CONCEPT DESIGNS FOR A GROYNE FIELD ON THE FAR NORTH NSW COAST

I Coghlan[1], J Carley[1], R Cox[1], E Davey[1], M Blacka[1], J Lofthouse[2]
[1] Water Research Laboratory (WRL), School of Civil and Environmental Engineering, The University of New South Wales, Manly Vale, NSW
[2]Tweed Shire Council (TSC), Murwillumbah, NSW

Introduction

On the open coast of NSW, many options exist to adapt to the hazards of erosion and recession. Perhaps the most common historical approach to counter the erosion and recession hazard is to construct a seawall or revetment to protect the existing foreshore. Other alternatives include the construction of a submerged breakwater, assisted beach recovery and/or beach nourishment. For beaches with a littoral drift imbalance, the construction of one or more groyne structures is a further possibility. This paper presents two different concept designs for a long term groyne field at Kingscliff Beach.

Background Information

Case Study: Kingscliff Beach

Kingscliff Beach, located at the southern end of Wommin Bay on the far north coast of NSW (Figure 1), is a section of the Tweed coastline with built assets at immediate risk from coastal hazards. Ongoing erosion in the last few years has resulted in substantial loss of beach amenity and community land. Storm erosion episodes between 2009 and 2012 severely impacted the Kingscliff Beach Holiday Park (KBHP). This section is also affected by moderate ongoing underlying shoreline recession (WBM, 2001).

To manage the Kingscliff Beach foreshore (Figure 2) in the longer term, Tweed Shire Council (TSC) is considering a combination of several of the following options:

- undertaking various beach works – dune reconstruction and vegetation, fencing, access-ways and stormwater management;
- undertaking beach nourishment between the northern end of Kingscliff Beach Bowls Club (KBBC) and the northern training wall of Cudgen Creek;
- construction of a terminal seawall between an existing rock seawall protecting KBBC to the north and an existing secant pile seawall at Cudgen Headland Surf Life Saving Club (CHSLSC) to the south;
- construction of a groyne field between the northern end of KBBC and the northern training wall of Cudgen Creek; and/or
- planned retreat.

TSC was specifically requested to reconsider the last two points by the NSW Minister for the Environment following advice received from the NSW Coastal Panel in

December 2011 (NSW Coastal Panel, 2011). This paper considers the second last point only.

WRL was engaged by TSC to prepare two different concept designs for a long term groyne field at Kingscliff Beach. The first groyne field concept design assumed erosion protection would be provided by large scale beach nourishment in conjunction with the groynes. The second design assumed erosion protection would be provided by a terminal seawall fronting KBHP in conjunction with the groynes.

Figure 1: Location (Aerial Photo 23/06/2008)

Figure 2: Site Details (Aerial Photo 21/07/2011)

Groyne Field Design Considerations

Groynes are structures that extend from the shore into the active zone of littoral drift transport and control the natural movement of beach material and are analogous to natural headlands. They alter the orientation of the beach to be more in line with incident wave crests and intercept longshore currents, reducing littoral drift transport and promoting sediment accretion on their updrift side. Groynes do not directly counter erosion and recession, but provide assistance in developing a more stable shoreline and sand buffer, or transfer the processes to other locations.

The basis of groyne field design must include consideration of littoral processes, functional design and structural design (Balsillie and Berg, 1972).

Littoral processes are probably the single most important process influencing the effective operation of groynes. Littoral drift transport results from longshore currents in (and seaward of) the surf zone caused by waves that arrive obliquely to the shore and, to a lesser extent at Kingscliff Beach, by longshore wave height variations and longshore tide and wind driven currents. The bulk of littoral drift transport occurs within the surf zone and the cross-shore distribution of the transport is determined by water depth and the cross-shore distribution of sediments and wave height. If no littoral drift bypassing of a groyne head occurs, the shoreline downdrift of a groyne will generally erode/recede. Conversely, if full bypassing of a groyne occurs, the shoreline updrift of a groyne will generally not continue to accrete.

Functional groyne design covers includes aspects of length (Figure 3), crest level (Figure 4), width (Figure 3), spacing (Figure 3), permeability, orientation, siting (location) and sediment budget. If littoral processes are well understood, the most important functional aspects are the water depth (Figure 4) at the head of each groyne (i.e. length) and groyne spacing.

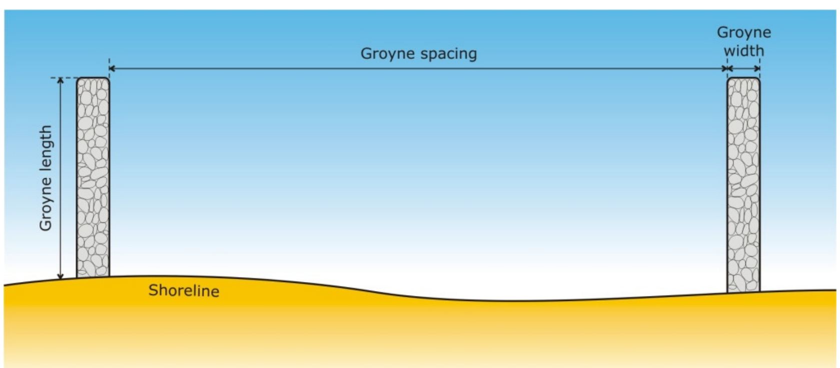


Figure 3: Functional Groyne Design – Plan View

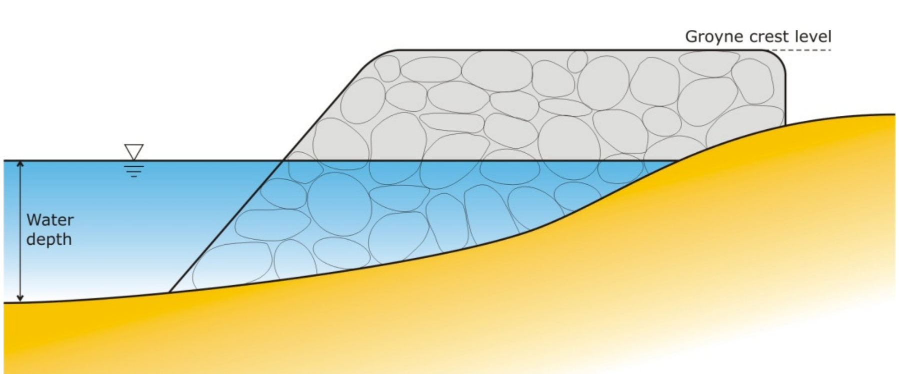


Figure 4: Functional Groyne Design – Side View

Structural groyne design considers appropriate construction materials and techniques to prevent failure of the groynes as a result of wave forces, currents forces, sediment loading and debris impacts. The most important structural decision affecting the overall geometry of groynes is the selection of the expected sand scour level at the toe which determines the maximum wave forces on the groynes and required armour mass.

In the development of the two groyne field concept designs, WRL considered the performance of similar structures nearby and reviewed design guidance set out in the literature.

Groynes and Training Walls in the Region

An inventory of the condition and effectiveness of existing nearby structures was prepared as recommended in the US Army Corps of Engineers (USACE, 1992) methodology. The best indication of how a proposed structure will perform is the performance of a similar structure in a similar physical environment. This evaluation of how nearby groynes and training walls (which are effectively long groynes) are performing provided an indication of how the proposed groyne field at Kingscliff Beach would perform. Characteristics of each of the training walls and groynes that have been constructed along the coast between Noosa (southern Qld) and Byron Bay (northern NSW) were documented. Summarising these groynes and training walls provided some detailed information and guidance for the concept design process for Kingscliff Beach as it gave an indication of whether the structures perform adequately in terms of trapping sediment and withstanding the wave conditions onsite.

Along the coast between Noosa and Byron Bay, nine entrances with training walls (some with two training walls, others with just one) and eleven groynes (including four at Maroochydore Beach, two at Palm Beach and two at Kirra Beach (Figure 5) were documented. With the exception of Maroochydore Beach, these structures are predominantly constructed from rock, with concrete cubes used on the Gold Coast Seaway training wall heads and the northern training wall of the Tweed River. Effective structure lengths were estimated using aerial photographs and readily available literature. Note that the effectiveness of each structure's function as a littoral drift barrier is more dependent on water depth at its head rather than length. Some of the structures are not perpendicular to the shoreline, however, orientation has not been included in this table. Crest and toe levels have also been included based on literature or estimates by WRL. The available characteristics for each of the structures are summarised in Table 1. Structure types were denoted as training walls (TW) or groynes (G).

Figure 5: Kirra Point Groyne, Qld (Photo 07/07/2013, Prior to 2013 Restoration)

Table 1: Groynes (G) and Training Walls (TW) in Southern Qld and Northern NSW

Location	TW or G?	Year of Construct.	Av. Sand Level at Head (m AHD)	Length (m)	Crest Level (m AHD)	Construct. Material
Noosa River (S)	TW	1978	-1.0	55	3.0	Rock
Noosa Woods	G	1983	-2.0	125	3.0	Rock
Maroochydore Beach 4 (N)	G	2001-03	-1.0	65	1.5	Geo. Containers
Maroochydore Beach 3	G	2001-03	-1.0	50	1.5	Geo. Containers
Maroochydore Beach 2	G	2001-03	-1.0	100	1.5	Geo. Containers
Maroochydore Beach 1 (S)	G	2001-03	-1.0	100	1.5	Geo. Containers
Mooloolah River (W)	TW	Late 1960s	-2.0	255	4.0	Rock
Mooloolah River (E)	TW	Late 1960s	-3.0	150	4.0	Rock
Gold Coast Seaway (N)	TW	1986	-3.0	210	4.0	Rock,Conc Cubes
Gold Coast Seaway (S)	TW	1986	-7.0	450	4.0	Rock,Conc Cubes
Tallebudgera Creek (S)	TW	1978	-2.0	190	3.5	Rock
Palm Beach (N – 21st Ave)	G	1980	-1.0	55	2.0	Rock
Palm Beach (S – 11th Ave)	G	1980	-1.0	75	2.0	Rock
Currumbin Creek (N)	TW	1980	-2.0	160	3.0	Rock
Currumbin Creek (S)	TW	1973	n/a	200	2.0	Rock
Miles Street (North Kirra)	G	1974	+3.0	120	3.0	Rock
Kirra Point	G	1972	-3.0	160	3.0	Rock
Tweed River (N)	TW	1962-65	-5.0	425	5.5-6.5	Rock,Conc Cubes
Tweed River (S)	TW	1962-65	-4.0	200	6.0	Rock
Cudgen Creek (N)	TW	1966	-1.0	120	3.0	Rock
Cudgen Creek (S)	TW	1966	-1.5	120	3.0	Rock
Mooball Creek (N)	TW	1966-67	-1.0	75	2.2-2.5	Rock
Mooball Creek (S)	TW	1966-67	-1.5	100	2.0	Rock
Kendall's (New Brighton)	G	1970s	+1.0	25	2.5	Rock
Brunswick River (N)	TW	1960-1962	-2.0	275	4.0-3.5	Rock
Brunswick River (S)	TW	1960-1962	-3.0	200	4.5	Rock
Jonson St Spur, Byron Bay	G	1975	-0.5	40	5.0	Rock

Of the eleven groynes, Miles Street Groyne at North Kirra, constructed in 1974, and Kendall's Groyne, constructed at New Brighton in the 1970s are considered very short (extending to approximately +3 and +1 m AHD, respectively) and are not having any impact on the shoreline alignment (WorleyParsons, 2009 and WBM Oceanics, 2000). These were constructed when the beaches were extremely eroded, so they may have originally had some effect on sand transport however, they are now perched high on the beach. The two groynes at Palm Beach constructed in 1980 (Splinter et al, 2011) and the Jonson Street Spur Groyne in Byron Bay can also be considered short, and were estimated to extend to approximately -1, -1 and -0.5 m AHD respectively. Consideration is presently being given to extending the Palm Beach Groynes to approximately -3 m AHD (BMT WBM, 2013). Note that the Jonson Street Spur Groyne was originally the second (central) of three spur groynes; however, the other two groynes at either end of the Jonson Street coastal protection works now have negligible action as littoral drift barriers and have been excluded from the inventory on this basis. The four groynes at Maroochydore Beach are composed of 2.5 m^3 sand-filled geotextile containers extending to approximately -1 m AHD and were constructed between 2001 and 2003. While these groynes are also considered relatively short, they have successfully stabilised Maroochydore Beach for over 10 years (Hornsey et al, 2011). Noosa Woods Groyne and Kirra Point Groyne are much longer, extending to approximately -2 and -3 m AHD respectively. Noosa Woods Groyne was completed in January 1983 accompanied by 220,000 m^3 of nourishment sand (Coughlan, 1989). This sand was eroded and in 1988 another 140,000 m^3 was placed on the beach. Since then, regular beach nourishment exercises have placed 80,000 m^3 of sand on the beach every two years (Chamberlain and Tomlinson, 2006).

Kirra Point Groyne was originally constructed in 1972 extending seaward to -5 m AHD (Robinson and Patterson, 1975) with an approximate length of 180 m, but was then shortened by 30 m in 1996 (WorleyParsons, 2009). The groyne currently extends to approximately -3 m AHD (WorleyParsons, 2009) and is generally considered to be fulfilling its function of protecting Coolangatta/Greenmount Beach. At the time of writing, approvals were being sought to lengthen the groyne by 30 m to improve downdrift recreational surfing amenity, which would effectively return the structure to its original length. Miles Street Groyne, located approximately 500 m west of the Kirra Point Groyne, originally had a length of 120 m which was also shortened by 30 m in 1996 (WorleyParsons, 2009). Design parameters for the original Kirra Point Groyne (1972) are reproduced in Table 2.

Table 2: Kirra Point Groyne Design Parameters (source: WorleyParsons, 2009)

Design Parameter	Design Value
Alignment	North-East
Length	183 m
Crest Elevation	3.05 m AHD
Armour (trunk)	5.1 to 8.1 tonne rock (5 to 8 ton)
Armour (head)	10.2 to 15.2 tonne rock (10 to 15 ton)
Design Wave Conditions	4.9 m
Side slopes (natural)	1V:1.25H to 1V:1.5H
Side slopes (design wave conditions)	1V:2.5H
Crest width	3.6 m

The Gold Coast Seaway training walls were constructed in 1986. The armour used on the seaway walls is composed of rock and concrete cubes. Approximately one million tonnes of rock was imported, with rock sizes up to 15 tonnes, and 4,500 concrete cubes between 20 and 25 tonnes were used to create the seaway training walls (Gold Coast City Council, date unknown).

No information was found regarding armour units on any of the other training walls or groynes in Queensland.

Within NSW, the performance of the Cudgen Creek training walls at the southern end of Kingscliff Beach is of particular relevance. They were designed as part of a flood mitigation scheme for the Cudgen Lake and Cudgen Creek area, with construction completed in 1966 (MHL, 1994). The condition of both training walls was assessed by Manly Hydraulics Laboratory in 1994 as part of an appraisal of all breakwaters and training walls in NSW. Significant findings from MHL's review of the Cudgen Creek training walls are outlined below.

When inspected in 1994, the armour size on the northern Cudgen Creek training wall was highly variable and had been poorly placed; subsequently the side slopes were variable (MHL, 1994). While it was reported that the trunk was in a reasonably good condition, there was clear evidence the head of the northern breakwater had failed. From observations, MHL (1994) suggested that the head may have retreated some six metres since its initial construction. Armour size calculations suggested that the armour stone on the head, estimated to be 0.2 to 4.1 tonnes, should be at least 4.5 tonnes for a structure slope of 1V:1.5H (MHL, 1994).

Damage was also noted on the southern Cudgen Creek training wall in 1994, with extensive damage on the creek side of the head (MHL, 1994). Rock armour from the head had moved around the corner to the north, subsequently entering the navigational channel. The necessary armour for the head was determined by MHL (1994) to be the same as for the northern training wall (at least 4.5 tonnes for a slope structure slope of 1V:1.5H). The measured armour size was generally less than 3 tonnes (maximum 3.4 tonnes), and subsequently undersized, as was the case for the northern training wall.

While it was never constructed, it is noteworthy that a concept design for a groyne field northwest of the Jonson Street Groyne at Byron Bay was developed by the NSW PWD (1978). The characteristics for a typical groyne are reproduced in Table 3.

Table 3: Proposed Belongil Groyne Field Design Parameters (source: NSW PWD, 1978)

Design Parameter	Design Value
Length	Extending seaward to the -3 m AHD contour
Crest Elevation	5 m AHD (seaward end) and 7 m AHD (landward end)
Armour (trunk)	10 tonne rock
Armour (head)	12-15 tonne rock
Side slopes	1V:1.5H

It is also noteworthy to mention two other locations, which are outside of the reference region, where groynes composed of sand-filled geotextile containers have been constructed.

A short groyne (extending to -0.5 m AHD) composed of 2.5 m^3 sand-filled geotextile containers exists at Cardwell in northern Queensland (Figure 6). As discussed in Carley et al (2011), Tropical Cyclone (TC) Yasi passed within 45 km of this structure in February 2011. While the structure was largely still in place following TC Yasi with minor displacement of some geocontainers, it does not have full exposure to the open ocean. The Cardwell Groyne has a crest level of 1 m AHD at the seaward end and 2.9 m AHD at the landward end. The toe level of the head of the groyne is -1 m AHD with a typical bed level at the head of approximately -0.5 m AHD.

Figure 6: Cardwell Groyne (Qld) following TC Yasi

A groyne field consisting of eight groynes composed of smaller 0.75 m^3 geotextile containers exists at Lucinda Beach in northern Queensland. These groynes are also relatively short (extending to approximately -1 m AHD), however, no further structural characteristics are available. The site is offered some protection from the open ocean by a series of islands and no geotextile containers were displaced during TC Yasi (Carley et al, 2011).

On the basis that the shortened Kirra Point Groyne (1996-2013) is fulfilling its protective function and that the conditions experienced at this site are broadly similar to those at the southern end of Kingscliff Beach, the key properties of this structure were adopted for the concept design of the long term groyne field layout for Kingscliff Beach.

Development of Groyne Field Concept Designs for Kingscliff Beach

Concept Design Conditions

Planning Horizon

Establishing the design working life of the proposed long term groyne field was critical for determination of subsequent design parameters. A nominal design life of 50 years was adopted for the long term groyne field.

A further consideration is that the maximum significant wave height that can reach the structure is a function of design water level due to depth limited wave conditions. The 1 in 100 year ARI event was selected for both wave conditions (height, period and direction) and water level conditions (tide plus anomaly).

Groyne Permeability

An important design decision was to consider whether impermeable or permeable groynes will be selected for Kingscliff Beach. Traditional impermeable groynes tend to block the nearshore current, interrupting the longshore sediment transport over the entire groyne length. Permeable groynes act differently to traditional groynes as they do not directly catch and trap sand. Instead, permeable groynes work by slowing the longshore current and decreasing the capacity of the current to transport sand. They may also reduce or eliminate the downdrift erosion/recession associated with impermeable groyne design under certain conditions. However, permeable groynes are more suited to less exposed locations than Kingscliff Beach. While limited design guidance for permeable groynes was collated in a literature review (Coghlan et al, 2013), impermeable type groynes were selected for concept groyne design. This selection was made on the basis that there are no long-lasting permeable groynes on marine coastlines in Australia or worldwide and that there are problems associated with damage to these structures from wave impacts.

Groyne Length

As discussed earlier, beach stabilisation using groynes is generally feasible in areas characterised by a dominant direction of littoral drift transport. Littoral drift transport at Kingscliff Beach is generally northward but occasionally southward (BMT WBM, 2010). Patterson (2007) suggests that the net annual longshore sand transport at the southern end of Kingscliff Beach (Sutherland Point) is 518,000 m^3/year northward.

The cross-shore distribution of littoral drift transport at Kingscliff Beach was approximated from two other studies in the region. WRL previously modelled the cross-shore distribution of littoral drift transport at the southern Gold Coast Seaway (Turner et al, 1998). Patterson (1999) modelled the cross-shore distribution of littoral drift transport on selected Tweed and southern Gold Coast beaches. Figure 7 compares the cross-shore distribution of littoral drift transport at the southern Gold Coast Seaway found by Turner et al (1998) with the distribution derived by Patterson (1999) at one representative location, Kirra.

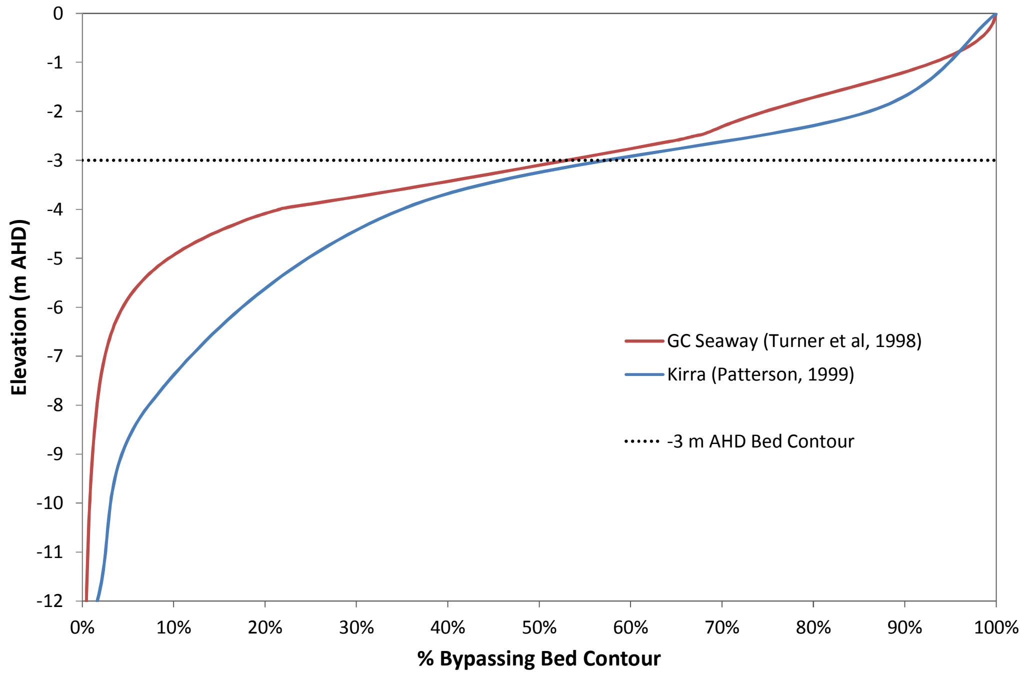


Figure 7: Comparison of the Cross-Shore Distribution of Longshore Transport from Two Studies

While some differences exist between the two distributions, good agreement was found for bed contours between -2 and -4 m AHD. In reality, the bypass curves shown in Figure 7 would be further modified by rip action against the groynes.

As discussed earlier, the nearby Kirra Point Groyne presently extends to the -3 m AHD contour and is generally considered to be fulfilling its function of protecting Coolangatta/Greenmount Beach. Note, however, that the bed level at the head of the Kirra Point Groyne is substantially modified by sand bypassing of the Tweed River training walls. Following consideration of the preceding information, it was assumed that the groynes would extend seaward to the -3 m AHD contour for concept design of the long term groyne field. On this basis, it is expected that approximately 50% of the net annual longshore sediment transport would bypass each groyne head (259,000 m^3/year).

Groyne Spacing

Kraus et al (1994) suggested that groynes on sandy beaches perform best if their spacing is two to four times the groyne length. Fleming (1993) cited the results of a survey of groyne installations in the UK. The ratio of groyne spacing to length was found to vary between 0.8 and 2.7, though it should be noted that (wave reflecting) timber groynes were the favoured construction method in the UK in 1993. These criteria have been developed for groynes which allow bypassing of littoral drift. These spacing rules are, thus, engineering “rules of thumb”.

The SPM (1984) recommended a spacing ratio of two to three, while the CEM (USACE, 2006) suggested a groyne spacing to length ratio of two to four.

Silvester (1992) presented a graphical procedure for estimating the ratio of groyne spacing to length. The ratio is a function of the incident wave angle and varies from two to fourteen. However, no field or laboratory data was cited to support this method.

Spacing is dependent on the trade-off between total groyne length and nourishment volume, as shown in Figure 8, with consideration also given to rotation in alignment within the cell due to seasonal or event changes in incident wave angle. Following consideration of the preceding information, a target groyne spacing not exceeding four times the effective groyne length was adopted.

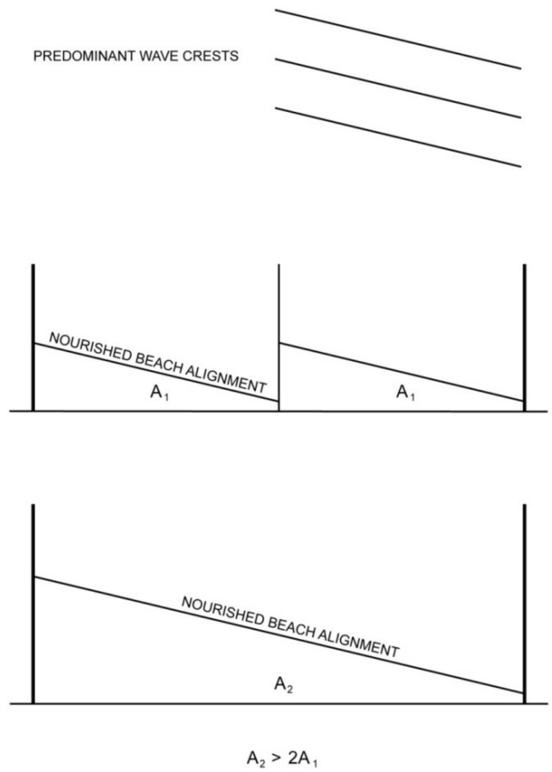


Figure 8: Effect of Groyne Spacing on Nourishment Volume

Groyne Orientation

Conflicting design philosophies for groyne orientations were summarised in the SPM (1984): "Examples may be found of almost every conceivable groin [sic] alignment and advantages are claimed by proponents of each". The SPM then recommended an orientation perpendicular to the shoreline. If groynes are angled slightly downdrift, more curvature of the beach in the shadow zone can develop due to enhanced diffractive effects around the groyne. However, angling of groynes downdrift to the long term average littoral drift can cause exacerbated erosion during events in which the drift direction is reversed. Although medium to long term reversal of the net littoral drift transport is not apparent along Kingscliff Beach, reversal of littoral drift does occur with the occurrence of waves from the easterly sector. On this basis, the SPM (1984) recommendation of orientation perpendicular to the coast was adopted for concept design. Note that this orientation is different to that of the Kirra Point Groyne.

Groyne Crest Level and Width

The crest level of each of the proposed groynes is influenced by several factors which will minimise the amount of construction materials used, control sand movement over the top of the groynes and accommodate land-based construction equipment that might operate directly on the structures. For practical construction (above high tide level), a crest level of 1 m AHD was adopted for core material along the full length of each groyne. Two layers of secondary armour would be placed over this core material and then finished with a concrete slab roadway. The resulting crest level would vary from 2.7 m AHD at the landward end to 3.2 m AHD at the seaward end of each of the proposed groynes. This crest level is similar to the Cudgen Creek training walls and the Kirra Point Groyne. A crest width for the core material of 3.0 m was adopted to facilitate access during construction.

Design Scour Level

A range of options were canvassed regarding determination of the design scour level at the head of each groyne. These are indicated below:

- Historical measurements of beach profile movement on natural beaches;
- Historical measurements of scour at the head of an existing groyne; and
- Erosion modelling.

Following consideration of each of these options, a design scour level of -5 m AHD was adopted on the basis that the typical bed elevation at the head of each groyne would be -3 m AHD (allowance for 2 m scour depth). It is understood that scour depths of 2 to 3 m were measured at the head of the original Kirra Point Groyne (extending to -5 m AHD) following cyclones in early 1974 (Robinson and Patterson, 1975).

Groyne Field Layouts

Groyne locations were determined through consideration of the location of existing structures. For both groyne field layouts, one groyne would be located at the northern end of the KBBC rock revetment. As such, down drift erosion/recession effects would impact the unprotected section of Kingscliff Beach to the north of Kingscliff Beach Bowls Club. A second groyne would be located approximately co-linear with the entrance road to Kingscliff Beach Holiday Park at the southern end of the park.

The target criterion of the groyne spacing not being more than four times the effective length has been complied with for both groyne field layouts (Table 4). Note that the two groynes for Layout 1 (with large scale beach nourishment) are longer than those for layout 2 (with a terminal seawall). This is because the nourished -3 m AHD contour is located approximately 50 m further seaward than the un-nourished -3 m AHD contour. Groyne Field Layout 1 is shown in Figure 9. Note that approximate positions of three typical groyne cross-sections (which are discussed in the following section) are also shown on Figure 9. Groyne Field Layout 2 has not been shown for brevity.

Table 4: Description of Long Term Groyne Field Layouts

Groyne Field Layout	Designation	Groyne Length (m)	Approx. Distance to Next Groyne (m)	Spacing/Length (-)
1	Northern Groyne	230	555	2.4
	Southern Groyne	195	555	2.8
2	Northern Groyne	176	555	3.2
	Southern Groyne	145	555	3.8

Figure 9: Long Term Groyne Field Layout 1 – Large Scale Beach Nourishment

Summary of Concept Design Conditions

A summary of the conditions adopted for the groyne field concept designs is presented in Table 5. For brevity, the derivation of the wave and water level conditions shown in Table 5 has not been included in this paper. The reader is directed to Coghlan et al (2012 and 2013) for more detailed descriptions of this information.

Table 5: 1 in 100 Year ARI Concept Design Conditions

Variable	**Present Day Value**	**2050 Value** (where different)
Design Offshore H_S (m)	8.1	
Design Offshore H_{RMS} (m)	5.7	
Design T_P (s)	13.1	
Design Still Water Level (m AHD)	1.72	
Wave Setup @ -5 m AHD Contour (m)	0.10	
Sea Level Rise (m)	0.00	0.40
Design Scour Level at the Groyne Head (m AHD)	-5.00	
Design Nearshore Water Depth @ -5 m AHD (m)	6.82	7.22
Design Nearshore H_S @ -5 m AHD (m)	4.15	4.40
Design Core Material Crest Level (m AHD)	1.0	
Design Core Material Crest Width (m)	3.0	
Design Groyne Length (m)	195-230 (Layout 1) 145-176 (Layout 2)	
Design Groyne Spacing (m)	555	
Number of Groynes (-)	2	

Groyne Construction Materials

Four different construction materials were assessed for suitability for the long term groyne field, as follows:

- Rock (greywacke or basalt);
- Sand-filled geotextile containers;
- Piles (timber or concrete); and
- Concrete (Hanbars).

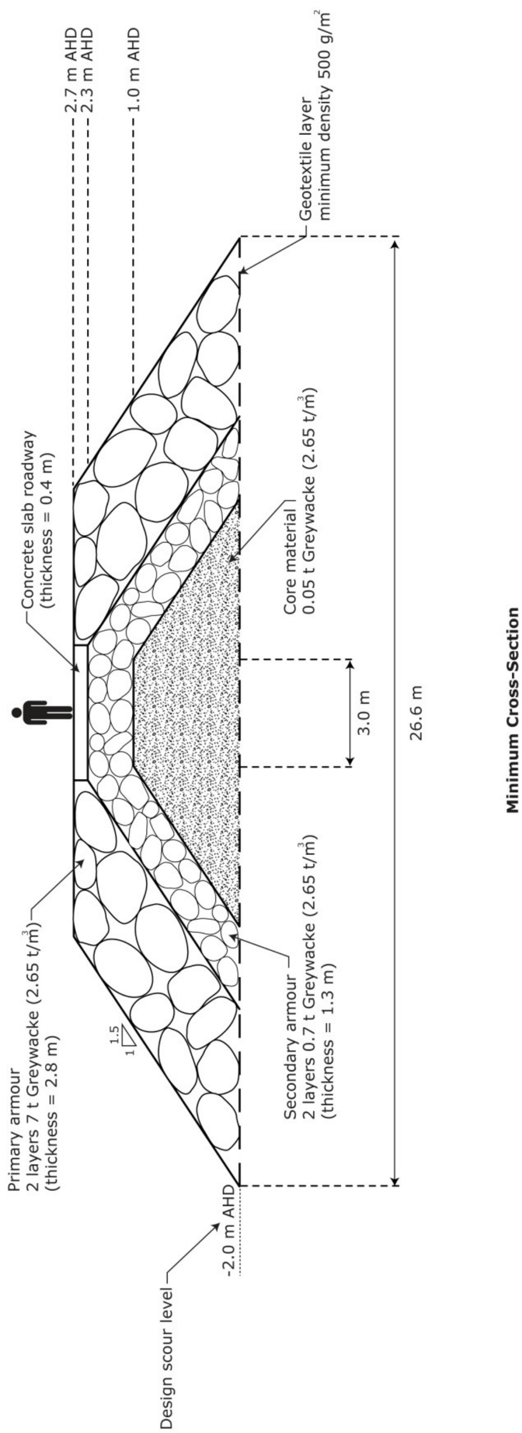
Enquiries with several quarries indicated that there was an abundance of greywacke rock but that the supply of basalt was more limited. However, it was not possible to acquire greywacke rock in sufficient quantities for construction with a median mass greater than 7.0 t. On the basis of hydraulic stability (Carley et al, 2011), sand-filled geotextile containers were found to be unsuitable for the groyne field if the design working life is 50 years. Since no evidence was found of long-lasting impermeable pile structures made from timber or concrete during the literature review, they were not considered further as construction materials. Hanbars are three-legged, pre-cast unreinforced concrete armour units (Figure 12) which provide a non-proprietary means of gaining stable armour on coastal structures where it is impractical to use quarry rock and are more economical than concrete cubes providing the same degree of protection. These armour units have been widely used in NSW.

Following consideration of potential construction materials, a combination of greywacke rock and concrete Hanbars were selected for both groyne field layouts. For economy, rock is recommended for use at the landward end of each groyne and Hanbars at the seaward end.

The following primary armour sizes were adopted for concept design:

- Scour Levels -4 to -5 m AHD (groyne head): 15 t Hanbar
- Scour Levels -2 to -4 m AHD (trunk typical): 10 t Hanbar
- Scour Levels -1 to -2 m AHD (trunk minimum): 7 t Greywacke

The minimum and typical concept design cross-sections for the proposed long term groyne field are shown in Figures 10 and 11, respectively. Note that a round head concept design cross-section has been omitted from this paper for brevity.



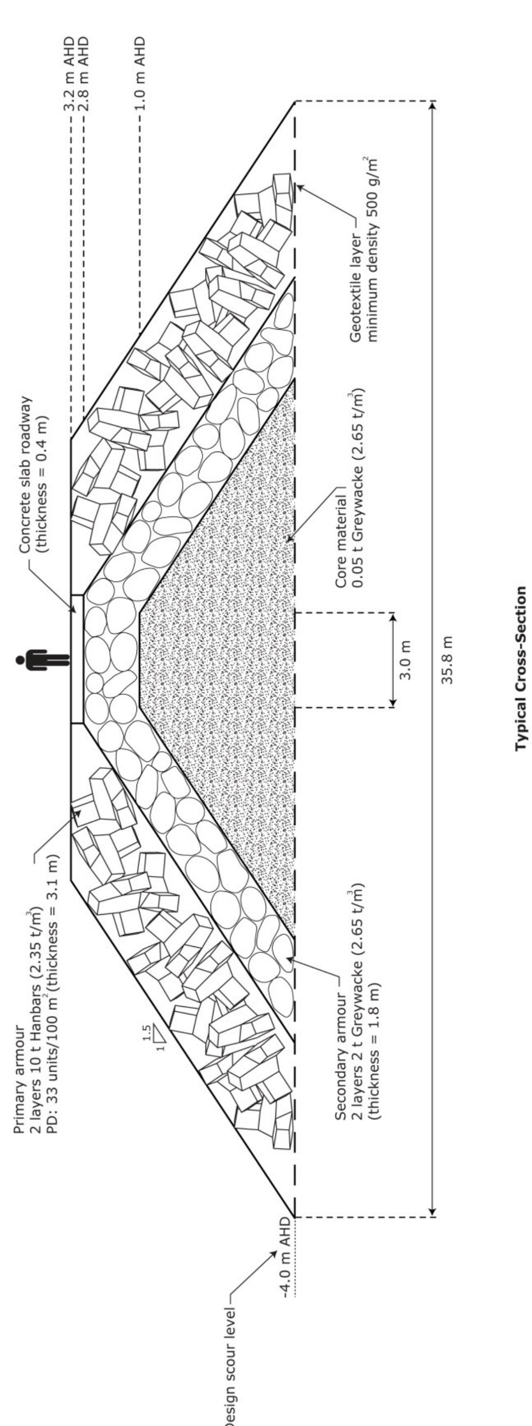


Figure 10: Minimum Groyne Section **Figure 11: Typical Groyne Section**

Figure 12: Placement of a Hanbar Armour Unit at Coffs Harbour, NSW

Economics

The capital cost estimates derived for the concept designs for groyne field Layouts 1 and 2 are approximately $15.3M and $12.5M, respectively. This includes $8.1M for the northern groyne and $7.2M for the southern groyne in Layout 1 as shown in Table 6. For Layout 2, the estimated cost is $6.7M for the northern groyne and $5.8M for the southern groyne. These cost estimates are only for initial construction and are based on itemised details set out in Coghlan et al (2013). Maintenance costs and costs for beach nourishment are excluded from these values. Lineal rate costs per metre of groyne length and per metre of shoreline protected have also been calculated.

Table 6: Capital Cost Estimate for Groyne Field Layouts

Groyne Field Layout	Capital Cost Estimate ($M ex GST)			Lineal Cost Estimate	
	Northern Groyne	Southern Groyne	Total	Total ($/m of structure)	Total ($/m of shoreline)
1	8.1	7.2	15.3	36,000	14,000
2	6.7	5.8	12.5	39,000	11,000

The initial lineal rate cost estimates for the construction of the groyne field ($36,000 to $39,000 per metre of structure) are significantly higher than those estimated by previous management studies (Umwelt, 2003 and 2005) exploring the use of groynes at Kingscliff Beach ($6,500 to $11,000 per metre of structure). However, the higher value cost estimates are considered realistic for a groyne field on the open coast of NSW. The estimated cost to lengthen the Kirra Point Groyne ($27,000 per metre of structure) is also of a similar order (GCCC, 2013) but slightly lower than the estimates for Kingscliff Beach, likely due to the use of rock armour only rather than rock and Hanbars.

The initial lineal rate costs per metre of groyne structure are 2-4 times the cost per metre of a typical terminal seawall on the open coast of NSW. However, when represented as costs per metre of shoreline protected, the lineal rate for a groyne field is comparable to a typical terminal seawall. The key difference is that it is necessary to undertake initial and ongoing beach nourishment in conjunction with the construction of a groyne field to provide coastal protection equivalent to that provided by a terminal seawall. The initial lineal rate costs for a groyne field in conjunction with beach nourishment at Kingscliff Beach are estimated to be approximately 3 times the cost per metre of shoreline protected by a terminal seawall (Coghlan et al, 2013). However, it should be noted that this combination of coastal management options would provide significant beach amenity (in addition to coastal protection) that would not be provided by a terminal seawall alone. In the absence of a terminal seawall, if a groyne field is constructed without initial beach nourishment, some beach amenity would be created/enhanced but coastal protection against a design storm erosion event would not be assured.

Summary

Two different concept designs were prepared for a long term groyne field to provide indirect protection to the southern end of Kingscliff Beach. The selection of groyne length (water depth at the head of each groyne), groyne spacing and expected sand scour level were the three most important design decisions affecting the overall geometry, design and cost of the groynes.

While the lineal rate costs per metre of shoreline protected for a groyne field are similar to a terminal seawall, it is necessary to undertake beach nourishment in conjunction with the construction of a groyne field to provide coastal protection against a design storm erosion event and allow sand bypassing at nearly pre-groyne conditions to reduce downdrift erosion/recession. The initial costs for the construction of a groyne field in conjunction with beach nourishment are approximately 3 times the cost of a seawall. While the designs were specifically developed for Kingscliff Beach, the groyne field layouts and their associated costs are broadly applicable for the northern half of the NSW open coast.

If large scale beach nourishment is undertaken to improve beach amenity at Kingscliff Beach, the construction of a groyne field would minimise the loss of placed sand towards the northern end of Wommin Bay from alongshore spreading. Regardless of the presence of a terminal seawall, inclusion of a groyne field with large scale beach nourishment would reduce the cost, volume and interval of ongoing nourishment campaigns.

Acknowledgments

Funding for the investigation presented was provided by Tweed Shire Council.

References

83 references relating to Kingscliff Beach and groynes are listed in Coghlan et al (2013). Only those directly cited in this paper are listed below.

Balsillie, J H and Berg, D W (1972), “State of Groin Design and Effectiveness”, Proceedings of the 13th International Conference on Coastal Engineering, Vancouver B.C., Canada, July.

BMT WBM (2010), Notes on Recent Erosion at Kingscliff, Brisbane.

BMT WBM (2013), “Palm Beach, Gold Coast: Management Options Feasibility Assessment” – Final Report (Revision 2), Brisbane.

Carley, J T, Coghlan, I R, Blacka, M J, Cox, R J and Hornsey, W (2011), "Performance of Sand Filled Geotextile Container (Geocontainer) Structures in North Queensland during Tropical Cyclone Yasi", Proceedings of Australasian Coasts and Ports Conference 2011, Perth, WA.

Chamberlain, S and Tomlinson, R (2006), Noosa River Entrance Channel Dynamics, Published by the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC).

Coghlan, I R, Carley, J T, Shand, T D, Blacka, M J, Cox, R J, Davey, E K and Blumberg, G P (2012), *Kingscliff Beach Foreshore Protection Works: Part A – Alternative Terminal Seawall Designs and Beach Nourishment*, WRL Technical Report 2011/25, Draft, December.

Coghlan, I R, Davey, E K, Carley, J T, Blacka, M J and Cox, R J (2013), *Kingscliff Beach Foreshore Protection Works: Part C - Groyne Field Assessment*, WRL Technical Report 2012/18, Draft, May.

Coughlan, P M (1989), "Noosa Beach - Coastal Engineering Works to Mitigate the Erosion Problem", Proceedings of the 9th Australasian Conference on Coastal and Ocean Engineering, Adelaide, SA.

Fleming, C A (1993), "Groynes, Offshore Breakwaters and Artificial Headlands" in Coastal, Estuarial and Harbour Engineer's Reference Book, Edited by M b Abbot and W A Price, Chapman and Hall, London.

Gold Coast City Council (Date Unknown), The Gold Coast Seaway.

Gold Coast City Council (2013), "Project Kirra", Accessed 24/10/2013 at http://www.goldcoast.qld.gov.au/project-kirra-17206.html,

Hornsey, W P, Carley J T, Coghlan, I R and Cox, R J (2011) "Geotextile Sand Container Shoreline Protection Systems: Design and Application", Geotextiles and Geomembranes, Volume 29, Issue 4, Special Edition: Geosynthetics in Hydraulic Applications, pp. 425-439.

Kraus, N C, Hanson, H and Blomgren, S H (1994), "Modern Functional Design of Groin Systems", Proceedings of the 24th International Conference on Coastal Engineering, Kobe, Japan, October.

Manly Hydraulics Laboratory (1994), NSW Breakwaters - Asset Appraisal, MHL Report 645.

NSW Coastal Panel (2011), Coastal Erosion at Kingscliff: Advice to the Minister for the Environment.

NSW Public Works Department (1978), *Byron Bay - Hasting Point Erosion Study*, Report No. 78026, November.

Patterson, D C (1999), "Longshore Sand Transport Modelling for Tweed River Entrance Sand Bypassing Project", Proceedings of Australasian Coasts and Ports Conference 1999, Perth, WA.

Patterson, D (2007), "Comparison of Recorded Brisbane and Byron Wave Climates and Implications for Calculation of Longshore Sand Transport in the Region", Proceedings of the Australasian Coasts and Ports Conference 2007, Melbourne, The Institution of Engineers Australia.

Robinson, D A and Patterson, D C (1975), "The Kirra Point Groyne – A Case History", Proceedings of the 2nd Australasian Conference on Coastal and Ocean Engineering, Gold Coast, Queensland.

Silvester, R (1992), "Design of Seawalls and Groins" in Handbook of Coastal and Ocean Engineering, Vol. 1, Wave Phenomena and Structures", Edited by J H Herbich, Chapter 23, pp. 1070-1080.

Splinter, K D, Strauss, D R and Tomlinson, R B (2011), "Assessment of Post-Storm Recovery of Beaches Using Video Imaging Techniques: A Case Study at Gold Coast, Australia", IEEE Transactions on Geoscience and Remote Sensing, 49 (12), pp. 4704-4716.

SPM (1984), Shore Protection Manual, US Army Coastal Engineering Research Center, Vicksburg, Mississippi, USA.

Turner, I L, Tomlinson, R and Watson, M (1998), *Numerical Modelling of Sediment Movement and Budget at Seaway*, WRL Technical Report 1998/08, April.

Umwelt (2003), Tweed Shire Coastline Management Study Stage 1, Values Assessment.

Umwelt (2005), Tweed Shire Coastline Management Study Stage 2, Management Objectives.

US Army Corps of Engineers (1992), *Coastal Groins and Nearshore Breakwaters*, Engineer Manual 1110-2-1617, Washington D.C.

US Army Corps of Engineers (2006), *Coastal Engineering Manual*, Engineer Manual 1110-2-1100, Washington D.C., Volumes 1-6.

WBM Oceanics (2000), Byron Shire Coastline Hazard Definition Study, Final Report, Brisbane.

WBM (2001), "Tweed Coastline Hazard Definition Study" – Final Report (Revision 3), R.B12876.002.03.doc, Brisbane, (Council has advised that the stated year of 2007 is a typographical error, with 2001 being the correct year of issue).

WorleyParsons (2009), TRESBP Kirra Groyne Effects Study.