Appendix 14

Summary of sediment sources and sinks

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

Appendix 14 Summary of sediment source and sinks

In this report the sources and sinks of sedimentary material have been summarised at a coastal subcell level within Cells 2, 3 and 4 (Motyka and Brampton, 1993). The details of sources or sinks in each of the subcells, as well as boundary activity are given below. This review was based on published information available during Stage 1 of the study (to April 2001).

At the time of finalising the main report (July 2002) additional information has been presented on the geological context of sources, pathways and sinks (Appendix 10 to the main report) and the results from the computational modelling of sediment transport have been used to examine the boundary fluxes (Appendix 12 to the main report).

The information has been summarised in a series of tables:

Table 1 sources
Table 2 sinks
Table 3 pathways

Conversions from volume to dry mass in tonnes has been made assuming the dry density of sediment was 2000 kg/m^3. The quoted unit M tonnes is equivalent to 10^9 kg.

Subcell 2a – Flamborough Head to Sunk Island

Sources
Subcell 2a covers the Holderness coast which is renowned for crumbling cliffs and wave-induced erosion. Unsurprisingly then, this subcell contains a large source of both fine and medium sediments, which originate from cliff and coastal erosion. Estimates of the quantity of fine sediment supplied to the North Sea from this region vary between 1.4 and 4.8 M tonnes per year (McCave, 1987, Balson, 1999). Medium sediment supply is estimated to be 1.1 to 2.4 M tonnes per year (ABP, 1996, Balson, 1999) and Balson (1999) suggested that up to 0.8 M tonnes per year of coarse material enters the North Sea from the Holderness cliffs.

The Humber estuary is also a source of sediment to the North Sea with between 0.05 and 0.225 M tonnes of fine and medium sediment entering the North Sea per year with a greater portion of the total amount arriving in the winter months (Odd and Murphy, 1992, Gerritsen *et al*., 2000

Sinks
The saltmarshes on the northern side of the Humber estuary are a sink for fine grained sediments which enter the estuary from the Lincolnshire coast and from Holderness around Spurn Head (ABP, 1996).

General
There is a general southern movement of sediment along the Holderness coast with most of the fine sediment being carried offshore and eventually deposited in the German Bight or the Thames estuary (ABP, 1996).

Subcell 2b – Immingham to Donna Nook

Sources
Dumping of dredging waste is common in the Humber area and this is a source of fine sediment to the North Sea system of approximately 3.41 M tonnes per year (Gerritsen *et al.*, 2000).

Sinks
Although the Humber is a source of fine and medium sediments, the saltmarshes on its northern and southern banks are sinks for recirculated fine sediments. McCave (1987) estimated that 0.0634 M tonnes of sediment accumulates each year in the saltflats of the Humber estuary.

General
The local circulation in the Humber estuary region is such that fine and medium sediment are output across the width of the estuary and fine sediments only move up the estuary on the southern shore (ABP, 1996).

Subcell 2c – Donna Nook to Gibraltar Point

Sources
Cliff and coastal erosion are the main sources of sediment (fine and medium) in this subcell. ABP (1996) estimate a total of 0.045 M tonnes per year of fine sediment is derived from the Lincolnshire coast and supplied to the North Sea. Some offshore banks in the region may act as sources of medium sediments during extreme tidal conditions (Motyka and Brampton, 1993).

Sinks
There is a general accretion of fine and medium sediments at Gibraltar Point (ABP, 1996).

General
Offshore of the coast at this point are sand waves whose asymmetry indicated a northwards movement of sediment[1] (ABP, 1996), however, the coastal transport of sediment is on average directed south.

Subcell 2d – Gibraltar Point to Snettisham

Sources
There are effectively no sources in the Wash area.

Sinks
The Wash is generally considered to be a relatively large sink in the North Sea system. Sediments eroded from the Lincolnshire coast are transported into the Wash for deposition along with sediments from other regions of the Norfolk coast. Fine sediment in the range 0.79 to 6.8 M tonnes per year (ABP, 1996, McCave, 1987) are deposited in the Wash with approximately 0.014 M tonnes per year of medium sediment also being deposited (ABP, 1996).

General
Although rivers do carry sediment into the Wash it generally does not tend to leave the area and thus does not contribute to the sediment transported in the North Sea system (ABP, 1996).

[1] The results for sandwave asymmetry in the present study (Appendix 15 to the Sediment Transport Report, EX4526) indicate transport to the south.

Subcell 3a – Snettisham to Sheringham

Sources
Sediment may be eroded from the offshore features such as sand banks and deposited on the North Norfolk coastline, however, it is generally accepted that this transport is insignificant in comparison to the erosion of the coast and cliffs in this region. These contribute up to 2.4 M tonnes per year (Odd and Murphy, 1992) of fine and medium sediment to the North Sea.

Sinks
The north Norfolk marshes are a sink for fine sediment where approximately 0.104 M tonnes accumulates per year (McCave, 1987).

General
Sediment is generally transported in a westerly direction along this coast with much of the fine sediment being deposited in the Wash area. There is a 'drift parting' located in the region of Sheringham (ABP, 1996).

Subcell 3b – Sheringham to Lowestoft

Sources
Cliff erosion of up to 0.8 M tonnes per year (Balson, 1999) and coastal erosion of up to 0.665 M tonnes per year (McCave, 1987) contribute as a source to the North Sea system from this subcell region. Banks located offshore can contribute medium sediment to the North Sea sediment concentration during extreme storm events (ABP, 1996).

Sinks
Although no quantitative data is available for this area, it is speculated (ABP, 1996) that the bank system offshore of this subcell is a long term sink of sediment derived from the coastal region.

General
There is a large eastwards plume carrying suspended sediment offshore in this area (ABP, 1996, Dyer and Moffatt, 1998). The plume is much more defined in winter and coincides with the location of the north Norfolk offshore banks. Apart from this plume, the general transport of sediment is in a southwards direction.

Subcell 3c – Lowestoft to Felixstowe

Sources
Again, in this subcell, cliff erosion is a major sediment source with up to 1.2 M tonnes per year of material being liberated from the coastal region (Odd and Murphy, 1992).

Sinks
This region exhibits a large number of ness structures which are generally considered to be sediment sinks but which are mobile and exhibit periodic changes in their morphology and coastal location. Medium and coarse sediment appear to accumulate at the points where the coastal orientation changes giving rise to ness structures (ABP, 1996). Offshore banks in this region are also sediment sinks with a growth and decay cycle of 100-150 years (ABP, 1996).

General
Most sediment transport in the subcell is southwards along the coast with some offshore directed flux to the offshore banks (ABP, 1996).

Subcell 3d – Felixstowe to Canvey Island

Sources
A relatively large number of rivers enter the North Sea in this subcell providing a source of approximately 3.75 M tonnes per year of fine sediment (Odd and Murphy, 1992). The Thames estuary is also a source in this area of fine sediments producing between 0.24 and 0.69 M tonnes per year (Gerritsen *et al.*, 2000, Odd and Murphy, 1992). The area offshore of the Thames is used for dumping the products of dredging and this practice is a source of 0.3 M tonnes per year of fine sediment (Gerritsen *et al.*, 2000). The coast in this area is also eroding at a rate of 0.12 M tonnes of fine sediment per year (ABP, 1996).

Sinks
As the rivers entering the North Sea through this subcell provide a supply of sediment, so the mudflats and saltmarshes on their perimeters provide a sink for approximately 0.1 M tonnes of fine sediments (McCave, 1987) per year. The Thames estuary, the largest of the estuary systems in this area, also acts as a sink for fine sediment although how much accretion occurs in the Thames is unknown (ABP, 1996).

General
There is a general southwards trend of sediment transport along the coast in this cell although tidal currents appear to disperse sediment offshore after erosive events (Motyka and Brampton, 1993).

Subcell 4a – Isle of Grain to North Foreland

Sources
There is a substantial amount of cliff erosion at the Isle of Sheppey where 0.45 M tonnes of fine and medium sediment enters the North Sea per year (Nicholls *et al.*, 2000). There is some evidence of saltmarsh erosion in the area also which contribute between 0.015-0.03 M tonnes per year of fine sediment to the North Sea system (ABP, 1996).

Sinks
The sinks in this subcell are most likely to be the shallow flats and banks.

General
There is a westwards flow of sediment along the coast of this subcell with reduced flux values as the Thames estuary is approached (Motyka and Brampton, 1993).

Study Area Boundaries

Northern
There is a general, unquantified southwards flux over the northern boundary of the study region (Motyka and Brampton, 1993).

Eastern
A large plume of suspended fine sediments exists in the region of the north Norfolk offshore banks (especially in the winter months when the sediment concentrations are increased), this passes through the eastern boundary of the study area (Dyer and Moffatt, 1998).

Dover Straits
According to Velegrakis *et al.* (1999) sediment enters the study region through the Dover Straits at a rate of between 2.5 and 44.6 M tonnes of fine sediment per year.

References

ABP 1996 Southern North Sea Sediment Transport Study - Literature review and conceptual sediment transport model. May 1996, Report No. R546, ABP Research and Consultancy Ltd, Southampton

Balson, P. S. 1999 The holocene coastal evolution of eastern England: evidence from the offshore southern North Sea. In: *ASCE Coastal Sediments '99 Volume Two*. Ed.: N. C. Kraus and W.G. McDougal. pp 1284-1294

Dyer, K. R. and T. J. Moffat 1998 Fluxes of suspended matter in the East Anglian plume Southern North Sea. *Cont. Shelf Res.*, **18.** pp 1311-1331

Eisma, D. and J. Kalf 1987 Dispersal, concentration and deposition of suspended matter in the North Sea. *J. Geol. Soc*., *London*, **144.** pp 161-178

Gerritsen, H., R. J. Vos, T. van der Kaaij, A. Lane and J. G. Boon 2000 Suspended sediment modelling in a shelf sea (North Sea). *Coast. Engng*., **41**. pp 317-352

Huthnance, J. M. 1991 Physical oceanography of the North Sea. *Ocean & Shoreline Management*, **16.** pp 199-231

McCave, I. N. 1987 Fine sediment sources and sinks around the East Anglian Coast (UK). *J. Geol. Soc., London*, **144.** pp 149-152

Motyka, J. M. and A. H. Brampton 1993 Coastal Management: Mapping of littoral cells. Report SR 328, HR Wallingford, UK.

Nicholls, R. J., A. Dredge and T. Wilson 2000 Shoreline change and fine-grained sediment input: Isle of Sheppey Coast, Thames Estuary, UK. In: *Coastal and Estuarine Environments: sedimentology, geomorphology and geoarchaeology*. Eds.: K. Pye and J. R. L. Allen. Geological Society, London, Special Publications **175**. pp 305-315

Odd, N. V. M. and D. G. Murphy 1992 Particulate Pollutants in the North Sea. Report SR 292, HR Wallingford, UK.

Velegrakis, A. F., D. Michel, M. B. Collins, R. Lafite, E. K. Oikonomou, J. P. Dupont, M. F. Huault, M. Lecoutourier, J. C. Salomon and C. Bishop 1999 Sources, sinks and resuspension of suspended particulate matter in the eastern English Channel. *Cont. Shelf Res*. **19.** pp 1933-1957

Subcell/Boundary	Type	Frequency	Location	Sediment Size	Quantity/Comments	Dry Mass (M tonnes/yr)	Reference
2a Flamborough Head-Sunk Island	Cliff Erosion	Mostly winter	Holderness	F	1.4-1.8e6 m^3/yr - transported offshore as suspension	2.8-3.6	ABP (1996)
					3.9e6 dry tonnes/yr	3.9	Odd and Murphy (1992)
					1.4e6 tonnes/yr - unknown whether wet or dry measurement	1.4	McCave (1987)
					1.8-2.4e6 m^3/yr - 60% of estimated total	3.6-4.8	Balson (1999)
	Cliff Erosion	Mostly winter	Holderness	M	0.55e6 m^3/yr - mostly transported south as bedload in longshore drift	1.1	ABP (1996)
					0.9-1.2e6 m^3/yr - 30% of estimated total	1.8-2.4	Balson (1999)
	Cliff Erosion	Mostly winter	Holderness	C	0.3-0.4e6 m^3/yr - 10% of estimated total	0.6-0.8	Balson (1999)
	Estuary	Increased in winter	Humber	F+M	0.225e6 dry tonnes/yr	0.225	Odd and Murphy (1992)
				F	0.05e6 tonnes/yr	0.05	Gerritsen *et al.* (2000)
					0.13e6 dry tonnes/yr	0.13	Delft
2b Immingham-Donna Nook	Dumping	Annual	Humber	F	3.41e6 tonnes/yr	3.41	Gerritsen *et al.* (2000)
2c Donna Nook-Gibraltar Point	Coastal Erosion	Annual	General	F	0.0225e6 m^3/yr	0.045	ABP (1996)
2d Gibraltar Point-Snettisham							

Table 1 Summary of sources for the study area. Sediment size key: F – Fine (muds, silts), M – Medium (sands), C – Coarse (gravels).

Subcell/Boundary	Type	Frequency	Location	Sediment Size	Quantity/Comments	Dry Mass (M tonnes/yr)	Reference
3a	Coastal Erosion	Annual	Snettisham-Gore Point	F+M	0.018e6 m^3/yr	0.036	ABP (1996)
Snettisham-Sheringham			Gore Point-Brancaster	F+M	0.0016e6 m^3/yr	0.0032	ABP (1996)
			Brancaster-Burnham	F+M	0.0025e6 m^3/yr	0.005	ABP (1996)
			Wells-Blakeney Point	F+M	0.0035e6 m^3/yr	0.007	ABP (1996)
			Blakeney Point-Sheringham	F+M	0.017e6 m^3/yr	0.034	ABP (1996)
			Gore Point	F+M	2.4e6 dry tonnes/yr	2.4	Odd and Murphy (1992)
			Sheringham	F+M	2.0e6 dry tonnes/yr	2	Odd and Murphy (1992)
3b	Cliff Erosion	Annual	Sheringham-Cromer	F+M	0.07e6 m^3/yr	0.14	ABP (1996)
Sheringham-Lowestoft			Cromer-Walcott	F+M	0.025e6 m^3/yr	0.05	ABP (1996)
			General	F	0.17-0.2e6 m^3/yr - 1/3rd of total of 0.5-0.6e6	0.34-0.4	Balson (1999)
				M+C	0.33-0.4e6 m^3/yr - 2/3rds of total of 0.5-0.6e6	0.66-0.8	Balson (1999)
	Coastal Erosion	Annual	Gorleston-Lowestoft	F+M	0.005e6 m^3/yr	0.01	ABP (1996)
			Cromer	F	0.665e6 tonnes/yr	0.665	McCave (1987)
	Offshore Banks	During extreme storms	General	M	Unknown		ABP (1996)
3c Lowestoft-Harwich	Coastal Erosion	Annual	Thorpness	F	1.2e6 dry tonnes/yr	1.2	Odd and Murphy (1992)
			Lowestoft-Southwold	F+M	0.017e6 m^3/yr	0.034	ABP (1996)

Table 1 Sources (cont.)

Subcell/Boundary	Type	Frequency	Location	Sediment Size	Quantity/Comments	Dry Mass (M tonnes/yr)	Reference
3d	Coastal Erosion	Annual	General	F	0.12e6 tonnes/yr	0.12	ABP (1996)
Harwich-Canvey Island	Estuary	Annual	The Naze	F	3.75e6 dry tonnes/yr	3.75	Odd and Murphy (1992)
			Thames	F	0.69e6 dry tonnes/yr	0.69	Odd and Murphy (1992)
					0.24e6 tonnes/yr	0.24	Gerritsen *et al.* (2000)
	Dumping	Annual	Thames	F	0.3e6 tonnes/yr	0.3	Gerritsen *et al.* (2000)
4a	Saltmarsh Erosion	Annual	General	F	0.0075-0.015e6 m^3/yr	0.015-0.03	ABP (1996)
Isle of Grain-North Foreland	Cliff Erosion	Annual	Isle of Sheppey	F	0.45e6 tonnes/yr	0.45	Nicholls *et al.* (2000)
Dover Straits	Influx	Annual	General	F	2.5-44.6e6 tonnes/yr	2.5-44.6	Velegrakis *et al.* (1999)
					22-30e6 tonnes/yr	22-30	Huthnance (1991)
					10e6 tonnes/yr	10	Eisma and Kalf (1987)
					13.6e6 tonnes/yr	13.6	Gerritsen *et al.* (2000)
Eastern Boundary							
Northern Boundary				F	10.5e6 tonnes/yr - supply from North Atlantic, not necessarily over northern boundary of study region	10.5	Gerritsen *et al.* (2000)
Sea bed erosion				F	6-7.5e6 tonnes/yr	6-7.5	Dyer and Moffat (1998)
					9-13.5e6 tonnes/yr - value for whole of North Sea area	9-13.5	Gerritsen *et al.* (2000)

Table 1 Sources (cont.)

Subcell/Boundary	Location	Frequency	Sediment Size	Quantity/Comments	Dry Mass (M tonnes/yr)	Reference
2a Flamborough Head-Sunk Island	Coastal Sand Dunes	Annual	M	Unknown		ABP (1996)
2b Immingham-Donna Nook	Humber Estuary and Saltmarshes	Annual	F	0.0634e6 tonnes/yr	0.0634	McCave (1987)
2c Donna Nook-Gibraltar Point	Gibraltar Point	Annual	F	Unknown		ABP (1996)
2d Gibraltar Point-Snettisham	The Wash	Annual	F	6.8e6 tonnes/yr - rivers entering Wash area do not contribute to North Sea SPM budget 0.79-1.6e6 tonnes/yr	6.8 0.79-1.6	ABP (1996) McCave (1987)
			M	0.014e6 tonnes/yr	0.014	ABP (1996)
3a Snettisham-Sheringham	North Norfolk Marshes	Annual	F	0.104e6 tonnes/yr	0.104	McCave (1987)
3b	Inshore banks	During summer	M	Unknown - speculation		ABP (1996)
Sheringham-Lowestoft	Offshore banks	Longterm	M	Unknown - evidence suggests that the north Norfolk offshore banks are a result of modern hydrodynamics		ABP (1996)

Table 2 Summary of sinks in study area. Sediment size key as Table 1

Subcell/Boundary	Location	Frequency	Sediment Size	Quantity/Comments	Dry Mass (M tonnes/yr)	Reference
3c	Orfordness	Cyclic	C	Unknown - speculation		ABP (1996)
Lowestoft-Harwich	Nesses	Periodic	M+C	Unknown - Mobile sinks which form where orientation of the coast changes and migrate north and south along the coast		ABP (1996)
	Offshore banks	Periodic	M+C	Unknown - Grow and decay on a 100-150 year cycle		ABP (1996)
3d	Estuaries - General	Annual	F	0.1e6 tonnes/yr	0.1	McCave (1987)
Harwich-Canvey Island	Thames	Annual	F+M	Unknown		ABP (1996)
4a Isle of Grain-North Foreland						
Dover Straits						
Eastern Boundary	Outflux	Mostly in winter	F	6.6e6 tonnes/yr - sediment transport pathways indicate sediment travels out of study region via plume over north Norfolk sand banks and much is deposited in the German Bight	6.6	ABP (1996)
			F	6-7.5e6 tonnes/yr - plume moving eastwards over Norfolk sand banks region, 25-30% of a total of 25e6 tonnes/yr moving over 3^{o}E line of longitude	6-7.5	Dyer and Moffat (1998)
Northern Boundary	Outflux	Annual	F	11.4-14.3e6 tonnes/yr - flux to North Atlantic, not restricted to study area	11.4-14.3	Gerritsen *et al.* (2000)
Sea bed deposition	Outer Silver Pit	Annual	F	1-4e6 tonnes/yr	1-4	Gerritsen *et al.* (2000)
	Oyster grounds	Annual	F	2e6 tonnes/yr	2	Dyer and Moffat (1998)

Table 2 Sinks (cont.)

Subcell/Boundary	Direction	Sediment Size	Comments	Reference
2a Flamborough Head-Sunk Island	Southwards	F+M		ABP (1996)
2b	Westwards	F	Southern coast of the Humber estuary only	ABP (1996)
Immingham-Donna Nook	Eastwards	F+M	Discharge from Humber estuary	ABP (1996)
2c Donna Nook-Gibraltar Point	Southwards	F		ABP (1996)
2d Gibraltar Point-Snettisham			No general transport - whole area is a sink	ABP (1996)
3a Snettisham-Sheringham	Westwards	F	Transported into the Wash Drift parting located at Sheringham	ABP (1996) ABP (1996)
3b	Southwards	F		ABP (1996)
Sheringham-Lowestoft	Offshore	M	Contributing to maintenance of offshore banks	ABP (1996)
3c	Southwards	M+C		Motyka and Brampton (1993)
Lowestoft-Harwich	Offshore	M	Contributing to maintenance of offshore banks	ABP (1996)
3d	Southwards	F+M	Transport around the coast into the Thames estuary	ABP (1996)
Harwich-Canvey Island	Offshore	F	After storms, tidal transport seawards	Motyka and Brampton (1993)
4a Isle of Grain-North Foreland	Westwards	F+M		Motyka and Brampton (1993)
Dover Straits	Northeastwards		Influx to study area	ABP (1996)
Eastern Boundary	Eastwards		Most flux is out of the study area over the north Norfolk sand bank field	ABP (1996)
Northern Boundary	Southwards		Along coast flux from northern England into study area	ABP (1996)

Table 3 Summary of transport routes in study area