The Last Global Warming?
Archaeological Survival in
Australian Waters

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The Department of Archaeology and the Graduate Program in Maritime Archaeology gratefully acknowledges the financial support provided by Comber Consultants Pty Ltd, the Australasian Institute for Maritime Archaeology (AIMA) and the Faculty of Educations, Humanities, Law and Theology (EHLT) Faculty Research Budget in the printing of this volume.
Flinders University Maritime Archaeology Monographs Series

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About Graduate Programs in Maritime Archaeology:
Biography

David Nutley is a Maritime Archaeologist with the NSW Heritage Office’s Underwater Cultural Heritage Program, a qualified Occupational Diver (Level 2) and accredited Dive Supervisor.

He has over 20 years experience in maritime heritage management, including curatorial (Australian National Maritime Museum, Sydney), extensive field survey, significance assessment, archaeological report writing, policy, strategic and public education experience. In 1988 he established and coordinated the development of an underwater cultural heritage management program for New South Wales. He continues this work with the New South Wales Heritage Office.

He initiated and continues to develop the Maritime Heritage Online web site for New South Wales (http://maritime.heritage.nsw.gov.au).

David has a Graduate Diploma in Maritime Archaeology, a Graduate Diploma in Aboriginal Education (Distinction), a Master of the Built Environment (Heritage Conservation) and, in 2005, completed a Master of Maritime Archaeology with a focus on submerged Indigenous sites in Australia (Distinction). In the 1970s and early 1980s David specialised in Indigenous education and cultural studies in north Queensland and the Torres Strait Islands.

He was President of the Australasian Institute for Maritime Archaeology (AIMA) from 1997-2002, Senior Vice-President from 2003-2005 and is currently Vice-President.

He is a member of ICOMOS and Australia’s representative on the International Committee for Underwater Cultural Heritage (ICUCHI), an ICOMOS scientific committee. As a member of that committee he has completed coediting a booklet on Underwater Cultural Heritage @ Risk, a joint project of UNESCO and the International Council on Monuments and Sites. In July 2006, at the invitation of the Egyptian cultural authorities and UNESCO, he participated in an international workshop studying opportunities for constructing an underwater museum or other innovative means to provide access to the inundated remains of the port of Alexandria, dating from at least the 4th century BC.
Preface

Abstract

This archaeological study examines the potential for inundated cultural heritage to survive the process of inundation within the context of the Australian Indigenous cultural landscape and during periodic or permanent immersion in coastal, riverine and lacustrine environments. The creation of physical evidence of human occupation is a product of cultural values, geography and resource availability across time. Where it survives is a factor of interplay between environment and the composition of the physical evidence itself. Understanding of this interplay assists in understanding the dynamics of any specific cultural group including their values and economics.

In order to investigate currently observable impacts a survey was conducted within the confines of North Arm, Sydney Harbour. This site was chosen as a suitable representative setting from which to develop predictions for a wider range of site types as well as geographical and regional environments and micro-environments. A global comparison of available literature was also undertaken and demonstrated a range of approaches used in searching for and investigating inundated cultural heritage sites. The review revealed a considerable gap between literature about inundated sites and that currently available for terrestrial settings.

The study shows that there is no doubt that a variety of Indigenous Australian habitation sites and displaced artefacts have survived in defined hydrodynamic and geological settings and through different eras. It identifies the need for predictive modelling to prioritise future research and as a basis for synthetic, multidisciplinary, regional studies and as an approach essential to effective understanding of inundated Indigenous sites within wider social economic and religious contexts.
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On the subject of librarians, the staff of Flinders University for their attention to my external student needs and for the staff at Sydney University’s Fisher and Madsen libraries for their responsiveness to a student enrolled in another university.

Mark Staniforth, my supervisor from Flinders University Adelaide for prompting me to set out on this venture and for his encouragement and support throughout its development.

And my wife, Jillian Comber, for her understanding, patience tireless support and humour when most needed.
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Human beings and water resources are inextricably linked. This association holds true whether the water bodies are coastal or inland, tidal, seasonal or permanent. It is inevitable that physical evidence of human exploitation of this resource finds its way underwater - whether through direct human activity (underwater constructions, discards, accidents) or environmental change. Where this physical evidence is deposited is a product of cultural values, geography and resource availability. Where it survives is a factor of interplay between environment and the composition of the physical evidence itself. Understanding this interplay assists in understanding the dynamics of any specific cultural group including their values and economics. The continuing knowledge within Indigenous communities is important in developing these understandings, and is complementary to examination of environmental, physical and early ethnographic evidence.

This study examines the potential for inundated Indigenous cultural heritage in Australia to survive the process of inundation within the context of periodic or permanent immersion in coastal, riverine and lacustrine contexts. As an island continent, Indigenous occupation of Australia was closely tied to the use of maritime and estuarine locations. The earliest archaeological evidence of human occupation in Australia has been found at the site of a dry inland lake, Lake Mungo and dated, amidst ongoing discussion, to around 60,000 years BP (Attenbrow 2002b:152). Ideas about how this occupation came about vary from Aboriginal belief in evolution within Australia (Attenbrow 2002b:152) to arrival from the sea (Flood 1983: 29-39). During maximum glaciation, 15 000 -18 000 years BP sea levels are estimated to have fallen up to 130m below current levels (Inman 1983:89). Shorelines shifted out onto the continental shelf and, in places, much closer to the commencement of the continental slope and the 200m contour (Figure 1) for a period of 10 000 years (Roy 1998:368). A sea voyage in an undocumented form of raft or boat would then have involved an open-water crossing of some 50-90 kilometres from Sunda (Indonesia) (White and O’Connell 1982:42-53; Flood 1983:32).

Other theories explain the subsequent spread of settlement across the country. Some, but not all, take account of the interplay between people and water sources. Joseph Birdsell’s radiational model (Figure 2) is notable in not having a focus on water as a central component of its argument (Birdsell 1957:47-69). The basis of this model is the assumption that populations expanded from a given point of entry and according to factors related to group size, generation length and rates of reproduction. The weakest part of this model is that it ignores a primary issue - that people are attracted to water and to the food resources associated with it.
Figure 1. Extent of the Australian continental shelf (adapted from auSEABED, INSTAAR, UnivColorado 2002 and Geoscience Australia GEODATA TOPO 10M 2002)

Figure 2. Birdell’s radiational model (after Flood 1983:78)

In contrast, Sandra Bowdler’s model (Bowdler 1977:205-246) is one of coastal colonisation by people who, having arrived from island origins, were intrinsically prepared for and at home with coastal environments. Bowdler's model is one of initial coastal expansion (Figure 3) followed by inland migration, initially via major river and lake systems.
A third model was developed by Horton (1981:21-27) who suggests that a major driving force for expansion was the availability of fresh water. As the coast is not always the greatest supplier of fresh water, such as parts of the north west coast of Western Australia and the Great Australian Bight. Horton’s model sees expansion across and through the continent, as well as some coastal expansion, according to the natural wetlands available at the time (Figure 4).

Since availability of water and its associated food resources is a central issue for all societies it is not surprising that research into Indigenous ‘maritime’ heritage in Australia has been a feature of the archaeological investigation, recording and documentation for many years (Dix and Meager 1976; Haddon 1935). A 1980 Australian Archaeological Association Conference on *Coastal Archaeology in Eastern Australia* sponsored by the Australian National University, (Bowdler 1982) was an important initiative in assembling some of the current research at that time. Fourteen years later a second substantial volume of papers (Hall and McNiven 1999) arose from a follow-up symposium *Australian Coastal Archaeology: Current Research and Future Directions*. 

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**Figure 3.** Bowdler’s model of initial coastal expansion (after Flood 1983:78)

**Figure 4.** Horton’s model of expansion via fresh water pathways (Flood 1983:78)
However, 25 years after the first coastal archaeology conference in Australia, there are still many gaps in the understanding of Indigenous maritime culture. One area that has been largely overlooked is the potential of underwater sites. This has been acknowledged by researchers since the late 1980s (e.g. Dortch et al. 1990, Dortch 1997; Flemming 1982a, 1982b, 1983a, 1983b). The need to develop techniques and predictive models in order to provide appropriate management of this unique component of Australia’s underwater cultural heritage has also been identified (Nutley 2000:1).

Apart from infrastructure development projects such as dams and artificial lakes, sites of human occupation and activity become permanently inundated through two main causes: long term environmental changes resulting in an absolute or eustatic sea level rise and global and regionalised isostatic and tectonic activity (Chappell 1982; Everard 1980) (Figure 5). Areas of long-term habitation by Indigenous populations in Australia have been inundated by virtue of either or both of these causes. Inundation may be periodic, relating to seasonal changes in lake/river levels, or episodic, caused by tsunamis or similar storm events. What is not well known is where these sites are most likely to have survived the many facets of the inundation process.

![Figure 5. Diagrams of eustatic and isostatic determinants of sea level (Nutley 2005)](image)

Potential areas for the existence of Indigenous maritime heritage include lakes (natural and artificial), rivers and coastal environments. Each of these has their own general geological, hydrological and climatic characteristics as well as the characteristics of subdivisions and micro-environments within those subdivisions. These characteristics are examined in Chapter 5 in developing predictions for the likely survival of specific types of cultural sites subjected to inundation. Appendix A summarises the determinants of site survival, while Appendix B provides a glossary of specific terms used throughout this study.

The principle argument of this current study is that currently observable impacts at the land water interface are representative of the types of impacts experienced during the inundation process. As noted by Attenbrow and Steele (1995:47), “In prehistoric studies historical descriptions are often used to interpret the archaeological record of an area.” Such observations should therefore serve as indicators of the survival and condition of previously inundated sites. Therefore, an examination is made for the presence of such observations within existing site research at the land-water interface as well as in permanently inundated settings. This is used to develop a methodology for supplementary, targeted, site surveys. The combined data is then discussed and analysed. The results are the foundation of a predictive model for areas of high or low survival potential of specific Indigenous site types in Australia and recommendations for further research.
This literature review develops an underlying theme of interaction between environmental factors and cultural materials in determining the spatial location and survival of inundated Indigenous cultural heritage in Australia. The basis of this is the application of Schiffer’s (1987) defining work on archaeological site formation processes to the underwater environment, an application that has been demonstrated by Stewart (1999:565-587). Schiffer articulates a range of depositional and post-depositional processes including intentional and accidental deposition. He cautions care in interpreting deposits that may have originated from the disposal of refuse as this may result in associations within a site of materials that were never used together (Schiffer 1987:19-21).

Impacts of waves, tides and currents on archaeological sites have been taken up by, amongst others, Stewart (1999:582-583) and Waters (1992:251). While these are primary features of coastal areas and important features of estuarine areas, waves and currents are also factors within all water bodies including, albeit of a minimal nature, marshlands.

To date, all studies regarding inundated sites in Australia appear to consider the process of terrestrial sites becoming inundated but not other mechanisms through which cultural materials may end up underwater. Such considerations are important to understanding artefact deposits in a submerged environment and are discussed later in this study.

A central component of understanding the survival of inundated sites is to incorporate information from the geological, hydrographic and marine biology record. This data is essential in shedding light on the archaeological record by identifying key issues related to the interaction of artefacts and sites with geological, hydrographic and biological factors. Unfortunately, to date, such surveys have not been configured to address archaeological considerations directly. However, valuable implications can be drawn from geological surveys regarding geological evolution such as that undertaken by the New South Wales Department of Mineral Resources (Roy 1998:361-385), even though the focus of these surveys is the economic prospects of heavy minerals, gold and marine aggregate deposits.

**Australian Indigenous Heritage on the Edge**

Most studies on Indigenous heritage at or near the interface between land and water have included those related to coastal environments, including the intertidal zone, and the terrestrial, or at least seasonally terrestrial, component of lakes and rivers. The investigation of permanently submerged sites or of their potential is very limited, the most notable being...
the work at Lake Jasper (Dortch 1997; Dortch et al. 1990) and the Cootamundra Shoals survey, (Flemming 1982a, 1982b) both in Western Australia.

The following is a review of the available literature that pertains to four environmental contexts (coastal, riverine, lacustrine, wetlands) and with a specific review of stone fish traps due to their inherent resilience to inundation and their occurrence across a number of environmental contexts.

**Coastal archaeological studies**

The majority of the world’s population has lived in the past, and continues to live, along the coast. Prior to the development of agriculture most inland areas could not support large populations. As sea levels began to rise rapidly shortly before 14,000 years ago it probably triggered massive movement and ecological readjustment of the human population inhabiting the Asian Pacific rim. (Dixon 1993:123)

Existing coastal archaeological studies provide an archaeological context for the inundated environment. They provide indicators of coastal morphological change and the range and location of site types that could have experienced inundation along the coastal regions. From an examination of these studies, observations are made in Chapter 4 about the influence of environmental factors on the survival of inundated Indigenous site types in Australia.


The potential for the existence and location of inundated Indigenous sites is related to environmental and coastal geomorphological factors (Chappell 1982:69-78; Roy 1998:361-385), as well as the duration, demographics and cultural practices of human habitation. The characteristics of the continental shelf (width, depth and slope and the interplay of coastal and riverine hydrology and sediment transportation) are critical to site survival. The actual establishment of the original site is a factor of sea level history (Figure 6), demographics, cultural practices, resource availability.

For example, on the east coast of Australia north of 31°S the continental plain begins to turn down into the continental slope zone between 70-130m (Roy 1998:371), a depth at which habitation sites could conceivably have been established during the lowstand at Last Glacial Maximum (LGM). South of 33°S, however, this change occurs at 140-150m. This depth is certainly below the LGM and thereby excludes the possibility of habitation sites ever being established. Landward of the continental slope, the near-horizontal outer continental shelf plain is shallower than 100m north of 31°S and deeper to the south of this latitude. The opportunity for any initial establishment of habitation in this region is therefore also higher in the north than in the south (Roy 1998:372).

Paradigms for Australian prehistory began with a belief in long-term socio-economic and demographic stability (Birdsell 1957). As mentioned in the introduction, his radiational occupation pattern ‘filled’ the country to the capacity of its various environmental zones. Subsequently, archaeologists such as Bowdler (1977) and Horton (1981) argued that occupation patterns involved initial exploitation of those areas that were richest in resources, the coastal plains. Bowdler argued that following an initial coastal occupation, Indigenous groups then began moving inland utilising river and wetland corridors, either permanent or
seasonal. She also argued that the early Indigenous populations had an inherent understanding of coastal living, based on the presumption that they arrived from Asia by sea and were therefore familiar with coastal environments. Others have argued that there was no reason to believe that people would not move inland when food and water permitted (Hiscock and Wallis 2005:34-50).

![Figure 6](image_url)

**Figure 6.** Late Quaternary and Holocene sea level history, southeastern Australia (Troedson et al. 2004:12 after Roy and Boyd 1996)

These patterns of occupation and the duration of occupation are important elements in predicting the survival of sites during inundation. Early observations of apparent coastal intensification (Megaw 1974; Wade 1967) and population increases (Hughes and Lampert 1982; Lampert and Hughes 1974) were followed by strong debate about the significance of these phenomena (Beaton 1983, 1985; Lourandos 1980, 1983, 1985). A common element of much of the 1980s and of subsequent discussion (Dortch 1997; Head 2000; Rowland 1992, 1996) confirms a belief in the potential of coastal environments to reveal details of the demographics and spatial realignments of Indigenous populations. This potential exists
whether demographics and spatial realignments have been in response to the rise and fall of sea levels or to cultural and social evolution, or both.

Although Australian studies are quite incomplete in identifying environmental determinants for the survival of inundated Indigenous site types, significant studies have been undertaken by Beaton (1985), Bird (1992, 1995), Chappell (1982), Flemming (1982a, 1982b), Littleton et al. (1994) and Rowland (1989, 1992, 1996).

A 1982 survey of Cootamundra Shoals in the Timor Sea about 200km north-west of Darwin (Figure 7) deployed divers to visually locate and inspect key underwater features including cliffs, terraces and submerged reefs and fossil beach ridges (Flemming 1982a, 1982b). Cootamundra Shoals was chosen due to its proximity with a potential point of initial migration from South East Asia and due to its broad and relatively shallow continental shelf.

![Figure 7. Locality map, Cootamundra Shoals (OziExplorer, D&L Software 2005)](image)

The majority of the objectives of the Cootamundra Shoals project related to environmental documentation, although one objective was to find sites indicating human occupation, including shell middens, the debris of human occupation sites, rock shelters, caves and stone tools. No evidence of prior human occupation was found during the survey, which was likely a reflection of the dynamic nature of the Timor Sea including strong seas, large tides, strong currents and the associated erosion of coastal features during inundation. In addition, in this tropical area, the high level of marine life including coral reef formation is likely to bury any artefactual material and unlikely to leave coastal features in any state resembling their original form. Nevertheless, the Cootamundra Shoals study provided the initial impetus in Australia for inundated cultural landscapes to be considered as an area of archaeological investigation.

Rowland considers how inundation affects site survival and therefore the distribution of midden or other site types on the Queensland coast. In particular, he considers the potential
influence of sea level changes during the Holocene in accounting for the comparatively few midden sites that pre-date 2,000 BP (Rowland 1992:67-77). In doing so, he refers to Beaton’s time lag theory, where site formation does not immediately follow a rise in sea level, which helps explain variations in the age and distribution of sites (Beaton 1985:12). Rowland notes that at both a local and regional level “climatic, tidal change, shelf geometry and sediment supply…” as well as other shoreline geologically determined formations are factors that will influence the impact of coastal inundation (Rowland 1983:67; 1989:70). In addition, he observes that the timing, rate and duration of sea level rise and retreat of inundation is determined by isostatic occurrences (Hopley 1982, 1986 in Rowland 1989:70). These include “change in ice volumes, tectonic uplift or subsidence, progressive growth of coral, erosive processes and other episodic phenomenon, including cyclones and storm surges and minor shifts in climatic regimes” (Rowland 1989:70).

Rowland identifies cyclones and accompanying sea-level surges as being the greatest threat to site preservation. He provides an estimate from Lourenz (1981) that in the last 5,500 years “some 28,000 cyclones may have affected sea-level behaviour, 12,000 may have passed over the north-east coastline of Australia.” (Rowland 1989:72). Detailed evidence of the impact of storm surges associated with tropical cyclones at Upstart Bay has also been provided by Bird (1992, 1995). While these studies focus on understanding impacts on the survival of terrestrial sites, in combination, they also increase our understanding of the potential for sites to survive the process of inundation.

An investigation of the impact of storm surges associated with tropical cyclones at Upstart Bay on the northeast Queensland coast (Bird 1992, 1995) provides insight into the potential effects of coastal morphodynamics on the survival of midden sites and scatters. Following a baseline survey in 1987, Upstart Bay was devastated by cyclones in 1988 and again in 1989 (Bird 1995:57). Of 93 sites recorded during the 1987 baseline survey, primarily shell middens and scatters, 51 were completely obliterated in the wake of the two cyclones and a number of the remaining sites were severely compromised (Figure 8). The close chronological proximity of the two cyclones was clearly atypical and exacerbated the site damage in the absence of a period of aggradation. However, Bird has also been able to demonstrate that normal coastal morphodynamics are continuing to alter the state of preservation of sites in Upstart Bay. Post-cyclonic event erosion is occurring in areas no longer protected by high fore-dunes. At the same time, some areas of the southern part of the beach are prograding and providing ‘capping’ and protection of archaeological sites (Bird 1995:58).

Storm surge can have a significant impact on land sites, but the impact on inundated sites may not be so significant. This is illustrated by the 2004 Asian tsunami. While not a storm surge, the tsunami demonstrated that shipwrecks in Galle Harbour in Sri Lanka, even in shallow water, were almost unscathed while the foreshore and much of the town was destroyed (Parthesius et al. 29 March 2005).

This tsunami also helps to illustrate that sea level rises, whether short term surge events or long term climatic changes, have a major impact on human occupation sites. The concentration of human populations in all countries and throughout time is typically in the coastal and near coastal areas (Dixon 1993:123). Coastal regions are accompanied by higher levels of precipitation and accompanying flows of freshwater streams and rivers, exceptions include areas such as the Great Australian Bight. Compared to the inland areas of a large land mass like Australia, coastal areas are relatively rich in plant and animal life. They are also adjacent to the greatest concentration of marine life in coastal shallows and estuaries. There is every reason to believe that the major focus of early occupation had a distinct coastal flavour in so far as the populations at contact were predominantly centred near the climatically moderating influences of the sea (Dixon 1993:123).
Internationally, there is a variety of work on the potential for human occupation sites to have survived on the seabed. In 1983, Masters, working on ancient and present-day lagoon sites off southern California, identified three factors that effect site survival during transgressive sea level changes: the nature of the site, the location of the site and the duration of surf zone passage (1983:211). Other works develop this theme and together provide a guide to developing predictions for site survival in Australian conditions.

Melanie Stright has documented dozens of sites and potential sites along what is described as the continental shelf adjacent to the United States of America (Stright 1990:439-453). Stright identifies a range of site types, including shell middens, fish weirs, rock quarries, human burials and secondary depositions, which, in given settings have the ability to survive Holocene marine transgression. Favourable settings suggested for site preservation include protected bays and anaerobic estuarine mud. Burial prior to inundation (alluvial, swamp, marsh and/or estuarine deposits) and at a depth that is below subsequent shoreface erosion is identified as being a probable key factor in site preservation (Stright 1990:454). The 1990 study of the North American continental shelf provides other recommendations in predicting the location of surviving inundated sites. These include the presence of a broad, flat, shelving coast and associated low energy wave activity; the use of “sea-level curves”; identification of landforms associated with human subsistence; and differentiation between erosive and low-energy coastal transgression (Stright 1990:454). At the same time, Murphy (1990:52-54) was advocating that high-energy environments should not be disregarded. He illustrates how, at the shallow (2-6m), high-energy, Douglass Beach site off the east coast of Florida, barrier-island migration can preserve sites from the mechanical impact of inundation and retain a high degree of integrity. As seen above, this is confirmed by the Upstart Bay survey results in 1995 (Bird 1995:58). Furthermore, Murphy argues that their “linearity, elevation and characteristic sedimentary profile” make them suitable targets for remote sensing surveys (Murphy 1990:54).

Stewart (1999:572) includes reference to an additional site formation process, the rate of inundation. He notes that gradual inundation combines the mechanical forces of wave action, and alternating wet and dry states of artefacts within a site as resulting in site destruction and, at best the removal of any surviving artefacts from their original spatial context. Paradoxically, when sea level change is rapid, Inman (1983:39) suggests there is little
probability of finding evidence of habitation. He argues that although rapid marine transgression is conducive to minimal erosion of coastal sites, it is the least conducive to the development of a substantial number of established sites in the first place. Relatively stable conditions associated with slow marine transgression do favour increased biotic productivity (Ricklis and Blum 1997:304, 306) and “the concentration and permanency of cultural deposits” (Inman 1983:39), but these conditions are also associated with maximum erosion and other site disturbance factors. As this current study focuses on the observation of the interface of identified sites with water bodies there has been less emphasis on pre-inundation site concentration than would be necessary when selecting areas of potential surviving inundated sites. However, this factor is considered in regard to site survival determinants in Chapter 5.

Underwater and intertidal excavations at Montague Harbour since 1989 (Reinhardt et al. 1996:35-46; Delgado 1997:282) confirm that in a well-protected embayment, human occupation sites can survive post-glacial sea level rises. Importantly, it demonstrates that transgression within the harbour has resulted in differentiation between the integrity of intertidal and submerged deposits. Perhaps surprisingly, the intertidal deposits retain a higher degree of integrity to those that are permanently inundated. Benthic bioturbation, the disturbance of sediments by aquatic flora and fauna, is identified as a major factor in post-inundated site disturbance (Delgado 1997:60, 283; Stewart 1999:578-581). This is a significant observation as it suggests that site deformation does not necessarily reduce after inundation. Additional consideration needs to be given to the duration in which the current intertidal deposits have been exposed at the land-water interface compared to the duration that the submerged deposits were exposed within that same zone. Continuing Geoarchaeological work at Montague Harbour during spring 2005, focused on determining whether the submerged cultural materials have any stratigraphic integrity. The methodology being used is primarily “statistical analysis of the various components artefact distribution mainly, but also sediment matrices, and a couple of other variables” (Easton 2005).

In 1977 at Corral Beach, near Los Angeles, California, three in-shore sites associated with the Southern Coastal Chumash people were located and surveyed in depths of about 4.5-9.7m of water (Muche 1978:101). The assemblage of artefacts identified in the survey at site 1 included a scraper, points, pestles, a knife, fish hooks and, most significantly, a fire pit consisting of “fire-blackened rock, charcoal, burned bones, and vegetable material” (Muche 1978:102). The variety of this assemblage led to the conclusion that this was no random or accidental assemblage but a drowned habitation (Muche 1978:103, 107). As such, the work at this site provides very firm evidence of the ability of inorganic as well as organic materials from an estuarine context to survive coastal inundation without complete randomisation. The existence of a protective barrier of large rock outcroppings that delineate the perimeters of the original stream bed are identified as having been a key to the survival of this site by forming a buffer from prevailing winds and surge (Muche 1978:102).

Tom Koppel (2003) explores evidence for a coastal colonisation of North America and considers the potential for finding archaeological evidence on the seabed in 400 feet of water off California. Initially he outlines search efforts during 1994 off British Columbia in Canada. Dredging jaws were used to locate artefacts on the seabed in 80 feet of water adjacent to rich land deposits off Richardson Island and Matheson Inlet (Koppel 2003:134-146). While a number of artefacts were located, they were inconclusive whether they were in situ or randomised finds. Perhaps the major shortcoming of that technique includes the high cost and the inability to determine whether artefacts were in situ or had migrated from shoreline sites. The researchers identified the need to locate underwater features such as stable, drowned beaches on which to focus subsequent efforts (Koppel 2003:146). Conducting underwater archaeological searches adjacent to terrestrial landscapes with numerous recorded habitation sites may be the best means for increasing the likelihood of recovering artefacts. However, if
the sites being pursued are nearly 10 000 years BP or older then it should not be assumed that terrestrial resources and population densities at current onshore sites are any reflection of the demographics of earlier dates. As Ricklis and Blum have noted, there is evidence to suggest that:

...prehistoric occupation of the shoreline was a discontinuous phenomenon dependant upon a complex interrelationship among geomorphic processes, sea level dynamics, and estuarine productivity.

(Ricklis and Blum 1997:306,309)

Large-scale archaeological surveys at Langstone Harbour on the south coat of England (Allen and Gardiner 2000) and at Strangford Lough in Ireland (McErlean et al. 2002) provide a wealth of information on both methodology and potential outcomes of intertidal and shallow water archaeological investigation. The archaeological survey of the maritime cultural landscape at Strangford Lough investigated the experience of a range of maritime coastal site types and of submerged landscapes. While noting the survival of inundated forests in peat and estuarine silts, this study also clearly identifies the powerful coastal morphological aspects associated with sea level change.

Sea level change during the Holocene produced the erosion of the pre-existing landscape, leaving eroded surfaces from which material was removed and infilled topographic lows where it was deposited. ... the pre-existing irregular Glacial landscape has been planed by wave and tidal action during and since the Holocene rise in sea level to form a composite planar surface with both erosional and depositional elements. (McErlean et al. 2002:32)

Similarly, at Langstone Harbour the intertidal archaeological survey conducted in the 1990s observes that this too was an eroded rather than a drowned landscape (Allen and Gardiner 2000:219). Both these studies provide invaluable information on the behaviour of a range of materials subjected to a variety of environmental conditions and clearly demonstrate both the difficulty and potential of site survival during inundation.

The majority of studies to date reveal a bias towards shallow water sites and identify difficulty in finding in situ remains, the latter being consistent with Schiffer’s contention that deposited artefacts do not always remain at their original archaeological context (Schiffer 1987:99). Stright (1990) acknowledges the frequent difficulty in determining whether artefacts have been found in situ or have been redeposited and attributes this to activities such as dredging and recreational diving. (1990:439, 453). Furthermore, she notes that less than a sixth of the sites were discovered through controlled archaeological investigations (Stright 1990:453). Accordingly, she uses the term ‘sites’ to “designate any locality of archaeological material, whether or not it is an in situ archaeological deposit” (Stright 1990:439). This current study uses Stright’s definition of a site.

Riverine archaeological studies

The dynamics of river morphology demonstrate the impact of rivers on cultural deposits and provide background to the discussion of site survival determinants and their implications for survival of specific riverine site types in Chapter 5.

The erosion cycle is “a geomorphic principle of fluvial denudation” (Morisawa 1968:7). Surprisingly, there has been little in the way of studies that indicate the impact of rivers on archaeological sites. However, riverbank erosion processes not only assisted to locate the first physical evidence of Indigenous occupation in the south-west forest of Tasmania, (Jones 1981:54-59), and demonstrated the impact of at least a part of this process on archaeological remains. In this instance, a large riverbank tree, a Northofagus (possibly a Tasmanian Myrtle), had fallen, tearing out some of the earth and exposing a patch of clay and a number of stone tools. These included a quartz core and associated component flakes.
Studies related to rivers have included analysis of riverside campsites and middens (eg, Attenbrow and Steele 1995; Attenbrow 2002b) as well as fish traps. Attenbrow’s (2002a) investigation of the resource and land use patterns around Sydney Harbour suggests estuary fishing was predominantly a lower estuary activity while exploitation of shell resources was distributed evenly throughout the harbour (Attenbrow 2002a). Site formation observations from such studies have a bearing on what may or may not survive inundation.

Archaeological investigations by Wolfe (1992), and Bower and Staniforth (1993) of the riverbed adjacent to Queens Wharf on the Parramatta River in New South Wales (Figure 9) reveal important information about distribution of artefact material across a riverbed. The implications for the impact of riverine hydrology on the artefact density are discussed in Chapter 4.

Lacustrine archaeological studies

Platt and Wright (1991:58) divide lakes into two main categories, those that are: hydrologically open, which have an outlet, and those that are hydrologically closed, which have no outflow and may be perennial or ephemeral depending on climate.

They note that hydrologically open lakes have relatively stable shorelines compared to perennial or ephemeral lakes where the interplay of inflow and evaporation is more critical (Platt and Wright 1991:58). Spring fed sinkholes are examples of a hydrologically open system that can provide extremely stable conditions. This has been shown through archaeological investigation within a sinkhole at Warm Springs, Florida. In this still water setting, constant temperature 30.56°C (87°F) and highly mineralised anaerobic water provide exceptional preservation conditions below 2m, which has resulted in preservation of prehistoric remains, including a burial site on a 12-metre ledge dated to 10,200 BP (Murphy 1978:123, 125).

The ability for a range of archaeological habitation site types to survive both periodic and prolonged inundation is demonstrated at the Ohalo II submerged prehistoric campsite in Israel on the Shore of the Sea of Galilee. This site dates to 19,500 BP and was exposed in recent years following a major drop in the lake water level. Here the range of in situ remains
includes “six brush huts, six concentrations of hearths, a grave, and small installations” (Tsatskin and Nael 2003:409).

O’Sullivan (1998) highlights the immense preservation powers of lake and marsh systems by identifying a range of complex sites that have survived inundation. While most of these sites have been already ‘dry’ or accessed by artificial lowering of water levels (O’Sullivan 1998:118), the application and potential of underwater survey is also discussed (O’Sullivan 1998:193, 200, 201). O’Sullivan comprehensively discusses the potential and priorities of archaeological research on lake settlement in Ireland and the need for multidisciplinary, regional, landscape studies (O’Sullivan 1998:3,187-205,207). This has influenced the discussion on survival in the lacustrine environment in this current study (Chapter 5) and the methodology discussed in Chapter 3.

In Australia, the dating of lake shorelines indicates that current lake levels are similar to those that existed 40 000 BP but that they have not been stable over the entire period. Glacial period aridity caused these lake levels to lower from about 25 000 BP and again during the Last Glacial Maximum from 18-22 000 BP (Dortch 2004:26, 27). Post-glacial warming from around 15 000 BP to 10 500 BP caused these lake levels, in both mountainous and arid regions, to return to their previous levels. It can be presumed that these retreating shorelines would have been followed by Indigenous populations and suggests that many shorelines that were inhabited between 25 000 BP and 10 500 BP are now submerged. This provides Australia’s lake systems with potential to have preserved and recorded, in an inundated environment, thousands of years of Indigenous occupation during the Last Glacial Maximum (LGM).

The large number of sites and artefact deposits at Lake Victoria in New South Wales (Hudson and Bowler 1997) and an underwater survey of Lake Jasper (Dortch et al. 1990; Dortch 1997) in southwestern Western Australia (Figure 10) illustrate the enormous potential of lakes as repositories and protectors of Indigenous sites.

**Figure 10.** Locality map, Lake Jasper (OziExplorer, D&L Software 2005)
This survey of Lake Jasper in southwestern Western Australia is the most important work to date to focus on understanding the potential of submerged archaeological evidence in lakes. The survey was undertaken when the lake was at a low level. Scattered stone artefacts were located in association with stumps of trees and grass-trees (*Xanthorrhoea preissii*). The grass trees were in their growth position, leading to the conclusion that they had been part of a pre-inundation environment (Dortch et al. 1990:43). The following year a diving survey (Dortch et al. 1990:44) at Lake Jasper collected about 100 stone artefacts from four sites. This was in addition to about sixty artefacts collected from three exposed sites the previous year when the lake level was lower.

The significance of the Lake Jasper survey was to confirm the potential for undertaking archaeological investigation of inundated Indigenous sites. It also began the development of methods and disciplines for their analysis such as linking the investigation with known terrestrial and tidal sites in the region including fish traps at Wilson Inlet and Broke Inlet (Dix and Meagher 1976; Dortch et al. 1990:50). In addition, it raised the prospect for further work on inundated Aboriginal landscapes such as Warren Beach in southwest Western Australia (Figure 11). At Warren Beach, tree stumps dating to about 8340 BP, apparently in growth position, were reported to lay submerged hundreds of metres out to sea (Merrilees 1979:120).

![Figure 11. Locality map, Warren Beach (OziExplorer, D&L Software 2005)](image)

A 1994 study of Lake Victoria (Littleton et al. 1994) (Figure 12) provided important insights into the process of inundation on Aboriginal sites in inland lakes although the study dealt only with that portion of the lakebed that is now normally or seasonally exposed. Analysis of archaeological, geomorphic, stratigraphic and sedimentary information was then undertaken in 1998 in order to develop a framework for long-term management of the lake (Hudson and Bowler 1997:1-2). The implications of the Lake Victoria work will be discussed in Chapter 5.

O’Halloran (2000) investigated two inundated villages at Hume Reservoir on the New South Wales and Victorian border (Figures 13 and 14) to identify threats impacting on inundated archaeological sites. This study did not include specific Indigenous sites or any underwater archaeological fieldwork, and only observed those inundated sites that are periodically exposed. However, it provides valuable information on the impacts of inundation upon
cultural sites (O’Halloran 2000:9-10) and has influenced the development of the lacustrine
determinants of site survival discussed in Chapter 5.

Figure 12. Locality map, Lake Victoria (OziExplorer, D&L Software 2005)

Figure 13. Locality map, Hume Reservoir (OziExplorer, D&L Software 2005)

Wetland environments

Wetlands have been shown to have provided important resources for Indigenous Australian
communities since at least the mid-Holocene (Head 1987:439-440). Indeed, it has been
argued that “fixed plot horticulture” practiced in wetlands was a precursor to later “dry
farming and irrigation techniques” (Sherratt 1980:313), providing a strong indicator of the
potential of these areas to be repositories of archaeological remains. Lesley Head’s work at
Discovery Bay (Figures 15 and 16) in southwestern Victoria (Head 1987, 1988) provides evidence of the impact of sea level rise up to about 6000 BP on the formation of wetland areas, stabilisation of sea levels at around 6000 BP and subsequent erosion to about 4000 BP (Head 1987:440). This setting provides evidence of the likelihood of the survival of sites in the adjacent inundated coastal waters.

Figure 14.  Aerial view of Hume Reservoir (Geoscience Australia 2003)

Figure 15.  Locality map, Discovery Bay, south-western Victoria (OziExplorer, D&L Software 2005)
In 1973, wood and stone artefacts were recovered from peat deposits at Wyrie Swamp in South Australia. These included three complete boomerangs, one broken boomerang, a short spear, two types of digging stick, a carved wooden barbed javelin fragment and chart tools and flakes that were found in a layer dated between 10,200 ±150 – 8,990 ± 120 BP (Luebbers 1975:39). Further confirmation of the potential of wetland peat deposits was recorded at Wingecarribee Swamp in New South Wales where artefact scatters were found extending into swamp and, in places, predating the onset of peat accumulation (McDonald 2003: 61).

**Fish traps**

Stone fish traps, which exist in inland rivers as well as in estuarine and coastal areas (Bowen and Roland 1999; Campbell 1982; Martin 1988; Vale 1998; Welz 2002) are a relatively robust site type, which will be considered in conjunction with field survey work in Chapter 4 and discussed further in Chapter 5. Not all structures that look like fish traps are Indigenous in origin however, although some are similar to Indigenous designs, including the crescent pattern common in the Torres Strait (MacFarlane 1948:22). Structures in Tasmania (Stockton 1984:12-13) and Cremorne, Sydney Harbour (Attenbrow 1996) have historical accounts of their construction. Such sites may or may not be in areas equivalent to those chosen by Indigenous populations. However, due to their structural similarity, they may still contribute to understanding the impacts of inundation on this site type.

An example of a complex system designed to increase the intensification of a food supply, which will be discussed in Chapter 6, is the extensive complex of marine stone fish traps located at Hinchinbrook Island in North Queensland (Figure 17) (Campbell 1982; Gray and Zann 1988).
A significant regional study of marine and estuarine stone fish traps at Eyre Peninsula and the West Coast of South Australia was undertaken in 1986 and 1987 (Martin 1988). The study provides a broad coverage of published and unpublished literature about all forms of Aboriginal fish traps up to 1988 and is an important reference work.

Additional information comes from another significant study, *Indigenous Fish Traps and Weirs of Queensland* (Bowen and Rowland 1999). The terms of reference of this study is specifically Queensland but it includes a wide-ranging review of information sources about Queensland sites. In addition it develops site profiles for fish traps and weirs and a predictive model of site location as well as identifies Indigenous management practices (Bowen and Rowland 1999:2). The authors recommend research into a number of areas including the taphonomy of traps and weirs (Bowen and Rowland 1999:56-57) though they do not specifically direct this to include the process of inundation. The *Indigenous Fish Traps and Weirs of Queensland* is an important complementary work to that of Martin (1988) as it includes references to studies of many sites, both of Aboriginal and Torres Strait Island origin, inland and coastal (Bowen and Rowland 1999:4-6).
The Torres Strait fish traps mentioned above were a central component of Torres Strait Islander food collection techniques and were reported as being on the shores of “practically every island” (Haddon 1935:159). In some areas, mats and branches were used to form traps at the mouths of creeks (Bowen and Rowland 1999:5). Stone fish traps also occurred throughout the Torres Strait but most frequently in the eastern islands (Bowen and Rowland 1999:4). Torres Strait Island stone fish traps have been variously described in the form of arcs, a series of wide loops and rectangular, sometimes as multiple-pen traps and sometimes as single-pen traps, with some structures being over 100m in length (Bowen and Rowland 1999:6; MacFarlane 1948:22).

The stone fish traps of the Ngembah at Brewarrina (Ngunnhu) (Figure 18) consist of a large complex of stone walls about one kilometre in length (Figure 19). A 1994 Conservation Plan incorporates a history of the fish traps since the 1850s including surveys and condition descriptions (Hope and Vines 1994:1). The report provides a record of the durability of these periodically inundated structures within a major Australian inland river.

Figure 18. Locality map, Brewarrina in northwestern New South Wales (OziExplorer, D&L Software 2005)

**Human Impacts**

Research into the impacts of new dams, reservoirs and canals can increase understanding of an archaeological site’s ability to survive the process of inundation. Some of the most valuable information on the impacts of inundation on sites of Indigenous cultural heritage has come through mapping, testing and monitoring studies associated with dam or reservoir construction in the United States of America (Lenihan et al. 1977; May et al. 1978). The focus of these studies was to identify archaeological site formation processes within these contexts. It was argued that this information would help to avoid later misinterpretation of these and similar sites (May et al. 1978:109). A corollary is that these assessment and monitoring studies provide insight into the impacts of natural inundation processes. They also provide important details about site investigation methodology that can be applied to a range of inundated archaeological sites.
Figure 19. Brewarrina fish traps (Nutley 2004)

The work at Table Rock reservoir, Missouri, looks specifically at two riverine site types, rock shelters and open sites. The Missouri study assesses a number of site formation factors including currents, waves and changes in water levels as well as pedoturbation (May et al. 1978:109). Of particular relevance to interpretation of the field observations in Chapter 4 and discussion in Chapter 5 of the current study are the investigations conducted at inundated rock shelters designated 23 BY 8 and 23 BY 162 (May et al. 1978:109). The first of these sites has been permanently submerged since the reservoir filled in about 1959. Observations included the presence of stones of various sizes. The difficulty posed by these stones for site interpretation is that they could have been part of the original ground surface or transported into the site through beach erosion on either side of the opening of the shelter (May et al. 1978:110). High levels of phosphorous were identified in the sediment layer raising the issue of whether the natural accumulation of phosphorous in lake sediments may serve to “mask the limits of human occupation within the shelter” (May et al. 1978:114). Further complications arose in interpreting the presence of stone artefacts (flakes) found in this site. The researchers could not be certain that these were not washing into the shelter from an adjacent eroding site at the land-water interface, particularly with accompanying evidence of current induced sediment ripples (May et al. 1978:114). Given that the currents in a reservoir are typically minimal, this observation has important implications for sites in more turbulent settings.

The second rock shelter, 23 BY 162, is “subject to frequent intermittent exposure” (May et al. 1978:110). This shallower site provides a significant contrast in site formation. The deeper shelter at site 23 BY 8 was presumably inundated rapidly and with a minimum period of wind induced wave action. The periodic exposure of the higher site 23 BY 162, makes it far more susceptible to mechanical, chemical and, by virtue of increased light and oxygen, biological disturbance. In the Table Rock Reservoir setting biological disturbance is predominantly a
result of mussel activity. Excavation demonstrated considerable loss of the upper soil horizon and reduced levels of phosphorous through erosion and leaching (May et al. 1978:114,117).

Conclusion

This literature review has demonstrated a range of approaches used in searching for and investigating inundated cultural heritage sites. The review has included both terrestrial and underwater perspectives. A collaboration of these approaches, as occurred at Lake Jasper, increases the potential of further research in this area. The coastal studies at Strangford Lough and the archaeological research on lake settlement in Ireland have shown that this potential is dramatically increased when combined with broader thematic or landscape perspectives.

Nevertheless, there remains a considerable gap, both in Australia and overseas, between available literature about investigation, documentation and analysis of underwater sites and that achieved in terrestrial settings. There has been some significant development of principles of site formation processes but the majority of work is site specific.

In Australia, some important preliminary research has been undertaken but this has been largely isolated and undeveloped. What is clear is the considerable scope for increased understanding of impacts occurring at the land-water interface and how this shapes the survival of given site types in particular settings. These key elements arising from the literature review, site formation process and thematic and landscape perspectives, have shaped the methodology described in Chapter 3.
This study has an emphasis on observational experience, predictive modelling and the need to consider these within a broader landscape or thematic setting in order to establish research priorities. It draws upon site formation principles as articulated by Schiffer (1987) and Stewart (1999:565-587) and combines an analytical and interpretive review of existing research integrated with data collected during site survey.

Since an important and necessary aspect of this study is the utilisation of information about distributions and movements of continental and inland waters it also has a significant palaeohydrological component as defined by Baker (1998:1).

**Ethnographic and Archaeological Records**

The review of key literature in Chapter 2 demonstrates the extent and nature of Indigenous habitation within the Australian landscape. This information, including the coastal intensification demographics debate has been utilised in considering potential inundated Indigenous sites and in selecting site types and locations for further examination. In the face of inundation, populations inevitably retreated. Since population levels, duration of occupation, site frequency and resource utilisation are important factors in site survival, these factors have been taken into consideration in this current study in addressing the question of survival of site types in given environmental conditions.

Previous studies dealing with specific archaeological investigations of underwater sites have identified some key parameters for site survival. These findings have been applied to the interpretation of the specific site observations included in this study. They also assist in developing a predictive model of the extent and nature of inundated Indigenous sites in Australia.

The review of the international experience regarding investigation of submerged or submerging archaeological sites has provided a context for examining the effects of inundation in the Australian setting. This includes consideration of sites that were terrestrial and are now inundated and sites that are periodically exposed.

A representative site study was conducted at Middle Cove, Sydney Harbour and the results are discussed in Chapter 4 and contextualised in Chapter 6 through examination and discussion of sites within other Australian environmental contexts (Figure 20). These are sites
where there is a significant archaeological record of current or previous periodic or permanent inundation of Indigenous sites and include:

Coastal: Hinchinbrook Island (Queensland); Discovery Bay (Victoria)

- Riverine: freshwater: and Darling River (New South Wales)
- Riverine: tidal/estuarine: Sydney Harbour, Parramatta River, Yowaka River (New South Wales)
- Lakes: Lake Jasper (Western Australia); Lake Victoria (New South Wales);
- Wetlands: Wyrie Swamp (South Australia); Wingecarribee Swamp (New South Wales)

Figure 20. Map identifying location of key Australian sites referred to in this study (OziExplorer, D&L Software 2005)

Additional sites that have not been subjected to this same level of archaeological examination are referred to where they provide additional illustration of site responses to inundation.

An examination of these sites assesses their environmental context in terms of geology, slope and hydrographic experiences as well as the nature and durability of key cultural materials found on the site and the likely reaction of these materials to the process of inundation.

References have been sourced through Australian and international libraries and other document repositories including the Internet.
Physical Geography

Principles of physical geography including the general geological history of Australia as well as hydrological processes, coastal processes, slope and weathering, are considered in relation to impacts of cultural sites during inundation. Specific investigation is made of coastal, lake and river formation.

Direct survey work is used to demonstrate that the process of inundation is not a matter of passively ‘swamping’ the landscape but one that places enormous pressures on archaeological sites, even in relatively benign environments. In many other settings, extreme scouring, abrasion, removal of large quantities of earth and sediments and rock will be shown to make survival either extremely unlikely or impossible.

From this analysis indicators of site survival, randomisation or destruction are developed. This model takes cognisance of environmental factors, (wind, hydrodynamics, abrasion, biological and chemical activity, geomorphological processes), geography and the composition, context and inherent durability or fragility of specific archaeological site types. The model does not focus on the process of accretion or prograding that buries cultural deposits but on the process of erosion as it is an erosive force accompanying short or long-term inundation that impacts most directly on the survival of submerged archaeological sites.

Information on coastal processes along the New South Wales coast has drawn on the geomorphological work of Chappell (1982), the Geological Survey of New South Wales (1994, 1997, 2005), the International Geological Correlation Programs project on late quaternary coastal records of rapid change (Number 367, 1996) and the Coastal Council of New South Wales (Chapman et al. 1982). The morphology and hydrology of rivers and lakes has drawn on relevant archaeological investigations as well as that of geomorphologists (Anadón and Cabrera 1991; Baker 1998; Gregory and Walling 1979; Morisawa 1968).

Survey

Indigenous participation and consultation is important to all phases of fieldwork. Such participation and consultation respects and acknowledges the role of Indigenous people in the management and protection of their own cultural heritage. It also facilitates the two-way sharing of information. Continuing knowledge within communities (oral history) is a method of identifying likely or remembered sub-tidal structures, such as fish traps, which have not been recorded or of describing the original extent and complexity of such structures within the broader cultural landscape. The combined results provide information that Indigenous communities can use for education, tourism and management. The survey at Middle Cove was undertaken in association with David Watts, Aboriginal Heritage Advisor to Lane Cove Council and the survey at Yowaka River was undertaken in association with Graham Moore, Aboriginal Sites Officer, NSW National Parks and Wildlife Service.

The site at Middle Cove and discussed in Chapter 4 was identified through such consultation. It builds upon the evidence of existing Australian and international archaeological research and assesses observable impacts at the current land-water interface. The site, in the Sydney suburb of Middle Cove, Sydney (Figure 21), is within the protected waterway of North Arm, Sugarloaf Bay, being a portion of Middle Harbour, one of three main divisions of Port Jackson. Here the impacts of even a low hydrodynamic environment are seen to be quite significant. The choice of this site provides opportunities for analogies with coastal, riverine and lake contexts. While an extensive survey of such sites is beyond the scope of this current study, the sample site demonstrates the potential for a much broader study of the survival and spatial and compositional distribution of inundated Indigenous sites in Australia.
Observations at the site in North Arm, Middle Cove are supported in Chapter 5 by observations recorded informally at other relevant sites in including:

- Estuarine: Stone fish traps on Yowaka River, southern NSW
- Riverine: Stone fish trap site at Brewarrina, central NSW
- Lacustrine: Midden site at Lake Cargelligo, central NSW

![Figure 21. Aerial view of Sydney Harbour and Middle Cove (Geoscience Australia 2003)](image)

Each site is recorded photographically and the sites at Middle Cove (Chapter 4) and Yowaka River (Chapter 5) are accompanied by scaled drawings. Observations include the impacts of gravitational forces, water flow, wind, and flora and faunal activity on specific materials and site types and, specifically, included:

<table>
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<tr>
<th>Geophysical environment</th>
<th>Artefactual composition and susceptibility in saline and fresh water to:</th>
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<td>Chemical Impacts</td>
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<td>Shell/bone</td>
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<td>Geological setting and composition</td>
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<td>Hydrological characteristics of the site</td>
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<td>Speed of water level rise or fall</td>
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<td>Fetch over water to land-water interface</td>
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<td>Dominant wave direction</td>
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<td>Strength of water flow: Tidal and non-tidal</td>
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<td>Frequency and duration of inundation and exposure episodes</td>
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<td>Slope</td>
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<td>Degrading and prograding shorelines</td>
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All observations were made without excavation or other disturbance to the sites. No distinction or examination was made concerning sites from particular periods. Nor have the
sites been chosen to distinguish between natural impacts or impacts due to human activities, (including the development of infrastructure such as port facilities, dams, agriculture and grazing, riverbank stabilisation) or global warming.

The observation of interaction at the land-water interface demonstrates most clearly the ‘real time’ interaction between an archaeological site and a body of water mass, whether that water is relatively still or is aggressively encroaching.

At Middle Cove the three site types represented in the survey are a rock overhang, a constructed stone barrier similar to a fish trap (but possibly of European origin) and eroding shell middens. These include organic and inorganic materials as well as site types that are fragile and those that are relatively resistant to wind, waves and chemical reaction. The organic materials are the shell middens and their component parts. All observations of midden deposits in this study were in locations above the water line. The inorganic materials are the rocks that comprise the constructed stone barrier as well as the rock shelter and rock platform. Midden material was present in cross-section in a number of locations.

The Middle Cove sites are situated behind a series of coastal barriers and in a relatively protected environment in comparison with other coastal locations that bear the full force of southeasterly winds and seas.

**Conclusion**

The sites examined in the following chapter at Middle Cove, Sydney Harbour, have a strong interrelationship of ethnographic, archaeological and environmental qualities. They are sites for which related and/or comparative ethnographic and archaeological information is available and that possess distinct hydrological and other geophysical characteristics. The sites are located in an estuarine setting and have been at the current land-water interface during the current relatively stillstand and therefore have the potential to have been inhabited for a significant period. These qualities make this a suitable representative area for developing predictions about the effects of inundation in other geographical contexts.
A survey was conducted of a site at Middle Cove in Middle Harbour, one of three main divisions within great Sydney Harbour (Figure 22), to observe impacts at the current land-water interface. The site contains three main elements: (1) extensive shell midden within the banks of the cove; (2) a rock overhang with adjacent tidal rock shelf; and (3) a low, wall of unworked sandstone blocks forming a tidal enclosure.

Figure 22. Topographic map of the Middle Cove subject area (1:25 000 topographic map 9130-3N Third Edition, Parramatta River)
Regional Setting

Physiography

The estuarine site is in North Arm, a part of Sugarloaf Bay, also known as Castle Cove, at the base of a steep slope within Harold Reid Reserve on the north side of the Middle Cove peninsula (Figure 23). Middle Cove is within the Sydney Region, which is centrally located on the coast of New South Wales. The Sydney Region extends over 85km from Broken Bay in the north to the Woronora Plateau in the south and, from the coast, 80km westward to the foothills of the Blue Mountains (Figure 24). The Sydney Region covers an area of approximately 4080 sq km and contains a large assemblage of natural and cultural features (Baker et al. 1986:4).

Figure 23. Navigation chart showing depths (in metres) adjacent to Middle Cove subject area (AUS200 Port Jackson)

Middle Cove peninsula, a portion of the suburb of Middle Cove, lies between the suburbs of Castle Cove to the north and Castlecrag to the south. Scotts Creek flows into North Arm about 500m to the west of the subject site. The densely vegetated northeastern side of Middle Cove peninsula slopes steeply down to Sugarloaf Bay and to a series of rock platforms and outcrops.

Access to the site is by a rough walking track accessed from the eastern end of North Arm Road, Middle Cove or by boat.

The barrier effect of landforms separating Middle Cove peninsula and the waters of North Arm from the Pacific Ocean provide protection from strong currents and oceanic surge. In addition, this area is subject to minimal boat wash due to the absence of mooring facilities and the proximity to upper estuarine shallows. Leisure boats that enter the area are small launches, few in number and travel at speeds of about 2-3 knots. In combination with the presence of three site types, Middle Cove provides an ideal location for assessing impacts of gentle
estuarine inundation at the land-water interface. The GPS position for the site is: Zone 56H: 335083E 6259256N (Datum AGD66).

**Figure 24.** Geological setting of Middle Cove (Howell and Benson 2000:6)

**Flora and fauna**

The extensive middens within the study area demonstrate that shellfish were a strong component of Indigenous diet in this area. While fish were probably a part of this diet, it is likely that most fishing activity occurred on the lower reaches of Sydney Harbour where increased nutrients, larger volumes of water and the semi-diurnal tidal flow encouraged higher fish stock concentrations.

In these upper estuarine reaches, terrestrial food sources would have been more abundant and reliable. Woodlands and open or dry sclerophyll forests grow on the deeply dissected sandstone plateaux of the Sydney Region. These mixed eucalypt communities thrive in the nutritionally impoverished Hawkesbury Sandstone soils. The open canopy, with trees ranging in height from 5-30m, permits the entry of sunlight ensuring the growth of a well-developed shrub layer with a discontinuous herbaceous stratum (Baker et al. 1986:6).

*Eucalyptus* and *Angopora* species such as *Angophora costata* (smooth-barked apple), *Eucalyptus gummifera* (red bloodwood) and *Eucalyptus racemosa* dominate the canopy. The understorey includes *Banksia serrata*, *spinulosa* and *integifolia* (old man banksia, hairpin banksia and coastal banksia), various heaths and grevilleas, *Acacias*, *Allocasuarinas* and members of the *fabaceae* family (pea flowers), *Lomandra longifolia*, native grasses and ferns (Baker et al. 1986:6).

These diverse and complex plant communities would have provided the original people of this area, the Cammeraigal, with a significant food resource as well as materials for wooden artefact manufacture. In addition, it is habitat for many native animals including possums, koalas, goannas, bandicoots and echidnas as well as birds including the eastern rosella,
southern yellow robins and eastern spinebills, all potentially contributing to dietary requirements (Attenbrow 2002b:37-45).

Geology

Geologically, the Sydney Region occupies the central portion of the Sydney Basin. Exposed sediments date from the Middle Triassic, about 230 million BP. The Narrabeen shales and sandstones outcrop at the northern and southern extremities of the Sydney Basin. They are overlain by Hawkesbury Sandstone, which is covered by the Wianamatta Shale Group (Baker et al. 1986:4).

Middle Cove (Figure 24) and the surrounding sandstone area of the north shore are located at the southern end of the Hornsby Plateau within the Sydney Basin. Intruding between the Hornsby Plateau and the Woronora Plateau (a second sandstone plateau south of Botany Bay), is an eastern extension of the Cumberland Plain, a complex of low, undulating hills of Wianamatta Shale that forms the southern shore of Port Jackson. To the west, the region is bounded by a third sandstone plateau, the Blue Mountains (Baker et al. 1986:4).

The Hornsby Plateau, where Middle Cove is located, consists of Hawkesbury Sandstone shaped into dramatic outcrops. These outcrops form overhangs and rock shelters suitable for habitation and protection from the elements. They also provide surfaces suitable for rock art, engraving and for shaping or sharpening ground edge axes and other tools. Sandstone rock platforms along the coast and estuaries were used for fishing and gathering other sea resources such as shellfish (Attenbrow 2002b:52, 54, 82, 105, 106, 145-151).

Other lithic materials suitable for stone tool manufacture and available along the coast and Cumberland Plain include silcrete, chert, tuff, quartz and basalt. (Attenbrow 2002b:43).

European impact on the study area

The surrounding landscape includes the residential suburbs of Middle Cove, Castle Cove and Castlecrag. Around the foreshores remnant Hornsby Plateau vegetation still exists (Figure 25), providing an indication of the pre-contact landscape.

![Image of Hornsby Plateau vegetation](image-url)
The context of the rock platform and underwater deposits appeared relatively undisturbed. Impact from boat wash, and riverbank development is minimal compared to the more intensely populated or industrialised sections of the lower reaches of the harbour.

A headland-walking track passes above the rock platform and the platform itself is accessible via unofficial breakaway tracks. The slope of the headland above the rock platform is very steep and heavily vegetated.

The upper levels of the constructed stone barrier sit upon the rock platform (Figure 26, 27 and 28). Portions of the stone barrier in the tidal zone appear to have been partially disturbed, possibly through human intervention and periodic floodwater currents. Other sandstone blocks lie permanently underwater forming a batter between the rock platform and the silt bed of the North Arm estuary (Figure 29). The presence of these sandstone blocks along the submerged estuarine banks is suggestive of periodic collapse of the adjacent land surface. This collapse could pre or post late Holocene sea level rises.

![Figure 26. North Arm overhang, rock platform and stone barrier (Nutley 2005)](image-url)

**Indigenous context**

The densely vegetated and rocky landscape bordering Middle Harbour provided the Cammeraigal with a rich habit with a variety of food and other resources. Their diet would have included fish and other seafood, roots, tubers, other edible plants, including seaweed, and supplemented with meat. The Cammeraigal would have ranged from 35 to 60 people, however people generally camped, travelled, foraged, fished and hunted in extended family groups or bands (Hinkson 2001:xix-xxv).
Aboriginal occupation in the Sydney basin has been the subject of detailed recording as part of the Port Jackson Archaeological Project since 1989 (Attenbrow 2002a). This and subsequent work has contributed greatly to understanding of the life of the Aboriginal people who lived around the shores of Port Jackson at the time of British colonisation (Attenbrow 2002a; 2002b). Attenbrow’s study showed that there are over 400-recorded middens in the Port Jackson catchment. To date, her study has indicated that sites adjacent to estuarine conditions were shell middens and those in the freshwater zones were archaeological deposits. She concluded that many of the sites were relatively undisturbed and capable of providing much needed information about past activities of the coastal communities. Her excavations have provided a date of around 10,000 BP for Aboriginal occupation in the Port Jackson catchment (Attenbrow 2002b:2-3).

The constructed stone barrier at Middle Cove was not recorded in Attenbrow’s study. Its form is very similar to sites recorded by Attenbrow at Cremorne Point (Figure 30), and shown to be wading pools of European origin (Attenbrow 1996). While there is no hard evidence for the origin or function of the Middle Cove stone barrier, whether it is an Aboriginal fish trap or a European structure, its similarity to Indigenous structures provides a site that is comparable to them.

**Hydrology and Sea Level Fluctuations**

North Arm, Middle Cove, is a deeply recessed indentation formed within the Hawkesbury sandstone. At lowstand, the valley would only have carried fresh water from Scotts Creek and the runoff from surrounding hills. During the current stillstand, the waters of the bay are fed by tidal seawater and freshwater runoff, chiefly from Scotts Creek. The estuarine setting protects the cove from the oceanic storm and swells of the southeastern Australian coast but reflects the semi-diurnal, microtidal regime of this region including a maximum spring tide range of less than 2.0m (Roy 1998:367).
Figure 28. Overhead view of stone barrier at low and high tide (Nutley 2005)

Water depth adjacent to the site is about 7m within a steeply sloping batter from the adjacent peninsular of Yeoland Sugarloaf to the north and Willoughby Sugarloaf to the south. The bed of the estuary is covered with a layer of sand and fine sediments with no apparent sand-wave patterns or ridges suggestive of rapid flow rates. Tidal waters reaching this area have all but expended their momentum in negotiating the convoluted landforms of Port Jackson. Even during flood, freshwater flows from Scotts Creek (Figure 31) are mild due to a limited catchment area and low gradient approaching North Arm at Middle Cove.
Figure 29. Permanently inundated rocks on batter below stone barrier (Nutley 2005)
Figure 30. Stone barrier wading pool structure, Cremorne Point (Nutley 2005)

Figure 31. Junction of Scotts Creek (left) with North Arm estuary (right) (Nutley 2005)
The fetch of water adjacent to the site is limited to a maximum of 150m to the opposite northeast bank and about 1000m to the east-southeast (Figure 32). As the bay is protected by the ridges of Yeoland Sugarloaf to the north, Willoughby Sugarloaf to the south and Sugarloaf Point to the east, wind generated waves are minimal and typically would not exceed a few centimetres in normal conditions or 150-200mm in a gale.

Figure 32. View along North Arm to east (Nutley 2005)

The dominant wind direction in Sydney is from the southeast. However, the headlands of Middle Harbour have a strong influence over wind direction. The funnelling effect of the peninsulas around North Arm produces predominantly easterly and, to a lesser extent, northwesterly winds. Neither of these wind directions impact directly onto the southern bank of North Arm and any wave action that develops tends to be blown past the site, rather than into it.

The intertidal area of the southern bank extends from the low water to high water mark with periodic wind waves extending the high water mark marginally, as does periodic flooding. The total tidal height is about 2m. Additional erosion would be generated by direct rainwater runoff from the slopes of the cove; wind erosion; dislocation from fauna activity and dislocation associated with the occasional fall of trees and rocks. In the subject area, this erosion is strengthened by the steepness of the banks, which in places are almost vertical.

There is no evidence of an accreting shoreline at Middle Cove, which, due to its steep slope is in a constant state of slow degradation.

It is assumed that the inundation of North Arm at Middle Cove occurred over the period between c.10 000 BP and c.6 000 BP, coinciding with the stabilisation of current sea-levels (Head 1987:440) and the occupation of the Sydney Basin c.10 000 BP (Attenbrow 2002b:2-3). Previously the intertidal and submerged areas of North Arm, the current rock platform, and submerged batter at the sides of the current bed of the cove, would have been a part of the vegetated Yeoland Sugarloaf peninsula with the bed of the cove being an extension of Scotts...
Creek. The rock overhang, now subject to periodic tidal inundation, could have been an occupation site. Its form and proportions would have been conducive to such use with a ceiling height of up to 4m, length of overhang 6m and depth to the rear wall of 4-5m. It connects directly to the open rock platform on which the stone barrier has been constructed and has views to the north and east along the expanse of North Arm and Sugarloaf Bay. Even with its base swept clean by periodic inundation, the site still provides shelter for contemporary visitors, as evidenced by the presence of recent campfire remains. Prior to 10,000 BP, the rock overhang and the midden deposits, (which are between 1-50m distance from the overhang, and currently observed at 2-3m above the waters of the cove), would have been 7-9m above the creek.

**Observations**

The Aboriginal sites and stone barrier at Middle Cove were observed to consist of organic and inorganic materials. Midden deposits were sighted in cross section during the study, all in locations above the water line. The middens were located adjacent to the constructed stone barrier and rock overhang but not within the overhang, presumably due to periodic tidal flow scouring.

The inorganic site components, sandstone rocks, rock platform and rock overhang, although in a relatively protected environment, show signs of slow and gentle weathering. Weathering has resulted in dramatic, long term sculpturing of the rock overhang but was almost negligible on rocks forming the constructed stone barrier.

Gravitational force is a major factor in this setting given the steeply sloping banks of the cove. In three of the four areas of exposed midden material, oyster shell, mussels and other bivalves were observed to have fallen up to 1.5 metres from their original location (Figure 33).

Along the embankment immediately above and adjacent to the constructed stone barrier, sandstone blocks had fallen from the embankment onto the rock platform (Figure 34). Such falls are occurring through erosion of the earth, including midden material, surrounding those slabs. Each block of sandstone lost from the ridge is accompanied by loss of grasses and shrubs that consolidate the soil and exposes a new face of unconsolidated midden material. The falling slab may also dislodge material in its path.

On the rock platform, the constructed stone barrier and the submerged batter within the water body of the cove, gravity appears to play an almost negligible role. Once the fallen slabs reach the platform, their kinetic energy is expended. Even small rocks are unlikely to move again except through a force that is not primarily gravitational. The rocks within the constructed stone barrier are further stabilised by a thick cluster of colonising oysters. The oysters cement many of these rocks together to form almost a single unit (Figure 35).

Below water, sandstone blocks on the batter are not consolidated by oyster colonies and are lighter than above water counterparts through water displacement buoyancy. Nevertheless, they show immense stability and give no sign of recent movement and/or active erosion. This reflects their hydrological environment with its absence of dynamic wave action or strong currents. The only indication of water impacting on these rocks are their slightly waterworn edges.

Waterpower is typically much more powerful at the land-water interface even within the protection of North Arm. Along the southern bank there are up to three wave cut platforms: one at the mean-low-water mark, one at the average low-water mark and, in places, a third platform at the high-water mark. On the platform and within the rock overhang recesses a scattering of lightweight driftwood, thin twigs and branches only (Figure 36), suggests that water flows into these areas and its ability to introduce new materials into this location.
The absence of any residual earth or midden material also indicates that this water flow, albeit gentle, has effectively scoured away any earlier deposits. This scouring action is also evident at the high water mark. Bare earth and exposed midden material is visible in a number of locations to the east of the rock overhang. In most locations there is no sign of earth or shell
immediately below the exposed deposit, an indication that material fallen from this exposed face has been carried away at tidal flow and/or by wind and rain (Figure 37).

Figure 34. Fallen sandstone block on rock platform (Nutley 2005)

Figure 35. Sandstone blocks and oyster colonies along barrier wall (Nutley 2005)
Figure 36. Waterborne driftwood within rock overhang (Nutley 2005)

Figure 37. Exposed cross-section of midden. Note the absence of fallen earth or shell on rock platform surface (Nutley 2005)
In two locations, the disturbed midden material had not yet washed or blown away. One of these was where an access path enters onto the rock platform (Figure 38). This path has formed a channel through a substantial deposit of midden material that is being carried by human feet and rainwater onto a gently sloping section of rock platform near the top of the tidal range.

![Figure 38. Disturbed midden along length of access path (Nutley 2005)](image)

At a second location, 3 metres to the west of this point, a deposit of earth within a 300mm opening of a hollow of a large sandstone boulder had been recently disturbed, most likely by a small animal (Figure 39). This material, including shell and bone was lying in a loose scatter in and near the entrance to the hollow. Its disturbance and lack of compaction ensure that it will be washed away in the next heavy downfall or peak high tide.

![Figure 39. Disturbed midden at entrance to hollow in sandstone boulder (Nutley 2005)](image)
At present sea levels, there is a steady destruction of midden deposits at this location. The absence of any deposits, apart from driftwood, within the rock overhang demonstrates that gentle hydrological conditions within the cove have removed any archaeological deposits. There is no indication that deposits are continuing to survive even at the margin of the regular high water mark. Any surviving components of these deposits are being removed from their original context and redeposited as sediments at the bottom of North Arm.

**Conclusion**

The investigation of observable impacts within the confines of North Arm demonstrates that even in an area with limited exposure to wave action, shell midden deposits are extremely vulnerable to inundation, particularly when associated with steep slopes or flat rock shelves periodically awash during high tides or floods. Survival of these deposits in an undisturbed state in the North Arm setting could only occur if the deposit was (a) particularly deep, (b) inundation was particularly rapid and (c) the deposit was trapped on a rock platform in deep fissures or under fallen sandstone slabs preventing scouring action of waves and currents.

The North Arm sites suggest that the inherent strength of rock shelters or constructed rock barriers in a protected estuarine setting provides significant resistance to mechanical and biological attack, providing an enhanced ability to survive relatively undisturbed both during and following inundation. The following Chapter discusses how the observations at North Arm compare with sites in exposed coastal, riverine and lacustrine environments. This discussion considers the mechanisms for inundation in Australia and the implication of the observations for determinants of site survival in Australian coastal and inland waters.
Discussion

Coastal Inundation

As shown in the literature review (Chapter 2), there is considerable scope in Australian archaeological studies for further identification of environmental determinants for inundated Indigenous site survival. Existing studies do not adequately consider the range and location of coastal sites that could have survived inundation.

Many of the studies discussed in the literature review focus on the likely social impacts of the loss of coastal lands during Holocene inundation of Indigenous sites and the potential for Pleistocene inundation. The potential of these inundated coastal sites to shed further light on that debate is suggested from time to time. Flemming (2005:22) recently stated that studies on the continental shelf are ‘integral’ to understanding human occupation patterns in Britain and Northern Europe. It cannot be assumed that locating such sites is just a matter of getting adequate technology and funding. The North Arm estuarine survey has demonstrated the difficulties of in situ depositional site survey even in a protected area. Circumstances have changed little since 1983 when Kraft noted that few, if any, significant sites had been found on the continental shelves (Kraft 1983:88). As established in Chapter 2, the significance of sites discovered incidentally to dredging or mineral research can be limited through the absence of accurate positioning and adequate information on extent or stratigraphy. What is first needed, as suggested by Masters (1983:211), is a clear understanding of the nature of marine transgression along particular coastlines and the resultant probability of the survival of sites of any type.

Within North Arm, the dynamics associated with a specific shoreline have been shown to be central to the survival of evidence of previous human occupation. Coastal dynamics include the interplay of currents, sediment supply, the frequency, intensity and direction of storms as well as the inherent structural strength and slope of landforms and marine substrates. A predominantly eroding shoreline where the sediment budgets are carried away by tidally induced littoral drift, river flow or long-shore currents is not conducive to site survival (Chapman et al. 1982:246, 247). Sea level rises can create semi-protected estuarine environments behind sandstone or other rock barriers (Figure 40). Roy (1998:362) has noted that barriers and sand bodies within Quaternary valley-fills have produced “estuarine and lagoonal sediment deposits that extend onto the inner shelf”. In these settings, the survival of depositional sites and stone structures such as estuarine, stone, fish traps is marginally enhanced.
At Warren Beach, also in southwestern Western Australia, tree stumps dating to about 8340 BP, apparently in ‘growth position’, were reported to lay submerged hundreds of metres out to sea (Merrilees 1979:120). Tree stumps in growth position have also been recorded in Sydney Harbour (off Garden Island) and in Botany Bay, dated to ca 8000-9000 BP (Roy 1983:41-91). These are significant findings. They suggest areas where hydrodynamics of coastal inundation have not entirely destroyed or randomised the submerging landscape. Traces of human habitation may therefore have also survived within these contexts, although, to date, no further work has confirmed or refuted this potential.

Arguably, depositional sites with the greatest potential to survive inundation in a coastal setting are those that originate in coastal lakes and wetlands. This is supported by the findings at Wyrie Swamp (Luebbers 1975) and Wingecarribee Swamp (McDonald 2003). Discovery Bay in southwestern Victoria (Head 1987), is an example of a high-energy, eroding coastline with associated wetlands and provides important evidence of the impact of sea level rise in this area up to about 6000 BP. The rise in sea level led to the formation of wetland areas that once existed seaward of those that have survived to the present day. Stabilisation of sea levels at around 6000 BP and subsequent erosion to about 4000 BP (Head 1987:440) recreated the coastline and wetland configuration. A schematic reconstruction of wetland formation (Figure 41) and erosion (Figure 42) processes demonstrates this impact and the potential for destruction or survival of archaeological deposits. Sea level rises are associated with a rise in the coastal water table creating swamps behind a barrier of coastal dunes. McDonald (2003:61) describes a similar water table rise as ‘sealing’ archaeological deposits at Wingecarribee Swamp. In a coastal environment, erosion of the frontal dunes, drains swamps exposing their peat beds to ongoing attrition.

Even in the relatively protected environmental conditions of North Arm, it has been shown that rapid inundation is a key requirement for site survival. The conclusion is that few if any archaeological features would have sufficient physical resistance to survive the full force of coastal waves on an oceanic coast like New South Wales. However, where quarry sites, rock shelters, constructed stone barriers or depositional material are entombed within a deposit of silt or aeolian sand or peat behind a frontal barrier prior to a rise in sea level they may endure after the eventual destruction of that barrier.
Figure 41. Schematic reconstruction of wetland creation during sea level rise, Discovery Bay (Head 1987:442)
If these sites do exist off shore, they are likely to lie beneath original layers of sand or mudstone or peat. They would also lie under an accumulation of marine aggregate and silt, and, as described at Strangford Lough (as described in Chapter 2), in a topographical setting levelled by erosion and quite alien to the original forms. Locating such sites would seem extremely problematic. To date, intact sites found in a marine environment have been invariably close to extant shore sites. There have been indicators that relatively deep open-ocean sites could exist in ancient submerged river channels and in sediment cores containing peat and artefacts from beneath the Bering and Chukchi Seas (Dixon 1999:25). However, there is no evidence of in situ deep-water archaeological sites surviving on any continental shelf.

**Riverine Inundation**

Riverbanks vary dramatically according to the terrain and the age of the river as well as the volume of water delivered from the catchment area. The heights of riverbanks vary from that of a gorge to just a few centimetres. Regardless of height, they are typically steep sided whether passing through mountains, tracking through alluvial plains or interacting with tidal surges in estuarine areas. This is a reflection of the ongoing and flood generated erosion.

Opportunities for sites to survive in the high-energy environment of youthful rivers are probably non-existent. In a mature river, sites could be buried under sediment during flood. This is the setting of stone fish traps at Greig’s Flat on the Yowaka River in southern New South Wales (Figure 43). In early 2005, two stone fish traps/weirs were recorded by the author as part of this inundated sites study. The Yowaka River sites clearly demonstrate the durability of fish weirs (structures related to fish traps but built across the width of a stream).
The Yowaka River sites are located in a region that is characterised by isolated estuaries that, in their lower reaches, are barrier estuaries with infill of Pleistocene and Holocene alluvial deposits (Geological Series Sheet SJ/55-4), (Figure 44). Deposition in the Pambula estuary is strongly controlled by bedrock constrictions.

![Figure 44](image)

**Figure 44.** Aerial view of Yowaka River and district in relation to weir sites (1:25 000 topographic map 8824-2S second edition, Pambula)

The first of these fish weirs (Site A) is located in the approaches to one of these bedrock constrictions and at the upper limit of tidal flow at Greig’s Flat, an alluvial basin set amid ranges of Late Devonian volcanic and sedimentary rock (Geological Series Sheet SJ/55-4; Troedson and Hashimoto 2004:42). This area is typically subject to low hydrodynamic activity, except during flood. A major flood in 1989 (Figure 45) resulted in severe riverbank damage. This changed the main channel of the river, and deposited a large volume of sediment on the fishing weir and associated traps. When the river returned to its normal level (Figure 46) the sediment deposit began to support a variety of grasses and melaleuca shrubs. The weir formation Site A (Figure 47) and that of a second downstream weir (Figure 48) appear to have suffered some deformation at the time but remain substantially intact. Neither weir nor associated traps have been maintained for many years and their continued existence bears testament to their durability in the face of riverine processes. This durability is discussed in Chapter 5.

Here, the periodic flooding of the valley has a major impact. Large deposits of alluvial mud are deposited on the site and there is significant sideways erosion on the adjacent riverbank (Figure 49). Any riverbank artefact deposits in the path of this sideways erosion could be significantly degraded through dislocation and subsequent abrasion. However, minor downward scouring was observed in the minimal dislocation of the stone fish trap barrier and traps. The implication is that there are opportunities for some site types to survive in a permanently drowned river valley.
In a river’s ‘old age’, alluvial deposition may be significant during flood but erosion is minimal. In this setting, there is perhaps the highest level of opportunity for sites to survive in a permanent or periodically submerged state. However, as shown at North Arm, (see Chapter 2), this is dependent on whether they are deposits or constructed stone barriers. It is also likely to depend on whether they are constructed in the river (fish traps); deposited in the river (canoes, implements); inundated through sea level rises; or inundated through the construction of dams or artificial lakes, particularly if the inundation occurs rapidly. Midden and hearth remains at Polia Station on the banks of the Darling River in western New South Wales (Nutley and Smith 2003:23,25-26) are an example of how fragile sites adjacent to an ‘old age’ river can survive periodic inundation (Figure 50).
Figure 47. Survey plan of fish weir A (Nutley 2005)
Figure 48. Fish weir B. Arrow indicates distribution across river (Nutley 2005)

Figure 49. Riverbank erosion, Yowaka River (Nutley 2005)
It would seem less likely that riverbank sites could survive any significant erosion associated with a change in river course or bioturbation associated with long term inundation. The exception could be a natural or artificial event that converted the stream into a dam or lake. Where such sites have gained the protection of an accumulated depth of alluvial deposit there may be a likelihood of surviving permanent inundation.

Site formation observations have a bearing on what may or may not survive inundation. “Stratigraphic discontinuity beneath the drip line” has been identified for rock shelter depositional integrity (Attenbrow and Steele 1995: 50). This strongly suggests that even with a relatively gentle process of inundation, the chances of a rock shelter deposit surviving the impact of floodwaters, tidal surge or even gentle wave action are slim. This conclusion is supported by the observations made at North Arm, if one assumes that the rock shelter once contained a shell midden. The structures themselves may survive but aside from chemical or biological factors, depositional material would be washed out and, at best, are significantly compromised. A current survey, by the author and others, of potential inundated rock shelters in South West Arm, Port Hacking, in Sydney may eventually lead to physical testing of this theory.

As noted in the literature review, understanding the pattern of artefact distribution in a riverine environment was assisted by an archaeological investigation of the riverbed adjacent to Queens Wharf on the Parramatta River in New South Wales (Figure 51) (Wolfe 1992; Bower and Staniforth 1993). This investigation was undertaken in the upper navigable reaches of the river. No Indigenous cultural heritage was identified but the project illustrated the pattern of distribution of artefact deposits in a riverine setting. Sampling of sediments across the river demonstrated that both sedimentation and the concentration of artefact deposit was highest near the riverbank and trailed off quickly 3m from the riverbank. No artefacts were recovered below of depth of 1.5m of sediment (Wolfe 1992:34) or from the sample sites (Figure 52) in the middle reaches of the river.
Figure 51. Locality map, Queens Wharf, Parramatta (Universal Publishers 2005)

Figure 52. Riverbed test pit transects, Parramatta River (Wolfe 1992:Local Plan 1)

A higher level of shore-generated deposition, as compared to material dropped from riverboats, may partly account for the pattern of artefact recovery. However, the almost complete absence of mid-stream artefacts, where the strength of the river flow is at its peak, suggests removal of artefacts to lower and quieter reaches of the river. By virtue of both of
these mechanisms, initial deposition patterns and the nature of river hydrology, this work is likely to be a reflection of the normal depositional pattern in such riverine environments. The Queens Wharf investigation therefore suggests factors for consideration in searching for submerged riverine inundated deposits that are of Indigenous origin.

**Lacustrine Inundation**

Lakebeds, and particularly swamps, are potentially one of the most favourable environments on which cultural remains can survive in a submerged environment. This is confirmed by archaeologists who have used the interaction of people with lake systems to locate and investigate some of Australia’s better-known early Indigenous sites. As described in Chapter 2, Lake Victoria in New South Wales (Hudson and Bowler 1997) and Lake Jasper in Western Australia (Dortch et al.; Dortch 1997), illustrate the enormous potential of lakes as potential repositories and protectors of Aboriginal sites.

The favourable nature of lakes as cultural repositories is largely related to their hydrodynamic characteristics although chemically they also support the long-term preservation of many organic materials such as wood. They are not usually characterised by high-energy wave action unless they are exceptionally large. A deep protective deposit of organic sediment arising from aquatic life, as well as from non-aquatic life falling into the lake, overlies many lake beds.

The 1989 survey of inundated Indigenous sites in Lake Jasper in Western Australia illustrated a common difficulty for archaeological work underwater, limited visibility. This limitation is true for most lake environments, with the exception of limestone sinkholes. Limited visibility precludes a visual survey of the whole of the lakebed, particularly when a large proportion is covered in a thick layer of organic sediment. At Lake Jasper this was reported to range from a few millimetres to half a metre. The sediment layer can be considerably more in some lakes. To accommodate these issues, the survey structured around transects enable the lakebeds to be sampled quickly and efficiently and to identify and eliminated those areas where sediment precludes visual survey of the lakebed (Dortch et al. 1990:45).

Evidence of Aboriginal occupation has been located to the edge of the lowest recorded level of Lake Victoria. It is speculated in the 1994 study that such material also exists in the area that is permanently inundated, an area that was not included in that survey (Littleton et al. 1994:168). The extent of site disturbance underwater is not known but it is likely to be covered by silt and in an environment that is cool, low in oxygen and relatively free from the mechanical abrasion associated with wind, grazing, wave action and strong currents. Such an environment would be conducive to the preservation of organic materials, such as implements constructed from wood.

Many of the taphonomic processes that have distributed other finds will also have resulted in artefactual material being distributed in the lower lakebed. While it is possible to conclude that those areas now permanently underwater will be similar in composition to the sites that have been surveyed to date, this clearly may not be the case. For example, the absence of fish traps located in the ‘dry’ areas that were included in the 1994 study cannot be taken as a conclusion that such features do not exist in what was previously a natural lower level of the lake.

There is a clear need for future management studies to include the submerged cultural heritage of the lake. The 1994 survey does note the need for further investigation of the lower lake bed (Littleton et al. 1994:xiii) although the authors did not consider the employment of underwater archaeological survey techniques but suggested waiting until the lake falls to a lower level (Littleton et al. 1994:135). There is great potential to expand the findings of the 1994 study to include the area that remained inundated at that time. Underwater
archaeological survey techniques would be an invaluable means of providing an even clearer picture of the extent, duration and nature of at least 18,000 years (Littleton et al. 1994:1) of Aboriginal occupation of this area.

Importantly, the 1994 study establishes that most of the materials found around the shore of the lake are not *in situ* but have been transported by various means including water, wind and erosion of shoreline cliffs (Littleton et al. 1994:vii). Therefore, even within the relatively tranquil hydrodynamics of an inland lake, the process of inundation, as at North Arm, appears to take a significant toll on cultural heritage sites.

As noted in the literature review, the investigation of two inundated villages at Hume Reservoir on the New South Wales and Victorian border by O’Halloran (2000) provides valuable information on the impacts of inundation upon cultural sites (O’Halloran 2000:9-10). O’Halloran examined several issues including the effect of wave action and water level fluctuations particularly those involving periodic inundation and exposure (O’Halloran 2000:125). The study clearly demonstrates that the periodic inundation and exposure is associated with heightened rates of erosion and dispersal of artefacts (O’Halloran 2000:125). This has important ramifications for the potential survival of inundated Indigenous sites. An extension of this study could be applied to permanently inundated sites.

Taken together, these studies support the view that, typically, lakes are bodies of relatively still, fresh water that attract a diversity of fauna and flora. Together these three resources are of considerable importance to human economies. Physical evidence of this relationship between people and lakes can reflect both the material culture and social practices of a society. In lakes, inundated material culture is much less subject to disturbance from scouring, grinding and dispersal associated with waves and surge along the coast. As in the ocean, organic materials can become buried in silt and have potential for preservation over a very long period. The worked surfaces of stone implements are likely to survive with less post-depositional abrasion. Although, as shown by O’Halloran, (2000), wind induced abrasion may occur pre-inundation as well as through any periodic exposure during droughts or at other times when lake levels are low.

Even in a lake, the survival of less robust site types, including shell middens, during the inundation process is less likely. While the effects of transgression on midden sites is poorly understood (Delgado 1997:370), the middens on the shores of Lake Cargelligo (Figures 53 and 54) in Central New South Wales demonstrate the vulnerability to water erosion of this site type. Here, at the land-water interface erosion is significant although it is only subject to relatively gentle shoreline wave action. With the combined impacts of wave action and bioturbation it is difficult to envisage such sites enduring a slow, natural inundation process. As with a riverine environment, rapid filling of the lake because of natural or artificial damming would provide the best conditions for the survival of such sites.

**Stone Fish Trap Inundation**

The survival of fish traps in a riverine setting has been discussed previously; however, fish traps occur in many forms throughout Australian riverine, estuarine and coastal areas and on offshore islands (Bluith 2002; Bowen and Roland 1999; Campbell 1982; Hope and Vines 1994; MacFarlane 1948; Martin 1988; Vale 1998; Welz 2002). They range from those built from organic materials like saplings, brush and grass, to stone structures. Some traps combine both stone and organic materials. Stone constructions can consist of a single curved wall while others are intricate complexes, for example, those at Hinchinbrook Island in north Queensland (Campbell 1982), Brewarrina in western New South Wales (Hope and Vines 1994) and Lake Condah in Victoria (Bluith 2002).
As suggested previously, stone fish traps are perhaps the site types most likely to survive the process of inundation. Examples of these in intertidal zones or areas of periodic inundation exist throughout Australia and Martin (1988) includes discussion of their various forms and distribution. The characteristics and location of these structures have a significant bearing on their potential survival of the inundation process.

As highlighted in the literature review, an example of a system designed to increase the intensification of a food supply is the extensive complex of marine stone fish traps located at Hinchinbrook Island in North Queensland (Figure 55). The island lies off the coast near Cardwell, separated from the mainland by a narrow, mangrove-lined channel. The fish traps are located on the western side of the island at and near Missionary Bay. The complex consists of a number of different types of traps and there has been discussions that these
funnel traps were possibly worked with baskets whereas other traps may have been harvested with spears. Campbell’s description of the site is as follows:

The combined total area of the tidal fish traps at Scraggy Point is about 21,600 sq m. … Observations … suggest that there are trap systems belonging to a number of difference ages and stages of development, probably at least three… The youngest is of course generally best preserved and is still heavily cemented by rock oysters…The oldest system extends mostly below present low water and at least one spot runs stratigraphically below the youngest. All of the systems are subdivided into many different sorts of components: raceways, loops, pools, funnels, breakwaters and “arrowheads” with various connecting walls. The best preserved walls… are… about 0.5-0.8m high… (Campbell 1982:101)

Figure 55. Aerial view of Hinchinbrook Island fish trap complex (M Bird collection)

From archaeological analysis of land sites, including shell middens, Campbell has established that Aboriginal use of the area began about 2000 years ago. He predicts that this date may well be extended following further research (Gray and Zann 1988:3). As noted above, Campbell has observed that, stratigraphically, at least one section of wall runs below the youngest section of the complex. It is quite possible that the process of inundation will have resulted in further stratigraphic layers although there has been no investigation of this possibility to date. Further investigation of Campbell’s observation that the “oldest system extends mostly below present low water” (Campbell 1982:101) would provide additional evidence of the duration of human habitation in this area.

The stone fish traps of the Ngembah people at Brewarrina consist of a large complex of stone walls extending along about one kilometre of the river bed (Hope and Vines 1994:1) (Figure 56). Their extent and positioning within a major river system provide an insight into the ability of this site type to survive riverine inundation. The structure was engineered to enable the Ngembah to take advantage of fish movements both upstream and downstream as well as varying river levels. This was accomplished by an ingenious arrangement of upstream and downstream openings and a sequence of large and small ‘yards’ at various river levels through which the fish could be driven (Hope and Vines 1994:22, 27). The Conservation Plan for this site concludes that only about five per cent of the original system survives in substantially intact form in relation to their original alignment and height (Hope and Vines 1994:46). By analysing this small but significant sample of the structure, the Conservation
Plan develops a ‘Use Model’ that combines the observed structures with the hydrographic characteristics of the river. It concludes that:

In general, the construction exhibits a degree of sophistication and economy, with rocks tightly placed, often with their length in to the wall rather than along it, so providing greater strength and knitting the courses together. Larger stones are placed on the top (like capping stones on a dry stone wall) and give greater stability to the structure. (Hope and Vines 1994:51)

The use of these larger ‘capping stones’ in the Brewarrina fish traps has also been observed on fish trap weirs on the New South Wales south coast on the Yowaka River (personal observation, Nutley 2005).

The observations at North Arm, Middle Cove, provide a clear example of the vulnerability of Indigenous sites in Australia to the process of inundation. With the exception of stone fish traps and quarries, the artefact material in Indigenous sites is typically small and light-weight and susceptible to the combined forces of gravity, wind, rain, wave action and current.

There are five major mechanisms through which Indigenous sites in Australia may move from a terrestrial to an inundated setting. These mechanisms are sea level rises, river diversions, ongoing shoreline erosion, water-catchment infrastructure projects such as dams and weirs and gravitational momentum. The role of gravity in moving artefacts from a terrestrial deposit into a submerged landscape is one area that has perhaps received less attention than it deserves. In addition to the collapse of sites undercut by erosion, when watercraft founder during use or when fishing hooks, fishing barbs or other equipment are lost or discarded.

The importance of this can be observed at North Arm where shell midden was collapsing from the bank of the estuary even without a sea level rise. Stewart (1999:583) considers the effects of gravity within a submerged environment. Gravity is a factor in determining the rate at which items within a terrestrial setting move into an encroaching estuary, stream, lake or any other water body. A steep slope will hasten the downward migration whereas a reduced slope will minimise that movement.

Floating vessels that founder or artefacts discarded in an inundated environment are likely to survive in particular settings. They can immediately bypass the mechanical pounding of sites at the land-water interface as well as the stresses associated with repeated wetting and drying.
Origins therefore need to be considered in interpreting any artefacts that are located in an inundated environment, as they may not represent an actual occupation site.

**Site Survival Determinants**

Vast areas of the Australian continental shelf were once part of the terrestrial landmass. However, what is not clearly understood are the conditions and extent to which sites have survived the inundation process.

In a hydro-dynamically active coastal or riverine environment, there is a strong likelihood that even robust structures will eventually be levelled. In such an environment, stone tools are likely to become waterworn to the point where they are no longer recognizable.

Estuarine systems with backwaters, mud flats, swampland or marsh environments are capable of trapping and protecting cultural materials in ever-increasing layers of sedimentation and organic materials. Artefacts that settle into an anaerobic environment, whether a layer of silt or in a deep water, low oxygen, low light environment, are likely to avoid the abrasive, chemical and biological attack otherwise endured during gradual inundation. A boomerang in the Australian Museum collections, which was located in the Parramatta River, is likely to be post-contact in age but could still be of Aboriginal manufacture. One end appears to have been subjected to biological attack, whilst the remainder, assumed to have been buried in mud, was unmarked (Attenbrow 2005, pers. comm.). In the event that global sea levels rise and there is sufficient sedimentation then some estuarine sites may survive under the continental shelf.

No underwater studies have yet been undertaken in Australia on Indigenous sites inundated as the result of dam and weir construction. However, the rapidity of dynamic hydrological forces is highly likely to result in the preservation of these sites, particularly those that are more or less permanently inundated. Perhaps the major danger to these sites is through lack of awareness of their location and consequent disturbance by boat wash, marine biological studies or dam maintenance activities.

The literature review, field observations and foregoing discussion identify two key determinants of site survival: environmental factors and artefactual composition. These are summarised in Appendix A (Tables 1 and 2).

**Implication of Site Survival Determinants for Specific Site Types**

Environmental factors and artefactual composition (Appendix A, Tables 1 and 2) enable predictions to be made about conditions necessary for inundated Indigenous sites to survive and remain in situ, as follows:

1. Shell middens are highly vulnerable to the processes of inundation and likely only to survive rapid, low energy inundation unless deeply buried in consolidated sediments or peat prior to inundation within a high-energy environment.

2. Carved trees are highly vulnerable to the processes of inundation and likely only to survive in conditions of rapid, low energy inundation within a freshwater environment. To survive in a high-energy environment they would need to be deeply buried in consolidated sediments or peat prior to inundation.

3. Bora rings of mounded and compacted earth constructions are highly vulnerable to the processes of inundation and unlikely to survive even with rapid, low energy inundation. Bora rings that are rock structures would have far greater resistance.
4. Fish traps constructed with organic materials such as saplings or woven materials are highly vulnerable to the processes of inundation and likely only to survive rapid, low-energy inundation unless deeply buried in consolidated sediments or peat prior to inundation within a high-energy environment. However, fish traps constructed from stone are moderately vulnerable to the processes of inundation but likely to survive relatively intact except within a high-energy environment.

5. Stone artefact scatters are moderately vulnerable to abrasion and dislocation during slow inundation but very likely to survive rapid, low-energy inundation.

6. Rock outcrops quarried for stone artefact manufacture are highly resistant to the processes of inundation due to their intrinsic hardness. These sites are vulnerable only to slow inundation in a high-energy environment. Where they have survived, they would be visible to remote sensing equipment such as side scan sonar. However, they would require close investigation to distinguish them from unquarried rock.

7. Rock shelters and rock art sites would be moderately resistant to the processes of inundation due to their bulk. However, depositional material within the shelter is likely to survive only where the original depth of deposit was considerable or in those areas where the deposit is located in recessed floors, within fissures or trapped under fallen boulders. Even then, survival is only likely during relatively rapid inundation in a low-energy environment. Engravings are unlikely to survive long on soft sandstone. Organic paints and charcoal within the shelter are likely to be vulnerable to colonising marine organisms and chemical attack. Sandstone that absorbs red ochre may retain that stain but may equally be susceptible to absorbing additional masking colouration from waterborne minerals. It is possible within some limited contexts, that inundated rock shelters will retain diagnostic features. In other contexts, it may simply be possible to determine from the structural characteristic of a formation that it had potential to be a shelter.

In all the above circumstances, rapid, low energy inundation provides the best conditions for site survival. The implications of this analysis are for the potential of predictive mapping to guide the focus and priorities of future research. This mapping involves identifying those areas where rapid, low energy inundation is likely to have occurred and where pre-inundation resource availability was likely to be conducive to the development of specific habitation site types. Some key potential areas are considered in the following conclusion to this study.
Although a considerable amount of Australian research relates to inundated Indigenous sites, much of this relationship, with a couple of exceptions (Flemming 1982b; Dortch et al. 1990; Dortch 1997), is indirect. Research has largely focused on terrestrial contexts from which implications can be drawn about the existence and potential of inundated sites. This is not research directly focused on investigating inundated sites in coastal, riverine or lacustrine environments. Excellent site formation analytical work by authors such as Bird (1992, 1995), Fullagar et al. (1999), Hall (1999), Head (2000) and Rowland (1983, 1989, 1992, 1995, 1996,1999), have focused on those agents of change that influence the coastal terrestrial archaeological record. Many studies have also dealt with the relationship of coastal Indigenous communities and have considered the impacts of sea level changes on site formation and population demographics. In transferring this focus and these perspectives to the submerged landscape, it is necessary to extrapolate the relevance from either a terrestrial or an international context.

The reason for the current sparse literature on submerged Indigenous sites in Australia is due to the relatively small numbers of archaeologists with expertise in Indigenous and underwater cultural heritage management. As a result, the investigation of underwater cultural heritage has focused primarily on the much more visible presence of historic shipwrecks and, to a lesser extent, on submerged aircraft and harbour infrastructure.

The investigation of existing literature and limited field investigations highlights the considerable opportunities for additional, targeted, multidisciplinary and integrated research. The initial priority is to identify and map areas of high and low probability where inundated sites may have survived in the inundated landscapes of Australia’s coastal and inland waters. Without this framework, future site-specific research is likely to result in futile searches or be determined by disarticulated chance finds.

This current study demonstrates that survival of inundated sites is a factor of the interplay between environment and site composition. Therefore, predictive research and mapping of areas of high and low probability for the survival of inundated sites needs to target specific environmental and site types. The work necessitates a close collaboration between Indigenous communities, archaeologists, geomorphologists and hydrologists.

In a coastal setting, predictive mapping needs to include a focus on sea-level curves; identifying submerged landforms associated with habitation and subsistence; erosion modelling to determine extent of land surface removal during inundation; a full compilation
of reported inundated sites in Australia; identification of coastal areas associated low energy wave activity; and, mapping of offshore peat beds.

The development of sea-level curves for the Australian Continental Shelf (see Stright 1990:454) would greatly assist in demonstrating shorelines during particular phases of inundation of the continental shelf. This would enable predictions to be made about landforms, resources and potential pre-inundation occupation sites. Potential submerged coastal landforms associated with habitation and subsistence include drowned rivers, lakes, bays, saline coastal swamps, lagoons, sinkholes, quarries (outcrops of cryptocrystalline rock), well-drained topographic highs (on flat coastal plans with natural levees), caves, rock overhangs. Such information would derive from existing or targeted side-scan, sub-bottom and bathymetric surveys to locate submerged features that are analogous to terrestrial sites (sites near aquatic features, stone quarries and the openings to river estuaries (Faught 2004:278; Faught and Donoghue 1997:450-451).

The construction of an erosion model to determine the extent of land surface removal during inundation would assist by eliminating those areas and time zones that cannot have survived on the continental shelf. In the southern mid-Atlantic Bight of North America it has been estimated that erosion “shears off the upper between 5 to 15m of subaerial shoreface” (Hoyt et al. 1990:149) and there is scope to interpret this in Australian contexts.

The compilation of known inundated sites in Australia would assist in directing research to confirm their existence, nature and condition and to incorporate these within broader landscape studies. This compilation would also assist in refining a probability map for site survival.

There is a need to identify areas of broad, flat, shelving submerged coasts and associated low energy wave activity. These are areas conducive to gentle yet rapid burial conditions, similar to many of the marine waters in Florida (Johnson and Stright 1992:118). Areas with prime potential include the Gulf of Carpentaria, the north-west shelf considered by Flemming (1982b), and the drowned river valleys of Backstairs Passage between Kangaroo Island and the mainland in South Australia (Flatman et al. 2005:8). Of these, the Gulf of Carpentaria (Figures 57 and 58) may prove to be the most productive. It has relatively shallow waters, (large areas are less than 30 metres and much of it is considerably less than 50 metres), and has a fetch that in most directions, apart from north-south, is less than a thousand kilometres. East-west, the fetch is limited to less than 700km.

The mapping of offshore peat beds would assist in investigation of an environment in which artefacts have been trapped prior to the collapse of coastal barriers. Having moved below sea level due to isostatic, eustatic or tectonic factors, they would then have considerable resistance to inundation.

In an estuarine setting, the mapping exercise needs to focus on identification of low energy areas of anaerobic estuarine mud and other sediment layers. Upper estuarine areas, though possibly inundated at a later stage, also have potential for the preservation of habitation sites and may be advance by the current survey being conducted at South Arm, Port Hacking. While estuarine sites are not a part of the deeper and much earlier continental shelf landscape, mapping the areas of estuarine sedimentation may well provide direction to some very early, very accessible and intact inundated sites. These areas are also perhaps most vulnerable to dredging and other port infrastructure, marina and foreshore development programs.

In a riverine setting, the conclusion of this study is that Indigenous sites are unlikely to survive within youthful river systems and only extremely robust stone constructions are likely to survive even in a mature river system. In rivers that have reached a state of ‘old age’, stone fish traps and weirs are still the most likely sites to survive. To date the only stone fish trap
sites to be recorded are those that are still at their operational depth, which is at the tidal or seasonal level of the river system.

![Hydrographic chart of the Gulf of Carpentaria showing characteristically shallow depths over large portions of the gulf (AUS305)](image)

Figure 57. Hydrographic chart of the Gulf of Carpentaria showing characteristically shallow depths over large portions of the gulf (AUS305)

However, deposition of silt and consolidation by colonising vegetation was observed by the author at a stone fish weir in the Yowaka River at Greig’s Flat site in southern New South Wales (Figure 59). This indicates the ability for a river to bury these structures in situ within river silt. The site at Greig’s Flat is at the upper limit of tidal flow. The site has survived periodic extreme flood events demonstrating not only its ability to withstand the forces associated with this but also the effect that such structures can have in trapping large amounts
of silt. In the event of any marked increase in sea level, this site would eventually be submerged within estuarine waters and it is conceivable that subsequent deposits of river rock and sand would permanently bury the structure. Therefore, there is potential to investigate earlier usage of such structures at lower sea levels. Such sites could, for example, be expected to be located downstream of any recorded structures.

Figure 58. SE sector of Gulf of Carpentaria, demonstrating extent of tidal flats and shallow, poorly surveyed inundated areas resulting from a relatively undynamic hydrological environment (AUS303)
6. CONCLUSION

In a lacustrine setting, the potential for predictive mapping includes a focus on those locations where there are significant concentrations of Indigenous sites on the exposed shoreline, such as exists at Lake Victoria in southwestern New South Wales and confirmed at Lake Jasper in south-western Western Australia. Other permanent freshwater systems such as the South Australian sinkholes also have considerable potential to contain deposits of tools or other equipment that were discarded intentionally or accidentally. The potential and importance of these sites cannot be underestimated, as demonstrated in Florida where inlands waters have been an important source of Paleo-Indian artefacts (Johnson and Stright 1992:118).

Finally, there is potential for the mapping of surviving marshlands and an assessment of their individual potential as repositories of inundated Indigenous heritage. Marshlands are not only a considerable source of food and other resources but also provide one of the best conditions for the preservation of cultural materials. There is a minimum of alternate states of wet and dry, a virtual absence of currents, surge, or wave action and deep deposits of anaerobic silt. Even though this is partially offset by bioturbation in the rich rotting humus of the marsh bed, occupation sites or artefact scatters that become trapped in marshlands could, as shown in the Literature Review in relation to Wyrie Swamp and Wingecarribee Swamp, be expected to be intact.

A critical challenge in establishing the location of inundated Indigenous sites in Australia will be in identifying appropriate techniques that are matched to site types and environmental conditions. No single technique will apply to all circumstances. While new technologies may develop it is likely that the main approach will involve new application of existing techniques or refinements of old techniques using the usual tools of underwater archaeology, including diver based visual surveys, remote operated videos (ROVs), side scan sonar, sub-bottom profilers and core sampling. Of these, perhaps the technology with the greatest potential to provide conclusive evidence will be core sampling. Core samples taken in the Gulf of Carpentaria in 1997 are reported to have identified non-marine fluvial deposits ranging from
125000 BP to 10000 BP (Garcial et al. 2001). The value of oceanic core sample data through examination of foraminifera deposits to interpret sea surface and atmospheric temperatures to model broad-scale change in climatic conditions is also well documented (Dortch 2004:26, 27). In an environment where sheer-sided excavation spits are rarely even remotely possible, core sampling provides a controlled stratigraphically intact sample that can be analysed under controlled conditions. In both deep and shallow water sites core sampling surveys may well prove to be a most cost effective technique to both broad-scale and site specific mapping of potential areas of inundated habitation sites and, if appropriate, for subsequent and more traditional 'open-cut' methods of excavation.

Environmental factors can be devastatingly destructive of underwater heritage sites. Paradoxically they are also powerfully protective. As shown in this study, there is no doubt that a variety of Indigenous Australian habitation sites and displaced artefacts have survived in a variety of defined hydrodynamic and geological settings and through different eras. The challenge in investigating these sites is to begin the process of predictively modelling the Australian coast, rivers and lakes and testing that modelling against localised and broad-scale investigations using appropriate archaeological techniques. Predictive modelling provides a basis for synthetic, multidisciplinary, regional studies rather than site-specific investigations. This approach is essential to effective understanding of inundated Indigenous sites within wider social economic and religious contexts.
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## Appendix A: Determinants of Site Survival

### Table 1. Determinants of site survival

<table>
<thead>
<tr>
<th>Environmental factors</th>
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<tbody>
<tr>
<td>Speed of water level rise</td>
<td>Rapid inundation minimises the opportunity for mechanical, chemical and biological attack. Slow or repeated inundation and exposure maximises the degradation of sites and individual artefacts.</td>
</tr>
<tr>
<td>Fetch over water to land-water interface</td>
<td>A short fetch minimises wave height and consequently minimises wave-induced erosion.</td>
</tr>
<tr>
<td>Dominant wind direction</td>
<td>Sites facing the dominant wind direction are far more susceptible to wave action and destabilisation from wind, rain and falling trees.</td>
</tr>
<tr>
<td>Dominant wave direction</td>
<td>A direct response to the dominant wind direction and producing the most destructive of the on-shore forces influencing site survival.</td>
</tr>
<tr>
<td>Strength of water flow</td>
<td>Largely related to a riverine environment but also an aspect of estuaries and long-shore coastal currents. A strong flow of water will not only undermine sites but also result in greater dispersal of the component parts.</td>
</tr>
<tr>
<td>Tidal and non-tidal</td>
<td>Non-tidal water-bodies will result in less damage from frequent wetting and drying as well as minimising the strength of water flow over the site. This may however be offset by the extreme changes between a saturated environment and a ‘baked earth’ environment during drought as well as the impact of grazing animals on the exposed sediment flats during periods of low water.</td>
</tr>
<tr>
<td>Frequency and duration of inundation and exposure episodes</td>
<td>See ‘tidal and non-tidal’ above.</td>
</tr>
<tr>
<td>Slope</td>
<td>A steep slope is accompanied by a marked increase in the gravitational factor. Earth, vegetation, rocks and any associated deposits of cultural material are more likely to be destabilised and result in the loss of integrity of the original site formation.</td>
</tr>
<tr>
<td>Geological composition</td>
<td>Sites protected by coastal barriers, whether igneous rock, sandstone or sand dunes, but with a healthy budget of sand or silt are much more likely to already be below sea level by the time that the coastal barrier is broken down and to therefore be spared the worst of the erosive forces of wave action.</td>
</tr>
<tr>
<td>Prograding/aggrading shorelines</td>
<td>Prograding/aggrading shorelines that provide habitation sites and artefact deposits with a protective depth of overburden may provide a sufficient buffer to ensure long term survival during subsequent and relatively rapid inundation.</td>
</tr>
</tbody>
</table>
### Table 2. Artefactual composition

<table>
<thead>
<tr>
<th>Chemical Impacts - susceptibility to permanent inundation in saline/fresh water</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shell/bone</strong></td>
</tr>
<tr>
<td><strong>Wood</strong></td>
</tr>
<tr>
<td><strong>Fibre (eg, woven from leaf, grass, reeds)</strong></td>
</tr>
<tr>
<td><strong>Charcoal</strong></td>
</tr>
<tr>
<td><strong>Stone</strong></td>
</tr>
</tbody>
</table>

### Mechanical Impacts

**(i) Susceptibility to abrasion:**

| **Shell/bone** | Highly susceptible to mechanical abrasion. |
| **Wood** | Highly susceptible to mechanical abrasion. |
| **Fibre** | Highly susceptible to mechanical abrasion. |
| **Charcoal** | Highly susceptible to mechanical abrasion. |
| **Stone** (flaked or ground stone artefacts and stone structures): | Moderately susceptible to mechanical abrasion, with greater resistance from metamorphic rock and some igneous rock and less resistance from sedimentary rock. |

**(ii) Susceptibility to dislocation:**

| **Shell/bone** | Highly susceptible to dislocation. |
| **Wood** | Highly susceptible to dislocation. |
| **Fibre** | Highly susceptible to dislocation. |
| **Charcoal** | Highly susceptible to dislocation. |
| **Stone** (flaked or ground stone artefacts and stone structures): | Susceptibility to dislocation is proportional to size - small flaked stone artefacts moving sooner/easier than larger items. |

**(iii) Susceptibility to Biological attack**

| **Shell/bone** | Mildly susceptible to biological attack. |
| **Wood** | Highly susceptible to biological attack unless buried. |
| **Fibre** | Highly susceptible to biological attack unless buried. |
| **Charcoal** | Minimally susceptible to biological attack. |
| **Stone** | Mildly susceptible to biological attack through abrasion from grazing fish and sea urchins and other colonising fauna and flora. |
Appendix B: Glossary of Terms

This Glossary of terms is adapted and developed from Baker (1998); Davis (1997:49); McEvilly (2004); (May et al. 1978:117); (Morisawa 1968:7); Stright (1990:439); Schiffer (1987:7); Troedson et al. (2004:XI-XIX).

aeolian: originating from the action of wind.

aggradation: vertical accumulation of sediment resulting in an increase in the elevation of the land surface or the shoaling of a water body.

archaeological site: any locality where archaeological material is located, whether or not it is an in situ archaeological deposit.

alluvial deposit: clay, silt, sand, gravel, or similar unconsolidated detrital material, deposited by channelled or overbank stream flow.

bioturbation: the mixing of sediment by burrowing animals such as clams and worms.

Bora ring: an Aboriginal Australian ceremonial area surrounded by earthen or stone mounds.

carved tree: a tree where Aboriginal Australians have removed the bark and carved ceremonial designs into the wood of the tree.

coastal barrier: a shore-parallel deposit of sand- to gravel-sized sediment, primarily formed through the action of waves and longshore currents, but generally modified by aeolian and tidal processes. Main components of a coastal barrier include beach, dune, and backbarrier flat. The coastal barrier may be largely separated from the mainland by a barrier lagoon or an estuary, or backed by other sedimentary deposits and bedrock.

continental shelf: relatively shallow (generally less than 200 m water depth) part of the sea floor fringing continental landmasses, extending as a platform from the coastline offshore.

eustatic: a large-scale, absolute rise or fall of sea level, for example, resulting from the decay or development of ice-sheets. Since oceans and their marginal seas are interconnected, the effect is world wide.

drowned river valley: coastal water bodies formed through the marine inundation of former river valleys, such as that resulting from the postglacial marine transgression. Such valleys are generally narrow and deeply embayed in plan form, and a common setting for estuaries.

estuary: a coastal water body that receives inputs of water and sediment from fluvial and marine sources, and that is regularly or intermittently affected by tides. Generally formed through marine inundation of river valleys and other topographic depressions as a result of marine transgression or subsidence.

facies: in sedimentary geology, the set of characteristics of sediment that identify its origin within a particular depositional environment.

fish traps: structures that channel fish into a confined space that can be closed off to prevent escape.
**fish weirs**: barriers constructed across the width of a water body to impede or channel the passage of fish. Unlike dams, they do not raise the water level or prevent fish from continuing along the stream. They may have a channelled opening that can be closed off but unlike fish traps, they do not form a closed holding pen.

**fluvial**: produced by the action of a stream or river.

**geomorphology**: characteristics and evolution of landforms, and their study.

**glacial (period)**: an ice age.

**hightstand**: a period of relatively high sea level that exceeded modern levels

**Holocene**: the most recent part of the Quaternary, starting approximately 10 000 years before present.

**hydrology**: a geophysical science that develops explanatory, predictive models for water related phenomena and an applied science that is a branch of civil and environmental engineering.

**in situ**: in the natural or original position. Applied to culturally generated artefacts, as well as naturally occurring rock and soil.

**isostatic**: subsidence and rebound of the continental lithosphere (Earth’s crust) owing, for example, to an increase or decrease in the weight of an ice sheet.

**lacustrine**: formed in or submerged by a lake.

**lithic**: in reference to sediments or rocks, consisting of particles which are composed of rock fragments, as opposed to a single mineral such as quartz or feldspar.

**lowstand**: a period of relatively low sea levels, such as those associated with glacial.

**‘mature’ river**: characterised by a more gradual gradient and within a wider valley than in its youthful stage. A river begins to deposit the sediments. Channel erosion is diminished and erosion is directed sideways so that the river begins to meander.

**mud**: in sedimentology, collective term for deposits consisting predominantly of clay- and silt-sized particles.

**‘old age’ river**: a river that has entered, or has formed, wide, open floodplains.

**organic mud**: fine-grained sedimentary deposit consisting primarily of clay- to silt-sized particles, a substantial proportion of which is derived from the partial decomposition of organic matter.

**outcrop**: an exposure of bedrock, or of older sedimentary deposits emerging through a cover of younger deposits.

**palaeohydrology**: the interdisciplinary study of past occurrences, distributions and movements of continental waters linking scientific hydrology to the sciences of Earth history and past environments.

**peat**: a marsh or swamp deposit predominantly composed of preserved or partially decomposed plant remains.

**pedoturbation**: includes not only biological processes, (bioturbation), but also chemical churning, mixing, and cycling of soil materials

**Pleistocene**: the earlier part of the Quaternary, between approximately 1.8 million and 10 000 years before present.

**prograding**: seaward migration of shoreline caused by progressive sediment deposition. Antonyms: **degrading, eroding**

**Quaternary**: in the geologic timescale, the most recent period in Earth’s history, from
approximately 1.8 million years ago to the present. Subdivided into the Pleistocene and Holocene.

**riverine:** formed in or submerged by a river

**regression:** a relative fall in sea level resulting in the retreat or contraction of the sea from land areas, and the consequent evidence of such withdrawal (such as enlargement of the area of deltaic deposition) Also denotes shoreline progradation due to sediment deposition. **Anonym:** transgression

**saline swamp:** swamps experiencing regular to intermittent tidal inundation by saline to brackish waters. In southeastern Australia, vegetated by mangroves and/or saltmarshes.

**sand:** sedimentary particles with a grainsize within the range of 0.063 mm to 2.0 mm, and sedimentary deposits predominantly consisting of such particles.

**sediment:** geological material consisting of loose mineral particles and/or biogenic material such as shell fragments and vegetal remains. In mineral sediments, the particles are derived initially from the weathering of bedrock, and are transported away from their source by various physical processes, such as stream flow, waves, tides, and wind. Deposition occurs when these processes lose their competency (sufficient energy level) to maintain the particles in transport.

**semi-diurnal tides:** tidal regime in which approximately two tidal cycles occur within a day.

**silt:** sedimentary particles with a grainsize within the range of 0.004 mm to 0.063 mm and sedimentary deposits predominantly consisting of such grains.

**site formation processes:** the factors the create historic and archaeological records

**stillstand:** a period where sea levels remain relatively static

**stratigraphy:** the science of the description, correlation, sequencing and classification of strata in sedimentary deposits, including the interpretation of cultural and natural depositional environments of those strata.

**subaerial:** under terrestrial conditions.

**tectonic:** pertaining to the structure and movement of the earth’s crust.

**tidal flat:** a broad, near-horizontal coastal plain formed through sediment deposition, mostly exposed at low tide but totally submerged at high tide. Tidal flats are common in estuarine, deltaic, and backbarrier environments, but can also occur along oceanic coastlines where wave processes are weak.

**transgression:** a relative sea-level rise, generally associated with landward migration of the shoreline. **Anonym:** regression.

**weathering:** process by which exposure to atmospheric agents, such as oxygen and moisture, and physical processes, such as waves and wind, causes rocks and minerals to physically and chemically break down at or near the Earth’s surface. Weathering constitutes the preliminary stage in the conversion of bedrock to sediment.

‘youthful’ river: a river channel flowing though a steep, irregular slope and accompanied by falls, rapids, and V-shaped valleys in a high-energy environment where erosion is at its most intense. This energy is focused on downcutting the channel bed meaning that the river rarely, if ever, breaks out of the confines of the established stream.