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Project: Regional Shingle Sediment Budget Report

Oldstairs Bay to Sandwich Bay

Environment Agency

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Issue	Revision	Description	Authorised
01	-	Draft Report for Consultation	J. Clarke
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Summary

A shingle sediment budget for Oldstairs Bay to Sandwich Bay was generated to gain an understanding of sediment movements through the frontage. The entire frontage is characterised by persistent longshore transport in a northerly direction.

- Deal shows a net export of sediment, losing 10,600m^3/yr. 400m^3/yr is thought to enter the frontage from the cliffs at South Foreland, causing Deal to export 11,000m^3/yr into Sandwich Bay. Oldstairs Bay and the groyne bays fronting Sandown Castle are shown as some of the areas that struggle to retain shingle.

- The sediment budget was split at Princes Golf Course, Sandwich Bay in an attempt to exclude the influence of fine sediment on the sediment budget. The northern section of Sandwich Bay is made up of predominately sandy beach material and so was not considered as part of the shingle sediment budget.

- Sandwich Bay shows a net import of sediment, gaining 8,000m^3/yr. Transport rates reduce with distance northwards, due to the reduced exposure to wave attack from the higher foreshore, and gradually reducing feed from updrift frontages. 3,000m^3/yr of shingle is transported past Princes Golf course entrained within the mixed composition of the beaches.

These trends are analysed over various temporal and spatial scales in the following report.

1.0 Introduction

This report details the regional shingle sediment budget for Oldstairs Bay to Sandwich Bay. A sediment budget is essential in defining longshore sediment transport rates, sediment pathways and areas of erosion and accretion, within defined boundaries, over a given period in time (Kana, 1995). The budget provides transparent and quantitative evidence of beach losses, gains and sediment pathways, in combination with both natural and artificial movements of beach grade material. The outcomes of this report will feed into Beach Management Plans (BMP). The report primarily focuses on the shingle sediment movement, as this has the most importance to beach management operations.

The data used for this report has been sourced from the Strategic Regional Coastal Monitoring Programme (SRCMP). The topographic beach data has been extensively collected since 2003 using ground based GPS measurements, LiDAR and bathymetric surveys. This data is analysed and reported over small management units, with very little regional analysis undertaken. Therefore, this report will take the local analysis to the regional scale to gain a greater insight into beach behaviour over interconnected sediment sub-cells.

The sediment budget is analysed over a range of spatial scales. Each spatial scale has been assigned a level relating to how much detail is provided, as shown below:

Level 1 – Very-fine analysis polygons
Level 2 – Fine analysis polygons
Level 3 – Coarse Sediment Budget
Level 4 – Regional Sediment Budget

The method for the production of the shingle sediment budget is discussed in detail in Appendix A. The transparent and repeatable methods will allow future budgets to be conducted and analysed using the same techniques developed here. The limitations and solutions in the methodology have been highlighted at the relevant stages and justifications made wherever possible.

2.0 Study Area

As this is a predominately shingle sediment budget, the analysis focuses around the beached frontages of Deal and Sandwich Bay. South Foreland to Hope Point have also been included in an attempt to identify possible sources of material. As the dominant drift direction is from South to North, management units are always considered with the most southerly unit first.

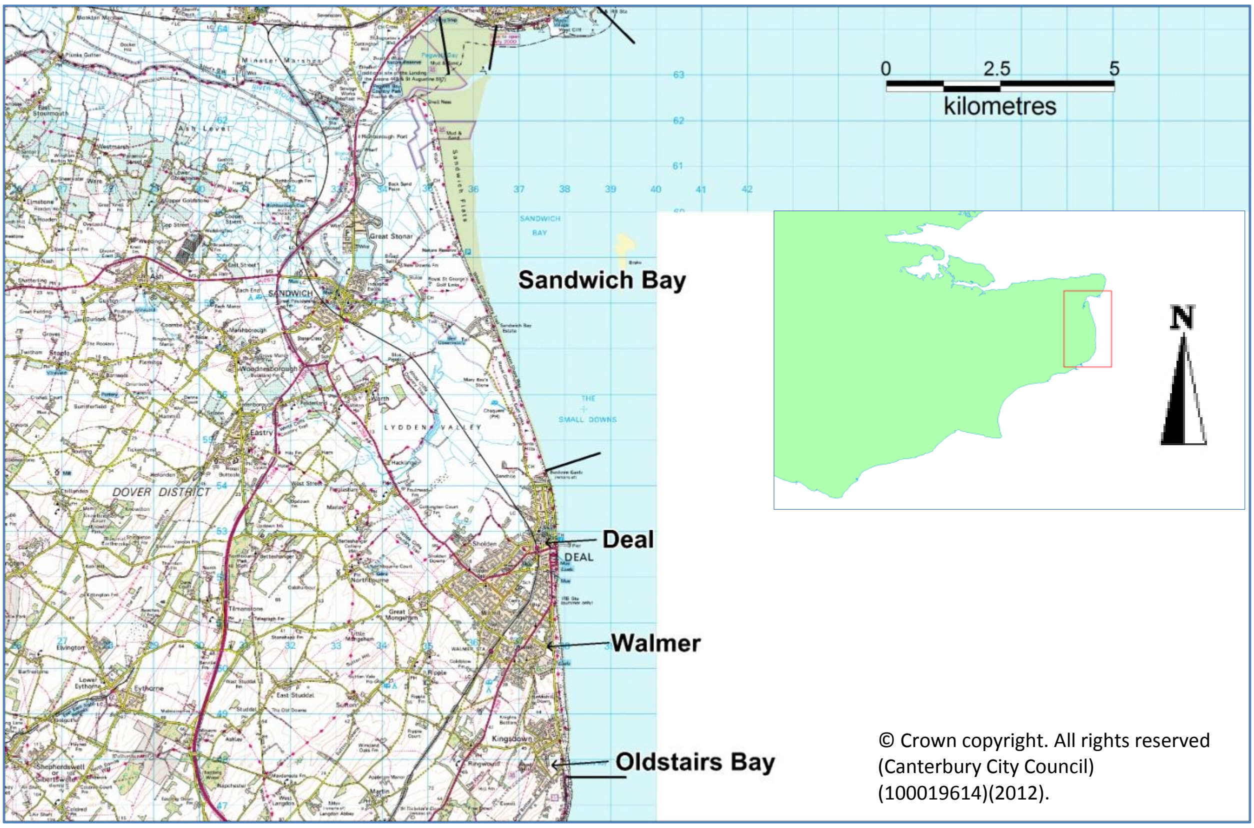


Figure 2-1 Location of study area

2.1 South Foreland to Hope Point

Cretaceous chalk cliffs extend from the most southerly point at South Foreland to the cliffs behind Oldstairs Bay. The cliffs, fronted by a chalk platform, are largely unprotected, providing a small amount of beach material through intermittent chalk falls. With the predominance of southerly waves, this material is eroded and transported northwards.

2.2 Oldstairs Bay to Sandown Castle

The low-lying beach from Oldstairs Bay to Sandown Castle is composed of coarse shingle thought to have been formed from offshore deposits. The beach is narrow in the south at Oldstairs Bay, getting wider at Walmer and then narrowing again in the north. The beach forms a steep slope angle at about 1:5 and the beach toe is typically not exposed at low water (at around -3.0mAOD). Net drift is in a northerly direction although this coast can be seen to be bidirectional under a northerly wave climate. Consequently, Oldstairs Bay shows a net loss of material (due to a limited feed from the cliffs at Hope Point). 45,000m^3 of recharged material was placed in the Bay in spring 2004 and regular recycling attempts to hold the coast in its current position.

2.3 Sandwich Bay

Sandwich Bay is a largely open stretch of coast extending from Sandown Castle to Pegwell Bay. The sediment type varies with distance northwards, composed of shingle in the south and predominately sand in the north. The beach toe is higher than at Deal reducing exposure to wave attack. The north of the unit contains Shellness Spit, historically a site of accretion. Nevertheless over recent years, the spit has begun eroding as the river Stour cuts into the spit. Pegwell Bay is made up of fine sediments with very little beach grade material. While there is the potential for material to move from north to south, it is thought the input from Pegwell Bay into Sandwich Bay is close to 0.

The sandy northern section has been excluded from analysis as this is predominately a shingle sediment budget. Figure 2.2 shows the change in beach morphology and grain size through Sandwich Bay. As the beach slope is a function of the grain size and the wave climate (and the wave climate should be relatively similar between these locations) this serves as a valuable indicator to the change in sediment type through the unit. In the south at Sandown castle, there is a very coarse sediment type with the beach showing a gradient of around 1:10. The beach becomes more mixed with distance northwards until the transitional zone at the Royal St Georges golf club. The profile shows a slight shallowing (1:12) as well as a more mixed grain size. The grain size becomes more mixed, until it is almost completely sand at the end of the transitional zone. The profile taken through the sandy section clearly shows the change in morphology to a sandy beach and consequently a slope of around 1:30. In an attempt to exclude the sand system from the shingle budget, the budget has been stopped at the Princes Golf Club. This does not form a complete littoral cell, so shingle will naturally be transported out of the unit. Therefore, this sediment budget cannot be completely balanced, with a volume of material being transported out of the unit.

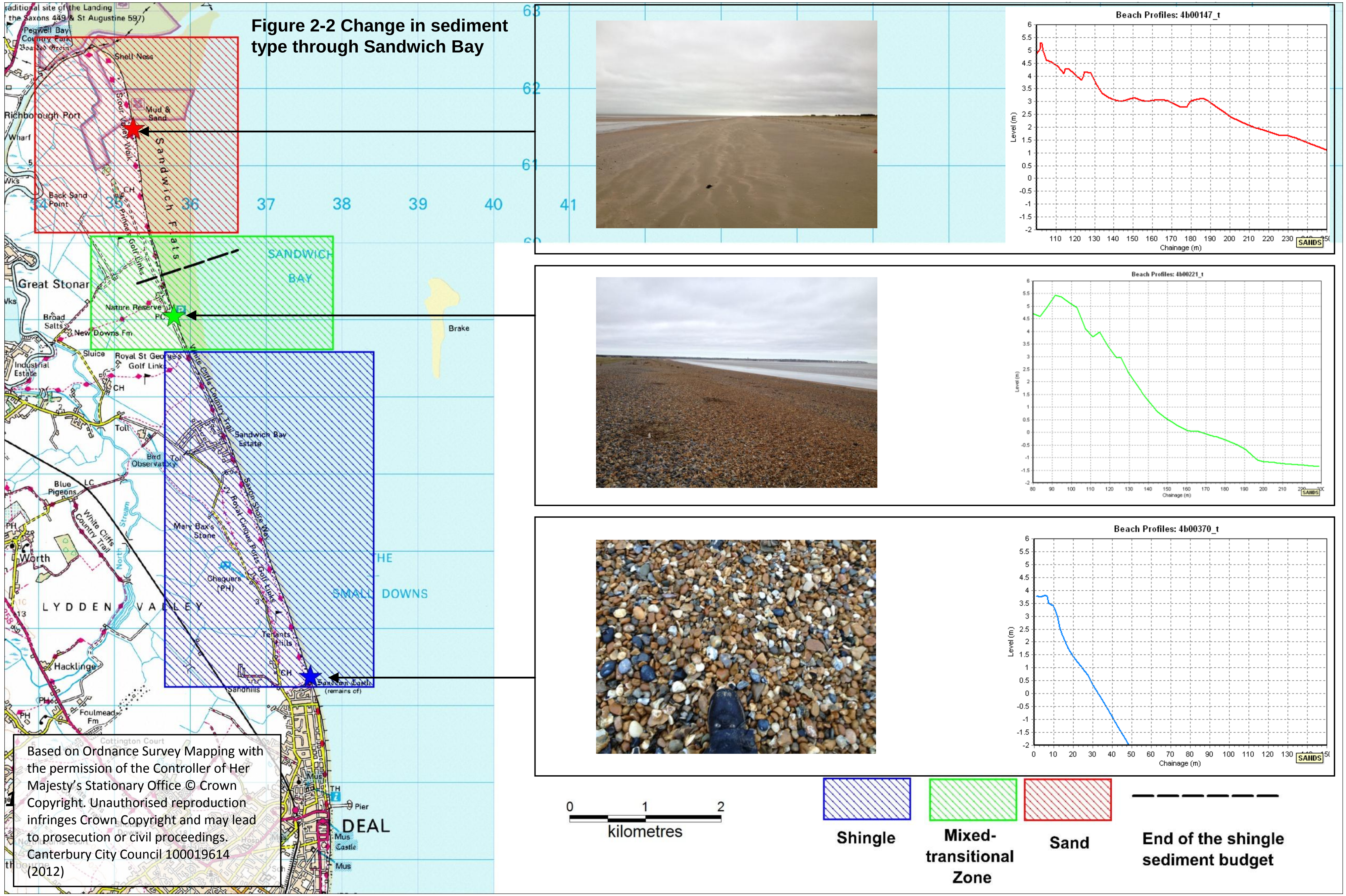


Figure 2-2 Change in sediment type through Sandwich Bay

3.0 Methodology

3.1 Source data

In order to undertake the sediment budget a review of all topographic data was conducted (Table 3.1). This review was focussed on the topographic survey data from both ground based GPS and aerial LiDAR sources, over the 2012-2003 period, the longest available timescale since regular monitoring began. Where both LiDAR and GPS measurements were available, GPS was preferentially chosen due to the tailored nature of the surveys. This data was used in the formulation of the sediment budget explained below. For more information, refer to Appendix A.

Table 3-1 Available DTM's and Difference Models for Frontages

Frontage	Management Organisation	SRCMP Survey Units (Phase III)	Available DTM's	Data Type	Difference models
South Foreland	Dover District Council	4cSU01	2008,2009,2011, 2012	Lidar	2008-2009, 2009-2011, 2011- 2012
St. Margaret's at Cliffe	Dover District Council	4bSU08	2008,2009,2011, 2012	Lidar	2008-2009, 2009-2011, 2011- 2012
Hope Point	Dover District Council	4bSU07	2008,2009,2011, 2012	Lidar	2008-2009, 2009-2011, 2011- 2012
Deal	Dover District Council	4bSU06	2003-2012	Ground Based GPS	All years
Sandwich Bay	Environment Agency	4bSU05	2003-2012	Ground Based GPS	All years

3.2 Generation of the Sediment Budget (Level 3 and 4)

A sediment budget presents a quantitative model of the magnitude of volumetric change, sediment transport rates and losses and gains within a self-contained coastal cell, in a defined period of time (Rosati and Kraus, 1999). At its most basic, using the principles of conservation of mass (volume), it is an attempt to balance all inputs into a cell with all outputs leaving a cell as shown in Equation 1 below (Adapted from Rosati and Kraus, 1999):

$$\sum Qinput - \sum Qoutput - \Delta V + P - R + L = Residual \qquad (1)$$

Where:

- Q_{input} - Volume input from the updrift cell
- Q_{output} - Volume output into the downdrift cell
- ΔV - Volumetric change within the cell
- P - The material placed into the cell e.g. beach replenishment
- R - The material removed from the cell e.g. beach recycling
- L - The losses to attrition and material lost during placement.

The Residual is the volume of the cell remaining or the degree to which the cell is balanced. In a balanced sub-cell the residual should near 0 or be no larger than the combined error in the data collection.

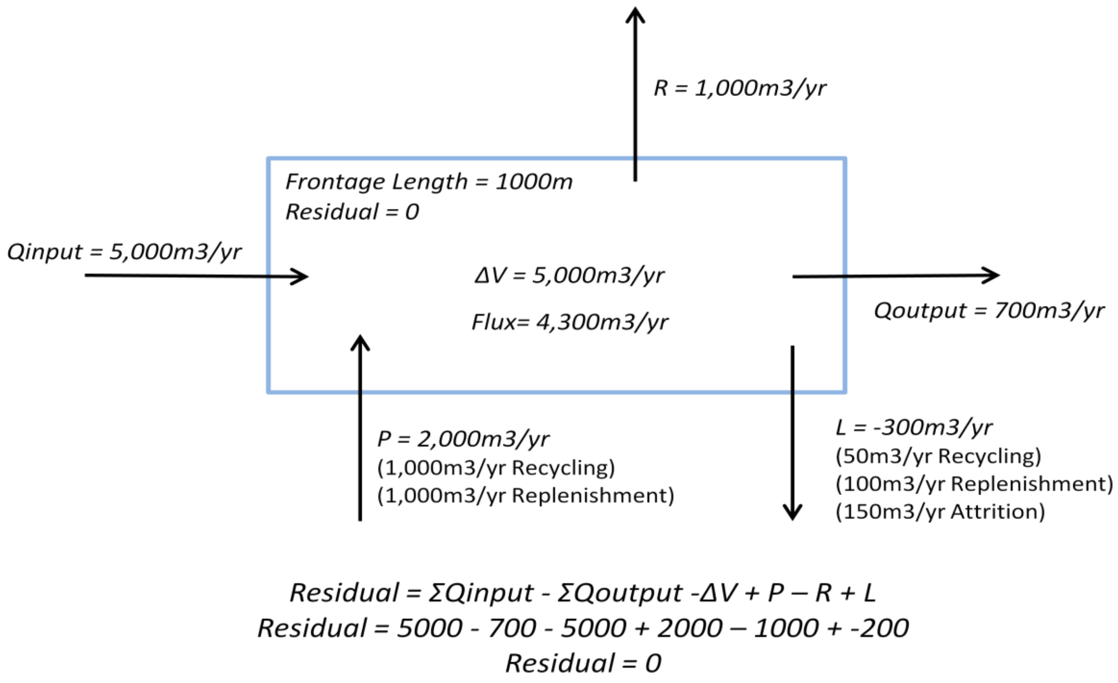


Figure 3-1 Sample balanced sediment cell

Volumetric change in each SRCMP polygon was calculated through analysis of the difference models shown in Table 3.1. Different methods for calculating *ΔV* were explored in depth provided in Appendix A. All replenishment and recycling logs were collated and *P* and *R* were calculated for each polygon.

Losses expected on this frontage can be broadly split into three categories, attrition losses, replenishment losses and recycling losses. Offshore losses are not considered significant due to the predominance of coarse grained sediments and the topography and geomorphology of the beaches. The losses applied to each cell are shown in the table below, with justification for the figures applied provided in Appendix A.
.

Table 3-2 Losses to a sediment cell

Source of Loss	Loss	Reference
Attrition	0.15m^3/m/year	Dornbusch et al. 2003
Losses during replenishment	10%	Clarke and Brooks 2008
Losses during recycling	5%	Clarke and Brooks 2008

While the SRCMP polygons (Level 2) are useful in providing detailed losses and gains over a management unit, they are too fine when considering the regional view of the sediment budget. Polygons exhibiting similar coastal behaviour were grouped together to create a coarser system of sub-cells, or the Level 3 analysis sub-cells. This set of sub-cells now contained values for $\Delta V, P, R \ and \ L$. Using these figures, the average annual flux can be calculated through:

$$Flux = \Delta V - P + R - L \qquad (2)$$

The flux can be thought of as the volume of sediment added (when flux is negative) or removed (when flux is positive) of the sediment system. This is an important parameter for working out what volume of sediment is actually being exported out of the cell after all losses, extractions and placements have been excluded.

With the residual nearing 0 in a closed sub-cell, Equation 1 can be solved for Q_{input} *and* Q_{output}. Starting at the most western extent of Eastbourne where the sediment input from Beachy Head into the frontage is known to be minimal or $Q_{input} = 0$:

$$Qoutput = -(\Delta V - P + R - L) + Qinput \qquad (3)$$

The Q_{output} of the updrift cell then feeds the downdrift cell as the Q_{input} and the next cell can be balanced. Examples of this can be found in Appendix A.iii. An overview budget was also developed helping to place the changes within the context of management frontages (Level 4). This can provide feedback on those frontages that are significantly gaining or losing material. Equation 1 can be applied over the whole sediment budget with the residual determining whether or not the cell can be thought of as a self contained sediment unit.

Finally, when using the Q_{output} figures to assess sediment transport rates it needs to be recognised that an *a priori* assumption of net transport direction has been made. In most areas along the study a distinct net transport direction prevails each year but is obviously composed of transport in either direction. For a large scale sediment budget covering several years, annual net transport is the crucial factor though locally and on operation time scales, actual rates are invariably different in both magnitude and direction.

3.3 Historic beach calculation

Historic beach DGMs were generated through an assumed relationship between the MHW, beach crest and beach toe elevation. MHW marks were mapped from historical images from the 1890's, 1910's and 1930's. For a more in depth methodology on the creation of historic DGMs from historical maps refer to Appendix C. The elevations used to generate the DGMs are shown below.

Table 3-3 Data used to generate Historic DTMs

Cell	Height (mAOD)					Distance from MHW (m)	
	Back of Beach**	Crest **	MHW*	Beach Toe **	MLW*	Beach Crest (L1)	Beach Toe (L2)
Deal	5.8	5.8	2.20	-1.95	-1.95	13.44	
Sandwich Bay (South)	5.2	5.2	2.20	-1.80	-1.95	11.20	32.58
Sandwich Bay (Middle)	4.6	4.6	2.20	-1.00	-1.95	8.95	26.06

* Note: found from Admiralty tide curves; ** Found through analysis of SANDS profiles

4.0 Results

The results have been split into their various temporal and spatial scales. Note: Level 2 (SRCMP polygons) are not analysed, as this level was a processing level used to gain volumetric change values to feed into the Level 3 analysis. Level 2 was considered to be too fine to conduct a sediment budget analysis over a regional scale. As this is a feeder report for the individual Beach Management Plans, full analysis of trends will be discussed at length in that report.

4.1 *Level 1 - Volumetric Change per 50m Length*

The year on year volumetric change has also been analysed in the following pages to gain an insight on the variability around the mean volumetric change (ΔV) used in the sediment budget analysis in Section 4.2 and 4.3. The methodology for the production of the contour plots is explained in depth in Appendix A. The plots show the volumetric change for each 50m stretch of coast over the whole budget. The X axis refers to the distance along shore from Oldstairs Bay, and the Y axis refers to time. The Z axis is the volumetric change recorded for each 50m wide polygon over each monitoring period, calculated through analysis of the difference models. The data used to generate the plots are shown in the second plot, with a red dot representing a data point on the contour plot. There is a continous data set throughout this unit. Where there is missing data, change is interpolated from known points. On the whole, the frontage is characterised by large, relatively stable sections where there is little change through time. There is a section of gradually increasing beach volumes at the spit in the north of Sandwich Bay, followed by an area of rapidly eroding coastline just north of the spit. The area from Polygon 240 onwards is mainly sand so is excluded from analysis. The frontages are explored in more depth in the following pages.

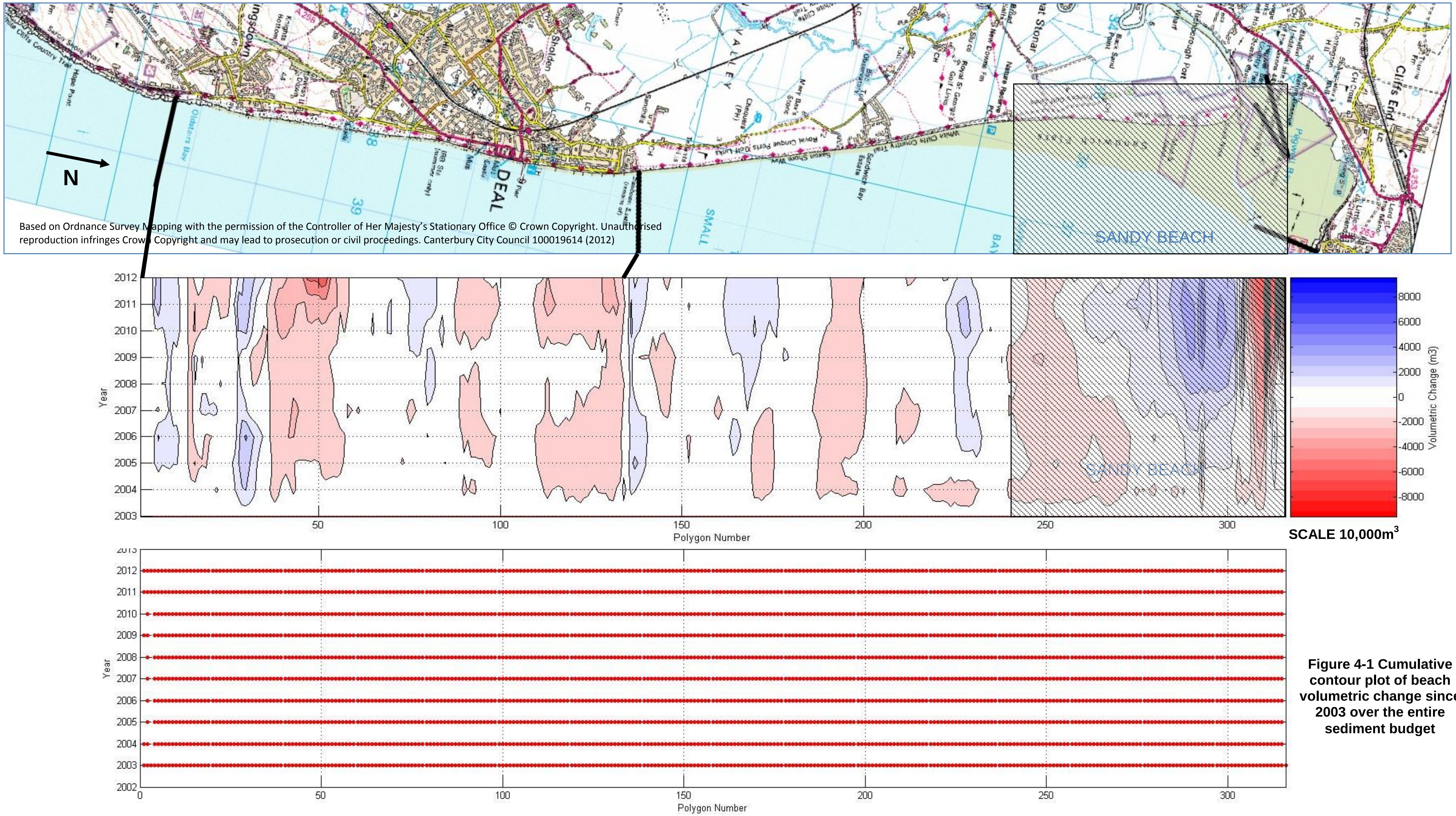


Figure 4-1 Cumulative contour plot of beach volumetric change since 2003 over the entire sediment budget

4.1.1 Oldstairs Bay to Sandown Castle

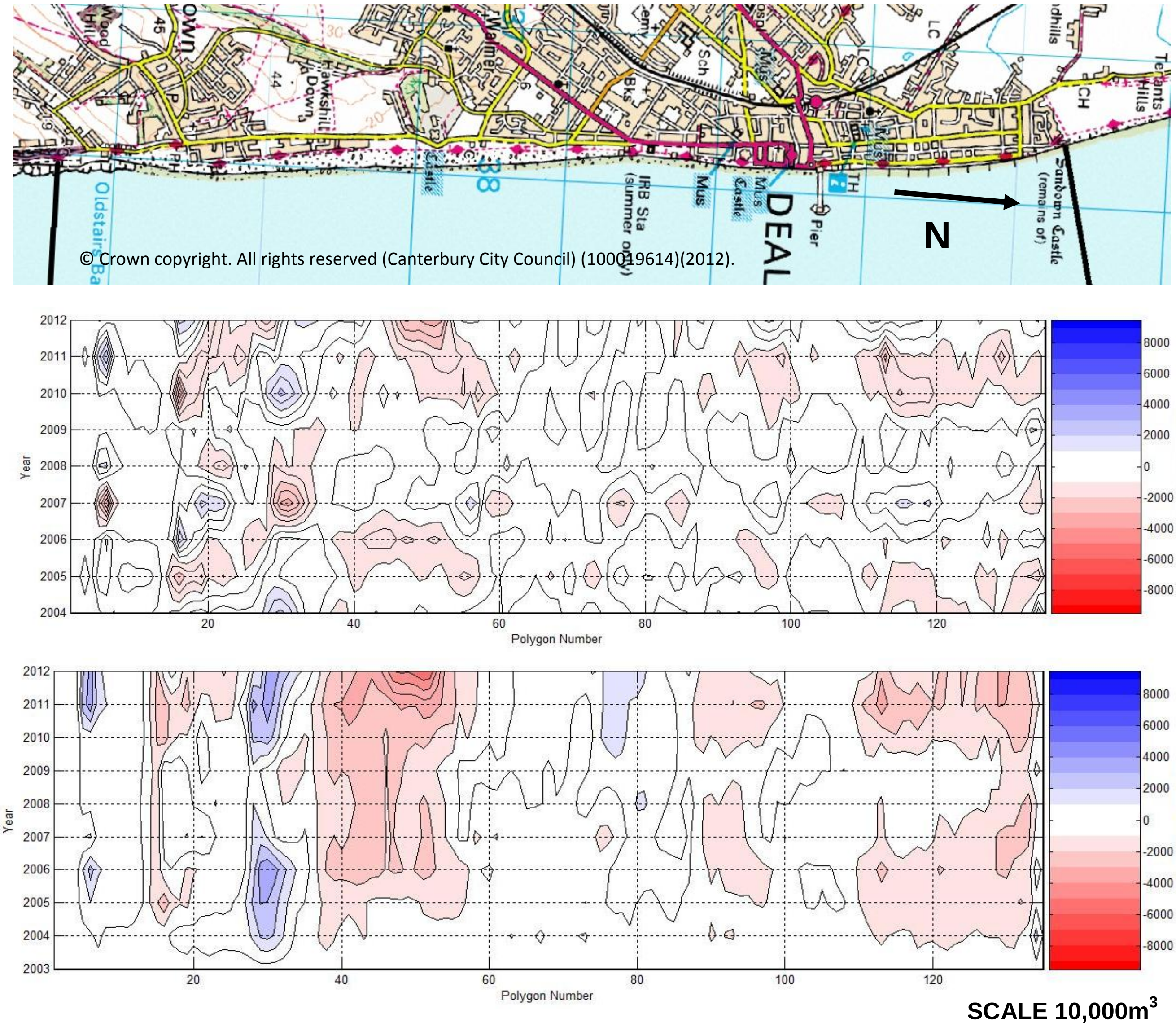


Figure 4-2 Year on year (top) and Cumulative (bottom) contour plot for beach volumetric change in Deal since 2003

The Deal frontage shows a relatively stable coastline, with no area losing or gaining a significant volume in a yearly trend. Polygons 1-10 and 30 - 35 show gains in 2006, 2011 and 2012 as a direct result of beach recycling. The schemes have had some success in maintaining beach volumes at a near 2003 volume. The losses at 40 to 58 are a combination of natural losses due to longshore transport and anthropogenic extraction for the recycling in the previously mentioned polygons. The loss in 2012 seems particularly large although this is due to 23,000m^3 being removed in the spring of 2012. The rest of the unit shows natural changes, with the northern section in the groynes fronting Sandown Castle showing to be the most erosive section of the coast.

4.1.2 Sandwich Bay

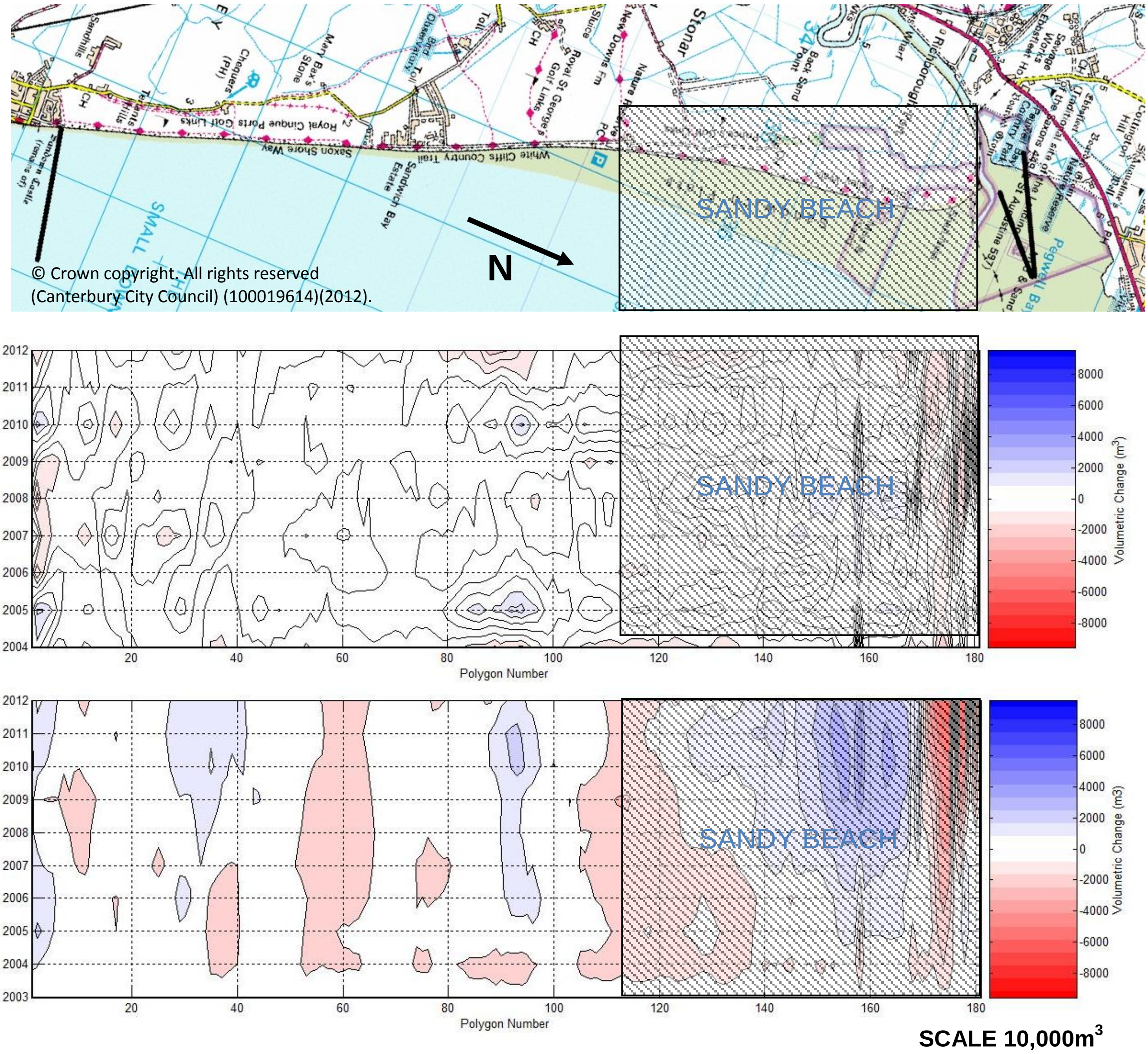


Figure 4-3 Year on year (top) and Cumulative (bottom) contour plot for beach volumetric change in Deal since 2003

The transition between shingle and sandy beaches is shown between Polygons 100-120. Since this is a shingle sediment budget, the data has been greyed out so as to not be analysed as part of the same sediment system. The majority of Sandwich Bay shows small changes in beach volume over time. Pockets of erosion and accretion are noted throughout the shingle cell highlighting the open nature of the coastline, with material able to move with restriction through the cell.

Figure 4.4 summarises the findings from the Spatio-temporal plots by providing a cumulative annual loss or gain from each frontage over the reporting period. This can provide a direct comparison between each frontage, to identify their behaviour in relation to the adjacent frontages. The volumetric change in shingle has been isolated from the sandy beaches in the north of Sandwich Bay so as to not hide the trends of the analysis. As shown by the contour plots, Deal has shown a loss of material, despite recharge and recycling schemes to increase beach volumes. Sandwich Bay has shown a large volumetric increase in material. The total change shows a small increase in material on this frontage due to the material deposited through recharge schemes. The deposition of 45,000m^3 in 2004 at Deal is not registered as a large total increase in material. This could be due to large immediate losses after placement or it could be due to an error in the recording of the actual volume of recharged material.

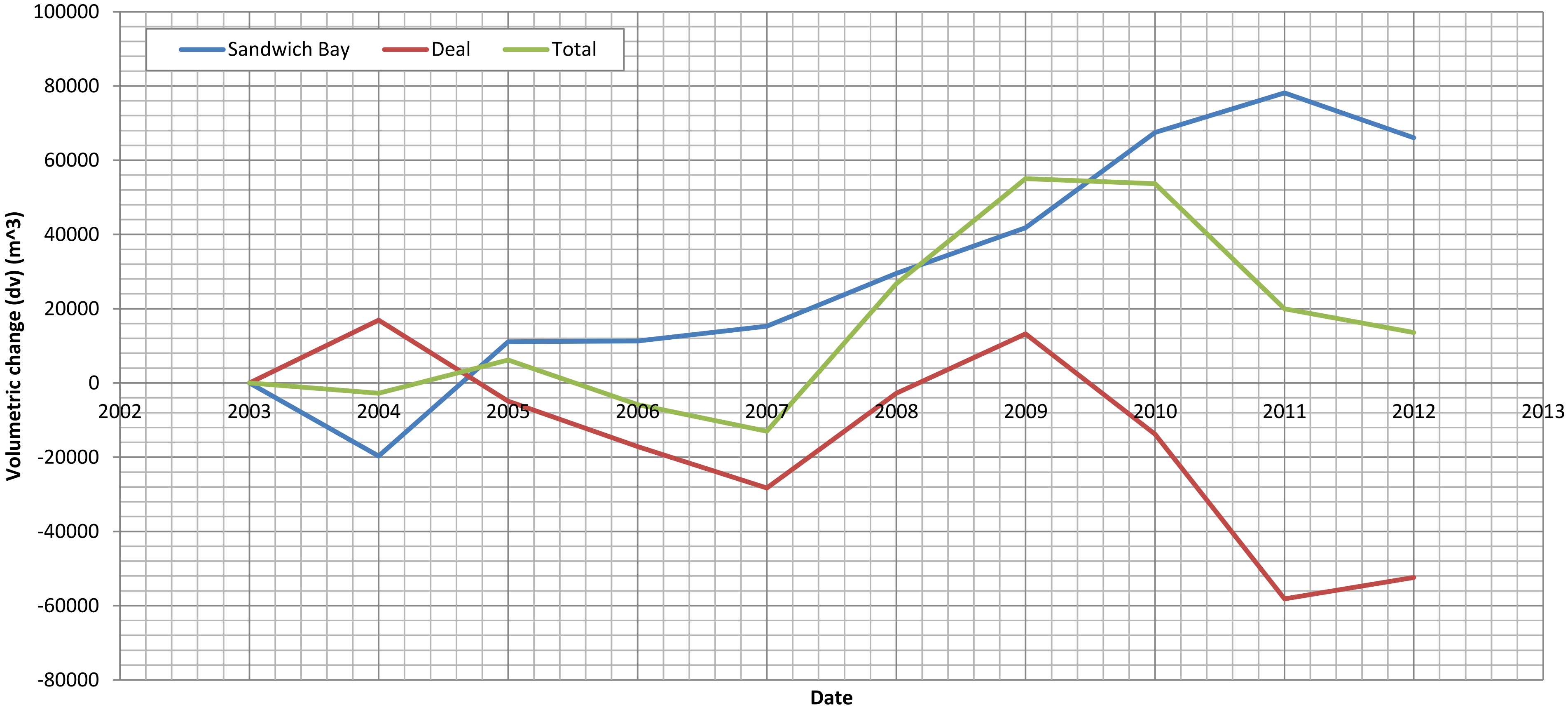


Figure 4-4 Cumulative volumetric change (dv) on all frontages since 2003

4.2 Level 3 - Coarse Sediment Budget

The level 3 sediment budget breaks down the management units into sub-cells according to similar coastal processes. The data is provided in visual and tabular format in the proceeding pages.

Significant problems were encountered during the computation of actual beach volumes added from the Dover cliffs. Difference models were extremely noisy, due to the difficulties in mapping cliff lines from Lidar data. In addition, rock falls produced large areas of accretion and then loss as cliff material was washed away. The actual volume of beach grade sediment added through these methods is debatable but often considered negligible. Hence, an attempt at quantifying the sediment transport rates on cliffed frontages provides too many problems and so was not fed into the sediment budget figures. Dornbusch (2005) calculated flint inputs from Kingsdown cliffs to be in the order of 400-500m^3/yr, with the lower limit chosen to be used in the sediment budget. Although this is a very small volume of material, it acknowledges the fact that some beach grade sediment feeds Oldstairs Bay.

With the input of 400m^3/yr from Dover cliffs, transport rates increase with distance northwards through Kingsdown. The regular amount of recycling and recharge works contribute to increasing volumes of material entering the Walmer frontage, increasing from 1,200m^3/yr at Oldstairs Bay to 11,095m^3/yr entering Walmer. North of Walmer castle shows increased beach volumes and show some ability to trap the material entering from the south, decreasing transport rates to 7,300m^3/yr. The north of the unit from Deal Pier to Sandown castle shows erosive tendencies contributing to an increase in the rate of transport, leading to 11,000m^3/yr being transported into Sandwich Bay.

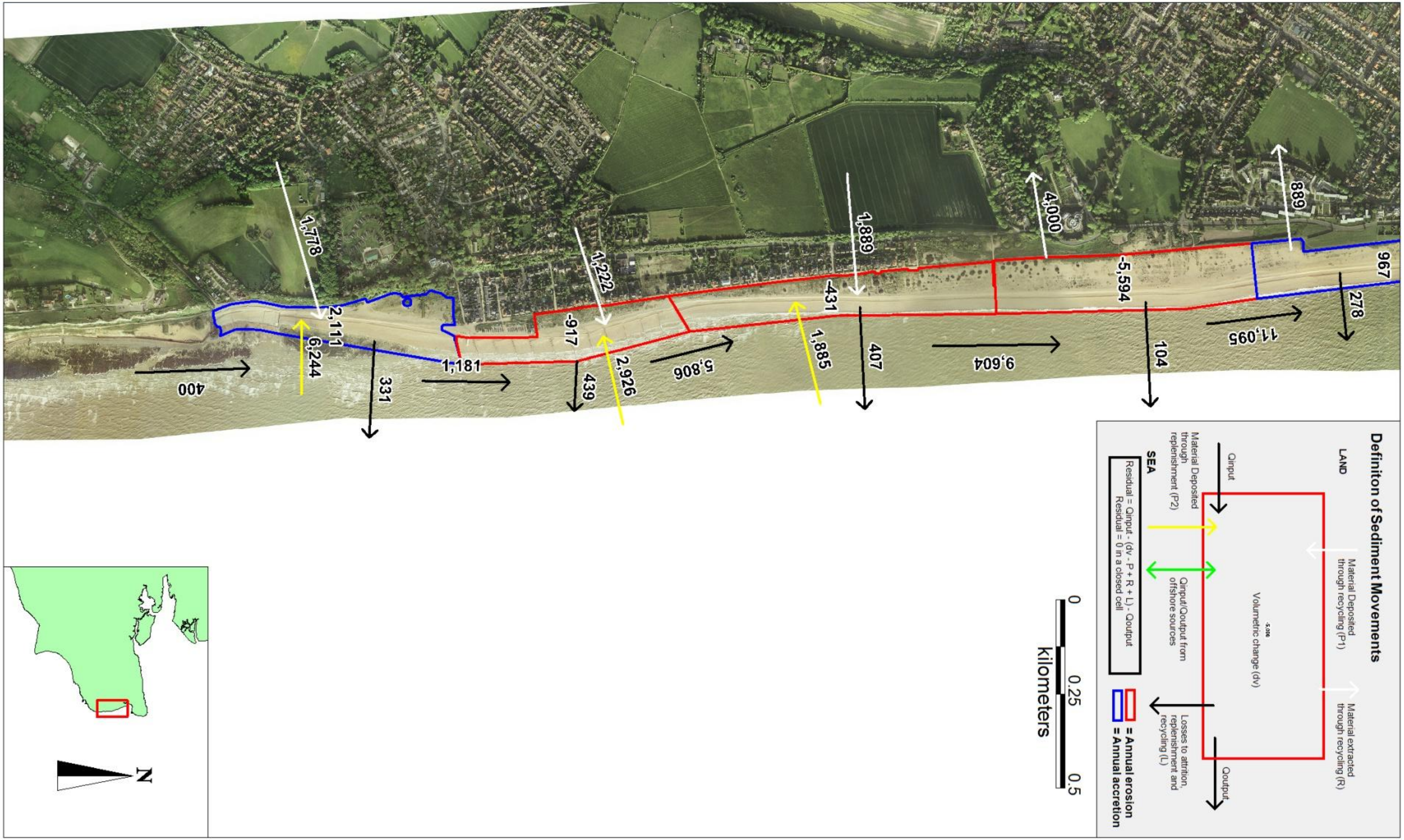
Transport rates largely decrease with distance northwards despite the beach becoming more open in nature. This is partly due to a reduction in the depth of the beach toe. In the south at Deal, the tide rarely goes off the beach toe, with the beach toe residing at around -2.7 to -3.0mOD (below MLWS). This means that the beach is constantly being exposed to wave action, with shingle movement occurring constantly during the tidal cycle. As you travel north, the beach toe becomes higher at around 2.0m at Sandown to -0.4mOD at Shellness Spit. As the beach toe becomes higher, the beach is exposed to wave action for a smaller duration reducing the amount of time longshore drift of shingle can be acting over. This provides justification for the reduction of transport rates into the Sandwich Bay frontage.

2,796m^3/yr is transported out of this sediment budget onto the mixed beaches immediately north. This volume seems reasonable given the amount of shingle still visible in the beaches close to the end of the budget.

Table 4-1 Level 3 - Coarse Sediment Budget (m^3/yr)

Cell	Sub-cell	Average annual change (ΔV)	Recharge (P1)	Recycling		Losses			Average annual flux (ΔV-P+R-L)	Qoutput
				Deposition (P2)	Extraction (R1)	Attrition (L1)	Recharge (L2)	Recycling (L3)		
Input from Dover Cliffs										400
Deal	1 Oldstairs Bay	2,111	1,444	1,778	0	-97	-144	-89	-781	1,181
	2 Kingsdown	-917	2,926	1,222	0	-86	-293	-61	-4,626	5,806
	3	-431	1,885	1,889	0	-125	-189	-94	-3,798	9,604
	4 Walmer Castle	-5,594			-4,000	-104	0	0	-1,491	11,095
	5	967			-889	-105	0	0	1,961	9,134
	6	1,934				-87	0	0	2,021	7,113
	7 South of Pier	-652				-124	0	0	-528	7,641
	8 North of Pier	398				-55	0	0	453	7,188
	9	-1,701	0	0	0	-95	0	0	-1,607	8,795
	10 Sandown Castle	-2,310	0	0	0	-95	0	0	-2,214	11,009
Sandwich Bay	1 Royal Cinque Ports Golf Club	590	0	0	0	-88	0	0	678	10,331
	2	1,184	0	0	0	-141	0	0	1,325	9,007
	3	2,442	0	0	0	-156	0	0	2,597	6,409
	4	-969	0	0	0	-121	0	0	-848	7,257
	5 Sandwich Bay estate	102				-71			173	7,084
	6 Royal St George's Golf Club	1,745	0	0	0	-117	0	0	1,862	5,222
	7 Princes Golf Club	2,102	0	0	0	-144	0	0	2,246	2,976
Oldstairs Bay to Sandwich Bay		1,000	6,256	4,889	-4,889	-1,809	-626	-244	-2,576	

Note: Sub-cell location diagrams are located in Section 6.0.


967
278
889
11,095
104
-5,594
4,000
9,604
1,889
407
-431
1,885
5,806
2,926
1,222
439
-917
1,181
331
2,111
1,778
6,244
400
Definiton of Sediment Movements
LAND
Material Deposited through recycling (P1)
Material extracted through recycling (R)
Volumetric change (dv)
Qinput
Qoutput
Material Deposited through replenishment (P2)
Qinput/Qoutput from offshore sources
Losses to attrition, replenishment and recycling (L)
SEA
Residual = Qinput - (dv - P + R + L) - Qoutput
Residual = 0 in a closed cell
= Annual erosion
= Annual accretion
0
0.25
0.5
kilometers
N

South East Regional Coastal Monitoring Programme

Level 3 - Sediment Budget

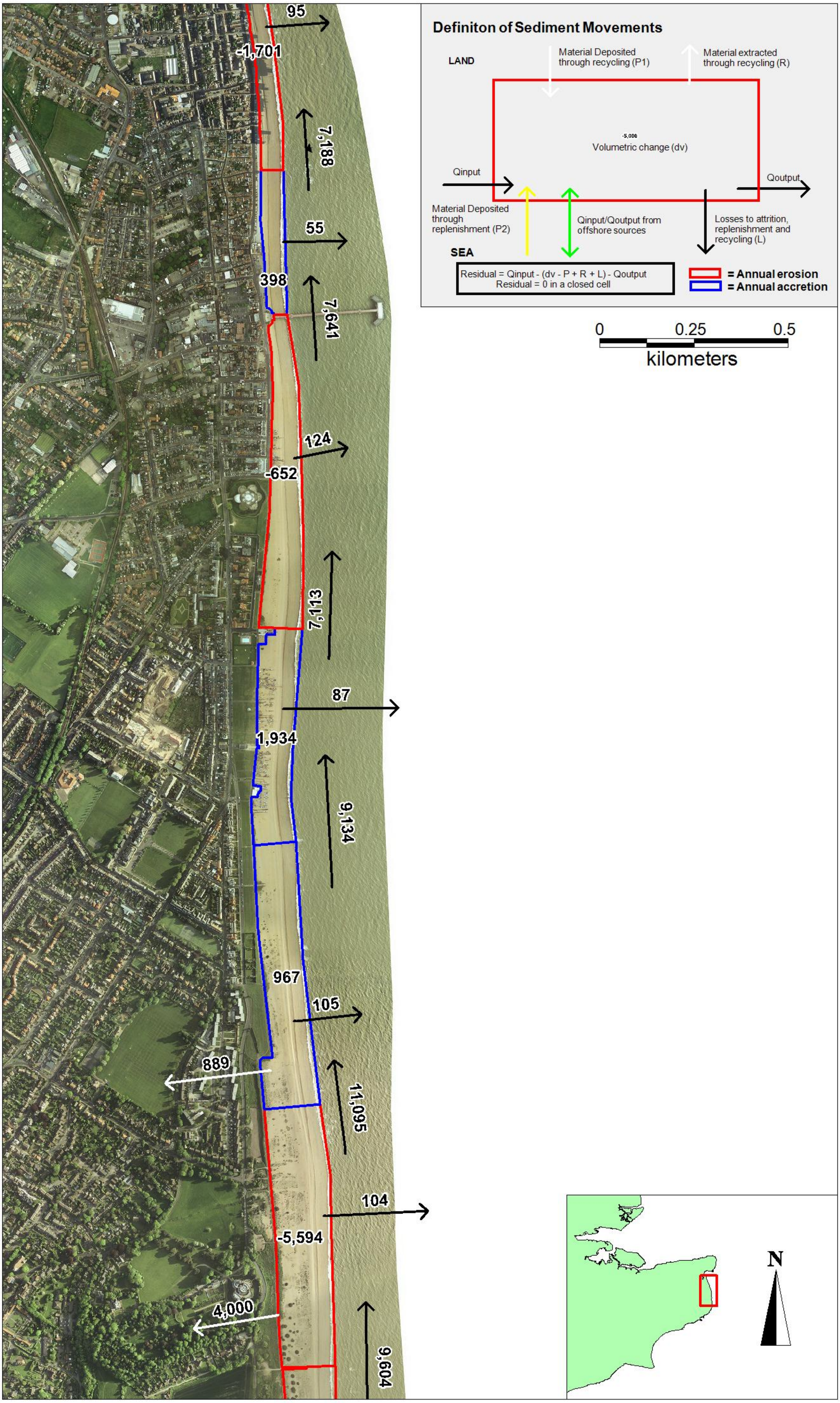


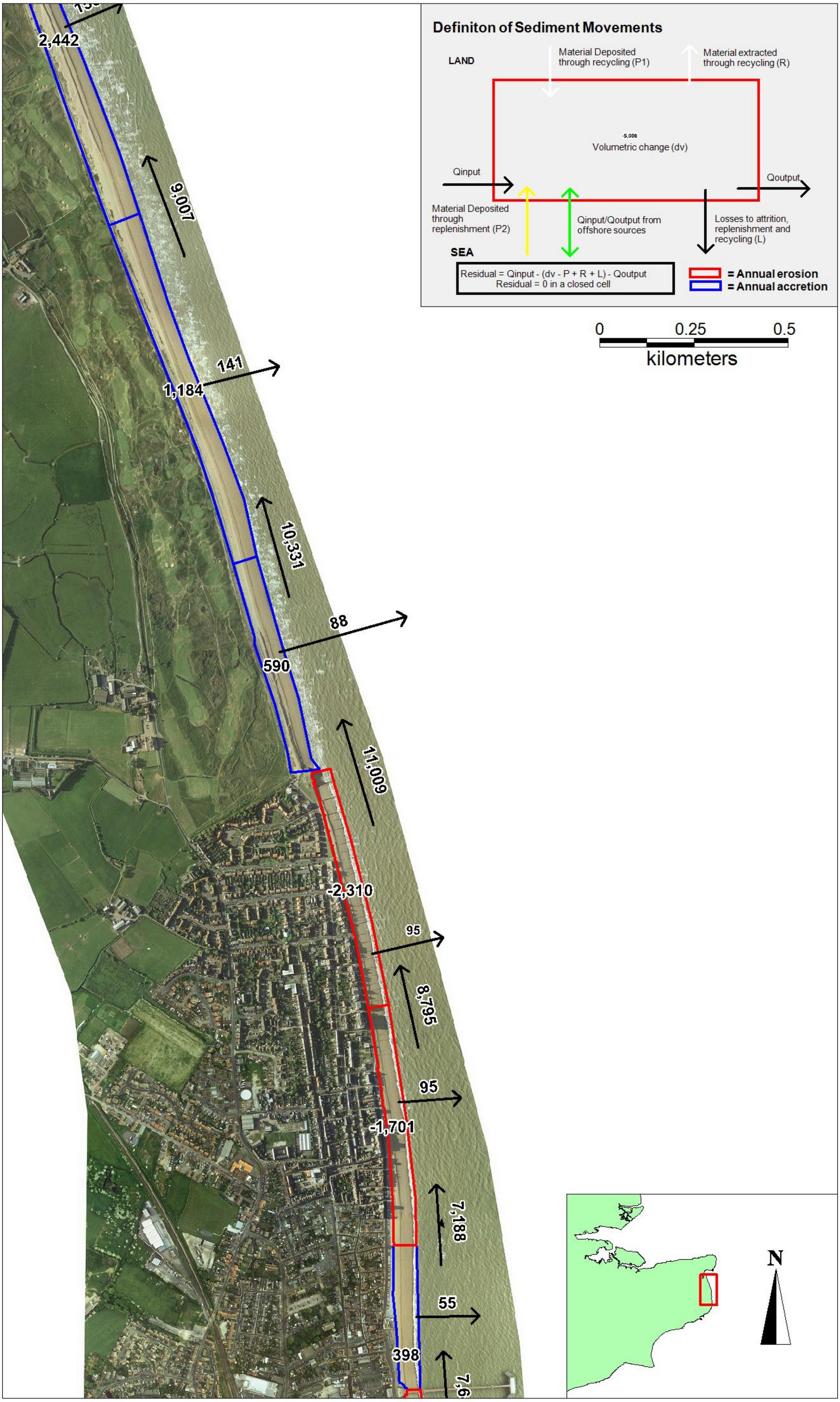
Plate 2 (2 of 5)

Walmer to Deal

Oldstairs Bay to Sandwich Bay Sediment Budget

South East Regional Coastal Monitoring Programme

Level 3 - Sediment Budget



Oldstairs Bay to Sandwich Bay Sediment Budget

Sandown

Plate 2 (3 of 5)

South East Regional Coastal Monitoring Programme

Level 3 - Sediment Budget

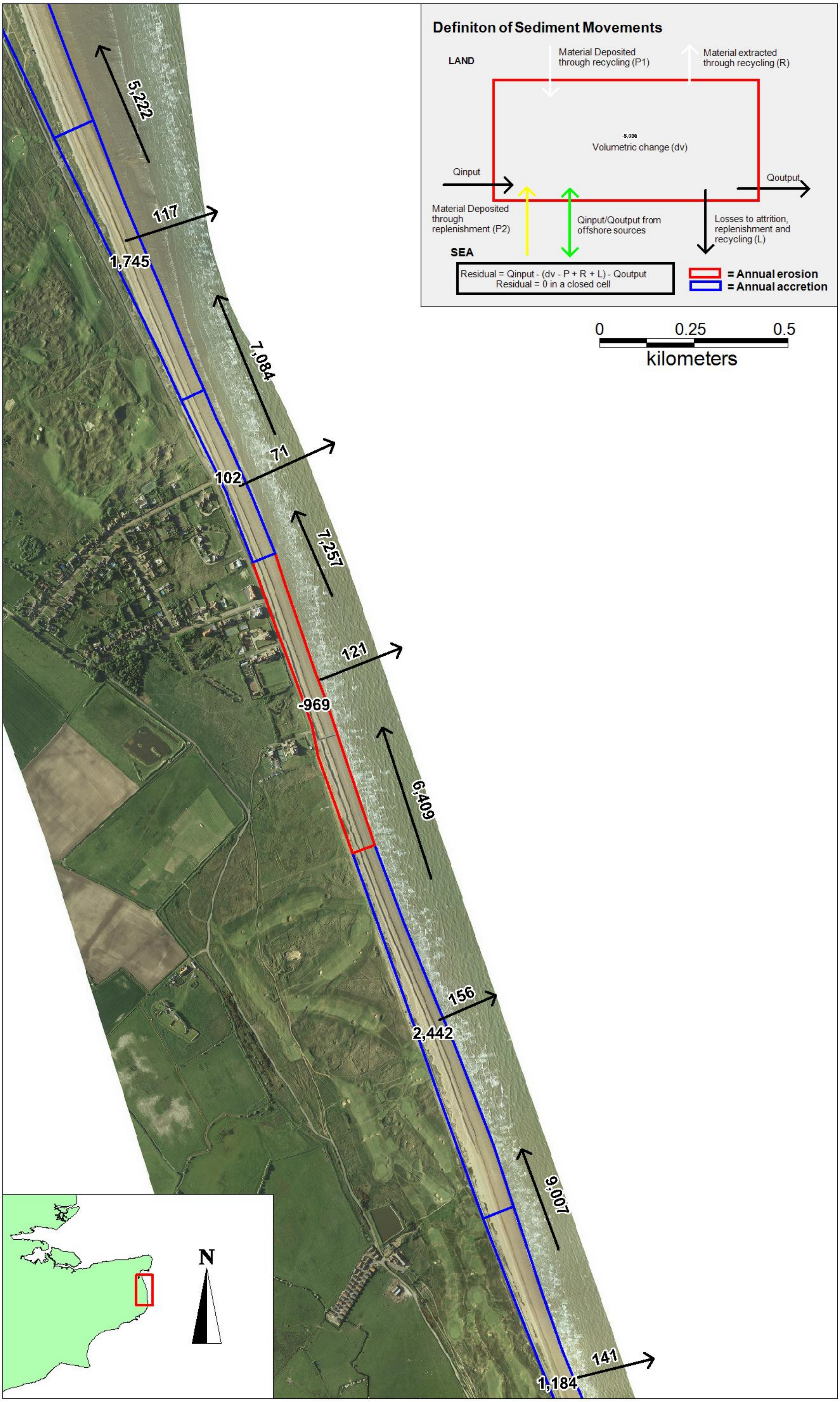


Plate 2 (4 of 5)

Sandwich Bay - 1

Oldstairs Bay to Sandwich Bay Sediment Budget

South East Regional Coastal Monitoring Programme

Level 3 - Sediment Budget

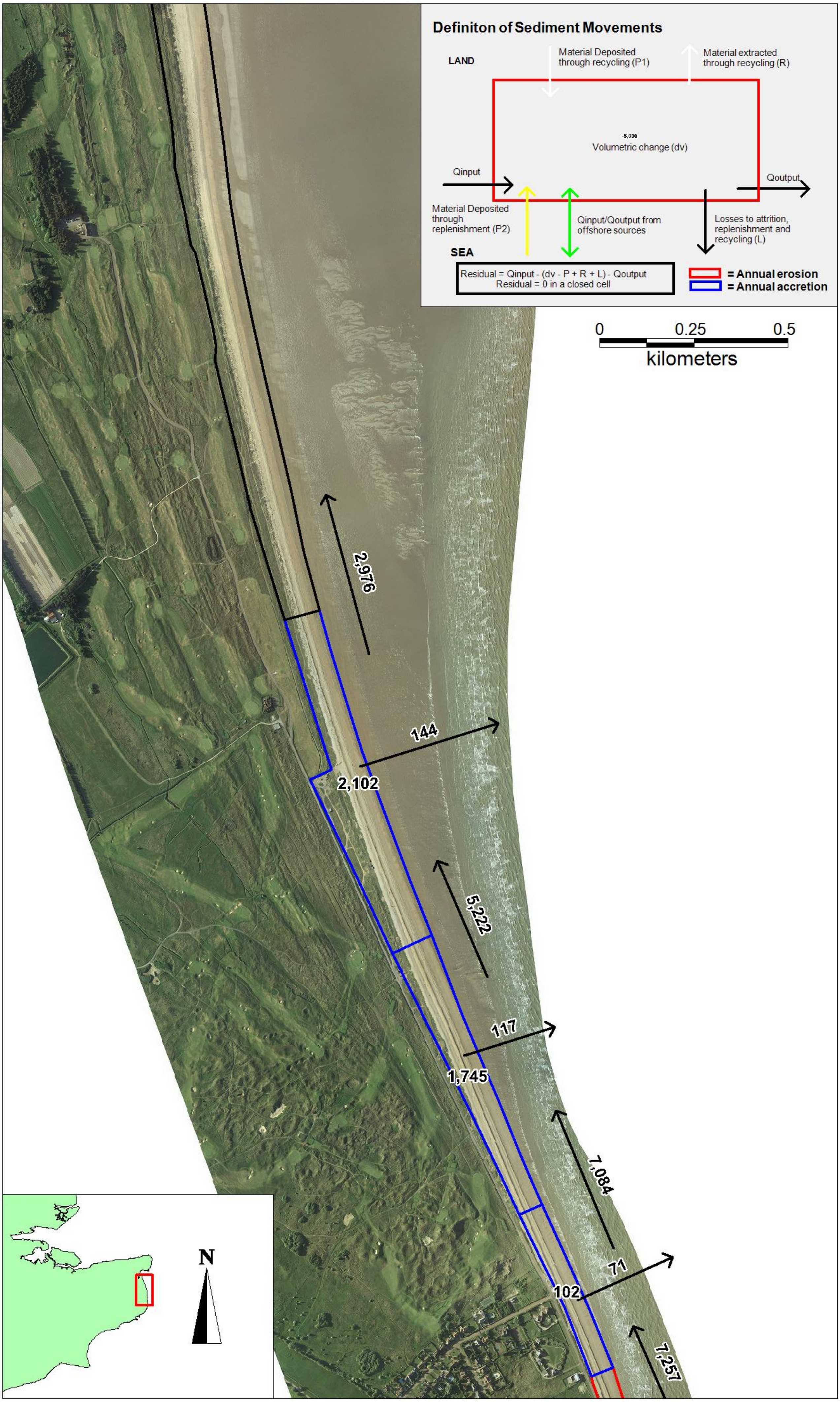


Plate 2 (5 of 5)

Sandwich Bay - 2

Oldstairs Bay to Sandwich Bay Sediment Budget

4.3 Level 4 - Regional Sediment Budget

The level 4 sediment budget has been analysed and displayed in both tabular and visual formats on the following pages to summarise the Level 3 coarse sediment budget.

The sediment budget shows that Deal is exporting 11,009m^3/yr. Sandwich Bay gains in total 8,033m^3/yr, leaving a residual 2,976m^3/yr of shingle to be transported onto the northern beaches. This budget cannot be completely closed as the transition from shingle to sand makes the isolation of an individual shingle cell difficult. The 2,976m^3/yr transport rate seems reasonable given the amount of shingle still present in the beaches north of the end of this budget.

Table 4-2 Level 4 - Regional Sediment Budget (m^3/yr)

		Oldstairs Bay to Sandown Castle	Sandwich Bay	Deal to Sandwich Bay
Average Annual Change (ΔV)		-6,196	7,196	1,000
Recharge (P1)		6,256	0	6,256
Recycling	**Deposition (P2)**	4,889	0	4,889
	Extraction (R1)	-4,889	0	-4,889
Losses	**Attrition (L1)**	972	837	1,809
	Recharge (L2)	626	0	626
	Recycling (L3)	244	0	244
Average Annual Flux (ΔV-P+R-L)		-10,609	8,033	-2,576
Qinput		400	11,009	
Qoutput		11,009	2,976	

Level 4 - Regional Sediment Budget

South East Regional Coastal Monitoring Programme

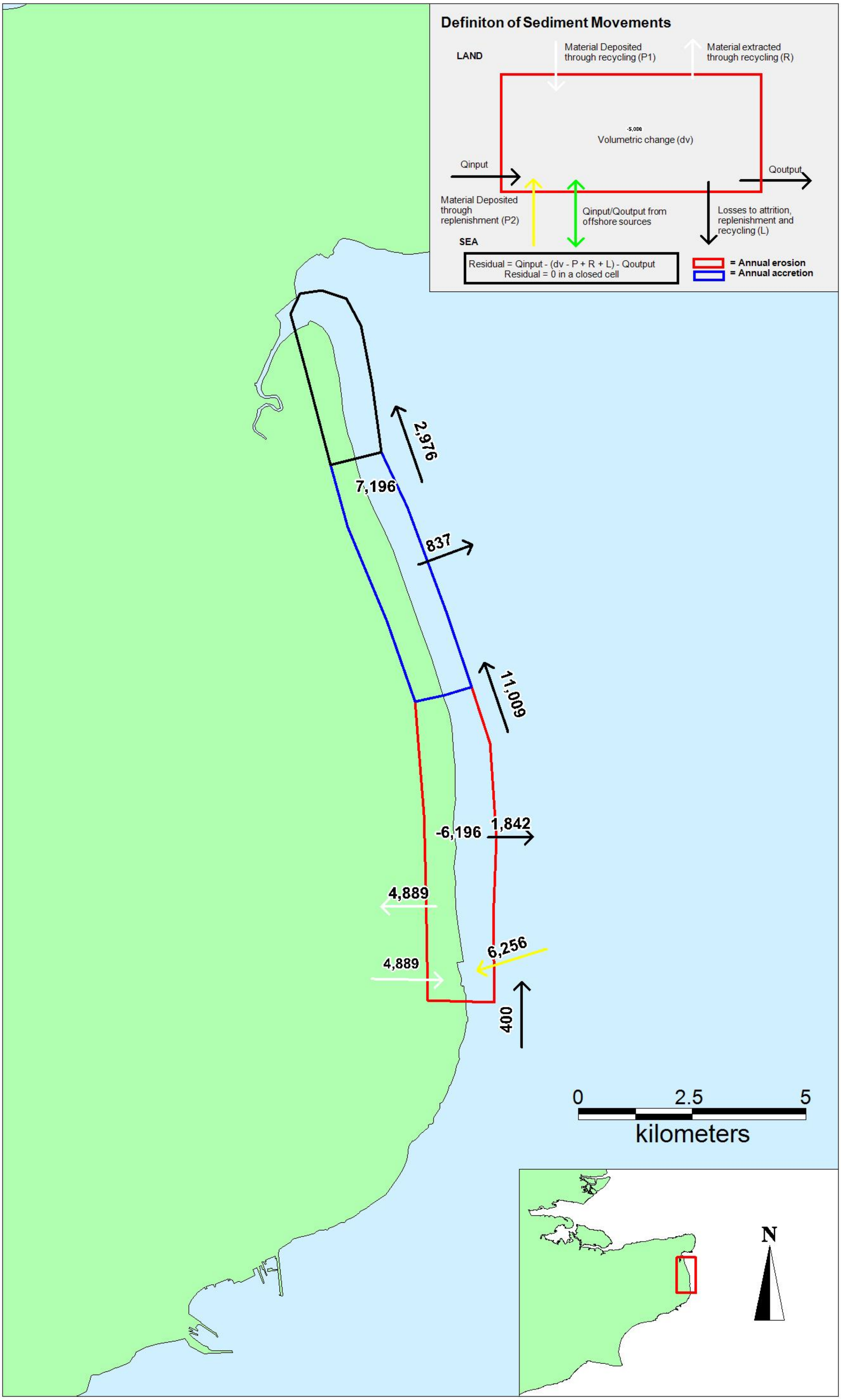


Plate 1 (1 of 1)

Oldstairs Bay to Sandwich Bay Sediment Budget

4.4 Level 4 – Beach Volumes

Beach volumes over all timescales were calculated for each frontage to show the actual total volumes of sediment rather than just the volumetric change. The method for the calculation of these volumes is provided in Appendix B. The beach volumes show logical and conceivable beach volumes over the majority of frontages and time scales. This provides confidence in both the methodology for calculating the volumetric change and the methodology for calculating the beach volume. The data helps to put the more recent volumetric changes explored through the contour plots and sediment budgets into perspective. Taking Deal as an example, the recent losses of shingle are very small in comparison to the long term trend showing a net gain in sediment.

Table 4-3 Beach Volumes over various time periods

	Beach Volume (m^3)												
	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	1930	1910	1890
Oldstairs Bay to Deal	2,915,974	2,910,194	2,954,605	2,981,589	2,965,605	2,940,067	2,951,219	2,963,464	2,985,307	2,968,382	2,745,646	2,840,439	2,777,956
Sandwich Bay	2,459,435	2,471,554	2,460,897	2,435,229	2,422,916	2,408,710	2,404,736	2,404,494	2,373,699	2,393,413	2,125,652	2,179,705	2,335,199

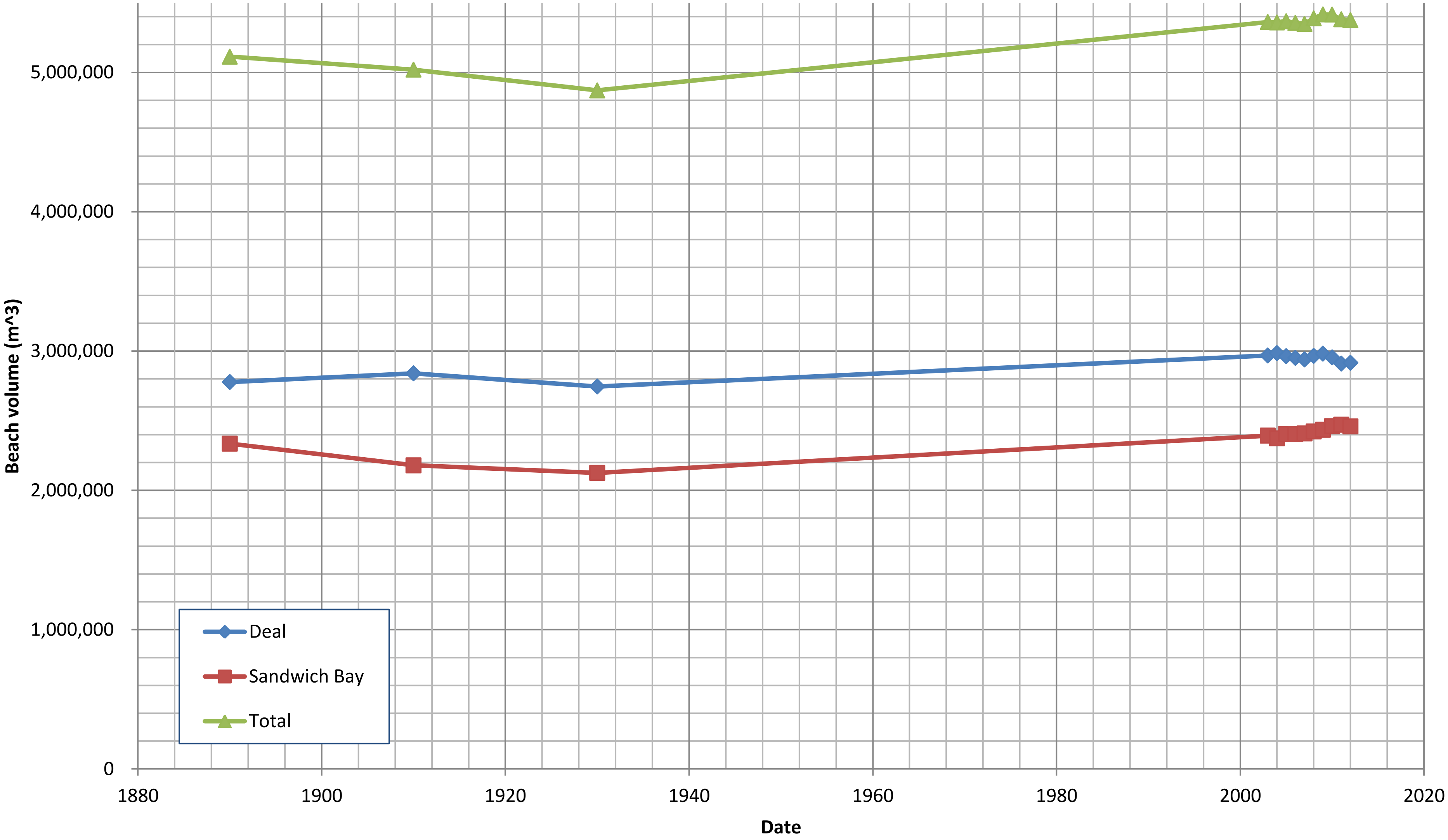


Figure 4-5 Comparison of beach volumes since 1870

4.5 Historic Volumetric Change (Level 4)

The historic beach volumetric change has also been provided to help place the most recent changes and sediment budget interpretations into the context of a longer time scale. Stive et al. (2002) identified that the spatial and temporal scale of an analysis are interlinked. When looking over very small timescales, a very fine spatial analysis is possible. As the analysis of historic beach change is over multiple decades, it is unfeasible to view beach volumetric changes on a small spatial scale (Stive et al., 2002). Therefore, analysis of historic beach volumetric change has been undertaken at Level 4 as the most appropriate spatial scale to the temporal period of the analysis.

Table 4-4 Historic beach volumetric change since 1890

		Volumetric Change (m^3)		
		Oldstairs Bay to Deal	Sandwich Bay	Total Change
1910-1890	Change	62,483	-155,494	-93,011
	Annual Change	3,124	-7,775	-4,651
1930-1910	Change	-94,793	-54,053	-148,846
	Annual Change	-4,740	-2,703	-7,442
2003 -1930	Change	222,736	267,761	490,496
	Annual Change	3,094	3,668	6,792

The annual rate is provided to place volumetric changes into perspective. This assumes a linear rate of change between the known beach volumes which is a significant and erroneous assumption. Consequently, no analysis of annual rates of change is undertaken in the following pages. The analysis of beach volumetric changes since 1890 seeks to justify the figures provided in Table 4.4, rather than explain why those changes occur which was deemed to be outside the scope of this report.

4.5.1 Oldstairs Bay to Sandown Castle

Deal has shown relative stability over the last 100 years, gaining 190,000m^3 since 1890. Between 1910 and 1890 the beach gained 60,000m^3, while it lost 95,000m^3 between 1930 and 1910 before finally returning to an accretive trend, gaining 220,000m^3 to 2003. However, there is significant spatial variability within these trends.

Oldstairs Bay has shown a significant retreating trend over the last 100 years, losing 862,253 m^3 since 1910. This has caused over 100m of cutback as shown by the Figure below. Figure 4.7. shows two images taken from the cliffs above Kingsdown, the large recession shown in the historical mapping is reflected in these images. The historic images show the army MOD firing range was not present until the mid 20th century. The large scale erosion since 1930 could possibly be a result of the defences put in place at the firing range limiting the supply of material from the cliffs at Hope Point.

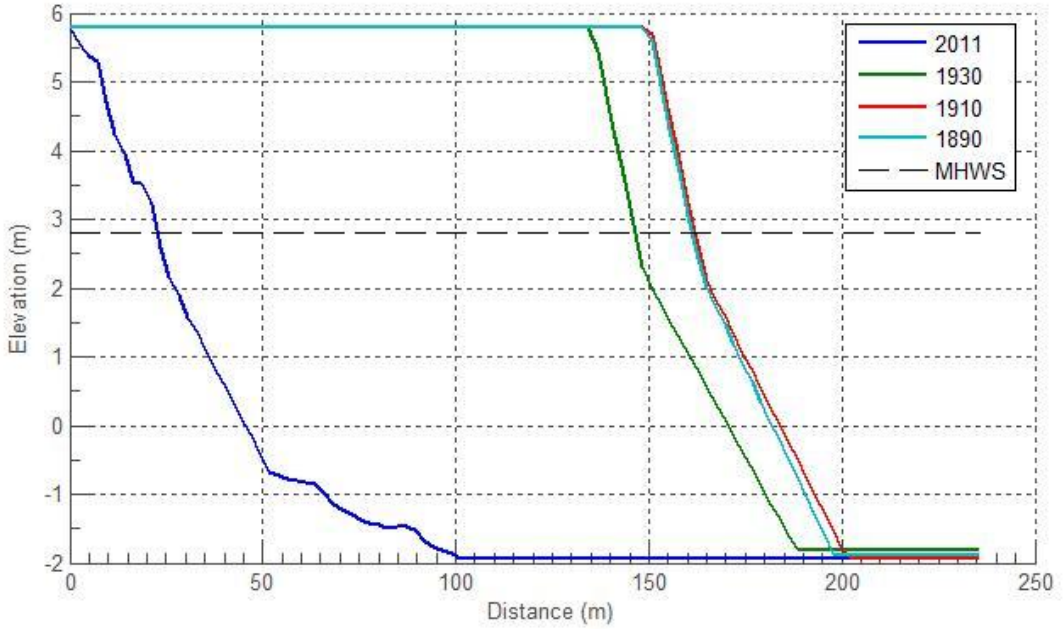


Figure 4-6 Historic Change at Oldstairs Bay

Figure 4-7 Oldstairs Bay in 1949 (left) and 2008 (right)

Source: dover.gov.uk; CCC

By contrast, the middle of the unit has gained a large volume of material, possibly a result of the erosion at Oldstairs Bay. The figure below shows the profile translating seawards by 50m from 1930 to 2003.

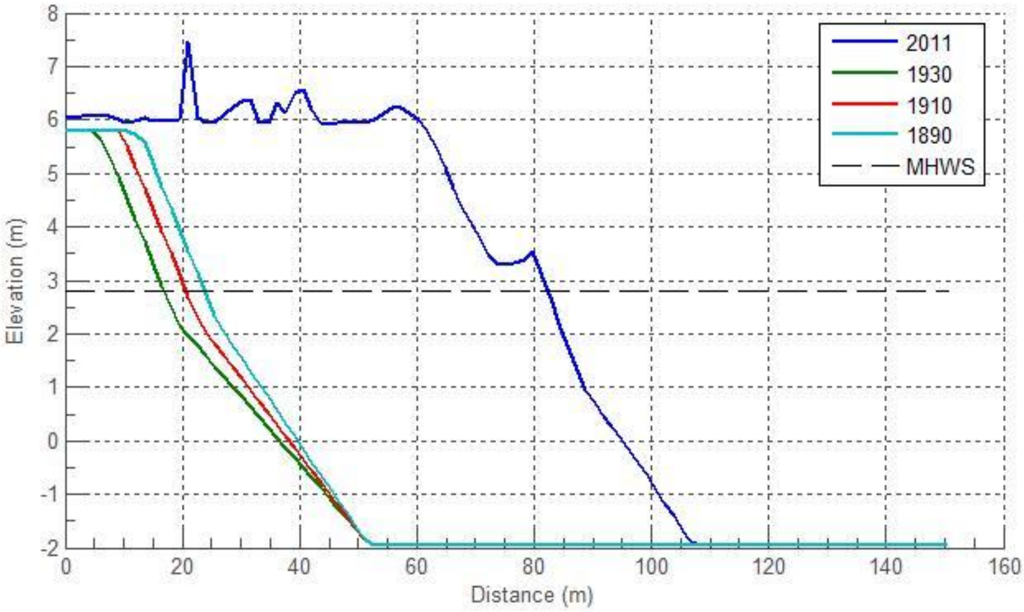


Figure 4-8 Historic change at Deal

Finally at the northern extent of the unit, the beach returns to an erosive trend, albeit in small volumes. The changes experienced in this unit are typically low, due to the constrained nature of the frontage. Sandwich Bay shows much larger changes due to the presence of open beaches and limited beach management.

4.5.2 Sandwich Bay

By contrast to the north of the unit, the south of the unit has shown relative stability, with minor changes tended towards erosion as the coastline reorientates itself to the dominant wave direction. The profile shown below shows a retreat of 8m from the 1890 profile which over a 120 year timescale shows a very minor change.

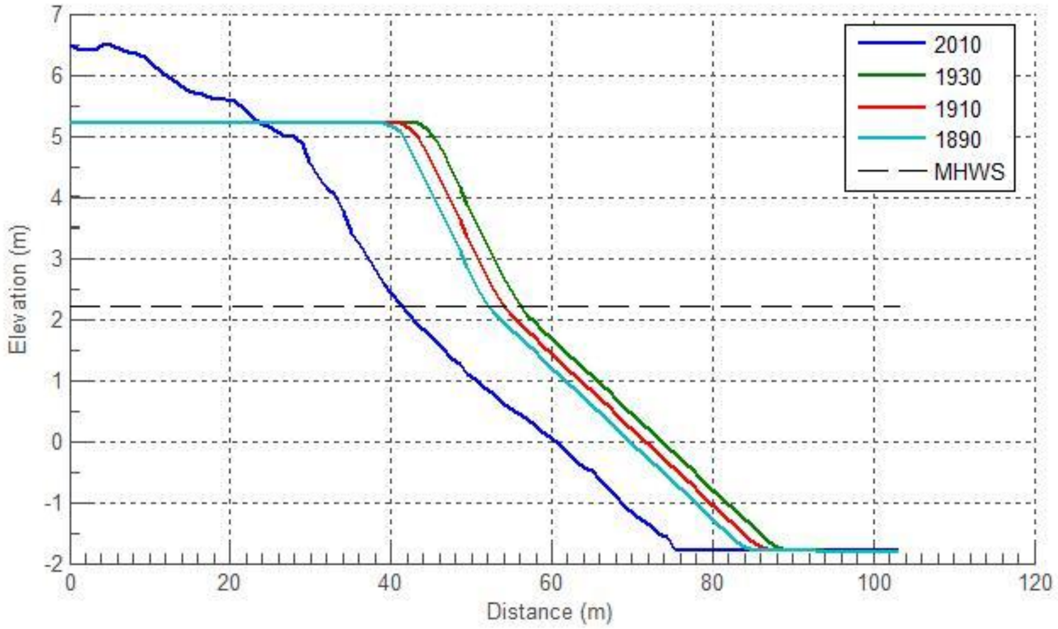


Figure 4-9 Historic Change in Sandwich Bay

The relative stability shown in the southern section and the significant volume increase seen in the north reflect the findings of the sediment budget. Again, the feed from the south does not solve the gain in the north, highlighting a potential onshore feed of sediment at the spit.

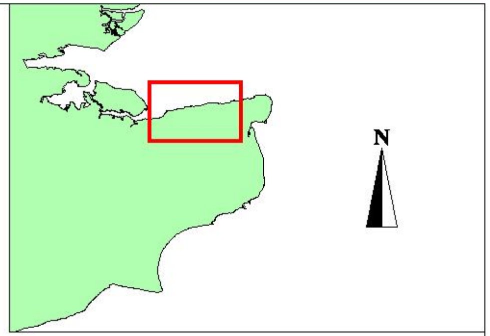
5.0 Available data

The data that can be provided with regards to the above analysis is shown in the table below. The data will be provided in CD format when the report has been finalised.

Table 5-1 Available GIS data

Data	Type	Description
GIS (1)		**AVAILABLE FROM CANTERBURY CITY COUNCIL**
	DTMs	2012 -2003 DTMs for all frontages
	Difference Models	For all frontages
	Analysis Polygons	Level 1 - 50m length
		Level 2 - SRCMP Polygons
		Level 3 - Coarse Polygons
		Level 4 - Regional Polygons
	Historic	Historic feature lines for all frontages
		Historic DTMs for all frontages in 1890, 1910 and 1930
		Historic difference models, 1910-1890, 1930-1910, 2011-1930
	Sediment Budget	Polygons as above
		Level 3 sediment movements
		Level 4 sediment movements
GIS (2)		**AVAILABLE FROM THE ENVIRONMENT AGENCY**
	Lidar	All available Lidar data sets
SPREADSHEETS		**AVAILABLE FROM CANTERBURY CITY COUNCIL**
	Level 1	All Level 1 data in .txt format
	Level 2-4	All levels data in .xlsx format
PLATES		**AVAILABLE FROM CANTERBURY CITY COUNCIL**
	1 and 2	All plates in .jpg format
REPORT		**AVAILABLE FROM CANTERBURY CITY COUNCIL**

6.0 Sub-cell Location Diagrams



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Oldstairs Bay to Sandwich Bay Sediment Budget

Plate 3 (1 of 1)

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