ON RISING AND FALLING SEA LEVELS, SPIT DYNAMICS AND AN 1872 SURVEY OF BYRON BAY

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Abstract

The Australian continent's two eastern most beaches, north and south of Cape Byron, are directly influenced by the Coral and Tasman Seas as well as the South Pacific and Southern Ocean. The recent discovery of an accurate 1872 survey of the track running along the two beaches can be used to definitively assess the impacts of sea level and storm patterns on the coast over the past 135 years. We need to look back over at least a century to assess the influence of rising sea levels and the coast's vulnerability to future erosion. The 1872 survey provides the possibility of numerically testing assessment methodologies currently used for prediction of climate change impacts of sea level rise on future coastlines.

On rising and falling sea levels

Examination of sea level curves over different time scales, over 100, 000 years to annual or even shorter periods demonstrates that sea level is rarely at the long term trend but mostly, above or below trend. As sea level rises at variable rates, short term rise rates can be at much faster. A sea level curve for late Pleistocene and Holocene was derived for 300,000 years, a period, covering the last two Ice Age cycles, it is estimated some 27 of which occurred it the Pleistocene. Examples of trends of both rising and falling sea levels are provided by fossil shorelines and dated reefs. On the east coast this evidence is represented by abandoned dunes fields and in places by sand sheets, such as at Kurnell, Stockton, Foster, Broadwater and the sand islands of SE Queensland.

Helman (2007) presented a description of Australia's east coast, from Fraser Island (Qld) to Victoria, beginning with the first European observations in 1770, through the start of sea level rise in the 1820's and subsequent changes from an increasing rate of sea level rise.

Last thousand years

A thousand year trend of sea level was prepared (Helman, 2007) from geomorphic evidence, studies of Aboriginal shoreline middens, the advance and retreat of New Zealand glaciers (Figure 1). This trend curve was compared with a modelled sea level curve generated by Hadley Centre, UK (2004), which shows agreement of the trend but more detail including the signature of the major volcanic eruptions; Tambura, Krakatoa, Pinatubo. A possible multi centennial cycle (Little Ice Age) and recent accelerating rise, attributed to human induced warming.

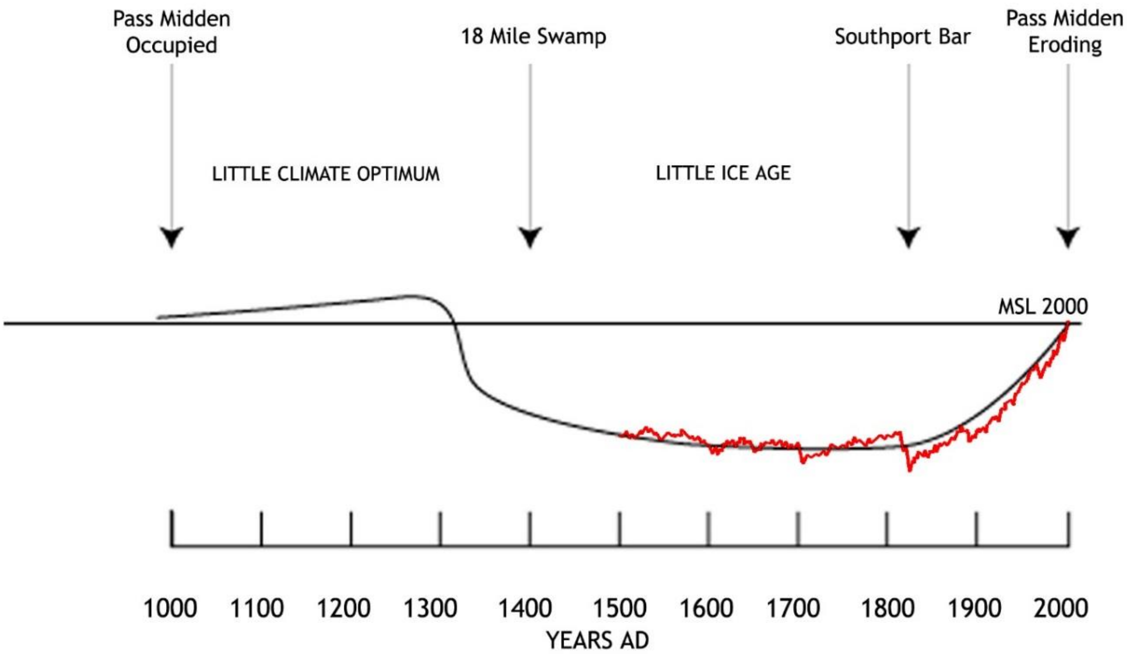

Figure 1. 1000 year curve (Helman 2007)

Swept Prism

The concept of the dynamic swept prism was proposed by Chapman and Smith (1982) as, the dynamic part of coastal process from the inland extent of storm wave action, to the offshore extent of storm wave movement of bottom sediments. In sedimentary structures the position of the Swept Prism marks a complete change in depositional process. Inland, are those features left by falling sea level and seaward and those structures formed by rising sea level. Inland of the present coastal alignment are structures made by falling sea levels, to sea ward of the swept prism are deposits from rising sea level. Smith and Jackson (1990) examined these features on the Gold Coast as shown in Figure 2. The strata to seaward are linear beds with no concentrated heavy mineral lenses.

The exception to this arrangement, are dunes made from carbonate sands i.e. on Double Island Point, and off northern Fraser Island both, at lower sea levels and cemented into Break Sea Spit, to the north. Contrary to some opinions there is no evidence to support the view that sediments are carried up the continental slope with sea level rise. This is a common view especially in government reports; unfortunately it is not supported by physical evidence. On the contrary, sediments are accumulated on shore when the sea level falls. Offshore deposits of sand i.e. SSB's off headlands are exposed to Aeolian deposition. On the south side of Cape Byron and Broken Head sands have been deposited all the way to top the hill. In the current trend of rising sea levels, no sand is being deposited on these hill slopes.

Mining for gold and other valuable minerals in the concentrations of black beach sands had commenced at Ballina in 1870 following the west coast beach gold rush in the 1850's and the New Zealand west coast in the 1860's, and later in old dunes inland for example, at Black Rocks. The importance of the heavy mineral lenses is that they are only at one site in the swept prism, at the toe of the storm face. Heavy minerals are only deposited in severe storms being the only time that a 'boil' is created at the storm face. Heavy minerals are not deposited higher than storm tide level, and are not concentrated lower than the swept prism, being dispersed in offshore beds

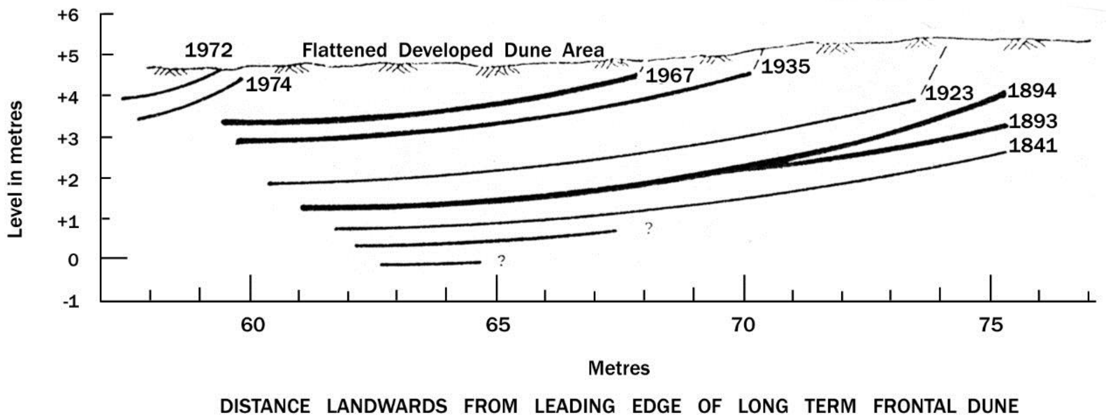

Figure 2. Beach heavy mineral lenses exposed on construction site, Gold Coast, Smith and Jackson 1990

Shoreline Erosion

Analysis of records confirms that the southern shoreline of bays is subject to long term recession. This recession is attributed to sea level rise (some 140mm, since 1820) causing a loss of inshore sand to the bay floor, and offshore loss to the shelf sand body (SSB), such as south of Cape Byron. Long term shoreline erosion has meant that since 1884 when Belongil Spit was subdivided (DP 1621) there has been the loss of a 'beautiful beach', the access road (The Esplanade), the Public Reserve (R1082) and over the century to 1974 the loss of some 30 lots subdivided along the coast at; Byron Bay, Belongil Spit and Sheltering Palms, to sea level rise.

Erosion has dominated public debate (using flawed understanding of coastal process) for six decades and many lots, public reserve and the Esplanade eroded or had planning permission withdrawn. A major Public Works study at Byron Bay (PWD 1978) presented a range of measures to address the problem and recommend a number of options for mitigation and ongoing planning restricts on sea front property. The impact of storms is well-understood (Callaghan and Helman (2008) and Helman and Tomlinson (2008), but often the changes that occur are too subtle to be observed. For example, an Australian veteran surf lifesaver on the north coast maintains that 'I have been on this beach since nippers, for over half a century and the coast is not eroding'. This exposes the problem that people are unable to visually see the subtle changes on dunes and beaches.

Helman (2007) examined the recorded changes to the coastline and compared them to: - available records of observed annual mean sea level, severe storms, and interannual oscillations of the Southern Oscillation Index (SOI) and multi decadal oscillations of the Interdecadal Pacific Oscillation (IPO). For the 120 years of reliable records, IPO and sea level inversely correlates (Figure 3). In addition, it was found that major energy periods on the coast were largely associated with negative phases of IPO.

Consistent findings deduced from coastline indicators suggest that the coast has been influenced by a slowly rising sea level trend from the early 1800's to present. This slowly rising sea level has resulted in: permanent coastal changes, breaching of coastal dunes, barrier island formation and growth of flood tide deltas. The coastline has been moving inland throughout the last 180 years but this has been largely unperceived as the rate of sea level rise has been low. Little concern has been raised as most of the eroded land is public reserve, which has acted as a coastline buffer. This implies the impacts of future erosion periods are likely to be far more severe than any experienced during the last 200 years.

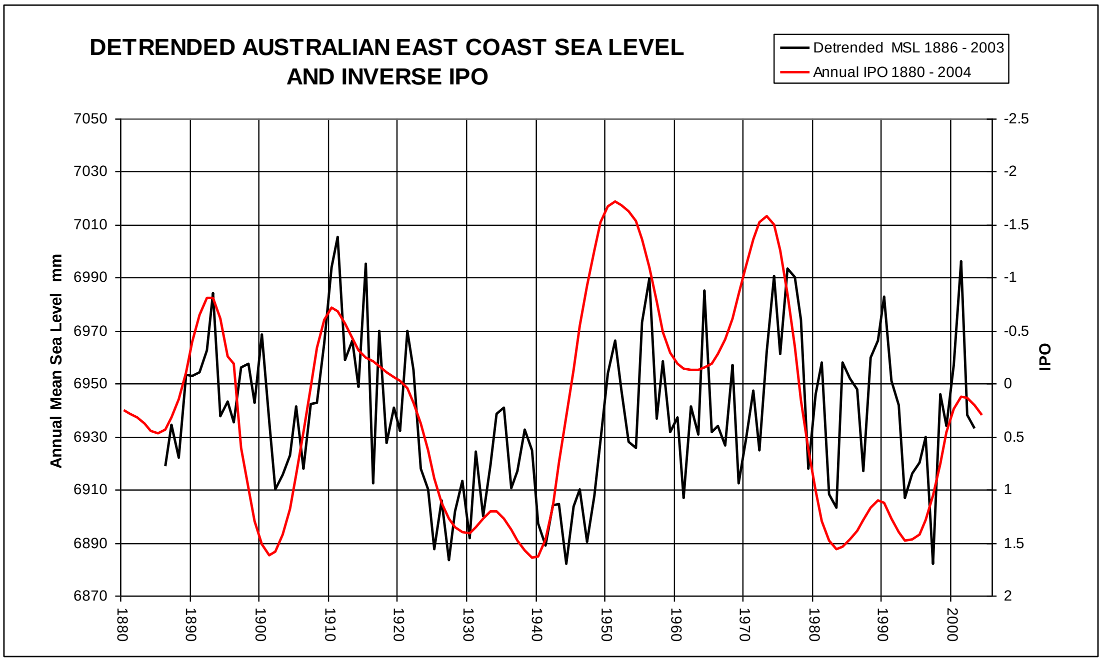

Figure 3. Interdecadal Pacific Oscillation and Sea Level

1872 survey

Recent discovery of an accurate 1872 survey (Figure 4) of 'the track' running along the two beaches Byron and Tallow north and south of Cape Byron can be used to assess the impacts of sea level rise and storm patterns on the coast over the past one and a half centuries. By looking back over at least a century, an assessment can be made of the influence of rising sea levels and the coast's vulnerability to future erosion. The 1872 survey provides the possibility of numerically testing assessment methodologies currently used for prediction of climate change impacts of sea level rise on future coastlines.

Accurate descriptions of coastal features before 1900 are limited. When combined with other evidence, the brief descriptions of coastlines shown on early surveys add to understanding of storm erosion and recession of coastal dunes.

Interpretation of 1872 coastal features noted on T19

T19 shows several coastal features not previously known (Helman 2007). For example:

- erosion of Pleistocene dunes north of Belongil Creek which is also confirmed by Howard's 1883 survey;
- the mouth of Belongil Creek some 2 km north of present position is also confirmed in the 1883 survey;
- there is no evidence of erosion of Pleistocene dunes at Clarkes Beach as found by Howard 15 years later;
- evidence of aeolian sand accumulation on Tallow Beach

- Taylors Lake shown with entrance to the south and unaffected by coastal process as depicted in the 1884 portion survey (Helman 2007).

1872 was in the early part of an extreme storm period associated with strong negative IPO that went from the 1860's to 1890's (Helman 2007). Coastline erosion is shown by a comparison of T19 (1872) with Howard's survey of Cape Byron Bay in 1883. This shows erosion during this 15 years period with the storm face further inland. The question of why Howard did not locate Barling's T19 posts, 'placed according to regulations', is puzzling. Had the posts already been eroded?

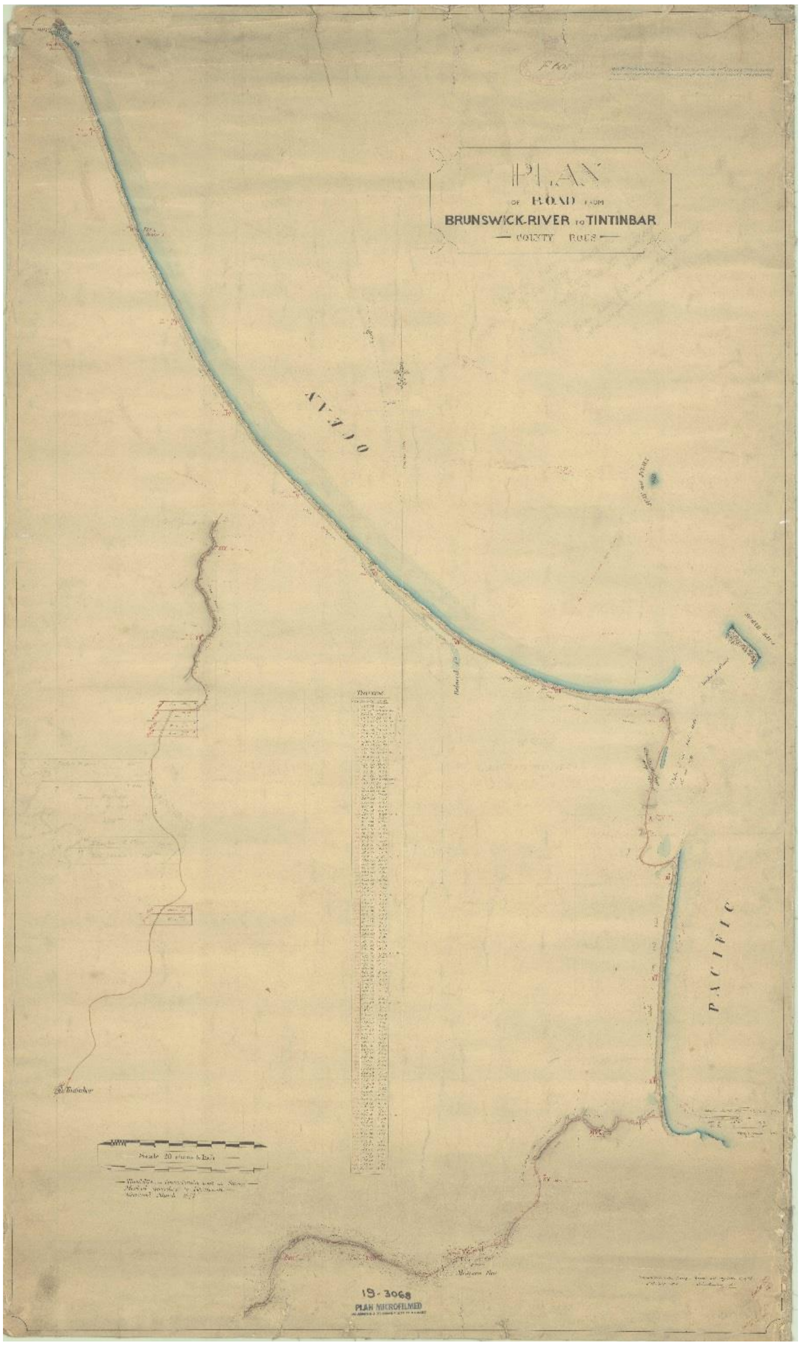

Fig 4. Byron and Tallow compartments. Plan T 19 Surveyed by Edward Barling March 1872

Other features of T19 include:

- Brunswick River mouth - Entrance controlled by bedrock outcrop on beach to north, facing SE
- Inland of Brunswick Beach - barren heath (old sand dunes) covered with honeysuckle (Banksia) and swampy (swales) with Teatrees [sic] *swampy* Melaleuca. Tyageragh *Auriferous sand (*beach gold rush had started on east coast at Ballina, 1870)
- Belongil Creek entrance - 2km further north than present and evidence of flood breach
- Description of barrier dune as 'soft dark sandstone' showing erosion face in coffee rock. Exposed indurated humate is evidence of erosion
- Clarkes Beach - strata of black previously deposited storm faces (Helman 2007) with layers of heavy mineral sands
- Tallow Creek mouth - washed out in storms
- Tallow Beach (Suffolk Park), 'low hillocks of blown white sand', influence of orientation. Taylors Lake, no evidence of subsequent wash out

Barling's survey provides geomorphic evidence confirming sea level rise over a century and a half. No similar accurate surveys along east coast beaches in the late 1800's have been found in Australia. The information from this 1872 survey is of considerable importance *as it can help answer questions on how the coast has altered over the last century of* gradual sea level rise and the influence of climate variation on coastline recession.

The T19 survey raises some interesting research opportunities, including:

- Measured recession can be compared to east coast sea level change for 143 years
- Numerical test of Brunn's equation (limited assumptions)
- Behavior of the zeta curve rotation (Chapman 1978) for two differently aligned compartments and the relationship of any rotation to sea level change
- Coastline models of wind/wave changes
- Test Shoreline Translocation Model
- Calibrate recent coastline simulation programs SIMCLIM, MEPBAY, etc
- Erosion in IPO phases, and does the SL faster rise in negative phase (Goring and Bell 2001)

An initial plot of the T19 traverse shows that the present shoreline is several hundred meters further inland, and the present coast has been altered by erosion from sea level rise.

International perspectives on response to sea level rise

All European Union coastal states are to some extent affected by sea level rise. About twenty thousand kilometres of coasts, nearly 30%, faces serious impacts, with 15,100km of coast actively retreating. Some 2,900 km of coastline is retreating despite coastal protection works, another 4,700 km has been artificially stabilised with massive walls, mostly in Holland. Between 1999 and 2002, some 300 houses had to be abandoned as a result of imminent coastal erosion risk and another 3,000 houses have experienced a market value decrease. IPCC estimates that the number of coastal properties affected by sea level rise will increase dramatically. The European Commission funded a study to look at the issue, the findings show: Lack of space for the inland coastal movement results in 'coastal squeeze'. It was noted:

- Current planning practices do not address coastal erosion.
- The understanding of decision-making in coastline process is inadequate.

- The cost of coastal erosion is supported financially by the public.
- Traditional approaches and construction of protective structures to counteract coastal erosion may be counterproductive.

In the United States, some coastal states have sea level rise policies as have many overseas countries and individual states. On the Florida coast, during the 1900's sea rise was rapid, twice as fast as NSW. Florida and other adjacent states have been grappling with sea level rise issues we are now facing. For example, in 1971 the US state of Florida introduced a retreat policy of rolling coastal easements, to separate coastal development form the dynamic coastline. The first attempt at protection, is often timber walls, beach scrap or pump sand, rock dykes and finally engineered rock or other solid material. When walls damaged in storms, then retreat is considered (See Gisbourne District Council and the decision of High Court NZ 1996).

In Australia, the Byron Shire Council first introduced a coastal planning scheme, after Council was dismissed by the NSW government. The administrator employed a planner to prepare a new LEP, the shoreline section, with PWD advice and was Part J. It only turned into a 'retreat' plan, with 'moveable' dwellings, after Court action by the shoreline residents. A removable building scheme was called for by shorefront residents. An example of a retreat planning scheme by Fleurieu Peninsular Council, SA is documented by Niven and Barsley (2013).

Discussion

Regardless of any mitigation strategies - even when emissions of greenhouse gas are reduced - sea level will continue to rise for centuries due to time lags in the ocean-atmosphere system and the slow warming process of deep ocean basins - we are committed to long term sea level rise. The influence of rising sea level, possibly at an accelerating rate, will result in the coastline moving faster inland. This is shown by all indicators and demonstrated over the last century by accurate surveys. The moving coastline has breached seaward meander bends of coastal rivers and waterbodies, resulting in permanent openings and formation of barrier islands. Freshwater lakes formed behind dune barriers during the late Holocene have also been breached.

How would such a future system be integrated with present legislation, common law, planning, real estate markets, property security (for mortgage) and insurance?

In the popular media, significant weather events, such as severe storms, prolonged droughts or major floods are cited as evidence of climate change. It should be of major concern for all climate scientists to clearly distinguish between accepted climate variability events and climate change. The study, on which this paper is based, is an examination of long term coastal dynamics on the Australian east coast, and attempts to clarify the distinction between climate change and climate variability. The study used observations of climate and coastal response made during two centuries of European settlement. Many geomorphic aspects of the study's findings, show the distinction between climate change and variability is of much wider significance and relevant to many other areas of science. Coastal sedimentary systems have major physical inertia that responds to climatic drivers while eliminating much of the minor oscillations associated with climatic systems - 'wobble'. The findings discussed are applicable to both geomorphic and ecological systems and to the widest range of planning, management and economic interests.

On the Australian east coast, two hundred years of coastal dynamics show distinct differences between positive and negative phases of Interdecadal Pacific Oscillation (IPO), allowing separation of long term climate change and variability phases. Negative phases of IPO typically have storms, above trend sea level rise and coastal erosion; positive phases by drought, below trend sea level rise and stable coastal conditions. Climate scientists now use ENSO (SOI) as a climatic indicator which at times is problematic. Over decades IPO is demonstrated as an important and interactive index essential in describing climatic influence on natural systems.

Natural climatic variation is often confused with climate change in the media, climate change can only be assessed over centuries, while variability occurs in distinct phases that last for decades. Variability phases are characterised by either storms or recurring drought. Planning and preparing for different phases of variability will help ameliorate hardship experienced by many during periods of droughts and severe storms. Understanding variability phases will enable climate change effects to be more accurately identified and will greatly benefit all sectors of planning and management, particularly in agriculture and fisheries.

It is essential to understand the relationship between future sea level rise and coastline recession. Due to decadal climatic variability of sea level (Helman 2007) it is necessary to measure this relationship over periods exceeding a decades so the past can help predict the future.

T19 provides a valuable resource showing the position of the beach in 1872 before any coastal settlement had taken place. It provides a 143 year period to measure the relationship between shoreline position and sea level rise. Reliable sea level observations have been made at Sydney since 1886 (Hamon 1987) with sea level trend back to 1840 from analysis sea level records in Tasmania (Pugh and others 2002). The variation between the orientations of the two compartments suggest that any consistent findings between these two compartments may be generally applicable. But orientation difference should resolve questions related to the difference between sea level rise and curve rotation. What we have is documented changes to the coastline at regular intervals for the two eastern most compartments on the Australian coast, including more recent surveys since 1872 – e.g. Howard's 1884 survey of Cape Byron Bay; periodic beach mining lease surveys from 1888 to 1970's when good coverage is available in air photos and satellite images; annual mean sea level variation from 1886 and sea level trend back to 1840, and changes to position and character Belongil spit and creek mouth over 143 year period.

Conclusions

Sea levels are rising, and have been since 1820's, at first by global forces and now increasingly by greenhouse pollution. Long term sea level rise is projected to continue rising for several centuries even with effective greenhouse abatement (IPCC 2013).

What type of institutional system should we be considering to adequately deal with long term management of coastal land?

As the results of future research the policy and planning benchmarks may need to be revised, periodically, every 5 years or when necessary. Rapidly improving ocean research using satellite technology, deep temperature sensing are regularly updating views on deep ocean warming process, regional variations and recent research on accelerating rates of sea level rise.

Adaptation strategies have limitations, for example there is usually no space or it is unsuitable to move directly inland if a retreat options is considered, e.g. Wooli. In general the approach of local authorities has been to try soft engineering and when this is washed away a fork in the decision path is reached: build hard walls or retreat or planning controls. To a greater or lesser extent these are based on past rates of sea level rise but future rates may be radically different.

Legislative and common law has maintained an organised system for a long period but is presently not in a position to provide a coherent framework for long term policy implementation on sea level rise (Corkill (2012, 2013, 2013a). Responses to sea level rise and coastal erosion have to be addressed by all levels of government.

There is a need to strengthen coastline planners' knowledge of sea level rise and coastal erosion with coastal erosion risk and cost being included in planning and investment decisions.

The NSW government is to be applauded for considering and releasing a policy on sea level rise. The broad thrust of the policy and the initial benchmark settings are supported. Areas of policy detail that are less clear include how implementation will occur and how disagreements over conflicting values of shoreline landholders and beach users will be resolved.

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