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The dynamic behaviour of a river-dominated tidal inlet, River Murray, Australia

B. Shuttleworth, A. Woidt, T. Paparella, S. Herbig, D. Walker*

Centre for Applied Modelling in Water Engineering, School of Civil and Environmental Engineering, The University of Adelaide, Adelaide 5005, Australia

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Abstract

Australia's largest river, the River Murray, discharges to the southern ocean through a coastal lagoon and river-dominated tidal inlet. Increased water extractions upstream for irrigation have led to significantly reduced flows at the mouth and, as a result, the area is undergoing rapid change, particularly with regard to the rate at which sediment is being transported into the lagoon. Based on detailed and accurate bathymetric surveys it has been possible to estimate that the rate of lagoon in-filling is of the order of 100,000 m^3 per year for the period June 2000 to May 2003, although the actual rate shows significant year to year variability. Dredging of the lagoon commenced in 2000 in an attempt to reverse the trend.

In an effort to understand the behaviour of the inlet a one-dimensional numerical model of the inlet has been developed. The model extends the original of van de Kreeke by including a dynamic inlet throat area based on predicted river flows and a sediment transport module to predict the resulting net sediment transport. Comparisons with water level data collected on both the ocean and lagoon sides of the mouth have shown that the model is able to predict the attenuation and lag of the tidal signal reasonably well. The sediment transport model was based on predicted sediment concentrations in the surf zone and was found to predict the rate of sediment in-filling to an acceptable level of accuracy. It is envisaged that the model will be a useful management tool, especially since it is possible to manipulate river discharges to the mouth.

Keywords: tidal inlets; coastal lagoon; sediment balance; numerical models

1. Introduction

The stability of tidal inlets has been the subject of investigation since the 1930s when O'Brien (1931, 1969), in a field study of inlets in the United States, found inlet channel area could be related to the tidal prism, and also to the average throat velocity over a tidal cycle. In addition to the throat velocity Bruun (1978) introduced the ratio between longshore transport and tidal prism as a useful indicator of stability. Hume and Herdendorf (1992) demonstrated the effectiveness of these relationships, with good correlations being found between throat area and peak discharge, mean or maximum velocity and tidal prism. The idea of an equilibrium relationship, however, is not appropriate for situations where a river discharges through the inlet and a number of researchers (e.g. Komar, 1996; Dillenburg et al., 2004) have noted that river flow will be important in determining inlet behaviour. In some earlier work Ogawa et al. (1984) derived a modified area/tidal prism relationship taking river flows into account. The influence of river flows is further demonstrated in what are referred to as seasonally open inlets where the inlet may block during dry periods, only to be re-opened by

* Corresponding author.
E-mail address: david.walker@adelaide.edu.au (D. Walker).

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seasonal flows (Bally, 1987; Tanaka et al., 1996; Elwany et al., 1998; Ranasinghe and Pattiaratchi, 1999).

The mouth of the River Murray, shown in Fig. 1, provides an example of an inlet to a coastal lagoon, the Coorong, where much of the behaviour is driven by river flows. Over the last 50 years the size and position of the mouth and the build-up of sediment in the lagoon have been observed to alter considerably. In 1981 the mouth was completely closed by a plug of sand. In fact closure should be considered a relative term since an inlet may be considered open or closed based on the level of the tide. For example, a closed mouth at low tide may allow inflows at high tide. At the time the mouth closed it was initially only at low tide but coastal processes built-up a plug of sand that closed it completely. The final closure followed an extended period with no flow from the river during which time significant volumes of sand entered the mouth and were deposited on an extensive area of shoals and tidal flats in the lagoon. Fig. 2 shows the mouth at the time of closure and Fig. 3 shows the mouth in May 2000. The closure highlighted a number of environmental and social concerns, such as the risk of flooding in the lower lakes area should river flows arrive, the effects on the breeding cycle of fish populations inhabiting the Coorong, and general concerns about water quality in the Coorong. In addition the Coorong is one of the 1401 wetlands covered by the Ramsar Convention on Wetlands which was signed in Iran in 1971 with the purpose of protecting wetlands of international importance. The range of concerns is in line with an observation by Goodwin (1996) that "interest in tidal inlets has expanded to incorporate water quality, ecological, flooding and public safety issues".

Work since the 1981 closure of the Murray mouth has focussed on the effects of reducing river flows and how management might best use a diminishing river flow to maintain an effective opening. The hydrologic effects of regulation have been discussed by many authors (Harvey, 1988; Thomson, 1992; Walker and Jessup, 1992; Bourman and Barnett, 1995; Blanch et al., 1999; Walker, 2000; Close, 2002) and it is believed significant, based on numerical water-balance modelling of the whole river system, that average annual and monthly flows are substantially lower than they were under natural conditions. For the purpose of this work natural conditions are assumed to refer to those that were in existence prior to the construction of the barrages and the many dams and reservoirs that now exist along the river. For example, in 1994 the flow at the Murray mouth was only 21% of the natural annual median. The median annual natural flow now is exceeded only 8% of the time, compared to 50% of the time under natural conditions, and drought conditions occur at the mouth 1 in 2 years rather than 1 in 20 under natural conditions.

The closure in 1981 demonstrated a need to understand the physical processes of a coastal inlet and lagoon system that, while dynamic, also showed a trend towards a congested state. In the past, authors have used a number of means to estimate net transport through

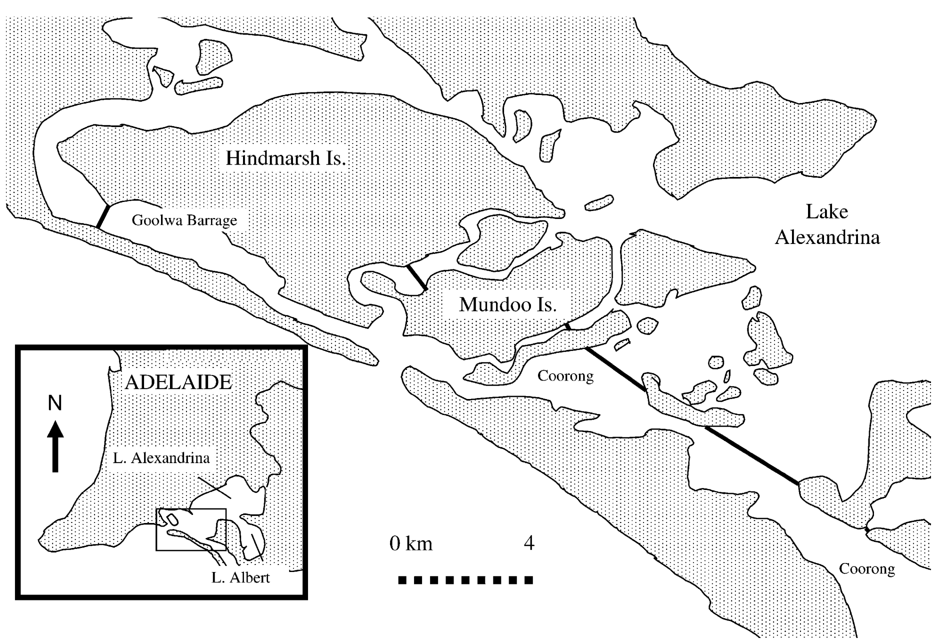

Fig. 1. The River Murray mouth and environs. Lake Alexandrina is one of two fresh-water lakes protected from coastal waters by a series of five barrages. The Goolwa Barrage has a water level recorder on the ocean side. The coastal lagoon, known as the Coorong, extends for a distance of approximately 140 km to the south-east.