TECHNICAL MEMO

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Subject: West Beach Coastal Processes Modelling
Assessment of Structural Options

1 Introduction

DHI was engaged by the Department for Environment and Water (DEW) to undertake investigation of the West Beach sediment cell to identify the causes of long term and ongoing recession of the shoreline and to evaluate a range of management options for this sediment cell.

During this project, a detailed analysis of bathymetry data, coastal profiles and historical nourishment volumes has led to the development of a conceptual model of the coastal processes causing erosion at West Beach. The understanding of the coastal processes allowed the establishment and calibration of a coastal sediment transport model of the West Beach sediment cell.

In August 2018, the assessment of four coastal management options was documented in a detailed technical report (Ref. /1/). The four assessed options were:

- Scenario 1: Do nothing
- Scenario 2: Mass nourishment at approximately 10 years intervals
- Scenario 3: Interim management which comprises of:
  - Small scale initial nourishment
  - Extension of the West Beach seawall
  - Back-passing 30,000 m^3 pre-summer
- Scenario 4: Large scale back-passing from Northern Sediment cells

In addition to these four scenarios mostly composed of soft management actions, 2 additional scenarios featuring hard structures have been assessed. This addendum provides details of these two additional scenarios and the results of the simulation and should be read as a complement of the technical report mentioned earlier (Ref./1/).

2 Additional mitigations options

As described in Ref. /1/, four mitigation options have already been assessed using Shoreline Modelling. The two additional management options assessed and documented in this addendum are described in this section.

2.1 Principle

To complement the three soft management options previously assessed, it has been decided to investigate the potential benefits that hard structures could have to mitigate the erosion problem at West Beach.

There are numerous types of shapes and designs for structural protections (groynes, seawalls, breakwaters, artificial headlands. For this assessment, it has been decided to assess the effect of shore-parallel breakwaters. A structure of this type has been constructed in Semaphore (see Figure 2.1) and it has been demonstrated through the analysis of the historical profile data that this structure had a locally positive impact on the volume of sand in the lee of the breakwater (see Ref. /1/) even though light consequential downdrift erosion just north of the structure (see Hart St. profile in Figure 2.2) has been observed.

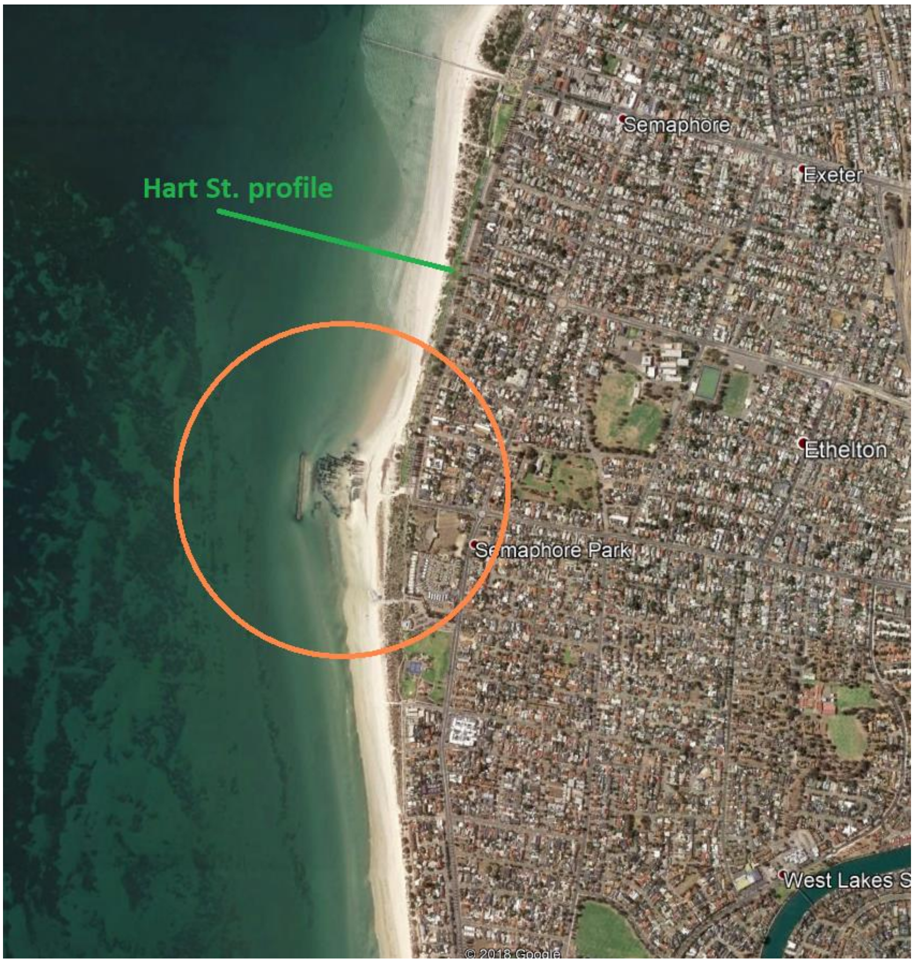

Figure 2.1 Offshore breakwater constructed in Semaphore in the late 1990s and location of the cross-shore profile presented in the figure below.

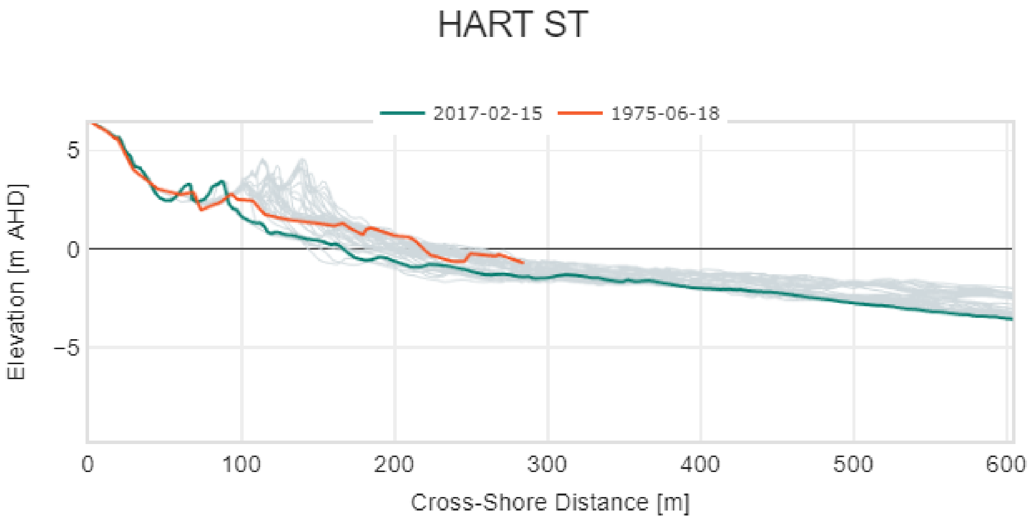

Figure 2.2 First (orange), last (green) and all other cross-shore profiles measured at Hart St. just north of the Semaphore breakwater.

The principle of the assessed structures is to create salients in front of West Beach SLSC, using two detached shore-parallel breakwaters. Depending on the structure size and position in relation to the surf zone, either salients or tombolos can form in the lee of the structures, as described in the figure below.

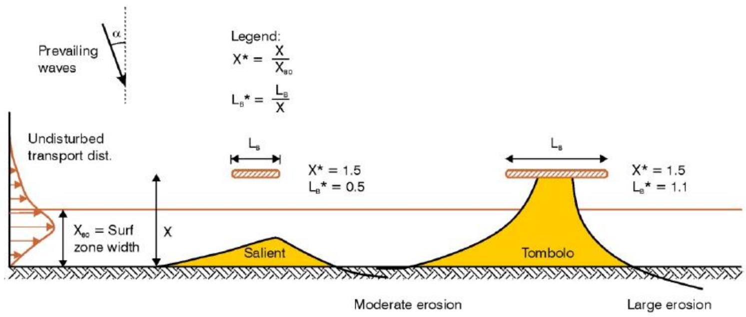

Figure 2.3 Definition of parameters characterising detached breakwaters and accumulation forms (from Ref. /2/).

In order to immediately stabilise the coastline and avoid downdrift erosion related to the construction of the structure, an initial nourishment of the expected shape of the accumulation in the lee of the structure is necessary.

The design of the structures for numerical modelling described in the Section 2.2 is based on assessed equilibrium orientation and estimated surf zone width from Ref. /1/.

2.2 Description of the scenarios

The conceptual structures implemented in the two scenarios (Scenario 5a and 5b) are based on the following characteristics, inspired from the shore-parallel breakwater at Semaphore. Figure 2.4 illustrates the bathymetry resulting from these considerations (in the green rectangle).

- Two shore-parallel breakwaters facing West Beach and aimed at forming salients.
- Each breakwater is 200 m long and 20 m wide. The distance between the two breakwaters centre points is 650 m. The two structures are located approximately 300 m offshore and following the -5 m AHD contour.
- The elevation of the breakwaters is provisionally set to +3 m AHD. With this height, the breakwater would provide protection in an all-tide and wave conditions. This is considered acceptable for the purpose of these preliminary simulations, aiming at demonstrating the principles of sand balance when including offshore structures.
- The scenarios feature prefilled salients in the lee of the structures and a 30 m to 50 m beach in front of the SLSC, as illustrated in the figure below. Immediately north of the seawall, the conceptual prefilled salient would approximately provide an 80 m wide beach. The profile at the prefilled salient is based on a theoretical equilibrium profile (Dean) from +3 m AHD to -5 m .
  With these assumptions, 500,000 m^3 to 600,000 m^3 is a rough approximation of the required volume necessary to achieve the initial total nourishment indicated in the green area in the figure below.

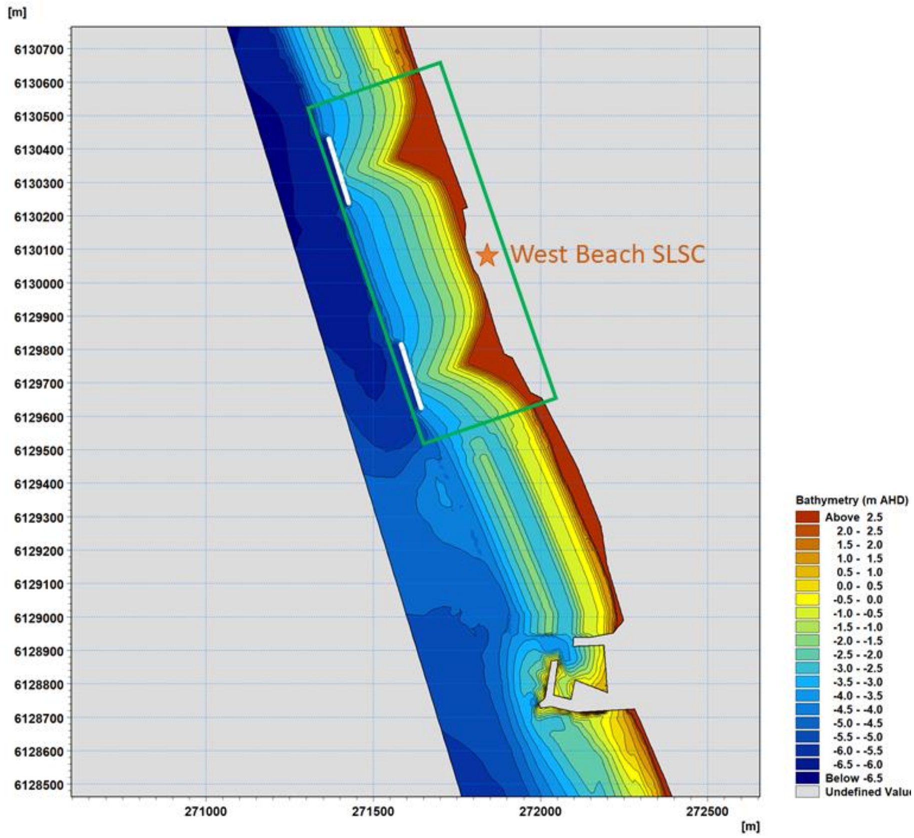

Figure 2.4 Initial bathymetry for the two additional scenarios simulated using the Shoreline Model. The green rectangle indicates the area specifically affected by adjustments for Scenario 5a and 5b.

Based on the structures described above, the two following scenarios have been assessed:

- **Scenario 5a**: No intervention in addition to the structures and prefilled salients.

- **Scenario 5b**: Structures complemented by a pumping system transferring 115,000 m³/yr from the northern beaches. This volume of sand corresponds to the estimated littoral drift along West Beach (see Ref. /1/). The replenishment is located just north of the northern structure.

The methodology and the results are described in the Section below.

3 Modelling of additional mitigation options

3.1 Methodology

The methodology applied for the simulation of the two scenarios is the same as described in the Ref. /1/. For Scenario 5b, bed level sources have been added, as illustrated in the Figure below.

These sources are active from the beginning of the simulation in order to tentatively replicate a fully established protection scheme and skipping the transition period following the construction of the structures.

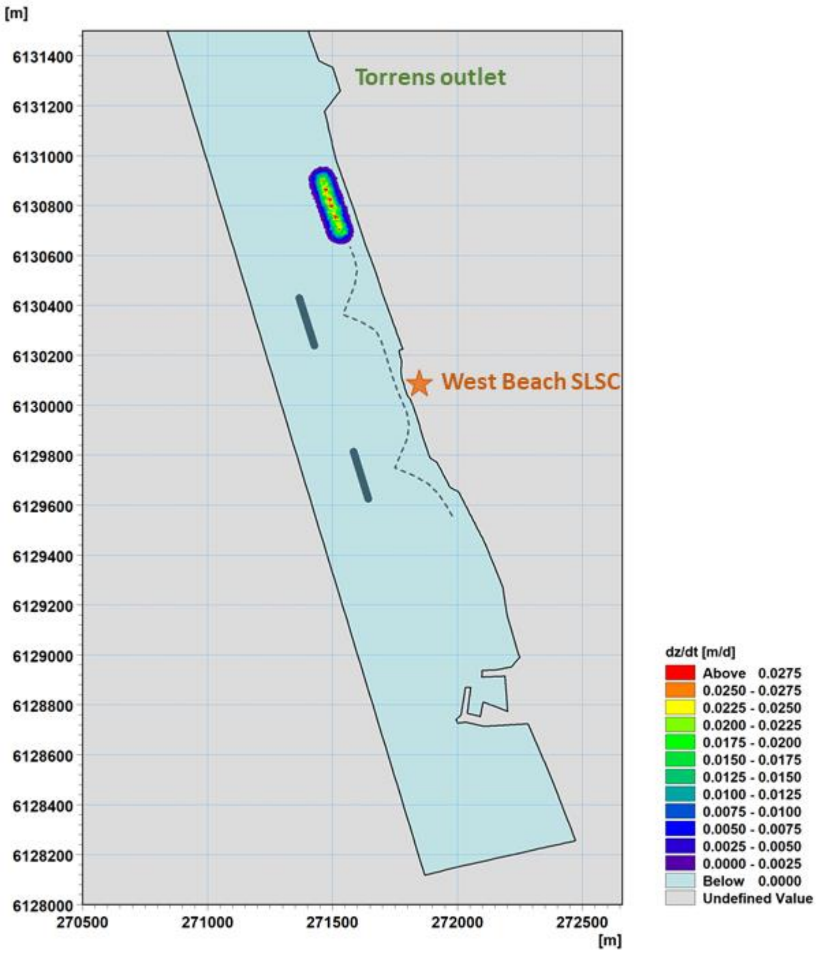

Figure 3.1 Bed level source map for scenario 5b. Values are in m/day and signify rate of change in bed level due to beach replenishment.
The position of the breakwater and the initial nourishment are indicated in grey.

3.2 Results

The comparison of the predicted shoreline position after 2 years, 4 years, 6 years and 7.5 years for the structural scenarios are shown in Figure 3.3. To facilitate the comparison with the previously simulated management options, the results from the 4 scenarios described in Ref. /1/ are included as well.

As a reminder, the initial shoreline position at the beginning of the scenarios which include initial sand replenishment is indicated in Figure 3.2.

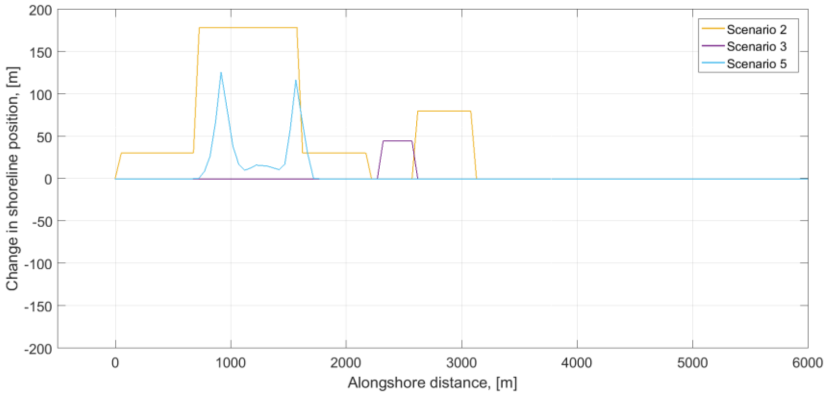

Figure 3.2 Initial shoreline positions for the scenarios requiring preliminary replenishment (Scenario 5a and 5b have similar initial shorelines).

The following comments can be made on the 2 additional scenarios (5a and 5b), in comparison with the previously reported management options:

- The coastline updrift and in the lee of the breakwaters is stabilised after an initial adjustment of the shoreline in the first 2 years from the artificial initial condition.
- In **Scenario 5a**, the sand is trapped in the lee of the breakwaters and therefore provides the expected protection at West Beach. However, significant downdrift erosion is predicted just north of the second breakwater due to lack of sand coming from the south. The presence of the offshore breakwaters therefore shifts the acute erosion problem from just north of the boat ramp to just north of the structures. The magnitude of the downdrift erosion is significant and even more pronounced than in the Scenario 1 ("do nothing"). This is because the structures trap all the sand on the south end of West Beach, so the supply of sand to the northern beaches is reduced to practically nothing.
- The additional mitigation in the form of nourishment in the order of 115,000 m^3/yr included in **Scenario 5b** provides sufficient supply of sand to counter the chronic erosion along the beach downdrift from the structure seen in Scenario 5a. It can also be noted that part of the sand discharged north of the breakwaters is occasionally transported towards south when waves are coming from north and therefore accumulates in the lee of the structures.

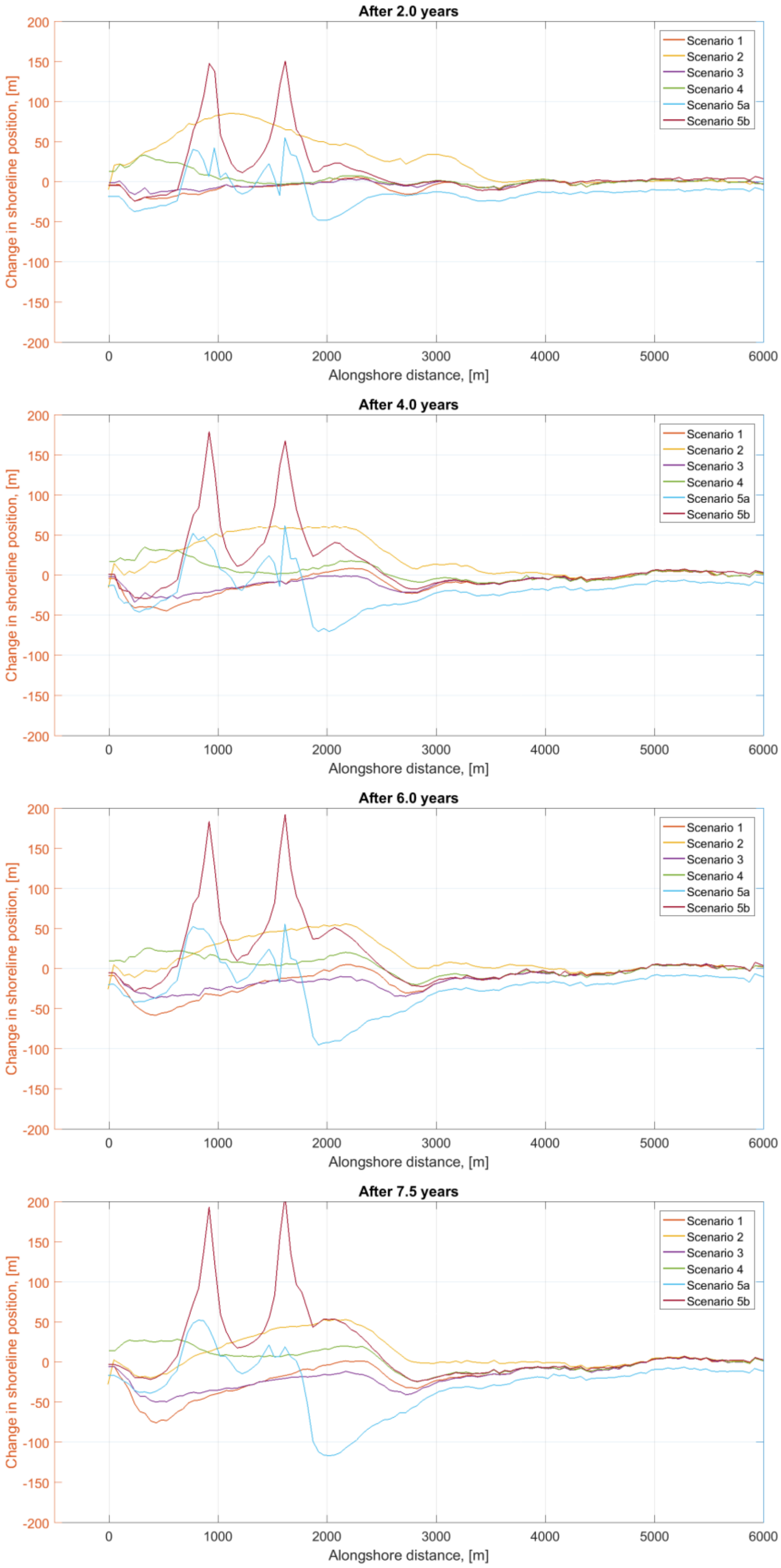

Figure 3.3 Simulated evolution of the shoreline for the 6 management options.

4 Discussion

The modelling results presented in 3.2 highlight the following results:

- The tested breakwaters would provide local protection along the shoreline by maintaining salients in the lee of the structures.
- The consequence of the stabilisation of this stretch of coast is a significant erosion just north of the structures, due to the lack of sand supply from south, as it is now trapped by the structures. In other words, the structures simply translate the erosion problem at West Beach further north.
- In the tested scenarios, a significant volume of sand has been introduced to prefill the salients anticipated to be formed in the lee of the structures. Without this initial filling, the salients would be generated by captured sand travelling from south (mostly) and from north (occasionally) and the resulting erosion would be significantly higher due to the initial building of the salients.
  This highlights the importance of associating the construction of the breakwaters with the pre-filling of the salients.
- To counter the chronic erosion just north of the structures, additional intervention would be required, as if no structures were built. A total volume of approximately 115,000 m^3/yr (in the order of magnitude of the estimated littoral drift) seem to be sufficient to counter the erosion downdrift of the structures.
  Alternatively, an option would be to repeat these structures all the way to Semaphore in order to stabilise the entire stretch of coast, which would result in a very expensive solution. This alternative solution would also require significant volumes of additional sand in order to prefill the salients in the lee of each structure.

Other types of structures such as groynes could have been tested. However, the conclusion detailed above would still valid for this type of structures since structures do not solve the underlying problem which is lack of sand supply.

In addition to the sand-related considerations, the following comments can be made regarding the shore-parallel breakwater as constructed in Semaphore:

- Structures may capture seagrass wrack which cannot easily be removed. If this is the case, the trapped seaweed may rot and cause bad smells.
- The lee zone eddies generated by the structure may be dangerous for swimmers.
- As they obscure the view of the sea, many people perceive that coastal breakwaters are unsightly because they constitute a foreign element in the coastal landscape.

5 References

/1/ DHI, August 2018, *West Beach Coastal Modelling Processes, Assessment of Coastal Management Options.* Technical report prepared for DEW.

/2/ DHI, February 2017, *Shoreline Management Guidelines.* Book publicly available: https://www.dhigroup.com/upload/campaigns/ShorelineManagementGuidelines_Feb2017.pdf.