Poole Bay Nearshore Beach Replenishment Trial

Pre-monitoring report

Dr Travis Mason & Jon Evans, Channel Coastal Observatory

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1. INTRODUCTION

An extensive monitoring programme is in place to assess the evolution of a trial seabed recharge project. The primary purpose of the monitoring is to establish whether material from the seabed recharge moves onshore to the beach, but a key secondary aim is to determine the potential impacts of the deposition upon sensitive/protected marine features, particularly given the proximity of the Poole Rocks MCZ. The trial monitoring programme comprises the following activities to track the dispersal of the deposited material:

- beach (topographic) surveys
- swath bathymetry (multibeam) surveys
- seabed tracer study
- wave, currents and turbidity monitoring
- tidal monitoring
- silt monitoring

However, an important facet of the nearshore trial monitoring programme will be to examine the results in context with longer-term natural changes, both in terms of the transport rates and pathways of the recharge, and in the hydrodynamic conditions experienced. An extensive database of morpho- and hydrodynamic conditions in Poole Bay is available, dating back to 2002. The aim of this report is to analyse and quantify longer-term (~15 years) environmental conditions, based on data existing prior to the start of the trial. The report will focus on:

- sediment mobility
- sediment type
- hydrodynamics – wave climate and tidal regime

2. EXISTING DATA

A summary of the pre-trial baseline data is given in Table 1. Most of the pre-existing data has been collected as part of the national network of regional coastal monitoring programmes, and is in the public domain as Open Government Licence data via the Channel Coastal Observatory's website. The level of detail of all surveys is consistent and all are carried out to a rigorous specification and subsequently quality-controlled.

Topographic data includes beach surveys conducted at a temporal interval of approximately every three months, and includes post storm surveys. Single beam bathymetry surveys have been carried out annually. An extensive swath bathymetry (multibeam) survey was carried to International Hydrographic Organisation Order 1a standard by the Maritime and Coastguard Agency (MCA) as part of the UK Civil Hydrography Programme in 2012; these data are made freely available by the MCA.

Area	Survey type	Standard, coverage and resolution	Comments
Inter-tidal beach	Beach surveys	RTK GPS surveys or laser scans (2 profile surveys plus one baseline survey from which a DTM can be derived). Cross-shore profiles are at 100 m intervals. Surveys extend from the seawall to the Mean Low Water Springs contour. Includes post-storm profile surveys	3 surveys per year, 2003 to present
	Lidar	1 m resolution, shoreward of Mean Low Water contour	3-yearly since 2003, latest survey 2013/14
	Aerial photography	10 cm resolution, shoreward of MLWS contour	2001, 2002, 2005, 2008 and 2013
Seabed	Swath (multibeam) bathymetry	IHO Order 1a (navigation safety standard), 100% seafloor coverage, 1m resolution	Conducted for Maritime & Coastguard Agency, 2012
		Deposition trial area	2013
	Single-beam bathymetry	Cross-shore profile lines at 50m intervals	Annually, 2002 to 2014
	Substrate	Surficial seabed sediment type, derived from swath bathymetry survey plus backscatter and sediment sampling	2012, 2013, 2014
	Dive records	Inner Poole Patch Rocks	University of Southampton
	Silt deposition		
Hydrodynamics	Waves	Datawell Directional Waverider Mk III	July 2003 to present
	Tides	National Network A-class gauge, bubbler, 15 minute elevations plus residuals	1996 to present, managed and quality-controlled to European Sea- Level Service standards by NTSLF
		GLOSS-standard WaveRadar REX on Swanage Pier, 10 minute elevations plus residuals	2007 to present, managed and quality-controlled to European Sea Level Service standards by CCO

Table 1: Summary of pre-trial baseline information

3. SEDIMENT MOBILITY

3.1 Beach topography

Topographic surveys have been carried out either using a fixed-base laser scanner (Figure 1), or with RTK-GPS, based on the Environment Agency's Specification for topographic surveys. The scanner captures millions of data points within a radius of about 150 m. The scanner is moved along the beach to ensure that there are no blind spots in data capture. The beach structures, backing cliffs or dunes are also captured in great detail. The laser cannot reliably collect data over a wet surface, so the beach area close to MLWS is captured by a surveyor taking continuous RTK-GPS measurements, at a minimum interval of 5 m, and including all breaks of slope. The accuracy of both the laser scan and RTK-GPS systems is:

Figure 1: Laser scanner

- Plan ± 15 mm
- Vertical ± 15 mm

The resulting point cloud of thousands of data points is down-sampled to produce a Digital Terrain Model (DTM) at a resolution of 1m. A recent DTM can be subtracted from an earlier DTM to produce a difference model, quantifying the elevation changes between the two surveys. An example of 5-year changes along this frontage is shown at Figure 2, where the difference in elevation is colour-coded, red representing erosion and blue accretion. Note that although vertical differences of ± 15 mm can be identified, in practise only elevation differences of ± 25 cm can realistically be considered as anything other than “noise”, given the inherent daily changes in the beach caused by people walking on the beach and other human activity.

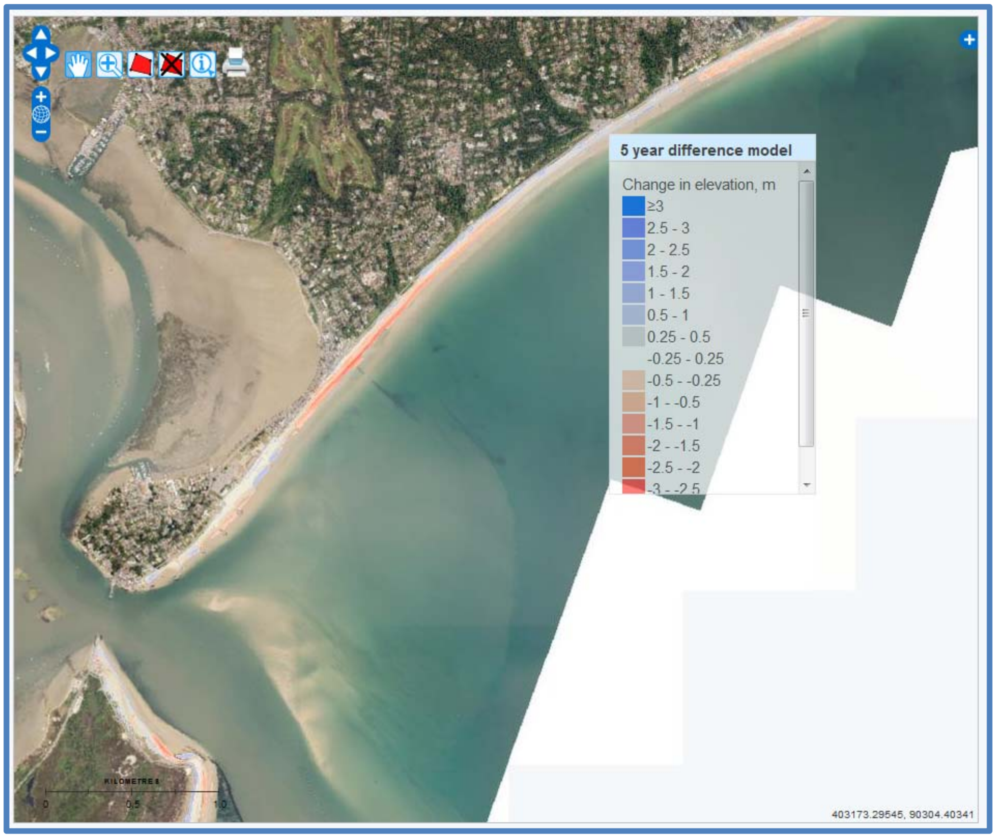


Figure 2: 5-year difference model

Furthermore, there are extensive beach management operations along the entire Poole Bay frontage, with a result that it is very difficult to assess purely "natural" change. For example, approximately 1.1 million m^3 of sand dredged from Poole Harbour channels and approaches was used to replenish beaches at Swanage, Poole and Bournemouth during the winter of 2005/2006. The Poole frontage was recharged with 450,000 m^3 of sand in 2006 with top-up recharge of 139,000 m^3 in November/December 2014. The management activities on the beach can be seen clearly in Figure 3, which shows the aerial imagery of the beach trial area since 2001.

The net volumetric changes along the beach trial areas are given in Table 2, for surveys after the major recharge in 2006. Sediment transport volumes and rates are calculated over an area common to all surveys. The net volumetric changes given in Table 2 represent broadly annual variations (since the full "baseline" surveys take place once per year usually in the spring) and thus may disguise variations on a seasonal or shorter timescale. The annual baseline surveys are supplemented by beach profiles twice a year, typically in the summer and autumn (the location of the profiles is superimposed on Figure 10 below). Using the profile survey results, the changes in cross-sectional area can be calculated relative to a Master Profile which bounds the measured profile – typically represented by the seawall at the back of the beach and the elevation of Mean Low Water Springs being the seaward boundary. Figure 4 and Figure 5 show a time series of surveys at Profile 5f00509 (the closest to the deposition area), The lengthy period of storms during the winter of 2013/2014 left the beach denuded of sand (Figure 6).

Figure 3: Ortho-photography of beach trial area, 2001 to 2013

Survey dates		No. days	Net volumetric change (m^3)	Net volumetric change per day (m^3 day^{-1})	Sediment transport rate (m^3 m^{-2} day)	Comments
28/06/2006	20/06/2007	358	-33,776	-94	-0.0006	RTK GPS surveys
20/06/2007	12/06/2009	724	-43,261	-60	-0.0004	RTK GPS surveys
12/06/2009	17/06/2010	370	12,026	33	0.0002	RTK GPS surveys
17/06/2010	07/04/2011	295	6,417	22	0.0001	RTK GPS surveys
07/04/2011	22/03/2012	351	-4,995	-14	-0.0001	RTK GPS and Laser scan surveys
22/03/2012	01/05/2013	406	-12,026	-35	-0.0002	Laser scan surveys
01/05/2013	04/04/2014	339	-46,418	-137	-0.0008	Laser scan surveys
04/04/2014	07/02/2015	309	128,391	416	0.0025	Beach replenished Nov 2014 Laser scan surveys

Table 2: Net volumetric change in common beach trial area

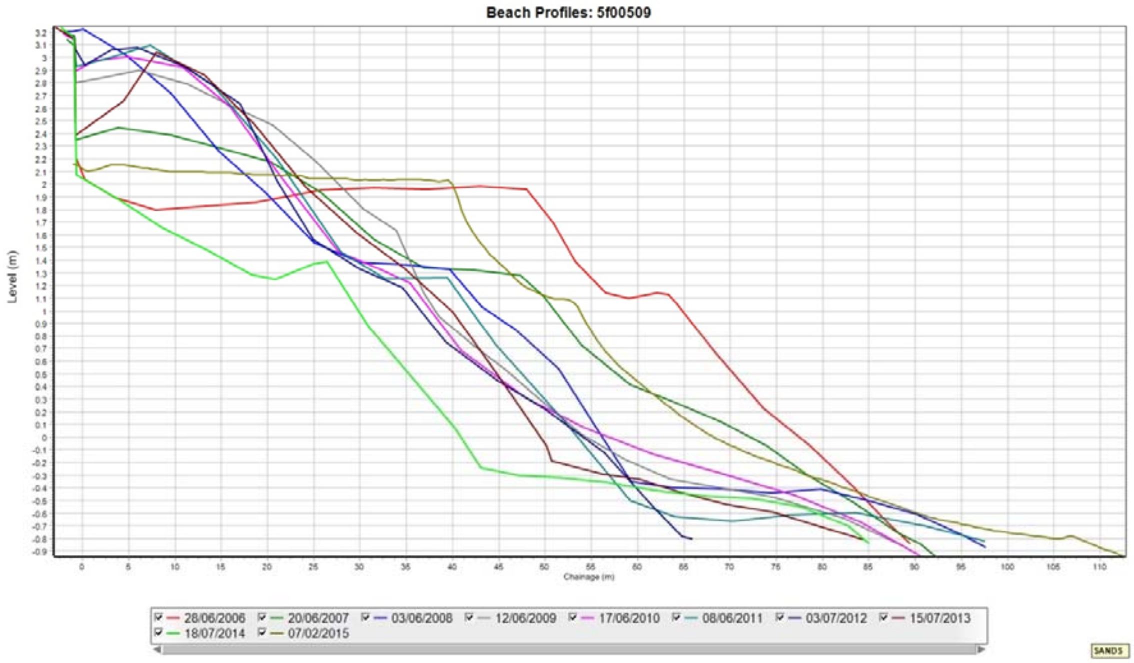


Figure 4: Profile 5f00509 (2006 to 07 Feb 2015)

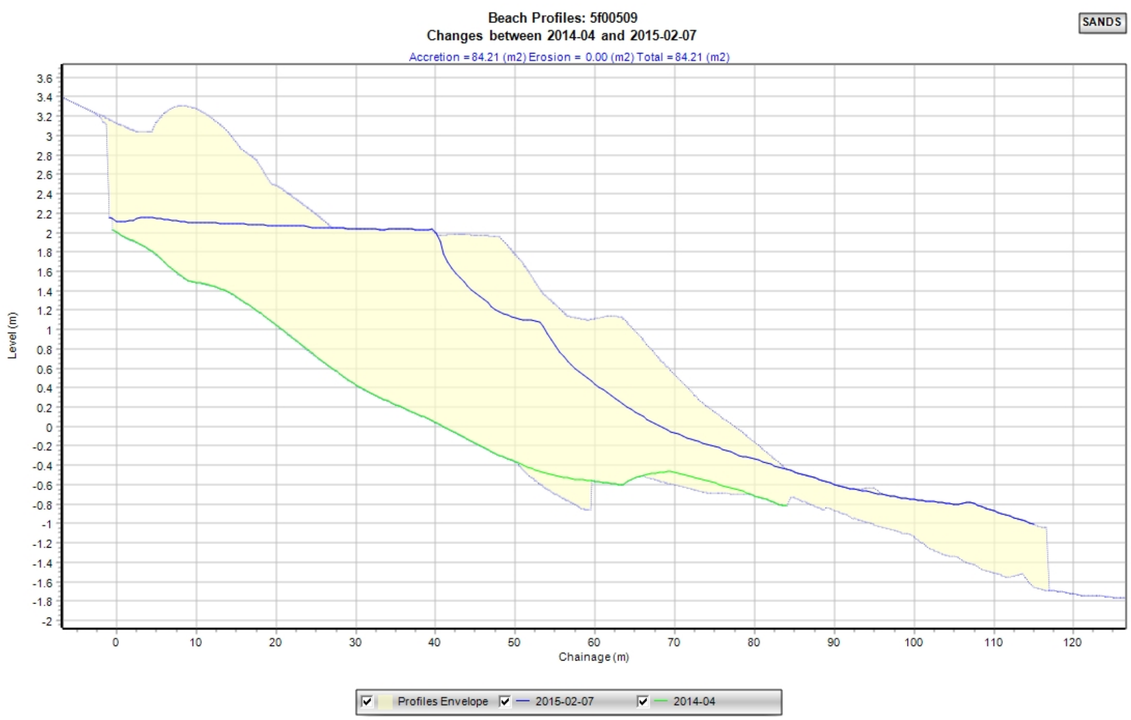


Figure 5: Profile envelope 5f00509 (2006 to pre-trial survey 07 Feb 2015, including 2 most recent pre-trial surveys; the green profile shows the low state of the beach prior to the replenishment in Nov 2014)

Figure 6: Beach erosion at Sandbanks following winter 2013/14 storms
Photo: David Robson, Borough of Poole

3.2 Bathymetry

The Maritime and Coastguard Agency's Civil Hydrography Programme completed an extensive swath (multibeam) bathymetry survey of Poole Bay, excluding port authority areas, in 2012 (HI 1366). The surveys are carried out to the International Hydrographic Organisation (IHO) Order 1a standard. This is the survey standard used for navigation safety (charting) surveys. 100% of the seafloor is isonified, giving complete coverage of the seabed (Figure 7). Processed data are output at 1m resolution. The Total Propagated Uncertainty (TPU) of the survey was:

- Horizontal (THU) < 2 m
- Vertical (TVU) 0.2 - 0.3 m

Borough of Poole commissioned a swath bathymetry survey of the trial area in 2013,

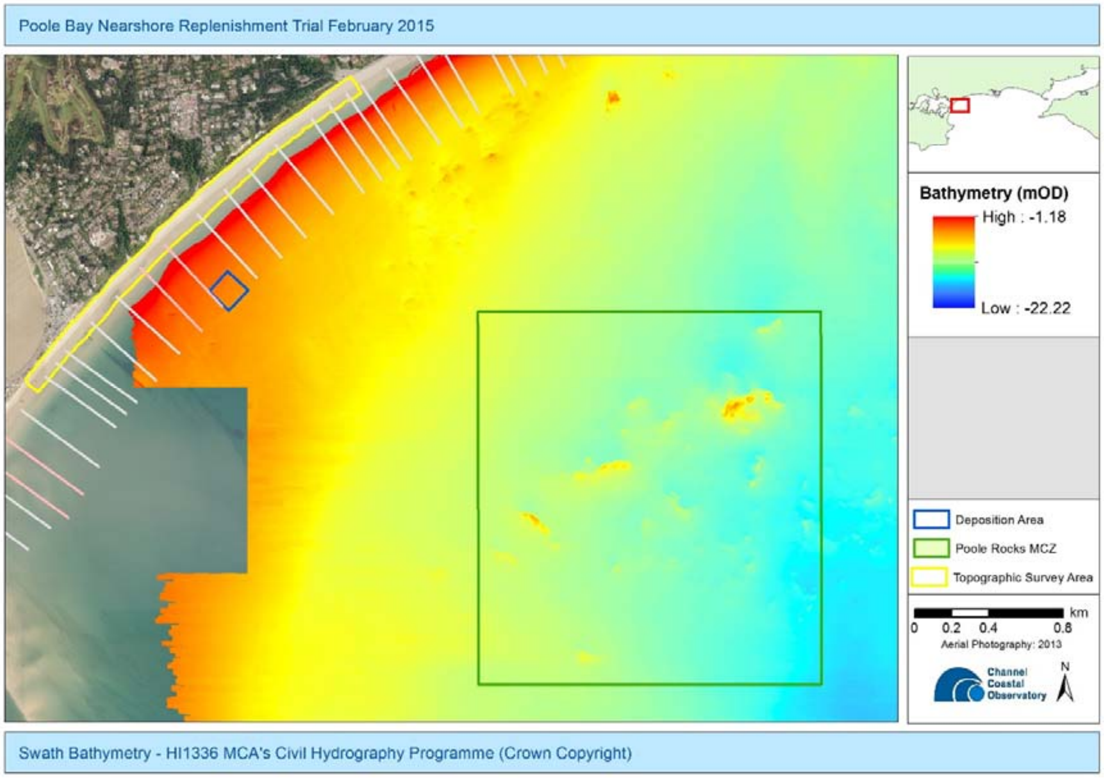


Figure 7: Swath bathymetry, MCA's Civil Hydrography Programme, HI1366 (Crown Copyright)

An assessment of the longer-term seabed sediment mobility in the nearshore region is based upon a time series of single beam profile surveys. It is only seldom that the bathymetry and topographic surveys have taken place sufficiently close in time for the surveys to be effectively merged into a single profile. Hence, the analysis is performed separately for the single beam profiles, but in the same manner as for the topographic profiles. The single beam profiles are an extension of the topographic profiles, and the cross-shore distance (chainage) is calculated from common start-of-line co-ordinates.

Figure 8 and Figure 9 show an 8-year time series of single beam surveys for Profile 5f00509 (profile closest to the deposition area), where it can be seen that the majority of vertical changes occurs within about 250 m of the shore, mostly due to on-offshore movement of a semi-permanent bar. The same pattern of sediment movement is observed at all measured bathymetry profiles within the beach trial area (see profile graphs in Annex A).

Longer-term cross-sectional area changes along individual single beam profiles are shown in Figure 10 (note that the profiles shown on Figure 10 represent their true location and surveyed length). The maximum change observed within the beach trial area is ~120 m^2, along Profile 5f00509, which is ~450 m long. This response is typical of the Poole Bay coastline from Poole Harbour entrance to Hengistbury Head (Figure 11).

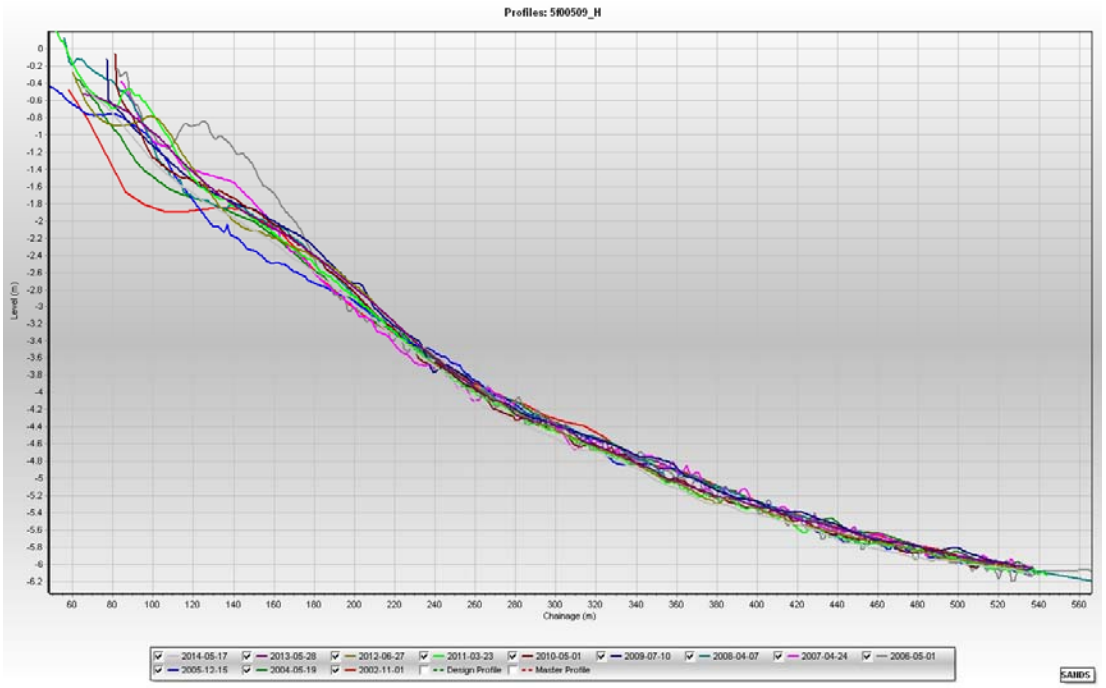


Figure 8: Bathymetry profile 5f00509 (2002 to May 2015)

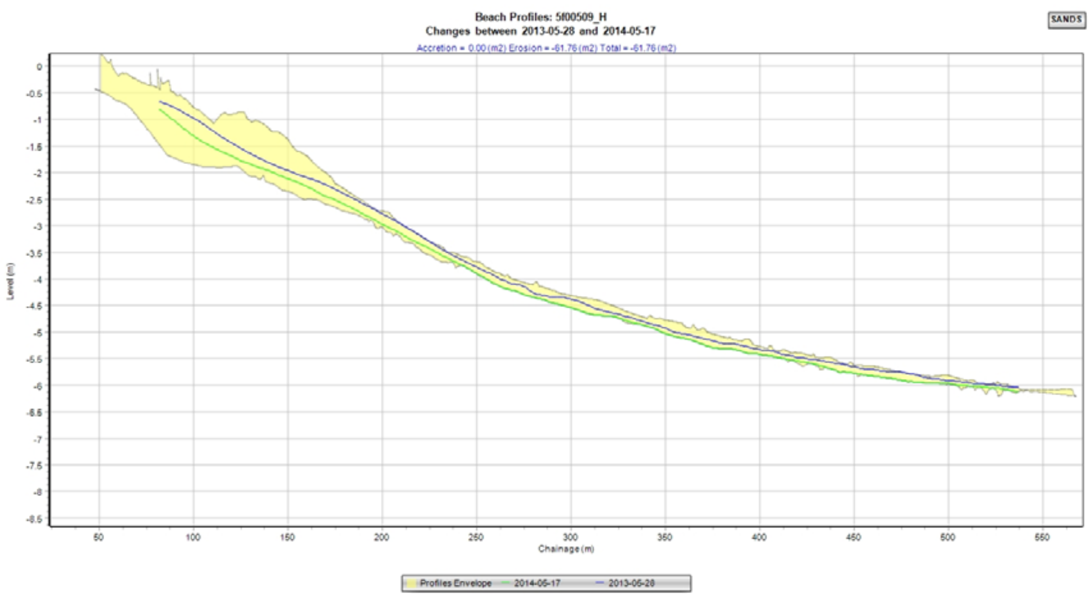


Figure 9: Bathymetry profile envelope 5f00509 (2002 to May 2015, including 2 most recent profiles)

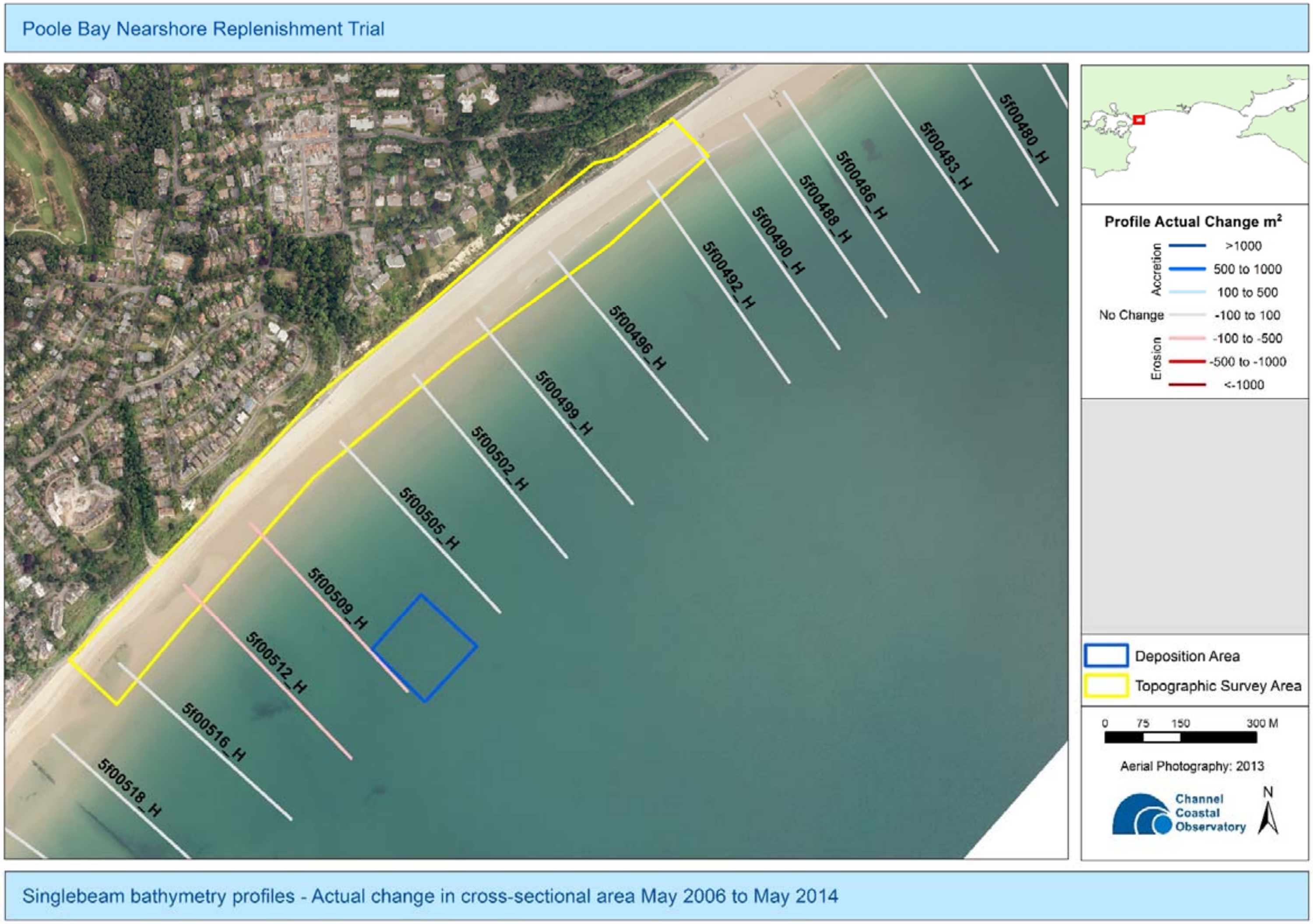


Figure 10: Longer-term change in bathymetry cross-sectional area (trial area)

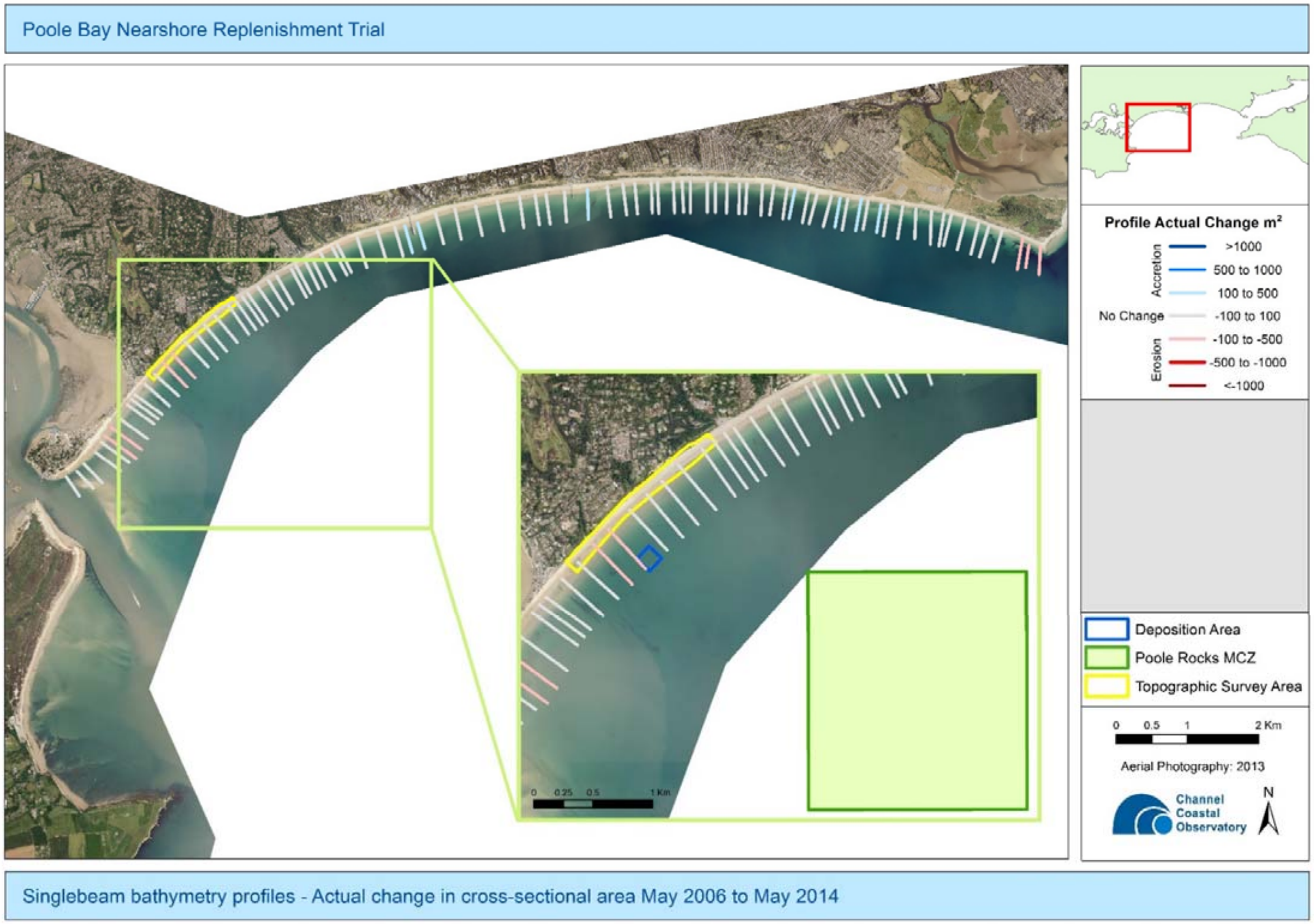


Figure 11: Longer-term change in bathymetry cross-sectional area (Poole Bay frontage)

4. SEABED SUBSTRATE

4.1 Surficial sediment

A seabed substrate map for HI 1366 was kindly provided by the Maritime and Coastguard Agency. The substrate mapping was derived from the acoustic backscatter information collected with the swath bathymetry, along with some ground-truthing from grab samples. The substrate type for the western part of Poole Bay, including the Poole Rocks MCZ area is shown in Figure 12. The trial area is shown more detail in Figure 13, where it can be seen that the substrate inside the trial area can be classified entirely as sand and gravely sand, surrounded by areas of sand and gravel ribbons. This is the only pre-existing substrate mapping in the trial area.

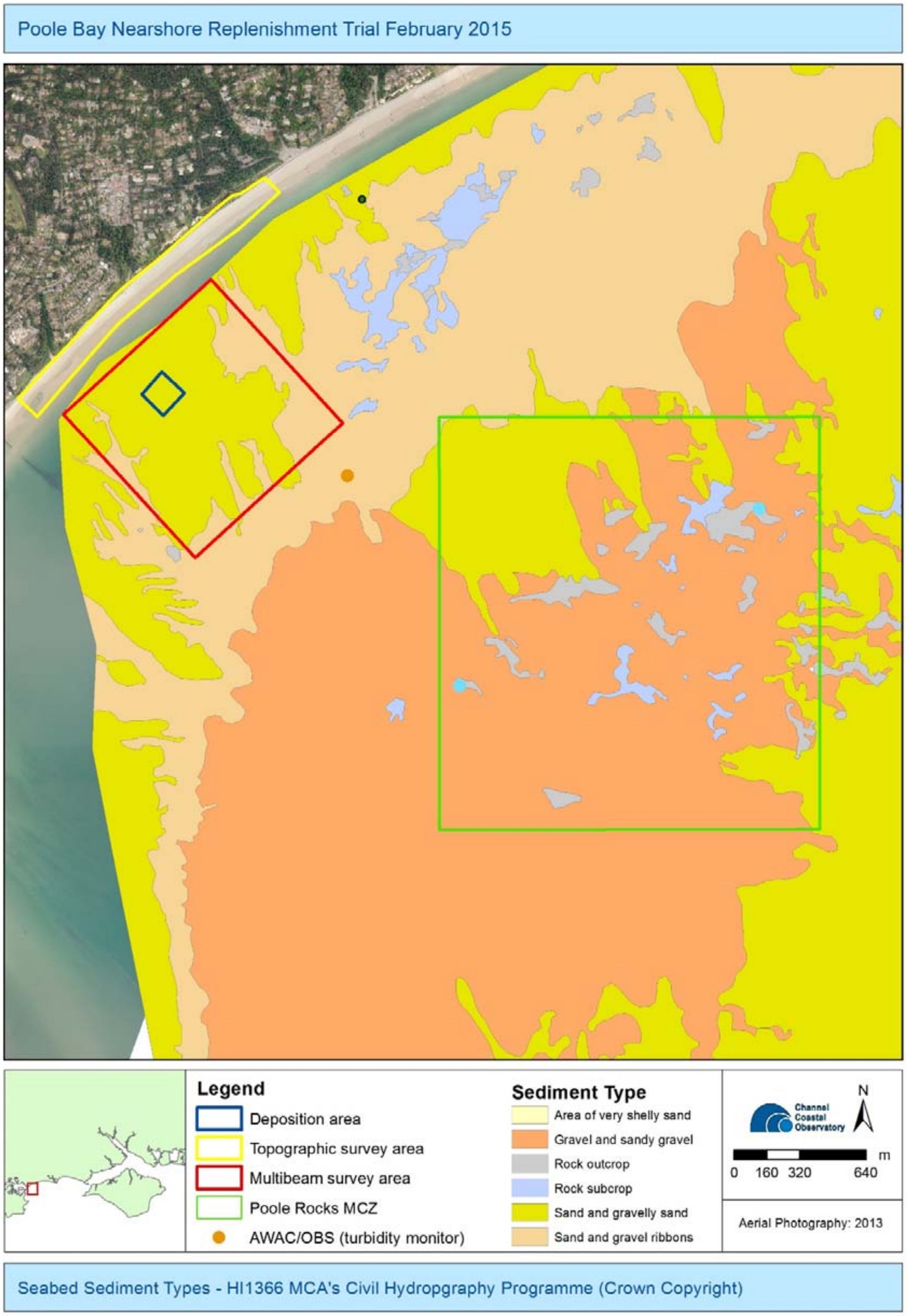


Figure 12: Seabed sediment types (western Poole Bay), MCA's Civil Hydrography Programme, HI1366 (Crown Copyright)

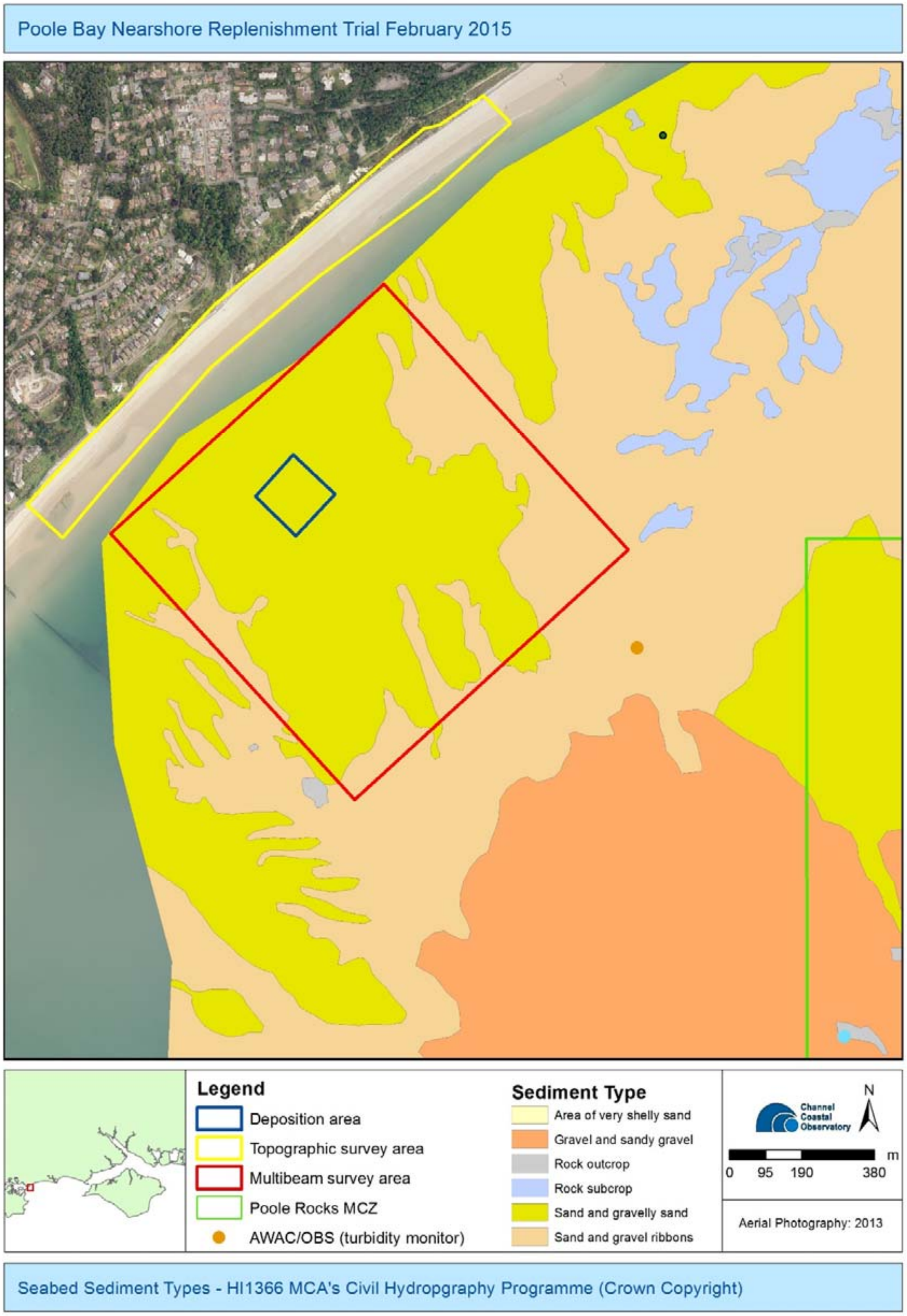


Figure 13: Seabed sediment types (trial area), MCA's Civil Hydrography Programme, HI1366 (Crown Copyright)

4.2 Sediment samples

Sediment grab samples were collected at 3 locations along 4 shore-normal transects spanning the trial area, in August 2013 and October/November 2014. The samples were sieved to derive particle sizes at 0.5 ϕ intervals (sands and gravel fractions). An example of the results is given at Figure 14 or the sample closest to the deposition site (BP09 offshore), with all results shown in Annex B.

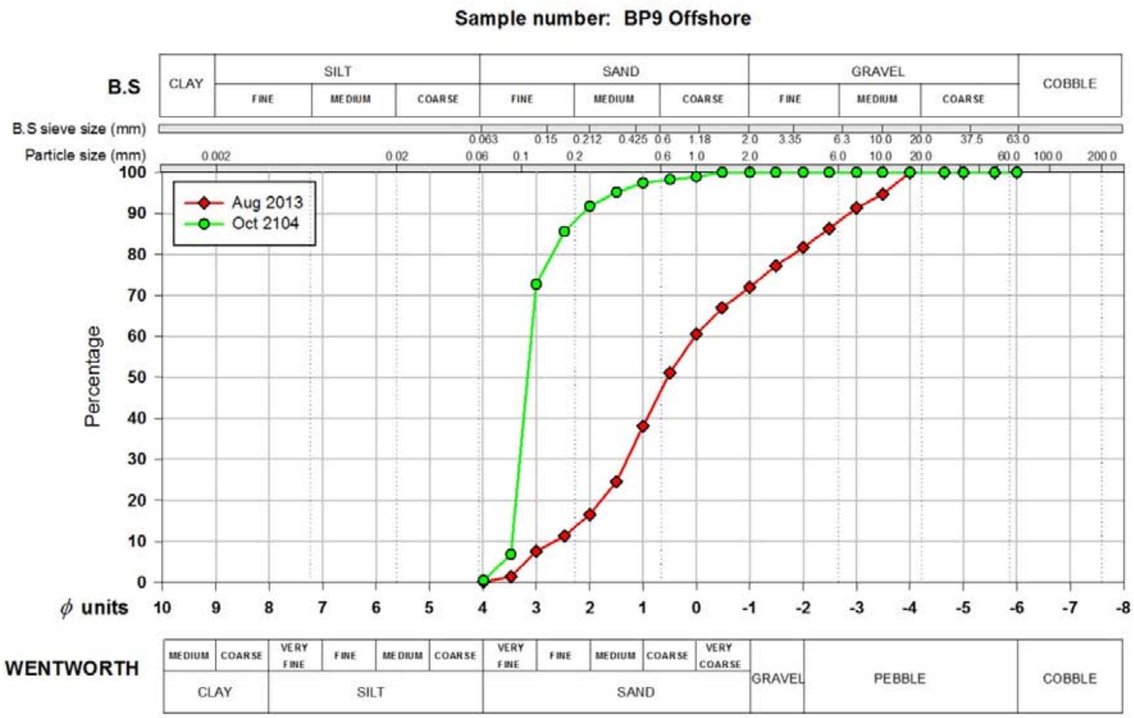


Figure 14: Particle Size Analysis for sample BP09

5. HYDRODYNAMICS

5.1 Waves

Long-term wave conditions are measured by a Datawell Directional Waverider (DWR) buoy off Boscombe Pier, operated by the Channel Coastal Observatory (Figure 15 and Figure 16). The Datawell buoy is the industry-standard for wave measurement and has been adopted by the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology as the instrument against which all other wave measuring devices are to be tested.

Figure 15: Datawell Directional Waverider buoy off Boscombe (Fugro EMU Limited)

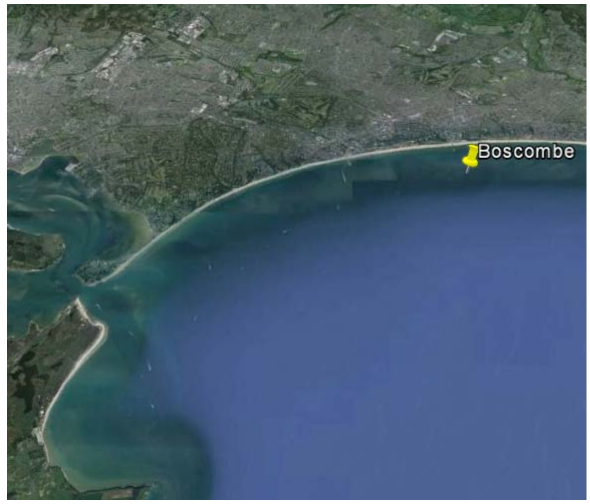


Figure 16: Location of Boscombe Directional Waverider buoy (Google mapping)

The buoy has been deployed since 2003. It is located in approximately 10 m CD water depth, and measures continuously at 1.28 Hz. Data parameters (Table 3) are calculated every 30 minutes, and are subsequently quality-controlled and archived by the Channel Coastal Observatory.

Parameter	Abbreviation (units)
Significant wave height	Hs (m)
Maximum wave height	Hmax (m)
Zero-crossing wave period	Tz (s)
Peak wave period	Tp (s)
Direction (peak)	Dirp (^{o}N)
Spread	Spd (^{o})
Sea temperature	SST (^{o}C)
Energy spectrum	(m^2s)

Table 3: Wave parameters measured by the Directional Waverider buoy

The wave climate (based on ~12 years of measured data) can be characterised by the average wave conditions together with a measure of the frequency and magnitude of storms. The monthly averages of all measured parameters are given in Table 4.

Month	Hs (m)	Tp (s)	Tz (s)	Dirp (°N)	SST (°C)
January	0.74	9.2	4.4	180	8.1
February	0.60	9.5	4.5	177	7.1
March	0.50	8.5	4.2	178	7.6
April	0.42	7.1	4.0	178	9.6
May	0.44	6.1	3.7	178	12.4
June	0.41	5.7	3.5	180	15.7
July	0.44	5.3	3.4	184	17.9
August	0.44	5.4	3.5	184	18.7
September	0.45	6.4	3.7	179	17.7
October	0.65	6.7	3.9	176	15.3
November	0.68	7.7	4.3	179	12.4
December	0.68	8.4	4.3	180	9.4

Table 4: Monthly average of measured wave parameters (Jul 2003 to Mar 2015)

The principle wave direction is SbySSW (Figure 17).

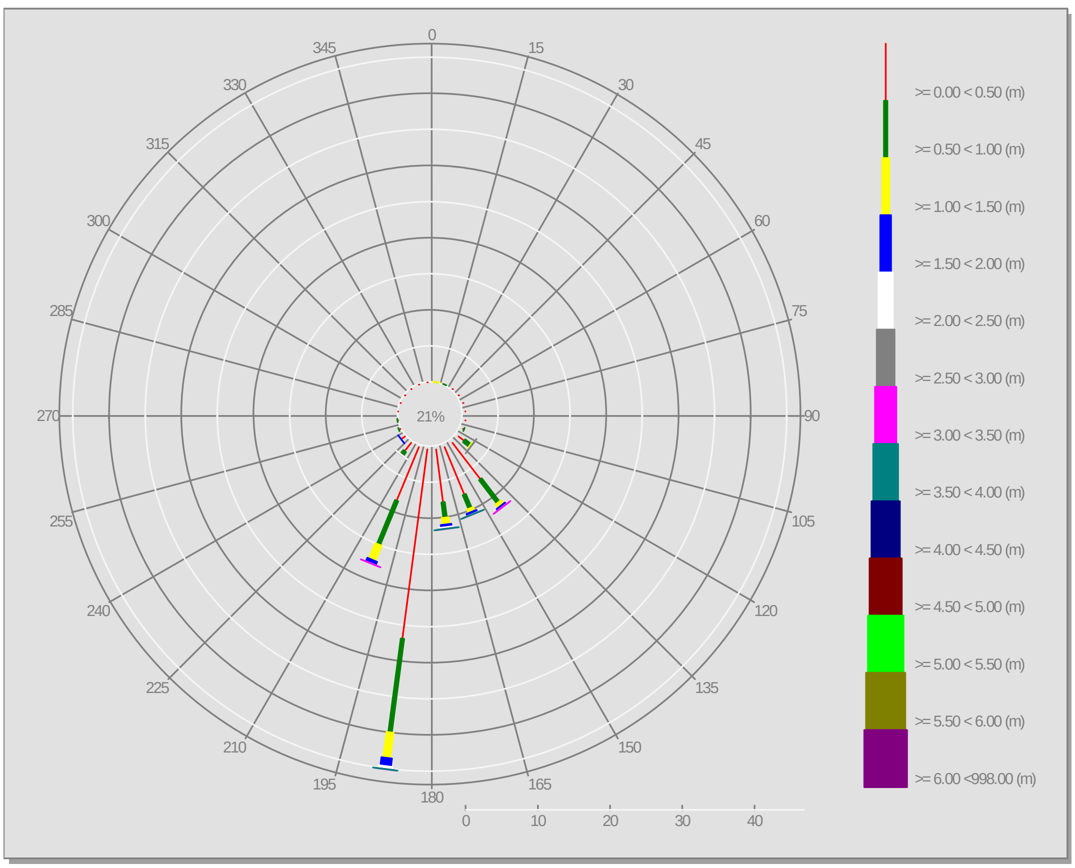


Figure 17: Wave rose (Hs vs. Direction) for Boscombe DWR, Jul 2003 - Dec 2014

Since the buoy has been operational for more than 10 years, Hs return periods can be calculated for up to 100 years, as shown in Table 5.

Return period (years)	Significant wave height (m)	Comments
1	3.3	No depth-limitation
2	3.5	
5	3.8	
10	4.0	Depth-limited at MLWS
20	4.1	
50	4.4	
100	4.6	

Table 5: Hs return periods for Boscombe DWR

The approximate 0.25 year return period Hs is used as a storm threshold to indicate the 3 or 4 storms which are of operational significance to the coastal engineer in a typical year. Using the peaks-over-threshold method recommended by the CIRA Beach Management Manual (Rogers *et al*., 2010), the highest Hs of each storm is shown in a storm calendar for the Boscombe DWR (Figure 18).

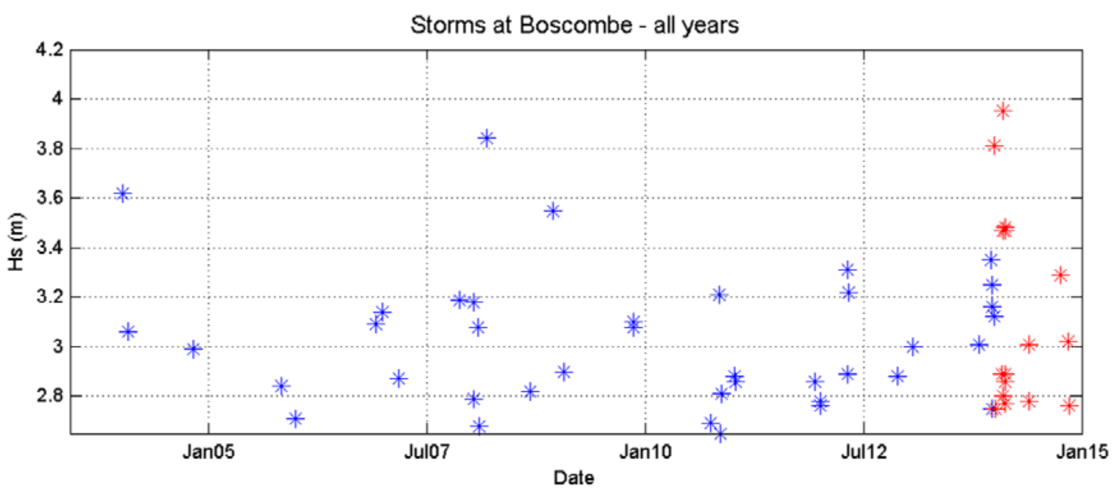


Figure 18: Storm calendar for Boscombe DWR

Wave height exceedance is a useful parameter to help assess how stormy a given year is in comparison to others i.e. 1% exceedance in 2008 = 2.02 means that 99% of measured waves were lower than 2.02m. The annual wave height exceedance for Boscombe DWR is given in Figure 19, where it can be seen that based on 10% exceedance, 2014 was similar to 2006, but for all smaller % exceedance, 2014 was the stormiest since measurements began in 2003.

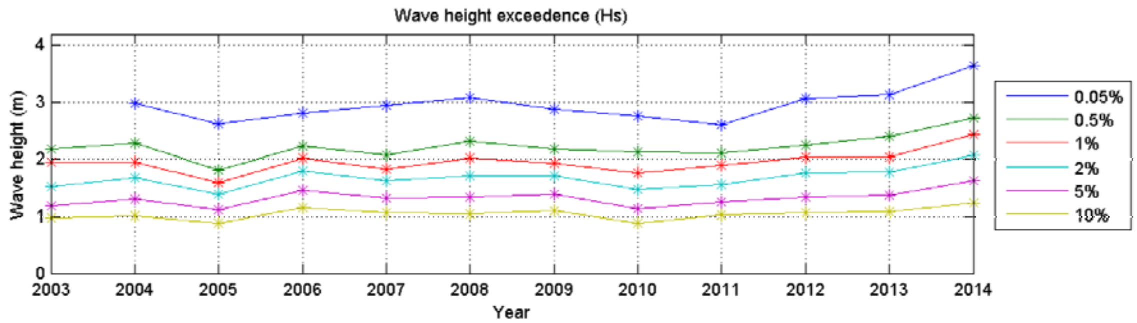


Figure 19: Hs exceedance at Boscombe DWR

5.2 Tides

Tidal elevations are measured by a gauge on Bournemouth Pier, which was first deployed in 1996. The gauge is one of the 44 A-class network operated by the National Sea level and Tidal Facility (http://www.ntslf.org/), but was badly damaged during storms in October 2013 and was out of action for nearly a year.

Tidal elevations are also measured by the Channel Coastal Observatory's tide gauge on Swanage Pier. The instrument is a GLOSS-standard Rosemount WaveRadar REX (Figure 20). Tidal elevations are recorded at 10 minute intervals. The REX has been deployed since 2007.

Both instruments show the tidal regime in Poole Bay to be micro-tidal, with a spring range of ~1.2m at Swanage (Table 6). The annual extreme and surge maxima at Swanage are given in Table 7.

Figure 20: WaveRadar REX on Swanage Pier

Observation period	January 2008 to December 2012	
Tide Level	Elevation (OD)	Elevation (CD)
HAT	1.22	2.62
MHWS	0.81	2.21
MHWN	0.44	1.84
MSL	0.26	1.66
MLWN	0.08	1.48
MLWS	-0.29	1.11
LAT	-1.34	0.06

Table 6: Tide levels at Swanage Pier

Year	Annual extreme maxima		Annual surge maxima		Z_0 (OD)	Annual recovery rate
	Elevation (OD) *(Surge)*	Date/Time	Value (m)	Date/Time		
2008	1.66 *(0.64)*	10-Mar-2008 10:10	0.91	10-Mar-2008 05:40	-	94%
2009	1.33 *(0.53)*	09-Feb-2009 20:50	0.80	19-Jan-2009 05:20	0.242	90%
2010	1.34 *(0.43)*	30-Mar-2010 08:20	0.65	12-Nov-2010 16:00	0.263	96%
2011	1.14 *(-0.04)*	30-Aug-2011 21:20	0.39	07-Jan-2011 14:30		97%
2012	1.53 *(0.39)*	14-Dec-2012 09:00	0.64	25-Apr-2012 16:40	-	96%
2013	1.32 *(0.26)*	04-Nov-2013 08:30	0.67	27-Oct-2013 23:40	-	98%

Table 7: Annual maxima at Swanage Pier tide gauge

There are is no available measured tidal current data within Poole Bay. The nearest tidal diamond to the trial area is in Swanage Bay at 50° 39.23'N 001° 54.98'W in approx. 9.5 m water depth CD (Table 8).

Time (hours)	Direction (°)	Spring rate (knots)	Neap rate (knots)
-06h	344	1.4	0.7
-05h	346	1.2	0.6
-04h	354	1.0	0.5
-03h	004	0.7	0.3
-02h	029	0.3	0.2
-01h	157	0.3	0.1
HW	**179**	**0.8**	**0.4**
+01h	180	1.1	0.5
+02h	178	1.2	0.6
+03h	172	1.1	0.6
+04h	156	0.6	0.3
+05h	026	0.3	0.1
+06h	347	1.2	0.6

Table 8: Tidal diamond off Swanage Bay (source: Admiralty Total Tide)

5. OTHER OBSERVATIONS

5.1 Silt traps

Prior to the Poole Bay nearshore replenishment trail, the only measurements of turbidity are sedimentation rates obtained from silt traps (Collins 2010). The methodology for the silt traps can be found in the report (attached as Annex C). Two silt traps were re-installed in April 2014 at 3 sites (at Outer Poole Patch, Wrasse Reef and the artificial reef. The traps at Outer Poole Patch were recovered on 25 October 2014, but the others were lost presumably due to dragging of commercial fishing gear through the area. All 6 sediment traps (2 each at 3 sites) were re-established on this date and will be recovered/replaced before and after the sand deposition.

5.2 Species

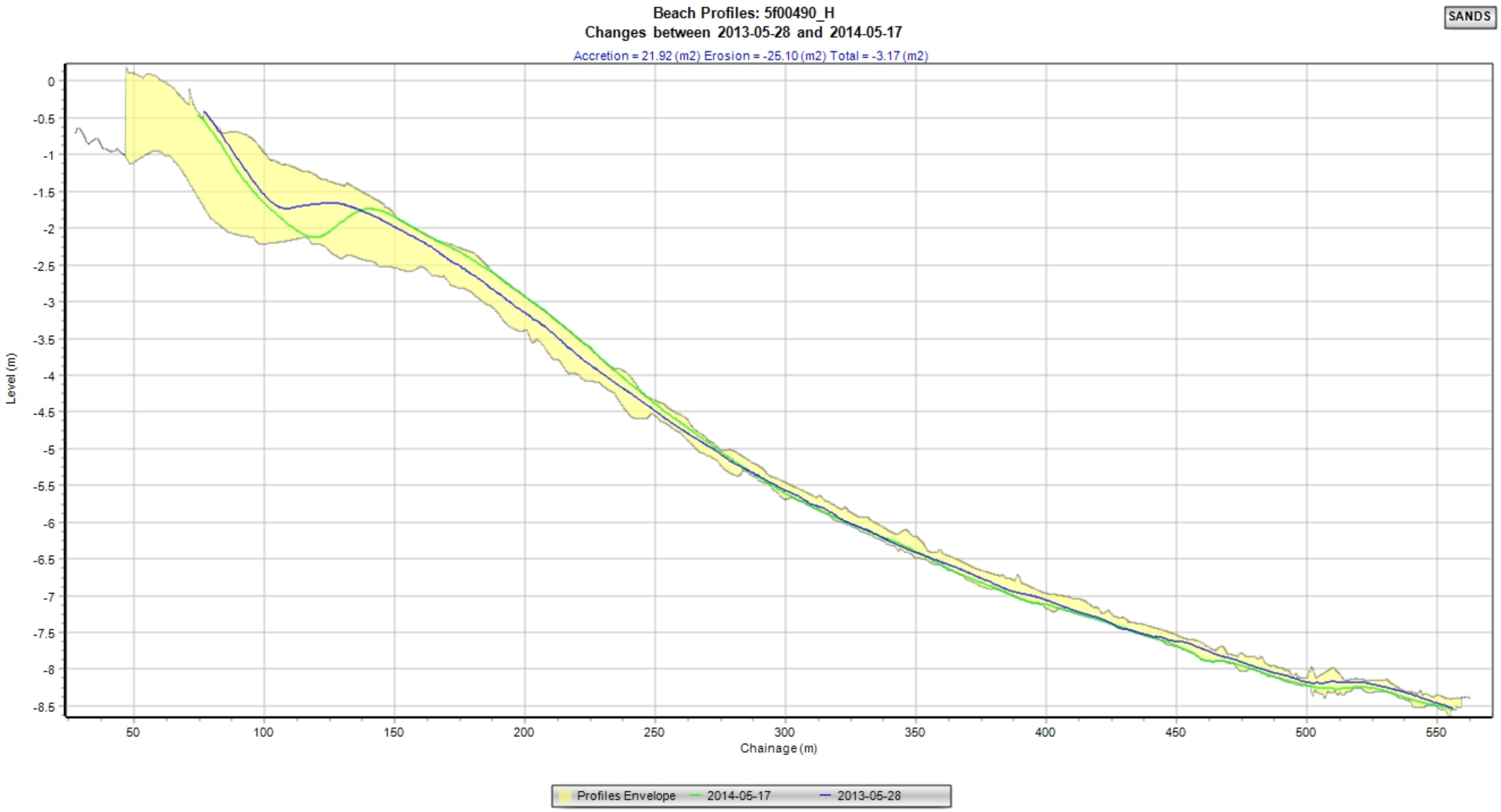
Inner Poole Patch is a low profile rocky reef measuring approximately 70m x 20m, 2m high, above a sandy seabed 5m deep. Due to the deferment of the sand deposition which had been planned for March 2014, it was impracticable (poor weather, winter dieback of the algae) to undertake a pre-survey of Inner Poole Patch in autumn 2014. Dr Collins undertook a diving and photo-transect survey (4-man HSE team) of the Inner Poole Patch reef on 30 July 2014. The species list from this survey (see Annex D) was compiled from diver observation and sample collection.

REFERENCES

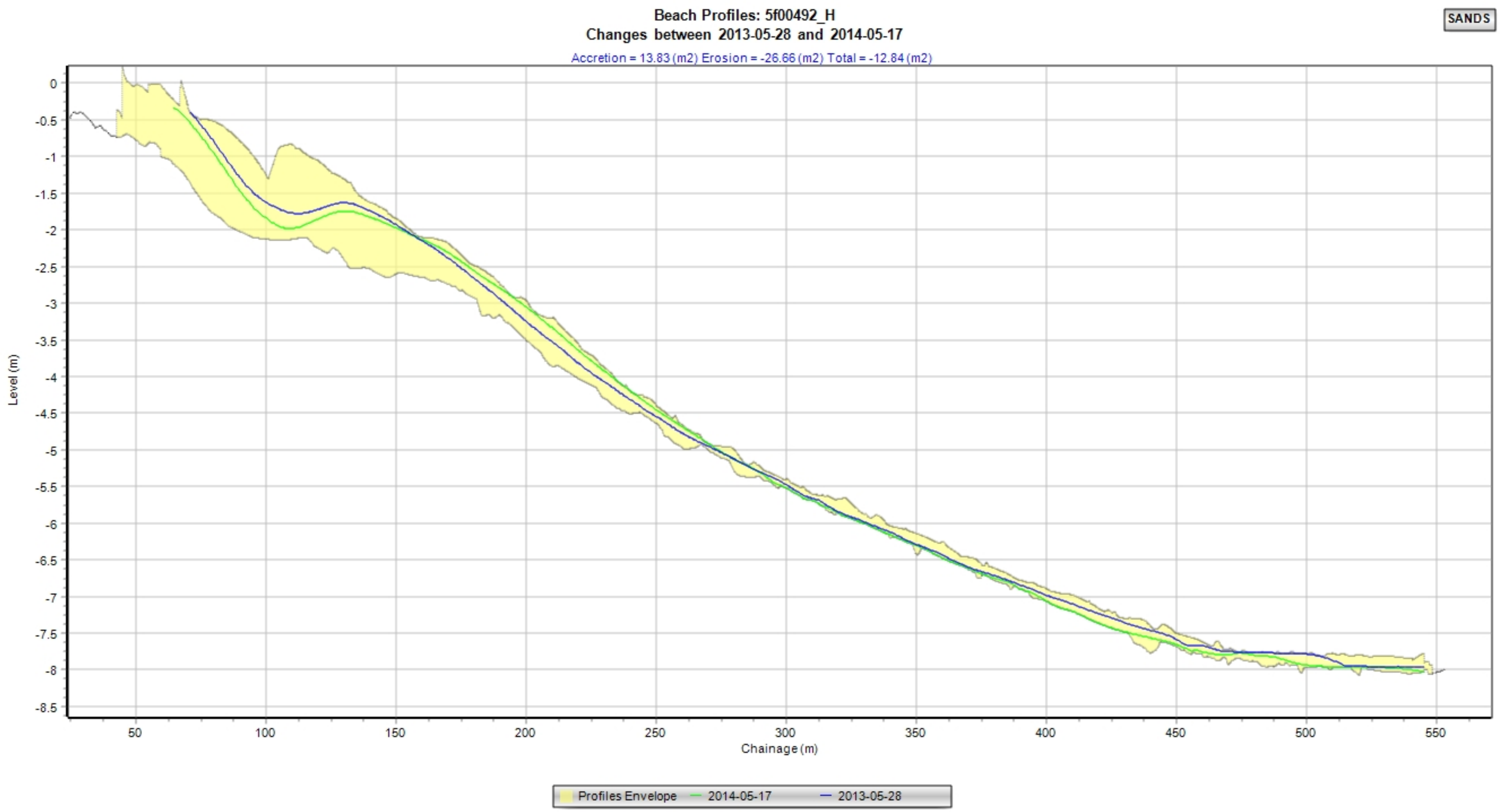
Collins, K. (2010). Poole Harbour Channel deepening EIA studies 2005-9, unpublished report, School of Ocean and Earth Science, University of Southampton – attached as Annex C

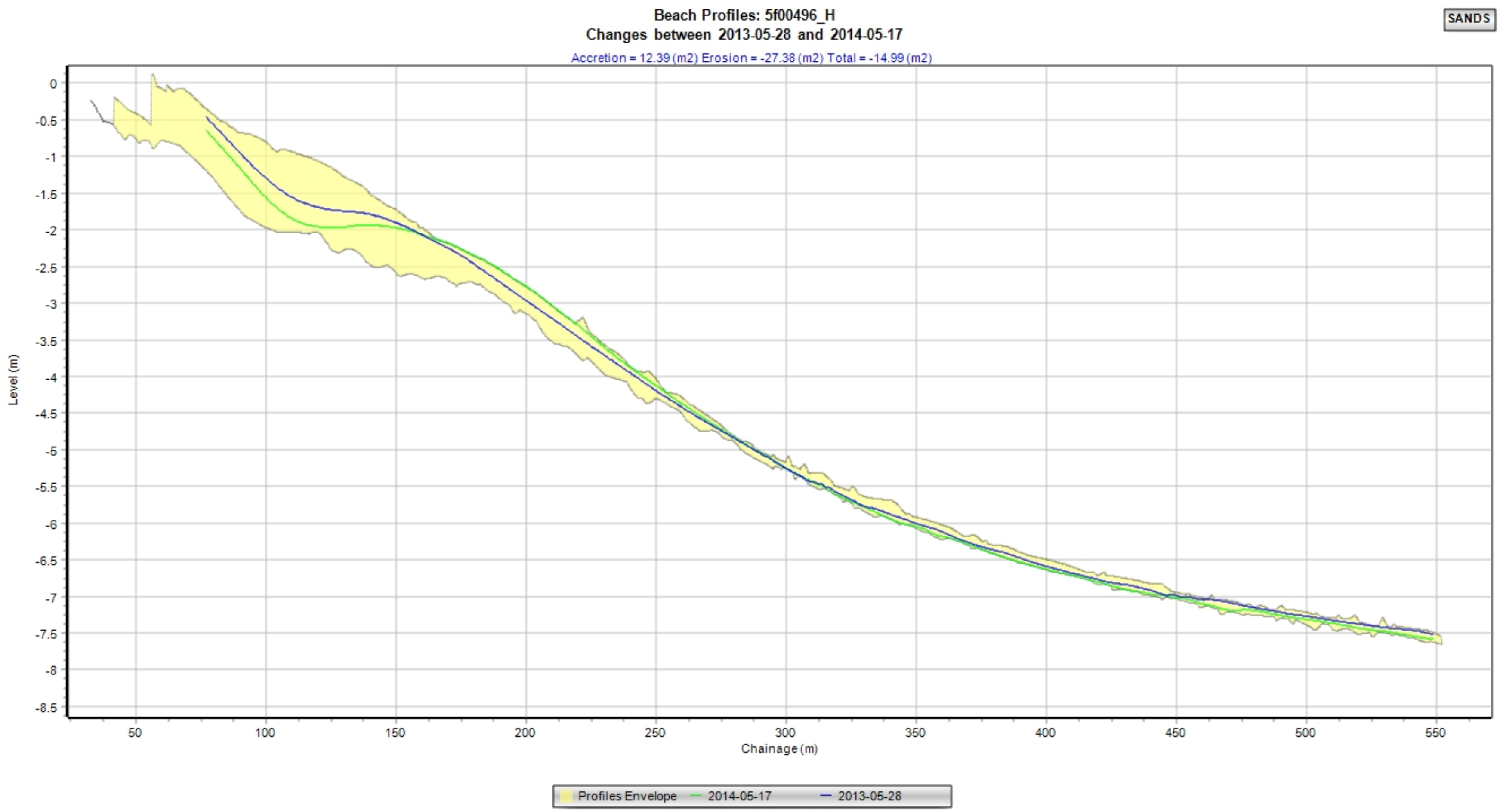
Rogers, J., Hamer, B. and Brampton, A. (2010). Beach Management Manual (2nd edition); CIRIA

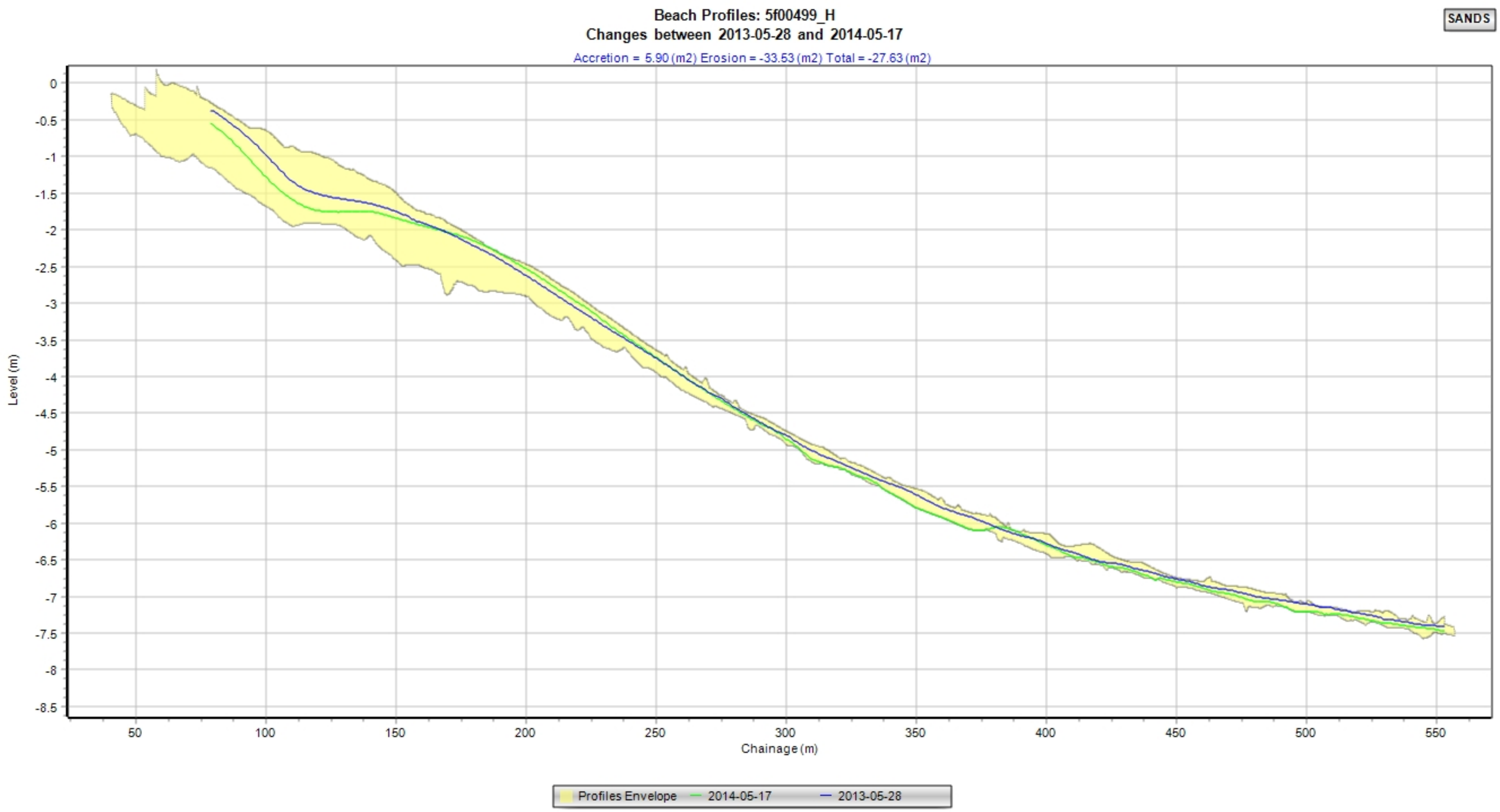
ANNEX A – SINGLE BEAM BATHYMETRY PROFILES[1]



[1] Note that the two most recent profiles are shown on the graph, together with the profile envelope for annual surveys since 2002/3


Beach Profiles: 5f00492_H
Changes between 2013-05-28 and 2014-05-17
Accretion = 13.83 (m2) Erosion = -26.66 (m2) Total = -12.84 (m2)
SANDS
Level (m)
Chainage (m)
Profiles Envelope
2014-05-17
2013-05-28


Beach Profiles: 5f00496_H
Changes between 2013-05-28 and 2014-05-17
Accretion = 12.39 (m2) Erosion = -27.38 (m2) Total = -14.99 (m2)
SANDS
Level (m)
Chainage (m)
Profiles Envelope
2014-05-17
2013-05-28


Beach Profiles: 5f00499_H
Changes between 2013-05-28 and 2014-05-17
Accretion = 5.90 (m2) Erosion = -33.53 (m2) Total = -27.63 (m2)
SANDS
Level (m)
Chainage (m)
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
-5.5
-6
-6.5
-7
-7.5
-8
-8.5
50
100
150
200
250
300
350
400
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500
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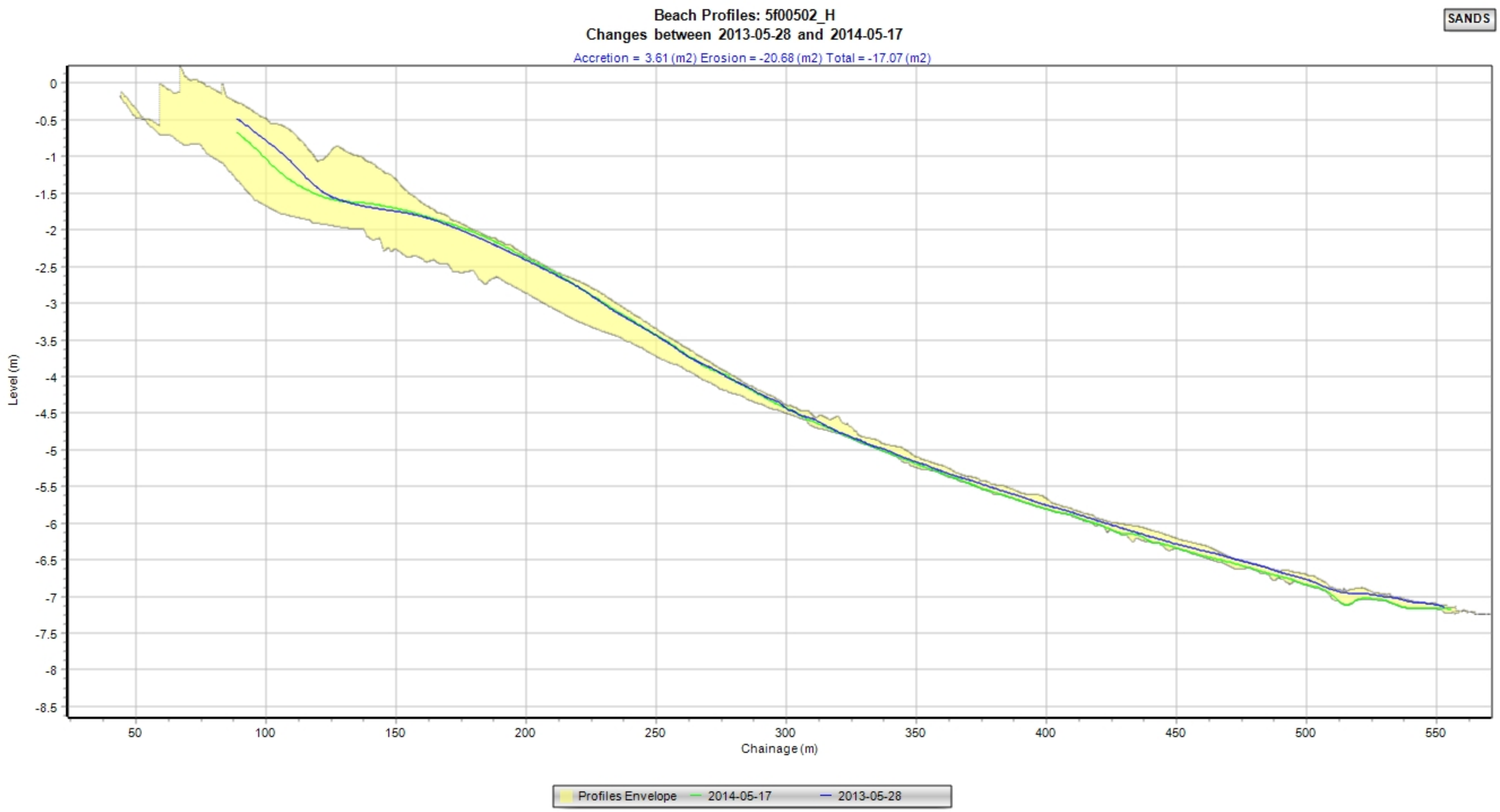
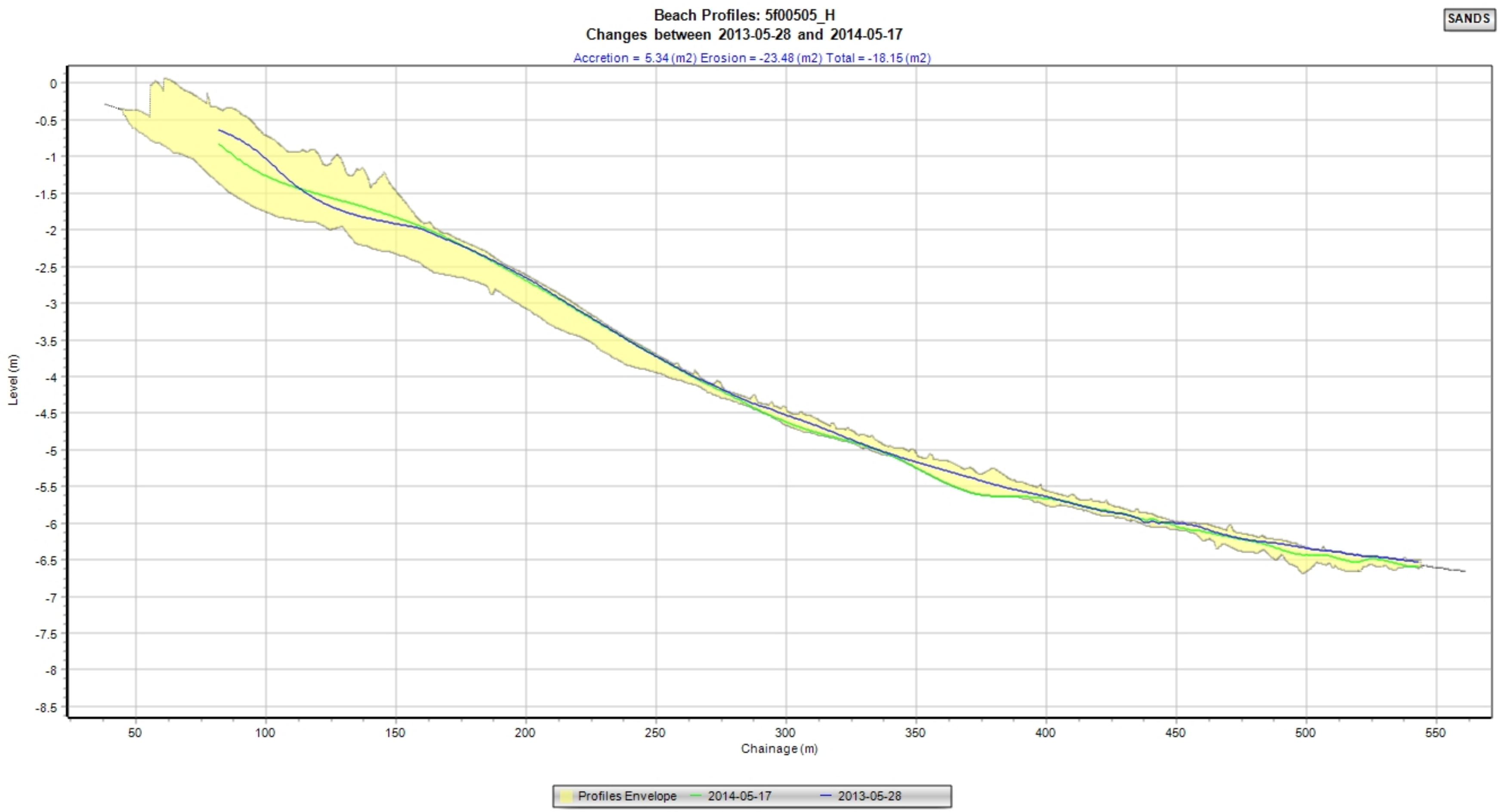
Profiles Envelope
2014-05-17
2013-05-28


Beach Profiles: 5f00502_H
Changes between 2013-05-28 and 2014-05-17
Accretion = 3.61 (m2) Erosion = -20.68 (m2) Total = -17.07 (m2)
SANDS
Level (m)
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
-5.5
-6
-6.5
-7
-7.5
-8
-8.5
50
100
150
200
250
300
350
400
450
500
550
Chainage (m)
Profiles Envelope
2014-05-17
2013-05-28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SANDS
Level (m)
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-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
-5.5
-6
-6.5
-7
-7.5
-8
-8.5
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Chainage (m)
Profiles Envelope
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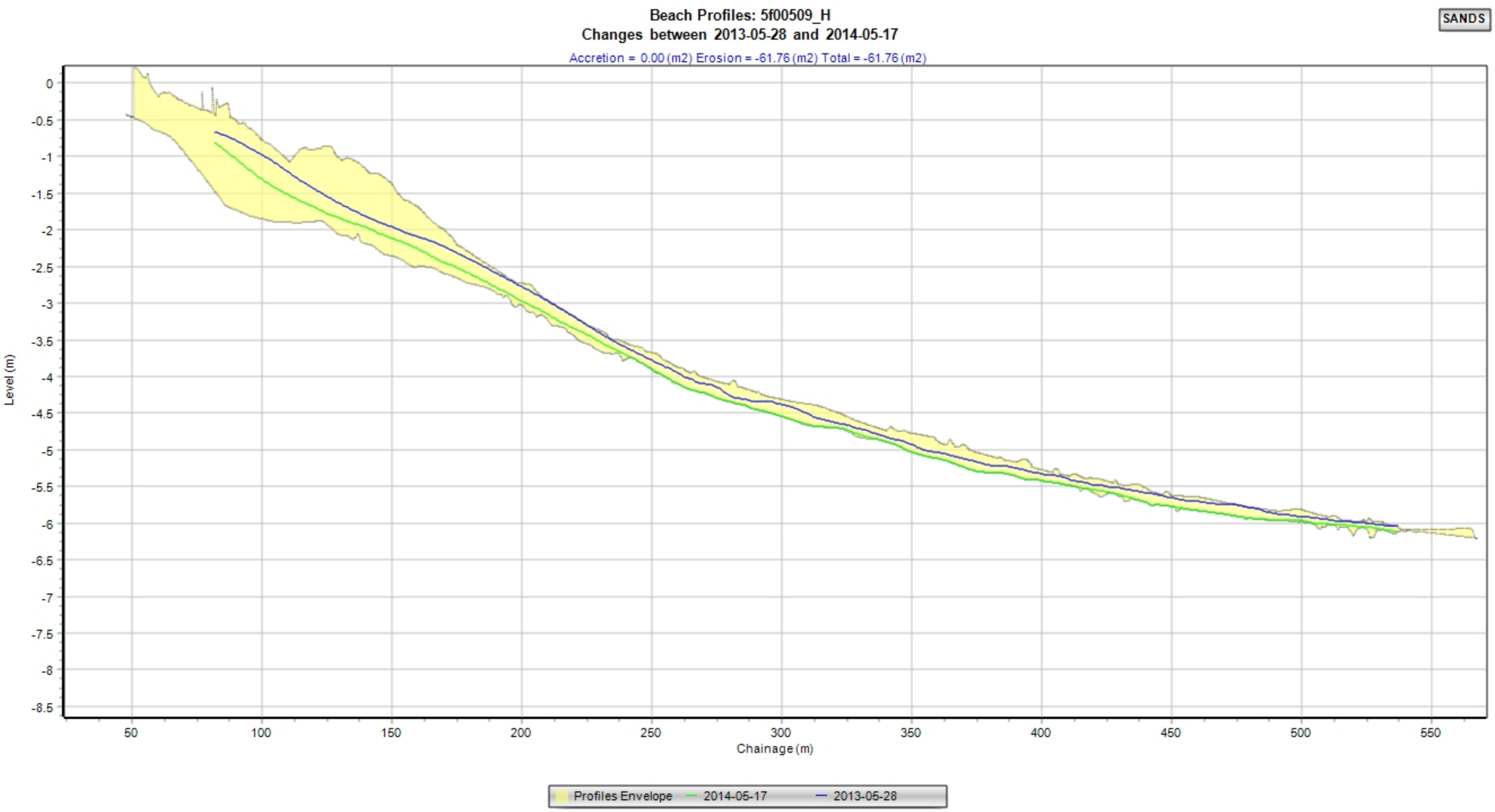
2013-05-28


SANDS
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Level (m)
Chainage (m)
Profiles Envelope
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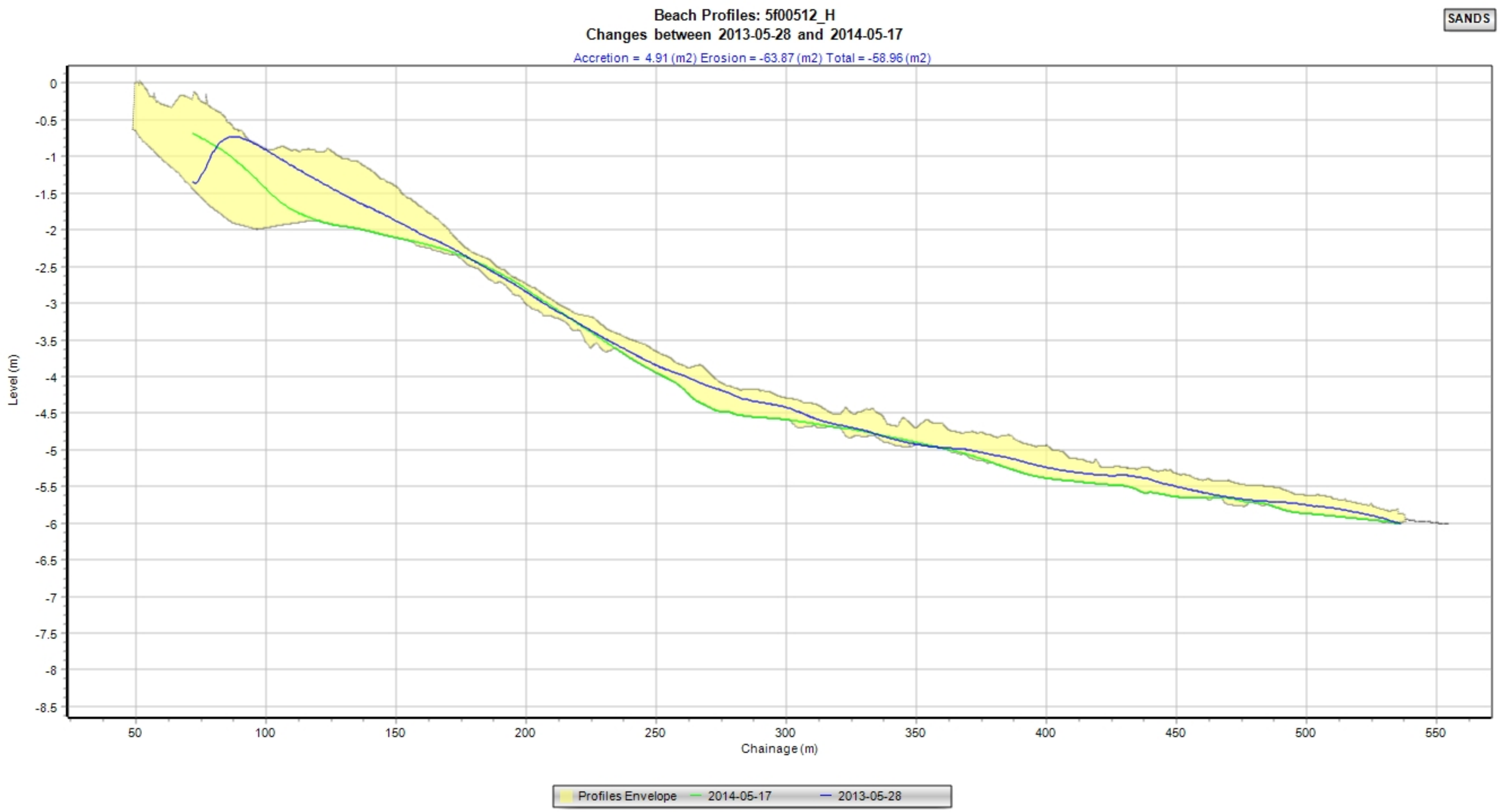
2013-05-28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Level (m)
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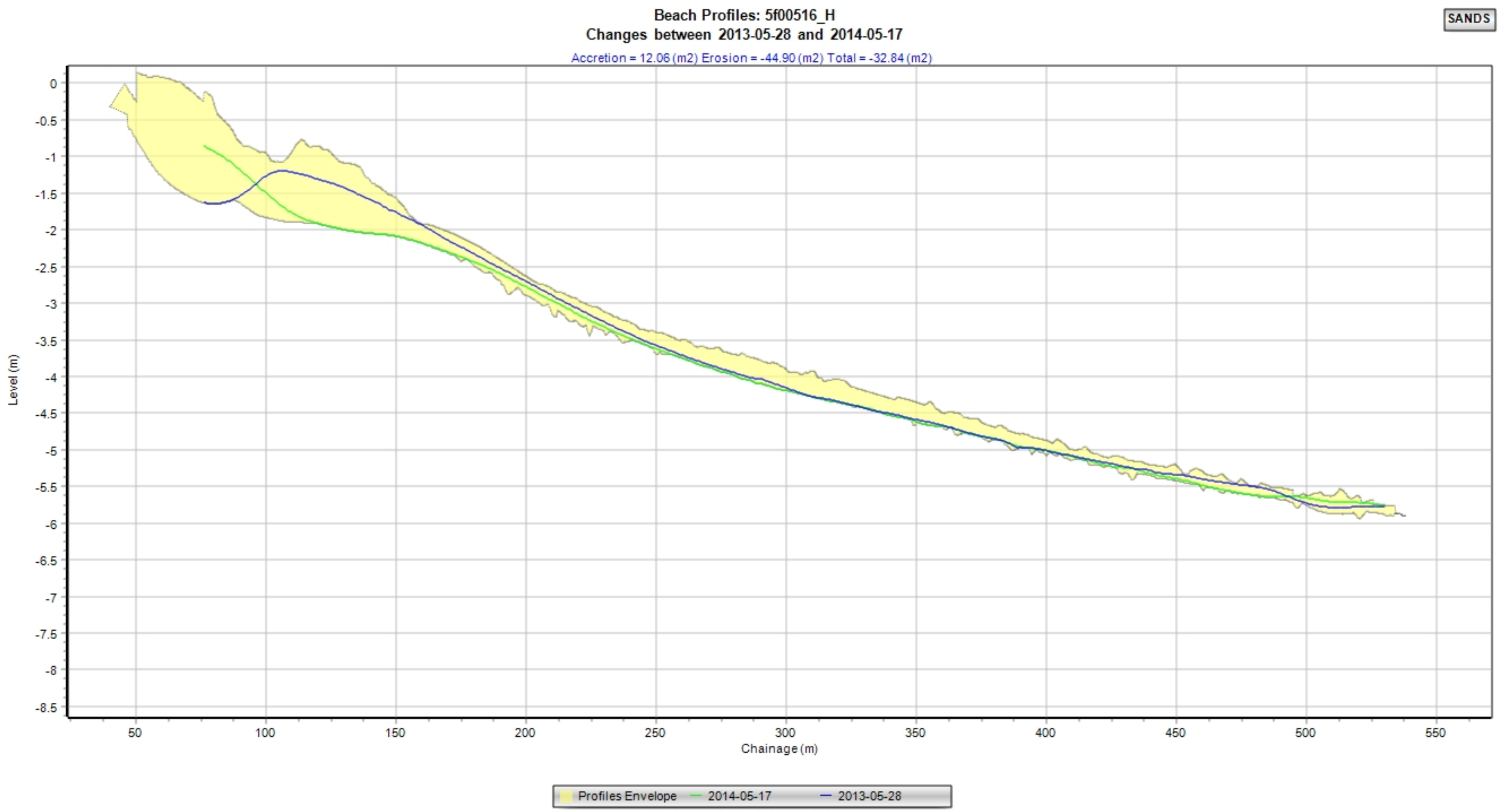
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
-5.5
-6
-6.5
-7
-7.5
-8
-8.5
50
100
150
200
250
300
350
400
450
500
550
Chainage (m)
Profiles Envelope
2014-05-17
2013-05-28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SANDS
Level (m)
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-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
-5.5
-6
-6.5
-7
-7.5
-8
-8.5
50
100
150
200
250
300
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400
450
500
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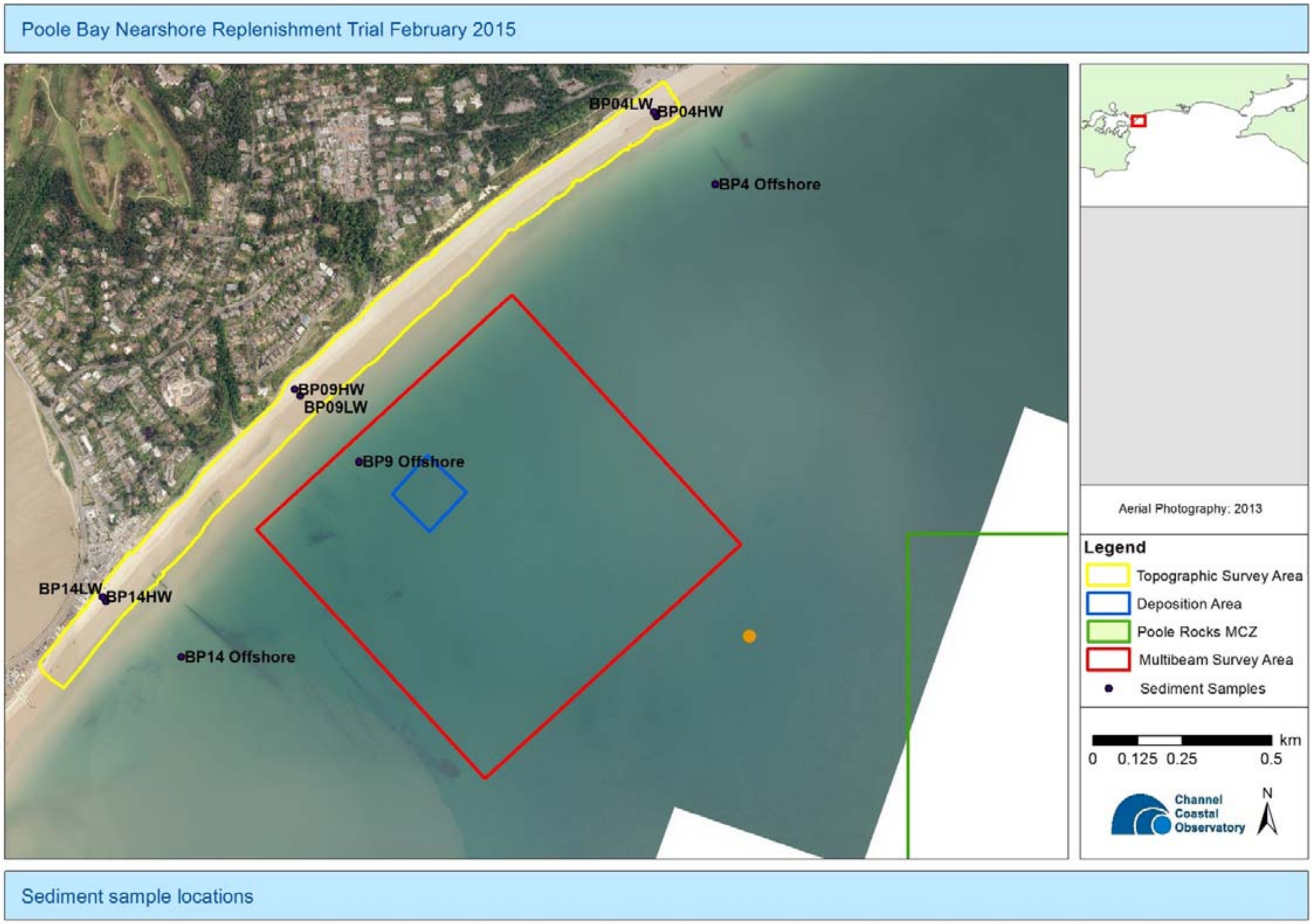
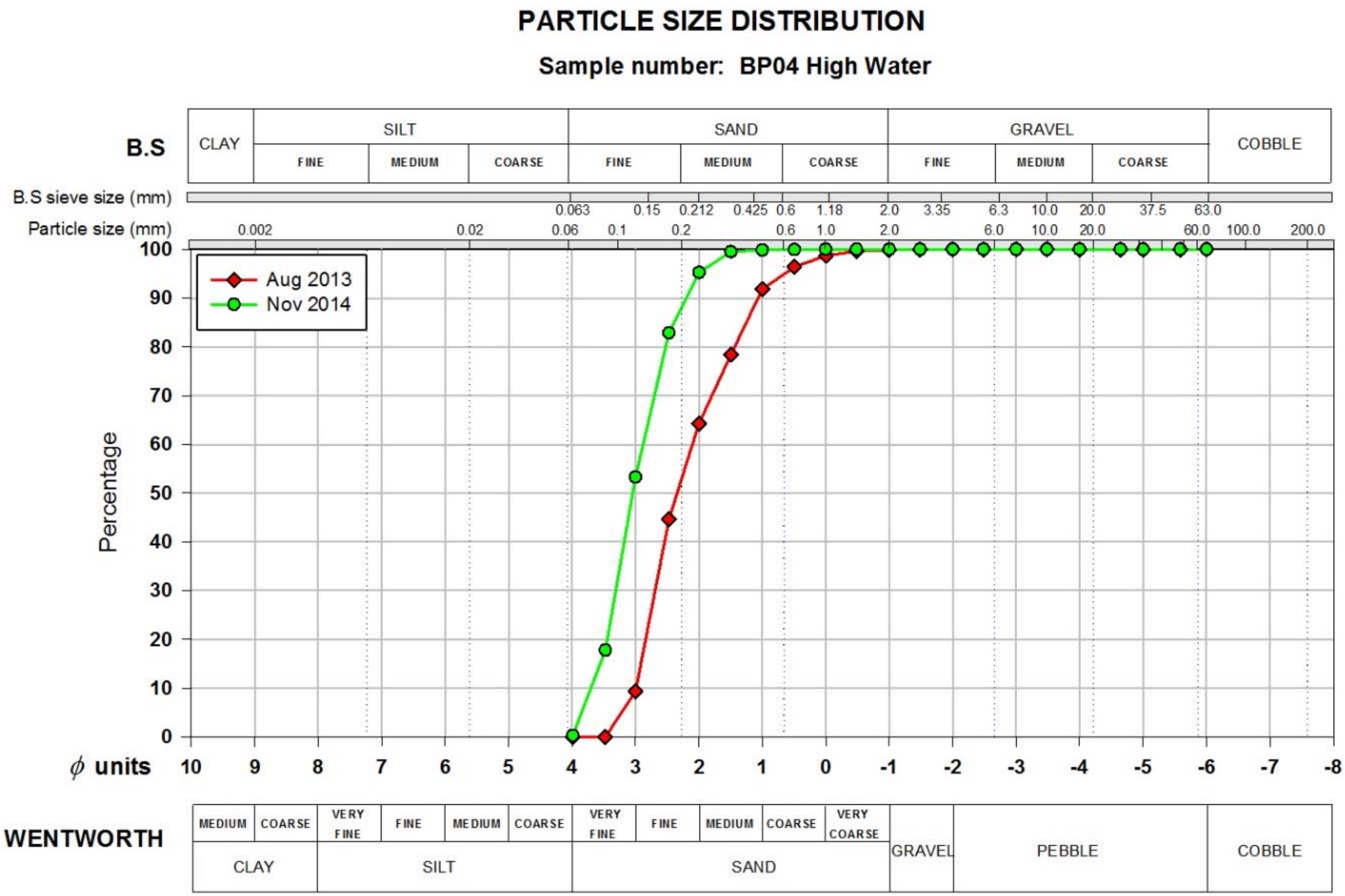
Chainage (m)
Profiles Envelope
2014-05-17
2013-05-28

ANNEX B - SEDIMENT SAMPLING



Sediment sample locations


PARTICLE SIZE DISTRIBUTION
Sample number: BP04 High Water
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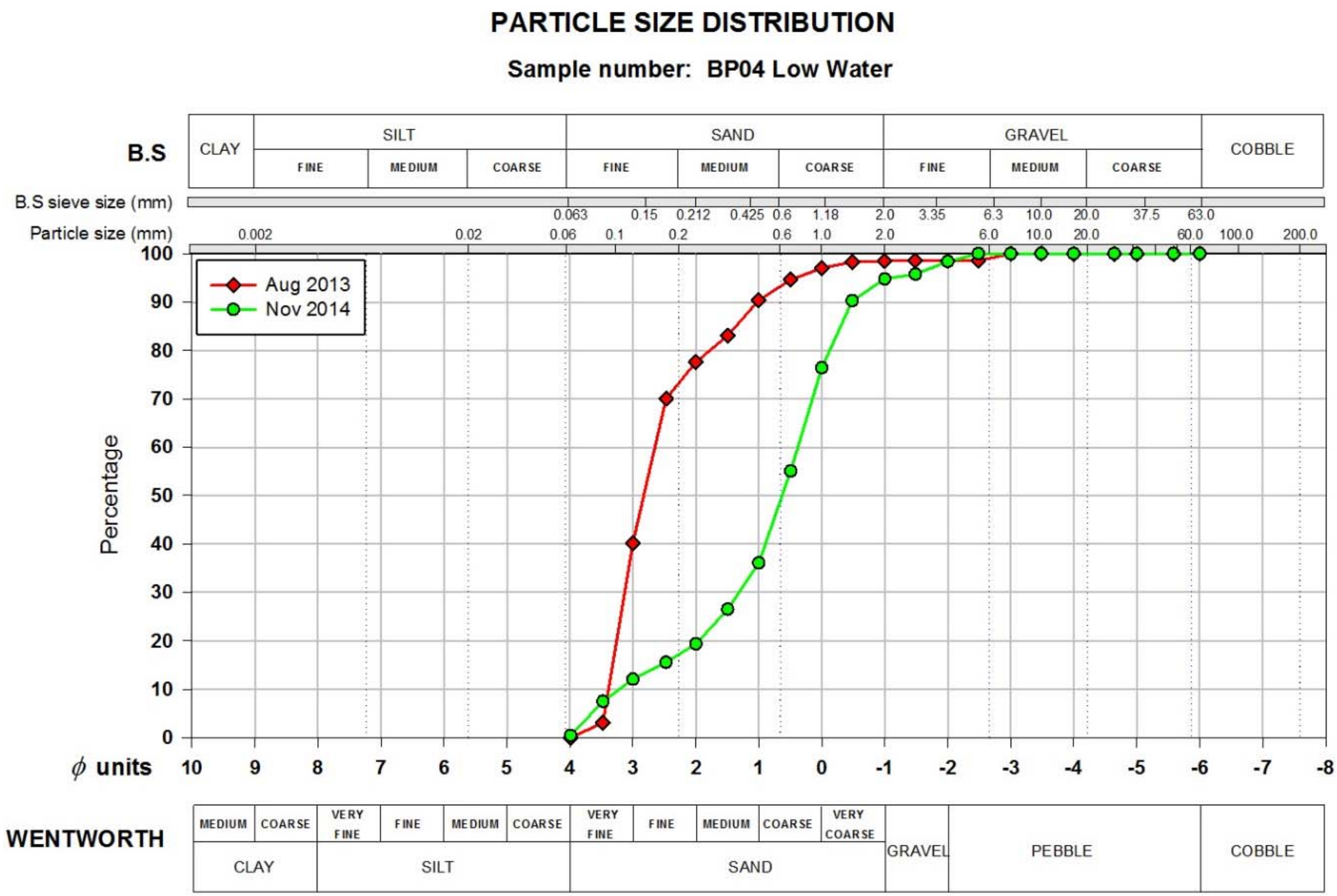
CLAY
SILT
SAND
GRAVEL
COBBLE
FINE
MEDIUM
COARSE
B.S sieve size (mm)
0.063 0.15 0.212 0.425 0.6 1.18 2.0 3.35 6.3 10.0 20.0 37.5 63.0
Particle size (mm)
0.002 0.02 0.06 0.1 0.2 0.6 1.0 2.0 6.0 10.0 20.0 60.0 100.0 200.0
Percentage
Aug 2013
Nov 2014
ϕ units
WENTWORTH
VERY FINE
VERY COARSE
PEBBLE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Sample number: BP04 Low Water
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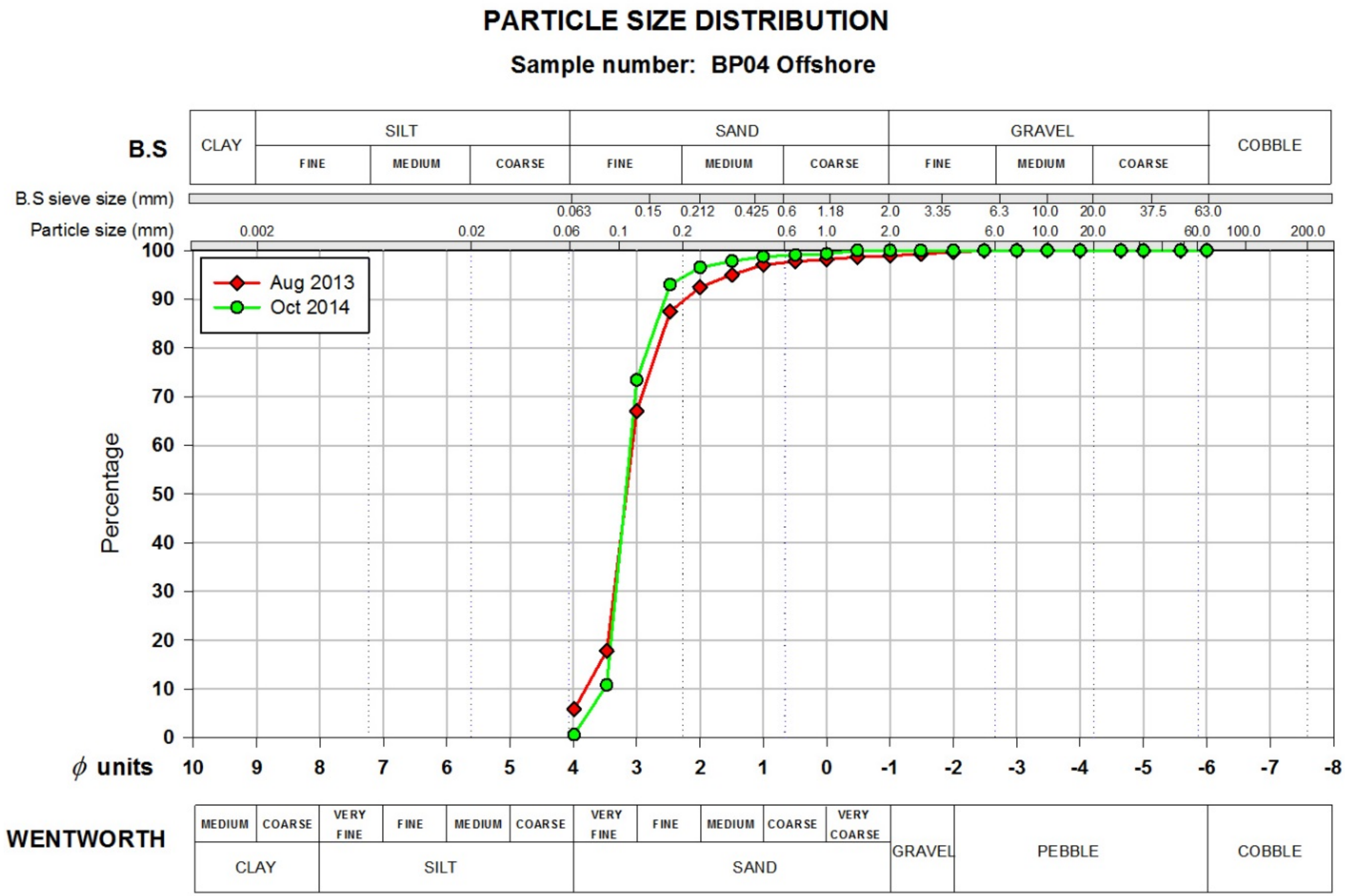
CLAY
SILT
SAND
GRAVEL
COBBLE
FINE
MEDIUM
COARSE
B.S sieve size (mm)
Particle size (mm)
Aug 2013
Nov 2014
Percentage
ϕ units
WENTWORTH
VERY FINE
VERY COARSE
PEBBLE


PARTICLE SIZE DISTRIBUTION
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CLAY
SILT
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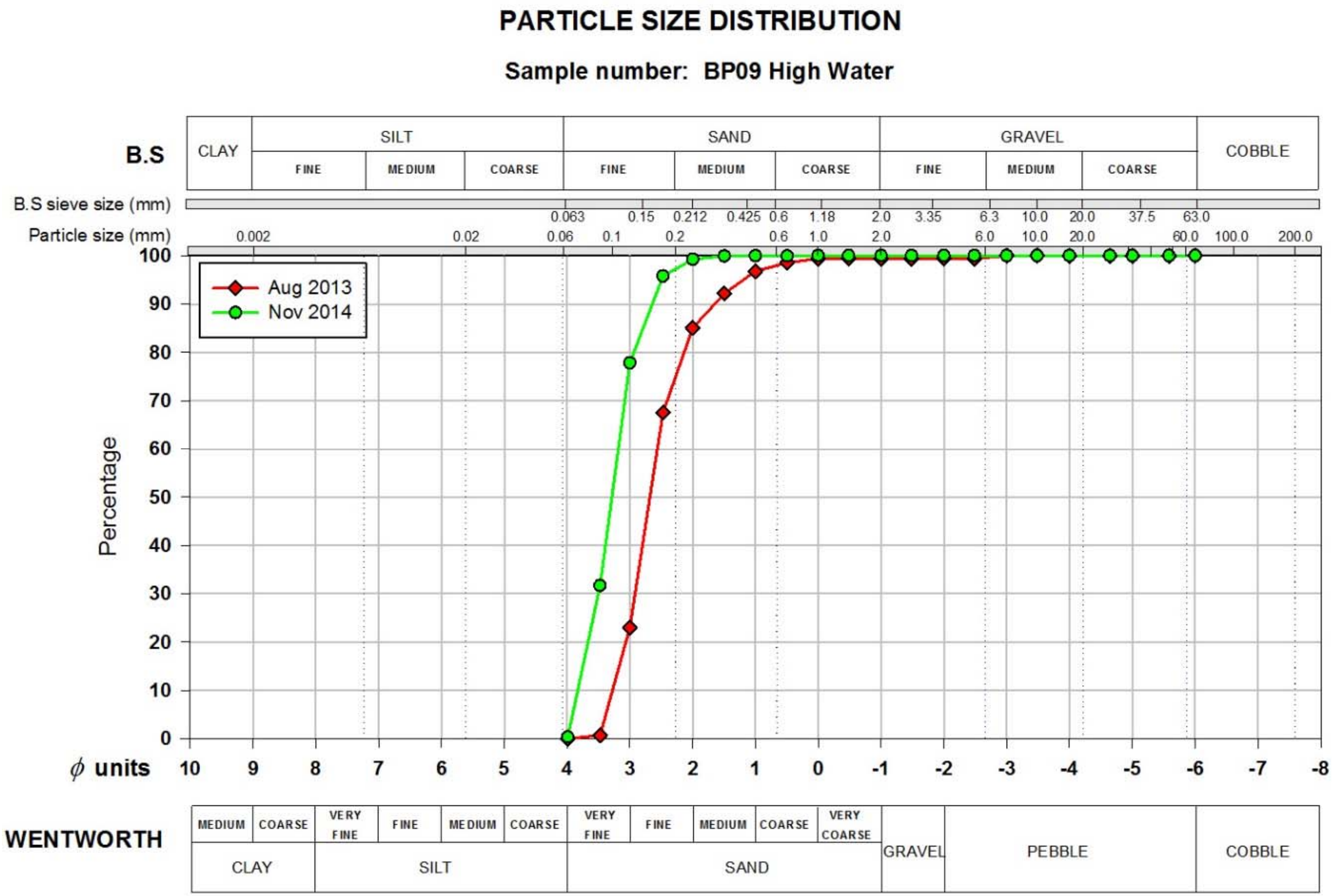
MEDIUM
COARSE
SAND
FINE
MEDIUM
COARSE
GRAVEL
FINE
MEDIUM
COARSE
COBBLE
B.S sieve size (mm)
0.063 0.15 0.212 0.425 0.6 1.18 2.0 3.35 6.3 10.0 20.0 37.5 63.0
Particle size (mm)
0.002 0.02 0.06 0.1 0.2 0.6 1.0 2.0 6.0 10.0 20.0 60.0 100.0 200.0
Percentage
0 10 20 30 40 50 60 70 80 90 100
Aug 2013
Oct 2014
ϕ units
10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8
WENTWORTH
MEDIUM
COARSE
VERY FINE
FINE
MEDIUM
COARSE
VERY FINE
FINE
MEDIUM
COARSE
VERY COARSE
CLAY
SILT
SAND
GRAVEL
PEBBLE
COBBLE


PARTICLE SIZE DISTRIBUTION
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SILT
SAND
GRAVEL
COBBLE
FINE
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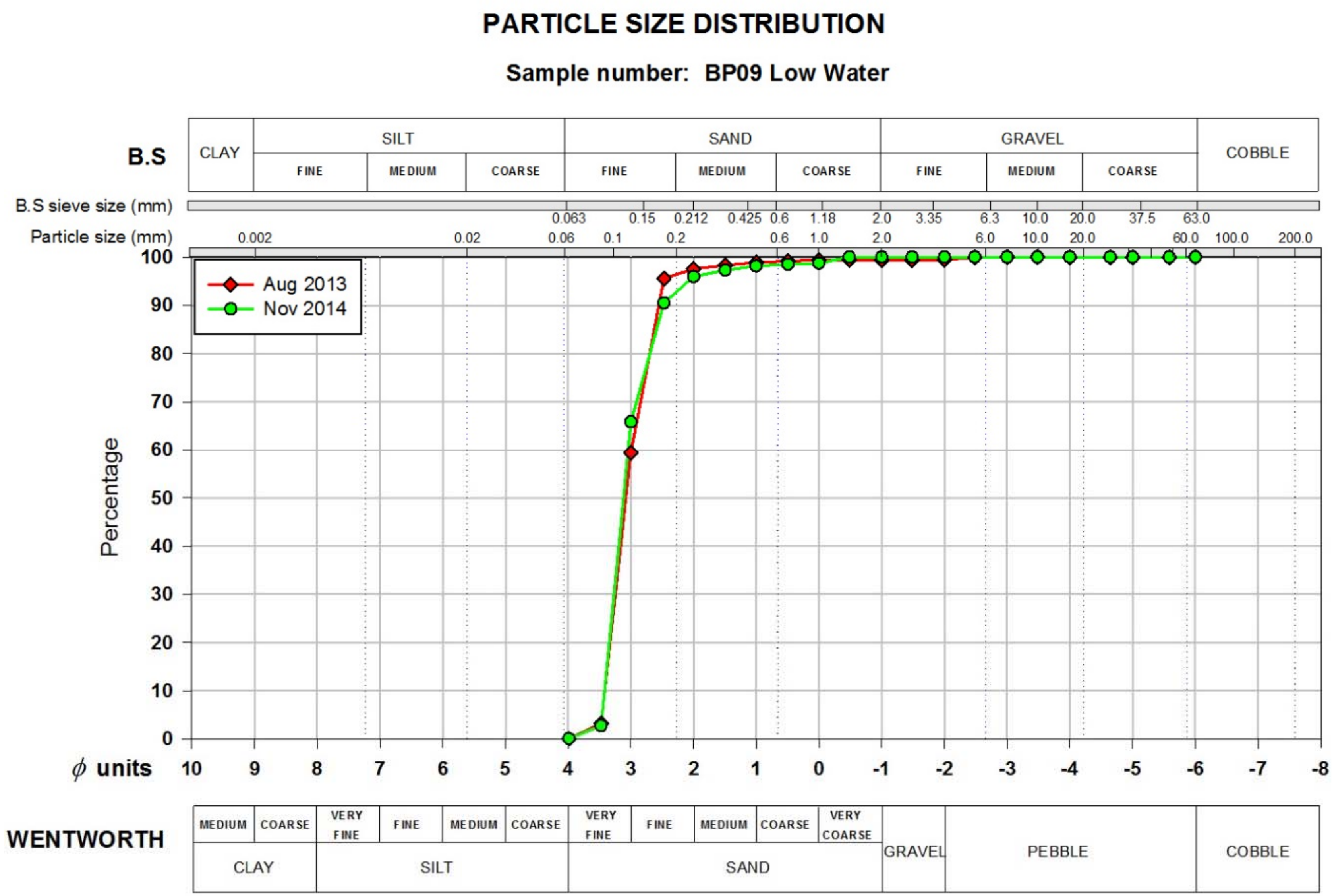
COARSE
B.S sieve size (mm)
0.063 0.15 0.212 0.425 0.6 1.18 2.0 3.35 6.3 10.0 20.0 37.5 63.0
Particle size (mm)
0.002 0.02 0.06 0.1 0.2 0.6 1.0 2.0 6.0 10.0 20.0 60.0 100.0 200.0
Aug 2013
Nov 2014
Percentage
100 90 80 70 60 50 40 30 20 10 0
ϕ units
10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8
WENTWORTH
MEDIUM COARSE VERY FINE FINE MEDIUM COARSE VERY FINE FINE MEDIUM COARSE VERY COARSE
CLAY SILT SAND GRAVEL PEBBLE COBBLE


PARTICLE SIZE DISTRIBUTION
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SAND
GRAVEL
COBBLE
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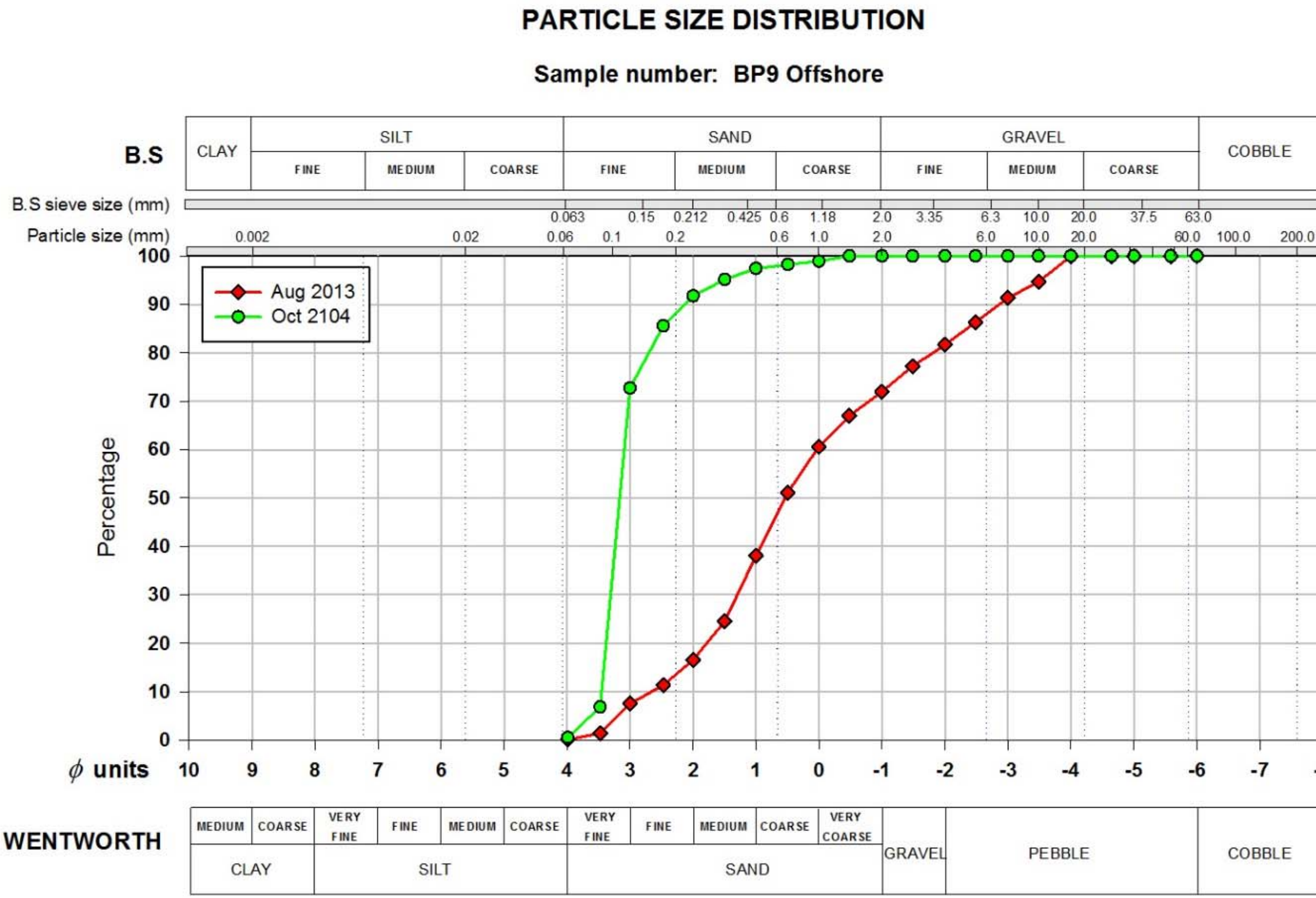
COARSE
B.S sieve size (mm)
0.063 0.15 0.212 0.425 0.6 1.18 2.0 3.35 6.3 10.0 20.0 37.5 63.0
Particle size (mm)
0.002 0.02 0.06 0.1 0.2 0.6 1.0 2.0 6.0 10.0 20.0 60.0 100.0 200.0
Aug 2013
Nov 2014
Percentage
100 90 80 70 60 50 40 30 20 10 0
ϕ units
10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8
WENTWORTH
MEDIUM
COARSE
VERY FINE
FINE
MEDIUM
COARSE
VERY FINE
FINE
MEDIUM
COARSE
VERY COARSE
CLAY
SILT
SAND
GRAVEL
PEBBLE
COBBLE


PARTICLE SIZE DISTRIBUTION
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SILT
SAND
GRAVEL
COBBLE
FINE
MEDIUM
COARSE
B.S sieve size (mm)
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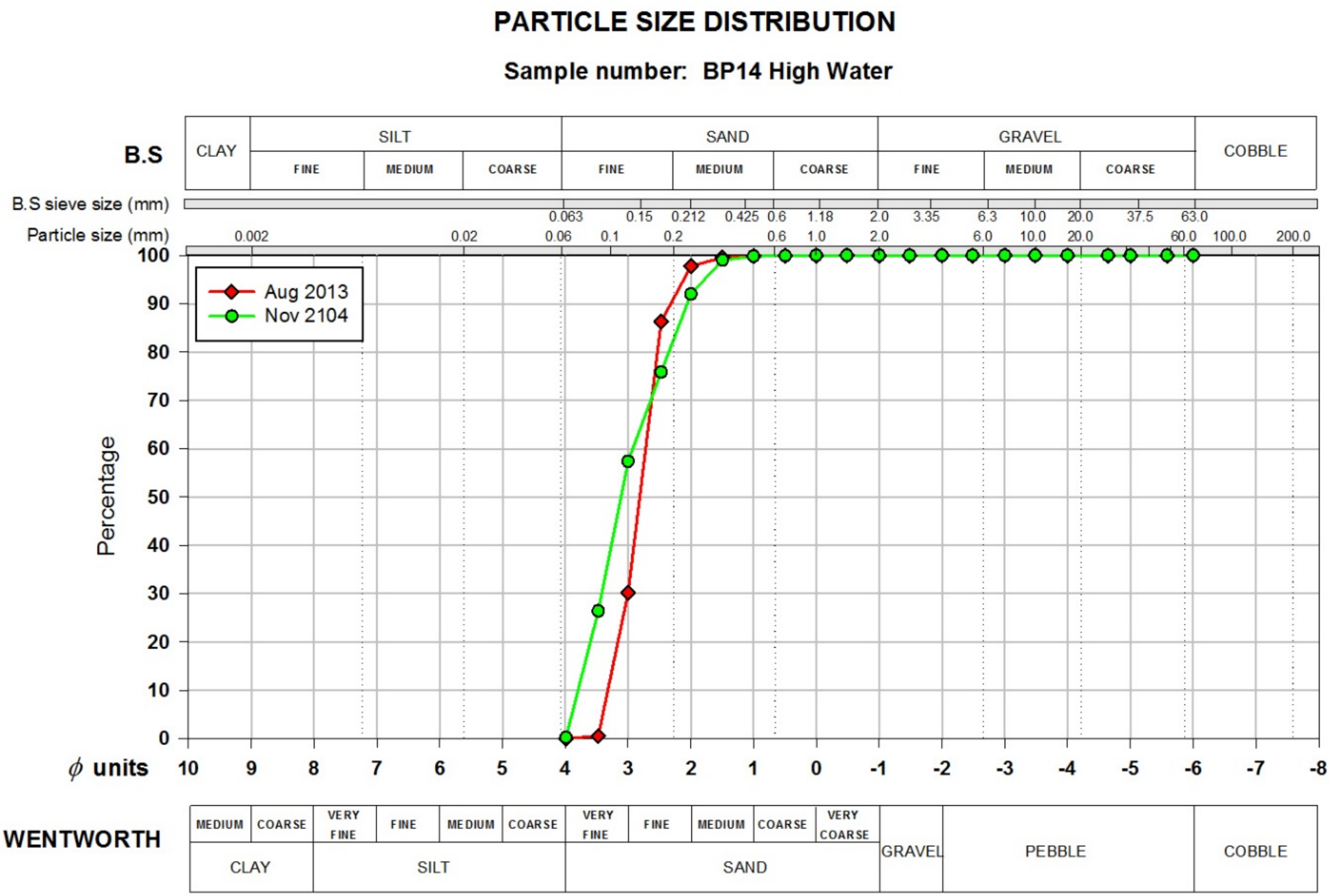
0.212
0.425
0.6
1.18
2.0
3.35
6.3
10.0
20.0
37.5
63.0
Particle size (mm)
0.002
0.02
0.06
0.1
0.2
0.6
1.0
2.0
6.0
10.0
20.0
60.0
100.0
200.0
Aug 2013
Oct 2104
Percentage
ϕ units
WENTWORTH
VERY FINE
VERY COARSE
PEBBLE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Sample number: BP14 High Water
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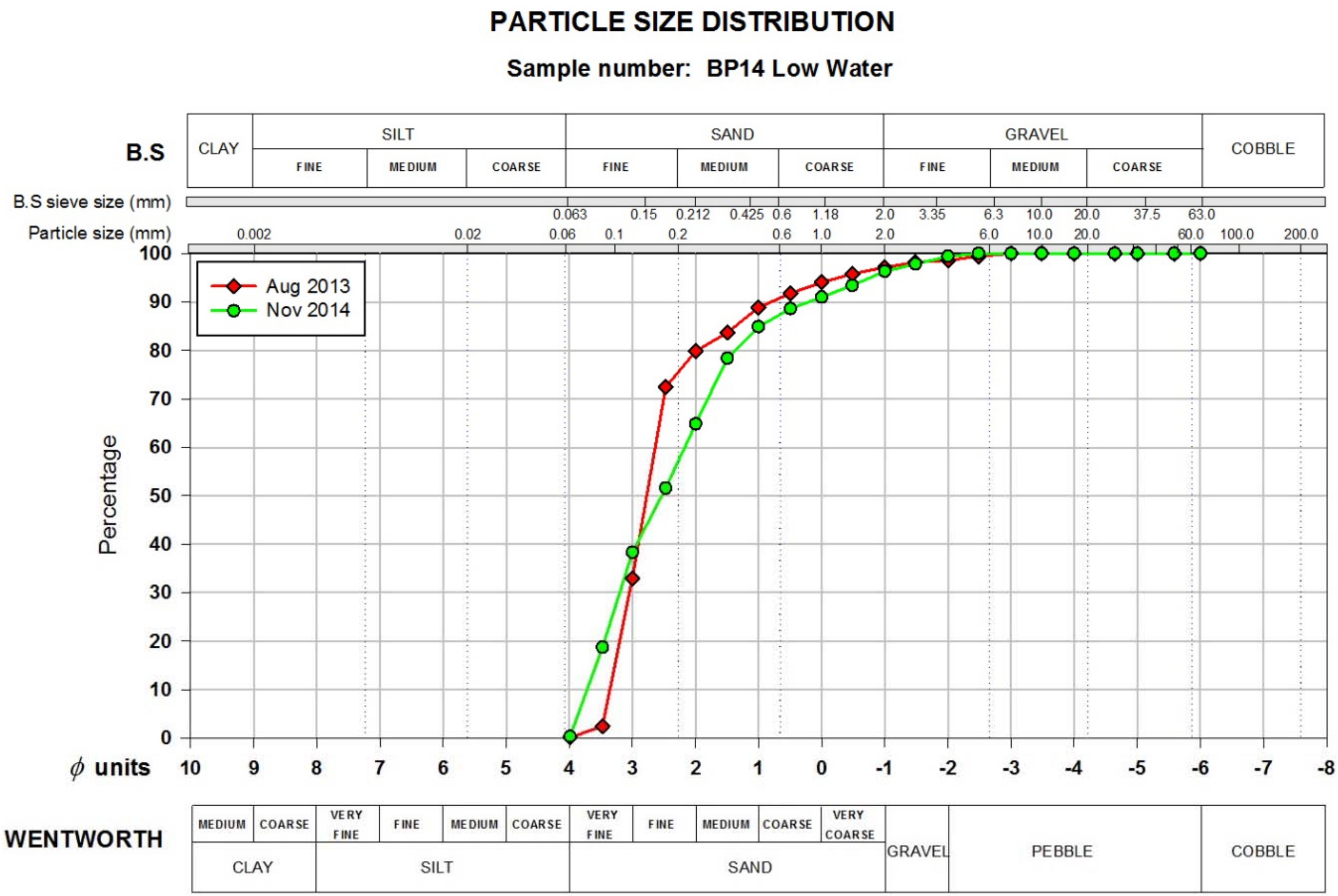
FINE
MEDIUM
COARSE
SAND
GRAVEL
COBBLE
B.S sieve size (mm)
Particle size (mm)
Percentage
Aug 2013
Nov 2104
ϕ units
WENTWORTH
VERY FINE
VERY COARSE
PEBBLE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Sample number: BP14 Low Water
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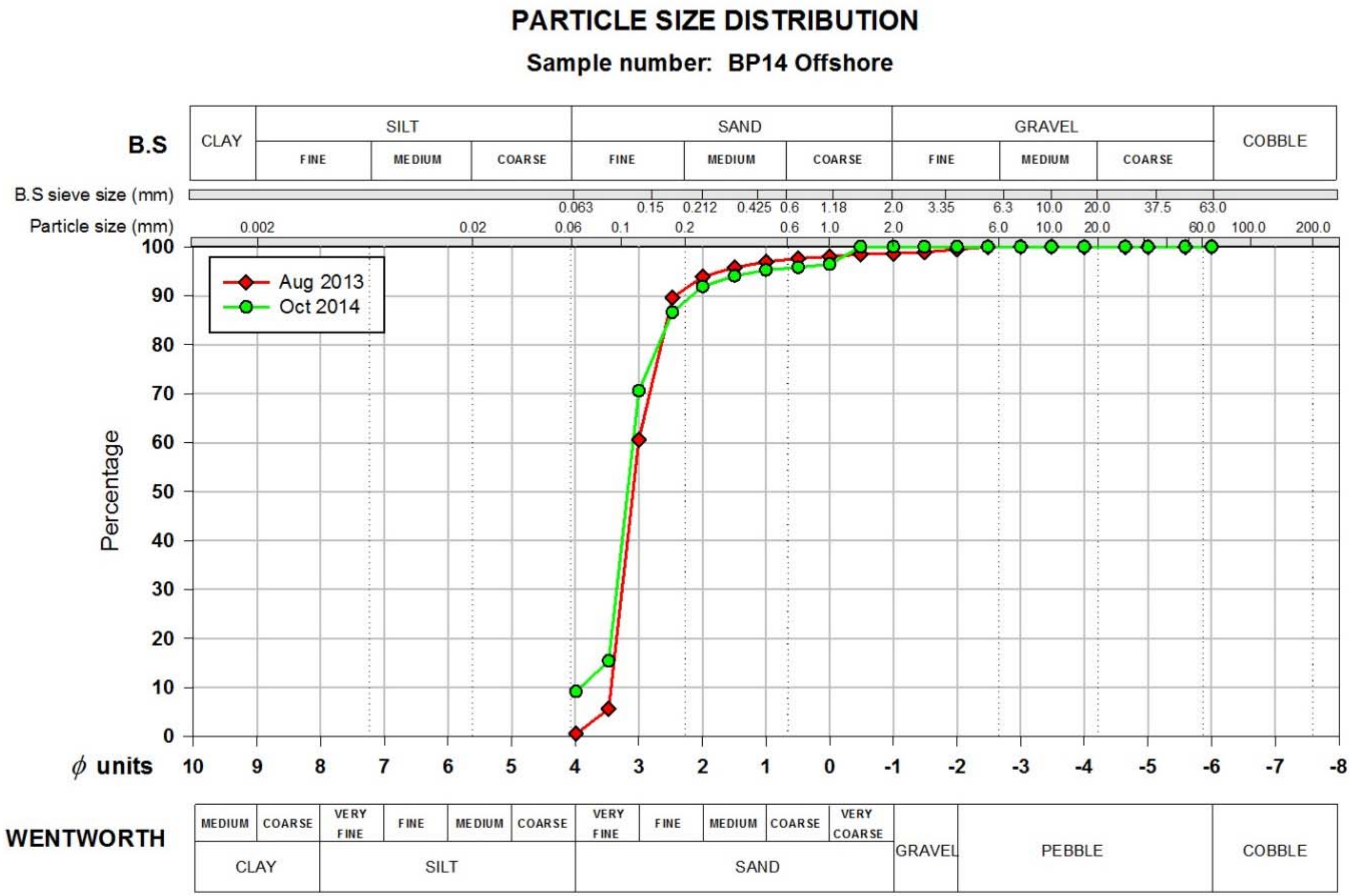
SILT
SAND
GRAVEL
COBBLE
FINE
MEDIUM
COARSE
B.S sieve size (mm)
0.063 0.15 0.212 0.425 0.6 1.18 2.0 3.35 6.3 10.0 20.0 37.5 63.0
Particle size (mm)
0.002 0.02 0.06 0.1 0.2 0.6 1.0 2.0 6.0 10.0 20.0 60.0 100.0 200.0
Percentage
Aug 2013
Nov 2014
ϕ units
WENTWORTH
VERY FINE
PEBBLE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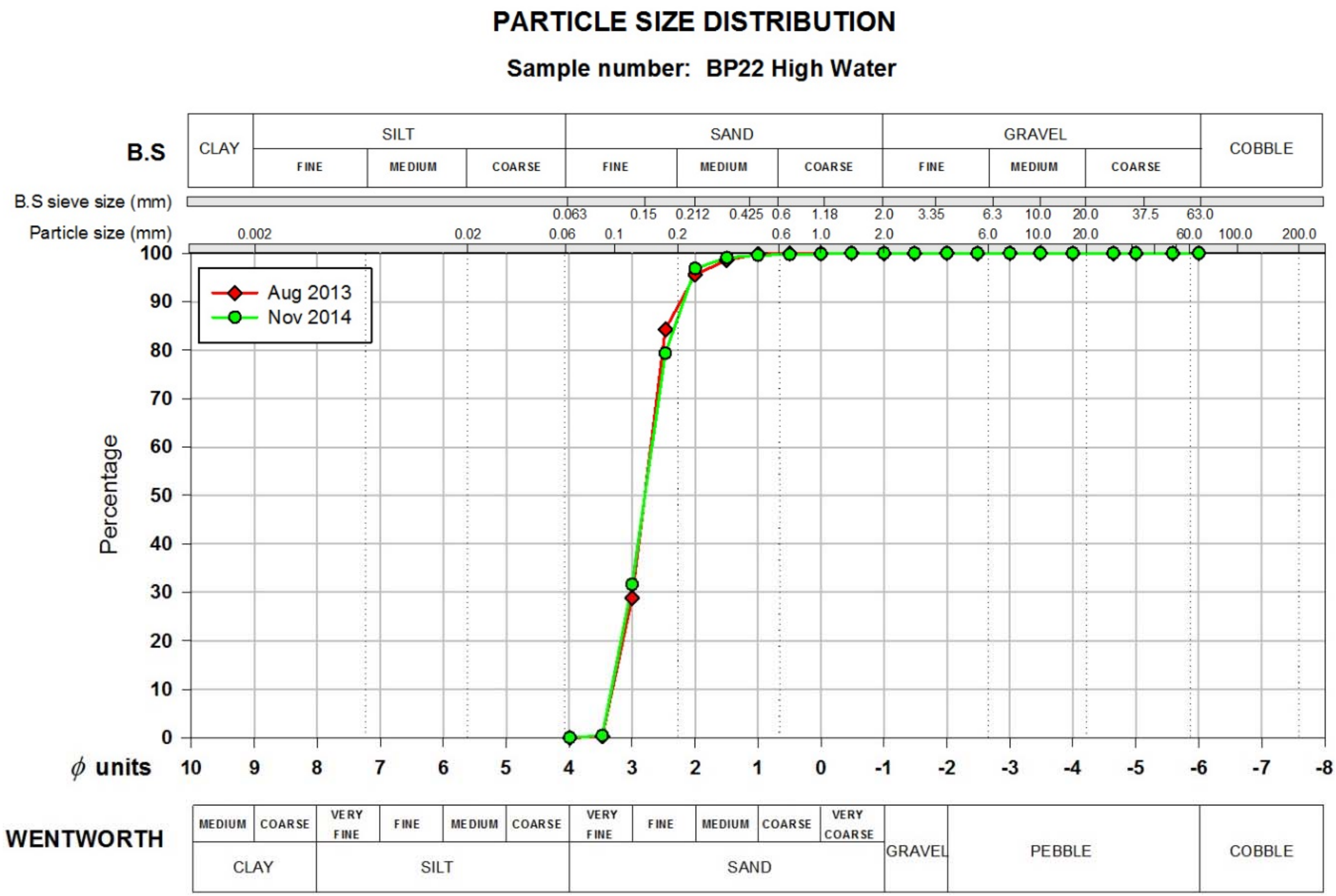
SILT
SAND
GRAVEL
COBBLE
FINE
MEDIUM
COARSE
B.S sieve size (mm)
Particle size (mm)
Percentage
Aug 2013
Oct 2014
ϕ units
WENTWORTH
VERY FINE
VERY COARSE
PEBBLE


PARTICLE SIZE DISTRIBUTION
Sample number: BP22 High Water
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CLAY
SILT
FINE
MEDIUM
COARSE
SAND
FINE
MEDIUM
COARSE
GRAVEL
FINE
MEDIUM
COARSE
COBBLE
B.S sieve size (mm)
0.063 0.15 0.212 0.425 0.6 1.18 2.0 3.35 6.3 10.0 20.0 37.5 63.0
Particle size (mm)
0.002 0.02 0.06 0.1 0.2 0.6 1.0 2.0 6.0 10.0 20.0 60.0 100.0 200.0
Percentage
100 90 80 70 60 50 40 30 20 10 0
Aug 2013
Nov 2014
ϕ units
10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8
WENTWORTH
MEDIUM
COARSE
VERY FINE
FINE
MEDIUM
COARSE
VERY FINE
FINE
MEDIUM
COARSE
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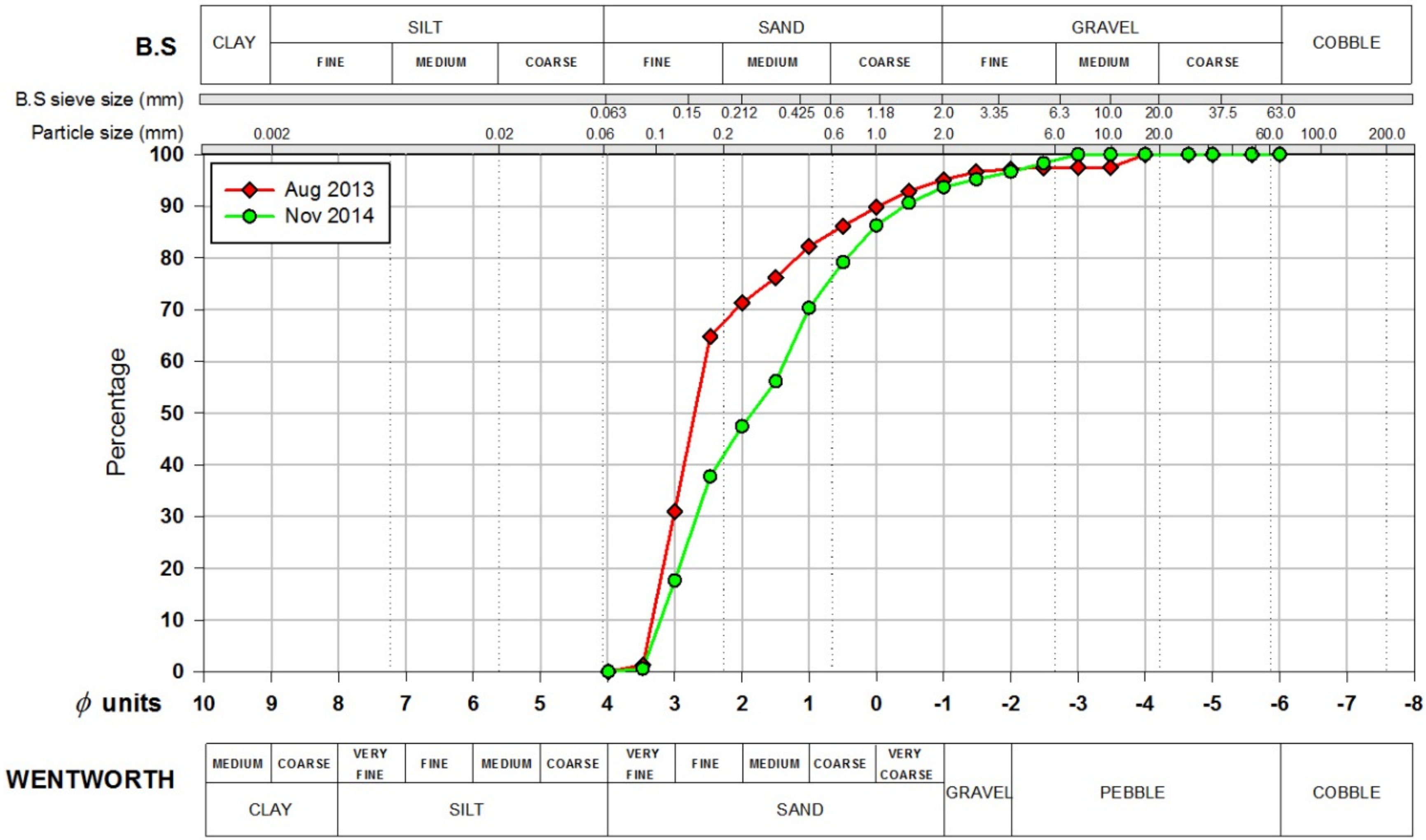
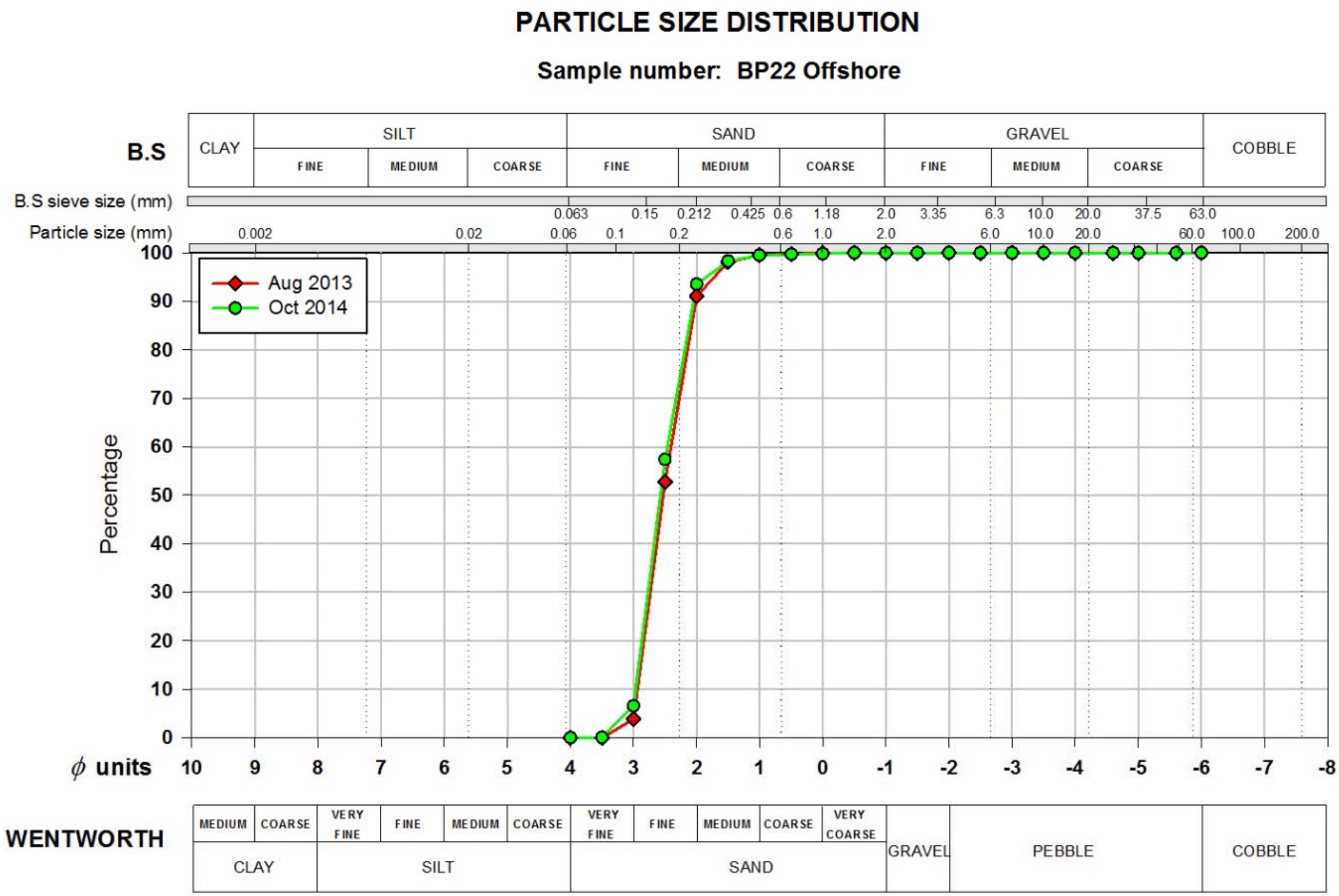
CLAY
SILT
SAND
GRAVEL
PEBBLE
COBBLE

PARTICLE SIZE DISTRIBUTION

Sample number: BP22 Low Water




PARTICLE SIZE DISTRIBUTION
Sample number: BP22 Offshore
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SILT
SAND
GRAVEL
COBBLE
FINE
MEDIUM
COARSE
B.S sieve size (mm)
Particle size (mm)
Percentage
Aug 2013
Oct 2014
ϕ units
WENTWORTH
VERY FINE
VERY COARSE
PEBBLE

Poole Harbour Channel deepening EIA studies 2005-9

Final Report to Poole Harbour Commissioners

February 2010

Dr Ken Collins
School of Ocean and Earth Science, University of Southampton
National Oceanography Centre, Southampton SO14 3ZH
Tel/Fax : 023 8059 6010 email kjc@noc.soton.ac.uk

Poole Harbour deepening EIA studies 2005-9
February 2010

Summary
This study includes the key areas for biological monitoring detailed in Section 5 of the Poole Harbour Approach Channel Deepening EIA: Proposed Monitoring Programme, (Haskoning 2005). Studies undertaken in Poole Bay and Poole Harbour were:

2005-9	Sedimentation rate studies, Poole Bay
2005-6	Seagrass (*Zostera marina*), Studland Bay and Poole Harbour
2000-9	Maerl (*Phymatolithon calcareum*) density off Ballard Down
2005-9	Reef species
2005-6	Algal densities on Poole Bay patch reefs
2005-6	Pink seafan (*Eunicella verrucosa*)
2005-6	Biogenic worm reefs (*Sabellaria spinulosa*) off Swanage

The sedimentation studies and diver observations point to retention of silt from the dredging disposal within Poole Bay. Modelling (by HR Wallingford, see Haskoning 2005) of silt from the disposal ground suggested that it would be carried anti-clockwise around Poole Bay with some deposition during neap tides but re-suspension during spring tides. The extra silt remaining from the dredging and disposal is remobilised during storms and presumably largely re-settling in the Bay. There is some indication that sedimentation rates are returning to pre-dredging levels.

One of the concerns was that increased sediment levels would adversely a range of organisms by smothering or simply inhibiting growth. Algae grow on the upper horizontal surfaces of the many patch reefs, thus could be particular vulnerable to increased sedimentation. No impact on reef algal density was found. Similarly a range of established reef associated species was examined in each of the 3 years post-dredging, with no evidence for loss. There was no effect on the rare Pink seafan (*Eunicella verrucosa*).

Seagrass (*Zostera marina*) traps sediments and requires light to grow so again is vulnerable to excess sedimentation. No impact was observed from detailed shoot density studied (in the summers before and after deepening) in the Harbour, adjacent to the Training Bank and in Studland Bay.

Another species, *Sabellaria spinulosa* which form a biogenic reef habitat off Swanage of high nature conservation had been largely destroyed by fishing (dredging and trawling immediately prior to the channel deepening. There was no evidence for increase sediment accumulation at this site.

The free-living calcareous algae maerl occurs in a narrow band off Ballard Down. Its density remained stable 2000-3, showed a decline in density of 40% post-dredging and disposal, but has remained stable subsequently (2006-9). In hindsight the maerl should have been surveyed in summer 2005, immediately prior to channel deepening. It is considered highly probable that the decline is attributable to the extra suspended sediment load arising from the dredging and disposal operations over winter 2005/6.

As the Spoil Ground is close to the maerl and *Sabellaria* areas, prior to the Channel deepening the author requested that CEFAS/DEFRA consider moving this licensed disposal area further eastward and seaward. Given that modeling predicted movement of material would be SW-NE and not directly towards the maerl, disposal was limited to sector furthest from the Harbour. Since there has been an impact on the maerl, movement of the Spoil Ground should be considered for future capital dredging disposal.

Contents

Figures

Tables

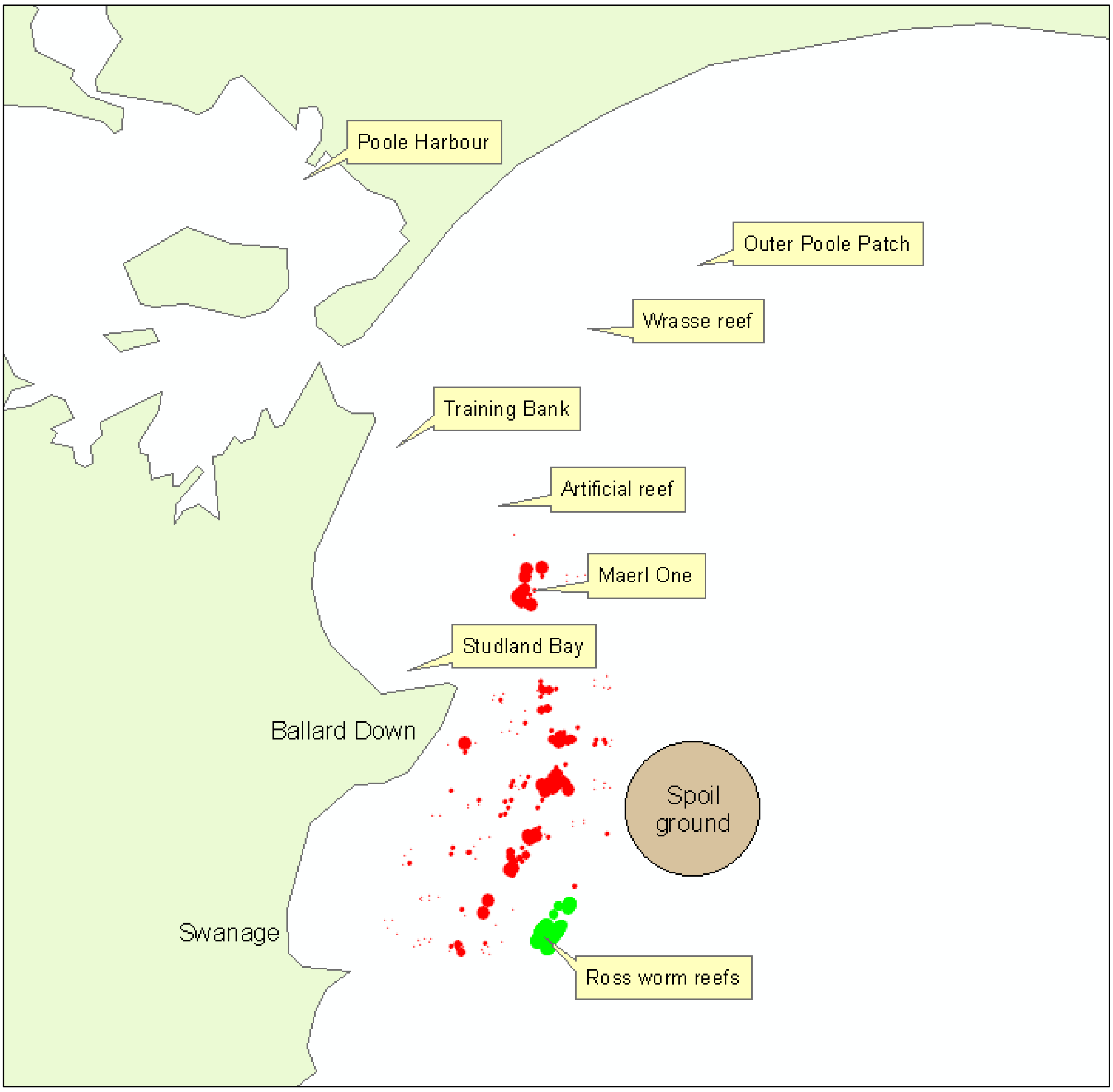

Figure 1 The main study sites described in this report. The size of the red dots is proportional to maerl density.

1. Introduction

The Poole Harbour Approach Channel Deepening EIA (Haskoning 2005) modeling predicted that fine sediments from disposal of dredged material at the Spoil Ground off Ballard Down would circulate anticlockwise around Poole Bay. There was concern expressed by the fishing and diving communities that the dredging of the Poole Harbour channel and subsequent disposal and beach recharge would cause excessive siltation in the Bay with consequent adverse impacts on the resident marine life. The author having dived routinely in Poole Bay over the past 30 years was aware that much of the Bay is silty. This suggested that sedimentation rates were naturally higher than along the adjacent open coast, so a simple sediment trap monitoring programme was started in advance of the channel deepening.

This study includes the key areas for biological monitoring detailed in Section 5 of the Poole Harbour Approach Channel Deepening EIA (Haskoning 2005). Studies undertaken in Poole Bay and Poole Harbour describe here are:

2005-9	Sedimentation rate studies, Poole Bay
2005-6	Seagrass (*Zostera marina*), Studland Bay and Poole Harbour
2000-9	Maerl (*Phymatolithon calcareum*) density off Ballard Down
2005-9	Reef species
2005-6	Algal densities on Poole Bay patch reefs
2005-6	Pink seafan (*Eunicella verrucosa*)
2005-6	Ross worm reefs (*Sabellaria spinulosa*) off Swanage

2. Methods

All of the fieldwork described was carried out by SCUBA diving, with a core team of HSE divers often supported by volunteer student and sport divers.

2.1. Sedimentation studies

Sedimentation studies were conducted with pairs of sediment traps (vertical tubes 40cm x 8cmID) at each of the 4 sites indicated in Fig.1 and replaced by divers at 1-2 monthly intervals. The deployments represent a gradient from the area of heaviest predicted (Haskoning, 2005) sedimentation (Outer Poole Patch), through Wrasse Reef, the Artificial Reef and to Maerl One a site within the northern part of the maerl bed

Figure 2. Diver preparing to replace sediment traps on the Artificial Reef, Poole Bay

At each site 2 cylinders (300mm length by 65mm ID) were mounted vertically close to the seabed. Three of the sites are by reefs, affording protection from disturbance by trawling/dredging, so the sediment traps are simply attached to vertical steel posts with elastic cord and cable ties (Fig.2). The remaining site, Maerl One is on open seabed and here a concrete anti-trawl block to hold the sediment traps was deployed in June 2005. The low pyramidal shape was designed to allow fishing dredges, nets, or anchors to slide over the block.

At each site, new sediment traps are taken down by divers, capping and replacing those in place. In the lab the sediment trap contents were passed initially through a coarse 500µ sieve to remove large seaweeds and mobile fauna (crabs and molluscs) and finally washed through a 63µ sieve to collect the silt fraction. After settling and removal of supernatant liquid, this fraction was dried for 24hours at 100^{o}C.

2.2.Seagrass
At each study site a pair of divers each measured the shoot density within a 30x30cm quadrat and measured the maximum blade length within that quadrat. Using a tape measure (and noting the direction of travel) these measurements were repeated at 5 m intervals over a 30m distance yielding 14 measurements at each site. The position of the starting point for each transect was recorded using the support vessel GPS.

2.3.Maerl
The maerl density was determined by pairs of divers with a 0.5m^2 quadrats collecting all the live (pink) maerl on and just under the surface sediment. Divers, marked by a surface marker bouy, collected 2 quadrats then drifted or swam with the current for about 10mins and repeated the collection. Their position was tracked by the surface support vessel. Samples were sorted and dried before weighing.

2.4.Reef species
Reef associated species were recorded by divers using an underwater checklist on a slate backed up by underwater photography and sample collection to check identification in the laboratory.

2.5.Algal density
Algae density as percentage coverage within 30x30cm quadrat was recorded as well as measuring the maximum blade length within that quadrat.

2.6.Pink seafan
Specimens were photographed and measured *in-situ* by divers.

2.7. Sabellaria reefs
The extent and density of *Sabellaria spinulosa* was mapped by both by towed video-sledge and diver surveys.

3. Sedimentation rate studies

The sediment traps at the 4 sites indicated in Fig.1 were replaced at approximately 1-2 monthly intervals May 2005 to Dec 2009. It was not usually possible to replace all on the same day. A spreadsheet was set up with 1 day per row and columns for each of the 2 sediment traps at each of the 4 sites. Daily sedimentation (dry weight silt fraction <64µ) was assumed to be constant from the day of deployment to recovery. In this way average monthly sedimentation was calculated for the whole study period (Fig.3 below)

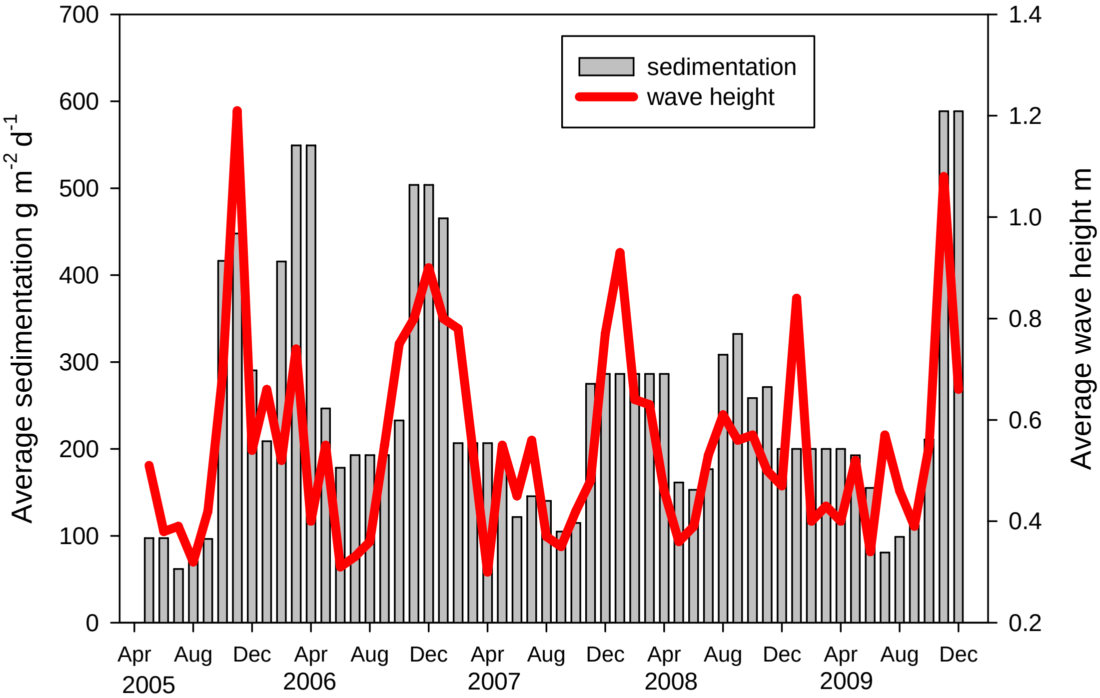

Figure 3. Average sedimentation rates from 4 sites in Poole Bay and average monthly wave height May 2005 - Dec2009.

Storms re-suspend the seabed sediment in Poole Bay. It was very evident from this study that higher sediment accumulation coincided with winter storms. The second plot in Fig.3 above plots monthly average wave height calculated from the Boscombe Wave Rider Buoy data: (http://www.channelcoast.org/data_management/real_time_data/charts/?chart=66&tab=stats&disp_option) There is a trend in the relationship between average monthly wave height and sedimentation rate (Fig.4, r^2 =0.40). Applying this relationship to the wave height predicts a sedimentation rate which is compared to the observed values in Fig.5. Notable periods of excess sedimentation are in spring 2006 following the dredging and disposal over winter 2006/7. This is interpreted as there having been deposition of fine sediment in Poole Bay carried in from the dumping site as predicted by the HR modelling. However this has remained in the Bay much longer than the predicted period, years rather than just a spring-neap interval. This reservoir of excess sediment observed by divers within the Bay is being re-suspended during storms. Observations in autumn 2007 suggested that the sedimentation levels were returning to pre-dredging levels, though this has not been evident in 2008 data.

There have been other inputs of sediment to Poole Bay from disposal at the Spoil Ground and recharge of beaches (Table 1). When material is pumped onto beaches finer material is washed out and dispersed.

Table 1. Potential winter sediment inputs to Poole Bay (m^3)

	2005/6	2006/7	2007/8	2008/9	2009/10
Spoil Ground	700,000	10,000	70,000	10,000	70,000
Beach recharge	110,000	80,000	30,000	74,000	

The summer of 2005 shows much lower levels of sedimentation than predicted (Fig.5). Given that the relationship between wave height and sedimentation has largely been derived from post-dredging data and assuming that the there is a new reservoir of silt within the Bay, this is not surprising.

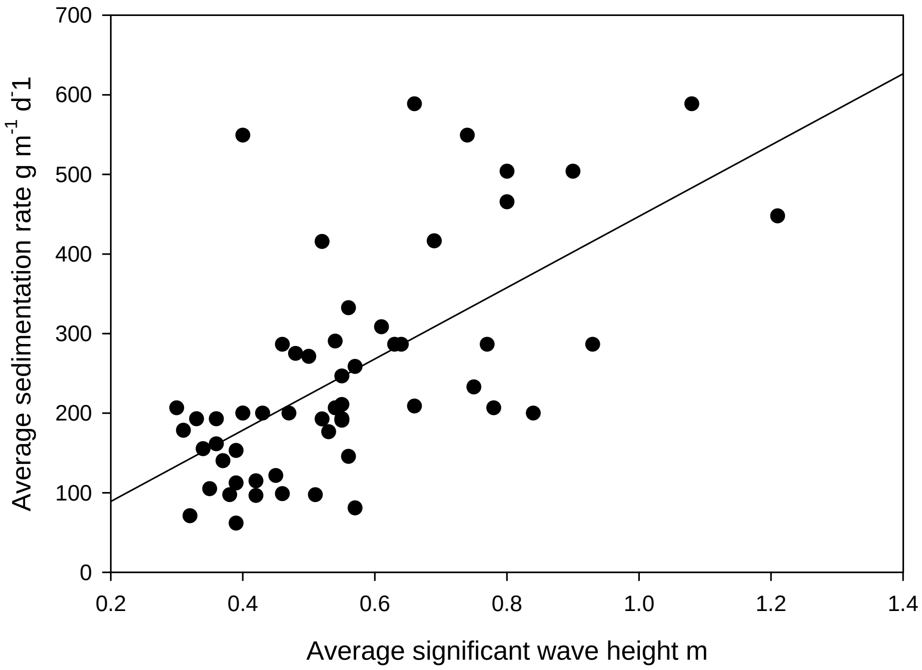

Figure 4. Plot of average monthly significant wave height (Boscombe) vs average monthly sedimentation rate.

The complicating factor with seabed sediment traps is that storm wave action re-suspends seabed sediments adding to the background sediment flux. To avoid the impact of predominantly winter storms just the summer daily fluxes have been analysed in Fig.6 above. All post-deepening summer sedimentation rates remain significantly greater than the pre-deepening values from 2005 (Mann-Whitney Rank Sum Test, P = <0.001).

It would have been useful to have data for several years prior to the channel deepening rather than just from May-Nov 2005. The summers of 2005-6 had lower average wave heights than subsequently. Summer 2006 with similar average wave height clearly has increased sedimentation rates. The sediment that accumulated in the bay from the dredging and disposal was presumably being re-mobilised by both tidal and wave action.

The relatively (~20%) increased average wave heights through summers of 2007-9 could be expected to create greater sediment re-suspension. Fig.4 suggests linear relationship of sedimentation with wave height, thus a 20% increase in wave height would be expected to produce a 20% increase in sedimentation if there were no other factors. Sedimentation in 2007-9 (especially 2008) all exceed this which suggests that there is still a residue of unconsolidated sediment in the bay which is probably decreasing with time, either by being flushed out of the system or becoming consolidated into the seabed. The main problem hindering reaching a conclusion is the lack of long term sedimentation data before this study.

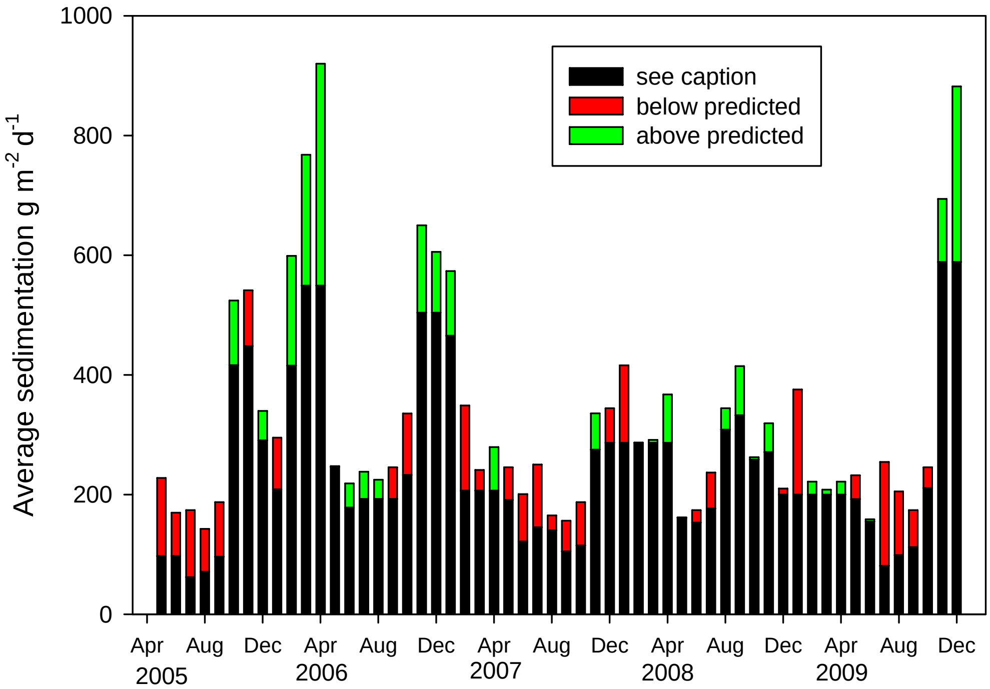

Figure 5 Comparison of predicted sedimentation rate (from wave height, Fig 4) compared to observed. If the predicted level is above observed then the difference is indicated by the red bar. If predicted is less than observed then the excess is indicated by the green bar.

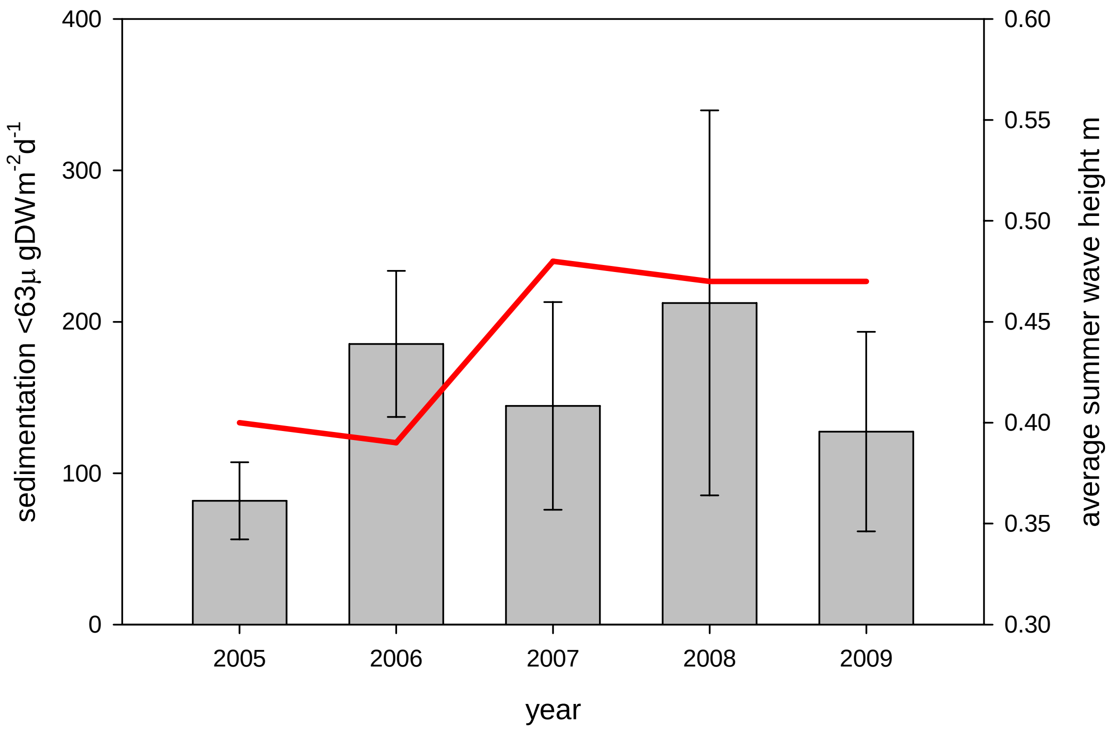

Figure 6. Average summer (7 May - 7 Sep) daily sedimentation rates from 4 sites in Poole Bay each year. Error bars represent ±1 standard deviation. The red line shows average wave height (Boscombe, May-Aug).

3.1 Diver seabed observations
The following photographs taken by Dr Lin Baldock in summer 2006 show fresh sediment deposited on the existing seabed following the winter dredging and disposal.

Figure 7. Poole Bay seabed south of Outer Poole Patch, courtesy of Dr Lin Baldock

Fresh silt sediment scooped by the diver's hand, covering the existing seabed (14.05.06)

Chain of the slipper limpet *Crepidula fornicata* deeply buried in soft, silty sediment.(14.04.07)

Coarse, firm gravelly sand beneath a layer of fine, unconsolidated silt (14.04.07)

4. Seagrass, Studland Bay and Poole Harbour

Detailed quantitative studies of the seagrass were undertaken by divers in Studland Bay, adjacent to the Poole Harbour entrance Training Bank and at one bed within the Harbour (Fig.1). These surveys were undertaken pre-dredging in July 2005 and exactly repeated post-dredging in July 2006. No significant changes in shoot density or blade length were found

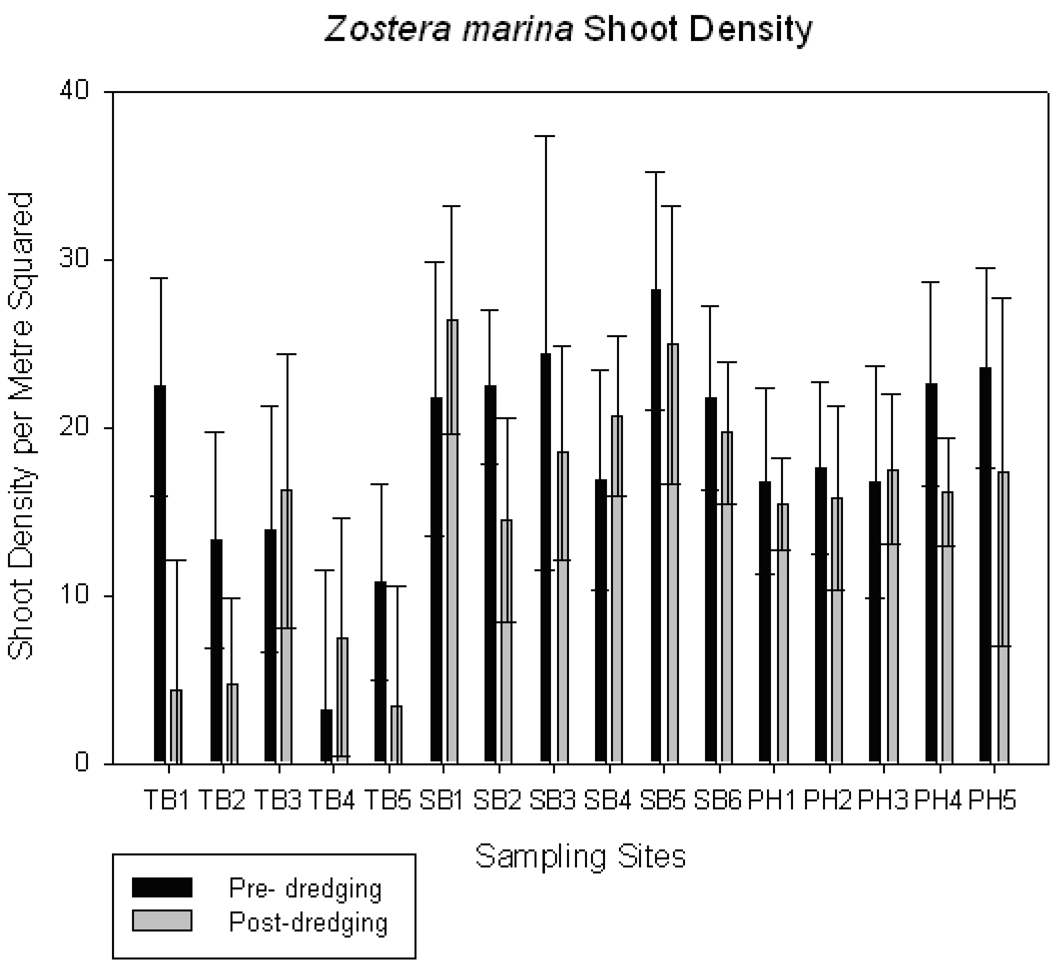

Figure 8. Average seagrass shoot densities (± 1 standard deviation) from before and after dredging (2005 and 2006, respectively). Site notation: TB=Training Bank, SB=Studland Bay and PH=Poole Harbour (shown in Fig.1).

5. Maerl density studies

The maerl (*Phymatolithon calcareum*) bed off Ballard Down is the most easterly known in the English Channel. Being at the edge of its range its is likely to be particularly sensitive to natural variations and anthropogenic disturbance. It was systematically surveyed 2000-3 by divers with 0.5m^2 quadrats collecting all the live (pink) maerl. There is a core area of greatest density (indicated by the bold red dots in Fig.1) corresponding to the tidal jet stream around the headland determined by ADCP (acoustic doppler current profiler studies (Mitchell and Collins, 2002). This core area was sampled in 2000, 2001 and 2003 the latter deliberately re-sampling sites from the previous 2 years to prove the validity of the survey technique. Whist the density remained stable 2000-3, a significant decline (Kruskal-Wallis One Way Analysis of Variance on Ranks, P = <0.001) was found in 2006.

Table 2. Maerl density (gDWm^{-2}) statistics 2000-6

Year	samples	average	median	minimum	Maximum
2000	54	64.8	53.6	2.0	164.4
2001	28	76.4	79.4	10.0	130.2
2003	32	70.8	63.6	18.4	153.6
2006	53	43.2	39.4	0.6	94.8

The results of maerl quadrat surveys (n=28 in 2006, n=94 in 2008) confirm the decline post-dredging reported above. The densities have been analysed in clusters shown in Fig.9 below, the post dredging data being compared directly with pre-dredging sites within 125m or within 250m. Results are summarised in Table 2 below. It is difficult to closely replicate sampling sites whilst drift diving, the sampling method used. Pre-dredging data was identified as being within a fixed radius (250m and 125m) from post-dredging sampling sites. Whilst the 250m buffer zones yield larger comparative data sets than the 125m zones, the differences are small.

Table 3 Comparison of maerl densities (gDW m^{-2}) average densities (and standard deviation) recorded in the areas indicated in Fig.1, within 125 and 250 m of the post-dredging survey.

	Pre-dredging<125m			Pre-dredging<250m			Post-dredging		
Group	N	Avg	Std	n	Avg	std	n	Avg	Std
A	6	47.4	21.5	14	46.7	19.9	26	30.3	14.4
B	6	1.1	1.4	12	0.7	1.1	8	0.3	0.4
C	12	25.4	23.5	12	25.4	23.5	8	27.3	7.4
D	8	10.5	5.3	12	8.3	5.4	4	3.6	3.0
E	10	21.0	10.3	12	20.5	9.6	10	11.8	3.2
F	2	6.9	2.5	10	4.5	2.5	4	5.1	4.4
G	8	15.2	5.5	8	15.2	5.5	12	6.9	5.4
H	24	39.8	15.2	24	39.8	15.2	32	17.6	7.4
I	8	45.1	12.6	16	43.3	15.5	18	19.9	8.8

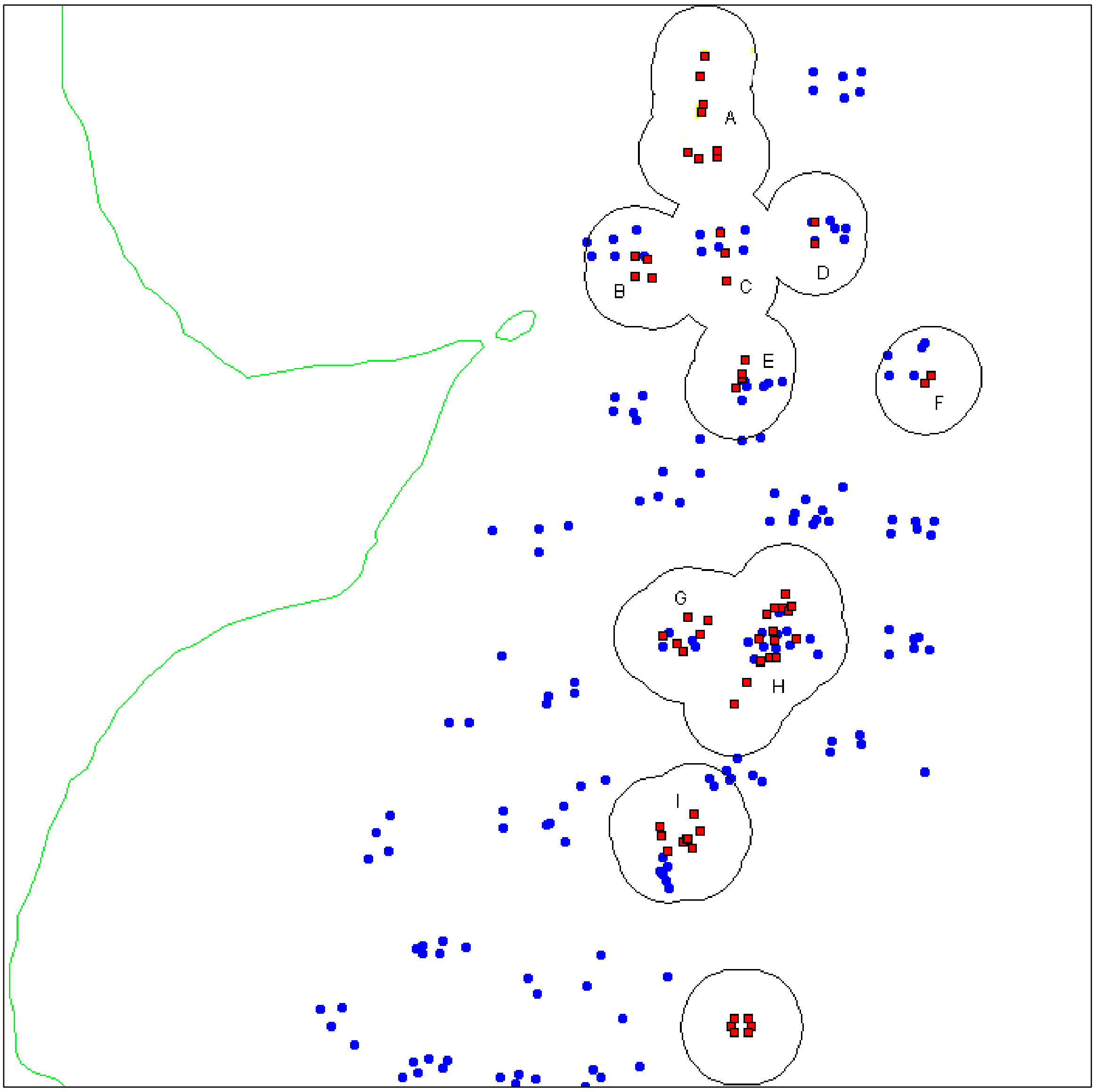

Figure 9 Maerl survey points, pre-dredging (2000-3, blue dots) and post dredging (2006-8, red squares). The labelled buffer zones A-I around the clusters of post-dredging surveys are used to select the pre-dredging data for direct comparison.

Significant declines are evident in groups A, G and I (t-Test p= 0.005, 0.003, <0.001 respectively) and E and H (Mann Whitney Rank Sum Test p=0.016 and <0.001 respectively). The apparent decline in group B is not statistically significant. Reducing the buffer zones to 125m, removes group E as having shown significant decline.

The average density post dredging is 60% of that pre-dredging (across the 9 areas, using both buffer zone radii).

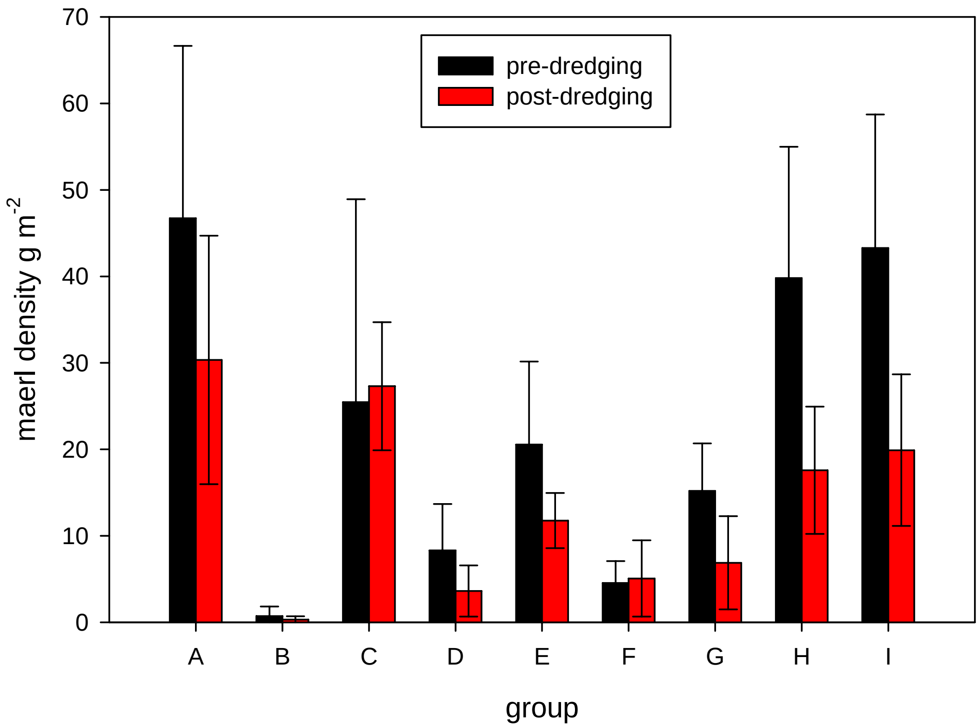

Figure 10. Comparison of average post-dredging data with pre-dredging sites within 250m, data from Table 2. The error bars indicate 1 standard deviation.

Another method of representing the maerl density data is shown in Fig 11 below. Here the density data pre- and post-dredging have been interpolated (method IDW, 500m fixed radius) within ArcView 3.2 then the surfaces compared. The core band of denser maerl is very evident in the 2000-3 data (left Fig.11). Lower values in the 2006-8 (centre Fig.11) are evident simply from the common classification colour scale. This is confirmed by the extensive areas of loss (right Fig.11).

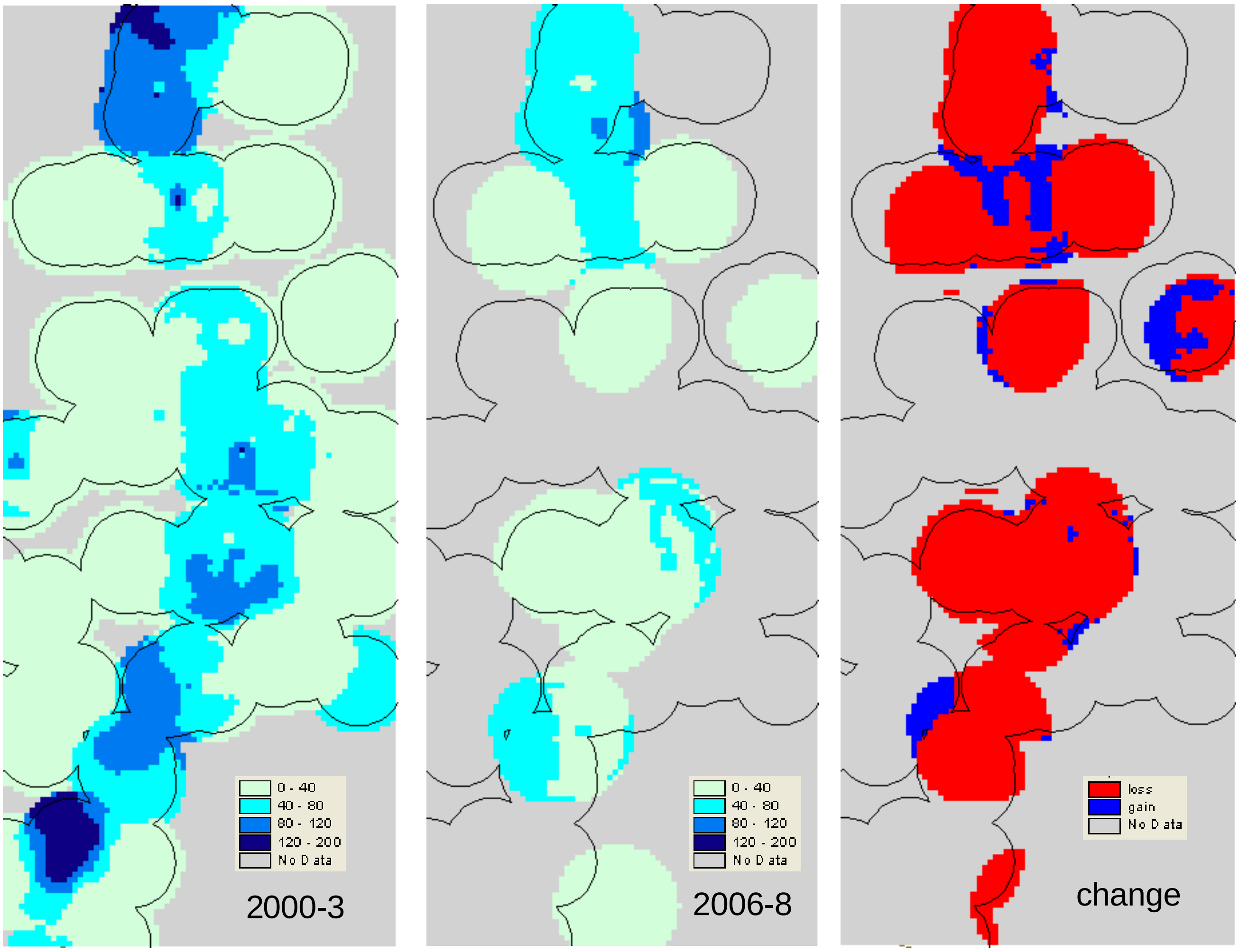

Figure 11. Interpolated maerl density (g m^{-2}) 2000-3 (left), 2006-8 (centre) and net change (right).

3.1.Maerl growth studies

A novel environmental monitoring technique was explored in collaboration with Prof. Christine Maggs, Queens University Belfast. Studies by Buchan (2005) showed that the Poole Bay maerl rhodoliths contain both annual growth rings and monthly sub-rings representing growth during the summer. These were detected by electron microscope examination of sections. Prof. Maggs' team has been using micro CT scanning of whole specimens. Samples of maerl collected in August 2007 were similarly examined by electron microscopy at NOCS by Wright (2008). Analysis of these did not detect any change in maerl growth patterns in the years prior to and post the dredge spoil disposal campaign in the winter of 2005/2006.

Maerl is very sensitive to increase in fine sediment loading in suspension and deposition, even very small amounts will cause it to die (Wilson and Maggs, 2004). It is probable that increased sediment loading in Poole Bay as a result of the dredged spoil disposal in the winter of 2005/2006 may simply have killed maerl rhodoliths outright rather than impacting their growth rates.

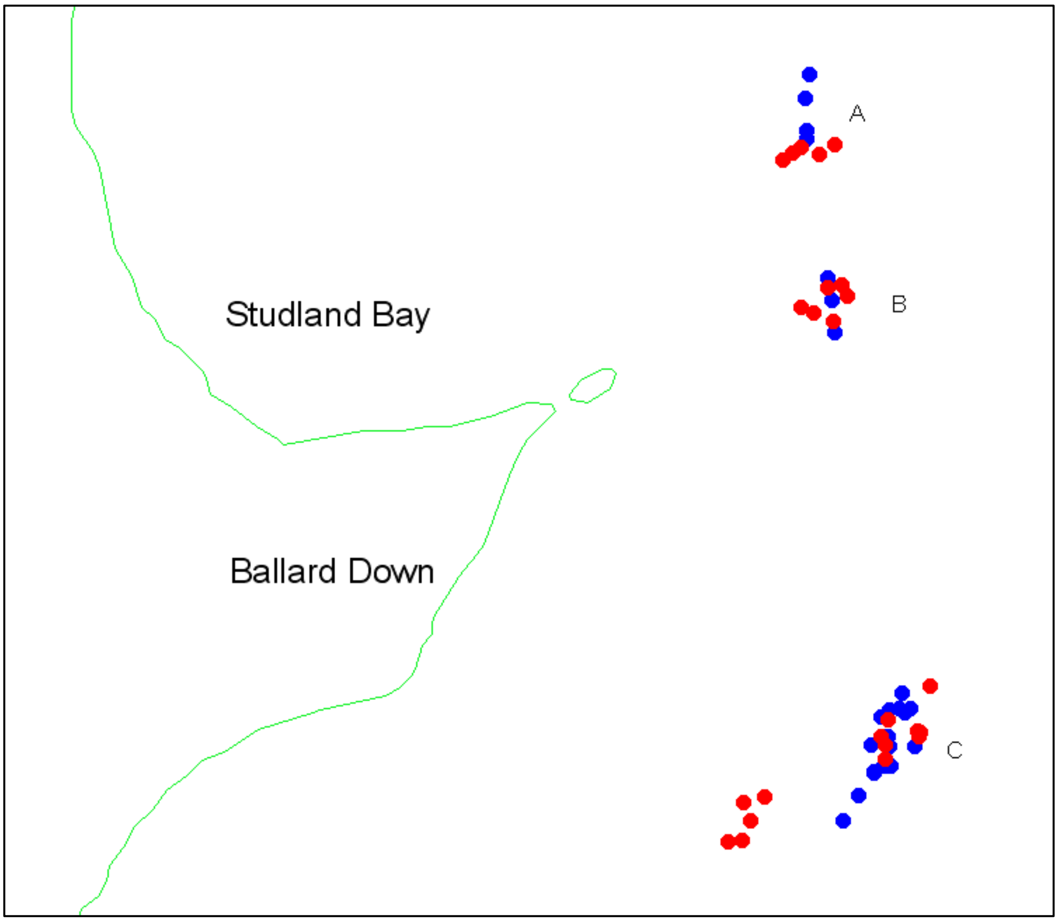

Figure 12. Maerl surveys 2006 (blue dots) and 2009 (red)

During summer 2009 maerl sites surveyed in 2006 (following dredging) were re-surveyed to determine if there had been any further change in density three years after dredging. Comparing only samples within 125m of (as described at the start of this section) from the areas A-C in Fig.12 above the average density for 2006 was 15.8 ±8.7g m^{-2} (n=33) compared to 17.5 ±7.3g m^{-2} (n= 31). Statistically (Mann-Whitney Rank Sum Test) there is no significant difference between the values but the marginal increase is consistent with the slow growth of rhodoliths over the intervening 3 years.

Summarising the maerl story, the density remained stable 2000-3, showed a decline in density of 40% post-dredging and disposal, but has remained stable subsequently (2006-9). In hindsight the maerl should have been surveyed in summer 2005, immediately prior to channel deepening. However it is considered highly probable that the decline is attributable to the extra suspended sediment load arising from the dredging and disposal operations over winter 2005/6

6. Reef biota studies

Mallinson *et al.* (1999) documented the colonisation of the Poole Bay artificial reef since its deployment in 1989 alongside the biota of natural patch reefs in Poole Bay. This provides a baseline for comparison of species occurrence post-dredging. One of the potential impacts of increased sedimentation in Poole Bay could be increased silt thickness on reef surfaces which, in turn, may adversely affect sessile fauna and flora growth.

Table 3 below lists the species present before the dredging and post-dredging (2006 to 2009). There is no evidence for loss of any species.

Table 4 Species of reef fauna and flora present before and after dredging.

Taxon	Species	common names
PORIFERA	*Dysidea fragilis*	
	Esperiopsis fucorum	shredded carrot sponge
	Hemimycale columella	
	Hymeniacidon perleve	
	Leucosolenia complicate	
	Suberites carnosus	
CNIDARIA	*Aglaophenia parvula*	
	Halecium halecinum	
	Hydrallmania falcate	
	Laomedea flexuosa	
	Nemertesia antennina	antenna hydroid
	Plumularia setacea	
	Tubularia larynx	
ANNELIDA	*Bispira volutacornis*	twin spiral worm
	Pomatoceros triqueter	keel worm
CRUSTACEA	*Acasta spongites*	Barnacle
	Balanus crenatus	Barnacle
CRUSTACEA	*Cancer pagurus*	edible crab
	Carcinus maenas	green shore crab
	Galathea squamifera	squat lobster
	Galathea strigosa	squat lobster
	Homarus gammarus	European lobster
	Maja squinado	spiny spider crab
	Necora puber	velvet swimming crab
	Pagurus bernhardus	hermit crab
	Pagurus cuanensis	hermit crab
	Palaemon serratus	Prawn
MOLLUSCA	*Calliostoma zizyphinum*	painted topshell
	Crepidula fornicate	slipper limpet
	Gibbula cineraria	grey topshell
	Ocenebra erinacea	Tingle
	Ostrea edulis	European oyster

Table 3.cont. Species of reef fauna and flora present before and after dredging.

Taxon	Species	common names
BRYOZOA	*Bicellariella ciliate*	
	Bugula plumose	
	Chartella papyracea	
	Flustra foliacea	Hornwrack
	Pentapora foliacea	Ross 'coral'
	Disporella hispida	
	Electra pilosa	
TUNICATA	*Aplidium punctum*	
	Ascidia mentula	
	Clavelina lepadiformis	Light bulb sea squirt
	Polycarpa sp.	
	Styela clava	
	Diplosoma listerianum	
ALGAE	*Bryopsis plumose*	
Green	*Cladophora sp.*	
Brown	*Undaria pinnatifida*	
Red	*Calliblepharis ciliate*	
	Delesseria sanguinea	sea beech
	Gracilaria bursa-pastoris	
	Griffithsia corallinoides	
	Heterosiphonia plumose	
	Lithothamnion type crust	coralline crust
	Phyllophora crispa	
	Phyllophora pseudoceranoides	
	Plocamium cartilagineum	
	Rhodymenia holmesii	
	Spyridia filamentosa	

7. Reef Algae

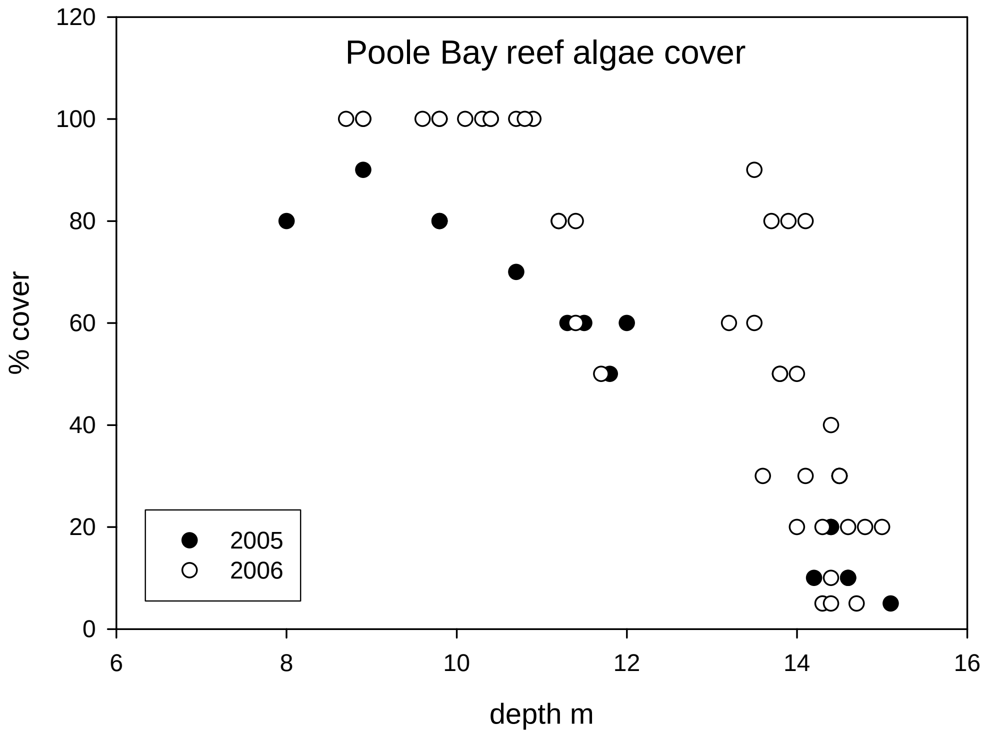

Figure 13. Poole Bay patch reef algae cover on horizontal surfaces determined in summer 2005 and 2006.

The small patch reefs within the Bay support typically a mixture of brown (*Dictyota dichotoma*) and red algae (*Calliblepharis ciliata*) species shallower than 10mCD and purely red algae below this depth. One of the potential impacts of increased sedimentation in Poole Bay could be increased silt thickness on horizontal reef surfaces which may adversely affect algal growth. To check this, algal coverage and maximum height were measured at a range of depths (8-15m) on several patch reefs in summer 2005 and again in summer 2006, post-dredging.

There is no evidence for any adverse impact post-dredging.

8. Pink sea fans, *Eunicella verrucosa*

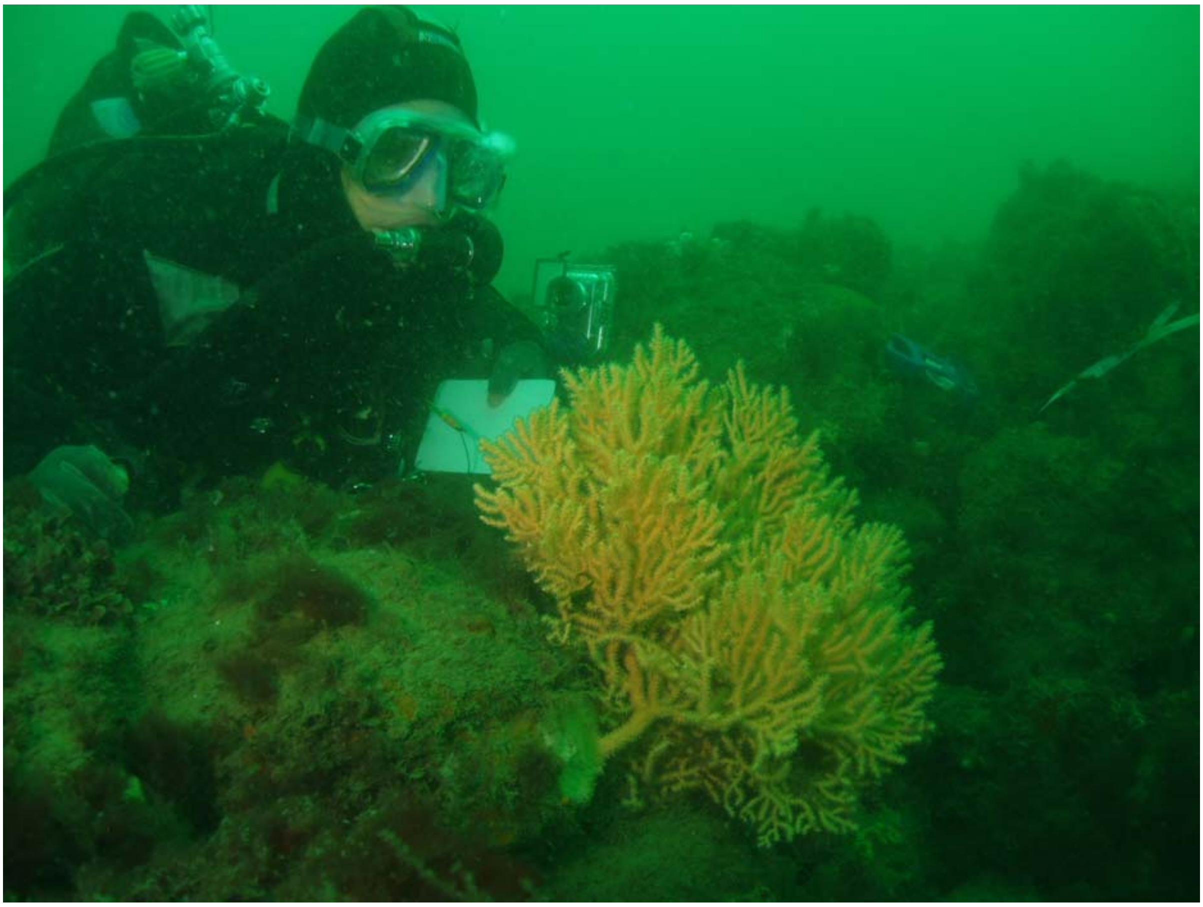

Figure 14. Healthy pink sea fan growing on a Poole Bay patch reef, photographed August 2006, post-dredging/disposal

Poole Bay represents the eastern-most extent of the pink sea fan, *Eunicella verrucosa*, along the English Channel. To date four specimens have been found on isolated patch reefs within Poole Bay. Of these, two were relocated in summer 2006. Fig.14 shows one which has clearly has not suffered from raised suspended matter levels during the previous winter . The second specimen was located attached beneath an overturned rock slab, presumably moved by recent hauling of pot lines. The rock was returned to its original position and the sea fan found to be remarkably unaffected by this event or the dredging/disposal.

9. Ross worm reefs

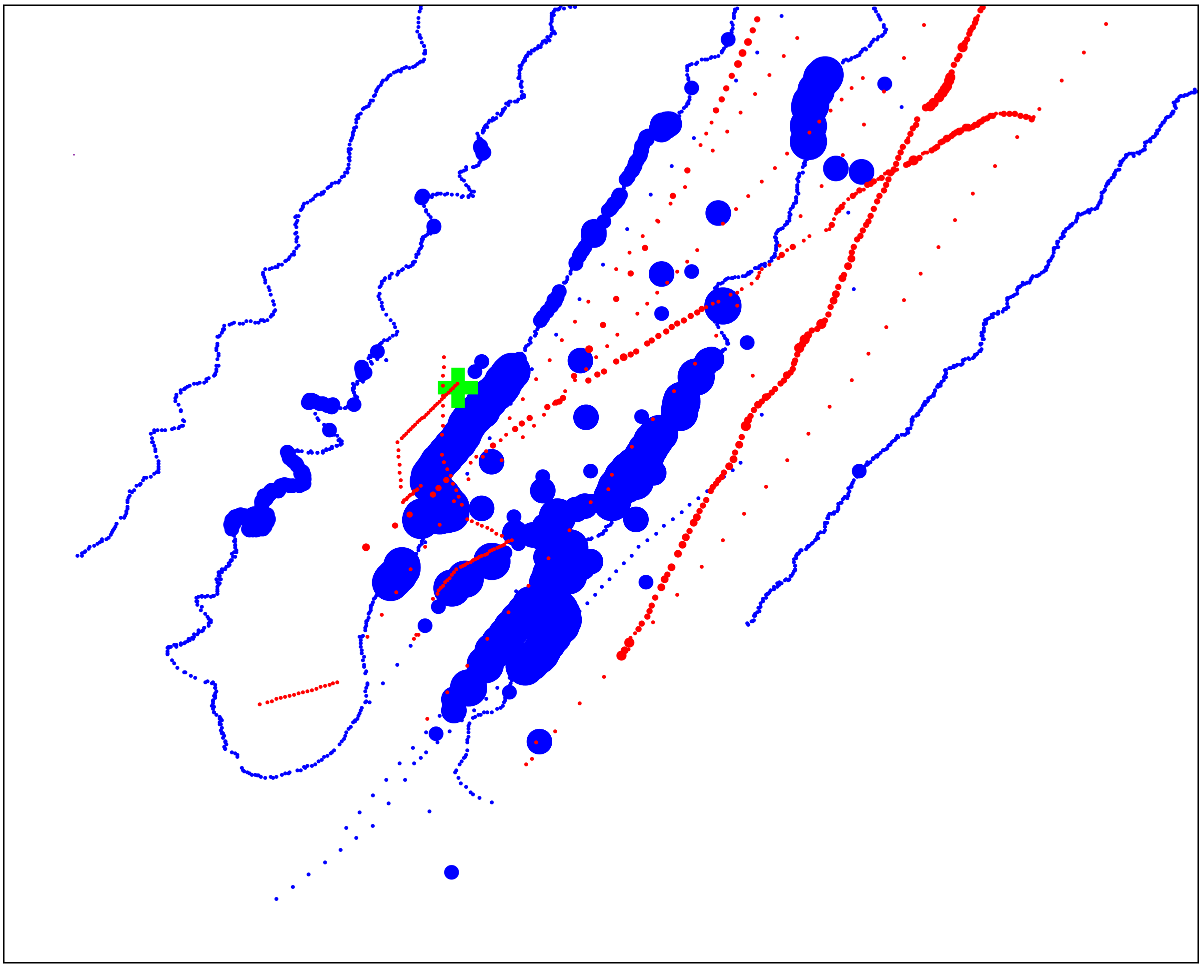

Figure 15. Core Sabellaria reef area off Swanage (see Fig.1) approximately 1 km2, showing results of surveys 2002-4 (blue dots) and 2005-6 (red dots). Dot size is proportional to density with the smallest dot size representing absence of Sabellaria reefs. The green cross marks the location the sediment depth monitoring site.

The extent and density of the *Sabellaria spinulosa* reefs off Swanage have been monitored by towed seabed video sledge and drift diving since 2002. In 2004 some indication of damage by trawling was first noticed within the core area shown in Fig.15 above. It was considered essential to carry out a thorough survey in 2005 prior to the Poole Harbour dredging and spoil disposal. It was very evident that no extensive areas of undisturbed reef remained in the core area. Typically the reefs existed (prior to 2004) as irregular mounds 2-10m across and 0.5 high. Surveys in 2005 and 2006 showed that these had almost universally been levelled with only a thin band of damaged tubes around their perimeter. Small clumps still remained in the lee of isolated rocks and reefs, plus a patch of small reef clumps to the north of the area enclosed by Fig.15.

No detrimental effects attributable to the spoil disposal were noted. The sediment depth monitoring site (a series of metal poles in the seabed) showed no new accumulation of sediment post disposal.

10. Conclusions

The sedimentation studies and diver observations point to retention of silt from the dredging disposal within Poole Bay. Modelling (by HR Wallingford, see Haskoning 2005) of silt from the disposal ground suggested that it would be carried anti-clockwise around Poole Bay with some deposition during neap tides but re-suspension during spring tides. The extra silt remaining from the dredging and disposal is remobilised during storms and presumably largely re-settling in the Bay. There is some indication that sedimentation rates are returning to pre-dredging levels.

One of the concerns was that increased sediment levels would adversely a range of organisms by smothering or simply inhibiting growth. Algae grow on the upper horizontal surfaces of the many patch reefs, thus could be particular vulnerable to increased sedimentation. No impact on reef algal density was found. Similarly a range of established reef associated species was examined in each of the 3 years post-dredging, with no evidence for loss. There was no effect on the rare Pink seafan (*Eunicella verrucosa*).

Seagrass (*Zostera marina*) traps sediments and requires light to grow so again is vulnerable to excess sedimentation. No impact was observed from detailed shot density studied (in the summers before and after deepening) in the Harbour, adjacent to the Training Bank and in Studland Bay.

Another species, *Sabellaria spinulosa* which form a biogenic reef habitat off Swange of high nature conservation had been largely destroyed by fishing (dredging and trawling immediately prior to the channel deepening. There was no evidence for increase sediment accumulation at this site.

The free-living calcareous algae maerl occurs in a narrow band off Ballard Down Its density remained stable 2000-3, showed a decline in density of 40% post-dredging and disposal, but has remained stable subsequently (2006-9). In hindsight the maerl should have been surveyed in summer 2005, immediately prior to channel deepening. It is considered highly probable that the decline is attributable to the extra suspended sediment load arising from the dredging and disposal operations over winter 2005/6.

As the Spoil Ground is close to the maerl and *Sabellaria* areas, prior to the Channel deepening the author requested that CEFAS/DEFRA consider moving this licensed disposal area further eastward and seaward. Given that modeling predicted movement of material would be SW-NE and not directly towards the maerl, disposal was limited to sector furthest from the Harbour. Since there has been an impact on the maerl, movement of the Spoil Ground should be considered for future capital dredging disposal.

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ANNEX D – INNER POOLE PATCH STUDY

Species recorded on Inner Poole Patch 30 July 2014

Rachel Fell & Dr Ken Collins

Phylum	Group	Species	English name	Lin	Nick
PERIFORA	sponges	Amphilectus fucorum	shredded carrot sponge		r
		Dysidea fragilis		r	
		Hymeniacidon perleve		o	
		indet.	sponge crust	o	
CNIDARIA	hydroids	Laomedea sp.			
ANNELIDA	worms	Bispira volutacornis	twin spiral worm	r	r
		Pomatoceros sp.	keel worm	o	
CRUSTACEA	barnacles	Cirrepdia indet.	barnacles	f	
	crabs	Necora puber	velvet swimming crab	o	
MOLLUSCA	sea slugs	Elysia viridis		p	
	gastropods	Crepidula fornicata	slipper limpet	f	s
		Gibbula cineraria	grey topshell	r	
		Rissoa parva		p	
BRYOZOA	foliose	Amathia lendigera		p	
		Bowerbankia cf pustulosa			o
		Chartella papyracea		o	o
		Flustra foliacea	hornwrack		o
	encrusting	Electra pilosa		f	
		indet.	orange bryozoan crust		o
		indet.	red bryozoan crust	f	
TUNICATA	seasquirts	Aplidium punctum		o	
		Botryllus schlosseri	star ascidian	p	
		Corella eumyota			r
		Polycarpa sp.			r
		Styela clava	leathery sea squirt		r
	didemnids	didemnidae indet		o	
PISCES	fish	Crenilabrus melops	corkwing wrasse	o	
		Ctenolabrus rupestris	goldsinny wrasse	o	o
		Gobiusculus flavescens	two-spot goby	f	o
		Labrus bergylta	ballan wrasse	o	
		Parablenius gattorugine	tompot blenny	o	
		Syngnathus acus	gtrater pipefish	r	
		Trisopterus luscus	pout	f	f

Phylum	Group	Species	English name	Lin	Nick
ALGAE	green	Cladophora pellucida		r	r
		Cladophora sp.		p	
		Ulva lactuca	sea lettuce	o	
		Ulva sp.			r
	brown	Dictyopteris membranacea			o
		Dictyopteris polyp		o	
		Saccharina latissima (juv.)			r
		Saccorhiza polyschides			r
		Sporochnus pedunculatus			r
		Taonia atomaria (epiphytic)			r
	red	Aglaothamnion byssoides (=tenuissimum)		c	
		Asparagopsis armata falkenbergia phase			o
		Bonnamaisonia asparagopsis		r	o
		Brongniartella byssoides		o	o
		Calliblepharis ciliata		c	a
		Callophyllis laciniata		o	f
		Ceramium sp.			p
		Chondrus crispus			o
		Compsothamnion thuyoides		p	
		Cryptopleura ramosa		f	s
		Dasya pumicosa		o	
		Dudresnaya veerticillata		o	o
		Gracilaria sp.			r
		Hypoglossum hypoglossoides		o	
		Monospora pedunculata		f	
		Naccaria wiggii			r
		Phyllophora crispa		o	
		Phyllophora pseudoceranoides		f	
		Plocamium cartilagineum		o	o
		Rhodomenia pseudopalmata		f	
		Rhodophyllis divaricata		o	
		Sphondylothamnion multifida		c	
		Spyridia filamentosa		a	

ACFOR Key a = abundant, c = common, f = frequent, o = occasional, r = rare. p = present, s = sampled