

Coastal Management Issues for the Mouth of the River Murray, South Australia

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Abstract *This paper examines the management issues relating to the potential closure of the mouth of Australia's largest river. The importance of maintaining the river mouth is outlined, together with the implications of restricted river flow and the management response following the most recent closure of the mouth in 1981. One of the major unresolved issues is the question of responsibility and funding, which has arisen because of overlapping jurisdictions on either side of the river mouth and a lack of jurisdiction for the mouth itself, which is an administrative boundary.*

Introduction

The River Murray has the highest mean annual runoff (22,700,000 MI) of any Australian river and together with its tributaries it forms the largest river system (1,056,000 km²) in the country (Brown, 1983). However, the Murray Mouth, which is in the state of South Australia, became completely blocked with marine sediment in 1981 and this prompted a government enquiry into the causes of the blockage and the implications of this for management.

The Murray Mouth is not important for navigation but the area around the mouth is significant for recreation and its value as a fishery. In addition the adjacent Coorong Lagoon has a high conservation significance. These factors, together with the potential for flooding and deterioration of water quality, caused public concern following the 1981 blockage of the Murray Mouth.

The River Murray is South Australia's most important water resource, providing water for irrigation, stock, domestic, and industrial purposes over a large area of the state. In dry periods the river supplies up to 90 percent of water for metropolitan Adelaide, which has a population approaching one million. The River Murray catchment is mainly in the eastern states of Australia and there are no major tributaries downstream of the South Australian border. In South Australia the river has a low-gradient 630-km course from the border to the sea. It enters Lake Alexandrina and the Coorong Lagoon before flowing out to sea in Encounter Bay (Figure 1).

Five barrages were built near the Murray Mouth in the late 1930s to combat problems of salt water incursions into the lower reaches of the river and the terminal lakes. These barrages were constructed upstream of the channel connecting the Murray Mouth to the Coorong (Figure 1), thus maintaining tidal flushing of this hypersaline coastal lagoon.

Since the barrages were constructed there have been about twenty periods when there has been no flow through the barrages for 100 consecutive days or more. During this time an extensive flood tidal delta has built up (Bourman and Harvey, 1983) and is increasing

in size. In the 1940s a small vegetated sand island existed. Today the vegetated section of the delta covers an area of 2,000 m² surrounding the original sand island which is now up to 4 m high. An additional area of 3,000 m² of sand flat has formed on the seaward side of the delta and is becoming progressively more stabilized as it is colonized by vegetation. The development of this flood tidal delta is discussed in detail by Bourman and Harvey (1983). An analysis of river flows and in particular the implications of low flow is also discussed elsewhere (Engineering and Water Supply Department, Adelaide, 1981).

Although lack of river flushing is a major factor in the buildup of sediment within the mouth, this sedimentation is also related to tides, sea and weather conditions, littoral drift, and to some extent aeolian sand. The tides are microtidal in range with a spring high-water range of 0.8 m at nearby Victor Harbor, although storm surges of over a meter may influence sediment deposition. Low tides affect the flushing of the mouth by reducing the size of the tidal prism within the inlet. During the mouth closure of 1981, unusually calm sea conditions combined with a period of low tides to produce sediment accretion at the Mouth. Simultaneously with the constriction at the Mouth the tidal amplitude within the Coorong decreased, providing even less internal flushing.

Littoral drift approaches the Mouth from both directions (Harvey, 1983), although the rate of drift has not been calculated. Littoral drift has probably been an important influence on the position of the Mouth, which has fluctuated over a distance of 1.4 km since it was first surveyed in 1837 and even more during the Holocene (Bourman and Harvey, 1983).

The wave climate at the Mouth is characterized by persistent year-round moderate to high swell with storm seas superimposed. Wave data from Cape Northumberland to the southeast of the Murray Mouth indicate a modal swell wave of 2–4 m for 62 percent of the year and superimposed locally generated waves of > 1.0 m for 68 percent of the year (Short and Hesp, 1980). High swell (> 4.0 m) occurs 6 percent of the time and high energy storm waves (> 2.5 m) for 12 percent of the time. The swell approaches the Murray Mouth from the southwest and storm-generated waves are predominantly from the south and southwest. The coast at the Mouth has a high offshore gradient producing only 20 percent loss of wave power (Short and Hesp, 1980). Thus the high energy conditions are a major factor controlling the influx of marine sediment to the Mouth.

Storm tides of up to 1.5 m can raise water levels outside the Mouth, but this factor is dissipated by the large body of water inside the mouth. A more significant effect may be caused by a relative sea level rise and in particular any eustatic sea level rise resulting from the Greenhouse Effect over the next 50 years.

Management Issues Relating to Closure of the Murray Mouth

The Murray Mouth became completely blocked with marine sediment in April 1981, causing concern for rising salinity levels in the adjoining Coorong Lagoon and the potential for damage to the ecology and associated fishing and tourism industries. The fishing industry alone has an estimated income of \$1.5 million per annum from the area, although the potential value of the fishery is estimated to be around \$4.0 million per annum. Unless the Mouth was opened artificially it was feared that there would be a deleterious effect on the fishing industry and the general ecology of the Coorong, which in turn would affect the tourist industry. In addition, the rising waters could cause flood damage in surrounding areas.

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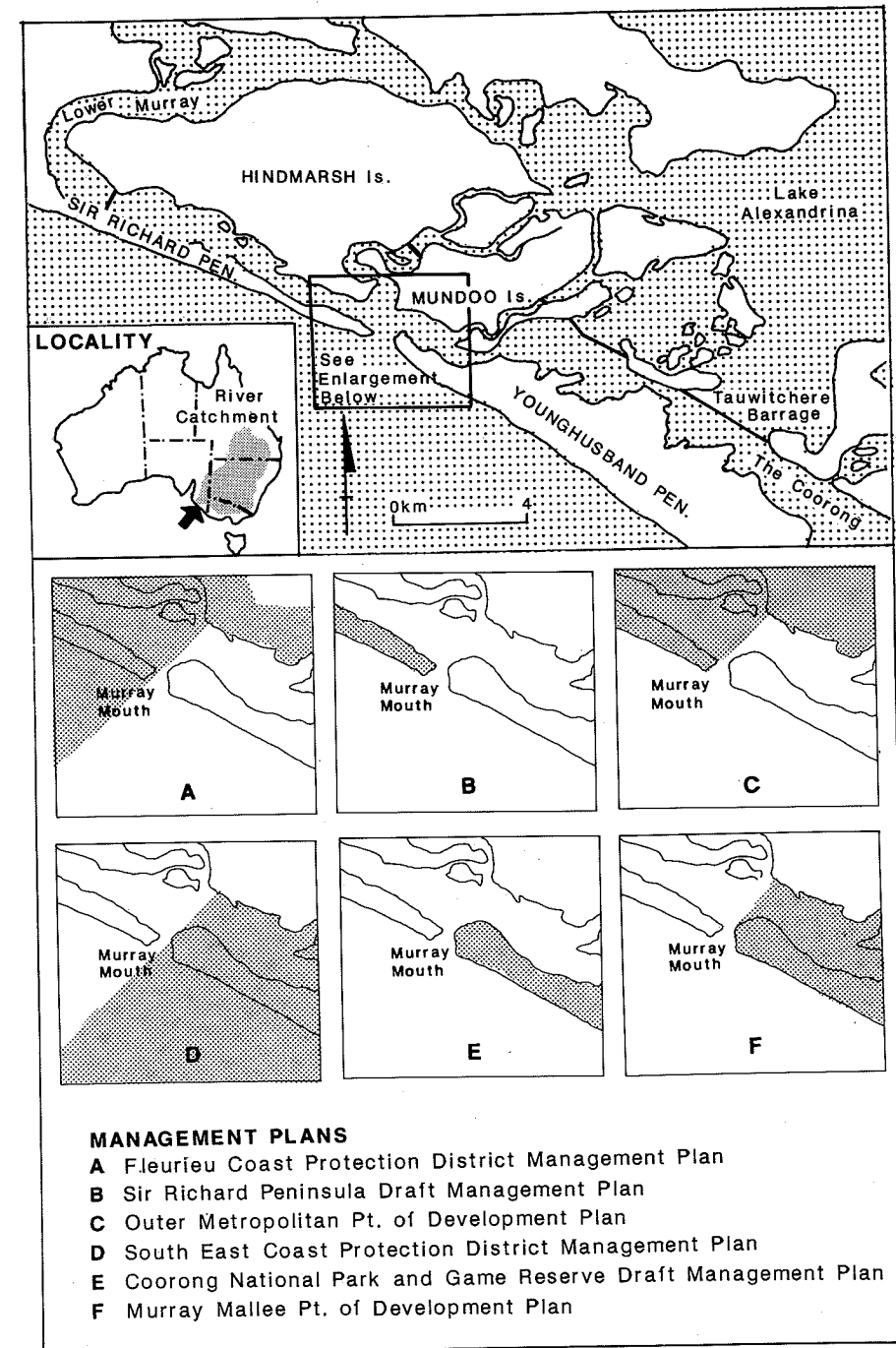


Figure 1. Location map of the Murray Mouth and area covered by management plans.

The closure of the Murray Mouth affects the activities of at least five separate South Australian Government departments: Department of Fisheries, Department of Environment and Planning, Engineering and Water Supply Department, Department of Marine and Harbors, and the Department of Tourism. In addition, the River Murray Commission (involving the Commonwealth and three state governments) has a responsibility for the flow in the river and two local councils have a responsibility for the foreshore near the Mouth. Although there are a number of authorities involved, there is no particular authority or defined responsibility for remedial action in response to the blockage of the Mouth. However, there is equally no obstacle to the Government performing works on Crown land in the public interest.

Within South Australia the River Murray (including the Mouth) is a proclaimed watercourse pursuant to the Water Resources Act (1976 and amendments to 1981). Under this Act the Crown could be responsible for removing an obstruction to river flow, but since the Act is aimed at conserving water, the opening of the Mouth would have the opposite effect. However there is nothing in the Act to prevent an artificial opening of the Mouth.

The River Murray is also a proclaimed harbor pursuant to the Harbors Act (1936-74 and amendments to 1981). Under this Act the Minister of Marine is to maintain and cleanse harbors at his discretion, but since the Act is aimed at the management and control of port services and shipping activities there appears to be no obligation to maintain a navigable channel in the Murray Mouth, which is rarely used because of the high energy coast and unpredictable shoals. The Act, however, does not prevent the Minister from maintaining a navigable channel.

The use of River Murray water involves a number of states, and consequently an agreement between the various governments governs the quantity and quality of water reaching South Australia. This agreement is incorporated in the River Murray Waters Act (1983). A blockage of the Murray Mouth could in the terms of River Murray Waters Agreement (1982), clause 34, be attributable to "the construction, maintenance, operation or control of any works provided for in this Agreement or the former Agreement." The River Murray Commission is not required under the Act to clear the Mouth. It may have the power to meet the costs of clearing the Mouth if it wished to do so, even though it would not be obliged to do so.

In addition the Murray Mouth is subject to the Coast Protection Act (1972-75 and amendments to 1985), which is directed more towards combating erosion of the coast rather than problems associated with accretion. The Mouth is included in the management plans for both the Fleurieu Coast Protection District (1984) and the South East Coast Protection District (1986), but the boundary for these protection districts is the Mouth itself (Figure 1). Although the closure of the Mouth is raised as an issue in the South East Coast Protection District Management Plan, neither the Coast Protection Act or the management plans have any policies relating to closure of the Murray Mouth.

Also, any development in the area would be subject to the Planning Act and associated Development Control Regulations contained within the Development Plan (Planning Act 1982, amendments to 1987 and Development Plan). However, this Plan is divided into a number of parts, two of which have the Murray Mouth as a boundary (Figure 1). At present, development at the Murray Mouth is limited to a few shacks on the Younghusband Peninsula.

On the seaward side of the Mouth the foreshore (down to low water mark) on Sir Richard Peninsula is the responsibility of the Goolwa and Port Elliot Council, and on the Younghusband Peninsula the responsibility of the Meningie Council pursuant to the

Harbors Act. However, this responsibility stops at the Mouth itself since it is a proclaimed harbor. Within the Mouth the foreshore is the responsibility of the Department of Marine and Harbors.

The peninsulas on either side of the mouth are controlled by different bodies. The Younghusband Peninsula is part of the Coorong National Park pursuant to the National Parks and Wildlife Act (1972-74 and amendments to 1981). A Draft Management Plan (1984) was prepared for this park but has not yet been approved, largely because of the contentious issue of off-road vehicle access to the ocean beach.

On the opposite side of the Mouth, most of the land on Sir Richard Peninsula is vested in the Minister, Water Resources for the purposes of the River Murray Waters Act. Recently a Draft Management Plan for Sir Richard Peninsula (1987) has been prepared. This plan considers a number of management options for the peninsula, including a plan to construct fencing costing \$30,000 per km at the tip of the peninsula, where it is most sensitive to erosion.

Previous Studies of Multiple and Conflicting Interests Relating to Coastal Management

The issues of policy determination for the Murray Mouth and the problems of overlapping jurisdiction can be related to previous studies outside Australia in three ways: 1) the ecological issues in policy determination; 2) the problem of overlapping jurisdiction; and 3) case studies from similar biophysical environments.

First, the ecological concern about the closure of the mouth can be related to a discussion in the first issue of this journal where Walker (1973) raised the issue of the role of science, and in particular ecological arguments, in natural resource policy making. He questioned the method by which ecologists determined the value of wetlands preservation and challenged the myth of scientific proof in policy determination. This article sparked a response (Odum and Skjei, 1974) which argued for the scientific value of wetlands and suggested that any uncertainty in the applicability of scientific findings does not detract from their value in policy formation. In reply Walker (1974) suggests that the scientific evidence on wetland productivity merely leads to economic arguments and traditional values whereas the determination of the values themselves remain an issue and, according to Walker, the preservationists have more to contribute to this argument than the scientists.

Second, the problem of overlapping jurisdictions in coastal management has been raised by a number of authors outside Australia. In the United States, the Coastal Zone Management Institute (1974) produced a technical guide in which they illustrated boundary definition problems in the coastal zone and in particular the recognition of jurisdictional units. This document raised the problem of having a variety of jurisdictions which may conflict with any attempt to develop a comprehensive coastal zone program. The Massachusetts coastal wetlands was quoted as an example where a specific area is controlled and protected by numerous jurisdictions at the local, state, and federal levels (Coastal Zone Management Institute, 1974).

In a general discussion of coastal policy issues, Ditton, Seymour, and Swanson (1977) discuss the resolution of conflict in coastal management and point out that before the United States Coastal Zone Management Act of 1972 there were twenty federal bureaucracies which had an oversight of some aspects of coastal management. In addition, the federal presence prevents the confusion of numerous state regulatory systems (Ditton, Seymour, and Swanson, 1977).

Similarly, Mazmanian and Sabatier (1983) illustrate the problem of coastal jurisdiction with a discussion of the Californian Coastal Commissions 1972–77. It was estimated that approximately fifteen counties, forty-five cities, forty-two state agencies, and seventy federal agencies had jurisdiction over some aspect of coastal resources. In response, a Coastal Plan adopted in 1975 recommended, amongst other things, a broadened jurisdiction for the coastal agency with an allowance of four years for local governments to bring their land use plans and zoning ordinances into conformity with Coastal Plan policies. Mazmanian and Sabatier use the largely successful coastal land use regulations in California as an example to demonstrate the applicability of their theoretical framework and conditions for the implementation of public policy (Mazmanian and Sabatier, 1983).

Third, recent case studies draw parallels between the biophysical parameters of the Murray Mouth and the related management issues. In Massachusetts a coastal study of the Wood End Inlet reveals that a prograding flood tidal delta is gradually infilling the inlet, although National Park Service regulations protect the inlet from being artificially closed (Ashley, 1987). However, the study, which is directed at the hydraulics and longevity of the inlet, stops short of examining the management implications of closure.

Another study examines the conservation problems and management options for the Bot River estuary in South Africa (Bally, 1987). This case study is particularly interesting since the issues of a closed river mouth, potential for flooding, and effect on a fishery closely parallel the Murray Mouth example. The Bot River estuary has been subject to artificial opening every two to five years for the last one hundred years. This practice has allowed fish breeding within the estuary. In 1977 the Cape Department of Nature and Environmental Conservation put an end to the practice of artificial opening on the grounds that the estuary should be allowed to develop into a completely natural system (Bally, 1987).

Opposition to this policy came from three sources: 1) fishermen who claimed that fish could no longer enter the estuary; 2) a yacht club which was concerned about flood levels and weed growth; and 3) a local municipality concerned about flooding of a caravan park. The pressure to open the estuary resulted in authorities artificially breaching the estuary in 1981 at a level 1.7 m above MSL (Bally, 1987). However, the lack of seawater flushing reduced salinities and killed nine fish species and the mouth was reopened to allow seawater in. Subsequently further conflict developed because of rising salinities and low water levels. In 1984 high water levels and storm waves caused damage to the yacht club, but authorities resisted pressure to reopen the estuary (Bally, 1987).

The above case studies place the Murray Mouth example in context, although many of the problems of overlapping jurisdiction elsewhere relate to the control of development in the coastal zone. This is not the case with the Murray Mouth, where the issues are more closely related to the natural environmental issues of the South African example. However, the Bot River estuary in South Africa does not have the same problems of overlapping jurisdiction as the Murray Mouth and unlike the Murray Mouth could be effectively managed as either a partial estuary or as a freshwater coastal lake.

Management Response to the Murray Mouth Closure of 1981

Although there was not a clear mandate for any authority to open the Murray Mouth, the Engineering and Water Supply Department of South Australia considered that it was most appropriate for that Department to act in the public interest. Consequently the Mouth was artificially opened in July 1981, to prevent flooding of towns, shack sites, and agricul-

tural land around the lakes. After the Mouth was opened, strong river flows maintained the opening, which increased to a maximum width of 150 m and a depth of 7 m. In the four months to December 1981 a total flow in excess of 7 MI flowed out to sea.

The Australian Commonwealth Senate Standing Committee on Science and the Environment undertook an enquiry into the implications of low flow and the closure of the Mouth. The Senate Standing Committee visited the Mouth on May 15, 1981, and held a public hearing in Adelaide June 22–23, 1981.

The Senate Standing Committee issued a report in November 1981 recommending that a number of measures were appropriate for action by the South Australian Government:

- (1) The more stringent controls on the activities of off-road vehicles being considered by the South Australian Government should be introduced as soon as possible.
- (2) The relevant South Australian authorities should closely monitor the environment of the Coorong and in particular the impact of fluctuations in salinity and water levels in order to benefit native flora and fauna.
- (3) In view of the widespread public concern at the recent closure of the Murray Mouth, the Engineering and Water Supply Department should consider the advisability of keeping the public fully informed of its investigations into the possible long term solution to the periodic restriction of the Murray Mouth.

Following on from the Commonwealth Senate Standing Committee's recommendations, the South Australian Engineering and Water Supply Department monitored the behavior of the Mouth. In June 1982 there was a renewed concern that the Mouth could close again. The South Australian Minister for Water Resources approved the formation of the Murray Mouth Advisory Committee (MMAC) to oversee the monitoring of the Mouth. The MMAC has now prepared two progress reports. The first of these (Murray Mouth Advisory Committee, Progress Report No. 1, 1983) examined some of the physical factors involved in closure of the Mouth and identified a number of management options including:

- (1) Use of freshwater stored in the Lower Lakes to clear the Mouth when necessary;
- (2) Dredging the inlet to improve tidal flow;
- (3) Provision of temporary groynes to prevent sand being delivered to the Mouth and carried in by tides;
- (4) Installation of drift fencing on the Youngusband Peninsula.

In the event of closure in 1983 it was recommended that drift fencing be erected on the Youngusband Peninsula. It is interesting to note that the Draft Management Plan for the Coorong National Park does not contain a similar management strategy. It was also recommended that the Mouth should be artificially opened prior to adequate winter flow, or if flow was not adequate, to wait until spring. In any event there was a need to have an opening in spring–early summer to facilitate Mulloway breeding. It was also recommended that if remedial action was necessary, then the River Murray Commission would be requested to bear the cost. However, no action was taken in 1983.

Since the first report in 1983, the MMAC has continued to monitor the Mouth and to conduct further research. These results are presented in a second progress report (Murray Mouth Advisory Committee, Progress Report No. 2, 1987). First, the flood tidal delta is increasing in size and gradually becoming stabilized with vegetation. Second, the area of

shoals within the Mouth is also increasing in size. Third, there is evidence that there is a gradual increase in average salinity levels in the Coorong. Fourth, the fishery in the Coorong is adversely affected by reduced freshwater flow rates and restriction of the Mouth. Fifth, the probability of low flow events (similar to those preceding closure of the Mouth in 1981) has increased significantly with regulation of the river and have a recurrence interval of six to eight years. A severely restricted Mouth is substantially cleared by an outflow of 20,000 MI per day for one month or more.

In the event of closure of the Mouth the report has similar recommendations to those contained in the first progress report. If winter river flows are adequate then the Mouth should be artificially opened. If the flows are not adequate it is recommended that the Coorong be connected to the Lower Murray channel as well as the major portion of a common channel to the sea, followed by dredging an opening to the sea prior to adequate river flows. If flows are inadequate it may still be necessary to dredge an opening to the sea in late spring-early summer to facilitate Mulloway breeding (1).

A number of options were also considered by the MMAC in 1987 to prevent closure of the Mouth. Construction of permanent groynes was ruled out because of the variable position of the Mouth. Temporary groynes were also considered, but the cost factor is above that required to open the Mouth artificially once it became closed. The cost for temporary groynes is estimated to exceed \$0.5 million and the groynes would have to be reconstructed at intervals of five to ten years.

A second option identified in the first progress report was to use water stored in the lakes to clear the Mouth. The cost of using water stored in the lakes solely for clearance of the Mouth would have too great a risk factor for South Australia's water supply. For example, the existing water allocation policy limits withdrawals from the river by imposing a penalty charge of \$620 per MI (River Murray Water Resources Review, Management Proposals, 1987). A similar hypothetical cost factor applied to the required 20,000 MI per day for flushing purposes indicates that if costs were considered they would be prohibitive. However, the second progress report in 1987 presents results which demonstrate that although spill from the lakes is unlikely by itself to be sufficient to clear the Mouth, it could be effective if combined with fresh water flow in order to clear some of the sand at the Mouth.

A third option, to erect drift fencing on the Younghusband Peninsula to prevent wind-blown sand from entering the Mouth, would only result in a partial amelioration of the problem. For this reason it has not been costed.

The fourth and main option is dredging within the inlet. This is still considered to be the most cost-effective method of clearing the Mouth. The cost for this option is likely to be between \$0.25 million and \$0.3 million.

In addition, the report recommends that further investigations and a monitoring program be carried out. First, there is a need to investigate the effects of Mouth restrictions on the economics of the fishing industry. Second, it is necessary to determine the relationship between freshwater flows, Mouth restrictions, and Coorong salinities. Third, the report recommends monitoring of (1) vegetation colonization of the flood tidal delta and the tips of the two peninsulas, (2) flow through the Mouth itself at times of significant flow change, (3) the form of the channels and sand bars within the Mouth (using hydrographic surveys and aerial photography), (4) tidal fluctuations downstream of Goolwa and Tauwichee barrages and comparison with sea tides at Victor Harbor, and (5) the bathymetry of the Goolwa and Tauwichee channels. It is estimated that the monitoring program alone, if approved, would cost around \$150,000 per annum.

Discussion

There is still some debate over the funding of the proposed management strategies, but funds would come from either South Australia or the River Murray Commission or a combination of both. Of the five state departments involved, only the departments of Tourism and Fisheries would benefit by way of income to the industries they serve. Thus it would be difficult to justify funding from the other departments.

The management response has attempted to solve the problem at the mouth of the river in isolation from the rest of the river instead of integrating a management strategy with overall river management or with the strategies contained in the juxtaposed management plans at the Murray Mouth. It would, for example, be possible to incorporate management principles relating to the Murray Mouth into each of the management plans surrounding the Mouth. In addition, upstream river management could be modified to allow sufficient water through the barrages to flush the Mouth. For example, the MMAC noted that a severely restricted Mouth is substantially cleared by an outflow of 20,000 MI per day for one month or more.

Although preliminary flushing experiments have been conducted by the Engineering and Water Supply Department using water from lakes Alexandrina and Albert, there is clearly a need for further research to investigate the linkages between river mouth closure, tides, sea state, freshwater flows, and Coorong salinities. It is unlikely that a detailed study would be conducted unless the management of the area became a political issue.

There is also the issue of sea level rise which has not yet been addressed, although the South Australian Coast Protection Board has already adopted a policy of ensuring that new development can be protected from a 0.15 m per 100 years eustatic sea level rise. This figure is an estimate based on worldwide tide gauge data, the accuracy of which is still open to debate. There is also the debatable level of Greenhouse Effect sea-level rise which has to be considered. A sea-level rise of up to 1.0 m within the next fifty years would cause greater erosion of the peninsulas on either side of the Mouth, create a wider expanse of wetlands inside the Mouth, and cause a more frequent overtopping of the barrages.

The barrages at the Murray Mouth are intended to keep the freshwater lake level above sea level. However, the sea currently flows over the barrages several times a year. A significant relative sea-level rise in the area may require the barrages to be raised. Interestingly, one water management option being considered by the South Australian Government is to construct a weir at Wellington, upstream of the terminal lakes Alexandrina and Albert (Mazmanian and Sabatier, 1983). Although this option is not currently economically or environmentally favorable, it could become a viable alternative to raising the barrages at the Murray Mouth if some of the higher Greenhouse Effect sea-level predictions occur.

The case of the Murray Mouth has implications in general for the management of river mouths where a number of authorities have overlapping jurisdictions on either side of the river and the river itself is used as an administrative boundary. The Murray Mouth management involves various state authorities, whereas the issues may become compounded if a river mouth forms the boundary for separate governments. For example, the training walls or jettied entrance of the Tweed River at the Queensland/New South Wales state boundary in eastern Australia has interrupted the northerly littoral drift of sand. Consequently the New South Wales coastal management strategies may adversely affect

the Queensland coast and may require an integrated approach to coastal management at the state boundary.

Conclusions

It is apparent that the use of the River Murray as an administrative boundary has resulted in the juxtaposition of various authorities, none of which have any direct responsibility for the Murray Mouth. This is highlighted by the number of management plans on either side of the Murray Mouth which fail to address the management problems relating to the potential closure of the Mouth. No fewer than six separate authorities have a management responsibility for the sand bodies on either side of the Mouth and possibly three authorities have some form of responsibility for the Mouth itself.

The fact that the responsibility for maintenance of the Mouth is not clearly defined and the fact that the Mouth has a variable position has created a reluctance by any authority to accept that responsibility. There is also debate over funding for any ameliorative action taken to prevent closure of the river mouth. Unlike many of the overseas case studies, which illustrate problems relating to overlapping jurisdiction; this case study illustrates overlapping jurisdiction on either side of the Murray Mouth and a lack of jurisdiction for the Mouth itself, which is an administrative boundary.

Elsewhere many problems of overlapping jurisdiction in the coastal zone often relate to issues of development control or conflicts in use. This is not the case for the Murray Mouth, where a natural event has environmental consequences. There are management parallels with the Bot River estuary in South Africa. However, the Bot river mouth does not appear to have the same jurisdictional problems as the Murray Mouth and, unlike the Murray Mouth, could be effectively managed as either a partial estuary or as a freshwater lake.

The management response for the Murray Mouth has been to investigate the physical parameters relating to the closure of the Mouth itself rather than to integrate management of the Mouth with the adjacent sand bodies or with the overall river management. In particular, the upstream effects of river regulation and consequent periods of low flow are important factors for consideration in the coastal management of the Murray Mouth.

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Note

1. "Mulloway," or *Argyrosomus hololepidotus*, occurs around the subtropical and temperate shores of Africa and Australia. Although Mulloway is not a commercially important species in South Australia, the Coorong is the only known breeding area and consequently is of high conservation significance.

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