Estuaries of Australia in 2050 and beyond

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Abstract
In late September 2013, Springer published the 2014 book edited by Eric Wolanski "*Estuaries of Australia in 2050 and Beyond*", which is part of the series *"Estuaries of the World"*.

The book addresses the question: Is Australia's growing human population and economy environmentally sustainable for its estuaries and coasts by 2050?

The book has detailed studies of eighteen iconic Australian estuaries and bays. They can be divided in three types based on the human impact, namely (1) estuaries that bore the full pressure of the historical developments, (2) estuaries being degraded, and (3) estuaries that are still relatively pristine. This knowledge was synthesised in a chapter by Eric Wolanski and Jean-Paul Ducrotoy in the concluding chapter of the book. In that chapter, they suggest what Australian estuaries may look like in 2050 based on socio-economic decisions that are made now. It is shown that governance and sustainable development are only practiced where there is a large urban population demanding a high quality of life, such as in southern capital cities and key coastal tourism cities whose livelihood requires clean estuarine and coastal waters. Elsewhere in the country, particularly in the tropical regions, the policy of development at all costs is still practiced although it is hidden behind environmental protection legislation that is however routinely bypassed. This book also details the changes that are needed in governance to ensure sustainable development of Australian estuaries.

Introduction: Estuaries of the World
Springer Publishers have decided to publish a book series entitled "Estuaries of the World", whose chief editor is Jean-Paul Ducrotoy. The rationale behind this initiative is driven by necessity of humanity endangering the very habitats that made economic developments possible while maintaining a high quality of life for the 50% of the human population worldwide living near estuaries and the coast. From an ecological point of view, estuaries are amongst the most endangered areas in the world. Pollution, eutrophication, urbanization, land reclamation, over fishing and exploitation continuously threaten their future. There is a need for robust science to be carried out but also to make existing scientific information much more manageable by non-specialists, without compromising the quality of the information (Ducrotoy and Yanagi, 2008). These books are intended for researchers, practitioners, undergraduate and graduate students in all disciplines who are dealing with complex problems and looking for cutting-edge research as well as methodological tools to set up truly transversal science and technology projects, such as the restoration of damaged habitats.

This book "Estuaries of Australia in 2050 and beyond" is the first book in this series. It attempts to answer the questions: Is Australia's rapidly growing human population and economy environmentally sustainable for its estuaries and coasts? What is needed to enable sustainable development? To answer these questions, this book reports detailed studies of a number of iconic Australian estuaries and bays by leading Australian estuarine scientists. The book also has a Prologue by Mr Malcolm Fraser, former Prime Minister of Australia, which bridges environmental science, population policy and sustainability. That knowledge is then synthesised in time and space across Australia to suggest what Australian estuaries will look like in 2050 and beyond based on socio-economic decisions that are made now, and changes to governance that are needed to ensure sustainability.

The Geography of Australian Estuaries

Australia is a vast continent with a land surface area of 7.7 x 10^6 km^2 with a wide variety of natural settings that shaped the estuaries before they were impacted by humans. Australia has a long history of human inhabitation lasting several tens of thousands of years and a very short modern history that started with British settlement in 1788 (Flannery, 1994). The human population at that time was very small, estimated at about 0.35 x 10^6. It is likely that most rivers and estuaries were then healthy ecosystems. However, the human population, even if small compared to present values, had substantially modified the vegetation cover over the watersheds through the use of man-made bushfires, and thus impacted the estuaries, but the amount of that impact is largely unknown.

The large watersheds of Australia are shown in Fig. 1, the largest watershed being that of the Murray-Darling River, which comprises about 14% of the total area of Australia. In addition, there are numerous small watersheds; many of them are mangrove-fringed in the tropics and sub-tropics.

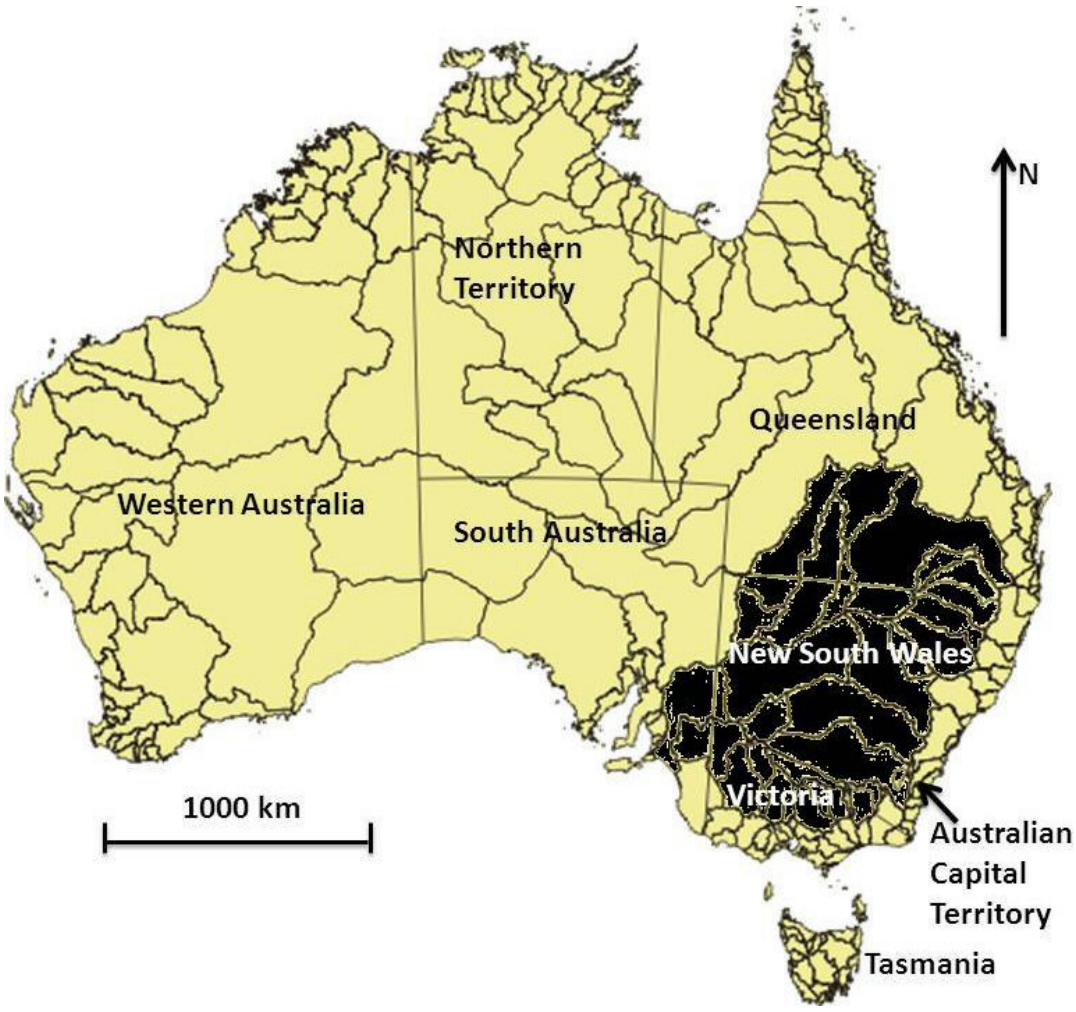

Fig. 1: The political map and the watershed map of Australia. The darkened area is the watershed of the Murray-Darling river basin.

It is apparent from this figure that the political map of Australia was drawn with no regard to the hydrology. This leads to economic, administrative and political constraints that, in issues dealing with water resources result in the Australian State governments cooperating little with each other and with the Australian Commonwealth (i.e. federal) government. It is still as if the

land, the river, the estuary and the sea were not part of the same system. Large-scale, intensive irrigation farming has been developed in the most suitable catchments in the temperate south. Agriculture requires water, but the availability of water in Australia varies markedly from year to year, with rainfall characterised by a succession of 'good years' (i.e. years with well above average rainfall) and 'poor years' (i.e. years with well below average rainfall; Fig. 2). 'Poor years' commonly occur in succession of several years. Using short term rainfall data from 'good years', water resources managers have commonly over-estimated the availability of water during 'poor years' and thus commonly they have over-allocated water that can be used for irrigation with insufficient water available in 'poor years' for both irrigation and the environment. During 'poor years' the usual management policy in Australia has been to satisfy the needs for irrigation first and neglect the environmental needs of the rivers and estuaries.

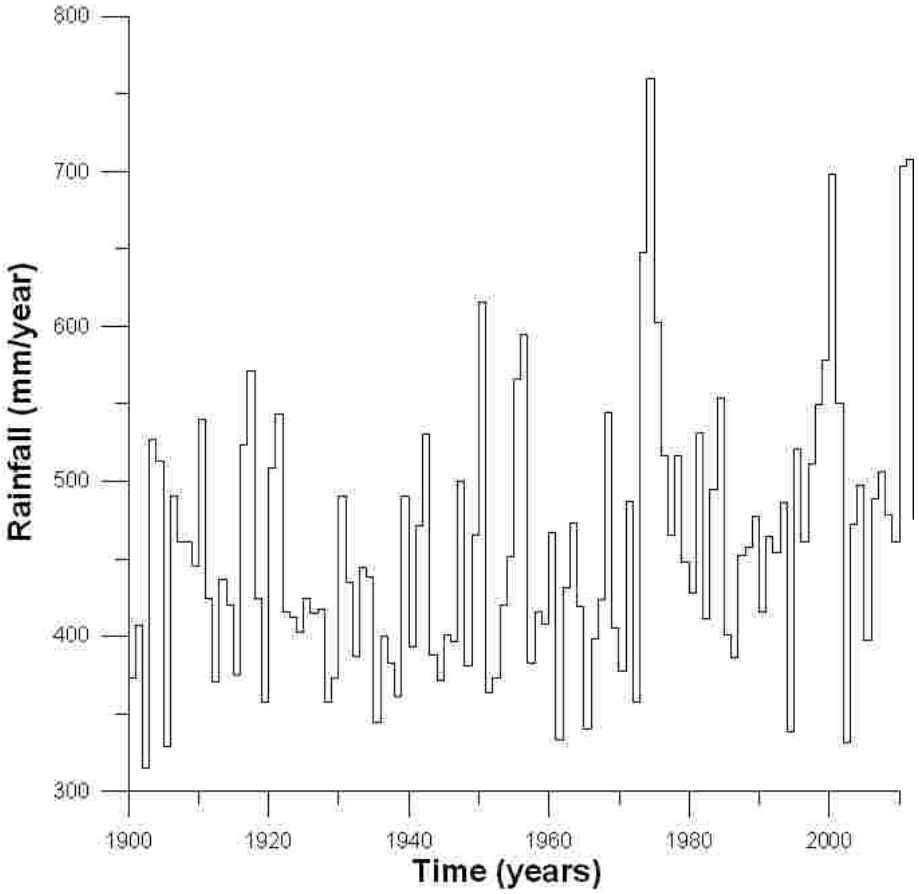

Fig. 2: Time-series plot of Australia-wide annual rainfall from 1900 to present. The data were provided by the Commonwealth Bureau of Meteorology.

The resulting impact of such water usage policies on the estuary is most evident in the Murray-Darling River (Fig. 1). The river catchment extends to several States and there is no catchment water authority; the water resources managers in the various riparian States upstream of South Australia commonly have over-allocated irrigation water licences in their own States and ignored the cumulative impacts on the river from similar allocation in the other riparian States. During 2005-06, which were 'poor years', water extractions were over 9,000 GL from 6,530 GL of inflow, the balance being due to using of water stored in impoundments in previous 'good years' (Murray–Darling Basin Ministerial Council 2007). As a result during such 'poor years' zero or negligible river flows reached the sea for months at a time. This is totally a man-made environmental crisis and the results for the Coorong/Murray Estuary are devastating, and this is described in a chapter in the book by Jochen Kaempf.

Human Population

The anthropogenic impact on Australian estuaries will increase rapidly in the future because the human population of Australia in modern history is rapidly increasing (Fig. 3). The population is now 23 million (23 x 10^6). By 2100, the population curve is expected to reach between 30 and 100 x 10^6 depending on the rates of immigration.

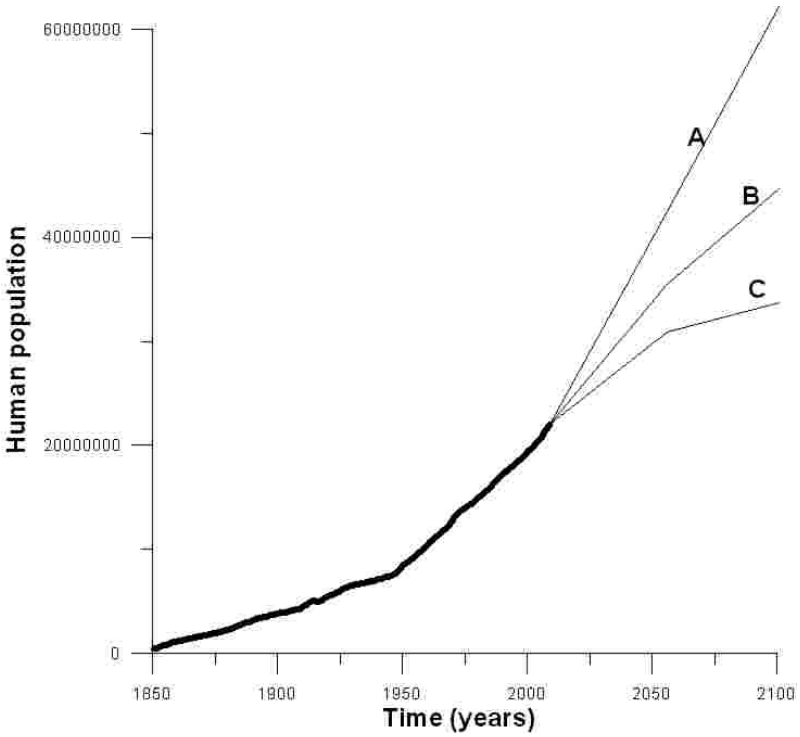

Fig. 3: Time series-plot of the human population in Australia (thick line) since 1850 until present, and in the future as scenarios A, B and C that depend on likely rates of immigration. The data were provided by the Australian Bureau of Statistics.

While this population S-curve somewhat resembles that in North America following mass immigration (Daniels, 1990), the spread of the population differs greatly between the North American and the Australian continents. While there are numerous large inland cities in North America, such is not the case in Australia. The main reason for this difference is the rainfall distribution that in North America enables human settlement over much of the continent while in Australia rainfall is largely restricted to a narrow coastal strip. The country is divided between a tropical North and a temperate South. As a result much of the human population is concentrated along the temperate coast where rainfall allows it (Fig. 4), but not along the tropical coast where rainfall is abundant but historically people has been reluctant to settle. All these facts combine to make Australia have scarcely more than two persons per km^2 of total land area. However the population density is large along the temperate coast where reliable rainfall occurs. Australia is one of the world's most urbanised countries as 89% of its population live in urban areas mainly near estuaries and coasts.

The State of Watersheds and Rivers

Most Australian rivers in the temperate areas and many on the tropics are already impacted by changes to river flows and pollution by nutrients, pesticides and herbicides from large-scale irrigation farming that was encouraged by State governments policy of expanding the water supply while environmental management was a secondary consideration (Hussey and Dovers 2006; Petheram et al. 2008). Approximately 85% of the rivers' length is affected by catchment disturbance (NLWRA, 2000). Of the regulated and unregulated rivers for which data are available, over 80% are modified to some extent and nearly 30% are substantially modified.

Nutrient (mainly phosphorus) and suspended sediment loads are greater than natural levels for over 90% of the length of Australian rivers and are severely modified in almost 10% of total river length (NLWRA, 2000).

These farm-derived nutrients, sediment and also pesticides and herbicides reach the estuaries and coastal waters, which they degrade. In most cases the environmental degradation is local and this affects mainly the local community. In some cases this degradation is significant for Australia at the national level; such is the case for the Great Barrier Reef of Australia. Coral calcification rates have declined by 15% since 1990 (De'ath et al., 2009), and coral cover has declined by nearly 50% over the last 27 years (De'ath et al., 2012). Farm-derived nutrients, sediment, pesticides and herbicides are responsible for this degradation of the Great Barrier Reef, the management of which does not include managing land-use in the adjoining catchments (Brodie and Waterhouse, 2012). This is probably the most spectacular case of failed coastal management in Australia from ignoring to manage the entire ecosystem including the watershed as one system (Wolanski, 2007; Mee, 2012). This degradation will be further exacerbated by planned, massive coal export ports and industrial developments in or adjacent to the Great Barrier Reef Marine Park, an issue about which in 2012 the UNESCO World Heritage Committee expressed particular concern and at present is evaluating if the Great Barrier Reef should be officially listed as a World Heritage *at risk*.

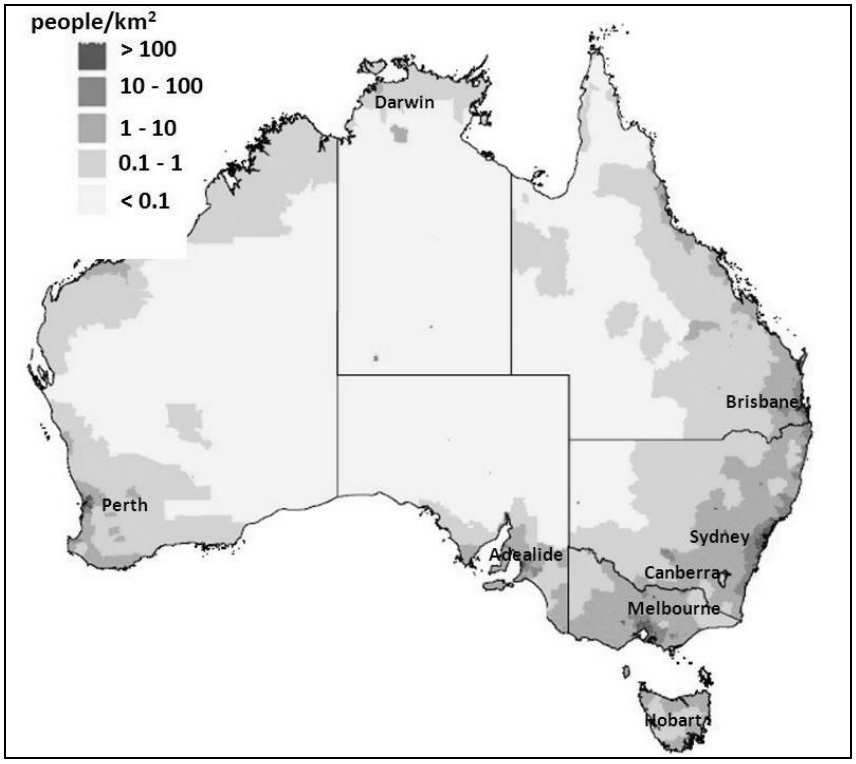

Fig. 4: Distribution map of the human population density and location of capital cities (modified from Regional Population Growth, Australia).

Case Studies: The State of Knowledge

Only a limited number of Australian estuaries have been studied in great detail – indeed there are not enough estuarine scientists in Australia to study all the estuaries, neither is there enough research funding. Nevertheless this book brings together the majority of the detailed studies of Australian estuaries and coastal waters. The study sites are shown in Fig. 5.

The case studies of Australian estuaries in this book can be divided in three types based on the human impact, namely (1) estuaries that bore the full pressure of the historical developments, (2) estuaries being degraded, and (3) estuaries that are still relatively pristine. For type (1) the case studies focus on Sydney Estuary, the Coorong/Murray-Darling Estuary, Port Philip Bay,

and the Tamar Estuary. For type (2) the case studies focus on the Gold Coast Broadwater, the Hawkesbury Estuary, the Burdekin flood plains, Moreton Bay, the Ord River estuary, Brisbane peri-urban estuaries, South Australia gulfs, Hervey Bay, and Darwin Harbour. For type (3) the case studies focus on the Mary River estuary and floodplains in the Northern Territory and Deluge Inlet.

The response of these estuaries to the human impact is described in the book in detail, and it is shown to depend strongly on the geomorphology and hydrology, and thus on the geographic location of each estuary.

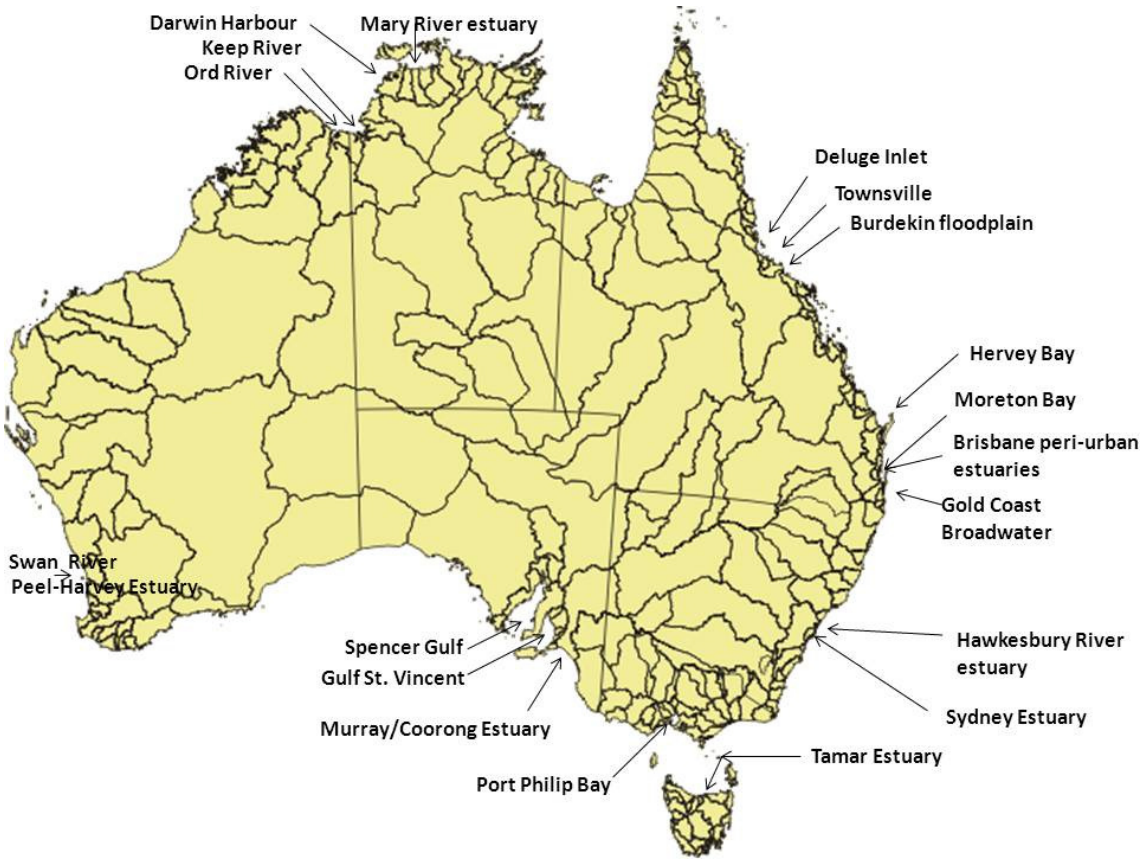

Fig. 5: A location map of the estuaries and coastal waters featured in the book.

A Socio-Economic Classification of Australian Estuaries

These case studies demonstrate, through the writing of eminent Australian estuarine scientists, how these estuaries function and this knowledge requires merging the physical, chemical and biological oceanography, the ecosystem processes, and the human impact. The studies describe most types of Australian estuaries from pristine estuaries to estuaries heavily impacted by urbanisation, harbour operations, industrialisation, and intensive irrigation and water management schemes in the river catchments.

The basic science has been done in some estuaries particularly those in the capital cities, and is being done in other estuaries. This makes it possible to understand, at least as a first order approximation, how these brackish water ecosystems function. This enable the scientists to forecast with some confidence and some uncertainty what these estuaries may look like by 2050 based on political and socio-economic decisions that are made now, just like the decisions made a few decades ago dictate what these estuaries look like now. This book shows that Australia has much to learn by understanding the lessons from the past and from each estuary. It is clear that these lessons can then be applied to all Australian estuaries in order to ensure an environmentally sustainable Australia where the estuaries will keep delivering the full range of ecosystem services that the population expects in order to maintain a high quality of life.

The principal factors governing the health of Australian estuaries, and often preventing sustainable development of estuaries, are

- The baggage of history of development at all costs
- The lack of sharing of water resources between State governments
- Rapid urbanisation around estuaries
- Chemical pollution
- Eutrophication
- Historical over-irrigation and lack of governance for water
- Limits set to restoration
- Social inequity
- Single industrial drivers in suburbs and regional towns
- Present rapid growth of irrigation in the tropics
- Conflicts of interest by State governments

Australia still has several slightly affected and even pristine estuaries – such pristine estuaries are a rarity in the world outside Australia. These estuaries are by themselves an Australian gift to the world of what pristine rivers and estuaries look like. Two chapters in this book address such systems. These pristine estuaries are precious and should not be used and abused.

The Future of Australia's Estuaries

There are calls for a large increase in migration to Australia in order to rapidly increase the human population so as to create a 'big Australia'.

At the same time, to develop their economy the States with water and vast tracts of potentially arable land – i.e. mostly in the tropical regions of Queensland, Western Australia and the Northern Territory where the human population is presently small (Fig. 3) - are pushing for large-scale irrigation projects to be made possible by the proposed construction of up to 100 dams, so that Australia can develop large-scale irrigated agriculture as the market exists in view of the growth of the human population worldwide. By this scheme Australia would become the food bowl of Asia if not the world.

As a result most estuaries throughout Australia – including most of the presently little impacted estuaries in much of Australia's tropics - are now threatened by new projects of urbanisation, irrigation, mining, or industrialisation. Australian States generally recognise that threat. Developments in Australia are now subject to meeting environmental criteria set by legislation and this requires environmental impact studies; although as shown in case studies in this book , State governments can and do essentially bypass this process when they want.

Encouragingly however more recently the concept of sustainable development is starting to be discussed in Australia.

Additional changes may also come from climate changes that may impact the water yield of river catchments as a result of changes of the temperature, evaporation and rainfall. As the case studies in this book demonstrate, engineering and technology by themselves do not provide a solution to sustainable development of Australian estuaries. When assessing the environmental impact of developments, Australian engineering consultants commonly state that the impact will be minimal – without quantifying this statement – and rarely do they value the ecosystem services provided by the estuaries and the quality of life to the people. Common statements by State governments and the engineering community of 'world's best practices' when discussing environmental sustainability of estuaries is not backed by facts as the case studies in this book illustrate.

Thus the answer to the question “Is Australia’s growing human population and economy environmentally sustainable for its estuaries and coasts by 2050?” may be, based on the socio-economic decisions made now, (1) possibly yes in large cities as long as the population is pro-active in demanding a high quality of life, which implies healthy waterways, and (2) probably not in rural and remote areas and especially so in the tropics.

Hopefully this pessimistic prediction may turn out to be incorrect. Australia is privileged to have a number of eminent estuarine scientists. Hopefully future enlightened governments will emerge that will make socio-economic decisions compatible with a sustainable Australia and will call on these scientists to help provide a safe future for Australian estuaries in 2050 and beyond.

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