly have an effect on cross-sectional strength and the shape of the femur’. Given this, the possibility must be considered that rather than mobility, the changes recognised in the Roonka assemblage may relate, in part, to the nature of physical labour conducted by women. The strain and stresses resulting from the collection and relocating of large, heavy hauls of *Typha* spp. may be one candidate.

2.6 An emphasis on change or a change in emphasis?

The economic diversity recognised in historical observations of Aboriginal people frames the late Holocene record in the MDB. It is undoubtedly a seductive picture, and there is a temptation to view it as the ultimate outcome of some trajectory—technologies and economies honed to this refined endpoint. Without a similar overlay, there is also a risk that earlier evidence of change and innovation is overlooked, or at least understated (e.g. Lourandos 1997:299–300). A number of researchers have questioned whether the BSR captures a distinct period of diversification in diet across the Holocene-Pleistocene boundary or was simply part of a longer-term trend that could be described more appropriately as changes in emphasis within a consistent resource base (Dobney et al. 1999; Edwards 1989; Humphrey 2012). A similar scenario might be considered for the 50,000-year record of Aboriginal occupation captured in the MDB. It is debatable whether this

record describes clear directional change defined in large part by distinct, diverse and innovative late Holocene socio-economic systems. Instead, people seem to have been exploring their options from the get-go, and if anything, the evidence describes a nested assemblage throughout the entire occupation timeline, though with a continually shifting emphasis placed on a specific resource or resource group. Furthermore, there is evidence that complex processing technologies requiring high handling costs, such as grinding and netting, have a long tradition in the MDB and occur within timelines seemingly independent of high population densities and intensified systems (Balme 1995; Field and Fullagar 1998; Fullagar et al. 2015). This evidence poses a challenge to the underlying presumptions of foraging theory as applied in the MDB (e.g. Bird and O'Connell 2012:46–47).

Balme and Hope's exhaustive surveys and analysis of 216 middens in the greater Darling region (Balme 1995; Balme and Hope 1990) remains one of the most comprehensive assessments of subsistence strategies undertaken in the MDB, to date. These surveys used a combination of radiocarbon dating (88 determinations) and geomorphological interpretation to frame a Lower Darling chronology. Importantly, this included the assessment of groups of time-related sites from small geographic spaces (e.g. the Lake Tandou lunette) from which the amalgamated assemblage could be seen as representative of discrete and persistent residential nodes. Faunal remains were differentiated on the basis of in situ/well-defined deposits (e.g. excavated contexts, intact lenses or well-defined and clearly associated lags) or eroded deposits. A conservative approach saw conclusions based largely on the former. A variety of species, notably the mammal component, were consistently associated with less-defined (eroded) sites for which an association with cultural material could not be confidently assumed. Balme (1995:11) concluded that of the mammal species, *Bettongia* spp. were the only component that could be confidently related to in situ archaeological deposits.

The most notable change in both the character and diversity in the Darling River assemblages occurred in the period 9,000–5,000 years BP with the development of larger and more diverse assemblages and the inclusion of larger numbers of fish and bird remains. The earlier Pleistocene assemblages were essentially small, single-species deposits interpreted as the refuse from single foraging events. Whilst the study did not include survey beyond the immediate area of rivers and lakes, Balme (1995:12) asserted that 'Aboriginal people were more than casual users of these

[aquatic] resources', and despite the bias in survey coverage, riverine and lacustrine environments are likely to have remained the key defining element of regional subsistence. A greater input from non-aquatic resources may have accommodated periods of hydrological stress¹¹. A variety of fishing techniques were likely to be represented. The use of gill nets in the Pleistocene assemblages of sites TNL 20 and 36 was suggested in the consistent size range of otoliths. The investment of time and energy¹², and the specialist knowledge required to make gill nets was considered a clear indication of the integral nature of aquatic resources across an extended timeline. The evidence, in summary, suggested that a consistent range of resources and related collection strategies had persisted in this region of the MDB over a period of 27,000 years (Balme 1995:18).

As above, Balme's thesis preferenced 'well-defined' midden material. If, for argument sake, the alternative is considered, i.e. recognising all faunal material as part of cultural deposits, the data collected by Balme might indicate a continuing contribution from mammals, though with a marked reduction in diversity during the early Holocene. This reduced diversity is seen principally amongst the smaller species (*Muridae* spp., *Antechinus* sp. and *Sminthopsis* sp.) and is coeval with the expanded exploitation of fish and birds. In addition to the ubiquitous presence of freshwater mussel, commonalities across the time brackets described by Balme would also include yabby, emu egg, golden perch, hare wallaby and wombat (*Vombatus* spp.). A real-world scenario might fall somewhere between this and Balme's original and conservative interpretation. A comparison of on-site and off-site faunal remains could inform this discussion. If the range of fauna identified in eroded contexts within archaeological sites is not replicated beyond the site boundaries, this would tend to suggest a cultural origin.

It might also be expected that historical accounts, or aspects of them, could be extrapolated to at least the last several thousand years, though the discrepancy between the late Holocene record described by Balme, and the historical observations of resource diversity, are stark. The differences between direct observation and archaeological evidence highlight the biases that

¹¹ Freshwater mussel derived ¹⁴C ages clustered around distinct intervals at 35, 24, 13, 7 and less than 100 years BP.

¹² Satterthwait (1987:615) estimated that a 5 cm mesh waterfowl net measuring 18.3 x 12.2 m would require 7,500 – 9,000 m of cord and 90,000 individual knots and would take between 97–112 days to manufacture beyond the collecting and processing of the plant fibre.

would perpetuate more broadly throughout the record. With this in mind, it is worth reiterating the key observation of Balme (1995:18) that despite these obvious biases, the evidence suggests that a consistent range of subsistence strategies had persisted in this region over a period of 27,000 years, and that this included the continuing and embedded use of aquatic habitats. A similar conclusion was reached by Allen (1972:351) in respect to the greater lower Darling region. Species representing a diverse array of habitat (terrestrial and aquatic), habit (arboreal, burrowing, flying, ground dwelling) and size, are all represented, and an equally diverse range of procurement strategies is implied. This included an early and continuing use of netting, with all the social implications attached to it.

On the lower Murray, the mid to late Holocene archaeofauna recovered from the Ngaut Ngaut (Devon Downs) (Hale and Tindale 1930; Smith 1978, 1982) and Tungawa (Fromm's Landing) (Mulvaney 1960:54; Mulvaney et al. 1964) shelters are essentially representative of the modern riverine taxa, though Hale and Tindale (1930) identified potential change that was indicative of increased aridity during the period of occupation at Ngaut Ngaut. Similarly, the open site assemblage at Roonka examined by Paton (1983; see also Pretty 1986) indicated that a relatively stable economic pattern had continued from a basal age of 8.5 ka. Stable carbon and nitrogen isotope analyses from the late Holocene Roonka burials suggest a dietary contribution of as much as 40% from fish and mussel (Pate 1995a, 2000:70). These assemblages are representative of the broad suite of species, habitat and procurement strategies recognised in historical observations from this region (see also Wilson et al. 2022).

2.7 Chapter summary

Interpretations of the MDB record, as outlined in this chapter, have drawn upon a broad scope of evidence and methodological approach, and have applied data gathered across varying geographic and temporal scales. Several key themes propagate through the discourse; namely the timing and nature of initial colonisation, the socio-cultural responses to climate-forced shifts in riverine/lacustrine ecology, and population dynamics tied to these shifts. The synthesis of radiocarbon dating through time-series analyses have tended to reinforce the common narrative of late Holocene intensification as being a transformative process within the MDB, defining categorical states before and after. They also, however, hint at potentially long lead times in which

the foundations of change may have taken form (Williams et al. 2015b).

The notion of 'demographic packing' and/or environmental change as forcing agents tend to underpin most interpretive frameworks in the MDB. In respect to the Darling River record, for example, Balme (1995:19) concluded that whilst aggregation events may be represented in the late Pleistocene evidence, there was no suggestion of 'base camps' during this period. Clark (1987:46) had similarly argued that there was 'simply not enough [archaeological] material present to support the interpretation that there was any form of permanent or semi-permanent settlement along the [Willandra] lake shorelines'. This contrasts with a Holocene pattern where more sedentary behaviours and higher Aboriginal populations are implied by larger and more frequent sites containing more diverse material assemblages. These higher Aboriginal populations are thought to have generated increasingly complex social relationships that imposed some restrictions on mobility. It has been theorised that a broadening of diets to include a greater emphasis on seed grinding, a high-cost though reliable dietary component, was required to compensate for the reduced foraging range and longer periods of residency.

As is the case elsewhere, the late Holocene record in the Riverland includes multiple lines of evidence that suggest change in socio-economic systems. The rapid and widespread introduction of oven mounds is perhaps the most obvious archaeological expression of this and represents one notable addition in terms of a site-type along the MDB timeline. As with the grinding evidence, mounds point to an increased emphasis in the collection, processing and consumption/use of vegetation through the late Holocene. This assessment may be supported by a stable carbon and nitrogen isotopic analysis of the Roonka skeletal assemblage by Pate (1995a, 2000), which identified a shift from terrestrial protein during the early Holocene to a higher component of vegetable foods and/or freshwater mussels (see also Smith 1982:115) during the late Holocene, at least in the older male component.

As with the intensification debate more broadly, understanding the stimuli behind these changes remains the fundamental conceptual issue. Morgan (2015:195-198) asserted that the process of intensification must have worked in a 'dynamic, feedback-mediated, stepwise or cyclical manner' with resource pressure arising from population change, stimulating 'changes in technology, work

strategies, or social norms, and vice versa'. The question is whether the MDB evidence necessarily reflects fundamental reorganisations of socio-economic systems or simply changes in emphasis. As Balme (1995) contended, MDB peoples have always been able to accommodate fluctuations in their resource base, at times emphasising the use of particular resources over others. The development of large-scale middens around the terminal Pleistocene on both the Darling and Central Murray regions, for instance, illustrates a major upscaling in the collection of a resource found throughout the entire MDB record. These middens point to the repeat, large scale and targeted collection of shellfish, and imply a very different scenario of mobility and logistical strategy than the ephemeral nature of much of the Pleistocene record.

The open-site nature of much of the MDB record imposes some inherent biases and complications in interpretation. In acknowledging these caveats, the weight of evidence highlights the following compelling features along the MDB timeline:

- Initial occupation in the MDB began sometime between 50–45 ka and appears to have been centred specifically on the Willandra, Menindee and Lake Tyrell systems until around 29 ka. These complexes of large capacity lakes appear to have defined the limits of expansion into the southwestern MDB. Importantly, initial occupation of equivalent lacustrine environments attached to the River Murray corridor occurred significantly later.
- As Pardoe (1995:701) asserted, lakes have operated as 'early and continuing nodes for occupation and group affiliation' in the MDB. Lakeside assemblages have also tended to be more diverse than equivalent age channel sites and invariably include terrestrial and aquatic components that are suggestive of central base foraging.
- A lag of 20,000 years exists between the earliest evidence of MDB occupation and anything approaching large-scale settlement within the River Murray corridor.
- Indisputable ^{14}C evidence of occupation in the Lower Murray region occurs from around 8.5 ka though an earlier (20–16 ka) OSL-based assessment is provided for burials on the Roorka East Bank (Robertson and Prescott 2006). The increase in the rate of ^{14}C determinations from the early Holocene in the MDB is partly attributable to the inclusion of Lower Murray sites. Interpretations of Holocene population increase based on ^{14}C frequencies may, therefore, relate to pan-regional rather than sub-regional patterns.
- The character and distribution of riverine middens changes noticeably c. 15 ka. This includes the development of large-scale deposits of freshwater mussel (*A. jacksoni*)

positioned on high banks, cliff-lines and SBDs overlooking the then active channels throughout the Central Murray and Lower Darling regions.

- The introduction of oven mounds represents an additional element of economies in discrete parts of the basin during the late Holocene, including the Riverland. The implications of mound use, simply in terms of the scale of processing, are significant and are likely to be centred around an upscaling in plant use.
- A late Holocene increase in the use of plant foods is also suggested in isotopic, dental and palaeopathological evidence, and in the proliferation of grinding technologies.
- An increasing number of clearly demarcated burial sites/cemeteries were established and maintained along the Murray River and its lake systems through the Holocene.
- A detailed ethnohistorical record provides a demonstrable context for the late Holocene record and describes a complex array of subsistence and social practices. These display commonalities across large parts of the MDB, as well as distinct regional differences.

CHAPTER THREE: RIVERINE LANDSCAPES OF THE WESTERN MURRAY-DARLING BASIN

3.1 Introduction

A large body of geomorphological literature exists for the various river systems of the MDB. Previous interpretations relating specifically to the Riverland, however, are few, and dated. Early work undertaken by Gill (1973a) on the Chowilla floodplain remains the most comprehensive local study, to date, though the chronology established in this study (Gill 1973a:83–84) has been revised by later work (e.g. Chen 1995). More recent local studies (ABARES 2011; Hollingsworth 1990; Rural Solutions SA 2007; Sharley and Huggan 1995) have canvassed riverine geomorphology largely as a side to soil reconnaissance, vegetation surveys and groundwater investigations, and provide limited chronological or interpretive detail.

In the absence of local interpretation, geomorphological schema developed elsewhere in the MDB provide an essential framework for this thesis. Principal amongst these is work conducted by Prendergast et al. (2009) in the Lindsay Island-Neds Corner region, located upstream of the South Australian border (Figure 1-2). Other comparative studies include reconstructions based on digital elevation models (DEM) together with other remote sensing technologies, dating programs, soil analyses and field-based research (Clark et al. 2010; Clarke et al. 2008; Fitzsimmons 2017; Fitzsimmons and Barrows 2010; Fitzsimmons et al. 2013; Fluin and Gell 2008; Fluin et al. 2007, 2009; Gell et al. 2009; Gell et al. 2006; Kemp 2001; Kemp et al. 2017; Kemp and Rhodes 2010; Kemp and Spooner 2007; Kotsonis et al. 1999; Page 1994; Page et al. 2001; Page et al. 2009; Page and Nanson 1996; Page et al. 1991, 1996; Pain et al. 2011; Tan et al. 2009; Williams et al. 1991).

As elsewhere, the MDB witnessed profound environmental change across the last glacial-interglacial cycle. Responses in riverine systems to changing hydroclimate manifest in a variety of ways including the development of discrete channel complexes, floodplain terracing and fluctuations in lake conditions. This chapter describes the key processes that have shaped riverine environments in the south-western Murray-Darling Basin and presents a palaeoenvironmental narrative spanning the currently documented timeline of Aboriginal occupation in this region.

3.2 Processes and common landforms

The rivers of the southwestern MDB can be described as low gradient¹³, meandering, single-thread, scrolled systems (Nanson and Croke 1992:462; Schumm 1981; Thoms and Walker 1992) in which the fluvial-alluvial landscape is developed through the continual migration of the main river channel. This migration consumes older surfaces, continually recycling sediments through erosion and redeposition (Nanson 1986:1472). An accretionary ridge and swale topography develops naturally as meanders expand through erosion of a cut-bank (outer) and lateral accretion of sediment on point bars on the inner bank (Figure 3-1). Characteristic source bordering dunes (SBD) may also form where the point bar and channel deposits are prone to deflation, for instance where there is regular and extended drying of the floodplain. Beyond the main channels, vertical accretion of the floodplain occurs in crevasse splays, levees and backplain deposits during periods of flood (Bridge 2003; Galloway and Hobday 1983; Nanson 1986; Nanson and Croke 1992:462). The gradual closure of meander loops and the capture of flows via chute channels can lead to meander cut-off, isolating the defunct channel as an oxbow lagoon (see example in Figure 3-1). These wetlands are a common feature of the Riverland floodplains. More substantial, and potentially rapid, adjustments in floodplain operation can also occur through channel avulsion.

As well as lateral migration, floodplain surfaces undergo continual vertical adjustment through cycles of incision and aggradation (Figure 3-2). These cycles of cut-and-fill are reflected in the development of terracing over the long-term, though short-term adjustments can also occur, for instance in response to catastrophic events. These cycles are accompanied by changes in the frequency, duration and height of floodplain inundation as the spread of floodwater adjusts to a renewed topography and base-level. Responses in the habitat mosaic are an inevitable consequence. Discerning the pace of these adjustments is difficult given the sheer complexities of floodplain topography and the unknowable variation in flows through time, though as a general guide, Nanson (1986:1471–1472) has suggested that incision may be followed by a period of rapid re-filling and then a slower and more gradual reforming of the floodplain as it approaches equilibrium with the hydrological regime.

¹³ In the upper Riverland, the River Murray falls on average approximately 4 cm/km between Locks 6 and 3 (Overton et al. 2006).

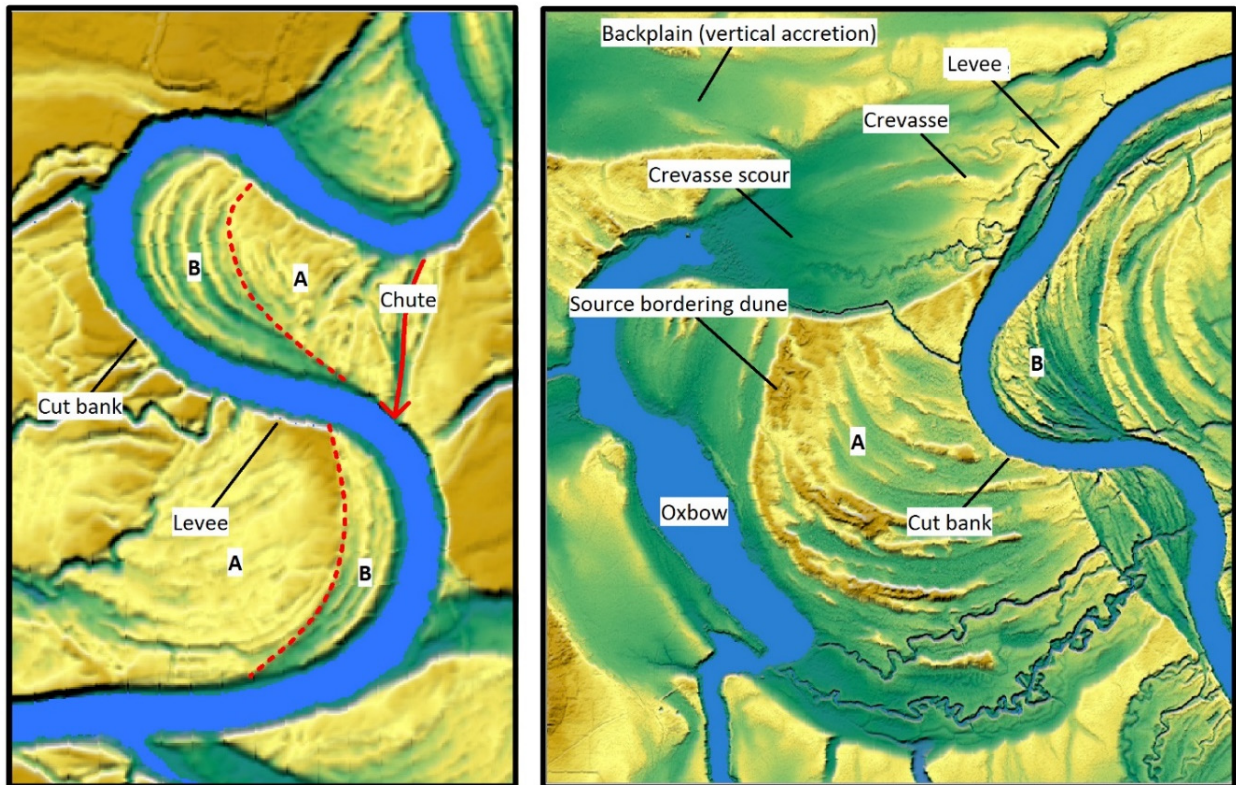


Figure 3-1: Common floodplain elements. A sequence of meander scrolls that developed under different flow regimes are marked as A (older) and B (younger) in each slide.

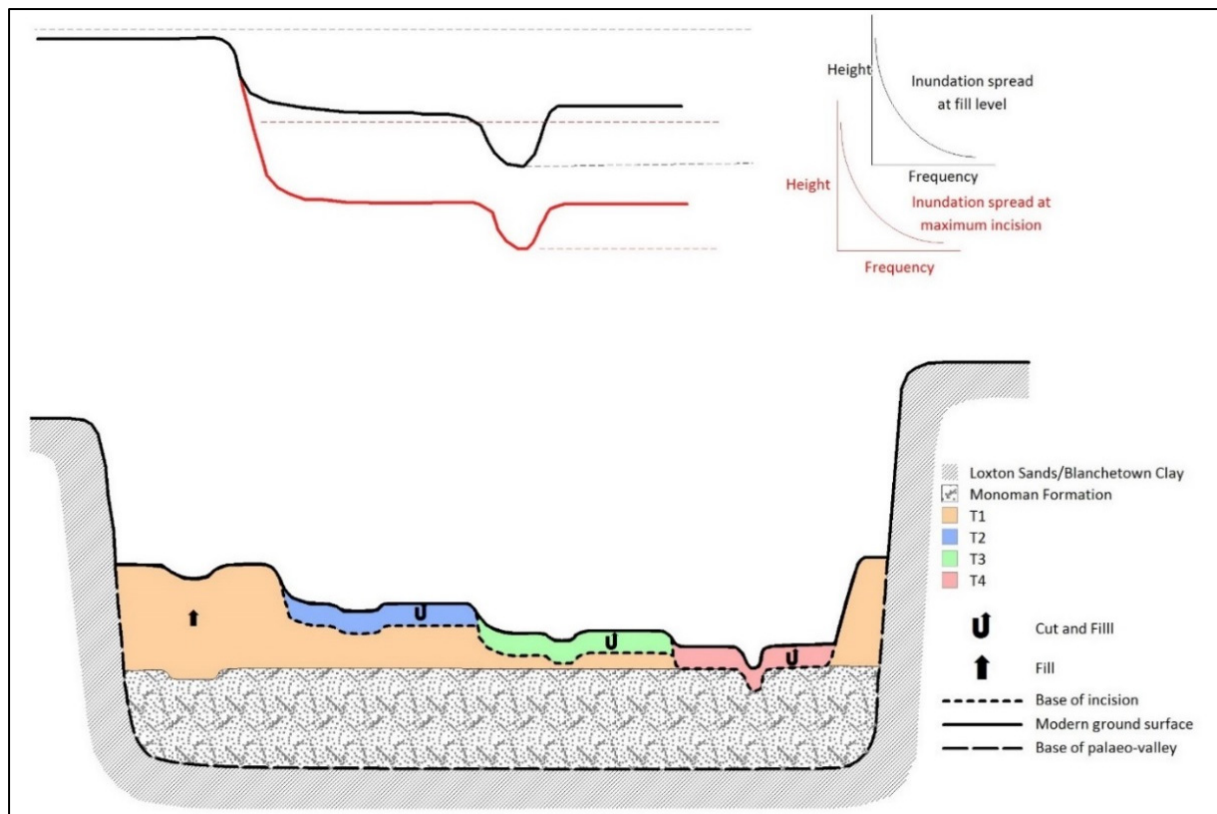


Figure 3-2: Schematic representation of the cut-and-fill process in respect to the terracing in the Riverland floodplains.

The flood inundation modelling (FIM) of the Pike floodplain presented in Montazeri and McCullough (2016) broadly illustrates the consequences of the cut-and-fill process. The flow rates, recurrence interval and heights of three key steps in the FIM at Pike are presented in Table 3-1. As seen, a reduction in base level of one metre is roughly equivalent to stepping down through the flow rates or essentially increasing the return periods compared to the modern scenarios. Between the 95–55 GL/day and 55–35 GL/day scenarios, a metre drop would reduce the extent of floodplain inundation by approximately 49% and 67%, respectively. Flood heights (and extents) that are currently experienced on a yearly basis would occur on a three-yearly cycle, biannual flooding would occur on average every five years. The frequency of longer period flooding events would also be reduced. In the 90-day scenario presented in Montazeri and McCullough (2016), a reduction of one metre in base-level would essentially see all areas beyond the main channels inundated at a return period of five years or more. This would include all the major wetlands on the Pike floodplain. The viability of a range of floodplain species dependent on the long-term and frequent inundation of these habitats would be compromised under these conditions.

Whilst these scenarios are unique to the topography and hydrology of the modern Pike floodplain, the underlying process would have applied equally to the palaeolandscapes. It would also be expected that the transitions between terraces would have seen potentially rapid reconfigurations of the habitat mosaics, and any impacts would also be compounded by reductions in flood duration. The upshot is that continual, perhaps rapid and/or punctuated changes in the base level, brought about by cycles of floodplain incision and aggradation, would have seen recurrent adjustments in habitat. These adjustments would have been further complicated by inflow conditions. Far from being a static landscape, the riverine corridor represents a constantly shifting canvass with change occurring on seasonal, decadal, millennial and longer timescales. This variability has been **the** context of Aboriginal occupation and lifeways.

Table 3-1: A summary of floodplain inundation based on Lock 5 data and modelled for the Pike floodplain.

Flow rate	35 GL/day	55 GL/day	95 GL/day
Return period (years)	1	2	5
Description of floodplain inundation	Flows largely contained within deeper channels and lagoons connected to river with modest, if any broader floodplain inundation	Anabranh creeks and deeper backplain lagoons inundated	Broadscale floodplain inundation including backplain areas outside channels and lagoons
Water elevation (m AHD)	~13.6	14.5	16.3
Area inundated (Ha)	760	2317	>4585

3.3 Indicators of change

Palaeoenvironmental reconstructions in the MDB have tended to emphasise three geomorphological elements: namely terracing, channel planform and lunettes. The development of all landscape elements can be related to inflow conditions which, in the case of most MDB rivers, are governed by run-off into the headwater catchments and are rarely attributable to local factors. Local context is, however, revealed with complementary evidence that includes soil development and the activation cycles seen in terrestrial dunes.

3.3.1 Terracing and channel planform

Terracing is a common feature of MDB rivers and has been previously described in the Riverland by Gill (1973a). Terracing has been viewed by some as an adjustment to sea level (Gill 1973a:47; Helfensdorfer et al. 2020; Mackay and Eastburn 1990; Rogers 1978:15, 1990; Twidale and Bourne 2009:212) whereby a gradual incision of the valley occurred as sea levels fell to the LGM low-stand and infilling of the valley subsequently occurred as sea levels rebounded to the c. 8 ka highstand. This scenario may, however, apply more specifically to the coastal reaches of the river (De Carli 2020; Hubble et al. 2014). Further upstream, terracing is likely to be influenced more so by cycles of fluvial incision and aggradation related to climate induced hydrological transitions (Bowler 1978; Bowler and Harford 1966; Bridge 2003: Figure 9.9; Brown 1997; Daley and Cohen 2018; Hosfield and Chambers 2005; Kemp 2001; Kemp et al. 2017; Kemp and Rhodes 2010; Luebbers 1995; Ogden et al. 2001; Page 1994; Page et al. 2001; Page et al. 2009; Page and Nanson 1996; Page et al. 1996; Pels 1964, 1966, 1971:45; Prendergast et al. 2009). In this scenario, incision of a new terrace occurs as enhanced fluvial activity promotes the lateral migration of channels and the development of wide channel belts (Kemp et al. 2017:360; Page and Nanson 1996). Vertical aggradation then occurs across the stabilised terrace. This cut-and-fill scenario may be punctuated by catastrophic events which have a capacity to reform floodplains, stripping and reconfiguring landforms, potentially (re)incising terraces or promoting channel avulsion over the short term (Erskine and Peacock 2002; Lake et al. 2006; Nanson 1986; Nanson and Croke 1992). Changes in channel planform invariably accompany hydrological transitions. According to Schumm (1981), channel planform is controlled by stream power, sediment size, bank stability and load type (suspended or bedload) (Figure 3-3). In broad terms, channel planform varies between the two extremes of wide, shallow, high energy, bedload channels, and narrower, deeper, lower energy,

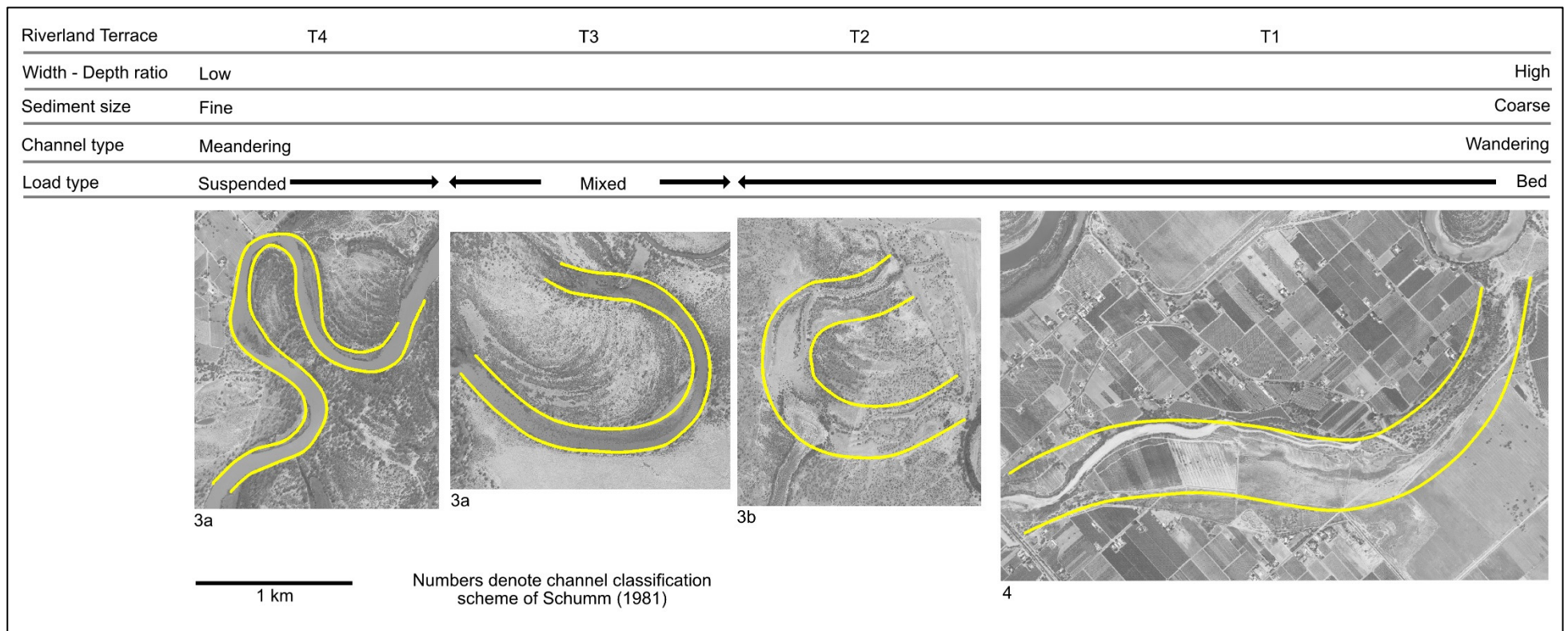


Figure 3-3: Classification of Riverland channel morphologies based on Schumm (1981). Examples shown here are from the Pike floodplain with Bookmark Creek shown on the far right.

suspended load channels (Galloway and Hobday 1983:71). Low variance flows tend toward more sinuous channels whereas high variance (flashy) flows tend to straighten channels and extend meander wavelengths (Mackay and Eastburn 1990). SBDs form through the deflation of sediments from regularly exposed (and dry) channels and point bars (Kemp and Spooner 2007), and as such, are a key indicator of the seasonality, and regularity, in flows. SBDs, for instance, are commonly associated with the broad-channel systems that persisted in the MDB until c. 15 ka, though are absent in younger systems. The nature of flow regime is further illustrated in the character of overbank deposits including levees, crevasses and backplain sediments.

3.3.2 Lunettes

Lunettes are a common feature of lakes across the MDB, forming characteristic transverse dunes around the leeward shorelines. Lunette sedimentation is intimately linked to the filling characteristics of lakes, oscillating between the two extremes of well sorted clean quartz sands derived from wave-agitated shorelines during lake full conditions, and finer pelletal clay sediments with or without a saline component deflated from exposed lake beds during periods of low or oscillating levels (Barrows et al. 2020; Bowler 1983, 1986; Bowler et al. 2012; Williams et al. 1991) (Table 3-2). According to Bowler (1973:331–334), the deposition of saline clay in lunettes requires cycles of short-lived inundation and rapid drying under high evaporation rates to promote the efflorescence of salts (gypsum) and produce the pelletal clay aggregates capable of deflation. Palaeosols, commonly characterised by clay illuviation, carbonate or gypsum precipitation, tend to develop across lunettes during periods of relative landscape stability (Fitzsimmons 2017:6; Fitzsimmons et al. 2019). These attributes have seen lunettes play a key role in palaeoenvironmental reconstructions in the MDB (Barrows et al. 2020; Bowler 1978, 1998; Bowler et al. 2012; Bowler et al. 1970).

A total of 17 lunette-fringed lakes occur within the Central Murray corridor between Lake Bonney and Lake Victoria (Figure 3-4). The Riverland lunettes occur in three locations; the northern margin of the Chowilla floodplain, the Calperum floodplain and at Lake Bonney. The Lake Bonney lunette is the largest local example, rising 35 m above the modern lake and extending 2 km to the east of its present shoreline. This lunette is, however, dwarfed by the Lake Victoria lunette, a function of the relative size of these two lake basins. At Calperum, lunette fringed lakes occur in two distinct

belts; an outer belt of salina and an inner belt of intermittent lakes that have developed in a set of distinctively elongate meander scrolls.

Table 3-2: Sedimentary facies and related hydrological conditions identified in lunette lakes (after Bowler et al. 2012).

Phase	Description	Environment
Quartz sand dunes (QSD)	Clean, well-sorted fine to medium sands deposited initially along wave effected beaches and subsequently blown onto dunes extending behind the beach.	Lake full conditions and may be associated with a corresponding gravel beach deposit.
Pelletal clay dunes (PCD)	These sediments include clay aggregates deflated from regularly exposed lake beds.	Irregular, possibly short-lived filling of the lake basin. Higher salinity conditions are also implied.
High-salinity-groundwater dunes (HSGD)	Highly saline (gypsum) clay.	The PCD phase may extend to HSGD phase as inundation ceases entirely. Groundwater seepage and evaporation concentrates salts at the lake's surface, forming a 'fluffy' easily deflated and highly saline clay.
Palaeosol	Typically, reddish, stiff fine sand to clayey sand with or without carbonate and may include rhizomorph structures, or gypcrete.	Soils develop during periods of landscape stability and reduced sediment supply to the lunette.
Territorialisation	This period may be associated with the advance of terrestrial dunes and sand sheets into lunette basins.	Lunette lakes may eventually become recolonised by terrestrial vegetation if groundwater influence is reduced.

3.3.3 Terrestrial dunes

Beyond the riverine corridors, the MDB is essentially a vast aeolian landscape defined in large part by close-packed, longitudinal dunefields of the Woorinen Formation (WFm) (Bowler and Magee 1978; Pell et al. 2001). Phases of dune activation describe an episodic change in climate and vegetation in the western MDB over the last 0.5 Ma (Bowler 1976a; Bowler et al. 1976; Bowler et al. 2006:193; Bowler and Magee 1978; Brown and Stephenson 1991; Churchward 1961, 1963a, 1963b; Fitzsimmons et al. 2013; Fitzsimmons et al. 2007b; Hesse 2016:24; Lawrence 1966; Lomax et al. 2011:724, 731–734; Twidale et al. 2007:46–47). Lomax et al. (2011:731–734; see also Fitzsimmons et al. 2013) have identified five phases of dune activity in the western MDB from late MIS 3 to MIS 1. This includes a major two-phase period between 38–18 ka that stabilised during a small peak in effective precipitation around 25 ka, two clusters between 14–12 ka and 8–5 ka, and a recent reactivation. This is broadly consistent with the dune activation cycles identified in the Willandra Lakes region by Fitzsimmons et al. (2019) between 15.0–12.0 ka, 8.8–7.6 ka, at 4.0, and then staggered over the last millennia. The activation phases also correspond broadly with the schema originally proposed by Churchward (1961), as summarised in Table 3-3. Lomax et al. (2011) also identified earlier activation phases at 63–72 ka, 80–111 ka and potentially >140 ka.

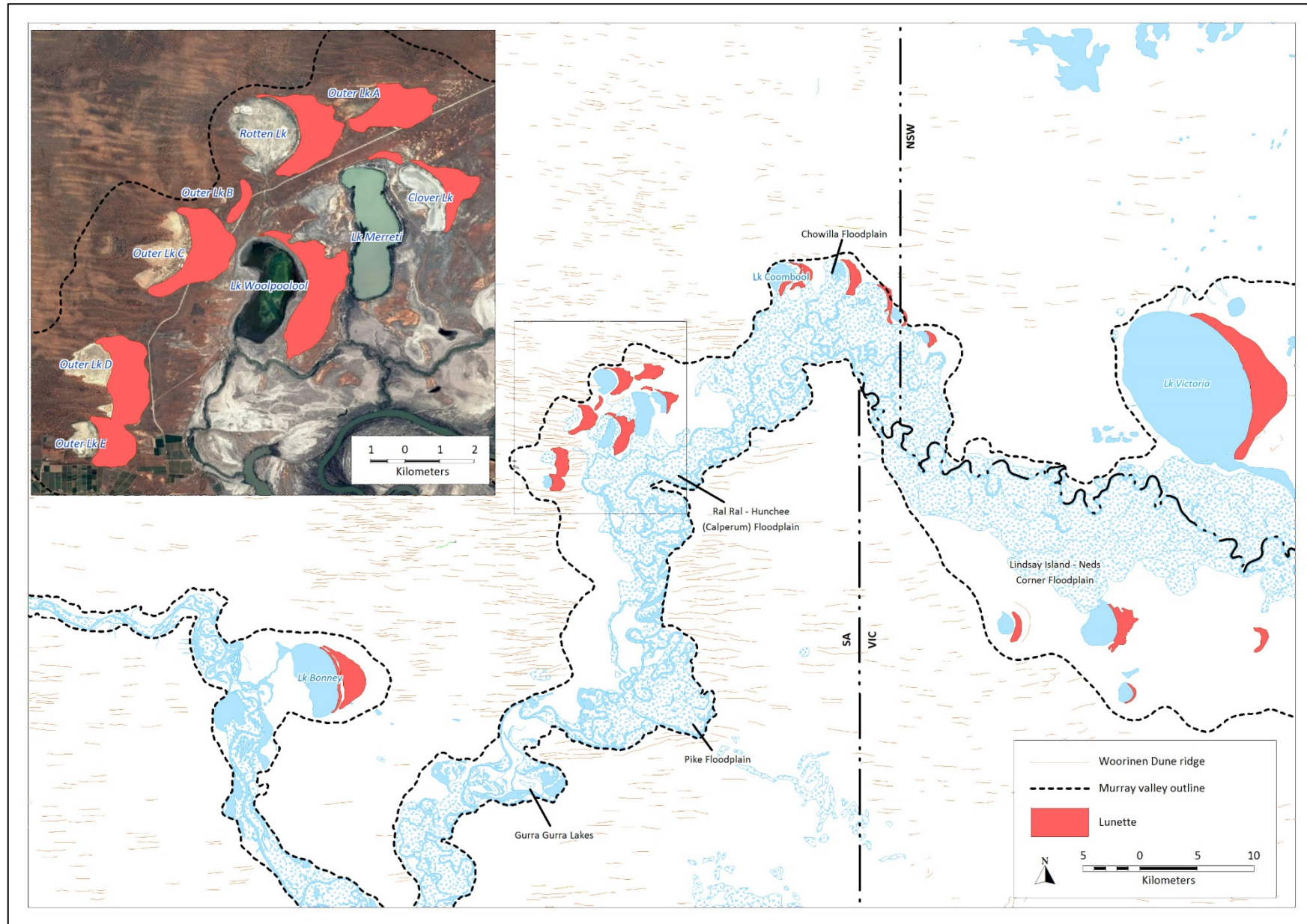


Figure 3-4: Lunettes located within the Central Murray corridor between Lake Bonney and Lake Victoria. Inset shows the Calperum lunettes.

Table 3-3: WFm members based on Churchward (1961) and Lawrence (1966) in comparison to the activation phases identified by Lomax et al. (2011). The phase codes adopted in this thesis (Phases I-VI) are also shown.

Member	Age (ka)	Description	Evidence of pedogenesis	Phases based on Lomax et al. (2011)	Phase code
Piangil	modern	Undifferentiated yellowish orange sand with some thin bedding. Munsell 7.5 YR 7/6.	Absent.	recent	VI
-	-	-	-	8–5 ka	V
Kyalite	15.5	Non-calcareous to weakly cemented reddish brown calcareous clayey sand. Munsell 7.5 YR 6/6.	Limited differentiation or pedal development. Carbonate tends to occur as rhizomorphic structures.	14–12 ka	IV
Speewa	24	Non-calcareous to calcareous clayey sand loam, coherent, moderately porous. Munsell 5 YR 5/8.	Highly differentiated soil forming peds. Illuviation, carbonate as nodules and disseminated.	25–18 ka	III
Bymue	30	Differentiated calcareous clayey sand soil (carbonate and clay illuviation) forming peds. Munsell 5 YR 4/8.	Illuviation, carbonate as nodules and disseminated.	38–25 ka	II
Miralie	?	Mottled labile and plastic clays and sand.	Deeply weathered.	72–63 ka 111–80 ka >140 ka	Ic Ib Ia

The dune phases are partitioned by major palaeosols that developed at around 34 ka, 28 ka, 24 ka, 16 ka and from 9–6 ka (Bowler and Polach 1971; Brown and Stephenson 1991; Churchward 1961, 1963b; Gill 1973a, 1973b; Lawrence 1966). These palaeosols are also represented in regional lunettes (e.g. Williams et al. 1991) and act as key chronological markers. Nodular, pisolitic, sheet, and tubular (e.g. rhizomorphic) forms of carbonate are common in these soils (after Wright 2007:Table 2.1). Aeolian dust (parna) represents a significant regional source of CaCO_3 in south-eastern Australia (Chen et al. 2002:8). Importantly, the progressive development of WFm dunes and palaeosols provide some insight into the cyclic nature of local climate and a context beyond riverine corridors that are largely influenced by remote factors, specifically catchment inflows. The interaction between these aeolian landscapes and the riverine corridors also provide insights into the functioning of the floodplains, with dunes transgressing during periods of reduced flooding and being sculpted by periods of more regular inundation.

3.4 A palaeoenvironmental narrative from 50 ka

A wealth of geomorphological and other palaeoenvironmental evidence from across the MDB suggests relatively consistent basin-wide responses in riverine systems to the major climatic transitions straddling the last glacial–interglacial cycle. The evidence, as summarised in Table 3-4

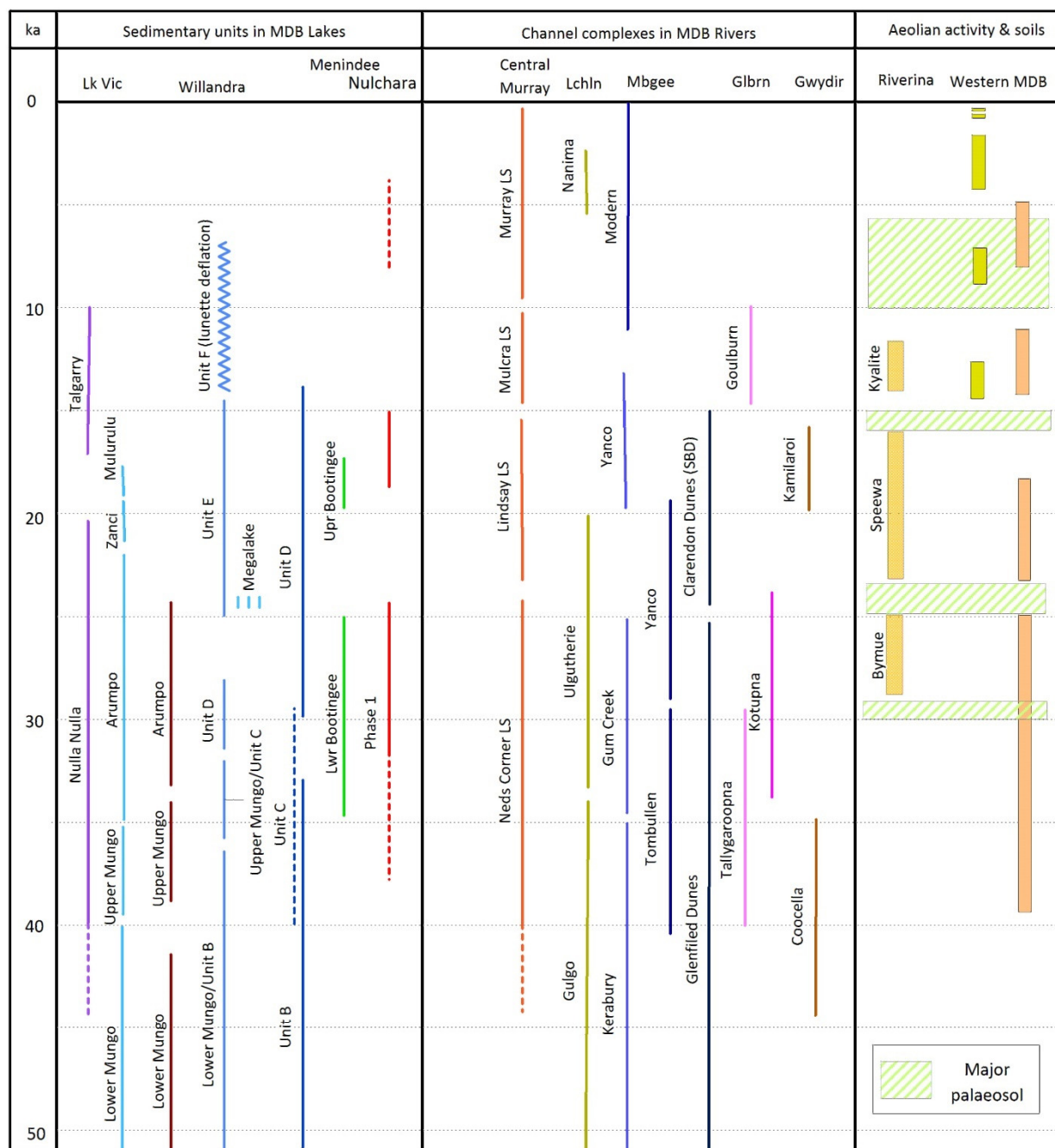
and Figure 3-5, identifies five broadly defined hydrological stages represented in discrete palaeochannel systems, terracing and lunette sequences (see for example Page and Nanson 1996:943). Whilst the timing across individual catchments may differ (Hesse et al. 2018), these stages are thought to have transitioned around 35 ka, 24 ka, 15 ka and 10 ka. This evidence is complemented by a range of pedological, pollen and lake chemistry records that provide fine detail in palaeoclimate reconstructions. In outline, the varied evidence describes relatively wet conditions between 50–35 ka, increasingly arid conditions punctuated by brief pluvial events through MIS 2¹⁴ and continuing into early MIS 1, an early Holocene pluvial, mid Holocene aridity and then heightened variability under ENSO cycling (Fitzsimmons et al. 2013). These changes in climate¹⁵ have manifest in a general trend toward diminishing peak inflows to MDB floodplains over the past 40,000 years and a change in hydrological regime from high energy, short duration seasonal flooding, to a regime of lower peak volume coupled with more regular and sustained flows.

Table 3-4: Broadly defined hydrological stages recognised in the MDB.

Stage	Age (ka)	General characteristics
I	> 35	Broad, large capacity, single-thread bedload channels. Perennial conditions maintained in large capacity lakes with quartz sand lunettes (QSD facies) developing around wave-affected shorelines.
II	35–24	Continuation of large capacity, single-thread bedload channels with high peak volume, though increasingly seasonal and irregular flows. Fluctuating lake levels (alternating QSD and PCD facies) with deposition of pelletal clays (PCD facies) onto lunettes during periodic deflation of exposed and salinised lakebeds.
III	24–15	Continuation of broad, large capacity, single-thread bedload channels. Highly seasonal, high peak volume flows promote development of source bordering dunes within typically broad, arcuate meander scrolls. Significantly reduced lake capacity with desiccation and deflation of salinised lakebeds—PCD facies dominate.
IV	15–10	Significant reduction in meander wavelength, channel width and peak flows. More sinuous meander scrolls coupled with a cessation of SBD development indicates a less pronounced seasonality of flow, greater stabilising riparian vegetation and longer inundation periods. Return to regular lake filling episodes though in reduced capacity basins.
V	< 10	Further reduction in meander wavelength, channel width and peak flows. Floodplains take on their modern form.

¹⁴ The last three MIS are: MIS 3 (57–29 ka), MIS 2 (29–14 ka), MIS 1 (14 ka to modern) (Cohen and Gibbard 2019; Lisiecki and Raymo 2005; Railsback et al. 2015).

¹⁵ According to Petherick et al. (2013; see also McGowan et al. 2009), the key drivers of climate across temperate Australia are the Walker Circulation and the interrelated and modulating systems of the ENSO, the Pacific Decadal Oscillation (PDO), Indian Ocean Dipole (IOD) and the Southern Westerly Wind (SWW) circulations. The relative position of the Inter-Tropical Convergence Zone (ITCZ) over northern Australia also determines the degree of monsoonal rainfall into the upper Darling River catchment. At a local scale, changes in rainfall (and inflows from the headwater catchments) are related to the circulation of atmospheric moisture, while on a local scale, air temperature, moisture content and wind speed interact as controls on effective precipitation.



REFERENCES

MDB Lakes

Lake Victoria

Chen (1995), Kefous (1981)

Willandra

Bowler (1998); Bowler et al. (2003)

Barrows et al. (2020)

Fitzsimmons et al. (2014)

Fitzsimmons et al. (2015)

Smith (2019)

Menindee

Hope et al. (1983)

Belarabon-Nulchara

Williams et al. (1991)

MDB Rivers

Central Murray

Prendergast et al. (2009)

Lachlan River

Kemp and Rhodes (2010)

Murrumbidgee River

Page (1994); Page et al. (1996);

Page & Nanson (1986)

Mueller et al. (2018)

Page et al. (2001)

Goulburn River

Bowler (1978)

Page (1994); Bowler (1978)

Gwydir River

Pietsch et al. (2013)

Aeolian activity & soils

Churchward (1961)

Lomax et al. (2011)

Fitzsimmons et al. (2012)

Bowler & Polach (1971);
Brown & Stephenson (1991);
Churchward (1961, 1963b);
Gill (1973); Lawrence (1966)

Figure 3-5: Major sedimentary and morphological phases identified in fluvial/alluvial systems in the MDB.

3.4.1 The early glacial (late MIS 3)

There is general agreement across a range of palaeoclimate data to indicate that significantly wetter conditions than modern had persisted across the late MIS 3–MIS 2 transition in south-eastern Australia. Highstand conditions were maintained in lakes across the MDB and its arid fringes during this period (Bowler et al. 1976; Chappell 1991; Cohen et al. 2011; Deckker et al. 2011; Fitzsimmons et al. 2015; Gillespie et al. 1991; Habeck-Fardy and Nanson 2014; Harrison 1993; Herczeg and Chapman 1991; Macumber 1991; Magee et al. 2004; Mueller et al. 2018; Reeves et al. 2013:4). Along the north-eastern margin of the Flinders Ranges, shorelines formed around a vast waterbody incorporating the modern Lakes Frome, Blanche, Callabonna and Gregory (Lake Mega-Frome) during a series of highstand events between 68–60 ka and 48–45 ka (Cohen et al. 2011:97). Sustained high lake levels saw quartz sand lunettes form around the shorelines of MDB lakes, represented by the Lower Mungo, Lower Bootingee and Nulla Nulla sedimentary units in the Willandra Lakes, Menindee Lakes and at Lake Victoria, respectively (Bowler 1998; Bowler et al. 2003; Fitzsimmons et al. 2014; Hope et al. 1983) (Figure 3-5).

These conditions tracked a long cooling trend that saw glaciation in the Australian Alps by at least 32 ka (Late Kosciuszko glaciation)¹⁶ (Barrows et al. 2002; Barrows et al. 2001; Kemp and Spooner 2007; Petherick et al. 2013; Reeves et al. 2013). The cooling trend was accompanied initially by higher runoff into the headwater catchment (Kemp and Rhodes 2010; Kemp and Spooner 2007; Pietsch et al. 2013). High sediment yields 'fuelled the construction of point bars on downstream alluvial plains' (Kemp and Rhodes 2010:749) and along broad, shallow, laterally migrating sandy bedload channels fed by seasonal pulses that are likely to have been orders of magnitude greater than modern flows (Mueller et al. 2018; Page and Nanson 1996; Prendergast et al. 2009:60). Discharges of 5–10 times larger than contemporary flows have been modelled for the equivalent palaeochannels on the Riverine Plain (Kemp and Rhodes 2010; Kemp and Spooner 2007; Page and Nanson 1996). Higher precipitation rates and run-off efficiency (Hesse et al. 2018:105) are likely to have been augmented by seasonal melts generated from ever larger snowpacks accumulating in the Alps (Barrows et al. 2020; Fitzsimmons et al. 2013; Kemp and Spooner 2007). These high capacity rivers formed a series of distinct channel complexes in the Riverine Plain (Kerabury,

¹⁶ Barrows et al. (2001) identify three glacier advances in the Late Kosciuszko glaciation at approximately 32 ka (Headley Tarn Advance), 19 ka (Blue Lake Advance) and 17 ka years ago (Mt Twynam Advance).

Tallygaroopna), eastern watershed (Coocalla) and along the Central Murray corridor (Neds Corner Land System) (see Figure 3-5).

3.4.2 Toward the LGM nadir (MIS 2)

Toward the close of MIS 3, variable conditions had begun to impact catchment inflows, leading to instability in lacustrine systems (Bowler 1976b; Bowler et al. 2012; Hesse et al. 2004). Alternating saline-freshwater conditions in the Willandra system from 35 ka is recorded in the Arumpo Unit (Barrows et al. 2020; Bowler 1998; Bowler et al. 2012) and was coeval with the initiation of the Ulgutherie (Lachlan River), Gum Creek (Murrumbidgee River) and Kotupna (Goulburn River) channel complexes on the Riverine Plain (Bowler 1978; Kemp and Rhodes 2010; Page 1994; Page et al. 2001). On the western margin of the MDB, a filling period between 33.4–29 ka recorded at Lake Mega-Frome (Cohen et al. 2012:99) occurred within a longer drying trend. Beyond the riverine corridors, increasingly arid conditions saw the activation of terrestrial dune-fields and deposition of loess¹⁷ (Bowler 1976a, 1976b, 1986; Butler 1956; Dare-Edwards 1984; Hesse and McTainsh 1999, 2003; Lomax et al. 2011; Page and Nanson 1996; Prendergast et al. 2009:68) as grasslands and chenopod shrublands replaced the woodland communities (Cupper 2005; Field et al. 2002).

Climatic instability culminated in a brief pluvial c. 24 ka. At Lake Mungo, this manifest in a distinctive notch cut into the lunette during a sustained, albeit short-lived rise in lake levels of 5 m, representing a staggering volume increase in lake capacity of 250% (Fitzsimmons et al. 2015:10). A limnological study undertaken at Lake Surprise in south-western Victoria, suggests that a long, gradual decline in moisture balance from 30 ka was interrupted by a wetter period of up to 1,500 years c. 24.5 ka (Falster et al. 2018:117). The stabilisation of terrestrial dunes and lunettes, and widespread soil development across the western MDB is also recorded at this time (Lomax et al. 2011:731–734) with palaeosols separating the lower and upper units of the Lake Tyrrell, Lake Victoria and Lake Tandou lunettes, for instance (Chen 1995; Gill 1973a:Figure 44; Hope et al. 1983; Macumber 1991; Richards and Weber 2004).

¹⁷ OSL dating of loess in the central tablelands of NSW by Hesse et al. (2003) suggests that these deposits had been accumulating for a significant period leading up to the LGM, potentially earlier than 50 ka.

This brief pluvial occurred within the context of a broader aridification trend. The 'expansion of the arid zone on the semi-arid desert margins' subsumed much of the semi-arid grasslands of the modern MDB (Fitzsimmons et al. 2013:90; Fitzsimmons et al. 2015:11) (Figure 3-6). According to Falster et al. (2018), peak aridity in south-eastern Australia is likely to have occurred between 21.5–18.5 ka BP. Throughout this period, the River Murray would have resembled a modern desert river in which instream habitats are intermittently connected during periods of flow, water is maintained only in the deeper sections of the riverbed or where intersected by water tables, and floral communities exhibit a distinct 'pulse-reserve' character with the ability to survive extended periods of no or low flow (Capon et al. 2016:243, 246). A substantially reduced tree cover is suggested in the genetics of the modern river red gums which indicate an elimination or at least a significant reduction to 'isolated fragments' of woodland during the LGM and a re-population from the north as climatic conditions subsequently improved (Reid et al. 2016:50). Change in vegetation composition would have seen concomitant responses in mammalian diversity, particularly amongst the arboreal or semi-arboreal species (Stewart et al. 2010:196).

The initial instability in lacustrine systems amplified, resulting in more sustained deposition of saline sediments onto the surfaces of MDB lunettes. At Lake Victoria, a lunette chronology established through TL (Chen 1995) and ^{14}C (Gill 1973a; Kefous 1981, 1983) dating identified a major transition from the basal Nulla Nulla Sand to the overlying Talgarry Sand at around 24–22 cal ka. The Talgarry Sand includes interbeds of greyish silty sand impregnated with gypsum clay, indicative of deflation from a salinised lakebed. This sequence is replicated along other riverine corridors that, importantly, are fed by sub-catchments across the full latitudinal spread of the MDB. Salinisation at Lake Tandou on the Darling Anabranh (northern catchment), for instance, is recorded in the Upper Bootingee unit by 20 ka (Hope et al. 1983). In the Willandra system (central catchment), a brief period of intense lunette development from 23–19 ka is represented by the Zanci/Unit E sediments (Bowler 1998; Fitzsimmons et al. 2014:359, 362). On the upper River Murray (southerly catchment), the mega Lake Kanyapella began contracting from 25 ka with a lunette forming around a significantly reduced basin by 19 ka (McPherson et al. 2012; Stone 2006b). Kefous (1983:173–174) has argued that riverine conditions along the Central Murray are likely to have been at their most severe by 19 ka.

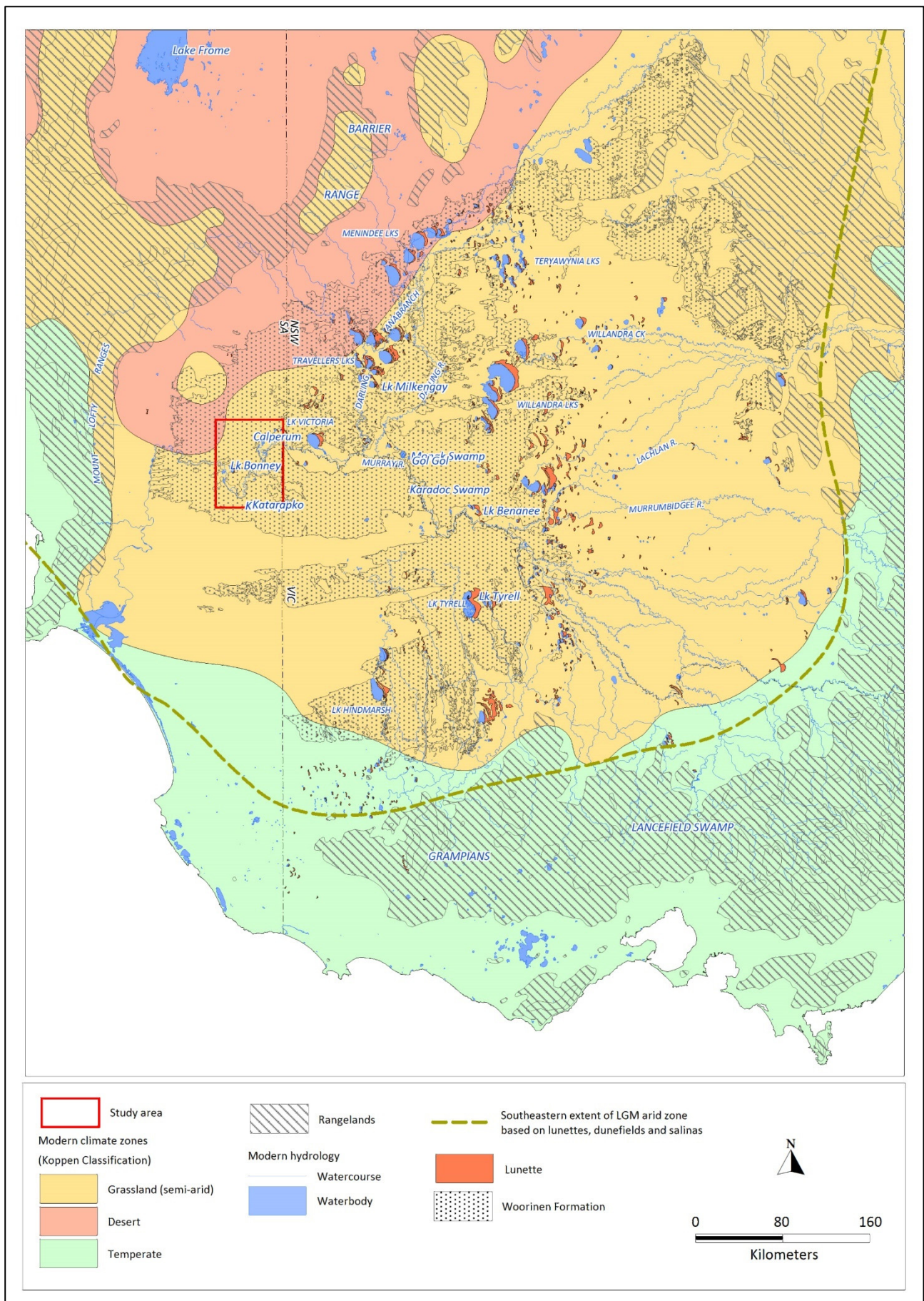


Figure 3-6: The approximate boundary of the expanded Pleistocene arid zone overlain on the modern climatic zones in south-eastern Australia.

Page and Nanson (1996) suggest that bank-full volumes within the equivalent LGM-phase Yanco palaeochannels along the Murrumbidgee River are likely to have been four and a half times that of the modern flows (see also Mueller et al. 2018). This image of high-volume rivers flowing through desiccated landscapes seems somewhat incongruous (Hesse et al. 2004:95; Kemp et al. 2017), though reflects upon the seasonality of flows and the delivery of water from distant headwater sources (Kemp et al. 2017:8–9). The development of vertosol soils across the Lindsay Island Land System at Neds Corner has been interpreted by Prendergast et al. (2009:69), for instance, as evidence of large scale overbank events drying quickly under prevailing arid LGM conditions.

A pronounced seasonality in inflows is also illustrated in the persistent development of SBDs throughout this period (Page 1994). Along the lower Murray, south of Morgan, sub-parabolic dune-fields of the Bunyip Sand (Brown and Stephenson 1991:273-276; Firman 1972, 1973) developed as source bordering features east of the river gorge. This unit developed as a two-phase sequence (Firman 1972) throughout the late Pleistocene and Holocene, though the lower age is poorly constrained. Rogers (1978) has suggested a maximum age for the Bunyip Sand of 18 ka, though this is certain to be an underestimate. The unit is not mapped upstream of Waikerie, though the type-section identified by Firman (1973) relates to the Chowilla–Murtho area (opposite Calperum) where climbing sand sheets extend onto the eastern slopes of the valley. Similar features also occur around the eastern margin of the Pike floodplain. Pedogenic carbonate in the Bunyip Sand, and the extensive nature of the dune-fields (dune lobes extend up to 25 km from the Murray valley), indicate a relatively long period of sediment supply, relating this unit to the highly seasonal flows associated with the pre-15 ka bedload channels. The lunette fringed lakes of the MDB were periodically filled by these large volume floods—LGM age middens of golden perch and freshwater mussel in the Willandra and Menindee systems attest to this (Long et al. 2014; Smith 2019)—though these lakes also endured lengthy deflationary episodes between freshwater flushes.

Low rainfall persisted over the MDB lowlands in the period leading to the LGM, as expressed in regional dune activation from c. 38 ka. Winter rainfall is also likely to have been captured in longer-lasting snow packs as ambient temperatures fell, with seasonal melts delivered during brief but intense flushes. The LGM represented a nadir in this cycle, with shortened run-off periods compounded by more arid conditions. Flows to the lower end of the system would have passed through desiccated floodplains with increasing volumes of water diverted to recharge and re-

saturate emptied channels, lakes and floodplain sediments.

3.4.3 MIS 2–MIS 1 transition

The transition from the LGM to the current interglacial occurred in a non-linear fashion, marked by a series of millennial-scale climatic episodes. A brief, though widespread humid phase c. 17–15 ka, is recognised in a variety of regional evidence (Fitzsimmons et al. 2013) that includes the stabilisation of dune-fields and soil development, speleothem growth at Mairs Cave (Flinders Ranges) and at Naracoorte (Treble et al. 2017:667), and the development of beach-ridges around a vastly expanded Lake Frome (Cohen et al. 2011). This phase, which marked the final glacial advance in the Australian Alps (Mt Twynam Advance), was followed by renewed dune activation across the central-western MDB between 14–12 ka¹⁸ (Fitzsimmons et al. 2013; Fitzsimmons et al. 2019). By the close of MIS 2, regional lake levels had fallen to their lowest levels (Bowler 1981; Dodson 1977; Luly 1993) and vegetation communities across the Murray plains had been completely restructured with few tree and tall shrub taxa remaining (Cupper 2005:549). Broadly similar conditions existed well beyond the margins of the MDB, for instance in the Flinders Ranges, Lake Frome and Strzelecki regions (Fitzsimmons et al. 2007a; Fitzsimmons et al. 2007b; Singh and Luly 1991; Treble et al. 2017).

A marked shift in hydrological conditions c. 13 ka saw the large dimension channels replaced by a more sinuous, mixed load system more akin to the modern regime, though the timing of this transition is somewhat confused between catchments (Bowler 1978; Kemp and Rhodes 2010:749; Mills et al. 2013; Mueller et al. 2018; Ogden et al. 2001; Page and Nanson 1996:934–944; Page et al. 1991, 1996:324; Prendergast et al. 2009). This change in channel morphology is the most conspicuous of all transitions recognised in the MDB and included a marked reduction in meander wavelength, channel width and sediment size, and the reduced development of SBDs. All of these

¹⁸ This late peak in MIS 2 aridity approximates the Antarctic Cold Reversal (ACR), a brief reversal in an otherwise warming trend out of the LGM recognised in Antarctic ice cores and sea surface temperatures (SSTs) records. The ACR is dated to approximately 14.5–12.9 ka (after Sagredo et al. 2018) and is generally regarded as having limited expression in the mainland Australian record compared to higher latitudes (see for instance Hinojosa et al. 2019; Pedro et al. 2015; Reeves et al. 2013). It did not, for instance, result in the redevelopment of glaciers amongst the Australian Alps or Tasmanian highlands (Barrows et al. 2002). The coeval dune activity in the western MDB may, however, suggest some relationship.

traits are indicative of a reduction in peak flow, sediment load and seasonality of flows. Sustained through-flows are also suggested by a pulse of clay accumulating offshore from the mouth of the River Murray between 13.5 and 11.5 ka (Gingelle et al. 2007:268; see also Mojtahid et al. 2020). A permanent highstand was in place at Lake George within the alpine catchment between 14.2–8.3 ka (Fitzsimmons and Barrows 2010:594).

Singh and Luly (1991) attribute vegetation changes at Lake Frome from 13 ka to an initiation of the Australian monsoon and a (re)introduction of summer rainfall. Similar monsoonal incursions are likely to have impacted the northern Darling River catchment. The lengthier inundation cycles recognised in the deglacial MDB floodplains were possibly sustained by this combination of alpine and monsoonal-sourced water. Increased rainfall is likely to have been a regional phenomenon, with tree and tall shrub taxa expanding (Forbes et al. 2019) and peat formation initiated at many wetland sites in south-eastern Australia c. 12 ka (Kershaw et al. 1993; Kershaw et al. 2004).

3.4.4 The Holocene

Fitzsimmons et al. (2014: see also Jones et al 1998 and Quigley et al. 2010) cite various evidence of a shift from hyper-aridity to wetter conditions across the Pleistocene–Holocene boundary. This period of ameliorated climate leading into the Mid Holocene Climatic Optimum (MHCO) saw major rises in lake levels (Bowler 1981:436; Chappell 1991; Williams et al. 1991) and falling lake salinity (Kemp et al. 2012) across south-eastern Australia. Importantly, this includes the maar lakes of western Victoria (e.g. Lake Keilambete) that ‘act as sensitive rainwater gauges’ given their reliance on small localised catchments (Kemp et al. 2012:73). Lake Tyrell reactivated as an ephemeral lake between 11.5 and 7.4 ka (Luly 1993), representing a staggering reversal of conditions in this salina.

A low energy anabranch system characterised by highly sinuous, suspended load channels and slow channel migration (Gippel and Blackman 2002; Ogden et al. 2001; Thoms et al. 2000:24) was established during the early Holocene across multiple MDB riverine corridors, and has essentially continued to the present day (Bowler 1978; Kemp 2001; Page et al. 2001; Pietsch et al. 2013; Prendergast et al. 2009). The downscaling in flow extremes seems to have supported increased floristic diversity in the floodplains including an expansion of macrophyte and woodland communities (Forbes et al. 2019). Black box (*E. largiflorens*), river red gum (*E. camuldalensis*) and

bulloak (*Casuarinna luehmannii*) communities reminiscent of the modern riverine woodlands had re-established in the Riverland during this period (Gill 1973a:46–47). Across the western MDB, the arid climate assemblage of asteraceous herbfields and chenopodiaceous low shrublands transitioned to a mosaic of tall and low shrubland communities (Cupper 2005: 549; Thomas et al. 2001). The eucalypt (mallee) and casuarina dominated woodlands that characterise the modern landscape had reached their maximum extent by the early Holocene (Cupper 2005; Kershaw 1995; McGlone et al. 1992; Thomas et al. 2001).

The MHCO, however, occurred within a longer trend defined, in large part, by variability (Fitzsimmons and Barrows 2010:595; Holdaway et al. 2002; Kemp et al. 2012; Tudhope et al. 2001). An oscillating pattern in water salinity at Lake Jacka, western Victoria, for instance, occurred on cycles of roughly ~1500 years throughout the Holocene with short-lived, low salinity phases identified by Kemp et al. (2012:73–74) c. 8800, 7200, 5900, 4800, 2400, 1300 and 400 years BP (see also Bowler 1981, Wilkins et al. 2013). This variability amplified, possibly in a stepwise fashion during the mid to late Holocene under the influence of increased ENSO cycling, and has accommodated a general trend toward drier conditions (Allan 1988; Donders et al. 2007; Fitzsimmons et al. 2013; Gell et al. 2005; Gouramanis et al. 2013; May et al. 2015; McGlone et al. 1992; Reeves et al. 2013). Marx et al. (2009) have argued that a general aridification of southern Australia occurred between 4.8–0.9 ka based on the accumulation of Australian-sourced dust in New Zealand peat bogs. The MDB represented the major dust contributor in the period 7.5–2.5 ka. A progressive increase in aeolian activity is also registered in loess accumulation in the Australian Alps from c. 5.5 ka which peaked in the last 1.6 ka following a brief reduction in aeolian input at c. 2 ka (Stanley and De Deckker 2002:215). At Lake Callabonna, beyond the north-western margin of the MDB, a series of at least three highstand beach-ridges developed c. 3.5, 2.7 and 1 ka and ‘interrupted the generally more arid and variable climate conditions during the late Holocene’ (May et al. 2015:164).

According to Quigley et al. (2010), the magnitude of climatic change may have been greatest at the close of the MHCO than during any subsequent period. Higher salinity is recognised in lakes across south-eastern Australia by the mid Holocene (Bowler 1981; Tyler 2017) with lake levels approaching their lowest values by 3.5 ka (Deckker 1982; Jones et al. 1998:68). Importantly, variation in lake levels suggest that the recent Millennium Drought may have been ‘a relatively

minor event' in the context of the last 1500 years where the evidence depicts multi-decadal events (Abram et al. 2020:16; Barr et al. 2014:129). Palaeoclimate modelling conducted by Ho et al. (2015:2) suggests that both dry and wet epochs exceeding decadal limits were ten times more likely over the last ~3,000 years than those identified in the instrumental records, with notable dry periods occurring c. 2400, 2200, 1000, 600 and 300 years BP. Regional pollen data also shows evidence of increased late Holocene aridity across the western MDB and beyond, including a decline in Casuarinaceae woodlands and an increase in chenopod shrublands in the area of Lake Frome (Singh and Luly 1991), the Darling Anabranch (Cupper et al. 2000), and across the south-eastern dune-fields more broadly (Cupper 2005:551). In a study of the Barmah Choke avulsion, Stone (2006a) interpreted a shift to a colder and drier riparian and hinterland taxa from the mid Holocene. Furthermore, Stone argued that the Moira Lake basin, part of the Barmah wetlands complex, rarely flooded for several millennia over this period with floodwater largely contained to in channel flows until the last 500 years.

Fine temporal fluctuations in hydrology across the last several thousand years are also revealed along the Murray corridor in SA in the diatom records of wetland sediments (Gell et al. 2005:450; Gell et al. 2009; Tibby et al. 2020). At Tareena Billabong on the Chowilla floodplain, lagoonal sediments began to accumulate during a period of relatively high rainfall around 5.4 ka (Gell et al. 2005). Pollen records indicate that this tree-dominated period was replaced by an increase in lignum and chenopod shrubs as reliable inflows to the relatively deep waterbody gave way to a wetting and drying regime alternating between regular input from the main river and phases of shallow, brackish water from around 3.8 ka (Gell et al. 2005:450). A brief period of wetter conditions after 2.5 ka was followed by a return to high variability and more arid conditions evidenced by a fluctuating, though gradual and sustained rise in water salinity (Gell et al. 2005:450–451). This drying trend may have accommodated a short wetter phase c. 800–500 BP (Tibby et al. 2020). Given this context, it is worth noting that the late Holocene archaeofauna recovered from the Ngaut Ngaut (Hale and Tindale 1930) and Tungawa (Mulvaney 1960; Mulvaney et al. 1964) rockshelters, located on the lower Murray, track little if any change in species diversity (see also Wilson et al. 2022). On this basis, it can be assumed that the late Holocene fluctuations in water quality did not trigger a wholesale restructuring in riverine ecology, at least in terms of species diversity.

The gross trends in the Holocene record, i.e. early Holocene wet–mid Holocene dry–late Holocene variability, are also reflected in a high-resolution flood record preserved in two sediment cores collected on the lower Murray that extend from approximately 7.6–3.3 ka (De Carli 2020; De Carli et al. 2016; Hubble et al. 2014). Sediments in these cores were provenanced to either the Darling or Murray catchments based on mineralogical properties and describe an episodic influence from the former. High energy flood pulses represented by packets of coarser sediment (referred to as Facies C) are staggered along the cores and occur where the contributions from both systems coincide. The average return-period for Darling River events increases during the mid Holocene (De Carli 2020:150), a trend that is replicated in both cores. This pattern indicates a reduced influence of monsoonal incursions into the northern MDB through the mid Holocene before a potential re-establishment around 3.4 ka (see also Singh and Luly 1991). Hydroclimate phases may have spanned century-long timescales (De Carli 2020:153).

3.5 Insights gained through archaeofauna

Archaeofauna represents an invaluable, though perhaps underutilised source, of complementary palaeoenvironmental data. Within the MDB, archaeofauna is dominated by two species of freshwater bivalve, *A. jacksoni* and *V. ambiguus*, with site assemblages often comprised exclusively of these materials. More diverse assemblages have been reported from the Darling River (Balme 1995; Balme and Hope 1990), the Willandra Lakes (Allen 1972, 1998; Long et al. 2014; Walshe 1998), Lake Victoria (Gill 1973a; Marshall 1973) and lower Murray (Hale and Tindale 1930; Mulvaney 1960:54; Mulvaney et al. 1964; Pretty 1977a; Smith 1978, 1982; Wilson et al. 2022; Wilson 2017).

A common observation in these analyses is that similar taxa are represented across the full occupation timeline and consist almost entirely of the suite of modern species found in the respective areas (see for example Allen 1972:18; Hope 1978). On this basis, Balme (1995:18; see also Allen 1972:351) argued that consistent subsistence strategies had endured in the Darling River region over the full record of occupation with aquatic resources having remained an embedded component. Allen (1972:19, 324, 326, 348) too, argued that the Darling River–Willandra region lunette assemblages were built around an essentially modern arid/semi-arid fauna, and despite the presence of a number of more arid-adapted species in the earlier part of the sequence, the evidence indicated limited environmental change in this region across the last

'30,000 years'. A similar assessment is provided for the Holocene record in the lower Murray (Hale and Tindale 1930; Mulvaney 1960:54; Mulvaney et al. 1964; Pate 2017; Paton 1983; Pretty 1977a; Smith 1978, 1982; Wilson et al. 2022). In essence, despite the broadscale changes recognised in the physical landscapes and vegetation communities across the south-western MDB (Cupper 2005; Field et al. 2002; Fitzsimmons 2017; Fitzsimmons et al. 2013; Lomax et al. 2011), people appear to have maintained access to, and utilised a similar suite of, terrestrial and aquatic animals across the last glacial-interglacial cycle.

Unfortunately, the chronological resolution in the datasets varies on scales from a radiocarbon age, archaeological unit or geological formation, potentially masking finer detail in the record. A more resolved dataset does, however, exist in the form of the large number of ^{14}C ages derived from freshwater mussel shell recovered from middens (Figure 3-7). Both species of freshwater mussel have salinity limits and disappear from salinised streams, often requiring long rebound periods for mature stock to redevelop (Mackay and Eastburn 1990:312; Walker 2017:33; Walker et al. 2001:18-19). These traits would have impacted the viability of freshwater mussel as a staple food during periods of repeat or continuous deterioration in riverine habitat, providing an obvious connect to the nature of flows and water salinity. Assuming that freshwater mussel was collected whenever available, transitions from shell to non-shell periods (and vice versa) would indicate shifts in baseline riverine condition and reflect one of two likely scenarios; a response in resource strategy to shifts in riverine ecology (e.g. Balme and Hope 1990:99) or a change in the number of people collecting shell (Williams 2013; Williams et al. 2015b; Williams et al. 2015c). The ^{14}C evidence, as shown in Figure 3-7, indicates a continual adjustment in the use of freshwater mussel in the MDB with a number of conspicuous gaps in shell-derived ages occurring between 34–32 ka, 26–23 ka, 18–17 ka and 13–11 ka. Both inter and intra-regional trends are recognised, suggesting that patterns in shell collection had differed between the more northerly (Darling and Willandra) and southerly (Murray above the Darling) sub-catchments. The ^{14}C evidence also tallies with the hydrological stages identified in Table 3-4 and depicts a staggered use of freshwater mussel until the Stage III/Stage IV transition, reflecting the sensitivity of riverine habitats to the high energy though flashy and increasingly irregular inflows leading into and straddling the LGM. The synchronous development of large-scale middens in multiple regions corresponds with the most distinctive change in hydrological regime (Phase IV) though it's not until approximately 8 ka that relatively continuous shell and/or charcoal records are reported along both the Darling and Murray systems. This period saw the floodplains take on their modern form.

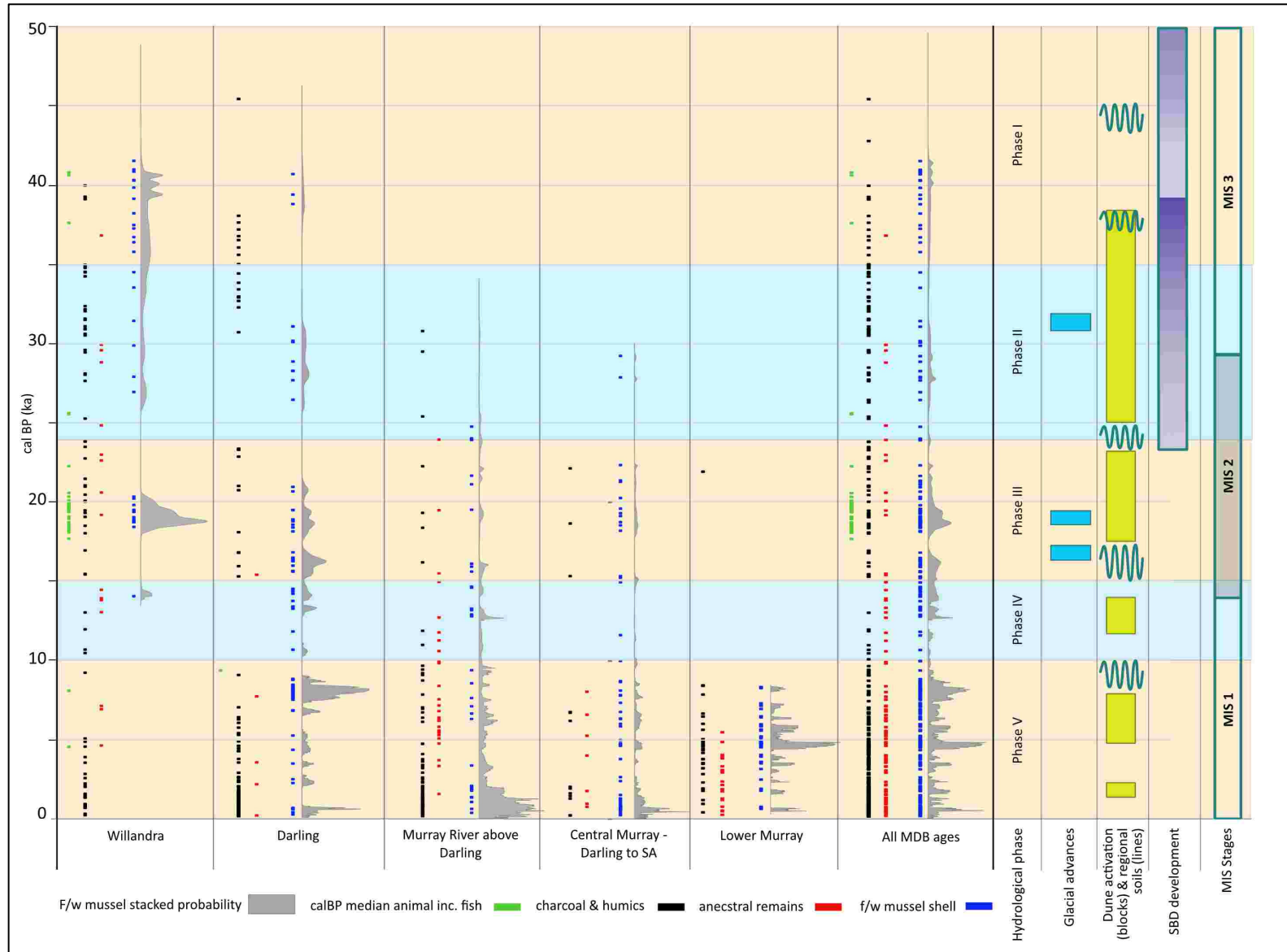


Figure 3-7: The median ages of shell and other derived ^{14}C estimates from subregions of the MDB in relation to major hydrological phases, glacial advances, dune cycles and soil development. Palaeoenvironmental stages are adapted from Barrows et al. (2001), Fitzsimmons et al. (2014: Figures 6, 7 & 8); Kemp and Rhodes (2010: Figure 1); Lomax et al. (2011: Figure 6).

CHAPTER FOUR: THE RIVERLAND

4.1 Introduction

The Riverland floodplains are draped with a staggering array of Aboriginal archaeology, though literally, within a stone throw of the valley margins, site frequencies decline rapidly. Sites within the mallee hinterland tend to be located, almost exclusively, at ephemeral waterpoints (clay pans, soakages). The archaeological evidence appears to depict a longstanding focus of Aboriginal lifeways centred on this narrow riverine corridor.

This chapter is presented in two parts. The first provides an ethnohistorical and archaeological context for this research. The second part includes a description of the hydrology and ecology of the modern Riverland floodplains as context to the Aboriginal economic and social systems observed at contact. The ecological responses witnessed during the recent Millennium Drought are also outlined and set the scene for the environmental shocks and longer-term shifts in hydrology indicated in the deeper-time geomorphological record.

4.2 Aboriginal people of the Riverland

4.2.1 Introduction

Pardoe (2003:51) observed that while each of the major MDB rivers had their own unique economic and social characteristics, they all supported large, dense, sedentary populations that maintained strict and exclusive territorial boundaries, and were riverine focused. This could aptly describe the image of Riverland Aboriginal communities at the time of European contact. It is evident that Riverland peoples were employing an elaborate suite of food production, capture and collection strategies that not only exploited the diverse riverine habitat mosaic, but actively manipulated this mosaic to maximise returns. This included a heavy investment in netting. Large hauls of both plant and animal resources are reported, with fish, bulrush, freshwater mussel, bird eggs and waterbirds, featuring prominently in historical accounts. These accounts invariably relate people to the narrow riverine corridor, with few references to the surrounding mallee plains other

than the use of Aboriginal trackways¹⁹ (e.g. Finniss 1966:25). Taplin (1879:20–21), for instance, describes the ‘Moorundie Tribe’ as occupying the river from Mannum to Overland Corner and a narrow tract 12–13 miles from the river. There is, however, an obvious bias in the reporting—Aboriginal people were invariably observed along the river corridor as this is where the observers invariably were. The mallee fringes were likely to have represented an essential supplement to a vaguely predictable river. Indeed, archaeological materials are commonly associated with ephemeral water points beyond the valley (see Paton 1983; Westell 2020; Westell and Wood 2018; Woolmer 1974:21).

While the lifecycles of riverine food staples were relatively predictable, the seasonal and longer-term variation in flows, i.e. the ultimate mechanism behind floodplain productivity, would have represented an inherent risk. Several historical accounts, for instance, record local people having difficulty obtaining fish during high floods (e.g. Blyth 1865). This risk may have been negated to some extent through strategies configured around a broad pool of resource that included a range of spatially and seasonally distributed staples. Within the diverse habitat mosaic, search and procurement effort was also low for a range of foods. This scenario differed from other parts of the MDB. Allen (1974:311–312), for instance, has argued that the unpredictability of resource triggers along the Darling River was negated through more opportunistic and flexible strategies, broader seasonal movements into the hinterland, and a diet incorporating a large component of lower ranked terrestrial grasses and hard cased seeds that are more typically associated with arid zone economies.

Consistent social practices, traditions and economic systems recognised across the western MDB, also support the notion of broad regional affiliations and the exchange of both intellectual and economic capital. The detail captured in the Ngurunderi and Eagle and Crow narratives highlight an intimate knowledge of a broad geographical space and cultural linkages through spiritual tradition from the Darling River to the Lower Murray and Lakes (Berndt and Berndt 1993:21, 240–242; Tindale 1939). Ceremonial gatherings were arranged amongst neighbouring groups (Eyre

¹⁹ During his initial expedition, Sturt was informed by an ‘old man’ near Lake Bonney that Sturt’s party would continue northwest along the river before turning south. The man re-joined Sturt’s party south of Morgan, probably in the area of Moorundie, presumably after travelling along a mallee pathway.

1845:219–222) and long standing trade partnerships extending from the Lower Murray and Lakes to the Darling junction were enshrined in formalised relationships, such as the *ngengampi* tradition (Berndt and Berndt 1993:118).

Regional affiliations extended to the adoption of common social traits, including the treatment of the dead. Upstream of the Riverland, Hawdon (1952) observed a number of burial grounds, regularly containing around 30 graves that were usually surmounted by branch structures with thatched reed rooves, and scattered with mourning caps manufactured from a lime clay plaster. A similar description is provided by O'Halloran (1904 cited in Burke et al. 2016) of a cemetery at Horner's Nest (Chowilla Floodplain), a possible reference to the Chowilla Orangery cemetery (Anon 1904:10, 1921a:38). Various accounts describe similar practices throughout the adjoining regions (Angas 1847:86–87; Beveridge 1883:29; Blackwood and Simpson 1973:143; Bonney 1883:135; Eyre 1845:354; Browne in Finniss 1966; Krefft 1865:78; Littleton 2002; Littleton and Allen 2020; Mitchell 1839:112; Sunderland and Ray 1959; Taplin 1879:29; Worsnop 1897:61). The use of mourning caps had apparently extended upstream from Morgan (Angas 1847:86–87; Taplin 1879:29; cf. Allen 1972:116) and as far as '400 miles' above the Darling River junction (Curr 1886:238).

4.2.2 Demography

On the 28th January 1830, Charles Sturt's initial expedition along the Murray passed the Lindsay River and entered the Chowilla floodplain. The party met with three groups of people in quick succession, comprising 230 people in total, and later encountered another group of around 60 in the area of the Calperum floodplain (Sturt 1833:Vol II 131–135). The following day, the party 'fell in' with a group of 270 people, described by Sturt as one of the largest groups on the banks of the Murray for many miles. Several days later, in the area of Lake Bonney, Sturt again encountered a large group of people. Sturt's observations are closely replicated by Joseph Hawdon's account of the first of what would become regular overlanding stock drives through the Riverland in late summer/autumn of 1838 (Hawdon 1952)²⁰.

²⁰ By 1840 the overlanding route had become the principal route from the east to the Adelaide markets (Holmes 1948:37) with the overland track taking on the appearance of a 'high road' (*South Australian Register* 5/9/1840, p.2).

Some caution should be exercised when interpreting these numbers, as it would be expected that the appearance of intruders would have naturally raised concern and curiosity. It is unlikely that Sturt's and Hawdon's parties would have been noticed and then ignored. Instead, a more likely scenario would be that people became aware of, and then followed the parties, possibly being described on multiple occasions in separate diary entries. When Sturt arrived near Cobdogla, for instance, people he had previously encountered near Chowilla were there to greet him:

We found our friends ready to introduce us to a large assemblage of natives. On asking them how they had passed us, they pointed directly east to the spot at which we had parted. By crossing from one angle to the other, they had performed in little more than half a day, a journey which it had taken us two long days to accomplish (Sturt 1833:138)²¹.

Introduced diseases had also impacted Aboriginal communities along the River Murray before the arrival of Sturt (Burke et al. 2016; Dowling 1990), though the full extent of this impact remains conjecture.

Eyre's (1842) description of 'many detached parties' between Moorundie and Lake Victoria during an expedition in January–February 1842, provides an impression of regular groups of people encamped along the river corridor, though the overwhelming impression gained from the historic literature is of a network of key population centres. Overland Corner, Lake Bonney and Chowilla are repeatedly referenced throughout the early contact period and beyond (Anon 1919; Buchanan 1924; Hawdon 1952; Moorehouse 1841; O'Halloran 1904; Schell 1914a; Sturt 1833; O'Halloran cited in Woolmer 1974:14). These centres were linked through a system of trackways, or the foot-paths described by Sturt (1833) which were exploited by the overlanding teams (see also Burke et al. 2016; Browne in Finniss 1966; Woolmer 1986).

Burke et al. (2016) have suggested that the Riverland was a 'highly territorialised area' and

²¹ Similar trackways are described by Burke et al. (2016) including a major route between Lake Bonney and Moorundie (see also Browne in Finniss 1966; Woolmer 1986).

references to local 'tribes', for instance the Chowilla (Grosvenor 1979:6), Lake Bonney (Eyre 1842, 1845:219) and Overland Corner tribes (Corporal Shaw cited in Taplin 1879:28–29), implies a system of differentiated territories. Taplin (1879:26) noted that 'the same language is spoken all up the Darling, for 500 miles by land; but on the Murray, above and below the junction, the language changes every, say forty miles'. Similarly, James Coutts Crawford, one of the early overlanders, noted territorial limits along the river corridor of between 30 to 40 miles, with Aboriginal 'ambassadors' required to negotiate passage across these boundaries (Pike 1965). Based on the 'tribal boundaries' proposed by Tindale (1974), this thesis relates principally to Erawirung country, with boundaries in the area of Chowilla between this group and the Maraaura and Ngintait, and downstream of Barmera with the Ngawait (see also Berndt and Berndt 1993:305; Brown 1918) (Figure 1-2). Three clans were identified within the 'Overland Corner Tribe' by Corporal Shaw as the Yerraruck, Rankbirit and Willoo (Taplin 1879:28), further indication of a tiered system of tenure. The use of Aboriginal 'ambassadors' by Hawdon's party (Hawdon 1952: March 8), and others²², highlight protocols around negotiated passage, presumably across tenure boundaries. Eyre (1842) recognised the importance of access protocols when traversing this area (see also Sturt 1833:126), suggesting that conflict between overlanders and Aboriginal groups was in part a consequence of:

... those travelling down the river [to] think of little more than how to get through such a district as speedily as possible. Under this influence, few probably make those allowances which are required, and will not incur that trouble which is necessary to bring about an amicable understanding with the aborigines.

There is also ample evidence of cooperative arrangements between groups, no more so than in the coordinated resistance to continuing territorial incursions by overlanding parties (Burke et al. 2016)²³. Eyre's account of a congregation of roughly 600 people at Lake Victoria from numerous 'tribes belonging to the river at some distance below the junction of the Rufus' (Eyre 1842,

²² Eyre's trip to Lake Victoria in May 1842 included a Moorundie Aboriginal person who would not proceed beyond Lake Bonney, and Lake Bonney people who accompanied him further upstream. Berndt and Berndt (1993:117) refers to *prigi* (messengers) sent before trading parties to arrange meetings (see also Sturt 1833:126).

²³ When Moorehouse reached the Murray, he was informed that most of the people had travelled upstream to congregate and attack an overlanding party (*South Australian Register* 11/09/1841, p.2).

1845:252) speaks to the relationships established along extended lengths of the river. This gathering is certain to have included people from the Riverland which, according to Eyre, had been essentially vacated (Eyre 1842). Eyre's account of this excursion, conducted in May 1842, again describes a system built around family groups or clans, 'tribes' comprising a number of clans and related to specific sections of the river corridor, and broader regional affiliations. Eyre (1842) found that:

... the various families were all congregated in large tribes, and the tribes were visiting one another. Near Lake Bonney I met large tribes thus assembled, consisting together of about 150 natives: these were the Narwijjerook and Karminbola tribes, belonging to Lake Bonney and the river for some distance on either side of it ...

Regional alliance networks extended to trade, which according to Berndt and Berndt (1993:117–118), included the exchange of skin cloaks and rugs, mats and baskets, *Typha* fibre, oil and vegetables from the lower Murray for stone axes, hardwood, weapons and shields with mid-Murray groups. Kimber (1969:4) described several trade routes and trackways criss-crossing the high mallee plains south of the river corridor, including a Wotjobaluk route through Nhill–Murrayville–Pinnaroo and to the Riverland. Trade items on these routes had included reed and yabby-claw necklaces, pipe-clay, red ochre, stone axes, reeds for spears, nets and twine, baskets and boomerangs (Kimber 1969). Chert and silcrete extracted from Erawirung-controlled quarries around Renmark, is the likely source of raw material used in the manufacture of flaked artefacts in sites throughout the southern and northern mallee (Westell 2017, 2020, 2021a; Wood et al. 1997) and in downstream locations such as Ngaut Ngaut (Tindale 1974). Basalt axes imported from central western Victoria and possibly Queensland (Andison 1953:1; Kimber 1969) are occasionally found in the Riverland (e.g. Wood 2005: see also the SAM collection data).

4.2.3 Foods and materials

Historical observations of Aboriginal people in this region around contact describe a highly diversified, though largely riverine-based Aboriginal economy exploiting a range of terrestrial and aquatic foods. These included the meat and eggs of various bird species (emu, duck, black swan), kangaroo, rat kangaroo (bettong), yam daisy, marsh club rush, bulrush, freshwater mussel and

tortoise (meat and eggs) (Beveridge 1883; Hawdon 1952:23; Humphries 2007; Scott 2005). Berndt and Berndt (1993:79, Appendix VI) described a similar range of staples in relation to the Lower Murray and Lakes that were seasonally distributed so that ‘a well-balanced diet’ was maintained throughout the year (see also Angas 1847 and Wilson et al. 2022). A similar scenario of widely available, diverse and seasonally distributed foods can also be assumed for the Riverland (see Jones 2016b:102–105). This image obviously runs counter to Webb’s (1984) interpretation of periodic dietary stress in the late Holocene skeletal evidence; a disparity that perhaps reflects the differing scales of observation represented in historical and archaeological data.

The species that feature most prominently in ethnohistorical accounts in terms of their contribution as food or material are summarised in Appendix I, with their seasonal availability, collection and cooking methods (where applicable) listed in Table 4-1. This list is intentionally limited to information pertaining to the Riverland and adjacent regions. As can be seen, autumn and winter saw a narrower range of foods able to be exploited and a higher component of terrestrial mammals, bird eggs and aquatic reeds and rushes. At this time, starch reserves in *Typha* spp. are thought to be the highest (Gott 1999:41). In addition, there is significant crossover in cooking techniques and, as such, it is difficult to assign styles of combustion feature represented in the archaeology to specific foods or food groups, in a general sense.

The breadth of dietary items, the collection methods, processing and cooking techniques described in the Riverland, are recognised across large parts of the central and western MDB, including the Darling River region (see for example Allen 1972; Allen 1974; Angas 1847; Berndt and Berndt 1993; Clarke 2009, 2013; Dowling 1990; Hawdon 1952; Krefft 1865; Mitchell 1839; Sturt 1833). As elsewhere, food collection strategies included a heavy investment in netting which is described in the procurement of various food stuffs that include birds, fish, turtle and land animals (kangaroo, emu, bettong) (Anon 1919; Beveridge 1865, 1883; Eyre 1845:259, 286–287; Finniss 1966; Grosvenor 1979:8; Krefft 1865:72; Nott 1924; Robinson and Clark 2000:48; Schell 1914a; Smyth 1878:314). Eyre (1845:286) referred to netting as ‘the most destructive mode of taking [birds] of any that is practised’ and was widespread along ‘the whole line of the Murray ... for fishing and for catching emu and kangaroo’ (Eyre 1832-1839:156-157).

Table 4-1: Seasonal distribution, collection and cooking methods of key staple foods identified in ethnohistoric observations as summarised in Appendix I (darker green represents the main collection times).

Genus	J	F	M	A	M	J	J	A	S	O	N	D	Collection method	Cooking method
Kangaroo													Speared, netted	Oven
Bandicoot													Dug out of burrows and clubbed	Open coals
Possum													Killed in tree hollows with clubs	Open coals
Emu													Netted, speared	Oven
Bustard													Decoys, speared	Open coals
Duck													Speared, clubbed, netted	Oven & open coals
Murray cod													Speared, netted, bone hook line	Oven & open coals
Golden perch													Speared, netted, bone hook line	Open coals
Freshwater mussel													Diving with basket	Open coals & oven (dependent on quantity)
Yabby													Wading	Open coals
Tortoise													Speared or collected by hand	Open coals
Goanna													Dug out of burrow	Open coals
Bird eggs													Hand collected; canoes used to access	Raw, open coals
Tortoise eggs													Hand collected	Raw, open coals
Yam daisy													Dug with 'yam-stick'	Raw, oven, open coals
Typha													Hand collected	Raw, oven, open coals
Marsh Club rush													Hand collected	Raw, open coals
Nardoo													Hand collected, ground	Cakes baked in open coals

The reminiscences of Theodore Schell, published in the *Murray Pioneer and Australian River Record* (26/02/1914, p.6), provide the following observations of net use specifically relating to the Riverland:

... great hauls [of cod] were caught with their net. These were made from reeds, all of which had to be chewed with their teeth so that they became pliable; they were often thirty to forty yards long. Cod fish live in hollow logs under the water, and the native with a small hand net would dive away down to one of these big old logs, place the net over the end of it, and gently tap, tap the log with a piece of wood.

... At snaring the wild ducks they were equally expert, and made their reed nets fifty yards wide by about ten deep. One of these they would stretch from tree to tree across some of the fairly narrow creeks. ... As soon as the convey [of ducks] would fly close an aboriginal would fling a piece of bark high into the air, and the birds, thinking it was a duck hawk, would swoop down and be trapped. I have seen great numbers caught by means of the net.

Nott (1924) described 'cordage factories' near Moorunde where groups of women would initially strip and chew rushes, the fibre would be dried in front of fires before men would roll the

processed material into twine and weave 6-inch mesh nets used in emu drives. Local accounts refer to rushes and marah-mallow²⁴ being sweated in ovens and then scraped with mussel shells in the production of rope and string (Drill 1904:2), a method essentially the same as that described by Angas (1847:55). Reeds were also used extensively in basketry. Browne (in Finniss 1966) observed Aboriginal women making small baskets, approximately 8 inches wide, from rushes and used for carrying needles and 'other small things'.

4.2.4 Floodplain management

Examples of floodplain management recorded across the south-western MDB extended to the construction of weirs and fish traps across rivers and flood runners, and the manipulation of water through the excavation of diversion channels (Beveridge 1883:48; Curr 1993; Eyre 1845; Humphries 2007; Kelly 2014; Krefft 1865; Pardoe and Martin 2001; Robinson and Clark 2000:44, 47–48; Smyth 1876:314; Sturt 1849; Worsnop 1897:100). These strategies were obviously grounded in an intimate working knowledge of the complex floodplain topography, its influence on inundation extents and frequencies, and the highly nuanced responses in individual floodplains to seasonal flows that were only vaguely predictable.

In the vicinity of Overland Corner, Dr Harris Browne, a member of Sturt's 1844–45 expedition, noted a dam built across a channel leading from the river to a lagoon made for catching fish and constructed with rods stuck into the ground in a double row 1 foot apart. This structure was filled with lignum to slow the fish and make it easier to spear or take in nets in 'immense' quantities (Finniss 1966). Large hauls of fish from weir traps were reportedly able to sustain groups for periods of months as flood waters receded from inundated backplain areas (Beveridge 1883:48; Eyre 1845:253; Krefft 1865; Smyth 1876). According to Clarke (2009:154), fish traps built in the River Murray itself, were a navigation hazard for paddle steamers prior to the construction of the locks in the 1920s.

Smith (1930) refers to trenches measuring up to three hundred yards long and five feet deep,

²⁴ Clarke (1985) suggested that the Australian Hollyhock (*Lavatera plebeian*) is probably the 'mallow' described in historical accounts as the source of fibre used by the Kurna of the Adelaide Plains for making string artefacts, including nets.

excavated alongside the river in the lower lying areas of the floodplain. These ‘trenches’ are most likely a reference to the natural swale and ridge topography preserved in the meander scrolls across the lower parts of the floodplain rather than artificially constructed channels (contra Clarke 2009:153), though this natural topography may have been modified in some ways. Fish would enter these food-rich habitats as flood waters rose and became stranded as water receded. At this time, people would ‘wade into the shallow water and scoop the fish into baskets made especially for this purpose’ (Smith 1930). Despite the resources obtained from these areas, very little archaeological evidence is found in the lower, densely wooded and rugged parts of the floodplains. This disconnect between archaeological evidence and historical observation, is one worth considering—a material record does not, in and of itself, reflect the roles that habitats may have served. Other land management practices, such as burn-offs, are also certain to have modified floodplain habitats to some degree. Gott (1982, 1999), for instance, has suggested that the large-scale harvesting and burn-off of *Typha* may have controlled the spread of this otherwise invasive plant.

4.3 The archaeological evidence

4.3.1 Introduction

A significant amount of archaeological investigation and site data has been amassed throughout the Riverland, primarily through commercial consultancy reporting. Three baseline surveys conducted on the Chowilla (Wood et al. 2005), Katarapko (Wood and Westell 2009, 2010) and Pike (Wood and Westell 2014b) floodplains, provide the most comprehensive synthesis of this material, to date. Beyond these studies, other notable work includes surveys commissioned for the then proposed Chowilla Dam (as summarised in the Volume 34 of the Memoirs of the National Museum of Victoria), a departmental survey of archaeological sites upstream of Renmark (Edmonds 1993), research-based studies by Dowling (1990) and Lenehan (1998), and theses completed as part of the Calperum research program (Dardengo 2019; Incerti 2018; Jones 2016b; Munt 2022; Ross 2018; Thredgold 2017). A small component of the Riverland sites have been incorporated into broader regional discussions, notably the Katarapko cemeteries (Littleton 2007; Littleton and Allen 2007), the Riverland mounds (Westell and Wood 2014) and several sites recorded during the Calperum research project (Roberts et al. 2020; Roberts et al. 2021b). A list of 1071 archaeological sites located between Lake Bonney and the NSW border has been compiled for the purpose of this

research from consultancy reporting, SAM archives, media and other historical references. Summary details are provided as supplementary data. Most of these locations have been documented since the early 2000's during iterative survey conducted for floodplain rehabilitation schemes initiated, in large part, in response to the Millennium Drought. The suite of site type identified in this region is consistent with the broader MDB, with open scatters, oven mounds, burials and scarred trees being the most frequently reported (Table 4-2). Importantly, much of the previous site recording has been qualitative, a consequence of the site-avoidance methodologies applied in the majority of studies. Few accounts provide significant detail on site content, structure or context. The detail captured in the SAM data is particularly vague. Despite the variable currency and standard of site recording, it is possible to broadly characterise the Riverland archaeology from this data.

Table 4-2: Site types and numbers reported in the Riverland.

Site type	Count
Burial	20
Mound	153
Quarry	6
Quarry & associated scatter	3
Open scatter	405
Open scatter & burial	57
Open scatter & mound	72
Open scatter, mound & burial	9
Modified tree	339
Rock shelter	2
Historic	4
Engraved art	1
TOTAL	1071

4.3.2 Common site types and their content

4.3.2.1 Open scatters

Open scatters of freshwater mussel shell, heat retainer and stone artefacts, in some combination, are the most frequently reported site type within the Riverland, accounting for 725 (68%) of the total site listing. Open scatters vary markedly in size and form, from small discrete features of less than 20 m², to sprawling complexes extending for several kilometres. Larger sites tend to occur adjacent to water features in areas providing continual access to the floodplain under various inundation scenarios, or around the valley margins (Wood et al. 2005; Wood and Westell 2009,

2010). Most sites are essentially surface features, with relatively few deeply stratified deposits having been reported²⁵. A common descriptive term used in the site records is 'diffuse'.

Combustion features are a common element of open scatters, occurring as collections of heat retainer or as fire-hardened sediment with or without an ash/charcoal matrix. A range of cooking techniques are suggested, including surface cooking, shallow pit cooking and features developed through multiple firings (oven mounds). This is consistent with the range of historically observed techniques, as listed in Table 4-1. Where present, heat retainer is usually baked sediment in the lower parts of the floodplain or calcrete nodules on the higher (T1) terrace and cliff-line.

Faunal materials are almost exclusively comprised of the freshwater bivalves *V. ambiguus* and to a lesser extent *A. jacksoni*, with occasional references to other elements including *N. sublineata* sp. (3 sites), quoll (1), bandicoot (1), turtle (1), yabby (1), lizard (1), emu egg (3), bird bone (1), unidentified small mammal (5) and fish (3). Only 4.7% of all open scatter descriptions explicitly describe shell as being absent, though relatively large volumes of shell are identified in only 3.3% of the sites. Whilst a dominance of freshwater mussel is replicated in the MDB, this is clearly unrepresentative of the range of foods reportedly collected by Aboriginal people around the time of European contact, including bird, fish, turtle and various land animals (see Chapter 4.1.3).

Stone artefact assemblages are invariably dominated by unmodified flakes manufactured in silcrete and chert, with minor components of quartz, quartzite, basalt and sandstone also noted (see for instance Incerti 2018; Thredgold 2017). Where a retouch component is identified, it usually comprises simple retouched flakes, though more elaborate forms are occasionally reported, including adzes in a small number of sites. Chert and silcrete are likely to have been sourced from seams in the Karoonda Surface, a deep pedogenic zone in the Loxton-Parilla Sands, which outcrops at various locations around the valley perimeter. Formal, large scale quarries in

²⁵ Deeply stratified cultural deposits include middens located on the Loch Luna floodplain, within the Lake Bonney foredunes (LBAC_26, 32, 39), within low sand sheets on top the confining cliffs between Pike and Murtho (PikeAWE15_10, Pike River Site 1, Paringa Midden 2), incorporated into the occasional scree slope (Murtho Forrest Midden), in floodplain dunes (Pike River Burial 2), and in a series of middens identified along Katarapko Creek (KatMar17_02) and Pyap Lagoon (PHY17_02).

this unit have been identified at Sugarloaf Hill (Loch Luna), Stony Ridge (Lake Bonney), Cape Horn (Pike floodplain) and the Memdelbuik Chert Mine at Spring Cart Gully (Tindale 1974; Woolmer 1974:21). Basalt edge ground axes have been recorded in at least one mound (Whirlpool Corner Site 2 - Wood 2005) while the SAM collections include a small number of additional examples. These axes were presumably sourced from the greenstone belt of central Victoria or possibly from Queensland (Andison 1953:1; Kimber 1969).

Grinding implements form a minor component of local assemblages though are widespread (Figure 4-1) with potentially higher frequencies reported on the Chowilla and Pike floodplains, and in the area of Lake Bonney. The grinding material referred to in the SAM collections is summarised in Appendix II, and includes multiple objects from Chowilla, Moorook (Yatco Lagoon) and New Residence (Pyap Lagoon) (see Chapter 4.3.3 for further discussion of the grinding assemblage). Grinding materials occur almost exclusively on the floodplains and are absent from cliff top sites. While Pardoe (2003:51) found that soft seed grinders and hard seed mortars were spatially separated in the Menindee Lakes region, with the latter often co-located with ovens in locations remote from large habitation areas, this does not seem to be the case in the Riverland. Instead, diverse grinding assemblages are occasionally reported from the same or adjacent site in this region. Woolmer (1974:21) describes grindstone quarries half a mile east of Lake Bonney and 30 miles north of Overland Corner. It is also possible that grinding material was imported into the area from western New South Wales as an extension to a trade system linking the Darling and Murray through Lake Victoria (Luebbers and Ellender 1991:51). Howitt (1904) describes trade down the Darling River in 'slabs of stone, and hard and heavy pestles of granite for pounding and grinding seeds and tough tubers'.

It is also likely that the extant lithic assemblages are biased through the actions of collectors and that the readily identifiable objects had been a focus of these activities. Table 4-3 lists the artefacts collected from the then proposed Chowilla Dam project as reported by Casey (1973). Whilst the nomenclature is outdated, it nonetheless provides a more realistic impression of the diversity in local assemblages. Of particular note are the grinding materials and the large numbers of adzes, a distinctive late Holocene implement (Holdaway and Stern 2004; Veth et al. 2011).

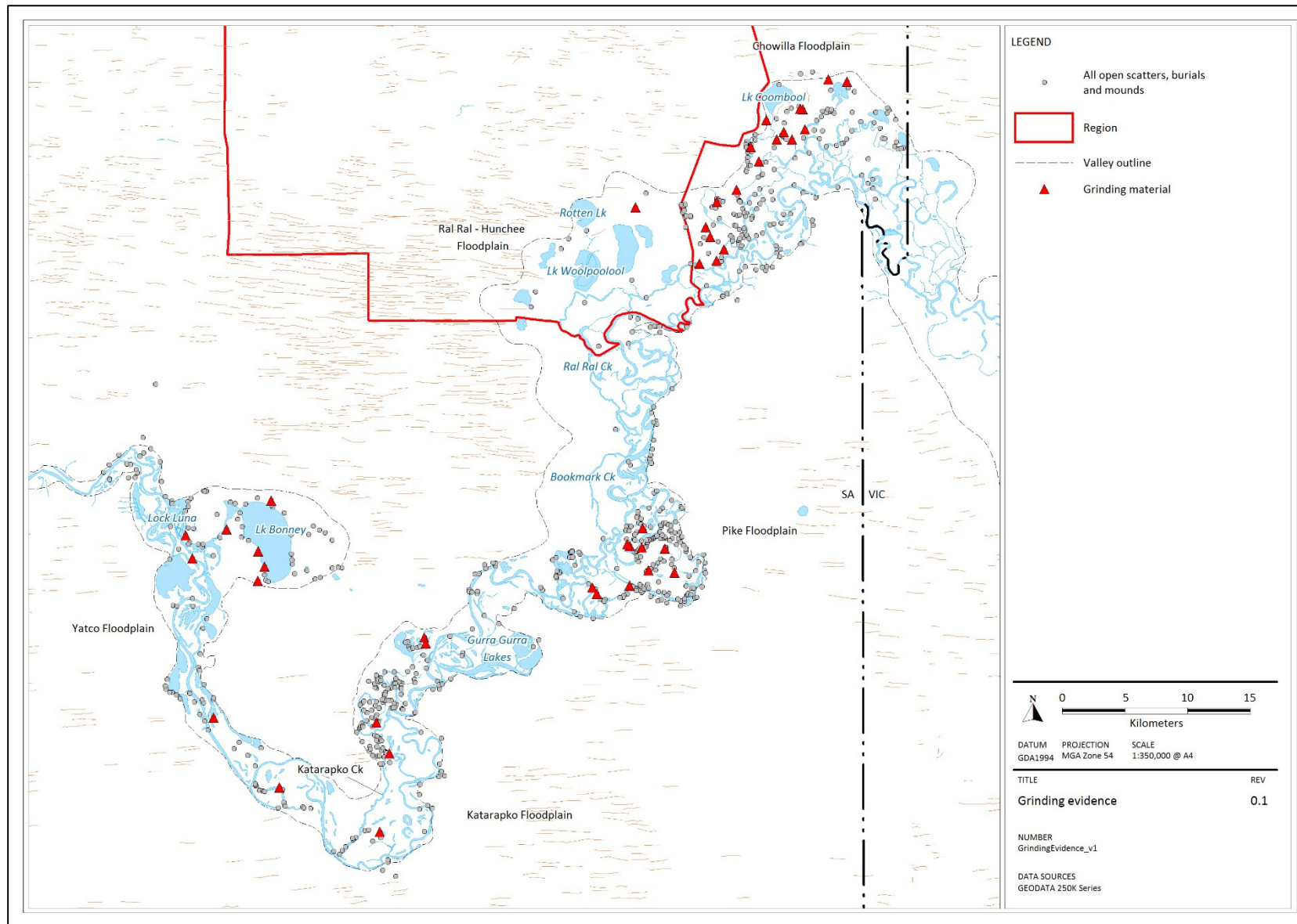


Figure 4-1: The distribution of documented grinding materials in the Riverland.

Table 4-3: Summary of artefacts collected and recorded from the proposed Chowilla Dam Impact Area (Casey 1973:209).

Artefact type	Number	Additional Notes Recorded
Adze	39	Two are similar to tula. Many are worn down into slug form. Width ranges from 20–40 mm with average width of 32mm. Several highly patinated.
Side scrapers	2	Discoidal and other types absent.
Retouched flakes and fragments	15	
Utilised flakes	4	Edge damage chipping observed.
Highbacked elongate uniface implements	5	Four are of quartzite and one is sandstone. Length ranges from 90–130 mm. All are approximately 50 mm wide.
Uniface choppers	4	
Horeshoof cores	7	Do not appear to have been used as choppers.
Unidirectional cores	8	
Multidirectional cores	12	
Hammerstones	6	
Milestones	25	Nine lower and sixteen upper. Fragments and whole included.
Mortars	15	With saucer-shaped hollows. Four demonstrate anvil damage.
Pestles or pounding stones	11	All elongated. Three with hammer damage.

4.3.2.2 Oven mounds

Oven mounds represent one of the most common site types in this region, with a total of 269 having been reported from 234 sites (Figure 4-2) (see for example Jones et al. 2017; Jones et al. 2022; Westell and Wood 2014). Etheridge (1893) was one of the first to describe mounds in any detail in the region (near Morgan), referring to large, circular accumulations of ash, charcoal and oven rock up to 25 m in diameter and half a metre high. References to this mound type appear frequently in local newspaper articles and historical accounts (Angel 1949; Roysland 1977:25). Structurally, the Riverland mounds are generally consistent in form, comprising circular accumulations of baked clay fragments contained within an ash/charcoal-rich matrix (Figure 4-4 and Figure 4-3). Maximum diameters range between 3–50 m and heights to 0.7 m (Westell and Wood 2014:46). Mounds are often impacted by rabbits, with spoil heaps and in excavated profiles suggesting a homogenous structure consistent with a repeat excavation, firing and rake-out of ovens, as suggested by Edmonds and Long (1998:51) for examples in south-western NSW. While mound content varies, most contain small numbers of stone artefacts and diffuse, fragmented freshwater mussel shell. Seventeen mounds are reported to contain no shell or artefacts, though occasional shell lenses and dense disseminated material are also identified. Archer Russell (1921c), for instance, describes large mounds of dark ashy earth, thickly impregnated with broken mussel shell and bones at Ral Ral Creek, while Wood and Westell (2015) report two closely located mounds at Katarapko (KatSFM15_01) containing densely packed freshwater mussel.

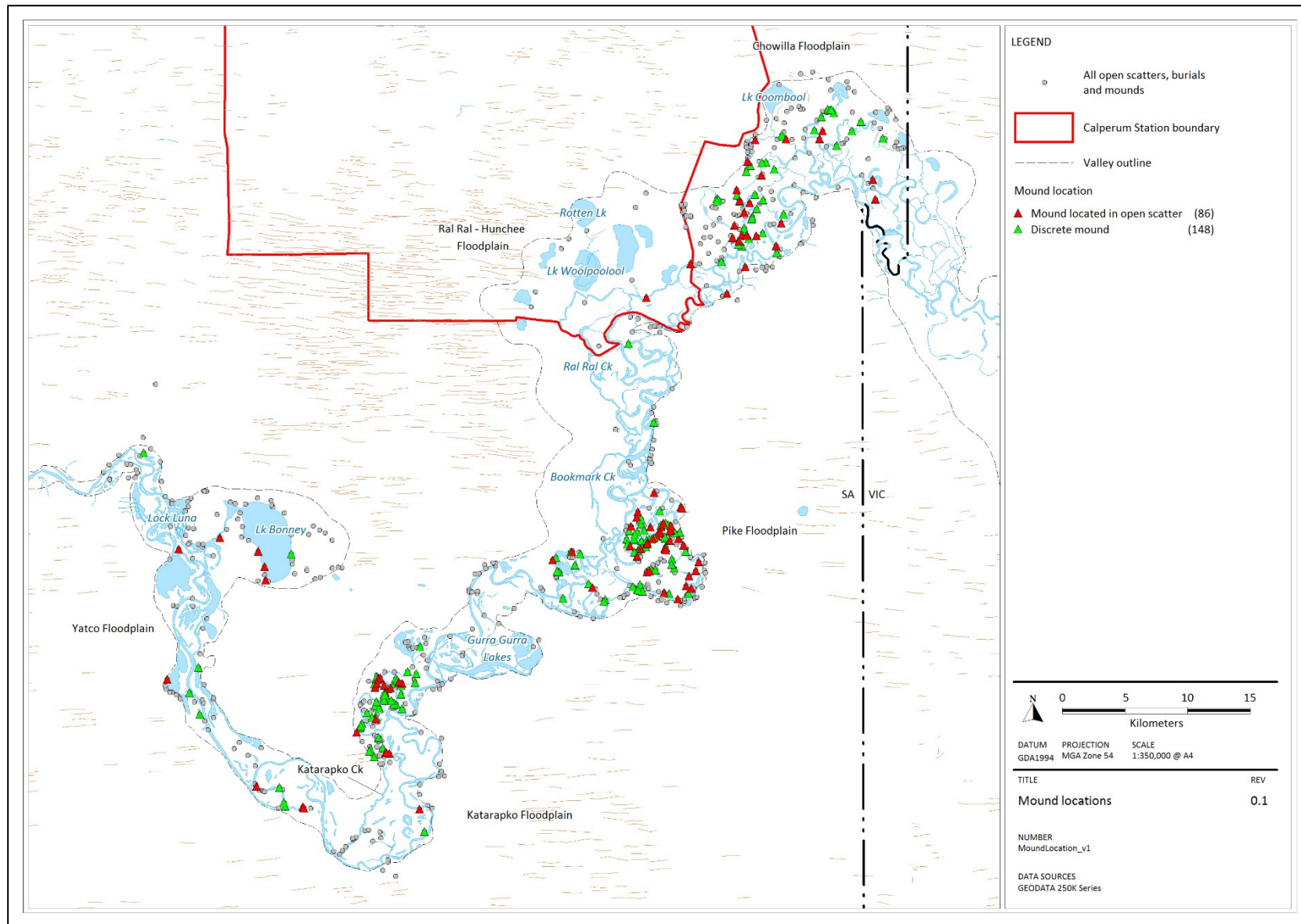


Figure 4-2: Locations of documented oven mounds in the upper Riverland.



Figure 4-4: Site PFBS14_50, a typical example of a Riverland mound. The gravelly texture seen in the image is baked clay heat retainer (Photograph C. Westell, 2014).



Figure 4-3: Homogenous mound structure exposed in rabbit warren excavated into site PFBS14_01, Pike floodplain (Photograph C. Westell, 2014).

Jones (2016:106) concluded that whilst shell was common in the Calperum mounds, it was probably related to the casual consumption of shellfish rather than a primary function of the mounds. Mound clusters identified at Calperum were considered by Jones (2016b:94–95) to reflect a regular, seasonally-based use of specific wetland areas. Larger mounds developed where the topography provided extended access to wetlands under various flooding scenarios and a sequential use of mounds occurred in response to the annual flood cycle (Jones 2016b:111–112). This scenario is consistent with Westell and Wood's (2014:54) suggestion that the placement of Riverland mounds reflected the 'distribution of the [plant] resource, availability of [damp] clay for use as heat retainer, together with fuel wood and water for steaming'. Beveridge (1883:37) saw mounds as having been positioned where game and other sources could be procured with 'the least expenditure of time and labour'.

There has been no reported evidence to suggest that the Riverland mounds functioned as habitation areas, e.g. hut bases. Rather, they appear to have 'functioned as repeat use pit ovens situated at accessible and reliable stands of aquatic vegetation' (Westell and Wood 2014:57), consistent with Klaver's (1998) assessment of the Murrumbidgee examples. The consistent and relatively limited lithic assemblages typically recognised on and adjacent to mounds also suggest a single activity unrelated to habitation (Thredgold 2017:125–126, 134; Westell and Wood 2014:53).

4.3.2.3 Burials and cemeteries

Burial sites are common and widely distributed in the Riverland, representing 4.5%, 5%, and 9.5% of the currently documented site inventories on the Pike, Chowilla and Katarapko floodplains, respectively. Typical of the broader River Murray (Littleton 1999; Littleton and Allen 2007:Table 2), burials are a common feature of floodplain dunes, though smaller numbers of burials also occur within levees and terraces. Unlike other MDB locations, burials are rarely reported in Riverland mounds. The discovery of at least four burials in a mound at Paringa is reported by Angel (1949) as 'unusual'. Most burials are associated with some other occupation material though relationships are often difficult to discern as most occur in eroded contexts. The exclusivity of cemetery use proposed by Pardoe (1993b) is replicated in a number of Riverland sites (Blackwood and Simpson 1973; Dowling 1990; Wood and Westell 2014b:57), though this is not a consistent trait. In a synthesis of the Riverland burial data, Wood and Westell (2014b) suggest that while solitary and

small groupings of burials are widely distributed, large burial grounds containing multiple internments are staggered along the course of the river. Burial grounds containing 50 or more individuals are reported in this region with anecdotal evidence of 150 individuals buried in sites at Overland Corner (Anon 1919) and Lake Bonney (Dowling 1990).

4.3.3 The grinding assemblage

Terminologies used to describe grinding material in the MDB invariably relate to the schema developed by Smith (1985), despite its detractors (for example Gorecki et al. 1997). Smith argued that soft seed, hard seed and non-specific grinding activities produce distinctive morphologies. Millstones were used in tandem with mullers to process soft seeds while hard seeds and seed cases were processed using mortars and pestles. Non-specific activities, i.e. fruits, bone, plant and mineral processing could be achieved on amorphous grinding implements. Within the MDB, Pardoe et al. (2019) have identified what they consider to be a distinctive anvil typology related to the processing of native peach/quandong kernels (*Santalum acuminatum*). These 'quandong stones' typically comprise hard, distinctively polished quartzite cobbles with a smooth, stream-rolled surface and one or more deep, circular pits on one surface and a larger 'mortar bowl' on the other (Pardoe et al. 2019:8).

Grinding implements are widespread in the Riverland, though form a minor component of the lithic assemblages. Formal millstones (as defined by Smith 1985) made on sandstone blocks, are extremely rare and most commonly represented by incomplete fragments. Instead, the bulk of grinding material takes the form of water worn quartzite or silcrete cobble topstones (pestles) and large silcrete grinding bases (mortars) displaying shallow circular depressions. Several references describe substantial sized blocks; the largest measuring 1.1 x 0.6 m (Anon 1942).

The Riverland floodplains are easily accessible from several large regional townships and are a popular recreational destination for the general public. One consequence of this ready access is the interference and removal of archaeological material. Indeed, a reading of local media accounts identifies the 'Collector' as a major taphonomic agent. Reporting on an excursion to Woolpoolool, Merreti and Coombool Lakes, Archer Russell (1924) states 'there are few places on the Murray - indeed I know of none - where the archaeologist may gather a richer harvest'. He collected, among

other items, 'nardoo stones' and grindstones. On a previous occasion, Russell claims to have collected 'as many artefacts as they could carry' from a series of sites around the western edge of the Ral Ral Creek floodplain. In reference to the Huncree Creek area, Anon (1942) reported that 'over the whole area people from Adelaide interested in stone age people have been digging small holes and searching for axes of which few remain'. From these, and other descriptions, it is evident that the relative paucity of grinding material in the extant assemblages may not be representative. In order to counter this bias, an inventory of the grinding material held in the South Australian Museum (SAM) archaeological collections at the Netley Storage Facility was collated. The bulk of these materials are provenanced to the Chowilla floodplain. This inventory is presented in Appendix II. The collections include a broad range of grindstone morphology, though are heavily weighted toward large grinding bases and cobble topstones. This is consistent with media descriptions and the extant assemblages. A cursory inspection of an additional set of boxes recently donated to the SAM by the Berri National Trust, identified a number of large tabular grinding bases (millstones). It is assumed that this collection had originated from the Riverland. The SAM collections also include a large number of basalt edge ground axes, again an item rarely identified in the extant assemblages.

The Riverland grinding assemblage can be described in two broad classes; grinding base or topstone. Six distinct types within these classes can be identified on the basis of raw material selection, mass, shape, usewear and the shape of the working surfaces, all of which appear to relate to distinctive design attributes and presumed applications. These morphologies are summarised in Table 4-4 and illustrated in Figure 4-5 through Figure 4-10. It is likely that Type I and III Grinding bases, and Type II and III Topstones were imported into the Riverland region. The grinding materials include the full breadth of soft and hard seed processing types described by Smith (1985), including examples of millstones and mullers, implements that are generally ascribed to the processing of soft grass seeds and are typical of arid-zone economies (Field et al. 2003).

It can be assumed that plant resources featured prominently in grinding applications, though a broader range of tasks may have extended to the pulverising of bone and pigments, and the maintenance of wooden implements (Gorecki et al. 1997; Hayes 2015; Smith 1985). Plant materials identified in the historical literature as having required the use of grindstones include

marsh club rush and nardoo (see Appendix I). The term ‘nardoo stone’ is used frequently in newspaper accounts and probably refers to the large grinding blocks and pounders used to initially break the sporocarp casings and process the hard nardoo seed. These are likely to be similar to the hard seed implements described by Pardoe (2003:48) in the Menindee Lakes region.

Grinding technologies are heavily implicated in the notion of late Holocene intensification and the move to diversified diets. Unfortunately, the lack of contextual information limits the ability to assign the SAM material to any firm chronology. At this stage, and based on the diverse grindstone morphologies, all that can be said is that a range of grinding applications had been implemented within the Riverland at some point(s) along a timeline. The diverse grinding assemblage appears consistent with that observed in the Lake Victoria (Casey 1973), Menindee Lakes (Pardoe 2003) and Murrumbidgee (Pardoe and Martin 2001) regions. Indeed, the extent and range of grinding materials in the Riverland appears to have more in common with the Central Murray and Darling River regions than the Lower Murray (see summary in Paton 1983) or Upper Murray. On the face of it, the presence of millstones and mullers within a riverine landscape seemingly flush with resource appears counter-intuitive and blurs any distinction between a riverine economy and that of the arid zone. Pardoe (2003) made a similar observation in regard to the Menindee Lakes, though his assertion that the use of terrestrial cereals in the Darling region differentiated it from the Murray may warrant some review based on the Riverland evidence.

Table 4-4: Grindstone morphologies recognised in the Riverland sites and in the SAM collections.

Type	Sub-Type	Type based on Smith (1985)	Description
Grinding base	I	Mortar	Waterworn cobble with shallow to deep, highly polished abraded circular facets typically on upper and lower surfaces, with or without hammer dressing or pitted usewear.
	II	Mortar	Coarse indurated sandstone and silcrete, crudely shaped blocks often in excess of 10 kg with single shallow to deep ground facet on one surface either circular or elongate and often extending to edges of block. The working surfaces are often hammer dressed and/or pitted and rarely polished, suggesting a combination of percussive and abrasive wear.
	III	Millstone	Large, tabular sandstone blocks with broad, shallow ground facet on upper surface occasionally extending to rim of block. Most commonly edge trimmed, with or without hammer dressing.
Grinding topstone	I	Muller	Planoconvex profile on typically thin sandstone piece with heavy polish on working surface.
	II	Pestle	Indurated sandstone cobble with single or multiple planated working surface.
	III	Pestle	Indurated sandstone or quartzite elongate (conical) cobbles with single polish and percussive wear on working surface located at broad end of cobble.

Grinding Base: Type I (Mortar after Smith 1985)

Waterworn cobble preforms with shallow to deep abraded circular facets typically on upper and lower surfaces, with or without hammer dressing. Includes examples in indurated sandstone and quartzite cobbles.



A59525 Chowilla - Indurated (silicified) sandstone



A17282 Chowilla - Quartzite, 2.5 kg



A56532 Chowilla - Quartzite



A56532 Chowilla - Quartzite

Figure 4-5: Examples of Type I Grinding Bases (mortars) held in the SAM collection.

Grinding Base: Type II (Mortar after Smith 1985)

Coarse indurated sandstone, crudely shaped block often in excess of 10 kg with single shallow to deep ground facet on one surface either circular or elongate and often extending to edges of block, with or without hammer dressing.



A21039 Renmark – Indurated (silicified) sandstone



A59527 Chowilla – Indurated (silicified) sandstone



A46045 Lake Woolpoolool – Indurated (silicified) sandstone



A20392 Overland Corner – Indurated (silicified) sandstone

Figure 4-6: Examples of Type II Grinding Bases (mortars) held in the SAM collection.

Grinding Base: Type III (Millstone after Smith 1985)

Large, tabular sandstone blocks with broad, shallow ground facet on upper surface extending to rim of block. Most commonly edge trimmed, with or without hammer dressing.



A54222 Chowilla - Sandstone



A31125 Lake Merreti – Sandstone 15.5 kg



A42418 Paringa – Sandstone.

Figure 4-7: Examples of Type III Grinding Bases (millstones) held in the SAM collection.

Grinding Topstone: Type I (Muller after Smith 1985)

Planoconvex profile on typically thin edge trimmed sandstone piece with heavy polish on working surface.



A56531 Chowilla - Sandstone



A59488 Lake Merreti – Indurated sandstone



A59488 Chowilla - Sandstone



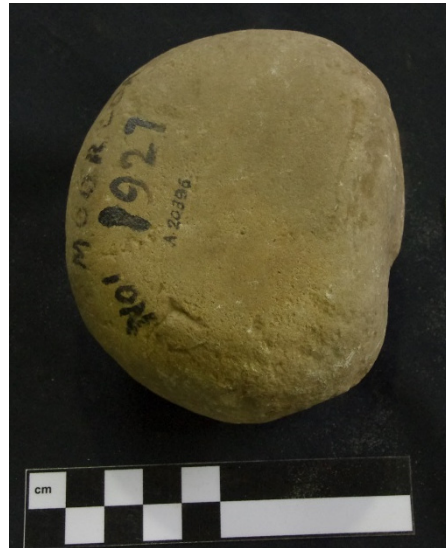
Figure 4-8: Examples of Type I Grinding Topstones (mullers) held in the SAM collection.

Grinding Topstone: Type II (Pestle after Smith 1985)

Squat indurated sandstone cobble with single planated and occasionally polished working surface.



A58487 Chowilla – Indurated (silicified) sandstone



A20396 Moorook – Indurated (silicified) sandstone



A20393 Overland Corner – Indurated (silicified) sandstone



A59487 Chowilla - Sandstone

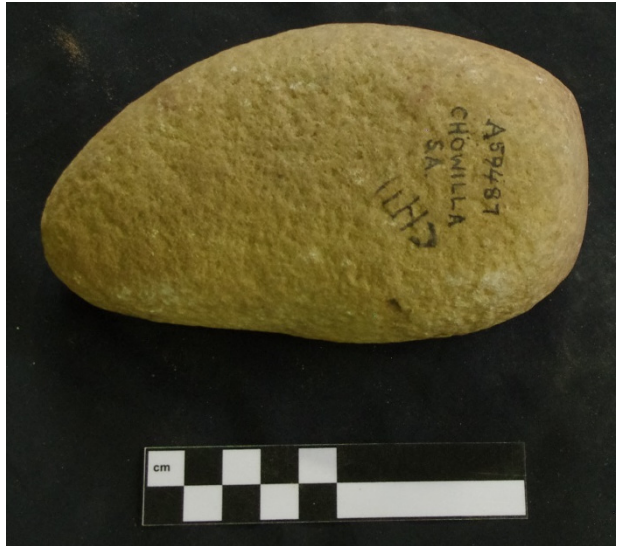
Figure 4-9: Examples of Type II Grinding Topstones (pestles) held in the SAM collection.

Grinding Topstone: Type III (Pestle after Smith 1985)

Conical indurated sandstone or quartzite elongate cobble with single polish and percussive wear on working surface located at broad end of cobble.



A56530 Chowilla – Indurated (silicified) sandstone



A59487 Chowilla – Indurated (silicified) sandstone

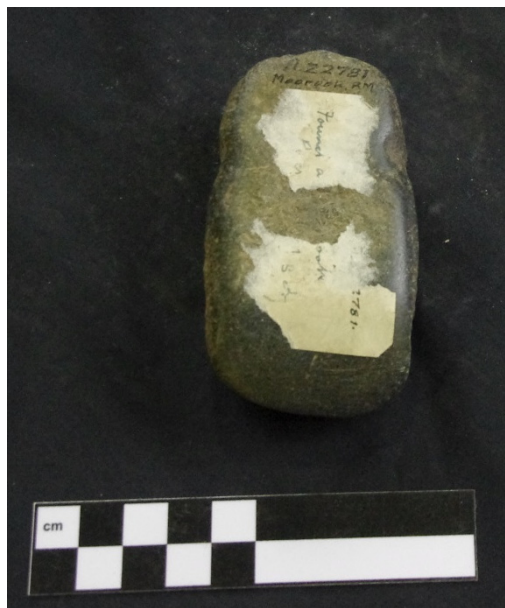
Figure 4-10: Examples of Type III Grinding Topstones (pestles) held in the SAM collection.

Edge ground axes

Basalt, flake preform, variable polish extending from tapered blade, with or without waisting.



A28746 Above Renmark – Basalt, non-waisted



A22781 Moorook – Basalt, single waisted

Figure 4-11: Examples of edge ground axes held in the SAM collection.

4.3.4 Site distribution & chronology

Riverland archaeology is focused on the Murray valley with site frequencies declining rapidly with distance from the valley margins (Dowling 1990; Edmonds 1995; Luebbers 1989a, 1989b; Nicholson and Wood 1993; Paton 1983). Luebbers (1989a; 1989b:15), for instance, proposed a notional zone of 'archaeological sensitivity' extending 300 m either side of the valley edges. A similar scenario exists in the Central Murray within NW Victoria, where Garvey (2017:85) notes that sites typically occur close to the modern river or its ancestral anabranches. The drop-off in the extent and frequency of archaeological sites in the Riverland is often abrupt.

Small amounts of freshwater mussel shell have been identified in sites 15-20 km from the river, though sites depicting longer-term or repeat occupation are absent within this zone. Whilst people were clearly accessing the mallee hinterland, with forays provisioned in part with floodplain foods, they were evidently returning to occupation nodes along the river itself. A distinct pattern of mallee-based occupation is described in the deeper mallee to the south and north of the river corridor. In these areas, large occupation sites, describing a more sustained settlement, have been recorded around springs, soakages and larger interdunal basins (McEntee 1945; Westell 2020; Wood et al. 1997).

The common aim of the baseline studies commissioned on the Chowilla (Wood et al. 2005), Katarapko (Wood and Westell 2009, 2010) and Pike (Wood and Westell 2014b) floodplains, was to identify spatial trends in site distribution, to synthesise this into predictive modelling, and apply this modelling to inform infrastructure planning. The predictive models were based on a series of 'land units' identified through soil reconnaissance and vegetation surveys (ABARES 2011; Hollingsworth 1990; Rural Solutions SA 2007; Sharley and Huggan 1995). These included the active floodplain, low relict meander plain, high relict meander plain and higher terraces. The baseline studies identified a number of trends that are replicated across the three anabranch floodplains, as follows:

- The relative archaeological sensitivity of land units varies. Largest numbers of sites, for instance, occur in the relict meander plain, principally along stream channels and across elevated levees on the scroll plains. Highest site densities occur around the highland margins and within the dunes, levees and lunettes in the floodplains.

- Individual site types tend to occupy distinct settings indicating a separation of site-specific activities within the floodplain. Mounds, for instance, are a particular feature of the stream and lagoon banks (e.g. approximately 92% of all mounds on the Pike floodplain), hearths and isolated artefacts tend to define the elevated backplain areas remote from the river while burials are most frequently located within levees and dunes.
- There is a tendency for all site types to cluster along the margins of landforms rather than within them. Wood et al. (2005:68) attributed this to the subtle topography commonly formed along these margins which is likely to have 'marked the lateral extent of various flooding scenarios' along which people would have periodically relocated their campsites and focused economic activities. Landform boundaries also maintain much of the larger vegetation presumably used as a source of fuel wood and structural material.
- A rapid drop-off in site frequency occurs with distance from water features, including permanent and ephemeral features.
- A clustering of sites occurs in a zone defining the lateral extent of large-scale flooding.
- Larger sites occur around the margins and higher parts of the floodplains that provide connectivity between the highland and floodplain during various inundation scenarios.
- Very few sites occur in the lower parts of the floodplains, and relatively few sites (principally scarred trees and middens) occur along the modern channel of the river itself except where it abuts a higher terrace. A similar observation was made by Gill (1973a:43).
- Sites tend to cluster around the floodplain margins. This includes continuous middens extending for hundreds of metres or more along the confining slopes and cliff-line.

The patterning of archaeological sites within the valley suggests that wetlands, lagoons, lakes and anabranch creeks were the foundation of the local economy. Mobility and procurement strategies, at least those witnessed at the time of contact, seem to have been built, in large part, around the seasonal proliferation in waterbirds (meat and eggs), floral species (tubers) and the feed induced booms (fish, macropods, birds) associated with these habitats. A number of locations stand-out in terms of the extent of Aboriginal archaeology, including several large oxbow systems (Eckert Wide Water, Disher Creek Lagoon, Hancock Creek, Snake Creek, Loch Luna, Tanyaca Creek), lakes (Coombool Swamp, Lake Bonney) and stream courses (Katarapko Creek).

4.3.5 Chronology

Prior to this research, direct age estimates returned for Riverland sites were limited to eight ages returned on ancestral remains from the K1 burial ground, located on the Katarapko floodplain. These estimates ranged between 350 ± 200 BP (ANU-6899) [595 – 568 cal BP] and $4,700 \pm 140$ BP (ANU-6896) [5655 – 4960 cal BP] (Dowling 1990).

Additional traits suggest that the extant Riverland archaeology is heavily biased toward the Holocene. Despite the potential for the burial of archaeological material through regular flooding and aggradation of floodplain surfaces, there are few instances where cultural deposits have been identified at any significant depth. This is despite reported instances of deep natural and artificial profiles. The floodplain archaeology tends to be draped over landforms rather than incorporated into them, albeit for shallow deposits noted in aeolian sand sheets, source bordering dunes and along stream bank levees. Deeper deposits tend to occur in scree sediments around the periphery of the floodplains or in the more mobile dunes. Notably, archaeological materials in lunettes tend to occur either as lags in active sand sheets or on the intact surfaces of lunettes, with limited material seen in profile. Where this is observed, it is always shallow and always above palaeosols (e.g. Wood and Westell 2013; Wood and Westell 2014a). The impression is that lunette sites relate to the modern basins and flooding scenarios rather than development of the lunettes themselves. This is an obvious departure from the lunette records studied elsewhere in the MDB.

4.4 The modern Riverland floodplains

4.4.1 Hydrology

The River Murray in SA is an exotic, dry-land river, with inflows derived primarily from a headwater catchment situated within the eastern Australian highlands over 700 km upstream of the Riverland (Thoms and Sheldon 2000; Walker et al. 1995:90). Between the SA border and Overland Corner, the river flows through a valley up to 9 km wide and incised 30 m or more into the Murray High Plains (MHP) (Figure 4-12). The valley incorporates a series of contiguous anabranch floodplains (Figure 1-2) and is bounded by an abrupt escarpment and scree, or a subtler slope draped by WFM dunes or climbing sand sheets (Bunyip Sand equivalent). An indurated ferricrete horizon (the Karoonda Surface) is contained within upper unit of the Tertiary age Loxton–Parilla Sands (Firman

1966; Jennings 2009:23; McLaren et al. 2011:1097) and forms occasional benches along the valley cliff (Figure 4-13 and Figure 4-14). This horizon was the source of the silcrete and chert that dominate local artefact assemblages.

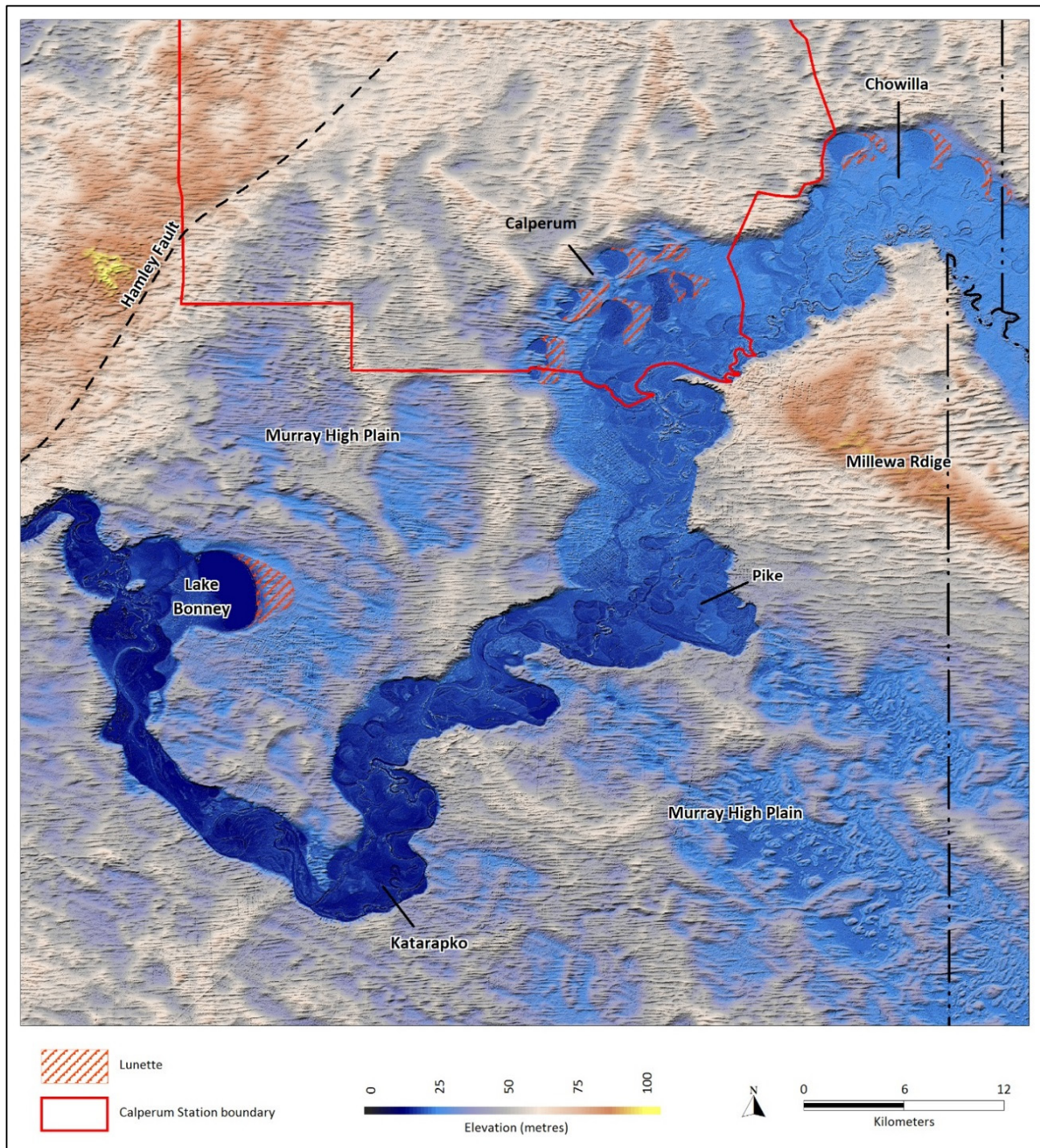


Figure 4-12: Regional topography and main physiographic elements including the incised Murray River valley, the linear (EW) dune-fields of the Woorinen Formation, major lunettes and individual floodplains within the valley, the Millewa Ridge and the valley-gorge transition coinciding with the Hamley fault line.



Figure 4-13: Massive seams and blocks of silicified and ferruginous sandstone within the Karoonda Surface exposed in the confining cliff-line at Murtho (Photograph C. Westell, May 2016).

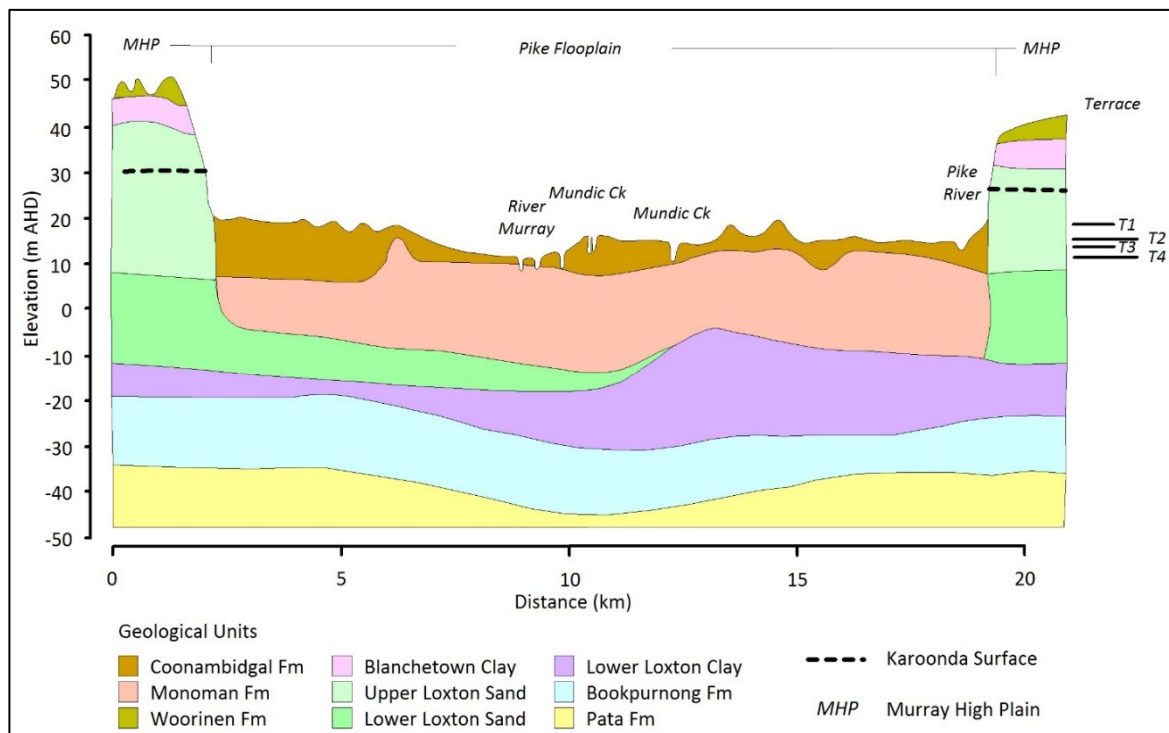


Figure 4-14: Geological cross section of the Pike Floodplain adapted from Australian Water Environments (AWE) and CMC (2012:Figure 6.6).

Under natural (unregulated) conditions, inflows to the Riverland floodplains would decline in late summer and autumn. The floodplains would be largely dry at this time except for the deeper channels connected to the River Murray. The river itself may have contracted to a series of discontinuous pools (Sharley and Huggan 1995:87–98). Flows would begin to rise in late autumn/winter, gradually filling the deeper watercourses and anabranh creeks at levels of

around 30 GL/day before flood peaks in excess of 50 GL/day in late spring–early summer increased the level of wetland connection, inundating all major streams and overspilling banks into the broader floodplain (DEWNR 2013; Ecological Associates and Australian Water Environments 2008; Robinson et al. 2015). There was no permanent flow in the anabranch creeks under median and drought conditions prior to regulation (Yan et al. 2005). Flows of 80 GL/day occur once every 2–3 years (Sharley and Huggan 1995).

Late summer flood pulses can occur from monsoonal encroachments into the upper Darling catchment (Simpson et al. 1993:3673). Interannual flow variability is also high (Simpson et al. 1993; Walker 1986; Walker et al. 1995:86–88) with historical data summarised by Mills et al. (2013:555) describing an oscillating pattern of drought and flood on cycles of several decades or more. A change between the two climatic modes occurs in a sudden, discontinuous, step-like manner. Within these modes, a tighter clustering of wet and dry years relates in part to the ENSO 5-year return interval (Simpson et al. 1993), though flood patterns remain only vaguely predictable. The size, the return period and duration of inflows into SA under natural and regulated regimes are shown in Table 4-5. The 1956 flood was the highest on record at 341 GL/day.

Table 4-5: Comparison of natural and regulated flows in the Murray River (source: Bloss et al. 2015; Ecological Associates and Australian Water Environments 2008). The 341 GL/day relates to the 1956 flood.

River Murray flows to SA (GL/day)	Number of times flows occur in 100 years		Duration (number of months flow is exceeded)	
	Natural	Regulated	Natural	Regulated
5	100	100	11.8	11.9
10	100	94	10.1	4.6
20	99	63	7.8	4.6
30	96	51	6.4	3.9
40	91	40	4.9	3.3
50	79	30	3.9	2.7
60	59	21	3.9	2.5
70	49	15	3.6	2.9
80	45	12	3.2	2.6
90	37	11	3.1	2.1
100	32	9	2.9	2.0
120	23	5	2.2	2.8
150	12	4	2.2	1.5
225	-	1	-	-
341	-	0.4	-	-

Far from being generic landscapes, the unique configurations of each of the Riverland floodplains results in unique responses to flooding. The large temporary lagoons and wetlands maintained under the modern regime in former lunette basins, for instance, are landscapes that are specific to Chowilla, Calperum and Lake Bonney, though their flood responses also vary. During the first stock drive through the region in March-April 1838, Joseph Hawdon noted that the backplain areas extending from Chowilla to Renmark were barren, despite their appearance of being annually flooded (Hawdon 1952). Saltwater was seen gushing from a spring onto the Chowilla floodplain and Hawdon observed that many of the floodplain pools were saline. Lake Bonney, however, was full of freshwater and teeming with birdlife. While it could be expected that flood pulses migrate downstream, impacting floodplains in a sequential manner, the persistence of water at Lake Bonney into early Autumn suggests a more permanent inundation of this waterbody. During the same season, though several years after Hawdon's expedition, Edward John Eyre met with the Lake Bonney 'Tribe' who had relocated to the river as the lake had dried (Eyre 1842). Again, these two observations illustrate variability in floodplain inundation, both geographical and temporal.

The Riverland lies within the modern semi-arid zone, in a temperate climate of cool winters and dry, warm to hot summers (ABARES 2011). Rainfall is unpredictable over the long term with a yearly range between 441–121 mm recorded over the period 1984–2016 (Riley 1988). Drought occurs frequently and evaporation rates exceed rainfall in every month (Australian Bureau of Meteorology 2017).

4.4.2 Riverine ecology and some insights from the Millennium Drought

The ecological health and complexity of floodplains is ultimately governed by, and sensitive to, cycles of flooding. Pulses in river flow promote responses such as seed germination, trigger breeding in a variety of fish and bird species, determine breeding success and are key in the provision of food (Ballinger and McNally 2006; Cale 2009; Graham and Harris 2005; Junk et al. 1989; Leigh et al. 2010a; Newall et al. 2008:13; Poff et al. 1997; Walker et al. 1995:93–94; Ye et al. 2014:34; Young 2001). Reductions in the periodicity, length and volume of inflows can have profound and cascading effects on floodplain taxa. The correlation between flow conditions and salinity is particularly relevant in the case of the Riverland, where flows not only act to flush and dilute accumulated salt, but also saturate sediments and temper the influx of saline water entering

the valley from the highland aquifers (DEWNR 2012:13; Magee 1991; Telfer et al. 2012; Yan et al. 2005) (Figure 4-14). The input of aquifer-sourced salt compounds an increase in water salinity that occurs naturally from headwaters to coast (Walker 2006:265).

The modern (unregulated) regime of regular wetting and drying cycles, provides optimal conditions for species diversity, supports booms in various food chain elements, and the recruitment²⁶ across a broad suite of floodplain taxa (Young 2001). The life cycles of many floodplain species are timed to either avoid or exploit flows of variable magnitude (Poff et al. 1997:775). The native fish species are, for instance, a 'warm water' assemblage, with water temperature important for their reproduction, optimal functioning and growth (Humphries 2005; Reid et al. 2009; Thoms et al. 2000:47). The larger fish species (Murray cod, trout cod, catfish, golden and silver perch) generally spawn as water temperatures rise in late spring/early summer (Humphries et al. 1999:132) and the success and scale of recruitment is dependent on the arrival of flood pulses at this time.

Overbank flooding is an important mechanism in the delivery of food to fish populations. Reduced connectivity between the river channel and wetlands leads to population decline. The survivorship of larval/juvenile stages for at least some species, including golden perch, is improved by increased river flow and floodplain inundation (Ye et al. 2009). According to King et al. (2003), optimum conditions for fish recruitment occur when rising water temperature and flooding coincide, when flood pulses are predictable, when the rise occurs at a slow to moderate pace, and when floods last for months rather than weeks and extend across large areas of floodplain. Yabby (*Cherax destructor*) are also a temperature dependent species, requiring water temperatures above 16° C to be active. Many of the aquatic plant species are also water depth-sensitive, with optimal growth requiring a specific range and timing of inundation to coincide with seasonal tuber development and flowering (Blanch 1997; Thoms et al. 2000:42; Wallace 2011:54).

Just as major floods promote large-scale recruitment in faunal and floral communities, reductions in flow, and in particular reductions in flood frequency, invariably trigger negative responses (Alexander et al. 2008:187, 192; Thoms et al. 2000:42). Newall et al. (2008:158–165), for instance,

²⁶ Recruitment refers to the survival of individuals to reproductive age.

identified noticeable changes in the vegetation condition in the Chowilla and Calperum floodplains over the 20-year period straddling the Millennium Drought. The frequency of medium scale flooding (10–30 GL/day) was significantly reduced during this drought (Holland et al. 2013:1). Most vegetation communities were impacted to some degree through a lack of watering and increased salinity, though impacts to semi-permanent and fringing aquatic vegetation were the most noticeable. Importantly, the decline in black box communities²⁷, which occupies a range of habitat and has relatively high salinity tolerances, indicated that the floodplain was under broadscale stress, an observation repeated along the broader river corridor (Jensen and Walker 2017:223; Newall et al. 2008:158, 163).

While vegetation is able to accommodate short term perturbations within tolerances, long-term change will trip it into an exhaustion state (Rogers and Ralph 2011:8–9). The loss of a tree layer and change to simpler low shrubland communities is the ‘ultimate fate’ of vegetation in areas of rising salinity (Stewart et al. 2010:233-235). Newall et al. (2008:163) considered the trajectory induced by the Millennium Drought to be close to the threshold of permanent change in vegetation communities in the Riverland floodplains. Persistent low flow conditions saw a change from drought-tolerant to salt-tolerant communities and a lack of recruitment conditions for many of the riparian species (Zampatti et al. 2011:69; see also Jensen and Walker 2017, Kingsford 2000, Wallace 2011:50). The riparian woodland, sedge and reed communities are the least tolerant with common reed, bulrush, club-rush, lignum, river red gum, river box and river coobah all susceptible to the effects of salt (Dunlop et al. 2005; Roberts and Marston 2011). Vegetation acts as a key structural element for various riverine fauna with changes in composition having a direct impact on bird, fish, reptile and mammal populations (Roberts and Marston 2011; Stewart et al. 2010; Young 2001:97). Critical fish habitat is provided by submerged, emergent and floating plants as well as the snags and root ball masses of large, water-reliant trees. Fish populations are directly related to the health and concentration of these vegetation types and the provision of instream habitat (Beyer et al. 2011:34, 46; Cadwallader 1978; Phipps 1999:10; Zampatti et al. 2011). Historically, fallen trees had been considered an impediment to navigation and until recently were systematically removed from channels. The decline in native fish populations can be attributed, in part, to loss of this habitat.

²⁷ An increase from 6% to 82% in the number of unhealthy or dead trees was recorded over a 20-year period.

Avifauna, arguably the defining element of the River Murray floodplains, are also critically dependent and responsive to inundation (Leslie 2001; Reid et al. 2009). It has been observed that waterbirds will abandon nests if floodwater recedes too quickly (Ballinger and McNally 2006:96; Reid et al. 2009) with inundation periods of 4–5 months key to the successful breeding and survival to independence of most species, and longer (6–8 months) for some, e.g. the Black Swan (Reid et al. 2009; Swirepik et al. 2015; Wallace 2011:57). Bird populations respond dramatically to flood conditions, with major flood events supporting populations for decades and populations crashing during drought. A study conducted by Selwood et al. (2015) on the Barmah Forest avifauna recorded a substantial decline in the majority of species across the Millennium Drought. Close to a third of all species observed in the early stages of the drought were not recorded in the latter stages, and fewer than half of these species reappeared in the immediate period after the drought broke. These responses could be attributed directly to a decline in the local forest conditions and consequential impacts on food and habitat. Selwood et al. (2015:1706–1707) concluded that ‘four years of average to well-above-average rainfall is inadequate to offset losses from a 13-year drought’. The effect can be persistent when systems do not have the capacity to recover between drought events.

Salinisation is an inevitable consequence of reduced flood frequency. The incised nature of the Murray valley as it enters the Riverland makes it particularly susceptible to changes in inflow conditions, as any reduction is invariably associated with a greater influx and accumulation of salt sourced out of the saline aquifers of the MHP (DEWNR 2012:13; Magee 1991; Telfer et al. 2012; Yan et al. 2005). The impacts of salinisation on riverine ecology are pervasive. Both species of freshwater mussel, for instance, have salinity limits and populations are known to disappear in salinised streams, principally through mortality amongst the glochidia (larval stage of mussel) (Walker 1981:51, 1986, 2017:33; Walker et al. 2001:18-19). *A. jacksoni* is much less tolerant of drying than *V. ambiguus*, with 50% and total mortality in the former occurring within 12 and 31 days out of water, respectively (Walker 1981:85). Bimodal size distributions noted in mussel populations have been attributed to periods of drought. *A. jacksoni* populations took up to ten years to fully rebound from the 1967–69 drought (Mackay and Eastburn 1990:312), while mussel shoals in Lake Alexandrina were ‘obliterated’ during the Millennium Drought and have been slow to recolonise (Walker 2017:42). Similar impacts are recognised in the early life stages of fish and crustacea (Mills and Geddes 1980).

The Riverland floodplains incorporate a range of terrestrial and aquatic habitat (Table 4-6), though the distinction between these is often blurred given the variation in flows over the short and long-term. This variability creates significant heterogeneity in the habitat mosaic (Rogers and Ralph 2011; Thoms et al. 2000). The terrestrial habitats are largely defined by vegetation community, in turn closely related to inundation regime (dictated by elevation) and soil type (Newall et al. 2008:11; Rural Solutions SA 2007:Appendix I). The main vegetation associations at Calperum are shown in Figure 4-15.

The aquatic habitats include a diverse array of channels and waterbodies. Prior to regulation, all of these waterbodies were intermittent or ephemeral, including the River Murray itself. Of the various aquatic habitats, billabongs are recognised as one of the most ecologically productive and diverse (Blanch 1997; Brock and Cassanova 1997; Graham and Harris 2005:3) and can retain water for often longer periods than other waterbodies (Butcher and Reid 2002). The recruitment of various fish species is linked, to some extent, to the connection of the river and the 'massive biomass of microscopic organisms' supported in these wetlands during the breeding period (Cale 2009; Thoms et al. 2000:37). Most billabongs support communities of emergent macrophytes when full and herbaceous vegetation available to grazing animals when dry (Graham and Harris 2005:3).

Poff et al. (1997:770–771) list the five 'critical components of flow regime that regulate ecological processes' as magnitude, frequency, duration, timing (seasonality) and rate of change (flashy or stable) of hydrologic conditions (see also Leigh et al. 2010a). Some of the broad implications on floodplain ecology through changes in these components are presented in Table 4-7. Table 4-8 identifies the differences in the inundation requirements for survival and recruitment for various vegetation communities.

Table 4-6: The main terrestrial vegetation communities and aquatic habitats found in the Riverland floodplains.

Terrestrial	
Habitat	Distribution and detail
River red gum woodlands	Narrow belts along regularly inundated watercourses with denser forest occurring across the lowest parts of floodplain (T4). Red gums are highly water dependent with the tight woodland belts reliant on direct watering and soil moisture (Rogers and Ralph 2011:22).
Black box woodland	Typically located on higher elevations on T2 and T3, commonly seen along the terrace margins, and at greater distances from the watercourses and wetlands than river red gums. An understorey of grass/forb or chenopod shrubs is typical.
Lignum shrubland	Occurs as a distinct community across gilgai terrain in drainage depressions on T2, or in association with river red gum, black box and river cooba on T3 and T4.
Chenopod shrubland	Typifies the high, sandy soils of T1 and is also a common element of the higher T2 surfaces.
Herbfield	Ephemeral wetlands and areas of the floodplain subject to inundation.
Grassland	Ephemeral wetlands and areas of the floodplain subject to inundation.
Samphire shrubland	This community is likely to have expanded through salinisation of the post-regulation floodplains and occur predominantly across T3.
Mallee woodland	Mallee woodlands extend into the valley from the Murray High Plain where WFM dunes have transgressed into the valley.
Aquatic	
Habitat	Distribution and detail
Semi-permanent and ephemeral channels	These include the River Murray course and the network of larger anabranch and other distributary channels. These contain submergent, emergent and free-floating vegetation. Fast flowing channels, i.e. the River Murray channel and the larger anabranches, are habitat for the river mussel, river snail and Murray crayfish, all of which are locally extinct due to reduced post-regulation flows. Native fish species display clear habitat differentiation, with water velocity a key determinant. The anabranch waterways, for instance, are critical habitat for large body fish such as Murray Cod and Callop which tend to occupy the faster flowing channels and occupy waterways containing woody debris, emergent and riparian vegetation (MDBA 2012:12; Newall et al. 2008:102-103; Zampatti et al. 2011).
Intermittent and ephemeral waterbodies	Examples of intermittent lakes, billabongs and swamps occur throughout the floodplains, ranging in size, depth and flood duration. These typically contain submergent, emergent and free-floating vegetation with reed/sedge communities a common around the shorelines. The lagoon mussel and yabby occupy slow flowing and still water habitats, including billabongs and backwaters. Unlike the lagoon mussel, the river mussel does not tolerate low oxygen, high temperatures and dehydration (Sheldon and Walker 1989; Walker 1986), and as such, is not found in billabongs. The broader non-permanent floodplain areas are not critical habitat for native fish, though the delivery of food into the main channels from these areas during flood is likely to see responses in fish populations (Humphries et al. 1999:131-132).
Salinas	These include a number of former floodplain depressions and lakes situated around the periphery of the floodplain that have become isolated from regular inundation.

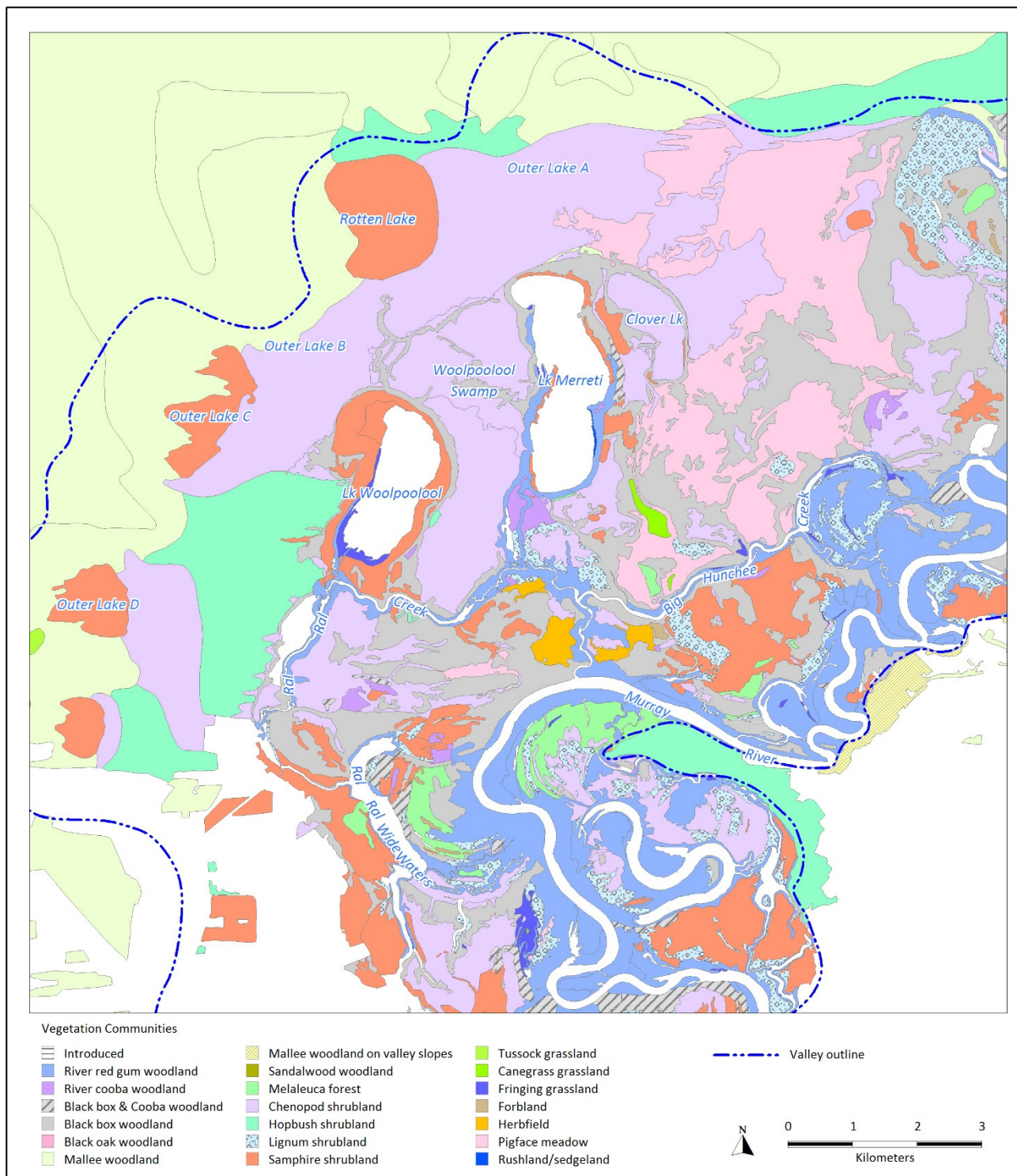


Figure 4-15: Vegetation communities on the Calperum floodplain (source: SA Vegetation GIS dataset).

4.5 Chapter summary

The Millennium Drought spanned a period of roughly 20 years. The responses in riverine ecology to this event were both profound and complex and provide some cues to the floodplain ecologies that are likely to have defined past settings. To summarise, changes in hydrology in the MDB over the last 50 ka have centred primarily around the volume and duration of flooding, coupled with changes in inter-flood period. An early (> 35 ka) regime of regular, fast flowing, large capacity rivers maintained perennial conditions in lakes across the MDB. While peak volume was maintained, increasing variability in lake conditions from c. 35 ka suggest less reliable flows and shorter flood lengths, a pattern that amplified during the LGM. A regime akin to the modern system (lower peak volume, though regular and lengthier flood cycles) was installed around the terminal Pleistocene and has largely persisted throughout the Holocene, though has been punctuated by millennial-scale episodes of lower or more irregular inflows.

Ethno-historical observations describe a highly diversified though largely riverine-based Aboriginal economy in the Riverland, incorporating most elements of a diverse habitat mosaic into a broad diet breadth based around several key staples. Given the trajectories identified during by the Millennium Drought, it cannot be assumed that the habitats and species recruited into these subsistence systems had occurred in the deeper time landscapes, at least not in their current form. Based on the requirements of various floodplain species, it is possible to describe an ecology structured around a regime of high energy though short duration flooding. Gross differences to the modern regime would include the following:

- A reduced extent and/or diversity in riparian vegetation (woodland/sedgeland/reedbeds), and the range of fauna reliant on these habitats (e.g. large bodied fish, waterbirds, turtle).
- Across the broader floodplain, water from large-scale floods would have spread but not persisted, and vegetation is likely to have been dominated by chenopod shrublands, samphire, herbfields and grasslands. Black box woodlands may have persisted depending on flood frequency given its wider salt tolerance. Amongst aquatic plants, nardoo is noteworthy in terms of its broad range of growing conditions and salinity tolerances.
- The recruitment of waterbirds is dependent on long flood seasons, and a less diverse and populous avifauna would be expected during regimes of flashy flow. Suitable habitat for waterbirds may have contracted to isolated, fragmented habitat.
- Salinisation, a natural consequence of shorter and/or less frequent flooding, has a direct

impact across all trophic levels. Higher salinity is invariably associated with a reduction in biomass and species diversity (both floral and faunal), increasing the likelihood of boom-bust scenarios and potentially driving some species to localised extinction.

- Large spreading floods, albeit short-lived, might have promoted annual pastures for grazing animals, though this would be complicated by the availability of year-round potable water and the impacts of salt.
- Water temperature is a key determinant in the reproduction and growth of various aquatic plants and animals, including most native fish species (Cadwallader 1978:213) and yabby. Estimates of ambient temperatures during the LGM range from 4-6°C (Petherick et al. 2013) to as much as 9°C lower (Miller et al. 1997) than modern values. Lower water temperature might also be expected from the faster flows derived from seasonal snow melts. The consequences of lower ambient and water temperatures is unclear, though some reduction in productivity is a likely outcome, and impacts on the breeding success amongst some species is a distinct possibility (Bowler et al. 2012:291). Lower temperatures tend to reduce biomass and the length of growing seasons in a more general sense, both in aquatic and terrestrial ecosystems (Bowler et al. 2012:291; Pate 2017).
- Whilst a range of waterfrontages are seen in the older floodplains, including examples of oxbows, it is doubtful whether these had functioned in a similar way as their contemporary counterparts given the nature of earlier flooding regimes.

Floodplain health and productivity is ultimately dictated by water availability, and the evidence of palaeoenvironmental stress recognised in fluvial-alluvial systems upstream of the Riverland would naturally be compounded in downstream locations 'more distant from effective water supply' (Bowler et al. 2012:273). A significant increase in salinity occurs naturally as one progresses downstream through the system (Simpson and Herczeg 1991:Figure 3), and is further exacerbated in the Riverland through the interaction with the saline aquifers of the MHP.

It would be expected that Aboriginal subsistence strategies, and the social systems supported by them, would have accommodated the reconfiguration of the Murray valley on various scales, from the productivity of individual wetlands to floodplain-wide habitat responses. The suite of landforms and the characteristics of inundation regimes would have had direct influence on the range and distribution of habitat, the short and long-term predictability and reliability of

resources, and the availability and form of water. The choices embedded in residential and logistical mobility, and the timing and scale of resource procurement, would have accommodated the unique characteristics of each phase in the River's evolution. It is also important to note that the diverse habitat mosaic recognised in the modern floodplains is, in large part, an artefact of a complex topography developed through the process of terracing. A simpler habitat mosaic built around a simpler valley topography can be imagined for the earlier floodplains.

In summary, the context of Aboriginal occupation in the Riverland, as with the MDB more broadly, has been one of continual and profound landscape change. This has tracked what is essentially a tale of four rivers, defined by distinct hydrological regimes across the last glacial-interglacial cycle. The incised nature of this down-basin setting introduces a set of additional factors, notably the interaction of saline groundwater sourced out of the MHP aquifers. When all is considered, the evidence indicates that the modern floodplains, recognised for their diversity and productivity in habitat, emerged out of a relatively depauperate system (see also Pardoe 1995).

Table 4-7: The influence of flow conditions on riverine ecology (summarised from Gippel and Blackman 2002; Poff et al. 1997; Purczel et al. 2016; Thoms et al. 2000; Walker et al. 1995; Ye et al. 2014).

Aspect	Implications
Reduced flood duration	- Reduced recruitment in waterbirds (4-5 months standing water is typically required). - Reduced recruitment and viability of freshwater mussel (Walker 1981:51, 97, 1986). - Reduced viability of sedge and rush communities (e.g. Typha) with rapid draw-down (Nicol and Ganf 2000:306). - Reduced fish recruitment (Cadwallader 1986). - Increased salinisation with cascading impacts recognised across all habitat and species, at all trophic levels. Reduced availability and quality of potable water is likely to have influenced a range of habitat (Stewart et al. 2010:196), leading to the contraction of freshwater-reliant species to the fringes of more regularly flooded waterbodies.
Reduced variability in flow	- Reduced range of bank habitat. - Loss of cues for invertebrate reproduction, fish movement and plant reproduction. - Reduced hydraulic diversity. - Reduced frequency of movement of organic material from floodplain and backwaters affecting seasonal nutrient availability. - Altered species composition and reduced species diversity.
Decreased frequency of flooding periods	- Reduction or loss of species requirements for reproduction and regeneration. - Loss or redistribution of habitat. - Reduced input of organic material from floodplain to river leading to reduced fish reproduction success. - Lack of spawning in large-bodied fish (Ye et al. 2014:38). - Increased salinity and consequences on a range of floral and faunal species, notably riparian vegetation and freshwater mussel.
Rapid rates of rise and fall	- Siltation. - Failure of seedling establishment and recruitment. - Stranding of fish eggs above water. - Abandonment of waterbird nests and population decline in bird and other species.
Permanent raised groundwater	- Root zone logging and dieback. - Increased evaporation from shallow saturated zone leading to salinisation.
Reduced flow magnitude	- Lowered near-channel groundwater profiles affecting deep-rooted riparian vegetation reduced bedload and suspended sediment transport. - Increased sedimentation and drowning of coarse sediment by fines. - Reduced habitat diversity through altered bed character, hydraulics, vegetation and channel morphology. - Reduced connection between channel and floodplain and sediment/organics exchange. - Increase in drought periods on floodplain. - Changes to the structure of habitats. - Failure of seed bank on floodplain through drought. - Loss of cues for invertebrate reproduction, fish movement and plant reproduction.
Increased flow magnitude	- Bank erosion and the associated loss of riparian trees. - Displacement of fish eggs and young.
Degree of drawdown	- May involve cessation of flows in river and loss of connectivity between fish and other species populations.

Table 4-8: The survival and recruitment requirements of vegetation on the Riverland floodplains (adapted from Newall et al. 2008:Tables E1 & E2; Swirepik et al. 2015).

Vegetation community		Recurrence interval (yrs)			Duration (mths)	Timing*	Magnitude (GL/day)			Inter-flood timing (yrs)		
		General	Channel	Billabong & Swamps			General	Channel	Billabong & Swamps	General	Channel	Billabong & Swamps
Aquatic permanent	Survival	Annual			Permanent	Permanent		3	26	1	0	1
	Recruitment		Annual	1-2	Permanent	Permanent		50	40		0	1
Aquatic semi-permanent	Survival	1 in 2			3-6	Spr-Aut		40		1		
	Recruitment	9 in 10			Permanently wet or moist	Spr - late Sm	40			1		
Fringing aquatic reed & sedge	Survival	1 in 2			6	Wn - early Spr		25-30	45-60	1-2		
	Recruitment	~yearly			3 (Sm) - 6 (Wn)	-		25-30	45-60	6-9 mths		
River Red gum	Survival	1 in 3			4-7	Wn - Spr	50-80			2		
	Recruitment	7-9 in 10			4	Spr	50-80			Serial inundation required 2-3yrs		
Lignum	Survival	1 in 3-10			6	Sm	50-70			Complete drying required between floods		
	Recruitment	1 in 2-8			4	unknown	50-70			Complete drying required between floods		
Chenopod	Survival	1 in 10			2-4	Not critical	>70			>2		
	Recruitment	1 in 10			To saturate surface soil, with slow recession	unknown	>70			unknown		
Black box	Survival	1 in 30			2-4	Not critical	70 - 300			30		
	Recruitment	1 in 10			To saturate surface soil, with slow recession	Unknown	70 - 300			unknown		

CHAPTER FIVE: METHODS AND MATERIALS

5.1 Introduction

The methods applied in this research have sought to address the research themes and questions. The development of geomorphological models for the Calperum and Pike floodplains has been a key element in this. These models are based on various spatial datasets and field studies. The models have directed an archaeological survey strategy aimed at sampling settings relatable to a timeseries in landscape development. The models have also been extrapolated to the broader River Murray corridor in the upper Riverland in order to contextualise the regional inventory of archaeological sites and compare the Calperum and Pike results against this broader dataset. Archaeological site recording has focussed primarily on context and content. This has involved a two phase approach whereby an initial phase of qualitative site recordings (Phase 1) was complemented with quantitative sampling, dating and excavation in a smaller selection of sites (Phase 2). Particular attention has been paid to the typology and context of grinding materials. Geophysical and geoarchaeological techniques have been applied in order to address specific lines of enquiry in a small number of sites. The fundamental approach taken in this research has been to minimise, wherever possible, any physical impact to cultural heritage sites. To this end, the use of archaeological excavation has been minimal. Instead, the discussion and conclusions reached in this thesis are based largely on natural exposures of archaeology.

5.2 Literature review

The literature review has focused on aspects of regional geomorphology, archaeology and floodplain ecology. Regarding the archaeology, a range of documentary and archival resources have been reviewed including unpublished reports produced for commercial consultancies, a small number of research-based projects, ethnohistorical resources including media articles and published local histories, and site information represented by the SAM collections database. This data is largely qualitative in nature and is used to evaluate the representativeness of the Calperum and Pike results against the broader Riverland.

5.3 Data management

Spatial data generated during the literature review and field studies have been managed as a series of GIS layers using the MapInfo Professional platform. The layers are summarised in Table 5-1. Scanned copies of paper-based field recording sheets are provided in the supplementary material and include site records and various excavation forms. Microsoft Excel spreadsheets have been used to collate various regional datasets and manage laboratory sorting, excavation and radiocarbon dating results.

Table 5-1: GIS data layers generated through this research.

Table name	Detail
CalperumCollatedData_Sites	Series of polygons delineating the site boundaries and including attributes that provide a unique site identifier, site type, content, general description, date recorded and midpoint location.
CalperumCollatedData_Isolated Finds	Series of point objects at the location of each find and including attributes that provide a unique identifier, find type, general description, date recorded and midpoint location.
CalperumCollatedData_Survey	Series of line objects depicting the centreline of each transect and including attributes that provide a unique identifier to each transect, field stage and date of survey.
CalperumCollatedData_SurfaceSamplingSQ	Series of point objects depicting the centre of each surface sample. Attributes include a unique sample identifier and extent of sample in square metres.
CalperumCollatedData_Excavation	Series of point objects depicting the centre of each excavation. Attributes include the site and excavation reference.
CalperumCollatedData_14C	Series of point objects depicting the location of each ¹⁴ C sample. Attributes include the site and sample reference, lab code and calibrated age range.
CalperumCollatedData_OSL	Series of point objects depicting the location of each OSL sample. Attributes include the site and sample reference, lab code and age range.
CalperumCollatedData_GeoAuger	Series of point objects depicting the location of each auger. Attributes include the site and auger reference.
CalperumCollatedData_GeoLogs	Series of point objects depicting the location of each stratigraphic log. Attributes include the site and auger reference.

5.4 Permits obtained under the *South Australian Aboriginal Heritage Act 1988*

The *Aboriginal Heritage Act 1988* (AHA) is the primary legislative framework applicable to the management of Aboriginal heritage in South Australia. Archaeological investigations interact with procedures and permitting requirements under various sections of the AHA. Regardless of the ethics agreements reached with RMMAC at the initiation of this research (see front materials for details of ethics and community engagement), any permit application triggers an entirely independent consultation process under s13 of the AHA. The upshot of this is that permits can take up to 6 months or longer to obtain. The permits do not allow for a review of study methods or scope, regardless of the approaches agreed to by the relevant traditional owner group. In

effect, all potential methods and locations for dating and/or excavation must be identified within the initial field sessions. Admittedly, this has not been achieved fully in this research, and a range of additional sites that could have provided contributions have been excluded (see Chapter 7.4). This includes several sites associated with the outer lakes and the T3 scrolls.

5.5 Field studies

5.5.1 Geomorphological mapping

An initial geomorphological model for the Calperum floodplain was developed through a collation of various mapping products (Table 5-2) into a GIS (MapInfo Professional), identifying and tracing landforms, and assigning these landforms to the terrace sequence based on elevation, channel and meander planform, and other landscape characteristics. A tentative landscape chronology was based on a review of equivalent geomorphologies recognised in the MDB. Ground truthing of this initial model (re)assessed criteria including topography, vegetation, landforms, sediment type and degrees of pedogenesis.

Sediment logs were obtained at natural exposures and were supplemented with an auger program that sought to clarify stratigraphic relationships in several locations (Figure 5-1). An example of a sediment recording sheet is provided in Appendix III (the full set is provided in the Supplementary Material). Transects between a selection of logs on the Calperum floodplain were tied to OSL, ^{14}C and/or relative chronologies to develop a more refined landscape chronology. At Pike, stratigraphic relationships were established through ^{14}C dating of archaeological features exposed in natural and artificial profiles along the cliff line and were supplemented with a series of small-scale excavations conducted in site PikeSP16_05. OSL sampling in this site provided further context and interpretation of a hearth feature exposed in the cliff.

^{14}C samples were recovered from two auger holes located in the dry bed of Clover Lake and in a floodplain depression north of Big Huncree Creek. A manually operated, 75 mm diameter Dormer soil auger was used to extract sediment in 10–15 cm blocks which were described in the field before being placed into double zip-lock bags. The auger head was cleaned between each block to limit cross-contamination. Bulk sediment samples were collected for the purpose of ^{14}C dating

after considering the stratigraphy intercepted in each column.

Table 5-2: GIS data used in the mapping of the floodplain geomorphology.

Data source	Theme				
	Landform	Vegetation	Elevation	Hydrology	Soils
Aerial photography – Google Earth/Bing Aerial	X	X		X	
1:50K and 1:100K topographic mapping	X		X	X	
Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid, Geoscience Australia	X		X		
ALOS Global Digital Surface Model (AW3D30), Japanese Aerospace Exploration Agency (JAXA)	X		X		
NatureMaps (online via Enviro Data SA website), SA Department for Environment and Water		X			
ABARES (2011)					X
Sharley and Huggan (1995)	X	X			X
SA Department for Environment and Water Flood SA Vegetation GIS Dataset		X			X
SA Department for Environment and Water Flood Inundation Modelling (FIM)				X	
MDBA River Murray Flood Mapping (1956 flood boundary)				X	

5.5.2 Archaeological Survey

An archaeological survey strategy aimed to sample the various landscape settings and landscape timeseries identified in the geomorphological model. The boundary between terraces T1 and T2, various lunettes, SBDs and Wfm dunes that had transgressed into the western margin of the floodplain were prioritised. The field survey was conducted by teams of up to four people with each transect centreline captured with a handheld GPS (Garmin GPSMap64). Pedestrian transects were conducted using a purposeful rather than systematic methodology whereby areas of high ground surface visibility and exposure were targeted along transects rather than trying to accommodate a fixed grid. Pro forma Isolated Find and Site recording sheets were used, examples of which are provided in Appendix IV. Survey conditions (ground surface visibility, exposure, background effect) were routinely noted. The field survey conducted at Pike aimed to more accurately describe the extent of several previously recorded open scatters of shell midden, hearth materials and stone artefacts on the high cliff-line overlooking the south-eastern margin of the floodplain. These sites included PikeAWE15_10 (Westell 2015), PikeSP16_01 and Pike_SP16_05 (Wood and Westell 2016c) and PikeSP16_07 (Wood and Westell 2016b).

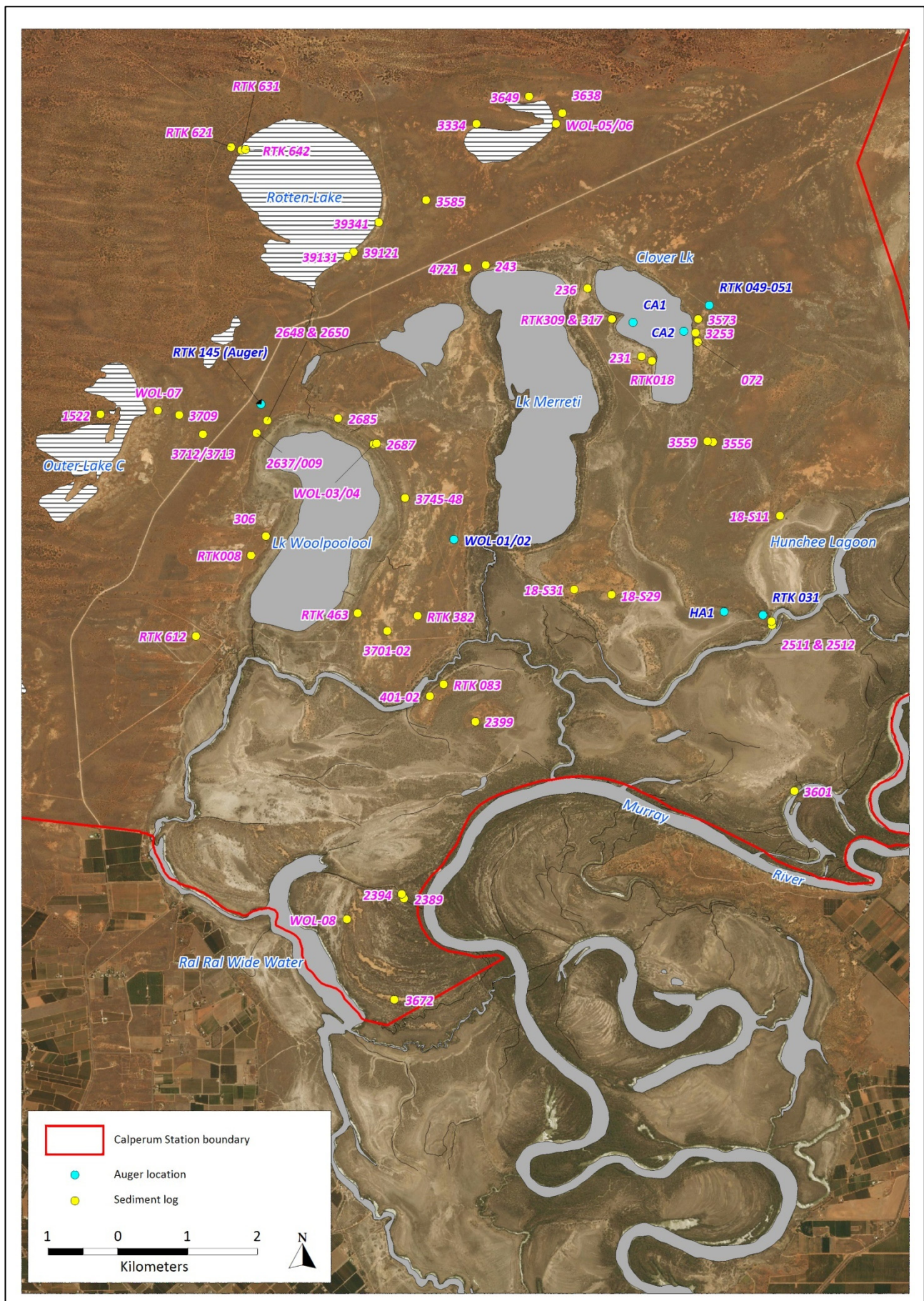


Figure 5-1: The locations of sediment logs and auger excavations conducted at Calperum.

5.5.3 Site recording

5.5.3.1 *Distinguishing natural from anthropogenic deposits*

There is a clear risk of confusing natural and cultural deposits in floodplain environments. Naturally deposited shell can often form lensed features stranded along high watermarks. Wildfires bake sediment and lay down deposits of ash and charcoal. The criteria used to distinguish natural from anthropogenic materials are outlined in Table 5-3 and Table 5-4 and follow well-established standards (see for example Burke and Smith 2004:Table 7.2; Garvey 2017:90).

5.5.3.2 *Site recording, definitions and attributes*

Field studies were conducted over a series of seven week-long sessions between April 2017 and September 2020. The focus of this research has been open scatters that contain, in some combination, faunal material, stone artefacts, hearth material and/or oven mounds. Ancestral remains are also common component of these sites (see below).

The initial field sessions sought to collect qualitative data (referred to as Phase I recording) and identify sites that, on first impressions, would benefit from further analysis (referred to as Phase 2 recording). The information recorded at each site varied during the Phase I assessments, though typically included the following aspects:

- *Content*. This included a basic account of the faunal, lithic and heat retainer components and whether skeletal remains were present. Estimates of artefact populations and artefact types were made where possible.
- *Context*. Sites were generally described to a terrace and landscape context (dune, lunette, sand plain, stream bank, stream levee, beach, terrace edge, cliff-line, scree).
- *Structure*. Terms included scattered, clumped, in situ, eroded or stratified.
- *Condition*. The classification scheme applied by Fanning et al. (2009a) to the condition of hearths has been applied more broadly in this research. This includes the descriptive terms of buried, partially exposed, intact, disturbed, scattered and remnant.

Table 5-3: Criteria used to distinguish between natural and cultural deposits of shell.

Cultural deposits of shell • <i>Species selection.</i> Riverland middens are invariably comprised of either of the two species of freshwater mussel, <i>V. ambiguus</i> or <i>A. jacksoni</i>, with the gastropod <i>N. sublineata</i> forming a minor element where present. • <i>Size selection.</i> Midden shell will include a narrow size range of individual shells. • <i>Articulation.</i> Bivalves in midden will be disarticulated. • <i>Life position and context.</i> Midden shell will generally occur in contexts other than their natural growing conditions and not in life-position. • <i>Extent.</i> The boundaries of midden deposits will be well-defined, often forming horizontal lenses that may or may not be laterally extensive. • <i>Associated materials.</i> Middens will invariably incorporate other cultural materials, e.g. artefacts, heat retainer. • <i>Evidence of burning.</i> Shell may or may not show evidence of burning (see Garvey 2017:96).	 Clumped midden of <i>V. ambiguus</i> in site CAP17_14.	 Disarticulated, size-selected and stacked <i>V. ambiguus</i> in site CAP17_14 with associated heat retainer and stone artefacts.
Natural deposits of shell • <i>Species selection.</i> Natural deposits may include a range of non-economic species. • <i>Size selection.</i> Natural deposits may include a range of individual sizes. • <i>Articulation.</i> Bivalves may be articulated. • <i>Life position and context.</i> Natural deposits will only occur where the species grow, they may be life-position and recently deposited shell may retain some periostracum. • <i>Extent.</i> Natural deposits may vary in extent and may be ill-defined. • <i>Associated materials.</i> Shell will invariably occur in natural sediment with no associated archaeology. • <i>Evidence of burning.</i> Shell will not be burnt.	 Periostracum preserved on naturally deposited <i>A. jacksoni</i>. Photo C. Westell (September 2017, Katarapko floodplain).	 <i>A. jacksoni</i> deposited along the Murray River bank following a recent flood. Photo C. Westell (September 2017, Katarapko floodplain).

Table 5-4: Characteristics of cultural and natural burning.

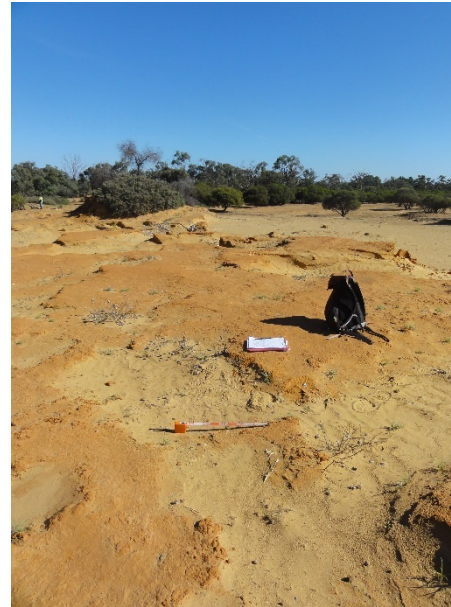
Culturally burnt sediments • Commonly circular deposits with well-defined boundaries • Heat retainer will generally be limited to fist-sized and sub-rounded peds • Ash/charcoal are commonly disseminated in deposit • Most commonly associated with other cultural material • Can occur in areas away from natural vegetation • Heat retainers may include imported material, e.g. calcrete	 Rounded, fist-sized heat retainer typical of cultural deposits. <i>Photo C. Westell (May 2014, Pike floodplain).</i>	 Ash, charcoal and fragmented shell disseminated through a mound deposit. <i>Photo C. Westell (May 2014, Pike floodplain).</i>	 A hearth feature built out of calcrete rubble typical of the higher (older) land surfaces. <i>Photo C. Westell (October 2013, Lake Bonney lunette).</i>
Naturally burnt sediments • Often linear, tracing the outline of fallen logs radiating out from a stump • Blocky material often larger than fist-sized and angular • It is common to see a separation of the baked sediment and ash/charcoal rather than disseminated throughout the deposit • Occurs in areas of natural vegetation • Formed in naturally occurring sediment	 Long, linear deposits of backed sediment typical of fallen logs and other debris smouldering on clay-rich soils. <i>Photo C. Westell (March 2015, Katarapko floodplain).</i>	 Large blocks of baked and oxidised clay tend to develop around more intense fires, e.g. the trunks and roots of red gums. <i>Photo C. Westell (March 2015, Katarapko floodplain).</i>	 Smouldering debris tends to separate the baked sediment from the ash and charcoal deposit, as seen here, rather than the evenly disseminated material typically seen in archaeological context. <i>Photo C. Westell (October 2017, Pike floodplain).</i>

Soils

- Typically contained to the higher parts of the floodplain and along the confining cliff-lines
- No associated ash or charcoal
- Generally, not associated with cultural materials other than in lag deposits
- Laterally extensive



Soils tend to be laterally extensive and include nodular calcrete limited to the higher (older) parts of the floodplain and, as in this case, the confining slopes of the valley. *Photo C. Westell (July 2018, Pike floodplain).*



Soils are common at the base of the T2 SBDs and can be laterally extensive. *Photo C. Westell (May 2014, Pike floodplain).*



Deep red carbonate soil development on the T1 surface. *Photo C. Westell (April 2017, Calperum floodplain).*

Only basic information (e.g. a location and general description) was recorded in relation to some sites and site types due to the following reasons:

- A series of oven mounds were recorded outside of the formal survey coverage along Hunchee and Ral Ral Creeks. These mounds are the subject of a concurrent research program (see for example Jones et al. 2022).
- Only cursory detail was recorded for burial sites where site recording would have necessarily required traversing the locations of ancestral remains. As per the protocols established with RMMAC, burial locations were specifically excluded from any interference. The location and a general description of any human remains were recorded for the purposes of ongoing management by RMMAC.
- The locations of scarred trees were noted but no detail was recorded for these sites as a more detailed analysis was being undertaken as part of a concurrent research project (Dardengo 2019; Dardengo et al. 2019). The locations of any trees were provided to this research.

Phase 2 assessments included the collection of ^{14}C and OSL samples, more detailed recording of key sites, and a limited program of excavation. Midden content was also (re)assessed and quantified in a selection of sites using a 1x1 m drawing grid (Figure 5-2). All of the ^{14}C sampling points were included in this sampling. The drawing grid acted as a control in recording, forcing a more rigorous assessment of midden content and the detection of smaller fractions that might otherwise be masked by the larger fragments of shell, e.g. fine bone, otoliths and gastroliths. The intention of this sampling was to provide a quantitative measure of midden content and assess whether these deposits are, as the regional data suggests, composed almost exclusively of freshwater mussel. The site recording at Pike aimed to improve upon the detail in a series of previously reported sites, establish some quantitative measure of their content, collect radiocarbon and OSL samples, and conduct a limited program of excavation in site PikeSP16_05.

As in most regional contexts, archaeological materials pervade the Riverland landscapes beyond the extent of clearly delineated 'sites', forming a diffuse *background scatter* of isolated artefacts and dispersed hearth material. Whilst this material may not occur in a discernible feature(s), it nevertheless delineates structure within the archaeological landscape that might reveal the spatial

and temporal organisation of past human behaviour. The 'gaps' in the landscape are a critical and informative element. The locations and basic detail (type/material) of all isolated finds were recorded. For the purposes of this research, 'site' boundaries have been recorded where there is a clear association between cultural material within a maximum distance of 30 m. Ultimately, however, it is context that is the key consideration and some flexibility is required to accommodate variable ground surface visibility and background effects.



Figure 5-2: Amy Roberts, Marc Fairhead and Catherine Morton using a 1x1 m drawing grid to scrutinise midden content in site CAPR17_19.

5.5.3.3 Stone artefact identification and nomenclature

The floodplains are essentially free of rock other than in scree slopes along the valley cliff lines or where calcrete nodules occur in soil profiles within the older land surfaces. It can be assumed, therefore, that any rock located in the floodplains is potentially artefactual. Detailed metrical analysis of stone artefacts is not a critical aspect of this thesis²⁸. Where required, definitions and terminologies follow the conventions presented in (Holdaway and Stern 2004) for the flaked component. In terms of grinding material, implements were described as either upper or lower grindstones with additional reference to the sub-types described in Table 4-4.

²⁸ Concurrent research undertaken as part of the broader Calperum Research Project has applied metrical, typological and usewear analyses to the material assemblages at Calperum (see for example Incerti 2018; Munt 2022; Thredgold 2017).

5.5.3.4 Identification of shell species

The identification of the two commonly reported species of freshwater mussel, *V. ambiguus* and *A. jacksoni*, has been used as a key element in relating the development of middens to the landscapes they occupy. Distinguishing between the two species can, however, be difficult, as the morphology of both species can vary significantly in relation to flow and can merge between the two (Balla and Walker 1991; Walker 1981; Walker et al. 2001). The shell valves are also typically fragmented in archaeological contexts. In general terms, however, *A. jacksoni* is distinguished by its asymmetry, thicker more robust shell, winged appearance and posterior ridges extending from the umbo across the external surface of the valves. *A. jacksoni* is also larger, growing to a maximum length of approximately 170 mm, 55% larger than *V. ambiguus* (108 mm), though the growth of both species can be arrested by irregular flooding or drought (Walker et al. 2001).

5.5.4 Excavation

In establishing research protocols with RMMAC, the approach has been to use excavation sparingly and to minimise impacts to sites throughout the broader range of field techniques. All excavation locations were approved and overseen by RMMAC representatives. The excavations at Calperum aimed to investigate a small number of locations where there was potential for stratified deposits. This has allowed a comparison between sub-surface and surface deposits, informed a discussion on taphonomy, and recovered a representative assemblage that can be associated with robust chronological data. Excavations were conducted at three sites at Calperum (CAPR17_14, CAPR18_S37 and CAPR18_S41) and a single site at Pike (PikeSP16_05).

Excavations progressed using a standard single-context or natural stratigraphy method, whereby each context or stratigraphic unit (SU) is defined by a unique set of physical properties and is removed either in toto or as a series of thinner excavation units (XU). The excavation workflow was as follows:

- Natural ground surfaces were photographed and described.
- A Leica TS09 Total Station (TS) was referenced to known datums established using DGPS (Leica GS16/CS35 receiver/tablet combination) and with data corrected through the SmartNet Aus Satellite Positioning facility.
- The test pit was defined using a string line and metal pegs.

- Starting elevations and all subsequent x-y-z positions were recorded using the TS.
- An initial clearance of vegetation was conducted where necessary.
- Loose/friable sediment was removed using hand trowel, nylon brushes and metal dust pans. A forked and bladed mattock was employed in stiff/hard sediment.
- All roots were cut with secateurs and removed in segments in order to maintain the integrity of the surrounding sediments.
- All excavated sediments were placed into standard weight buckets (220 gm) then dry sieved through nested 5/2.5/1 mm screens. The use of a 1 mm base screen was deemed appropriate given the potential presence of fine bone, e.g. fish (but see Vale and Gargett 2002). Sediments that passed through the sieves were collected on tarpaulins. Nested 7/5/3 mm screens were used in excavation units XU4 and XU5 in PikeSp16_05 TP04A as the damp soil could not be passed through the 1 mm screen.
- Excavations progressed within excavation units (XU) defined by either the boundaries of stratigraphic units (SU) or a thickness of no more than approximately 10 cm.
- Excavations were documented via Trench (TR), Context (SU), Level (XU), Special Find, Master Bag and Photographic Log forms, examples of which are presented in Appendix V. The TR/SU/XU forms capture the following information:
 - *Trench (TR) Record.* Site ID, Trench ID, date and time, location including starting and finishing levels (x-y-z), lists of SU and XUs and any accompanying drawings and post excavation sampling (e.g. ^{14}C , OSL, column, microstratigraphy).
 - *Context (SU) Record.* Context ID, starting levels, sieve sizes, corresponding XUs, photographic record, context type and description (Munsell colour code, pH, composition, sorting, consistency, soil structure, inclusions), stratigraphic relationships with other SUs, the methods used to excavate, accompanying drawings/notes and interpretation.
 - *Level (XU) Record.* Level ID, starting levels, photographic record, pH recordings, gross excavated bucket weights, repatriated materials (i.e. not kept for laboratory analyses), in situ finds or other samples.
- Cultural materials recovered during the excavation were placed into plastic zip-lock bags labelled with date, site, trench, SU, XU, material type and screen size. These bags were then placed within a second zip-lock bag with a plastic label inserted with all information repeated.
- The x-y-z position of any in situ finds were recorded using the TS and documented on a

Special Finds Register.

- Section drawings were completed for a least two trench walls.
- Photographs were taken throughout the excavation process, including completion images.
- All sediments not retained for laboratory analyses were backfilled into the test pits at the completion of all necessary reporting, section drawings and photography.
- All materials not consumed in the laboratory analyses will be repatriated at the completion of this research.

5.5.5 Geophysical prospecting in CAPR18_S41

Combustion features are a common element of the Riverland archaeology and take the form of discrete hearths, pit ovens, baked soil pedestals and larger oven mounds. Collections of baked sediment are particularly common across the higher terraces, though dating in these areas is problematic given the deflated nature of these landscapes and features and the poor retention of charcoal/ash. A number of locations were identified where features had been at least partially preserved under sand drifts, potentially limiting the extent of erosion. This included site CAPR18_S41.

In order to develop a methodology for locating buried combustion features in this site, and potentially others, a gradiometry survey was conducted in the eastern section of the site. A similar prospecting technique has been applied with some success by Ross (2018) and Fanning et al. (2009a). In his study conducted at Calperum, Ross (2018:90) had reported identifiable magnetic signatures for partially buried combustion features in sandy soils, though found that the fully deflated features provided 'very low and sometimes no magnetic reading', consistent with the findings of Aspinall et al. (2009:22). According to Linford and Cant (2001:244: see also Herrejon Lagunilla et al. 2019), the ash layer in combustion features 'provides the most significant source of magnetisation' and a greatly reduced anomaly relating to the thermally altered soil substrate is retained following the removal of the ash layer. On this basis, an optimal scenario for detection would exist where a rapid burial of the feature occurred following the combustion event, protecting the integrity of the feature and retaining the detrital ash and charcoal (i.e. the target for radiocarbon dating). Site CAPR18_S41, appeared to fulfil these criteria.

The survey was conducted by Assoc. Prof. Ian Moffat (Flinders University) with the following description provided by him. The survey employed a Bartington Grad601-2 gradiometer with survey lines collected at a 0.5 m spacing and 8 samples per meter using a zigzag spacing and a range of 100nT. Six adjacent 20x20 m grids covered a total area of 60x40 m. The raw data was gridded using Snuffler software using the destripe and interpolate filters before being exported as an image file for interpretation.

Three potential targets were identified in the gradiometry survey with the most significant response located at the southern extent of the grid. A 1.0x0.5 m test pit (TP02) was located across this target and extended to a hard, basal clay. The pit intersected several small fragments of baked sediment though did not reveal an in situ feature or any other cultural material. The additional targets corresponded to a piece of rusted iron and a deeply scuffed kangaroo pad containing no obvious material in the excavated surface or in the spoil. Neither of these targets were investigated further.

5.6 Chronological methods

5.6.1 ¹⁴C Dating

5.6.1.1 Site and sample selection

In most instances it can be assumed that open scatters of archaeological materials represent a sequence of activities conflated onto a single surface, and that within these deposits, spatial associations do not necessarily translate to temporal associations. With this in mind, the radiocarbon dating aimed to target multiple features within a small number (24) of sites rather than single age estimates from a broader sample of sites. The majority of samples were collected from features exposed on the surface or in profiles exposed in natural or excavated contexts. In most cases, these features were not laterally extensive and are assumed to represent discrete events rather than having accumulated over multiple episodes. Examples included discrete clumped and lensed deposits of shell and individual hearths. A further 12 ¹⁴C determinations were returned on sediment recovered at various depths from three augers; two located in the bed of Clover Lake and one located in a shallow floodplain depression north of Huncree Creek, together with sediment samples from two naturally exposed profiles at Rotten Lake and Lake Woolpoolool.

5.6.1.2 Sample collection

The ^{14}C sampling focussed on the removal of small amounts of archaeological shell or charcoal from existing exposures, in the first instance. These exposures included both natural ground surfaces and exposed profiles developed along eroded channels, scalds, shallow rills, vehicle track cuttings and a mechanically excavated trench in the case of samples CAPR-023 & 024. This surface sampling was supplemented with excavations conducted in a small number of sites. All sampling (and excavation) locations were sanctioned by RMMAC representatives.

^{14}C sample locations were recorded using DGPS, either on the actual sample location or natural ground surfaces where samples were removed from profiles. Stratigraphic sections were drawn where appropriate and notes taken on the context, condition and type of each sample material. A pro-forma sample collection sheet was used to record various details including potential contamination, soil and landscape context (see Appendix VI). Broader RTK transects were undertaken across most sample locations to help in the interpretation of stratigraphic context.

Archaeological samples were removed with either steel tweezers or trowel, loose sediment was removed using the tweezers or a nylon brush, the cleaned sample was then weighed using digital scales before being placed in an alfoil packet and into a plastic zip-lock bag. The outside of the bag was labelled with the Site ID, Sample ID, Date and the collectors initials. This detail was repeated on a tag placed inside the bag. The samples that could not be cleaned in the field were re-opened and sediment removed again using tweezers and/or nylon brush. The samples were stored in a plastic tub before being sent to the Waikato University Radiocarbon Laboratory (New Zealand), Beta Analytic Laboratory (Florida, USA) or the ANSTO facility in Sydney.

In regard to the dating of soil organics, bulk sediment samples of approximately 100 gm were recovered from within clearly defined sedimentary units and placed in zip-locked bags. These were labelled and sent to the Waikato University Radiocarbon Laboratory (New Zealand). No attempt was made to separate the organic fraction from these sediments prior to the sample submission.

5.6.1.3 Laboratory techniques and calibration

The majority of ^{14}C samples were analysed at the Waikato University Radiocarbon Dating Laboratory and the ANSTO Lucas Heights facility (Fink et al. 2004). A single charcoal sample was analysed by Beta Analytic. A combination of AMS and conventional dating techniques were applied. Standard physical and chemical pre-treatments were undertaken, as summarised in Table 5-5, and included testing for calcite recrystallisation on shell samples by staining with Fiegl's solution (Friedman 1959)—the test was negative for all samples. Age determinations were returned as both Unrounded Conventional Radiocarbon Ages (CRAs) (with 1 sigma errors) and calibrated ranges. All CRA have been (re)calibrated using the SHCal20 atmospheric curve (Hogg et al. 2020) using OxCal v4.3.2 (Bronk-Ramsey 2009). Calibrated age-ranges are reported at 95.4% probability. As demonstrated by Gillespie et al. (2009), any potential reservoir effect for the freshwater mussel shells was not expected to be significant.

Table 5-5: Physical and chemical pre-treatments used on C14 samples.

Lab	Material	Physical pre-treatment	Chemical pre-treatment
Waikato	Shell	Surfaces cleaned, washing in ultrasonic bath.	Sample tested for calcite recrystallisation. Washed in acid solution 0.1N HCl followed by rinsing and drying.
Waikato	Sediment	Visible contaminants removed.	Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried.
ANSTO	Shell	Surface cleaned using a Dremel drill.	Surface etched using 0.5 M HCl 3-5 minutes, rinsed multiple times using Milli-Q water and then oven dried at 60 degree C. Stained using Feigl's solution at room temperature for confirmation of complete aragonite (i.e. no calcite contamination). The stain was removed using 0.25 M HCl, rinsed multiple times with Milli-Q water, oven dried. Shells were then hydrolysed, CO ₂ transferred and graphitised.
ANSTO	Charcoal	Surface of charcoal was scrapped with a new scalpel blade and charcoal cut into small fragments.	Treated with 2 M HCl, 60 deg.C, 2 hours, rinsed with Milli-Q water and treated with 3 cycles of 2% NaOH solution, 60 deg.C, 1 hour each, rinsed with Milli-Q between alkali steps. Last two NaOH treatments gave a clear solution at the end of the hour, indicative of no humics remaining. Treated with 2 M HCl, room temperature, 1 hour Rinsed with Milli-Q water, Oven dried at 60 degree C after which the charcoal was combusted, CO ₂ transferred and graphitised.
Beta Analytic	Organic sediment		Acid washes to remove carbonates.

5.6.2 Typological dating

The two species of freshwater mussel common to the Riverland occupy distinct habitats, with *V. ambiguus* occurring in slow flowing environments such as billabongs, lagoons and slower flowing streams, and *A. jacksoni* occupying faster flowing watercourses (Walker 1981). The two species are generally not found together (Mackay and Eastburn 1990; Walker 1981). The presence of one or

the other species in middens, therefore, demonstrates the nature of the waterbody that was exploited, and by implication, offers a relative chronology between the development of a midden and the habitat it is associated with.

A number of radiocarbon ages returned on Calperum mounds during this research, and a concurrent research program (see Jones et al. 2022), have confirmed a late Holocene timeline for this site type. This is consistent with regional dating (see Chapter 2). A mid-late Holocene limit is also assumed for adzes, as per Veth et al. (2011).

5.6.3 OSL dating

5.6.3.1 Sample selection

A total of 12 OSL samples were collected at Calperum (Figure 5-3) and aimed to key-in a relative landscape chronology to an absolute timeline. The dating has focused on various stages in lunette development (samples WOL-01 to 07, WOL-12), the progressive development and ultimate conversion of large diameter palaeochannels to more sinuous deglacial channels (samples WOL-08, WOL-09), and highstand events registered at Rotten Lake (WOL-10 and 11) and Lake Woolpoolool (WOL-03 and 04). An additional aim was to determine a likely age range for a distinctive palaeosol that has developed across multiple landscapes at Calperum including the lunettes and SBDs associated with the older T2 meander scrolls. This palaeosol represents an important chronological marker in this, and other, Riverland floodplains. OSL sampling conducted at Pike aimed at providing a more robust chronology and context for a hearth feature that had returned an initial ^{14}C age c. 44–42 cal kBP (Wk-50694). Appendix VII provides images and a context for each of the OSL sample locations.

5.6.3.2 Field and laboratory methods

OSL sample collection and laboratory analyses have been conducted by Kathryn McDonnell and Professor Nigel Spooner (Prescott Environmental Luminescence Laboratory, University of Adelaide). The majority of samples were obtained from cleaned exposures in naturally exposed profiles. Samples were also obtained from two excavated profiles; the first in a late LGM SBD (WOL-08) and the second (Pike-01) collected from an excavated section exposing the hearth

feature at Pike. A standard collection method involved hammering an opaque metal tube horizontally into the cleaned section. The tube was removed and capped at both ends to minimise light exposure. Individual and grouped samples were recovered.

The basic concept underpinning OSL dating is that a luminescence signal in quartz grains is reset following their exposure and 'bleaching' by sunlight or heat (see overview by Mellett 2013). A luminescence signal begins to accumulate once the grains are removed from sunlight, e.g. buried or shaded, as electrons re-occupy charge defects in the crystalline structure of quartz under the influence of natural sources of ionising radiation in soil (Uranium, Thorium and Potassium radionuclides) and cosmic sources. This is a relatively straightforward concept, though in practice, many factors will influence the luminescence signal. Bleaching can be incomplete in some circumstances, e.g. where sediment transport occurs under an opaque medium (muddy water), where transport is insufficient to allow full bleaching or where quartz grains are coated (e.g. iron oxide on older aeolian sands). Bioturbation, illuviation, soil development and the penetration of sediment through cracks and other voids can also complicate the signal. Sediments of various depositional ages can potentially be relocated vertically and horizontally through the profile via these mechanisms (Roberts et al. 2000:460).

An OSL sample will most likely incorporate components from a column of sediment with potentially complex mixing histories and luminescence cycles superimposed throughout this column. These factors, among many, need to be considered, and it is the reason why an understanding of geomorphic context is essential when interpreting OSL ages. It is also important to remember that OSL ages do not relate to the age of the sediment per se, but rather, reflect the timing and nature of the most recent bleaching of the sediment. Aeolian sediments are well-suited to OSL dating as they are likely to have experienced periods of complete or near-complete bleaching given the nature of sediment transport and deposition (Arnold and Roberts 2011:392). However, complex phases of deflation, re-exposure and sedimentation can fully or partially reset OSL signals and complicate any interpretation of the original landform being dated. Evidence of bioturbation and variable degrees of soil development were identified at all of the OSL sampling locations (see examples in Figure 5-4).

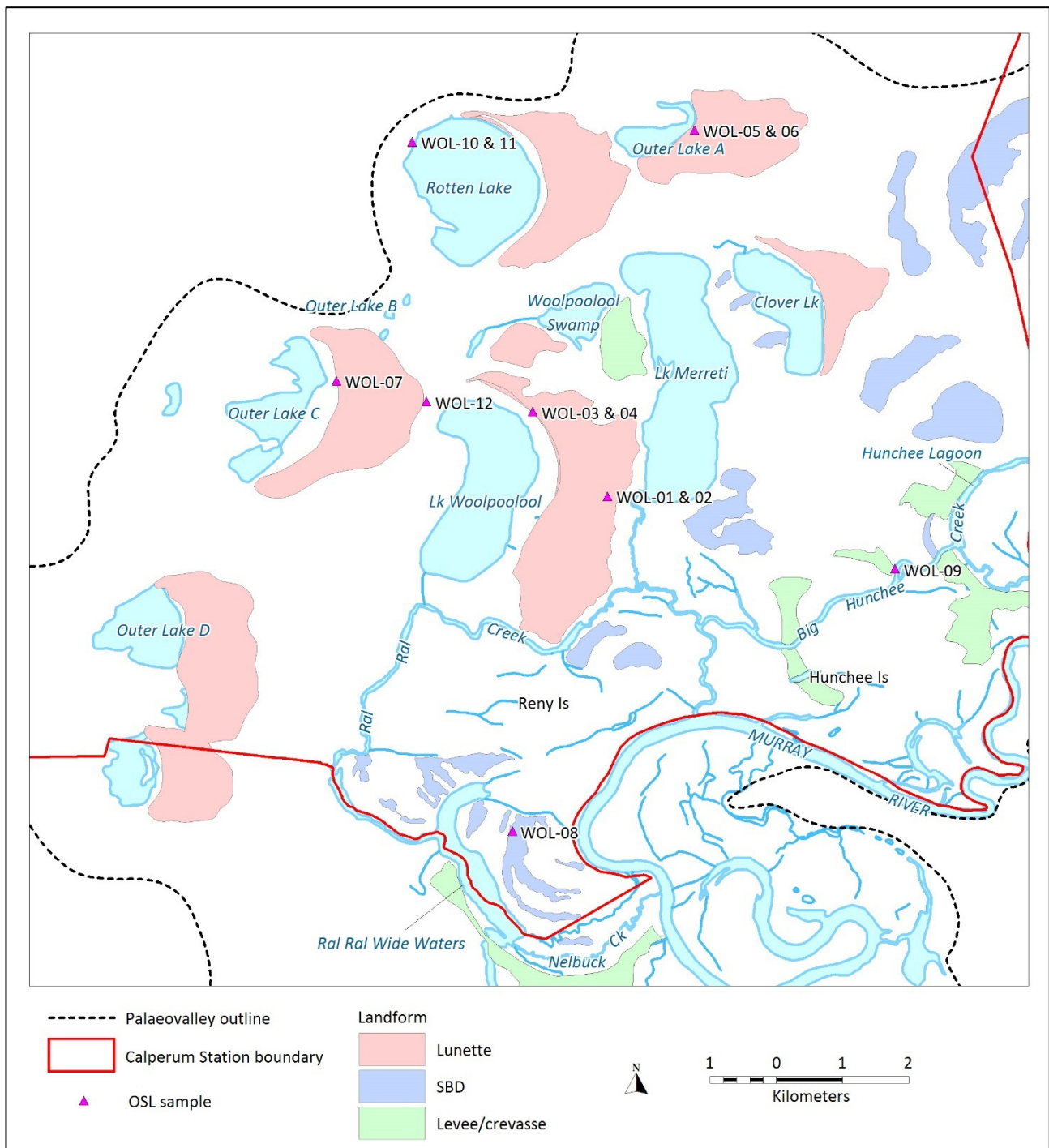


Figure 5-3: The location of OSL sampling at Calperum.

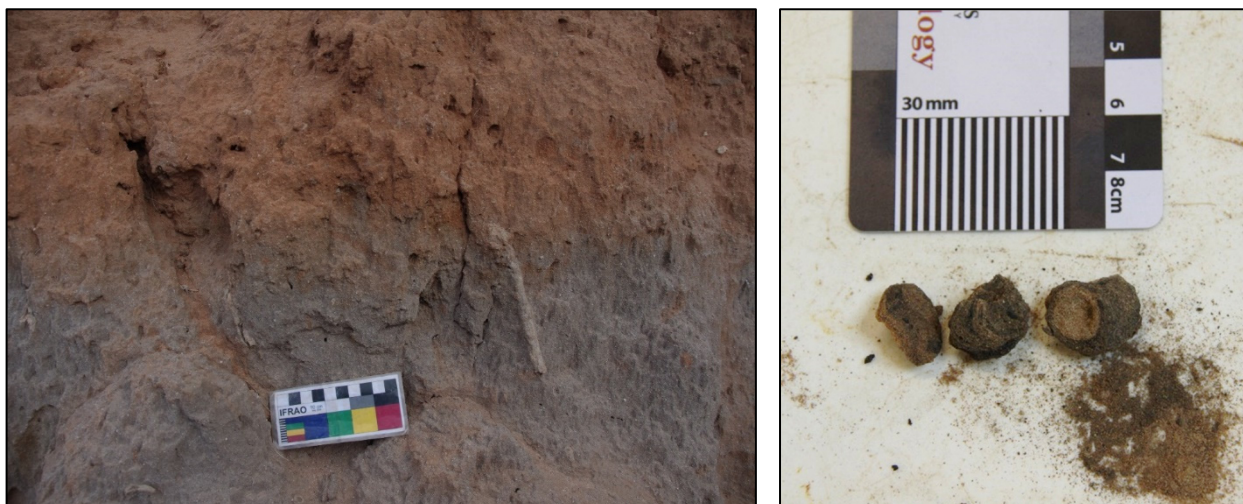


Figure 5-4: Insect tubules straddling the contact between sedimentary units at OSL sampling location WOL-10/11 and recovered during the excavation of the hearth feature at Pike near OSL sample Pike-02. Fine, light coloured sand can be seen incorporated into tubules that intersect the hearth feature.

A detailed account of laboratory methods and analysis is provided in the two OSL reports included in the supplementary material. In summary, radionuclide contributions to the environmental dose-rates were obtained from the light exposed sediment ends of the tube sample together with bulk raw sediment samples collected from each location. These sediments were assayed for Uranium, Thorium and Potassium. Water content was determined by overnight drying (at 125°C) and reweighing of each sample. Water content was used to correct the field gamma spectrometry data to dry dose-rate. The cosmic ray contributions to the environmental dose rate was determined by the depth of each sample and its elevation and latitude, following Prescott and Hutton (1994). Individual dose-rates were applied to each sample based on nuclide, water and cosmic ray contributions, following Kreutzer et al. (2012) and Kreutzer et al. (2018).

Standard sample preparation included an initial acid wash to remove carbonates followed by an ultrasonic bath in dilute sodium hydroxide to breakdown clay aggregates and remove remaining organic material. A sequence of rinsing, drying, sieving and density separation then isolated the quartz grains. These were etched in 40% HF acid to remove the outer 6-8 µm of the grains then washed in 25% HCl acid before re-sieving to obtain the 212–250 µm fraction used for the single grain OSL determination. Luminescence measurements were obtained using a Risoe TL/OSL-DA-20 reader with single grain OSL attachment. Analyses were conducted on a 10x10 array of 300 µm diameter depressions, with each depression occupied by a single quartz grain, i.e. total of 100 grains per run. For each sample, a total of 800 grains were processed over a ‘pilot study’ and series of regeneration doses.

High overdispersion (OD) values were recorded in all results and multiple populations were identified in the kernel density plots. This result would be unexpected in aeolian sediments unless these had experienced post-depositional mixing, e.g. via bioturbation or soil processes. Given the OD values and evidence of multiple populations, the use of a Central Age Model (CAM) or Minimum Age Model (MAM) would potentially mask a complex post-depositional history. Instead, the use of Finite Mixture Models (FMix) (see Arnold and Roberts 2009; Roberts et al. 2000) were considered the most appropriate in generating the OSL ages. FMix modelling is essentially an exercise in regression where the standard deviations of the D_e data set are calculated against an increasing number of components until no significant improvement in defining the data can be achieved (Arnold and Roberts 2009). Single-grain OSL enables the identification of multiple inputs that could otherwise be smoothed over when analysing a 'bulk' aliquot sample. Non-representative populations can then be identified and treated as such in the analyses. Statistical analyses were conducted using the R-package 'Luminescence' (Kreutzer et al. 2018; Kreutzer et al. 2012) with rejection criteria used to rule-out grains exhibiting insufficient luminescence or where the dose response characteristics were unsuitable. The adopted FMix were based on lowest Bayesian Information Criterion (BIC) scores (see Arnold and Roberts 2009).

5.7 South Australian Museum Collections

The SAM archaeological collections relating to the Riverland region were viewed during a visit to the SAM Netley Storage Facility in April 2018. The purpose was to assess the potential biases in the extant assemblages brought about by collectors. Specific attention was paid to the grinding material, the bulk of which, is provenanced to the Chowilla floodplain, i.e. immediately upstream of Calperum. An inventory of this material, including some basic metrical and descriptive data, is presented in Appendix II. The data includes the type of implement (based on the classifications outlined in Table 4-4), dimensions, material, type and the extent of modification seen on each specimen (macrowear only). Each specimen was photographed. Images and metrical and attribute detail is provided in the supplementary material.

5.8 Other laboratory methods

5.8.1 Sorting of excavated material

Materials recovered during excavations were relocated to the Flinders University Archaeology Research Laboratory (ARL) for curation and sorting. The contents of each bag were emptied onto cleaned sorting trays and examined under a bench magnifying lamp. Sediments were separated from the archaeological residues using steel tweezers, dentist picks and nylon brushes. The archaeological materials were then sorted into classes of shell, bone, stone artefacts and heat retainer. Each class was weighed on digital scales and general descriptions were entered into an excel spreadsheet, provided in the supplementary material, along with estimates of NISP and MNI. The material was photographed using a digital SLR or a Dinolite and Microscope-mounted camera where was required. Additional ^{14}C samples were recovered from the sorted material.

5.8.2 PXRF (Portable X-ray Fluorescence Spectroscopy)

PXRF assays were conducted on sediments recovered from auger and sediment log locations as a means of further characterisation, and with the specific aim of detecting gypsum content. As per Williams et al. (2020), dry ex-situ sediments were pulverised to homogenise the sample and sieved through 2 mm screens. Samples were then assayed using a Brucker 'Tracer 5i' model pXRF unit in 3 phase mode over three 20-second scans following a successful calibration check. Scanner accuracy was assessed against the OREAS 45d standard. All scans were conducted using the GeoExploration Oxide-3 analytical mode (method and setup) on sediment packed into pXRF cups and scanned under 4 μm polyethylene film. As per Knight et al. (2021), the cups held a minimum thickness of 10 mm of uncompacted sediment. No attempt was made to calibrate the assay specifically to the material composition. Instead, the simplified sample preparation and default machine settings were used to determine gross elemental composition as a semi-quantitative assessment.

The following elemental trends were expected for key changes in gross mineralogy:

- Aluminium is the key indicator of clay mineral content. Clay may have been delivered to the floodplain by water and/or aeolian dust. Dare-Edwards (1984:338) identified illite $((\text{K}, \text{H}_3\text{O})(\text{Al}, \text{Mg}, \text{Fe})_2(\text{Si}, \text{Al})_4\text{O}_{10}[(\text{OH})_2, (\text{H}_2\text{O})])$ and kaolin $(\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4)$ as the dominant clay mineralogy in regional loess.

- Sulphur with a corresponding trend in Calcium may indicate gypsum ($\text{CaSO}_4[\text{H}_2\text{O}]_2$).
- Sulphur with corresponding trends in Calcium and Magnesium may indicate dolomite ($\text{CaMg}[\text{CO}_3]_2$).
- Calcium with no corresponding trend in Sulphur may indicate calcite (CaCO_3).

5.8.3 Acid test

Two drops of 10% HCl were applied to sediments to detect calcite (CaCO_3) by effervescence following the method described in King (nd).

5.8.4 Geoarchaeological methods applied in Pike_SP16_05

A suite of geoarchaeological methods and analyses will be applied to further contextualise and characterise a hearth feature located in site PikeSP16_05. The analyses will be conducted by Assoc. Prof. Ian Moffat, Assoc. Prof. Mike Morley and Dr. Rachel Rudd as an extension to this thesis. In summary, these analyses include grainsize, LOI (Loss On Ignition), magnetic susceptibility (magsus) and ICP-MS (Inductively Coupled Plasma Mass Spectrometry) applied to a sediment column and micromorphology blocks intersecting the feature and its confining sediments, as shown in Figure 5-5. Some of the initial findings of this study are presented in Chapter 6.3.4.4. Additional results will be published separately.

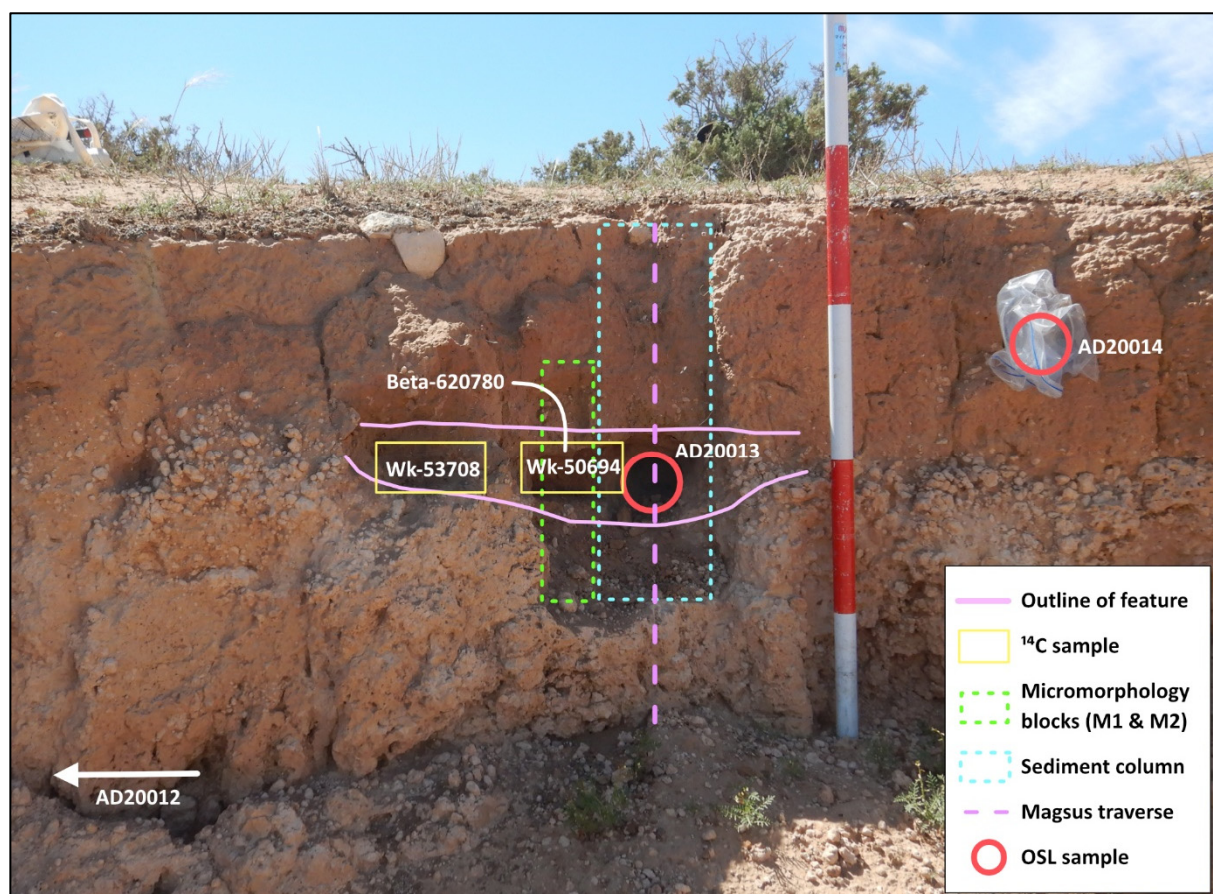


Figure 5-5: The combustion feature identified in site PikeSP16_05. Shown are the locations of the micromorphology section, the sediment column and magnetic susceptibility traverse, OSL and ^{14}C sampling locations, and the inferred base of the original pit feature.

CHAPTER SIX: RESULTS

6.1 Introduction

This chapter presents the results of the geomorphological and archaeological surveys, mapping and analyses conducted at the Calperum and Pike floodplains. OSL and ^{14}C age estimates and relative chronologies are used as basis of a landscape interpretation with some correlations and departures from a broader MDB narrative highlighted. The composition, character and chronology of the archaeology is also summarised. A more fully developed discussion is presented in Chapter 7.

6.2 Floodplain geomorphology

6.2.1 Landscape chronology

A landscape chronology has been framed around 15 OSL ages, 89 ^{14}C ages of archaeological material and a further 16 ^{14}C sediment ages (organics) recorded from the Calperum and Pike floodplains (Figure 6-1 and Figure 6-2). All the OSL results display relatively high overdispersion (OD), a result that would be expected where sediments are deposited in active environments or where the sediment column is prone to continual turnover through the effects of bioturbation or soil development (Roberts et al. 2000:460). As such, Fmix models have been used to determine a series of 3 to 7–component Fmix models, as summarised in Appendix X and illustrated in a series of Abanico plots in Figure 6-3. The components were assessed against their geomorphological contexts to identify the most likely contribution from a primary depositional unit (PDU) at the point of sampling. Interpreting the OSL component ages has not been straightforward, though the results are broadly consistent with an initial interpretation based on both regional and local geomorphology. The OSL ages are complemented with 105 ^{14}C ages (Appendix XI) that provide further insights into the chronology of both surface and sub-surface sediments. Episodic aridity, for instance, is illustrated by ages returned on archaeological material within an aeolian cover, while wetter phases are implied by middens associated with highstand beach ridges at Lake Woolpoolool and Clover Lake. Changes in hydrological setting are further illustrated in the nature of sediments recovered from three auger excavations conducted at Calperum and related to a ^{14}C chronology (see auger locations in Figure 6-1).

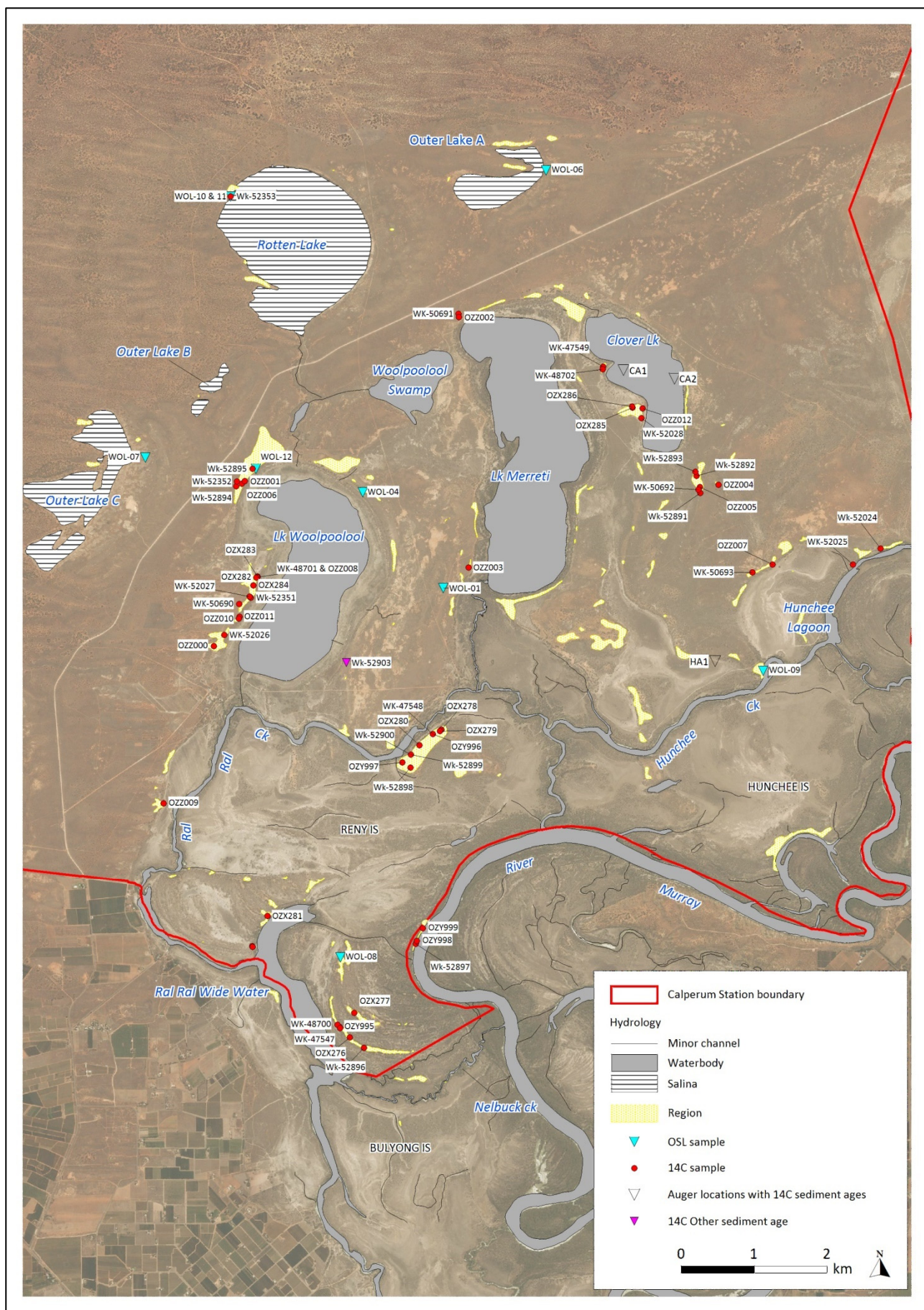


Figure 6-1: The locations of OSL and ¹⁴C dating at Calperum.

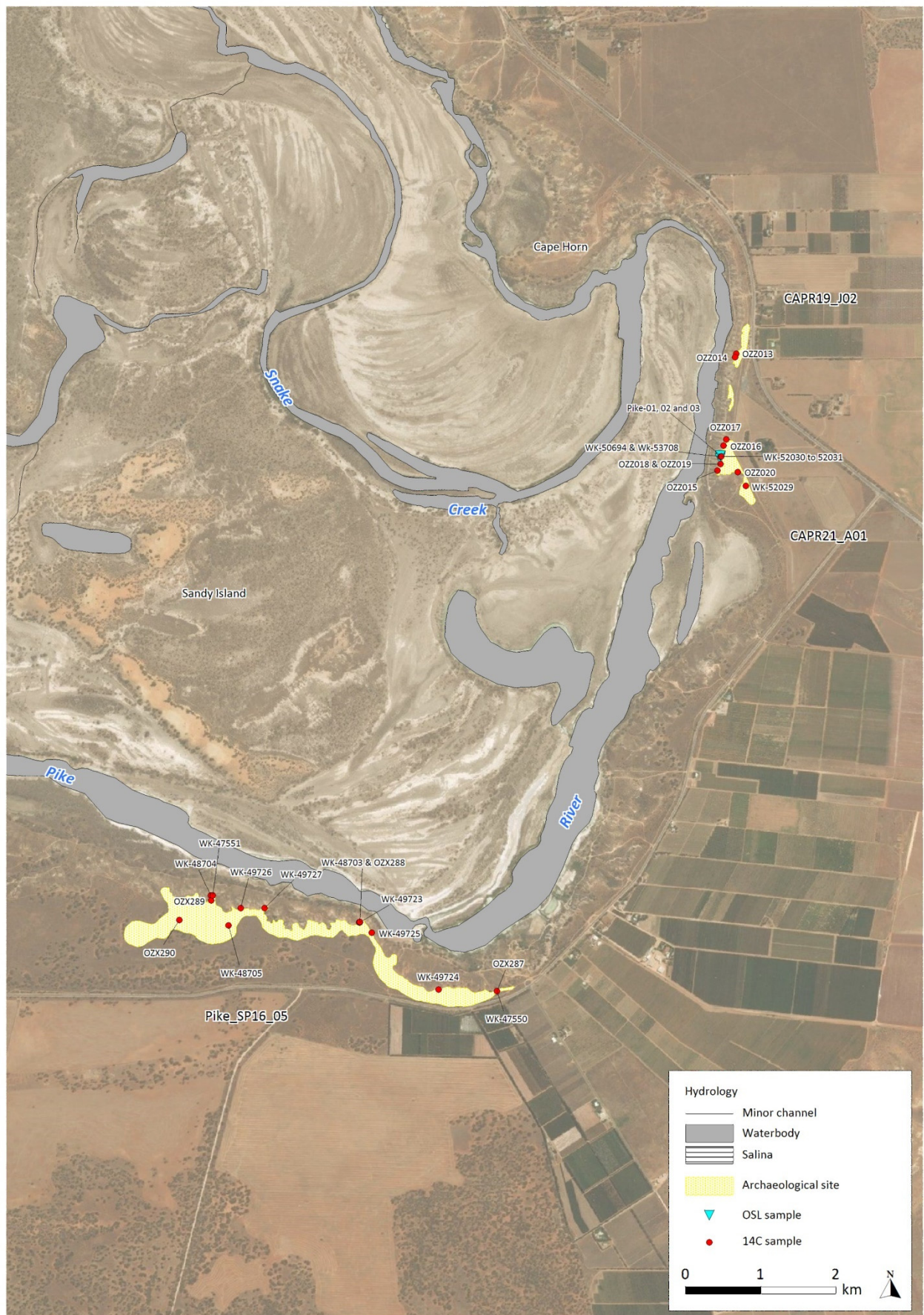


Figure 6-2: The locations of OSL and ^{14}C dating at Pike.

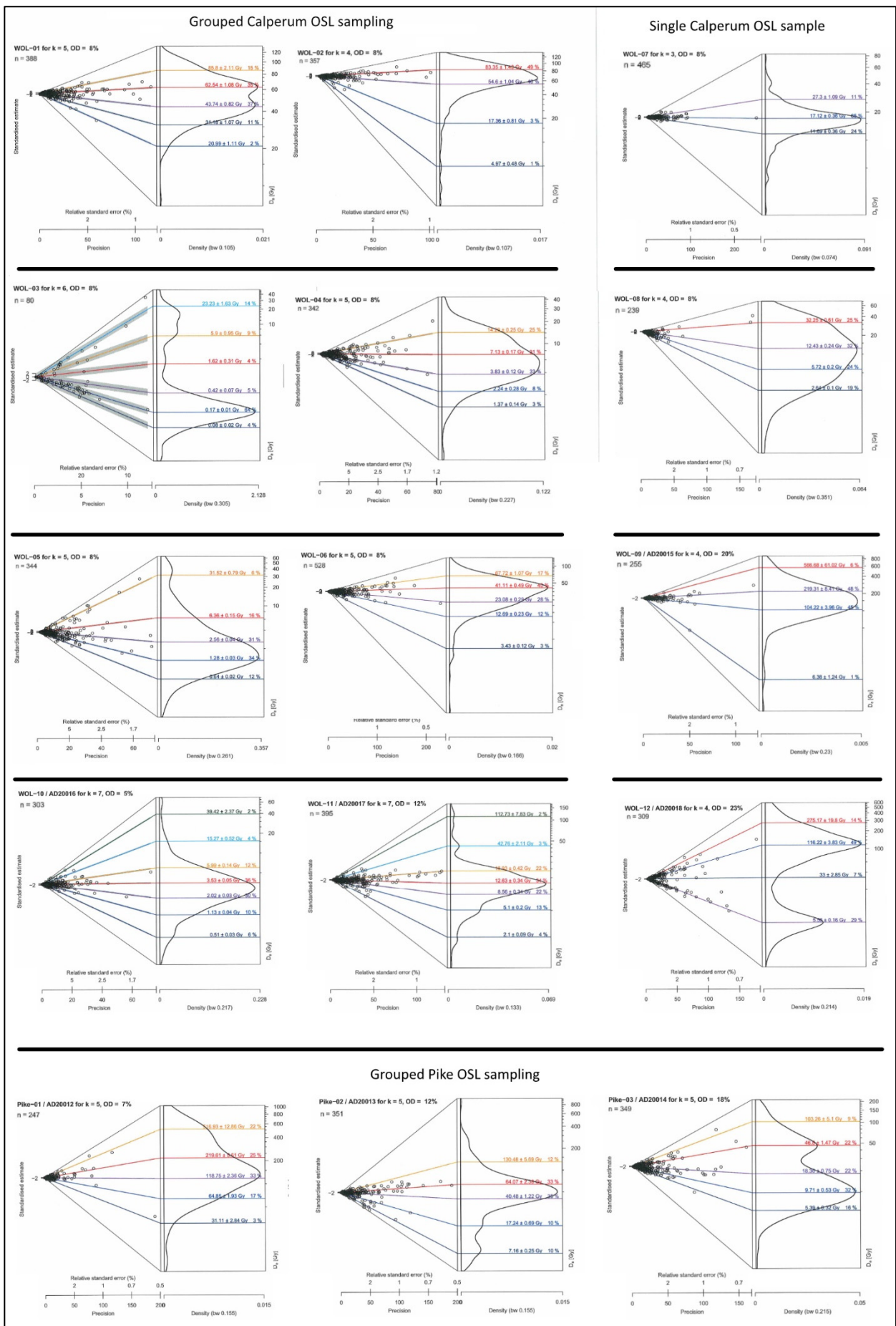


Figure 6-3: Abanico plots for OSL ages at Calperum (12 age estimates) and Pike (3 age estimates).

The combined OSL and ^{14}C chronologies frame an interpretation of landscape development. This is constructed principally around a sequence of four alluvial terraces with all other landforms able to be related to this basic structure. At Calperum, the terrace sequence is preserved progressively south across the floodplain with the oldest terrace (T1) hugging the northern edge of the floodplain and the youngest (T4) accommodating the modern River Murray course around the southern edge (Figure 6-4 and Figure 6-5). The floodplain architecture at Pike is more confused with the extant terraces partitioned within the floodplain (Figure 6-6 and Figure 6-7).

The terraces can be differentiated on the basis of elevation, channel and meander planforms (Figure 6-8), the presence/absence of SBDs, sediment type and pedology. Based on the classification scheme developed by Nanson and Croke (1992), the terraces have transitioned from high-energy non-cohesive (Class A) floodplains to medium-energy non-cohesive (Class B) floodplains (see Figure 3-3). The terracing tends to truncate earlier systems rather than be captured by them, though there is some inheritance of former landscapes. The modern oxbows and anabranch streams, for instance, occupy the traces of palaeochannels.

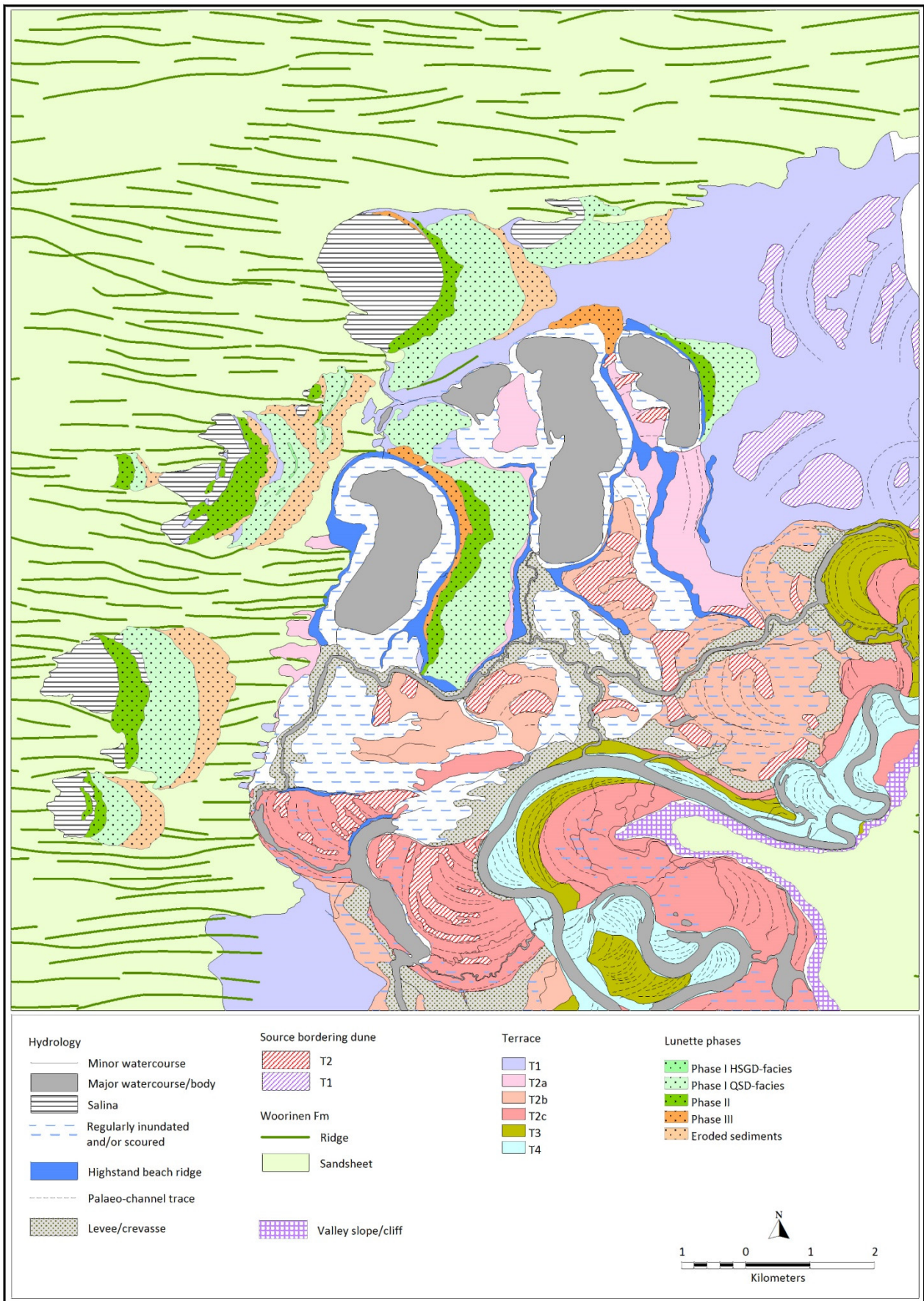


Figure 6-4: An interpretation of the Calperum floodplain geomorphology.

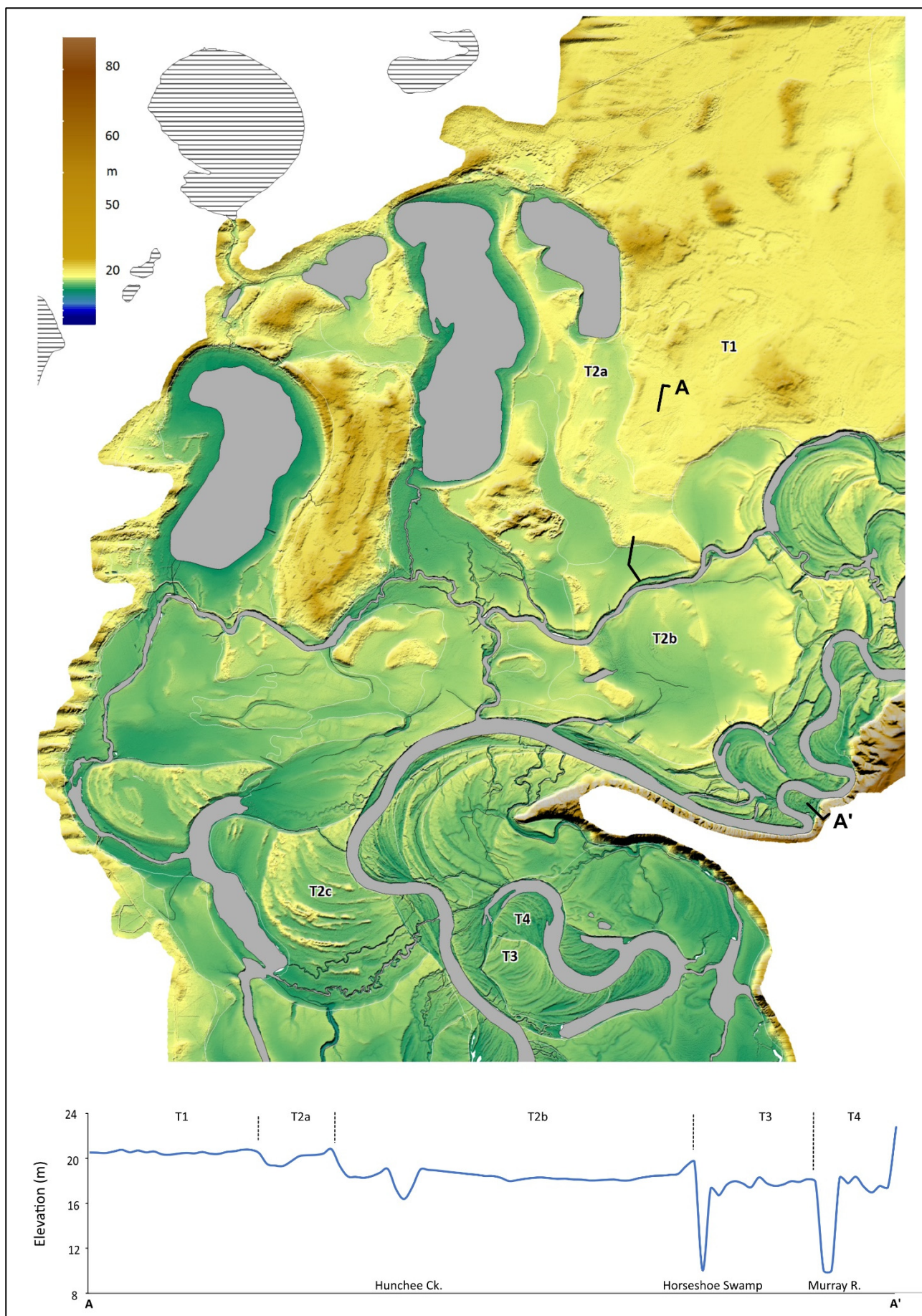


Figure 6-5: Topography across the Pike floodplain (surface based on Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid, Geoscience Australia).

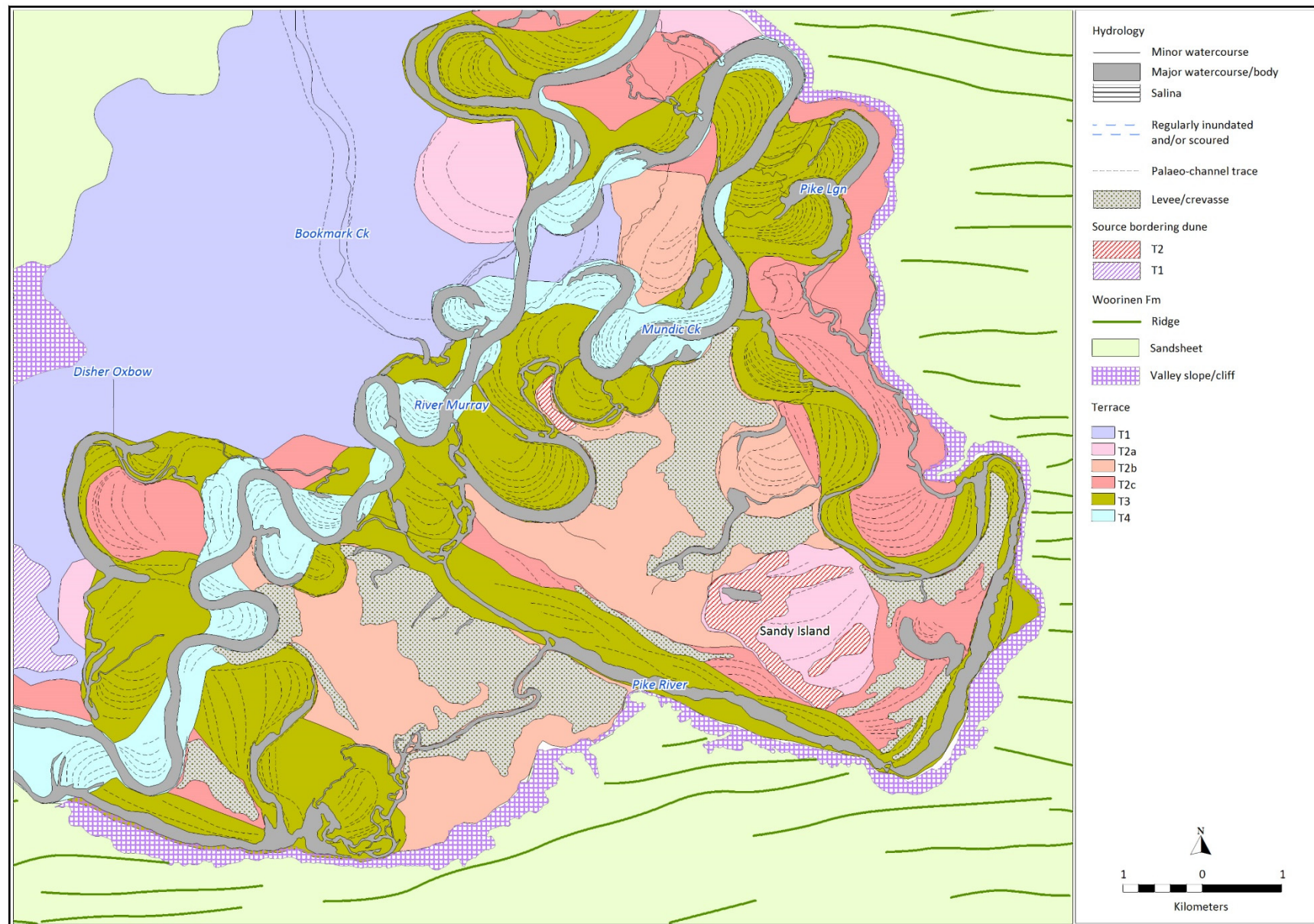


Figure 6-6: An interpretation of the Pike floodplain geomorphology.

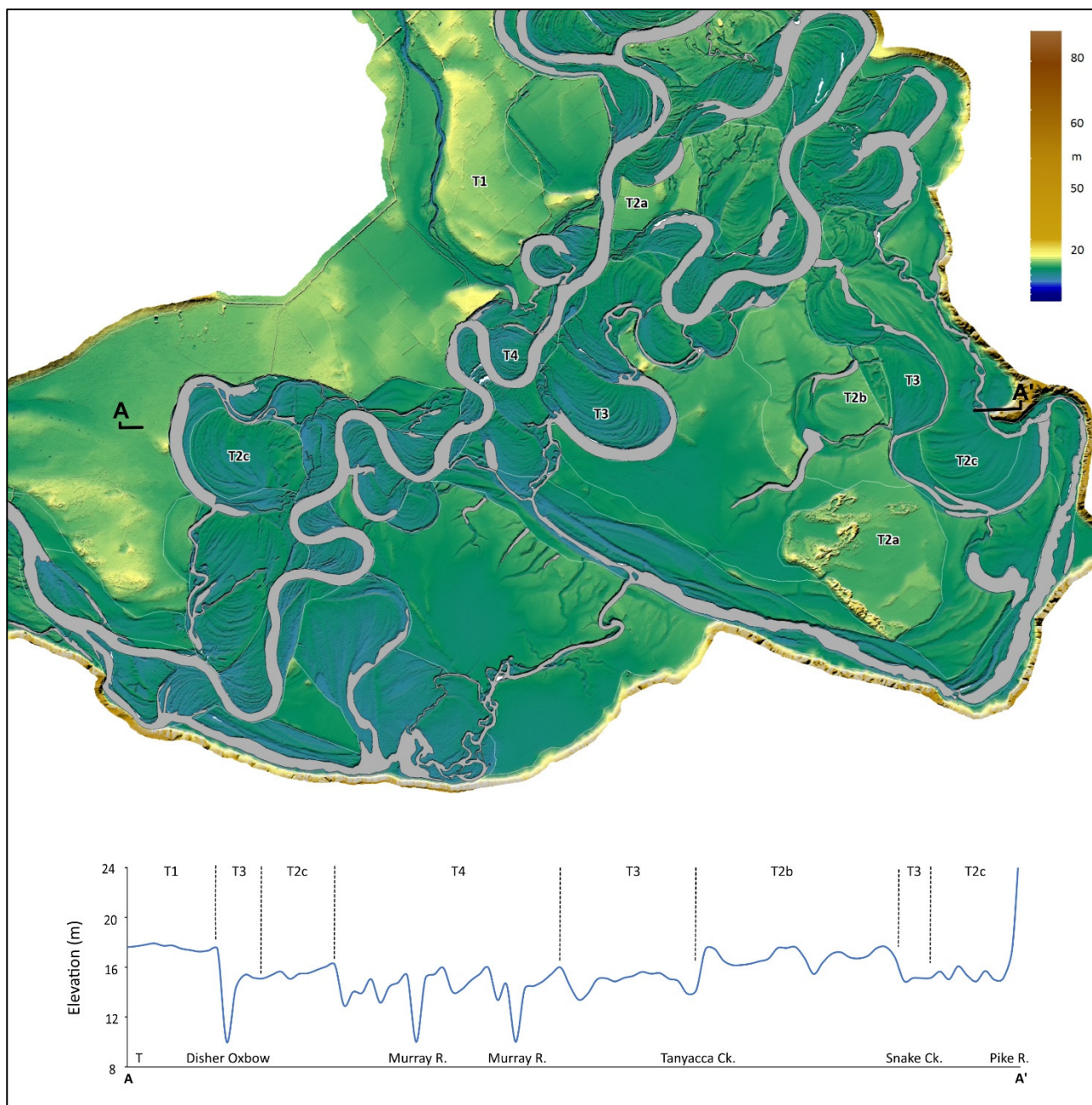


Figure 6-7: Topography across the Pike floodplain (surface based on Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid, Geoscience Australia)

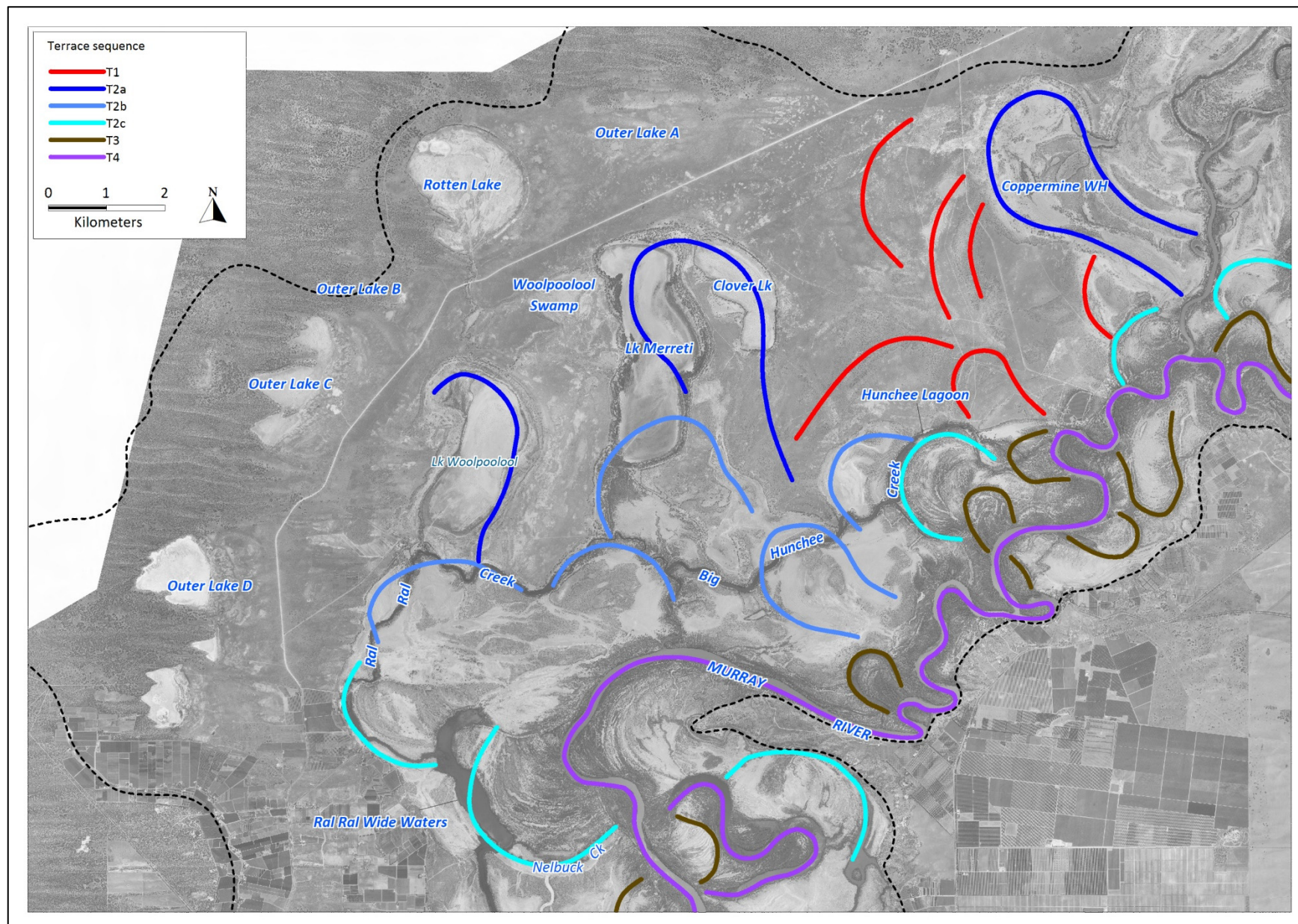


Figure 6-8: Generalised meander forms in each of the terraces on the Calperum floodplain.

6.2.2 Terrace T1

Terrace T1 (Figure 6-9) represents the oldest fluvial landscape preserved within the valley and lies 4–5 m above T4. At Calperum, this terrace encompasses elevated land around the northern margin of the floodplain and to the east of Clover Lake. The original landforms associated with this terrace are poorly preserved and the terrace is largely concealed by an aeolian cover. Several broad, arcuate channel traces in excess of 350 m wide are, however, preserved east of Clover Lake. Bookmark Creek, in the area of Renmark, is the best-preserved example of a T1 channel within the broader Riverland (Figure 6-6). These wandering/meandering channels are bounded by broad sand levees and/or SBDs and the terrace itself is essentially a sandplain. Soil carbonate is also common and occurs as nodular calcrete and rhizomorphic structures in often deep pedogenic zones.

Terrace T1 had evidently developed under a regime of energetic flows capable of transporting relatively coarse sediments in broad bedload channels. Given the degree of pedogenesis, the terrace is also likely to be of considerable antiquity. No direct dating of T1 was undertaken, though the dating of T2a sediments to 44.3 ± 2.0 (AD20015) provides a minimum age. At Roonka Flat, Rogers (1990) obtained a single TL-age of 77–53 ka for ‘Upper Terrace Deposits’ that are described as pedologically structured, coarse sand with nodular calcrete. Kotsonis et al. (1999) suggested that the transition between the ‘High Level Terrace’ and ‘Low Level Terrace’ in the Hattah Lakes and River Murray occurred sometime in the period 60–35 ka. These references to ‘Upper’ or ‘High’ terrace deposits are likely to be analogous to T1 at Calperum.



Figure 6-9: Eroded T1 surface at Calperum under chenopod shrub community. A Woorinen Formation dune is visible in the background.

6.2.3 Lunette lakes and Woorinen dune-fields

Three distinct phases of lunette development are preserved at Calperum (Figure 6-10). Phase I is dominated by QSD-facies sediments indicative of persistent freshwater conditions. Phase II is characterised by saline HSGD-facies (gypsum) sediments in the outer lakes and irregular sedimentation of quartz sand and clay across the inner lunettes (QSD/PCD-facies). The most recent Phase III lunettes mark a return to a QSD-facies environment in the inner lakes. Lunette orientation in respect to the lake basins also identifies distinct changes in climatic setting with a dominant WNW wind direction during Phase I shifting slightly more NW during Phase II before a marked rotation to the SW during Phase III. This last rotation demonstrates a shift to a prevailing south westerly dominated climate across the deglacial period and the re-establishment of regular lake full conditions. Fitzsimmons (2017) cites similar evidence in the Willandra system with an earlier change in prevailing climate centred on a brief pluvial c. 24 ka.

The gradual incision and terracing of the Calperum floodplain has resulted in the abandonment and/or contraction of the lunette lakes, replicating the basin-in-basin scenario described by Chen (1995) in respect to Lake Victoria. This process has tended to produce a series of discrete ridges and other topographic features around the majority of lunette basins, as illustrated in Figure 6-11. The inferred differences in elevation between the terraces are generally consistent with those proposed by Prendergast et al. (2009) for equivalent terraces in the Lindsay Island area, though the local evidence suggests a staggered transition both within and between each terrace. Cliff erosion (CE) is also a conspicuous element in the profiles and includes three notable examples highlighted in Figure 6-11. CE1 is a common feature of all the outer lakes where it significantly impacts the Phase II lunettes. This indicates that a period(s) of regular flooding in the outer lakes had occurred prior to the complete closure of most of these lakes. Evidence of post-LGM highstands take the form of beach-ridges perched along terrace edges at Lake Woolpoolool and Merreti-Clover and the truncation of Wfm dunes along the western margins of Lake Woolpoolool and Rotten Lake.

Another notable feature is the distinctive notch etched into the outermost lunette ridge of Lake Woolpoolool (W1). This forms a steep, 1.5–2.5 m high bank that is traceable for approximately 2.8 km (Figure 6-12) and extends around the eastern edge of a 300–380 m wide flat-lying surface. The

consistent and traceable form and base elevation of this feature, together with the levelled lake-side surface, suggests that the notch had developed through etching along a static water line. This interpretation is supported by additional evidence in the broader floodplain where groups of etched lines tend to occur in narrow elevation bands corresponding to this elevation (24.8–26.1 m) and a slightly higher elevation (26.9–28.1 m) (Figure 6-13 and Figure 6-14). A similar etch-line corresponds to the high-water mark of the 1956 flood (23–24 m band in Figure 6-13) suggesting that relatively short events can produce lasting impacts, or that similar 1956-magnitude events had occurred in the past. Kefous (1983:28) identified similar etched features at Lake Victoria.

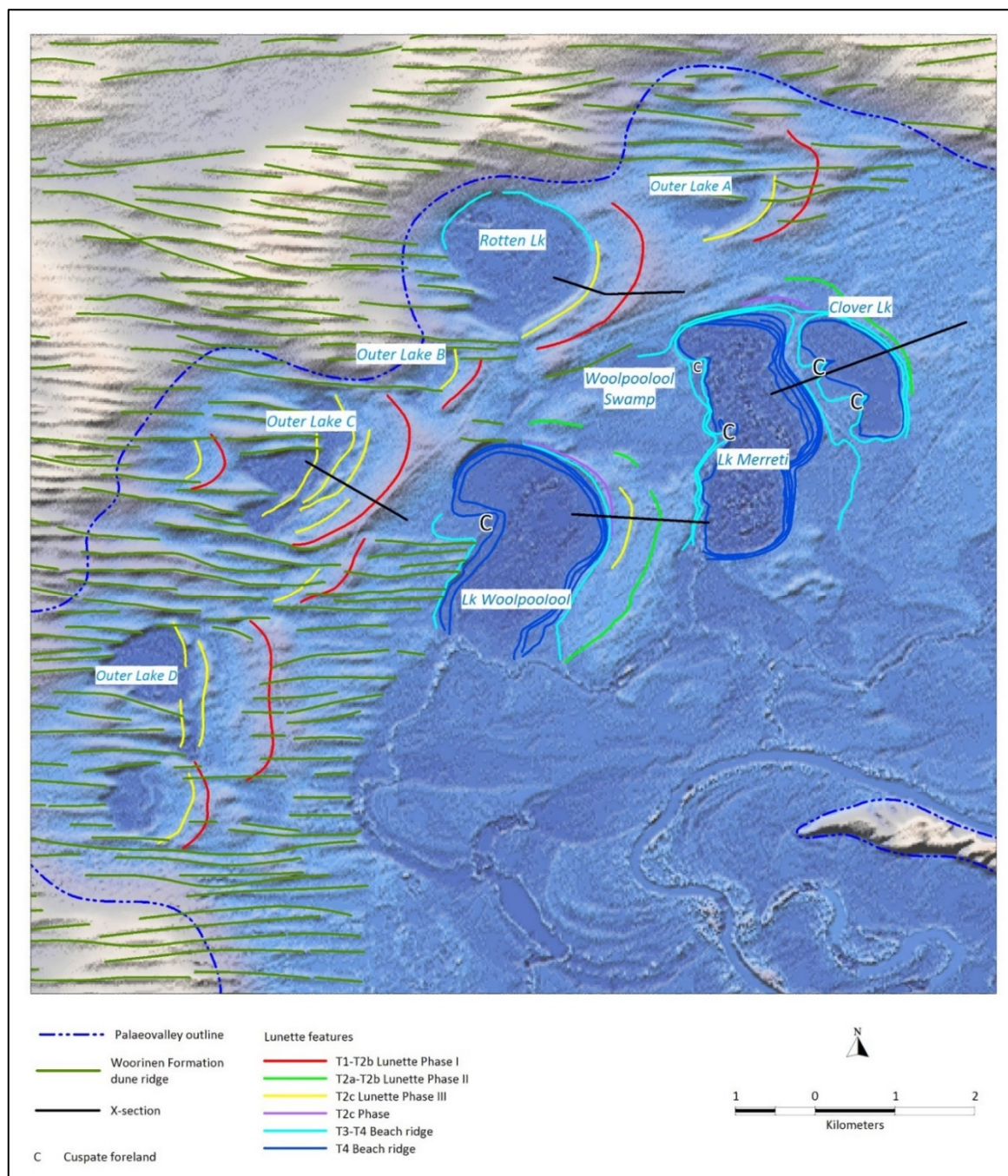


Figure 6-10: Topographic features associated with the Calperum lakes and assigned to the terrace sequence. Features include the various lunette ridges (Phases I–III), beach-ridges and strandlines.

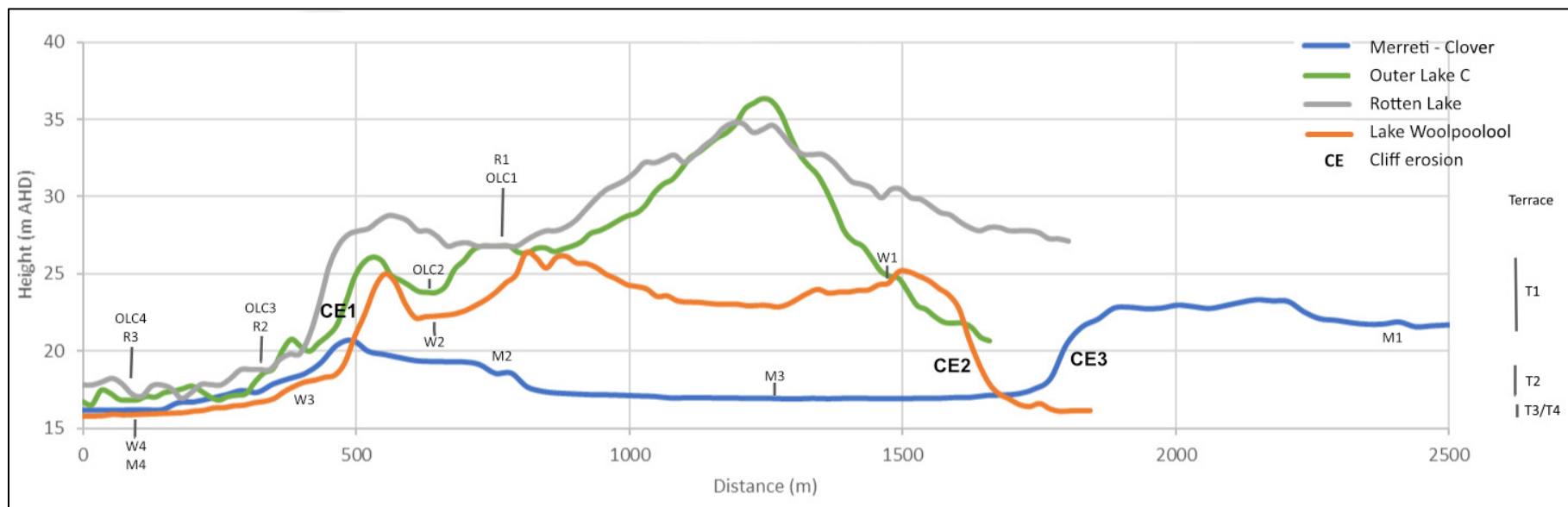


Figure 6-11: Surface profiles across a selection of the Calperum lakes showing topographic features and the terrace sequence. The height differences have required the meshing of three elevation datasets; RTK data, Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid, Geoscience Australia and the ALOS Global Digital Surface Model (AW3D30), Japanese Aerospace Exploration Agency (JAXA). Appendix XIV shows the height differences between these.

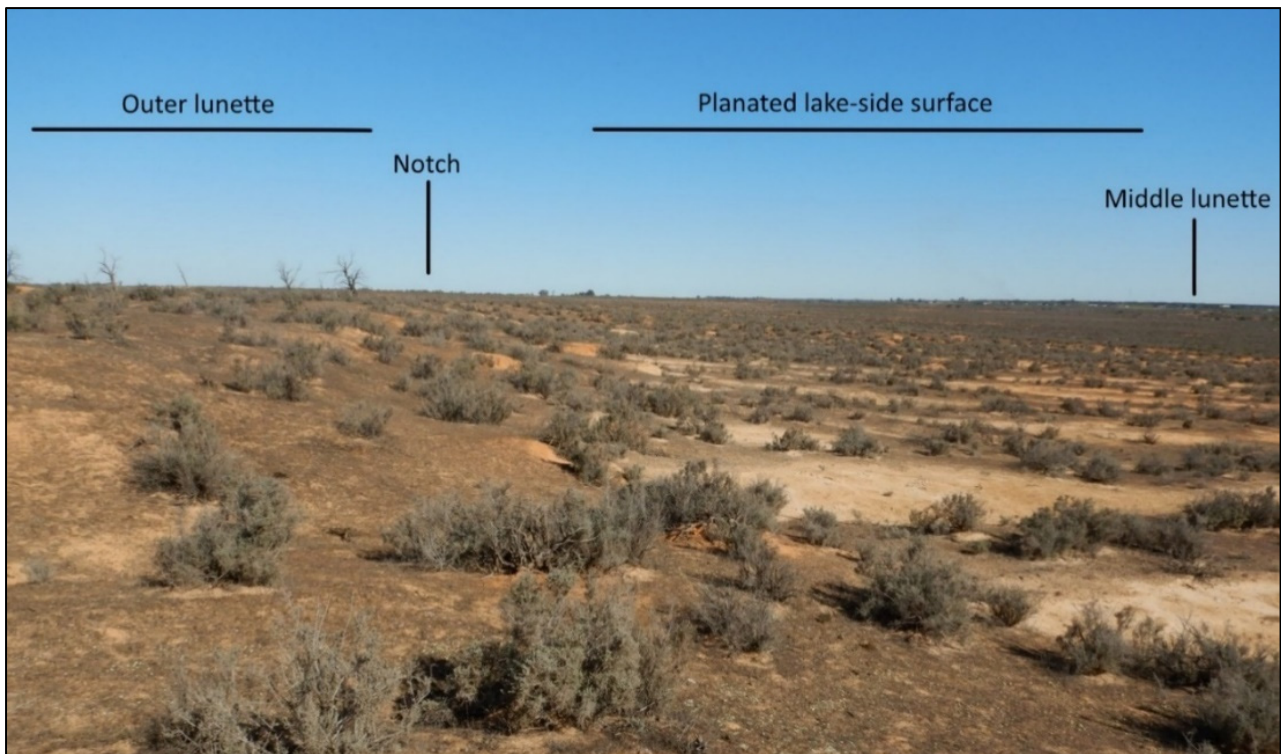


Figure 6-12: View looking south along the notch etched into the outer lunette at Lake Woolpoolool.

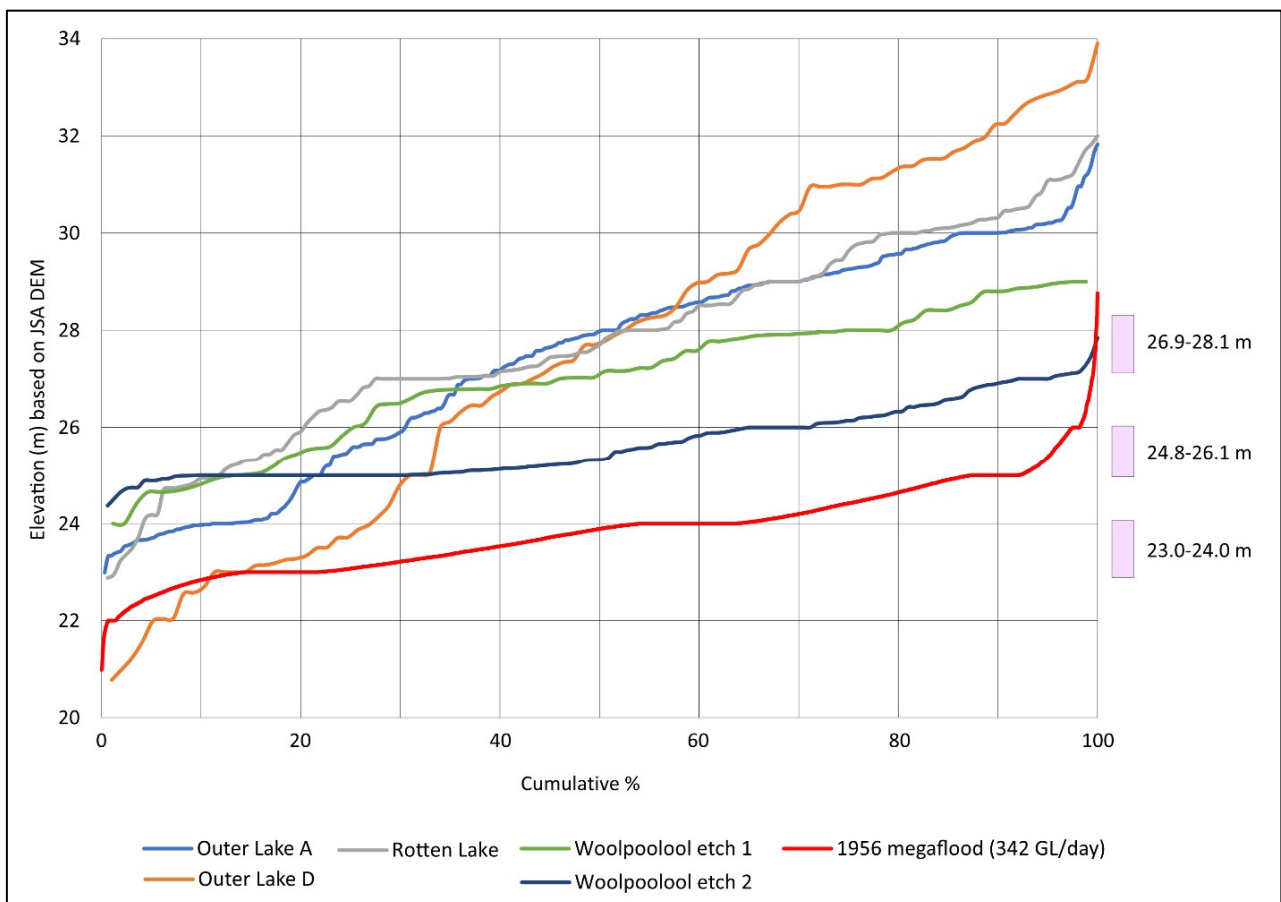


Figure 6-13: The elevations of etched lines visible on the Calperum floodplain compared to the height of the 1956 megafood. Elevations are derived from the JSA DEM and based on a 10 m sampling of the traced lines.

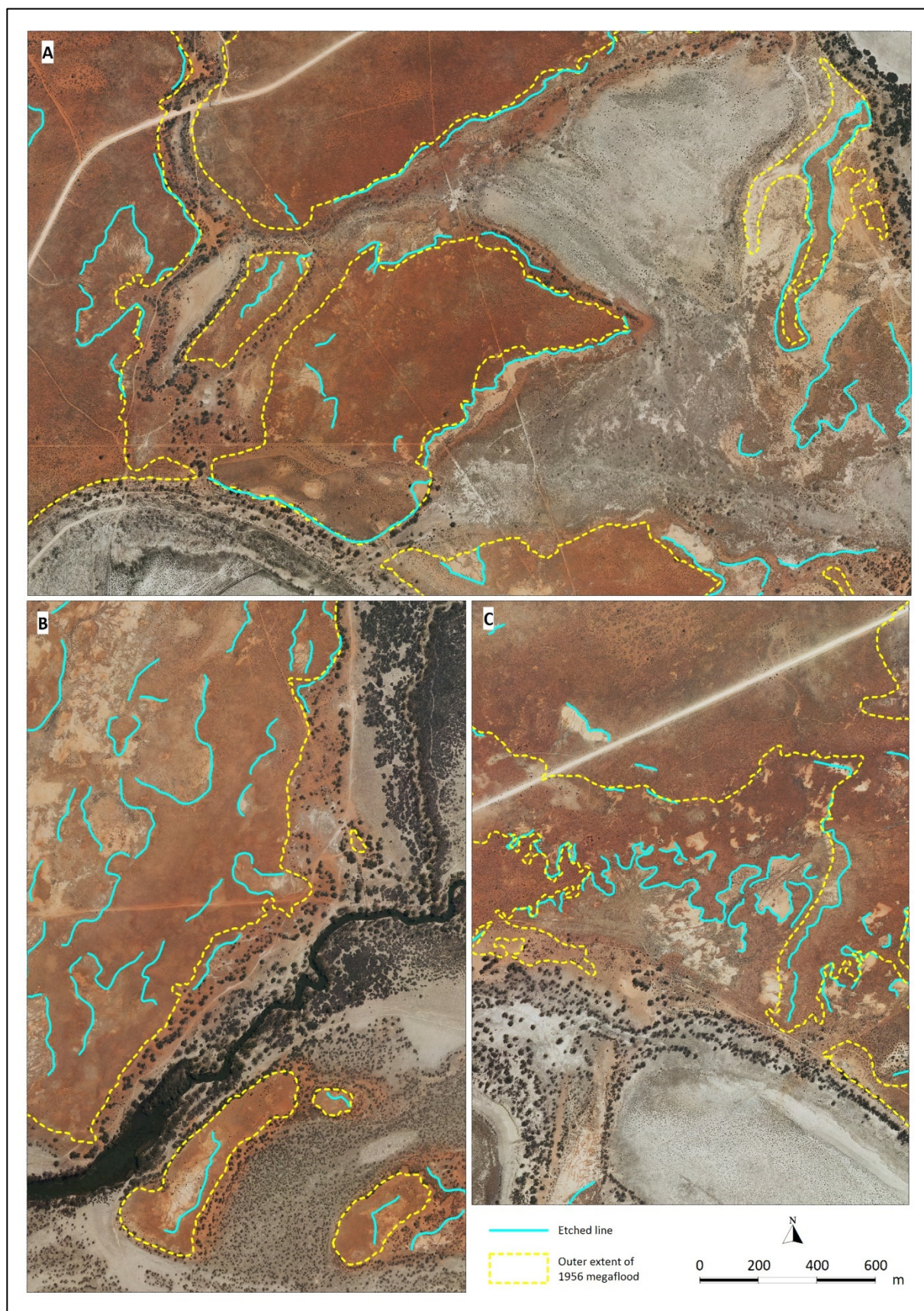


Figure 6-14: Examples of etched lines at Calperum in comparison to the extent of the 1956 megaflood: A - northern margin of Lake Woolpoolool and Woolpoolool Swamp, B - southern section of the Woolpoolool lunette and C - northern margin of Clover Lake.

6.2.3.1 The outer lunette lakes

Under the modern hydrological regime, Rotten Lake is the only outer lake that maintains a connection to the River Murray (via an inlet creek to Lake Woolpoolool), though water enters the lake only during the most extreme flood events. Wfm dunes also obstruct the inlet creek, and without at least periodic flooding, these dunes are likely to fully impede the channel. This interplay between Wfm dunes and the floodplain is a complication to be considered in the sediment histories of all the outer lakes. A basic structure repeated across all of the outer lakes is illustrated in Figure 6-15 and Figure 6-16 in respect to Outer Lake C. This consists of QSD/PCD lunette ridges (Phase I) developed around larger and more elevated basins; inner HSGD ridge(s) (Phase II) bounding the modern salina and Wfm dunes that transgress west to east into, and in some instances fully across, the lakes.

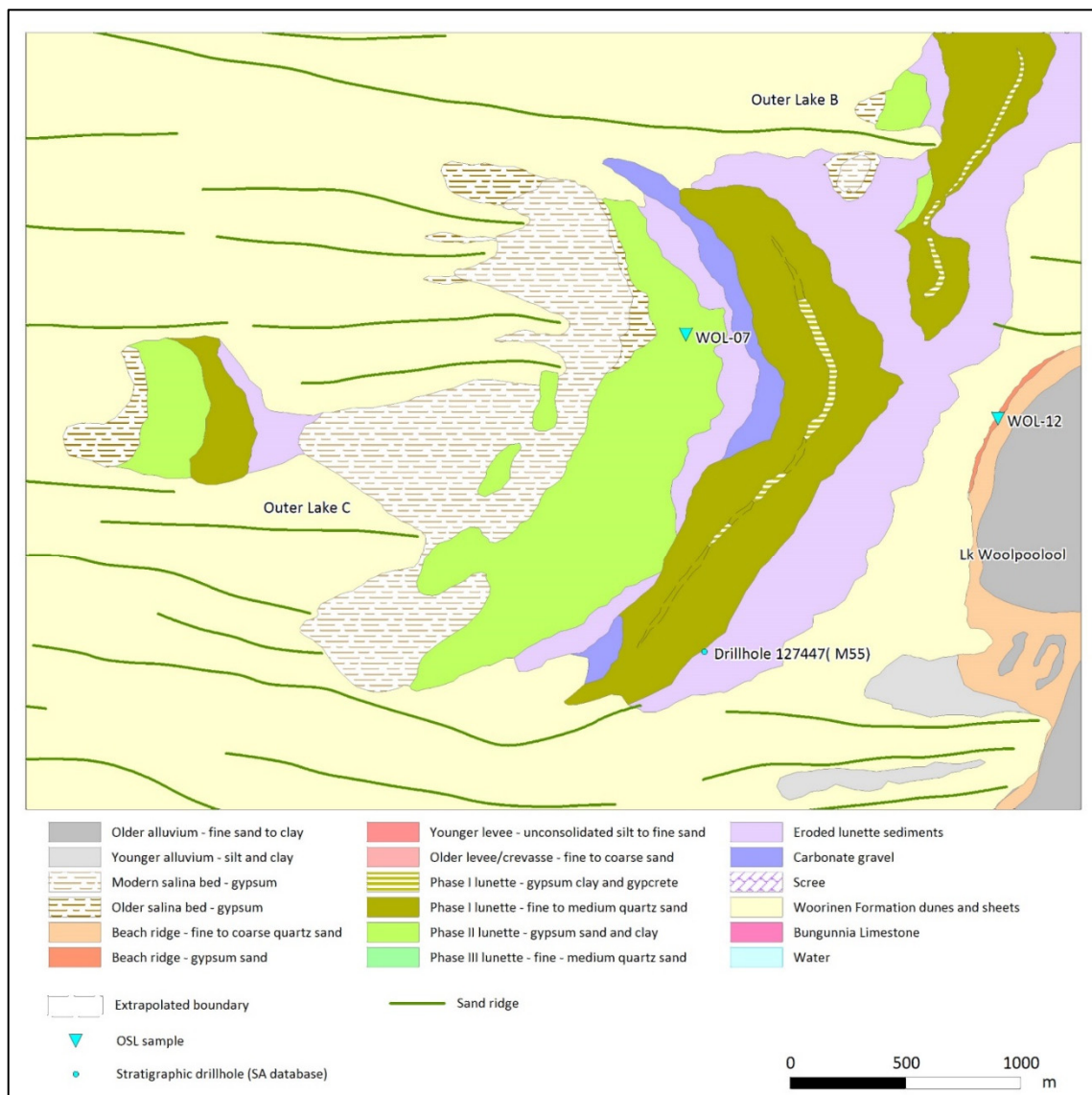


Figure 6-15: Surface sediments in the area of Outer Lake B and C.

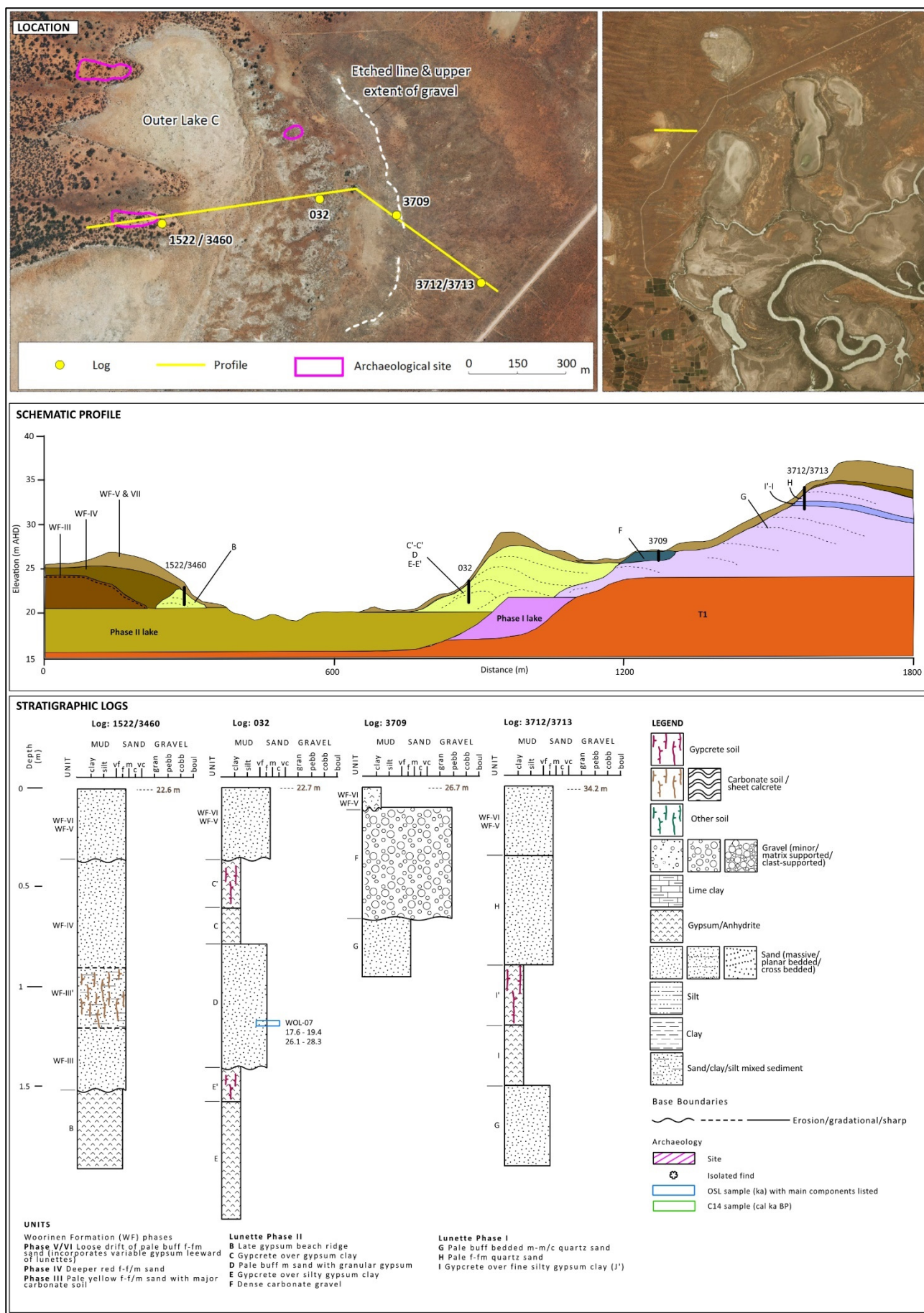


Figure 6-16: Schematic profile across Outer Lake C.

Natural exposures across the Phase I lunettes suggest a structure dominated by medium to coarse quartz sand and clayey sand (Units G-H-I in Figure 6-16), suggestive of a QSD-facies dominated environment of perennial or intermittent freshwater. A thin bed of gypsiferous clay (Unit I) in the upper part of the Rotten Lake, Outer Lakes B and C lunettes marks a discrete salinisation phase prior to a major contraction of the lakes to the Phase II ridges. These observations are consistent with a stratigraphic drill hole previously recorded on the crest of the Outer Lake C lunette (127447 [M55], SA Geodata Database—see location in Figure 6-15) which describes medium grain red brown ferruginous-calcareous-gypsiferous sand with higher clay content from 2–3 m and overlying a medium–coarse grain, weakly cemented ferruginous quartz sand.

OSL samples WOL-05 (Ad19142) and WOL-06 (Ad19144) were located in a low ledge in the upper slope of the Phase I lunette at Outer Lake A (Figure 6-17). WOL-05 was located at a depth of 10 cm within a thin cover of yellowish-red fine medium sand capping the section (Unit A1). Two major components of 2.08–1.94 ka (31%) and 1.05–0.97 ka (34%), and a minor component of 5.16–4.8 ka (16%) confidently relate this unit to the mid to late Holocene mobilisation of the lunette surface (WFm Phase VI). WOL-06 was located at a depth of 80 cm directly below WOL-05 within a stiff, poorly sorted clayey fine–medium sand (Units A2-A3). Planar bedding in this unit is largely overprinted by a deep, mottled and blocky soil that continues below the base of the exposed section. This profile drapes the lunette topography and is likely to incorporate a mixture of sediments repeatedly reworked across the eroding lakeside slope of the lunette. The high clay content may be explained by periodic deflation of an exposed lakebed or contributions from regional loess. As discussed elsewhere in this thesis, loess records in the MDB extend from earlier than 50 ka and through the LGM (Hesse et al. 2003). Prendergast et al. (2009) identified ~30 cm of aeolian carbonate clay (termed *parna*) accumulated on the Neds Corner floodplain probably over multiple cycles from late MIS 3. This complex history is reflected in major components in sample WOL-06 of approximately 11.6–11.0 ka (28%) and 20.7–19.5 ka (40%). In this sample, a minor (17%) component of 33.2–33.0 (17%) ka is interpreted as an upper age constraint on the original Phase I lunette and is consistent with a major contraction of the outer lakes sometime prior to 27 ka, as illustrated in sample WOL-07 (Ad19145) (see below).

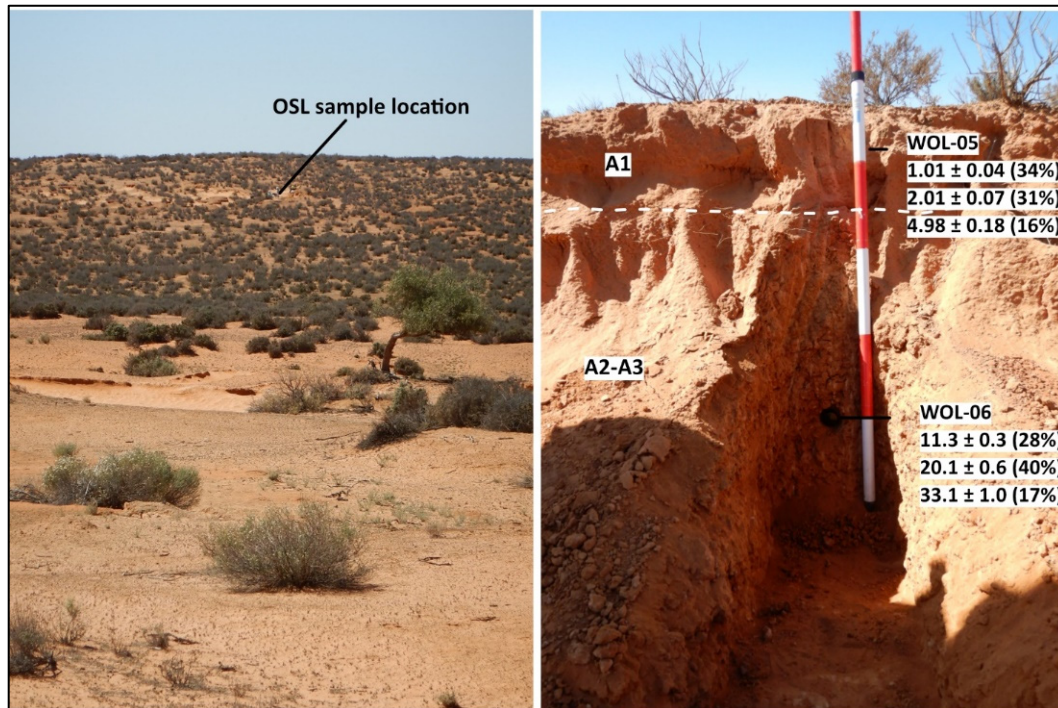


Figure 6-17: View looking east to OSL sampling location WOL-05/06 on the Outer Lake A lunette (left) and the exposed section showing the OSL component ages (right).

The c. 33 ka age also suggests that the latter stages of Phase I lunette development in the outer lakes had been coeval with similar QSD/PCD-facies lunettes in the inner lakes (see below). With the exception of the discrete gypsum unit (Unit I), regular inundation and water connectivity across the floodplain to at least c. 33 ka is implied in this evidence. This scenario changes abruptly, however, following a major contraction of the outer lakes. This contraction ushered in a protracted saline phase represented by thick HSGD-facies dominated lunettes (Phase II) at Outer Lakes B, C and D and Rotten Lake (Figure 6-18). Based on OSL sample WOL-07 located in the Phase II lunette at Outer Lake C (Figure 6-19), this phase began well before c. 27 ka. This phase was also complex. WOL-07, for instance, was collected from a thin lenticular unit of pale buff quartz and gypsum sand wedged between two units of gypsum clay. The major component (65%) in WOL-07 translates to an OSL age of 28.3–26.1 ka and is interpreted as the PDU (Unit D). Each gypsum unit is capped with a gypcrete palaeosol (C' and E'), a stratigraphy that is repeated at Rotten Lake (Figure 6-20) and is reflective of episodic lake filling, salinisation and landscape stability in the period leading to and straddling the LGM. This pattern is essentially a repeat of the stratigraphy identified at Lake Victoria (Chen 1995), Lake Tandou (Hope et al. 1983), Lake Tyrell (Macumber 1991) and Bunda-Nulchara Lake (Williams et al. 1991), linking local climatic phases to a broader regional pattern.



Figure 6-18: View looking southwest along the gypsum lunette at Rotten Lake.

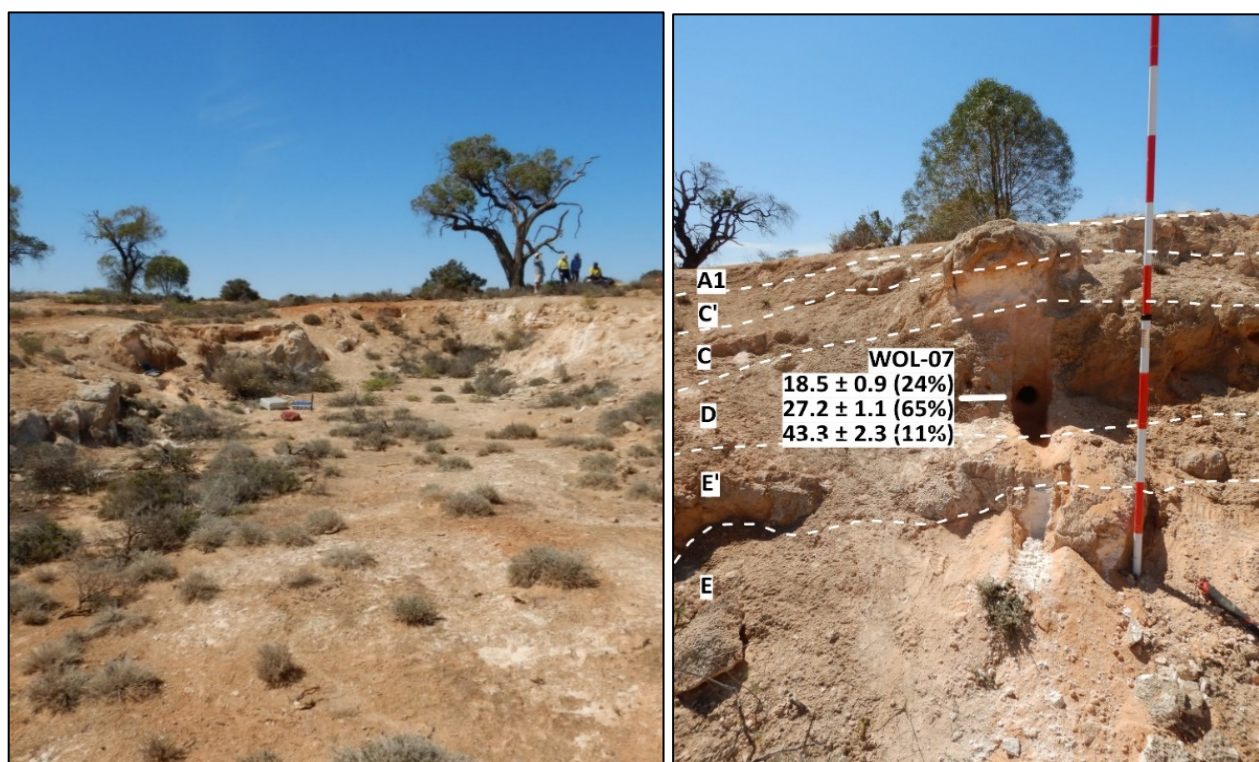


Figure 6-19: Context images of OSL sample WOL-07. The landscape view is looking south from the bed of Outer Lake C to the lunette. OSL component ages are shown in the section image.

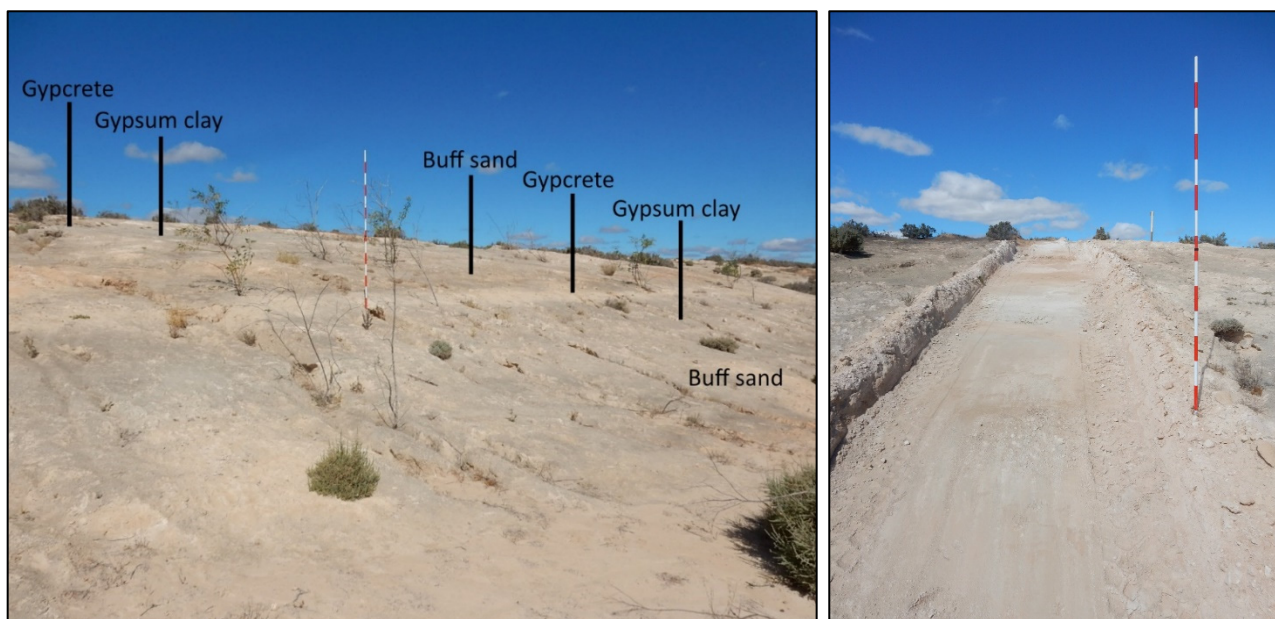


Figure 6-20: The complex HSGD stratigraphy exposed in the Rotten lake lunette (scale = 2 m). Unit D dated to c. 27 ka at Outer Lake C in OSL sample WOL-07 is equivalent to the buff sand seen adjacent to the range pole in the Rotten Lake lunette.

The contraction of the outer lakes predates a major salinisation phase recognised elsewhere in the MDB, e.g. the Talgarry Sand at Lake Victoria (Chen 1995) and Zanci/Unit E in the Willandra system (Fitzsimmons et al. 2014). In the outer lakes, salinity may have been a response, at least in part, to the staggered incision of terraces T2b and T2c. As the fluvial corridor migrated progressively south in the floodplain, the outer belt of lakes functioned in an overflow system that relied increasingly on water connectivity through the inner lakes and a series of anabranch creeks. With a gradual lowering of the floodplain, the frequency and height of inundation in the outer lakes would have been reduced, exposing the lakes to greater groundwater influence and allowing Wfm dunes to advance into the lake beds and further impede inflows. This scenario would be compounded by the infrequent and/or short duration flooding suggested in the development of SBDs in both T2b and T2c.

Saline conditions in the outer lakes are likely to have persisted across the LGM and also impacted the inner floodplain where gypsum occurs in shallow alluvium in borrow pits north of the Calperum homestead, around the eastern shoreline of Lake Woolpoolool and in drill hole data adjacent to Ral Ral Creek at the inlet to Lake Woolpoolool (Drill hole 126971, SA Geodata Database). Personal observations of gypsum clay deposited over the Lake Bonney lunette indicates that salinisation had impacted the Riverland floodplains more broadly, including the largest lake in

this region. The implications of this cannot be overstated. A ^{14}C age of 17,028–16,664 cal BP [Wk-52903] was returned on sediment from near the top of the saline clay in an exposure on the eastern shoreline of Lake Woolpoolool.

The transgression of WfM dunes into the Calperum floodplain to distances of up to 5 km is also testament to the desiccated nature of the MHP during the hyper-aridity of the LGM and provides a stark contrast to the densely wooded and stabilised mallee dune-fields observed today. The complete closure of Outer Lakes A, B, C and D saw dunes transgress across these lake floors (Figure 6-21 and Figure 6-22). The younger component in WOL-07 (i.e. 18.5 ± 0.9 ka) provides a minimum age for the transgression of these dunes assuming that the gypsum lunette ridges required an unimpeded fetch across an open lakebed to develop. A likely scenario, therefore, is that the dunes transgressed during the LGM, and that a carbonate soil exposed in these ridges corresponds to a gap in regional dune activity identified by Lomax et al. (2011) c. 18–15 ka. Subsequent dune reactivations have exposed this soil and shifted younger aeolian sediments progressively eastward across the defunct lake beds.

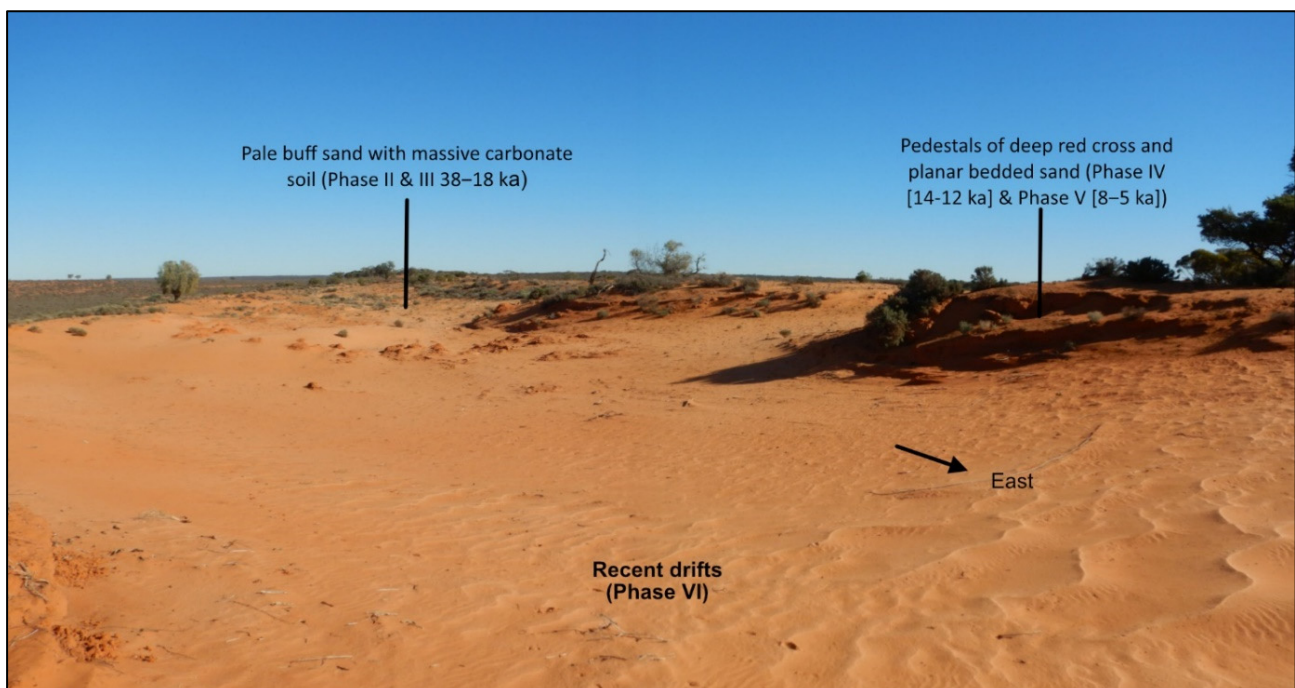


Figure 6-21: Dune phases exposed around the northern margin of Outer Lake A.

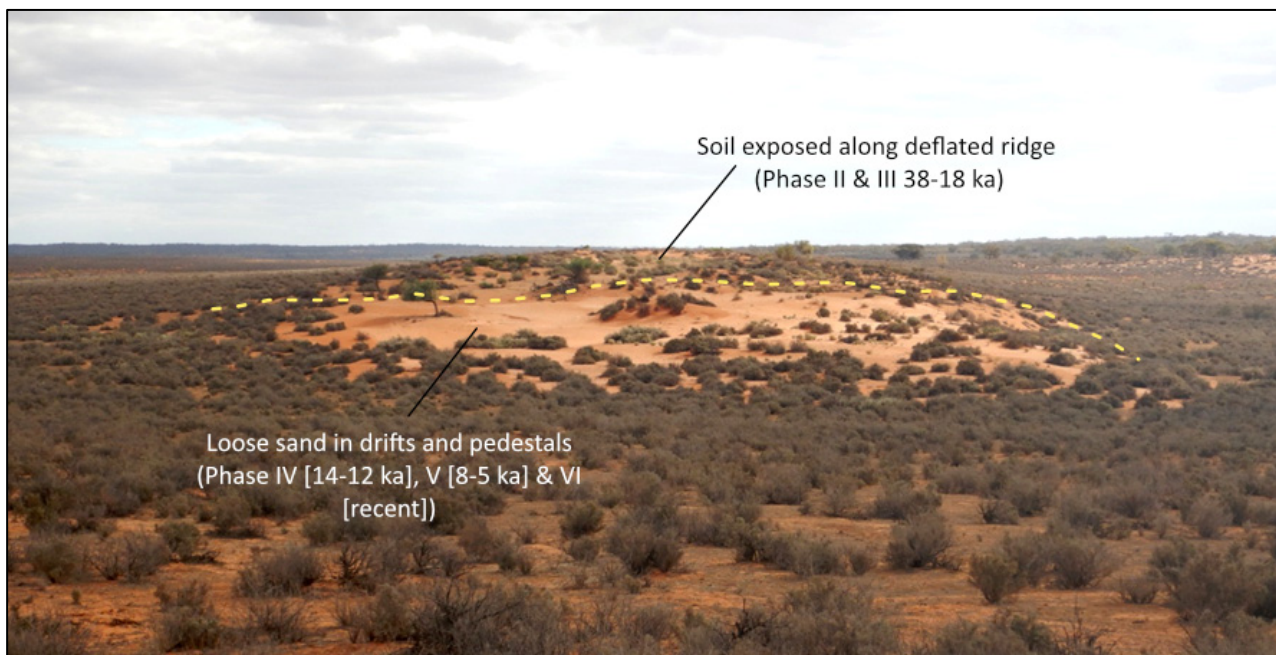


Figure 6-22: A dune transgressing the bed of Outer Lake A. The dotted line separates pre and post-LGM phases.

The development of a sandy beach around the northern margin of Rotten Lake together with cliff erosion of the earlier Phase II lunette marks a return to more regular filling. This transition is illustrated along a shallow gully on the north-western margin of the lake (Figure 6-23 and Figure 6-24). Here, a basal silty sand containing crystalline gypsum (Unit R) is exposed around the edge of the modern salina. A light grey saline mud with root casts and interpreted as a marsh facies (Unit Q) sits above Unit R and is overlain by a medium-coarse quartz beach sand (Unit P). A rubbly scree (Unit O) is exposed around a low ledge cut into the base of the valley slope at the western end of the section, and together with the beach sand, is capped with a thin unit of fine-medium red sand that has been reworked into a small fan and aeolian cover centred on the gully (Unit N).

Fine, waterworn fragments of freshwater mussel recovered from the upper section of the beach sand returned a ^{14}C age of 7,940–7,740 cal BP (Wk-52353), relating the peak freshwater phase to the MHCO. This sample was coupled with OSL sample WOL-10 (Ad20016) which produced two main components of 4.7–4.3 ka (36%) and 2.7–2.5 ka (30%). These components are younger than the ^{14}C age, though a minor (12%) component of 7.9–7.3 ka provides a close correlation. OSL sample WOL-11 (Ad20017) was located in the underlying saline mud (Unit Q) with results consistent with this unit (marsh facies) being deposited to at least c. 11.6–10.8 ka and possibly as early as 17.4–16.2 ka. A younger component 8.0–7.2 ka provides a close comparison to the minor component in the beach sand (Unit P), providing further confidence in this chronology.

The presence of freshwater mussel shell in this section, and as midden content in various open scatters at Rotten Lake, suggests that inflows were of sufficient magnitude to breach the lake sill and of a duration and frequency to support viable mussel habitat. This is consistent with evidence of a regional pluvial straddling the Pleistocene-Holocene boundary. Lake Tyrell, for instance, reactivated as an ephemeral lake between 11.5 and 7.4 ka (Luly 1993) coinciding with major rises in regional lake levels (Bowler 1981:436; Chappell 1991; Gouramanis et al. 2013; Williams et al. 1991). In summary, this gully profile depicts the transition from short period LGM flooding and rapid desiccation of the saline lakebed, through irregular inundation (marsh) and then a significant and regular filling of Rotten Lake leading into the MHCO. Again, the modern lake fills only during the most extreme flood events, providing an obvious contrast to the magnitude of the early Holocene freshwater phase.

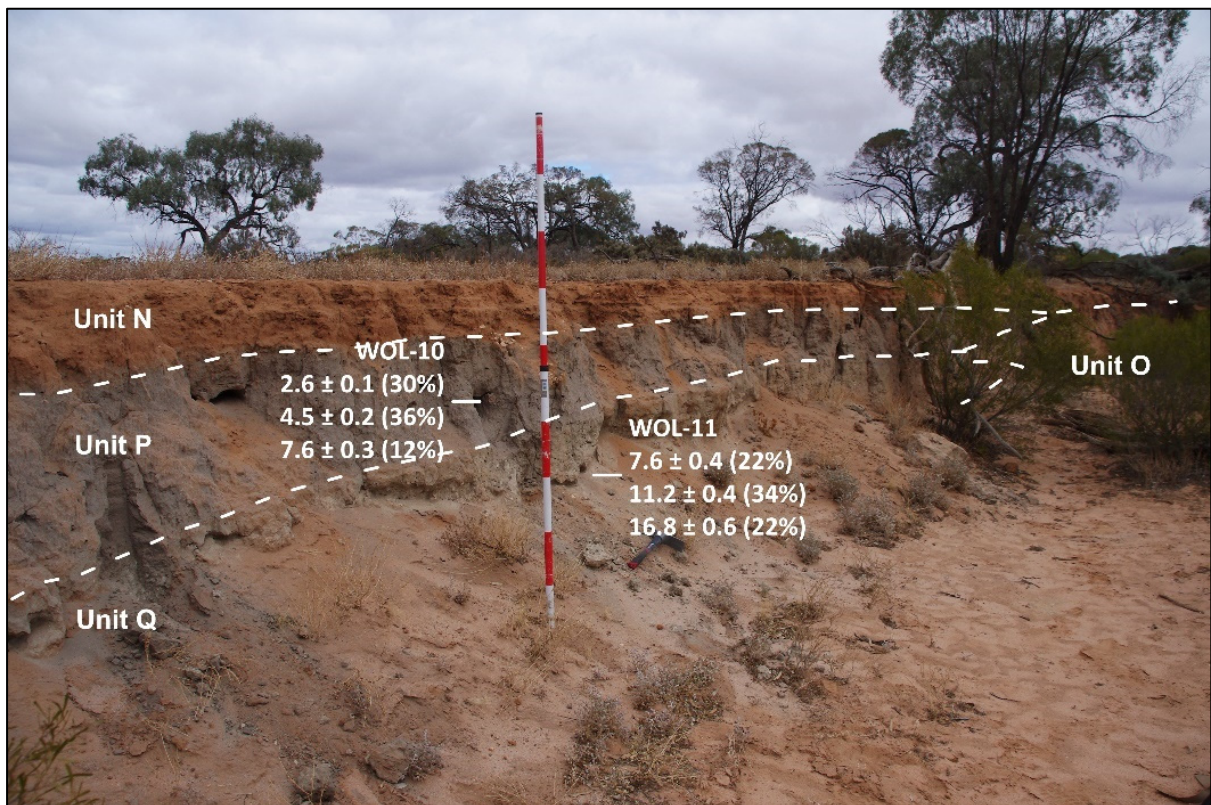


Figure 6-23: Stratigraphy exposed in gully erosion on the north-western margin of Rotten Lake.

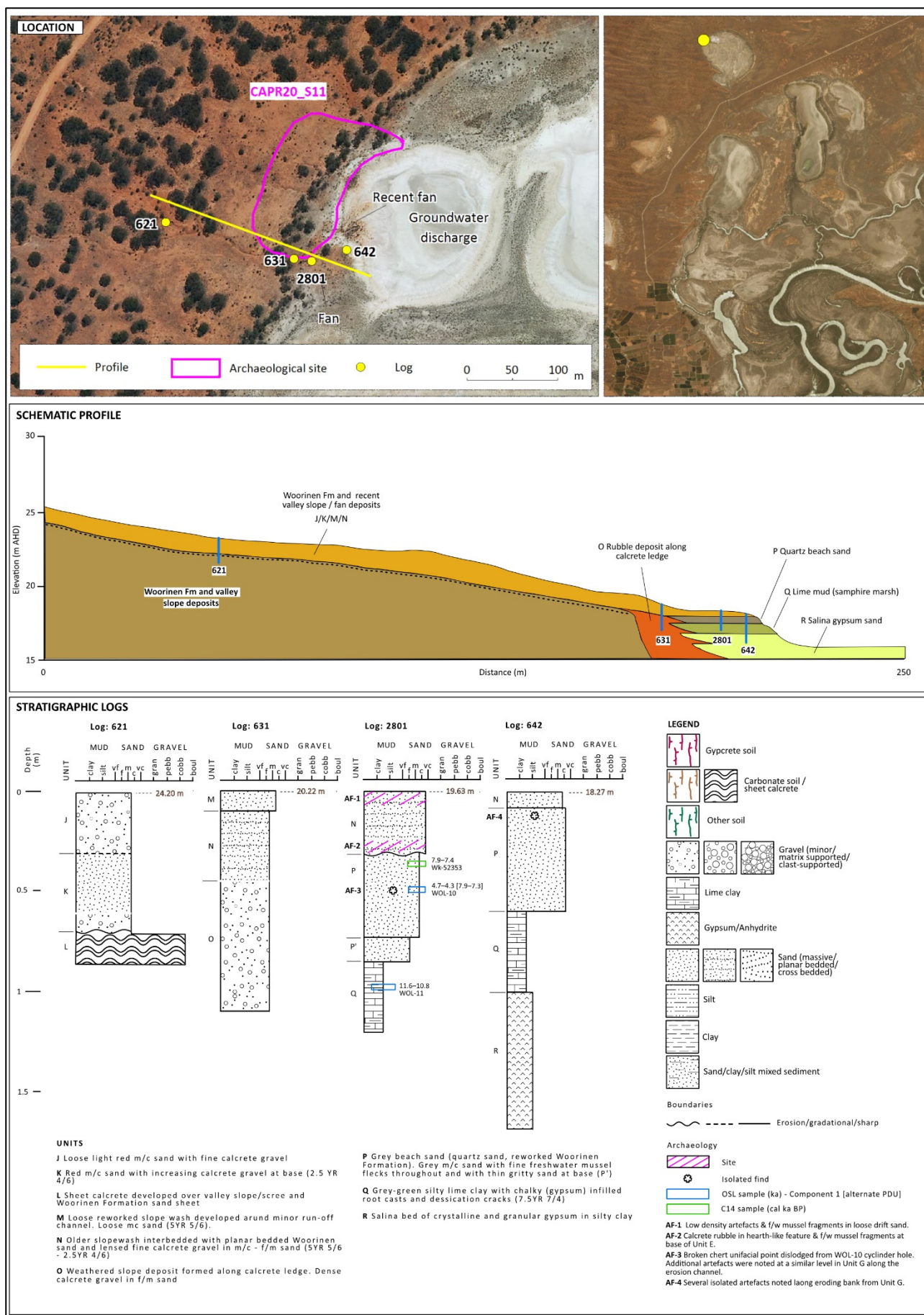


Figure 6-24: Sediment logs and schematic profile across the north-western margin of Rotten Lake.

In some respects, the developmental history of the outer lakes is the most informative in illustrating conditions along the river corridor. Acting as an overflow system, these lakes have remained hypersensitive to water connectivity in the floodplain. The switch to HSGD-facies lunettes some time prior to 27 ka marks a substantial shift in the nature of inflows, and specifically, a reduction in either the duration and/or frequency of flooding. This may have been complicated by the lowering of the floodplain as terrace T2b developed, though evidence suggests that the saline conditions registered in the outer lakes became more pervasive in the Riverland floodplains across the LGM (see further discussion below).

Advances in Wfm dunes either contributed to, or responded to, the closure of most of the outer lakes and offer some insights into conditions beyond the river valley. Indeed, the high mallee plains probably resembled a landscape more akin to a mobile sandy desert than the wooded dune-fields seen today, providing a stark biogeographical context to the riverine corridor. These conditions appear to have moderated c. 11 ka, and further improved to the MHCO, by which time freshwater mussel populations had re-established in Rotten Lake, albeit temporarily.

6.2.3.2 *The inner lunette lakes*

The inner lakes at Calperum are centred on a series of T2a meander scrolls. Coppermine Waterhole, located immediately east of the Calperum Station boundary, represents the best-preserved example of these scrolls (Figure 6-25), though a series of point bars retained in the interior of the Lake Merreti-Clover scroll also provide some indication of their original structure. Broad sand sheets developed as source bordering features around the eastern sides of these scrolls, creating an irregular topography that formal lunettes would subsequently develop across.

Exposure across the inner lake lunettes takes the form of shallow deflations and scalding that commonly extend to a hard palaeosol surface. This palaeosol is likely to be polycyclic. OSL samples WOL-01 (Ad19138) and WOL-02 (Ad19139) were placed in a low ledge exposing the palaeosol at the rear of the Lake Woolpoolool Phase I lunette (Figure 6-26). Major components in the two samples overlap at ages of ~38.7 ka and 26.7 ka, with a major younger component of 19.1 ± 0.6 ka also returned on the bedded sand sampled in WOL-01. These three components are interpreted as phases of early lunette development initiated by c. 39 ka overprinted by an initial palaeosol c. 24

ka and subsequent sedimentation overprinted by a younger soil c. 18–15 ka. As summarised in Chapter 3, regional lunette stages, such as the Nulla Nulla and Talgarry units at Lake Victoria, are partitioned by a major palaeosol developed c. 24 ka.

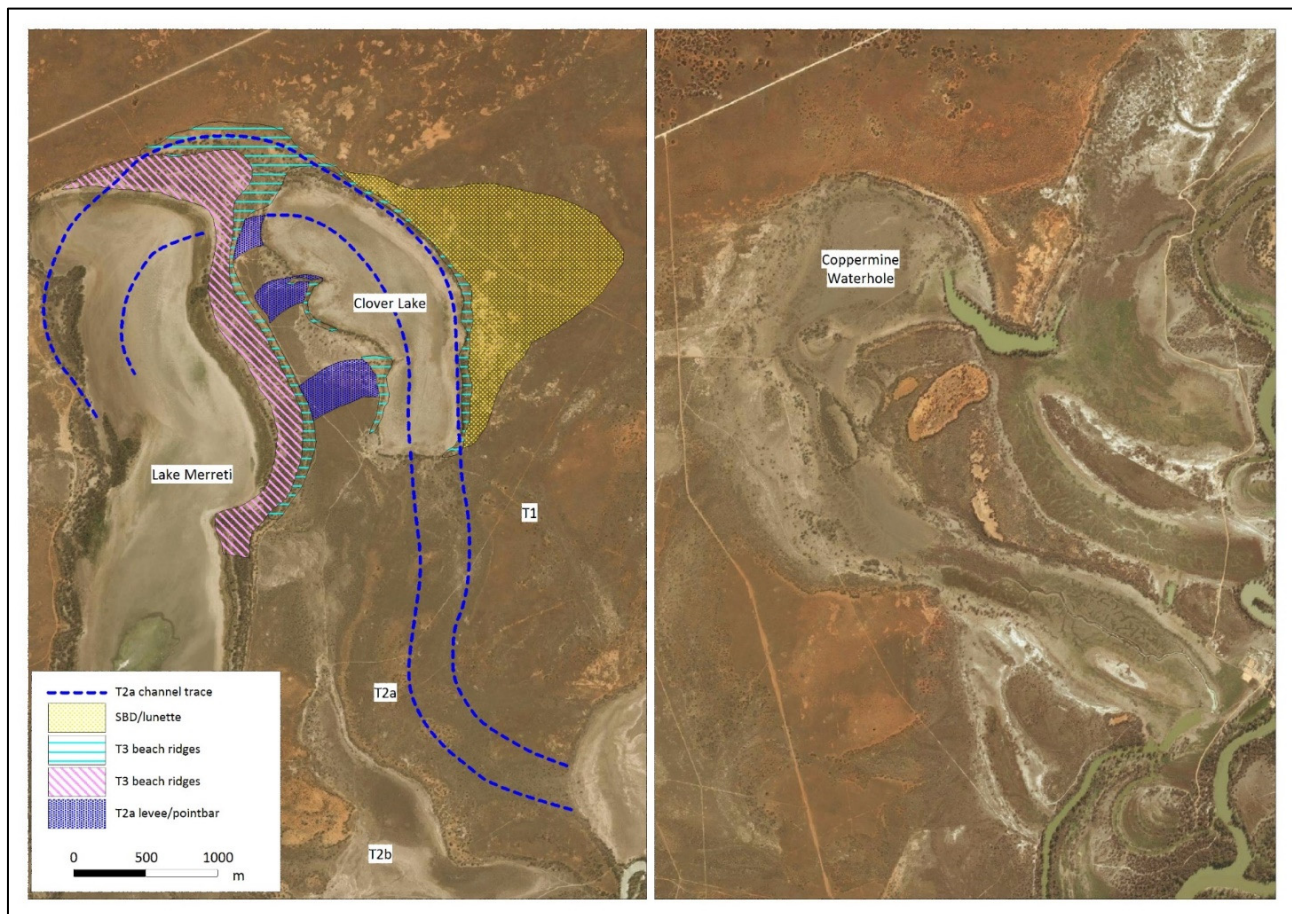


Figure 6-25: Lakes Merreti and Clover in respect to the original T2a meander scroll (left) and an equivalent T2a scroll centred on Coppermine Waterhole (Chowilla floodplain) with interior point bars and SBDs preserved (right).

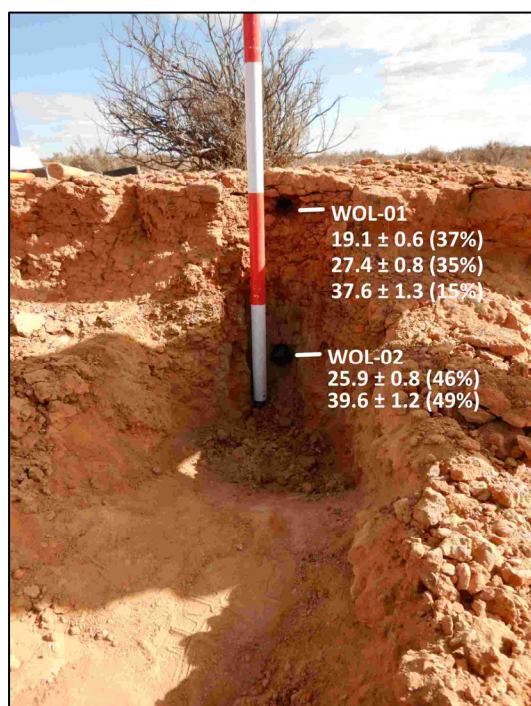


Figure 6-26: OSL samples WOL-01 and WOL-02.

The Phase I sediments (Units H, I, J and K in Figure 6-27) are characterised by fine to coarse quartz sand and clayey sand. Gypsum content in Units J and I may be suggested in a coupled Ca-S increase in the pXRF assay (Figure 6-28). The palaeosol appears to lie conformably over the Phase I lunette, arching across the crest of the lunette before sloping west to the lake. Overlying the palaeosol is a thin cover of unconsolidated, bedded sand (Units E, F and G) that attains a thickness of typically less than 1–1.5 m. A complex stratigraphy and the repeated development of lags in these units is suggestive of periodic deflation and remobilisation of the lunette surface across the LGM. The lags are commonly expressed as thin beds of fine carbonate granules and very coarse sand.

The palaeosol dips steeply, or is possibly truncated, along the eastern margin of Lake Woolpoolool where younger sediments pinch out along a shallow gully. These comprise Unit A—a loose cover sand reworked from highstand T3/T4 beaches, Unit B—a low, broad sandy beach-ridge extending south from a larger Phase III lunette, and Unit C—a basal greenish-grey clay containing minor crystalline gypsum and a blocky, vertosol texture. A ^{14}C age estimate of 17,028–16,664 cal BP (Wk-52903) was returned on sediment from Unit C at a depth 30 cm below the Unit B–C contact. Similar saline clay is exposed in a shallow borrow pit 800 m to the southwest of Lake Woolpoolool (Log 612 in Figure 6-29), on the western margin of Clover Lake, and as a low terrace in the Woolpoolool Swamp basin. The surface elevation of this unit in each location correspond to within 30 cm. The unit is interpreted as alluvium deposited across a salt-affected LGM floodplain.

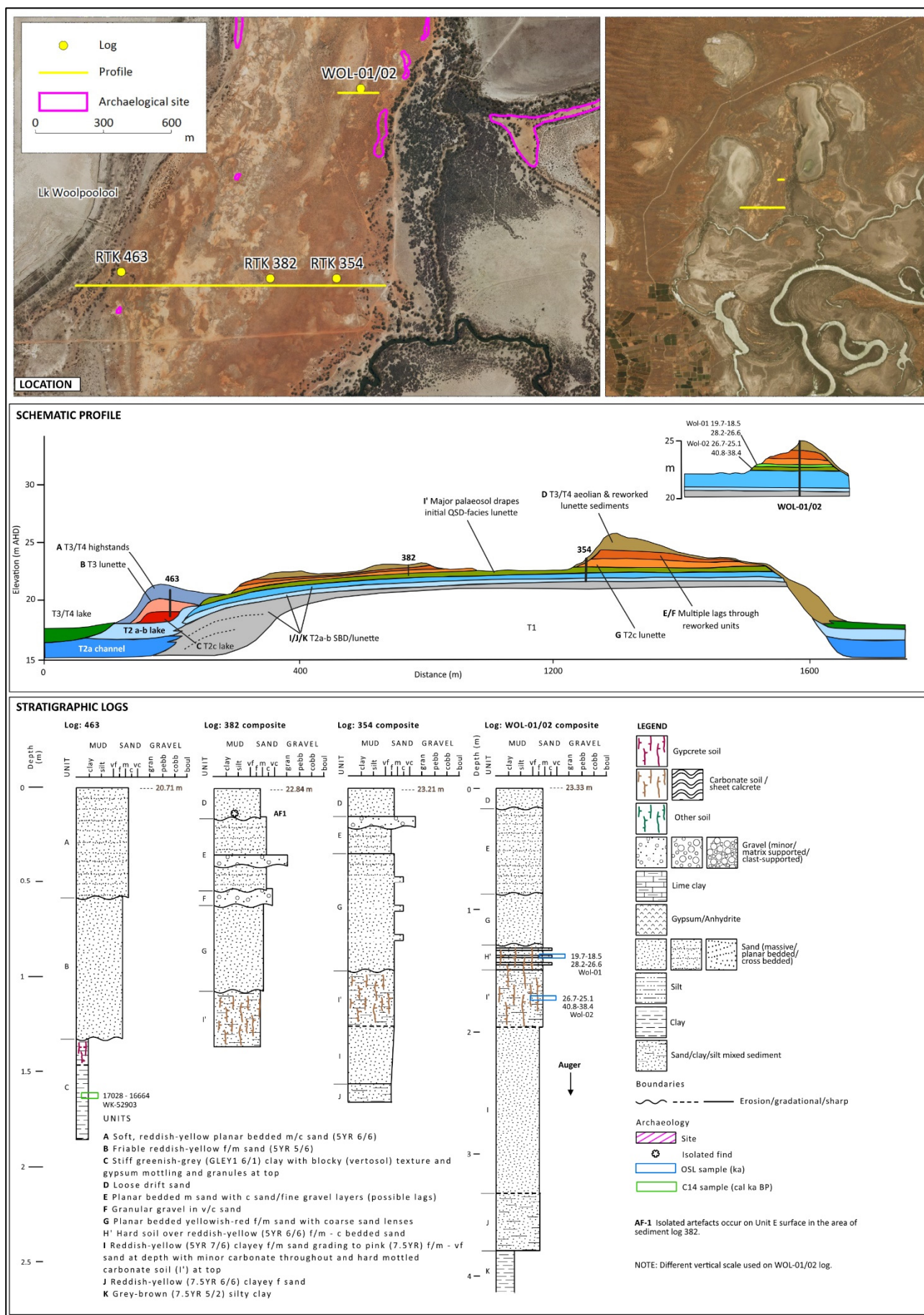


Figure 6-27: Schematic interpretation through the southern section of the Lake Woolpoolool lunette.

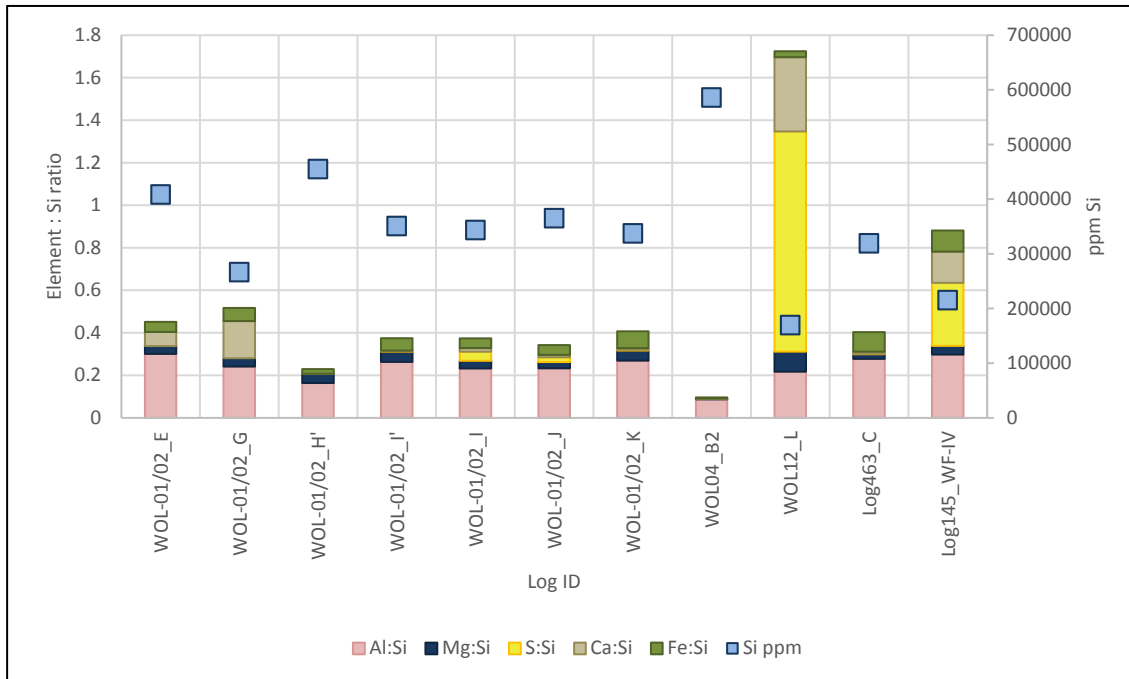


Figure 6-28: PXRF assays of sedimentary units from various locations around Lake Woolpoolool including OSL sampling locations WOL-01/02, WOL-04 and WOL-12.

In Log 463, Unit C is overlain by a broad, low ridge of fine-medium quartz sand (Unit B) forming the southerly extension to a more significant beach-ridge and Phase III lunette that wraps around the north-eastern margin of Lake Woolpoolool. The lunette is composed of a complex sequence of fine-medium to very coarse quartz sand, partitioned into three units (B1/B2/B3) by weakly developed soils (Figure 6-31). OSL samples WOL-03 (Ad19140) and WOL-04 (Ad19141) were located in an exposed section on the western side of a sand quarry cut into the base of the lunette (Figure 6-32). Here, a loose surface unit (AA) has deflated out of the quarry pit and sits on a planar bedded quartz sand (Unit A) that is confidently dated by WOL-03 to the early 1900s and is likely attributable to the broadscale destabilisation of land surfaces brought about by grazing and rabbits. A stockyard built in the late 1800's was located immediately north of the sampling location. The second component in WOL-03, albeit minor (14%), equates to an OSL age of 17.9–15.4 ka. Two units in the underlying lunette (Units B3 and B2) are exposed in the section with each comprising fine-medium sand with weakly developed soils in the upper parts. The lower unit (B2) is also noticeably stiffer. WOL-04 was placed at the B2–B3 contact with major components recorded at 4.2–3.9 ka (33%), 7.8–7.2 ka (31%) and 14.5–15.5 ka (25%).

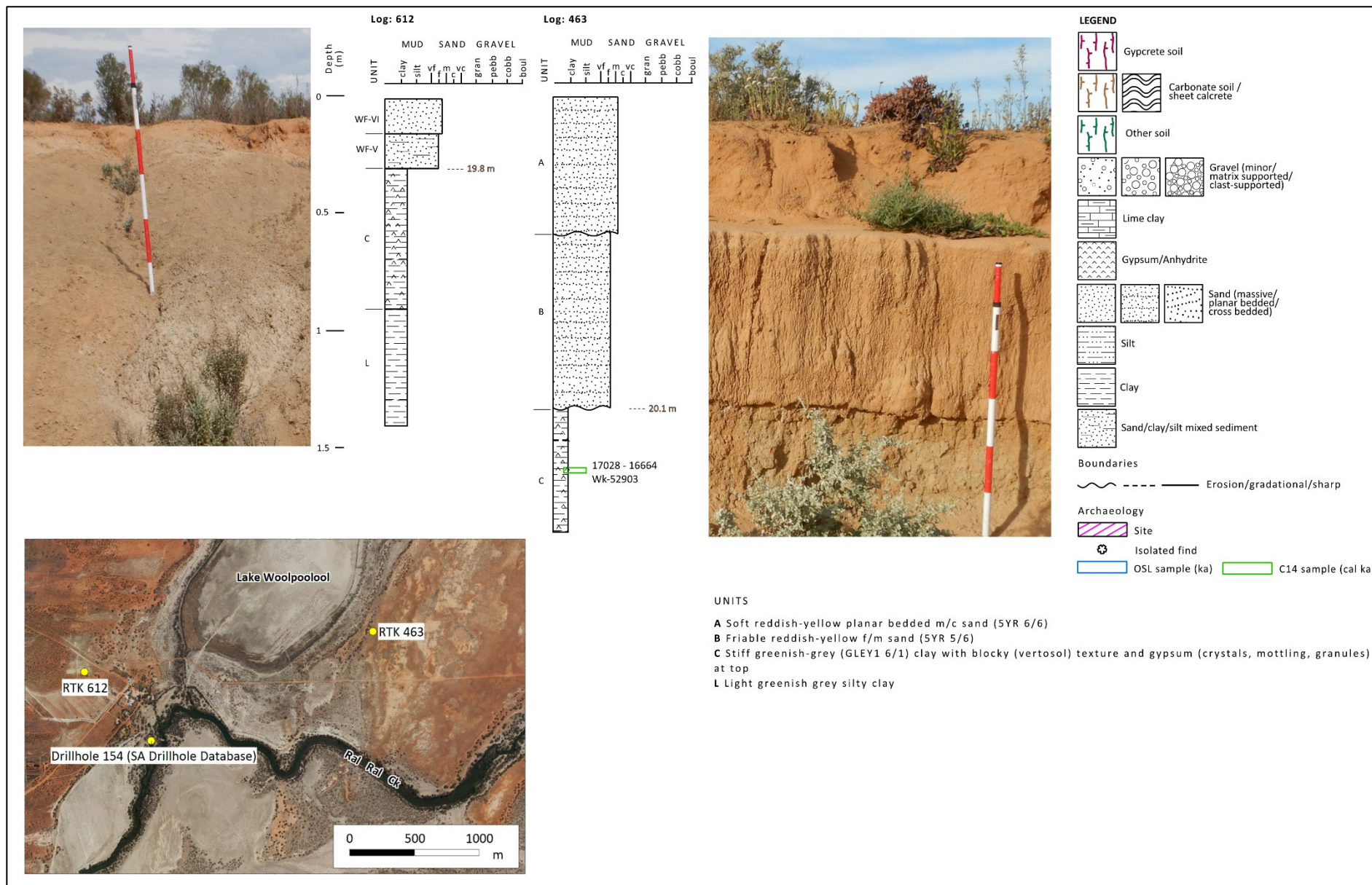


Figure 6-29: Saline (gypsiferous) clay exposed in a borrow pit west of Lake Woolpoolool (left) and shallow gully erosion on the south-eastern margin of the lake (right).

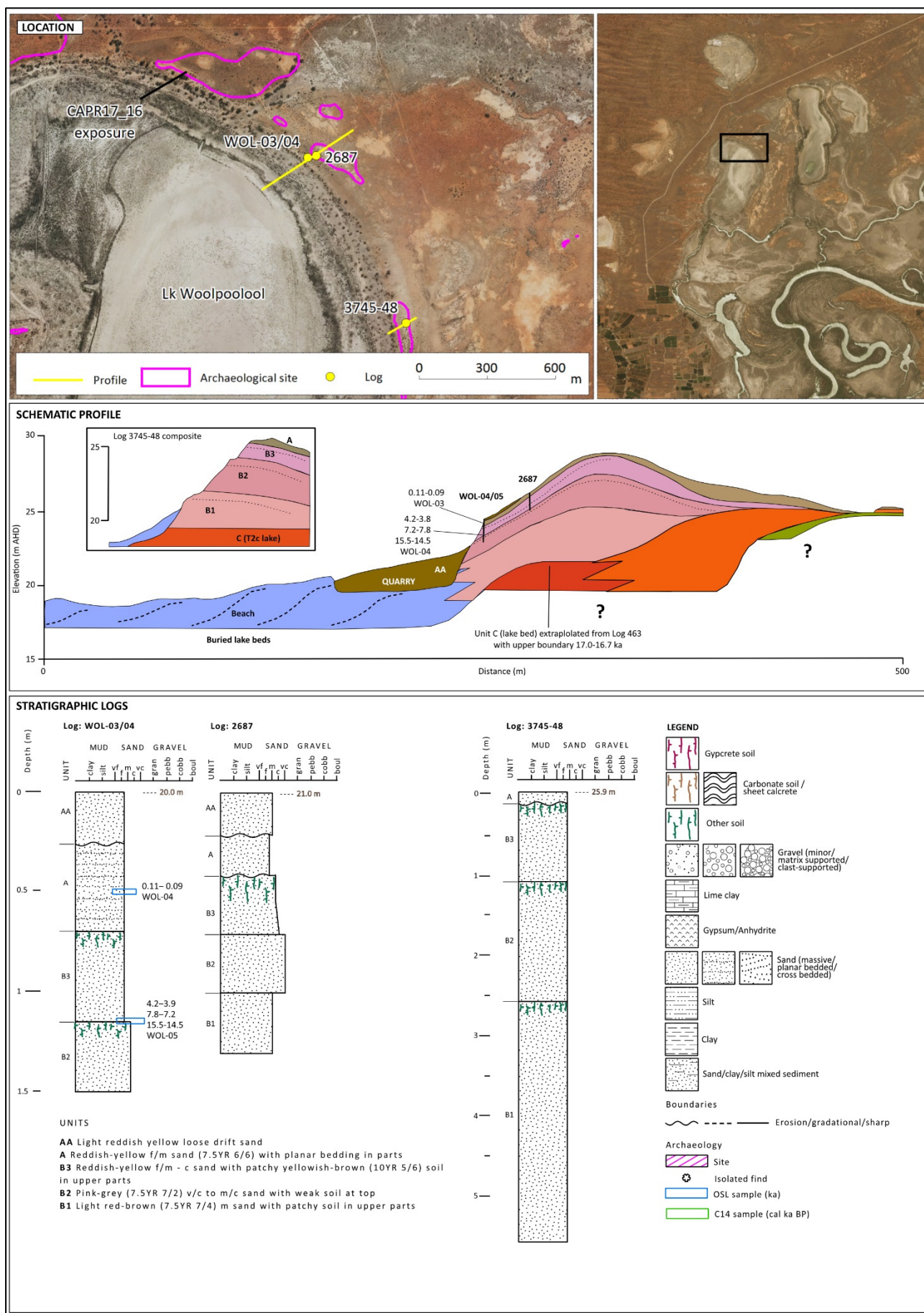


Figure 6-30: Schematic interpretation through the north-eastern lunette (Phase III) at Lake Woolpoolool.



Figure 6-31: Exposure across the Phase III lunette at Lake Woolpoolool in the area of archaeological site CAPR17_16 showing the weakly developed soils partitioning the lunette sediments.

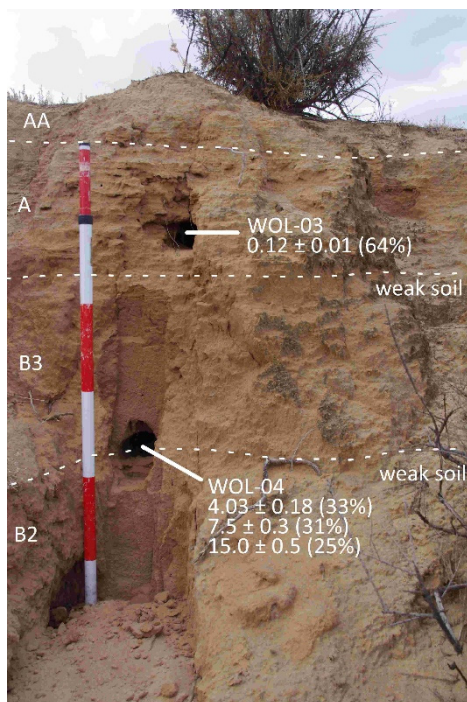


Figure 6-32: The exposed section at OSL samples WOL-03 and WOL-04 (the range pole increments are 20 cm).

The scale of this Phase III lunette and the clean, medium to coarse quartz sand, is indicative of the rapid deposition of sediments derived from wave-agitated shorelines. The weak soils and differences in sediment compaction suggest that the lunette had accreted in a staggered fashion over three depositional phases, possibly expressed in the OSL components in WOL-04. On this basis, the initial Phase III lunette is likely to have developed sometime prior to c. 15 ka, linking this to a humid phase identified in regional palaeoclimate proxies c. 18–15 ka (Fitzsimmons 2017;

Lomax et al. 2011). A long hiatus or erosional period between this initial phase and the deposition of unit B3 is suggested in the distinct compaction differences between B2–B3 and the major OSL component ages, i.e. c. 15 and 7.5 ka. It is notable that these two components are coeval with periods of ameliorated climate (18–15 ka) and the early Holocene pluvial that manifest in the reinundation of Rotten Lake, respectively.

At some stage, regular lake filling truncated the distal edges of WFm dunes along the western shoreline of Lake Woolpoolool, reworking a stiff carbonate soil into a gravel beach-ridge along the rim of the adjoining terrace. Midden shell dated to 9.3 ka on top of the gravel ridge provides a minimum age for this highstand. This beach-ridge, together with a series of additional ridges at Lakes Woolpoolool and Merreti, are shown in Figure 6-33. The extent of the 1956 megaflood is provided for comparison and approximates a distinct etch line evident in Figure 6-33. The 1956 event did not, however, develop a corresponding ridge and it can be assumed that these features relate to static or repeat levels of consistent inundation rather than short-lived events. A series of cusate forelands preserved in the inner lakes correspond closely to the height of flooding associated with return periods of two to three years (50–80 GL/day) under the modern (unregulated) regime.

The northern margins of the inner lakes also interact with aeolian sheets that merge with long tail slopes extending leeward of the outer lake lunettes. A schematic interpretation of these sediments at Lake Woolpoolool is shown in Figure 6-34 based on logs recorded in a shallow auger (Log 145) and exposures along a high ledge bounding the northern shoreline of the lake. Unit L comprises a fine, granular gypsum sand and forms a distinctive ridge packed against the ledge (Figure 6-35). The gypsum content in this beach-ridge and at the top of WFm-IV sediments, is evident in the pXRF assays shown in Figure 6-28. A series of ^{14}C ages returned on freshwater mussel shell contained within and under WFm-V sediments span the period 9.1–5.6 ka. These ages should provide a minimum age for unit L, though are contradicted by OSL sample WOL-12 (Ad20018) which was placed within unit L and included two distinct components at 8.6–7.8 ka (29%) and 179–163 ka (49%). The older component is difficult to place and raises some concern around the accuracy of the OSL result. Indeed, the presence of gypsum in the inner lakes c. 8.6–7.8 ka is difficult to reconcile given that Rotten Lake appears to have shifted from a salina to marsh environment c. 11.2 ka and had been repopulated by freshwater mussel c. 7.8 ka.

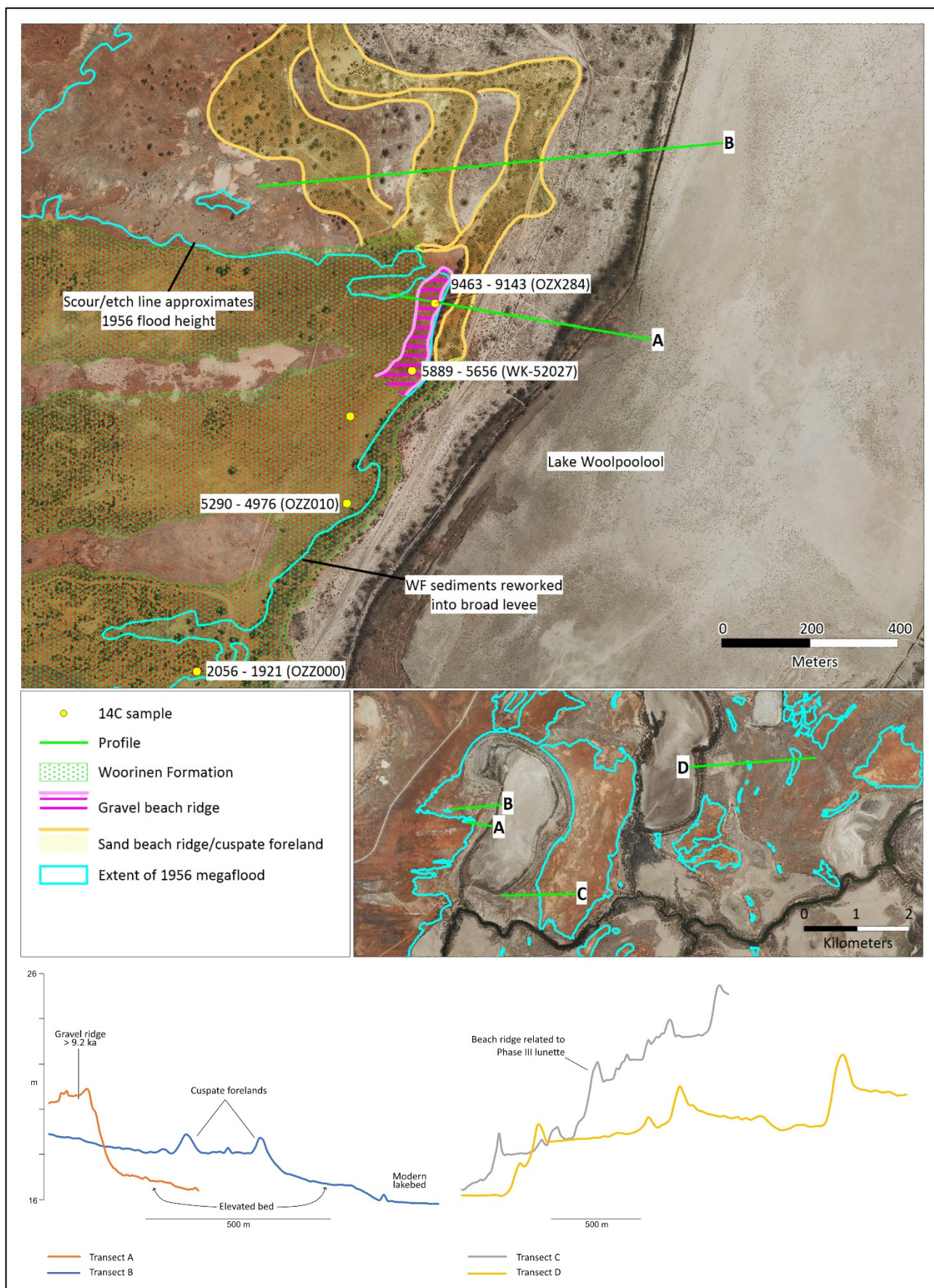


Figure 6-33: Beach-ridges preserved around the inner lakes.

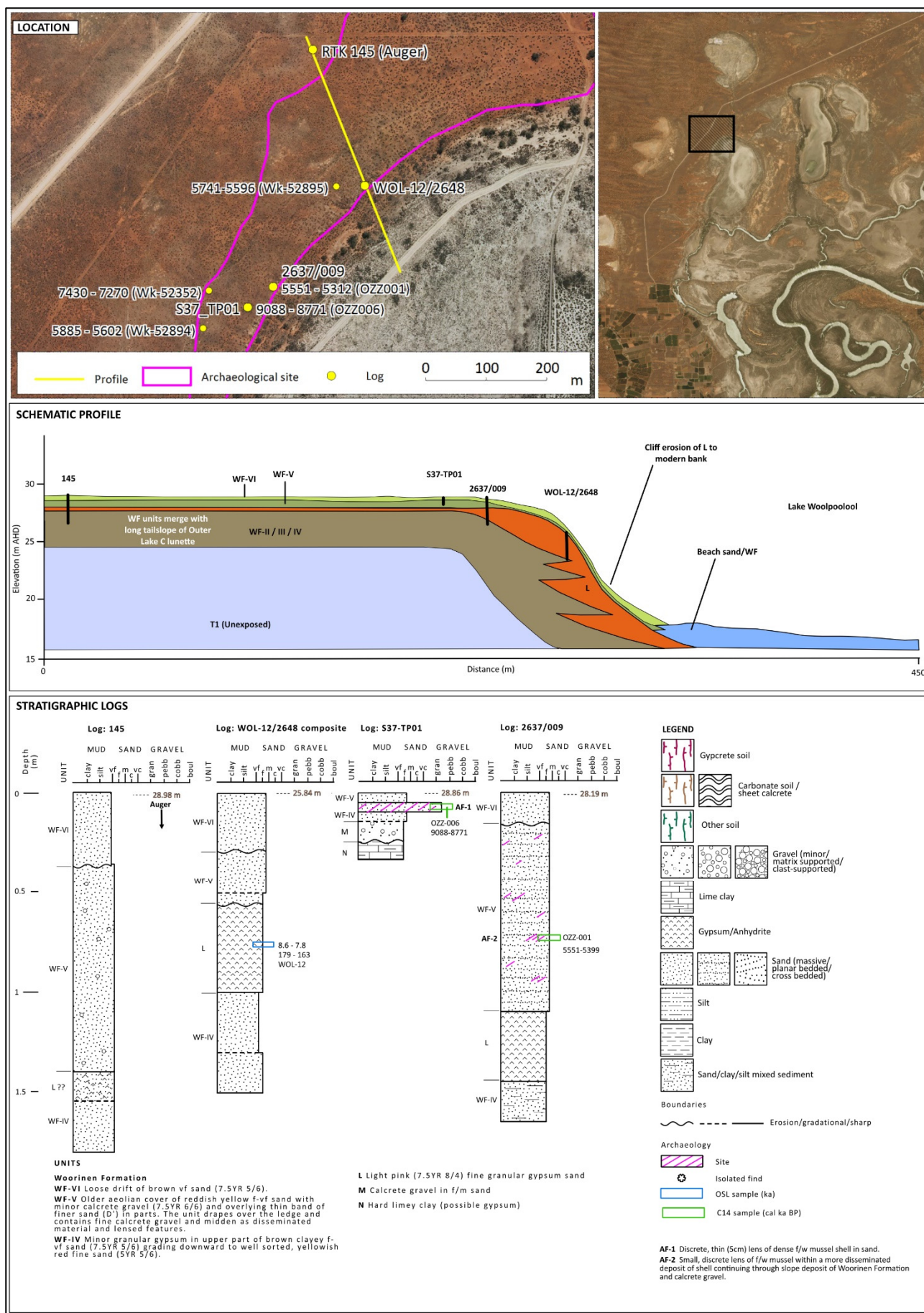
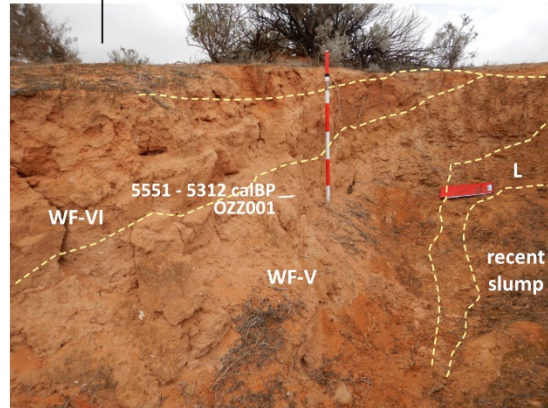
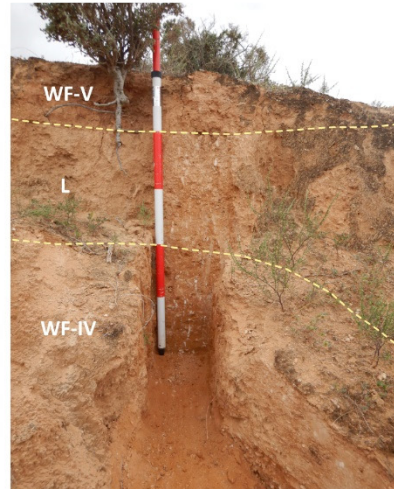


Figure 6-34: Schematic profile across north-western margin of Lake Woolpoolool.

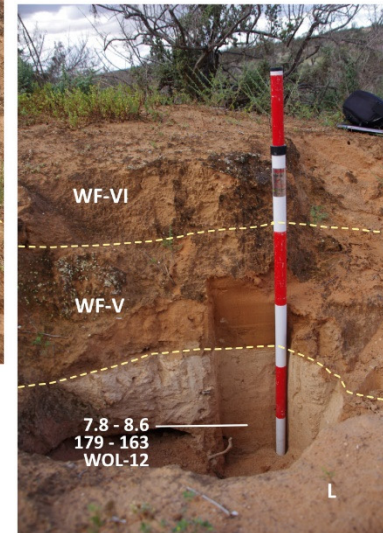
5885-5602 (Wk-52894)
7430-7270 (Wk-52352)
9088-8771 (OZZ006)
recorded within & under
WF-V above ledge



Log 2637



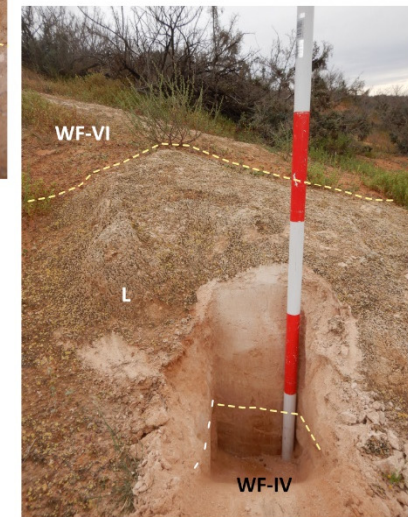
Log 009



Log WOL-12



View looking east from near Log WOL-12



Log 2648

Figure 6-35: The gypsum ridge exposed along the northern margin of Lake Woolpoolool including the WOL-12 sampling location.

Figure 6-36 provides some context to this gypsum unit by summarising the ^{14}C ages returned on archaeological materials at Calperum²⁹ against various palaeoenvironmental data that include aeolian activation cycles and dry-wet phases identified in various regional proxies (summarised from Chapter 3). As seen, the component age of 8.6–7.8 ka returned on Unit L corresponds with an aeolian phase identified by Fitzsimmons et al. (2013) in the Willandra region and sits between wet phases identified at Lake Jacka by Kemp et al. (2012). Given this, a brief, intense salinisation phase may be plausible. Alternatively, wetter conditions during the early Holocene may have liberated immense quantities of gypsum out of Rotten Lake or from saline aquifers, redepositing this salt initially into the inner lakes at Calperum (principally Lake Woolpoolool) before it could be fully mitigated by subsequent flooding. Personal observations of an equivalent gypsum ridge at Lake Limbra (Chowilla floodplain) indicates that this period of salinisation was not unique to Calperum. The weight of evidence suggests some error in the OSL age result for WOL-12. The re-bleaching of the sediment after its original deposition is not indicated in the distinct bimodal character of the sample. The stratigraphic relationship between unit L and ^{14}C ages returned in and under WFm sediments suggests an age closer to c. 12 ka for the gypsum unit. As discussed in Chapter 6.2.7, this would be consistent with ^{14}C dating of a discrete gypsum clay intercepted in an auger excavation adjacent to Huncree Creek.

Additional insights into floodplain conditions are interpreted from the ^{14}C ages. It has been noted, for instance, that freshwater mussel shell has a propensity to decay when exposed, and a rapid burial of this material is a general requirement for its preservation in archaeological contexts. ^{14}C ages returned on in situ lenses of intact shell valves are, by implication, likely to reflect the real-time development of a covering sediment rather than incorporating any significant lag or periods of re-exposure following the original deposition of the midden. The freshwater mussel ages recovered from aeolian sediments at Calperum include a number of ages returned on shell lenses formed at the base of, or interface between aeolian units c. 8.7 ka, 5.6 ka, 5.4 ka, 3.5 ka, 0.8 ka and 0.5 ka. From this, it can be concluded that these land surfaces had been reformed through aeolian activity at various stages staggered throughout the Holocene.

²⁹ ^{14}C sampling at Calperum relates principally to freshwater mussel shell. Five charcoal samples are also represented.

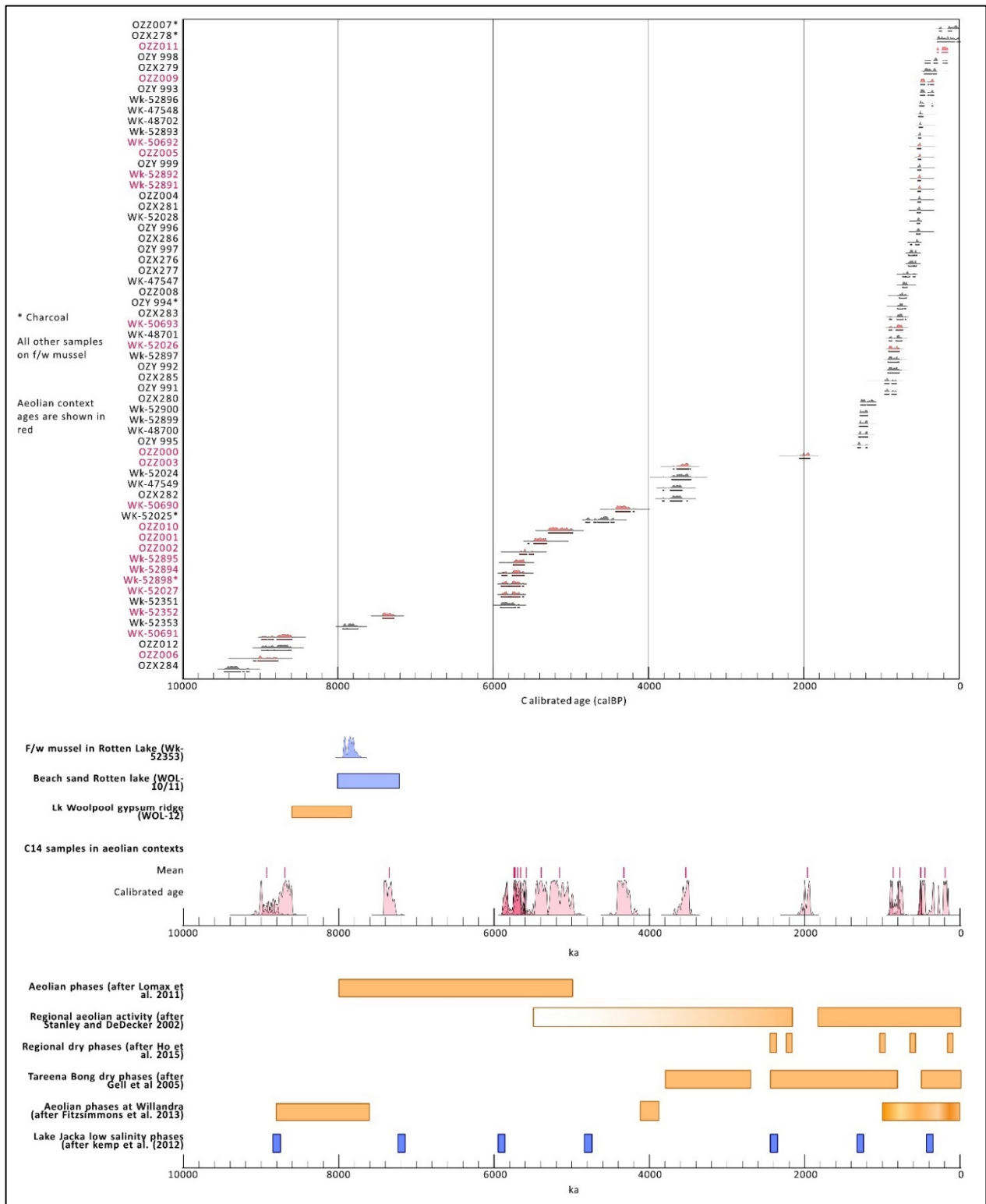


Figure 6-36: Calibrated ages on freshwater mussel shell midden and charcoal at Calperum in relation to various palaeoenvironmental data.

The ^{14}C ages derived from freshwater mussel also provide an impression of baseline conditions in the floodplain, as both species of mussel have salinity limits. These ages span the Holocene though are unevenly distributed with periods unrepresented or with noticeably lower frequencies between 8.4–5.9 ka and 3.6–1.4 ka. The age results represent a relatively intensive sampling exercise, and regardless of the number of people exploiting the resource, an argument can be made that shell should be represented in the ^{14}C distribution if it was available. Periods of lower ^{14}C frequency broadly coincide with a phase of regional dune activity between 8–5 ka (Lomax et al. 2011) and increased salinity in the River Murray wetlands (Gell et al. 2005:450) and regional lakes (Deckker 1982; Jones et al. 1998:68) from ~3.5 ka. It is notable, however, that evidence of aridity over the last millennia does not coincide with gaps in midden development. The evidence of ameliorated freshwater conditions in Rotten Lake c. 7.9–7.7 ka also falls within a period of low ^{14}C frequency.

A schematic interpretation of the development of the inner lakes at Calperum is presented in Figure 6-37. In summary, the dating evidence indicates that the inner lakes developed c. 39 ka, following the abandonment of T2a scrolls and their conversion to lagoonal habitats. Freshwater conditions appear to have persisted in these lakes over much of their development, though phases of salinisation are registered as minor gypsum content in the Lake Woolpoolool lunette, saline alluvium dated to c. 18 ka, a gypsum beach-ridge that is likely to have developed at Lake Woolpoolool c. 12 ka and patchy exposures of crystalline gypsum in the high ledge bounding the northern edge of Lake Merreti. Linn (1995) reported Aboriginal burials ‘encased’ in gypsum at the top of Lake Merreti.

Another feature in the evolution of the inner lakes becomes apparent when considering the age and elevations of c. 13.9 ka sediments recovered from augering in Clover Lake and an alluvial clay (Unit C) preserved beyond the modern lake margins and dated to 17,028–16,664 ka (Wk-52903) at Lake Woolpoolool. An elevation difference of approximately 4.5 m exists between these units, illustrating a significant readjustment in the floodplain and incision of the inner lakes sometime after 16.8 ka but prior to 13.9 ka. Based on FIM modelling of the modern floodplains (see Chapter 3-2), an incision of this magnitude is certain to have excluded large areas of the floodplain from inundation.

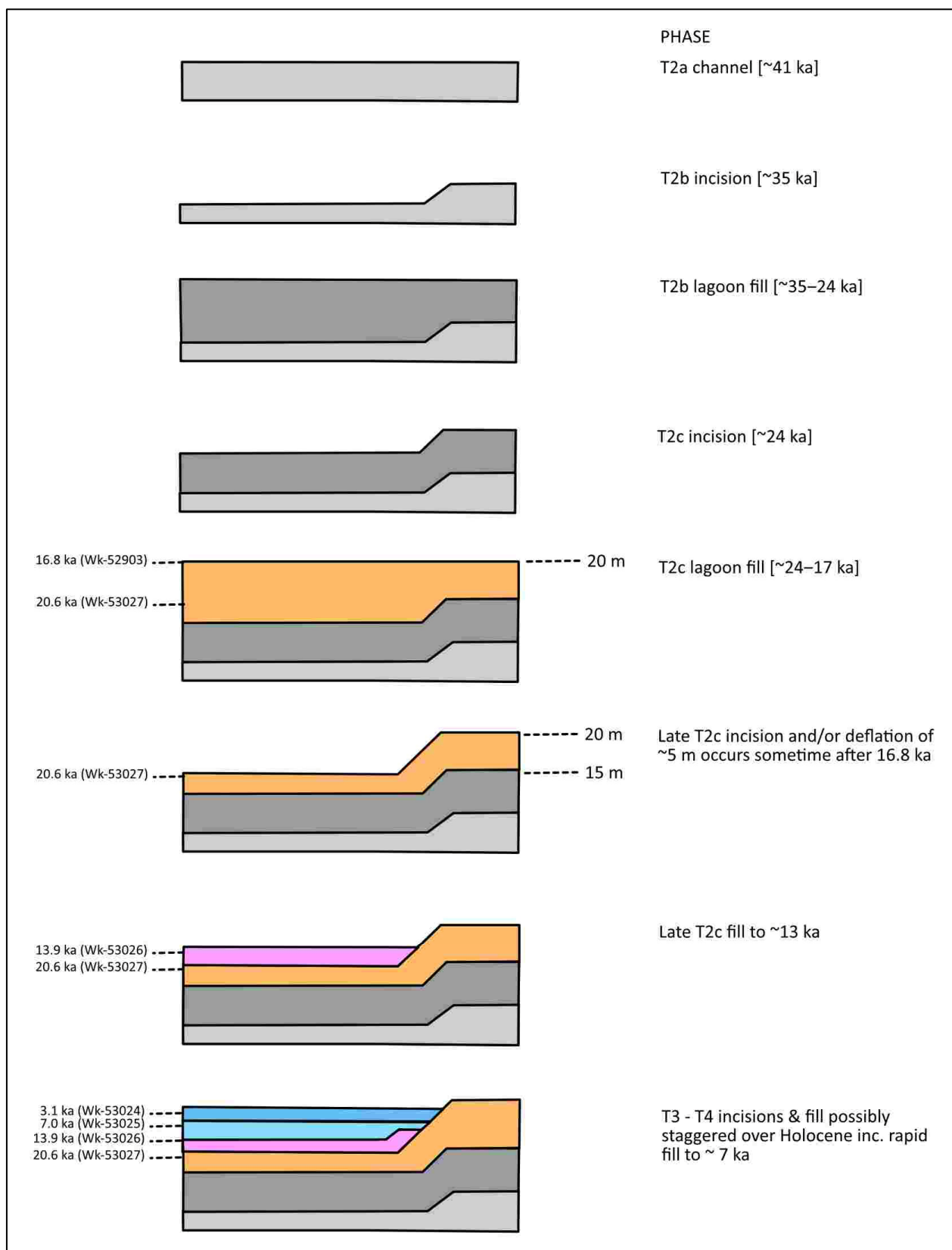


Figure 6-37: Schematic interpretation of the inner lake stages based on the dating results and unit elevations.

A series of cusped forelands in the inner belt of lakes provide evidence of sustained periods of inundation throughout the Holocene. These features develop through the long-shore drift of sediments under the influence of prevailing wind and wave action during lake-full conditions. Examples are seen around the western shorelines of most of the inner lunette lakes, illustrating a prevailing south-westerly wind direction characteristic of the modern setting. The forelands occur at two elevations below the gravel beach-ridge at Lake Woolpoolool, indicating a gradual incision of the floodplain through the development of T3–T4. The contraction of the inner lakes is also represented by a series of low, regressive sandy shorelines and strandplains.

6.2.4 The sequence of bedload channels

Terrace T2 occupies the greater part of the Calperum floodplain and includes a sequence of three sub-terraces (T2a, T2b, T2c). All sub-terraces developed around laterally migrating scrolled (Order B3b) and backswamp floodplains (Order B3c). The sub-terraces incorporate a total elevation difference of less than 1.5 m and are differentiated more so on the basis of meander form (see Figure 6-8) and soil development. Single thread channel traces up to 250–350 m wide are identifiable across all sub-terraces and accommodate the most substantial oxbows currently active in the Riverland floodplains, including Ral Ral Wide Water at Calperum. Broad crevasse splays, levees and SBDs are conspicuous elements of the T2 sub-terraces (Figure 6-38). The T2 scrolls are contained within an extensive flat to subtly undulating terrain that is elevated 1–3 m above T4. SBDs rise a further 6–8 m above the general level of the terrace. Sediments are predominantly grey clay vertosols on the vertically accreting floodplain with sandier material occurring in levees, crevasses and source bordering features. Calcrete is absent though a well-developed palaeosol is present in SBDs associated with T2a and T2b (Figure 6-39) and a less developed soil is observed in T2c SBDs where these have been truncated.

A transect across a T2b cut-bank and the adjacent floodplain north of Hunchee Creek is tied to OSL sample WOL-09 (Ad20015) and a series of ^{14}C ages in the schematic interpretation presented in Figure 6-40. WOL-09 (Figure 6-41) was recovered from a fine-medium to coarse sand containing fine shell flecks that are assumed to be freshwater mussel. This unit (Unit E) is interpreted as T2a fluvial sand. Two dominant components of essentially equal weight translate as OSL ages 46.3–42.3 (45%) and 97.4–89.0 (48%) ka in a 4-component model. The younger age correlates well with

the upper units in the Lake Woolpoolool Phase I lunette, being between 1,500–7,900 years older based on the error ranges. This age difference incorporates the cut-off of the original T2a scroll and expansion of the channel to a lagoon habitat fringed by the broad SBD and later lunette terrain. The other major component is assumed to relate to older alluvial/fluvial material recycled into the T2a channel and levee. These results relate T2a to a hydrological phase recognised in the MDB between c. 55–35 ka and associated with large dimension palaeochannels on the Riverine Plain, e.g. the Gulgo and Kerabury channels, and deposition of the Lower Mungo Member and Nulla Nulla Sand in the Willandra and Lake Victoria systems, respectively (Figure 3-6). In Log 2512, yellowish-red to brown clayey fine sand (Units C and D) is interpreted as the younger T2b levee draped over the cut-bank. These units are overprinted by a patchy, mottled soil and are overlain by undifferentiated very-fine sand (Unit B) and a loose cover sand (Unit A) representing material sourced out of the subsequent T2c and later floodplains or reworked from the older levee.



Figure 6-38: A high SBD developed through reworking of point bar sands in T2c.



Figure 6-39: A deep palaeosol exposed across the crest of an eroded T2b SBD.

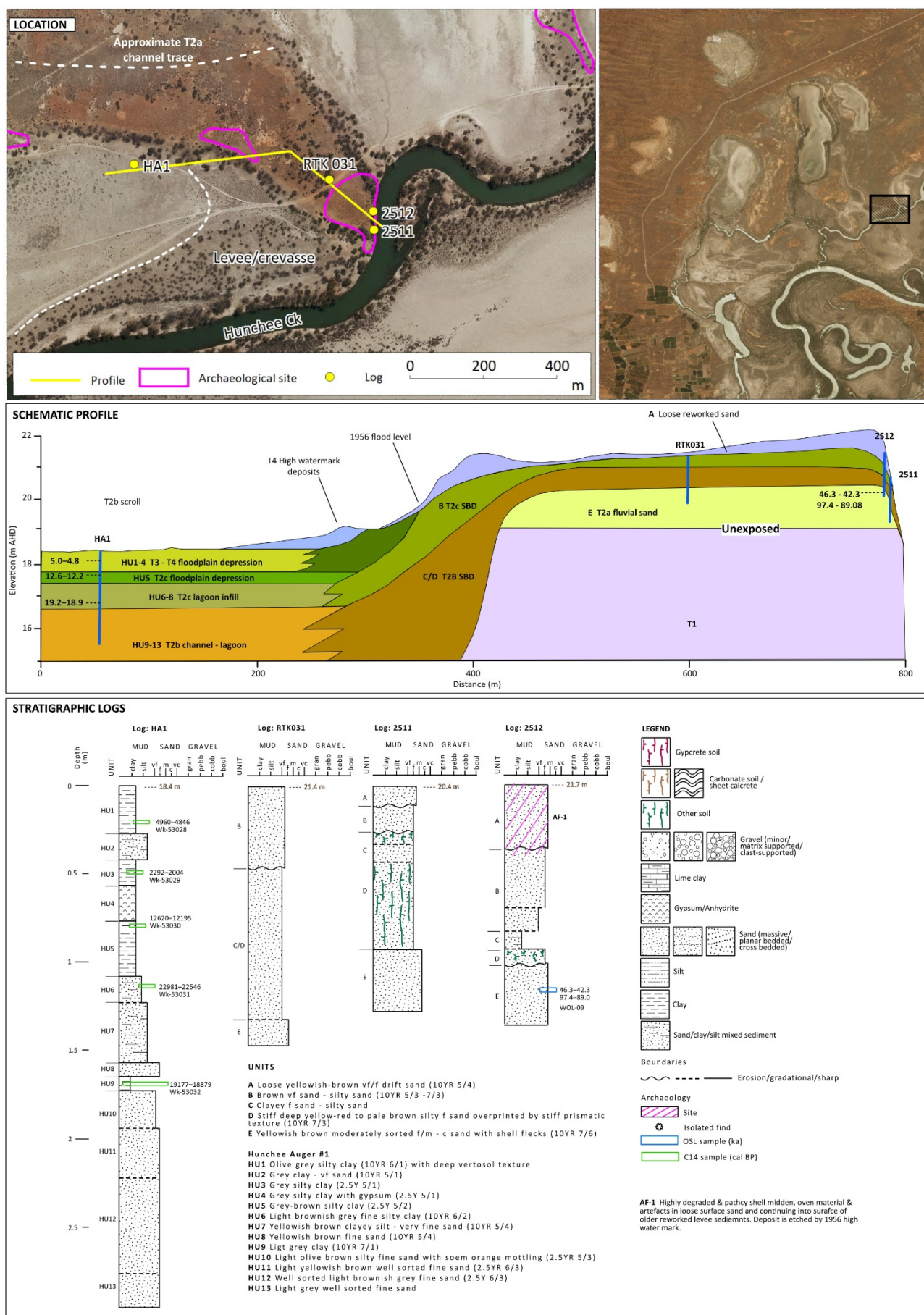


Figure 6-40: Schematic interpretation through a T2b cut-bank exposed along Hunchee Creek.

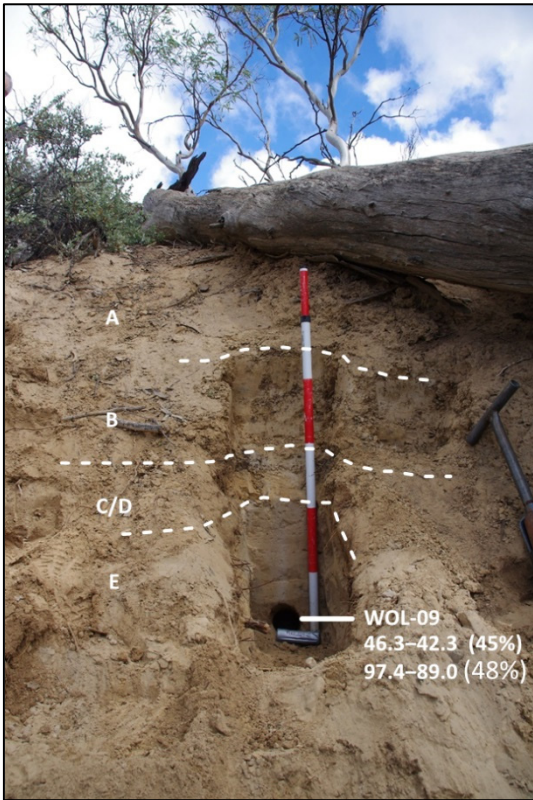


Figure 6-41: OSL sample location WOL-09.

Auger HA1 was located in a floodplain depression on the outer edge of the T2b channel trace. Five ^{14}C ages were staggered along the upper 1.5 m of the column and included two inverted ages. The upper inversion is unsurprising given the deep vertosol surface, and given its context, Wk-53029 is interpreted as a younger intrusion. The deepest age (19.2–18.9 ka, Wk-53032) was recovered from a neatly defined clay (Unit HU9), relating the middle section of the column to the LGM and T2c floodplain/lagoon, and the lower section to the original T2b channel.

The timing of T2b remains poorly constrained based on the dating evidence presented here, though it obviously postdates the deposition of T2a sediments c. 43 ka. SBDs associated with the T2b scrolls are also overprinted by a deep, red soil that is consistent with the 24 ka feature draping the Phase I lunettes (Figure 6-42). The SBDs were clearly in place prior to this soil. A more definitive assessment of the timing of T2b will require additional dating, though a tentative appraisal relates T2b to a hydrological phase identified in the MDB between 35–24 ka. That phase was associated with the middle sequence of bedload channels on the Riverine Plain (Ulgutherie, Tombullen, Tallygaroopna, Gum Creek, Kotupna channels) and the deposition of the Arumpo/Unit C and Lower Bootingee units in the Willandra and Menindee lake systems, respectively (see Figure 3-5). A major adjustment in the Calperum floodplain is evidenced in the contraction of the outer lakes sometime prior to 27 ka and is likely, therefore, to be related to the incision of T2b.



Figure 6-42: Two palaeosols preserved in T2b SBD topography within archaeological site CAPR18_S29; a younger thin carbonate soil (left) and older, deeper deep red soil overprinting the original T2b feature.

Sub-terrace T2c formed around the last phase of bedload channels. Two T2c scrolls occupy the far southwestern section of the Calperum floodplain while a third scroll lies to the east of the River Murray (see Figure 6-4). OSL sample WOL-08 (Ad19146) was collected from a shallow excavation in an SBD associated with the penultimate channel in the younger scroll at Calperum (Figure 6-43). In this instance, the dominant component (25%) is assumed to represent the PDU, providing an age range of 16.5–15.5 ka for the original SBD (Unit G)³⁰. Lesser components are interpreted as inputs from an overburden (Unit F) that has been remobilised during flooding and deflation. The characteristic deep-red palaeosol seen in T2a and T2b is absent in T2c, though a palaeosol is exposed where SBDs have been truncated (a regional soil developed c. 18–16 ka). Given that a younger T2c scroll is preserved to the east, the combined dating, soil and geomorphological evidence, relates this sub-terrace to the period encapsulating the LGM from c. 24 to sometime after 16 ka. The Yanco and Acres channel complexes of the Riverine Plain and Darling River, provide regional correlates (Bowler et al. 1978; Page and Nanson 1996; Page et al. 1996). As with T2c, these systems are characterised by large diameter, high peak flow, bedload channels. The extensive complexes of associated SBDs suggest a pronounced seasonality to flows. Prendergast et al. (2009:69) obtained an OSL age of 17.2 ka on a source bordering dune within the T2 equivalent in the Lindsay Island region. The initial development of T2c also tallies with the contraction of the 32 ka shoreline of Lake Kanyapella in the period ~ 25–19 ka (Stone 2006).

³⁰ Fine flecks of shell, presumed to be freshwater mussel, were also submitted for dating from an exposure of Unit G south of WOL-08 (see Figure 6-46) though did not survive pre-treatment.

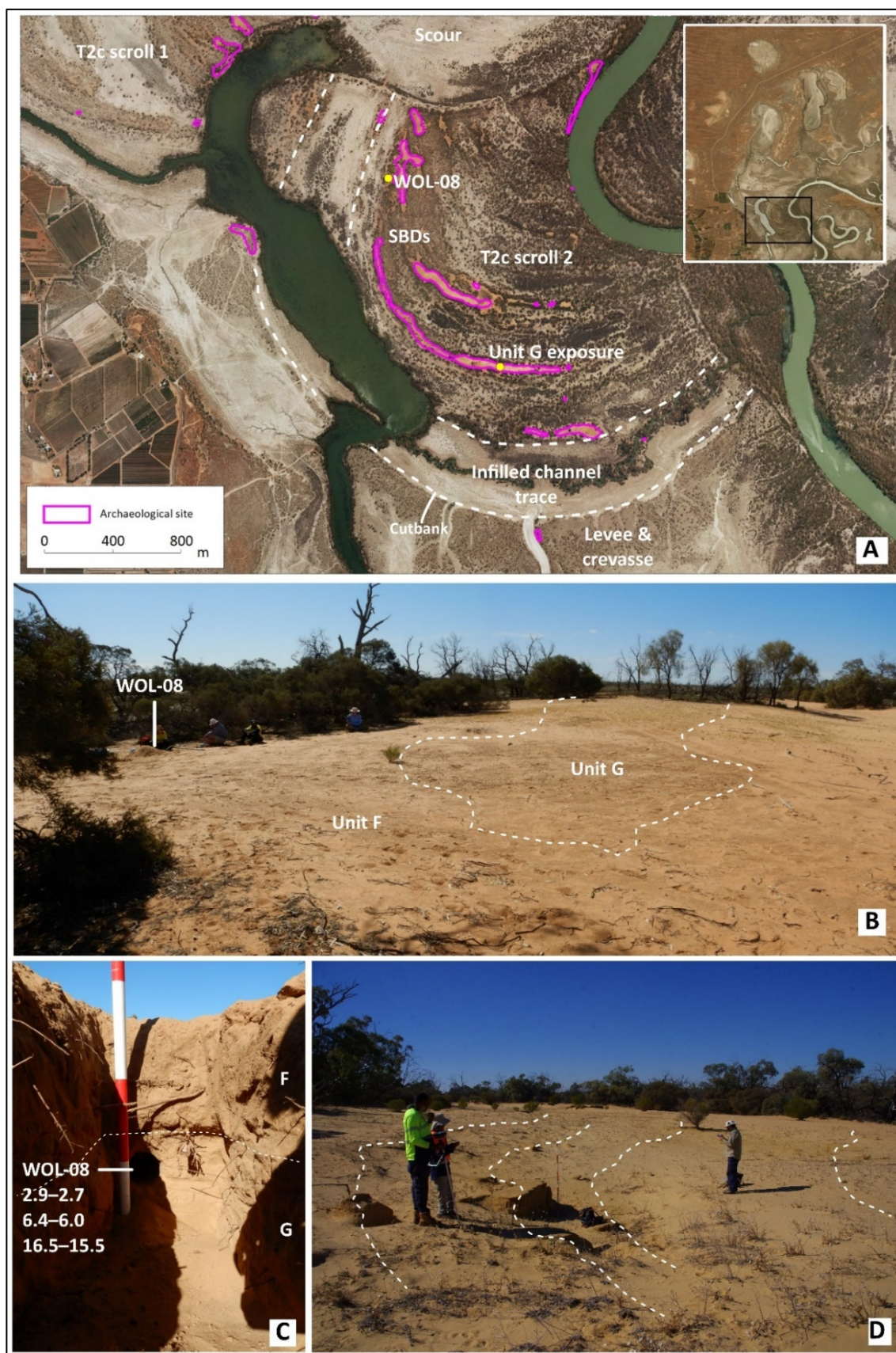


Figure 6-43: (A) The structure of T2c scrolls at Calperum, (B) context image of WOL-08 looking north, (C) the WOL-08 profile and (D) view looking south across a deep deflation in a SBD in T2c (scroll 2) and exposure of the angle bedded Unit G (dashed lines shows the trend of the bedding) (see A for location).

6.2.5 Nooreela's intervention: a floodplain transformed

The transition from T2c to terrace T3 marks the most significant change in hydrology captured in the Riverland floodplains. This manifest in a marked reduction in channel width and meander wavelength, and a notable absence of SBDs. In combination, this evidence indicates more consistent flows, a less pronounced seasonality to flows and/or vegetation able to more effectively mitigate deflation. Common landforms include channel traces, narrow levees perched on cut-banks, oxbows and tightly spaced ridge-swale meander topography (Figure 6-44). Terraces T3 and T4 display very similar characteristics, though with the narrower and more sinuous channels in the latter indicating a further reduction in peak flows. Channel migration under the modern regime is reported to be slow (Gippel and Blackman 2002).

The transition to T3 is likely to have occurred c. 13–12 ka assuming the development of the third and youngest T2c scroll (to the east of the Calperum boundary) occurred over several thousand years after the 16.5–15.5 ka SBD (see above). This interpretation is slightly younger than the 15 ka timing suggested by Prendergast et al. (2009) for the Lindsay–Mulcra Land System transition, though is consistent with evidence of more regular inundation of the Calperum floodplain, including the establishment of a marsh facies in Rotten Lake, the sculpting of Wfm dunes at Lake Woolpoolool and the development of beach-ridges along terraces bounding the inner lakes. Populations of freshwater mussel re-established in Rotten Lake, albeit temporarily by 7.8 ka, locating the peak of this early Holocene pluvial within the MHCO.



Figure 6-44: River red gum (*E. camaldulensis*) / black box (*E. largiflorens*) woodland, and lignum and chenopod shrubland on the undulating ridge and swale topography typical of T3 and T4.

6.2.6 The Pike floodplain

The essential elements of the Calperum floodplain geomorphology are repeated at Pike, though with the notable absence of lunette-fringed lakes and the inclusion of a high valley cliff. The palaeovalley margin at Calperum is buried under cover of Woorinen Formation sediments. As with the Calperum floodplain, a relative sequence in the terracing at Pike has been identified on the basis of channel and scroll morphology, pedology and relative elevations. Archaeological survey and dating at Pike has focused on a series of shell middens perched around the valley cliff line overlooking the south-eastern corner of the floodplain. The basic geological structure exposed in the cliff is annotated in Figure 6-45 and consists of quartzose sands of the Loxton-Parilla Sand overlain by the Blanchetown Clay/Bungunnia Limestone and capped by an aeolian sequence of WFm dunes and sand sheets. The upper section of the Loxton-Parilla Sand is overprinted by the Karoonda Surface palaeosol, a ferruginised/silicified zone that forms characteristic benches extending out from the cliff (Figure 6-46). The upper surface of the Blanchetown Clay is invariably formed by coarse boulder calcrete which has been used in the construction of heat retainer ovens along the cliff (Figure 6-47). The WFm in this area consists of a clayey fine to coarse quartz sand that and is likely to incorporate materials sourced from and/or transported over the floodplain. These sediments may have originally extended from source bordering features or climbing sand sheets associated with T1 and earlier floodplains. A modern analogue is illustrated in Figure 6-45. This source bordering material is equivalent to the Bunyip Sand, a unit that extends out of the Murray valley at various points in the mid and lower Murray regions (Brown and Stephenson 1991; Firman 1966; Gill 1973a; Lomax et al. 2011). Deposition of the Bunyip Sand in the lower Murray extends from at least 28 ka through to the Holocene based on OSL ages presented in Lomax et al. (2011), though the lower age is poorly constrained.

An interpretation of the subsequent development of the cliff-line is shown in Figure 6-48 and describes T2-age scrolls migrating progressively toward the south-eastern edge of the floodplain, eroding sediments packed against the valley margin and eventually impacting and eroding the cliff-line itself. The River Murray subsequently migrated within a narrow corridor paralleling the base of the cliff before major avulsions to the centre and western side of the floodplain occurred during the development of T3 and T4, respectively.

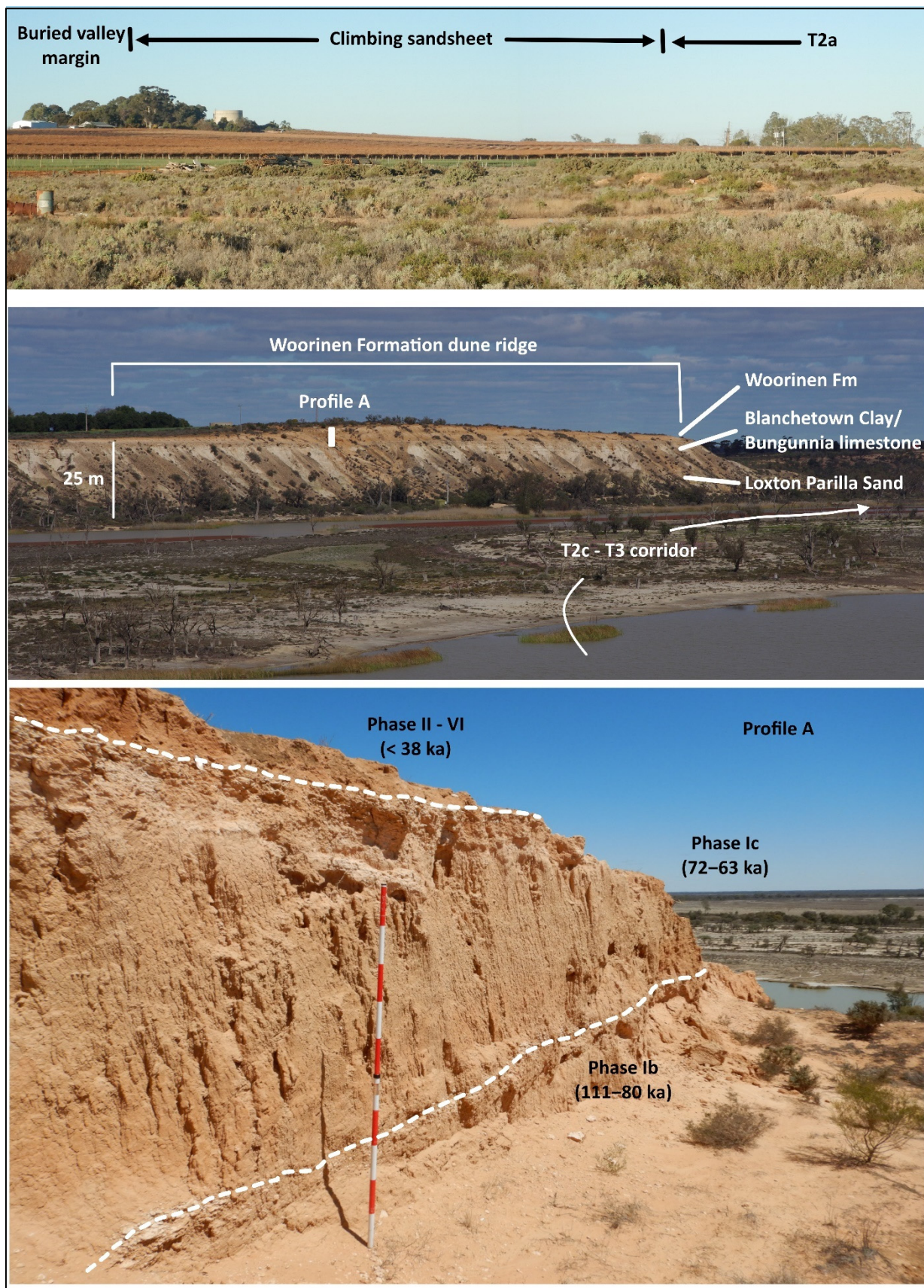


Figure 6-45: The geological context of the Pike cliff-line showing (top) an example of a climbing sand sheet at the Cobdogla floodplain, (middle) the geology truncated along the eastern side of the floodplain in the area of site PikeSP16_05, and (bottom) Woorinen Formation sediments exposed in an artificial cutting in the area of site PikeSP16_05.



Figure 6-46: A characteristic bench formed in the Karoonda Surface around the eastern side of the Pike floodplain.



Figure 6-47: View looking east along the southern cliff-line at the Pike floodplain with the coarse calcrete boulder surface capping the Blanchetown Clay and underlying Woorinen Formation sediments.

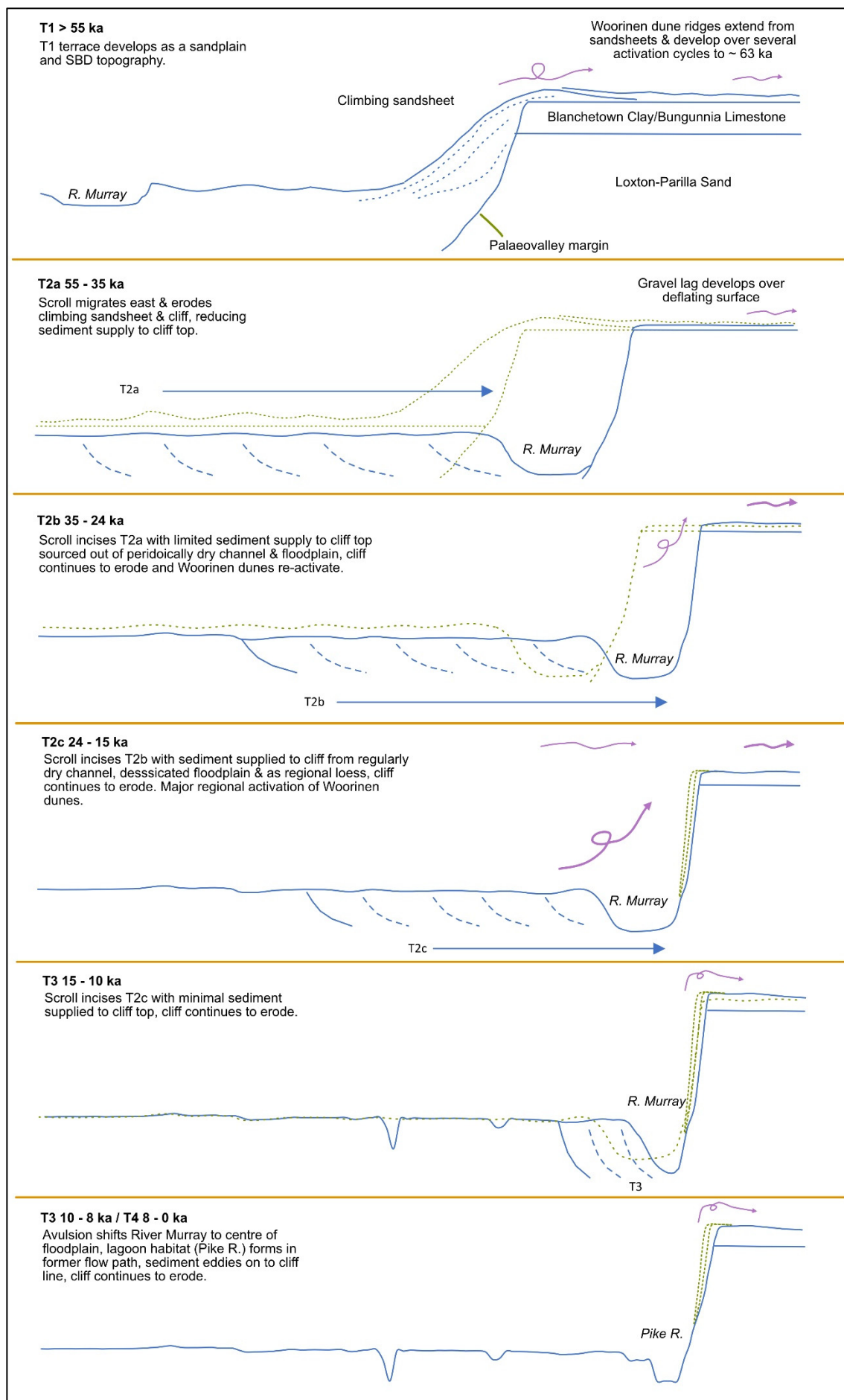


Figure 6-48: The development of the south-eastern section of the Pike floodplain.

A series of palaeosols exposed within the Woorinen sediments partition cycles of dune reactivation. The chronology shown in Figure 6-45 assumes a correlation with the cycles identified by Lomax et al. (2011) in the south-western MDB. The most pervasive soil extends through the upper section of the Phase 1c sediments (see Figure 6-49). The soil is separated from overlying sediments by a unit of calcrete gravel supported in a sand matrix. OSL dating in site PikeSP16_05 (Figure 6-49) suggests that PS-1c had formed over a dune that was in place by at least 72.2–67.8 ka (OSL sample Pike-01 [AD20012]). This age relates to sediments located approximately 1 m below the palaeosol. All of the archaeology recorded around the cliff sits above PS-1c, being excavated into the gravel unit or deposited within or on top of the overlying Phase II–VI Wfm sediments. Ages returned on freshwater mussel (*A. jacksoni* and *V. ambiguus*) and *N. sublineata* midden within the Phase II–VI sediments span the period 29,845–28,977 cal BP (OZX288) to 2728–2435 cal BP (Wk-48705) (Figure 6-50). Charcoal recovered from a hearth feature excavated into the underlying gravel unit in PikeSP16_05 returned three inconsistent ages of 43,940–42,294 cal BP (Wk-50964), 36795–35819 cal BP (Beta-620780) and 28,780–28290 cal BP (Wk-53708). Neither the depth of archaeological material below current ground surfaces or its height above PS-1c offers a reliable indicator of age within or between sites (see examples in Figure 6-51).



Figure 6-49: Geochronological framework for the palaeosol PS-1c and hearth feature in PikeSP16_05 based on OSL and ¹⁴C age estimates.

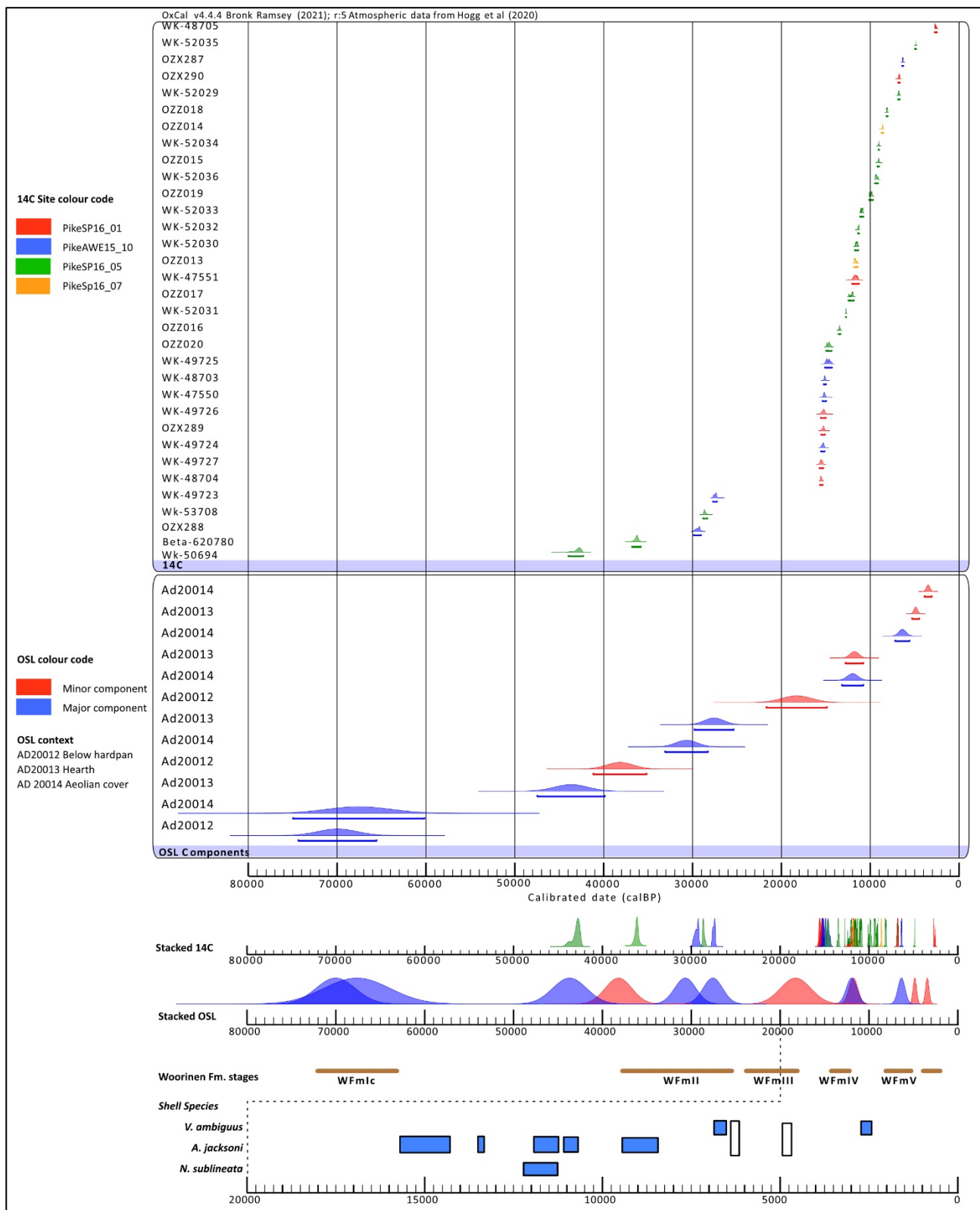


Figure 6-50: (Top) Calibrated ^{14}C ages returned on archaeological materials along the Pike cliff-line colour coded by site) and OSL Fmix components at PikeSP16_05. (Bottom) ^{14}C and OSL ages are arranged as stacked plots below the main graph and related to Woorinen Formation phases and the dated shell species. The clear blocks in the shell species plot relate to undiagnostic materials. 2-sigma ranges are shown below each PDF in the main plot.

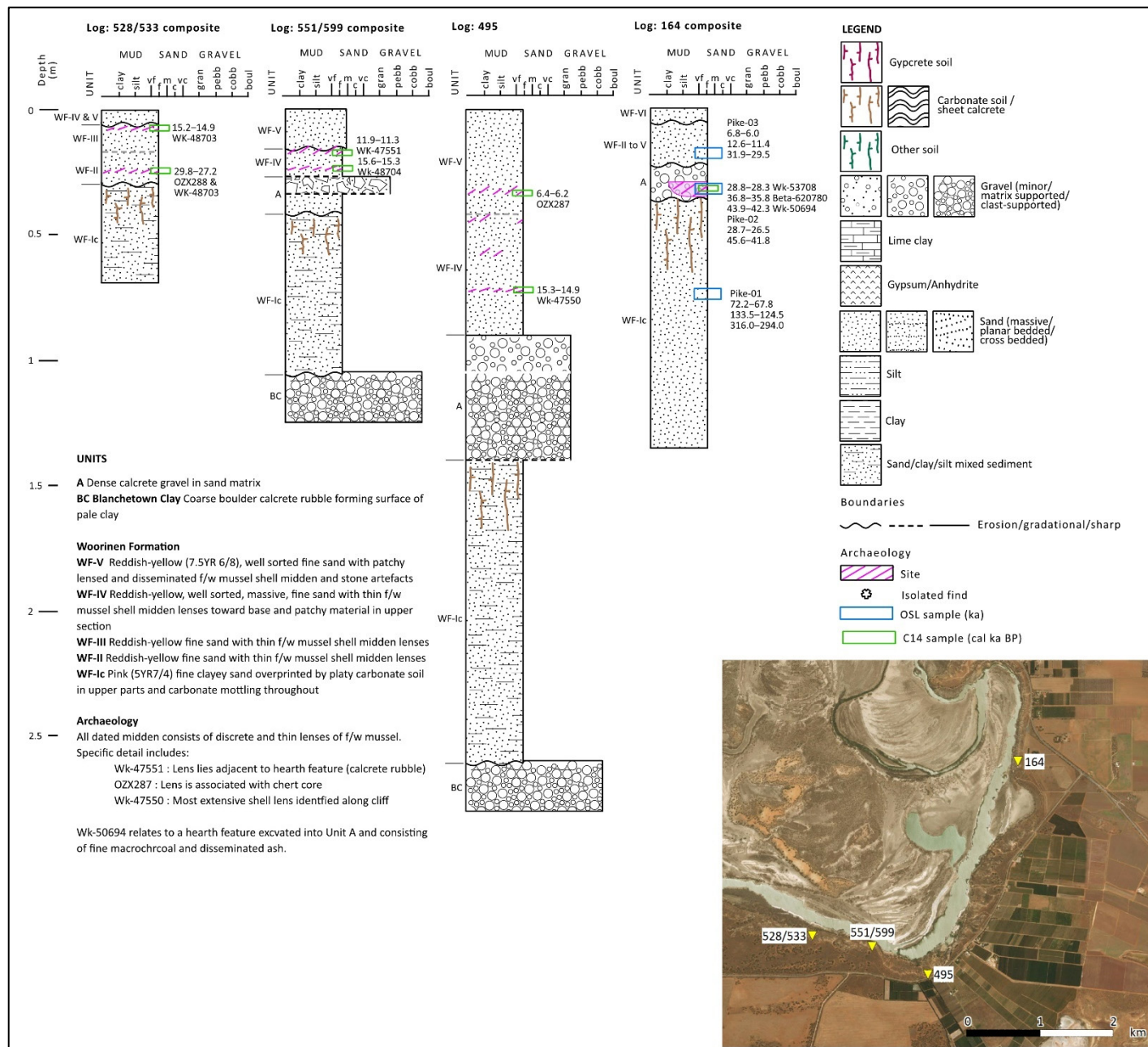


Figure 6-51: Sediment logs recorded at various locations around the Pike cliff-line.

The development of the Pike floodplain was punctuated by at least two major avulsions. The first occurred during the development of terrace T3 (see Avulsion Point 1 in Figure 6-52) and had the effect of converting approximately 16 km of the River Murray channel into the Pike River anabranch as the fluvial corridor transitioned to the centre of the floodplain. The freshwater mussel species represented in the ^{14}C ages shown in Figure 6-50 consist predominantly of *A. jacksoni* with the exception of samples OZX290 (6,846–6,569 cal BP), WK-48705 (2,728–2,435 cal BP) and other fragmentary material recovered from excavations that are most certainly *V. ambiguus* (see outlined blocks in the species plot in Figure 6-50). This suggests that a high-flow environment had persisted in the Pike River anabranch for a time following the first avulsion before a lentic habitat had established by at least c. 6.7 ka. This timing is consistent with a reduction in sustained flows through the Pike River with the establishment of T4 c. 8 ka. The second avulsion occurred when the late Holocene river breached a T2 terrace remnant in the north-western section of the floodplain. In this instance, approximately 13 km of River Murray frontage was converted into the Mundic Creek wetlands and connectivity between the river and the Pike River anabranch was further reduced. Based on diatom assemblages, Fluin et al. (2009) posited that a reduction in river flows sometime in the period 1,790–700 cal BP saw permanent higher salinity conditions established in the Pike-Mundic wetlands. It is possible that this change was a consequence of the late Holocene avulsion rather than a change in flow regime. If so, this timing is conspicuously similar to evidence of a catastrophic event identified in the Calperum floodplain sometime prior to c. 1,300 BP (see Chapter 7.2).

Another curious aspect in the dating results at Pike is the relatively narrow band of *N. sublineata* ages c. 12.1–11.2 cal kBP. Both Garvey (2017) and Prendergast et al. (2009) describe a mixture of *N. sublineata* and *A. jacksoni* content in c. 15 ka middens located in the Neds Corner floodplain, though all ^{14}C dating reported for these middens is based on the latter. It is assumed that the collection of both species was contemporaneous. The spread of *N. sublineata* ages in Figure 6-50 is based on a sample of only four estimates and further dating of this species is required to confirm a pattern. However, changes in the Pike River habitat with the establishment of the T3 hydrological regime c. 13 ka may be tentatively suggested. Optimal habitat for *N. sublineata* consists of hard surfaces in free-flowing water, e.g. submerged timber or macrophyte stems. A re-establishment of river red gum fringing woodland with improved T3 flows might be envisaged (see Forbes et al. 2019; Reid et al. 2016:50), and would have provided the habitat required by *Notopala* spp..

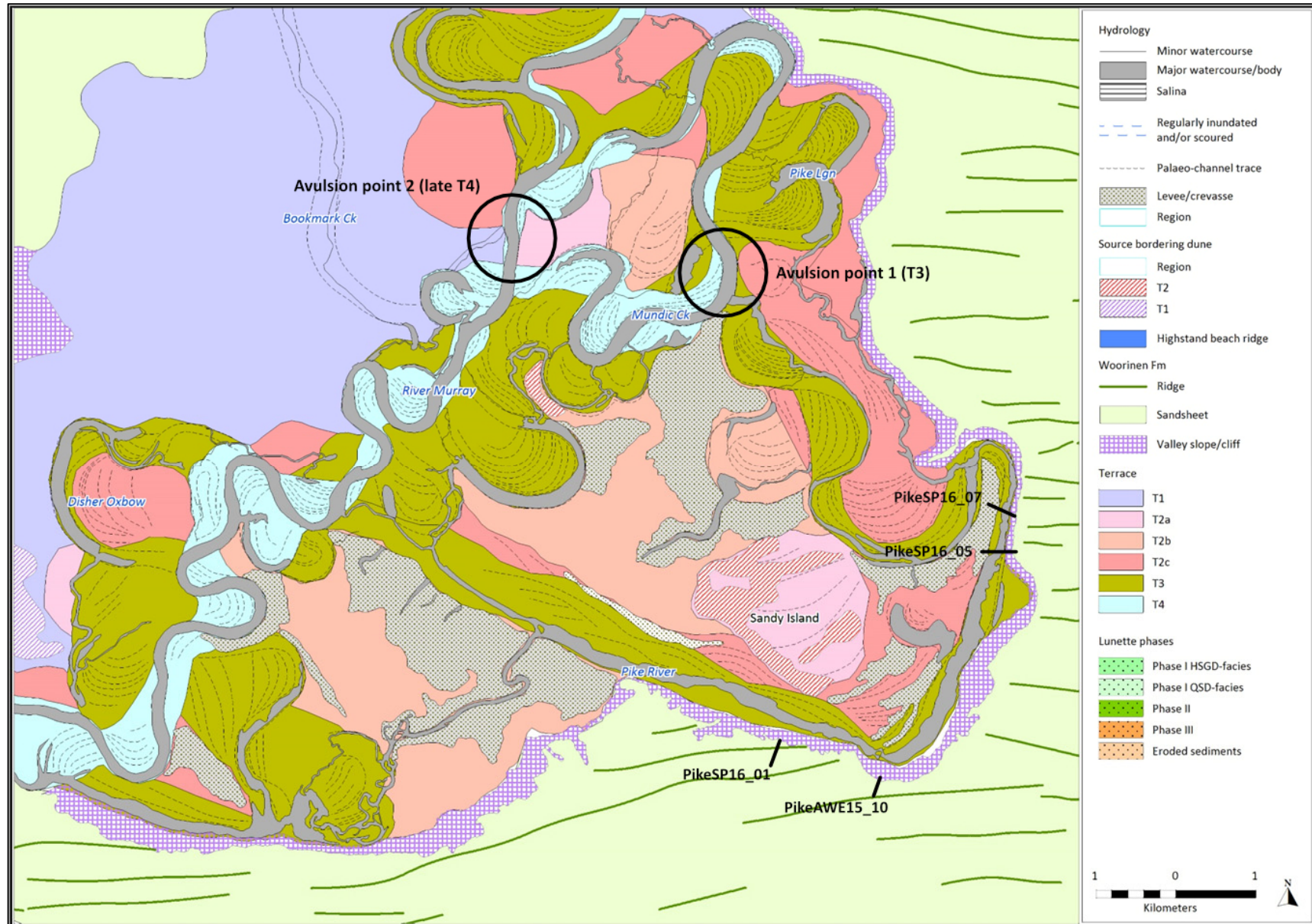


Figure 6-52: Examples of major channel avulsions in the Pike floodplain. Also shown are the locations of the open scatters subject to dating.

6.2.7 Auger excavations at Clover Lake and Big Hunchee Creek

Mapping of the surface geology was supplemented with a limited program of augering. This included the collection of ^{14}C samples on sediments recovered from two locations on the dry bed of Clover Lake and a third from a floodplain depression north of Big Hunchee Creek. Sediments were initially described in the field (colour, texture, inclusions) and again in the laboratory where pXRF analysis was employed as a means of further characterisation. The sedimentary records in both locations extend to beyond ~ 20 ka. Whilst there is general agreement in the ^{14}C ages recovered from the Clover augers, two inversions occur in the Hunchee auger (Figure 6-53). As shown by Wang et al. (1996), the continual cycling of organic carbon can mask the true age of sediments. Typically, a ^{14}C age will be younger than the original depositional context. This potential is considered alongside additional evidence in the following interpretation.

The two Clover Lake augers were placed 700 m apart on the dry lakebed; CA1 at the western side of the basin and CA2 at the eastern. The auger locations have equivalent elevations of 17.1 m. A suggested age-depth trend is shown in Figure 6-53 based on seven ^{14}C ages that span the period ~ 20.6 –1.3 ka. If a simple linear relationship is assumed between each age in each auger, as shown in Figure 6-53, relatively consistent sedimentation rates in Clover lake are suggested, though in reality, this trend is likely to mask more complex cycles of infill and incision/deflation. Inflows to Clover Lake may have been complicated to some extent by the (re)development of a broad beach-ridge across the inlet channel. This ridge has the same orientation as the Phase III lunette at Lake Woolpoolool and, as such, probably developed in the period c. 18–15 ka. The sedimentary environments of the two auger locations also differ slightly as small fans extend from the base of the lunette into the eastern side of the lake to CA2. Despite this, sediment characteristics are essentially replicated in the two augers with fine to very fine quartz sand shifting to a higher clay/silt fraction in the upper units (Figure 6-55). This fining upward trend is reflected in the pXRF assays where a shift to higher Al, Fe and Mg values suggestive of a greater clay content occurs prior to c. ~ 7.8 ka. Calcium values across the augers appear independent of sulphur suggesting that if gypsum was present in Clover Lake, it did not accumulate in significant quantities or as a discrete unit(s). This result is surprising given the presence of gypsum in Lake Woolpoolool and descriptions of gypsum in locations surrounding Lake Merreti. Fine flecks of shell occur in the lowest unit in CA2. No other macrofossils were identified.

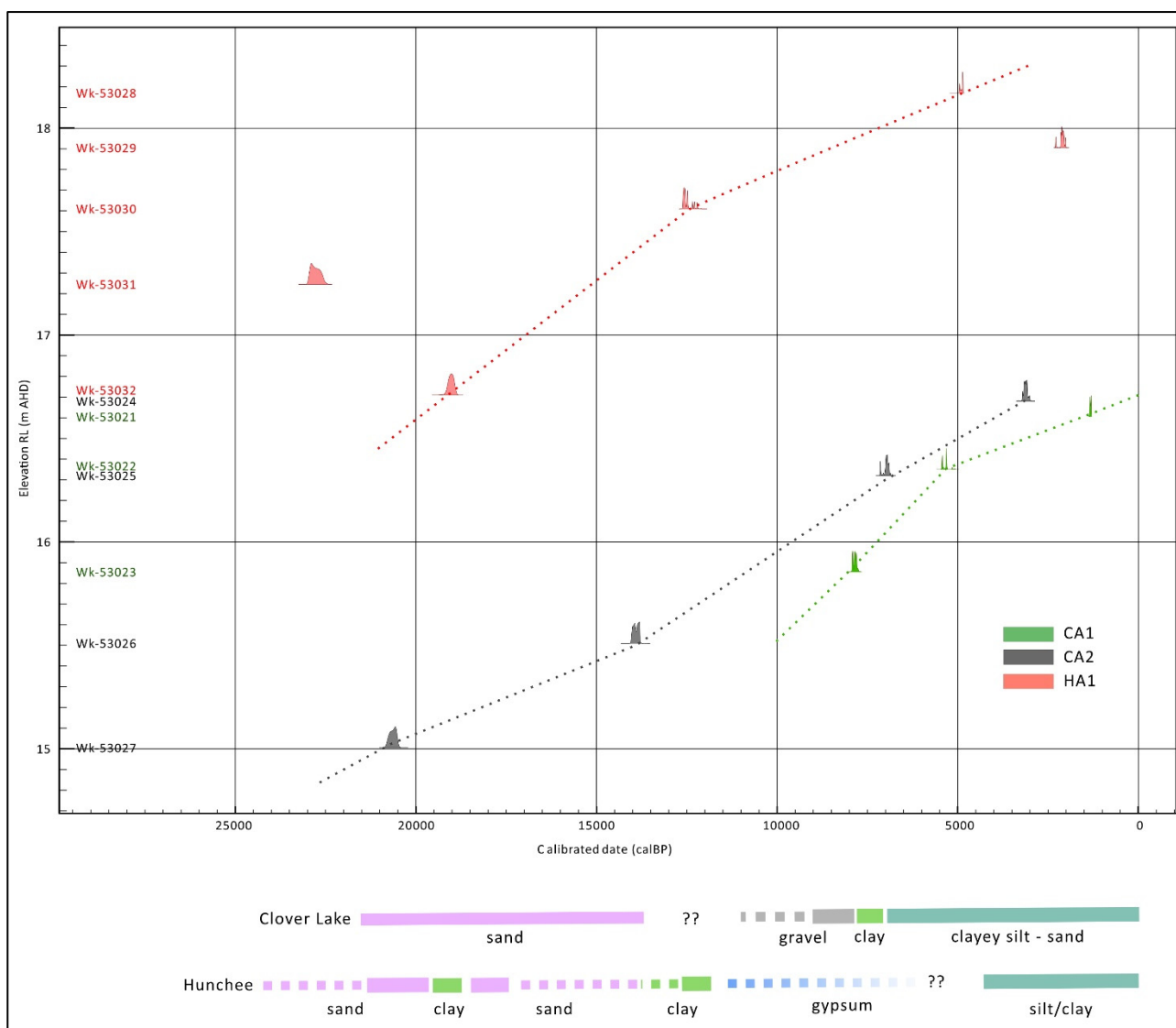


Figure 6-53: Age depth plot for the auger sediments. The dashed lines link reliable ^{14}C ages and provide generalised trends for the Clover and Hunchee sites. Sediment characteristics are presented below the graph with solid blocks able to be related to ^{14}C age estimates and dashed lines requiring interpolation. Time brackets with no reliable data are indicated by question marks.

Both of the sediment columns at Clover Lake are partitioned by a unit of poorly sorted fine to coarse sub-rounded gravel supported in a silty clay matrix. The gravel is formed on a coarse carbonate-cemented quartz sand. Calcite was confirmed by a strong effervescence with dilute HCl. A narrow bench of similar material extends around the northern side of a small foreland ~200 m northwest of CA1 (Figure 6-55). The bench sits ~2.5 m above a ^{14}C age of 7,934-7,752 cal BP (Wk-53023) returned from the upper boundary of the gravel unit in auger CA2. The gravel obviously post-dates the cementation process and the absence of gravel in the lower sandy units suggests a maximum age for that process of 14,030–13,975 cal BP (Wk-53026). The gravel unit predates a

relatively rapid infilling of the lake and may, therefore, have been deposited during a phase(s) of incision that had concluded c. 7.8 ka and was associated with the development of T3 and/or T4.

The Hunchee auger was located in a shallow backplain depression formed in a T2b channel trace 450 m north of Big Hunchee Creek. A chronology in this auger is framed around five ^{14}C age estimates that range between ~22.7–2.1 ka. This includes two inverted ages (see Figure 6-56). A suggested age-depth trend is shown in Figure 6-53. As with the Clover Lake augers, auger HA1 captures what is essentially a fining upward trend with sediment deposited under mild flows (fine-medium sand) changing to noticeably finer, slackwater sediment (clay and silty clay). This shift is initially marked by a thin clay unit dated to 19,177–18,879 cal BP [Wk-53032]. The timeline captured in this auger extends from a likely transition from T2b to T2c at ~24 ka and an initial oxbow environment formed in the abandoned T2b channel trace (sand with shell) through subsequent phases of lagoon infill and floodplain accretion. A discrete unit of gypsiferous clay lies immediately above a ^{14}C age of 12,620–12,195 cal BP (Wk-53030). The narrow Ca–S band and distinctive character of this unit suggests that this is primary gypsum and not a secondary deposit. Unfortunately, the poor ^{14}C resolution makes it difficult to relate the gypsum unit to a reliable timeframe, though a relationship with the gypsum beach-ridge formed at Lake Woolpoolool might be considered (see Chapter 6.2.3.2). If correct, this locates the gypsum unit toward the end of a period of regional dune activation (aridity) identified by Lomax et al. (2011) c. 14–12 ka.

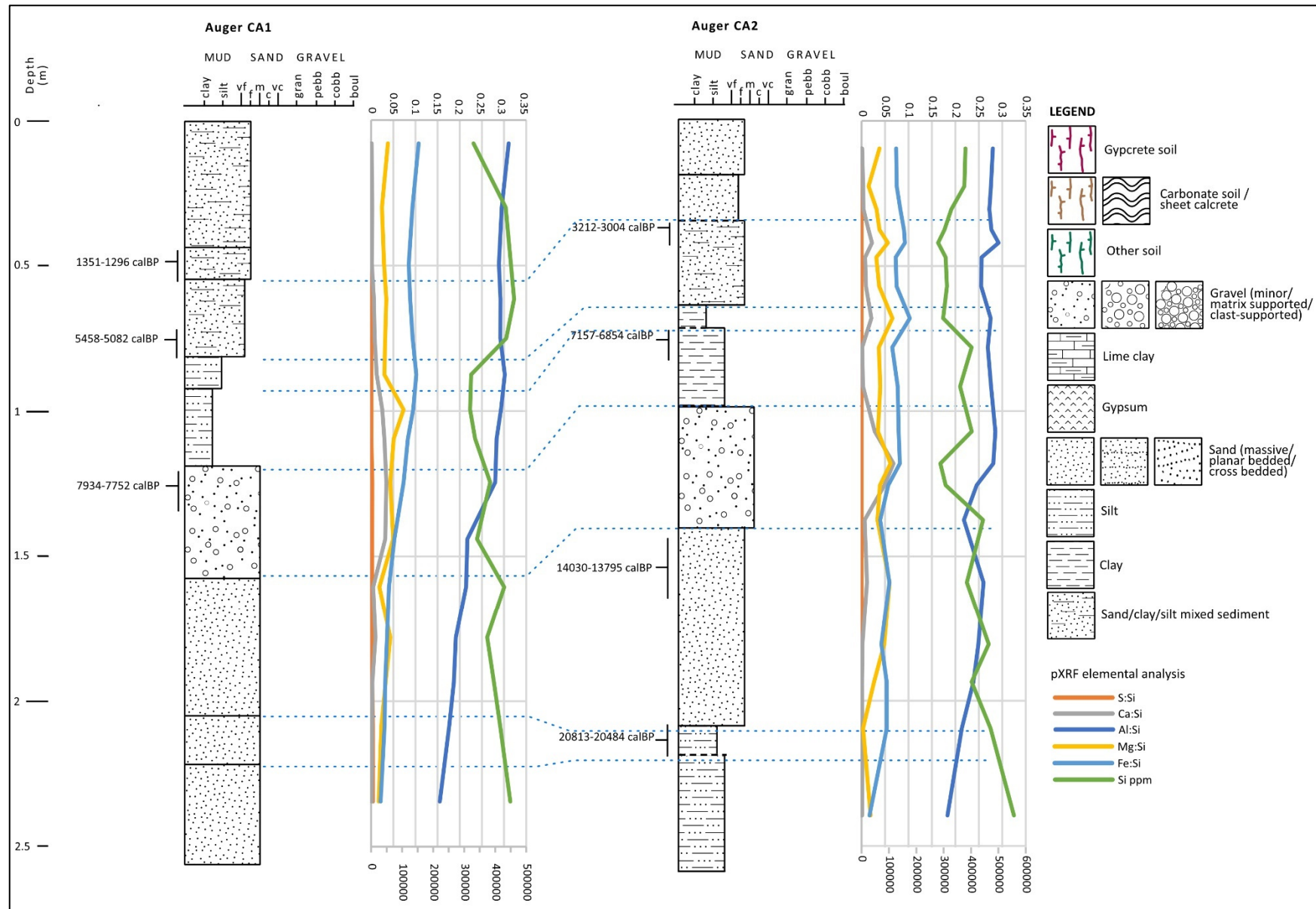


Figure 6-54: Sediment logs and pXRF assays for the Clover Lake auger excavations.

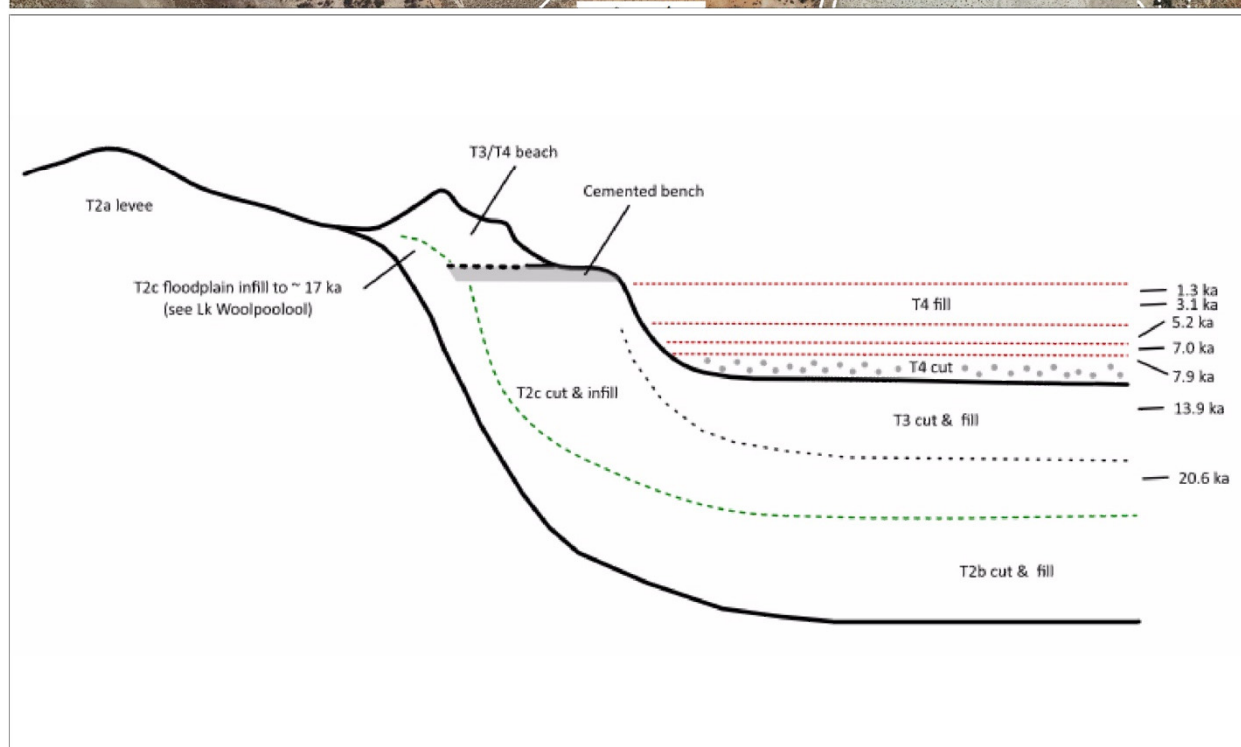
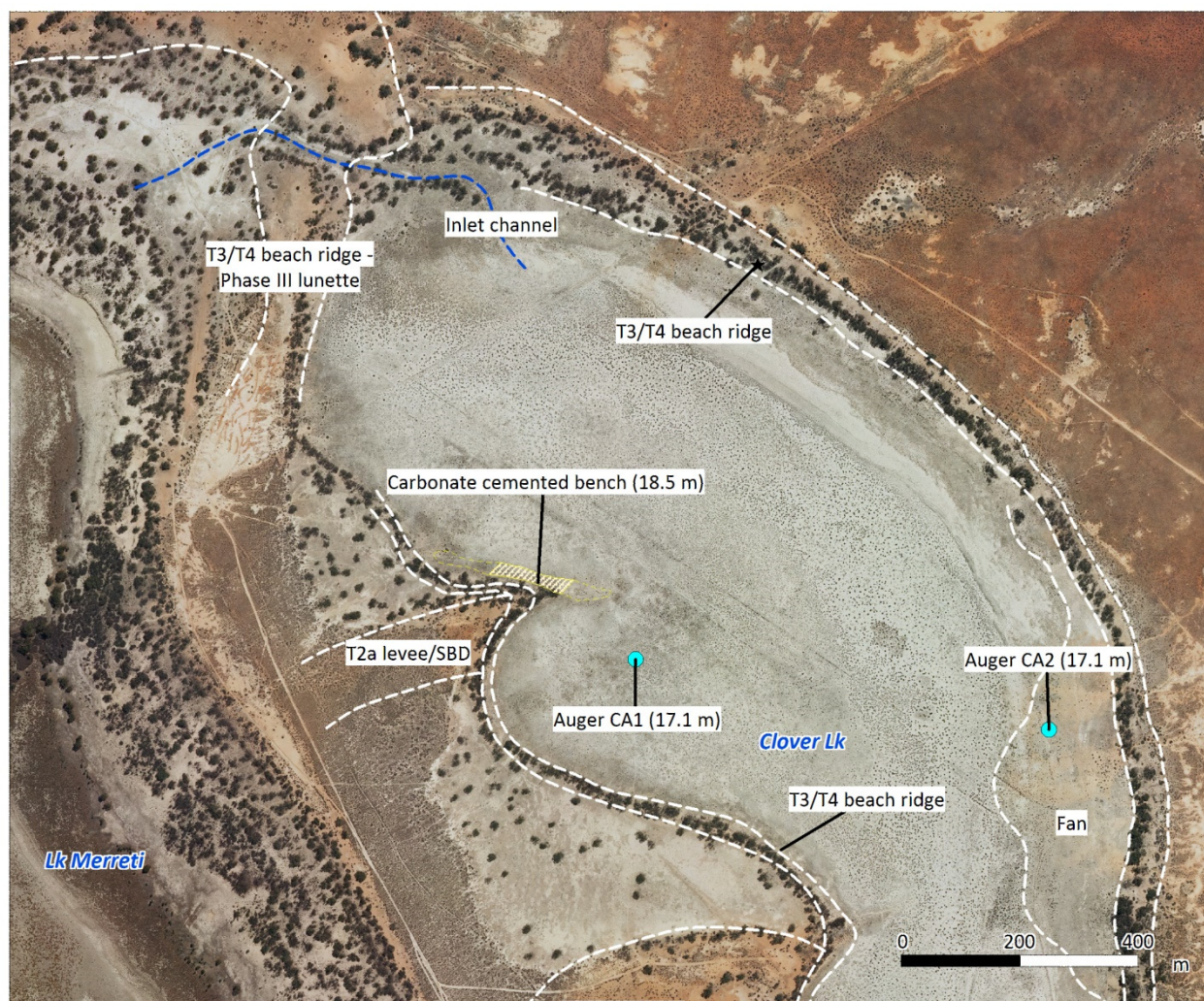


Figure 6-55: Schematic interpretation of the Clover Lake sedimentary record (also see Figure 6-56).

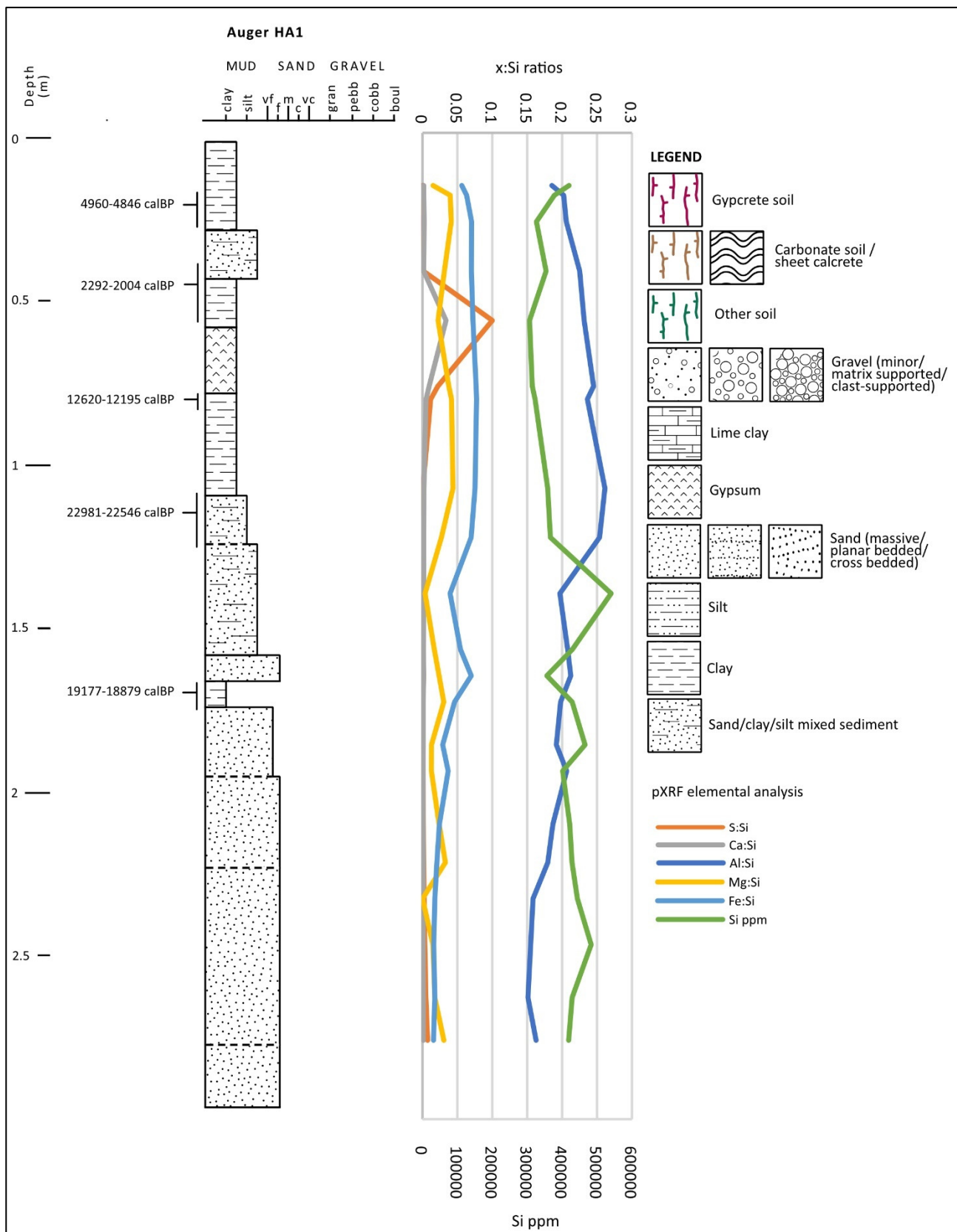


Figure 6-56: Sediment logs and pXRF assay for the Hunchee auger excavation.

6.2.8 Revisiting the Monoman–Coonambidgal distinction

Two valley fill formations have long been recognised in the SA section of the River Murray; the deeper sand/gravel Monoman Formation and overlying clay/silt-dominated Coonambidgal Formation (Brown and Stephenson 1991; De Carli 2020; Gill 1973a). In outline, it has been assumed that the Monoman Formation was deposited in braided systems during a period of valley incision associated with lower LGM sea levels. This was subsequently overlain by a finer grain upper valley fill of Coonambidgal Formation sediments as sea levels rose post-LGM (De Carli 2020). The Monoman Formation is, however, fully concealed by Coonambidgal sediments and is reported entirely from drilling intersections. Stratigraphic relationships and chronology remain somewhat confused. Two ^{14}C ages returned on 'a horizon of fossil logs' exposed during trenching at Chowilla have been cited as a basal age for the Coonambidgal Formation and span a combined calibrated range of 8.3–4.2 ka (Gill 1973a:46-47). The Australian Stratigraphic Units Database cites the upper age for the Monoman formation as Holocene, though the presence of megafaunal remains (*Phascolonus gigas* and *Macropus ferragus*) at Chowilla (Gill 1973a:Figure 40; Marshall 1973) indicates a deeper Pleistocene age, possibly in excess of 40 ka (Hocknull et al. 2020) for the initiation of this unit.

The geomorphological evidence presented in this thesis demands a reappraisal of the simple Monoman-Coonambidgal distinction. This research has identified landscapes preserved across the Riverland floodplains that extend to at least 40 ka and include T2c scrolls that were active during the maximum marine lowstand c. 18 ka. Alluvial fill associated with the younger T3 and T4 terraces drapes the lower lying topography in the floodplain but does not fully conceal Pleistocene landscapes. An alternate scenario is to consider T1 as the final stages of a longer valley-filling sequence extending from a gravel bearing unit referred to as the Monoman Formation and which is significantly older than had been previously suggested. The development of T2a scrolls by at least 43 ka defines the start of a sequence of incisions by broad, bedload systems that persisted across the early glacial and LGM and incorporate sediments deposited in a range of fluvial, alluvial and source bordering aeolian contexts within the valley. The floodplain was further incised by mixed and suspended-load channel systems from the end of the deglacial c. 13–12 ka through the Holocene. Defining the Monoman as the sequence of bedload systems and the younger Coonambidgal Formation as the mixed and suspended load channel systems seems a legitimate basis for a revised Monoman-Coonambidgal division.

6.3 Archaeology

6.3.1 Survey coverage and conditions

The archaeological survey strategy at Calperum was guided by the geomorphological modelling and focused on several key landscape settings that included the inner and outer lake lunettes, WfM dunes extending into the western margin of floodplain and various T2 scrolls and related cut banks. Areas accessible under a range of inundation levels were also preferred, ostensibly the outer edge of the floodplain and elevated terrain within the floodplain. This survey focus was supplemented with transects conducted across the T1 surface east and south of Clover Lake and the cut-bank of a T3 scroll in the south-eastern corner of the floodplain. A range of palaeolandscapes were captured in this coverage, as summarised in Table 6-1, and allow a direct comparison in the archaeological signature of equivalent settings across a landscape timeseries. Total survey coverage extended over approximately 12.2 km² of the Calperum floodplain (Figure 6-57). Approximately 4 linear km of Pike floodplain cliff-line was assessed (Figure 6-58), though this figure is in the context of a far greater coverage described in unpublished survey reports.

Survey conditions (visibility, background effect and exposure) provided generally high levels of effective coverage. At Calperum, extensive areas of bare and eroded ground were commonly encountered and several years of below average rainfall had reduced the ground covers. Intense erosion commonly manifests as shallow deflation surfaces and scalding, with deeper profiles largely restricted to the gullied lake margins, channel banks and deeper deflation hollows within WfM dunes and SBDs. Effective coverage was impacted to some degree by dense leaf litter and vegetation along levees fringing the active waterways and within the T3 and T4 scrolls. Surveys conducted in these areas tended to focus on exposed channel banks. The Riverland floodplains are essentially free of stone other than some nodular calcrete on the older land surfaces, and as such, the background effect was low. The Pike cliff-lines provide what is essentially a continuous section cut through the aeolian cover and several archaeological sites. Beyond the cliff, however, exposures are limited to shallow deflations, vehicle track cuttings and rabbit warrens.

Table 6-1: Palaeolandscapes captured in the survey coverage.

Phase	Lake/lagoon	Channel	Terrestrial
T1	- Outer lake lunettes	- Possibly the Pike cliff	- Backplain areas at Calperum
T2a	- Outer lake lunettes and lake margins - Inner lake margins including SBD/lunette surfaces	- Possibly the Pike cliff - Cut-bank around the northern edge of the Calperum floodplain and east and south of Clover Lake - SBDs in the interior of the Merreti-Clover basin	- Backplain areas at Calperum
T2b	- Outer lake gypsum lunettes and lake margins - Inner lake margins including lunette surfaces	- Pike cliff-line - Cut-bank south of the inner lakes - SBDs south of Lake Merreti and Ral Ral Creek	- Backplain areas at Calperum
T2c	- Outer lake gypsum lunettes and lake margins including WFm dunes - Inner lake margins including lunettes - Oxbow in older T2c scroll in south-western section of Calperum floodplain	- Pike cliff-line - Cut-bank around northern edge of Bulyong Island - Meander scrolls and SBDs centred on Ral Ral Wide Water	- Backplain - WFm dunes
T3	- Outer lake margins including WFm dunes - Inner lake margins including north-easternQSD-facies lunette - Ral Ral Wide Water and Huncree Lagoon oxbows - Pike cliff (late T3)	- Pike cliff (early T3) - Cut-bank around scroll in south-eastern corner of floodplain - Cut-bank around Huncree Lagoon	- Backplain - WFm dunes
T4	- Early Holocene freshwater phase beach, lunette and margins of outer lakes - Inner lake margins including WFm dunes - Ral Ral Wide Water and Huncree Lagoon oxbows - Pike cliff	- Cut-bank along River Murray	- Backplain - WFm dunes

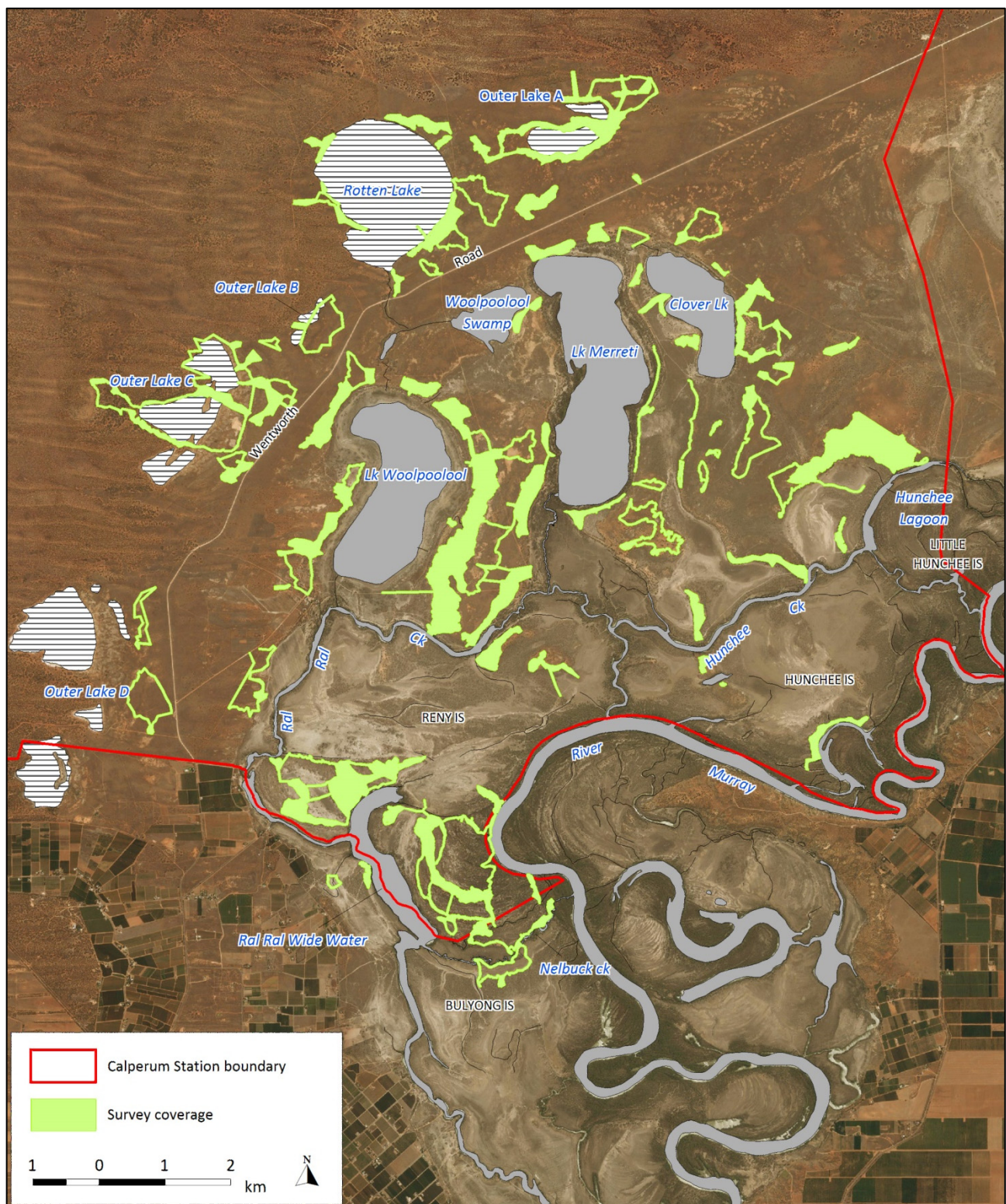


Figure 6-57: The archaeological survey coverage at Calperum.

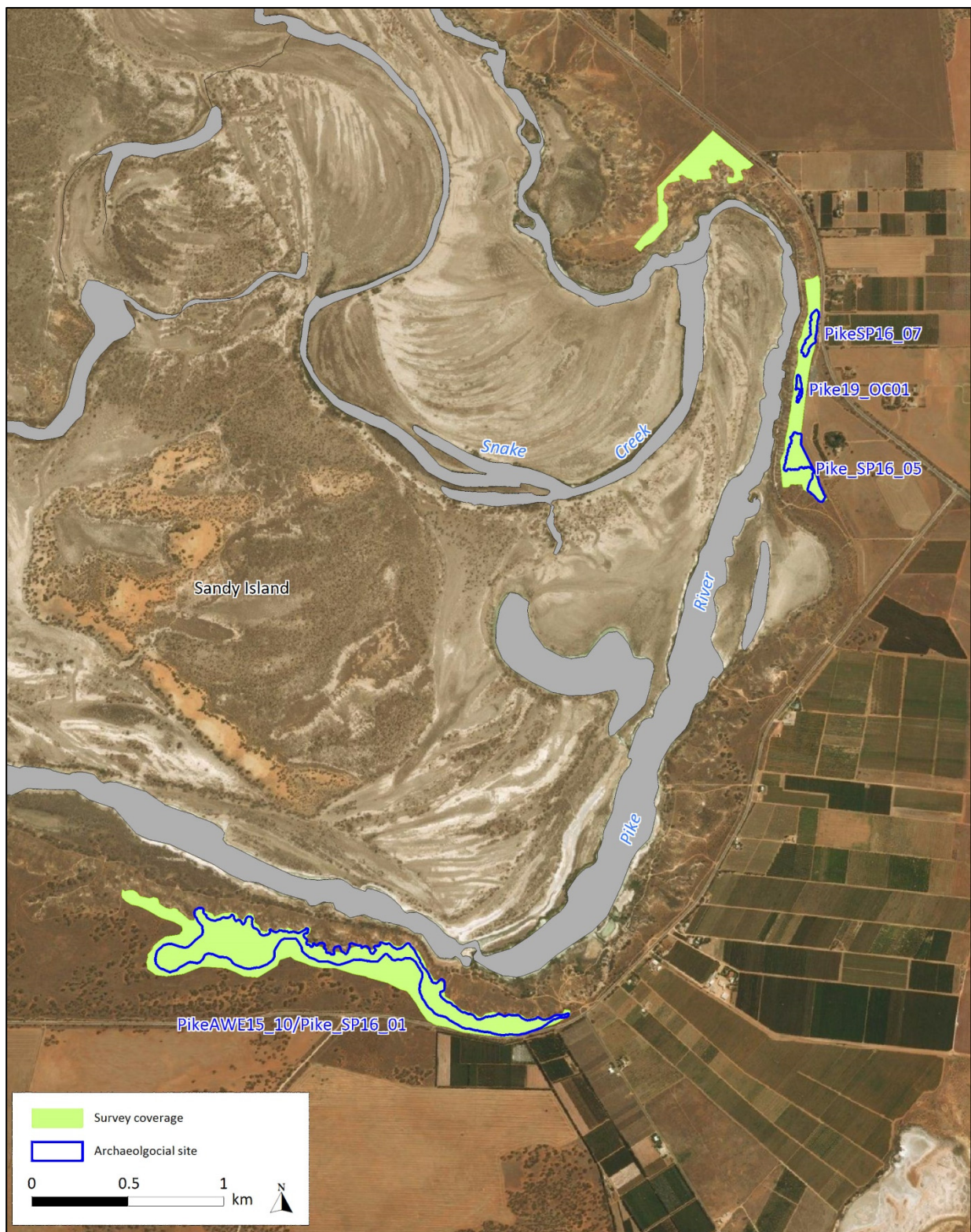


Figure 6-58: The archaeological survey coverage at the Pike floodplain showing the locations of archaeological sites specifically assessed during this research.

6.3.2 Sites recorded

A total of $n=116$ archaeological sites were recorded within the survey coverage at Calperum. Summary details are provided in Appendix VIII and in the Supplementary Material. Their locations are shown in in Figure 6-59. A summary of these sites, based on the materials and features present, is provided in Table 6-2. Stone artefacts, hearth material (heat retainer/ash/charcoal) and freshwater mussel shell are common elements, occurring in 93, 98 and 67 sites, respectively. The majority of sites include some combination of these three components. Ancestral remains are present in 30 Calperum sites and occur almost exclusively in combination with some other occupation material. Estimated numbers of individual burials within sites ranged from 1 to 30 with a total estimate of burial numbers within the surveyed area of 164³¹. The five sites (re)recorded at Pike (Figure 6-58) comprise open scatters of freshwater mussel shell, stone artefacts and heat retainer hearths.

Oven mounds (21) were recorded as discrete features (8) or as components of more complex sites (13 mounds spread over 8 sites). Importantly, these figures relate to the mounds recorded within the formal survey coverage conducted as part of this research. The locations of an additional 17 mounds were also noted outside of this coverage, principally along Hunchee Creek, Hunchee Lagoon, Ral Ral Creek and Ral Ral Wide Water. A concurrent research program and survey strategy specifically directed toward oven mounds has identified in excess of 60 mounds at Calperum (Jones 2016b; Jones et al. 2017; Jones et al. 2022). Only a fraction of these are captured in Table 6-2. Similarly, scarred trees are a common element of the cultural heritage landscape, though fall outside the specific aims of this thesis and are not reported in Table 6-2. As with the oven mounds, scarred trees located at Calperum have been the subject of a dedicated research program (Dardengo 2019; Dardengo et al. 2019).

Minor site components include historic materials (glass, tin, porcelain, clay pipe, telegraph insulator) which most commonly form part of broader pre/post-contact assemblages (see also Munt 2022). An extremely rare example of earthworks was also recorded in site CAPR17_08

³¹ Burials occur in a third of all sites, though roughly 58% are contained in just six sites; CAPR17_02 (15), CAPR17_09 (30), CAPR17_10 (12), CAPR17_23 (7), CAPR18_S17 (20) and CAPR18_S31 (11). As per protocols established with RMMAC, these locations were specifically avoided. Numbers are, therefore, indicative only.

comprising a shallow excavated channel connecting two basins within the interior of a T2c meander scroll (see further discussion in Chapter 6.3.9).

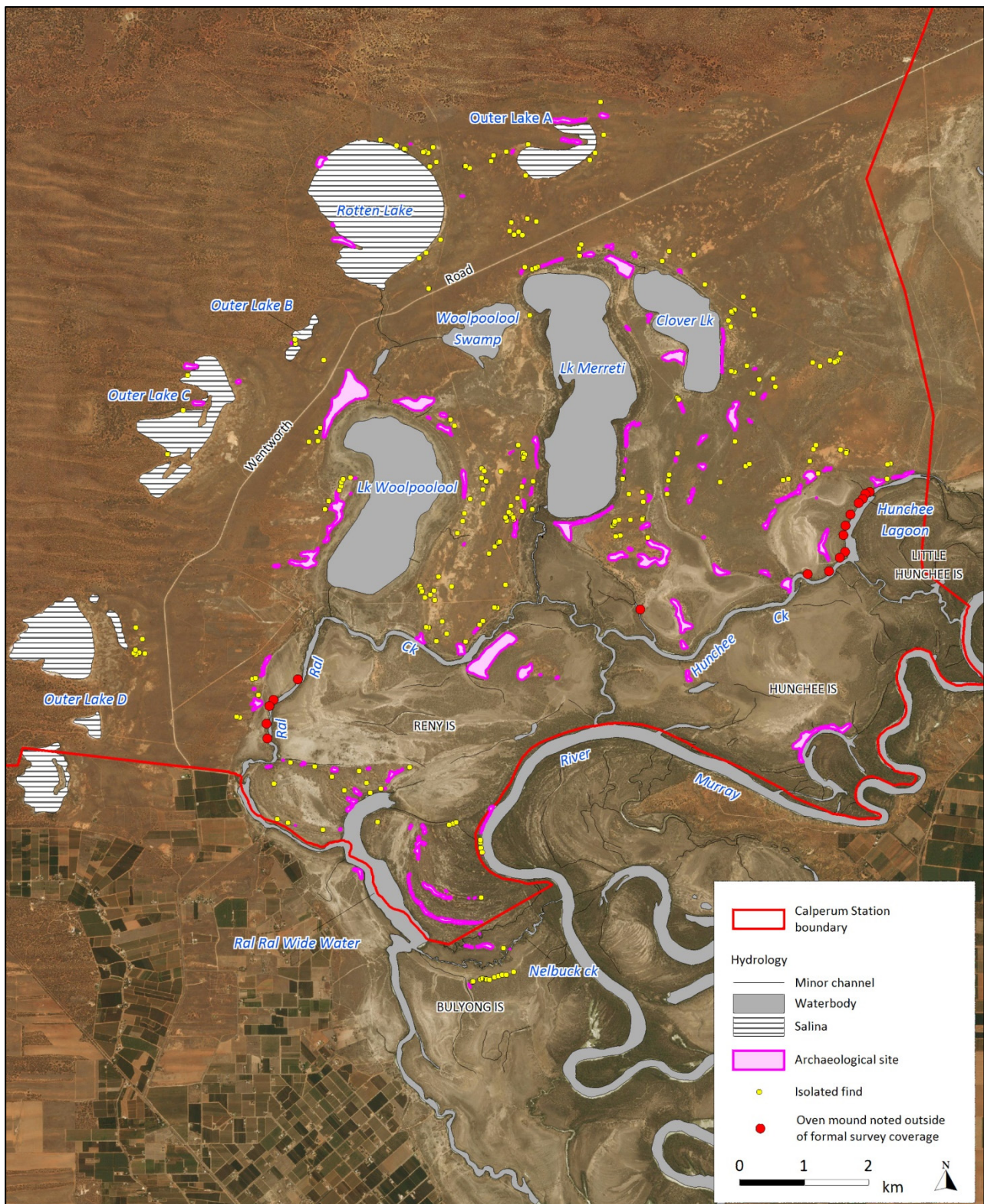


Figure 6-59: Archaeological sites and isolated finds recorded at Calperum.

Table 6-2: A breakdown of site types and site components recorded at Calperum.

Site Type_Materials present*	No. sites	Components							
		Artefacts	Hearths	Midden (shell)	Other faunal	Oven mound	Burial	Historic material	Earthworks
Hist	1							1	
OpenScatter_A-H	25	25	25						
OpenScatter_A-H/B	3	3	3				3		
OpenScatter_A-H/EW	1	1	1						1
OpenScatter_A-H/Hist	1	1	1					1	
OpenScatter_A-H-M	28	28	28	28					
OpenScatter_A-H-M/B	18	19	19	19			19		
OpenScatter_A-H-M/B/Hist	2	2	2	2			2	2	
OpenScatter_A-H-M/Hist	1	1	1	1				1	
OpenScatter_A-H-Mf	1	1	1		1				
OpenScatter_A-H-M-Mnd	3	3	3	3		3			
OpenScatter_A-H-M-Mnd/B	2	2	2	2		2	2		
OpenScatter_A-H-Mnd	2	2	2			2			
OpenScatter_A-M	3	3		3					
OpenScatter_A-M/B	1	1		1			1		
OpenScatter_A-Mf	1	1			1				
OpenScatter_A-M-Mnd	1	1		1		1			
OpenScatter_H	6		6						
OpenScatter_H-M	4		4	4					
OpenScatter_H-M/B/Hist	1		1	1			1	1	
OpenScatter_M	1			1					
OpenScatter_M/B	2			2			2		
OpenScatter_Mnd	8					8			
TOTAL	116	94	99	68	2	16	30	6	1

*Materials present: A – Artefacts, H – Hearth, M–Midden shell, Mf–Other faunal, Mnd–Oven mound, B–Burial, EW–Earthworks, Hist–Historic material

The Calperum archaeology replicates patterns identified in the predictive modelling conducted on the Chowilla, Pike and Katarapko floodplains (Wood et al. 2005; Wood and Westell 2009, 2010, 2014b). Key factors in site distribution include the proximity to water features maintained under the modern regime, proximity to landform boundaries and the lateral extent of major flood extents. Significant variation occurs in the scale of sites in individual settings with the most substantive deposits continuing along the Pike cliff-line, within T2c SBD surfaces, on the terrace margins fringing the inner lakes, and bounding the T3 scroll and oxbow in the south-eastern section of the floodplain.

The majority of sites (~80%) comprise small hearth groupings or midden clumps occupying areas of less than 1600 m² (Figure 6-60). With the exception of a relatively small group of sites at Calperum, and the majority of sites at Pike, the sites are also commonly described as ‘low density’ or contain discrete, densely packed or clumped shell or hearth material separated by a diffuse intervening scatter. A clear contrast exists between the character of the Calperum and Pike sites, however, with the latter forming components of what is essentially a contiguous deposit of shell midden, heat retainer and low density artefacts continuing along the bounding cliff-line over approximately 4 km. Personal observations of midden with the same composition, presentation and stratigraphic context at locations including Murtho, Paringa, Loxton, Gurra Gurra and Pyap, suggest a continuation of this style of site over approximately 100 river kms in the upper Riverland. Tentative observations as far downstream as Morgan, may suggest a far greater distribution.

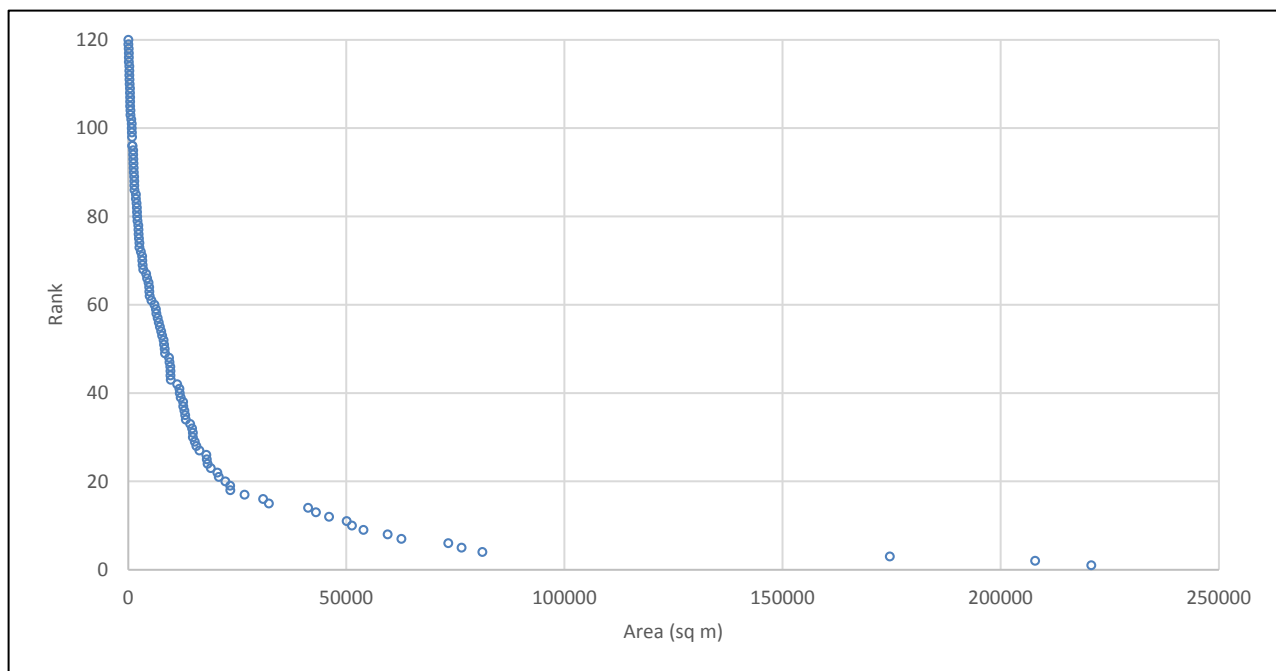


Figure 6-60: The size characteristics of all sites recorded at Calperum and Pike.

The recorded sites are invariably associated with some degree of erosion, either deflation, shallow rills or deeper gulying. Furthermore, each of the sites located along the Pike cliff and along the River Murray bank are essentially sectioned by erosion. On this basis, it is evident that relatively few sites contain deeply stratified deposits, an observation that is consistent with previous assessments of Riverland archaeology. Where excavation has taken place, cultural materials were

recovered from variable depths, though in situ lensed features are invariably found at, or near, the surface. Furthermore, where midden lenses are exposed, these tend to be thin (<10 cm) and discrete features. No thickly mounded shell middens were recorded, though several substantive features have been reported elsewhere in the Riverland (see Chapter 4.3). Oven mounds are a notable exception, and while most examples comprise only thin deposits of accumulated oven debris, several features in excess of ~50 cm thick were also noted.

Media articles relating to Calperum tend to emphasise the margins of Lake Merreti-Clover and Ral Ral Creek where accounts describe 'camp sites and kitchen middens out of number' (Archer Russell 1924) and 'middens and mounds of dark ashy earth thickly impregnated with broken mussel shell and bones' (Archer Russell 1921b) (see Table 1-1). A midden and cemetery along the northern side of Lake Merreti (possibly a reference to CAPR17_24) is described as containing a large quantity of mussel shell and animal bone (Anon 1887). No deposits fitting these descriptions were identified during this research in these specific locations. If the original accounts are accepted as accurate, one plausible explanation is that the natural decay of the material record had accelerated over the past century through the combined effects of pastoral landuse, rabbits and river regulation. A more sobering thought is that the constant replenishment of a material record in a landscape filled with people and activity had ceased within several decades of contact. The media accounts may ultimately provide testament to a peopled landscape that would hitherto be transformed by absence.

Combustion features include examples of surface lit fires, shallow pit ovens and more complex oven mounds. Charcoal is rarely retained other than in the oven mounds. Heat retainer has been utilised in the majority of extant features and is readily identifiable as sub-rounded, moulded clumps of baked sediment often retained within a sediment matrix. Calcrete nodules were used as heat retainer around the periphery of the floodplain and exclusively along the Pike cliff-line. Non-heat retainer fires are represented as more angular, blocky material often eroding from a residual of fire-hardened sediment. It may be the case that the more informal style of cooking represented by these surface features is under-reported in the archaeology and is more likely to be confused with evidence of natural burning.

The diverse range of combustion features implies an equally diverse range of cooking applications. As summarised in Table 4-1, open coal fires were used to cook a range of small mammals, birds, fish and shellfish, while ground ovens were typically constructed for larger game and larger volumes of material. There is, however, considerable crossover between food groups. Ethnohistorical observations of oven mound use relate these features to the large-scale processing of aquatic vegetation, an observation that finds some support in their exclusive distribution around wetland habitats at Calperum and in the broader Riverland (see Jones 2016b; Jones et al. 2017; Jones et al. 2022; Westell and Wood 2014). Of the 255 isolated finds, approximately half relate to dispersed fragments of baked sediment, illustrating the widespread use of fire beyond the confines of site boundaries and presumably through the in-field preparation and consumption of food. The implication is that the faunal assemblages represented in the formal sites will not provide a comprehensive food-list. It is a given that people will have been processed, treated, consumed and disposed of food items in ways that ultimately affect their subsequent detection in the archaeological record.

Artefacts invariably occur in low density and in low numbers in the sites. Where reliable estimates have been recorded (85 sites), artefact numbers of less than 100 were recorded in close to 85% of these sites. Lithic assemblages are dominated by unmodified flakes manufactured in chert and silcrete with lesser components of angular fragments, cores, retouched flakes and grinding material. Similar characteristics have been previously identified in lithic assemblages at Calperum by Thredgold (2017) and Incerti (2018). A small number of artefacts manufactured in quartz, quartzite and mafic volcanic were also noted. Grinding materials were located in 43 sites (37%) and included examples of millstone fragments, mullers, mortars and pestles (see further discussion in Chapter 6.3.8). Formal blades were identified in a small number of sites with the blade reduction observed in CAPR18_S03 representing a unique assemblage.

The frequency of shell and additional faunal elements in the sites at Calperum and Pike are summarised in Table 6-3. As described elsewhere in the Riverland, and in the broader MDB, faunal assemblages are overwhelmingly dominated by the two species of freshwater mussel, *A. jacksoni* and *V. ambiguus*. Species identification was hindered to some extent by the fragmentary nature of much of the shell. Regardless, it is apparent that *V. ambiguus*, i.e. the lagoonal species, dominates the Calperum assemblages. *A. jacksoni* was confidently identified in only four sites at Calperum;

two being located on the bank of the River Murray (CAPR18_S23, CAPR18_S24), one on the bank of a T3 scroll (CAPR19_O01) and one on the Ral Ral Creek anabranch (CAPR17_19). Conversely, the Pike sites are comprised almost exclusively of *A. jacksoni* and to a lesser extent *N. sublineata*. Additional elements include emu eggshell, small unidentifiable fragments of mammal bone, fish (otoliths and bone), yabby (gastroliths and carapace) and turtle. Where present, these materials most commonly occur as a single occurrence in individual sites. Two notable exceptions are CAPR17_10, where a dense spread of fish and small mammal bone occurs in a discrete feature, and CAPR19_J12, where the remains of over twenty yabbies were scattered throughout the site.

A number of rarely reported objects were also recorded. These include a bone point fashioned out of a short, broad section of bone shaft in site PikeSP16_05 (Figure 6-61), a *V. ambiguus* valve with serrated retouch along one edge (Figure 6-62) and noted in a small midden clump in site CAPR17_23 (this had a related ^{14}C age of 542-517 cal BP [OZX286]), a perforated shell fragment recovered from excavation trench TP01 in CPAR17_14 (Figure 6-63) and a flaked tektite identified in CAPR18_S37 (see Roberts et al. 2020). Further detail and regional context for the serrated and perforated fragments is provided in Roberts et al. (2021b).

Table 6-3: The number of sites and sampling locations containing various fauna.

Location	Total	Mollusc				Eggshell		Bone			Yabby	Turtle
		V. ambiguus	A. jacksoni	N. sublineata	Unid mollusc	Emu	Unid	Large mammal	Small mammal	Fish		
Calperum												
Site descriptions	116	73	4	1	-	4	-	1	7	-	6	1
Sampling areas	93	85	4	1	-	1	-	2	3	3	1	-
Pike												
Site descriptions	5	2	4	5	-	-	-	-	-	-	-	-
Sampling areas	29	3	22	5	-	-	-	-	-	-	-	-



Figure 6-61: Exterior (left) and interior (right) images of the bone point located in site PikeSP16_05.

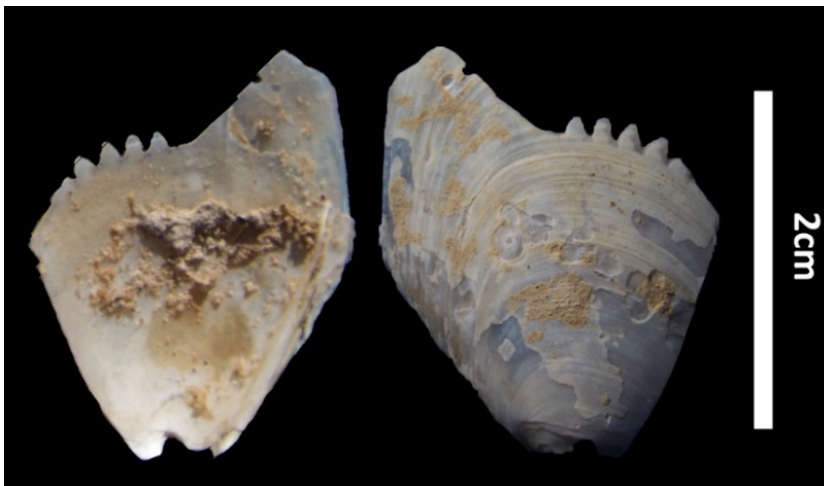


Figure 6-62: Interior (left) and exterior (right) images of the serrated shell located in site CAPR17_23.



Figure 6-63: Exterior (left) and interior (right) images of the perforated shell recovered from excavation trench TP-01 in site CAPR17_14.

6.3.3 Surface sampling

The qualitative site recordings were supplemented with semi-quantitative assessments using of a 1x1 m drawing grid placed over surface exposures, together with detailed inspections of exposed lensed features. Of the 60 gridded samples and additional 59 lens samples, 82 were directly associated with ^{14}C age determinations. A full account of the sampling is presented in Appendix IX with a summary presented in Table 6-4. The gridded sampling covered a total area of approximately 197 m² spread over 24 sites. Given the highly fragmented presentation of shell, the collection of accurate NISP and MNI counts was abandoned in order to increase the time dedicated to spatial coverage. In the majority of instances, only approximate NISP/MNI numbers were collected. In order to limit a potential bias relating to the differential treatment and disposal of faunal remains within an occupation area, an effort was also made to sample various locations within more complex sites, e.g. locations that might be centred on an oven, be peripheral to an oven, be within a clumped midden and more diffuse parts of a scatter.

As with the qualitative site descriptions, freshwater mussel dominates the surface samples. *V. ambiguus* is reported in 88 samples and *A. jacksoni* in 22 samples. There were no instances where both species were reported in the same sample, and indeed, the two species were rarely recorded in the same site (exceptions include the Pike sites, and CAPR17_19 and CAPR19_O01 on the Calperum floodplain). *N. sublineata* was recorded in five of the Pike samples. Importantly, where this species occurs in late Holocene middens at Calperum, it does not present in the same densely packed deposits as seen in the Pleistocene archaeology at Pike. On this basis, it appears that this species had been specifically targeted as an economic resource in the Pleistocene floodplains but collected incidentally during the Holocene. As noted in Chapter 6.2.6, ^{14}C ages returned on *N. sublineata* in the Pike sites also span a narrow timeline c. 12.1–11.2 k calBP.

Additional elements identified in the sampling include emu egg shell, unidentified bone, mammal bone, fish (bone, otolith) and yabby (gastrolith and carapace), a result that essentially replicates the qualitative site descriptions. Where bone was identified, it was fragmentary and undiagnostic. On the basis of the extrapolated circumference of bone fragments and the diameter of cortical bone, it is tentatively suggested that both small and large mammals are represented. Heat retainer was noted in 55 of the sampling locations and stone artefacts were identified in 43. The lithic

assemblages included examples of unmodified flakes, cores, retouched flakes (including adzes and geometrically backed segments), angular fragments and grinding material.

The shell recorded at Calperum tends to be dominated by the smaller component of what might be expected in natural populations of *V. ambiguus* and *A. jacksoni*, whereas the *A. jacksoni*-dominated middens at Pike include valve sizes more representative of a natural range³². A set of near complete *A. jacksoni* in site CAPR19_O01 is shown in Figure 6-64 alongside the typically larger individuals found in PikeSP16_01, for example. Admittedly, this observation is based on an extremely small sample given the typically fragmented presentation of shell (Figure 6-65), though it is tentatively supported by counts of annular rings on larger fragments. Up to eight annular rings were noted on larger fragments of *V. ambiguus* excavated from CAPR17_14 (Lake Woolpoolool), for instance, confirming that these were mature though not necessarily fully grown individuals. The breakage pattern in itself might also provide proxy evidence of a bias toward less robust, thinner/smaller and younger individuals at Calperum.

The lack of a robust sample makes it difficult to assess whether mussel colonies at Calperum were, at times, exploited to such a degree that individual shells were unable to develop to their full growth potential. It is also noted that a similar breakage pattern may be indicative of high treadage or a range of other factors. However, based on qualitative, though consistent observations, it is tentatively suggested that this scenario may indeed be the case, i.e. that the Calperum middens illustrate a more sustained exploitation of freshwater mussel colonies that skewed the natural size range of both *V. ambiguus* and *A. jacksoni*. In respect to *N. sublineata*, the broad size range (see Figure 6-66) indicates an indiscriminate collection method of this shell species as opposed to an initial size selection. These shells were possibly dragged *en masse* from biofilms on submerged logs and reed stems. Small conical gastropods, possibly *Plotiopsis balonnensis* (Robert Jones pers. comm. 2021), were recovered from the *N. sublineata* lens in excavation trench TP03 in PikeSP16_05 are a likely bycatch, and again, indicate an indiscriminate collection method for *N. sublineata*.

³² According to Walker et al. (2001), both species of freshwater mussel reach maturity within 3–4 years. *V. ambiguus* and *A. jacksoni* can grow to maximum valve lengths of ~110 and 170 mm, respectively.

Table 6-4: A summary of archaeological materials identified in surface samples and at additional ¹⁴C sampling locations in each site.

Site_ID	No. SQ	SQ_Size (sq m)	Additional 14C samples	Shell	Bone			Mammal	Bird	Fish	Unid	Yabby	Combustion material*	Lithics**
				V. <i>ambiguus</i>	A. <i>jacksoni</i>	N. <i>sublineata</i>								
CAPR17_05	-	-	1	x									HR	fl (1)
CAPR17_09	2	8	1	x									HR	fl (1)
CAPR17_10	10	59	1	x				5		catfish (1)			HR/SS	fl (18), gst-ts (1)
CAPR17_14	6	18	5	x							1	1	HR	fl (33), r/u fl (1)
CAPR17_17	01	4	-	x									HR	
CAPR17_19	11	17	8	x		x				perch (1)			HR	
CAPR17_22	2	8	-	x									HR	fl (2)
CAPR17_23	1	2	3	x									SS	fl (2), cr (2), a-frg (1)
CAPR18_A09	5	9	-	x						unid (1)			HR/SS	fl (1), a-frg (1), r/u fl (1)
CAPR18_S02	-	-	1	x									HR	fl (1)
CAPR18_S06	6	25	2	x									HR	fl (38), cr (1), adze (1), bck seg (1)
CAPR18_S08	3	7	1	x									HR	
CAPR18_S11	-	-	1	x										
CAPR18_S24	-	-	3			x							HR	
CAPR18_S25	-	-	2			x								
CAPR18_S36	4	17	-	x					emu egg (1)				HR	fl (11), a-fgr (1), gst-ts (1)
CAPR18_S37	-	-	5	x									HR	nd
CAPR18_S41	-	-	5	x									HR	
CAPR19_M03	-	-	1	x										
CAPR19_O01	5	8	-	x			x						HR	
PikeAWE15_10	2	7	7			x							HR	fl (9)
PikeSP16_01	2	8	7	x		x							HR	fl (3)
PikeSP16_05	-	-	3			x	x							
PikeSP16_07	-	-	2			x	x							

* HR – heat retainer, SS – stained soil ** fl – flake, a-frg – angular fragment, gst-ts – grinding topstone, bck seg – backed segment



Figure 6-64: A comparison of consistent *A. jacksoni* sizes noted in CAPR19_O01 (left) and PikeSP16_01 (right). The CAPR19_O01 sample includes valves that are significantly smaller than the growth potential in natural populations illustrated in the PikeSP16_01 sample.

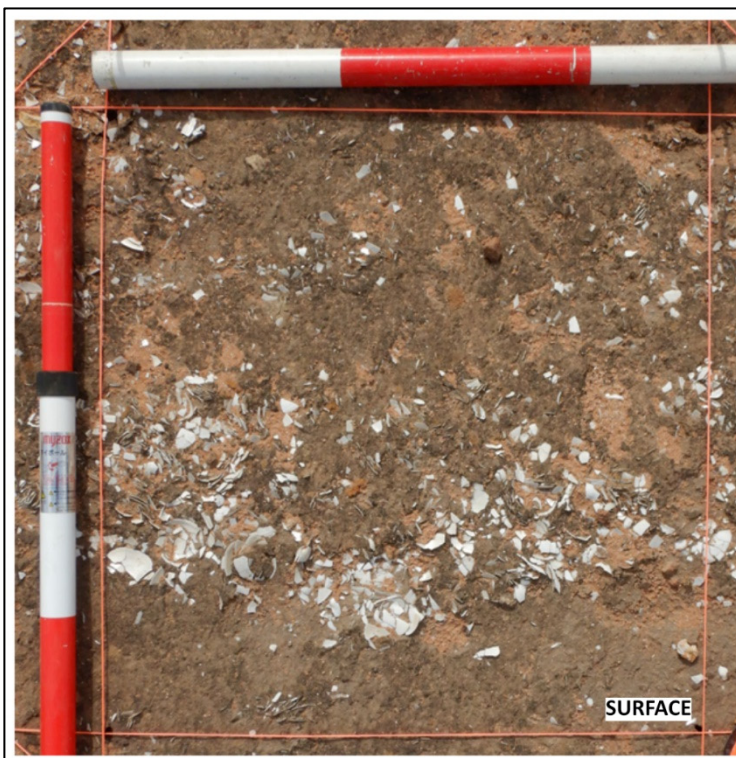


Figure 6-65: The breakage pattern in *V. ambiguus* collected from CAPR17_14 trench TP01.



Figure 6-66: The size range of *N. sublineata* from excavation trench PikeSP16_05 TP03.

6.3.4 Excavation

Excavations were conducted in four sites and a total of eight trenches. In summary, the recovered faunal, combustion and lithic material essentially replicates the results of both the surface sampling and qualitative site recording. Fauna is dominated by freshwater mussel with minor fish, yabby and small fragments of unidentified bone also recovered. The shell invariably occurs as fragmented material with very few complete valves preserved. As such, species identification has relied largely on the material exposed in the surrounding areas and, as with the site records, can be confidently assigned to *V. ambiguus* at Calperum and *A. jacksoni* at Pike, for the most part. No diagnostic bone fragments were recovered in any of the excavations, though as with the material assessed in the surface samples, the thickness of the cortical bone suggests mammal rather than fish, rodent or bird. Very few stone artefacts were recovered. A summary of each excavation is provided in the following sections.

6.3.4.1 CAPR18_S37

CAPR18_S37 (Figure 6-67) is situated on a high terrace overlooking the north-western margin of Lake Woolpoolool. The terrace is overlain by a long, gently sloping sand sheet extending east from the Outer Lake C lunette and is truncated by an abrupt bank which dips steeply over approximately 5–6 m to a beach developed around the shore of Lake Woolpoolool. The site is one of the larger open scatters recorded at Calperum, occupying an area of approximately 21 ha and comprising a patchy exposure of shell midden including several dense accumulations continuing through the central and western sections of the site and along the eastern boundary. These concentrations are linked through a more diffuse scatter of shell, stone artefacts and heat

retainer. Midden is typically exposed in shallow (10–30 cm deep) track cuttings and in deflation hollows, scouring, rills, animal tracks and around rabbit warrens. Small amounts of shell are also observed in a slope deposit draping the terrace margin. The midden is comprised exclusively of *V. ambiguus*. Stone artefacts occur in low numbers and comprise unmodified flakes in chert and silcrete together with a small number of cores and at least one grinding topstone. A retouched flake developed on a tektite has also been reported in this site (Roberts et al. 2020).

The site was selected for excavation given its relatively protected location on a high bank well above regular flood level under the modern regime. The development of a long tail slope and aeolian cover extending east of the Outer Lake C lunette also highlighted a potential for the burial of cultural material. Surface exposures suggested a relatively dense, albeit patchy, midden.

Trench TP01

A single 50x50 cm trench (TP01) was excavated in the south-western section of the site adjacent to an exposure of fragmented shell brought to the surface through animal scuffing (Figure 6-68). The excavation continued to a hard, carbonate subsoil at a depth of only 18 cm. Four stratigraphic units were identified (SU1–4) with archaeological material contained for the most part to a discrete, thin shell lens in SU2 (Figure 6-69). Disseminated shell fragments continued into SU1 and SU3. Few diagnostic fragments were recovered though all shell noted in the broader scatter is *V. ambiguus*. No artefacts or hearth material were recovered.

A single ¹⁴C sample (shell) from the top of SU2 returned an age of 9088–8771 cal BP (OZZ006). This is the oldest of a series of age estimates grouped through the south-central section of the site and returned on discrete midden features exposed in track cuttings (Wk-53894 and Wk-53895) and deflations (Wk-52352) within the aeolian cover, or incorporated as a patchy lens in slope deposits (OZZ001) (see Figure 6-67 and 6-35). As described in Chapter 6.3.2, OSL sample WOL-12 was placed in a gypsum sand packed against the terrace and included a major component of 8.6–7.8 ka. This age is difficult to reconcile against additional evidence in the floodplain, including the reinundation of Rotten Lake by c. 7.8 ka and dating of midden shell in this site.

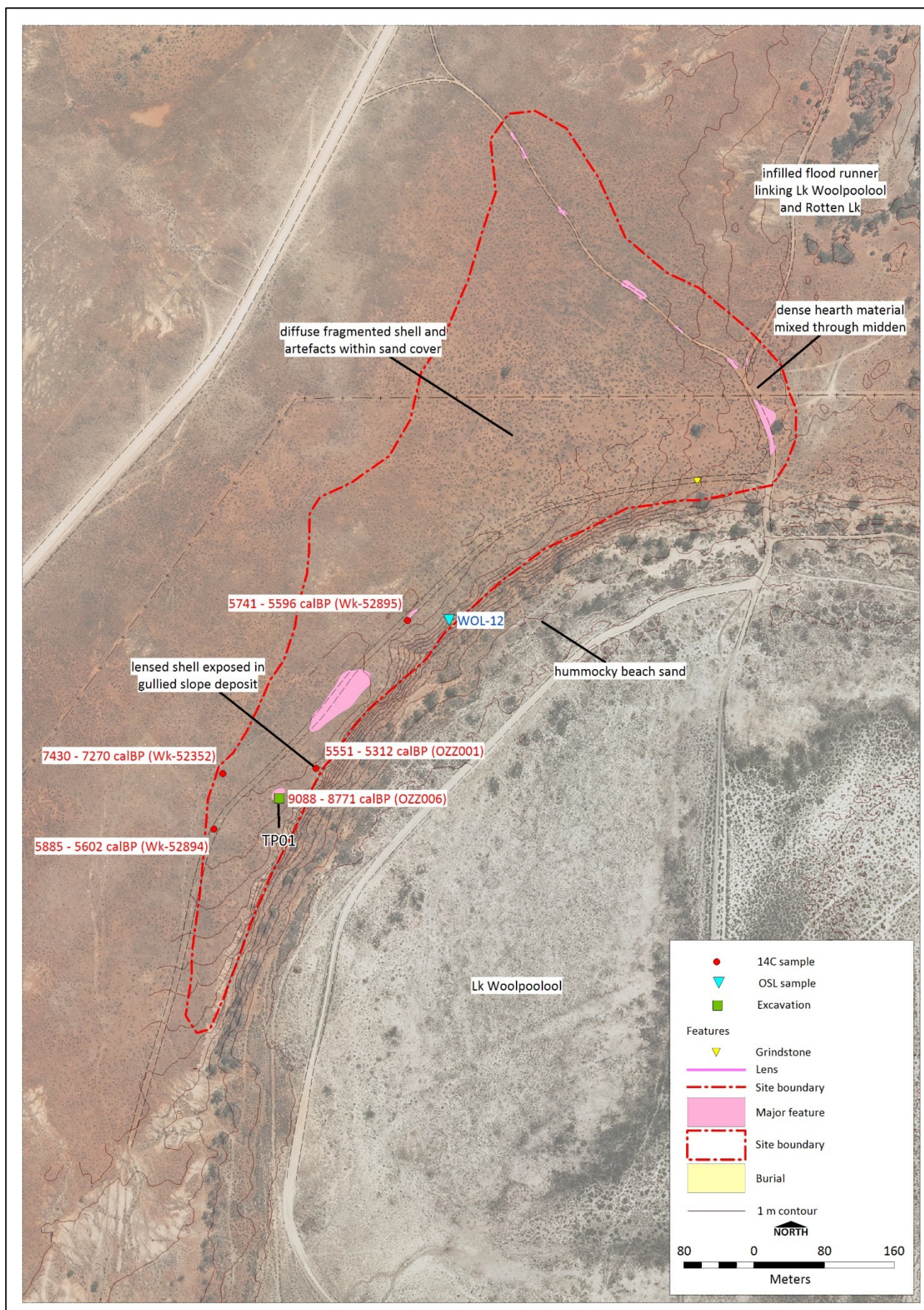


Figure 6-67: CAPR18_S37 site plan showing ^{14}C sampling results and the location of TP01.

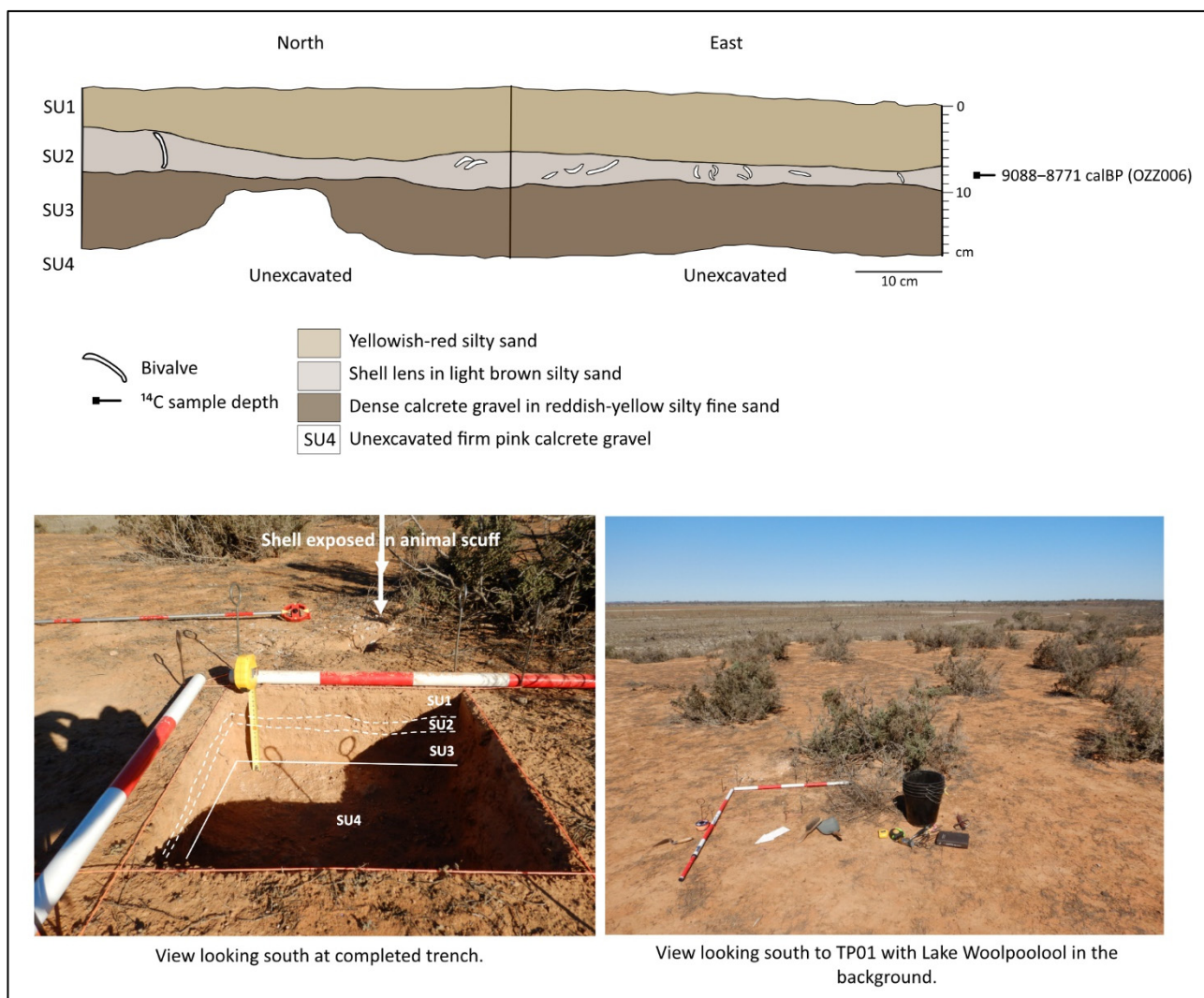


Figure 6-68: North and east sections drawings of TP01 (CAPR18_S37) together with context images.

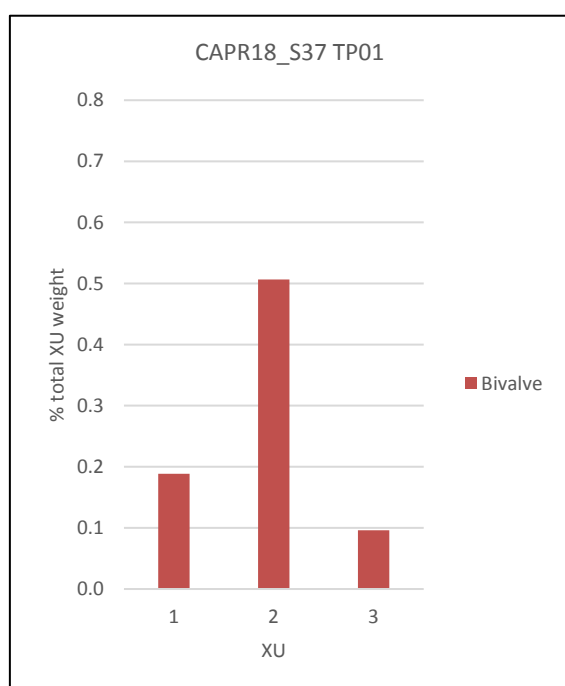


Figure 6-69: The weight of shell expressed as a percentage of the total bucket weights in each XU in excavation trench CAPR18_S37 TP01.

Table 6-5: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴C samples in CAPR18_S37 TP01.

SU	Description	Munsel	XU	Bucket weight (net kg)	Depth (cm)		pH	Dating		
					Min	Max		Depth	Material	Age (lab code)
1	Loose, yellowish-red silty fine sand with minor inclusions of small calcrete nodules (<20 mm) and fragmented <i>V. ambiguus</i> .	5YR 5/6	01	24.0	0	4				
2	Dense, fragmented <i>V. ambiguus</i> fragments in loose – friable, light brown silty fine sand with minor small calcrete pebble inclusions.	5YR 6/4	02	9.3	4	7	8.0	4 cm	<i>V. ambiguus</i>	9088–8771 cal BP (OZZ006)
3	Dense calcrete gravel (<30 mm diameter) in friable, reddish-yellow silty fine sand matrix. Small amount of highly fragmented shell.	5YR 6/6	03	26.7	7	19	8.5			
4	Firm, pink calcrete gravel with chalky appearance.	-	-	Unexcavated			-			

Table 6-6: Summary of fauna, combustion material and lithics recovered from CAPR18_S37 TP01.

Fauna											
SU	XU	Shell	NISP*	Wt (gms)	Fish (element/NISP)	Mammal (element/NISP)	Yabby (element/NISP)	Unid bone (element/NISP)	Combustion material (no.)	Artefact type (no.)	Other notes
1	1	<i>V. ambiguus</i>	570	44							Disseminated shell
2	2	<i>V. ambiguus</i>	170	46							Thin, densely packed shell lens
3	3	<i>V. ambiguus</i>	170	25							Disseminated shell

*approximate NISP values only

6.3.4.2 CAPR17_14

This extensive (5.1 ha) open scatter continues along the margin of a high terrace and across two dune ridges truncated at the western shoreline of Lake Woolpoolool (Figure 6-70). A diffuse scatter of stone artefacts continues to the north across a lower sandy beach-ridge. The site is formed around a series of exposures of dense shell midden partitioned by a more diffuse scatter. Stone artefacts and hearth material occur in low densities throughout. Two burial locations were also identified together with a range of historic material including flaked glass and a clay pipe stem (see Munt 2022). A series of ^{14}C ages returned on exposures of shell midden include samples OZZ006 and OZX284 which provide a minimum age of ~9.5–8.7 ka for the development of a prominent Wfm dune and a carbonate soil within this dune. The soil is exposed on the southern slope of the dune and is assumed to be the source of gravel reworked into a low beach-ridge extending along the terrace edge to the north (see Figure 6-70).

Trench TP01

Excavation trench TP01 (50x50 cm) was located in the northern section of the site where a series of ^{14}C samples had returned median calibrated ages of between ~0.8 cal kBP (OZX283 and Wk-48701) and ~3.7 cal kBP (OZX282) on exposed midden. The trench was centred on sample Wk-48701. The surrounding terrace retains a relatively deep covering sand and offered some potential for stratified deposit extending between, and beyond, the late Holocene chronology already established in the ^{14}C sampling.

The excavation continued to a hard, silty sand surface (SU4) at a depth of 48 cm (Figure 6-71). Four stratigraphic units were identified (SU1–4) (Table 6-7) with archaeological material contained for the most part, to a thin lens of freshwater mussel shell (SU1) exposed at the surface (Table 6-8, Figure 6-72). Disseminated shell fragments and heat retainer continued through SU2 and SU3 in no discernible features other than a vague band in SU3 between a depth of 24–29 cm. SU4 remained unexcavated. The shell presented as typically small, angular fragments with the occasional complete valve of *V. ambiguus* also identified. The broader scatter is comprised exclusively of *V. ambiguus*. Additional fauna included two fish vertebrae, two yabby gastroliths and a small undiagnostic bone fragment presumed to be mammal based on the thickness of the cortical bone. Six stone artefacts, all comprising chert flakes, together with fragments of baked sediment were also recovered. A single ^{14}C age of 770–680 cal BP (OZZ008) was returned on shell

from a depth of 32 cm in SU3. Based on the calibrated ranges of this sample together with Wk-48701 recovered from SU01, a likely scenario is that TP01 captures at least two closely timed phases of midden development between 770–735 cal BP together with a significant turnover and fragmentation of the initial deposit in the intervening period.

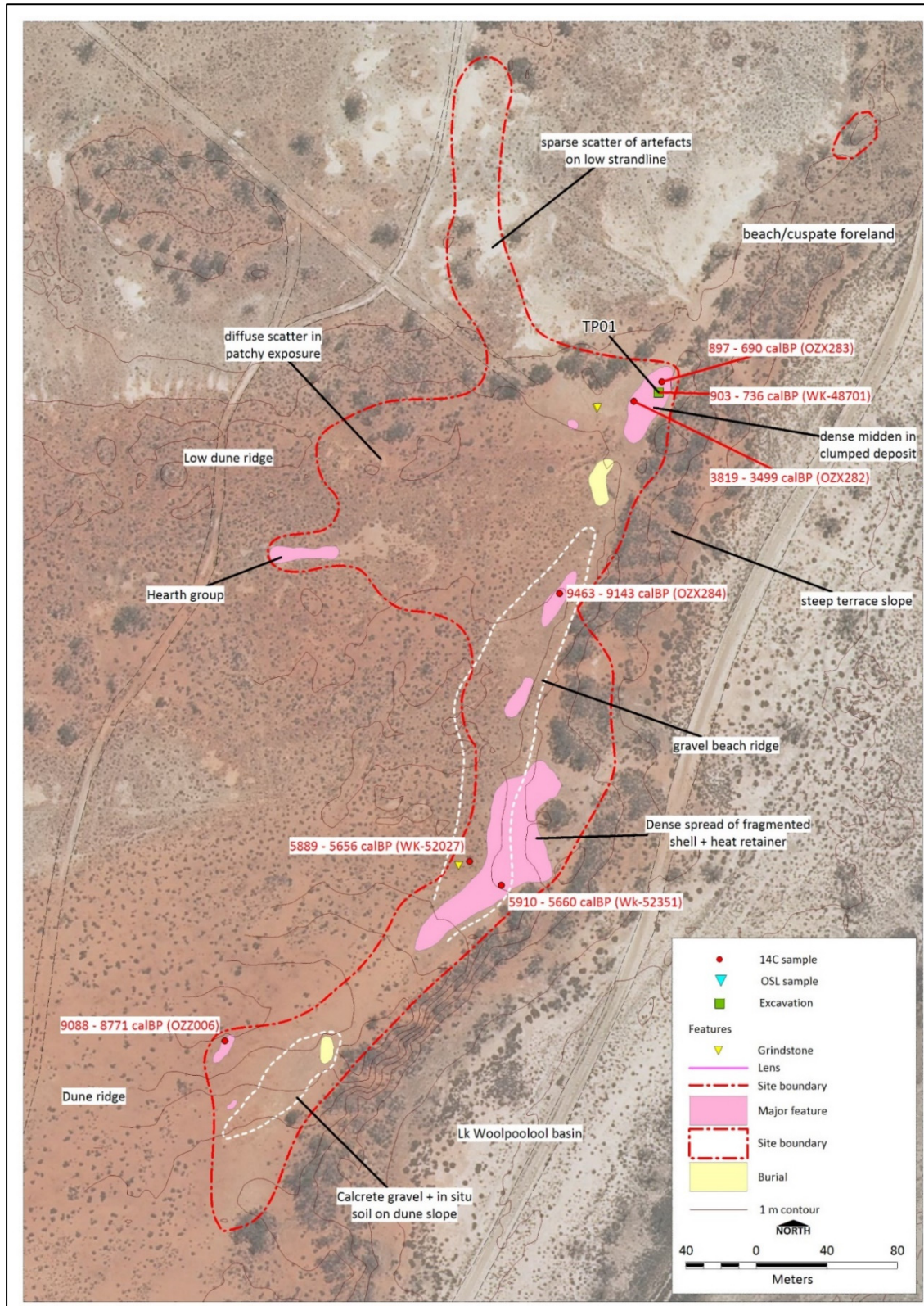


Figure 6-70: CAPR17_14 site plan showing ¹⁴C sampling results and the location of TP01.

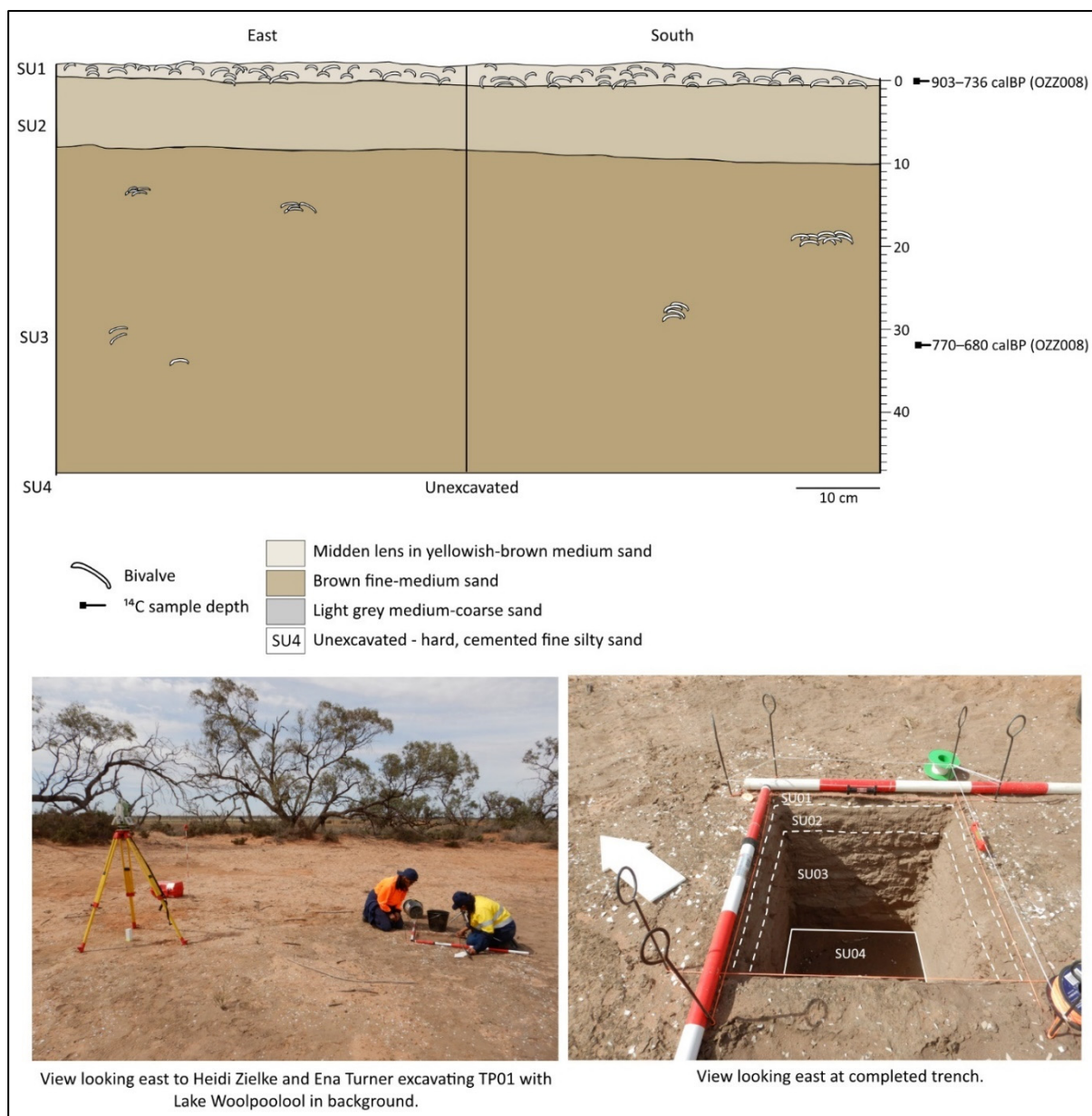


Figure 6-71: Section drawing and context images of TP01 (CAPR17_14).

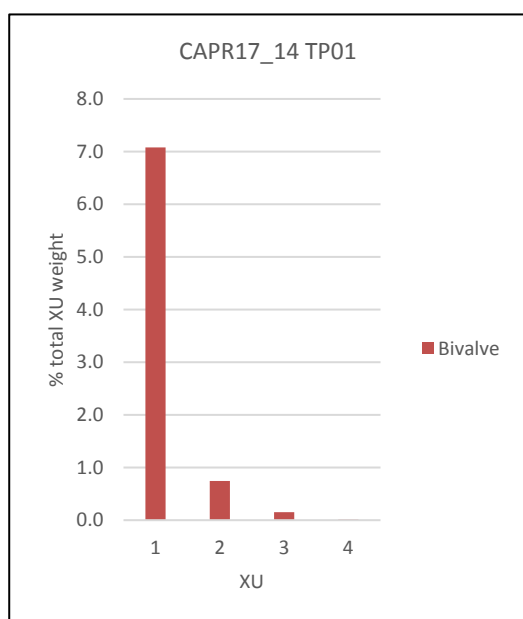


Figure 6-72: The weight of shell as a percentage of the total bucket weights in each XU in excavation trench CAPR17_14 TP01.

Table 6-7: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴C samples in CAPR17_14 TP01.

SU	Description	Munsel	XU	Bucket weight (net kg)	Depth (cm)		pH	Dating		
					Min	Max		Depth	Material	Age (lab code)
1	Densely packed shell (<i>V. ambiguus</i>) midden small number of associated heat retainer fragments and stone artefacts exposed on deflationary surface in loose dark yellowish-brown medium sand. Potential ash staining.	10YR 4/4	1	9.85	0	2	8.0	Surface	<i>V. ambiguus</i>	903–736 cal BP (Wk-48701)
2	Loose pale brown fine-medium sand with minor fragmented shell valves disseminated throughout and as small clumps toward base of unit.	10YR 6/3	2	21.94	2	10				
3	Loose, light grey medium-coarse sand with minor heat retainer in vague band ~24-29 cm in no discernible feature and minor fragmented shell throughout.	10YR 7/2	3	58.18	10	33		32 cm	<i>V. ambiguus</i>	770–680 cal BP (OZZ008)
			4	39.02	33	47				
4	Hard, cemented fine silty sand.	-	Unexcavated		47	-	-			

Table 6-8: Summary of fauna, combustion material and lithics recovered from CAPR17_14 TP01.

Fauna											
SU	XU	Shell	NISP*	Wt (gms)	Fish (element/NISP)	Mammal (element/NISP)	Yabby (element/NISP)	Unid bone (element/NISP)	Combustion material (no.)	Artefact type (no.)	Other notes
1	1	<i>V. ambiguus</i>	2800	678			Gastrolith (1)		Bck sed (10)	Cht fl (1)	6-7 annular rings on valve fragments
2	2	<i>V. ambiguus</i>	801	163					Bck sed (25) Mcharc (3)	Cht fl (1)	Includes a perforated fragment
3	3	<i>V. ambiguus</i>	1450	88	Unid (vert/1)	Unid (cortical bone/1)	Gastrolith (1)		Bck sed (100) Mcharc (4)	Cht fl (4)	
3	4	<i>V. ambiguus</i>	125	5					Bck sed (15) Mcharc (100)	-	

*approximate NISP values only

6.3.4.3 CAPR18_S41

This site is located in a backplain area relatively remote from any water frontage. The site is perched on the edge of a terrace overlooking a broad samphire and chenopod marshland to the west. Based on flood inundation modelling, the marsh would be inundated at a minimum of a 1 in 10-year flood under unregulated conditions. The terrace is truncated by a distinct slope of ~2 m elevation that is traceable for over 2 km and is interpreted as the outer cut bank of a T2a scroll. This scroll had extended north of the site through what is now the modern Lake Merreti–Clover basin with the marshland formed in the infilled T2a channel trace. The setting, therefore, captures an extended period of floodplain development from an original channel bank formed ~43 ka. A series of discrete midden and midden/hearth features continue across the site area of 4.1 ha with a diffuse scatter lying between. An outlying site (CAPR19_M03) located 160 m to the northeast is similarly developed around a series of three discrete, clumped midden features. It was anticipated that a series of ¹⁴C samples (shell) from shell midden spread across CAPR18_S41 and from CAPR19_M03 would capture an extended chronology reflecting this landscape context. However, all ages fell within a remarkably short time span of 535–490 cal BP based on the calibrated ranges. Excavations were conducted in two locations (Figure 6-73) in order to test this chronology.

Trench TP01

TP01 (50x50 cm) was positioned adjacent to a densely packed shell midden exposed in a stiff silty sand in the surface of a vehicle track (Figure 6-74). This appeared to sit below a thin shell lens exposed in a loose sand cover 36 m to the south of TP01 and dated to 538–490 cal BP (WK-50692). Four units were identified in TP01 (Table 6-9) with a thin midden lens intercepted as SU2. No material other than fragmented valves of *V. ambiguus* were recovered (Table 6-10). The excavation continued to a depth of 22 cm within SU4; a firm, fine sand that required the use of a pronged mattock to penetrate. An age of 527–493 cal BP (OZZ005) was returned on shell fragments from SU2, again falling within the narrow period represented by the surface sampling.

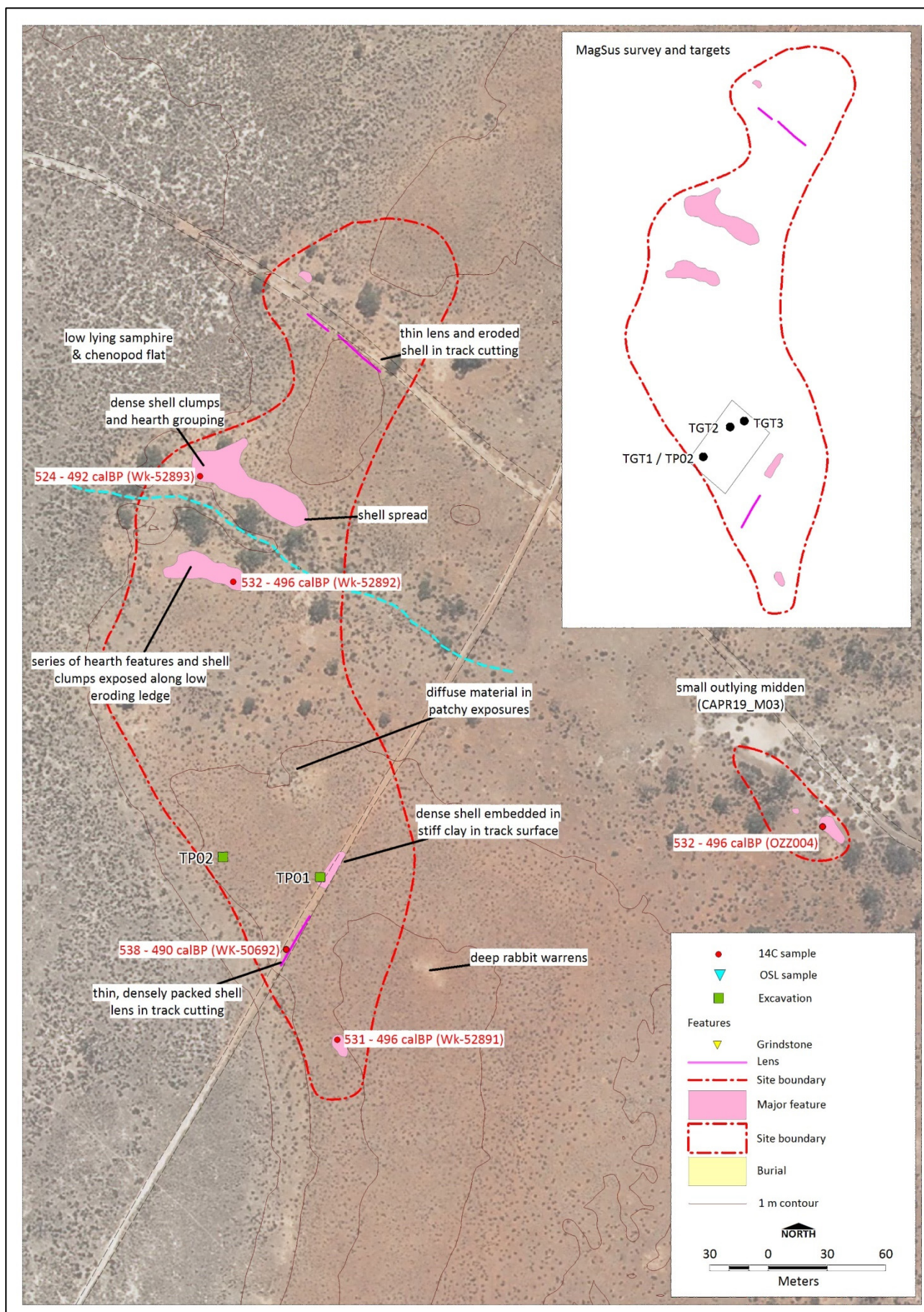


Figure 6-73: CAPR18_S41 site plan showing ^{14}C sampling results and the locations of TP01, TP02 and the magsus survey and targets (TGT).

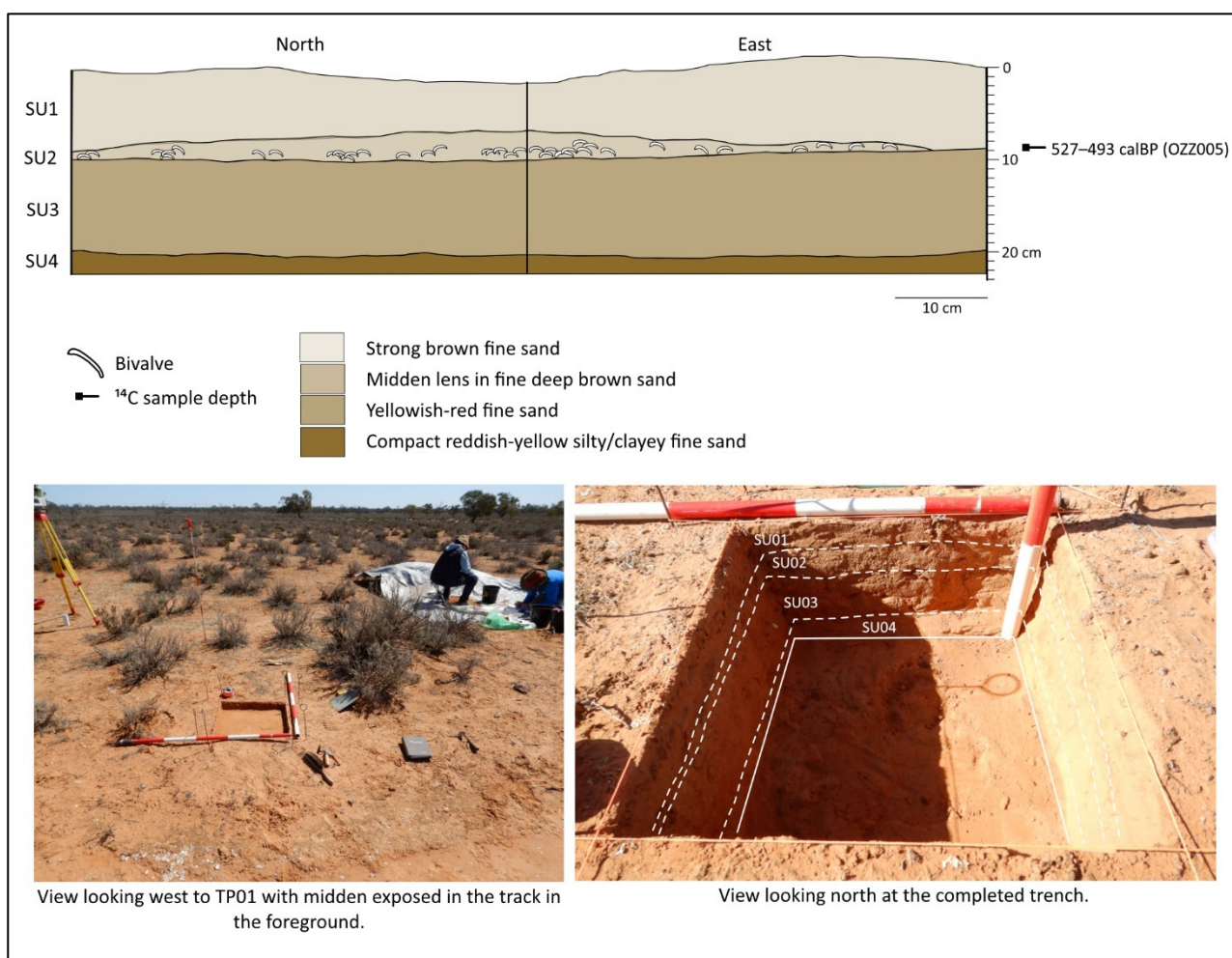


Figure 6-74: North and east section drawings of TP01 (CAPR18_S41) together with context images.

Table 6-9: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴C samples in CAPR18_S41 TP01.

SU	Description	Munsel	XU	Bucket weight (net kg)	Depth (cm)		pH	Dating		
					Min	Max		Depth	Material	Age (Lab code)
1	Loose, strong brown fine sand with small amount (<5 gms) of finely fragmented shell. No other inclusions.	7.5YR 5/6	01	22.0	0	5	7.0			
2	Thin lens of densely packed, fragmented <i>V. ambiguus</i> in deep brown fine sand.	7.5YR 4/6	02	27.3	5	11	7.0	9 cm	<i>V. ambiguus</i>	5741–5596 cal BP (Wk-52895)
3	Friable, yellowish-red fine sand with minor amount (<2 gm) of finely fragmented shell.	5YR 5/6	03	24.9	11	20	7.5			
4	Compact, stiff reddish-yellow silty fine sand – clayey sand with single small (5 mm) calcrete nodule.	5YR 4/4	04	2.3	20	22	-			

Table 6-10: Summary of fauna, combustion material and lithics recovered from CAPR18_S37 TP01.

Fauna										
SU	XU	Shell	NISP*	Wt (gms)	Fish (element/NISP)	Mammal (element/NISP)	Yabby (element/NISP)	Unid bone (element/NISP)	Combustion material (no.)	Artefact type (no.)
1	1	<i>V. ambiguus</i>	217	12						
2	2	<i>V. ambiguus</i>	410	19						Discrete, thin lensed feature
3	3	<i>V. ambiguus</i>	16	9						Termite tunnel in upper 4 cm
4	4	<i>V. ambiguus</i>	1	<1						

*approximate NISP values only

Trench TP02

TP02 (100x50 cm) was positioned over the most significant of three magsus targets identified by Dr Ian Moffat as potential buried combustion features (see Chapter 5.4.5). Excavation continued across three stratigraphic units (Figure 6-75, Table 6-11) to a hard, basal clay (SU3) at only 14.5 cm depth. The excavation intersected several small fragments of baked sediment though did not reveal an in situ feature or any other cultural material that would otherwise explain the magsus response (Table 6-12).

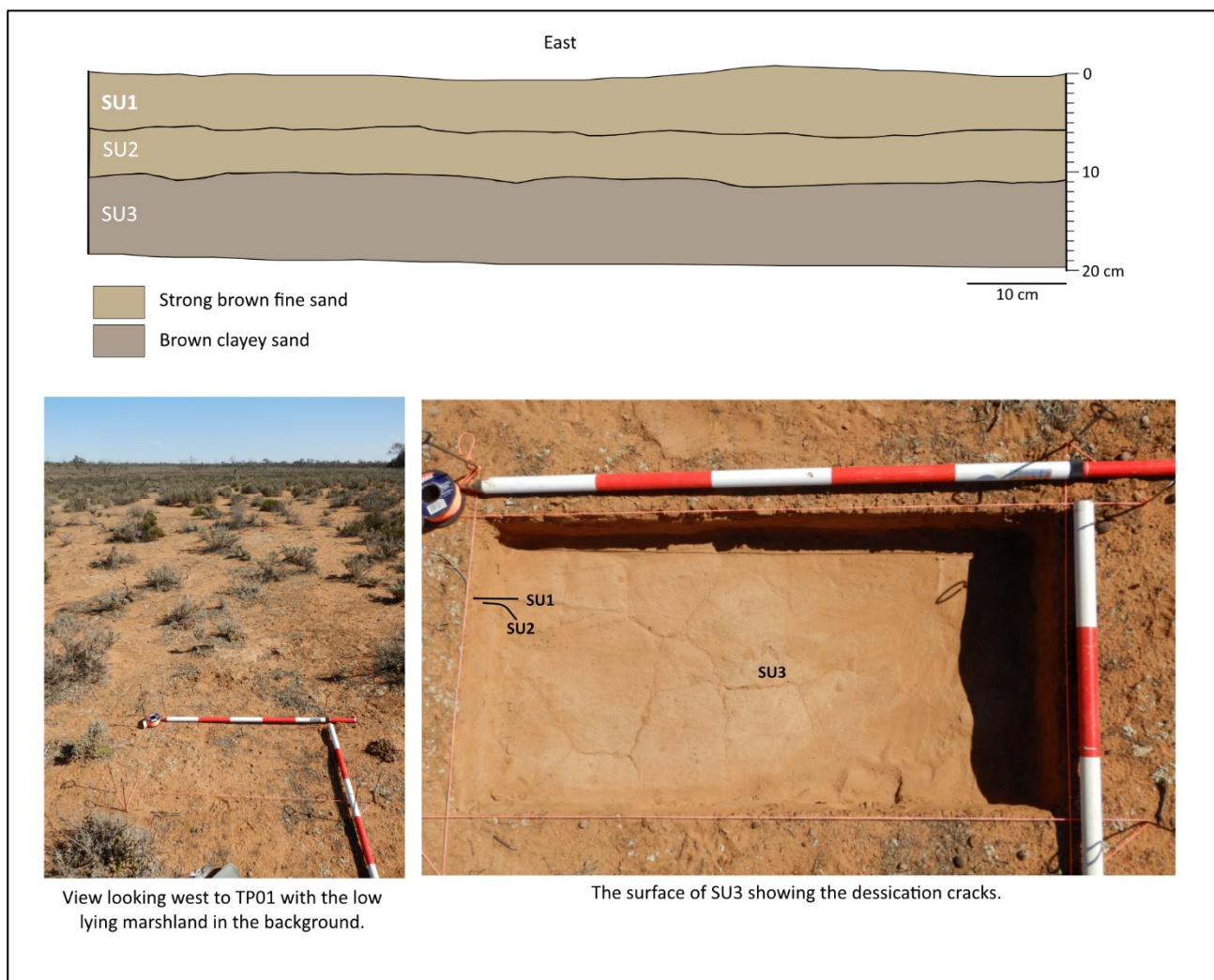


Figure 6-75: East section drawing of TP02 (CAPR18_S41) together with context images.

Table 6-11: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴C samples in CAPR18_S41 TP02.

SU	Description	Munsel	XU	Bucket weight (net kg)	Depth (cm)		pH	Dating		
					Min	Max		Depth	Material	Age (Lab code)
1	Weak, well sorted, strong brown fine sand.	7.5YR 4/6	01	72	0	8				
2	Friable, strong brown fine sand with several fragments of baked sediment.	7.5YR 4/6	02	20.3	8	15				
3	Firm, brown clayey sand with no inclusions. Required mattock to excavate.	7.5 YR 4/4	03	34.2	15					

Table 6-12: Summary of fauna, combustion material and lithics recovered from CAPR18_S37 TP02.

SU	XU	Fauna						Combustion material (no.)	Artefact type (no.)	Other notes
		Shell	NISP*	Wt (gms)	Fish (element/NISP)	Mammal (element/NISP)	Yabby (element/NISP)	Unid bone (element/NISP)		
1	1									
2	2								Bck sed (15)	Baked sediment in no feature
3	3									Desiccation cracks in surface

*approximate NISP values only

6.3.4.4 PikeSP16_05

PikeSP16_05 forms part of a semi-continuous scatter of shell midden, hearth material and artefacts continuing around the south-eastern cliff-line of the Pike floodplain. The site is typical of the broader scatter and is characterised by a series of thin, densely packed lenses of shell midden exposed around the eroding rim of the cliff and a patchy exposure continuing away from the cliff edge (Figure 6-76). Shell is dominated by *A. jacksoni*, though *N. sublineata* also represents a common element. *V. ambiguus* is occasionally identified and tends to occur in surface exposures away from the cliff. Intact and eroded hearth features together with typically low densities of stone artefacts continue throughout the site. The site occupies an area of 2.3 ha, though the eastern boundary continues into the adjoining property and was unable to be fully defined. The northern boundary and central part of the site have also been truncated by excavations relating to the installation of irrigation pipes and a quarry, respectively.

The site extends across a broad (~250 m wide), 6.5 m high, east–west trending dune ridge that, based on OSL dating, appears to have developed to at least c. 70 ka (see Chapter 6.2.6). A deep carbonate palaeosol has formed across the original feature and is overlain by a thin, patchy cover of unconsolidated calcrete gravel and aeolian sand. The migration of the river corridor has truncated the dune, producing a spectacular, 30 m high cliff that rises sharply across a narrow, boulder scree from the floodplain (Figure 6-77). A narrow shelf formed on the upper surface of the Blanchetown Clay juts out from the base of the older dune at the top of the scree. A series of large, tilted sediment blocks along the cliff in the area of PikeSP16_05 also suggest that erosion had undercut sediments between this shelf and a platform developed on the overlying dune palaeosol (Figure 6-78).

Excavations were conducted in four locations in PikeSP16_05 (Figure 6-76) with the complementary aims of investigating the structure of the aeolian cover, to intercept and determine a reliable chronology for the cultural deposit, sample and compare ages of *N. sublineata* and *A. jacksoni* midden, and recover a charcoal sample from a combustion feature contained in a gravel unit below the upper aeolian cover sand (TP02) (Figure 6-77).



Figure 6-76: PikeSP16_05 site plan showing the locations of 14C sampling on surface exposures and the test pits.



Figure 6-77: View looking north along the Pike cliff with TP02 (hearth) adjacent to the range pole. The Pike River anabranch is visible in the left of the image.



Figure 6-78: View looking north along the Pike cliff showing the relationship between the loose aeolian cover and underlying hardpan. Also shown are tilted sediment blocks suggestive of undercut erosion.

Trench TP01

TP01 was laid out as a 1.0 x 0.5 m trench orientated east-west and positioned ~8 m from the rim of the cliff. Thin midden lenses and a group of calcrete cobbles with the appearance of a hearth feature had been sectioned by erosion along the adjacent cliff (Figure 6-79). The hearth rested on a unit of dense, fine-medium calcrete gravel. The two stratigraphic units identified in TP01 (Figure 6-80, Table 6-13) and can be directly correlated to the cliff exposure. Both units are based on a fine aeolian sand though with an increasing component of calcrete gravel toward the base of SU2. The excavation of SU2 occurred in a smaller (50 x 30 cm) portion of the trench and continued to a stiffer calcrete rubble surface at a depth of 58 cm.

A small amount of finely fragmented bivalve and several intact *N. sublineata* were recovered together with a single rabbit bone (Table 6-14). The valve fragments were too small to be identified to genus. A small amount of charcoal was also recovered. The archaeological materials in TP01 were disseminated throughout the units in no discernible feature. Shell fragments from the upper section of SU1 and from ~36 cm depth in SU2 returned calibrated ages of 8177–8020 cal BP (OZZ018) and 10,128–9563 cal BP (OZZ019), respectively. Given the presence of lensed features along the cliff, the impression from TP01 is of a site developed around a series of discrete and spatially separated features that have been continually reworked into the aeolian cover. This assessment is further supported by results in trench TP04A (see below).

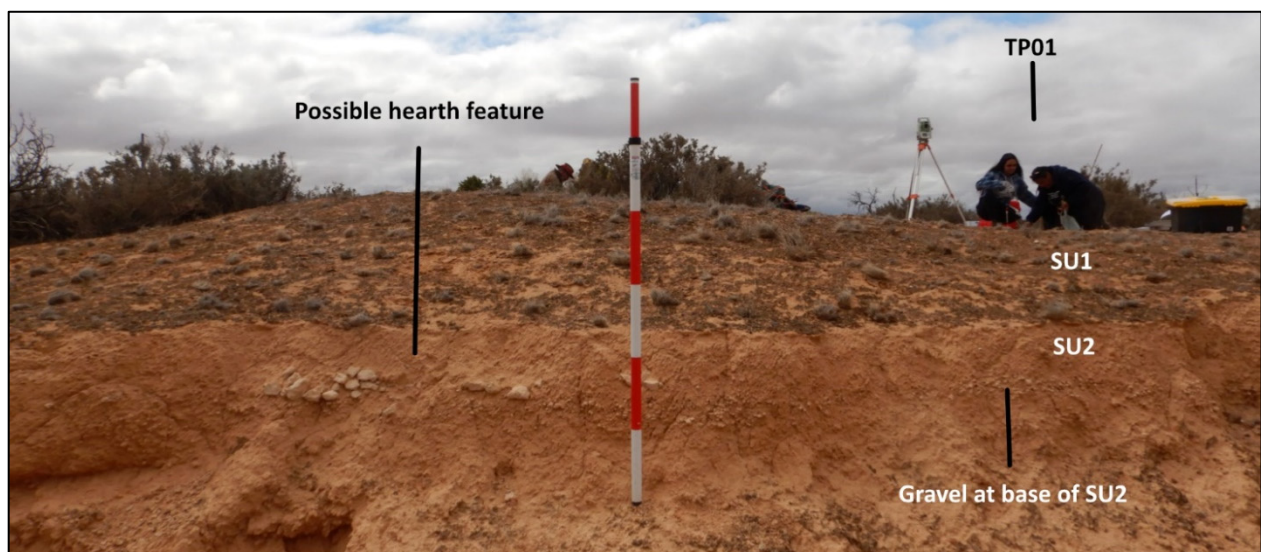


Figure 6-79: View looking east to the cliff with stratigraphy extrapolated from TP01. Also shown is a possible hearth feature.

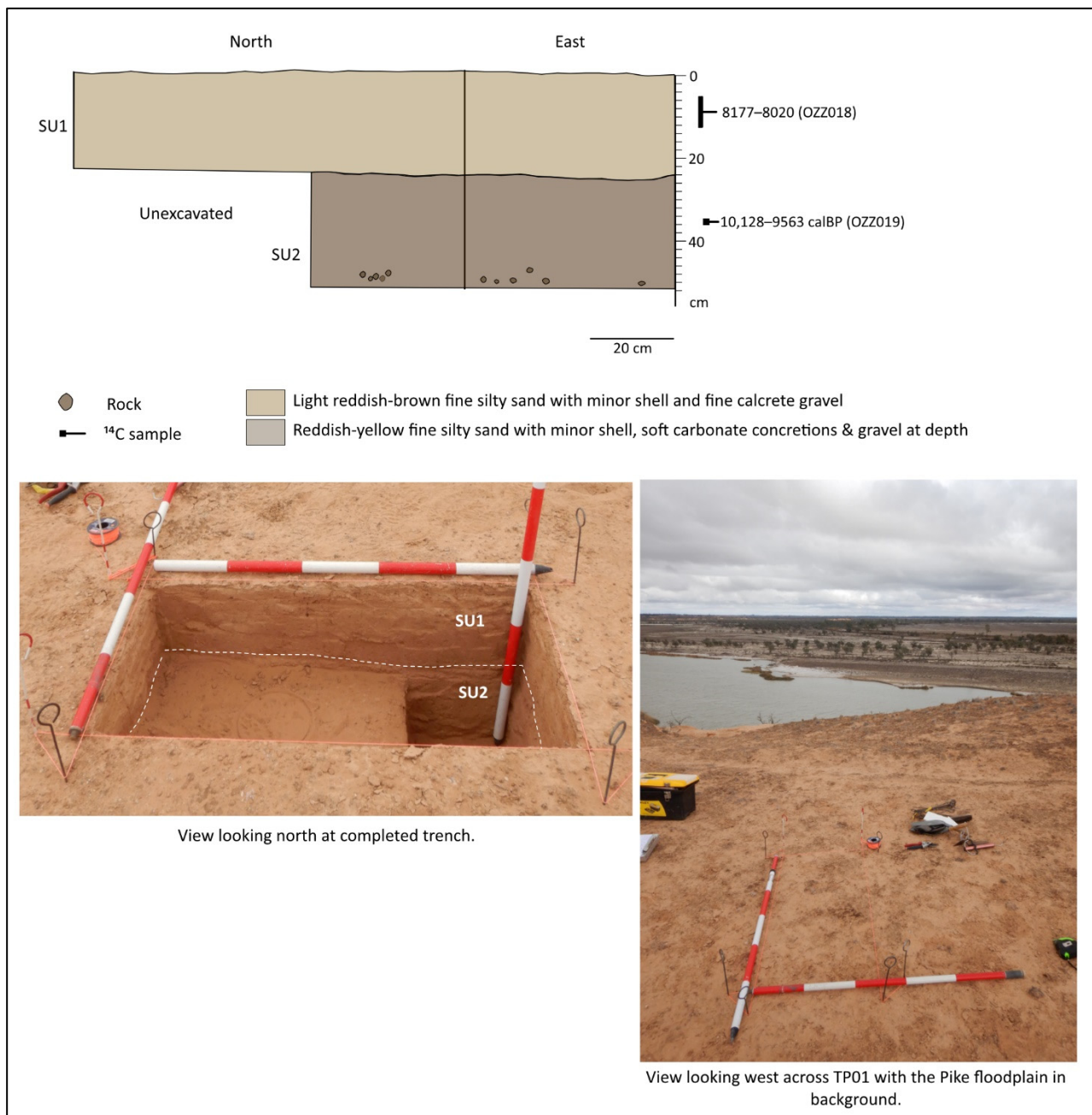


Figure 6-80: Section drawing and context images of TP01 (PikeSP16_05).

Table 6-13: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴C samples in PikeSPS16_05 TP01.

SU	Description	Munsel	XU	Bucket weight (net kg)	Depth (cm)		pH	Dating		
					Min	Max		Depth	Material	Age (Lab code)
1	Loose – friable light reddish-brown silty fine sand with minor calcrete gravel and finely fragmented shell inclusions.	5YR 6/4	XU1	80.72	0	11	8.5	0–11 cm (sieve)	Bivalve	8177–8020 cal BP (OZZ018)
			XU2	76.44	11	27	8.4			
2	Friable, reddish-yellow silty fine sand with soft carbonate concretions (possibly rhizomorphic), disseminated finely fragmented shell inclusions and harder calcrete gravel at base.	5YR 6/6	XU3	23.84	27	50	-	36 cm	Bivalve	10,128–9563 cal BP (OZZ019)

Table 6-14: Summary of fauna, combustion material and lithics recovered from in PikeSPS16_05 TP01.

Fauna											
SU	XU	Shell	NISP*	Wt (gms)	Fish (element/NISP)	Mammal (element/NISP)	Yabby (element/NISP)	Unid bone (element/NISP)	Combustion material (no.)	Artefact type (no.)	Other notes
1	1	Unid bivalve	345	18.6				Rabbit (long bone fragment/1)	Mcharc (40) Calcrete (8)	Silc a-frg (1)	
		<i>N. sublineata</i>	1	0.2							
1	2	Unid bivalve	230	13.3							
		<i>N. sublineata</i>	3	1.0							
2	3	Unid bivalve	41	9.4					Mcharc (12)		

*approximate NISP values only

Trench TP02

The principal aim of TP02 was to obtain a charcoal (dating) sample from a combustion feature exposed in the eroding cliff edge. The feature was situated within a gravel unit below the upper aeolian cover and resting directly on a palaeosol hardpan (Figure 6-81). Whilst hearths are exposed elsewhere along this cliff, this feature appeared unique in respect to the retention of ash/charcoal. In this instance, the basal hardpan may have prevented leaching, added stability to the feature and aided the preservation of the calcite-rich wood ash. The feature had been sectioned by natural erosion with only the outer extremities of the original feature remaining in situ. The extant feature was lenticular in profile, measured approximately 45 cm in diameter and was 9 cm thick. Ash/charcoal filled a shallow basin excavated in the dense calcrete rubble. No archaeological material was exposed directly above the feature though a series of thin midden lenses and hearths were exposed in the cover sand around the continuation of the cliff. ^{14}C ages of between 9130–8778 cal BP (OZZ015) and 14,912–14,298 cal BP (OZZ020) were returned on these midden lenses.

A 25 cm wide section was cut back to a maximum depth of 10 cm at the base of the excavation to expose a fresh, vertical face approximately 25 cm height. Four stratigraphic units (SU1-SU4) were identified in this excavated face and in the exposures above and below (Figure 6-83 and Table 6-15). The combustion feature was contained to SU3 with an increase in gravel differentiating the upper (SU3a) and lower (SU3b) parts of this unit. The excavation continued to the base of SU3a at a depth of 38 cm below the natural ground surface. The outer edges and lower portion (SU3b) of the feature were retained in situ for the purpose of additional analyses.



Figure 6-81: A comparison between the ash/charcoal-rich hearth feature assessed in TP02 (left) and a nearby feature located higher in the aeolian sand cover (right).

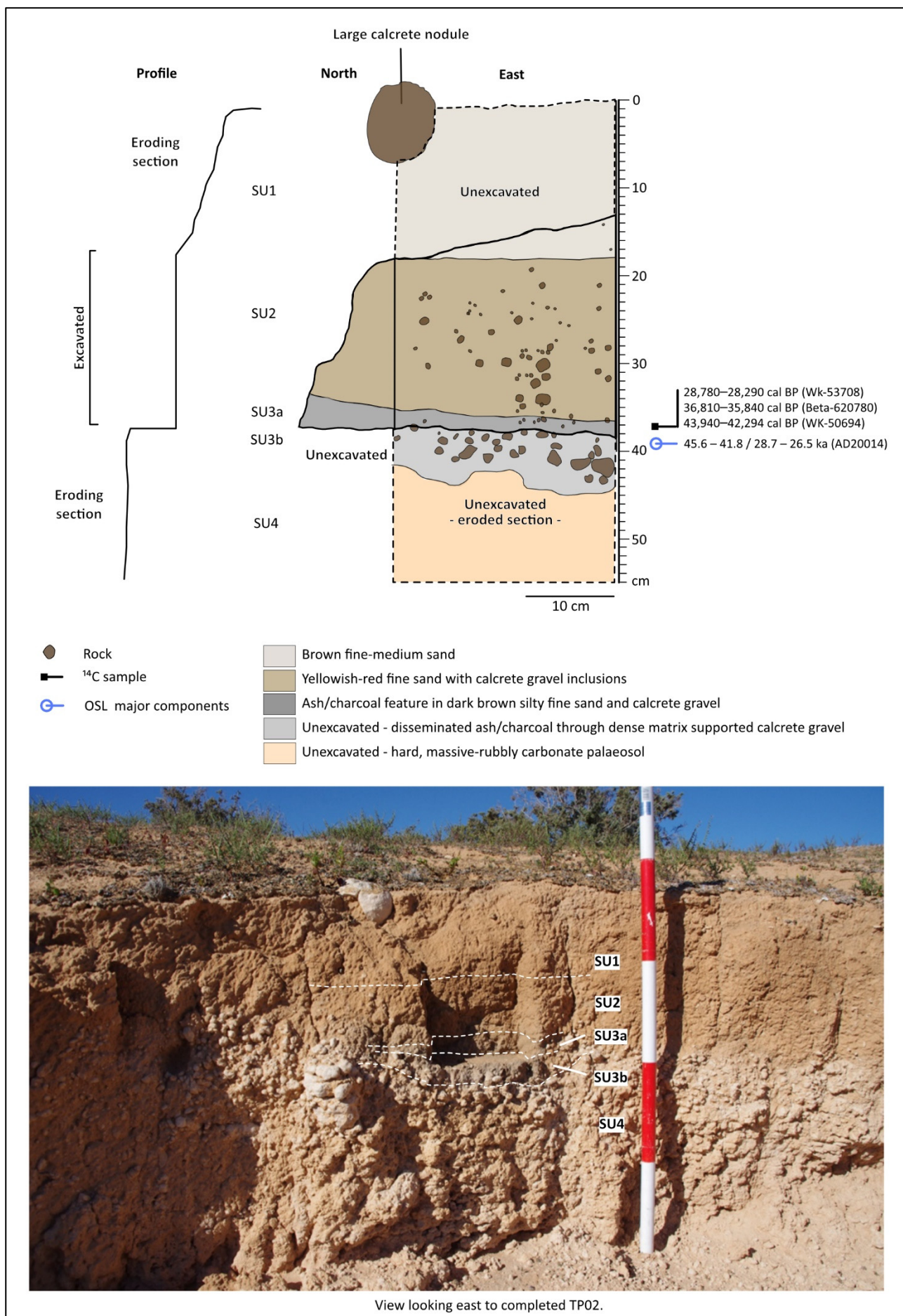


Figure 6-82: Section drawing and context image of TP02 (PikeSP16_05).

Table 6-15: Summary of the stratigraphic (SU) and excavation (XU) units and ¹⁴C/OSL sampling in PikeSP16_05 TP02.

SU	Description	Munsel	XU	Bucket weight (net kg)	Depth (cm)		pH	Dating		
					Min	Max		Depth	Material	Age (Lab code)
1	Unexcavated. Friable, brown fine-medium sand with minor calcrete gravel inclusions – also see large cobble at the unexcavated surface of the unit.	7.5 YR 5/4	-	-	0	19	-			
2	Friable, yellowish-red fine sand with calcrete gravel inclusions.	5YR 5/8	XU1	2.16	19	33	8.5			
3a	Friable, dark brown silty fine sand with disseminated charcoal and ash and fine calcrete gravel.	7.5YR 3/2	XU2	1.16	33	38	9.5	33–38 cm	Charcoal	43,940–42,294 cal BP (Wk-50694)
									Charcoal	36,716–35,752 cal BP (Beta-620780)
									Charcoal	28,780-2,290 cal BP (Wk- 53708)
3b	Unexcavated. Disseminated ash through matrix supported calcrete gravel.	-	-	-	38	44	-	35–42 cm	OSL	40.6 ± 1.9 / 25.6 ± 1.0 kBP (AD20014)
4	Unexcavated. Hard, massive carbonate palaeosol.	-	-	-	44	-	-			

Table 6-16: Summary of fauna, combustion material and lithics recovered from PikeSp16_05 TP02.

Fauna											
SU	XU	Shell	NISP*	Wt (gms)	Fish (element/NISP)	Mammal (element/NISP)	Yabby (element/NISP)	Unid bone (element/NISP)	Combustion material (no.)	Artefact type (no.)	Other notes
2	1										
3a	2								Mcharc (4)		Upper part of discrete, lenticular ash/charcoal feature

*approximate NISP values only

An age of 43,940–42,294 cal BP (WK-50694) was returned on a small amount (<1 gm) of fine charcoal recovered from SU3a. This result identified the feature as a significant outlier in respect to the Pike chronology. As such, two additional ^{14}C samples were recovered and OSL was employed as an independent dating method. The repeat ^{14}C age estimates were collected from the northern and eastern edges of the feature. These returned age estimates of 28,780–28,290 cal BP (Wk-53708) and 36,716–35,752 cal BP (Beta-620780), respectively. Advice provided by Dr Fiona Petchey (Waikato Radiocarbon Dating Laboratory) is that neither sample analysed at Waikato provided optimal material for dating. Both Wk-50694 and Wk-53708 had values above the recommended minimum of 50% carbon during combustion used by the Waikato laboratory as a quality indicator of potential contamination. The values were 64.4% and 51%, respectively. However, Wk-53708 was only slightly above this threshold and, as such, Wk-50694 can be considered the better ‘quality’ sample of the two. Similarly, the sample analysed by Beta Analytic was submitted as micro-charcoal, though was treated as organic sediment with no discernible charcoal present after pre-treatment.

OSL sample Pike-02 (Ad20013) was taken from within the base of the feature (see Figure 6-49 and Figure 6-82) and included two near identically weighted components of 45.6–41.8 and 28.7–26.5 ka in the 5-component Fmix model. These results, as summarised in Figure 6-83, provide no definitive confirmation of the 43,940–42,294 cal BP age, and indeed, can be read in ways that essentially support arguments in favour of either of the Waikato ^{14}C results.

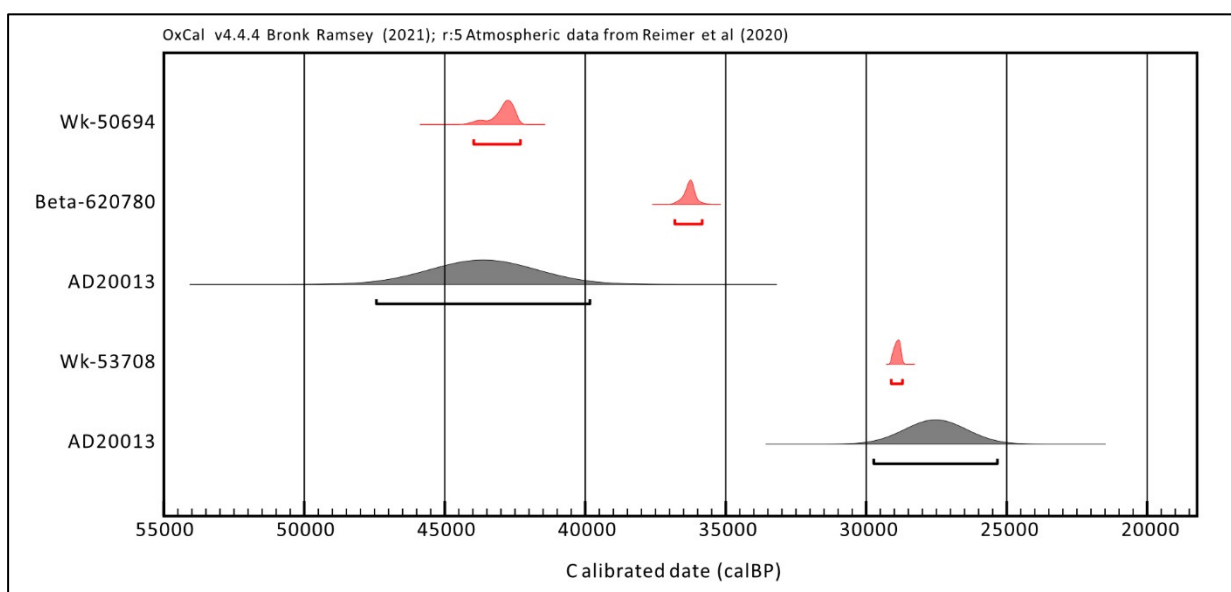


Figure 6-83: The dating results from the PikeSP16_05 hearth including the ^{14}C sampling (red) and main components in OSL sample Pike-02 (AD20013).

Arguments in favour of the older result can be made in terms of context. No other archaeological material has been identified along the Pike cliff in an equivalent context as SU3³³ (see Chapter 6.3.5). The hearth feature also sits at the base of SU3 and the upper surface appears to have been truncated, providing an impression of a disconformity prior to deposition of the overlying aeolian sand (SU2). A component in OSL sample Pike-03 (Ad20014) of 31.9–29.5 ka provides a minimum age for sediment above the hearth and below the more recent sand cover. The upper sand appears to have been deposited and remobilised from c. 15 ka based on midden shell ages within it. Some circumstantial evidence can equally be cited in favour of the younger result. The c. 29.3 ka result provides a close correlation with the age of a midden lens in site PikeAWE15_10 (see OZX288 and Wk-49723 in Appendix XI) and ages reported on a shell lens at Lake Victoria c. 29 ka (Abdulla et al. 2019), potentially linking these three features to a discrete pulse of regional occupation. The c. 36 ka result (Beta-620780) has no support in the OSL sampling and is regarded as the least reliable. The implications of accepting or rejecting the older result are significant. Based on the data generated in this research, these alternative ¹⁴C ages define the earliest known projection of Aboriginal occupation into this region. This either occurred very early in the MDB record (c. 43 ka) or significantly later (c. 29 ka).

The hearth feature will be the subject to a suite of geoarchaeological analyses independent of this thesis. Preliminary results of these analyses confirm the stratigraphic interpretation presented above. Some of the defining characteristics are summarised in Table 6-17. This includes a distinct increase in carbonate content at the top of SU2 and an increase in organic carbon at SU3a, further illustrating a separation between the top of the hearth feature and the base of SU2.

The analyses are also directed along three fundamental lines of enquiry; is this a combustion feature, is this feature anthropogenic and is the geochronology supported? In relation to combustion, it is known that high temperature fires (natural or anthropogenic) provide a mechanism for the enhancement of magnetic properties in soils. Measurements of frequency dependence (X_{fd}), i.e. the ‘percentage difference in mass susceptibility at two different frequencies of applied AC field’, can illustrate the presence of secondary ultrafine grains of magnetic material

³³ Wk-52030 (see TP04A below) was returned on a single *N. sublineata* specimen that is likely to have been displaced from a lens in the overlying sand (SU2).

formed under these conditions (Dalan and Banerjee 1998:7, Table 1). Both field (volume specific) and laboratory (mass specific) magus analyses were performed on a sediment column recovered through the southern edge of the feature and provide evidence of a magnetic contrast with the surrounding sediments. Large numbers of fine charcoal fragments, some retaining a woody structure, were also identified in thin sections recovered from the micromorphology blocks, confirming that this is a combustion feature, though curiously, there is no definitive evidence of thermal alteration of the surrounding or incorporated sediment.

The question as to whether the feature is anthropogenic is more difficult to resolve. However, some fine bone fragments have been identified in the micromorphology blocks and the most likely explanation for this association is the deliberate disposal of bone into a cooking fire. Structurally, the thin lenticular feature of approximately 45 cm diameter certainly resembles a shallow, sectioned pit oven. Heat retainer has not been utilised in this instance, and cooking on open coals in a shallow pit is a likely scenario. If the feature related to a natural fire event, it might also be expected that similar examples would occur along the cliff or that the feature would be more laterally extensive.

Table 6-17: Key features in the sediment analyses at TP02.

Unit	Grainsize	LOI
SU1	Poorly mixed fine-very fine sand	Consistently low carbonate and organic content in aeolian quartz sand
SU2	Notable increase in coarse-granular component to 2–5% reflecting the breakdown of calcrete inclusions	Distinct increase in carbonate to ~4-5% reflecting calcrete inclusions
SU3a	Increase in coarse-granular component to 5–10%	Ash/charcoal registered as slight increase in organic component to ~2-3%
SU3b	Further increase in coarse-granular component to ~12% in denser calcrete gravel resting directly on hardpan surface	
SU4	Increase in silt/clay and reduction in coarse-granular component in massive carbonate soil	Rapid and significant increase in carbonate to >10%

Trench TP03

This 50 x 25 cm trench sought to recover part of a densely packed *N. sublineata* lens exposed and eroding around the rim of the cliff and a deep cutting (Figure 6-85). A single stratigraphic unit was identified (SU1) and removed in one excavation unit (XU1) (Table 6-18) containing the 5–8 cm shell lens. The unit rested directly on dense calcrete gravel (Figure 6-84). Approximately 430 *N. sublineata* shells together with single fragments of unidentifiable bivalve and bone were

recovered (Table 6-19). No artefacts or combustion materials were identified. A ^{14}C age of 12,143–11,840 cal BP (OZZ017) was returned on a sample of *N. sublineata*.



Figure 6-85: View looking west to TP03 with the Pike River in the background.

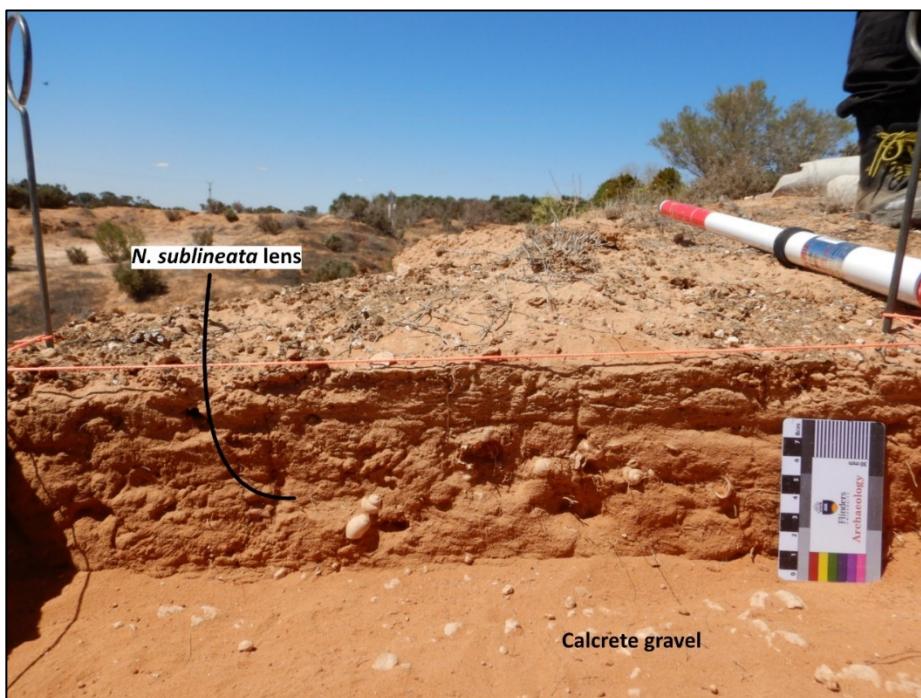


Figure 6-86: View of the eastern wall of the shallow excavation in TP03 showing in situ *N. sublineata*.

Table 6-18: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴C samples in PikeSP16_05 TP03.

SU	Description	Munsel	XU	Bucket weight (net kg)	Depth (cm)		pH	Dating		
					Min	Max		Depth	Material	Age (Lab code)
1	Loose, yellowish-red, well-sorted fine sand with minor calcrete gravel inclusions.	5YR 5/6	XU1	17.46	0	8	8.5	0–8 cm (sieve)	<i>N. sublineata</i>	12,143–11,840 cal BP (OZZ017)

Table 6-19: Summary of fauna, combustion material and lithics recovered from PikeSP16_05 TP03.

Fauna											
SU	XU	Shell	NISP*	Wt (gms)	Fish (element/NISP)	Mammal (element/NISP)	Yabby (element/NISP)	Unid bone (element/NISP)	Combustion material (no.)	Artefact type (no.)	Other notes
1	1	Unid bivalve	1	0.2							
		<i>N. sublineata</i>	430	309.7							

*approximate NISP values only

Trench TP04A

This trench was situated 3.6 m from TP02 and aimed to establish a reliable chronology through the sand sheet and expose any potential occupation surface extending around the hearth in TP02. The trench extended to a maximum depth of 87 cm across four stratigraphic and thirteen excavation units (Table 6-20). The 1.0 x 1.0 m trench was reduced to a 50 x 50 cm portion at XU9 and required the use of a forked mattock below this XU. The excavation continued to the continuation of the hardpan surface exposed in the cliff. A small amount of archaeological material was recovered, predominantly small fragments of mussel valve disseminated throughout the profile (Figure 6-88) and a small number of *N. sublineata* in the lower units. The quantity of shell and number of fine charcoal fragments increased in SU3 (XU11–12). These materials occurred in small randomly distributed clumps and disseminated fragments recovered in the sieves rather than clearly discernible or laterally extensive features. A vague banding toward the top of SU2 and at the top and bottom of SU3 can, however, be interpreted in Figure 6-87.

A series of seven ¹⁴C age estimates were returned on bivalve (4), *N. sublineata* (2) and charcoal (1) samples through the profile (Table 6-20). On the basis of these results, together with the highly fragmented presentation of the shell and notable changes in sediment compaction, the stratigraphy in TP04A is interpreted as follows:

- SU3 accumulated over a rubble surface from approximately 12.7 ka (Wk-52030) to at least 9.3 ka (Wk-52036) and included the episodic development of bivalve (most likely *A. jacksoni* based on the shell exposed in the broader site) and *N. sublineata* midden. These materials, together with charcoal, were reworked through trampling and/or deflation, though accumulated during the gradual accretion of the sand cover. This has preserved a vague stratigraphy. Older ages of ~14.6 ka (OZZ020) and 13.4 ka (OZZ016) were returned on bivalve fragments exposed in an equivalent unit in the broader site area and extend this pattern by approximately 2,000 years.
- A deflationary episode redeposited older sediment as unit SU2, resulting in the first of two inverted ¹⁴C ages (11,085–10,725 cal BP, Wk-52033).
- Midden was deposited toward the top of SU2 at 4,869–4,728 cal BP (Wk-52035).
- A second major deflationary episode redeposited sediment as unit SU1, again incorporating older midden shell as highly fragmented and disseminated material (see 9080–8781 cal BP, WK-52034).

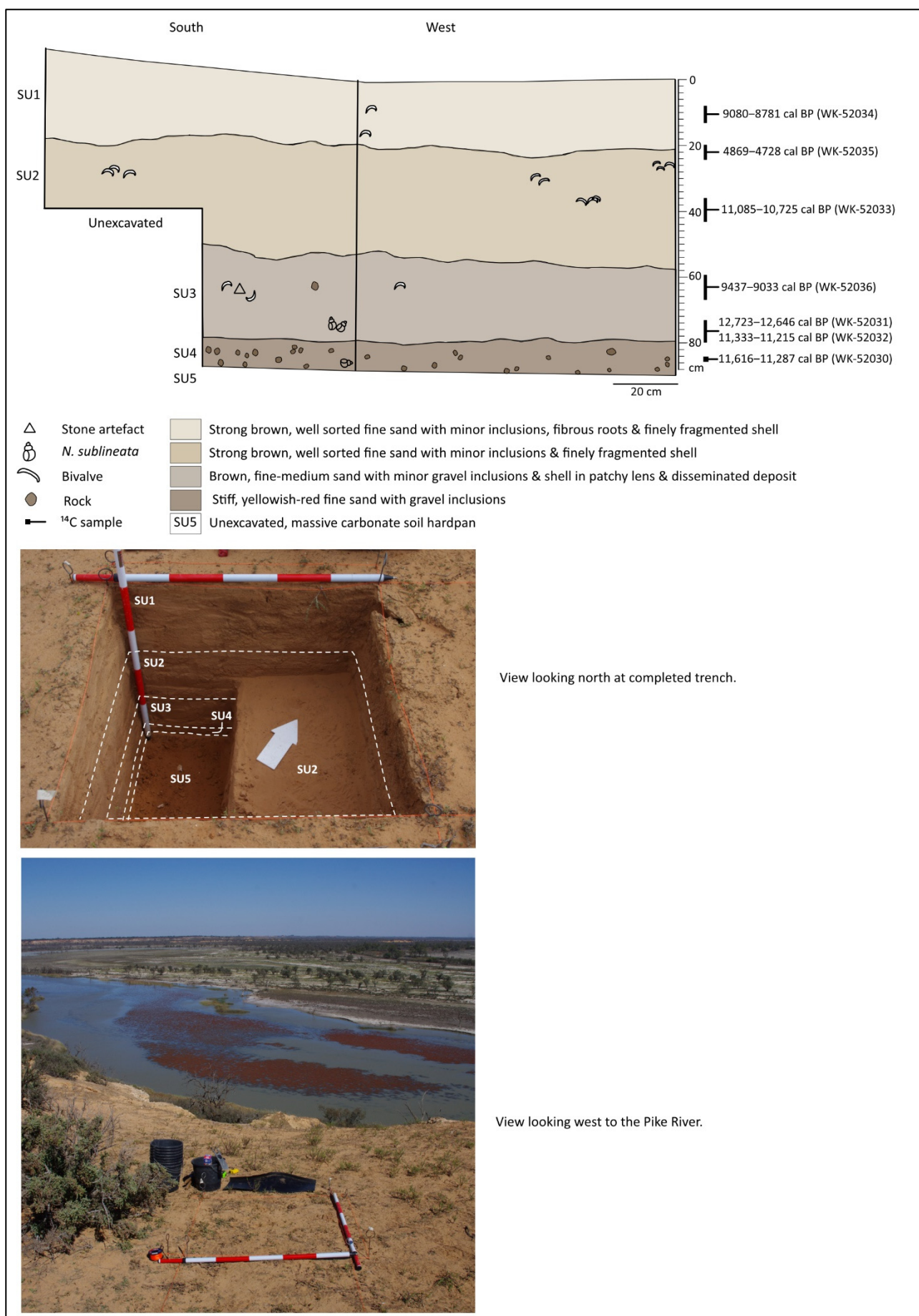


Figure 6-87: Section drawing and context images for PikeSP16_05 TP04A.

Table 6-20: Summary of stratigraphic (SU) and excavation (XU) units and ¹⁴C samples in PikeSP16_05 TP04A.

SU	Description	Munsell	XU	Bucket weight (net kg)	Depth (cm)		pH	Dating		
					Min	Max		Depth	Material	Age (Lab code)
1	Loose, strong brown, well sorted fine sand with minor fine calcrete gravel inclusions and disseminated, finely fragmented shell. Some plant fibres.	7.5YR 5/6	1	58.22	0	6	8.5	8–13 cm (sieve)	Bivalve	9080–8781 cal BP (WK-52034)
			2	46.08	6	8				
			3	52.88	8	13				
			4	67.84	13	20				
2	Loose, strong brown, well sorted fine sand with minor fine calcrete gravel inclusions and disseminated, finely fragmented shell.	7.5YR 5/6	5	85.02	20	24	8.5	20–24 cm (sieve)	Bivalve	4869–4728 cal BP (WK-52035)
			6	91.4	24	31				
			7	82.32	31	36				
			8	90.1	36	43		36–43 cm (sieve)	Bivalve	11,085–10,725 cal BP (WK-52033)
			9	59.86	43	51				
3	Friable-stiff, brown fine-medium sand with minor calcrete gravel inclusions and freshwater mussel and <i>N. sublineata</i> as disseminated and small clumped deposit. Required mattock to excavate.	7.5YR 5/4	10	31.02	51	55		55–70 cm (sieve)	Bivalve	9437–9033 cal BP (WK-52036)
			11	72.92	55	70				
			12	57.78	70	82		70–82 cm (sieve)	Charcoal	12,723–12,646 cal BP (WK-52031)
4	Friable-stiff, yellowish-red fine sand with calcrete gravel inclusions requiring forked mattock to excavate.	5YR 5/6	13	18.86	82	87	9.5	85 cm	<i>N. sublineata</i>	11,333–11,215 cal BP (WK-52032)
5	Unexcavated. Massive carbonate soil hardpan.	-	Unexcavated		87	-				

Table 6-21: Summary of fauna, combustion material and lithics recovered from PikeSP16_05 TP04A.

SU	XU	Fauna					Combustion material (no.)	Artefact type (no.)	Other notes
		Shell	NISP*	Wt (gms)	Fish (element/NISP)	Mammal (element/NISP)	Yabby (element/NISP)	Unid bone (element/NISP)	
1	1	Unid bivalve	132	8.6					Bivalve likely <i>A. jacksoni</i> based on site content
	2	Unid bivalve	11	0.6					Cht fl (1)
	3	Unid bivalve	25	0.7					
	4	Unid bivalve	64	4.2					
		<i>N. sublineata</i>	4	0.2				Mcharc (3)	
2	5	Unid bivalve	47	2.8				Unid (cortical bone/1)	
		<i>N. sublineata</i>	2	0.2					
	6	Unid bivalve	60	6.1					
		<i>N. sublineata</i>	25	1.8				Mcharc (1)	Silc fl (1) Small silcrete pebble 18 mm diameter also in XU
	7	Unid bivalve	35	4.2					
	8	Unid bivalve	145	13.0					
	9	Unid bivalve	85	4.2				Unid (cortical bone/2)	
		<i>N. sublineata</i>	5	4.6					
	10	Unid bivalve	6	1.9					
		<i>N. sublineata</i>	17	1.3				Fcharc (-)	
3	11	Unid bivalve	245	37.1					
		<i>N. sublineata</i>	15	12.7					
	12	Unid bivalve	1	8.0					
		<i>N. sublineata</i>	205	92.1				Mcharc (28)	Silc cr (1)
4	13	<i>N. sublineata</i>	17	1.3					

*approximate NISP values only

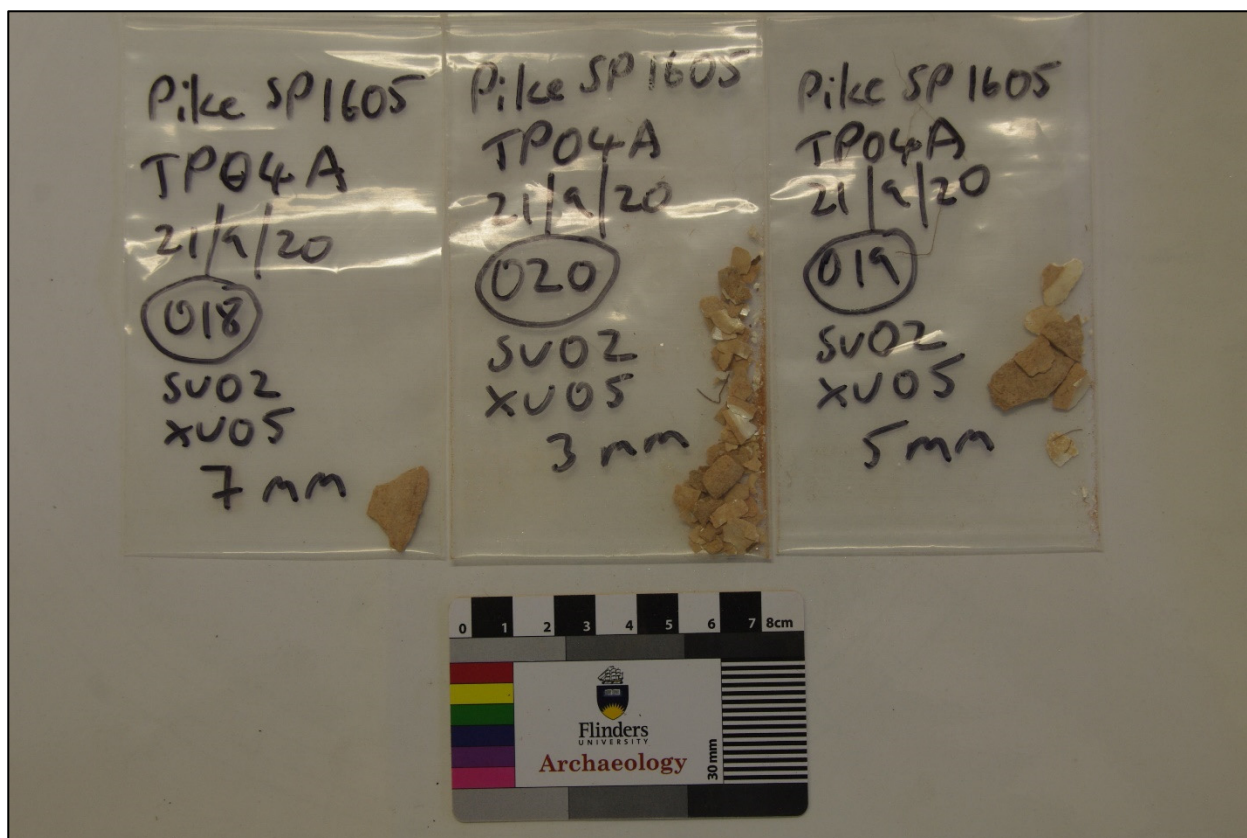


Figure 6-88: The typical presentation of bivalve in PikeSP16_05 TP04A.

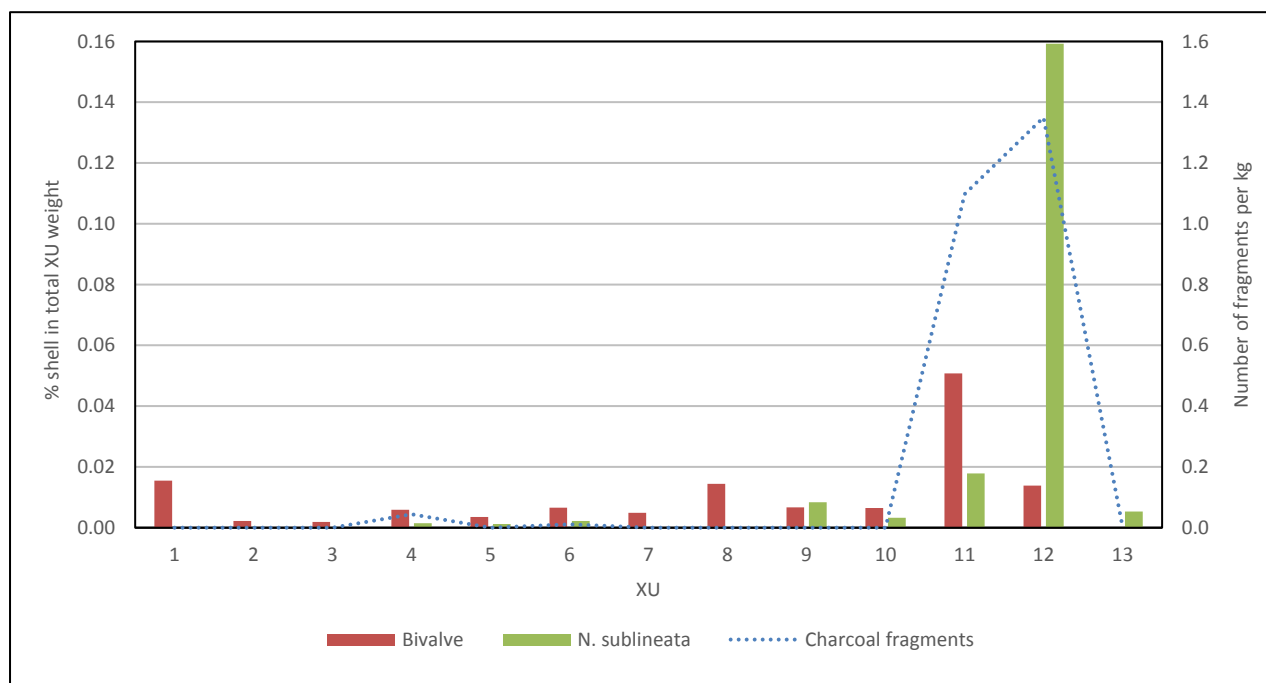


Figure 6-89: Distribution of shell expressed as a weight percentage of the total excavated sediment from each XU together with the number of charcoal fragments per kg of sediment excavated in PikeSp16_05 TP04A.

6.3.5 The PikeAWE15_10 irrigation trench and other exposures

The Pike cliff line essentially replicates a continuous excavated profile over several kilometers. This profile intersects several archaeological sites, and numerous features in these sites. The stratigraphy observed in PikeSP16_05 is replicated along this entire cliff line, though with the thickness of individual units varying markedly. This is a clear function of the complex and irregular topography developed during the various phases of aeolian sedimentation.

Figure 6-90 and Figure 6-91 show a natural exposure of shell midden in site PikeSP16_01 and a schematic cross-section along a deep trench excavated for irrigation piping in site PikeAWE15_10, respectively. These two contexts highlight the variable thickness of sedimentary units. In the example from PikeSP16_01, a small feature is exposed at the top of an extremely thin cover of Woorinen Formation sediments. At PikeAWE15_10, a relatively thicker cover of loose sand is preserved in the area of the cutting, though within 40 m west of this location, this unit has been stripped from a deep deflation hollow. Similar complex terrain developed over relatively short distances, is likely to extend along and beyond the cliff edge. The lenses exposed in these sections are also typical of the Pike record. All lenses of shell are located in the upper sand above a dense gravel unit that rests on a deeper, pervasive palaeosol and hardpan. As above, these examples suggest that the hearth feature exposed in PikeSP16_05 is indeed situated in a unique context. All of the visible lenses also form relatively discrete and compact features, providing an impression of repeat, though discrete, episodes of occupation.



Figure 6-90: A midden lens c. 15.4 ka exposed at the top of a thin cover of Woorinen Formation sediments.

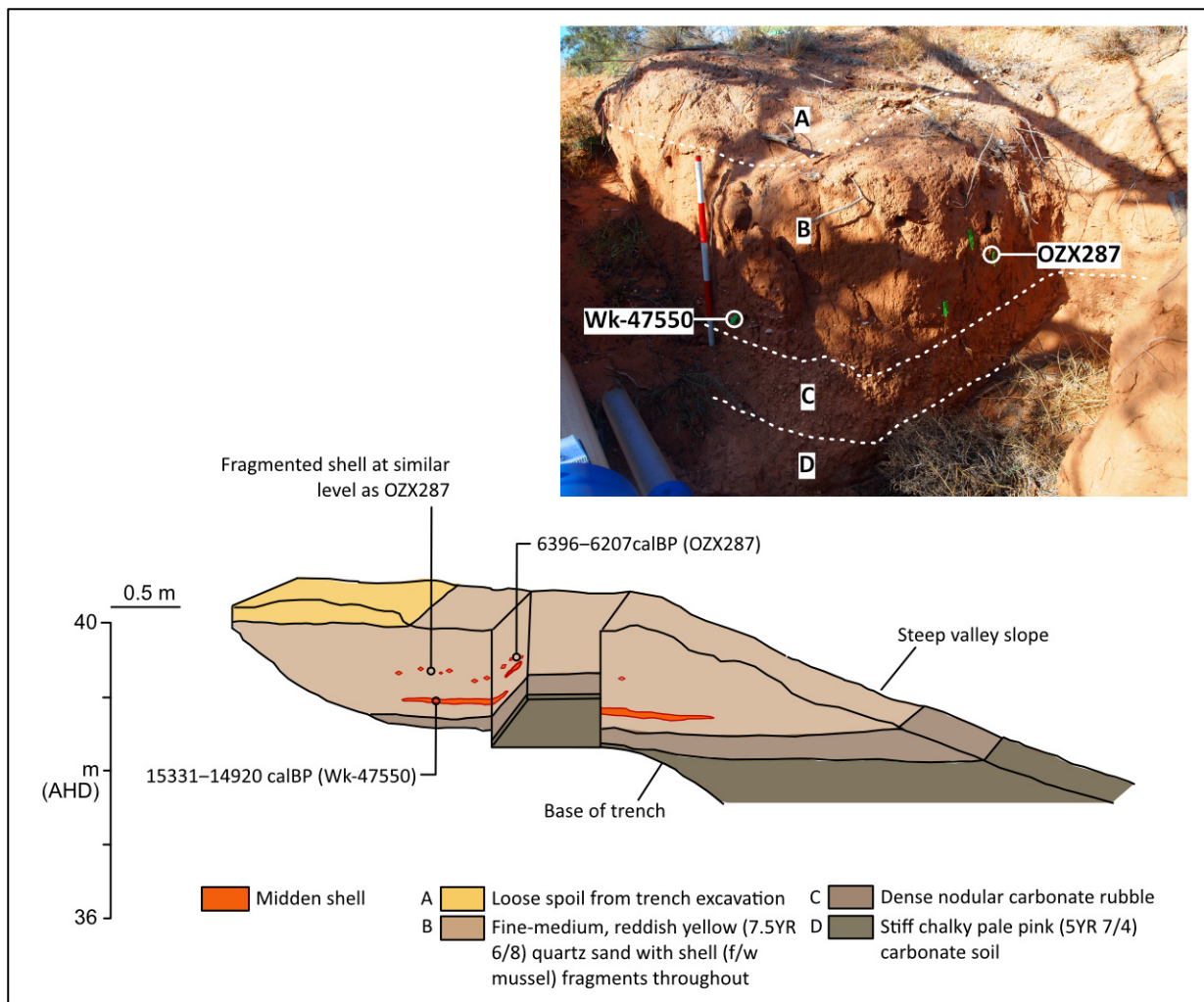


Figure 6-91: Schematic of the stratigraphy sectioned by an irrigation trench in site PikeAWE15_10.

6.3.6 ^{14}C chronology

A total of 89 ^{14}C age estimates were returned on surface (56), excavated (15) and naturally exposed subsurface (18) samples of archaeological charcoal (7) and shell (82) (Appendix XI). Whilst the intention was to obtain a similar number of shell and charcoal ages, it was found that detrital carbon had commonly leached from combustion features or was otherwise unsuitable for reliable age determinations. The bias toward shell ages poses an obvious issue for interpretation in that changes in ecology may have impacted the availability (and collection) of freshwater mussel independent of demographic change. An economy may have simply adjusted to the availability, or otherwise, of freshwater mussel. According to Walker (1981:97), self-sustaining populations of both *A. jacksoni* and *V. ambiguus* are unlikely to persist in salinities in excess of 3.5 gm/l. Periods of lower ^{14}C frequency do, indeed, correlate with phases of regional dune activation, i.e. aridity. However, the methodological approach of intensive survey coverage across a timeseries in landscapes, and with a focus on context, has been applied specifically to counter the potential

biases in ^{14}C sampling and to value-add and validate the ^{14}C data.

The age results range from 253–modern cal BP (OZZ007) to 43,940–42,294 cal BP (Wk-50694). Only two ages (OZZ007, OZX278) potentially date to after European contact based on the error ranges. Both of these ages were returned on charcoal. The youngest shell-derived age falls within the range 1666–1805 CE. It is worth reflecting here that the historical accounts of Aboriginal people collecting shell identify at least one gap in the ^{14}C sampling—this period is unrepresented despite direct observation of the activity (Angas 1847:55, 90, 92; Eyre 1845; Hawdon 1952; Roysland 1977). It is a given that similar real world gaps will occur in the data and any discussion built upon ^{14}C must acknowledge the inherent smoothing required. With this caveat acknowledged, several observations are outlined here, and are developed more fully in Chapter 7.

All age estimates at Calperum are Holocene with the oldest being 9463–9143 cal BP (OZX284). This is despite a deeper Pleistocene record identified at Pike. Furthermore, with the exception of Wk-52898 (5895–5606 cal BP) no pre-5,000 year ages were reported on archaeological materials beyond the inner lakes at Calperum (see Table 6-22). A minor component in OSL sample WOL-10, coupled with a ^{14}C age of 7940–7740 cal BP (Wk-52353), provides an approximate age for a sand unit containing several stone artefacts exposed in gully erosion adjacent to site CAPR20_S11. The excavation required to accommodate the dose-meter at OSL sample WOL-10 at Rotten Lake dislodged one of these artefacts.

Table 6-22: Minimum and maximum age ranges within each habitat zone at Calperum and Pike.

Floodplain	Habitat	Maximum age (cal BP)	Minimum age (cal BP)
Calperum	Outer Lake	7940–7740	-
	Inner Lake	9463–9143	284–145
	Anabranh	5895–5606	280–modern
	T2 scroll oxbow	4806–4441	510–339
	Hunchee backplain	903–727	253–modern
	River Murray	915–772	440–153
Pike	Cliff	43,940–42,294	2728–2435

The ^{14}C ages display a step-like distribution, as observed in Figure 6-92. This pattern is interpreted in Figure 6-93 and Table 6-23 as a sequence of 13 ^{14}C phases comprising age groupings and transitions between these groupings. Transitional phases include examples of both gradual and abrupt differences in the age results. The span of age groupings is shown in Figure 6-94. Importantly, Phase 13 is represented across all habitat settings at Calperum, though not at Pike, where only two age estimates postdate sample OZX290 (6396–6207 cal BP) (see Table 6-22). Over a third of all age results also fall within Phase 13, i.e. the last 1200 years.

The outliers in the Pike chronology (Phase 1–2) are significant for a number of reasons. These represent the earliest documented Aboriginal occupation in the MDB downstream of Lake Victoria, and potentially, provide the only evidence of early MDB occupation projecting outside of the Willandra and Menindee systems. As importantly, these ages suggest that a representative chronology across a timeline extending to at least 29 ka, and potentially as far as 43 ka, should be preserved here. Clearly, there has been a loss of archaeological materials and sites brought about through the continual erosion of the cliff, though despite this, a deep Pleistocene record has been retained and is currently exposed along the Pike cliff line.

As discussed in Chapter 6.3.4.4, there is some uncertainty around the charcoal-derived ages returned on the combustion feature in PikeSP16_05. The feature rests on a carbonate soil that is likely to have formed from c. 63 ka based on the regional dune chronology suggested by Lomax et al. (2011) and OSL sample Pike-01. The combustion feature forms a ‘sump’ that would have potentially pooled water, and there is a risk that old-carbon could have saturated and contaminated the charcoal. Whilst charcoal is less prone than shell to contamination, it is not immune. Old-carbon can physically enter the woody structure of charcoal as microscopic grains or chemically replace organic carbon through mineralisation (Bird 2013; Bird et al. 2002). Importantly, however, the Pike sample Wk-50694 retained a carbon content of 64%, a figure that is well above levels that would otherwise raise concern of contamination (Fiona Petchey pers. comm. 2021). In the samples analysed by Bird et al. (2002) at the Nauwalabila I rockshelter, for instance, the carbon content in unaltered charcoal ranged from ~36–47% and altered material 4–47% though typically around 25% (see further discussion in Chapter 6.2.7). The processes that introduce ‘old’ carbon can, of course, also introduce younger carbon.

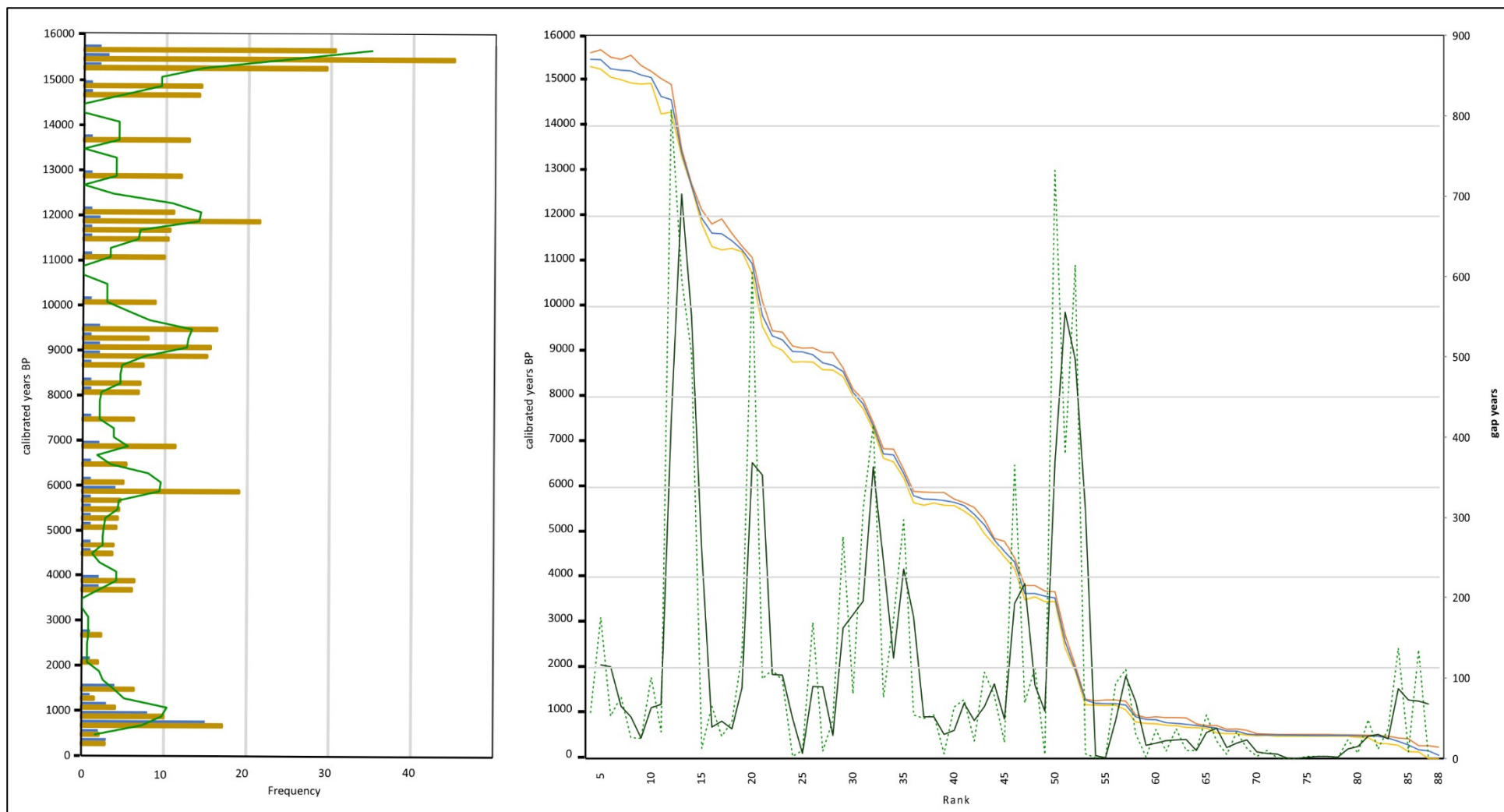


Figure 6-92: A summary of the counts and ranking of ^{14}C ages younger than 16 ka. The bar graph on the left shows the counts of median calibrated ages within 200-year bins (green), together with counts corrected for taphonomic loss (orange) and a 600-year moving average (green line) of the corrected values following the methods established by Williams (2012). The graph on the right includes minimum, maximum and median calibrated age values (yellow-orange-blue lines) based on the 95.4% probability range together with the minimum gap between successive ranked calibrated ranges (dashed green line) and a 2-point moving average of the minimum gap (solid green line).

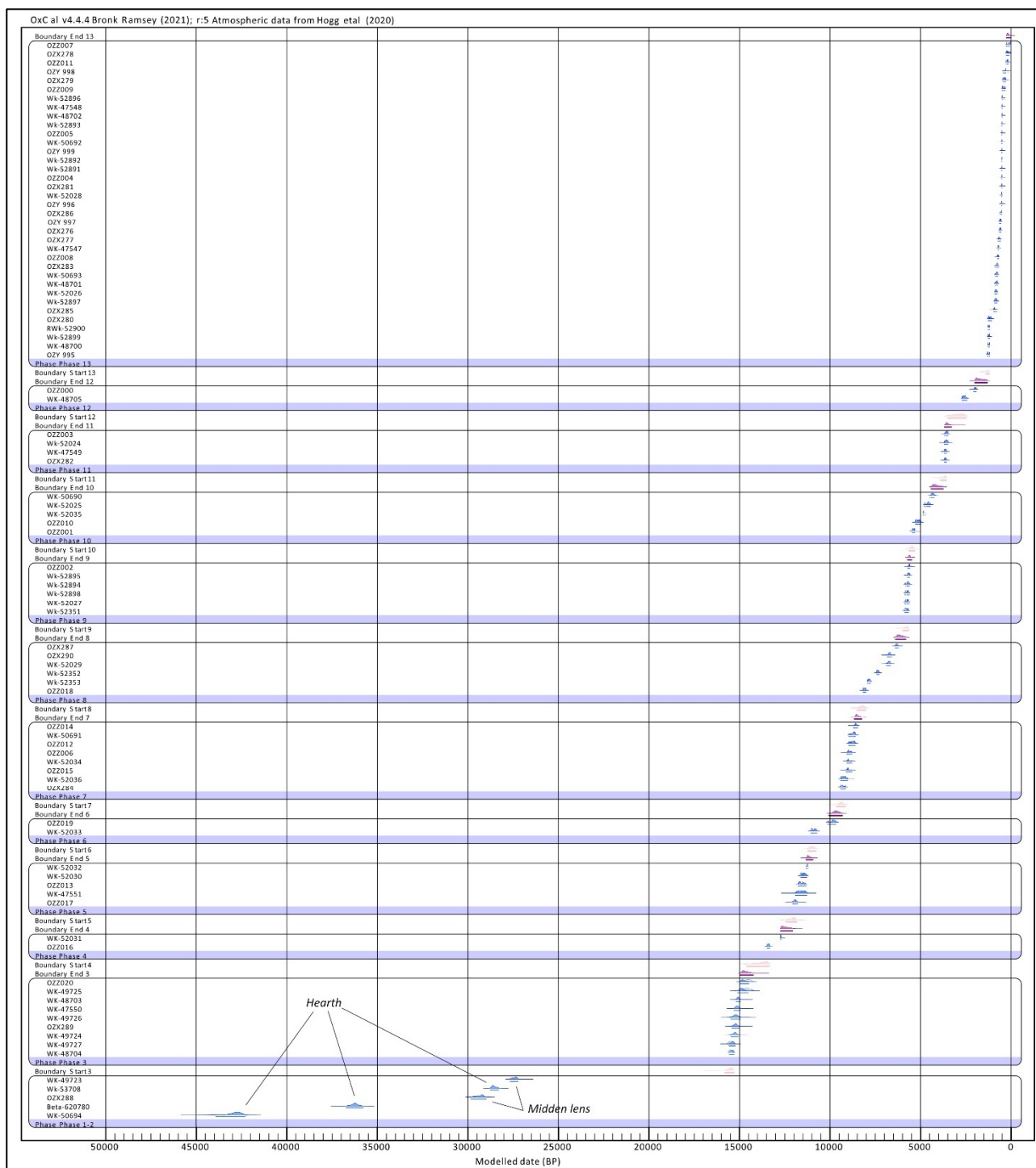


Figure 6-93: Interpreted phases and phase boundaries represented in the full set of ^{14}C age estimates. The lower and upper boundaries for each phase from Phase 3 onward were determined using the 'Boundary' function in OxCal 4.4. The three ^{14}C ages in Phase 1-2 relate to a hearth in PikeSP16_05 and a midden lens in PikeAWE15_10, as annotated.

Table 6-23: Phase types and spans based on modelled boundaries represented in the full set of ^{14}C results (ages are shown at a 95.4% probability range).

Phase ID	No. ^{14}C samples	Phase type	Span Modelled (BP)	
			From	To
13	5	Cluster	1385	31
12	2	Transition	3484	1327
11	4	Cluster	3890	3297
10	5	Transition	5619	3755
9	6	Cluster	5969	5490
8	6	Transition	8503	5821
7	8	Cluster	9267	8257
6	2	Transition	11220	9328
5	5	Cluster	12424	10955
4	2	Transition	14583	12070
3	9	Cluster	15801	14246
1-2	5*	-		

* Phase 1-2 includes repeat sampling conducted on a hearth and midden lens at Pike in sites PikeSP16_05 and PikeAWE15_10, respectively.

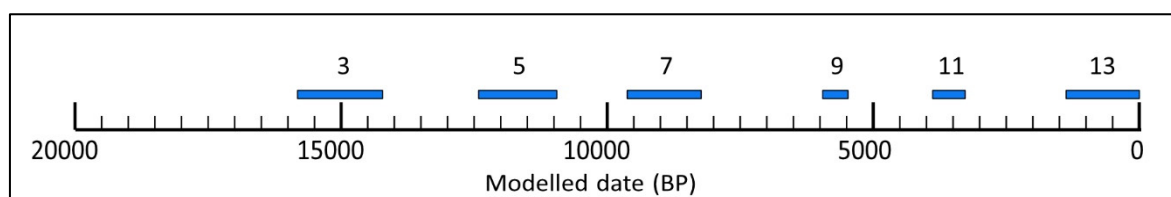


Figure 6-94: The spans of ^{14}C age clusters.

6.3.7 Chronology based on typology

Two aspects of the archaeological record provide an opportunity for typological dating; adzes and oven mounds. According to Veth et al. (2011:10), adzes appear in the Australian archaeological record from around 3.7 ka. Adzes recovered during excavations of the Ngaut Ngaut (Devon Downs) (Hale and Tindale 1930) and Tungawa (Fromm's Landing) (Mulvaney 1960) rockshelters on the Lower Murray, provide a local provenance for this late Holocene chronology (see Smith 1982:Figure 2). As discussed in Chapter 2.5.1.2, oven mounds are also a distinctly late Holocene feature in the MDB with the oldest reported example initiated at approximately 4.9 ka (Martin 2006) and over 78% of all ^{14}C ages falling within the last 2,000 years (Jones 2016b:16; Jones et al. 2022). A similar spread of mound ages is reported by Jones et al. (2022) at Calperum where n=14 calibrated ages from various stratigraphic units in six mounds ranged between 3981–3723 cal BP

(OZZ566) (site HIS_2_21) and 283–modern (OZZ572) (site HIS_2_23). Additional ages of 4812-4525 cal BP (Wk-52025) and 960-805 cal BP (OZX285) were returned on a charcoal feature immediately below mound HCN21 and a shell fragment recovered from the surface of a small mound in site CAPR17_23, respectively. Mounds were identified in twelve of the 120 Calperum and Pike sites while adzes were noted in a further seven sites.

6.3.8 The grinding assemblage

Grindstones were identified in 42 sites and as 5 isolated finds. An estimated 94 individual grindstones were noted, all of which were identified at Calperum. As summarised in Table 6-24, Type II topstones (pestles) dominate the total set (75.5%) and comprise 97.3% of all topstones. Type II grinding bases (mortars) comprise 14.9% of the total set and dominate this class (63.6%). Some examples of the Calperum grinding bases and topstones are shown in Figure 6-95 and Figure 6-96, respectively. The locations of the grinding material are shown in Figure 6-97. In assessing the nature and distribution of the grinding material it's worth revisiting the early media accounts of the area. These refer to grindstones being collected and removed from the floodplain, and it can be assumed, therefore, that the extant material is a fraction of the original assemblage. The material that remains is consistent with the SAM collections (see Appendix II) and illustrates a dominance of hard seed processing or other applications of pounding/crushing techniques.

Table 6-24: A summary of grinding materials identified in the survey coverage (see Table 4-6 for Type descriptions).

	Base				Top		
	Type I	Type II	Type III	Quandong stone	Type I	Type II	Type III
Number	3	14	3	1	1	71	1
% of total	3.2	14.9	4.3	1.1	1.1	75.5	1.1
% of class	13.6	63.6	18.2	4.5	1.4	97.3	1.4



Figure 6-95: Examples of Type I (A, B), Type II (C, D, E) and Type III (F, G, H) grinding bases identified at Calperum together with a possible 'Quandong stone' (I).

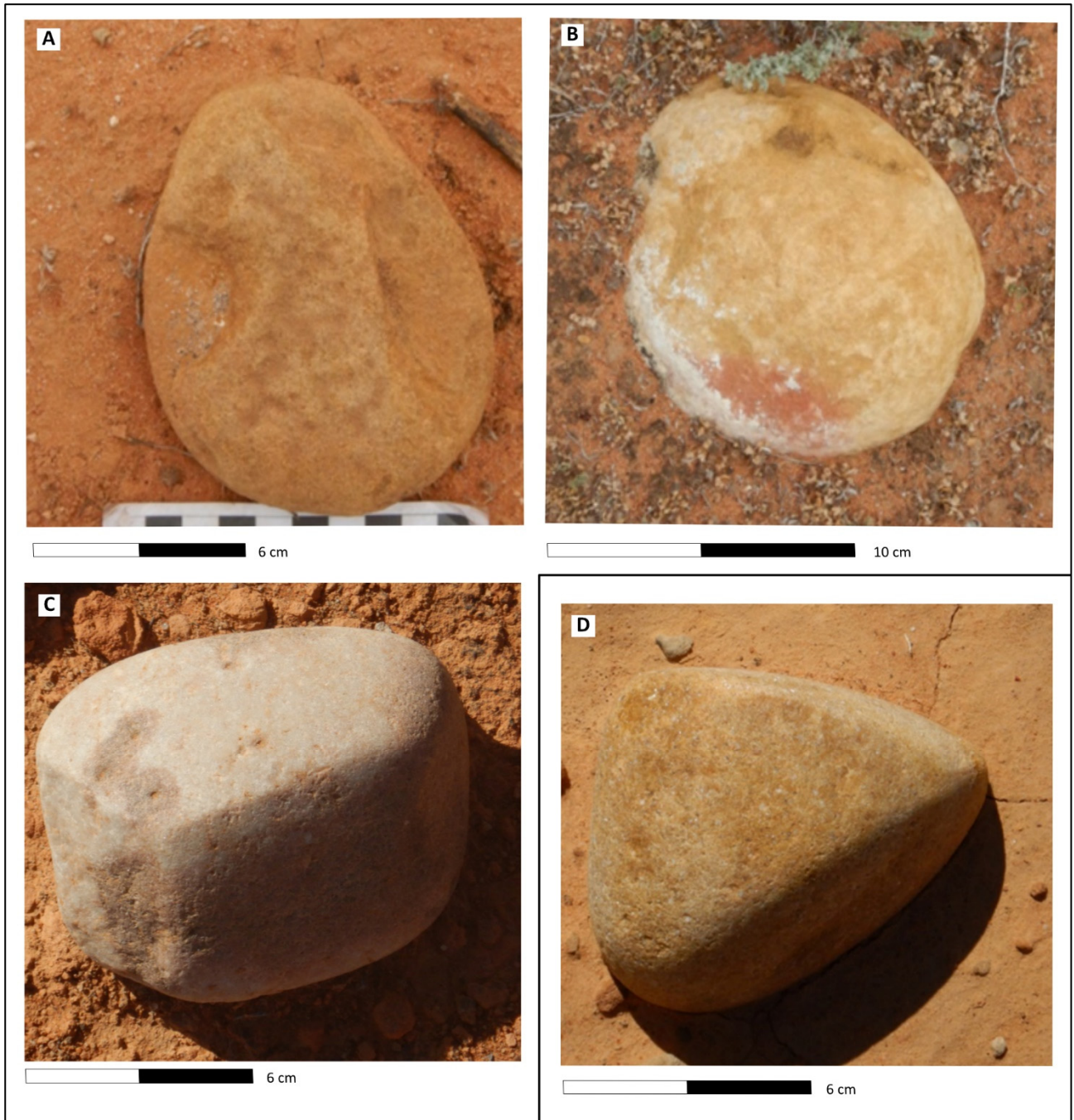


Figure 6-96: Various Type II (A, B, C) and Type III (D) grinding topstones (pestles) recorded at Calperum.

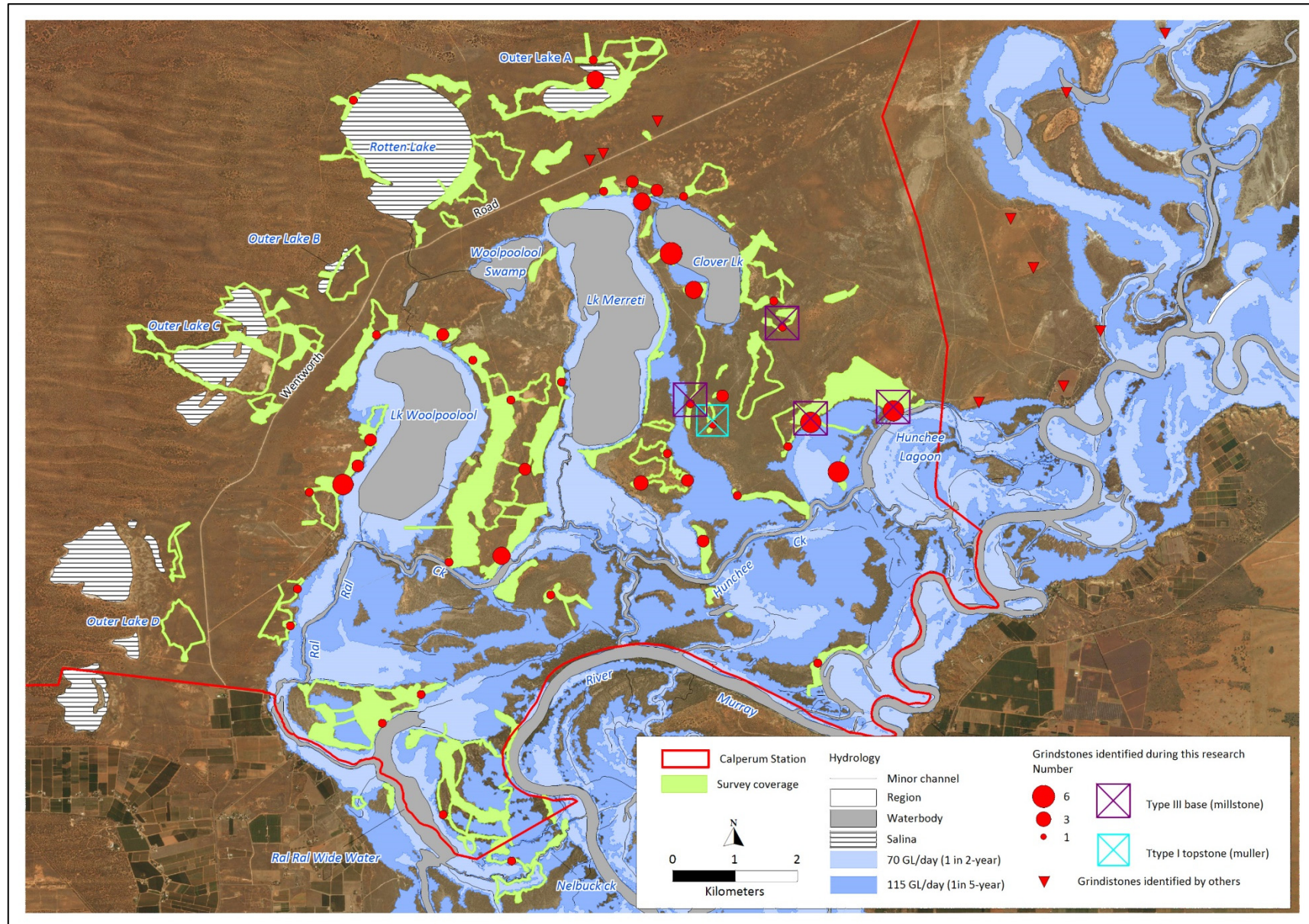


Figure 6-97: The distribution of extant grinding material in the area of the Calperum floodplain.

It has also been suggested that stone materials used for grinding are likely to have been imported into this region (see for instance Anon 1921b). This is certain to be the case for large cobbles of quartz, volcanic and quartzite, as well as a variety of sandstone that has been used exclusively as Type III grinding bases (millstones) and presents typically as thin, heavily worn edge fragments (see image H in Figure 6-95). Pardoe (2015) reports two sources of sandstone used in the manufacture of grinding bases (millstones) in the MDB; the Broken Hill and Scropes Ranges Sandstone from northwest of the Menindee Lakes, and the Lachlan River tabular indurated sandstone from the mid-reaches of the Lachlan River. Sources of blocky silcrete typical of the Type II bases (mortars), and tabular sandstone typical of the Type III bases (millstones) occur at Murtho (see Figure 4-13) directly opposite the Calperum floodplain, and at other locations in the upper Riverland. A yellow-red fine grain sandstone commonly used as Type II topstones outcrops along the valley cliffs downstream of Overland Corner. The source of the waterworn cobble preforms is less certain though it is possible that gravel beds occur along the main river channel but are permanently masked by water in the regulated system.

Grinding materials are unevenly distributed with the majority situated around the outer extent of seasonally inundated land rather than within the interior of the floodplain or more permanent waterbodies. A similar pattern continues into the Chowilla floodplain east of the Calperum Station (see previously reported locations in Figure 6-97). These areas are characterised by chenopod shrubland, pigface meadows and narrow belts of black box woodland fringing ephemeral wetlands. These areas would have had immediate access to a range of plant foods identified in ethnohistorical observations including nardoo, club rush, pigface and saltbush. With the exception of several locations, there appears to be no clear association between grinding evidence and *Typha* spp. habitat. Curiously, all examples of grindstones commonly recognised in the processing of soft grass seed (Type III bases [millstones] and Type I topstones [mullers]) occur in a relatively confined area between Lakes Merreti/Clover and Hunchee Lagoon (see Figure 6-97), again within chenopod/black box communities. The absence of grinding material outside of the floodplain along the Pike cliff is consistent with a pattern recognised in the Riverland (see Chapter 4.3.2).

The majority of grindstones occur in eroded contexts. None can be confidently related to a direct age estimate with the exception of a single topstone in CAPR17_14. In this instance, both the artefact and an adjacent in situ lens of shell midden are embedded to a similar depth in a

compacted sand. An age of 5889–5656 cal BP (Wk-52027) was returned on shell fragments within 15 cm of the artefact. Given the durability and utility of grinding material, there is a potential that these artefacts were recycled over an extended timeline. As such, this ¹⁴C age could be regarded as a terminus ante quem for the artefact. In a number of other instances, the stratigraphic context of grinding material can be broadly related to the dating of archaeological materials. For example, in situ midden shell dated to 3814–3568 cal BP (Wk-47549) in CAPR17_22 is embedded in a subsoil that dips under a loose cover sand containing grinding material. This, and similar relationships build to a conclusion that the recorded grinding material is likely to be constrained to a mid to late Holocene chronology. In no situation, is there any compelling evidence to suggest a deeper timeline. The apparent absence of grinding material in the Pleistocene archaeology along the Pike cliff is also telling.

6.3.9 Evidence of earthworks in CAPR17_08

Historical observations of weirs and other forms of earthworks constructed by Aboriginal people exist in this region. Dr Harris Browne's account of a dam and fish trap near Overland Corner is the most descriptive in terms of a local reference. In this instance, wooden rods had been stuck into the ground in a double row 1 foot apart and filled with lignum to slow the fish and make them easier to spear (Finniss 1966). Other references exist to weir traps built across flood runners channels (Beveridge 1883:48; Eyre 1845:253; Krefft 1865; Smyth 1876). George Augustus Robinson, the Victorian Protector of Aborigines, described poles set for duck nets and weirs in several locations on the Chowilla floodplain (Robinson and Clark 2000:48). The preservation of these features would undoubtedly be compromised by the natural decay of plant materials used in their construction, together with the sedimentation and active erosion in these settings. Very few fish traps or other forms of ground modifications are reported in the inventories of archaeological sites, both in the Riverland and greater MDB (see example in Pretty 1977b).

An excavated channel was identified in site CAPR17_08 (Figure 6-98). The channel deepens a natural swale in an SBD ridge and connects a deep basin south of the ridge and an area of floodplain to the north (Figure 6-99). The lowering of the swale, even by 20-30cm, would have seen the basin fill at flows in the order of 95 GL/day, i.e. at a return period of one in two or three years. The southern edge of the basin is formed by another dune ridge which, based on flood

inundation modelling³⁴, prevents rising water from flowing directly into the basin. This is despite the basin lying approximately 60 cm below the surrounding floodplain. Given this depth, the basin would not fully drain as flood waters receded, and instead, would retain a substantial volume of water. Flows into the basin via the channel are evidenced by the development of sand bars extending into the basin. No similar evidence is seen around the inlet.

The channel intersects a stiff soil developed in the SBD which appears to have been excavated and relocated into spoil heaps either side of the channel. These spoil heaps are evident in a DEM constructed from RTK data intersecting the channel and shown in Figure 6-99. A number of stone artefacts were found on top of this spoil. Heat retainer (baked clay) occurs as partially preserved hearth features and scattered material on sloping ground rising above both sides of the channel. There are some copped trees in the area (cut with steel blades), though no other historic materials or features were identified in the general area of the channel. Instead, the evidence suggests a deeper antiquity to this feature and points to a form of landscape manipulation that is rarely preserved in the extant archaeology of the River Murray floodplains.



Figure 6-98: View looking south along the excavated channel in site CAPR17_08 with the gravel spoil seen to the left of the range pole .

³⁴ The FIM used here was developed by Daniel McCullough, Senior Hydrologist, Water Science Unit, Department for Environment and Water, as part of modelling of the Weir 5 reach. DEW have kindly provided this data for use here.

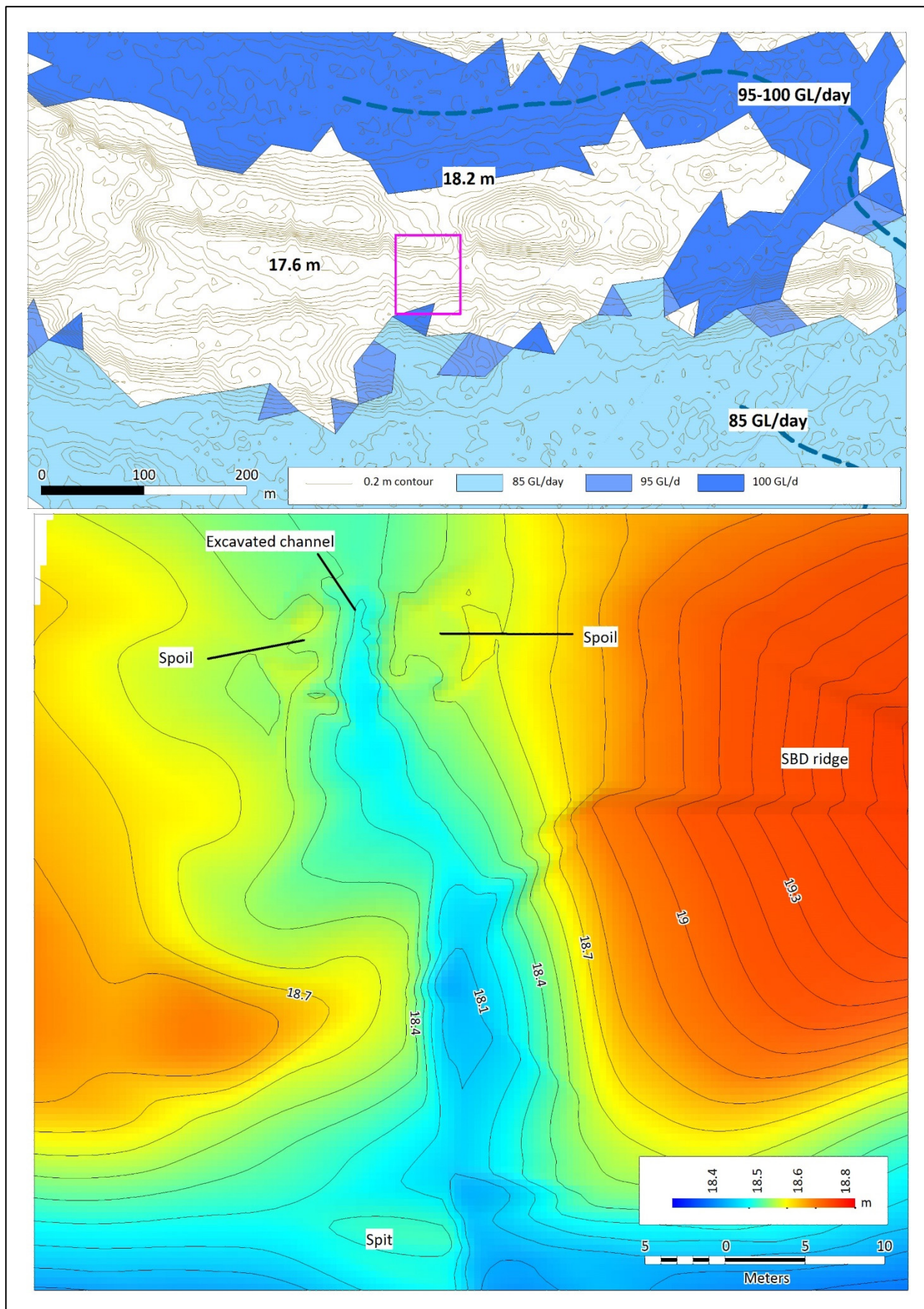


Figure 6-99: (Top) Flood inundation modelling showing the diversion of rising waters to the west and north of the basin and (bottom) the topography in the area of earthworks in site CAPR17_08.

6.3.10 A taphonomic profile

Riverine environments are inherently destructive and, as such, there remains a distinct risk that bias can be introduced into archaeological records. Luebbbers (1995), for instance, argued that high flows and related erosion during the period 20–10 ka had essentially stripped sites from the lower floodplain in the area around Karadoc Swamp. Balme and Hope (1990) assigned short gaps in the development of middens during the late Pleistocene to a lack of aggrading sedimentary environments more suited to the preservation of organic materials. The process of stream migration does not necessarily cease following meander cut-off. Banks can also migrate over short timeframes. The bank of Katarapko Creek, for instance, eroded several metres during a single flood event in 2016–17, leading to the widespread erosion and in some instances the total destruction, of middens and oven mounds. Bank instability can be promoted by extended periods of low river flows (Hubble and Carli 2015). A number of sites at Calperum have obviously been sectioned by the migration of cut banks. This includes examples along the banks of the main river channel, minor flood runners and oxbows.

Archaeological sites occupying all but the highest elevations in the floodplain would have developed under a constant interplay with seasonal flooding. It can be envisaged that occupation phases would have been periodically interrupted by floods, with related materials potentially buried, eroded and/or displaced. The T2 phase regimes were also characterised by high energy flood pulses impacting the floodplain through broad and shallow channels. Overbank flooding of these palaeochannels is evidenced in often extensive crevasse deposits. Negative evidence along these waterfrontages should, therefore, be treated with some caution. Whilst the modern regime is characterised by a gentler rise and fall, high flow events do occur periodically. In the Lower Murray trench, Mulvaney et al. (1964) cited the abrupt erosion of archaeological deposits in the Tungawa rockshelter as evidence of a megaflood ~3,000 years ago. Evidence of late Holocene catastrophic flooding in both the Calperum and Pike floodplains is described in Chapter 6.

Impacts can also register around the outer extents of highstand events, particularly where these are maintained over extended periods of time (O'Halloran and Spennemann 2002). These effects are on display at Lake Bonney, where an artificially maintained water level has seen the shoreline regress over tens of metres, foredunes stripped away and consequential impacts occur to cultural heritage (Wood and Westell 2008a). Examples of etching at Calperum are discussed in detail in

Chapter 6.2.3 and illustrated in Figure 6-14. An example of highstand erosion is also illustrated in the excavation results from site CAPR17_14 (Figure 6-100). Here, a steep topography had evidently (re)developed in the terrace at some stage during the period c. 3.6–0.8 ka based on the relative elevations of a series of ^{14}C ages across this site.

Sites are, however, capable of surviving inundation, and indeed, floods can provide some benefits to site preservation by promoting stabilising ground covers and top-dressing sites with sediment. Of the 116 Calperum sites, 37.9% (44) would have been at least partially impacted by a 1 in 4-year flood under natural flows and 49.1% at a 1 in 10-year flow (see Table 6-25 and Figure 6-101). A total of 99 (75.9%) sites were submerged by the 1956. Importantly, a range of elevations exist along various types of waterfrontage and across the range of habitat within the floodplain. In effect, there are no particular settings where all sites would necessarily be submerged and potentially destroyed and/or masked by the effects of regular flooding. The ^{14}C ages returned on materials within the various FIM extents complement this discussion with essentially the full range of ages reported at Calperum represented in sites inundated at a 1 in 10-year or higher event. Clearly, an extended record has survived in these sites despite inundation by both semi-regular (1 in 10-year) and more extreme flood events. The valley cliff also provides a setting beyond any possible effect of inundation.

The Riverland floodplains provide a complex taphonomic mosaic of sediment, erosion, moisture and salinity conditions. Following the ‘essential research approach’ championed by Shahack-Gross (2017), the archaeological record is first considered within this context. The schema outlined by Kibblewhite et al. (2015) provides a convenient basis for reducing this complexity into a taphonomic profile based on the properties and settings of various soil types. Five dominant units are considered relevant; a **Calcisol** terrain incorporating the older terraces, dunes and lunettes, **Gypisol** in the Phase II lunettes, **Fluvisol** across the T2c, T3 and T4 scrolls, **Solonetz** in the salt-affected areas of the floodplains and **Arenosol** terrain incorporating the active aeolian dunes and sand sheets. Some key implications are presented in Table 6-26. In summary:

- Neutral to mildly alkaline conditions extend across most settings and pH readings taken routinely through the excavation process were neutral to mildly alkaline (7.0–9.0). These conditions should provide ideal environments for the preservation of shell (aragonite) and bone (hydroxyapatite) (Stein 1992:Figure 1).

- Site contexts are, however, often comprised of free-draining sediment that would permit leaching and high variability in moisture content. These conditions are known to promote the loss of bone through dissolution (Hedges 2002).
- The regular inundation of many of the sites and elevated soil salinities have implications for the preservation of archaeofauna, and in particular, bone (Henderson 1987 cited in Baxter 2004; Kibblewhite et al. 2015).
- Sediment movement is arguably the most significant taphonomic influence on sites in the study area. Sites were commonly located on dynamic surfaces such as dune and lunette surfaces, levees, cut-banks and SBDs. Subsequent erosion has acted to decontextualise, destabilise and physically degrade large numbers of sites, in whole or in part. As discussed in Chapter 6.2.2, the combined effect of pastoral land use, rabbits and river regulation has probably amplified the processes of deflation and scalding (see also Holdaway et al. 2002). As with the effects of inundation, these impacts are not universal, and examples of in situ midden, hearths and other features/structures within sites were routinely recorded and specifically targeted during the ^{14}C sampling.

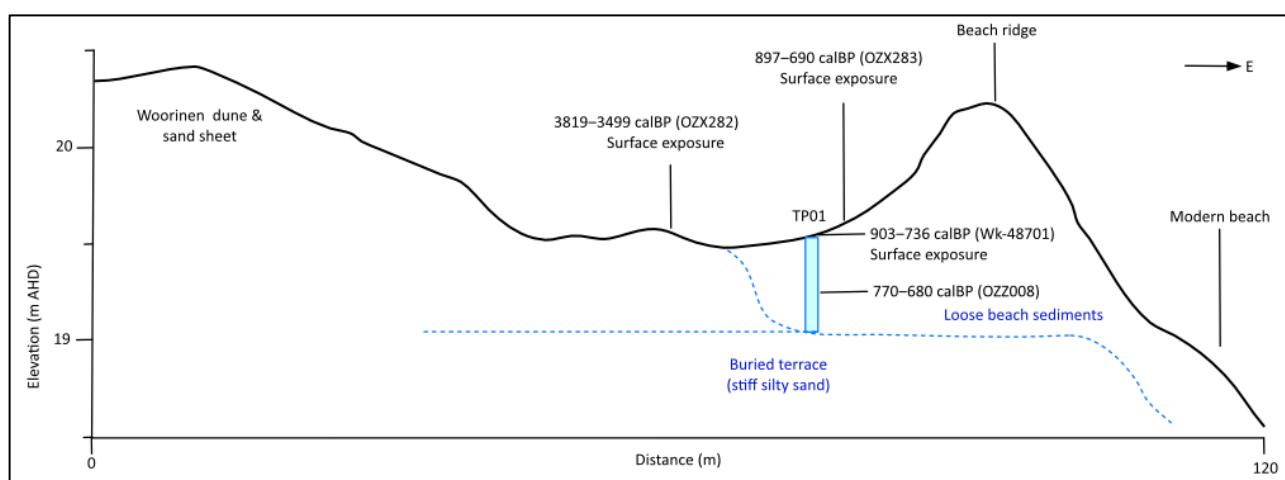


Figure 6-100: A stratigraphic interpretation of CAPR17_14 TP01.

Table 6-25: Numbers of sites and ^{14}C sampling locations impacted at various FIM extents at Calperum.

Return period	1 in 1-yr	1 in 2-yr	1 in 4-yr	1 in 10-yr	1 in 100-yr	above 1956
FIM	FIM_50	FIM_70	FIM_115	FIM167	FIM_340	>340
Number of sites impacted	12	21	44	57	88	32
Number of ^{14}C ages within FIM	0	0	0	10	27	31
min cal BP	-	-	-	153	153	145
max cal BP	-	-	-	8980	8984	9463

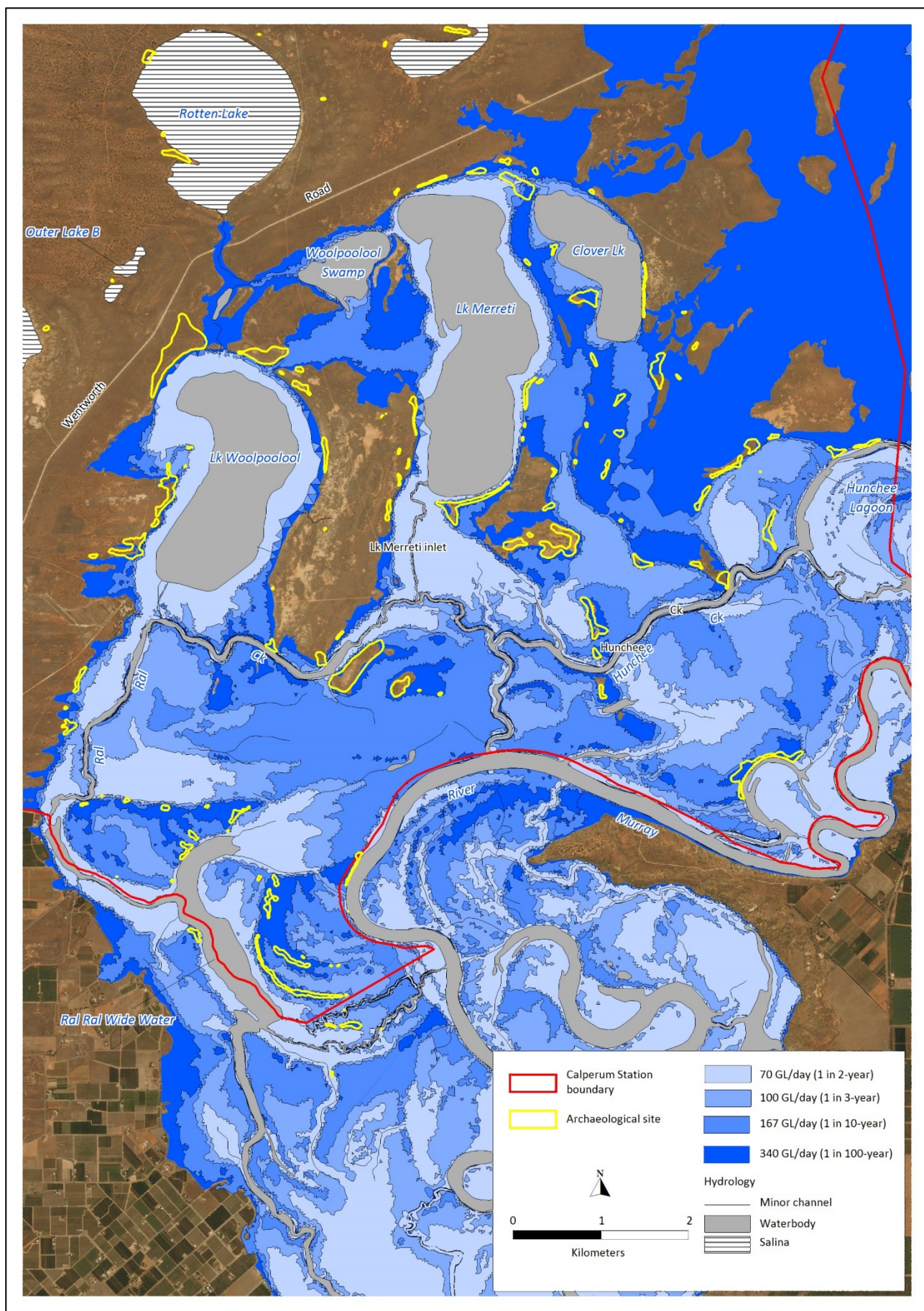


Figure 6-101: Archaeological sites at Calperum in relation to the extent of flooding associated with 1 in 2, 3, 10 and 100-year flows.

Table 6-26: Key natural taphonomic components to consider in the research area (after Baxter 2004; Karkanas 2010; Kibblewhite et al. 2015).

Factor	Detail	Terrain type				
		Calcisol	Gypisol	Fluvisol	Solonetz	Arenosol
		T1, older WF	Phase II lunettes	Scrolls, terraces, levees, shorelines, SBDs	Salt-affected floodplains and terraces	Dunes, sand sheets, SBDs, lunettes
pH	Possibly the most significant factor in preservation with poorer preservation of human and animal bones & teeth (hydroxyapatite $[\text{Ca}_5(\text{PO}_4)_3\text{OH}]$, protein (collagen) fibres and shell and avian bone (aragonite and calcite $[\text{CaCO}_3]$) occurring with lower pH soils. Preservation is higher in neutral or slightly alkaline soils.	Good Typically alkaline conditions	Good Typically neutral to alkaline conditions	Variable Higher pH in organic clay and neutral in undifferentiated quartz sand. Soil development can lower pH in topsoil.	Variable Typically alkaline conditions	Moderate Higher pH in upper leached unit, more alkaline in lower unit
Soil salinity	Crystallisation and associated expansion of salts deposited within internal structures of bone can crack and flake bone and accelerate physical degradation.	Good	Poor	Neutral	Poor	Good
Moisture & biological oxidation	Moisture promotes chemical interactions with soil with higher levels of preservation in dry (arid/semi-arid) conditions. Free draining unsaturated conditions promote decay, compared to permanently saturated (waterlogged) and anaerobic conditions.	Good	Good	Variable Soils may be seasonally inundated	Poor Soils may be seasonally inundated	Poor Free draining soils promote leaching
Soil stability, exposure and physical weathering	Rapid and sustained burial aids preservation whereas unstable/degrading contexts that (re)expose materials favour degradation.	Variable Large scale scalding and deflation occurs though aeolian drapes are also common	Variable Sediments can be prone to deflation	Variable Poor in active settings (crevasses, levees, beach-ridges), good in vertically accreting settings	Neutral Soil movement in cracking clay (vertosols/gilgai) can be severe	Moderate to Poor Sediments are prone to deflation.
Soil chemistry	Ca-rich soils can retard the dissolution of bone. Chloride-rich soils may promote loss of calcium.	Good	Neutral	Neutral Typically formed on quartz sand and clay	Poor	Good

One of the key motivations in conducting excavation in this research has been developing a commentary around the potential loss of faunal material following exposure. In their assessment of the Darling River record, Balme (1990) and Balme and Hope (1990), for instance, noted that organic materials deteriorated rapidly following exposure but the preservation of even the more fragile material in newly exposed sites was generally excellent, even in older sites. Organic remains were absent on the older, exposed red sand plains (Balme 1990:18). The key observation during this research is that the fauna recovered during the excavations essentially replicates the results of both the surface sampling and general site recording. On this basis, the almost exclusive presence of freshwater mussel shell in middens cannot be attributed solely to the taphonomic loss of other elements following exposure. Importantly, older land surfaces are being continually exposed, including lunettes that are directly relatable to systems intensively studied elsewhere in the MDB. On the basis of the current research, together with a summary of previous reporting in the Riverland, the inescapable conclusion is that diverse assemblages, similar to those occasionally recognised elsewhere in the MDB, are extremely rare or simply do not occur in the Riverland. Whether they did or not remains uncertain.

Taphonomic loss and bias is assumed in the Riverland sites, but there is little utility in simply stating that ‘things are missing’ rather than suggesting ‘what is missing’. The long lists of resources observed in the historical accounts provide some guide, but the extent to which this list can be extrapolated to the archaeological record is conjecture. Did the Riverland economy function almost exclusively around the harvesting of freshwater mussel? The simple answer is no—shell middens reflect a specific intent. Building a narrative almost exclusively around these sites is, therefore, problematic. Hearths, for instance, are likely to relate to the cooking of various foods (see Eyre 1845:Vol II) that are simply unrepresented in the archaeological record.

The preservation of archaeological material is influenced by the nature in which it was initially processed (breakage/crushing/cooking) and deposited, its initial sedimentary environment (aggrading, stable, degrading) and the physical, chemical and biological contexts it is subsequently subjected to (e.g. Andrews 1995:149-150; Karkanas 2010; Kibblewhite et al. 2015; Shahack-Gross 2017; Wolverton et al. 2010). The starting point, however, is the unique combinations of the treatment, preparation, processing, sharing, social context and disposal methods applied to different foods. In her analysis of a Willandra assemblage, Walshe (1998) for instance, argued that

the chemical and physical alteration noted on a significant proportion of bone in the Mungo B assemblage must have arisen through its incorporation into large, high temperature fires, possibly constructed to cook larger game. This, together with subsequent scavenger behaviours probably acted to bias the extant assemblage. The treatment of food refuse is likely to have differed to suit specific circumstances and with the intentions of maintaining hygiene, controlling pests and organising domestic spaces, among other things (Meehan 1982).

It has been suggested by Westell and Wood (2014) that the configuration of the anabranch floodplains in the upper Riverland may have promoted a separation of activity areas, whereas in the Lower Murray, processing activities and occupation spaces may have been conflated into narrow zones extending along the margins of the gorge (see also Angas 1847:58). Westell and Wood (2014) related this scenario specifically to oven mounds, though it might equally apply to other forms of occupation and processing sites. In effect, the separation of activity areas in the more complex floodplains of the upper Riverland may have reduced the diversity and content of faunal material deposited into open context sites. A broader sampling of a wider range of site type and context may be required to compile representative food lists in these complex floodplains.

The paucity of faunal material (other than shell) in the open scatters at Calperum also contrasts to the assemblages recovered from a series of three open context sites investigated by Wilson et al. (2022) in the Lower Murray; namely the Murrawong, Kangerang and Pomberuk sites. In all three instances, low numbers of diagnostic faunal remains were recovered, though despite this, 16 unique taxa were able to be identified (Wilson et al. 2022:7). Importantly, however, these sites retained deeply stratified and in situ cultural deposits. Faunal remains were recovered from total excavated depths of typically 60–80 cm, and potentially as deep as 104 cm at Murrawong³⁵. These materials were related to a ¹⁴C chronology extending to c. 8.3 ka at Murrawong, c. 5.9 ka at Kangerung and c. 6.4 ka at Pomberuk (Wilson et al. 2022:Tables 1, 2 and 3). No similar stratified deposits were identified in the Calperum archaeology, whether in situ or exposed through erosion.

Bone is also best-preserved where sediments remain stable, are neutral to slightly alkaline, have low salinity and where they are either permanently saturated or dry (see Table 6-26). At Calperum,

³⁵ Shell recovered from 104 cm in the Murrawong excavation may have fallen from the wall of the pit (Wilson et al. 2022:4).

and in the broader Riverland, high salinity, mobile ground surfaces and seasonal variations in soil moisture content are common. This may have contributed, at least in part, to a paucity and/or loss of faunal material in the open scatters at Calperum. The variable condition of human bone identified in the burial sites at Calperum and in the broader Riverland may provide some cues to the preservation of faunal bone. Various elements of the human skeleton are relatively thick and robust, though despite this, the ancestral remains identified at Calperum were invariably found in a fragile, chalky and highly fragmented state. Similar observations had been made by Archer Russell (1923) in the 1920s of burial sites along Ral Ral Creek. Relatively intact human bone was noted only where active deflation had recently exhumed the remains (e.g. sites CAPR17_09, CAPR17_10) or where remains have been exposed in sediment profiles and remained largely covered (e.g. see the Lake Limbra example described in Chapter 7.4.7). Evidently, bone is best preserved where it is rapidly buried (e.g. interred) and where it remains buried. A rapid breakdown of surface-deposited bone, e.g. bone discarded into refuse heaps, might be envisaged. It is also worth noting that the faunal assemblages described by Wilson et al. (2022), whilst diverse, were far less varied than the Holocene assemblages recovered from the Lower Murray rockshelter deposits at Nguat Ngaut and Tungawa (see Wilson et al. 2022 Supplementary Material Table S2; see also Hale and Tindale 1930; Mulvaney 1960; Mulvaney et al. 1964; Smith 1978, 1982).

The approach taken in this research has been to use midden ages as a framework that can be value added by relating other evidence of occupation within an understanding of landscape development. Importantly, there is no compelling evidence that riverine processes would necessarily erase or grossly bias the entire record given the varied topography and elevations across, and beyond, the valley. Highstand events do impact the shorelines of waterbodies, cut banks are continually migrating and there have been periods where sites are less likely to have been buried and preserved. However, the sheer complexity of these floodplains, and the provision of a high confining cliff-line, provides opportunities for preservation. The survey strategy has also sampled the full breadth of landscape setting and emphasised locations that would mediate, to some extent, the complex taphonomic setting; principally the outer edge of the inner lakes, elevated SBDs and other dunes within the floodplain, cut banks of abandoned scrolls, lunettes and the cliff-line. In summary, we can be confident that patterns can still emerge here despite taphonomic bias.

CHAPTER SEVEN: DISCUSSION

7.1 Introduction: A landscape defined by change

The climatic shifts across the last glacial-interglacial cycle have manifest in MDB riverine corridors in a variety of ways. Within the Riverland, a sequence of terracing developed as the floodplains adjusted to distinct hydrological settings. Landscapes relating to each phase are preserved, at least partially, and provide an opportunity to relate the record of Aboriginal occupation in this region to a timeseries in landscape development. In outline, large capacity channels of terrace T2a were in place in the Riverland by at least c. 43 ka. These had incised an existing floodplain developed around large dimension channels of terrace T1. Lunettes that were developing around perennial lakes in T1 continued to accrete under freshwater conditions (QSD-facies) through the incision and subsequent development of terrace T2a. Evidence of a discrete saline phase in the outer lakes heralded a more significant shift to persistent saline conditions by at least 27 ka, coeval with the incision of terrace T2b. Large, gypsum (HSGD-facies) lunettes began to develop around the outer lakes from this time. Gypsum is also potentially detected in a pXRF assay of lunette sediments around the inner lakes, though salt appears to have been largely mitigated from the inner floodplain. The hydrological setting across this period is also complex, as evidenced in the sequential deposition of sand, gypsum clay and gypcrete soils in the Phase II lunette at Rotten Lake.

A brief period of landscape stability c. 24 ka manifest in a deep palaeosol that pervades much of the Calperum landscape before a renewed deterioration in climate saw reduced water connectivity across the floodplain. The majority of outer lakes became isolated as WFm dunes transgressed into the floodplain across the LGM. During the development of terrace T2c, the floodplain was fed by large capacity, though frequently dry, channels. LGM aridity was briefly interrupted by a regional³⁶ humid phase that saw the stabilisation of dune-fields and soil development between 18–14 ka (Fitzsimmons et al. 2013:84, 92; Lomax et al. 2011) and the rapid development of QSD-facies lunettes around the north-eastern shorelines of the inner lakes at Calperum. This pluvial was short-lived, however, and was followed by the reactivation of dunes

³⁶ The geographic extent of this 18–14 ka humid phase is reflected in a period of speleothem growth in both the Flinders Ranges and at Naracoorte, and a highstand level at Lake Frome (Fitzsimmons et al. 2013:92).

across the central-western MDB between 14–12 ka, by which time Wfm dunes and sand-sheets had advanced up to 5 km into the Riverland floodplains and were impacting the western shoreline of Lake Woolpoolool. The River Murray was essentially flowing through a mobile, sandy desert, and it is likely that the iconic eucalypt forests that define the modern river had been eliminated, or at least significantly reduced, to isolated fragments by this time (Reid et al. 2016:50).

The pattern of powerful, though highly seasonal flooding gave way to a system of mixed-suspended load channels tracing out more sinuous meanders in terrace T3 by c. 13 ka. More regular flows saw a gradual reinundation of Rotten Lake from at least c. 11 ka. This peaked by c. 8 ka, by which time a sandy beach was forming around the northern shoreline of the lake and freshwater mussel had repopulated the lake. This timing agrees with a period of increased through-flows to the mouth of the river between 13.5–11.5 ka (Gingelle et al. 2007:268; see also Mojtabid et al. 2020). Based on the inundation requirements of the modern riverine flora and fauna (see Chapter 4.4.2), this transition would have utterly transformed the riverine ecology and seen the emergence of a floodplain more recognisable in the modern system; woodlands of river red gum and black box, reedbeds and sedgeland, diverse and productive riparian habitats and large avifauna populations.

Further reductions in meander wavelength and channel width occurred with the development of T4, though the timing of this transition remains poorly constrained based on the dating evidence presented here. If conditions at Rotten Lake are taken as a baseline, a transition in hydrology may have been more closely aligned to the start of the MHCO c. 8 ka (see for example Quigley et al. 2010) than the slightly earlier (10 ka) timing suggested by Prendergast et al. (2009) in respect to the Mulcra-Murray transition at Neds Corner. Further evidence of a climatic transition at this time is seen in the reactivation of regional dune-fields between 8–5 ka (Lomax et al. 2011).

Variability has been **the** defining aspect of the Holocene climate, and in particular the ENSO-influenced mid-late Holocene. However, the absence of SBDs and the uniformity in the T3 and T4 scrolls argue against wholesale or sustained changes in inflow conditions. Instead, a pattern of slowly migrating, sinuous, low peak volume, single thread channels contained within anabranch floodplains appears to have been established at the close of the deglacial and persisted across the

entire Holocene. Whilst aeolian phases reflect a changing context to the riverine corridor, a relatively stable ecology appears to have been maintained within the valley itself, as attested by the archaeofauna recovered from the Ngaut Ngaut (Hale and Tindale 1930) and Tungawa (Mulvaney 1960; Mulvaney et al. 1964) rockshelters on the lower Murray, for instance. The assessment of diatom assemblages in Riverland wetlands across the late Holocene (Fluin and Gell 2008) also indicate little evidence of elevated salinity compared to current levels, and whilst the relative abundance of plant taxa fluctuates, a consistent tree, shrub and herb/grass assemblage (as represented in macrofossil and pollen records) appears to have existed in these floodplains across the last few millennia.

This is not to say that the habitat mosaic remained static. Rather, continual readjustments simply occurred within parameters defined by a consistent scroll pattern and within ecological tolerances. Within these parameters, major reconfigurations in floodplain architecture are recognised. This includes notable examples of channel avulsion at Calperum and Pike. At Calperum, a broad thalweg overprints a fully developed T4 meander and can be traced downstream of the south-western scrolls to an avulsion point in a T3 terrace (Figure 7-1). The modern River Murray exploits this cutting. Further adjustments are seen downstream where an immature scroll pattern is emerging from a conspicuously straight reach, suggestive of a catastrophic event carving out this remarkably uniform feature. Evidence of this event is also suggested in the geomorphology and archaeology associated with the Ral Ral Wide Water oxbow. As seen in Figure 7-1, an extensive scour extends from Woolenook Bend into the upstream end of the oxbow, the northern edge of the T2c scroll has been reshaped by this scouring, and the upper part of the oxbow has been pushed past (west of) the original T2c channel trace. Despite the LGM age of the scroll, freshwater mussel shell middens associated with this waterbody appear to be exclusively late Holocene with an age estimate of 1,307–1,183 cal BP (OZY995) being the oldest of seven shell-derived ^{14}C ages. A plausible scenario is that a catastrophic event sometime prior to c. 1.3 ka had (re)excavated the Ral Ral Wide Water oxbow and this 'new' habitat had been incorporated into subsistence activities. Indeed, this area appears to have become a significant node in the floodplain based on the extant archaeology.

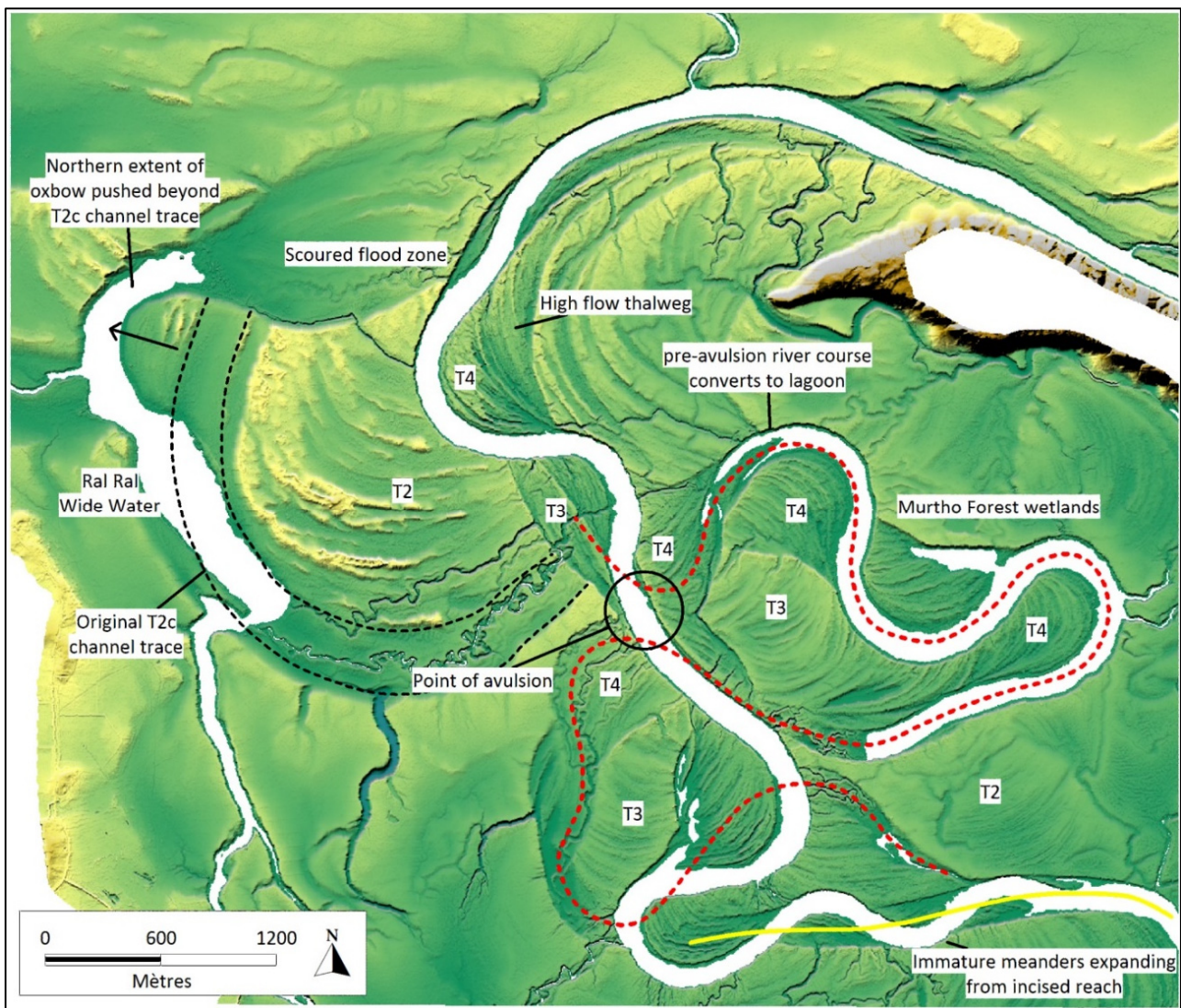


Figure 7-1: Topography in the southern section of the Calperum floodplain showing the late Holocene avulsion.

A similar late Holocene avulsion is also seen on the Pike floodplain. In both cases, avulsion resulted in the conversion of channel to lagoonal habitats with the creation of the Murtho Forest and Mundic Creek wetlands at Calperum and Pike, respectively. These types of continual and/or punctuated adjustments in landscape are certain to have played out across the entire history of floodplain development. Smaller changes in microhabitat also occur on intra-annual timeframes (Leigh et al. 2010b:42–43). In effect, these reconfigurations in the habitat mosaic, some of which occur on the scale of lived experience, would have required continual and concomitant adjustments in Aboriginal lifeways, sometimes subtle and at other times more significant. Consider, for instance, that the late Holocene avulsion at Pike converted approximately 13 linear kilometres of river channel frontage to wetland habitat.

Considerable variability would have overlain this sketch outline, with long term trends incorporating hydroclimatic cycles modulated by seasonal, intra-decadal (ENSO), multidecadal (PDO) and quasi-millennial systems (Gell 2020:626; McGowan et al. 2009; Petherick et al. 2013; Petherick et al. 2008; Reeves et al. 2013). Multiple palaeosols observed in Wfm dunes, all of the lunette phases, and in SBDs, are testimony to environmental cycles both within and between each hydrological phase. Activation cycles in the Wfm dunes also illustrate the periodic desiccation and denudation of the high plains beyond the valley margins. Unsurprisingly, the LGM witnessed major dune advances, though the Holocene record is also characterised by the repeat mobilisation of aeolian sediments as the MDB accommodated a general trend toward drier conditions (Marx et al. 2009; Stanley and De Deckker 2002). Ho et al. (2015:2) have suggested that relatively drier periods in the MDB occurred c. 2400, 2200, 1000, 600 and 300 years BP.

The Millennium Drought provides some insight into the potential scale and pace of ecological responses to environmental shocks. The effects of similar long-term droughts are pervasive and cascade through all trophic levels. Rebound periods can also be lengthy. In respect to the Barmah Forest avifauna, Selwood et al. (2015:1706–1707) concluded that ‘four years of average to well-above-average rainfall is inadequate to offset losses from a 13-year drought’. The effects can be persistent when systems do not have the capacity to recover between events. The trends observed during the Millennium Drought can be extrapolated to the cumulative impacts across more significant and sustained transitions in hydroclimate, for instance the periods of heightened aridity recognised in the dune activation cycles.

Sedentism along the River Murray has been canvassed in terms of the highly productive ecology of this riverine corridor and the perceived reliability in water and dietary resources (Pate and Owen 2014). Ultimately, however, these are fragile and only vaguely predictable landscapes. The floodplains and related habitat mosaics have always been dynamic and complex, evolving under the influence of various processes driven ultimately by climate. The degree of sedentism observed in this region at the time of European contact occurred in spite of these conditions, and through flexible socio-economic systems that were able to accommodate variability.

Cycles of cut and fill are certain to have represented one of the more critical factors influencing water connectivity and the makeup of the habitat mosaic in the floodplains. These periodic readjustments in base level have had the effect of altering the range, extent and duration of inundation. The total elevation difference between terraces T2a to T4 is currently less than 4 m, though this modern topography reflects the most recent period of infill as terrace T4 has matured. More significant floodplain incisions may be masked by this and previous phases of infill. This is illustrated in a stratigraphic profile recorded by Gill (1973a:Figure 40) of a deep test pit excavated for the then proposed Chowilla Dam. The profile extended to a depth of 18 m and included two ^{14}C age estimates of $7,200 \pm 140$ BP (GaK 2513) [6267–5740 cal BP] and $4,040 \pm 100$ BP [2872–2278 cal BP] obtained on what Gill (1973a:46-47) described as a ‘horizon of fossil logs’ (river red gum, black box and casuarina) found between a depth of 8.2 and 10.1 m. The 8 m of overburden provides some indication of the potential degrees of incision and pace of subsequent infill. Habitats associated with the initially incised terraces are also likely to have differed from more mature and broader scrolled floodplains, providing yet another element to consider when contextualising the occupation record. Importantly, however, the complexity seen in the modern floodplain architecture is in large part a consequence of these cycles, and while periods of incision undoubtedly redrew the habitat mosaic, this process has provided the essential template for the sheer diversity and productivity seen in modern riverine corridor. In effect, the landscape was primed—all that was needed was to add reliable water.

7.2 Rivers die from the bottom up

The explanatory models of environmental change in the MDB have tended to emphasise headwater conditions as central to the character of rivers and lakes across the basin (see for example Hesse et al. 2018; Kemp and Rhodes 2010). It is important to recognise, however, that the MDB is fundamentally a cascading system in which the continual uptake of water has a compounding effect. Floodplains are continually reshaped, their capacity to absorb, retain or redirect water is forever influencing the nature of flow transmission (Hesse et al. 2018:88; Kemp et al. 2017:7; Walker 2006)³⁷. On this point, two major reconfigurations in the MDB are worth considering; these being the Willandra and Darling avulsions (Figure 7-2). The redirection of

³⁷ Walker (2006:254) suggested half the rainfall across the MDB would have discharged through the mouth of the river under pre-regulation flows. This figure is as low as 4% in the regulated system (Simpson and Herczeg 1991:5).

Willandra Creek to the Lachlan River had begun c. 24 ka and was complete by 17–15 ka (Kemp et al. 2017) while the ancestral Darling River avulsed to the modern corridor in the period 10–8 ka (Balme 1990). Both avulsions diverted water away from lake systems that occupy areas of approximately 1,200 km² and into river flows that ultimately converge on the River Murray and Riverland.

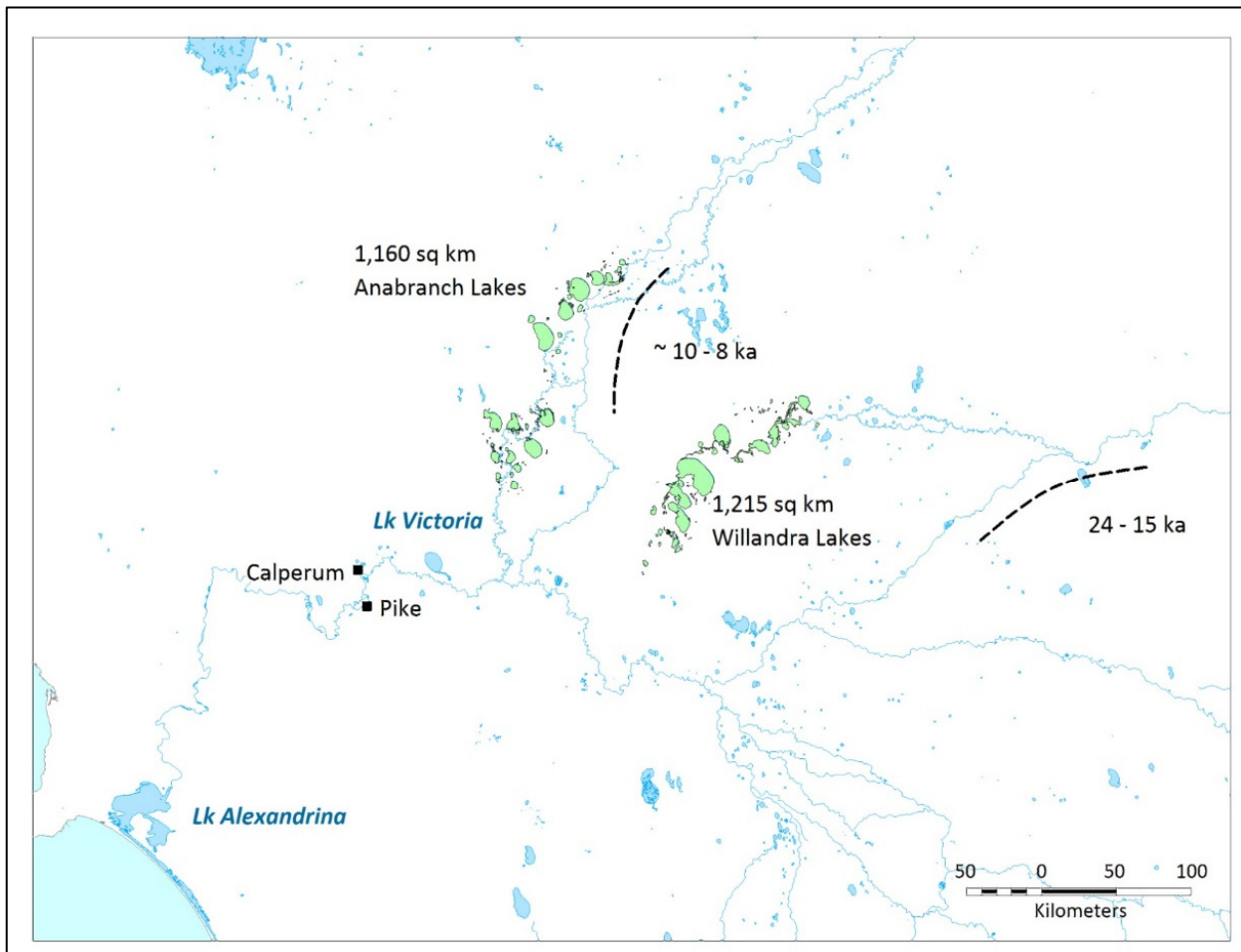


Figure 7-2: The timing of the Willandra Creek and Darling River avulsions.

The evidence of freshwater conditions in Rotten Lake across the early Holocene illustrates a remarkable turn-around in inundation ranges, particularly when considering that this occurred in the context of floodplain incisions to T3 and T4. Whilst a specific link between this re-inundation and upstream avulsions may be difficult to support, or model, it is nonetheless worth considering in reconstructions of palaeohydrology in the lower end of the system. Hubble et al.'s (2021:39) suggestion that Darling River-sourced water 'dominated' Murray flows across a relatively short period c. 7 ka (based on sediment mineralogy) is also noteworthy in the context of the Darling avulsion. It is also worth reflecting that despite La Niña conditions producing high rainfall and flooding across the Darling River catchment in early 2022, this event did not trigger an overbank

flood in the Riverland as large volumes of water were artificially diverted into the Menindee Lakes storage. This might provide a modern analogue to a palaeohydrological system, and an illustration of the inflows required to A) fill and overflow the Menindee system and B) benefit the Riverland floodplains.

The consequences of any reduction or inconsistency in inflows are also amplified in areas more remote to the headwater catchment. As the adage goes, ‘rivers die from the bottom up’, a trait brought into sharp relief during the Millennium Drought. As described in Chapter 4.4, salinity has profound consequences, and perhaps the most significant consequence, on riverine ecology. In the Riverland, floodplain salinity is modulated by the duration, frequency and volume of inflows, but is also complicated by discharge from saline aquifers. In this respect, the high bounding cliff-lines of the valley act as both a blessing and curse—confining water when it arrives but also creating a depicentre for saline groundwater. This has demanded the development of various salt interception schemes over recent years which essentially ring the Riverland floodplains (Figure 7-3). Ironically, the recharge of regional groundwater tables through periods of higher rainfall (e.g. the ~24 ka pluvial) may have acted to promote subsequent inflows of saline groundwater into the incised valley, compounding the effects of less reliable LGM inflows and contributing to the remarkable salt loads seen in the outer lakes at Calperum.

The Riverland also lacks the large capacity lake complexes found further upstream, with Lake Bonney representing the only vaguely comparable feature. A lack of water security would have been a disadvantage to Aboriginal occupation in this region during the periods of flashy and/or infrequent flooding, for instance during the LGM. Based on the structure of terrace T2c, water was delivered to the Riverland though high peak volume, though narrow seasonal flows. These types of powerful, though flashy flow, tend to benefit larger lake basins that are capable of collecting and retaining water over extended periods of time, regardless of the length of the high-volume flood (Hesse et al. 2018). Kemp et al. (2017:8–9) has suggested that the water balances in these lakes are influenced in large part by these peak events rather than regular seasonal trends. The lake systems occupying the lower reaches of the Darling and anabranches, for instance, hold water for periods of up to five years after floods (Balme and Hope 1990). It might be expected that the smaller capacity lakes of the Riverland would drain back to the river, evaporate and/or salinise more quickly, representing a water resource potentially as ephemeral as the river itself. Oats were

able to be cultivated on the dry bed of Lake Bonney from time to time (see SLSA Photographic Record B 10413, 'Cropping in Lake Bonney'), a clear illustration of the ephemeral nature of this waterbody. A record of early and sustained occupation upstream of the Riverland seems to make perfect sense in a context of water security and the relative stability in habitat provided by the larger capacity lake systems.

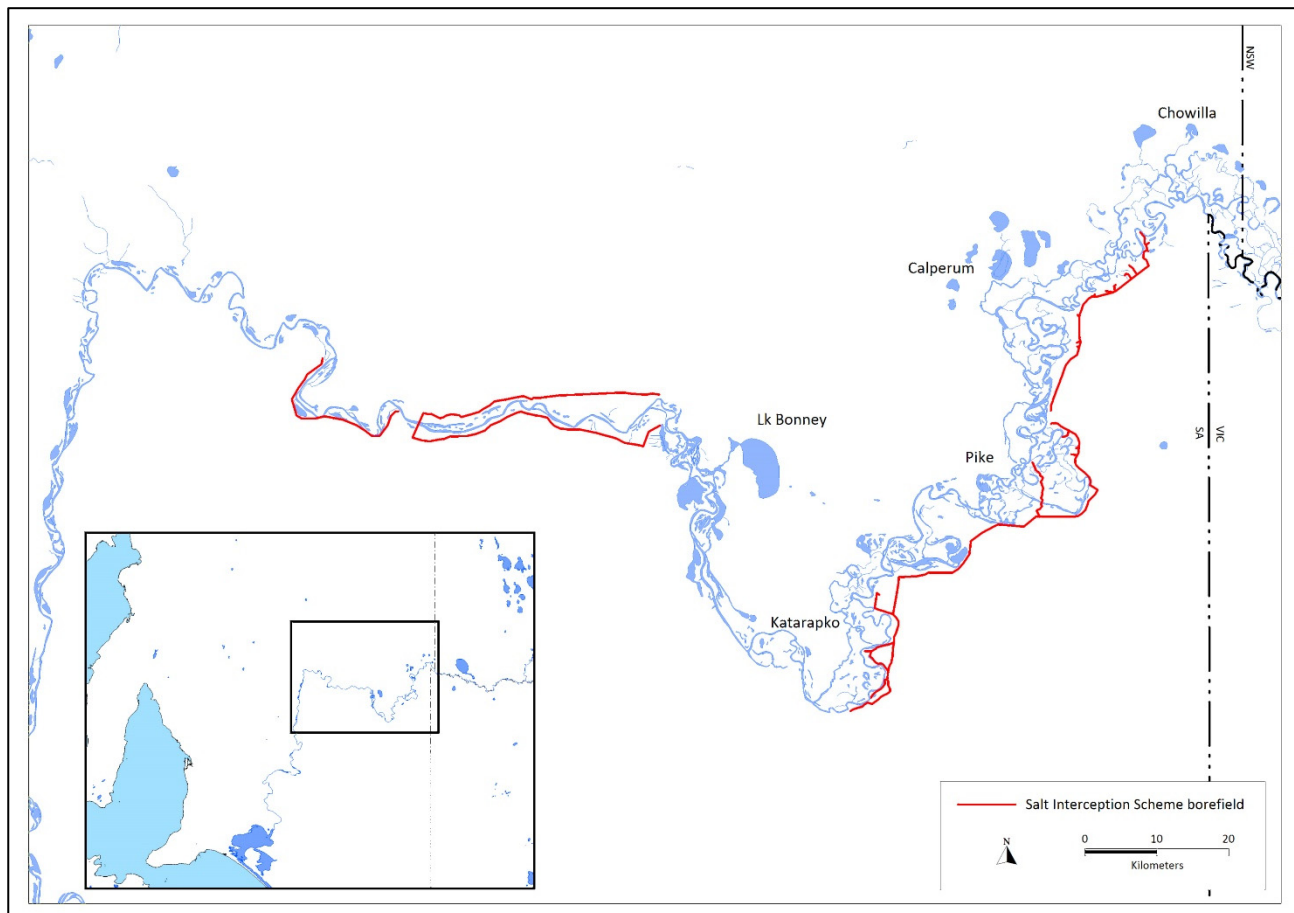


Figure 7-3: The extent of salt interception scheme borefields developed in the Riverland.

7.3 An age-old problem: palimpsests and the considered use of ^{14}C ages

Interpretations of MDB archaeology have been cast amongst a large set of ^{14}C age determinations, and ^{14}C evidence also frames this thesis. We need to constantly remind ourselves, however, that ^{14}C ages represent specific events in a site's history; a fire being lit, a meal being eaten, the death of an individual. The temporal limits of site-use may be as discrete as the date itself, though will more realistically extend well beyond each event. Few sites have been dated at a resolution able to decipher the full intricacy of site-use, and invariably, interpretation relies heavily on interpolation. Surovell and Brantingham (2007) critiqued the use of temporal frequency

distributions as a stand-alone proxy for modelling population levels, noting the inherent taphonomic biases involved in shaping these distributions. These factors are particularly critical in the interpretation of the MDB record given the potentially erosive nature of riverine environments and the fact that most sites occur in open contexts.

If age determinations are to be applied to demographic modelling, it cannot be assumed that it's a case of like for like. The implications of an age obtained on a hearth compared to an oven mound, a small shell heap compared to an extensive lens, or an isolated burial to an individual interred within a cemetery, are likely to be very different. This is perhaps the biggest criticism of time-series approaches where arguments are built around pooled sets of age determinations from often broad regions with limited appreciation or discrimination of their site-specific context. It is the situational variables of ^{14}C ages that are key to understanding their meaning. As Attenbrow and Hiscock (2015:34) have argued, 'counts of dates and summed calculations may inspire demographic hypotheses but do not directly test them, no matter how elaborate the calculation'. The degree to which an occupation timeline is artificially smoothed between individual dates and across potential discontinuities can also produce very different interpretations of the same data (Allen et al. 2008; Stern 1994).

Establishing a valid chronology in open context sites can be particularly difficult. It is probably the case that these sites, which account for the majority of the MDB and Riverland archaeology, had developed over multiple episodes of occupation. Where ground surfaces are stable or degrading, materials relating to each episode may accumulate into palimpsests (*sensu* Bailey 2007). In these circumstances, spatial relationships will not necessarily equate to temporal relationships, hiatuses and unconformities may be difficult to identify, and the rates of accumulation will differ depending on the erosional context. These processes have been studied exhaustively in the western plains of New South Wales where a detailed program of OSL and ^{14}C dating has described a complex occupation history in a landscape where aggradation and deflation is likely to have been a major factor in the accumulation and scale of surface deposits (defined largely by hearths and stone artefacts) (Fanning et al. 2009b; Holdaway et al. 2008; Holdaway et al. 2005; Rhodes et al. 2009). Key conclusions of these studies were that the archaeological record is ultimately dictated by the differential preservation of land surfaces, that accumulation histories can differ substantially across relatively small areas, that settlement histories cannot be reconstructed by

simply locating 'sites' in space, and that any valid interpretation must be framed around an understanding of the landscape history (Fanning et al. 2009b:133, 142: see also Holdaway et al. 2009).

The NSW studies provide an important cautionary note; interpretation of ^{14}C distributions can only be valid when considering the context and site-specific implications of the ^{14}C ages themselves. Indeed, the studies concluded that, at least in the western NSW record, the apparent late Holocene increase in the quantity of archaeological materials could be accounted for by geomorphic processes and the 'cumulative action of chance erosion events' without the need for intensified land-use patterns (Fanning et al. 2009b:142). The record of occupation was probably defined by repeat, small-scale events occurring in temporal clusters that were separated by substantial breaks in occupation tied to cycling of the ENSO climatic phenomena (Holdaway et al. 2002). This conclusion has far reaching implications in respect to the intensification narrative. Indeed, Holdaway et al. (2008) concluded that arguments in favour of late Holocene intensification based on dating evidence may be fatally compromised through a lack of consideration of site formation processes and geomorphic contexts. Despite this and other criticisms (Attenbrow and Hiscock 2015; Hiscock 2008; Williams 2012:579), ^{14}C age frequencies and their perceived correlation to population levels continue to underpin many of the arguments regarding intensification (e.g. Williams 2013; Williams et al. 2015a; Williams et al. 2015b; Zeanah et al. 2017).

Archaeological interpretations are, in essence, products of scale and resolution. At what point should ^{14}C datasets be considered directly relatable and able to accurately define societal pathways? In the case of this research, can 89 ages gathered from two Riverland floodplains define an occupation chronology? Ultimately, valid interpretation requires 'judgement and argument rather than binary acceptance/rejection' (Contreras and Meadows 2014). The methodological approach taken in this thesis has been strongly influenced by the NSW studies. It recognises, fundamentally, that archaeological interpretation must be founded in an understanding of landscape processes and validated by various scales of observation and multiple lines of evidence. In recognising that open scatters are likely to represent palimpsests, the dating program has targeted multiple features within a small number of sites rather than rely on single age estimates from a broader sample of sites. Intensive survey coverage with a focus on **context** is

used a means of value-adding, and validating, the ^{14}C data.

An important observation here is that whilst archaeological materials were occasionally identified at depth in the excavations conducted at the Calperum and Pike floodplains, a similar level of stratigraphic detail can be interpolated from natural and artificial exposures within the majority of sites. In addition, in no instance did a ^{14}C age returned on excavated material predate material sampled from unexcavated contexts within the same site. This provides some confidence that a representative chronology can be developed through a strategic, though necessarily intensive ^{14}C sampling, of materials exposed across natural ground surfaces.

Holdaway et al. (2002) have argued that ‘the power of archaeological inference, comes not from the reconstruction of the reasons for single events, but from analysing the pattern in material that accumulates from multiple events’. The ‘events’ represented by the ^{14}C dataset collected during this research are summarised in Figure 7-4 and are grouped in respect to a series of habitat zones. As discussed previously, methodological constraints meant that not all habitat settings were able to be sampled.

7.4 Linking landscapes and archaeology

The archaeological sites and dating results are contextualised within a series of landscape vignettes in the following sections. Comparisons are made between equivalent landscape settings across a time series of landscape development in order to elucidate change in the ways that Aboriginal people have interacted with the habitat mosaic. There are some limitations imposed by the data and survey coverage that need to be acknowledged. Notably, the direct dating of occupation materials in several landscape settings has not been possible due to the progress of the research and timelines required in permitting under the AHA. Sites associated with the outer lakes at Calperum and the T3 scroll in the south-eastern corner of the Calperum floodplain, represent two obvious gaps in the ^{14}C sampling. Despite these omissions in the sampling, the consistent trends observed in the spatial distribution and context of sites provide support for the arguments presented in this research.

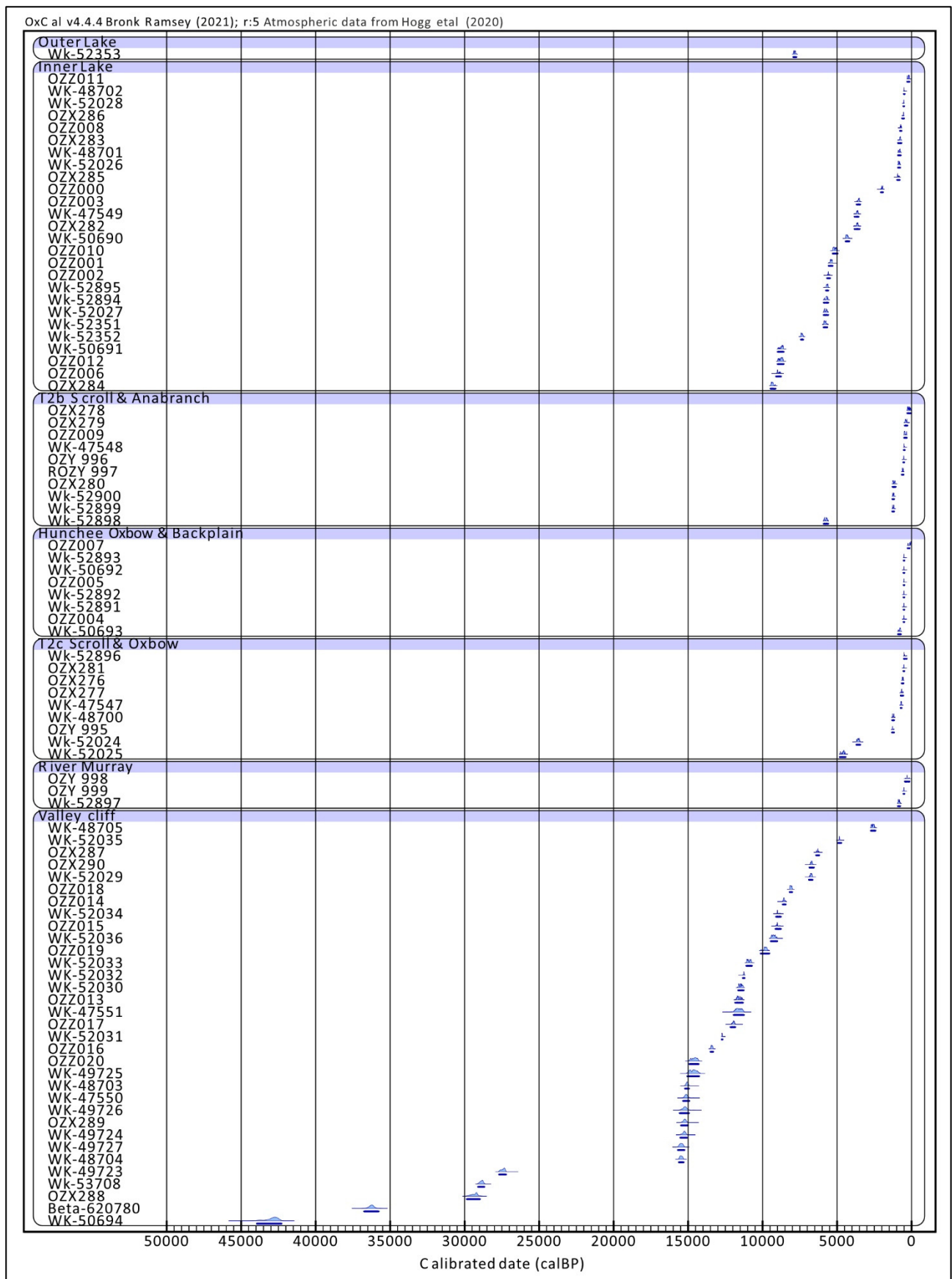


Figure 7-4: All reported calibrated ^{14}C ranges grouped to habitat zones. The 95.4% probability range is shown as lines under the individual PDFs.

7.4.1 The outer lakes

All but five of the sites recorded in association with the outer lakes at Calperum were located on deflated surfaces within WFm dunes, often forming lags on a well-developed palaeosol that is likely to have formed in the period ~18–16 ka. No archaeological material was identified within or below this soil or occurred in any exposed section around the margins of the deflation hollows, with the exception of a single feature in site CAPR19_J02. In this case, the thin ashy feature (Figure 7-5) appears to originate from the top of WFm Phase V (8–5 ka) sediments and is associated with a small scatter of finely fragmented and undiagnostic burnt bone. The outer lake sites also tend to occur at the eastern extent of the dunes, i.e. the more recent stages of expansion, and often where these extend into the lakebeds (Figure 7-6). Several sites fall outside of this norm:

- CAPR19_J01 comprises a midden of dense freshwater mussel shell situated on a loose cover of fine gypsiferous sand deflated from (i.e. post-dating) the HSGD-facies Phase II lunette at Rotten Lake.
- CAPR20_S11 extends across the lower slope of the palaeovalley margin to a sandy beach on the north-western shoreline of Rotten Lake (see further description below).
- Two hearth sites are exposed in deflation surfaces incised into a shallow cover sand at Rotten Lake (CAPR19_M04) and Outer Lake A (CAPR19_M12) (Figure 7-5).
- A telegraph insulator reduction site (CAPR18_S44) was located at Outer Lake C in the area of what appears to be a materials laydown associated with the installation of the telegraph line c. 1870 (Figure 7-6) (see Munt 2022 for further discussion of this site).

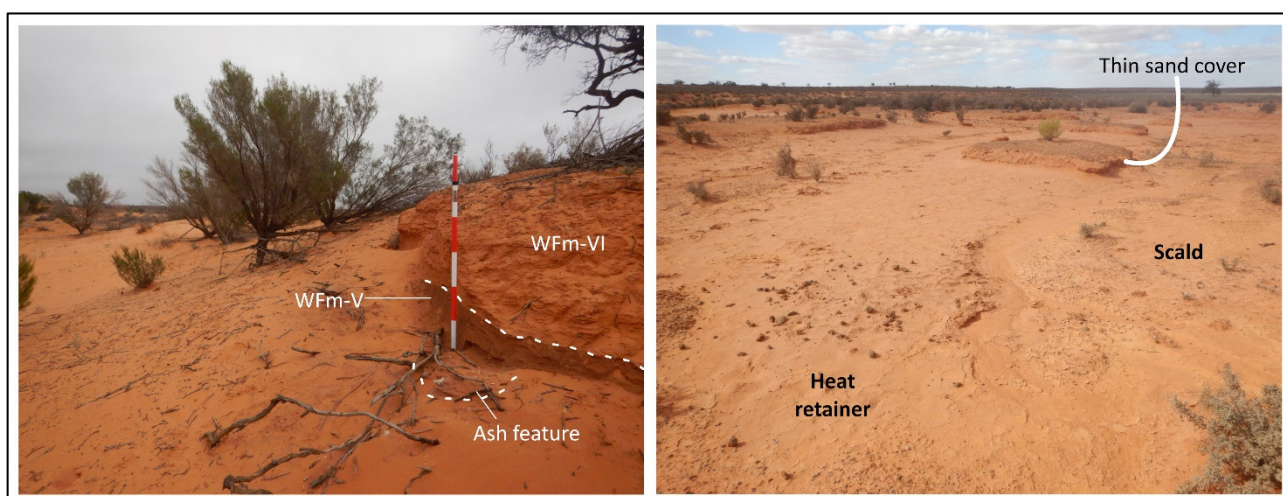


Figure 7-5: Context images of hearth features in site CAPR19_J02 (left) and CAPR19_M12 (right). WFm-V sediments date to 8–5 ka.

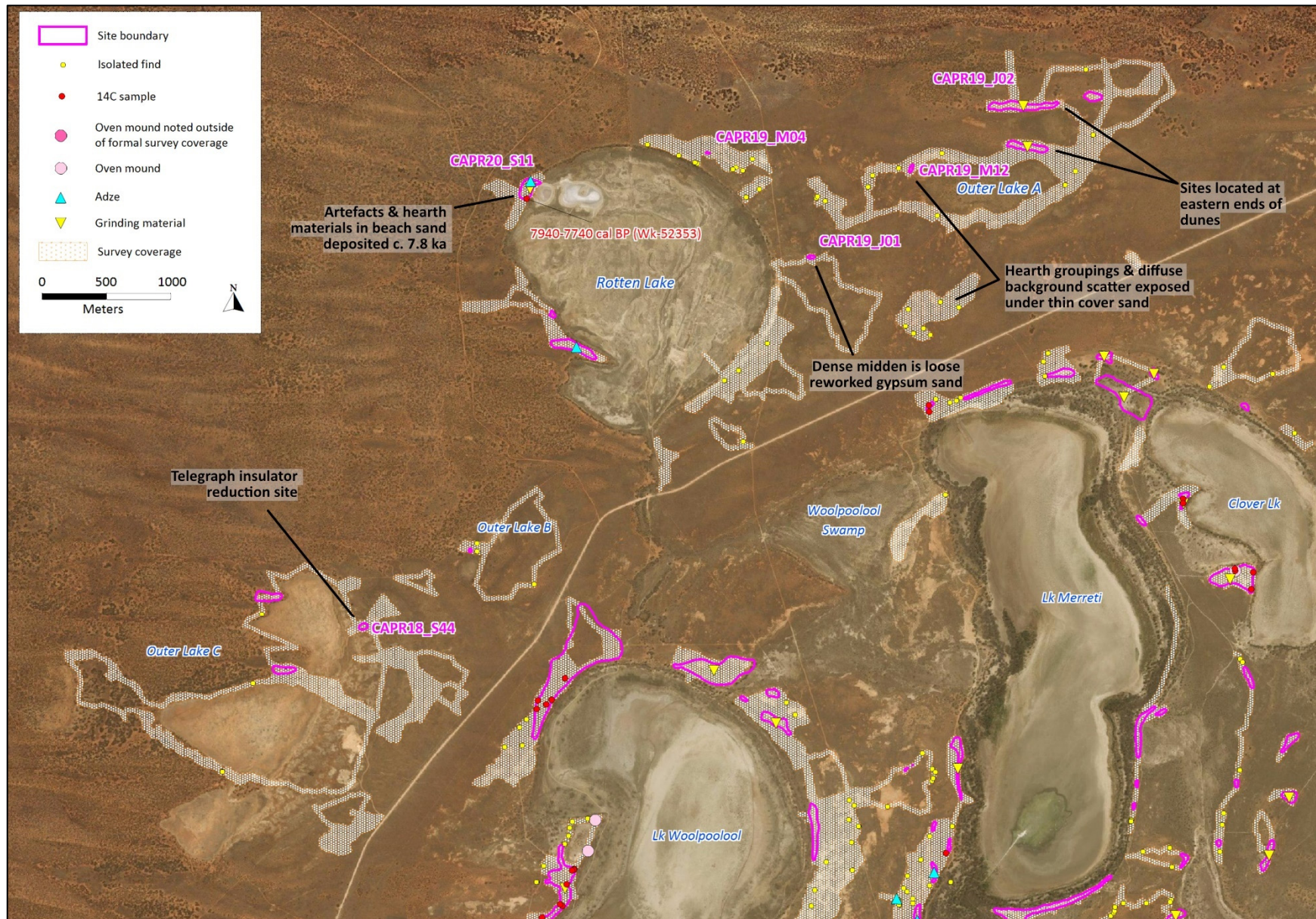


Figure 7-6: The distribution of archaeological sites and isolated finds in the area of Rotten Lake and Outer Lakes A and C.

An extremely diffuse spread of isolated finds (scattered heat retainer, stone artefacts, fragments of freshwater mussel) also extends beyond the modern lake shorelines across the lunette ridges and T1 surface. This material is most commonly exposed in shallow deflations in a similar context to CAPR19_M04 (see Figure 7-5). Shell midden exposed under a similar sand sheet north of Lake Merreti returned a maximum age of 8980–8593 cal BP (WK-50691) and it is reasonable to expect that a similar age constraint extends to the broader landscape. As discussed in Chapter 6.2.3.2, the entire Holocene was punctuated by reactivations of the aeolian sand sheets. No examples of more deeply stratified material were identified in or around the outer lakes, despite examples of gully erosion continuing around most of the lunette slopes.

The consistent patterning of archaeological sites and materials in association with the outer lakes is illustrated in Figure 7-6 in respect to Rotten Lake, and Outer Lakes A and C. The paucity of archaeology across the outer lake lunettes is striking, even more so given the extent of survey coverage, exposure and visibility. These results are replicated in equivalent settings in the broader Riverland, including at Lake Bonney (Wood and Westell 2013). The potential taphonomic loss and/or modification to archaeology brought about by exposure and erosion of the Phase I lunette surfaces must be acknowledged as these surfaces are of considerable antiquity and remain highly dynamic. However, if intensive and/or persistent occupation had occurred around these early lacustrine settings, it might be expected that higher frequencies of the more durable materials, e.g. heat retainer or stone artefacts, would be preserved in context. Based on the sheer weight of survey coverage, it appears that occupation in these settings occurred on an ephemeral basis, if at all. This conclusion is supported by the inner lake record (see below) and provides an obvious contrast to equivalent settings in the MDB. Hope et al. (1983), for instance, reported archaeology in ‘all exposures’ in the Lake Tandou lunette, including human and animal bone, shell fragments, otoliths, gastroliths, heat retainers and artefacts.

The combined volume of freshwater mussel shell noted in several sites at Rotten Lake points to a period(s) of local collection rather than its importation from the inner floodplain. Whilst direct dating of these middens has not been possible, fine fragments of waterworn mussel valve incorporated into a beach sand at Rotten Lake are likely to identify the last period of sustained inundation in this lake. One of these fragments was dated to 7940–7740 cal BP (Wk-52353), a result that closely matches a minor component in the OSL sample WOL-10 placed within the beach

sand (Figure 7-7). The excavation required to accommodate the dose meter at WOL-10 also dislodged a retouched, broken chert flake. Additional artefacts and heat retainer were noted in the same unit immediately east of the OSL sampling location (Figure 7-7) and continuing to the north of the gully outlet along the eastern boundary of site CAPR20_S11. The presence of an adze in this site extends the period of (re)occupation to within the last several thousand years (Holdaway and Stern 2004; Veth et al. 2011). Adzes were also noted in several additional outer lake sites.

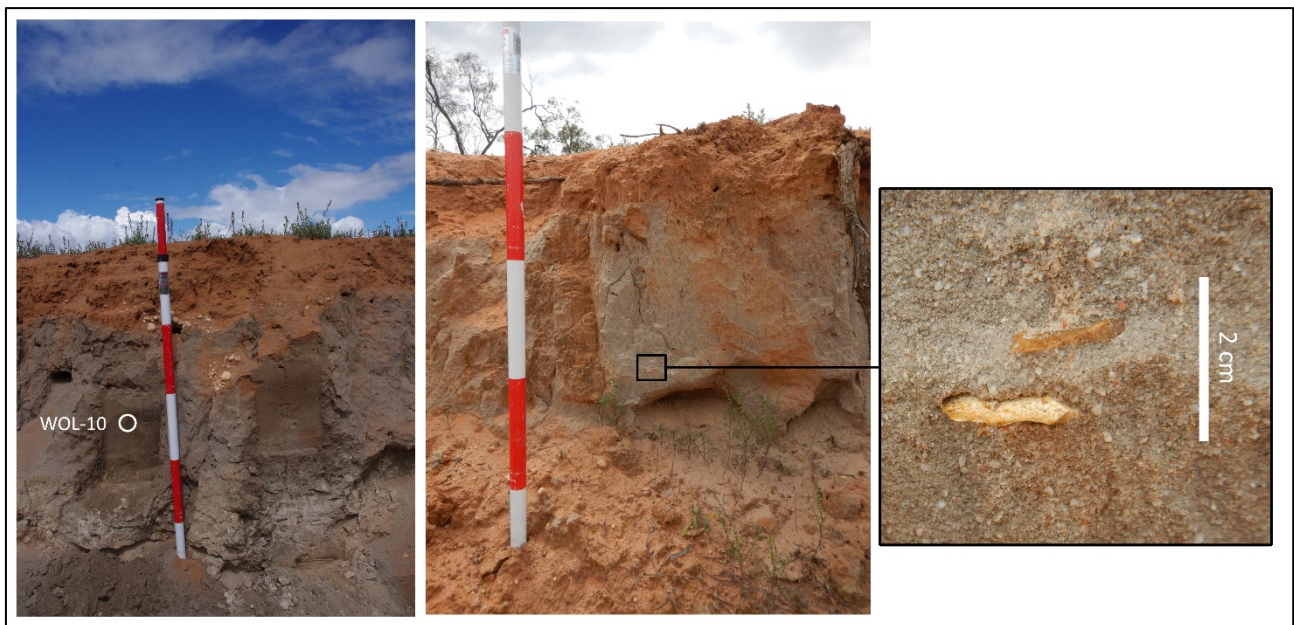


Figure 7-7: The grey beach sand exposed in shallow gully erosion on the north-western shoreline of Rotten Lake. OSL sample WOL-10 (left) was collected from the southern wall of the gully and dislodged a broken, retouched chert point. Two additional flakes (middle and right images) were identified in the northern wall of the gully immediately downstream, and slightly below the level of WOL-10. ^{14}C sample Wk-52353 (7940–7740 cal BP) comprised a fragment of freshwater mussel shell recovered from the top of the beach sand upstream of WOL-10.

The faunal assemblages of the outer lake sites also differ from the inner floodplain with emu eggshell and large and small mammal bone identified in several sites. This material occasionally occurs in dense spreads of finely fragmented and burnt bone. This pattern is repeated in a number of similar locations in the Riverland, including the dune-fields straddling the palaeovalley margins at Katarapko and Chowilla (see Westell 2021b). A similar presentation of faunal material is rarely observed in the inner floodplain. A number of distinctive ashy features were also noted in these Wfm dune-located sites and appear to represent a specific cooking application distinct from the heat retainer fires that are invariably found in the inner floodplain.

In summary, and based on the preservation of bone, the context of sites on relatively younger WfM landforms, and the age of an artefact-bearing unit at Rotten Lake, the archaeology in this habitat zone is most likely Holocene in age, and is certain to postdate the dune WfM-IV reactivation phase c. 14–12 ka. An age of c. 7.8 ka can be inferred for at least some component of the archaeology at Rotten Lake based on ^{14}C and OSL sampling of an artefact-bearing unit (beach sand), while adzes in several sites and flaked telegraph insulator in sites CAPR19_J02 (Outer Lake A) (Figure 7-8) and CAPR18_S44 (Outer Lake C), provide further age-constraints based on typology.



Figure 7-8: A core (left) and reduction floor (right) developed in telegraph insulator in site CAPR18_S44.

7.4.2 The inner lakes

As with the outer lakes, a clear patterning in the archaeology can be related to the palaeolandscapes of the inner lakes. In this case, extensive, though patchy archaeological deposits tend to hug the modern shorelines with limited material extending onto the older lunette surfaces or along the WfM dunes and sand-sheets extending to the western shorelines of the lakes (Figure 7-9). Various exposures (dune deflations, scalding, gully erosion) also indicate that these sites comprise shallow, thinly stratified deposits.

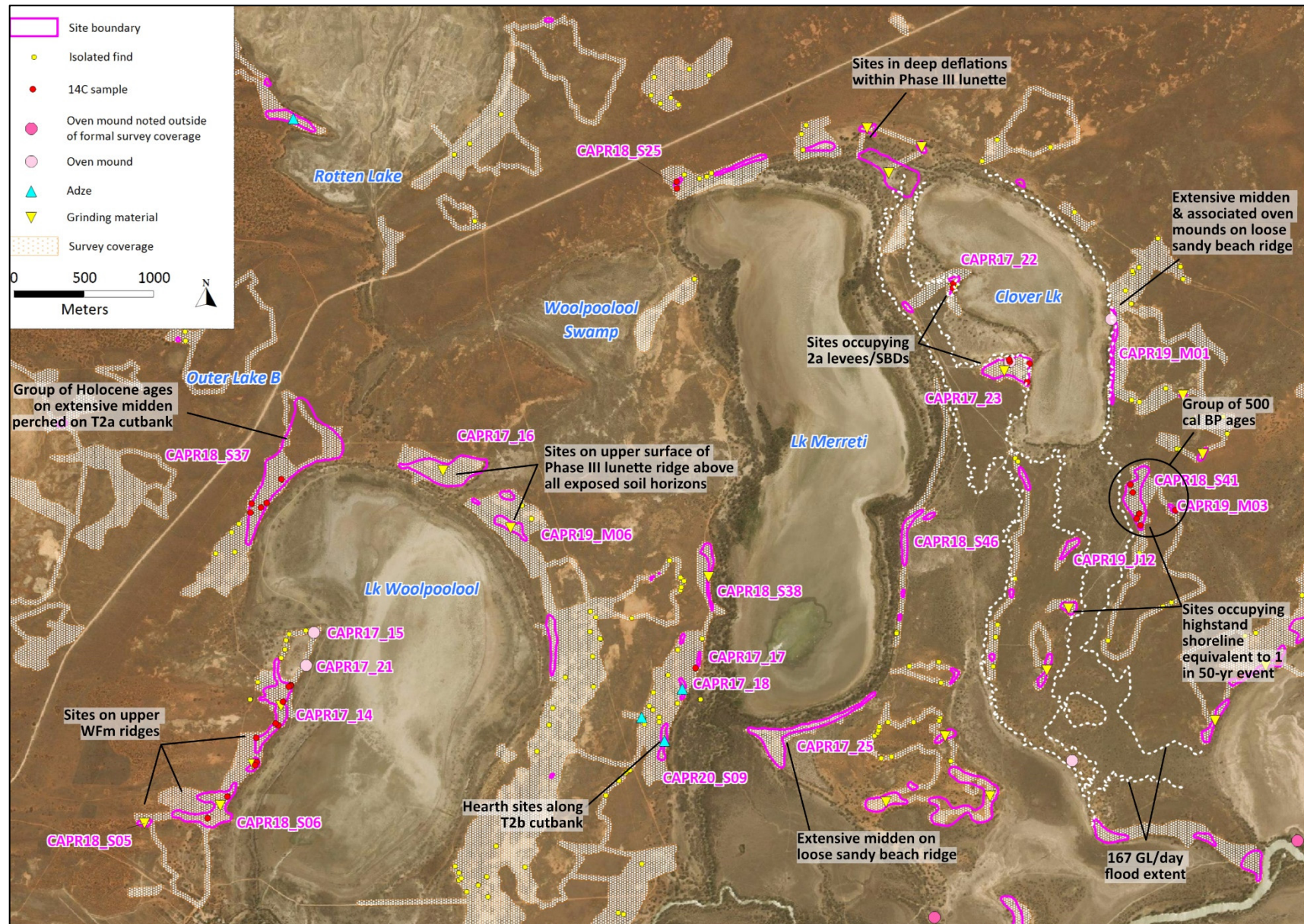


Figure 7-9: Sites and survey coverage associated with the inner lakes.

All ^{14}C sampling results in the inner lake sites are Holocene with the earliest middens developing during ^{14}C Phase 7 (Figures 7-4, 7-10 and 7-11). This phase includes a cluster of ages spanning the period 9.7–8.3 ka and is represented in both the Calperum and Pike datasets (Figure 6-93, Table 6-23), i.e. in both lacustrine and channel-based settings. Two shell-derived ^{14}C ages were located on top of beach-ridges elevated above the modern lake shorelines in sites CAPR17_14 and CAPR17_23. These identify a minimum age of highstand(s) associated with either the development of the Phase II lunettes c. 18–15 ka or the later reinundation of Rotten Lake from c. 11 ka. Additional age estimates locate middens within or prior to phases of WfM (re)activation across the Holocene. In CAPR18_S25, for instance, a thin unit of planar bedded, medium to coarse aeolian sand overlies and contains discrete shell midden clumps dated to c. 8.7 ka and 5.6 ka (Figure 7-11). Isolated finds recorded beyond the lake shorelines invariably occur within deflations or scalding in this shallow aeolian cover.

The structure of the original T2a scrolls is largely obscured and/or modified by subsequent landscape development. However, the original cut-banks approximate the high ledge continuing around the northern margins of the lakes, and levees and SBDs are preserved in the interior of the Merreti-Clover scroll. Again, all age results in sites located in these settings are Holocene with the oldest being 8984–8602 cal BP (OZZ012) in site CAPR17_23 (see Figure 7-11). A group of sites continuing along the bank of the original T2a channel trace south of Clover Lake are located in a loose, pale coloured sandy ridge which, based on dating results in CAPR18_S41 and CAPR19_M03, is interpreted as a shoreline feature that developed during a brief highstand c. 550–500 cal BP (see further discussion in Chapter 7.5.3.1). This ridge is superimposed on the original T2a channel bank and levee. The shell content dated in these and all other sites in the broader area is exclusively *V. ambiguus*, i.e. is unrelated to the original high flow channel. The preservation of yabby carapace in CAPR19_J12 also provides further evidence of a relatively recent development of this particular assemblage.

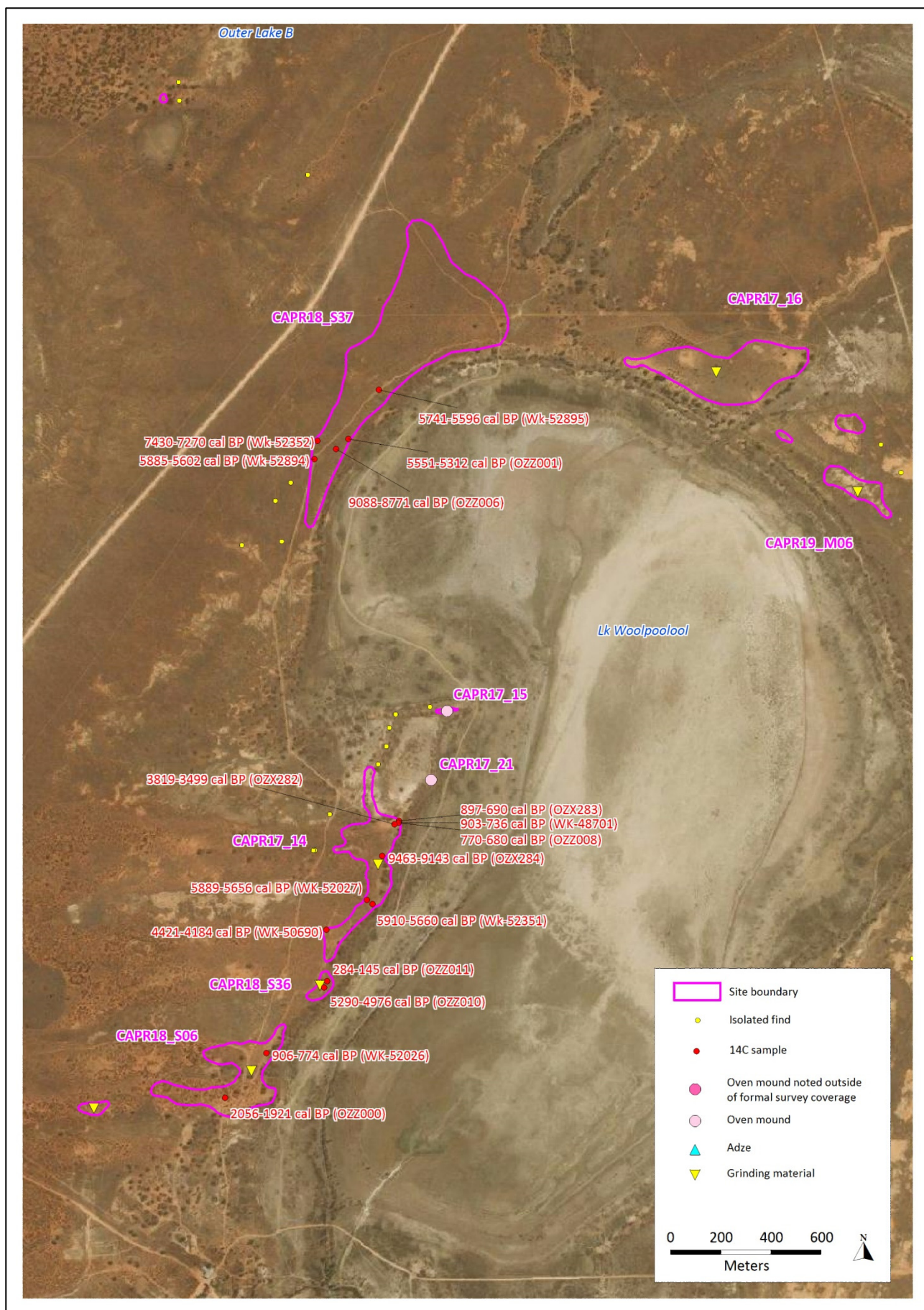


Figure 7-10: ¹⁴C dating results and other locations associated with Lake Woolpoolool.



Figure 7-11: ^{14}C sampling and other locations in the area of Lakes Merreti and Clover.

The archaeology preserved along the high cut bank of a T2b scarp incised into the eastern side of the Lake Woolpoolool lunette is also telling (see Figure 7-9), with all sites likely to be Holocene based on direct dating of shell, their exposure in a thin sand cover tied to the mid-late Holocene via direct dating in CAPR17_17, and the presence of adzes. Oven mounds were also identified in a number of inner lake sites.

The only evidence of a potentially earlier occupation associated with the inner lakes is in the form of a series of hearths preserved along the crest of the Phase III lunette at Lake Woolpoolool in site CAPR19_M06. These hearths are exposed in sand pedestals formed at the top of a light coloured sand (unit B2) that has an interpreted OSL age of c. 15 ka (see Chapter 6.2.32 and Figure 7-12). Unit B2 is capped by a thin cover of light red sand (Unit B3) which is likely to have been deposited from c. 7.5 ka. A diffuse scatter of artefacts and a single calcined yabby claw extends across the deflation surfaces between the pedestals. The B2 age relates the hearth features to the widespread development of channel-based middens at Pike during ^{14}C Phase 3 at c. 15 ka. Importantly, however, no equivalent-scale middens are preserved in CAPR19_M06, or in any other exposure along the Phase III lunette, despite extensive exposure and gullying along the lunette slope and crest (see Figure 7-12). Indeed, the absence of stratified archaeology in the extensive gully erosion along this lunette, the core of which formed to c. 15 ka, is one of the more telling aspects of the Calperum archaeology.

As with the outer lakes, a series of archaeological sites are situated on Wfm dunes extending to the western shorelines of the inner lakes. These ridges were evidently in place prior to a highstand event c.11 ka, providing a potentially older context than the outer lake archaeology. There is no compelling argument, however, for an association between these dune-located sites (e.g. CAPR18_S06, CAPR17_14) and the late Pleistocene development of the ridges themselves, or the soils developed in them. Where the survey included transects extending along these ridges, very few sites were identified away from the lake margins. Instead, the inner lake archaeology is closely aligned to the Holocene shorelines, and where exceptions do occur, e.g. CAPR18_S05, archaeological materials clearly occupy Holocene contexts such as a loose cover sand or deflated surfaces in this cover. A similar observation was made around the floodplain margin continuing south of Lake Woolpoolool and west of Ral Ral Creek.



Figure 7-12: A hearth feature eroding from Unit B2 sediments in the phase III lunette at Lake Woolpoolool. Images show the extrapolation of OSL sample WOL-03 and 04 results across the surface of the lunette and the extent of exposure across the lunette slope.

The inner lake ^{14}C data depicts a series of clusters across the Holocene (Figure 7-4). However, given the level of ^{14}C sampling and the extent of archaeology preserved around these lakes, it is the two transitional phases c. 8.5–5.9 ka (Phase 8) and c. 3.5–1.3 ka (Phase 12) that are perhaps the more notable aspects. Both phases straddle periods of aridity identified in regional climate proxies (see Figure 6-36). The widespread development of freshwater mussel shell midden from c. 1.2 ka is also clearly evident in the inner lake ^{14}C results and in the extensive archaeological deposits situated in the sandy beach-ridges and cusped forelands around all of the inner lakes. Grinding materials are also a common element of the inner lake assemblages. In the case of CAPR17_14, a Type II grinding topstone (pestle) is associated with a shell-derived ^{14}C age of 5889–5656 cal BP (WK-52027), i.e. within ^{14}C Phase 9.

In summary, no occupation evidence in the inner lakes can be confidently related to the Phase I lakes or the T2a scrolls the lakes had formed in. This interpretation is supported by previous surveys conducted at equivalent lakes at Chowilla (Coombool Swamp, Lake Limbra, Gum Flat and

Lake Littra) (Wood et al. 2005; Wood and Westell 2014a) and at Lake Bonney (Wood and Westell 2008a, 2013) where the contrast between the archaeology preserved around the Holocene shorelines and older Pleistocene lunette surfaces is similarly stark. As with the Calperum record, there are few examples where a geomorphological context provides a compelling argument for a deeper Pleistocene occupation. One notable exception occurs at Lake Limbra (Chowilla floodplain) where a series of burials are eroding from a fine, massive deep-red sand along the crest of the Phase III lunette. A complex relief in these units has been infilled by a fine gypsiferous olive-grey clayey sand. In lieu of direct dating, these burials are certain to be pre-Holocene, and as with CAPR19_M06, are tentatively assigned to a period around c. 15 ka based on their stratigraphic context. An older age cannot be ruled out (see further discussion in Chapter 7.4.7).

7.4.3 The T2 bedload channels

Landscape settings associated with the T2 sub-terraces were subject to intensive survey, with approximately 9.7 linear km of cut-bank and various levee and SBD surfaces sampled. This included T2 waterfrontages that have converted to the oxbows and anabranh creeks that remain active in the modern floodplain.

7.4.3.1 Hunchee Lagoon and the T1 backplain

Hunchee Lagoon occupies a T3 channel trace that was active no later than c. 8 ka. An older (T2b) infilled scroll extends to a high cut-bank to the west of the lagoon and is currently occupied by an ephemeral wetland. A large scour and series of flood runners connect the upstream end of Hunchee Lagoon and the current River Murray, indicating that the lagoon is influenced by periodic high flow events that potentially maintain and/or re-excavate the lagoon bed. These flows have continued to erode the western bank of the lagoon. A broad, shallow levee and crevasse deposits extend over the western bank, again indicating regular overbank flooding.

The patterning of archaeological sites within this relatively compact area includes several notable features (Figure 7-13). The most conspicuous aspect is the alignment of oven mounds along the banks of the regularly inundated courses of Hunchee Lagoon and the Big Hunchee Creek anabranh. ¹⁴C ages were returned on a charcoal feature (4806-4441 cal BP [Wk-52025]) and

midden lens (3694-3455 cal BP [Wk-52024 cal BP]) below two of these oven mounds. The charcoal feature was exposed within a well sorted silty sand (levee deposit) overlaying a stiff clay base. The shell sample was *V. ambiguus*, consistent with the establishment of a lagoon habitat and viable mussel colonies prior to 3.6 ka. These two mounds had evidently developed well after the establishment of a lagoon habitat and were preceded by midden development (see Jones et al 2022 for further analyses of these mounds).

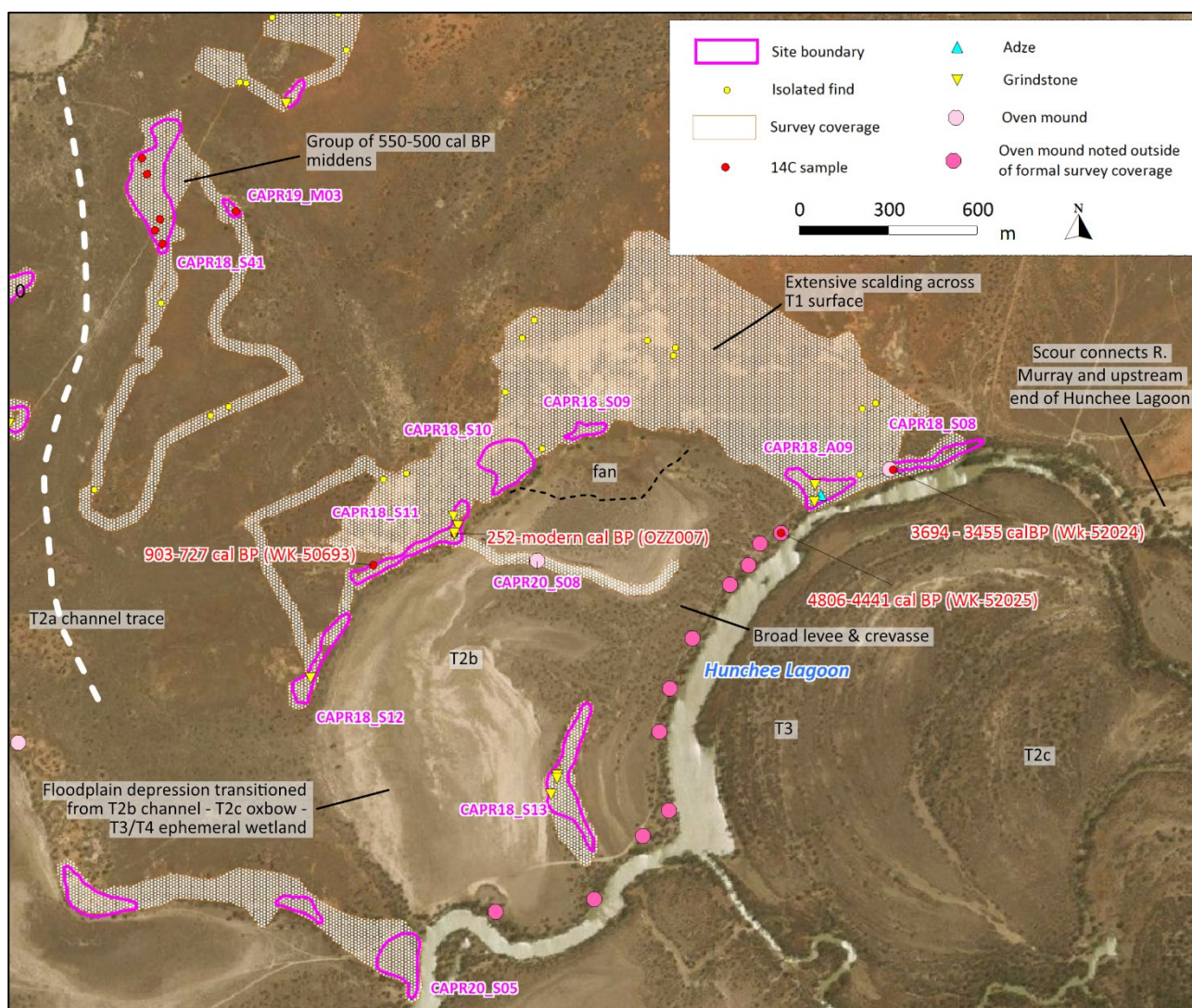


Figure 7-13: Sites, survey and dating results in the area of Hunchee lagoon.

Only one mound (CAPR20_S08) was located beyond this setting, in this case occupying the bank of a shallow ephemeral wetland in the infilled T2b scroll. No formal mounds were identified along the T2b cut-bank or adjacent terrace beyond the active waterfrontages. Instead, sites in these settings are characterised by dense scatters of heat retainer and a low density of artefacts eroding out of, and from the lower boundary of, a light red aeolian cover (Figure 7-14). A ^{14}C age of 903–

727 cal BP (Wk-50693) was obtained from an exposure of clumped midden shell exposed within this cover in site CAPR18_S11, providing a minimum age for the extensive scatters of heat retainer in, and at the base of, the aeolian unit. A lower age constraint for this aeolian unit remains poorly defined, though based on gullied exposures in sites CAPR18_S09 and S10, it is apparent that these scatters are not associated with the underlying T2b levee/crevasse deposits. Again, shell midden exposed under a similar sand sheet north of Lake Merreti returned a maximum age of 8980–8593 cal BP (WK-50691) and it is reasonable to expect that a similar age constraint extends to the broader landscape. A loose hummocky drift sand overlies the redder aeolian sand and has collected amongst the narrow black box woodland along the T2b cutbank. A single ^{14}C age of 252-modern cal BP (OZZ007) was returned on charcoal recovered from a hearth in a deflation hollow in this recent drift.

Dense, contiguous deposits of freshwater mussel shell midden in this area are limited to three open scatters; two perched along a high bank at the northern end of Hunchee Lagoon (CAPR18_A09, CAPR18_S08) and the third on the high bank of Big Hunchee Creek (CAPR20_S05). As above, a midden lens contained in levee sediment below an oven mound in site CAPR18_S08 returned an ^{14}C age of 3694-3455 cal BP (Wk-52024 cal BP).

A grouping of open scatters located in the backplain west of Hunchee Lagoon are aligned along a cutbank of an infilled T2a channel that is currently occupied by samphire marshland. Under modern conditions, this marshland inundates at a return period in excess of ten years. The tightly constrained group of midden ages in this relatively remote location may, therefore, define a period of persistently higher flood level that saw viable mussel populations establish and mature in the area currently occupied by the marshland. This short pluvial may have spanned a period of perhaps tens of years between 550–500 cal BP based on the ^{14}C sampling in sites CAPR18_S41 and CAPR18_M03. This timing accords with evidence of a wetter phase along the River Murray corridor c. 500 BP (Stone 2006a; Tibby et al. 2020; Tibby et al. 2018). CAPR18_S41 occupies a sand levee that formed around the shoreline of this highstand. This levee drapes a far older feature that extends along the terrace margin and is interpreted as the original T2a levee (Figure 7-15). This feature is represented by a unit of fine sand and calcrete gravel exposed at a depth of approximately 45 cm in rabbit warrens immediately east of CAPR18_S41.

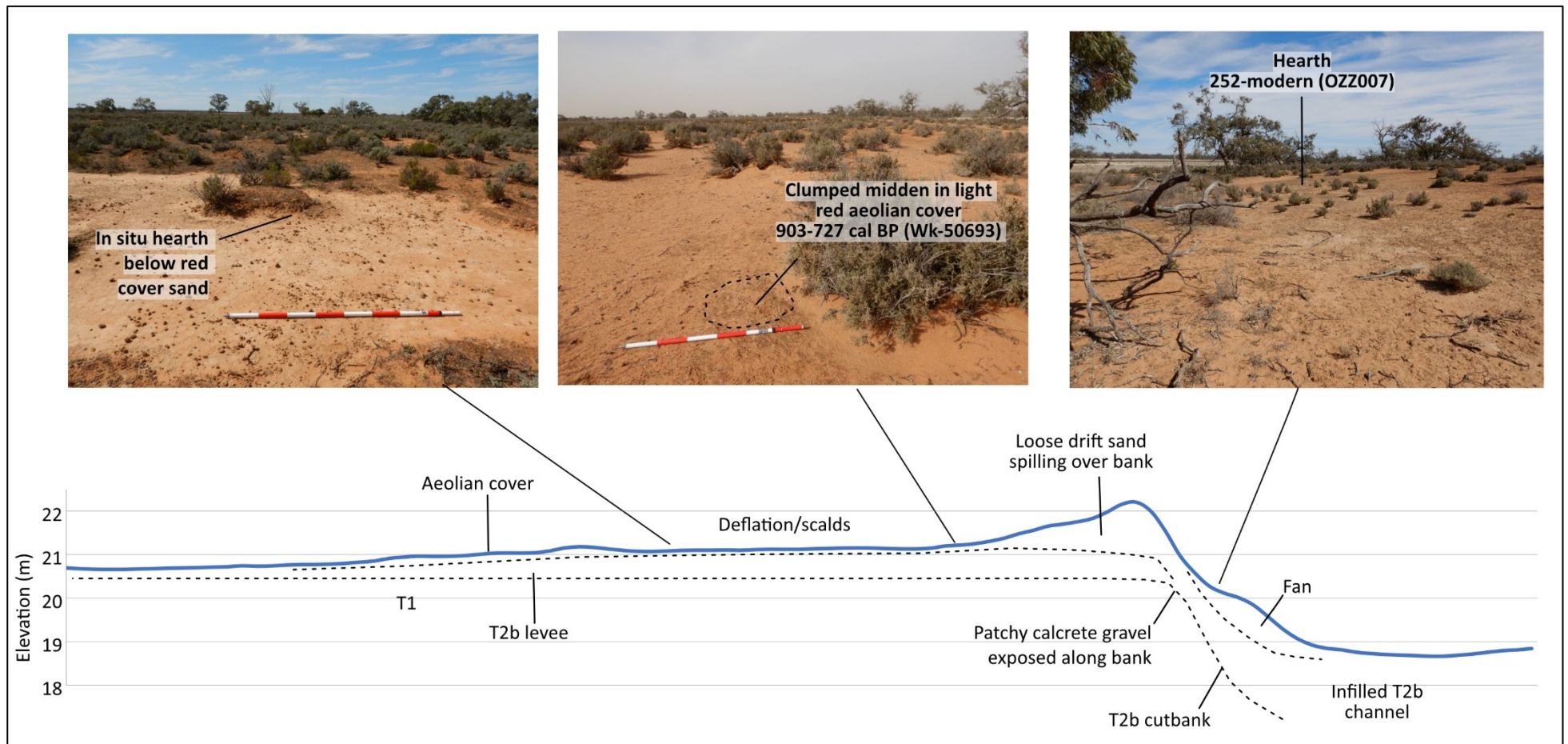


Figure 7-14: The relationship between ^{14}C ages and stratigraphy in the area of CAPR18_S10 & S11.

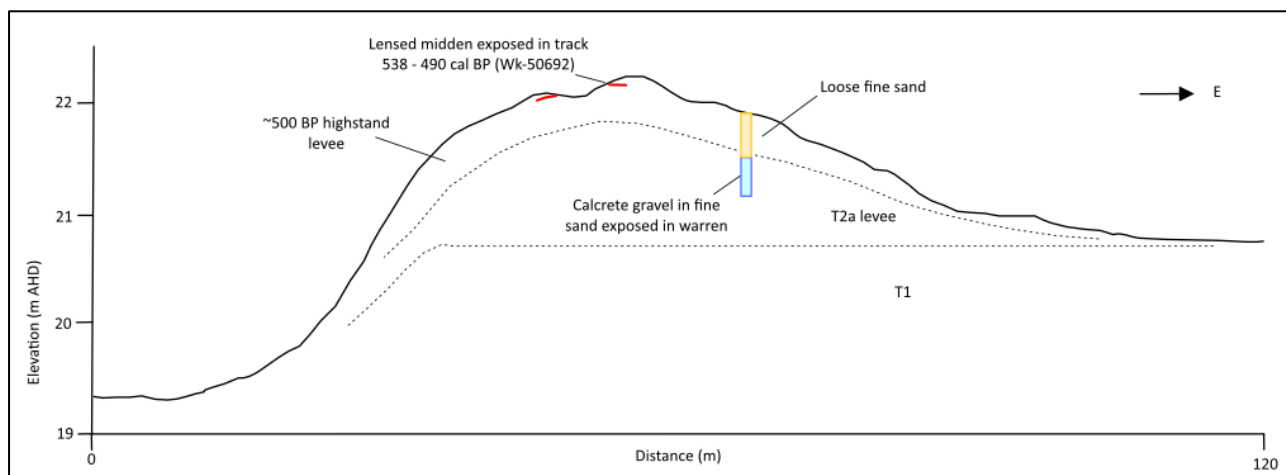


Figure 7-15: An interpretation of the stratigraphy and context of the midden exposed across the southern section of CAPR18_S41.

The direct dating evidence, geomorphological setting and typological constraints suggested by the mounds and occasional adze (see CAPR18_A09), indicate that the archaeology in this area had formed within broadly similar timelines from the mid Holocene. Mounds may have become an ever more dominant feature over the last few millennia (Jones et al. 2022), though a higher resolution in the dating evidence would benefit this discussion. It is also worth noting that the majority of mounds lie above flood inundation levels to at least 100 GL/day. As such, access constraints imposed by regular seasonal flooding, in and of themselves, are unlikely to explain the clear distinction between the mound-dominated waterfrontages and hearth-dominated backplain. Water depth would, however, have been a critical factor in the collection of *Typha* spp. with a rising late winter-spring flood permitting people to wade into the water and gain purchase on the *Typha* spp. shafts and rhizomes. The separation of distinct site types across this small geographic space may, therefore, relate directly to activities conducted over a seasonal timeframe with shell and *Typha* spp. resources harvested and processed along the more permanent waterfrontages and hearth-dominated activities relating to the backplains and seasonally inundated wetlands (see Table 4-1). A similar separation in activity is not universally observed in the floodplain archaeology. Grinding material is also a conspicuous component of the assemblages along the T2b cut-bank and backplain and includes a diverse range of grinding morphologies that may be related to both milling and pounding activities (Figure 6-97). This pattern continues to the east of the Calperum Station boundary (Wood and Westell 2016a). Again, these distinct differences are interpreted as a seasonal organisation of subsistence activity, in this case incorporating a seasonal shift from mound to grinding-based activities.

The distribution of archaeological materials across the T1 surface beyond the immediate area of Hunchee Lagoon is governed largely by exposure within an aeolian cover. This is commonly expressed as shallow deflations and scalding. Limited survey was conducted across T1, though this is complemented to some extent by previous coverage conducted along a narrow corridor paralleling Wentworth Road (Wood 2002) and to the east of the Calperum boundary (Wood and Westell 2016a). The results of these combined studies and the current research describe a diffuse background and small open scatters of stone artefacts and heat retainer commonly exposed on scalded floors bounded by thin sand sheets. As described in Chapter 6.2.3.2, various ^{14}C ages from c. 8.5 ka through the Holocene have been returned on midden shell below and within these sand sheets around the northern edge of Lake Merreti and elsewhere.

7.4.3.2 The Ral Ral–Hunchee anabranh and T2b scrolls

Terrace T2b formed in the period c. 35–24 ka. A sequence of two scrolls (labelled as Scroll I and II in Figure 7-16) are preserved in the centre of the Calperum floodplain and are partitioned by the Ral Ral-Hunchee anabranh. Lengths of high cut-bank, levees and SBDs are preserved in and around these scrolls. Site CAPR17_19 extends across a large extant SBD bounded in the north by Ral Ral Creek. Intensive ^{14}C sampling in this site targeted a series of discrete surface exposures of clumped midden, stratified lenses of shell in three locations, and hearths in the eastern and western sections of the site. Both hearths were located amongst dense scatters of heat retainer. The ^{14}C ages (see Figure 7-4) can be assigned to essentially three periods, as follows:

- **Period 1.** A single charcoal-derived age c. 5.7 ka is a clear outlier in the dating. The related hearth feature is eroding from a thin cover of fine–medium red sand near the crest of the SBD (Figure 7-17 and Unit ‘A’ in Figure 7-18). A dense spread of heat retainer and a small number of artefacts extend onto the adjoining deflation surface across a pale-coloured sand (Units C and D) and continue onto an exposure of a thick, hard palaeosol (Unit E). No midden was directly associated with the hearth material or artefacts.
- **Period 2.** The second group of three ages were returned on lensed shell exposed in gully erosion in the eastern and western sections of the site. The ^{14}C ages overlap in the period 1270–1177 cal BP. All lenses were contained to a pale buff sand that forms a sediment wedge packed against the older SBD terrain and which thickens toward the western extent of the site. The upper surface of this unit (labelled as ‘B’ in Figure 7-18) lies approximately 50 cm above the 1956 flood height. A mass movement of sediment reworked from the T2b

SBD or packed against it during an extreme flood event(s) c. 1.2 ka is suggested in two equivalent ^{14}C ages returned on small exposures of lensed shell separated by ~8 cm in a shallow gully.

- **Period 3.** The remaining five ^{14}C age results in CAPR17_19 were returned on shell (n=4) and charcoal (n=1) and are staggered from c. 650 cal BP through to modern. This includes two ages c. 500 cal BP returned on thin shell lenses exposed in a rabbit warren at depths of 22 (Wk-47548) and 29 cm (OZY996). These lenses are laterally extensive, illustrating a gradual development of sediment uninterrupted by any significant erosive event.

The sites perched along the T2b cut-banks tend to be dominated by heat retainer hearths and stone artefacts. Dense midden typically occurs as discrete features in a small number of sites where these abut the active water frontages or ephemeral wetlands. If shell had been collected *en masse* from the T2b channels, this is not reflected in the Calperum evidence, or alternatively, had occurred at a level that hasn't translated in the extant archaeology. Furthermore, all shell noted in these sites is *V. ambiguus*, i.e. collected from lagoonal habitats post-dating the original channel settings. Direct dating in these sites is limited to a single shell-derived age c. 3.5 ka in CAPR17_17, though adzes were noted in several additional assemblages.

The patchy nature of sites in this setting is in the context of extensive and contiguous areas of exposure, notably along the high bank paralleling the Lake Merreti inlet creek. The site complex in the interior of T2b scroll I (see CAPR18_S29, S30 and S31) is clearly related to remobilised SBD sediments. Importantly, the deflation surfaces within this area extend to, and through, a distinctive deep-red palaeosol that is likely to have formed c. 24 ka. Continuous profiles through these older sediments are provided around the margins of deflation hollows and high sediment residuals (Figure 7-19). No archaeological material was identified in any of these sections.



Figure 7-16: Sites, survey and ^{14}C results in the area of the T2b scrolls centred on the Ral Ral - Hunchee Creek anabranh. The dashed white lines indicate the position of the final channel in each scroll.

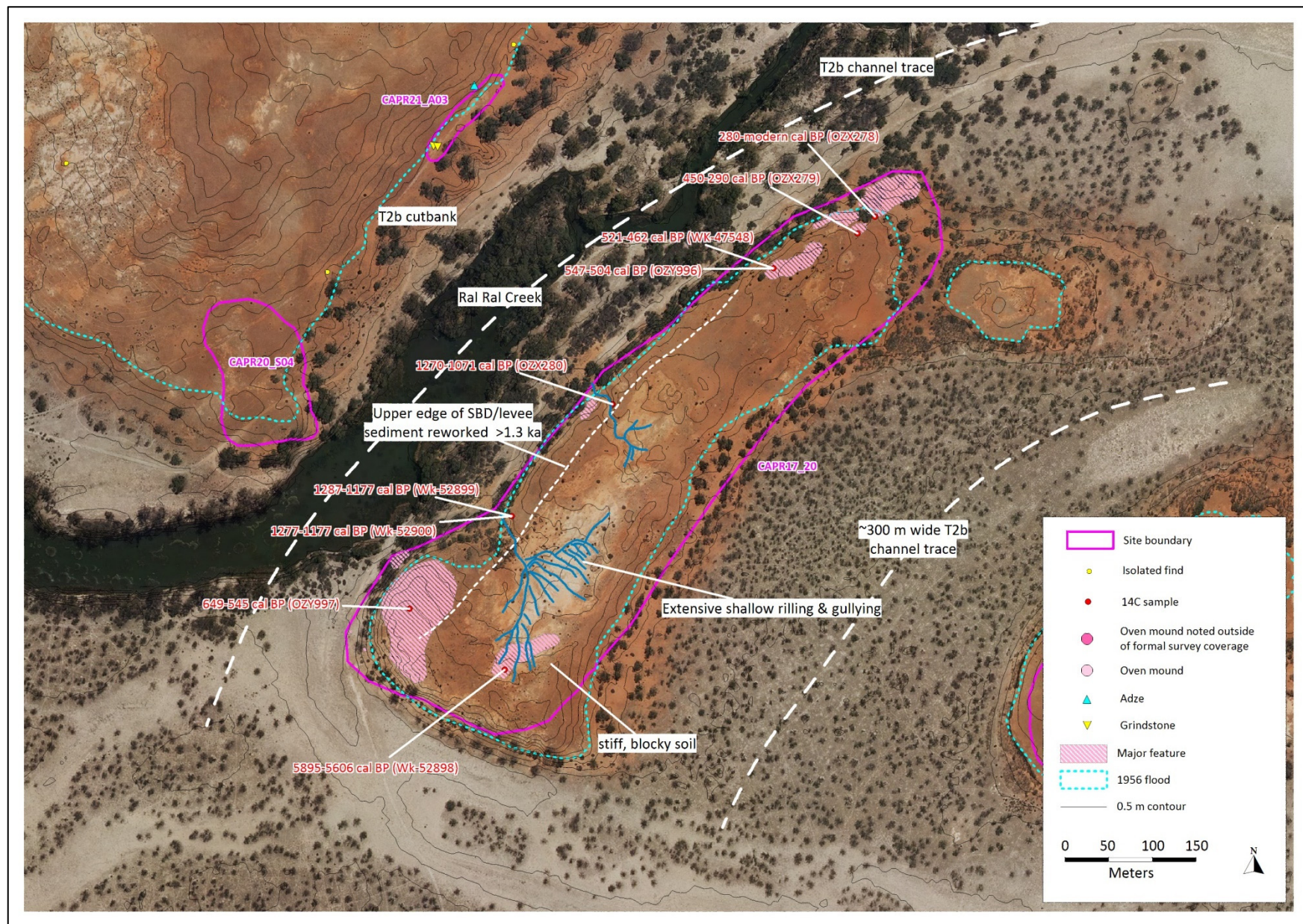


Figure 7-17: Plan of CAPR17_19 showing the dating locations and major features. The dashed white lines indicate the position of the final channel in each scroll.

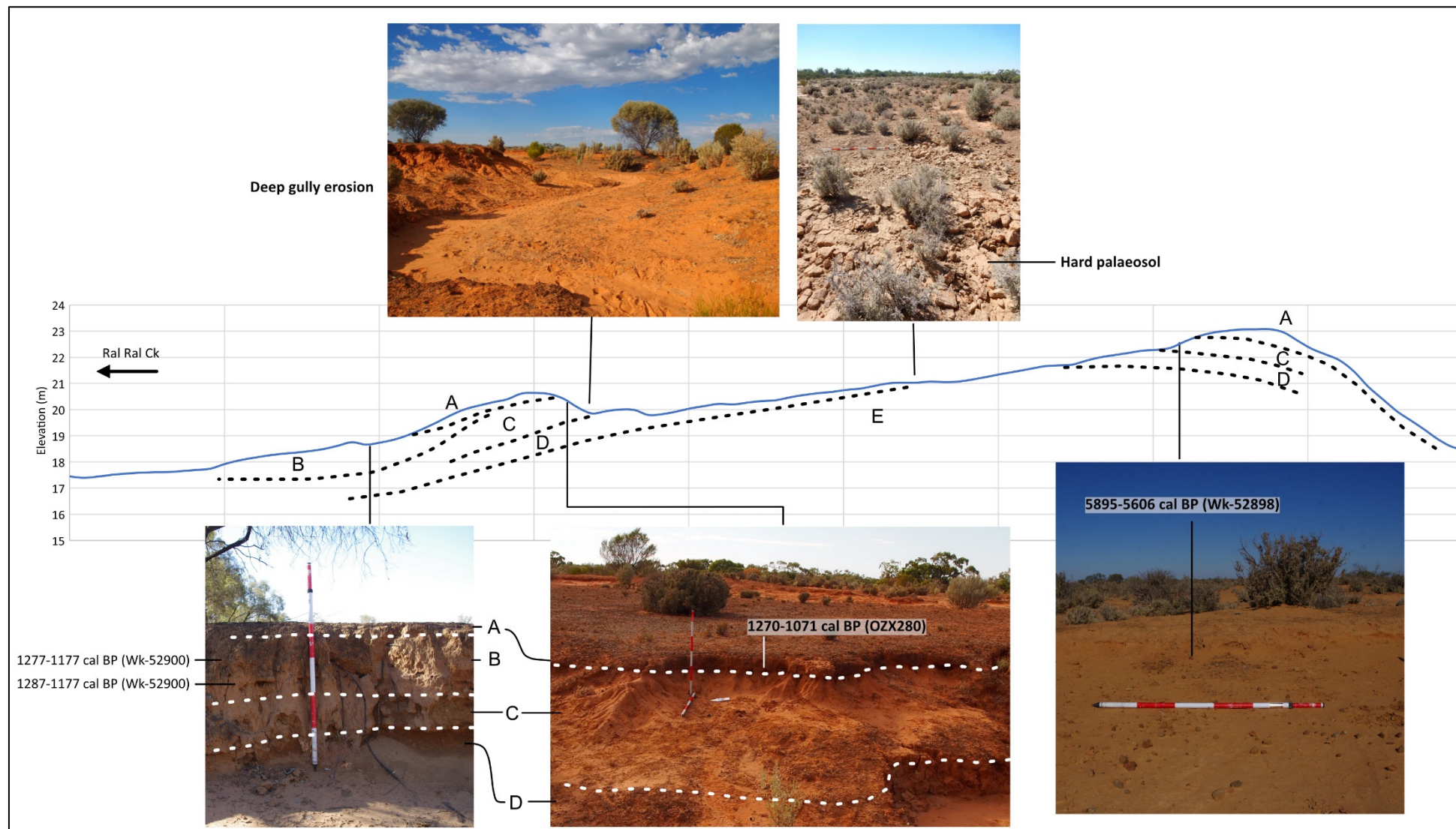


Figure 7-18: Stratigraphic interpretation of a T2b SBD in site CAPR17_19.



Figure 7-19: The typical extent of deflation and examples of pedestalled sediment in site CAPR18_S29.

7.4.3.3 T2c scrolls centred on the Ral Ral Wide Water oxbow

A sequence of two T2c scrolls preserved in the south-western section of the Calperum floodplain mark the latter stages of the large, bedload channels. These scrolls (labelled Scroll I and II in Figure 7-20) postdate the 24 ka palaeosol and are bracketed by an OSL age of 16 ka returned on SBD sediment associated with the penultimate channel in Scroll II (see Chapter 6.2.4). A weakly developed palaeosol is exposed within several SBDs and may be related to a regional soil phase c. 18–16 ka. Given this, it can be assumed that each scroll had expanded over periods of roughly 4,000 years with Scroll I truncated by Scroll II c. 20 ka and Scroll II abandoned with the incision of a third scroll preserved to the east of the modern River Murray course c. 16 ka (Scroll III). The sheer detail preserved in these landscapes provides an opportunity to scrutinise the intra and inter-scroll development in fine resolution. A sequence of at least 21 channels is able to be defined in the swale and SBD terrain. The high cut-bank and levee/crevasse deposits relating to the final channel in Scroll II are also preserved along the northern side of Bulyong Island. Following the incision of Scroll III, this channel transformed into the proto-Ral Ral Wide Water oxbow and infilled to its current form through the subsequent incisions of T3 and T4. Flows along the lower reach of the original oxbow are now restricted to a narrow flood runner (Nelbuck Creek). Thus, this section of the floodplain captures a detailed sequence of landscape change from T2c river frontages, through a sequence of two T2c oxbows and later stage infilling of the billabongs with the establishment of the modern floodplain.

Archaeological sites in this area tend to occur on the SBD surfaces, though invariably where these closely parallel or are truncated by the scroll margins. Few sites are recorded in the interior of the scrolls, and in these rare instances, the sites tend to reflect a specific activity other than general occupation, e.g. dedicated cemeteries (CAPR17_09) or earthworks (CAPR17_08). On the face of it, the distribution of sites in these scrolls suggests an association with the modern waterfrontages rather than the channels the SBDs had originally developed along. This is further evidenced in the exclusive presence of *V. ambiguus* in the middens, relating these sites to lagoonal rather than channel habitats.

The extent of archaeology associated with the Scroll II SBD paralleling Ral Ral Wide Water and all other settings in this area, also supports the notion of a relatively recent occupation. No middens of equivalent scale as those seen in CAPR17_10 occur along the infilled Scroll I oxbow or along the high cut-bank forming the northern edge of Bulyong Island. The only site recorded along the Bulyong Island bank comprises a large oven mound (i.e. late Holocene typology) and associated midden in site CAPR17_12 overlooking an active lagoon. Additional oven mounds are located on Nelbuck Creek, Ral Ral Wide Water and Ral Ral Creek (see 'MD' labels in Figure 7-20).

The absence of shell middens along the Bulyong Island bank, i.e. the main River Murray bank formed c. 16 ka, is also curious in light of the densely packed *A. jacksoni* middens that developed along the Pike cliff from c. 15.5 ka. A complete erasure of sites along the cut-bank seems unlikely. Instead, the absence of midden, or any other substantive archaeology along the T2c Scroll II cut-bank, suggests:

- An abrupt develop of the Pike middens, and preferential use of channel habitat and resources (*A. jacksoni*) during the phase in which the original Ral Ral Wide Water oxbow would have first established; or
- A lag in the populating of the oxbow by colonies of *V. ambiguus*; or
- A rapid infill of the abandoned channel trace so that mussel populations would not have occupied and persisted in the oxbow; or
- A significant lowering of the floodplain and/or irregular flooding beyond the active River Murray channel during the development of Scroll III.

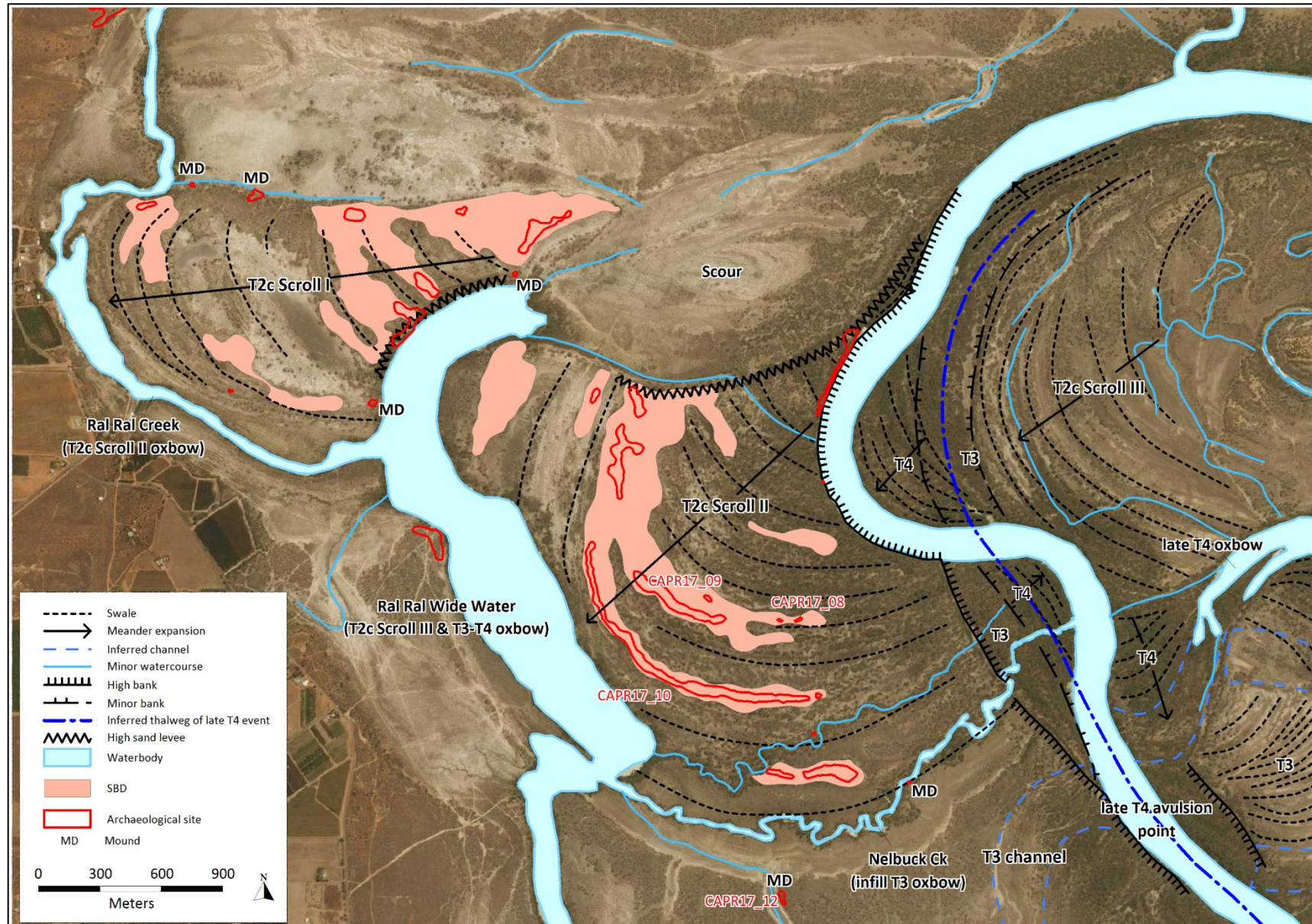


Figure 7-20: The sequential development of T2c scrolls in the south-western section of the Calperum floodplain.

There is also no evidence that the SBD-located archaeology had developed contemporaneously with the original SBD terrain. This is illustrated in Figure 7-21 in respect to sites CAPR17_09 and CAPR17_10. In both sites, archaeological materials and ancestral remains are exposed in deflation surfaces continuing along the crests of the SBDs. Large sand drifts have accumulated east of the ridges, representing the most recent deflation phase. Archaeological materials, including clumped midden and hearths are common across the upper intact surfaces of the SBDs while lags fill the deeper deflation hollows. In CAPR17_09, human remains interred in a flexed-upright position have been truncated to such a degree that half a metre or more of sediment is likely to have deflated post-burial. In situ midden and a series of hearths drape what is likely to have been a more subtle deflation terrain that this burial was excavated into. A ^{14}C age of 724–567 cal BP (OZX277) was returned on this midden.

CAPR17_09 forms one of the larger cemeteries on the Calperum floodplain and was evidently used almost exclusively for this purpose. The closely located site CAPR17_10, on the other hand, is characterised by a series of dense spreads of midden shell and heat retainer and more discrete clumped features. As with CAPR17_09, this material clearly pre-dates the most recent deflation and drapes (post-dates) the fully formed SBD. No archaeological material was identified in any profiles exposed in the extensive, and occasionally deep deflation hollows that expose the original SBD structure (Figure 7-21).

A total of seven ^{14}C estimates were returned on midden shell sampled from sites CAPR17_05, CAPR17_09 and CAPR17_10 located in the immediate area of the Ral Ral Wide Water oxbow. Age results include two estimates c. 1300 cal BP and then a set of ages from c. 950 cal BP through to 450 cal BP. A further n=4 calibrated ranges spanning the period 960-327 cal BP are reported by Jones et al. (2022) from the oven mound CAPR17_04 (referred to as RRWWS3 in Jones et al. 2022). As above, a number of additional oven mounds occur throughout this area, being located on the banks of Ral Ral Wide Water, Nelbuck Creek and an unnamed floodrunner.

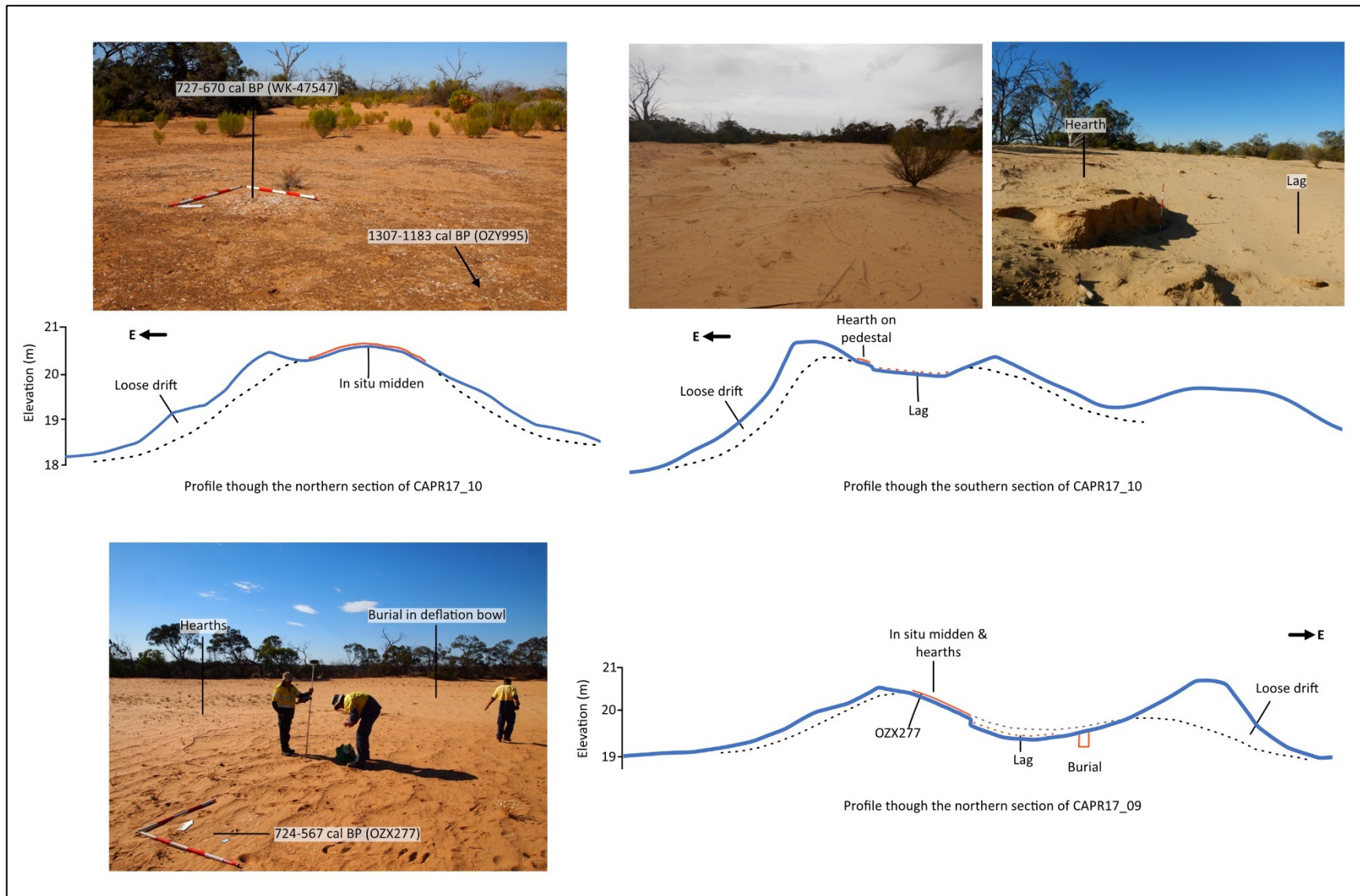


Figure 7-21: Profiles across SBDs in CAPR17_10 (top) and CAPR17_09 (bottom).

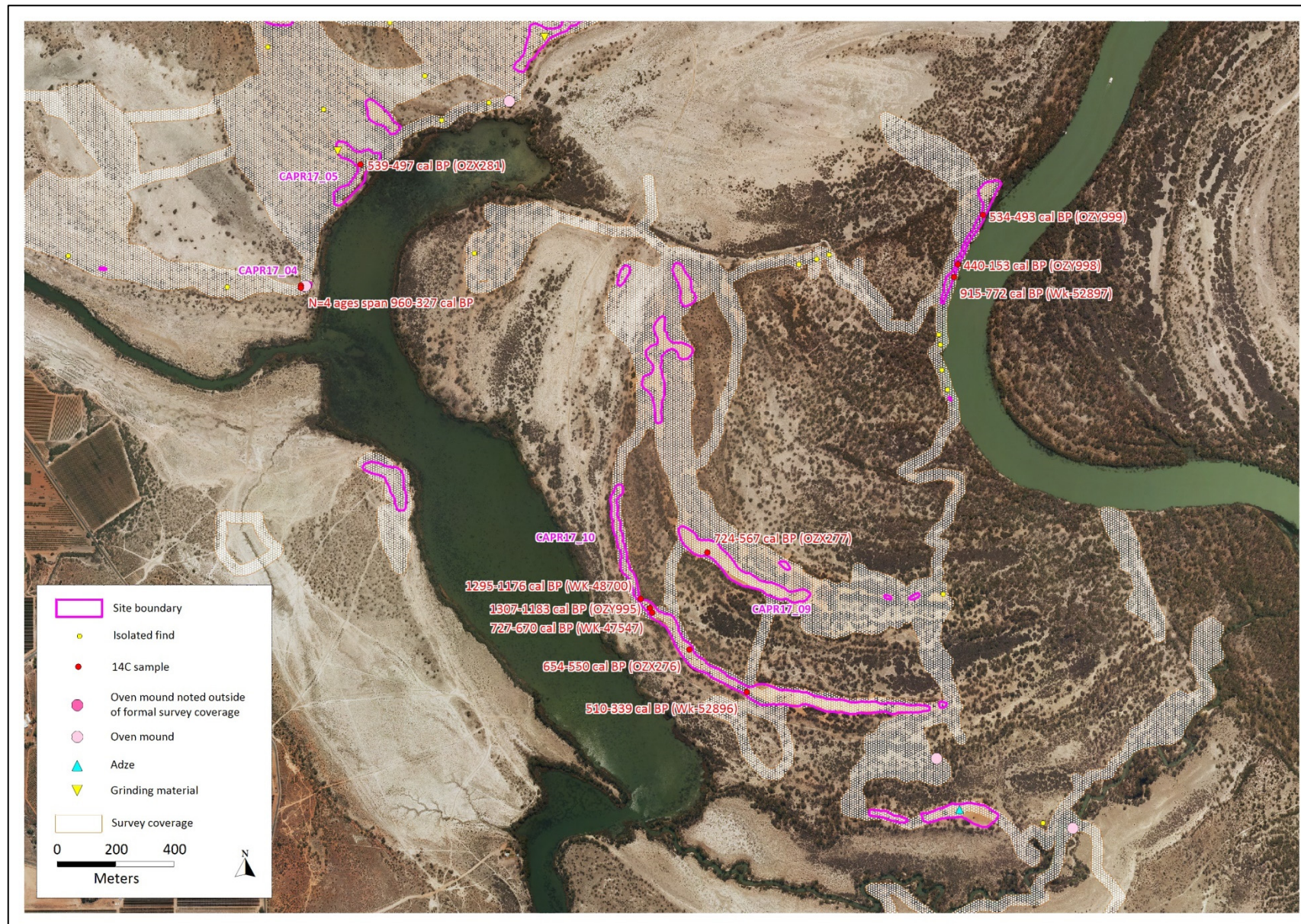


Figure 7-22: Sites, survey and ¹⁴C dating results in the T2c scrolls at Calperum.

In summary, the distribution of sites along the active waterfrontages, the dating evidence, and geomorphological contexts of archaeological sites provide compelling evidence of a late Holocene occupation centred on the Ral Ral Wide Water oxbow. As discussed in Chapter 7.1, a plausible explanation for this constrained timeline may lie in the apparent (re)excavation of the oxbow during a catastrophic flooding event sometime prior to c. 1.3 ka. The absence of archaeology related to the original development of the T2c scrolls adds further support to a seemingly abrupt development of channel-based freshwater mussel shell middens in this region c. 15.5 ka.

7.4.4 T3 scroll

Terrace T3 is likely to have established by c. 13 ka and developed over a period of 4,000–5,000 years across an early Holocene pluvial. A limited amount of survey coverage was dedicated to this terrace, essentially a single survey block along the high cut-bank of a T3 scroll in the south-eastern section of the Calperum floodplain. This bank formed around the last active channel in the T3 scroll prior to meander cut-off and incision of T4. The bank, therefore, is likely to have formed c. 8 ka. A semi-continuous exposure of patchy to densely packed shell midden, hearths, ashy deposits and formal oven mounds, together with several burials, were identified in this area as site CAPR10_O01 (Figure 7-23). The site extends in a typically narrow band over a distance of 1.2 km around the bank of a large oxbow (Horseshoe Swamp). No dating was able to be conducted in the site. However, the presence of both *A. jacksoni* and *V. ambiguus* suggests that occupation had straddled the conversion from the T3 channel to a lagoon habitat c. 8 ka. The presence of oven mounds extends this timeline to the late Holocene.

As discussed in Chapter 6.3.3, a set of near complete *A. jacksoni* valves located in CAPR19_O01 were all found to be less than 70 mm in length, i.e. less than half the maximum potential length of this species. This provides tentative evidence that shells were being harvested before they could fully develop. The impression of an intensive occupation along the T3 channel and later T4 oxbow also provides a stark contrast to the scant archaeology associated with cut-banks relatable to T2b and T2c, as described in the preceding sections. This pattern cannot be dismissed simply as a product of taphonomic loss. Indeed, this and all evidence in the floodplain builds toward an inevitable conclusion that the nature of Holocene occupation and resource use was unlike any preceding phase in the development of the Calperum floodplain.

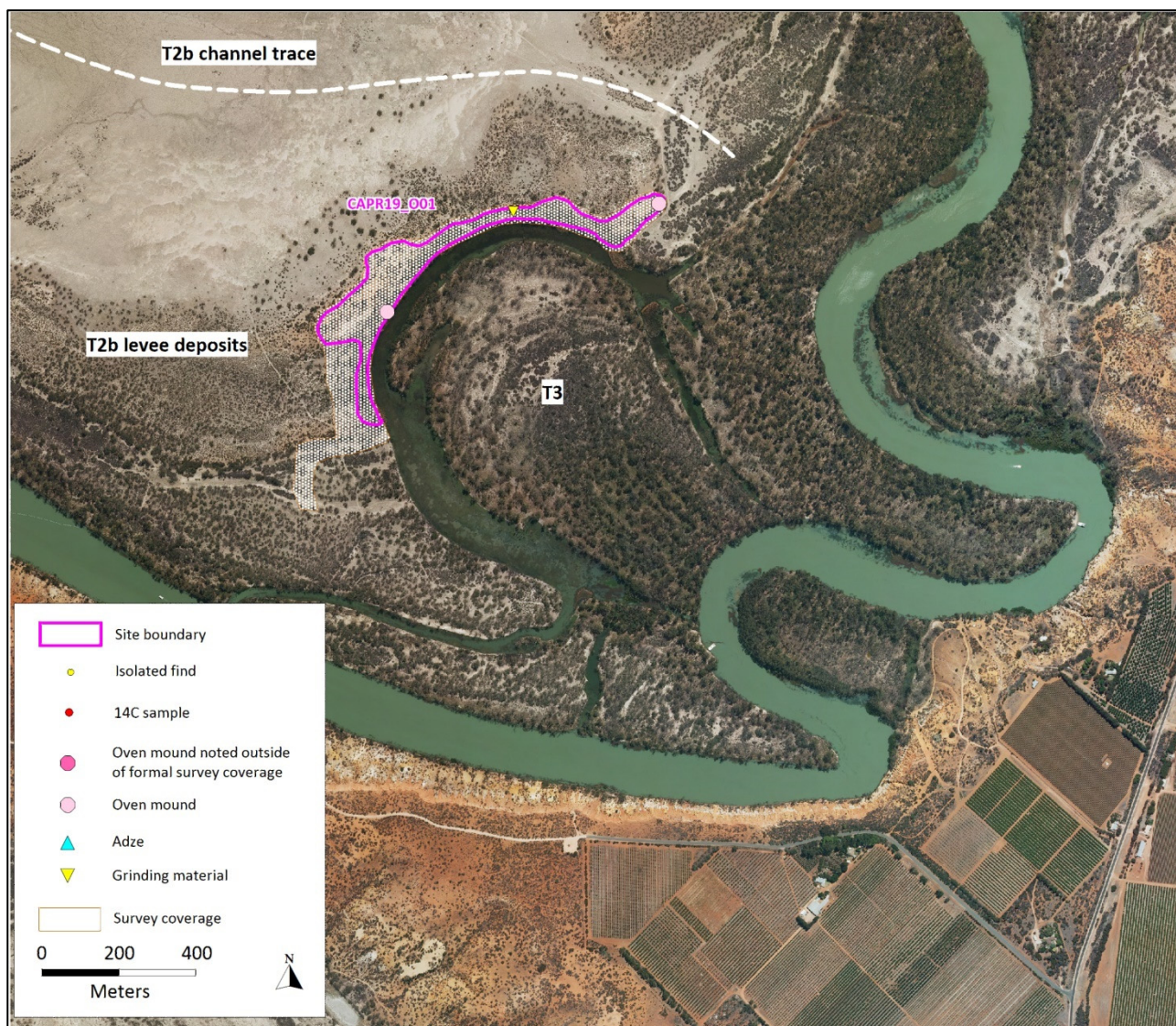


Figure 7-23: Archaeology associated with a T3 scroll and Horseshoe Lagoon in the south-eastern section of the Calperum floodplain.

7.4.5 River Murray

Survey along the course of the modern River Murray focused on the area of T2c scrolls in the south-western section of the Calperum floodplain (see Figure 7-22). Here, the river is migrating west from Woolenook Bend and impacting a high cut-bank incised into T2c Scroll II. A series of thinly lensed *A. jacksoni* middens, hearths and ashy features are contained to a narrow silt levee capping the bank. Three ¹⁴C age estimates were returned on shell fragments, spanning an age range of 915–772 cal BP (Wk-52897) to 440–153 cal BP (OZY998) and recovered from lensed midden features sectioned along the riverbank. The older midden age on this active cut-bank provides some indication of the slow pace of channel migration under the modern regime. As with the T3 sample described above, the laterally extensive, shell-dominated deposits along this T4 cut-

bank provide a clear contrast to equivalent settings in the earlier scrolls.

7.4.6 The Pike record

The scale and nature of middens preserved around the Pike cliff-line is replicated throughout the Central Murray corridor. In this location, the cliff is capped with a thin cover of WFm sediment overlaying a deep palaeosol that is likely to have developed in the period 60–40 ka (see Chapter 6.2.6). All the recorded archaeology, with the exception of a single heath feature in site PikeSP16_05, is contained to the loose aeolian cover above the palaeosol. Neither the depth of archaeological material below the current ground surfaces, or its height above the palaeosol, offers a reliable indicator of age within or between sites.

¹⁴C ages returned on freshwater mussel (*A. jacksoni* and *V. ambiguus*) and *N. sublineata* shell span the period 29,845–28,977 cal BP (OZX288) to 2728–22435 cal BP (Wk-48705), though the vast majority of shell-derived ages occupy the period of 15–6 ka. The initial, large-scale development of midden relates to the final stages of T2c. Evidence of reduced SBD formation in the last T2c scroll opposite Calperum (see Chapter 7.5.3.3) suggests an improved hydrology toward the latter stages of a brief humid phase in the western MDB c. 18–15 ka. A period of lower age frequency (¹⁴C Phase 4) exists between this early development of middens and a subsequent re-development of middens c. 12 ka (¹⁴C Phase 5), suggesting of a staggered (re)occupation of the Riverland floodplains over the T2–T3 transition. The shell species also suggests that a high-flow environment had persisted in the Pike River anabranch for a time following an initial channel avulsion to the centre of the floodplain. A lagoonal habitat had established by at least c. 6.7 ka when *V. ambiguus* were being relocated onto the cliff line.

The valley cliff-lines appear to have been preferentially used for establishing and maintaining large-scale sites over this period. This assessment is based on the extensive survey coverage conducted at Calperum and a review of previously documented archaeology in the broader Riverland. The motivation in locating these sites along the valley cliff-line is conjecture, perhaps related to the nature of flows, the rates at which flooding rose and fell, or some cultural or other consideration. The densely packed middens along the Pike cliff might also provide proxy evidence for an associated material culture as it would be expected that some form of container would have

been employed in relocating the volume of shell represented in these sites. Nets or woven bags might be considered as candidates, offering some insight into the antiquity of fibre production in the MDB (see Balme 1990, 1995).

7.4.7 Other Riverland settings

The Calperum and Pike results find support in the broader Riverland where consistent observations can be drawn from a review of the reported archaeological sites and their contexts. The lunette complex and surrounds of Lake Bonney, the largest Riverland lake, remain key in the evaluation of Riverland archaeology. Survey, to date, provides a reasonable sample of the various lunettes stages (see for example Wood and Westell 2008a, 2013; Wood and Westell 2019), though this is far from exhaustive and there remains ample scope for a more detailed assessment. It is beyond doubt, however, that the intense occupation manifest in the archaeology of the Holocene shoreline is not replicated in the older lunettes. Where sites occur amongst the lunettes, these are reported in loose sand drifts of reworked lunette sediment (see -A- in Figure 7-24) or in WFm ridges and sand-sheets extending onto (post-dating) the lunettes (-C-). Importantly, no stratified cultural deposit has been recorded in the extensive gully erosion across the various lunette phases (-B-). The semi-continuous complex of open scatter, mound and burial sites extending around the Holocene shoreline and foredunes (-D-), including a series of cusate forelands (-E-), provides a marked contrast to the older lunette slopes and ridges. To the west of Lake Bonney, Sugarloaf Hill represents one of several major sources of chert/silcrete in the Riverland and might be considered a priority for further survey. Woolmer (1974:21) suggested that the Loch Luna/Chambers Creek area surrounding Sugarloaf Hill represented the 'most comprehensive camping ground in the Riverland region'. T1 and T2a channel traces and terracing (-G- and -H-, respectively) are preserved in this area. Where sites extend to these older waterfrontages (-F-), they tend to occur on WFm ridges that transgress into the floodplain.

The Chowilla complex of lunette-fringed lakes (Coombool Swamp, Lake Limbra, Gum Flat and Lake Littra) is shown Figure 7-25. As with Lake Bonney, the extent of reported survey across the Chowilla lunettes is patchy. Personal observations of the Lake Limbra lunette also suggests that the extent of sites associated with that lunette may be overstated. Indeed, where sites can be confidently attributed to comprehensive survey coverage, for instance at Coombool Swamp

(Wood et al. 2005) and Lake Littra (Wood and Westell 2014a), sites located on the lunette surfaces tend to be small, discrete features, and contained to the loose surface sediments above palaeosols (see Wood and Westell 2014a:19). One notable exception is a group of burials located at Lake Limbra that are contained within a stiff, red palaeosol overprinting the Phase II lunette (Figure 7-26). A fine, greenish-grey clayey sand drapes a topography formed in this palaeosol. These burials appear to be contained in a Pleistocene context. Beyond the lakes, extensive open scatters continue along the inlet creeks to Coombool Swamp (including Brandy Bottle Waterhole) and Lake Limbra (Hancock Creek) (Figure 7-25).

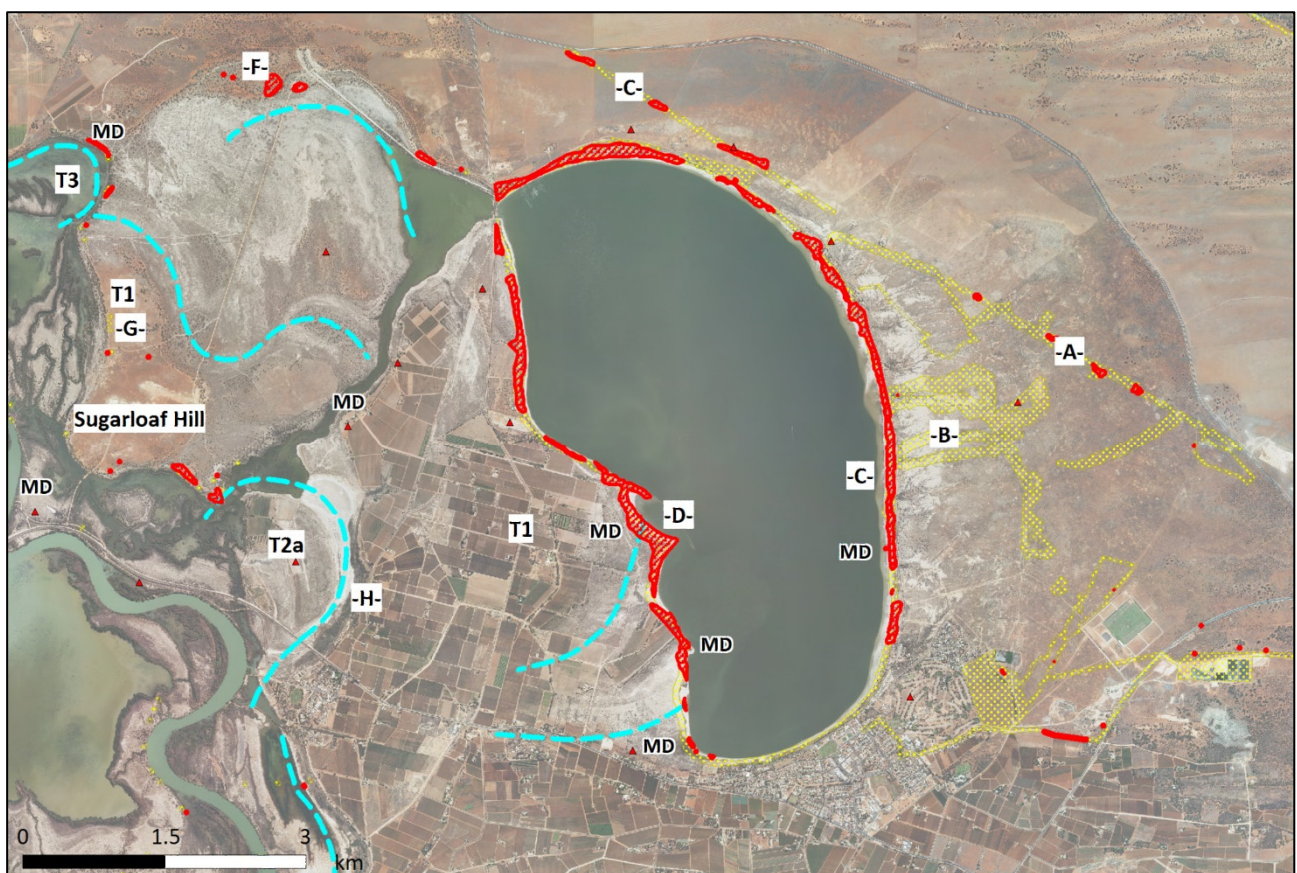


Figure 7-24: Open scatters, mounds and burials (all shown in red) recorded in the area of Lake Bonney. The dashed blue lines indicate palaeochannel traces. Yellow shading indicates the extent of survey coverage. The label MD indicates the locations of late Holocene oven mounds. See text for descriptions of the -x- annotations.

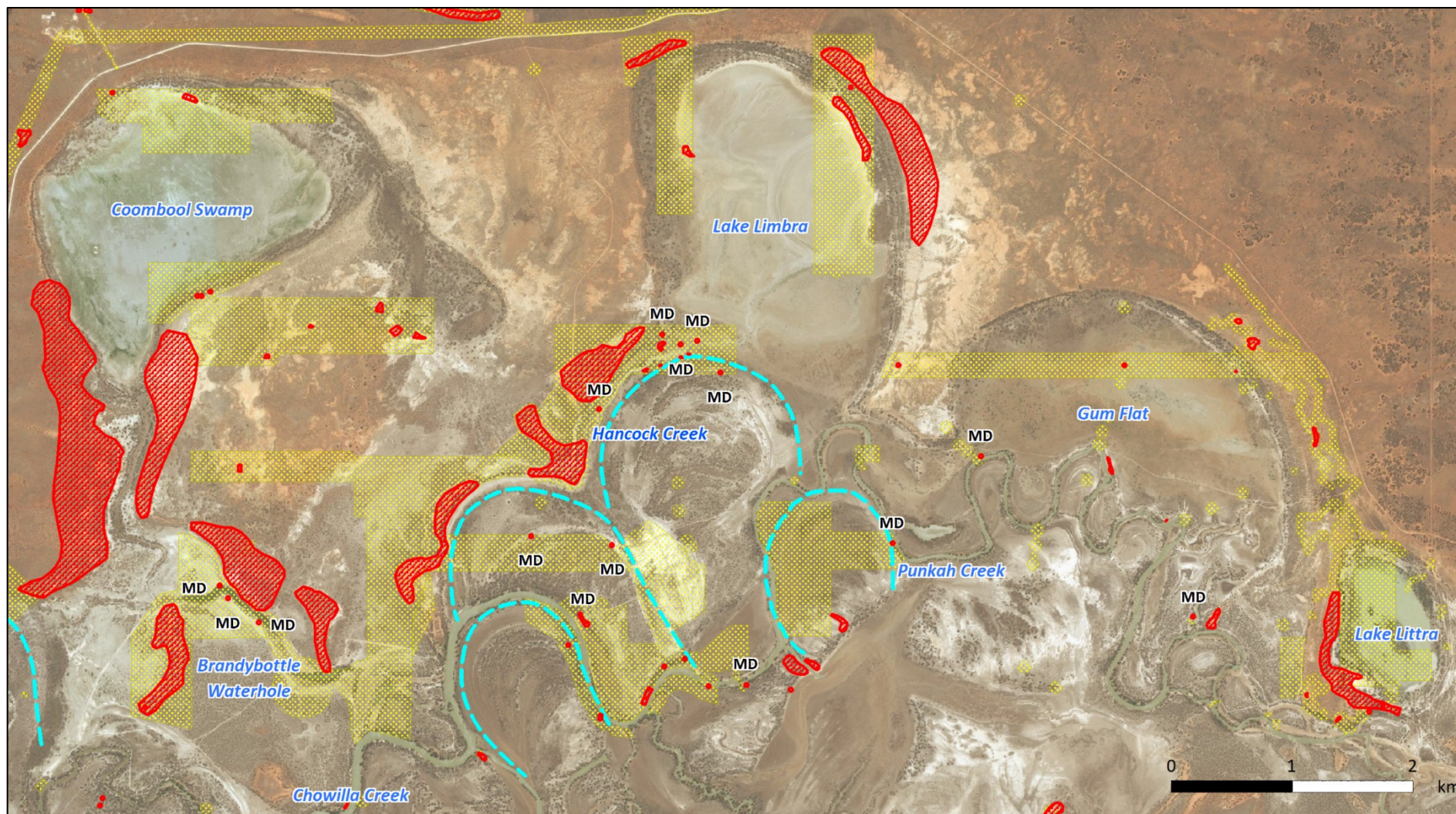


Figure 7-25: Open scatters, mounds and burials (all shown in red) recorded in the area of the lunette-fringed lakes on the Chowilla floodplain. The dashed blue lines indicate palaeochannel traces. Yellow shading indicates the extent of reported survey coverage. The label MD indicates the locations of late Holocene

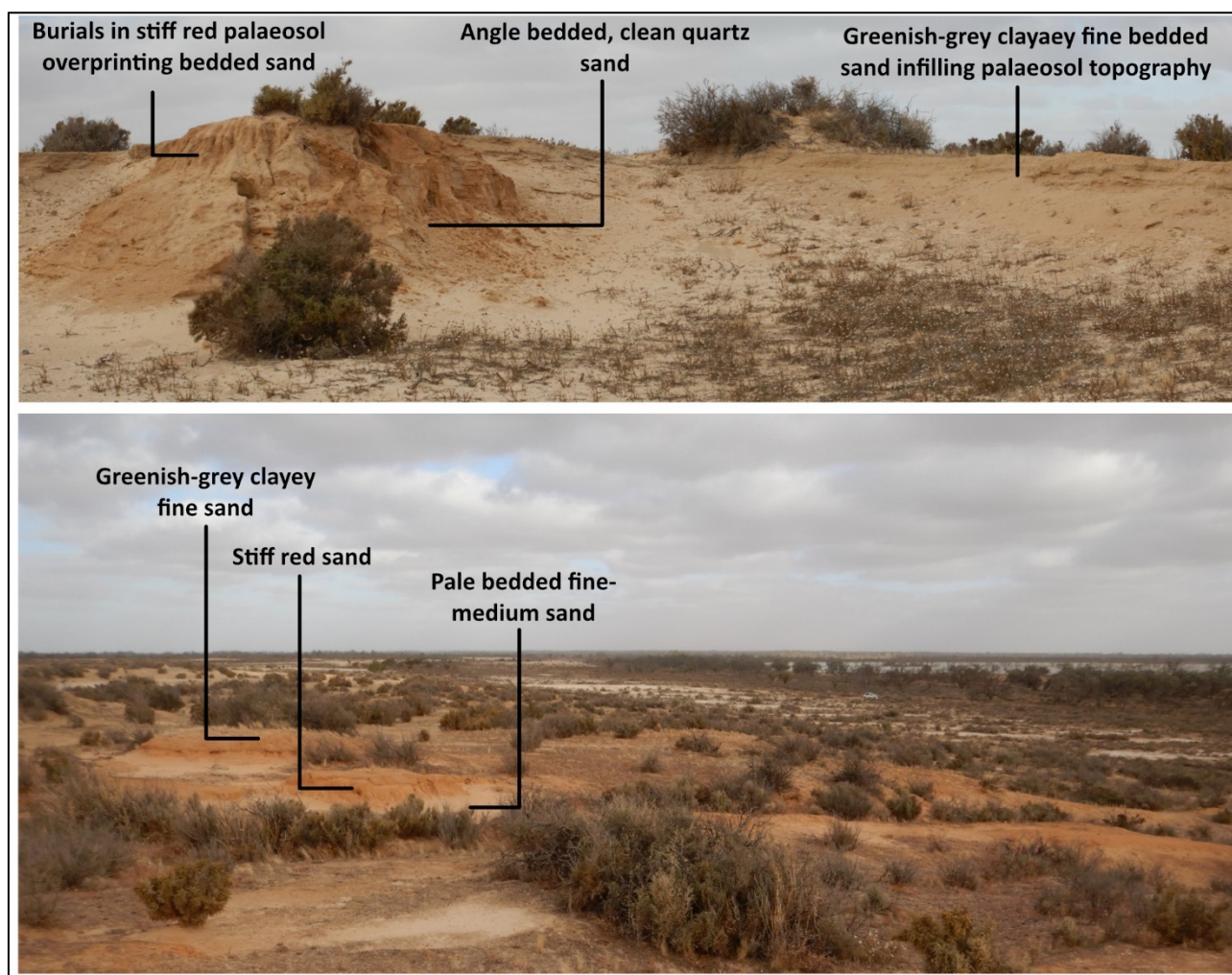


Figure 7-26: (Top) The stratigraphy and Pleistocene context of burials exposed along the crest of the Lake Limbra lunette. (Bottom) View looking south along the lunette with the modern shoreline of Lake Limbra seen in the right of the image.

Oxbow lagoons maintained under the modern hydrology are consistently associated with complex and extensive occupation sites. Indeed, these are amongst the most substantial archaeological features in the Riverland. Several examples are illustrated in Figure 7-27. These wetlands are invariably formed in T2c and T3 channel traces. Where these traces have infilled, sites tend to hug the floodrunner creeks established in the channel traces rather than the older cut-banks (see -A- annotation in Figure 7-27). As seen at Ral Ral Wide Water, sites located amongst SBDs in the T2 scrolls also tend to be positioned where these dunes intersect the oxbows or regularly inundated areas of floodplain (-B-) rather than tracking along the ridges themselves. Exceptions to this include areas of dune within the interior of meander scrolls that had invariably been dedicated as cemeteries. The oxbow-located site complexes invariably contain late Holocene oven mounds and rarely occur beyond the extent of silt levees and narrow belts of black box woodland fringing the modern banks of the wetlands. Whilst the majority of site descriptions are qualitative, it is

apparent that the shell content in oxbow-located sites is comprised of *V. ambiguus*, relating occupation to the lagoons rather than earlier channel habitats. Again, this observation is entirely consistent with the Calperum evidence, and together with the presence of large numbers of oven mounds, illustrates a Holocene, or at least a post-T2c occupation of these oxbow habitats.

Oxbow habitats would have existed in some form during each terrace stage, though would have functioned differently given the changes in hydrology. The aquatic and riparian ecology sustained by the flashy flood cycles of the T2 and earlier systems would have been distinctly different to that maintained under the Holocene regime of long flood seasons. A consistent contrast exists between the archaeology preserved along the banks of lagoon habitats formed over the various terrace stages. In summary, where T2 and earlier channel traces are infilled, there is little, if any, evidence, to suggest that similar levels of occupation were maintained at these palaeo-wetlands as those that remain active in the modern floodplain. As above, sites tend to hug the banks of flood runner creeks within these infilled channels or continue along crevasse channels extending from these channels where ephemeral wetlands are maintained. This pattern is illustrated in the example of Eckert Wide Water in Figure 7-27. There remains, however, significant opportunity to assess older, defunct wetland habitats, and several locations are highlighted in Figure 7-27 (see -C- annotation).

As the assessment of the Calperum and Pike floodplains suggests, there is compelling evidence in the broader Riverland that the staggering array of archaeological sites and materials contained along the River Murray had developed in essentially two distinct phases. The first was centred on the main river channel and is preserved along the high bounding cliff line of the valley. The second phase encompassed the Holocene and saw the broader mosaic of habitat incorporated into Aboriginal economic strategies. Based on a review of the reported archaeology, there is little, if any, evidence of a deeper timeline. However, there remains ample opportunity to test this assessment. Specifically, the valley cliff line, cut-banks of palaeochannels, the major sources of stone material (e.g. the Memdelbuik, Cape Horn and Sugarloaf Hill chert/silcrete quarries), and the lunettes at Lake Bonney and the Chowilla complex, should be prioritised.

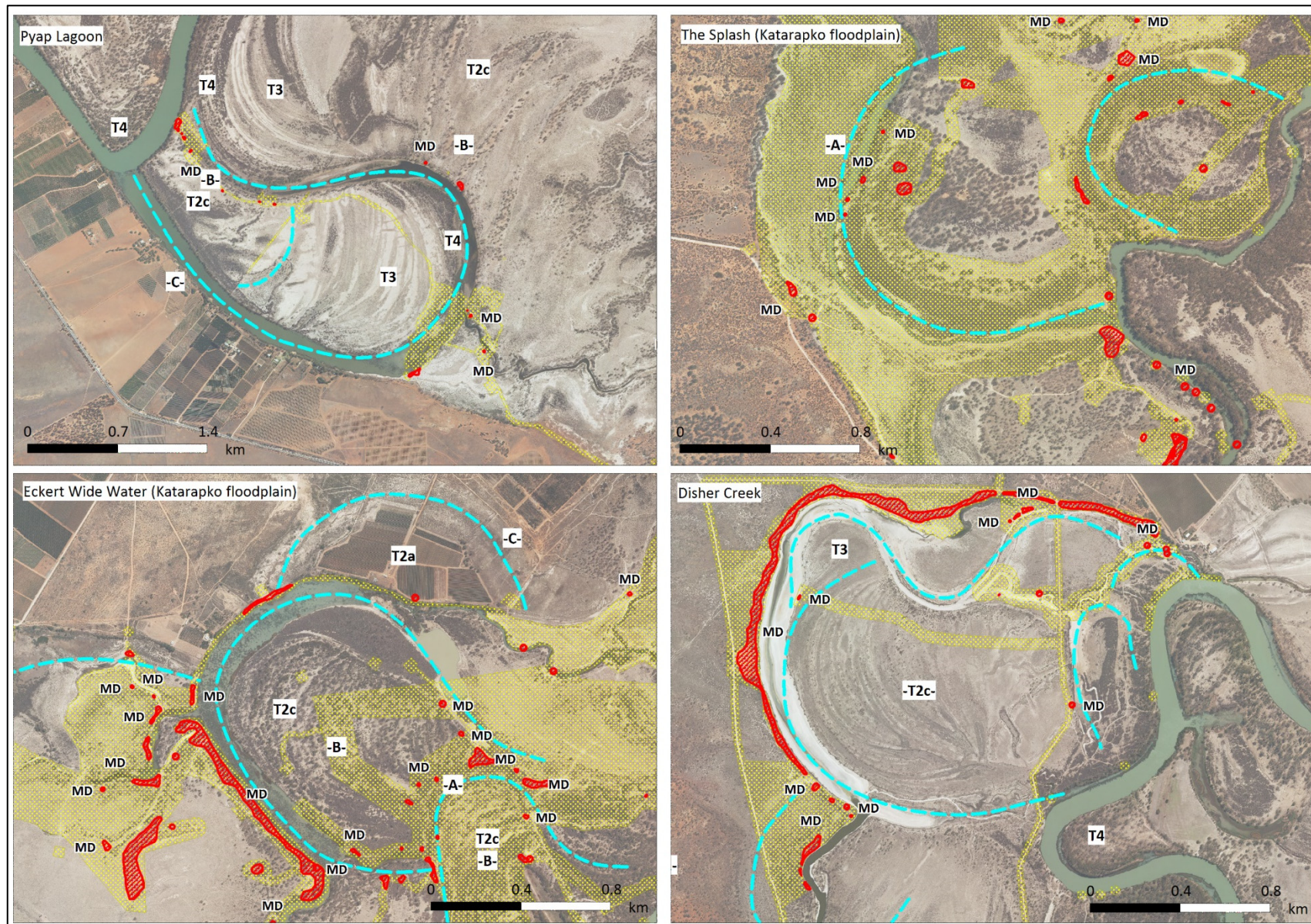


Figure 7-27: Open scatters, mounds and burials (all shown in red) recorded in the area of major oxbows in the Riverland. The dashed blue lines indicate palaeochannel traces. Yellow shading indicates the extent of survey coverage. The label MD indicates the locations of late Holocene oven mounds. See text for descriptions of the -x- labels.

7.5 A proposed timeline in Riverland occupation

In interpreting a history of the Aboriginal peopling and lifeways in the Riverland there are several caveats that need to be restated. **First**, basing a narrative almost exclusively on the dating of freshwater mussel shell middens has the potential to track ecological conditions that may or may not be directly correlated with demographic changes. **Second**, the nature of these middens is at odds with the diverse array of resources represented in ethnohistorical observations, highlighting a potential bias in the extant archaeology. A gender-bias might also be represented in these observations. Hawdon (1952), for instance, noted that the diet of women and children consisted of wild yams, mussel and tortoise while men used nets to catch ducks and kangaroos. Pate's (2006:232) isotopic analysis of the Holocene Roonka assemblage indicated a distinction between the adult male and adult female/child diets, with the latter consuming significantly more ^{13}C depleted foods such as aquatic and terrestrial plants and freshwater shellfish than the adult males. **Third**, the paucity of other taxa limits the discussion around past economic strategies. The assumption made here, albeit tentative, is that a spatial relationship between sites and habitats equates to habitat use. **Fourth**, the floodplain represents a complex taphonomic setting and it is inevitable that the material record has, and continues to be, compromised to some degree.

Archaeological records reflect a myriad of factors that include, among other things, levels of residential and logistical mobility, the nature of site use, the use of a landscape, and the specific arrangements and intent in the collection, processing and disposal of a resource(s). When inferring change, any argument must consider how these variables might translate in the material record—would a shift in resource emphasis or a patchier, though nevertheless persistent use of a landscape, reduce archaeological visibility, for example. Veth et al.'s (2017) approach to LGM 'discontinuities' drives home the point that valid argument rests in both the resolution in the data and an ability to canvas scenarios at both local and regional scales. There is, admittedly, a heavy reliance on shell in this research, but again, the approach taken here is exploit the remarkable detail preserved in the palaeolandscapes to value-add this data. Having teased out the relationships between the archaeology and landscapes, the discussion now turns to aspects of MDB archaeology central to this thesis. Much of the discussion returns to the ^{14}C age results in the context of environmental phases recognised in the regional geomorphology (Figure 7-28), in respect to local habitat zones and the context of grinding and oven mounds (as summarised in Figure 7-29), and the phases suggested in the 89 age determinations (Figure 6-92 and Figure 6-93).

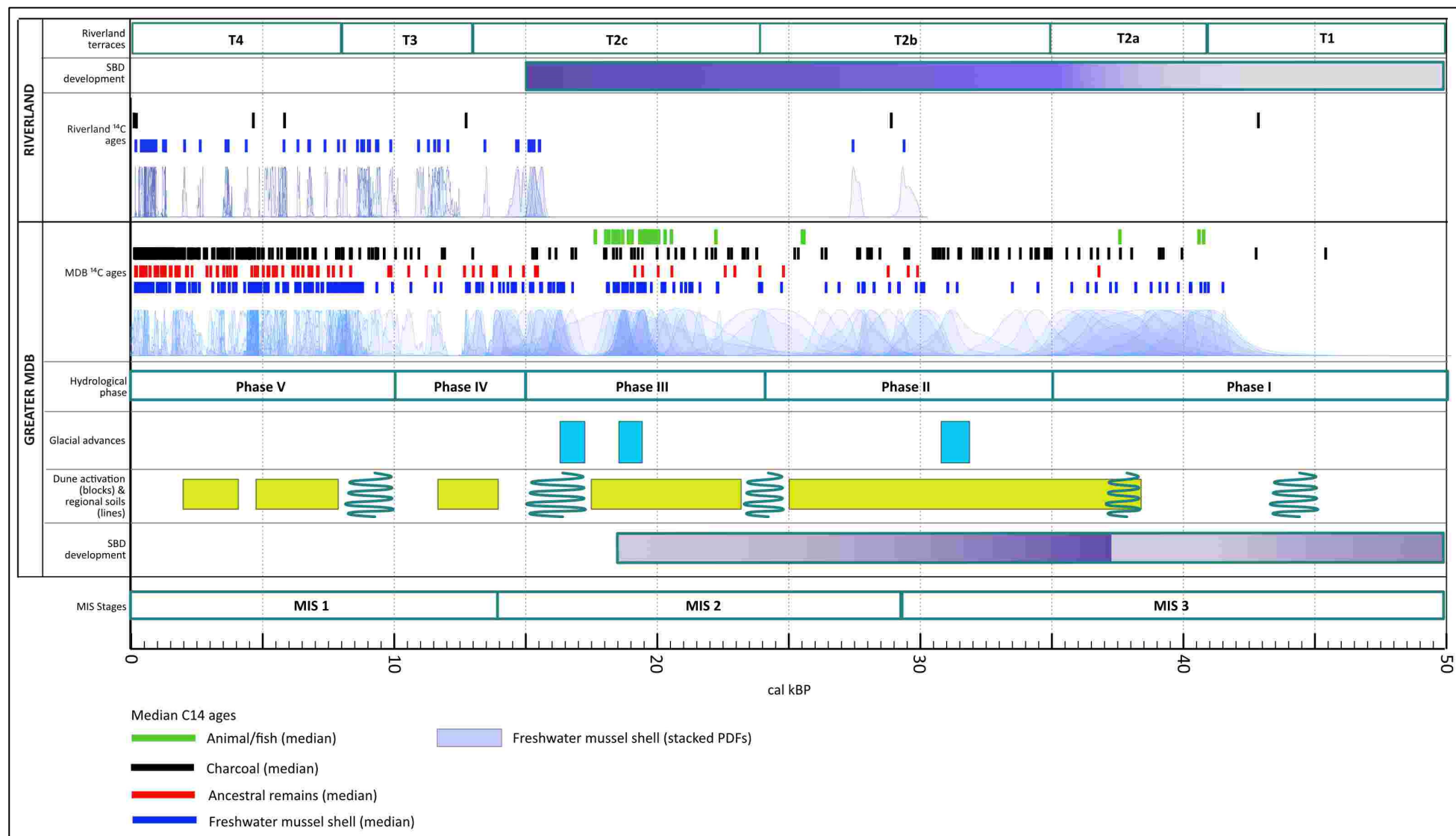


Figure 7-28: The Riverland ^{14}C age results and terrace boundaries in relation to the MDB dataset and major environmental phases. The dataset established in this research is based on the two species of freshwater mussel (*A. jacksoni* and *V. ambiguus*), the freshwater snail (*N. sublineata*) and a small number of charcoal samples.

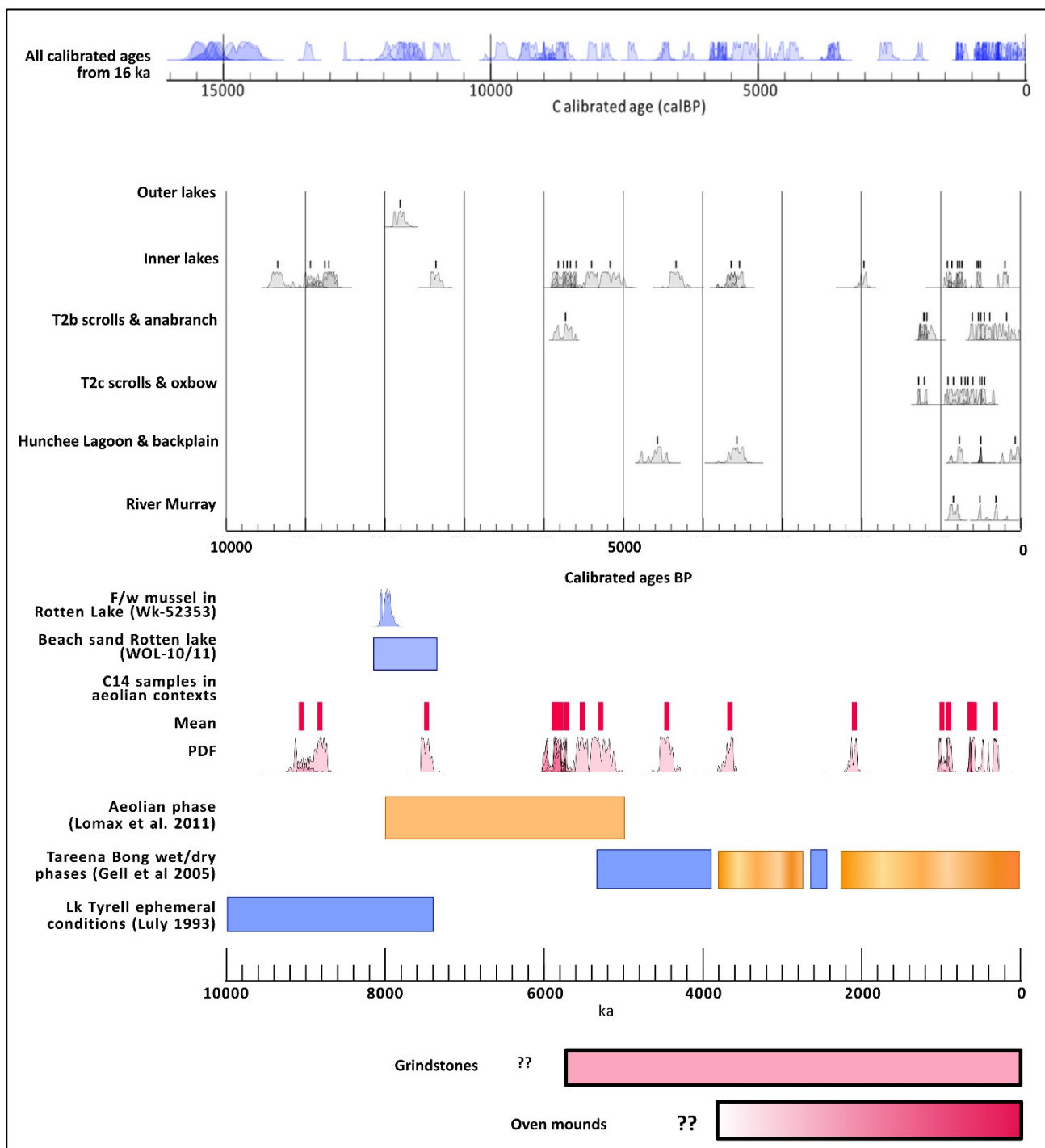


Figure 7-29: (Top) Stacked plots of the calibrated ^{14}C ages from 16 ka and in each habitat zone at Calperum with median ages are shown as vertical lines above each PDF. (Bottom) Context of the Holocene record and introduction of grinding and oven mounds.

7.5.1 A lag to River Murray settlement?

The timing of the initial peopling of Sahul continues to be the subject of vigorous debate (Clarkson et al. 2017; Clarkson et al. 2018; Hublin 2021; O'Connell et al. 2018; Sun et al. 2021; Williams et al. 2021). There is, however, general consensus that a phase of rapid migration through the period 50–45 ka had encapsulated the diverse array of geographic settings across the continent (e.g. Hamm et al. 2016; Hiscock 2008:45–62; Hiscock and Wallis 2005). The MDB continues to feature in debates around this continental dispersal, and for a time, the deep-time Willandra record set the agenda in the discussion (Bowler et al. 1970). Indeed, there remains an understandable temptation to view the Willandra system as central to an MDB record with all else developing from, and relatable, to it.

Greater water availability (see Cohen et al. 2012:11) may have supported this rapid dispersal (Hiscock and Wallis 2005; Hughes et al. 2017), though the negative 'push' or positive 'pull' factors (sensu Anthony 1990:898) remain elusive elements in the discussion. Populations are unlikely to have expanded to such a degree, for instance, that 'demographic packing' pressured this expansion. The population scenario promoted by Williams (2013) considers a low, though widely dispersed, population that stabilised soon after colonisation. A consideration of the elements and timeframes in the colonisation process are also rarely discussed. A cumulative process might, however, be envisaged, wherein a set of skills and technologies are applied to familiar resources in locations beyond a known territory. A period of familiarisation more fully integrates the nuances of this frontier zone through adaptation and innovation. Strategies gradually morph into a distinct set of strategies honed through knowledge investment and specifically tailored to a suite of resource. And the process advances.

When the combined MDB ¹⁴C evidence is considered, there is a relatively consistent spread of ages from an initial occupation registered at the Menindee Lakes c. 46 ka (Cupper and Duncan 2006) and possibly as early as c. 50 ka in the Willandra system (Bowler et al. 2003). Subsequent trends, however, vary markedly on a sub-regional scale, most notably in the seemingly staggered pulses in the freshwater mussel component. One observation is that the Willandra and Darling records, i.e. the more northerly catchments, have early and more consistent ¹⁴C records across the period 45–30 ka compared to more southerly parts of basin.

The Riverland offers an opportunity to scrutinise the colonisation process as it played out in the MDB. The 43 ka result at Pike remains a clear outlier in the Riverland dataset with only one other feature (a midden lens dated to c. 29 ka) falling within the intervening period to 15 ka. There is, however, some uncertainty around the 43 ka age with repeat charcoal samples returning ages of approximately 36 ka and 29 ka. If accurate, the 43 ka result indicates that the initial peopling of the MDB had projected beyond the central lake systems and into the River Murray corridor. The paucity of archaeology across the related landscapes, however, points to a very different mode of occupation than that reflected in the Willandra and Menindee records, and hints at discrete episodes and potential gaps in occupation, or alternatively, a pattern founded in high levels of mobility that simply didn't produce a detectable signature in the extant archaeology. The archaeology associated with the lunette fringed lakes is the most telling in this regard, with the older Pleistocene ridges essentially devoid of relatable archaeological material.

The younger (c. 29 ka) midden lens at Pike falls within the same general timeline as a relatively synchronous increase in freshwater midden ages along the Darling River, and midden and charcoal-derived ages in the River Murray corridor below and above the Darling junction c. 31–26 ka. This includes the earliest dated midden at Lake Victoria (Abdulla et al. 2019). A continuous shell/charcoal record continues in the Willandra data from the time of initial occupation and throughout this period. The River Murray data, however, remains extremely scant in comparison, and again, leaves an impression of divergent records between the more northerly and southerly catchments. A pattern of ephemeral occupation along the Murray corridor appears to have persisted to c. 25–24 ka before more substantial occupation sites develop as far downstream as Lake Victoria. It is not until c. 15 ka, however, that similar evidence appears in the Riverland.

In summary, the Riverland evidence supports the notion of a considerable lag in sustained Aboriginal occupation beyond the systems of large capacity lakes through the central MDB. The earliest sites in the Riverland that might be considered reflective of an intensive utilisation of a riverine resource (freshwater mussel) occur from c. 15 ka. This result is in the context of intensive survey coverage of LGM and pre-LGM landscapes including lunettes, high cut-banks and SBDs related to T2a, T2b, T2c scrolls, and WFm dune-fields, both during and prior to this research. Similar settings have retained far older evidence of Aboriginal occupation upstream of the Riverland. This disparity cannot be explained simply by taphonomic loss.

Bowler et al. (2012) stated that ‘the genuine desert nature of the glacial maximum environments remain difficult for us to visualise today’. The trends in riverine ecology associated with the Millennium Drought might, however, be seen as analogous to the trajectories of intense desertification across the LGM (Mackay and Eastburn 1990:103–108). The collapse in a range of species and habitat, a reduced quality and availability of water, a greater influence of saline groundwater entering and accumulating in the floodplains, and high siltation rates impacting wetlands, are all scenarios that might be considered when contextualising occupation of the LGM riverscape. The Millennium Drought led to significant impacts to the food staples recognised in the historical observations of Aboriginal people in this region (birds, fish, molluscs) and under similar and longer-term conditions, these and other resources, are likely to have occupied isolated and fragmented habitats. This scenario may have been accommodated in a pattern of high residential mobility, expressed in the early hints of occupation at Pike c. 43 ka and 29 ka.

Is it possible that people were in the Riverland during an early phase of MDB settlement centred on the Willandra and Darling systems but left traces that are simply undetectable in the archaeology? Probably, though a reasonable conclusion is that the lifeways of Aboriginal peoples in this region had differed substantially to locations further upstream over a period of approximately 30,000 years.

Fitzsimmons et al. (2019) have argued that the notion of refugia within the MDB cannot be supported until additional datasets are gathered around the provenance and movement of raw materials and information on palaeodiets and foraging strategies. The Riverland dataset attests to an extended period in which this region lay on the periphery of a more continuous record of occupation, at the margins of a deeper Pleistocene occupation in the MDB. Lake Victoria appears to have represented the downstream limit to sustained occupation through the height of the LGM. This lake is the last large capacity lake in the MDB system, and in an LGM hydrology defined by flashy though high volume flows, would have represented a more stable ecology than the Riverland. The Riverland pattern might best be described as a series of incursions and more extended pulses of occupation projecting out and back from this lake, or alternatively, as a pattern of occupation founded in high levels of mobility and imperceptible in the extant archaeology.

7.5.2 The 15 ka 'event'

The proliferation of freshwater mussel shell middens c. 15 ka at Pike is a defining element in the distribution of ^{14}C ages. Evidence in the upper Riverland from as far afield as Murtho and Loxton points to a regional development of these characteristic middens and draws links to a consistent pattern that encapsulates essentially the entire Central Murray corridor. There is some suggestion in midden exposures at Morgan, that the phenomenon may have extended over a far greater geographic scale. These middens developed following a short period of relatively lower ^{14}C age frequencies in all sub-regions of the MDB between 18–17 ka (in all dated materials) and at the end of the last midden phase in the Willandra sequence (see Bowler et al. 2012:Figure 6) prior to the complete avulsion of Willandra Creek (Kemp et al. 2017). It also coincides with a change in the general character of regional middens with the appearance of the first large-scale deposits along the Darling and Central Murray corridors, for instance. The evidence bears all the hallmarks of a grand reorganisation in regional economy and demography, defined in large part, by the expanded use of riverine corridors.

In the Riverland, the widespread and seemingly synchronous development of these middens defined a dramatic upscaling in the use of a resource (freshwater mussel) that had been exploited by Aboriginal people throughout the entire MDB timeline. These distinctive middens also switch on and off over a relatively short time span of between 379–1042 years based on the calibrated age ranges. A set of midden-derived ^{14}C ages from 17.5–15.3 ka at Lake Victoria suggest that this trend may have initiated slightly earlier upstream of the Riverland. The assemblages of shell, bettong, yabby, nail tail wallaby, fish, lizard and bird bone identified by Kefous (1983:107–108) at Lake Victoria also reflect upon a diversified economic repertoire in place at this time, though forming part of a nested assemblage that is replicated throughout the entire record of MDB occupation (see Chapter 3.6).

A peak in the development of SBDs in the T2c scrolls from 24 ka to 16 ka, and evidence of saline conditions in the Calperum floodplain c. 17 ka, attests to a period of floodplain stress prior to the development of these middens. The heightened seasonality in inflows implied by this evidence is coeval with the last glacial advances in the Australian Alps (see Figure 7-28). Colder alpine conditions may have retained snow packs over longer seasons and released melts as relatively short, though large-volume flood events. The development of SBDs is, however, less-pronounced

in the subsequent formation of a late-stage T2c scroll that is likely to have developed c. 16–13 ka, suggesting that the 15 ka middens developed during a period of more regular flushing and potential desalination of the floodplains. A period of relative stability in the dune-fields beyond the river corridor is also registered at this time (Fitzsimmons 2017; Lomax et al. 2011).

Middens, as with all archaeological sites, are likely to have fulfilled very different roles suited to nature and demands of occupation. Morrison (2013), for example, viewed the intensive collection of *Anadara granosa* in Cape Yorke Peninsula as reflective of a flexible economic strategy able to respond to annual and intra-annual variability in the productivity of estuarine habitats. Morrison's assessment provides a useful comparative case study in respect to the spectacular scale of the 15 ka middens at Pike. The essential question is what intent and context do these middens actually reflect? The following scenarios might be considered:

- *A resident population shifting emphasis to a resource made available through a change in hydrology.* More reliable and lengthy through-flows are implied in the presence of *A. jacksoni* in the middens as this species has relatively low salt and anaerobic tolerances (Walker 1981, 2017). As above, however, there is simply no evidence identified in this research to suggest that a sustained or intensive use of the Riverland floodplains had occurred prior to the 15 ka event. Freshwater mussel may have formed a disproportionate component of a narrowly focused economy at this time, though these middens do not appear to have represented an upscaling or shift in an existing local economy. These middens appear in a landscape essentially devoid of archaeological sites.
- *A highly mobile population focusing on resource nodes made available through a change in hydrology.* *A. jacksoni* are known to preferentially occupy sharp bends where deeper channels tend to form and retain water over longer periods, though the pan-regional development of these middens argues against a scenario in which the Pike anabranch may have represented a resource node.
- *An increase in the use of a resource by a larger resident population.* If this scenario had occurred, one would imagine a commensurate archaeological visibility across a range of habitat settings. Instead, these middens have a very specific association with the T2c channels. A broader visibility across a range of floodplain habitats does not occur until c. 9 ka.
- *Increased sedentism with an improved, deglacial riverine ecology.* A scenario in which

regular incursions or an existing pattern of high residential mobility in the Riverland was supplanted by longer periods of residency, provides a good fit to the evidence. Again, an earlier and more continuous record is preserved at and above Lake Victoria and the Riverland may have laid at the periphery of this occupation node until the proliferation of middens c. 15 ka.

- *A wave of migration with an initial focus on reliable, recognisable and easily obtained resources.* Commonalities exist between all MDB floodplains, and skillsets and technical knowhow are likely to have been transferable to all. But these are not generic landscapes, with each floodplain having its own unique traits. The intricacies of each floodplain would have demanded long periods of familiarisation, possibly spanning generations and encompassing a range of flooding scenarios to fully appreciate. In the early phases of exploration and familiarisation, an emphasis may have been placed on the low hanging fruit such as freshwater mussel. While individual shells represent a small meat mass (Garvey 2017), *A. jacksoni* can occur at extraordinary concentrations (Walker 1981), and the collection of large numbers of shells could be achieved without the need for extended foraging. No occupation evidence of similar age was identified in the Calperum floodplain other than a series of hearth sites with no associated shell along the Phase III lunette ridge at Lake Woolpoolool (see Chapter 7.4.2). The evidence indicates a pattern of occupation and resource use c. 15 ka that was focussed on a very specific habitat (the main river channel). The presence of the freshwater snail *N. sublineata* is also an important aspect of the cliff-top middens, though may be related to a second phase of midden development (see further discussion in Chapter 7.4.6). Garvey (2017) has highlighted *N. sublineata* as a significant component of the c. 15 ka age Homestead Midden at Neds Corner. This species does not occur in similar concentrations in any of the younger middens, again, suggesting a heavy reliance on low-yield taxa from a narrow habitat range during the initial phase(s) of sustained occupation.

These last two scenarios are considered the most applicable. The 15 ka middens undoubtedly reflect upon an improved hydrology, though also a heavy reliance on a low-rank, reliable and ubiquitous riverine resource. If a migration into this region had occurred, it was likely to have been part of an expansion out of multiple lacustrine settings, registered across multiple riverine corridors in the south-western MDB. A downstream expansion out of Lake Victoria is suggested in

the earlier development of large-scale middens at this lake c. 17.5 ka. That equivalent middens did not develop in the Riverland during the period of ameliorated climatic c. 24 ka is also a curious aspect of this and may hint at the importance of full deglaciation in the southern alpine catchment on Riverland hydrology. Modern inflows to the River Murray are determined primarily by run-off and snow-melt from the upland catchment during winter-spring, with approximately 40% of the total yield received from just 2% of the catchment area above Albury (Thoms et al. 2000:23). Alternatively, the divergent patterns may define the timeframes required to establish a new ecology and install the economic systems able to optimise the use of this new context. The conspicuous component of extremely large specimens of *A. jacksoni* in the Pike middens is also noteworthy. Evidently, freshwater mussel was exploited by Aboriginal people in the Riverland at levels that did not noticeably skew the natural size ranges in these populations.

The proliferation of middens c. 15 ka is followed by a lower frequency of ^{14}C ages in the period 14–12 ka. This timeline coincides with the Antarctic Cold Reversal (ACR), a ‘millennial-scale cooling event’ that interrupted the warming trend of the deglacial period (Blunier et al. 1997:51, Figure 1; Jouzel et al. 1985; Pedro et al. 2015). Evidence of environmental conditions during this period is somewhat confused. This ‘gap’ in midden ages is coeval with a period of renewed Wfm dune activation, and there is some suggestion that deteriorating conditions beyond the valley were mirrored in a higher salinity phase in the riverine corridor. SBD development, however, appears to wane through this period, and a greater flow transmission through to the Lower Lakes is registered in sediments accumulating off the mouth of the river (Gingelle et al. 2007). The short-lived or staggered development of middens through this period is, however, likely to reveal tipping points in riverine ecology across the terminal Pleistocene where the viability of freshwater mussel as an economic staple may have periodically collapsed.

Regardless of their role, the large-scale, though pulse-like development of middens, offer a stark contrast with the ephemeral nature of much of the Pleistocene record, and arguably represent the first move toward semi-sedentary Aboriginal lifeways along this section of River Murray corridor. The diversified economies reported in ethnohistorical observations provide an overlay to the late Holocene. However, the staggering adjustments represented in these initial phases of intensive Riverland occupation attest to a far deeper timeline of dynamism in socio-economic systems and population dynamics across the MDB. Similar scale spikes in midden development as those

observed c. 15 ka and c. 12 ka are not repeated until the very late Holocene, though drawing direct comparison between these phases should be treated with caution. In effect, shellfish (*A. jacksoni* and *N. sublineata*) may have been a mainstay during the early peopling of the Riverland, but perhaps over time became a supplement in more well-established economies, a resource fulfilling very different roles under very different circumstances. Shell middens may be over-represented in an early phase of settlement as people relied more heavily on a reliable and familiar resource. This assessment of an early emphasis on low-rank, r-selected taxa, flips the simple OFT equations on their head, or at least adds another dimension to them, requiring a consideration of resources in the context of the phases of Aboriginal exploration and discovery, familiarisation and consolidation.

The geographic extent of the 15 ka middens remains unclear, though personal observations suggest that shell midden with the same composition and presentation as the Pike sites occurs at Morgan. Cotton (1933) described stratified lenses of *Notopala* spp. near Sunnyside on the Lower Murray and interpreted these as a natural mortality of shell in 'old river beds' of the River Murray. The site is, however, situated significantly higher than the modern river (quoted as 90 m higher) and the lenses occur below an Aboriginal midden of freshwater mussel. This site is clearly worth re-evaluating in light of the Pike results.

7.5.3 Holocene change?

Balme (1995) argued that distinct changes in the nature of occupation along the Darling River had occurred across the Pleistocene–Holocene boundary. This manifest as more numerous, frequently used and larger Holocene-age sites containing a greater variety of foods and other archaeological materials. According to Balme, this change was brought about by an increase in population, whereby constraints on mobility demanded the utilisation of a broader suite of resources in the context of more sedentary lifestyles, a repeat of the BSR narrative.

Multiple lines of evidence also suggest a change in the ways Aboriginal people had interacted with the Riverland floodplains during the Holocene. As Balme had recognised in the Darling River record, the most noticeable element in this is the manifestly different scale of occupation sites attributable to equivalent settings across the landscape timeseries. The archaeology associated

with oxbow lagoons provides one obvious example. Oxbows had formed through meander cut-offs over all terrace stages, though there is simply no comparison between the archaeological signature of the T3 and T4 oxbows and the earlier defunct T2 habitats. The diffuse background scatter and occasional hearth groupings contained in the older lacustrine shorelines and lunette surfaces offers an equally stark contrast to the sprawling complexes continuing around the Holocene beaches and foredunes.

The geomorphological evidence identifies an early Holocene pluvial that had initiated by at least c. 11 ka and peaked by c. 8 ka. The initial development of recognisable middens beyond the main river channel occurred in the context of this improved riverine ecology, as Aboriginal people began collecting freshwater mussel and presumably other resources from the inner lakes at Calperum from c. 9.3 ka. A steady, though light spread of ^{14}C age results continues to c. 6 ka, commensurate with an expanding knowledge of the complex Riverland landscapes and the nuances of seasonal and longer-term hydrology, building to an optimised set of strategies that more fully incorporated the habitat mosaic through systems of food production and collection. Again, the early spikes in midden development c. 15 ka and c. 12 ka reflect upon an intensive, though very specific use of the habitat mosaic.

The introduction of oven mounds is another obvious expression of Holocene change and represents an undeniable juncture in the Riverland record. A range of ^{14}C ages recovered from below and within four oven mounds at Calperum are presented in Jones et al. (2022) and are consistent with a mid Holocene introduction of this site type in the Riverland. The oldest of four mounds was in use by at least 3.9 ka with the remaining three used over the last 1,000 years. A shell fragment recovered from an additional mound feature in CAPR17_23, located on the western shoreline of Clover Lake, was dated to 960–805 cal BP (OZX285), again falling within the last 1,000 years. Midden exposures in this site were also dated to 8984–8602 cal BP (OZZ012), 624–517 cal BP (OZX286) and 543–507 cal BP (WK-52028), illustrating pre and post-mound aspects in a subsistence economy.

The scale and implications of the repeated use of oven mounds sets them apart from any other combustion feature—there is simply no overlap in typology. When considering the frequency of

this site type in the Riverland floodplains, it is also safe to assume that multiple mounds were operating contemporaneously in various locations and that the uptake of mound use was rapid (see Jones et al. 2022). The seemingly synchronous uptake of oven mound use across the MDB also speaks to an interconnectedness of people and diffusion of intellectual capital, technological and cultural innovations across the basin. Ethnohistorical observations provide compelling evidence relating oven mounds to the bulk harvesting and processing of aquatic vegetation for food and fibre, and specifically *Typha* spp. These materials were value-added in the production of netting, a technology geared toward strategies of mass-capture (notably of waterbirds and fish) that would typically benefit large groups of people. Netting was a hallmark of regional economies at the time of European contact. Nott (1924), for instance, described ‘cordage factories’ near Moorunde where men and women would process fibre into nets.

Oven mounds represent one of the few aspects of Riverland archaeology that can be confidently assigned to a ‘new’ activity, though the extent to which other technologies were abandoned, modified or incorporated, remains conjecture on the basis of this research. What can be said is that sites containing shell midden and hearths appear along channel habitats in the Riverland c. 15 ka, around the inner lakes from 9 ka, outer lakes c. 7.8 ka and on anabranch creeks and oxbows from c. 5.7 ka. The early use of mounds from at least c. 3.9 ka (Jones et al. 2022) coincides with a period of lower frequency in midden ages (Figure 7-30). At this time, shellfish gathering, a greater processing and consumption of *Typha* spp. and presumably the production and varied applications of netting formed complementary aspects of an expanded economic system. This pattern continued across, and may have been a solution to, the period of heightened ENSO variability and stress in the riverine ecology (Gell et al. 2005:450; Jones et al. 2022). It was only within the last 1,000 years that the proliferation of both shell middens and oven mounds would manifestly redefine the cultural landscape, signifying an apparent increase in total economic capacity that would suggest a larger Aboriginal population (see Figure 7-30). Admittedly, this interpretation is based on a small set of mound ages, and the discussion will benefit greatly from a more refined and representative mound chronology.

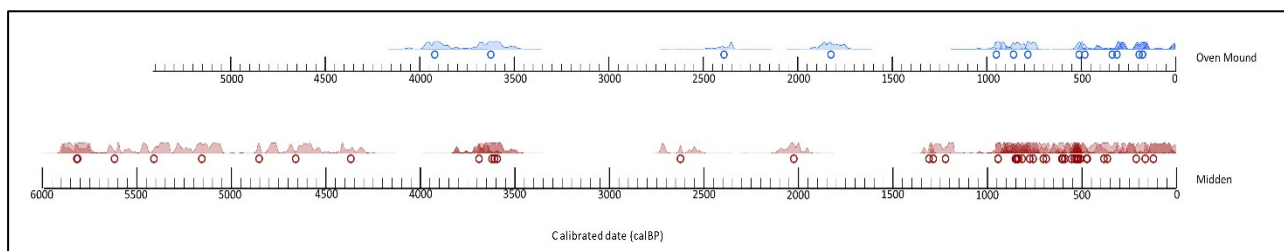


Figure 7-30: The calibrated ^{14}C ages returned on midden shell at Calperum younger than 6 ka and the age ranges from oven mounds reported by (Jones et al. 2022). Mean ages are shown as circles under the individual PDFs.

As with oven mounds, the proliferation of grinding activity is recognised as a defining aspect of Holocene economies both within and beyond the MDB (see Balme 1991:6–7; Hayes 2015; Smith 1986, 1988, 1989; Zeanah et al. 2017). It is worth reiterating that Pleistocene evidence of seed use does exist in the MDB, and has been attributed by Fullagar and Field (1997:306) to evidence of an early use of broad spectrum diets. As discussed in Chapter 6.3.8, there is some confidence that grinding was being applied by at least c. 5.7 ka at Calperum, and based on the frequency and distribution of grindstones both here, and in the broader Riverland (see Chapter 4.3.3), this activity had become an embedded component in subsistence enterprise. Grindstone typologies are dominated by pounding/grinding implements that are suggestive of a hard-seed and/or tuber processing kit (see Table 6-24). However, the diverse grindstone morphologies also suggest a range of other processing requirements.

Nardoo (*Marsilea drummondii*) was a known staple in parts of the MDB (see for example Pardoe 2003:48) and if the frequent references to ‘nardoo-stones’ in the Riverland reflect direct observation, nardoo is also a likely candidate as a food staple in this region. The broad growing conditions and high salt tolerances of this species would have seen it emerge as one constant in a landscape otherwise defined by variability. Other plants known to have required the use of grinding included marsh clubrush (*Bolbeschoenus medianus*), varieties of saltbush, pigface (*Mesembryanthemum* spp.) and other tubers and roots (see Appendix I).

In reviewing the context of each of the previously reported instances of grinding material in the Riverland (see Appendix II), there are few locations where an older application of grinding can be considered possible. In the area of Lake Bonney and the Loch Luna wetlands, for instance, several sites containing grindstones occur on, though clearly post-date, Pleistocene landscapes. The Tuit’s Ridge site at Lake Bonney (Dowling 1990), for instance, is situated on a Phase II lunette ridge,

though is contained within a thin aeolian cover post-dating the formation of the lunette. Similarly, grinding materials located in T2c SBDs on Katarapko Island (Wood and Westell 2009) and in the Tanyaca Creek scroll on the Pike floodplain (Wood and Westell 2014b) are located in redeposited sediments rather than being associated with the original landforms. There are other instances where grinding materials occur in Holocene levees topping older cut-banks. Locations where an older context cannot be dismissed include several sites fringing the lunette lakes at Chowilla (Coombool Swamp, Lake Limbra) and the cut-banks overlooking the inlet creeks to these lakes (Hancock Creek, Brandy Bottle Waterhole) (see various site descriptions in Wood et al. 2005). The absence of grinding material in the deeper chronology represented in the Pike sites is a telling aspect in this narrative, though could equally reflect upon a differential use of resources and associated processing requirements between the two contexts of valley floor and cliff-line.

The high frequency of grindstones in the Riverland is a curious element in a landscape seemingly awash with high-ranked resources. Ultimately, the application of grinding reflects a resource baseline defined by consistency in food production and a range of supplements rather than a focus on the top-tier staples. The evidence also indicates that grinding activities had predated the introduction of oven mounds, i.e. were a precursor to an ever broadening emphasis placed on plant foods in the subsequent period of heightened ENSO variability. As with oven mounds, the aspects of plant use represented by grinding seem to have complemented rather than supplanted existing subsistence activities. There is also no evidence in the dating to suggest that population increase, in and of itself, was a forcing agent in the introduction of grinding. In this case, however, the introduction of grinding occurs at the start of a phase of relatively higher ^{14}C frequency (^{14}C Phase 9) which included the first directly dated material beyond the inner lakes (a hearth feature in CAPR17_19 on the Ral Ral Creek anabranch). Importantly, the exponential increase in midden ages from c. 1.2 ka, occurs significantly later than the introduction of grinding and mounds. Grinding is invariably credited to a labour investment by Aboriginal women (see for example Sturt 1849:79; Tindale 1939), and its uptake and/or proliferation undoubtedly reflects upon shifts in gendered roles.

The coincidence of lower ^{14}C frequencies and the activation of terrestrial dunes c. 8–5 ka and 4–2 ka is a conspicuous aspect of the Holocene archaeology. ^{14}C ages returned on shell lenses within and under the aeolian cover at Calperum illustrate the broadscale and potentially episodic

(re)mobilisation on ground surfaces. Heightened aridity at these times may have impacted upon river flows, but also, and perhaps more critically, diminished resource opportunities and accessibility in the mallee plains fringing the river corridor. Historical observations describe the mallee plains as the poor cousin to the river, an environment that accommodated seasonal occupation as temporary water became available in ephemeral catches and pans (see for example Gill 1973a:89). These early observations may be misleading, however, as most observers of Aboriginal people were located on the Murray corridor as it formed a transport, trade and settlement corridor for European colonists. In this context, the significance of the mallee plains may have been understated. For example, European stockmen regularly observed Aboriginal people hunting in the area of ephemeral claypans around Hawk's Nest Dam, in the mallee hinterland north of Lake Bonney (Sullivan 1932). The phases of heightened aridity may have limited access to what was, in reality, an essential pool of complementary resources in the mallee. It is also notable that the introduction of grinding c. 5.7 ka and oven mounds c. 3.9 ka (Jones et al. 2022) occurred at, or within, the establishment of these relatively arid phases. A heavier reliance on plant resources in periods of ecological stress may have been a common factor in the application of both of these two distinct economic strategies.

The Holocene evidence presented in this research reflects upon a gradual change in resource use and an ever greater emphasis on plant resources. The trend in ^{14}C ages can best be described as 'staggered', though there is a reluctance to equate this pattern directly to Aboriginal population levels given the heavy reliance of one aspect of an economy (shell collection) in the dating. There is, however, no doubt that the very late Holocene record demonstrates a unique circumstance, and, in this case, there is support for a relatively higher population extracting significantly more resources than during any preceding time. Late Holocene occupation ultimately translated to the ethnohistorical accounts of large Aboriginal populations supported by a broad-based economy and elaborate suite of food collection and production strategies (Eyre 1845; Hawdon 1952; Schell 1914a; Sturt 1833). These strategies extended to the direct manipulation of floodplain hydrology through the operation of weirs and other structures (Beveridge 1883:48; Eyre 1845:253). The maintenance of repeat-use facilities, the persistent use of specific sites such as oven mounds and the highly territorialised system of tenure (Burke et al. 2016; Eyre 1845; Taplin 1879; Tindale 1974) implies a pattern of exceptionally low residential mobility. There are certain to be elements of this that can be drawn from a deeper timeline, though the question remains as to how far back this

image can be extrapolated given the distinctive change observed in the archaeological landscape over the last millennia. It is also worth noting that an early Holocene pluvial appears to have resulted in significant levels of water connectivity in the Calperum floodplain, though this did not translate in the archaeology in a similar fashion as that witnessed over the last millennia. The social and economic responses to improved ecological conditions at either end of the Holocene appear to have been manifestly different.

Burial practices along the River Murray corridor have provided yet another perspective on societal change through the Holocene, and specifically, the role of place maintenance in signalling behaviour (Pardoe 1988a:9; but also see Littleton 2002). Pardoe (1993a:88) noted that ‘virtually no skeletal evidence’ is found on the River Murray prior to 13 ka with the earliest use of dedicated cemeteries becoming widespread by 6 ka and ‘well defined and numerous in the last 4 ka’ (Pardoe 1988a:9, 14, 1988c). A range of ^{14}C ages spanning the Holocene have been returned on skeletal material from the river corridor upstream of the Calperum floodplain between Lindsay Island and Keera Station, while a series of five ^{14}C ages from the Katarapko floodplain included a single age c. 5.4 ka and four ages from c. 1.4–0.3 ka (Figure 7-31). Burial locations were specifically excluded from detailed assessment during this research with only basic descriptions collected for the purpose of ongoing management of these places. As such, a set of very general observations are presented here.

All ^{14}C ages returned on archaeological materials at Calperum are Holocene and there is no instance where an older age could be argued for any of the ancestral remains. As with the broader archaeology, sites drape older landscapes though clearly post-date them. Only two individual burials can be related tentatively to ^{14}C ages in sites CAPR17_19 and CAPR17_09, with age constraints of 450 and 750 cal BP likely in these cases, respectively. Burial sites are distributed widely across the Calperum floodplain though a smaller set of sites containing larger numbers of burials are clustered in three discrete areas; the T2b SBD complex east of the Lake Merreti inlet channel, SBDs in T2c Scroll I and SBDs in T2c Scroll II (see Figure 7-32). Again, in all locations, there is no compelling argument to suggest that burials had occurred coeval with the formation of the original landscapes.

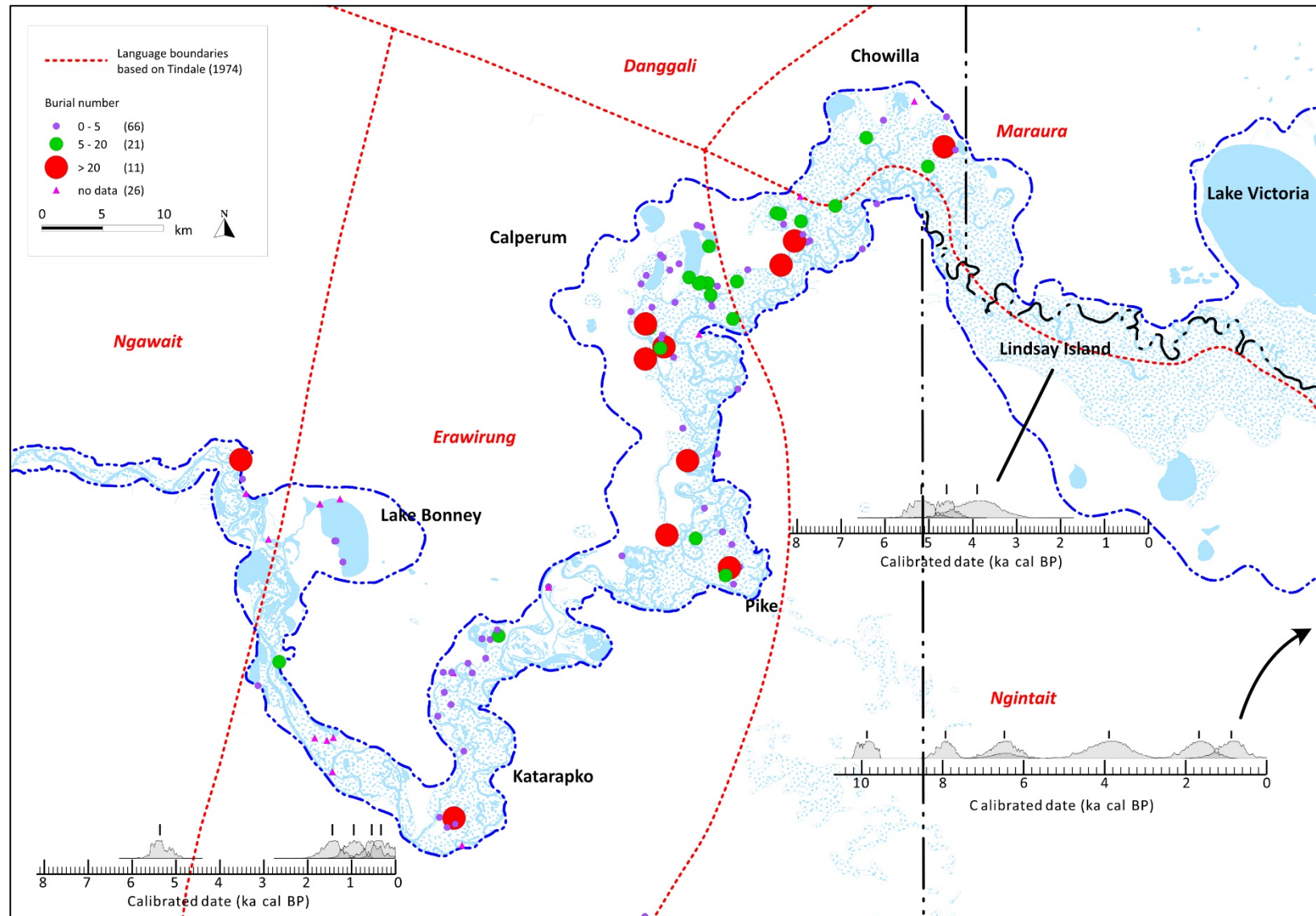


Figure 7-31: Locations and scale of burial sites in the upper Riverland. Also shown are the language boundaries identified by Tindale (1974) and ^{14}C ages returned on skeletal remains from the Katarapko floodplain, the Lindsay Island area (Pardoe 1993a; Polach et al. 1978) and Keera Station (Blackwood and Simpson 1973; Pardoe 1993a). Median ages are shown as vertical lines above the ^{14}C age PDFs.

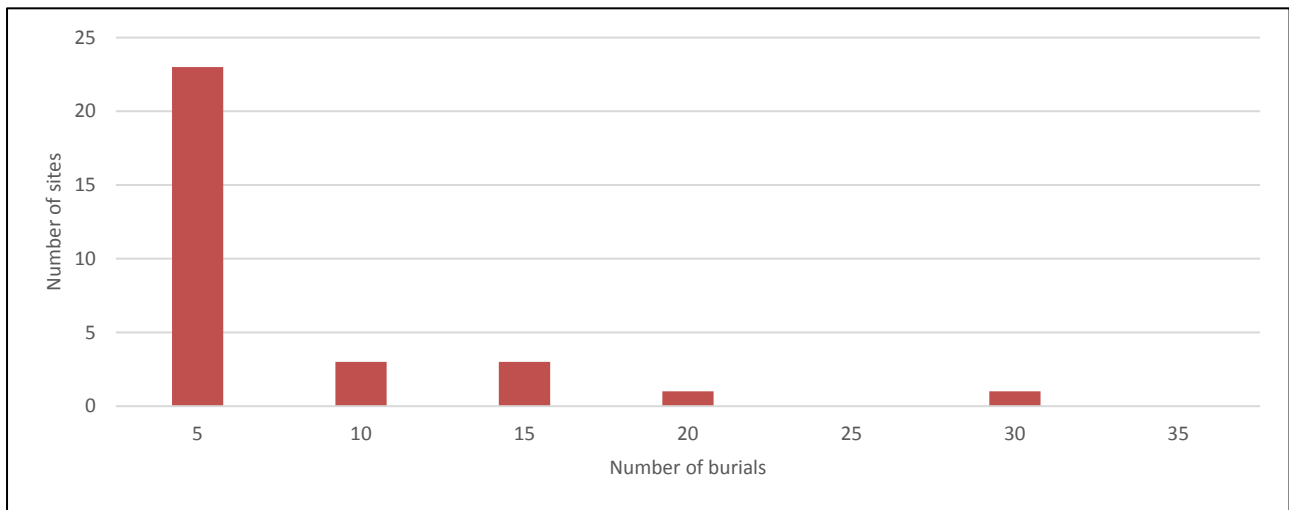


Figure 7-32: Estimated maximum number of individual burials recorded in each burial site on the Calperum floodplain during this research.

When the broader Riverland dataset is considered (Figure 7-31), Calperum is identified as one of several distinct clusters of burial sites; the others being located in the upper Chowilla, lower Chowilla, Pike, upper Katarapko, lower Katarapko, Pyap and Lake Bonney–Overland Corner floodplains. This provides confidence in the representative nature of the Calperum archaeology given that this floodplain appears to have operated as an occupation node rather than a more peripheral or transitory part of the river corridor where a patchier record might have developed.

7.6 Chapter Summary: The relevance of HBE and population models

Any notion that the River Murray had provided a constant, reliable and predictable backdrop to Aboriginal occupation is debunked by the geomorphological evidence presented in this thesis. This environment is only vaguely predictable and is prone to ecological shocks. Major transitions in hydroclimate have seen the habitat mosaics completely redrawn. The process of terracing in the floodplain has been a critical element in this. The initial phases of incision are certain to have reduced water connectivity across the floodplains and impacted all habitats, though most notably the peripheral lakes and wetlands. These habitats are, at times, capable of supporting immense resources. Staggering numbers of waterbirds can occupy the seasonal lagoons, for instance, with more than 23,000 birds observed on Lake Merreti during a single day (Newall et al. 2008:51). Regular inundation of these areas is an important mechanism in the delivery of food to fish populations, with reduced linkages between the river channel and wetlands inevitably leading to population declines. Major shifts in a resource base could be envisaged during phases of

floodplain incision and subsequent infill. These shifts would also be modulated by changes in hydroclimate. In effect, the context of Aboriginal occupation has been a continual adjustment in the habitat mosaics, both within and beyond the valley. And herein lies the issue in applying HBE models to the Riverland record. In a system that is only vaguely predictable and ever-changing, can viable systems ever be retained or improved upon over the long term, or would the continual shifts in ecology demand a continual re-learning of these landscapes, and, at times, the establishment of entirely new strategies? Would the value ranking of individual resources or resource groups remain static in an ever-changing context?

Economic diversity would have undoubtedly been key in this landscape, with a broad diet breadth and suite of food collection techniques providing an essential level of flexibility. The application of grinding technologies in a riverine setting seemingly awash with resources is a clear manifestation of this. The large number of implements described as 'nardoo-stone' is noteworthy, relating grinding effort to a plant species able to persist across various growing conditions. Allen (1998:218) had considered the diverse range of food resources in the early Willandra and Darling records as based in opportunistic encounter, a description that perhaps risks relegating this to something apart from an organised strategy. In reality, this diversity **was** the strategy, and indeed, has been the hallmark of MDB economies since the get go, so much so, that the notion of a Broad Spectrum 'Revolution' or the construction of economic 'niches' is hard to support in this region. A shifting emphasis within a nested assemblage and suited to environmental opportunity, economic capacity and social demands, is perhaps a more accurate appraisal of the evidence.

The distinctive middens that developed in the Riverland from c. 15 ka (¹⁴C Phase 3) illustrate a focus on the main river channel and intensive utilisation of *A. jacksoni* and *N. sublineata* populations. These sites may have served as bases from which the floodplains were accessed, though the paucity of relatable archaeology beyond these locations illustrates an ephemeral use of the broader habitat mosaic. In this instance, and again in ¹⁴C Phase 9 c. 12 ka, shellfish would have fulfilled a specific role suited to periods of familiarisation in a complex habitat mosaic. The collection of shellfish continued throughout the subsequent history of occupation, though served very different roles as the intergenerational flow of knowledge saw strategies homed in the full breadth of habitat; the inner lakes, outer lakes, oxbows, anabranch creeks and mallee fringes. The application of grinding by at least c. 5.7 ka, and the bulk processing of plant foods and materials in

oven mounds c. 3.9 ka (Jones et al. 2022), represent adjustments in resource emphasis. The coincident timing of these economic aspects, lower ^{14}C frequencies, and phases of heightened aridity (manifest in dune activation), is a conspicuous aspect of the Holocene archaeology, a case of necessity driving innovation and adaptation.

This region is known to have supported some of the highest Aboriginal populations at the time of European contact not because of a greater reliability of food and water, but rather, the economic strategies built around the spatial and temporal nuances of these resources. Riverland people were employing strategies grounded in an intimate knowledge of the complex floodplain topography, its influence on inundation extents and frequencies, and the highly nuanced responses in individual floodplains to seasonal flows that were only vaguely predictable. This understanding was employed in the direct manipulation of hydrology and fish populations through the operation of weirs and channels (e.g. Finniss 1966), strategies that, by any measure, fall within the realm of Low Level Food Production (*sensu* Smith 2001). The bulk processing of plant resources from the mid Holocene (e.g. grinding, oven mounds) and the use of mass-capture techniques (e.g. netting) were strategies perhaps less about population than the seasonal and longer term nature of resource distribution, making the most of the boom–bust cycles inherent in this landscape. If the ^{14}C dataset amassed during this research is considered as a valid proxy of occupation intensity/population levels, there is no clear indication that the introduction of grinding activity or the use of oven mounds had been initiated by population pressure. Instead, these formed parts of a continual pattern of adaptation and flexibility. The simple OFT equations fail to adequately accommodate the dynamic nature of these, or similar, landscapes.

There is no doubt that the very late Holocene record illustrates a unique situation. The marked increase in shell-derived ^{14}C ages from 1200 years cal BP (^{14}C Phase 13) occurs abruptly and potentially tracks a similar increase in oven mound use from the close of the late Holocene peak in ENSO-cycling. A relatively higher Aboriginal population extracting significantly more resources than during any other preceding time is a valid interpretation.

The population modelling presented in Williams et al. (2008) and Smith et al. (2008) finds some support in the Riverland evidence, most notably in the long period of ephemeral occupation

through the LGM, lower ^{14}C frequencies over the peak phase of ENSO variability and exponential increase in ages over the last 1200 years (see Figure 7-33). The staggered trend in ^{14}C results might also reflect the boom–bust variability suggested by Smith et al. (2008). Again, some caution must be exercised here given the heavy reliance on shell-derived ages. It would be legitimate to ask whether an apparent reduction in shell collection over the period of heightened ENSO reflects a lower population or simply a shift in emphasis to accommodate a unique set of environmental conditions? Similarly, the proliferation of middens c. 15 ka is certainly spectacular, but is also contained to a very specific habitat, and the notion that the scale of these middens can be related directly to population is tentative at best. A resource and habitat continually targeted by small bands of people over multiple forays into and through this region, is a scenario that could equally applied to these deposits.

As seen in Figure 7-33, a comparison between the Riverland and greater MDB dating also highlights some contradictory and/or divergent trends. The lag to sustained Riverland occupation is clearly evident, with the earliest evidence of intensive utilisation of a riverine resource in this region occurring within ‘population event 5’ proposed by Smith et al. (2008). The clusters in ^{14}C ages in the Riverland tend to extend over short intervals within each of the population events proposed by Smith et al. (2008) or, in several cases, fall outside of these events.

Williams et al. (2008:255) suggested that the modelled population decline across the period of heightened ENSO variability was of such ‘disproportionate amplitude’ that it may have represented a ‘critical human-environment threshold’ and initiated a major restructuring of socio-economic systems. In this sense, ‘threshold’ is assumed to mean the limit to which the resilience of systems was able to maintain their ‘essential function, identify and structure’ (sensu Degroot et al. 2021). Adjustments in habitat use during this period may be identified in the Riverland ^{14}C data with gaps occurring in the anabranch and oxbow records. Similarly, the MDB data within this period witnessed a sharp decline in channel-based ^{14}C ages though lake-based ages were maintained (see Figure 2-3). This provides a pointer to the relative sensitivity of channel habitats to declines in flow transmission and the relative importance of lakes as resource fall-backs during these times.

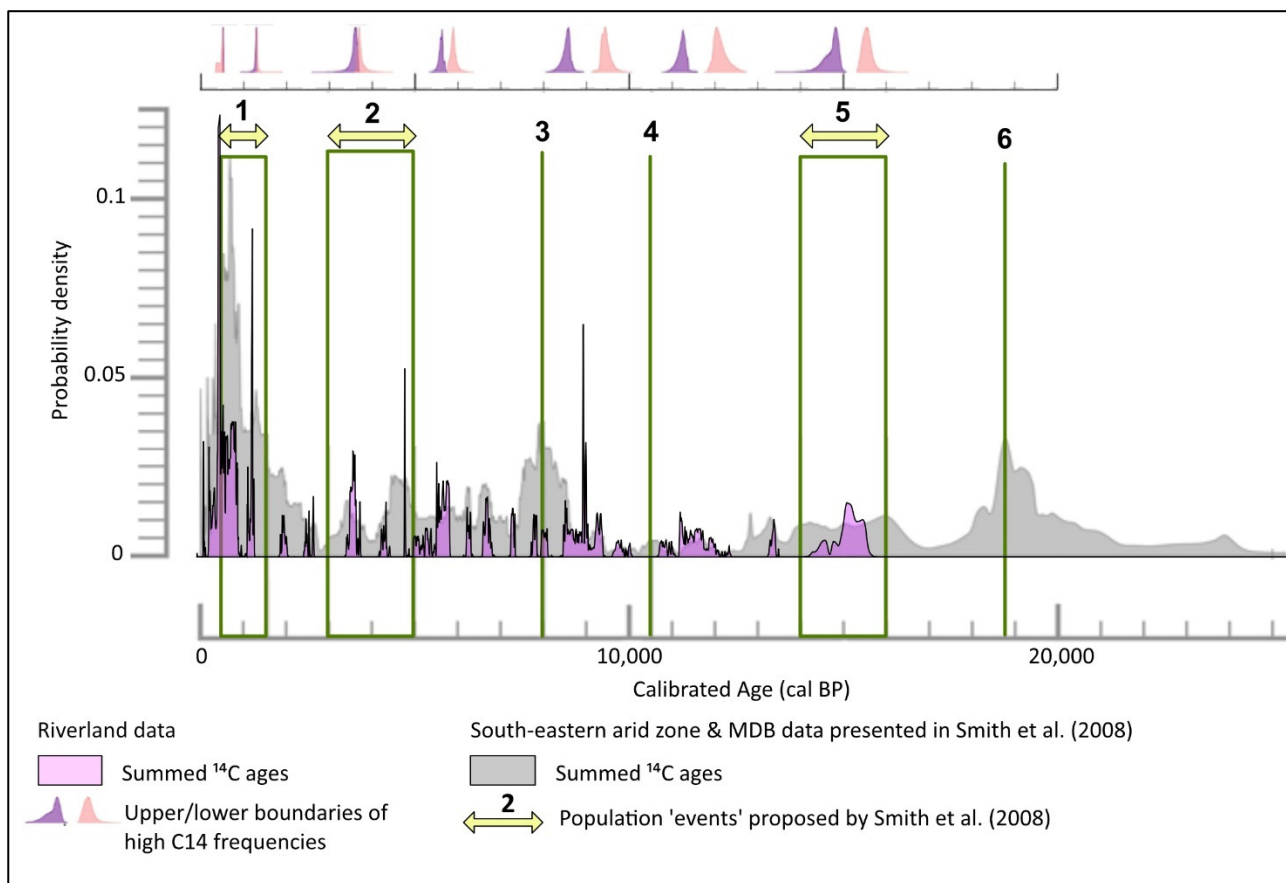


Figure 7-33: A comparison between summed ^{14}C ages derived from archaeological materials in the Riverland and the modelling proposed by Smith et al. (2008) of the MDB data (base graph is adapted from Smith et al. 2008 Figure 3).

As discussed above, there is no doubt that the very late Holocene captured a distinct phase in the history of Aboriginal occupation with the potentially synchronous proliferation of shell middens, mounds and burials. This corresponds with the period in which Williams et al. (2008) had proposed a significant increase in human activity across multiple regions in the continent. Importantly, all aspects of the archaeology recognised in the modern floodplains (grinding material, oven mounds, cemeteries) were in place prior to the ENSO-phase of ecological stress.

The notion that the MDB had acted as a 'persistent node' and potential refugia throughout the LGM desertification (Williams et al. 2013) cannot be directly tested here, though if a node existed, there is no evidence to suggest the Riverland had formed part of it. Instead, the absence of ^{14}C ages across the LGM and the paucity of archaeology in the related landscapes, is interpreted as either a pattern of extreme mobility or one developed at the margins of more persistent occupation. Lake Victoria emerges as a prime candidate as a regional node. The apparent absence of LGM-related archaeology in the Riverland together with the staggered trend in ^{14}C ages,

ultimately reflects upon an increasing sensitivity to inflow conditions in the downstream parts of the basin. A shift from ephemeral to permanent occupation in the Riverland occurred in a staggered fashion concomitant with periods of improved hydroclimate c. 15 ka (^{14}C Phase 3) and c. 12 ka (^{14}C Phase 5). Importantly, the extensive archaeology found along the riverine corridor in the Lower Murray (i.e. downstream of the Riverland) is almost exclusively Holocene and emerged after the peak of an early Holocene pluvial, as identified in the re-establishment of freshwater conditions in Rotten Lake³⁸. Personal observations of Pike-like middens at Morgan may, however, indicate that the terminal Pleistocene deposits may be more extensive than the current dating evidence suggests.

In my experience, the RMMAC community see themselves as having been shaped fundamentally by their river—culture, heritage, environment are indivisible elements of their identity. Perhaps then, it is time to move past the ideological deliberations around social and environmental determinism and embrace a position of ‘soft-determinism’, wherein the physical environment is viewed as ‘a delimiter of possible action rather than a prescriptive agency’ (Coombes and Barber 2005:303); opportunity rather than constraint. The increasingly complex habitat mosaic and an overlay of shifting hydroclimate provide the context to Aboriginal occupation in the Riverland. In effect, the gradual development of the Riverland floodplains would have seen increased heterogeneity and accessibility to a broader scope of potential food resources distributed on a seasonal basis. Earlier strategies embedded in mobility were replaced by a more sedentary pattern around the terminal Pleistocene as the landscape shifted from a scenario of resource nodes in a relatively simple landscape to mosaics in a more complex and complicated valley topography. A continual shift in resource emphasis, the use of sleeper technologies and a heavy reliance on tertiary taxa have provided an essential template to accommodate variability in this landscape. It also provided the foundations for the unique Aboriginal societal structures recognised in the ethnohistories along the Central Murray River corridor (Burke et al. 2016) where individual floodplains emerged as the defining unit of what can, in any sense of the word, be described as sedentary occupation.

³⁸ Some caution may be required when assessing the Lower Murray ^{14}C ages as very few sites beyond the valley confines appear to have been dated. The dataset, whilst extensive, may therefore include some bias in the sampling.

CHAPTER EIGHT: CONCLUSIONS

8.1 Revisiting the research questions

This research is founded in the premise that riverine processes can aid in the interpretation of archaeological records rather than be seen simply as taphonomic agents. To this end, this dissertation examines a record of Aboriginal occupation and lifeways against a backdrop of landscape development in the Calperum and Pike floodplains, two of a series of anabranch floodplains located within the River Murray corridor in the upper Riverland region of SA. Landscape settings capable of capturing evidence of Aboriginal occupation and lifeways over a period extending from at least c. 43 ka are preserved in these floodplains.

Major themes and conceptual frameworks in both MDB geomorphology and archaeology are explored in the introductory chapters. The methods and strategies employed in this research have aimed to contribute to three interrelated themes: A) the apparent lag of 20,000 years between early MDB occupation and intensive settlement along the River Murray corridor; B) the timing and nature of early Riverland occupation and the potential in this to inform an understanding of the colonisation history of the MDB; and C) supposed Holocene change in Aboriginal socio-economic systems. All three aspects are canvassed through an appreciation of the processes that form and transform riverscapes, and are framed around the following questions:

- How has the riverine corridor in the Riverland region of SA evolved over the period from the initial Aboriginal peopling and subsequent occupation?
- How has change in the riverine environment been accommodated in Aboriginal socio-economic pathways?
- Can the explanatory models applied within and beyond the Australian context adequately address these pathways?
- How can the local pathways inform a broader regional narrative?

The research methodology is described in Chapter 5 and has centred around the development of a geomorphological model from spatial data (topographic mapping, DEMs, vegetation mapping) and

field-based studies. This model is tied to an absolute timeline through the use of OSL and ^{14}C dating, and in this respect, represents the first major effort to link evidence of hydrological stages recognised in the MDB to a reliable geochronology in this region. The geomorphological model informed an archaeological survey and dating strategy which aimed to temporally relate the archaeology to the landscapes it occupies. The conclusions reached in this research are based on a complementary use of archaeological survey, excavation, surface sampling, analysis of site content and an intensive use of ^{14}C sampling. These research methods were applied to a series of archaeological sites in the Calperum floodplain and along the cliff-line overlooking the Pike floodplain and provide a template applicable to the interpretation of other riverscapes.

The following synopsis canvasses the inter-related themes and questions addressed in this thesis.

Hydroclimatic stages and riverine responses

There is general agreement in the timing of major responses in MDB riverscapes to hydroclimate transitions over the last glacial-interglacial cycle. As summarised in Chapter 3.4 and Table 3-4, five broadly defined hydrological stages can be identified. Stages I–III were defined by large, powerful bedload channels. The presence of SBDs across these phases is a characteristic of a regime of high volume, though highly seasonal flooding. Less reliable inflows during Phase III led to salinisation in the lowland floodplains and lacustrine systems of the MDB (see Figure 7-28). Lower peak-volume, though lengthier flooding cycles during the deglacial period (Stage IV) saw a dramatic reduction in channel widths and meander lengths, and the cessation of SBD development. A riverine ecology more akin to the modern systems was established at this time. The floodplains took on their current forms across Stage V and under the heightened influence of ENSO across the late Holocene.

The results of the geomorphological modelling and dating conducted during this research are presented in Chapters 6.2 and are generally consistent with evidence from the MDB. Some subtle differences are, however, identified. Evidence of hydrological stress leading into the LGM, for instance, appears to have been amplified in the Riverland. This led to the intense salinisation of lacustrine habitats around the outer edge of the Calperum floodplain. Salt also appears to have impacted the broader Riverland floodplains at this time, representing an ongoing landscape legacy

that continues to affect the modern floodplains. At the height of LGM aridity, the river flowed through a sandy desert, denuded of woodland and with vast mobilised dune-fields transgressing into the river valley.

A decoupling from the LGM appears to have occurred in a staggered fashion over the period 18–12 ka. An OSL age of 16.5–15.5 ka (Ad19146) returned on the penultimate SBD in the Calperum floodplain (in terrace T2c) marks a change to a less pronounced seasonality in through-flows. At c. 13–12 ka, the broad, bedload channels that had defined the floodplains from c. 42 ka gave way to a pattern of more sinuous, narrower channels in terrace T3. A floodplain more reminiscent of the modern system emerged under significantly improved water connectivity that culminated in the re-establishment of ephemeral freshwater conditions from c. 11 ka in Rotten Lake, one of the outer salina at Calperum. Freshwater mussel populations appear to have established in this lake by at least 7.8 ka (Chapter 6.2.3.1), representing a staggering reversal in inundation extents in this floodplain. This is consistent with evidence of an early Holocene pluvial in south-eastern Australia. WfM dunes that had transgressed to the inner lakes at Calperum were truncated and sculpted by more regular lake filling sometime prior to c. 9.2 ka by which time freshwater mussel (*V. ambiguus*) was being collected *en masse* by Aboriginal people from the inner lakes and redeposited into recognisable middens.

Local responses to long-term shifts in hydroclimate manifest in episodes of valley incision and infill (cut-and-fill), building to a sequence of four inset terraces in the Riverland floodplains. As discussed in Chapter 6.2, all other landforms can be related to this basic architecture. The process of terracing has generated increasing heterogeneity in the floodplains and provided the foundation for the broad suite of seasonally distributed resources known to have been utilised by Aboriginal people in this region at the time of contact. The extent, duration and frequency of flooding are all critical factors in the short and long-term distribution of these resources (Chapter 4.4.2) and are likely to have accommodated significant variability through the modulating effects of various climate systems. Regional palaeoclimate proxies describe multi-decadal drought events over the last 1500 years, for instance (Abram et al. 2020:16; Barr et al. 2014:129; Ho et al. 2015:2). Floodplain heterogeneity, seasonal distribution and the long-term variability and viability of resources, were accommodated in diversified Aboriginal economic strategies. The use of low-yield

tertiary taxa remained a critical element of these strategies.

Assessments and implications of ^{14}C distributions

The use of timeseries analyses in interpreting Aboriginal societal pathways have come to the fore in recent years (see for example Smith et al. 2008; Williams 2012, 2013; Williams et al. 2013; Williams et al. 2015b; Williams et al. 2015c). These analyses are invariably based on data pooled from vast geographic and temporal spaces. The implications of the MDB ^{14}C dataset is explored in Chapter 2. This thesis is similarly based on an interpretation of ^{14}C ages, though the methods and strategies applied here have sought to value-add this data by scrutinising the relationships between landscapes and the ^{14}C and other archaeological evidence. In addressing the research questions, the approach has been to recognise the context and implications of individual ^{14}C ages and extrapolate this evidence through scales of archaeological site, landscape, floodplain and region. The combined ^{14}C results are assessed as a series of phases defined by a clustering in age estimates and transitions between these clusters (see Figure 6-92, Figure 6-93 and Table 6-23). The ^{14}C trends, and other data, are related to the themes and questions in this research are canvassed under the following headings.

The nature and timing of early Riverland occupation

On the basis of the documented archaeology, the earliest phase of Aboriginal occupation in the MDB occurred sometime between 50–45 ka (Bowler et al. 2003; Cupper and Duncan 2006). Subsequent occupation appears to have been contained, for the most part, to the networks of large capacity lakes through the central western MDB; i.e. the Willandra and Menindee Lakes, with all else lying at the margins of these persistent occupation nodes until c. 24 ka. At this time, more permanent occupation in the area of Lake Victoria and the upper portion of the central River Murray corridor appears to have been established. This coincides with a brief pluvial that is recognised in the MDB as a short digression from a longer aridification trend leading to the LGM (Fitzsimmons et al. 2015; Lomax et al. 2011).

Early evidence of occupation in the Riverland is identified in a hearth feature exposed along the high cliff-line bounding the Pike floodplain. ^{14}C and OSL sampling in this feature provide support

for either of two scenarios; an age of c. 43 ka or 29 ka (see Chapter 7.5.6). Two lines of circumstantial evidence tend to favour the younger result. First, a discrete lens of shell midden exposed in the cliff several kilometres from the hearth returned two ages that essentially overlap with the 29 ka age. Second, the earliest evidence of occupation in the broader central River Murray corridor (at Lake Victoria) also occurs at c. 29 ka (Abdulla et al. 2019), potentially linking the two Pike features to a single, short-lived episode of occupation registered at multiple locations in this region. The earlier age of c. 43 ka cannot be ruled out, however, and is supported by its context and an interpretation of an OSL age obtained in the feature. This sample was also considered the more reliable of the two analysed by the Waikato laboratories (Fiona Petchey pers. comm. 2021). There is a potential that the earliest, exploratory phase of Aboriginal occupation in the MDB had indeed projected into the Riverland.

The implications of either scenario are significant in terms of understanding the process of Aboriginal colonisation as it has played out in the MDB. As importantly, either of the c. 43 ka or c. 29 ka results at Pike suggest that the archaeology preserved along this cliff-line should, with all things being equal, canvass a representative record of Aboriginal occupation across this extended timeline and that the distribution of ^{14}C ages would reflect a real-world scenario. The lack of archaeology attributable to the LGM landscapes surveyed at Calperum adds further confidence in the dating results, highlighting the utility in applying geomorphological interpretation in combination with the two complementary datasets of survey and dating. The paucity of evidence cannot be dismissed as simply an artefact of taphonomic loss. Rather, the evidence presented in this thesis supports the notion that a significant lag had occurred between initial Aboriginal occupation in the MDB and persistent occupation in the River Murray corridor, or at least, a style of occupation able to be detected in the extant archaeology.

A consistent spread of ^{14}C ages between the Darling-Murray River junction and Lake Victoria across the LGM (see Figure 3-7) highlights this section of the central River Murray corridor as a potential occupation node during a period of extreme ecological stress along the riverine corridors and hinterland. Lake Victoria represents the last, large capacity lake in the MDB system, and would have benefited from the regime of high volume, though highly seasonal flows suggested in the character of the LGM terrace (T2c). The lag to sustained occupation in the Riverland reflects upon the increasing sensitivity in riverine ecology to inconsistent water

transmission and reduced water security beyond Lake Victoria. Aboriginal people may have employed strategies to accommodate this, perhaps through greater mobility, but the Riverland evidence indicates that any such strategy was manifestly different to that employed from c. 15 ka.

The 15 ka transformation

A series of c. 15 ka ^{14}C ages obtained from extensive middens of *A. jacksoni* and *N. sublineata* along the Pike cliff-line highlights a transformative period in Aboriginal occupation in the Riverland (see Figure 7-4). The large-scale development of middens represents a shift in resource use, though this appears to have been centred specifically on the main River Murray channel. No archaeology can be confidently assigned to equivalent age settings in the Calperum floodplain. The first pulse of these distinctive middens also developed over a relatively short period of time of between 379–1042 years based on the calibrated age ranges, and appears to have essentially switched off during a phase of renewed aridity c. 14–12 ka (Lomax et al. 2011).

The Pike results are consistent with a marked shift in the nature of occupation across the MDB toward the end of a brief, 3000-year long phase of ameliorated climate from 18 ka. As at Pike, this shift manifest in the form of extensive middens of the freshwater mussel *A. jacksoni* and the gastropod *N. sublineata*. These deposits are found along the valley cliff-lines over hundreds of river kilometres through the central River Murray corridor. The staggered development of these middens in the Riverland might be interpreted in one of two ways. The first places the middens within phases of migration wherein the heavy exploitation of a low-yield, though readily available taxa (freshwater shellfish), supported a period of familiarisation in a complex riverscape. Aspects of the Riverland floodplains would have been replicated in all riverine settings in the MDB, with subsistence strategies transferable between each through limited modification. However, long periods of knowledge investment would have been required to optimise strategies in these complex habitat mosaics. The second scenario is similar to that proposed by Clark and Hope (1985:83), whereby an ecology more favoured to the growth of freshwater mussel made them relatively more accessible and/or abundant than other foodstuffs, supporting a period of resource specialisation. A link

to Aboriginal population increase is not necessarily implied in either scenario. Instead, the middens may have developed as existing cultural, social and economic strategies founded in high residential mobility shifted, albeit temporarily, to the intensive exploitation of a specific resource (shellfish colonies) and habitat zone (channel) following a marked change in riverine ecology.

It is also posited here that the early pulse-like nature of occupation was a direct consequence of the hyper-sensitivity of the Riverland floodplains to the climatic shifts emerging out of the LGM. The Millennium Drought highlighted salt as a critical influence on riverine ecology in the Riverland and the importance of consistent, regular and lengthy flood cycles in mitigating the effects of it. The proliferation of middens c. 15 ka also occurred following the last glacial advance recorded in the Australian Alps c. 17 ka (Barrows et al. 2001) (Figure 7-28), illustrating a critical relationship between conditions in the Riverland and water transmission from the southern parts of the alpine headwater catchment.

A consolidation recognised across the Holocene

As outlined in Chapter 7.6.3, this research identifies several aspects of change in Aboriginal interactions with the Riverland floodplains across the Holocene. Grinding was introduced by at least c. 5.7 ka (see Chapter 6.3.8) and based on the prevalence and diverse morphologies of grindstones, became an embedded part of the subsistence economy. Oven mounds were in use at Calperum from at least c. 3.9 ka (Jones et al. 2022), and based on a compelling corpus of ethnohistorical observations, can be confidently attributed to the bulk processing of *Typha* spp. for food and fibre. The initial introduction of both grinding and oven mounds does not appear to have followed periods of enhanced site development, based on the ¹⁴C dataset. In both cases, there is no compelling evidence to suggest that an expanded repertoire of economic strategies had been driven by significant population increases, a key element in the intensification narrative as applied in the MDB. Rather, these strategies appear to represent a shifting emphasis toward plant resources, or changes in the processing of plant resources, from the mid Holocene. This change may, however, have supported subsequent increases in Aboriginal population.

The last millennia

The archaeological landscape was manifestly transformed from c. 1.2 ka through an abrupt increase in the development of middens across all habitat zones at Calperum (see Figure 7-4) and an apparent increase in the use of oven mounds (Jones et al. 2022). Four of the five ^{14}C burial ages from the Katarapko floodplain also fall in the period c. 1.4–0.3 ka (Figure 7-31). In combination, this compelling evidence points to an increase in total economic capacity relatable to a relatively larger Aboriginal population. A number of preconditions were fundamental in this:

- The move toward greater heterogeneity in the floodplain mosaic had provided the foundation for a diverse suite of seasonally distributed resources.
- Technologies applied from the mid Holocene had included aspects geared toward the mass-processing of plant foods (grinding, oven mounds) and mass-capture of waterbirds, fish and other fauna (implied in the fibre production associated with mound use). Initially applied to exploit boom-bust cycles in resource availability from the mid Holocene and across the subsequent phase of peak ENSO variability, the context and productive capacity of these technologies changed with an improved hydrology and water connectivity in the habitat mosaic.
- A long period of knowledge investment had been fully-articulated in a diverse array of Aboriginal subsistence strategies homed in the floodplains rather than imported to them.
- The riverine ecology rebounded from c. 2 ka with reduced ENSO-forced variability. However, it would be wrong to equate this with stability. Instead, the very late Holocene is defined by multi-decadal drought events (Abram et al. 2020:16; Barr et al. 2014:129; Ho et al. 2015:2). The diversified economy, and a heavy reliance on plant foods, provided the essential template to accommodate this variability.
- Ecological conditions in the mallee plains, an essential complement to the riverine economy, stabilised following the peak phase of ENSO variability.

In effect, these landscapes were primed, Aboriginal technologies, economic strategies and social systems were in place to extract high yields and accommodate variability, and a permanent occupation had long been consolidated, building upon knowledge investments in this complex riverscape. With a reduction in ENSO variability, improved economic

opportunities were acted upon by Aboriginal peoples through the diverse array of food collection and production strategies described in the ethnohistorical observations. These strategies ultimately supported some of the largest Aboriginal populations and the sedentary lifeways observed at the time of European contact.

Support for ^{14}C timeseries interpretations

This research offers general support to the interpretations of regional ^{14}C trends proposed by Williams et al. (2015b), and others. However, in this case, an appreciation of context and a complementary application of exhaustive survey coverage (approximately 12.2 km² of the Calperum floodplain and 4 linear km of Pike floodplain cliff-line) and intensive ^{14}C sampling (n=89 samples), has added a level of confidence in the ^{14}C trends. It has also highlighted nuances that risk being overlooked in pan-regional datasets. Indeed, an examination of the Riverland and the broader regional datasets demands a new appreciation of the intra- and inter-regional complexities and divergent records of Aboriginal lifeways within the basin. The evidence amassed during this research highlights yet another unique pathway that can be related, at least in part, to the cascading nature of the MDB system and the sensitivities in riverine ecology to water transmission. The consequences on flow variability in the Riverland were highlighted during the Millennium Drought and shed some light on the challenges that Aboriginal socio-economic strategies employed across the lower parts of the MDB had needed to accommodate.

The role of population as instigator of change is also hard to support here. Instead, a shifting emphasis placed on particular resources and strategies to accommodate circumstance seems the simplest overlay to the evidence. Initial phases of exploration and familiarisation may have been supported by a heavy reliance on a specific habitat and resource group, but the role of these resources morphed as the intricacies of this landscape became more fully understood and capitalised on. Again, flexible solutions were a necessity in this landscape—resilience ultimately expressed through diversity. As Rosen and Rivera-Collazo (2012:3640) argued, social resilience is ultimately supported by systems of broad economic strategy built upon long-term social memory and accumulated experience. The application of grinding technologies in a landscape seemingly flush with resources is the ultimate expression of this.

8.2 Further directions in research

The following aspects might be considered in future Riverland research.

Isotopic analysis

There is a wide body of literature on the use of the isotopic composition in shell, fish and other organic remains in assessing past environmental conditions. Mn/Sr (Tynan et al. 2005) ratios in freshwater mussel and Sr/Ca, Ba/Ca and $\delta^{18}\text{O}$ ratios in fish otoliths (Long et al. 2014) for instance, have been used to identify salinity levels at the Loveday floodplain and at Lake Mungo, respectively. As described in this thesis, salinity is a key determinant in the reproductive success of various riverine/lacustrine species, including food staples identified in the Riverland archaeology, notably freshwater mussel, fish and *Typha* spp.. The Riverland middens should be seen as an invaluable record of past ecological conditions, describing an unregulated waterway during various hydrological phases. Importantly, the middens might elucidate the variability in riverine ecology and the pace at which habitats rebound from periods of environmental stress. As I have argued in this thesis, change is the context of Riverland occupation, though the pace and scale of this remain poorly resolved. The complication in isotopic studies is, however, the sheer diversity and natural variation in salinity conditions related to regular seasonal trends, the connectivity of various habitats over these trends, longer term changes in connectivity and the influence of saline aquifers. There is no simple correlation between salinity and climate, and the highly nuanced factors would need to be considered in any assessment.

Landscape chronology

The dating strategy (OSL and ^{14}C) has focused on key developmental phases in the floodplain; e.g. the age of lunette phases and the transitions between channel systems. It should be acknowledged, however, that this program has been constrained significantly by resourcing, to such a degree that the outline presented here demands further scrutiny and validation. A more resolved chronology obviously exists and given the scope of discussion developed around this initial exercise, the local evidence provides reason to pursue this. Palaeoenvironmental reconstructions in the MDB have understandably focused on lunettes given the remarkable archives these landforms embody, and the option to further investigate the Riverland lunettes should be paramount. The highly resolved stratigraphy seen in the Lake Rotten Phase II lunette

should be highlighted as a candidate for further analyses. This and other lunettes, provide a significant potential in further integrating palaeoenvironmental reconstructions across the MDB. The research conducted by Fitzsimmons et al. (2014) provides a scope of methodological and theoretical approach that could be applied in building a regionally standardised and relatable dataset.

Pollen and Diatom Analyses

The interpretation of landscape change presented in this research is based, for the most part, in the physical changes in landscape. The interpretation would clearly benefit through an integration of additional palaeoenvironmental datasets. Pollen provides one obvious option. The augering conducted in Clover Lake and adjacent to Hunchee Creek was intended to produce a pollen history that could be tied to ^{14}C data. This would supplement the Holocene record presented in Gell et al. (2005) and provide a gross comparison with a deeper LGM record. Bulk sediment samples were recovered and sent to an external laboratory for this purpose. Despite initial treatment of the samples, complications arising from the forced shut-downs of the laboratory through COVID-19, have meant that these samples were not able to be fully analysed in the timeframe of this research. It is the intention to publish these results at a later stage in some form.

Diatom analyses would provide further context to the archaeological record. However, as with isotopic studies, it will be crucial that geomorphological settings are accommodated in any analysis. As argued in this thesis, changes in water connectivity in the floodplains arises as much from reconfigurations in the physical landscape as much as inflow conditions. Anthropogenic influences are also likely to have been critical in water quality and the vegetation composition of aquatic habitats, though this consideration is lacking in the diatom/pollen studies reviewed in this research. The effect of large-scale harvesting, curation and burn-offs of *Typha* spp. in the wetlands must surely have had some influence on water quality that would need to be considered. A charcoal history may also provide further insights into land management strategies.

Regional age distributions

The Riverland evidence casts a new light on the almost exclusively Holocene record documented

in the Lower Murray (Hale and Tindale 1930; Mulvaney 1960:54; Mulvaney et al. 1964; Smith 1978, 1982; Wilson et al. 2012; Wilson 2017). The representativeness, or otherwise, of that record demands further scrutiny on the basis of the current research. Establishing a reliable occupation chronology in the space between the Riverland and Lower Murray will also be critical in developing a pan-regional discussion.

Canoes

Historical observations suggest that canoes manufactured from river red gum (*E. camaldulensis*) bark had played a significant role in transport, access to and across inundated floodplains, and subsistence enterprise in the Riverland (see for example Archer Russell 1920). However, evidence provided in plant genetics suggests that the LGM saw a significant reduction of red gum woodlands (Butcher et al. 2009:204, 206; Reid et al. 2016:50). This would have limited access to this material resource. The utility of canoes on fast-flowing T2 rivers and in regularly dry (and accessible) floodplains might also be questioned. The use of canoes, and its ramifications in terms of resource strategies, may therefore, provide yet another component in changing economic systems and habitat use across the Holocene, potentially expanding the seasonal accessibility of floodplain resources. This represents an interesting line for further enquiry—what habitats, resources and subsistence practices specifically required the use of canoes and what are the implications for a pre-watercraft economy? Beveridge (1883:36), for instance, describes masses of bird eggs collected by canoe. It is also noteworthy that a bark canoe features in the creation narrative of *Ngurunderi*, providing a potential link between this narrative and the establishment of river red gum habitat in the river corridor.

8.3 A summation: Transformations in a Peopled Riverscape

This research paints a picture of a riverscape defined by dynamism and complexity. The long-term interactions of Aboriginal peoples with this riverscape are equally complex, accommodating of change and built upon knowledge investments that would ultimately support some of the largest populations in Australia prior to European contact. The presence of trade items such as greenstone axes and grinding bases provide some insight into the scale of social networks that intersected this region (Kimber 1969; Luebbers and Ellender 1991).

Indeed, just as all major tributaries of the Murray River have merged upstream of the Riverland, it is possible that this region was a conduit for intellectual and material capital, capturing and morphing ideas and cultural practices from across the basin. The archaeological signature of the Riverland appears to be an amalgam of the broader MDB with oven mounds, large-scale cemeteries and the widespread use of diverse grinding assemblages representing elements seen in disparate parts of the basin.

This research has identified a potential in the Riverland to build a greater appreciation of the varied nature of Aboriginal socio-economic pathways across the MDB. An important outcome of this research are the insights it provides into the processes of exploration and the initial peopling of the MDB. It is possible, based on the archaeology preserved at Pike, that the earliest Aboriginal peopling of the MDB had projected into the Riverland by c. 43 ka. For a long period of time leading to and straddling the LGM, however, this region appears to have accommodated pulses of occupation extending downstream from more persistent nodes, or perhaps supported a distinct mode of occupation that is simply indiscernible in the archaeological landscape. The abrupt development of extensive shell middens from c. 15 ka marks the earliest intensive exploitation of a riverine resource in this region, a focus on a low-yield though easily obtained resource that had potentially supported an early phase of familiarisation. Ongoing knowledge investments built toward a broader use of the complex habitat mosaics across the early Holocene with subsequent adjustments and refinements accommodating variability, arguably the defining aspect of this riverscape.

Ultimately, the evidence presented in this thesis dispels any notion of long-term continuity or stasis in Aboriginal society in the deep past in this region, and instead, points to continual and sometimes abrupt responses and adjustments, and a unique set of solutions to an ever-changing context. There is perhaps no better illustration of this capacity to innovate, adapt and problem-solve, than the contact history of the Riverland. Within a short period following contact c. 1830, Aboriginal people had acquired an entirely new language and skillset, and had through necessity identified and exploited economic niches, not only supporting the European population through traditional food gathering, but forming an integral part of the regional economy and providing an essential workforce in a range of industries from river navigation to pastoralism (Roberts et al. 2021a; Roberts et al. 2017).

The parallels in the evidence offered in this thesis and the Nooreela narrative are captivating, and worth reiterating here—that a profound change in the physical nature of the river occurred, that Aboriginal settlement had originated in the north (upstream) with Lake Victoria being the origin, and that change had provided the basis of new economic opportunities and systems of governance in this region. The specific mention of Lake Victoria is particularly noteworthy. The Riverland might just have been at the periphery of occupation, centred at or above this lake, before Nooreela's benevolent intervention.

Today, the river is faced with a predicament brought about by years of neglect and water mismanagement. For most, it is difficult to get past a sense of helplessness when confronted with the inertia of policy makers. For the RMMAC community, this extends to a profound sense of loss. In solidarity with a community that have been so generous in sharing their knowledge, wisdom and experiences, and permitted me the freedom to explore their deep past, this thesis concludes with a simple plea to those who might listen—please, just add water.

REFERENCES

- Abdulla, K., Barkindji Maraura Elders Council and E. Dillon 2019 Collaborative Research and New Dates at Lake Victoria, NSW. Paper presented to the Australian Archaeological Association Annual Conference 2019, Gold Coast, 10-13 December, 2019.
- Abram, N.J., J.A. Hargreaves, N.M. Wright, K. Thirumalai, C.C. Ummenhofer and M.E. England 2020 Palaeoclimate perspectives on the Indian Ocean Dipole. *Quaternary Science Reviews* 237(1):106–302.
- Alexander, P., D.L. Nielson and D. Nias 2008 Response of wetland communities to inundation within floodplain landscapes. *Ecological Management and Restoration* 9:187–195.
- Allan, R.J. 1988 El Nino Southern Oscillation influences in the Australasian region. *Progress in Physical Geography* 12(3):313–348.
- Allen, H.R. 1972 Where the crow flies backwards. Unpublished PhD thesis, Australian National University, Canberra.
- Allen, H.R. 1974 The Bagundji of the Darling River: cereal gatherers in an uncertain environment. *World Archaeology* 5(3):309–322.
- Allen, H.R. 1998 Reinterpreting the 1969-1972 Willandra Lakes archaeological surveys. *Archaeology in Oceania* 33(3):207–220.
- Allen, H.R. 2015 The past in the present? Archaeological narratives and Aboriginal history. In A. MacGrath and A.A. Jebb (eds), *Long History, Deep time: Deepening histories of place*, pp.171–202. Canberra: ANU Press and Aboriginal History Inc.
- Allen, H.R. and S. Holdaway 2009 The archaeology of Mungo and the Willandra Lakes: looking back, looking forward. *Archaeology in Oceania* 44(2):96–106.
- Allen, H.R., S. Holdaway, P. Fanning and J. Littleton 2008 Footprints in the Sand: appraising the archaeology of the Willandra Lakes, Western New South Wales, Australia. *Antiquity* 82:11–24.

- Andison, L.M. 1953 *Berri: Hub of the upper Murray. a brief history of the Berri Irrigation Area with 31 photographs*. Berri, South Australia: South Australian Country Women's Association.
- Andrews, P. 1995 Experiments in Taphonomy. *Journal of Archaeological Science* 22:147–153.
- Angas, G.F. 1847 *Savage Life and Scenes in Australia and New Zealand*. London: Smith, Elder and Company.
- Angel, H. 1949 'Aboriginal bones found near Hughe's Bend', *Murray Pioneer* 7 July 1949 p.1.
- Anon 1887 'The Water Commission upon the Murray River', *South Australian Register* Monday 30 May 1887 p.6.
- Anon 1904 'The tomb of a king', *Critic* Wednesday 9 Novemer 1904 p.10.
- Anon 1919 'The early history of the Cobdogla District', *Murray Pioneer and Australian River Record* 25 April 1919 p.7.
- Anon 1921a 'Blacks on the Murray', *Chronicle* Saturday 13 August 1921 p.38.
- Anon 1921b 'A search for Stone', *Advertiser* Thursday 28 July 1928 p.6.
- Anon 1942 'Fine native mortar discovered', *Murray Pioneer and Australian River Record* Thursday 8 January 1942 p.6.
- Anthony, D. 1990 Migration in Archaeology: The Baby and the Bathwater *American Anthropologist* 92(4):895–914.
- Archer Russell, G.E. 1920 'Gumland and River: The Old Inhabitants', *Journal* 27 November 1920 p.6.
- Archer Russell, G.E. 1921a 'Among the campsites of the Ral Rals', *Journal* Saturday 12 November 1921 p.6.
- Archer Russell, G.E. 1921b 'Attune with Nature', *Journal* Saturday 5 November 1921 p.6.
- Archer Russell, G.E. 1921c 'Murray Tramps: A burial ground of the Ral Rals', *Journal* Saturday 19 November 1921 p.6.

- Archer Russell, G.E. 1923 'Relic Hunting on the Ral Ral', *Register* Wednesday 24 January 1923 p.10.
- Archer Russell, G.E. 1924 'Relics of Native Work: Specimen Hunting on the Murray, Flints and Stone Implements', *Journal* Saturday 28 June 1924 p.4.
- Arnold, L.J. and R.G. Roberts 2009 Stochastic modelling of multi-grain equivalent dose (D_e) distributions: Implications for OSL dating of sediment mixtures. *Quaternary geochronology* 4(3):204–230.
- Arnold, L.J. and R.G. Roberts 2011 Paper I – Optically stimulated luminescence (OSL) dating of perennially frozen deposits in north-central Siberia: OSL characteristics of quartz grains and methodological considerations regarding their suitability for dating. *Boreas* 40:389–416.
- Asmussen, B. and P. McInnes 2013 Assessing the impact of mid-to-late Holocene ENSO-driven climate change on toxic *Macrozamia* seed use: a 5000 year record from eastern Australia. *Journal of Archaeological Science* 40:471–480.
- Aspinall, A.C., C. Gaffney and A. Schmidt 2009 *Magnetometry for Archaeologists*. Lanham, USA: AltaMira Press.
- Atici, L. 2009 Specialisation & diversification: animal exploitation strategies in the terminal Pleistocene, Mediterranean Turkey. *Before Farming* 2009(3):1–17.
- Attenbrow, V. and P. Hiscock 2015 Dates and demography: are radiometric dates a robust proxy for long-term prehistoric demographic change? *Archaeology in Oceania* 50:30–36.
- Australian Bureau of Agriculture and Resource Economics and Sciences (ABARES) 2011 Pike Floodplain salinity and connectivity investigation. Unpublished report prepared for Murray-Darling Basin Policy and Reform, Government of South Australia, Department of Water.
- Australian Bureau of Meteorology 2017 Climate statistics Renmark 1957-2002. Accessed 15 September 2017 from
<http://www.bom.gov.au/climate/averages/tables/cw_024016.shtml>.
- Australian Water Environments (AWE) and CMC 2012 Pike and Katfish salinity risk assessment. Unpublished report prepared for Department for Environment, Water and Natural Resources.

- Bailey, G. 2007 Time perspectives, palimpsests and the archaeology of time. *Journal of Anthropological Archaeology* 26(2):198–223.
- Balla, S.A. and K.F. Walker 1991 Shape and variation in the Australian freshwater mussel. *Hydrobiologia* 220(2):89–98.
- Ballinger, A. and R. McNally 2006 Floods in an arid continent: The landscape context of flooding in the Murray-Darling Basin. *Advances in Ecological Research* 39:85–105.
- Balme, J.M. 1990 A Pleistocene tradition: Aboriginal fishery on the lower Darling River, western New South Wales. Unpublished Phd thesis, Australian National University, Canberra.
- Balme, J.M. 1991 The antiquity of grinding stones in semi-arid western New South Wales. *Australian Archaeology* 32:3–9.
- Balme, J.M. 1995 30,000 years of fishery in western New South Wales. *Archaeology in Oceania* 30(1):1–21.
- Balme, J.M. and W. Beck 1996 Earth mounds in southeastern Australia. *Australian Archaeology* 42:39–51.
- Balme, J.M. and J. Hope 1990 Radiocarbon dates from midden sites in the lower Darling River area of western New South Wales. *Archaeology in Oceania* 25(3):85–101.
- Barkindji Maraura Elders Council and E. Dillon 2020 Nulla Lunette: Radiocarbon Dating of Cultural Heritage Sites in the Lake Victoria Lunette. Unpublished report prepared for NGH Consulting.
- Barr, C., J. Tibby, P. Gell, J. Tyler, A. Zawazki and G.E. Jacobsen 2014 Climate variability in south-eastern Australia over the last 1500 years inferred from the high-resolution diatom records of two crater lakes. *Quaternary Science Reviews* 95:115–131.
- Barrows, T., K. Fitzsimmons, S. Mills, J. Tumney, D. Pappin and N. Stern 2020 Late Pleistocene lake level history of Lake Mungo, Australia. *Quaternary Science Reviews* 238:1–22.
- Barrows, T.T., J.O. Stone, L.K. Fifield and R.C. Cresswell 2002 The timing of the Last Glacial Maximum in Australia. *Quaternary Science Reviews* 21:159–173.

- Barrows, T.T., J.O. Stone, L.K. Fifield and R.G. Cresswell 2001 Late Pleistocene glaciation of the Kosciuszko Massif, snowy mountains, Australia. *Quaternary Research* 55:179–189.
- Baxter, K. 2004 Extrinsic factors that effect the preservation of bone. *Nebraska Anthropologist* 62:38–45.
- Beaton, J. 1983 Does intensification account for changes in the Australian Holocene archaeological record. *Archaeology in Oceania* 18:94–97.
- Bellchambers, J.P. 1931 *A Nature-lovers Notebook*. Adelaide: Nature Lover's League.
- Bellwood, P. 2011 The checkered prehistory of rice movement southwards as a domesticated cereal—From the Yangzi to the equator. *Rice* 4(3-4):93–103.
- Bender, B. 1978 Gatherer-hunter to farmer: a social perspective. *World Archaeology* 10:204–222.
- Berndt, R.M. and C.H. Berndt 1993 *A world that was: the Yaraldi of the Murray River and The Lakes, South Australia*. Melbourne: Melbourne University Press.
- Bettinger, R.L. 1977 Aboriginal human ecology in Owens Valley: prehistoric change in the Great Basin. *American Antiquity* 42(1):3–17.
- Beveridge, P. 1865 A few notes on the dialects, habits, customs, and mythology of the lower Murray Aborigines. *Transactions and Proceedings of the Royal Society of Victoria* 6:14–24.
- Beveridge, P. 1883 Of the Aborigines inhabiting the great lacustrine and riverine depression of the Lower Murray, Lower Murrumbidgee, Lower Lachlan and Lower Darling. *Proceedings of the Royal Society of New South Wales* 17:19–74.
- Beveridge, P. 1899 *The Aborigines of Victoria and Riverina*. Melbourne: Hutchinson.
- Beyer, K., S. Gerhig, S. Leigh, J.M. Nicol and B.P. Zampatti 2011 Intervention monitoring at the Katarapko Native Fish Demonstration Reach ("Katfish Reach"), South Australia: Progress Report F201/000994-1. SARDI Research Report Series No. 250. Adelaide: South Australian Research and Development Institute (SARDI).
- Binford, L.R. 1968 Post-Pleistocene adaptations. In S.R. Binford and L.R. Binford (eds), *New Perspectives in Archaeology*, pp.313–341. Chicago: Aldine.

- Bird, D.W. and R. Bliege-Bird 2000 The ethnoarchaeology of juvenile foragers: shellfishing strategies among Meriam children. *Journal of Anthropological Archaeology* 19:461–476.
- Bird, D.W., R. Bliege-Bird and B.F. Coddling 2016a Pyrodiversity and the Anthropocene: the role of fire in the broad spectrum revolution. *Evolutionary Anthropology* 25:105–116.
- Bird, D.W. and J.F. O'Connell 2006 Behavioral ecology and archaeology. *Journal of Archaeological Research* 14:143–188.
- Bird, D.W. and J.F. O'Connell 2012 Human Behavioural Ecology. In I. Hodder (ed.), *Archaeological Theory Today*, pp.29–49. ProQuest Ebook Central: Polity Press.
- Bird, M.I. 2013 Charcoal. In S.A. Elias (ed.), *The Encyclopedia of Quaternary Science*, pp.353–360. Amsterdam: Elsevier.
- Bird, M.I., D. O'Grady and S. Ulm 2016b Humans, water, and the colonization of Australia. *Proceedings of the National Academy of Sciences USA* 113(41):11477–11482.
- Bird, M.I., C.S.M. Turney, L.K. Fifield, R. Jones, L.K. Ayliffe, A. Palmer, R. Cresswell and S. Robertson 2002 Radiocarbon analysis of the early archaeological site of Nauwalabila I, Arnhem Land, Australia: implications for sample suitability and stratigraphic integrity. *Quaternary Science Reviews* 21(2002):1061–1075.
- Birdsell, J.B. 1957 Some population problems involving Pleistocene man. *Cold Spring Harbor Symposia on Quantitative Biology* 22:47–69.
- Blackwood, R. and K.N.G. Simpson 1973 Attitudes of Aboriginal skeletons excavated in the Murray valley region between Mildura and Renmark, Australia. *Memoirs of the National Museum of Victoria* 34:99–150.
- Blanch, S.J. 1997 Influence of water regime on growth and resource allocation in aquatic macrophytes of the Lower River Murray, Australia. Unpublished PhD thesis, Department of Zoology and Botany, University of Adelaide, Adelaide.
- Bleed, P. and A. Matsui 2010 Why didn't agriculture develop in Japan? A consideration of Jomon ecological style, niche construction, and the origins of domestication. *Journal of Archaeological Method and Theory* 17:356–370.

- Bliege-Bird, R., D.W. Bird, B.F. Coddling, C.H. Parker and J.H. Jones 2008 The “fire stick farming” hypothesis: Australian Aboriginal foraging strategies, biodiversity, and anthropogenic fire mosaics. *PNAS* 105(39):14796–14801.
- Bliege-Bird, R., N. Taylor, B.F. Coddling and D.W. Bird 2013 Niche construction and Dreaming logic: Aboriginal patch mosaic burning and varanid lizards (*Varanus gouldii*) in Australia. *Proceedings of the Royal Society of Britain* 280:1–7.
- Bloss, C., G. Eckert and L. Cetin 2015 *River Murray flood mitigation planning: Assessment of flood consequences*. DEWNR Technical Report 2015/56. Adelaide: Government of South Australia, through Department of Environment, Water and Natural Resources.
- Blunier, T., J. Schwander, B. Stauffer, T. Stocker, A. Dallenbach, A. Indermuhle, J. Chappellaz, D. Raynaud and J.M. Barnola 1997 Timing of the Antarctic Cold Reversal and the atmospheric CO₂ increase with respect to the Younger Dryas event. *Geophysical Research Letters* 24(21):2683–2686.
- Blyth, A. 1865 Report of the Protector of Aborigines, January 5, 1865. Adelaide: Government of SA.
- Bogucki, P. 1995 Prelude to agriculture in north-central Europe. *MASCA Research Papers in Science and Archaeology* 12:105–116.
- Bonney, F. 1883 *On Some Customs of the Aborigines of the River Darling, New South Wales*. London: Harrison and Sons.
- Bourman, R.P., C.V. Murray-Wallace, C. Wilson, L. Mosley, J. Tibby, D.D. Ryan, E.D. De Carli, A. Tulley, A.P. Belperio, D. Haynes, A. Roberts, C. Westell, E.J. Barnett, S. Dillenburg, L.B. Beheregaray and P.A. Hesp 2022 Holocene freshwater history of the Lower River Murray and its terminal lakes, Alexandrina and Albert, South Australia, and its relevance to contemporary environmental management. *Australian journal of earth sciences* 69(5):605–629.
- Bowler, J.M. 1973 Clay dunes: their occurrence, formation and significance. *Earth Sciences Reviews* 9:315–338.
- Bowler, J.M. 1976a Aridity in Australia: age, origin and expression on aeolian landforms and sediments. *Earth Sciences Reviews* 12:279–310.

- Bowler, J.M. 1976b Recent developments in reconstructing late Quaternary environments in Australia. In R.L. Kirk and A.G. Thorne (eds), *The Origin of the Australians*, pp.55–77. Canberra: Australian Institute of Aboriginal Studies.
- Bowler, J.M. 1978 Quaternary climate and tectonics in the evolution of the Riverine Plain. In J.L. Davies and M.A.J. Williams (eds), *Landform Evolution in Australasia*, pp.70–112. Canberra: Australian National University Press.
- Bowler, J.M. 1981 Australian salt lakes. *Hydrobiologia* 82:431–444.
- Bowler, J.M. 1983 Lunettes as indices of hydrologic change: a review of the Australian evidence. *Proceedings of the Royal Society of Victoria* 95:147–168.
- Bowler, J.M. 1986 Spatial variability and hydrologic evolution of Australian lake basins: analogue for Pleistocene hydrologic change and evaporite formation. *Palaeogeography, Palaeoclimatology, Palaeoecology* 54:21–41.
- Bowler, J.M. 1998 Willandra Lakes revisited: environmental framework for human occupation. *Archaeology in Oceania* 33:120–155.
- Bowler, J.M., R. Gillespie, H. Johnston and K. Boljkovac 2012 Wind v water: Glacial maximum records from the Willandra Lakes. In S.G. Harberle and B. David (eds), *Peopled Landscapes, Archaeological and Biogeographic Approaches to Landscapes*, pp.271–296. Terra Australis 34. Canberra: ANU E Press.
- Bowler, J.M. and L.B. Harford 1966 Quaternary tectonics and the evolution of the riverine plain near Echuca, Victoria. *Journal of the Geological Society of Australia* 13(2):339–354.
- Bowler, J.M., G.S. Hope, J.N. Jennings, G. Singh and D. Walker 1976 Late Quaternary climates of Australia and New Guinea. *Quaternary Research* 6:359–394.
- Bowler, J.M., H. Johnston, J.M. Olley, J.R. Prescott, R.G. Roberts, W. Shawcross and N.A. Spooner 2003 New ages for human occupation and climatic change at Lake Mungo, Australia. *Nature* 421(6925):837–840.
- Bowler, J.M., R. Jones, H. Allen and A.G. Thorne 1970 Pleistocene human remains from Australia: a living site and human cremation from Lake Mungo, western New South Wales. *World*

Archaeology 2(1):39–60.

Bowler, J.M., A. Kotsonis and C.R. Laurence 2006 Environmental evolution of the Mallee region, western Murray Basin. *Proceedings of the Royal Society of Victoria* 118(2):161–210.

Bowler, J.M. and J.W. Magee 1978 Geomorphology of the Mallee region in semi-arid northern Victoria and western New South Wales. *Proceedings of the Royal Society of Victoria* 90:5–25.

Bowler, J.M. and H.A. Polach 1971 Radiocarbon analyses of soil carbonates: an evaluation from paleosoils in southeastern Australia. In D. Yaalon (ed.), *Paleopedology*, pp.97–108. International Society of Soil Science and Israel University Press.

Bowler, J.M., E. Stockton and M. Walker 1978 Quaternary stratigraphy of the Darling River near Tilpa, New South Wales. *Proceedings of the Royal Society of Victoria* 90(1–2):79–88.

Bradshaw, C.J.A., K. Norman, S. Ulm, A.N. Williams, C. Clarkson, J. Chadœuf, S.C. Lin, Z. Jacobs, R.G. Roberts, M.I. Bird, L.S. Weyrich, S.G. Haberle, S. O'Connor, B. Llamas, T.J. Cohen, T. Friedrich, P. Veth, M. Leavesley and F. Saltr  2021 Stochastic models support rapid peopling of Late Pleistocene Sahul. *Nat Commun* 12(1):2440-11.

Brian, D. 2006 Harry Lourandos, the 'Great Intensification Debate', and the representation of Indigenous pasts. In B. David, B. Barker and I.J. McNiven (eds), *The Social Archaeology of Australian Indigenous Societies*, pp.107–122. Canberra: Aboriginal Studies Press.

Bridge, J.S. 2003 *Rivers and floodplains: forms, processes and sedimentary record*. Oxford: Blackwell Publishing.

Brock, M. and M. Cassanova 1997 Plant life at the edge of wetlands: ecological responses to wetting and drying patterns. In N. Klomp and I. Lunt (eds), *Frontiers in Ecology: Building the Links*, pp.181–192. Oxford: Elsevier Science.

Brock, S.F. and C.S. Ruff 1988 Diachronic patterns of change in structural properties of the femur in the prehistoric American southwest. *American Journal of Physical Anthropology* 75:113–127.

Bronk-Ramsey, C. 2009 Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1):337–360.

- Broughton, J.M., M. Cannon and E.J. Bartelink 2010 Evolutionary ecology, resource depression, and niche construction theory: applications to central California hunter-gatherers and Mimbres-Mogollon agriculturalists. *Journal of Archaeological Theory* 17:371–421.
- Brown, A.G. 1997 *Alluvial geoarchaeology: floodplain archaeology and environmental change*. Cambridge: Cambridge University Press.
- Brown, C.M. and A.E. Stephenson 1991 Geology of the Murray Basin, south eastern Australia, BMR Bulletin 235. Canberra: Australian Government Publishing Service.
- Brown, R. 1918 Notes on the social organisation of Australian tribes. *Journal of the Anthropological Institute of Great Britain* 48:222–253.
- Buchanan, A. 1924 Diary of a journey overland from Sydney to Adelaide with sheep: July - December 1839. *Proceedings Royal Geographical Society of Australasia, South Australian Branch* 24(1922-23):50–76.
- Builth, H., A.P. Kershaw, C. White, A. Roach, L. Hartney, M. McKenzie, T. Lewis and G. Jacobsen 2008 Environmental and cultural change on the Mt Eccles lava-flow landscapes of southwest Victoria, Australia. *The Holocene* 18(2):413–424.
- Burke, H. and C. Smith 2004 *The Archaeologist's Field Handbook*. Crows Nest, NSW: Allen & Unwin.
- Burke, H.A., A. Roberts, M. Morrison, V. Sullivan and River Murray and Mallee Aboriginal Corporation 2016 The space of conflict: Aboriginal/European interactions and frontier violence on the western Central Murray, South Australia, 1830–41. *Aboriginal History* 40:145–179.
- Butcher, P.A., M.W. McDonald and J.C. Bell 2009 Congruence between environmental parameters, morphology and genetic structure in Australia's most widely distributed eucalypt, *Eucalyptus camaldulensis*. *Tree Genetics & Genomes* 5:189-210.
- Butcher, R. and M. Reid 2002 Floodplain wetlands: the jewels of the Murray River. *Victorian Naturalist* 119(3):102–106.
- Butler, B.E. 1956 Parna, an aeolian clay. *Australian Journal of Science* 18:145–151.
- Cadwallader, P.L. 1978 Some causes of the decline in range and abundance of native fish in the

Murray–Darling River System. *Proceedings of the Royal Society of Victoria* 90:211–224.

Cale, B. 2009 Literature review of the current and historic flooding regime and required hydrological regime of ecological assets on the Chowilla Floodplain. Unpublished report prepared for South Australian Murray–Darling Basin Natural Resources Management Board.

Capon, S., J. Porter and C. James 2016 Vegetation of Australia's desert river landscapes. In S. Capon, C. James and R. Michael (eds), *Vegetation of Australian Riverine Landscapes: Biology, Ecology and Management*, pp.239–258. Canberra: CSIRO Publishing.

Carleton, W.C. and H.S. Groucutt 2021 Sum things are not what they seem: Problems with the interpretation and analysis of radiocarbon-date proxies. *The Holocene* 31(4):630–643.

Carlson, K.J., F.E. Grine and O.M. Pearson 2007 Robusticity and sexual dimorphism in the postcranium of modern hunter-gatherers from Australia. *American Journal of Physical Anthropology* 134:9–23.

Casey, D.A. 1973 Aboriginal stone artefacts from the Murray River region between Mildura and Renmark, Australia. *Memoirs of the National Museum of Victoria* 34:209–214.

Chappell, J. 1991 Late Quaternary environmental changes in eastern and central Australia, and their climatic interpretation. *Quaternary Science Reviews* 10:377–390.

Chatters, J.C. 2009 Cultural stasis and change in northern North America: a macroevolutionary perspective. In A. Prentiss, I. Kuijt and J. Chatters (eds), *Macroevolution in Human Prehistory*, pp.235–251. New York: Springer.

Chen, X.Y. 1995 Geomorphology, stratigraphy and thermoluminescence dating of the lunette dune at Lake Victoria, western New South Wales. *Palaeogeography, Palaeoclimatology, Palaeoecology* 13:69–86.

Chen, X.Y., M.J. Lintern and I.C. Roach (eds) 2002 *Calcrete: characteristics, distribution and use in mineral exploration*. Kensington, WA: Cooperative Research Centre for Landscape Environments and Mineral Exploration.

Churchward, H.M. 1961 Soil studies at Swan Hill, Victoria, Australia. *Journal of Soil Science* 12:73–

- Churchward, H.M. 1963a Dune moulding and parna formation. *Australian Journal of Soil Research* 1:103–116.
- Churchward, H.M. 1963b Some aspects of soil development on aeolian materials. *Australian Journal of Soil Research* 1:117–128.
- Clark, J.D.A., D. Gibson and H. Apps 2010 The use of LiDAR in applied interpretive landform mapping for natural resource management, Murray River alluvial plain, Australia. *International Journal of Remote Sensing* 31(23):6275–6296.
- Clark, P. and J. Hope 1985 Aboriginal burials and shell middens at Snaggy Bend and other sites in the central Murray River. *Australian Archaeology* 20:68–89.
- Clark, P.M. 1987 Willandra Lakes World Heritage Area archaeological resource study. Unpublished report prepared for NSW Department of Environment and Planning and The Western Lands Commission.
- Clarke, J.D.A., C.F. Wong, H. Pain, H. Apps, D. Gibson, J. Luckman and K. Lawrie 2008 Geomorphology and surface materials: Lindsay-Wallpolla and Lake Victoria–Darling Anabran. CRC LEME Restricted Report 261R, 74 pp. (Reissued as Open File Report 237, CRC LEME, Perth, 2008).
- Clarke, P.A. 1985 The importance of roots and tubers as a food source for southern South Australian Aborigines. *Journal Anthropological Society of South Australia* 23(6):2–13.
- Clarke, P.A. 2009 Aboriginal culture and the riverine environment. In J.T. Jennings (ed.), *Natural History of the Riverland and Murray Lands*, pp.142–161. Adelaide: Royal Society of South Australia.
- Clarke, P.A. 2013 The Aboriginal ethnobotany of the Adelaide region, South Australia. *Transactions of the Royal Society of South Australia* 137(1):97–126.
- Clarke, P.A. 2018 Plant food. In F. Cahir and I.D. Clark (eds), *Aboriginal biocultural knowledge in south-eastern Australia : perspectives of early colonists*, pp.55–72. Clayton South, Vic: CSIRO Publishing.

- Clarkson, C., Z. Jacobs, B. Marwick, R. Fullagar, L. Wallis, M. Smith, R.G. Roberts, E. Hayes, K. Lowe, X. Carah, A. Florin, J. McNeil, D. Cox, L.J. Arnold, Q. Hua, J. Huntley, H.E.A. Brand, T. Manne, A. Fairbairn, J. Schulmeister, L. Lyle, M. Salinas, M. Page, K. Connell, G. Park, K. Norman, T. Murphy and C. Pardoe 2017 Human occupation of northern Australia by 65,000 years ago. *Nature* 547(7663):306–310.
- Clarkson, C., R.G. Roberts, Z. Jacobs, B. Marwick, R. Fullagar, L.J. Arnold and Q. Hua 2018 Reply to comments on Clarkson et al. (2017) 'Human occupation of northern Australia by 65,000 years ago'. *Australian Archaeology* 84(1):84–89.
- Clarkson, C., M. Smith, B. Marwick, R. Fullagar, L.A. Wallis, P. Faulkner, T. Manne, E. Hayes, R.G. Roberts, Z. Jacobs, X. Carah, K.M. Lowe, J. Matthews and S.A. Florin 2015 The archaeology, chronology and stratigraphy of Madjedbebe (Malakunanja II): A site in northern Australia with early occupation. *J Hum Evol* 83:46–64.
- Cockburn, T. 2003 Stable isotopes and residential mobility in South Australia: determining residential mobility patterns of ancient South Australian Aboriginal populations employing multiple isotope analysis. Unpublished Honours thesis, Department of Archaeology, Flinders University, Adelaide.
- Codding, B.F. and D.W. Bird 2015 Behavioral ecology and the future of archaeological science. *Journal of Archaeological Science* 56:9–20.
- Codding, B.F., R. Bliege-Bird and D.W. Bird 2011 Provisioning offspring and others: risk – energy trade-offs and gender differences in hunter–gatherer foraging strategies. *Proceedings of the Royal Society of Britain* 278:2502–2509.
- Cohen, K.M. and P.L. Gibbard 2019 Global chronostratigraphical correlation table for the last 2.7 million years, version 2019 QI-500. *Quaternary International* 500:20–31.
- Cohen, T.J., G.C. Nanson, J.D. Jansen, B.G. Jones, Z. Jacobs, J.R. Larsen, J.H. May, P. Treble, D.M. Price and A.M. Smith 2012 Late Quaternary mega-lakes fed by the northern and southern river systems of central Australia: Varying moisture sources and increased continental aridity. *Palaeogeography, Palaeoclimatology, Palaeoecology* 356-357(2012):89–108.
- Cohen, T.J., G.C. Nanson, J.D. Jansen, B.G. Jones, Z. Jacobs, P. Treble, D.M. Price, J. May, A. Smith,

- L.K. Ayliffe and J.C. Hellstrom 2011 Continental aridification and the vanishing of Australia's megalakes. *Geology* 39(2):167–170.
- Contreras, D.A. and J. Meadows 2014 Summed radiocarbon calibrations as a population proxy: a critical evaluation using a realistic simulation approach. *Journal of Archaeological Science* 52:591–608.
- Coombes, P. and K. Barber 2005 Environmental determinism in Holocene research: causality or coincidence? *Area* 37(3):303–311.
- Cotton, B. 1933 Recent Australian Viviparidae and a fossil species. *Records of the South Australian Museum* 5(1):339–344.
- Coutts, P.J.F., R.K. Frank, P. Hughes, R.L. Vanderwal and Victorian Archaeological Survey 1978 *Aboriginal Engineers of the Western District, Victoria*. Records of the Victorian Archaeological Survey, Report No. 0158-9679. Melbourne: Ministry for Conservation.
- Coutts, P.J.F. and Victoria Archaeological Survey 1977 *Aboriginal Prehistory in North Western Victoria*. Melbourne: Victorian Archaeological Survey.
- Cupper, M.L. 2005 Last glacial to Holocene evolution of semi-arid rangelands in southeastern Australia. *The Holocene* 15(4):541–553.
- Cupper, M.L., A.N. Drinnan and I. Thomas 2000 Holocene palaeoenvironments of salt lakes in the Darling Anabranch region, south-western New South Wales, Australia. *Journal of Biogeography* 27:1079–1094.
- Cupper, M.L. and J. Duncan 2006 Last glacial megafaunal death assemblage and early human occupation at Lake Menindee, southeastern Australia. *Quaternary Research* 66:332–341.
- Curr, E.M. 1886 *The Australian Race: its origin, languages, customs, place of landing in Australia, and the routes by which it spread itself over that continent, in four Volumes*. Melbourne: Government Printer.
- Curr, E.M. 1993 *Recollections of squatting in Victoria: then called the Port Phillip District from 1841-1851*. Melbourne: George Robertson.
- Dalan, R.A. and S.K. Banerjee 1998 Solving archaeological problems using techniques in soil

magnetism. *Geoarchaeology: An international Journal* 13(1):3–36.

Daley, J.S. and T.J. Cohen 2018 Climatically-controlled river terraces in eastern Australia. *Quaternary* 1(23):1–20.

Dardengo, M. 2019 A living archive: an archaeology of culturally modified trees at Calperum Station in the South Australian Riverland. Unpublished Masters thesis, College of Humanities, Arts and Social Sciences, Flinders University, Adelaide.

Dardengo, M., A. Roberts, M. Morrison and River Murray and Mallee Aboriginal Corporation 2019 An Archaeological Investigation of Local Aboriginal Responses to European Colonisation in the South Australian Riverland via an Assessment of Culturally Modified Trees. *Journal of the Anthropological Society of South Australia* 43:33–70.

Dare-Edwards, A.J. 1984 Aeolian clay deposits of southeastern Australia — parna or loessic clay. *Transactions of the Institute of British Geographers* 9(3):337–344.

David, B. and T. Denham 2006 Unpacking Australian prehistory. In B.R. Davies, B. Barker and I.J. McNiven (eds), *The social archaeology of Australian indigenous societies*, pp.52–71. Canberra: Aboriginal Studies Press.

David, B. and H. Lourandos 1997 37,000 years and more in tropical Australia: Investigating long-term archaeological trends in Cape York Peninsula. *Proceedings of the Prehistoric Society* 63:1–23.

De Carli, E. 2020 The River Murray's geomorphic legacy – Shedding light on environmental change from Holocene floods to Millennium Drought extremes, School of Geosciences, Faculty of Science, The University of Sydney,

De Carli, E., T. Hubble, D. Penny, D. Petley, T. Job, R. Hamilton, S. Clarke, P. Gadd, H. Brand and A. Helfensdorfer 2016 9000-year Murray River flood record discovered. Accessed 3/05/2109 from <<http://ozewex.org/9000-year-murray-river-flood-record-discovered/>>.

Deckker, P.D. 1982 Holocene ostracods, other invertebrates and fish remains from shores of four maar lakes in southeastern Australia. *Proceedings of the Royal Society of Victoria* 94(4):183–220.

- Deckker, P.D., J.K. Magee and J.M.G. Shelley 2011 Late Quaternary palaeohydrological changes in the large playa Lake Frome in central Australia, recorded from the Mg/Ca and Sr/Ca in ostracod valves and biotic remains. *Journal of Arid Environments* 75:38–50.
- Degroot, D., K. Anchukaitis, M. Bauch, J. Burnham, F. Carnegy, J. Cui, K. de Luna, P. Guzowski, G. Hambrecht, H. Huhtamaa, A. Izdebski, K. Kleemann, E. Moesswilde, N. Neupane, T. Newfield, Q. Pei, E. Xoplaki and N. Zappia 2021 Towards a rigorous understanding of societal responses to climate change. *Nature* 591(7851):539–550.
- Denham, T., J. Atchison, J. Austin, S. Bestel, D. Bowdery, A. Crowther, N. Dolby, A. Fairbairn, J. Field, A. Kennedy, C. Lentfer, C. Matheson, S. Nugent, J. Parr, M. Prebble, G. Robertson, J. Specht, R. Torrence, H. Barton, R. Fullagar, S. Haberle, M. Horrocks, T. Lewis and P. Matthews 2009 Archaeobotany in Australia and New Guinea: Practice, potential and prospects. *Australian Archaeology* 68:1–10.
- Department of Environment Water and Natural Resources (DEWNR) 2012 Basin Salinity Management Strategy - South Australia's Annual Report 2011-12. Adelaide: Government of South Australia.
- Department of Environment Water and Natural Resources (DEWNR) 2013 Riverine Recovery Pike floodplain hydraulic modelling 2012–13. Adelaide: Government of South Australia.
- Djekic, A. 1980 An archaeological survey of the Rufus River Groundwater Interception Scheme. Unpublished report prepared for NSW National Parks and Wildlife Service and South Australian Governemnt Engineering and Water Supply Department.
- Dobney, K., M. Beech and D. Jacques 1999 *Hunting the broad spectrum revolution: the characterisation of ealry Neolithic animal exploitation at Qermez Dere, northern Mesopotamia*. Zooarchaeology of the Pleistocene/Holocene boundary: Proceedings of a symposium held at the 8th Congress of the International Council for Archaeology (ICAZ), Vicotria, British Columbia, Canada, August 1998. British Archaeological Reports International Series.
- Dodson, J. 1977 Late Quaternary palaeoecology of Wylie Swamp, southeastern South Australia. *Quaternary Research* 8:97–114.

- Dodson, J., R. Fullagar, J. Furby, R. Jones and I. Prosser 1993 Humans and megafauna in a late Pleistocene environment from Cuddie Springs, north western New South Wales. *Archaeology in Oceania* 28(2):94–99.
- Donders, T.H., S.G. Hamerle, G. Hope, F. Wagner and H. Visschera 2007 Pollen evidence for the transition of the eastern Australian climate system from the post-glacial to the present-day ENSO mode. *Quaternary Science Reviews* 26:1621–1637.
- Dow, G.K. and C.G. Reid 2015 The origins of sedentism: climate, population, and technology. *Journal of Economic Behavior & Organization* 119:56–71.
- Dowling, P.J. 1990 Violent Epidemics: Disease, Conflict and Aboriginal Population Collapse as a Result of European Contact in the Riverland of South Australia. Unpublished MA thesis, Department of Prehistory and Anthropology, Australian National University, Canberra.
- Drill 1904 'Blackboy's biography: sold to slavery - an Australian Huckleberry Finn', *Sunday Times* Sunday 3 July 1904 p.2.
- Dunlop, J., G. McGregor and N. Horrigan 2005 Potential impacts of salinity and turbidity in riverine ecosystems: Characterisation of impacts and a discussion of regional target setting for riverine ecosystems in Queensland.
- Ecological Associates and Australian Water Environments 2008 Pike River floodplain management plan. Unpublished report prepared for South Australian Murray-Darling Basin Natural Resources Management Board.
- Edmonds, V. 1993 A survey of Aboriginal Sites along the River Murray from Renmark to the South Australian border. Unpublished report prepared for Aboriginal Heritage Branch, Department of State Aboriginal Affairs South Australia.
- Edmonds, V. 1995 An Archaeological survey of the proposed OFC route between Morgan and Murbko, the Riverland, South Australia. Unpublished report prepared for Telecom Australia.
- Edmonds, V. 1997 Bowen Park Aboriginal Shell Midden Salvage Report. Unpublished report prepared for Sunraysia Environmental.

- Edmonds, V. 1998 An archaeological assessment of Pump Hill, Merbein, northwest Victoria. Unpublished report prepared for Lower Murray Water, Mildura.
- Edmonds, V. 2007 Mitchell's Almond Project, Sub-Surface Testing and Salvage, Hattah-Wemen-Kulkyne 2 & 3 (AAV 7428-0926 & 0924). Unpublished report prepared for Timbercorp.
- Edmonds, V. and A. Long 1998 Balpool Station Piggery. Archaeological Survey, Sub-Surface Excavations and Monitoring on Balpool Station, near Deniliquin, Western NSW. Unpublished report prepared for Bunge Meat Industries. Pty Ltd.
- Edwards, A. and J.F. O'Connell 1995 Broad spectrum diets in arid Australia. *Antiquity* 69(265):769–783.
- Edwards, P.C. 1989 Revising the Broad Spectrum Revolution: and its role in the origins of Southwest Asian food production. *Antiquity* 63:225–246.
- Erskine, W.D. and C.T. Peacock 2002 Late Holocene flood plain development following a cataclysmic flood. In F.J. Dyer, M.C. Thoms and J.M. Olley (eds), *The structure, function and management implications of fluvial sedimentary systems*, pp.177–184. Wallingford: IAHS Press.
- Eshed, V., A.V. Gopher, R. Pinhasi and I. HersHKovitz 2010 Paleopathology and the origin of agriculture in the Levant. *American Journal of Physical Anthropology* 143:121–133.
- Etheridge, R. 1893 The Mirnong heaps at the north west bend of the River Murray. *Royal Society of South Australia Transactions and Proceedings* 17(1):21–24.
- Eyre, E.J. 1832-1839 *Autobiographical narrative of residence and exploration in Australia, 1832-1839*. London: Caliban Books.
- Eyre, E.J. 1842 'South Australia: expedition of Mr Eyre to Lake Victoria', *Geelong Advertiser* Monday 28 March 1842 p.4.
- Eyre, E.J. 1845 *Journals of Expeditions of Discovery into Central Australia and Overland from Adelaide to King George's Sound, in the Years 1840–1, Volume II*. London: T. & W. Boone.
- Falster, G.J., J. Tyler, K. Grant, J. Tibby, C. Turney, S. Lohr, G. Jacobsen and A.P. Kershaw 2018 Millennial-scale variability in south-east Australian hydroclimate between 30,000 and

10,000 years ago. *Quaternary Science Reviews* 192:106–122.

Fanning, P.C., S.J. Holdaway and R.S. Phillips 2009a Heat-retainer hearth identification as a component of archaeological survey in western NSW, Australia. In A. Fairbairn, S. O'Connor and B. Marwick (eds), *New Directions in Archaeological Science*, pp.13–23. Terra Australis 28. Canberra: ANU E Press.

Fanning, P.C., S.J. Holdaway, E.J. Rhodes and T.G. Bryant 2009b The surface archaeological record in arid Australia: Geomorphic controls on preservation, exposure and visibility. *Geoarchaeology* 24(2):121–145.

Fekadu, K. 2014 The paradox in environmental determinism and possibilism: a literature review. *Journal of Geography and Regional Planning* 7(7):132–139.

Ferrier, A. and R. Cosgrove 2012 Aboriginal exploitation of toxic nuts as a late-Holocene subsistence strategy in Australia's tropical rainforests. In S.G. Haberle and B. David (eds), *Peopled Landscapes*, pp.103–120. Terra Australis 34. Canberra: ANU Press.

Field, J. and R. Fullagar 1998 Grinding and pounding stones from Cuddie Springs and Jinmium. In R. Fullagar (ed.), *A Closer Look: Recent Australian Studies of Stone Tools*, pp.95–108. Sydney: Archaeological Computing Laboratory, School of Archaeology, University of Sydney.

Field, J.H., J.R. Dodson and I.P. Prosser 2002 A late Pleistocene vegetation history from the Australian semi-arid zone. *Quaternary Science Reviews* 21:1023–1037.

Field, J.H., R. Fullagar, J. Dortch, A. Dutkiewicz and P. Gordon 2003 Sandstone quarries and grinding stone manufacture: survey and excavation at Yambacoona Hill in south eastern Australia. *Australian Archaeology* 56:46–47.

Fink, D., M. Hotchkis, Q. Hua, G. Jacobsen, A.M. Smith, U. Zoppi, D. Child, C. Mifsud, H.v.d. Gaast, A. Williams and M. Williams 2004 The ANTARES AMS facility at ANSTO. *NIM B* 223-224:109–115.

Finniss, H.J. 1966 Dr Harris Browne's journal of the Sturt Expedition, 1844-45. *South Australiana* 5(1):23–54.

Firman, J.B. 1966 Stratigraphy of the Chowilla area in the Murray Basin, South Australia. *Quarterly*

Notes of the Geological Survey of South Australia 20:3–7.

Firman, J.B. 1972 Renmark, South Australia Sheet SI/54-10, International Index. 1:250000
Geological Series - Explanatory Notes. Adelaide: Geological Survey of South Australia.

Firman, J.B. 1973 Regional stratigraphy of surficial deposits in the Murray BASin and Gambier
Embayment. Adelaide: Geological Survey of South Australia.

Fitzsimmons, K.E. 2017 Reconstructing palaeoenvironments on desert margins: new perspectives
from Eurasian loess and Australian dry lake shorelines. *Quaternary Science Reviews* 171:1–
19.

Fitzsimmons, K.E. and T.T. Barrows 2010 Holocene hydrologic variability in temperate
southeastern Australia: An example from Lake George, New South Wales. *The Holocene*
20(4):585–597.

Fitzsimmons, K.E., J.M. Bowler, E.J. Rhodes and J.M. Magee 2007a Relationships between desert
dunes during the late Quaternary in the Lake Frome region, Strzelecki Desert, Australia.
Journal of Quaternary Science 22(5):549–558.

Fitzsimmons, K.E., T. Cohen, P.P. Hesse, J. Jansen, G.C. Nanson, M. Jan-Hendrik, T.T. Barrows, D.
Haberlah, A. Hilgers, T. Kelly, J. Larsen, J. Lomax and P. Treble 2013 Late Quaternary
palaeoenvironmental change in the Australian drylands. *Quaternary Science Reviews*
74:78–96.

Fitzsimmons, K.E., E.J. Rhodes, J.W. Magee and T.T. Barrows 2007b The timing of linear dune
activity in the Strzelecki and Tirari Deserts, Australia. *Quaternary Science Reviews*
26(2007):2598–2616.

Fitzsimmons, K.E., C. Spry and N. Stern 2019 Holocene and recent aeolian reactivation of the
Willandra Lakes lunettes, semi-arid southeastern Australia. *The Holocene* 29(4):606–621.

Fitzsimmons, K.E., N. Stern and C.V. Murray-Wallace 2014 Depositional history and archaeology of
the central Lake Mungo lunette, Willandra Lakes, southeast Australia. *Journal of*
Archaeological Science 41:349–364.

Fitzsimmons, K.E., N. Stern, C.V. Murray-Wallace, W. Truscott and C. Pop 2015 The Mungo mega-

Lake event, semi-arid Australia: non-linear descent into the last Ice Age, implications for human behaviour. *PLoS ONE* 10(6). doi: 10.1371/journal.pone.0127008.

Flannery, K.V. 1969 Origins and ecological effects of early domestication in Iran and the Near East. In P.J. Ucko and G.W. Dimbleby (eds), *The Domestication and Exploitation of Plants and Animals*, pp.73–100. London: Duckworth.

Flannery, K.V. 1986 *Guila Naquitz: archaic foraging and early agriculture in Oaxaca, Mexico*. New York: Academic Press.

Fluin, J. and P. Gell 2008 Sediment derived scenarios of wetland status and change, the lower River Murray, SA. Unpublished report prepared for SA Murray Darling Basin Natural Resources Management Board.

Fluin, J., D. Haynes and J. Tibby 2007 Paleolimnological evidence for the independent evolution of neighbouring terminal lakes, the Murray Darling Basin, Australia. *Hydrobiology* 591:117–134.

Fluin, J., D. Haynes and J. Tibby 2009 An environmental history of the Lower Lakes and the Coorong. Unpublished report prepared for South Australian Department for Environment and Heritage.

Forbes, M., N. Jankowski, T. Cohen, F. Hopf, D. Mueller, M. Bird, S. Haberle and Z. Jacobs 2019 Palaeochannels of Australia's Riverine Plain - Reconstructing past vegetation environments across the Late Pleistocene and Holocene. *Palaeogeography, Palaeoclimatology, Palaeoecology* Journal Pre-proof.

Frankel, D. 1982 An account of Aboriginal use of the yam daisy. *The Artefact* 7(1-2):43–45.

Freeman, J., M.A. Peeples and J.M. Anderies 2015 Toward a theory of non-linear transitions from foraging to farming. *Journal of Anthropological Archaeology* 40:109–122.

Friedman, G.M. 1959 Identification of carbonate minerals by staining methods. *Journal of Sedimentary Research* 29:87–97.

Fullagar, R. and J.H. Field 1997 Pleistocene seed-grinding implements from the Australian arid zone. *Antiquity* 71:300–307.

- Fullagar, R., E. Hayes, B. Stephenson, J.H. Field, C. Matheson, N. Stern and K.E. Fitzsimmons 2015 Evidence for Pleistocene seed grinding at Lake Mungo, south-eastern Australia. *Archaeology in Oceania* 50:3–19.
- Galloway, W.E. and D.K. Hobday 1983 *Terrigenous clastic depositional systems: applications to petroleum, coal and uranium exploration*. New York: Springer-Verlag.
- Gammage, B. 2011 *The Biggest Estate on Earth: How Aborigines Made Australia*. Sydney: Allen & Unwin.
- Garvey, J. 2013 Paleoenvironments and human adaptation in the semi-arid Murray River Valley of northwestern Victoria. *Excavations, Surveys and Heritage Management in Victoria* 2:119–124.
- Garvey, J. 2017 Australian Aboriginal freshwater shell middens from late Quaternary northwest Victoria: Prey choice, economic variability and exploitation. *Quaternary International* 427:85–102.
- Gell, P.A. 2020 Restoring Murray River floodplain wetlands: Does the sediment record inform on watering regime? *River Research and Applications* 36(4):620–629.
- Gell, P.A., S. Bulpin, P. Wallbrink, G. Hancock and S. Bickford 2005 Tareena Billabong - A palaeolimnological history of an ever-changing wetland, Chowilla Floodplain, lower Murray-Darling Basin, Australia. *Marine and Freshwater Research* 56:441–456.
- Gell, P.A., J. Fluin, J. Tibby, G. Hancock, J. Harrison, A. Zawadzki, D. Haynes, S. Khanum, F. Little and B. Walsh 2009 Anthropogenic acceleration of sediment accretion in lowland floodplain wetlands, Murray–Darling Basin, Australia. *Geomorphology* 108:122–126.
- Gell, P.A., J. Fluin, J. Tibby, D. Haynes, S. Khanum, B. Walsh, G. Hancock, F. Little, J.S. Rowan, R.W. Duck and A. Werritty 2006 Changing fluxes of sediments and salts as recorded in lower River Murray wetlands, Australia. *International Association of Hydrological Sciences Publication* 306:416–424.
- Gill, E.D. 1973a Geology and geomorphology of the Murray River region between Mildura and Renmark, Australia. *Memoirs of the National Museum of Victoria* 34:1–98.

- Gill, E.D. 1973b Palaeopedology of the Murray River region between Mildura and Renmark, Australia. *Memoirs of the National Museum of Victoria* 34:241–251.
- Gillespie, R. 1998 Alternative timescales: a critical review of Willandra Lakes dating. *Archaeology in Oceania* 33:169–182.
- Gillespie, R. 2002 Dating the first Australians. *Radiocarbon* 44(2):455–472.
- Gillespie, R. and B.W. Brook 2006 Is there a Pleistocene archaeological site at Cuddie Springs? *Archaeology in Oceania* 41:1–11.
- Gillespie, R., D. Fink, F. Petchey and G. Jacobsen 2009 Murray-Darling basin freshwater shells: Riverine reservoir effect. *Archaeology in Oceania* 44(2):107–111.
- Gillespie, R., J.W. Magee, J.G. Luly, E. Dlugokencky, R.J. Sparks and G. Wallace 1991 AMS radiocarbon dating in the study of arid environments: Examples from Lake Eyre, South Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 84:333–338.
- Gingelle, F., P.D. Deckker and M. Norman 2007 Late Pleistocene and Holocene climate of SE Australia reconstructed from dust and river loads deposited offshore the River Murray mouth. *Earth and Planetary Science Letters* 255:257–272.
- Gippel, C. and D. Blackman 2002 Review of environmental impacts of flow regulation and other water resource developments in the River Murray and Lower Darling River system. Unpublished report prepared for Murray-Darling Basin Commission.
- Gorecki, P., M. Grant, S. O'Connor and P. Veth 1997 The morphology, function and antiquity of Australian grinding implements. *Archaeology in Oceania* 17(1):141–150.
- Gott, B. 1982 Ecology of root use by the Aborigines of southern Australia. *Archaeology in Oceania* 17(1):59–67.
- Gott, B. 1983 Murnong - *Microseris scapigera*: A study of a staple food of Victorian Aborigines. *Australian Aboriginal Studies* 2:2–17.
- Gott, B. 1999 Cumbungi, *Typha* species: A staple Aboriginal food in southern Australia. *Australian Aboriginal Studies* 1:33–50.

- Gouramanis, C., P. De Decker, A.D. Switzer and D. Wilkins 2013 Cross-continent comparison of high-resolution Holocene climate records from southern Australia — Deciphering the impacts of far-field teleconnections. *Earth Sciences Reviews* 121:55–72.
- Graham, P. 1986 Australian history at Roonka. *Journal of the Historical Society fo South Australia* 14:107–122.
- Graham, R. and J.H. Harris 2005 *Floodplain inundation and fish dynamics in the Murray-Darling Basin: Current concepts and future directions*. Canberra: Cooperative Research Centre for Freshwater Ecology.
- Grosvenor, G.A. 1979 *Red Mud to Green Oasis*. Adelaide: Raphael Arts.
- Habeck-Fardy, A. and G.C. Nanson 2014 Environmental character and history of the Lake Eyre Basin, one seventh of the Australian continent. *Earth-Science Review* 132:39–66.
- Hale, H.M. and N.B. Tindale 1930 Notes on some human remains in the lower Murray valley. *Records of the South Australian Museum* 4:145–218.
- Hamm, G., P. Mitchell, L.J. Arnold, G.J. Prideaux, D. Questiaux, N.A. Spooner, V.A. Levchenko, E.C. Foley, T.H. Worthy, B. Stephenson, V. Coulthard, C. Coulthard, S. Wilton and D. Johnston 2016 Cultural innovation and megafauna interaction in the early settlement of arid Australia. *Nature* 539(7628):280–297.
- Hardin, G.L. 2009 Environmental determinism: broken paradigm or viable perspective? Unpublished PhD thesis, Department of Educational Leadership and Policy Analysis, East Tennessee State University, Johnson City.
- Harrison, S.P. 1993 Late Quaternary lake-level changes and climates in Australia. *Quaternary Science Reviews* 12:211–231.
- Hawdon, J. 1952 *The journal of a journey from New South Wales to Adelaide (the capital of South Australia) performed in 1838 by Mr. Joseph Hawdon*. Melbourne: Georgian House.
- Hawkes, K. and J.F. O'Connell 1992 On Optimal Foraging Models and subsistence transitions. *Current Anthropology* 33(1):63–66.
- Hayes, E. 2015 What was ground? A functional analysis of grinding stones from Madjedbebe and

Lake Mungo, Australia. Unpublished Phd thesis, Centre for Archaeological Science, School of Earth and Environmental Sciences, University of Wollongong, Wollongong.

Hedges, R.E.M. 2002 Bone diagenesis: an overview of processes. *Archaeometry* 44(3):319–328.

Helfensdorfer, A.M., H.A. Power and T.C.T. Hubble 2020 Atypical responses of a large catchment river to the Holocene sea-level highstand: The Murray River, Australia. *Nature Scientific Reports* 10(7503):1–15.

Henderson, J. 1987 Factors Determining the State of Preservation of Human Remains. In A. Boddington, A.N. Garland and J.R. C (eds), *Death, Decay, and Reconstruction: Approaches to Archaeology and Forensic Science*, Manchester: Manchester University Press.

Herczeg, A.L. and A. Chapman 1991 Uranium-series dating of lake and dune deposits in southeastern Australia: a reconnaissance. *Palaeogeography, Palaeoclimatology, Palaeoecology* 84(1):285–298.

Herrejon Lagunilla, A., A. Carrancho, J.J. Villalain, C. Mallol and C.M. Hernandez 2019 An experimental approach to the preservation potential of magnetic signatures in anthropogenic fires.(Research Article)(Report). *PLoS ONE* 14(8):e0221592.

Hesse, P.P. 2016 How do longitudinal dunes respond to climate forcing? Insights from 25 years of luminescence dating of the Australian desert dunefields. *Quaternary International* 410:11–29.

Hesse, P.P., G.S. Humphreys, B.L. Smith, J. Campbell and E.K. Peterson 2003 Age of loess deposits in the Central Tablelands of New South Wales. *Australian Journal of Soil Research* 41(6):1115–1131.

Hesse, P.P., J.W. Magee and S. van der Kaars 2004 Late Quaternary climates of the Australian arid zone:a review. *Quaternary International* 118-119:87–102.

Hesse, P.P. and G.H. McTainsh 1999 Last Glacial Maximum to early Holocene wind strength in the mid-latitudes of the Southern Hemisphere from aeolian dust in the Tasman Sea. *Quaternary Research* 52:343–349.

Hesse, P.P. and G.H. McTainsh 2003 Australian dust deposits: modern processes and the

Quaternary record. *Quaternary Science Reviews* 22(18-19):2007–2035.

Hesse, P.P., R. Williams, T.J. Ralph, K.A. Fryirs, Z.T. Larkin, K.E. Westaway and W. Farebrother 2018 Palaeohydrology of lowland rivers in the Murray-Darling Basin, Australia. *Quaternary Science Reviews* 200:85–105.

Hill, E.C. 2014 Temporal changes in mobility and sexual division of labor in Holocene South Australians: an analysis of external bone metrics in the Roonka Flat sample. Unpublished MA thesis, Graduate Faculty, Texas Tech University, Lubbock, Texas.

Hill, E.C., A.C. Durband and K. Walshe 2016 Risk minimization and a Late Holocene increase in mobility at Roonka Flat, South Australia: an analysis of lower limb bone diaphyseal shape. *American Journal of Physical Anthropology* 161:94–103.

Hill, K., H. Kaplan, K. Hawkes and A. Hurtado 1987 Foraging decisions among Ache hunter-gatherers: New data and implications for optimal foraging models. *Ethology and Sociobiology* 8:1–36.

Hilton, C.E. and R.D. Greaves 1995 Mobility patterns in modern human foragers. *American Journal of Physical Anthropology, Supplement* 20:111.

Hinojosa, J.L., C.M. Moy, M. Vandergoes, S.J. Feakins and A.L. Sessions 2019 Hydrologic change in New Zealand during the last deglaciation linked to reorganisation of the southern hemisphere westerly winds. *Palaeoceanography and Palaeoclimatology* 34(12):2158–2217.

Hiscock, P. 2008 *Archaeology of ancient Australia*. London and New York: Routledge.

Hiscock, P. and L.A. Wallis 2005 Pleistocene settlement of deserts from an Australian perspective. In P.M. Veth, M.A. Smith and P. Hiscock (eds), *Desert peoples: Archaeological perspectives*, pp.34–57. Melbourne: Blackwell.

Ho, M., S. Kiem and D.C. Verdon-Kidd 2015 A palaeoclimate rainfall reconstruction in the Murray-Darling Basin (MDB), Australia: Assessing hydroclimatic risk using palaeoclimate records of wet and dry epochs. *Water Resources Research* 51:8380–8396.

Hockett, B.S. and N.F. Bicho 2000 The rabbits of Picareiro Cave: small mammal hunting during the

Late Upper Palaeolithic in the Portuguese Estremadura. *Journal of Archaeological Science* 27:715–723.

- Hocknull, S.A., R. Lewis, L.J. Arnold, T. Pietsch, R. Joannes-Boyau, G.J. Price, P. Moss, R. Wood, A. Dosseto, J. Louys, J. Olley and R.A. Lawrence 2020 Extinction of eastern Sahul megafauna coincides with sustained environmental deterioration. *Nature communications* 11(2250):1–14.
- Hogg, A.G., T.J. Heaton, Q. Hua, J.P. Palmer, C.S.M. Turney, J. Southon, A. Bayliss, P.G. Blackwell, G. Boswijk, C.B. Ramsey, C. Pearson, F. Petchey, P. Reimer, R. Reimer and L. Wacker 2020 SHCal20 Southern Hemisphere Calibration, 0–55,000 years cal BP. *Radiocarbon* 62(4):759–778.
- Holdaway, S.J., M. Douglass and P. Fanning 2012 Landscape scale and human mobility: geoarchaeological evidence from Rutherfords Creek, New South Wales, Australia. In S.J. Klaving and E.N. Guttman-Bond (eds), *Landscape archaeology between art and science from a multi- to an interdisciplinary approach*, pp.279–294. Amsterdam: Amsterdam University Press.
- Holdaway, S.J., P. Fanning and E. Rhodes 2008 Challenging intensification: Human-environment interactions in the Holocene geo-archaeological record from western New South Wales, Australia. *The Holocene* 18:403–412.
- Holdaway, S.J., P. Fanning and J. Shiner 2005 Absence of evidence or evidence of absence? Understanding the chronology of Indigenous occupation of western New South Wales, Australia. *Archaeology in Oceania* 40(2):33–49.
- Holdaway, S.J., P.C. Fanning, M. Jones, J. Shiner, D.C. Witter and G. Nicholls 2002 Variability in the chronology of late Holocene Aboriginal occupation on the arid margin of southeastern Australia. *Journal of Archaeological Science* 29:351–363.
- Holdaway, S.J., P.C. Fanning and J. Littleton 2009 Assessing the frequency distribution of radiocarbon determinations from the archaeological record of the Late Holocene in western NSW, Australia. In A. Fairbairn, S. O'Connor and B. Marwick (eds), *New Directions in Archaeological Science*, pp.1–11. Terra Australis 28 Canberra: ANU Press.

- Holdaway, S.J., P.C. Fanning, E.J. Rhodes, S.K. Marx, B. Boyd and M.J. Douglas 2010 Human response to Palaeoenvironmental change and the question of temporal scale. *Palaeogeography, Palaeoclimatology, Palaeoecology* 292:192–200.
- Holdaway, S.J. and N. Stern 2004 *A record in stone : the study of Australia's flaked stone artefacts*. Study of Australia's flaked stone artefacts. Melbourne: Museum Victoria.
- Holland, K.L., C.J. Turnadge, J.M. Nicol, S.L. Gehrig and A.D. Strawbridge 2013 Floodplain response and recovery: comparison between natural and artificial floods. Unpublished report prepared for Goyder Institute for Water Research.
- Hollingsworth, I.D. 1990 A reconnaissance soil survey of the Chowilla Anabranch system of the River Murray in South Australia and New South Wales. Unpublished report prepared for Murray-Darling Basin Commission by the Loxton Research Centre, South Australian Department of Agriculture.
- Holmes, J.M. 1948 *The Murray Valley: a geographical reconnaissance of the Murray Valley and a new design for its regional organisation*. Sydney: Angus and Robertson.
- Holt, B.M. 2003 Mobility in Upper Paleolithic and Mesolithic Europe: evidence from the lower limb. *American Journal of Physical Anthropology* 122:200–215.
- Hope, J. 1978 Pleistocene mammal extinctions: The problem of Mungo and Menindee, New South Wales. *Alcheringa* 2(1):65–82.
- Hope, J. 1986 *Human paleoecology in western NSW*. Proceedings of an International Conference on Landscapes of the Southern Hemisphere Roseworthy Agricultural College, Roseworthy, South Australia, September 2-9, 1986.
- Hope, J. 1993 Pleistocene archaeological sites in the central Murray-Darling basin. In M.A. Smith, M. Spriggs and B. Frankhauser (eds), *Sahul in Review: Pleistocene Archaeology in Australia, New Guinea and Island Melanesia*, pp.183–196. Canberra: Department of Prehistory, Research School of Pacific Studies, Australian National University.
- Hope, J. 1998 *The cultural heritage of Lake Victoria: the nature, significance and conservation needs of the cultural heritage of Lake Victoria*. Lake Victoria: finding the balance—a response to the competing interests of cultural heritage, environment and resource use.

Canberra: Murray Darling Basin Commission.

Hope, J., A.J. Dare-Edwards and M.L. McIntyre 1983 Middens and megafauna: Stratigraphy and dating of Lake Tandou lunette western New South Wales. *Archaeology in Oceania* 18(1):45–53.

Hosfield, R.T. and J.C. Chambers 2005 Pleistocene geochronologies for fluvial sedimentary sequences: an archaeologist's perspective. *Journal of Quaternary Science* 20(3):285–296.

Howitt, A.W. 1904 *Native Tribes of South-East Australia*. London: Macmillan and Co. Limited.

Hubble, T. and E.D. Carli 2015 Mechanisms and Processes of the Millennium Drought River Bank Failures: Lower Murray River, South Australia. Goyder Institute for Water Research Technical Report Series. Report No. 15/5 Adelaide: Goyder Institute for Water Research.

Hubble, T., E. De Carli, S. Clarke, D. Penny, R. Hamilton, D. Petley and P. Gadd 2014 The lower Murray River's Mannum Muds: a Holocene age lacustrine deposit in a bedrock gorge. Accessed 1 February 2020 from
<https://www.researchgate.net/publication/278029507_THE_LOWER_MURRAY_RIVER'S_MANNUM_MUDS_A_HOLOCENE_AGE_LACUSTRINE_DEPOSIT_IN_A_BEDROCK_GORGE>.

Hubble, T.C.T., A.M. Helfensdorfer, T. Job and H.E. Power 2021 Evidence for substantial Darling River flows is preserved in 7,000-year-old laminated muds deposited at Monteith, lower Murray river valley: A challenge to the conventional view of insignificant Darling River flows during the mid-Holocene. *Quaternary Australasia* 38(2):32–41.

Hublin, J.J. 2021 How old are the oldest Homo Sapiens in far East Asia? *PNAS* 118(10):1–3.

Hughes, P.J., M.E. Sullivan and P. Hiscock 2017 Palaeoclimate and human occupation in southeastern arid Australia. *Quaternary Science Reviews* 163:72–83.

Humphrey, E.S. 2012 Hunting specialisation and the Broad Spectrum Revolution in the early Epipalaeolithic: Gazelle exploitation at Urkan e-Rubb Ila, Jordan Valley. Unpublished PhD thesis, Department of Anthropology, University of Toronto, Toronto.

Humphries, P. 2005 Spawning time and early life history of Murray cod, *Maccullochella peelii peelii*

(Mitchell) in an Australian river. *Environmental Biology of Fishes* 72:393–407.

Humphries, P. 2007 Historical Indigenous use of aquatic resources in Australia's Murray-Darling Basin, and its implications for river management. *Ecological Management and Restoration* 8(2):106–113.

Humphries, P., A.J. King and J.D. Koehn 1999 Fish, flows and flood plains: Links between freshwater fishes and their environment in the Murray-Darling river system, Australia. *Environmental Biology of Fishes* 56:129–151.

Hynes, R.A. and A.K. Chase 1982 Plants, sites and domiculture: Aboriginal influence upon plant communities in Cape York Peninsula. *Archaeology in Oceania* 17(1):38–50.

Incerti, G.L. 2018 An Analysis of Surface Lithics at Calperum Station, Riverland, South Australia. Unpublished Masters thesis, Department of Archaeology, Flinders University of South Australia, Adelaide.

Ingold, T. 1993 The temporality of the landscape. *World archaeology* 25(2):152–174.

Jennings, J.T. 2009 *Natural history of the Riverland and Murraylands*. Adelaide: Royal Society of South Australia.

Jensen, A.E. and K.F. Walker 2017 Sustaining recovery in red gum, black box and lignum in the Murray River valley: clues from natural phenological cycles to guide environmental watering. *Transactions of the Royal Society of South Australia* 141(2):209–229.

Jochim, M.A. 1988 Optimal foraging and the division of labor. *American Anthropologist* 90(1):130–136.

Jochim, M.A. 1998 *A Hunter-Gatherer landscape: southwest Germany in the Late Paleolithic and Mesolithic*. New York: Springer Science+Business Media.

Johnson, C.N. and B.W. Brook 2011 Reconstructing the dynamics of ancient human populations from radiocarbon dates: 10 000 years of population growth in Australia. *Proceedings of the Royal Society of Britain* 278:3748–3754.

Johnston, H. 1990 The Dareton Aboriginal Shell Midden. Unpublished report prepared for Victoria Roads and Traffic Authority.

- Johnston, H. 1993 Pleistocene shell middens of the Willandra Lakes. In M.A. Smith, M. Spriggs and B. Frankhauser (eds), *Sahul in Review: Pleistocene Archaeology in Australia, New Guinea and Island Melanesia*, pp.197–203. Canberra: Department of Prehistory, Research School of Pacific Studies, Australian National University.
- Jones, E. 2006 Prey choice, mass collecting, and the wild European rabbit (*Oryctolagus cuniculus*). *Journal of Anthropological Archaeology* 25:275–289.
- Jones, E.L. 2016a *In search of the Broad Spectrum Revolution in Paleolithic southwest Europe*. Springer Briefs in Archaeology. New York: Springer.
- Jones, R. 2016b Plains, Plants and Planning: An Analysis of Indigenous Earth Mounds at Calperum Nature Reserve, South Australia. Unpublished MA thesis, Department of Archaeology, Flinders University, Adelaide.
- Jones, R., M. Morrison, A. Roberts and River Murray and Mallee Aboriginal Corporation 2017 An analysis of Indigenous earth mounds on the Calperum Floodplain, Riverland, South Australia. *Journal of the Anthropological Society of South Australia* 41:18–62.
- Jones, R., A. Roberts, C. Westell, I. Moffat, G. Jacobsen, R. Rudd and River Murray and Mallee Aboriginal Corporation 2022 Aboriginal earth mounds of the Calperum Floodplain (Murray Darling Basin, South Australia): New radiocarbon dates, sediment analyses and syntheses, and implications for behavioural change. *The Holocene*. doi: <https://doi.org/10.1177/09596836221095981>.
- Jones, R.N., T.A. MacMahon and J.M. Bowler 1998 A high resolution Holocene record of P/E ratio from closed lakes, western Victoria. *Palaeoclimates* 3:51–82.
- Jouzel, J., C. Lorius and L. Merlivat 1985 Abrupt climatic change: the Antarctic ice record during the late Pleistocene. In W.H. Berger and L.D. Labeyrie (eds), *Abrupt climatic change : evidence and implications*, Dordrecht, Netherlands ;: Kluwer Academic Publishers.
- Junk, W.J., P. Bayley and R.E. Sparks 1989 The flood pulse concept in river-floodplain systems. *Canadian Special Publication of Fisheries and Aquatic Sciences* 106:110–127.
- Kalish, J.M., G.H. Miller, C. Tuniz, J.C. Pritchard, A. Rosewater and E. Lawson 1997 *Otoliths as records of palaeoenvironments: Comparison of radiocarbon age and isoleucine*

epimerization in Pleistocene golden perch Macquaria ambigua otoliths from Willandra Lakes. Sixth Australasian Archaeometry Conference handbook, Australian Museum, Sydney, 10-13 February 1997.

Karkanis, P. 2010 Preservation of anthropogenic materials under different geochemical processes: A mineralogical approach. *Quaternary International* 214:63–69.

Kefous, K. 1981 The chronology of the Lake Victoria lunette—Some recent evidence. *Australian Archaeology* 13:8–11.

Kefous, K. 1982 Prehistoric site patterning in the Victorian Mallee. *Archaeology in Oceania* 17(2):98–99.

Kefous, K. 1983 Riverain: water availability and Aboriginal prehistory of the Murray River, Lake Victoria area, western New South Wales. Unpublished MA thesis, Australian National University, Canberra.

Kelly, D. 2014 Archaeology of Aboriginal fish traps in the Murray-Darling Basin, Australia. Unpublished MA thesis, School of Environmental Sciences, Charles Sturt University, Wagga Wagga.

Kelly, R.L. 1995 *The foraging spectrum: diversity in Hunter–Gatherer lifeways*. Washington: Smithsonian Institution Press.

Kemp, J. 2001 The Hydrology, Geomorphology and Quaternary Palaeochannels of the Lachlan Valley, New South Wales. Unpublished PhD thesis, Australian National University, Canberra.

Kemp, J., T. Pietsch, A. Gontz and J. Ollet 2017 Lacustrine-fluvial interactions in Australia's riverine plains. *Quaternary Science Reviews* 166:352–362.

Kemp, J., L.C. Radke, J. Olley, S. Juggins and P.D. Deckker 2012 Holocene lake salinity changes in the Wimmera, southeastern Australia, provide evidence for millennial-scale climate variability. *Quaternary Research* 77:65–76.

Kemp, J. and E. Rhodes 2010 Episodic fluvial activity of inland rivers in southeastern Australia: Palaeochannel systems and terraces of the Lachlan River. *Quaternary Science Reviews*

29(5-6):732–752.

- Kemp, J. and N.A. Spooner 2007 Evidence for regionally wet conditions before the LGM in southeast Australia: OSL ages from a large palaeochannel in the Lachlan Valley. *Journal of Quaternary Science* 22(5):423–427.
- Kent, S. 1989 *Farmers as hunters: the implications of sedentism*. Cambridge: Cambridge University Press.
- Kenyon, A.S. 1912 Camping place of the Aborigines of south east Australia. *Victorian Historical Magazine* 7(2):97–110.
- Kershaw, A.P. 1995 Environmental change in greater Australia. *Antiquity* 69:656–675.
- Kershaw, A.P., Australian Heritage Commission and Monash University Centre for Palynology and Palaeoecology 1993 *Identification, classification and evaluation of peatlands in Victoria*. Clayton (Victoria): Dept. of Geography and Environmental Science, Monash University.
- Kershaw, A.P., J. Tibby, D. Penny, H. Yezdani, R. Walkley, E.J. Cook and R. Johnston 2004 Late Pleistocene and Holocene vegetation and environmental history of the Western Plains of Victoria, Australia. *Proceedings of the Royal Society of Victoria* 116(1):139–161.
- Kibblewhite, M., G. Tóth and T. Hermann 2015 Predicting the preservation of cultural artefacts and buried materials in soil. *Science of the Total Environment* 529(2015):249–263.
- Kimber, R.G. 1969 Ngarkat: An extinct tribe of mallee Aborigines. *Journal of the Anthropological Society of South Australia* 7(6):2–5.
- King, A.J., P. Humphries and P.S. Lake 2003 Fish recruitment on floodplains: the roles of patterns of flooding and life history characteristics. *Journal of Fisheries and Aquatic Sciences* 60:773–786.
- King, H.M. nd The "Acid Test" for carbonate minerals and carbonate rocks. Accessed 14/08/2020 from <<https://geology.com/minerals/acid-test.shtml>>.
- Kingsford, R.T. 2000 Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia. *Austral Ecology* 25:109–127.

- Klaver, J.M. 1998 Late Holocene occupation of the central Murrumbidgee riverine plain.
Unpublished PhD thesis, Department of Archaeology and Anthropology, Australian National University, Canberra.
- Knight, R.D., B.A. Kjarsgaard and H.A.J. Russell 2021 An analytical protocol for determining the elemental chemistry of Quaternary sediments using a portable X-ray fluorescence spectrometer. *Applied Geochemistry* 131:1–15.
- Kotsonis, A., K.J. Cameron, J.M. Bowler and E.B. Joyce 1999 Geomorphology of the Hattah Lakes region on the River Murray, south-eastern Australia: A record of late Quaternary climate change. *Proceedings of the Royal Society of Victoria* 111(1):27–42.
- Kreff, G. 1865 On the manner and customs of the aborigines of the Lower Murray and Darling. *Transactions of the Philosophical Society of New South Wales* 1862–65:61–78.
- Kreutzer, S., C. Burrow, M. Dietze, M.C. Fuchs, C. Schmidt, M. Fischer and J. Friedrich 2018 Luminescence: Comprehensive Luminescence Dating Data Analysis: R package version 0.8.6. Accessed from <<https://CRAN.R-project.org/package=Luminescence>>.
- Kreutzer, S., C. Schmidt, M.C. Fuchs, M. Dietze, M. Fischer and M. Fuchs 2012 Introducing an R package for luminescence dating analysis. *Ancient TL* 30(1):1–8.
- Lake, S., N. Bond and P. Reich 2006 Floods down rivers: from damaging to replenishing forces. *Advances in Ecological Research* 39:41–62.
- Laland, K.N. and M.J. O'Brien 2010 Niche Construction Theory and archaeology. *Journal of Archaeological Method and Theory* 17:303–322.
- Lance, A. 1993 A Study of Two Aboriginal Shell Midden Sites, Gol Gol New South Wales.
Unpublished report prepared for NSW Public Works Department.
- Larsen, C.S. 2006 The agricultural revolution as environmental catastrophe: Implications for health and lifestyle in the Holocene. *Quaternary International* 150:12–20.
- Latham, K.J. 2013 Human health and the Neolithic Revolution: An review of impacts of the agricultural transition on oral health, epidemiology, and the human body. *Nebraska Anthropologist* 187:95–102.

- Lawrence, C.R. 1966 Cainozoic stratigraphy and sturcture of the Mallee Region, Victoria.
Proceedings of the Royal Society of Victoria 79(2):517–554.
- Leigh, C., F. Sheldon, R.T. Kingsford and A.H. Arthington 2010a Sequential floods drive ‘booms’ and wetland persistence in dryland rivers: A synthesis. *Marine and Freshwater Research* 61:896–908.
- Leigh, S.J., S.L. Gehrig, P.J. Wilson, B.P. Zampatti and J.M. Nicol 2010b Intervention monitoring of fish and fish habitats witihin Katarapko Anabranh system ('Katfish' Demonstration Reach): Before intervention surveys 2010 and 2011. SARDI Research Report Series No. 634. SARDI Publication No. F2010/000994-2 Adelaide: SARDI.
- Lenehan, R. 1998 The Repatriation of Aboriginal Cultural Artefacts: a viable option? Unpublished PhD thesis, Department of Archaeology, Flinders Univeristy, Adelaide.
- Leslie, D.J. 2001 Effect of river management oncolonially-nesting waterbirds in the Barmah-Millewa Forest, south eastern Australia. *Regulated Rivers: Research & Management* 17:21–36.
- Lilley, I. 2008 Apocalypse Now (and avoid the rush): human dimensions of climate chnage in the Indo-Pacific. *Archaeology in Oceania* 43(1):35–40.
- Linford, N.T. and M.G. Cant 2001 Geophysical evidence for fires in Antiquity: Preliminary Results from an Experimental Study. *Archaeological Prospection* 8:211–225.
- Linn, R. 1995 Calperum Station: oral history project. Unpublished report prepared for Australian Nature Conservation Agency.
- Lisiecki, L.E. and M.E. Raymo 2005 A Pliocene-Pleistocene stack of 57 globally distributed benthic $\delta^{18}\text{O}$ records. *Paleoceanography* 20(1).
- Littleton, J. 1999 East and west: burial practices along the Murray River. *Archaeology in Oceania* 34:1–14.
- Littleton, J. 2002 Mortuary practices on the Hay Plain: Do cemeteries exist? *Archaeology in Oceania* 37:105–122.
- Littleton, J. 2007 Time and memory: historic accounts of Aboriginal burials in south-eastern

Australia. *Aboriginal History* 31:103–121.

Littleton, J. and H. Allen 2007 Hunter-gatherer burials and the creation of persistent places in southeastern Australia. *Journal of Anthropological Archaeology* 26:283–298.

Littleton, J. and H. Allen 2020 Monumental landscapes and the agency of the dead along the Murray River, Australia. *World archaeology* 52(1):120-132.

Littleton, J., F. Petchey, K. Walshe and F.D. Pate 2017 A preliminary redating of the Holocene Roonka burials, south-eastern Australia. *Archaeology in Oceania* 52(2):98–107.

Littleton, J., R. Scott, G. McFarlane and K. Walshe 2013 Hunter-gatherer variability: Dental wear in South Australia. *American Journal of Physical Anthropology* 152:273–286.

Lomax, J., A. Hilgers and U. Radtke 2011 Palaeoenvironmental change recorded in the palaeodunefields of the western Murray Basin, South Australia, new data from single grain OSL-dating. *Quaternary Science Reviews* 30:723–736.

Long, K., N. Stern, I.S. Williams, L. Kinsley, R. Wood, K. Sporcica, T. Smith, S. Fallon, H. Kokkonen, I. Moffat and R. Grun 2014 Fish otolith geochemistry, environmental conditions and human occupation at Lake Mungo, Australia. *Quaternary Science Reviews* 88:82–95.

Lourandos, H. 1983 Intensification: a Late Pleistocene - Holocene archaeological sequence from southwest Victoria. *Archaeology in Oceania* 18(2):81–94.

Lourandos, H. 1985 Intensification and Australian prehistory. In T. Price and J. Brown (eds), *Prehistoric Hunter-Gatherers: The Emergence of Complexity*, pp.385–414. London: Academic Press.

Lourandos, H. 1988 Palaeopolitics: Resource intensification in Aboriginal Australia and Papua New Guinea. In T. Ingold, D. Riches and J. Woodburn (eds), *Hunters and Gatherers 1: History, Evolution and Social Change*, pp.148–160. Oxford: Berg.

Lourandos, H. 1997 *Continent of Hunter-gatherers. New Perspectives in Australian Prehistory*. Cambridge: Cambridge University Press.

Lourandos, H. 2016 Constructing 'Hunter Gatherers', constructing 'Prehistory': Australia and New Guinea. *Australian Archaeology* 67:69–78.

- Lourandos, H. and A. Ross 1994 The great 'Intensification Debate': Its history and place in Australian archaeology. *Australian Archaeology* 39:54–63.
- Luebbers, R.A. 1989a An Archaeological Assessment of impacts associated with the Woolpunda Groundwater Interception Scheme. Unpublished report prepared for Engineering and Water Supply Department.
- Luebbers, R.A. 1989b An Archaeological Survey of the Woolpunda Salt Interception Scheme: A report on the Evaporation Basin and Well Heads. Unpublished report prepared for Engineering and Water Supply Department.
- Luebbers, R.A. 1995 An Archaeological Survey of Karadoc Swamp Northwest Victoria. Unpublished report prepared for Mildura Aboriginal Corporation.
- Luebbers, R.A. and I. Ellender 1991 An Assessment of Archaeological Aboriginal Sites in the Northwest of Victoria. Unpublished report prepared for Victorian Archaeological Survey, Melbourne.
- Luly, J.G. 1993 Holocene palaeo-environments near Lake Tyrell, semi-arid northwestern Victoria, Australia. *Journal of Biogeography* 20:587–598.
- Mackay, N. and D. Eastburn 1990 *The Murray*. Canberra: Murray Darling Basin Commission.
- Macumber, P.G. 1991 *Interaction between groundwater and surface systems in northern Victoria*. Melbourne: Department of Conservation and Environment.
- Magee, J.W. 1991 Late Quaternary lacustrine, groundwater, aeolian and pedogenic gypsum in the Prungle Lakes, southeastern Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 84:3–42.
- Magee, J.W., G.H. Miller, N.A. Spooner and D. Questiaux 2004 Continuous 150 k.y. monsoon record from Lake Eyre, Australia: Insolation-forcing implications and unexpected Holocene failure. *Geology* 32(40):885–888.
- Maggiano, I.S., S. Schultz, H. Kierdorf, T.S. Sosa, C.M. Maggiano and V.T. Blos 2008 Cross-sectional analysis of long bones, occupational activities and long-distance trade of the classic Maya from Xcambo': archaeological and osteological evidence. *American Journal of Physical*

Anthropology 136:470–477.

Marshall, L.G. 1973 Fossil vertebrate faunas from the Lake Vicotria region, S.W. New South Wales, Australia. *Memoirs of the National Museum of Victoria* 34:151–172.

Marshall, Y. 2006 Introduction: Adopting a sedentary lifeway. *World Archaeology* 38(2):153–163.

Martin, S. 2006 Inscribing the plains: Constructed, conceptualized and socialized landscapes of the Hay Plain, south eastern Australia. Unpublished PhD thesis, University of New England, Armidale.

Martin, S. 2010 Archaeological research, characterisation and predictive modelling project. Part of the recording of Aboriginal use and values on the Lowbidgee and Lower Lachlan Rivers wetlands under the NSW Rivers Environmental Restoration Program (RERP). Unpublished report prepared for NSW Department of Environment, Climate Change & Water.

Martin, S. 2011 Palaeoecological evidence associated with earth mounds of the Murray Riverine Plain, south-eastern Australia. *Environmental Archaeology* 16(2):162–172.

Marx, S.K., H.A. McGowan and B.S. Kamber 2009 Long-range dust transport from eastern Australia: A proxy for Holocene aridity and ENSO-type climate variability. *Earth and Planetary Science Letters* 282:167–177.

May, J.-H., S.G. Wells, T.J. Cohen, S.K. Marx, G.C. Nanson and S.E. Baker 2015 A soil chronosequence on Lake Mega-Frome beach ridges and its implications for late Quaternary pedogenesis and paleoenvironmental conditions in the drylands of southern Australia. *Quaternary Research* 83(2015):150–165.

McEntee, C.M. 1945 The Aborigines of the Peake-Lameroo district. *Proceedings of the Royal Geographical Society of South Australia* 46:49–54.

McGlone, M.S., A.P. Kershaw and V. Markgraf 1992 El Niño/Southern Oscillation climatic variability in Australasia and South America palaeoenvironmental records. In H.F. Diaz and V. Markgraf (eds), *El Niño: Historical and Paleoclimatic Aspects of the Southern Oscillation*, pp.435–462. Cambridge: Cambridge University Press.

McGowan, H.A., S.K. Marx, J. Denholm, J. Soderholm and B.S. Kamber 2009 Reconstructing annual

inflows to the headwater catchments of the Murray River, Australia, using the Pacific Decadal Oscillation. *Geophysical Research Letters* 36(6):L06707.

McLaren, S., M.W. Wallace and T. Reynolds 2011 The Late Pleistocene evolution of palaeo megalake Bungunna, southeastern Australia: a sedimentary record of fluctuating lake dynamics, climate change and the formation of the modern Murray River. *Quaternary Science Reviews* 30:1086–1111.

McNiven, I.J., B. David and B. Barker 2006 The social archaeology of Indigenous Australia. In I.J. McNiven (ed.), *Social Archaeology of Australian Indigenous Societies*, pp.2–19. Canberra: Aboriginal Studies Press.

McPherson, A., D. Clark, M. Cupper, C.D.N. Collins and G. Nelson 2012 The Cadell Fault: A record of long-term fault behaviour in south-eastern Australia. Paper presented to the Australian Regolith and Clays Conference, Mildura, Victoria, 7-10 February 2012.

Meehan, B. 1982 *Shell bed to shell midden*. Canberra: Australian Institute of Aboriginal Studies.

Mellet, C.L. 2013 Luminescence dating. In C.L. E (ed.), *Geomorphological techniques (online edition)*, pp.1–11. London: British Society for Geomorphology.

Millard, A.R. 2014 Conventions for reporting radiocarbon determinations. *Radiocarbon* 56(2):555–559.

Miller, G.H., J.W. Magee and A.J.T. Jull 1997 Low-latitude glacial cooling in the Southern Hemisphere from amino-acid racemisation in emu eggshells. *Nature* 385:241–244.

Mills, B.J. and M.C. Geddes 1980 Salinity tolerance and osmoregulation of the Australian Freshwater Crayfish *Cherax destructor*. *Australian Journal of Freshwater Research* 31:667–676.

Mills, K., P. Gell, P.P. Hesse, R. Jones, P. Kershaw, R. Drysdale and J. McDonald 2013 Paleoclimate studies and natural-resource management in the Murray-Darling Basin I: Past, present and future. *Australian Journal of Earth Sciences* 60:547–560.

Mitchell, T.L. 1839 *Three expeditions into the Interior of Eastern Australia, with descriptions of the recently explored region of Australia Felix, and of the present colony of New South Wales*, 2

volumes. London: T. & W. Boone.

- Mittag, U., A. Kriechbaumer, M. Bartsch and J. Rittweger 2015 Form follows function: A computational simulation exercise on bone shape forming and conservation. *Journal Musculoskelet Neuronal Interact* 15(2):215–226.
- Mojtahid, M., E. Michel and P.D. Decker 2020 From “source to sink” – A new perspective on the past dynamics of the Murray Canyon Group from benthic foraminiferal communities. *Marine Micropaleontology* 160:101877.
- Montazeri, M. and D. McCullough 2016 SARFIIP – Pike floodplain hydraulic modelling: Natural, current and basin plan flow scenarios, DEWNR Technical Note 2016/03. Adelaide: Department of Environment, Water and Natural Resources (DEWNR).
- Moorehouse, M. 1841 'Fatal recontre with the Murray natives', *South Australian Register* 11 September 1841 p.2.
- Morgan, C. 2015 Is it intensification yet? Current archaeological perspectives on the evolution of hunter-gatherer economies. *Journal of Archaeological Research* 23:163–213.
- Morrison, M. 2013 Niche production strategies and shell matrix site variability at Albatross Bay, Cape York Peninsula. *Archaeology in Oceania* 48(2):78–91.
- Mueller, D., Z. Jacobs, T.J. Cohen, D.M. Price, I.V. Reinfelds and J. Shulmeister 2018 Revisiting an arid LGM using fluvial archives: A luminescence chronology for palaeochannels of the Murrumbidgee River, south-eastern Australia. *Journal of Quaternary Science* 2018:1–17.
- Mulvaney, D.J. 1960 Archaeological excavations at Fromm's Landing on the lower Murray River, South Australia. *Proceedings of the Royal Society of Victoria* 72(2):53–86.
- Mulvaney, D.J. 1999 *Prehistory of Australia*. St Leonards, NSW: Allen & Unwin.
- Mulvaney, D.J., G.H. Lawton and C.R. Twidale 1964 Archaeological excavations of Rock Shelter No. 6 Fromm's Landing, South Australia. *Proceedings of the Royal Society of Victoria* 77(2):479–520.
- Munro, N.D. 2003 Small game, the younger dryas, and the transition to agriculture in the southern Levant. *Mitteilungen der Gesellschaft für Urgeschichte* 12:47–71.

- Munro, N.D. 2004 Small game indicators of human foraging efficiency and early herd management at the transition to agriculture in south-west Asia. In J. Brugal and J. Desse (eds), *Petits animaux et sociétés humaines: du complément alimentaire aux ressources utilitaires*, pp.515–531. Sophia Antipolis: CEPAM, CNRS.
- Munro, N.D. 2009 Epipaleolithic subsistence intensification in the southern Levant: the faunal evidence. In J.J. Hublin and M.P. Richards (eds), *The Evolution of Hominin Diets: Integrating Approaches to the Study of Palaeolithic Subsistence*, pp.141–155. Dordrecht: Springer Science and Business Media.
- Munt, S.D. 2022 Use-wear analysis of Aboriginal flaked stone, glass and porcelain from Calperum Station, South Australia. Unpublished PhD thesis, College of Arts, Humanities and Social Sciences, Flinders University of South Australia, Adelaide.
- Murray Darling Basin Authority (MDBA) 2012 Assessment of environmental water requirements for the proposed Basin Plan: Lower River Murray (in-channel flows). Publication No. 46/12 Canberra: Murray Darling Basin Authority.
- Murray Darling Basin Authority (MDBA) 2020 Where is the Murray-Darling Basin. Accessed 1/10/2020 from <<https://www.mdba.gov.au/discover-basin/landscape/geography>>.
- Nanson, G.C. 1986 Episodes of vertical accretion and catastrophic stripping: a model of disequilibrium floodplain development. *Geological Society of America Bulletin* 97(12):1467–1475.
- Nanson, G.C. and J.B. Croke 1992 A genetic classification of floodplains. *Geomorphology* 4:459–486.
- Newall, P., L. Lloyd, P. Gell and K. Walker 2008 Riverland Ramsar Site ecological character description. Unpublished report prepared for South Australian Department of Environment and Heritage.
- Nicholson, A. and V. Wood 1993 From the Ranges to the Riverland: An archaeological study of a proposed gas pipeline route from Angaston to Renmark, Loxton and Berri, and to Murray Bridge, South Australia. Unpublished report prepared for Kinhill Engineers Pty Ltd. and the Pipeline Authority of South Australia.

- Nikita, E., Y.Y. Siew, J. Stock, D. Mattingly and M.M. Lahir 2011 Activity patterns in the Sahara Desert: An interpretation based on cross-sectional geometric properties. *American Journal of Physical Anthropology* 146:423–434.
- Nott, W. 1924 *When I was a Boy, Moorundee, River Murray*. [Unpublished manuscript]. Adelaide: SA Museum. AA238/01.
- O'Connell, J.F. and J. Allen 2004 Dating the colonization of Sahul (Pleistocene Australia-New Guinea): A review of recent research. *Journal of Archaeological Science* 31:835–853.
- O'Connell, J.F. and J. Allen 2015 The process, biotic impact, and global implications of the human colonization of Sahul about 47,000 years ago. *Journal of archaeological science* 56:73–84.
- O'Connell, J.F., J. Allen, M.A.J. Williams, A.N. Williams, C.S.M. Turney, N.A. Spooner, J. Kamminga, G. Brown and A. Cooper 2018 When did Homo sapiens first reach Southeast Asia and Sahul? *Proceedings of the National Academy of Sciences, USA* 115(34):8482–8490.
- O'Halloran, C. and D.H.R. Spennemann 2002 Wave action impact on archaeological sites in a freshwater reservoir: The case of Lake Hume, New South Wales. *Australian Archaeology* 54(1):6–12.
- O'Halloran, T. 1904 From Adelaide along the River Murray to the Rufus and Lake Victoria. *Proceedings of the Royal Geographical Society of Australasia: South Australian Branch* 7:70–91.
- Odling-Smee, F.J., K.N. Laland and M.W. Feldman 2003 *Niche Construction: The neglected process in evolution*. Monographs in Population Biology. Princeton and Oxford: Princeton University Press.
- Ogden, R., N. Spooner, M. Reid and J. Head 2001 Sediment dates with implications for the age of the conversion from palaeochannel to modern fluvial activity on the Murray River and tributaries. *Quaternary International* 83:195–209.
- Overton, I.C., K. McEwan and J.R. Sherrah 2006 The River Murray floodplain inundation model - Hume Dam to lower lakes, CSIRO water for a healthy country Technical Report 2006. Canberra: CSIRO.

- Page, K.J. 1994 Late Quaternary Stratigraphy and Chronology of the Riverine Plain, Southeastern Australia. Unpublished PhD thesis, Department of Geography, University of Wollongong, Wollongong.
- Page, K.J., A.J. Dare-Edwards, J.W. Owens, P.S. Frazier, J. Kellett and D.M. Price 2001 TL chronology and stratigraphy of riverine source bordering sand dunes near Wagga Wagga, New South Wales, Australia. *Quaternary International* 83-85:187–193.
- Page, K.J., J. Kemp and G. Nanson 2009 Late Quaternary evolution of Riverine Plain paleochannels, south-eastern Australia. *Australian Journal of Earth Sciences* 56(Supplement 1):19–33.
- Page, K.J. and G. Nanson 1996 Stratigraphic architecture resulting from Late Quaternary evolution of the Riverine Plain, south-eastern Australia. *Sedimentology* 43(6):927–945.
- Page, K.J., G. Nanson and D.M. Price 1991 Thermoluminescence chronology of late Quaternary deposition on the Riverine Plain of south-eastern Australia. *Australian Geographer* 22:14–23.
- Page, K.J., G. Nanson and D.M. Price 1996 Chronology of Murrumbidgee River palaeochannels on the Riverine Plain, south-eastern Australia. *Journal of Quaternary Science* 11(4):311–326.
- Pain, C.F., J.D.A. Clarke and V.N.L. Wong 2011 Applied geomorphic mapping for land management in the River Murray corridor, SE Australia. In M.J. Smith, P. Paron and J.S. Griffiths (eds), *Developments in Earth Surface Processes (Volume 15)*, pp.489–505. Oxford: Elsevier.
- Papathanasiou, A. 2005 Health status of the Neolithic population of Alepotrypa Cave, Greece. *American Journal of Physical Anthropology* 126:377–390.
- Pardoe, C. 1988a The cemetery as symbol: The distribution of Aboriginal burial grounds in southeastern Australia. *Archaeology in Oceania* 23(1):1–16.
- Pardoe, C. 1988b The Mallee Cliffs Burial (central River Murray) and population based archaeology. *Australian Archaeology* 27:45–62.
- Pardoe, C. 1988c *Prehistoric Aboriginal cemeteries of the River Murray: a report on the study of burial locations in south-east Australia*. Canberra: Australian Institute of Aboriginal Studies.
- Pardoe, C. 1993a The Pleistocene is still with us: Analytical constraints and possibilities for the

study of ancient human remains in archaeology. In M.A. Smith, M. Spriggs and B. Frankhauser (eds), *Sahul in Review: Pleistocene Archaeology in Australia, New Guinea and Island Melanesia*, pp.183–196. Canberra: Department of Prehistory, Australian National University.

Pardoe, C. 1993b Wamba yadu, a later Holocene cemetery of the central River Murray. *Archaeology in Oceania* 28:227–234.

Pardoe, C. 1994 Bioscapes: the evolutionary landscape of Australia. *Archaeology in Oceania* 29:182–190.

Pardoe, C. 1995 Riverine, biological and cultural evolution in southeastern Australia. *Antiquity* 69:696–713.

Pardoe, C. 2003 The Menindee Lakes: a regional archaeology. *Australian Archaeology* 57:42–53.

Pardoe, C. 2010 Global human variation : polarised positions and alternative perspectives. *Before Farming* 2010(3):133–153.

Pardoe, C. 2015 Grinding Stones of the Lachlan River: Archaeological studies along the Lachlan River: Condobolin, Lake Cargelligo, West Wyalong and Hillston regions. [Pamphlet] Canberra: Colin Pardoe Bio-Anthropology & Archaeology.

Pardoe, C., R. Fullagar and E. Hayes 2019 Quandong stones: A specialised Australian nutcracking tool. *PLoS ONE* 14(10).

Pardoe, C. and S. Martin 2001 Murrumbidgee province Aboriginal cultural heritage study. Unpublished report prepared for New South Wales National parks and Wildlife Service and Aboriginal Communities of the Region.

Pate, F.D. 1995a Palaeodietary inferences from bone collagen stable carbon isotopes at Roonka Flat, South Australia. *Australian Archaeology* 40:57.

Pate, F.D. 1995b Stable carbon isotope assessment of hunter-gatherer mobility in prehistoric South Australia. *Journal of Archaeological Science* 22:81–87.

Pate, F.D. 1997 Bone chemistry and paleodiet: Reconstructing prehistoric subsistence-settlement systems in Australia. *Journal of Anthropological Archaeology* 16:103–120.

- Pate, F.D. 1998 Bone collagen stable nitrogen and carbon isotopes as indicators of past human diet and landscape use in southeastern South Australia. *Australian Archaeology* 46:23–29.
- Pate, F.D. 2000 Bone chemistry and palaeodiet: bioarchaeological research at Roonka Flat, lower Murray River, South Australia 1983-1999. *Australian Archaeology* 50:67–74.
- Pate, F.D. 2006 Hunter-gatherer social complexity at Roonka Flat, South Australia. In B. David, B. Barker and I.J. McNiven (eds), *Social Archaeology of Australian Indigenous Societies*, pp.226–241. Canberra: Aboriginal Studies Press.
- Pate, F.D. 2017 Diet, mobility and subsistence-settlement systems in the late Holocene lower Murray River Basin of South Australia: Testing models of Aboriginal seasonal mobility and sedentism with isotopic and archaeological data. *Journal of the Anthropological Society of South Australia* 41:123–171.
- Pate, F.D., R. Brodie and T.D. Owen 2002 Determination of geographic origin of unprovenanced Aboriginal skeletal remains in South Australia employing stable carbon and nitrogen isotope analysis. *Australian Archaeology* 55:1–7.
- Pate, F.D. and T.D. Owen 2014 Stable carbon and nitrogen isotopes as indicators of sedentism and territoriality in late Holocene South Australia. *Archaeology in Oceania* 49:86–94.
- Pate, F.D., G.L. Pretty, R. Hunter, C. Tuniz and E.M. Lawson 1998 New radiocarbon dates for the Roonka Flat Aboriginal burial ground, South Australia. *Australian Archaeology* 46:36–37.
- Paton, R.C. 1983 An analysis of Aboriginal subsistence in the lower Murray District, South Australia. Unpublished Honours thesis, Department of Prehistory and Anthropology, Australian National University, Canberra.
- Pedro, J.B., H.C. Bostock, C.M. Bitz, F. He, M.J. Vandergoes, E.J. Steig, B.M. Chase, C.E. Krause, S.O. Rasmussen, B.R. Markle and G. Cortese 2015 The spatial extent and dynamics of the Antarctic Cold Reversal. *Nature Geoscience* 9(January 2016).
- Pell, S.D., A.R. Chivas and I.S. Williams 2001 The mallee dunefield: Development and sand provenance. *Journal of Arid Environments* 48:149–170.
- Pels, S. 1964 The present and ancestral Murray River. *Australian Geographical Studies* 2:111–119.

- Pels, S. 1966 Late Quaternary chronology of the riverine plain of southeastern Australia. *Journal of the Geological Society of Australia* 13:27–40.
- Pels, S. 1971 River systems and climatic changes in southeastem Australia. In D.J. Mulvaney and J. Golson (eds), *Aboriginal Man and Environment in Australia*, pp.38–46. Canberra: Australian National University Press.
- Petherick, L., H. Bostock, T.J. Cohen, K.E. Fitzsimmons, J. Tibby, M.S. Fletcher, P. Moss, J. Reeves, S. Mooney, T. Barrows, J. Kemp, J. Jansen, G. Nanson and A. Dosseto 2013 Climatic records over the past 30 ka from temperate Australia - A synthesis from the Oz-INTIMATE workgroup. *Quaternary Science Reviews* 74:58–77.
- Petherick, L., H. McGowan and P. Moss 2008 Climate variability during the Last Glacial Maximum in eastern Australia: evidence of two stadials? *Journal of Quaternary Science* 23(8):787–802.
- Phipps, L.A. 1999 Ecological responses to wetland flow regime management in the Riverland, South Australia. Unpublished Bachelor of Environmental Management thesis, School of Geography, Faculty of Social Science, Flinders University, South Australia.
- Phoca-Cosmetatou, N. 2003 Subsistence changes during the Late Glacial? The example of ibex exploitation in southern europe. In M. Patou-Mathis and H. H Bocherens (eds), *Le rôle de l'environnement dans les comportements des chasseurs-cueilleurs préhistoriques*, pp.39–54. Oxford: British Archeological Reports.
- Pietsch, T.J., G.C. Nanson and J.M. Olley 2013 Late Quaternary changes in flow-regime on the Gwydir distributive fluvial system, southeastern Australia. *Quaternary Science Reviews* 69(2013):168–180.
- Pike, D. 1965 The diary of John Coutts Crawford: extracts on Aborigines and Adelaide, 1839 and 1841. *South Australiana* 4(1):3–15.
- Poff, N.L., J.D. Allan, M. BAin, J.R. KArr and L.L. Prestegard 1997 The natural flow regime: a paradigm for river conservation and restoration. *BioScience* 47:769–784.
- Polach, H.A., M.J. Head and J.D. Gower 1978 ANU radiocarbon date list VI. *Radiocarbon* 20(3):360–385.

- Prendergast, A.L., J.M. Bowler and M.L. Cupper 2009 Late Quaternary environments and human occupation in the Murray River Valley of northwestern Victoria. In A. Fairbairn, S. O'Connor and B. Marwick (eds), *New Directions in Archaeological Science*, pp.55–76. Terra Australis 28 Canberra: ANU E Press.
- Prescott, J.R. and J.T. Hutton 1994 Cosmic ray contribution to dose rates from luminescence and ESR dating: large depths and long-term variations. *Radiation Measurements* 23:497–500.
- Pretty, G.L. 1977a The cultural chronology of the Roonka Flat: A preliminary consideration. In R.V.S. Wright (ed.), *Stone tools as cultural markers*, pp.288–331. Canberra: Australian Institute of Aboriginal Studies.
- Pretty, G.L. 1977b *Ngaiawang folk province : preliminary inventory of the cultural landscape*. Adelaide: Anthropology and Archaeology Branch, South Australian Museum.
- Prokopec, M. 1979 Demographical and morphological aspects of the Roonka population. *Archaeology & Physical Anthropology in Oceania* 14(1):11–26.
- Quigley, M.C., T. Horton, J.C. Hellstrom, M.L. Cupper and M. Sandiford 2010 Holocene climate change in arid Australia from speleothem and alluvial records. *Holocene (Sevenoaks)* 20(7):1093–1104.
- Railsback, L.B., P.L. Gibbard, M.J. Head, N.R.G. Voarintsoa and S. Toucanne 2015 An optimized scheme of lettered marine isotope substages for the last 1.0 million years, and the climatostratigraphic nature of isotope stages and substages. *Quaternary Science Reviews* 111(C):94–106.
- Reeves, J.M., T.T. Barrows, T.J. Cohen, A.S. Kiem, H.C. Bostock, K.E. Fitzsimmons, J.D. Jansen, J. Kemp, C. Krause, L. Petherick, S.J. Phipps and O.I. Members 2013 Climate variability over the last 35,000 years recorded in marine and terrestrial archives in the Australian region: an OZ-INTIMATE compilation. *Quaternary Science Reviews* 74:21–34.
- Reid, J., A. Arthur and H. McGuinness 2009 Waterbirds. In I.C. Overton, M.J. Colloff, T.M. Doody, B. Henderson and S.M. Cuddy (eds), *Ecological outcomes of flow regimes in the Murray-Darling Basin. National Water Commission by CSIRO Water for a Healthy Country Flagship.*, pp.120–161. Canberra: CSIRO.

- Reid, M., S. Bickford, P. Gell and C. Kenyon 2016 A history of Australia's riverine habitats and vegetation. In S. Capon, C. James and M. Reid (eds), *Vegetation of Australian Riverine Landscapes: Biology, Ecology and Management*, pp.45–64. Canberra: CSIRO Publishing.
- Rhodes, E.J., P.C. Fanning, S.J. Holdaway and C. Bolton 2009 Archaeological surfaces in western NSW: Stratigraphic contexts and preliminary OSL dating of hearths. In A. Fairbairn, S. O'Connor and B. Marwick (eds), *New Directions in Archaeological Science*, pp.189–200. Terra Australis 28 Canberra: ANU E Press.
- Richards, T., C. Pavlides, K. Walshe, H. Webber and R. Johnston 2007 Box Gully: New evidence for Aboriginal occupation of Australia south of the Murray River prior to the last glacial maximum. *Archaeology in Oceania* 42(1):1–11.
- Richards, T. and H. Weber 2004 Lake Tyrrell Aboriginal Cultural Heritage School: A report on Activities of the Aboriginal Community Heritage Investigations Program. Melbourne: A.A. Victoria.
- Riley, S.J. 1988 Secular change in the annual flows of streams in the New South Wales section of the Murray-Darling Basin. In R.F. Warner (ed.), *Fluvial geomorphology of Australia*, pp.245–266. Sydney: Academic Press.
- Rillardon, M. and J. Brugal 2014 What about the Broad Spectrum Revolution? Subsistence strategy of hunter-gatherers in Southeast France between 20 and 8 ka BP. *Quaternary International* 337:129–153.
- Roberts, A., H. Burke, M. Tutty, C. Westell and The River Murray and Mallee Aboriginal Corporation 2021a From loop-holes to labour: Aboriginal connections to Calperum and Chowilla pastoral stations, South Australia. *Transactions of the Royal Society of South Australia* 145(2):218-241.
- Roberts, A., W. Duivenvoorde, M. Morrison, I. Moffat, H. Burke, J. Kowlessar and J. Naumann 2017 'They call 'im Crowie': an investigation of the Aboriginal significance attributed to a wrecked River Murray barge in South Australia. *The International journal of nautical archaeology* 46(1):132–148.
- Roberts, A., C. Morton, C. Westell, H. Burke, M. Morrison and River Murray and Mallee Aboriginal

- Corporation 2020 A report on a tektite (australite) artefact from Calperum Station in the western central River Murray region, South Australia. *Australian Archaeology* 86(1):75–79.
- Roberts, A., C. Westell, C. Wilson, M.C. Langley, River Murray and Mallee Aboriginal Corporation and Ngarrindjeri Aboriginal Corporation 2021b Aboriginal serrated and perforated shell artefacts from the Murray River, South Australia. *Archaeology in Oceania* n/a(n/a).
- Roberts, J. and F. Marston 2011 *Water regime for wetland and floodplain plants: a source book for the Murray–Darling Basin*. Canberra: National Water Commission.
- Roberts, R.G., R.F. Galbraith, H. Yoshida, G.M. Laslett and J.M. Olley 2000 Distinguishing dose populations in sediment mixtures: a test of single-grain optical dating procedures using mixtures of laboratory-dosed quartz. *Radiation measurements* 32(5):459–465.
- Robertson, G.B. and J.R. Prescott 2006 Luminescence dating at the archaeological and human burial site at Roonka, South Australia. *Quaternary Science Reviews* 25:2586–2593.
- Robertson, S. 2007 Sources of bias in the Murray Black collection: Implications for palaeopathological analysis. *Australian Aboriginal Studies* 2007(1):116–130.
- Robinson, G.A. and I.D. Clark 2000 *The Journals of George Augustus Robinson, Chief Protector, Port Phillip Aboriginal Protectorate, Volume Five: 25 October 1845 – 9 June 1849*. Melbourne: Heritage Matters.
- Robinson, R.J., N.J. Souter, N.G. Bean, J.V. Ross, R.M. Thompson and K.T. Bjornsson 2015 Statistical description of wetland hydrological connectivity to the River Murray in South Australia under both natural and regulated conditions. *Journal of Hydrology* 531:929–939.
- Rogers, K. and T.J. Ralph 2011 *Floodplain wetland biota in the Murray-Darling basin: water and habitat requirements*. Melbourne: CSIRO Publishing.
- Rogers, P.A. 1978 1:250,000 Geological Series Explanatory Notes: Chowilla South Australia Sheet SI/54-6 International Index. Adelaide: Geological Survey of South Australia.
- Rogers, P.A. 1990 Late Quaternary stratigraphy of the Roonka archaeological sites. *Quarterly Geological Notes, Geological Society of South Australia* 113:6–14.
- Rosen, A.M. and I. Rivera-Collazo 2012 Climate change, adaptive cycles, and the persistence of

foraging economies during the late Pleistocene/Holocene transition in the Levant. *PNAS* 109(10):3640–3645.

Ross, A. 1981 Holocene environments and prehistoric site patterning in the Victorian mallee. *Archaeology in Oceania* 16(3):145–155.

Ross, A. 1985 Archaeological evidence for population change in the middle to late Holocene in southeastern Australia. *Archaeology in Oceania* 20(3):81–89.

Ross, D. 2018 Archaeo-Geophysics – Mapping The Magnetic, Resistive and Electromagnetic Past: A geophysical study of Indigenous Earth Mounds at Calperum Nature Reserve, South Australia, Department of Archaeology, Flinders University, Adelaide.

Ross, D., M. Morrison, K. Simyrdanis, A. Roberts, I. Moffat and River Murray and Mallee Aboriginal Corporation 2019 A geophysical analysis of Aboriginal earth mounds in the Murray River Valley, South Australia. *Archaeological Prospection* 26:313–323.

Rowland, M.J. 1999 Holocene environmental variability: have its impacts been underestimated in Australian pre-History? *The Artefact* 22:11–48.

Roysland, D. 1977 *A pioneer family of the Murray River*. Adelaide: Rigby.

Ruff, C.S. 1987 Sexual dimorphism in human lower limb bone structure: relationship to subsistence strategy and sexual division of labor. *Journal of Human Evolution* 16:391–416.

Rural Solutions SA 2007 Reconnaissance Soil Survey Murray River National Park Eckert Creek (Katarapko). Unpublished report prepared for South Australian Department of Environment and Heritage.

Sagredo, E.A., M.R. Kaplan, P.S. Araya, T.V. Lowell, J.C. Aravena, P.I. Moreno, M.A. Kelly and J.M. Schaefer 2018 Trans-Pacific glacial response to the Antarctic Cold Reversal in the southern mid-latitudes. *Quaternary Science Reviews* 188(2018):160–166.

Satterthwait, L. 1987 Socioeconomic implications of Australian Aboriginal net hunting. *Man, New Series* 22(4):613–636.

Schell, T. 1914a 'Men of the River, Pioneers and Pathfinders: No. 2 - John Theodore Schell, An Old Man's Reminiscences (continued)', *Murray Pioneer and Australian River Record* Thursday 28

January 1914 p.7.

Schell, T. 1914b 'A vanished race: Interesting Native customs', *Murray Pioneer and Australian River Record* Tuesday 26 February 1914 p.6.

Schumm, S.A. 1981 Evolution and response of the fluvial system, sedimentologic implications. *Society of Economic Paleontologists and Mineralogists Special Publication* 31:19–29.

Scott, A. 2005 *Historical evidence of native fish in the Murray-Darling Basin at the time of European settlement—from the diaries of the first explorers*. Canberra: Cooperative Research Centre for Freshwater Ecology.

Selwood, K.E., R.H. Clarke, S.C. Cunningham, H. Lada, M.A. McGeoch and R.M. Nally 2015 A bust but no boom: Responses of floodplain bird assemblages during and after prolonged drought. *Journal of Animal Ecology* 84:1700–1710.

Shahack-Gross, R. 2017 Archaeological formation theory and geoarchaeology: State-of-the-art in 2016. *Journal of Archaeological Science* 79(2017):36-43.

Sharley, T. and C. Huggan 1995 *Chowilla Resource Management Plan*. Canberra: Murray Darling Basin Commission.

Simpson, H.A., M.A. Cane, A.L. Herczeg, S.E. Zebiak and J.H. Simpson 1993 Annual river discharges in southeastern Australia related to El Nino Southern Oscillation forecasts of sea surface temperatures. *Water Resources Research* 29:3671–3680.

Simpson, H.J. and A.L. Herczeg 1991 Salinity and evaporation in the River Murray Basin, Australia. *Journal of Hydrology* 124(1991):1–27.

Singh, G. and J. Luly 1991 Changes in vegetation and seasonal climate since the last full glacial at Lake Frome, South Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 84:75–86.

Sladek, V., M. Berner and R. Sailer 2006 Mobility in central European late Eneolithic and early Bronze Age: femoral cross-sectional geometry. *American Journal of Physical Anthropology* 130:320–332.

Smith, B.D. 2001 Low-level food production. *Journal of Archaeological Research* 9(1):1–43.

- Smith, B.D. 2007 Niche Construction and the behavioral context of plant and animal domestication. *Evolutionary Anthropology* 16:188–199.
- Smith, B.D. 2011a A Cultural Niche Construction theory of initial domestication. *Biological Theory* 6:260–271.
- Smith, B.D. 2011b General patterns of niche construction and the management of ‘wild’ plant and animal resources by small-scale pre-industrial societies. *Philosophical Transactions of the Royal Society of Britain* 366:836–848.
- Smith, B.D. 2015a A comparison of Niche Construction Theory and Diet Breadth Models as explanatory frameworks for the initial domestication of plants and animals. *Journal of Archaeological Research* 23:215–262.
- Smith, M.A. 1978 A note on the fauna from Devon Downs Shelter. *Australian Archaeology* 8:19–21.
- Smith, M.A. 1982 Devon Downs Reconsidered: Changes in Site Use at a Lower Murray Valley Rockshelter. *Archaeology in Oceania* 17(3):109–116.
- Smith, M.A. 1985 A morphological comparison of central Australian seed grinding implements and Australian Pleistocene age grindstones. *The Beagle* 2:23–38.
- Smith, M.A. 1986 The antiquity of seed grinding in arid Australia. *Archaeology in Oceania* 21:29–39.
- Smith, M.A. 1988 The pattern and timing of prehistoric settlement in Central Australia. Unpublished PhD thesis, University of New England, Armidale.
- Smith, M.A. 1989 The case for a resident human population in the Central Australian Ranges during full glacial aridity. *Archaeology in Oceania* 24:93–105.
- Smith, M.A. 2015b What sort of seed grinding at Pleistocene Lake Mungo? *ARCHAEOLOGY IN OCEANIA* 50(3):175–176.
- Smith, M.A., A.N. Williams, C.S.M. Turney and M.L. Cupper 2008 Human–environment interactions in Australian drylands: Exploratory timeseries analysis of archaeological records. *The Holocene* 18(2):389–401.

- Smith, R. 1930 *Myths and legends of the Australian Aborigines*. London: Harrap.
- Smith, T.E. 2019 Depositional History and Palaeoenvironments of the Lake Mulurulu Lunette, Willandra Lakes World Heritage Area, New South Wales. Unpublished PhD thesis, Australian National University, Canberra.
- Smyth, R.B. 1876 *The Aborigines of Victoria: With notes relating to the habits of the natives of other parts of Australia and Tasmania compiled from various sources for the Government of Victoria*. Melbourne: J. Ferres, Government Printer.
- Smyth, R.B. 1878 *The Aborigines of Victoria: With notes relating to the habits of the natives of other parts of Australia and Tasmania Volumes I and II*. Melbourne: John Crrey, O'Neil.
- Stanley, S. and P. De Deckker 2002 A Holocene record of allochthonous, aeolian mineral grains in an Australian alpine lake implications for the history of climate change in southeastern Australia. *Journal of paleolimnology* 27(2):207–219.
- Stein, J.K. 1992 *Deciphering a shell midden*. San Diego, Calif.: San Diego, Calif. : Academic Press.
- Stern, N. 1994 The implications of time-averaging for reconstructing the land-use patterns of early tool-using hominids. *Journal of Human Evolution* 27:89–105.
- Stern, N., J. Turney, K. Fitzsimmons and P. Kijewski 2013 Strategies for investigating human responses to changes in landscape and climate at Lake Mungo in the Willandra Lakes, Southeast Australia. In D. Frankel, S. Lawrence and J. Webb (eds), *Archaeology in Technology and Environment: Intersections and Transformations*, pp.31–50. New York, NY: Routledge.
- Stewart, H.J., R. Brandle and J.N. Foulkes 2010 *Impacts of salinity on the fauna of the Murray River Valley floodplain South Australia 2002-2004*. Adelaide: Science Resource Centre, Department for Environment and Heritage, South Australia.
- Stiner, M.C. 2001 Thirty years on the “Broad Spectrum Revolution” and paleolithic demography. *PNAS* 98(13):6993–6996.
- Stiner, M.C. 2004 Small game use and expanding diet breadth in the eastern Mediterranean basin during the Paleolithic. In J. Brugal and J. Desse (eds), *Petits animaux et sociétés humaines*:

du complément alimentaire aux ressources utilitaires, Actes des XXIV Rencontres internationales d'Archéologie et d'Histoire d'Antibes 2003, pp.499–513. Antibes: APDCA.

- Stiner, M.C. and S.L. Kuhn 2016 Are we missing the “sweet spot” between optimality theory and niche construction theory in archaeology? *Journal of Anthropological Archaeology* 44:177–184.
- Stiner, M.C., N.D. Munro and T.A. Surovell 2000 The tortoise and the hare: small-game use, the broad-spectrum revolution, and Paleolithic demography. *Current Anthropology* 41:39–73.
- Stock, J.T. and A.A. McIntosh 2016 Lower limb biomechanics and habitual mobility among mid-Holocene populations of the Cis-Baikal. *Quaternary International* 405:200–209.
- Stone, T. 2006a The late-Holocene origin of the modern Murray River course, southeastern Australia. *The Holocene* 16(5):771–778.
- Stone, T. 2006b Late Quaternary rivers and lakes of the Cadell tilt block region, Murray Basin, southeastern Australia. Unpublished PhD thesis, University of Melbourne, Melbourne.
- Stone, T. and M.L. Cupper 2003 Last Glacial Maximum ages for robust humans at Kow Swamp, southern Australia. *Journal of Human Evolution* 45:1–13.
- Sturt, C. 1833 *Two expeditions into the interior of southern Australia: during the years 1828, 1829, 1830 and 1831: With observations of the soil, climate, and general resources of the colony of New South Wales*. London: Smith, Elder and Co.
- Sturt, C. 1849 *Narrative of an expedition into Central Australia, performed under the authority of Her Majesty's government, during the years 1844, 5, and 6: Together with a notice of the province of South Australia in 1847 / by Charles Sturt*. London: T. and W. Boone.
- Stutz, A.J., N.D. Munro and G. Bar-Oz 2009 Intensification and sedentism in the terminal Pleistocene Natufian sequence of el-Wad Terrace (Israel). *Journal of Human Evolution* 56:294–306.
- Suby, J.A. 2014 Porotic hyperostosis and cribra orbitalia in human remains from southern Patagonia. *Anthropological Science* 122(2):69–79.
- Sullivan, M. 1932 'The Ghost of Paddy Evans: A Hawk's Nest Mystery, as told by Michael Sullivan',

Murray Pioneer and Australian River Record Thursday 30 June 1932 p.5.

- Sun, X.-F., S.-Q. Wen, C.-Q. Lu, B.-Y. Zhou, D. Curnoe, H.-Y. Lu, H.-C. Li, W. Wang, H. Cheng, S.-W. Yi, X. Jia, P.-X. Du, X.-H. Xu, Y.-M. Lu, Y. Lu, H.-X. Zheng, H. Zhang, C. Sun, L.-H. Wei, F. Han, J. Huang, R.L. Edwards, L. Jin and H. Li 2021 Ancient DNA and multimethod dating confirm the late arrival of anatomically modern humans in southern China. *Proc Natl Acad Sci U S A* 118(8):e2019158118.
- Sunderland, S. and L.J. Ray 1959 A note on the Murray Black collection of Australian Aboriginal skeletons. *Proceedings of the Royal Society of Victoria* 71(1):45–48.
- Surovell, T.A. and P.J. Brantingham 2007 A note on the use of temporal frequency distributions in studies of prehistoric demography. *Journal of Archaeological Science* 34:1868–1877.
- Swirepik, J.L., I.C. Burns, F.J. Dyer, I.A. Neave, M.G. O'Brien, G.M. Pryde and R.M. Thompson 2015 Establishing environmental water requirements for the Murray-Darling Basin, Australia's largest developed river system. *River Research and Applications* 32(6):1153–1165.
- Tan, K.P., K.C. Lawrie, L. Halas, C.F. Pain, J.D.A. Gibson, H. Apps, K. Culen, R. Brodie and V. Wong 2009 Methodology for the customised products developed as part of the River Murray Corridor Victorian AEM mapping project, Geoscience Australia, Professional Opinion 2009/12. Canberra, ACT: Geoscience Australia.
- Taplin, G. (ed.) 1879 *The folklore, manners, customs and languages of the South Australian Aborigines*. Adelaide: E. Spiller, Acting Govt. Printer.
- Telfer, A., R. Burnell, J. Woods and Y. Weir 2012 River Murray floodplain salt mobilisation and salinity exceedances at Morgan, MDBA Publication No 53/12. Canberra: Murray-Darling Basin Authority.
- Telford, R.J., E. Heegaard and J.B. Birks 2004 The intercept is a poor estimate of a calibrated radiocarbon age. *The Holocene* 14(2):296–298.
- Thomas, I., N.J. Enright and C.E. Kenyon 2001 The Holocene history of mediterranean type plant communities, Little Desert National Park, Victoria, Australia. *The Holocene* 11(6):691–697.
- Thoms, M.C. and F. Sheldon 2000 Lowland rivers: an Australian introduction. *Regulated Rivers:*

- Thoms, M.C., P. Sutter, J. Roberts, J. Hoehn, G. Jones, T. Hiullmann and A. Close 2000 Report of the River Murray Scientific Panel on Environmental Flows: River Murray – Dartmouth to Wellington and the Lower Darling River. Unpublished report prepared for Murray Darling Basin Commission.
- Thoms, M.C. and K.F. Walker 1992 Morphological changes along the River Murray, South Australia. In P.A. Carling and G.E. Petts (eds), *Lowland floodplain rivers: geomorphological perspectives*, pp.235–249. Chichester: Wiley.
- Thredgold, J. 2017 An analysis of lithics at Calperum Station, South Australia, to examine the function of late Holocene mound sites along the Lower Murray River. Unpublished MA thesis, Department of Archaeology, Flinders University, Adelaide.
- Tibby, J., K. Adamson and A.P. Kershaw 2020 An 1800-year water-quality and vegetation record from Junction Park Billabong, Murray River, Australia: an assessment of European impacts and sensitivity to climate. *Journal of Paleolimnology* 63:159–175.
- Tibby, J., J.J. Tyler and C. Barr 2018 Post little ice age drying of eastern Australia conflates understanding of early settlement impacts. *Quaternary science reviews* 202:45–52.
- Tindale, N.B. 1939 Eagle and Crow Myths of the Maraura Tribe, Lower Darling River, New South Wales. *Records of the South Australian Museum* 6:39–60.
- Tindale, N.B. 1940-1956 *Journal on Campsites and Stone Implements of the Australian Aborigines; and others; Notes, etc.* [Digitised Journal]. Adelaide: South Australian Museum. AA 338/1/40/1.
- Tindale, N.B. 1957 Culture succession in South Eastern Australia from late Pleistocene to the Present. *Records of the South Australian Museum* 13(1):1–49.
- Tindale, N.B. 1974 *Aboriginal Tribes of Australia: their terrain, environmental controls, distribution, limits, and proper names*. Berkeley: University of California Press.
- Treble, P.C., A. Baker, L. Ayliffe, T.J. Cohen, J.C. Hellstrom, M.K. Gagan, S. Frisia, R.N. Drysdale, A.D. Griffiths, A.D. Borsato and A. Borsato 2017 Hydroclimate of the Last Glacial Maximum and

deglaciation in southern Australia's arid margin interpreted from speleothem records (23-15 ka). *Climate of the Past* 13(6):667–687.

Tudhope, A.W., C.P. Chilcott, M.T. McCulloch, E.R. Cook, J. Chappell, R.M. Ellam, D.W. Lea, J.M. Lough and G.B. Shimmield 2001 Variability in the El Niño-Southern Oscillation through a glacial-interglacial cycle. *Science* 291(5508):1511–1517.

Turney, C.S.M. and D. Hobbs 2006 ENSO influence on Holocene Aboriginal populations in Queensland, Australia. *Journal of Archaeological Science* 33:1744–1748.

Tutchener, D. and D. Claudie 2022 Beyond 'contact' and shared landscapes in Australian archaeology. *Australian Archaeology* 88(1):84–91.

Twidale, C.R. and J.A. Bourne 2009 Course of the lower River Murray in South Australia: effects of underprinting and neotectonics? *Proceedings of the Royal Society of Victoria* 121(2):207–227.

Twidale, C.R., J.A. Bourne, N.A. Spooner and E.J. Rhodes 2007 The age of the palaeodunefield of the northern Murray Basin in South Australia: preliminary results. *Quaternary International* 166:42–48.

Tyler, J. 2017 *Past climate variability in south-eastern Australia: progress and potential from sediment archives*. Flinders University Archaeological Seminar Series, Flinders University, South Australia, 12/10/2017.

Tynan, S., S. Eggins, L. Kinsley, S.A. Welch and D. Kirste 2005 *Mussel shells as environmental tracers: an example from the Loverday Basin*. CRC LEME Regional Regolith Symposia 2005, Adelaide and Canberra, Landscape Environment and Mineral Exploration.

Ugan, A. 2005 Does size matter? Body size, mass collecting, and their implications for understanding prehistoric foraging behavior. *American Antiquity* 70(1):75–89.

Ulm, S. 2013 'Complexity' and the Australian continental narrative: themes in the archaeology of Holocene Australia. *Quaternary International* 285:182–192.

Vale, D. and R.H. Gargett 2002 Size Matters: 3-mm Sieves Do Not Increase Richness in a Fishbone Assemblage from Arrawarra I, an Aboriginal Australian Shell Midden on the Mid-north

- Coast of New South Wales, Australia. *Journal of archaeological science* 29(1):57–63.
- Veth, P., P. Hiscock and A. Williams 2011 Are Tulas and Enso Linked In Australia? *Australian Archaeology* 72(1):7–14.
- Veth, P., I. Ward, T. Manne, S. Ulm, K. Dutchfield, J. Dortch, F. Hook, F. Petchey, A. Hogg, D. Questiaux, M. Demuro, L. Arnold, N. Spooner, V. Levchenko, J. Skippington, C. Byrne, M. Basgall, D. Zeanah, D. Belton, P. Helmholz, S. Bajkan, R. Bailey, C. Placzek and P. Nendrick 2017 Early human occupation of a maritime desert, Barrow Island, North-West Australia. *Quaternary Science Reviews* 168:19–29.
- Walker, K.F. 1981 Ecology of freshwater mussels in the River Murray. *Australian Water Resources Council Technical Paper* 63.
- Walker, K.F. 1986 The Murray-Darling river system. In B.R. Davies and K.F. Walker (eds), *The Ecology of River Systems*, pp.631–694. Dordrecht: Dr W. Junk Publishers.
- Walker, K.F. 2006 Serial weirs, cumulative effects: the Lower River Murray, Australia. In K.R. T (ed.), *The Ecology of Desert Rivers*, pp.248–279. Cambridge: Cambridge University Press.
- Walker, K.F. 2017 Reproductive phenology of river and lake populations of freshwater mussels (*Unionida: Hyriidae*) in the River Murray. *Molluscan Research* 37(1):31–44.
- Walker, K.F., M. Byrne, C.W. Hickley and D.S. Roper 2001 Freshwater mussels (*Hyriidae*) of Australasia. In G. Bauer and K. Wächtler (eds), *Ecology and Evolution of the Freshwater Mussels Unionoida*, pp.5–31. Berlin: Springer-Verlag.
- Walker, K.F., F. Sheldon and J.T. Puckridge 1995 A perspective on dryland river ecosystems. *Regulated Rivers: Research and Management* 11:84–104.
- Walker, P.L., R. Richman, T. Gjerdrum and V.A. Andrushko 2009 The causes of porotic hyperostosis and Cribra Orbitalia: a reappraisal of the iron-deficiency-anemia hypothesis. *American Journal of Physical Anthropology* 139:109–125.
- Wallace, T.A. 2011 An ecological assessment of benefits and risks associated with the proposed management actions for the Pike River and its floodplain. Unpublished report prepared for South Australian Department for Water.

- Walshe, K. 1998 Taphonomy of Mungo B assemblage: indicators for subsistence and occupation of Lake Mungo. *Archaeology in Oceania* 33(3):201–206.
- Wang, Y., R. Amundson and S. Trumbore 1996 Radiocarbon dating of soil organic matter. *Quaternary Research* 45:282–288.
- Webb, S. 1984 Intensification, population and social change in south-eastern Australia: the skeletal evidence. *Aboriginal History* 8:154–174.
- Webb, S. 1989 *Prehistoric Stress in Australian Aborigines: a palaeopathological study of a hunter-gatherer population*. BAR International Series 490. Oxford: British Archaeological Reports.
- Westcott, D.J. 2014 The relationship between femur shape and terrestrial mobility patterns. In K.J. Carlson and D. Marchi (eds), *Reconstructing Mobility: Environment, Behavioral, and Morphological Determinants*, pp.111–132. New York: Springer.
- Westell, C. 2015 Indigenous Heritage Assessment of the AWE Pike and Katarapko 2015 Observation and Production Test Well Drilling Program, Riverland Region, South Australia. Unpublished report prepared for SA Department for Environment and Water.
- Westell, C. 2017 Report of an Aboriginal heritage survey of Pichinga (Butchers Soak), Murray mallee, South Australia. Unpublished report prepared for NRM Communities Natural Resources SA Murray-Darling Basin and River Murray and Mallee Aboriginal Corporation.
- Westell, C. 2020 Danggali Landscape Conservation Action Plan: An Aboriginal Heritage assessment of selected dam closures. Unpublished report prepared for South Australian Native Title Service, River Murray and Mallee Aboriginal Corporation and Natural Resources SA Murray Darling Basin.
- Westell, C. 2021a Danggali Landscape Conservation Action Plan: An Aboriginal Heritage assessment of selected dam closures: January 2021. Unpublished report prepared for South Australian Native Title Service (SANTS), River Murray and Mallee Aboriginal Corporation (RMMAC) and Natural Resources SA Murray Darling Basin (Natural Resources SAMDB).
- Westell, C. 2021b SARFIIP Site Protection Measures, Riverland Region, South Australia. Unpublished report prepared for River Murray and Mallee Aboriginal Corporation

(RMMAC) and Department for Environment and Water (DEW).

- Westell, C. and V. Wood 2014 An introduction to earthen mound sites in South Australia. *Journal of the Anthropological Society of South Australia* 38:30–65.
- Westell, C. and V. Wood 2018 An overview of documented Indigenous heritage within the northern Mallee, South Australia. Unpublished report prepared for South Australian Native Title Service, River Murray and Mallee Aboriginal Corporation and Natural Resources SA Murray Darling Basin.
- Wilkins, D., C. Gouramanis, P.D. Deckker, L.K. Fifield and J. Olley 2013 Holocene lake-level fluctuations in Lakes Keilambete and Gnotuk, southwestern Victoria, Australia. *The Holocene* 23(6):784–795.
- Williams, A., C.M. Santoro, M.A. Smith and C. Latorred 2008 The impact of ENSO in the Atacama Desert and Australian arid zone: exploratory time-series analysis of archaeological records. *Chungará (Arica)* 40:245–259.
- Williams, A.N. 2012 The use of summed radiocarbon probability distributions in archaeology: a review of methods. *Journal of Archaeological Science* 39:578–589.
- Williams, A.N. 2013 A new population curve for prehistoric Australia. *Proceedings of the Royal Society of Britain* 280:1–9.
- Williams, A.N., S.D. Mooney, S.A. Sisson and J. Marlon 2015a Exploring the relationship between Aboriginal population indices and fire in Australia over the last 20,000 years. *Palaeogeography, Palaeoclimatology, Palaeoecology* 432:49–57.
- Williams, A.N. and M.A. Smith 2013 AustArch3: a database of ¹⁴C and luminescence ages from archaeological sites in southern Australia. *Australian Archaeology* 76:102.
- Williams, A.N., S. Ulm, A.R. Cook, M.C. Langley and M. Collard 2013 Human refugia in Australia during the Last Glacial Maximum and Terminal Pleistocene: a geospatial analysis of the 25–12 ka Australian archaeological record. *Journal of Archaeological Science* 40:4612–4625.
- Williams, A.N., S. Ulm, I.D. Goodwin and M. Smith 2010 Hunter-gatherer response to late Holocene climatic variability in northern and central Australia. *Journal of Quaternary*

Science 25(6):831–838.

Williams, A.N., S. Ulm, M. Smith and J. Reid 2014 AustArch: a database of 14C and non-14C ages from archaeological sites in Australia - Composition, compilation and review (Data Paper). *Internet Archaeology* 36.

Williams, A.N., S. Ulm, C.S.M. Turney, D. Rohde and G. White 2015b Holocene demographic changes and the emergence of complex societies in prehistoric Australia. *Plos ONE* 10(6):e0128661.

Williams, A.N., P. Veth, W. Steffen, S. Ulm, C.S.M. Turney, J.M. Reeves, S.J. Phipps and M. Smith 2015c A continental narrative: human settlement patterns and Australian climate change over the last 35,000 years. *Quaternary Science Reviews* 123:91–112.

Williams, E. 1988 *Complex hunter-gatherers: late Holocene example from temperate Australia*. Oxford, England: B.A.R.

Williams, M.A.J., N.A. Spooner, K. McDonnell and J.F. O'Connell 2021 Identifying disturbance in archaeological sites in tropical northern Australia: Implications for previously proposed 65,000-year continental occupation date. *Geoarchaeology* 36(1):92–108.

Williams, M.A.L., P.D. Decker, S.A. Adanson and M.R. Talbot 1991 Episodic fluvial, lacustrine and aeolian sedimentation in a late Quaternary Desert margin system, central western New South Wales. In M.A.J. Williams and A.P. Kershaw (eds), *The Cainozoic in Australia: a reappraisal of the evidence*, pp.258–287. Geological Society of Australia Special Publication 18.

Williams, R., G. Taylor and C. Orr 2020 PXRF method development for elemental analysis of archaeological soil. *Archaeometry* 62(6):1145–1163.

Wilson, C., S. Fallon and T. Trevorrow 2012 New radiocarbon ages for the Lower Murray River, South Australia. *Archaeology in Oceania* 47(3):157–160.

Wilson, C., A. Roberts, D. Fusco and Ngarrindjeri Aboriginal Corporation 2022 New data and syntheses for the zooarchaeological record from the Lower Murray River Gorge, South Australia: Applying a ngatji lens. *Australian Archaeology*.

- Wilson, C.J. 2017 Holocene archaeology and Ngarrindjeri Ruwe/Ruwar (Land, Body, Spirit): a critical Indigenous approach to understanding the Lower Murray River, South Australia. Unpublished Phd thesis, Department of Archaeology, Flinders University, Adelaide.
- Wolverton, S., C.R. Randklev and J.H. Kennedy 2010 A conceptual model for freshwater mussel (family: Unionidae) remain preservation in zooarchaeological assemblages. *Journal of archaeological science* 37(1):164–173.
- Wood, V. 2002 Proposed high voltage transmission line between South Australia and NSW (SNI): results of the heritage and archaeological survey of the South Australian section - Monash to the SA/NSW border. Unpublished report prepared for Sinclair Knight Merz.
- Wood, V. 2005 Indigenous cultural heritage study: groundwater investigations program, Murtho, Riverland region, South Australia. Unpublished report prepared for River Murray SIS Team Department of Water, Land and Biodiversity Conservation.
- Wood, V., V. Edmonds and C. Westell 2005 *Tjowila* (Chowilla) floodplain: baseline Indigenous cultural heritage study: Volume 1. Unpublished report prepared for Department of Water, Land and Biodiversity Conservation and the Department of Environment and Heritage.
- Wood, V., K. Hunt and C. Westell 1997 Ngarkat site recording project: a survey of Aboriginal archaeological sites. Unpublished report prepared for Australian Heritage Commission.
- Wood, V. and C. Westell 2008a An Aboriginal cultural heriatge survey of Lake Bonney, Barmera, Riverland Region, South Australia. Unpublished report prepared for South Australian Murray – Darling Natural Resources Management Board, Aboriginal Affairs & Reconciliation Division, and the First Peoples of the River Murray and Mallee Native Title Claimants.
- Wood, V. and C. Westell 2008b An Aboriginal heritage study of the proposed Murtho SIS scout wells, Riverland, South Australia. Unpublished report prepared for Australian Water Environments.
- Wood, V. and C. Westell 2008c An Aboriginal heritage study of the proposed Murtho SIS scout wells, Riverland, South Australia: Stage 2. Unpublished report prepared for Australian Water Environments.

- Wood, V. and C. Westell 2009 Katfish Reach: baseline indigenous heritage assessment. Volume 1. Unpublished report prepared for Department of Environment and Heritage, Murraylands Region.
- Wood, V. and C. Westell 2010 Katfish Reach: baseline indigenous heritage assessment. Addendum report: extended predictive model. Unpublished report prepared for Department of Environment and Heritage, Murraylands Region.
- Wood, V. and C. Westell 2012 Aboriginal heritage survey of the Riverine Recovery Project (RRP) - Wetland Project Element: Phase 1B (Lake Merreti, Lake Woolpolool, Beldora Wetlands and Murbko South), Riverland, South Australia. Unpublished report prepared for Department of Environment, Water and Natural Resources.
- Wood, V. and C. Westell 2013 Aboriginal heritage survey for the Lake Bonney rabbit control project, Barmera, Riverland region, South Australia. Unpublished report prepared for River Murray and Mallee Aboriginal Corporation and Natural Resources South Australian Murray-Darling Basin.
- Wood, V. and C. Westell 2014a Aboriginal heritage survey of the rabbit control project at Lake Littra, Chowilla, Riverland, South Australia. Unpublished report prepared for Natural Resources SA Murray-Darling Basin.
- Wood, V. and C. Westell 2014b Pike River Floodplain baseline Indigenous heritage assessment Volumes I and II. Unpublished report prepared for Department of Environment, Water and Natural Resources.
- Wood, V. and C. Westell 2015 SARFIIP Feasibility and Investigations Phase: Katarapko Floodplain (Katfish Reach) Indundation Measures: Stage 1. Unpublished report prepared for Department of Environment, Water and Natural Resources.
- Wood, V. and C. Westell 2016a Aboriginal heritage assessment of portion of section 17 Out of Hundred (Chowilla) CR6140/112, Riverland Region, South Australia. Unpublished report prepared for Protected Areas Unit, Conservation and Land Management Branch, Department of Environment, Water and Natural Resources.
- Wood, V. and C. Westell 2016b Aboriginal heritage assessment of the Pike Groundwater

Interception Scheme Highland Pipeline Route, Riverland Region, South Australia.
Unpublished report prepared for Department of Environment, Water and Natural Resources.

Wood, V. and C. Westell 2016c Indigenous Heritage Assessment of the AWE Pike and Katarapko 2016 Scout and Production Well Drilling Program, Riverland Region, South Australia.
Unpublished report prepared for Department of Environment, Water and Natural Resources.

Wood, V. and C. Westell 2019 Aboriginal heritage assessment of the maintenance program for the North West Bend to Monash 132kv transmission line, South Australia. Unpublished report prepared for ElectraNet.

Woolmer, G. 1974 *Riverland Aborigines of the past: an Aboriginal history of the Barmera region*. Barmera: Woolmer.

Woolmer, G. 1986 *Overland Corner: a history of the Overland Corner and its hotel*. Barmera: Woolmer.

Worne, H.A. 2002 Lower-limb biomechanics and behaviour in a middle Mississippian skeletal sample from west-central Illinois. Unpublished MA thesis, Graduate School of Binghamton University, State University of New York, New York.

Worsnop, T. 1897 *The prehistoric arts, manufactures, works, weapons, etc. of the aborigines of Australia*. Adelaide.

Wrangham, R., D. Cheney, R. Seyfarth and E. Sarmiento 2009 Shallow water habitats as sources of fallback foods for hominins. *American Journal of Physical Anthropology* 140(4):630–642.

Wright, V.P. 2007 Calcrete. In D.J. Nash and S.J. McLaren (eds), *Geochemical Sediments and Landscapes*, Carlton, VIC: Blackwell Publishing.

Yan, W., S.R. Howles and Z. Marsden 2005 Chowilla Floodplain Numerical Groundwater Model. Unpublished report prepared for Department of Water, Land and Biodiversity Conservation.

Ye, Q., K. Cheshire, B. Henderson and E. Dovers 2009 Native Fish. In I.C. Overton, M.J. Colloff, T.M.

- Doody, B. Henderson and S.M. Cuddy (eds), *Ecological outcomes of flow regimes in the Murray-Darling Basin*, pp.96–119. Canberra: CSIRO.
- Ye, Q., G.C. Giatas, K.T. Aldridge, S.N. Bengier, C.M. Bice, J.D. Brokkes, L.B. Bucater, K.J.M. Cheshire, C.R. Cummings, T.M. Doody, F.M. Fairweather, K.A. Frahn, J.F. Fredberg, S.L. Gehrig, K.L. Holland, S.J. Leigh, R.E. LEster, K.B. Marsland, J.M. Nicol, R.L. Oliver, I.C. Overton, J.L. Pritchard, A.D. Strawbridge, L.A. Thaites, C.J. Turnadge, P.K. Wilson and B.P. Zampatti 2014 *Ecological responses to flooding in the lower River Murray following an extended drought: synthesis report of the Murray Flood Ecology Project*. Adelaide: Goyder Institute for Water Research Technical Report Series.
- Yeshurun, R., G. Bar-Oz and M. Weinstein-Evron 2014 Intensification and sedentism in the terminal Pleistocene Natufian sequence of el-Wad Terrace (Israel). *Journal of Human Evolution* 70:16–35.
- Young, W.J. 2001 *Rivers as ecological systems—the Murray-Darling Basin*. Canberra: Murray-Darling Basin Commission.
- Zampatti, B.P., S.J. Leigh and J.M. Nicol 2011 Fish and aquatic macrophyte communities in the Chowilla anabranch system, South Australia: a report of investigations from 2004–2007. *SARDI Research Report Series* 525(F2010/000719-1).
- Zeanah, D.W., B.F. Coddling, R. Bliege-Bird and D.W. Bird 2017 Mosaics of fire and water: the co-emergence of anthropogenic landscapes and intensive seed exploitation in the Australian arid zone. *Australian Archaeology* 83(1-2):2–19.
- Zeder, M.A. 2012 The Broad Spectrum Revolution at 40: resource diversity, intensification, and an alternative to optimal foraging explanations. *Journal of Anthropological Archaeology* 31:241–264.
- Zeder, M.A. and M.D. Spitzer 2016 New insights into broad spectrum communities of the Early Holocene Near East: the birds of Hallan Çemi. *Quaternary Science Reviews* 151:140–159.

APPENDICES

Appendix I: A selection of ethnohistoric observations of Aboriginal food staples in the Central Murray region (including the Riverland) and adjoining regions

Reference	Location	Detail	Timing of collection	Collection & Processing Techniques
Birds				
Black Swan (<i>Cygnus atratus</i>)				
Eyre (1845)	Murray River general reference	Meat eaten	-	Clubbed, speared
Bird eggs				
Beveridge (1883:36)	Upstream of Wentworth	Eggs collected in season with accounts of canoes arriving back in camp laden down to the water with eggs.	Spring and summer	Hand collected from canoes
Duck (unspecified species)				
Grosvenor (1979:8)	Riverland (Renmark)	Driven into nets made from reeds and grass strung across creeks by throwing boomerangs above the flocks.	-	Nets
Hawdon (1852)	-	Meat	Summer - Autumn	Nets
Schell (1914b)	Riverland (General)	Describes reed nets fifty yards wide and about ten feet deep hung between trees across narrow creeks to catch 'great numbers' of ducks driven into the nets by a bark decoy. Also describes people wading into the water covered with shrimp-weed and catching ducks with a small snare made of kangaroo sinew.	-	Nets, snare
Drill (1904)	Darling River	Describes method of catching ducks using a rope tied across a creek or small river, then 10ft net is suspended in middle to within 3ft of water, ducks are scared down river toward snare, then a piece of wood is thrown in to the air and people make whistle imitating the sound of a hawk, birds dive in fright into snare with heads stuck in mesh. ... cooking duck. A hole is made then heated stone is placed at bottom of pit, then a layer of peppermint tree (??) leaves then birds on top, then next layer of stones, then covered with earth.	-	Nets, cooked in earth oven
Angas (1847:100)	Lower Murray - Moorundie	Caught in nets hung over creeks with birds driven into nets by bark piece thrown above them.	-	Nets
Musk duck (<i>Biziura lobata</i>)				
Anon (1919)	Riverland (Overland Corner)	Groups of people in bark canoes and others swimming, each carrying a long spear.	-	Spear from canoes
Teal and black duck (<i>Anas gibberifrons</i> or <i>castanea</i> , <i>A. superciliosa</i>)				
Anon (1919)	Riverland (Overland Corner)	Describes people catching teal and black duck in their 'hundreds' using a long broad net tied between trees across a creek. A piece of bark was trimmed in the shape of a carpenter's broad axe, with a handle and thrown above flocks of ducks to scare them into nets. 'Hundreds of ducks were caught in a single haul'.	-	Nets
Emu (<i>Dromaius novaehollandiae</i>)				

Reference	Location	Detail	Timing of collection	Collection & Processing Techniques
Angas (1847:99)	Lower Murray - Moorundie	Caught in very large nets twenty yards long and five feet high made from the roots of the marsh-mallow, baked and chewed and then spun. Birds are driven into nets then speared.	-	Nets, spears
Eyre (1845 Vol II:278)	unspecified	-	-	Speared, netted or caught in pit falls
Mallee fowl (<i>Leipoa ocellata</i>)				
Eyre (1845 Vol II:274)	-	Eggs collected in season	-	Hand collected
Waterfowl (unspecified)				
Beveridge (1883:36)	Upstream of Wentworth	Water fowl of countless type caught in nets on lagoons and lakes	-	Nets
Eyre (1845:283-88)	unspecified	Netting birds is the most destructive mode of taking them of any that is practised. Provides detailed description of netting across creeks running into lagoons where the birds congregate. Whistling to imitate a hawk sends the birds down and into the net. Recounts an excursion with small group who managed to procure 20-30 ducks daily for many successive days.	-	Noose, snare, speare and nets.
Plants				
Bulrush, Cumbungi, Coopers Reed (<i>Typha spp.</i>)				
Angas (1847:89)	Lower Murray - Moorundie	Angas refers to bulrush as the 'staff of their existence', with rhizome fibre scraped with mussel shells, chewed and spun into rope. 'Kilns' were used to steam bulrush root, presumably a reference to oven mounds.	-	Steamed, chewed
Beveridge (1883:36)	Upstream of Wentworth	Beveridge describes 'kumpung' as growing plentifully around the edges of lagoons and lakes with considerable effort dedicated in procuring it in 'abundance'. The raw shoots were eaten in Spring in great quantities.	Spring	Dug out, eaten raw
Gott (1982, 1983, 1999 Appendix I)	Various MDB locations	Gott provides extensive ethnohistorical information including accounts of bulrush being eaten all year round though especially in winter when other foods were scarce.	All year, reliance in winter	-
Eyre (1845 Vol II:269)	Murray River general reference	Eyre describes the flag or cooper's reed as one of the most important root crops, harvested more or less during all seasons of the year but best after floods have 'retired and the tops have become decayed and been burnt off'. The root is roasted in hot ashes.	All year	Dug out, roasted

Reference	Location	Detail	Timing of collection	Collection & Processing Techniques
Krefft (1865)	Lower Murray and Darling	Describes Typha roots, or Wongal, as a major crop for periods of the year (January or February), with roots collected from swamps by women in 'large bundles' and roasted in inground ovens. Consumed hot or used to provision 'hunting excursions'. Food resource may have been secondary to the tough fibre extracted from the roots. After roasting, the root was chewed by everyone with the fibre lumps collected and spun into threads used for fishing-nets and other domestic utensils. Nets were a 'staple article of barter' between the tribes inhabiting the reed-beds and those parts where no Wongal was produced. Krefft states that 'If we take into consideration the large nets for catching water-fowl in use, it is indeed astonishing how great the perseverance of these people (and how sound their teeth) must have been, and it is not to be wondered at that the possession of one of these nets has always been considered to be a sort of fortune to its owner.'	January - February	Dug up, roasted, fibre chewed and spun into twine
Mitchell (1839:81)	Upstream of Wentworth	Describes 'great numbers' of lofty ash-hills, used chiefly for the roasting of balyan (or bulrush).	-	Roasted (oven mounds)
Smyth (1972:214)	Murray Districts	Young shoots eaten in August as they emerge, with rhizomes dug up in summer and chewed for carbohydrates with pith/fibre turned into string for netting.	Spring and summer	Dug up, eaten raw and steamed
Herbs and roots (unspecified)				
Sturt (1849:100)	Central Murray	'They appeared to live chiefly on vegetables during the season of the year that we passed up the Murray [September], herbs and roots certainly constituted their principal food'	September	-
Marsh clubrush (<i>Bolboschoenus medianus</i>)				
Angas (1847:101)	Lower Murray (Moorundie)	'Poolilla' triangular species of grass or reed eaten by the Moorunde people	-	-
Eyre (1845 vol II:254, 269)	Murray River general reference	The belillah is another important bulbous root, which grows on lands subject to floods. It is about the size of a walnut, of a hard and oily nature, and is prepared by being roasted and pounded into a thin cake between two stones. Immense tracts of country are covered with this plant on the flats of the Murray, which in the distance look like the most beautiful and luxuriant meadows.	Late Summer after flood waters have receded	Roasted, pounded/ground
Anon (1919)	Lake Bonney	..when the lake was dry, an much valued edible root known as "Pullilla" was harvested	late summer - early winter	-
Common nardoo (<i>Marsilea drummondii</i>)				
Nash (2004)	NW Victoria	The hard spore cases were collected, broken up on grindstones and the spores separated from the outer cases. The spores were moistened and pounded into damper	Sporocaps harden as water dries Nov - Mar	Ground

Reference	Location	Detail	Timing of collection	Collection & Processing Techniques
Smyth (1972:209, 214-216)	Murray Districts	Used as a fall back food along the Murray in poor seasons. Poor nutritional content and needs to be supplemented with other foods . Sporocarp crushed, seeds removed and roasted in ashes, put in wooden bowl and winnowed, ponded on stone, back in bowl and mixed with water and made into rolls that are baked and eaten.	-	Roasted, ground, winnowed
Nitre bush (<i>Nitraria billardierei</i>)				
Eyre (1845 Vol II:271)	Murrumbidgee and Murray Rivers	Several varieties found in large quantities on the saline flats bordering parts of the rivers. A staple in its season.	Spring - early Summer	Hand collected and eaten raw
Peppergrass (<i>Lepidium spp.</i>)				
Eyre (1845 Vol II:254) - based on Martin's (2006:73) interpretation	Borders of Murray lagoons	The tops, leaves and stalks of a kind of cress, gathered at the proper season of the year, tied up in bunches, and afterwards steamed in an oven, furnish a favourite, and inexhaustible supply of food for an unlimited number of natives. When prepared, this food has a savoury and an agreeable smell, and in taste is not unlike a boiled cabbage. In some of its varieties it is in season for a great length of time, and is procured in the flats of rivers, on the borders of lagoons, at the Murray, and in many other parts of New Holland.'	'Great length of time'	Hand collected
Pigface (<i>Mesembryanthemum spp.</i>)				
Angas (1847:101)	Lower Murray (Moorundie)	Fleshy leaves and fruit eaten	-	-
Eyre (1845:252, 269)	Lake Victoria	Large group of people supplementing fish catch with leaves of pigface. Eaten as a kind of relish. Fruit used when ripe as after drying.	When 'full vigour of the plant begins to decline' - late Spring/Summer	-
Reed (unspecified)				
Schell (1914b)	Riverland general reference	These [nets] were made from reeds, all of which had to be chewed with their teeth so that they became pliable; they were often thirty to forty yards long.	-	-
Drill (1904)	Darling River (Menindee)	.. native rope and string manufactured from marah-mallows and rushes sweated in a native oven and then scraped. String used to make nets and other appliances used to catch birds, fish and other animals.	-	Nets
Roots (unspecified)				
Brock (1844:25)	Central Murray	Observed women beating roots that had been cooked under ashes between two stones into a pulp	September	Under ashes in oven
Rushes (unspecified)				

Reference	Location	Detail	Timing of collection	Collection & Processing Techniques
Finniss (1966)	Riverland (Northwest Bend)	Observed women making small baskets out of rushes	Late winter	-
Roysland (1977:54)	Riverland (Renmark - Ral Ral)	Women made baskets out of rushes (and turtle shells)	-	-
Seed (unspecified)				
Smyth (1972:214)	Murray-Darling Districts	Industrial scale harvesting of seeds. Women carrying bark bowls full of seed back to camp where it was ground between a flat millstone and topstone.	-	Ground
Yam dasiy (<i>Microceris lanceolata</i>)				
Angas (1887 Vol I:55, 58)	-	Staple	-	Steamed
Beveridge (1883:36)	Upstream of Wentworth	Yam growing in areas subject to seasonal inundation are largely consumed	-	-
Gott (1983)	Victoria/South Australia	See various references	probably all year round though lesser in winter	Ovens
Hawdon (1852)	Lake Victoria region	Women's food	-	-
Smyth (1972:49, 209)	River Murray general reference	Dug up and eaten by the children and adults in all places where it grows. Mirrn-ynong heaps mostly near water and at the margin of a forest or belt of timber.	Spring/Summer	Dug out
Worsnop (1897)	River Murray general reference	Aborigines of the great River Murray have fashioned out of a very hard wood shovels used in digging out native parsnip (murnong???). Cooking in ground ovens.	-	Dug out with wooden shovel
Fish				
Fish (unspecified)				
Angas (1847)	Lower Murray (Moorundie)	Fish attracted to fires lit in canoes at night time	-	Speared from canoe
Beveridge (1883:36)	Upstream of Wentworth	As a rule the food of the aborigines consists of fish principally, of which, for 8 months in the year they have a super abundance; so much so indeed is their supply during those months they cannot nearly consume it all, consequently quite a moiety [sic] is absolutely wasted. Weirs erected at outpour creeks.	8 months of the year	Weir, spear
Davis (in Smyth 1972, Vol II:314)	River Murray general reference	Nets used along the river, weirs built across inlet creeks to billabongs in summer at low water and made with stakes and sticks.	Summer	Weir
Eyre (1845:252)	Lake Victoria	600 people living on fish caught in nets	May	Nets

Reference	Location	Detail	Timing of collection	Collection & Processing Techniques
Eyre (1845:252, 259-263, 266)	Murray River general reference	Fish are abundant from December when the flood peaks begin to recede. Nets set in grass and stick weirs built across backwaters as the floodplains begin to empty back into the main channel, various spearing techniques. Large numbers of people rely on these weirs for their sole subsistence. 'Unlimited supply' of fish, 'incredible' number of fish, 'sole' source of subsistence. 'Great numbers' of fish taken in nets. Nets are the 'most destructive mode of catching fish, and generally secures the finest and largest'. Nets made from rushes and bouyed with dry reeds bound into bundles and weighted down with stones. Long but shallow (2-3 feet) gill net made with large mesh stretched across a lagoon between poles or spears stuck into mud, left in lagoon overnight. Fish also caught in small hooped net that divers take to bottom of water amongst reeds in search of fish. Fish caught amongst flooded reed beds from canoes using 'pine' (possibly mulga or Cypress spp.) spears. Spearing at night done by fire light using a wood sourced from the 'brush of the tableland stretching beyond the Murray' probably sandalwood. Fish retarded by blackwater events (flushing) easily caught. '... never seen the natives use hooks of their own manufacture, nor do I believe that they ever made any, though they are glad enough to get them from Europeans'.	As floods inundate (Spring), September, December, periods of flood (Spring - early Summer), as water recedes (late Summer)	Nets (hoop and gill), weirs, spear, hook and line (possibly an introduced technology)
Finniss (1966)	Riverland (Overland Corner)	Noticed dam built across channel connecting river and lagoon made for catching fish, slight rods stuck into the ground in double row filled with lignum to slow the fish to make capture easier by spear or by net	-	Weir, spear
Hawdon (1852)	Lake Victoria region	Fish is their 'principal article of food and they procure it in great abundance'	Late summer - autumn	-
The South Australian Gazette January 5, 1865	Riverland general reference	Fish, which is their chief article of food, was very scarce in consequence of the flooded state of the river.	January	-
The South Australian Gazette March 23, 1865	Murray Districts	I issued twine to make nets for catching ducks, the water being too high for fishing. It takes three pounds of twine to make a net.'	March	Net (introduced twine)
Golden perch (<i>Macquaria ambigua</i>)				
Angas (1847:92)	Lower Murray (Moorundie)	Fish speared	-	Spear
Murray cod (<i>Maccullochella peelii</i>)				
Angas (1847:92)	Lower Murray (Moorundie)	Taken on crude hooks	-	Hook and line

Reference	Location	Detail	Timing of collection	Collection & Processing Techniques
Anon (1919)	Riverland (Overland Corner)	They would dive into the river with hand nets about 18in. in diameter and would rarely fail to catch fairly large fish. In catching the largest cod they used a poop net, about live feet across, in the shape of a half moon. They worked in pairs and dived down into about 8 or 10 feet of water, where they knew there was a large hollow log in habited by the cod. One held the net over one end of the log, while the other by means of a large sharpened pliable stick.'	-	Net (hoop)
Schell (1914b)	Riverland general reference	... Cod they would catch with a Mungo pole, and great hauls were caught with their net. These were made from reeds, all of which had to be chewed with their teeth so that they became pliable; they were often thirty to forty yards long. Cod fish live in hollow logs under the water, and the native with a small hand net would dive away down to one of these big old logs, place the net over the end of it, and gently tap, tap the log with a piece of wood. The cod, frightened, would swim out and be caught in the net and be brought to the surface. A native could keep under water for a long while.	-	Net, spear
Crustaceans				
Freshwater lobster (<i>Euastacus armatus</i>)				
Eyre (1845:265, 267)	Murray River general reference	Generally collected by women. Speared from under rocks under base of cliff or among logs, or collected by hand.	-	Spear, hand collection
Yabby (<i>Cherax destructor</i>)				
Angas (1847:90)	Lower Murray (Mooriundie)	-	Eaten 8 months of the year	Roasted on coals
Eyre (1845:252, 265, 267)	Lower Murray (Moorundie)	When the Murray annually inundates the flats, fresh water cray fish make their way to the surface in such vast quantities that I have seen 400 natives live on them for weeks'. Caught by women walking in coordinated line and groping with hands and feet with yabbies put into net suspended around women's neck. Two - three hours work to procure family's needs for a day.	Spring - summer	Hand collected, placed in nets
Finniss (1966)	Riverland (Lake Bonney)	Sturt's expedition were brought crayfish by Aboriginal people	Late Winter	-
Shellfish				
Freshwater mussel (unspecified)				
Angas (1847:55, 90, 92)	Lower Murray (Mooriundie)	Daily staple, also used as knives, cooked in ashes	-	Roasted on coals
Berndt and Berndt (1993:563)	Lower Murray	The collection season was short from about the end of spring to the end of summer as it was impossible to gather mussels in winter as the mussels migrated deep into the mud	Spring - summer	-

Reference	Location	Detail	Timing of collection	Collection & Processing Techniques
Eyre (1845:267-268)	River Murray general reference	Muscles of very large kind collected by women by diving to bed and filling small nets hung around their necks.	-	Hand collected in nets
Hawdon (1852)	Riverland general reference	Hawdon saw heaps of mussel along the river bank on a daily basis, associated it specifically with women's food (March 2), but then Hawdon observed (Mar 14) men carrying mussel shells in small nets slung over their shoulders on a spear west of Lake Bonney.	Late summer - autumn	-
Roysland (1977:25)	Riverland (Renmark)	Described as a regular staple	-	-
River mussel (<i>Alathyria jacksoni</i>)				
Angas 1887(1):55, 58	Lower Murray	Described as a regular staple	-	Roasted
Reptiles				
Goanna (<i>Varanus</i> spp.)				
Roysland (1977:25)	Riverland (Renmark)	Regular staple. Chopped it up into cutlets, insides and all, then laid it on a piece of wire netting and grilled it on the coals.	-	Roasted on coals
Turtle (<i>Chelodina</i> spp.)				
Angas (1847)	Lower Murray (Moorundie)	Collected in summer	Summer	-
Eyre (1845:259, 267)	unspecified	Turtle up to twelve pounds taken in the same nets used for fishing'	-	Nets
Hawdon (1852)	Lake Victoria	Caught by women, plentiful in the river (March 2), saw group feeding on tortoise (March 5)	March	-
Roysland (1977:25)	Riverland (Renmark - Ral Ral)	Caught for meat and eggs dug from around waterholes	-	Dug out
Smyth (1972:197)	Murray Districts	A great many turtles are caught during the summer months	Summer	-
Mammals				
Kangaroo (<i>Macropodidae</i> spp.)				
Angas (1847)	Lower Murray (Moorundie)	Caught in nets made from marsh-mallow that were baked and chewed and spun into twine	-	Nets
Eyre (1845:276-277)	River Murray general reference	Speared, netted or caught in pit falls	-	Nets, spear, pit traps
Finniss (1966)	Riverland (Lake Bonney)	Kangaroo stomach filled with offal roasted - a great delicacy amongst old Aboriginal men	Spring	Roasted
Hawdon (1852)	-	Driven into nets	-	Nets

Reference	Location	Detail	Timing of collection	Collection & Processing Techniques
Schell (1914b)	Riverland general reference	... Kangaroos were ambushed and speared, the natives showing great cunning in so disposing themselves that the roo seldom had a chance. Kangaroo nets were also used and were hung in the scrub. They were very large, very tough, and made entirely from kangaroo sinews.	-	Net, spear

Appendix II: A summary of grinding material held in the SAM archaeological collections and provenanced to the upper Riverland

A#	Lot	Artefact_type	Material	Macrowear_A	Macrowear_B	General comments	Provenance/Context
A59525	4056	Mortar	Sandstone	Crushing		Circular, tabular cobble, facets both surfaces, yellow ochre. Silicified sandstone.	Chowilla II
A21039	4056	Mortar	Sandstone	Polish		Thick block single ground facet 1 surface, partially edge trimmed, patchy colouring, silicified sandstone.	Renmark
A56530	4056	Pestle/Anvil	Sandstone	Polish	Crushing	Used as pestle with bevelled surface on one end. Also used as an anvil on one side. Silicified sandstone.	Chowilla, SA
A54222	4052	Other	Sandstone			Silicified sandstone block with possible amorphous use.	Chowilla, SA
A58487	4052	Pestle	Sandstone	Polish	Crushing	Silicified sandstone round cobble with single planated surface, with a small shallow facet, crushed, grinder.	Chowilla, SA
A53911	4055	Pestle	Sandstone	Polish		Large sandstone cobble grinder with a single planated working surface.	Pike River Lagoon, Hd Paringa, Site 1
A59527	4055	Mortar	Silcrete	Polish		Large angular block with shallow facet and polish on one surface.	Chowilla II, WA1
A20393	4055	Pestle	Sandstone	Polish		Silicified sandstone cobble, single planated surface with polish.	Overland Corner
A20396	4061	Pestle	Sandstone	Polish	Crushing	Large silicified sandstone cobble, single planated working surface, crushing around perimeter.	Moorook
A20389	4061	Pestle	Sandstone	Polish		Silicified sandstone cobble, single planated surface, polished, percussive wear around perimeter.	New Residence
A20400	4061	Pestle	Sandstone	Polish	Crushing	Silicified sandstone large heavy cobble, single planated working surface with polish and 1 negative flake, possible pitting on working surface, around perimeter percussive wear.	Moorook
A46045	4051	Mortar	Sandstone	Polish		Silicified sandstone (silcrete) large block with a single deep ground depression, 133x142 on 1 surface. 1 of a pair.	Lake Woolpoolool
A46045	4051	Pestle	Sandstone	Polish		Silicified sandstone small cobble, single planated surface. 1 of a pair. Writing on artefact said '1 found on edge of' so maybe not a pair.	Lake Woolpoolool
A20398	4070	Pestle	Sandstone	Polish		Silicified sandstone large cobble, single planated working surface with polish with possible percussion around perimeter.	Moorook 1
A31126	4070	Pestle	Sandstone	Polish		Silicified sandstone large rounded cobble with a single planated working surface with convex to perimeter of surface polish, possible residue.	Lake Merreti, western shore, Renmark
A20392	4070	Mortar	Other	Polish		Large, coarse feldsarenite cobble with a single ground working surface.	Overland Corner

A#	Lot	Artefact_type	Material	Macrowear_A	Macrowear_B	General comments	Provenance/Context
A54222	4059	Mortar	Sandstone	Polish		Sandstone (real) large rounded cobble with single planated working surface, with shallow ground facet. Discolouration in ground surface.	Chowilla
A59487	4059	Pestle	Sandstone	Polish	Crushing	Sandstone (real) large rounded cobble with a single planated working surface with polish and small pit marks from percussion on 1 surface.	Chowilla
A54222	4059	Pestle	Sandstone	Polish		Sandstone (real) large heavy rounded cobble with a single planated working surface. Heavy polish extending to the rim of the surface. 3 more pestles in same box.	Chowilla
A56532	4057	Mortar	Sandstone	Polish		Silicified sandstone large cobble with ground working surfaces, 2, with facets. Lovely.	Chowilla Dam Site
A56532	4057	Mortar	Sandstone	Polish		Silicified sandstone cobble with two ground facets, one has been used as a core, removing some flakes extending onto ground surfaces. The end looks to have been planated.	Chowilla Dam Site
A54447	4054	Millstone	Sandstone	Polish		Silicified sandstone, small tabular planoconvex fragment with extreme polish on 2 surfaces, described as boomerang polishing stone. Looks similar to small fragment southern end of Lake Merretti. Possible millstone fragment.	Lettons Swamp, 5 miles south of Renmark
A56531	4054	Muller	Sandstone	Polish		Sandstone, thin tabular cobble with a heavy polish on one surface, planoconvex, edge trimmed the full perimeter.	Chowilla Station
A59488	4054	Muller	Sandstone	Polish		Sandstone (real) with 2 flat angled surfaces (classic muller).	Chowilla, SA
A54222	4054	Mortar	Sandstone	Polish		Sandstone (real) fragment of a mortar, thin tabular block with single working surface, ground, shallow facet, fragment of a larger piece.	Chowilla
A59488	4054	Muller	Sandstone	Polish		Sandstone (real) thin tabular piece with heavy polished working surface with convex working surface.	CH1. Chowilla, SA
A59488	4054	Muller	Sandstone	Polish		Sandstone (real) small thin tabular piece with heavy polish on 1 working surface, convex. Worn to a nub!!	Chowilla, SA. CH1.
A31125	47	Millstone	Sandstone	Polish		Large 15.5kg sandstone tabular block, two concavities on one surface, red/brown residue	Western shore, Lake Merreti
A42418	39	Millstone	Sandstone	Polish		Large c. 6kg sandstone tabular block, one ground facet, opposite surface has polish but no depression, fragment (estimated length extra 20cm based on shape), dark red/brown residue around perimeter of concave bowl	Paringa
A28870	4202	Muller	Sandstone	Polish		Sandstone (real) thin cobble plana-convex working surface, heavy polish.	West bank, Lake Merreti

A#	Lot	Artefact_type	Material	Macrowear_A	Macrowear_B	General comments	Provenance/Context
A50284	2045	Mortar	Sandstone	Polish		Silicified sandstone large (7.5kg) block with single abraded facet on 1 surface (nardoo stone)	Katarapko Creek
A20387	2061	Pestle	Sandstone	Polish		Silicified sandstone large cobble (1.5kg) with single ground working surface with possible small pitted area - dubious.	Lake Bonney
A17282	2061	Mortar	Basalt	Polish		Large flat cobble (2.5kg) with ground circular facets on 2 surfaces. Extensive hammer dressing on one 2 surface. River cobble. Basalt??	SA border on River Murray
A59487	2061	Pestle	Sandstone	Polish		Silicified sandstone large oblong cobble (2kg) with a single small ground working surface on one end (5x5cm). Same as previous pounder type.	Chowilla
A20390??	1236	Mortar	Sandstone	Polish		Silicified sandstone large round cobble (7kg) with single working surface, shallow abraded facet. Nardoo stone.	New Residence
A56536	4069	Pounder	Quartzite	Crushing		Double waisted small quartzite cobble.	Lake Coombool, Chowilla
A28746	1060	Edge ground axe	Basalt	Polish		Small, ground axe, 2 surfaces with bevelled edge, butt reduced and hammer dressed.	Above Renmark
A4364	1130	Edge ground axe	Basalt	Polish		Small, ground axe, 2 surfaces with bevelled edge, butt trimmed and hammer dressed. 1 negative scar relating to usewear damage.	Overland Corner
A22781	1132	Edge ground axe	Basalt	Polish/Striations		Small edge ground hatchet, bevelled blade, butt appears to be trimmed slightly, shallow waisting.	Moorook

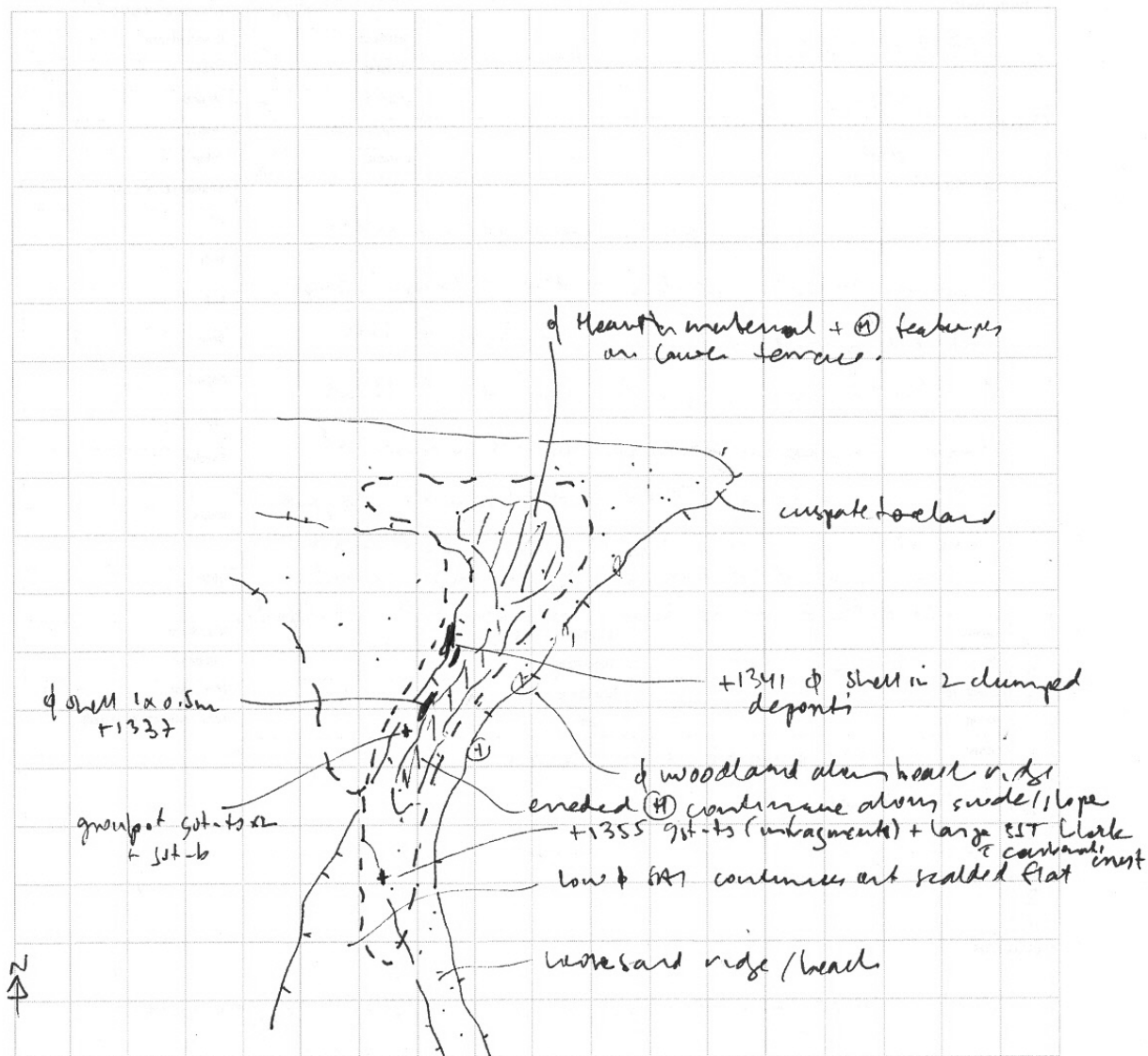
Appendix III: An example of a sediment recording log

LOG ID: WOL-01/02 composite		GPS: 47°16'14"N + 102°01'02"W (3534)													
DATE: 24/4/24		CONTEXT: upper units of dunes near creek edge.													
RECORDER: UN															
UNIT/AGE	SCALE (m)	SEDIMENT	GRAINSIZE							MUNSELL	DETAIL	ARCHAEOLOGY	SAMPLING		
			MUD clay silt	SAND vf m vc	GRAVEL gran pebb cobb boul	SAMPLE TYPE*	BAG_ID								
25.23 24.52 24.10	0 96 94								A A B	5YR 6/8 5YR 5/8 5YR 6/6	planner bed fine sand margin f/w sand PS fine clastic sand underlying.		OSL WOL-01 OSL WOL-02		
	1.43 1.35 1.82								C	7.5YR 2/4 5YR 7/6	fine - vt sand & minor carbonate				
	3.18								D	2.5YR 6/6	deeper f. clayey sand.				
	3.67 2.4								E	7.5YR 5/8	overlying (??)				
INTERPRETATION:												IMAGES:			
												* immediate response in dark water i. high clay content in PS (loss??) → Shale for minor component in OSL final		① 9208 5684-85 on profile 86-18 view to SW.	

* 14C/OSL/SED/ENV/ARCH

Appendix IV: An example of a Site Recording Sheet

SITE ID/NAME: Cape 17-22		Site Type/Features/Materials present				
DATE: 19/9/18		Artefacts	☒	Modified tree		
RECORDER: aw		Skeletal		Hearth	☒	
		Midden	☒	Mound		
		Knapping floor		Quarry		
		Historic	☒	Other		
SITE DESCRIPTION Large exposure of hearth material (features & dispersed/eroded spread), midden (dumped, lenses + diffuse spread) and low numbers of stone artefacts across sandy terrace. Bulk of hearth material occurs in NE corner of site. Midden tends to be dumped deposit exposed as in sites lenses around top + upper slope of eroding edge of sand sheet. Artefacts occur in low numbers & of variable size.					Modified tree detail	
					Lth	
					Wth	
					R/g	
					Base	
					Aspect	
					Type	
					Species	
					Height	
					Girth	
LITHIC	Quartz		Silcrete	f, cov, silt-b		
	Chert	f, cov	Chalcedony			
	Quartzite		Sandstone	silt-b		
	Basalt		M/Sed			
	Other	clay pipe stem fragment.				
FAUNAL	f/w mouse					
SKELETAL	—					
LANDFORM						
Sandy sheet on terrace, western shore of Lower Lake						
VEGETATION						
B. box., clumped						
CONDITION						
moderate - poor - lightly eroded.						
RECOMMENDATIONS						



COORDINATES (node no./detail)

*Mapping Datum to be used is GDA94.

+1331 - +1355 ~ boundary	+1337 d shell dump		
	+1341 d " " x2		

PHOTOGRAPHY (Image no./detail):

3897 gnt-b + ts (x1)	3895/96 clay pipe stem fragment
3898/85 - N along eroding edge of dune	
3899/91 - S " "	
3892/93 d heartland material in NE to at site	
3894 d lens of material	

Appendix V: Examples of Excavation Recording Sheets

Trench Record

Complete this form for each new trench or test pit that is opened.

Site: <u>Pike SP16_05</u>	Trench No.: <u>TP01</u>	Trench Code: <u>AVSP16-05-TP01</u> (Site/Trench #)
Date/time opened: <u>7/10/19 10:30</u>	Trench supervisor: <u>C. Wether</u>	
Trench bounding coordinates. UTM GDA 94 Zone <u>54</u> or other: _____		
(Record full extent of trench (2 decimal places). Sketch point locations)		
Point No / X / Y / Z / Description		
Start	End	End
TS +100	TS 108	+115 top SU02
+101	109	+116 unexcavated
+102	110	+117 bottom
+103	111	+118
		+119
		+120
		+121
		+122
		4 MN.
Context and level register:	Post excavation sampling	
(List all contexts and associated levels)	(List all samples taken once excavation is complete, e.g. C14, column, context, soils)	
SU01 x401	C14?	
x402		
SU02 not excavated.		
DW01 north + east walls.	Section drawings (list plan numbers and area drawn)	
© completion photos	None - no structure through	
x566/67 → Ad.	columns SU01.	
x568 structure	Completion photos: (C)	
	5651-5652-5653-AN	
Excavation rationale, methods and general notes:		
x High Pike City adjacent to hearth feature and three benches in wall. Area of interest in site material. x SU02 was excavated from surface 50x30cm area of trench given time constraint. First began at start of 1st subunit early. Soil (soil + tubules not collected) with rough excavation then downed when short fragment (SU01) seen.		

Trench Closure

Are all context forms enclosed?

Yes ☒

Are all level forms enclosed?

Yes ☒

Date/time closed: 7/10/19 13:20

Project	Calperum CW PhD			Date(s)	7/10/19
Site	PikeSP16-05	TR/TP_ID	TP01	Supervisor(s)	CW/AR/MF

003	TP01	SU001	XU001	5mm	shell	x C14
004	TP01	SU001	XU001	3mm	shell	
005	TP01	SU001	XU001	1mm	shell	
006	TP01	SU001	XU001	3mm	Bone	
007	TP01	SU001	XU002		Total finds.	
008	TP01	SU001	XU002	5mm	Shell	x C14
009	TP01	SU001	XU002	3mm	shell	
010	TP01	SU001	XU002	1mm	shell	
011	TP01	SU001	XU002	5mm	Stone.	
012	TP01	SU001	XU002	1mm (3mm)	Charcoal	
013	TP01	SU001	XU002	5mm	Stone artefact	
014	TP01	SU002	XU003	- SF01	(C14) shell (special find)	x C14
015	TP01	SU002	XU003		Total finds	
016	TP01	SU002	XU003	5mm	5mm Shell.	
017	TP01	SU002	XU003	3mm	8mm	
018	TP01	SU002	XU003	1mm	8mm & bulk.	
019	TP01	SU002	XU003	5mm (3mm)	Burnt (?) Caliche	
020	TP01	SU002	XU003	1mm	Charcoal.	

Context Record

Trench Code: Pile SP16-05 - TPO1

Context ID: Su01 Area or Quad (If applicable) -

Date/time opened: 7/10/19 10:30 Recorder: C. Weyfem
(1 person only)

Excavators: C. Weyfem
(List all)

Sieve sizes used: (list from coarsest to finest):

1. 5 mm
2. 3 mm
3. 1 mm
4. mm

Catch tray?

☐ Y or ☒ N

Excavation Units (XUs) Excavate all contexts in arbitrary spits. Complete a level form for each spit..

XU depth: mm to ~15cm

Notes: continuous spit to Su02 surface.

Number of levels excavated: 2

Pre-excavation recording tasks (Always complete all fields below before commencing excavation of a new context)

Scale Plan Drawn? Y ☐; Plan Number: _____; Drawn by: _____

Draw at 1:20 scale. Ensure trench, context and area details are noted.

Vertical photographs taken? Y ☒; Camera name: C. compact.; Image Nos: 563Y

Include north arrow. Must be 'top down', full frame photo ideally with 50mm lens. Avoid flash photography. Also complete digital image pro-forma with each camera.

Photogrammetric photos taken? Y ☐; Camera name: _____; Image Nos: _____
Use a 50mm lens at a consistent distance of 2m from trench, taken diagonally from each corner and every 50cm along walls. Use manual settings where possible. Aim for an even distribution of consistent photographs around the trench boundary. Use camera stand ~50cm in height. Aim is to capture both floor and walls in 3D.

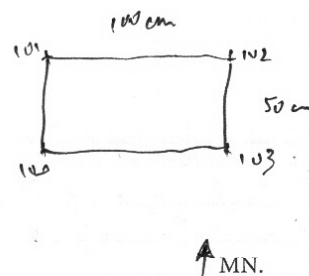
Other pre-excavation recording: _____

Context Starting levels. UTM GDA 94 Zone _____ or other: _____

(Record full extent of starting levels. Sketch point locations.).

Point No / X / Y / Z / Description:

<u>48</u>	<u>100</u>			
<u>101</u>				
<u>102</u>				
<u>103</u>				



Context type: ☒ Deposit ☐ Fill ☐ Cut ☐ Structural ☐ Other: _____

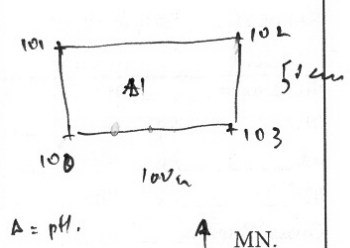
Stratigraphic Matrix

						Above this context
This context	<u>Su01</u>					
						Below this context

Matrix notes:

Fill: 1. Compaction 2. Colour 3. Composition/Particle size (>10%) 4. Inclusions (<10%) Occ ☐ Mod ☐ Freq ☐ 5. Thickness and extent 6. Other comments 7. Method and conditions	Description (See MOLAS guidelines)	Cut: 1. Shape in plan 2. Corners 3. Dimensions/depth 4. Break of slope (top) 5. Sides 6. Break of slope (bottom) 7. Base 8. Orientation 9. Inclination of axis 10. Truncated 11. Other comments
	1. loose - friable 2. 54P 6/4 3. fine calc sand. 4. 1 calcite nodules. 5. full extent area of +P, flat surface ^{top} flat to SU02 6. minor fibrous roots @, worms, ant hole. 7. gravel, boulders.	
	- continuous with 7 minor variations related to fibrous roots etc. - minor fragmented shell continuous through SU01 - got dense under features exposed along with but did not intercept and here is not expansive deposit over cliff top.	
Your interpretation/discussion: fine sand drift, likely basin - mobile at times, linear - ~ 2.5m above calcite.		
Supplementary notes, plans, samples or data > no plan drawn per continuous SU.	Context closure checklist (To be completed by trench supervisor): Context metadata: ☒ Pre-excav. recording: ☒ Context description: ☒ Stratigraphic Matrix: ☒ Interp/discussion: ☒ Level forms attached: ☒ Trench form updated? ☒ Date/time closed: 7/10/19 13:15	

Level/XU Record

Trench Code: <u>016/016-05 7001</u>																					
Context ID: <u>5001</u> ; Level number: <u>XU 01</u>																					
Date/time context opened: <u>7/10/19</u> <u>10:30</u>	Recorder: <u>C. W. [signature]</u> (1 person only)																				
Starting levels (Height ASL)																					
<table border="0" style="width: 100%;"> <tr> <td style="width: 50%;">Pt. ID; Z</td> <td style="width: 50%;">Pt. ID; Z</td> </tr> <tr> <td><u>100</u>; _____m;</td> <td>_____;</td> </tr> <tr> <td><u>101</u>; _____m;</td> <td>_____;</td> </tr> <tr> <td><u>102</u>; _____m;</td> <td>_____;</td> </tr> <tr> <td><u>103</u>; _____m;</td> <td>_____;</td> </tr> </table>	Pt. ID; Z	Pt. ID; Z	<u>100</u> ; _____m;	_____;	<u>101</u> ; _____m;	_____;	<u>102</u> ; _____m;	_____;	<u>103</u> ; _____m;	_____;	sketch relative positions and indicate north 										
Pt. ID; Z	Pt. ID; Z																				
<u>100</u> ; _____m;	_____;																				
<u>101</u> ; _____m;	_____;																				
<u>102</u> ; _____m;	_____;																				
<u>103</u> ; _____m;	_____;																				
Mean Starting Level: _____m ASL. Mean End Level _____m ASL (complete once new level opened) Mean XU Depth _____cm																					
Pre-excavation recording tasks (Always complete all fields below before commencing excavation of a new context)																					
Scale Plan Drawn? Y ☐ N ☒ ; Plan Number: _____; Drawn by: _____ Draw at 1:20 scale. Ensure trench, context and area details are noted on plan. If plan has been drawn already, or if there are no visible features, a plan is not required.																					
Vertical photographs taken? Y ☒ ; Camera name: <u>C. W. [signature]</u> ; Image <u>5638</u> Nos: _____																					
Include north arrow. Must be 'top down', full frame photo ideally with 50mm lens. Avoid flash photography. Also complete digital image pro-forma with each camera.																					
Sediment pH readings: Take 1 reading near centre of each 50cm ² square. Indicate locations on plan, above. Ensure instrument is inserted ≤ depth of spit.																					
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Number</th> <th>Area</th> <th>pH</th> </tr> </thead> <tbody> <tr> <td><u>1</u></td> <td><u>8.5</u></td> <td></td> </tr> <tr> <td> </td> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> <td> </td> </tr> </tbody> </table>		Number	Area	pH	<u>1</u>	<u>8.5</u>															
Number	Area	pH																			
<u>1</u>	<u>8.5</u>																				
Notes on excavation (e.g. difficulties, observations, methods. Record finds overleaf): <u>Mild effort, but generally large for [unclear]</u> <u>minimal [unclear]</u>																					
Gross Weight of Bulk residues (as excavated) (Include weight of bucket OR calibrate scales for bucket. Only use standard bucket for all weighing)																					
<table border="0" style="width: 100%;"> <tr> <td>01: <u>6.8</u> kg</td> <td>05: <u>8.3</u> kg</td> <td>09: <u>10.8</u> kg</td> <td>13: _____ kg</td> <td>17: _____ kg</td> </tr> <tr> <td>02: <u>8.7</u> kg</td> <td>06: <u>7.2</u> kg</td> <td>10: _____ kg</td> <td>14: _____ kg</td> <td>18: _____ kg</td> </tr> <tr> <td>03: <u>10.1</u> kg</td> <td>07: <u>9.6</u> kg</td> <td>11: _____ kg</td> <td>15: _____ kg</td> <td>19: _____ kg</td> </tr> <tr> <td>04: <u>11.4</u> kg</td> <td>08: <u>9.8</u> kg</td> <td>12: _____ kg</td> <td>16: _____ kg</td> <td>20: _____ kg</td> </tr> </table>		01: <u>6.8</u> kg	05: <u>8.3</u> kg	09: <u>10.8</u> kg	13: _____ kg	17: _____ kg	02: <u>8.7</u> kg	06: <u>7.2</u> kg	10: _____ kg	14: _____ kg	18: _____ kg	03: <u>10.1</u> kg	07: <u>9.6</u> kg	11: _____ kg	15: _____ kg	19: _____ kg	04: <u>11.4</u> kg	08: <u>9.8</u> kg	12: _____ kg	16: _____ kg	20: _____ kg
01: <u>6.8</u> kg	05: <u>8.3</u> kg	09: <u>10.8</u> kg	13: _____ kg	17: _____ kg																	
02: <u>8.7</u> kg	06: <u>7.2</u> kg	10: _____ kg	14: _____ kg	18: _____ kg																	
03: <u>10.1</u> kg	07: <u>9.6</u> kg	11: _____ kg	15: _____ kg	19: _____ kg																	
04: <u>11.4</u> kg	08: <u>9.8</u> kg	12: _____ kg	16: _____ kg	20: _____ kg																	
Gross Weight: _____kg.																					
Sieve size= _____mm (Include weight of bucket OR calibrate scales for bucket. Only use standard bucket for all weighing)																					
<table border="0" style="width: 100%;"> <tr> <td>01: _____ kg</td> <td>04: _____ kg</td> <td>07: _____ kg</td> <td>10: _____ kg</td> <td>13: _____ kg</td> </tr> <tr> <td>02: _____ kg</td> <td>05: _____ kg</td> <td>08: _____ kg</td> <td>11: _____ kg</td> <td>14: _____ kg</td> </tr> <tr> <td>03: _____ kg</td> <td>06: _____ kg</td> <td>09: _____ kg</td> <td>12: _____ kg</td> <td>15: _____ kg</td> </tr> </table>		01: _____ kg	04: _____ kg	07: _____ kg	10: _____ kg	13: _____ kg	02: _____ kg	05: _____ kg	08: _____ kg	11: _____ kg	14: _____ kg	03: _____ kg	06: _____ kg	09: _____ kg	12: _____ kg	15: _____ kg					
01: _____ kg	04: _____ kg	07: _____ kg	10: _____ kg	13: _____ kg																	
02: _____ kg	05: _____ kg	08: _____ kg	11: _____ kg	14: _____ kg																	
03: _____ kg	06: _____ kg	09: _____ kg	12: _____ kg	15: _____ kg																	
Gross Weight: _____kg.																					
Less Individual bucket weight: _____kg x _____ buckets = _____kg Net Weight: _____kg																					
Sampling Notes:																					
<table border="0" style="width: 100%;"> <tr> <td style="width: 20%;">Sample size</td> <td style="width: 20%;">Sample weight</td> <td style="width: 20%;">No. of Bags</td> <td style="width: 40%;">Sample ID numbers (e.g. Trench 1, Context A-3, Sample Type, Bag Number)</td> </tr> <tr> <td>_____%</td> <td>_____kg</td> <td>_____</td> <td>_____</td> </tr> </table>		Sample size	Sample weight	No. of Bags	Sample ID numbers (e.g. Trench 1, Context A-3, Sample Type, Bag Number)	_____%	_____kg	_____	_____												
Sample size	Sample weight	No. of Bags	Sample ID numbers (e.g. Trench 1, Context A-3, Sample Type, Bag Number)																		
_____%	_____kg	_____	_____																		

Sieve size= _____ mm (Include weight of bucket OR calibrate scales for bucket. Only use standard bucket for all weighing)				
01: _____ kg	04: _____ kg	07: _____ kg	10: _____ kg	13: _____ kg
02: _____ kg	05: _____ kg	08: _____ kg	11: _____ kg	14: _____ kg
03: _____ kg	06: _____ kg	09: _____ kg	12: _____ kg	15: _____ kg
Gross Weight: _____ kg.				
Less Individual bucket weight: _____ kg x _____ buckets = _____ kg Net Weight: _____ kg				
Sampling Notes: _____				
Sample size	Sample weight	No. of Bags	Sample ID numbers (e.g. Trench 1, Context A-3, Sample Type, Bag Number)	
_____ %	_____ kg	_____	_____	

Sieve size= _____ mm (Include weight of bucket OR calibrate scales for bucket. Only use standard bucket for all weighing)				
01: _____ kg	04: _____ kg	07: _____ kg	10: _____ kg	13: _____ kg
02: _____ kg	05: _____ kg	08: _____ kg	11: _____ kg	14: _____ kg
03: _____ kg	06: _____ kg	09: _____ kg	12: _____ kg	15: _____ kg
Gross Weight: _____ kg.				
Less Individual bucket weight: _____ kg x _____ buckets = _____ kg Net Weight: _____ kg				
Sampling Notes: _____				
Sample size	Sample weight	No. of Bags	Sample ID numbers (e.g. Trench 1, Context A-3, Sample Type, Bag Number)	
_____ %	_____ kg	_____	_____	

Field quantification of repatriated materials Please enter any supplementary data entry on Android Handset. Ensure materials are thoroughly hand sorted where bulk samples are being discarded.				
Type: _____	Number: _____	Diameter Max: _____	Min: _____	Weight: _____ kg
Type: _____	Number: _____	Diameter Max: _____	Min: _____	Weight: _____ kg
Type: _____	Number: _____	Diameter Max: _____	Min: _____	Weight: _____ kg
Type: _____	Number: _____	Diameter Max: _____	Min: _____	Weight: _____ kg

In situ finds or samples (artefacts, C14 samples, etc, removed individually)				
Pt. ID	Type/Description	Sample ID numbers (e.g. Trench 1, Context A-3, Sample Type, Bag Number)		
_____	_____	_____		
_____	_____	_____		
_____	_____	_____		
_____	_____	_____		
_____	_____	_____		
_____	_____	_____		
_____	_____	_____		
_____	_____	_____		
_____	_____	_____		

Supplementary notes, plans, samples or data _____ _____ _____ _____ _____ _____ _____ _____ _____ _____	Context closure checklist (To be completed by trench supervisor): Metadata: ☒ Level data: ☒ Pre-excav. recording: ☒ Excavation data: ☒ Field quantification: ☒ Trench form updated: ☒ ENSURE ALL SAMPLES ARE DOUBLE TAGGED/ AND BAGGED BEFORE OPENING NEW LEVEL! Date/time closed: 21/10/19 11:45
--	--

Appendix VI: Example of a ^{14}C sample collection sheet

C14 SAMPLE COLLECTION CHECKLIST

Site ID:	CAPR17-19		Sample ID (8 character maximum):	CAPR-07
Site type:	midden/open scatter.			
Collection date:	9/14/2018		Collected by:	C. Westell
Collection Method:	tweezer - all foil - zip lock.			
Sample Type & completeness:	shell complete values x 2		Species	HA: Jacksoni (or fast flow J. antiquum).
Weight (gms):	9.24 10.9			
Location:	Datum		Easting	
	MGA Zone		Northing	
	Detail	RTK 081		
SAMPLE CONTEXT	Sediment type	medium sand / red		
	Surface or Depth (cm) & (Z-coordinate)	surface - but probably ripped from shallow sub-surface		
	Associated cultural material	heavily, low density artefacts.		
	Relationship to other samples	Sample ID	Stratigraphic location	
	Wet or dry	Dry.		
	Related feature/unit	dense midden probably extensive		
Unit ID	- in shallow sub-surface			
In situ or eroded	er in ripped ∴ some vertical displacement			
SITE CONTEXT	Landscape	SBD coast.		
	Geology	alluvium		
	Associated sites	-		
	C14 Taphonomy & Contamination (carbonate/organic soil/rootlets/water)	-		
Pretreatments (e.g. removal of sediment, drying or chemical):	none			
Sample storage:	zip lock - container - flinders			
Estimated age:	~450 BP			

Appendix VII: Descriptions of the OSL sampling locations

Sample_ID	Location and context	Rationale	Images
WOL-01 (Ad19138) & WOL-02 (Ad19139)	Outer (eastern) extent of Lake Woolpoolool lunette on a low pedestal immediately west of the Woolpoolool 'notch'. The pedestal is capped by a distinctive, 14cm thick light red/buff (5YR 7/6) palaeosol overprinting a fine, mottled clayey sand extending to the base of the pedestal (~45cm). The palaeosol forms a laterally extensive sheet across much of the outer lunette and dips west across the surface of the lunette before plunging under the inner ridge. The distinctive soil is also seen in various locations across the Calperum floodplain, capping T2b SBDs in the southern section of the floodplain and a sand spreads east of Clover and Merreti Lakes. It is also seen within equivalent geomorphic contexts beyond Calperum, including SBDs at Pike. The soil, therefore, forms an important chronological marker across the broader Calperum floodplain and Riverland region. Two OSL samples were taken, the first in the soil and second below it. An overlying unit of undifferentiated fine quartz sand forms a distinctive notch rising immediately east of the pedestal. This unit has been stripped from the sample location.	No archaeological materials are incorporated into or seen below this soil in any context within the Calperum floodplain, though material occurs as a lag on top of the soil. This soil (and age), therefore, provides a useful age constraint on various archaeological sites. The two samples aimed to establish: • A minimum age for development of the outer lunette ridge at Lake Woopoolool. • A minimum age for the incision of T2a scrolls into the T1b terrace both here and in the Clover/Merreti basin. The lunettes post-date these scrolls. • A maximum age for soil development (the soil postdates sedimentation). • The potential polygenetic nature of the soil.	 

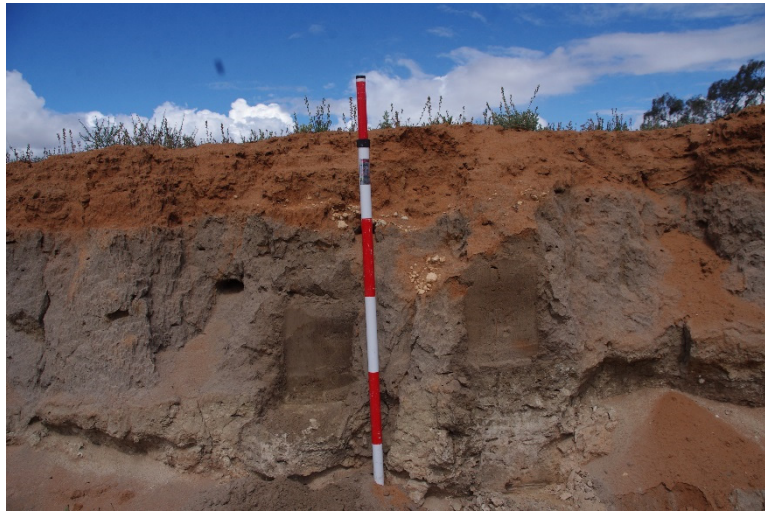
Sample_ID	Location and context	Rationale	Images
WOL-03 (Ad19140) & WOL-04 (Ad19141)	Deep, 1.6 m profile exposed in sand quarry incised into the base of the western (lakeside) slope of the inner quartz sand lunette on the north-eastern shoreline of Lake Woolpoolool. The profile is comprised of moderately sorted medium-coarse quartz sand, grading from light red (5YR 5/4) to light buff (5YR 7/8) at depth. The upper 16cm of the profile is comprised of a recently deflated cover overlying a 48cm thick unit of thin, low angle bedded sand. A massive sand then continues to the base of the cutting. There is no indication of soil development or deflationary periods (disconformities) within the lower unit though a deeper red colour occurs in the upper 40 cm of the unit. A clear disconformity occurs toward the top of the section where loose, planar bedded sands overlay a massive underlying unit. More recent drift sand caps the section. No archaeological materials were noted in this profile or anywhere along the quarry cutting or broader lunette slope, despite extensive gullying and other exposures. Sites are present on the surface of the lunette approximately 60m east of the sampling. The two OSL samples were taken at depths of 56 cm and 102 cm, i.e. at the base of the bedded sand and mid section of the profile in the massive sand.	The lunette forms a distinctive feature around the north-eastern side of Lake Woolpoolool, with equivalent features identified in the Merreti-Clover basin and at Rotten Lake. The orientation of the lunette in respect to the lake basin marks a distinct change in prevailing wind, and a reinundation of the floodplain at levels significant enough to temporarily refill Rotten Lake. The lunette, therefore, marks a major transformation from an LGM to deglacial-influenced floodplain. The two samples aimed to establish: • A developmental history for this lunette ridge. • A minimum age for the key hydrological transition. • A maximum age for archaeological sites developed on top of the lunette.	 

Sample_ID	Location and context	Rationale	Images
WOL-05 (Ad19142) & WOL-06 (Ad19144)	These two samples were collected from a cleaned surface continuing to 95 cm in an eroding ledge toward the top of the outer lunette at Outer Lake A. The section has exposed a deep, mottled palaeosol with blocky/prismatic texture overprinting a fine clayey sand. The parent material consists of a light red (5YR 5/6), fine-medium clayey sand. Fine, low angle bedding is overprinted by the blocky soil texture and minor rymorphic carbonate. A thin cap of fine-medium sand overhangs the profile slightly, typical of exposures continuing around this and the other outer lunette basins. A clear disconformity occurs between this and the underlying two unit. No archaeological materials are incorporated into this or similar exposures around the lunette or across the broader lunette surface itself. Extensive archaeological sites (open scatters) are recorded on Wfm dunes that have transgressed across the lake basin, i.e. following the terrestrialisation stage in the lake and post-dating the lunette. The two OSL samples were taken at depths of 13 cm within the upper soil capping, and at 80 cm toward the base of the profile.	The two samples aimed to establish: • A minimum age for development of the lunette, and equivalent features associated with the outer lakes. • The relationship between the upper and lower units. • A maximum age for soil development, i.e. the soil postdates sedimentation. • A minimum age for the transgression of Wfm dunes into the lake basin.	 

Sample_ID	Location and context	Rationale	Images
WOL-07 (Ad19145)	Profile exposed in a quarry cutting on the lakeside edge of the inner HSGD lunette at Outer Lake C. A single OSL sample was taken within a thin lenticular unit of fine quartz sand at a depth of 85 cm. The sand lens pinches out against a basal gypsum unit toward the southern end of the cutting. The full sediment profile exposed in the cutting extends to a depth of 180 cm, and consists of an upper gypcrete cap (0-26 cm), overlying a pure, fine, white (7.5 YR 9.5/1) powder gypsum (26-44 cm), a moderately well sorted, light buff fine-medium quartz sand impregnated with fine crystal gypsum (44-105 cm) and a second gypcrete soil overlying powder gypsum. The sand forms a thin, lenticular unit fully contained within the gypsum clays, resting directly on top the lower gypcrete soil and pinching out both down and up slope along the profile.	The development of gypsum lunettes across all the outer lunette basins marks a major transition in floodplain connectivity. The sequence of two gypcrete soils and intervening quartz sand unit is replicated here and at Rotten Lake, identifying episodic conditions in these lakes (prior to the terrestrialsation phase in Outer Lake C). The sample aimed to establish: • A chronological framework for this lunette, and equivalent features associated with the outer lakes. • A maximum age for the upper gypcrete soil, i.e. the soil postdates sedimentation. • A minimum age for the lower gypcrete soil. • A minimum age for floodplain incision resulting in reduced connection between the active floodplain and this backplain basins.	 

Sample_ID	Location and context	Rationale	Images
WOL-08 (Ad19146)	Gentle western slope of SBD developed around point bar toward the western (outer) edge of broad T2c meander scroll. The profile consists entirely of a fine, pale buff (10 YR 6/4), well sorted sand with fine shell flecks throughout. No sedimentary structures or soil development were noted though a stiff, mildly developed soil is exposed in older SBDs within this scroll. A broad, thick unit of deflated sand extends from the eastern (opposite) side of the SBD while the western slope and crest is actively deflating. A single OSL sample was taken at a depth of 45 cm.	This is the penultimate SBD developed in what is the last of the broad palaeochannel scrolls at Calperum. As such, the original feature probably formed immediately prior to the conversion from LGM to deglacial regimes. The profile would, however, potentially relate to the redeposition of sand through flooding and/or deflation (this landform remains highly active). A low density scatter of hearth material, midden shell and artefacts occurs immediately east of the site though no archaeolgocial material is associated with the profile. As such, the OSL age would also provide a maximum age for the archaeolgocial record in this location. The sample aimed to establish: • A chronological framework for this SBD, and equivalent features on other floodplains. • A maximum age for the conversion of large capacity to smaller and more sinuous palaeochannels. • A maximum age for the extensive archaeology extending throughout the SBD.	 

Sample_ID	Location and context	Rationale	Images
WOL-09	Deep profile exposed through a T2b cut bank and levee truncated by the northern bank of Big Huncree Creek. Five stratigraphic units are exposed through the profile, comprising from top to bottom (A) loose fine clayey sand, (B) soft very fine sand, (C) soft light buff fine clayey sand, (D) stiff light buff fine sand with red mottling (soil) and (E) well sorted fine sand with fine shell flecks. The profile captures the original levee (E), soil development within the feature (D) and subsequent sediment drapes (C/B) and more recent remobilised sediments (A). A single OSL sample was taken at a depth of 90 cm within the undifferentiated fine sand interpreted as the original levee. The underlying terrace (T1b) is concealed by slumped sediments along the creek bank.	This levee developed on a high cut-bank of what was the third in the sequence of broad arcuate meander scrolls developed between the initial incision of the Lake Merreti/Clover basin and the south-western scrolls. A scatter of hearth material, midden shell and artefacts occur across the modern surface of the SBD though no archaeolgocial material is associated with the profile. The sampling aimed to establish: • A chronological framework for this levee/meander. • An age for the middle sequence of large capacity palaeochannels. • A maximum age for archaeology in this area.	

Sample_ID	Location and context	Rationale	Images
WOL-10/ WOL-11	Profile exposed along recent, shallow gully erosion on the north-western shoreline of Rotten Lake. The profile has re-exposed a quartz sand beach below a thin drape of WFm sand and overlying a stiff saline clay, interpreted as a former lake bed. The profile extends west where the beach sand pinches out against a deeper red clayey sand. Further west, this clayey sand drapes over a benched area formed on shallow calcrete. The profile captures the transgression of the Woorinen sand sheet into the western side of the palaeo-valley margin, soil development in this sheet, and then subsequent re-activation of aeolian sedimentation interrupted by highstand events in the lake. An initial highstand cuts the bench and deposits the clay bed, while a more recent highstand event overprints the former lakebed and reworks aeolian sediments into a sandy beach. This later event is possibly related to the development of a narrow quartz beach-ridge/lunette around the north-eastern shoreline of Rotten Lake and cliff erosion seen in the gypsum lunette on the southern and eastern shorelines. Two OSL samples were taken. WOL-10 was placed within the beach sand at a depth of 60 cm, WOL-11 was placed at 105 cm in the underlying saline clay. A single broken retouched chert flake was dislodged from the WOL-10 hole and two additional flakes were noted along the continuation of the gully erosion east of the sampling location. A low density scatter of artefacts and fragmented midden shell continues across the bench and sand slope northwest of the samples.	The profile captures a sequence of depositional environments in Rotten Lake that can be tied to broader geomorphic features in and around the lake and broader floodplain. The conversion from a saline lakebed to quartz sand beach marks a major change in lake hydrology, whether during a brief highstand or longer period event. The interplay with WFm sediments provides further insight into the interplay between terrestrial and aquatic conditions. The sampling aimed to: • Establish an age for the highstand event in Rotten Lake identified in this beach unit and other geomorphological features. • Place the more recent activation of WFm sediments within a timeline. • Provide a relative chronology for archaeology in this area.	 

Sample_ID	Location and context	Rationale	Images
WOL-12	Profile exposed in a rabbit warren through the upper unit of a lunette overlaying the high bank on the north-western shoreline of Lake Woolpoolool. The profile consists of a 60 cm deep unit of undifferentiated buff fine medium aeolian sand overlying a thin light brown fine sand and deeper fine clay sand containing seed gypsum. The profile is situated toward the top of the 8 m high lunette. An extensive open scatter of midden shell, hearth material and low density stone artefacts continues across the top of the lunette. A single OSL sample was obtained from the gypsum unit.	The profile captures a period of salinisation in the inner lakes at Calperum (gypsum phase lunette) prior to the development of a quartz sand lunette and series of sandy beach-ridges. A thick aeolian drape marks an end to lunette development and movement of WFm sediments from the west/northwest. ^{14}C dating of shell toward the base of this sand sheet returned an age estimate c. 9.1 ka. The salinisation of the inner lakes at Calperum is significant as it suggests broadscale deterioration in floodplain condition. Equally, the conversion from saline to freshwater conditions in the lake marks a major amelioration in floodplain condition. The sampling aimed to: • Establish a minimum age for saline conditions in Lake Woolpoolool. • Establish an age for the conversion of saline to freshwater conditions in Lake Woolpoolool. • Provide a maximum age for the reactivation of WFm sediments. • Complement the ^{14}C chronology for archaeology in this area.	

Appendix VIII: Archaeological sites identified during this research

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR17_01	Phase 1	Series of low density scatters of lithics (unmodified flakes) and hearth material (in situ and degraded features) in series of deflations within SBD.	11803	T2c	Scroll_SBD	Scroll_Levee		Oxbow	Site is in loose hummocky sand and deflations in reworked SBD. Sand reformed into levee along edge of active floodplain scour. Postdates SBD, no soil in loose cover.	late Holocene
CAPR17_02	Cursory only	Low density lithics, dense hearth materials, minor midden shell and 15+ individual burials in large deflation.	6457	T2c	Scroll_SBD			Oxbow	Site is in deflation in reworked SBD. Postdates SBD and period of reworking of SBD.	late Holocene
CAPR17_03	Phase 1	Ashy sediment, baked clay and 1 chert flake on levee overlooking Ral Ral Creek.	153	T2c	Scroll_Levee			Anabranh	Modern bank of narrow anabranh floodplain.	late Holocene
CAPR17_04	Phase 2 (C14)	Large, 45 cm high oven mound comprising dense baked heat retainer in ashy matrix, low density lithics and shell.	891	T2c	Scroll_Swale	Scroll_Levee		Oxbow	Modern bank of oxbow.	960-805 cal BP (max) – 500-327 cal BP (min)
CAPR17_05	Phase 2 (C14)	Low density midden and hearth material along sandy levee and continuing into deflating SBD containing 5+ burials, low density lithic, midden and hearth scatter.	13054	T2c	Scroll_SBD	Scroll_Levee		Oxbow	Site is in deflation in reworked SBD and along high sand levee formed along scroll edge. Postdates SBD and period of reworking of SBD.	Late Holocene; 539-497 cal BP
CAPR17_06	Phase 1	Broad mound, dense heat retainer in ashy matrix, no lithics, fragmented shell	339	T2c	Scroll_Levee			Oxbow	Modern levee fringing broad floodout.	late Holocene
CAPR17_07	Phase 1	Small exposure of dense midden clump	258	T2c	Scroll_SBD			Inundated	Loose sand cover on top of reworked SBD. Intact feature.	late Holocene
CAPR17_08	Phase 2	Shallow excavated channel cut through T2 SBD ridge with small scatter of hearths and artefacts extending either side.	430	T2c	Scroll_SBD			Inundated	Soil in SBD has been dug out to form channel, i.e. channel post-dates soil. Artefacts and hearth material on and in loose sand cover (modern)	late Holocene
CAPR17_09	Phase 2 (C14/SS)	Extensive burial ground in dune deflation with patchy - low density midden (inc. shell and emu egg shell), lithics and hearth material. Burials occur in groupings and individually.	23387	T2c	Scroll_SBD			None	Deep deflations are recent (see loose drifts), midden slopes with deflation profile therefore post-dates SBD and deflation of SBD.	Late Holocene; 724-567 cal BP
CAPR17_10	Phase 2 (C14/SS)	Extensive, patchy scatter of midden, lithics (flakes/cores) and hearth material, as well as at least 12 burials exposed in long narrow deflating dune. Artefacts occur in low densities throughout. Midden drapes surface with no material exposed in situ in deep deflations. Burials occur as grouping in southern part of site and as individuals in northern part.	50082	T2c	Scroll_SBD			Oxbow	Deep deflations are recent (see loose drifts), midden drapes SBD profile including deflation topography therefore post-dates SBD and deflation of SBD.	Late Holocene; 1307-1183 cal BP (max) – 510-339 cal BP (min).

Site_ID	Record Level	Description	Area (m²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR17_11	Phase 1	Burials (5) grouped at eastern end of extensive low density and patchy scatter of lithics (flakes), heat retainer and midden.	14837	T2c	Scroll_SBD			Anabranh	Deflations and loose sand cover post-dating SBD.	Modern surface and adzes = late-Holocene
CAPR17_12	Phase 1	Large mound and ashy deposit, dense baked clay in ash/charcoal matrix at junction of crevasse channel and Nelbuck Ck basin surrounded by scatter of fragmented shell and low density lithics.	1263	T2c	Scroll_Cutbank			Minor WC	Modern levee capping former cutbank and crevasse.	Oven mound = late Holocene
CAPR17_13	Phase 1	Small, low oven mound truncated by Nelbuck Ck., no shell or artefacts noted.	109	T2c	Channel			Anabranh	Modern levee of flood runner I in-filled T2c channel trace.	Oven mound = late Holocene
CAPR17_14	Phase 2 (SS/Exc/C14)	Extensive lithic, midden and hearth complex over foreland on western shoreline of Lk Woolpoolool. Material occurs as clumped and diffuse scatter. 3+ burials are grouped in south east terraced area. Historic material (glass, clay pipe stem).	51277	T2a	WFm_Dune	Terrace	Beach ridge	Inner lake	Drapes surface of WFm ridge (above palaeosol exposed in deflation), extends over beach ridge formed in palaeosol gravel and onto lower terrace and cusplate foreland formed in loose sand cover.	Relatable to various context but post-dating paleosol (18-15 ka??) and beach ridge (12 ka based on Rotten Lake highstand) so less than 12 ka. C14 results span 9463-9143 cal BP (max) – 770-680 cal BP (min). Also note historic material inc. worked glass.
CAPR17_15	Phase 1	Small ashy mound and low density lithic (fl) scatter on cusplate foreland western shore Lk Woolpoolool	810	T4	Beach ridge			Inner lake	On loose, modern beach ridge.	Oven mound = late Holocene
CAPR17_16	Phase 1	Patchy to dense scatter of fragmented and clumped and lensed shell, artefacts and minor eroded hearth material over series of dune deflations. Several burials present.	76436	T3	Lunette			Inner lake	Looks to drape deflation surface in Phase III lunette (16ka). No material exposed in extensive cutting along front of lunette or in deep deflations - only lag.	Surface of lunette only, and in deflation. Less than 16 ka.
CAPR17_17	Phase 2 (C14/SS)	Thin midden lens in shallow aeolian cover (above deep palaeosol), scattered heat retainer and minor lithics (fl) in scalded surface around rear of Lk Woolpoolool lunette.	1983	T2a	Lunette	WFm_Sheet		Inner lake	Embedded in shallow aeolian cover resting above deep palaeosol.	Adzes in similar context, mid Holocene aeolian cover; 3680-3460 cal BP
CAPR17_18	Phase 1	Dense heat retainer and minor lithics (fl, r/u fl, adze), in scalded T1 surface around rear of Lk Woolpoolool lunette.	3223	T2a	Lunette	WFm_Sheet		Inner lake	Embedded in shallow aeolian cover and as lag on palaeosol.	Adzes= mid Holocene

Site_ID	Record Level	Description	Area (m²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR17_19	Phase 2 (C14/SS)	Patchy to dense scatter of midden shell, lithics and hearth material across SBD overlooking Ral Ral Creek. Dense hearth complex in eastern section. Midden lens (x2) extend over burial in centre of site and as clumped deposit across eastern side of site. Also get 2 lenses exposed in shallow gully, all C14 is late Holocene.	174599	T2b	Scroll_SBD			Anabranh	Stratified deposit in loose sediment packed against original SBD (and palaeosol). No material exposed in or under deeper palaeosol. Lensed hearth in shallow aeolian cover.	Various contexts but absence of material exposed at depth in gully other than in loose sand. C14 range 5895-5606 cal BP (max) – 280-modern cal BP (min). Burial below 547-504 cal BP but assumed to be excavated through midden.
CAPR17_20	Phase 1	Minor hearth and lithics (fl) in scalded surface around rear of Lk Woolpoolool lunette.	1403	T2a	Lunette	WFm_Sheet		Inner lake	In simialr context to other scatters in scalded shallow aeolian cover draping rear of lunette.	Mid-late Holocene
CAPR17_21	Phase 1	Small, low mound on cusplate foreland western shore of Lk Woolpoolool, no shell, minor lithics (fl).	437	T4	Beach ridge			Inner lake	Loose sandy ridge fringing modern shoreline	Oven mound = late Holocene
CAPR17_22	Phase 2 (C14/SS)	Low density lithics (fl, cr, gst), dense hearth complex and clumped midden as in situ lenses and scattered material over sandy ridge (SBD) on west shore of Clover Lake. Hearths occur in dense complex in north as well as scattered material. Clay pipe stem.	4333	T2a	Scroll_SBD	Beach ridge		Inner lake	Lensed midden occurs in shallow aeolian cover draping SBD and in loose pale sand sheet merging with beach ridge.	Post-dating SBD and after sand sheet and beach ridge forms across terrace margin around lake shoreline. Shallow lenses in WFm cover. C14 range 3814-3568 cal BP (max) – 517-469 cal BP (min) but cannot rule out older material inc. hearth complex. Holocene.
CAPR17_23	Phase 2 (C14/SS)	Extensive though generally low density lithic scatter (fl, cr, a-frg, gst), small oven mound feature, in situ clumped and scattered midden shell, and discrete burial cluster in deflation surfaces across SBD. Again, get hearth grouping as well as discrete features.	43027	T2a	Scroll_SBD	Beach ridge		Inner lake	Lensed midden occurs in shallow aeolian cover and embedded in top of beach ridge. No obvious association with original SBD.	Post-dating SBD and after sand sheet and beach ridge forms. Shallow lenses in WFm cover and flood sediments. C14 range 8984-8602 cal BP (max) – 543-507 cal BP (min) but potentially 12 ka beachridge.

Site_ID	Record Level	Description	Area (m²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR17_24	Cursory only	Cursory Record Only - Extensive low density scatter of lithics and degraded hearth material. Grinding material is conspicuous.	62630	T3	Beach ridge	Terrace		Inner lake	As lag in loose drifts on Holocene strandplain/beach ridges.	Holocene
CAPR17_25	Cursory only	Cursory Record Only - Extensive low density scatter of lithics and degraded and in situ hearth material, and several highly degraded burials in broad dune deflation above Lk Merreti inlet creek Grinding topstones occur in collection in north west.	59486	T4	Beach ridge			Inner lake	Draped over surface of loose sand beach ridge with no stratified material in deflated hollows.	Mid-late Holocene
CAPR18_A01	Cursory only	Cursory Record Only - Fragmented bone scatter in deflation with artefacts and shell remains.	4866	T3	Beach ridge			Inner lake	No stratified material in deflation slopes	Holocene
CAPR18_A02	Cursory only	Cursory Record Only - small deflation hollow containing single burial, dense lithic scatter and dispersed hearth material	3456	T3	Beach ridge			Inner lake	Loose sand, draping deflation topography	Holocene
CAPR18_A03	Cursory only	Cursory Record Only - scatter of lithics and hearth material in scald on beach ridge.	2404	T3	Beach ridge			Inner lake	??	??
CAPR18_A09	Phase 1	Extensive scatter of clumped and dispersed midden, discrete and dispersed hearths, hearth groupings and low density artefacts (fl, a-frg, r/u fl, adze, gst) over terrace above Hunchee Lagoon. Some shallow (~15 cm) lensed material.	13215	T1	Terrace	Scroll_Cutbank		Oxbow	Shallow stratified material under red aeolian cover and continuing into and over loose sandy levee fringing cutbank.	Adzes = late Holocene but potential older midden and hearths. Cut bank is T3 therefore ~ 8 ka maximum age unless related to T2b scroll. Exclusively <i>V. ambiguus</i> therefore likely Holocene scenario.
CAPR18_S01	Phase 1	Large scatter of patchy to dense midden (including lensed deposit to ~ 40 cm), diffuse hearth material and artefacts (fl) over sand levee fringing Ral Ral Wide Water.	9763	T2c	Scroll_Levee	Scroll_Cutbank		Oxbow	Material exposed in unconsolidated silt and loose sand over deeper terrace sediment. Looks to be younger (T3 or T4) drape over T2c cutbank.	All <i>V. ambiguus</i> , hence lagoon phase <15 ka but also appears in loose levee sand c.f. deeper terrace. Possibly <15 ka, but likely Holocene.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR18_S02	Phase 2 (C14)	Extensive though patchy scatter of artefacts, hearth material, midden and at least one potential burial exposed around eastern extent of dunes at floodplain boundary. Midden as clumped deposit and diffuse spread. Historic material includes glass, porcelain, tin. Potential mound at far eastern end of site.	15277	T2a	WFm_Dune	Beach ridge		Inundated	Far eastern end of WFm ridge (i.e. late stage) in shallow cover sand, and in loose sandy beach formed at high water mark. Some in situ shell in consolidated sand exposed track surface (see 14C) with all archaeology in or above this unit.	14C age (497 - 327 calBP) is related to unit that can be extrapolated under the bulk of exposed archaeology. Also, historic materials. Mound = late Holocene.
CAPR18_S03	Phase 1	Small knapping floor (fl, bld, hst) on edge of dune outside edge of floodplain.	959	T2a	WFm_Dune			Inundated	Far eastern end of WFm ridge (i.e. late stage) adjacent to floodplain. Exposed through deflation of shallow cover.	Modern dune surface, late Holocene
CAPR18_S04	Phase 1	Long patchy to low density scatter of artefacts (fl, gst-ts) and hearth material at dune/floodplain boundary. Material exposed in shallow sub-surface (<10 cm) along dam cutting.	12610	T2a	WFm_Dune	Terrace		Inundated	Far eastern end of WFm ridge (i.e. late stage) in shallow cover sand, and in loose sandy beach formed at high water mark.	Late stage WFm dune and beach sand, late Holocene
CAPR18_S05	Phase 1	Small scatter of artefacts, dispersed hearth material and minor shell fragments on dune.	3311	T2a	WFm_Dune			None	Upper surface of WFm dune exposed as potential lag from loose cover above consolidated sand.	Later stage WFm sediments so mid-late Holocene
CAPR18_S06	Phase 2 (C14/SS)	Extensive complex site of midden clumps and diffuse spread, hearth features and scattered material, and low to moderate density artefacts (fl, cr, a-frg, gst) over series of dunes intersecting Lk Woolpoolool margin. Dense hearth grouping in NE.	53923	T2a	WFm_Dune	Terrace		Inner lake	Various contexts in WFm dune but predominantly in loose, light coloured upper sand at eastern end of ridge (i.e. late stage) and in hummocky spread beyond dune. See also some in situ material in terrace surface (inc. burial).	C14 range 2056-1921 cal BP – 906-774 cal BP but potentially older Holocene deposit.
CAPR18_S07	Phase 1	Small exposure of hearth material and several artefacts (fl) on deflated dune surface. Hearths occur in grouping.	8116	T1	WFm_Dune			Outer lake	Loose sand cover on edge of older WFm ridge. Original ridge post-dates gypsum lunette and is pre-soil (18-16 ka). Later reactivation 14-12 ka and younger.	Eastern end of dune in loose cover, Holocene
CAPR18_S08	Phase 2 (C14/SS)	Oven mound and long patchy surface scatter of midden continuing along high terrace edge. Some sub-surface shell dug out of rabbit warrens, but no deeply stratified deposit expose in cut bank.	9684	T3	Scroll_Cutbank	Scroll_Levee		Oxbow	Shallow silt levee under b/box formed over T3 cutbank probably no older than ~8 ka.	T3 cutbank and oven mound; mid to late Holocene. C14 3694 - 3455 calBP on shell lens under mound.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR18_S09	Phase 1	Small exposure of hearth material and artefacts (fl, r/u fl) on terrace edge within scalding. Hearth exposed in gully at shallow depth under loose aeolian cover.	4117	T2b	Scroll_Cutbank	Terrace		Inundated	Thin aeolian sheet over T2b cutbank and levee.	No stratified deposit identified at depth in gully, and in situ hearth in thin late stage aeolian sheet. Probably late Holocene though potentially older Holocene.
CAPR18_S10	Phase 1	Large, low density scatter of hearth material (in features and dispersed deposit) and artefacts (fl, a-frg, gst) exposed over heavily scalded sand spread on top terrace edge.	20440	T2b	Scroll_Cutbank	Terrace		Inundated	Thin aeolian sheet over T2b cutbank and levee.	No stratified deposit identified in any of the shallow gully, in situ hearths in thin late stage aeolian sheet. Probably late Holocene though potentially older Holocene.
CAPR18_S11	Phase 2 (C14)	Long narrow exposure of hearth material, low density artefacts (fl, gst) and extremely patchy midden over 460x50m along terrace edge and continuing across sand drape onto floodplain margin.	16342	T2b	Scroll_Cutbank	Terrace		Inundated	Thin aeolian sheet over T2b cutbank and levee.	No stratified deposit identified terrace edge, in situ hearths in loose, thin late stage aeolian sheet and sand drape over terrace edge. Probably late Holocene though potentially older Holocene. C14 results include 903-727 cal BP & 252-modern cal BP.
CAPR18_S12	Phase 1	Long, narrow scatter of hearth material and low number of artefacts (fl, a-frg, gst) along terrace edge. Large hearth feature is mound-like but not on same scale or has been eroded (see edge feature incorporating mound).	12591	T2b	Scroll_Cutbank	Terrace		Inundated	Thin aeolian sheet over T2b cutbank and levee.	No stratified deposit identified terrace edge, some in situ hearths in loose, thin late stage aeolian sheet. Probably late Holocene though potentially older Holocene.

Site_ID	Record Level	Description	Area (m²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR18_S13	Phase 1	Extensive scatter of hearth material, low to high density artefacts (fl, cr, bld, gst) and diffuse fragmented midden, as well as at least 5 individual burials displaced from rabbit warrens on levee.	26687	T2c	Scroll_Levee			Anabranh	Reworked (by flooding) levee.	Material appears to be surface or shallow subsurface in loose sand with exception of interred burials. Old landform (T2c?) but shell and sandy context appears 'fresh'. Also, all V. ambiguus, so most likely associated with Hunchee Alagoon phase post 8 ka.
CAPR18_S14	Phase 1	Small scatter of midden shell as clumped feature and diffuse material, artefacts (fl) and diffuse hearth material over deflated sandy surface overlooking Ral Ral Creek.	2066	T2c	Scroll_SBD	Scroll_Levee		Anabranh	Reworked SBDs formed into high sand levee.	Loose sand, post-dating original T2c SBD, intact midden clump despite active surface, edge of active floodplain; late Holocene.
CAPR18_S15	Phase 1	Highly eroded mound on edge of terrace.	261	T2c	Terrace	Scroll_Levee		Anabranh	Reworked SBDs formed into sand levee at high water mark.	Loose sand, post-dating original T2c SBD, oven mound, late Holocene.
CAPR18_S16	Phase 1	Two oven mounds and peripheral deposit of eroded hearth material, shell and artefacts (fl) on eroding terrace slope	2304	T2c	Terrace	Scroll_Levee		Inundated	Reworked SBDs formed into sand levee at high water mark.	Loose sand, post-dating original T2c SBD, oven mound, late Holocene.
CAPR18_S17	Phase 1	Deflation hollow with numerous burials exposed amongst low density artefacts (fl), hearth and clumped and diffuse midden.	4908	T2c	Scroll_SBD			Inundated	Deflation surface within reworked SBD sediment.	Loose sand (no soil evident), post-dating original T2c SBD and reworking of SBD, edge of active floodplain; Holocene.
CAPR18_S18	Phase 1	Small exposure of hearths and unmodified flakes in deflated area of sand sheet. Hearth grouping occurs in eastern section of site.	1151	T2c	Scroll_SBD	Scroll_Levee		Inundated	Deflation surface within reworked SBD sediment.	Loose sand (no soil evident), post-dating original T2c SBD and reworking of SBD, edge of active floodplain; Holocene.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR18_S19	Phase 1	Low density scatter of artefacts (fl), midden and hearth material in broad deflation surface over 150x50m. An isolated burial was also identified.	6018	T2c	Scroll_SBD			Inundated	Deflation surface within reworked SBD sediment.	Material tends to drape fully formed surface of reworked SBD, significantly post-dates original 16 ka SBD. <i>V. ambiguus</i> therefore unrelated to channel phase. Holocene.
CAPR18_S20	Phase 1	Series of dune deflations containing patchy clumped and diffuse midden, hearth material, low density artefacts (fl) and at least one burial.	18212	T2c	Scroll_SBD			Inundated	Deflation surface within reworked SBD sediment.	Material drapes fully formed surface of reworked SBD i.e. significantly post-dates original 16 ka SBD. <i>V. ambiguus</i> therefore unrelated to channel phase. Holocene.
CAPR18_S22	Phase 1	Small, dense deposit of shell with minor hearth rock and artefacts (fl) on narrow dune.	416	T2c	Scroll_SBD			Inundated	Surface of SBD.	Material drapes fully formed surface of 16 ka SBD. <i>V. ambiguus</i> therefore unrelated to (post-dating) channel phase. Likely Holocene but potentially T3 lagoon phase (terminal Pleistocene). See though equivalent cutbank south of Nelbuck Ck with no sites.
CAPR18_S23	Phase 1	Small exposure of in situ (lens) midden and hearth features eroding along high bank of River Murray. Shell lens is ~ 3 cm thick and composed of <i>A. jacksoni</i> . Part of complex of similar exposures.	56	T4	Scroll_Cutbank			River Murray	In situ in thin silt levee capping modern bank on actively eroding (recent) meander.	Actively eroding bank (migrating west) with no material exposed at depth in older terrace, therefore site must be late Holocene.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR18_S24	Phase 2 (C14)	Long, narrow semi-continuous midden deposit exposed along cut bank of River Murray in typically thin lens in silt levee to depth of ~ 5 cm. Also, two broad ashy deposits and hearth features.	9649	T4	Scroll_Cutbank			River Murray	In situ in thin silt levee capping modern bank on actively eroding (recent) meander.	Actively eroding bank (migrating west) with no material exposed at depth in older terrace, therefore site must be late Holocene. C14 range 915-772 cal BP – 440-153 cal BP.
CAPR18_S25	Phase 2 (C14)	Small exposure of in situ (lens) and dispersed shell, hearth material and several artefacts in heavily scalded thin sand sheet adjacent to shallow gully.	2143	T2a	Scroll_Cutbank	WFm_Sheet		Inner lake	Two lenses of shell within thin WFm unit above massive sand and below thin, pale-coloured loose cover. No material exposed at depth in adjacent gully through deeper terrace, so all contained to aeolian sheet.	C14 range 8980-8593 cal BP – 5660-5478 cal BP is probably representative of broader site given depth of in situ lensed material across in aeolian cover.
CAPR18_S26	Phase 1	Small scatter of midden (in clumped deposit and dispersed), several artefacts and dispersed hearth material on low sand ridge topping cut bank at northern margin of Lk Merreti.	5314	T2a	Scroll_Levee	Beach ridge		Inner lake	In surface of beach ridge higher than regular/semi-regular modern regime flooding.	Unrelated to regular modern flooding and equivalent height of >9ka ridge at Woolpoolool and Merreti, therefore potentially early Holocene or younger.
CAPR18_S27	Phase 1	Small exposure of artefacts (fl, manu), hearth and clumped midden material on top narrow sand ridge.	1421	T2a	Scroll_Levee	Beach ridge	WFm_Sheet	Inundated	In surface of loose sand reworked from beach ridge.	Likely to be late Holocene.
CAPR18_S28	Phase 1	Small, low density scatter of arefacts (fl, gst) and hearth material in dune deflation and scalds. Hearths tend to occur in groupings.	6743	T2a	Scroll_SBD	WFm_Sheet		Inundated	In surface of loose sand sheet reworked from SBD.	Mid - Late Holocene?

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR18_S29	Phase 1	Extensive and complex scatter of generally diffuse artefacts (fl, cr, r/u fl, gst), hearth (features and dispersed material), midden (in clumps in south east) and at least 5 burials in series of deflations. Dense highly fragmented bone spreads are likely to be small mammal.	81202	T2a	Scroll_SBD			Inundated	Contained to complex, reworked SBD topography post-dating major palaeosol (c. 24 ka ?). Some material in loose pale sand likely to relate to most recent mobilisation of sediment.	No stratified material in deflation pedestals, all material deposited in pre-existing deflation topography. Intact clumped/mounded shell in good condition despite active deflation therefore relatively modern. Some fine bone preserved on surface, again, points to recent deposit. All material above palaeosol interpreted as 24 ka. All <i>V. ambiguus</i> therefore unrelated to T2b channel. Mid-late Holocene but some potential for older (post soil). Also note glass artefact.
CAPR18_S30	Phase 1	Tight cluster of burials in dune deflation and associated low density of artefacts (fl), shell and hearth material.	2343	T2a	Scroll_SBD			None	Contained to pale sand likely to relate to most recent mobilisation of SBD terrain.	No stratified material in deflation pedestals. Mid-late Holocene.
CAPR18_S31	Phase 1	Extensive low density scatter of artefacts (fl, a-frg, gst) including number of grindstones, hearth material (in situ and dispersed) and grouped and individual burials in large deflation area. Highly fragmented bone in small spread may be small mammal.	22288	T2a	Scroll_SBD			Inundated	Contained to complex, reworked SBD topography post-dating major palaeosol (c. 24 ka ?). Some material in loose pale sand likely to relate to most recent mobilisation of sediment.	No stratified material in deflation pedestals, all material deposited in pre-existing deflation topography. All material above palaeosol interpreted as 24 ka. Holocene but some potential for older (post soil).
CAPR18_S32	Phase 1	Small exposure of artefacts (low density) (fl), dispersed hearth material and mussel shell (clumped and diffuse fragmented deposit) on low sand ridge	2037	T2a	Beach ridge			Inner lake	Surface of broad beach ridge related to regular highstand under modern (T4) conditions.	Fresh looking shell on modern highstand beach ridge. Mid-late Holocene assuming consistent inundation regime.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR18_S33	Cursory only	Small, highly eroded scatter of low density artefacts (fl, cr), several hearth features (as eroded spread) and fragmented shell around base of sand sheet.	2905	T2a	Scroll_SBD			Inundated	In surface of loose sand sheet reworked from SBD.	Mid - Late Holocene?
CAPR18_S34	Phase 1	Small exposure of shell, hearth and artefacts (fl) on beach ridge.	690	T4	Beach ridge			Inner lake	In loose, mobile surface of modern beach ridge.	Late Holocene
CAPR18_S35	Phase 1	Small exposure of ashy soil and fragmented shell in deflating beach ridge.	813	T4	Beach ridge			Inner lake	In loose, mobile surface of modern beach ridge.	Late Holocene
CAPR18_S36	Phase 2 (C14/SS)	Small exposure of dense midden in clumped deposit as well as minor artefacts (fl, gst-ts) and hearth material.	4811	T2a	WFm_Dune	Beach ridge		Inner lake	Various contexts within site area including stiff subsoil in WFm ridge and loose drift over this subsoil. Post-dates major palaeosol and formation of beach ridge c. 16 ka (?).	C14 sampling includes 5290-4976 cal BP – 284-145 cal BP but potentially older material equivalent to CAPR17_14 (early through late Holocene)
CAPR18_S37	Phase 2 (SS/Exc/C14)	Extensive, patchy deposit of clumped shell midden, low density artefacts (fl, cr, gst) and scattered hearth material exposed across high bank overlooking Lk Woolpoolool and continuing north across terrace. Dense midden occurs as lensed features and extends into slope deposits and stratified material.	207908	T2a	Scroll_Cutbank	Terrace	Beach ridge	Inner lake	Various contexts within site area including stiff subsoil in WFm sheet and loose, hummocky drift sand and slope deposit. No material in or under gypsum unit exposed along ledge. Material in aeolian sheet that drapes (post-dates) the gypsum unit.	C14 sampling range 9088 - 8771 calBP – 5551 - 5312 calBP. Potentially older material though post-dating gypsum ridge, and potentially younger midden (see other midden ages around Lk Woolpoolool through to modern).
CAPR18_S38	Phase 1	Patchy exposure of midden, hearth material and low density artefacts (fl, gst) in track cutting and erosional scalds on high terrace lunette slope overlooking Lake Merreti.	12056	T2a	Lunette	WFm_Sheet		Inner lake	Material is either eroding out of loose, shallow aeolian cover or deposited onto existing scalds in cover. No deeper stratified material in shallow rills and deeper cuttings.	14C ages from c. 8.9 through 3 ka reported in and under equivalent aeolian cover. Also see adzes in continuation of site to the south. Holocene.
CAPR18_S39	Phase 1	Small exposure of hearth features on low sand ridge.	1367	T2a	Scroll_Cutbank	Beach ridge		Inundated	In surface of loose sand reworked from beach ridge.	Likely to be late Holocene.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR18_S40	Phase 1	Exposure of intact and dispersed hearth features and low density artefacts (fl, cr, a-frg) on eroding sand sheet	7029	T2a	Scroll_SBD	Beach ridge		None	In surface of T2a SBD reworked into low beach ridge at inundation level higher than regular/semi-regular modern regime flooding. No deeper stratified material exposed in shallow borrow pit/dam.	Unrelated to regular modern flooding and equivalent height of >9ka ridge at Woolpoolool and Merreti, therefore potentially early Holocene or younger. See also group of c. 500 BP ages on middens on opposite side of marsh.
CAPR18_S41	Phase 2 (SS/Exc/C14)	Patchy, clumped and lensed midden together with scattered hearth features (as groupings and individual features) and low density artefacts (fl) exposed over sand sheet.	41253	T2a	Scroll_Cutbank	Beach ridge		Inundated	Looks to be broad sandy beach ridge developed over original T2a cutbank. Material exposed at surface and in shallow subsurface, including stiff sub-soil. No deep stratified material in gully or track cutting, or in carbonate gravel brought up by rabbits and relating to older T2a levee.	Tight range of C14 results between 531 - 496 calBP – 524 - 492 calBP may suggest beach developed during short-lived highstand c.500-500 BP. No relationship to older cutbank or levee.
CAPR18_S42	Phase 1	Small exposure of artefacts and dispersed hearth material in series of scalds around western edge of broad sand sheet	3191	T1	Scroll_SBD	WFm_Sheet		None	In shallow cover of loose aeolian sand draping/reworking older SBD.	On surface of loose aeolian sheet; late Holocene.
CAPR18_S43	Phase 1	Hearths, artefacts (fl) and fine bone deposit in series of dune deflations. Hearths retain ashy soil and are associated with bone scatters. Small chert knapping floor with artefact sat low density beyond this feature.	11752	T1	WFm_Dune			Outer lake	Loose sand cover on eastern extent (most recent) of WFm ridge. Original ridge post-dates gypsum lunette and is pre-soil (18-16 ka). Later reactivation 14-12 ka and younger.	Eastern end of dune in loose cover; Holocene
CAPR18_S44	Phase 1	Scatter of telegraph ceramic insulator flakes and cores on former telegraph alignment.	2558	T1	Lunette			Outer lake	Loose cover.	Ceramic post c.1870.
CAPR18_S45	Cursory only	Small scatter of artefacts (fl), emu egg and ochre fragment in dune deflation.	516	T1	WFm_Dune			Outer lake	Deep deflation in loose sand cover on eastern extent (most recent) of WFm ridge. Site was established in existing deflation topography.	Eastern end of dune in loose cover; Holocene
CAPR18_S46	Phase 1	Surface deposit of clay heating elements, shell fragments (dispersed and clumped) and low density artefacts (fl) in deflations along beach ridge.	14654	T4	Beach ridge			Inner lake	In loose, mobile surface of modern beach ridge.	Late Holocene

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR19_J01	Cursory only	Cursory Detail Only. Small exposure of clumped midden, hearth material and artefacts in loose gypsum/sand sheet eroded out of lunette.	1154	T1	Lunette	WFm_Sheet		Outer lake	In remobilised Phase II lunette sediment (fine gypsum sand), dense fwm midden likely to be sourced locally from Rotten Lake during pluvial - see OSL/C14 on NW shoreline c. 8 ka.	c. 8 ka
CAPR19_J02	Cursory only	Cursory Detail Only. Low density scatter of artefacts and hearth material in series of large dune deflations. Also fragment of insulator.	30921	T1	WFm_Dune			Outer lake	In late stage WFm sediments and as a lag resting on stiff palaeosol. No material exposed in situ in deflation walls. Intact hearths suggest site formed in existing deflation topography.	late stage WFm sediments and topography; probably mid - late Holocene
CAPR19_J03	Cursory only	Cursory Detail Only. Low density scatter extending beyond burial (x4) in deflating sand body (T2b levee) reformed around high water mark.	7793	T2b	Scroll_Levee	Beach ridge		Anabran	In situ midden in loose sand cover above palaeosol.	Unrelated to 24 ka palaeosol, <i>V. ambiguus</i> therefore unrelated to original channel, and in loose cover sand; Holocene.
CAPR19_J04	Cursory only	Cursory Detail Only. Dense spread of hearth material on sand sheet	1280	T2b	Scroll_SBD			Inundated	Draped over surface of T2b SBD and possibly eroded out of thin aeolian cover.	Semi-intact features suggest relatively recent development and/or exposure. Probably Holocene though can't dismiss potentially older feature.
CAPR19_J05	Cursory only	Cursory Detail Only. Dense, discrete spread of hearth material.	395	T2b	Scroll_SBD			Inundated	Draped over surface of T2b SBD and possibly eroded out of thin aeolian cover..	Probably Holocene based on aeolian cover though can't dismiss potentially older feature.
CAPR19_J06	Cursory only	Cursory Detail Only. Dense scatter of hearth material on low sandy ridge.	1771	T2c	Scroll_Levee	Beach ridge		Inundated	In surface of T2c levee sediment reworked into highwater beach.	<i>V. ambiguus</i> therefore unrelated to original channel, in loose cover sand; Holocene.
CAPR19_J07	Cursory only	Cursory Detail Only. Group of three hearths eroding along sandy ledge formed in surface aeolian cover.	281	T2a	Lunette	WFm_Sheet		None	Eroding from thin, loose aeolian cover formed over Phase I lunette.	See various C14 ages in aeolian cover ranging from 3 ka through 8 ka. Similar timeline possible.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR19_J08	Cursory only	Cursory Detail Only. Single prone supine burial with some shell fragments associated.	29	T2a	Lunette	WFm_Sheet		None	Buried immediately under thin, loose aeolian cover formed over Phase I lunette.	See various C14 ages in aeolian cover ranging from 3 ka through 8 ka. Similar timeline possible.
CAPR19_J09	Cursory only	Cursory Detail Only. Single burial (highly fragmented) and shell fragments on lunette crest.	1169	T3	Lunette			Inner lake	In reworked surface of Phase III lunette.	Lunette upper age C. 15 ka but material is in remobilised surface therefore post-dates. Younger than 15 ka.
CAPR19_J10	Cursory only	Cursory Detail Only. Part of complex site in dunes around NE edge of Merreti. Low density eroded scatter of artefacts and shell midden including multiple grindstones.	9373	T3	Beach ridge			Inner lake	In deep deflation hollow formed in sandy beach ridge.	Site established in existing deflation topography so post-dating beach ridge/foredune. Age ?? but highstand ridge could be early Holocene pluvial.
CAPR19_J11	Cursory only	Cursory Detail Only. Low density artefact scatter in foredune.	1916	T3	Beach ridge			Inner lake	In loose sand and shallow deflation hollow formed in beach ridge.	Site post-dates beach ridge/foredune. Age ?? but highstand ridge could be early Holocene pluvial.
CAPR19_J12	Cursory only	Cursory Detail Only. Dense scatter of yabby carapace, fragmented mussel, hearth group and low density artefacts on low sand ridge.	7276	T2a	Scroll_Levee			Inundated	On surface of reformed original landform.	On surface, well-preserved yabby carapace, recent/modern.
CAPR19_J13	Cursory only	Cursory Detail Only. Hearth complex with minor artefacts inc muller in low sand spread	8218	T2a	Scroll_Levee			None	On surface of reformed original landform in loose sand.	Includes semi-intact hearths, on surface of reformed landscape. Age uncertain but likely Holocene, probably late Holocene given
CAPR19_M01	Phase 1	Narrow, extensive midden, artefact (fl, a-frg) and hearth complex continuing along beach ridge on eastern shore of Clover Lake. Hearths tend to occur in groupings. Two mound-like features occur in the northern section of the site. Shell occurs as dense clumped deposits and as diffuse scatter. Artefacts occur as diffuse scatter.	11215	T4	Beach ridge			Inner lake	On surface of Holocene beach ridge.	Oven mounds = late Holocene, but potential older Holocene material. Material in surface of beach ridge with no stratified deposit seen in shallow gully.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR19_M02	Phase 1	Small exposure of 3 hearths and 2 artefacts on edge of scald in sand sheet.	852	T1	WFm_Sheet	BckPln		None	Eroding out of thin unconsolidated aeolian cover.	See various C14 ages in aeolian cover ranging from 3 ka through 8 ka. Similar timeline possible.
CAPR19_M03	Phase 2 (C14)	Series of midden clumps and eroded hearths in small exposure on east side of sand sheet. A small amount of material is exposed in shallow subsoil in rabbit warren.	1761	T1	Scroll_SBD	BckPln		None	In unconsolidated cover sand in reformed surface of T2a levee.	Intact clumped midden in shallow surface of landform (see lensed material in rabbit warren). C14 age 532 - 496 calBP is consistent with other materials in broader site complex.
CAPR19_M04	Phase 1	Two hearths in eroded surface of NE lunette of Rotten Lake.	268	T3	Lunette	WFm_Sheet		Outer lake	Eroding out of thin unconsolidated aeolian cover draping older landform (lunette).	See various C14 ages in aeolian cover ranging from 3 ka through 8 ka. Similar timeline possible.
CAPR19_M05	Phase 1	Series of hearth features exposed around the edge of a broad scalded surface together with minor shell fragments and artefacts (fl).	4677	T2a	Lunette	WFm_Sheet		Inundated	Eroding out of thin unconsolidated aeolian cover draping older landform (Phase I lunette).	See various C14 ages in aeolian cover ranging from 3 ka through 8 ka. Similar timeline possible.
CAPR19_M06	Phase 2 OSL	Series of hearth features exposed along crest of Phase III lunette at Lake Woolpoolool. Minor shell fragments, a yabby claw and low density scatter of artefacts (fl, gst) also present.	14817	T3	Lunette			Inner lake	In surface of fully formed lunette inc. in upper unit of original landform.	Lensed material in western slope in unconsolidated recent unit (see OSL WOL-03/04). No stratified deposit in deeper lunette sediment. OSL age in upper lunette sediment c. 15 ka provided terminus post quem.
CAPR19_M07	Phase 1	Small exposure of in situ hearths and low density artefacts (fl) exposed in low sand pedestal on edge of scalded surface on Lk Woolpoolool lunette.	506	T2c	Lunette	WFm_Sheet		None	Eroding out of thin unconsolidated aeolian cover draping older landform (Phase I lunette).	Age of irregular pale quartz sand cover across western slope of Phase I lunette is poorly constrained likely remobilised repeatedly. Likely age Holocene though older age possible.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR19_M08	Phase 1	Complex site of discrete hearth features and low density artefacts (fl, cr, gst) merging into dense shell and ashy soil (mound-like feature) along bank of Ral Ral Creek. Site extends from palaeosol surface and onto T4 highstand beach ridge.	9685	T4	Channel/levee	Beach ridge		Anabranh	In light coloured, unconsolidated silt/sand forming beach ridge over older surface and in thin modern levee fringing anabranh creek.	Associated with modern watercourse and highstand beach, oven mound component is late Holocene though additional material possibly older Holocene.
CAPR19_M09	Phase 1	Series of hearths and low density artefacts (fl, cr) eroding along edge of scalded surface on highstand beach ridge.	433	T4	Beach ridge			Inner lake	In light coloured, unconsolidated silt/sand forming beach ridge over older surface.	In unconsolidated sediment formed around highwater beach ridge; late Holocene.
CAPR19_M10	Phase 1	Long narrow exposure of hearth material, minor shell and low density artefacts (fl, r/u fl, cr, gst) exposed across deflated WF ridge extending into Outer Lake A. A group of gst-ts occur in western end of site. Some white ochre/kaolin fragments also present. A carbonate patina is present on some artefacts.	12869	T1	WFm_Dune			Outer lake	Continues from older WFm ridge onto late stage WFm sediments and as a lag resting on stiff palaeosol. No material exposed in situ in deflation walls.	Probably Holocene given preservation of emu egg and continuation of site onto late stage WFm sediments though carbonate patina on some artefacts is noteworthy. No stratified material exposed in situ in deflation pedestals. Likely Holocene, most likely mid-late Holocene.
CAPR19_M11	Cursory only	Cursory Detail Only. Patchy exposure of typically clumped midden shell, eroded hearths and low density artefacts (fl) continuing along rim of high ledge and across narrow sandy ridge at northern edge of Lk Merreti. Ridge looks to be formed in gypsum sand. See media reference to burials 'encased' in gypsum around edge of Lake Merreti. A dense scatter of artefacts occurs on broad sandplain/beach around lake edge (pers. comm. M. Fairhead). A single human tooth had been located in this site previously.	8426	T2a	Scroll_Cutbank	Beach ridge	WFm_Sheet	Inner lake	Shallow surface of unconsolidated red WFm sand sheet draping older gypsum ridge.	See 14C ages in deeper WFm unit in 8980-8593 cal BP and 5660-5478 cal BP. These ages provide terminus post quem for this site.
CAPR19_M12	Cursory only	Series of in situ hearths exposed in scalding across sand sheet.	1223	T1	WFm_Sheet			Outer lake	In unconsolidated WFm cover.	Mid to late Holocene based on 14C ages in equivalent cover.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR19_O01	Phase 1	Extensive and complex scatter of patchy to dense midden shell, hearths, ashy deposits and low density artefacts (fl, r/u fl, cr, a-frg, gst) continuing along high cutbank of T3 scroll. A series of burials occur in dune deflations around the western boundary of the site. In situ midden lenses occur in shallow silt levee.	73361	T3	Scroll_Cutbank			Oxbow	In unconsolidated levee sand capping late T3 cutbank and continuing onto reworked T2b levee sediment.	Site is associated with late T3 scroll (c. 8ka). Shell content includes <i>A. jacksoni</i> and <i>V. ambiguus</i> , therefore captures conversion from channel to oxbow. Oven mounds are late Holocene component. Early to late Holocene.
CAPR20_S01	Phase 1	Extensive scatter of hearth material (features and eroded), low density artefacts (fl, gst) exposed across western section of SBD. No shell. Hearth grouping occurs in SW corner of site.	32237	T2b	Scroll_SBD	WFm_Sheet		Inundated	Shallow surface of unconsolidated red WFm sand sheet draping older SBD.	No stratified material in shallow gully, all material contained to remobilised (aeolian) surface of older landform. Holocene.
CAPR20_S02	Phase 1	Large scatter exposed across southern extent of Lk Woolpoolool lunette at Ral Ral Creek in low hummocky sand sheet. Site is exposed in track cuttings with boundary extrapolated. Minor shell. Site comprise mostly of intact and eroded hearths and relatively large lithic assemblage (fl).	15647	T2b	Scroll_Cutbank	Channel/levee		Anabanch	In unconsolidated surface and sand draping older cutbank and merging with modern levee along anabanch.	No stratified material in deeper cuttings but some midden exposed below loose recent drift in consolidated sediment. Likely Holocene.
CAPR20_S03	Phase 1	Part of complex of patchy scatters of midden (including dense clumped deposits in south), hearth material and artefacts (fl, a-frg, gst-ts) continuing from Ral Ral Ck along a T2b cutbank levee. Burials (x2) have been excavated by rabbits in the southern section of the site.	7559	T2b	Scroll_Levee	Channel/levee	Beach ridge	Anabanch	In unconsolidated sandy surface draping older cutbank and levee and reworked along lower edge by highwater mark.	Likely Holocene.
CAPR20_S04	Phase 1	Part of complex of patchy scatters continuing from Ral Ral Ck along a T2b cutbank levee. This component includes patchy to diffuse midden (including one clumped feature), hearth material and artefacts (fl, a-frg, gst-ts). Burials (x5) occur in two areas in dune deflations and are associated with dense hearth grouping.	46028	T2b	Scroll_Levee	Beach ridge		Inundated	In unconsolidated sandy surface draping older cutbank and levee and reworked along lower edge by highwater mark.	Intact midden clumps and hearth features following deflation topography in loose sediment. Likely Holocene.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR20_S05	Phase 1	Large open scatter extending over high cutbank overlooking Ral Ral Creek. Patchy to dense midden occurs across loose sand cover along with hearth material and low density artefacts. Hearths occur as dense heat retainer in SE corner of site (possible mound) as well as ashy soil.	18935	T2b	Scroll_Cutbank	Scroll_Levee	Channel/levee	Anabranh	In unconsolidated sandy surface draping older cutbank and levee and reworked along lower edge by highwater mark.	In loose sediment (no stratified deposit in consolidated subsoil - see various track exposures) and hugging modern anabranh bank. Oven mound=late Holocene component. Likely Holocene for broader deposit.
CAPR20_S06	Phase 1	Small exposure of hearth material and a possible fish bone on T2b cut bank.	6344	T2b	Scroll_Cutbank			Inundated	In unconsolidated sandy surface draping older cutbank and levee.	Loose sandy surface draping older landform. Likely Holocene.
CAPR20_S07	Phase 1	Large, semi-continuous exposure of midden (dense clumped features and diffuse scatter), hearths and artefacts (fl, gst) in series of deflations along T2b cutbank and reworked highstand ridge.	18006	T2b	Scroll_Cutbank	Beach ridge		Inundated	In unconsolidated sandy surface draping older cutbank and levee and reworked along lower edge by highwater mark.	Intact midden clumps and hearth features following deflation topography in loose sediment. Likely late Holocene.
CAPR20_S08	Phase 1	Discrete, small mound located on edge of shallow basin.	161	T2c	Scroll_Levee	Beach ridge		Minor wetland/depression	Beach on edge of seasonal wetland.	Oven mound=late Holocene.
CAPR20_S09	Phase 1	Long, narrow exposure of hearth material (features and dispersed) and low density artefacts (fl, r/u fl) along high bank bounding Lake Merreti inlet creek. Material occurs as a lag on a palaeosol surface. Several adzes (late Holocene). Hearths occur in dense grouping and scattered.	9472	T2a	Scroll_Cutbank	Terrace	WFm_Sheet	Inner lake	Eroding out of thin unconsolidated WFm sheet across rear slope of Phase I lunette. Lag onto major palaeosol.	Adzes=late Holocene. 14C age of 3680-3460 cal BP in CAPR17_17 under same thin aeolian cover provides likely terminus post quem.
CAPR20_S10	Cursory only	Low density scatter of artefacts (fl, cr), highly fragmented midden and hearth material (features and eroded) continuing along Phase III lunette at Lake Woolpoolool. An isolated burial may also be present in the form of several fragments of bone.	17908	T2c	Lunette	Beach ridge		Inner lake	Unconsolidated sand forming remobilised cover over Phase III lunette and merging into modern beach ridges.	No stratified material exposed in lunette slope; unconsolidated cover suggest Holocene age.

Site_ID	Record Level	Description	Area (m²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
CAPR20_S11	Phase 2 (C14/OSL)	Diffuse scatter of fragmented shell, hearth material and artefacts (fl, r/u fl, gst) across sloping ground on NW shoreline of Rotten Lake. Site continues to beach sand. Anvil has appearance of 'quandong stone'.	14215	T1	Cliff/valley margin	Beach ridge	WFm_Sheet	Outer lake	Various contexts including shallow WFm cover and deeper beach sand. No stratified material below beach sand exposed in gully.	Tula adze=late Holocene. Older components (artefacts) exposed in gully tied to OSL and 14C age 7940 - 7740 calBP. Some artefacts below 14C age but no stratified material below beach sand.
CAPR20_S12	Phase 1	Extensive scatter continuing along dune ridge and slopes extending to western shoreline of Rotten Lake. Shell occurs as small clumps of dense midden and diffuse scatter. Artefacts (fl, cr, a-frg, r/u fl, adze) occur in low densities. Hearths (intact and dispersed material) continues throughout the site in no significant groupings.	20752	T1	WFm_Dune			Outer lake	Deflation surfaces across various WFm stage sediments and as lag on carbonate palaeosol.	Intact features continue onto most recent WFm surface. Adzes=late Holocene. Likely Holocene.
CAPR20_S13	Phase 1	Small exposure of hearth material in shallow deflation in loose sand sheet on western edge of Rotten Lake.	1395	T1	WFm_Sheet	Cliff/valley margin		Outer lake	Deflation in loose sand, late stage WFm.	Late Holocene
CAPR21_A01	Phase 1	Dense hearth material and low density scatter of artefacts (fl, cr, a-frg, r/u fl, adze) exposed in track cutting. Shell occurs as highly fragmented and diffuse material.	2576	T2b	Scroll_Cutbank	Lunette		Anabranh	Eroding out of unconsolidated aeolian sheet draping older lunette slope. Looks to be etch line along slope.	Adzes=late Holocene.
CAPR21_A02	Phase 1	Small exposure of dense hearth material and mound feature together with small number of artefacts (fl, a-frg) and clumped midden within deflation hollow on beach ridge.	959	T2a	Scroll_Cutbank	Beach ridge		Minor wetland/depression	In deflation hollow in loose, sandy ridge formed around highwater mark on edge of ephemeral wetland.	Oven mound=late Holocene.
CAPR21_A03	Phase 1	Small, low ashy mound on bank of flood runner.	151	T2c	Scroll_Swale	Channel		Anabranh	On bank of floodrunner contained to terrace formed in infilled T2c channel trace.	Oven mound=late Holocene.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
PikeAWE15_10 /Pike_SP16_01	Phase 2 (SS/Exc/C14)	Extensive scatter of clumped and dispersed midden, discrete and dispersed hearths, hearth groupings and generally low density artefacts (fl, a-frg, r/u fl, cr) extending along Pike cliff line in typically narrow band. Site widens in the west to include hearth groupings in deflated dune ridges set back from the cliff. Highly degraded through vehicle tracks, quarrying and erosion. Midden lenses occur at variable depths in aeolian cover but all above major palaeosol surface. Forms part of semi-continuous deposit continuing around valley cliff.	220759		WFm_Sheet	Cliff/valley margin		Anabran	Aeolian cover capping high valley cliff line above major anabran creek.	Lensed and eroded material is contained to unconsolidated aeolian cover (sand) above deep palaeosol. Stratified material at various heights above palaeosol. Range of 14C ages between 29845-28977 cal – 2728-2435 calBP. <i>A. jacksoni</i> -dominated midden suggest occupation initiated when river corridor abutted/was forming cliff line with <i>V. ambiguus</i> content post-dating avulsion. Pre-LGM, deglacial and Holocene periods represented.

Site_ID	Record Level	Description	Area (m ²)	Terrace	LS_1	LS_2	LS_3	Immediate water	Context interpretation	Age interpretation & C14
PikeSP16_05	Phase 2 (SS/Exc/C14)	Extensive scatter of clumped and dispersed midden, discrete and dispersed hearth materials, and low density artefacts (fl, a-frg, cr) extending though aeolian sheet on top of Pike cliff line. Eastern boundary remains provisional and is based on private property fenceline only. Highly degraded through vehicle tracks and erosion. Midden lenses occur at variable depths in aeolian cover but all above major palaeosol surface. Forms part of semi-continuous deposit continuing around valley cliff.	23423		WFm_Sheet	Cliff/valley margin		Anabranh	Aeolian cover capping high valley cliff line above major anabranh creek.	Lensed and eroded material contained to unconsolidated aeolian cover (sand) above deep palaeosol with exception of single hearth feature. Stratified material at various heights above palaeosol. Range of 14C ages between 43940-42294 cal BP – 4869-4728 calBP. A. <i>jacksoni</i> -dominated midden suggest occupation initiated when river corridor abutted/was forming cliff line with V. <i>ambiguus</i> content post-dating avulsion. Pre-LGM, deglacial and Holocene periods represented.
PikeSP16_07	Phase 2 (C14)	Patchy exposure of thinly lensed shell midden (<i>A. jacksoni</i> and <i>N. sublineata</i>) in thin aeolian cover on top high valley cliff line. Low number of artefacts and rare hearth material.	8381		WFm_Sheet	Cliff/valley margin		Anabranh	Aeolian cover capping high valley cliff line above major anabranh creek.	Lensed and eroded material contained to aeolian sand above palaeosol. Stratified material at various heights above palaeosol. Range of 14C ages between 11827-11324 cal – 8641-8453 calBP. A. <i>jacksoni</i> -dominated midden suggest occupation initiated when river corridor abutted/was forming cliff line. Deglacial period represented.

Appendix IX: Content summaries from gridded and C14 sampling locations.

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
								Unid. Shell	V. ambiguus	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
			Emu	Other								Mammal	Fish			
CAPR17_05	CAPR_014*	1	OZX281	539–497	Fragmented shell within dense clumped feature (in situ and eroded) in broader scatter		fl (1)		x							
CAPR17_09	SQ1	4			In situ, fragmented midden	x			x							
CAPR17_09	SQ2	4	OZX277	724–567	Midden clump adjacent to group of hearths within low density artefacts		fl (1)		x							
CAPR17_10	CAPR-125*	1	Wk-52896	510–339	Fragmented and intact valves from shell spread		fl (1)		x							
CAPR17_10	SQ1	16			Bone spread within midden, hearth, burial site		fl (1)							unid (>250 frags of burnt, small mammal inc. femur)	catfish? (inc 3 vert ~12mm diam, mandible)	
CAPR17_10	SQ2	6			Fragmented shell in midden clump		fl (1)		x							
CAPR17_10	SQ3	4			Fragmented shell in small, dense midden clump with minor HR	x			x							
CAPR17_10	SQ4	9			Fragmented shell in midden clump with minor HR	x			x					unid (long bone frag 6x1 cm, small mammal)		
CAPR17_10	SQ5	4	OZX276	654–550	Incomplete valves in clumped midden with minor HR	x	fl (2)		x					rabbit? (phalange)		
CAPR17_10	SQ6	4			Highly fragmented valves in clumped midden adjacent to in situ hearth and HR spread		fl (2), gst-ts (1)		x							

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
								Unid. Shell	V. ambiguus	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
			Emu	Other								Mammal	Fish			
CAPR17_10	SQ7	6			Fragmented midden associated with dense HR	x	fl (1)		x							
CAPR17_10	SQ8	9	Wk-47547	727–670	Fragmented and complete valves in dense midden	x	fl (5)		x					Large mammal (2 long bone frags)		
CAPR17_10	SQ9	9	OZY995	1307–1183	Intact and fragmented valves in discrete midden clump associated with HR, series of clumped features	x	fl (2), a-frg (1)		x							
CAPR17_10	SQ10	4	Wk-48700	1295–1176	Midden spread associated with scatter of shell and low density artefacts	x	fl (3)		x							
CAPR17_14	CAPR_017*	1	WK-48701	903–736	In situ midden clump within extensive scatter	x	fl (?)		x							
CAPR17_14	CAPR_018*	1	OZX284	9463–9143	In situ midden clump on gravel beach-ridge		fl (?)		x							
CAPR17_14	CAPR_054*	1	WK-50690	4421–4184	Discrete, small, clumped midden feature				x							
CAPR17_14	CAPR-091*	1	Wk-52351	5910–5660	Dense area of fragmented shell in broader scatter				x							
CAPR17_14	CAPR-092*	1	WK-52027	5889–5656	Shallow, small clump of shell associated with shell scatter and embedded gst-ts		gst-ts (1)		x							
CAPR17_14	SQ1	4	OZX282	3819–3499	Midden clump of fragmented valves	x	fl (8)		x							

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
								Unid. Shell	V. ambiguus	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
			Emu	Other								Mammal	Fish			
CAPR17_14	SQ2	4	OZZ008	770–680	Large midden clump. Note random orientation of valves.	x	fl (12)		x							
CAPR17_14	SQ3	4	OZX283	897–690	Large, in situ midden clump contained in grey-stained soil (ash??).	x	fl (11)		x					Unid (thin sliver)		gast (1)
CAPR17_14	SQ4	3			Two discrete midden clumps on dune ridge associated with in situ hearth	x	fl (2)		x							
CAPR17_17	SQ1	4	OZZ003	3680–3460	Thin lensed exposure of midden				x							
CAPR17_19	CAPR_007*	1	OZX279	450–290	Dense fragmented shell exposed in shallow rip associated with minor HR and artefacts	x	x	x								
CAPR17_19	CAPR_008*	-	OZY996	547–504	Thin shell lens in wall of rabbit warren				x							
CAPR17_19	CAPR_009*	-	WK-47548	521–462	Thin shell lens in wall of rabbit warren	x			x							
CAPR17_19	CAPR_010*	-	OZX280	1270–1071	Thin shell lens in wall of shallow gully		fl (1)		x							
CAPR17_19	CAPR_050*	1	OZY997	649–545	Dense clump of fragmented shell in broader scatter				x							
CAPR17_19	CAPR-127*	1	Wk-52898	5895–5606	Small number of shell fragments with shallow in situ hearth feature	x	x		x							
CAPR17_19	CAPR-128*	-	Wk-52899	1287–1177	Small, lens of fragmented shell at 22 cm depth				x							
CAPR17_19	CAPR-129*	-	Wk-52900	1277–1177	Small, lens of fragmented shell at 30 cm depth				x							

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
								Unid. Shell	V. ambiguus	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
			Emu	Other								Mammal	Fish			
CAPR17_19	SQ1	1			Partly in situ midden				x							
CAPR17_19	SQ2	2			Fragmented shell (including large fragments) in midden exposure				x							
CAPR17_19	SQ3	3			Dense midden clump, partly in situ				x							
CAPR17_19	SQ4	2			Portion of clumped midden feature within complex of surface exposures.				x							
CAPR17_19	SQ5	2			Low density scatter of fragmented shell within series of clumped features				x						unid (oto)	
CAPR17_19	SQ6	2			Fragmented shell in partly in situ clump	x			x							
CAPR17_19	SQ7	1			Highly fragmented shell in dense scatter				x							
CAPR17_19	SQ8	1			Fragmented shell in spread associated with HR	x	fl (1)		x							
CAPR17_19	SQ9	1			Highly fragmented shell	x			x							
CAPR17_19	SQ10	1			Highly fragmented shell in spread.	x			x							
CAPR17_19	SQ11	1			Highly fragmented shell concentration in general spread.	x			x							

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
			Lab-code	cal BP				Unid. Shell	V. ambiguus	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
												Emu	Other	Mammal	Fish	
CAPR17_22	SQ1	4	Wk-48702	517–469	Fragmented shell in discrete midden clump in series of similar features associated with HR and ashy soil	x	fl (1)		x							
CAPR17_22	SQ2	4	Wk-47549	3814–3568	Discrete clumped midden exposed in rill with minor HR (dense HR extends outside sample)	x	fl (1)		x							
CAPR17_23	CAPR_019*	1	OZX285	960–805	Fragmented shell in oven feature (ashy sediment and HR)	x			x							
CAPR17_23	CAPR_074*	1	OZZ012	8984–8602	Small (<20 cm) midden clump with associated HR and artefacts in broader scatter	x	fl (?), a-frg (?)		x							
CAPR17_23	CAPR-094*	1	WK-52028	543–507	Small collection of <15 valves in scatter of HR and low density artefacts	x	fl (1), cr (1)		x							
CAPR17_23	SQ1	2	OZX286	624–517	Small, discrete midden clump of fragmented and complete valves. Ashy stained soil.		r/u shell		x							
CAPR18_A09	SQ1	1			Shell spread excavated from rabbit warren				x							
CAPR18_A09	SQ2	2			Highly fragmented valves in midden spread				x							
CAPR18_A09	SQ3	3			Highly fragmented valves in midden spread associated with in situ and eroded HR with ashy stained soil	x			x						unid (1 vert)	

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
								Unid. Shell	V. ambiguous	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
			Emu	Other								Mammal	Fish			
CAPR18_S02	CAPR_071*	1	OZZ009	497–327	Ashy soil, midden spread and low density artefacts	x	fl (?)		x							
CAPR18_S06	CAPR-090*	1	WK-52026	906–774	Dense clump of fragmented and intact shell associated with minor HR and artefacts	x	cr (1)		x							
CAPR18_S06	SQ1	2	OZZ000	2056–1921	Fragmented valves in midden clump	x	fl (1)		x							
CAPR18_S06	SQ1a	1			Dense midden in discrete clump away from broader spread.				x							
CAPR18_S06	SQ2	4			Midden and hearth spread. Dense HR within sample area.	x	fl (7)		x							
CAPR18_S06	SQ3	4			Low density scatter of HR and fragmented shell.	x	fl (1)		x							
CAPR18_S08	HCN20_04*	-	Wk-52024	3694–3455	Thin, dense shell lens in levee below mound				x							
CAPR18_S08	SQ1	3			Dense spread of fragmented shell extending from oven mound in association with HR and ashy soil	x			x							
CAPR18_S08	SQ2	2			Fragmented shell.				x							
CAPR18_S08	SQ2	2			Highly fragmented shell spread.				x							
CAPR18_S08	SQ4	2			Midden spread on gentle sandy slope with minor HR.	x	fl (2)		x							
CAPR18_S08	SQ5	2			Shallow in situ lens of midden				x							
CAPR18_S11	CAPR_065*	1	WK-50693	903–727	Small midden clump				x							

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
								Unid. Shell	V. ambiguus	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
			Emu	Other								Mammal	Fish			
CAPR18_S24	CAPR_051*	-	OZY998	440–153	Thin lens of fragmented and intact valves in shallow lensed feature associated with minor HR and ashy soil	x				x						
CAPR18_S24	CAPR_052*	-	OZY999	534–493	Fragmented and intact valves in shallow, extensive lensed feature associated with minor HR and ashy soil	x				x						
CAPR18_S24	CAPR-126*	1	Wk-52897	915–772	Intact and fragmented valves from shell lens within and below thin ashy deposit	x				x						
CAPR18_S25	CAPR_057*	-	WK-50691	8980–8593	Small, thin lens of shell over ~15 cm exposed in pedestal at 14 cm depth				x							
CAPR18_S25	CAPR_058*	-	OZZ002	5660–5478	Small, thin lens of shell over ~15 cm exposed in pedestal at 10 cm depth				x							
CAPR18_S36	SQ1	4			Dense midden clump on gravel bank		fl (3)		x					unid (3mm thick, calcined)		
CAPR18_S36	SQ2	6	OZZ010	5290–4976	Small exposure of dense fragmented and intact shell with minor HR	x	fl (4)		x							
CAPR18_S36	SQ2a	1			Fragmented shell in dense midden				x							
CAPR18_S36	SQ3	4	OZZ011	284–145	Exposure of dense, fragmented midden		fl (6)		x			1				
CAPR18_S36	SQ3a	3			Dense fragmented shell excavated out of shallow grade adjacent to hearth	x	gst-ts (1)		x							

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
								Unid. Shell	V. ambiguus	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
			Emu	Other								Mammal	Fish			
CAPR18_S36	SQ4	7			Fragmented midden associated with dense spread of HR and artefacts extending from in situ hearth	x	fl (24), r/u fl (adze, bck bld)		x							
CAPR18_S36	SQ5	7			Dense fragmented shell within broader midden with associated HR and artefacts	x	fl (12)		x							
CAPR18_S37	CAPR_056*	-	OZZ001	5551–5312	Fragmented shell in patchy lens in slope deposit				x							
CAPR18_S37	CAPR_063*	-	OZZ006	9088–8771	Thin shell lens				?							
CAPR18_S37	CAPR-093*	1	Wk-52352	7430–7270	Low density scatter of fragmented shell within scatter				x							
CAPR18_S37	CAPR-123*	1	Wk-52894	5885–5602	Fragmented and intact valves from dense shell in small in situ clump associated with intact and eroded HR	x	x		x				x			
CAPR18_S37	CAPR-124*	1	Wk-52895	5741–5596	Fragmented and intact valves from dense shell in small in situ clump associated with eroded HR and low density artefacts	x	x		x							
CAPR18_S41	CAPR_061*	-	WK-50692	538–490	Thin lens over 80 cm at 8 cm depth in track cutting				x							
CAPR18_S41	CAPR_062*	-	OZZ005	527–493	Thin shell lens				x							
CAPR18_S41	CAPR-120*	1	Wk-52891	531–496	Fragmented and intact valves from small in situ clump with minor HR	x			x							

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
								Unid. Shell	V. ambiguus	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
			Emu	Other								Mammal	Fish			
CAPR18_S41	CAPR-121*	1	Wk-52892	532–496	Fragmented and intact valves from dense shell in small in situ clump with intact hearth	x			x							
CAPR18_S41	CAPR-122*	1	Wk-52893	524–492	Fragmented and intact valves from dense shell in small in situ clump associated with intact and eroded HR	x			x							
CAPR19_M03	CAPR_060*	1	OZZ004	532–496	Discrete clumped shell feature (one of a series of similar features)				x							
CAPR19_O01	SQ1	1			Fragmented shell eroding along oxbow bank mixed with HR	x			x							
CAPR19_O01	SQ2	1			Fragmented shell in in situ midden on oxbow bank mixed with HR	x			x							
CAPR19_O01	SQ3	1			Fragmented shell interspersed with nearly complete valves eroding along oxbow bank with HR	x			x							
CAPR19_O01	SQ4	2			Fragmented shell eroding along oxbow bank					x						
CAPR19_O01	SQ5	1			Fragmented, eroding midden associated with in situ hearth on oxbow bank	x		x								
PikeAWE15_10	CAPR_023*	-	WK-47550	15331–14920	Thin, densely packed lens of shell exposed at ~70 cm in artificial cutting over ~3 m					x						

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
			Lab-code	cal BP				Unid. Shell	V. ambiguus	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
												Emu	Other	Mammal	Fish	
PikeAWE15_10	CAPR_024*	-	OZX287	6396–6207	Patchy, thin lens of fragmented shell		fl (1)			x						
PikeAWE15_10	CAPR_025*	-	OZX288	29845–28977	Thin, densely packed lens of shell exposed at ~8 cm over 50 cm					x						
PikeAWE15_10	CAPR_026*	-	WK-48703	15205–14945	Thin lens of intact and fragmented shell exposed at surface over 30 cm					x						
PikeAWE15_10	CAPR_040*	-	WK-49723	27680–27228	Thin lens of intact and fragmented shell exposed in cliff at 12 cm depth over 80 cm					x						
PikeAWE15_10	CAPR_041*	-	WK-49724	15517–15076	Thick lens of densely packed shell and minor HR	x				x						
PikeAWE15_10	CAPR_042*	-	WK-49725	15046–14265	Patchy lens of fragmented shell in slope deposit					x						
PikeSP16_01	CAPR_027*	-	OZX289	15470–15023	Lens of intact and fragmented shell exposed in shallow scald					x						
PikeSP16_01	CAPR_028*	-	WK-47551	11934–11259	Small shell clump exposed in cliff over ~20 cm adjacent to hearth	x				x						
PikeSP16_01	CAPR_029*	-	WK-48704	15616–15308	Thin, patchy lens of intact and fragmented shell exposed in cliff at 5 cm depth over 20 cm					x						
PikeSP16_01	CAPR_030*	1	OZX290	6846–6569	Fragmented shell associated with eroded hearth	x			x							

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
								Unid. Shell	V. ambiguus	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
			Emu	Other								Mammal	Fish			
PikeSP16_01	CAPR_031*	1	WK-48705	2728–2435	Fragmented shell associated with eroded hearth and low density artefacts	x	fl (2)		x							
PikeSP16_01	CAPR_043*	-	WK-49726	15558–14946	Thick lens of densely packed shell associated with HR (intact and eroded feature)	x				x						
PikeSP16_01	CAPR_044*	-	WK-49727	15677–15251	Patchy lens of fragmented shell over 60 cm					x						
PikeSP16_05	CAPR_077*	-	OZZ015	9130–8778	Thin, patchy lens exposed at 8 cm depth in eroding cliff over ~1 m					x						
PikeSP16_05	CAPR_078*	-	OZZ016	13490–13320	Thin lens exposed at 8 cm depth in eroding cliff over ~1.2 m					x						
PikeSP16_05	CAPR_080*	-	OZZ017	12143–11840	Thin lens exposed at 6 cm depth in eroding cliff over ~1m						x					
PikeSP16_05	CAPR_081*	-	OZZ018	8177–8020	Fragmented shell recovered from excavation at ~20 cm			X								
PikeSP16_05	CAPR_083*	-	OZZ019	10118–9562	Fragmented shell recovered from excavation at ~42 cm			X								
PikeSP16_05	CAPR_084*	-	OZZ020	14912–14298	Several shell fragments in thin lens at 31 cm depth					x						
PikeSP16_05	CAPR-095*	0.25	WK-52029	6855–6645	Thin, dense lens of shell at 5 cm depth				x							

Site_ID	Sample_ID	Sample size (m2)	Associated 14C		Context	Heat retainer	Artefacts	Faunal								
								Unid. Shell	V. ambiguus	A. jacksoni	N. sublineata	Eggshell		Bone		Yabby
			Emu	Other								Mammal	Fish			
PikeSP16_05	CAPR-098*	0.25	WK-52030	11616–11287	Single shell excavated at 88 cm depth in aeolian sheet, possibly part of N. sublineata lens above						x					
PikeSP16_05	CAPR-100*	0.25	WK-52032	11333–11215	Thin lens excavated at 78 cm in aeolian sheet						x					
PikeSP16_05	CAPR-101*	0.25	WK-52033	11085–10725	Patchy lens excited at 42 cm depth					x						
PikeSP16_05	CAPR-102*	0.25	WK-52034	9080–8781	Fragmented shell excavated at 10 cm depth			X								
PikeSP16_05	CAPR-103*	0.25	WK-52035	4869–4728	Fragmented shell excavated at 21 cm depth			X								
PikeSP16_05	CAPR-104*	0.25	WK-52036	9437–9033	Fragmented shell excavated at 65 cm depth					x						
PikeSP16_07	CAPR_075*	-	OZZ013	11827–11324	Small (<20 cm) thin lens of shell at 42 cm depth						x					
PikeSP16_07	CAPR_076*	0.35	OZZ014	8641–8453	Clumped midden (~70x50 cm) exposed as shallow lensed and surface feature					x						

Abbreviations: HR – heat retainer, fl – flake, r/u – retouched/usewear, cr – core, gst-ts – grinding topstone, unid – unidentified, vert – vertebrae, gast – gastrolith, oto – otolith

* Qualitative account based on materials exposed in the immediate area of the 14C sampling points only

Appendix X: OSL results

Field ID	UoA #	OD %	No. grains accepted	Total dose-rate (Gy/ka)	Palaeodose Gy	Age ka	% Grains	Age range (ka)		Context and interpretation
								max	min	
WOL-01	Ad19138	8	388	2.28 ± 0.06	21.0 ± 1.1	9.2 ± 0.5	2	9.7	8.7	Upper unit of the initial Lake Woolpoolool lunette overprinted by a deep, red palaeosol. OSL result captures the mixing of c. 39–26 ka lunette sediments prior to soil development then an introduction of c. 19 ka sediment post-soil.
					31.2 ± 1.1	13.6 ± 0.6	11	14.2	13.0	
					43.7 ± 0.8	19.1 ± 0.6	37	19.7	18.5	
					62.5 ± 1.1	27.4 ± 0.8	35	28.2	26.6	
					85.8 ± 2.1	37.6 ± 1.3	15	38.9	36.3	
WOL-02	Ad19139	8	357	2.11 ± 0.05	5.0 ± 0.5	2.4 ± 0.2	1	2.6	2.1	
					17.4 ± 0.8	8.2 ± 0.4	3	8.6	7.8	
					54.6 ± 1.0	25.9 ± 0.8	46	26.7	25.1	
					83.4 ± 1.5	39.6 ± 1.2	49	40.8	38.4	
WOL-03	Ad19140	8	80	1.40 ± 0.04	0.1 ± 0.0	0.1 ± 0.0	4	0.1	0.0	Staggered development of quartz sand lunette on north-eastern margin of Lake Woolpoolool from c. 15–4 ka then Intensive erosion of sand sheet c. 120 years ago with the introduction of stock.
					0.2 ± 0.0	0.1 ± 0.0	64	0.1	0.1	
					0.4 ± 0.1	0.2 ± 0.1	5	0.3	0.2	
					1.6 ± 0.3	1.2 ± 0.2	4	1.4	0.9	
					5.9 ± 1.0	4.2 ± 0.7	9	4.9	3.5	
					23.2 ± 1.6	16.6 ± 1.3	14	17.9	15.3	
WOL-04	Ad19141	8	342	0.95 ± 0.03	1.4 ± 0.1	1.4 ± 0.2	3	1.6	1.3	
					2.2 ± 0.3	2.4 ± 0.3	8	2.7	2.1	
					3.8 ± 0.1	4.0 ± 0.2	33	4.2	3.9	
					7.1 ± 0.2	7.5 ± 0.3	31	7.8	7.2	
					14.3 ± 0.3	15.0 ± 0.5	25	15.5	14.5	
WOL-05	Ad19142	8	344	1.28 ± 0.04	0.6 ± 0.0	0.5 ± 0.0	12	0.5	0.5	Late Holocene aeolian surface overlying upper unit of the Outer Lake A lunette overprinted by a deep mottled soil. Mixing of c. 33–25 ka lunette sediments prior to soil development.
					1.3 ± 0.0	1.0 ± 0.0	34	1.1	1.0	
					2.6 ± 0.0	2.0 ± 0.1	31	2.1	1.9	
					6.4 ± 0.2	5.0 ± 0.2	16	5.2	4.8	
					31.5 ± 0.8	24.7 ± 0.9	6	25.6	23.8	
WOL-06	Ad19144	8	528	2.04 ± 0.05	3.4 ± 0.1	1.7 ± 0.1	3	1.8	1.6	
					12.7 ± 0.2	6.2 ± 0.2	12	6.4	6.0	
					23.1 ± 0.3	11.3 ± 0.3	28	11.6	11.0	
					41.1 ± 0.5	20.1 ± 0.6	40	20.7	19.5	
					67.7 ± 1.1	33.1 ± 1.0	17	34.1	32.1	
WOL-07	Ad19145	8	465	0.63 ± 0.03	11.7 ± 0.4	18.5 ± 0.9	24	19.4	17.6	Thin sand unit deposited c. 27 ka on inner lunette at Outer Lake C wedged between units of gypsiferous clay (with associated gypcrete soils).
					17.1 ± 0.4	27.2 ± 1.1	65	28.3	26.1	
					27.3 ± 1.1	43.3 ± 2.3	11	45.6	41.0	
WOL-08	Ad19146	8	239	2.02 ± 0.05	2.6 ± 0.1	1.3 ± 0.1	19	1.4	1.3	Original T2c SBD developed c. 16 ka with younger reworked sediments c. 6–1 ka introduced to sampling location.
					5.7 ± 0.2	2.8 ± 0.1	24	3.0	2.7	
					12.4 ± 0.2	6.2 ± 0.2	32	6.4	6.0	
					32.3 ± 0.6	16.0 ± 0.5	25	16.5	15.5	
WOL-09	Ad20015	20	255	2.35 ± 0.06	6.4 ± 1.2	2.7 ± 0.5	1%	3.2	2.2	T2a fluvial sand with input from older T1 sediments.

Field ID	UoA #	OD %	No. grains accepted	Total dose-rate (Gy/ka)	Palaeodose Gy	Age ka	% Grains	Age range (ka)		Context and interpretation
								max	min	
					104.2 ± 4.0	44.3 ± 2.0	45%	46.3	42.3	
					219.3 ± 8.4	93.2 ± 4.2	48%	97.4	89.0	
					566.7 ± 61.0	241.0 ± 27.0	6%	268.0	214.0	
WOL-10	Ad20016	5	303	0.79 ± 0.04	0.5 ± 0.0	0.7 ± 0.0	6%	0.7	0.7	Clean, grey quartz beach sand (WOL-10) wedged between lime mud (see WOL-11) and overlying red sand deposited in small fan and aeolian sheet. A small fragment of freshwater mussel shell recovered from the beach sand immediately above the OSL sampling returned a calibrated age of 7940–7840 consistent with a minor (12%) component in the OSL result. The two main components reflect the continual turnover and rebleaching of the loose sand surface. The lime mud is interpreted as a transitional phase between a hypersaline salina and freshwater reinundation of the lake over an early Holocene pluvial.
					1.1 ± 0.0	1.4 ± 0.1	10%	1.5	1.4	
					2.0 ± 0.0	2.6 ± 0.1	30%	2.7	2.5	
					3.5 ± 0.1	4.5 ± 0.2	36%	4.7	4.3	
					6.0 ± 0.1	7.6 ± 0.4	12%	8.0	7.2	
					15.3 ± 0.5	19.5 ± 1.1	4%	20.6	18.4	
					39.4 ± 2.4	50.2 ± 3.8	2%	54.0	46.4	
WOL-11	Ad20017	12	395	1.09 ± 0.03	2.1 ± 0.1	1.9 ± 0.1	4%	2.0	1.8	
					5.1 ± 0.2	4.7 ± 0.2	13%	4.9	4.5	
					8.6 ± 0.3	7.9 ± 0.4	22%	8.3	7.5	
					12.6 ± 0.3	11.6 ± 0.4	34%	12.0	11.2	
					18.9 ± 0.4	17.4 ± 0.6	22%	18.0	16.8	
					42.8 ± 2.1	39.3 ± 2.2	3%	41.5	37.1	
					112.7 ± 7.8	104.0 ± 8.0	2%	112.0	96.0	
WOL-12	Ad20018	23	309	0.71 ± 0.02	116.2 ± 3.8	164.0 ± 8.2	49%	172.2	155.8	Granular gypsum in quartz sand forming low ridge packed against the outer (northern) bank of the Lake Woolpoolool basin.
					33.0 ± 2.9	46.6 ± 4.3	7%	50.9	42.3	
					5.6 ± 0.2	7.9 ± 0.3	29%	8.2	7.6	
					275.2 ± 19.8	389.0 ± 31.0	14%	420.0	358.0	
Pike-01	Ad20012	7	247	1.7 ± 0.04	31.1 ± 2.8	18.3 ± 1.7	3%	20.0	16.6	43 ka hearth (Pike-02) resting on deep carbonate palaeosol overprinting MIS-4 dune (Pike-01). The major component (33%) in Pike-02 is consistent with a calibrated ¹⁴ C age of 43,940–42,828 cal BP returned on charcoal from the hearth feature. The hearth is contained to a gravel unit below younger aeolian sand with a staggered sedimentation/remobilisation continuing through to the Holocene cover (Pike-03).
					64.9 ± 1.9	38.2 ± 1.5	17%	39.7	36.8	
					118.8 ± 2.4	70.0 ± 2.2	33%	72.2	67.8	
					219.6 ± 5.6	129.0 ± 4.5	25%	133.5	124.5	
					516.9 ± 12.9	305.0 ± 11.0	22%	316.0	294.0	
Pike-02	Ad20013	12	351	1.47 ± 0.04	7.2 ± 0.3	4.9 ± 0.2	10%	5.1	4.7	
					17.2 ± 0.7	11.8 ± 0.5	10%	12.3	11.3	
					40.5 ± 1.2	27.6 ± 1.1	35%	28.7	26.5	
					64.1 ± 2.4	43.7 ± 1.9	33%	45.6	41.8	
					130.5 ± 5.7	89.0 ± 4.0	12%	93.0	85.0	
Pike-03	Ad20014	18	349	1.53 ± 0.04	5.4 ± 0.3	3.5 ± 0.2	16%	3.7	3.3	
					9.7 ± 0.5	6.4 ± 0.4	32%	6.8	6.0	
					18.4 ± 0.8	12.0 ± 0.6	22%	12.6	11.4	
					46.8 ± 1.5	30.7 ± 1.2	22%	31.9	29.5	
					103.3 ± 5.0	67.6 ± 3.7	9%	71.3	63.9	

Appendix XI: ^{14}C results

Site_ID	Depth (cm)	TP/Trench	SU	XU	Lab Code	CRA	d(13C)	cal range cal BP	Material	Method
CAPR17_05	0				OZX281	520 ± 25	-11.2 ± 0.1	539–497	Shell (V. ambiguus)	AMS
CAPR17_09	0				OZX277	765 ± 30	-7.8 ± 0.2	724–567	Shell (V. ambiguus)	AMS
CAPR17_10	0				WK-48700	1369 ± 19	-	1295–1176	Shell (V. ambiguus)	AMS
CAPR17_10	0				OZY995	1405 ± 20	-9.4 ± 0.3	1307–1183	Shell (V. ambiguus)	AMS
CAPR17_10	0				WK-47547	814 ± 21	-	727–670	Shell (V. ambiguus)	AMS
CAPR17_10	0				OZX276	660 ± 25	-10.2 ± 0.2	654–550	Shell (V. ambiguus)	AMS
CAPR17_10	0				Wk-52896	457 ± 20	-7.1 ± 0.3	510–339	Shell (V. ambiguus)	AMS
CAPR17_14	0				OZX282	3435 ± 25	-5.6 ± 0.1	3819–3499	Shell (V. ambiguus)	AMS
CAPR17_14	0				OZX283	905 ± 25	-6.1 ± 0.1	897–690	Shell (V. ambiguus)	AMS
CAPR17_14	0				WK-48701	939 ± 18	-7.0 ± 0.2	903–736	Shell (V. ambiguus)	AMS
CAPR17_14	0				OZX284	8360 ± 30	-10.6 ± 0.1	9463–9143	Shell (V. ambiguus)	AMS
CAPR17_14	0				WK-50690	3937 ± 26	-6.6 ± 0.8	4421–4184	Shell (V. ambiguus)	AMS
CAPR17_14	0				Wk-52351	5081 ± 22	-8.2 ± 0.8	5910–5660	Shell (V. ambiguus)	AMS
CAPR17_14	0				WK-52027	5051 ± 17	-7.6 ± 0.3	5889–5656	Shell (V. ambiguus)	AMS
CAPR17_14	32	TP01	SU3	XU4	OZZ008	870 ± 20	-3.5 ± 0.1	770–680	Shell (V. ambiguus)	AMS
CAPR17_17	0				OZZ003	3365 ± 25	-6.7 ± 0.3	3680–3460	Shell (V. ambiguus)	AMS
CAPR17_19	0				OZX278	185 ± 25	-22.9 ± 0.1	280–modern	Charcoal	AMS
CAPR17_19	0				OZX279	330 ± 30	-8.3 ± 0.1	450–290	Shell (A. jacksonii)	AMS
CAPR17_19	0				OZY996	545 ± 25	-6.8 ± 0.4	547–504	Shell (V. ambiguus)	AMS
CAPR17_19	0				WK-47548	473 ± 21	-	521–462	Shell (V. ambiguus)	AMS
CAPR17_19	0				OZX280	1295 ± 30	-13.2 ± 0.1	1270–1071	Shell (V. ambiguus)	AMS
CAPR17_19	0				OZY997	645 ± 25	-8.0 ± 0.1	649–545	Shell (V. ambiguus)	AMS
CAPR17_19	0				Wk-52898	5045 ± 21	-	5895–5606	Charcoal	AMS
CAPR17_19	0				Wk-52899	1357 ± 18	-11.5 ± 0.5	1287–1177	Shell (V. ambiguus)	AMS
CAPR17_19	0				Wk-52900	1345 ± 16	-10.0 ± 0.5	1277–1177	Shell (V. ambiguus)	AMS
CAPR17_22	0				WK-47549	3433 ± 21	-	3814–3568	Shell (V. ambiguus)	AMS
CAPR17_22	0				WK-48702	475 ± 17	-7.1 ± 0.2	517–469	Shell (V. ambiguus)	AMS
CAPR17_23	0				OZX285	1045 ± 25	-7 ± 0.1	960–805	Shell (V. ambiguus)	AMS
CAPR17_23	0				OZX286	585 ± 20	-6.7 ± 0.1	624–517	Shell (V. ambiguus)	AMS

Site_ID	Depth (cm)	TP/Trench	SU	XU	Lab Code	CRA	d(13C)	cal range cal BP	Material	Method
CAPR17_23	0				OZZ012	7960 ± 30	-8.8 ± 0.3	8984–8602	Shell (V. ambiguus)	AMS
CAPR17_23	0				WK-52028	540 ± 17	-5.2 ± 0.3	543–507	Shell (V. ambiguus)	AMS
CAPR18_S02	0				OZZ009	410 ± 20	-11.0 ± 0.1	497–327	Shell (V. ambiguus)	AMS
CAPR18_S06	0				OZZ000	2070 ± 25	-9.7 ± 0.1	2056–1921	Shell (V. ambiguus)	AMS
CAPR18_S06	0				WK-52026	963 ± 17	-4.0 ± 0.3	906–774	Shell (V. ambiguus)	AMS
CAPR18_S11	0				WK-50693	923 ± 26	-7.0 ± 0.8	903–727	Shell (V. ambiguus)	AMS
CAPR18_S11	0				OZZ007	115 ± 25	-23.7 ± 0.2	253–modern	Charcoal	AMS
CAPR18_S24	0				OZY998	290 ± 25	-10.9 ± 0.3	440–153	Shell (A. jacksonii)	AMS
CAPR18_S24	0				OZY999	505 ± 25	-10.0 ± 0.3	534–493	Shell (A. jacksonii)	AMS
CAPR18_S24	0				Wk-52897	968 ± 20	-6.2 ± 0.6	915–772	Shell (A. jacksonii)	AMS
CAPR18_S25	0				WK-50691	7932 ± 27	-4.6 ± 0.8	8980–8593	Shell (V. ambiguus)	AMS
CAPR18_S25	0				OZZ002	4895 ± 25	-6.4 ± 0.1	5660–5478	Shell (V. ambiguus)	AMS
CAPR18_S36	0				OZZ010	4510 ± 20	-10.3 ± 0.2	5290–4976	Shell (V. ambiguus)	AMS
CAPR18_S36	0				OZZ011	220 ± 15	-6.7 ± 0.1	284–145	Shell (V. ambiguus)	AMS
CAPR18_S37	0				OZZ001	4705 ± 30	-6.6 ± 0.1	5551–5312	Shell (V. ambiguus)	AMS
CAPR18_S37	0				Wk-52352	6464 ± 23	-6.6 ± 0.8	7430–7270	Shell (V. ambiguus)	AMS
CAPR18_S37	0				Wk-52894	5024 ± 21	-6.4 ± 0.3	5885–5602	Shell (V. ambiguus)	AMS
CAPR18_S37	0				Wk-52895	4988 ± 21	-6.8 ± 0.6	5741–5596	Shell (V. ambiguus)	AMS
CAPR18_S37	4	TP01	SU2	XU2	OZZ006	8090 ± 30	-8.8 ± 0.1	9088–8771	Shell (??)	AMS
CAPR18_S41	0				WK-50692	500 ± 26	-3.4 ± 0.8	538–490	Shell (V. ambiguus)	AMS
CAPR18_S41	0				Wk-52891	509 ± 19	-5.4 ± 0.3	531–496	Shell (V. ambiguus)	AMS
CAPR18_S41	0				Wk-52892	508 ± 20	-4.9 ± 0.3	532–496	Shell (V. ambiguus)	AMS
CAPR18_S41	0				Wk-52893	496 ± 19	-3.5 ± 0.3	524–492	Shell (V. ambiguus)	AMS
CAPR18_S41	9	TP01	SU2	XU2	OZZ005	500 ± 20	-6.2 ± 0.1	527–493	Shell (V. ambiguus)	AMS
CAPR19_M03	0				OZZ004	510 ± 20	-3.7 ± 0.3	532–496	Shell (V. ambiguus)	AMS
CAPR20_S11	38				Wk-52353	7040 ± 22	-6.3 ± 0.8	7940–7740	Shell (V. ambiguus)	AMS
HCN20	20				Wk-52024	3386 ± 45	-8.5 ± 0.3	3694–3455	Shell (V. ambiguus)	Conventional
HCN21	60				WK-52025	4118 ± 21	-	4806–4441	Charcoal	AMS
PikeAWE15_10	69				WK-47550	12722 ± 64	-6.8 ± 0.5	15331–14920	Shell (A. jacksonii)	Conventional

Site_ID	Depth (cm)	TP/Trench	SU	XU	Lab Code	CRA	d(13C)	cal range cal BP	Material	Method
PikeAWE15_10	32				OZX287	5540 ± 35	-7.7 ± 0.1	6396–6207	Shell (??)	AMS
PikeAWE15_10	8**				OZX288	25080 ± 150	-9.5 ± 0.1	29845–28977	Shell (A. jacksonii)	AMS
PikeAWE15_10	0				WK-48703	12679 ± 30	-7.0 ± 0.2	15205–14945	Shell (A. jacksonii)	AMS
PikeAWE15_10	12**				WK-49723	23166 ± 124	-8.7 ± 0.2	27680–27228	Shell (A. jacksonii)	Conventional
PikeAWE15_10	0				WK-49724	12825 ± 59	-9.7 ± 0.2	15517–15076	Shell (A. jacksonii)	Conventional
PikeAWE15_10	59				WK-49725	12509 ± 75	-9.3 ± 0.2	15046–14265	Shell (A. jacksonii)	Conventional
PikeSP16_01	0				OZX289	12800 ± 60	-7.1 ± 0.1	15470–15023	Shell (A. jacksonii)	AMS
PikeSP16_01	5				WK-47551	10114 ± 99	-8.1 ± 0.5	11934–11259	Shell (A. jacksonii)	Conventional
PikeSP16_01	5				WK-48704	12975 ± 26	-8.7 ± 0.3	15616–15308	Shell (A. jacksonii)	AMS
PikeSP16_01	0				OZX290	5930 ± 35	-12.5 ± 0.1	6846–6569	Shell (V. ambiguus)	AMS
PikeSP16_01	0				WK-48705	2534 ± 20	-8.8 ± 0.2	2728–2435	Shell (V. ambiguus)	AMS
PikeSP16_01	6				WK-49726	12788 ± 94	-8.4 ± 0.2	15558–14946	Shell (A. jacksonii)	Conventional
PikeSP16_01	12				WK-49727	12968 ± 64	-8.1 ± 0.2	15677–15251	Shell (A. jacksonii)	Conventional
PikeSP16_05	8				OZZ015	8120 ± 30	-7.5 ± 0.1	9130–8778	Shell (A. jacksonii)	AMS
PikeSP16_05	6				OZZ016	11580 ± 35	-8.0 ± 0.2	13490–13320	Shell (A. jacksonii)	AMS
PikeSP16_05	31				OZZ020	12470 ± 35	-7.3 ± 0.1	14912–14298	Shell (A. jacksonii)	AMS
PikeSP16_05*	33-38				Wk-53708	24631 ± 83	-	29112–28709	Charcoal	AMS
PikeSP16_05*	33-38	MM1			Beta-620780	31920 ± 606	-	36795–35819	Organic sediment	AMS
PikeSP16_05	0-11	TP01	SU1	XU1	OZZ018	7325 ± 30	-10.8 ± 0.1	8177–8020	Shell (??)	AMS
PikeSP16_05	36	TP01	SU2	XU3	OZZ019	8825 ± 30	-7.6 ± 0.3	10118–9562	Shell (??)	AMS
PikeSP16_05*	33-38	TP02	SU2	XU2	WK-50694	39309 ± 606	-	43940–42294	Charcoal	AMS
PikeSP16_05	5-8	TP03	SU1	XU1	OZZ017	10295 ± 35	-10.2 ± 0.3	12143–11840	Shell (N. sublineata)	AMS
PikeSP16_05	8-13	TP04A	SU1	XU3	WK-52034	8104 ± 19	-6.9 ± 0.3	9080–8781	Shell (A. jacksonii)	AMS
PikeSP16_05	36-43	TP04A	SU2	XU8	WK-52033	9599 ± 21	-5.9 ± 0.3	11085–10725	Shell (A. jacksonii)	AMS
PikeSP16_05	20-24	TP04A	SU2	XU5	WK-52035	4306 ± 17	-6.5 ± 0.3	4869–4728	Shell (??)	AMS
PikeSP16_05	70-82	TP04A	SU3	XU12	WK-52031	10747 ± 26	-	12723–12646	Charcoal	AMS
PikeSP16_05	70-82	TP04A	SU3	XU12	WK-52032	9919 ± 20	-9.4 ± 0.3	11333–11215	Shell (N. sublineata)	AMS
PikeSP16_05	55-70	TP04A	SU3	XU11	WK-52036	8313 ± 59	-9.6 ± 0.3	9437–9033	Shell (A. jacksonii)	Conventional
PikeSP16_05	85	TP04A	SU4	XU13	WK-52030	10037 ± 21	-7.0 ± 0.3	11616–11287	Shell (N. sublineata)	AMS

Site_ID	Depth (cm)	TP/Trench	SU	XU	Lab Code	CRA	d(13C)	cal range cal BP	Material	Method
PikeSP16_05	5	TP05	SU1		WK-52029	5957 ± 37	-8.2 ± 0.3	6855–6645	Shell (V. ambiguus)	Conventional
PikeSP16_07	42				OZZ013	10105 ± 30	-11.3 ± 0.1	11827–11324	Shell (N. sublineata)	AMS
PikeSP16_07	3				OZZ014	7830 ± 30	-9.0 ± 0.1	8641–8453	Shell (A. jacksonii)	AMS

* These three ages were returned on a single hearth feature. Beta-620780 was returned on microcharcoal and charcoal powder recovered from a micromorphology block and was categorised by Beta Analytic laboratories as 'organic sediment'.

** These two ages were returned on a single discrete midden lens.