Cyfoeth Naturiol Cymru
Natural Resources Wales

Kenfig Phase 1
Dune Rejuvenation Works

Overview Report

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Kenneth Pye Associates Ltd

Report No: 43

Date: July 2013

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Contents

1. Introduction

Kenfig Burrows represents one of the largest remaining sand dune areas in Wales and forms a key constituent of the Kenfig SSSI and the Kenfig SAC. Prior to the 19th century, sand-dunes fringed virtually the whole of Swansea Bay between Mumbles and Porthcawl, but during the past 150 years large areas have been lost due to industrial and urban development. In 1941 bare sand covered approximately 154 ha at Kenfig (17.4% of the site), but by 2009 this figure had declined to only 4 ha, representing 0.5% of the site (Figure 1; Howe *et al*., 2012). The loss of pioneer dune and dune slack habitats has had a significant negative impact on the conservation status of the European site.

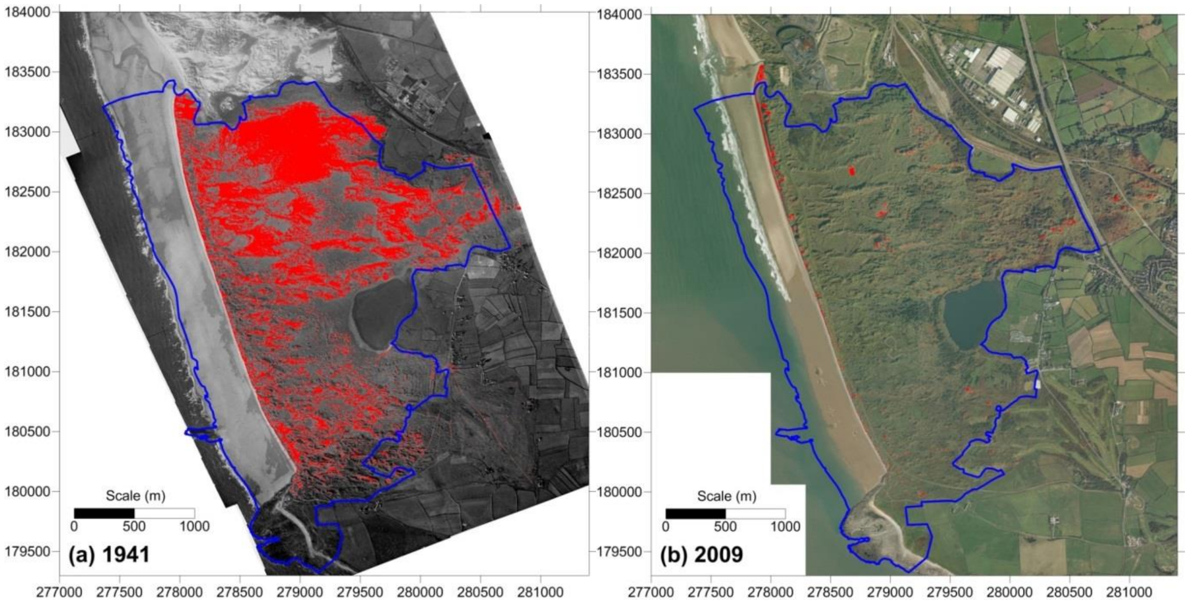


Figure 1. The extent of bare sand (red) at Kenfig Burrows in (a) 1941, and (b) 2009. The blue line indicates the SAC boundary.

Following an initial study to evaluate options for dune rejuvenation at the site (Pye & Blott, 2011), a Phase 1 trial covering approximately 5 ha was initiated in late January 2012.

The work was undertaken using two JCB diggers and two Volvo dumper tucks (Figure 2). The objective was to strip turf from an area defined by the side-walls and windward crest of a stabilised parabolic dune lying east of the haul road, and also from an area linking the seaward side of the haul road and the beach. The crest height of a sand ridge located midway between the haul road and the sea was lowered to reduce the barrier to wind flow, and the sand cliff at the back of the beach was lowered and graded to promote free movement of wind-blown sand from the beach into the dune system. The stripped turves were placed in a number of locations chosen to enhance the parabolic morphology of the main dune; these included the lower parts of southern 'arm' of the dune on either side of the haul road, and the basal part of the windward slope leading to the crest of the dune.

Figure 2. Turf stripping, Kenfig Phase 1, February 2012 (photograph supplied by David Carrington, Bridgend Borough Council).

Figure 3. Completed turf stripping, seaward end of Kenfig Phase 1, March 2012 (photograph supplied by Mike Howe, NRW)

Figure 4. Aerial photograph of the Kenfig Phase 1 dune rejuvenation area (arrowed), March 2012. (photograph provided by Mike Howe, NRW)

Topographic monitoring surveys of the site were undertaken by KPAL in July 2012, October 2012 and March (2013) and compared with a 2009 LiDAR digital terrain model to document the nature of morphological and sedimentological changes (KPAL, 2012a,b, 2013). A number of sediment samples were also collected in May 2012 and May2013 to determine the threshold wind velocities required for aeolian entrainment. This report provides an overview of the changes over the period of monitoring makes a number of recommendations for future monitoring.

Proposals for a second phase of dune rejuvenation, located in the area immediately north of Phase 1, were prepared in October 2012 (KPAL, 2012c) and further works were carried out in February - March 2013. These are the subject of a separate monitoring programme which will be reported independently.

2. Monitoring Methods

2.1 Topographic surveying

The ground survey was conducted using a ‘base and rover’ surveying technique. The first two surveys were carried out using a Leica Viva GPS SmartRover GS15 Receiver mounted on a 2 m pole and a Leica Viva CS15 GNSS Field Controller. The surveys made use of an RTK control station at Mumbles Head. A position for the base station was chosen towards the centre of the site, on a high point to maximise potential for a good quality mobile telephone signal (for GPRS corrections). Two wooden posts were inserted into the ground to act as local temporary benchmarks.

The equipment used in the third survey consisted of a Leica RX1250 SmartRover with ATX 1230GG Smart Antenna, GFU24 Seimens MC75 mobile phone and RX1250XC controller mounted on top of a 2m pole. The system was set to SmartRover RTK mode, using GPRS corrections from the Leica SmartNet network. The position of the Reference Station (temporary benchmark 1) was keyed in using the coordinates recorded earlier from the SmartRover, with the site coordinate system being transformed from WGS84 to OSGB36 using the One Point Localisation Method. The Reference Station was then instructed to begin transmitting corrections using a Pacific Crest ADL Vantage ADLV-2 radio transceiver.

The Leica RX1250 SmartRover set-up was then changed to RTK Radio mode, with the mobile phone being replaced with a Pacific Crest PDL GFU15-2 radio receiver. Once connected successfully to the reference station, the survey began using the SmartRover. The radio set-up allowed the SmartRover to be used to a distance of approximately 2 km from the reference station. The survey began and finished with the position and elevation of Benchmark 2 being determined, to assess survey accuracy and precision. Accuracy was generally very good with measurements of elevation on average being accurate to better than 10 mm, and measurements of precision on average being better than 7 mm.

The x,y,z coordinates of 1100 to 1500 points were determined in each survey. The survey points were taken primarily to define features of interest and along specified transect lines, with some additional points taken in the intervening areas. The data were gridded using a kriging algorithm in the Golden Software Surfer package to allow construction of a digital elevation model (DEM). The search distance was specified to include all data in the data set, and an anisotropy value of 1 was assigned (no directional bias given to the data). Areas beyond the limits of the survey, were blanked from the DEM. Areas of deep standing water were not surveyed also blanked from the DEM.

2.2 Fixed point photography

During each survey photographs were from a number of fixed points to provide a visual record of changes in the vegetation cover and surface character. The locations of the points from which photographs were taken and reproduced in this summary report are shown in Figure 5.

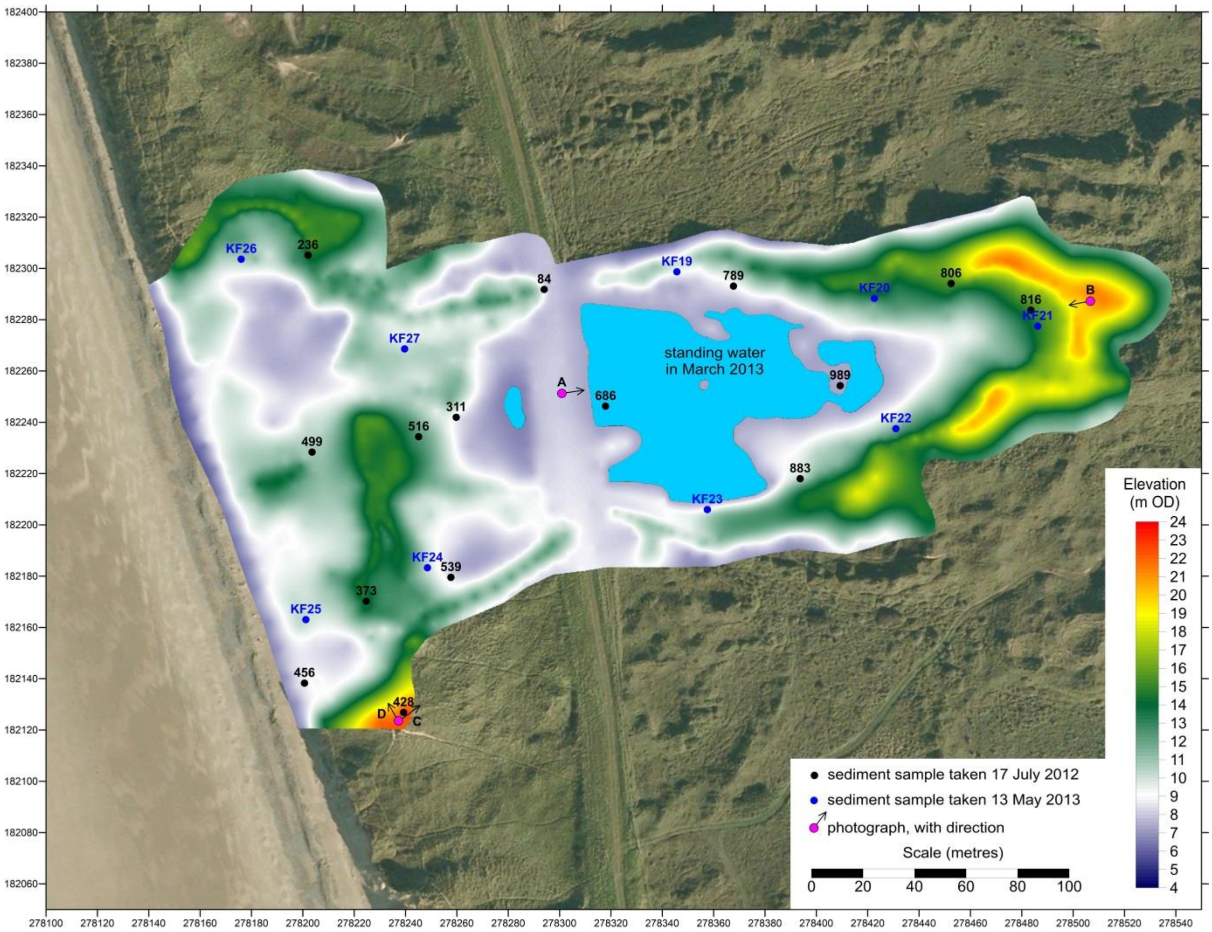


Figure 5. Locations of sediment samples taken in July 2012 and May 2013, and locations of fixed-point photography reproduced in this report. The base-map DTM is taken from the survey on 8 March 2013.

2.3 Sediment characterization

Surface sediment samples were collected using a plastic scoop and returned to the laboratory for particle size analysis. The sampling locations are plotted on Figure 5. The sample suite collected in July 2012 was analysed by laser diffraction using a Coulter LS230 instruments and the particle size frequency distribution determined at interpolated 'quarter-phi' intervals. The second suit of samples collected in May 2013 was analysed by dry sieving at quarter phi intervals. Previous work (Blott & Pye, 2006) has demonstrated that there is typically a 10-15% offset in median diameter (d50) values calculated by laser diffraction compared with dry sieving, large due to particle shape effects (the laser technique assumes perfectly spherical particles). However, the differences in d50 size observed between the two sampling periods have only a minor effect on the threshold wind velocities calculated using previously published experiment relationships (Bagnold, 1941; Hsu, 1974; see data in Appendix 1).

3. Results

3.1 Topographic changes

DEMs of the rejuvenation area, based on the ground surveys in July 2012, October 2012 and March 2013, are compared in Figure 6. Difference maps showing the interpolated height differences between the 2006 LiDAR survey and the July 2012 (post rejuvenation works) survey are shown in Figure 7a. Differences between the 17 July 2012 and that of 8 October 2012 survey are shown in Figure 7b, and differences between the October 2012 and March 2013 survey are shown in Figure 7c. Elevation changes along a number of specified cross-sections are shown in Figure 8.

Figure 7a shows the pattern of turn stripping and sand re-distribution, plus the effects of some sand mobilization by wind between the completion of the works in March 2012 and the time of the first survey in July 2012. The increases in height of the marginal dune ‘arms’ on either size of the haul road are very largely due to the placement of turves and loose sand by the earth mobbing equipment. The increase in surface level around the base of the windward slope leading to the dune crest is due to the combined effect of turf placement and windblown sand deposition. Areas shown in blue in Figure 7a represent areas where turf was stripped and/ or loose sand removed for placement in former depression areas (e.g. those between profile line E and the beach).

Figure 7b shows relatively slight changes in surface level between July and October 2012. The main changes occurred on the seaward side of the haul road where wind scour caused the formation of an erosional pit in the north - south aligned sand ridge. Some reduction in surface level also occurred to wind-induced removal of sand on the north-eastern side of the deflation corridor, and there was some accretion on the north-west facing slopes of the deflation corridor.

Figure 7c shows two areas coloured red where the surface level increased dramatically between October 2012 and March 2013; these are areas where sand was mechanically placed during the Phase 2 rejuvenation works in February - March 2013. Similarly, the large area of surface lowering (shown in blue) on the north side of the rejuvenation area, east of the haul road, represents an area from which additional turf and sand was mechanically removed during the Phase 2 rejuvenation works. Other changes in surface level across the remainder of the Phase 1 rejuvenation area principally reflect natural patterns of wind-induced erosion and accretion over the period.

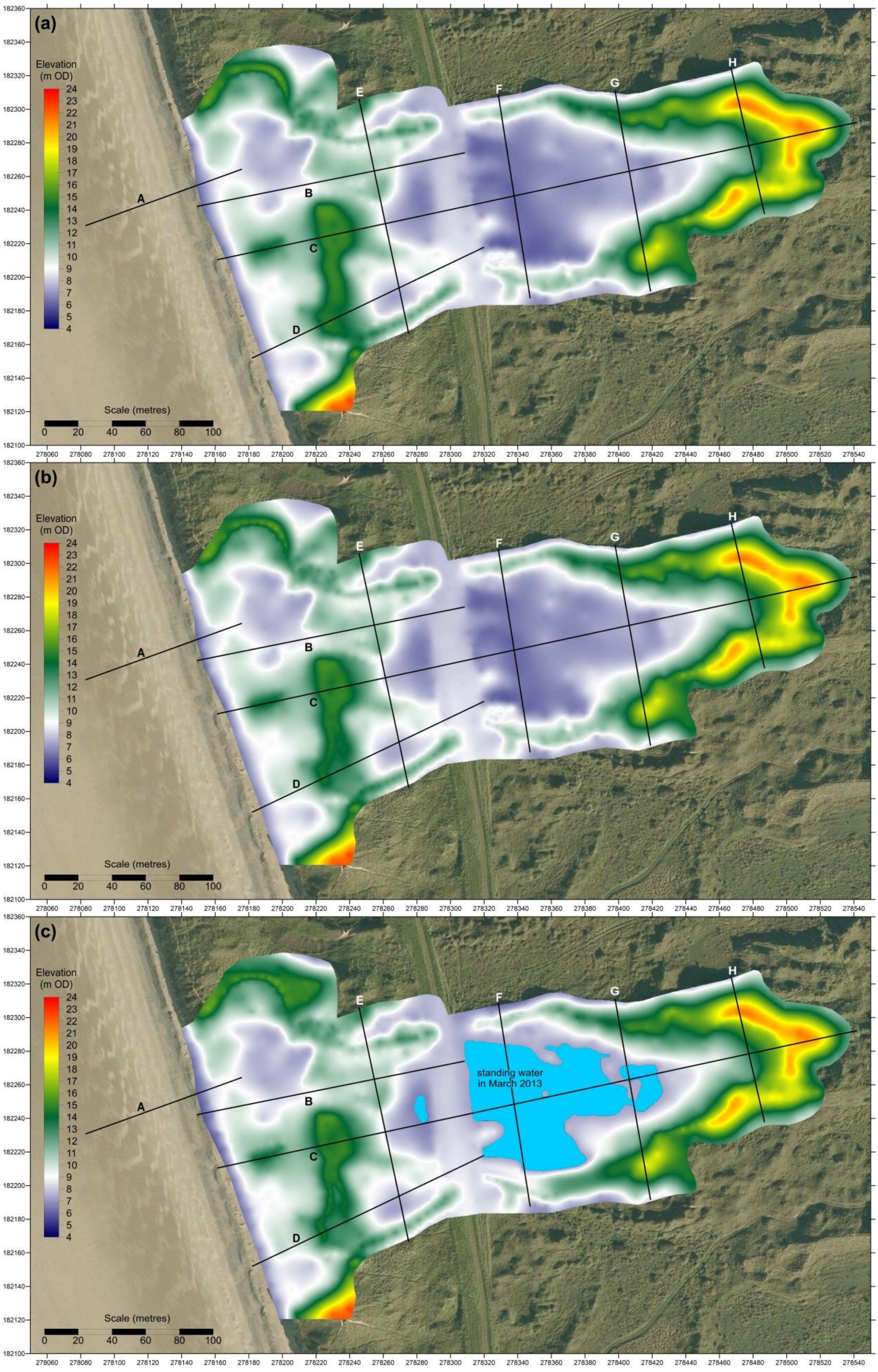


Figure 6. Digital terrain models of the Kenfig Phase 1 dune restoration works, from ground surveys conducted on (a) 17 July 2012; (b) 9 October 2012; and (c) 8 March 2013.

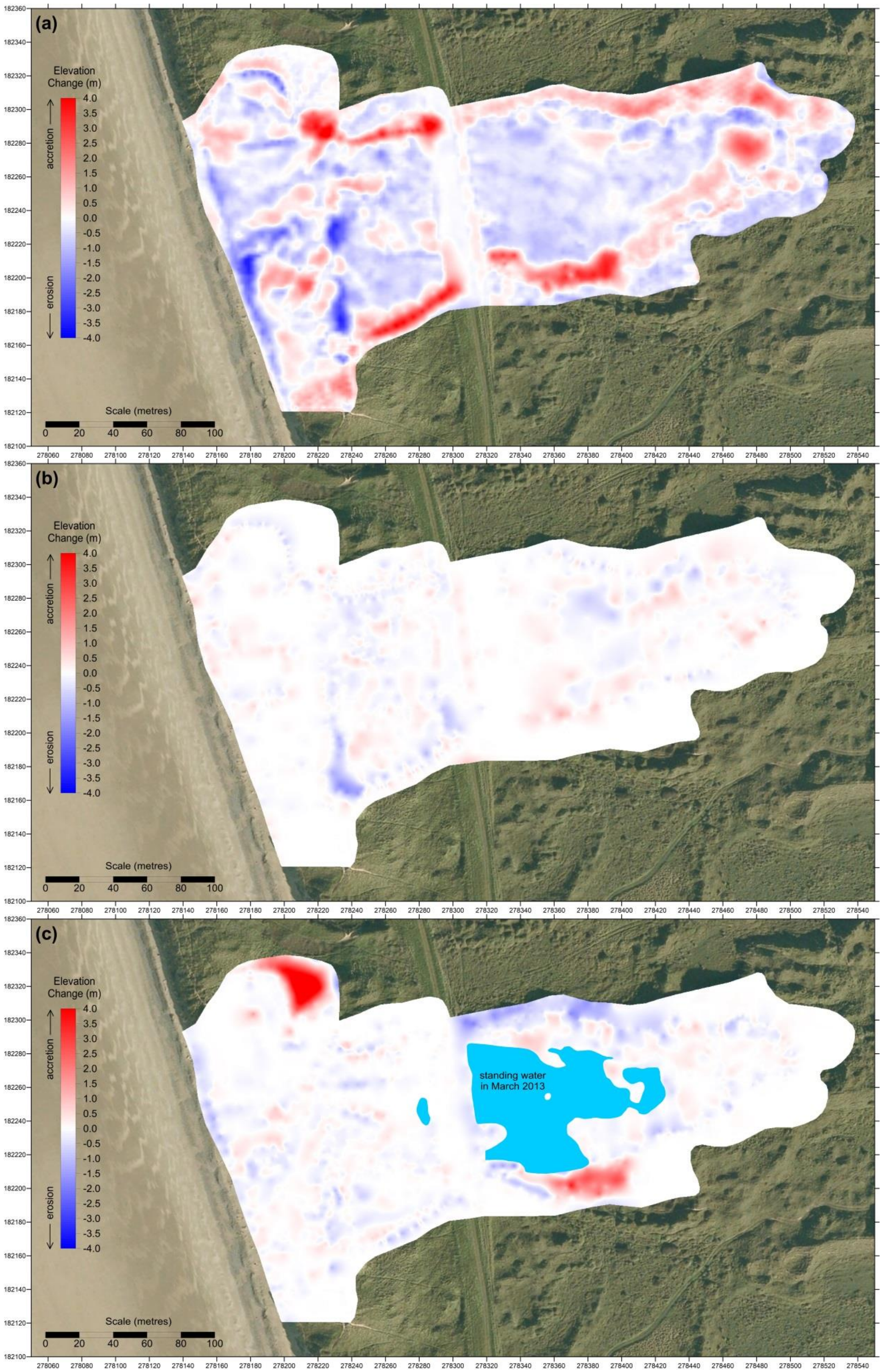


Figure 7. Changes in elevation from LiDAR and ground surveys: (a) 26/02/2006 (LiDAR) to 17 July 2012; (b) 17 July 2012 to 9 October 2012; and (c) 9 October 2012 to 8 March 2013.

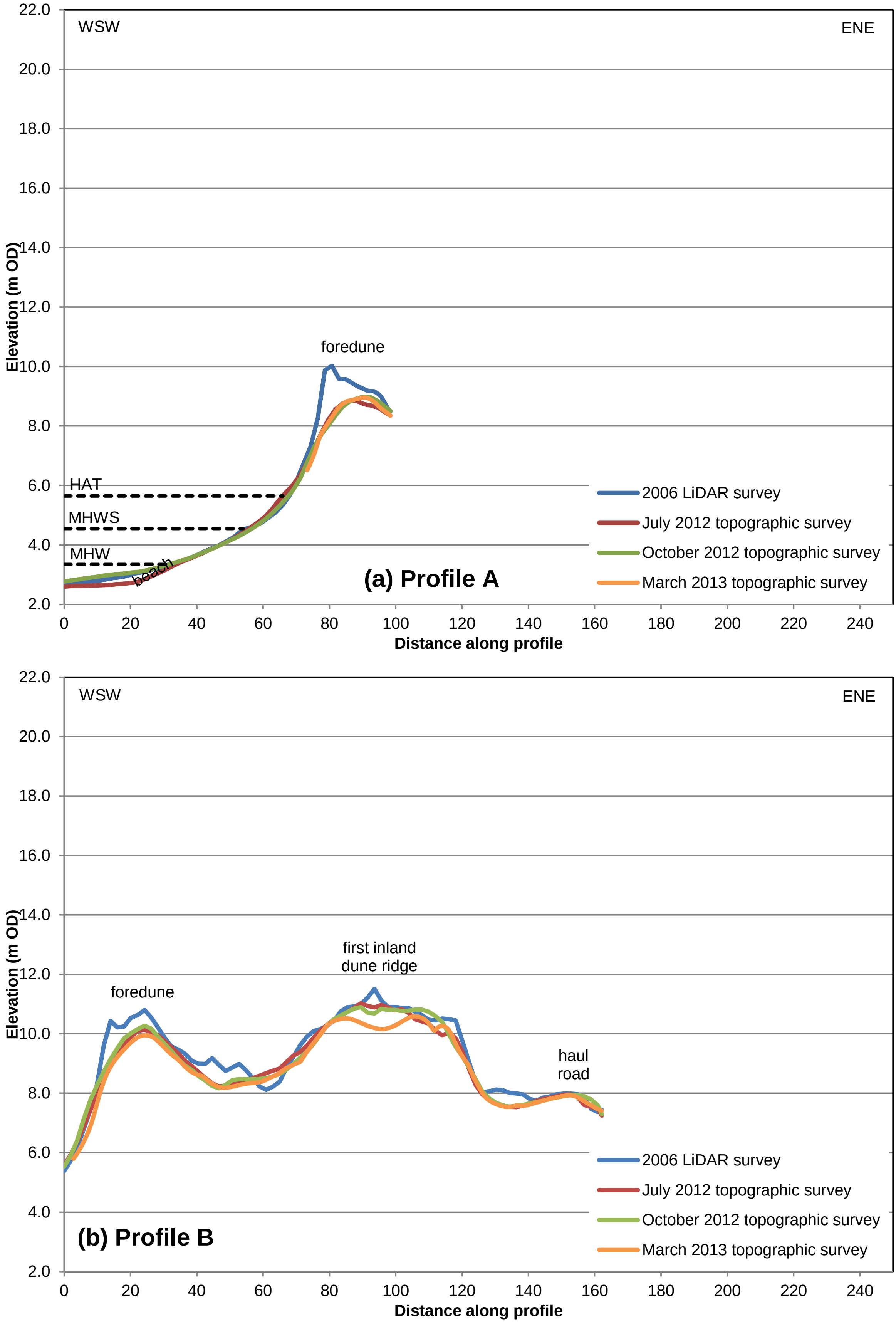
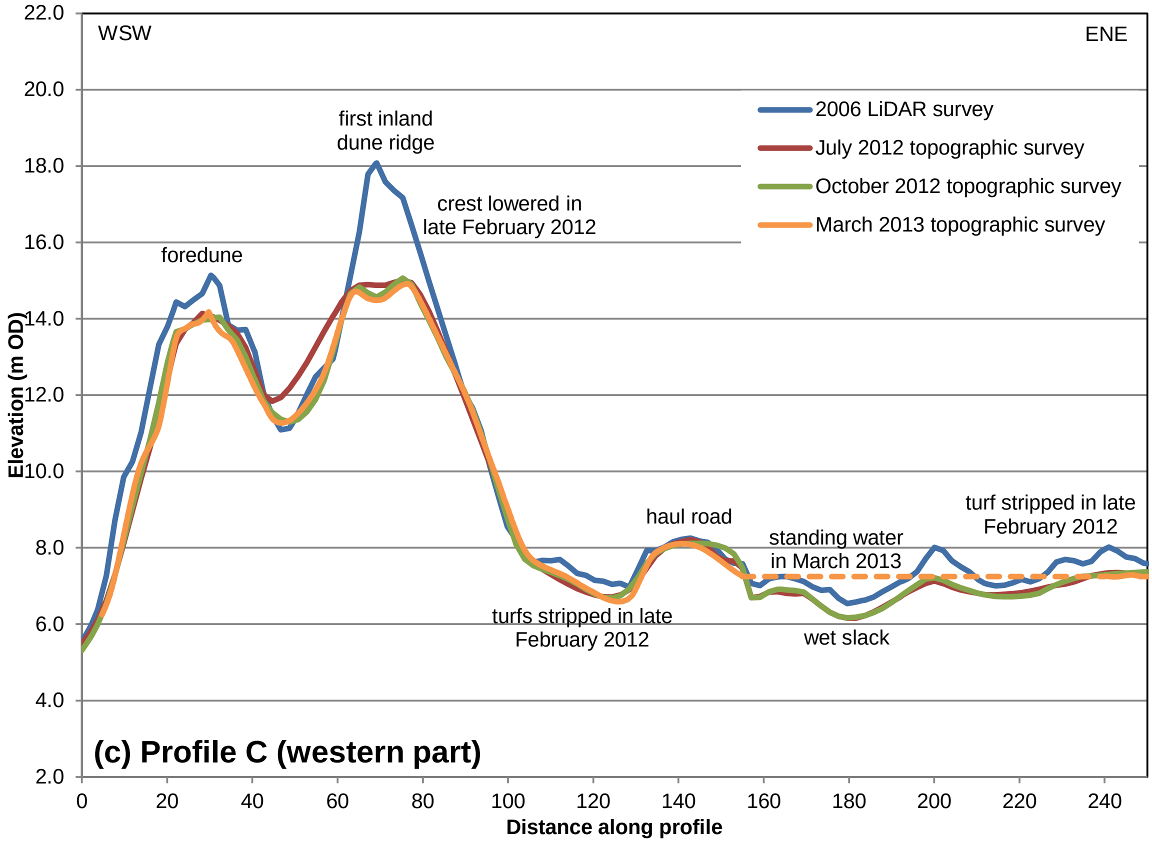
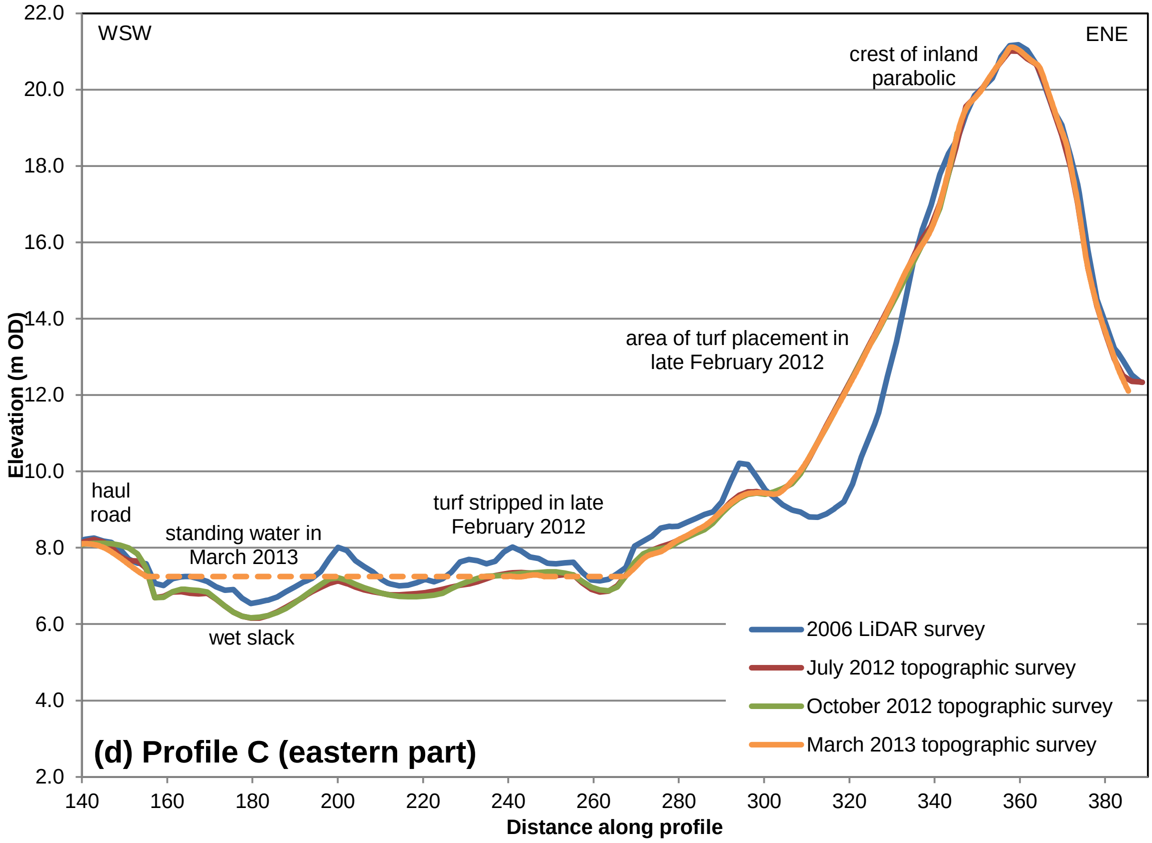


Figure 8. Sections across the Kenfig Phase 1 site, surveyed by LiDAR (26/02/2006) and RTK-GPS (17/07/2012, 09/10/2012 and 08/03/2013). Locations are shown on Figure 6.





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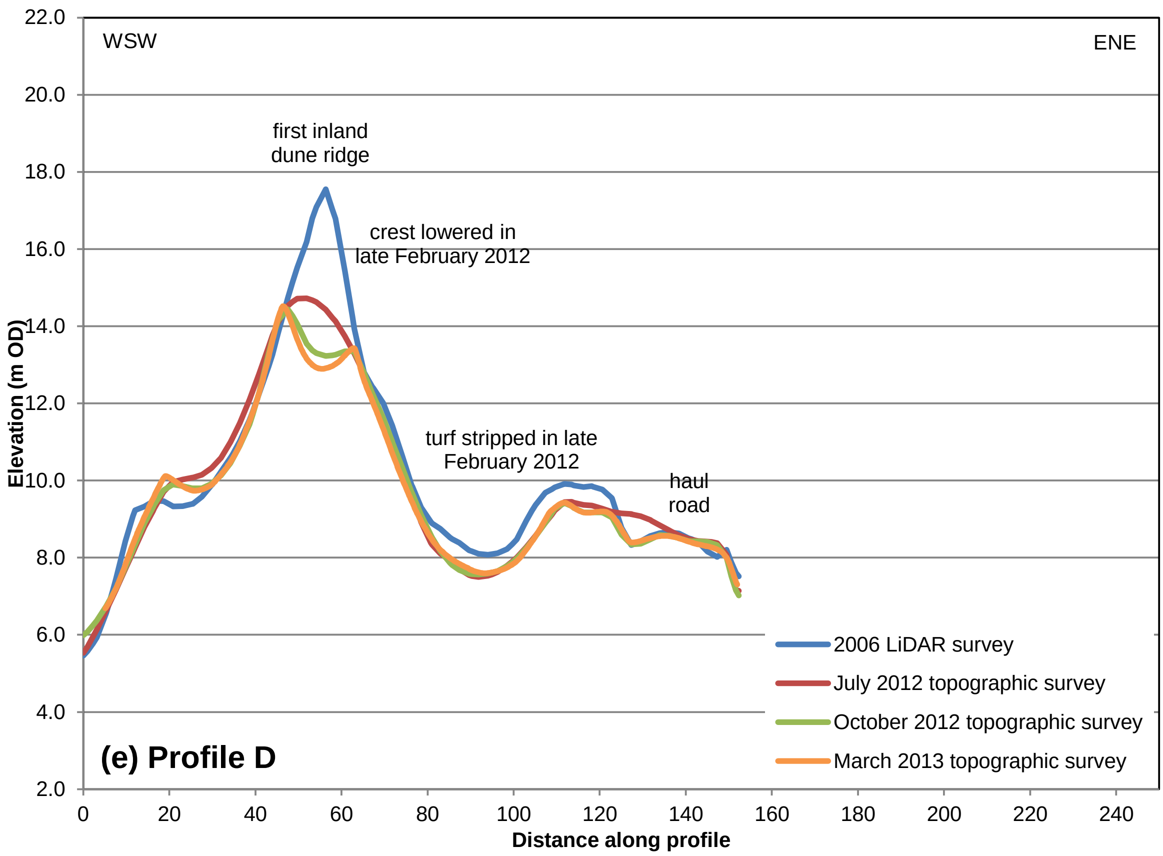

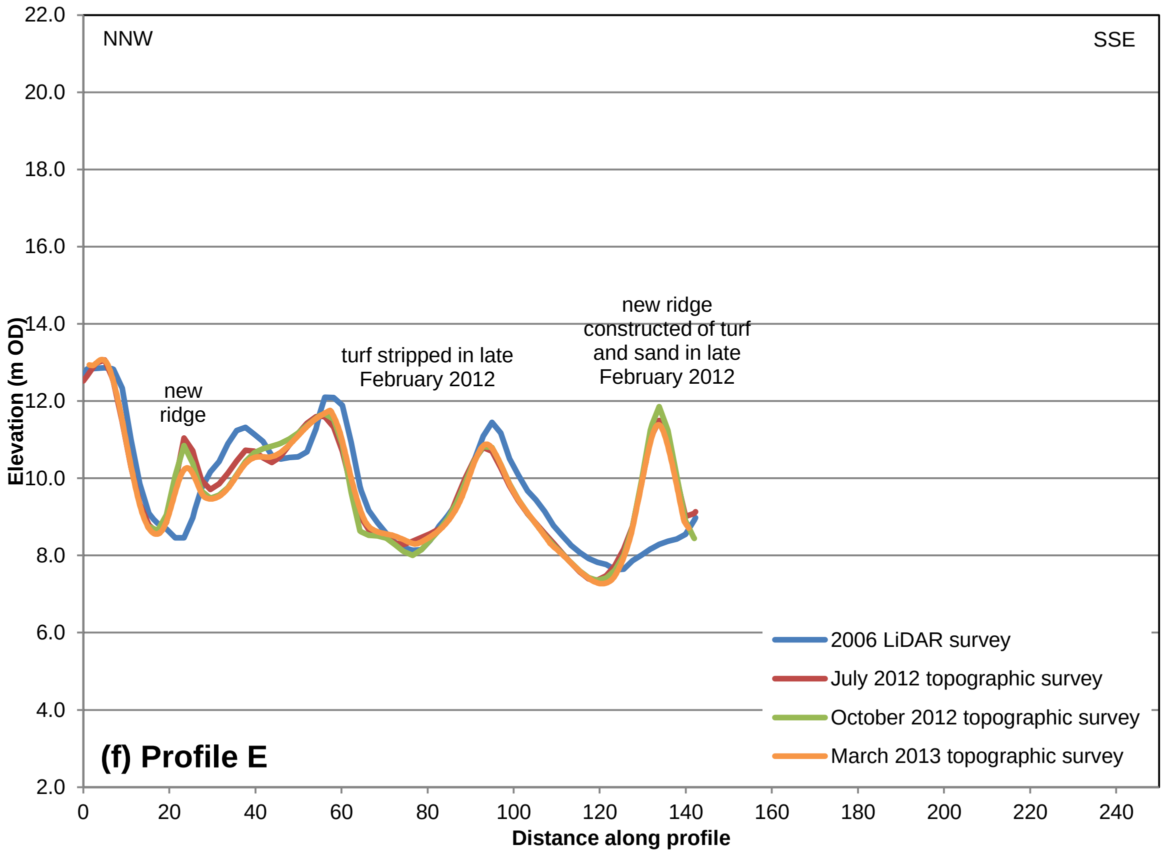

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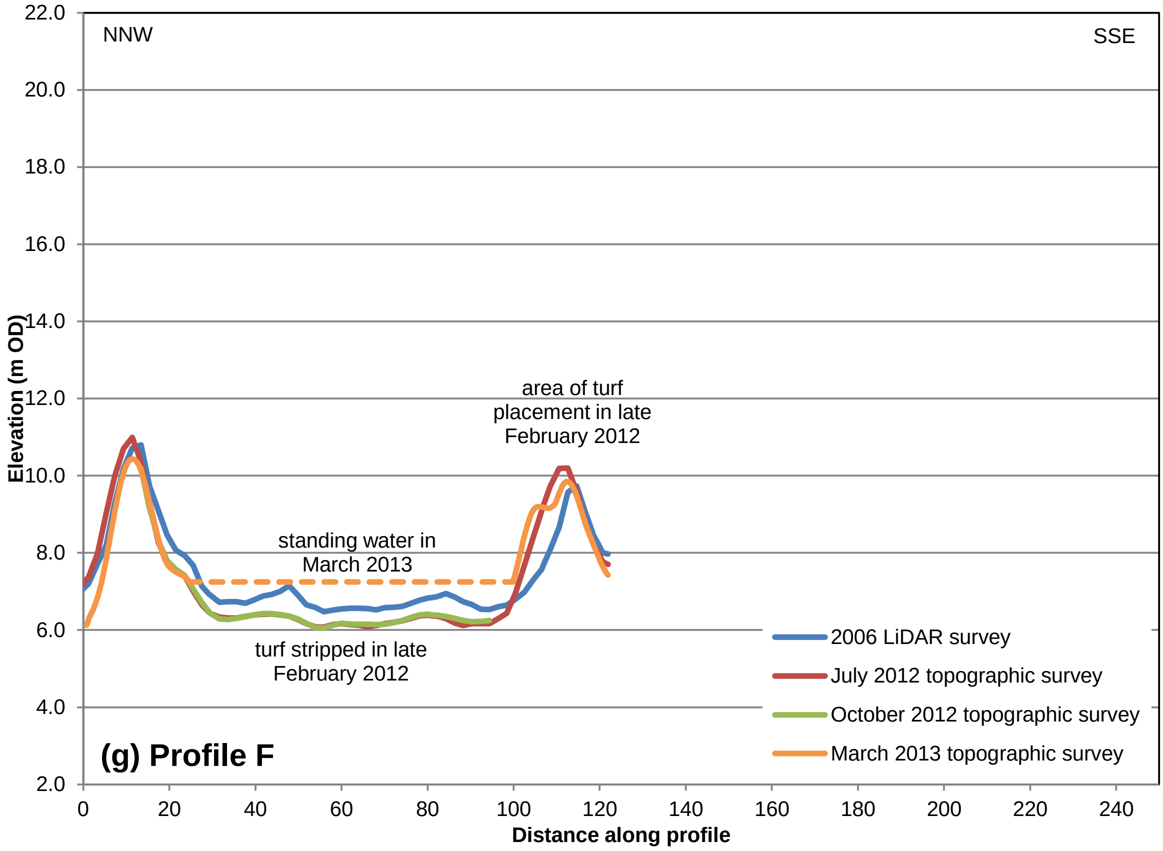

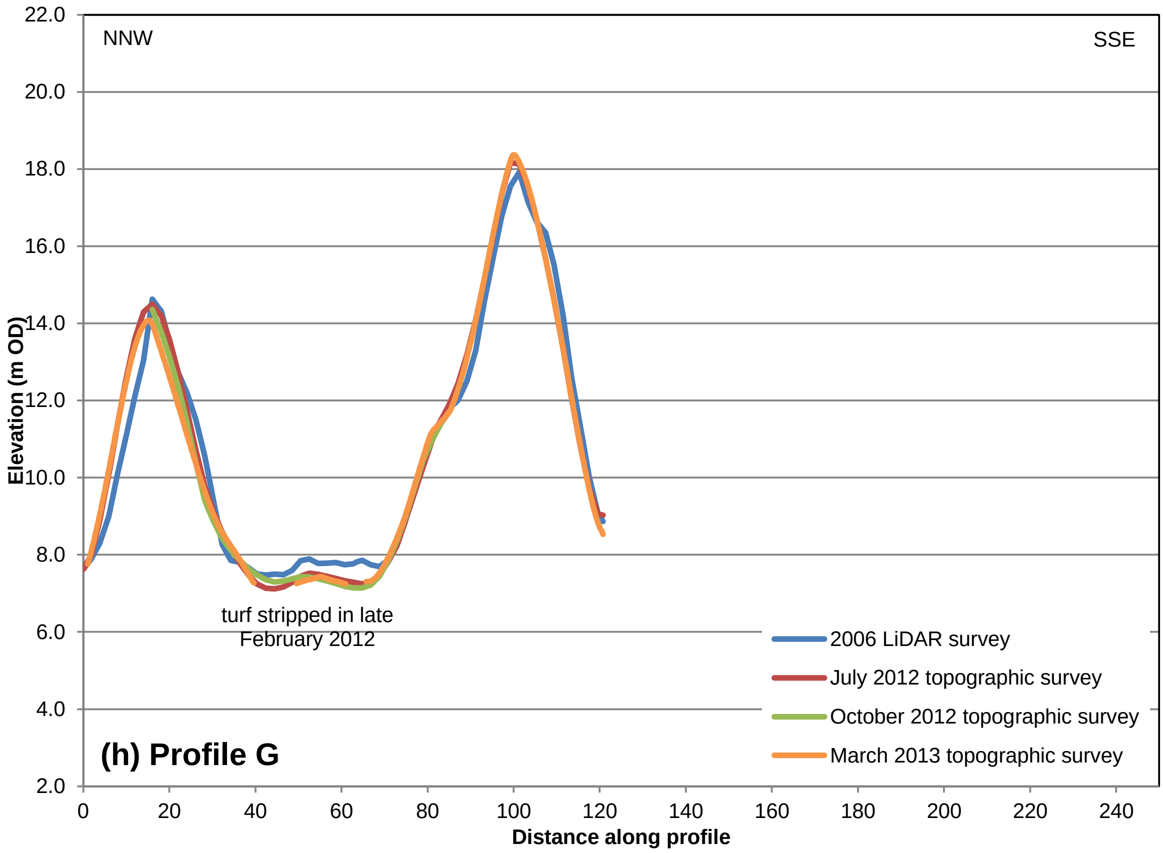

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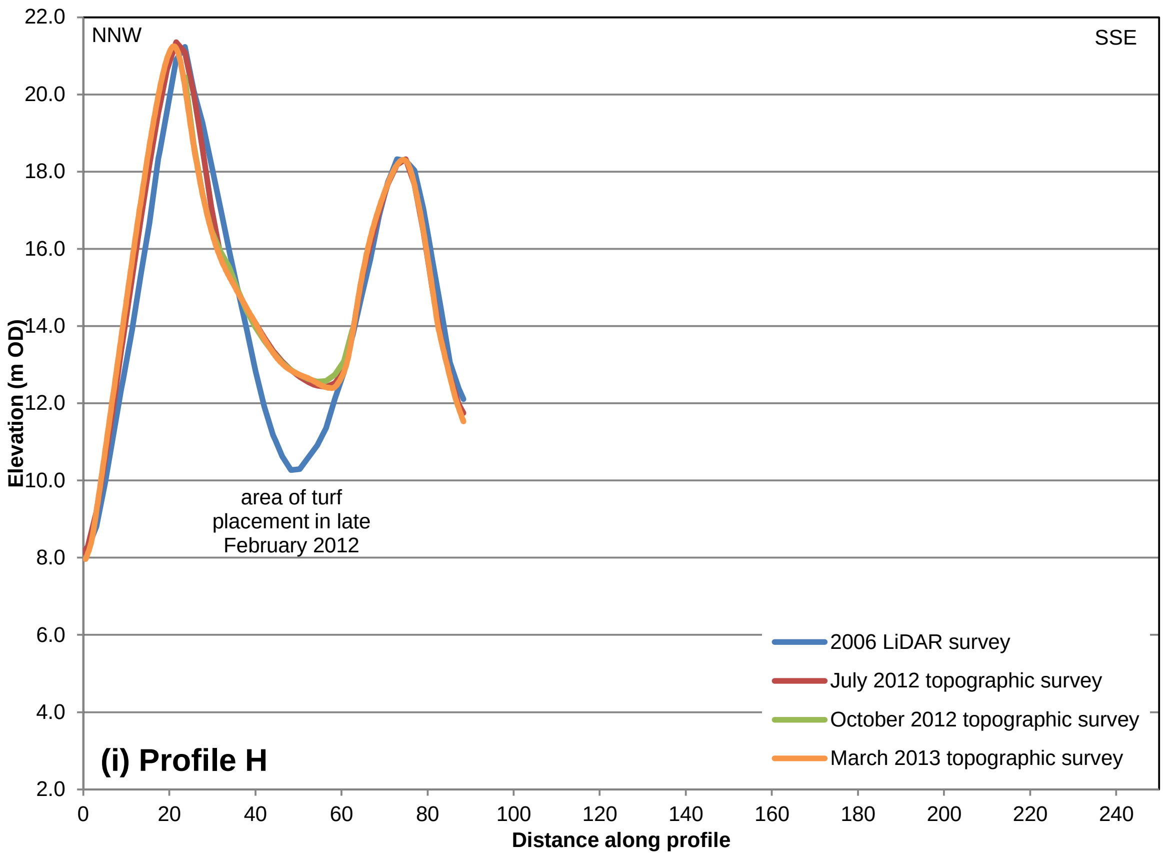


Figure 8. continued.

3.2 Fixed point photography

Photographs showing changes in the surface character and vegetation cover, viewed from a number of fixed points, are shown in Figures 9, 10, 11 & 12. On completion of the turf stripping and sand moving operation most of the area was left bare. However, by mid July 2012 significant plant regrowth had occurred, principally of bramble dewberry and marram. This reflects the facts that the turf stripping operation generally did not completely remove or kill the plant roots, and the wet spring of 2012 favoured plant recovery.

Area showing significant vegetation re-growth on the west side of the haul road were sprayed with herbicide in early July 2012, and by the time of the October 2012 survey the density of vegetation cover in this area showed an evident reduction compared with the earlier survey (Figure 9). However, regrowth from buried turves was evident within the eastern part of deflation corridor east of the haul road (Figures 11 & 12). Some of these turf blocks were physically removed during the winter of 2012-13 and placed on the margins of the site. Largely as a result of this intervention, vegetation cover within the deflation corridor and on the dune stoss slope was thin and patchy at the time of the site visits in February and March 2013, despite heavy rains which created a large area of standing water in the deeper parts of the deflation trough.

Figure 9. Photograph comparison D, taken from the crest of the summit of the high dune at the southern end of the site, looking north: (a) March 2012; (b) 17 July 2012; (c) 8 March 2013.

Figure 10. Photograph comparison C, taken from the crest of the summit of the high dune at the southern end of the site, looking north-west: (a) March 2012, shortly after the works were completed, supplied by David Carrington (Bridgend Council); (b) 17 July 2012; (c) February 2013; (d) 8 March 2013.

Figure 11. Photograph comparison B, taken from the crest of the inland parabolic dune looking westwards towards the sea: (a) 17 July 2012; (b) 9 October 2012; (c) February 2013; (d) 8 March 2013.

Figure 12. Photograph comparison A, taken from the haul road looking eastwards along the axis of the parabolic dune: (a) 17 July 2012; (b) 9 October 2012; and (c) 8 March 2013.

3.3 Sediment characterization

The sediment analysis results (presented in Appendix 1) showed that the Phase 1 rejuvenation site is characterised by well to very-well sorted mean sands. Small volumetric quantities of fines (silt and clay size material) indicated by the laser diffraction analyses largely represents low density organic matter which has almost no effect on the weight percentage sieve analysis data. The median size of the sand generally lies in the range 230 to 300 µm, corresponding to a threshold wind velocity range of 11 to 13.9 knots at a height of 10 m.

4. Discussion

4.1 Effect of wind conditions and rainfall on sand mobility

The wind record for Mumbles Head on the western side of Swansea Bay for the period June 2000 to May 2013 shows that winds from the west and southwest are dominant both in terms of frequency and velocity (Figure 13). Wind speeds greater than 11 knots, equivalent to a moderate breeze (Table 1) on average blew for 50% of the time during this period. Winds between 11 and 28 knots blew for 45% of the time, and winds of near-gale (Force 7) or higher velocity blew for 5% of the time, mainly from the southwest (Table 1; Figure 13). The record also shows a subsidiary, but significant wind component from the east-south-east.

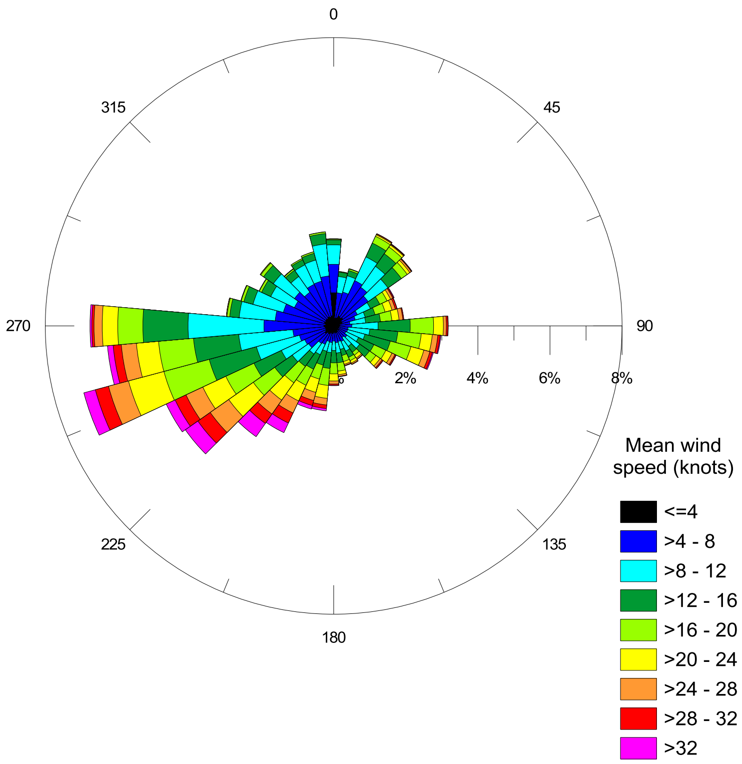


Figure 13. Wind rose constructed from hourly mean wind speed and direction records at Mumbles Head for the period June 2000 to May 2013.

Table 1. Beaufort wind force scale and descriptive terms. Source: UK Met Office.

Beaufort scale	Limit of wind speed (knots)	Descriptive terms	% winds at Mumbles 2000-13
0	<1	Calm	1.5
1	1-3	Light air	4.2
2	4-6	Light breeze	13.1
3	7-10	Gentle breeze	25.1
4	11-16	Moderate breeze	26.1
5	17-21	Fresh breeze	14.5
6	22-27	Strong breeze	9.4
7	28-33	Near gale	4.2
8	34-40	Gale	1.5
9	41-47	Severe gale	0.3
10	48-55	Storm	0.1
11	56-63	Violent storm	<0.1
12	64+	Hurricane	0

The cumulative wind run calculated for Mumbles Head for the period June 200 to May 2013 shows strong net transport potential in an easterly direction, with a number of short-lived reversals, notably in 2003, 2010 and early 2013 (Figure 14).

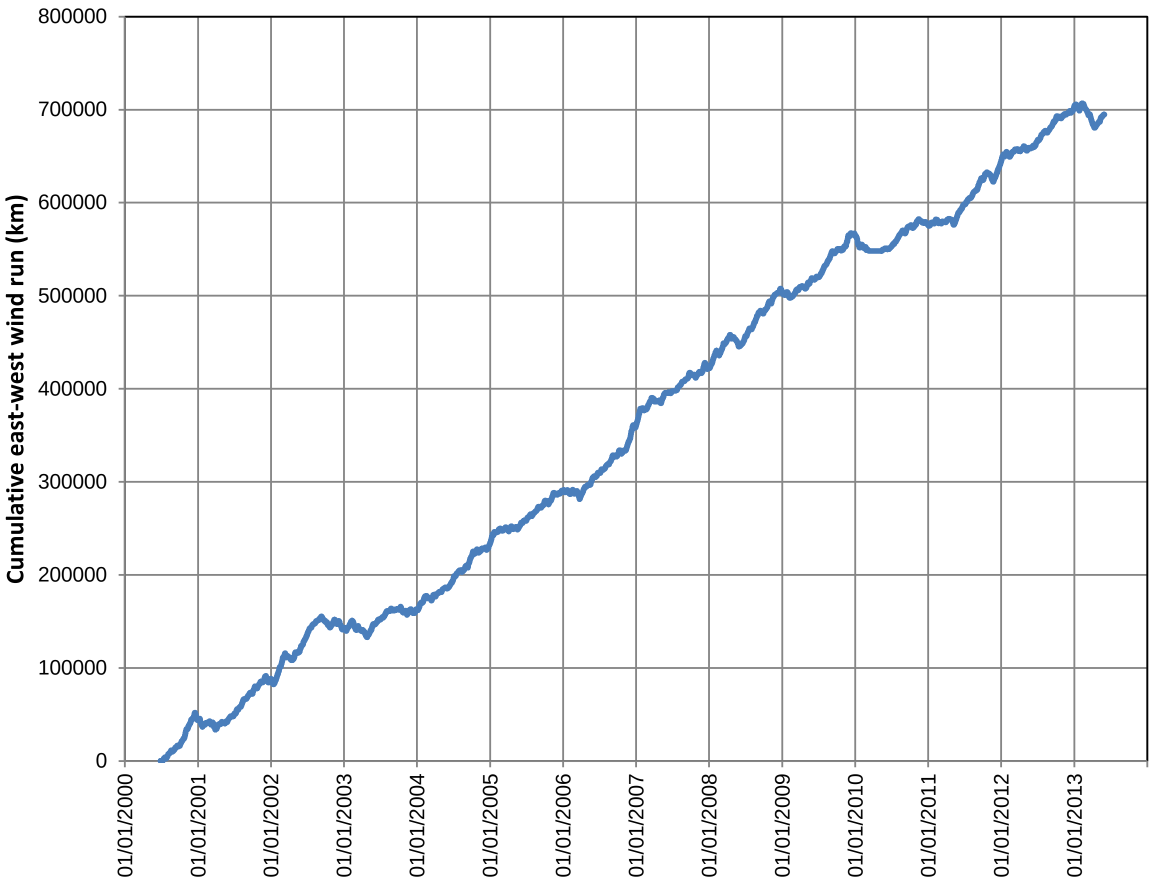


Figure 14. Cumulative wind run in an easterly (positive) or westerly (negative) direction. Calculated from mean wind speed and direction records at Mumbles Head for the period June 2000 to May 2013.

No reliable wind data are available for Kenfig, but consideration of the location and exposure of the site suggests that northwesterly winds will be of greater relative importance than at Mumbles Head, although westerly to southwesterly winds are still likely to be dominant.

The Mumbles record shows that the period February 2012 to May 2012 was one of relatively low wind velocities, with a period of strong north easterlies during April (Figure 15). June, July and September 2012 were relatively windy, with strongest winds from the southwest, although winds in August, October and November were generally light and variable. Stronger winds occurred in December 2012 and January 2013, mainly from the west and southwest but also from the east and northeast. Winds in February 2013 were again variable and generally light, although the later part of the month and early March were characterised by a period of relatively strong winds from the east - east-southeast. Winds in April and May 2013 were again relatively light and variable, through with a significant occurrence of strong breezes from the southwest during May.

The occurrence of winds in excess of the threshold for aeolian sand transport at Kenfig, and near-gale or higher wind speeds, is shown in Figure 16. Figure 17 shows that the vast majority of winds above these thresholds were directed from the south to westerly quadrant.

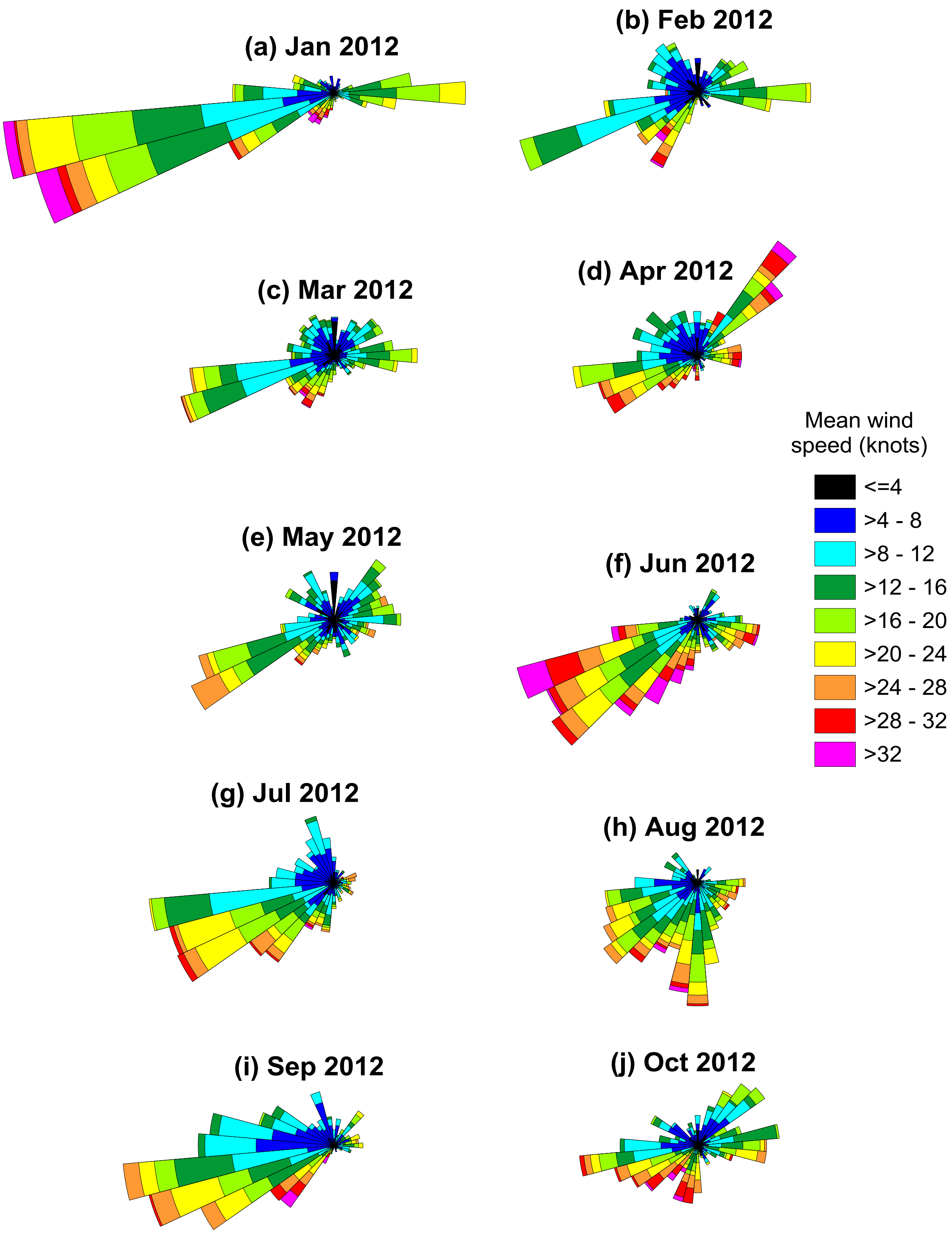
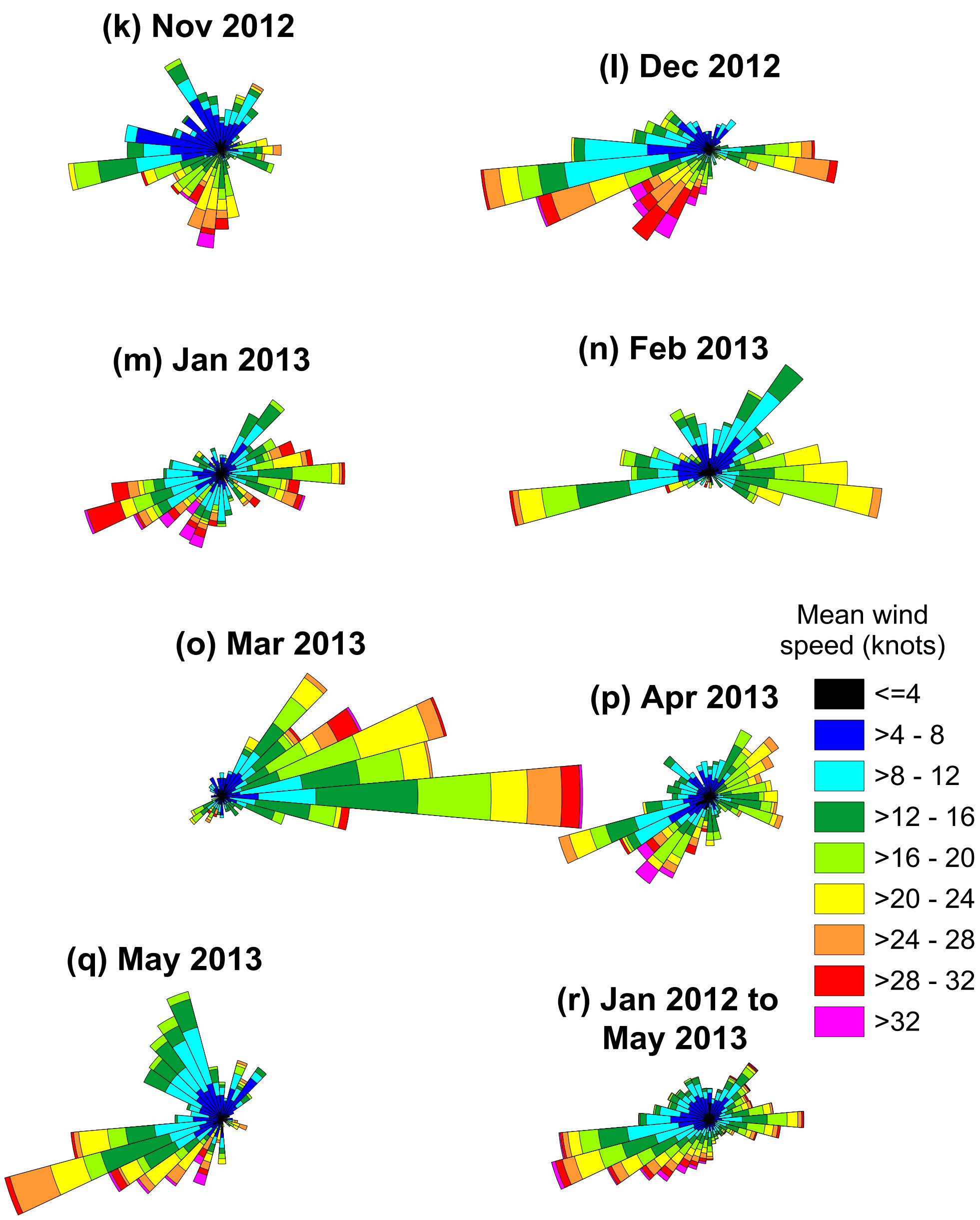


Figure 15. Wind roses constructed from hourly mean wind speed and direction records at Mumbles Head, monthly for 2012 to 2013.



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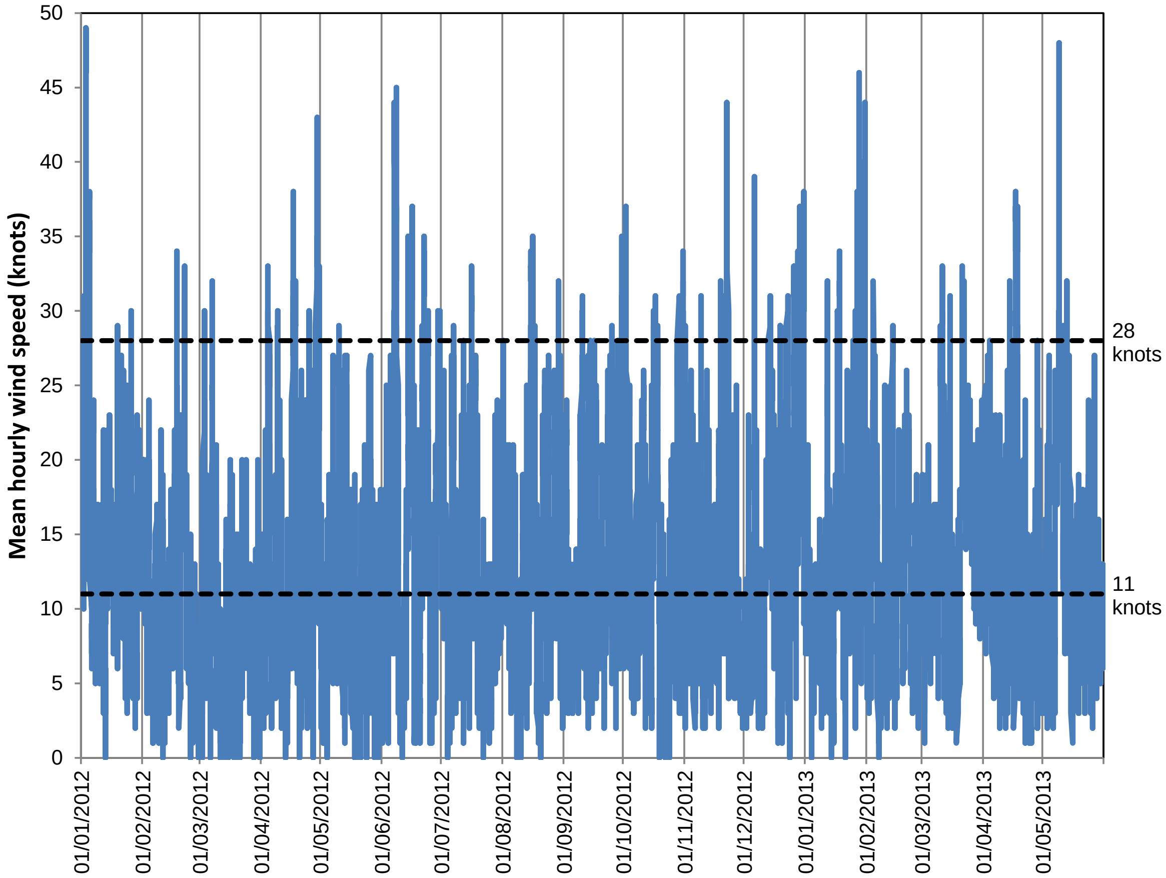

Figure 16. Hourly wind speed recorded at Mumbles Head for the period January 2012 to May 2013. The sand entrainment threshold, also coinciding with the limit of moderate breeze (11 knots) and lower limit of near gale (28 knots) are also shown.

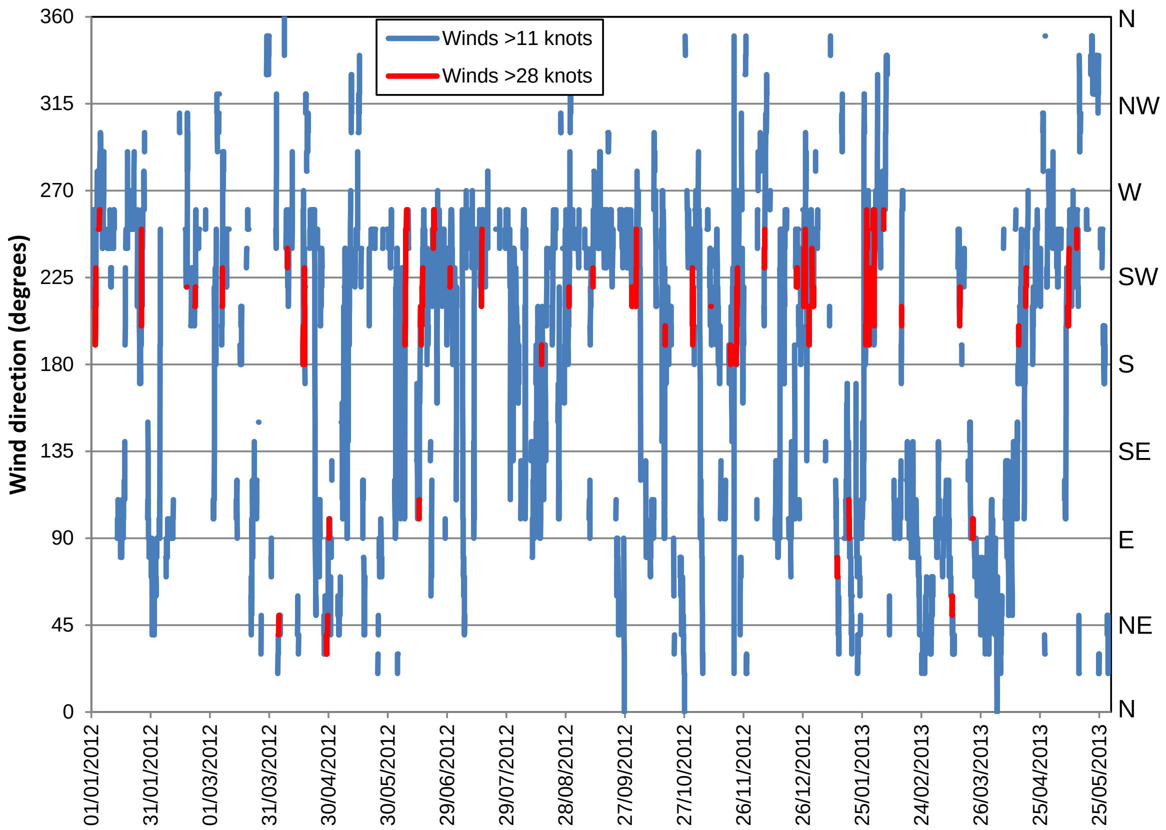

Figure 17. Hourly wind direction recorded at Mumbles Head for the period January 2012 to May 2013, for winds greater than moderate breeze and the sand entrainment threshold (11 knots, blue), and greater than near gale (28 knots, red).

Monthly rainfall recorded near Kenfig Visitor's Centre since 2002 shows a marked seasonal pattern with highest values in the winter months, The highest monthly rainfall in the period of record occurred in November 2009 (271 mm), but the period April 2012 to January 2013 experienced unusually sustained wet conditions when every moth received more than 100 mm of rainfall (Figure 18), the maximum being in December (252 mm). The result was extensive flooding on the Kenfig Reserve and in other parts of South Wales. Monthly mean wind speeds during this period were also relatively low (12 to 15 knots). The effect of the wet summer of 2012 was that the groundwater levels did not show the usual fall during the summer months, and the continuing rainfall in the autumn and winter caused the level in dip-well 3/2, located relatively sloe to the Visitor Centre, toe reach 10.4 m OD, the highest recorded level ever (Figure 19). These conditions favoured sand stability and plant growth.

Since February 2013 rainfall has been lower than average and the groundwater levels have again fallen back to more normal levels. Drying of the sand has lowered the threshold for aeolian entrainment and plant growth has been retarded, increasing the potential for active aeolian processes and sand mobility.

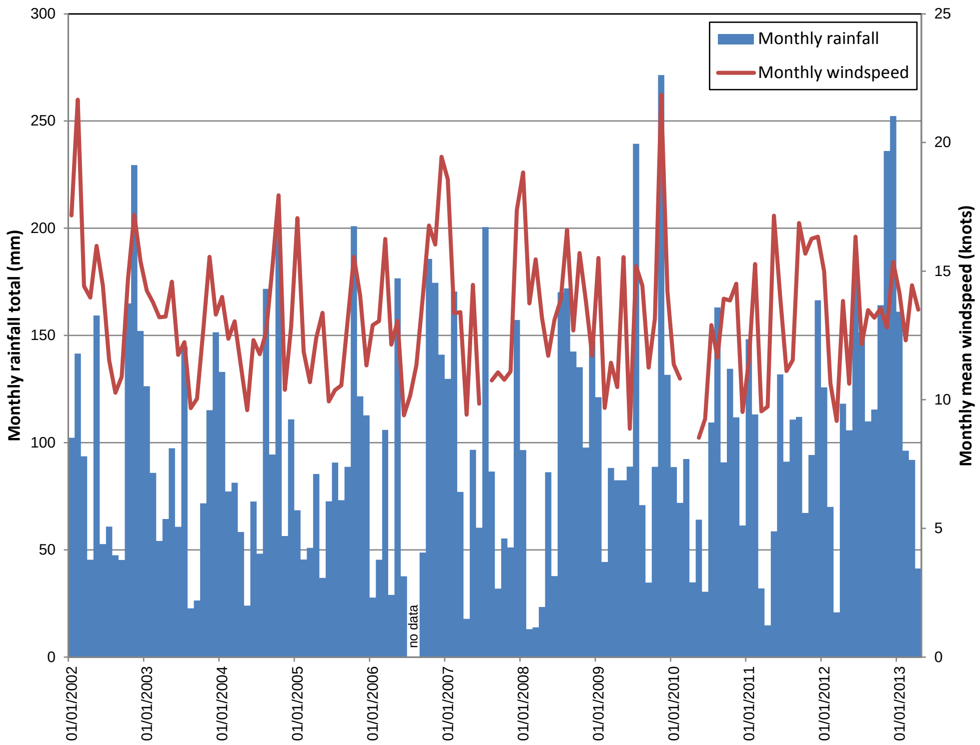

Figure 18. Monthly rainfall totals recorded at Kenfig Nature Reserve, and mean monthly wind speed recorded at Mumbles Head. Both for the period January 2002 to April 2013, ignoring months with <85% data completeness.

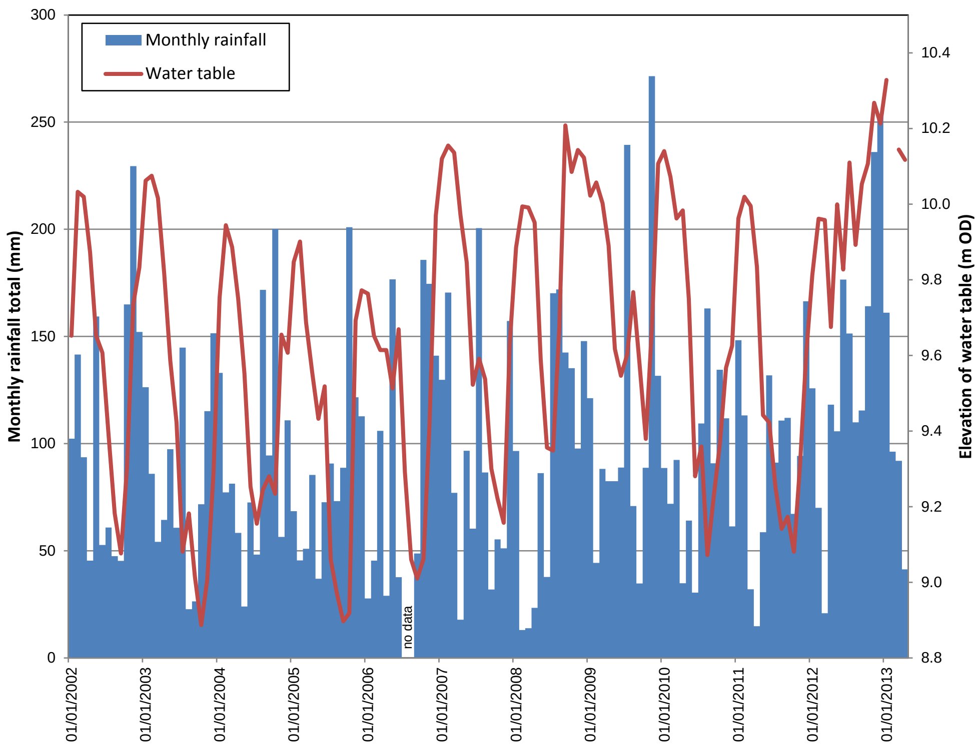

Figure 19. Monthly rainfall totals recorded at Kenfig Nature Reserve, and monthly water table levels recorded in Dipwell 3/2 at Kenfig Burrows, for the period January 2002 to April 2013.

4.2 Topographic survey methodology

The RTKS ground survey methodology used was found to work reasonably well in the Kenfig area although periodic problems were encountered with loss of the RTK signal, requiring the system to be re-booted. The modified methodology used in the third survey, involving the use of a fixed local base station, was found to be considerable more efficient than that used in the first two surveys were a mobile receiver attached to the rover was used. The latter is highly susceptible to loss of the mobile phone network signal in areas of complex dune terrain.

In an area of irregular topography measuring 5 ha is size, a considerable number of points must be surveyed to give an adequate representation of the surface features. Gaps in data coverage can present problems in grid generation, kriging and DEM construction. This methodology is therefore better suited to repeat surveys of specific points, profile lines or features of interest than to areal relief mapping.

Experience gained in monitoring of the dune rejuvenation areas at Newborough Warren has indicated that, in the absence of repeat LiDAR surveys, the most comprehensive, accurate and cost-effective survey data can be obtained by using RTK GPS to determine the positions and heights of a number of control points across the area of interest, followed by drone (unmanned-min-aircraft) 3D aerial photography survey. The ground-based GPS control point data provide a sound basis for rectification of the aerial imagery, allowing construction of a DEM with horizontal and vertical accuracy of better than 20 cm across large areas of open ground.

5. Conclusions and Recommendations

The year following completion of the Phase 1 dune rejuvenation works saw weather conditions which largely precluded large-scale sand blowing but favoured plant growth. Since February 2013 drier conditions have returned, allowing drying of the sand and retarding plant growth. Periods of strong easterly winds during a dry period in February - March accomplished significant sand movement in a seawards direction. This was followed by significant landwards transfer under the influence of strong southwesterly winds in April and May. The continued existence of bare, mobile sand areas will depend on the balance of rainfall, wind speeds and evaporation in the coming months and years.

Intervention in the form of herbicide application and removal of re-growing turves was required in 2012. Such measures may be required again if wetter, less windy conditions return.

Experience gained through the topographic monitoring undertaken so far has indicated that ground-based RTK GPS methods work effectively in this area, but are best suited to repeat surveying along defined transect lines and for feature mapping. Better spatial coverage, more suited to the construction of accurate DEMS and surface level change maps, could be obtained by combining RTKS surveying of ground control points with3-D drone aerial photography surveys, as has recently been done in monitoring the dune rejuvenation sites at Newborough Warren. This could be done at annual or bi-annual intervals.

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7. Particle Size Data

APPENDIX 1 - PARTICLE SIZE DATA

Table A1. Particle size characteristics of dune samples collected at the Kenfig Burrows restoration site in July 2012 and May 2013. Statistics are calculated using GRADISTAT software (Blott & Pye, 2001), mean and sorting using the formulae of Folk & Ward (1957).

ID	Mean (µm & class)		D50 (µm)	Mode (µm)	Mean (phi)	Sorting (phi & description)		Gravel (%)	Sand (%)	Mud (%)
Samples collected 17 July 2012										
84	242	FS	242	245	2.05	0.35	VWS	0.0	100.0	0.0
236	285	MS	282	270	1.81	0.56	MWS	0.0	98.5	1.5
311	320	MS	316	296	1.64	0.60	MWS	0.0	98.9	1.1
373	303	MS	292	270	1.72	0.66	MWS	0.0	98.8	1.2
428	278	MS	277	270	1.85	0.48	WS	0.0	98.3	1.7
456	265	MS	265	270	1.92	0.40	WS	0.0	100.0	0.0
499	268	MS	268	270	1.90	0.40	WS	0.0	100.0	0.0
516	279	MS	278	270	1.84	0.46	WS	0.0	99.0	1.0
539	300	MS	296	296	1.74	0.62	MWS	0.0	98.8	1.2
686	252	MS	254	270	1.99	0.47	WS	0.0	97.3	2.7
789	295	MS	295	296	1.76	0.50	WS	0.0	98.8	1.2
806	237	FS	238	245	2.08	0.42	WS	0.0	98.4	1.6
816	268	MS	269	270	1.90	0.45	WS	0.0	98.6	1.4
883	242	FS	244	245	2.05	0.43	WS	0.0	98.0	2.0
989	271	MS	271	270	1.88	0.50	MWS	0.0	98.0	2.0
Samples collected 13 May 2013										
KF19	275	MS	274	231	1.86	0.33	VWS	0.0	100.0	0.0
KF20	200	FS	201	231	2.32	0.35	VWS	0.0	100.0	0.0
KF21	233	FS	231	196	2.10	0.34	VWS	0.0	100.0	0.0
KF22	233	FS	233	196	2.10	0.33	VWS	0.0	100.0	0.0
KF23	241	FS	243	275	2.05	0.36	WS	0.0	100.0	0.0
KF24	221	FS	213	196	2.18	0.32	VWS	0.0	100.0	0.0
KF25	241	FS	244	275	2.05	0.32	VWS	0.0	100.0	0.0
KF26	291	MS	290	275	1.78	0.47	WS	0.0	100.0	0.0
KF27	256	MS	259	275	1.97	0.39	WS	0.0	100.0	0.0

Mean Size Classification:
VCS (very coarse sand)
CS (coarse sand)
MS (medium sand)
FS (fine sand)
VFS (very fine sand)

Sorting Descriptions:
VWS (very well sorted)
WS (well sorted)
MWS (moderately well sorted)
MS (moderately sorted)
PS (poorly sorted)
VPS (very poorly sorted)

Table A2. Sediment textural classifications, according to Folk (1954) and Blott & Pye (2012), from the samples collected in July 2012 and May 2013. Fluid threshold velocities are calculated using the D50 particle size of each sample using formulae proposed by Bagnold (1941) and Hsu (1974).

ID	Textural Class		Fluid Threshold Velocity	
	Folk (1954)	Blott and Pye (2012)	at surface ($cm\ s^{-1}$)	at 10 m (knots)
Samples collected 17 July 2012				
84	sand	sand	23.3	12.3
236	sand	very slightly muddy sand	25.1	13.2
311	sand	very slightly muddy sand	26.5	13.9
373	sand	very slightly muddy sand	25.5	13.4
428	sand	very slightly muddy sand	24.9	13.1
456	sand	sand	24.3	12.8
499	sand	sand	24.5	12.9
516	sand	sand	25.0	13.1
539	sand	very slightly muddy sand	25.7	13.5
686	sand	very slightly muddy sand	23.9	12.5
789	sand	very slightly muddy sand	25.7	13.5
806	sand	very slightly muddy sand	23.1	12.2
816	sand	very slightly muddy sand	24.6	12.9
883	sand	very slightly muddy sand	23.4	12.3
989	sand	very slightly muddy sand	24.6	12.9
Samples collected 13 May 2013				
KF19	sand	sand	24.7	13.0
KF20	sand	sand	21.3	11.2
KF21	sand	sand	22.8	12.0
KF22	sand	sand	22.9	12.0
KF23	sand	sand	23.3	12.3
KF24	sand	sand	21.9	11.5
KF25	sand	sand	23.4	12.3
KF26	sand	sand	25.5	13.4
KF27	sand	sand	24.1	12.7

Table A3. Particle size frequency distribution (volume %) of samples collected on 17 July 2013 determined by laser diffraction: reported at ‘quarter phi’ intervals.

Size	Sediment sample number (waypoint number)														
(µm)	84	236	311	373	428	456	499	516	539	686	789	806	816	883	989
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
1400	0.0	0.3	0.1	0.4	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
1180	0.0	0.8	1.4	1.1	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.0	1.2	1.9	1.7	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0
850	0.0	1.2	1.4	1.9	0.8	0.0	0.0	0.6	1.3	0.0	0.7	0.0	0.0	0.0	0.6
710	0.0	1.2	1.3	2.0	1.4	0.0	0.0	1.0	1.1	0.0	1.2	0.0	0.0	0.0	1.1
600	0.0	1.1	1.9	2.2	0.8	0.0	0.0	0.5	1.3	0.0	1.0	0.0	0.0	0.0	0.6
500	0.0	2.4	4.9	4.2	1.8	0.6	0.3	1.9	3.7	0.5	3.3	0.0	1.1	0.0	2.0
425	0.3	5.6	9.1	6.7	5.2	3.7	3.7	5.7	7.4	3.2	7.9	1.2	4.9	1.5	5.3
355	4.9	12.1	15.8	11.8	12.3	10.9	11.7	13.0	13.5	9.6	15.2	6.3	12.3	7.1	11.9
300	14.4	17.2	18.2	15.3	17.9	18.1	19.0	18.2	16.9	16.1	18.8	13.6	18.2	14.8	16.9
250	25.7	21.4	19.0	18.8	22.4	24.8	24.9	22.4	19.5	22.6	20.7	22.4	22.9	23.3	21.3
212	24.9	16.7	12.8	15.2	17.4	20.7	19.9	17.5	14.8	19.6	14.7	21.8	18.1	21.6	17.2
180	18.1	10.4	7.1	10.1	10.8	13.5	12.6	11.0	9.4	13.8	8.8	17.1	11.8	15.8	11.5
150	9.5	4.9	3.0	5.2	5.0	6.5	6.0	5.3	4.7	7.7	4.2	10.5	6.1	9.0	6.2
125	2.1	1.1	0.6	1.3	1.1	1.3	1.4	1.1	1.2	2.4	1.2	3.6	1.8	2.8	2.0
106	0.1	0.3	0.1	0.2	0.3	0.0	0.3	0.1	0.2	0.6	0.3	0.8	0.5	0.7	0.5
90	0.0	0.3	0.2	0.2	0.3	0.0	0.1	0.2	0.2	0.4	0.3	0.3	0.3	0.5	0.3
75	0.0	0.3	0.2	0.2	0.4	0.0	0.0	0.3	0.2	0.5	0.2	0.3	0.3	0.5	0.3
63	0.0	0.2	0.1	0.1	0.2	0.0	0.0	0.2	0.2	0.3	0.1	0.3	0.2	0.3	0.3
pan	0.0	1.5	1.1	1.2	1.7	0.0	0.0	1.0	1.2	2.7	1.2	1.6	1.4	2.0	2.0

Table A4. Particle size frequency distribution (weight %) of samples collected on 13 May 2013, determined by dry sieving at 'quarter phi' intervals.

Size	Sediment sample number								
(µm)	KF19	KF20	KF21	KF22	KF23	KF24	KF25	KF26	KF27
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
850	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
710	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1
600	0.3	0.1	0.0	0.0	0.0	0.0	0.0	1.4	0.4
500	0.6	0.3	0.3	0.0	0.0	0.0	0.4	3.7	0.9
425	2.5	0.7	0.8	0.3	1.6	0.4	1.0	7.1	2.0
355	7.4	2.3	1.9	2.7	4.4	2.1	3.9	14.5	6.5
300	27.3	4.1	10.9	9.0	11.6	5.7	11.0	17.7	14.9
250	22.6	7.9	26.5	29.3	28.6	19.3	30.4	25.8	31.6
212	30.1	26.3	20.4	20.6	20.1	22.9	21.2	11.7	17.4
180	6.2	24.8	28.1	28.1	24.0	36.3	25.9	13.2	19.3
150	2.2	27.2	8.1	7.1	6.4	8.9	4.8	3.0	4.9
125	0.3	4.4	1.6	2.3	2.4	3.5	1.2	1.0	1.7
106	0.0	1.4	1.2	0.4	0.7	0.7	0.2	0.2	0.2
90	0.0	0.5	0.2	0.1	0.1	0.3	0.0	0.0	0.1
75	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
63	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
pan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Data Archive Appendix

Data outputs associated with this project are archived at 'Topographical Survey of Kenfig Dune Rejuvenation Work project 420, media 1438' on server–based storage at Natural Resources Wales.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] An Excel file named (Kenfig Dune Survey Data 13-05-2013.xls) of data points (x,y,z)

[C] A series of GIS layers on which the maps in the report are based.

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