REGOLITH-LANDFORM MAPPING OF THE SHOALHAVEN RIVER DELTA AND HINTERLAND, NSW: TOWARDS A MODEL FOR LANDSCAPE CHANGE AND MANAGEMENT

Andrew T. Christian & S.M. Hill

CRC LEME, Division of Science and Design, University of Canberra, Canberra, ACT 2601

INTRODUCTION

Coastal landscapes are dynamic, hosting a range of ongoing regolith and landscape processes. Regolith-landform mapping has the potential to represent the landscape features and their attributes in these areas, but to date there has been little detailed regolith-landform mapping of coastal areas. As a result the applications of these maps for representing, understanding and managing these areas has been largely overlooked. Furthermore, considering the extremely dynamic nature of both long-standing landscape processes and more recent anthropogenic activities, the temporal validity of these maps is uncertain (in other words, how definitive is a regolith-landform map in an area subject to considerable landscape change?). This work is the first detailed (≥ 1:25,000) regolith-landform map of a coastal area to be produced, and the following provides an overview of this mapping program as well as considering some of its applications and implications.

The Shoalhaven River Delta and hinterland encompasses a diverse range of major landscape features including mostly cleared coastal and alluvial sediments of the coastal plain and forested mountains and hills of the Illawarra Escarpment (part of the Great Escarpment of Eastern Australia). The area has been extensively studied by geomorphologists and soil scientists (e.g. Bryant *et al.* 1996, 1997, Nott *et al.* 1996, Nott 1998, Walker 1962, 1984, Woodroffe *et al.* 2000, Wright 1970, Young *et al.* 1996). However, these studies have mostly been concerned with delta evolution, coastal processes and soil mapping. The region hosts a major ASS and PASS (acid sulphate soil and potential acid sulphate soil) problem and as such has been identified as a nationally significant 'ASS hotspot' (Woodworth 2000), towards which funding has been allocated to provide remedial assistance to the problem. The problem has major implications for the local dairy, fishing and tourism industries. Previous soil and landscape mapping has had limited success in delineating the extent of ASS and PASS problems, with recently published ASS maps along the NSW coast mainly showing broad patterns at regional (1:25,000) scale (Tulau 1997a, 1997b). Furthermore, the intense remediation efforts within some of the dairy pastures have suppressed the landscape expression of problem areas. An integration of a range of landscape attributes within a detailed regolith-landform context has previously not been undertaken, and offers new insights into the region's landscape and some of its management problems.

STUDY AREA SETTING

The Shoalhaven River Delta (SRD) and hinterland includes the township of Nowra, approximately 150 km SSE of Sydney (Figure 1). The area is subject to a mild temperate climate with mean daily temperatures typically reaching 15.8°C in the winter and 25.8°C in the summer. Nowra experiences a mean annual rainfall of approximately 1,029 mm, with a range of 700 mm to 1,600 mm (BOM).

The study area is within the southern half of the Permian-Triassic Sydney Basin, which in this area mostly consists of the Shoalhaven Group of latite tuffs and lavas underlain by coarse to fine grained sedimentary sequences comprising the Berry Formation and Nowra Sandstone (Rose 1966). The Shoalhaven Delta has formed from the deposition of alluvial, fluvial and marine sediments that have accumulated to form a complex sedimentary pile (Young *et al.* 1996, Umitsu *et al.* 2001). Seven Mile Beach and Comerong Island form a sand barrier of numerous beach ridges developed almost entirely from the deposition of sediments sourced from the Shoalhaven River (Wright 1970). Behind this sand barrier, an infilling of estuarine sediments comprises the base of the sedimentary pile with radiocarbon dating suggesting deposition occurred between 5,500 and 3,500 years BP (Woodroffe *et al.* 2000). The upper part of the stratigraphy of the Shoalhaven Delta includes estuarine and alluvial muds with over-bank deposits and levee formations. The effects of tsunami surges have been identified, stripping alluvium and truncating fluvial channels, having a major influence on erosional processes in the Shoalhaven River and its adjacent floodplains (Young *et al.* 1996). These past events have formed the basis of how the Shoalhaven floodplain evolved, and has continued evolving, to create the dynamic landscape seen today.

In: Roach I.C. ed. 2002. *Regolith and Landscapes in Eastern Australia*, pp. 8-13. CRC LEME.

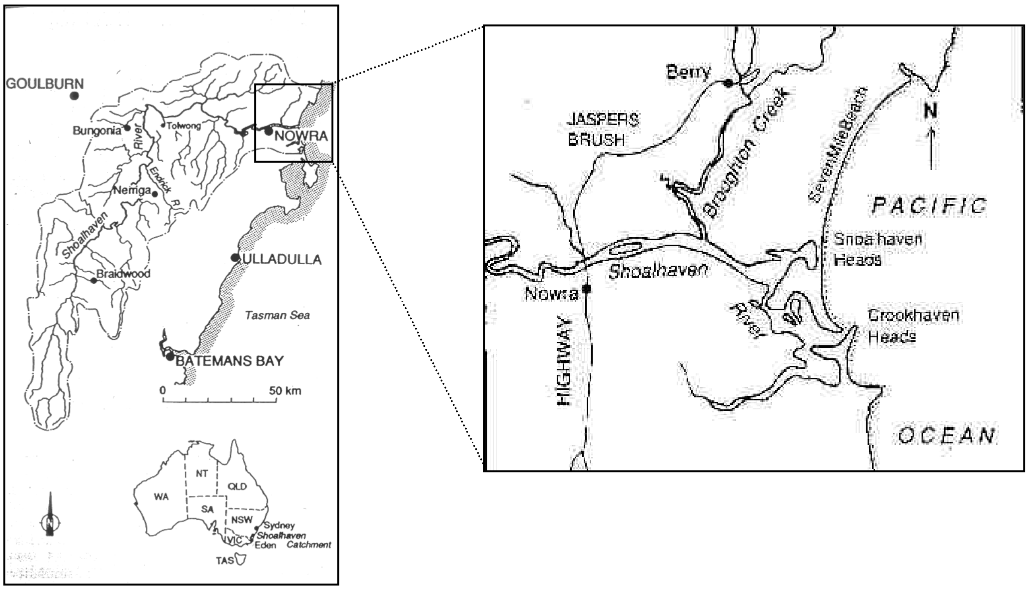

Figure 1: Location of the Shoalhaven Catchment Area (Nott *et al.* 1996) and Lower Shoalhaven River Delta incorporating the study area (after Pease 1994).

The major vegetation communities within the study area include:

- warm-temperate rainforest within the escarpment area;
- tall open sclerophyll forest dominated by *Eucalyptus spp.* mostly within the escarpment and adjacent uplands;
- littoral rainforest along parts of Seven Mile Beach and Comerong Island; and,
- heathland and shrubland mostly on the coastal and deltaic lowlands.

The distribution of these different communities generally relates to landscape-associated variations with respect to temperature, aspect, drainage, regolith substrate, and slope gradients. Many parts of the area have been cleared for urban development (e.g. Nowra and Shoalhaven Heads) or pasture (including a majority of the Shoalhaven Delta). The study area includes several national parks and reserves, such as the Red Rocks and Black Ash Nature Reserves on the escarpment plateau and Seven Mile Beach and Comerong Island National Parks adjacent to the Shoalhaven River mouth entrance.

REGOLITH LANDFORMS

The regolith-landform units of the Nowra/Berry Special Regolith-Landform Sheet have been devised in accordance with the descriptions of Pain *et al.* (in press).

Alluvial Sediments

These sediments consist of clays, silts, sands and gravels of a wide range of compositions including locally derived lithic fragments and organic-rich sediments to more widely transported quartzose and clay-rich materials. They are mostly confined to channels (ACar, ACa_1, ACa_2, ACa_3, ACap) and adjacent depositional plains (Aap, Apd_1, Apd_2), with some also deposited within swampy depressions and tidal flats (Aaw, Act) and along the axis of high- to low-gradient valley systems (Aed_1, Aed_2). Some alluvial sediments are isolated from the contemporary drainage systems and occur within erosion rises (Aer) including those associated within terrace remnants in the Jaspers Brush area. These materials mostly occur in low-lying areas, particularly along the Shoalhaven River channel and tributaries.

Colluvial Sediments

Colluvial sediments consist of a range of materials including soil-sized particles comprised of fine silts and clays, quartzose sands, coarse lithic fragments and sub-angular boulders that have been associated with down-slope movement under the influence of water, wind or gravity. These colluvial materials are typically found on slopes where erosion and transportation of weathered materials has occurred. Material composed of colluvium is associated with low- to high-gradient erosional rises (Cer_1, Cer_2), but many map units consist of colluvial material that were too small to map and are therefore documented as minor attributes.

Estuarine Sediments
Estuarine sediments consist of fine silts and sands deposited from tidal currents in an estuary or lagoon. These sediments are typically light to dark in colour, composed of fine silty sands with organic matter. These sediments range from being closely associated with tidal flats dominated by mangrove communities (OEct), to alluvial plains with consolidated vegetation communities (OEap), and lagoon inlets where river flow is by-passed and dominated by tidal ebb and flow (OEag). These sediments are mainly composed of reworked fluvial sediments and floodplain silts that typically accumulate in low energy zones.

Coastal Sediments
Coastal sediments consist of beach sands and dune sands that are typically deposited by wave processes. Beach materials typically consist of coarse to fine quartzose sands with calcareous fragments derived from shell fragments and minor organic matter (Obcc). Dune sands typically consist of similar quartzose and calcareous materials but with a higher percentage of organic material and increased soil development (Ocd_1, Ocd_2, Ocd_3). These materials form a majority of Seven Mile Beach National Park and the dune succession and beach of Comerong Island.

Weathered Bedrock
In-situ material is bedrock or indurated materials that have undergone varying degrees of weathering with little to no transport of weathered materials. The Lower Shoalhaven Catchment, hinterland and Coolangatta Mountain consist predominantly of weathered bedrock ranging from slightly weathered (SS) to moderately weathered (SM) materials. Exposed bedrock occurs predominantly where bluffs, scarp retreats and mountain tops resist weathering processes. These units are comprised of dominantly yellow-brown coloured surface materials derived from sub-angular/sub-rounded ferruginised stained gravels with low to moderate quartz content and poorly sorted coarse to fine quartzose sands.

DISCUSSION: TEMPORAL SIGNIFICANCE OF REGOLITH-LANDFORM MAPS

Methods of producing maps of different time slices
Regolith-landform maps at both 1:25,000 and 1:100,000 were produced using enlarged 1:50,000 colour air photographs from 1997 and fieldwork between February and September 2002. Selected areas were then mapped using the photographs listed in Table 1.

Table 1: Aerial photos used for temporal change assessment of significant areas.

Air Photo Year	Type	Scale (Approx.)
1949	B & W	1:50,000
1961	B & W	1:40,000
1970	B & W	1:65,000
1974	B & W	1:40,000
1984	B & W	1:40,000
1997	Colour	1:50,000

Assessment of RLU changes with time
Each aerial photo was used to identify areas of change and boundaries associated with regolith-landform assemblages over a 50 year period. Most of the RLU boundaries have not changed, particularly within the upland area of the Illawarra escarpment, however, those areas that have changed include:

- alluvial swamps and associated estuarine lowlands that have been cleared and now host pasture, suppressing their more recent landscape expression, and therefore their ability to be shown on more recent maps;
- channel margins, particularly along the Shoalhaven River, where there has been erosion or sedimentation;
- the vicinity of the Shoalhaven River mouth-, which has undergone opening and closure over time and influenced the distribution of sedimentation; and,
- urban areas, that have greatly expanded.

Alluvial and Estuarine Swamps
Since 1949 there has been an increase in the amount of land used for agricultural purposes in the study area. This has been largely achieved through the excavation of drainage canals in low-lying, swampy areas. The development of these drains is evident on aerial photographs from 1949 through to 1997. Many of these swampy lowlands were originally stable areas of PASS but, once drained, they become ASS and toxic products from these soils leach into the surrounding waterways and affect plants, animals and marine

ecosystems. Some of the landscape expressions of these areas include surface scalding and vegetation die-off as a result of ASS development, and in these cases the extent of some of this landscape degradation can be assessed using a succession of aerial photos. However, many areas have been regularly remediated through the expensive application of lime, and the surface signatures of the underlying ASS problems are more difficult to detect from the contemporary regolith-landform expression. This temporal regolith-landform mapping approach provides a 4-dimensional view of the former swamps that have been drained and continually remediated for pastoral activities and now host potentially hidden ASS-related hazards.

Channel erosion and sedimentation

Significant changes in sedimentation and erosion over the last 50 years can be seen in the area. These are most prominent along the Shoalhaven channels between Numbaa Island and Comerong Island. Numbaa Island has been a small island adjacent to the mouth of Broughton Creek with little vegetation colonising the channel bar in 1949. Increased sedimentation between 1961 and 1970 enabled vegetation to colonise and stabilise the bar where it has aggraded upstream to its present location, where it now almost joins the riverbank at Numbaa. Similar sedimentation also occurred at Regatta Island, where it has become wider and been colonised by vegetation, and at Old Man Island where riparian vegetation of predominantly casuarinas and mangroves has hosted sediment deposition. In contrast, O'Keefes Point and the adjacent area on Comerong Island (where Berry's Canal meets the Shoalhaven River) has been eroding due to river flow, tidal scour and boat wash. According to AWACS (1999), a revetment was constructed on this bank at Comerong Island in 1961 and is still in place in the 1974 photos. The 1984 photos however, show the degradation of the revetment and the existing bank leading to noticeable erosive bank scalloping in the 1984 and 1997 photos (Figure 2).

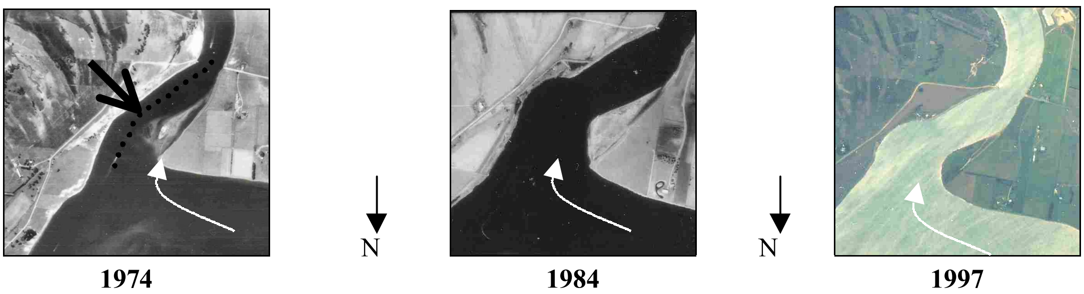

Figure 2: Estuary bank erosion at Comerong Island, opposite O'Keefes Point. 1974: Revetment in place. 1984: Revetment collapse and bank erosion. 1997: Further bank erosion encroaching on access road. Scale is approximately 1cm = 400 m. White arrow denotes flow direction. Reproduction of aerial photos consisting of Kiama 1974 Run 6 2288 #22, 1984 Run 6 3389 #191, 1997 Run 6 4344 #38 by permission of NSW Land and Property Information.

The dynamics of sedimentation and erosion over this timeframe has had major impacts on infrastructure and terrestrial and estuarine habitats. Housing on the edge of river channels is now under threat due to the undercutting of banks by tidal scour, boat wash and periods of high stream discharge. The 4D regolith-landform mapping has the potential to depict this and as such can be used as a tool to develop landscape management strategies. The extent of the impact of the regolith and landscape changes on marine habitats is less certain. For example, as a result of the construction of Berry's Canal, the Shoalhaven River near Shoalhaven Heads now carries a reduced stream flow, which has promoted channel sedimentation. This has implications for the delivery of sediment to the coastal system, the characteristics of the channel system immediately upstream of the coast (reducing boat access and launching capabilities, including the smothering of oysters and other changes to marine habitats), and even the nature of water flow and circulation and its impact on the influxes and storage of heavy metals and acid waters in the area. During recent field mapping it was noted that mangrove seedlings are now beginning to colonise the estuary banks and sand bars in the area of the former Shoalhaven River outlet to the sea.

Shoalhaven River Mouth

A major change at the Shoalhaven River mouth includes the intermittent opening and closure of the entrance. The aerial photographs from the six time periods since 1949 show two periods (1961 and 1974) where the river entrance is open, while the other photographs showed it to be closed. A more detailed assessment of the river mouth dynamics requires examination over closer time intervals, however it appears that during periods of low river flow, the entrance closes and sediment build up from marine, estuarine and fluvial sediments occurs. Coastal storms and beach erosion would also contribute to maintaining the river mouth opening, however a recent beach stabilisation program may limit the frequency of river mouth opening in the future. The removal of water from the Shoalhaven River at places like Tallowa Dam, thereby reducing stream flow, also has the potential to impact on landscape change at the Shoalhaven River mouth. During times of prolonged closure, new vegetation typically colonises and stabilises the beach and dunes in the area.

Urbanisation

Since 1949, the township of Nowra and smaller urban areas situated on the delta such as Bomaderry, Berry, Shoalhaven Heads and Crookhaven Heads have expanded. Development in these areas, especially the low-lying urban areas at Berry, Shoalhaven Heads and Crookhaven Heads, has in the past been prone to flooding during periods of high rainfall. This introduces risk assessment and possible emergency procedures that may need to be implemented based on evacuation routes and high relief safe areas within the landscape. Urban change can be measured based on the expansion of residential areas. Over the years, temporal change assessment can show the physical distribution associated with urban growth.

For urban expansion to proceed, land assessment is required before development can commence. Regolith-landform mapping provides a greater appreciation and increased awareness of suitable materials and landscape processes that may influence urban development. For example, RLUs that are associated with swampy depressions and prone to flooding should be avoided for urban development, unless proper precautions are taken. In general, the extent of alluvial units on the regolith-landform map closely corresponds with the areas most prone to flood hazards. The regolith-landform characteristics are typically concealed by urbanisation, therefore concealing many of the regolith and landscape features that can impact upon urban development. For example, urban areas may be undesirably developed on areas with PASS and ASS with their disturbance possibly resulting in corrosion of infrastructure and release of toxic solutions.

CONCLUSION

The Shoalhaven River Delta and immediate hinterland have been mapped and characterised with respect to regolith-landform features and their changes over time. This is a new way of representing this landscape. The significance and applications of this is enhanced by the detailed mapping scale (1:25,000) and the sequence of maps representing the landscape change over a fifty year time frame. The landscape in low-lying areas is very dynamic, suggesting that mapping of such areas may need to be revised on a regular time scale (in some cases < 50 years). Other areas, such as uplands, are more stable over time. The detailed 4-dimensional regolith-landform mapping approach has significant implications for land and environmental management, particularly in areas that have undergone agricultural development and urbanisation. In this study area this could well be used to manage ASS hazards, as well as coastal and alluvial sedimentation and erosion.

REFERENCES

AWACS 1999. *Shoalhaven River Estuary Data Compilation Study*. Australian Waters and Coastal Studies Pty Ltd. **95/34**.

BOM. http://www.bom.gov.au/.

BRYANT E.A., YOUNG R. & PRICE D.M. 1996. Tsunami as a Major Control on Coastal Evolution, Southeastern Australia. *Journal of Coastal Research* **12(4)**, 831-840.

BRYANT E.A., YOUNG R., PRICE D.M., WHEELER D.J. & PEASE M.I. 1997. The Impact of Tsunami on the Coastline of Jervis Bay, Southeastern Australia. *Physical Geography* **18(5)**, 440-459.

NOTT J. 1998. Unravelling the evolution of drainage patterns in the Shoalhaven Catchment; a brief case history. *In:* EGGLETON R.A. ed. *The State of the Regolith*. Geological Society of Australia **Special Publication 20**, 50-53.

NOTT J., YOUNG R. & MCDOUGALL I. 1996. Wearing Down, Wearing Back, and Gorge Extension in the Long-Term Denudation of a Highland Mass: Quantitative Evidence from the Shoalhaven Catchment, Southeast Australia. *Journal of Geology* **104**, 224-232.

PAIN C., CHAN R., CRAIG M., GIBSON D., KILGOUR P. & WILFORD J. in press. *RTMAP Regolith Database Field Book and Users Guide (2nd Ed.)*. CRCLEME **Report 138**.

PEASE M.I. 1994. *Acid Sulphate Soils and Acid Drainage, Lower Shoalhaven Floodplain; NSW.* Master of Science thesis (unpublished). Department of Geography, University of Wollongong, Wollongong.

ROSE G. 1966. *Wollongong 1:250,000 Geological Series Sheet*. NSW Department of Mines, Sydney.

TULAU M.J. 1997a. Acid Sulphate Soil Risk Map Burrier/Berry (2nd Ed.). NSW Department of Land and Water Conservation.

TULAU M.J. 1997b. Acid Sulphate Soil Risk Map Yalwal/Nowra (2nd Ed.). NSW Department of Land and Water Conservation.

UMITSU M., BUMAN M., KAWASE K. & WOODROFFE C.D. 2001. Holocene palaeoecology and formation of the Shoalhaven River deltaic-estuarine plains, southeast Australia. *The Holocene* **11(4)**, 407-418.

WALKER P.H. 1962. Terrace Chronology and Soil Formation on the South Coast of NSW. *Journal of Soil Research* **13(2)**, 179-187.

WALKER P.H. 1984. Terrace Formation in the Illawarra Region of New South Wales. *Australian Geographer* **16**, 141-146.

WOODROFFE C.D., BUMAN M., KAWASE K. & UMITSU M. 2000. Estuarine Infill and Formation of Deltaic Plains, Shoalhaven River. *WETLANDS (Australia)* **18(2)**, 72-84.

WOODWORTH J. 2000. *ASSAY: A Newsletter About Acid Sulphate Soils.* NSW Agriculture, No. 27. Accessed: 11/04/02. http://www.agric.nsw.gov.au/Arm/acidss/index.html.

WRIGHT I.D. 1970. The Influence of Sediment Availability on Patterns of Beach Ridge Development in the Vicinity of the Shoalhaven River Delta, NSW. *Australian Geographer* **11(3)**, 336-348.

YOUNG R., WHITE K.L. & PRICE D.M. 1996. Fluvial Deposition on the Shoalhaven Deltaic Plain, Southern New South Wales. *Australian Geographer* **27(2)**, 215-233.