



NSW Coastal Panel

Coastal erosion at Kingscliff

Advice to the Minister for the Environment



Photo: G Pezzimenti 8 November 2011.

December 2011

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ISBN 978 1 74293 690 1

OEH 2012/0492

May 2012

Executive Summary

In late October 2011, the Minister for the Environment requested advice from the NSW Coastal Panel concerning the management of beach erosion at Kingscliff in the Tweed local government area. Specifically, the Minister requested advice on two terms of reference:

1. The Coastal Panel's opinion is sought on the cause of the recent erosion at Kingscliff, including whether this erosion is likely to continue, and if so, under what circumstances.
2. Recommendations on potential short and long term technically feasible and cost-effective strategies for managing erosion at Kingscliff. This is to include a review of the strategies in the 2005 Tweed Coastline Management Plan (CMP) and any other strategies proposed by Tweed Shire Council or otherwise considered worthwhile by the Panel.

The Panel has prepared advice and recommendations on the two terms of reference following consideration of available information including reports, photogrammetric analysis and historic aerial photography, a site inspection and the knowledge, experience and expertise of the Panel members.

The Panel has found that the current impacts of coastal erosion on assets and infrastructure at Kingscliff are predominantly due to natural causes. Superimposed on broad natural processes are potential localised impacts caused by human built, structures and other modifications. This intervention and impact commenced with sand mining dating from the 1930s until 1980s resulting in complete reshaping and loss of the foredune area, and continued with the training of the Cudgen Creek entrance in 1967, construction of a sea wall to protect the Bowls Club in 1967.

In response to recent storm events, the construction of temporary protection works on the beach have resulted in localised erosion impacts which have in turn required further protection works to be constructed to mitigate their impacts. In the short-term the need for continued effort to manage the impacts of erosion is evident. In the Panel's view, this should be undertaken as part of a coordinated approach that considers the short term impacts in a longer term context.

The nature and timing of the erosion events have required Tweed Shire Council to respond to a situation that was not contemplated in the management plan prepared for the area. The result has been a mixture of temporary protection works along the beach. In the Panel's view, the nature of the response has seen the continued progression of erosion in a northerly direction with a continued threat to infrastructure and assets on the beach front. Two key issues arise – loss of beach amenity and access and the potential risk to public safety.

Council have previously considered various long-term options for responding to the current erosion problems at Kingscliff, with estimated capital costs in the range of \$8 - \$36 million. The Panel considers that an additional option involving a field of groynes constructed on the beach at Kingscliff should be considered by Council.

Recommendations

The Coastal Panel recommends that:

1. the Minister notes that the predominant cause of the erosion at Kingscliff is natural and episodic, and is likely to continue when the certain conditions occur, namely:
 - a. a series of storms or other natural events (such as a single large storm, cyclone or large East Coast Low) deplete the beach of the required capacity to withstand an erosion event;
 - b. waves occur from a predominantly easterly direction for an extended period of time;

- c. there is a build up of sand to the south of the Cudgen Creek training walls;
 - d. a sand 'wave' moves around the Cudgen Creek headland creating an erosive rip in front of it causing sand to be removed from the beach and transported out of the beach compartment (either offshore or along the beach).
- 2. the Minister notes that secondary localised erosion impacts are likely to persist due to the end effects and other localised effects caused by structures built on the beach to date.
- 3. the Minister notes that there is no single long term solution to the erosion problems, and it is likely that a combination of approaches will be necessary in the short term and long term. Options that should be thoroughly investigated include a terminal seawall complemented by ongoing beach nourishment, a field of groynes with or without beach nourishment in the short term and planned retreat in the long term.
- 4. the Minister writes to Tweed Shire Council asking it to work jointly with the neighbouring Byron Shire Council on a regional or sediment compartment-based coastal processes study to update current understanding of physical coastal processes in this region, with incorporation of the Panel's advice on the causes of the recent erosion. This study would assist the Councils in preparing their coastal zone management plans.
- 5. the Minister notes that the Office of Environment and Heritage will work with the Department of Finance and Services to develop clear guidance concerning the application of the Natural Disaster Assistance Scheme to coastal erosion areas. Guidance should cover appropriate strategies, materials and approaches for declared coastal erosion emergency events.
- 6. the Minister requests Tweed Shire Council to work with Office of Environment and Heritage and Department of Primary Industries (Crown Lands) to prepare a strategy, including necessary environmental assessment and approvals, for the management of the remaining unprotected section of beach (between the Holiday Park and Bowls Club) for activation at the sign of a further erosion event in the short term.
- 7. a revised Coastal Zone Management Plan be prepared by Council by the end of 2013 which:
 - a. incorporates the short term management strategy for the remaining unprotected section of beach;
 - b. includes a plan for the ongoing monitoring of beach erosion with trigger points for responses of individual actions;
 - c. includes an economic assessment of the relative costs and benefits of the short and long term options for managing the beach at Kingscliff;
 - d. includes an analysis and assessment of the technically feasible management options for the site – in the short and long term. Short term options will require the consideration of a combination of a terminal seawall or a field of groynes and/or beach nourishment. Long term options should examine a retreat option where buildings with non-essential beachfront functions that are well within the 100 year hazard line are relocated.

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1 Introduction

Over the past 12 – 18 months, the coastal township of Kingscliff, located in the Tweed Shire local government area, has experienced severe erosion, resulting in significant loss of the foreshore and placing specific infrastructure at risk. In response Tweed Shire Council (TSC) has undertaken various emergency works, to provide protection for parts of the beach and avoid any further loss of the foreshore or damage/loss of buildings located in close proximity to the coastline.

In response to these recent events, the Minister for the Environment has written to the NSW Coastal Panel seeking advice with respect to the management of the beach erosion at Kingscliff and has provided the following terms of reference:

1. The Coastal Panel's opinion is sought on the cause of the recent erosion at Kingscliff, including whether this erosion is likely to continue, and if so, under what circumstances.
2. Recommendation on potential short and long term technically feasible and cost-effective strategies for managing erosion at Kingscliff. This is to include a review of the strategies in the 2005 Tweed Coastline Management Plan (CMP) and any other strategies proposed by Tweed Shire Council, or otherwise considered worthwhile by the Panel.

The following paper addresses these terms of reference and provides some background and history in both the recent events and erosion and management as has occurred at Kingscliff over the past 60 – 70 years. It has been developed using available literature sources and historical documentation, discussions with key personnel, results from a site inspection completed on 8 November 2011 and other available data and information.

TSC is actively developing and investigating new strategies to address the current erosion threat and long-term management options for Kingscliff. The Panel considers that it would be beneficial to provide a supplementary report to the Minister for the Environment in mid 2012 to reflect the results of the new investigations, once completed.

2 Location

Kingscliff is located on the northern NSW coast approximately 10 km south of the Tweed River entrance, near the Queensland border. The section identified as Kingscliff lies at the southern-most end of Dreamtime Beach / Kingscliff Beach, which is a 7 km wide embayment, stretching from Fingal Head in the north to Sutherland Point in the south (see Figure 1). The Cudgen Creek river entrance is located at the southern end of the beach and there is a foreshore reserve between the main street (Marine Parade) and the beach. Located on this foreshore reserve are four buildings of significance, the Kingscliff Bowls Club, the Kingscliff Beach Holiday/Caravan Park, the Kingscliff Amenities Hall, and the Cudgen Headland Surf Life Saving Club (SLSC), all of which reside within the Immediate or 50 year Coastal Erosion Hazard area (Figure 2 and Figure 3) (WBM Oceanics, 2001). Adjoining developed areas and Marine Parade are also under threat from erosion in a 50 to 100 year timeframe.

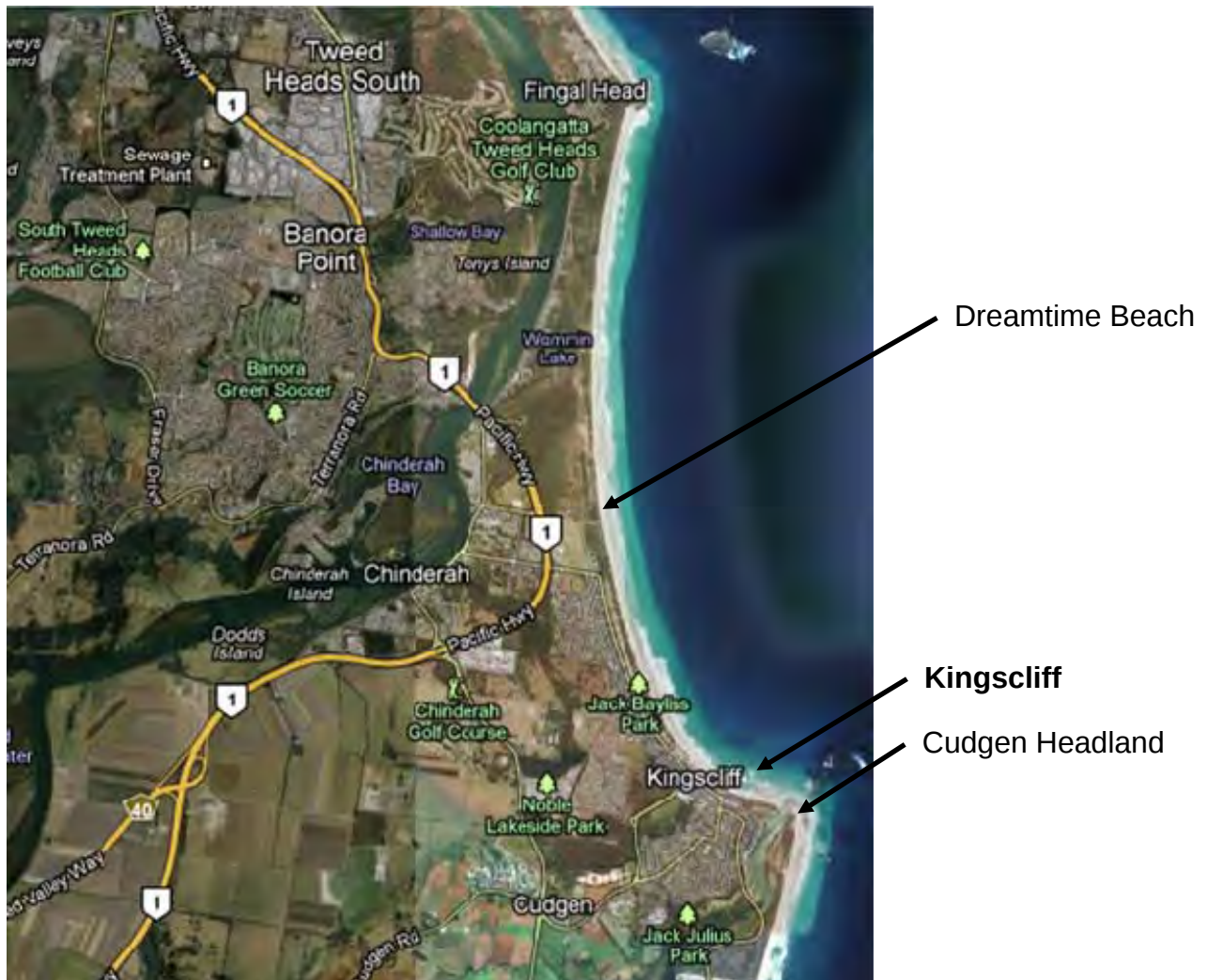


Figure 1 - Kingscliff Location

Source: Google maps

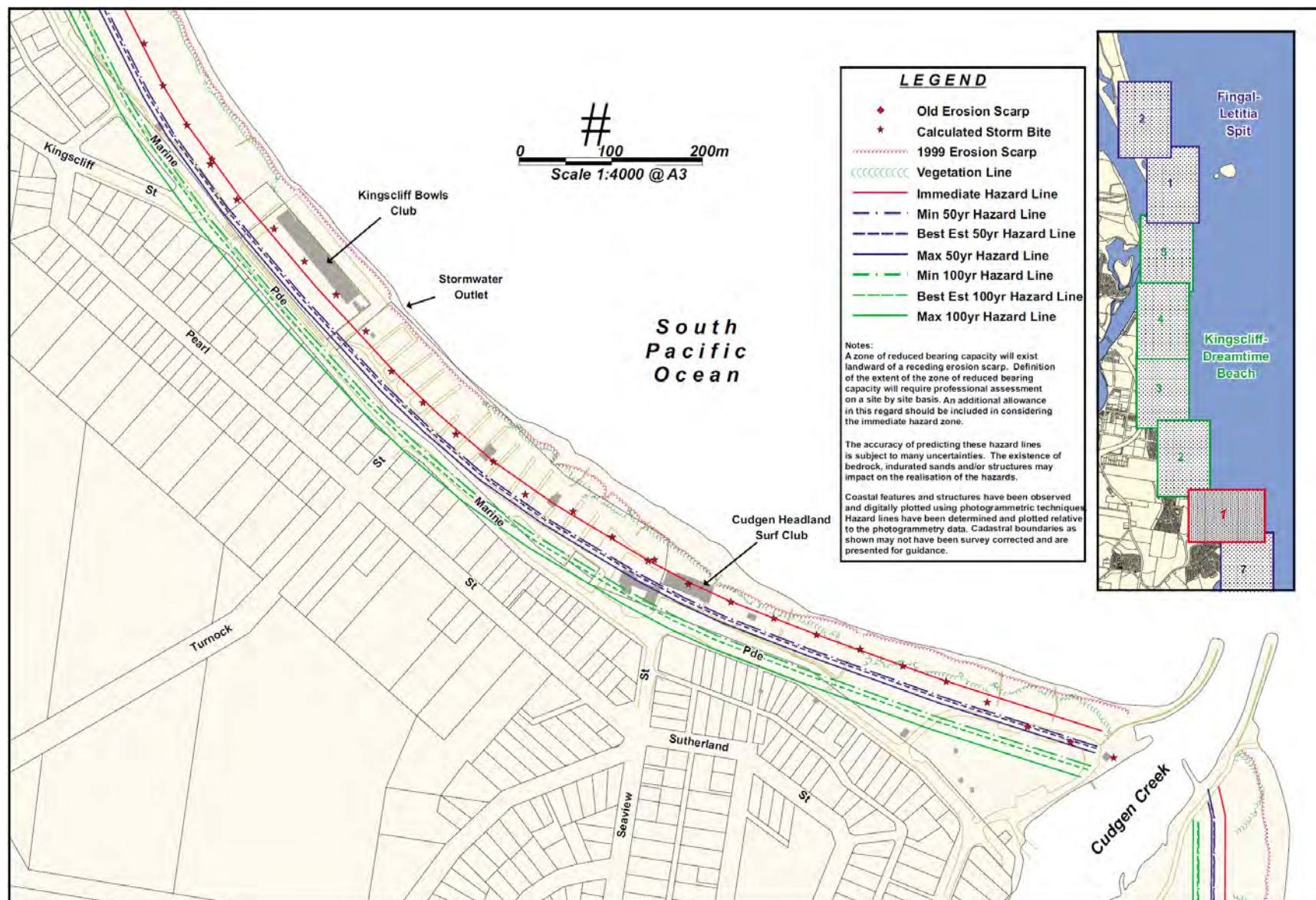


Figure 2 - Hazard lines identifying the immediate, 50 year and 100 year hazard areas (WBM, 2001).



Figure 3 - Kingscliff Coastal Hazard Lines (Immediate, 2050 and 2100) overlaid on aerial image of the area (image courtesy of Tweed Shire Council), based on updated calculation (WRL, 2010).

3 Background/History

3.1 Coastal Geology / Geomorphology

The present day coastline of Kingscliff has resulted from the accretion of sand mainly through marine processes (Roy, 1975). It has reached a mature stage of development and the embayment between the headlands is suggested by Roy (1975) to be almost completely infilled. Roy (1975) hypothesised that the coastline has entered a long-term erosional stage (i.e. it is no longer accreting or building up sand deposits). Roy (1975) suggests that this erosional trend is gradual but may be masked by more dramatic cut and fill processes caused by short-term changes in the wave climate. The narrow dune and beach system can be considered as a mature coastline and therefore is likely to experience episodic periods of coastal erosion.

From a geological perspective, Kingscliff is located on the seaward margin of a coastal plain which is characterised by straight beaches and narrow, low-relief coastal dunes, backed by swampy sand flats and floodplains which infill the generally small coastal valleys (Roy, 1975). Where the dunes are intact, they are highest in the area to the north of the Bowls Club where their height is approximately 10 metres above mean sea level. Areas around Cudgen Creek have also been affected by heavy mineral sand mining up until around the 1980s.

3.2 Photogrammetry and historical aerial photographs

Examination of available photogrammetric profiles and historic aerial photography for Kingscliff shows that there has been considerable variability in the beach profile since the earliest available photogrammetry in 1944 (see Attachment A).

Of note in the southern portion of the beach is the loss of foredune area evident in profiles from 1944 and 1962. After this time, a significant area of the foredune is no longer present. Sand mining occurred extensively throughout this area during that time, including reshaping of the foredune, dredging operations and realignment of the Cudgen Creek river entrance (DPW, 1980).

Although heavy mineral sand mining operations are likely to have resulted in a relatively small volume of sand being removed from the beach, they have redistributed sediment across the beach profile such that the foredune is no longer providing a buffer for replenishment of sand lost from the active beach during natural coastal processes. Photogrammetric analysis shows that the foredune evident in the 1940s and early 1960s has never returned to its previous state.

Copies of available photogrammetric profiles for the length of the beach compartment are provided as **Attachment A**.

3.3 Previous storm events and related protection works

Over the past 60 to 70 years, Dreamtime Beach has been affected by several well documented storm events, resulting in severe erosion in and around the Kingscliff region (WBM Oceanics, 2001). These events have led to the installation of a series of protection works, which includes:

- the training of the Cudgen Creek river entrance through the construction of rock training walls in 1967, to alleviate the flood problem of the Cudgen Lake and Cudgen Creek area (see Figure 3) and to prevent the meandering of the creek entrance channel along Dreamtime beach, which occurred prior to these works;
- the construction of a terminal (permanent rock) seawall in front of the Kingscliff Bowls Club in 1967, to protect the club from ongoing storm and erosion problems (the seawall was upgraded in 1995);

- the planting of *Casuarina* spp., Norfolk Island pines (*Araucaria heterophylla*) and *Pandanus* spp. along the foreshore in 1974 to help stabilise the dunes and enhance amenity following erosion events;
- the more recent 2010-11 protection works (as shown in Figure 4). This includes:
 - o a vertically piled concrete seawall in front of the Cudgen Headland SLSC (as recommended after completion of the 2005 Tweed Shire Coastline Management Plan, constructed in June 2010);
 - o works initiated to address episodic erosion including the extension landwards of the northern training wall at Cudgen Creek. It is understood that this work was undertaken as erosion had commenced at the southern end of Dreamtime Beach and it was considered possible that Cudgen Creek could break through and bypass the training walls at its entrance;
 - o low rock protection works (not designed as full seawall protection) were installed to be contiguous with the extended Cudgen Creek training walls, continuing in a northerly direction to the piled concrete wall in front of the Surf Club. These works were funded under Natural Disaster Assistance Scheme (NDAS) and the work was completed in early 2011;
 - o Council also undertook a short term beach nourishment program in early 2011 which provided 14,000 m³ of sand to the southern end of Kingscliff. The sand was sourced from the lower reaches of Cudgen Creek.
 - o a temporary geotextile sandbag wall immediately to the north of the Cudgen Headland SLSC and extending in front of part of the Holiday Park to prevent the collapse/loss of the premises from recent erosion activity, constructed in October 2011.
 - o A 60 metre long temporary rock revetment located north of the geotextile sandbag wall, constructed in December 2011 to protect an amenities block at the Holiday Park.

In terms of impacts along Dreamtime Beach both anecdotal and recorded evidence suggest five key erosive periods: 1954, 1967, 1974, 1996 and 1999 (WBM Oceanics, 2001). It is now well recognised that the erosion events of 1954, 1967 and 1974 were some of the most severe experienced along the Tweed Shire/Kingscliff area.

In February 1954, a tropical cyclone tracked directly over Tweed Heads, with waves over 15 metres high reported along Dreamtime Beach, reaching 180 m landward than the usual waters edge. Sand erosion resulted in a 1.8 metre high escarpment and was suggested to have receded close to and threatened the Cudgen Headland SLSC (DPW, 1980).

During 1967, extensive erosion occurred along Kingscliff associated with a period of storm events, and culminating with an East Coast Low (ECL) in June 1967. This resulted in TSC seeking funds from the State Government for protective works for the Kingscliff Bowls Club and led to the construction of a terminal rockwall in front of the Bowls Club. Also in 1967 the entrance to Cudgen Creek was stabilized by constructing training walls. The main impact of the training walls were that the creek could no longer meander along Dreamtime Beach, giving the southern foreshore of the beach a measure of protection not realised prior to the construction of the training walls (WBM Oceanics, 2001).

In February and March 1974, tropical cyclones Pam and Zoe struck the northern NSW coast resulting in foreshore erosion and flooding. The most extensively damaged section of the Dreamtime Beach was the southern section in front of the Kingscliff village, where the beach was reduced in width to the base of the northern training wall (DPW, 1980). In the area around the

Holiday Park, the Bowls Club and the Marine Parade Reserve, the erosion removed trees from the top of the erosion escarpment.

Following the 1974 events, a coastal process study was prepared in this region (DPW, 1978). Since this time, it appears that a relatively calmer period has initiated. Although a few significant erosion events have occurred (i.e. 1996 and 1999), overall erosion is considered to have been moderate, with most beaches showing signs of general recovery (WBM Oceanics, 2001). During the mid 1990's, further work was also undertaken on the seawall protecting the Bowls Club, upgrading the works to an appropriate engineering standard and extending the design life of the Bowls Club to 100 years (Umwelt, 2005). However, no other works to protect the Surf Club, Holiday Park or any additional public amenities was carried out during this period.

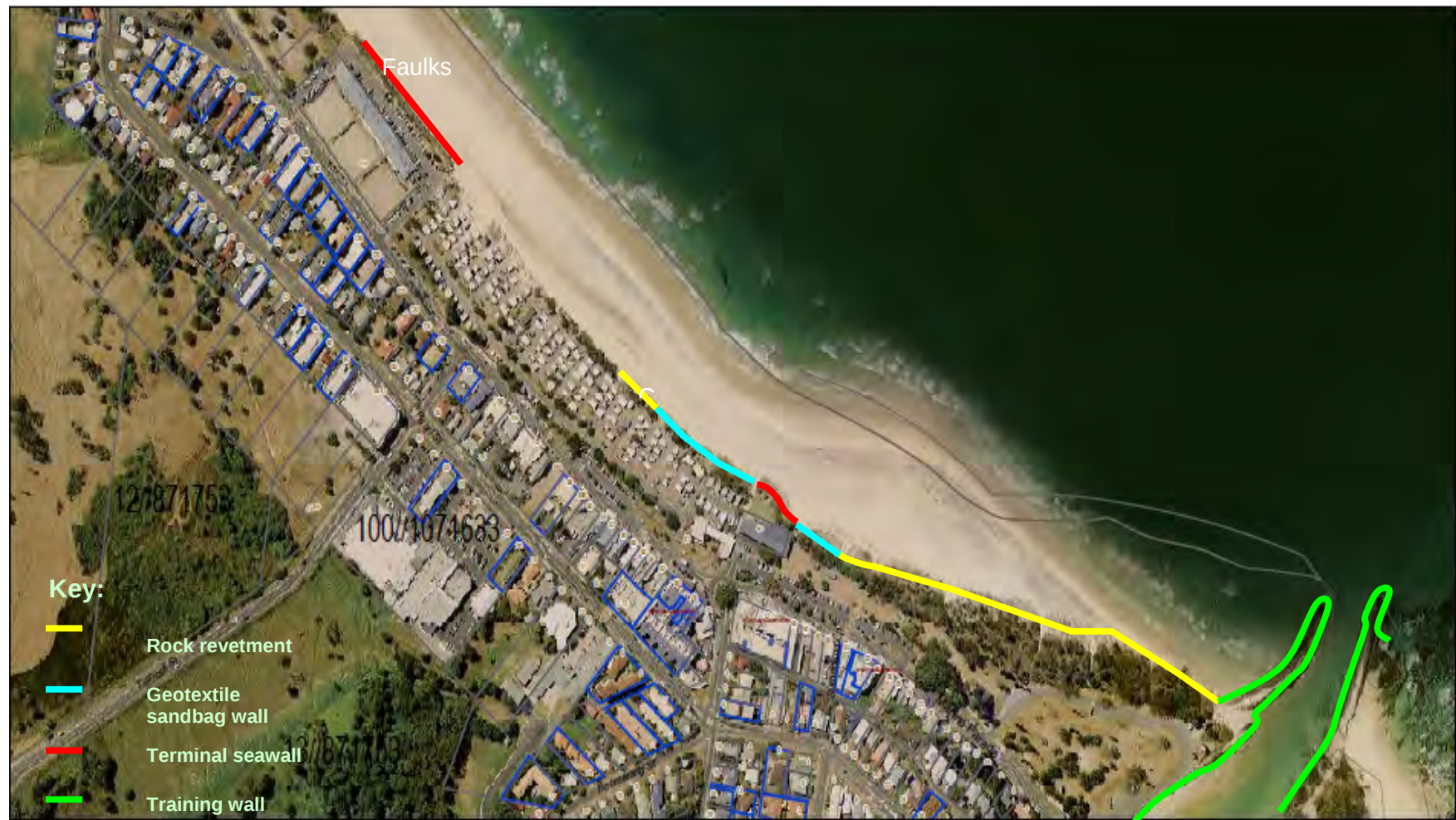


Figure 4 - Indicative location of protection works on Dreamtime Beach at Kingscliff as at December 2011.

4 Recent/Current Erosion

More recently events from 2009 to 2011 have resulted in a return of the erosion trend along Kingscliff, the result of which appears to be responsible for the current conditions. Between January and May 2009, the Tweed and Byron Bay Waverider buoys registered five storms in close succession and with significant wave heights greater than 3 metres (Figure 5). This was then followed by a large storm generated from an ECL in May 2009 (Proudfoot and Peterson, 2011). These storms are reported to have caused large amounts of sand to be transported both southward along the beach south of Cudgen Head, and northwest along Dreamtime Beach away from Kingscliff (Patterson, 2010), and resulted in the development of a large erosion scarp along Dreamtime Beach.

In May 2010, the southern end of Kingscliff experienced another severe erosion event, this time resulting in the loss of approximately 2 hectares of the vegetated dune along a 200 metre stretch of beach (Proudfoot and Peterson, 2011). This erosion appears to be the product of large waves from an easterly direction and the previous 2009 storm events which had resulted in the previous lowering of the beach profile and left little sand in the southern end of the embayment.

Significant erosion of the foreshore from this event prompted TSC to request funds from the State Government's Natural Disaster Assistance Scheme (NDAS). Funding was subsequently provided, and a low rock revetment (or seawall) was built between the northern Cudgen Creek training wall and the Cudgen Headland Surf Club (Figure 6). These works were completed at a cost of \$594,000, which included reinstatement of parking areas at the truncated ends of the road. In June 2010, concrete piling of the Surf Club was also undertaken to construct a vertical piled seawall to offer additional protection to the Club. This work, costing nearly \$400,000, was carried out as part of the longer-term Tweed Shire Coastline Management Plan and received a 50% subsidy under the Government's Coastal Management Program.

It should be noted that the purpose of NDAS funded rock revetment would appear to be to maintain the current alignment of the foreshore. However, as this revetment was placed in response to an emergency, it was not designed as a seawall, and it was known that overtopping of the wall could occur – i.e. it would fail should a significant storm event occur. Sand nourishment works were also completed at this time with sand pumped from Cudgen Creek for the purpose of nourishing Kingscliff Beach and burying the rock wall. These works were completed in February 2011 (Lofthouse, pers comm., 2011).

Following the completion of the works listed above, a further erosion event occurred in April 2011. This resulted in the nourished sand being moved out of the most southerly section of the Dreamtime Beach compartment, which in turn re-exposed the rockwall between the Cudgen Creek training wall and the Cudgen Headland SLSC. Despite the loss of nourished sand however, the rock revetment appears to have performed well in maintaining the foreshore alignment and preventing further erosion of the dune and reserve.

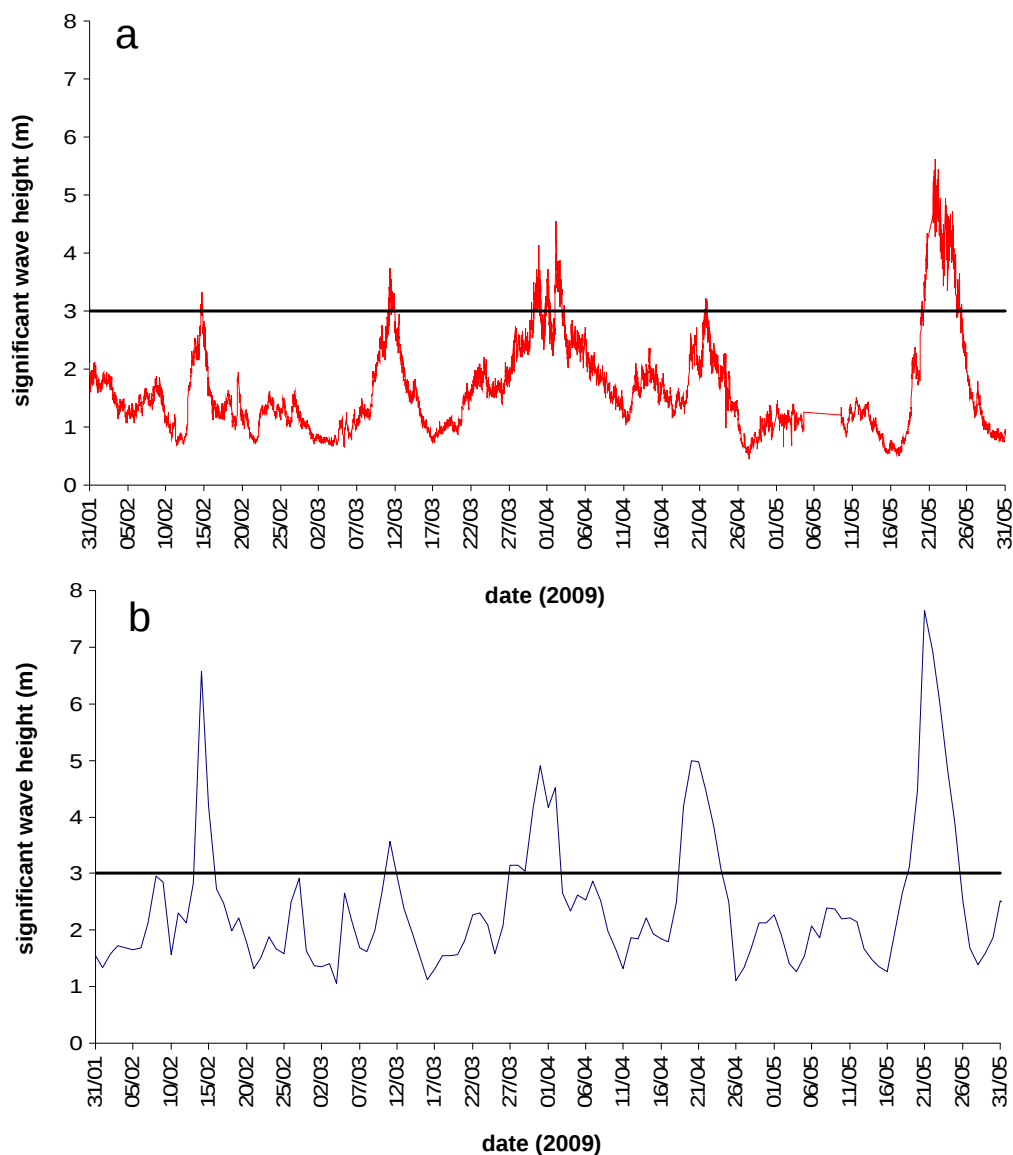


Figure 5 - Significant wave heights during the 2009 erosion period (January - May) measured at (a) the Tweed Waverider Buoy and (b) the Byron Bay Waverider Buoy. Differences in heights between figures can be attributed to possibly sheltering of the Tweed Buoy due to areas of extensive offshore reef. The horizontal black line illustrates the 5 events with a significant wave height of over 3m.

Since this time (the April 2011 event), erosion effects now appear to have migrated further north, resulting in the exposure of the newly constructed vertically-piled concrete seawall of the SLSC, eroding into the foreshore in front of the Holiday Park and resulting in the loss of several caravan park lots (14 Powered Sites, 5 Cabins and 2 Villas). This prompted TSC to undertake further emergency management works, which included the removal of the onsite cabins, and the construction of a temporary 4 metre high geotextile sandbag wall, to stop outflanking the SLSC and to provide further protection in front of the club house and for part of the Holiday Park (Figure 7). The total costs of these temporary protection measures were approximately \$500,000.

In July 2011 a combination of spring high tides, high swell and the deepened nearshore conditions led to the partial failure of the sandbag wall. The original works were intended to be temporary works until longer term arrangements were put in place. In light of the erosion process occurring at

Kingscliff, longer term works may be required, due to the length of time that the foreshore is likely to be subject to erosion, the period anticipated for recovery of the beach and the time the works are expected to remain in place.

TSC has acknowledged that longer term arrangements need to be developed to respond to the ongoing erosion. Council has been investigating longer term options since 2004. It is currently investigating sand sources for a long term sand nourishment program and design feasibility for a terminal seawall. Over the last two years, Council and the State Government have spent approximately \$1.5 million on short-term erosion protection works. While these works provide a varying degree of erosion protection, they have impacted on beach amenity and some of the works present a potential risk to public safety (eg the potential for collapse of the steep geotextile bag seawall and the potential for injury to beach users accessing the beach over the rock revetments).

5 Advice concerning Terms of Reference

5.1 Term of Reference 1

The Coastal Panel's opinion is sought on the cause of the recent erosion at Kingscliff, including whether this erosion is likely to continue, and if so, under what circumstances

The recent erosion experienced at Kingscliff is primarily due to natural processes, including a coincidence of climatic and oceanographic conditions. However, secondary localized erosion is likely to have been exacerbated by factors such as the more recent emergency works, designed to protect particular sections of the foreshore or infrastructure from further erosion or collapse. The magnitude of the erosion experienced in recent times is in line with expectations based on an understanding of physical coastal processes from previous studies. Previous erosion events of similar or greater magnitude have occurred at Kingscliff in 1954, 1967 and 1974.

Kingscliff and Dreamtime Beach forms part of a large regional system of beaches along the far north NSW coast, in which there is a substantial littoral transport of sediment north through the system at rates typically around 450,000 to 500,000 m³/yr (DPW, 1978; Patterson *et al*, 2011), although can vary up to 550,000 m³/yr (Patterson, 2010). However, rates of sand transport at each beach, and within compartments of the various beaches are not necessarily equal on short term cycles. In particular, there are specific months (or years) where the transport rates may not be equal, leading to temporary differentials in sand movements either into or away from various beaches and their compartments.

Kingscliff is particularly susceptible to variability in sand supply with marked differences in supply coming from the south of Cudgen Headland, and littoral transport away from Kingscliff, northwest along Dreamtime Beach. Also of particular relevance to Kingscliff, is the movement of periodic sand pulses, in which large quantities of sand tend to accumulate and travel as an episodic sand wave through the compartment.

This process typically involves an initial build up of sediment on the immediate updrift side of a headland, or in the case of Kingscliff, the rock reef associated with Cudgen Headland and southern Cudgen Creek training wall. As the sand pulse moves around the headland and into the embayment, it forms a sand wave and attaches to the beach as an elongate spit (**Figure 8**). This then initiates a topographically controlled rip that migrates in advance of the wave, and is often associated with severe localised beach erosion. Eventually the sand wave merges with the foreshore further along the beach, infilling the previous rip channel and causing a slight accretion (Short, pers comm. 2011).

In light of the above, the primary cause of the more recent erosion events experienced at Kingscliff can be attributed to a combination of:

- successive storm events from 2009 – 2011 which removed sand from the embayment, increasing the vulnerability to future erosion events;
- an extended period of large waves proliferating from the east; and
- a periodic sand pulse which has recently entered the embayment from the southern end.

Although the initial 2009 events produced little in the way of visual erosion, most likely owing to the amount of sediment that had previously built up in the compartment, it was significant enough to

deplete the sediment load offshore, and subsequent events in 2010 resulted in more identifiable and severe erosion (**Figure 9**).

Since the April 2011 event, in which the nourished sand was moved out of the compartment exposing the rock wall between Cudgen Creek and the Surf Club, a new sand pulse has now also entered the embayment, to form a sand wave at the southern end of the compartment. This has replenished the sand reserves in front of the rock wall (**Figure 6**). The consequences of this process has led to a migratory erosional rip occurring in front of the advancing sand wave, thus displacing erosion effects further north and producing a deeper (rip) channel in front of the SLSC and the Holiday Park. It is expected that the sand wave will continue to migrate along the beach in a northerly direction.

TSC's response to this erosion was to install temporary geotextile sandbag protection measures as the erosional rip migrates further north (see section 3.3 and **Figure 7**). However, the design of these temporary protection measures are such that they tend to encourage wave reflection, rather than wave absorption. As a result erosion has been further exacerbated along the base of the works and at the leading edge, or northern end, of the geotextile sandbag wall, leading to a deeper rip channel along this section of the beach. Additionally, further north where the geotextile sandbag wall terminates, end effects of the wall increased erosion for a distance of approximately 10 to 20 metres from the northern end of the geotextile sandbag wall (**Figure 10** and **Figure 13**).

As at December 2011, TSC have now also constructed a 60 metre rock revetment (discussed in section 3.3). It is, however, expected that erosion at the northern end of this seawall will occur in the short term, due to end effects.

Although the causes for the recent erosion along Kingscliff Beach are readily identified, these and previous erosion cycles experienced along the NSW coastline are postulated to be linked to larger systems influenced by both the Southern Oscillation Index (SOI) and the Pacific Decadal Oscillation (PDO) (Goodwin, 2005). Along Kingscliff beach, historical analysis would suggest severe erosion events (i.e. 1954, 1967 and 1974) have tended to historically occur during negative phases of the PDO and periods of La Nina associated with positive SOI values (Proudfoot and Peterson, 2011). The more recent erosion events have also occurred during positive SOI periods, with 2010 events coinciding with the onset of an extended La Nina Phase and the beginning of another negative trend in the PDO.

In light of the above, the prospect of continuing erosion along Kingscliff remains in all likelihood a strong possibility at least in the short term, with periodic episodes likely over a longer term cycle. At present the current sand wave is yet to move north along the embayment and continues to generate a topographically controlled erosional rip adjacent to the SLSC and Holiday Park. It is expected this sand wave will eventually move further northwards and at which point the sediment is likely to replenish sand reserves in front of the Surf Club and Holiday Park, however the timeframe at which this will occur is unknown. At present current weather predictions for late 2011/early 2012 have also suggested a strengthening of the current negative PDO and La Nina phase (BOM, 2011; NOAA, 2011), which based on previous trends may signal the potential for further or ongoing erosion.

Recommendations

1. the Minister notes that the predominant cause of the erosion at Kingscliff is natural and episodic, and is likely to continue when the certain conditions occur, namely:
 - a. a series of storms or other natural events (such as a single large storm, cyclone or large East Coast Low) deplete the beach of the required capacity to withstand an erosion event;
 - b. waves occur from a predominantly easterly direction for an extended period of time;
 - c. there is a build up of sand to the south of the Cudgen Creek training walls;
 - d. a sand 'wave' moves around the Cudgen Creek headland creating an erosive rip in front of it causing sand to be removed from the beach and transported out of the beach compartment (either offshore or along the beach).
2. the Minister notes that secondary localised erosion impacts are likely to persist due to the end effects and other localised effects caused by structures built on the beach to date.



Figure 6 - Terminal rock revetment between Cudgen Headland SLSC and the Cudgen Creek training wall (present in the background). The photo shows the current sand pulse that has recently moved into the embayment and now resides at the southern end of the compartment in front of the wall.
 Photo M. Daley 8 November 2011.



Figure 7 - Looking north from the terminal rock revetment towards Cudgen Headland SLSC and the Holiday Park showing both the piled concrete foundations and temporary geotextile sandbag wall.
 Photo: M Daley 8 November 2011.

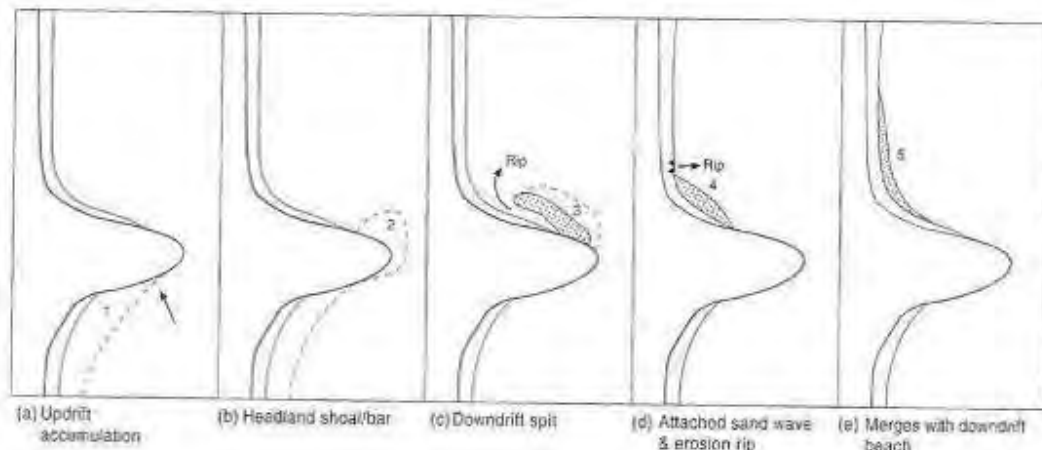


Figure 8 - Schematic illustration of headland sand bypassing. (a) Initially longshore sand transport, causes sand to accumulate updrift of a headland. (b) The sand manifests itself as a substation subaqueous sand wave on the tip and immediately downdrift of the headland. (c) The sand moves around the headland and along the downdrift beach, attaching as an elongate spit. (d) As the sand attaches to the beach it initiates a topographically controlled rip that migrates in advance of the wave, often causing localised beach erosion. (e) The sand finally merges with the beach causing slight accretion. From Short (1999).



Figure 9 - Looking south from Faulks Park following erosion events of 2010. Also evident are the end effects of Cudgen Creek training walls. Photo: B Gibbs 12 August 2010.



Figure 10 - Northern end of the geotextile sandbag seawall (looking south) showing both collapse of the wall and end effects which have produced further erosion of the Holiday Park. Photo: M Daley 8 November 2011.



Figure 11 – Most recent (60 metre) rock extension in front of the further part of the Holiday Park and the amenities block. Photo: B. Fitzgibbon 14 December 2011.

5.2 Term of Reference 2

Recommendation on potential short and long term technically feasible and cost-effective strategies for managing erosion at Kingscliff. This is to include a review of the strategies in the 2005 Tweed Coastline Management Plan and any other strategies proposed by Tweed Shire Council, or otherwise considered worthwhile by the Panel.

5.2.1 Management Options identified by Tweed Shire Council

TSC has been actively working to understand and manage the impacts of coastal hazards within its local government area for at least the last ten years. Specifically, a Coastal Hazard Definition Study (CHDS) was completed in 2001 (WBM Oceanics, 2001), a Coastline Management Study (CMS) was completed in 2003 (Umwelt, 2003) and a Coastline Management Plan (CMP) was developed in 2005 (Umwelt, 2005).

Based on the hazard study, the management plan considered five options for Kingscliff that aimed to address potential long term erosion problems. The approach taken was to develop management options and responses for assets and infrastructure within the 50 year coastal hazard area for existing development and the 100 year coastal hazard area for undeveloped areas. The Panel acknowledges that finding a balance between short and long-term technically feasible and cost effective strategies for managing coastal erosion is a complex exercise with different options presenting their own challenges and opportunities.

As part of the 2001 CHDS, a number of assets at Kingscliff were identified as being within the Immediate Coastal Erosion Hazard area (Figure 2 and Figure 3). These included the Bowls Club, Cudgen Headland Surf Club and the Kingscliff Holiday Park. In addition, the Kingscliff Amenities Hall was found to be within the 50 year hazard area. Parts of Marine Parade (including parts of Kingscliff Village and private dwellings) are also under threat in the 50 year and 100 year hazard areas. In response, the 2005 CMP identified five potential management options. These were investigated in terms of their technical feasibility and cost effectiveness, and were the subject of public consultation. Each of these options are discussed below.

The 2005 CMP and supporting studies considered the following shortlisted options for managing erosion at Kingscliff on the basis of a 50 year hazard area:

1. A do nothing approach;
2. Construction of long-term (permanent) seawall with sand nourishment;
3. Construction of a groyne adjacent to the Bowls Club with sand nourishment;
4. Construction of a groyne at Murphys Road with sand nourishment;
5. A long-term implemented planned retreat option.

Option 1: The **do nothing approach** was dismissed by TSC as not realistic due to the nature of assets at threat from coastal erosion, and the high likelihood of erosion occurring. Especially since the current erosion events of the last 12 – 18 months, it is also unlikely that a do nothing approach would be acceptable to the community. The cost of doing nothing as a management option was not valued by Council.

Option 2: The construction of **long-term (permanent) seawall with sand nourishment** was adopted as Council's preferred strategy at the time of completion of the CMP. The CMP proposed a shoreline parallel seawall of 500 metres in length, constructed of quarried rock in a sloping configuration situated as far landward as possible. It was proposed to extend from the Cudgen Headland Surf Club in a northerly direction to meet up with the existing Bowls Club seawall. No

works were proposed for the area to the south of the Surf Club. Community support was provided for this option on the provision that beach amenity was also maintained and that there were no adverse impacts (Umwelt, 2005).

It was proposed to maintain beach amenity through the placement of sand on the beach as part of a nourishment strategy. Beach access was also to be formalised as part of this strategy. The initial capital cost estimate for the seawall was \$4.2 million with an ongoing annual maintenance budget of \$0.04 million. Initial beach nourishment with 250,000 cubic metres of sand was also proposed at an estimated cost of \$3.8 million and an annual maintenance budget of \$0.05 million. Beach scraping would also be carried out following the placement of the sand on the beach as part of the nourishment strategy. The total cost for this option was estimated at \$8.2 million capital costs with an ongoing maintenance budget of \$0.1 million per year. It was identified as a short to medium term option to be implemented over the next 5 and 10 years.

After completion of the CMP, Patterson Britton and Partners were commissioned to prepare an environmental assessment for the proposed seawall. As part of their commission, they recommended altering the length, material and design of the seawall considerably. The proposed seawall was modified to be only 80-100 metres in length and to be situated in front of the Cudgen Headland SLSC. The design was also modified to be more vertical in nature and the construction material was modified to be piled concrete rather than quarried rock. This revised proposal was estimated to result in savings in the order of \$3 million. The piled concrete vertical seawall was constructed during 2010.

As part of the longer-term management plan Patterson Britton and Partners (2006) also proposed that a 15 metre linear beachfront reserve be created inside the Kingscliff Holiday Park boundary to act as a buffer against coastal erosion, in an associated redevelopment of the Holiday Park. It is understood that Council was proposing to implement this strategy in conjunction with a redesign of the Holiday Park. However, this had not occurred prior to the current erosion being evident. It is understood that redevelopment of the Holiday Park cannot be pursued until the current erosion risk is reduced through the proposed major sand nourishment strategy (Lofthouse, pers comm., 2011).

Option 3: The third option in the CMP was the **construction of a large groyne adjacent to the Bowls Club with sand nourishment**. A single bypassing groyne approximately 250 metres long was proposed, located at the northern end of the Bowls Club, and constructed perpendicular to the shoreline. It would be designed to trap sand and prevent its movement further north through littoral drift. The groyne construction was to be accompanied by initial beach nourishment of one million cubic metres, with 300,000 cubic metres to the north of the groyne and 700,000 cubic metres to the south of the groyne. The capital cost for the groyne was estimated at \$1.6 million with an annual maintenance budget of \$0.3 million. In addition, the capital cost of the nourishment was estimated at \$15 million bringing the total cost for this option to \$16.6 million in capital costs and \$0.6 million per year in maintenance costs.

Option 4: A fourth option was the **construction of a groyne at Murphys Road (approximately 1.8km north of the Bowls Club) with sand nourishment**. The groyne was proposed to be 350 metres long and would require a sand volume of 2.2 million cubic metres of sand (1.8 million cubic metres placed to the south of the groyne and 400,000 cubic metres placed to the north of the groyne). The estimated capital cost for the groyne was \$3.8 million and an annual maintenance budget of \$0.08 million. The capital cost of the nourishment was estimated at \$33 million with annual ongoing costs of \$0.09 million. The total estimated capital cost for this option was \$36.8 million, with annual costs of \$0.17 million per year.

Option 5: A long-term implemented **planned retreat** option was also canvassed by TSC in the 2005 CMP. This option was indicated to have a similar cost to implement as Option 2, although no exact costing was provided. There are no direct maintenance costs associated with this option. The long-term planned retreat options excluded the relocation of the Bowls Club due to the previous construction of protection works in front of the Bowls Club. The CMP also identified alternative sites for the Kingscliff Holiday Park, most notably on the southern side of the Cudgen Creek entrance.

As the costs of Option 2 and Option 5 were considered by Council to be similar, following community consultation, Council adopted Option 2, which was subsequently modified (5.2.2).

5.2.2 Implementation of works by Council

Although Option 2 was adopted following completion of the CMP, this option was implemented in a modified form based on the advice of Patterson Britton and Partners received in 2006. Council has constructed a 80-100 metre piled concrete seawall in front of the Cudgen Headland Surf Club (as noted in section 3.3). This seawall was constructed as part of as stage 1 of the longer-term Kingscliff foreshore protection and nourishment strategy, rather than in response to the recent erosion activity. To date, the piled concrete wall has withstood erosion after experiencing direct wave action due to the loss of sand from the beach in front of the Surf Club. However, it is reported that the club does experience strong vibrations from time to time due to wave impacts on the wall at high tides and in large swell events.

Following completion of the vertically piled concrete seawall, the recent erosion activity has resulted in end effects becoming apparent. In response TSC has undertaken a series of further (emergency) protection works, as described in section 3.3.

The Panel considers that it is highly likely that further end effects will become apparent in the short term following the recent completion of the 60 metre rock revetment, and that erosion will continue to move ahead of the protection works, until it is necessary for protection works to extend the length of the beach to at least the Bowls Club. Council should consider the potential for end effects (DECCW 2010).when making decisions on future protection works

Although TSC completed a coastline management plan as advocated by the NSW Government since 1988, a number of short term and emergency actions have been undertaken that were not addressed in the CMP. In addition to the completion of the concrete piled column wall in front of the Cudgen Headland SLSC as planned in the subsequent amendment to the CMP, in the last 12-18 months a series of erosion events have resulted in Council undertaking a number of short-term protection works, as noted in section 3.3.

5.2.3 Potential Short-term Options

Although an immediate hazard area had been identified during the CMP process, nearly all options in the plan related to the medium to long term or a 50 or 100 year planning period. No contingency was made for erosion occurring in the immediate hazard area in the short term. As a result, Council have proceeded to undertake a number of short-term actions, in order to protect areas of the foreshore and infrastructure at risk. The absence of a plan for short term actions appears to have contributed to a piecemeal approach to coastal protection. While the short-term works have reduced erosion threats to Faulks Park and the Surf Club to a variable extent, they appear to have transferred the erosion and its impacts further north to the Holiday Park.

Given the Christmas and holiday period are approaching, both Kingscliff and the Holiday Park represent an important economic hub for Tweed Shire, as well as businesses located along Marine

Parade, which are reported to heavily rely on tourism and guests of the Holiday Park for income. Current conditions at Kingscliff therefore pose two short-term problems.

- Potential public safety risks associated with the geotextile sandbag wall, and piping and debris from the Holiday Park either protruding from the erosion escarpment or located on the beach at the toe of the escarpment (**Figure 13**). Some of this material has been removed or covered by the most recent rock revetment (Figure 15), which now affords additional protection to the Holiday Park's amenities block.
- the loss of beach access and amenity at present and over the summer months, including the public perception of this problem.

The most pressing issues regarding the short-term management options for Kingscliff need to consider both the current erosion and its likelihood of continuing, and the resulting potential public safety and beach amenity risks along Dreamtime Beach. The installation of various different short-term protective measures (albeit not as part of a formal emergency plan) further exacerbates this issue, given the potential for differences in behaviour of these works under future high wave conditions.

In terms of the works completed to date, the Panel does not consider this piecemeal approach to be desirable, as it has resulted in a series of disjointed protection measures of varying ability to withstand erosion at a cost of approximately \$1.5 million. While these works appear to have reduced the erosion threat to the infrastructure/asset(s) they were design to protect, this has resulted in the transference of the erosion effects further north to the Holiday Park, a problem which is expected to continue.

A protection strategy creates a differential potential for erosion between protected and unprotected areas of a beach. Should TSC continue with a protection strategy, then Council will most likely need to implement a full protection strategy along the length of the beach from the Cudgen Creek training walls to the Bowls Club. Such an approach could result in some erosion north of the Bowls Club. However, it should be noted that the current protection structure in front of the Bowls Club does not appear to be suffering from end effects due to the volume of sand in front of that structure, and that this beach has been stable for some time. The likelihood of such erosion occurring would be higher if the beach in front of the existing seawall was depleted of sand and the wall was directly exposed to wave action.

The timing for the completion for any additional works will be reliant on the rate of the erosion progressing along the beach, and the availability of funding and material for construction. Any further short term protection options however, should only be viewed as interim measures while longer-term management options are considered.

The Panel understands that the Water Research Laboratory (WRL) of the University of NSW has been commissioned by TSC to develop design options for a terminal wall structure to protect Council assets and the town centre in the longer term. Their report is not yet available to enable the Panel to comment on the short or long term possible outcomes from their study. However, the Panel is also concerned that current or any further protection works between the SLSC and Bowls Club (either temporary or permanent) will most likely lead to periods where there is no beach in front of the seawalls. This may result in difficulties and potential safety risks for surfers wanting to access the surf during these periods, particularly under high tide conditions or high swell conditions.

It is understood that this issue is not within the scope of the current WRL commission (Lofthouse pers comm. 2011). The Panel considers that the impact of coastal processes, impacts on public

safety and beach amenity in the future should be considered as part of the design feasibility stage of any proposed works.

In relation to the short-term management options, the Panel suggests TSC consider combining other potential strategies that may offer protection to Council assets, with the priority of providing a sandy beach for most of the time. In the Panel's view, the need to retain a beach must be linked to the naturally occurring processes and migration of sand waves in the southern part of the embayment (see Section 5.1).

Impacts of the current emergency protection works could be mitigated through a further beach nourishment program. Such a program may also provide an additional and immediate supply of sand to the compartment, offset the more recent sand losses, and to mitigate actions necessary to continue to provide beach access and protect beach amenity as a result of ongoing erosion conditions. However, it is important to note that while this is likely to be effective in the short term, nourished sand will continue to move northwards through the compartment and require ongoing long-term maintenance.

Also likely to affect such responses are the influences of sand waves, which will also continue to periodically impact the southern end of Dreamtime Beach. Any plan to nourish the beach in the short-term should therefore not only consider the source, cost and placement of this nourishment, but also its timing in relation to the movement of these sand waves. The Panel therefore believes nourishment is only part of the solution and should be seen as a supplement to the natural flow of sand around the Cudgen Headland and the Cudgen Creek training walls. The Panel understands that TSC is undertaking a scoping study on beach nourishment to be completed in the first half of 2012.

An alternative the Panel believes also worth considering is to permanently widen the beach to lessen the impacts of future erosion. This would involve trapping some of the naturally moving sand between the Cudgen Creek training wall and the Bowls Club, whilst still allowing some bypassing to the north to meet the requirement of longshore sediment supply north of the Bowls Club (to minimise erosion impacts).

The Panel suggests that Council investigate the potential use of a field of groynes, preferably with a bypassing function, to widen the beach by creating an artificial sediment compartment between the Bowls Club and the southern end of Dreamtime Beach. This option should allow for the alongshore bypassing of sand when the sand trapped between the groynes reaches a certain level. This approach, if carefully modelled and constructed using appropriate materials, could provide both a short term and medium term solution, and improve beach amenity. The length of the groynes is likely to be shorter than those previously assessed by TSC. The detailed feasibility assessment and design (including the length, orientation, materials and alignment) of the field of groynes would need to be investigated as a coastal engineering project.

5.2.4 Potential Long-Term Options

Recommendations on longer term options for the managing erosion at Kingscliff need to consider the natural coastal processes in operation. In particular, this involves the movement of sand pulses (which vary in both nature and scale) through the Dreamtime Beach compartment. These are often superimposed on other effects such as spring tide cycles, storm events, longer-term climate cycles such as the El-Nino Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), and factors such as the rotation of the beach due to changes in the direction of prevailing wave direction (Short *et al*, 1995).

Dreamtime Beach at Kingscliff is currently experiencing a period of erosion, which has been compounded by the most recent pulse of sand entering the embayment. Such events have occurred at Kingscliff in the past (**Figure 14**) and can also be expected to occur again into the future, associated with this natural cycle and the movement of sand into and through the beach compartment. It is also important to understand, as the sand wave continues to migrate further north along Dreamtime Beach and in front of the SLSC and Holiday Park this section of the beach is expected to recover. However, as previously identified, the timeframe for this sand movement is unknown. Therefore, although the beach will eventually recover, the same natural phenomenon will occur again in the future.

Although in the 2005 CMP a series of long-term management options for Kingscliff were considered, it appears that a preference for protection was effectively established in the 1960s, through the construction of the Bowls Club seawall. This preference appears to have continued through the subsequent construction of various emergency and temporary works noted in section 3.3. Only a small proportion of the beach between Cudgen Creek and the Bowls Club has no protection works in place (see Figure 4).

Whilst the geotextile sandbag wall appears to have provided short-term protection for the Holiday Park and the Cudgen Headland SLSC, it is important to note these latest measures are only designed as a temporary response. If a long-term protection strategy is to be adopted, this would require a properly designed and constructed terminal seawall, along with significant sand nourishment to preserve both public access and amenity of the beach. Such an approach is also likely to incur significant costs due to the need for ongoing nourishment owing to the longshore sediment transport acting along Dreamtime Beach and erosion resulting seaward of the wall during storm events.

The alternative options identified in the 2005 CMP were reviewed by the Panel. The **single large groyne option** (option 3), either at the Bowls Club or further along the beach at Murphys Road, is likely to provide increased protection to Kingscliff through a widening of the beach. It is also acknowledged that such a structure would likely be obtrusive at the beachface and cause significant interference with the natural coastal processes, namely the longshore sand transport. This therefore would need a detailed investigation to determine how to minimise impacts further along the beach.

As previously identified in the shorter term options (Section 5.2.3), the Panel's suggestion for a field of groynes, offers an alternative to the single groyne option and could also be implemented as a part of the longer-term management strategy, allowing for a permanent widening of the beach. This option is also likely to be less obtrusive on the beachface, have less impact on visual amenity and would still allow for natural sand bypassing to continue. Such an option however, would still require investigation from an environmental and economic standpoint, and whether this proposal is technically viable from an engineering perspective. Any design of a groyne field (slotted or otherwise) would also have to consider agreements currently in place with the Tweed River Entrance Sand Bypass Project and contractual obligations in the littoral sand supply with the state of Queensland.

A **long term planned retreat option** (option 5), involving the more permanent solution of the relocation of the Holiday Park, also has a number of merits in the context of the long-term management for the area, given that the Holiday Park is both a temporary and relocatable asset. This option would likely allow the area along the foreshore to recover, allowing it to act as a natural buffer zone and help to maintain or restore beach amenity, and have the least impact in modifying the natural processes that occur at present. Episodic erosion would still occur. This option is also likely to incur significant upfront costs, especially in the initial stages involving the removal and relocation of the current infrastructure and any new facilities required to be constructed as part of

the relocation. It would have little to no direct maintenance costs. It would also allow for the return of the foredune area which would act as a natural buffer for the developed areas behind the beach, including Marine Parade.

This decision would also need to consider the effects of both the Bowls Club and Surf Club and the terminal seawall structures already put in place at both these locations. Assuming that the ongoing erosion of the foreshore continues, this is likely to result in both sites remaining proud of the erosion escarpment, effectively protruding onto the beach. The alternative would be for the permanent relocation of all of these sites, although this may be questionable considering the expenditure in upgrading the Bowls Club seawall to a 100 year design life, and the more recent protection afforded to the Surf Club in the vertical concrete piling. In the longer term, Marine Parade and the town centre may also come under threat from erosion and a subsequent strategy would then be required.

Such an approach will require considering any social costs associated with a relocation of the Holiday Park and account for these associated tradeoffs of relative environmental, social and economic impacts, including from a cumulative perspective. It should be noted that the 2005 CMP has already identified some alternative sites for the Holiday Park.

In determining appropriate long term management options for the beach, the cost of existing protection works should be regarded as sunk costs in economic terms. There is no single solution that will encompass short term and long term concerns. Rather, it is likely that a staged approach will be necessary. This has the advantage of building in an adaptive management approach, as well as spreading costs over a longer period of time. A number of options require further investigation. Consideration of options may differ in the short term and long term, and should be mindful of public access and safety and beach amenity, as well as balancing the environmental, social and economic issues.

Recommendations

3. the Minister notes that there is no single long term solution to the erosion problems, and it is likely that a combination of approaches will be necessary in the short term and long term. Options that should be thoroughly investigated include a terminal seawall complemented by ongoing beach nourishment, a field of groynes with or without beach nourishment in the short term and planned retreat in the long term.
4. that the Minister requests Tweed Shire Council to work with Office of Environment and Heritage and Department of Primary Industries (Crown Lands) to prepare a strategy, including necessary environmental assessment and approvals, for the management of the remaining unprotected section of beach (between the Holiday Park and Bowls Club) for activation at the sign of a further erosion event.
5. the Minister notes that the Office of Environment and Heritage will work with the Department of Finance and Services to develop clear guidance concerning the application of the Natural Disaster Assistance Scheme to coastal erosion areas. Guidance should cover appropriate strategies, materials and approaches for declared coastal erosion emergency events.

5.2.5 Future studies and plans

It is understood that TSC is proposing to prepare a Coastal Zone Management Plan in 2013, to update its 2005 Coastline Management Plan. In preparation for this, TSC have commissioned a number of studies looking at effective and technically feasible cost-effective strategies for managing the erosion at Kingscliff.

This includes:

- options and feasibility design for a terminal seawall;
- an operational design and environmental impact statement for sand dredging and a delivery pipeline from the Tweed River for the purposes of sand nourishment; and
- a socio-economic review for the Kingscliff foreshore.
- an updated coastal process and hazard definition study

Given the importance of longshore sediment transport in this area and the similar issues being dealt with by the adjoining council to the south, Byron Shire Council, the Panel suggests that there may be some merit in considering the definition of coastal hazards from a regional or sediment compartment perspective through a combined effort between Tweed and Byron shires.

Given the importance of sand pulses along this section of coast, it will be important for the study to include an improved understanding of the role of these pulses in the delivery of sand around Cudgen Creek and its subsequent impact on the Kingscliff beach. The study should also consider the possibility for ongoing monitoring of these pulses. This may then assist in understanding when these pulses can be expected to occur, and to ensure council can be better prepared to manage its impact (i.e. sand nourishment could be potentially put in place).

Given the studies underway, the Panel recommends that consideration of these studies be made before making any further decisions for a long-term management strategy. In this regard, the Panel suggests further advice be provided to the Minister in mid 2012 once this additional information is available.

Recommendations

6. that the Minister requests Tweed Shire Council to work with Office of Environment and Heritage and Department of Primary Industries (Crown Lands) to prepare a strategy, including necessary environmental assessment and approvals, for the management of the remaining unprotected section of beach (between the Holiday Park and Bowls Club) for activation at the sign of a further erosion event.
7. a revised Coastal Zone Management Plan be prepared by Council by the end of 2013 which:
 - a. incorporates the short term management strategy for the remaining unprotected section of beach;
 - b. includes a plan for the ongoing monitoring of beach erosion with trigger points for responses of individual actions;
 - c. includes an economic assessment of the relative costs and benefits of the short and long term options for managing the beach at Kingscliff;
 - d. includes an analysis and assessment of the technically feasible management options for the site – in the short and long term. Short-term options will require the consideration of a combination of a terminal seawall or a field of groynes and/or beach nourishment. Long-term options should examine a retreat option where buildings with non-essential beachfront functions that are well within the 100 year hazard line are relocated.



Figure 12 – Looking towards the Holiday Park showing end effects of temporary protection works and the current risk posed to the amenities block and pumping station located immediately behind the escarpment. Photo: G Pezzimenti 8 November 2011.



Figure 13 – Cable and Piping Infrastructure currents protruding from the erosion escarpment adjacent to the Holiday Park. Photo: M. Daley 8 November 2011.



Figure 14 – Previous sand wave events that have occurred at Kingscliff. Three prior events on photographic record show the impacts of sand waves in 1971, 1987 and 1999 with erosion occurring along Kingscliff beach in front of the wave. The 2010 photo shows the beach state prior to the most recent 2011 sand wave, with sand shown to be building up on the southern side of Cudgen Headland, before its subsequent movement into the embayment.



Figure 15 – Recent (December 2011) rock revetment works installed to protect the amenities block and sewer pumping station of the Kingscliff Holiday Park. Photo: B. Fitzgibbon 14 December 2011.

Glossary

Term	Definition
Accretion	The gradual accumulation of sand to a beach
Beach compartment	The beach between two headlands or artificial structures (eg breakwaters)
Beach erosion	The offshore movement of sand from a beach during storms. In this report, erosion is used for short term landward coastal change and recession is used for long term coastal change. The opposite of erosion is accretion
Beach nourishment	The supply of sediment by mechanical means to supplement sand on an existing beach or to build up an eroded beach.
Coastal erosion hazard area	An area calculated to be vulnerable to coastal erosion from an extreme storm event or a series of storms over various time periods eg, currently vulnerable (immediate hazard area) or vulnerable in 2050 or 2100. These hazard areas are bounded by coastal erosion hazard lines.
Downdrift	The direction of the predominant movement of sand along a coastline (the opposite direction to updrift). This is generally a northerly direction in NSW.
East Coast Low	An intense low-pressure weather system that occurs, on average, several times each year off the south-eastern coast of Australia.
El Nino-Southern Oscillation	A climate phenomenon, associated with warmer/drier and cooler/wetter weather patterns in eastern Australia (see also Southern Oscillation Index).
Elongate spit	A small tapered point of sand or gravel that projects out from the shoreline.
Embayment	An indentation in a shoreline forming an open bay
End effects	Erosion at the end of a natural or artificial structure (i.e. a seawall), due to the structure creating wave turbulence and reflecting incoming waves onto the beach
Erosion rip	Beach erosion caused by a rip current
Escarpment	See scarp
Foredune	The first clearly distinguishable, vegetated and mature stable dune formation landward of the water (note – there may be a smaller unvegetated dune located seaward of the foredune, known as an incipient dune).
Geotextile	Strong synthetic permeable fabrics used in civil engineering construction projects
Groynes	Low walls built on a beach at right angles to a shoreline and extending into the ocean, to trap sediment transported by longshore currents. Typically, sediment buildup on the updrift side of a groyne is offset by erosion on the downdrift side.
Groyne Field	A system of regularly spaced groynes along a section of shoreline.
Littoral (or longshore) transport	The transport of sand along a coastline due to wave-generated currents. In NSW, this occurs in a northerly direction.
Outflanking	Movement around the side of a structure (eg erosion around the side of a seawall)
Pacific Decadal Oscillation	A pattern of Pacific climate variability that shifts phases on at least inter-decadal time scale, usually about 20 to 30 years.
Photogrammetry	The use of aerial photographs to produce topographic information (eg contour maps) of the earth's surface and features of the built environment
Recession (shoreline)	The progressive landward shift in the average long-term position of the coastline. It represents the long term balance between erosion and accretion and occurs when erosion dominates

Term	Definition
Revetment	A form of seawall, usually with a sloping face and commonly flexible
Rip (currents)	Concentrated currents flowing back to sea perpendicular to the shoreline.
Scarp	A nearly vertical slope along a beach resulting from storm wave erosion
Seawall	A wall built parallel to the shoreline to limit erosion and recession.
Sediment compartment	A section of the coastline in which sediment is largely or completely confined
Significant wave height	The average height of the highest one third of waves recorded over a specific period.
Southern Oscillation Index	An index based on the difference in air pressure between Darwin and Tahiti. This is closely related to the El Nino-Southern Oscillation.
Swell	Ocean waves which were generated from a distant source, such as a storm located hundreds of kilometres from the local area (ie waves unrelated to local wind conditions).
Terminal seawall	A seawall constructed generally at the back of a beach and often buried under sand
Training walls	Walls constructed at the entrances of estuaries and rivers to improve navigability by stopping the meandering of the entrance over time.
Updrift	The direction opposite to the predominant littoral transport of sand along a coastline (the opposite direction to downdrift). This is generally a southerly direction in NSW.
Waverider bouy	A floating device placed offshore to measure ocean wave patterns

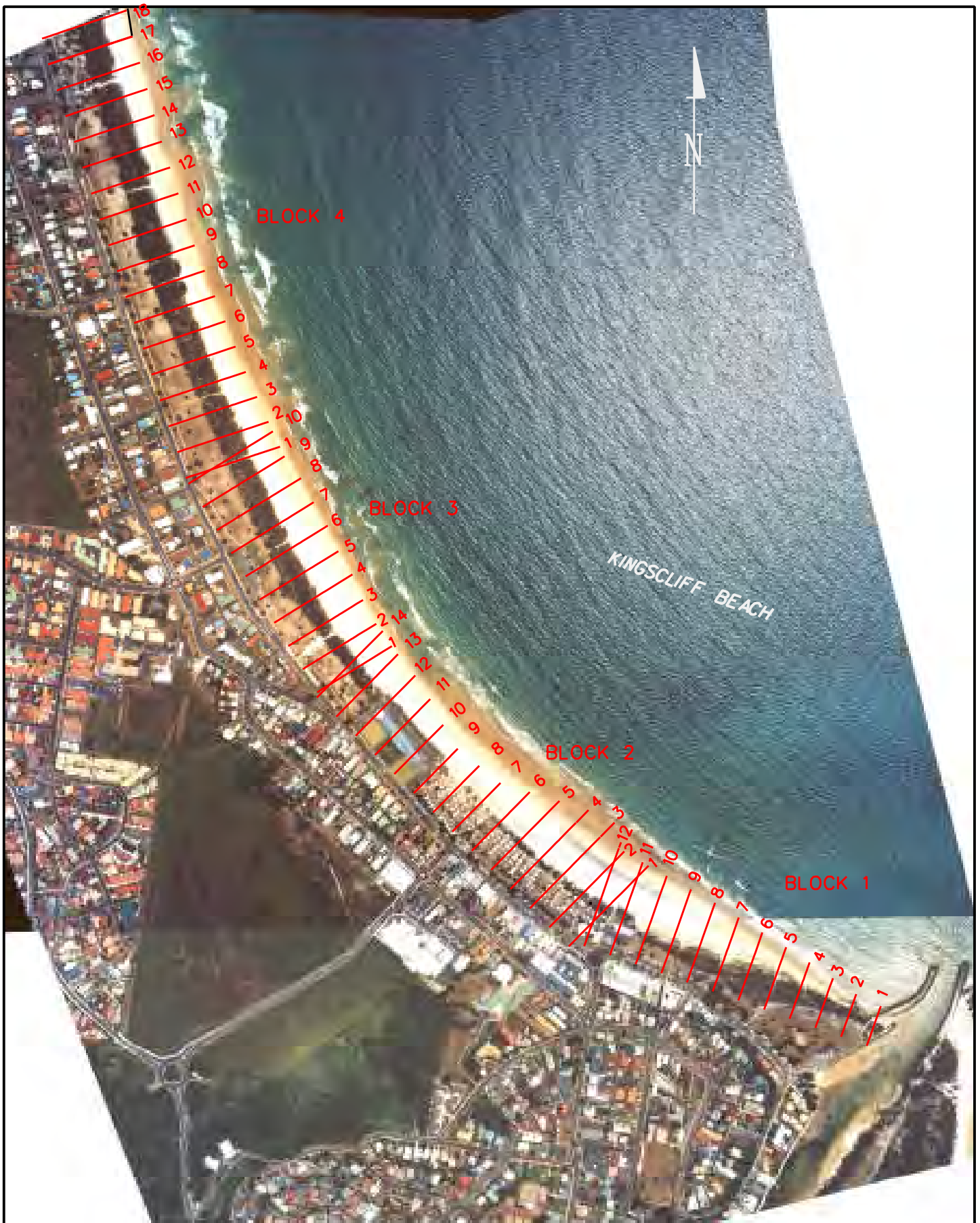
Abbreviations

Abbreviation	Explanation
BOM	Bureau of Meteorology
CHDS	Coastal Hazard Definition Study
CMS	Coastline management study
CMP	Coastline management plan
DECCW	Department of Environment, Climate Change and Water
DPW	Department of Public Works
ECL	East Coast Low
ENSO	El Nino-Southern Oscillation
NDAS	Natural Disaster Assistance Scheme
PDO	Pacific Decadal Oscillation
SLSC	Surf Life Saving Club
SOI	Southern Oscillation Index
TSC	Tweed Shire Council
WRL	Water Research Laboratory (of the University of NSW)

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Attachment A – Beach photogrammetric profiles



NOTES:

1. Orthophoto image was prepared by DECC from vertical aerial photography flown on 26th of January 2010.
2. Unauthorised reproduction and/or the use of the maps for any other purpose is expressly forbidden.
3. Co-ordinate system is Intergrated Survey Grid (ISG) and co-ordinates are in metres.

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 OPERATIONAL POLICY UNIT
 URBAN COASTAL WATER REFORM
 PO Box 2185 Dangor 2309 www.dnr.nsw.gov.au

100 0 100 200
 Scale in metres



Environment,
 Climate Change
 & Water

KINGSCLIFF
26/01/2010

Photogrammetrist: R.Clout & C.Gray

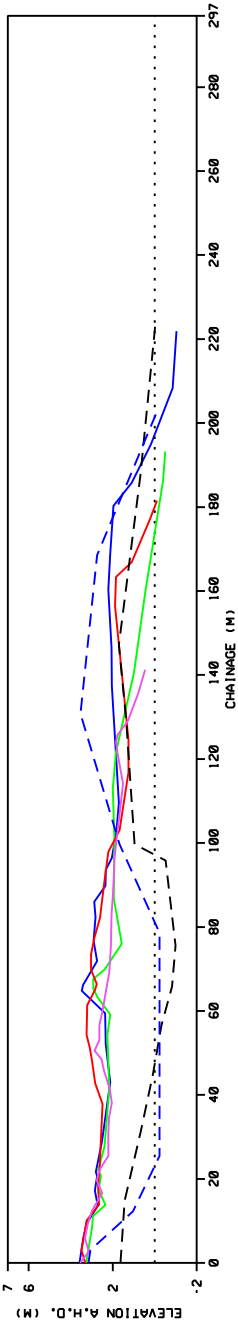
Project Supervisor : Bruce Coates

Date : AUGUST 2010

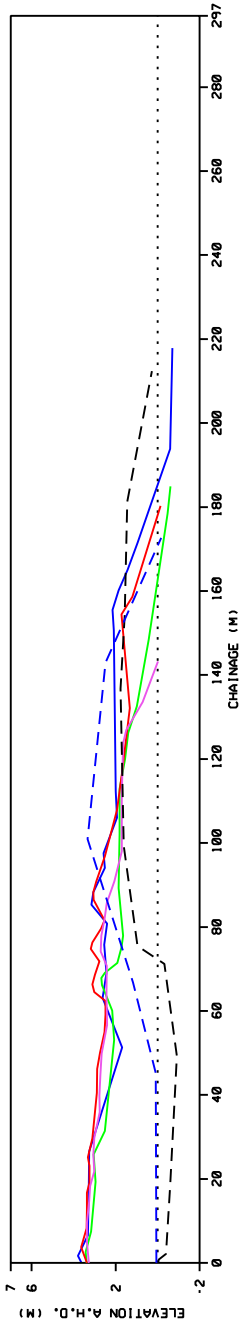
KINGSLIFF BLOCK 1
PROFILES 1 - 4

LEDGEND

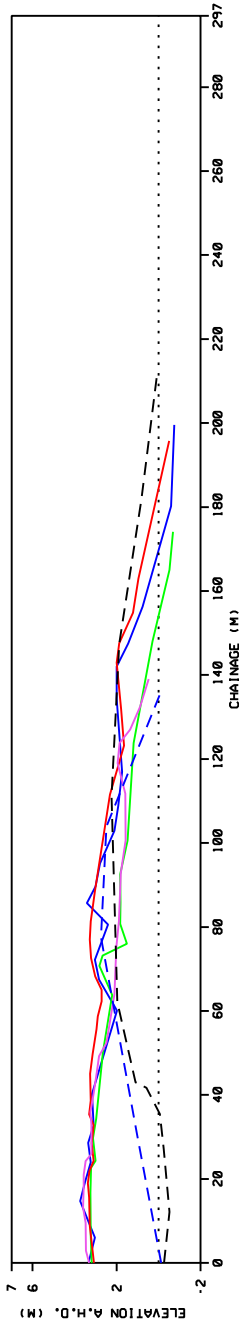
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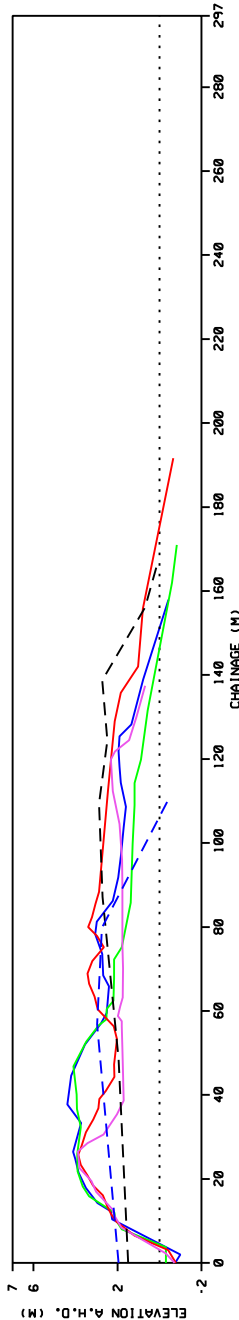
PROFILE 4



PROFILE 3



PROFILE 2

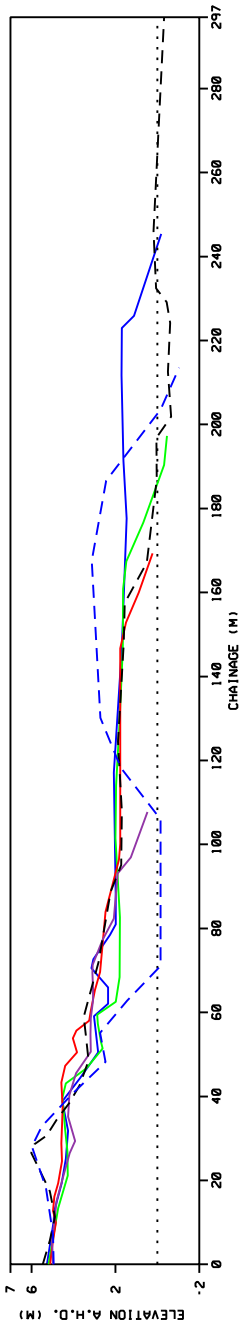


PROFILE 1

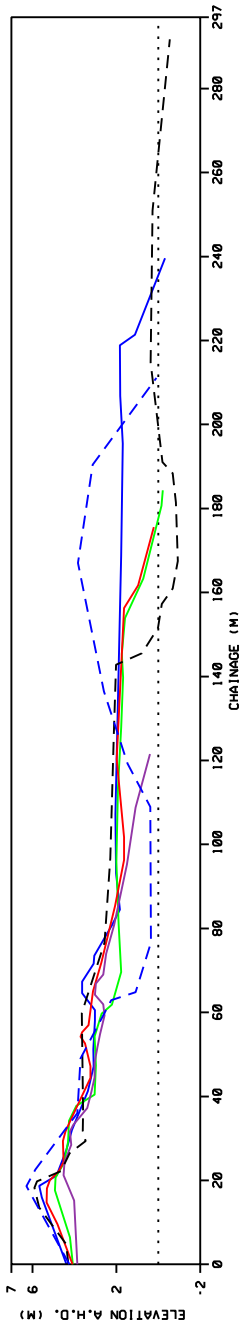
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PROFILES 5 - 8

LEGEND

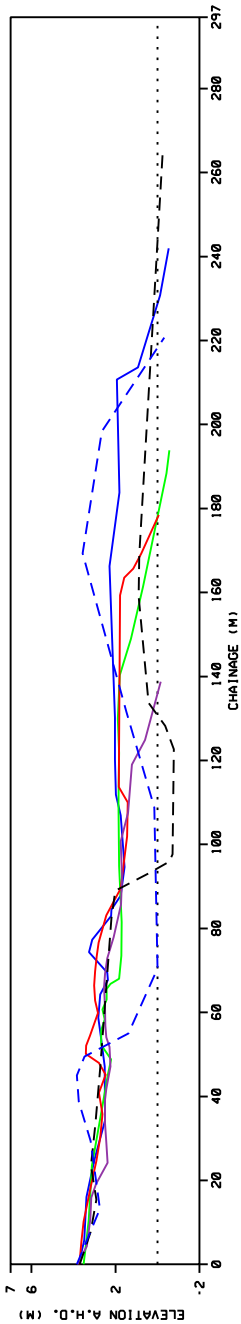
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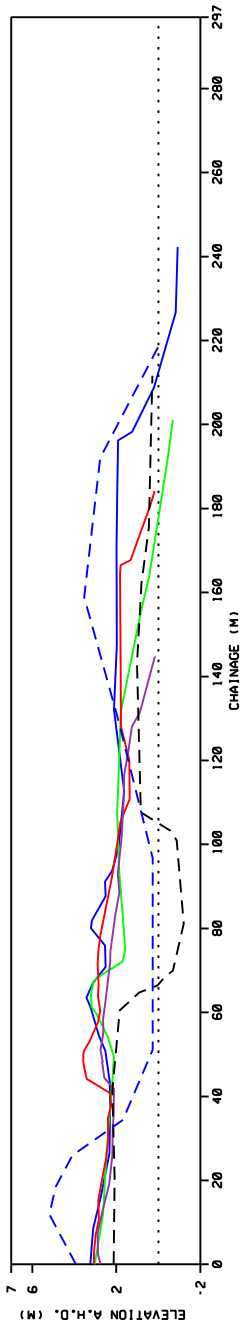
PROFILE 8



PROFILE 7



PROFILE 6

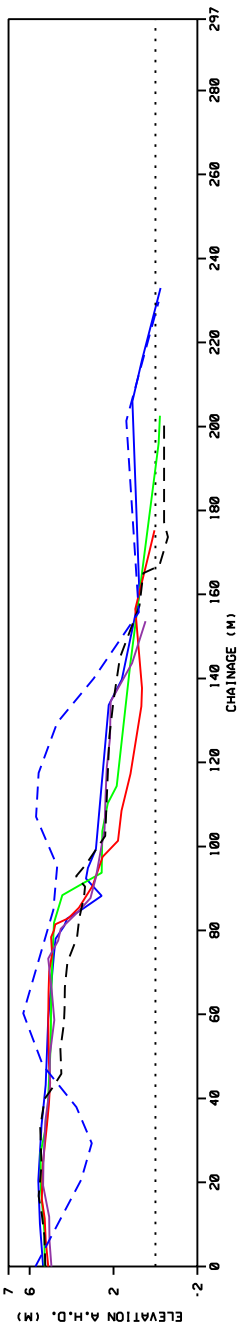


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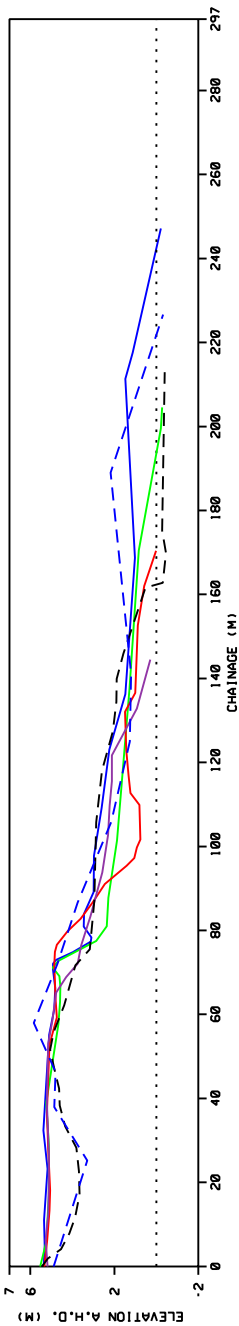
KINGSCLIFF BLOCK 1
PROFILES 9 - 12

LEDGEND

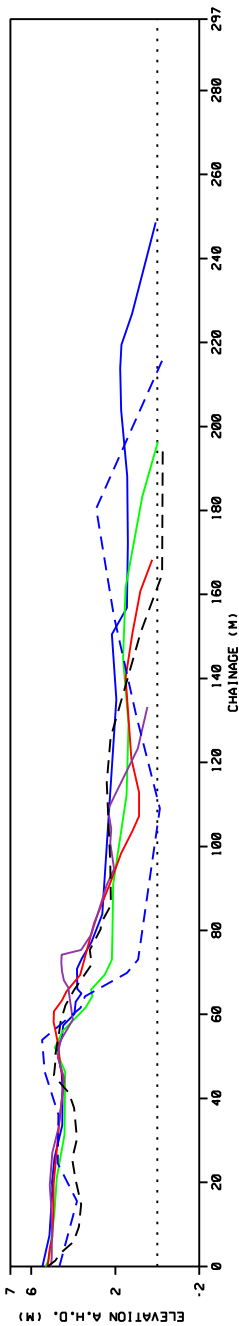
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- 1962
- 1947



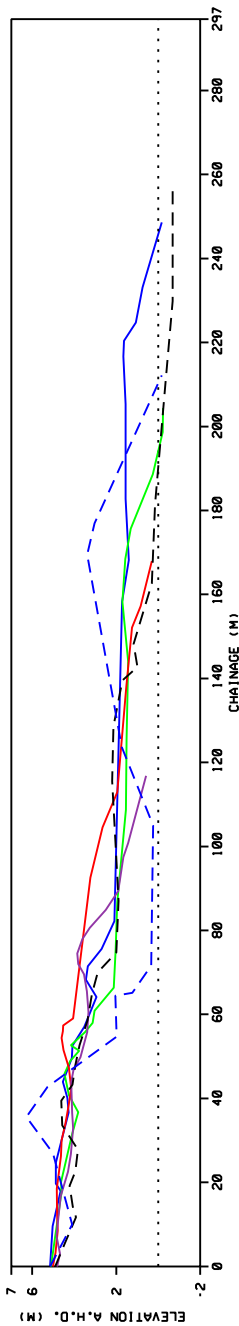
PROFILE 12



PROFILE 11



PROFILE 10

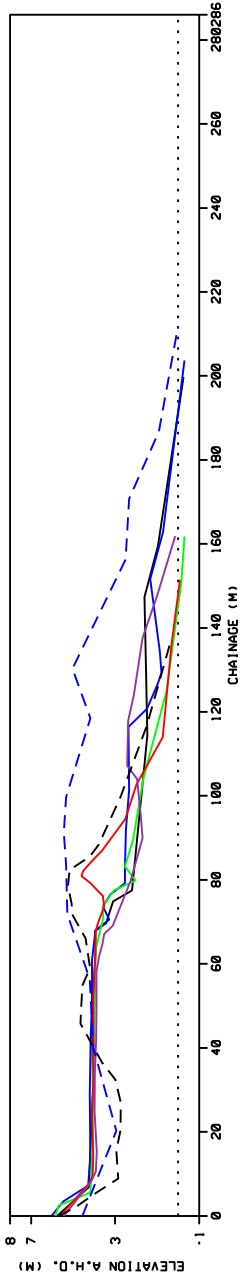


PROFILE 9

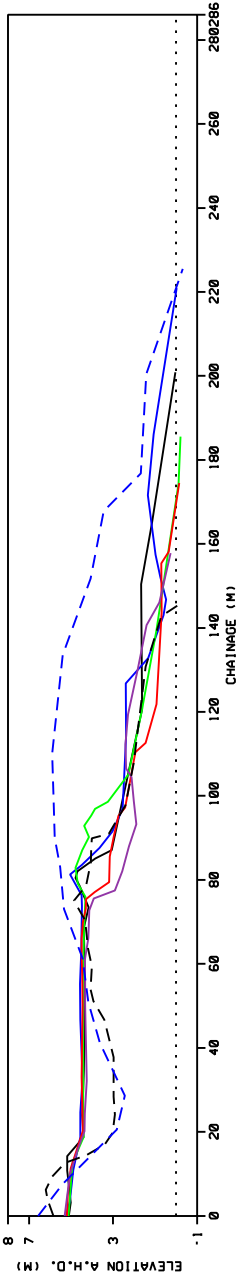
KINGSCLIFF BLOCK 2
PROFILES 1 - 4

LEDGEND

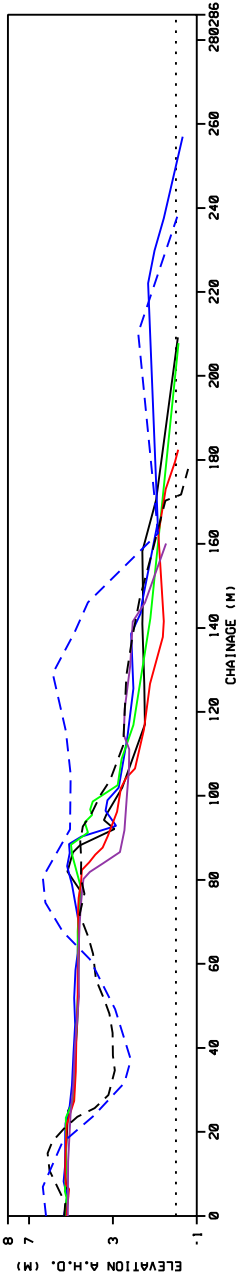
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- 1987
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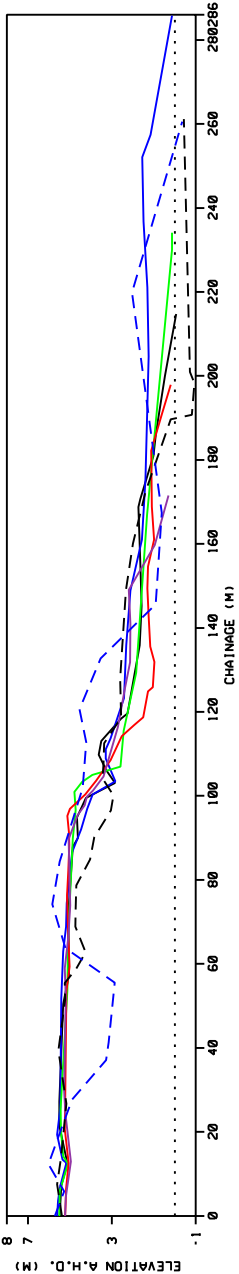
PROF ILE 4



PROF ILE 3



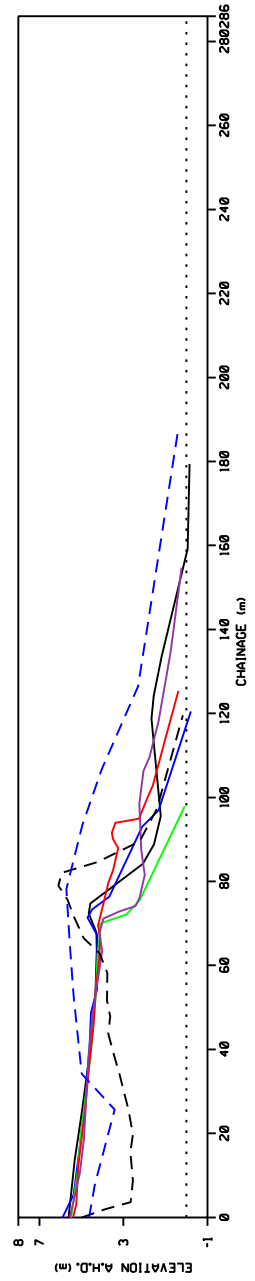
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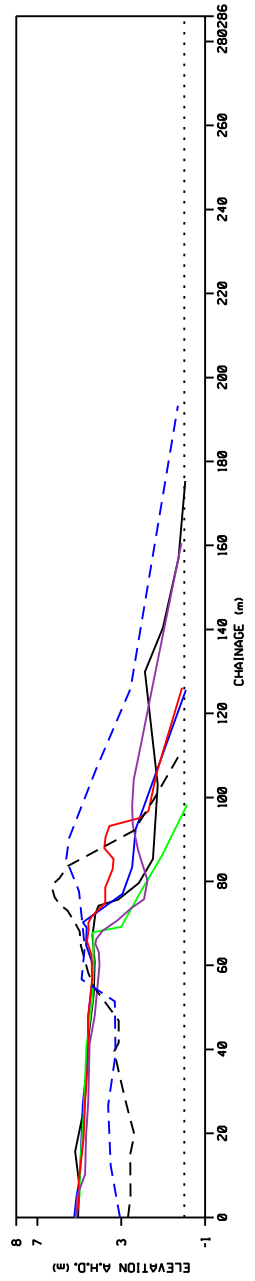
PROF ILE 1

KINGSLIFF BLOCK 2
PROFILES 5 - 8

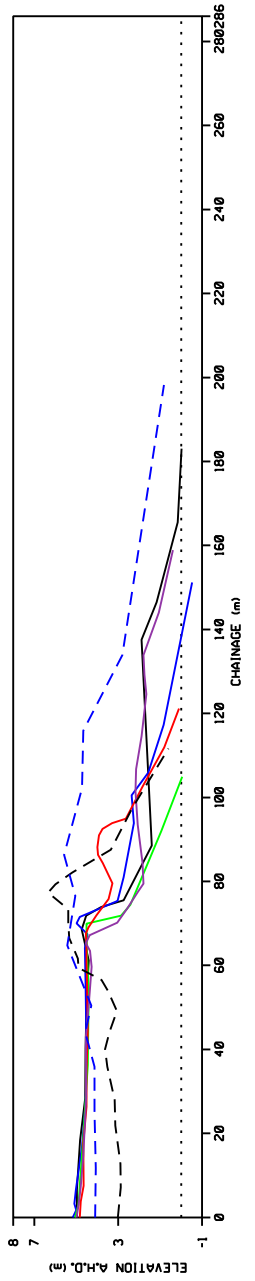
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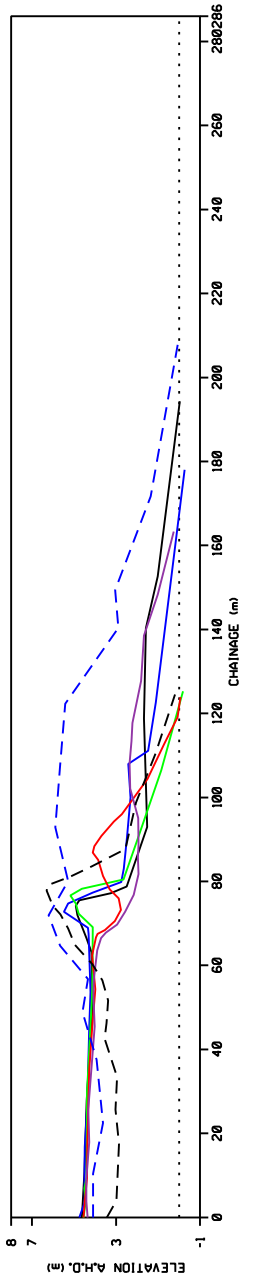
PROFILE 8



PROFILE 7



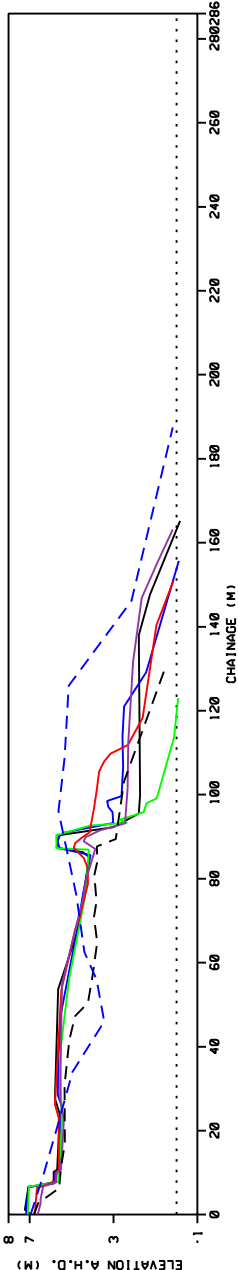
PROFILE 6



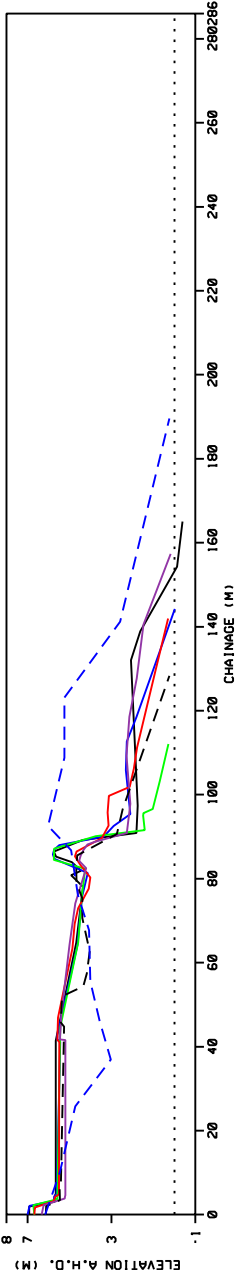
PROFILE 5

KINGSLIFF BLOCK 2
PROFILES 9 - 12

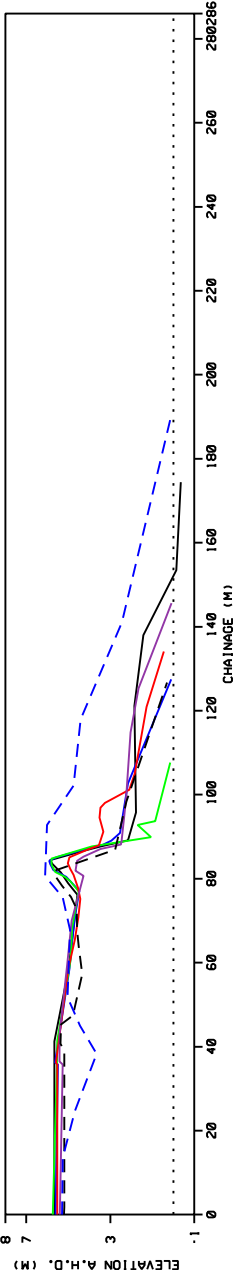
- LEDGEND
- 2010
 - 2004
 - 1999
 - 1987
 - 1977
 - 1962
 - 1947



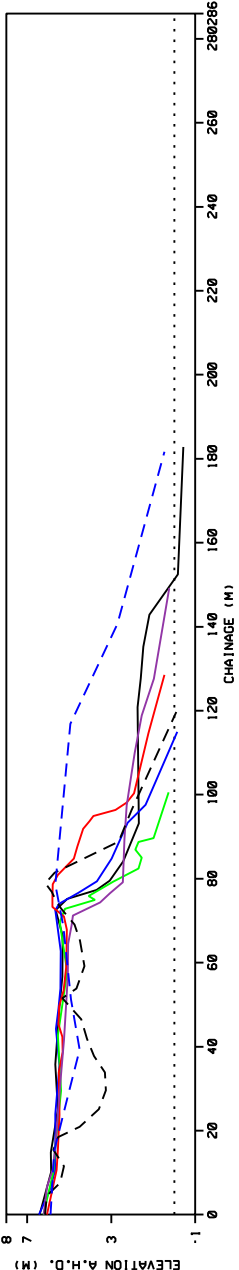
PROFILE 12



PROFILE 11



PROFILE 10

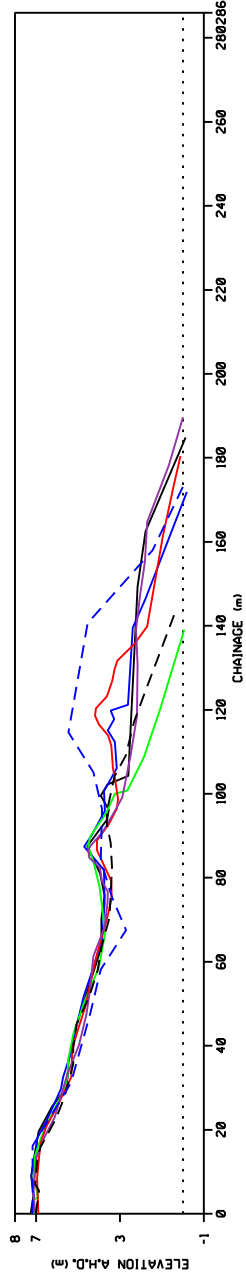


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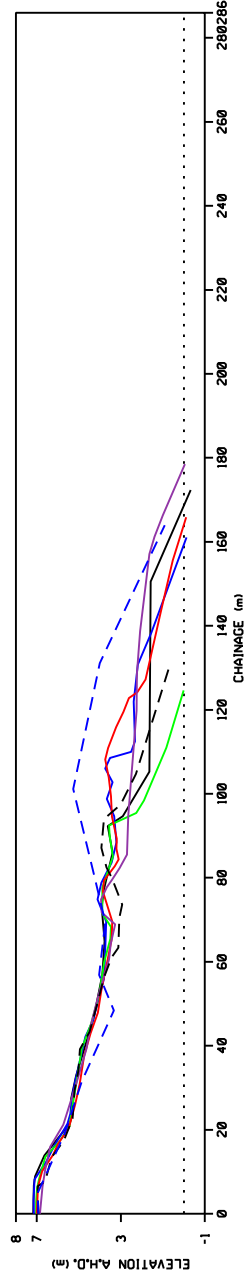
KINGSLIFF BLOCK 2
PROFILES 13 - 14

LEDGEND

- 2010
- 2004
- 1999
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- - 1962
- - 1947



PROFILE 14

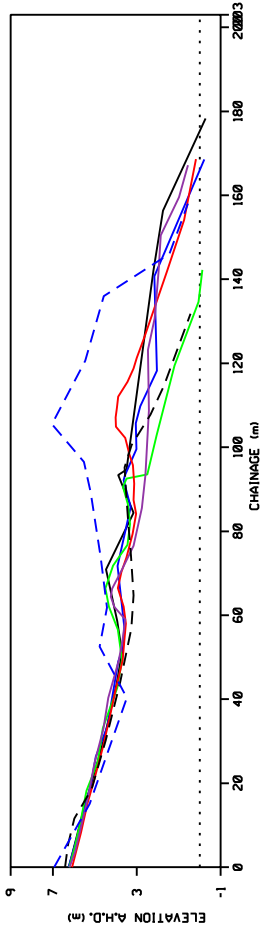


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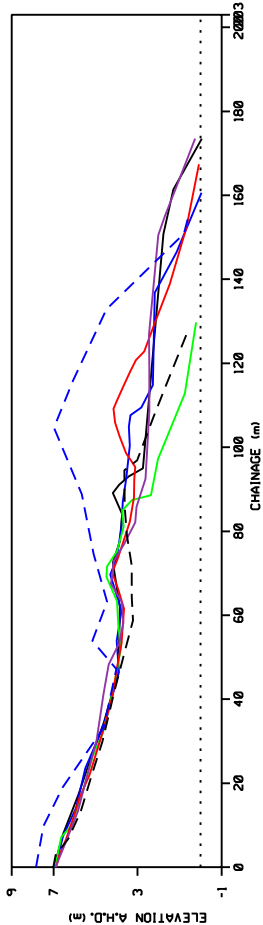
KINGSLIFF BLOCK 3
PROFILES 1 - 4

LEGEND

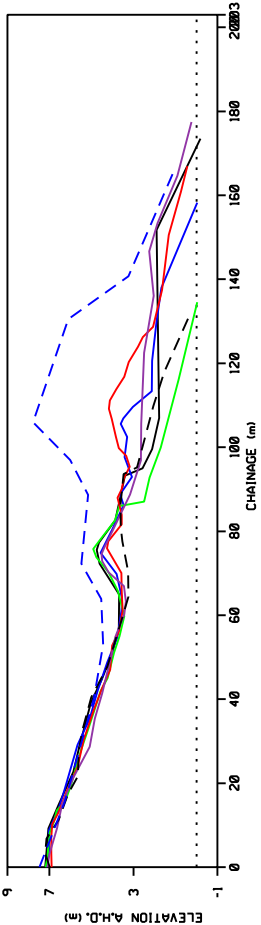
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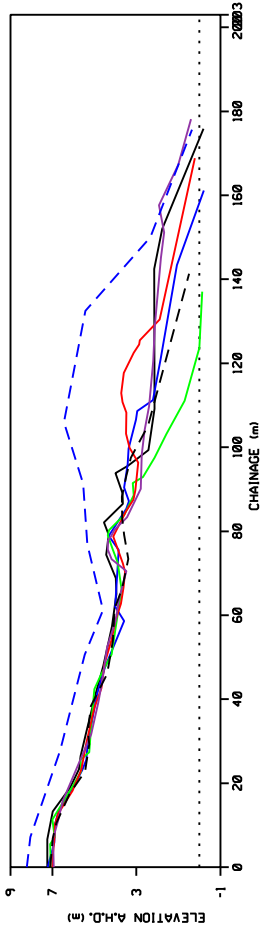
PROFILE 4



PROFILE 3



PROFILE 2

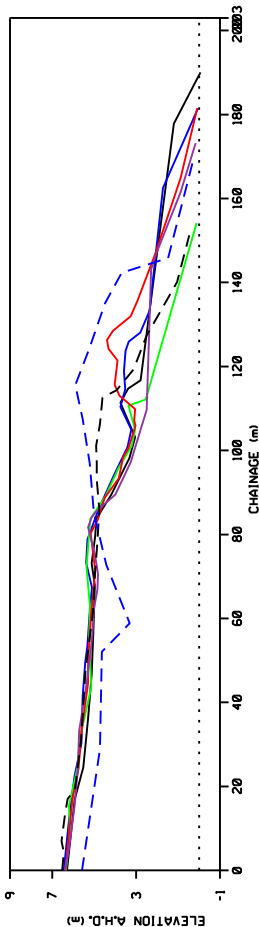


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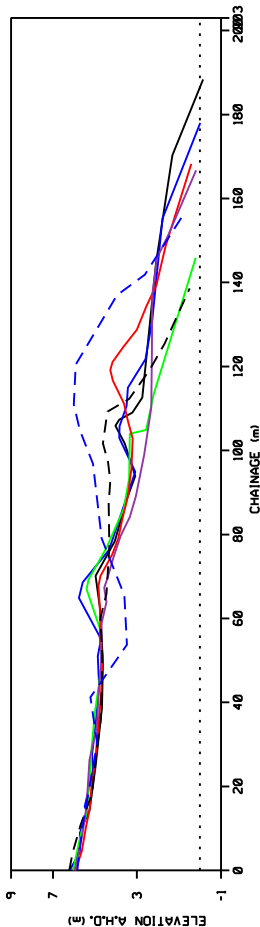
KINGSLIFF BLOCK 3
PROFILES 5 - 8

LEDGEND

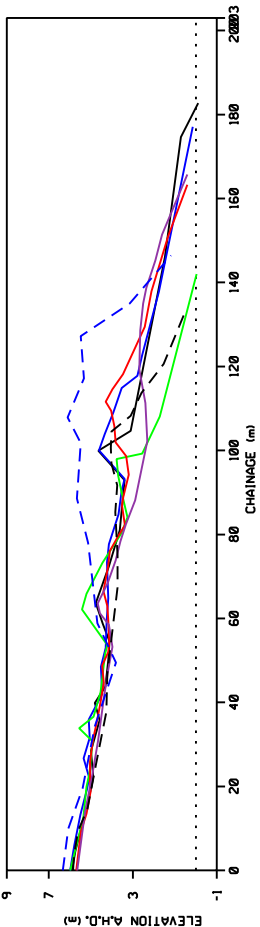
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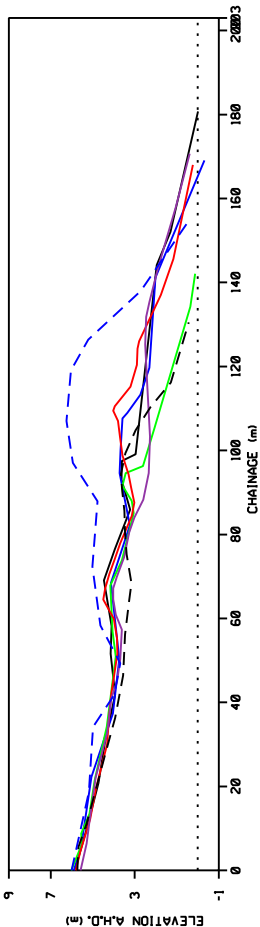
PROFILE 8



PROFILE 7



PROFILE 6

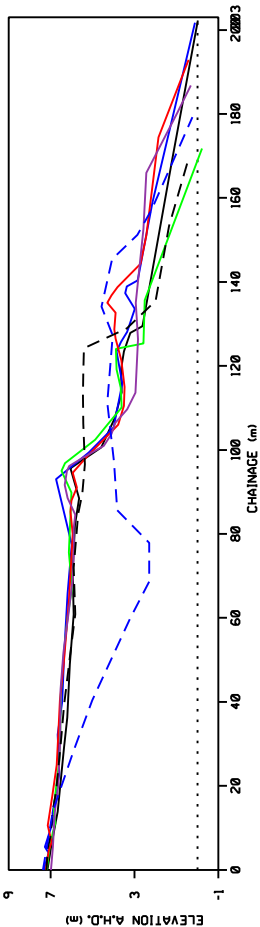


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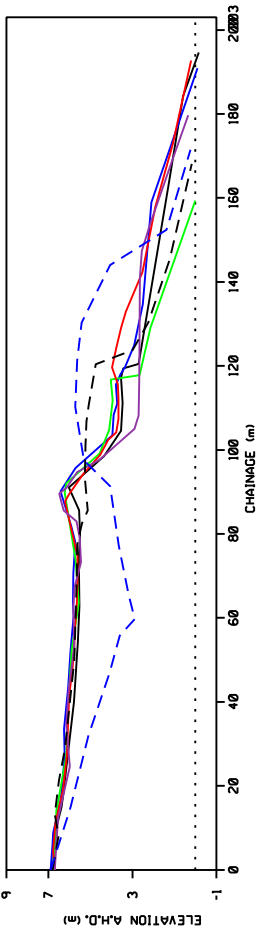
KINGSLIFF BLOCK 3
PROFILES 9 - 10

LEGEND

- 2010
- 2004
- 1999
- 1987
- 1977
- 1962
- 1947



PROFILE 10

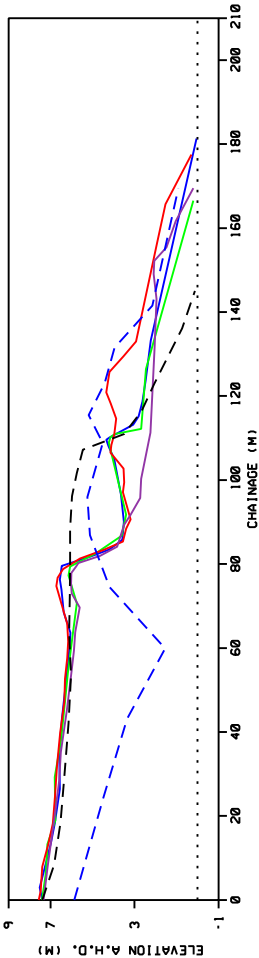


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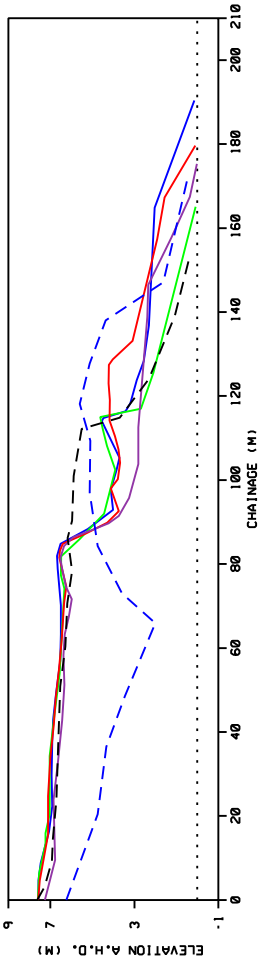
KINGSLIFF BLOCK 4
PROFILES 1 - 4

LEGEND

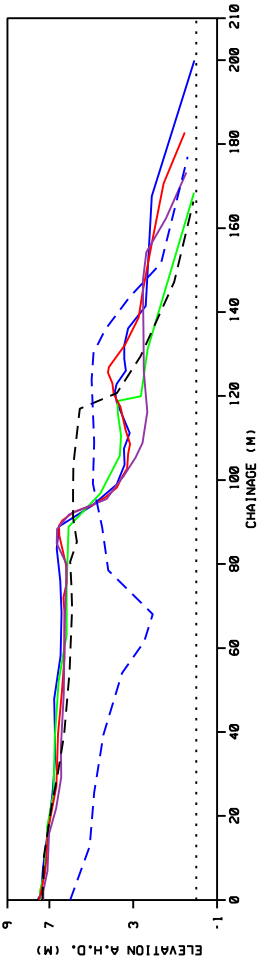
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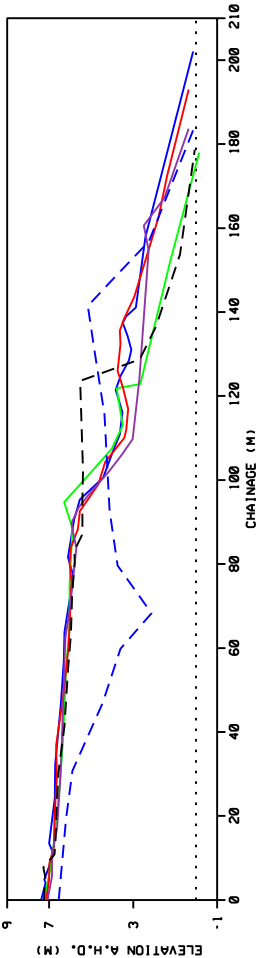
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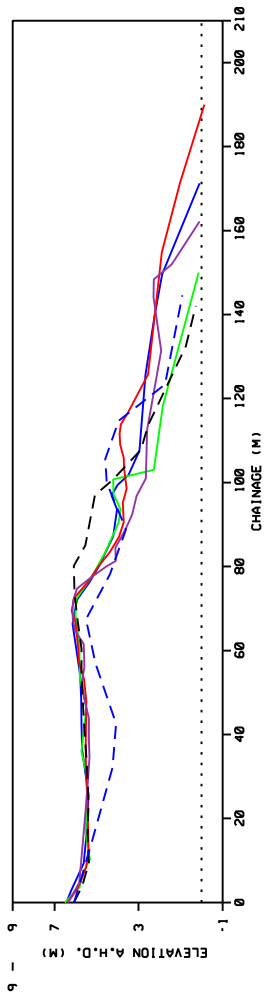
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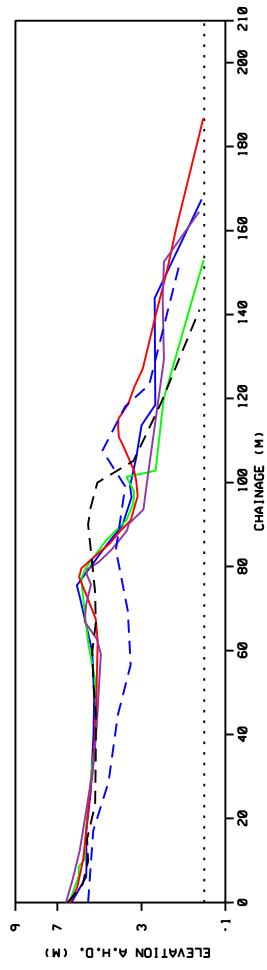
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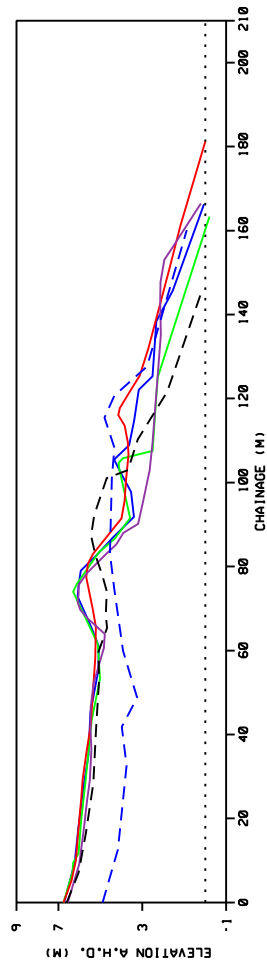
PROFILE 1



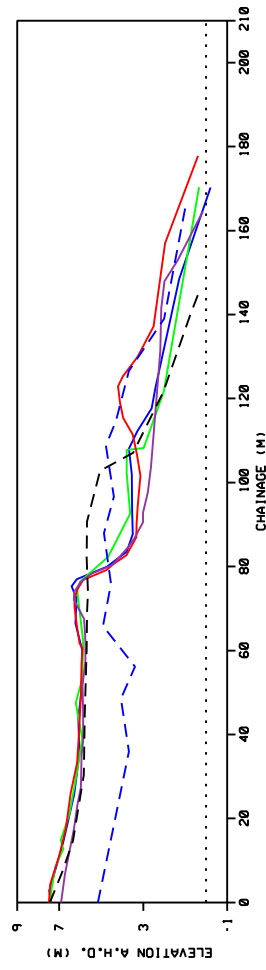
PROFILE 8



PROFILE 7



PROFILE 6



PROFILE 5

KINGSLIFF BLOCK 4
PROFILES 5 - 8

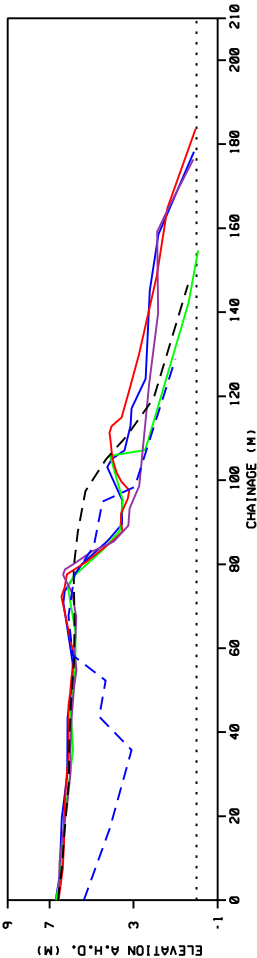
LEDGEND

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- 1987
- 1977
- 1962
- 1947

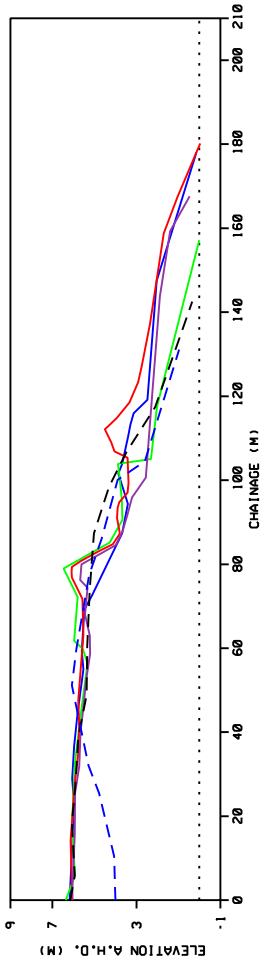
KINGSLIFF BLOCK 4
PROFILES 9 - 12

LEDGEND

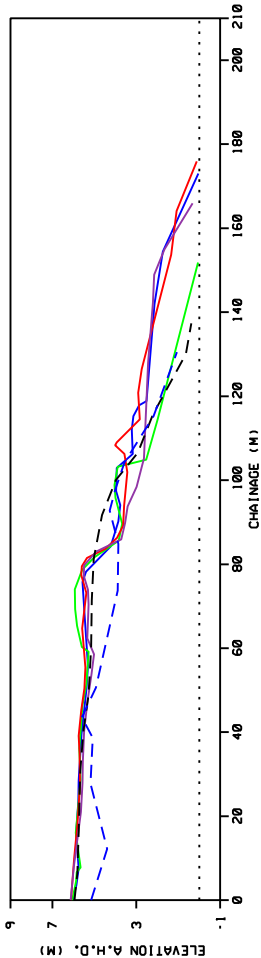
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- 1987
- 1977
- 1962
- 1947



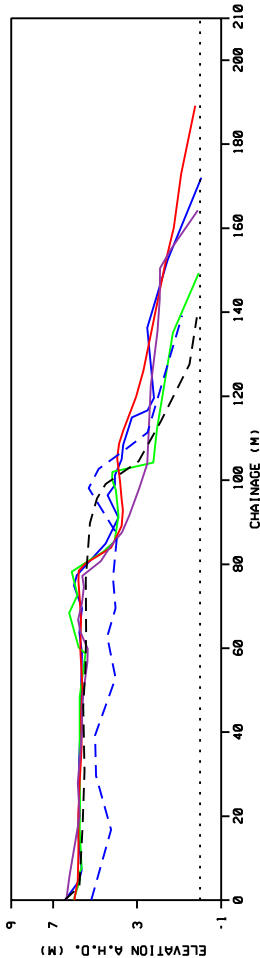
PROFILE 12



PROFILE 11



PROFILE 10

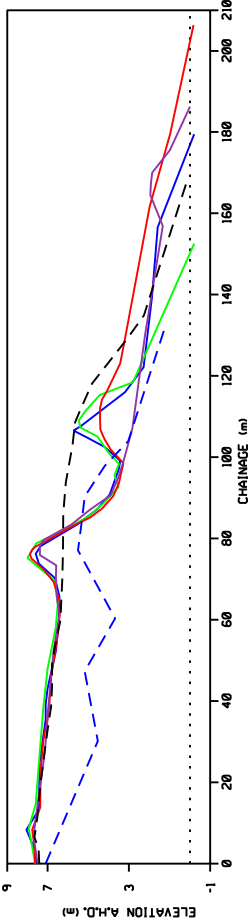


PROF ILE 9

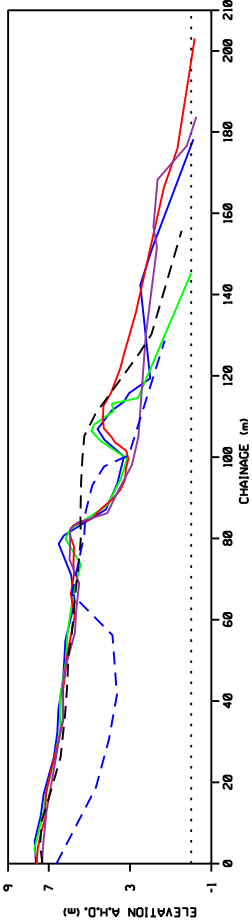
KINGSCLIFF BLOCK 4
PROFILES 13 - 16

LEDGEND

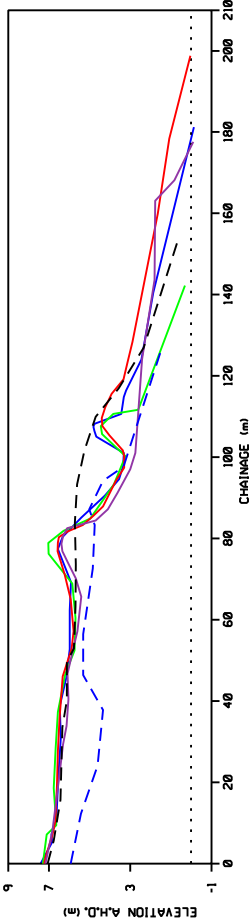
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- 1947



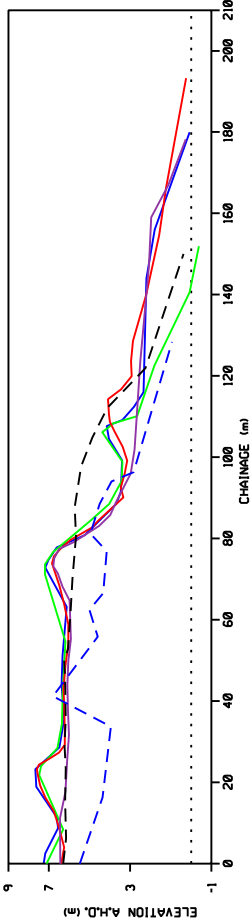
PROFILE 16



PROFILE 15



PROFILE 14

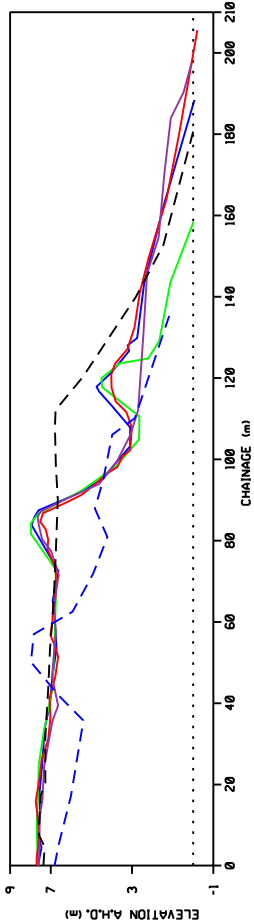


PROFILE 13

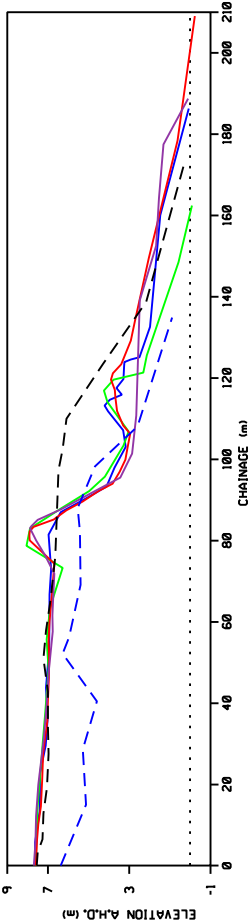
KINGSLIFF BLOCK 4
PROFILES 17 - 18

LEDGEND

- 2004
- 1999
- 1987
- 1977
- 1962
- 1947



PROFILE 18



PROFILE 17