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Research Notes

The Murray Mouth Flood Tidal Delta

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The River Murray enters the sea in Encounter Bay, South Australia (Figure 1), providing the only open ocean link for Australia's largest river system via the terminal lakes Alexandrina and Albert, and a hypersaline coastal lagoon, the Coorong. The plan of the Encounter Bay coastline approximates the pattern of the oceanic swell waves, which approach the coast with a periodicity of 14 to 16 seconds, and provide a wave climate of persistent year-round moderate to high energy southwest swell. Beach drift initiated by local storm-generated waves appears to approach the Murray Mouth from opposite directions, but dominantly from the southeast. This contention is supported by the occurrence of the highest and widest part of the coastal barrier towards the northern extremity of the Younghusband Peninsula (Figure 1), which in turn has influenced the general location of the modern Murray Mouth. In detail, however, the position of the mouth has fluctuated over a range of some 1.4 km since it was first surveyed in 1839 (Johnston 1917; Thomson 1975). Field investigations suggest even greater variation during the Holocene.

River discharge is essential to the long-term maintenance of the current Murray Mouth, but it is evident that during extended periods of low river discharge the mouth has been maintained by wave action and tidal flushing. The oceanic outlet of the River Murray is essentially a tidal inlet restricted by the accumulation of dune material on the flanking spits of Sir Richard and Younghusband Peninsulas. The significance of marine processes for the morphology of the mouth is evident from the presence of flood tidal deltaic deposits in the lagoon immediately landward of the mouth.

Tidal deltas can occur either side of tidal inlets but flood tidal deltas are generally larger than ebb tidal deltas because of the predominantly inward movement of sand. Research into tidal deltas and inlets is documented by Wright (1978) and Boothroyd (1978), and a morphological model of flood tidal deltas and associated terminology is provided by Hayes and Kana (1976).

Narrow tidal inlets restrict water flow so that on a flood tide the ocean water level is at a higher elevation than that of the lagoonal or estuarine waters, thereby creating a hydraulic gradient. Consequently the flood tide pours through the narrow opening, scouring it and transporting sediment into the lagoon or estuary where it forms flood tidal deltaic deposits. At low tide the hydraulic gradient is reversed, leading to the scouring of the inlet and movement of sediment seawards. Under favourable conditions an ebb tidal delta will form on the seaward side of an inlet, but often the sediments are redistributed by wave activity, as is the case at the Murray Mouth where sediments form an offshore bar.

Flood tidal deltaic sediments in the mouth of the Murray River were recorded in early surveys (1839, 1857, 1876 and 1914) and were depicted as sand shoals (Johnston 1917). An oblique aerial photograph taken in 1938 also reveals plumes of deltaic sandy sediments. Between October 1980 and April 1981 a flood tidal delta in the Murray Mouth had built up to such an extent that it closed the mouth of the fourth longest river system in the world (Figure 1).

The location and characteristics of the Murray Mouth are expressions of the dynamic interplay of fluvial, wave, tidal and aeolian processes. The mouth morphology is dominated by fluvial activity during high flow conditions such as in 1956 when flows of up to 326 000 ML/day (megalitres per day) significantly widened the mouth and scoured the deltaic sediments. During low river conditions the barrages (see Figure 1) are often completely closed to prevent saltwater incursions into the terminal lakes. At such periods of 'no flow' the marine processes dominate the physiography of the mouth. This has been enhanced by reduced freshwater inputs into the Coorong Lagoon resulting from drainage modifications in the southeast of S.A. Naturally occurring periods of low flow have taken place in the past; for example Captain Charles Sturt in 1830 was prevented from reaching the open sea in his whale boat because of extensive shoaling towards the mouth. Since the construction of the barrages in the late 1930s there have been sixteen occasions when the barrages have been completely closed and river flow stopped for 100 or more consecutive days. During these periods maximum sediment accrual occurred on the flood tidal delta. Photographic data show a large delta had formed by 24 April 1945 after 250 days of no flow and also by 23 March 1949 (see Figure 2) after 90 days of no flow. The deltaic sediments at this time were stable

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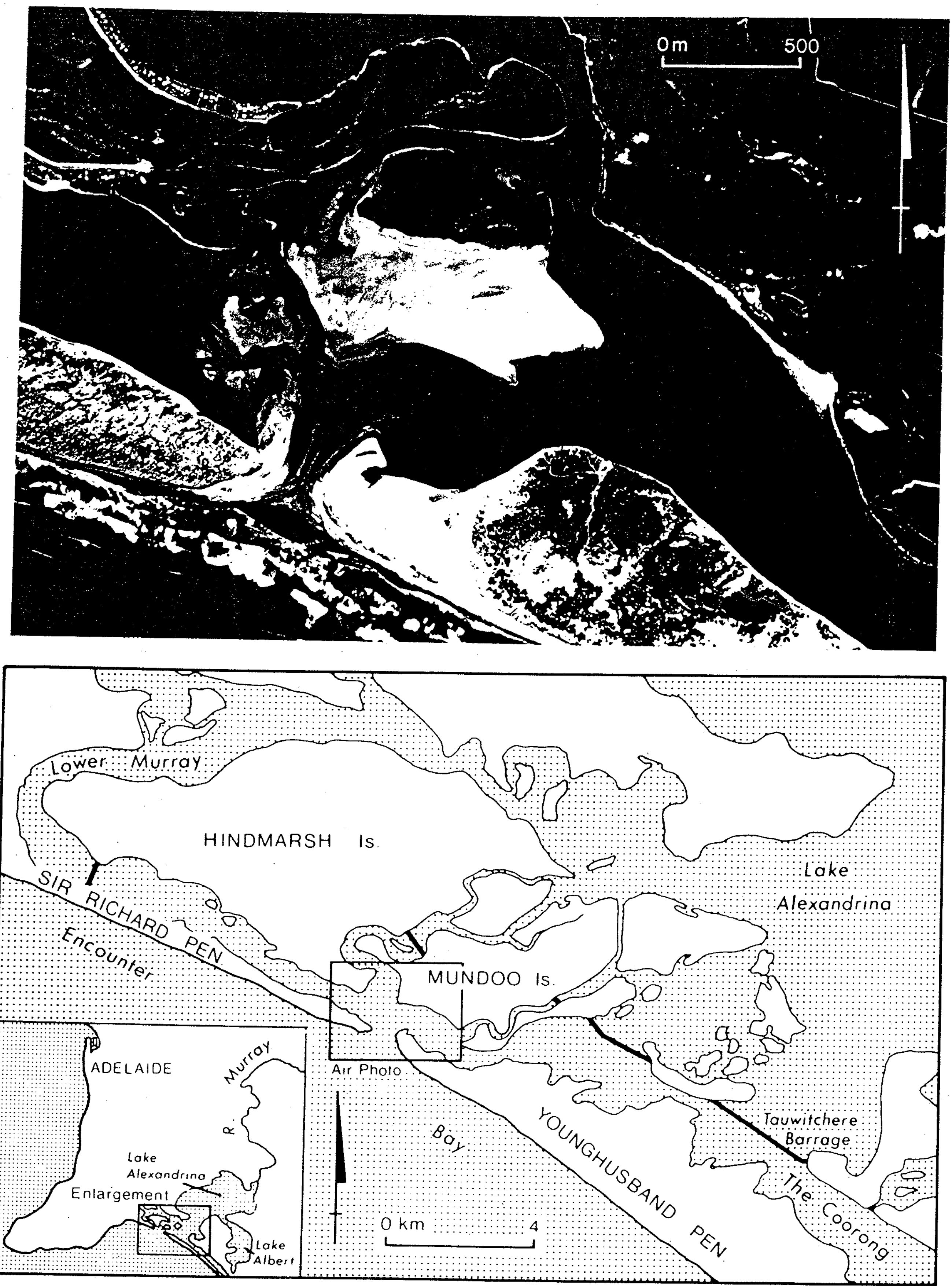

Figure 1: Location map and photo (April 1981) of the Murray Mouth flood tidal delta

enough to support a few shrubs on an incipient dune (see Figure 2), which formed the core of the stablized deltaic sediments and is now known as 'Bird Island'. This island was stable enough to survive the largest historic flood of the Murray in 1956.

By 1960 the central dune had increased in size (see Figure 2) and a large area of the flood tidal sediments had been colonized by samphire and grasses. River flow at the time of the photograph was 63 000 ML/day. Major periods of deltaic sediment accumulation occurred in 1966 as shown on 13 May 1966 after 181 days of barrage closure, and also during the 1967-8 drought when the barrages were closed for a record 529 days, over which time the Murray Mouth was maintained solely by marine processes. A storm surge in 1968 was significant in clearing the mouth of accumulating sediments. By 1968 further dune building indicated progressive stabilization of the deltaic sediments. On the 30 April 1981 the mouth became completely closed (see Figures 1 and 2) by a massive accumulation of sediment on the delta after the barrages had been closed for 196 days. Almost 20 000 tonnes of sand accumulated at the site of the mouth in a four-week period, building a sand bar across the mouth.

The sediments forming the Murray Mouth flood tidal delta are largely beach and dune sands of marine origin interspersed with lenses of coarser shell material. The delta has been progressively stabilizing around a central dune core up to 4 m in height and carrying a climax coastal dune vegetation including shrubs such as *Acacia sophorae, Olearia axillaris, Leucopogon parviflorus,* and even the exotic *Lycium ferocissimum*. On the younger frontal dune (see Figure 2), which is between 1 and 2 metres in height, only a few shrubs occur at the western end amongst the dominant colonizing grasses. In the lee of the two distinct dune areas organic rich muds and silts are present in the supratidal environment where samphire and grass species dominate.

Rapid buildup of the deltaic sediments in 1981 was related to lack of fluvial action, unusually calm sea conditions and a period of low high tides. The Murray

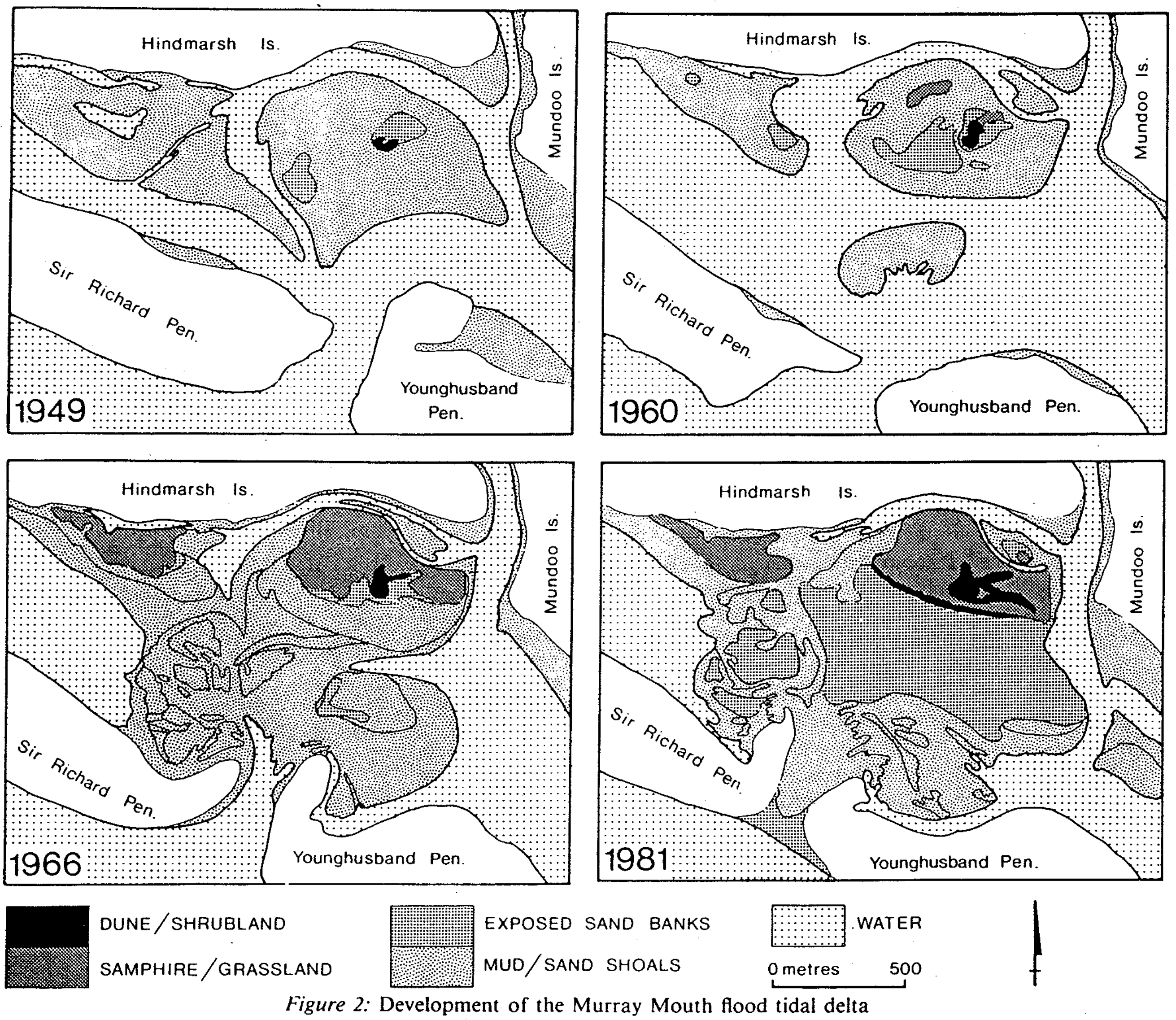

Figure 2: Development of the Murray Mouth flood tidal delta

Mouth is in a micro-tidal environment with a tidal range of less than 1 m (0.8 m at Victor Harbour), and analysis of tides downstream of the Tauwitcherie Barrage illustrates a diminishing tidal range associated with the gradual closure of the mouth during both the 1967-8 and 1980-1 periods. A storm-induced high water level of 1.77 m in April 1968 was sufficient to clear the mouth slightly before river water was discharged through the barrages. In the 1980-1 period there was a partial clearing of the mouth by high tides in June and July of 1980, but relatively calm sea conditions between August 1980 and May 1981 resulted in a complete closure of the mouth. The mouth was partially reopened on 6 May by a high tide of 1.8 m but by 14 May was completely closed again with only an occasional tidal incursion during June.

By the end of July additional sediment derived from cliffing of the foredunes, especially on Sir Richard Peninsula, was deposited on the bar by overwash processes. This, together with material from aeolian sand drift built up the sand bar across the mouth to a minimum elevation of 1.72 m. It appeared unlikely that the mouth would be opened naturally by tides, and sufficient river flow would only be achieved by water levels in excess of the 1956 flood levels (1.43 m lake level). Consequently the mouth was artificially opened on 15 July by the excavation of two channels, the second channel being dug after the first began filling with sediment. The second and deeper channel on the Sir Richard Peninsula side of the mouth produced a strong flow which subsequently severely eroded the dunes of Sir Richard Peninsula on their landward side.

The morphology of the Murray Mouth flood tidal delta in 1981, with its sediment plumes, birdsfoot distributary patterns and hooked spits (Figure 1) is analogous to flood tidal deltaic forms elsewhere, such as the tidal delta formed by the oceanic breaching of the Hatteras Island barrier during a storm in 1962 (El-Ashry and Wanless 1965), and the tidal delta of East Moriches Inlet formed in 1931 when a storm broke through Fire Island and initiated movement of beach sediments into quiet lagoonal waters. Although these three deltas display similar morphologies due to the dominant incursion and overwash of sediments into protected waters, the location of the Murray Mouth tidal delta is related to fluvial rather than oceanic breaching of a barrier system.

In Australia various tidal deltaic forms occur particularly on the coasts of New South Wales and Victoria. For example, both flood and ebb tidal deltas occur at the mouth of the Shoalhaven River (Wright 1970, 1976) and under conditions of low river flow a wave dominated environment causes bar sands to enter the mouth which eventually closes until it is breached by the next flood (Wright 1976). At Mallacoota organic materials and fines have contributed to a permanent flood tidal delta with vegetated islands. In other places simple embankment types of deltas have formed in response to a restricted tidal range and a high energy coastline, where coastal sediments are pushed into the inlet to form a wide threshold between the sea and the estuary. This threshold is normally traversed by a single channel such as at Wagona Inlet and at the entrances to Illawarra, Conjola, Burrill, Tuross and Wallaga Lakes (Bird 1967). In some cases the narrowness of the dammed bedrock valley is undoubtedly an important factor in the morphogenesis of these simple threshold single channel deltas.

The Murray Mouth flood tidal delta appears to be a classic landform example from a micro-tidal environment on a high energy coastline. The barrages, a short distance upstream from the delta, not only artificially restrict or cut off river flow, but also reduce the magnitude of the tidal prism. In addition the southeast drainage modifications have reduced freshwater inputs into the Coorong Lagoon. The consequence of the altered regime at the Murray Mouth has been the progressive stabilization of the formerly ephemeral flood tidal delta. This may produce severe management problems in the future with potential deleterious effects upon the ecology of the Coorong Lagoon in particular. It is of considerable significance that wave and tidal action has dominated over river discharge to such an extent that flood tidal deltaic sediments blocked the oceanic outlet of one of the world's largest river systems.

Acknowledgements

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