East Kent ENGINEERING PARTNERSHIP

CANTERBURY CITY COUNCIL

Engineering Services
Military Road
Canterbury
CT1 1YW

Client: Environment Agency

Project: Regional Shingle Sediment Budget Report

Rye Harbour to Folkestone

Environment Agency

SOUTH EAST COASTAL GROUP
MANAGING THE SHORELINE

Canterbury City Council
Strategic Monitoring
Military Road
Canterbury
Kent
CT1 1YW

Tel: 01227 862401
Fax: 01227 784013
e-mail: Strategic.Monitoring@canterbury.gov.uk
Web Site: www.se-coastalgroup.org.uk
www.channelcoast.org

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Management Units:	**4cSU16 – 4cSU08**
Author:	**C. Milburn**
Checked By:	**A. Dane**
Approved By:	**J. Clarke**

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Summary

A shingle sediment budget for Rye Harbour to Folkestone was generated to gain an understanding of sediment movements through the frontage. Three sections of this coastline are predominantly sand and have been removed from the sediment budget. The unit includes one drift convergence and one drift divergence along the 43km coastline.

- Camber Sands consists of extensive sand dunes with sand foreshore and has consequently been removed from the shingle budget. The beach gains in the region of 5,000m^3/year which is sourced offshore.

- Jury's Gap to Greatstone-on-Sea is heavily influenced by the west to east longshore drift. Jury's Gap is the start of the shingle sediment budget and with no longshore material to feed this unit, from Camber Sands; it is acutely erosive and requires intense management. The net annual export from Jury's Gap is in the order of 32,159m^3/year. This material is transported into Lydd Ranges.

- Lydd Ranges receives little beach management and heavily relies on the replenishment in Jury's Gap to maintain its beach levels. Lydd Ranges is losing approximately 60,000m^3/year of its own beach, in addition to the 32,159m^3/year acquired form Jury's Gap. The net export of shingle is 92,506m^3/year.

- Dungeness beach has been losing material since 2007 when the annual beach recycling ceased, increasing the net transport rate to 115,560m^3/year into Romney Sands.

- Romney Sands has the largest volume change of 87,066m^3/year. The beach accumulates all material transported into the unit from Dungeness and an additional 1,346m^3/year sourced offshore towards the north of the unit. The section of sand at Greatstone-on-Sea has not been included in the sediment budget.

- Dymchurch (south) transports material into Romney Sands (6,970m^3/year). It also exports 902m^3/year northwards which is lost across the large span of sandy beach. The sand section of Dymchurch is excluded from the sediment budget.

- Hythe Ranges to Folkestone has a predominant longshore drift of west to east. Hythe Ranges is relatively stable, only transporting 774m^3/year into Hythe.

- Hythe is heavily reliant on beach management to maintain beach levels within its rock groyne bays. A total of 3,232m^3/year is transported west to east into Folkestone.

- Sandgate to Folkestone is the end of the sediment budget where the residual for a balanced budget should equal zero. The residual is -37m^3/year which suggests the budget has worked well. Folkestone is also heavily dependent on beach management to sustain beach levels.

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 Rye Harbour to Folkestone. 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

Throughout the entire sediment budget analysis, the frontage has been split into 9 sections (or cells) which broadly coincide with SRCMP survey units (Table 3.1). This also serves to maintain the boundaries between different beach management organisations which allows for easy accounting of the anthropogenic management on the individual frontages. Despite the split drift direction this report refers to the cells west to east.

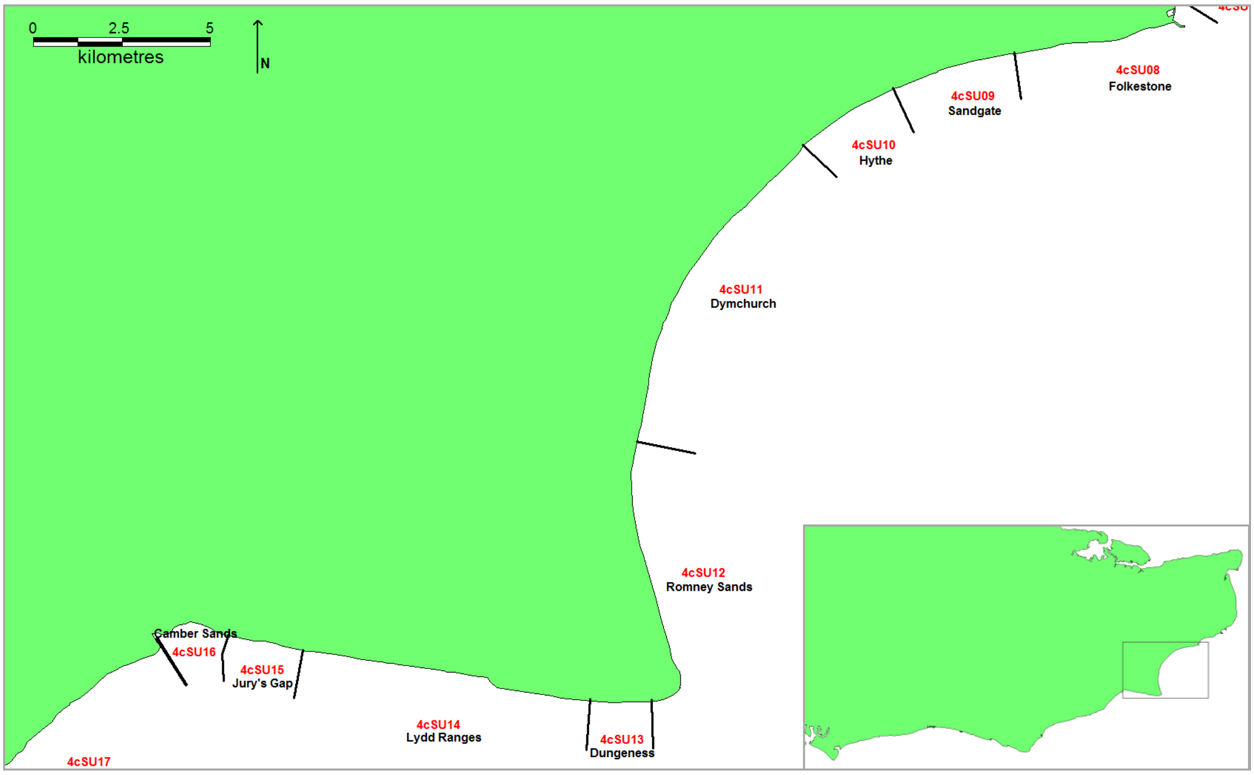


Figure 2-1 Location of study area

2.1 Camber Sands

Camber Sands is the only sand dune system in East Sussex. The dunes are within the Camber Sands and Rye Saltings Site (SSSI) and the Site of Nature Conservation Importance (SNCI). The position of the Rye Harbour in the south is sheltering Camber Sands and creating a local reverse in the drift direction, east to west, with material input from Jury's Gap. There are no defences along this beach as the marram grass and dune vegetation naturally sustain the beach. Since 1870 the MHW line has advanced seaward by 800m in the west and 120m in the east. There have been no recycling schemes or capital schemes within this unit. The alignment of the Rother training wall and sediment type of the intertidal area at Camber suggest that there is no shingle input into the system from further west. This beach is excluded from the sediment budget as the beach is sand.

2.2 Jury's Gap

Jury's Gap is approximately 2.1km in length and consists of a mixed sand and shingle beach overlying a sandy intertidal platform that narrows from west to east. The longshore drift direction is predominantly west to east however it is accepted that a small volume of shingle is transported into Camber and rests on top of the sand beach. Jury's Gap consists of a timber groyne field and seawall which attempt to slow the transport rate of material east. This frontage has been heavily managed since the 1990s using beach recycling and replenishment to maintain the crest levels. Prior to 2007 material was extracted from the eastern section of the ness in the Romney Sands section; however since 2007 material has been imported from the inland Denge Quarry. Approximately 30,000m^3 is imported annually.

2.3 Lydd Ranges

Lydd beach is recognised internationally for its nature conservation importance and is used as the MoD firing range; access to the beach is limited to closing times of the ranges. Towards the western extent of the unit the shingle beach is held loosely by timber groynes but the rest of the beach is predominantly open. The longshore drift direction is west to east with material from Jury's Gap helping to sustain the beach at Lydd. The beach is reprofiled once per annum, in December, to return the beach to a 1 in 200 year protection level. At low tide the western section reveals a large sandy foreshore but the eastern side often remains covered.

2.4 Dungeness

Dungeness is the only beach in the UK to have a defence standard of 1 in 10,000. The shingle beach is essential to the protection of Dungeness nuclear power station. Prior to 2007 material was deposited on this beach by EDF Energy to maintain the 1 in 10,000 bund, from Romney Sands. Since, little material has been anthropogenically added. The longshore drift direction is west to east and Dungeness is constantly fed material from Lydd Ranges. There are no hard defences on this beach, except the wall of the Power Station.

2.5 Romney Sands

Romney Sands accommodates the convergence of two drift directions, south to north and north to south. There are no hard defences along this coastline. The sand dunes at Greatstone-on-sea and the wide berm protect the infrastructure behind the beach. As a result, the site was used as a Borrow Pit to increase beach levels at Jury's Gap and Dungeness, until 2007. Planning permission ceased in 2007 and the site has not been touched since. A short stretch of beach is excluded from the sediment budget at Greatstone-on-sea as the beach is a combination of sand dune and sand beach.

2.6 Dymchurch

Dymchurch is split into a shingle beach in the west and a small sand beach in the east both with timber groynes and concrete sea wall collaboratively protecting the low lying hinterland. The beach is part of the Dungeness SAC, the Dungeness to Pett Level SPA and falls partly within the Dungeness Romney Marsh and Rye Bay SSSI. The longshore drift direction is predominantly north east to south west, transporting material from the east through Dymchurch to Romney Sands. In 2003 260,000m^3 was deposited on the Dymchurch frontage as part of the Littlestone sea defence scheme which protected the town against 1 in 200 year storm events. In 2008/09 28,800m^3 was deposited in front of Littlestone Golf Club northwards. A large section of this beach, between Jesson Outfall and Hythe Ranges, is excluded from the sediment budget as the beach is sand.

2.7 Hythe Ranges

The shingle plateau at Hythe Ranges is used by the MoD as a military training range. The area is protected by a revetment of rock armour stone and long term erosion has created a shallow embayment within which timber groynes have been used with some success to stabilise the shoreline. The western end of the frontage is further embayed and is therefore more stable than the eastern end. The longshore drift direction here is west to east. No beach recycling or maintenance has taken place since.

2.8 Hythe

Hythe and Sandgate beaches are predominantly shingle with a west to east drift direction. The beach has been anthropogenically changed since the 1800s and has been constrained by a seawall since the 19th century resulting in coastal squeeze. Neighbouring cell Hythe Ranges was allowed to retreat by up to 60m. In 1996 the timber groynes were removed and 2 large rock groynes replaced them. Regular beach recycling is undertaken to maintain these beach levels.

2.9 Sandgate to Folkestone

The most eastern cell of the sediment budget is Sandgate to Folkestone; a shingle beach consisting of large bays separated by rock groynes, towards the west, and crenular bays in the east. The furthest eastern extent locates the Harbour. The harbour acts a terminal structure which does not allow material to enter the cell from the east. Longshore drift direction here is west to east. No material is thought to leave this unit east due to the large harbour arm.

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
Camber Sands	Environment Agency	4cMU16	2003, 2007-2012	Ground Based GPS	2003-2007, 2007 onwards
Jury's Gap	Environment Agency	4cMU15	2003, 2007-2012	Ground Based GPS	2003-2007, 2007onwards
Lydd Ranges	Environment Agency	4MU14	2003, 2004, 2009, 2011, 2012	Ground Based GPS	2003-2004, 2004-2009, 2009-2011, 2011 onwards
Dungeness	Environment Agency	4cMU13	2003-2012	Ground Based GPS	All years
Romney Sands	Environment Agency	4cMU12	2003-2012	Ground Based GPS	All years
Dymchurch	Environment Agency	4cMU11	2003-2012	Ground Based GPS	All years
Hythe Ranges	Shepway District Council	4cMU10	2003-2012	Ground Based GPS	All years
Sandgate	Shepway District Council	4cMU09	2003-2012	Ground Based GPS	All years
Folkestone	Shepway District Council	4cMU08	2003-2012	Ground Based GPS	All years

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

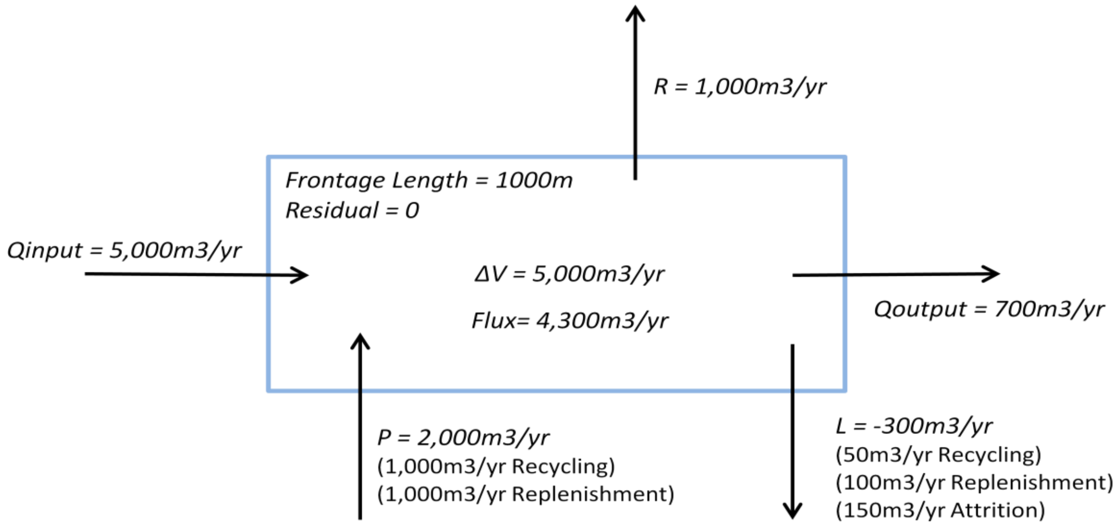
A sediment budget presents a quantitative model of the magnitude of volumetric change, sediment transport rates and losses and gains within a self-contained coastal cell, in a defined period of time (Rosati and Kraus, 1999). At its most basic, using the principles of conservation of mass (volume), it 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.



$$Residual = \Sigma Qinput - \Sigma Qoutput - \Delta V + P - R + L$$
$$Residual = 5000 - 700 - 5000 + 2000 - 1000 + -200$$
$$Residual = 0$$

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:

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

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 4 can be solved for Q_{input} *and* Q_{output}. Starting at the most western extent of Rye Harbour where the sediment input from Winchelsea Beach 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 4 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 1870's, 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)
Camber Sands (W)	10	10	2.68	2.4	-2.62	27.32	2.28
Camber Sands (C)	19	19	2.68	3	-2.62	60.92	-2.61
Camber Sands (E)	6.5	6.5	2.68	1.5	-2.62	14.26	9.61
Jury's Gap	7.5	7.5	2.68	0.75	-2.62	17.99	15.72
Lydd Ranges	6.5	6.5	2.68	-2.5	-2.62	14.26	42.18
Dungeness	6	6	2.68	-2	-2.62	12.39	38.11
Romney Sands (N)	8	8	2.68	2	-2.62	19.86	5.54
Romney Sands (C)	6	6	2.68	0	-2.62	12.39	21.82
Romney Sands (S)	6	6	2.68	-2.5	-2.62	12.39	42.18
Dymchurch (S)	6	6	2.68	-2.5	-2.62	12.39	42.18
Dymchurch (N)	1	1	2.68	0	-2.62	-6.27	21.82
Hythe Ranges	6	6	2.7	-2	-2.35	12.32	38.27
Sandgate	5.5	5.5	2.7	-2	-2.35	10.45	38.27
Folkestone	5	5	2.7	-2	-2.35	8.59	38.27

* 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.

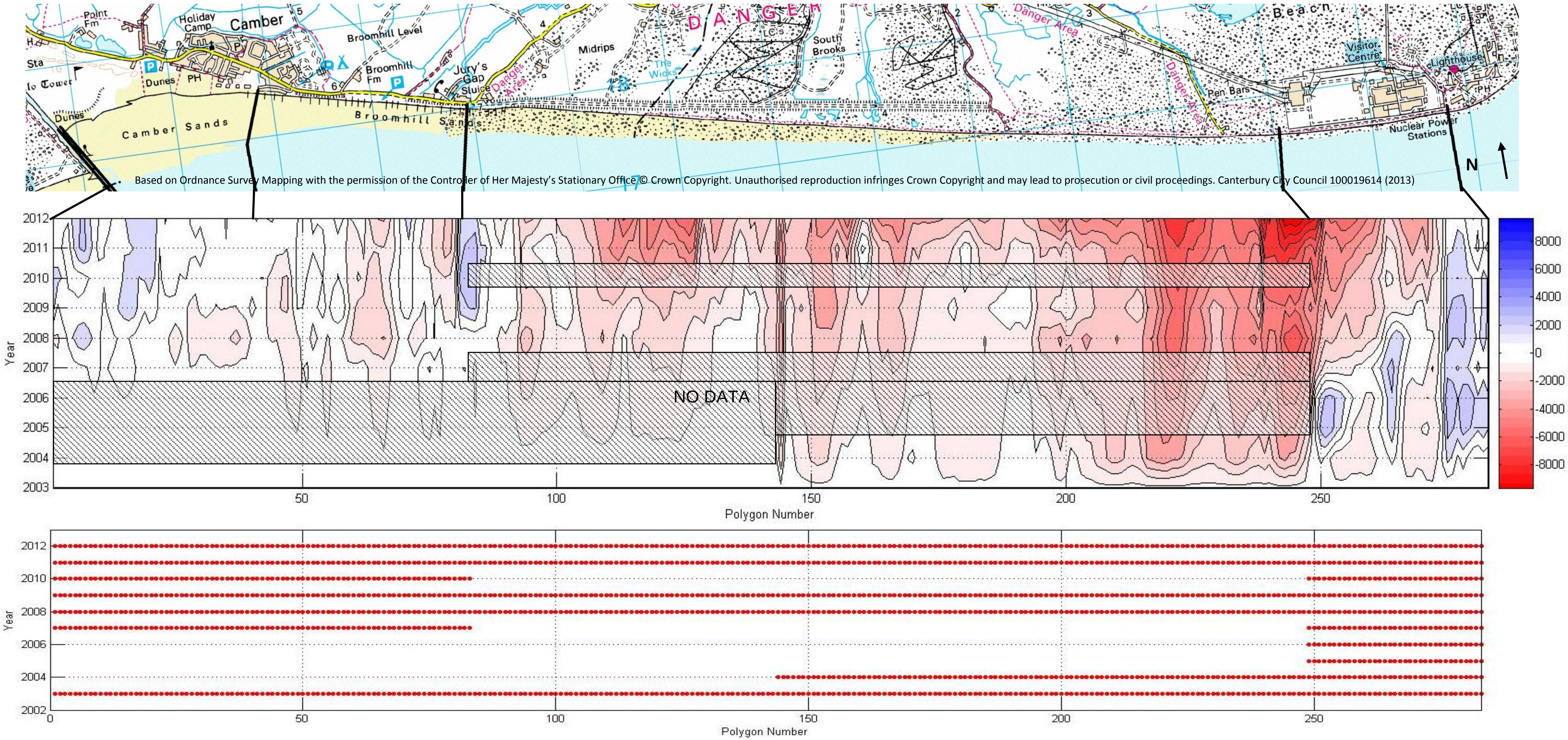


Figure 4-1 Cumulative contour plot of beach volumetric change since 2003 over the entire sediment budget

The contour 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 Rye Harbour, 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 frontage is clearly split into highly erosive and accretive sections, Camber Sands shows minimal volumetric change, Jury's Gap appears relatively stable however beach replenishment maintains the naturally erosive beach. Lydd Ranges is highlighted as persistently erosive as the berm height is maintained but is allowed to roll inland. Dungeness indicates erosion toward the west and accretion towards the east. In Figure 4.2 Romney Sands indicates continued accretion since 2007; prior to this the site was used as a borrow pit. Dymchurch, Hythe Ranges and Hythe to Sandgate are relatively stable and Folkestone appears particularly accretive, however Hythe and Sandgate to Folkestone are heavily skewed by the recycling works.

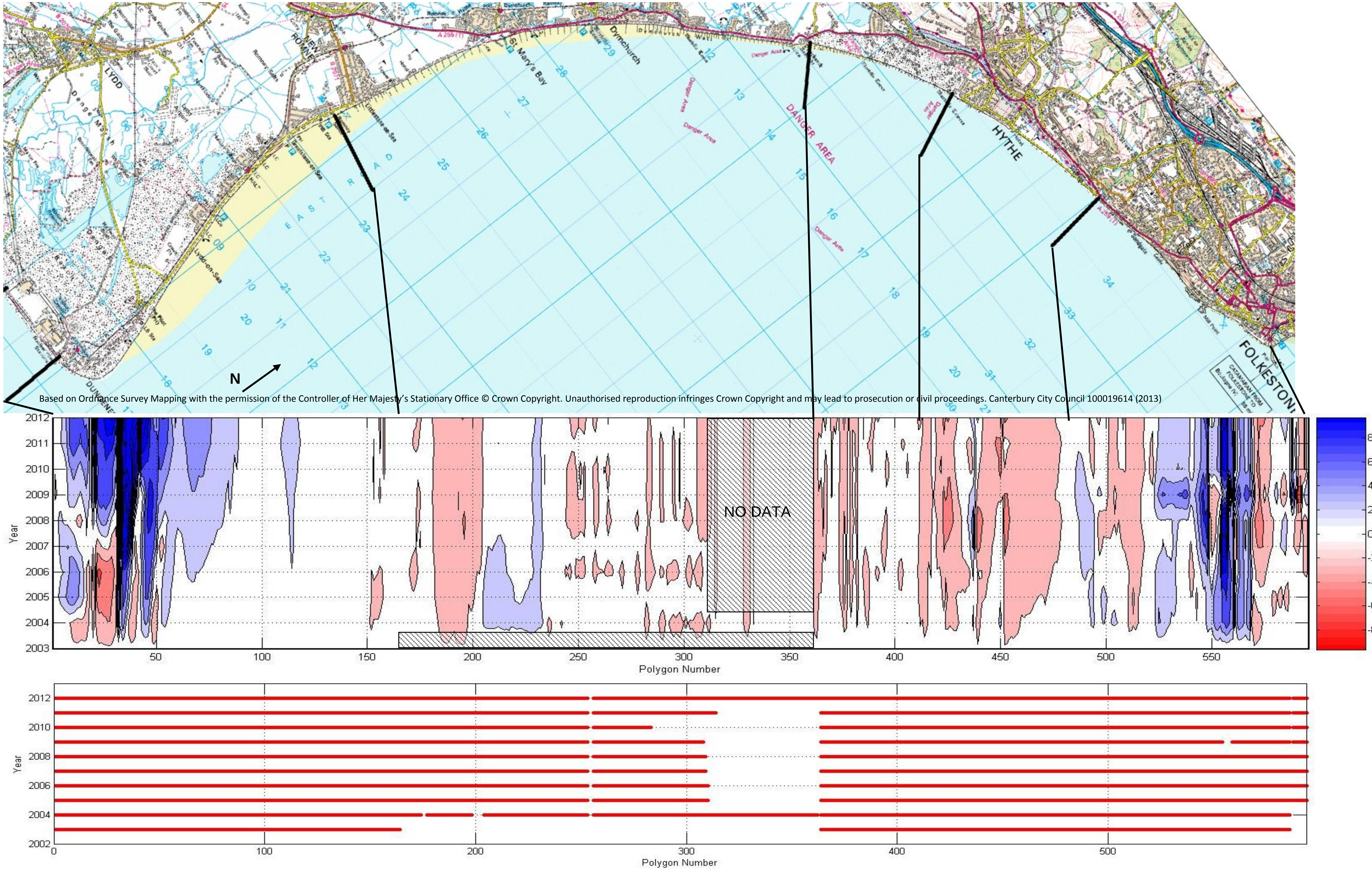
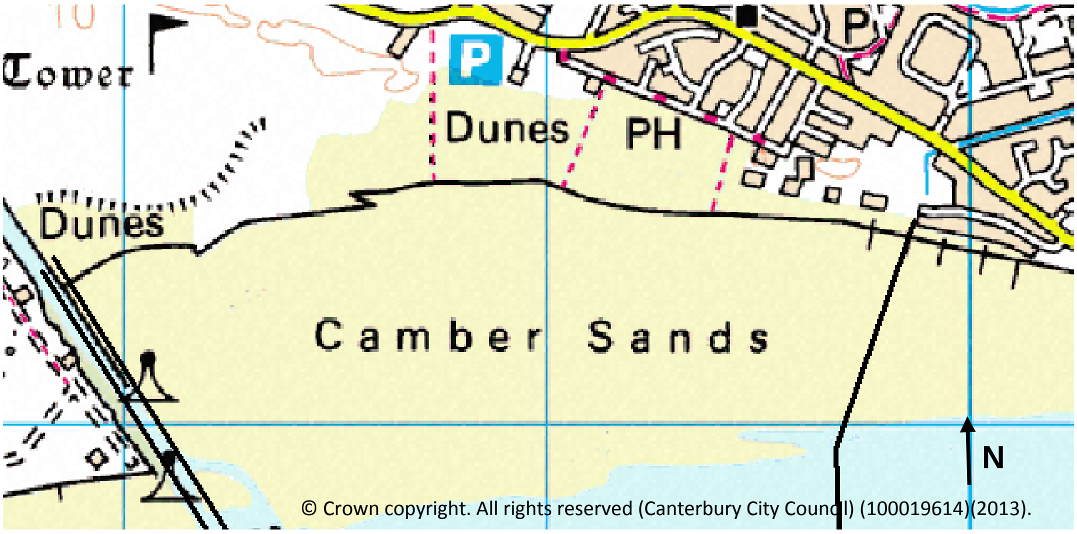
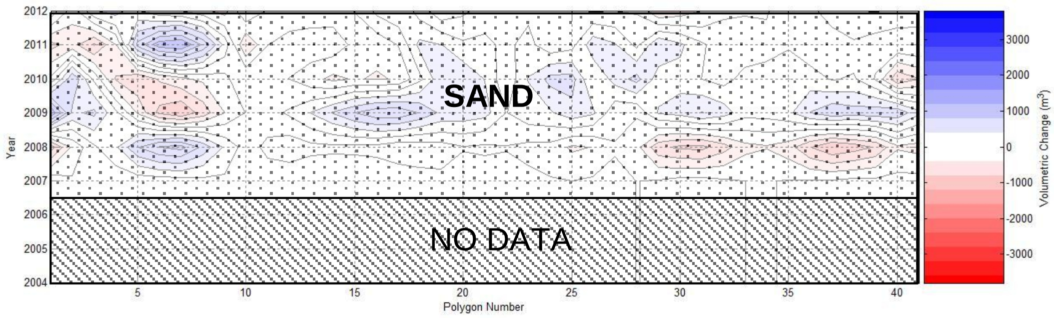


Figure 4-2 Difference Plot, Cumulative Contour Plot and Availability Plot for beach volumetric change across the east of the frontage

4.1.1 Camber Sands





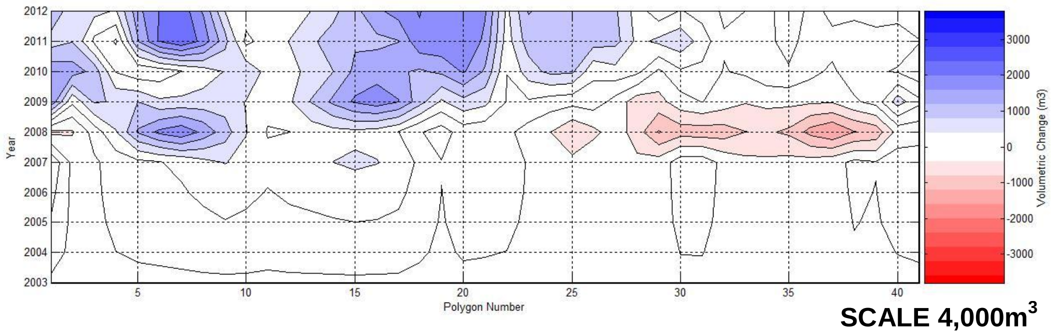
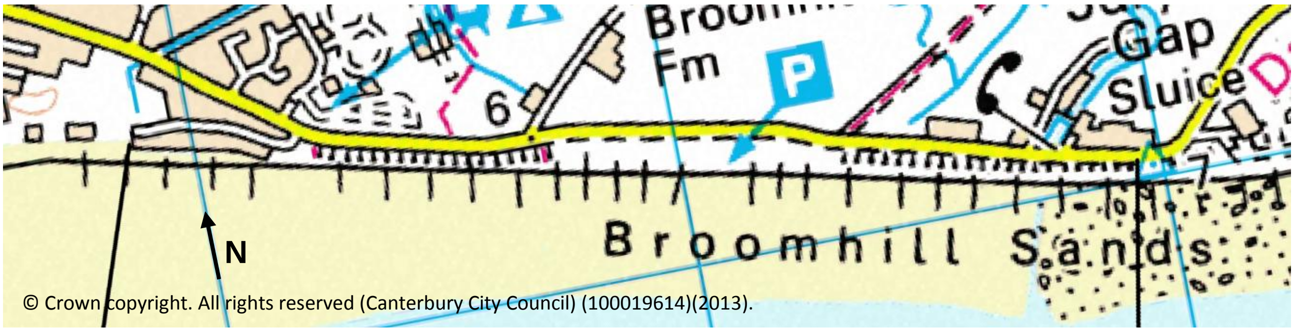


Figure 4-3 Difference Plot and Cumulative Contour plot for beach volumetric change at Camber Sands since 2003

No data was collected in 2004, 2005 or 2006; however the volumetric change was calculated between 2003 and 2007. The difference plot (top) shows hash for no data. The cumulative plot (bottom) includes the 2003-2007 volume change; however the change is relative small. The dominant drift direction along this stretch of coast is west to east. The prominence of Rye Harbour ensures no material is transported from Winchelsea. It is thought that the majority of gains are sourced offshore. Anecdotal evidence implies that small volumes of material enter from Jury's Gap however they are small enough to be discounted. The beach demonstrates localised losses and gains year on year and is regarded as stable (+/-3,000m^3/year).

Due to the sandy nature of this unit, it has not been included in the shingle sediment budget.

4.1.2 Jury's Gap



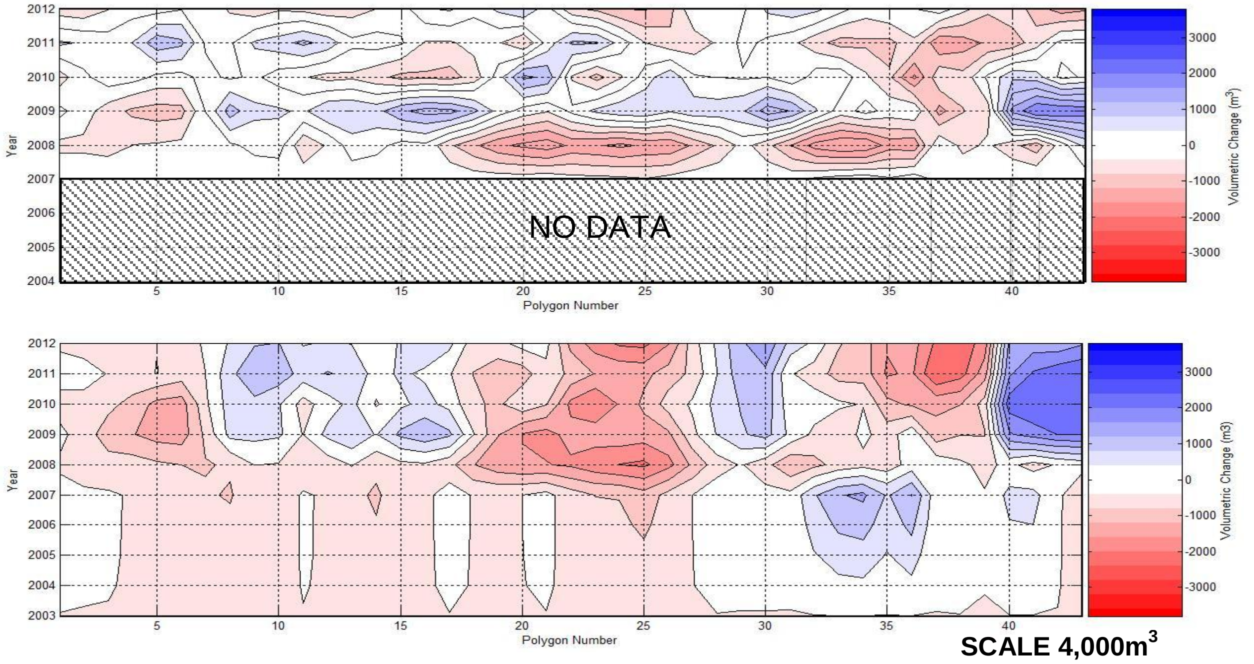
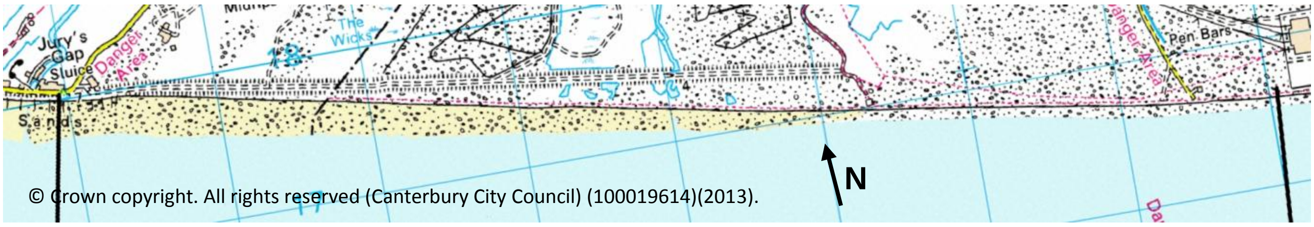


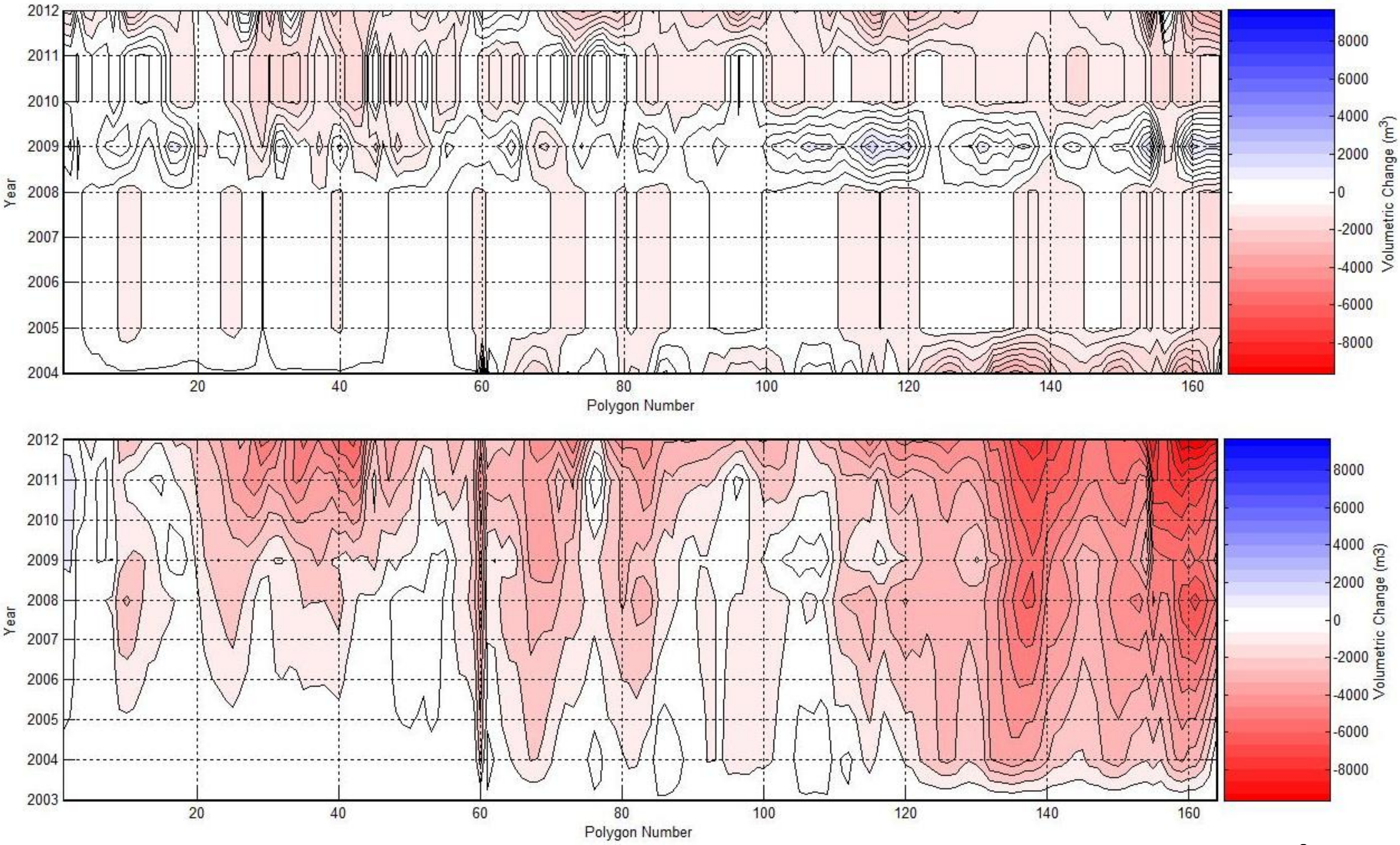
Figure 4-4 Difference Plot and Cumulative Contour plot for beach volumetric change at Jury's Gap since 2003

The boundary between Camber Sands and Jury's Gap separates the sediment type; sand dunes at Camber and the shingle beach at Jury's Gap. Jury's Gap is the start of the shingle sediment budget and as a result is highly erosive and needs an external source to maintain the beach levels. No data was collected in 2004, 2005 or 2006; however the volumetric change was calculated between 2003 and 2007. The difference plot (top) shows hash for no data. The cumulative plot (bottom) includes the 2003-2007 volume change; however the change is relative small.

Neither the difference plot or the cumulative plot emphasise the extent of the losses experienced at Jury's Gap as the erosion is masked by annual replenishment of 25-30,000m^3/year of quarry material. The beach is characterised by sections of erosion and accretion.

4.1.3 Lydd Ranges





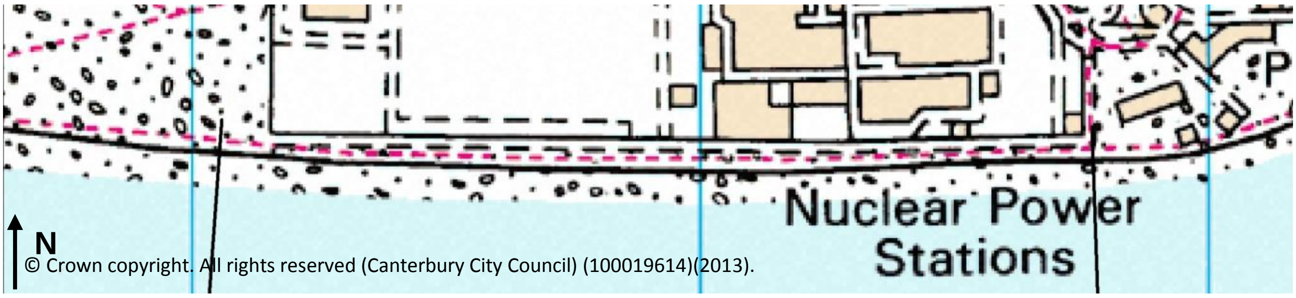
SCALE 10,000m^3

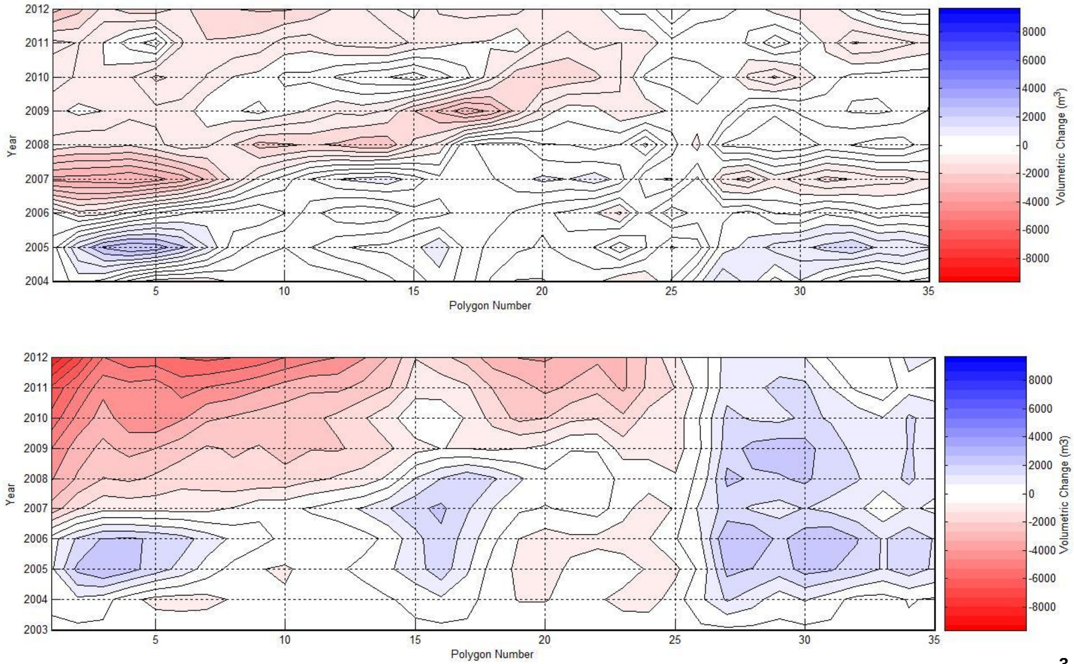
Figure 4-5 Difference Plot and Cumulative Contour plot for beach volumetric change at Lydd Ranges since 2003

Lydd Ranges is heavily erosive with material lost across the whole frontage. Due to its designated status the beach rarely receives beach material and largely relies on the feed from Jury's Gap. The first few groyne bays receive material as part of the Jury's Gap replenishment, and can be managed three times per year to maintain beach levels. This is reflected in the difference and cumulative plots by smaller losses in the west.

The difference plot (top) shows 2008 to 2009 to have gained material, in the region of 45,000m^3, along the eastern stretch of the beach. All other years have lost large volumes of material. The cumulative contour plot (bottom) emphasises the persistent loss over time, particularly towards the east of the unit, next to Dungeness. There are two sections of beach which are particularly erosive, Polygons 130 to 142 (500m stretch, 650m west of the eastern lookout) and 155 to 166 (eastern look out to the east).

4.1.4 Dungeness





SCALE 10,000m³

Figure 4-6 Difference Plot and Cumulative Contour plot for beach volumetric change at Dungeness since 2003

This open beach is the natural divide between eroding Lydd and accreting Romney Sands. This is reflected in the difference plot (top) and cumulative plot (bottom) as the western half of this 1.8km beach is persistently erosive and the eastern half is more accretive. Prior to 2007 Polygons 1 to 15 received annual recycling of approximately 30,000m^3 to retain the 1 in 10,000 year tsunami bund in front of the nuclear power station. Since 2007 this recycling has stopped and despite the reprofiling of the bund since 2007 to maintain the level of protection, the beach volume has dropped by 106,000m^3.

4.1.5 Romney Sands

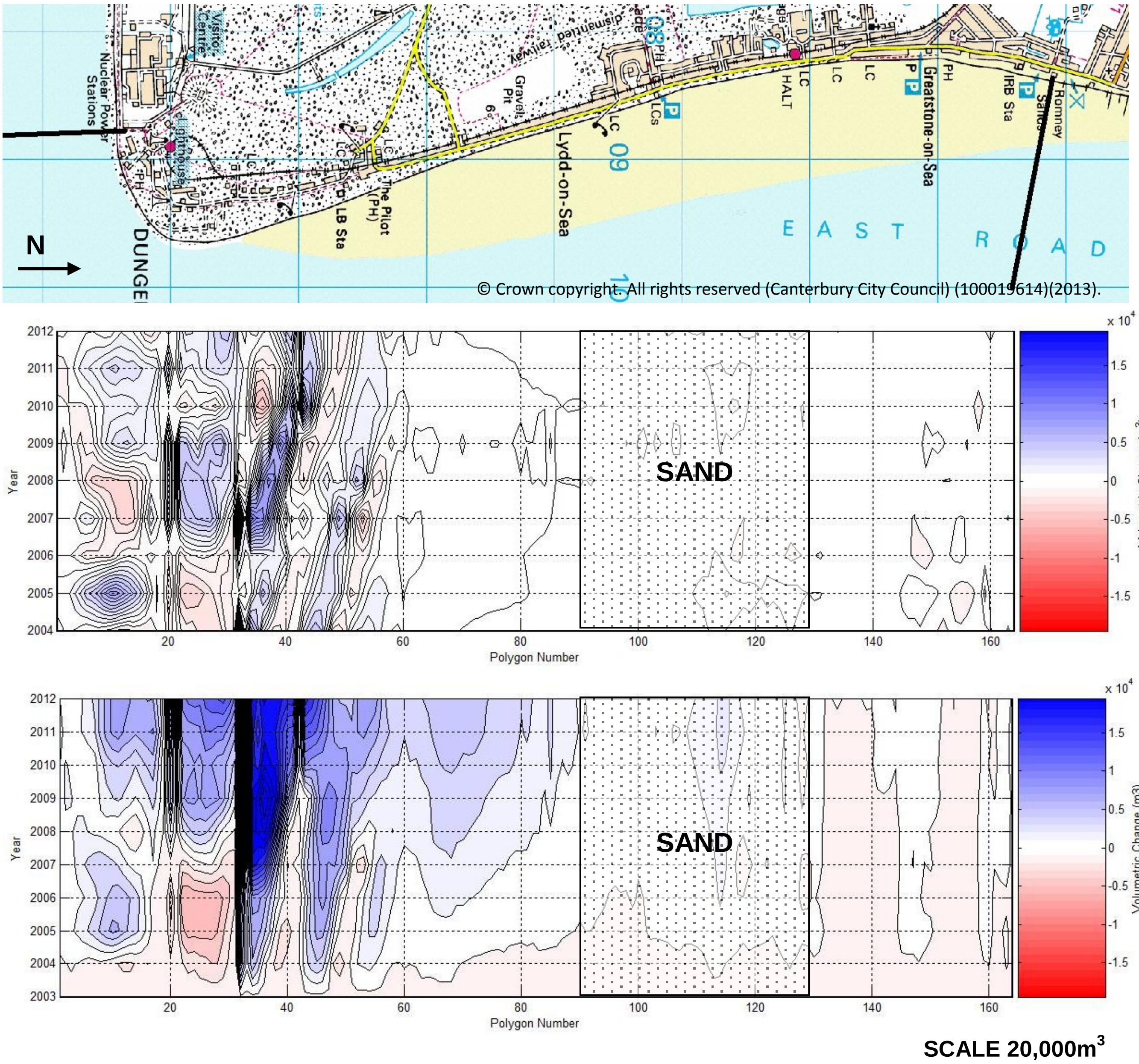


Figure 4-7 Difference Plot and Cumulative Contour plot for beach volumetric change at Romney Sands since 2003

Romney Sands beach runs north to south and is the only open beach to trap and accumulate material. The dominant drift direction is south to north until Lydd-on-sea, 2km north of the Pilot PH. There is a drift convergence between Romney Sands Holiday Park and Williamson Road, Lydd-on-sea, so north of the holiday park material is transported from Dymchurch.

Polygons 20 to 30 represent the main section of the Borrow Pit which prior to 2007 extracted material for Jury's Gap and Dungeness. Since its abandonment in 2007 the beach has started to accrete material annually to form a large protrusion. The difference plot (top) supports this indicating a larger gain of material post 2007. The cumulative plot (bottom) highlights the increasing span of accretion further north in Polygons 40-60 during 2009 to 2012.

4.1.6 Dymchurch

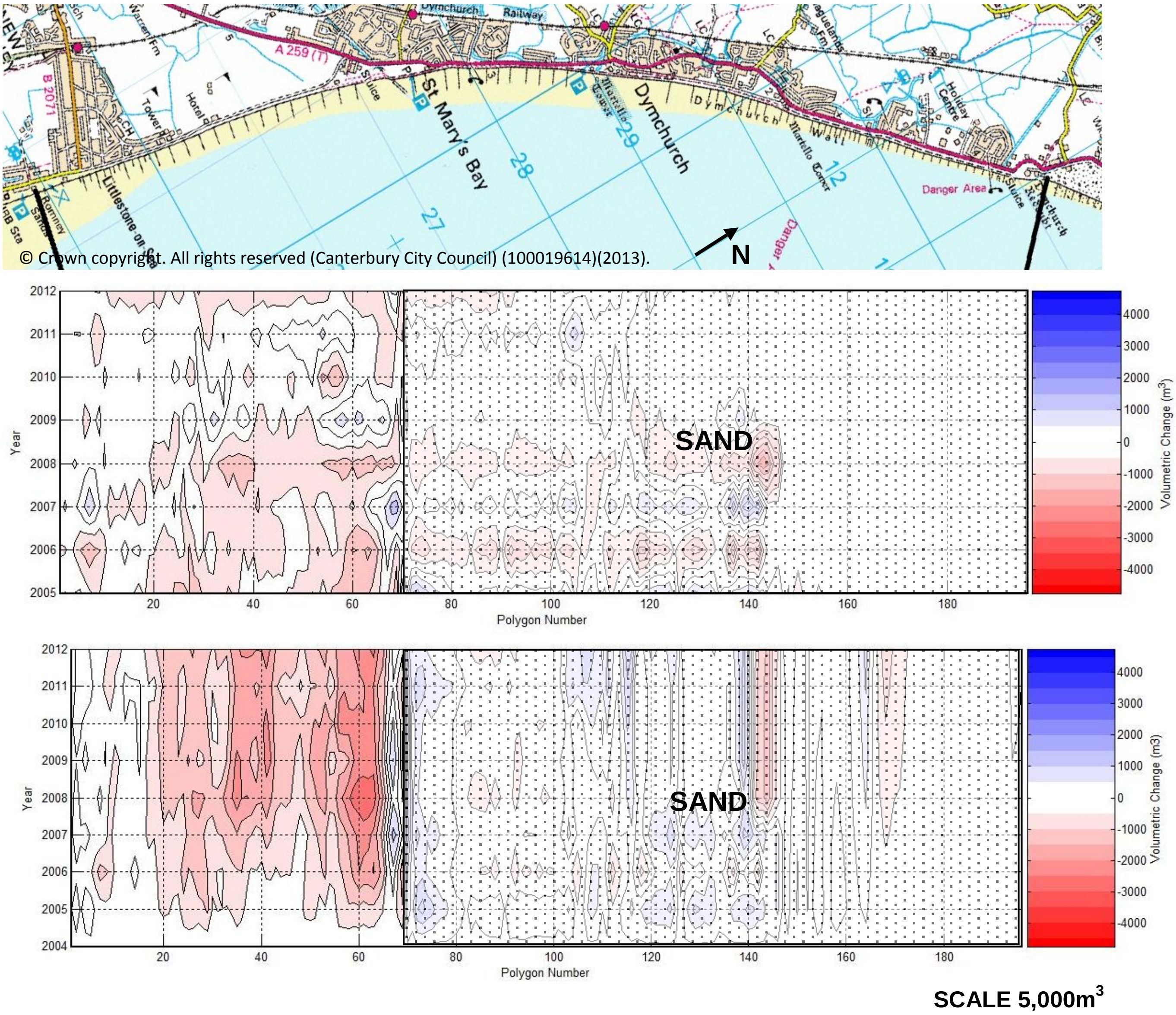
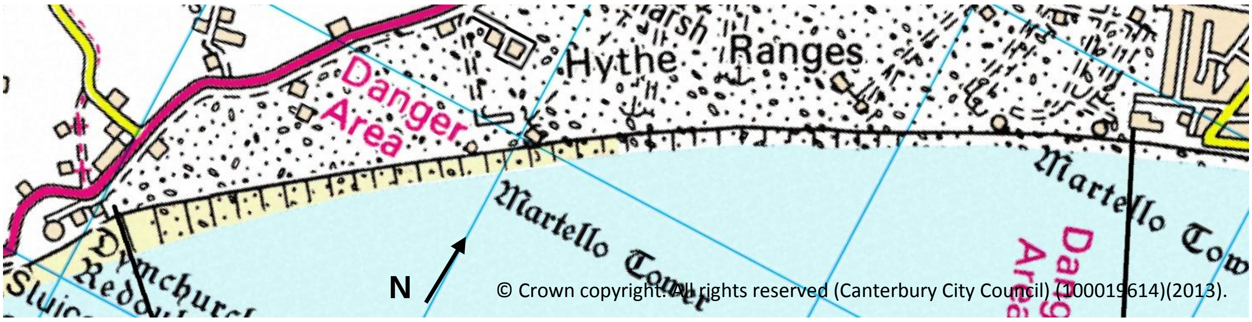
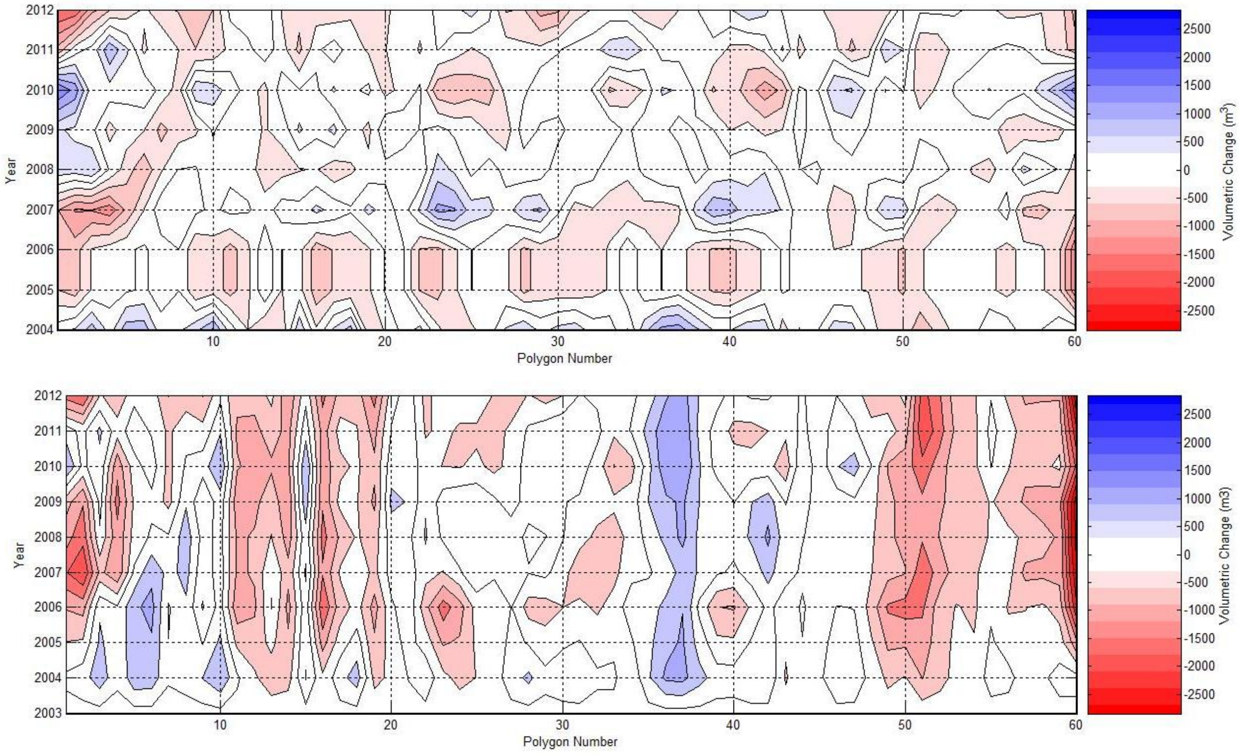


Figure 4-8 Difference Plot and Cumulative Contour plot for beach volumetric change at Dymchurch since 2004

Dymchurch beach is split into an eroding and accreting section. Polygons 75 to 200 have been excluded as the beach is sand. The difference plot shows small gains and losses across the whole frontage. All changes are +/- 3,000m^3.

4.1.7 Hythe Ranges



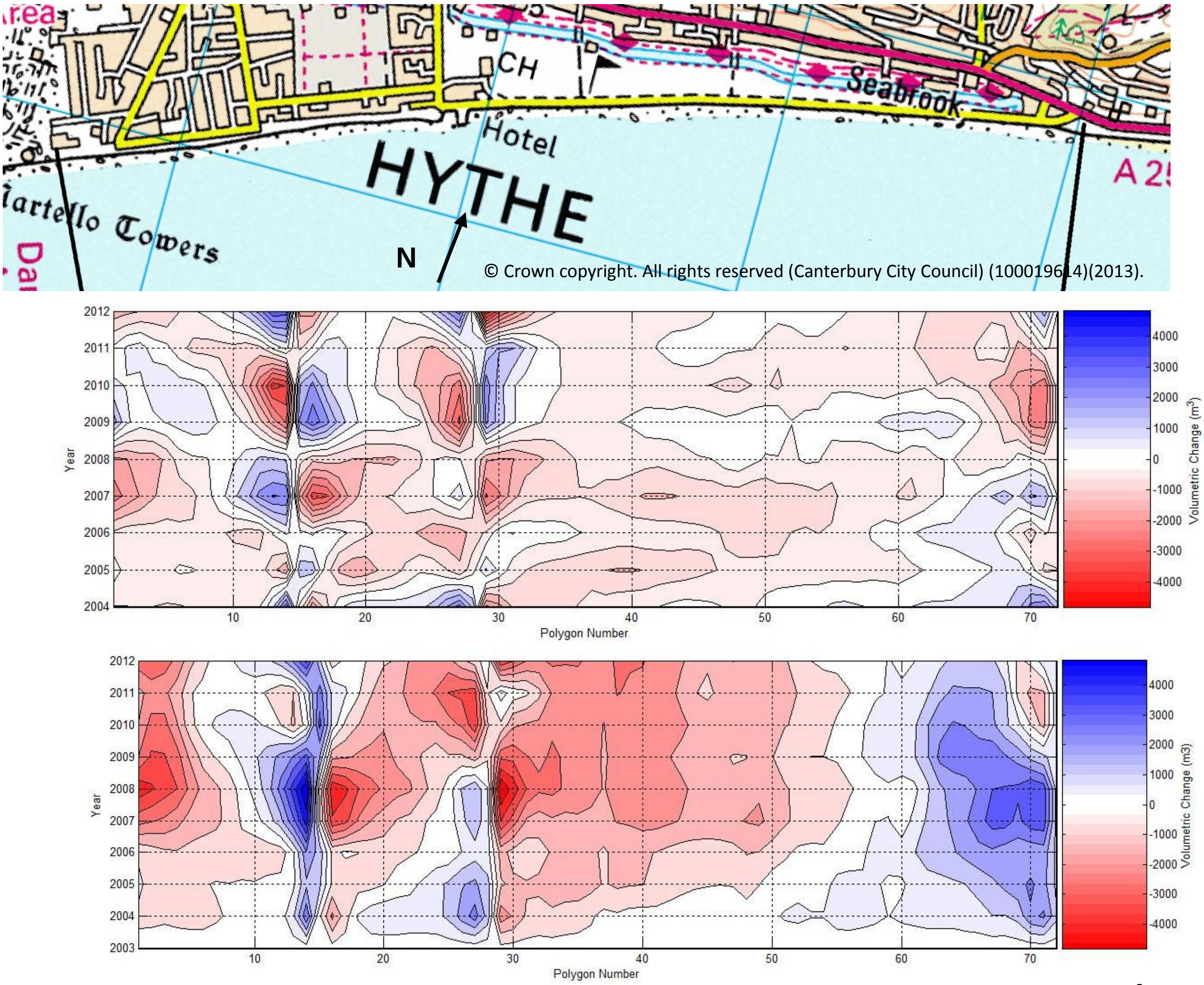


SCALE 3,000m^3

Figure 4-9 Difference Plot and Cumulative Contour plot for beach volumetric change at Hythe since 2003

Hythe Ranges is a MoD firing range, fronted by a heavily groyned shingle beach. The groyne field is visible in the difference and cumulative contour plots; the difference plot (top) shows sporadic gains and losses across the whole frontage. During 2005 and 2006 the majority of the frontage lost material. The cumulative plot shows the eastern end to be the most erosive section as the last polygon covers the start of Hythe beach which is the end of the Hythe timber groyne field and the start of the widely spaced rock groynes. The last polygon (60) undergoes biannual recycling to maintain beach levels.

4.1.8 Hythe

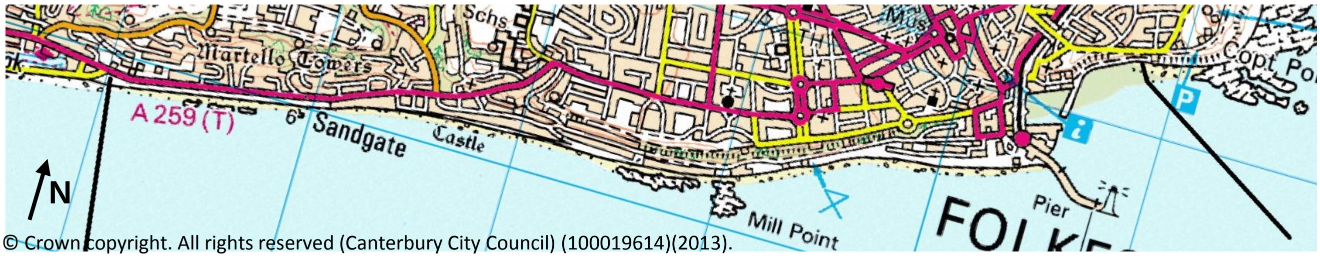


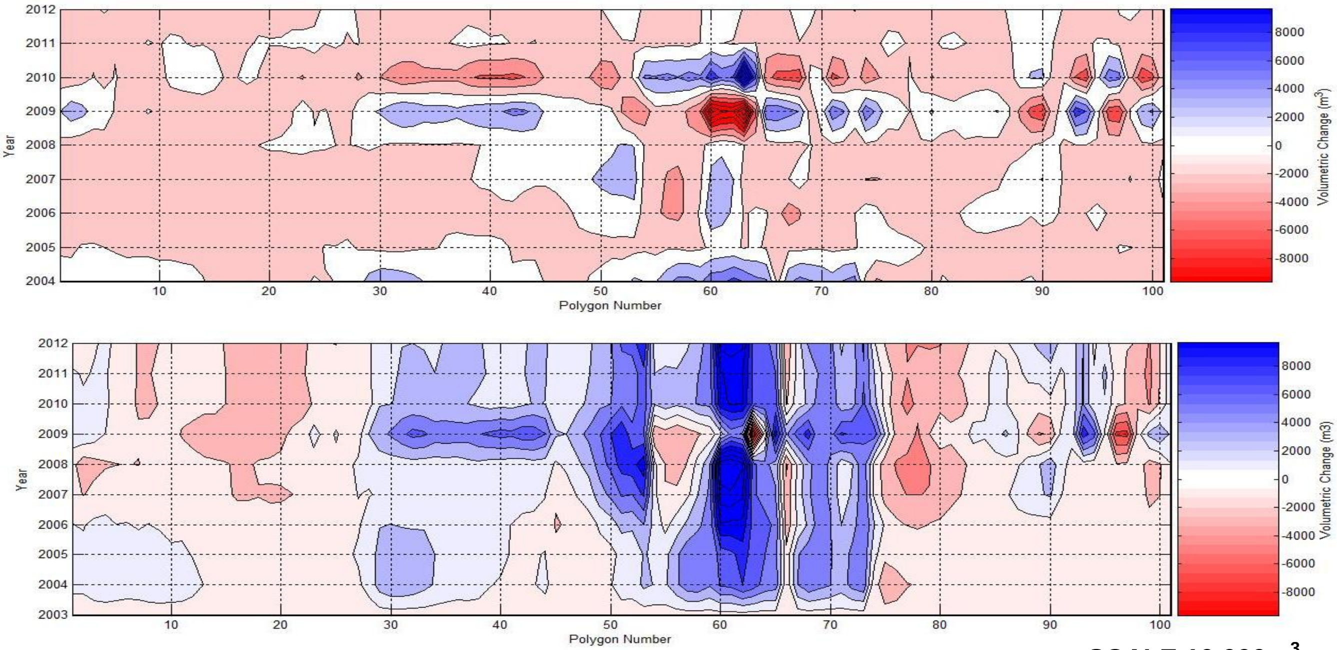
SCALE 5,000m^3

Figure 4-10 Difference Plot and Cumulative Contour plot for beach volumetric change at Hythe since 2003

Hythe is heavily managed and subject to biannual recycling within its rock groyne bays. Both the difference and the cumulative plots clearly illustrate the rock groyne layout of the beach. The losses shown in Polygons 1 to 5 are a result of the material being transported west to east, adjacent to a timber groyne field of Hythe Ranges which reduces material into Hythe. The gains in polygon 14/15 show material accumulating on western side of the groyne but being lost from the eastern side of the groyne (Polygon 16/17). The same scenario occurs around polygons 26 to 29. It must be noted that this contour plot is skewed by the amount of recycling and anthropogenic movement of material.

4.1.9 Sandgate to Folkestone





SCALE 10,000m^3

Figure 4-11 Difference Plot and Cumulative Contour plot for beach volumetric change at Folkestone since 2003

The beach between Sandgate and Folkestone is heavily managed and receives beach recycling twice per year to maintain beach levels. Polygons 45 to 75 indicate large volumes of change; the difference plot (top) suggests this as a large gain in 2004 which loses and gains accordingly until 2008. Beach recycling tends to take place within the unit, with small volumes exported into Hythe.

Polygons 63 to 67 experienced losses in 2008 which were accentuated by the lack of recycling activities between March 2007 and June 2008. The large gain in 2009 was the attempt to raise beach levels in the first recycling event. The 2008/09 loss is seen in the cumulative plot (bottom) as the colours go to light blue, followed by the gain in 2009/10 as the contours return to dark blue.

Polygons 85 to 102 represent the crenular bays and the eastern side of the harbour. The changes within these bays and the harbour are localised. Material is thought to pass over and around the rock groynes and transported east. Contrasting the rest of the sediment budget, the crenular bays are swash aligned, not drift aligned, and are prone to erosion within days of beach management. Material is thought to be transported offshore out of the bays with less emphasis on longshore transport. The most eastern crenular bay is thought to feed the bay west of the harbour as the beach is an extraction site which needs an input of 1,000m^3/year to balance the cell.

Figure 4.12 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. This frontage is characterised by two extremes, Romney Sands has gained approximately 750,000m^3 since 2003 and Lydd Ranges has lost approximately 550,000m^3 since 2003. The remaining beaches are classed as relatively stable.

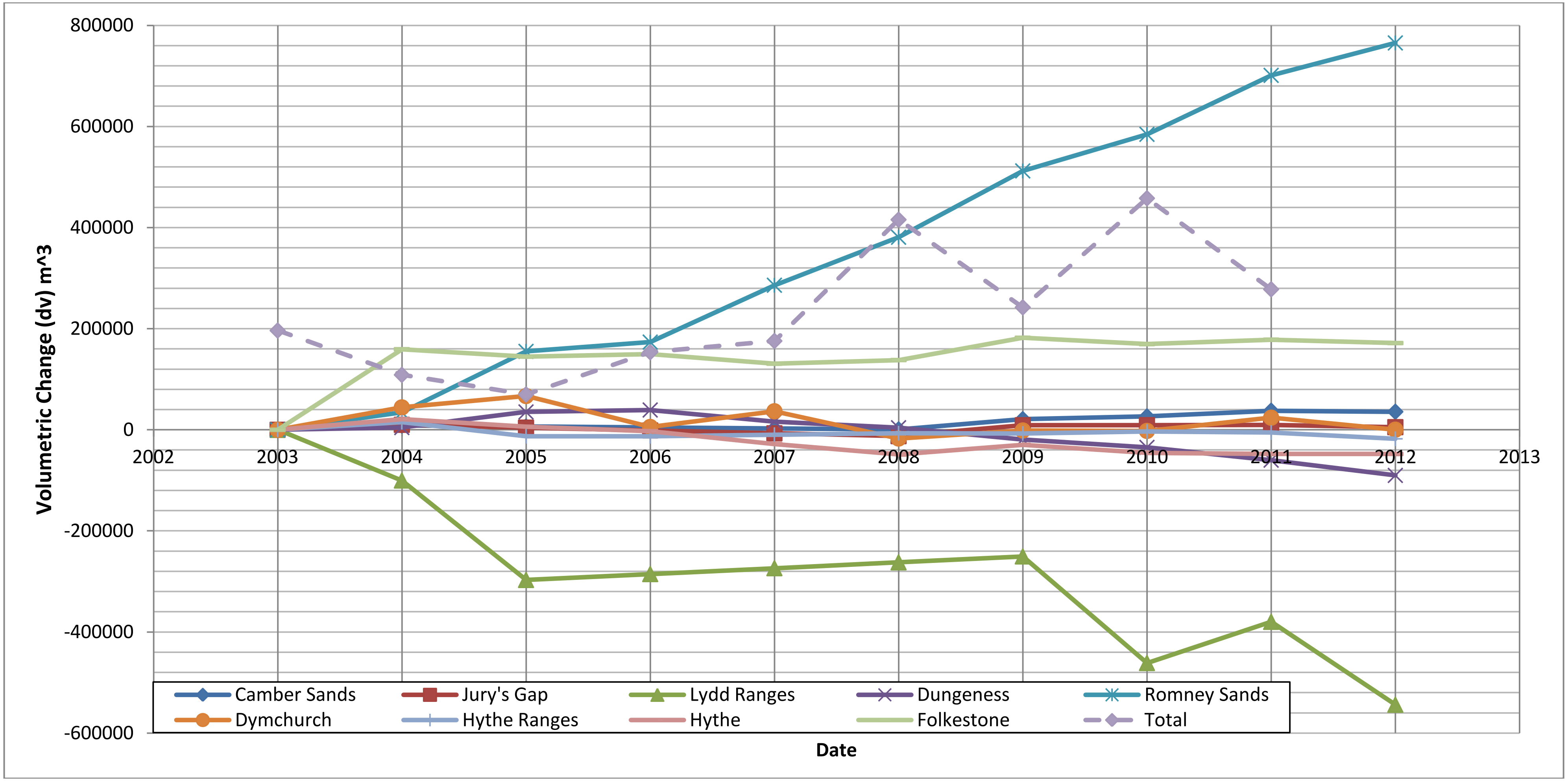


Figure 4-12 Spatio-temporal plot 2003-2012

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.

Explanation of beach behaviour between Rye Harbour and Folkestone Harbour

As the methodology has been designed to calculate shingle sediment transport rates, Camber Sands (CS1), one sub-cell in Romney Sands (RS6) and the central and northern sections of Dymchurch (DY3) cannot be considered as part of the shingle sediment budget, as they are predominately sandy beaches.

Camber Sands is accreting in the region of 4,900m^3/year. Although this is removed from the sediment budget it must be acknowledged that this material has not been transported from Jury's Gap and is most likely sourced offshore from the foreshore at Nook Point, Winchelsea and onshore migrating sand bars. Camber Sands is reasonably protected due to the orientation of the coastline and the adjacent terminal structure at Rye Harbour, reducing the longshore drift rates to the east. Material can move onshore during an easterly but has little wave energy to transport material out of the sub-cell.

Jury's Gap forms the shingle sand divide and is the start of the longshore movement which is indicative of the high erosion rates. Material is transported from Jury's Gap, through Lydd, Dungeness and Romney Sands to Lydd-on-Sea in Romney Sands. Transport rates are reduced north of the old Borrow Pit as large volumes of material accumulate here. The material which moves north into RS5 leaves a shortfall of 1,346m^3/year which is believed to be a result of onshore movement as the sub-cell north (RS6) is excluded from the sediment budget on the basis that the beach is sand.

Dymchurch is approximately 1/3 shingle stretch and 2/3 sand. The southern stretch of coastline (shingle) indicates a north to south drift direction. Sub-cell DY2 transports material from south to north. The central and northern sections of Dymchurch were excluded from the sediment budget. If the sand dV (5,649m^3/year) was included in the calculations the results for Hythe Ranges, Hythe and Sandgate to Folkestone would be skewed and not representative. The sand gain is most likely to be a result of onshore movements and for these reasons has been excluded.

Due to the exclusion of Polygons 3, 4, 5 and 6 at Dymchurch, the sediment budget is balanced eastwards from Hythe Ranges to Folkestone. The initial forward balancing of the budget from Hythe eastwards caused 3,000m^3/year to pass the large groynes in Folkestone, with a residual at Folkestone Harbour of 3,000m^3/year. Whilst this suggests that the budget is performing well, the transport rates past the bays seem too large given their controlling nature. This error (residual) is generated further up the coast, produced as a combined error of the general rules for attrition, recharge and recycling as well as the survey error in the data collection. If the calculated losses from any one of these three assumed losses were lower than actual losses, then the error is transported down the coast and compounded with distance. Consequently, an attempt at quantifying this loss was made through weighting the residual to the length of the unit, providing an additional 'unaccounted' loss for the associated cells. Effectively, the residual is divided equally across the frontage so that errors are not compounded through the unit.

$$Distance\ Weighted\ Residual\ (DWR) = \ Length\ of\ cell.\left(\frac{residual\ for\ section}{length\ of\ section}\right)$$

This forced the transport rate past the groynes to <1,000m^3/year and reduced the alongshore transport rates to those to be expected on this type of frontage. Between Hythe and Folkestone the drift direction is predominantly west to east; both Sandgate and Folkestone undergo intense beach management which counteracts the drift direction to maintain beach levels. This report aimed to calculate realistic beach movement in these two units by splitting the groyne bays into two, to show natural losses and gains. It has been assumed that no material pass two of the rock groynes, between FK7 and FK8, and FK9 and FK10. The transport rate has been stopped at both of these groynes and started at 0 in attempt of replicating actual transport rates. Sub-cells FK9 and FK10 is a single crenular bay with no material presumed to be coming in or out. As a result the beach is swash aligned and the offshore losses are higher than other sub-cells. The residual at Folkestone is 0 due to the DWR.

The Dymchurch scheme in 2003 saw 260,000m^3 of shingle deposited. The beach was only partially surveyed in the 2003 BMP as the beach was still cordoned off from the coastal works. The baseline year for this study was 2004, immediately after the scheme was completed. The performance of this scheme was investigated by Herrington (2009) which was found to have lost 64,238m^3 in the first 4 years. Consequently, 8,000m^3/year (64,000m^3/8yrs) was applied as a total loss to the frontage (as it was deemed to have not been transported downdrift).

The total residual for this frontage is 9,822m^3/year, or that 9,822m^3/year is overcompensated for in the system. Given that this frontage is 45.3km in length, producing an error equal to 0.21m^3/m/year, it shows that the budget and methodology are working relatively well. However, as already discussed above, this frontage contains three distinct sand systems which are thought unlikely to impact the shingle sediment budget (at Camber Sands, Romney Sands - Greatstone, and Dymchurch central/east).

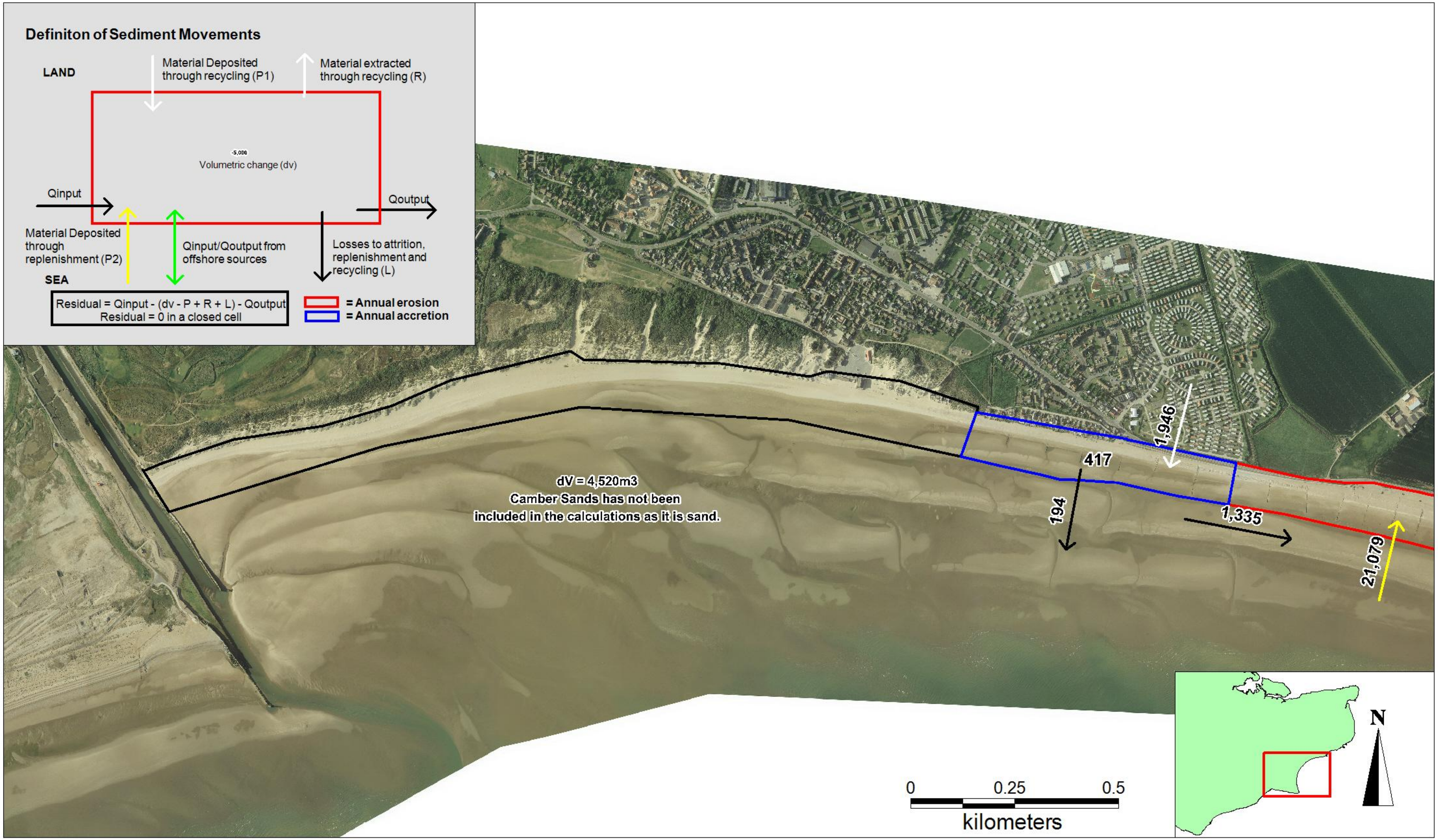
Table 4-1 - Level 3 - Coarse Sediment Budget (m^3/yr)

Cell	Sub-cell	Average annual change (ΔV)	Recharge (P1)	Recycling		Losses			Average annual flux (ΔV-P+R-L)	Distance Weighted Residual (DWR)**	Qoutput*
				Deposition (P2)	Extraction (R1)	Attrition (L1)	Recharge (L2)	Recycling (L3)			
Camber Sands	CS1	4,520	0	0	0	386	0	0	4,906	0	0
Jury's Gap	JG1	417	0	1,946	0	97	0	97	-1,335	0	1,335
	JG2	-369	21,079	12,323	0	223	2,108	616	-30,824	0	32,159
Lydd Ranges	LR1	-5,936	959	815	0	246	96	41	-7,328	0	39,487
	LR2	-10,518	0	0	0	275	0	0	-10,243	0	49,730
	LR3	-16,628	0	61	0	420	0	3	-16,265	0	65,995
	LR4	-26,802	0	0	0	291	0	0	-26,510	0	92,506
Dungeness	DU1	-10,031	0	13,979	0	257	0	699	-23,055	0	115,560
Romney Sands	RS1	9,669	0	0	0	119	0	0	9,788	0	105,772
	RS2	16,551	0	0	14,449	91	0	0	31,091	0	60,233
	RS3	38,670	0	0	14,449	215	0	0	53,334	0	21,347
	RS4	15,362	0	0	0	247	0	0	15,609	0	5,738
	RS5	6,813	0	0	0	271	0	0	7,084	0	-1,346
	RS6	2,337	0	0	222	234	0	0	2,793	0	
	RS7	257	0	0	1,756	38	0	0	2,050	0	-2,050
Dymchurch	DY1	-4,841	250	1,319	538	335	4,025	66	-1,446	0	-4,920
	DY2	-3,485	375	1,978	0	198	4,038	99	-1,504	0	902
	DY3	5,648	398	1,319	0	938	40	66	4,974	0	
Hythe Ranges	HR1	-913	0	0	0	146	0	0	-767	263	504
	HR2	-89	0	0	0	101	0	0	12	182	311
	HR3	451	0	0	0	99	0	0	550	179	-418
	HR4	-1,487	0	0	0	105	0	0	-1,382	190	774

Qoutput* Positive numbers represent a west to east drift and negative numbers represent an east to west drift
DWR** refers to the Distance Weighted Residual explained in Section 4.2.
Note: hashed out cells imply that volumes were removed from the shingle sediment budget as they were sandy beaches.

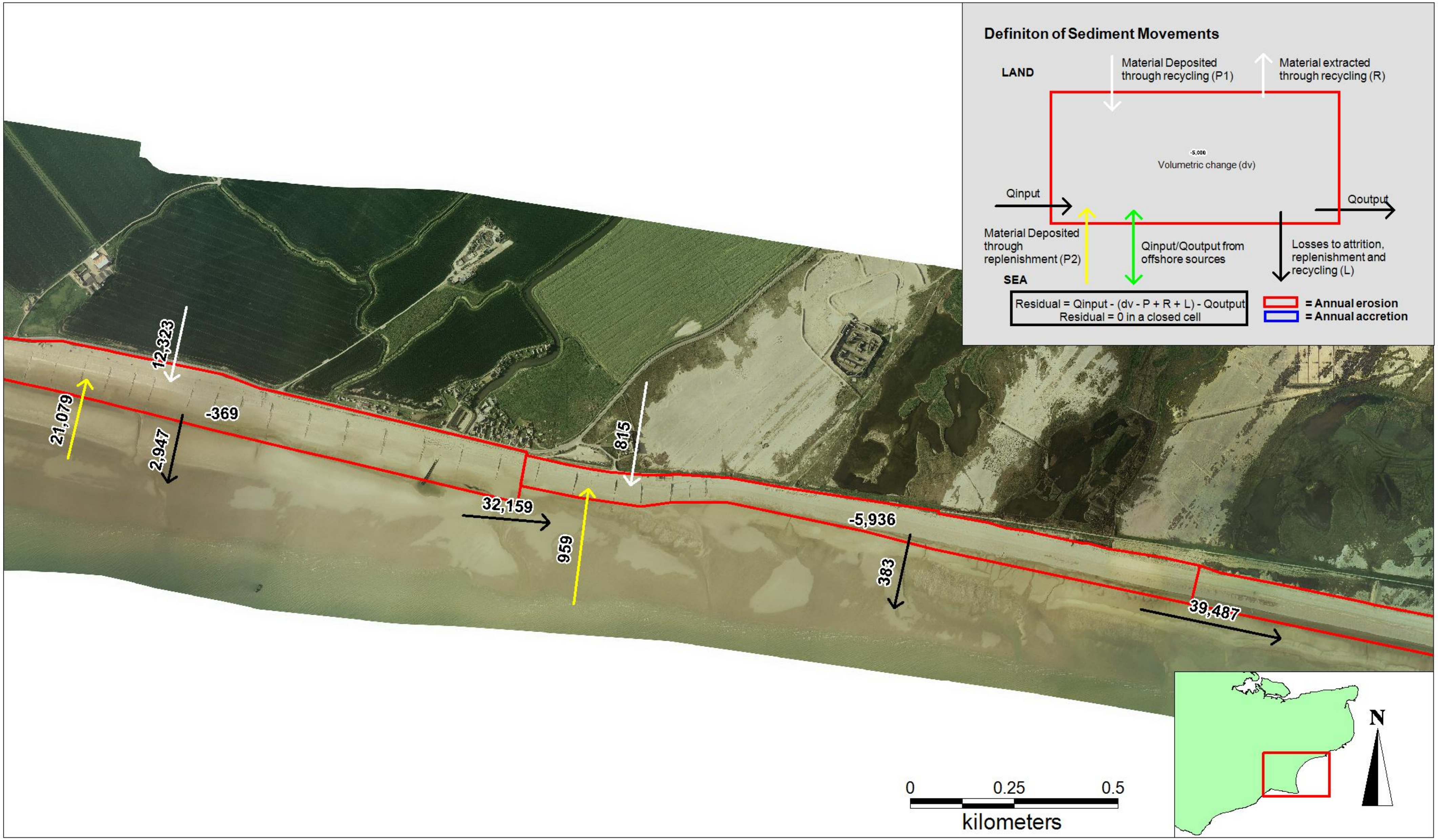
Cell	Sub-cell	Average annual change (ΔV)	Recharge (P1)	Recycling		Losses			Average annual flux (ΔV-P+R-L)	Distance Weighted Residual (DWR)**	Qoutput*
				Deposition (P2)	Extraction (R1)	Attrition (L1)	Recharge (L2)	Recycling (L3)			
Hythe	HY1	-1,151	0	368	0	32	0	18	-1,468	58	2,183
	HY2	4	0	7,841	0	42	0	392	-7,403	76	9,510
	HY3	1,286	0	0	6,313	32	0	0	7,630	57	1,823
	HY4	-472	0	6,853	0	50	0	343	-6,932	89	8,666
	HY5	-820	0	0	7,065	48	0	0	6,293	87	2,286
	HY6	-3,311	0	6,663	0	90	0	333	-9,551	163	11,674
	HY7	-1,438	0	0	0	69	0	0	-1,369	125	12,918
	HY8	-318	0	0	0	77	0	0	-242	138	13,021
	HY9	767	0	0	8,774	89	0	0	9,630	160	3,232
Folkestone	FK1	-2,674	0	6,404	0	83	0	320	-8,675	151	11,756
	FK2	-1,035	0	0	0	84	0	0	-951	152	12,555
	FK3	75	0	441	0	41	0	22	-304	73	12,785
	FK4	816	0	770	0	92	0	38	177	167	12,442
	FK5	3,809	0	0	7,930	100	0	0	11,838	180	423
	FK6	-1,497	0	9,157	0	34	0	458	-10,163	62	10,524
	FK7	2,267	0	140	8,294	34	0	7	10,462	62	0
	FK8	131	0	812	0	27	0	41	-613	368	245
	FK9	-632	0	133	628	26	0	7	-106	351	0
	FK10	-76	0	1,031	0	14	0	52	-1,042	0	1,042
	FK11	-139	0	533	498	13	0	27	-134	0	1,176
	FK12	-1,212	0	0	871	76	0	0	-265	0	1,441
	FK13	1,419	0	0	0	59	0	0	1,478	0	-37
Rye Harbour to Folkestone		15,468	22,914	74,476	71,247	6,554	10,291	3,724	9,893	3,332	

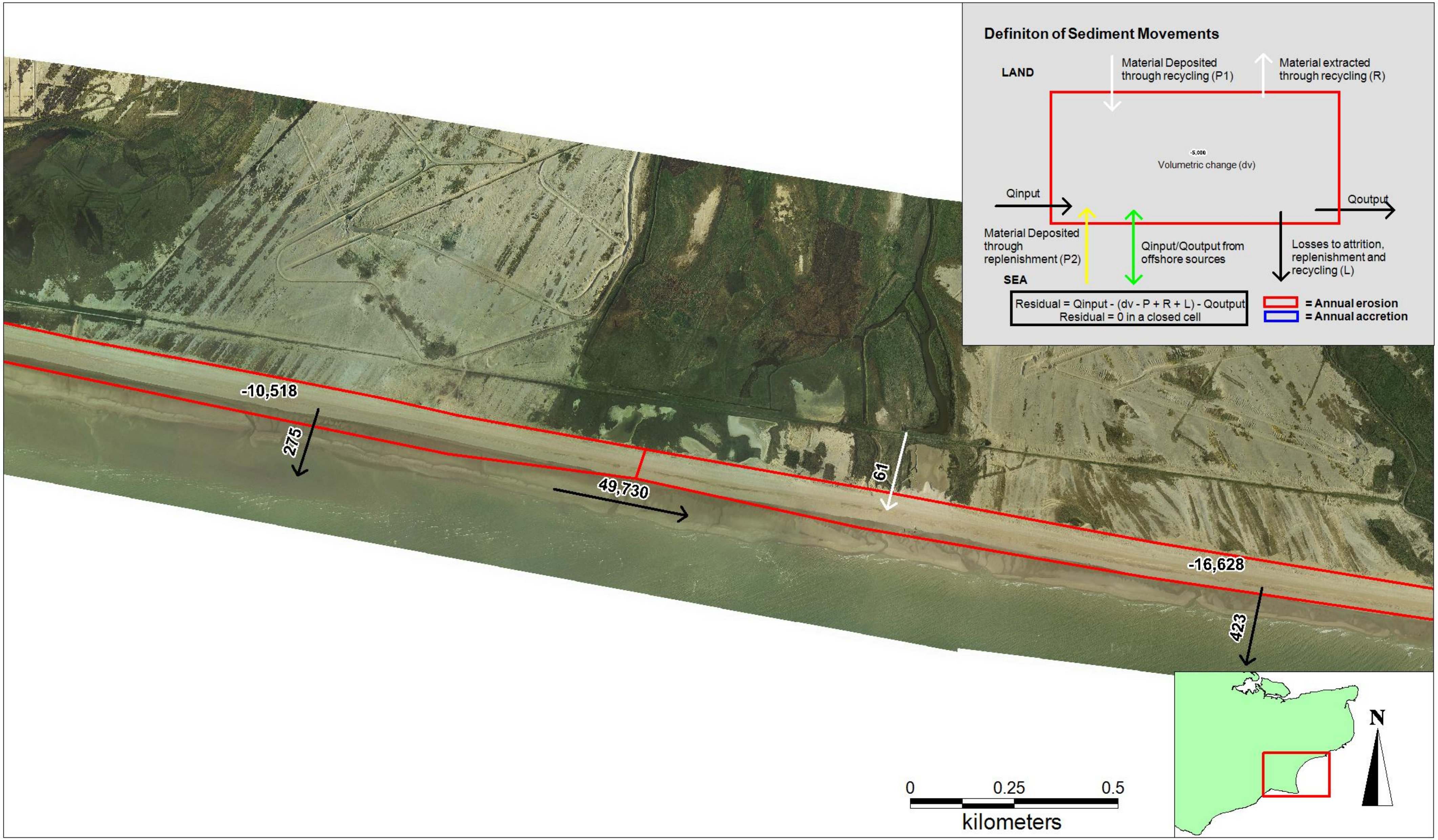
Qoutput* Positive numbers represent a west to east drift and negative numbers represent an east to west drift.
DWR** refers to the Distance Weighted Residual explained in Section 4.2.
Note: hashed out cells imply that volumes were removed from the shingle sediment budget as they were sandy beaches.

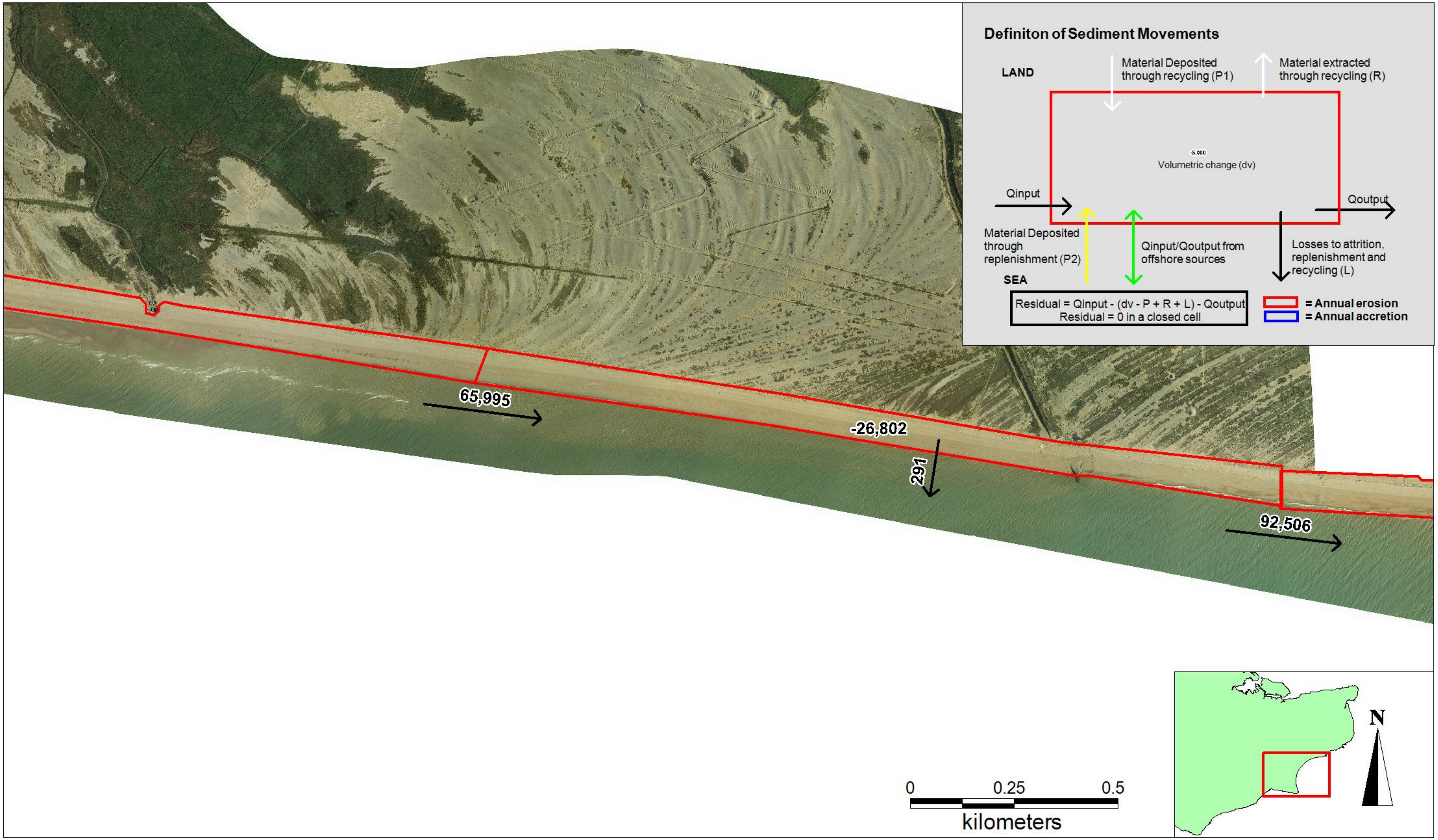


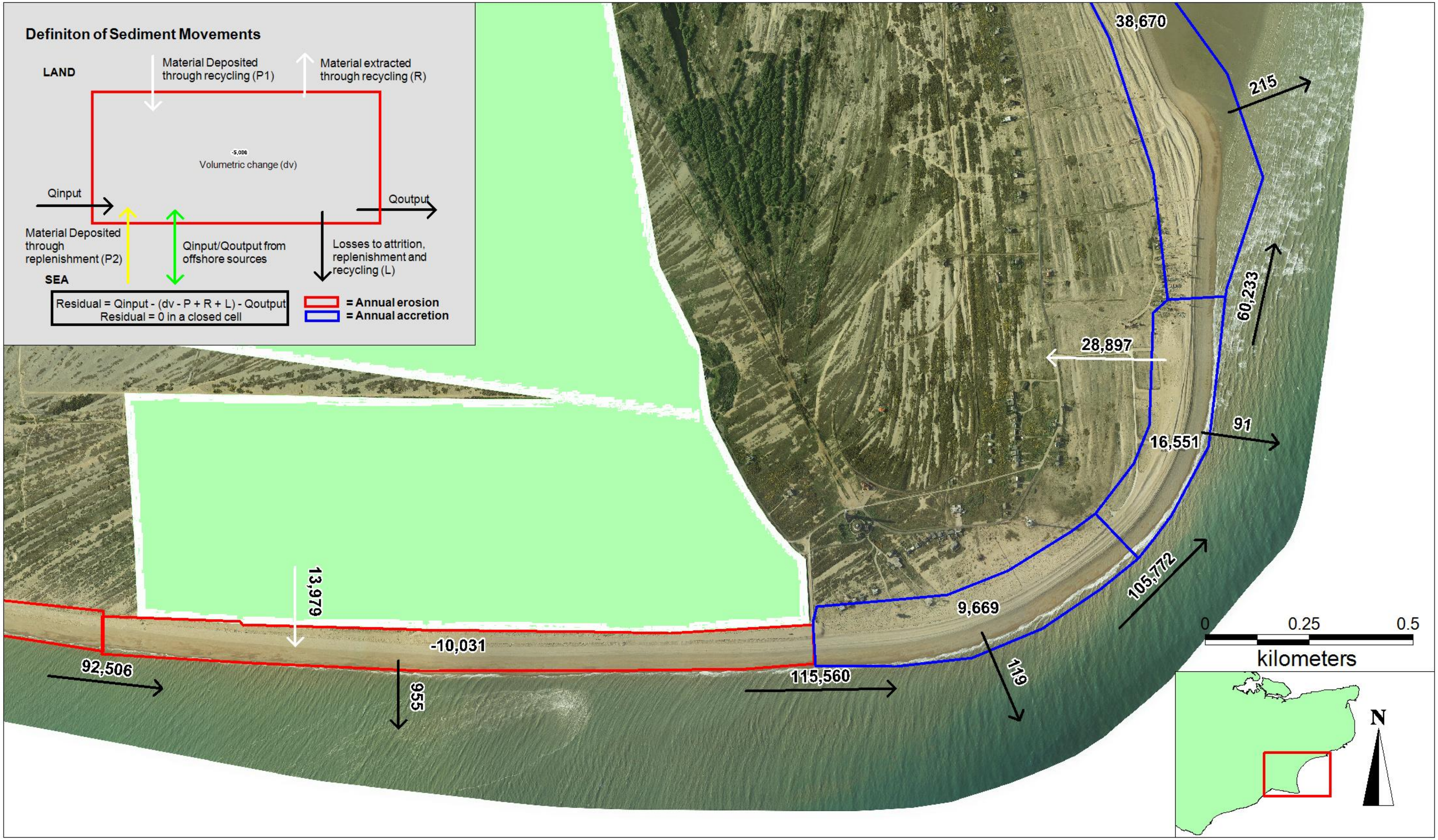
Rye Harbour to Folkestone Sediment Budget

Camber Sands


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
12,323
21,079
-369
2,947
815
32,159
959
-5,936
383
39,487
0
0.25
0.5
kilometers
N

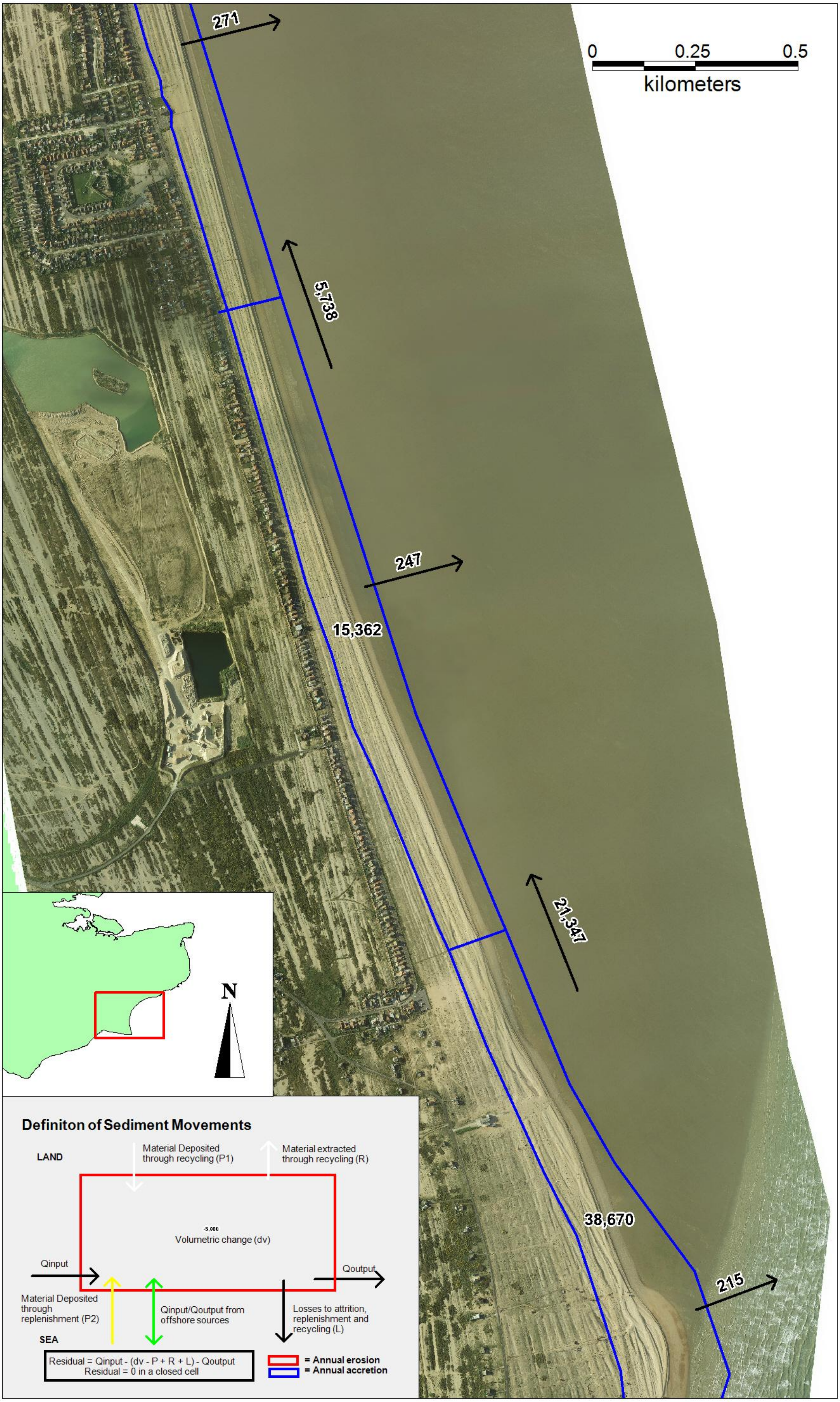

Definiton of Sediment Movements
LAND
Material Deposited through recycling (P1)
Material extracted through recycling (R)
Volumetric change (dv)
Qinput
Qoutput
Material Deposited through replenishment (P2)
Qinput/Qoutput from offshore sources
Losses to attrition, replenishment and recycling (L)
SEA
Residual = Qinput - (dv - P + R + L) - Qoutput
Residual = 0 in a closed cell
= Annual erosion
= Annual accretion
-10,518
275
49,730
61
-16,628
423
0
0.25
0.5
kilometers
N


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
65,995
-26,802
291
92,506
0
0.25
0.5
kilometers
N


Definiton of Sediment Movements
LAND
Material Deposited through recycling (P1)
Material extracted through recycling (R)
-5,000
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
38,670
215
60,233
28,897
91
16,551
105,772
9,669
119
13,979
-10,031
92,506
955
115,560
0
0.25
0.5
kilometers
N

South East Regional Coastal Monitoring Programme

Level 3 - Sediment Budget

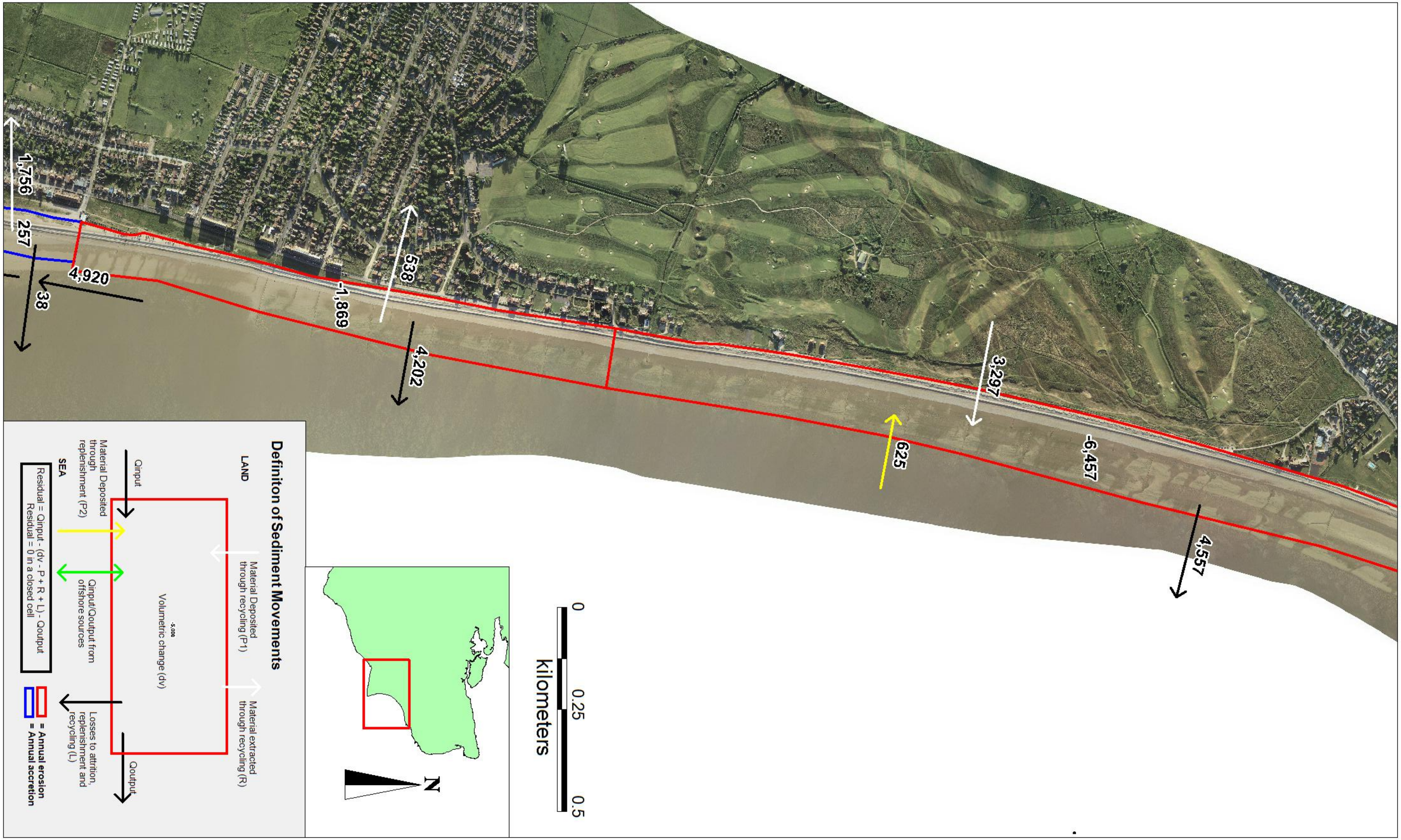


Rye Harbour to Folkestone Sediment Budget

Romney Sands - 1

Plate 2 (6 of 14)


1,756
257
2,050
38
dV = 2,793m^3
This part of Romney Sands has been excluded
from the calculations as it is sand.
1,346
6,813
271
0
0.25
0.5
kilometers
N
Definiton of Sediment Movements
LAND
Material Deposited
through recycling (P1)
Material extracted
through recycling (R)
-5,000
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


1,756
257
4,920
38
-1,869
538
4,202
3,297
625
-6,457
4,557
0
0.25
0.5
kilometers
N
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

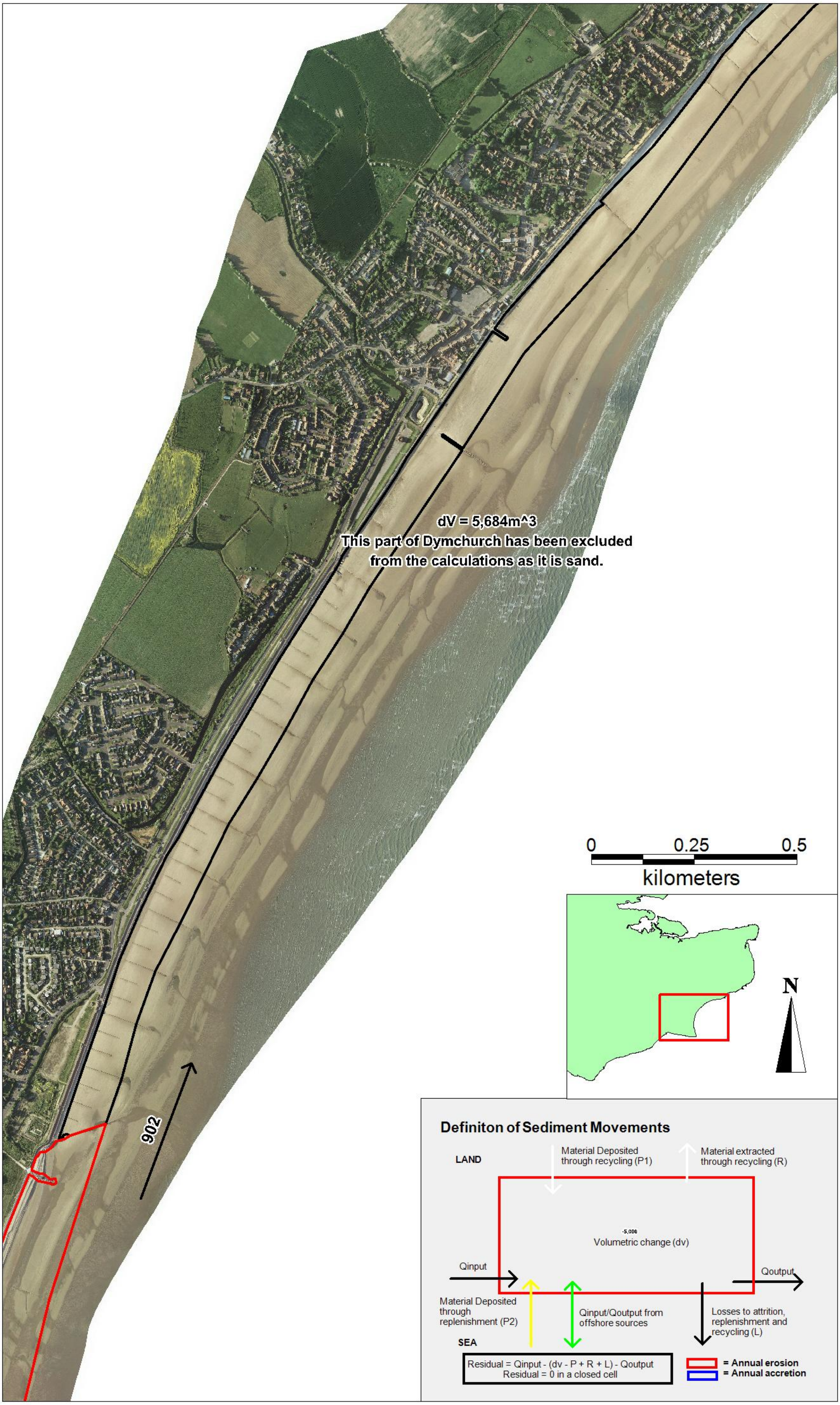
South East Regional Coastal Monitoring Programme

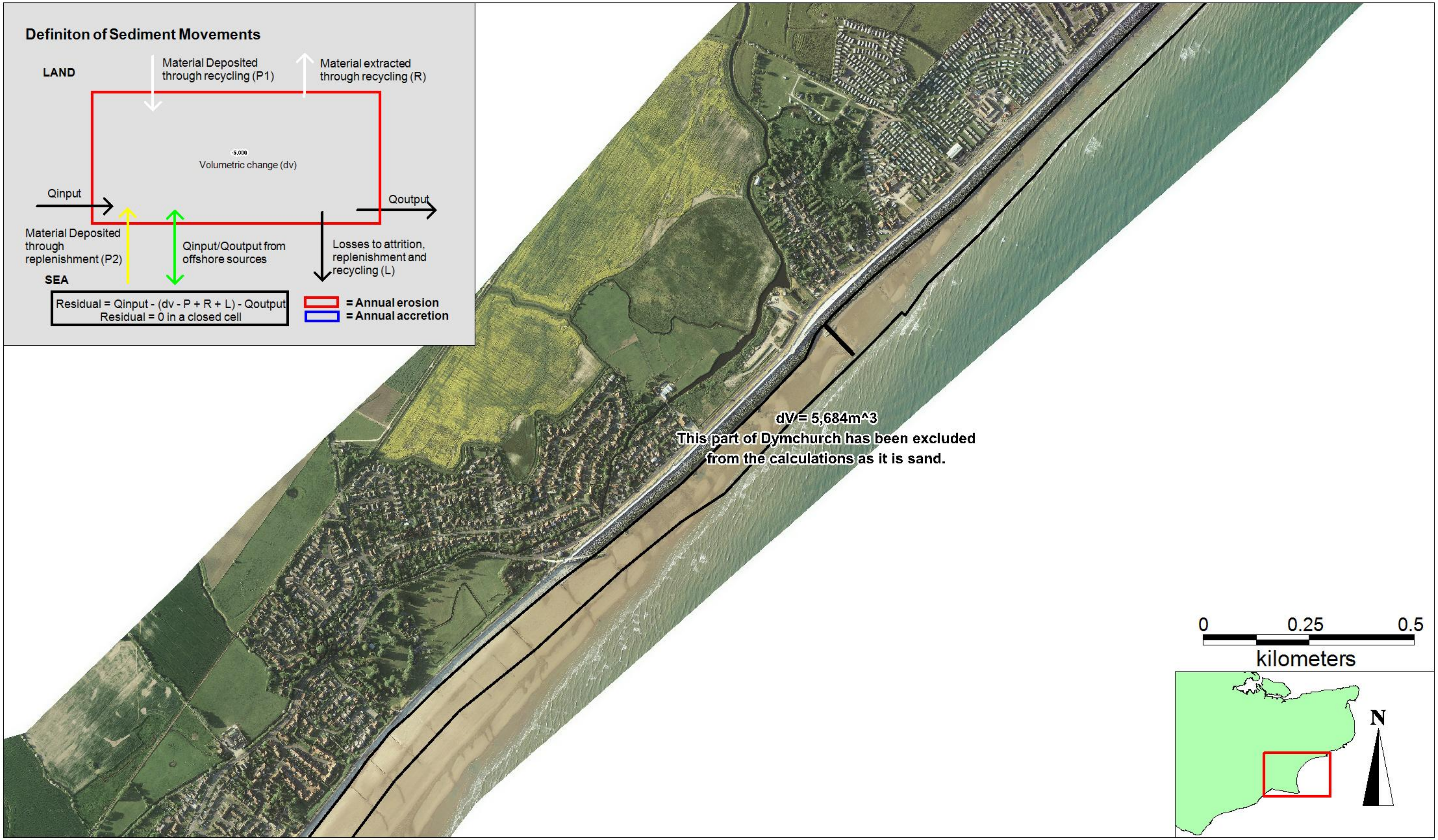
Level 3 - Sediment Budget

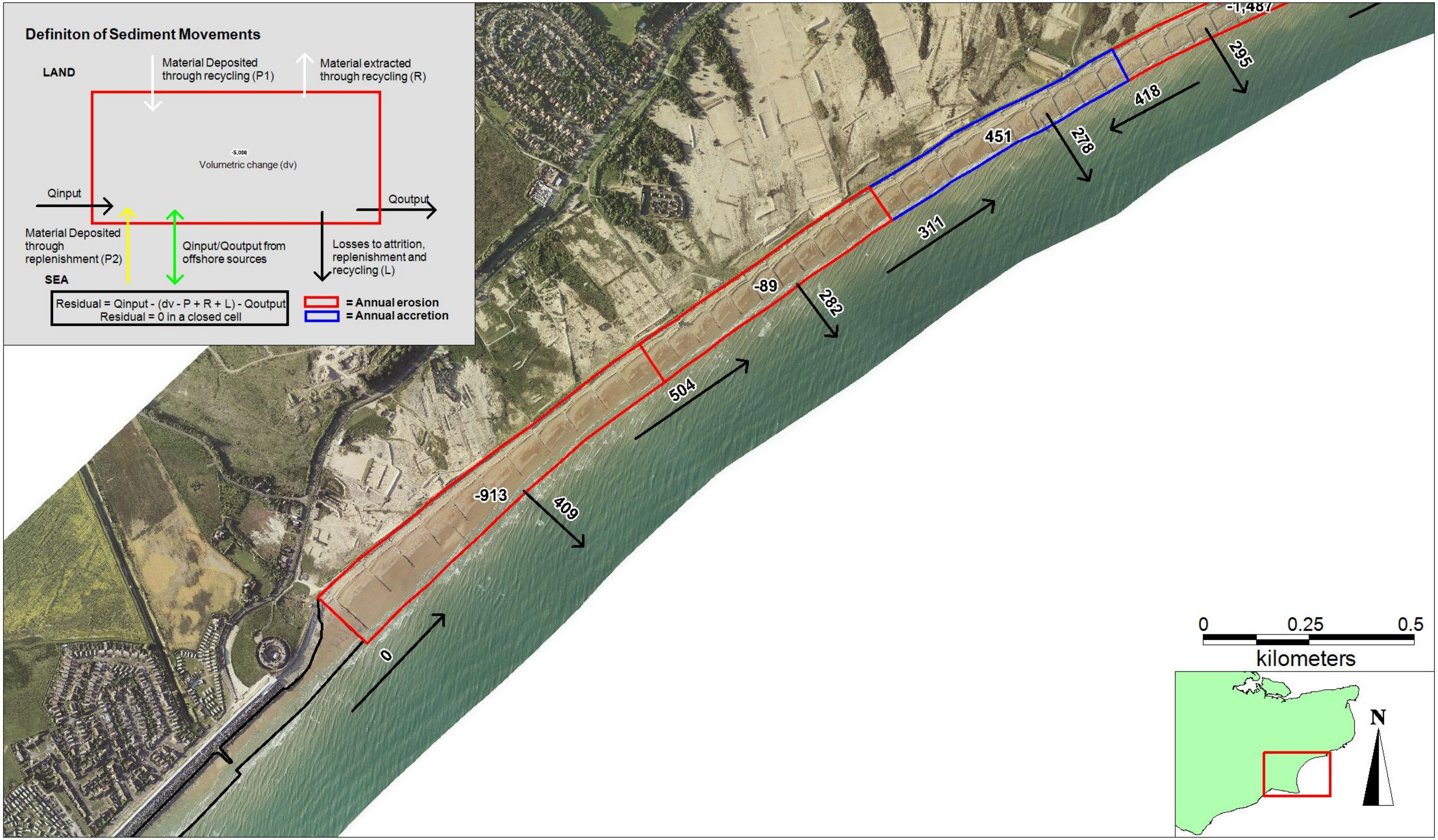
Plate 2 (9 of 14)

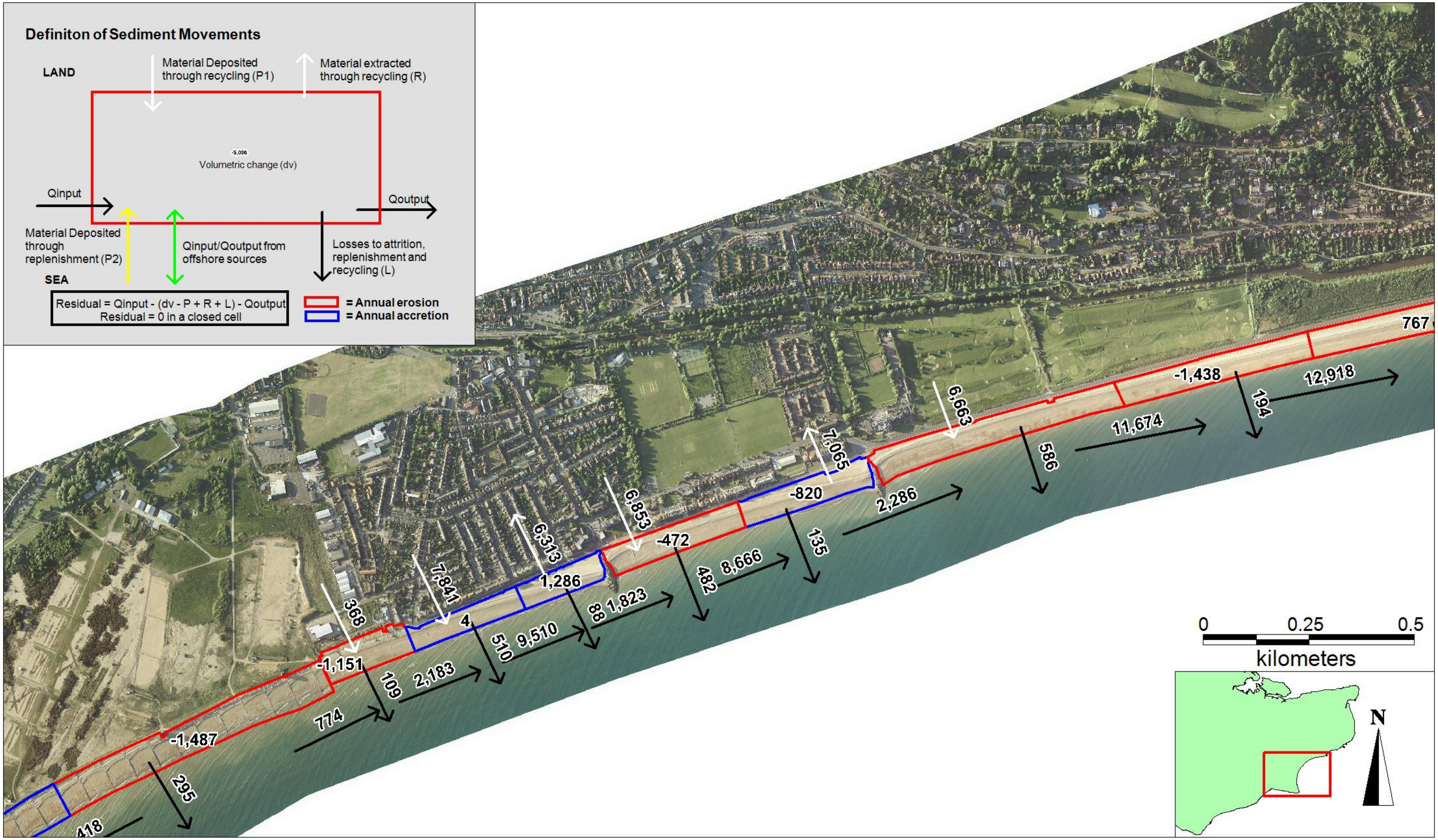
Dymchurch - 2

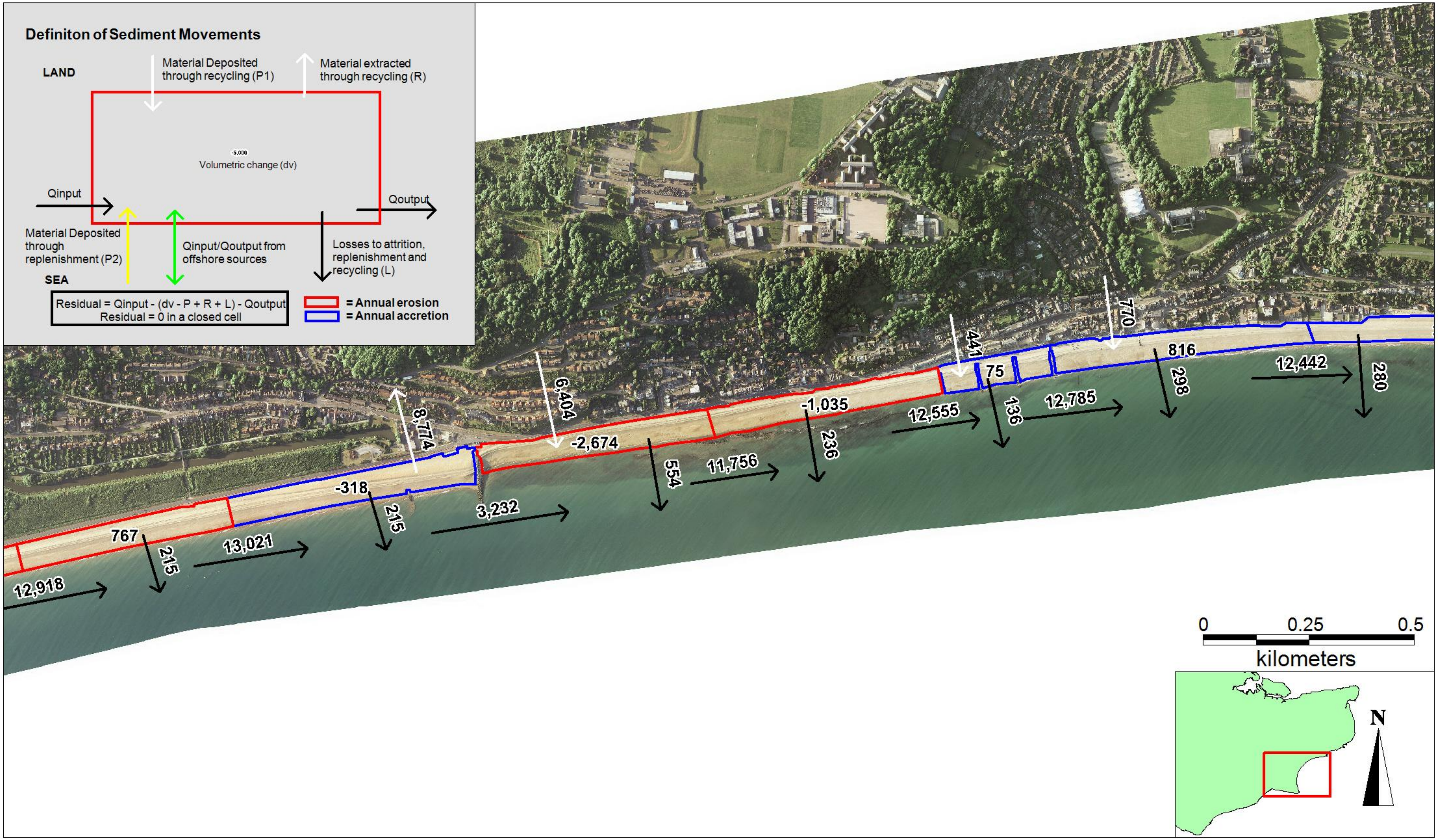
Rye Harbour to Folkestone Sediment Budget

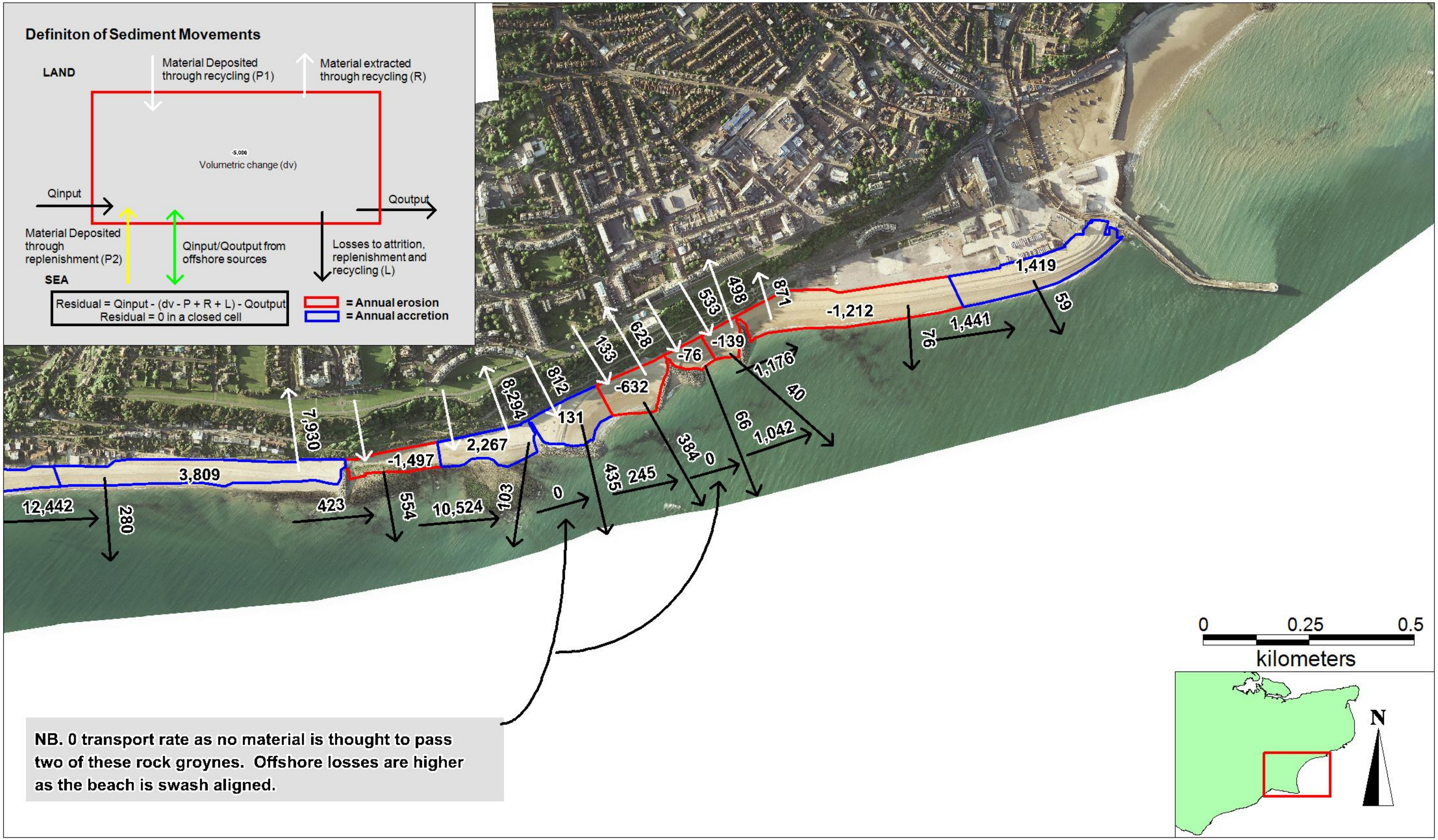



Definiton of Sediment Movements
LAND
Material Deposited through recycling (P1)
Material extracted through recycling (R)
Volumetric change (dv)
Qinput
Qoutput
Material Deposited through replenishment (P2)
Qinput/Qoutput from offshore sources
Losses to attrition, replenishment and recycling (L)
SEA
Residual = Qinput - (dv - P + R + L) - Qoutput
Residual = 0 in a closed cell
= Annual erosion
= Annual accretion
dV = 5,684m^3
This part of Dymchurch has been excluded from the calculations as it is sand.
0
0.25
0.5
kilometers
N


Definiton of Sediment Movements
LAND
Material Deposited through recycling (P1)
Material extracted through recycling (R)
-5,000
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
-1,487
295
418
451
278
311
-89
282
504
-913
409
0
0
0.25
0.5
kilometers
N


Definiton of Sediment Movements
LAND
Material Deposited through recycling (P1)
Material extracted through recycling (R)
-5,000
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
767
-1,438
12,918
194
6,663
11,674
586
7,065
-820
2,286
6,853
-472
135
6,313
8,666
482
1,286
1,823
88
7,841
4
9,510
510
368
-1,151
2,183
109
774
-1,487
295
418
0
0.25
0.5
kilometers
N


Definiton of Sediment Movements
LAND
Material Deposited through recycling (P1)
Material extracted through recycling (R)
-5,000
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
12,918
767
215
13,021
-318
215
8,774
3,232
6,404
-2,674
554
11,756
-1,035
236
12,555
441
75
136
12,785
770
816
298
12,442
280
0
0.25
0.5
kilometers
N


Definiton of Sediment Movements
LAND
Material Deposited through recycling (P1)
Material extracted through recycling (R)
-5,000
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
12,442
280
3,809
7,930
423
-1,497
554
10,524
2,267
103
8,294
812
131
0
435
-632
133
628
245
384
0
-76
533
-139
498
871
66
1,176
40
1,042
-1,212
76
1,441
1,419
59
NB. 0 transport rate as no material is thought to pass two of these rock groynes. Offshore losses are higher as the beach is swash aligned.
0
0.25
0.5
kilometers
N

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 total average annual flux for Rye Harbour to Folkestone is 9,822m^3/year. This figure can also be referred to as the residual for the whole budget, where in a closed system this residual should near 0. With the various assumptions in methodology in mind and the error in the data collected in SRCMP surveys; this residual shows the budget seems to be performing very well.

Jury’s Gap, Lydd Ranges and Dungeness export material through the system which accumulates in Romney Sands. Dymchurch, Hythe Ranges, Hythe and Sandgate to Folkestone are relatively stable. Folkestone and Sandgate are naturally erosive frontages heavily managed to maintain beach levels.

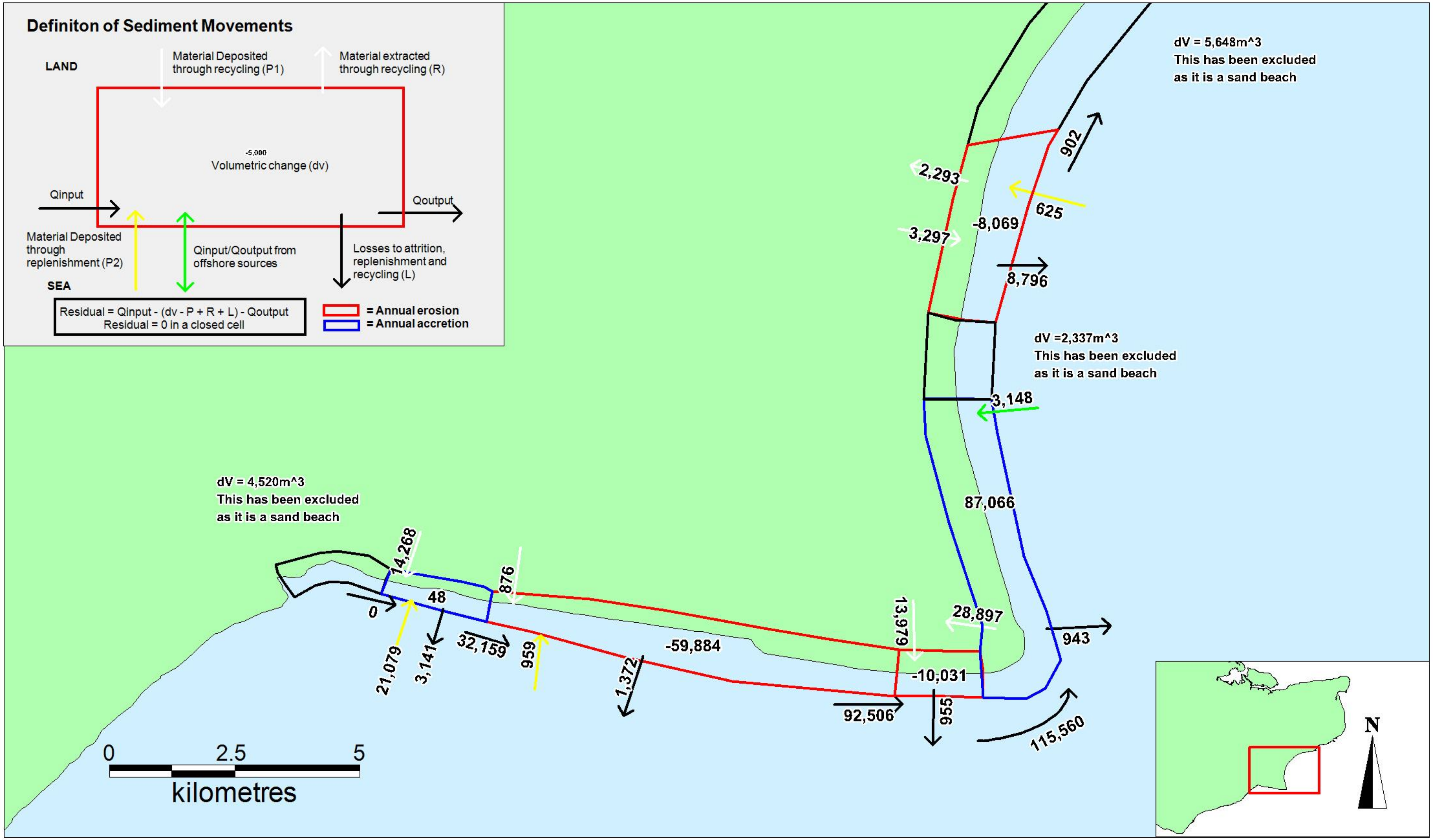
Table 4-2 Level 4 - Regional Sediment Budget

		Average Annual Change (m^3/yr)											
		CAMBER SANDS	Jury's Gap	Lydd Ranges	Dungeness	Romney Sands	ROMNEY SANDS (SAND)	Dymchurch	DYMCHURCH (SAND)	Hythe	Sandgate	Folkestone	Camber Sands to Folkestone
Average Annual Change (ΔV)			48	-59,884	-10,031	87,066		-8,069		-2,037	-5,451	1,250	2,892
Recharge (P1)			21,079	959				625					22,664
Recycling	Deposition (P2)		876	13,979						21,725	19,422	73,567	
	Extraction (R1)				28,897					22,151	18,220	71,562	
Losses	Attrition (L1)		1,233	257	943					527	683	4,981	
	Recharge (L2)		96									10,266	
	Recycling (L3)		44	699						1,086	971	3,678	
Average Annual Flux (ΔV-P+R-L)			-32,159	-60,347	-23,055	116,907		-902		-1,587	-3,411	1,702	-2,851
DWR**										813	953	1566	3,333
Qoutput*			32,159	92,506	115,560	-1,346		902		774	3,232	-37	

Qoutput*; Positive numbers indicate a west to east drift direction and negative numbers indicate east to west drift direction.
DWR** refers to the Distance Weighted Residual explained in Section 4.2.

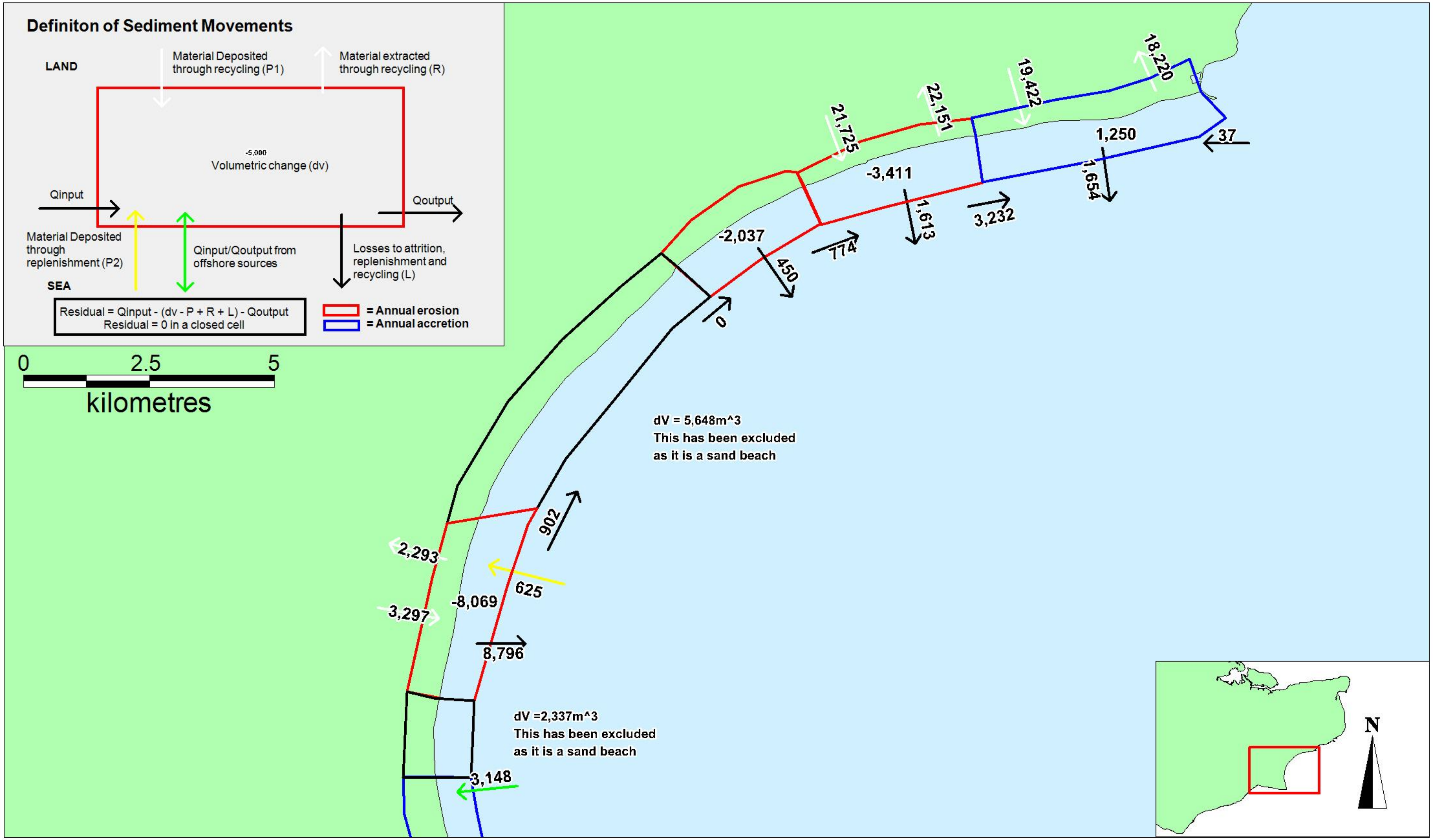
Note:

1) Camber Sands (CS1), Romney Sands (sand) (RS6) and Dymchurch (sand) (DY3) were removed from the shingle sediment budget as they are sandy beaches.
2) Romney Sands ends at RS5 as RS6 is sand.
3) Dymchurch includes RS7, DY1 and DY2. DY3 is excluded as it is sand.



Rye Harbour to Folkestone Sediment Budget

Plate 1 (1 of 2)



Rye Harbour to Folkestone 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.

Note: although Camber Sands and Romney Sands show a beach volume of 0 throughout this is only relative to the 2003 volume. The change since 1890 has been so significant that when taken away from the 2003 volume it yields a negative beach volume.

Table 4-3 Beach Volumes

	BEACH VOLUME (m^3)												
	2012	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**1930**	**1910**	**1890**
CAMBER SANDS	247,557	249,572	238,279	232,809	212,565	220,214	220,214	220,214	220,214	211,843	0	0	0
JURY'S GAP	629,700	634,328	633,639	633,510	611,924	634,366	624,508	624,508	624,508	614,649	487,533	284,501	448,677
LYDD RANGES	2,134,329	2,298,340	2,216,875	2,427,707	2,381,154	2,381,154	2,381,154	2,381,154	2,577,893	2,678,274	6,529,970	8,463,092	9,110,720
DUNGENESS	889,013	919,197	944,411	959,928	983,241	995,407	1,018,391	1,014,536	983,677	979,258	842,906	902,097	873,137
ROMNEY SANDS	3,547,855	3,483,710	3,367,086	3,294,716	3,163,523	3,068,558	2,956,055	2,937,684	2,816,985	2,782,585	0	0	0
DYMCHURCH	1,114,968	1,138,735	1,112,571	1,113,428	1,096,423	1,150,347	1,119,291	1,180,494	1,157,944	1,113,694	732,749	0	0
HYTHE RANGES	716,930	729,550	731,529	727,366	727,922	725,108	722,009	722,009	749,683	734,780	817,379	950,315	1,139,935
SANDGATE	939,352	939,624	941,654	957,520	938,309	959,056	984,436	993,140	1,008,451	987,279	764,151	649,630	858,526
FOLKESTONE	1,298,924	1,305,604	1,296,817	1,309,394	1,265,342	1,258,173	1,277,013	1,272,223	1,286,731	1,127,394	251,422	574,218	557,026

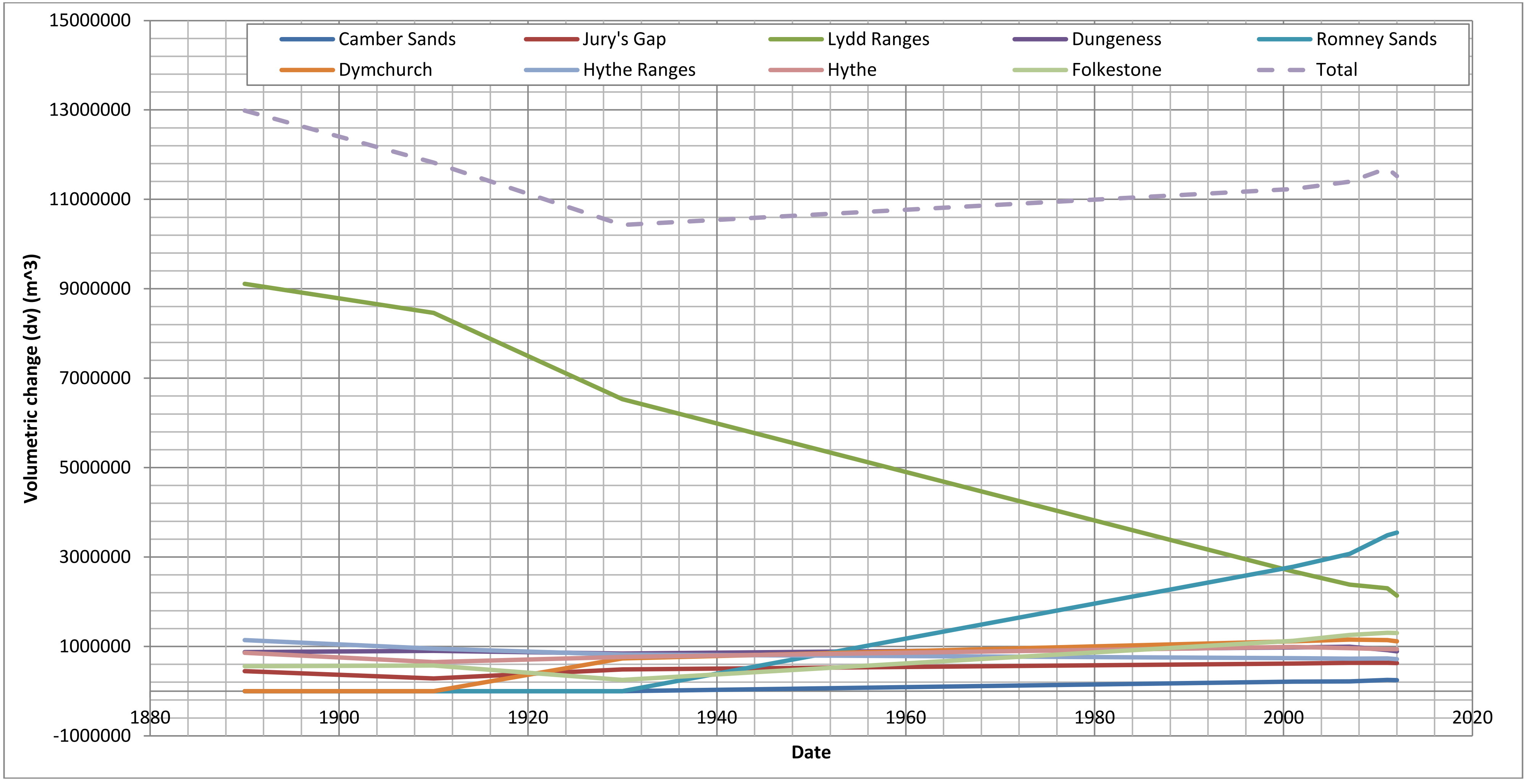


Figure 4-13 Comparison of beach volumes since 1890

Figure 4.13 has been provided to show the relative changes in total beach volume over a longer period of time. This helps to put the more recent volumetric changes explored through the contour plots and sediment budgets into perspective. Taking Romney Sands as an example, it shows that the recent gain of material is quicker than the historic rate of accretion.

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.

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 4.6, rather than explain why those changes occur which was deemed to be outside the scope of this report.

Table 4-4 Historic beach volumetric change since 1890

		Volumetric Change (m3)									Total Change (m^3)
		Camber Sands	Jury's Gap	Lydd Ranges	Dungeness	Romney Sands	Dymchurch*	Hythe	Sandgate	Folkestone	
1910-1890	Change	343,312	-164,176	-647,628	28,960	838,334	-	-189,620	-208,896	17,192	-525,803
	Annual Change	17,166	-8,209	-32,381	1,448	41,917	-	-9,481	-10,445	860	-26,290
1930-1910	Change	2,089,708	203,032	-1,933,122	-59,191	1,669,014	-	-132,936	114,521	-322,796	1,944,283
	Annual Change	104,485	10,152	-96,656	-2,960	83,451	-	-6,647	5,726	-16,140	97,214
Baseline - 1930	Change	1,199,052*	146,833*	-4,592,380**	136,352***	5,964,885***	-	-101,943***	223,128***	877,141***	3,853,068
	Annual Change	15,777	1,907	-62,059	1,818	79,531	-	1,359	2,975	11,695	53,003

* Baseline is 2007
** Baseline is 2004
*** Baseline is 2003

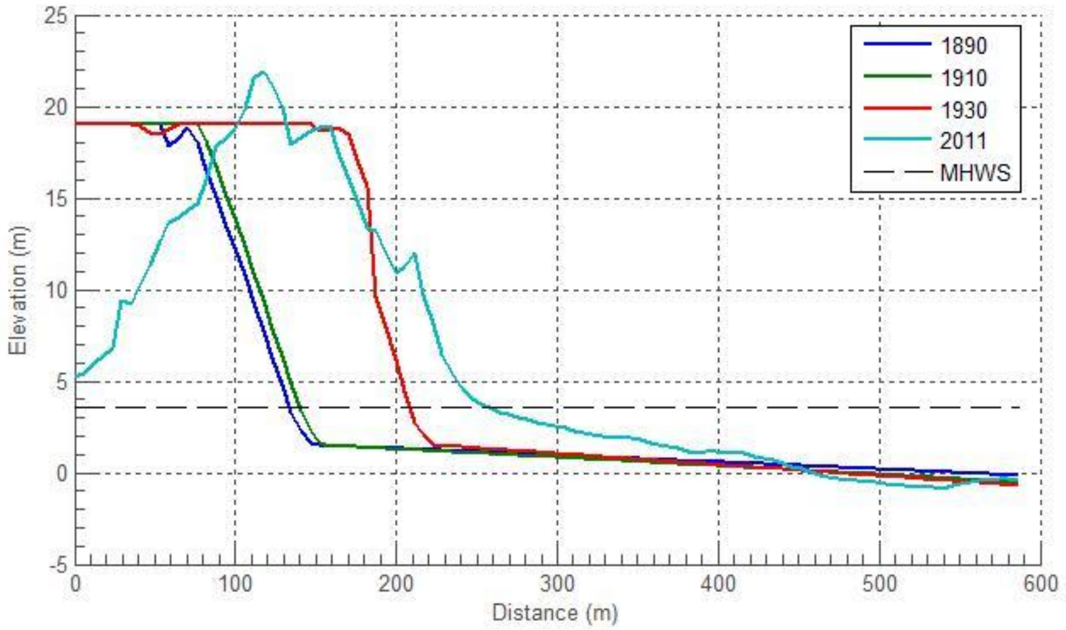
NB. Dymchurch historic mapping does not provide accurate volumes and cannot be used.

4.5.1 Camber Sands

The extensive sand dunes of Camber Sands have vastly grown since the late 1800s. In total the beach has gained 3,700,000m^3 during 1890 and 2012. The position of Rye Harbour restricts the area the dunes have to grow which has resulted in an expansion of the west and central section's; changing the orientation of the beach over time.

Camber Sands is not regarded as part of the shingle sediment budget as an annual accretion of 5,000m^3 is not thought to have entered from Jury's Gap. This gain is more likely to be an onshore feed from the sandy foreshore of Winchelsea Beach and Camber Sands. Aeolian and fluvial influences are also thought to add a small percentage to the fine sediment beach. Figure 4.14 shows a cross section through the central area of Camber Sands from 1890 to present, demonstrating the large gain of material during 1910 and 1930. The western section shows the largest gain during 1930 and 2012.

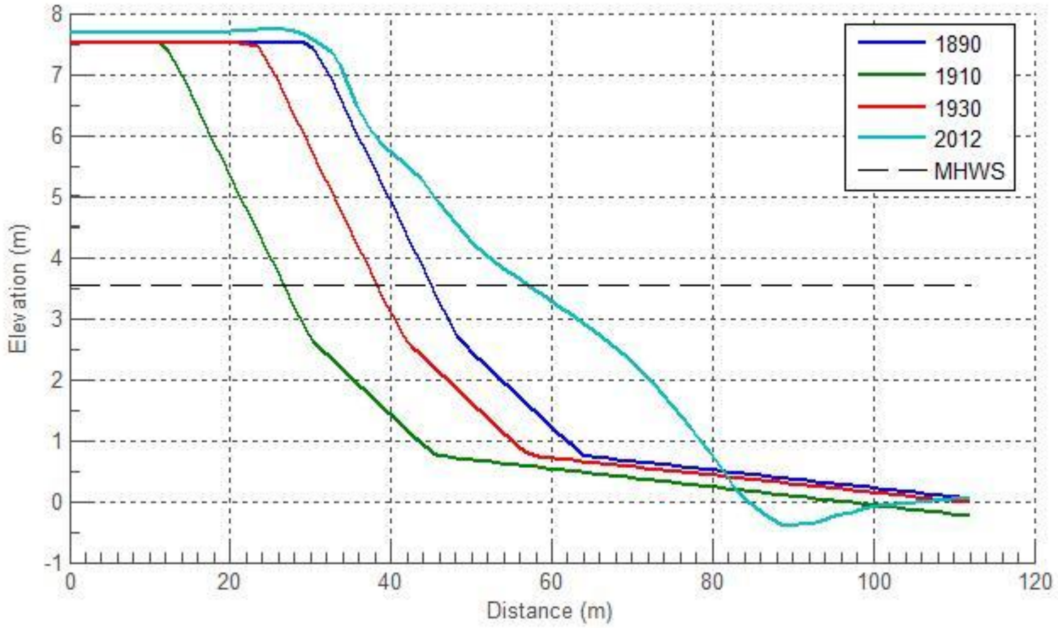
Figure 4-144 Cross section through DTM's in Camber Sands in 1890, 1910, 1930 and 2011



4.5.2 Jury's Gap

The shingle sand split is located to the western side of Jury's Gap and is considered the start of the transport of shingle to the east. Historically this beach lost material during 1890 and 1910 (164,200m^3) causing the beach slope to retreat by approximately 18m. During 1910 and 1930 the beach gained 203,000m^3, which saw the slope advance seaward by 11m. More recently (1930 to 2007) the beach gained a further 146,800m^3 however this value is skewed since 1990 by large volumes of beach recycling and replenishment. In total, 540,100m^3 has been deposited on this frontage during 1990 to 2007, and a further 205,600m^3 to 2012. Without human intervention this beach would have breached in the 1990s. Figure 4.15 shows a cross section through the centre of Jury's Gap indicating the current beach to be healthier than ever.

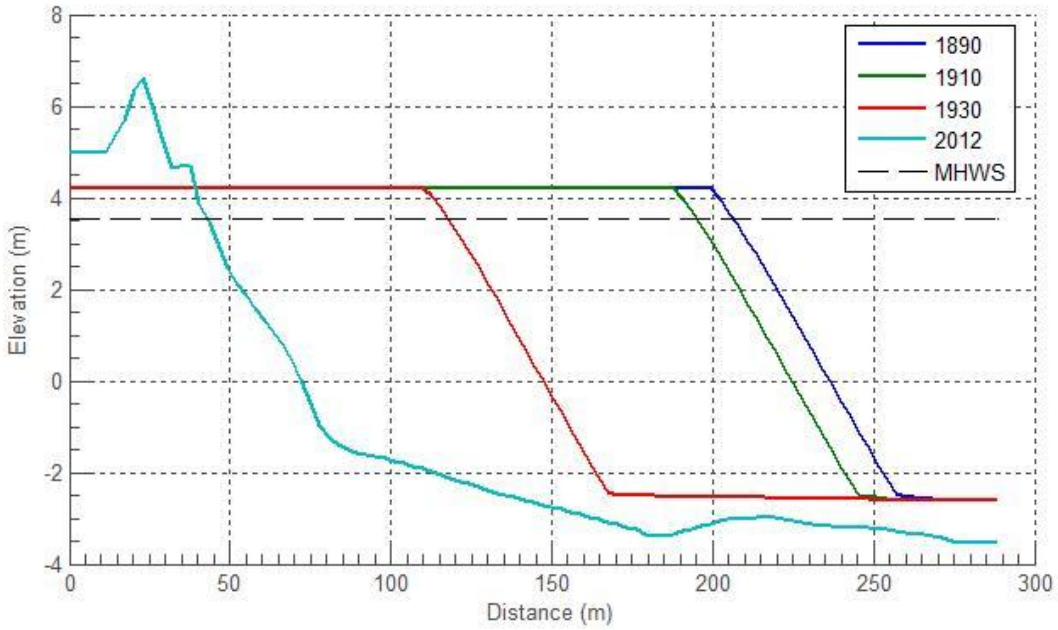
Figure 4-15 Cross section through DTM's in Jury's Gap in 1890, 1910, 1930 and 2012



4.5.3 Lydd Ranges

Lydd Ranges is historically, and currently, the most erosive section of the sediment budget. The beach levels are maintained at +5.0mAOD and +6.0mAOD but the beach is allowed to roll inland as there is no fixed structure behind the berm. During 1890 and 1910 647,600m^3 was lost. This was followed by a further 1,933,100m^3 loss during 1910 and 1930 allowing the beach to retreat by 80m. 1930 to 2012 sees a further loss of 4,418,200m^3 and a retreat of 70m inland. Some sections responded differently to others and the cross section in Figure4.16 highlights the largest loss to be 1910 to 1930. To combat the persistent losses, Lydd receives most of the material deposited at Jury's Gap which gradually feeds through the beach to Dungeness.

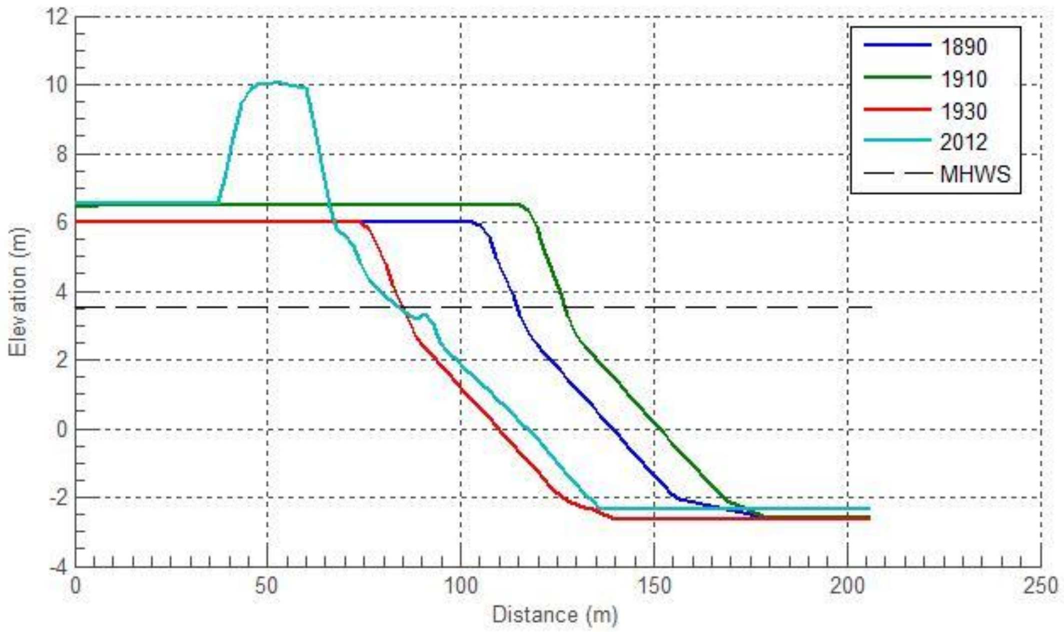
Figure 4-16 Cross Section from 1890, 1910, 1930 and 2012 at Dungeness



4.5.4 Dungeness

Dungeness beach is 1.8km in length and has varied by much smaller volumes. It gained 28,960m^3 during 1890 and 1910 which advanced 10m. The beach then lost 59,200m^3 during 1910 to 1930 causing the beach to retreat 45m. More recently, 1930 to 2007, the frontage gained 152,500m^3. However, this gain is superficial as the beach received 593,850m^3 of material during 1990 and 2007 to create and sustain a 1 in 10,000 tsunami bund, which can be seen in Figure 4.18. This changes the 152,500m^3 gain into a 441,300m^3 loss.

Figure 4-17 Cross Section from 1890, 1910, 1930 and 2012 at Dungeness



4.5.5 Romney Sands

Romney Sands is the most accretive beach within this sediment budget. Historically it has gained 8,758,200m^3 and advanced seaward by 370m. Figure 4.18 maps the MHW line to indicate change over time; aerial photography is 2008. This site was used as a borrow pit during the 1990s to 2007 and in total has had 1,120,200m^3 extracted to replenish Jury's Gap and Dungeness. Since 2007 this beach growth has accelerated further as the Borrow Pit was made redundant. Figure 4.19 illustrates a cross section through the old Borrow Pit; the area of substantial accretion.

Figure 4-18 MHW level mapped for 1890, 1910, 1930 and 2012 at Romney Sands

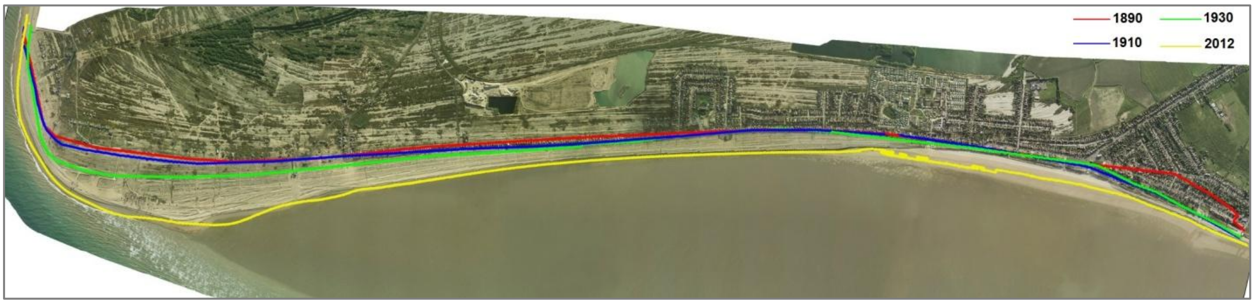
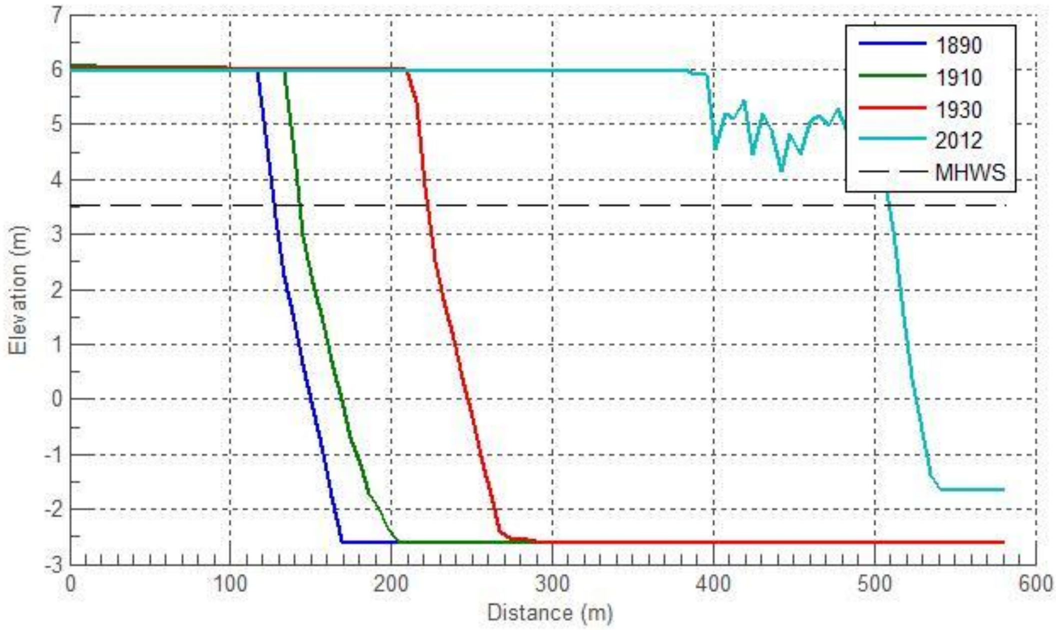


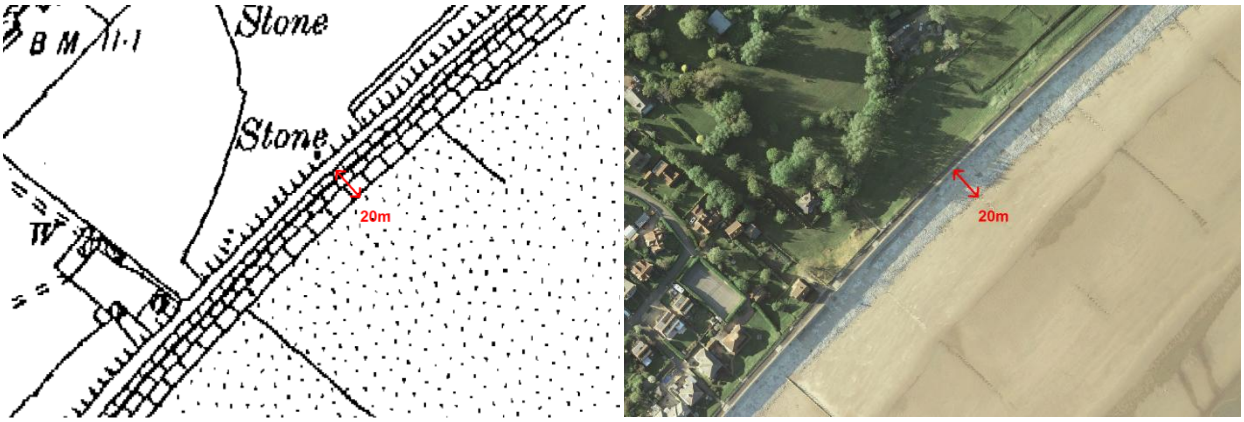
Figure 4-19 Cross Section from 1890, 1910, 1930 and 2012 at Romney Sands



4.5.6 Dymchurch

Dymchurch is unable to be mapped due to the MHW line being on the rock revetment on the historic mapping which does not allow interpolation of the beach levels. Current aerial photography indicates the historic and current sea wall to be the same width and position, with the sand beach foreshore starting near the base of the wall. Figure 4.20 demonstrate the current and historic maps showing the same information.

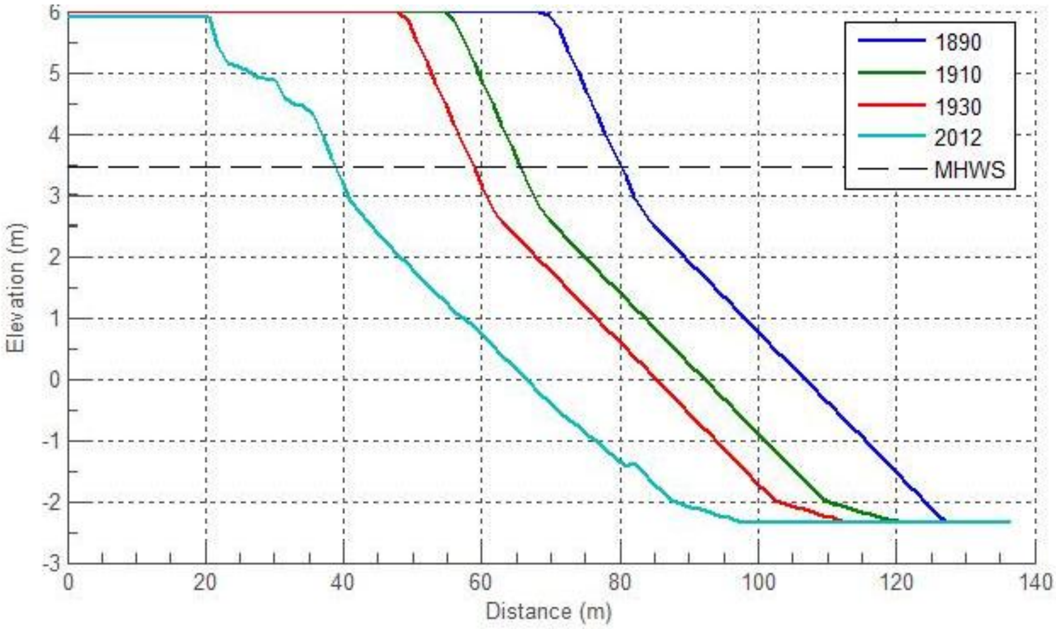
Figure 4-20 MHW level mapped for 1890, 1910, 1930 and 2012 at Romney Sands



4.5.7 Hythe Ranges

Hythe Ranges has lost material since 1890. During 1890 and 1910 the beach lost 189,600m^3, this slightly reduced in 1910 to 1930 to 133,000m^3 and since the introduction of larger timber groynes this volume has reduced further to 92,000m^3 during 1930 and 2007. Figure 4.21 is a cross section through the eastern end of the beach, highlighting large losses from 1890 to 1910 and 1930 to present.

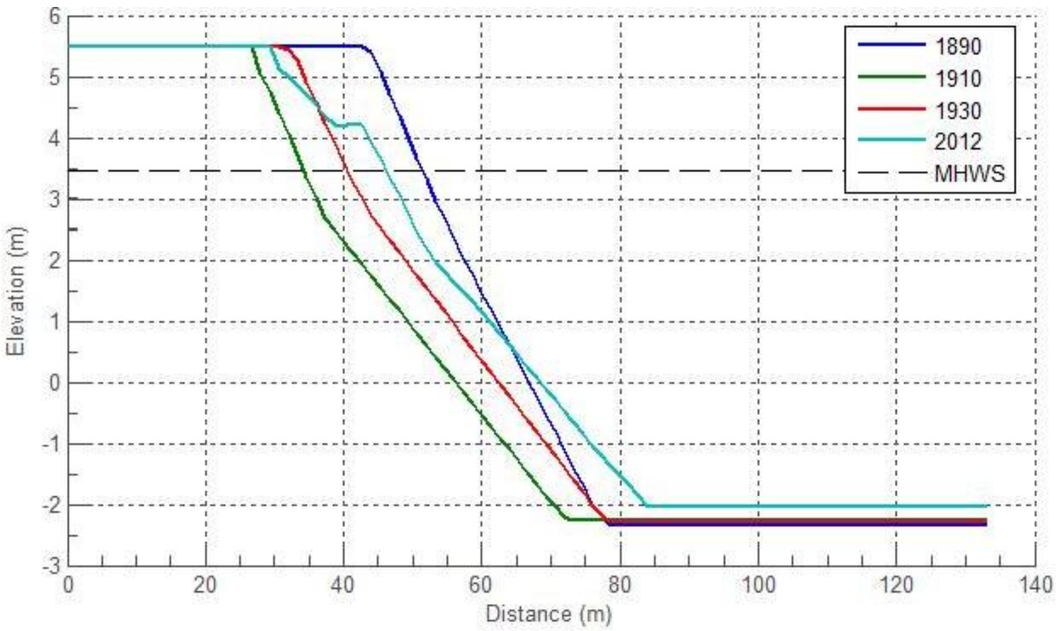
Figure 4-21 Cross Section from 1890, 1910, 1930 and 2012 at Hythe Ranges



4.5.8 Sandgate

Sandgate beach shows a loss of 208,900m^3 during 1890 and 1910. Between 1910 and 1930 this changed to a gain of 114,500m^3. More recently, in 1930 to 2007, this has decreased to a gain of 194,900m^3. Since heavy anthropogenic influences have restricted the beach movement in and out of Sandgate, beach recycling currently takes place biannually to sustain beach levels. Figure 4.22 indicates a fairly stable beach face since the 1890s; however this is not without beach management.

Figure 4-22 Cross Section from 1890, 1910, 1930 and 2012 at Sandgate

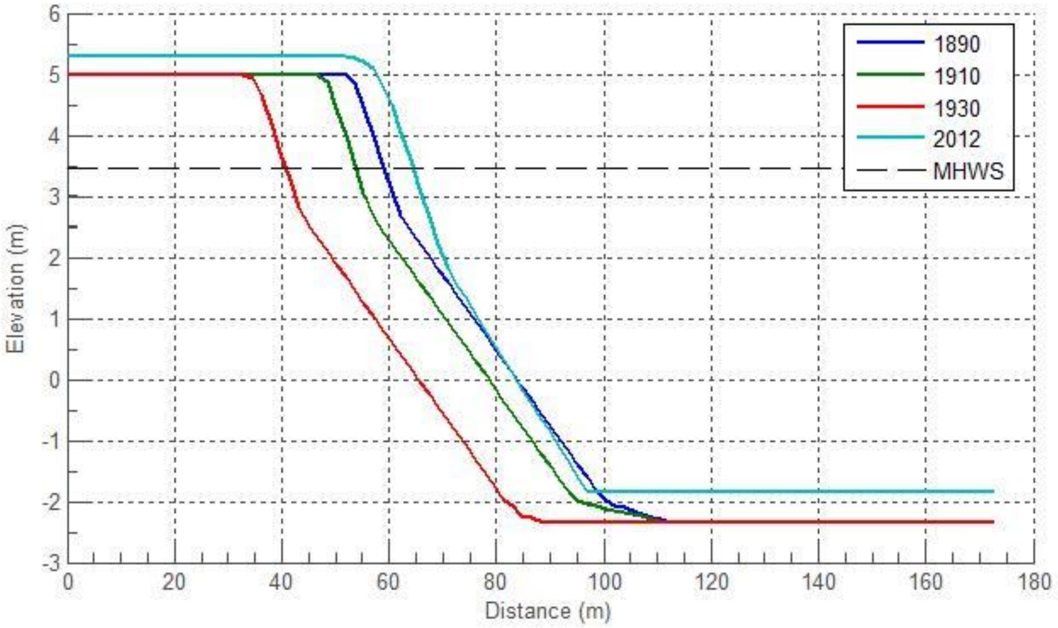


4.5.9 Folkestone

The most eastern unit of the sediment budget is Folkestone. A large harbour arm stops all material from bypassing the harbour and is therefore the end of the sediment budget. Due to the west to east drift direction for the majority of the sediment budget material should collect within this unit. Similar to Sandgate this unit is heavily managed and skews the natural beach movement.

During 1890 and 1910 the beach gained 17,200m^3. Between 1910 and 1930 the beach lost -322,800m^3 and more recently in 1930 to 2007 the beach has gained 1,007,000m^3.

Figure 4-233 Cross Section from 1890, 1910, 1930 and 2012 at Folkestone



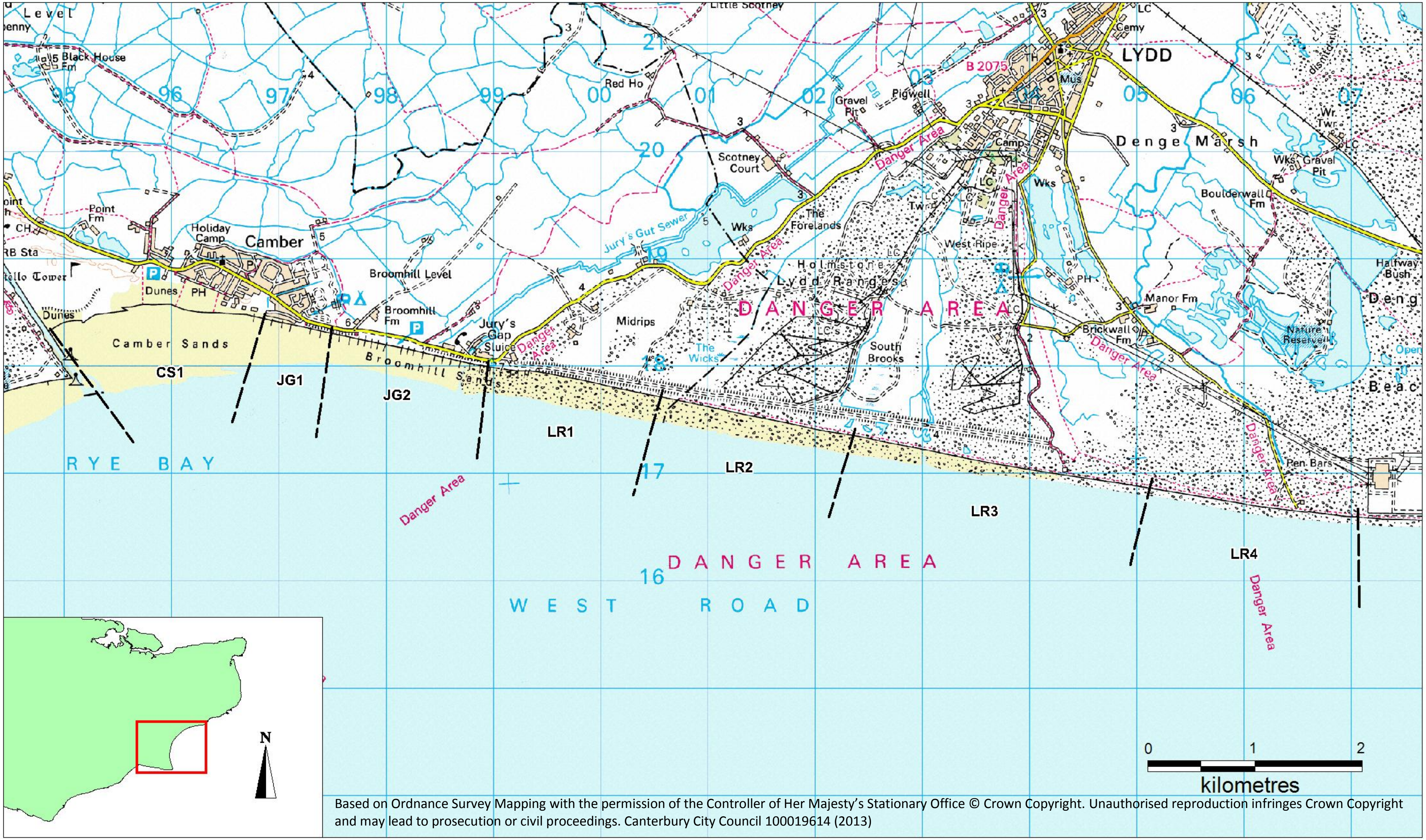
5.0 Available data

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.

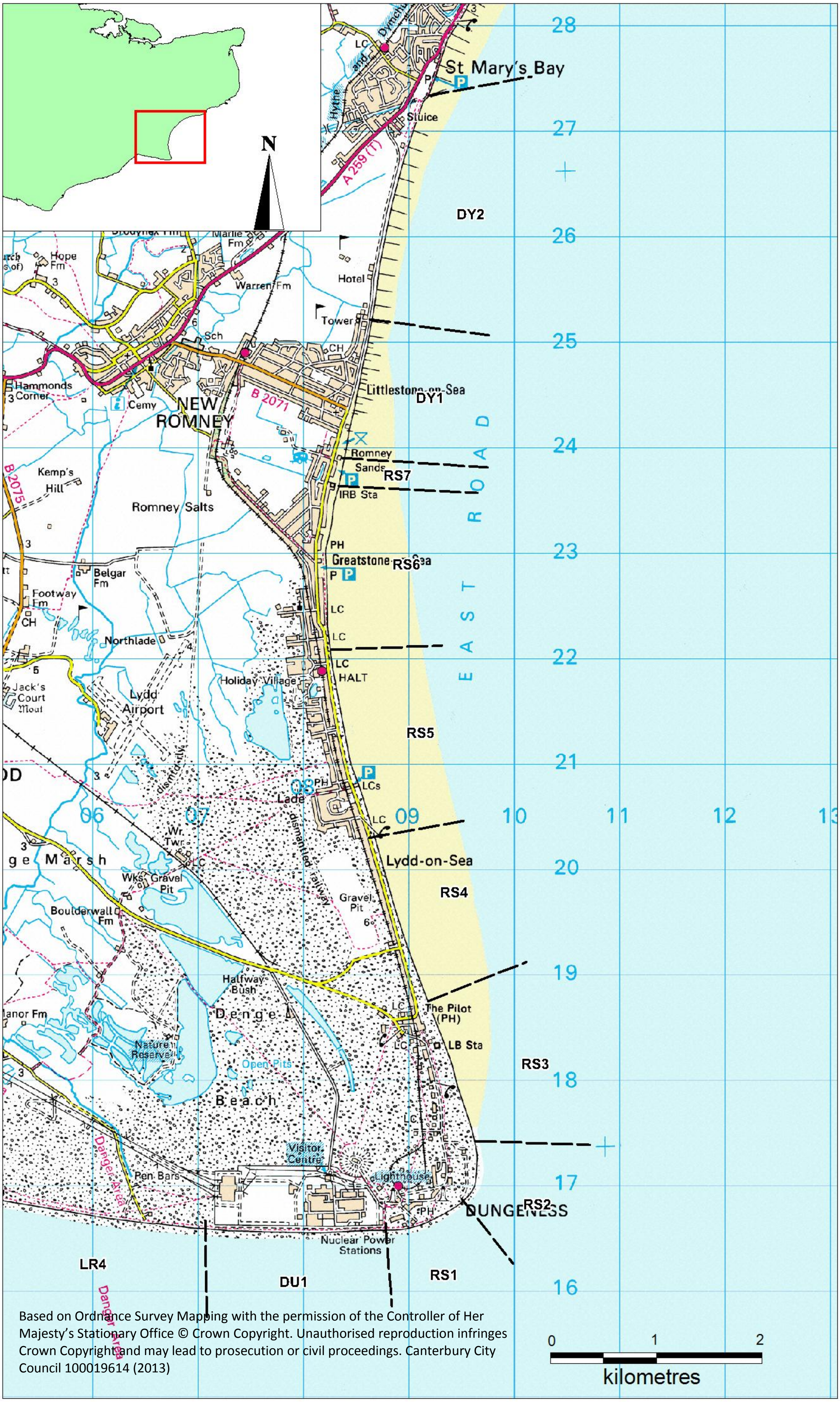
Table 5-1 Available GIS data

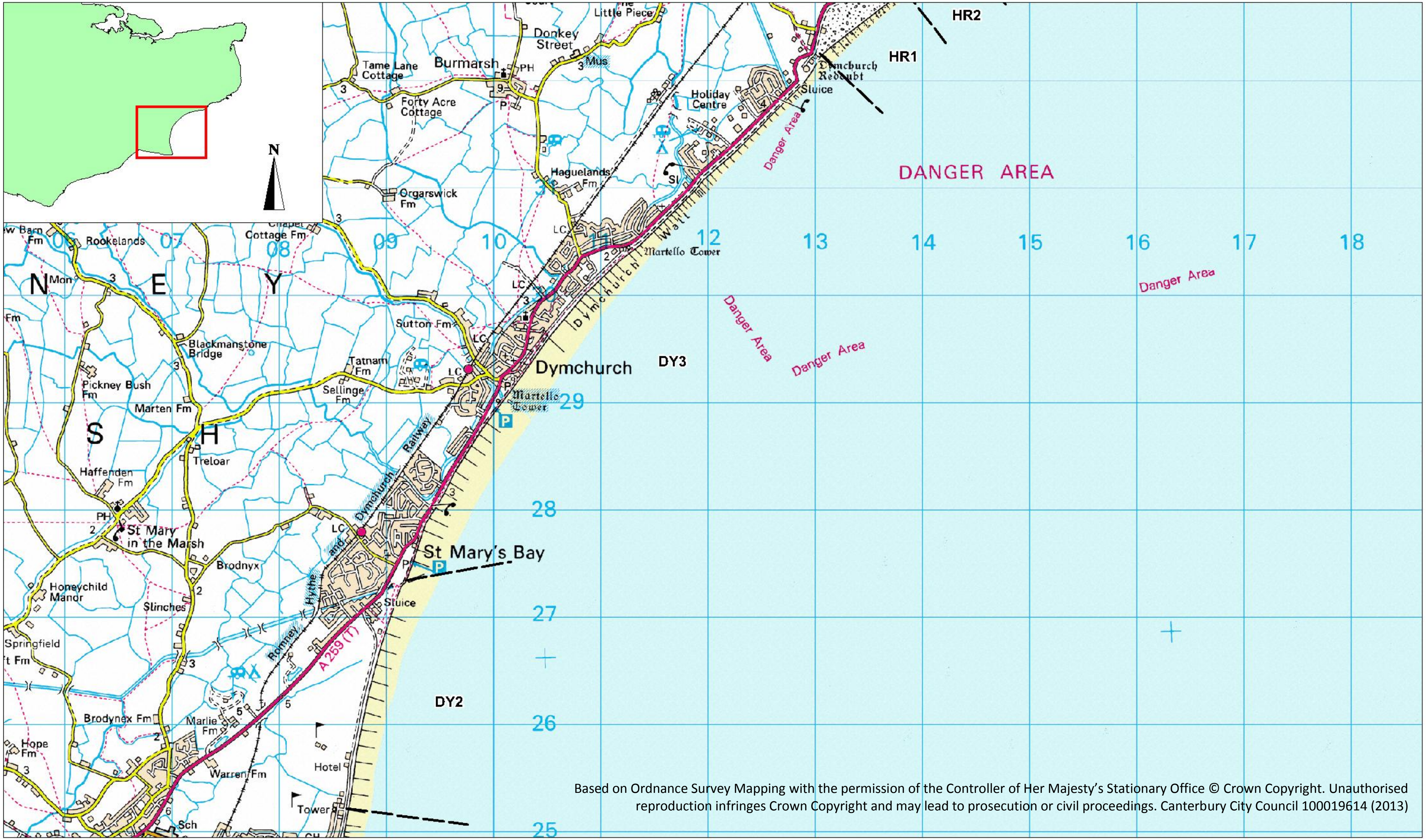
Data	Type	Description
GIS (1)		**AVAILABLE FROM CANTERBURY CITY COUNCIL**
	DTMs	2012 -2003 DTMs for all frontages
	Difference Models	For all frontages
	Analysis Polygons	Level 1 - 50m length
		Level 2 - SRCMP Polygons
		Level 3 - Coarse Polygons
		Level 4 - Regional Polygons
	Historic	Historic feature 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**

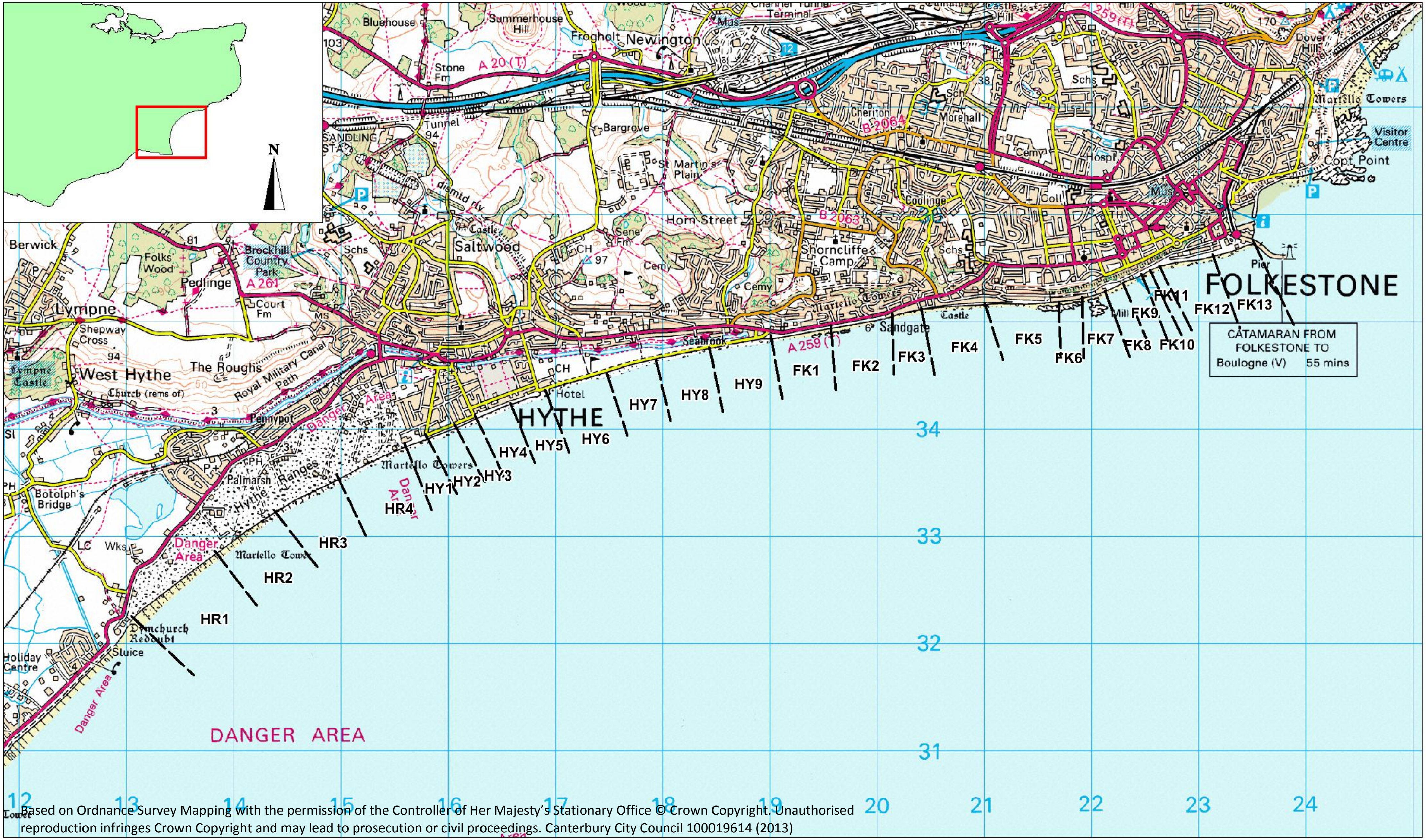
6.0 Sub-Cell Diagrams


CS1
JG1
JG2
LR1
LR2
LR3
LR4
Camber
Camber Sands
Broomhill Sands
Broomhill Level
Jury's Gap Sluice
Midrips
Lydd Ranges
Holmstone
DANGER AREA
LYDD
Denge Marsh
Scotney Court
The Forelands
South Brooks
Manor Fm
Brickwall Fm
Boulderwall Fm
Nature Reserve
Pen Bars
RYE BAY
WEST ROAD
Danger Area
0
1
2
kilometres
N

Rye Harbour to Folkestone Sediment Budget




HR2
HR1
DY3
DY2
DANGER AREA
Danger Area
Dymchurch
St Mary's Bay
Burmarsh
St Mary in the Marsh
Dymchurch Redoubt
Martello Tower
Holiday Centre
Sluice
N


N
HR1
HR2
HR3
HR4
HY1
HY2
HY3
HY4
HY5
HY6
HY7
HY8
HY9
FK1
FK2
FK3
FK4
FK5
FK6
FK7
FK8
FK9
FK10
FK11
FK12
FK13
HYTHE
FOLKESTONE
West Hythe
Lympne
Saltwood
Sandgate
Seabrook
Shorncliffe Camp
Newington
Horn Street
Botolph's Bridge
Palmarsh
Hythe Ranges
Dymchurch Redoubt
Danger Area
DANGER AREA
Royal Military Canal
The Roughs
Pedlinge
Berwick
Cheriton
Morehall
Copt Point
CATAMARAN FROM FOLKESTONE TO
Boulogne (V) 55 mins
31
32
33
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