NSW GOVERNMENT
Department of Planning

High resolution terrain mapping of the NSW Central and Hunter coasts for assessments of potential climate change impacts

Final project report

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Department of Planning Climate Change Impacts and Adaptation Research Project

High resolution terrain mapping of the New South Wales Central and Hunter coasts for assessments of potential climate change impacts

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CONTENTS

SUMMARY

The project has provided four councils and their communities with detailed topographic information with which to make informed decisions about risk assessment and management in low lying coastal areas on the Central and Hunter Coasts for any potential sea level rise scenarios.

Elevation provides a proxy for risk to climate change associated coastal inundation/recession for low lying areas and for identifying what the adaptation strategies might be to minimise those risks, bearing in mind the economic consequences of adaptation options, as well as the consequences of the 'do nothing approach'. This project has:

- developed a whole-of-government approach to the development of an agreed technical specification for high resolution terrain data capture using Light Detection and Ranging (LiDAR) technology and the terms of agreement necessary to secure the intellectual property to the data on behalf of the government;
- collected elevation data to a very high resolution (ie 0.15m vertical and 0.6m horizontal) over approximately 1240km^2 of the Central and Hunter Coasts using airborne laser scanning technology, also referred to as LiDAR;
- integrated the LiDAR elevation data with a range of existing state and local government spatial datasets in a demonstration of an approach to assessing built, natural and cultural assets potentially at risk to climate change associated sea level rise;
- completed negotiations with the Department of Lands for arrangements to support the long term management of the data and its general distribution to the widest possible range of stakeholders with an interest in coastal land use planning and natural resource management in NSW;
- explored current national approaches to incorporating climate change related sea level rise into land use planning and summarised a range of potential adaptation responses for land use planning in NSW; and,
- contributed to key objectives of federal government initiatives such as the National Climate Change Adaptation framework.

It is anticipated that the pilot project results will:

- be of direct benefit to councils in the study area;
- demonstrate a range of LiDAR applications to those councils that have already collected similar data;
- encourage other councils to consider collecting LiDAR data for their areas; and
- inform planning guidelines for climate change in coastal areas.

ACKNOWLEDGEMENTS

This pilot project would not have been possible without the funding and support of the NSW Government's Climate Change Impacts and Adaptation Research Program and the NSW Department of Planning.

Realisation of the project's objectives has relied on the cooperation of all levels of government, generous cash contributions to the LiDAR survey from the Hunter Water Corporation and Lake Macquarie City Council and oversight of the project management by the Steering Committee. The Steering Committee is comprised of representatives from the NSW Department of Environment and Climate Change and Department of Lands, Local Government (Port Stephens, Newcastle City, Lake Macquarie City, Wyong and Gosford Councils), the Hunter-Central Rivers Catchment Management Authority, Geosciences Australia and an independent coastal expert. Staff from the Department of Planning's Coastal Branch and Sustainability Unit are thanked for their assistance with the spatial data compilation, analyses and report preparation. John Hudson is acknowledged as project manager and lead author and Paula Douglas as project supervisor.

1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report identifies to a *very high confidence*[1] the link between human activities, global warming and the consequent impacts on the global climate system (IPCC 2007a; b). In the six years since the IPCC Third Assessment Report (2001), a clear consensus has emerged in support of the scientific evidence for human-induced climate change and the IPCC Fourth Assessment Report is considered a reliable foundation on which policy-makers can now build (Nature, 2007a). The climate change debate has now shifted to issues related to the likely magnitude and rate of change, the most appropriate actions for mitigation of future greenhouse gas emissions and realistic adaptation strategies for the unavoidable impacts caused by past emissions (IPCC 2007c).

In Australia, the importance of early action on climate change has been recognised by federal and state governments (Natural Resources Management Ministerial Council, 2006; Council of Australian Governments, 2007). A key federal initiative in this regard is the National Climate Change Adaptation Framework endorsed by the Council of Australian Governments in April 2007. This framework, intended to guide actions by all levels of government over the next five to seven years, identifies coastal zone vulnerability to climate change as a priority area for action (COAG, 2007). At a state level, the NSW Greenhouse Plan (2005) foreshadowed the need to initiate adaptation programs and develop adaptation strategies to those climate change impacts likely to be unavoidable (NSW Greenhouse Office, 2005). An action of the Greenhouse Plan relevant to coastal communities is to "research likely coastal impacts and investigate the feasibility of a coastal adaptation program" (Action 2.6; NSW Greenhouse Plan 2005).

The NSW Government's Climate Change Impact and Adaptation Program provides new funding to address key actions of the NSW Greenhouse Plan. The Department of Planning's Climate Change Impacts and Adaptation Project for the Central and Hunter Coasts is funded under this program and represents an important step towards developing climate change adaptation strategies for the state's coastal regions.

This report has been prepared for the NSW Department of Environment and Climate Change in line with the reporting requirements of the Memorandum of Understanding between the Directors General of the Cabinet Office and Department of Planning for the project entitled

[1] *Very high confidence* represents a >90% likelihood of occurrence/outcome or, alternatively, at least a 9 out of 10 chance of being correct (IPCC 2007b)

“High resolution terrain mapping of the New South Wales Central and Hunter Coasts for land use planning assessments of potential climate change impacts on coastal communities”. This report lists achievements at the completion of the project in September 2007. Appendices detail project management (Appendix A), terrain survey specifications and tendering (Appendix B), spatial information compilation and modelling (Appendices C & D) and tabulated spatial modelling data results (Appendix E).

2. PROJECT RATIONALE, OBJECTIVES AND MANAGEMENT

The inadequacy of generally available high resolution coastal elevation data has been identified as a significant impediment to a meaningful quantification of risk related to coastal hazards modified by climate change and, by inference, effective coastal planning (AGO, 2006; COAG, 2007). While uncertainty around predictions of climate change are understood (IPCC, 2007a; Kerr, 2006), less well understood is the fundamental lack of reliable elevation data to test the consequences of these uncertainties on coastal communities and their socio-economic fabric (Walsh et al., 2004; AGO, 2006). This project sought to capture high resolution terrain information for a section of the New South Wales coast as part of a pilot study to demonstrate the value of this type of data in integrated and adaptive coastal management.

The project proposal identified the following key objectives:

1) Collect high resolution terrain information over a priority section of the NSW coast to support the assessment of the potential impacts of climate change-induced shoreline erosion, flooding and coastal inundation on infrastructure, socio-economic and natural assets;
2) Through a case study, demonstrate the relevance of high resolution terrain data to informed land use planning decisions at both the regional and local scales;
3) Establish agreed protocols and arrangements for the long-term management, access to and distribution of government-funded, high resolution terrain data;
4) Through workshops conducted in each coastal catchment management area, demonstrate the importance of high resolution terrain information to (a) the assessment of potential climate change-induced coastal risks (ie. shoreline erosion and inundation of low lying land) and (b) relevance to the incorporation of climate change considerations into catchment, regional and local environment planning; and,
5) Summarise the study findings in a final report which is to include a discussion on the value of generally available high resolution terrain information to support state and local government planning initiatives for the NSW coast.

Objectives 1 to 3 were to be completed at the conclusion of project Stage 3 (June 2007) while objectives 4 and 5 were to be delivered at the end of project Stage 4 in September 2007.

This report summarises results to the end of Stage 4 and describes how objectives 1 to 5 have been successfully achieved at the completion of the project. Further background to the project is contained in Hudson and Douglas (2006) and the Climate Change Impacts and

Adaptation Research Program Memorandum of Understanding (NSW Department of Planning, 2006a).

Project management has been coordinated through a Steering Committee comprised of representatives from federal, state and local government with independent input from a coastal expert.

Project Steering Committee Membership and Affiliation

Member	Affiliation
John Hudson (Chair/Project Manager)	NSW Dept. of Planning
Jennifer McAllister (or delegate)	NSW Dept. Environment & Climate Change
Bob Denholm	NSW Data & Information Management Working Group (Dept. Environment & Climate Change)
Neil Kelleher	NSW Dept. Environment & Climate Change
Neil Saintilan	NSW Dept. Environment & Climate Change
Alan Garside	NSW Dept. Lands
Santina Penissi / Sian Fawcett	Wyong Shire Council
Symon Walpole	Lake Macquarie City Council
Greg Flynn	Gosford City Council
Bruce Petersen	Port Stephens Council
John Asquith	Hunter - Central Rivers CMA
Brendan Brooke	Geosciences Australia
Bruce Thom	Independent expert advisor (Coastal Management)

Since the inception of the project in June 2006, the committee has met on eight occasions to monitor progress and to advise and endorse key project decisions including study area selection, terrain survey technology and technical specifications, tender process and contractual terms of agreement to secure intellectual property rights to survey deliverables and reporting. In addition to these meetings, some thirty seven presentations have been given to project partners, government agencies, research organisations and the general public either as project briefings or presentations at public forums. See Appendix A for further information.

The report contains background information on climate change science, the potential impacts for coastal areas and the government policy response and initiatives to date. This is followed by an account of the study area selection and project case study results. The report concludes with a summary of the main project achievements. A considerable amount of technical information has been compiled during the course of the project which relates to high resolution terrain mapping technologies, contract arrangements for acquisition of terrain

information and geographic information systems (GIS) modelling of spatial datasets. The bulk of this information is contained in the report appendices and selectively referred to in the body of the report.

3. CLIMATE CHANGE SCIENCE, GOVERNMENT POLICY RESPONSE AND INITIATIVES

Climate change is viewed as an issue of national significance requiring coordinated action on the dual challenges of emissions mitigation and adaptation. The recent Federal Government Budget (2007-2008) makes specific mention of climate change and the serious long-term threat it represents to the nation (Australian Government, 2007).

The scientific evidence for global warming, climate change and their potential impacts are summarised in the IPCC Fourth Assessment Report (IPCC 2007a; 2007b; 2007c) which is widely acknowledged as the authoritative reference on climate change science and a basis for policy formulation on greenhouse gas emissions reduction and adaptation. The main findings of the IPCC 2007 Fourth Assessment as they relate to changed global climate are:

- Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture.

- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.

- For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES[2] emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.

Projected changes in global average temperatures and sea level for a range of greenhouse gas emissions scenarios are summarised in Figure 1.

[2] SRES refers to the IPCC Special Report on Emission Scenarios (2000) and the emission scenarios contained therein. The SRES scenarios outline a range of population growth, economic activity and technological change contexts for global greenhouse gas emissions.

Table SPM.3. *Projected global average surface warming and sea level rise at the end of the 21st century. {10.5, 10.6, Table 10.7}*

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Table notes:
[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth System Models of Intermediate Complexity and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs).
[b] Year 2000 constant composition is derived from AOGCMs only.

Figure 1. Scenarios of global temperature change and sea level rise (extract from IPCC 2007a).

Best estimates and likely ranges for global average surface air warming for six scenarios suggest a potential increase in temperature from 1.1°C to 6.4°C by 2100. Similarly, modelled scenarios indicate global sea level rise may be as little or as much as 0.18m/0.59m at the end of the 21st century. The figures for sea level rise are considered to be too conservative by some climate change scientists based on more recent analyses of climate observations, particularly the rates of ice sheet melt from Antarctica and Greenland. (Rahmstorf et al., 2007). A review of actual observations of carbon dioxide concentration, temperature and sea level from 1990 to 2006 has shown, amongst other things, that the observed sea level rise has been faster than the climate models have projected for the Fourth Assessment Report and closely follow the IPCC Third Assessment for an upper limit of an 88cm rise between 1990 and 2100.

The IPCC Fourth Assessment Report acknowledges the limitations of current climate models in addressing changes in ice flows but states that an understanding of these processes is limited and there is no consensus on their magnitude (IPCC, 2007a). The report does however concede that if ice flow rates from Greenland and Antarctic were to grow linearly with global average temperature change then the upper ranges of sea level rise for the assessed scenarios would likely increase by 0.1 to 0.2m, making the upper limit for sea level rise 0.79m by 2100 (A1F1 Scenario 0.59m + 0.2m).

A range of impacts as a function of global average temperature rise are summarised in Figure 2.

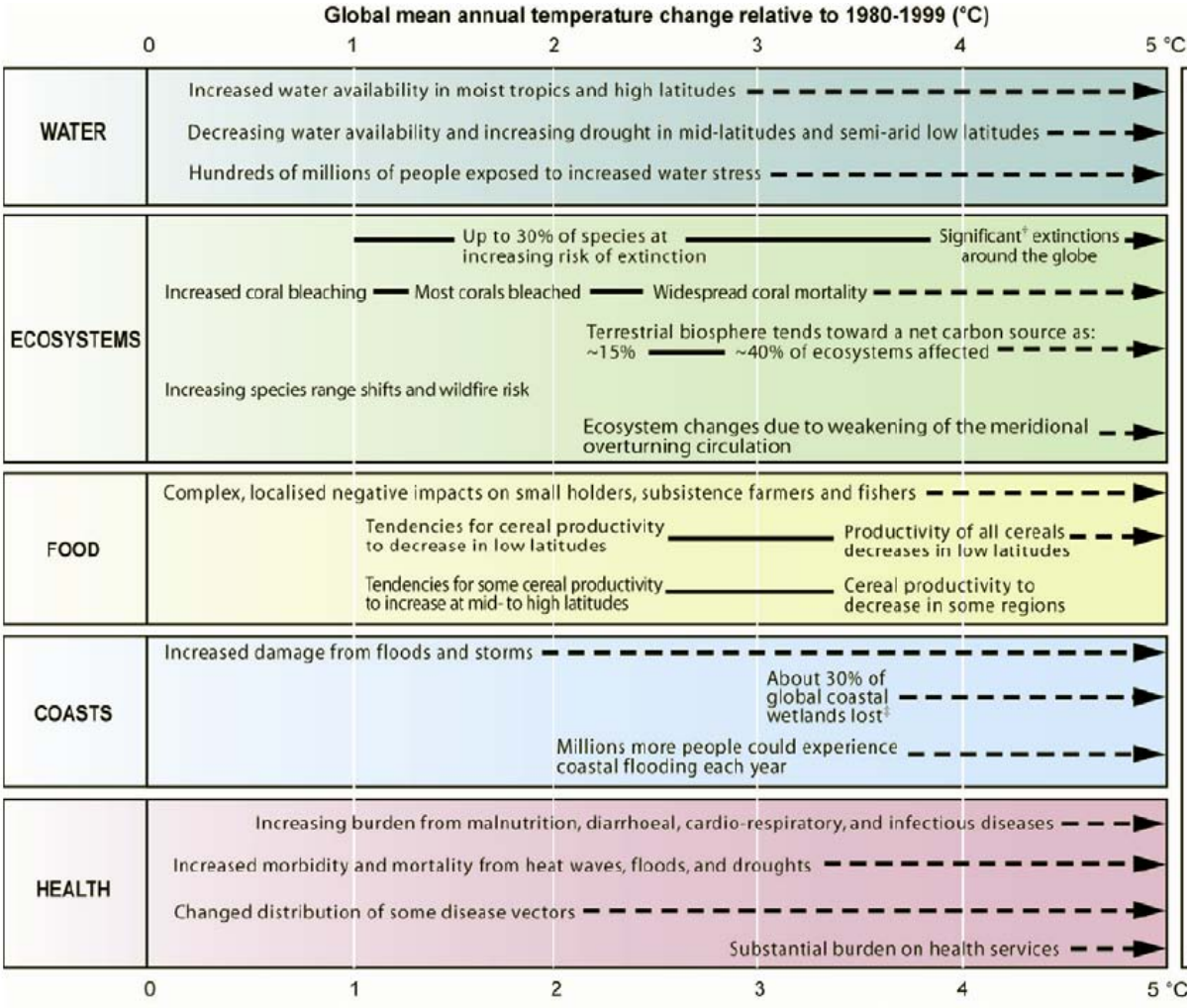


Figure 2. Illustrative examples of global impacts projected for climate changes (and sea-level and atmospheric carbon dioxide where relevant) associated with different amounts of increase in global average surface temperature in the 21st century. The black lines link impacts, dotted arrows indicate impacts continuing with increasing temperatures. Entries are places so that the left hand side indicates approximate onset of a given impact. Adaptation to climate change is not included in the estimates. Confidence levels are high for all statements (extract from IPCC, 2007b).

The principal impacts on coasts will be due to rising sea levels and the increased frequency and intensity of storms which will lead to adverse consequences for coastal communities and the built and natural environments. For eastern Australia, ongoing coastal development and population growth are expected to exacerbate risks from sea-level rise and increases in the severity and frequency of storms and coastal flooding by as early as 2050 (IPCC, 2007b). It has been noted that global warming of 2°C and above is viewed as the threshold for dangerous climate change and will require global containment of greenhouse gases below 535 parts per million (ppm), current concentrations are around 430ppm (Nature, 2007b). While Australia has substantial adaptive capacity owing to its well-developed economy and scientific and technical capabilities, there are constraints to implementation of adaptive strategies and major challenges from changes in extreme events while some natural systems are seen to have limited adaptive capacity (IPCC 2007b). Across all scenarios, the benefits

of early action in relation to the mitigation of greenhouse gas emissions and adaptation are highlighted just as it is recognised that adaptation to the impacts of past and present greenhouse gas emissions will be unavoidable (NSW Greenhouse Office, 2005; Preston and Jones, 2006; Stern, 2006).

For NSW, climate change related sea level rise and an increased frequency and intensity of storms has the potential to impact virtually all aspects of occupation of the low lying coastal areas including:

- loss of sandy beaches, especially where they are backed by seawalls;
- increased flood levels in the tidal reaches of estuaries by approximately the amount of sea level rise, this will be especially significant around coastal lakes and lagoons;
- changed estuarine tidal regimes (flows and elevation);
- problems with local drainage in the lower estuaries and adjacent to beaches where falls are currently small, potentially exacerbating nuisance storm flooding (increased frequency and water depths);
- reduction in under bridge clearances; and,
- landward migration of mangroves and salt marshes in areas of no development and, where development restricts migration, potential loss of threatened and endangered species.

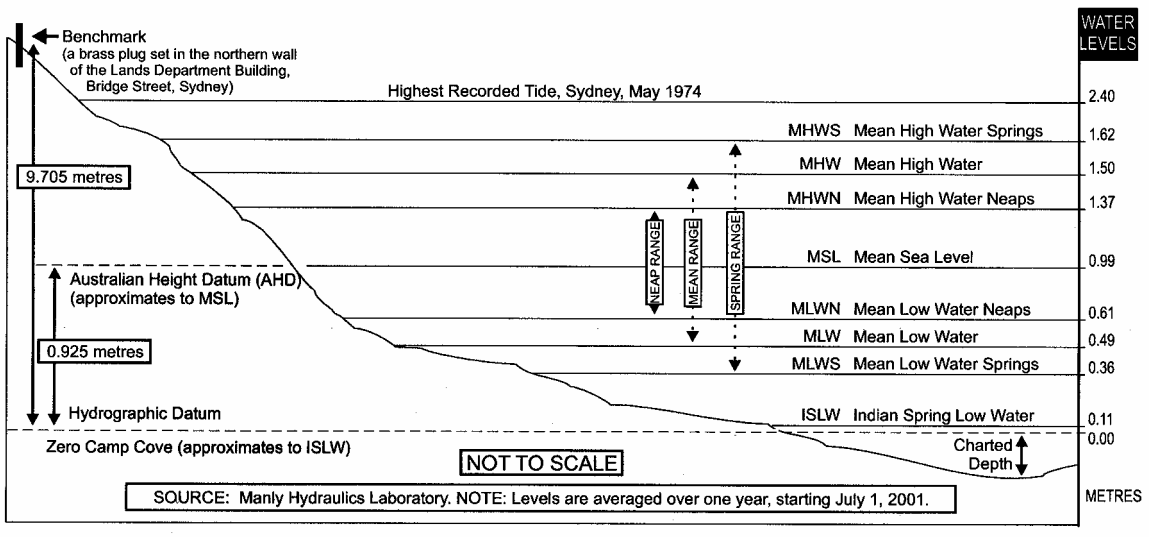
A range of responses may include:

- pressure for beach protection which will require ongoing sand nourishment and further engineering structures;
- for low-lying areas, bunding and pump-out of stormwater may be required, especially where coupled with rising water tables;
- a requirement for the modification and /or relocation of sewage system infrastructure (eg. mains and pumps) in low lying areas impacted by elevated sea levels;
- wharves, jetties, marinas and boat ramps may become inoperable at current locations and require refitting; and,
- revision of emergency response planning for community evacuation in natural disasters.

An often overlooked phenomenon in relation to climate change impacts in coastal areas are the incremental effects of rising sea levels and the potential for areas to be inundated more frequently on high tides, the so-called “Venice effect” (Thom, 2007). While the destructive impact of extreme events related to climate change are clearly of concern, it may be that the increased frequency of flooding of low lying coastal areas represents a more significant issue for coastal communities, particularly in relation to the maintenance of important infrastructure such as roads, stormwater and sewage systems. The ocean tidal planes recorded for

Sydney Harbour and their relationship to the Australian Height Datum is shown in Figure 3. In the same figure, a plot of the possible cumulative impact of a global sea level rise of 0.88m by 2100 (IPCC Third Assessment) on recorded tide and water levels at Sydney is shown. Amongst other things, the plot suggests for a 0.88m global sea level rise, present day Mean High Water Springs may be below the 2100 Mean Sea Level.

a)



b)

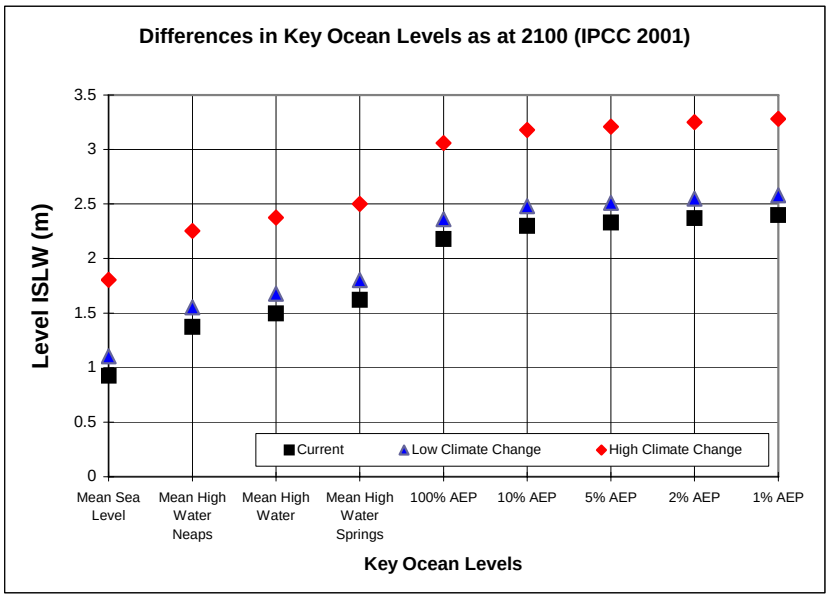


Figure 3 a) Ocean tidal planes measured at Sydney Harbour. MHL 2006. b)The difference in key ocean levels for various climate change scenarios to year 2100 (IPCC 2001). Diagram demonstrates that current Mean High Water Springs will be below the 2100 Mean Sea Level for the high climate change scenario (ie. 0.88m sea level rise by 2100). The potential impact of a 0.88m rise by 2100 on the Annual Exceedance Probability (AEP) of recorded water levels is also shown. (extract from Lord et al., 2005).

A long term change in present day ocean levels and tidal planes due to global warming could

lead to a change in estuarine tidal regimes (eg. tidal prism, water levels and flows) with potential impacts on foreshore alignment and stability, siltation and shoal formation and foreshore inundation levels (NSW Dept. Natural Resources, 1992; Manly Hydraulics Laboratory, 2003). This is a critical consideration when planning for climate change in low lying areas around estuarine foreshores remote from the open ocean coast.

Governments at all levels recognise climate change as a major pressure on the sustainable management of the social, economic and environmental well-being of coastal areas (Natural Resource Management Ministerial Council, 2006; COAG, 2007). At the national level, NSW contributes to the formulation of policy on climate change for coasts through the Framework for a National Cooperative Approach to Integrated Coastal Zone Management as a member on the Intergovernmental Coastal Advisory Group (ICAG). This framework identifies managing the impacts of climate change on coastal communities as a priority issue for national collaboration (NRMC, 2006). Similarly, NSW has contributed to the National Climate Change Adaptation Framework, endorsed by the Council of Australian Governments in April 2007 (COAG, 2007) and intended to guide actions by all levels of government over the next five to seven years on prioritised adaptation responses to climate change. At the state level, climate change is an important consideration in a range of existing NSW coastal legislation, policies and guidelines including:

- NSW Coastal Policy 1997 (Objective 2.2) *"to recognise and consider the potential effects of climate change in the planning and management of coastal development"*;
- State Environmental Planning Policy 71 – Coastal Protection (Clause 8(j)), Gives effect to the NSW Coastal Policy;
- Standard Local Environment Plan (Clauses 30 (1) (iv) and 30 (2) (f)), requires that councils "*recognise and accommodate coastal processes and climate change*";
- Coastal Regional Strategies, developed to accommodate increasing coastal populations in a sustainable way, are underpinned by the Coastal Policy. Among other things, the strategies seek to ensure future urban development is not located in areas of high risk from natural hazards including sea level rise, coastal recession, rising water tables and flooding. Councils are to assess such hazards according to the Government's Floodplain Development Manual and Coastal Zone Management Manual both of which include consideration of climate change and sea level rise;
- NSW Floodplain Development Manual, guides councils in the development and implementation of detailed local floodplain risk management plans;
- NSW Coastline Management Manual, guides the development of locale specific coastal zone management plans under a risk management framework; it specifically mentions the need to incorporate climate change considerations in management

plans;

- NSW Estuary Management Manual, guides councils in developing plans for the sustainable management of the state's estuaries;
- Draft Coastal Zone Management Manual (in prep), integrates the Coastline and Estuary Management Manuals to reflect the Coastal Policy;
- Coastal Design Guidelines for NSW 2003, supports the consideration of planning responses to address shoreline retreat and sea level rise over a 100 year timeframe; and,
- NSW State Infrastructure Strategy 2006/7-2015/6, identifies climate change as the environmental issue influencing infrastructure planning and spending over the coming decades.

Global warming has emerged as an issue of international significance, primarily in response to the publication of the IPCC Fourth Assessment Report on the observed and potential future impacts of climate change and independent economic modelling of the associated costs (Stern, 2006). These and other studies are encouraging all levels of government to review their respective positions and responsibilities on climate change. While government policy and guidelines on this issue will continue to evolve as new information becomes available, important initiatives like the NSW Government's Climate Change Impacts and Adaptation Research Program promote early action on understanding the potential impacts and consequences for the state's population.

4. THE CENTRAL AND HUNTER COASTS PILOT STUDY

4.1 Background

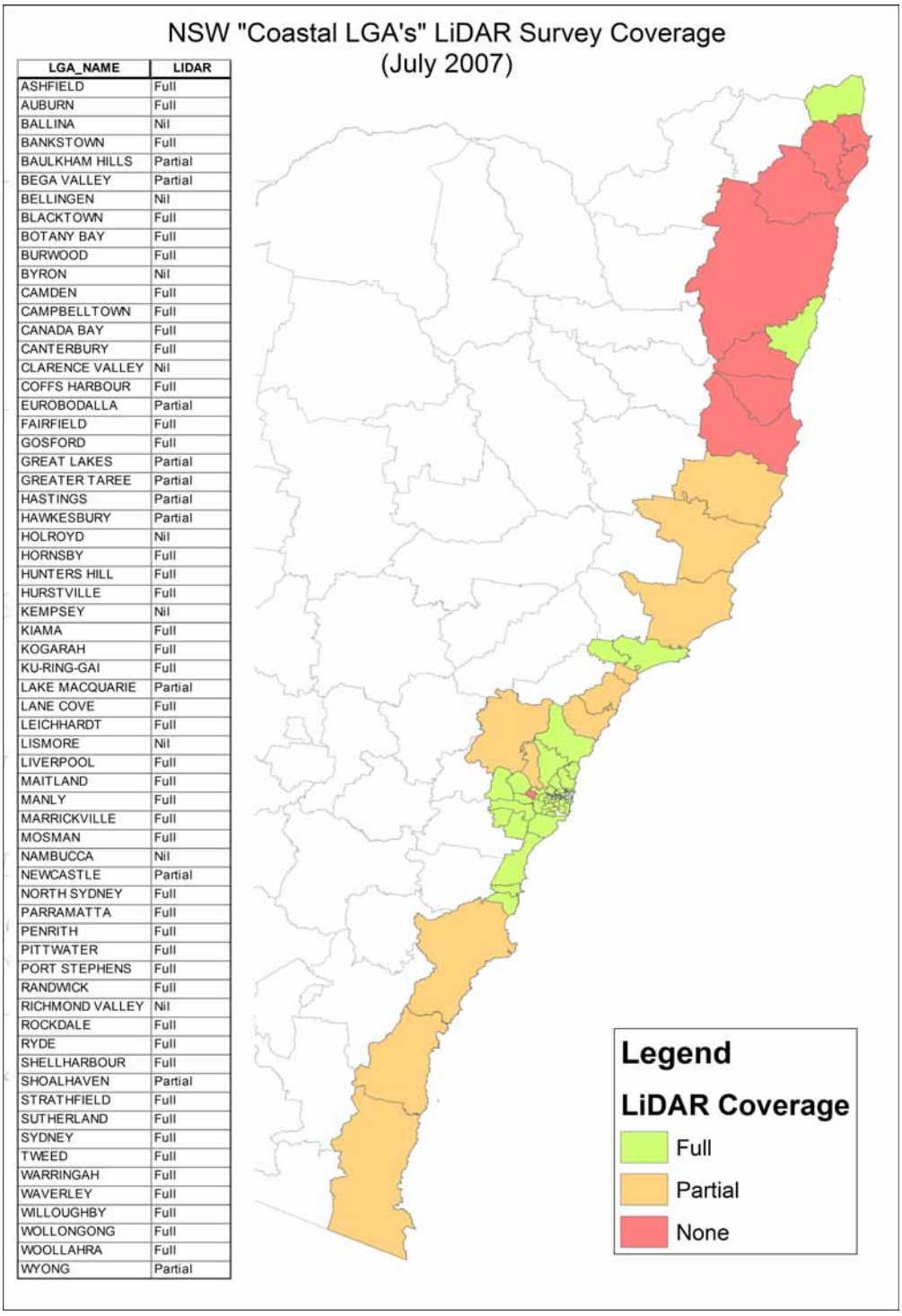
A fundamental driver for the project is that realistic and defensible adaptive responses to changed coastal hazards must use the best information available. The State Government's Comprehensive Coastal Assessment (NSW Department of Planning, 2007) highlighted this issue in relation to the available topographic information for the coast and the general inadequacy of this information for quantifying risk related to coastal hazards modified by climate change.

For much of the NSW coast the best generally available terrain information is based on topographic and orthophotographic maps produced prior to the late 1980's. Importantly, for predicting potential impacts of climate change these maps define either the 10m or 2m contour as their lowest elevation information inland from the shoreline and must be considered suited to only a generalised assessment of coastal risk (Sharples, 2006; Voice et al., 2006).

The limitations of existing topographic information in land use management has been recognised by a number of coastal councils, particularly where flooding is a significant consideration. Research by the Department of Planning's Coastal Branch in early 2006, subsequently updated in June 2007, has established that some 55 councils had either independently acquired or had access to high resolution terrain data for either all or part of their local government areas (Figure 4). The majority of these were in the Wollongong-Sydney-Newcastle metropolitan area. In all cases the terrain data has been collected commercially using airborne Light Detection and Ranging (LiDAR)[3] technology, also referred to as airborne laser scanning, with the contractors providing the data in formats suited to incorporation into council spatial information systems (GIS/CAD).

The digital elevation models (DEM) produced from the LiDAR surveys commonly have vertical and horizontal accuracies of better than 0.3m Root-Mean-Square (RMS) and 0.6m RMS respectively. The current project specification calls for vertical and horizontal accuracies of 0.15m RMS and 0.6m RMS respectively. Apart from the classified ground and non-ground LiDAR point data,

[3] Light Detection and Ranging (LiDAR). A technology that determines distance to a surface using laser pulses. Distance is computed by measuring the time delay between transmission and detection of the reflected signal.



LGA_NAME	LIDAR
ASHFIELD	Full
AUBURN	Full
BALLINA	Nil
BANKSTOWN	Full
BAULKHAM HILLS	Partial
BEGA VALLEY	Partial
BELLINGEN	Nil
BLACKTOWN	Full
BOTANY BAY	Full
BURWOOD	Full
BYRON	Nil
CAMDEN	Full
CAMPBELLTOWN	Full
CANADA BAY	Full
CANTERBURY	Full
CLARENCE VALLEY	Nil
COFFS HARBOUR	Full
EUROBODALLA	Partial
FAIRFIELD	Full
GOSFORD	Full
GREAT LAKES	Partial
GREATER TAREE	Partial
HASTINGS	Partial
HAWKESBURY	Partial
HOLROYD	Nil
HORNSBY	Full
HUNTERS HILL	Full
HURSTVILLE	Full
KEMPSEY	Nil
KIAMA	Full
KOGARAH	Full
KU-RING-GAI	Full
LAKE MACQUARIE	Partial
LANE COVE	Full
LEICHHARDT	Full
LISMORE	Nil
LIVERPOOL	Full
MAITLAND	Full
MANLY	Full
MARRICKVILLE	Full
MOSMAN	Full
NAMBUCCA	Nil
NEWCASTLE	Partial
NORTH SYDNEY	Full
PARRAMATTA	Full
PENRITH	Full
PITTWATER	Full
PORT STEPHENS	Full
RANDWICK	Full
RICHMOND VALLEY	Nil
ROCKDALE	Full
RYDE	Full
SHELLHARBOUR	Full
SHOALHAVEN	Partial
STRATHFIELD	Full
SUTHERLAND	Full
SYDNEY	Full
TWEED	Full
WARRINGAH	Full
WAVERLEY	Full
WILLOUGHBY	Full
WOLLONGONG	Full
WOOLLAHRA	Full
WYONG	Partial

Figure 4. LiDAR coverage of coastal councils in NSW. Map shows data availability and is based on council and LiDAR contractor advice at July 2007. Note that the data have been collected at different times, to different specifications and are used or made available under varying licence agreements. While the data may be available for a council area, not all councils have acquired the data from commercial suppliers.

councils typically purchase a range of LiDAR-derived elevation products suited to their specific business needs. Common LiDAR-derived products include digital terrain models (DTM) at varying resolutions (2m and 10m grids) and contours at 0.5m intervals. Beyond the highly accurate elevation data produced by the LiDAR surveys, an additional benefit is the

capacity for definition of above ground features such as building heights and tree canopies to similar vertical and horizontal resolutions.

High resolution terrain surveys using LiDAR technology are cost effective in terms of the range of applications for which the data can be used. Nonetheless they can be expensive, costing hundreds of thousands of dollars in some instances, and councils have sought a range of funding models to secure what is seen as data essential to their business needs. Council officers interviewed as part of the Department's 2006 research identified a multiplicity of uses for the data not possible with existing terrain information. For example, detailed assessment of modelled flood heights, locating key infrastructure, checking the accuracy of cadastral information, determining building heights, analysing viewsheds and monitoring vegetation canopy extents and structures. To date, there has been limited application of the data to undertaking assessments associated with climate change.

General access to these existing LiDAR datasets is hampered by licensing and survey specification issues. Typically, the data have been collected under contract-specific arrangements between councils and the contractor and suited to the individual requirements (specification) of the council. For example, in at least two cases councils have paid for data delivered in different horizontal map datums (ie. Australian Geodetic Datum 1966 and Geocentric Datum of Australia 1994) and to varying levels of accuracy (vertical and horizontal). Moreover, intellectual property rights allowing the distribution of the data have not been handled consistently to allow for free distribution of the LiDAR data and its products (ASCII XYZ laser data, digital elevation models, digital terrain models and contours).

4.2 Study Area Selection

The project focus was to be on one region with pressing coastal management issues sensitive to potential climate change-related sea level rise. Recent work associated with regional planning strategies as well as consultation with Catchment Management Authorities and council staff indicated several potential sites for the pilot study with the NSW Far North Coast and Central and Hunter Coasts seen as priority areas.

The Central and Hunter Coasts were selected as representative of many low lying developed areas along the NSW coast. They were also selected on the basis of a combination of coastal vulnerability, terrain data availability, project budget and logistic reasons. Key considerations included:

- Vulnerability to coastal hazards – the Central and Hunter Coasts contain the variety

of land use situations suited to trialling an assessment of existing and future vulnerability of coastal communities to climate change-related sea level rise scenarios;

- Availability of high resolution terrain data – no data was generally available for the area; and,
- Financial – as the project was to be managed from Sydney, expenditure on the LiDAR survey could be maximised by limiting travel expenditure.

Taken together, it was decided that savings in travel costs realised through selection of the Central and Hunter Coasts would facilitate maximum expenditure on the LiDAR survey and thereby deliver the greatest coverage possible.

The proposed study area took in the low lying sections within 10m of mean sea level of the Port Stephens, Newcastle City, Lake Macquarie City and Wyong Local Government Areas. Following the selection of this area, Gosford City Council expressed an interest in being a project partner. The Gosford City LGA is contiguous with the southern boundary of the proposed study area and the council had access to its own LiDAR data, albeit to a different specification to that proposed to be collected for this study. The project Steering Committee agreed to the incorporation of Gosford City Council into the study area. The project study area represents the area within which spatial modelling reported in the project case study would be undertaken. The final study area and LiDAR survey extent are shown in Figure 5.

The Central and Hunter Coasts study area (approximately 1,400 km^2) overlaps the Lower Hunter and Central Coast regions, both of which are the subject of state government regional strategies designed to guide land use to 2031 (Lower Hunter Regional Strategy, 2006; Draft Central Coast Regional Strategy, 2007). In the parlance of the “sea-change” phenomenon, the Central Coast is characterised by a community of “coastal commuters” occupying a suburban setting on the periphery of a major coastal city, Sydney. Similarly, the Lower Hunter is referred to as a “coastal city”, or a substantial conurbation beyond the state capital (Gurran et al., 2005). Both areas will experience significant developmental pressures over the coming decades with targets of an additional 224,250 people (831,000 in 2006), 151,000 new homes and 101,000 new jobs by 2031 (Lower Hunter Regional Strategy, 2006; Draft Central Coast Regional Strategy, 2006). The regional strategies state that future growth will not occur in areas exposed to natural hazards. Climate change is therefore seen as an important consideration and an area of ongoing research, confirming the value of the Central and Hunter Coasts as the project pilot study area.

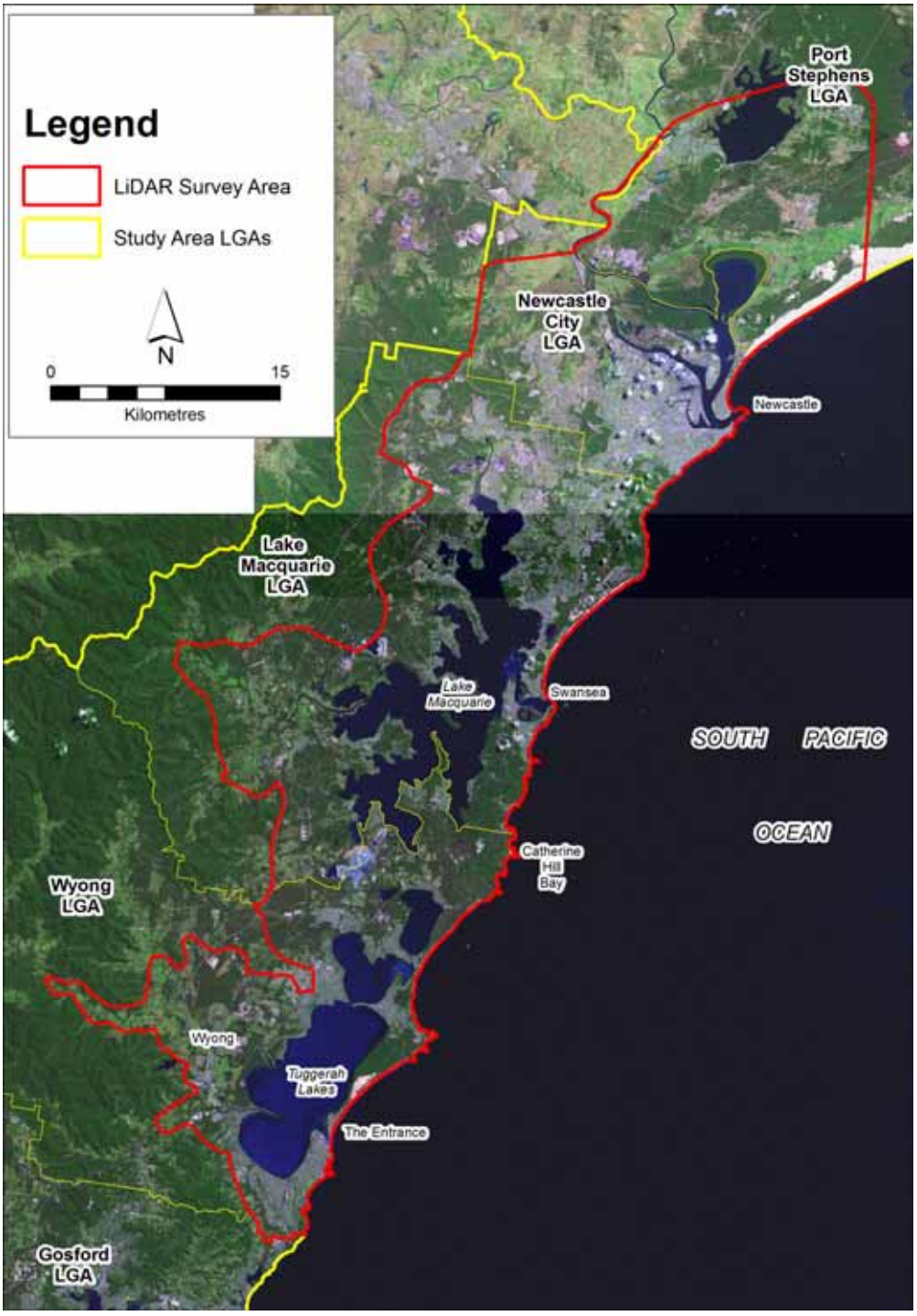


Figure 5. Climate change impacts and adaptation pilot study area on the NSW Central and Hunter Coasts. Study area takes in low lying areas (<10m above mean sea level) of the Port Stephens, Newcastle City, Lake Macquarie City, Wyong and Gosford City Local Government Areas. The LiDAR survey footprint (red outline) was determined by project funding and takes in low lying areas of the Port Stephens, Newcastle City, Lake Macquarie City and Wyong Local Government Areas. Note Gosford City LGA LiDAR data was collected independently of this project in 2005.

4.3 High Resolution Terrain Mapping

The conduct of a high resolution terrain survey over the study area, excluding the Gosford LGA, to one agreed specification was a key objective of the project. Equally important were securing the rights to the general use of the data and making provision for its distribution to a variety of government, industry, research and community stakeholders. These objectives were to be achieved through an open tender process for the acquisition of high resolution terrain data.

Development of a survey specification and list of deliverables for the tender involved consultation with local, state and national government bodies with either direct experience in these types of surveys or a high level of technical expertise in remote sensing methods. LiDAR technology was seen as the preferred method for delivering data meeting the immediate project objectives as well as the general needs of project partners, notably local government. The survey extent was determined by the project budget allocation from the Climate Change Impacts and Adaptation Program of $251,000 (ex GST). Technical specifications and deliverables were reviewed by the project Steering Committee prior to their acceptance and inclusion in contract tender documents. The main survey specifications and deliverables are set out below, further detail on technical specifications and the tender process can be found in Appendix B.

LiDAR Survey Specifications

Item	Description
A) Coverage	Continuous coverage over the Central and Hunter Coasts Study Area and extending beyond the Study Area boundary by 100 metres
B) Vertical Accuracy and Point Spacing	Vertical Accuracy: RMSE **0.15 metres or better** on clear ground, where RMSE represents accuracy to 1 sigma Average point density 1.3 metres
C) Absolute Horizontal Accuracy	RMSE **0.6 metres or better** on clear ground, where RMSE represents accuracy to 1 sigma
D) Time of Collection	LiDAR data over tidal areas must be collected within +/- 2 hours of local low tide so as to maximise data capture at elevations below 0m AHD

LiDAR Survey Deliverables

Description
LiDAR Datasets 1. Survey Flight Plan 2. Ground Control Cartographic Diagram 3. Quality Assurance Plan 4. Raw ALS Data All Returns 5. Raw ALS Data Ground Returns 6. Raw ALS Data Non Ground Returns 7. Tile Key Map Diagram Returns 8. Gridded DEM 2mX2m Bare Earth 9. Gridded DEM 10mX10m Bare Earth 10. Tile Key Map Diagram Gridded DEM 11. Smoothed Contours (0.5m interval) 12. Tile Key Map Smoothed Contours 13. LiDAR Intensity Image Mosaic 14. ALS Flight Lines 15. All Metadata to ANZLIC Standard

Following an open tender process conducted in late 2006, the contract for a high resolution terrain survey using LiDAR technology was awarded to Fugro Spatial Solutions P/L in January 2007. The survey was flown over a 1234km^2 area in January 2007 and the contract deliverables were provided to the Department of Planning in March 2007 for acceptance testing. Following a review of the contract deliverables to ensure they met the required specifications, particularly for vertical and horizontal accuracy, they were accepted by the Steering Committee in May 2007. A sample of the LiDAR data is shown in the digital elevation model in Figure 6.

The terms of agreement between the LiDAR contractor (Fugro Spatial Solutions P/L) and the Department of Planning are such that the state government owns the LiDAR contract deliverables and is free to distribute the data. The long term objective is for the state government custodian of elevation data, the Department of Lands, to manage access to and distribution of the LiDAR data. It is expected that selected data will become available to the widest possible audience at no charge through the Department of Lands online Spatial Information Exchange (http://www.maps.nsw.gov.au/). Where it is not technically feasible to deliver large datasets over the internet (eg. LiDAR point data of 100s of gigabyte in size), users will be able to request the data from the Department of Lands at a nominal cost (ie. $220 which represents the cost of data extraction and delivery) on portable hard disk drive in a similar manner to that currently used for the distribution of very large data sets.

By September 2007, a formal arrangement had been agreed between the Departments of Planning and Lands for the long-term management and distribution of the Central and Hunter Coasts LiDAR data consistent with the objectives of the project MoU. Project partners (ie. Departments of Planning, Lands and Environment and Climate Change; Port Stephens, Newcastle, Lake Macquarie and Wyong Councils; Hunter-Central Rivers CMA; and Hunter Water Corporation) had access to the complete LiDAR dataset from June 2007 for the purposes of familiarisation and application in a range of business processes.

4.4 Case Study

The pilot case study was designed to demonstrate how high resolution terrain data can be used by state government agencies, councils and catchment management authorities in examining the potential impacts of any climate change scenario on coastal communities. The approach taken was to apply spatial modelling techniques commonly available in geographic information systems (GIS) to identify the elevation of a selected range of built, natural and cultural assets in an assessment of their potential vulnerability to climate change related sea level rise and coastal inundation.

The modelling required the compilation of relevant spatial datasets from state and local government sources prior to use. Details of the data compilation and spatial analyses undertaken for the case study are contained in Appendices C and D respectively. Tabulated summaries of the elevation modelling are contained in Appendix E.

The results presented in this report emphasise the value of combining high resolution terrain data and existing spatial datasets held by state and local governments in examining the potential vulnerability of low lying coastal areas to the impacts of climate change at a range

of scales (ie. regional to local government area to building lot). The modelling has focussed on a restricted set of data to illustrate the ease with which the terrain data can be integrated with other spatial dataset, the results presented here do not constitute, nor are intended to be, a replacement for the detailed site-specific process modelling required to be undertaken for integrated coastal zone management (NSW Department. Natural Resources, 2007).

Regional Elevation Modelling

A fundamental product of the project was a digital elevation model (DEM) for the Central and Hunter Coasts (Figure 6). The DEM shows the distribution of low lying coastal areas potentially vulnerable to both contemporary hazards of flooding and shoreline erosion as well as future hazards associated with climate change (ie. elevated sea levels and increased storminess). These areas are typically located adjacent to the ocean entrances of estuaries (eg. Newcastle Harbour, Lake Macquarie, Tuggerah Lakes, Brisbane Waters) and along the floodplains of creeks and rivers draining to them. Not surprisingly, these areas are commonly comprised of unconsolidated to semi consolidated marine, estuarine and river sediments (Figures 7 and 8). The combination of low land elevations and erodible substrates adjacent to the coast are key indicators for potential vulnerability to climate change related sea level rise and increased storminess (Sharples, 2006). Of course elevated sea levels can occur under current climatic conditions, such as that experienced in the coastal storms that swept through the study area in June 2007. The terrain data collected for this project are equally relevant to assessments of coastal vulnerability for both contemporary and potential future coastal hazards.

The elevation data has been combined with a range of existing datasets describing land use zones, actual land use and assets within the low lying coastal areas. Selected results are shown in Figures 9 to 14 with further detail contained in the tabulated summaries in Appendix E. Figure 9 integrates the LiDAR terrain data with generalised local environment plan zonings for the entire study area to indicate which are the dominant land use zones below 10m AHD[4]. Figure 10 integrates the LiDAR terrain data with DECC mapped land uses.

[4]AHD Australian Height Datum - datum used for determination of elevations. Mean Sea Level is c.0m AHD

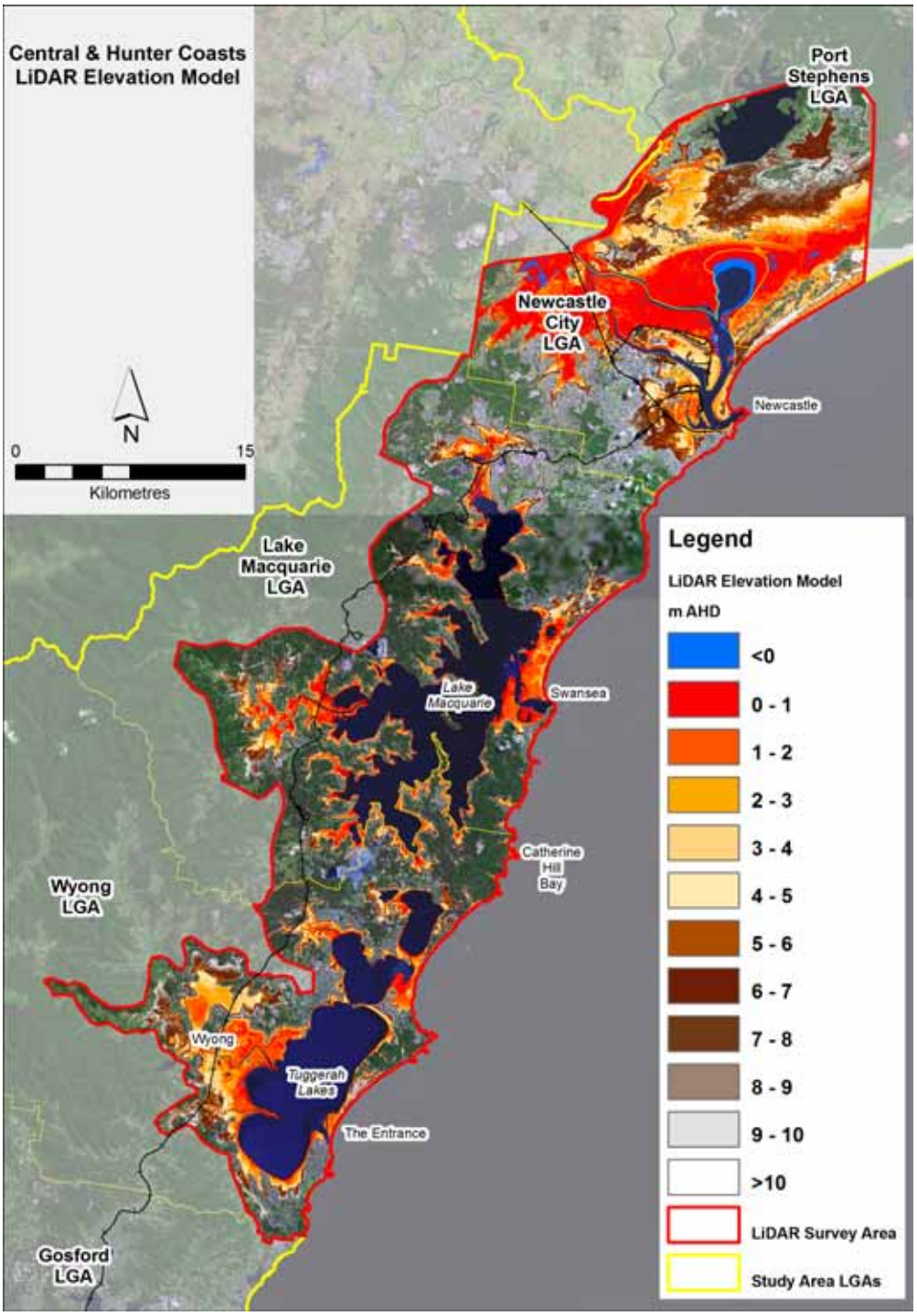


Figure 6. Digital elevation model (DEM) of NSW Central and Hunter Coasts. The DEM highlights areas below 10m AHD and is derived from the project LiDAR survey completed in January 2007. Survey area of c.1234km^2 includes Port Stephens (22% of LGA), Newcastle City (93%), Lake Macquarie (67%) and Wyong (40%) local government areas. Gosford LGA LiDAR-derived DEM (not shown) was acquired in 2005.

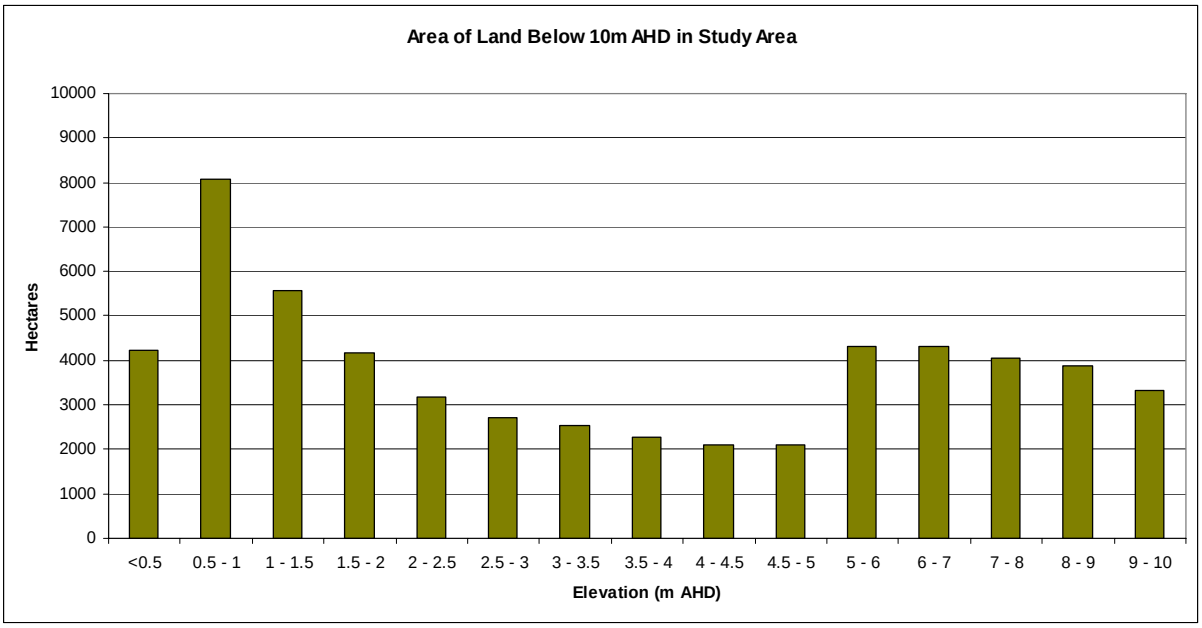


Figure 7. Area of low lying land in the study area (ie. Port Stephens, Newcastle, Lake Macquarie, Wyong and Gosford LGAs covered by LiDAR data). Derived from classified LiDAR DEMs. See Appendix E for tabulated data.

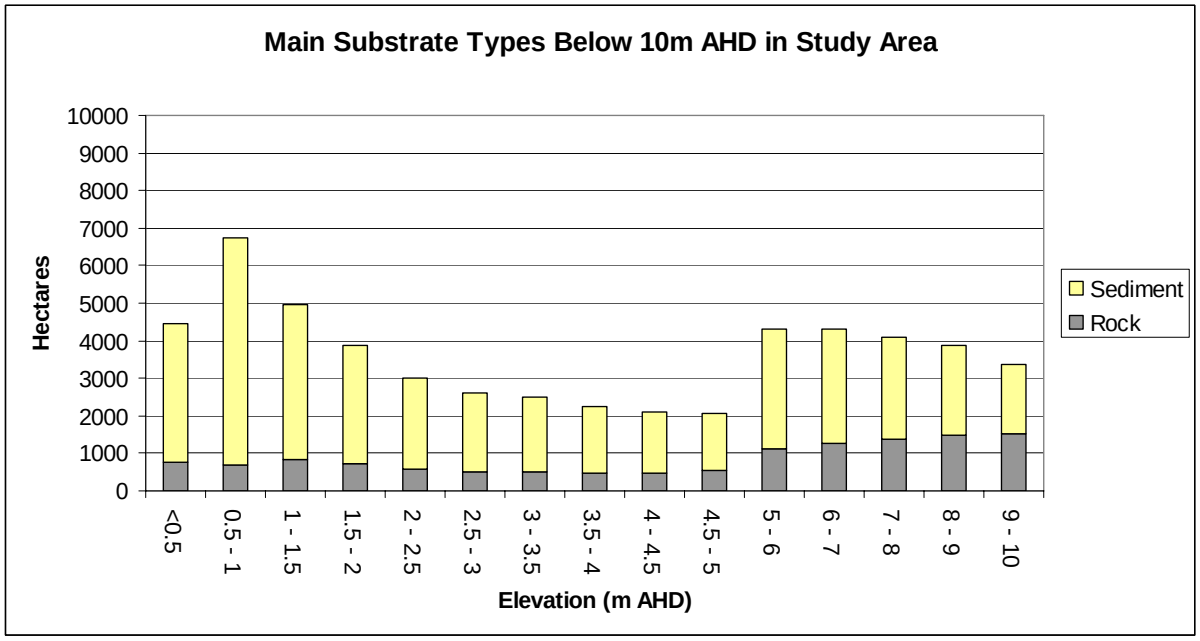


Figure 8. Simplified geology of low lying land in the study area. Based on LiDAR DEMs and 1:250,000 scale Geology. See Appendix E for tabulated data.

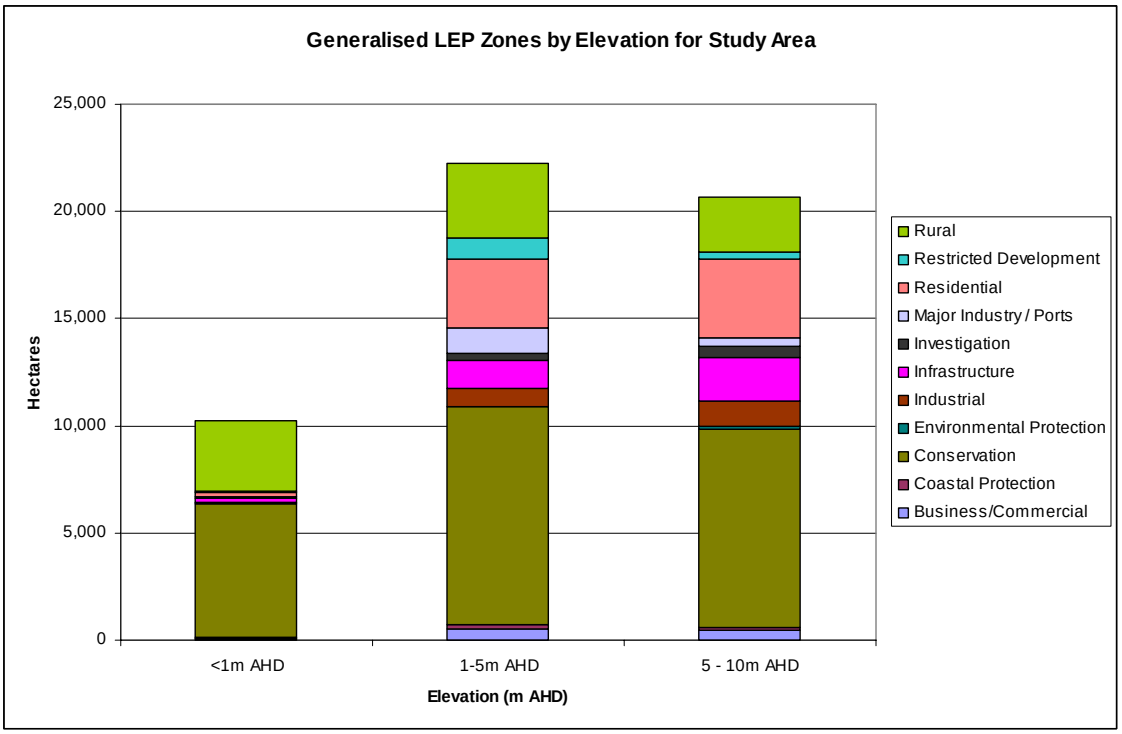


Figure 9. Summary of generalised Local Environment Plan zones by elevation below 10m AHD in the study area. For interval <1m AHD, the top three zonings are Conservation (6,256Ha), Rural (3,266Ha) and Infrastructure (209Ha). Residential accounts for 164Ha. Lake Macquarie LGA contains the highest proportion (111Ha) of Residential zoned land below 1m AHD. See Appendix C for information on LEP generalised zones and Appendix E for tabulated data.

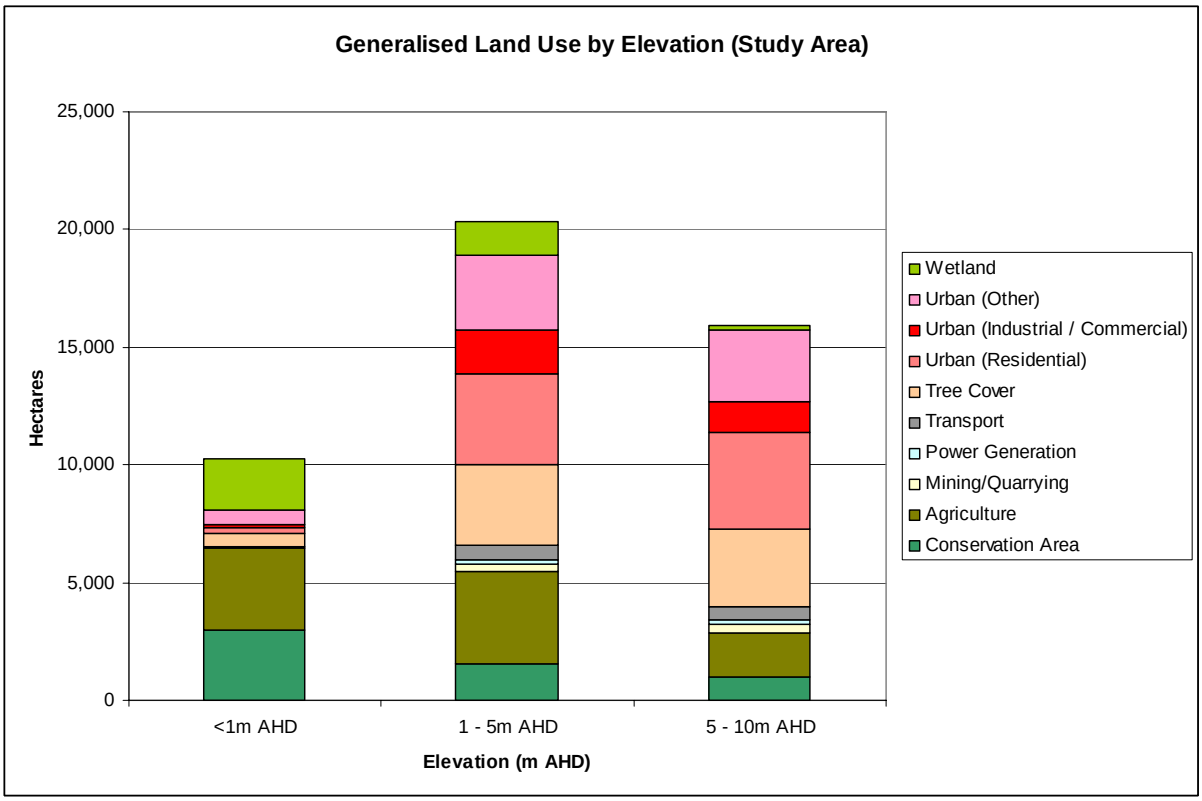


Figure 10. Summary of generalised Land Use categories by elevation below 10m AHD in the study area (ie. areas of Port Stephens, Newcastle, Lake Macquarie, Wyong and Gosford LGAs covered by LiDAR data). For the interval <1m AHD, the top three land use categories are Agriculture (3465Ha), Conservation (2975Ha) and Wetland (2198Ha). Total Urban Land Use for the interval <1m AHD is estimated at 952Ha of which 26% is Urban Residential. Lake Macquarie LGA has the largest area of Urban land use (c.382Ha) below 1m AHD. Figure based on combination of LiDAR DEMs and Department of Environment and Climate Change Land Use Mapping – Eastern New South Wales conducted since 2001. See Appendix E for tabulated data.

Local environment plan zones (Figure 9) represent potential land use, while generalised land use (Figure 10) represents actual land use. The two datasets are consistent in identifying that conservation and rural land uses dominate within 1m of mean sea level (MSL) and that residential zones (c.2%) and urban land use (c.9%) represent a relatively small proportion of the totals in the same interval. Total areas of residential zoning and urban land use increase markedly in the 1-5m elevation band (Figures 9 and 10).

Undoubtedly there are limitations in the absolute number of hectares for the zonings and land use reported here for reasons to do with the reliability of the underlying datasets[5]. However, what is clear is that the relative proportions of residential land zones and use increase markedly in elevation band 1-5m AHD. Comparable trends are observed for other indicators of urban land use in the study area such as the number of addresses (Figure 11) and length of road (Figure 12) both of which show a marked increase above the 1m AHD. For natural systems and indigenous cultural heritage the reverse pattern occurs (Figures 13

[5] Note that this conclusion extends to all datasets examined for this report. The absolute numbers of addresses, lengths of road, area of SEPP14 wetlands etc. presented here must be viewed as indicative only.

and 14), highlighting the challenge of managing issues of natural and cultural heritage versus urban development in the face of climate change associated sea level rise.

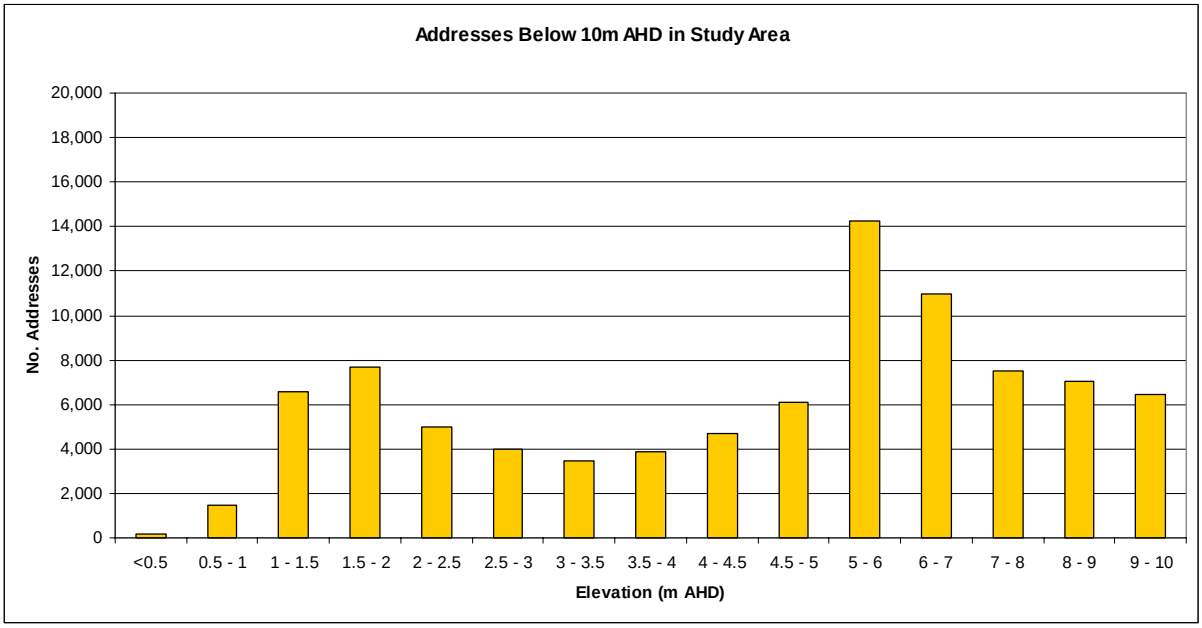


Figure 11. Number of addresses below 10m AHD in study area. Based on LiDAR DEMs and Geocoded National Address File (GNAF). See Appendix E for tabulated data.

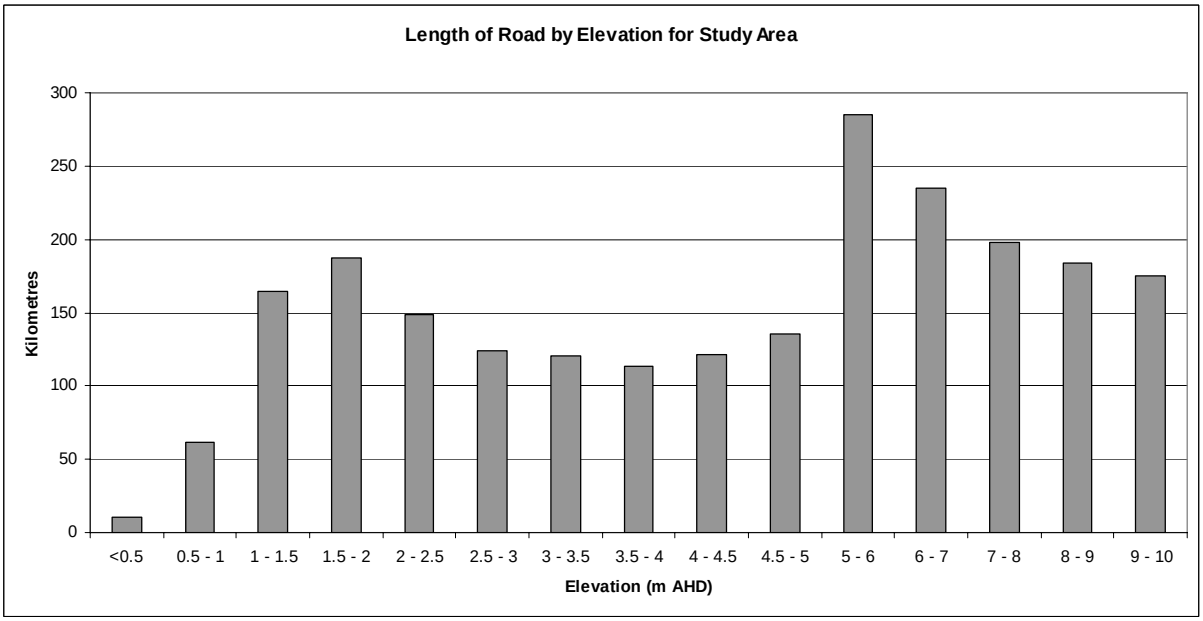


Figure 12. Length of road by elevation below 10m AHD in the study area. Of the 72km of road below 1m AHD in the study area, most occurs in Lake Macquarie (39%) followed by Newcastle (24%) and Gosford (16%) LGAs. See Appendix E for tabulated data.

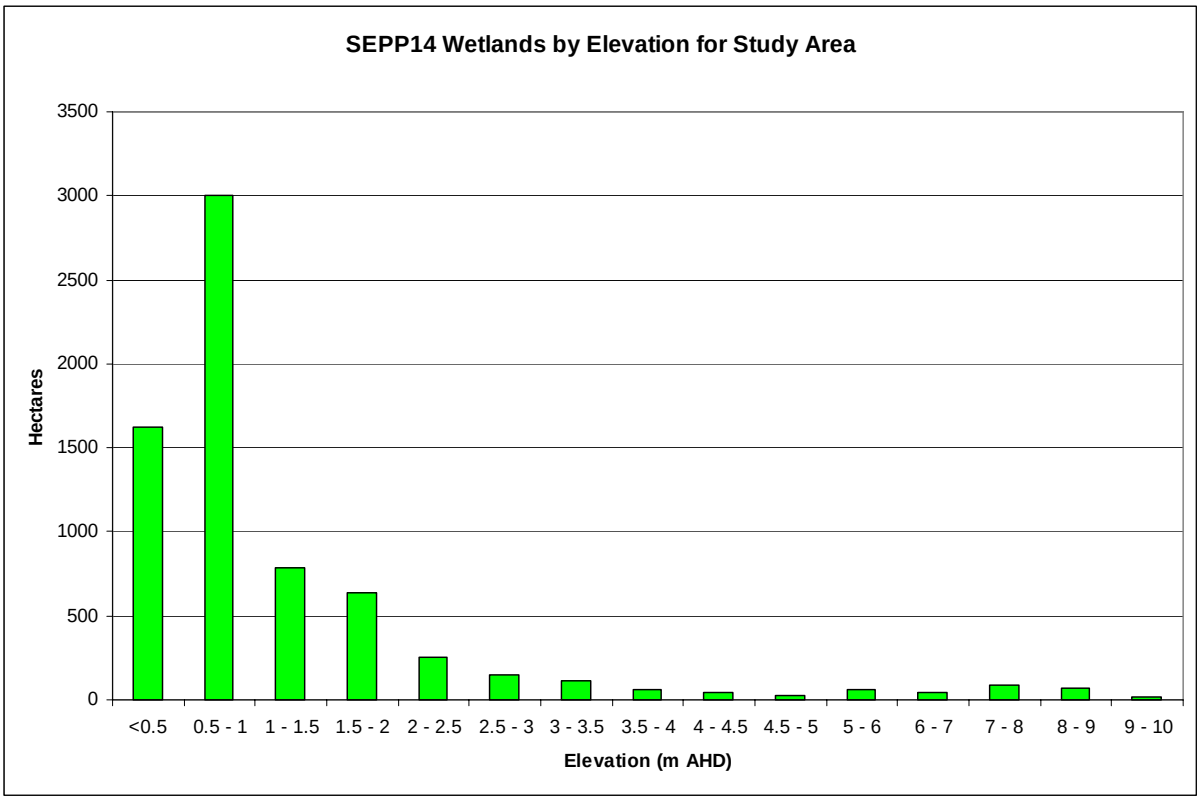


Figure 13. Area of SEPP14 wetlands below 10m AHD in study area. Of the 6,977Ha of SEPP14 wetlands below this elevation, 4,623Ha (66%) occurs within 1m of mean sea level. See Appendix E for tabulated data.

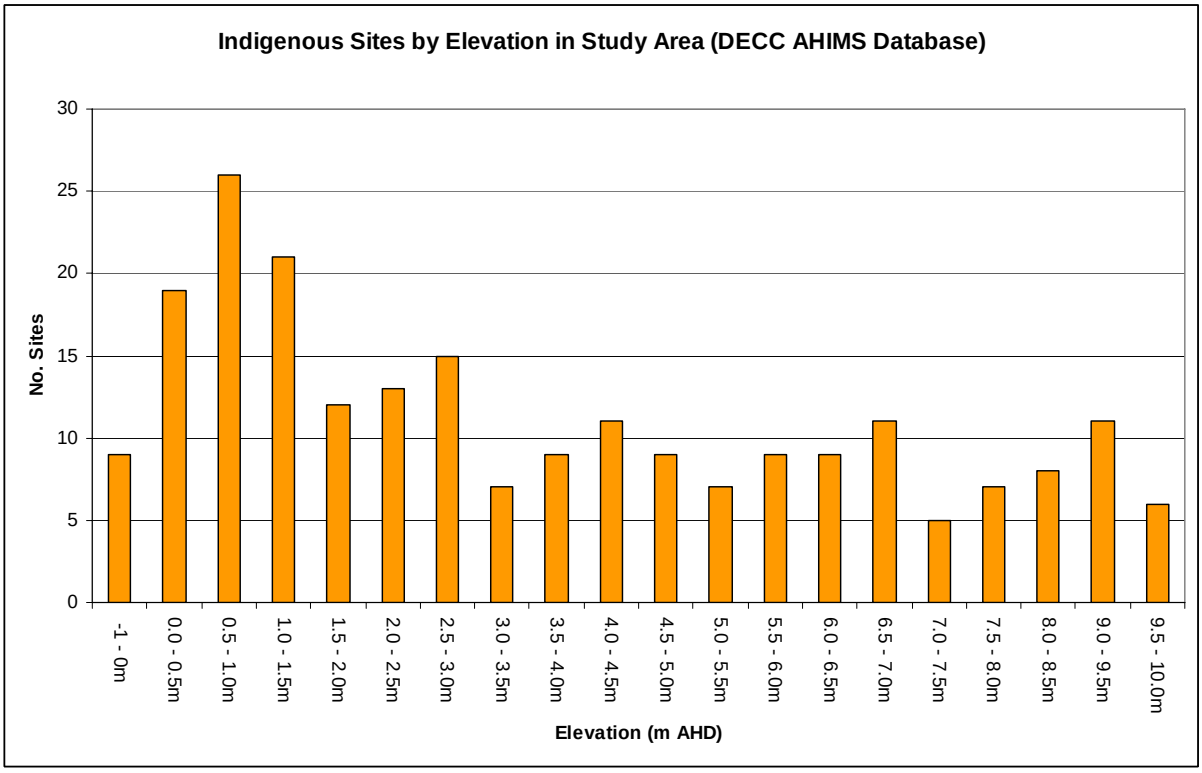


Figure 14. Number of classified indigenous cultural sites below 10m AHD in study area. Chart based on data from Aboriginal Heritage Information Management System (DECC). Middens and camp sites represent the main sites below 1m AHD.

Local Government Area Elevation Modelling

A similar set of analyses of asset types by elevation to that completed for the entire study area is available for each of the local government areas: Gosford City (Figures 15 to 23), Wyong Shire (Figures 24 to 35), Lake Macquarie City (Figures 36 to 46), Newcastle City (Figures 47 to 56) and Port Stephens (Figures 57 to 65). All figures are based on tabulated data found in Appendix E.

The figures contain summaries of elevation modelling for a mixture of available state and local government spatial data and illustrate how GIS information, whether it be point, line or polygon type features, are all amenable to analysis incorporating the LiDAR data. The local government area analyses describe different patterns of asset vulnerability to potential climate change associated sea level rise which are related to the local geomorphology. One constant in all LGAs is the proximity to present sea level of a range of asset types along exposed and protected shorelines.

The absolute numbers for assets by elevation presented in this report ultimately rely on the accuracy of the generally available datasets describing land use zonings, roads, railways, addresses and the like. No checking of the reliability of these datasets has been undertaken, datasets have been used “as supplied” by the respective data custodians. As such, the values shown in the following figures and charts and summarised in Appendix E should be viewed as indicative. In all instances a thorough assessment of asset vulnerability will require further analyses to verify the reliability of the datasets used in this report.

Gosford City LGA

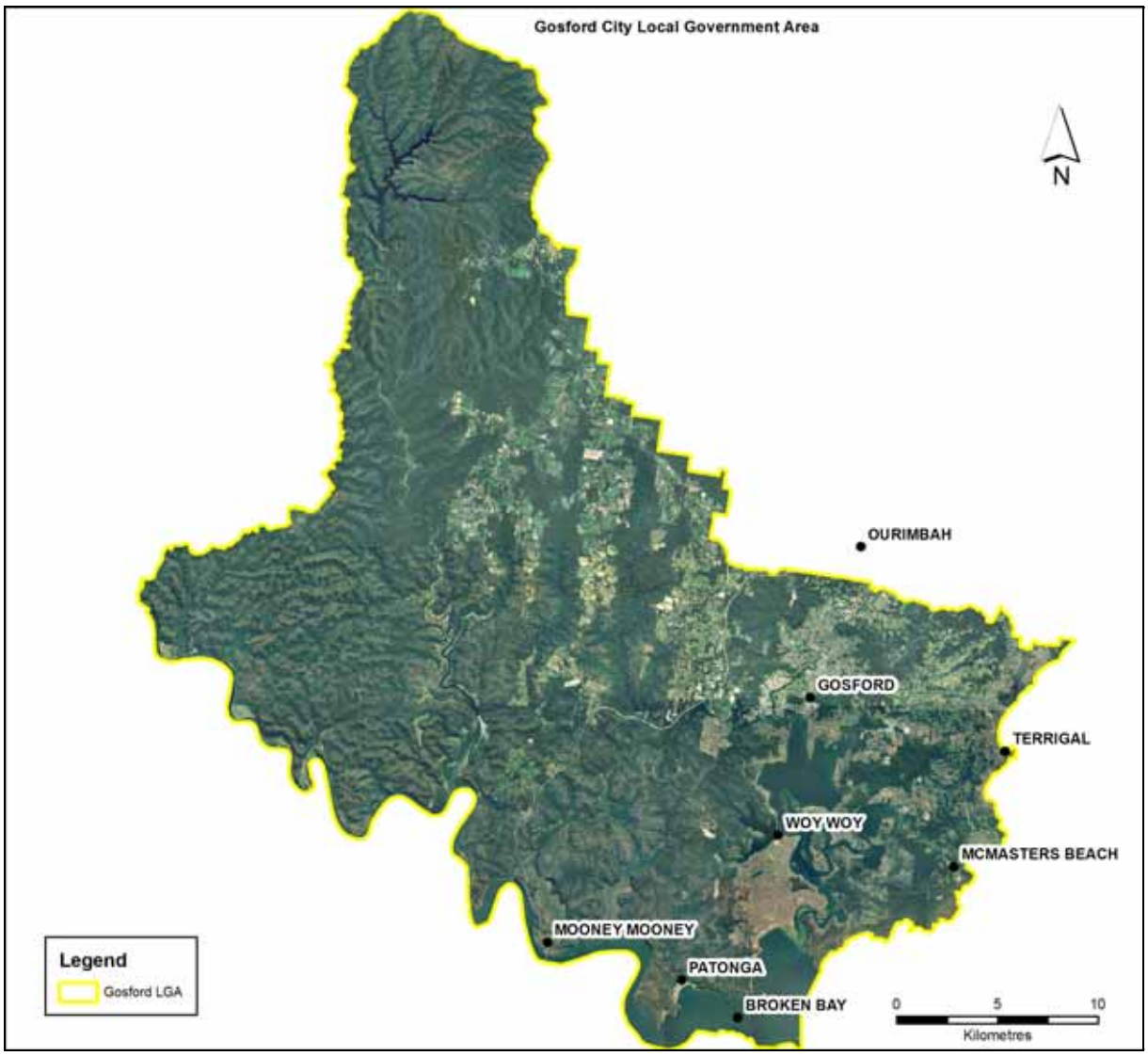


Figure 15. Gosford City Council local government area. Council acquired its own LiDAR and DEM in 2005 and analyses presented here are based on these data. Total LGA area is c.1,030Km^2, low lying areas examined for this project comprise c.11% of the LGA.

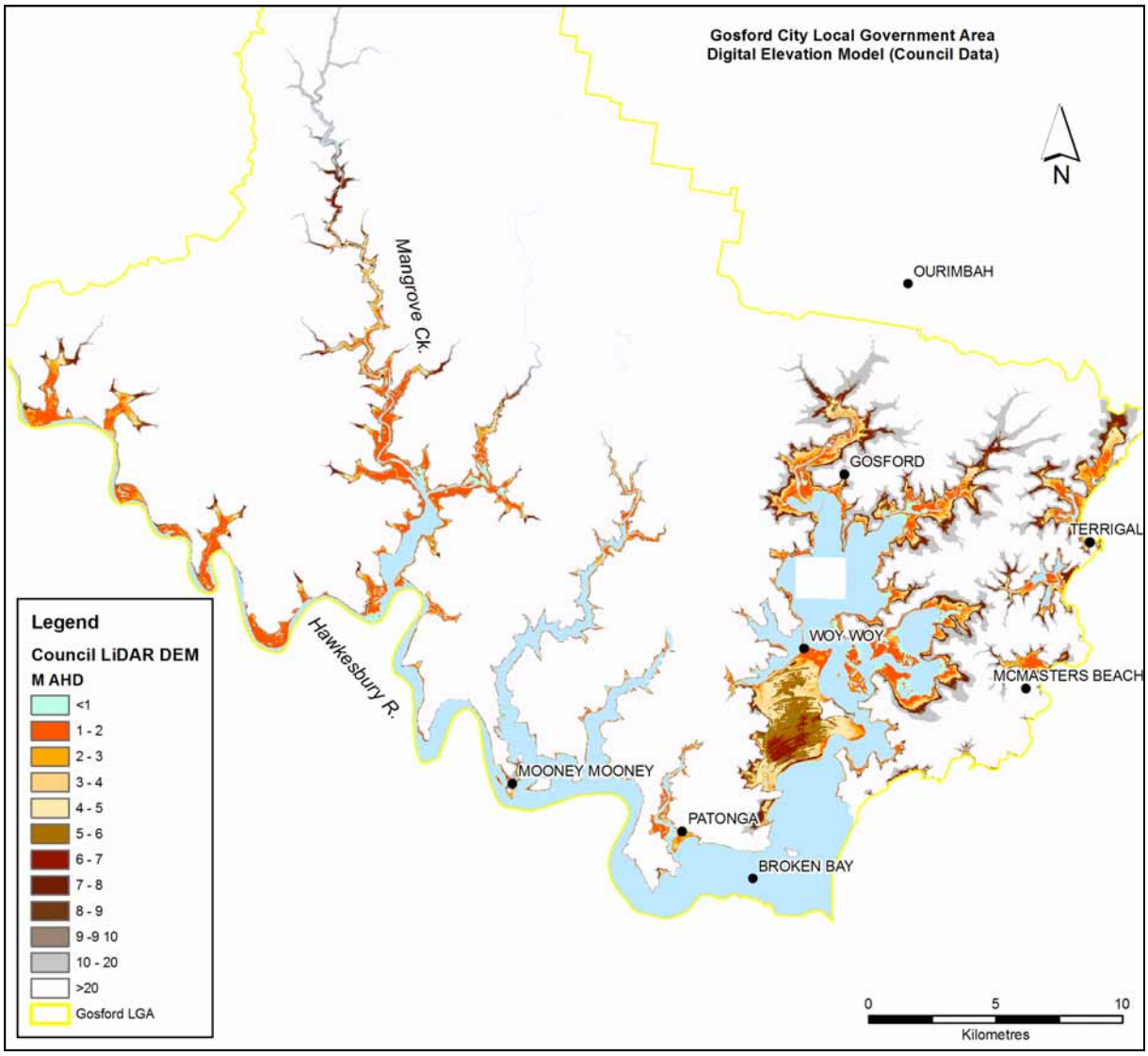


Figure 16. Digital elevation model (DEM) of areas below 20m AHD for the Gosford City LGA. Main areas of low lying land (<10m AHD) occur in the shorelines adjacent to Broken Bay, around the foreshores of Brisbane Waters and within the river valleys draining to the Hawkesbury River. Blank area in Brisbane Waters is an area of no data in DEM.

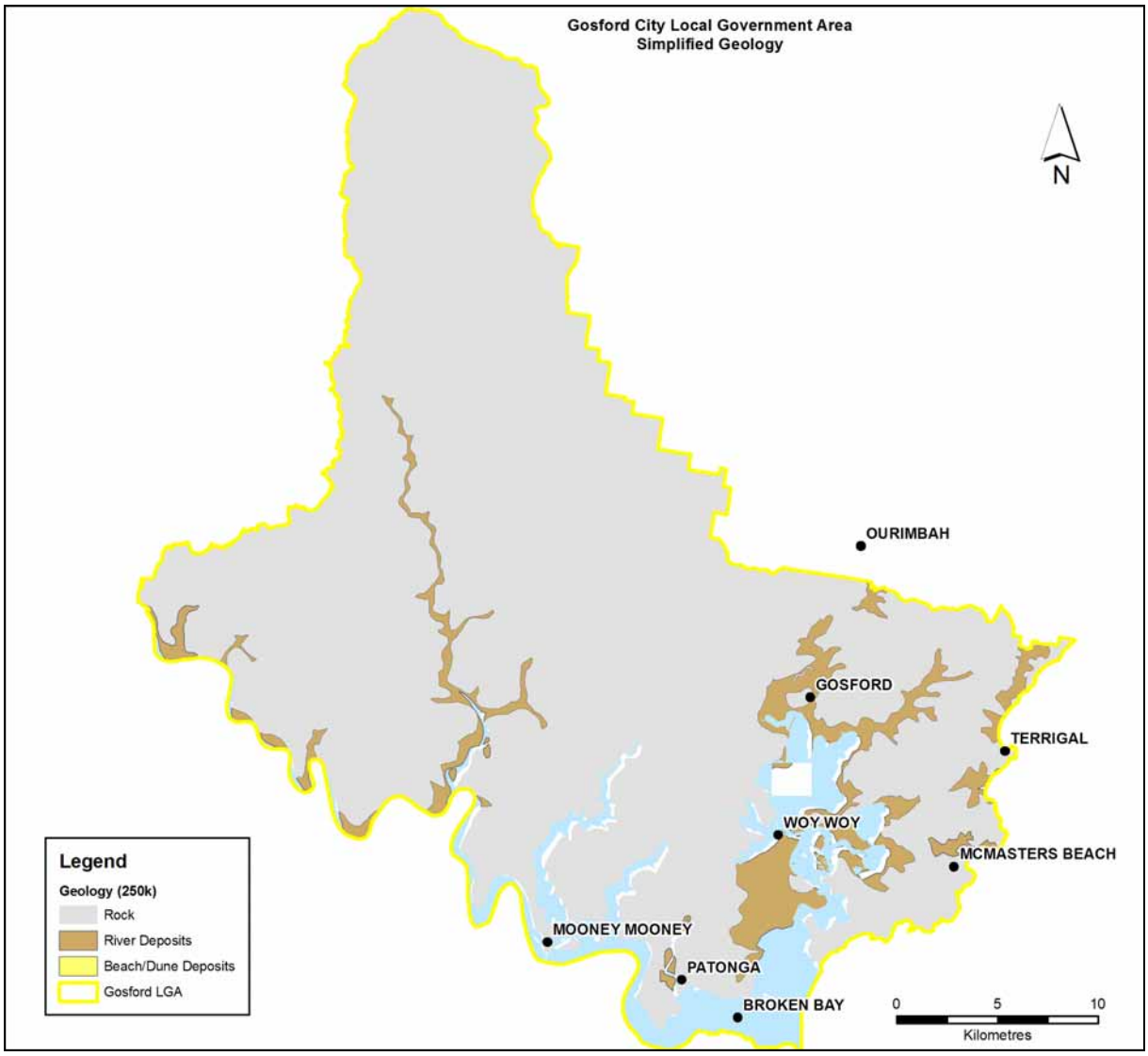
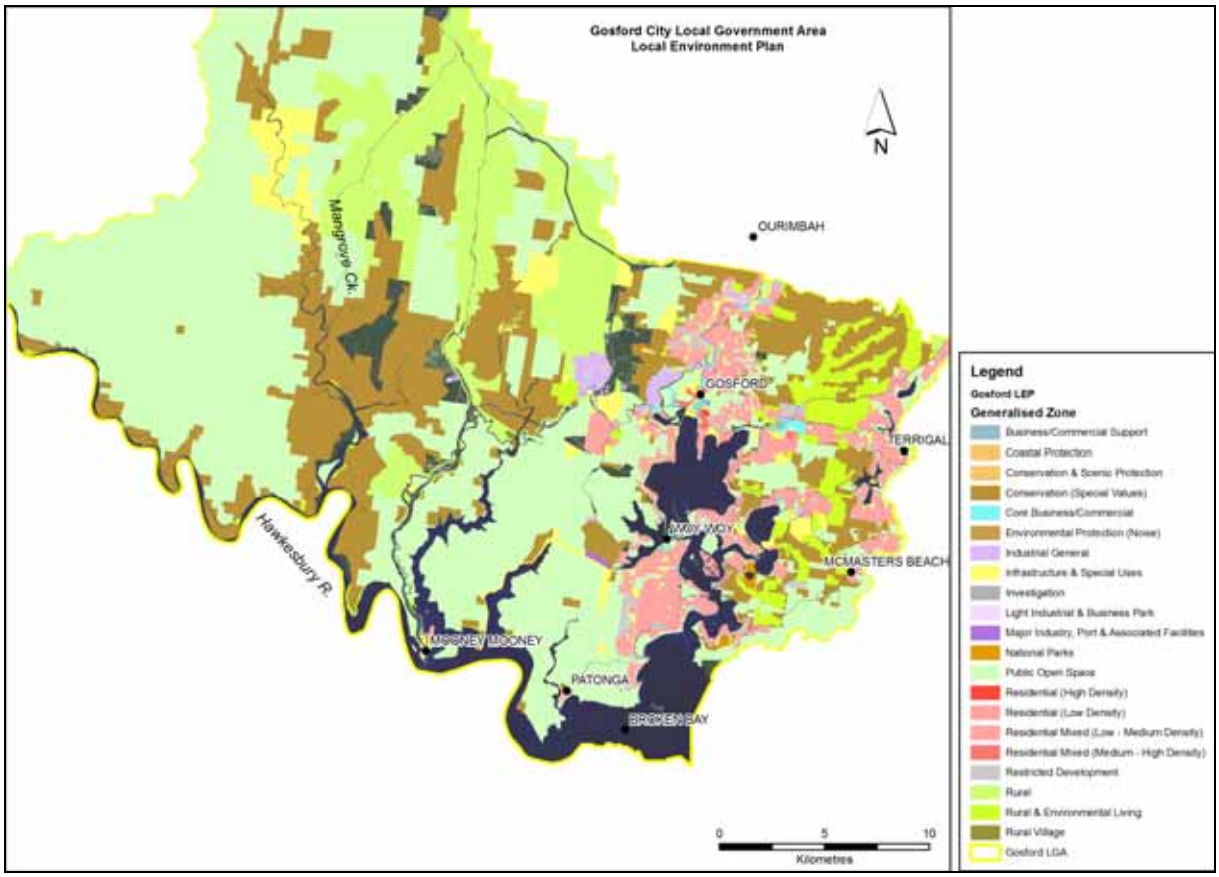


Figure 17. Main geological units of the Gosford City LGA. A comparison with the DEM for the same area will show majority (c.76%) of low lying areas are comprised of unconsolidated to semi-consolidated river and beach/dune deposits.



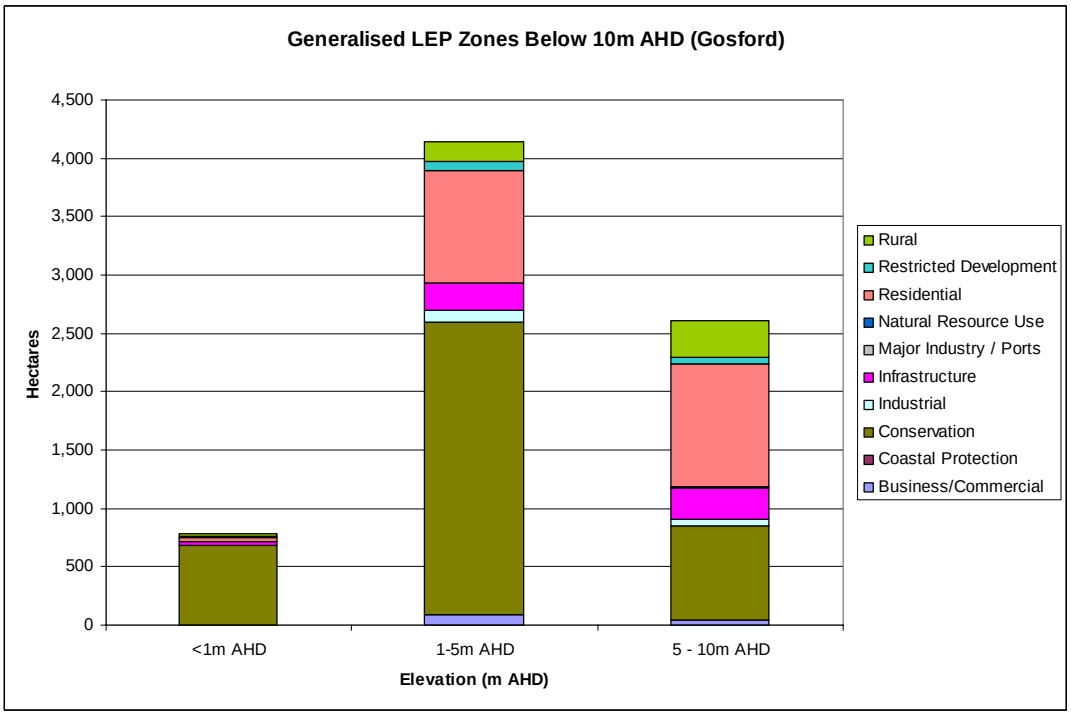
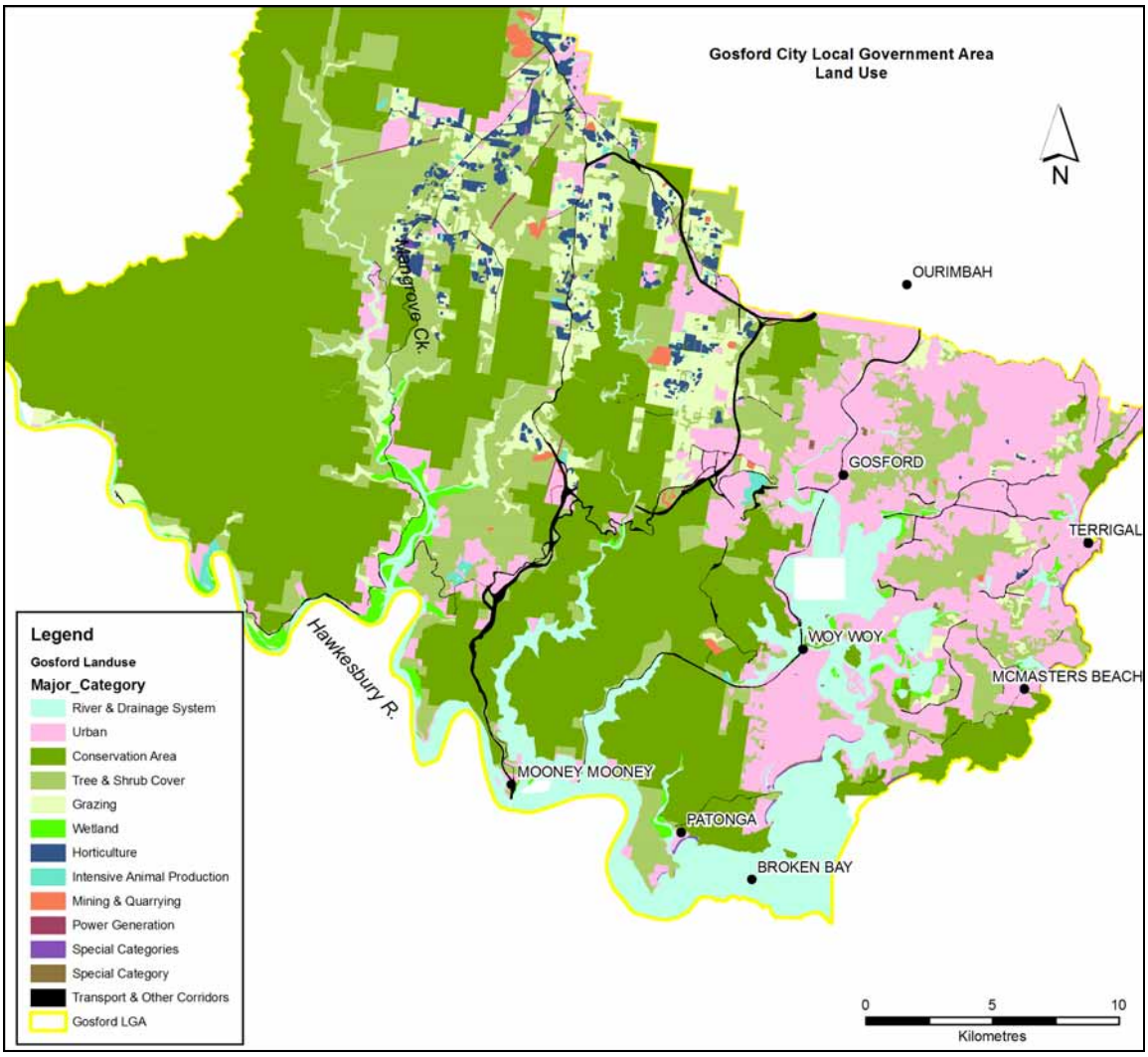


Figure 18. Map and chart showing generalised LEP zones and their distribution by elevation below 10m AHD for Gosford City LGA. For interval <1m AHD, the top three zonings are Conservation (684Ha), Residential (32Ha) and Infrastructure (28Ha). Note that number of categories in chart legend differs from that in map as former relates only to those zones encountered below 10m AHD.



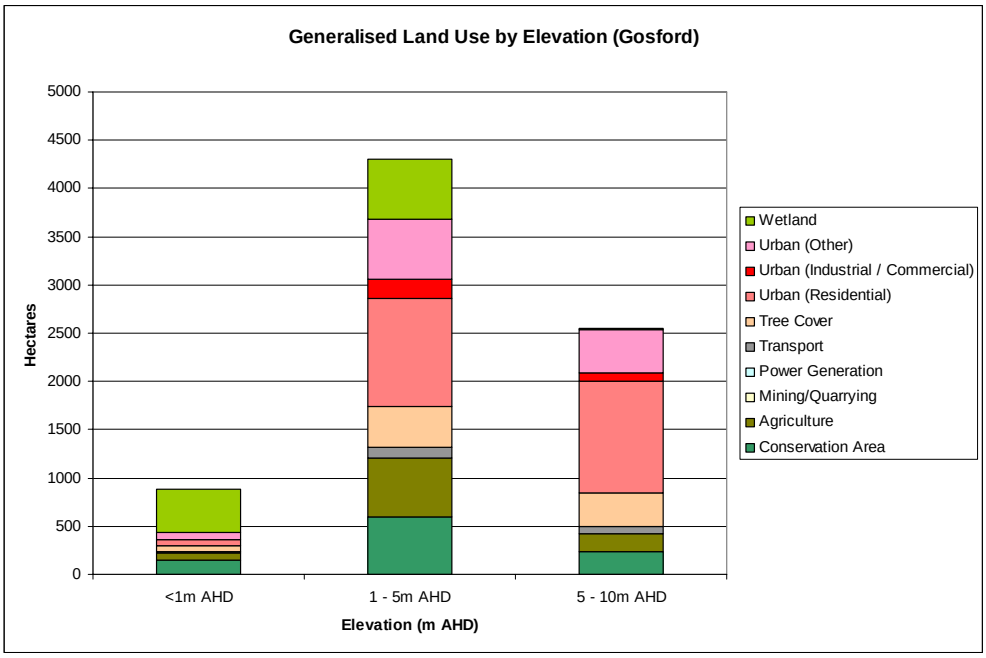
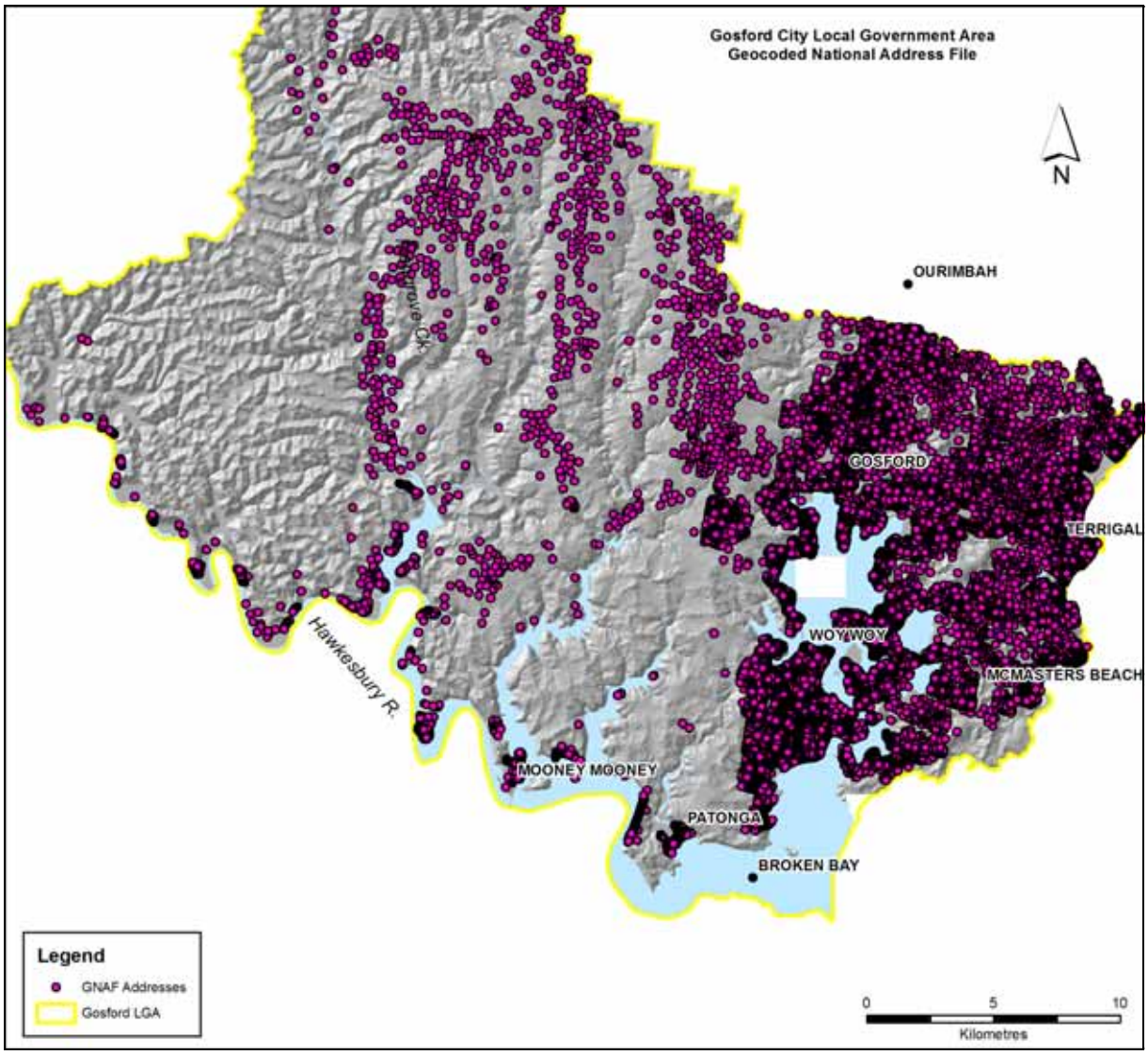


Figure 19. Map and chart showing generalised Land Use categories and their distribution by elevation below 10m AHD for Gosford LGA. For interval <1m AHD, major land use category is Wetland (444Ha), Urban Residential comprises 56Ha. Note that number of categories in chart legend differs from that in map as former relates only to those land uses encountered below 10m AHD.



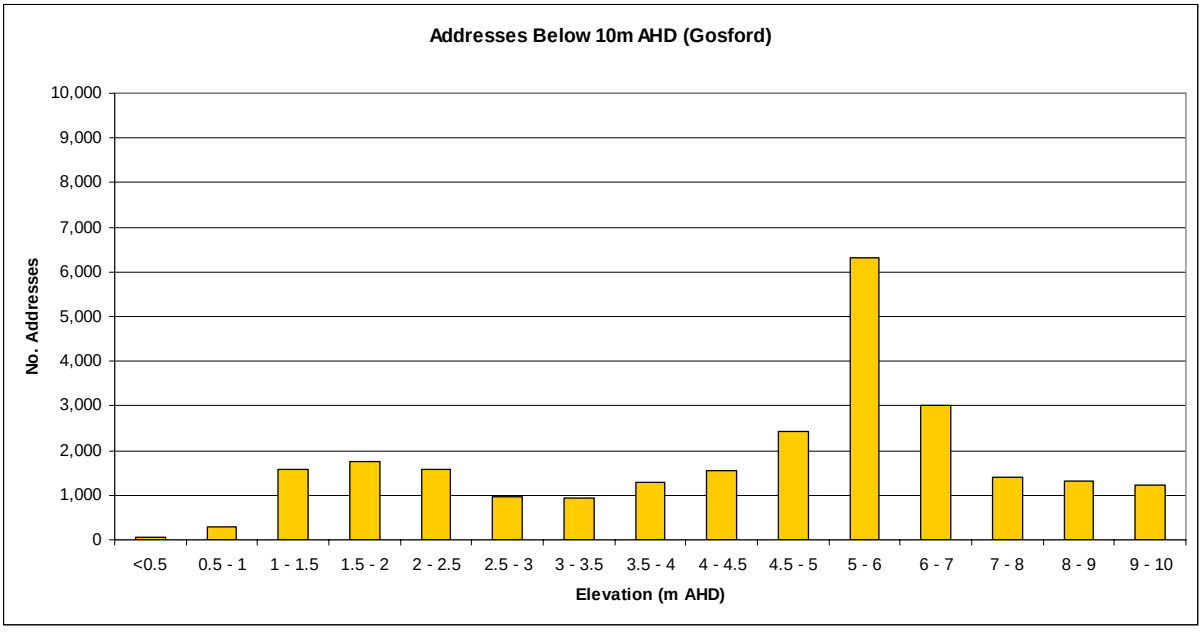
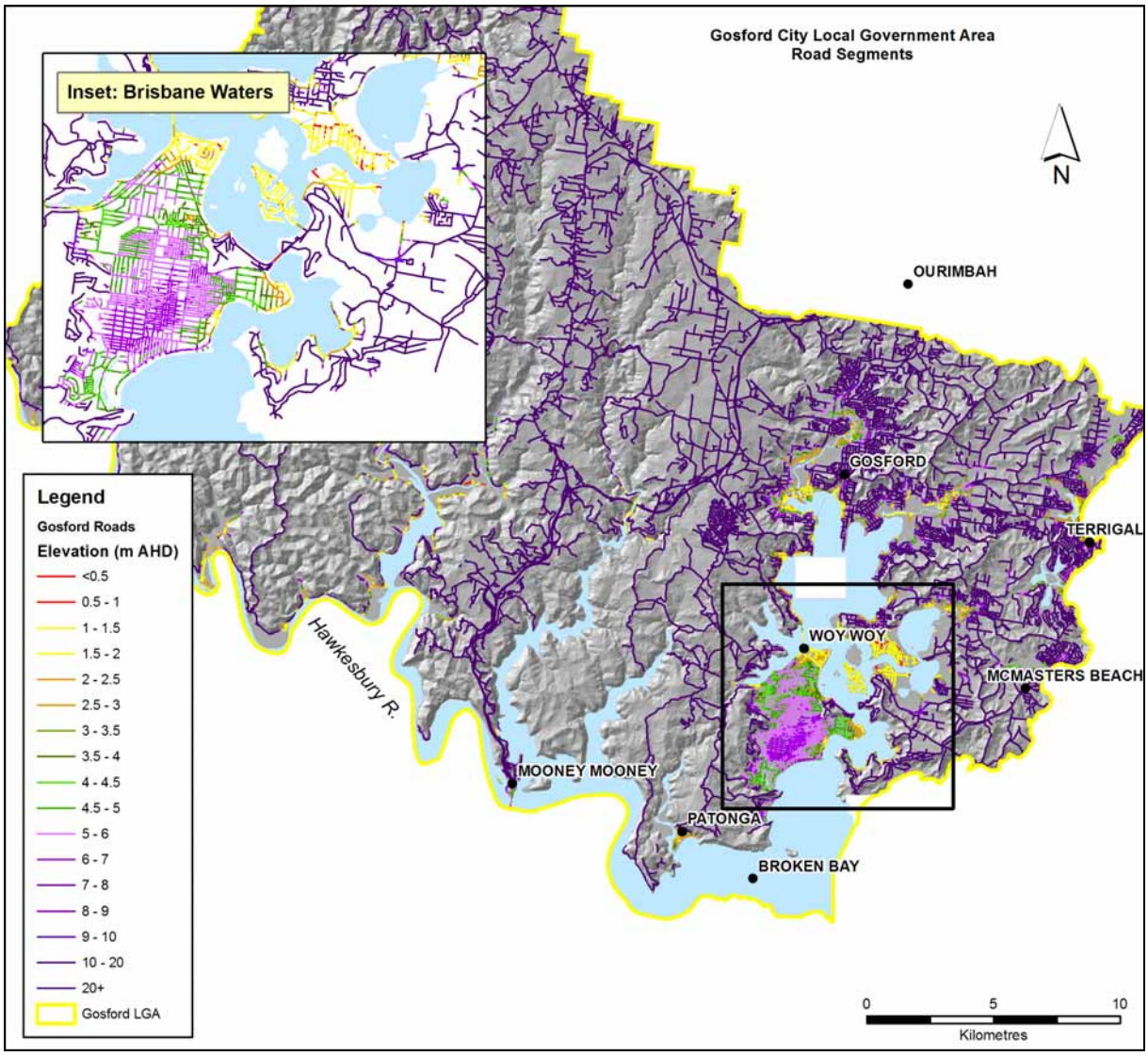


Figure 20. Map showing distribution of addresses in Gosford LGA. Chart classifies addresses from GNAF database by elevation below 10m AHD.



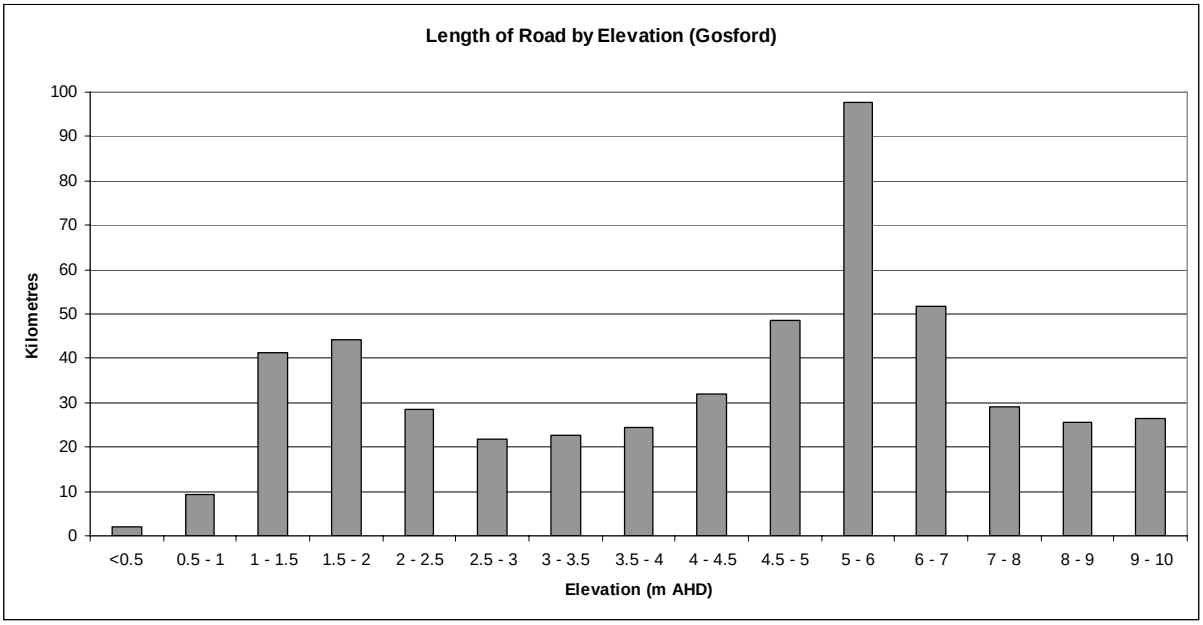


Figure 21. Map showing roads classified by elevation in Gosford LGA. Chart shows elevation of roads below 10m AHD.

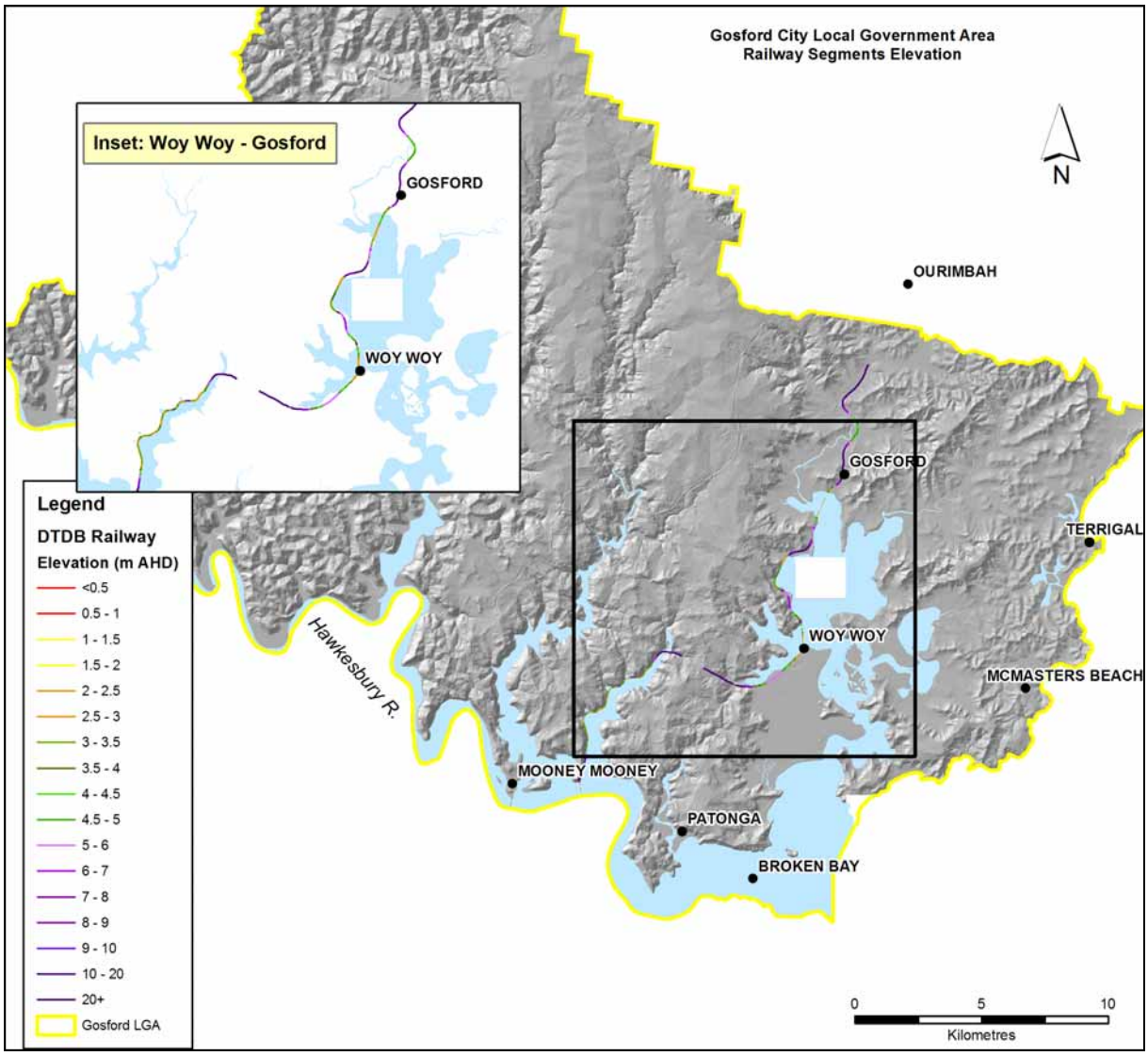
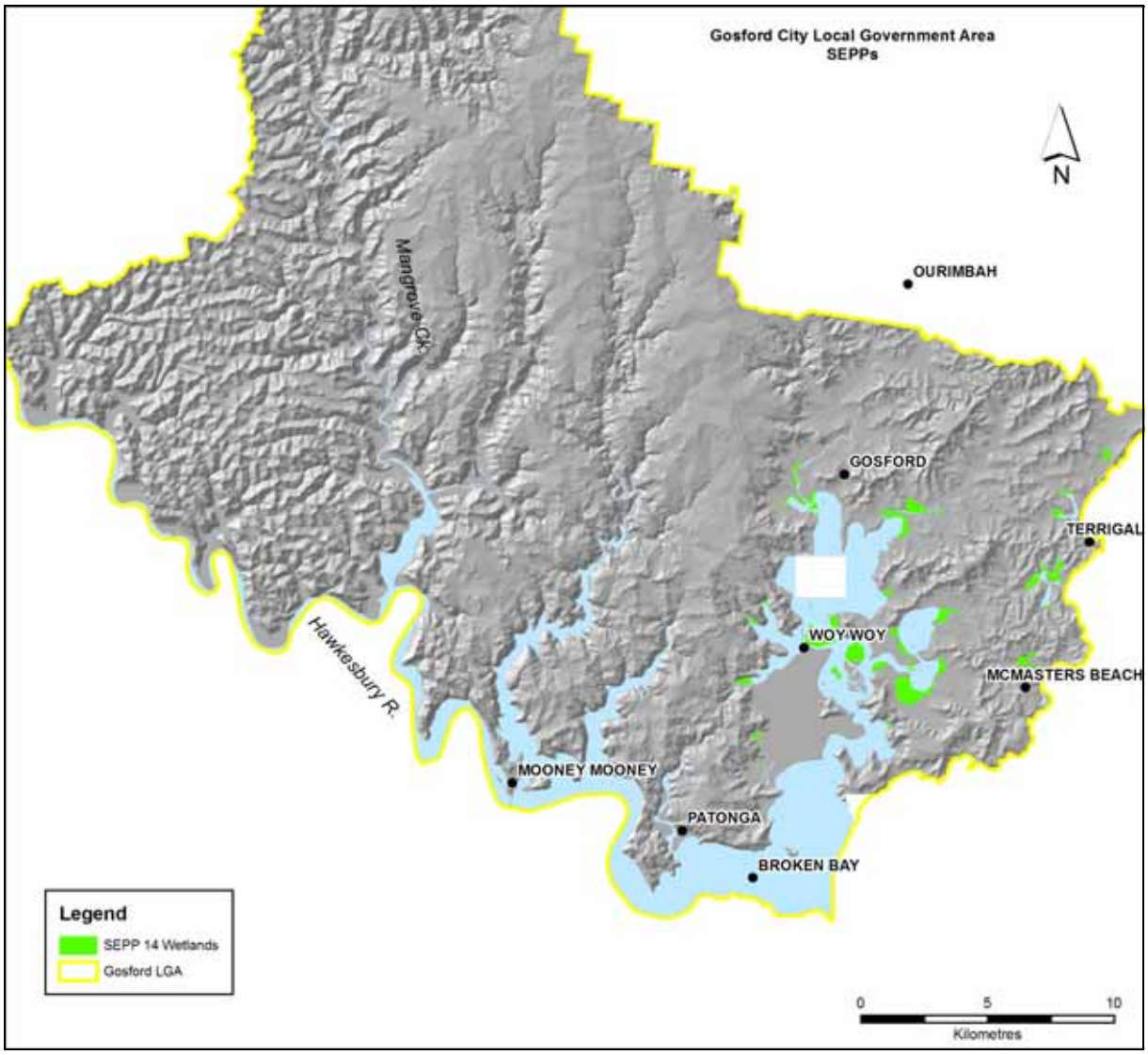


Figure 22. Elevation of main northern railroad in Gosford LGA.



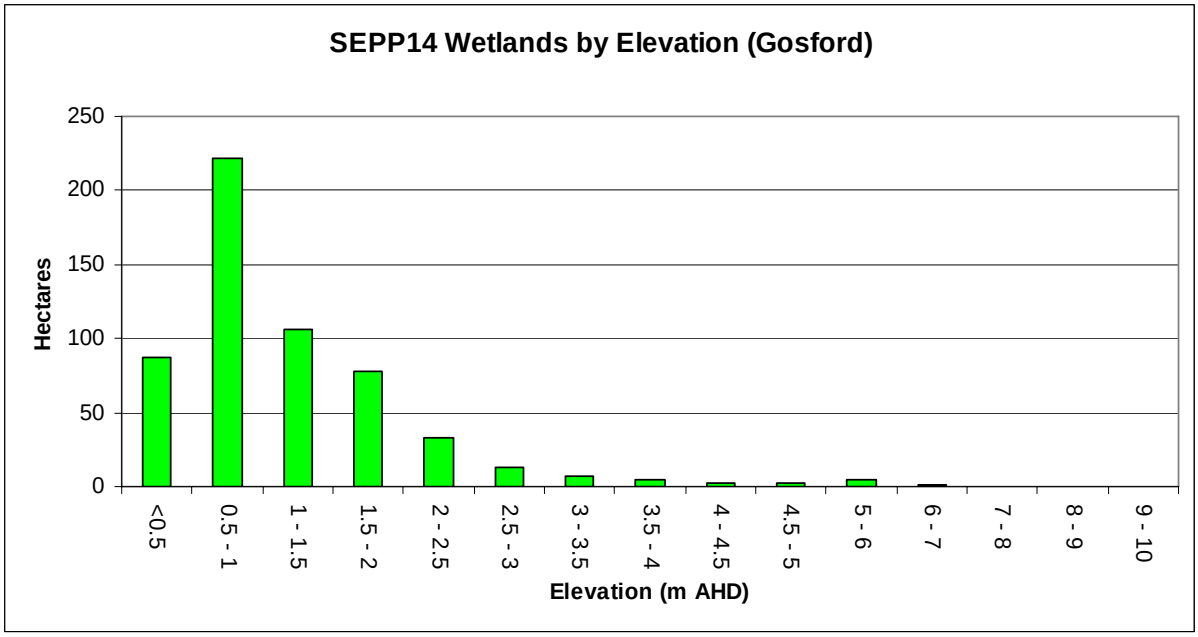


Figure 23. Map and chart showing distribution of SEPP14 Wetlands below 10m AHD in Gosford LGA.

Wyong Shire LGA

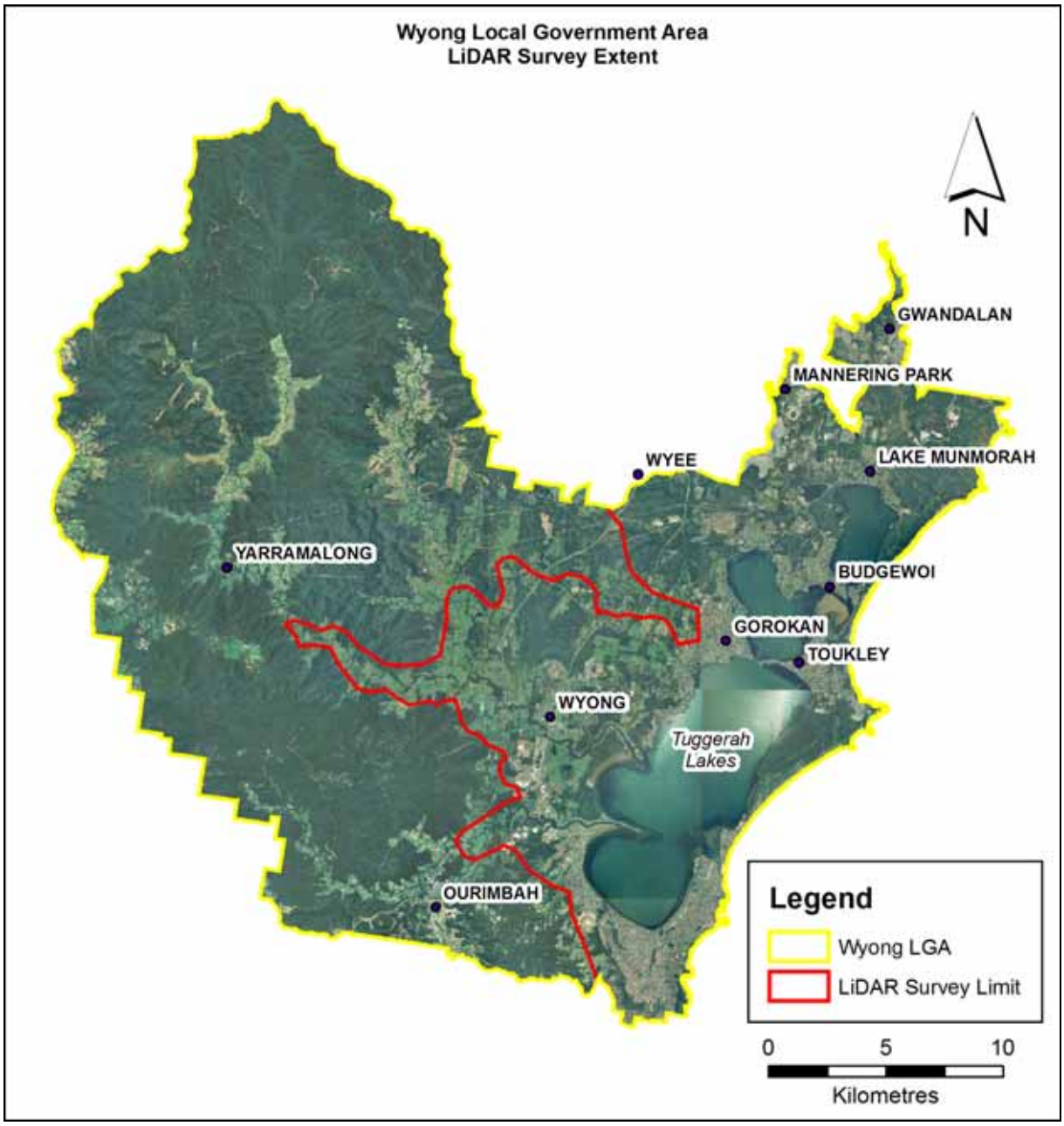


Figure 24. Wyong Shire Council local government area. LGA boundary and western limit of LiDAR survey conducted in January 2007 shown. Total LGA area is c.827Km^2, LiDAR covers approximately 40% of the LGA.

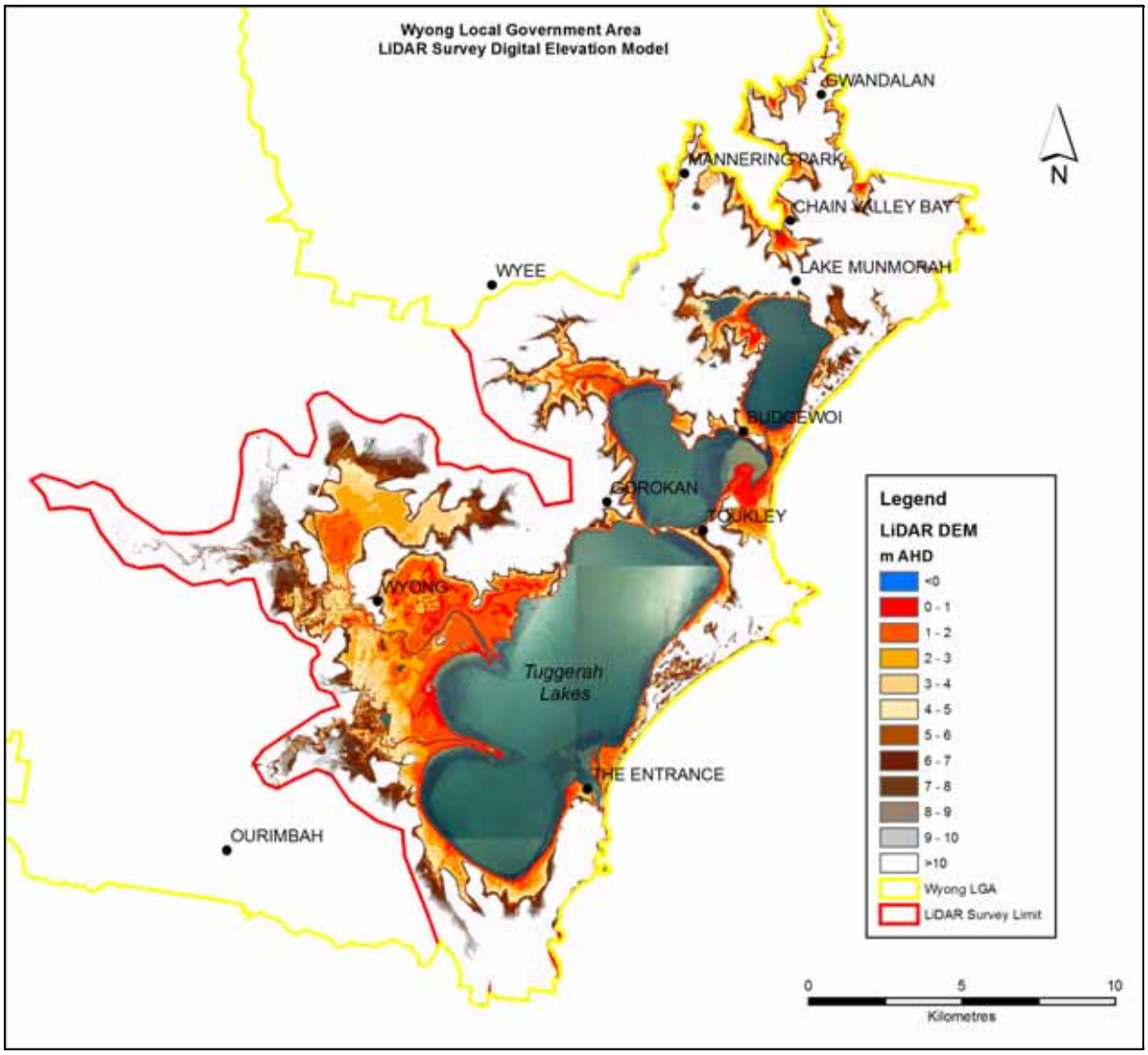


Figure 25. Digital elevation model (DEM) of the Wyong Shire LGA highlighting areas below 10m AHD. Major areas of low lying land occur around the entrance and foreshore of Tuggerah and Budgewoi Lakes and along the main drainage lines and river deltas on their western shores.

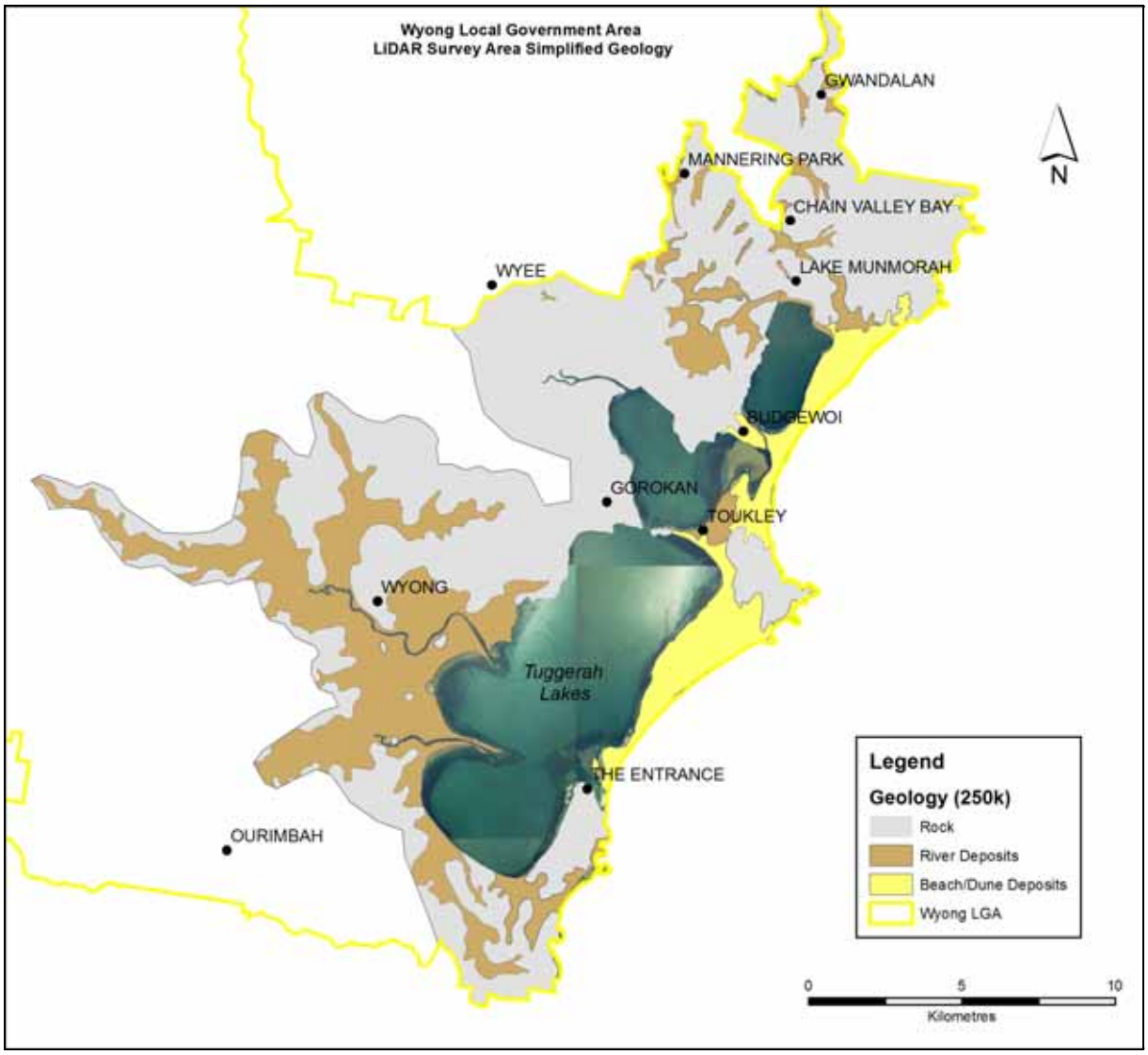
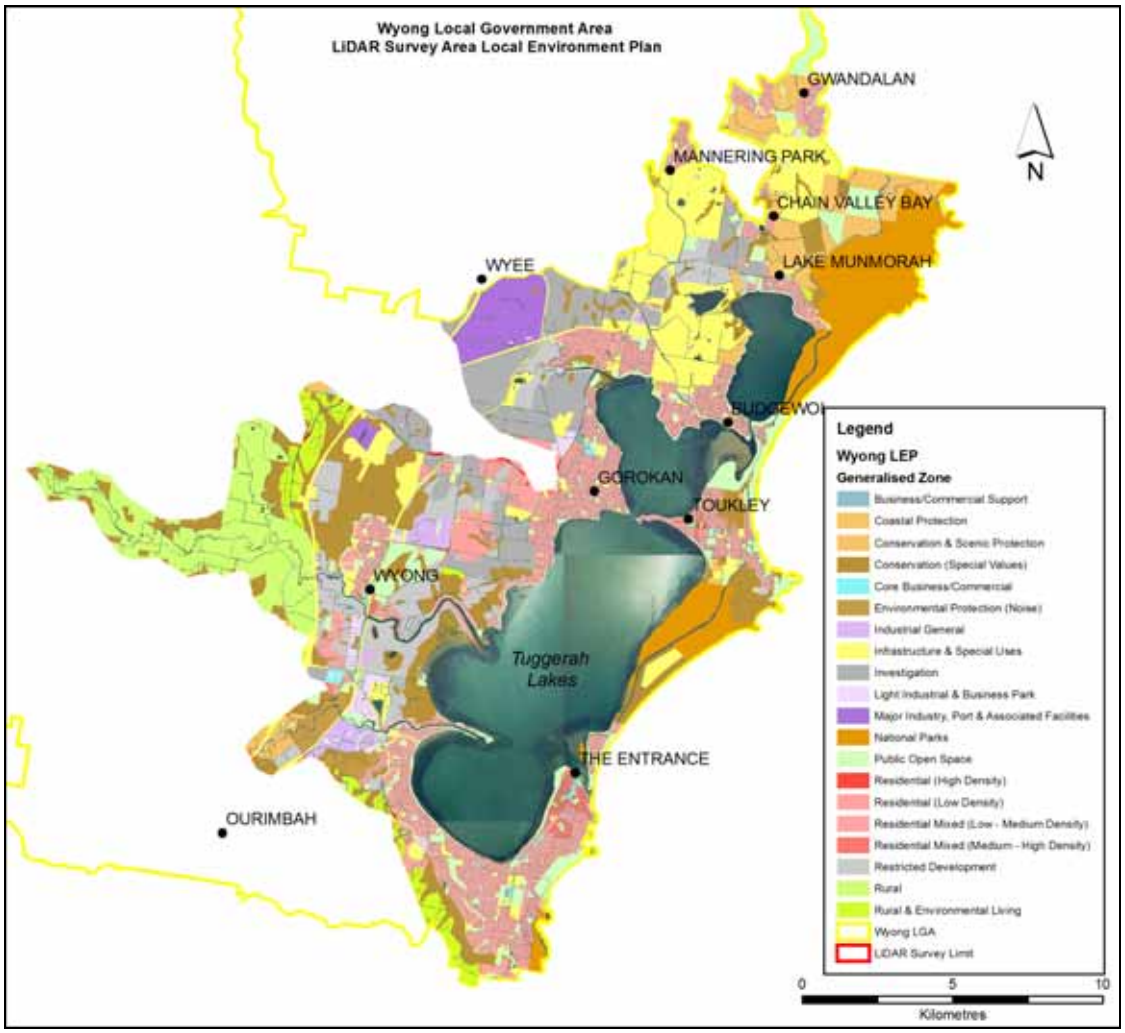


Figure 26. Main geological units of the Wyong Shire LGA. A comparison with the DEM for the same area will show a significant proportion of the low lying areas are comprised of unconsolidated to semi-consolidated river and beach/dune deposits.



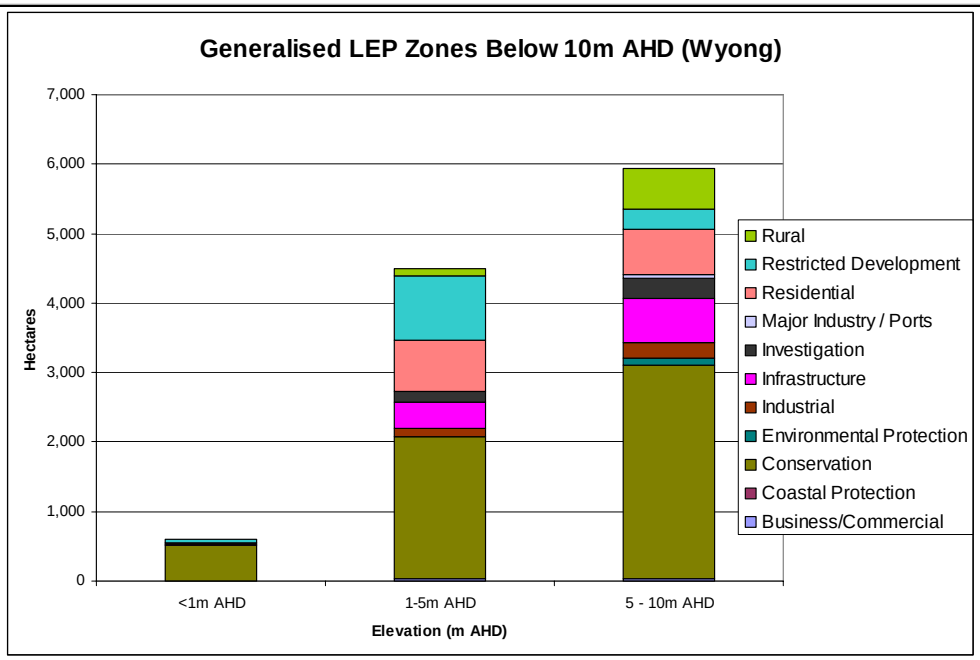


Figure 27. Map and chart showing generalised LEP zones and their distribution by elevation below 10m AHD for a section of the Wyong LGA. Below 1m AHD, the top three zonings are Conservation (516Ha), Restricted Development (57Ha) and Residential (16Ha). Note that number of categories in chart legend differs from that in map as former relates only to those zones encountered below 10m AHD.

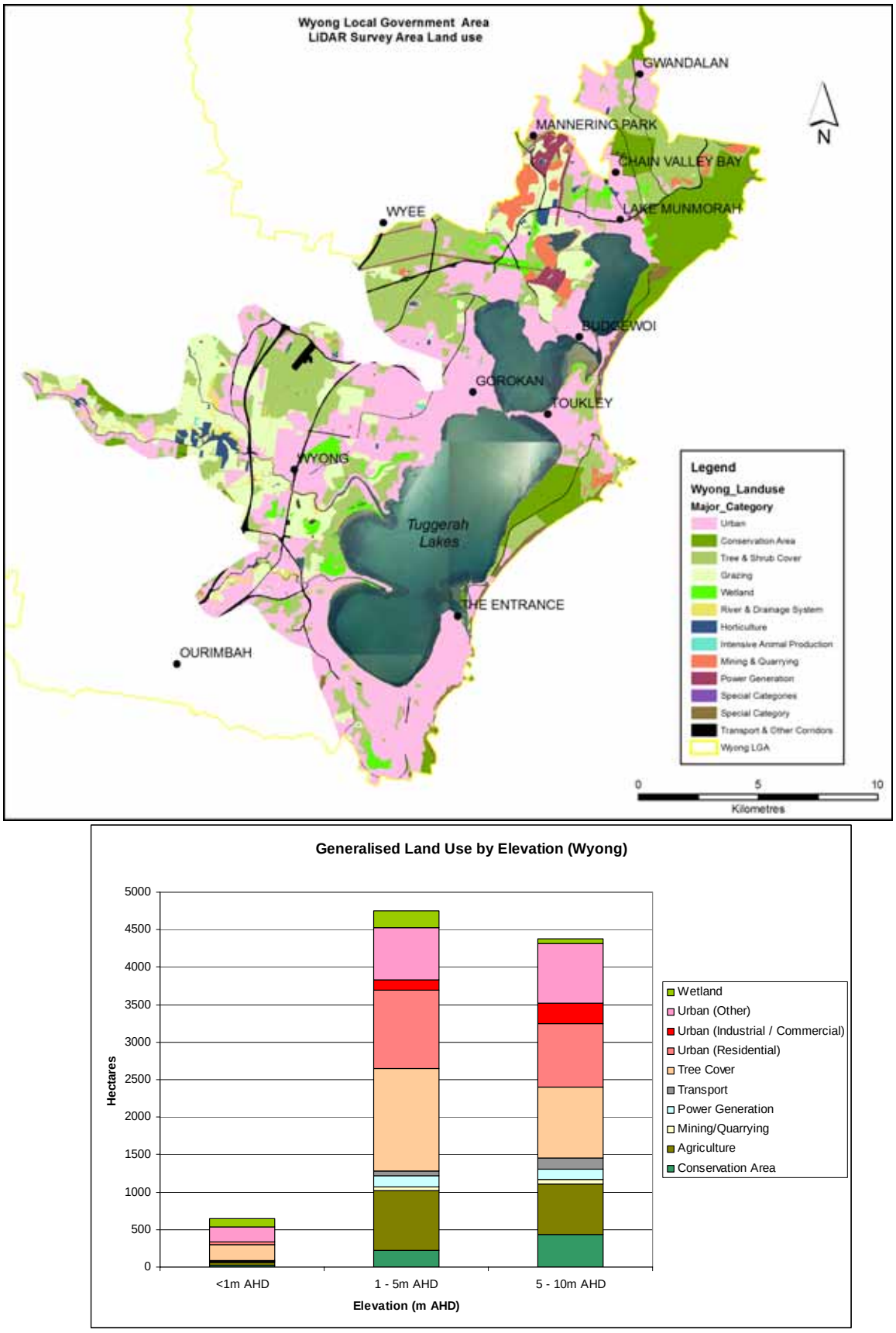
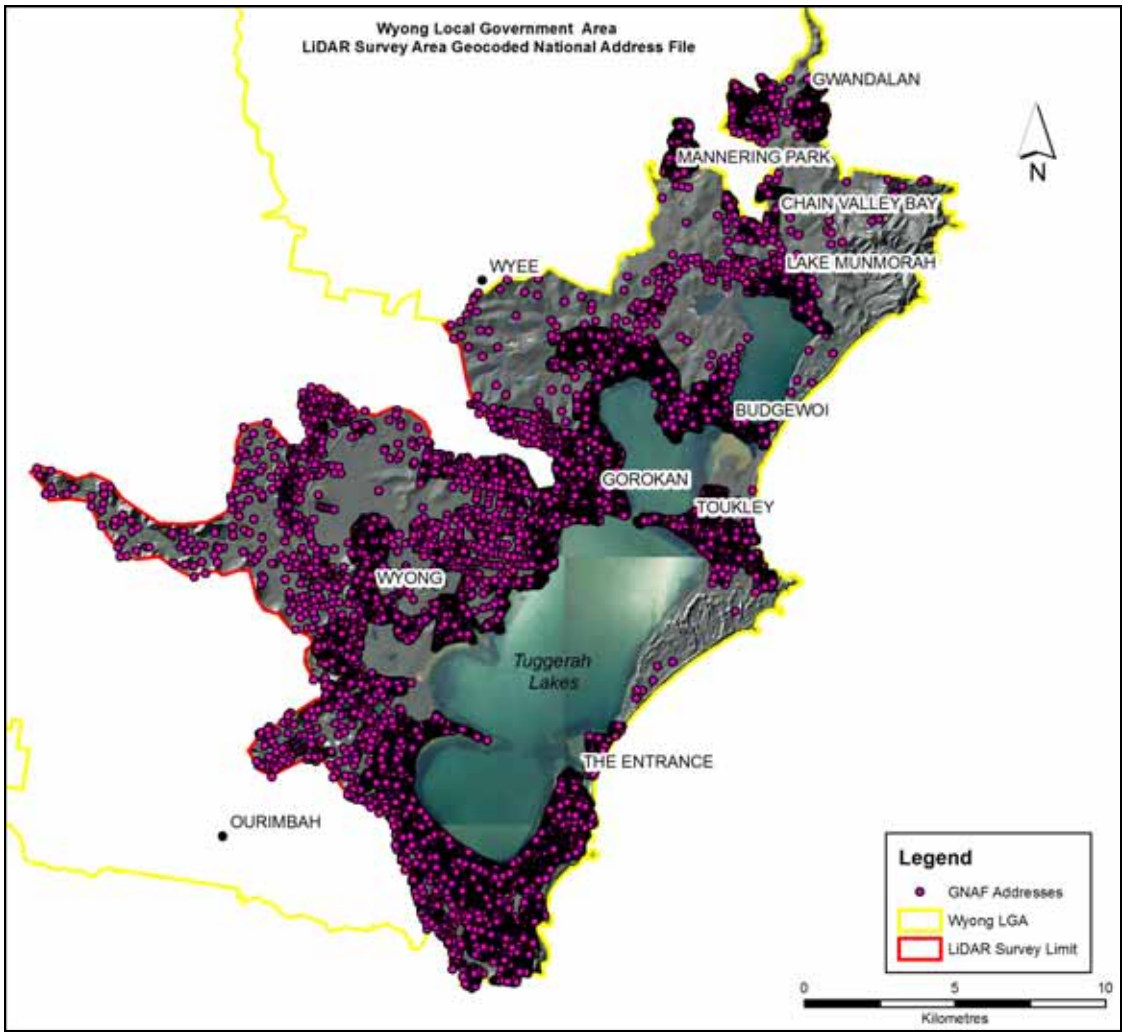


Figure 28. Map and chart showing generalised Land Use categories and their distribution by elevation below 10m AHD for a section of the Wyong Shire LGA. Below 1m AHD the main land use category is Tree Cover (221Ha), Urban Residential comprises 32Ha. Note that number of categories in chart legend differs from that in map as former relates only to those land uses encountered below 10m AHD.



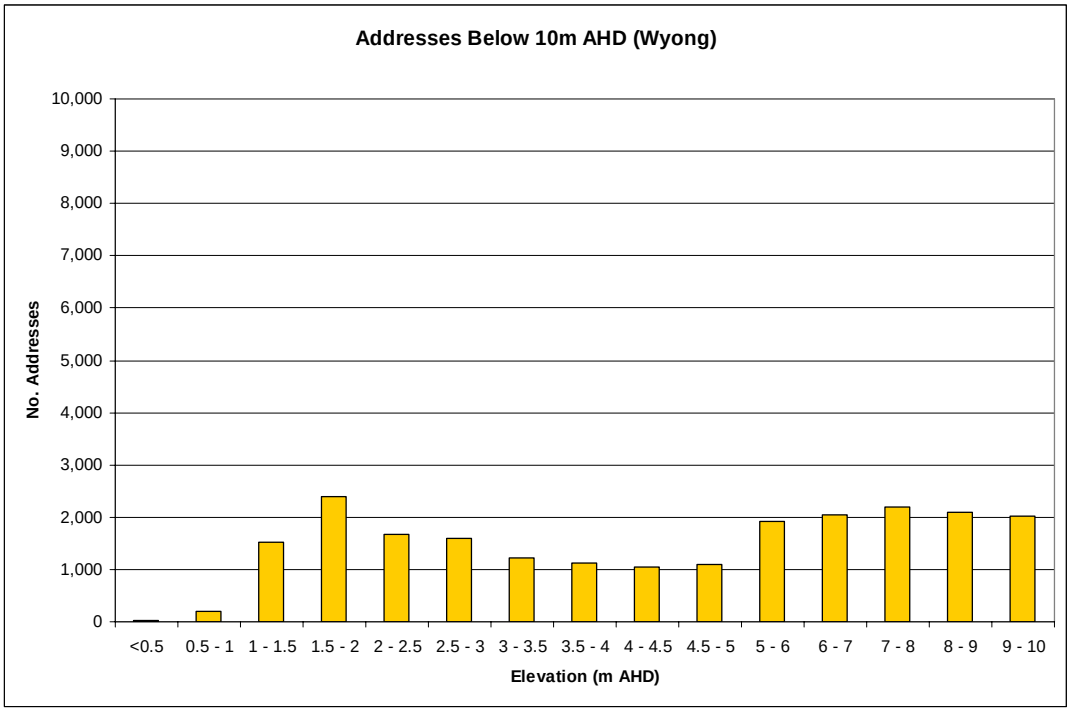
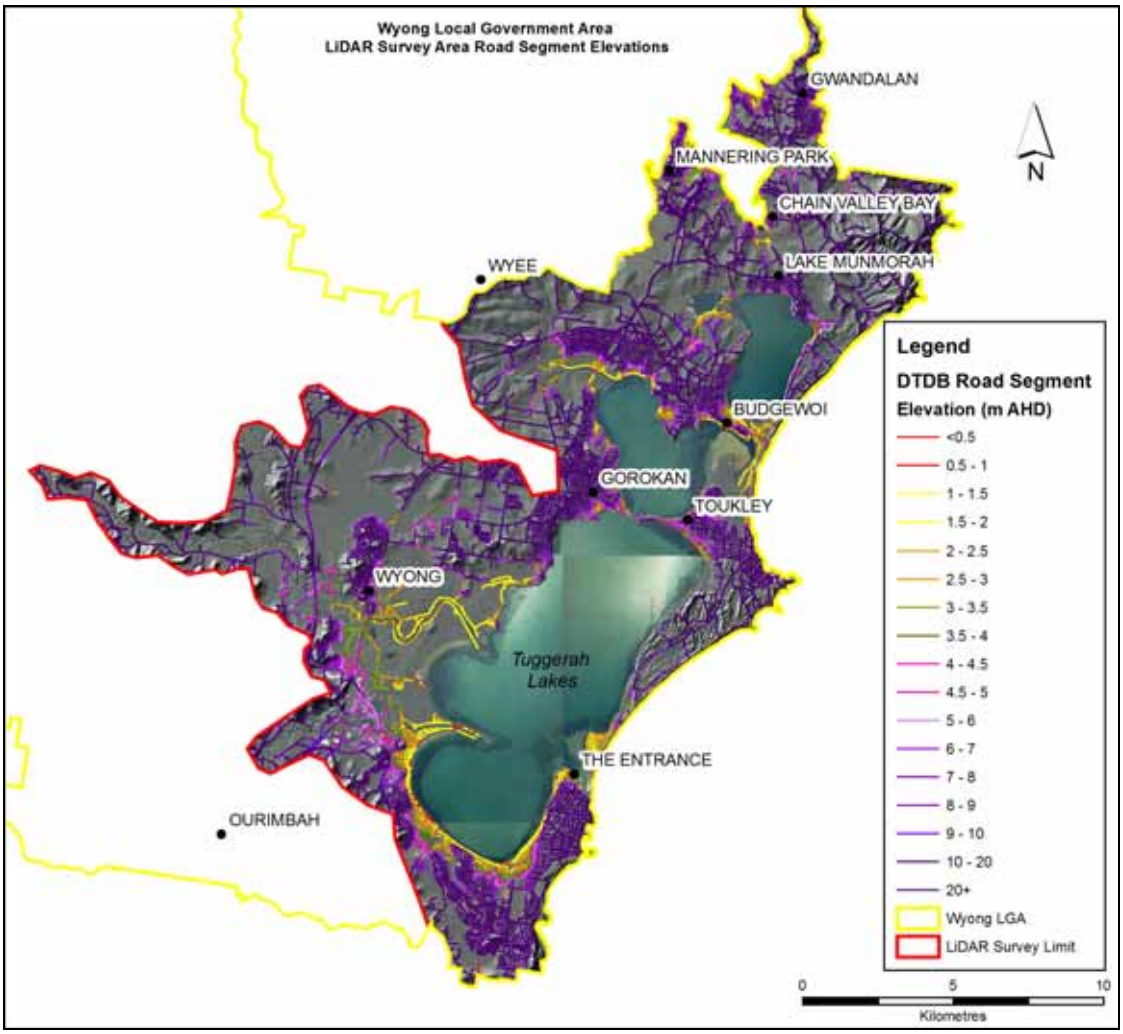


Figure 29. Map showing distribution of addresses in LiDAR survey area of Wyong LGA. Chart classifies addresses from GNAF database by elevation below 10m AHD.



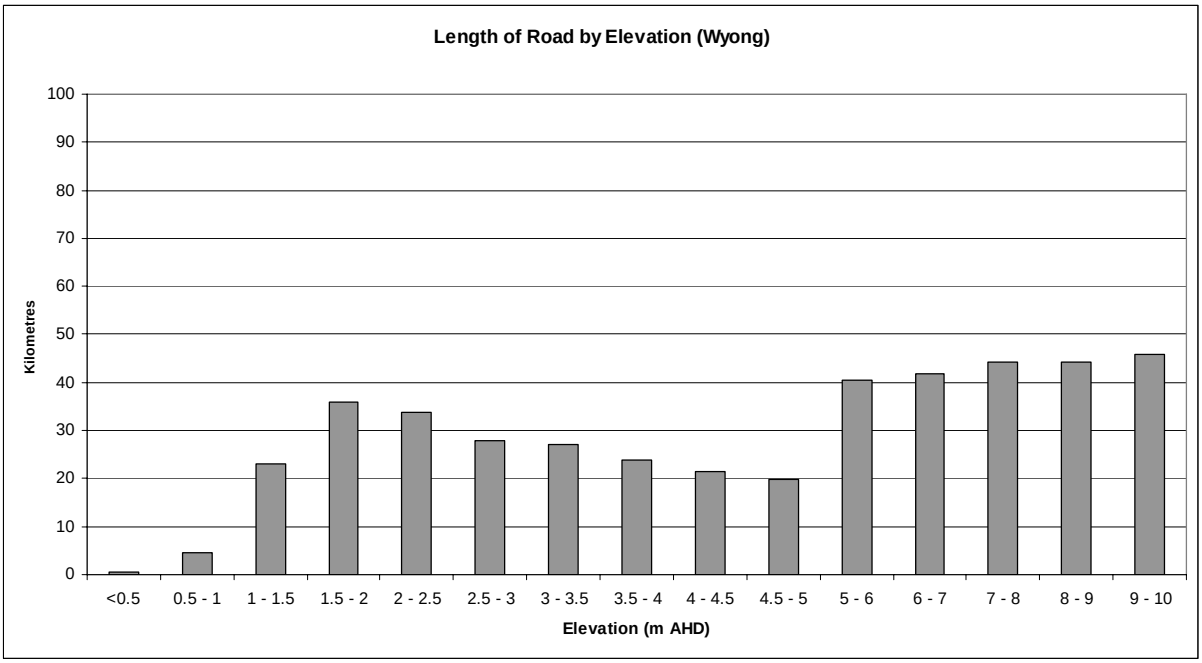


Figure 30. Map showing roads classified by elevation in LiDAR survey area of Wyong LGA. Chart shows elevation of roads below 10m AHD for map area.

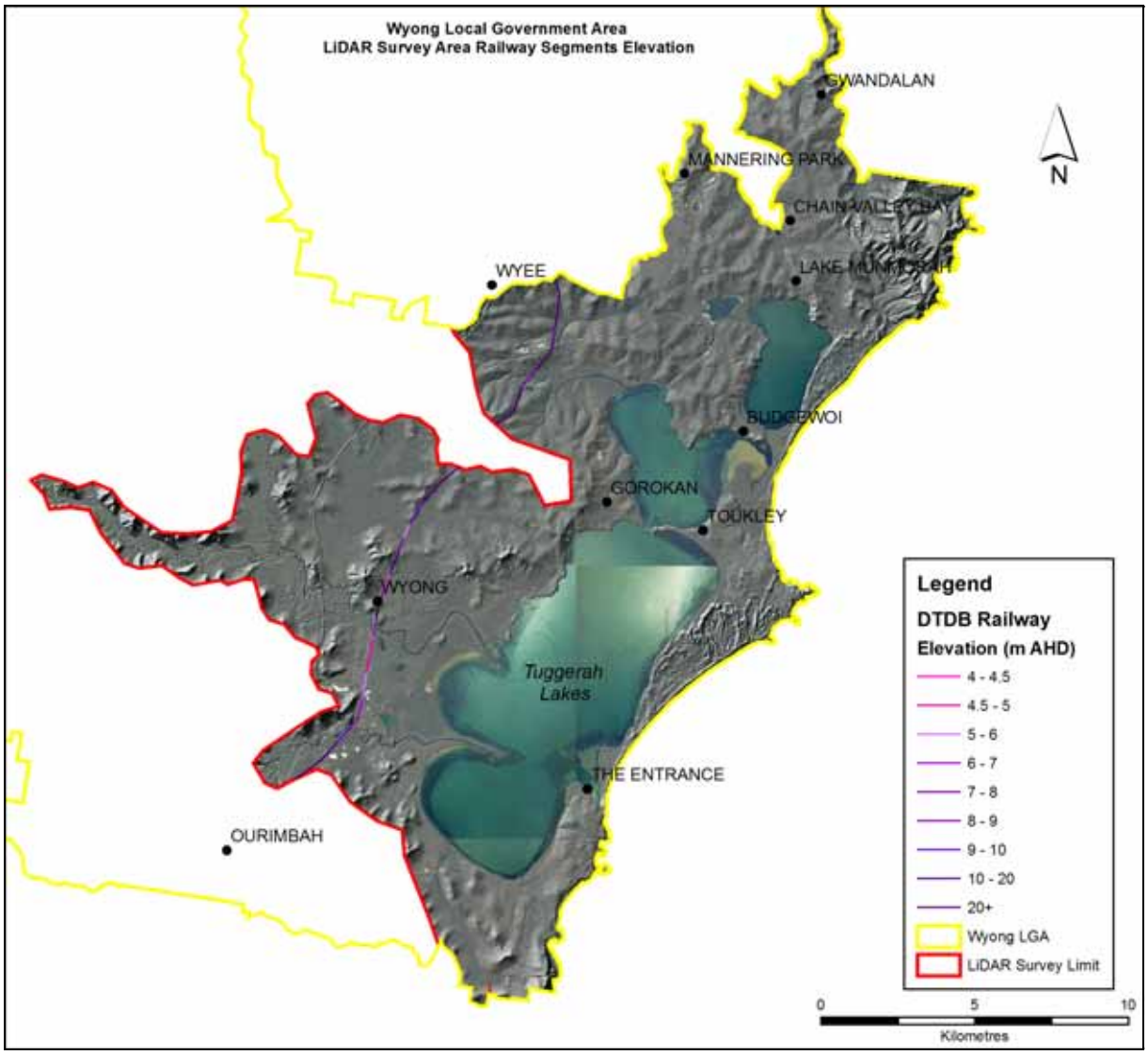
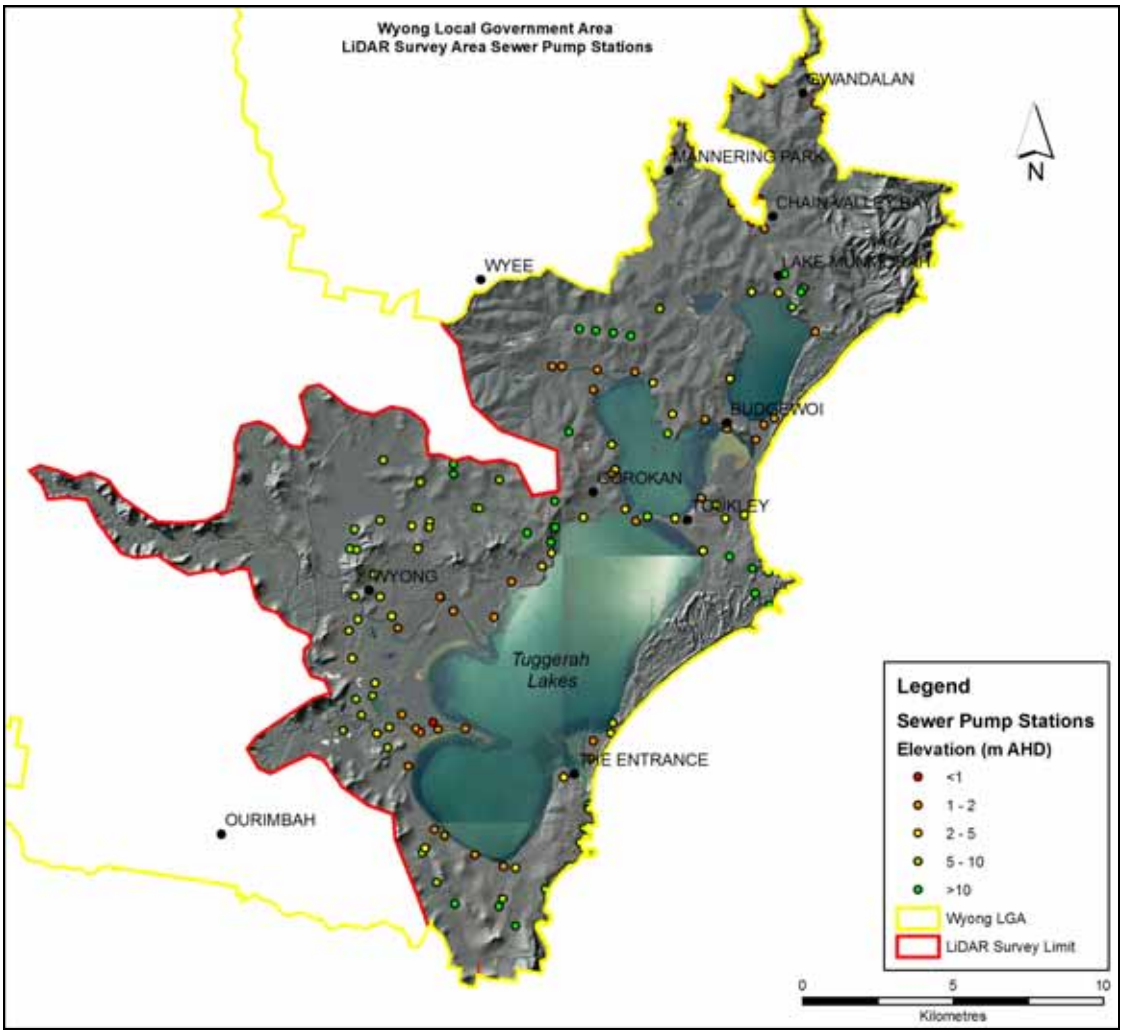


Figure 31. Elevation of main northern railroad in Wyong LGA.



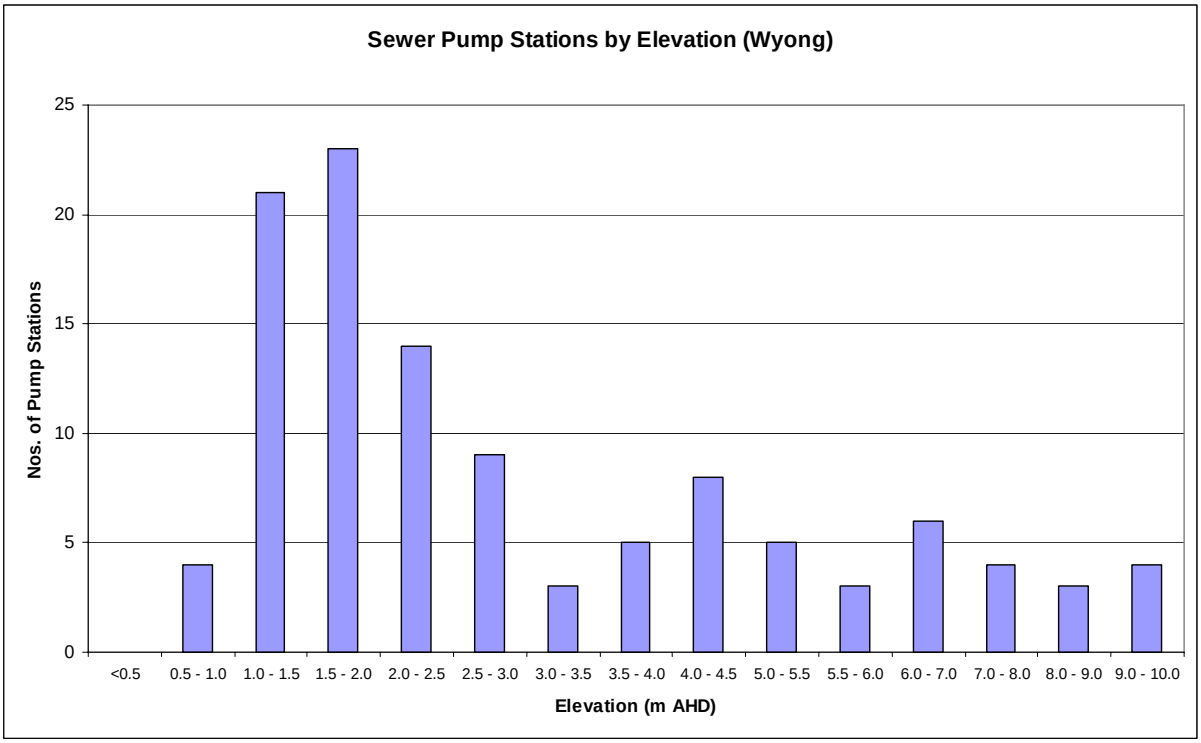
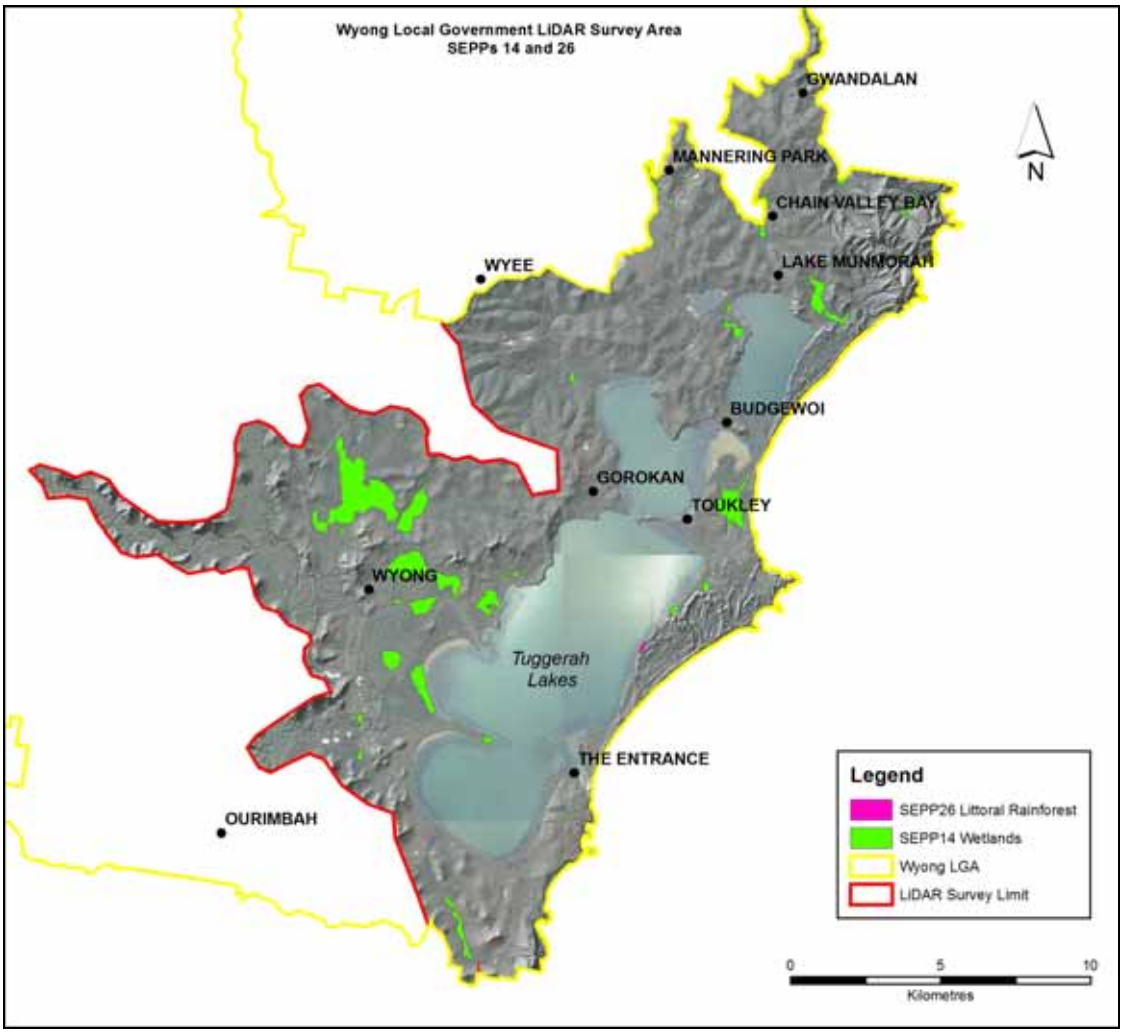


Figure 32. Ground level at sewer pump stations in LiDAR survey area of Wyong LGA (Council data). Majority of pumps below 2m AHD are located along southern and western foreshore of Tuggerah Lake.



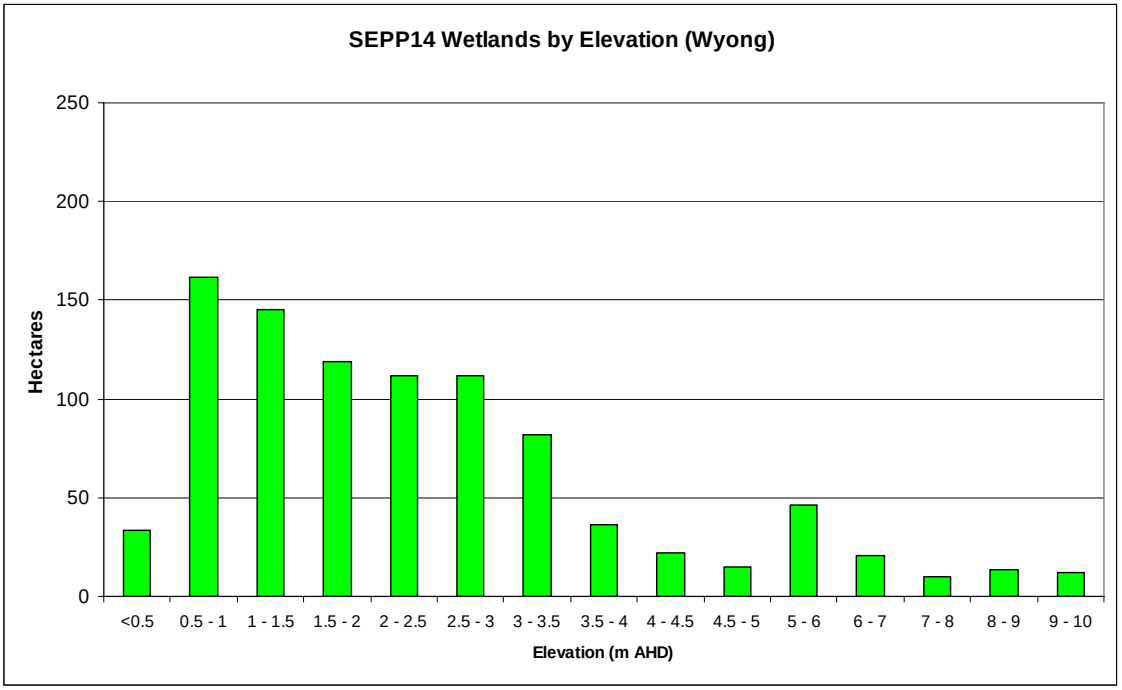
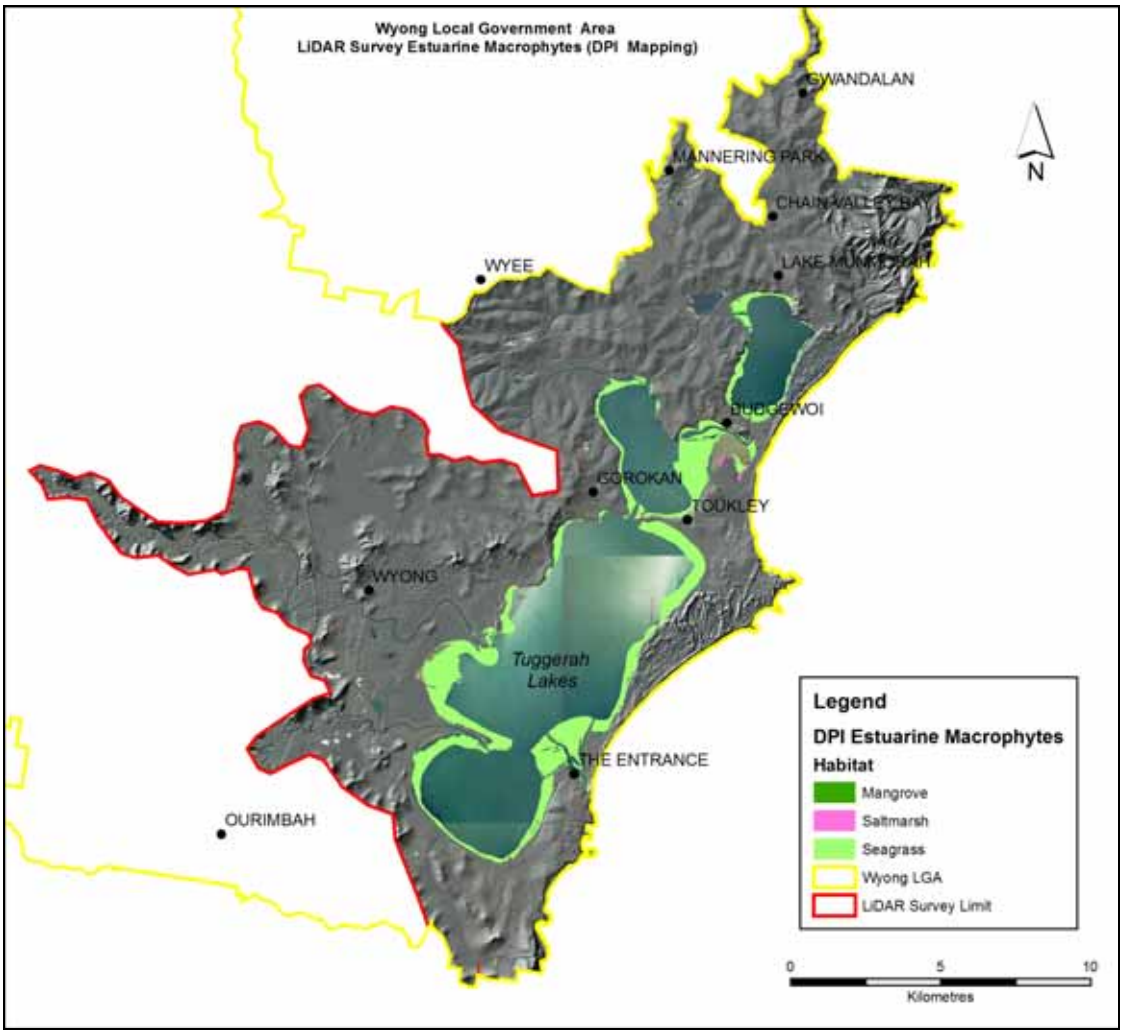


Figure 33. Map showing distribution of SEPP14 Wetlands in LiDAR survey area of Wyong LGA. Chart shows areas of wetland below 10m AHD for same.



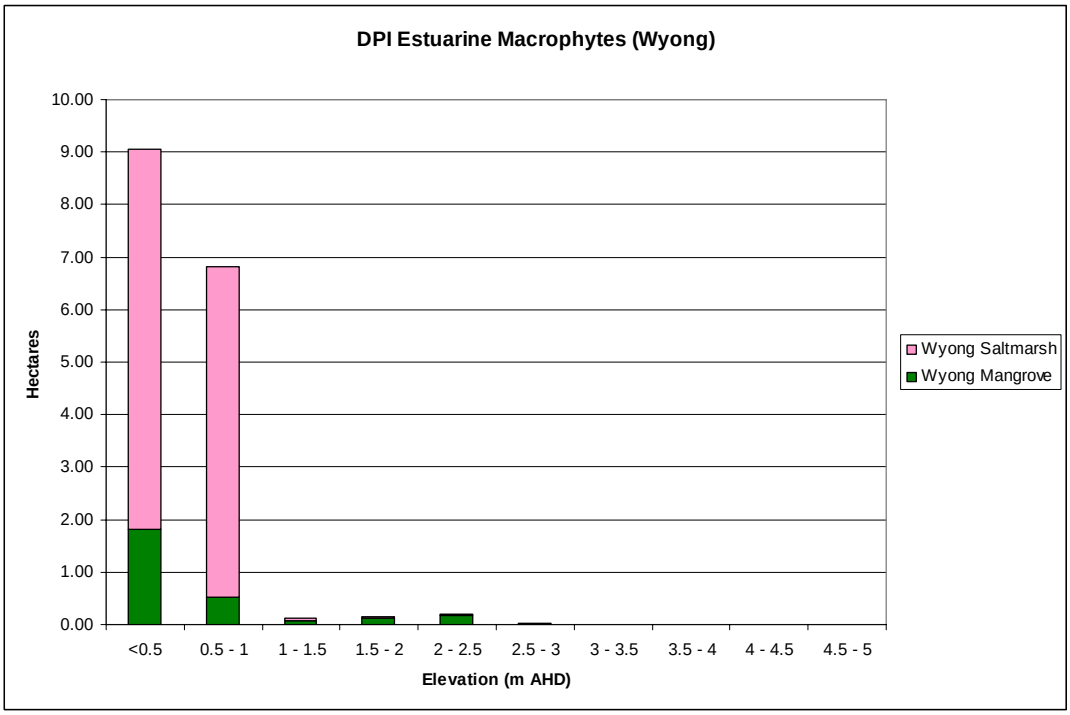
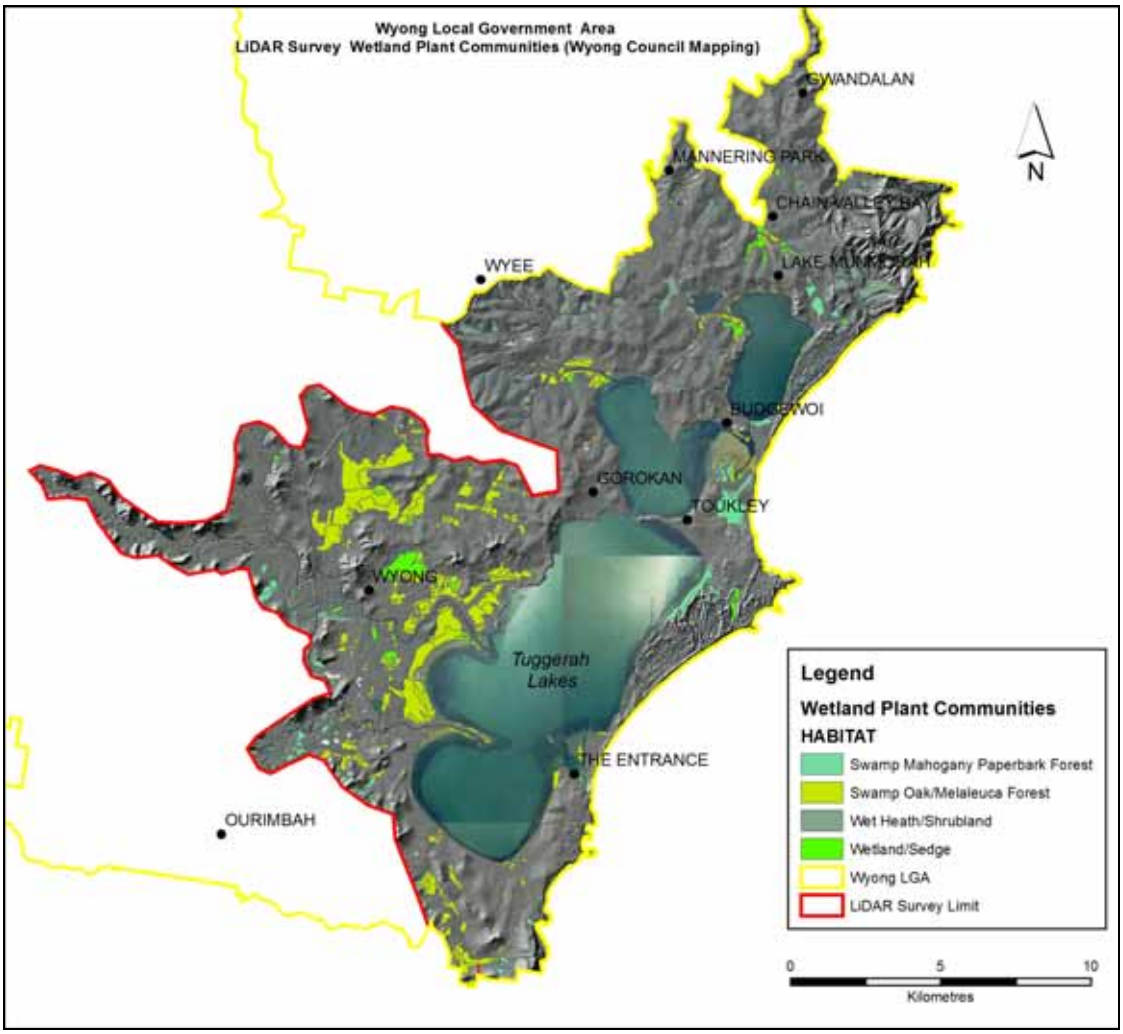


Figure 34. Estuarine macrophytes mapped by NSW DPI in LiDAR survey area of Wyong LGA. Chart shows hectares of mangrove and saltmarsh in map area. Note small chart scale range explains why saltmarsh areas difficult to identify on map.



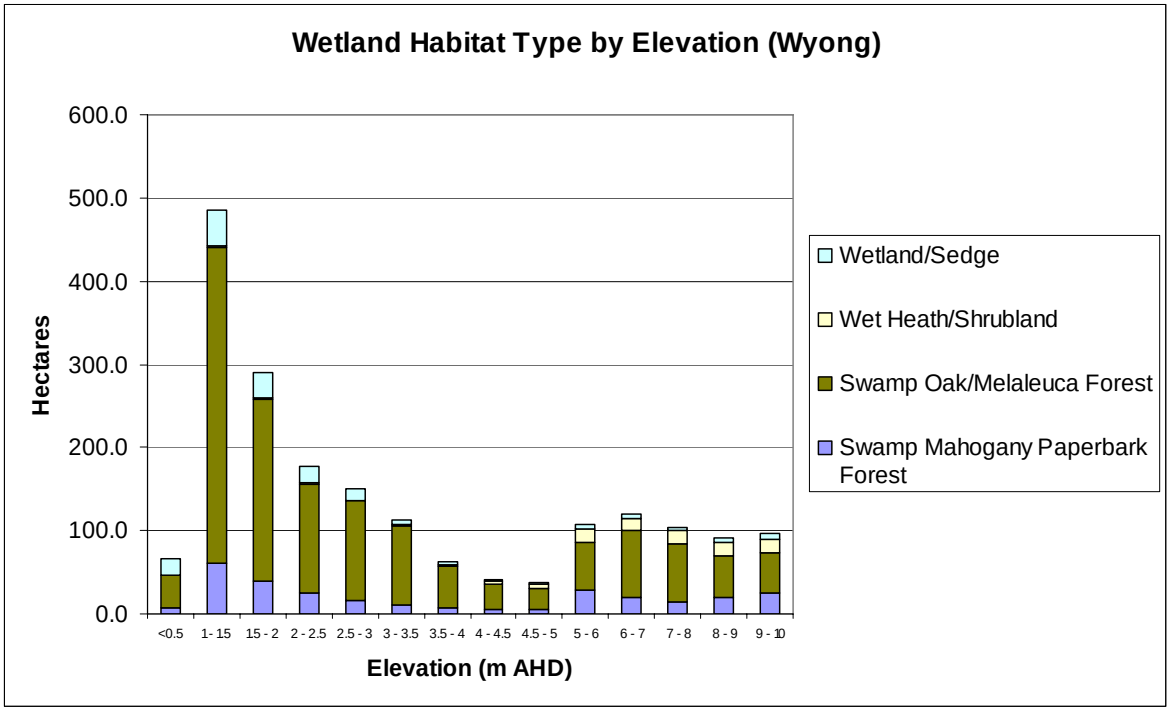


Figure 35. Map and chart of wetland plant communities within LiDAR survey area of the Wyong LGA (Council data). Extensive areas of Swamp Oak / Melaleuca Forest predominate in low lying areas of the Ourimbah and Wyong Creek catchments on the western shore of Tuggerah Lake.

Lake Macquarie City LGA

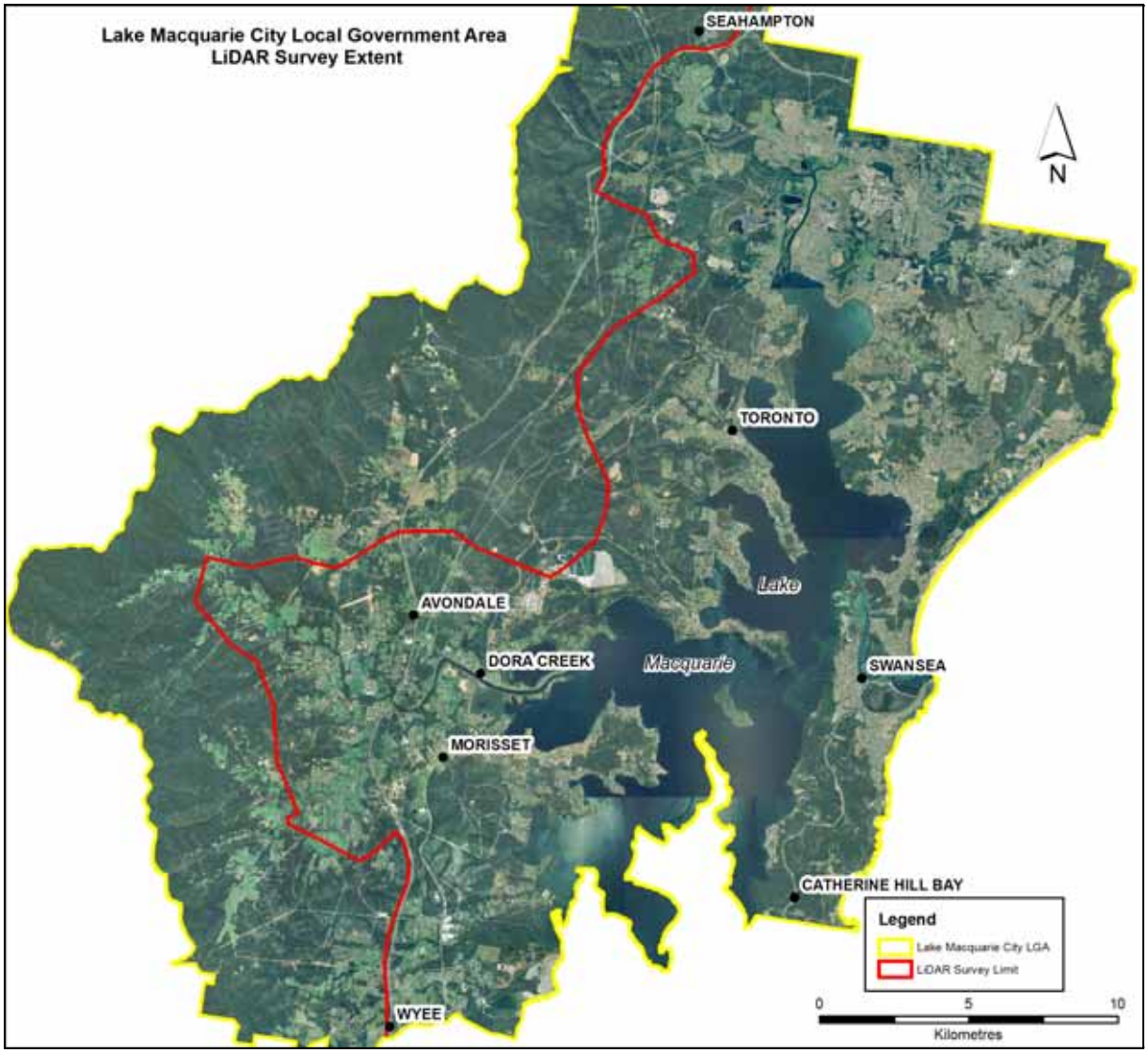


Figure 36. Lake Macquarie City Council local government area. LGA boundary and western limit of LiDAR survey conducted in January 2007 shown. Total LGA area is c.752Km2, LiDAR covers 67% of the LGA.

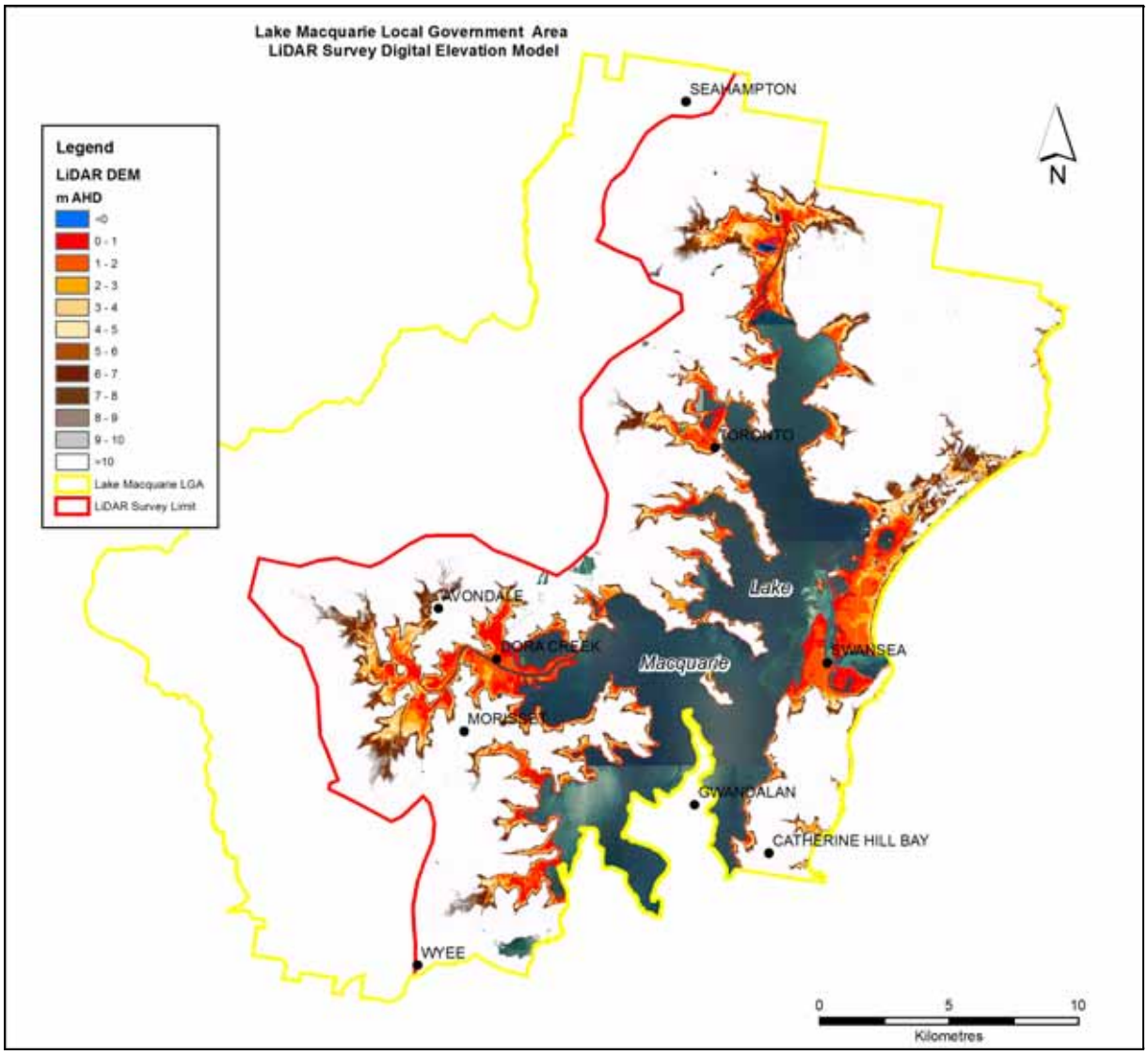


Figure 37. Digital elevation model (DEM) of the Lake Macquarie City LGA highlighting areas below 10mAHD. Major areas of low lying land occur around the entrance and foreshore of Lake Macquarie and along the main drainage lines and river deltas on its western shores.

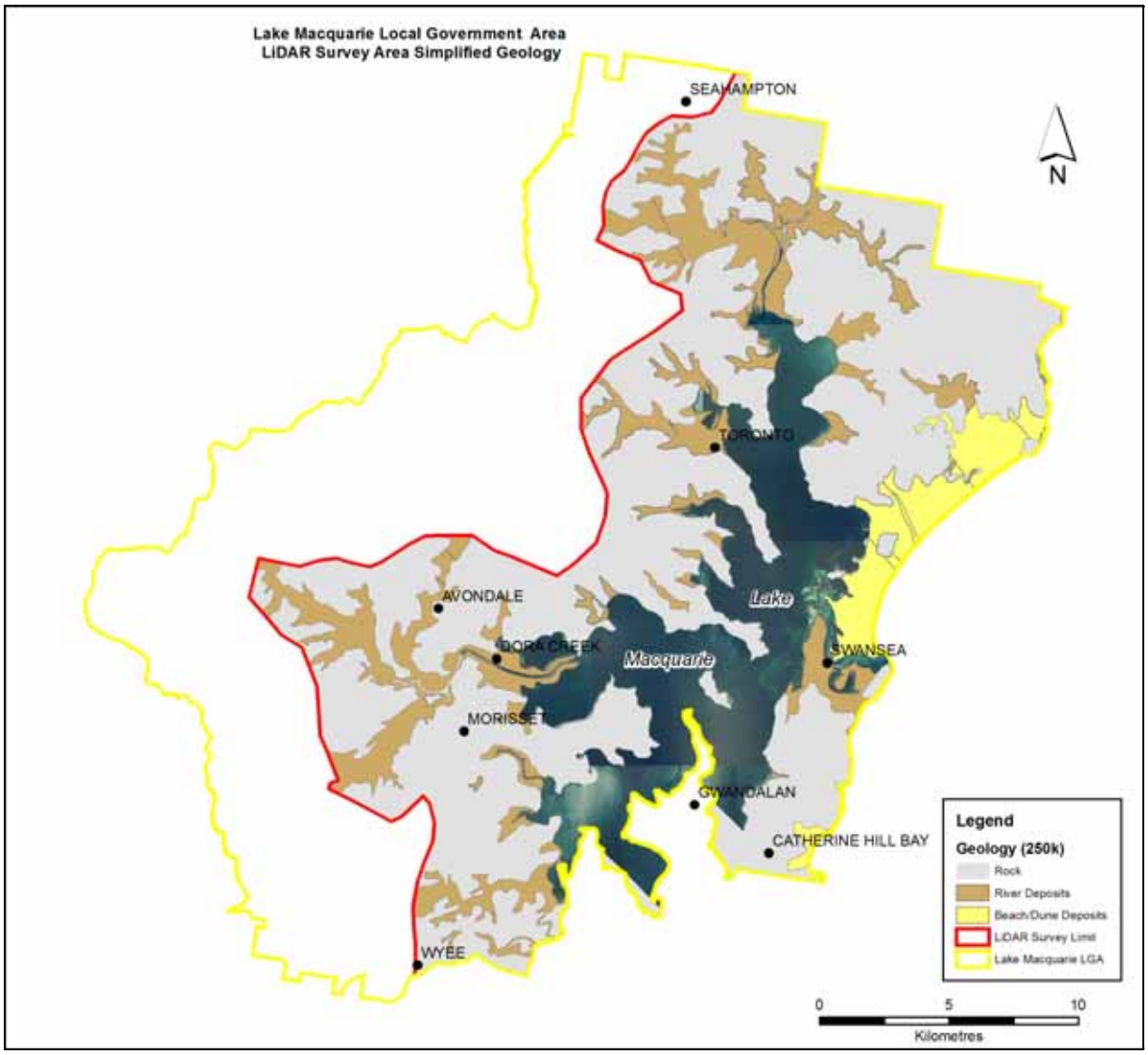
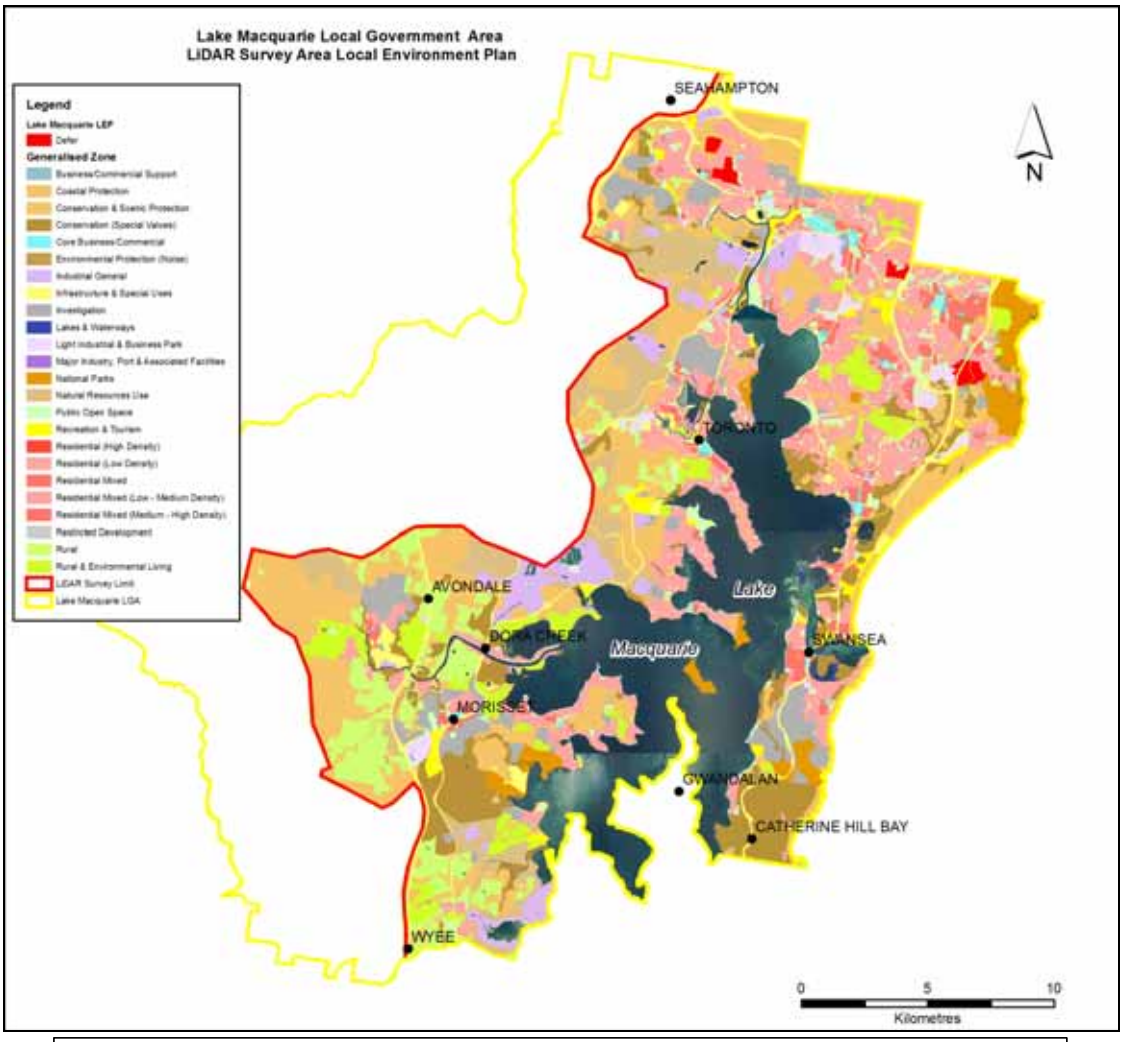


Figure 38. Main geological units of the Lake Macquarie City LGA. A comparison with the DEM for the same area will show low lying areas are comprised of unconsolidated to semi-consolidated river and beach/dune deposits.



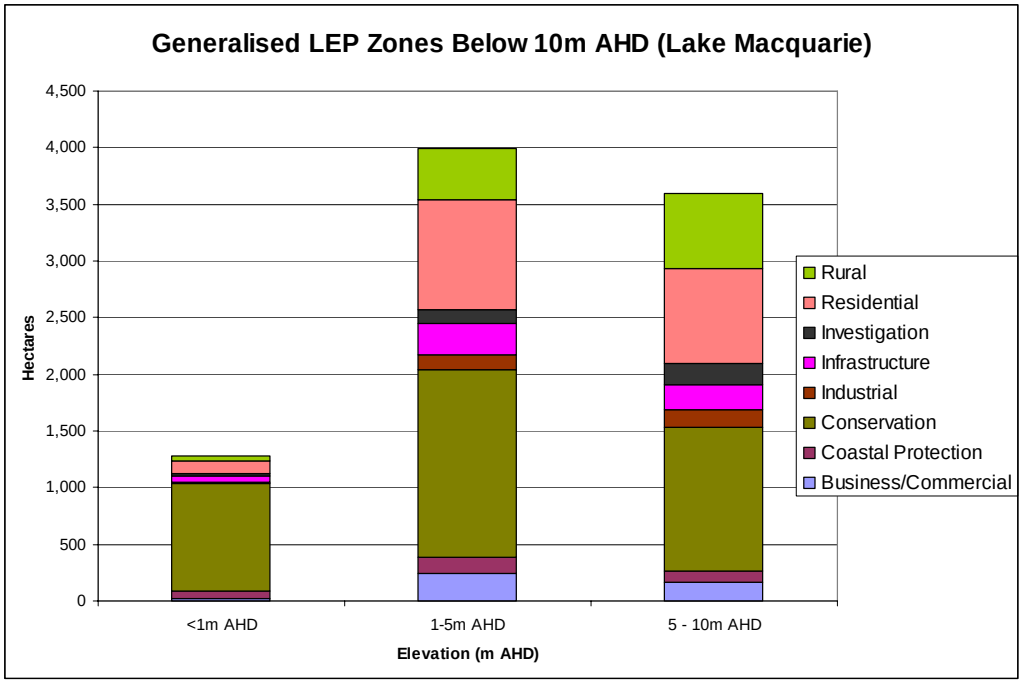
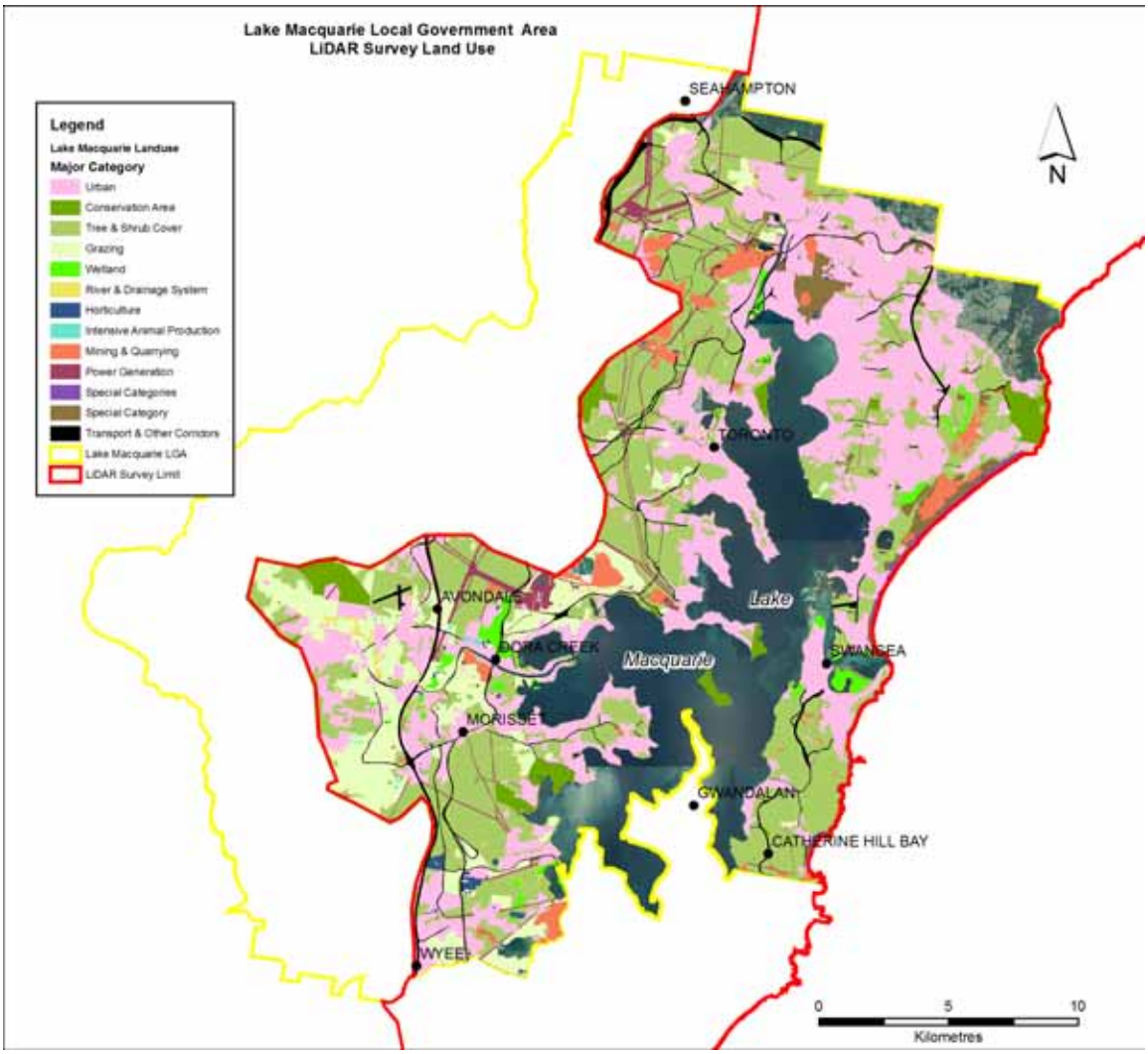


Figure 39. Map and chart showing generalised LEP zones and their distribution by elevation below 10m AHD for LiDAR survey area of Lake Macquarie LGA. Below 1m AHD, the top three zonings are Conservation (946Ha), Residential (111Ha) & Coastal Protection (59Ha). Note that number of categories in chart legend differs from that in map as former relates only to those zones encountered below 10m AHD.



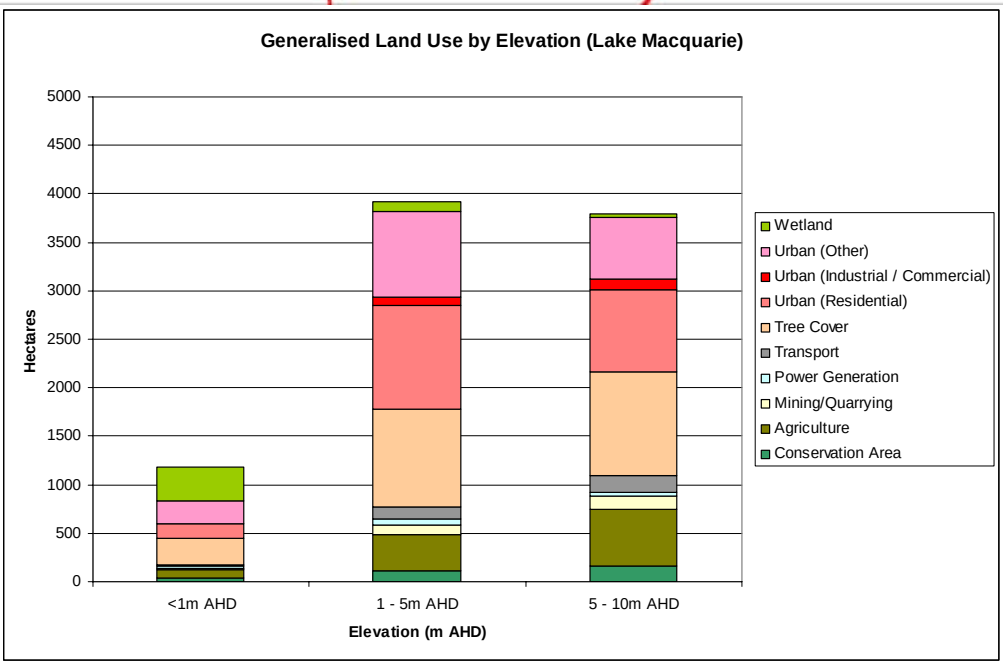
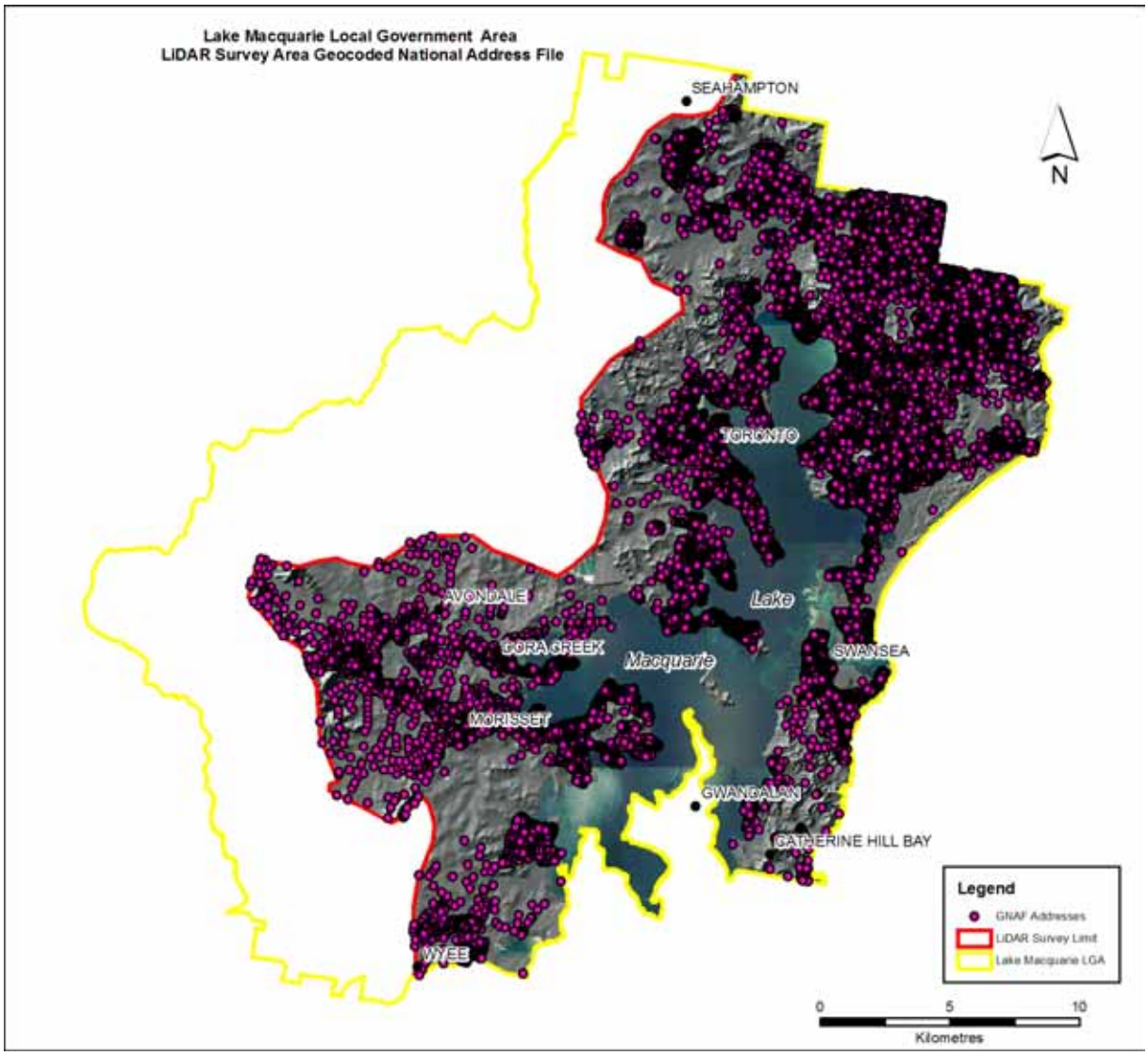


Figure 40. Map and chart showing generalised Land Use categories and their distribution by elevation below 10m AHD for section of Lake Macquarie LGA. Below <1m AHD, main land use category is Wetland (347Ha), Urban Residential comprises 148Ha. Note that number of categories in chart legend differs from that in map as former relates only to those land uses encountered below 10m AHD.



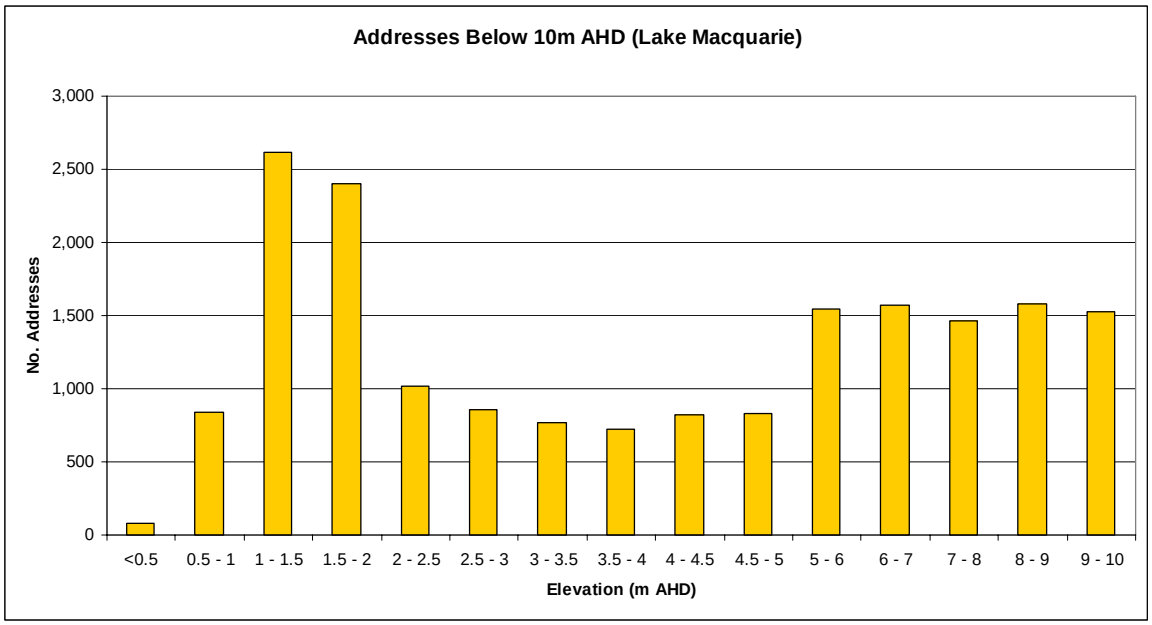


Figure 41. Map showing distribution of addresses in LiDAR survey area of Lake Macquarie City LGA. Chart classifies addresses from GNAF database by elevation below 10m AHD for map area.

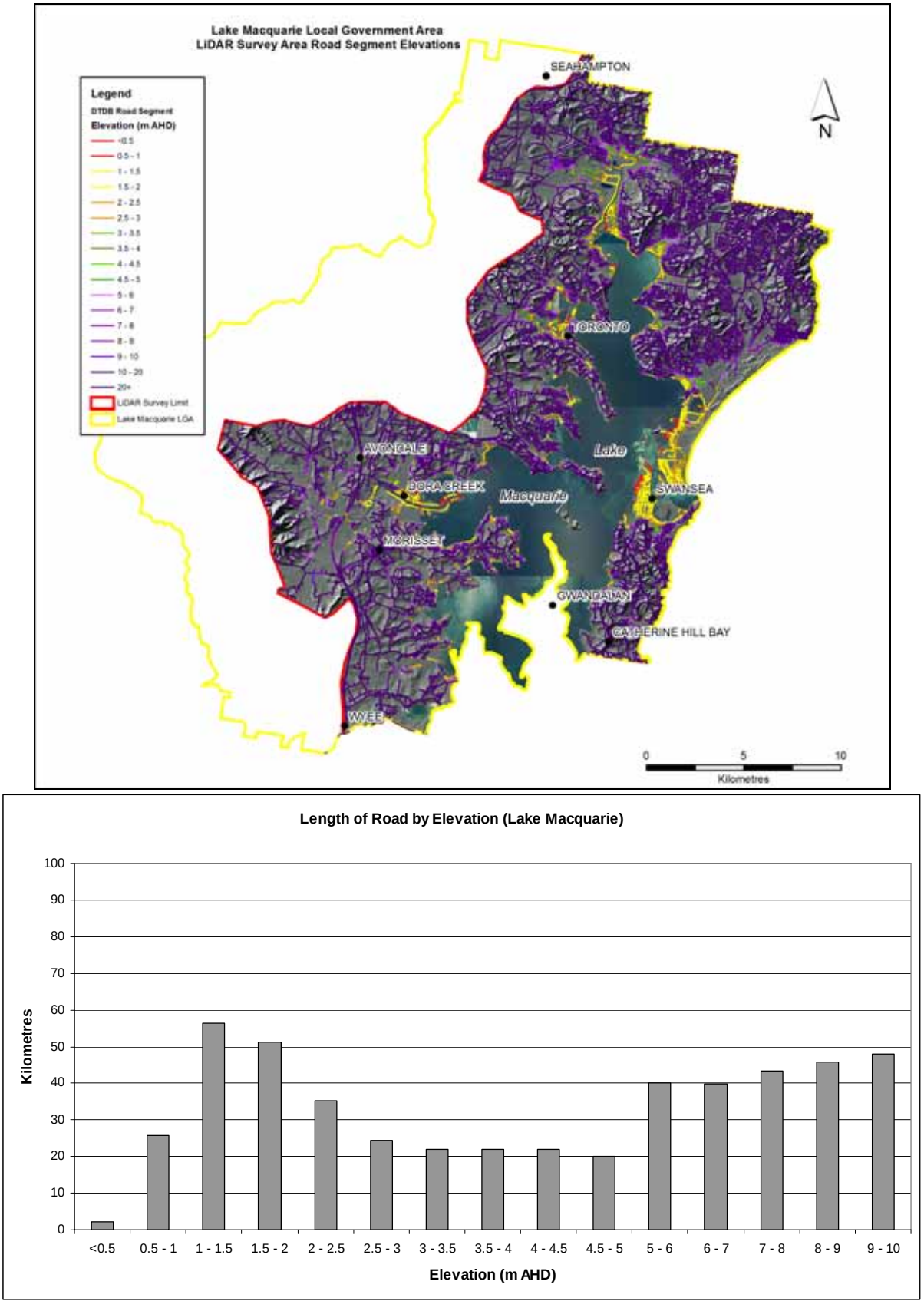


Figure 42. Map showing roads classified by elevation in Lake Macquarie City LGA. Chart shows elevation of roads below 10m AHD in map area.

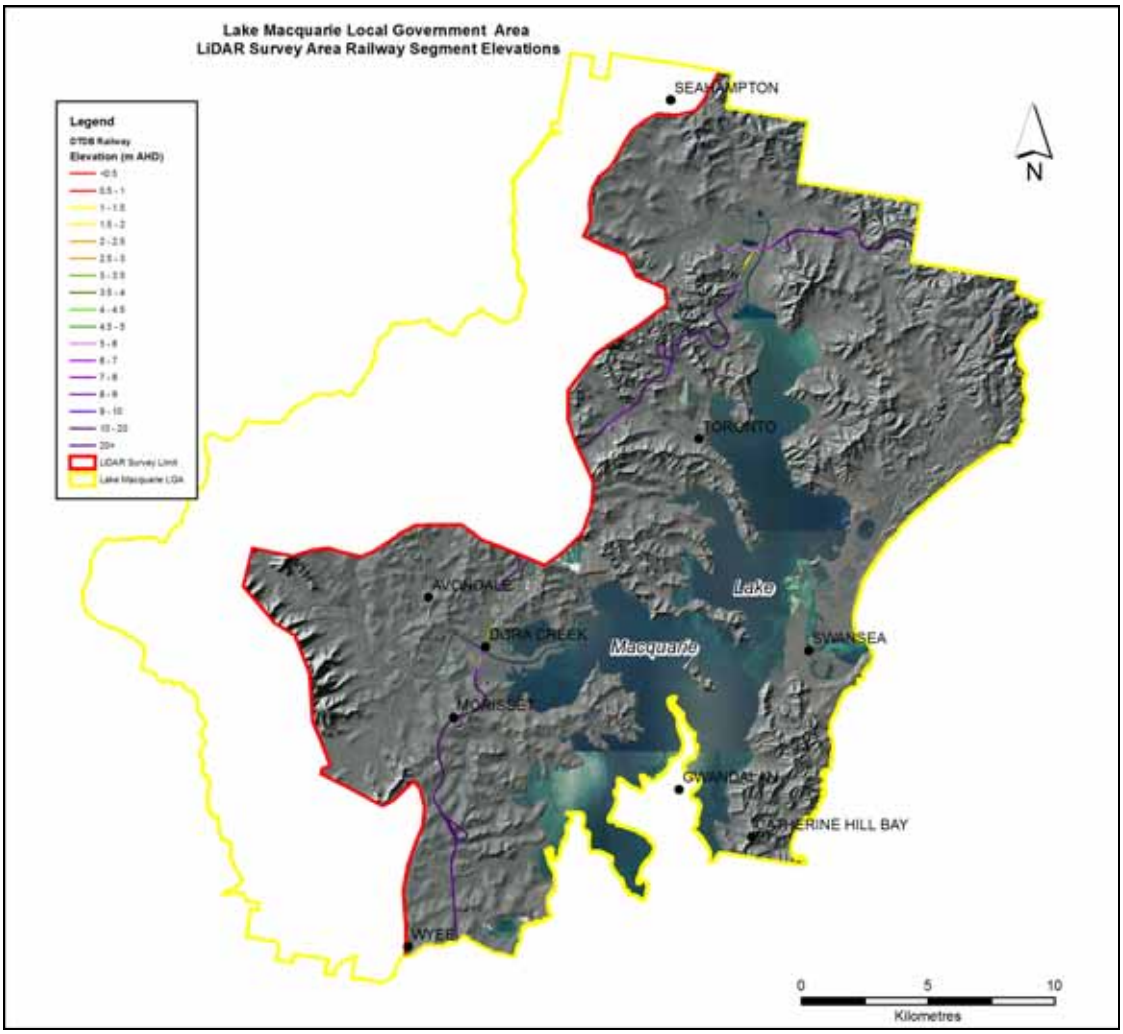
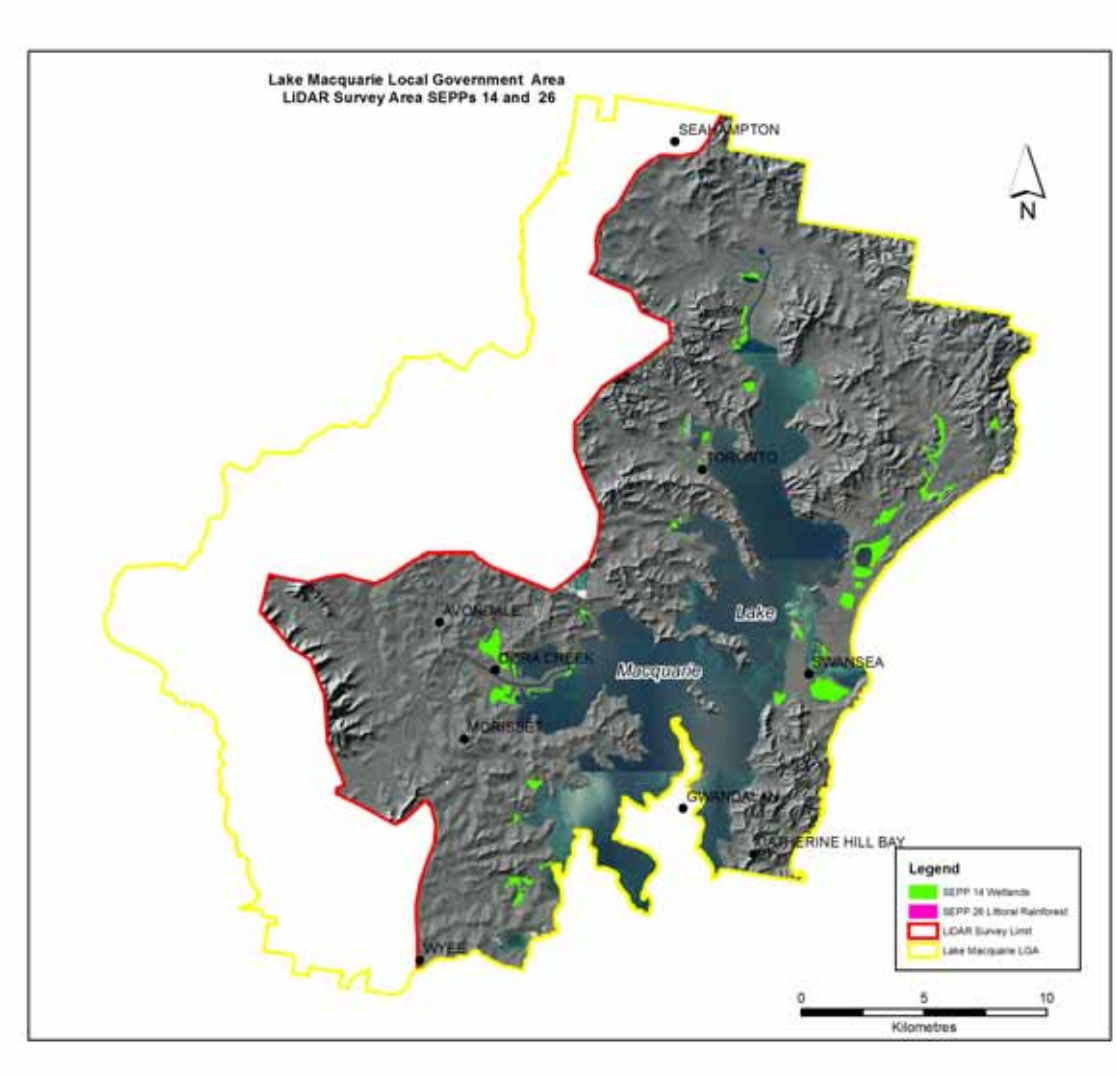


Figure 43. Elevation of main northern railroad in Lake Macquarie City LGA.



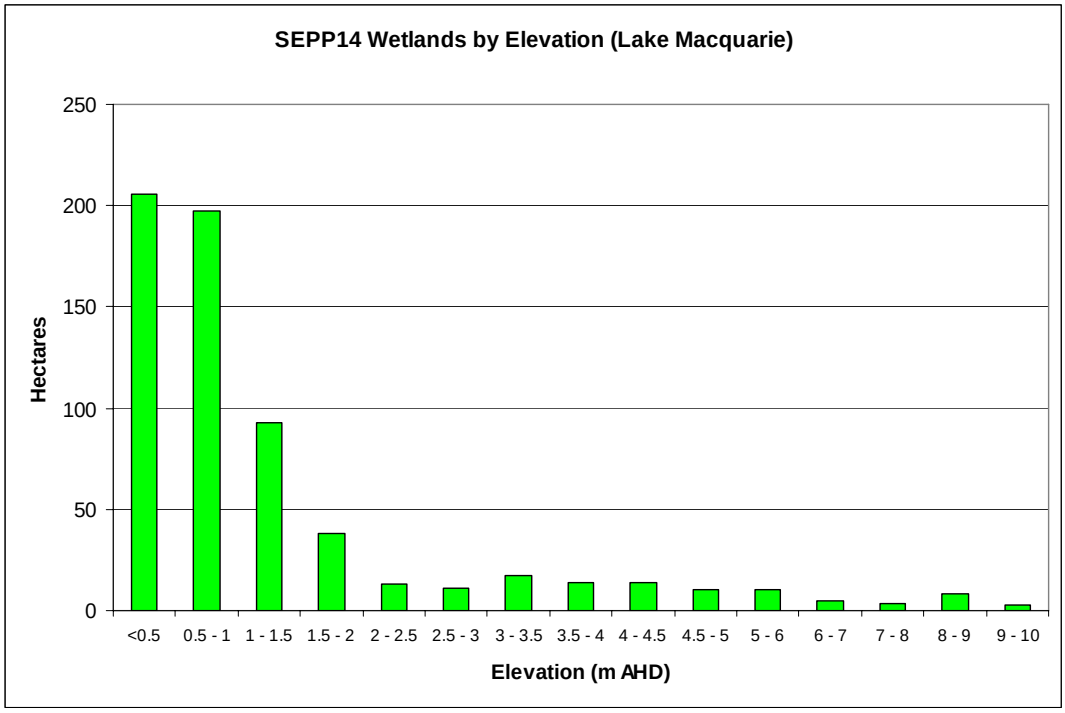
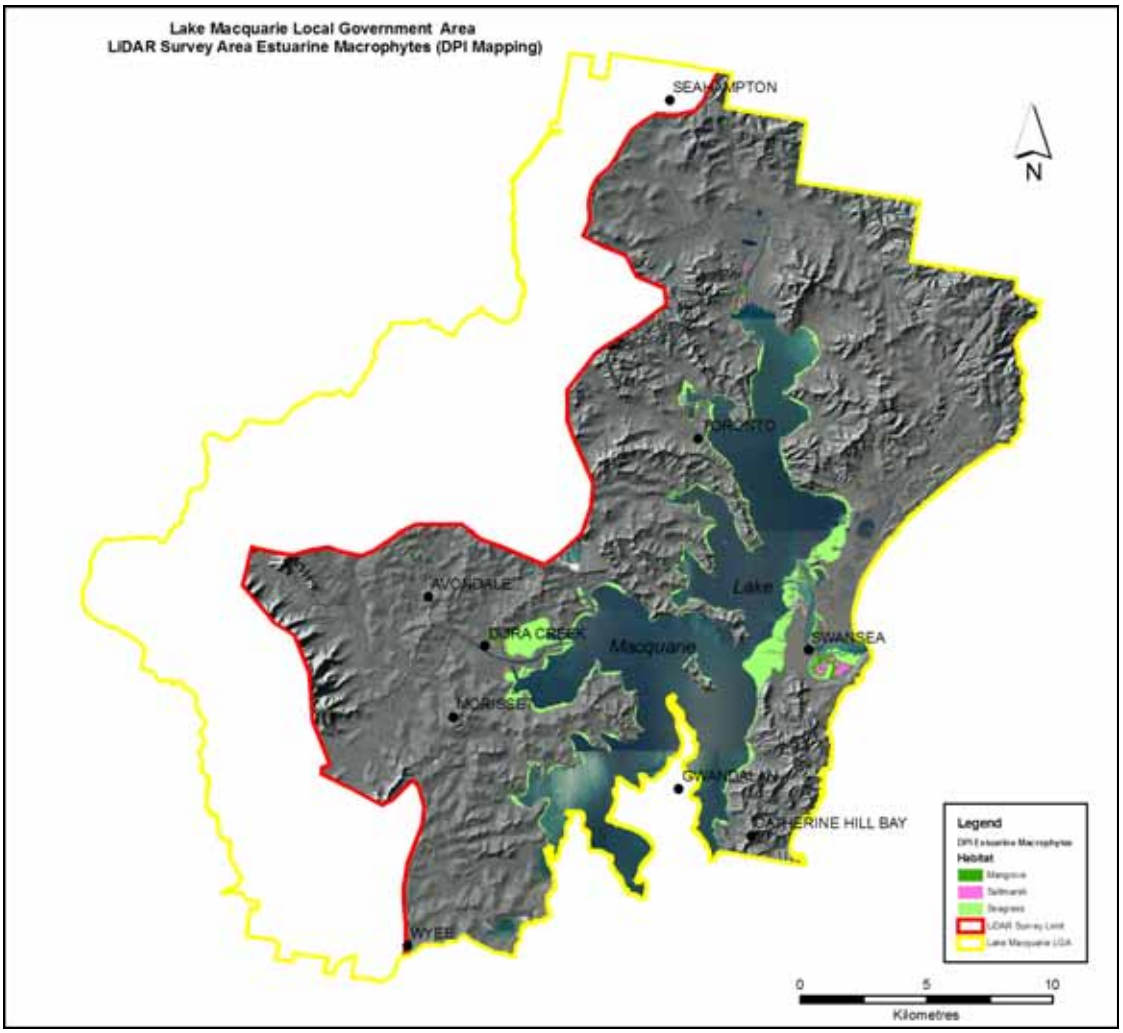


Figure 44. Map showing distribution of SEPP14 Wetlands in section of Lake Macquarie LGA. Chart shows areas of wetland below 10m AHD for same.



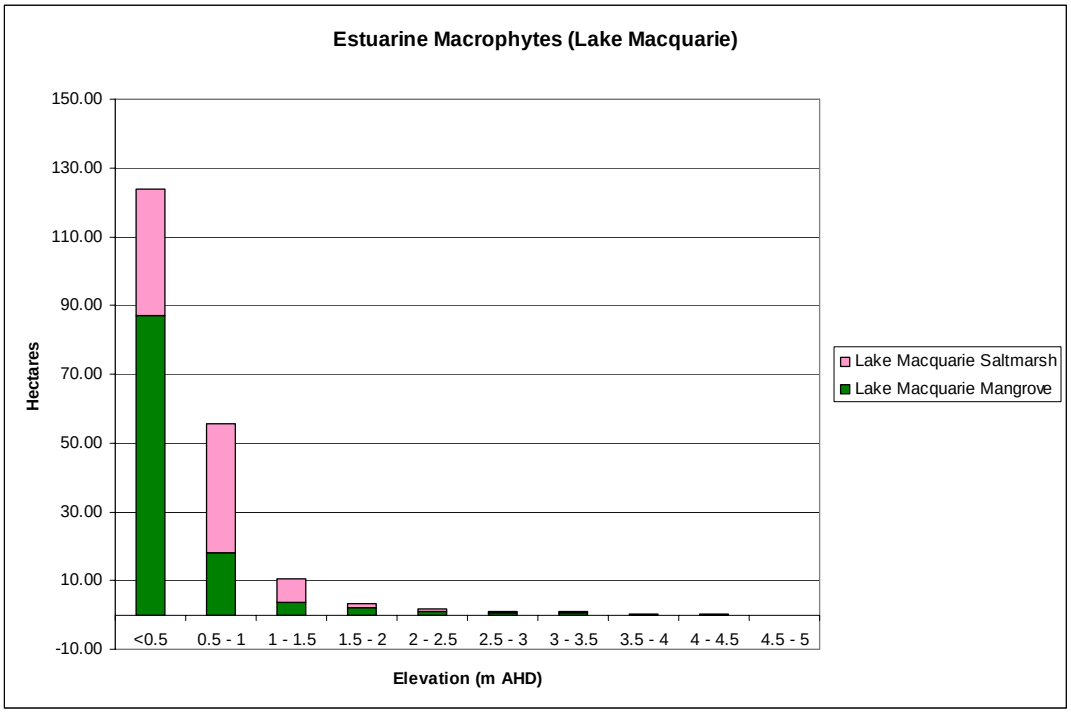
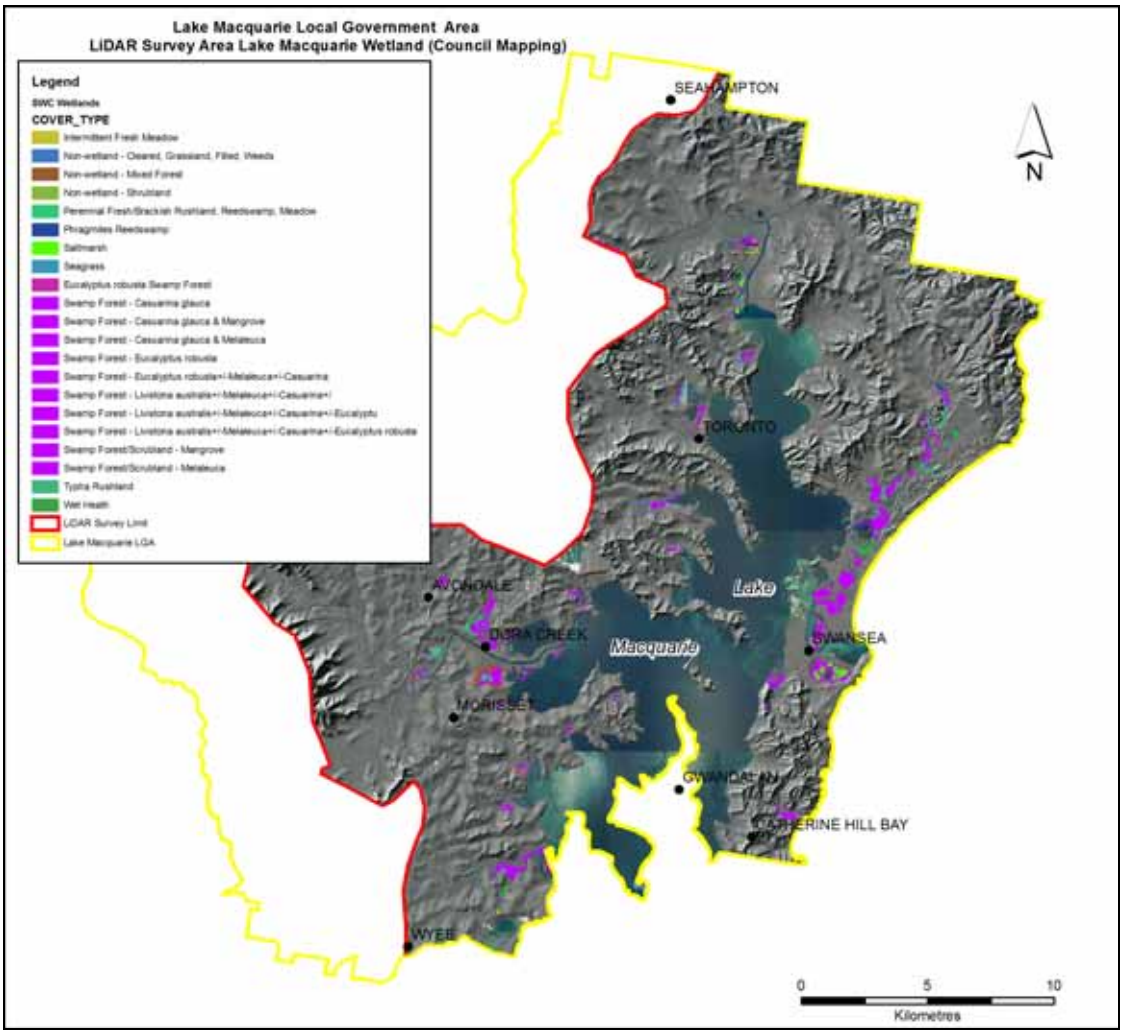


Figure 45. Estuarine macrophytes mapped by NSW DPI for Lake Macquarie. Chart shows hectares of mangrove and saltmarsh in map area.



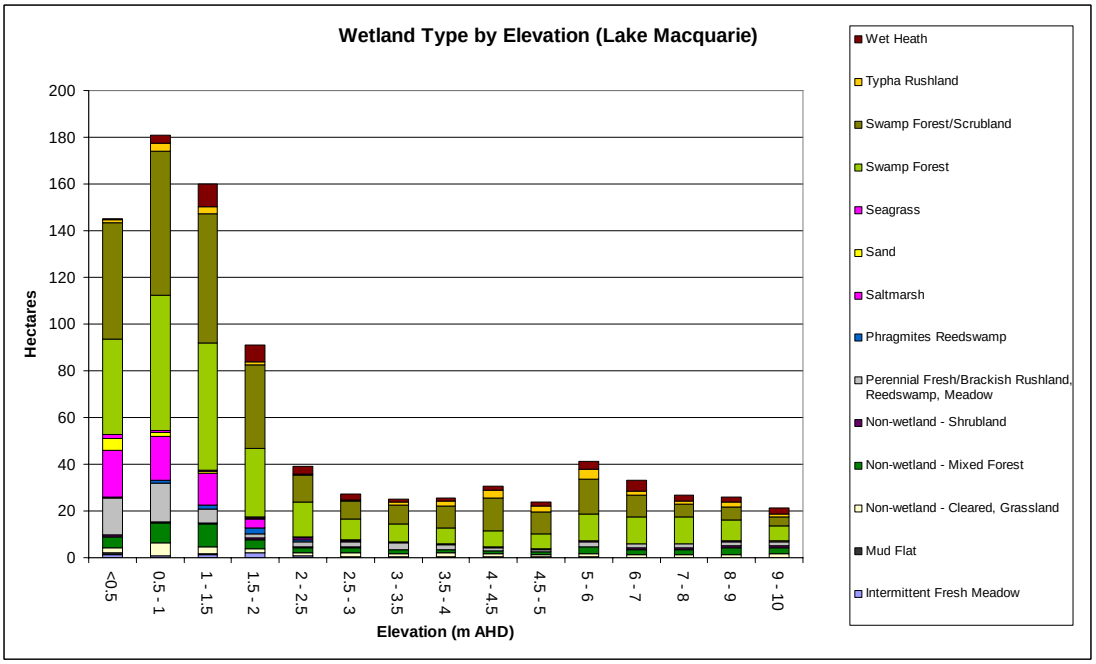


Figure 46. Map of wetland plant communities of Lake Macquarie City LGA (Council data). Swamp forest and saltmarsh dominate in area <1m AHD shown on map.

Newcastle City LGA

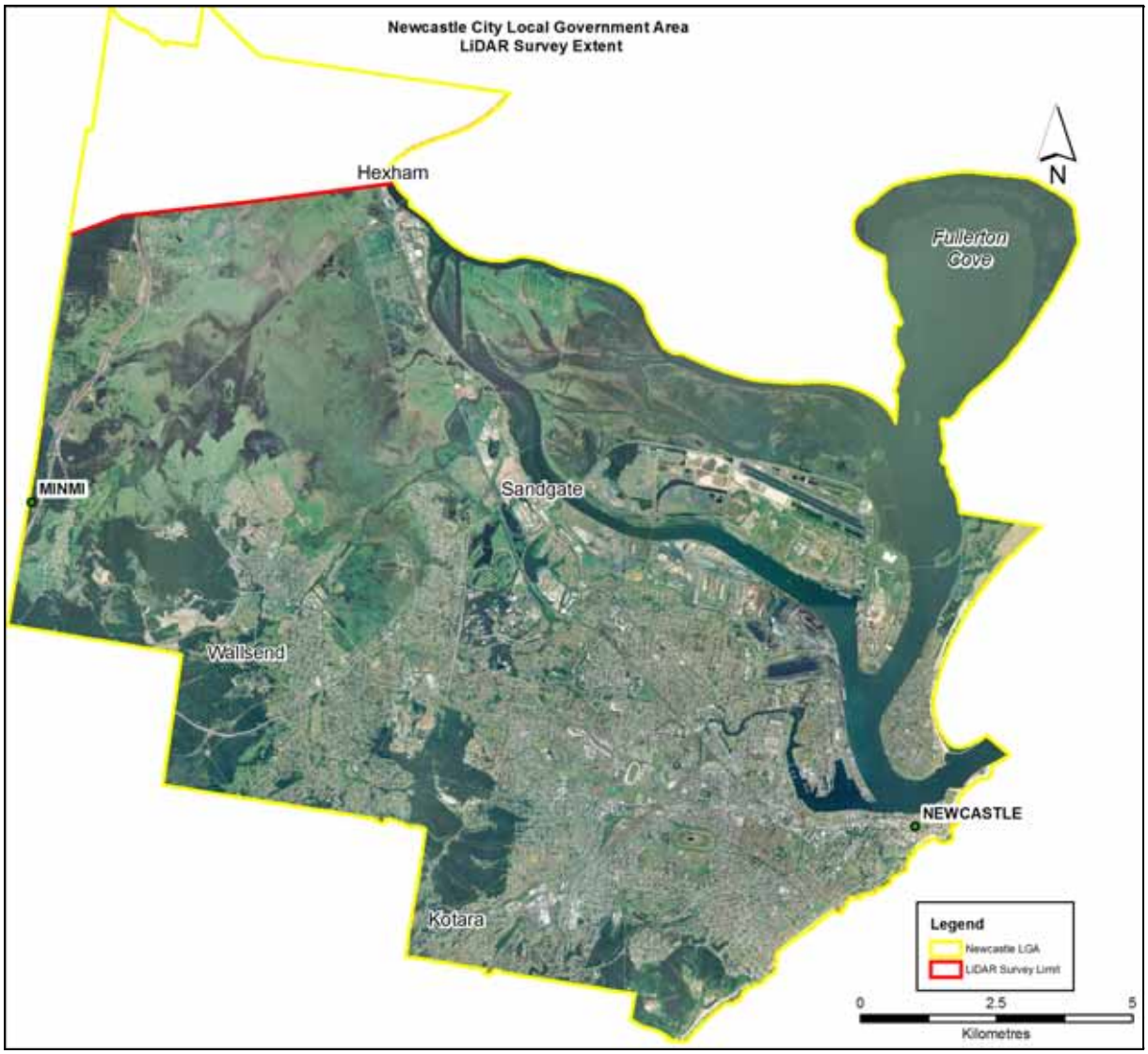


Figure 47. Newcastle City Council local government area. LGA boundary and western limit of LiDAR survey conducted January 2007 shown. Total LGA area is c.215Km^2, LiDAR covers 93% of the LGA.

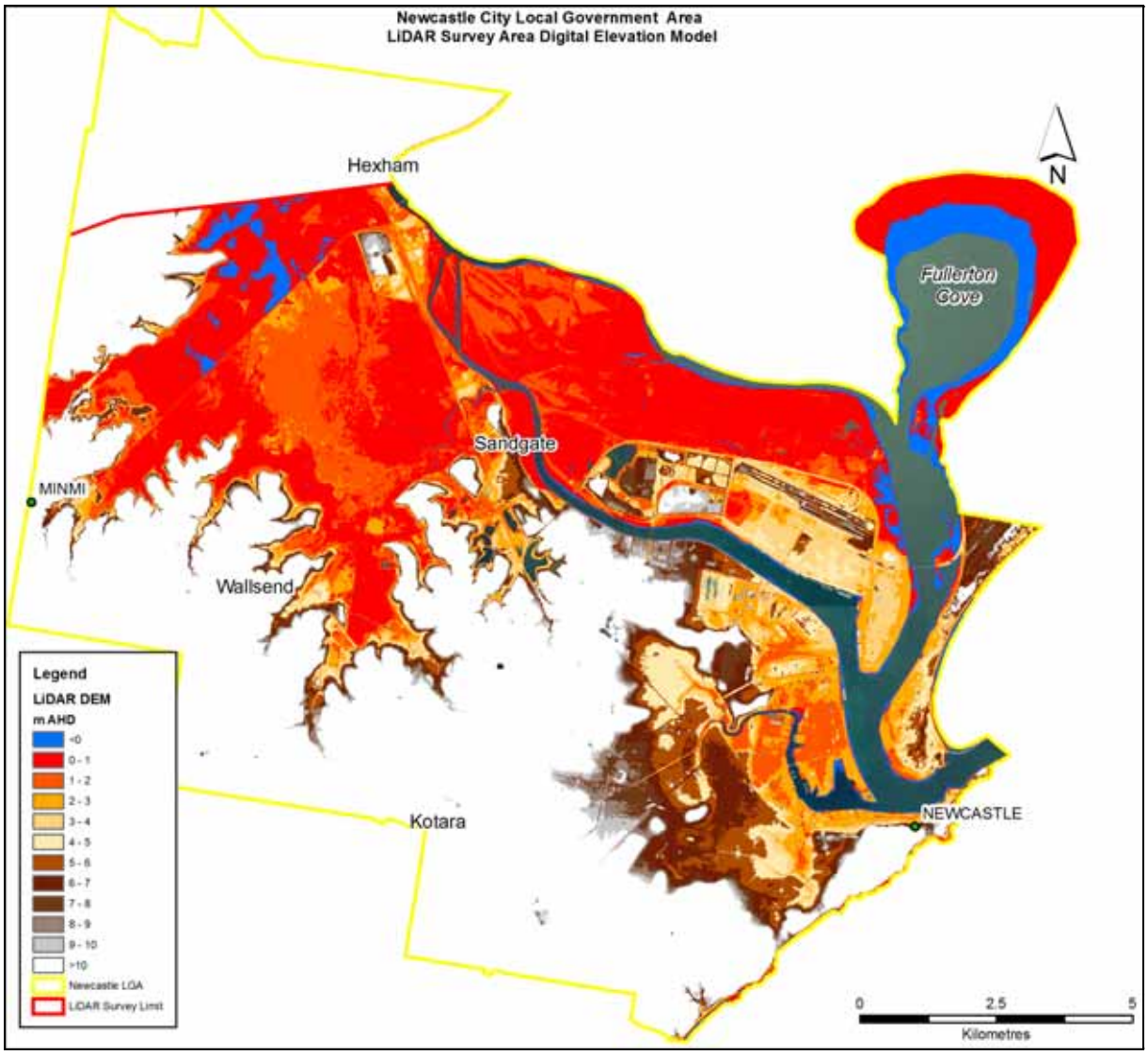


Figure 48. Digital elevation model (DEM) of Newcastle City LGA highlighting areas below 10m AHD. Major areas of low lying land occur along the course of the Hunter River and its estuary.

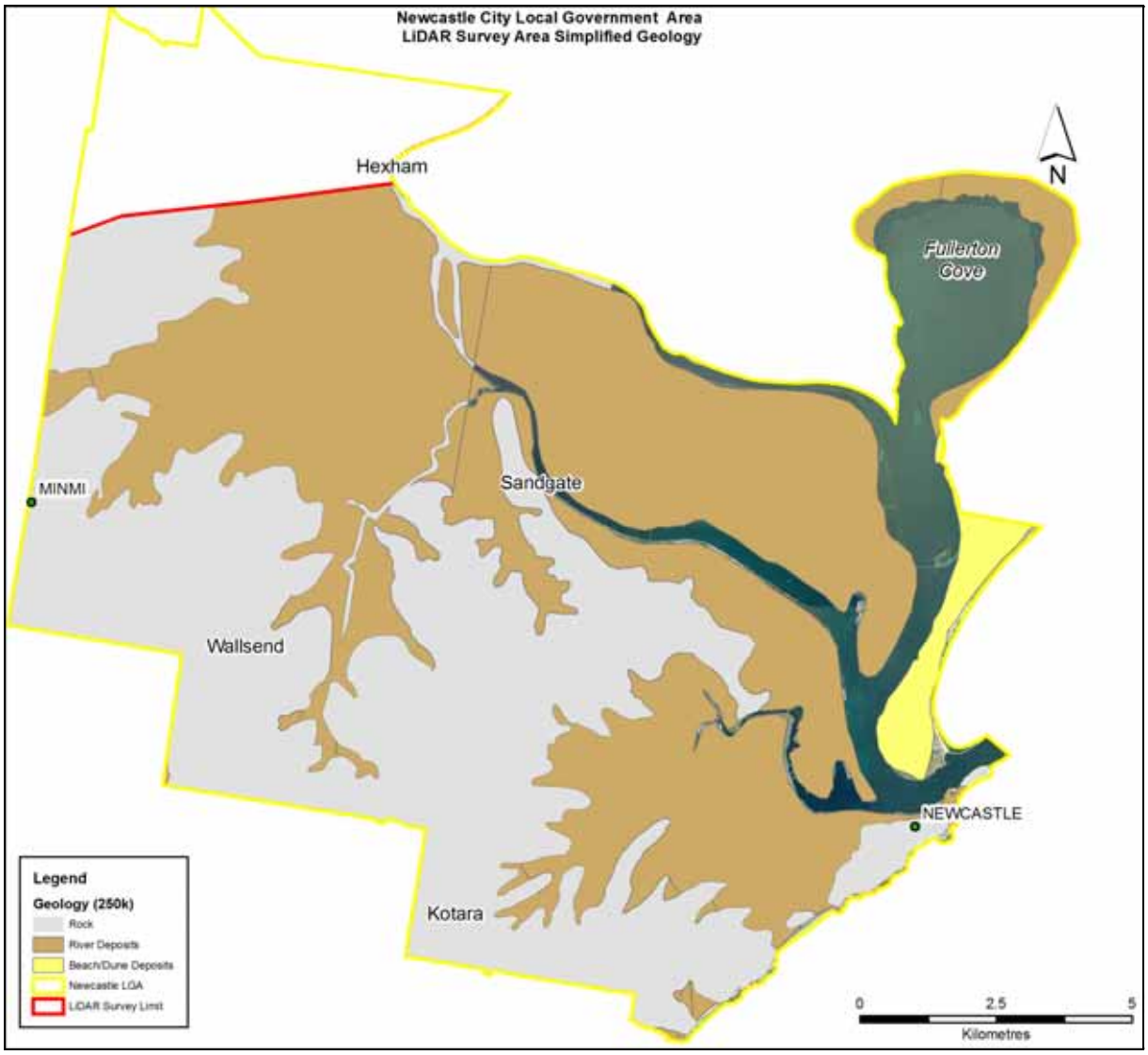
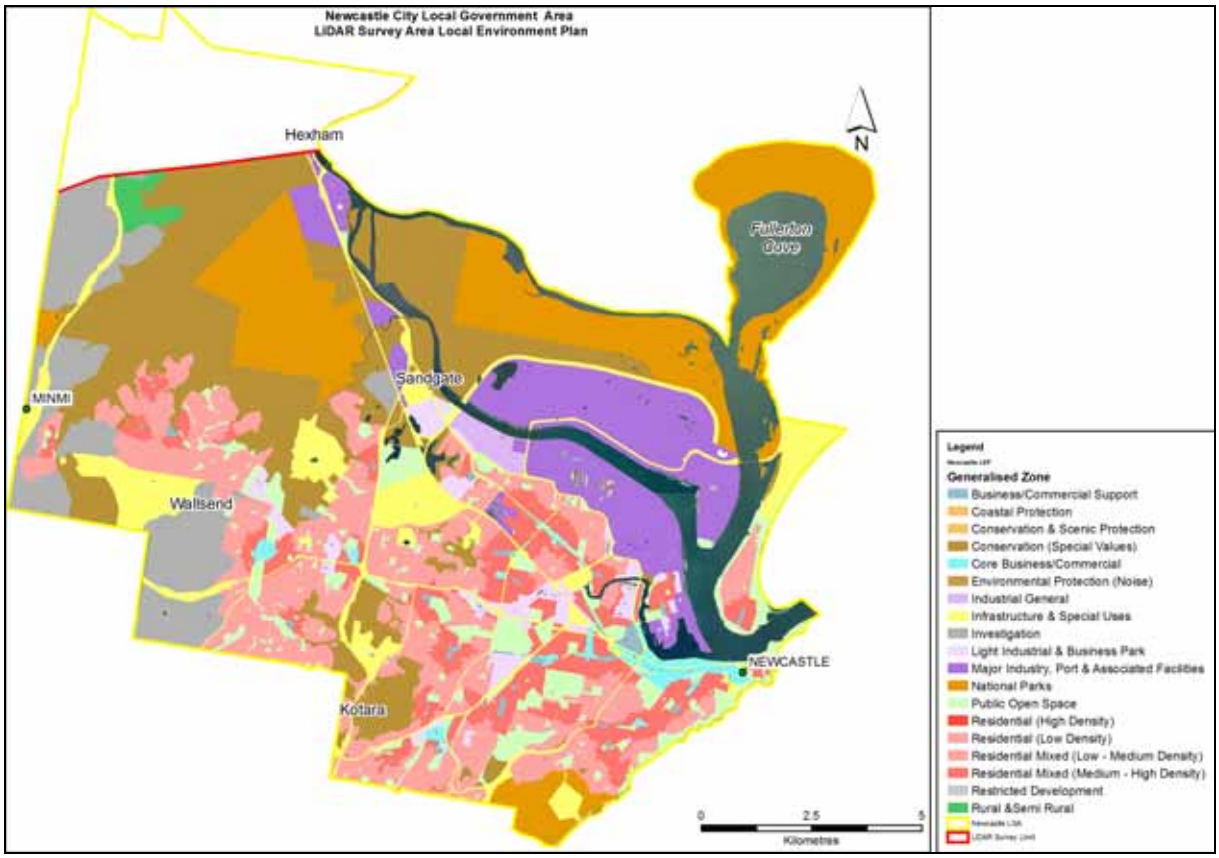


Figure 49. Main geological units of the Newcastle City LGA. A comparison with the DEM for the same area will show low lying areas are comprised of unconsolidated to semi-consolidated river and beach/dune deposits.



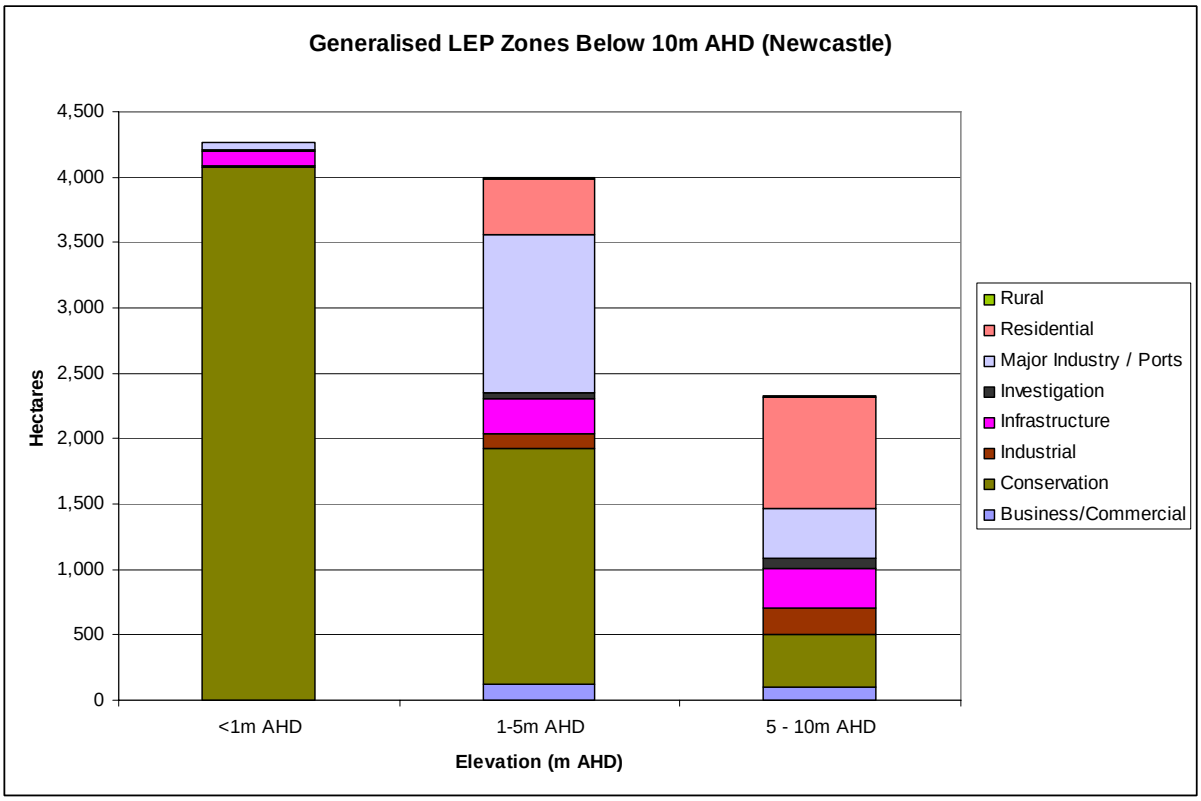
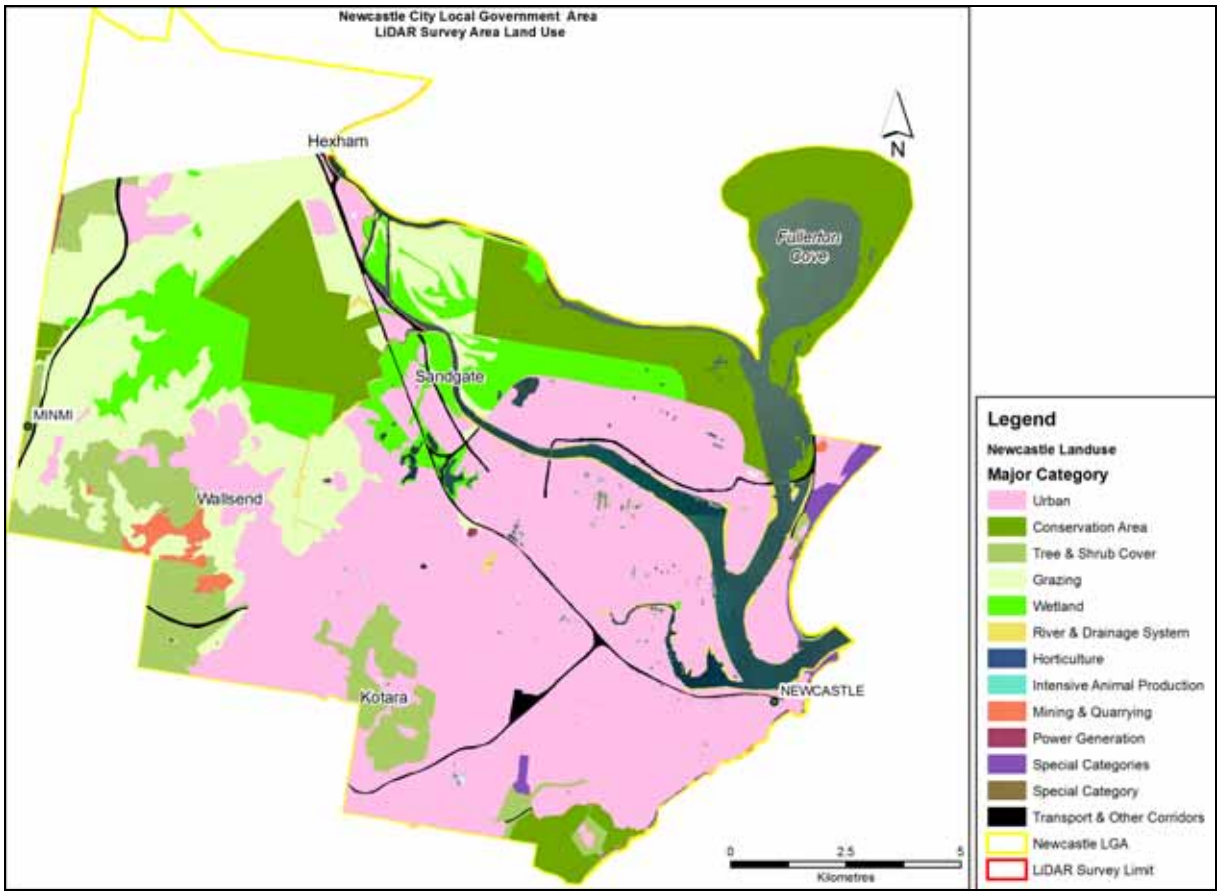


Figure 50. Map and chart showing generalised LEP zones and their distribution by elevation below 10m AHD for a section of the Newcastle City LGA. For interval <1m AHD, the top three zonings are Conservation (4077Ha), Infrastructure (116Ha) and Major Industry / Ports (56Ha). Residential is c.2Ha. Note that number of categories in chart legend differs from that in map as former relates only to those zones encountered below 10m AHD.



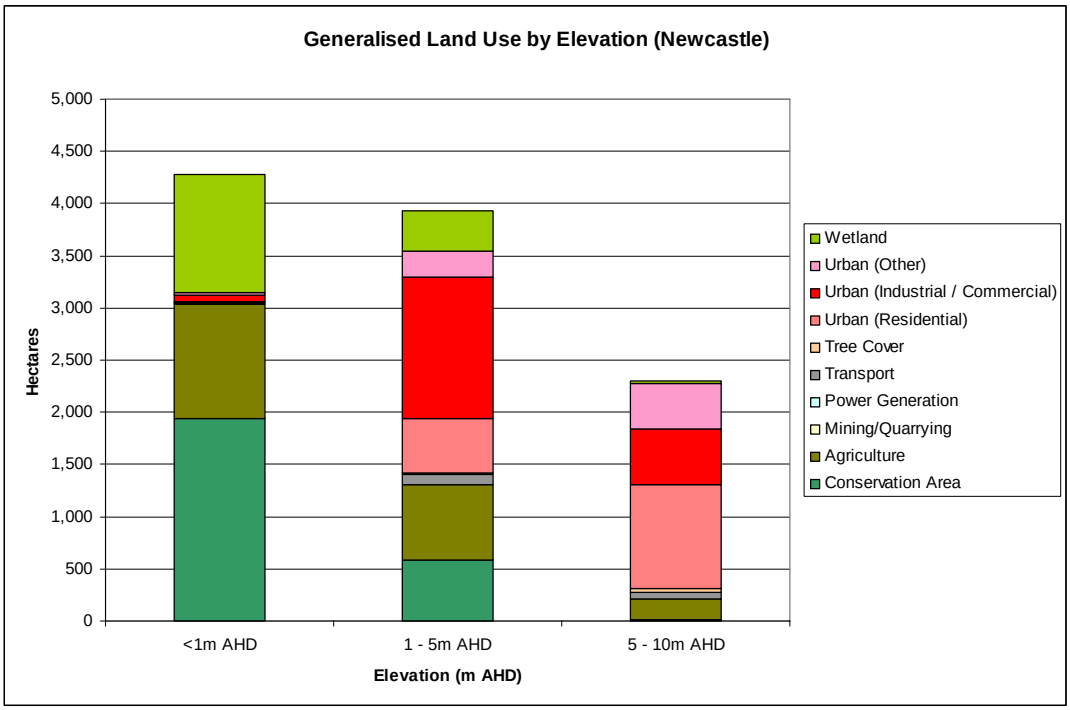
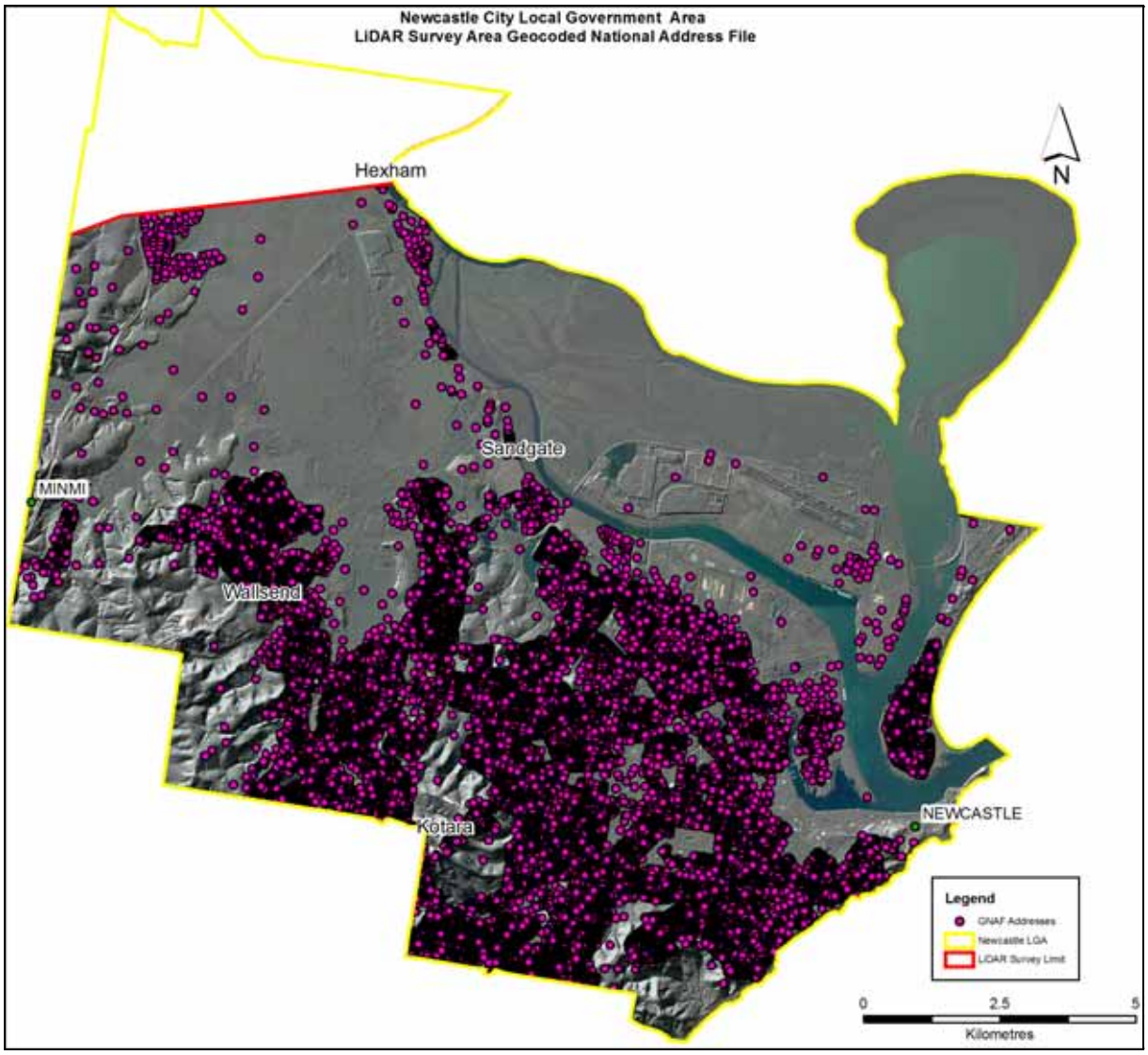


Figure 51. Map and chart showing generalised Land Use categories and their distribution by elevation below 10m AHD for a section of Newcastle LGA. Below 1m AHD, main land use category is Conservation (1941Ha), Urban Residential comprises 7Ha. Urban Industrial/Commercial (68Ha) is the highest of the study area for this elevation. Note that number of categories in chart legend differs from that in map as former relates only to those land uses encountered below 10m AHD.



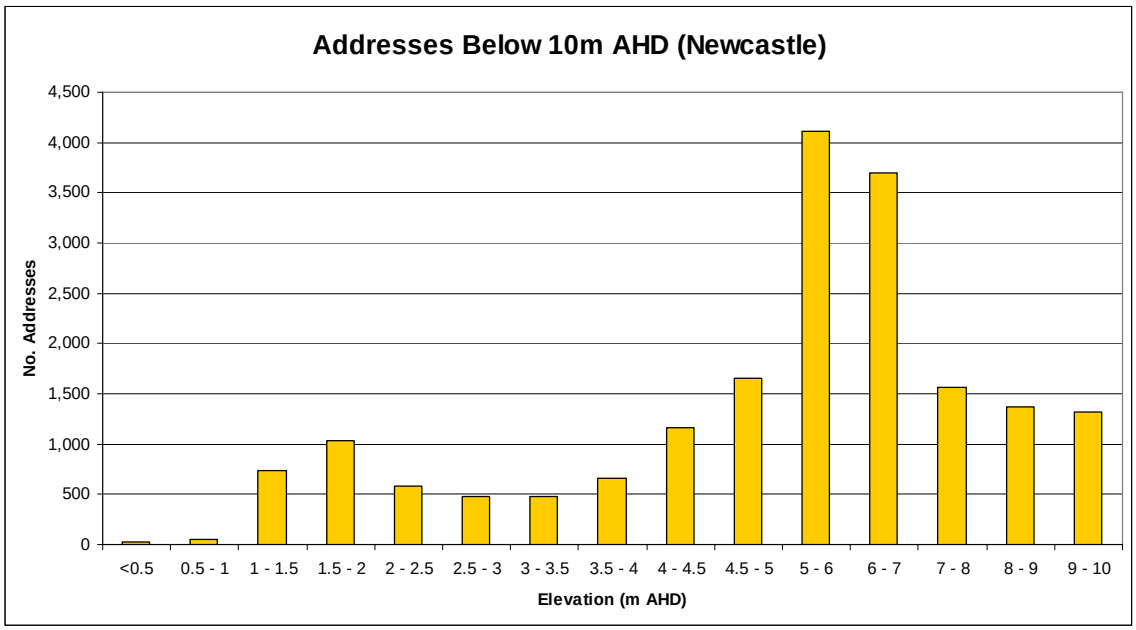
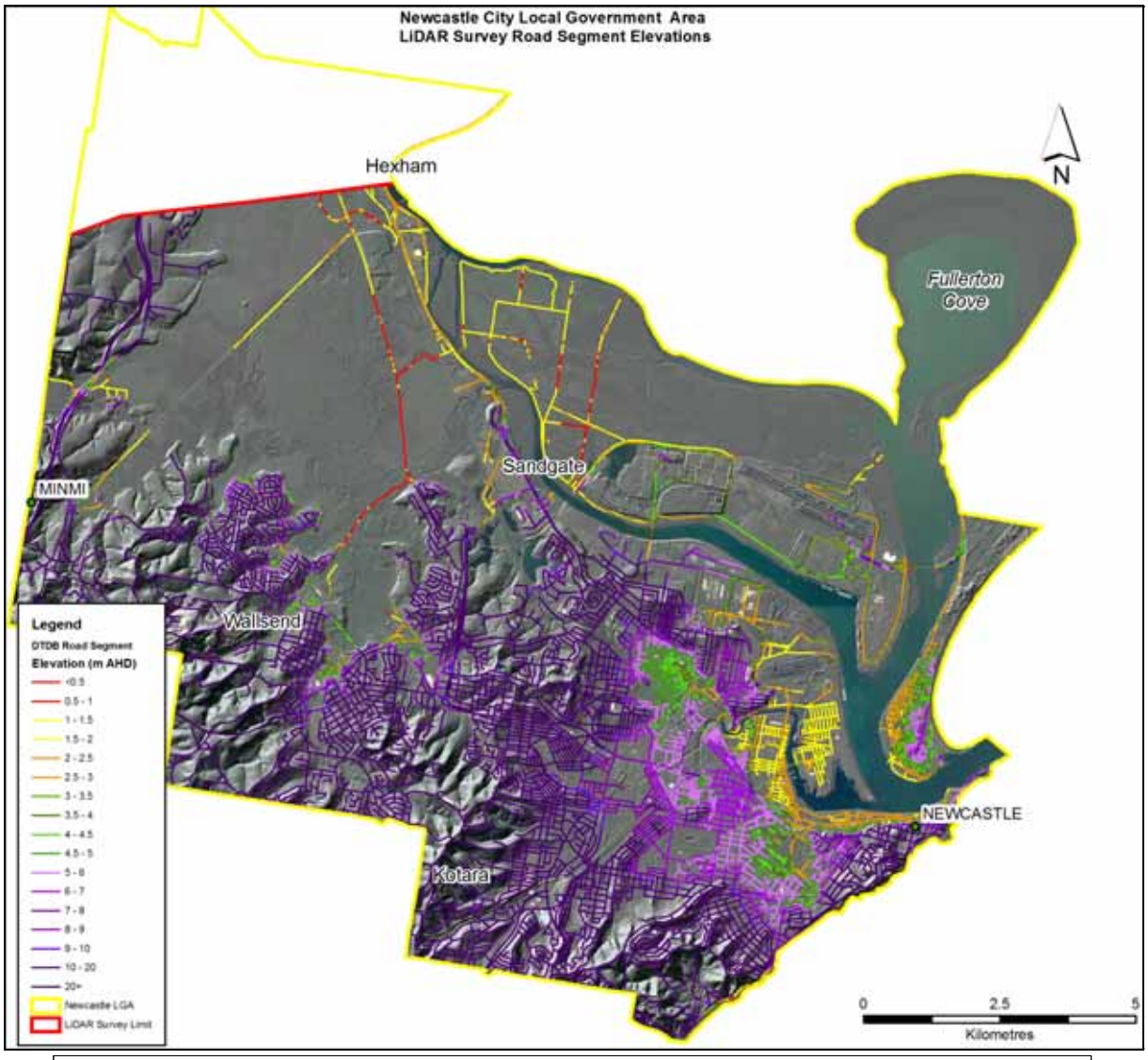


Figure 52. Map showing distribution of addresses in Newcastle City LGA. Chart classifies addresses by elevation below 10m AHD in map area.



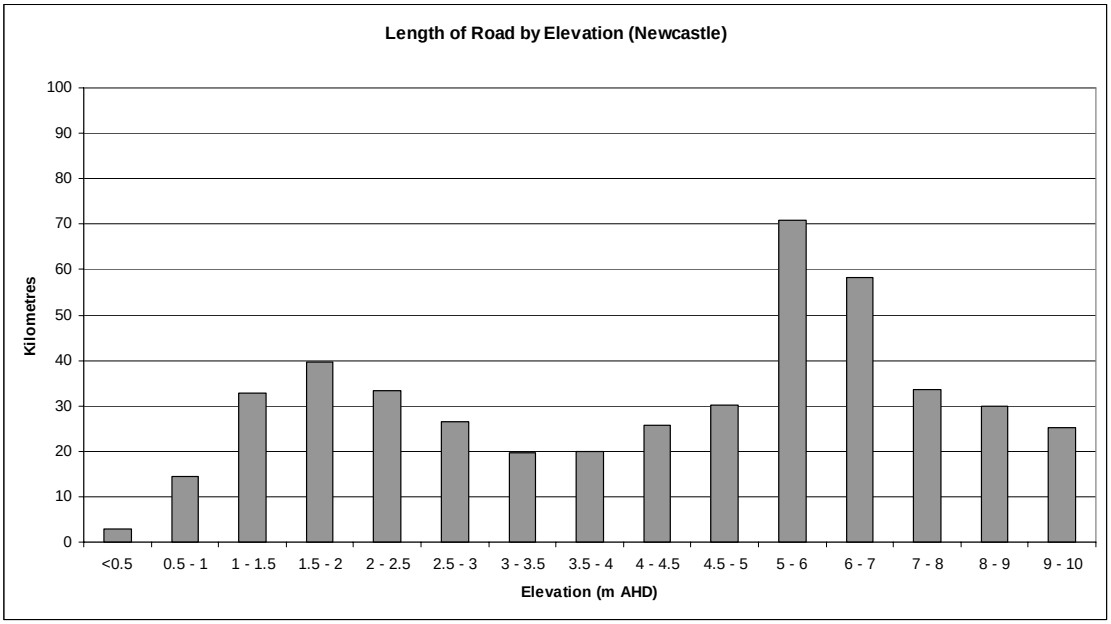


Figure 53. Map showing roads classified by elevation in Newcastle LGA. Chart shows elevation of roads below 10m AHD in map area.

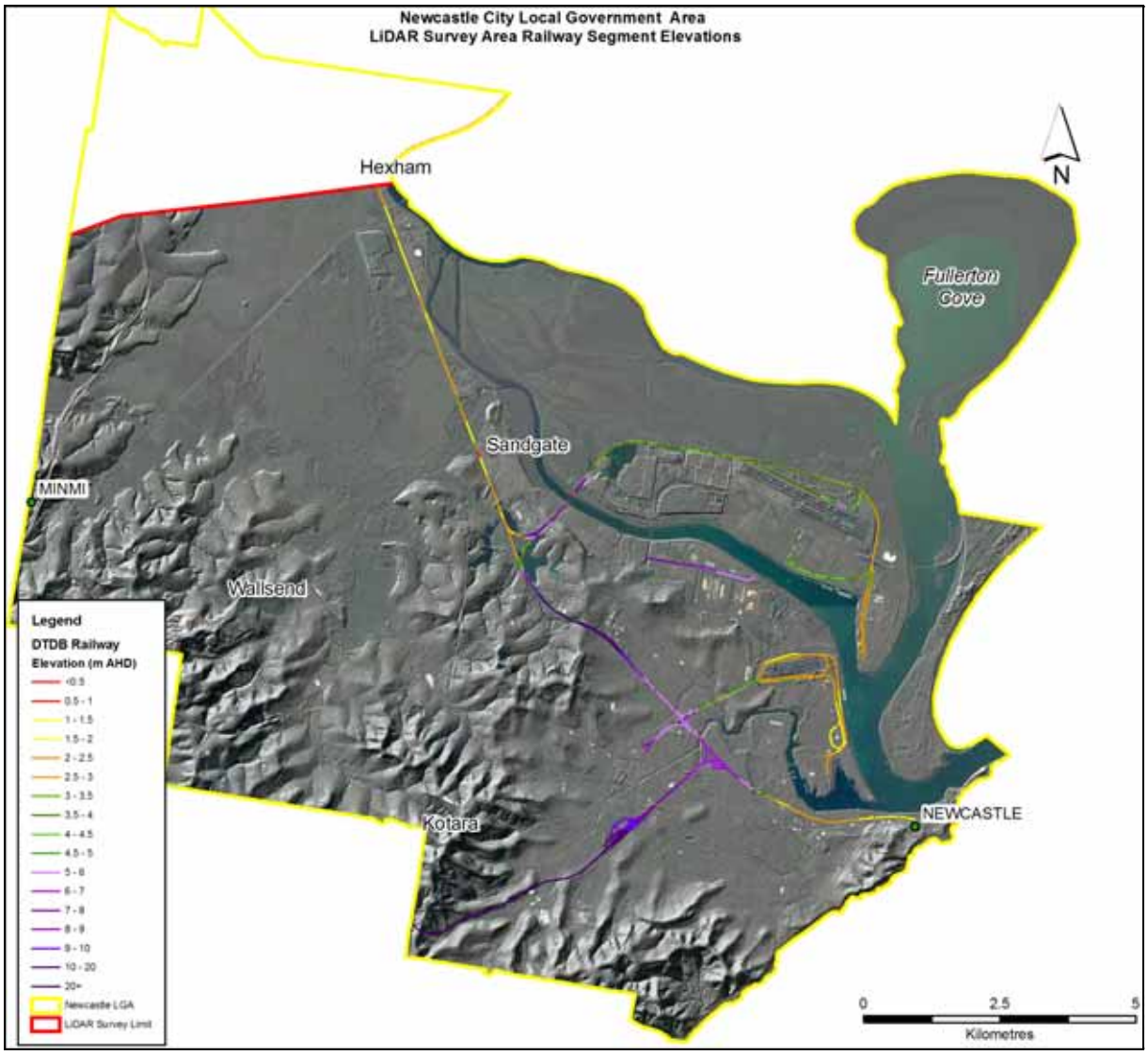
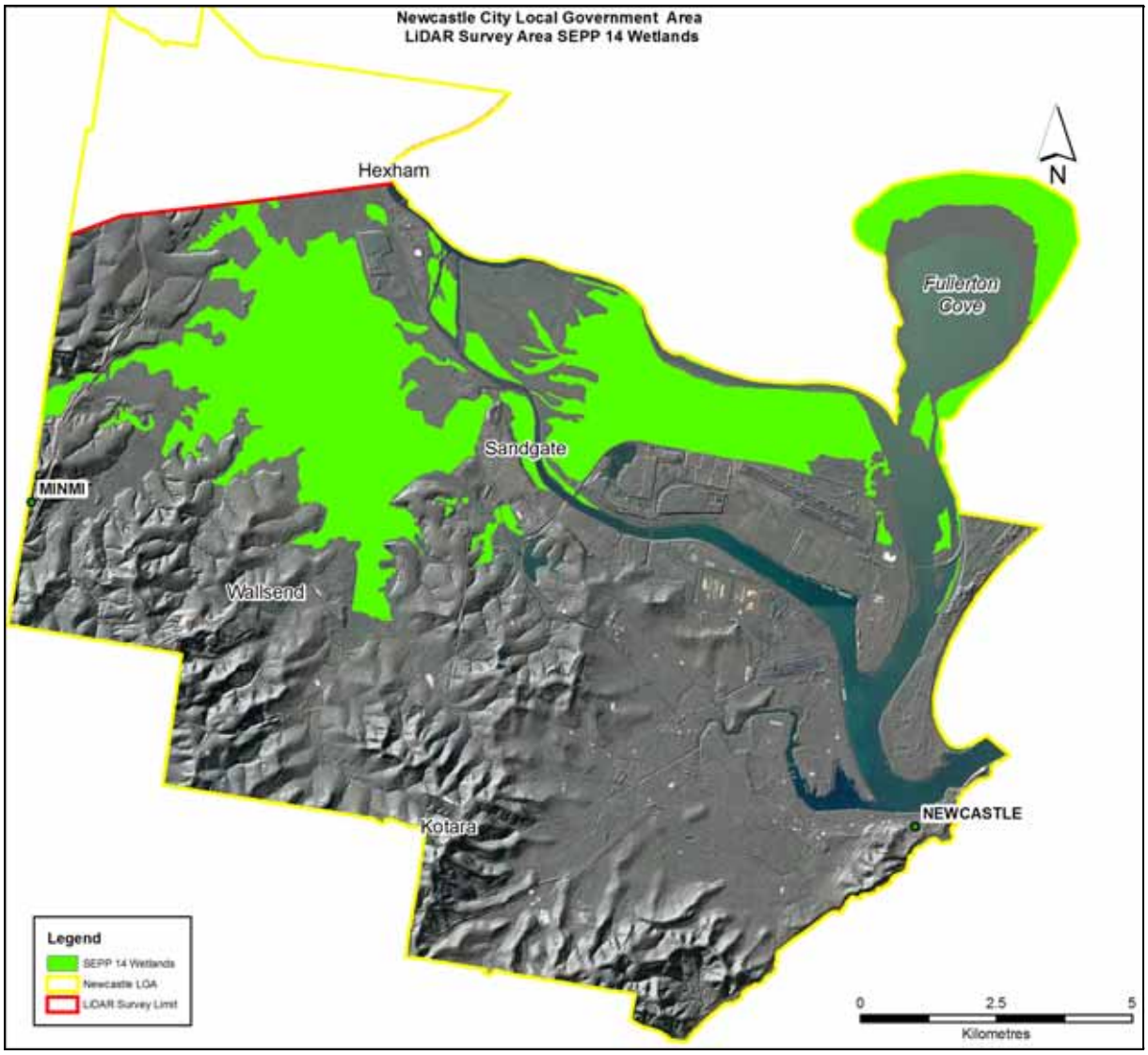


Figure 54. Elevation of main railroad lines in Newcastle City LGA.



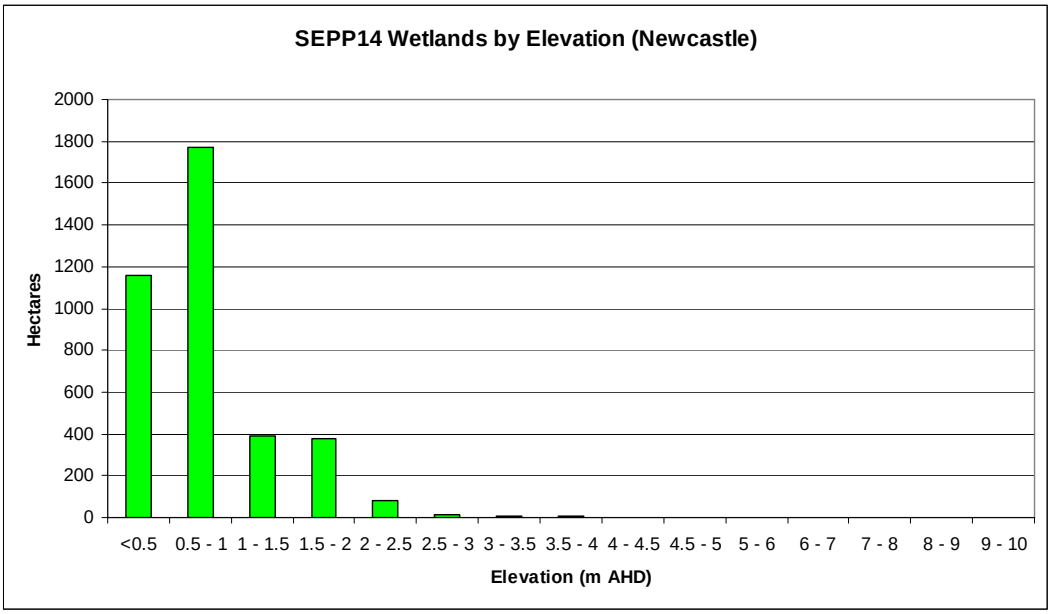
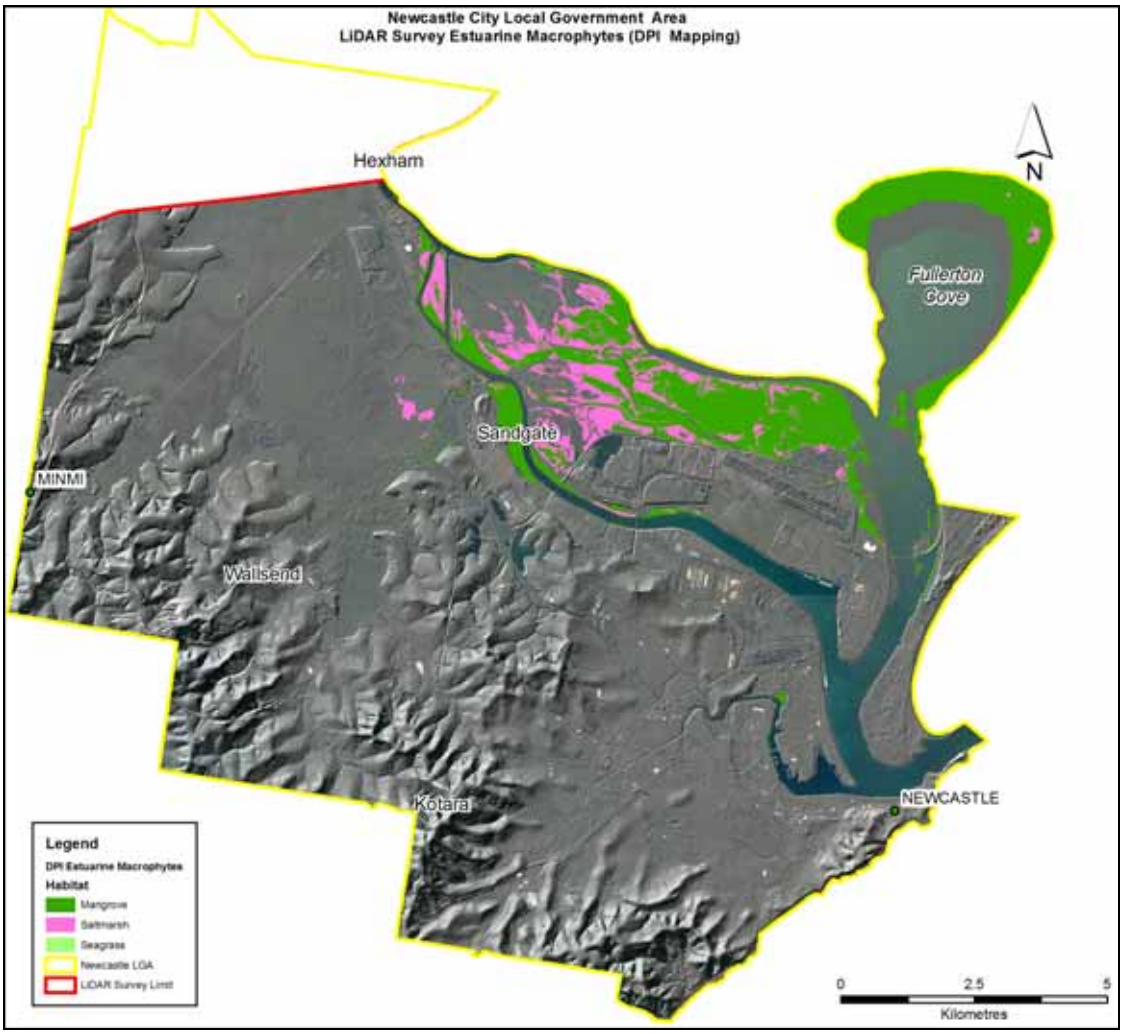


Figure 55. Map showing distribution of SEPP14 Wetlands in Newcastle LGA. Chart shows areas of wetland below 10m AHD in map area.



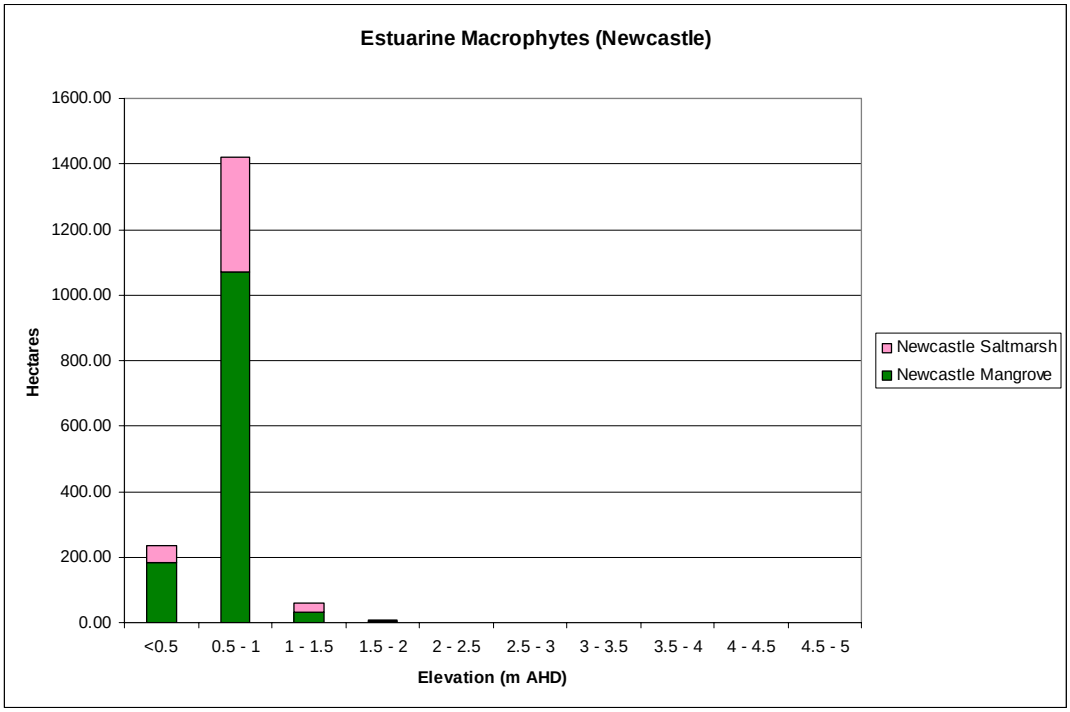


Figure 56. Estuarine macrophytes mapped by NSW DPI for Lower Hunter. Chart shows hectares of mangrove and saltmarsh for map area.

Port Stephens LGA

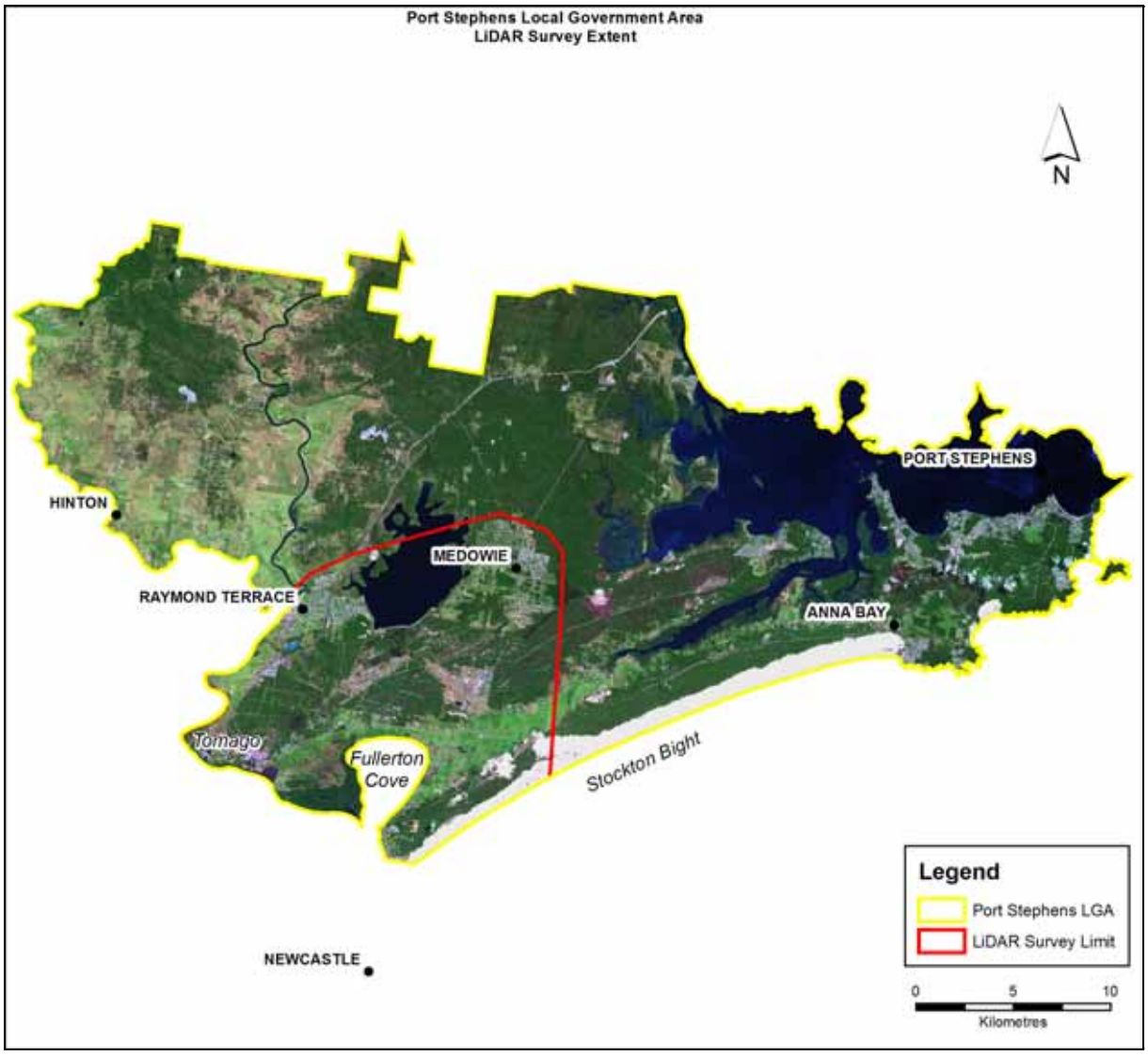


Figure 57. Port Stephens local government area. LGA boundary and northern limit of LiDAR survey conducted in January 2007 shown. Total LGA area is c.9,970Km2, LiDAR covers 22% of the LGA.

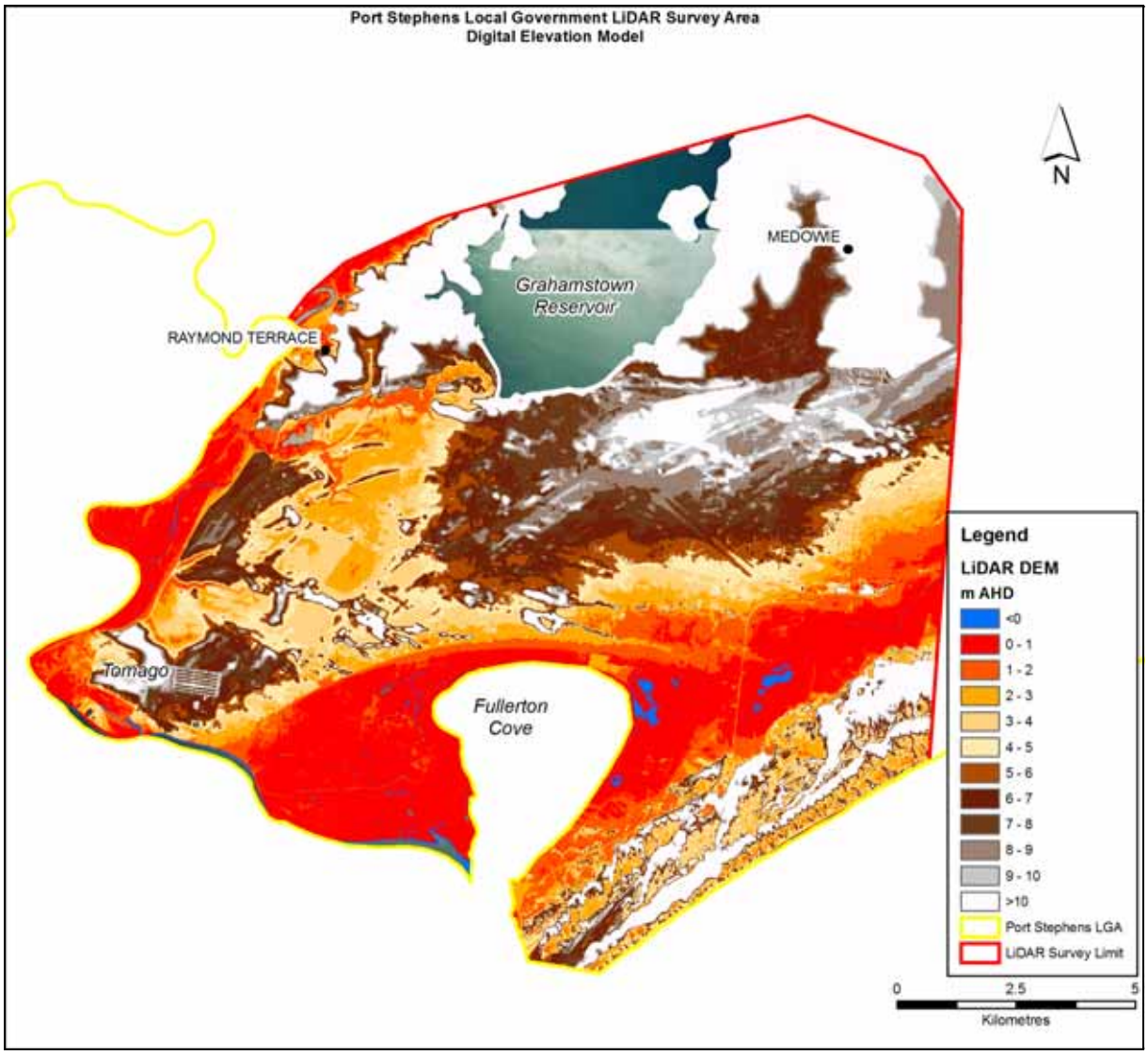


Figure 58. Digital elevation model (DEM) of southern portion of the Port Stephens LGA highlighting areas below 10m AHD. Major areas of low lying land occur adjacent to the Hunter River and its estuary as well as between the Inner and Outer Barrier systems of Stockton Bight to the north east of Fullerton Cove.

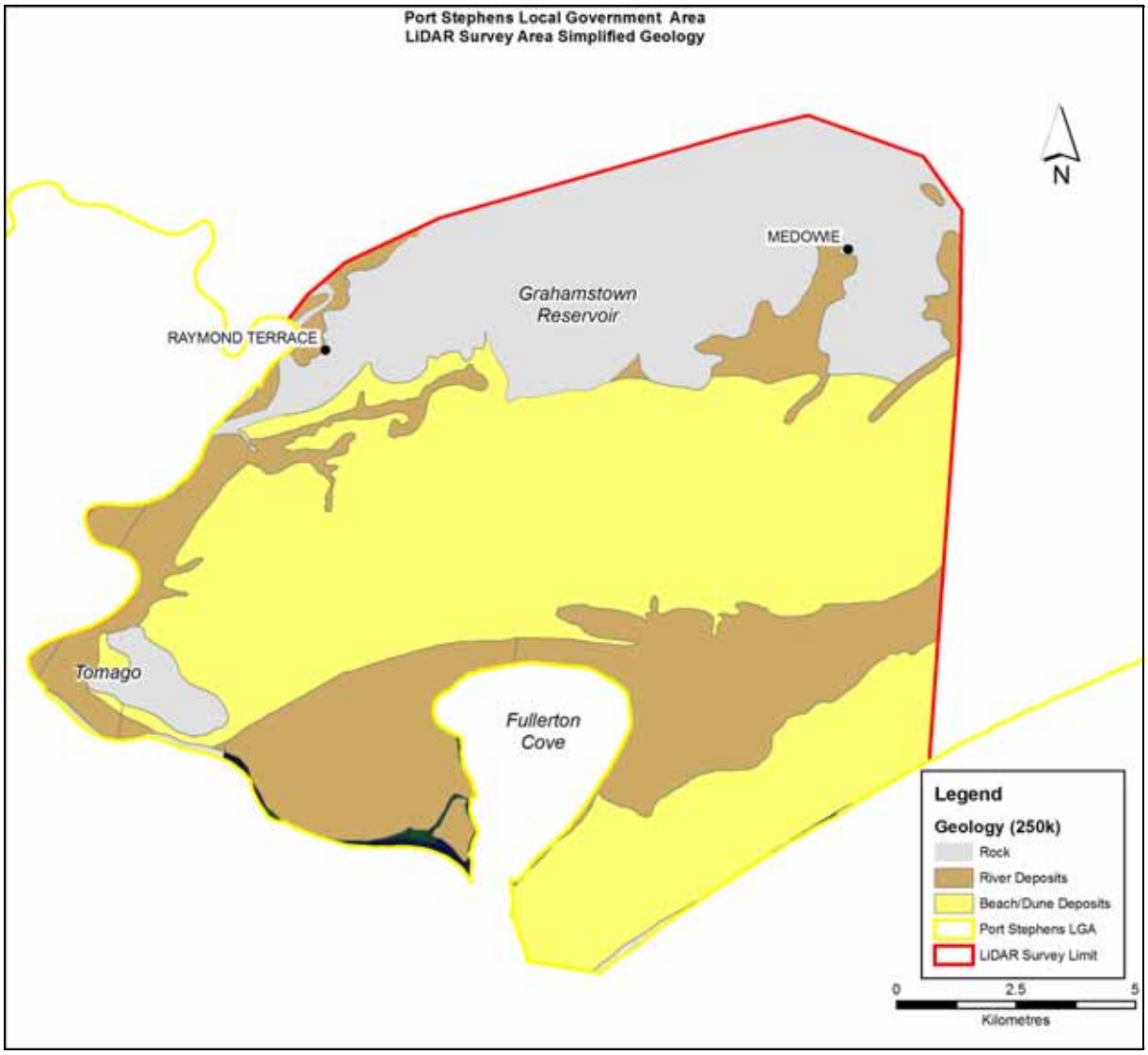
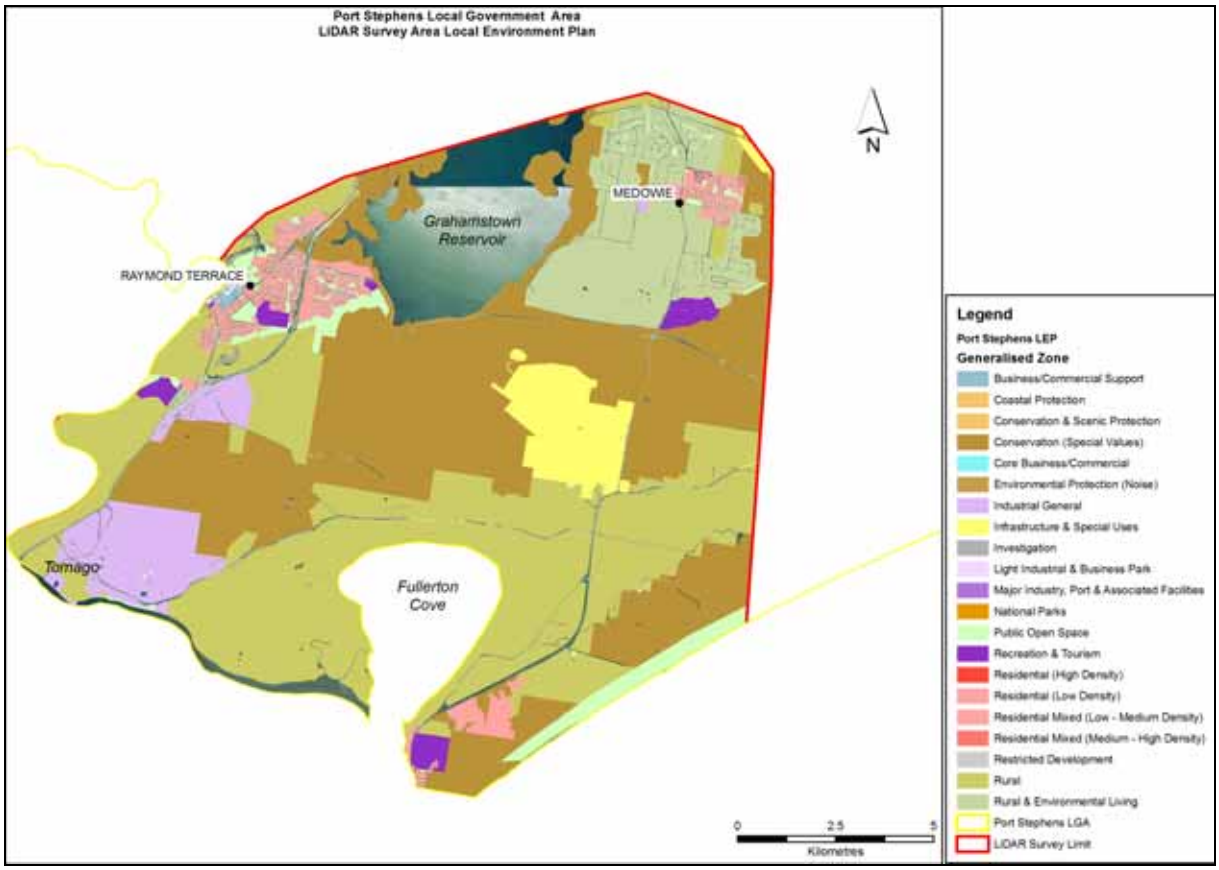


Figure 59. Main geological units of the southern portion of Port Stephens LGA. A comparison with the DEM for the same area will show a majority of low lying areas are comprised of unconsolidated to semi-consolidated river and beach/dune deposits.



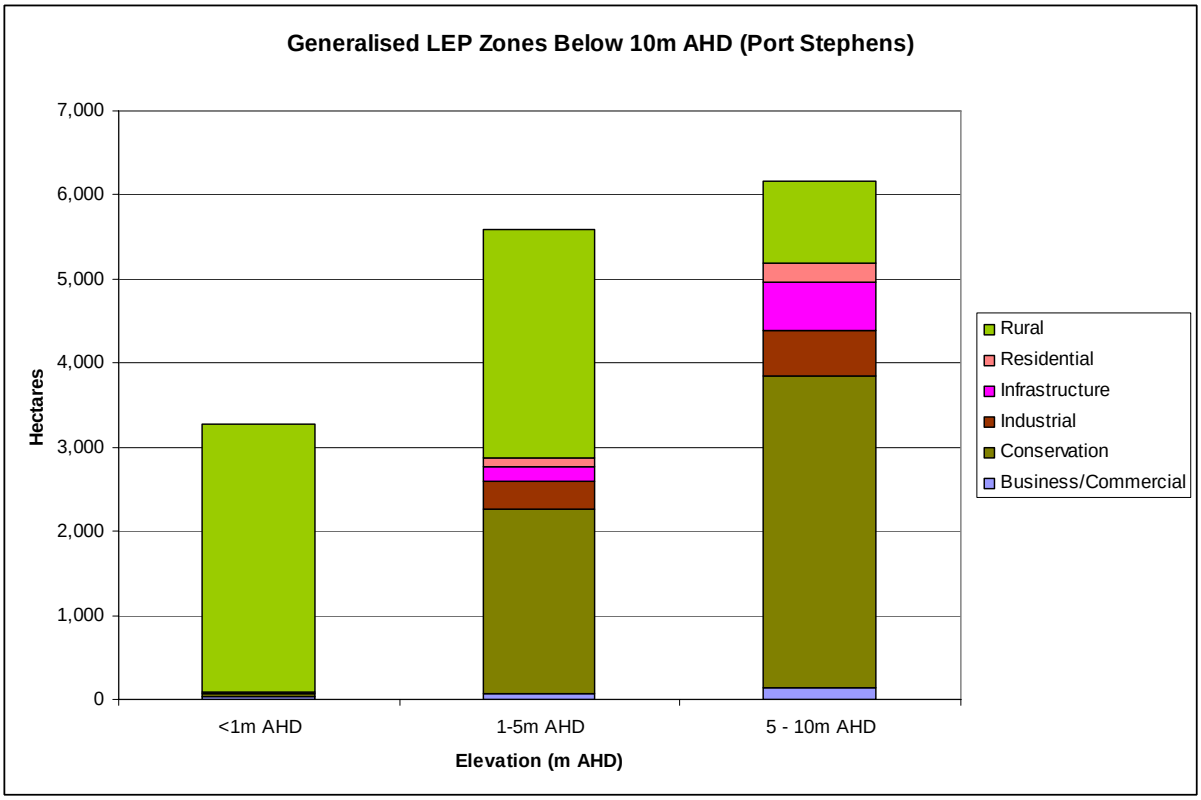
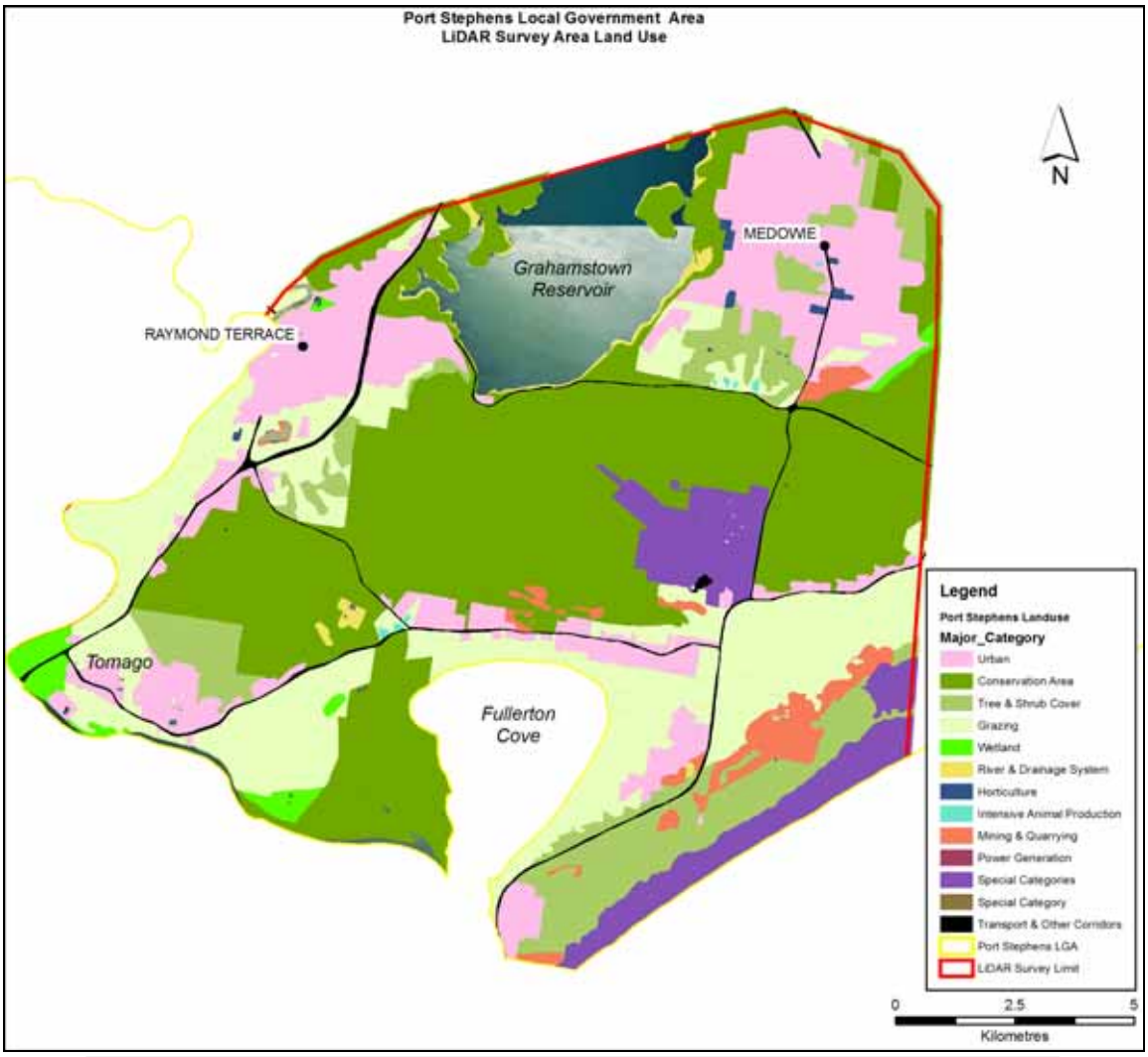


Figure 60. Map and chart showing generalised LEP zones and their distribution by elevation below 10m AHD for section of Port Stephens LGA. Below 1mAHD, the top three zonings are Rural (3192Ha), Conservation (35Ha) and Business/Commercial (32Ha). Residential represents 1Ha. Note that number of categories in chart legend differs from that in map as former relates only to those zones encountered below 10m AHD.



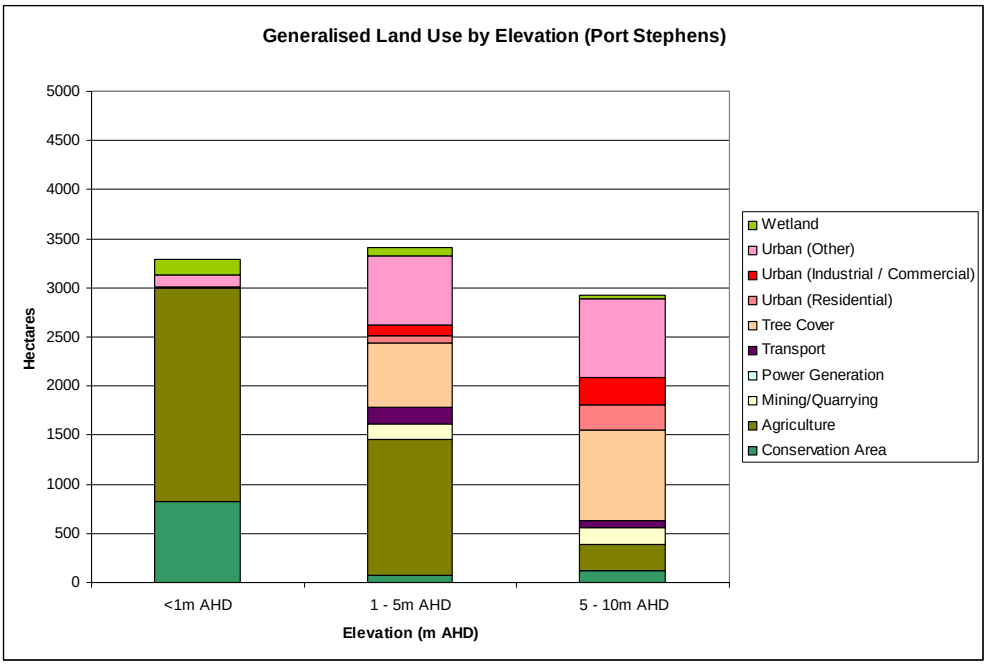
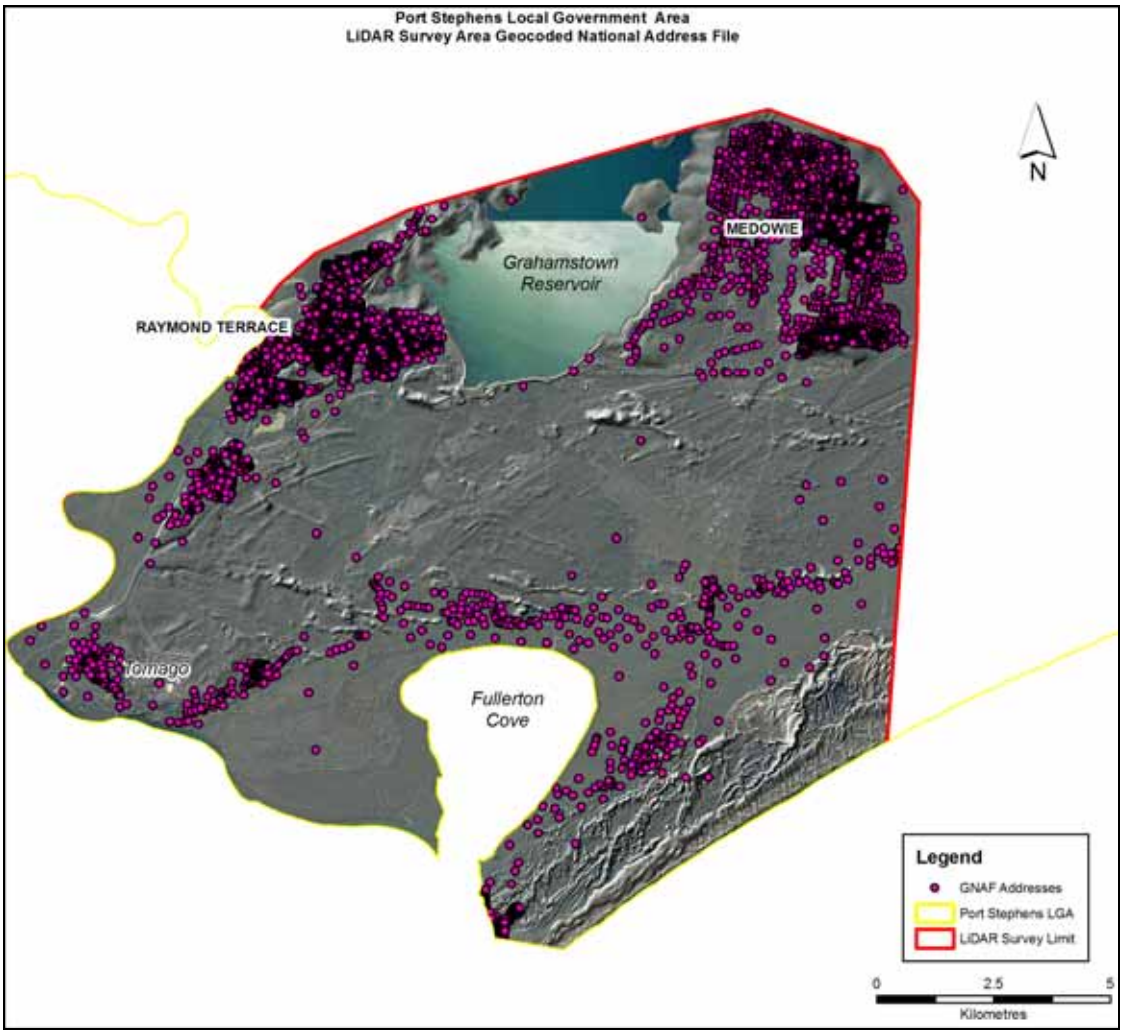


Figure 61. Map and chart showing generalised Land Use categories and their distribution by elevation below 10m AHD for section of Port Stephens LGA. Below 1m AHD, main land use category is Agriculture (2162Ha), Urban Residential comprises c.1Ha. Note that number of categories in chart legend differs from that in map as former relates only to those land uses encountered below 10m AHD.



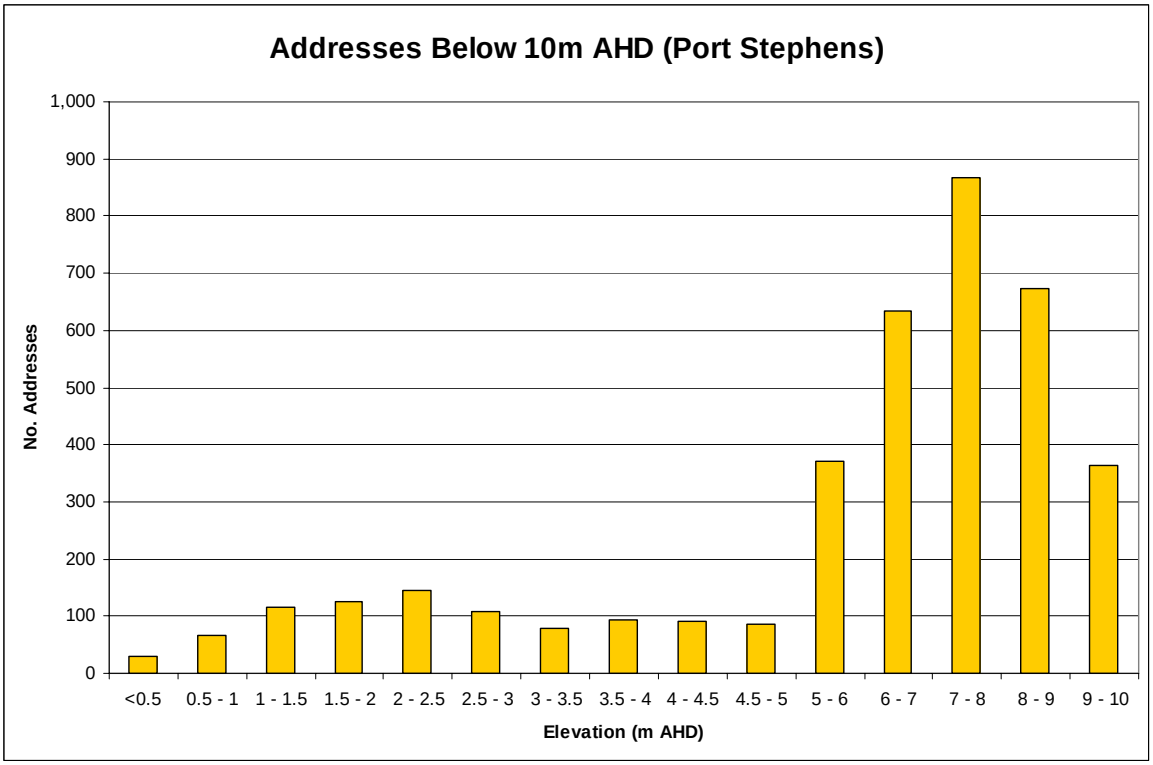
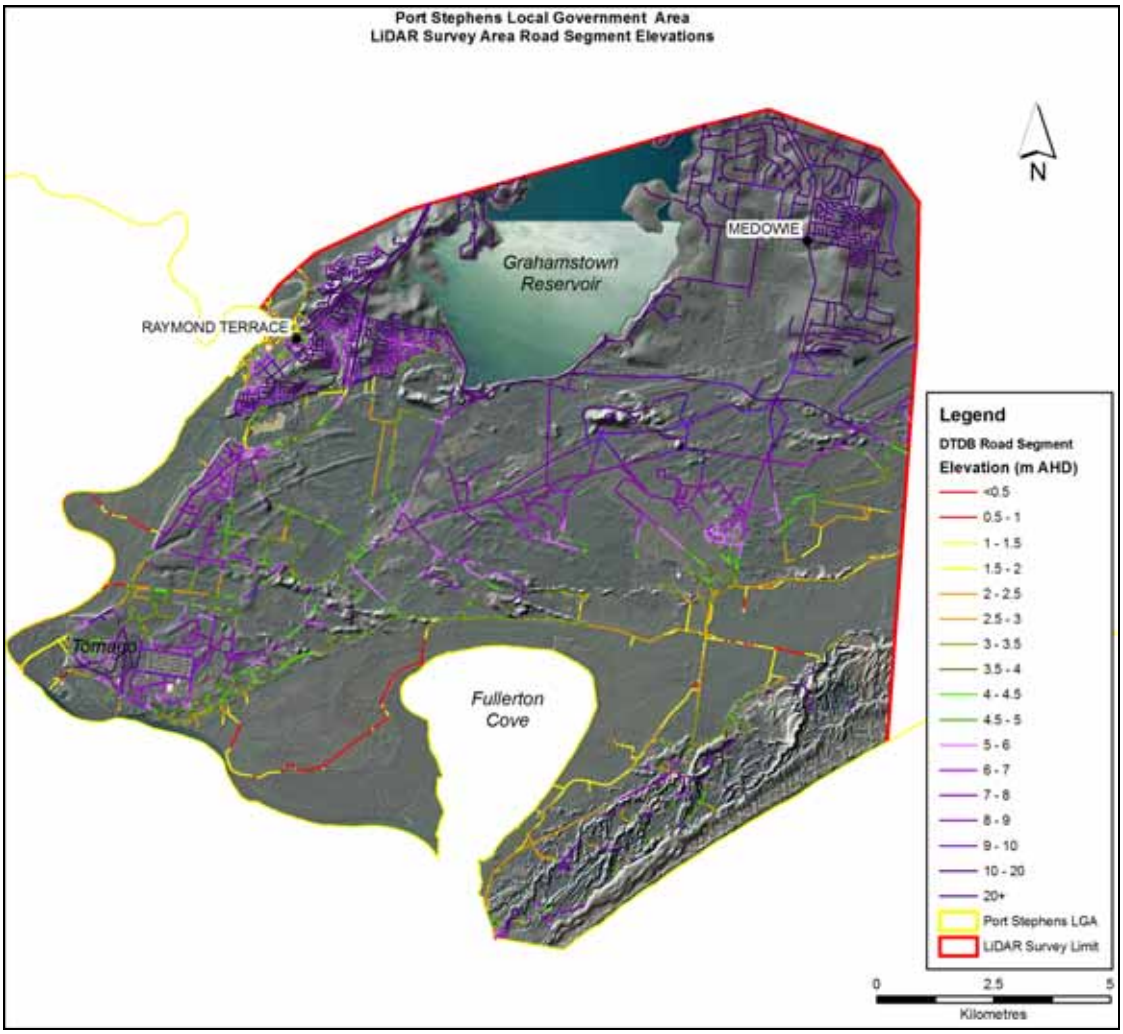


Figure 62. Map showing distribution of addresses in southern portion of Port Stephens LGA. Chart classifies addresses by elevation <10m AHD for map area.



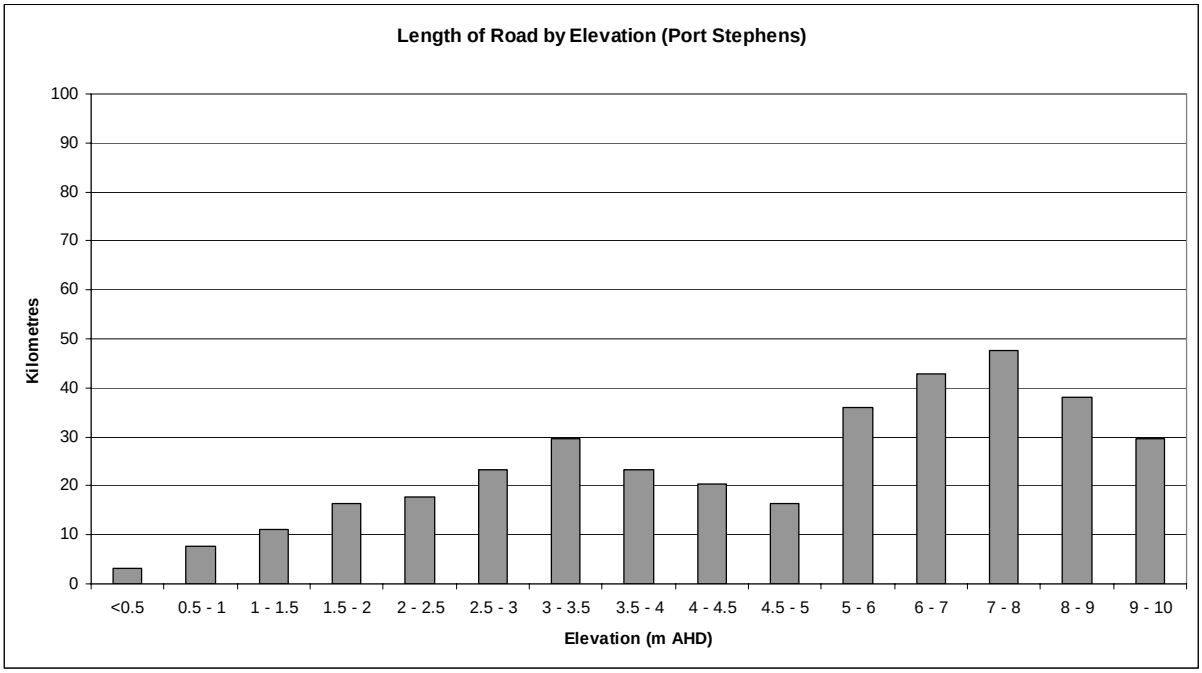
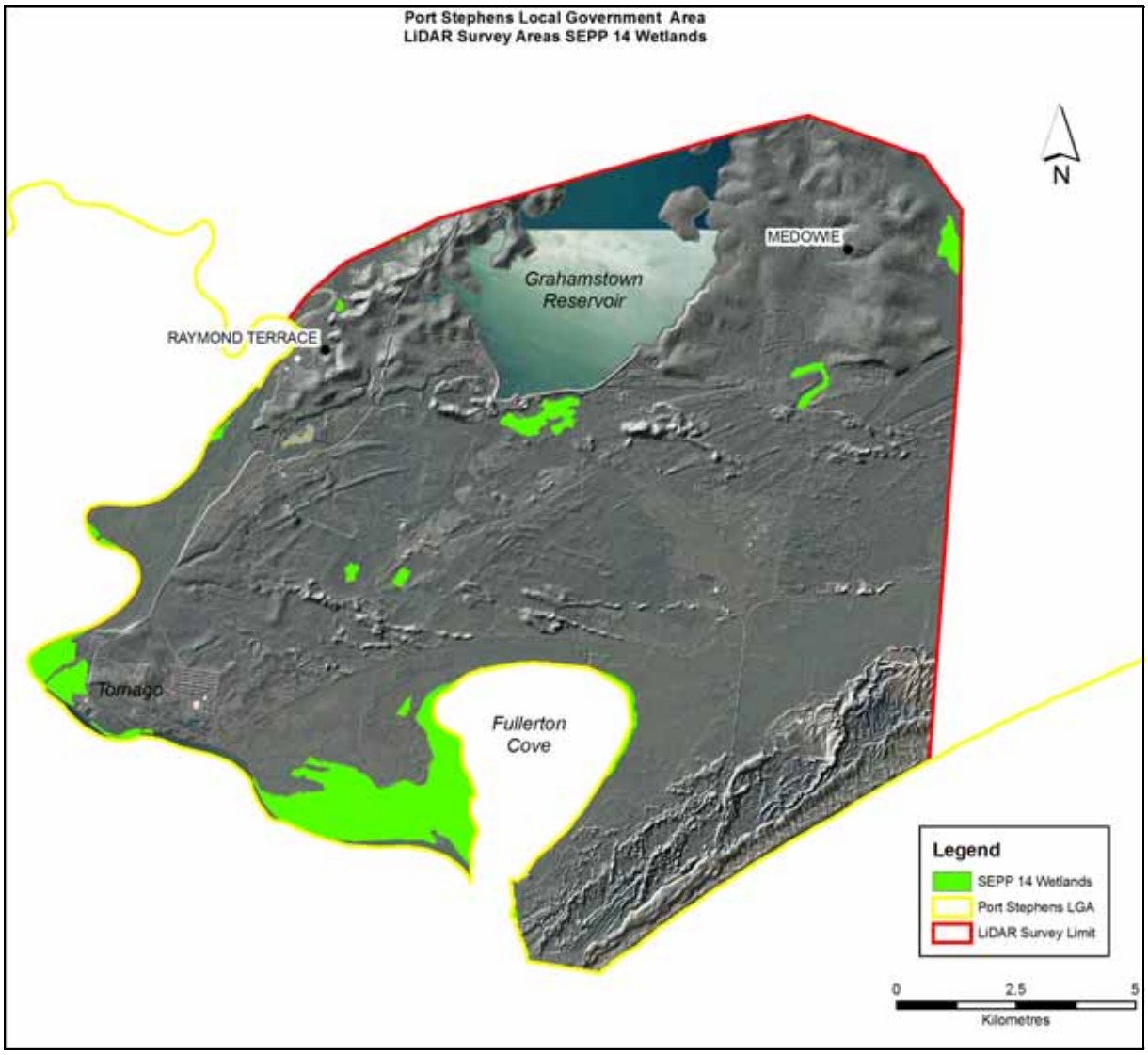


Figure 63. Map showing roads classified by elevation for southern portion of Port Stephens LGA. Chart shows elevation of roads below 10m AHD for map area.



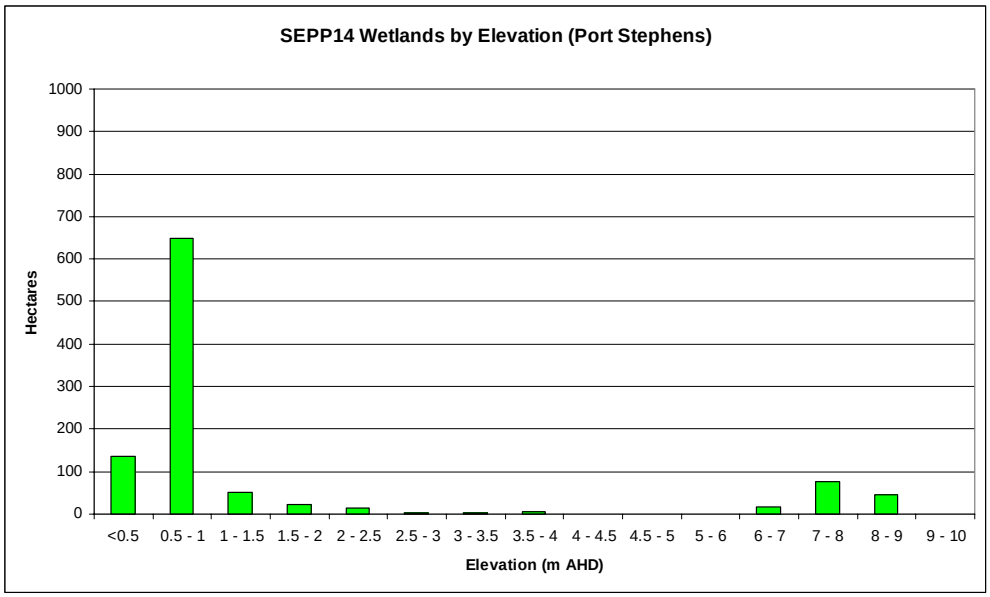
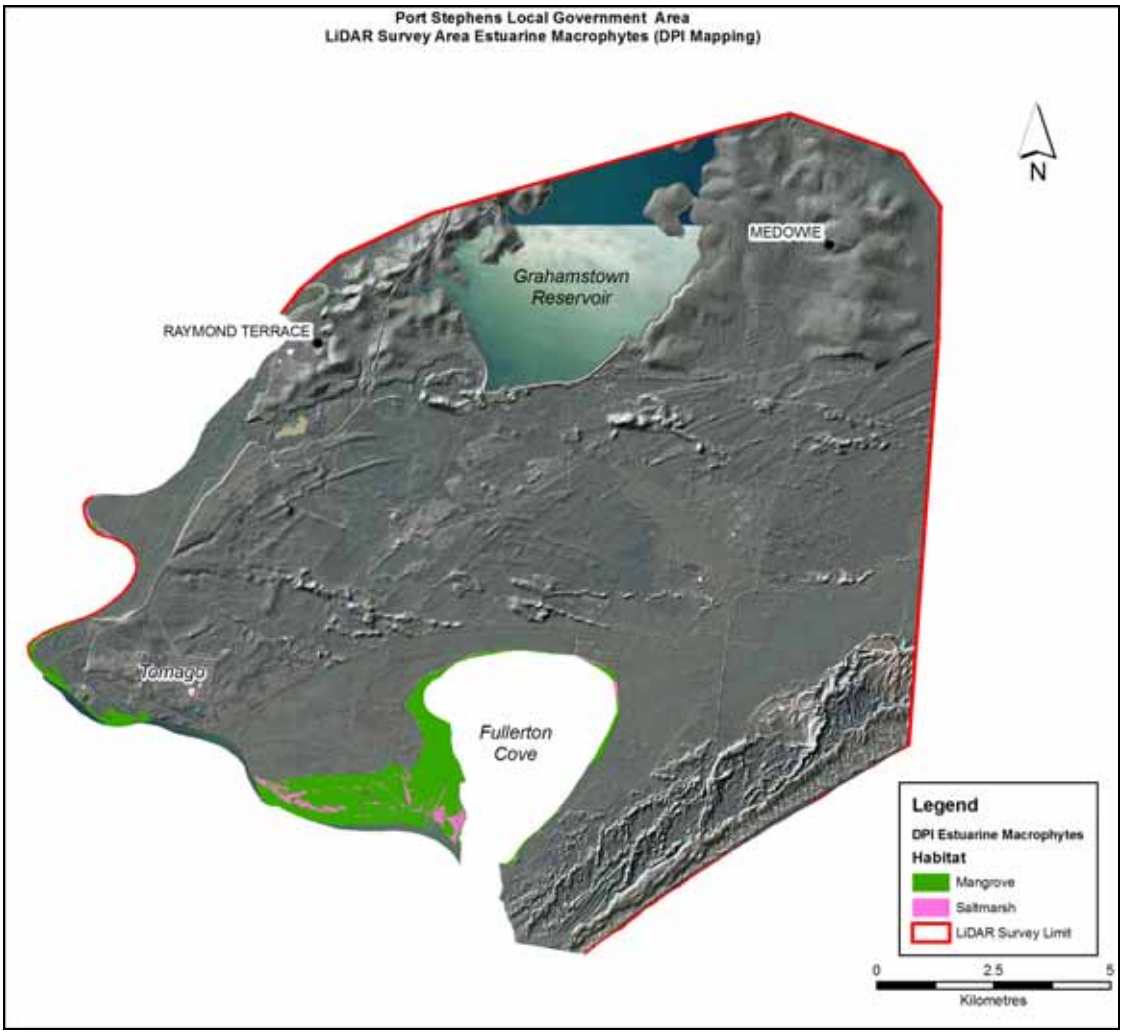


Figure 64. Map showing distribution of SEPP14 Wetlands in southern portion of Port Stephens LGA. Chart shows areas of wetland below 10m AHD for same.



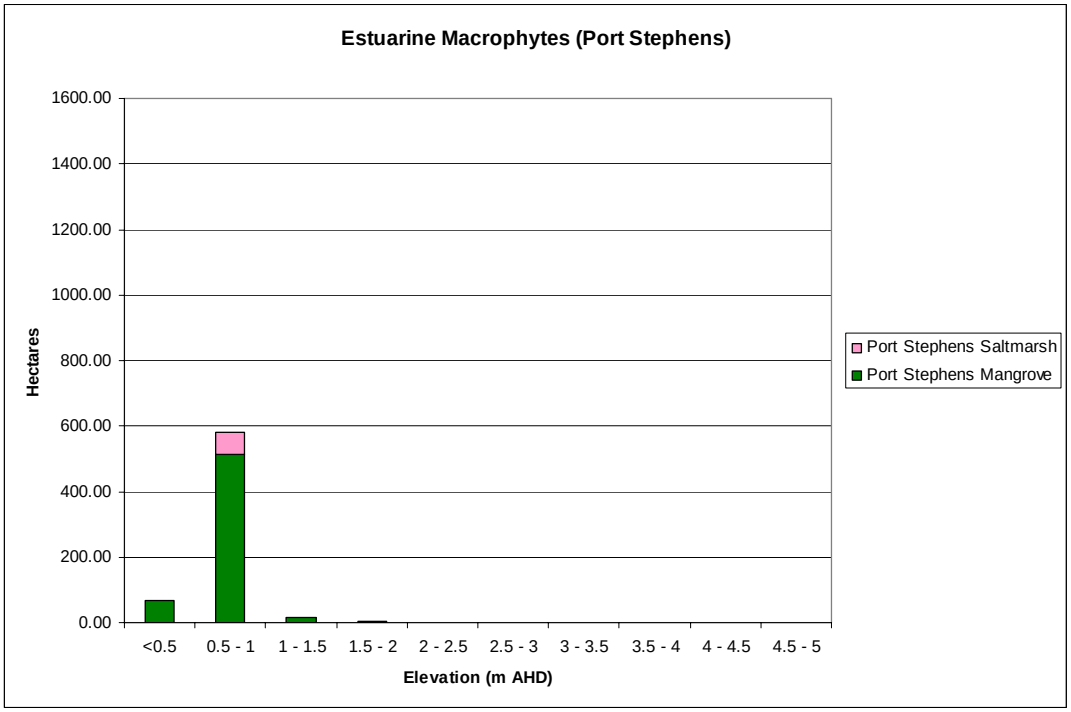


Figure 65. Estuarine macrophytes mapped by NSW DPI for Lower Hunter. Chart shows total hectares of mangrove and saltmarsh for this area.

4.5 Regional Workshops

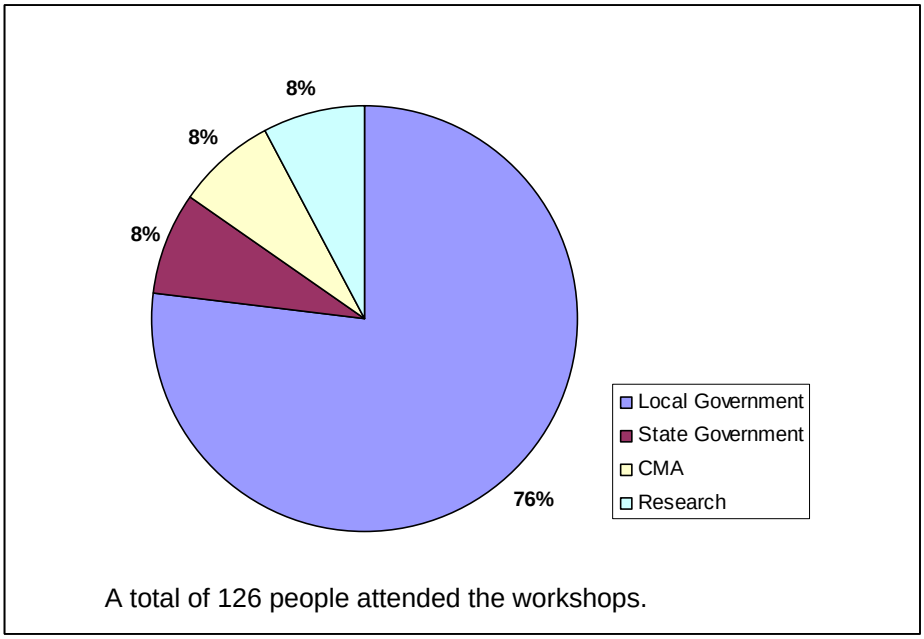
Regional workshops were held during August and September 2007 to demonstrate and promote the project objectives and achievements to a wide group of coastal planners and managers. The workshops, conducted in collaboration with each coastal catchment management authority, demonstrated the range of planning applications possible with LiDAR data, its cost effectiveness and relevance to other agencies, coastal CMAs and councils. Workshops also provided a forum for attendees to comment on the project and its implications for their respective responsibilities.

Six workshops were held which attracted a total audience of 126 planning and natural resource professionals, researchers and students from CMAs, state government agencies, local government and universities.

Regional Workshops

Date	Catchment Management Authority	Location
27/8/2007	Sydney Metropolitan CMA	Parramatta
29/8/2007	Hunter-Central Rivers CMA	Newcastle
30/8/2007	Northern Rivers CMA	Kempsey
31/8/2007	Northern Rivers CMA	Ballina
12/9/2007	Hawkesbury-Nepean CMA	Windsor
21/9/2007	Southern Rivers CMA	Batemans Bay

Workshop Attendee Affiliation



A total of 126 people attended the workshops.

The project objectives and results were generally well received, in particular the initiatives of making the LiDAR data generally available on a whole of government basis and explanation, by way of a case study, of how the LiDAR can be used in examining climate change associated impacts of sea level rise on coastal communities.

Further observations made by workshop attendees included the following.

- Councils have typically purchased LiDAR data for the purposes of floodplain mapping, flood risk modelling and, in some instances, construction of three dimensional models of built environments.
- In view of the likelihood of further LiDAR surveys by state and local government, there is strong support for the development of a standard specification for LiDAR data and contract deliverables for use on a whole of government basis.
- There are clear benefits in the involvement of a state government agency, such as the Department of Lands, in future state/federal funded LiDAR surveys to ensure technical specifications, contract deliverables and data access arrangements are addressed in a uniform manner.
- The emergence of remote sensing digital technologies, like LiDAR, is placing increased demands on the capacity (technical and staff) of state and local government spatial systems. There would therefore be value in government sponsored workshops on the application of remote sensing technologies for land use planning and natural resource management in order to facilitate the effective use of these technologies;
- Existing spatial data reliability and currency remain a critical consideration in planning for climate change related sea level rise impacts, as do the varying quality of the different data holdings of state and local governments.
- There is a pressing need for guidance from federal and state governments on planning for potential climate change impacts in coastal areas, notably the most appropriate planning horizon and the timing and likely magnitude of sea level rise, or at least a whole of government common “benchmark” sea level, against which proposals could be assessed consistently along the coast.

The following was also noted at the workshop.

- Subsequent to the preparation of the Central & Hunter Coasts LiDAR specification and tender documentation in mid 2006, DECC developed a LiDAR specification in mid 2007 which incorporates, is consistent with and extends this earlier work. The DECC LiDAR specification and tender documentation have the potential to be used in a State Contracts Control Board Period Contract, thereby giving state and local government standard documentation for the purposes of securing LiDAR survey

services.

- Consistent with the project MoU, the Department of Lands has undertaken to manage and distribute the Central & Hunter Coasts LiDAR data to all levels of government and research organisations at a nominal cost of data retrieval and delivery. Again consistent with the MoU, steps are currently underway to incorporate selected components of the LiDAR data (ie. 0.5m contours) into the Spatial Information Exchange (http://www.maps.nsw.gov.au/), making these data generally available to all through the internet.
- Support for the conduct of a government sponsored workshop showcasing LiDAR applications and procurement considerations, particularly for Local Government, is currently being explored with the Local Government and Shires Association and DECC.
- The NSW Department of Planning is currently drafting guidelines on how the planning system can respond to climate change in coastal areas, focusing on a set of qualitative principles and broad heads of consideration as part of a whole of government response.

4.6 Planning Responses to Climate Change Associated Sea level Rise

As part of the project case study, a review was conducted of planning responses to climate change related sea level rise at the international, national and state government levels that were in place at July 2007.

International and national literature on the incorporation of sea level rise projections in urban planning is summarised in Walsh et al. (2004). This paper identifies the main management strategies as being accommodation/no protection, protection, adaptation and retreat, concluding that in the medium term (decades), urban beaches will need protection (ie. sea walls and beach nourishment). For the longer term, managed retreat for some particularly at risk developed urban areas may need to be considered as other strategies become increasingly expensive. These general strategies for a planning response to sea level rise are reflected in some Australian jurisdictions as indicated in the following summaries.

The current Australian Government position is summarised in the Framework for a National Cooperative Approach to Integrated Coastal Zone Management (NRMMC, 2006) and the National Climate Change Adaptation Framework (COAG, 2007). As outlined in Section 3 of this report, both documents identify, amongst other things, the vulnerability of coastal communities to sea level rise, benefits of an integrated coastal zone management approach and priorities for action including a national assessment of coastal vulnerability and

identification of appropriate planning policies for the protection of the built environment and conservation of coastal ecosystems. Engineers Australia (1991; updated in 2004) provide specific guidelines for responding to the effects of climate change in coastal and ocean engineering based on IPCC (2001) scenarios to the year 2100, it also supports a proactive approach to integrated coastal zone management as a key to accommodating the long term effects of climate change for sustainable development of the coastal zone.

At a state level across Australia there has been a range of responses to incorporating sea level rise scenarios in land use planning, summarised in the following table (Appendix F provides further detail). Some of this information is included in a recent report on a "no-regrets" climate change adaptation policy for Australian local governments (AGO, 2007).

Summary of sea level rise, setbacks and planning timeframes used for Australian states and territories (July 2007)

State	Sea Level Rise Value	Setbacks	Timeframe
Victoria	No specific value – risk assessment of climate change impacts required	encouraged	100yrs
Queensland	0.3m over 50 years	Coastal building line required	50yrs
South Australia	0.3m to the year 2050 Development which could not reasonably be protected against sea level rise beyond 0.3m should be set back far enough to be safe for a 1m rise by 2100.		2050
Western Australia	The setback is based on the mean of the median of IPCC (2001) - 0.38m. A multiplier of 100, based on the Bruun rule is to be used to calculate setbacks, giving a value of 38m horizontal setback for sandy shores. For other shore types, horizontal setback is to be assessed in regard to local geography.	required	2100
Tasmania	Nothing specific, although has a detailed vulnerability assessment for the entire coast & is undertaking a climate change coastal risk assessment and management project.		
Northern Territory	Nothing specific, but is committed to developing plans for climate change adaptation.		

As noted previously (Section 3), New South Wales has existing statutory provisions that require consideration of climate change impacts in land use planning processes (Coastal

Protection Act 1979; Local Planning Directions under s117(2) of the Environmental Planning and Assessment Act 1979; State Environmental Planning Policy 71 and Standard Instrument Clauses; and Coastal Regional Strategies). Technical advice to local government on planning for climate change and sea level rise in coastal areas is provided by the Government's Coastline Management Manual (1990), Estuarine Management Manual (1992 and Floodplain Development Manual (2005). The Department of Environment and Climate Change, through its Coastal, Estuaries & Floodplain Management Branch, support local government in the application of these manuals.

Local government already has a number of planning mechanisms available to implement climate change adaptation strategies for both new and existing development including, but not limited to: zoning, setbacks, density controls, subdivision design, floor level controls, engineering works, house raising, acquisitions, emergency management and public education.

5. CONCLUSIONS

The high resolution terrain mapping project has successfully demonstrated the utility of LiDAR technology in examining the implications of potential climate change associated sea level rise for land use planning in the Central and Hunter Coast pilot study area. LiDAR terrain data, supplied at an accuracy of 0.15m RMS vertical and 0.6m RMS horizontal has proven to be suited to the spatial information requirements of all levels of government and a valuable tool with which councils can prioritise adaptation strategies for assets potentially at risk from inundation under current and future climates.

The Central and Hunter Coast pilot project has used the LiDAR data together with existing GIS layers, including land use zoning and actual land use, roads, addresses, wetlands and indigenous sites, to demonstrate how councils can cost effectively use LiDAR to undertake at least a first pass risk analysis to identify key assets potentially at risk.

The LiDAR data provides a rapid visual assessment of assets potentially at risk of whatever level of inundation is being considered, whether by floods, storm surge or sea level rise, or a combination of all the above. The results show that in the study area of approximately 1,400km^2, around 73km of roads, some 1660 addresses and approximately 164 hectares of residentially zoned land are located at ground elevations less than 1m AHD. Those assets increase substantially above the 1m AHD level.

This level of detail, made more easy to see by superimposing existing spatial layers on the LiDAR terrain data, will allow local councils to prioritise and plan future retrofitting programs to account for whatever level of risk is acceptable to their local communities. More specifically, the data will inform future land releases in order to minimise future vulnerability to sea level rise.

It is emphasised that the reliability of the absolute values for assets by elevation reported here rests substantially on the accuracy and currency of the spatial layers utilised for this project and provided by their respective state and local government data custodians. Further testing of these results will occur as project partners and others integrate the LiDAR elevation data with their own datasets in an examination of a range of land use planning exercises. In many cases it will be the first time the positional and elevational accuracy of many existing government datasets can be assessed, which in itself is a positive outcome of the project.

Apart from a demonstration of the value of LiDAR data in examining potential climate change

impacts in coastal areas, the project has had a number of other beneficial “spin-offs”. The project has, for the first time, developed a standard LiDAR specification based on a whole-of-government data acquisition model. Allied to this has been the drafting of contractual terms of agreement which secure the government’s intellectual property rights to the LiDAR data, thereby providing for the general distribution of the data to the widest audience at minimal cost. The specification and contract documents have been developed further by DECC for the purposes of government funded high resolution terrain surveys aimed at issues of flood modelling and biodiversity conservation in western NSW.

None of the above would have been possible without state government funding through its Climate Change Impacts and Adaptation Research Program and the contributions of the Departments of Planning, Environment and Climate Change and Lands, the councils in the study area (Port Stephens, Newcastle, Lake Macquarie, Wyong and Gosford), the Hunter - Central Rivers CMA, the Hunter Water Corporation and Geosciences Australia. Project partners are already using the LiDAR data for a variety of planning applications, including flood studies, flood risk modelling, reviews of major flood events and emergency response (eg June 2007 Central and Hunter Coast floods), climate change associated coastal inundation analysis, tsunami risk modelling, vegetation mapping, remote sensing validation, storm water harvesting strategies and ecological risk assessment. Further applications in auditing and monitoring changes in the built environment are also anticipated. In support of ongoing coastal research programs, the University of Sydney School of Geosciences has been given samples of the LiDAR data for student projects modelling the potential effects of sea level rise on shoreline recession and estuarine biodiversity.

It is hoped this work and related research into potential climate change impacts of sea level rise on coastal areas will help build consensus on practical adaptation responses with net economic, social and environmental benefits.

The collective experience of the project partners, researchers and others in the use of LiDAR data in a regional analysis of climate change issues in land use planning similar to that presented here, or more detailed site specific investigations that may follow, will serve to reinforce the importance of good information to reliable decision making.

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8. APPENDICES

Appendix A: Project Management.

Appendix B: LiDAR Survey Contract – Management, Specifications & Quality Assurance.

Appendix C: Spatial Data Compilation.

Appendix D: Spatial Modelling.

Appendix E: Spatial Modelling – Tabulated Summaries.

Appendix F: Jurisdictional Land Use Planning Responses to Climate Change Associated Sea Level Rise

Appendix A: Project Management

The Department of Planning Climate Change Impacts and Adaptation Research Project has been managed in a manner consistent with the project proposal included in the Memorandum of Understanding (MoU) dated May 2006 between the Cabinet Office and Department of Planning. Amongst other things, the proposal called for the formation of a project Steering Committee with representation drawn from key stakeholders in local, state and federal governments. The committee was to meet regularly to monitor project progress and expenditure and to endorse key actions. This appendix summarises project consultation and finances to the completion of project in September 2007.

The Steering Committee was formed in July 2006 and is comprised of representatives from local, state and federal government. Committee membership and affiliations are shown below. In April 2007 a restructure of state government departments led to the amalgamation of the Department of Environment and Conservation, Department of Natural Resources and NSW Greenhouse Office into the newly formed Department of Environment and Climate Change (DECC). The Steering Committee membership and affiliations are shown below.

Steering Committee Membership and Affiliations.

Member	Affiliation
John Hudson (Chair/Project Manager)	NSW Dept. of Planning
Jennifer McAllister (or delegate)	NSW Dept. Environment & Climate Change
Bob Denholm	NSW Data & Information Management Working Group (Dept. Environment & Climate Change)
Neil Kelleher	NSW Dept. Environment & Climate Change
Neil Saintilan	NSW Dept. Environment & Climate Change
Alan Garside	NSW Dept. Lands
Santina Penissi / Sian Fawcett	Wyong Shire Council
Symon Walpole	Lake Macquarie City Council
Greg Flynn	Gosford City Council
Bruce Petersen	Port Stephens Council
John Asquith	Hunter & Central Rivers CMA
Brendan Brooke	Geosciences Australia
Bruce Thom	Independent Expert Advisor

Newcastle City Council was invited to nominate a representative for the Steering Committee however Council indicated it would prefer to be kept informed of project progress through receipt of the regular committee meeting reports.

The Steering Committee first met on 27 July 2006 and has subsequently met at regular intervals, approximately monthly, on eight separate occasions. Apart from these regular meetings, the project manager has also provided a number of briefings to local and state government stakeholders along with public presentations on the project rationale and progress. A log of project meetings, briefings and presentations conducted over the course of the project is provided below. Two reports have been forwarded to DECC, one at the completion of project Stage 3 and the final report on completion of Stage 4 (this report).

The original project budget of $591,813 (ex GST) was comprised of a $381,400 cash grant from the NSW Greenhouse Office and a $210,413 in-kind contribution from the Department of Planning and other project partners. A majority of the cash grant ($287,100) was for the conduct of a high resolution terrain survey in the Central and Hunter Coasts study area. The proposal also identified the potential for cash contributions from project stakeholders on top of the grant from the NSW Greenhouse Office. The project has been successful in attracting additional funds of $46,000 from the Hunter Water Corporation ($35,000) and Lake Macquarie City Council ($11,000). At the completion of the pilot project all funds had been expended in line with the schedule set out in the MoU.

Log of Project Meetings, Briefings and Presentations

Date	Group	Location	Purpose
21/6/06	Dept. LANDS (Riparian Boundaries Working Group)	Sydney	Project briefing
27/6/06	Sydney Coastal Councils Group	Sydney	Project briefing
7/7/06	Dept. LANDS (Data & Information Management Working Group)	Sydney	Project briefing
11/7/06	Dept. Planning (Team Leaders)	Sydney	Project briefing
12/7/06	Qld. Dept. Natural Resources & Water	Sydney	Project briefing
17/7/06	Dept. Planning (Hunter Region)	Newcastle	Project briefing
18/7/06	Lake Macquarie City Council	Speers Point	Project briefing

Date	Group	Location	Purpose
26/7/06	Dept. Environment & Conservation (NSW Inter-agency Biodiversity and Climate Change Impacts and Adaptation Working Group)	Sydney	Project briefing
27/7/06	Steering Committee	Sydney	Meeting #1 Project initiation
9/8/06	Local Government & Shires Association	Sydney	Project briefing
9/8/06	University of Sydney (School of Geosciences)	Sydney	Project briefing
11/8/06	Dept. Natural Resources (Coasts/Estuary/Floodplain Group)	Gosford	Project briefing
11/8/06	Newcastle City Council	Newcastle	Project briefing
23/8/06	Allen Consulting Group	Sydney	Project briefing
31/8/06	Steering Committee	Gosford	Meeting #2
8/9/06	Hunter Water Corporation	Newcastle	Project briefing
25/9/06	Hunter & Central Coast Regional Environmental Management Strategy Group	Maitland	Project briefing
28/9/06	Steering Committee	Newcastle	Meeting #3
28/9/06	Newcastle City Council (Energy Resources Group)	Newcastle	Project briefing
10/10/06	Wollongong University (School Earth & Environmental Sciences)	Wollongong	Project briefing
26/10/06	Steering Committee	Wyong	Meeting #4
8/11/06	NSW Coastal Conference	Coffs Harbour	Presentation
27/11/06	Climate Summit (Local Government & Shires Association)	Sydney	Presentation
29/11/06	Port Stephens Council	Raymond Terrace	Project briefing
1/2/07	Steering Committee	Wyong	Meeting #5
15/2/07	Dept. LANDS (Riparian Boundaries Working Group)	Sydney	Project update
23/2/07	Premier's Climate Summit (NSW Greenhouse Office)	Sydney	Presentation
8/3/07	Steering Committee	Newcastle	Meeting #6
28/3/07	Steering Committee	Gosford	Meeting #7
17/5/07	Steering Committee	Manly Vale	Technical Workshop

Date	Group	Location	Purpose
13/6/07	Planning Institute of Australia (NSW)	Sydney	Technical Workshop
14/6/07	NSW Data & Information Management Working Group	Sydney	Technical Workshop
10/7/07	Department of Lands	Bathurst	LiDAR Data Technical briefing
11/7/07	Lake Macquarie Council	Speers Point	LiDAR Data Technical briefing
12/7/07	Department LANDS (Riparian Boundaries Working Group)	Sydney	LiDAR Data Technical briefing
12/7/07	Department of Planning (Snr Managers)	Sydney	Project briefing
30/7/07	NRAC (SC1 Coastal & Planning Standing Committee)	Sydney	Project briefing
1/8/07	DECC/DoP/Hunter Central Rivers CMA/Hunter Water Corp.	Newcastle	LiDAR Data Technical briefing
27/8/07	Sydney Metropolitan Catchment Management Authority & Councils in CMA area	Parramatta	Project Stage4 Consultation Workshop
29/8/07	Hunter-Central Rivers Catchment Management Authority & Councils in CMA area	Newcastle	Project Stage4 Consultation Workshop
30/8/07	Northern Rivers Catchment Management Authority & Councils in CMA area	Kempsey	Project Stage4 Consultation Workshop
31/8/07	Northern Rivers Catchment Management Authority & Councils in CMA area	Ballina	Project Stage4 Consultation Workshop
12/9/07	Hawkesbury-Nepean Catchment Management Authority & Councils in CMA area	Windsor	Project Stage4 Consultation Workshop
21/9/07	Southern Rivers Catchment Management Authority & Councils in CMA area	Batemans Bay	Project Stage4 Consultation Workshop
9/07	Steering Committee	Sydney	Final Meeting

Appendix B: High Resolution Terrain Mapping - LiDAR Survey Contract

Key objectives of the project were (1) acquisition of high resolution terrain information to a required specification for a priority section of the NSW coast using LiDAR (Light Detection and Ranging) technology and (2) provision for the distribution of the high resolution terrain data to a variety of government, research, community and industry stakeholders. This appendix summarises the tender process and confirms both objectives have been met.

The project focus was to be on one region with pressing coastal management issues sensitive to potential climate change-related sea level rise. The Steering Committee endorsed the selection of the Central and Hunter Coasts on the basis of a combination of coastal vulnerability, project budget and logistic reasons.

The terrain information was acquired through an open tender process conforming to state government policies and procedures. The project Steering Committee endorsed the tender technical specifications, conditions of contract, final tender documents and tender evaluation process. Tender documentation is contained in Department of Planning RFTCCIA06_01 "Provision of High Resolution Elevation data and Spatial Modelling Products of the NSW Central & Hunter Coasts for the NSW Department of Planning". The timeline for the tender process and subsequent data collection and acceptance are summarised below.

Dept. Planning Request for Tender CCIA06_01

Date	Activity
28/9/06	Steering Committee endorses tender documentation and evaluation methodology.
30/10/06	Open tender advertised in Sydney Morning Herald newspaper and nationally on CRC Spatial Web Site.
6/11/06	Pre-Tender briefing to potential contractors.
20/11/06	Tender closes.
15/12/06	Tender evaluation complete with recommendation for preferred tenderer.
2/1/2007	Contract awarded by Dept. of Planning to Fugro Spatial Solutions P/L.

The tender evaluation was conducted by representatives from Departments of Planning, Natural Resources and Lands and Wyong Shire Council. The contract with Fugro Spatial Solutions P/L delivers all intellectual property rights to the data to the NSW Government. Total contract price was $287,100 (ex GST).

LiDAR Contract Timeline

Date	Activity
January 2007	LiDAR Survey – Central & Hunter Coasts data acquisition.
March 2007	LiDAR Survey – Data delivery to Dept. of Planning for acceptance testing.
May 2007	Steering Committee endorses recommendation for acceptance of contract deliverables following acceptance testing.
6/6/07	Conditional release of LiDAR data to project partners ahead of project completion date (30/9/07)

The remainder of this appendix consists of the quality assurance plan report prepared by the Department of Planning in support of acceptance of contract deliverables. The report also contains details of the contract deliverables and their specifications.

NSW GOVERNMENT
Department of Planning

Report

Quality Assurance Plan for State Government Contract CCIA06_01 “Provision of High Resolution Elevation data and Spatial Modelling Products of the NSW Central & Hunter Coasts for the NSW Department of Planning”

May 2007

John Hudson
Project Manager
NSW Planning Climate Change Impacts and Adaptation Research Project

Executive Summary

The NSW Department of Planning high resolution terrain mapping contract CCIA06_01 involved the development of a technical specification and list of contract deliverables suited to a whole-of-government approach to the collection, distribution and application of LiDAR data. LiDAR (Light Detection and Ranging), also know as Airborne Laser Scanning, is a relatively new technology gaining widespread acceptance for regional high resolution terrain mapping, replacing traditional methods such as photogrammetry.

Acceptance of the Central and Hunter Coasts LiDAR survey and products was contingent on an independent validation of survey deliverables and their conformance or otherwise with the contract specification. This report summarises the results of an independent assessment of deliverables from the Department of Planning contract CCIA06_01. The assessment has been conducted by the NSW Department of Planning with the assistance of the NSW Department of Lands and Queensland Department of Natural Resources and Water.

Attachment A contains details of the Quality Assurance Plan, survey specifications and contract deliverables. The quality assurance plan sought to establish conformance of the LiDAR data with contract specifications for:

- accuracy (horizontal and vertical) of the LiDAR data;
- coverage;
- documentation; and
- digital file format.

Conformance was measured against a range of assessment criteria described in the quality assurance plan. Within the limits of the quality plan testing, the survey and deliverables were found to conform to contractual requirements. The recommendation is that they be accepted by Department of Planning following endorsement of the quality assurance report by the project Steering Committee.

Department of Planning does not warrant that the LiDAR data does not contain errors and that Planning shall be in no way liable for any loss, damage or injury suffered by the data user or any other person or corporation consequent upon the existence of errors in the LiDAR data.

Quality Assurance Plan Results

(a) Coverage Density

Requirement: Average point spacing does not exceed 1.3m.
Assessment: A random selection of 10% (n=142) of 1km X 1km surface point ("all ground and non ground returns") tiles was loaded into ArcGIS and calculations and visual estimates made of average point spacings. See Figure 1 for tiles selected. Calculated average point spacing ranged from 0.16m to 1.14m, with an average value of 0.63m. Visual inspections supported this result but did highlight variability in the point spacing across some tiles which appear related to artefacts of the LiDAR scanning process and compilation of LiDAR point data from separate flight lines.
Compliance: Deliverable meets specification.

(b) Completeness

Requirement: Any randomly sampled area of surface data points ("all ground and non ground returns") meets requirement for coverage completeness (no gaps between flight lines and/or minimum study area boundary overlap of 100m).
Assessment: A random selection of 10% (n=142) of 1km X 1km surface points ("all ground and non ground returns") tiles were loaded into ArcGIS and visual estimates made of coverage completeness. See Figure 1 for tiles selected. Additional tiles along the survey area boundary were examined to establish LiDAR point coverage extended 100m beyond the nominated survey area. The randomly selected data were found to be free of gaps and to extend the 100m beyond the survey boundary.
Compliance: Deliverable meets specification.

(c) Absolute Horizontal and Vertical Accuracy

Requirement: Individual differences between SCIMS data points and classified LiDAR ground data do not exceed RMSE requirements for vertical and horizontal accuracy (unless the point(s) can be justifiably eliminated due to uncertainties in SCIMS database).
Assessment: The Department of Lands provided an extract of the Survey Control Information Management System (SCIMS) database, being 23,249 surveyed marks over a number of Local Government areas from Port Stephens to Gosford. The data includes attributes on mark type, position, uncertainty, dates, etc., all of which are invaluable in undertaking this assessment. These marks were surveyed by a wide

variety of independent methods over a long period of time. SCIMS provides the best available independent dataset for evaluation of LiDAR. The survey marks are randomly spread over the project area and have well documented estimates of horizontal and vertical uncertainty.

There are however three significant issues which need to be considered in a SCIMS – LiDAR comparison:

- Mark Type: The assessment needs to consider the actual mark type and hence the likelihood that the mark provides a true estimate of the ground surface at that point. Attributes in SCIMS for mark type and monument location allowed particular marks to be removed from the assessment such as pillars, marks on building etc.
- Time Interval: It is difficult to assess whether a mark as originally installed and subsequently re-surveyed is still in its original position as at the day the LiDAR was flown. SCIMS marks were established continually over a long period. In this particular project, topographic data, ortho photography, Spot 5 imagery, SCIMS, and LIDAR were all acquired at quite different points in time. Hence the assessment is somewhat subjective.
- Reference Frame: Fundamental to the spatial information framework is the correlation of survey observations to existing survey marks. Nationally the fiducial framework has 8 stations, which serve as a datum for the 500km network, which serves as a framework for the 100km network, which serves as a framework for 20km… 5km densifications. While this whole to the part densification is well established for horizontal position, it is less rigorous for the propagation of height. In addition the height datum origin for a survey may or may not be documented in SCIMS. This merely reflects the evolution of the State height datum since the early 1970's.

The residuals between the SCIMS height values and the LiDAR surface were computed for all SCIMS marks in the project area. The characteristics of that data set can summarised as:

Total SCIMS Marks:	23,249
Marks within the LiDAR Project:	13,393
Mark Status Blank	11,698
D 1,181 (Not Assessed)	
F 152	
N 312	

S 3
U 47

Marks Flagged as Destroyed in SCIMS:	110 (Not Assessed)
Mark Type Pillar	5 (Not Assessed)
Mark Locality Roof / Building	11 (Not Assessed)
Marks with AHD and GDA Uncertainty	8,841

(AHD Uncertainty of Class C Order 3 or better)
(GDA Uncertainty of Class D Order D or better)

The results of the assessment is summarised as:

Marks included in assessment	8,372 (Assessed)
Residuals outside +/-0.3m (2 sigma)*	929
Marks removed from outliers based on characteristics as outlined above:	482 (No further Assessment)
Marks considered as possible outliers and candidates for further investigations:	447 (Assessment Needed)

*Survey convention for reporting reliability of survey marks is at the 95% confidence level, or 2 standard deviations. This exceeds the survey requirement for 68% confidence level, or 1 standard deviation.

In summary, there are 8372 independent survey marks that confirm the LiDAR to be within specification. There are 447 marks, or 5% of total marks assessed, that would require further investigation with local knowledge to eliminate those marks known to be in areas of topographic change due to civil works and mining. Based on these values compliance could be expressed at 95% confidence level.

The horizontal uncertainty of LiDAR is in the order of one metre. As such the horizontal uncertainty of LiDAR data can only be assessed where there are significant changes in elevation over a distance of less than one metre. It is not possible to assess the horizontal uncertainty of those LiDAR data points that are not associated with well defined features.

For ground points (eg. a point in an open area with typical terrain characteristics), the vertical uncertainty of a point has three basic contributing errors; a) the vertical uncertainty itself; b) the horizontal uncertainty and c) the uncertainty of the LiDAR striking the ground surface.

a) The vertical uncertainty has been addressed elsewhere in this report.

b) For ground points, the error contribution of horizontal uncertainty can be considered relative to three examples: 1) on flat ground the error contribution is zero, 2) on ground with a 1 in 10 slope means that the one metre error horizontally contributes 0.1 metre to the vertical component and 3) for vertical cliff faces the error contribution means the cliff face is displaced one metre in horizontal position.

c) LiDAR is a remotely sensed dataset and as such relies on the sheer number of points to provide confidence that the ground surface is modelled.

The assessment of vertical uncertainty did not, nor should it, separate these three contributing errors. The assessment of the LiDAR "system" has been demonstrated and the LiDAR - ground truth residuals are a combination of these three contributing uncertainties.
Compliance: Deliverable meets specification. Benefits of further local ground- truth checking noted especially where comparisons with legacy elevation datasets may be influenced by civil works, mining or other hitherto unrecognised factors.

(d) Data collected within “Low Tide” requirement

Requirement: Any randomly sampled intertidal area must show coverage and elevations consistent with data capture within specified tidal window of +/-2hours of local low tide (ie. below local mean High Water).
Assessment: Contour data for selected intertidal areas were examined to assess whether sufficient LiDAR points were collected below high tide elevations and landward so as to enable generation of a continuous contour at +0.5m AHD. Local coastal mean high water varies from c.+0.4m (neaps) to +0.65m (springs) AHD. For five sites distributed across the survey area (Fullerton Cove, Hunter River and Lake Macquarie entrances, Dora and Ourimbah Creeks fluvial deltas) contours are plotted to between +0.5 - 0m AHD. Each site has a continuous +0.5m contour. Contours for elevations to -0.5m AHD do occur along the estuary and open ocean shores at most sites however the reliability of contours below +0.5m AHD should be checked (overlaid) on the LiDAR intensity image which clearly depicts land/water boundary at the time of survey.
Compliance: Deliverable meets specification. Benefits of checking reliability contours in some locations below +0.5m AHD with LiDAR intensity image noted.

(e) Filtered Returns (non-ground)

Requirement: Any randomly sampled area shows consistency between clearly identifiable above ground features on the LiDAR intensity image and filtered non-ground returns.
Assessment: A random selection of 10% (n=142) of 1km X 1km “non ground returns” tiles were loaded into ArcGIS. See Figure 1 for tiles selected. A qualitative visual inspection of the data showed there is generally good correspondence between filtered non-ground points and clearly identifiable above ground features such as trees, buildings and bridges recognisable in the LiDAR intensity image. In some instances, areas were encountered where overlapping flight lines or points from the extreme edge of scans precluded clear identification of above ground features. It should be noted that the approach taken in processing LiDAR point clouds is primarily designed to derive a ground model that is accurate and clean. In order to achieve this any point that is not considered part of the clean surface (ie points from extreme edge of scan path or overlapping flight lines) is removed from the ground model and automatically classified as non-ground. This can result in certain flight line artefacts in non-ground data. Additional classification using LiDAR processing software (ie. point classification algorithms) are required to process non-ground points in order to unequivocally identify all above ground features.
Compliance: Deliverable meets specification. Benefits of further processing of non-ground points noted.

(f) Resolution of Grid Data

Requirement: Any randomly sampled digital terrain model (DTM) grid cell conforms to 2m and 10m grid cell size.
Assessment: A random selection of 10% (n=134) of 1km X 1km 2m and 10m DTMs tiles were converted to ESRI Grid format (from ASCII grid format) and loaded into ArcGIS. A visual assessment and on screen measurement of cell size confirmed the respective DTMs as 2m and 10m resolution. A review of raster dataset metadata autogenerated by ArcGIS also confirmed cell size for both DTMs.
Compliance: Deliverables meet specification

(g) Contour Database

Requirement: Any randomly sampled portion of the contour database conforms to coverage, interval, smoothness and ground level representation requirements.

Assessment: A random selection of 10% (n=135) of 1km X 1km contour tiles were loaded into ArcGIS and visually inspected. Inspected tiles showed the contour data to meet requirements for coverage, including 100m survey area overlap, interval (0.5m contour interval), attribution and smoothness. Representation of the ground level is dependent on the reliability of the DEM from which contours are derived (Item C above). Visual inspection of the contours indicates the contours appear to represent ground level where investigated.
Compliance: Deliverable meets specification.

(h) LiDAR Intensity Image

Requirement: Image mosaic conforms to coverage and file format specification. Image deficiencies due to cloud cover, smoke, intensity response to be noted and described in mosaic metadata statement.
Assessment: LiDAR intensity image delivered as continuous coverage over entire area and to 2m pixel resolution (raw LiDAR point spacing c.1m-2). Visual inspection of the image in ArcGIS shows the image to cover the entire study area, including 100m overlap, and to be of sufficient resolution to identify ground features such as roads, buildings, areas of vegetation and water.
Compliance: Deliverable meets specification.

(i) Contractor Survey and Quality Assurance Report

Requirement: Contractor to provide a report documenting operational and quality assurance components of the LiDAR survey.
Assessment: Fugro Spatial Solutions P/L provides report documenting operational and quality assurance components of LiDAR survey. Quality assurance states "Expected accuracy for the Central Coast & Port Stephens ALS survey elevation data is quoted as +/-0.01m at 67% confidence (1 standard deviation) and +/-0.2m at 95% confidence (1.96 standard deviations) respectively for clear flat and open terrain". Report states survey has met and exceeded specifications for vertical accuracy of LiDAR points.
Compliance: Deliverable meets specification.

(j) Dataset Key Diagrams

Requirement: Contract deliverables provided with key diagrams uniquely identifying 1km X 1km data tiles.
Assessment: Check of each of the contract deliverable and relevant key diagram, excluding LiDAR intensity image, confirms key diagrams suited to unique identification of individual point, grid and contour dataset tiles.

Compliance: Deliverables meet specification.

(k) File Formats

Requirement: Contract deliverables conform to nominated file formats.

Assessment: Check of each of the 12 contract deliverables confirms conformance with file format specification.

Compliance: Deliverables meet specification.

(l) ANZLIC Metadata

Requirement: Contract deliverables provided with ANZLIC metadata statement.

Assessment: Check of each of the 12 contract deliverables confirms corresponding metadata information provided.

Compliance: Deliverables meet specification.

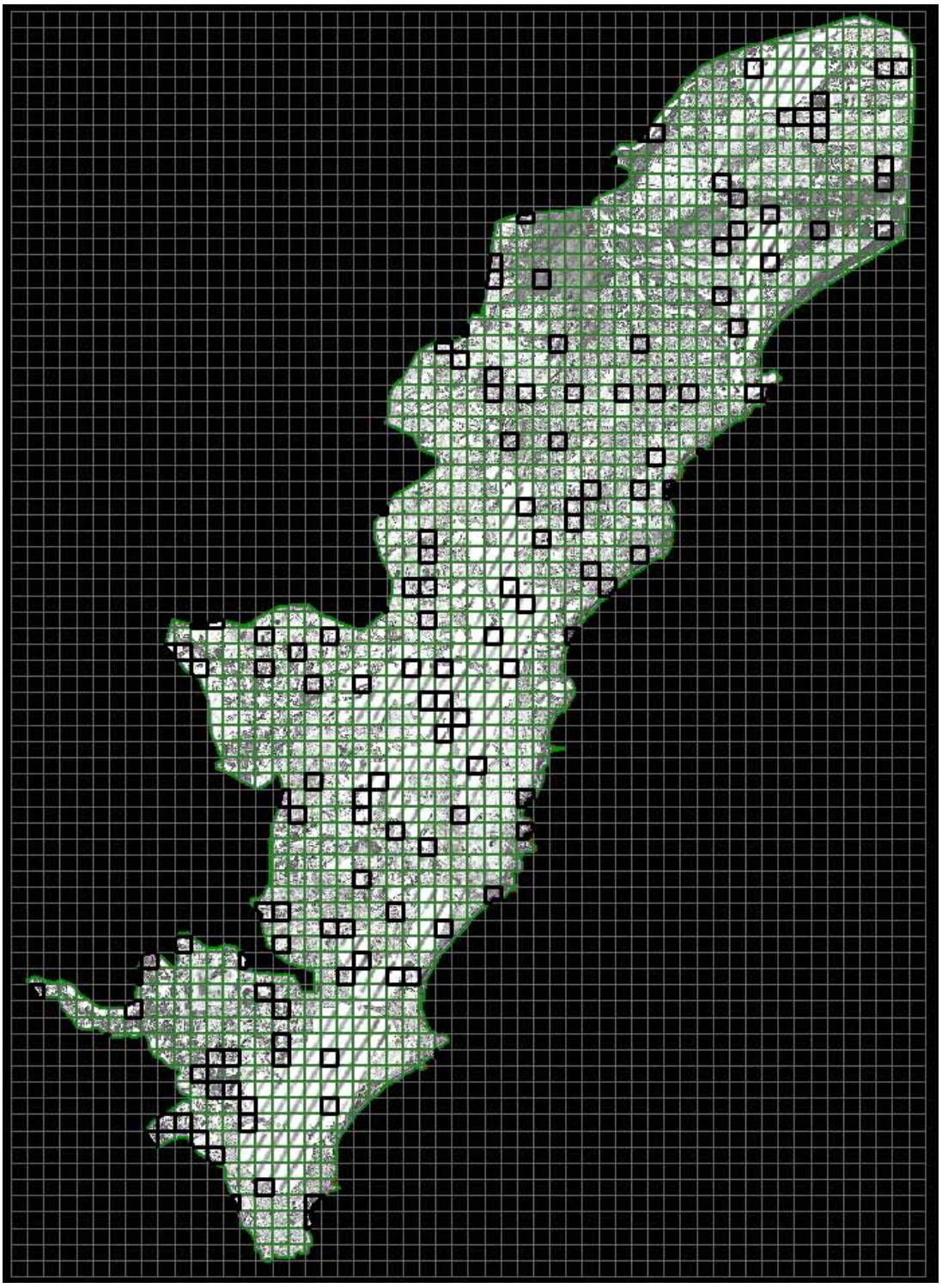

Figure 1. Screen shot from GIS showing randomly selected 1km X 1km square tiles (dark black polygons) within study area boundary (green polygon) overlaid on study area LiDAR intensity image mosaic.

Attachment A. Contract CCIA06_01 LiDAR Quality Assurance Plan

Background

Development of a LiDAR survey specification and list of deliverables involved consultation with local, state and national government bodies with either direct experience in LiDAR surveys or a high level of technical expertise in remote sensing methods. Survey specifications and deliverables were reviewed by the project Steering Committee prior to their acceptance. The agreed survey specifications and deliverables are set out below.

Contract Deliverables, Specifications and Study Area.

State Government contract CCIA06_01 identified a total of 12 deliverables (note DEM=Digital Elevation Model; DTM = Digital Terrain Model):

Deliverable	**Required Quality Assurance Deliverable**	**Relevant Project Phase**
Deliverable 1	LiDAR Survey flight plan (georeferenced shapefile format)	Prior to survey commencement and for review and acceptance by NSW Government.
Deliverable 2	Ground control configuration diagram (georeferenced shapefile format)	Prior to survey commencement and for review and acceptance by NSW Government.
Deliverable	**DEM Data Format**	**LiDAR DEM Elevation Product**
Deliverable 3	Space delimited ASCII File. X,Y,Z coordinates and return intensity value	All ground and non-ground returns. - all ground elevation returns *with* non-ground features.
Deliverable 4	Space delimited ASCII File. X,Y,Z coordinates and return intensity value	All ground returns. -all ground elevation returns *with no* non-ground features.

Deliverable	**DEM Data Format**	**LiDAR DEM Elevation Product**
Deliverable 5	Space delimited ASCII File. X,Y,Z coordinates and return intensity value	All non-ground returns. - all non-ground elevation returns *with no* ground features.
Deliverable 6	ESRI Point Shapefile	All ground and non-ground returns. - all ground elevation returns *with* non-ground features.
Deliverable 7	ESRI Point Shapefile	All ground returns.- all ground elevation returns *with no* non-ground features.
Deliverable 8	ESRI Point Shapefile	All non-ground returns. - all non-ground elevation returns *with no* ground features.
Deliverable	**DTM Data Format**	**LiDAR DTM Elevation Product**
Deliverable 9	ESRI 2 metre GRID	All ground returns. - all ground elevation returns *with no* non- ground features.
Deliverable 10	ESRI 10 metre GRID	All ground returns. - all ground elevation returns *with no* non- ground features.
Deliverable	**Contour Data Format**	**Elevation Product**
Deliverable 11	ESRI Shapefile	Contours always relate to ground level.
Deliverable	**Image Data Format**	**Image Product**
Deliverable 12	Image File – ECW format or similar	Mosaic Intensity Image.

Specifications for the survey and deliverables include:

Item	Description
A) Coverage	Continuous coverage over the Central and Hunter Coasts Study Area and extending beyond the Study Area boundary by 100 metres.
B) Vertical Accuracy and Point Spacing	Vertical Accuracy: RMSE 0.15 metres or better on clear ground, where RMSE represents accuracy to 1 sigma. Average point density 1.3 metres
C) Absolute Horizontal Accuracy	RMSE 0.6 metres or better on clear ground, where RMSE represents accuracy to 1 sigma.
D) Time of Collection	LiDAR data over tidal areas must be collected within +/- 2 hours of local low tide so as to maximise data capture at elevations below 0m AHD.
E) Physical File Format	**Digital Elevation Model (DEM)** *ASCII File* - Tiled to manageable file size. - Continuous coverage over the Study Area - Data edge joined between swaths along a common line with no overlap in final dataset - Space delimited Easting, Northing, Elevation and Signal Return Intensity (X,Y,Z and I fields). *ESRI Point Shapefile* - Tiled to manageable file size. - Continuous coverage over the Study Area - Data edge joined between swaths along a common line with no overlap in final dataset - Shapefile attribute tables to contain the following fields: Easting, Northing, Elevation and Signal Return Intensity (X,Y,Z and I fields).

	Digital Terrain Model (DTM) - 2 metre cell size elevation ESRI grid - 10 metre cell size elevation ESRI grid Each grid file: - Tiled to manageable file size. - Tiles consistent with DEM products - Continuous coverage over the Study Area **Contours** *ESRI Polyline Shapefile* - Tiled to manageable file size. - Continuous coverage over the Study Area. - Shapefile attributes to include elevation in metres to AHD. - Smoothed to produce cartographically acceptable contours. - Contours relate to ground level. In areas of high-rise and high density buildings, contours must reflect the indicated ground level as interpreted from the surrounding visible ground surface
F) Horizontal Datum	Geocentric Datum of Australia 1994 (GDA94) Projection: Map Grid of Australia, 1994 (MGA94), Zone 56
G) Vertical Datum	Metres to Australian Height Datum
H) Key Diagram	For each supplied elevation data product, an ESRI shapefile key diagram that delineates the extents of supplied DEM/DTM and Contour tiles with tile filename.
I) Metadata Statement	For each supplied elevation data product, a complete metadata statement to the current ANZLIC standard http://www.anzlic.org.au/infrastructure_metadata.html and containing information on: - Quality assurance methodology used to achieve required horizontal and vertical accuracies, including description of ground control method. - Elevation data acquisition period - DEM data extent, physical format and spatial reference information - Achieved DEM accuracies (absolute vertical, absolute horizontal)

	- Any limitations of data use and relevant data processing implications - Attribute field lists and field description. - Any other data of relevance to the derivation and use of the elevation product.
J) Delivery Media	USB Hard Disk Drive

The data was to be collected over the Central and Hunter Coasts study area.

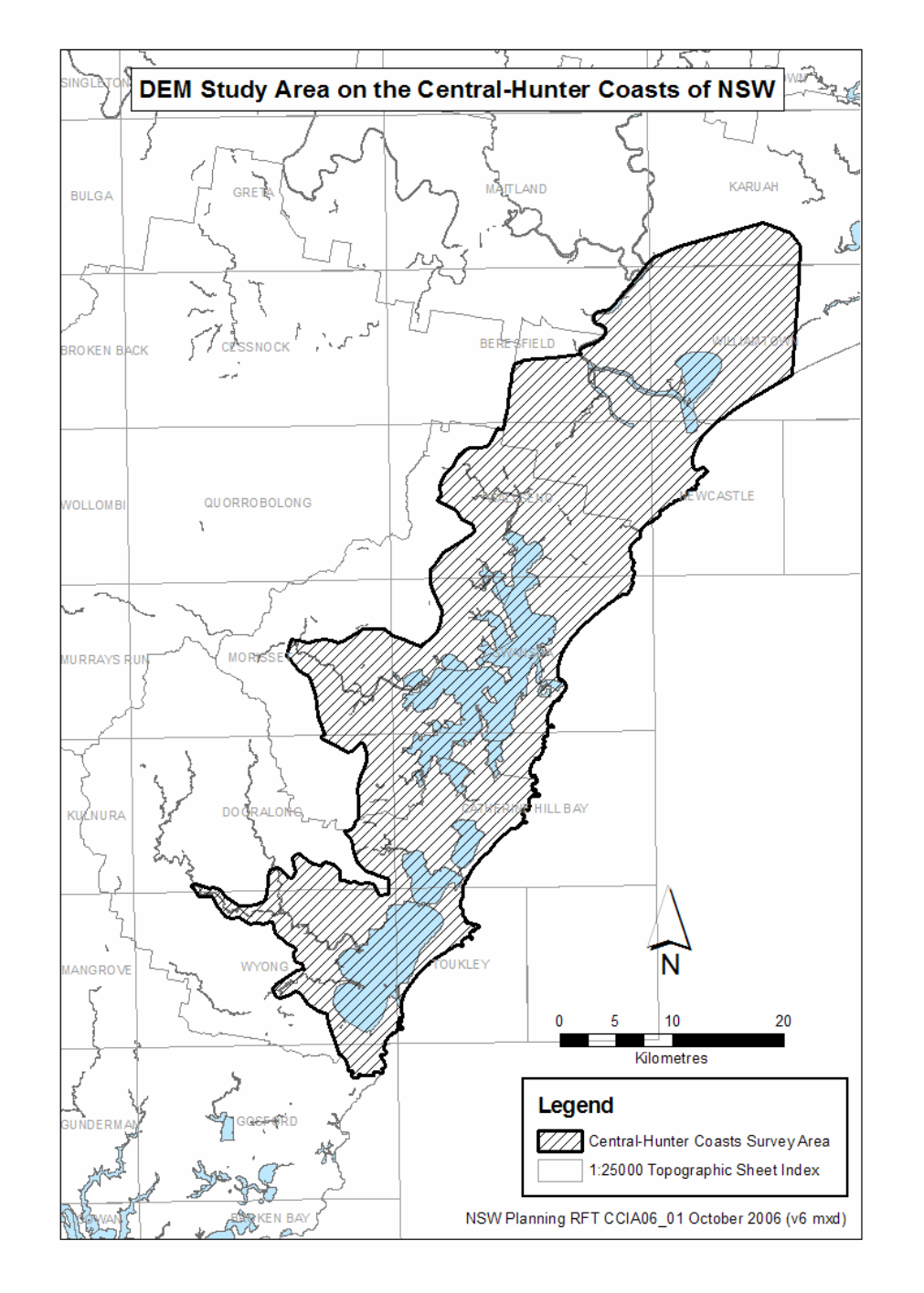

Figure 2. LiDAR Survey area on the Central and Hunter NSW Coasts. Approximate area 1240km^2 and taking in low-lying coastal areas within Wyong, Lake Macquarie, Newcastle and (part) Port Stephens local government areas.

The Quality Assurance Plan

An important step in the acceptance of any LiDAR survey is an independent validation that survey deliverables meet the required specification. While the contractor would normally provide a report demonstrating conformance with contract specifications, it was a condition of tender CCIA06_01 that an independent assessment of the survey data be undertaken prior to acceptance by government. The independent assessment is intended to assure compliance with contract specifications and enable users to determine the suitability of the data for their specific application. To this end, the Department of Planning collaborated with the NSW Department of Lands (LANDS) and Queensland Department of Natural Resources and Water (QDNRW) in formulating and undertaking an independent quality assurance plan of the Central and Hunter Coasts LiDAR survey contract deliverables.

Objectives

Specific objectives of the plan are to:

1. Determine whether the spatial accuracy (horizontal and vertical) of the LiDAR data as supplied is within the specification identified in the contract documents;
2. Determine whether the coverage of the LiDAR data as supplied complies with the survey area identified in the contract documents;
3. Determine whether the LiDAR data as supplied for intertidal areas meet the requirement for collection at “low tide”;
4. Determine whether all twelve contract deliverables as supplied are consistent with contract data and modelling requirements.

Contract Deliverables – Assessment and Compliance

Assessment

A GIS will be used to assess the spatial properties of the contract deliverables. Properties to be assessed are listed below. Percentages refer to proportion of delivered data to be included in the assessment.

(a) Coverage Density (Deliverables 3 and 6)

Random point data from Deliverables 3 and 6 (all ground and non ground returns) will be loaded into a GIS so that the average random point spacing can be checked for compliance with point spacing specifications (Specification Item B) for 5% of each tile.

(b) Completeness (Deliverables 3 and 6)

The LiDAR flight plan (Deliverable 1) will be investigated in conjunction with Deliverables 3 and 6 (all ground and above ground returns) to determine locations where gaps between scan lines are most likely. Random checks of Deliverables 3 and 6 will be carried out in areas to confirm no terrain has been missed in the airborne laser scanning process and that minimum study area boundary overlap requirements are met (ie. 100m).

(c) Absolute Horizontal and Vertical Accuracy (Deliverables 4 and 7)

Fundamental to this assessment is the independence of all spatial comparisons. The state government's Survey Control Information Management System (SCIMS) contains coordinates and related information for survey marks established under the direction of the Surveyor General and is maintained for the purposes of cadastral boundary definition, engineering surveys, mapping and a variety of other spatial applications. The SCIMS dataset provides a compilation of all "survey-accurate" coordinate triplets (latitude, longitude and height) as well as supporting metadata such as mark type, survey method and spatial uncertainty. The SCIMS is effectively randomly distributed across the LiDAR study area extents.

For the purposes of this quality assessment, NSW LANDS has provided an extract from the SCIMS database for the Central and Hunter Coasts study area. Within the proposed project extent there are 13548 SCIMS marks.

It is proposed to compute a 1m by 1m grid for the entire LiDAR extents based on all "ground" point raw data (Deliverable 4). Typically LiDAR would include in excess of 700000 points per square kilometre at the required specification. This project covers approximately 1250 square kilometres. An exact interpolator would be used to ensure the terrain model would accurately respect the actual LiDAR heights.

A LiDAR residual would then be computed for every SCIM survey mark. Based on the 1m grid, this interpolation would be undertaken by linear interpolation. To achieve a realistic statistical analysis all uncertainties will be quoted at the 95% confidence interval. As such every SCIM mark that falls outside the 95% CI will be assessed

against mark type; survey method; quoted uncertainty; last visit date and other information available from the SCIM database. See further information attached in the appendix.

The methodology offers the following benefits:

- the SCIM dataset is totally random in that every point is used;
- the data is independently acquired, and hence without correlation; and
- the sample size at 13548 check points is significant.

Any other datasets provided by Department of Planning would also be incorporated. Specifically this will include a reprocessing of the validation undertaken by the contractor (Deliverable 2). In addition, these may include Local Government datasets such as as-constructed surface models.

The necessity for a specific field program would only be considered following the assessment as outlined above.

Also available for the study area is a high resolution 5m DEM generated from the NSW Land Information Centre's Large Scale Contour Archive. The DEM is based predominantly on 2m contours from the 1:4000 scale orthophotomapping series. Historically, these types of topographic models have been generated by independent methods, typically photogrammetry, and in smaller projects by field survey.

Over the LiDAR extents, photogrammetric methods have been used to compute a digital elevation model associated with the 1:4000 standard mapping program. This dataset provides approximately 1-2 million comparison points. Aligned to the methodology as outlined above, the residuals for these points will be assessed against the 1:4000 mapping standards.

It is expected that in flat well-defined areas this 1:4000 mapping will serve as a valid comparison of uncertainty for the two datasets. In areas that are not well-defined this comparison will provide a valid estimation of the uncertainty for 1:4000 mapping in a broader context.

(d) Data collected within "Low Tide" requirement (Deliverables 4 and 11)

It was a requirement of the contract that the LiDAR be flown within a time limit with respect to low tide. Compliance with this requirement will be assessed by an automated computation of contours from 0 to 5 metres at 0.5m contour interval. A

visual inspection will identify where the Mean High Water Mark cannot be computed (ie there are no values below the MHW mark elevation to calculate), thereby indicating non-compliance.

(e) Filtered Returns (Deliverables 5 and 8)

Filtered LiDAR returns for all non-ground points (Deliverables 5 and 8) will be qualitatively assessed for reliability in terms of coincidence with non-ground features such as trees and buildings using intensity images (Deliverable 12) for 5% of each tile.

(f) Resolution of Grid Data (Deliverables 9 and 10)

Grid spacing measured using a GIS for a randomly selected portion (10%) of each tile.

(g) Contour Database (Deliverable 11)

A visual comparison of the contours supplied with contours generated at “e” above will be conducted for a randomly selected portion (10%) of each tile.

(h) LiDAR Intensity Images (Deliverable 12)

All images will be qualitatively assessed for coverage, overlap and incidence of cloud cover and/or smoke.

Compliance

Compliance with contract specifications will be identified using the following criteria. Resolution of any actual or perceived inconsistencies between the delivered contract materials and contract specifications will be addressed through a “compliance hierarchy” set out after the criteria.

(a) Coverage Density

Average point spacing does not exceed that specified (ie. 1.3m)

(b) Completeness

Any randomly sampled area with surface data points meets requirement for average point density spacing and/or minimum study area boundary overlap (100m).

(c) Absolute Horizontal and Vertical Accuracy

Individual differences between SCIMS data points and classified LiDAR ground data

do not exceed RMSE requirements for vertical and horizontal accuracy (unless the point(s) can be justifiably eliminated due to uncertainties in SCIMS database).

(d) Data collected within “Low Tide” requirement

Any randomly sampled intertidal area must show coverage and elevations consistent with data capture within specified tidal window (ie. Below local mean High Water Mark).

(e) Filtered Returns (non-ground)

Any randomly sampled area shows consistency between clearly identifiable above ground features on LiDAR intensity image and filtered returns.

(f) Resolution of Grid Data

Any randomly sampled grid cell conforms to specification.

(g) Contour Database

Any randomly sampled portion of contour database conforms to specification.

(h) LiDAR Intensity Images (Deliverable 12)

Image mosaic conforms to coverage and file format specification. Image deficiencies due to cloud cover, smoke, intensity response to be noted and described in mosaic metadata statement.

Compliance Management

Management of non-compliances between the contract specifications and contract deliverables will proceed in a staged fashion through negotiations between Planning and the contractor. The stages reflect the severity of non-compliance issues.

Stage1. Isolated non-compliances noted, documented by Department of Planning and referred to contractor for action. It is expected that given the minor nature of these types of errors they will be readily corrected by the contractor without the need for formal rejection of the relevant dataset(s).

Stage 2. Systematic non-compliances noted, documented by the Department of Planning and referred to contractor for action. Contractor to advise on how non-compliances will be addressed and undertakes to “make-good” the non-compliances to meet specification, the dataset(s) will not be formally rejected by Department of

Planning.

Stage 3. Where systematic non-compliances are noted and cannot be resolved in negotiations between Department of Planning and the contractor, formal rejection of the dataset(s) will occur and the dispute resolution component of the contract will be activated.

Reporting

The results of the quality assurance testing will be documented and incorporated into metadata statements for each of the relevant contract deliverables. The documentation will serve several purposes:

- Final payment will be made to the contractor when all contract deliverables meet the required specification.
- Results of the compliance testing for each contract deliverable incorporated into the metadata statement will enable users to establish the suitability of LiDAR dataset for their specific application(s).
- A summary of the quality assurance plan results will be included as a technical appendix to the final project report.

Appendix: SCIMS Background

The Survey Control Information System is a register of survey monuments and includes specific attributes associated with those monuments. It includes the horizontal and vertical coordinates; uncertainty; physical details (e.g. monument type); administrative details etc. The types of survey monuments that are included in this information system are listed on the Department of Lands website (Table 1)

Table 1: Mark Type:

CP	Mapping Control Point
CR	Cadastral Reference Mark
GB	Geodetic Bench Mark
MM	Miscellaneous Survey Mark
PM	Permanent Mark
SS	State Survey Mark
TS	Trigonometrical Station

http://www.lands.nsw.gov.au/survey_mapping/scims_online/terms_and_abbreviations)

Of relevance to the use of the SCIMS to assess the positional uncertainty is recognition of the different survey methods used to compile that dataset. National standards for positional uncertainty are used to indicate the horizontal (Table 2) and vertical (Table 3) uncertainty for the coordinates as listed in the SCIMS. These uncertainties are quoted at the 95% confidence level.

The physical monument also has a range of characteristics. Typically they are a standard brass plaque set in concrete at or very near ground surface, although they also include a variety of sub-surface and above surface monuments. Above surface monument may also be placed on building. The assessment of outliers needs to investigate the characteristics of the physical monument to distinguish between gross errors and any monument-to-ground offset.

The identification of SCIMS residuals that require additional manual investigation has been set at the two-sigma level (95% CI). This is in excess of the normal statistical bounds for gross errors of three-sigma (99.7% CI).

Table 2: Interpretation of SCIMS Class for Horizontal Coordinates:

Class	Typical Applications
3A	Special high precision surveys
2A	High precision national geodetic surveys
A	National and State geodetic surveys
B	State survey control networks
C	Cadastral control surveys
D	Cadastral and other surveys
E	Approximate and lower order surveys
U	Unknown or unreliable

http://www.lands.nsw.gov.au/survey_mapping/scims_online/class_and_order)

Table 3: Interpretation of SCIMS Class for Heights:

Class	Typical Applications ("d" in the table below refers to distance in kilometres)
L2A	Precise levelling - Forward and backrun misclose < 2√d
LA	1st Order levelling - Forward and backrun misclose < 4√d
LB	2nd Order levelling - Forward and backrun misclose < 8√d
LC	3rd Order levelling - Forward and backrun misclose < 12√d
LD	Levelling - Forward and backrun misclose < 18√d
LE	Levelling - Forward and backrun misclose < 36√d
2A	Precise trigonometric or GPS heighting - Standard deviations of observations < 3 (d+0.2) mm
A	Trigonometric or GPS heighting for state survey control - Standard deviations of observations < 7.5 (d+0.2) mm
B	Trigonometric or GPS heighting for cadastral control - Standard deviations of observations < 15 (d+0.2) mm
C	Trigonometric or GPS heighting - Standard deviations of observations < 30 (d+0.2) mm
D	Trigonometric or GPS heighting - Standard deviations of observations < 50 (d+0.2) mm

E	Trigonometric or GPS heighting - Standard deviations of observations < 100 (d+0.2) mm
U	Unknown or unreliable

http://www.lands.nsw.gov.au/survey_mapping/scims_online/class_and_order)

LiDAR Characteristics

The point density of LiDAR is in the order of 1.3m. The validation of the LiDAR relies on the assessment of residuals between a regular grid, computed at an interval of 1m, and the SCIMS heights.

It should be noted that any feature smaller than 1m will not be identified in the surface model. This exposes two scenarios:

- SCIMS monuments, such as survey pillars, have a height associated with the top surface of the pillar. The LiDAR surface will model the ground surface, which is typically 1 to 1.5 metres below the top of the pillar. As such the assessment of uncertainty will need to manually investigate all residuals to determine compliance with the specified uncertainties;

- Topographic features smaller than 1m will contribute to perceived uncertainties in the LiDAR surface. For example, a LiDAR point may be in the kerb and channel, while the SCIMS monument is located, a very short distance away, but above the kerb. Assessment of these types of discrepancies is considered to be not warranted and beyond the scope of this Quality Assurance Plan.

Appendix C: Data Compilation

The pilot case study necessitated the compilation of spatial datasets generally available to state and local governments and suited to the assessment of assets (built, natural and cultural) potentially at risk from climate change associated sea level rise impacts such as coastal inundation and shoreline erosion.

An inventory of data themes of interest was prepared to guide compilation of data on:

- Residential building and development
- Commercial building and development
- Industrial building and development
- Service infrastructure – roads, rail, airstrips, port facilities, telecommunications, electricity, gas, water, sewerage
- Social infrastructure, such as schools, hospitals, community centres etc.
- Agricultural activities
- Grazing activities
- Aquaculture
- Forested areas
- Foreshore amenities for sport and recreation
- Environmental (non-market) assets such as wetlands, near-shore marine areas, estuarine ecosystems, etc

The ultimate objective was to identify and compile relevant spatial datasets for the Central and Hunter Coasts study area to a standard datum and projection (Geocentric Datum of Australia - GDA94; Map Grid of Australia – MGA Zone 56) so as to facilitate their analysis with the newly acquired LiDAR elevation data. The spatial datasets could, for the first time, be "tagged" with accurate elevation data for the purposes of identifying assets potentially at risk from elevated sea levels. A related activity was to locate metadata statements for each dataset so as to assist project partners and stakeholders in assessing the relevance of the data for further analyses outside of that summarised here and to identify the availability of datasets for the entire NSW coast.

Data Selection & Compilation

The data selection and compilation exercise took place between November 2006 and April 2007. The geographic extent for data of interest was the Port Stephens, Newcastle, Lake Macquarie, Wyong and Gosford Local Government Areas. The most up-to-date spatial data was sought, as of 30 March 2007. See metadata statement links below for information on

data currency.

Discussions were held with staff from the NSW Department of Planning and other state and local government project partners to establish what useful data (ie. readily available and maintained by recognised data custodians) existed. Datasets compiled for the project are listed at the end of this appendix.

Most of the state government spatial datasets were sourced from the NSW Department of Environment and Climate Change (formerly Department of Natural Resources) corporate geodatabase ('Putney' SDE) which receives regular updates from NSW Department of Lands (Land and Property Information). Planning-specific datasets were sourced from the NSW Department of Planning corporate geodatabase ('Omega' SDE), notably Local Environment Plans (LEPs) and State Environment Planning Policies (SEPP's) for coastal wetlands (SEPP14), littoral rainforests (SEPP26) and the coastal zone (SEPP71). Councils in the study area were asked to provide their most up-to-date LEP information along with other spatial datasets on infrastructure and vegetation. The council LEPs were used to update the Department of Planning corporate geodatabase. LEP data was then exported from the corporate geodatabase for analysis. Datasets not generally available through the Departments of Planning and Environment and Climate Change geodatabases (eg. NSW wetland mapping conducted by Department of Primary Industries) were sourced from the Department of Planning Comprehensive Coastal Assessment package. In excess of 150 state government and council spatial datasets and their supporting metadata statements have been identified and compiled for the project (see list in Table C2 at end of appendix).

Data Preparation

All data processing was undertaken using ESRI ArcGIS9.1 software. For state government data, each dataset was exported from the corporate geodatabases and saved as an ESRI shapefile in its original geographic coordinate system (GCS GDA 1994). A shapefile produced from the Admin.LGAs feature class on the 'Putney' SDE (supplied by LPI) was subsequently used to clip all other dataset types (ie. point, line and polygon) to the study area extent.

Some GIS information contained multiple datasets, not all of which were of relevance to the project. Datasets of interest identified with the aid of the themes listed in the data inventory above were extracted and saved separately. These included components of the Department of Lands Digital Topographic Database (DTDB Topo and Building Complex Point) and the Department of Environment and Climate Change Land Use dataset.

The Department of Natural Resources Land Use dataset was of particular interest as it maps many land use themes of relevance to the project in a systematic manner across all LGAs. In view of this, the land use dataset was the subject of pre-processing prior to the extraction of individual layers (land use themes). This dataset was supplied as three individual ESRI shapefiles (Port Stephens_Newcastle, Lake Macquarie_Wyong and Gosford). The three were combined and an issue arose as land use codes were not consistent across all three datasets. For example, the Land use codes contained in the Port Stephens_Newcastle shapefile were entered under an attribute field called 'Tag' not 'LUse_Code' as was the case for the Lake Macquarie_Wyong and Gosford Landuse shapefiles. A single shapefile 'CCIARP_Landuse' was created by a union of the three shapefiles then a manual copying of field attributes from LUse_Code and Tag into a new field named 'LandUseCod'. Once these tasks were completed, a number of individual data layers were extracted for further analysis. Some polygon slivers and overlaps were encountered and wherever possible these were removed.

Data from each council was generalised so as to facilitate the spatial modelling. Generalisation of the LEPs involved the development of a uniform environmental planning code for all LEPs (ie. Gosford, Wyong, Lake Macquarie, Newcastle and Port Stephens LGAs). The results of this work are summarised in the Table C1 which "maps" the original LGA LEP code across to a generalised code for the entire study area.

Individual shapefiles exported from the corporate geodatabases were combined with other datasets into three separate ESRI personal geodatabases. The data were clipped to the study area extent and reprojected (Projection: MGA Zone 56 Datum: GDA 1994). A decision to create separate geodatabases was due to technical (personal geodatabases have a maximum size limitation of 4Gb) and data management (separation of state and local government derived data) considerations. The personal geodatabases were named "DoP" (contains majority of corporate geodatabase data), "LEP" (contains corporate LEP data only) and "Council" (contains council sourced data).

To aid in uniquely identifying each dataset, the following prefixes were employed:

- ADMIN: used for datasets consisting of known Administrative Boundaries (eg. Study area boundary, LGA boundary etc.);
- ECON: used for datasets consisting of economic assets (eg. State Forest, Aquaculture leases);
- ENV: used for datasets consisting of environmental assets (eg. wetlands, terrestrial vegetation communities);

- HAZARD: used for datasets identifying hazards (eg. Acid sulphate soils);
- INFRA: used for datasets consisting of service infrastructure assets (eg. roads, railway, sewer pipelines);
- PLAN: used for datasets of planning responsibilities or heritage (eg. SEPP's, LEPs)
- SOCIAL: used for datasets consisting of social infrastructure and assets (eg. hospitals, schools, sports grounds)

Secondary labels were used in some circumstances to identify the original data source:

- Crown: Crown data
- LGA: Local Government Area
- LU: DECC Land Use data
- TOPO: Lands Digital Topographic Database
- DCDB: Lands Digital Cadastral Database
- BCP: Lands Building Complex Point (a subset of the DTDB Topo dataset)

Table C2 lists all of the datasets compiled for the project, their source, custodian, approximate currency and location of metadata statement on the CANRI website. A majority of these datasets have been included in the spatial modelling described in Appendix D, priority was given to those datasets describing land use zonings and actual land use.

With the exception of the Local Environment Plan and DECC (DNR) Land Use datasets, all other datasets were used in the spatial modelling "as supplied". There has been no attempt to verify the integrity of the datasets beyond that documented in the relevant metadata.

TABLE C1 Generalised LEP Zones for the Project Study Area

Aggregate Zone	Code	Broad Description	Equivalent Zones in LEPs						
Hypothetical Name			Wyong	Lake Macquarie	Newcastle	Port Stephens	Gosford IDO	Gosford Planning Scheme Ordinance	Gosford City Centre LEP
Rural	1A	Primary production (including forestry) and compatible activities	1a, 1(f)	1(1)		1a	1a,1c	1a,1(b) 1(c)	
Rural & Semi Rural	1B	Rural and semi residential development compatible with surrounding land uses			1a				
Rural & Environmental Living	1C	Small rural residential holdings and non residential uses compatible with rural residential development	7c	1(2) 7(5)		1(c1)-1(c5)	7 (c2), 7(c3) 7(c5) 7(c6)		
Rural Village	1D	Areas in non urban areas that provide services to the rural population	1d				2	1 (d)	
Residential (low density)	2A	Detached housing of generally low density	2(a) 2e	2(1)				2a 2(f)	
Residential Mixed (low-medium density)	2B	Detached & dual occupancy, residential flat buildings generally not exceeding 2 storeys	2b		2a	2a		2b	
Residential Mixed Medium – High density & mixed housing	2C	Diverse forms of housing, residential flats, limited non residential development/commercial development that is compatible with residential development. Some tourism development.	2c 2g	2(2)	2b	2c		2c	
Residential (high density)	2D	High density residential development and compatible uses. Includes tourism development.	2d					2d	
Core Business/Commercial	3A	Diverse & compatible range of commercial retail, recreational and service industries that are typical and necessary for regional district and neighbourhood level Includes tourism services & development.	3a 3d	3(1)	3c, 3b			3a, 3b, 3c	City Centre zone
Aggregate Zone	**Code**	**Broad Description**	**Equivalent Zones in LEPs**						
Hypothetical Name			Wyong	Lake	Newcastle	Port	Gosford IDO	Gosford	Gosford City

				Macquarie		Stephens		Planning Scheme Ordinance	Centre LEP
Business/Commercial Support	3B	Lower intensity commercial and retail than 3A. Includes tourism services & development	3b	3(2)	3a, 3d	3a			City Centre Support zone
Industrial General	4A	Large scale industrial & storage, manufacturing & employment generating industries. Includes industrial research.	4a	4(1)	4c	4a		4a	
Light Industrial & Business Park	4B	Light industry to service surrounding needs and commensurate multi sector employment opportunities with some related retail and businesses	4b, 4c	4(2), 4(3)	4a	5g		4b	
Major Industry, Port & associated facilities	4C	Major industrial and employment development that by its nature is required or should be separated from other activities.	4e		4b			4d	
Infrastructure & special Uses	5	Major and local infrastructure alignment such as roads, railway (also defence purposes – Pt Stephens); community facilities and purposes	5a, 5b, 5c, 5d	5	5a, 5b	5a,5c	5, 5b, 1b	5a,5b,5d,5e	City Centre Special Use zone
Public Open Space	6A	Community land for public open space and recreation. Includes land that is intended to be acquired or used for such purposes. Incudes leisure and recreational/sports facilities.	6a, 6b, 6c	6(1)	6a	6a	6a, 6b, 6c, 6d	6a, 6b, 6d, 6e	City Centre Parks zone
Recreation & Tourism	6B	Land for commercial recreation and tourist uses including private recreation facilities such as clubs etc		6(2)		6c		6c	
Conservation (special values)	7A	Land that has special aesthetic ecological or conservation values (eg habitat corridors) including wetlands. Restricted development.	7a 7g	7(1)	7a,7b	7a,7c	7a		
Conservation & Scenic Protection	7B	Land that has scenic and environmental qualities. Development that will not compromise values is permitted though scale and type is restricted	7b	7(2) 7(3)			7b		
Aggregate Zone	**Code**	**Broad Description**	**Equivalent Zones in LEPs**						
Hypothetical Name			Wyong	Lake Macquarie	Newcastle	Port Stephens	Gosford IDO	Gosford Planning Scheme	Gosford City Centre LEP

								Ordinance	
Coastal Protection	7C	Sensitive coastal lands including coastal processes. Development to be sensitive to values and allow coastal processes to occur.	7d 7e	7(4)		7(f1), 7(f3), 7(w)	7d, 7e		
Environment protection – (Noise)	7D	Land adjacent to major noise generators. Development needs to be compatible with the adjacent land use.	7f						
National Parks	8	Land reserved under the NP& W Act	8a	8	8a			8	
Natural Resource Use	9a	Land for extractive, timber uses and rehabilitation of land after use	9				4	4c	
Restricted Development	9b	Flood prone, steep land and other constraints. Limit development and appropriate location and suitable construction of residential buildings on land that has these constraints.	1c					9a, 9b, 9c	
Investigation	10	Identify and protect rural land and land with potential ecological significance or urban development	10a	10	7c		1d		
Lakes & waterways	11	Ensure development of waterways occurs in principles of ESD (ie economic suitable use & protection of habitat and natural values)		11					

Table C2: State & Local Government Datasets

State Government Spatial Datasets

Theme	Dataset Name	Source	Custodian	General coverage	Version	Metadata

ADMIN	Admin_Crown_Lease	Putney SDE	LPI	Study Area	2006	http://www.canri.nsw.gov.au/nrdd/records/ANZNS0404000851.html
	Admin_Crown_Licence	Putney SDE	LPI	Study Area	2006	http://www.canri.nsw.gov.au/nrdd/records/ANZNS0404000851.html
	Admin_Crown_Other	Putney SDE	LPI	Study Area	2006	http://www.canri.nsw.gov.au/nrdd/records/ANZNS0404000851.html
	Admin_Crown_Reserve	Putney SDE	LPI	Study Area	2006	http://www.canri.nsw.gov.au/nrdd/records/ANZNS0404000851.html
	Admin_Crown_Roads	Putney SDE	LPI	Study Area	2006	http://www.canri.nsw.gov.au/nrdd/records/ANZNS0404000851.html
	Admin_Localities	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Admin_Marine_Parks	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0364000088.html
	Admin_Nat_Parks	Putney SDE	LPI	Study Area	2007	http://canri.nsw.gov.au/nrdd/records/ANZNS0208000008.html
	Admin_LGA_Gosford	Putney SDE	LPI	LGA	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404000748.html
	Admin_LGA_LakeMacquarie	Putney SDE	LPI	LGA	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404000748.html
	Admin_LGA_Newcastle	Putney SDE	LPI	LGA	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404000748.html
Theme	Dataset Name	Source	Custodian	General coverage	Version	Metadata
	Admin_LGA_PortStephens	Putney SDE	LPI	LGA	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404000748.html
	Admin_LGA_Wyong	Putney SDE	LPI	LGA	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404000748.html

	Admin_Study_Area	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404000748.html
ECON	Econ_Coal_Applic	Putney SDE	DPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0155000006.html
	Econ_Coal_Titles	Putney SDE	DPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0155000005.html
	Econ_DPI_Aquaculture_Leases	CCA - Aquaculture_Leases06	DPI	Study Area	2006	DoP Comprehensive Coastal Assessment DVD
	Econ_LU_Aquaculture	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Econ_LU_Crop	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Econ_LU_Graz	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Econ_LU_Mining	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Econ_LU_Plantation	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
Theme	Dataset Name	Source	Custodian	General coverage	Version	Metadata
	Econ_LU_Tourism	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Econ_Mineral_Applic	Putney SDE	DPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0155000004.html
	Econ_Mineral_Titles	Putney SDE	DPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0155000003.html

	Econ_StateForest	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0167000004.html
	Econ_TOPO_Aquaculture	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
ENV	Env_Estuarine_macrophytes	Supplied CD DPI	DPI	Study Area	2006?	http://canri.nsw.gov.au/nrdd/records/ANZNS0364000127.html
	Env_Geology_250k	Omega SDE	DPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0155000670.html
	Env_LU_Beach	Supplied DNR P. Bliss	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Env_LU_Cliff	Supplied DNR P. Bliss	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Env_LU_Conservation	Supplied DNR P. Bliss	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Env_LU_Native_Veg	Supplied DNR P. Bliss	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Env_LU_Wetland	Supplied DNR P. Bliss	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
Theme	Dataset Name	Source	Custodian	General coverage	Version	Metadata
	Env_MitchellLandscapes	Putney SDE	DEC	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0208000229.html
	Env_RamsarWetlands	Putney SDE	DEC	Study Area	2006	http://www.marine.csiro.au/nddq/ndd_search.Browse_Citation?txtSession=7
	Env_Soil_Landscapes	Omega SDE	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359000542.html
	Env_Water_Features	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS040400752.html

HAZARD	Hazard_ASS_Planning	Omega SDE	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100087.html
	Hazard_ASS_Risk	Omega SDE	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359000004.html
	Hazard_LU_Landfill	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Hazard_LU_Sewage_Disp	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
INFRA	Infra_BCP_Infrastructure	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Infra_DCDB_Road	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS040400752.html
	Infra_LU_Airstrip	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Infra_LU_Defence	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Infra_LU_Electricity	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
Theme	Dataset Name	Source	Custodian	General coverage	Version	Metadata
	Infra_LU_Govt	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Infra_LU_Marina	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Infra_LU_Railway	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Infra_LU_Reservoir	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html

	Infra_LU_Road	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Infra_LU_TrainingWork	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Infra_TOPO_Crossing	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Infra_TOPO_Elec_Trans	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Infra_TOPO_Ferry_Route	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Infra_TOPO_Pipeline	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Infra_TOPO_Railway	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Infra_TOPO_RoadSegment	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
Theme	Dataset Name	Source	Custodian	General coverage	Version	Metadata
	Infra_TOPO_Runway	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Infra_TOPO_Tower	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Infra_TOPO_Transport_Line	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Infra_TOPO_Transport_Point	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Infra_TOPO_Utility_Canal	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
PLAN	Plan_BCP_Council	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html

	Plan_Builtup_Areas	Omega SDE	LPI	Study Area	2004	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Plan_Topo_Builtup_Areas	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Plan_CD_Popn_2001	TPDC	DoP	Study Area	2001	DoP Comprehensive Coastal Assessment DVD
	Plan_GNAF	TPDC	DoP	Study Area	2000	http://www.psma.com.au/datasets/g-naf
	Plan_LEP	Omega SDE	DoP	Study Area	Various	See Relevant Council Web Site
	Plan_LU_Ind_Comm	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Plan_LU_Residential	Supplied by DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Plan_LU_Rural_Res	Supplied DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Plan_Minerals_s117	Supplied by DNR	DPI	Study Area	2004	DoP Comprehensive Coastal Assessment DVD
Theme	Dataset Name	Source	Custodian	General coverage	Version	Metadata
	Plan_SEPP_14	Supplied by DNR	DoP	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0157000002.html
	Plan_SEPP_26	Supplied by DNR	DoP	Study Area	2004	http://canri.nsw.gov.au/nrdd/records/ANZNS0157000046.html
	Plan_SEPP_71	Supplied by DNR	DoP	Study Area	2004	http://canri.nsw.gov.au/nrdd/records/ANZNS0157000050.html
	Heritage_AHIMS_Database	Supplied by DECC	DECC	Study Area	2006	http://www.canri.nsw.gov.au/nrdd/records/ANZNS0208000074.html
	Plan_TOPO_Industry	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html

SOCIAL	Social_BCP_CommunityFacility	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Social_BCP_Education	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Social_BCP_Hospital	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Social_BCP_Recreation	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Social_LU_CaravanPk	Supplied DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Social_LU_Edu_Uni	Supplied DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Social_LU_Recreation	Supplied DNR	DNR	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0359100121.html
	Social_TOPO_Cemetery	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html
	Social_TOPO_Recreation	Putney SDE	LPI	Study Area	2006	http://canri.nsw.gov.au/nrdd/records/ANZNS0404001262.html

Local Government Spatial Datasets

Theme	Dataset Name	Source	Custodian	General coverage	Version	Metadata
ADMIN	Admin_G_Contours10m	Gosford Council	Gosford Council	LGA	2006	See Council
	Admin_G_Contours2m	Gosford Council	Gosford Council	LGA	2006	See Council
ENV	Env_G_CreeksLines	Gosford Council	Gosford Council	LGA	2006	See Council
	Env_G_CreeksPoly	Gosford Council	Gosford Council	LGA	2006	See Council
	Env_G_Fauna06	Gosford Council	Gosford Council	LGA	2006	See Council
	Env_G_Flora2006	Gosford Council	Gosford Council	LGA	2006	See Council
	Env_G_SoilLandscapes	Gosford Council	Gosford Council	LGA	2006	See Council
	Env_G_Waterways	Gosford Council	Gosford Council	LGA	2006	See Council
	Env_LM_SWCWetlands_region	Lake Macquarie Council	Lake Macquarie Council	LGA	2006	See Council
	Env_W_vegetation	Wyong Council	Wyong Council	LGA	2006	See Council

	Env_W_wetland_dcp_poly	Wyong Council	Wyong Council	LGA	2006	See Council
	Env_W_wetland_lep_poly	Wyong Council	Wyong Council	LGA	2006	See Council
	Env_W_Wetland_Plant_Communities	Wyong Council	Wyong Council	LGA	2006	See Council
HAZARD	Hazard_G_FloodExtents2005	Gosford Council	Gosford Council	LGA	2006	See Council
	Hazard_LM_100yr_FloodHazard_region	Lake Macquarie Council	Lake Macquarie Council	LGA	2006	See Council
	Hazard_LM_100yr_Floodways_region	Lake Macquarie Council	Lake Macquarie Council	LGA	2006	See Council
	Hazard_N_FloodAffected_region	Newcastle	Newcastle	LGA	2006	See Council
	Hazard_W_1pct_Flood_DRAFT	Wyong Council	Wyong Council	LGA	2006	See Council
	Hazard_W_Mine_Subsidence_district	Wyong Council	Wyong Council	LGA	2006	See Council
	Hazard_W_Noise_Affected_Area	Wyong Council	Wyong Council	LGA	2006	See Council
INFRA	Infra_G_DrainagePipe	Gosford Council	Gosford Council	LGA	2006	See Council
Theme	Dataset Name	Source	Custodian	General coverage	Version	Metadata
	Infra_G_DrainagePit	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_G_DrainBoxCulvert	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_G_Roads	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_G_SEWER_GravityMain	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_G_SEWER_NetworkStructure	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_G_SEWER_Pit	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_G_SEWER_PressureMain	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_G_WATER_Fitting	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_G_WATER_Hydrant	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_G_WATER_NetworkStructure	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_G_WATER_NetworkStructuresPoly	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_G_WATER_WaterMain	Gosford Council	Gosford Council	LGA	2006	See Council

	Infra_G_WATER_WaterNetwork_Junctions	Gosford Council	Gosford Council	LGA	2006	See Council
	Infra_W_Sewer_Line	Wyong Council	Wyong Council	LGA	2006	See Council
	Infra_W_Sewer_Manholes	Wyong Council	Wyong Council	LGA	2006	See Council
	Infra_W_Sewer_Pump_Station	Wyong Council	Wyong Council	LGA	2006	See Council
	Infra_W_Water_Line_main_diameter	Wyong Council	Wyong Council	LGA	2006	See Council
	Infra_W_Water_Line_pump_stations	Wyong Council	Wyong Council	LGA	2006	See Council
	Infra_W_Water_Line_Trunk_mains	Wyong Council	Wyong Council	LGA	2006	See Council
	Infra_W_Water_Line_Water_Reservoirs	Wyong Council	Wyong Council	LGA	2006	See Council
PLAN	Plan_G_LEP_Zoning	Gosford Council	Gosford Council	LGA	2006	See Council
	Plan_LM_Heritage_items	Lake Macquarie Council	Lake Macquarie Council	LGA	2006	See Council
Theme	Dataset Name	Source	Custodian	General coverage	Version	Metadata
	Plan_LM_Lep2004_region	Lake Macquarie Council	Lake Macquarie Council	LGA	2006	See Council
	Plan_N_Infrastructure_Corridor_region	Newcastle	Newcastle	LGA	2006	See Council
	Plan_N_LEP2003_GAZ_region	Newcastle	Newcastle	LGA	2006	See Council
	Plan_N_LEP2003	Newcastle	Newcastle	LGA	2006	See Council
	Plan_N_LEPnotes_polyline	Newcastle	Newcastle	LGA	2006	See Council
	Plan_N_LEPnotes_region	Newcastle	Newcastle	LGA	2006	See Council
	Plan_N_LEPnotes_text	Newcastle	Newcastle	LGA	2006	See Council
	Plan_N_LGA	Newcastle	Newcastle	LGA	2006	See Council
	Plan_N_STNAME_text	Newcastle	Newcastle	LGA	2006	See Council
	Plan_W_council_owned_land	Wyong Council	Wyong Council	LGA	2006	See Council
	Plan_W_Denied_Access	Wyong Council	Wyong Council	LGA	2006	See Council
	Plan_W_FSBL	Wyong Council	Wyong Council	LGA	2006	See Council
	Plan_W_Height_Limitation	Wyong Council	Wyong Council	LGA	2006	See Council

	Plan_W_Heritage_LEP_1991_AM_101	Wyong Council	Wyong Council	LGA	2006	See Council
	Plan_W_Heritage_LEP_1991_AM_144	Wyong Council	Wyong Council	LGA	2006	See Council
	Plan_W_Lot_Amalgamation	Wyong Council	Wyong Council	LGA	2006	See Council
	Plan_W_Summerland_Point_Precinct	Wyong Council	Wyong Council	LGA	2006	See Council
	Plan_W_Zone_Polygon	Wyong Council	Wyong Council	LGA	2006	See Council
	Plan_W_zoning_lines	Wyong Council	Wyong Council	LGA	2006	See Council
SOCIAL	Social_G_ChildCareCentres	Gosford Council	Gosford Council	LGA	2006	See Council
	Social_G_DraftHeritageSites	Gosford Council	Gosford Council	LGA	2006	See Council
	Social_G_Schools	Gosford Council	Gosford Council	LGA	2006	See Council
Theme	Dataset Name	Source	Custodian	General coverage	Version	Metadata
	Social_N_Heritage_area_region	Newcastle	Newcastle	LGA	2006	See Council
	Social_N_Heritage_area_text	Newcastle	Newcastle	LGA	2006	See Council
	Social_N_Heritage_area	Newcastle	Newcastle	LGA	2006	See Council
	Social_W_childcare	Wyong Council	Wyong Council	LGA	2006	See Council
	Social_W_family_neighbourhood_centres	Wyong Council	Wyong Council	LGA	2006	See Council
	Social_W_health_services	Wyong Council	Wyong Council	LGA	2006	See Council
	Social_W_playgrounds	Wyong Council	Wyong Council	LGA	2006	See Council
	Social_W_schools	Wyong Council	Wyong Council	LGA	2006	See Council
	Social_W_sportsfields	Wyong Council	Wyong Council	LGA	2006	See Council

Appendix D: Spatial Modelling

Spatial modelling was conducted as part of the pilot case study. Using the LiDAR terrain data and selected state and local government spatial datasets, the modelling aimed to quantify the assets potentially at risk from climate change associated sea level rise and the related effects of coastal inundation and shoreline recession. The modelling is intended to be illustrative of the likely impacts rather than an absolute account of assets at risk and therefore cannot be viewed as a replacement for detailed, site-specific process investigations commonly used in risk assessments in coastal areas (DNR, 1990, 1992; 2007).

The modelling involved the use of LiDAR elevation data in regional and LGA-specific assessments of assets likely to be at risk for the entire study area. Technical aspects of this approach are detailed here with results summarised in Appendix E.

Regional Asset by Elevation Assessment Modelling

The modelling involved combining existing spatial datasets with the high resolution terrain data and classifying the former in terms of asset types by elevation. The GIS analysis is dependent on the type of spatial data (ie. points, lines or polygons) to be merged with the DEM with results presented as counts (point data), length (line data) and area (polygon data).

Digital Elevation Model (DEM) Preparation.

The LiDAR-derived 2m resolution DEM (0.15m vertical resolution) was separated into four data sets, one for each of the LGAs covered by the survey (Newcastle, Wyong, Lake Macquarie and Port Stephens), to reduce the size of the datasets. This process was carried out using the “extract as mask” tool in the ArcMap Spatial Analyst Toolbox. The 5m resolution DEM supplied by Gosford council was also clipped using the boundary of the Gosford LGA. Gosford Council was not in the LiDAR survey area but did have its own LiDAR derived elevation model (0.3m vertical resolution) collected in 2005. The result of this process was four 2m DEMs and one 5m DEM.

Each of the DEMs were reclassified into 17 classes as shown below using the reclassification tool in ArcGIS Spatial Analyst.

grid_code	Elevation range (m)
1	<0.5
2	0.5 - 1
3	1 - 1.5
4	1.5 - 2
5	2 - 2.5
6	2.5 - 3
7	3 - 3.5
8	3.5 - 4
9	4 - 4.5
10	4.5 - 5
11	5 - 6
12	6 - 7
13	7 - 8
14	8 - 9
15	9 - 10
16	10 - 20
17	20+

The reclassified grids were then converted to feature class polygons. The “Dissolve” tool was used to summarise and simplify the classified elevation polygons so that calculations could be carried out more easily. A new field was added to the classified elevation polygon datasets to show the elevation range represented by each of the classified numbers 1 – 17 (as shown in the table above). The “repair geometry” tool from the data management - features toolbox was run on each of the resulting classified elevation polygon datasets in order to tidy up the datasets for further analyses.

The classified DEM data were used to assign elevation values to selected state and local government data sets.

Polygon Dataset Analysis.

The “Union” tool from the ArcGIS Overlay Toolbox was used to combine state and local government polygon datasets required for analysis. In some cases, the resulting data sets were then “dissolved” to summarise the data and compress the size of the table. The “Repair Geometry” tool was run if needed to eliminate self intersecting lines.

The “Identity” tool from the ArcGIS Overlay Toolbox was then used to combine the elevation

information for each LGA with the "Unioned" data sets. The analysis resulted in the elevation information being appended to each polygon data set thereby facilitating an analysis of assets by elevation. Tables derived from the GIS data sets were exported to MS Excel for presentation and explanatory purposes. A list of data sets analysed and Excel summary tables is shown below.

Polygon Dataset Analysis Output Summary

Gosford City LGA

GIS Feature class	Excel Summary Table	Data sets contained in analysis
Gosford_ID_LU_dis	Gosford_landuse.xls	Landuse_Project
Gosford_ID_draft_heritage	Gosford_heritage.xls	Social_G_DraftHeritageSites
Gosford_ID_dis_coast	Gosford_coast_LEP.xls	LEP SEPP14 SEPP26 SEPP71 Agg_Zone (LEP planning code aggregated to common code for all study area) Coast_Class_merge (Open ocean zone classification)
Gosford_ID2	Gosford_coast_2.xls	Admin_Crown_lease Admin_Crown_licence Admin_Crown_Reserve Admin_Nat_Parks Econ_State_Forest Env_Est_macrophytes Env_Geology_250k Env_Soil_Landscapes Plan_Minerals_s117 Coast_Class_merge (Open ocean zone classification)

Wyong Shire LGA

GIS Feature class	Excel Summary Table	Data sets contained in analysis
Wyong_ID_wetlandplants_sportsfields	Wyong_wetlandPlants_sportsfields.xls	Env_W_Wetland_Plant_Communities Social_W_sportsfields
Wyong_ID_LU_dis	Wyong_landuse.xls	Landuse_Project
Wyong_ID_dis_coast	Wyong_coast_LEP.xls	LEP SEPP14 SEPP26 SEPP71 Agg_Zone (LEP planning code aggregated to common code for all study area) Coast_Class_merge (Open ocean zone classification)
Wyong_ID2_2	Wyong_coast_2_2.xls	Admin_Crown_lease Admin_Crown_licence Admin_Crown_Reserve Admin_Nat_Parks Econ_State_Forest Env_Est_macrophytes Env_Geology_250k Env_Soil_Landscapes Plan_Minerals_s117 Coast_Class_merge (Open ocean zone classification)

Lake Macquarie City LGA

GIS Feature class	Excel Summary Table	Data sets contained in analysis
LMac_ID_wetlands	LMac_wetlands.xls	Env_LM_SWCWetlands_region
LMac_ID_LU_dis	LMac_landuse.xls	Landuse_Project
LMac_ID_diss_coast	LMac_coast_LEP.xls	LEP SEPP14 SEPP26 SEPP71 Coast_Class_merge (Open ocean zone classification)
LMac_ID2	LMac_coast_2.xls	Admin_Crown_lease Admin_Crown_licence Admin_Crown_Reserve Admin_Nat_Parks Econ_State_Forest Env_Est_macrophytes Env_Geology_250k Env_Soil_Landscapes Plan_Minerals_s117 Coast_Class_merge (Open ocean zone classification)

Newcastle City LGA

GIS Feature class	Excel Summary Table	Data sets contained in analysis
Newcastle_ID_LU_dis	Newcastle_landuse.xls	Landuse_Project
Newcastle_ID_dis_coast	LMac_coast_LEP.xls	LEP SEPP14 SEPP26 SEPP71 Agg_Zone (LEP planning code aggregated to common code for all study area) Coast_Class_merge (Open ocean zone classification)
Newcastle_ID2	Newcastle_coast_2.xls	Admin_Crown_lease Admin_Crown_licence Admin_Crown_Reserve Admin_Nat_Parks Econ_State_Forest Env_Est_macrophytes Env_Geology_250k Env_Soil_Landscapes Plan_Minerals_s117 Coast_Class_merge (Open ocean zone classification)

Port Stephens LGA

GIS Feature class	Excel Summary Table	Data sets contained in analysis
PtSteph_ID_LU_dis	PtStephens_landuse.xls	Landuse_Project
PtSteph_ID_dis_coast	PtStephens_coast_LEP.xls	LEP SEPP14 SEPP26 SEPP71 LHRS Greenfield areas – (Source, Name, Proposed) Agg_Zone (LEP planning code aggregated to common code for all study area) Coast_Class_merge (Open ocean zone classification)
PtSteph_ID2	PtStephens_coast_2.xls	Admin_Crown_lease Admin_Crown_licence Admin_Crown_Reserve Admin_Nat_Parks Econ_State_Forest Env_Est_macrophytes Env_Geology_250k Env_Soil_Landscapes Plan_Minerals_s117 Coast_Class_merge (Open ocean zone classification)

Point Dataset Analysis

The “Extract values to points” tool from ArcGIS Spatial Analyst was used for each point data set combined with the 2m LiDAR derived DEM (Port Stephens, Newcastle, Lake Macquarie and Wyong) and the 5m DEM for point data sets in the Gosford LGA. The output from this tool was a new point data set with the elevation from the DEM added as a new field for each point.

Point Dataset Analysis Output Summary

Data Custodian	**Excel Summary Table**	**Data sets contained in analysis**
Gosford Council	CCIARP_Point.xls	Env_G_Fauna06data Env_G_Flora2006data Infra_G_DrainagePit_data Infra_G_SEWER_networkstructure_data Infra_G_SEWER_Pit_data Infra_G_Water_fitting_data Infra_G_WATER_Hydrant_data Infra_G_Water_network_junctions_data Infra_G_WATER_Network_Structure_data Social_G_ChildCareCentresData Social_G_SchoolsData
Wyong Council	CCIARP_Point.xls	Infra_W_Sewer_Manholes_data Infra_W_Sewer_Pump_station_data Infra_W_Water_line_pump_stns_data Social_W_family_neighbourhood_centresData1 Social_W_health_servicesData1 Social_W_playgroundsData1
Lake Macquarie	CCIARP_Point.xls	Plan_LM_Heritage_itemsData1
State Government (DTDB)	CCIARP_Point.xls	Infra_BCP_infra_data1 Infra_TOPO_transport_data1 Plan_TOPO_industry_data1 Social_BCP_CommFac_data1 Social_BCP_Education_data1 Social_BCP_Hospital_data1 Social_TOPO_Cemetery_data1 Social_TOPO_Recreation_d1
PSMA Australia	GNAF_study_area_rc.xls	Plan_GNAF_Study_Area_data

The size of the Geocoded National Address File (GNAF) point file for the study area LGAs necessitated extra processing prior to classification of addresses by elevation. The GNAF is the authoritative address index for Australia. It contains the State, Suburb, Street, Number and coordinate reference or Geocode for street addresses in Australia. Names are not part of the GNAF, nor does GNAF contain any personal information.

For the GNAF, the data was first separated into a dataset for each LGA. After the "Extract values to points" tool was run for each data set, the "-9999" values (ie. address points outside the DEM bounds) were deleted to reduce the size of the datasets. These separate point data sets were then merged back into one "study area" data set. The modified GNAF file was combined with the classified DEMs produced in the preliminary analysis to derive the number of addresses within each elevation level. Study area data stored as "PLAN_GNAF_study_area_data_rc2"

Line Dataset Analysis

The 'Intersect' tool from the Overlay Toolbox was used to combine each line dataset with the polygon DEM dataset for each LGA. These data sets were then 'dissolved' using the elevation/gridcode fields and any other relevant fields from the input data set. Summary tables were exported from the GIS as Excel format files.

Line Dataset Analysis Output Summary

GIS Feature class	**Excel Summary Table**	**Data sets contained in analysis**
Gosford LGA		
Coastal_DEM	Gosford_drainage_pipe.xls Gosford_roads.xls Gosford_drain_box_culvert.xls Gosford_Railway.xls	Gosford_DrainagePipeD Gosford_Infra_roads Infra_G__DrainBoxCulvert_D Topo_G_Railway_D
Wyong LGA		
Coastal_DEM	Wyong_Sewer_line.xls (No Summary) Wyong_Railway.xls Wyong_road_segment_d.xls	Infra_W_Sewer_lineD_dis Infra_W_water_reserveD Topo_W_Railway_Dis Topo_W_Road_segment_Dis
Lake Macquarie LGA		
Coastal_DEM	LMac_Railway.xls LMac_road_segment_d.xls	Topo_LM_Railway_Dissolve Topo_LM_road_segment

Newcastle LGA		
Coastal_DEM	Newcastle_Railway.xls Newcastle_road_segment_d.xls	Topo_NC_Railway_Dissolve Topo_NC_road_segment
Port Stephens LGA		
Coastal_DEM	PtSteph_road_segment_d.xls	Topo_PS_road_segment

Appendix E: Spatial Modelling Tabulated Results

Tabulated summaries of selected spatial modelling are presented here, organised by major environmental theme (physical, natural, built, cultural). The modelling provides an inventory of the various assets (built, natural and cultural) by elevation above mean sea level for the entire Central & Hunter Coast study area and individual Local Government Areas. Owing to their size and complexity, the results of the LEP and Land Use datasets analyses are presented at the end of the appendix. Maps and charts in the body of the report are derived from these summaries.

The results are based on a combination of the project LiDAR elevation data (Central & Hunter Coast LiDAR survey and Gosford LiDAR) and "as supplied" state and local government data. No attempt was made to verify the reliability of the latter and as such there can be no guarantee these datasets are free from errors which may have influenced the tabulated summaries.

The tabulated results should be viewed as indicative and relevant only to low lying areas below 10m AHD in each LGA.

Physical Attributes of Survey Area

Survey Area Elevation Bands to 20m AHD

Council	Elevation (m AHD)																
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*TOTALS (Ha)*
Gosford	n/a	2021.19	1703.89	1107.46	694.64	461.68	387.45	366.91	391.69	458.27	925.03	575.58	436.73	418.37	400.69	3719.79	14069.36
Wyong	260.05	608.34	937.20	855.78	688.37	607.66	553.15	481.91	435.86	430.49	890.81	898.29	893.14	904.99	946.22	7368.01	17760.26
Lake Macquarie	669.09	851.58	955.28	747.38	502.73	428.22	397.50	385.23	386.84	373.49	780.95	776.15	761.86	802.98	806.78	8414.41	18040.46
Newcastle	1986.26	2495.06	953.33	853.51	537.73	419.99	357.95	331.84	289.40	280.33	647.83	573.38	427.27	360.25	318.92	2186.73	13019.80
Port Stephens	1321.87	2110.00	1005.11	617.49	750.53	783.64	831.20	711.94	604.32	542.10	1059.83	1488.45	1544.92	1381.27	862.58	2911.42	18526.67
TOTALS (Ha)	4237.27	8086.17	5554.82	4181.63	3174.00	2701.19	2527.25	2277.82	2108.12	2084.68	4304.44	4311.84	4063.92	3867.86	3335.19	24600.36	81416.56

Source: LiDAR survey 2m DEM; Gosford 5m DEM and LPI LGA Boundaries.

Survey Area Simplified Geology to 20m AHD

Council	Lithology	Elevation (m AHD)																
		<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*TOTALS (Ha)*
Gosford	Alluvium	584.03	638.53	869.06	639.29	369.88	230.68	208.32	212.89	246.93	311.09	645.70	308.39	170.31	147.50	129.86	744.38	6456.83
	Rock	580.01	373.12	421.97	301.58	222.02	173.82	143.34	130.22	126.65	129.72	247.64	242.98	243.99	249.51	250.78	2816.24	6653.58
Wyong	Alluvium	95.33	387.32	660.58	590.96	464.28	404.53	351.28	281.48	242.28	245.96	506.07	456.46	420.40	398.14	413.81	2054.31	7973.18
	Rock	52.49	101.16	182.35	201.86	185.10	177.87	185.06	176.69	177.26	176.07	373.67	433.37	468.71	504.18	530.99	5262.51	9189.36
Lake Macquarie	Alluvium	362.62	614.19	740.25	570.27	350.06	295.45	260.45	245.83	247.03	228.20	464.31	445.79	404.77	410.83	384.02	2702.21	8726.28
	Rock	93.11	111.96	130.99	124.89	118.18	106.62	115.89	124.08	128.43	136.81	303.97	321.24	349.59	386.06	417.69	5626.90	8596.42
Newcastle	Alluvium	1380.45	2290.46	859.59	763.51	462.88	363.87	309.86	282.47	239.99	211.14	504.22	432.67	272.15	219.09	176.58	540.34	9309.27
	Rock	39.67	82.19	67.43	61.06	46.84	38.77	34.66	37.42	39.36	60.91	131.37	134.40	150.96	134.69	139.38	1620.12	2819.23
Port Stephens	Alluvium	1259.08	2130.07	993.07	619.57	759.00	817.97	888.47	751.80	626.34	548.18	1043.18	1415.97	1448.27	1243.05	733.94	1382.50	16660.46
	Rock	1.93	16.07	23.35	19.20	14.76	14.40	12.38	16.19	17.16	26.17	80.92	137.60	159.55	193.94	176.24	1694.99	2604.87
TOTALS (Ha)		4448.71	6745.07	4948.64	3892.19	2993.01	2623.97	2509.70	2259.08	2091.43	2074.24	4301.05	4328.87	4088.70	3887.01	3353.32	24444.51	78989.49

Source: LiDAR survey 2m DEM, DPI 250K Geology and LGA Boundaries.

Selected Natural Assets of Survey Area

SEPP14 Wetlands to 20m AHD

Council	Elevation (m AHD)																
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Total (Ha)*
Gosford	86.71	221.66	106.24	77.57	32.82	12.67	6.96	4.34	2.78	2.38	4.37	0.99	0.27	0.15	0.10	0.22	560.23
Wyong	33.40	161.81	145.12	119.13	111.72	111.71	81.65	36.13	22.15	14.84	45.98	20.62	9.68	13.59	12.29	25.69	965.52
Lake Macquarie	205.47	197.56	92.63	38.00	13.11	10.78	17.47	13.91	13.78	10.43	10.41	4.72	3.69	8.16	2.74	29.54	672.40
Newcastle	1160.45	1771.87	393.87	377.96	80.25	11.44	5.34	3.96	1.60	0.65	0.98	0.79	0.64	0.50	0.42	1.81	3812.53
Port Stephens	134.74	649.57	50.65	21.93	14.68	1.73	3.13	6.23	0.49	0.21	0.05	18.03	75.81	46.33	0.54	0.01	1024.14
Total (Ha)	1620.78	3002.46	788.50	634.59	252.58	148.34	114.55	64.58	40.81	28.52	61.78	45.16	90.09	68.73	16.09	57.26	7034.81

Source: LiDAR survey 2m DEM, DoP SEPP14, LPI LGA Boundaries.

SEPP26 Littoral Rainforest to 20m AHD

Council SEPP26	Elevation (m AHD)																
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Total (Ha)*
Wyong		0.01	0.02	0.05	0.62	1.01	0.84	0.55	0.45	0.32	0.52	0.33	0.26	0.24	0.19	0.70	6.11
Lake Macquarie	0.04	0.05	0.08	0.21	0.23	0.15	0.24	0.17	0.14	0.16	0.50	0.18	0.02	0.01	0.00		2.18
Total (Ha)	0.04	0.06	0.11	0.26	0.85	1.16	1.08	0.72	0.59	0.47	1.02	0.51	0.28	0.24	0.19	0.70	8.29

Source: LiDAR survey 2m DEM, DoP SEPP14, LPI LGA Boundaries. Note SEPP26 areas do not occur within the LiDAR survey footprint for all LGAs.

Wyong Council Wetland Habitats to 20m AHD

Swamp Mahogany Paperbark Forest	7.6	60.4	40.0	24.7	15.7	10.4	6.6	5.0	5.6	28.8	19.2	14.1	20.4	25.2	108.2	391.8
Swamp Oak/Melaleuca Forest	38.9	380.5	217.7	131.4	119.9	95.6	50.6	30.2	24.0	56.7	81.7	69.7	50.2	48.8	141.7	1537.7
Wet Heath/Shrubland		1.3	2.5	1.7	0.8	1.1	2.0	3.4	5.3	16.6	12.9	17.2	15.2	15.1	164.3	259.6
Wetland/Sedge	19.9	42.3	30.4	18.9	13.5	5.1	3.7	2.5	1.9	4.7	6.0	3.7	5.9	6.9	17.8	183.0
Total (Hectares)	66.4	484.5	290.5	176.7	149.9	112.1	62.9	41.1	37.0	106.8	119.8	104.8	91.6	96.0	432.0	2372.1

Source: LiDAR survey 2m DEM, Wyong Council Wetland Habitat Mapping.

Lake Macquarie Council Wetland Types to 20m AHD

Habitat Type	Eleavtion (m AHD)																
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Grand Total*
Intermittent Fresh Meadow	1.4	0.8	1.3	2.2	0.7	0.3	0.2	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	7.7
Mud Flat	0.8	0.2	0.2	0.1	0.0	0.1	0.2	0.2	0.2	0.2	0.3	0.1	0.1	0.1	0.0	0.1	2.9
Non-wetland - Cleared, Grassland, Filled, Weeds	2.1	5.4	3.2	1.8	1.5	1.5	1.5	1.5	1.2	0.7	1.1	1.3	1.3	1.2	1.7	9.6	36.7
Non-wetland - Mixed Forest	4.7	8.4	9.6	3.7	2.2	2.5	1.6	1.2	1.2	1.4	2.9	1.9	2.0	2.8	2.5	971.0	1019.8
Non-wetland - Shrubland	0.6	0.6	0.6	0.7	0.5	0.4	0.1	0.1	0.1	0.1	0.3	0.8	0.9	0.8	0.7	1.7	8.8
Perennial Fresh/Brackish Rushland, Reedswamp, Meadow	15.9	16.4	5.9	1.8	1.8	2.0	2.8	2.2	1.5	1.0	1.9	1.6	1.7	2.0	2.0	9.3	69.8
Phragmites Reedswamp	0.3	1.4	1.8	2.6	1.0	0.0				0.1	0.1	0.0	0.1	0.0		2.2	9.6
Saltmarsh	20.3	18.8	13.4	3.6	0.8	0.4	0.4	0.4	0.3	0.3	0.4	0.2	0.1	0.2	0.1	0.3	60.0
Sand	5.1	1.7	1.0	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	8.6
Seagrass	1.7	1.1	0.5	0.5	0.4	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0				4.7
Swamp Forest	41.0	57.9	54.4	29.5	15.0	9.1	7.4	6.6	6.6	6.3	11.5	11.4	11.2	9.0	6.5	27.3	309.5
Swamp Forest/Scrubland	49.8	61.6	55.5	35.8	11.2	7.8	8.3	9.5	14.0	9.2	15.0	9.3	5.9	5.4	3.8	25.1	327.1
Typha Rushland	1.0	3.1	2.7	0.9	0.5	0.5	1.3	2.1	3.4	2.8	4.2	1.5	1.1	2.1	1.4	12.6	41.3
Wet Heath	0.7	3.7	9.9	7.4	3.6	2.2	1.3	1.4	1.7	1.6	3.6	5.1	2.6	2.0	2.6	21.5	70.9
Grand Total (Hectares)	145.2	181.0	160.0	91.0	39.3	27.0	25.1	25.7	30.5	23.8	41.4	33.4	26.9	25.8	21.4	1080.9	1977.2

Source: LiDAR survey 2m DEM, lake Macquarie Council Wetland Mapping, LPI LGA Boundaries.

NSW DPI (Fisheries) Estuarine Macrophytes (excludes sea grass) to 20m AHD

Council	Habitat	Elevation (m AHD)										
		<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	Total (Ha)
Wyong	Mangrove	1.82	0.51	0.08	0.12	0.17	0.02					2.73
Wyong	Saltmarsh	7.24	6.30	0.05	0.02	0.04	0.01					13.66
Lake Macquarie	Mangrove	87.21	17.95	3.64	1.96	1.16	0.69	0.51	0.23	0.07	0.01	113.42
Lake Macquarie	Saltmarsh	36.61	37.63	6.72	1.42	0.44	0.35	0.30	0.11	0.02	0.01	83.62
Newcastle	Mangrove	182.24	1069.90	31.31	4.32	1.09	0.84	0.51	0.38	0.18	0.10	1290.87
Newcastle	Saltmarsh	53.96	350.85	29.51	3.24	0.71	0.13	0.00				438.40
Port Stephens	Mangrove	66.88	512.83	14.71	2.83	0.80	0.28	0.13	0.04	0.01		598.51
Port Stephens	Saltmarsh	2.61	67.23	2.80	0.11	0.01						72.74

Source: LiDAR survey 2m DEM, DPI Wetland mapping, LPI LGA Boundaries. Complete estuarine macrophyte mapping not available for all LGAs.

Selected Built Assets of Survey Area

Infrastructure (Roads) to 20m AHD

Council	Elevation (m AHD)															
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Totals (m)*
Gosford	1,890	9,284	41,307	44,088	28,400	21,891	22,578	24,289	32,073	48,552	97,769	51,787	28,998	25,695	26,365	236,480	741,445
Wyong	441	4,495	22,982	35,818	33,891	27,919	27,075	23,907	21,424	19,961	40,529	41,769	44,109	44,367	45,917	392,826	827,431
Lake Macquarie	2,175	25,675	56,492	51,316	35,204	24,360	21,910	22,068	21,931	20,160	40,065	39,952	43,366	45,748	47,970	493,114	991,505
Newcastle	2,823	14,401	32,918	39,509	33,213	26,586	19,593	19,920	25,840	30,278	70,981	58,188	33,550	30,024	25,313	209,863	673,001
Port Stephens	3,266	7,795	11,116	16,359	17,734	23,165	29,570	23,291	20,275	16,385	36,056	42,765	47,509	38,140	29,592	108,658	471,679
Totals (m)	10,595	61,651	164,815	187,091	148,442	123,921	120,725	113,476	121,544	135,336	285,401	234,461	197,533	183,974	175,157	1,440,940	3,705,062

Source: LiDAR survey 2m DEM, LPI DTDB Road Segment and LGA Boundaries.

Infrastructure (Railway) to 20m AHD

Council	Elevation (m AHD)																
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Total (m)*
Gosford	291	248	201	681	1,669	2,840	3,476	1,962	1,684	1,467	2,065	1,062	538	567	696	4,676	24,123
Wyong	13	11	34	46	25	27	48	219	996	410	1,626	1,274	1,006	933	1,764	7,337	15,768
Lake Macquarie	27	81	279	305	381	644	606	772	835	833	2,456	779	570	833	942	16,886	27,229
Newcastle	100	275	1,154	6,814	8,307	8,455	4,424	5,377	1,924	1,411	4,511	4,567	2,080	3,002	3,086	6,058	61,547
Port Stephens																	
Total (m)	430	615	1,667	7,846	10,382	11,965	8,554	8,330	5,439	4,121	10,659	7,681	4,194	5,336	6,488	34,958	128,667

Source: LiDAR survey 2m DEM, LPI DTDB Railway and LGA Boundaries.

Physical Addresses to 20m AHD

Council	Elevation (m AHD)																
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Total*
Gosford	48	282	1,592	1,743	1,570	966	927	1,284	1,558	2,418	6,310	3,022	1,402	1,324	1,218	11,573	37,237
Wyong	18	208	1,516	2,404	1,678	1,588	1,223	1,131	1,037	1,104	1,923	2,035	2,202	2,093	2,014	17,404	39,578
Lake Macquarie	83	842	2,616	2,401	1,019	853	769	727	825	832	1,545	1,567	1,462	1,579	1,530	15,944	34,594
Newcastle	21	57	740	1,038	581	472	484	663	1,165	1,651	4,108	3,703	1,570	1,374	1,320	12,073	31,020
Port Stephens	30	67	116	126	146	109	79	93	91	85	372	635	867	672	364	2,750	6,602
Total	200	1,456	6,580	7,712	4,994	3,988	3,482	3,898	4,676	6,090	14,258	10,962	7,503	7,042	6,446	59,744	149,031

Source: LiDAR survey 2m DEM, PSMA GNAF and LPI LGA Boundaries.

Infrastructure (Utility Buildings) to 20m AHD

Pump Station			3	3	2	1	2		1	1	3	1	3	3	1	5	29
Substation		1	1	1	1	1	5	1	1	1	4	3	1	5	4	12	42
Waste Treatment Plant		1			1		2	3	1	2		1	1		1	7	20
Water Treatment Plant														1		1	2
Total No.		2	4	4	4	2	11	4	4	4	7	5	5	9	6	25	96

Source: LiDAR survey 2m DEM, LPI DTDB Building Complex Point Utility Facility.

Infrastructure (Sewerage System) Wyong Council Local Government Area to 20m AHD

Wyong Council	Elevation (m AHD)																	
	<0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	6.0 - 7.0	7.0 - 8.0	8.0 - 9.0	9.0 - 10.0	10.0 - 20.0	*Total No.*
Sewer Pump Station		4	21	23	14	9	3	5	8	0	5	3	6	4	3	4	13	125

Wyong Council	Elevation (m AHD)																	
	<0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	6.0 - 7.0	7.0 - 8.0	8.0 - 9.0	9.0 - 10.0	10.0 - 20.0	*Total No.*
Sewer Manholes	10	171	611	755	562	526	422	432	404	393	365	395	798	728	675	664	5315	13226

Wyong Council	Elevation (m AHD)																
	<0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 6.0	6.0 - 7.0	7.0 - 8.0	8.0 - 9.0	9.0 - 10.0	10.0 - 20.0	*Total (m)*
Sewer Line	542	9,900	35,269	41,129	30,562	29,240	25,105	23,476	23,388	21,724	40,896	43,389	39,402	37,307	35,591	273,191	710,110

Wyong Council	Elevation (m AHD)																	
	<0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.5 - 6.0	6.0 - 7.0	7.0 - 8.0	8.0 - 9.0	9.0 - 10.0	10.0 - 20.0	*Total No.*
Water Line Pump Stations					1								2	3			4	10

Source: LiDAR survey 2m DEM, Wyong Shire Council Database.

Selected Cultural Assets of Survey Area

Sports Recreation Facilities to 20m AHD for Entire Survey Area

Recreation Facility	Elevation (m AHD)																
	<0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 6.0	6.0 - 7.0	7.0 - 8.0	8.0 - 9.0	9.0 - 10.0	10.0 - 20.0	*Total No.*
Camping Ground											1	2	1	3		4	11
Golf Course		2	2	1	3	1	1				1	1	1	1		3	27
Park	7	30	66	78	45	32	20	25	16	18	41	24	23	23	28	132	608
Showground			1					1	1		1						4
Sports Court			4	9	3	6	1	2	3	4	7	5	5	2		18	69
Sports Field		2	10	28	17	9	6	14	4	14	18	11	8	11	8	57	217
Total No.	7	34	83	116	68	48	28	42	24	36	69	43	38	40	36	214	926

Source: LiDAR survey 2m DEM, LPI DTDB Topo Recreation Facility.

Community Facilities to 20m AHD for Entire Survey Area

	<0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 5.5	5.0 - 6.0	6.0 - 7.0	7.0 - 8.0	8.0 - 9.0	9.0 - 10.0	10 - 20	*Total No.*
Ambulance				1	1	1		1	1			2	1	1		3	1	13
Art Gallery																1		1
Child Care Centre												1						1
Community Home				2	1	2	1	3	1			4	3	2	2	5	19	45
Community/Group Hall	1	3	2	4	1	2	1		5	5		3	9	5	7	4	23	75
Court House				1	1										2		2	6
Fire Station-Bush			1	2	1		1	3	1	1		2	1	1	1		7	22
Fire Station-Urban			1	2					3			3	3	4	1	1	11	29
Gaol								1					1					2
Govt. Authority Building				1	1	1	2										2	7
Health Care Centre												1						1
Hospital											1		2				2	5
Library			2	1								2	2	2		3	8	20
Local Govt Chambers					1		2									1	2	6
Medical Centre														1				1
Place Of Worship		2	4	6	6	1	3		5	6		9	12	6	7	6	79	152
Police Station				3			1	2	1				1	3	1		4	16
Post Office			4	7	3	1	1	2	3	3		6	7	1		3	22	63
SES Facility		1		2				1				2	1				2	9
Total No.	1	6	14	32	16	8	12	13	20	15	1	35	43	26	21	27	184	474

Source: LiDAR survey 2m DEM, LPI DTDB Building Complex Point Community Facility.

Historic Sites to 20m AHD for Entire Survey Area

	Elevation (m AHD)														
	<0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 6.0	6.0 - 7.0	7.0 - 8.0	8.0 - 9.0	9.0 - 10.0	10 - 20	*Total No.*
Historic Site		1		1					1					2	5
Lookout							1		2					1	4
Monument			2	2	3	1		2		1				1	12
Total No.		1	2	3	3	1	1	2	3	1				4	21

Source: LiDAR survey 2m DEM, LPI DTDB Topo Recreation.

Indigenous Sites to 20m AHD for Entire Survey Area

Site Type	Elevation (m AHD)																
	<0.5	0.5 - 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 2.5	2.5 - 3.0	3.0 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 6.0	6.0 - 7.0	7.0 - 8.0	8.0 - 9.0	9.0 - 10.0	10.0 - 20.0	*Total No.*
Aboriginal Place, Natural Mythological (Ritual)																1	1
Axe Grinding Groove	1				1					1			3	3		3	12
Axe Grinding Groove, Open Camp Site												1					1
Axe Grinding Groove, Shelter with Deposit																1	1
Bora/Ceremonial	1																1
Burial/s			1														1
Burial/s, Midden																1	1
Burial/s, Open Camp Site																1	1
Isolated Find	2					1					1				4	9	17
Isolated Find, Open Camp Site																1	1
Midden	12	20	13	10	5	5	4	6	4	4	5	9	3	3	2	21	126
Midden, Ochre Quarry														1			1
Midden, Open Camp Site															1	7	8
Midden, Quarry			1														1
Natural Mythological (Ritual)			1									1				1	3
Not Stated	1	6	5	9	12	23	8	7	8	6	10	6	4	6	9	29	149
Not an Aboriginal Site	1																1
Ochre Quarry		1															1
Open Camp Site	11	5	2	2	6	9	3	3	7	4	7	9	6	9	9	37	129
Open Camp Site, Scarred Tree	1																1
Quarry			1														1
Rock Engraving																1	1
Scarred Tree			2								3			1	1	1	8
Shelter with Art																1	1
Shelter with Art, Shelter with Deposit																1	1
Shelter with Deposit					1												1
Total No.	30	32	26	21	25	38	15	16	19	15	26	26	16	23	26	116	470

Source: LiDAR survey 2m DEM, DECC AHIMS database, LPI LGA Boundaries.

Local Environment Plan Analyses – Aggregate Zones by Elevation to 20m AHD

GOSFORD CITY COUNCIL LEP BELOW 20M AHD																	
Aggregate LEP Zone*	Elevation (m AHD)																
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Grand Total (Hectares)*
Business/Commercial Support														0.05	0.04	5.47	5.57
Coastal Protection			1.52	3.67	1.59	0.42	0.25	0.09	0.02	0.02	0.04	0.02	0.01	0.01	0.01	0.11	7.75
Conservation (Special Values)	26.14	213.06	518.57	270.11	144.60	94.75	73.20	58.68	55.60	50.59	83.95	77.21	75.26	67.17	60.64	722.60	2592.12
Core Business/Commercial	0.13	0.95	10.31	13.66	11.98	9.61	8.28	7.63	10.79	13.52	20.60	10.87	4.56	4.68	3.90	41.49	172.96
Industrial General	0.44	1.31	3.16	11.67	17.72	19.84	19.38	11.70	9.06	8.11	18.43	9.39	8.37	6.81	7.50	53.36	206.26
Infrastructure & Special Uses	14.40	13.45	22.10	26.02	24.59	26.66	30.54	28.31	32.45	38.28	70.25	51.03	47.79	52.90	55.05	323.57	857.38
Light Industrial & Business Park			0.02	0.84	0.95	0.24	0.04	0.02	0.02	0.01	0.02	0.00					2.16
Major Industry, Port & Associated Facilities	0.01	0.31	0.77	2.03	1.17	1.06	0.72	0.81	0.66	0.43	0.79	0.43	0.24	0.30	0.18	1.34	11.25
National Parks	0.94	18.51	9.15	3.57	2.59	1.62	1.29	1.03	0.78	0.95	1.88	1.31	1.03	0.46	0.22	0.23	45.57
Natural Resource Use										0.00	0.26	0.22	0.08	0.03	0.03	0.16	0.79
Public Open Space	101.53	321.90	307.67	267.58	164.80	116.03	98.96	89.50	87.66	82.44	131.50	89.68	78.53	71.61	67.85	622.83	2700.05
Residential (High Density)																0.07	0.07
Residential (Low Density)	3.36	29.85	128.93	121.27	91.71	51.87	52.41	69.39	80.87	123.87	298.64	143.26	102.99	99.69	96.79	949.90	2444.80
Residential Mixed (Low - Medium Density)	0.01	0.42	5.47	17.75	19.24	16.17	17.39	27.51	46.27	77.58	182.95	84.89	13.18	8.94	8.31	65.19	591.27
Residential Mixed (Medium - High Density)	0.01	0.02	0.58	1.35	1.16	0.74	1.02	0.77	0.90	0.77	1.79	2.77	3.32	4.53	4.52	36.57	60.80
Restricted Development	2.96	9.72	19.25	12.87	7.50	7.40	8.48	8.27	8.69	7.63	14.91	15.41	12.74	7.97	5.73	58.31	207.85
Rural	0.40	1.13	1.42	1.72	2.20	1.58	0.94	2.17	1.79	0.99	2.11	1.42	1.03	2.37	3.68	28.39	53.33
Rural & Environmental Living	5.63	13.62	28.60	24.48	16.61	12.32	14.20	17.82	20.12	22.21	54.60	56.84	61.86	67.23	66.72	688.69	1171.57
Rural Village	0.12	3.33	0.94	0.17	0.05	0.01	0.01	0.00	0.01								4.64
Grand Total (Hectares)	156.09	627.59	1058.47	778.76	508.46	360.32	327.10	323.70	355.70	427.38	882.73	544.74	411.00	394.74	381.14	3598.28	11136.20
TOTAL LGA AREA 102,656Ha																	
*See project notes on LEP zone aggregation.																	
Analysis represents c11% of LGA																	

Source: LiDAR survey 2m DEM, DoP LEP database (updated from Council data), LPI LGA Boundaries.

WYONG SHIRE COUNCIL LEP BELOW 20M AHD																	
Aggregate LEP Zone*	Elevation (m AHD)																
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Grand Total (Hectares)*
Business/Commercial Support				0.03	0.06	0.23	1.28	4.03	5.12	6.08	3.58	0.23	0.16	0.18	0.14	4.50	25.62
Coastal Protection				0.01	0.01	0.01	0.05	0.26	0.86	1.19	1.86	2.32	1.30	0.59	0.65	5.65	14.75
Conservation & Scenic Protection	0.89	4.47	8.39	11.51	11.88	10.06	11.11	12.12	15.30	15.06	31.07	37.11	41.99	51.22	54.74	387.81	704.71
Conservation (Special Values)	36.40	235.63	377.31	247.72	175.08	143.30	100.64	51.68	38.19	39.03	101.64	103.27	112.07	102.56	102.33	569.48	2536.33
Core Business/Commercial		0.01	0.27	0.76	1.49	1.70	2.49	1.98	2.19	0.85	2.41	3.03	3.97	6.59	8.11	33.82	69.68
Environmental Protection (Noise)	0.00	0.11	0.37	0.46	0.80	2.12	1.97	2.17	2.61	3.09	11.48	15.51	18.15	21.74	29.86	78.94	189.39
Industrial General		0.03	0.04	0.89	2.44	2.01	12.48	4.41	5.06	7.98	28.17	47.48	39.47	24.66	28.55	59.34	263.01
Infrastructure & Special Uses	2.87	6.02	16.09	25.35	28.71	40.64	63.01	67.98	69.85	70.29	136.56	129.55	126.40	125.87	120.86	1192.71	2222.76
Investigation	0.70	4.48	20.05	18.44	16.26	16.30	17.01	15.98	17.42	18.44	42.14	41.54	50.43	68.15	80.18	868.66	1296.17
Light Industrial & Business Park			0.01	0.35	2.18	5.99	12.26	17.82	16.06	26.20	40.46	14.98	1.94	1.95	1.43	9.75	151.38
Major Industry, Port & Associated Facilities							0.00	0.18	0.40	0.56	2.25	4.32	8.03	13.79	21.22	214.74	265.49
National Parks	8.03	10.39	13.65	15.73	18.60	19.16	18.19	16.92	17.78	20.31	62.80	64.97	63.06	62.42	65.15	544.87	1022.04
Public Open Space	44.29	175.44	168.60	126.03	85.93	65.54	53.11	51.46	41.91	38.07	66.15	55.81	44.37	43.04	37.80	266.01	1363.54
Residential (High Density)		0.00	0.14	0.72	0.07					0.00	0.12	0.22	0.48	0.21	0.29	3.03	5.29
Residential (Low Density)	1.75	13.79	100.27	131.27	90.62	89.53	66.35	56.03	49.47	47.03	85.52	94.50	99.96	101.51	104.58	848.26	1980.44
Residential Mixed (Low - Medium Density)	0.02	0.16	7.28	18.53	14.64	11.13	9.23	11.99	13.18	15.00	31.09	39.45	34.66	28.51	26.56	246.99	508.43
Residential Mixed (Medium - High Density)	0.18	0.01	0.03	0.57	2.96	2.84	0.78	1.08	1.60	1.36	2.57	3.07	3.35	3.81	3.46	51.31	78.97
Restricted Development	4.50	52.16	126.94	163.01	153.01	129.73	120.58	106.25	75.86	53.08	74.19	56.47	56.24	52.99	42.41	222.80	1490.23
Rural	0.00	0.74	2.39	3.16	6.24	6.97	8.31	12.89	20.34	27.29	87.15	106.70	112.14	113.04	122.63	845.58	1475.56
Rural & Environmental Living		0.02	3.63	2.05	1.77	1.67	1.53	1.83	1.92	1.99	4.23	3.43	5.93	13.47	16.14	285.45	345.06
Grand Total (Hectares)	99.63	503.46	845.45	766.61	612.75	548.96	500.37	437.04	395.09	392.90	815.43	823.97	824.12	836.30	867.10	6739.71	16008.88

TOTAL LGA AREA 82,703Ha

*See project notes on LEP zone aggregation.

Analysis represents c19% of LGA

Source: LiDAR survey 2m DEM, DoP LEP database (updated from Council data), LPI LGA Boundaries.

Source: LiDAR survey 2m DEM, DoP LEP database (updated from Council data), LPI LGA Boundaries.

LAKE MACQUARIE CITY COUNCIL LEP BELOW 20M AHD																	
Aggregate LEP Zone*	Elevation (m AHD)																
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Grand Total (Hectares)*
Business/Commercial Support	0.01	0.16	5.28	3.79	1.05	1.19	1.11	2.46	4.08	4.21	7.36	6.65	6.00	4.12	5.19	35.83	88.50
Coastal Protection	46.90	11.82	10.53	14.52	21.32	26.43	20.63	17.40	18.35	18.71	36.86	25.18	15.59	10.72	9.33	79.15	383.43
Conservation & Scenic Protection	42.82	84.49	94.58	84.50	70.44	62.28	64.36	64.17	59.53	58.72	139.54	147.15	138.10	162.19	167.86	1866.98	3307.72
Conservation (Special Values)	292.53	338.44	228.84	124.09	63.26	46.66	45.36	40.21	40.63	40.00	69.96	56.10	54.75	60.10	58.03	628.64	2187.59
Core Business/Commercial	0.15	1.47	7.46	8.27	2.75	1.84	2.65	3.82	4.20	4.08	8.46	10.90	13.77	12.18	10.50	68.36	160.88
Industrial General	5.86	12.08	11.87	15.14	15.10	12.46	10.35	10.35	7.97	7.61	19.53	16.93	15.89	16.47	20.95	489.43	687.98
Infrastructure & Special Uses	15.38	39.89	57.80	48.09	40.23	31.72	27.78	24.98	22.67	21.77	49.13	49.02	48.83	40.13	34.37	316.53	868.33
Investigation	3.39	13.84	22.93	10.23	11.33	12.00	11.88	14.67	15.66	15.52	35.07	37.07	37.21	37.86	38.55	497.44	814.67
Lakes & Waterways (Zone 11)	165.51	49.66	15.44	6.42	3.66	1.98	1.61	0.68	0.38	0.20	0.29	0.16	0.06	0.05	0.03	0.03	246.17
Light Industrial & Business Park	0.09	0.94	5.75	5.83	4.09	8.75	8.81	6.75	5.88	4.39	11.82	19.73	9.14	11.58	10.11	179.60	293.26
National Parks	44.83	18.69	12.24	15.44	15.82	11.00	9.61	8.33	8.52	8.47	17.63	15.56	15.26	15.12	15.34	169.32	401.19
Natural Resources Use	8.62	15.17	19.17	12.38	20.36	21.52	20.62	17.03	16.76	18.62	54.31	61.54	57.68	68.21	78.32	702.51	1192.81
Public Open Space	27.62	96.97	105.57	80.01	47.75	35.08	24.65	27.10	32.09	20.55	35.01	31.76	27.44	24.61	21.95	236.00	874.14
Recreation & Tourism	3.04	21.90	37.49	41.61	24.69	21.32	15.85	14.68	12.86	11.76	17.84	16.71	17.55	16.22	10.56	68.78	352.84
Residential (Low Density)	5.62	84.04	175.71	146.01	80.06	66.59	61.31	63.81	68.92	66.89	130.33	130.87	136.36	146.97	149.54	1474.24	2987.26
Residential Mixed	0.74	20.96	77.65	68.91	22.56	14.80	16.29	14.51	14.61	16.22	29.07	28.20	27.31	30.46	29.61	227.19	639.10
Rural	3.59	28.07	42.85	42.43	41.83	36.14	35.28	33.08	32.22	33.39	72.40	80.51	97.49	99.45	98.65	838.28	1615.65
Rural & Environmental Living	2.09	12.75	23.87	19.35	16.10	16.26	19.22	21.11	21.36	22.12	45.41	41.01	41.79	44.04	45.09	504.21	895.78
Grand Total (Hectares)	668.78	851.36	955.03	747.01	502.40	428.01	397.37	385.14	386.68	373.23	780.02	775.04	760.22	800.47	803.99	8382.53	17997.30
Grand Total (Hectares) Excluding Zone11	503.26	801.70	939.59	740.58	498.74	426.04	395.76	384.46	386.30	373.03	779.73	774.88	760.16	800.43	803.96	8382.50	17751.13

TOTAL LGA AREA 75,168Ha
*See project notes on LEP zone aggregation.
Analysis represents c24% of LGA

(PART) NEWCASTLE CITY COUNCIL LEP BELOW 20M AHD

Aggregate LEP Zone*	Elevation (m AHD)																
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Grand Total (Hectares)*
Business/Commercial Support		0.01	1.77	11.81	10.05	2.32	1.33	2.02	1.09	1.95	9.04	13.07	6.74	4.65	2.70	24.58	93.13
Conservation (Special Values)	994.86	1081.04	486.19	261.57	78.33	38.93	25.94	18.52	13.89	10.99	19.72	17.96	14.31	9.88	8.99	61.14	3142.26
Core Business/Commercial	1.48	0.60	1.23	5.77	30.54	15.75	11.11	8.36	8.84	9.48	20.61	25.32	9.96	5.61	3.67	12.53	170.85
Industrial General	0.39	0.16	0.15	0.13	0.12	0.12	0.13	0.12	0.12	0.13	1.28	1.77	3.27	10.62	18.72	59.57	96.78
Infrastructure & Special Uses	46.57	69.70	34.72	54.22	49.21	29.74	22.78	24.13	25.55	23.55	77.73	82.16	63.25	43.79	39.19	242.12	928.40
Investigation	1.15	5.55	4.18	4.74	6.01	4.57	5.57	4.27	5.58	6.23	13.51	14.82	15.49	15.84	16.43	232.23	356.17
Light Industrial & Business Park	0.67	2.32	23.93	31.92	18.25	8.08	5.92	8.00	11.45	11.41	35.89	40.65	36.30	23.56	22.32	61.29	341.95
Major Industry, Port & Associated Facilities	15.93	39.52	74.48	135.03	185.85	226.48	218.64	188.36	114.36	67.66	89.85	74.63	84.39	76.50	55.17	67.77	1714.60
National Parks	766.31	1206.72	261.81	245.53	54.16	5.65	1.38	0.89	0.70	0.62	1.11	0.95	1.06	1.28	1.23	16.03	2565.41
Public Open Space	20.61	7.31	23.84	56.27	64.23	47.57	26.11	22.85	20.93	31.04	99.02	84.49	62.42	53.38	31.17	194.56	845.81
Residential Mixed (Low - Medium Density)	0.00	0.17	4.91	11.36	19.86	27.32	21.98	31.38	51.10	55.76	120.48	64.37	71.27	61.83	70.46	750.66	1362.92
Residential Mixed (Medium - High Density)	0.17	1.72	25.42	27.06	12.75	10.49	14.99	21.60	34.63	60.61	157.64	151.39	56.49	50.31	44.62	384.74	1054.63
Rural &Semi Rural	1.02	0.44	0.45	0.32	0.36	0.49	0.43	0.35	0.36	0.46	1.25	1.64	2.32	3.01	4.25	58.39	75.55
Grand Total (Hectares)	1849.16	2415.26	943.08	845.72	529.73	417.51	356.29	330.85	288.59	279.89	647.13	573.22	427.26	360.25	318.92	2165.59	12748.46

TOTAL LGA AREA 21,503Ha

*See project notes on LEP zone aggregation.

Analysis represents c59% of LGA

Source: LiDAR survey 2m DEM, DoP LEP database (updated from Council data), LPI LGA Boundaries.

(PART) PORT STEPHENS COUNCIL LEP BELOW 20M AHD

Aggregate LEP Zone*	Elevation (m AHD)																
	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Grand Total (Hectares)*
Business/Commercial Support			0.07	1.29	4.05	0.87	0.65	0.80	0.73	0.99	3.03	2.73	1.87	1.69	0.44	1.34	20.56
Conservation (Special Values)	0.37	7.63	31.43	64.22	169.24	226.18	374.40	370.70	314.13	298.11	631.62	729.85	868.34	888.01	481.73	1377.08	6833.06
Industrial General	4.82	5.03	5.67	12.46	31.14	45.14	55.05	58.62	61.09	54.08	96.82	161.08	183.40	57.55	48.24	76.70	956.90
Infrastructure & Special Uses	0.01	1.06	1.16	3.65	11.33	13.33	21.39	28.01	49.51	53.19	97.69	97.48	158.20	134.55	76.29	84.77	831.63
Light Industrial & Business Park	0.00	0.00	0.37	3.80	5.24	2.17	0.92	0.46	0.58	0.51	0.33						14.40
Public Open Space	11.94	15.49	39.78	50.98	69.82	57.89	36.52	29.15	24.64	22.32	35.66	27.79	25.79	15.36	9.02	73.13	545.27
Recreation & Tourism	9.35	22.69	15.32	8.88	10.28	6.09	5.94	5.88	7.08	7.17	10.57	14.18	19.15	32.63	44.08	25.63	244.94
Residential Mixed (Low - Medium Density)		1.24	3.67	8.80	16.95	20.78	12.81	11.71	10.08	10.89	35.95	49.08	52.99	56.65	35.54	210.04	537.19
Rural	1218.18	1973.33	871.83	419.55	389.18	370.96	285.52	179.67	115.03	79.41	97.53	68.86	56.77	45.44	38.05	223.39	6432.70
Rural & Environmental Living						0.06	0.05	0.06	0.04	0.04	16.34	299.26	139.11	114.01	100.50	665.05	1334.53
Grand Total (Hectares)	1244.67	2026.48	969.29	573.63	707.24	743.48	793.25	685.07	582.93	526.73	1025.56	1450.30	1505.63	1345.89	833.89	2737.13	17751.17

TOTAL LGA AREA 97,345Ha

*See project notes on LEP zone aggregation.

Analysis represents c18% of LGA

Source: LiDAR survey 2m DEM, DoP LEP database (updated from Council data), LPI LGA Boundaries.

Land Use Analyses – Department of Environment and Climate Change Land Use Types by Elevation to 20m AHD

GOSFORD CITY COUNCIL AREAS BELOW 20M AHD																		
NSW Landuse Mapping Program Mapping Code & Landuse Class	LUMAP Landuse Code	Elevation (m AHD)																
	Elevation	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Grand Total (Hectares)*
Cliff/Rock Outcrop	109	9.67	4.85	3.52	2.81	2.46	1.81	0.96	0.59	0.46	0.47	0.82	0.62	0.56	0.46	0.38	2.70	33.15
Conservation Area - Foreshore protection, vegetated dune	99			0.02	0.11	0.20	0.46	0.94	0.92	1.44	1.44	2.02	1.44	0.73	0.25	0.45	1.51	11.92
Conservation Area - National Park	NP	24.42	120.02	141.23	132.36	99.61	63.12	47.72	41.39	35.66	31.87	55.74	49.99	46.98	42.79	38.35	424.21	1395.47
Conservation Area - State Forest	SF													0.12	0.48	1.49	22.65	24.75
Grazing - Degraded land (salt site, eroded area)	83													0.18	0.37	0.53	1.63	2.71
Grazing - Grazine irrigated pasture	6		0.05	0.86	5.74	1.72	0.22	0.13	0.00									8.72
Grazing - Grazing improved perrenial pasture	5	1.26	18.70	13.68	9.20	6.97	3.29	1.50	0.84	0.52	0.36	0.51	0.60	0.41	0.39	0.34	1.22	59.77
Grazing - Grazing volunteer, naturalised or improved pasture	4	2.08	51.77	135.24	121.06	68.96	49.41	40.02	30.31	24.66	23.63	40.29	38.64	35.10	32.54	29.00	186.19	908.91
Grazing - Grazing volunteer, naturalised or improved pasture	4TM	0.00	0.73	1.21	1.38	0.94	0.38	0.31	0.37	0.39	0.26	0.46	0.43	0.40	0.35	0.27	3.10	11.01
Grazing - Grazing volunteer, naturalised or improved pasture	4TS											0.19	0.22	0.72	0.89	1.09	9.25	12.36
Horticulture - Orchard	2								0.00	0.01	0.00	0.01	0.01	0.04	0.11	0.21	4.41	4.79
Horticulture - Vegetables	39													0.00	0.05	0.12	2.43	2.61
Intensive Animal Production - Abattoir	60	0.00	0.03	0.48	1.61	0.85	0.68	0.53	0.59	0.56	0.33	0.63	0.34	0.17	0.22	0.13	0.86	7.99
Intensive Animal Production - Horse stud	90	0.10	4.64	21.36	28.46	4.61	0.57	0.07	0.01	0.01								59.82
Mining & Quarrying - Quarry	7																1.14	1.14
Power Generation - Electricity substation	93				0.00	0.00	0.00	0.08	0.44	0.04	0.21	1.31	0.00	0.01	0.03	0.20	1.02	3.34
River & Drainage System - Drain	79	0.35	0.20	0.27	0.17	0.11	0.06	0.00	0.00									1.16
River & Drainage System - Drainage channel	57	0.02	1.19	5.33	0.69	0.03	0.00	0.01	0.00									7.26
River & Drainage System - River or creek or other incised drainage feature	12	104.50	70.10	77.40	63.92	46.38	27.55	18.88	12.08	11.13	8.98	14.28	15.18	14.29	12.52	9.16	16.57	522.92
Special Category - No identified use	97	0.27	0.41	0.41	0.54	0.85	0.89	0.47	0.38	0.55	1.07	2.91	3.12	1.03	0.58	0.40	1.90	15.79
Transport - Energy corridor	47														0.00	0.07	0.38	0.45
Transport - Railway	20	1.33	1.86	4.07	4.84	5.98	7.53	6.93	5.93	5.01	4.91	6.35	3.29	2.40	2.34	2.49	23.18	88.43
Transport - Road reserve	19	1.70	2.76	12.32	14.50	7.82	6.67	6.88	8.41	8.21	6.76	11.34	10.90	9.36	8.67	7.31	49.95	173.54
Tree Cover - Dense shrub growth, limited to nil grazing capacity	162																3.22	3.22
Tree Cover - Native forest	9	12.66	46.94	102.60	62.67	42.21	36.09	32.82	31.82	31.49	31.32	64.44	61.44	60.28	59.54	62.87	723.09	1462.25
Tree Cover - Native woody shrub	67	0.48	7.55	14.98	7.66	3.16	1.57	0.82	2.36	6.31	6.74	8.70	9.93	10.75	6.12	3.27	5.56	95.97
Tree Cover - Poplar plantation	52	0.01	0.03	1.14	5.28	0.94	0.05	0.03	0.02	0.02	0.01	0.02	0.00	0.00	0.00	0.00		7.56
Urban - Airstrip (Local/farmer, unsealed)	45	0.06	0.08	0.94	1.35	0.72	0.01											3.16
Urban - Caravan Park, mobile home village	94	1.06	1.34	3.99	6.35	4.82	4.96	7.15	6.41	1.85	2.96	5.16	5.14	4.81	5.04	4.27	13.33	78.64
Urban - Cemetry	50					0.01	0.02	0.05	0.05	0.09	0.24	0.69	0.58	0.86	1.04	0.70	5.17	9.49
Urban - Glider field for recreational activities	156					0.01	0.04	0.07	0.17	0.18	0.29	1.33	1.13	0.24	0.16	0.16	0.42	4.19
Urban - Government facility; goal, training centre, school	92	0.45	0.58	0.97	2.84	2.89	2.08	2.56	4.15	5.97	11.46	11.44	5.09	5.06	5.86	5.31	50.08	116.78
Urban - Hobby farm	151	1.24	1.52	4.20	5.12	4.52	4.91	7.14	8.08	9.01	8.25	14.22	11.13	12.03	8.34	7.31	72.28	179.30
Urban - Hobby farm	151TM						0.01	0.03	0.03	0.01	0.13	0.55	0.70	1.13	1.11	1.40	16.22	21.32
Urban - Hobby farm	151TS	0.00	0.02	0.98	1.21	0.39	0.26	0.13	0.15	0.17	0.24	0.37	0.48	0.67	0.63	0.62	4.42	10.75
Urban - Industrial, commercial	16	0.76	2.95	15.90	33.43	33.10	29.10	27.23	19.68	21.41	20.08	33.78	21.24	13.79	13.75	12.06	100.10	398.35
Urban - Landfill	33																3.39	3.39
Urban - Research facility	61												0.01	0.73	4.27	2.82	7.32	15.14
Urban - Residential	17	14.55	40.97	167.01	168.54	130.96	84.50	89.90	111.52	146.90	222.65	527.91	252.26	131.61	124.09	120.03	1141.42	3474.82
Urban - Resort style urban land use	149	0.94	0.85	0.88	0.40	0.12	0.12	0.10	0.12	0.16	0.20	0.45	0.58	0.53	0.30	0.04		5.80
Urban - Rural residential	18	1.19	5.88	10.62	8.83	6.98	6.30	8.79	12.50	14.03	14.58	36.22	35.02	41.93	45.63	45.57	477.53	771.62
Urban - Rural residential	18TM		0.80	1.84	0.36	0.15	0.09	0.44	0.62	0.59	0.67	3.32	6.45	4.77	4.19	3.56	45.81	73.65
Urban - Rural residential	18TS									0.03	0.06	0.31	0.33	0.37	0.47	0.58	30.37	32.54
Urban - Sewage disposal ponds	29	0.05	0.50	0.44	0.56	0.71	0.63	1.05	2.77	1.06	0.61	1.80	1.42	1.79	2.83	6.70	20.40	43.31
Urban - Small to medium forested blocks with isolated residential dwellings	152	4.05	9.05	23.20	22.25	15.65	11.91	10.38	8.71	8.94	7.79	12.98	11.21	11.63	13.64	14.39	159.63	345.41
Urban - Surf club and/or coastal car parking facilities	155	0.01	0.01	0.02	0.02	0.11	0.49	0.25	0.87	0.31	0.00	0.00						2.10
Urban - Urban recreation	31	13.37	33.23	61.65	51.28	27.99	19.88	20.44	24.75	34.72	36.17	49.40	16.47	13.18	11.68	11.69	55.63	481.52
Water Body - Beach	64	10.44	13.73	13.57	11.88	12.67	11.79	7.13	4.97	3.99	2.46	2.84	1.68	0.79	0.51	0.24	0.53	99.23
Water Body - Coastal Lake	105			21.21	61.85	6.59	1.51	0.46	0.26	0.19	0.13	0.15	0.10	0.08	0.07	0.03	0.10	92.74
Water Body - Estuarine waters	106	2259.10	744.35	249.77	102.40	58.62	33.90	16.56	7.85	4.57	3.08	3.07	1.54	1.23	1.19	0.75	3.83	3491.77
Water Body - Farm dam	8	0.01	1.48	0.47	0.87	0.51	1.84	0.74	0.31	0.32	0.41	0.60	0.99	0.96	0.71	0.64	6.64	17.49
Water Body - Sandspit, estuarine sand island	96	1.62	1.36	0.35	0.02	0.01												3.37
Wetland - Aquaculture; oyster and spoil sheds	98	0.09	0.04	0.05	0.53	0.32	0.14	0.07	0.04	0.02	0.03	0.03	0.02	0.00	0.00	0.00		1.38
Wetland - Coastal marsh	56								0.03	0.13	0.10	0.01						0.27
Wetland - Lagoon	76	0.05	9.95	18.35	4.65	1.31	0.46	0.96	0.47	0.12	0.04	0.04	0.06	0.05	0.05	0.02	0.13	36.70
Wetland - Mangrove	54	62.34	270.10	172.57	68.40	42.33	25.39	15.02	8.26	5.63	3.43	3.57	2.18	1.34	1.16	1.09	5.94	688.76
Wetland - Mudflat	55	12.74	88.70	199.10	30.91	10.44	3.76	2.01	1.35	0.91	0.58	0.90	0.76	0.79	0.63	0.61	0.86	355.03
Wetland - Swamp	23			1.66	4.57	0.18	0.12	0.11	0.07	0.06	0.02	0.02	0.00					6.79
Grand Total (Hectares)		2542.98	1559.30	1505.85	1051.63	655.89	444.57	377.89	360.64	387.82	455.00	921.21	572.71	433.91	416.03	398.73	3707.71	15791.88
Analysis represents c.18% of total LGA																		

WYONG SHIRE COUNCIL AREAS BELOW 20M AHD																		
NSW Landuse Mapping Program Mapping Code & Landuse Class	LUMAP Landuse Code	Elevation (m AHD)																
		<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Grand Total (Hectares)*
Cliff/Rock Outcrop	109	11.53	14.64	6.18	3.74	1.76	0.52	0.30	0.25	0.16	0.16	0.26	0.16	0.14	0.11	0.10	0.50	40.53
Conservation Area - Foreshore protection, vegetated dune	99		0.06	1.55	6.67	5.48	4.47	3.65	3.65	2.86	3.25	5.70	9.02	11.47	12.63	13.58	74.84	158.88
Conservation Area - National Park	NP	10.45	14.71	18.85	24.09	26.24	24.52	23.16	21.77	22.58	25.36	78.10	82.63	73.99	70.93	72.67	660.21	1250.26
Conservation Area - State Forest	SF												0.09	0.46	1.47	2.53	14.27	18.81
Grazing - Degraded land (salt site, eroded area)	83	0.14	11.41	7.87	9.04	7.03	15.60	7.76	0.90	0.19	0.12	0.13	0.08	0.10	0.82	1.75	8.30	71.22
Grazing - Grazing improved perrenial pasture	5									0.00	0.06	0.81	9.00	18.93	32.05	24.40	86.42	171.69
Grazing - Grazing volunteer, naturalised or improved pasture	4	1.89	19.17	121.16	104.85	107.08	85.53	103.11	84.16	70.04	54.40	83.79	77.06	69.03	71.79	100.19	754.51	1907.76
Grazing - Grazing volunteer, naturalised or improved pasture	4TM	0.00	2.12	2.63	0.28	0.65	1.12	1.04	0.07					0.03	4.07	4.16	0.00	16.19
Grazing - Grazing volunteer, naturalised or improved pasture	4TS					0.02	0.43	0.64	0.58	0.84	0.69	0.32	3.39	5.55	5.61	4.24	21.79	44.11
Grazing - wide road reserve	117		0.01	0.02	0.17	0.42	0.98	1.22	1.34	1.11	1.43	4.24	2.76	2.15	2.74	3.54	27.82	49.95
Horticulture - Eucalyptus oil plantation	120														0.01	0.30	2.50	2.82
Horticulture - Jojoba planting	154				0.00	0.22	0.28	0.06	0.03	0.01	0.00	0.00						0.61
Horticulture - Nursery	42					0.00	0.02	0.05	0.09	0.11	0.15	0.28	1.64	1.92	5.73	3.44	22.59	36.02
Horticulture - Orchard	2	0.19	1.80	2.48	0.91	0.53	0.25	0.13	0.09	0.06	0.06	0.09	0.09	0.05	0.05	0.04	2.11	8.93
Horticulture - Seed production, including clover seed	37				0.00	0.04	0.01	0.01	0.01	0.02	0.02	0.08	0.66	0.09				0.93
Horticulture - Shade house	81														0.01	0.30	8.40	8.71
Horticulture - Vegetables	39																3.24	3.24
Horticulture- Vineyard	3												0.00	0.00	0.01	0.01	6.82	6.84
Horticulure - Abandoned orchard and vine lands	87															0.00	1.88	1.88
Horticulure - Turf farm	88		0.00	0.01	0.08	0.05	0.05	0.11	0.60	1.32	2.68	14.96	23.29	38.20	27.98	14.97	17.58	141.89
Intensive Animal Production - Horse stud	90											0.01	0.21	1.19	1.18	1.77	2.17	6.53
Intensive Animal Production - Poultry	26c																0.69	0.69
Mining & Quarrying - conveyor belt	114		0.00	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.08	0.32	0.63	0.64	6.01	7.79
Mining & Quarrying - Fly ash dam, spoil dump	78	0.15	0.56	0.81	0.54	0.65	2.29	1.86	14.95	12.98	11.06	23.22	6.83	2.07	2.24	2.87	211.63	294.71
Mining & Quarrying - Mining site	44							0.00	0.54	0.87	0.68	0.58	1.04	3.06	4.00	4.37	42.47	57.62
Mining & Quarrying - Quarry	7											0.01	0.01	0.82	1.54	1.08	6.94	10.40
Mining & Quarrying - Restored mining lands	49																0.30	0.30
Mining & Quarrying - Restored sand mining area	95													0.25	2.12	1.07	22.26	25.69
Power Generation - electricity generation	112	0.33	0.28	0.42	0.91	0.69	2.63	12.48	2.13	3.13	12.30	8.59	6.50	8.46	7.86	8.19	80.19	155.08
Power Generation - Electricity substation	93				0.00	0.04	0.72	5.28	1.12	0.63	0.38	0.19	0.25	0.73	0.83	0.61	2.24	13.01
Power Generation - land controlled by power company	113	2.64	14.15	15.77	16.96	12.18	10.39	9.10	12.49	11.73	11.11	19.38	21.34	19.96	20.68	17.99	215.70	431.58
River & Drainage System - Canal	107	1.45	0.81	0.48	0.35	0.39	0.42	0.18	0.07	0.04	0.02	0.04	0.04	0.03	0.03	0.03	0.71	5.10
River & Drainage System - Constructed grass waterway for water disposal	119												0.06	0.84	0.62	0.14	0.43	2.10
River & Drainage System - Drain	79	0.43	1.68	2.17	1.71	1.13	1.20	1.80	1.47	1.03	0.68	0.51	0.07					13.87
River & Drainage System - Drainage channel	57						0.00	0.10	0.18	0.24	0.19	0.66	0.58	0.24	0.08			2.27
River & Drainage System - River or creek or other incised drainage feature	12	10.52	19.85	20.18	16.53	14.48	12.15	11.22	10.46	10.99	11.18	21.70	23.05	22.22	25.34	18.14	48.36	296.38
River & Drainage System - River training work	51	0.06	0.13	0.23	0.00													0.43
Special Category - No identified use	97													0.00	0.41	2.02	9.15	11.59
Transport - Energy corridor	47	0.04	0.20	0.51	0.71	0.66	0.81	0.84	1.73	3.04	2.20	4.02	3.72	2.91	2.21	2.18	33.68	59.45
Transport - Railway	20	0.01	0.05	0.13	0.22	1.42	2.45	5.18	5.23	4.47	4.92	8.38	6.46	5.55	6.39	7.64	39.05	97.56
Transport - Road reserve	19	0.54	0.92	1.65	5.12	7.52	6.03	3.13	2.87	3.62	4.78	16.26	17.37	22.34	21.55	21.58	200.49	335.77
Tree Cover - Native forest	9	6.47	43.16	91.09	95.99	52.98	34.88	23.53	24.77	19.08	19.45	44.32	61.38	60.53	76.50	80.67	368.72	1103.53
Tree Cover - Native woody shrub	67	6.14	103.40	116.34	68.58	60.25	69.18	33.71	24.49	18.98	8.15	9.44	3.71	2.89	4.97	7.04	65.99	603.26
Tree Cover - Recently burnt areas of woody vegetation	66																7.60	7.60
Tree Cover - Woodland	70	8.32	53.34	90.49	71.09	85.47	82.40	98.64	64.64	55.64	57.76	127.37	129.08	131.46	110.29	100.39	920.73	2187.11
Urban - Aerodrome/Airport	36										0.00	2.72	6.89	8.42	10.52	8.30	8.56	45.42
Urban - Caravan Park, mobile home village	94	0.08	1.75	9.41	10.81	4.89	4.86	3.77	3.67	4.92	3.73	6.51	7.53	7.57	6.69	5.48	50.57	132.24
Urban - Cemetry	50																1.04	1.04
Urban - Government facility; goal, training centre, school	92	0.03	0.23	2.33	4.11	2.16	1.52	0.67	0.86	1.10	1.29	3.67	3.28	4.82	4.85	6.18	67.25	104.33
Urban - Hobby farm	151	2.03	10.50	31.12	44.06	30.32	24.76	22.94	24.45	26.49	28.87	75.19	78.70	86.43	94.22	123.54	978.66	1682.26
Urban - Hobby farm	151TM	0.00	1.83	3.40	1.35	0.71	1.05	1.81	1.72	1.31	1.14	3.18	0.84	0.29	0.67	2.28	24.12	45.72
Urban - Hobby farm	151TS		0.00	0.12	2.12	0.86	1.89	4.73	4.82	2.13	0.98	1.90	4.00	6.90	4.50	5.03	55.61	95.59
Urban - Industrial, commercial	16	0.04	0.17	0.29	1.35	4.06	6.77	18.89	23.30	29.41	43.65	73.88	42.46	34.63	33.74	39.88	132.11	484.64
Urban - Industrial, commercial	16TM	0.00	0.05	0.09	0.12	0.14	0.19	0.30	0.35	0.48	1.00	8.51	18.49	4.97	0.28	0.00		34.98
Urban - Industrial, commercial	16TS	0.02	0.05	0.06	0.20	0.15	0.11	0.09	0.10	0.12	0.18	0.85	6.62	8.10	1.95	0.26	0.18	19.04
Urban - Landfill	33							0.01	0.10	0.30	0.18	0.26	0.18	0.18	0.26	0.47	11.39	13.32
Urban - Residential	17	5.59	26.27	153.06	210.29	158.02	139.03	108.31	102.16	92.31	84.12	157.49	174.65	169.06	165.94	171.71	1391.48	3309.48
Urban - Rural residential	18	8.93	18.72	11.31	9.91	7.06	5.42	5.32	5.68	6.29	6.96	13.95	13.96	14.44	20.49	24.56	344.80	517.81
Urban - Rural residential	18TM														0.01	0.10	7.84	7.96
Urban - Rural residential	18TS																2.80	2.80
Urban - Sewage disposal ponds	29			0.01	0.02	0.03	0.05	0.24	0.48	0.58	1.86	6.01	2.32	2.38	2.24	1.11	39.20	56.54
Urban - Small to medium forested blocks with isolated residential dwellings	152	0.40	0.83	2.45	3.39	2.47	2.79	1.80	1.73	1.21	1.02	1.54	1.25	1.38	1.53	1.79	15.05	40.62
Urban - Surf club and/or coastal car parking facilities	155	0.13	0.07	0.10	0.09	0.31	1.00	0.62	0.38	0.36	0.31	0.52	0.55	0.30	0.30	0.53	4.43	9.99
Urban - Tourist development, convention site	75							0.00	0.00	0.12	0.23	0.10	0.06	0.05	0.05	0.04	2.91	3.58
Urban - Urban recreation	31	34.54	115.70	100.34	64.68	39.64	26.92	19.29	21.18	14.34	11.55	24.97	22.55	17.49	19.12	14.40	102.95	649.65
Water Body - Beach	64	19.81	8.65	9.09	10.97	12.40	10.90	7.92	5.57	5.21	4.92	7.87	5.69	3.43	2.17	1.39	4.71	120.70
Water Body - Coastal Lake	105	79.54	24.16	5.12	1.92	0.69	0.33	0.30	0.10	0.09	0.05	0.07	0.01	0.00	0.00			112.38
Water Body - Farm dam	8	0.07	3.76	6.07	0.67	0.51	0.09	0.01	0.00				0.29	0.52	2.95	4.99	3.05	22.98
Water Body - Fish/Prawn farm	34																3.26	3.26
Water Body - Sandspit, estuarine sand island	96	0.59	1.05	0.84	0.26	0.39	0.60	0.85	0.63	0.41	0.26	0.50	0.52	0.37	0.02			7.28
Wetland - Coastal marsh	56	2.94	29.54	60.50	17.79	6.72	2.43	1.50	1.41	1.32	2.71	15.38	13.46	11.25	6.40	8.64	111.92	293.92
Wetland - Contructed wetland for conservation or water quality improvement	122									0.00	0.14	1.16	0.59	0.52	0.03			2.43
Wetland - Dunal swamp	73												0.00	0.75	0.15	0.14	0.94	1.98
Wetland - Mangrove	54	1.37	10.79	5.09	1.07	0.02	0.00	0.00										18.34
Wetland - Mudflat	55	12.98	11.47	0.13	0.41	4.09	3.72	1.92	1.32	0.75	0.60	0.39	0.05					37.84
Wetland - Swamp	23	8.03	34.71	30.43	37.20	21.04	11.84	2.81	0.74	0.41	1.04	10.36	1.43	0.66	0.22	0.08	2.94	163.92
Grand Total (Hectares)		238.44	602.76	932.40	851.36	684.07	605.60	552.42	481.46	435.44	430.05	890.42	898.01	892.90	904.79	945.53	7367.12	17712.75

Analysis represents c22% of total LGA

LAKE MACQUARIE CITY COUNCIL AREAS BELOW 20M AHD																		
		Elevation (m AHD)																
NSW Landuse Mapping Program Mapping Code & Landuse Class	LUMAP Landuse Code	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Grand Total (Hectares)*
Cliff/Rock Outcrop	109	5.45	2.11	1.37	1.40	1.96	1.54	1.74	1.50	0.72	0.58	1.13	0.72	0.77	0.71	0.79	5.62	28.11
Conservation - National Park	NP	16.75	15.10	9.11	9.92	9.70	7.24	6.47	5.49	5.55	5.95	13.63	11.98	11.53	11.34	11.39	112.24	263.39
Conservation - State Forest	SF											0.15	0.48	1.63	6.55	9.11	145.45	163.37
Conservation Area - Foreshore protection, vegetated dune	99	1.89	1.69	1.85	5.45	4.82	7.05	6.48	7.39	7.78	8.88	23.10	21.28	16.12	11.25	11.22	93.82	230.06
Conservation Area - SCA unused land	148				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.02
Grazing - Degraded land (salt site, eroded area)	83		0.00	0.03	0.02	0.02	0.02	0.09	0.64	0.41	0.17	0.85	1.50	0.67	0.27	0.35	6.68	11.71
Grazing - Firebreak	137																	0.00
Grazing - Grazing improved perrenial pasture	5	5.53	16.39	15.84	9.22	7.41	6.73	4.39	3.98	4.58	3.89	7.16	7.69	8.21	9.31	5.35	62.50	178.17
Grazing - Grazing volunteer, naturalised or improved pasture	4	14.75	43.79	54.28	39.22	35.91	31.21	31.21	36.05	36.82	38.37	91.40	95.27	103.65	104.38	101.79	1023.64	1881.76
Grazing - Grazing volunteer, naturalised or improved pasture	4TM									0.00	0.22	2.66	1.81	2.36	2.27	2.27	9.26	20.87
Grazing - Grazing volunteer, naturalised or improved pasture	4TS	5.43	1.12	1.52	0.79	0.24	0.67	2.02	3.63	0.59	0.42	1.08	2.77	4.07	5.80	5.97	63.81	99.93
Grazing - Secondary grassland	101	0.23	0.06	0.05	0.03	0.05	0.04	0.08	0.09	0.05	0.04	0.08	0.07	0.14	0.15	0.32	1.38	2.86
Grazing - wide road reserve	117																	0.00
Horticulture - Abandoned orchard and vine lands	87									0.08	0.23	0.25	0.27	0.33	0.18	0.19	8.14	9.67
Horticulture - Building associated with horticultural activities	53										0.74	0.98	0.16	0.03	0.02	0.02	0.20	2.15
Horticulture - Nursery	42														0.00	0.31	1.32	1.64
Horticulture - Orchard	2	0.00	0.03	0.18	0.18	0.07	0.08	0.04	0.07	0.08	0.06	0.08	0.08	0.08	0.08	0.07	1.76	2.95
Horticulture - Shade house	81	0.00	0.12	0.11	0.13	0.10	0.11	0.09	0.10	0.14	0.09	0.11	0.17	0.32	0.44	0.46	6.35	8.84
Horticulture - Vegetables	39	0.00	0.28	0.58	0.49	0.31	0.31	0.28	0.40	0.33	0.10	0.21	0.44	0.70	0.83	0.90	8.80	14.96
Horticulture - Vineyard grape and other fruits	3																	0.00
Horticulture- Seed production including clover	37																	0.00
Intensive Animal Production - Horse stud and/or horse breeding facilities	90																	0.00
Intensive Animal Production - Poultry	26c							0.01	0.05	0.10	0.19	0.39	0.57	1.12	1.50	1.88	15.47	21.28
Mining & Quarrying - Conveyor belt	114	0.00	0.05	0.20	0.61	0.52	0.24	0.16	0.25	0.35	0.31	0.73	0.61	0.60	0.58	0.40	2.61	8.21
Mining & Quarrying - Derelict mining land	43			0.28	0.97	1.66	1.99	1.46	2.72	3.97	3.66	11.26	18.82	13.56	18.43	15.14	48.61	142.53
Mining & Quarrying - Fly ash dam/spoil dump	78	1.59	7.21	12.62	14.70	9.75	6.91	1.59	0.29	0.30	0.36	0.67	2.28	1.39	0.81	1.63	124.78	186.88
Mining & Quarrying - Mining Site	44	3.80	6.30	5.13	4.15	3.82	3.60	2.80	4.26	3.62	3.36	8.22	5.22	5.33	5.45	4.49	87.90	157.44
Mining & Quarrying - Quarry	7	0.05	0.04	0.28	0.34	0.26	0.09	0.19	0.13	0.79	2.70	10.53	8.45	2.32	1.15	1.02	4.44	32.77
Mining & Quarrying - Restored mining lands	49																11.65	11.65
Mining & Quarrying - Restored sand mining area	95											0.04	0.41	1.08	1.47	2.87	37.18	43.06
Power Generation - Disused power station	153	0.17	0.15	0.17	0.64	3.49	3.00	1.15	1.00	0.45	0.50	0.61	0.74	0.25	0.18	0.18	1.36	14.05
Power Generation - Electricity generation (power station and stockpiles)	112					0.04	0.50	0.33	0.42	0.51	0.77	1.41	1.39	1.18	1.16	1.67	41.06	50.45
Power Generation - Electricity substation	93		0.00	0.06	0.25	0.06	0.04	0.08				0.00	0.06	0.20	0.18	0.37	15.19	16.50
Power Generation - Land controlled by power station, currently unused	113	9.78	8.72	8.86	9.31	7.52	5.53	4.85	3.79	2.66	2.45	4.36	3.85	4.58	4.88	6.82	170.02	257.97
River & Drainage System - Aquaculture	34																	0.00
River & Drainage System - Constructed grass waterway for water disposal	119		0.00	0.13	0.36	0.64	0.66	0.59	0.42	0.40	0.30	0.22	0.03	0.59	0.25	0.32	1.69	6.60
River & Drainage System - Drain	79	0.43	1.51	2.08	0.85	0.43	0.21	0.06	0.04	0.02	0.00							5.62
River & Drainage System - Drainage channel	57	3.94	1.59	0.54	0.54	1.30	0.39	0.16	0.11	0.09	0.13	0.35	0.11	0.02	0.03	0.12	2.12	11.55
River & Drainage System - River or creek or other incised drainage feature	12	32.19	30.65	15.30	6.13	2.63	1.21	0.54	0.37	0.47	0.63	2.71	2.94	3.10	2.77	2.28	4.08	108.00
River & Drainage System - River or creek or other incised drainage feature	12TS	1.40	2.27	3.01	3.93	4.39	4.16	3.81	2.93	3.09	3.08	7.08	6.29	4.08	3.75	1.82	4.94	60.01
River & Drainage System - River training work	51	1.78	0.25	0.14	0.23	0.12	0.04	0.07	0.07	0.00								2.71
River & Drainage System - Water supply pressure reservoir	80																	0.00
Special Category - No identified use	97	7.43	2.57	3.25	4.24	2.53	1.82	1.35	1.33	1.44	1.37	3.28	3.98	4.66	3.42	2.91	16.30	61.88
Transport - Energy corridor	47	1.78	2.81	2.38	2.70	4.78	5.56	6.33	5.32	5.49	5.18	8.21	12.31	12.26	11.67	15.20	192.74	294.73
Transport - Marina	100	0.24	0.39															0.63
Transport - Railway	20	0.28	1.34	2.43	2.72	2.31	2.26	2.11	2.25	2.25	1.94	3.35	4.05	3.37	3.62	4.19	55.32	93.79
Transport - Road reserve	19	2.06	5.40	12.41	10.72	11.80	9.25	6.51	6.37	5.70	7.12	16.57	18.18	19.20	19.81	18.51	172.15	341.75
Tree Cover - Native forest	9	49.49	113.45	151.11	115.65	80.15	74.83	71.75	68.12	63.49	64.26	136.35	156.81	155.66	158.94	174.40	1984.66	3619.12
Tree Cover - Native woody shrub	67	19.16	71.86	63.61	34.93	22.54	18.91	22.72	18.93	14.04	14.52	36.24	19.75	15.77	24.76	25.89	102.20	525.84
Tree Cover - Recently burnt areas of woody vegetation	66																4.09	4.09
Tree Cover - Treelot	25								0.00	0.04	0.05	0.57	0.58	0.67	0.81	0.76	4.58	8.04
Tree Cover - Woodland	70	8.29	12.80	15.80	14.63	14.72	13.91	11.09	10.28	13.31	11.13	25.62	27.59	29.80	37.96	34.87	417.30	699.11
Urban - Aerodrome/Airport	36	0.99	3.06	8.67	0.57												2.20	15.49
Urban - Caravan Park, mobile home village	94	0.19	5.56	12.08	7.27	3.60	1.47	1.07	1.64	1.64	1.84	3.99	3.86	3.74	2.71	1.49	12.44	64.57
Urban - Cemetry	50			0.05	0.07	0.10	0.16	0.17	0.19	0.27	0.44	1.47	0.87	0.88	0.63	0.83	13.33	19.47
Urban - Government facility; goal, training centre, school	92	0.75	1.90	2.80	3.39	5.03	3.78	3.19	3.85	4.81	6.03	13.58	15.05	14.13	14.19	13.94	75.15	181.56
Urban - Hobby farm	151	13.09	40.05	44.81	36.22	32.97	25.82	32.98	27.58	25.98	24.97	50.48	43.72	50.16	49.88	52.56	538.23	1089.52
Urban - Hobby farm	151TM	2.23	1.21	0.42	0.29	0.29	0.30	0.45	0.28	0.29	0.39	0.74	1.03	0.87	0.92	1.07	45.79	56.59
Urban - Hobby farm	151TS									0.00	0.28	0.66	0.53	0.51	0.54	0.94	20.21	23.68
Urban - Industrial, commercial	16	0.17	1.54	13.17	15.40	8.51	11.24	10.62	9.79	8.77	7.27	19.45	28.27	21.24	25.94	24.00	274.19	479.58
Urban - Landfill	33	0.03	0.17	1.23	3.57	4.55	3.99	2.46	1.64	0.70	0.36	0.58	0.45	0.25	0.27	0.21	1.76	22.22
Urban - Residential	17	19.77	127.87	291.38	240.59	110.24	88.93	83.93	83.98	90.72	89.08	170.30	163.55	165.49	175.87	174.53	1678.26	3754.48
Urban - Rural recreation (blocks isolated and not associated with an urban area)	130																4.74	4.74
Urban - Rural residential	18	8.58	17.60	11.90	9.93	8.55	8.55	7.19	6.98	7.51	8.55	17.63	20.65	22.95	23.47	26.08	272.89	479.02
Urban - Rural residential	18TM	0.00	0.00	0.02	0.20	0.26	0.30	0.29	0.28	0.27	0.31	0.49	0.48	0.48	0.42	0.39	20.47	24.65
Urban - Rural residential	18TS	0.54	1.15	0.55	0.39	0.30	0.41	0.41	0.33	0.24	0.18	0.40	0.39	0.36	0.24	0.23	5.68	11.79
Urban - Sewage disposal ponds	29	0.11	0.38	0.60	1.06	2.09	3.39	3.48	2.15	3.11	2.44	4.58	4.96	2.35	1.81	1.52	11.21	45.25
Urban - Small to medium forested blocks with isolated residential dwellings	152	1.78	2.42	4.77	3.69	1.03	0.37	0.47	0.50	0.45	0.59	1.75	3.15	5.60	8.34	12.51	102.60	150.03
Urban - Surf club and/or coastal car parking	155		0.02	0.35	0.68	0.55	0.00	0.00	0.01	0.01	0.18	0.27	0.54	0.37	0.16	0.14	1.39	4.67
Urban - Tourist development, convention site	75	0.11	0.28	0.39	0.85	0.70	0.53	0.54	0.63	0.45	0.58	0.97	0.77	0.69	0.88	0.66	4.69	13.73
Urban - University & other institutions	77					0.00	0.02	0.16	0.22	0.19	0.30	1.49	1.41	1.29	1.06	1.07	7.01	14.21
Urban - Urban recreation	31	36.55	94.02	107.34	91.59	57.12	40.56	32.04	33.07	34.68	20.73	28.69	23.97	22.93	17.93	15.40	145.92	802.53
Water Body - Beach	64	12.49	6.46	6.78	10.11	14.46	16.41	12.33	9.88	12.24	13.12	26.77	16.30	8.25	5.30	3.50	14.84	189.25
Water Body - Coastal Lake	105	122.88	32.40	10.09	3.51	1.80	0.79	0.43	0.29	0.23	0.20	0.33	0.19	0.09	0.04	0.02	0.02	173.31
Water Body - Farm dam	8	4.97	0.30	0.53	1.29	0.22	0.17	0.05	0.82	0.09	0.12	0.00					5.47	14.06
Water Body - Sandspit, estuarine sand island	96	2.01	1.01	0.89	0.96	1.00	0.78	0.79	0.31	0.07	0.01	0.00						7.83
Wetland - Coastal marsh	56	28.84	29.14	15.56	4.37	1.48	0.86	0.78	0.84	0.80	0.50	0.68	0.65	0.53	0.08	0.01	2.69	87.82
Wetland - Dunal swamp	73						0.61	4.11	5.93	10.28	8.85	6.43	1.50	3.50	11.50	3.87	34.16	90.75
Wetland - Lagoon	76	2.59	1.12	0.34	0.03	0.02	0.01	0.00										4.11
Wetland - Mangrove	54	45.35	11.07	1.90	0.94	0.42	0.17	0.06	0.01	0.01	0.00							59.93
Wetland - Mudflat	55	29.20	36.30	7.44	0.58	0.06	0.02	0.02										73.63
Wetland - Swamp	23	84.15	79.16	20.78	6.52	2.81	2.28	2.76	1.80	0.59	0.26	3.93	0.73	0.18	0.02	0.01	0.01	205.98
Grand Total (Hectares)	Grand Total	611.29	844.26	949.54	739.50	494.22	422.05	393.39	381.81	384.11	371.32	777.33	772.75	758.27	799.34	803.21	8368.77	17871.17
Analysis represents c24% of total LGA																		

(PART) NEWCASTLE CITY COUNCIL AREAS BELOW 20M AHD																		
		Elevation (m AHD)																
NSW Landuse Mapping Program Mapping Code & Landuse Class	LUMAP Landuse Code	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Grand Total (Hectares)*
Conservation Area - Foreshore protection, vegetated dune	99					0.01	0.23	0.21	0.60	0.65	0.76	1.27	0.10					3.82
Conservation Area - Nature reserve	NR	764.36	1175.15	263.52	249.90	54.86	4.39	0.27	0.07	0.05	0.05	0.09	0.08	0.08	0.10	0.11	0.74	2513.83
Conservation Area - SCA unused land	148	0.47	0.62	1.35	1.52	1.67	1.63	1.13	0.81	0.65	0.57	1.02	0.87	0.98	1.19	1.12	15.30	30.89
Grazing - Grazing volunteer, naturalised or improved pasture	4	534.72	547.07	344.74	146.84	72.03	45.54	28.79	26.89	25.04	20.30	34.42	38.34	38.82	35.25	36.16	314.69	2289.64
Grazing - Grazing volunteer, naturalised or improved pasture	4TM	0.06	2.05	0.81	1.39	0.74	0.65	0.87	0.82	0.98	1.29	3.02	2.10	2.04	2.21	2.48	38.38	59.88
Grazing - Grazing volunteer, naturalised or improved pasture	4TS	7.19	4.46	0.54	0.31	0.23	0.20	0.20	0.20	0.18	0.18	0.39	0.44	0.54	0.74	0.92	9.18	25.91
Grazing - Irrigated pasture	6	0.04	3.32	0.00														3.36
Grazing - Secondary grassland	101											0.42	0.44	0.87	1.19	0.67	6.40	10.00
Mining & Quarrying - Mining Site	44																1.94	1.94
Mining & Quarrying - Quarry	7																1.50	1.50
Mining & Quarrying - Restored sand mining area	95							0.00	0.01	0.01	0.01	1.76	3.21	0.26	0.00			5.26
Power Generation - Electricity substation	93															0.00	3.46	3.46
River & Drainage System - Drainage channel	57	0.22	1.32	0.95	0.81	0.29	0.05											3.64
River & Drainage System - River or creek or other incised drainage feature	12	128.70	28.34	12.44	10.88	11.19	4.83	2.46	1.21	0.56	0.75	1.32	1.15	1.10	1.55	0.43	0.15	207.06
River & Drainage System - River training work	51	1.41	0.19	0.20	0.22	0.25	0.32	0.31	0.35	0.39	0.24	0.59	0.59	0.10	0.08	0.06	0.35	5.66
Transport - Railway	20	0.59	3.65	5.59	12.47	12.11	4.36	3.02	1.76	1.72	1.69	10.24	11.64	4.99	6.40	15.76	20.27	116.26
Transport - Road reserve	19	2.77	4.98	4.97	12.78	13.37	6.95	5.32	7.90	9.29	1.61	2.31	4.05	2.84	2.96	2.37	17.43	101.91
Tree Cover - Native forest	9				0.00	0.03	0.32	0.77	2.07	1.30	1.51	3.60	3.58	4.45	5.00	6.40	96.50	125.54
Tree Cover - Native woody shrub	67				0.08	0.36	1.05	1.04	1.17	1.11	1.08	2.01	0.56	0.44	0.44	0.50	0.89	10.73
Urban - Caravan Park, mobile home village	94					0.07	0.68	1.48	1.62	1.46	0.24	0.06						5.61
Urban - Cemetry	50				0.09	0.24	0.58	0.77	1.01	1.03	4.77	18.32	4.98	1.44	0.86	0.43	2.57	37.09
Urban - Defence facility	32				0.53	0.37	0.18	0.15	0.15	0.12	0.11	1.16	6.05	2.49	2.44	1.88	8.61	24.25
Urban - Government facility; goal, training centre, school	92	0.03	0.01	0.37	0.53	0.54	0.42	0.29	0.28	0.34	0.66	2.95	21.63	32.68	11.95	4.20	5.13	82.03
Urban - Industrial, commercial	16	20.99	47.12	83.43	164.34	233.62	242.56	230.37	199.48	127.45	82.27	130.99	108.36	126.03	99.01	73.47	174.60	2144.09
Urban - Landfill	33	0.55	4.11	7.90	7.98	7.66	5.70	2.87	1.45	1.78	2.21	4.49	4.20	3.84	10.51	11.97	27.65	104.86
Urban - Residential	17	1.72	4.92	48.73	60.80	43.86	45.11	42.40	55.05	89.94	130.44	333.47	270.92	144.84	122.44	124.16	1176.71	2695.50
Urban - Residential	17TS																2.55	2.55
Urban - Rural residential	18	0.03	0.22	0.40	0.30	0.31	0.47	0.42	0.49	0.53	0.59	1.42	1.81	2.53	3.11	4.32	59.60	76.55
Urban - Sewage disposal ponds	29	0.29	1.59	1.71	1.06	0.69	1.21	1.77	0.79	0.84	0.55	1.75	0.75	0.45	0.82	2.30	11.61	28.18
Urban - Tourist development, convention site	75	0.34	0.04	0.04	0.04	0.02	0.02	0.02	0.38	0.10	0.04	0.07	0.05	0.04	0.04	0.04	1.52	2.78
Urban - University & other institutions	77					1.12	0.84	0.48	0.53	0.44	0.40	0.76	0.78	0.90	1.06	1.20	24.60	33.11
Urban - Urban recreation	31	4.89	2.02	12.09	31.14	39.03	27.17	14.80	15.20	14.32	20.31	74.30	77.13	47.15	44.64	23.14	128.64	575.98
Water Body - Beach	64	9.72	2.94	3.51	4.91	5.46	6.45	5.14	4.07	4.26	4.17	8.51	4.80	3.13	2.52	1.73	3.52	74.84
Wetland - Floodplain swamp	74			0.12	0.38	0.23	0.16	0.10	0.08	0.05	0.05	0.10	0.09	0.13	0.22	0.28	0.22	2.20
Wetland - Floodplain swamp, backswamp	21	354.54	170.52	84.51	104.13	12.17	0.27	0.06	0.04	0.03	0.02	0.03	0.02	0.02	0.01	0.00		726.37
Wetland - Mangrove	54	28.96	270.97	16.68	3.32	1.21	0.73	0.74	0.41	0.17	0.13	0.53	0.69	0.58	0.24	0.18	0.71	326.23
Wetland - Mudflat	55	75.15	183.71	25.53	5.21	1.82	0.94	1.44	1.00	0.56	0.03	0.03						295.42
Wetland - Swamp	23	21.29	33.11	30.98	30.39	21.37	15.91	10.20	5.87	3.97	3.22	6.37	3.96	3.47	3.29	2.61	10.75	206.76
Grand Total (Hectares)		1959.05	2492.42	951.12	852.34	536.94	419.92	357.88	331.77	289.31	280.26	647.74	573.37	427.26	360.25	318.91	2166.17	12964.71

Analysis represents 61% of total LGA

(PART) PORT STEPHENS COUNCIL AREAS BELOW 20M AHD																		
		Elevation (m AHD)																
NSW Landuse Mapping Program Mapping Code & Landuse Class	LUMAP Landuse Code	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	3 - 3.5	3.5 - 4	4 - 4.5	4.5 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 20	*Grand Total (Hectares)*
Conservation Area - Nature reserve	NR	303.48	526.91	40.69	13.87	4.26	6.66	2.43	1.16	0.62	0.61	0.81	0.61	0.53	112.24	4.83	0.29	1019.99
Conservation Area - State Forest	SF															0.61	59.53	60.14
Grazing - Grazing improved perrenial pasture	5	58.17	94.10	18.78	4.86	3.59	1.49	0.48	0.64	0.75	0.60	1.34	0.92	0.76	0.64	0.37	0.02	187.51
Grazing - Grazing volunteer, naturalised or improved pasture	4	869.24	1118.41	536.75	208.97	172.84	139.98	92.06	54.54	38.27	27.61	36.12	61.90	45.96	41.42	30.34	117.77	3592.18
Grazing - Grazing volunteer, naturalised or improved pasture	4R												0.01	0.29	1.01	1.45	1.64	4.40
Grazing - Grazing volunteer, naturalised or improved pasture	4TM			0.01	0.20	0.99	0.86	0.46	0.49	0.35	0.30	0.54	0.40	0.33	0.33	0.50	4.33	10.08
Grazing - Grazing volunteer, naturalised or improved pasture	4TS	6.57	11.61	6.94	5.96	9.10	10.70	12.81	6.98	6.86	5.67	6.61	7.43	4.00	5.16	7.74	35.02	149.17
Grazing - Irrigate pasture	6	0.36	1.96	2.85	0.39	0.18	0.22	0.85	1.35	2.46	1.92	1.16	0.01					13.71
Horticulture - Orchard	2											0.02	0.79	2.43	1.96	1.06	18.73	24.99
Horticulture - Vegetables	39	0.14	1.37	1.70	0.15	0.10											0.29	3.76
Intensive Animal Production - Poultry	26c						0.00	0.28	1.08	0.95	1.09	1.11	0.53	0.52	3.61	3.96	4.48	17.62
Mining & Quarrying - Derelict mining land	43		0.04	0.29	0.66	0.40	0.58	0.97	0.42	0.19	0.22	0.52	0.67	5.26	14.17	18.10	1.15	43.62
Mining & Quarrying - Mining Site	44	0.25	3.66	2.31	10.36	37.32	32.07	19.87	12.03	8.85	7.09	12.80	9.12	7.15	7.18	7.42	37.68	215.18
Mining & Quarrying - Restored sand mining area	95			0.53	2.76	1.52	3.99	3.70	3.77	3.39	3.53	9.88	11.45	15.97	14.38	27.00	64.56	166.44
River & Drainage System - Drainage channel	57	1.14	0.38	0.07	0.00													1.59
River & Drainage System - Flood or irrigation structure	71								0.08	0.10	0.18	0.43	0.33	0.29	0.29	0.74	2.08	4.52
River & Drainage System - River or creek or other incised drainage feature	12	10.72	10.75	4.94	1.71	0.74	0.37	0.06	0.01	0.00								29.28
Transport - Road reserve	19	1.34	6.18	17.18	22.04	28.38	30.32	26.81	18.46	12.52	8.98	15.20	14.57	20.00	14.82	17.14	57.03	310.98
Tree Cover - Native forest	9	0.02	4.02	37.29	59.15	73.30	82.86	109.92	88.48	62.85	52.75	103.44	279.33	155.66	127.19	108.14	348.71	1693.11
Tree Cover - Softwood plantation	14		0.02	3.09	3.49	30.85	20.37	7.05	3.34	2.80	2.36	3.66	2.79	1.01	0.00			80.85
Tree Cover - Woodland	70						0.54	3.12	4.12	4.76	7.46	14.66	57.25	50.84	10.50	2.19	1.53	156.95
Urban - Aerodrome/Airport	36					0.01	0.40	0.34	1.38	2.88	2.44	0.34						7.79
Urban - Caravan Park, mobile home village	94		0.06	1.22	4.99	1.83	3.06	1.33	1.32	1.22	0.32	0.12	0.10	1.95	0.10	0.10	1.29	19.03
Urban - Cemetry	50												0.01	0.11	0.83	0.92	0.60	2.47
Urban - Defence facility	32			0.00	0.35	6.74	8.95	20.53	26.29	46.51	50.85	96.86	98.02	135.82	49.43	1.54	0.45	542.34
Urban - Government facility; goal, training centre, school	92	0.02	0.06	1.19	1.35	1.60	0.92	0.61	1.03	1.71	1.47	2.57	9.70	5.96	1.90	1.76	2.89	34.73
Urban - Industrial commercial	16	2.21	2.24	2.37	6.01	10.49	12.29	15.69	18.77	23.09	17.14	42.10	71.65	96.98	31.20	34.14	23.14	409.50
Urban - Residential	17	0.07	0.68	5.82	12.76	11.79	8.59	7.37	8.36	7.88	9.37	40.37	60.75	62.11	58.93	34.48	193.50	522.83
Urban - Rural residential	18	6.68	99.60	126.35	72.15	48.80	41.67	36.30	35.52	24.55	14.12	15.00	78.45	69.22	77.80	72.96	654.07	1473.24
Urban - Rural residential	18TS													0.12	2.35	1.79	12.16	16.42
Urban - Sewage disposal ponds	29		0.00	0.00	0.00	0.10	2.52	1.20	0.61	0.67	1.32	1.48	0.53					8.43
Urban - Tourist development, convention site	75	0.57	0.86	0.38	0.89	0.44	0.73	1.03	0.34	0.24	0.15	0.28	0.24	0.26	0.52	0.59	4.28	11.81
Urban - Urban recreation	31	0.08	5.64	19.41	14.15	21.83	17.70	9.46	6.93	8.67	9.13	14.44	19.32	20.71	8.39	6.99	25.94	208.78
Water Body - Beach	64	10.47	3.31	4.19	21.24	40.94	49.81	43.30	37.09	33.70	27.42	45.72	31.21	23.84	21.02	17.88	197.87	609.02
Water Body - Foreshore or reserved land to water supply dam	59	20.35	83.41	132.59	127.87	230.58	302.13	411.49	374.73	303.88	285.41	587.19	666.95	811.84	729.39	451.51	914.81	6434.14
Water Body - Reservoir	46											0.24	0.80	2.43	2.24	0.79	114.29	120.79
Water Body - Water supply pressure reservoir	80							0.01	1.59	2.98	2.26	4.57	2.46	2.43	2.13	3.21	10.17	31.81
Wetland - Coastal marsh	56	0.21	46.03	27.37	16.86	10.52	2.94	0.91	0.58	0.16	0.03	0.01						105.62
Wetland - Floodplain wetland, backswamp	21	12.49	1.02	1.45	1.79	0.77	0.73	0.74	0.44	0.46	0.29	0.24	0.16	0.13	0.05	0.00		20.76
Wetland - Mangrove	54	10.73	64.69	7.68	2.28	0.44	0.11	0.01				0.00						85.94
Wetland - Mudflat	55	0.25	22.38	1.35	0.06	0.00												24.03
Wetland - Swamp	23													0.00	40.09	2.34	1.11	43.55
Grand Total (Hectares)		1315.55	2109.41	1004.78	617.32	750.44	783.58	831.20	711.94	604.32	542.10	1059.83	1488.45	1544.92	1381.27	862.58	2911.42	18519.10
Analysis represents 19% of total LGA																		

Appendix F: Planning Response to Climate Change in Coastal Areas: Other Australian States and New Zealand

Summary of sea level rise scenario used, shoreline setbacks required for land use planning and planning timeframes

State	SLR value	Setbacks	Timeframe
Victoria	No specific value – risk assessment of climate change impacts required	encouraged	100yrs
Queensland	0.3m over 50 years	Coastal building line required	50yrs
South Australia	0.3m to the year 2050 Development which could not reasonably be protected against sea level rise beyond 0.3m should be set back far enough to be safe for a 1m rise by 2100.	encouraged	2100
Western Australia	The setback is based on the mean of the median of IPCC (2001) - 0.38m. A multiplier of 100, based on the Bruun rule shall be used and gives a value of 38m horizontal setback for sandy shores. For other shore types, horizontal setback shall be assessed in regard to local geography.	required	2100
Tasmania	Nothing specific, although have a detailed vulnerability assessment for entire coast & are undertaking a climate change coastal risk assessment and management project.		
Northern Territory	Nothing specific, but are committed to developing plans for climate change adaptation.		

VICTORIA

The State Planning Policy Framework states that development should not occur where erosion is likely. Local planning schemes typically have generic statements stating that building is not to occur on land that is liable to erosion.

The Victorian Coastal Strategy (Victorian Coastal Council, 2002) http://www.vcc.vic.gov.au/strategy/ discusses the need for risk assessment with respect to the impacts of climate change, but does not provide detailed and specific guidance.

The Siting and Design Guidelines for Structures on the Victorian Coast (Victorian Coastal Council, 1998) http://www.vcc.vic.gov.au/siting/index.htm states that structures should be located as far back as practicable from the shoreline. Where a structure does not require a location on the water's edge, it should be set back to reduce the threat posed by coastal recession and wave attack.

QUEENSLAND

The EPA has designated 'coastal building lines' as a tool to regulate building work in areas prone to erosion in a coastal management district. Coastal building lines are declared under the *Coastal Protection and Management Act 1995* (Coastal Act) and are fixed by regulation or notice.
http://www.epa.qld.gov.au/ecoaccess/coastal_development/assessment_of_development_on_coastal_land/buildings_seaward_of_a_coastal_building_line/coastal_building_lines/

The coastal building line assists in maintaining a development-free buffer zone where coastal processes can occur naturally without the need for property protection works that can be costly and detrimental to sound coastal management outcomes.

The EPA has designated 'erosion prone areas' as the width of the coast that is considered to be vulnerable to coastal erosion and tidal inundation over a 50-year planning period. Where no regional coastal management plan has been prepared, an area within a designated Erosion Prone Area is taken to be a coastal management district under Section 168 of the Coastal Act.
http://www.epa.qld.gov.au/ecoaccess/coastal_development/assessment_of_development_on_coastal_land/erosion_prone_areas/

Calculation of the erosion prone area is based on:

- a short-term erosion component from extreme storm events;
- a long-term erosion component where gradual erosion is occurring;
- a shoreline recession component due to sea level rise associated with climate change; and
- a dune scarp component, where slumping of the scarp face occurs following erosion.

The estimated sea level rise is based on the best information currently available, and the current value adopted for use in erosion-prone area determination over a 50-year planning period is 0.3m.

SOUTH AUSTRALIA

The Coast Protection Board is the primary authority that manages coast and marine protection issues. Amongst other roles it provides advice on development application referrals, for development on 'coastal lands'.

The Coastal Protection Board Policy (30 August 2002) states that the Coast Protection Board accepts that mean global sea level has been rising over recent decades at approximately 1.5mm per year. http://www.environment.sa.gov.au/coasts/board.html

The Board uses the IPCC median sea level predictions as part of its hazard policy. The Policy also notes that the IPCC emphasises increased magnitude and frequency of extreme events, including storm surge.

State and local governments have endorsed the Board's standards and policy.

The Board is recommending an allowance of 0.3m for sea level rise to the year 2050, which replaces the 0.15m figure applied in South Australia since the early 1980s.

Development which could not reasonably be protected against sea level rise beyond 0.3m should be set back far enough to be safe for a 1m rise by 2100.

On the open coast consideration needs to be given to sea level rise, land subsidence, storm surge (storm tides), wave effects (run up and set up), erosion, recession or accretion.

WESTERN AUSTRALIA

The Western Australian Planning Commission is a statutory authority that undertakes a co-ordinating role across all aspects of Western Australia's planning processes.

Requirements for set-back distances are included in the State Coastal Planning Policy No 2.6 (gazetted 10 June 2003), which addresses land use planning and development issues specifically related to the protection and management of the coast.
http://www.wapc.wa.gov.au/Publications/139.aspx

Schedule 1, Section D of the Policy – 'Factors to be considered in calculating coastal processes setback' requires a range of factors to be considered when calculating a setback to protect development from physical processes on the coast. These factors are extreme storm sequence, chronic erosion or accretion and sea level change. The values for each factor are added to each other to determine total setback distance.

The setback to allow for sea level change is based on the mean of the median IPCC projection (2001). The vertical change of sea level between 2000 and 2100 is 0.38m. A multiplier of 100, based on the Bruun rule is used and gives a value for of 38m horizontal setback for sandy shores. For other shore types, setback is to be assessed with regard to local geography.

TASMANIA

The Department of Primary Industries and Water is undertaking a project – 'Climate Change and Coastal Risk Assessment and Management' aimed at producing a range of tools to assist with the development and implementation of adaptation and mitigation strategies.
http://www.dpiw.tas.gov.au/inter.nsf/ThemeNodes/MCLE-5WV6FF?open

This project aims to provide a strategic context and foundation for site-specific work by local planning authorities and private enterprise. Detailed asset management planning requires site-by-site analysis, and the outputs of this project will provide each local planning authority with the information and tools needed to commence their own analyses.

Project outputs are expected to include a range of planning and management resources, e.g. information sheets, plans and tools for use by various coastal zone managers. Additionally, the project aims to develop risk management plans for specific assets. These case studies will demonstrate the application of a risk management approach to the protection and management of coastal assets and values in Tasmania.

NORTHERN TERRITORY

Mangroves border 42% of the Northern Territory coastline – therefore attention is being directed at the implications of sea level rise and other climate change implications.