

Appendix 13

How do the computational modelling scenarios relate to reality?

Southern North Sea Sediment Transport Study, Phase 2 Sediment Transport Report

Appendix 13 How do the computational modelling scenarios relate to reality?

This Appendix is intended to be read in conjunction with Appendix 12 to the main report on computational modelling of sediment transport by tide, waves and surge.

Sediment transport in coastal waters depends primarily on the strength of the currents and the oscillatory velocities at the seabed produced by waves. The waves stir up the sediment (aided by the current), which is then transported by the current. The pattern of currents is produced by a combination of forcing by tides, winds and waves. In the Southern North Sea the tides are the dominant factor in generating currents, but wind and wave forcing cannot be ignored. This is especially true when considering the long-term net sediment transport, since in many areas the tidal currents are approximately symmetrical. Exactly symmetrical flood and ebb half-cycles would yield zero net sediment transport, so it is the departures from symmetry of the tidal currents, and the bias in wind- and wave-driven currents, that are important in determining the long-term sediment transport paths.

Taken over time-scales of decades, the sediment transport paths are the resultant of a large number of combinations of tide, wind and waves. Thus a representative selection of scenarios has been modelled in this study. The mean transport could be determined by taking a weighted mean of the individual scenarios, in which the weighting factor is the proportion of total time occupied by each scenario. An approximate indication of the time occupied by each scenario is given below.

Mean Spring Tide:

Spring tides occur every 14.8 days on average. The pattern of peak sediment transport rates depends on the degree of tidal asymmetry, with their directions and magnitudes determined by the strongest current (flood or ebb).

On the coastline of the study area, the Mean Spring tidal range varies from 5.7 m at Spurn Head, through 1.9 m at Lowestoft, to 3.8 m at Walton-on-the-Naze. However, individual spring ranges vary considerably about these values. Taking all the 24 spring tides in the year 2000 (for example), at Spurn Head three spring tides had a range as small as 5.0 m, and two as large as 6.9 m, compared with the mean of 5.7 m.

It is implicit in the scenario “Mean Spring Tide” that wave effects are negligible. If we take this to mean that the significant wave height H_s is less than 0.5 m, then long-term wave records at the Dowsing Light Vessel (Draper, 1991) (towards the centre of the study coastline), show that $H_s < 0.5$ m for 13% of the time.

Mean Neap Tide:

Neap tides also occur every 14.8 days on average. The Mean Neap Tide range in elevation varies along the study coastline from 2.8m at Spurn Head, through 1.1 m at Lowestoft, to 2.3 m at Walton-on-the-Naze.

The Mean Neap range is thus between about 50% and 60% of the Mean Spring range on this coastline. The peak current speeds on Mean Neap tides are also much smaller than on Mean Spring tides (typically between 50% and 60%). The sediment transport rate varies strongly with current, typically proportional to $U(U-U_{cr})^{2.4}$ (Soulsby, 1997), where U is the current speed, and U_{cr} is the threshold current speed below which sediment does not move. This means that for many locations the sediment transported on neap tides is considerably less than that which occurs on spring tides.

Mean Spring Tide plus Wave Stirring:

The addition of waves to a current greatly enhances the sediment transport rate, provided that the water is sufficiently shallow that the wave-induced oscillatory velocities penetrate to the seabed. The effect of the waves increases with wave height and wave period, and decreases with water depth. Waves can cause sediment to be transported by a current whose speed is less than the threshold value U_{cr} , due to their stirring effect. At current speeds slightly above threshold the waves can enhance the sediment transport rate by as much as 100 times. For larger current speeds the wave enhancement factor reduces, but can still be a factor of 10 for $U_{cr} = 1.0 \text{ ms}^{-1}$.

The modelling study took wave inputs of significant heights (H_s) and mean periods (T_m) of: 5 m and 10 s; 3 m and 10 s; 3 m and 6 s; 1 m and 5 s. The proportions of the time corresponding to these cases can be obtained from the long series of wave records at Dowsing Light Vessel (Draper, 1991). Dividing the waves into classes yields:

Class	Wave height H_s (m)	Wave period T_m (s)	Occurrence (% of time)
1	$0 < H_s < 0.5 \text{ m}$	All periods	13%
2	$0.5 \text{ m} < H_s < 2 \text{ m}$	All periods	70%
3	$2 \text{ m} < H_s < 4 \text{ m}$	$T_m < 8 \text{ s}$	15%
4	$2 \text{ m} < H_s < 4 \text{ m}$	$T_m > 8 \text{ s}$	0.8%
5	$H_s > 4 \text{ m}$	all periods	1.2%

Thus:

- Class 2, represented by $H_s = 1 \text{ m}$ and $T_m = 5 \text{ s}$ occurs for much the largest proportion of the time, but has relatively little effect on the sediment transport.
- Class 3, represented by $H_s = 3 \text{ m}$ and $T_m = 6 \text{ s}$, occurs for a significant fraction of the time and also has a significant enhancement effect on the sediment transport.
- Classes 4 and 5 both have a large effect on the sediment transport, but occur very rarely.

Class 4, represented by $H_s = 3 \text{ m}$ and $T_m = 10 \text{ s}$ can be considered representative of swell waves. These long-period waves, generated by Atlantic storms, penetrate readily to the seabed and stir up the sediments. Swell waves measured off Mablethorpe had periods of 8 to 14 s and heights up to 3.5 m (Hawkes et al, 1997). Within the study area, the largest swell occurs off south Norfolk/north Suffolk (Hawkes et al, 1997).

Mean Spring Tide plus Winter Wind:

Wind generates a drag on the sea surface so that water moves with the wind. This can produce a bias in the currents, which modifies the patterns of residual currents and net sediment fluxes produced by the tides alone. The effect on the current is proportional to the wind speed. It has a much stronger effect on the sediment transport, because of the strong dependence on current speed described earlier. Thus the sediment transport patterns in winter, when winds tend to be strongest, may be different to those in summer.

Mean Spring Tide plus (February 1993) Surge:

On rare occasions the track of North Atlantic depressions can be such as to stimulate, through the action of wind and atmospheric pressure, a surge of elevated water that runs at the same speed as the tidal wave southwards down the east coasts of Scotland and England. These are most damaging when they coincide with the movement of High Water of Spring Tides. They influence the sediment transport through various mechanisms:

- larger than normal currents
- higher than normal elevations reaching normally dry areas of beach or soft cliff

How do the computational modelling scenarios relate to reality?

- high waves generated by the winds producing enhanced stirring
- bias of the tidal currents by the winds.

The February 1993 surge was chosen because it had a large effect on water levels in the Lowestoft area. In terms of surge elevation, this surge had a 20-year return period.

However, individual surges can vary considerably in all the effects listed above, depending on the exact meteorological conditions, so this example should not be treated as representative of all surges, but provides a clear indication as to the magnitude of effect of a large surge event. The influence of surge events is discussed more generally in Appendix 7 to the main report.

References

Draper, L. (1991). Wave climate atlas of the British Isles. Offshore Technology Report, OTH 89 303, Department of Energy.

Hawkes, P J, Bagenholm, C, Gouldby, B P and Ewing, J. (1997). Swell and bi-modal wave climate around the coast of England and Wales. HR Wallingford Report, SR409, November 1997.

Soulsby, R L (1997). Dynamics of Marine Sands. Thomas Telford.

How do the computational modelling scenarios relate to reality?