IDENTIFYING SEDIMENT COMPARTMENT DYNAMICS ON THE ILLAWARRA COAST

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Abstract

This project aims to produce a framework for assessing compartment dynamics within two sediment compartments in the Illawarra region to assist in assessing coastal hazards. Sediment sources, pathways and sinks will be examined for the Wollongong and Illawarra Coast – South compartments, defined by Geoscience Australia and CoastAdapt. A compartment based approach allows for more holistic coastal planning and management which considers sediment transport at differing scales, and interconnectivity of beaches. This type of approach underpins national guidance on open coast risk assessment and has been incorporated within the NSW Coastal Reforms and the Draft Coastal Management Manual.

The adjacent sectors of the Wollongong Coast and Illawarra Coast-South compartments extend for approximately 30 km from Bellambi Point to Bass Point. The rock platform of Red Point marks the shoreline division between these two contrasting compartments. The Wollongong Coast is an urbanized relatively little studied leaky compartment, whereas the Illawarra Coast-South is a well-defined and confined compartment whose main sedimentary characteristics are represented by the infilling of the Lake Illawarra barrier estuary and the erosion-prone Warilla Beach.

This detailed examination of sediment resources brings together the state-wide coastal seabed mapping program being undertaken by the NSW Office of Environment and Heritage (OEH), and coastal geomorphological investigations being undertaken along the southern NSW coast by the University of Wollongong (UOW). These initiatives involve collation of historical data, sediment sampling, and the use of recently available sophisticated remote sensing technologies, such as terrestrial airborne LiDAR, single and multibeam bathymetry, sidescan sonar imagery, and underwater video and still camera.

Introduction

This project aims to produce a framework for assessing compartment dynamics within two sediment compartments in the Illawarra region to assist in assessing potential coastal hazard exposure and impacts. Herein, we present the initial

investigations undertaken by UOW and OEH, as well as the preliminary results for the examination of sediment resources along the Wollongong and Illawarra Coast – South secondary sediment compartments, as defined by Geoscience Australia (McPherson et al., 2015) and CoastAdapt (Eliot, 2016).

Compartments are natural subdivisions of the coastal zone that are useful for management and planning, and are separated by major obstacles to sediment transport, such as headlands (Chapman et al., 1982). Compartments identify coastal sectors within which to consider beach dynamics and the implications of engineering works and management strategies, especially at the state and local government levels, to reduce risks and protect coastal assets and values. A compartment-based approach allows for more holistic coastal planning and management which considers sediment transport across the relevant range of spatial and temporal scales, and interconnectivity of beaches.

The concept of coastal compartments was introduced in Australia by Davies (1974), and more recently has been promoted as a framework to underpin coastal and marine planning and management initially, in western Australia (e.g. Eliot *et al.,* 2011, Eliot *et al.,* 2013) and then nationally (Eliot 2016, Thom 2015). The national initiative was adopted on the advice of the former Coasts and Climate Change Council, managed by Geoscience Australia (Thom, 2015, McPherson et al., 2015), and subsequently incorporated as part of the Shoreline Explorer tool within CoastAdapt (https://coastadapt.com.au/, Eliot, 2016). Within NSW the coastal compartment approach underpins guidance on open coast risk assessment and has been incorporated within the NSW Coastal Management Act (2016) and the Draft Coastal Management Manual (OEH 2016).

The NSW Coastal Reforms represent new legislative and regulatory frameworks to better equip coastal communities to respond to existing and emerging challenges and opportunities. The new legislation, the Coastal Management Act 2016 (the Act), requires councils to consult with other councils that may occur within the same sediment compartment before adopting a coastal management program. The compartment boundaries listed in Schedule 1 of the Act were sourced from McPherson et al. (2015), which defines 47 coastal sediment compartments along the coast of NSW. Two of those are investigated here.

The adjacent sectors of the Wollongong Coast and Illawarra Coast-South compartments extend for approximately 30 km from Bellambi Point to Bass Point (Figure 1). The rock platform of Red Point marks the shoreline division between these two contrasting compartments.

The Wollongong Coast is an urbanized relatively little-studied compartment, composed of five sand deposits separated by headlands and the breakwaters of Port Kembla. Fishermans Beach and MM Beach (named after Metal Manufacturers, and also called North Port Kembla Beach) are small embayments (<1 km long) located south of the rocks that form the southern side of Port

Kembla. Fishermans Beach is a reflective beach protected by Red Point, Big Island and the rock platform that separates it from MM Beach to the north, which is more exposed to waves and usually has an attached bar and no rips (Short, 1993). The sand deposit known as Wollongong (City) Beach, has been heavily modified after the construction of Port Kembla to the south, and more recently its northern end near Flagstaff Hill has been reshaped by Wollongong City Council. Nowadays this beach extends for less than 3 km and is exposed to high waves which produce several rips along its length. Limited studies on sediments at Wollongong (City) Beach were conducted by Bryant (1984), who reported that, in 1981, the medium sand size material gets coarser towards the northern end of the beach, and that sediments consisted of rounded iron-stained quartz with less than 40 % of shell carbonate.

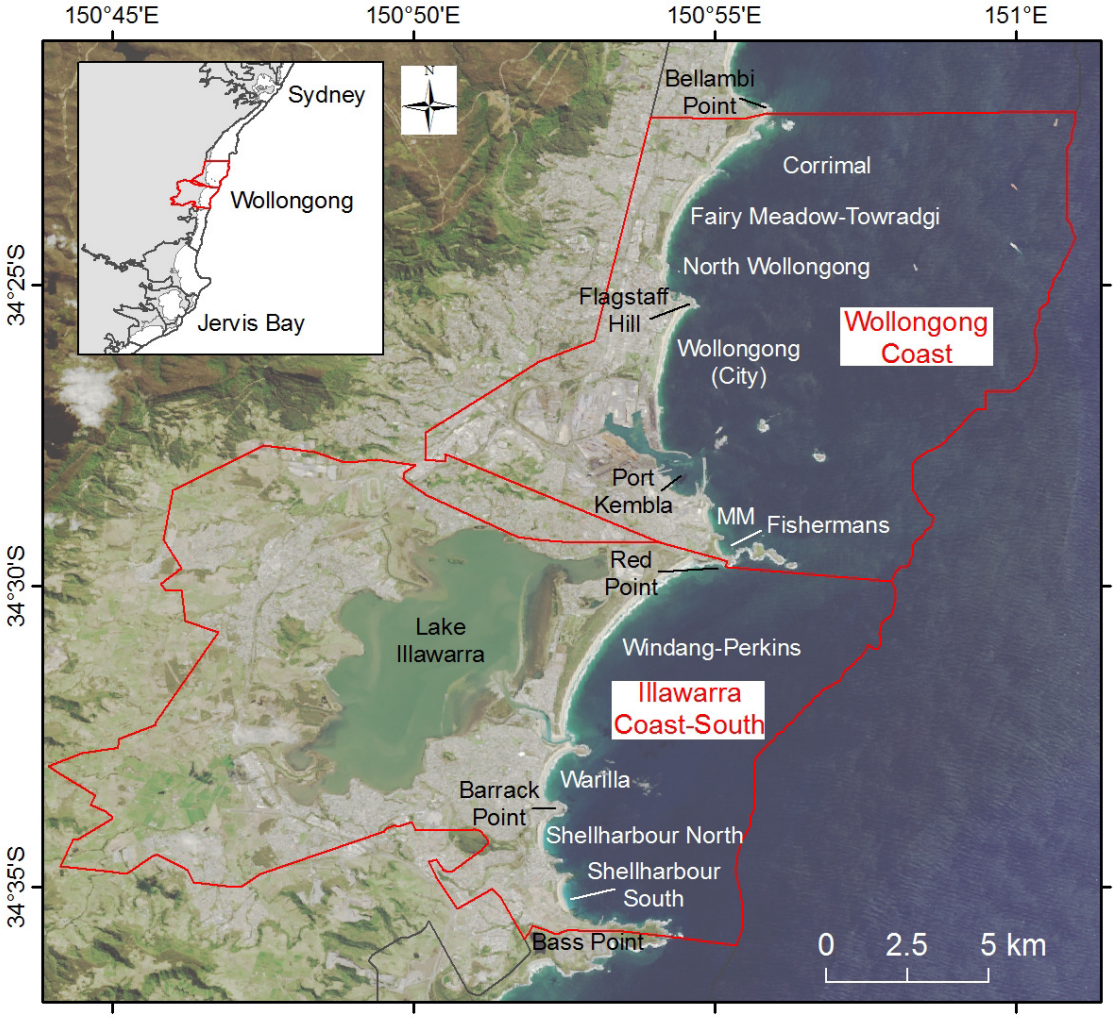

Fig. 1: Wollongong Coast and Illawarra Coast-South compartments as defined by Geoscience Australia (McPherson et al. 2015)

The next sand deposit to the north is approximately 3.5 km in length and is formed of the North Wollongong and Fairy Meadow-Towradgi Beaches. North

Wollongong is an east-facing beach partially protected by Flagstaff Hill from southeasterly waves. This beach fluctuates between transverse bar and rip, and low tide terrace types. Low rocks at the mouth of Fairy Creek separate North Wollongong Beach from Fairy Meadow-Towradgi Beach. The latter beach is of transverse bar and rip type, and can transition into rhythmic bar and beach type as the energy increases (Short, 1993). The middle and northern end of Fairy Meadow-Towradgi Beach have been reshaped recently in order to improve the line of sight from the lifeguard observation tower (WCC, 2017). The northern-most sand deposit of this compartment is 2.3 km long and formed by Corrimal Beach and the narrow strip of sand that runs until Bellambi Point. Transverse bar and rip type characterises Corrimal Beach, but with increasing energy a trough often separates the bar from the beach (Short, 1993). Reshaping of the dunes on the southern part of the beach occurred in 2016 (WCC, 2017).

The Illawarra Coast-South is a well-defined and confined compartment bound by Red Point and Bass Point (Figure 1). The main sedimentary characteristics are represented by the infilling of the Lake Illawarra barrier estuary and the erosion-prone Warilla Beach. This compartment is composed of four main sand deposits. Shellharbour South is a 1km long low tide terrace type of beach, mostly protected by Bass Point from southerly and southeasterly waves. A new marina with two groynes is currently under construction there. Shellharbour North beach has the same length as the south beach, however, it is more exposed to waves especially on the transverse bar and rip type northern end near Barrack Point (Short, 1993). The 2 km long transverse bar and rip type Warilla beach, to the north of Barrack Point, was heavily eroded during the 1970s storms, which resulted in the construction of an 850 m long rock wall along its southern end. A rhythmic longshore bar detached from the beach is often observed towards the middle-north end of this beach. A comprehensive analysis of morphodynamic changes at Warilla Beach over 10 years (1975-1985) was conducted by Clarke and Eliot (1988) who found that the greatest variation in volume stored occurred on the northern half of the beach.

North of Warilla Beach lies the entrance to Lake Illawarra, a barrier estuary at an intermediate stage of evolution (Roy et al. 2001). The southern wall was constructed in 2001 and the lake entrance was completely trained in 2007 to improve tidal flushing and to ensure that the entrance remained permanently open. Lake Illawarra is the largest estuary within the two compartments and as such, tends to act as a sink of both fluvial and marine sediments.

The 6.6 km long Windang-Perkins sand deposit north of Lake Illawarra entrance faces southeast with high waves producing a double bar system with the inner bar usually detached from the beach and cut by up to 30 rips along its length (Short, 1993).

Sand deposit extraction

The history of beach/dune sand exploitation in the Illawarra region is associated with the growth of Wollongong. Although the first occupation of the region dates back to the early 19th century, only after World War II, with the development of heavy industry, were huge quantities of sand needed as fill and construction material, and a large-scale sand extraction scheme started (Reffell, 1980). Approximately three million tonnes of sand was carted from the sand leases on the north of Windang Peninsula (Perkins-Windang Beach) over the period from 1948-1955. By the early 1950s, the once high dunes of north Windang had undergone significant depletion and between 1961 and 1966, an extra 1.8 to 2 million tonnes of sand was extracted from the north of Windang Peninsula (Reffell, 1980).

Sand extraction was not restricted to the Windang Peninsula. The first official sediment extraction at Corrimal Beach removed in the order of 10 thousand tonnes of material from the relatively small size barrier. The barrier of Fairy Meadow-Towradgi Beach was also subject to relatively large-scale extraction in the 1950s, with recorded evidence of both legal and illegal sand extraction, whereas Warilla Beach was connected with illegal sand extraction (Reffell, 1980).

Previous offshore studies

A bathymetric, seismic and magnetic survey was carried out off Wollongong, between Flagstaff Hill and Port Kembla, in 1972, by Lean and Peat (1972). In the surveyed area, water depths increase eastwards to a maximum of 30 m, with a trough formed west of Flinders Island (Figure 2). This hydrographic information indicated that rocky bottom covers more than 50 % of the nearshore studied area, mainly in the north and the southeastern corner, forming at least three distinct rock reefs.

Sediment thickness varies from 0 to approximately 14 m and most of the unconsolidated sediment is located close to the shore at the southern end of Coniston Beach, whereas the thickness decreases considerably in the nearshore towards the north. Most of the sediment deposited appears to have been filled in the old drainage channel of the estuary where Port Kembla sits nowadays. Four separate zones of distinct sediment type were observed: a clean medium to fine grained quartzose sand zone extending to 500 m offshore from the beach, and two muddy gravelly extremely poorly sorted grit zones offshore with rock and shell fragments, separated by a zone of muddy sand which coincides with parts of the bottom that are barren of rock outcrops.

Lean and Peat (1972) also identified a distinct difference in the character of the magnetic field on either side of a line between the northern breakwater and Flinders Island. This was interpreted as very likely to be the boundary between

the Dapto Latite Member (to the south) and the Budgong Sandstone (to the north).

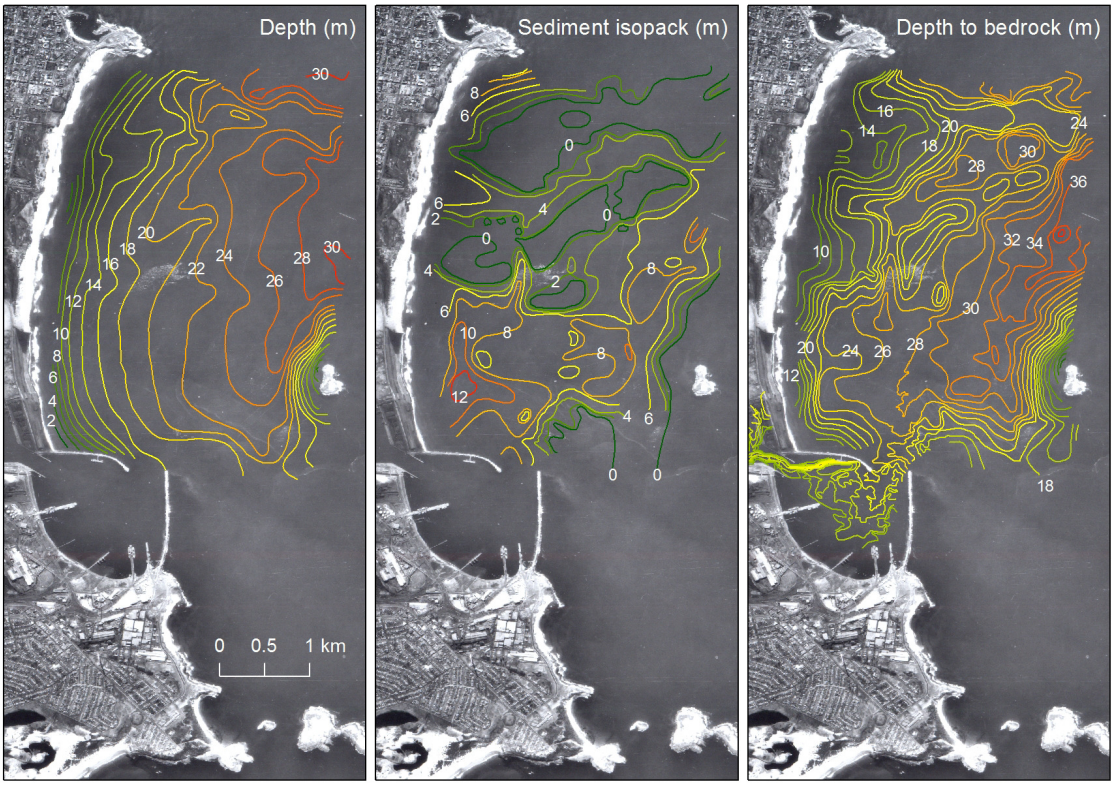

Fig. 2: Bathymetry, Sediment isopack and depth to bedrock after Lean and Peat (1972). Background image taken in 1972

Methods

The examination of sediment resources in the Illawarra region brings together the state-wide coastal seabed mapping program being undertaken by OEH, and coastal geomorphological investigations along the south coast by UOW. These initiatives involve collation of historical data including aerial imagery, sediment sampling, and the use of recently available sophisticated remote sensing technologies, such as terrestrial airborne LiDAR, single and multibeam bathymetry, sidescan sonar imagery and underwater video and still camera.

Historical aerial imagery provided by NSW Land and Property Information (LPI) was used in the identification of depositional sites and changes experienced on the coastline over time (Abuodha, 2009), as well as GIS analysis of photogrammetric surveys of beaches undertaken by OEH. Figure 3 shows the 1951 and 2008 aerial photographs of Red Point, the terrestrial boundary between the two studied compartments, and the extensive dune fields that once existed to the north of Windang Beach during sand mining and prior to urban development and revegetation of the sand dunes in late 1970s.

Multibeam bathymetry and backscatter data was collected by OEH over an area of 103 km^2 in 2016-2017 (Figure 4), covering most of the offshore area of the Wollongong Coast compartment between 15 and 50 m water depths. Sidescan sonar and singlebeam bathymetry data were collected by UOW in 2017 to fill in 11 km^2 of the nearshore between the multibeam surveyed area and the beach.

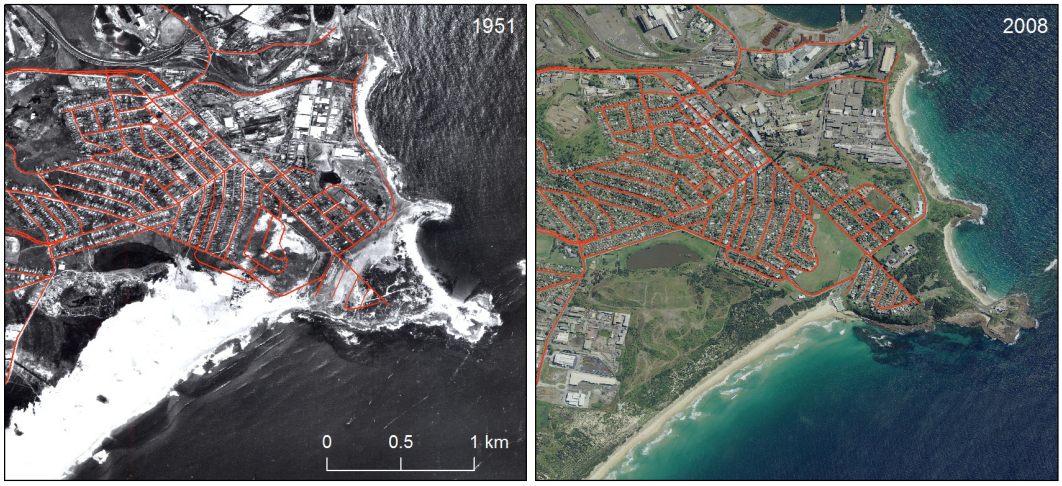

Fig. 3: Aerial photographs taken in 1951 and 2008 over the terrestrial boundary between the Wollongong Coast and Illawarra Coast-South compartments. Note the massive dune fields that existed in the 1951 image before/during extraction from the sand leases, and prior to urban development and dune stabilisation works

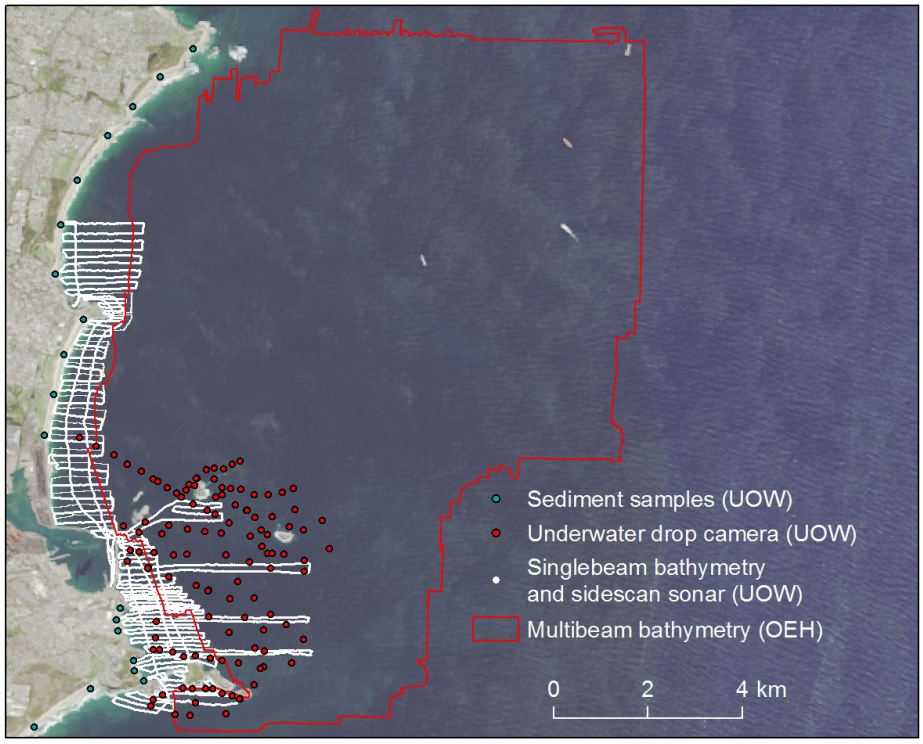

Fig. 4: Survey techniques undertaken by UOW and OEH for the examination of sediment resources along the Wollongong Coast Compartment

Underwater video camera deployments were made at 123 sites off Wollongong around the Five Islands in February and October 2017. Surficial sediment samples were collected in the swash zone of all major beach deposits of both studied compartments in October 2017. A minimum of three samples covering both ends and the middle of each beach was collected. Volumetric analyses of beach changes using airborne terrestrial LiDAR and existing RTK-GPS survey are being carried out at most beaches of both compartments.

Preliminary results and discussion

The Illawarra Coast-South is a well-defined and confined compartment with four pocket beaches and no sediment input from the south due to the prominence of the Bass Point headland. Given the prominence of Bass Point, it seems unlikely that wave processes can drive sand transport from Shellharbour South Beach, bypassing the rock platforms and reef flanking the village harbour and act as a source for Shellharbour North Beach. It is also unlikely that sand can bypass from Shellharbour North Beach to Warilla Beach due to the 600 m extension of the subaerial part of Barrack Point, despite the energy increase experienced by the northern part of the beach compared to Shellharbour South Beach.

Warilla Beach, on the other hand, has had a more complex history of sand volumes. Sand deposits are visible on the aerial photographs along the banks of Little Lake at the southern end of the beach, indicating probable influx of sand into this estuary from the nearshore. Following storms in the 1960s it became necessary to build a seawall along the southern half of the beach to protect houses constructed on the foredune. To the north, a loss of sand into the Lake Illawarra entrance was a major factor in the past, when a tombolo connected Windang Island intermittently to either Warilla or Perkins Beach, acting as a trapdoor for sand lost from Warilla Beach into the estuary (AWACS, 1991). During construction of the training walls in 2001 and 2007, approximately 300,000m^3 of sand was pumped onto Warlla Beach, largely burying the seawall (subsequently much of which became re-exposed in the June 2016 storm), and significantly changing beach morphology. Lake Illawarra appears to act as a sink for nearshore sediments, initially off Windang or Perkins Beach. Since emplacement of the training walls, the 3 km long entrance channel has continued to scour, and sands are being deposited in the flood-tide delta (Couriel et al., 2013).

A loss of nearshore sand out of the Illawarra Coast-South compartment bypassing Red Point may occur and will be the subject of further investigation. The shoreface area off Windang Peninsula appears devoid of rock reefs and a substantial amount of sand is still available there for beach supply. This will be confirmed by multibeam seabed mapping currently underway. Besides the surf club in the south, Windang-Perkins Beach has no infrastructure apart from the Port Kembla Pool Complex at the northern end. The historical evidence of massive dune systems that once existed in the area, together with the

predominantly northwards drift direction, suggest that sediments tend to be stored on the northern end of this compartment.

The Wollongong Coast compartment is composed of five sand deposits separated by headlands and the breakwaters of Port Kembla. Fishermans and MM Beaches are moderate-highly protected from wave action by Red Point and the Five Islands, and therefore, northwards drift of sediments from these two beaches appears unlikely. The offshore area around the Five Islands (Port Kembla south breakwater to Red Point) is formed by several rock reefs (Figure 5) and therefore not much unconsolidated sediment is available. Further north, Peat and Lean (1972) indicated the existence of a sand deposit bordered to north and south by extensive reef, which was also observed in the underwater video camera deployments (Figure 6). Despite the occurrence of unconsolidated substrate in the area, most of the nearshore is composed of rock reefs and therefore it appears that limited sand is available to support beach and shoreline stability.

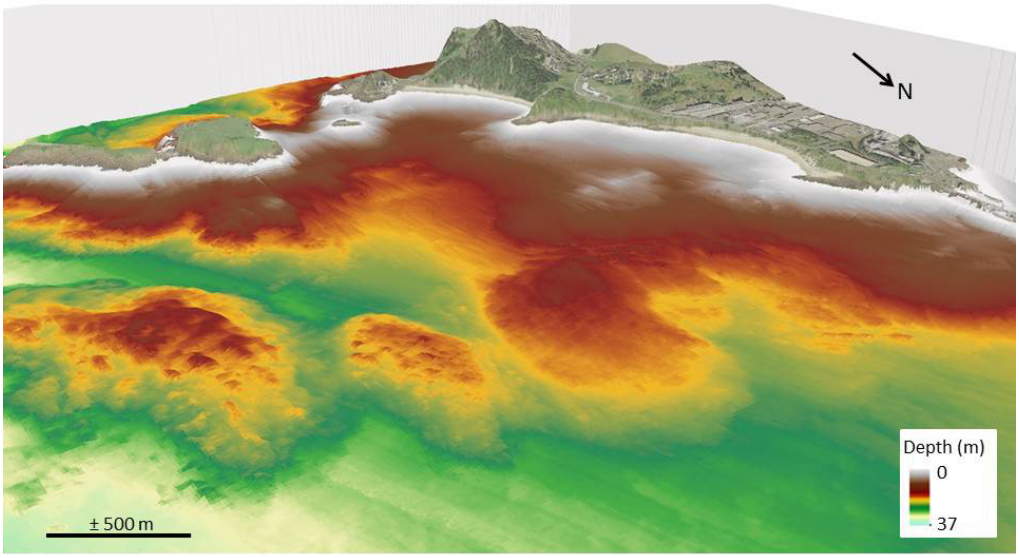

Fig. 5: Oblique view of 3D representation of the offshore area adjacent to Fishermans and MM Beaches, south of Port Kembla using the singlebeam, multibeam and airborne LiDAR collected by UOW, OEH and LPI, respectively

The relatively short extension of the rock platforms, and the orientation of the Wollongong (City), Fairy Meadow and Corrimal beaches with respect to the predominant swell direction suggests that some bypass of sediment via longshore drift occurs to the north towards Bellambi Point. However, a clearer assessment will be possible once the seabed mapping and sediment analyses have been completed.

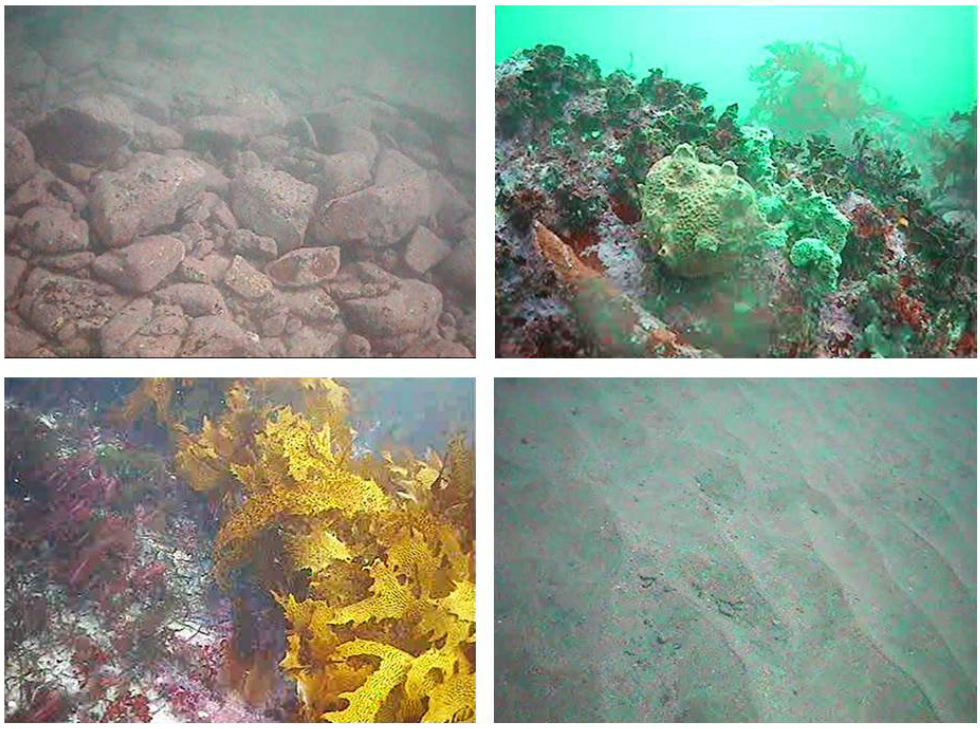

Fig. 6: Underwater drop camera showing different habitats at Five Islands. Bare rocky substrate (top left), rocky reef colonized by a variety of different sponge and macroalgae types (top right), rocky reef colonized by Kelp and other macroalgae (bottom left), and unconsolidated sandy substrate (bottom right).

Ongoing and future investigations

The preliminary results presented in the previous sections comprise part of an ongoing research program. More data collection and laboratory analyses are being carried out in order to better understand the sediment budgets and to implement the compartment-based framework to assist in assessing coastal hazards. Ongoing analyses include: i) completion of the seabed mapping and sediment sampling within these compartments; ii) grain size and mineralogy of beach and offshore sediments (Figure 7); iii) beach volumetric change using LiDAR and available RTK-GPS surveys; and iv) marine habitat mapping within the compartments, particularly around the Five Islands.

Fig. 7: Surficial beach sediment samples collected in the Illawarra Coast-South Compartment to be analysed for grain size and mineralogy

Conclusion

This paper aimed to outline a framework for assessing sediment dynamics within the adjacent Wollongong Coast and Illawarra Coast-South sectors, a 30-km stretch of the NSW coast between Bellambi Point (north) and Bass Point (south), marked by two contrasting compartments. The objective of the project is to develop an improved understanding of the sediment budgets within these compartments and to apply a sediment compartments approach to assessing the risk of coastal erosion and shoreline change.

The Wollongong Coast is an urbanized, leaky and apparently sediment deficient compartment composed of five sand deposits separated by headlands and the breakwaters of Port Kembla. The relatively short extension of the rock platforms, the orientation towards the predominant swell direction, and the differing behaviour of adjacent Wollongong (City), Fairy Meadow and Corrimal Beaches, suggest potential bypass of sediment via longshore drift towards Bellambi Point. MM and Fishermans Beaches are moderate-highly protected from wave action by Red Point and the Five Islands, and therefore, northwards drift of sediments from these two beaches seems unlikely.

The Illawarra Coast-South is a well-defined and confined compartment whose main sedimentary characteristics are represented by the infilling of the Lake

Illawarra barrier estuary. Warilla Beach is erosion-prone and seems unlikely to receive any input from Shellharbour North and South Beaches.

The preliminary results presented here form part of ongoing research intended to integrate onshore and offshore investigations with a focus on sediment movement within a hierarchy of coastal sediment compartments, with the objective of better informing the management of these sections of coast. The wider study will address fundamental questions regarding sediment dynamics in this region, including the potential for both cross-shore and alongshore sediment exchanges over the coming decades, and the implications for shoreline change.

Acknowledgement

This research has been possible thanks to funds provided by GeoQuest Research Centre Grant 2016 “Underwater mapping of rocky reefs in the Illawarra using different remote sensing techniques”, SMAH Research Partnership Grant 2017 “Sediment dynamics and stability of the Illawarra coast” and the NSW Government’s Climate Change Fund.

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