

COASTAL MORPHODYNAMICS AND POLICY: WHAT ARE THE LINKS?

***Bruce Thom,
Member of Wentworth Group of Concerned Scientists***

Introduction

This paper will explore the legacy of Don Wright on coastal science and management in NSW. Specifically, it will address the concept of morphodynamics, and how that concept can be applied to complex systems, characterised by stochastic, nonlinear, and multidimensional variables, in the development of coastal planning and management in NSW.

Don Wright's legacy: 40 years on

Don had two spells at Sydney University: first as an MSc student researching the geomorphology of the Shoalhaven delta in the late 60s; he came back after completing his PhD at LSU as an Associate Professor from 1974 to 1982; then he returned to the USA. At the Coastal Studies Institute at LSU he worked with colleagues on deltaic and beach systems that inspired his thinking in coastal morphodynamics culminating many years later in his seminal book on inner continental shelves (Wright, 1995). But it was what he stimulated whilst in Sydney is what I want to focus on in this paper.

Don was a remarkable coastal scientist. He demonstrated strengths in the field, as an experimenter and in modelling complex systems ranging from river-dominated deltas to high energy beaches. Not many of us coastal wonks can contribute in all three domains as he did with such focus and commitment. He built a team around him and with colleagues such as Andy Short and Peter Cowell formed the Coastal Studies Unit (CSU) from which flowed a great succession of coast and marine scientists. I had the privilege of working with and being inspired by Don first in our work in the Ord Delta (a joint ANU-LSU project 1971-2), on some of the beach experiments (Wright et al., 1979), in PNG (Thom and Wright 1983), and in writing our theory paper on coastal morphodynamics (Wright and Thom, 1977). This 1977 paper has relevance to coastal policy development and implementation today.

Coastal morphodynamics: theory and application

In a recent paper on beach morphodynamics, Short and Jackson (2013) kindly pay tribute to our 1977 paper, noting that the approach we articulated has been widely adopted (see also Cowell and Thom 1994). Relationships between topographic/geologic conditions, process inputs, sediment movements and resulting changes to surface form and underlying stratigraphy constitute the morphodynamic conceptual framework. A key feature of the approach is the emphasis on the mutual adjustment of form and process involving sediment transport over time leading to topographic change which has feedback and lag effects. The approach can be applied at a range of time scales.

Coastal morphodynamics involves an understanding of a set of principles (Wright and Thom, 1977). There is nothing new about these principles, but what we tried to do was bring them together to capture the complex physical nature of coastal systems. For instance, we expressed how different coastal depositional systems

could reflect either positive (self organising or change in state) or negative (self regulating or equilibrium tendency) feedback loops. The stochastic nature of external processes driving change to a given coastal system was placed in the context of inherited or antecedent conditions. We stressed the need to appreciate relaxation times and non-linear behaviour of the interacting processes and forms leading to uncertainty in outcomes. One distinction we were able to make was between changes driven by “internal” morphodynamic adjustments as sediment is moved within an area compared to changes driven by external or boundary conditions such as eustatic sea level rise or a change in wave climate. These principles have been applied in a range of studies in Australia across different coastal environments (deltas, estuaries, beaches, reefs) and over time scales from days to millennia (Chappell and Thom, 1986; Cowell and Thom, 1994; Short, 1999; Hesp and Short, 1999; Woodroffe, 2003; and Short and Jackson, 2013).

Many are familiar with the work stimulated by Don Wright on beach dynamics. This work took coastal science beyond the previous fragmented approach to beach studies and offered a time-space framework that highlighted the interdependence of processes and morphological responses across the full spectrum of beach types (Short and Jackson, 2013). Research by members of the CSU, using Australia’s vast range of beach-wave-tide environments, fostered the so-called Australian beach model (Short, 1999).

Less familiar are those studies which embrace the Quaternary evolution of coastal regions using the morphodynamic approach. John Chappell and I tried to bring together some of our own work and those of colleagues in a paper that reviewed coastal morphodynamics in northern Australia (Chappell and Thom, 1986). What this work showed was that while boundary conditions (waves, tides, sea level) may appear to be independent, the progressive accretion or erosion of nearshore sediments, or the growth of coral reefs, alters processes of wave refraction and attenuation, and even the tidal range. Thus it is unwise to attribute some local depositional feature to a variation of this or that boundary condition, unless all processes involved in the sediment transport system over time are understood. This led us to adopt the testable hypothesis that to explain Holocene changes in coastal dynamics one should first assume that boundary conditions were constant, and that past changes were the consequence on internal morphodynamics operating with a defined sediment budget, subject only to magnitude-frequency fluctuations of waves and winds.

The morphodynamic approach has moved beyond the conceptual and experimental stage which Don, John, Andy and I trialled in the 70s and 80s, based on extensive field work, to its application through the use of simulation modelling. Peter Cowell has demonstrated the value of “inverse modelling” moving away from deterministic solutions to evaluating a range of probable alternatives calibrated by field evidence thereby embracing many of the factors that influence shoreface geometry and mobility. His work with Peter Roy on the late Quaternary depositional sequence at Tuncurry using the Shoreface Translation Model (Cowell et al., 1995) is a classic demonstration of what can be achieved over this extended time period; his modelling skills was also shown in our joint study of the management of uncertainty in predicting climate change impacts on beaches in the Manly littoral cell (Cowell et al., 2006). This simulation modelling has been further expanded by two of Cowell’s PhD students, Marc Daley and Mike Kinsela, involving the analysis of complex interacting variables over time along different parts of the NSW coast. Dean Patterson has been doing similar work in northern NSW.

Coastal morphodynamics: management implications

There is increasing demand for predictions, or projections, of how coastal landforms will respond to environmental changes driven by global warming. It is quite common to use somewhat simplistic methods such as the Bruun Rule to provide answers. As a first approximation, this method may be satisfactory. However, there is increasing evidence for the application of more sophisticated approaches that factor in composition and form of the shoreface across a range of depths over which waves of varying magnitudes may work linked to sources, sinks and pathways of sediments that move within the coastal system from land, from offshore and alongshore. In addition, there is a growing need to provide a probabilistic approach to processes that covers time scales from instantaneous to seasonal, to annual, to decadal, and in some circumstances to centuries. This is a challenge to coastal science and engineering if it is to best inform management and planning decisions especially in areas of high coastal investment.

One expression of the need to improve predictive capacity is the emerging interest in Australia in defining coastal sediment compartments. Within each compartment it is possible to assess changes to sediment budgets. Again this is not new. The British have used the “sediment cell” approach to assist shoreline management planning since the 90s, and coastal manuals and guides such as the NSW Coastline Manual (1990) have recognised the value of the approach. There is currently a drive by Geoscience Australia to adopt a multiscale division of the Australian coast into primary, secondary and tertiary compartments that can be employed to improve the way governments can assess risk to built and natural assets at national and regional levels (see also Damara, 2013; WRL, 2013).

The sediment compartment approach goes to the heart of coastal morphodynamics. Immediately it is made clear to managers and planners that they are dealing with complex interacting systems that yield classic “wicked problems” for decision makers. It stresses the need to gather data on the regional character of the coastal system, not just on a “hot spot” location. Data must include offshore, shoreface, beach-dune, and flood-tide delta sediment composition, topographic form, and especially any topographic constraints on sediment movement. Defining sediment pathways using an array of techniques such as LiDAR can prove invaluable as demonstrated by the recent work of Damara (2013) in Western Australia. Bedrock controls as at headlands or offshore become important to understand the way different “cells” are closed to alongshore transport or leak from one compartment to another (Thom, 1989; WRL, 2013). The degree to which the “accommodation space” between headlands is filled with Holocene and/or Pleistocene sediments is also relevant. In this way sections of the coast can be mapped as sediment surplus or deficient (underfit versus overfit in the terminology of Daley and Cowell, 2012). Recent advice from the NSW Coastal Panel on the coastal management plan for Greater Taree Shire Council recognised the need to understand the significance of the sediment budget and especially problems created where there is a shoreface sediment deficit.

We have reached a state of knowledge where we can effectively model the range of factors that drive coastal change within a given coastal system. The conceptual basis for applying morphodynamic models on the open coast in particular is strong and cannot be ignored. In many areas in NSW there is sufficient data to calibrate the models. However, data deficiencies do exist especially offshore which places limitations on outputs of the models. Evidence of a geomorphic threshold being reached involving a switch from one state to another, or not, should be clear from field observations. This can be seen from photographic or survey records where a beach that had oscillated around a mean position over many years then changes to

one of sustained recession, or whether there is a capacity for post-storm event recovery even as sea levels continue to rise.

Of great value would be the use of models which incorporate regional sediment budgets to define future trends and hence hazard zones. An attribute of such an approach is the identification of what may be termed early or late responders to an external driver such as sea level rise or change in wave climate, or even an internal driver resulting from a change in tidal range in a coastal lake. Up to a certain threshold point, which may differ according to morphodynamic conditions, the geomorphic impact of a rise in mean sea level due to climate change may be masked by internal adjustments in sediment distribution.

Coastal morphodynamics: policy implications

It is very clear that coastal management and planning in NSW, and elsewhere in Australia, would be greatly improved if the morphodynamic approach was used to assist with the development of regional and local coastal zone management plans. In NSW the emphasis has been on local plans at the local council level with little attention to what is happening between LGAs. Frequently councils have relied on consultants, guided by the coast or estuary manual, to undertake local studies to assist with defining hazard lines that can then be used for a variety of purposes. There has been no requirement by the State Government to undertake regional studies of offshore sediment and rock conditions that may otherwise constrain the outputs of these local studies. Nevertheless, there have been studies in the past which have provided data which are invaluable in any regional assessment of sediment pathways especially those led by Angus Gordon at Byron and off Sydney. World-class offshore interpretation of sediment history and conditions at Tuncurry by Peter Roy shows what can be done. There should be no excuse for not adopting a more regional framework to assist local councils undertakes the assessment of assets at risk and how to improve and maintain coastal amenities.

What the morphodynamic approach requires is an assessment of regional physical factors that drive coastal change at different time scales. Dividing the coast into compartments that form the physical basis for coastal processes and sediment movements is a start. This will provide a planning framework that will cross council administrative boundaries but can then provide input into local plans as should be required by state planning policy and local council needs. We are not suggesting another layer of planning. Rather we are supporting the use of a regional approach, using the principles of coastal morphodynamics, to improve our capacity for risk assessment and asset protection. The approach is open to exploring scenarios of change using different combinations of external forces and internal adjustments as we seek to understand probable impacts of global warming and changes in population distribution and coastal uses. Clearly more investment is required in collecting information and in monitoring coastal change both on the open coast and in our estuaries and coastal lakes. But there is enough intellectual material and data to commence thinking and planning more strategically. It was Don Wright who from his brief stay in Sydney inspired many of us to seek to roll out his legacy and look at our coast as a dynamic, interacting, evolving biophysical system, the knowledge of which we can ignore at our peril.

References

Chappell, J. and Thom, B. (1986). Coastal morphodynamics in North Australia: review and prospect. *Australian Geographical Studies*, 24, 110-127.

- Cowell, P. and Thom, B. (1994). *Morphodynamics of coastal evolution*. In: Carter, R. and Woodroffe, C. (eds.) *Coastal Evolution: Late Quaternary Morphodynamics*. Cambridge University Press, Cambridge, 33-86.
- Cowell, P., Roy, P., and Jones, R. (1995). Simulation of large-scale coastal change using a morphological behaviour model. *Marine Geology*, 126, 45-61.
- Cowell, P., Thom, B., Jones, R., Everts, C. and Simanovic, D. (2006). Management of uncertainty in predicting climate-change impacts on beaches. *Journal of Coastal Research*, 22, 232-245.
- Daley, M. and Cowell, P. (2012). *Long-term shoreface response to disequilibrium stress: a conundrum for climate change*. 21st NSW Coastal Conference, Kiama.
- Damara Pty Ltd (2013). *Application of Geomorphic Frameworks to Sea-level Rise Impact Assessment*. Report 193-01-Rev 0.
- Hesp, P. and Short, A. (1999). *Barrier morphodynamics*. In: Short, A. (ed.) *Handbook of Beach and Shoreface Morphodynamics*. John Wiley, Chichester, 307-333.
- NSW Coastline Management Manual (1990). NSW Government, Sydney.
- Short, A. (1999). *Wave-dominated beaches*. In: Short, A. (ed.) *Handbook of Beach and Shoreface Morphodynamics*. John Wiley, Chichester, 173-203.
- Short, A. and Jackson, D. (2013) Beach morphodynamics. In: Shroder, J. (ed.) *Treatise on Geomorphology*, 10, 106-129.
- Thom, B. (1989). *Global climatic change: issues for the Australian coastal zone*. Prime Minister's Science Council, October, 1989, Australian Government Printing Office, 79-143.
- Thom, B. and Wright, L.D. (1983) *Geomorphology of the Purari Delta*. In: Petr, T. The Purari, Dr W. Junk Publishers, The Hague, 47-65.
- Water Research Laboratory (2013). *East Coast Study Project—National Geomorphic Framework for the Management and Prediction of Coastal Erosion*. WRL Research Report 253.
- Woodroffe, C. (2003). *Coasts—Forms, Process and Evolution*. Cambridge University Press, Cambridge.
- Wright, L.D. (1995). *Morphodynamics of Inner Continental Shelves*. CRC Press, Boca Raton, Florida.
- Wright, L.D. and Thom, B. (1977). Coastal depositional landforms: a morphodynamic approach. *Progress in Physical Geography*, 1, 412-459.
- Wright, L.D., Chappell, J., Thom, B., Bradshaw, M. and Cowell, P. (1979). Morphodynamics of reflective and dissipative beach and inshore systems, Southeastern Australia. *Marine Geology*, 32, 105-140.