Hunstanton Groyne Fields: appraisal of groyne effectiveness

Appendix B. Review of existing groyne structures

| 1.0

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Contents

B.1 Introduction

This appendix provides details on the existing groyne structures, in support of appraising the effectiveness of groynes across both the Borough Council of Kings Lynn and West Norfolk (BCKLWN) and the Environment Agency frontages. It focusses on the concrete and timber groyne stretches of shoreline.

B.1.1 Coastal setting

The study area frontage stretches from the start of the promenade at the northern end of Hunstanton to the end of the timber groyne field at Jubilee Bridge, Heacham.

Within the Shoreline Management Plan (SMP) (Royal Haskoning, 2010) the study frontage falls within two units (termed Policy Development Zones):

- PDZ2 – Wolferton Creek to South Hunstanton
- PDZ3 – Hunstanton Town

The subsequent Wash East Coastal Management Strategy (WECMS) (Royal HaskoningDHV, 2015) used the same units, but relabelled these Units B and C:

- Unit B – Hunstanton Town (PDZ3)
- Unit C – Wolferton Creek to South Hunstanton (PDZ2).

Whilst Unit B is at risk from erosion, Unit C is at risk from flooding. The preferred strategic approaches recommended by the Strategy are as follows:

- Unit B - to sustain the promenade, sea wall and groynes, and to replace them when needed, currently expected in 15-20 years. At that point, the most likely option is a replacement of the promenade and sea wall, but alternatives could be a rock revetment or beach recharge.
- Unit C - to continue to protect people, properties, caravan parks and environmental assets for the foreseeable future, until a trigger point is reached in terms of environmental impacts, affordability and risk to life. The preferred option includes continued maintenance of the groynes.

Note however, that the groyne frontage covered by this report extends only along sub-units C1 to C3.

A Coastal Management Plan has subsequently been produced for the Hunstanton frontage for BCKLWN (AECOM, 2019). This covers Unit B and the undefended cliff area to the north. The preferred management option presented is as follows:

- Unit B - to maintain the existing defences and then in the future to sustain the standard of protection through raising the heights of the defences. This includes refurbishment of the concrete and timber groynes to extend their defence life.

Monitoring and recycling activities along the Environment Agency frontage are determined by a Beach Management Manual, which was last updated in August 2014 (note that this report was not provided for this study).

B.2 Information reviewed

B.2.1 Previous studies and information

The table below summarises the key reports provided by BCKLWN and the Environment Agency reviewed for this appendix, from the most recent to the oldest.

Report	Produced for	Summary
Hunstanton Concrete Groynes (Peter Lawton, May 2020)	BCKLWN	Single page file note and accompanying photographs, with summary tabulation of remedial works and costs recommended for the concrete groyne structures.
Hunstanton Coastal Management Plan (AECOM, 2019)	BCKLWN	Sets out the 'road map' to deliver the SMP policy for the Hunstanton frontage over the next 100 years; this document considers and costs management approaches for Unit B. Primarily focussed on the seawalls and promenade but includes site inspection notes on the concrete and timber groynes along the BCKLWN frontage from 2017, although there is no information on their effectiveness.
Groyne Survey April 2015 to December 2016 (source unknown)	BCKLWN (assumed)	Visual inspection of extent of sediment accumulation against the groynes, recorded at seven points in time over the period.
Wash East Coastal Management Strategy (WECMS) (Royal HaskoningDHV, 2015)	Environment Agency and BCKLWN	Identifies the preferred strategic approaches for implementing the SMP policy for the frontage between Hunstanton cliffs and Wolferton Creek. This does not include any condition assessment of the timber groynes, but Appendix K1 (Baseline Coastal Processes, 2012) does include information extracted from NFCDD. There is, however, little information on their effectiveness.
Drawing 1190.10A – Groyne Works (St La Haye Ltd, August 2012)	BCKLWN	Drawing providing layout and details for remedial works to concrete and timber groynes.
Hunstanton Groyne Condition Survey Report (PAJ Lawton, January 2012)	BCKLWN	An update from the 2005 report (see below), with a re-assessment of condition and residual life. Options for works are presented, but these are solely concerned with reinstatement and maintaining the structures.
Hunstanton Sea Defence Condition Survey (Peter Lawton, June 2005)	BCKLWN	This is primarily a condition survey report based upon visual inspection. It contains information on each groyne along the BCKLWN frontage, including the start and finish co-ordinates, and length, of each structure.
Hunstanton to Heacham beach management. (Nunn R. & Beech N., 1998).	Proceedings of the ICE Coastlines, Structures and Breakwaters Conference, 1998.	This paper focussed on the Heacham frontage south of the Hunstanton Power Boat Ramp (i.e. the Environment Agency frontage). It reports that hard defences had traditionally been the adopted method of maintaining the sea defences, but in 1990, following extensive studies, a change in strategy was proposed which involved nourishment with dredged sand and shingle, with some recycling on an annual basis from south to north.
Timber Groyne Details - Section Drawings (BCKLWN, September 1982)	BCKLWN	Single drawing providing details on structural elements and materials for construction of timber groynes.
Concrete Groynes Details - Section Drawings (West Norfolk DC, July 1980)	West Norfolk District Council *(now BCKLWN)*	Single drawing providing details on structural elements and materials for construction of concrete groynes.
ICE Conference on the North Sea Floods of 31 January and 1 February 1953 (various, 1954)	Institute of Civil Engineers Conference	The proceedings of this conference discussing the 1953 floods contain some reference to the nature of works prior to that event. It seems apparent from this that also some seawall construction may have taken place, there is no mention of groynes other than much further south towards Wolferton. The same report goes on the describe the decisions taken for reinstatements of defences, which provide details on new seawalls, but makes no reference to groynes being constructed or reinstated.

B.2.2 Other information

Photographs of recent groyne condition provided by BCKLWN have been examined, as well as historic photographs identified through on-line searches.

Other industry and non-geographic-specific publications and information have been reviewed to inform this assessment; these are listed in the references section of this report.

B.3 Site walkover

Two site visits were undertaken. The purpose of these visits was specifically to consider the effectiveness of the groynes; they were not asset inspection condition surveys as had been undertaken previously. Nonetheless, some observations on condition, as might be relevant their effectiveness, were made.

The first site visit was undertaken in July 2021, which included representatives from BCKLWN and EA. It is expected that the beaches at this time were likely to be close to their fullest state and therefore observations made may be indicative of the maximum retention of beaches by groynes. This was also an opportunity to visually appraise the current composition and morphology of the beaches.

A second site visit was undertaken in November 2021. This was considered necessary to carry out further inspection of the groynes along the EA frontage in particular. Due to the recycling campaign earlier in 2021, which was understood to have included that frontage, beaches were potentially at their highest during the July visit, and several groynes were covered. The second inspection was therefore timed to inspect these groynes when some beach movement would have occurred, and the potential effectiveness of these structures could be better observed.

Specific points relating to individual groynes noted during the site visits are included in the sections below, with broader observations on effectiveness captured within the assessments presented in section B.3.

B.3.1 BCKLWN concrete groynes

Location	Estimated Length	Notes
Groyne 1	35-40m	Groynes are more embedded in the Carstone, or the Carstone level is higher than those groynes further south. Sand veneer over upper 20m within the bays, but 0.7-0.9m lower than top of planks. Little differential (perhaps 0.1m higher on northern faces).
Groyne 2	35-40m	
Groyne 3	35-40m	Sand veneer over upper 20m, but 0.7m below top of groynes either side. Seaward of that level drops to 1.2m below. Has been filled under exposed sections in places where beach has lowered (this continues to apply to many more groynes hereafter)
Groynes 4 to 6	-	All have sand sitting at top of bays to width of about 20m throughout, but level is about 1.2m lower than top of groynes (and with zero differential either side).
Groyne 4	40-45m	One exception here, where there is a differential in the sand of about 0.3m for 15-20m at top end, but noting that this is where the wall alignment also alters slightly, curving south. Gaps in planking in places
Groyne 5	50-55m	Seaward end of this has gone and been removed altogether.
Groyne 6	55-60 m	4 planks exposed. Seaward 6-10m of this groyne is falling over. This is the first one with the root undermined (next to the seawall), but anecdotally, they have all been like that in the past
Groynes 6 to 7	-	Noted that the sailing club launch here and concerns over the foreshore rocks (but noted that a 1953 photo shows exactly the same, i.e. foreshore uncovered).
Groyne 7	55m	1.2m height exposure (4 planks). Whole groyne has been undermined and, where there is a gap below planks a scour hole reaches a depth of up to 50cm below their underside. Repairs on south side of panels towards seawall

Location	Estimated Length	Notes
Groyne 8	55m	1.2m height exposure (4 planks). No differential in levels either side. Toe piling along wall between groynes 7 and 8 exposed. Notable much more wear and degradation of the concrete planks here than observed further north. A little gravel and shell had accumulated in July, but gone in November. Beacon missing.
Groyne 9	55-60 m	In July there was a slight differential either side of the groyne. But by November there was no differential in levels either side other than first 10m at root where there is a small area of shingle/pebble built up in corner on north face. But this was the only one of the groynes where this appeared in November – none of the rest have any build up against them at the top. A pile has rotated seaward part way along this groyne, indicating potential degradation of the in-situ concrete/steel post beneath the precast units.
General	-	Across the first few bays, in general the top c. 20m is covered by a sand veneer. Elsewhere it is sand/stony upper beach (but little of it). More of the Carstone appears to be exposed up closer to the wall. In places alongside the groyne this has been cut to a depth of about 0.4m before sand found in the crevices. Note sandflat/foreshore interface does not appear to be influenced by the groynes. In places where the sandflat dries out there are mussel beds at low water (noted around Groyne 6), indicating these are not generally covered by sand. Groyne 9 is close to what would appear to have been a previous timber structure. Between Groynes 9 and 10 is the base of an older concrete promontory, which has apparently only recently become exposed.

B.3.2 BCKLWN timber groynes

Location	Estimated Length	Notes
Groyne 10	90m	Groynes 10 hardly passible other than a gap in the staves where there is 0.5/0.6m exposed height).
Groynes 10 to 11 bay	-	Very rocky beach/foreshore covered in cobbles and pebbles. No upper beach.
Groyne 11	90m	No beach and up to 0.6m of groyne exposed at root for the first 12-15m. Up to 1.5m exposed height at end and condition there extremely poor/redundant. No differential in levels either side and no sign of transport past ends, but as noted elsewhere further below, the mild sand slope/sandflat interface starts at the ends.
Groynes 11 to 12 bay	-	Beach tapers to nothing between Groynes 12 and 11 – just cobbles strewn across foreshore with some sand deposit/veneer, bigger drop off wall here and to north, than further south.
Groyne 12	90m	Groyne 12 – closer to 1-1.2m exposed height at seaward ends. This (and Groynes 11 and 10) are in much poorer condition than those to the south of here. From here and remaining groynes to south, the top of groyne is buried in the beach up to several metres distance from the seawall.

Location	Estimated Length	Notes
Groyne 13	95m	Groyne 13 – trapped stones create a little differential – up to 30cm locally where they exist but nothing where they do not. About 50-55m exposed length of groyne (same for Groyne 15).
Groyne 14	95m	-
Groyne 15	85-90m	Groyne 15 – it does look here (and at 16, maybe others too) as if the sand foreshore does change angle slightly at the end of the groynes, steepening slightly to landward from this point. So maybe there are stones below trapping lower part and helping to retain a little more sand – perhaps the groynes have some modest impact (although the beaches remain woefully depleted).
Groyne 16	90-95m	Groyne 16 northward – the height of exposed groynes increases to closer to a metre at seaward ends.
Groyne 17	90m	Noted rock has been placed along seaward ends at base. Believed to not be a more recent addition but always there (potentially at least).
Groyne 18	90m	Groyne 18 – 55-60m exposed groyne length. Differential in a few places of 10-15cm, but only where some stones have been trapped to locally block sand.
Groyne 19	90m	Groyne 19. About 60-65m exposed, to a height of about 40cm. Groyne slope follows foreshore profile pretty much. No sign of any transport around the ends (same for all of these groynes). Nothing here to suggest being any higher or longer would make a difference to retention capability.
General	-	The timber groynes are all longer that the concrete groynes. Upper beach all stony/cobbles etc with only smattering of sand throughout. This is consistently about 35-40m wide throughout down to groyne 12 when it then goes to zero by groyne 11. This looks as if it is simply because wall curvature/embayment ends and the beach line itself is pretty much a straight line.

B.3.3 Environment Agency timber groynes

Location	Estimated Length	Notes
Groyne EA1	60m	Beach in vicinity of groynes EA1-EA5 are something of a contrast to those further south, with upper beach much wider and healthier sand, the groynes are largely still covered, beach is flatter than to the south and very little pebble/cobble visible. However, the top of sheet piles at toe of seawall are exposed. It is also notable that the tops of all of the groynes would appear to be lower than the bottom of the steps along the seawall.
Groyne EA2	55m	
Groyne EA3	65m	
Groyne EA4	75-80m	
Groyne EA5	85-90m	
Groyne EA6	120m	Steeper upper beach in this area, which pure shingle 10-16mm. Noted that the piles at bottom of seawall is not exposed but the wall construction looks to be a little different, so are possible deeper.
Groyne EA7	125-130m	

Location	Estimated Length	Notes
Groyne EA8	130m	This groyne (and one or two others here north and south) appear to be in a worse condition that those in the embayment to the south – assuming these are no older, then perhaps a sign of being more exposed/greater abrasion.
Groyne EA9	135m	Noted here but applies throughout this area, there is scouring down around the groynes themselves, which could be so from wave reflections and run off on ebb tides.
Groyne EA10	130m	-
Groyne EA11	60m	-
Groyne EA12	85m	Beaches north of here different to those to the south. From here north, below the upper gravel beach there is then sand slope that sits above the sandflat gently sloping down and presumably the remnants of the recycled material (maybe a little coarser, or simply not all removed yet). Notable, this transition from slope to sand flat does appear to coincide with the ends of the groynes, so although not evident, maybe these groynes on this stretch are doing something around this slight promontory and to the north?
Groyne EA13	75-80m	Lots of cobbles near top of beach rather than any sand. Wall lower concrete exposed to height of about 0.5m – too high to be a step so perhaps capping beam (but not exposing sheet piles). This is however a pinch point/promontory as move out of embayment to south onto a corner - that curvature continues through from about Groyne EA6.
Groyne EA14	85m	
Groyne EA15	80m	
Groyne EA16	85-90m	
Groyne EA17	85-90m	Marram starts at this point as end of curvature of wall to north. About 0.5-0.7m of groyne height exposed at seaward end. Lots of scour/deeper channel cutting around and along groynes however (about 30cm wide and deep) presumably as water runs off during ebb.
Groyne EA18	70m	Wider upper beach and groynes mostly covered. No lower sand beach – straight onto sandflat.
Groyne EA19	85-90m	-
Groyne EA20	85-90m	-
Groyne EA21	85-90m	Beach sandier at top but still plenty of gravel. Marrams through here, looks like some cutting in/scarp at top (about 30cm high).
Groyne EA22	85-90m	
Groyne EA23	85m	
Groyne EA24	85m	
Groyne EA25	65-70m	Marram no longer at back of beach.
Groyne EA26	60-65m	-
Groyne EA27	50-55m	Groynes 27 northward (from small rock mound) signals end of embayment created by alignment of seawall. But throughout that the beach line itself is perfectly straight rather than following line of wall.
Groyne EA28	40m	Very little beach here.
Groyne EA29	60m	Narrow upper beach very stony/pebbly upper beach with a bit of sand.
Groyne EA30	60-65m	

Location	Estimated Length	Notes
		Hard to see that these groynes are doing anything really – don't even seem to be trapping pebbles.
Groyne EA31	55-60m	Wall ends just south of here with a rock armoured beach access point. Clear curvature of coast to south indicates this is within a deeper embayment but wall has held shoreline further forward than natural at this point and to north.
General	-	There is much less pebble and cobble along here than found to the north along the Hunstanton main beach frontage, but where the upper beach is not wide some can be found along the foreshore, indicating a long-term movement of this material along the shoreline.

B.4 Groyne structures

This section reviews information regarding the structural components, to identify any particular aspects that could be indicative of their effectiveness.

B.4.1 BCKLWN concrete groynes

Groynes 1 to 9 consist of precast concrete piles and precast concrete planking, which is an unusual form of structure and not commonly found at other locations.

Anecdotally, (BCKLWN conversation during site walkover), it is thought that concrete groynes had originally been installed here circa 1955. However, a 1953 report by Kirkpatrick & Partners (1953) reported that at this time there were six precast reinforced concrete groynes along the North Promenade wall and records that these were built in 1943.

B.4.1.1 Structural details

The structural drawing dated 1980 shows the details for typical groyne elements (pre-cast planks and concrete posts) including reinforcement details.

Precast planks are 300mm deep, 160mm wide, and 2280mm long. These are slotted into precast posts which are shown to be 620mm square, 370mm high, which are themselves built around a core of 150mm square posts formed from angle steel and in-situ concrete, embedded 1m into the Carstone bed.

No further details are given on the number of planks per bay, nor length or elevation of each groyne, so the basis for design in respect of potential sediment trapping effectiveness is also unknown.

The project title on the drawing is '*Replacement of groynes at Hunstanton*', which infers that structures were previously located here, although there is no information about the nature, size, location or configuration of those, nor whether the older groynes were completely removed or not; these may be the groynes referred to in the Kirkpatrick & Partners report.

Concrete strength is shown on the drawings as 40MN/m^2. The cover to reinforcement is 50mm, which would be considered insufficient by today's standards. The concrete grade would have been considered, for its day, a high strength concrete. However, what is unknown is the type of cement used, and that makes a difference, as described in the box below (all based on information within BS6349-1-4, 2001).

Concrete subject to 'Regular -wetting/drying' (BS 6349-1-4:2021) would class it for a XSM4 condition. So, if the cement were one of a:

- CEM I, IIA, IIB-M, IIB-S, the cover for 30 years life would have needed to be 80+ mm. It would not be suitable for a 50-year life.
- IIB-P, IIB-Q, IIB-V, IIIA, the cover for 30 years life would have needed to be 50+ mm. The cover for 50 years life would have needed to be 60+ mm.
- IIB-V ≥25% Fly ash or IIIA ≥46% ggbs, the cover for 30 years life would have needed to be 40+ mm. The cover for 50 years life would have needed to be 50+ mm.
- IVB-V, IIIB, the cover for 30 years life would have needed to be 40+ mm. The cover for 50 years life would have needed to be 45+ mm.

The + relates to the construction tolerance with 5 mm being used for precast concrete, 10 mm for in-situ concrete and 15 mm for in-situ concrete cast in a marine environment.

So, for precast concrete, which is stated on the drawings and even the best cement type, the elements would be reaching the end of their design working life. For lower chloride-resisting cements the elements should have already reached the end of their design working life.

B.4.1.2 Condition

The three reports on the groynes in 2005, 2012 and 2020 (all by P. Lawton), provide some useful information on the concrete groynes, together with assessments of their condition and estimated residual life. They do not, however, inform the assessment of their effectiveness in retaining a beach; the assessment of requirements is solely around reinstatement and maintaining the structures. In fact the 2012 report goes as far as stating that '*It should be noted that this report is not concerned with the hydrodynamic efficiency of the groynes*.'

- **2005** – the concrete groynes were all assessed as being in 'Good' structural condition. The survey noted that there were very small areas of corrosion of the reinforcing steel beginning to show but concluded that no remedial works were needed to any of the concrete groynes. Residual life was determined as minimum five years, maximum 15 years, for all these structures.

- **2012** – the survey identified the concrete groynes to be in 'Good' condition requiring very little maintenance work to their structures. Residual life was again determined as minimum five years, maximum 15 years, for all these structures. However, the beach had been eroded from beneath two of the concrete groynes substantially reducing their effectiveness as beach control structures. Following this report, details were prepared for remedial works with drawing showing plans for in-situ concrete filling where voids had been identified beneath the pre-cast planks (which are presumed to have been carried out). The occurrence of this beach lowering beneath the base of the original structures is possible evidence of the ineffectiveness of these groynes to hold sediment.

- **2020** – further works were identified to infill the foundations on 37 bays across four groynes, reconstruct/replace two panels/bays on two other groynes, and demolish and make safe the seaward end on a seventh of the nine groynes. This file note however states that these works are required to '… *ensure that the concrete groyne structures continue to limit sediment movement …*'. However, although couched in terms of "ensuring they limit sediment movement", there is no indication of basis to suggest that they are or had actually been efficient in doing so. Essentially, this is just reinstatement of existing profiles and plugging gaps.

Appendix B1 to the Hunstanton Coastal Management Plan (AECOM, 2019), contains site inspection notes from 2017 and adds further notes on the structural condition of each groyne, concluding them to be in 'Fair' condition, and noting damage to them. No comment or assessment is made of their efficiency although it is noted that '*the beach* profile *appears to have dropped from when the groynes were originally installed. Gaps between bottom of groynes and beach level have been filled with a 'fill step' – a concrete fill below the original groyne structure to deal with lower material level, although some gaps were still observed*.'

During the recent site walkovers (2021) it is noted that for many of these groynes, the condition of the concrete on the structural elements is not as bad as might be expected given the potential aggressive abrasion that should be expected in a high energy mobile beach environment. This may therefore indicate that, unless the groynes have been covered for much of their lifetime (which they clearly have not), there has been a lack of coarse beach material regularly being mobilised along this frontage, suggesting limited supply onto this frontage. The exceptions to this were to the southern end, around Groynes 8 and 9, where the concrete on the planks shows more abrasion damage; which coincidentally is where the upper beach was a little higher during the site visits, with an accumulation of shelly gravels noted.

Nonetheless, the overall condition of these groynes must now be considered to be 'Poor' or even 'Very Poor'; the major issue throughout this groyne field appears to be one of overall structural stability rather than material degradation, and in particular lowering of the beach. Several groynes have one or more sections where there are gaps beneath the lowest planks – many have already been filled as part of the remedial works identified in 2012, but other gaps have since appeared. In one instance (Groyne 7) the scour hole reaches a depth of up to 50cm below the groyne underside.

Several groynes are also damaged or leaning at their seaward ends due to the same foreshore lowering, for example, Groyne 6 where three to four bays are collapsing. It is noted that the end of Groyne 5 has already been

removed. Fairly recent photographs (thought to be February 2020), show that the failure mechanisms appear to be necking of the in-situ posts below the main units due to lowering of beach, leading to corrosion of reinforcement and loss of the concrete. In several other locations, further planks have been displaced, probably either by movement of the piles as they have rotated and the interlock being lost, or through wave action.

Groyne 6 is exposed at the root, next to the seawall, although anecdotally (BCKLWN) most if not all have been subject to that in the past; in the case of Groyne 7 the entire original groyne is proud of the beach and substantial work has been necessary to further underpin the piles at the landward end. Presumably levels here and along some others were originally lower, as the groyne had been constructed four planks high, whereas others are only three planks. Although there is no measured information, it is thought that all of the groynes are built to a similar elevation and slope.

B.4.1.3 Interaction of structures with sediment movement

Clearly the groynes have the capacity to hold considerably more material if (i) sediment were arriving here and (ii) longshore transport was the dominant process. However, neither appear to be the case.

At the time of first site walkover, a little sand had accumulated in a triangle on the north sides of most groynes against the seawall, but otherwise there was little difference in beach levels either side, indicating little effectiveness in controlling alongshore sediment movement. This lack of influence was further apparent in November with no build-up even at the top of the beach across almost all the groynes. It is conceivable that the sand predominately deposited here is simply material that is in suspension, dropping out at the top of the tide, rather than being driven by longshore processes.

Evidently, not only have the groynes been ineffective in retaining much beach sediment, but they have also not helped to prevent further foreshore lowering either, with the Carstone exposures here similar to those seen along the cliff frontage immediately to the north.

The 2015-2016 Groyne Survey also reflects this. It is notable that throughout the seven surveys carried out across a 20-month period between April 2015 and November 2016, all identified that none of the concrete groyne walings was buried by sediment. That suggests either there is little supply of beach material to this frontage, or if there is a supply it was not building up and being retained by these groynes.

B.4.2 BCKLWN timber groynes

Groynes 10 to 19 are permeable timber zig-zag groynes consisting of timber piles and walings with intermediate posts (stakes), instead of timber sheet piles or planks, placed on a 'hit and miss' basis. This is again a very unusual and uncommon form of structure.

CIRIA (2020) report that the historic reasons for some groyne designs (generally before 1960) adopting a zig-zag alignment are not entirely clear, but believed to be primarily for the purpose of providing greater stability without the need for ties or structs to provide lateral support. There is also some thought that the zig-zag design can possibly create compartments to trap sediment, particularly at the top of shingle beaches, and that the design reduces the waves and/or currents running seaward along the downdrift side of the groyne, which would otherwise cause scour, although this is clearly not occurring here.

Anecdotally, (BCKLWN conversation during site walkover), it is thought that the timber groynes may have also originally been installed here circa 1955, but could be earlier, (1930's). Old photographs from the 1920's how timber structures with upright stakes, but it is not clear that these were similar to the zig-zag ones of today.

The WECMS (Royal HaskoningDHV, 2015) notes that, within Unit B, timber groynes were constructed in the early 1900s to manage beach erosion. However, no further details on form or location are provided.

B.4.2.1 Structural details

The structural drawing dated 1982 shows the details for typical groyne elements (timber king piles, walings and intermediate posts) plus fixings.

Timber king piles are shown as 229mm square, 3660mm long, with between 1000mm and 2000mm above the beach level (so between 1660mm and 2660mm embedded in the beach). These are spaced at 3050mm centres in a zig-zag pattern, with posts and walings between them at a 90° angle between each pair of piles (this results in a total length of structure of 6100mm for every 4313mm seaward distance of each groyne).

Twenty-nine timber posts are shown between each pair of king piles, with diameter of 100-125m, meaning the average gap between each would be approximately 30cm. These are shown to be 2280mm long, with between 500mm and 1500mm above beach level (so between 780mm and 1780mm embedded in the beach).

The top of each post is held between a pair of timber walings, measuring 75mm wide by 229mm deep, and 3400mm long and fixed at either end to a king pile.

The project title on the drawing is '*Replacement of timber zig-zag groynes at Hunstanton*', once more inferring that there were structures here too previously, although there is no information about the nature, size, location or configuration of those, nor whether the older groynes were completely removed or not.

The drawing shows the piles and walings were intended to be constructed of tanalised Douglas Fir, and the intermediate piles (stakes) should be '*hardwood, i.e. Ash or Oak*'. This would appear contrary to the principles for using timber in groynes, where the piles would more commonly be constructed from more resilient timbers (e.g. the oak referred to), and if a less robust material was also used (e.g. softwood such as Douglas Fir), then this would form the elements that are more easily replaced. However, a letter to the Lynn News (2016) from an individual involved in their construction does make reference to the '*intermediate Oak posts*'. Nonetheless, given the comparative degradation due to abrasion from sand and shingle, it is questionable whether the king piles and walings were actually constructed from a less resilient timber than those intermediate stakes.

For comparison with this design, zig-zag groynes constructed on a shingle beach on the south coast used hardwood king piles with treated softwood stakes between them. However, the softwood was observed to erode fairly rapidly, need regular maintenance, and require replacement after approximately 12 to 13 years (SCOPAC, 2010, van Rijn, 2018). Clearly the stakes along the Hunstanton and Heacham frontages have been there for a considerably longer time, but even if oak it would have been expected to require replacement within 15 to 25 years following their installation. Softwoods, such as Douglas Fir, have been used previously in groyne construction, but this is more likely where a short service life is required or if the groynes are reaching the end of their service life (CIRIA, 2020).

As with the concrete groynes, no further details are available on the required length or elevation of each groyne, nor is any information available regarding the number and spacing of the intermediate posts and thus level of permeability, so the basis for design in respect of potential sediment trapping effectiveness is also unknown.

B.4.2.2 Condition

The two reports on the groynes in 2005 and 2012 (both by P. Lawton) again provide useful information on the timber groynes, together with assessments of their condition and estimated residual life. As stated in section B3.1.2, they do not, however, inform the assessment of their effectiveness in retaining a beach. The assessment of requirements is solely around reinstatement and maintaining the structures, and the 2012 report states that '*It should be noted that this report is not concerned with the hydrodynamic efficiency of the groynes*.'

- **2005** – although noted that the timber stakes were heavily abraded, with the exception of two stub groynes (no longer considered) the timber groynes were all assessed as being in 'Good' condition. Remedial works were limited to renewal of the walings on five groynes. Residual life was determined as minimum five years, maximum 10 years, for all these structures.

- **2012** – the survey revealed that all of the timber groynes were in 'Fair' condition. However, all of the timber groynes needed a substantial amount of maintenance work to restore them to "Good" condition with four of the groynes requiring their seaward ends to be reconstructed. Residual life was changed to a minimum two years, maximum 10 years, for all these structures. Following this report, details were prepared for remedial works with drawing showing plans for waling replacement and pile top repairs (which are presumed to have been carried out) using hardwood timber. This also noted that '*all existing timber stakes to be left in-situ*'.

Appendix B1 to the Hunstanton Coastal Management Plan (AECOM, 2019), containing site inspection notes from 2017 adds further notes on the structural condition of each groyne, concluding them to be in 'Poor/Fair' condition, and noting damage to them. But again, no comment or assessment is made of their efficiency, although in several cases it is noted that '*the beach levels appear the same on either side of the groyne*'.

The most recent site walkovers (2021) noted the extreme level of degradation to the intermediate piles being highly visible across all of the groynes. Much larger gaps now exist between these posts than when constructed, and in this regard any potential trapping efficiency will be considerably reduced compared to when constructed. Given the significant deterioration of these fundamental components of the groynes, the overall condition has to be concluded to be 'Poor' or even 'Very Poor'. In several places the walings have also been damaged, split, or lost completely.

This would seem to be the result of years of abrasion from coarser sediments (in particular pebbles, shingle and sand) worked by the action of waves and tidal currents on a regular basis. This indicates that there is material within the vicinity, although this may not need to be a considerable amount to have this effect; wave energy will be expended on the structures and is notable that run-off channels exist along the base of each groyne, showing that this is where the tidal flows (and thus sediment in the water column) is being moved on every ebb tide.

B.4.2.3 Interaction of structures with sediment movement

The beach along this frontage has two distinct components: a coarse upper beach comprising pebbles and cobbles as well as shingle and a smattering of sand, and a shallow sandier lower beach extending out to the end of the groynes. Beyond this lies a low tide sandflat. From the November site walkover it was observed that the upper beach is generally of uniform height and width (35 to 40m) throughout most of this frontage, generally burying the root of each groyne, although this tapers out between Groynes 11 and 12 to become totally absent. However, the alignment of the seawall, and the curvature of the bay between the former pier location (now the Amusement Arcade) and the Power Boat Ramp appears to be more of an influence on this feature than the groynes, which aligns itself in a straight line rather than showing any plan form or elevation changes due to those groynes.

A similar situation was noted by the 2015-2016 beach surveys, which measured the number of walings covered by beach material over a 20-month period (noting the toe of this upper beach would be a little further seaward than the covered walings). The maximum was approximately 30% of the groyne length, and on average the buried length was between 15% and 20%. The variations in width of beach above the groynes have been estimated based upon those records, as shown in Figure B-1. These all showed no beach retention at Groyne 10, and a diminishing width of beach at Groyne 11. A slightly wider beach was observed from groyne 12 southward, although it is notable that the beach width narrowed again towards the Power Boat Ramp – Groynes 17 to 19. Over the period some increase in beach width was observed between Groynes 13 and 19.

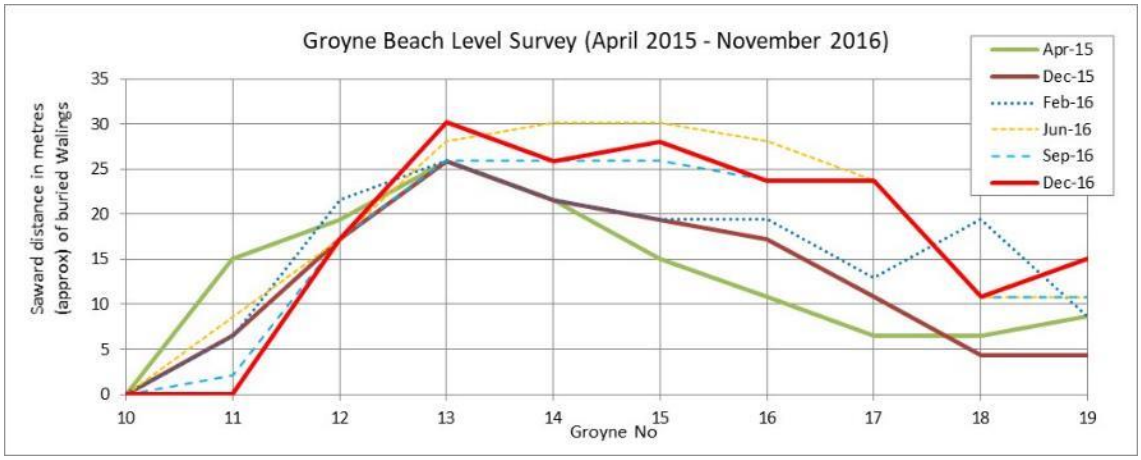


Figure B-1 Survey of groyne coverage (buried walings) between April 2015 and November 2016 (adapted from source: BCKLWN).

However, some caution needs be exercised in using this information as it does not accurately represent overall beach volumes and the extent of the upper beach beyond the buried walings is not captured. Also, despite the spatial and temporal fluctuations, the overall total number of walings covered by all groynes on all surveys was similar (between 60 and 80 in total, out of 420). This suggests either that the overall volume of upper beach sediments remained roughly the same rather than there being any supply of new material, or (but less likely) that the volume of any fresh material arriving on this frontage was being matched by the volume leaving, i.e. the groynes were having little effect on what was already a low beach.

The site walkovers noted that the lower sand beach is higher in elevation towards the southern end of the groyne field, with no more than 50 to 60cm exposed. Further north however, some of the groyne ends are up 1 to 1.5m above the level of the sand. Along the seaward ends of several of the timber groynes, rock has been placed around their base to resist further erosion and prevent overturning and collapse of the supporting piles and thus overall structure. There is no differential in sand levels either side of these groynes, other than a few centimetres locally (e.g. over a couple of metres length) where larger pebbles and cobbles have become trapped in the gaps between the stakes – which may have been part of the original design concept but that remains unknown.

The transition from lower beach to sandflat, does however appear to coincide with the ends of these groynes (although there is no indication of transport around those ends). They may therefore be having some modest effect on alongshore currents, helping to maintain a slightly higher level of sand in their lee, although this is a limited amount, perhaps due to a paucity of sediment supply.

B.4.3 Environment Agency timber groynes

The frontage for which the Environment Agency have responsibility extends south from Hunstanton Power Boat Ramp, with 31 groynes covering the length over which the seawall extends, to Jubilee Road Heacham. Also numbered 1 to 31, for the purpose of distinction and clarity in this study, these are referred to as EA1 to EA31.

Like the BCKLWN frontage, these are also of unusual design, being permeable timber zig-zag groynes consisting of timber piles and walings with intermediate posts (stakes). CIRIA (2020) report that the historic reasons for some groyne designs (generally before 1960) adopting a zig-zag alignment are not entirely clear, but believed to be primarily for the purpose of providing greater stability without the need for ties or structs to provide lateral support. There is also some thought that the zig-zag design can possibly create compartments to trap sediment, particularly at the top of shingle beaches, and that the design reduces the waves and/or currents running seaward along the downdrift side of the groyne, which would otherwise cause scour, although this is clearly not occurring here.

The timing of construction for the zig-zag groyne is not known. Exposed sections appear to have degraded to a similar extent to those on the BCKLWN frontage, so it is therefore possible that these were constructed to the same design and at a similar time to those to the north, although it is also possible that these predate them.

Anecdotal information suggests that they were constructed in the 1980s, and a survey of the Heacham Revetment by HR Wallingford (1987) refers to "Three fairly new zigzag groynes (circa) 1982", with design drawings also dating from this time. However, photographs of the Heacham frontage in 1978 indicates that zig-zag groynes were present at this time. In their paper, Nunn and Beech (1997) do note that following the flooding of 1953, '*works took the form of a variety of stepwork, seawalls, timber groynes and sleeper walls. Hard defences were substantially confined to Hunstanton, but following 1978 floods, more works were instigated.*' It is not clear where the latter refers to, but presumably the seawall and possibly the groynes along the Heacham frontage. They go on to say that *'historically our predecessors have attempted to maintain beach levels by the construction of groyne fields'*, which suggests that the structures are probably a bit older than the 1980/82 drawings, as at the time of the beach recharge strategy (1990) they would only have been there for less than 10 years.

B.4.3.1 Structural details

There are no past details available on the EA timber groynes. However, from inspection they look identical in form to those along the BCKLWN frontage directly to the north, other than varying in length. The details for those groynes are therefore replicated below, taken from BCKLWN structural drawing dated 1982, which shows the details for typical groyne elements (timber king piles, walings and intermediate posts) plus fixings.

Timber king piles are shown as 229mm square, 3660mm long, with between 1000mm and 2000mm above the beach level (so between 1660mm and 2660mm embedded in the beach). These are spaced at 3050mm centres in a zig-zag pattern, with posts and walings between them at a 90° angle between each pair of piles (this results in a total length of structure of 6100mm for every 4313mm seaward distance of each groyne). Twenty-nine timber posts are shown between each pair of king piles, with diameter of 100-125m, meaning the average gap between each would be approximately 30cm. These are shown to be 2280mm long, with between 500mm and 1500mm above beach level (so between 780mm and 1780mm embedded in the beach). The top of each post is held between a pair of timber walings, measuring 75mm wide by 229mm deep, and 3400mm long and fixed at either end to a king pile.

The drawing shows the piles and walings were intended to be constructed of tanalised Douglas Fir, and the intermediate piles (stakes) should be 'hardwood, i.e. Ash or Oak'. This would appear contrary to the principles for using timber in groynes, where the piles would more commonly be constructed from more resilient timbers (e.g. the oak referred to), and if a less robust material was also used (e.g. softwood such as Douglas Fir), then this would form the elements that are more easily replaced. However, a letter to the Lynn News (2016) from an individual involved in construction of the BCKLWN groynes does make reference to the 'intermediate Oak posts'. Nonetheless, given the comparative degradation due to abrasion from sand and shingle, it is questionable whether the king piles and walings were actually constructed from a less resilient timber than those intermediate stakes.

For comparison with this design, zig-zag groynes constructed on a shingle beach on the south coast used hardwood king piles with treated softwood stakes between them. However, the softwood was observed to erode fairly rapidly, need regular maintenance, and require replacement after approximately 12 to 13 years (SCOPAC, 2010, van Rijn, 2018). Clearly the stakes along the Hunstanton and Heacham frontages have been there for a considerably longer time, but even if oak it would have been expected to require replacement within 15 to 25 years following their installation. Softwoods, such as Douglas Fir, have been used previously in groyne construction, but this is more likely where a short service life is required or if the groynes are reaching the end of their service life (CIRIA, 2020).

Unfortunately, without further information, the basis for design and expectations in respect of potential sediment trapping effectiveness is also unknown.

B.4.3.2 Condition

The only previous study containing any information on the structures along this frontage is WECMS (Royal HaskoningDHV, 2015). This did not include any condition assessment of the timber groynes, but Appendix K1 (Baseline Coastal Processes, 2012) does include information extracted from NFCDD. Key points of note are:

- Inspection dates for the information in NFCDD varied but all were between 2006-2011.
- Overall condition was mostly 'Good' or 'Fair' (where 'Fair' is defined as '*More significant loss of section. Some movement of joints. Occasional plank missing*').
- Worst condition identified was also mostly 'Good' or 'Fair', although one groyne was noted as 'Very Good' whilst two others were noted as 'Poor' (defined as '*Severe loss of section. Movement of most joints. Several elements missing with structure severely weakened*').
- Residual Life estimates for one-third of all the groynes was 11 to 20 years. The estimated residual life for the remaining two-thirds was >20 years.

This report also mentions maintenance works carried out by the EA in respect of the sea defences, but groynes are notably absent from any discussion.

The most recent site walkovers (2021) noted a similar condition of these groynes, once exposed, to those along the BCKLWN frontage. with extreme level of degradation to the intermediate piles due to years of abrasion by coarse sediments. Much larger gaps now exist between these posts than when constructed, and in this regard any potential trapping efficiency will be considerably reduced compared to when constructed, although the design of these would not be conducive to blocking the transport of the finer sand and gravels placed by beach recycling operations. Given the significant deterioration of these fundamental components of the groynes, the overall condition has to be concluded to be 'Poor' or even 'Very Poor'.

Condition is more variable however, with some on the outer bend of the seawall in the vicinity of Groyne EA8 appearing to be in a worse condition to those further south – but that is probably due to the greater level of exposure compared to the wider and higher beach in the embayed area south of those.

It is notable that none of the groynes appear to be higher than the toe of the seawall, so will have little effectiveness in terms of holding a beach to a height that would ideally be desirable to help protect that structure.

B.4.3.3 Interaction of structures with sediment movement

The beaches along this frontage vary in size and form. Between Groynes EA1 and EA5 there is a higher wider upper beach with greater sand content. Beaches north of Groyne EA12 have two distinct components: a coarse upper beach comprising gravel sized shingle and a shallow sandier lower beach extending out towards the end of the groynes. Beyond this lies a low tide sandflat. South of Groyne EA12 there is simply an upper beach – very wide in the embayment area down towards Groyne EA27, and then narrower south of that promontory. From the November site walkover an estimate was made of each of these features, as shown below.

Groyne	Est. Length (Google Map)	Measured* Groyne Exposed (a)	*Therefore.. Groyne Covered (b)*	Width of Marram	Wall to toe of Upper Beach	Wall to edge of Sand Flat
E1	60			n/a		
E2	55			n/a		
E3	65	25	*40*	n/a	20-25	70-75
E4	75-80			n/a		
E5	85-90			n/a		
E6	120			n/a		
E7	125-130			n/a		
E8	130	115	*15*	n/a	10-15	80-90
E9	135			n/a		
E10	130			n/a		
E11	60			n/a		
E12	85	75	*10*	n/a	10-15	60-70
E13	75-80			n/a		
E14	85	75	*10*	n/a	20	
E15	80	55	*25*	n/a	30-35	
E16	85-90			n/a		
E17	85-90	40	*45-50*	0	55	
E18	70			yes		
E19	85-90			yes		
E20	85-90			yes		
E21	85-90	25	*60-65*	10-15	70-75	
E22	85-90			yes		
E23	85			0		
E24	85	45	*40*	n/a	50	
E25	65-70			n/a		
E26	60-65			n/a		
E27	50-55	35	*15-20*	n/a	25	
E28	40	25	*15*	n/a	25-30	
E29	60			n/a		
E30	60-65	40	*20-25*	n/a	30	
E31	55-60	25	*30-35*	n/a	40	

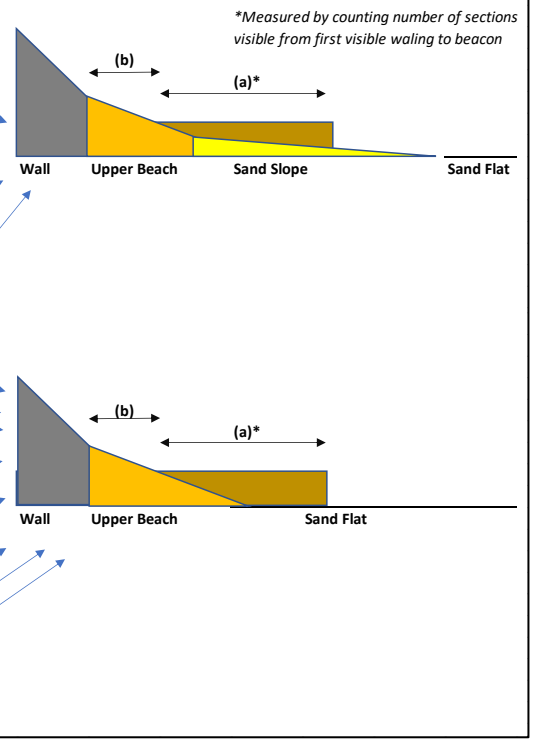


Figure B-2 Measurements made during the November site visit of groyne exposure and estimated beach widths.

Throughout all of the 31 Environment Agency groynes (a distance of 2.6km) there is no sand/shingle differential either side of them anywhere along their profiles. There were also no visible signs of any transport beyond the ends of the groynes. The sandflat features small sand ripples but there is no indication of groynes having any influence on those. The groynes do not even really seem to be trapping pebbles.

The site walkovers noted that the sand beach is higher in elevation towards the northern end of the groyne field, in the lee of the promontory formed by a change in wall alignment at the Power Boat Ramp and possible sheltering effect. In fact the seawall alignment and promontories formed by this appear to have more influence on beach width than the groynes – with a wider (but coarser) beach also found in the embayment further south between Groynes EA14 and EA27. Here however the groynes appear to be having no effect on the beach, which adopts a straight line throughout.

It is possible that the longer groynes EA6 to EA10 in particular are having a similar influence to those found on the BCKLWN frontage, influencing currents and helping to maintain a slightly higher level of sand in their lee, forming the lower beach on this slight promontory. But this remains a low beach regardless. Indeed none of the groynes reach an elevation at their root that would help beach build up in front of the seawall and thereby reduce exposure of the seawall. This is evidenced by the exposure of toe piling or capping beam in places, even with ongoing recycling.

There are also two outfalls – one between Groynes 2 and 3, which is slightly shorter than the groynes, and a longer one at the Power Boat Ramp, which extends beyond the end of groynes. During the November site visit it was observed that at the shorter outfall, the discharge drainage channel flowed southward; whilst at the Power Boat Ramp the drainage flowed northwards. This would suggest wave-driven southerly transport nearer the seawall, but further offshore, close to low water, the northward current flows may drive sediment in the opposite direction.

B.5 Other information on options and potential effectiveness

This section reviews any further information with respect to the effectiveness of the groyne fields on influencing sediment transport along the shoreline, any options that have been considered, and information on costs where available.

B.5.1 Nunn and Beech (1998)

The current FCERM strategy for the Unit C frontage was defined in the 1990's. Nunn and Beech (1998) report that a 1990 beach recharge strategy in 1990 followed determination that the sediment pathway from north to south needed an input of beach material, essentially confirming the absence/paucity of any natural supply. It goes on to state that whilst the recharge scheme had a degree of success, a subsequent recent review of the works identified weaknesses that could not be rectified by more intensive recycling. Issues included local beach erosion at the Power Boat Ramp (area A) but also in areas C, H, I and J (*refer to figure 2 in the paper*).

Following consideration of a number of options, a combination of hard and soft defences was proposed in the 1997 strategy. In respect of options, the paper notes that amongst the methods examined and rejected were 'construction of new beach control structures (groynes and breakwaters)' but does not elaborate why. It does not however discuss the effect or effectiveness of the existing groynes.

B.5.2 Hunstanton Sea Defence Condition Surveys

Condition assessment reports by Peter Lawton (2005, 2012 and 2020) focus just on groyne repairs, not other options.

All three previous surveys have identified repair works and associated costs ranging from:

- £8,200 in 2005 plus annual maintenance spends
- £27,100 in 2012
- £44,100 in 2020

These are somewhat immaterial in respect of this current study but do demonstrate that costs required for maintaining these structures was increasing on each and every survey.

B.5.3 WECMS (Royal HaskoningDHV, 2015)

Whilst the Wash East Coastal Management Strategy (WECMS) includes a very comprehensive review of coastal processes, there is no evidence presented of the effect on sediment movement of the existing groynes along this frontage, and there are some conflicting statements with respect to their perceived importance to the management approach. It is not clear whether the groynes along this frontage were considered to be effective or not and no evidence therein to support either way.

WECMS identifies that the preferred strategic approach for Unit B (Hunstanton Town) is to sustain the defences for now (including the groynes), and replace the promenade and seawall when needed in 10 to 15 years (but notably not appearing to include for replacement of the groynes in the Strategy Economics or SEA), or beach nourishment.

In Unit C (Wolferton Creek to South Hunstanton), the Strategy's preferred approach is to continue to provide protection for the foreseeable future, until a trigger point is reached in terms of environmental impacts, affordability and risk to life. It is not clear whether the groynes along this frontage were considered to be effective or not and little evidence to support either way. It also notes that the Beach Management Manual (Environment Agency, 2014) states that the aim during the recycling campaign is to achieve a seaward slope of 1 in 13, a beach crest level of 6.35 mODN and a minimum beach crest width of 5 m along the Heacham frontage.

B.5.4 Hunstanton Coastal Management Plan (AECOM, 2019)

The Hunstanton Coastal Management Plan (AECOM, 2019) has most previous information on options, although the primary focus of that plan and the options therein are concentrated on the linear defence, i.e. seawall and promenade. Nonetheless, there is some consideration of groynes, as follows.

The Stage 2 Options Appraisal Report (December 2018) considers the following:

- **Repair of groynes:** proactively repair the timber and concrete groynes to maintain their functionality, i.e. replace timber/concrete planks, piles and joints. Noted that repairing individual sections may no longer be feasible in the future and full replacement may be necessary, which could potentially act to trap more beach material on the frontage.

- **Groyne replacement:** largescale replacement of the existing groyne structures which would enable the groynes to be redesigned potentially increasing the height and/or length. Noted that this may lead to more material being trapped on the beach.

- **Rock groynes:** constructing new rock groynes to potentially improve the retention of sediment on the beach. Noted that this would be significantly more costly than working with the existing groyne structures.

Under the Maintain option, later short-listed, it is stated that '*This will help to sustain beach levels which will in turn support the defences at the back of the beach by absorbing wave energy along the frontage*.'

However, no assessment could be identified to substantiate any of these points regarding their effectiveness.

The main Plan document states that '*The existing timber groynes (Sections A-E) appear to be performing well and act to hold the beach material in front of the seawall, despite being in a mixed state of repair*' and '*The existing concrete groynes appear to retain some material; however, they are shorter than the timber groynes and are therefore not as effective at maintaining beach levels*'. It goes on to conclude that the preferred option for the timber and concrete groynes is to Maintain through refurbishment, stating '*Under the Maintain approach the existing timber and concrete groynes are to be refurbished to extend their design life and ensure they continue to retain material to protect the frontage. Refurbishment will involve replacing the parts of the defences that have deteriorated/failed to keep the groynes functioning to retain beach material. After the timber and concrete groynes have been refurbished the service life of the refurbished structures is estimated to be approximately 30 years (subject to continued maintenance).*'

But supporting evidence for the above points on their functioning cannot be found in any of the reports.

Estimated costs for maintaining, sustaining, or improving the groynes are set out within the Coastal Management Plan, from which the following tables have been extracted.

Table 4-37: Whole life cost estimates for works to existing concrete groynes

Approach	Options included in	Cash whole life cost	PV whole life cost
Refurbish existing groynes (30%)	Maintain Sustain	£2,218k	£671
Extend existing groynes (100%)	Improve	£4,526k	£1,628k
Replace with 126m timber groynes x9	Improve	£5,072k	£2,345k
126m rock groyne alternative x5	Improve	£4,526k	£1,628k

Note that a 60% optimism bias has been applied to Unit B costs
Note no allowance has been made at this stage for the demolition of existing groynes.

Table 4-32: Whole life cost estimates for timber groyne works

Approach	Options included in	Cash whole life cost	PV whole life cost
Refurbish the existing timber groynes	Maintain Sustain	£6,736k	£2,141k
New enhanced timber groynes	Improve	£10,054k	£3,415k
Alternative rock groynes	Improve	£5,604k	£2,369k

Note that a 60% optimism bias has been applied to Unit B costs

Estimated costs of the timber groyne refurbishments are provided in Table 5-11 from the Coastal Management Plan below. Whole life costs for the next 100 years in cash and PV terms are presented in Table 5-12 from the Coastal Management Plan (excluding on-going maintenance for the unit).

Table 5-11: Timber groyne refurbishment costs per section of defence in unit B

Section	Estimated cost of timber groyne refurbishment (approximately once every 30 years)
A	£461k
B C	£294k £299k
D	No groynes
E	£464k
F	No groynes
G	£478k
Total	**£1,996k**

Table 5-12: Whole life costs for repeat timber and concrete groyne refurbishments over the next 100 years (to coincide with timing of seawall options). Excluding on-going maintenance costs

Approach	Whole life cash cost	Whole life PV cost
Early refurbishment of timber groynes in sections A-C in year 5. Then refurbishments to coincide with the encasement of the seawall at the end of its residual life. Repeat refurbishments every 30 years. - Sections A-C years 5, 35, 65, 95 - Sections E years 15, 45, 75	£5,606k	£1,803k
Timber groyne refurbishments to coincide with the encasement of all of the seawall in Unit B at the same time in year 15, then every 30 years: - Sections A, B, C & E years 15, 45, 75	£4,553k	£1,352k
Timber groyne refurbishments to coincide with the encasement of all of the seawall in Unit B at the same time in year 15, then every 30 years. Concrete groyne refurbishments at the same time. - Timber groynes in sections A, B, C & E years 15, 45, 75 - Concrete groynes in sections G years 15, 45, 75	£5,987k	£1,777k

B.5.5 Other sources of cost information

The Environment Agency publication '*Cost estimation for coastal protection – summary of evidence*' (2015) provides example cost ranges from other previous schemes. These have been summarised below.

B.5.5.1 Timber groynes

Construction:

Source: Environment Agency 'Cost estimation for coastal protection - summary of evidence' SC080039/R7 (March 2015)		
		Cost/m
Bournemouth	£200k per groyne (length appears to be 75-80m long - *source Google Earth*)	£2,500
Worthing	£100k per groyne (70m long) - softwood construction	£1,429
Norfolk	£100k per groyne (100m long)	£1,000
Southwold (WDC)	£105k per groyne (45m long @ 110m spacing)	£2,333
Eastbourne	£320k per groyne (65-110m long)	£2,909
Swanage	£1,330 per metre length of groyne	£1,330

Maintenance:

Source: Environment Agency 'Cost estimation for coastal protection - summary of evidence' SC080039/R7 (March 2015)	
Bournemouth	£500 per groyne/year
Dover	£700 per groyne/year
GYBC	£1-2,000 per groyne/year
WDC	£1,500 per groyne for first 10 years, then reducing

It should be recognised, however that for zigzag groynes, the material length is longer. So, for every 4.3m length, it is necessary to allow for 6.1m of materials, e.g. a 90m long zigzag groyne will have the equivalent costs of a 128m long straight groyne. On that basis, therefore, a 90m zigzag groyne might cost between£128,000 and £372,000.

Along the BCKLWN frontage where there are 10 timber groynes of similar length, the total replacement cost is therefore likely to be between £1.3 and £3.7million. The maintenance costs average out to about £0.3million over 25 years. However, if adding 60% Optimism Bias, those costs could typically fall be between £3million and £6million for a 25 year scheme.

Along the Environment Agency frontage, where there are 31 timber groynes of varying length, the total replacement cost is likely to be between £2.9 and £8.3million, with maintenance costs averaging out to about £0.8million over 25 years. However, if adding 60% Optimism Bias, those costs could typically fall be between £6million and £14million for a 25 year scheme.

B.5.5.2 Concrete groynes

No information identified.

B.5.5.3 Rock groynes

Construction:

Source: Environment Agency 'Cost estimation for coastal protection - summary of evidence' SC080039/R7 (March 2015)		
		Cost/m
Southwold (WDC)	£200k per groyne (45m long @ 70-80m spacing)	£4,444
CIRIA Manual	£363k per groyne (70m long)	£5,186
Swanage	£2,410 per metre length of groyne (30-50m length)	£2,410
Swanage	£3,930 per metre length of groyne (175m length)	£3,930

The construction costs per metre run for rock groynes is about double that for timber, but the maintenance should be negligible by comparison. The length and spacing may also be different.

However, it should also be noted that larger T-shaped or Y-shapes groynes, as may be required to address the issues here, will be more expensive. Estimates made by Jacobs for similar structures on potential schemes elsewhere on the East Anglian coast suggest these could be between £1.5million and £2million apiece (including for 60% Optimism Bias). Estimates made by Jacobs for very large headland structures indicated these could be of the order of £6million to £8million apiece.

B.5.5.4 Beach management

Beach nourishment and recycling costs can be highly variable and are highly dependent upon the material size, the proximity of the renourishment site to the material source, and the volumes to be placed (generating potential economies of scale.

For these reasons, the cases presented in Environment Agency (2015) range from as little as under £2/m^3 through to over £30/m^3.

Typically, a cost of £15-20/m^3 might be anticipated for a large sand nourishment from a dredged source.

B.6 Site photographs

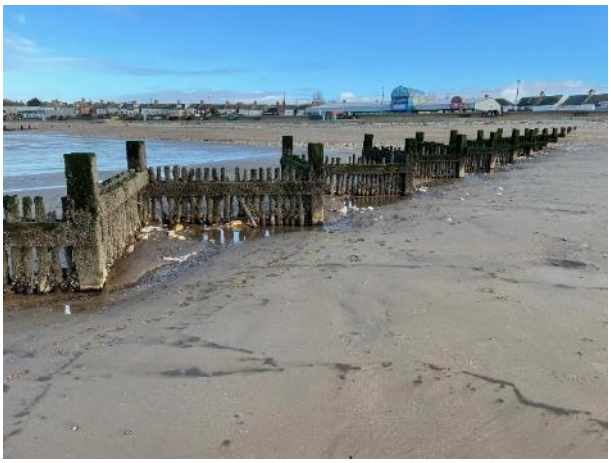
Below are a series of photographs taken during the site visits in July and November 2021, which illustrate points made in the main appendix text.

B.6.1 BCKLWN concrete groynes




B.6.2 BCKLWN timber groynes


Around Groynes 10 and 11



Just north of the Power Boat Ramp

B.6.3 Environment Agency timber groynes

Northern stretch to Groyne EA6

Groynes EA7 to EA10 (long groynes)


Embayment area (Left: Groyne EA17, Right: looking north from Groyne EA27)


Around Groyne EA28


Southern stretch: Groynes EA29 to EA31

B.7 References

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