OFFICE OF climate change

2011 Queensland king tide photographic survey

A sign of things to come

Tomorrow's Queensland: strong, green, smart, healthy and fair

Toward Q2 Tomorrow's Queensland

Queensland Government

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Cover photo: Mid Molle Island Spit, DERM

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Minister's foreword

Our coast is a quintessential element of our lifestyle. Not only is our 9500 kilometres of coastline involved in many of our favourite leisure activities, industries and environmental processes, it is also home to 85 per cent of Queenslanders.

We know that our coastline and coastal communities will come under increasing pressure from erosion and inundation from sea level rise and more intense extreme events such as tropical cyclones in the far north as a result of our changing climate. Gaining a better understanding of the impacts of climate change on Queensland coastal communities will help us all plan for and adapt to those impacts.

The Queensland Government has recently required coastal local governments to plan for a sea level rise of 0.8 metres by 2100, based on projections in the Intergovernmental Panel on Climate Change's Fourth Assessment Report released in 2007.

It is hard to imagine what a sea level 0.8 metres higher than the current level will mean for our coastline and our favourite beaches, bays, and parks, not to mention what it will mean for the fauna and flora in our wetlands, mangroves, estuaries, rivers and creeks along the coast.

The king tides we currently experience offer us a glimpse of what impact rising sea levels might have. We get high tides approximately every two weeks due to the combined gravitational pull of the earth, moon and sun. However, king tides – the highest tides of the year – only occur twice a year, in January/February and July/August.

In 2011 officers of the Coastal Impacts Unit of the Department of Environment and Resource Management, along with other regional government officers, photographed the king tides taking place around Queensland. This report provides a photographic record of the inundation that occurred around Queensland at that time - from the Brisbane River and foreshores of Moreton Bay, through Maroochydore, Heron Island, Yeppoon, Mackay, Townsville, Hinchinbrook, Cairns, Cooktown, Lockhart River, Yam Island in the Torres Strait, into the Gulf of Carpentaria to Weipa and Karumba.

Seeing really is believing and this photographic record of the king tides experienced this year gives us a greater understanding of what we can expect to experience on a more regular basis with rising sea levels.

It truly is 'a sign of things to come'.

The Honourable Vicky Darling MP
Minister for Environment

Executive Summary

The 2011 Queensland king tide photographic survey presents a snapshot of the 2011 summer king tides along the Queensland coast.

King tides are a natural phenomena that occur twice a year as a result of the combined influences from the sun and moon and their positions relative to the earth.

While king tides are not caused by climate change, they present a unique opportunity for coastal scientists and engineers to capture a glimpse of how sea-level rise (SLR) may impact the coastal zone in the future. King tide observations and photographic surveys provide a valuable visual record for future use in coastal planning and hazard mitigation along the Queensland coast, with particular importance in relation to climate change adaptation.

Although the summer 2011 king tides were considered a 'mild' event compared to previous king tides, photographing the 2011 king tides has provided a useful snapshot of likely impacts of future SLR, which may become the norm by the end of the century.

This report provides a selection of photographs which could be used as a point of reference for future king tide events. By engaging the broader community in such an event, the impacts of future SLR on the coast can be better understood and managed.

Brisbane City Council sign on Flinders Parade, Sandgate.
Photo: Margaret Robinson

Contents

Introduction

In response to growing community concern about the impacts of climate change on sea-level rise (SLR), the Department of Environment and Resource Management (DERM) undertook a state-wide photographic survey of the 2011 king tides around the Queensland coast.

This survey provides a snapshot of areas currently vulnerable to tidal inundation, as well as raises awareness about the potential impacts of future SLR along the Queensland coast. This and future surveys provide information to help Queensland respond to the potential impacts of climate change.

The summer king tide events forecast for the mornings of 21 January and 18–19 February were the largest predicted day-time tides in 2011. The summer king tides present a unique opportunity to capture images of a sea level that could become the norm in years to come.

Photographic surveys of the king tides provide a visual record of areas currently subject to tidal inundation and can assist coastal planners and managers to better understand the requirements of coastal hazard mitigation along the Queensland coast both now and in the future.

During the 2011 summer king tides photographic survey, more than 50 DERM, Maritime Safety Queensland (MSQ), Queensland Health, and Torres Strait Island Council employees volunteered to photograph king tides along the Queensland coast on the mornings of Friday 21 January for those in South East Queensland (SEQ), and Tuesday 18 February for those located north of Gladstone, capturing over 400 photographs. The Coastal Impacts Unit of the Queensland Climate Change Centre of Excellence also deployed field instrumentation to record the king tides at several locations in SEQ. In addition, data was obtained from a number of other agencies to compare the influence of the king tides in different coastal environments.

This report provides a brief explanation of the king tide phenomena, the use of king tides to investigate the impacts of SLR, and a selection of photographs from the 2011 king tides photographic survey. In addition, the report includes information on the king tide monitoring exercise carried out by Coastal Impacts Unit.

1: Currumbin Waters Canal. Backyard of residential property along Westari Court Currumbin Waters. Photo: Adrian Lavery

2: Currumbin SLSC car park. Wave overtopping edge of car park. Photo: Zoe Helyer & Eugene Immisch

3: Currumbin Creek Boardwalk. Water flooding public boardwalk. Photo: Zoe Helyer & Eugene Immisch

** full descriptions of photographs are provided in Appendix B*

1 Ocean water levels and tides

Ocean water levels can be influenced by:

- the prevailing astronomical tide
- weather and climate conditions (e.g. El Nino Southern Oscillation, winds, barometric pressure, storm events)
- oceanic processes (e.g. waves and currents)
- long term trends due to changes in ocean volume and/or land surface level.

1.1 What causes tides?

Tides are the periodic rise and fall of the water within oceans, seas, bays and other major water bodies, caused by the combined gravitational influences of the sun and moon and their positions relative to the earth.

Complex gravitational and centrifugal forces are applied to the earth's oceans by the sun, moon and the earth's rotation. The peak in tidal movement is dependent on the rotation of the earth, and the moon's orbital location.

Gravitational forces cause the tide to peak on opposite sides of the earth. As noted by Oberrecht (N.D.) the sun, which is 27 million times the moon's mass and 390 times the distance away from the earth, exerts an influence which is 45 per cent of that of the moon.

The moon orbits the earth in the same direction that the earth rotates. This accounts for a gradual and regular creep in the times of high and low tide each day. For the same point on the earth to align with the moon, the earth must complete one full rotation plus a small amount extra. This small extra rotation is slightly less than 15 degrees, which takes approximately 50 minutes to complete. Thus the tidal day is 24 hours and 50 minutes. Consequently the tidal cycle is changed by approximately 50 minutes each day.

The moon has a larger effect on the tides than the sun. The moon moves around the earth in an elliptical orbit that takes about 29 days to complete (a lunar month). The gravitational force is greatest when the moon is closest to the earth (perigee) and least when it is furthest from the earth (apogee—about two weeks after perigee).

4: Gold Coast Highway bridge. Bridge spanning Tallebudgera Creek. Photo: Megan Davis

5: Canal of Tallebudgera Creek. West of Melaleuca Drive. Photo: Megan Davis

6: Budds Beach, Surfers Paradise. Photo: Daniella Teixeira & Hamish Aiken

Whilst astronomical influences exert a widespread and predictable change in ocean water levels, localised changes and variations in tide levels are the result of topographic differences in the ocean floor and meteorological influences such as wind speed and direction, storm events and high or low pressure systems.

1.2 Predicting tidal levels in Queensland

Sea level has been measured at Queensland ports since around 1890. The use of waterways for industry and recreation has always been an important part of the Queensland lifestyle. The first significant work in tidal prediction was undertaken towards the latter part of the nineteenth century, with the installation of permanent tide gauges in the Brisbane River by the Harbours and Rivers Department. By 1878, six gauges were installed between Brisbane and Lytton, and the first tidal predictions were produced in 1891 (MSQ, 2010a).

Currently, DERM, MSQ, Queensland Port Authorities and the Australia Maritime Safety Authority operate a network of tide gauges along the Queensland coast. This network records tides, storm surge, and tsunami events. There are also two tide gauges operated by the Bureau of Meteorology specifically to monitor long-term SLR.

Figure 1: Location of tide gauges along the Queensland coast.

7: Burleigh Heads. Ocean view circuit, Burleigh Heads National Park. Photo: Jessica Rosewell

8: Tallebudgera Creek. David Fleay Wildlife Park. Photo: Jessica Rosewell

9: Cleveland Point. eastern side–wave encroaching onto footpath, road, and almost to Kiosk. Photo: Kimberley Marian

10: End of Lota Esplanade. Adjacent to vehicle access gate at end of Lota Esplanade. Photo: Galen Matthews

1.3 Spring tides

'Spring tide' is the term used to define the highest tide in each lunar month. A spring tide occurs every 14.5 days, when the earth, moon and sun all align in what is termed syzygy. In a lunar month the spring tide occurs at the peak of the combined gravitational attraction of the sun and moon during either a full or new moon. Due to these constantly changing astronomical influences, the spring tidal range varies from month to month.

1.4 King tides

As noted by MSQ (2010b), 'king tide' is a non-scientific term used to describe the highest spring tides of the year. These occur when the earth, moon and sun are aligned near perigee and perihelion. The combined influence of the moon's orbital position and the gravitational forces from the sun and moon result in the highest of the spring tides occurring during the summer months of December, January and February (when the southern hemisphere is closer to the sun) and also in the winter months of June, July and August (when the southern hemisphere is furthest away from the sun).

In any year there will be at least two spring tides that are the highest, one during summer and one during winter—these are what are referred to as king tides. Due to the nature of the alignment, the summer king tide takes place during daylight hours whilst the winter king tide occurs during the night.

During normal weather conditions, the height of the king tides will be similar from year to year. However in abnormal weather conditions (i.e. during severe storms, east-coast lows or tropical cyclones) lower air pressures and strong winds can elevate the sea level above the predicted astronomical tide height.

King tides in Queensland vary both spatially and temporally. The summer 2011 king tide occurred on 21 January in SEQ, whereas in areas north of Gladstone the king tide occurred almost a month later on 18 February. Between SEQ and Gladstone, the king tide occurred on 19 February.

11: Luggage Point. Facing down Brisbane River mouth to city. Photo: Damon Cheyne

12: Sandgate Road, Albion. The Brisbane River flooding and 7 News reporting the king tide. Photo: Robert Schwartz

13: Nudgee Beach Boardwalk. Adjacent mangroves flooded walkway. Photo: John Ryan

2 Climate change and sea-level rise

Sea levels are rising faster than expected (DERM 2010) and the Intergovernmental Panel on Climate Change (IPCC 2007) estimate 0.26–0.79 metres rise by 2100. Sea level has risen around Australia at a rate of about 1.2 mm per year since 1920. (Church J.A et al 2006).

Climate change, and in particular global warming, has been linked to sea-level rise (SLR), meaning that sea levels will be significantly higher in the future, resulting in the permanent inundation of low-lying coastal areas, higher storm surges, higher spring tides, receding shorelines and a multitude of flow-on effects.

Global warming describes the trend of increasing average global temperatures across the world, over decadal timeframes. It does not mean that every year is warmer than the previous year everywhere on earth.

Both natural and human-induced (anthropogenic) climate forcing can result in a changing climate, including greenhouse gas emissions, changing surface reflectivity and solar variability.

Many studies have been conducted using models of differing constraints to determine ocean temperatures in the future. Past studies have found that between 1961–2003, the global mean temperature rise was 0.037°C.

Climate-change induced SLR is caused by a number of factors including:

- **increases in ocean thermal expansion and ocean mass due to increasing global temperatures.**
  - During the 20th and 21st centuries, thermal expansion accounted for approximately 60 per cent of all SLR. It has been documented that thermal expansion will continue for centuries, even after stabilisation of greenhouse gas emissions.
- **melting of the Earth's glaciers and ice caps/sheets resulting in an increase in oceanic water volume.**
  - Studies have been conducted to model the impact of the melting of Greenland and Antarctica's glaciers, ice caps and ice sheets on ocean levels.
  - Past studies have found that during the period 1993–2003 the ice sheets contributed 0.8 millimetres/year to SLR.
  - Findings also show that over the last half-century the European Alps in particular are experiencing reduced winter accumulation and greater summer melting.
- **large scale changes to hydrological patterns.**
  - Large scale changes primarily refer to atmospheric circulation systems, such as ENSO.

14: Cabbage Tree Creek Jetty. The Jetty at the mouth of Cabbage Tree Creek. Photo: Kane Nielsen

15: Cabbage Tree Creek Esplanade. Allpass parade, Cabbage Tree Creek. Photo: Kane Nielsen

16: Sandgate Foreshore. South end of Flinders Parade. Photo: Gary Hart

3 2011 summer king tide

The peak of the 2011 summer king tide varied throughout Queensland. Within SEQ, the peak tide occurred on the morning of Friday 21 January. The peak occurred almost a month later for northern coastal areas, with the king tide predicted to be highest on the morning of Wednesday 19 February for coastal areas between Urangan and Gladstone, and Tuesday 18 February for areas between Gladstone and Port Douglas. Observed tide levels closely followed predictions, with some minor exceedances. The majority of DERM's tide gauges recorded water levels at highest astronomical tide (HAT) or slightly below.

Whilst the astronomical tide can be predicted, local weather conditions such as atmospheric pressure, water temperature, wind and wave conditions can influence the actual water level in a given region. The difference between the measured water level and the predicted water level is known as tidal anomaly and is referred to as the 'residual' water level in DERM's tide gauge figures presented in Appendix A.

3.1 January king tide

Each year, the predicted king tide level varies depending on the astronomical influences of the sun, moon and their position relative to the earth. These predictable astronomically driven factors combine with less predictable weather conditions and ocean processes, resulting in the total water level at a given time and location along the coast.

On the morning of 21 January 2011, the prevailing weather conditions and ocean processes were calm, with no strong onshore winds or large swell to exacerbate the already high water levels along the coast. As such, compared to other years, this king tide resulted in far less inundation and coastal erosion than previous king tides along the Queensland coast.

17: Reef Point Esplanade. Partial inundation of the road due to stormwater drain flooding. Photo: Jeff Shortell

18: Endeavour Esplanade Foreshore. Photo taken just north of Endeavour and Oyster Point. Photo: Mathew van Soest

19: Captain Cook Parade, Deception Bay. Foreshore inundation along Captain Cook Parade. Photo: Jeff Shortell

20: White Patch Esplanade, Bribie Island. White Patch Esplanade Bridge. Photo: Scott Bowden

A number of agencies operate tide gauges along the Queensland coast. Water levels are recorded at these tide gauges and this information can be displayed in graphical format depicting the predicted tide, actual tide, and the difference between the two—referred to as the residual. Time-series plots from the MSQ gauges at Southport and Whyte Island, and the DERM storm tide gauge at Mooloolaba, are shown in Figures 3–5 in Appendix A.

Residual plots from tide gauges along the east coast provide evidence that the king tide was a mild event, only slightly above predicted levels. Whyte Island had one of the highest recorded residual water levels in SEQ of 0.16 metres.

At 09:00 hours Australian Eastern Standard Time (AEST) on 21 January, the MSQ tide gauge at Southport measured a peak water level of 1.89 metres above lowest astronomical tide (LAT). This peak was slightly higher than the predicted tide level of 1.82 metres, and just below the HAT value of 1.91 metres.

At 10:40 hours AEST on 21 January, the MSQ tide gauge at Whyte Island measured a peak water level of 2.78 metres LAT. This peak was slightly higher then the predicted tide level of 2.62 metres, and just above the HAT value of 2.73 metres.

At 09:00 hours AEST on 21 January, the DERM storm tide gauge at Mooloolaba measured a peak water level of 2.13 metres LAT. This peak was slightly higher than the predicted tide level of 2.09 metres, and just below the HAT value of 2.17 metres.

The primary reasons for the 'mild' summer king tide in 2011 were the prevailing weather conditions and ocean processes. During the peak of the tide on 21 January, water levels were depressed by the influence of a high pressure system extending from the Tasman Sea to Rockhampton, and thus over much of the SEQ coastline. The high also resulted in calmer wind and wave conditions along the coast.

Additionally, a monsoon trough between Mornington Island and Cairns prevented a low pressure system forming over northern Queensland, and bringing strong onshore winds and changing ocean currents. The monsoon trough was in an active phase, causing moderate to fresh north-westerly winds in the Gulf Region.

The absence of strong onshore winds along the Queensland coast drastically reduced the impact of the 2011 king tide. Many regions experienced only minor inundation along the foreshore as can be seen in the photographs.

21: Maroochy River, Wharf Street. Wharf Street public Jetty. Photo: Rod Garner

22: Alexandra Surf Club, Mooloolaba. Looking towards beach access points M78 and M79. Photo: Rod Garner

23: Maroochydore River. Looking north towards the Maroochydore SLSC club house. Photo: John Gilbert

24: Lady Musgrave Island. Campsite beach entrance, western side. Photo: John Ferris

3.2 February king tide

In northern areas, the 2011 summer king tide was predicted to occur on a range of dates between 19 January–19 February. For the purposes of simplifying the 2011 king tide photographic survey, 18 February was chosen as the key date to photograph the king tide in parts of Queensland other than SEQ. This date was chosen as it was the predicted date for the summer king tide to occur in coastal areas from Gladstone to Port Douglas, representing a large portion of the developed Queensland Coast outside SEQ. Graphs from the Townsville, Cardwell, and Cairns tide gauges are displayed in Figures 6–8.

At 09:00 hours AEST on 18 February, the DERM storm tide gauge at Townsville measured a peak water level of 4.15 metres LAT. This peak was slightly higher then the predicted tide level of 4.01 metres, and just above the HAT value of 4.11 metres.

At 09:30 hours AEST on 18 February, the DERM storm tide gauge at Cardwell measured a peak water level of 4.24 metres LAT. This peak was higher then the predicted tide level of 3.97 metres, and above the HAT value of 4.13 metres.

At 09:20 hours AEST on 18 February, the DERM storm tide gauge at Cairns measured a peak water level of 3.46 m above LAT. This peak was slightly higher than the predicted tide level of 3.34 metres, and just below the HAT value of 3.50 metres.

In the Gulf of Carpentaria, king tide heights were well above predictions. This is because tides in the Gulf cannot be predicted as accurately as those on Queensland's east coast.

The prevailing north-west monsoons, active in the Gulf during the king tide period, also contributed to higher than expected tides over this period. Graphs from Weipa and Karumba tide gauges are displayed in Appendix A (Figures 9–10).

At 10:00 hours AEST on 21 January, the DERM storm tide gauge at Weipa measured a peak water level of 3.61 metres LAT. This peak was higher than the predicted tide level of 3.14 metres, and above the HAT value of 3.38 metres.

At 00:00 hours AEST on 21 January, the DERM storm tide gauge at Karumba measured a peak water level of 4.83 metres above LAT. This peak was higher than the predicted tide level of 4.34 metres, and just below the HAT value of 4.88 metres.

25: Mon Repos Conservation Park, Bundaberg. Mon Repos Beach boardwalk, inundated. Photo: John Ferris

26: Heron Island Jetty. Looking from the jetty at the inundated beach. Photo: Alan Hollis

27: Heron Island. In front of the QPWS turtle shelter—North Beach. Photo: Alan Hollis

28: The Venue—Townsville.
Photo: Rachel Allan & Brendan Meale

4 King tide water level monitoring

Prior to the king tide event on 21 January 2011, officers from the Coastal Impacts Unit deployed water level recording instruments at a number of sites to investigate local impacts of the king tides, and to compare actual tide levels with those predicted to occur.

DERM also obtained data from several other sources, including the Manly Hydraulics Laboratory (NSW), Maritime Safety Queensland, and the Bureau of Meteorology.

The instruments chosen to record the 2011 king tide event were self-contained In-Situ Level TROLL 500s, which measure the surface water elevation when submerged. These instruments were placed in a perforated PVC housing and attached as close as possible to the Lowest Astronomical Tide (LAT) by means of stainless steel banding (photos L2 and L3).

These instruments were chosen for their simple programming, in-situ recording capacity, reliability and accuracy. The instruments were programmed to record water levels every 30 seconds for several days either side of the king tide event. The instruments were then collected and the data recovered.

Two pressure transducers were deployed in the Tweed River. One was attached to the Tweed River Entrance Sand Bypassing (TRESBP) jetty at Letitia Spit, south of the Tweed River entrance, to record the water level. The other was deployed on Point Danger headland to record barometric air pressure. Another pair of pressure transducers were deployed at Cabbage Tree Creek, Deagon. These sites were chosen to contrast two different tidal environments, one of which is wave-influenced and the other dominated by estuarine processes with minimal wave influence.

A: Letitia Spit, New South Wales.

B: Letitia Spit, New South Wales.

C: Letitia Spit, New South Wales.

Installation of pressure transducers: Photographs A–C depict the installation of the pressure transducer equipment on the TRESBP jetty at Letitia Spit (photo B and C). In order to obtain an accurate water level at these locations, the equipment used to record water level were levelled in using a permanent survey mark or bench mark and survey equipment (photo A).

Tide data from a tide gauge located inside the Tweed River was provided by the Manly Hydraulics Laboratory (NSW), for the period 18–25 January 2011. This data was compared with tide data collected at Letitia Spit, located on the seaward side of the Tweed River. Both data sets are presented in Figure 11.

Note that the dataset for Letitia Spit does not extend as low as the Tweed River dataset due to the positioning of the pressure transducer above LAT. As the instrument can only record water level when submerged, the lowest level displayed reflects the level at which the instrument was attached to the jetty (approximately 0.25 metres LAT).

There is a clear distinction between the variability of the datasets due to the wave interference experienced at Letitia Spit compared with the protected gauge within the Tweed River. HAT at the Tweed River breakwater tide gauge is 1.91 metres above LAT.

With regard to the data collected by the Coastal Impacts Unit, it appears that the peak tide level exceeded HAT by approximately 0.25 metres during the January 2011 king tide event.

Tide and barometric pressure data from the tsunami warning station located on the Gold Coast sand bypassing jetty was supplied by the Bureau of Meteorology for the period of 10–31 January 2011. Note the variability in the average water level caused by the wave interference. The HAT recorded at the MSQ tide gauge inside the Gold Coast Seaway is 1.91 metres above LAT. With regard to tide data obtained by the Coastal Impacts Unit from this gauge, it appears that the peak tide level reached HAT but did not exceed it during the January 2011 king tide event (Figure 12).

30: Townsville Boat Ramp. Water level not far off being flush with the car park. Photo: Rachel Allan & Brendan Meale

31: Lucinda. Foreshore of Lucinda, near southern end, where large sand bags were used to limit beach erosion. Photo: Mark Parsons

29: Coast Guard Office, Townsville. Photo: Rachel Allan & Brendan Meale

32: Palm Creek, near mouth. Beach hut located inside the mouth of Palm Creek. Photo: Mark Parsons

Tide data from the tide recording station located at Pinkenba was provided by MSQ for the period of 19–26 January 2011. The Pinkenba data was compared to the Cabbage Tree Creek data collected by the Coastal Impacts Unit, with both datasets displaying similar tide levels apart from a slightly higher king tide recorded at Pinkenba. Note that the Pinkenba dataset extends lower than the Cabbage Tree Creek dataset due to the placement of the Cabbage Tree pressure transducer above LAT. As the instrument only records the water level when submerged, the lowest water level displayed reflects the level at which the instrument was attached to the jetty (at approximately 0.75 metres above LAT). HAT at the Cabbage Tree Creek mouth is 2.62 metres above LAT. This level was exceeded by approximately 0.2 metres during the January 2011 king tide event. The HAT at Pinkenba is 2.84 metres above LAT. This level was not exceeded during the same king tide event, thus demonstrating local tide variability (Figure 2).

It can be noted that at many coastal locations exposed to the influence of wave energy, tide levels appear to have reached or exceeded HAT. This fact is particularly important when considering king tide levels as a surrogate indicator for more permanent SLR along Queensland's open coast. It is probable that if a low pressure system and strong onshore winds and waves were experienced along the Queensland coast during the 2011 summer king tide, peak tide levels would have exceeded HAT by an even greater amount. As it was, the weather conditions on the day of the SEQ king tide were dominated by a large high pressure system and calm conditions.

Data from tide gauges around the world shows that the global sea level has risen by almost 0.2 metres since 1870 (Church & White 2011). Since 1993, satellites have been used to measure sea levels more accurately. Both sets of measurements show that the rate of SLR has accelerated. Coastal observations confirm that SLR has been occurring around Australia since at least 1920. Eastern Australia experienced extreme sea level events three times as often in the last half of the 20th century compared with the first half.

The Intergovernmental Panel on Climate Change (IPCC) (2007) has indicated that climate change is linked to increased emissions of greenhouse gases caused by human activity. Concentrations of atmospheric CO_2 are increasing rapidly, with the 2009 concentration level at 387 parts per million (ppm). Levels of atmospheric CO_2 are now at their highest concentration, much higher than the natural range of 172–300 ppm over the last 800 000 years. There is now 38 per cent more CO_2 in the atmosphere than at the start of the Industrial Revolution.

33: Port Hinchinbrook. At the edge of a coastal development along the northern spit at port entrance, water has passed rock sea wall. Photo: Emma Schmidt & Alex Tessieri

34: Port Hinchinbrook Spit. Hinchinbrook Marina, looking along the coastal development of Port Hinchinbrook. Photo: Emma Schmidt & Alex Tessieri

35: Edmund Kennedy Boardwalk. Boardwalk entrance at Edmund Kennedy just submerged by king tide. Photo: Emma Schmidt & Alex Tessieri

36: Flying Fish Point. Photograph taken directly in front of fish and chip shop. Photo: Brenton Haigh

4.1 Future sea levels

World wide there are more than 100 million people living less than 1 metre above the mean sea level recorded in 2002. Globally, SLR is threatening the existence of islands, low-lying coastal regions and deltaic coasts, with the potential for future displacement of millions of people worldwide.

The IPCC projects that global mean sea level will increase by up to 0.79 metres by 2100. Regional SLR will be affected by localised factors and land characteristics (DERM 2011). Modelling scenarios for medium emission levels have found that SLR along the Queensland coast could have an additional regional factor of 0.05 metres by 2070 (White 2011). The Queensland Government is currently using a benchmark SLR of 0.8 metres by 2100 for planning purposes.

With the projected increase in sea level, sea water inundation, which is presently only experienced during events such as king tides, storm surges, or tsunamis, will become more frequent in the future.

Since 1993 SLR trends have been matching the worst case projections from the IPCC reports. From 1990–2009, mean sea levels have increased by around 60 millimetres (or a rate of about 3 millimetres per year) (Church & White 2011).

37: Palm Cove Foreshore. Boat ramp in foreground and the jetty in background. Photo: Glenn Kvassay

38: Sweet Creek, Palm Cove. Photo from bridge located on Triton St. Resort and apartments in background, on the right side. Photo: Glenn Kvassay

39: Holloways Beach Central. Photo from near Matthew St and Oleander St intersection. Note the high tide mark. Photo: Ann Chalmers

40: Northern end of the Cairns Esplanade. Photo: Claire Murrell

41: Cooktown Boat Ramp area. Photo: Peter Kilshaw

42: Cooktown Foreshore. Photograph in front of cannon. Photo: Peter Kilshaw

43: Ratcliffe Road, Marton. Water level not far off house ground floor. Photo: Peter Kilshaw

44: Quintel Beach, Lockhart River. Lockhart River Barge Landing and picnic area. Photo: Pip Schroor

5 Impacts of sea level rise

Some of the key impacts associated with SLR include:

- localised tidal inundation and flooding of private and public land, including residential development, commercial and industrial precincts, sewage infrastructure, park reserves, buildings, roads, jetties, wharfs, pathways, boardwalks, car parks, etc.
- beach and dune erosion and scarping
- destruction of dune, mangrove and wetland ecosystems
- a reduction of the beach width between existing development and the high water mark. Many coastal areas have been developed in close proximity to HAT. Flow-on effects from a reduction in beach width include habitat loss, loss of coastal-hazard buffer zones and loss of social amenity
- reduction in clearance between the high water mark and the crests of revetment walls, groynes, seawalls, levies and other engineering structures put in place to protect development from coastal erosion and water overtopping
- submergence of gravity-dependent stormwater networks in coastal areas, resulting in ineffective stormwater drainage, localised flooding and poor-quality water discharged to the environment
- permanent opening of currently closed beach lagoon systems. For development surrounding these lagoons, a permanently open lagoon system may result in increased erosion and coastal hazards
- a rise in mean sea level, which will increase the height and extent of coastal inundation caused by storm surge
- loss of important cultural heritage sites such as middens, which are often already located in close proximity to current sea levels.

Sea level rise will not only have an impact on the human environment but also on important ecosystems and natural habitats which provide a range of ecological functions. For example, SLR will likely affect the nesting grounds of sea turtles and sea birds, with periodic or permanent flooding of these important nesting beaches, which may eventually cause a decline in population.

45: Evans Landing Boat Ramp, Weipa. Photo: Michael J. Beeby

46: Sunset Tavern, Karumba Point. Shoreline at low tide. Photo: Bevis Hayward

47: Sunset Tavern, Karumba Point. Shoreline an hour before King Tide. Photo: Bevis Hayward

Nesting sites such as Heron Island and Lady Musgrove Island are of major concern. A sea level rise of only 0.38 metres will permanently flood these beaches.

The 2011 king tide photographic survey can provide a valuable visual record of the impacts of increased sea levels. Whilst the sea levels observed in this survey currently only occur on the biannual king tide or during storm surge events, they may become the norm in the future. Photographs 26 and 27 show the impact current king tides have on these islands.

5.1 Storm surge

Storm surge is a local rise in the sea level caused by the combined action of severe winds and low-pressure systems (east coast lows and tropical cyclones) on the sea surface. Storm tide is the combined water level of a storm surge, wave set up, and the normal astronomical tide.

When a storm tide level is higher than HAT, it is likely to cause inundation and flooding in low-lying coastal areas. These areas are most susceptible and vulnerable to coastal flooding from a storm tide during the peak of a king tide event.

48: Sunset Tavern, Karumba Point. Shoreline at low tide. Photo: Bevis Hayward

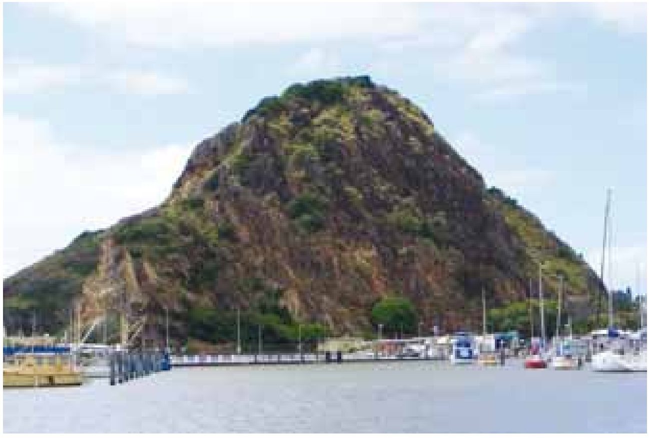
49: Sunset Tavern, Karumba Point. Shoreline an hour before king tide. Photo: Bevis Hayward

50: Mid Molle Island Spit. Spit located on the northern end of Mid Molle Island. Photo: Mark O'Brien

51: Pumpkin Island Resort, Keppel Bay. Photo: John Messersmith

As higher sea levels become more prevalent, it is highly likely that storm surges will increase in both height and frequency. Changes to local bathymetry and coastline alignment (as a result of higher sea levels) may also play a part. Factors such as width, depth and slope of the continental shelf, the scale of bays, headlands and islands or the influence of extensive reef areas all have the potential to affect storm surge height.

Figure 2 displays the variation in surge responsiveness due to the physical characteristics of a region and exemplifies how important these factors are when considering the intensity of a storm surge and the amplified impact it could have during a king tide. Due to their proximity to large-scale bays, areas such as Hervey Bay and Townsville would experience much greater inundation levels than regions without these features. This can also be said for Weipa and Karumba along the west coast, where extensive shallow water regions in the Arafura Sea are the cause of such high relative intensities.



52: Rosslyn Bay Harbour. Photo: John Messersmith

53: Yam Island. Jetty being swamped as a result of the king tide and ocean swells. Photo: Peter Armstrong

5.2 Benefits of future sea-level rise

While climate change and SLR are likely to cause an array of adverse impacts, there may be some economic benefits relating to shipping, ports and harbours. An increased sea level would result in increased draft within ports and harbours, thus allowing larger shipping capacity and longer tidal windows for deep draft vessels to manoeuvre in ports.

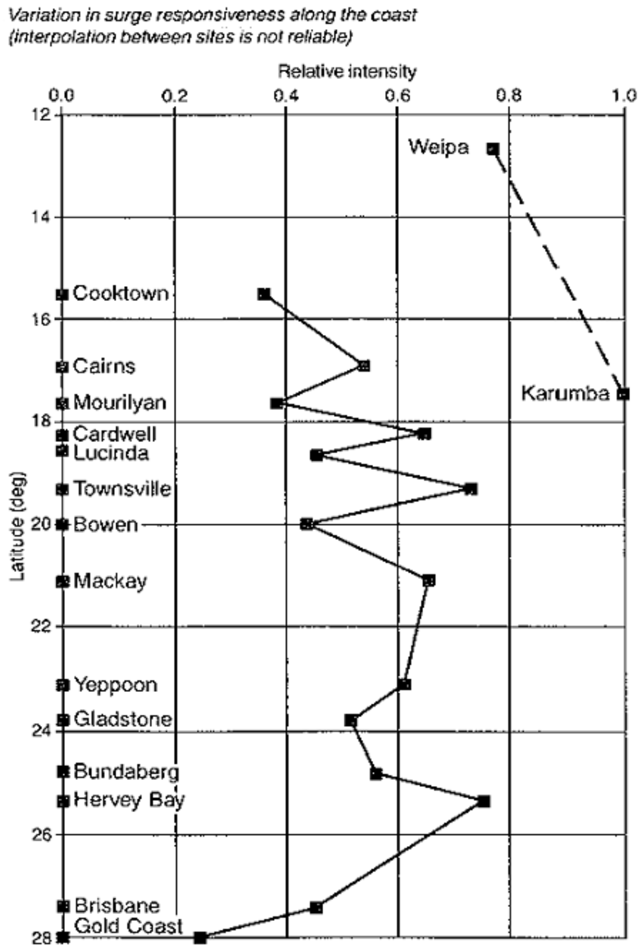


Figure 2: Storm surge intensity along QLD coast. Harper, 1998 p.9

54: Yam Island. Foreshore being battered as a result of king tides and monsoonal activity. Photo: Peter Armstrong

6 Impacts highlighted by the survey

This report provides a variety of photographs taken on the peak of the 2011 summer king tide on 21 January in SEQ and 18 February in areas outside SEQ.

These photographs provide a useful insight into the vulnerability of the Queensland coast to flooding from the sea, as well as identifying areas that will become progressively more vulnerable over time as sea levels continue to rise.

Some of the key impacts identified during the survey and displayed in these photographs include:

- localised tidal inundation and flooding of private and public land including residential developments, park reserves, car parks, roads, jetties, wharfs, pathways, boardwalks, cycle ways, bridge underpasses
- a reduction in bridge clearance (impacting users of both the waterway, and footpaths and cycleway underpasses)
- beach and dune erosion and scarping (which may result in vegetation and habitat loss and dangerous conditions for beach users)
- a reduction of beach width between existing developments and the high water mark (which may result in habitat loss, reduction in coastal-hazard buffers and loss of social amenity)
- a reduction in clearance between the high water mark and crest of revetment walls, groynes, seawalls, levies and other engineering structures put in place to protect development from coastal erosion and water overtopping of shallow sand islands (causing increased erosion and habitat loss)
- submergence of gravity-dependent stormwater networks in coastal areas, resulting in ineffective stormwater drainage and localised flooding.

55: Lammermoor Beach, Yeppoon. Beach access at the southern end of Lammermoor Beach. Photo: David Marshall

56: Ross Creek, south of Yeppoon. Junction of Ross Creek and Figtree Creek looking south-west at bridge over Ross Creek. Photo: David Marshall

57: Mackay Boat Ramp. Located at the mouth of the Pioneer River. Photo: Vicki Coburn

58: McEwen Beach. Looking west along the McEwen Beach stinger net enclosure. Photo: Jana Hummelshoj

7 Queensland Government actions

The Queensland Government's climate change strategy, *ClimateQ: Toward a Greener Queensland* (2009) contains a range of initiatives to reduce Queensland's emissions and adapt to the inevitable impacts of climate change.

Queensland's climate change adaptation strategy is currently being updated with public consultation occurring in the second half of 2011. The final strategy, due for release in early 2012, aims to better equip Queensland to deal with the impacts of climate change, such as sea level rise.

The *Queensland Coastal Plan*, released in March 2011 includes an updated sea level rise figure of 0.8 metres by 2100, based on the upper limit of the projections released in the IPCC Fourth Assessment Report (2007). This figure is used for determining coastal hazard areas which guide land-use planning and development decisions to reduce the risk to persons and property.

The *Queensland Coastal Plan* also contains coastal hazard maps that show areas at risk from storm tide inundation and erosion prone areas. The default storm tide inundation area is based on a 0.8 metre sea level rise by 2100 due to climate change.

Other initiatives to improve the understanding of local climate change impacts and the availability of mapping and data to support climate change vulnerability assessments of the coastal zone include:

- the Improved Coastal Mapping Project, which involves the creation of a digital elevation model of the Queensland coastline which will be used to develop interactive maps to identify vulnerable areas of the Queensland coast. Stakeholders, including developers and local governments, will be able to use the maps to identify and visualise areas likely to be at increased risk from coastal hazards
- the storm tide mapping project—as a result of this project storm tide inundation maps are now available for populated areas of Queensland most at risk from storm tides including the Burdekin, Whitsundays, Cairns, Mackay, Palm Island and Wide Bay Burnett
- the Gulf of Carpentaria Storm Tide and Inundation Study—this study will produce numerical simulations of tropical cyclone storm surge, waves and wave effects for the region, and inundation mapping of selected locations under current and future scenarios
- coincident flooding—through the National Disaster Resilience Program, QCCCE will determine the significance of the risk from coincident riverine flooding and storm tide inundation in coastal areas of Queensland
- tsunami modelling—numerical simulations of tsunami scenarios will assess the nearshore tsunami hazard for specific sections of Queensland's east coast and will be followed by inundation modelling of two locations
- wave and storm tide monitoring—the Queensland Government established a monitoring program in the 1970s and continues to maintain and collect data from 13 wave-rider buoys and 25 storm tide gauges located along the Queensland coast from the Gold Coast to Weipa
- the *Queensland Coastal Processes and Climate Change* (2011) publication which discusses the characteristics of Queensland's coast and coastal hazards, including those projected under climate change. It highlights the vulnerability of Queensland's different coastal regions as well as coastal management and adaptation options.

59: Port Denison, Bowen. Near Thomas Street drain looking south. Photo: Jacinta Oliver

60: Port Denison, Santa Barbara Parade, Bowen. At the old sailing club near the boat ramp. Photo: Jacinta Oliver

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Further reading

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Appendix A

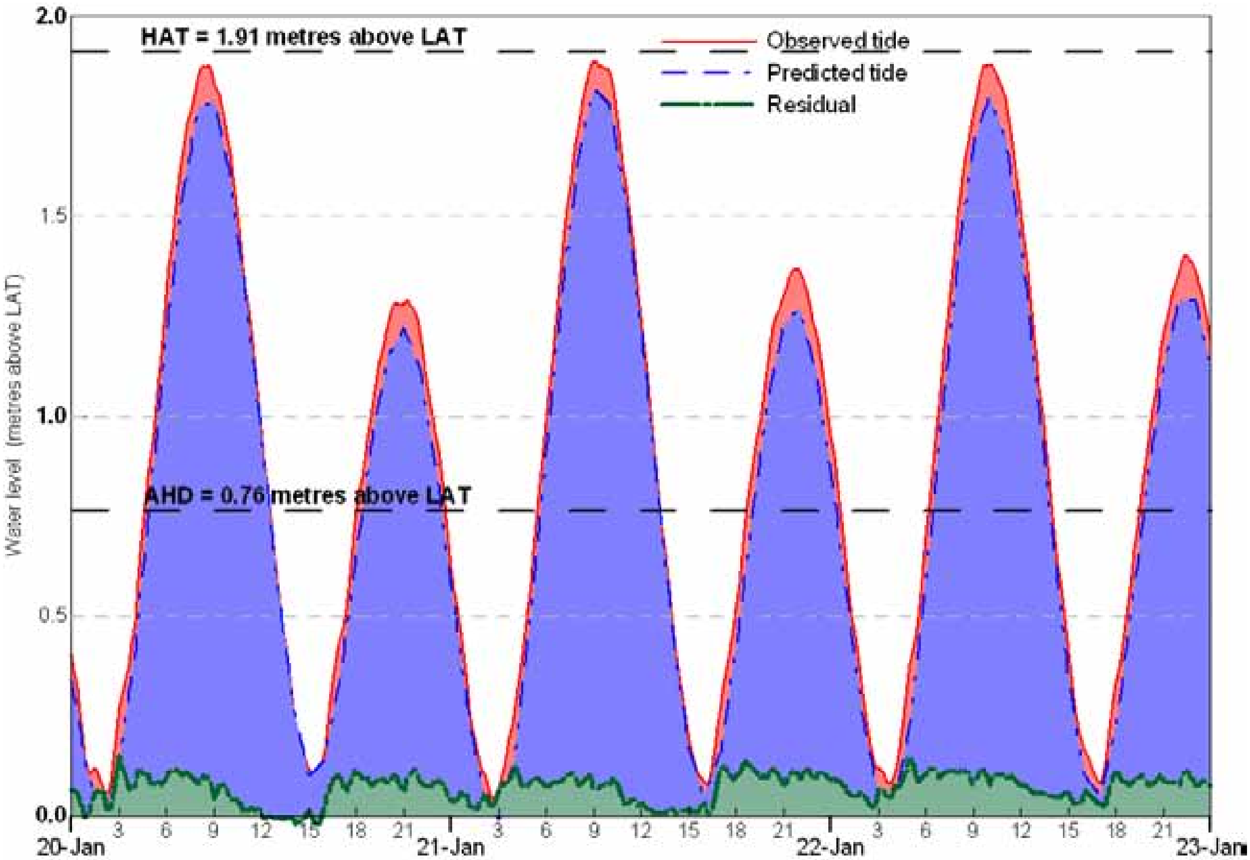

Figure 3: MSQ Southport tide gauge 20–22 January 2011

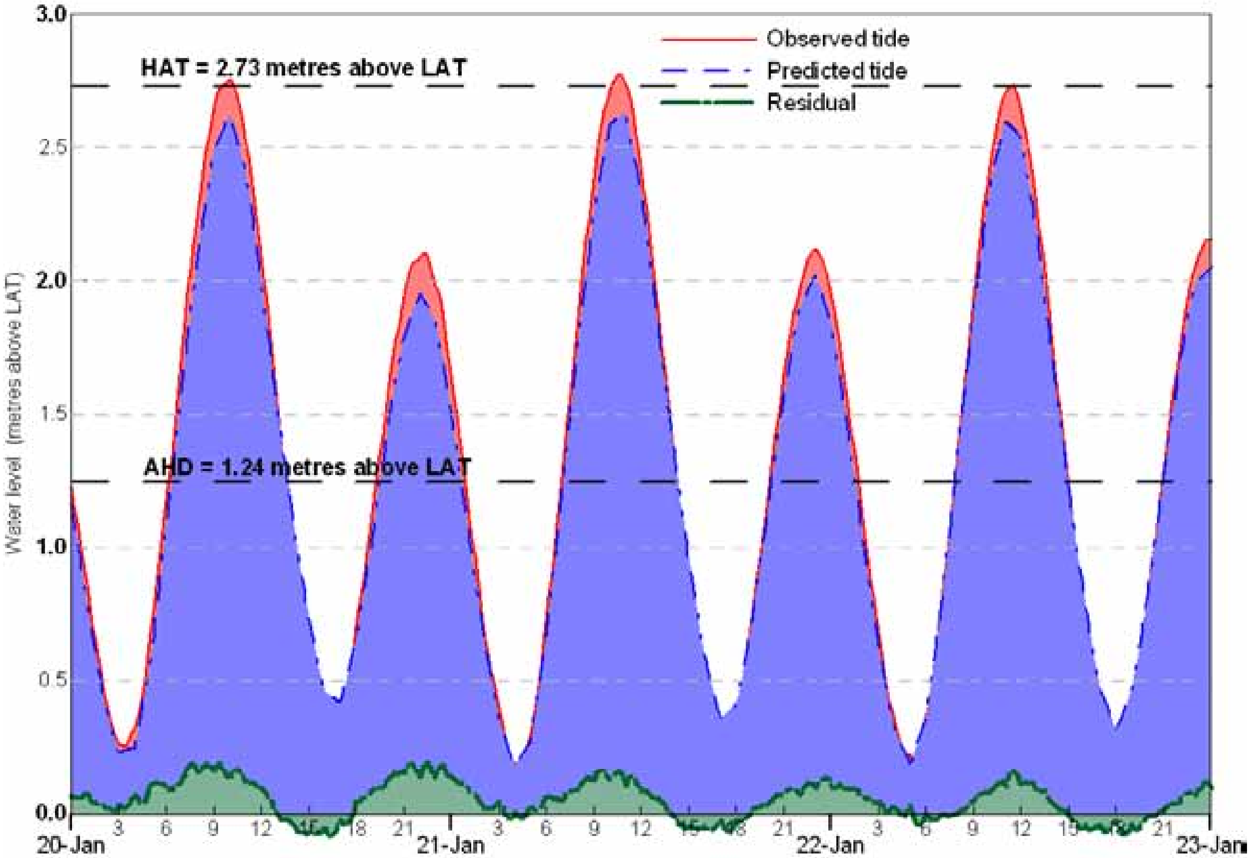

Figure 4: MSQ Whyte Island tide gauge 20–22 February 2011

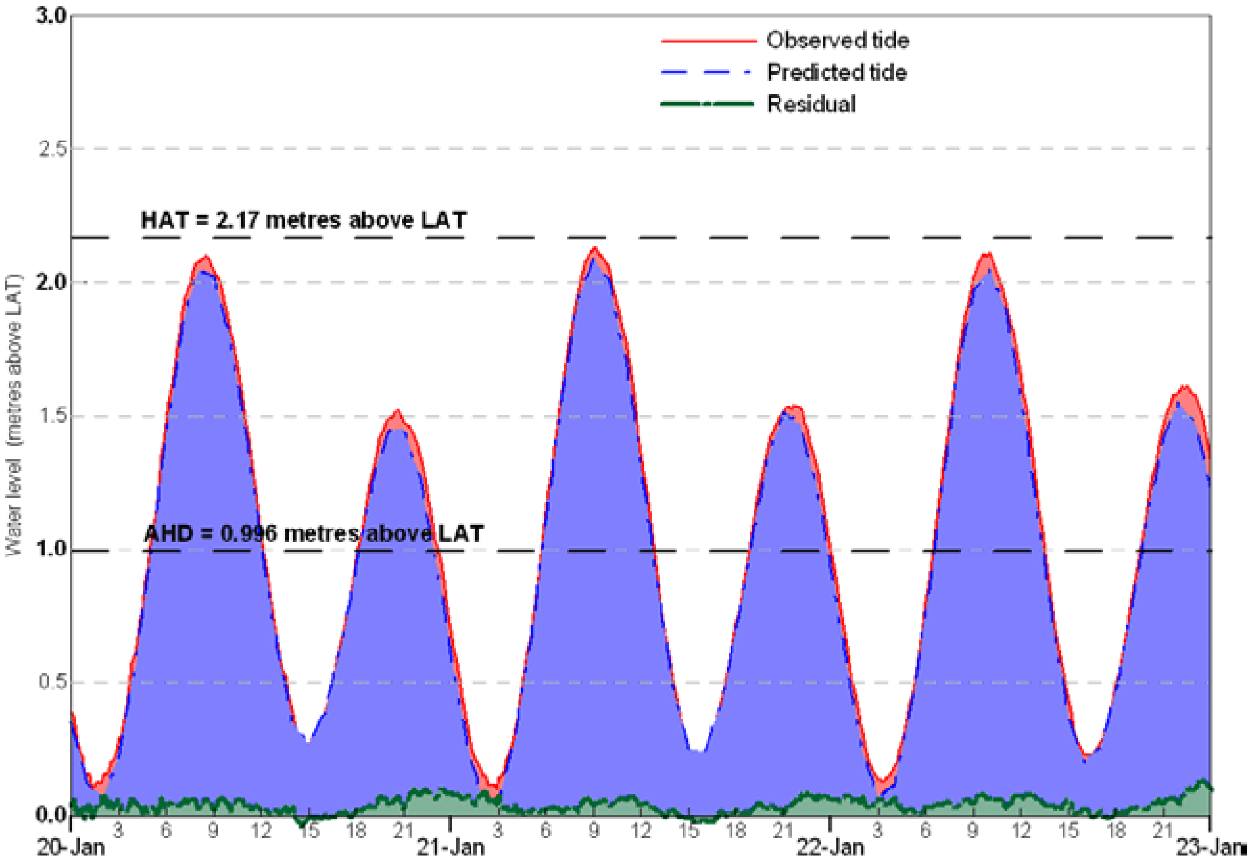

Figure 5: DERM Mooloolaba tide gauge 20–22 January 2011

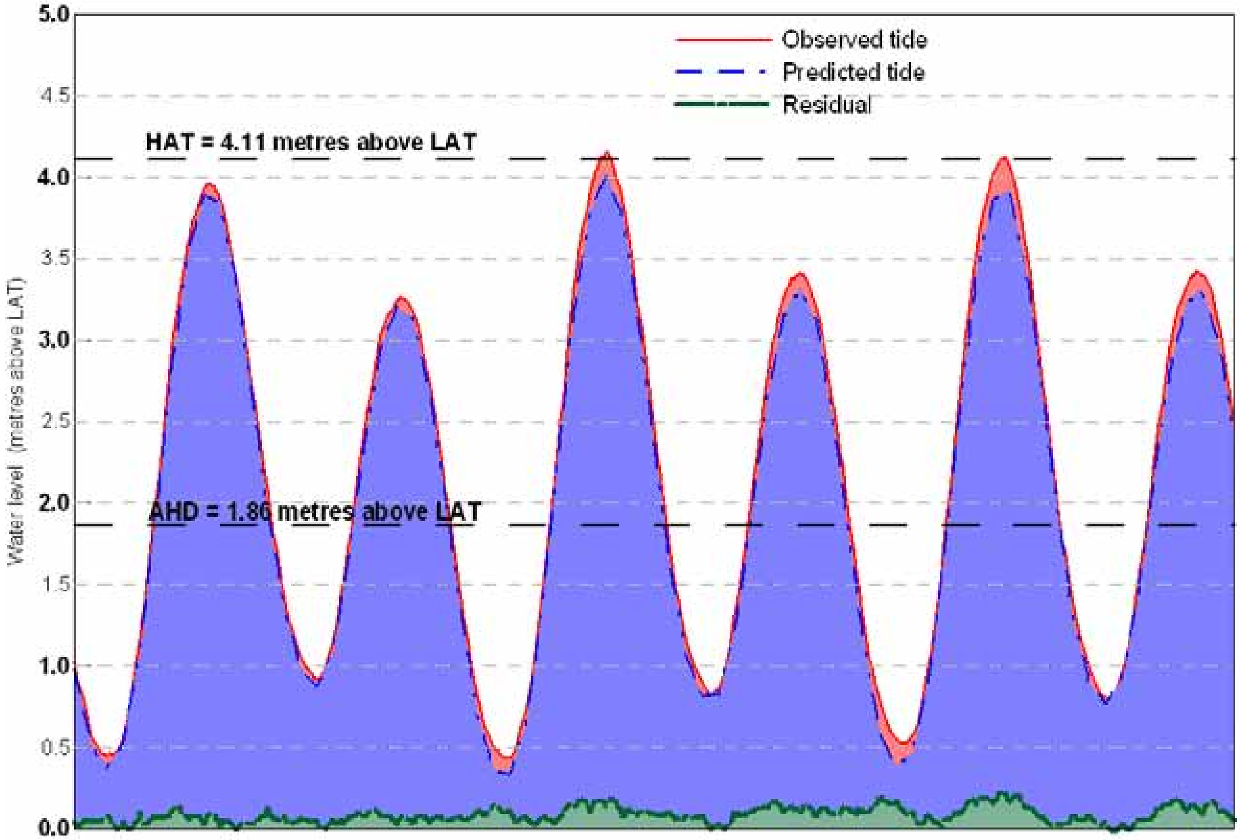

Figure 6: Townsville Tide gauge 17–19 February 2011

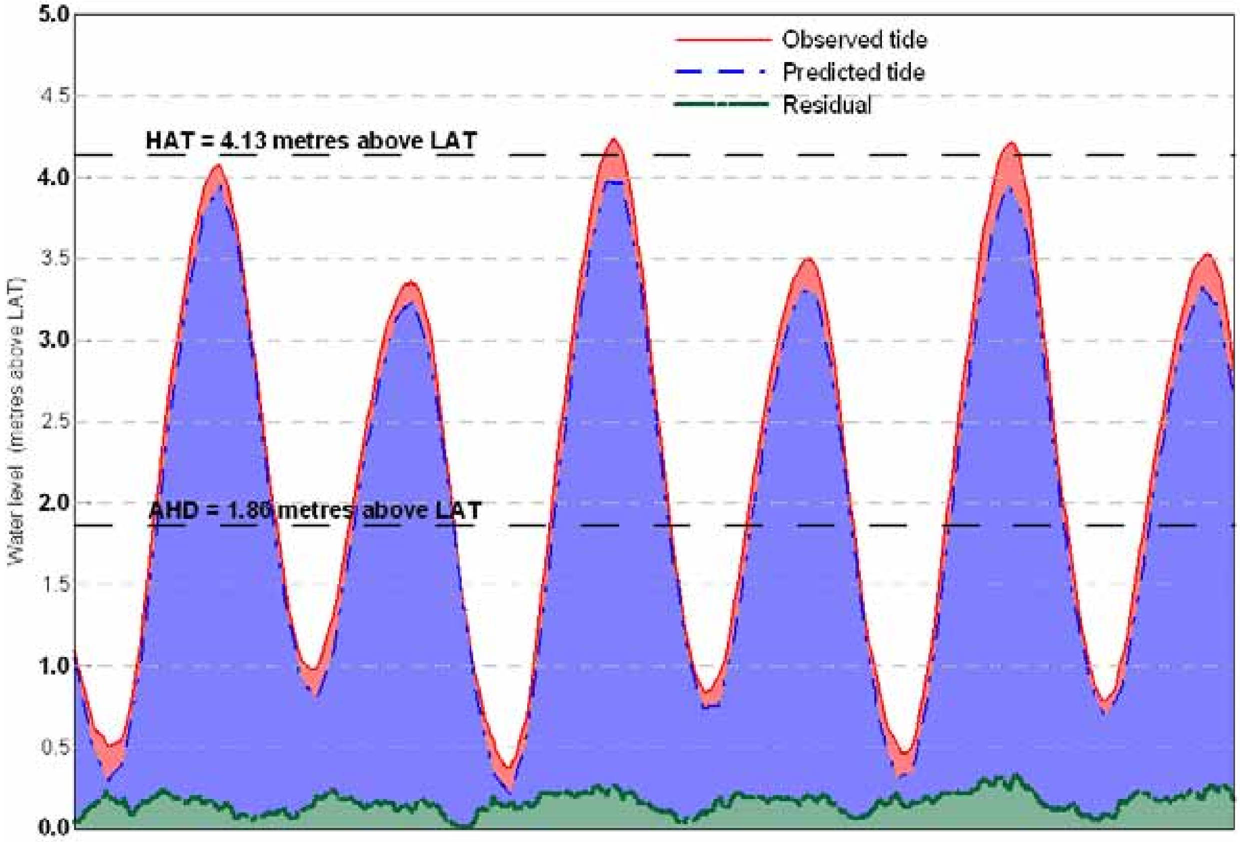

Figure 7: DERM Cardwell tide gauge 17–19 February 2011

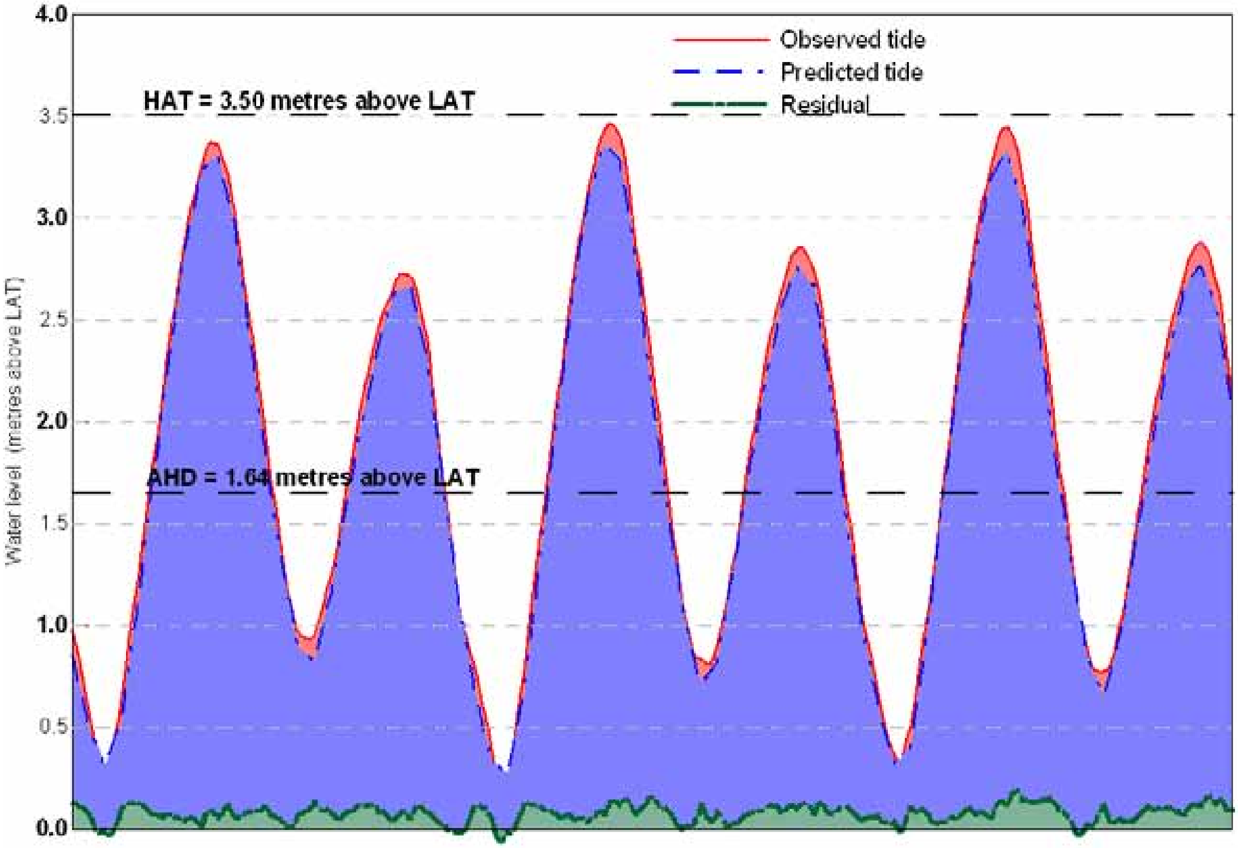

Figure 8: DERM Cairns tide gauge 17–19 February 2011

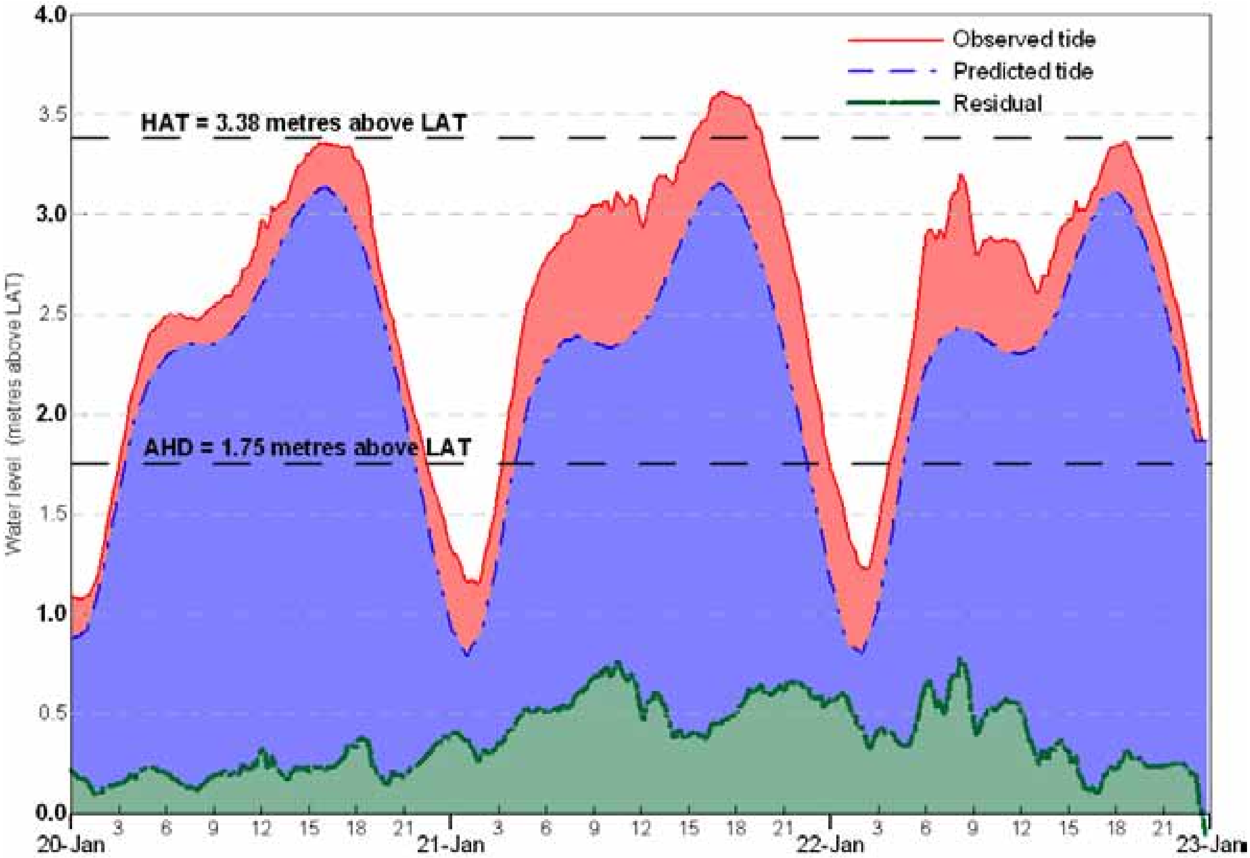

Figure 9: DERM Weipa tide gauge 20–22 January 2011

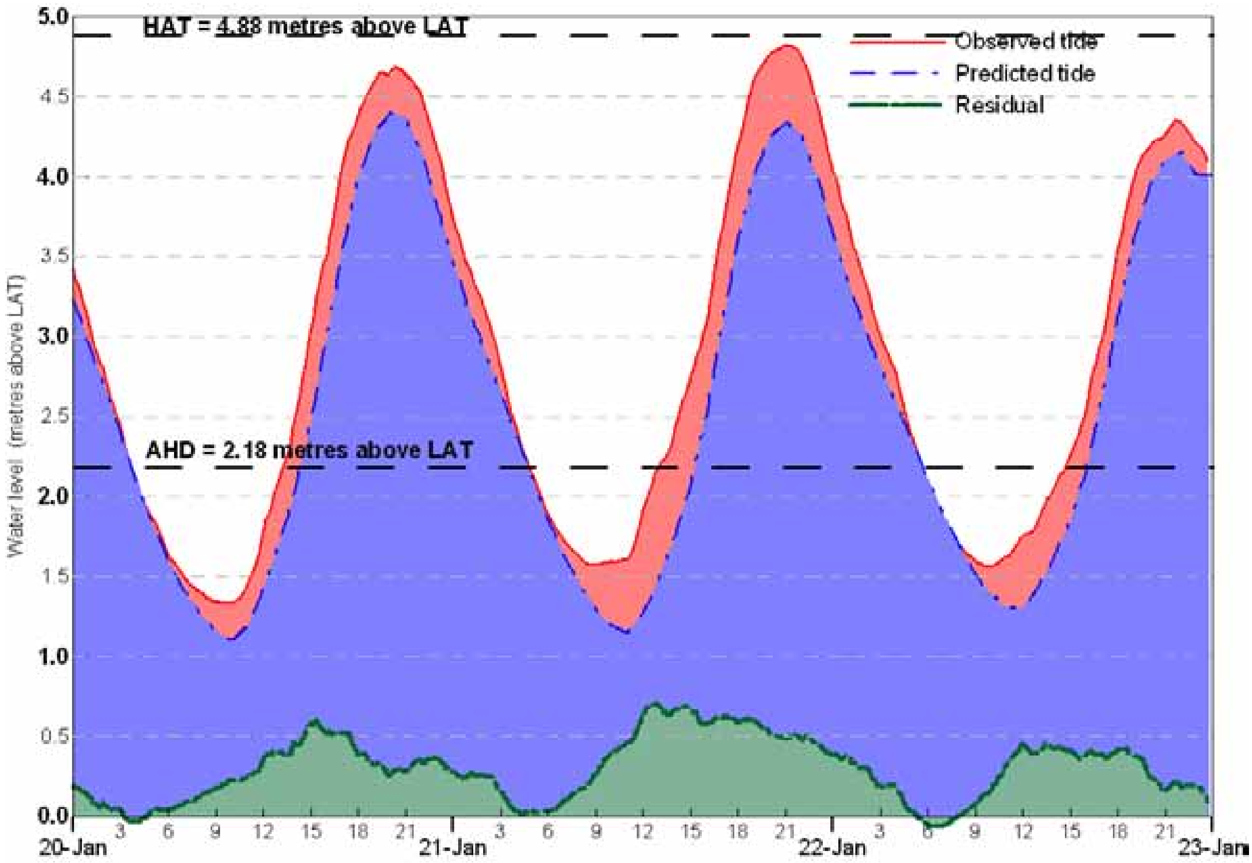

Figure 10: DERM Karumba tide gauge 20–22 January 2011

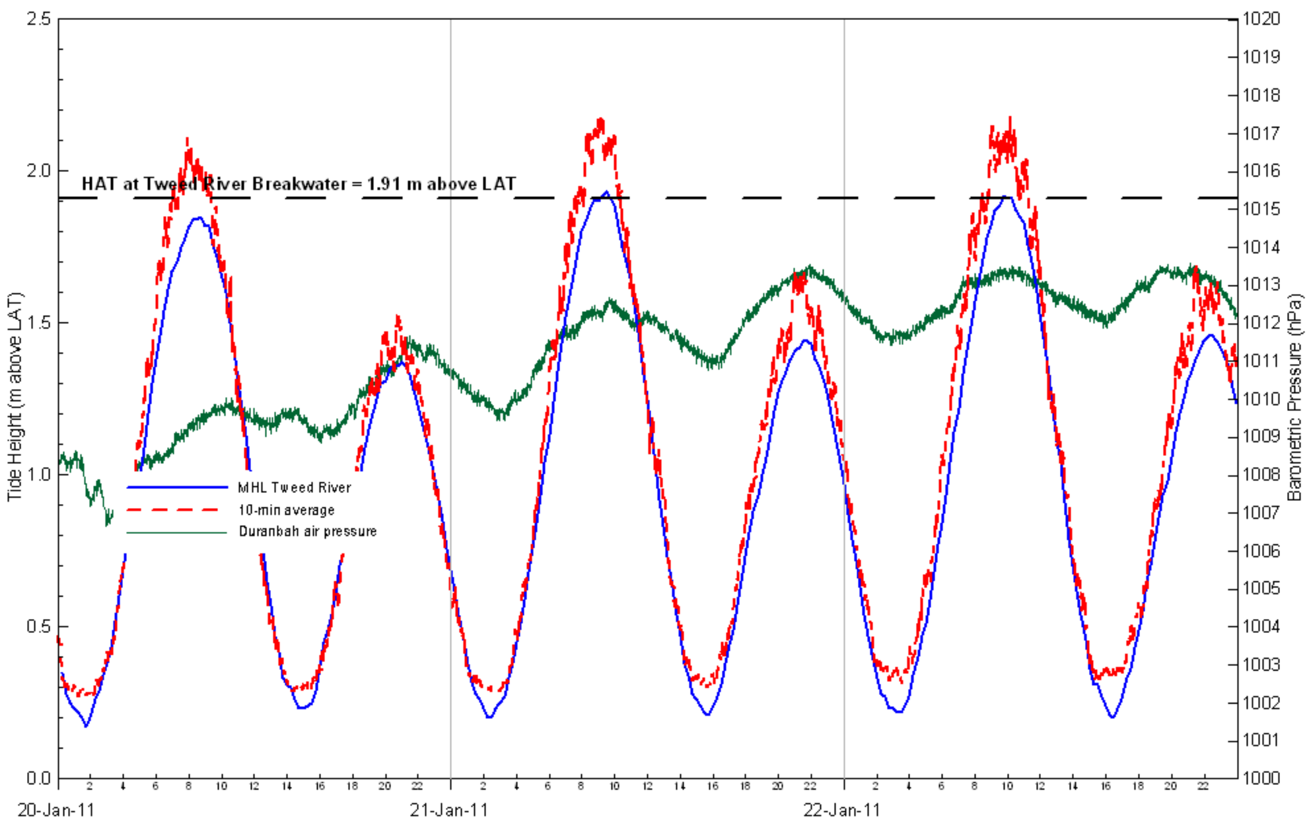

Figure 11: Pressure sensors Letitia Spit 20–22 February 2011

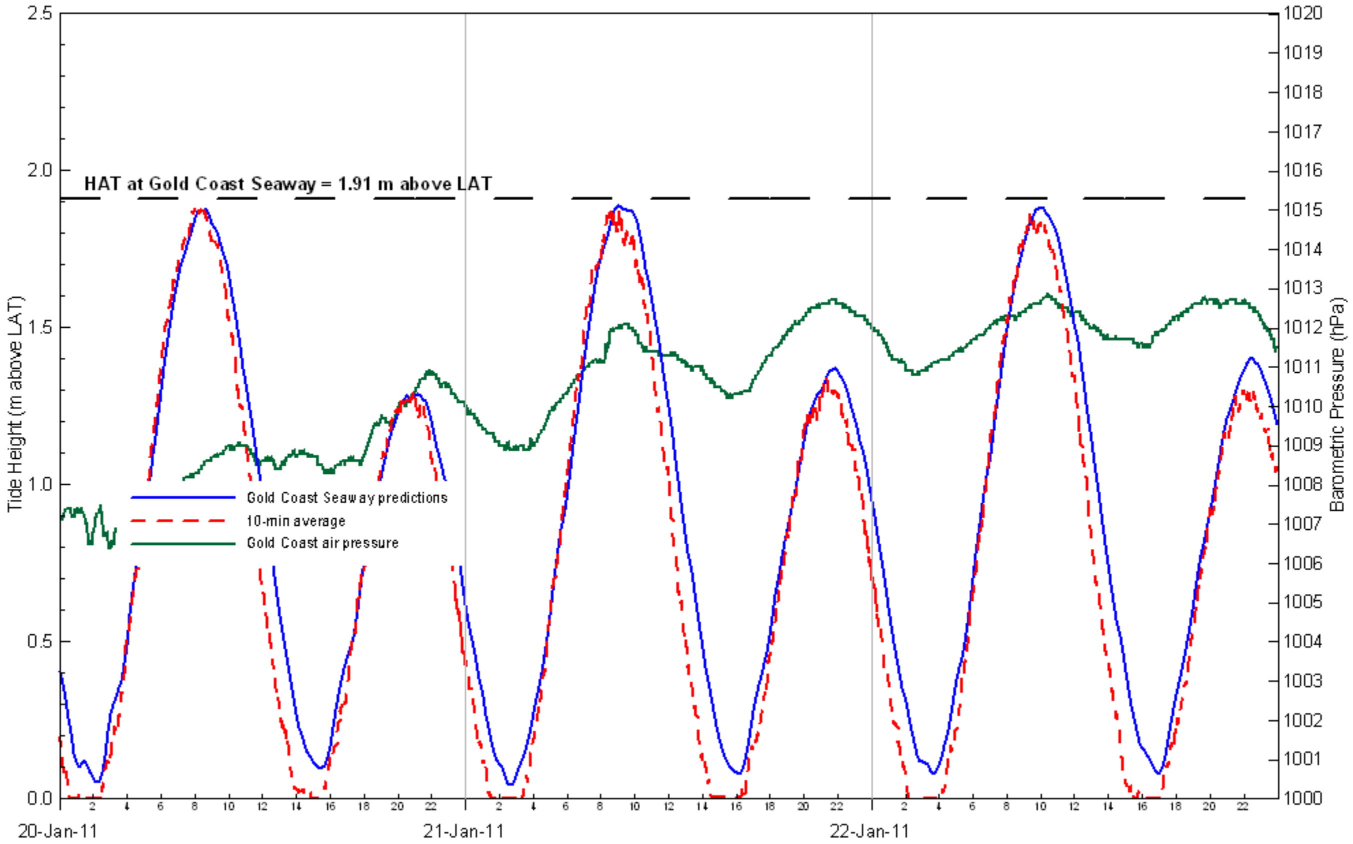

Figure 12: Pressure sensors Gold Coast Sand Bypass 20–22 February 2011

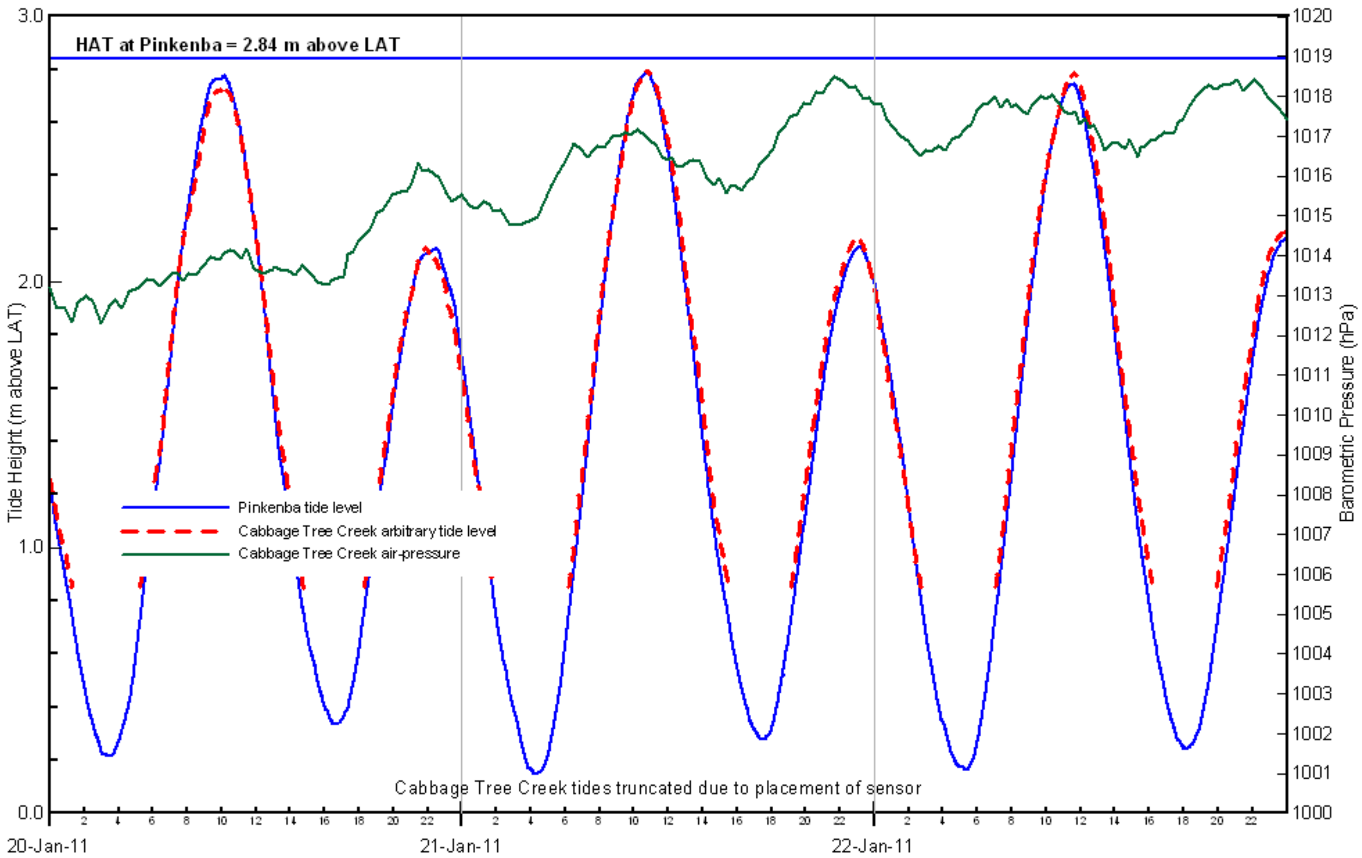

Figure 13: Pressure sensors Cabbage Tree Creek 20–22 February 2011

Appendix B: 2011 king tide photography details

1: Currumbin Waters Canal
[Backyard of residential property along Westari Court Currumbin Waters]
Captured: 21/01/11 @ 08:55
Direction: East
GPS: GDA94. 28°9.277'S 153°27.789' E.
Photo: Adrian Lavery

2: Currumbin SLSC car park
[Wave overtopping edge of car park]
Captured: 21/01/11 @ 09:08
Direction: North East
GPS: GDA94 28°07.976' S 153°29.407' E.
Photo: Zoe Helyer & Eugene Immisch

3: Currumbin Creek Boardwalk
[Between Thrower Drive and Gold Coast HWY]
Captured: 21/01/11 @ 09:21
Direction: North West
GPS: GDA94 28°07.946' S 153°28.625' E.
Photo: Zoe Helyer & Eugene Immisch

4: Gold Coast Highway Bridge
[Bridge spanning Tallebudgera Creek]
Captured: 21/01/11 @ 09:05
Direction: North
GPS: 28°05.923' S 153°27.447' E.
Photo: Megan Davis

5: Canal of Tallebudgera Creek
[West of Melaleuca Drive]
Captured: 21/01/11 @ 09:10
Direction: East
GPS: 28°06.287' S 153°27.087' E.
Photo: Megan Davis

6: Budds Beach, Surfers Paradise
Captured: 21/01/11 @ 09:03
Direction: North
GPS: GDA94 27°59.761'S 153°25.477' E.
Photo: Daniella Teixeira & Hamish Aiken

7: Burleigh Heads
[Ocean view circuit, Burleigh Heads National Park]
Captured: 21/01/11 @ 09:25
Direction: South-East
GPS: GDA94 28°05.867' S 153°27.382' E.
Photo: Jessica Rosewell

8: Tallebudgera Creek
[David Fleay Wildlife Park]
Captured: 21/01/11 @ 10:06
Direction: South-East
GPS: GDA94 28°06.537' S 153°26.671' E.
Photo: Jessica Rosewell

9: Cleveland Point
[Eastern side–waves encroaching onto footpath, road and almost to Kiosk]
Captured: 21/01/11 @ 10:40
Direction: South
GPS: GDA94 27°30.586' S 153°17.381' E.
Photo: Kimberley Marian

10: End of Lota Esplanade
[Adjacent to vehicle access gate at end of Lota Esplanade]
Captured: 21/01/11 @ 10:41
Direction: West
GPS: WGS84 27°28.416' S 153°11.563' E.
Photo: Galen Matthews

11: Luggage Point
[Facing down Brisbane River Mouth to city]
Captured: 21/01/11 @ 11:17
Direction: South-East
GPS: GDA94 27°22.925' S 153°09.245' E.
Photo: Damon Cheyne

12: Sandgate Road, Albion
[Photograph shows the Brisbane River flooding and 7 News reporting the king tide]
Captured: 21/01/11 @ 10:50
Direction: South
GPS: GDA94 27°26.184' S 153°02.601' E.
Photo: Robert Schwartz

13: Nudgee Beach Boardwalk
[Adjacent mangroves flooding onto walkway]
Captured: 21/01/11 @ 10:35
Direction: West
GPS: GDA94 27°20.662' S 153°05.886' E.
Photo: John Ryan

14: Cabbage Tree Creek Jetty
[Jetty at the mouth of Cabbage Tree Creek]
Captured: 21/01/11 @ 10:39
Direction: South-East
GPS: GDA94 27°19.707' S 153°05.220' E.
Photo: Kane Nielsen

15: Cabbage Tree Creek esplanade
[Allpass Parade, Cabbage Tree Creek]
Captured: 21/01/11 @ 10:40
Direction: North-East
GPS: GDA94 27°19.800' S 153°05.040' E.
Photo: Kane Nielsen

16: Sandgate Foreshore
[South end of Flinders Parade]
Captured: 21/01/11 @ 10:34
Direction: South-East
GPS: GDA94 27°19.200' S 153°04.481' E.
Photo: Gary Hart

17: Reef Point Esplanade
[Partial inundation of road due to stormwater drain flooding]
Direction: North
GPS: GDA94 27°12.002' S 153°06.748' E.
Photo: Jeff Shortell

18: Endeavour Esplanade Foreshore
[Photo taken just north of Endeavour and Oyster Point Esplanade junction]
Captured: 21/01/11 @ 10:37
Direction: South-West
GPS: GDA94 27°11.493' S 153°06.177' E.
Photo: Mathew van Soest

19: Captain Cook Parade, Deception Bay
[Foreshore inundation along Captain Cook Parade]
Captured: 21/01/11 @ 10:18
Direction: South-East
GPS: GDA94 27°10.695' S 153°01.782' E.
Photo: Jeff Shortell

20: White Patch Esplanade, Bribie Island
[White Patch Esplanade Bridge]
Captured: 21/01/11 @ 11:12
Direction: South
GPS: N/A
GPS: GDA94 27°02.154' S 153°07.932' E.
Photo: Scott Bowden

21: Maroochy River, Wharf Street
[Wharf Street public Jetty]
Captured: 21/01/11 @ 09:22
Direction: North
GPS: GDA94 27°39.029' S 153°05.507' E.
Photo: Rod Garner

22: Alexandra Surf Club, Mooloolaba
[Looking towards beach access points M78 and M79]
Captured: 21/01/11 @ 09:47
Direction: North
GPS: GDA94 26°39.901' S 153°06.775' E.
Photo: Rod Garner

23: Maroochy River
[Looking north towards Maroochydore SLSC club house]
Captured: 21/01/11 @ 09:40
Direction: North
GPS: GDA94 26°39.392' S 153°06.234' E.
Photo: John Gilbert

24: Lady Musgrave Island
[Campsite beach entrance, western side]
Captured: 21/01/11 @ 09:30
Direction: West
GPS: GDA94 23°54.600' S 152°23.478' E
Photo: John Ferris

25: Mon Repos Conservation Park, Bundaberg
[Mon Repos Beach boardwalk, from information centre, being inundated]
Captured: 21/01/11 @ 09:40
Direction: North
GPS: GDA94 24°47.743' S 152°26.741' E
Photo: John Ferris

26: Heron Island Jetty
[Looking from jetty at inundated beach]
Captured: 21/01/11 @ 09:25
Direction: South-East
GPS: WGS84 23°26.537' S 151°54.641' E.
Photo: Alan Hollis

27: Heron Island
[In front of QPWS turtle shelter – North Beach]
Captured: 18/02/2011 @ 08:22
Direction: West
GPS: WGS84 23°26.501' S 151°54.956' E.
Photo: Alan Hollis

28: The Venue–Townsville
Captured: 21/01/11 @ 09:40
Direction: North-East
GPS: WGS94 19°16.360' S 146°48.411' E.
Photo: Rachel Allan & Brendan Meale

29: Coast Guard–Townsville
Captured: 21/01/11 @ 10:12
Direction: North-West
GPS: WGS94 19°15.201' S 146°49.707' E.
Photo: Rachel Allan & Brendan Meale

30: Townsville Boat Ramp
[Water level not far off being level with car park]
Captured: 21/01/11 @ 10:12
Direction: West
GPS: WGS94 19°15.197' S 146°49.689' E.
Photo: Rachel Allan & Brendan Meale

31: Lucinda
[Foreshore of Lucinda, near southern end, where large sand bags were used to limit beach erosion]
Captured: 21/01/11 @ 10:22
Direction: West
GPS: WGS94 18°32.724' S 146°20.460' E.
Photo: Mark Parsons

32: Palm Creek, near mouth
[Beach hut located inside the mouth of palm creek, king tide approaching right at the hut]
Captured: 21/01/11 @ 10:04
Direction: South-East
GPS: GDA94 18°45.82' S 146°16.758' E.
Photo: Mark Parsons

33: Port Hinchinbrook
[At the edge of coastal development, along northern spit at port entrance, water has passed rock sea wall]
Captured: 21/01/11 @ 09:48
Direction: North
GPS: WGS94 18°16.618' S 146°02.971' E.
Photo: Emma Schmidt & Alex Tessieri

34: Port Hinchinbrook Spit
[Hinchinbrook Marina, looking along coastal development of Port Hinchinbrook]
Captured: 21/01/11 @ 09:48
Direction: North
GPS: GDA94 18°16.589' S 146°02.891' E.
Photo: Emma Schmidt & Alex Tessieri

35: Edmund Kennedy Boardwalk
[Boardwalk entrance at Edmund Kennedy National Park just submerged by king tide]
Captured: 21/01/11 @ 10:32
Direction: South
GPS: GDA94 18°12.746' S 146°00.756' E.
Photo: Emma Schmidt & Alex Tessieri

36: Flying Fish Point
[Photograph taken directly in front of fish and chip shop]
Captured: 21/01/11 @ 10:12
Direction: North-East
GPS: GDA94 17°30.189 S 146°04.568' E.
Photo: Brenton Haigh

37: Palm Cove Foreshore
[Boat ramp in foreground and jetty in backdrop
Captured: 21/01/11 @ 09:55
Direction: North
GPS: GDA94 16°44.418' S 145°40.291' E
Photo: Glenn Kvassay

38: Sweet Creek, Palm Cove
[Photo from bridge located on Triton St. Resort and apartments in background, on right side]
Captured: 21/01/11 @ 10:15
Direction: North
GPS: GDA94 16°75.063' S 145°66.977' E.
Photo: Glenn Kvassay

39: Holloways Beach Central
[Photo from near Matthew St and Oleander St intersection. Can see high tide mark]
Captured: 21/01/11 @ 11:03
Direction: North-West
GPS: GDA94 16°50.305' S 145°44.425' E
Photo: Ann Chalmers

40: Northern end of the Cairns Esplanade
Captured: 21/01/11 @ 10:00
Direction: North-East
GPS: GDA94 16°54.275' S 145°45.802' E.
Photo: Claire Murrell

41: Cooktown Boat Ramp area
Captured: 21/01/11
GPS: GDA94 15°27.653' S 145°14.9978' E
Photo: Peter Kilshaw

42: Cooktown Foreshore
[Photograph captured in front of cannon]
Captured: 21/01/11
GPS: GDA94 15°27.819' S 145°14.969' E
Photo: Peter Kilshaw

43: Ratcliffe Road Marton
[Water level not far off house ground floor]
Captured: 21/01/11
GPS: GDA94 15°27.720' S 145°11.603' E
Photo: Peter Kilshaw

44: Quintel Beach, Lockhart River
[Quintel Beach Lockhart River Barge Landing and picnic area]
Captured: 21/01/11 @ 10:25
Direction: South
GPS: GDA94 12°47.584' S 143°21.648' E
Photo: Pip Schroor

45: Evans Landing Boat Ramp, Weipa
Captured: 21/01/11 @ 16:56
Direction: South-East
GPS: GDA94 12°39.884' S 141°50.812' E
Photo: Michael J. Beeby

46: Sunset Tavern, Karumba Point
[Sunset Tavern shoreline at low tide]
Captured: 20/01/11 @ 13:01
Direction: South
GPS: GDA94 17°27.645' S 140°49.637' E.
Photo: Bevis Hayward

47: Sunset Tavern, Karumba Point
[Sunset Tavern shoreline an hour before king tide, due to fading light]
Captured: 20/01/11 @ 19:14
Direction: South
GPS: GDA94 17°27.645' S 140°49.637' E.
Photo: Bevis Hayward

48: Sunset Tavern, Karumba Point
[Sunset Tavern shoreline an hour before king tide, due to fading light]
Captured: 20/01/11 @ 19:14
Direction: South
GPS: GDA94 17°27.725' S 140°49.695' E.
Photo: Bevis Hayward

49: Sunset Tavern, Karumba Point
[Sunset Tavern shoreline an hour before king tide, due to fading light]
Captured: 20/01/11 @ 19:14
Direction: South
GPS: GDA94 17°27.725' S 140°49.695' E.
Photo: Bevis Hayward

50: Mid Molle Island Spit
[Spit located on northern end of Mid Molle Island]
Captured: 18/02/2011 @ 10:48
Direction: East
GPS: GDA94 20°14.768' S 148°49.721' E.
Photo: Mark O'Brien

51: Pumpkin Island Resort
Captured: 21/02/2011 @ 09:28
Direction: South
GPS: GDA94 23°05.547' S 150°54.003' E.
Photo: John Messersmith

52: Rosslyn Bay Harbour
Captured: 21/01/11 @ 09:58
Direction: East
GPS: GDA94 23°09.550' S 150°47.289' E.
Photo: John Messersmith

53: Yam Island
[Jetty been swamped as a result of king tide and ocean swells]
Captured: 22/01/11 @ 13:19
Direction: North
GPS: GDA94 17°27.725' S 140°49.695' E.
Photo: Peter Armstrong

54: Yam Island
[Yam Island foreshore been battered a result of king tide and ocean swells]
Captured: 22/01/11 @ 13:18
Direction: North
GPS: GDA94 09°53.909' S 142°45.992' E.
Photo: Peter Armstrong

55: Lammermoor Beach, Yeppoon
[Beach access at the southern end of Lammermoor Beach]
Captured: 18/02/2011 @ 09:10
Direction: East
GPS: GDA94 23°09.926' S 150°46.512' E

56: Ross Creek- South of Yeppoon
[Junction of Ross Creek and Figtree Creek looking south-west at bridge over Ross Creek]
Captured: 18/02/2011 @ 09:15
Direction: South-West
GPS: GDA94 23°08.241' S 150°45.061' E
Photo: David Marshall

57: Mackay Boat ramp
[Mackay boat ramp located at mouth of Pioneer River]
Captured: 18/02/2011 @ 11:00
Direction: North-East
GPS: GDA94 21°08.502' S 149°11.771' E.
Photo: Vicki Coburn

58: McEwen Beach
[Looking west along McEwen's beach stinger net enclosure]
Captured: 10/02/2011 @ 10:40
Direction: West
GPS: WGS84 21°15.200' S 149°12.378' E.
Photo: Jana Hummelshoj

59: Port Denison–Bowen
[Port Denison near Thomas Street drain looking south]
Captured: 18/02/2011 @ 10:38
Direction: South
GPS: WGS84 20°01.229' S 148°14.651' E.
Photo: Jacinta Oliver

60: Port Denison, Santa Barbara Parade. Bowen
[At old sailing club near boat ramp]
Captured: 18/02/2011 @ 10:44
Direction: North-East
GPS: WGS84 21°01.141' S 148°14.764' E.
Photo: Jacinta Oliver