

## Saltwater Intrusion, Lower Mary River, Northern Territory Australia.

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**ABSTRACT.**

The floodplains of the Lower Mary River lie close to Darwin and are a valuable cultural and economic resource. The floodplains support a wide variety of plant and animal communities that are dependant on the extensive freshwater system. This area has been extensively degraded by saltwater intrusion and as

the extent of the intrusion increases to expand much more of the freshwater habitat is under threat. This paper gives a brief overview of the studies that are being conducted in order to limit further saltwater intrusion.

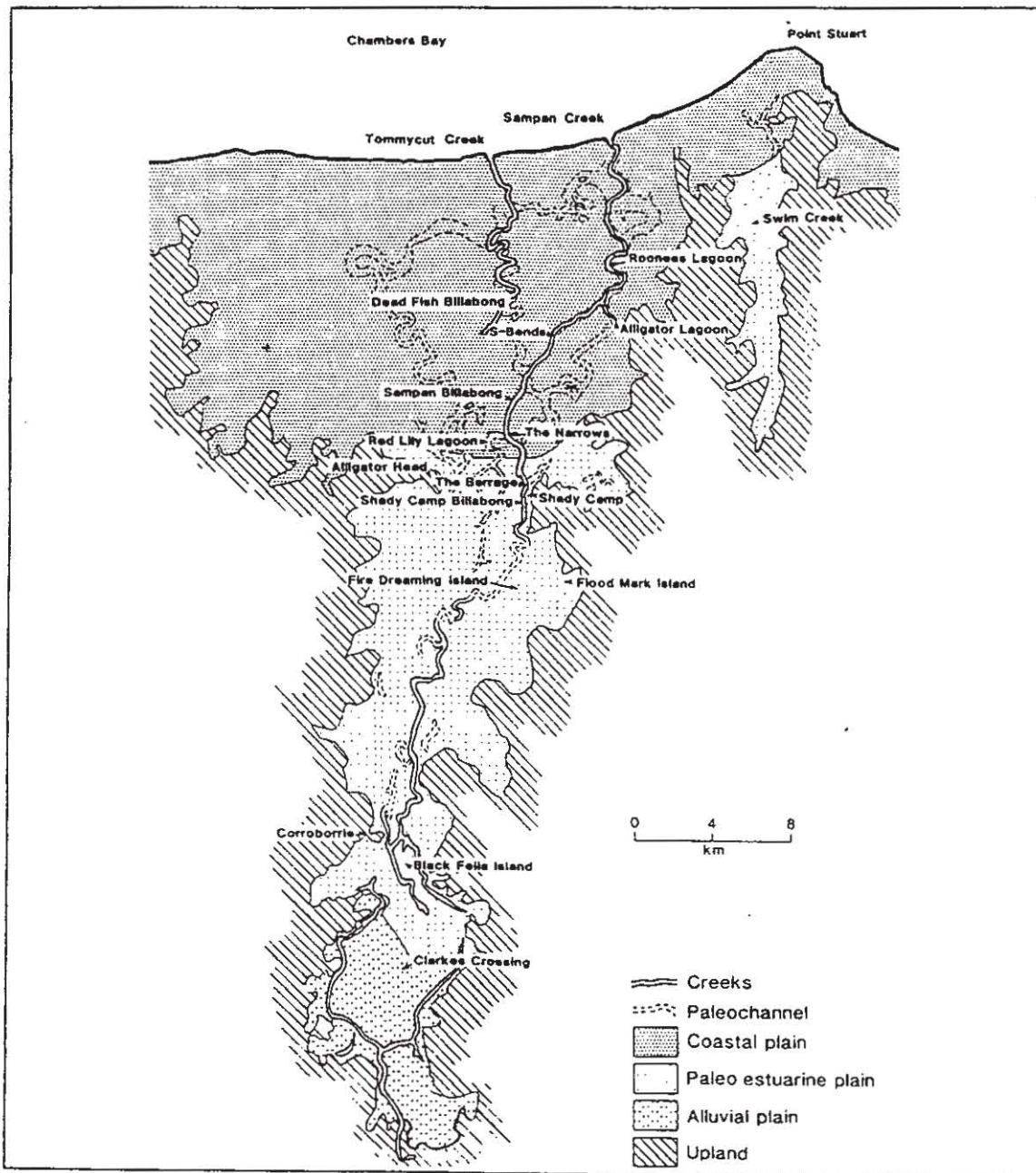


Figure 1. The Lower Mary River floodplains.

## INTRODUCTION.

The Mary River has a catchment area of 9000 square kilometres and drains northward into Chambers Bay via two tidal tributaries (Sampan and Tommycut Creeks) 80 kilometres to the east of Darwin (fig 1). The last 100 kilometres of river form the wetlands and 35 kilometres are under tidal influence. The wetlands cover an area of 3000 square kilometres and comprise a large area of salt marsh and an equally extensive area of fresh water billabongs. The climate is wet dry monsoonal and the average annual rainfall is 1500 millimetres, which falls in the wet season from November to March.

These wetlands support a great variety of life. They contain ecologically significant stands of paperbark (*Melaleuca*) forest, perhaps some of the largest in area in the top end of the Northern Territory. At present the region supports agriculture, commercial and recreational fishing, tourism and conservation parkland. It is the breeding ground for fish (especially barramundi) and many species of water birds. It has the densest population of saltwater crocodile per river kilometre in the Top End and is a valuable beef producing area.

The floodplains are unique amongst Northern Territory coastal floodplains as until recently there has been no significant estuarine development. This lack of estuarine development has not provided a distinct outlet for the annual wet season flood waters to escape to the sea. Annually this vast expanse of water spread out over a large area where it slowly evaporated and infiltrated. The floodplains have had several channels formed on them during the rapid progradation that began in the Holocene (Woodroffe et al 1993). Evidence from drill cores suggests that these channels were wider and shallower than those that are forming at present. Flow paths have changed their course on the floodplains over time and the mechanism of channel switching is not well understood. It is probable that the channel switching occurred concurrently with the formation and breaching of chenier ridges at the previous coastlines. When a chenier ridge forms it can create a barrier that limits the entry of tidal waters onto the floodplain. During this time the channels can fill

with alluvial sediments carried by the wet season floods. If a chenier is breached a new flow pathway is formed and the channels may change their course. Chenier formation has been episodic over the evolution of the floodplain with the last cheniers being formed between 1000 to 2000 years ago (Woodroffe et al 1993).

## SALTWATER INTRUSION.

Saltwater Intrusion has been increasing in the Lower Mary River wetlands since at least the 1940s. This is evident from an examination of aerial photographs and the water level recording station that existed at Roonees Lagoon (14 kilometres inland) from 1958. The main channel of Sampan Creek was at that time narrow and discontinuous. A survey of the channel form of Sampan Creek at Roonees Lagoon in 1963 shows that the width of the stream was 25 metres and the maximum depth was 1.5 metres. The 1994 survey shows that the stream is now 90 metres wide with a maximum depth of 7 metres (fig 2). It is evident from the available air photography that many changes have occurred to the network of channels on the Lower Mary floodplain. Most noticeable has been the growth in density of tributaries and the widening and deepening of the main channel. Associated with the increase in channel dimensions has been a marked increase in tidal range. In 1959 the tidal range at Roonees Lagoon was only small (a maximum of 0.3 metres) (fig 3) and the channel networks were only beginning to branch out onto the floodplains. When compared to Darwin Harbour tides which are indicative of the deep ocean tides it can be seen that spring tide conditions forced more water inland and that the Roonees Lagoon tide levels in 1959 are composed of two superimposed tides. One component of the tide shows the monthly spring and neap cycle while the other component shows the semidiurnal cycle. This indicates that some barrier may have been present that restricted the exchange of tidal waters between Roonees Lagoon and Chambers Bay. Current recorded water levels show that the tidal variations at this location are now at a maximum of 4 metres. It can be shown that the top of the main channel's banks are regularly overtopped by spring tides and that tides flow into the tributaries under all conditions (fig 4).



figure 2. Change in cross sectional form.

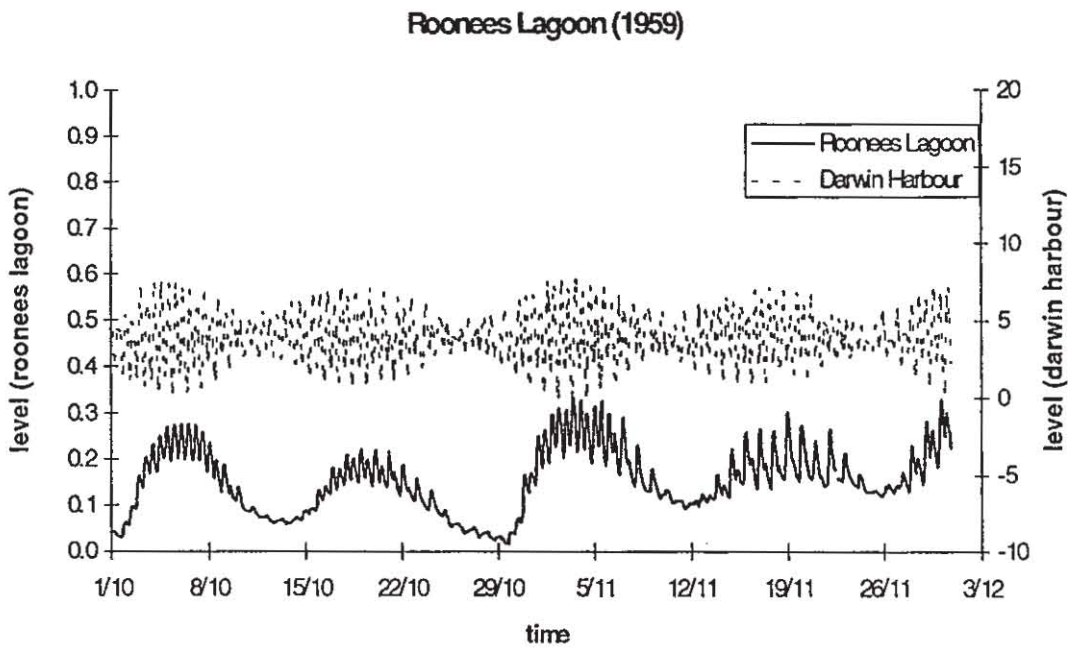


figure 3. 1959 tides at Roonees Lagoon compared to ocean tides (note difference in scale).

## Roonees Lagoon (1993)

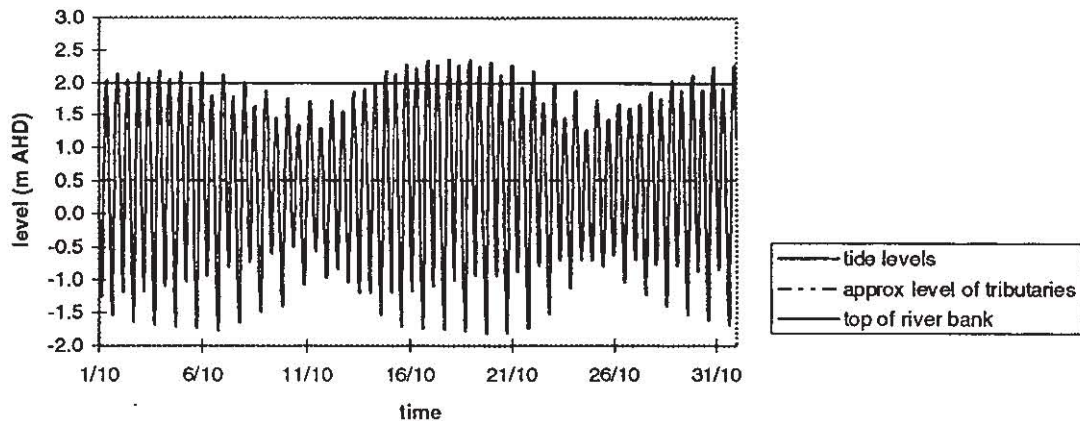


figure 4. 1993 tidal ranges at Roonees Lagoon.

Tidal variations were not seen at Shady Camp (35 kilometres inland) until 1980 where the maximum variation was 0.1 metres. This variation had increased to 0.5 metres by 1989 and in 1994 had reached a maximum of 2 metres. A barrage was constructed at this location in 1989 to prevent the saltwater from moving further upstream.

Tidal energy is persistent and the existing barriers that were at the coastline have deteriorated with time. Once these barriers, which are believed to be the chenier ridges, are breached their cemented resistant outer layer is severely weakened exposing them to erosional forces. As a result of this erosion more tidal energy is allowed to enter the Sampan and Tommycut Creek systems. This results in an increase in the volume of saltwater that can move into the channel networks. The channels respond by widening and deepening to accommodate the increased volume and this in turn applies more erosional stress on the system. Coupled with the increase in tidal volumes is the annual wet season flooding, the majority of which is borne by Sampan Creek. The additional concentration of energy results in the rapid erosion of the channel networks.

Bank slumping is prevalent throughout the tidal creek network. The large tidal range ensures that the banks remain saturated for much of the time. The banks have negligible shear resistance and continual positive pore pressures cause them to eventually slump into the river. This destroys the minor levees that have formed and the ensuing tides flood overland. The floodplain soils, which are black cracking clays, eventually sodify and lose coherence. The soil

texture becomes peppery and is removed by wind and tidal movement. Small tributaries form in these areas and extend by tidal gullying, which consists of headward retreat and bank undercutting.

At present the mouth of Sampan and Tommycut Creeks experience the same tidal range as the offshore ocean tides and show no sign of reaching equilibrium conditions in the near future as they are still actively eroding. The tributary networks continue to expand and the channels widen and deepen. This allows more saltwater onto the floodplains and the erosion hazard increases. It is not possible to predict what the system may evolve to if left unchecked but the worst case scenario is that Shady Camp will experience much larger tides which will result in the overtopping or sidestepping of the barrage and the invasion of the extensive upstream freshwater habitat by saltwater. Additionally, based on the rate of growth of the tributary network, the area between Sampan and Tommycut Creeks could become a large shallow tidal inlet and the extensive floodplains and freshwater habitats to the west of Tommycut Creek could be invaded.

The growth of the main channel and the tributary network has altered the drainage characteristics of the floodplains after the wet season. When the Lower Mary River was a discontinuous channel, with only a small opening to the sea, wet season floods would remain on the plains for long periods of time until the water was eventually removed by a combination of drainage, infiltration and evaporation. Now with an extensive network of tributaries, a continuous larger main channel

and a much wider interface with the sea, wet season floods drain more rapidly. Water level records show that in the 1960s the floodplains would be inundated for up to 8 months. Since the mid 1990s the floodplains are only remaining inundated for up to 4 months. It is likely that the expansion of the channel system is caused by the erosion of the chenier ridges at the coast. The degradation of the coastal barriers may possibly be the result of major coastal storms, cyclones or flood events which had sufficient energy to transport the nearshore sediments offshore to be lost from the littoral system. Alternately the instability of the estuary may be linked to the instability of the coast caused by high wave energies during a major coastal event. To investigate this matter further all available aerial photographs and satellite images need to be reviewed to examine the history of the entrance condition, with the objective of correlating the entrance degradation to known coastal storms, cyclones and flood events. It has also been suggested that overgrazing of buffalo on the floodplains this century created swim channels between billabongs that enhanced erosion of the channel network. Anecdotal evidence has alleged that commercial fishing enterprises dynamited the entrance in the mid 1950s to gain anchorages for their vessels.

#### MONITORING AND MODELLING.

In November 1991 a monitoring program was initiated to gain an overview of the fluvial, estuarine and coastal processes operating in the Lower Mary River catchment. The network is aimed at effectively and efficiently collecting data to allow construction and calibration of a numerical model to describe the hydrodynamics of the lower floodplain.

Gauging stations have been installed to represent different parts of the main channels and representative tributaries on Sampan and Tomnycut creeks.

To calibrate and verify the model tidal flow gaugings are performed simultaneously at gauging stations over complete tidal cycles. Gaugings commence as close as possible to the peak of the flood tide and continue to the peak of the next flood. Velocities are measured by profiling with a directional impeller type current meter suspended from a boat. Between 5 and 10 observations are made across each gauged section, taking care to ensure that the tidal stage does not change significantly during the gauging and so affect the accuracy of the measurement. Vertical profiles are observed at 0.2, 0.6 and 0.8 of the total depth below the

water surface. A submersible pump is attached near the current meter and samples are collected at each vertical and analysed for sediment concentration, temperature, pH and conductivity.

The monitoring and modelling program aim to assist in the understanding of the hydrodynamics which are now responsible in the rapid expansion of the tidal network.

Another component of the program is monitoring and modelling the changes to the channel forms. As the tidal effect continues to encroach further inland the channel form readjusts in response to the changing energy. Mapping these changes gives a clear indication of the state of the creek system. Regular cross section surveys over the length of Sampan Creek and its tributaries commenced in 1991 and have continued on a yearly basis. Parameters that are examined are width, area, hydraulic radius and width-depth ratio. Tidal channels tend to form fairly constant relationships between these parameters and distance from the mouth of the creek. It can be shown that Sampan Creek is changing in response to the increase in tidal energy. In 1991 Sampan Creek showed a regular pattern up to the S-Bends (23 kilometres from the coast) except for an anomaly near the entrance. This anomaly was mapped as a shoal in the creek. Upstream of the S-Bends the pattern became more erratic especially in terms of the width and width-depth ratios. Upstream of the S-Bends is a series of billabongs that have now been connected to the tidal system. The 1993 surveys show that a more regular pattern is beginning to form in this reach as the tidal energy incises a new channel. The anomalous area near the entrance now conforms more closely to the regular pattern as the bar is being removed.

#### REMEDIAL OPTIONS.

If the triggering mechanisms to saltwater intrusion of the floodplains were anthropogenic due to a combination of overgrazing and other destructive activities then remedial action is required. To combat the advance of saltwater, barrages have been constructed on several of the tidal tributaries. While this has successfully slowed the saline invasion of the floodplains it has done nothing to alleviate the problem of the continual increase of tidal energy entering the system. In any estuarine system the dominant energy comes from the twice daily tide cycle. Even during periods of flooding the semi diurnal tides advance upstream underneath the flood waters. As long as the main channel continues to erode at the mouth greater volumes

of saltwater will enter the system resulting in greater advance of saltwater over the floodplains resulting in a continued expansion of the tributary network. The only means by which this mechanism can be arrested is to reduce the tidal energy and hence volume of water that enters the creeks from the ocean.

The aim of the preliminary modelling exercise was to examine various remedial options and their relative merits in terms of impacts on tide levels and flows along the main channel. These levels and flows are critical to the conveyance of saline waters onto the floodplain.

Options that have been modelled include :

- Construction of one or more constrictions at the entrance of the main channels.
- Raising the bed levels at the entrance of the main channels (submerged weir).
- Construction of an offshore bar.

Preliminary results indicate that :

- The constriction at the entrance will certainly be effective in generating turbulence and hence a head loss, however both the banks and bed for some distance upstream and downstream may require protection. The turbulence and velocity regime downstream of the constriction during peak ebb and flood flows could scour the bed and banks if unprotected. The constriction configuration and required protection scheme may need to be tested using a scaled physical model.
- Raising the bed level by the construction of a submerged weir again would generate turbulence but significantly less than the constriction. Raising the bed level to a maximum of 0.5 metres below low tide was considered acceptable considering the draft of boats which operate in the estuary. The

raised bed again may generate velocity regimes causing bed and bank scour.

- Recharging of offshore shoals is an efficient means of reducing the tidal energy that enters the estuary. It is similar to the construction of a submerged weir but does not produce the same turbulence within the channel. Nearly all creeks and rivers have an associated offshore shoal. These shoals effectively reduce much of the ocean tidal energy from entering the estuary. Further modelling and survey of stable estuaries is required to determine the optimum placement and shape of the shoal.

#### CONCLUSION.

Saltwater intrusion has been occurring in the Lower Mary River since at least the 1940s and has been responsible for the degradation of much of the freshwater habitat. The main channel and tributary network continue to expand at a rapid rate and a large proportion of the floodplain previously unintruded is now under threat. The triggering mechanisms of saltwater intrusion are believed to have been a combination of coastal, fluvial and anthropogenic causes. Monitoring and modelling programs have been initiated to study the hydrodynamics of the floodplains with the aim of constructing and verifying a numerical simulation model. The model will be used to evaluate a range of remedial options. Preliminary modelling has suggested that the most effective action in remediation will be the construction of either entrance constrictions, raising channel bed levels or the recharge of offshore shoals.

#### REFERENCES.

Woodroffe, C.D., Mulrennan, M.E., and Knighton, A.D., (1991), *Geomorphology of the Mary River Plains*, N.T. Interim Report, Department of Geography, University of Wollongong for Conservation Commission, NT.