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Technical note

Project	Dawlish Warren & Exmouth BRTAS	**Date**	22 February 2012
Note	Options Description & Appraisal	**Ref**	GEEGAW/TN-17
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1 Introduction

1.1 The purpose of this note is to provide recommendations for the selection of preferred coastal defence options at Dawlish Warren and Exmouth to meet the objective to safeguard these beaches and their coastal defence function. The preferred management policy for both frontages is "Hold-the-Line" in the short-term. Solutions have therefore been developed that address the objective but do not compromise the ability to adapt the policy in the medium to long-term.

The following short list of recharge/recycling and retention options has been assessed for their technical feasibility in meeting the objectives and appraised for whole life estimated costs and environmental acceptability:

Dawlish Warren

- Option D0: Do Nothing [baseline]
- Option D1: Small Recharge Scheme (with Recycling)
- Option D2: Repair All Groynes & Small Recharge Scheme
- Option D3: Large Recharge Scheme (with Recycling)
- Option D4: Repair All Groynes & Large Recharge Scheme (with Recycling)
- Option D5: Repair Groynes at Neck & Small Recharge (with Recycling)
- Option D6: Repair/Extend Groynes at Neck & Small Recharge (with Recycling)
- Option D7: Repair All Groynes, Extend Groynes at Neck & Recharge

Exmouth

- Option E0: Do-nothing [baseline]
- Option E1: Recharge Only
- Option E2: Repairs to One Groyne & Recharge
- Option E3: Repairs to Two Groynes Recharge
- Option E4: Repairs to Two Groynes, One New Groyne & Recharge
- Option E5: Repairs to Two Groynes, Two New Groynes & Recharge

2 *Sediment Transport*

Numerical modelling was undertaken to develop an overall understanding of sediment movements around the mouth of the estuary due to the action of tides and waves. This understanding of existing coastal processes has been used to determine the most appropriate options to meet the objectives of the study. A summary of the findings of this model are presented in ***Figure 2-1***.

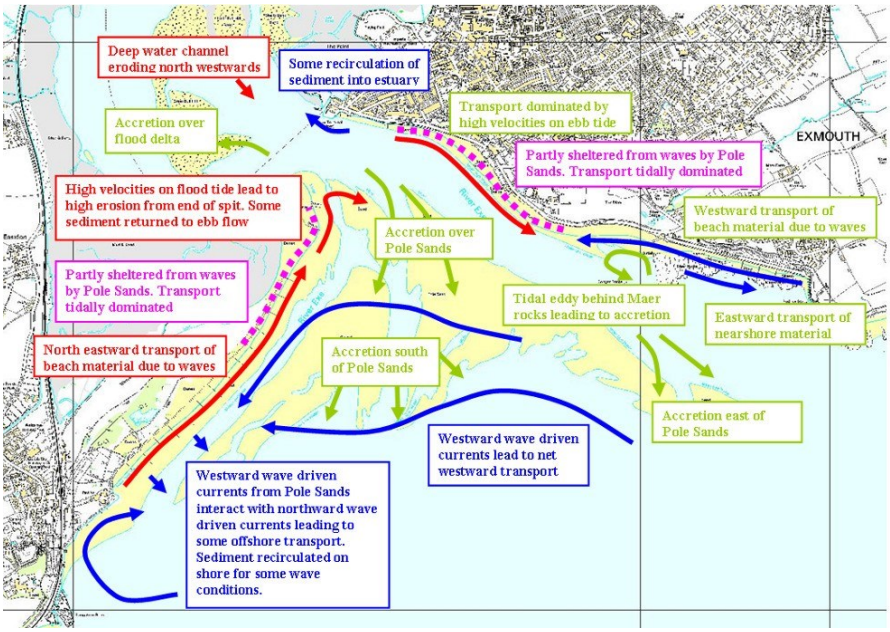

Figure 2-1: Summary of findings of the sediment transport model

Modelling results show that both the flood delta of Bull Hill bank and the ebb delta of Pole Sand are increasing in size and extent due to tidal currents. Pole Sand is shown to partially shelter both Exmouth Beach and Dawlish Warren beaches from wave action.

There is net north eastwards wave transport along Dawlish Warren beach due to the action of waves. This transport is higher at the western end and without active management a net loss of sediment from the southwest and an accumulation in the northeast is expected. Sediment transport at the north eastern end of Dawlish Warren is shown to be dominated by tidal currents with sediment removed from the beach and entering the main tidal flow out of the estuary. This sediment is shown to be deposited over the southern and eastern areas of Pole Sand.

For southerly wave conditions, westwards wave driven currents are set up along Pole Sand leading to the formation of sandbanks offshore from

Dawlish Warren spit. These currents are shown to provide a mechanism for recirculation of some sediment back to the south western end of the spit. Offshore sediment transport from Dawlish Warren is shown to be relatively small due to the sheltering effect of Pole Sands. However, during extreme storm events some erosion is expected to the foredunes along the back of the beach.

Sediment transport along the Exmouth frontage is shown to be complex, largely due to numerous rocky features along the coast line. Along the western section of Exmouth beach sediment transport is in a net south easterly direction and dominated by tidal currents. A tidal eddy to the east of Maer rocks is shown to lead to some accretion in this area. To the west of Maer rocks sediment transport along the beach is in a net westerly direction and dominated by the action of waves. However, slightly offshore transport is shown to be reversed due do interactions of the wave driven currents with rocks in this area resulting in recirculation of some sediment along this frontage.

3 *Option D0: Do Nothing*

An outline sketch of this option along is shown in ***Figure 3-1***.

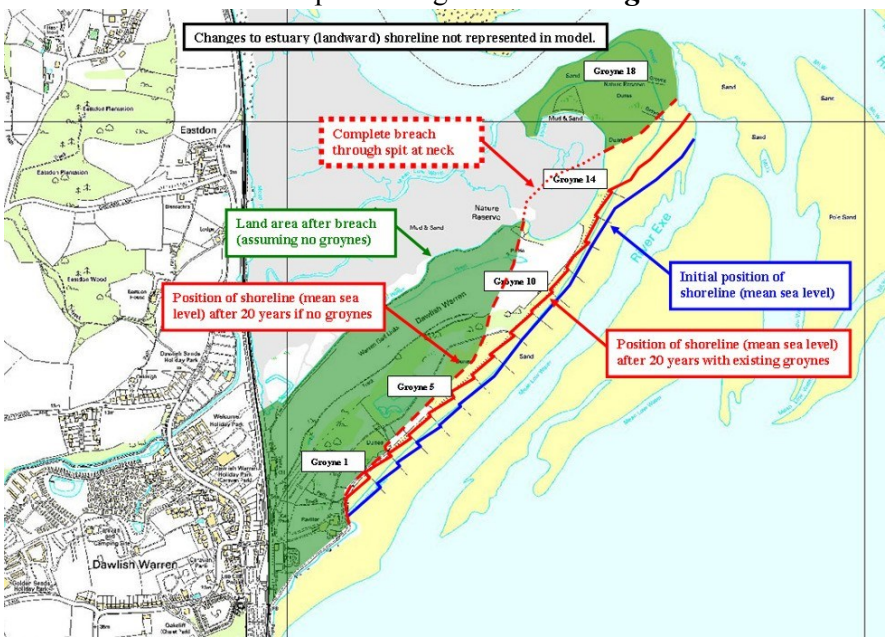

Figure 3-1: Layout of Option D0 (baseline) showing position of shoreline at the end of the short-term (20yrs)

The do-nothing option is include here as a baseline against which the other options have been assessed. This is effectively a 'walk-away' option where no capital or maintenance works would be undertaken other than removal of the existing groynes (as and when they fail) for safety reasons. This option is not expected to meet the technical objectives of the study as it does not help to safeguard the beaches and their flood defence function. However, it has been included as a baseline comparator.

3.1 Technical Objective

Results of the shoreline modelling show that based on the apparent performance of the existing groynes, the beach (MSL) would erode back to the toe of the seawall and dunes at the end of the short-term (20 years). This would result in a very high risk of undermining of the seawall and erosion of the foredunes, causing breach and flooding. A sensitivity test on the effectiveness of these groynes shows that if these groynes were completely removed, the shoreline from the eastern end of the seawall to the end of the spit would move significantly landwards resulting in a very large breach through the central section in the short-term. This scenario is supported by historical observations prior to construction of the existing groynes.

3.2 Cost Estimate

Whilst this is a do-nothing option and no capital or maintenance works are to be undertaken, an allowance has been included for removal of the groynes along the main frontage (upon failure) to ensure the safety of beach users. The two buried groynes at the eastern end of the spit are shown to remain buried throughout the short-term and are not therefore included in this removal cost. A summary of costs for this option are presented in ***Table 3-1*** and **Annex A**.

Description	**Cost (£k)**
MAINTENANCE WORKS	
Groyne removal (upon failure, where no recharge)	£30k x 14no.
TOTAL	
Cash cost	£420k
Optimism bias[1] (60%)	£252k
Present Value cost	**£672k**

Table 3-1: Summary of capital & maintenance cost estimates for the Do-nothing Option (20yrs)

[1] Optimism bias is the tendency for appraisers to be overly optimistic in early assessments of project in comparison to final values. To counter this HM Treasury issue guidance in the form of a percentage to increase the costs depending on the uncertainty surrounding the estimates. An optimism bias of 60% is used for projects at an early stage of consideration (FCERM-AG, EA 2010).

3.3 Environmental Objective

As might be expected, this option involves the least effect on the existing natural process of all options and would allow the Dawlish Warren spit to evolve naturally. No construction or maintenance work would disrupt the natural environment in the immediate-term unlike the other options. However, in the short-term the natural evolution of the spit is expected to result in a complete loss of the beaches as well loss of a significant proportion of the area of designated sites due to a wide breach at the central section of the dunes.

4 *Option D1: Small Recharge Scheme (with Recycling)*

An outline sketch of this option along is shown in ***Figure 4-1***.

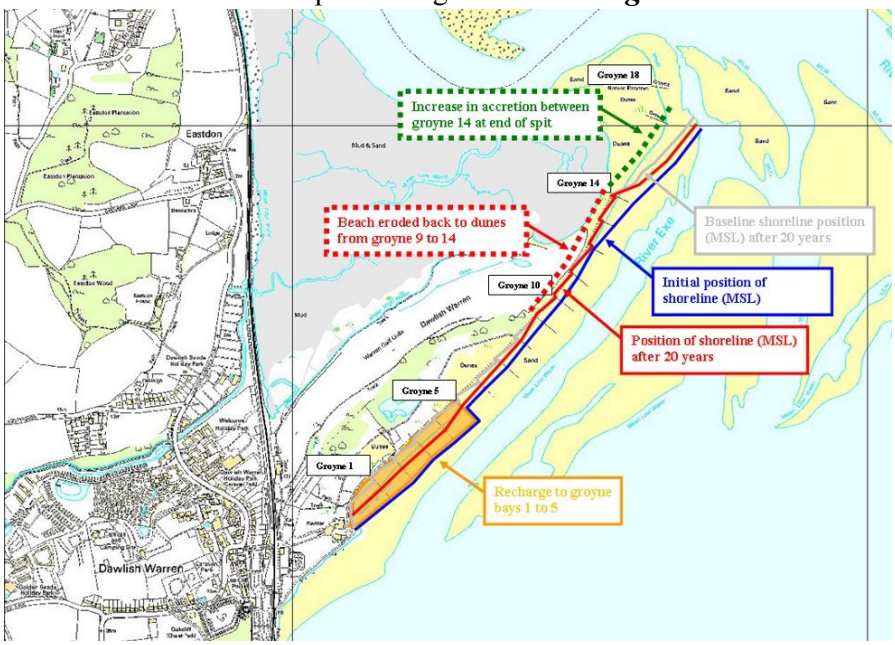

Figure 4-1: Layout of Option D1 showing position of shoreline at the end of the short-term (20yrs)

This option includes capital works to place 115,000m^3 of beach recharge at the western end of the frontage in groyne bays 1 to 5. No improvement works or maintenance would be undertaken to the existing groynes. However, those groynes that have not recently been propped (groynes 7-10) or are not protected by the proposed beach recharge are assumed to fail in the short-term and would need to be removed on safety grounds. Recycling of 25,000m^3 of beach material every 20 years from the eastern end of the spit between groynes 14 and 17 would also be an option under this scheme.

4.1 Technical Objective

Placement of beach material along the western end of the frontage results in a good improvement in protection to this area in the immediate-term. The predominant north-eastward drift of sediment will move this new material along the spit. However, it is shown that this smaller quantity of material coupled with the relative ineffectiveness of the existing groynes is insufficient to provide an increase in beach widths to the vulnerable central section at the neck. At the end of the short-term (20 years), the width of the beach along the western end would provide some improvement in the existing standard of protection in the short-term. However, the beach along the central section of the spit between groynes 9 and 14 is still shown to completely erode back to the toe of the dunes resulting in a very high risk

of breach. Accretion of beach material is shown to increase at the eastern end of the spit when compared to the baseline do-nothing option which would allow an option for recycling of this material to bolster the amenity beach at the western section. However, since this option results in a very high risk of breaching at the central section, it is not considered to meet the technical objectives to safeguard the beach and its flood defence function in the short-term.

4.2 Cost Estimate

An estimate of whole life capital and maintenance costs have been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 4-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£3,252 - 4,350k
MAINTENANCE WORKS	
Groyne removal (upon failure, where no recharge)	£30k x 5no.
TOTAL	
Cash cost	£3,925 - 4,500k
Optimism bias(1) (60%)	£2,655 - 3,000k
Present Value cost (NPV)	**£6,835 – 7,755k**

Table 4-1: Summary of capital and maintenance cost estimates for Option D1 (20yrs)

In addition to the above scheme, an increase in accretion at the eastern end of the spit would allow the option for recycling of beach material to bolster beach levels. The estimated whole life cash cost of this recycling is estimated to be £746k (NPV £388k).

4.3 Environmental Objective

This option involves some disruption to the natural environment due to initial capital beach recharge works to the western end of the spit. This work is expected to result in some impacts to the natural environment in the immediate-term. However, as no capital works are proposed to the groynes, this disruption would be limited to the western end of the spit only. In the short-term (20 years) continued maintenance and removal (upon failure) of the existing groynes is expect to result in some minor impacts to the natural environment. Despite the placement of additional beach material coastal processes under this option are likely to be largely unaffected. However, in the short-term the predicted recession is expected

to result in a high risk of breaching, which will affect the designated sites on the Dawlish Warren spit.

5 *Option D2: Repair All Groynes & Small Recharge Scheme*

An outline sketch of this option along is shown in ***Figure 5-1***.

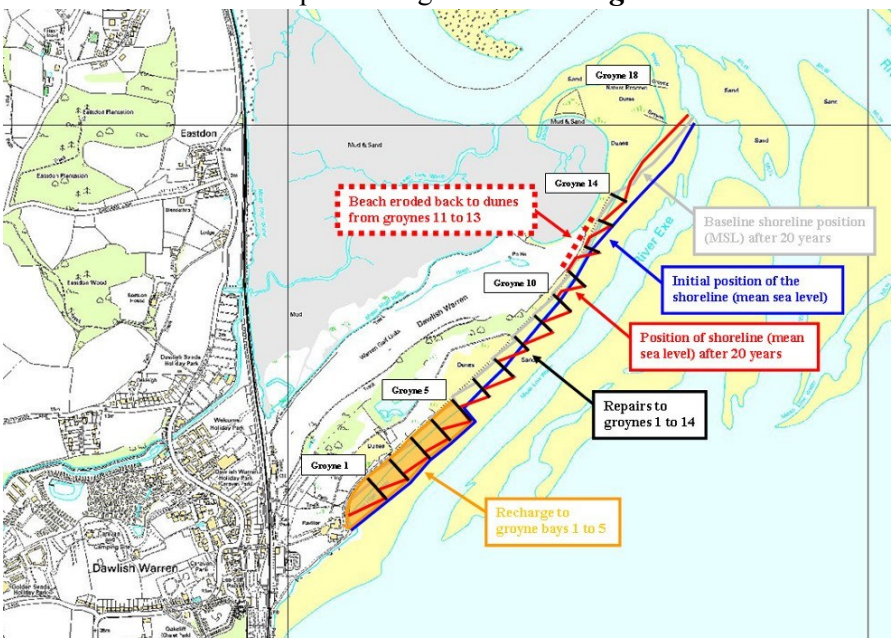

Figure 5-1: Layout of Option D2 showing position of shoreline at the end of the short-term (20yrs).

This option includes capital works to place 115,000m^3 of beach recharge at the western end of the frontage to groyne bays 1 to 5. Repairs to existing groynes (groynes 1-14) would be undertaken during the capital works to improve their function. This work may include replacement of old or missing boards to prevent material passing over, under or through the groynes. Ongoing annual maintenance of the groynes would continue under this option to ensure that the height of each groyne is kept at 2no. boards above active beach levels. Ongoing annual maintenance works to the beach are assumed to include minor re-profiling and clearance of sand from the seawall/promenade.

5.1 Technical Objective

Repairs to the existing groynes are shown to help retain the recharge material placed along the western sections of Dawlish Warren spit. The net north-easterly transport of sediment continues to move some of this material along the central sections of beach helping to improve beach widths between groynes 5 and 10 in the short-term (20 years). Further eastward, the beneficial effects from this material are shown to reduce resulting in recession of the beach at the neck of the spit between groynes 11 and 13. The length of dunes along this section therefore remains at risk of breach in the immediate to short-term. Improvements to the groynes

that help retain material along the western section of beaches is shown to result in an overall reduction of material reaching the eastern end of the spit. This results in a reduction in accretion at this location when compared to the baseline do-nothing option.

5.2 Cost Estimate

An estimate of whole life capital and maintenance costs have been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 5-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£3,252 - 4,350k
Groyne repairs	£20k x 14no.
MAINTENANCE WORKS	
Groyne removal (upon failure, where no recharge)	£30k x 5no.
Groyne maintenance	£1k x 14no./yr
Beach maintenance	£15k/yr
TOTAL	
Cash cost	£4,845 – 5,504k
Optimism bias[1] (60%)	£2,823 – 3,168k
Present Value cost	**£7,283 – 8,203k**

Table 5-1: Summary of capital and maintenance cost estimates for Option D2 (20yrs)

The above scheme shows a reduction in overall accretion at the eastern end of the spit. As such, no additional material is expected to be available for beach recycling under this option.

5.3 Environmental Objective

This option will result in a moderate amount of disruption to the natural environment in the immediate-term due to improvement works on the groynes along the whole length of the spit. Placement of beach recharge would also have an impact at the western end of the spit however, this is expected to be minor as material would be delivered by sea. Improvements to the groynes are expected to have a large effect on coastal processes and despite the continued, and increased, risk of breach at the neck of the spit, the existing designated sites are expected to be largely maintained in the short-term.

6 *Option D3: Large Recharge Scheme (with Recycling)*

An outline sketch of this option along is shown in ***Figure 6-1***.

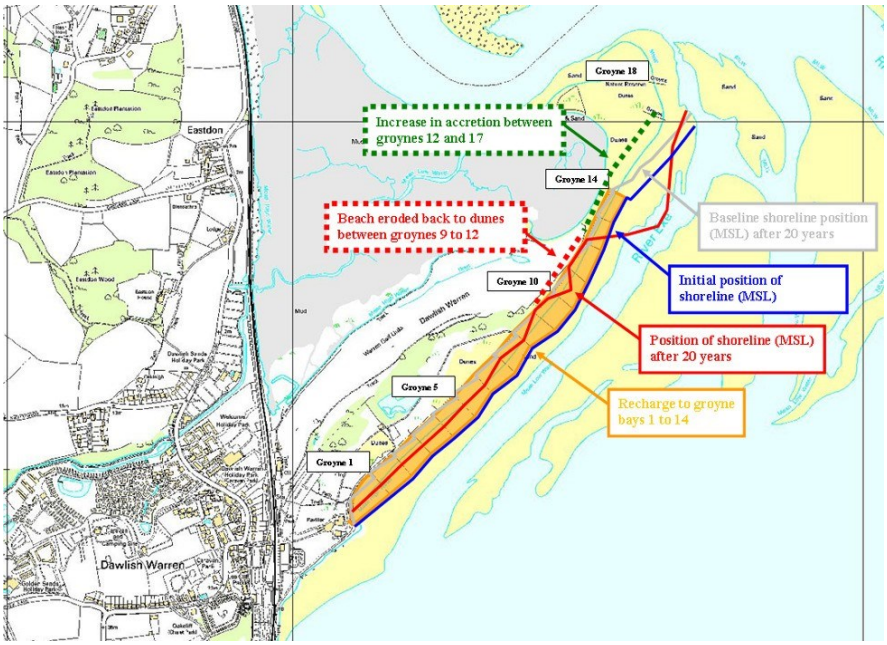

Figure 6-1: Layout of Option D3 showing position of shoreline at the end of the short-term (20yrs).

This option includes capital works to place 250,000m^3 of beach recharge material along the western and central areas to groyne bays 1 to 14, at the neck of the spit. Placement of this material will utilise, and fill, the existing groyne field. No capital or maintenance works would be undertaken to the groynes other than propping of groyne 12 (which is already showing signs of leaning) and a contingency for propping of one other before recharge works commence. Recycling of 25,000m^3 of beach material every 5 years from the eastern end of the spit between groynes 14 and 17 would also be an option under this scheme.

6.1 Technical Objective

Placement of beach recharge along the entire western and central sections would significantly improve beach widths in the immediate-term. However, without any improvements to the existing groynes the net north-easterly transport of sediment will quickly move this material along the spit. Whilst beach widths along the western section to groyne 8 remain relatively healthy at the end of the short-term, the beach is shown to recede significantly at the most vulnerable section at the neck between groynes 9 and 12. Loss of beach material in this area would result in a significant increase in risk of undermining and breaching of the dunes in this area. Since the existing

groynes are relatively ineffective at retaining the beach sediment, a large proportion of the additional recharge material is shown to be transported to the eastern end of the spit and accrete in the area between groynes 12 and 17 towards the end of the short-term. Whilst it is unlikely that the extent of accretion shown by the longshore modelling (Figure 6-1) would result in reality due to other nearshore processes, this does show that movement of material to the eastern end of the spit is expected to significantly increase. This would allow the option for frequent recycling of material back to the western end of the spit to help maintain the amenity beach and retain material on the frontage.

6.2 Cost Estimate

An estimate of whole life capital and maintenance costs have been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 6-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£6,607 – 8,400k
Groyne stabilisation	£42k x 2
TOTAL	
Cash cost	£6,942 – 8,484k
Optimism bias[(1)] (60%)	£4,505 – 5,430k
Present Value cost	**£11,767 – 14,235k**

Table 6-1: Summary of capital and maintenance cost estimates for Option D3 (20yrs)

In addition to the above scheme, an increase in accretion at the eastern end of the spit would allow the option for recycling beach material to bolster existing levels. The estimated whole life cash cost of this recycling is estimated to be £3,106k (NPV £2,130k).

6.3 Environmental Objective

This option involves placement of a large amount of beach recharge material along the western and central sections of the spit which may cause some disruption to the natural environmental in the immediate-term due to onshore works. However, with this material being delivered by sea disruption is unlikely to be significant. Very little construction works are to be undertaken to the existing groynes compared to the present regime which also help to limit impacts in the immediate-term. As with the previous option, in the short-term (20 years) continued maintenance and

removal (upon failure) of the existing groynes is expected to result in minor impacts to the natural environment. With the existing groynes remaining relatively ineffective and the addition of a large quantity of recharge material, some benefit to the existing natural processes along the spit are expected. However, in the short-term the predicted recession will result in an increased risk of breaching at the central section, which could affect the designated sites on the Warren.

7 *Option D4: Repair All Groynes & Large Recharge Scheme (with Recycling)*

An outline sketch of this option along is shown in ***Figure 7-1***.

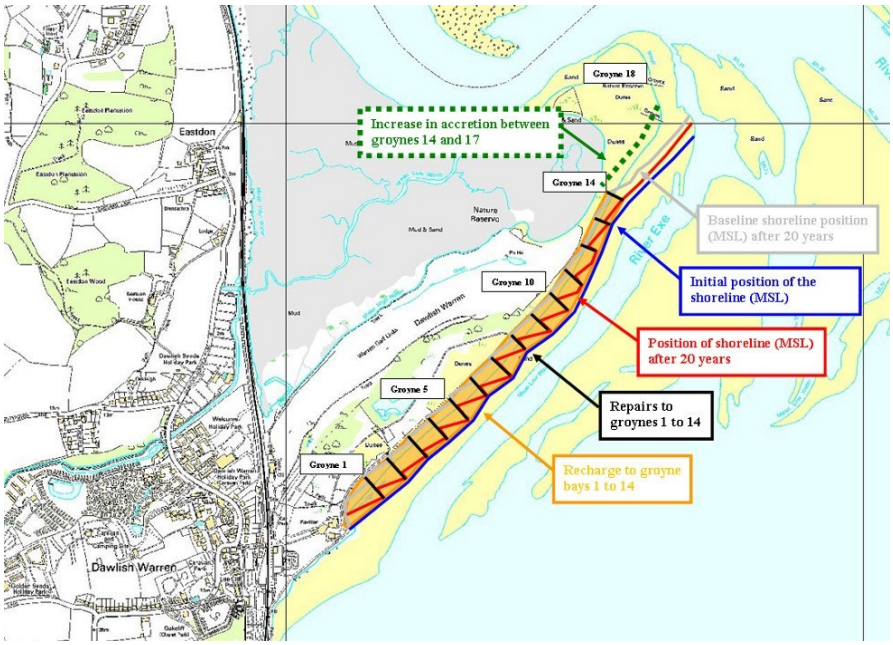

Figure 7-1: Layout of Option D4 showing position of shoreline at the end of the short-term (20yrs).

As with Option D3, this option also includes capital works to place 250,000m^3 of beach recharge material along the western and central areas to groyne bays 1 to 14, at the neck of the spit. However, in addition to this recharge, repairs to existing groynes (groynes 1-14) would also be undertaken during the capital works to improve their function. This work may include replacement of old or missing boards to prevent material passing over, under or through the groynes. Propping of groyne 12 (which is already showing signs of leaning) and a contingency for propping of one other before recharge is in place has also been allowed for. Ongoing annual maintenance of the groynes would continue to ensure that the height of each groyne is kept at 2no. boards above active beach levels. Annual maintenance works to the beach are assumed to be limited to minor re-profiling and clearance of sand from the seawall/promenade. Recycling of 18,000m^3 of beach material every 10 years from the eastern end of the spit between groynes 14 and 17 would also be an option under this scheme.

7.1 Technical Objective

The beach recharge material placed along the western and central sections of the Dawlish Warren spit is shown to largely remain in place due to the work undertaken to improve the performance of the existing groynes. The

beach material within the groyne bays is shown to align to the predominant wave direction but remain largely stable. The net north-easterly transport of sediment is shown to be reduced by these control structures. However some increase in accretion of material at the end of the spit is still likely which would allow the option of recycling of beach material back to the western end of the spit. This option is considered to be effective in meeting the technical objectives to safeguard the beach and its flood defence function in the short-term.

7.2 Cost Estimate

An estimate of whole life capital and maintenance costs have been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 7-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£6,607 – 8,400k
Groyne stabilisation	£42k x 2
Groyne repairs	£20k x 14no.
MAINTENANCE WORKS	
Groyne maintenance	£1k x 14no./yr
Beach maintenance	£15k/yr
TOTAL	
Cash cost	£7,802 – 9,344k
Optimism bias[1] (60%)	£4,673 – 5,598k
Present Value cost	**£12,215 – 14,683k**

Table 7-1: Summary of capital and maintenance cost estimates for option D4 (20yrs)

In addition to the above scheme, an increase in accretion at the eastern end of the spit would allow the option for recycling beach material to bolster existing levels. The estimated whole life cash cost of this recycling is estimated to be £1,050k (NPV £655k).

7.3 Environmental Objective

Since this option includes construction works to improve the existing groynes as well as a placement of a large quantity of beach material this scheme is likely to have the largest impact on the natural environment in the immediate-term. Whilst capital works to the groynes are expected to have a large effect on the existing natural processes by limiting the net north-easterly transport of material, this will be mitigated by the significant

amount of recharge material which will provide a source to maintain movement of material to the eastern end of the spit. Improvements to the groynes are therefore expected to result in only minor impacts to the natural environment in the short-term. This option is expected to largely maintain the existing footprint of the designated areas on Dawlish Warren spit.

8 *Option D5: Repair Groynes at Neck & Small Recharge (with Recycling)*

An outline sketch of this option along is shown in ***Figure 8-1***.

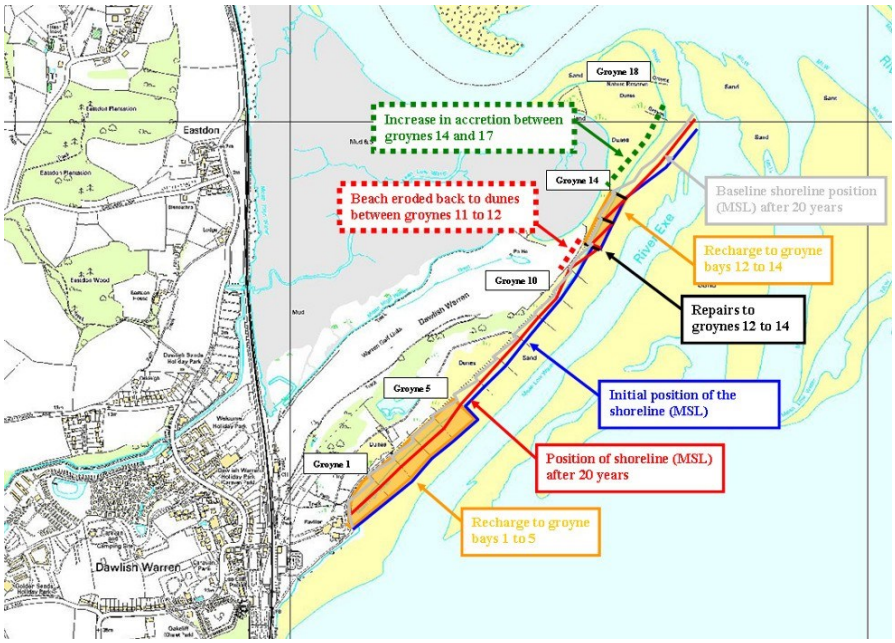

Figure 8-1: Layout of Option D5 showing position of shoreline at the end of the short-term (20yrs).

This option includes capital works to repair and stabilise groynes 12 to 14 located at the most vulnerable section at the neck of the spit. This work would include propping of groyne 12 which already showing signs of leaning and repairs to groynes 12-14, including replacement of old or missing boards to prevent material passing over, under or through the groynes. Capital works would be undertaken to place 115,000m^3 of recharge material at groyne bays 1 to 5 as well as a further 15,000m^3 of recharge to the improved groyne bays 12 to 14 to bolster this most vulnerable section in the immediate-term. As with the other options, ongoing annual maintenance of the groynes would continue to ensure that the height of each groyne is kept at 2no. boards above active beach levels. Annual maintenance works to the beach are assumed to be limited to minor re-profiling and clearance of sand from the seawall/promenade. Recycling of 18,000m^3 of beach material every 10 years from the eastern end of the spit between groynes 14 and 17 would also be an option under this scheme.

8.1 Technical Objective

Without the benefit of improvements to the existing groynes, beach recharge material placed along the western section of the spit is transported

eastwards with the net north-easterly drift of sediment. Beach widths in groyne bays 1 to 5 are shown to be reduced at the end of the short-term (20 years) but continue to provide some protection to the seawall and dunes, similar to the present situation. By the end of the short-term the easterly distribution of material is shown to provide some additional benefit to beach widths between groynes 5 and 10. However, further east, between groynes 11 and 12, the beach is shown to have receded significantly resulting in a risk of undermining and breach to the dunes in the short-term. Improvements to the groynes 12 to 14 and corresponding recharging of these bays is shown to result in healthy beach widths at the end of the short-term. However, since these groynes are relatively short, their effect at retaining this recharge material and slowing the net north-eastward drift of sediment is less. At the eastern end of the spit, a slight overall increase in accretion is shown compared to the baseline do-nothing case.

8.2 Cost Estimate

An estimate of whole life capital and maintenance costs has been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 8-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£3,868 – 4,800k
Groyne stabilisation	£42k x 1no.
Groyne repairs	£20k x 3no.
MAINTENANCE WORKS	
Groyne removal (upon failure, where no recharge)	£30k x 2no.
Groyne maintenance	£1k x 3no./yr
Beach maintenance	£15k/yr
TOTAL	
Cash cost	£4,860 – 5,542k
Optimism bias[1] (60%)	£2,897 – 3,306k
Present Value cost	**£7,479 – 8,571k**

Table 8-1: Summary of capital and maintenance cost estimates for Option D5 (20yrs).

In addition to the above scheme, an increase in accretion shows at the eastern end of the spit would allow the option for recycling beach material to bolster existing levels. The estimated whole life cash cost of this recycling is estimated to be £1,050k (NPV £655k).

8.3 Environmental Objective

Whilst work is only proposed to a few key groynes along the central section, access to these groynes would need to be provided along the western and central sections of the Dawlish Warren spit. This would result in slightly more disruption that simply at the site of the works. Placement of beach recharge along the western section and at the neck is likely to cause only small impacts to the natural environment as this material will be delivered by sea. Ongoing annual maintenance of the groynes and beaches would result in minor impacts in the short-term, however, the increased likelihood of a breach at the neck could result in an impact on the area of designated sites on the Dawlish Warren spit.

9 *Option D6: Repair/Extend Groynes at Neck & Small Recharge (with Recycling)*

An outline sketch of this option along is shown in ***Figure 9-1***.

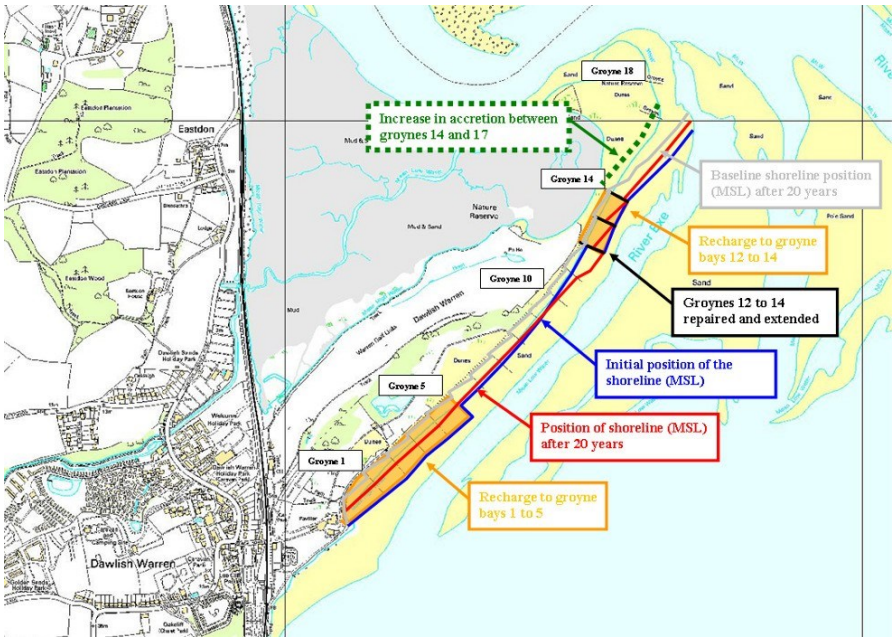

Figure 9-1: Layout of Option D6 showing position of shoreline at the end of the short-term (20yrs).

In addition to the repair and stabilisation of groynes 12 to 14, located at the most vulnerable section at the neck of the spit, these groynes would also be extended to provide increased protection to the dunes in the area. Work would include propping of groyne 12, which already showing signs of leaning, and repairs to groynes 12-14, including replacement of old or missing boards to prevent material passing over, under or through the groynes. Capital works would be undertaken to place 115,000m^3 of recharge material at groyne bays 1 to 5, as well as a further 30,000m^3 of recharge to fill the larger groyne bays 12 to 14. Ongoing annual maintenance of these three groynes would continue to ensure that the height of each groyne is kept at 2no. boards above active beach levels. Annual maintenance works to the beach are assumed to be limited to minor re-profiling and clearance of sand from the seawall/promenade. Recycling of 18,000m^3 of beach material every 10 years from the eastern end of the spit between groynes 14 and 17 would also be an option under this scheme.

9.1 Technical Objective

The construction work along the western section is similar to that undertaken under Option D1 resulting in similar improvements to beach widths in this area at the end of the short-term (20 years) when compared to

the baseline do-nothing option. However, additional improvements to groynes 12 to 14 helps to reduce sediment transport and retain more of this recharge material along the central section between groynes 5 to 12. Improvements to these groynes also help to retain the recharge material placed within these groyne bays. The result of this scheme shows a significant improvement in beach widths along the central section, importantly at the vulnerable section at the neck of the spit at groyne 11. Accretion at the eastern end of the spit is shown to be increased when compared to the do nothing baseline option which would allow an option for some recycling of this material. Overall, this option shows that the technical objective to safeguard the beach and its flood defence function is expected to be met in the short-term.

9.2 Cost Estimate

An estimate of whole life capital and maintenance costs have been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 9-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£4,210 – 5,250k
Groyne stabilisation	£42k x 1no.
Groyne repairs	£20k x 3no.
Groyne extension	£46k x 3no.
MAINTENANCE WORKS	
Groyne removal (upon failure, where no recharge)	£30k x 2no.
Groyne maintenance	£1k x 3no./yr
Beach maintenance	£15k/yr
TOTAL	
Cash cost	£5,341 – 6,130k
Optimism bias[1] (60%)	£3,140 – 3,614k
Present Value cost	**£8,128 – 9,391k**

Table 9-1: Summary of capital and maintenance cost estimates for Option D6 (20yrs).

In addition to the above scheme, an increase in accretion show at the eastern end of the spit would allow the option for recycling beach material to bolster existing levels. The estimated whole life cash cost of this recycling is estimated to be £1,050k (NPV £655k).

9.3 Environmental Objective

Impacts to the natural environment under this option are very similar to Option D5 with impacts in the immediate-term limited to construction activities for work to a few key groynes at the neck of the spit. Impacts would be slightly greater under this option due to the additional work to also extend the groynes. As with previous options, placement of beach recharge is likely to cause only small impacts in the immediate-term as this material will be delivered by sea. In the short-term, whereas the improved groynes are shown to have a blocking effect to sediment transport, placement of recharge material is also expected to have some bolstering effect on the natural processes with material still moving along the frontage and accreting at the eastern end of the spit. As the risk of a beach under this option is low, protection to the area of designated sites on Dawlish Warren spit is expected to be improved.

10 *Option D7: Repair All Groynes, Extend Groynes at Neck & Recharge*

An outline sketch of this option along is shown in ***Figure 10-1***.

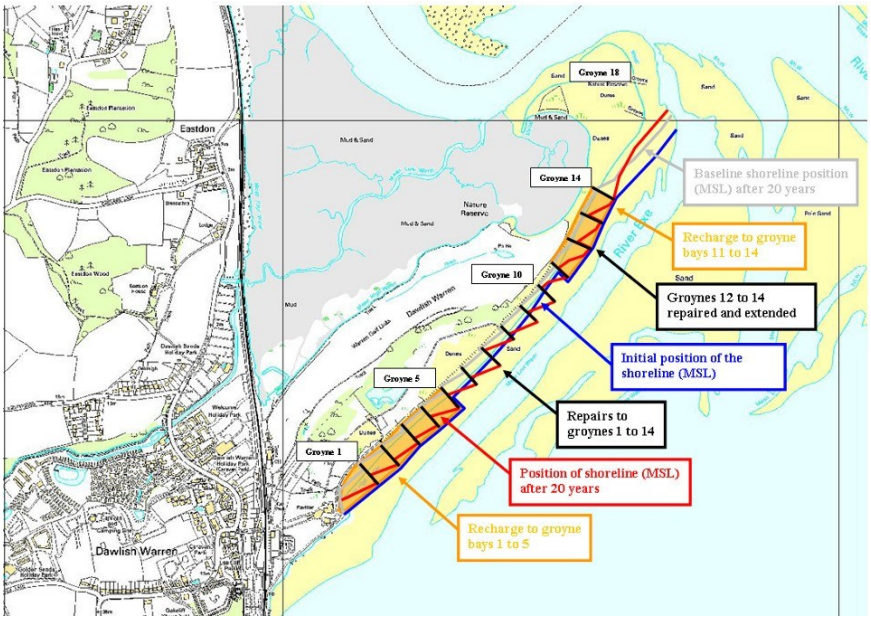

Figure 10-1: Layout of Option D7 showing position of shoreline at the end of the short-term (20yrs).

This option includes elements of Options D2 and D6 to present an improved combined scheme. Capital works would be undertaken to place 115,000m^3 of beach recharge at the western end of the frontage to groyne bays 1 to 5 (as Option D2). In addition to this, capital works would be undertaken to repair, stabilise and extend groynes 12 to 14 (as Option D6) and place a slightly larger quantity of 45,000m^3 of recharge to groynes bays 11 to 14. This longer length of recharge (now including groyne bay 11) also provides increased protection to the vulnerable section of dunes at the neck in the immediate-term. Repair work would include propping of groyne 12 which already showing signs of leaning and allow for propping of groynes 13 and 14 if required during the short-term. Work would also be undertaken to replacement of old or missing boards to prevent material passing over, under or through the groynes. Ongoing annual maintenance of the groynes would continue to ensure that the height of each groyne is kept at 2no. boards above active beach levels. Annual maintenance works to the beach are assumed to allow for minor re-profiling and clearance of sand from the seawall/promenade.

10.1 Technical Objective

As shown by Option D2, repairs to the existing groynes are effective at retaining the placed recharge along the frontage. The net north-easterly transport of sediment continues to move some of this recharge material along the central section resulting in good improvement in beach widths at the end of the short-term (20 years) when compared the baseline do-nothing option. However, this beneficial retention of material also means that less material is available for transport further along the spit where it is require to protection to vulnerable neck section. As shown by Option D6, groyne improvements and recharge to the groynes at the neck also provide good improvement in beach widths at the end of the short-term when compared to the do-nothing baseline. Overall the option shown good retention of material along the frontage, evident by the increased width of the amenity beaches along the western section and a reduction in accretion at the eastern end of the spit when compared to the do nothing baseline option. This option is therefore considered to be very effective at meeting the technical objectives to safeguard the beaches and their flood defence function.

10.2 Cost Estimate

An estimate of whole life capital and maintenance costs have been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 10-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£4,552 – 5,700k
Groyne stabilisation	£42k x 3no.
Groyne repairs	£20k x 14no.
Groyne extension	£29k x 3no.
MAINTENANCE WORKS	
Groyne removal (upon failure, where no recharge)	£30k x 5no.
Groyne maintenance	£1k x 14no./yr
Beach maintenance	£15k/yr
TOTAL	
Cash cost	£6,216 - £7,113
Optimism bias(1) (60%)	£3,589 – 4,192
Present Value cost	**£9,325 – 10,932**

Table 10-1: Summary of maintenance and capital cost estimates for Option D7

The above scheme shows a reduction in overall accretion at the eastern end of the spit. As such, no additional material is expected to be available for beach recycling under this option.

10.3 Environmental Objective

Impacts to the natural environment under this option are a combination of impacts under Option D2 and D6. A moderate amount of disruption to the natural environment would be expected in the immediate-term due to improvement works to all groynes. Placement of beach material has increased slightly when compared to previous options but is still unlikely to cause significant disruption as material will be delivered by sea. In the short-term, improvements to the groynes will result in a blocking effect to the natural coastal processes as evident by reduction in accretion at the eastern end of the spit. However, as the risk of a beach under this option is unlikely, protection to the area of designated sites on Dawlish Warren spit would be improved.

11 *Option E0: Do Nothing*

An outline sketch of this option along is shown in ***Figure 11-1***.

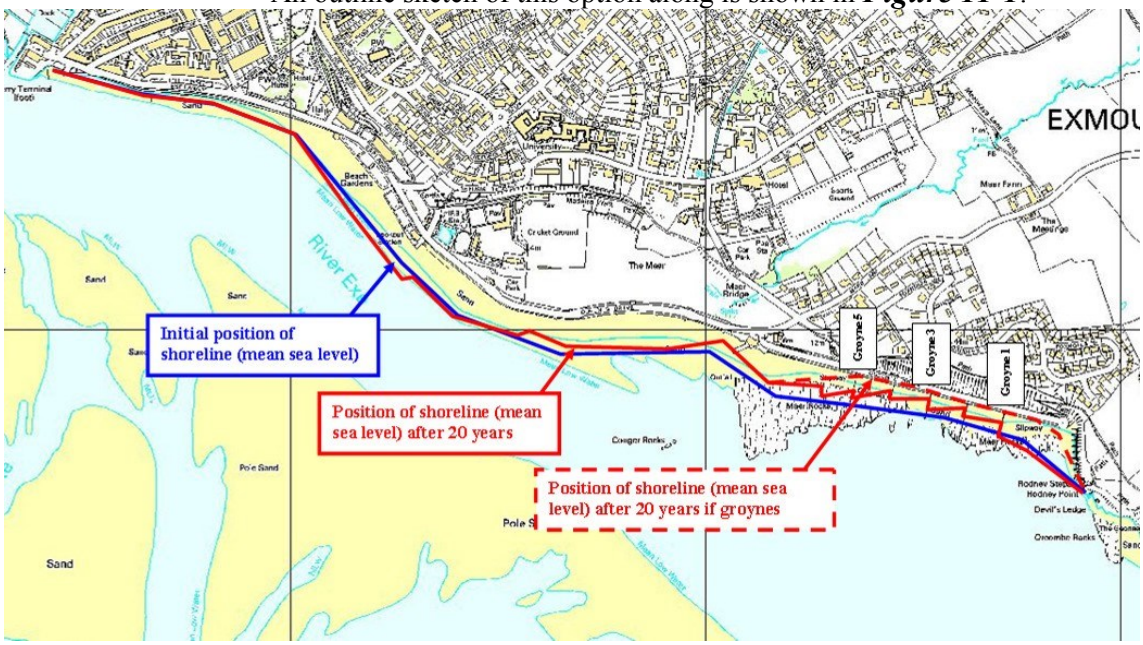

Figure 11-1: Layout of Option E0 showing position of shoreline at the end of the short-term (20yrs).

As with Option D0, the do-nothing option is include here as a baseline against which other options have been assessed. This is effectively a 'walk-away' option where no capital or maintenance works would be undertaken other than removal of the existing groynes for safety reasons as and when they fail. This option is not expected to meet the technical objectives of the study as it does not help to safeguard the beaches and their flood defence function. However, it has been included as a baseline comparator.

11.1 Technical Objective

The results of the shoreline modelling show that the beaches along the Exmouth frontage are, in general, relatively stable in the short-term. Along the western section of the frontage adjacent to the Octagon the shoreline shows a small amount of accretion in the short-term. Along the central section at the Maer a small amount of erosion is apparent at either end of the area of dunes. This is particularly noticeable between the dunes and the new lifeboat station where there is a moderate reduction in the width of the beach the end of the short-term (20 years). However, the most significant area of change is along the eastern section of the beach at Queens Drive where the beach is shown to erode almost back to the seawall. A sensitivity test on the effectiveness of these groynes shows that if these groynes were

completely removed, the beach material would be completely removed from this area resulting in a significant risk of undermining and collapse of the seawall in the short-term (20 years).

11.2 Cost Estimate

An estimate of whole life capital and maintenance costs have been determined based on the work to be undertaken for this option. Whereas it is considered unlikely that the groynes in this area would fail in the short-term a contingency sum has been included should they need to be removed. A summary of costs for this option are presented in ***Table 11-1*** and **Annex A**.

Description	**Cost (£k)**
MAINTENANCE WORKS	
Groyne removal (upon failure, where no recharge)	£30k x 6no.
TOTAL	
Cash cost	£180k
Optimism bias(1) (60%)	£108k
Present Value cost	**£288k**

Table 11-1: Summary of maintenance and capital cost estimates for Option E0

11.3 Environmental Objective

This option represents the least effect on the existing natural process of all options and would allow the Exmouth beaches to evolve naturally. Other than the removal of some groynes (should they fail) no construction or maintenance work is expected and disruption to the natural environment in the immediate-term is expected to be minimal. However, in the short-term lowering of beach levels may result in undermining and collapse of the seawall which is expected to result in larger impacts to the natural environment.

12 *Option E1: Recharge Only*

An outline sketch of this option along is shown in ***Figure 12-1***.

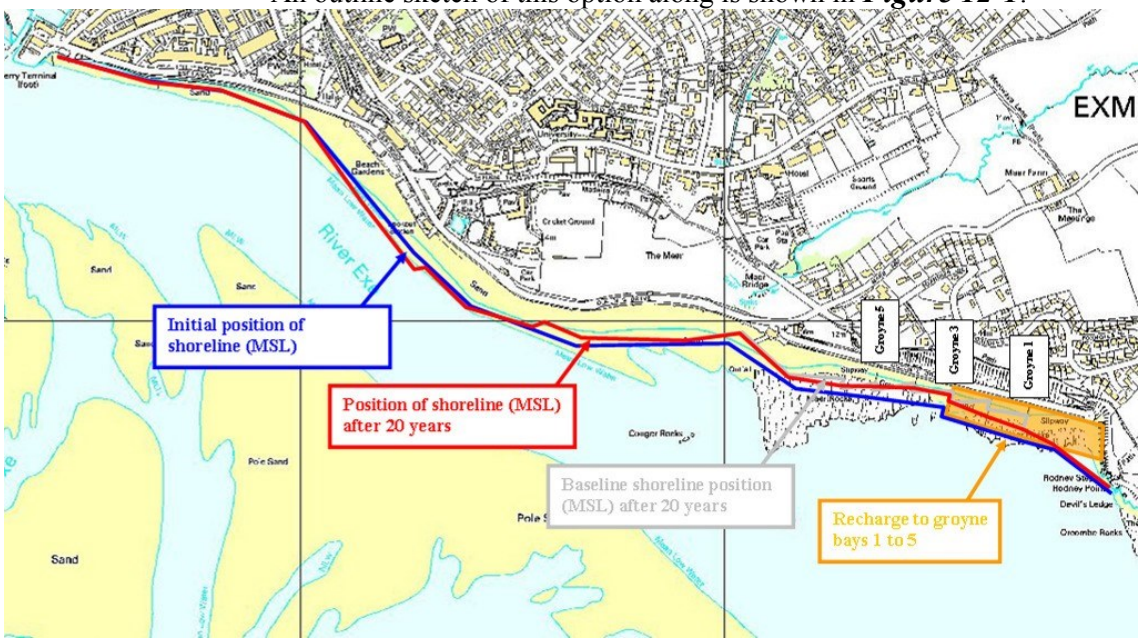

Figure 12-1: Layout of Option E1 showing position of shoreline at the end of the short-term (20yrs).

This option includes placement of 80,000m^3 of beach recharge material at the eastern end of the Exmouth frontage within groynes bays 1 to 3 (groynes numbered east to west for the purpose of this study). Ongoing annual maintenance of the groynes would continue under this option to ensure that the height of each groyne is kept at 2no. boards above active beach levels. Ongoing annual maintenance works to the beach are assumed to be limited to minor re-profiling and clearance of sand from the seawall/promenade.

12.1 Technical Objective

Beach recharge material has been placed at the eastern end of the frontage, at the location where the baseline option shows the greatest reduction in beach width. This recharge material is shown to be largely retained by the exiting groynes 1 to 3 however a loss of material along the rest of this eastern section results in a reduction in beach widths at the end of the short-term. Since the net western drift of material appears to be fairly small, the recharge material is not shown to have a benefit to the area of erosion at the eastern end of the Maer where beach widths shown no change to the current situation at the end of the short-term.

12.2 Cost Estimate

An estimate of whole life capital and maintenance costs have been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 12-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£2,726 – 3,300k
TOTAL	
Cash cost	£2,976 – 3,300k
Optimism bias[1] (60%)	£1,786 – 1,980k
Present Value cost	**£4,762 – 5,280k**

Table 12-1: Summary of maintenance and capital cost estimates for Option E1

12.3 Environmental Objective

This option is likely to result in very little disruption the natural environment in the immediate-term during construction since no construction works are proposed on the beach. Placement of beach recharge material is limited to the eastern end of the frontage and with this material being delivered by sea, any disruption is likely to be minor. Over the short-term no significant change is expected to the coastal processes due to the placement of recharge material.

13 *Option E2: Repairs to One Groyne & Recharge*

An outline sketch of this option along is shown in ***Figure 13-1***.

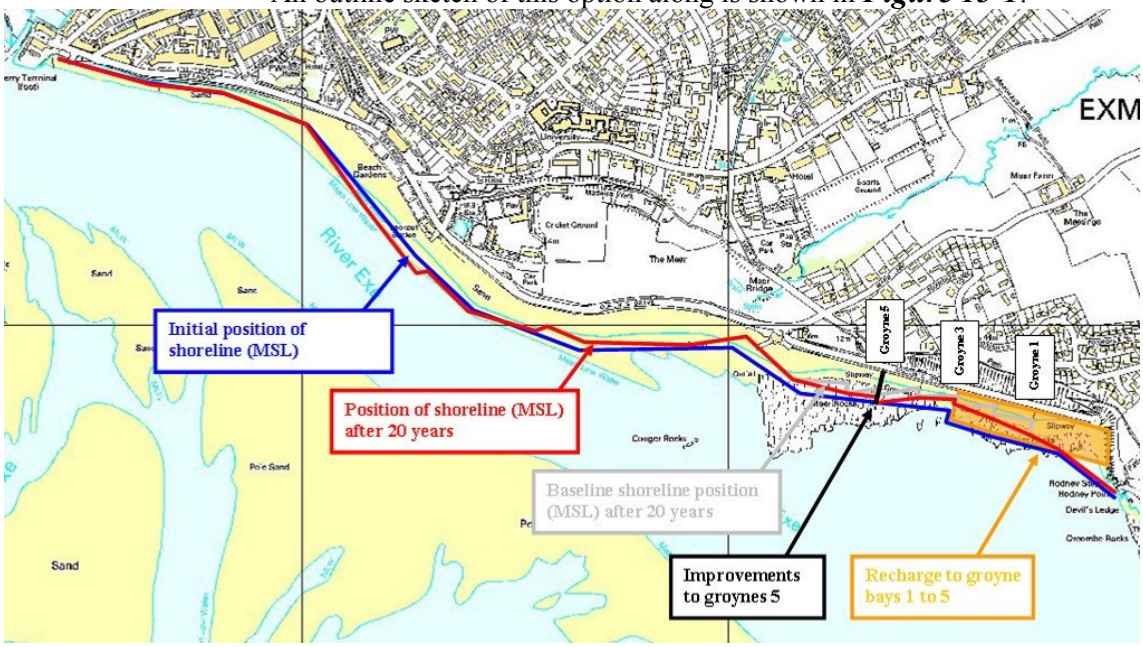

Figure 13-1: Layout of Option E2 showing position of shoreline at the end of the short-term (20yrs).

As with the previous scheme, this option includes capital works to place 80,000m^3 of recharge material to groyne bays 1 to 3. In addition to this, groyne 5 will be improved to help retain material at this critical section of the frontage. These improvements are expected to be achieved by replacing old or missing boards to prevent material passing over, under or through the groyne and where possible increasing the height of the top board. Ongoing annual maintenance of the groynes would continue under this option to ensure that the height of each groyne is kept at 2no. boards above active beach levels. Ongoing annual maintenance works to the beach are assumed to be limited to minor re-profiling and clearance of sand from the seawall/promenade.

13.1 Technical Objective

Beach recharge material placed at the eastern end for of the frontage continues to be largely retained by the exiting groynes 1 to 3 whilst improvements to groyne 5 help to maintain a wider beach at this location. However, whilst improvements this groyne at the down drift end of the section attempts to retain material in the updrift area around groyne bays 4, only a small improvement in beach widths at the critical location is evident. This is likely to be due to a combination of material filling in groyne bay 5

and subsequent and transport of material passed this bay. Further along the frontage, this option is shown to result in little change to the eroded beach areas at the Maer when compared to the do-nothing baseline case. This is likely to be due to the low transport rates along this frontage and material being retained along the eastern section.

13.2 Cost Estimate

An estimate of whole life capital and maintenance cost estimates have been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 13-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£2,726 – 3,300k
Groyne repairs	£20k x 1no.
MAINTENANCE WORKS	
Groyne maintenance	£1k x 1no./yr
Beach maintenance	£15k/yr
TOTAL	
Cash cost	£3,316 – 3,640k
Optimism bias[(1)] (60%)	£1,990 – 2,184k
Present Value cost	**£5,171 – 5,689k**

Table 13-1: Summary of maintenance and capital cost estimates for Option E2

13.3 Environmental Objective

As with the previous option, very little disruption to the natural environment is expected in the immediate-term other than for minor repair works to one of the groynes. Placement of beach recharge material is limited to the eastern end of the frontage and with this material being delivered by sea, any disruption is likely to be minor. Over the short-term no significant change is expected to the coastal processes due to the placement of recharge material.

14 *Option E3: Repairs to Two Groynes & Recharge*

An outline sketch of this option along is shown in ***Figure 14-1***.

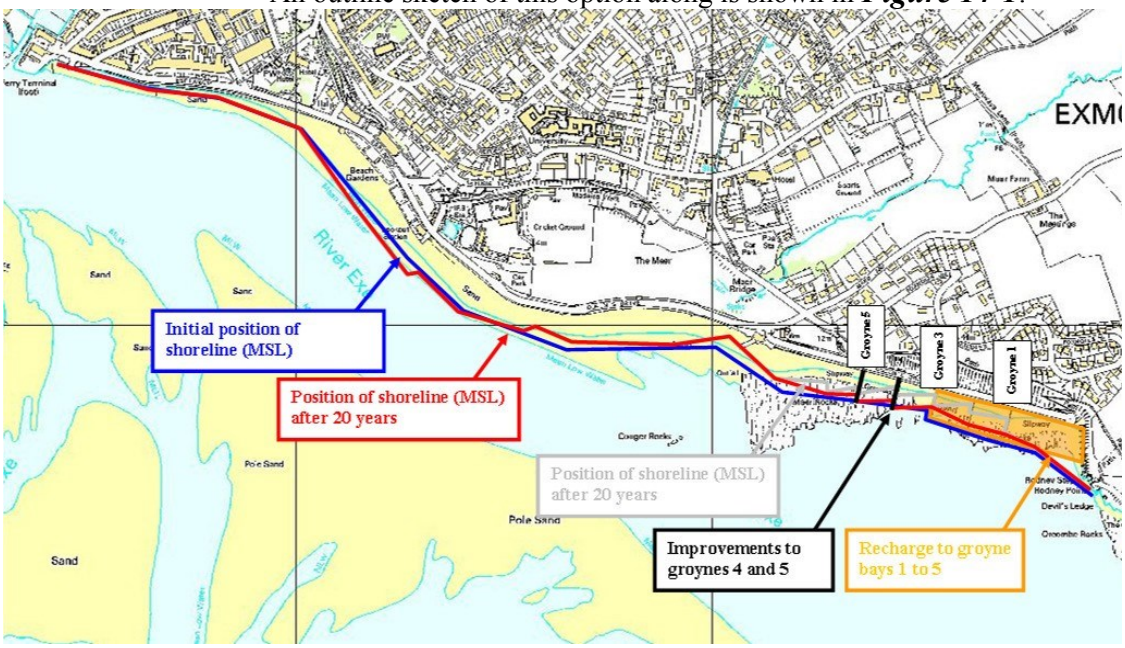

Figure 14-1: Layout of Option E3 showing position of shoreline at the end of the short-term (20yrs).

As with the previous scheme, this option also includes capital works to place 80,000m^3 of recharge material to groyne bays 1 to 3. In addition to this, groynes 4 and 5 will be improved to help retain material at this critical section of the frontage. These improvements are expected to be achieved by replacing old or missing boards to prevent material passing over, under or through the groyne and where possible increasing the height of the top board. Ongoing annual maintenance of the groynes would continue under this option to ensure that the height of each groyne is kept at 2no. boards above active beach levels. Ongoing annual maintenance works to the beach are assumed to be limited to minor re-profiling and clearance of sand from the seawall/promenade.

14.1 Technical Objective

Improvements to one further groyne at the eastern section are shown to be relatively effective at retaining beach material along the vulnerable frontage between groynes 3 and 4. Beach widths are shown to be significantly improved at the end of the short-term providing protection to the seawall and reducing the risk of undermining and collapse. However, the two areas of erosion at either end of the Maer are shown to be largely unchanged when compared to the baseline case.

14.2 Cost Estimate

An estimate of whole life capital and maintenance cost estimates have been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 14-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£2,726 – 3,300k
Groyne repairs	£20k x 2no.
MAINTENANCE WORKS	
Groyne maintenance	£1k x 2no./yr
Beach maintenance	£15k/yr
TOTAL	
Cash cost	£3,356 – 3,680k
Optimism bias(1) (60%)	£2,014 – 2,208k
Present Value cost	**£5,226 – 5,744k**

Table 14-1: Summary of maintenance and capital cost estimates for Option E3

14.3 Environmental Objective

As with the two previous options, very little disruption to the natural environment is expected in the immediate-term other than for minor repair works to two groynes. Placement of beach recharge material is limited to the eastern end of the frontage and with this material being delivered by sea, any disruption is likely to be minor. Over the short-term no significant change is expected to the coastal processes due to the placement of recharge material.

15 *Option E4: Repairs to Two Groynes, One New Groyne & Recharge*

An outline sketch of this option along is shown in ***Figure 15-1***.

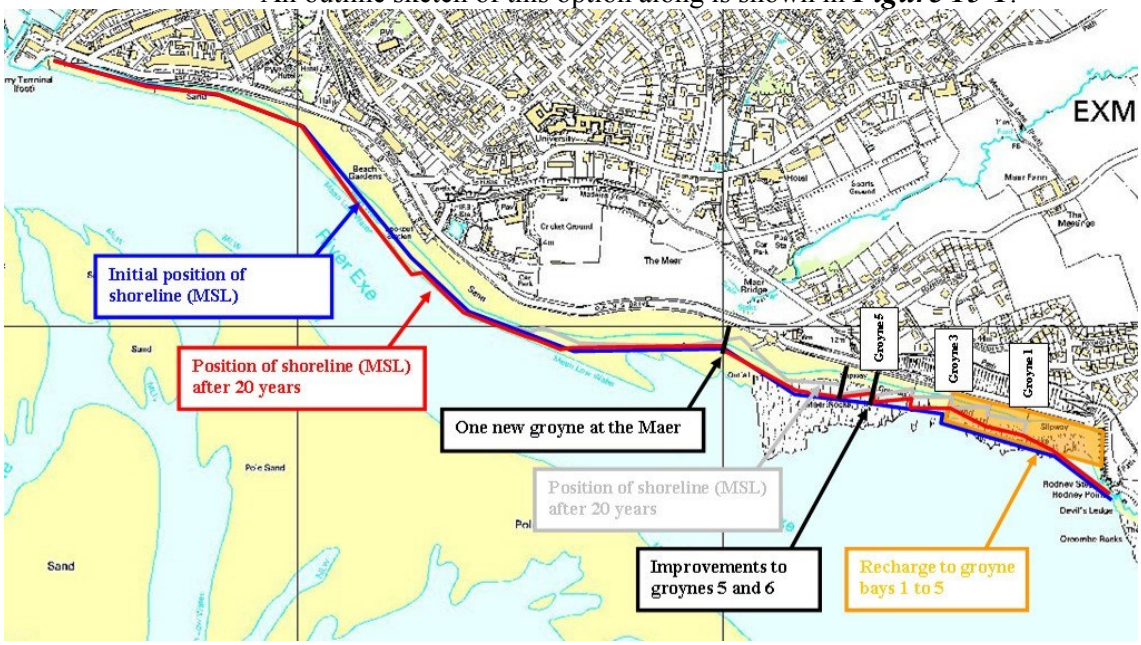

Figure 15-1: Layout of Option E4 showing position of shoreline at the end of the short-term (20yrs).

As with the previous scheme, this option also includes capital works to place 80,000m^3 of recharge material to groyne bays 1 to 3 and improvements to groynes 4 and 5 to help retain material at this critical section of the frontage. In addition to this, one new 70m long groyne will be constructed at the eastern end of the Maer to help to retain beach material and control the erosion evident in the baseline do-nothing case. Ongoing annual maintenance of all groynes would continue under this option to ensure that the height of each groyne is kept at 2no. boards above active beach levels. Ongoing annual maintenance works to the beach are assumed to be limited to minor re-profiling and clearance of sand from the seawall/promenade.

15.1 Technical Objective

The effect of recharge and improvements to the groynes along the eastern section at Queens Drive remain the same as the previous option. However, construction of the new groyne at the eastern end of the Maer is shown to have a beneficial effect in limiting recession of the beach in this area. At the end of the short-term, the beach width at the Maer is shown to remain relatively stable when compared with the baseline case.

15.2 Cost Estimate

An estimate of whole life capital and maintenance cost estimates have been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 15-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£2,726 – 3,300k
Groyne repairs	£20k x 2no.
Groyne construction	£108k x 1no.
MAINTENANCE WORKS	
Groyne maintenance	£1k x 3no./yr
Beach maintenance	£15k/yr
TOTAL	
Cash cost	£3,484 – 3,808k
Optimism bias(1) (60%)	£2,090 – 2,285k
Present Value cost	**£5,422 – 5,940k**

Table 15-1: Summary of maintenance and capital cost estimates for Option E4

15.3 Environmental Objective

This option presents some disruption to the natural environment in the immediate-term due to the construction of one new groyne at the eastern end of the Maer and minor repair works to two existing groynes. Placement of beach recharge material is limited to the eastern end of the frontage and with this material being delivered by sea, any disruption is likely to be minor. Over the short-term no significant change is expected to the coastal processes due to the placement of recharge material.

16 *Option E5: Repairs to Two Groynes, Two New Groynes & Recharge*

An outline sketch of this option along is shown in ***Figure 16-1***.

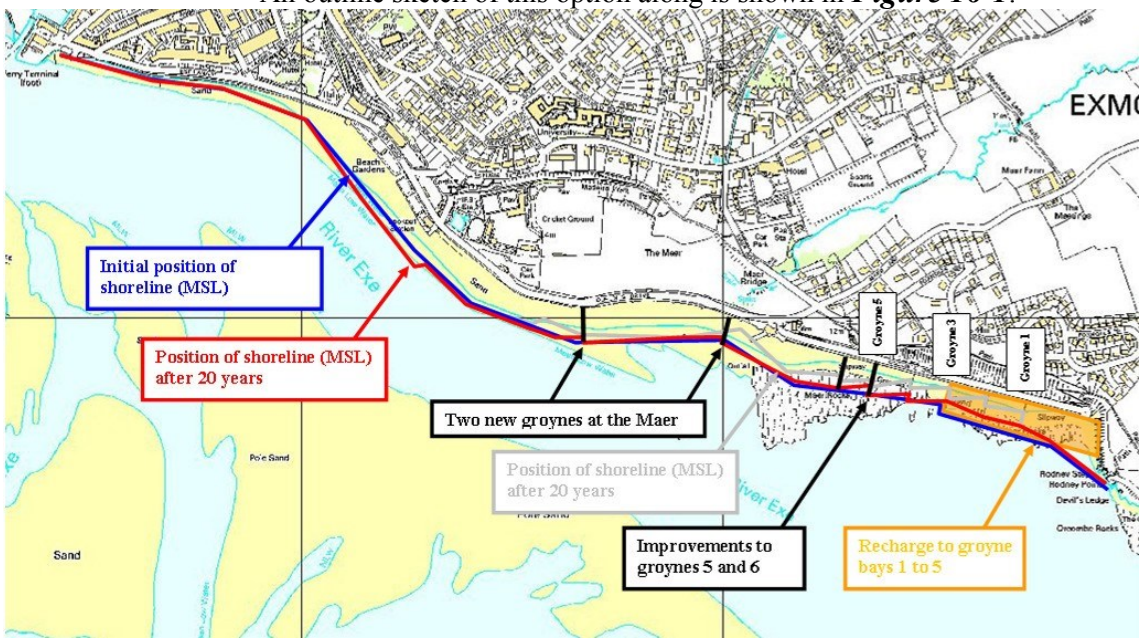

Figure 16-1: Layout of Option E5 showing position of shoreline at the end of the short-term (20yrs).

As with the previous two schemes, this option also includes capital works to place 80,000m^3 of recharge material to groyne bays 1 to 3 and improvements to groynes 4 and 5 to help retain material at this critical section of the frontage. However, this option includes construction of two new groynes at the eastern and western ends of the Maer to help to retain beach material and control the erosion identified in the Option E0 baseline case. Ongoing annual maintenance of all groynes would continue under this option to ensure that the height of each groyne is kept at 2no. boards above active beach levels. Ongoing annual maintenance works to the beach are assumed to be limited to minor re-profiling and clearance of sand from the seawall/promenade.

16.1 Technical Objective

As with the previous scheme, the effects of recharge and improvements to the groynes along the eastern section at Queens Drive remain the same. The new groyne at the eastern end of the Maer is shown to be effective in retaining beach material in this area and improving good beach widths at the end of the short-term. The new groyne at the western end of the Maer shows less benefit in improving beach widths in this area and is likely to be unnecessary unless erosion at this location increases.

16.2 Cost Estimate

An estimate of whole life capital and maintenance cost estimates have been determined based on the work to be undertaken for this option. A summary of costs for this option are presented in ***Table 16-1*** and **Annex A**.

Description	**Cost (£k)**
CAPITAL WORKS	
Licences, consents & royalties	£250k
Beach recharge (Pole Sands, Isle of Wight)	£2,726 – 3,300k
Groyne repairs	£20k x 2no.
Groyne construction	£108k x 2no.
MAINTENANCE WORKS	
Groyne maintenance	£1k x 4no./yr
Beach maintenance	£15k/yr
TOTAL	
Cash cost	£3,612 – 3,935k
Optimism bias(1) (60%)	£2,167 – 2,361k
Present Value cost	**£5,618 – 6,136k**

Table 16-1: Summary of maintenance and capital cost estimates for Option E5

16.3 Environmental Objective

This option presents similar impacts to the previous option with a slightly larger disruption to the natural environment due to the construction of two new groynes at the Maer and minor repair works to two groynes. Placement of beach recharge material is not expected to cause any significant impacts in the immediate-term and over the short-term no significant changes are expected to the coastal processes due to the placement of this recharge material.

17 Recommended Options

17.1 Appraisal of the options presented in this note shows that there is no single recharge/ recycling or retention option that meets all the objectives for technical, cost and environmental acceptability. Selection of the final preferred option is therefore expected to be a trade-off between objectives to provide a "Hold-the-Line" solution in the short-term.

17.2 Based on the appraisal scoring developed in the appraisal matrix presented in **Annex B**, the following options are recommended for consideration by the Steering Group:

Dawlish Warren

- Option D4: Repair All Groynes & Large Recharge Scheme
- Option D6: Repair/Extend Groynes at Neck & Recharge (including an option for recycling)

Exmouth

- Option E0: Do-nothing [baseline]
- Option E4: Repairs to Two Groynes, One New Groyne & Recharge
- Option E5: Repairs to Two Groynes, Two new Groynes & Recharge

Annex A1: Whole Life Cost Estimates - Dawlish Warren

Description	Option D0	Option D1	Option D2	Option D3	Option D4	Option D5	Option D6	Option D7
CAPITAL WORKS								
Licences & consents	-	£250k	£250k	£250k	£250k	£250k	£250k	£250k
Beach recharge	-	£3,525 – 4,350k	£3,525 – 4,350k	£6,607 – 8,400k	£6,607 – 8,400k	£3,868 – 4,800k	£4,210 – 5,250k	£4,552 – 5,700k
Groyne stabilisation	-	-	-	£42k x 2no.	£42k x 2no.	£42k x 1no.	£42k x 1no.	£42k x 3no
Groyne removal	£30k x 14no.	£30k x 5no.	£30k x 5no.	-	-	£30k x 2no.	£30k x 2no.	£30k x 5no.
Groyne repairs	-	-	£20k x 14no.	-	£20k x 14no.	£20k x 3no.	£20k x 3no.	£20k x 14no.
Groyne extension	-	-	-	-	-	-	£46k x 3no.	£92k x 3no.
MAINTENANCE WORKS								
Groyne maintenance	-	£1k x 14no./yr	£1k x 14no./yr	-	£1k x 14no./yr	£1k x 3no./yr	£1k x 3no./yr	£1k x 14no./yr
Beach maintenance	-	£15k/yr	£15k/yr	-	£15k/yr	£15k/yr	£15k/yr	£15k/yr
TOTAL								
Cash cost	£4,20k	£3,925 - 4,500k	£4,845 – 5,504k	£6,942 – 8,484k	£7,802 – 9,344k	£4,860 – 5,542k	£5,341 – 6,130k	£6,216 - £7,113
Optimism bias (60%)	£2,52k	£2,655 - 3,000k	£2,823 – 3,168k	£4,505 – 5,430k	£4,673 – 5,598k	£2,897 – 3,306k	£3,140 – 3,614k	£3,589 – 4,192
Present Value cost	**£672k**	**£6,835 – 7,755k**	**£7,283 – 8,203k**	**£11,767 – 14,235**	**£12,215–14,683k**	**£7,479 – 8,571k**	**£8,128-9,391k**	**£9,325 – 10,932**

RECYCLING (optional)								
Cash cost	-	£746k	-	£3,106k	£1,045k	£1,045k	£1,045k	-
Present value cost	**-**	**£388k**	**-**	**£2,130k**	**£655k**	**£655k**	**£655k**	**-**

Annex A2: Whole Life Cost Estimates - Exmouth

Description	Option E0	Option E1	Option E2	Option E3	Option E4	Option E5
CAPITAL WORKS						
Licences & consents	-	£250k	£250k	£250k	£250k	£250k
Beach recharge	-	£2,726 – 3,300k	£2,726 – 3,300k	£2,726 – 3,300k	£2,726 – 3,300k	£2,726 – 3,300k
Groyne removal	£30k x 6no.	-	-	-	-	-
Groyne repairs	-	-	£20k x 1no.	£20k x 2no.	£20k x 2no.	£20k x 2no.
Construct new groyne	-	-			£108k x 1no.	£108k x 2no.
MAINTENANCE WORKS						
Groyne maintenance	-	-	£1k x 1no./yr	£1k x 2no./yr	£1k x 3no./yr	£1k x 4no./yr
Beach maintenance	-	-	£15k/yr	£15k/yr	£15k/yr	£15k/yr
TOTAL						
Cash cost	£180k	£2,976 – 3,300k	£3,316 – 3,640k	£3,356 – 3,680k	£3,484 – 3,808k	£3,612 – 3,935k
Optimism bias (60%)	£108k	£1,786 – 1,980k	£1,990 – 2,184k	£2,014 – 2,208k	£2,090 – 2,285k	£2,167 – 2,361k
Present Value cost	**£288k**	**£4,762 – 5,280k**	**£5,171 – 5,689k**	**£5,226 – 5,744k**	**£5,422 – 5,940k**	**£5,618 – 6,136k**

Annex B1: Options Appraisal Matrix – Dawlish Warren

Description of Option	Technical Objective (A)	Cost Estimate (B)	Environmental Objective (C)	Rank AxBxC
D0: Do Nothing [baseline]	POOR (1). Loss of beach along all sections, high risk of breach and flooding, loss of recreational beach.	LOW (3). Very low whole life NPV cost of £0.7m.	POOR (1). No immediate impacts from construction, spit allowed to evolve naturally in short-term, significant risk of breach and loss of designated areas.	3
D1: Small Recharge Scheme (with Recycling)	POOR (1). Small improvement in beach width along western section, loss of beach along central section, high risk of breach and flooding, loss of recreational beach.	MODERATE (2). Moderate whole life NPV cost of £6.9-7.8m. Optional recycling NPV cost of £0.4m.	MODERATE (2). Small impacts from construction in immediate-term, coastal processes bolstered by recharge, spit allowed to evolve naturally in short-term, significant risk of breach and loss of designated areas.	4
D2: Repair all Groynes & Small Recharge Scheme	POOR (1). Moderate improvement in beach along western and central section, high risk of breach and flooding at central section, good improvement to recreational beach at western section.	MODERATE (2). Moderate whole life NPV cost of £7.3-8.2m.	MODERATE (2). Large impact from construction in immediate-term, coastal processes bolstered by recharge, spit allowed to evolve naturally in short-term, high risk of breach and loss of designated areas.	4
D3: Large Recharge Scheme (with Recycling)	MODERATE (2). Moderate improvement in beach along western section, high risk of breach and flooding at central section, good improvement to recreational beach at western section.	HIGH (1). High whole life NPV cost of £11.8-14.3m. Optional recycling NPV cost of £3.1m.	GOOD (3). Small impact from construction in immediate-term, natural processes bolstered by recharge, low risk of breach and protection to designated areas.	6
D4: Repair All Groynes & Large Recharge Scheme (with Recycling)	GOOD (3). Good improvement in beach width, flood protection and amenity along all sections.	HIGH (1). High whole life NPV cost of £12.3-14.7m. Optional recycling NPV cost of £0.7m.	MODERATE (2). Large impact from construction in immediate-term, large change to natural processes in short-term, low risk of breach and designated areas protected.	6 (preferred on technical)
D5: Repair Groynes at Neck & Small Recharge (with Recycling)	MODERATE (2). Moderate improvement in beach along western and central section, small risk of breach and flooding at central section, good improvement in amenity at western section.	MODERATE (2). Moderate whole life NPV cost of £7.5-8.6m. Optional recycling NPV cost of £0.7m.	MODERATE (2). Small impact from construction in immediate-term, small change to natural processes in short-term, moderate risk of breach and loss of designated areas.	6
D6: Repair/ Extend Groynes at Neck & Small Recharge Scheme (with Recycling)	GOOD (3). Good improvement in beach along all sections, small risk of breach and flooding at central section, good improvement in amenity at western section.	MODERATE (2). Moderate whole life NPV cost of £8.3-9.4m. Optional recycling NPV cost of £0.7m.	MODERATE (2). Small impact from construction in immediate-term, small change to natural processes in short-term, moderate risk of breach and loss of designated areas.	12
D7: Repair All Groynes, Extend Groynes at Neck & Recharge	GOOD (3). Good improvement in beach along all sections, small risk of breach and flooding at central section, good improvement in amenity at western section.	MODERATE (2). Moderate whole life NPV cost of £8.3-9.4m. Optional recycling NPV cost of £0.7m.	POOR (1). Large impact from construction in immediate-term, large change to natural processes in short-term, low risk of breach and protection to designated areas.	6

Annex B2: Options Appraisal Matrix - Exmouth

Description	Technical Objective (A)	Economical Objective (B)	Environmental Objective (C)	Rank AxBxC
E0: Do nothing (baseline).	MODERATE (2). Loss of beach along eastern section and moderate risk of undermining/ collapse of seawall, erosion at Maer, loss of some recreational beach.	LOW (3). Very low whole life NPV cost of £0.3m.	GOOD (3). No disturbance from construction or impacts in immediate-term, significant risk of undermining/ collapse of seawall resulting in impact to natural environment in short-term.	18
E1: Recharge only	MODERATE (2). Small improvement in beach along eastern section, moderate risk of undermining/ collapse of seawall, erosion at Maer, loss of some amenity beach.	MODERATE (2). Moderate whole life NPV cost of £4.8-5.3m.	MODERATE (2). Small impact from construction in immediate-term, coastal processes bolstered by recharge, high risk of undermining/ collapse of seawall resulting in impact to natural environment.	8
E2: Repairs to One Groyne & Recharge	MODERATE (2). Small improvement in beach along eastern section, moderate risk of undermining/ collapse of seawall, erosion at Maer, loss of some amenity beach.	MODERATE (2). Moderate whole life NPV cost of £5.2-5.7m.	MODERATE (2). Small impact from construction in immediate-term, coastal processes bolstered by recharge, high risk of undermining/ collapse of seawall resulting in impact to natural environment.	8
E3: Repairs to Two Groynes & Recharge	MODERATE (2). Good improvement in beach along eastern section, low risk of undermining/ collapse of seawall, erosion at Maer, amenity beach retained.	MODERATE (2). Moderate whole life NPV cost of £5.3-5.8m.	MODERATE (2). Small impact from construction in immediate-term, coastal processes bolstered by recharge, moderate risk of undermining/ collapse of seawall resulting in impact to natural environment.	8
E4: Repairs to Two Groynes, One New Groyne & Recharge	GOOD (3). Good improvement in beach along eastern section, low risk of undermining/ collapse of seawall, reduced erosion at Maer, amenity beach maintained.	HIGH (1). Highest whole life NPV cost of £5.5-6.0m.	GOOD (3). Moderate impact from construction in immediate-term, coastal processes bolstered by recharge, low risk of undermining/ collapse of seawall resulting in reduced impact to natural environment.	9
E5: Repairs to Two Groynes, Two new Groynes & Recharge	GOOD (3). Good improvement in beach along eastern section, low risk of undermining/ collapse of seawall, reduced erosion at Maer, amenity beach maintained.	HIGH (1). Highest whole life NPV cost of £5.6-6.2m.	GOOD (3). Moderate impact from construction in immediate-term, coastal processes bolstered by recharge, low risk of undermining/ collapse of seawall resulting in reduced impact to natural environment.	9