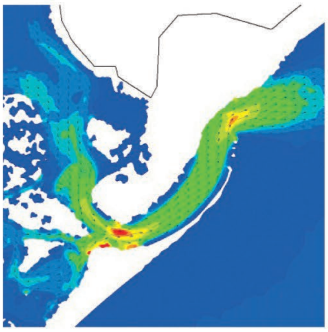
ABP Ipswich

Monitoring the Disposal of Maintenance Material in River Orwell

2019 Monitoring Period

December 2019

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Summary

ABP Ipswich undertook its annual dredging and bed levelling campaign between the 11 April and 20 April 2019, in which *circa* 25,600 t of maintenance dredge material was deposited within the River Orwell between Woolverstone Marina and Collimer Point. This total dredge volume was made up of *circa* 6,300 t from all river side cargo berths and *circa* 15,700 t from channel, Royal Harwich Yacht Club (RHYC) and through the bridge, and a further 3,700 t for dredging on behalf of the RHYC. This accounted for one quarter of the amount that can be dredged under the licence. To satisfy the conditions placed on the marine licence, ABP Ipswich undertook comprehensive monitoring for this dredge campaign (method agreed with Cefas and the MMO) to attempt to record the fate of the deposited material within the estuary, particularly the intertidal, at and beyond the immediate area of disposal. This report provides a discussion of the results arising from the March - April 2019 monitoring campaign and longer-term trends.

The results of the 2019 monitoring are consistent with the longer-term trends which indicate erosion in the down-estuary half of the monitoring area and stability up-estuary. Despite the increased supply of sediment, the effects of the dredge disposal remain small compared with the overall on-going natural variability. In 2019 there was evidence of morphological change around Collimer Point, however it is still difficult to identify the specific effects of the dredge disposal operations.

The monitoring has shown the effects of the disposal to be negligible in affecting morphological change on the mudflats, to the extent that the actual effects are almost impossible to measure. The natural variability caused by the natural flow and wave conditions dominate the functioning of the River Orwell and minimise the effects of the dredge-disposal. Hence, the monitoring has shown the effects of the disposal to be negligible in affecting morphological change on the mudflats.

This monitoring confirms the conclusions from previous years and support the decision made by the MMO that monitoring had "served its purpose" and could be restricted in future to the photography of graduated markers (Email from Lovett, N. MMO 24/04/2019[1]).

[1] Email: Lovett, N. MMO 24/04/2019.

> *"On review of the report and in consultation with Cefas, we advise that the monitoring undertaken so far has served its purpose. However, no significant impacts (positive or negative, e.g., localised areas of accretion) have yet been observed and minor changes cannot be conclusively attributed to the works. Accordingly, future monitoring should be updated and can afford to be relaxed, specifically, the Booner Tube monitoring can be terminated. We suggest leaving the graduated markers in situ, to provide a relaxed monitoring tool for subsequent works. Logistically, these can be easily surveyed during the works and although they do not provide detailed results, they do contribute additional data and could be useful for:*
>
> - *Providing a long-term record of any gradual changes in localised areas; and/or*
> - *Providing an indication of significant, localised and rapid changes (i.e., likely associated with the works)."*

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1 Introduction

Associated British Ports (ABP) Ipswich has a marine licence allowing the port to deposit maintenance dredged material, originating from the channel and berths at Ipswich in the River Orwell, between Woolverstone Marina and Collimer Point (Figure 1). This licence is granted subject to several conditions which are given within Section 3 of the licence.

One of these licence conditions, and the driver for this study, is the requirement for ABP Ipswich to carry out monitoring work to assess the effect of the disposal operation within the River Orwell with respect to siltation and general sediment transport from the deposit site. This monitoring has been undertaken by ABP Ipswich since 2004. Although the deposit ground has remained in the same location, the monitoring methodology was revised in 2013 with the reduction in the number of Booner Tubes and the inclusion of the stake monitoring to attempt to better capture the sediment transport processes arising from the disposal activities.

The outcomes of these monitoring campaigns have been previously assessed annually, whereby considerable differences with respect to accretion, erosion and sediment transport have been identified. The key outcomes identified from the previous monitoring and the subsequent assessments of the available information are as follows:

- Deposited material moves quickly through the monitoring area, predominantly in the main channel flows, i.e. the sediment is naturally transient;

- The different size characteristics of material deposited give rise to different patterns of sediment movement, with finer sediments present throughout the water column and coarser sediment predominantly found nearer to the bed;

- There is evidence of some sedimentation of finer material over high elevated mudflats, whilst coarser sediments are typically only observed to settle close to the channel on the lower mudflats. This, however, is variable from year to year and long-term measurements of mud flat levels indicate that any lasting sedimentary effects of the dredge disposals are negligible compared to the natural trends and variability; and

- In some years, during neap tides, there is evidence of some temporary accretion occurring in the middle of the original monitoring area towards the northern side of the estuary. However, this material was re-eroded as tidal ranges increased (i.e. towards and over springs) and the supply of material from the dredge/disposal ceases.

In general, the monitoring carried out prior to 2013 indicated that most of the deposited material is continually transient, predominantly moving in the main estuary flows. A proportion of this sediment is transported across the intertidal areas, where some deposition has been identified through sediment sorting (i.e. finer material being moved/deposited higher on the mudflat and the coarser fractions further down the profile). This deposition was typically seen to be temporary as the monitoring also identified natural erosion characteristics of the mudflats at times (even when disposal was occurring), especially during periods of higher wind and wave action. Overall, the monitoring showed the disposal strategy does supply additional material to/over the intertidal, but the amounts and variability were too small to be able to ascertain the absolute accretion/erosion effects. This indicates that disposal activity has negligible effects on the morphological changes occurring in the estuary. Continuation of the disposal within the estuary does however maintain the sediment budget of the estuary compared to depositing at an offshore location.

Whilst the monitoring prior to 2013 was comprehensive in answering the question posed in the original licence condition, following further discussions with Cefas and the Marine Management Organisation (MMO) in January 2013, a revision to the monitoring programme was agreed. The aim of the revision was to determine the actual accretion occurring from the disposal activity from the ongoing morphological trend, alongside the natural variability.

The overall area of monitoring was increased to record the presence of the deposited material within the estuary beyond both the immediate area of disposal and the existing monitoring area. To achieve this, the introduction of graduated measuring stakes within the estuary at appropriate locations was agreed with Cefas (pers. comm. Tammy Stamford, 15 February 2013). Further details of the revised monitoring methodology are provided in ABPmer, 2013.

ABP Ipswich undertook its annual dredging and bed levelling campaign between the 11 April and 20 April 2019, in which *circa* 25,600 t of maintenance dredge material was deposited within the River Orwell between Woolverstone Marina and Collimer Point. This total dredge volume was made up of *circa* 6,300 t from all river side cargo berths and *circa* 15,700 t from the channel, and through the bridge, and a further 3,700 t for dredging on behalf of the Royal Harwich Yacht Club (RHYC). This accounted for one quarter of the amount that can be dredged under the licence. To satisfy the conditions placed on the marine licence, ABP Ipswich undertook comprehensive monitoring for this dredge campaign (method agreed with Cefas and the MMO) to attempt to record the fate of the deposited material within the estuary, particularly the intertidal, at and beyond the immediate area of disposal. This report provides a discussion of the results arising from the March - April 2019 monitoring campaign and longer-term trends.

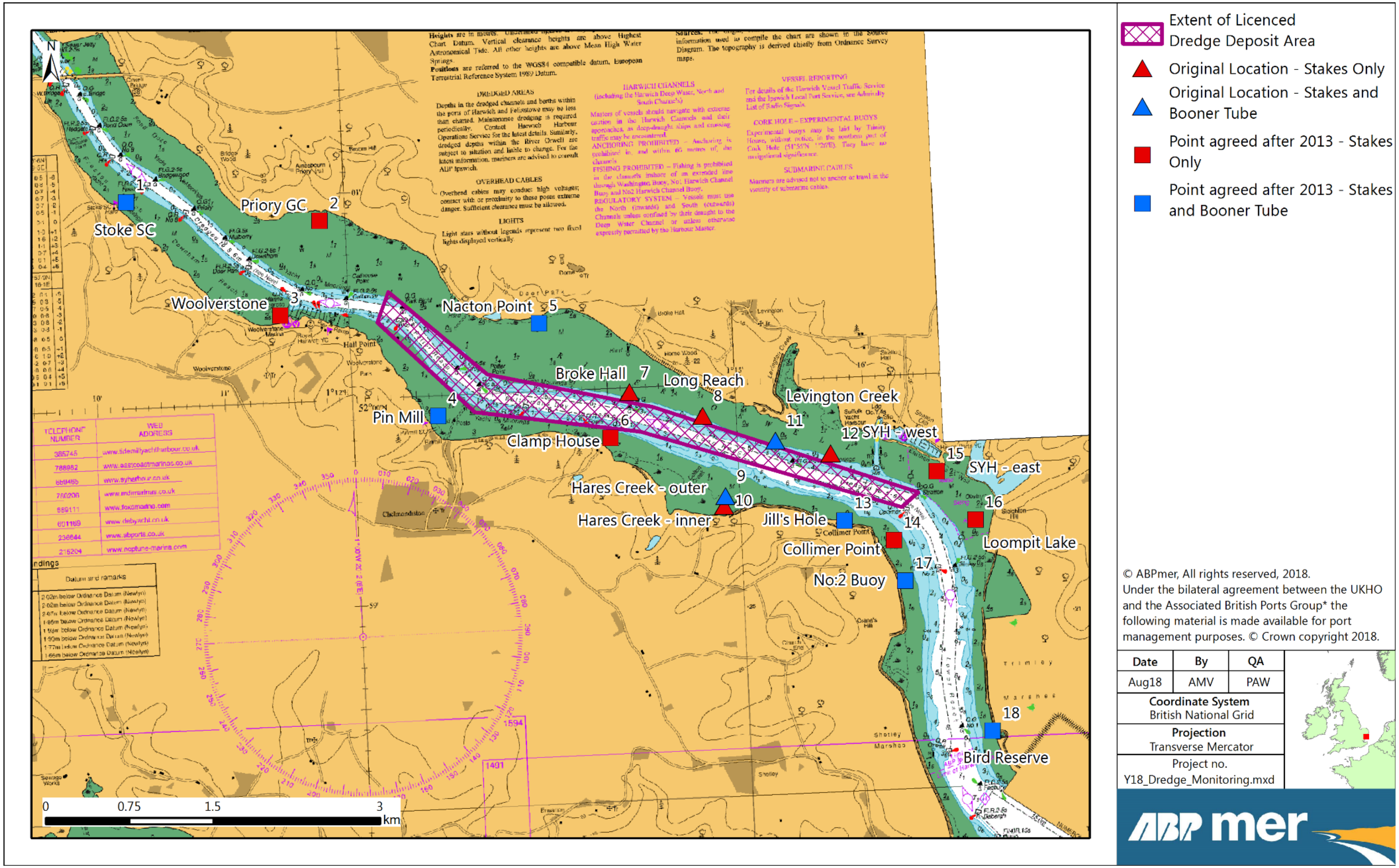


Figure 1. **Ipswich 2019 dredge-disposal monitoring - Stake and Booner Tube location**

2 Methodology

Three different methods for monitoring sediment transport were required for this year's monitoring campaign in accordance with the MMO licence to identify the fate of the deposited dredge material:

- Booner Tubes measuring the proportion of sediment in the near bed water column analysed for:
  - Total Suspended Sediments (TSS); and
  - Particle Size Analysis (PSA);

- Measuring stakes indicating direct erosion and accretion changes on the mud flats and bed sediment sampling at the measuring stakes (and subsequent particle size analysis (PSA). This was an additional requirement for this year's monitoring campaign under the current licence condition agreement.

2.1 Booner Tubes

Booner Tubes were deployed at eight positions throughout the River Orwell, shown in Figure 1 (blue icons), to help identify sedimentary processes (i.e. accretion, erosion and general sediment transport). The deployment locations for the Booner Tubes were agreed with Cefas prior to the commencement of the monitored dredge disposal campaign of June 2013. The positioning of two Booner Tubes at the original locations allows for the continuation of long-term analysis, with six newer locations spread further afield throughout the estuary.

The Booner Tubes were placed during Pre-disposal, During and Post-disposal to investigate if the sediment deposited can be seen within the tubes because of increased suspended sediment within the water column. The TSS were calculated by normalising the data over a 10-day period to allow for comparable results due to the different lengths of time for each tube deployment. A 10-day period was chosen for ease of comparison through all the years of assessment.

All eight tubes were recovered after each period and the sediment volume captured within the devices was measured and analysed for PSA in the ABPmer sediment laboratory which is a current participant in the NE Atlantic Marine Biological Analytical Quality Control Scheme (NMBAQC)[1].

For comparative purposes, samples taken from representative dredger locations (e.g. Orwell Bridge) were also subject to PSA testing. These samples were collected from the dredger hopper. The monitoring period over which the Booner Tubes collected samples (e.g. between individual deployment and recovery cycles) extended from 12 March 2019 to the 24 April 2019. This period was broken down into Pre, During and Post-disposal periods. Table 1 shows a summary of the mean tidal state and the tide conditions over the monitoring period along with the sampling dates. These tidal states can be compared with normal tidal characteristics of the estuary, shown in Table 2.

It should be noted that due to a delay in the proposed 2019 dredging campaign, the Pre-disposal period for sediment collection was considerably longer than the other two phases. Although the data has been standardised, this extended period with more variations in weather and tidal conditions could affect the overall certainty of the results.

[1] http://www.nmbaqcs.org/scheme-components/particle-size-analysis/current-participants/

Table 1. Booner Tube sampling dates

Monitoring Period	Activities	Date	Min. Tide	Max. Tide	Tidal Cycle Range
A Pre-Disposal	Booner Tubes deployed	12/03/2019	-0.1 mCD	4.3 mCD	4.4 mCD
	Booner Tubes recovered	10/04/2019			
B During Disposal	Booner Tubes deployed	11/04/2019	0.6 mCD	3.8 mCD	3.2 mCD
	Booner Tubes recovered	16/04/2019			
C Post-Disposal	Booner Tubes deployed	17/04/2019	0.0 mCD	4.2 mCD	4.2 mCD
	Booner Tubes recovered	24/04/2019			

Table 2. Tide level for the River Orwell based on Harwich tide gauge[2]

Descriptors		Level
Highest Astronomical Tide	(HAT)	4.40 mCD
Mean High Water Springs	(MHWS)	4.00 mCD
Mean High Water Neaps	(MHWN)	3.40 mCD
Mean Sea Level	(MSL)	2.14 mCD
Mean Low Water Neaps	(MLWN)	1.10 mCD
Mean Low Water Springs	(MLWS)	0.40 mCD
Lowest Astronomical tide	(LAT)	-0.10 mCD

2.2 Measuring stakes

In 2013, eighteen graduated measuring stakes were placed within the River Orwell with the aim of measuring potential rates of accretion/erosion across intertidal areas due to disposal activities (see Figure 1 for locations). Photographs were taken in March, April, October and November 2019 to coincide with the Pre, During and Post-disposal periods along with the late Autumn period. This photographic data has been maintained to add to previous results to provide an indication of longer-term trends. Analysis of all the photographs taken therefore provides information on any natural trends and/or seasonal variability that may be occurring in the estuary.

The assessment of the changes was made by visual inspection of the photographs, recording temporal changes in the vertical elevation of the mud surrounding the stakes. The 'centimetric' scale on the side of the stake allowed an estimation of localised seabed elevations to be made, wherever possible to the nearest 1 mm with the aid of photographic analysis. New graduated measuring stakes were placed next to the old stakes and synchronised, as the old graduations had become damaged in the same way as discussed in ABPmer (2017). For consistency, the old damaged stakes have not been removed to allow for comparison where available. It needs be noted that Stake No. 7 (Brokehall) had a new stake fitted in the 23 July 2018 as the original stake lost its tape graduations completely. Additionally, Stake No. 14 (Collimer Point) was lost over the summer and no observations within the autumn period on 31 October 2019 could be made.

2.3 Surface sediment samples

As per the methodology in 2013 (ABPmer, 2013) in addition to the Booner Tubes and the measuring stakes, surface sediment samples were also collected near to each of the 18 stake locations when the Booner Tubes were recovered at the end of the Pre-disposal monitoring period on the 10 April and 11 April 2019. These samples were subject to PSA testing and the results used to determine the long-term changes in the sediment composition in the vicinity of the deposit site.

[2] UKHO, 2019. Total Tide software

3 Results and Discussion

3.1 Tide and weather conditions

To assess the potential reasons for changes observed over the monitoring period, differences in the tidal and meteorological (wind) conditions within the River Orwell were also considered, along with the monitoring results.

The tidal statistics (Table 2) for the area show that for the Pre-disposal period the tidal range was larger than the During disposal and Post-disposal periods. Pre-disposal elevations approached HAT level partially because of the extended period of Pre-disposal monitoring which included a spring tide phase between 21 March and 23 March. During the disposal operations, the maximum tidal level was between MHWS and MHWN. This means that flows with the potential to transport sediment and are available for collection in the Booner Tubes would have been greater before the period of dredge disposal, particularly for locations at the higher elevations of the mudflat. This needs to be considered in the discussion of the results obtained, along with possible effects of the extended monitoring period.

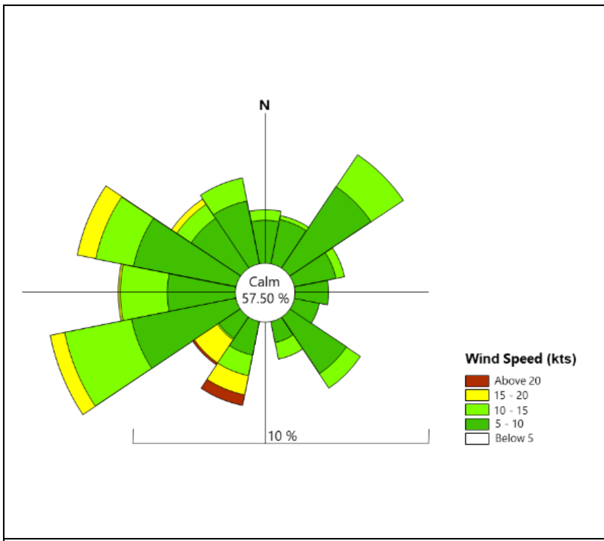
Table 3 specifies the daily-averaged and daily maximum wind speeds and predominant directions over the monitoring periods. Note that no data was available during the end of the Post-disposal period between the 21 April and 24 April 2019. Figure 2 also provides wind roses for the meteorological conditions observed at hourly intervals.

Daily-averaged wind speeds for the three monitoring periods varied from 3.6 to 5.1 knots with the lowest speeds occurring During and Post-disposal. Daily maximum wind speeds were significantly higher during the Pre-disposal phase with directions from all sectors. The highest winds were generally from the west with the maximum recorded wind of 42.6 knots from south-southwest. The wind direction distribution was similar for the During (Period B) and Post-disposal (Period C), with all winds from the eastern sectors (no westerly components) at much lower speeds than those that occurred during the Pre-disposal (Period A). The most dominant wind was from the NE.

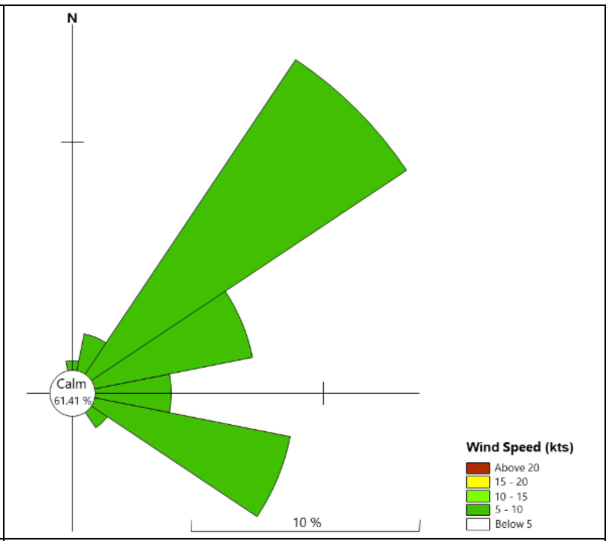
Table 3. Daily wind conditions for the period between 12 March and 21 April 2019

Monitoring Period	Date	Daily-Averaged Wind Speed (knots)	Daily Maximum Wind Speed (knots)	Daily Predominant Wind Direction* (degrees)
A - Pre-Disposal	12/03/2019 11/04/2019	5.1	42.6	W and NW
B - During Disposal	10/04/2019 17/04/2019	4.2	24.3	NE and SE
C - Post-Disposal	16/04/2019 24/04/2019	3.6	28.7	NE and SE

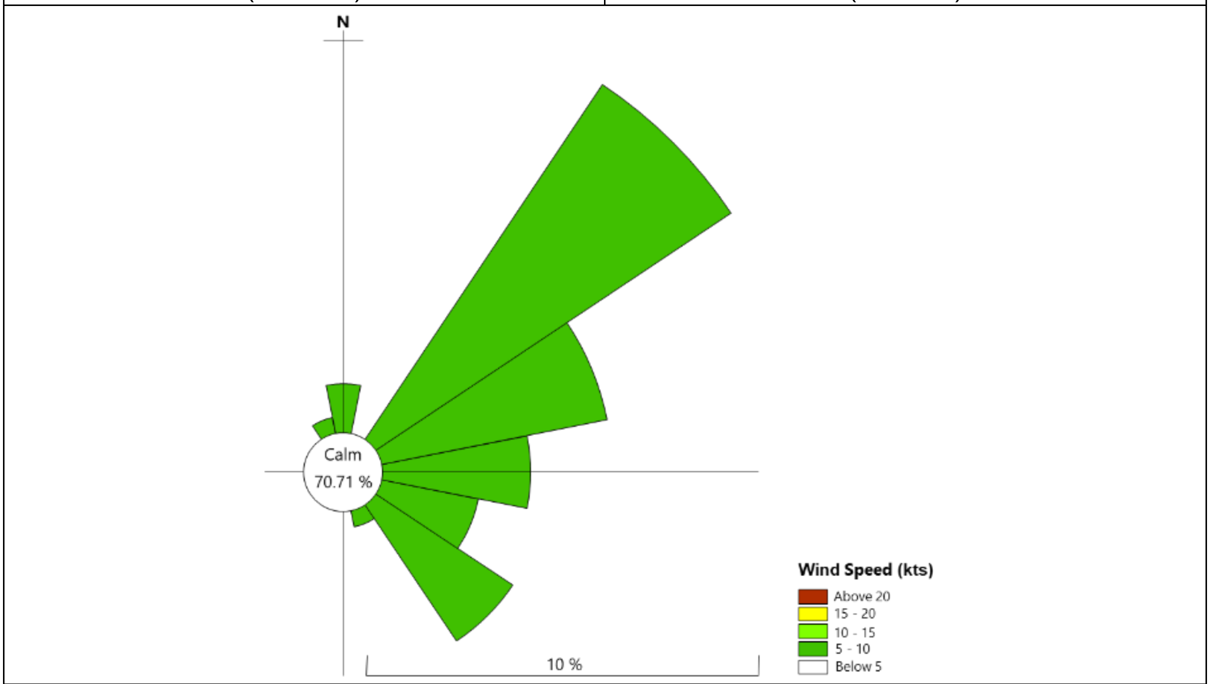
* Wind direction uses the Atmospheric convention (where winds come from).



Top Left: Pre -disposal period
(Period A)



Top Right: During disposal period
(Period B)



Bottom Post-disposal period up to 21 April
(Period C)

Figure 2. Wind roses of hourly wind speeds for the respective monitoring periods

Both Table 3 and Figure 2 tend to indicate that winds were more likely to affect sediment transport and create more disturbance in an down-estuary direction (and potentially more towards the northern bank) during the Pre-disposal period. During and Post-disposal the more dominant north-easterly winds were likely to disturb material in the up-estuary direction, and potentially more towards the southern side of the estuary. The actual effect of winds will vary with the tidal state, with the greatest potential influence on the mudflats at the higher states of the tide. This potential weather forcing needs to be considered when interpreting the Booner Tube results.

3.2 Booner Tubes

As detailed previously in Section 2.1 three deployments of Booner Tubes were positioned at the eight monitoring stations (see Figure 1), giving a total of 24 samples. The Pre-disposal (Period A) deployment of the Booner Tubes lasted for 29 days, the During disposal (Period B) deployment lasted for 6 days, and the Post-disposal (Period C) deployment of the Booner Tubes were in place for 7 days. Due to the variability in deployment time the TSS data were normalised to 10 days (rounded to the nearest ml) as in all previous reports (for comparison previous years analysis is shown in Appendix A).

3.2.1 Total suspended solids

The normalised volume of material collected in each Booner Tube for the Pre (A), During (B) and Post-(C) disposal periods are provided in Table 4. The particle size distribution of the material collected in the Booner Tubes were analysed; these results are discussed in Section 3.2.2. Table 4 also shows a comparison of TSS between Periods A and B (Pre and During disposal), and A and C (Pre and Post-disposal), as a percentage (%) difference.

Table 4. Normalised (to 10 days) TSS collected in the Booner Tubes

Position	Period A TSS (ml)	Period B TSS (ml)	Period C TSS (ml)	% Difference A from B	% Difference A from C
1 (south bank)	17	17	21	0	24
4 (south bank)	34	20	6	-42	-83
5 (north bank)	59	17	6	-72	-90
9 (south bank)	34	17	14	-50	-59
11 (north bank)	110	12	14	-89	-87
13 (south bank)	97	28	17	-71	-82
17 (south bank)	76	8	21	-89	-72
18 (north bank)	24	13	43	-45	78

With the exceptions of Positions 1 and 18 at the extremities of the monitoring, all positions had the highest normalised TSS values during the Pre-disposal period than the During or Post-disposal periods. Pre-disposal volumes of sediment collected in the Booner Tubes were generally greatest in a down-estuary direction within the more E to W orientated section of the estuary.

During and Post-disposal the volumes collected were similar but substantially less at most sites within the disposal area compared to the Pre-disposal monitoring. Detailed assessment suggests the amount of sediment collected was higher up estuary During disposal than Post disposal, despite the lower range tides and similar wind conditions which would have trended to assist movement up estuary.

The During and Post -disposal comparison does tend to suggest there was a small increase in suspended sediment concentrations (SSC) over the intertidal areas During the dredge disposal. However, this effect is small when compared to the Pre-disposal data, where the SSC was substantially higher. The distribution conforms well with the prevailing wind (wave) conditions that would have occurred during that period. This again indicates the effect of the dredge disposal operations over the mudflats is small compared to the natural variations from tide and weather variability.

3.2.2 Particle size analysis

The material collected in the Booner Tubes over the monitoring programme was also analysed for particle size distribution and the resulting analyses are presented in Appendix B. These results provide a graphical representation of the gravel, sand, silt and clay contained within each sample, thus indicating the size distribution of the sediment carried within the water column at each location for the monitoring periods. For comparative purposes, samples taken from the dredger whilst dredging at locations near the Grain Terminal, West Bank North and Orwell Bridge were also subject to PSA testing. These results are also shown in Appendix B and indicate the nature of the material being transported in the estuary resulting from the dredge disposal activity.

Comparison of the PSA statistics in Figure 3 shows the change in material grading from the Pre to During disposal periods, whereas Figure 4 compares Pre and Post-disposal periods.

The three samples analysed from the dredger hopper indicated that the removed material mainly consisted of medium and fine silts; with an average median grain size (D_{50}) of *circa* 12 µm (0.012 mm, see Appendix B). Therefore, if such material is transported through the Booner Tube positions following disposal, then an increase in the proportion of fine silt and clay materials within the Booner Tubes should result.

The Pre to During disposal changes (shown in Figure 3) were as follows:

- Positions 1, 11 and 13 showed an increase in the silt fraction. Positions 11 and 13 are on adjacent banks and are towards the down-estuary end of the designated disposal area. The Booner Tubes at these locations are also lower in the intertidal (0.5-1.5 mCD) than at other Positions throughout the disposal area therefore have greater potential to collect suspended sediment. The relatively large percentage changes at these two locations suggests material has been collected from the dredged sediment disposals, and the sediment plume has moved over the banks;
- Slight fining of material at Position 1. This can be attributed to a small shift in material type between the D_{10} and the D_{50} grain sizes; most likely resulting from exposure to predominantly north easterly wind directions during the period of sediment disposal. Furthermore, no clear change in the D_{50} grain size occurred during this period. These results indicate that the change is unlikely a result of plume effects from the dredge itself; and
- Positions 4, 5 and 9 show no clear changes in sediment size. Small variations likely reflect the natural variability at these sites. The locations of the Booner Tubes at these positions are relatively high in the intertidal (2-2.5 mCD), and therefore suspended material near to these positions may not have been fully captured for the lower range tide in the During disposal period.

The Pre to Post-disposal changes are shown in Figure 4, with the notable changes being:

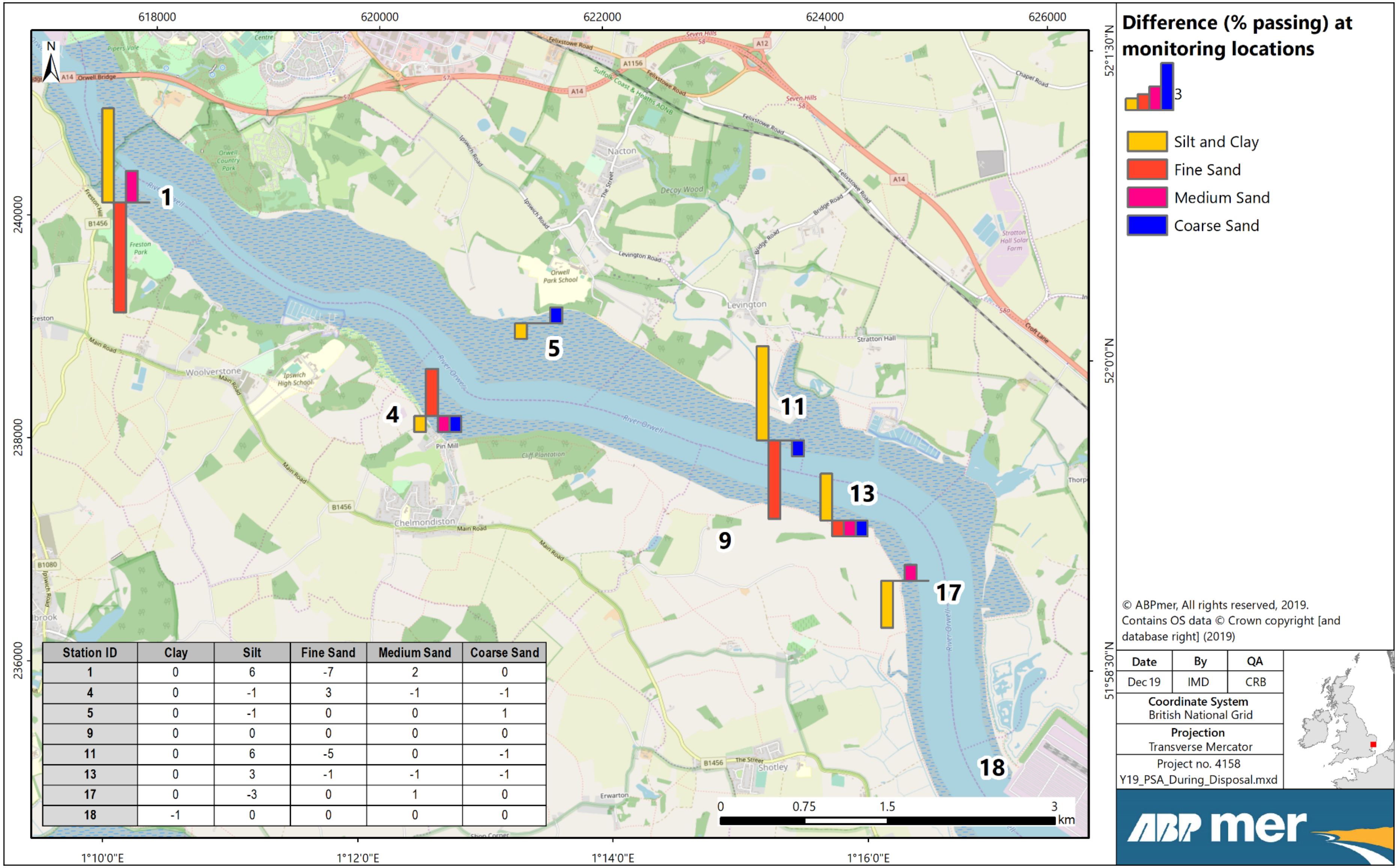
- Position 11 continued to show an increase in the silt fraction Post-disposal, whilst also showing a fining of the D_{50} grain size during this period. This possibly suggests an accretion of finer material in this area (potentially resulting from shelter from the north-easterly wind conditions); and
- All other Positions showed a coarsening of material; but particularly between Hares Creek and No. 2 Buoy (Positions 9, 13 and 17), where the Booner Tube indicated greater volumes of material passing Pre-disposal, which could have deposited hence 'fining' compared to the Pre-disposal samples. Post-disposal flow speeds would have increased compared to the During disposal phase removing the fines. Such hydrodynamic forcing may have effectively "flushed" finer Silt and Clay material out of the estuary during this period.

3.2.3 Conclusion of Booner Tube analysis

As described in Section 3.2.1, the greatest difference (a net decrease) in TSS volume occurred between the Pre-disposal period and the During disposal period itself. Individual increases in TSS occurred between the During disposal period and the Post-disposal period at positions outside of the disposal area (Positions 1,17 and 18). The particle size analysis indicates a slight increase in the contribution of fine silt and clay at Positions 11 and 13 During disposal, before a generally consistent coarsening (i.e. increase in fine and medium sands) throughout the Post-disposal period.

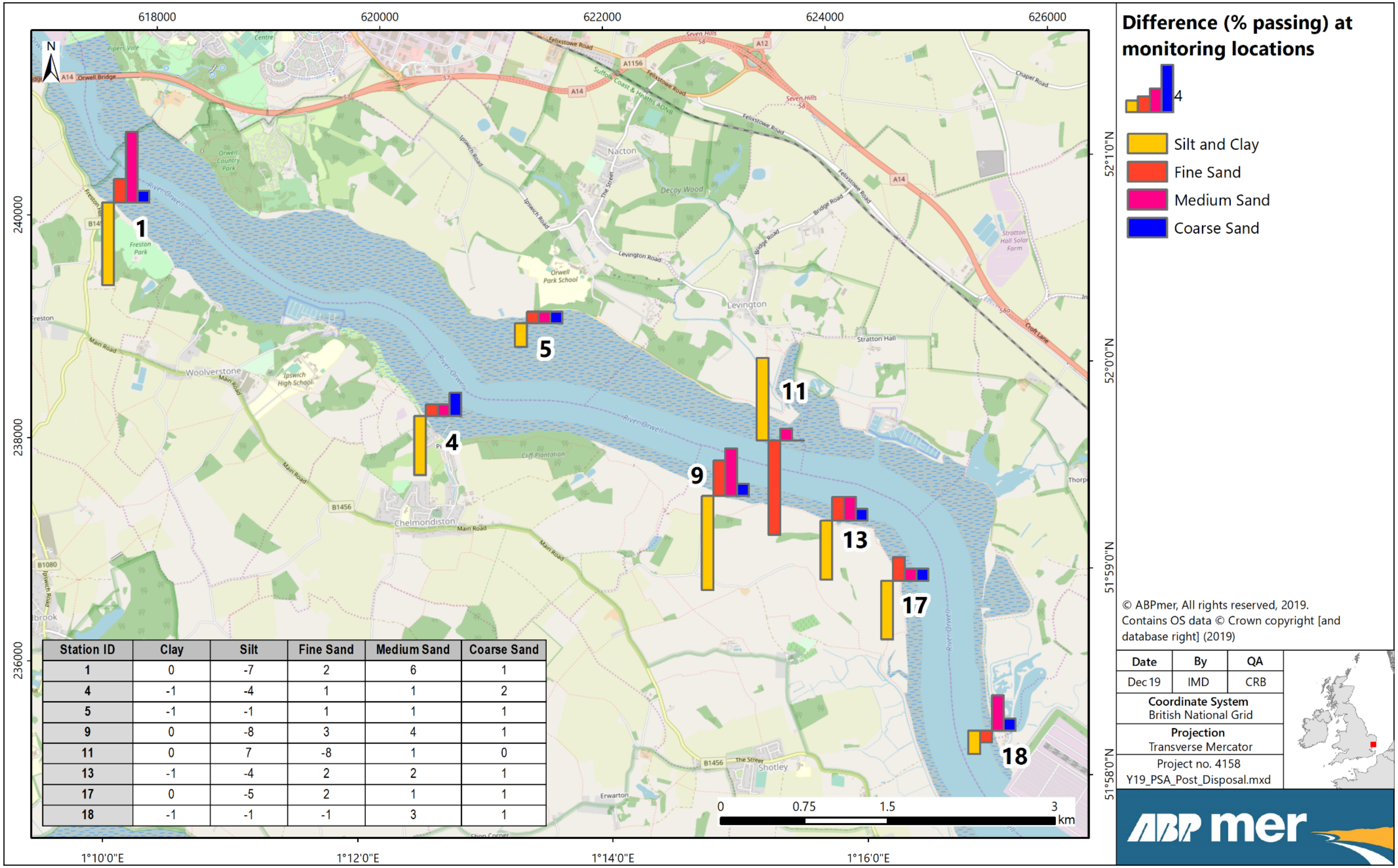
Both datasets suggest that the dredge material was quickly dispersed and initially being transported within the subtidal channel and lower areas of intertidal following disposal. Generally, negligible amounts of finer material appear to have moved into the upper intertidal Post-disposal, with only Position 11 showing consistent increases in finer material. Throughout the Post-disposal period much of the finer silt and clay appears to have been flushed out of the estuary, most likely due to a combination of changing wind conditions and contrasting spring/neap tidal phases during the respective monitoring periods. This is coherent with recent years of monitoring data (ABPmer, 2019; ABPmer, 2017).

As in previous years, monitoring the contribution of sediment from the dredge disposal remained difficult when considered against the natural variability occurring on areas of intertidal mudflats resulting from natural processes (i.e. wind conditions and tidal state). The results do tend to indicate, much greater movement and potential sedimentation at and around Collimer Point as a result of the dominant westerly wind conditions during the Pre-disposal phase.



Station ID	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand
1	0	6	-7	2	0
4	0	-1	3	-1	-1
5	0	-1	0	0	1
9	0	0	0	0	0
11	0	6	-5	0	-1
13	0	3	-1	-1	-1
17	0	-3	0	1	0
18	-1	0	0	0	0

Figure 3. Changes in particle size distribution within the Booner Tubes during disposal (Period B) compared to Pre-disposal (Period A)



Station ID	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand
1	0	-7	2	6	1
4	-1	-4	1	1	2
5	-1	-1	1	1	1
9	0	-8	3	4	1
11	0	7	-8	1	0
13	-1	-4	2	2	1
17	0	-5	2	1	1
18	-1	-1	-1	3	1

Figure 4. Changes in particle size distribution within the Booner Tubes post-disposal (Period C) compared to pre-disposal (Period A)

3.3 Measuring stakes

The dates of the stake monitoring programme are shown in Table 5 and Appendix C. This simplistic analysis shows there is considerable variability between any two measurements, but longer term some trends are apparent.

Table 5. Stake observation periods during 2019 monitoring period

Period	Dates To - From
Spring	12 March - 13 March 2019
Pre-disposal period	10 April - 11 April 2019
During-disposal period	16 April - 17 April 2019
Post-disposal period	23 April - 24 April 2019
Autumn	31 October - 01 November 2019

The stake measurements are grouped to represent the spatial extent of the long-term changes. The measured changes in bed elevation (shown in mm) are provided for each position over the complete monitoring period in Figure 5 and Figure 6 for the north and south banks respectively.

The previous monitoring of intertidal sedimentation undertaken in 2013 to 2017 (ABPmer, 2013; 2015; 2016; 2017 and 2018) had not highlighted any significant patterns of accretion or erosion at the locations of measured stakes directly relating to the dredge disposal, and therefore sedimentation could not be attributed to the disposal activities. Some locations, however, were starting to reveal longer term trends, primarily due to the natural on-going processes rather than because of the dredge disposal.

On the north bank, Figure 5 shows that most of the positions continue to show a near horizontal trend with an elevation variance of less than ±50 mm. This tends to indicate a relatively long-term stable mud flat, although most positions are marginally lower than 2013 and appear to have consistently lowered since 2018. The exception to this is Position 18 which continues to show a long-term accretion albeit the rates has slowed over time. This site is less exposed to variations in the wind/wave climate. Additionally Position 16 showed general accretion and greater variability in 2019, which goes against a long-term erosional trend. These latter Positions show accretion of *circa* 30 mm between the During-disposal and Post-disposal periods; but alone are not enough evidence to suggest a general accretion outside of natural variability as a result of the dredge disposal.

On the south bank (Figure 6), the majority of locations show near horizontal trends (i.e. relative stability) over the period of monitoring with a slightly larger variance (±100 mm) than the north bank. Some locations show small net erosion, whilst others show about the same magnitude of net accretion. Only Position 13 appears to show a significant long-term trend for erosion.

During the 2019 dredge disposal period a number of locations, particularly Positions 13, 14 and 17, around Collimer Point tend to show accretion at the Pre-disposal measurements compared to the previous autumnal level, with little change measured During the disposal, but rapid erosion Post-disposal, with the previous trend reinstated thereafter. This change is in line with the Booner Tube and PSA information at these locations. Together these data suggest the Pre-disposal winds tended to increase sediment movements over the mudflats causing accumulation around Collimer Point. There was little effect from the disposal, but the change in wind pattern and increasing tidal range caused the subsequent erosion.

As mentioned previously in Section 2.2, the stake at Position 14 was missing during this years' autumn monitoring period (see Figure 6). The sharp decrease of *circa* 120 mm may therefore be associated with an impact/disturbance that ultimately resulted in the stake being removed from this location.

On both Figure 5 and Figure 6, the period of dredge material disposal is indicated by dashed vertical lines. In these periods, there is little evidence of consistent sedimentation at many of the locations. In almost all locations the bed change monitored during these dredge disposal periods is only a few millimetres. This is considerably (over an order of magnitude) less than the overall measure of variance, which can be attributed more to the change in tidal and wind/wave conditions occurring.

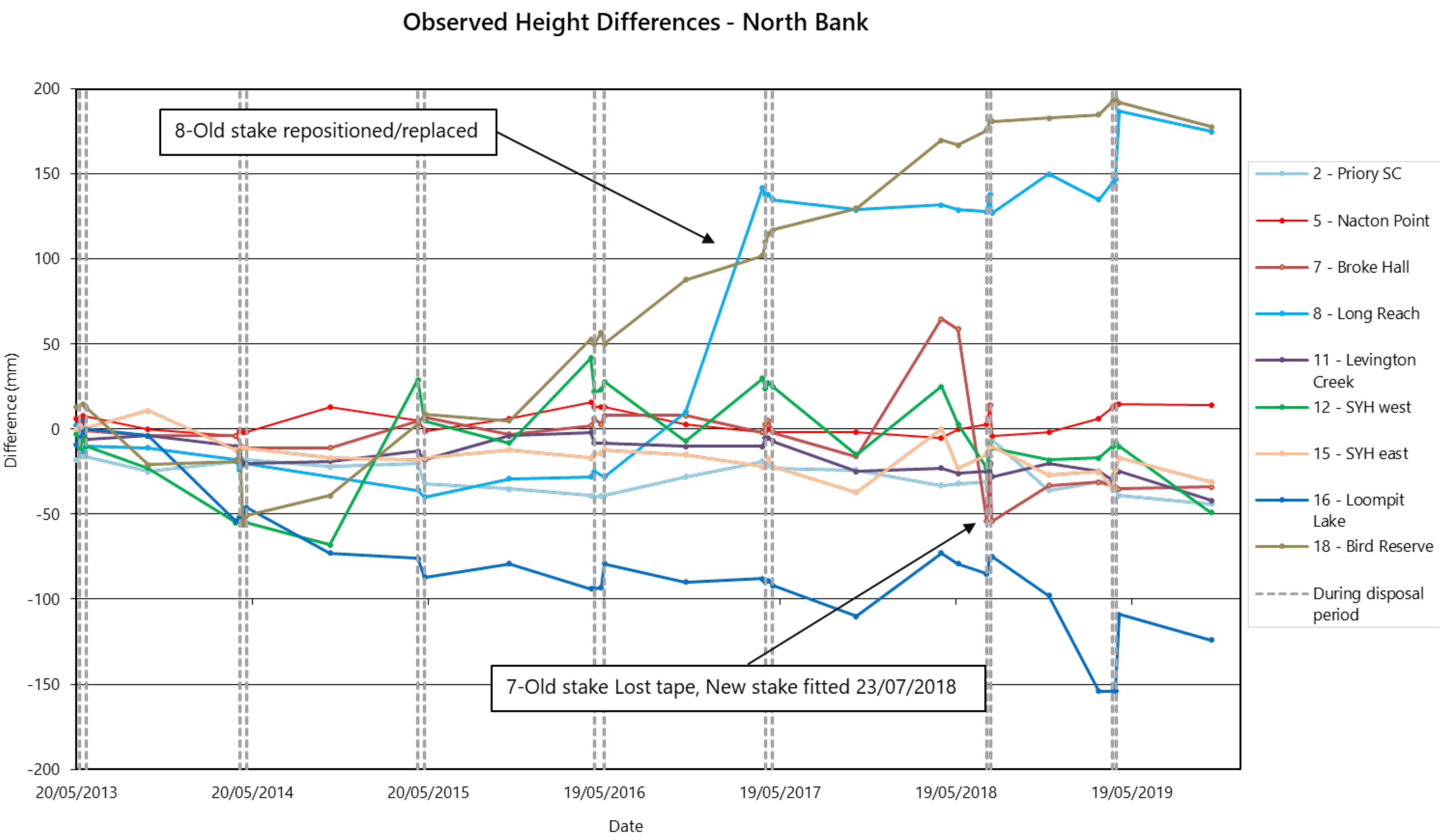


Figure 5. **Observed changes seen at the measuring stakes on the North Bank over the monitoring programme**

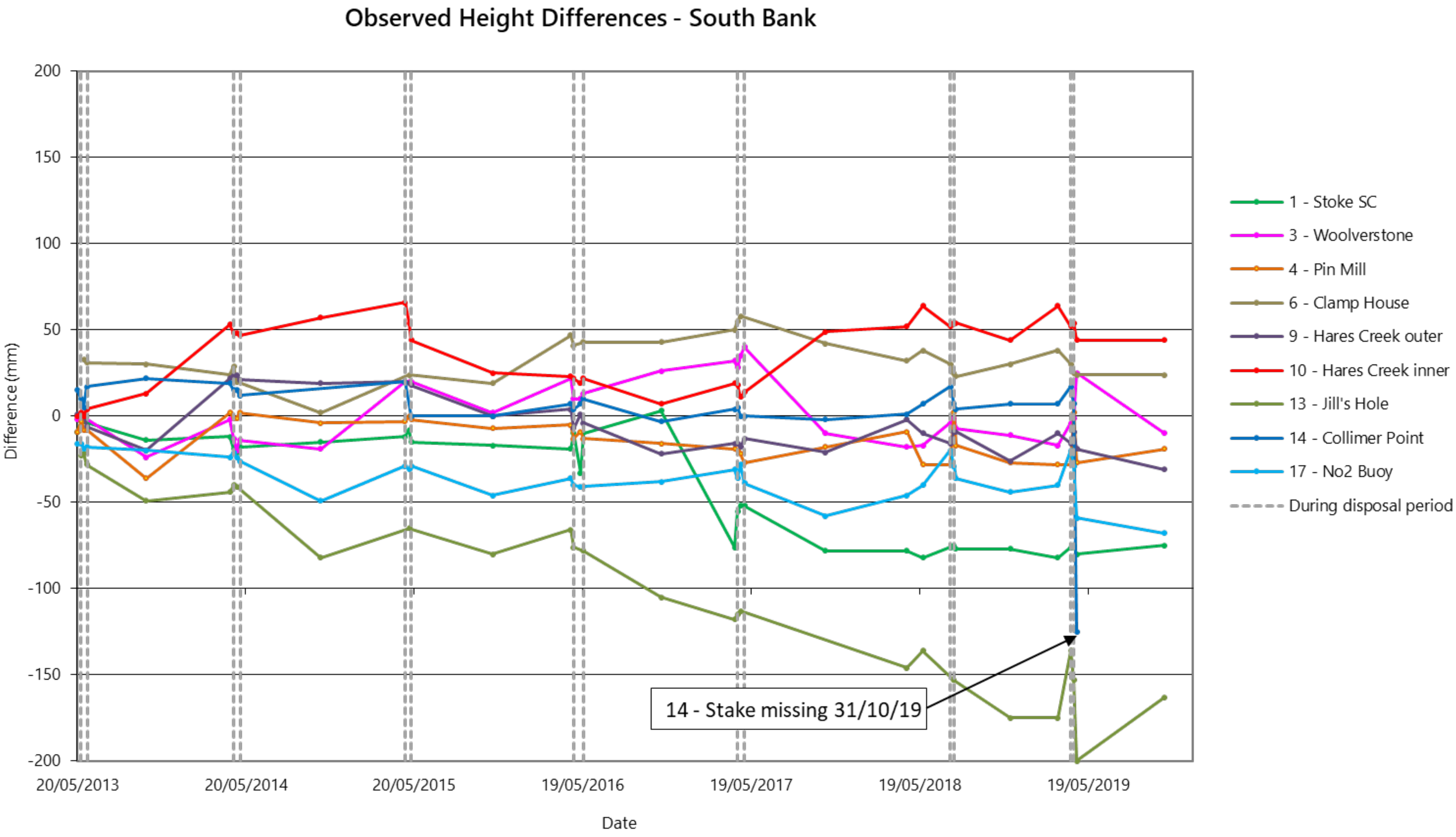


Figure 6. Observed changes seen at the measuring stakes on the South Bank over the monitoring programme

3.4 Grab samples

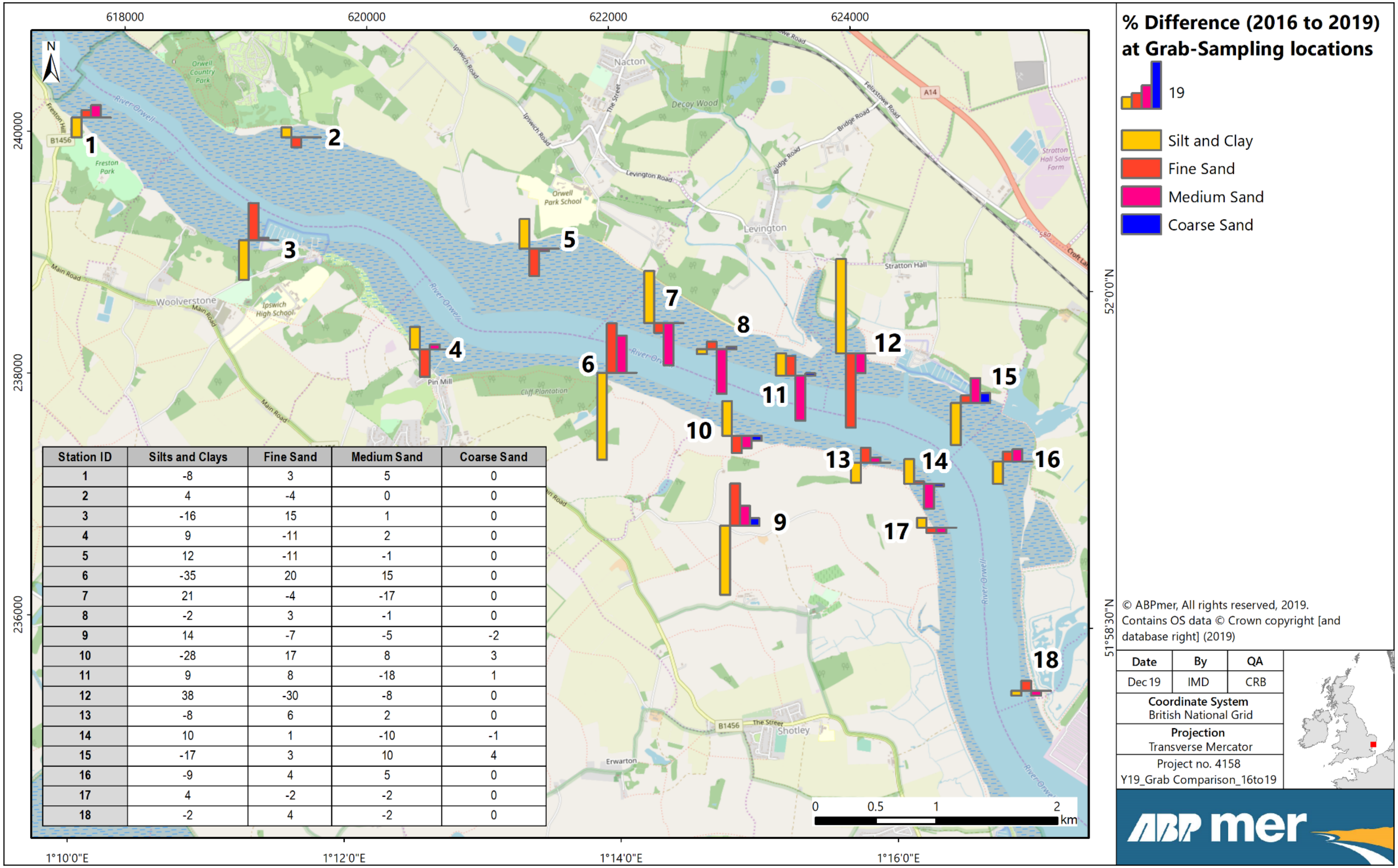
As detailed within the initial June 2013 monitoring report (ABPmer, 2013), sediment samples were taken at the 18 stake locations at the end of the Pre-disposal period for 2013. PSA testing of these surface grab samples was then undertaken. These samples have been used for baseline purposes, against which additional samples obtained during the 2016 monitoring period (28-29 April 2016) were analysed and compared for changes over a three-year period (see ABPmer, 2016).

Further samples have again been collected for this latest (2019) monitoring report and PSA testing undertaken (see Appendix B). The results have been compared to both the previous datasets. This aims to determine any changes in the general character of the intertidal over the last 3 years, as well as over a longer 6-year period since the monitoring began.

Figure 7 shows a comparison between 2016 and 2019 grab samples. During this 3-year period, positions within the disposal area on the north bank (Positions 5, 7, 8, 11 and 12) have generally become finer, whilst locations on the south bank (Positions 6, 9, and 13) show a general coarsening. Outside of the disposal area, positions up-estuary and down-estuary show a general coarsening, although the magnitude of this is small.

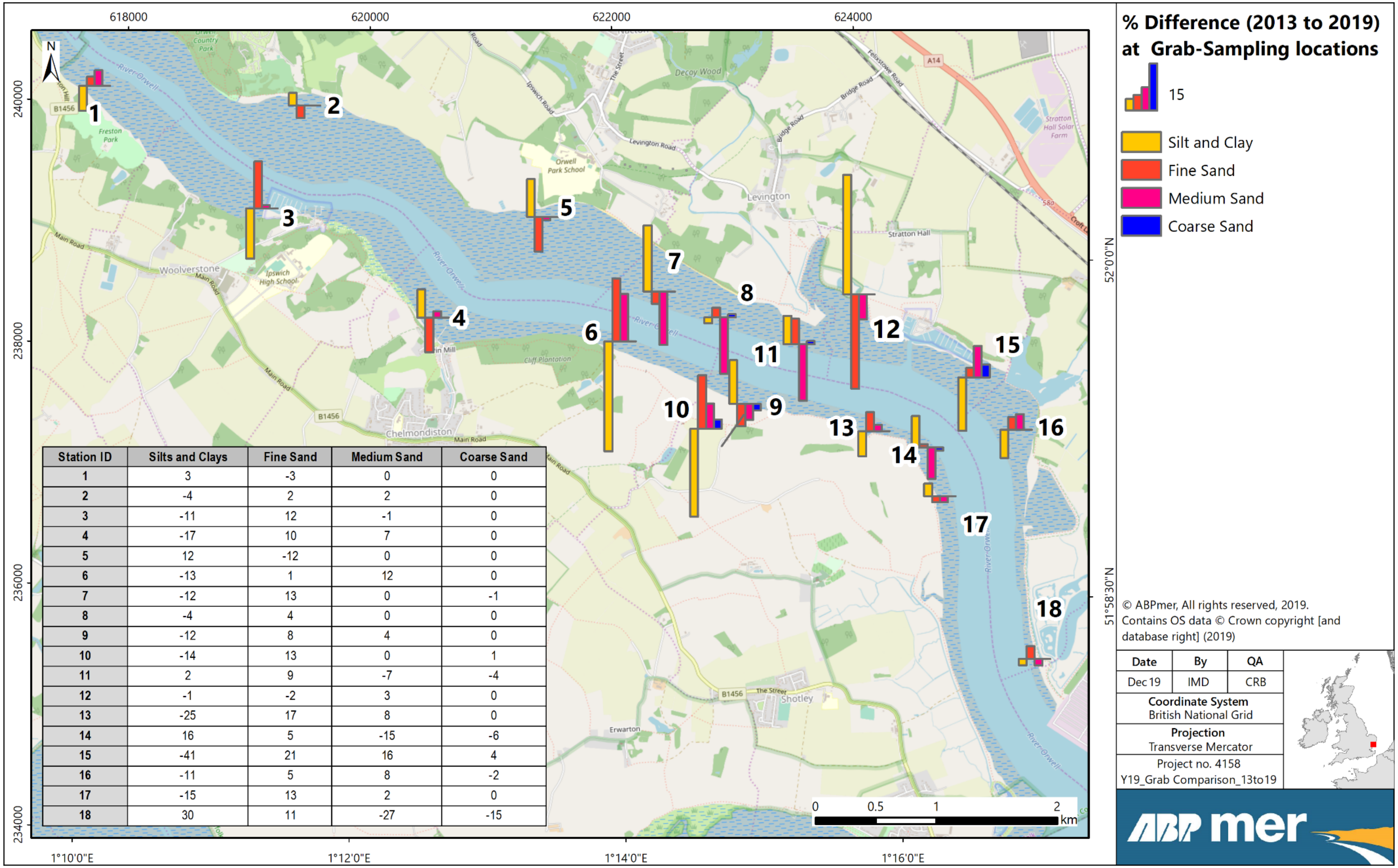
Figure 8 shows a comparison between the 2013 baseline and the 2019 samples. During this longer 6-year period, the general trend indicates that the fine (clay and silt) and very coarse sand sediment size fractions have been reduced and/or lost from the intertidal within the disposal area. This is particularly the case along the south bank. The exceptions to this pattern of coarsening are Positions 5, 14 and 18; which have showed an overall increase in the proportion of finer material. At Position 5 fining appears to have occurred predominantly during the last 3 years (see Figure 7). In contrast, most of the fining at Position 18 occurred between 2013 and 2016 (ABPmer, 2016.) These changes concur with the stake monitoring data at these specific positions (see Section 3.3), which show a small accretion (Position 5) and no change (Position 18) over the last year (see Figure 5). However, at Position 14 the fining appears to be more consistent, showing continued increases in silt and clay material between 2013-2016 (see ABPmer, 2016) and between 2016-2019 (Figure 7).

In general, little conclusive evidence can be found that indicates disposal of dredge material throughout the River Orwell has any significant long-term effect on varying the sediment erosion and accretion patterns within the estuary. The main drivers of the variability occurring in the estuary are the flows resulting from the variation in tidal range along with the wind wave conditions, particularly resulting from storms.



Station ID	Silts and Clays	Fine Sand	Medium Sand	Coarse Sand
1	-8	3	5	0
2	4	-4	0	0
3	-16	15	1	0
4	9	-11	2	0
5	12	-11	-1	0
6	-35	20	15	0
7	21	-4	-17	0
8	-2	3	-1	0
9	14	-7	-5	-2
10	-28	17	8	3
11	9	8	-18	1
12	38	-30	-8	0
13	-8	6	2	0
14	10	1	-10	-1
15	-17	3	10	4
16	-9	4	5	0
17	4	-2	-2	0
18	-2	4	-2	0

Figure 7. Changes in particle size distribution (2016 to 2019) from surface grab samples on the River Orwell



Station ID	Silts and Clays	Fine Sand	Medium Sand	Coarse Sand
1	3	-3	0	0
2	-4	2	2	0
3	-11	12	-1	0
4	-17	10	7	0
5	12	-12	0	0
6	-13	1	12	0
7	-12	13	0	-1
8	-4	4	0	0
9	-12	8	4	0
10	-14	13	0	1
11	2	9	-7	-4
12	-1	-2	3	0
13	-25	17	8	0
14	16	5	-15	-6
15	-41	21	16	4
16	-11	5	8	-2
17	-15	13	2	0
18	30	11	-27	-15

Figure 8. Changes in particle size distribution (2013 to 2019) from surface grab samples on the River Orwell

4 Conclusions

Based upon the findings of the monitoring programme for the 2019 dredging campaign, the following key conclusions can be made:

- Similar conclusion as the 2017 and 2018 campaigns (ABPmer, 2017; ABPmer, 2019) can be made regarding the results from the stake monitoring which identifies that changes (*circa* decimetres) in intertidal elevation can occur within the River Orwell over relatively short periods of time. Stake measurements in past years were inconclusive in providing sufficient evidence of intertidal sedimentation due to the dredge disposal campaigns. However, they continue to monitor the long-term natural changes which are only marginally modified by the annual disposal operations on a short timescale. These changes are at most small and often negligible with respect to the natural variation. In general, the stake monitoring indicates the trends predominantly result from the natural processes (tide and weather) within the estuary, with no changes to sedimentation patterns that can be specifically related to the dredge disposal;

- There is some evidence for ongoing morphological change surrounding Positions 13 (Jill's Hole) and 14 (Collimer Point). Whilst Booner Tube analysis in 2019 did not indicate a significant effect occurring from the dredge disposal, it did identify an accretionary effect, confirmed by stake and PSA analysis of bed sediments from storms during the Pre-disposal period. This accretion was, however, re-eroded following completion of the dredge under benign weather conditions. The long-term erosional trends at Position 13 (see Figure 6) and the existing trends at other locations were generally maintained. The area opposite Collimer Point on the north bank also shows greater variability than other locations e.g. Position 16, whilst Position 18 (Bird reserve) down-estuary continues to accrete albeit at a slowing rate; and

- Wind conditions varied in strength and direction between the different monitoring periods, as well as relatively large differences in tidal range. Wind conditions (also interacting with tidal state at the time) have been seen in past years to have an important influence on intertidal erosion/sediment disturbance at more exposed areas of the estuary. Consequently, with coincidental high tide phasing, wind induced waves over the intertidal zones could aid the removal of fine sediment with re-deposition elsewhere. During the 2019 campaign wind conditions were highly variable in both speed and direction prior to the dredge period. During the Pre-disposal phase the winds dominated from the westerly sectors with high speeds. The westerly winds caused increased suspension of sediment in a down-estuary direction, which accreted around Collimer Point. Wind speeds reduced significantly During and Post Disposal and blew from the easterly sectors, mainly the NE. These conditions were accompanied with re-erosion of the accreted material, particular during the higher tidal ranges of the Post-disposal phase. There was, however, little evidence of the effects of the dredge. Such conditions are likely to have encouraged the flushing of finer silt and clay away from the disposal area and potentially out of the estuary;

As concluded within the previous monitoring report (see ABPmer 2019), most of the previous monitoring has indicated that the natural variations occurring throughout the River Orwell are considerably greater than is evident from the dredge disposal surrounding the monitoring locations. Continuation of the current dredge disposal operations maintains the sediment in the system, compared to disposal offshore, but has little direct influence on the local intertidal areas that can be detected outside the natural variation. The latest monitoring datasets obtained during 2019 concurs with this statement, showing little evidence of direct changes resulting from dredge disposal.

As a result this monitoring continues to confirm the conclusions from previous years and supports the decision made by the MMO that the monitoring undertaken has "served its purpose"[1] and in future could be restricted in future to the photographs of the existing graduated markers (Email from Lovett, N. MMO 24/04/2019).

5 References

ABPmer, (2019). Monitoring the Disposal of Maintenance Material in River Orwell, 2018 Monitoring period, ABPmer Report No. R.3047, January 2019.

ABPmer, (2018). Monitoring the Disposal of Maintenance Material in River Orwell, 2017 Monitoring period, ABPmer Report No. R.2860, February 2018.

ABPmer, (2017). Monitoring of Disposal of Maintenance Material in River Orwell - 2016 Monitoring Period. ABPmer Report No. R.2771, February 2017.

ABPmer, (2016). Monitoring of Disposal of Maintenance Material in River Orwell - May 2015.
ABPmer Report No. R.2572, March 2016.

ABPmer, (2015). Monitoring of Disposal of Maintenance Material in River Orwell: April 2014. ABPmer Report No. R.2291, January 2015.

ABPmer, (2013). Monitoring of Disposal of Maintenance Material in River Orwell - June 2013. ABPmer Report No. R.2200, December 2013.

NE Atlantic Marine Biological Analytical Quality Control Scheme - Current Participants - PSA 2019-2020: http://www.nmbaqcs.org/scheme-components/particle-size-analysis/current-participants/

6 Abbreviations/Acronyms

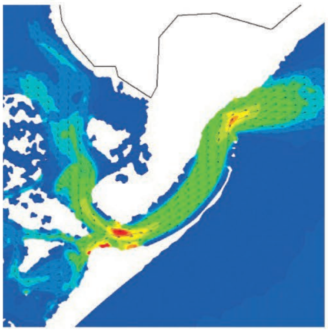
ABP	Associated British Ports
Cefas	Centre for Fisheries and Aquaculture Science
HAT	Highest Astronomical Tide
ID	Identity
LAT	Lowest Astronomical Tide
mCD	Metres Relative to Chart Datum
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
MMO	Marine Management Organisation
MSL	Mean Sea Level
NMBAQC	NE Atlantic Marine Biological Analytical Quality Control Scheme
PSA	Particle Size Analysis
RHYC	Royal Harwich Yacht Club
SC	Sailing Club
SSC	Suspended Sediment Concentrations
SYH	Suffolk Yacht Harbour
TSS	Total Suspended Solid
UKHO	UK Hydrographic Office

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

Appendices




Innovative Thinking - Sustainable Solutions

A TSS Historical Analysis

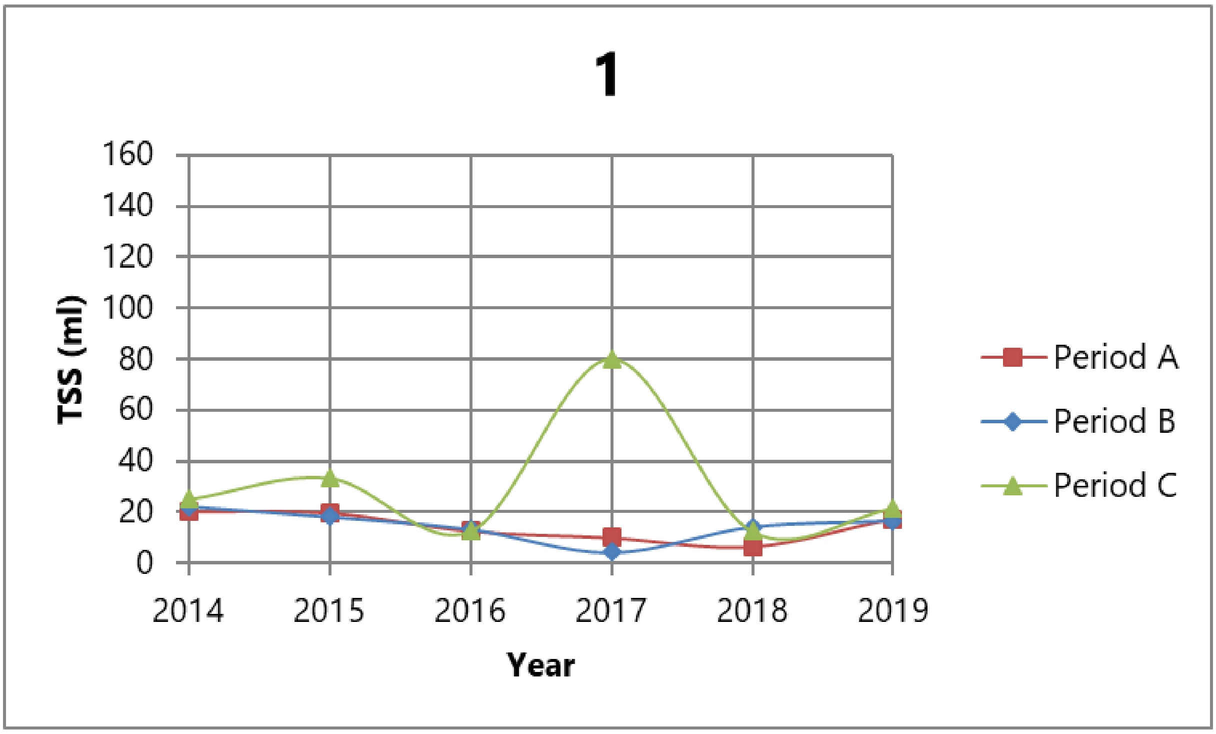


Figure A1. TSS in Booner Tube 1 - Stoke SC normalised to 10 days (South Bank)

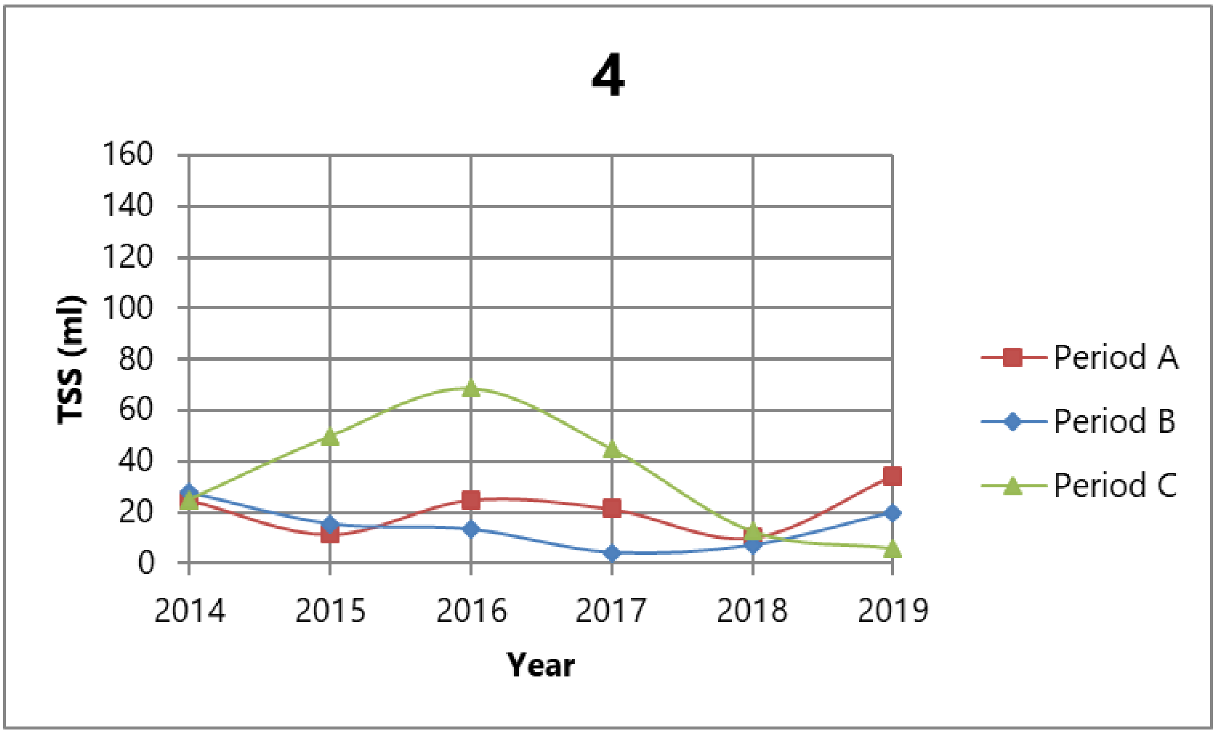


Figure A2. TSS in Booner Tube 4 - Pin Mill normalised to 10 days (South Bank)

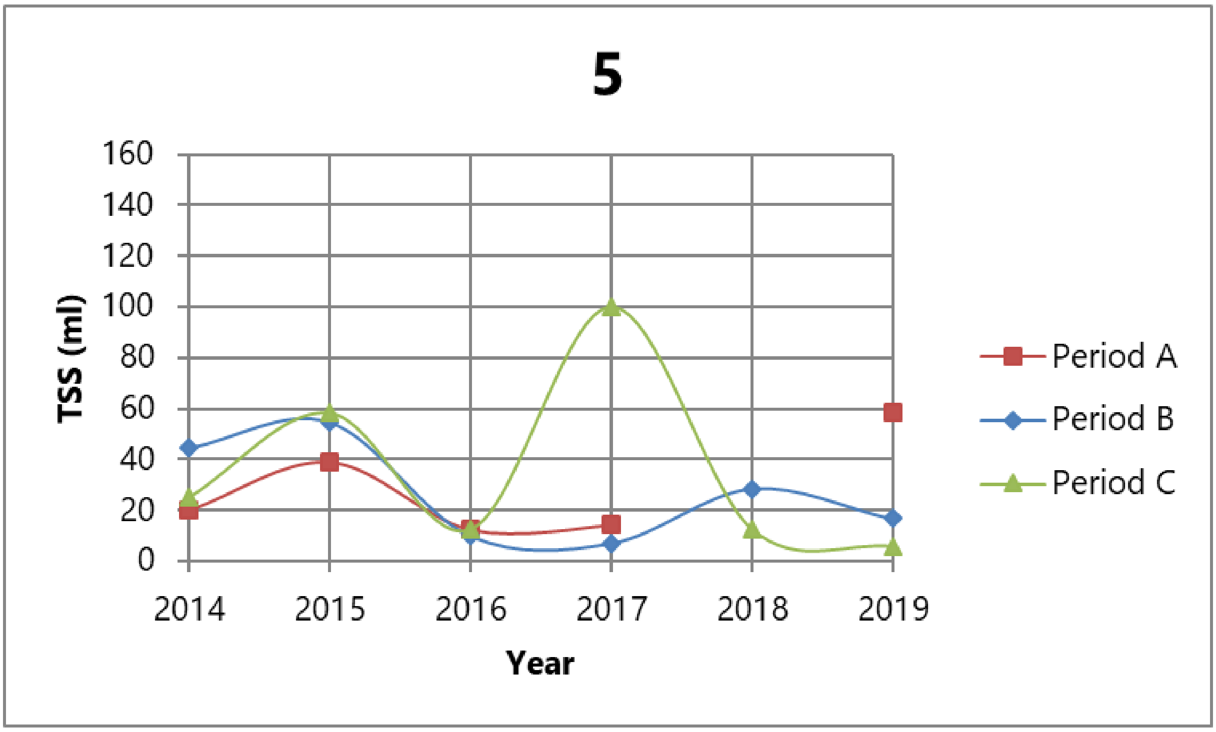


Figure A3. TSS in Booner Tube 5 - Nacton Point normalised to 10 days (North Bank)

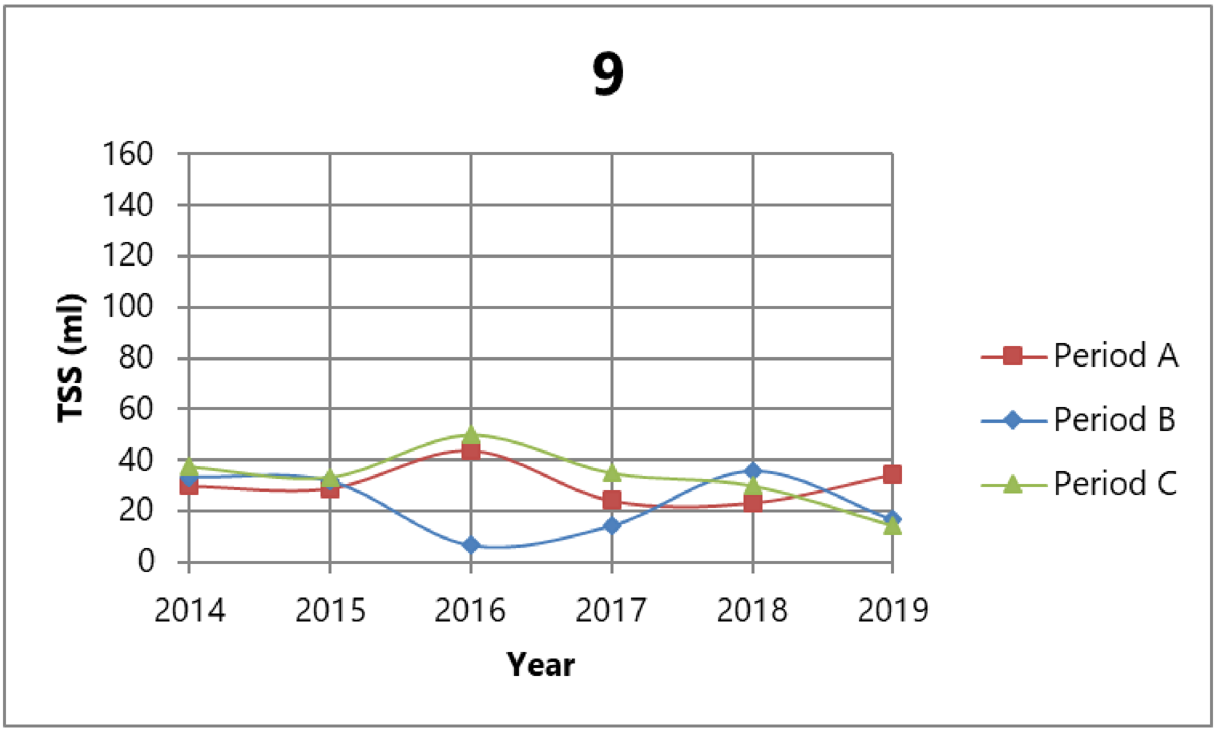


Figure A4. TSS in Booner Tube 9 - Hares Creek outer normalised to 10 days (South Bank)

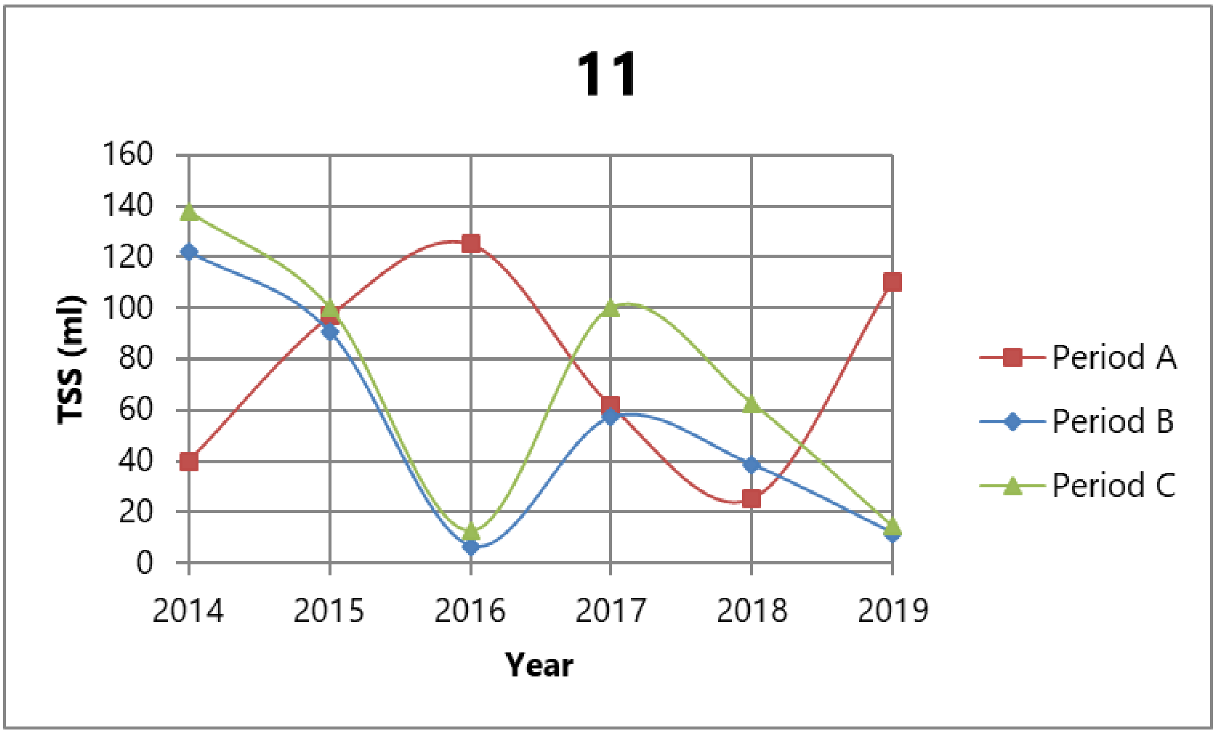


Figure A5. TSS in Booner Tube 11 - Levington Creek outer normalised to 10 days (North Bank)

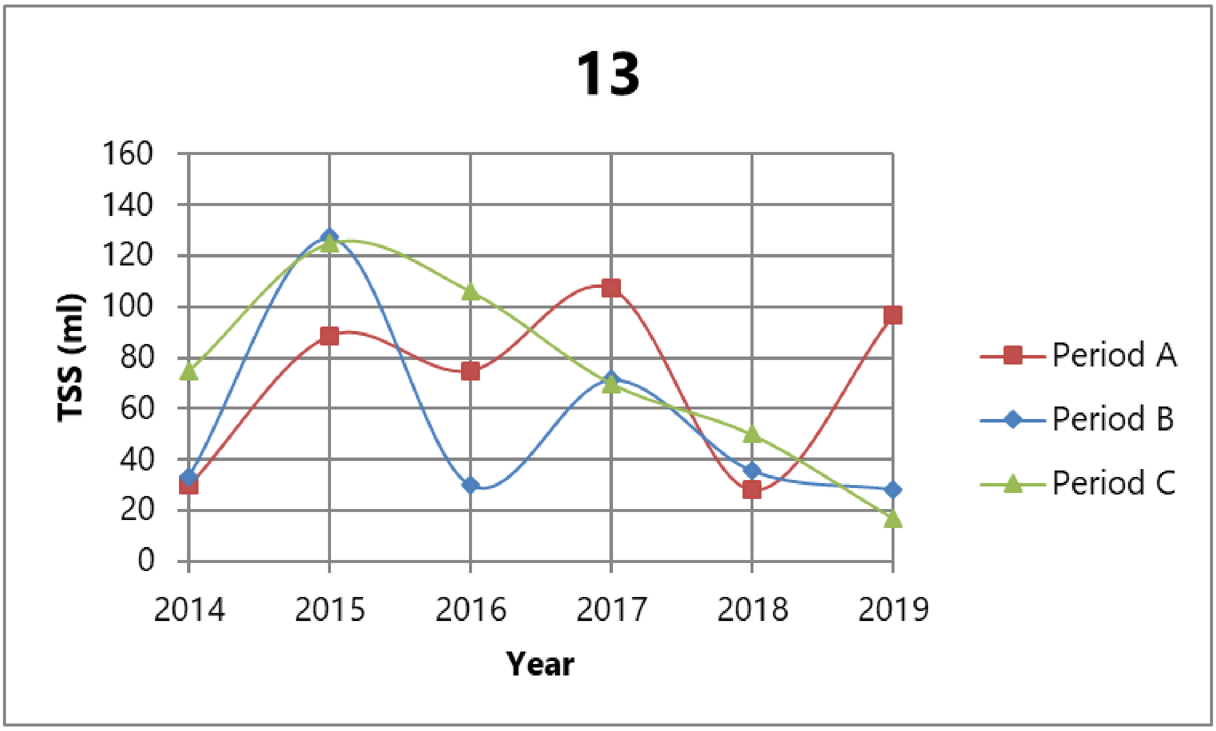


Figure A6. TSS in Booner Tube 13 - Jill's Hole normalised to 10 days (South Bank)

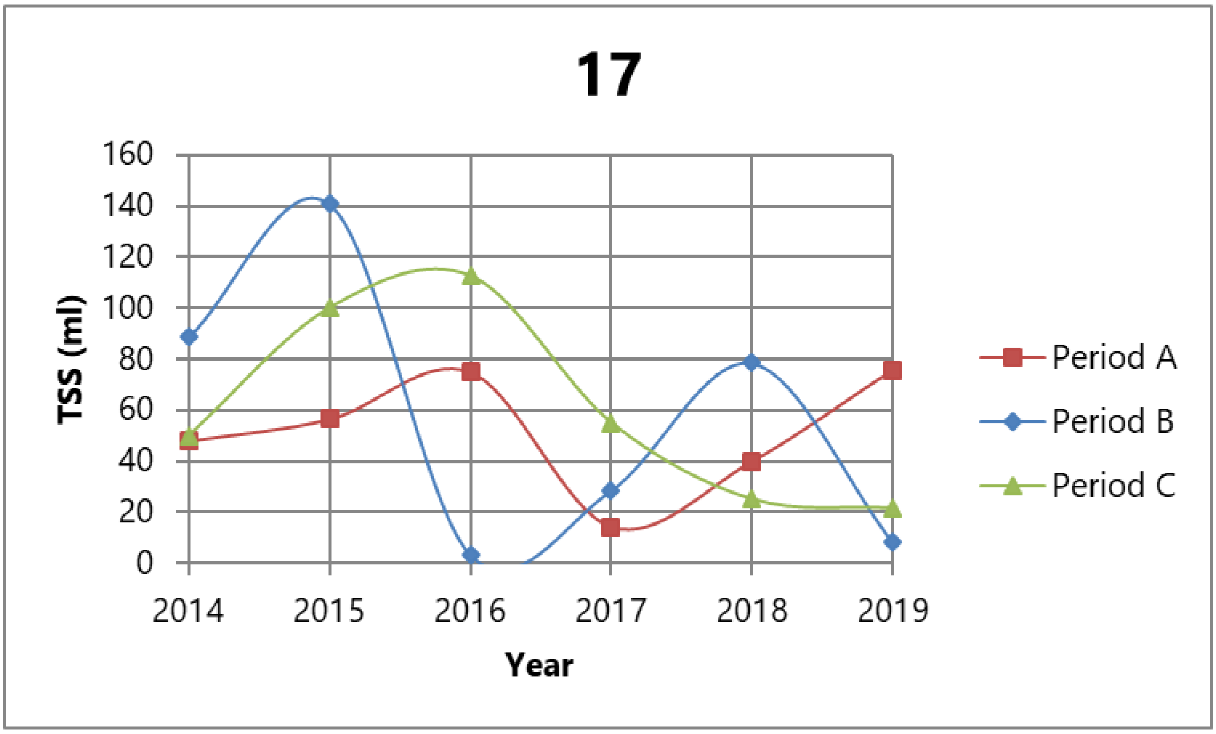


Figure A7. TSS in Booner Tube 17 - No. 2 Buoy normalised to 10 days (North Bank)

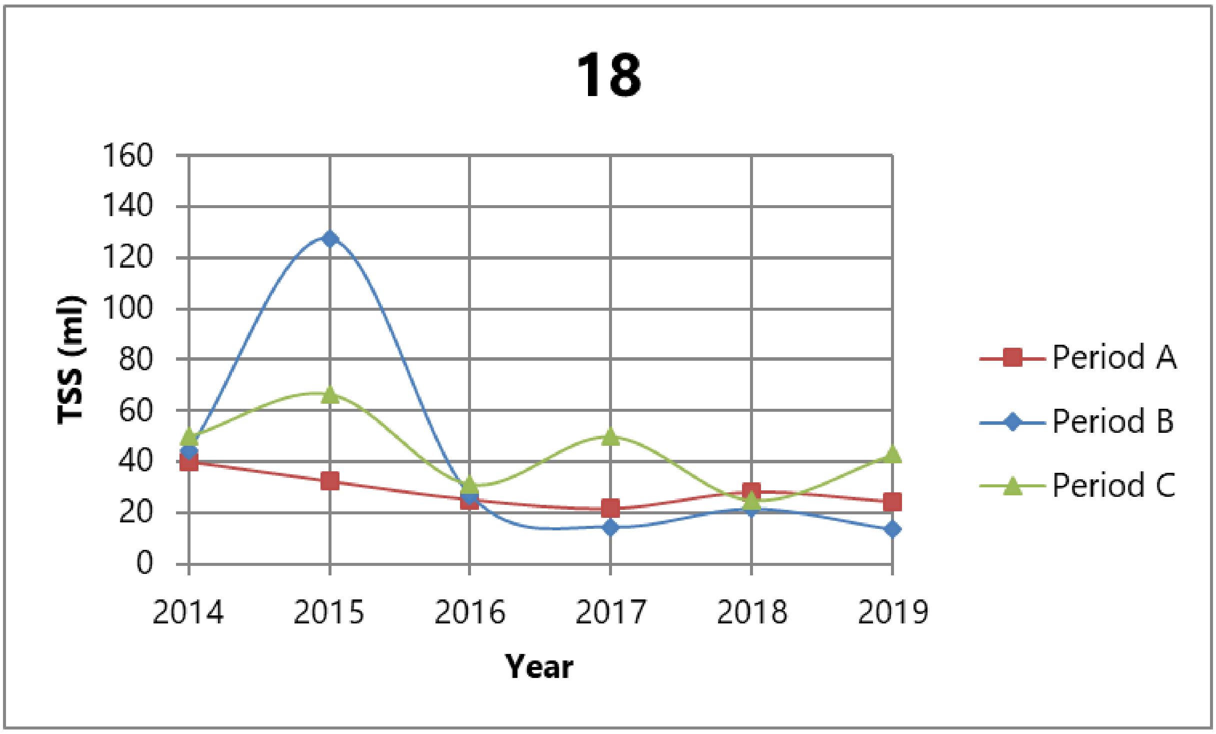


Figure A8. TSS in Booner Tube 18 - Bird Reserve normalised to 10 days (North Bank)

B Particle Size Analysis Report

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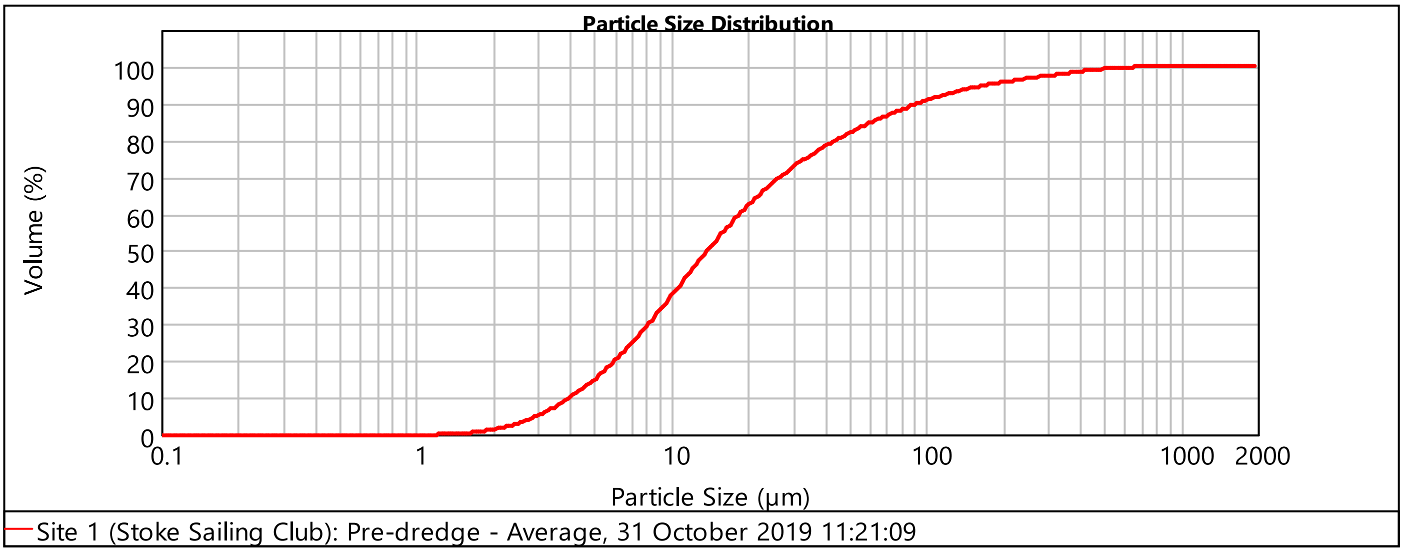
Particle Size Analysis Report

Sample Name:	Site 1 (Stoke Sailing Club): Pre-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	13.73 %
Sample Collected:		Weighted Residual:	0.793 %

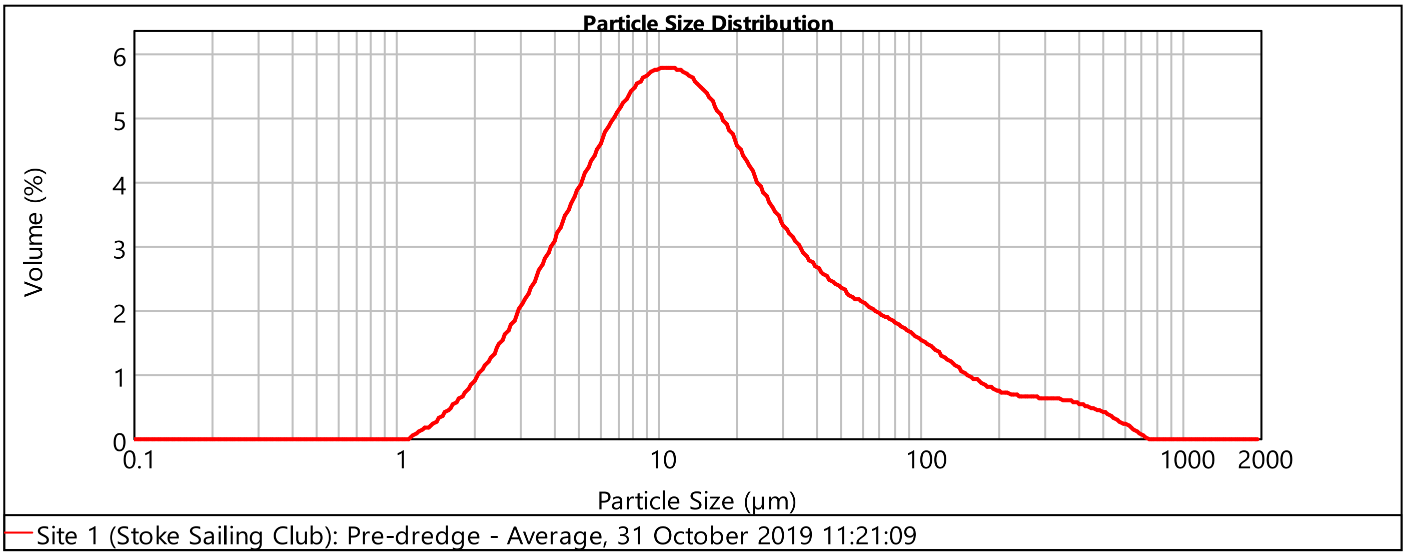
d(0.1): 4.012 µm   **d(0.5): 13.886 µm**   d(0.9): 92.471 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	19 %	42 %	22 %	11 %	4 %	0 %

Frequency Curve



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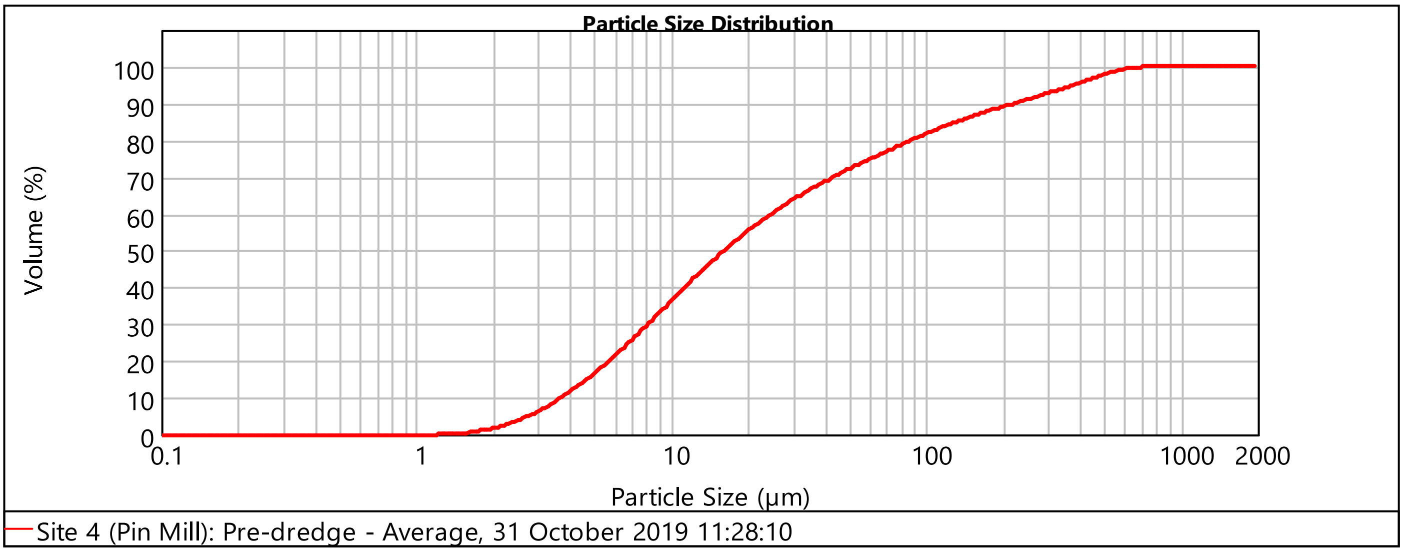
Particle Size Analysis Report

Sample Name:	Site 4 (Pin Mill): Pre-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	14.30 %
Sample Collected:		Weighted Residual:	0.930 %

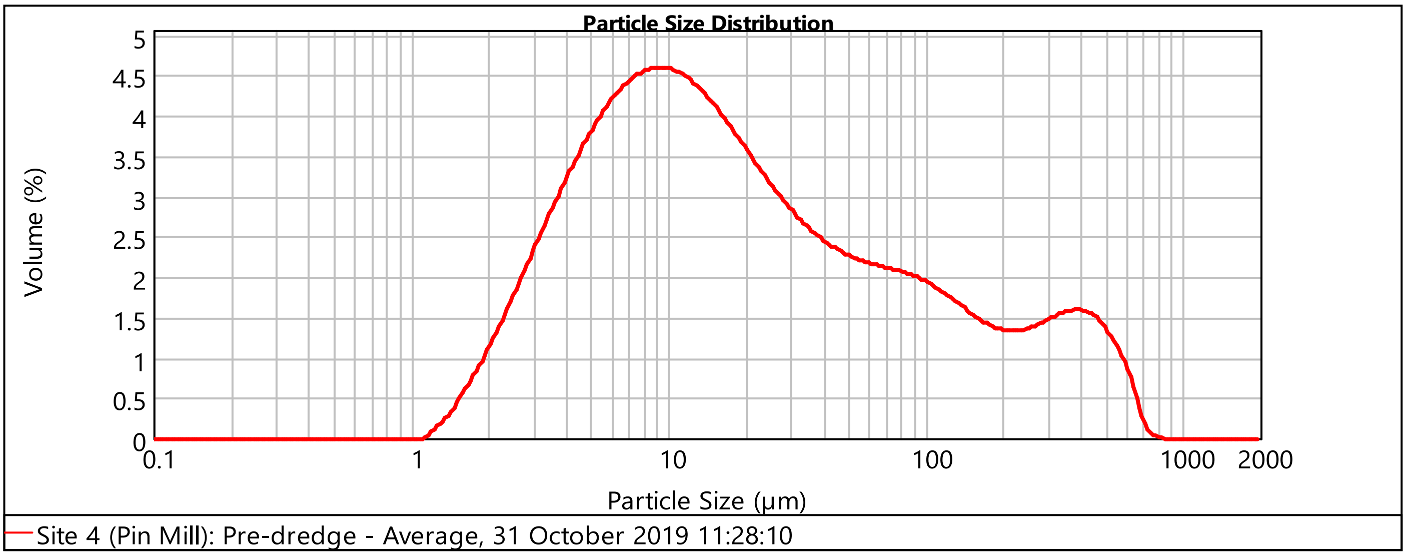
d(0.1): 3.710 µm **d(0.5): 16.118 µm** d(0.9): 220.043 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	20 %	34 %	20 %	14 %	10 %	1 %

Frequency Curve



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Particle Size Analysis Report

Sample Name: Site 5 (Nacton Quay): Pre-dredge - Average

Sample Source: Ipswich

Sample Collected:

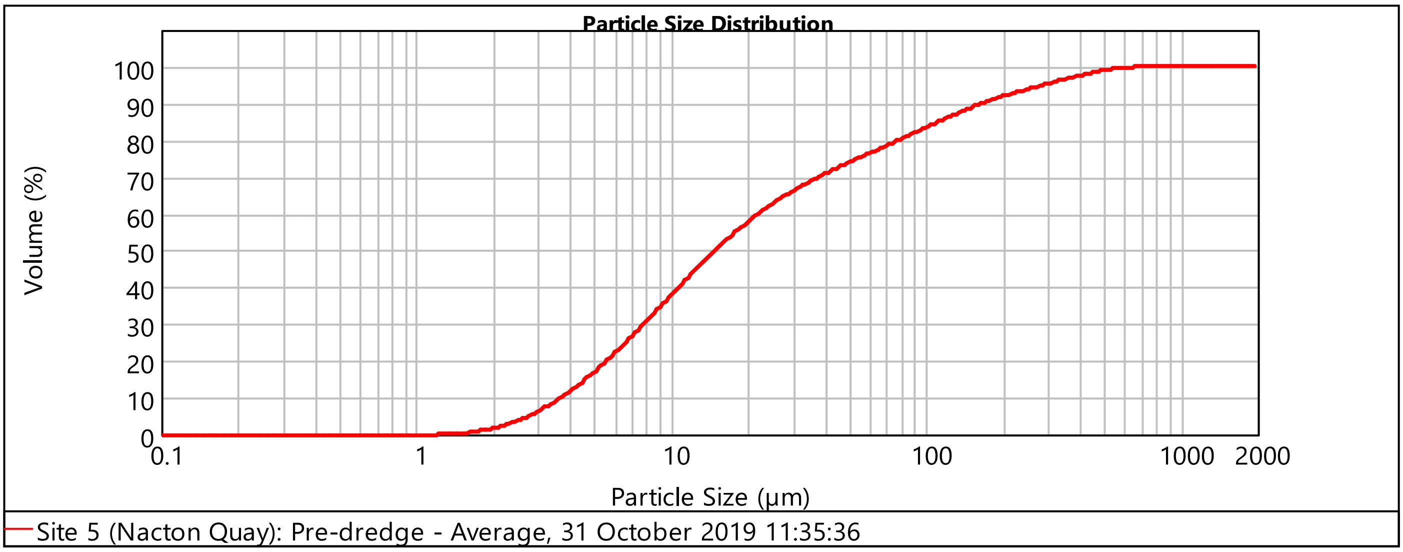
Measured by: IDavidson on 31 October 2019

Obscuration: 12.92 %

Weighted Residual: 0.858 %

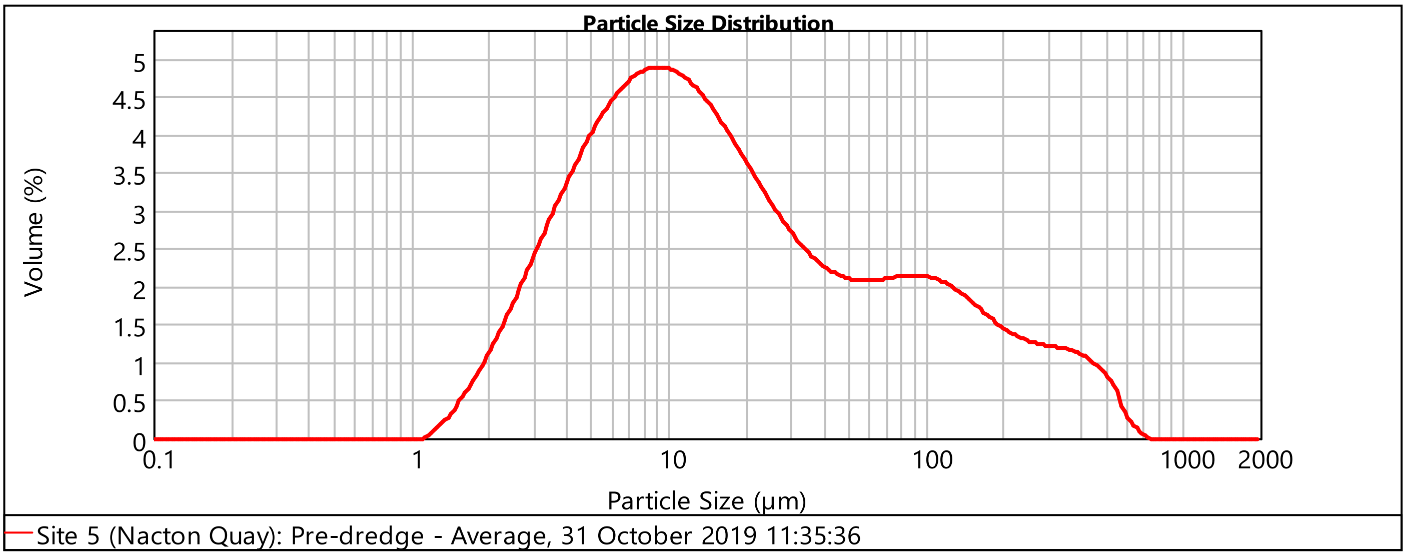
d(0.1): 3.687 µm | **d(0.5): 14.827 µm** | d(0.9): 165.122 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	20 %	36 %	19 %	15 %	8 %	0 %

Frequency Curve



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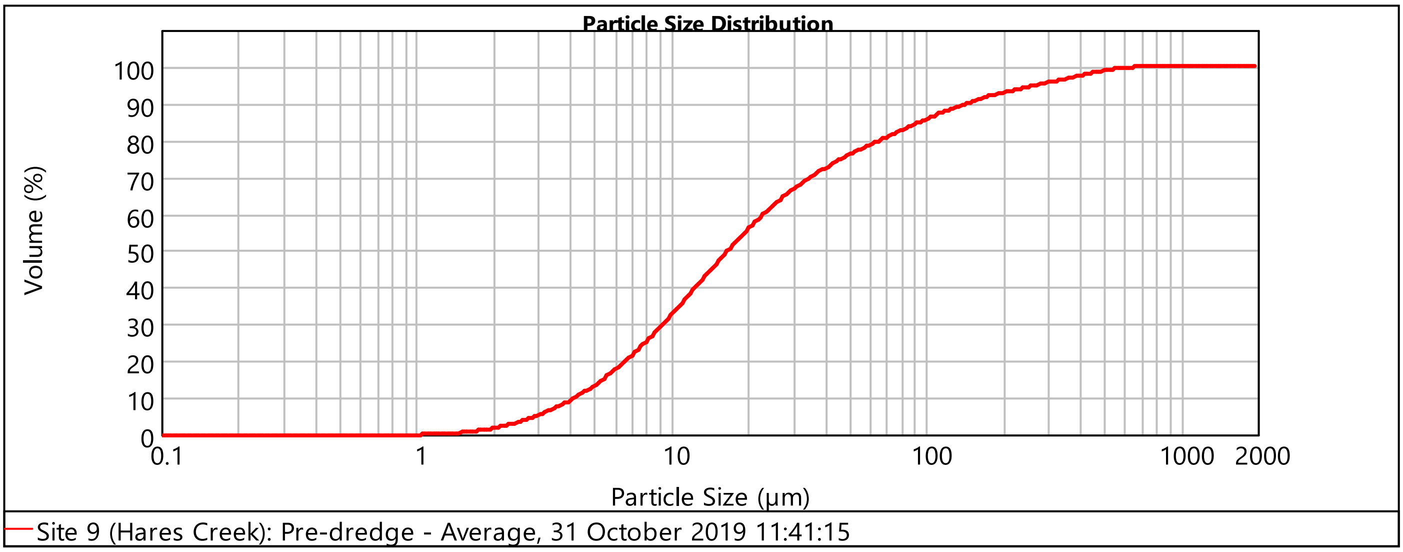
Particle Size Analysis Report

Sample Name:	Site 9 (Hares Creek): Pre-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	12.95 %
Sample Collected:		Weighted Residual:	0.738 %

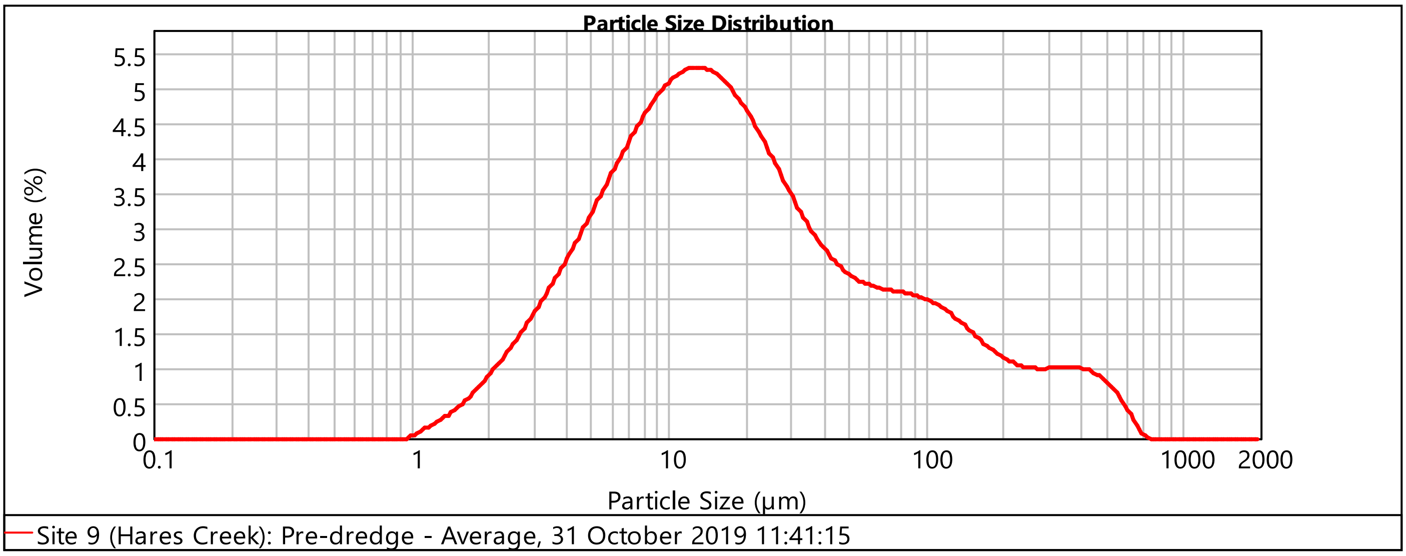
d(0.1): 4.180 µm **d(0.5): 16.704 µm** d(0.9): 143.049 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	16 %	38 %	23 %	14 %	7 %	0 %

Frequency Curve



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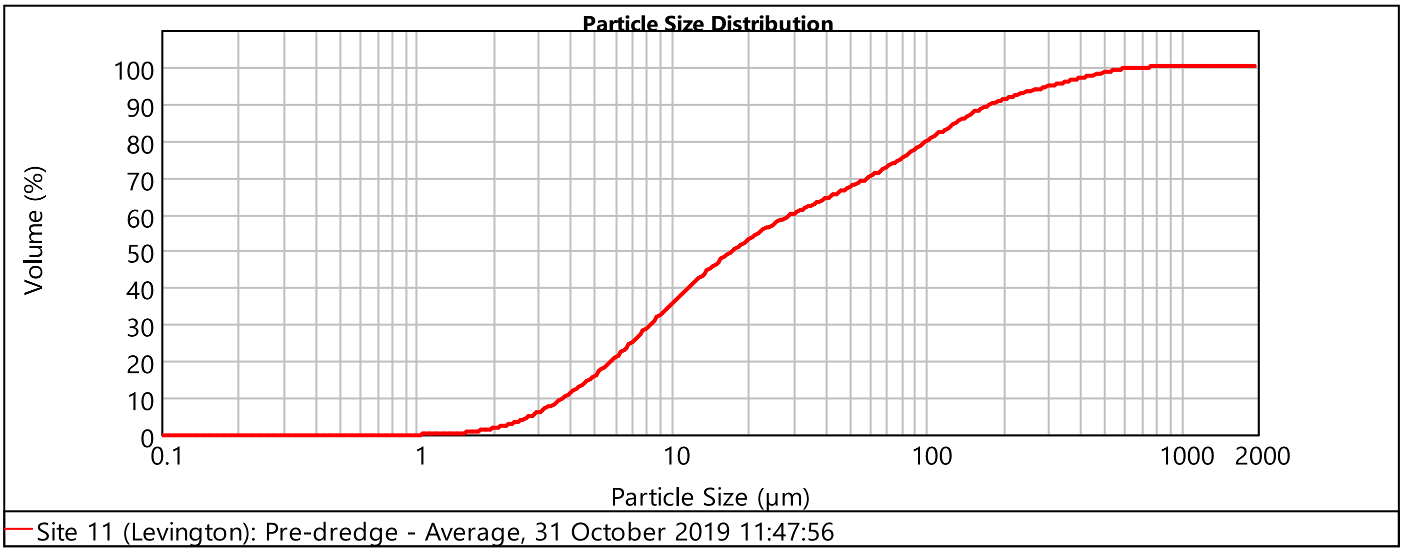
Particle Size Analysis Report

Sample Name:	Site 11 (Levington): Pre-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	14.32 %
Sample Collected:		Weighted Residual:	0.745 %

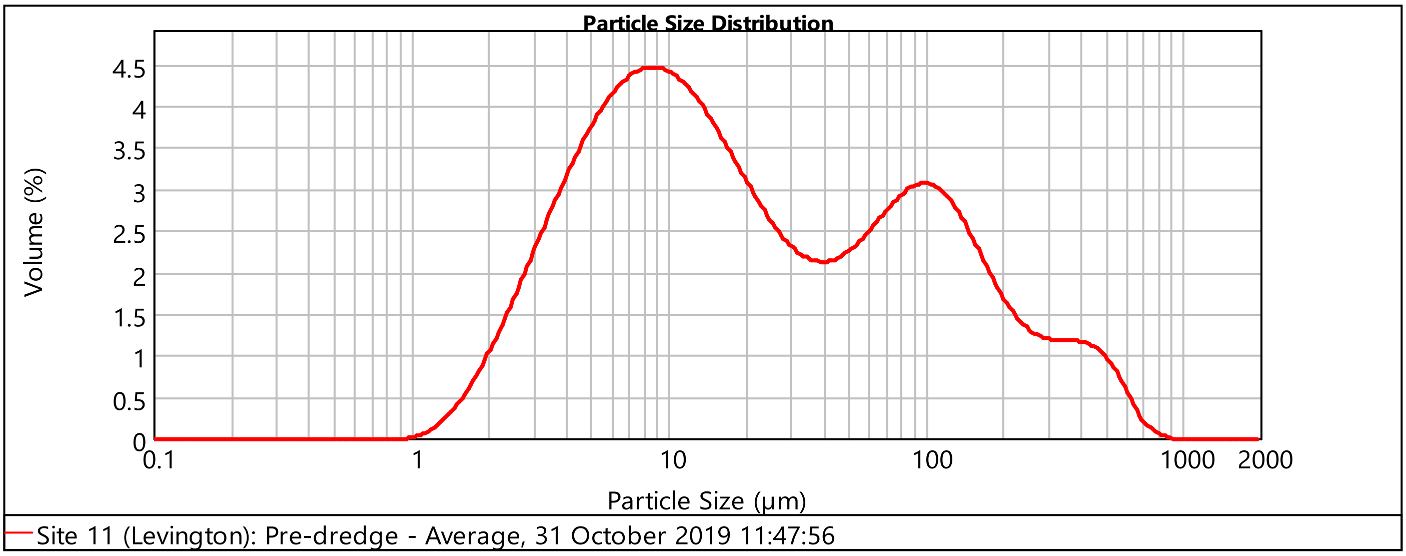
d(0.1): 3.799 µm   **d(0.5): 17.432 µm**   d(0.9): 182.912 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	19 %	32 %	17 %	21 %	8 %	1 %

Frequency Curve



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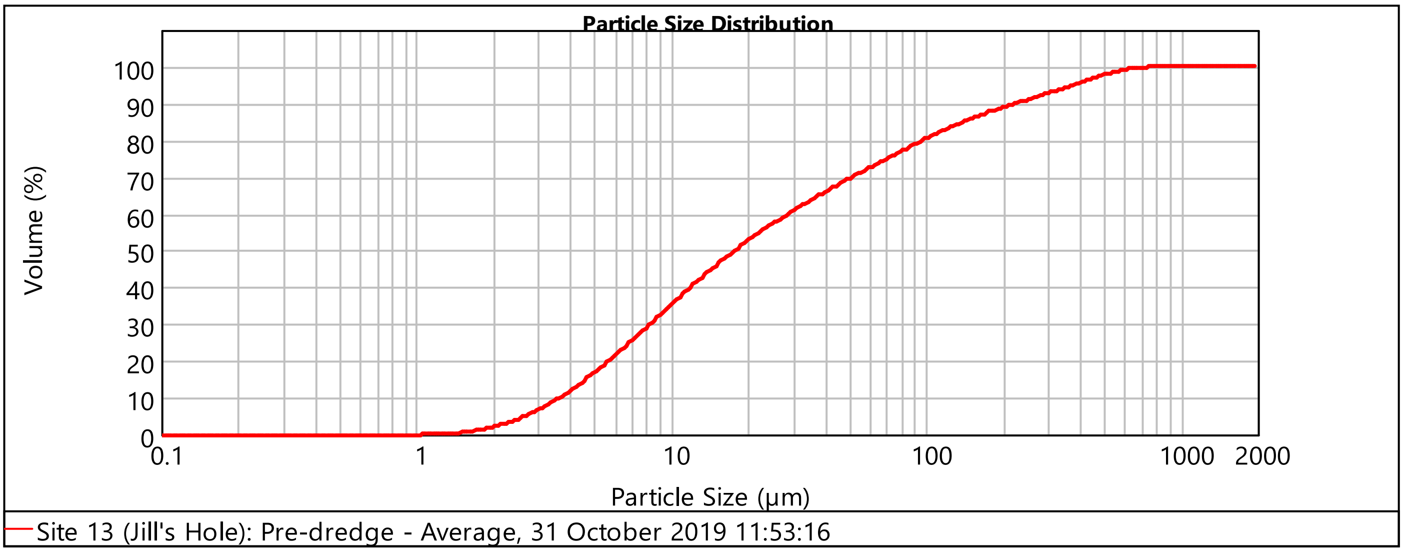
Particle Size Analysis Report

Sample Name:	Site 13 (Jill's Hole): Pre-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	17.94 %
Sample Collected:		Weighted Residual:	0.754 %

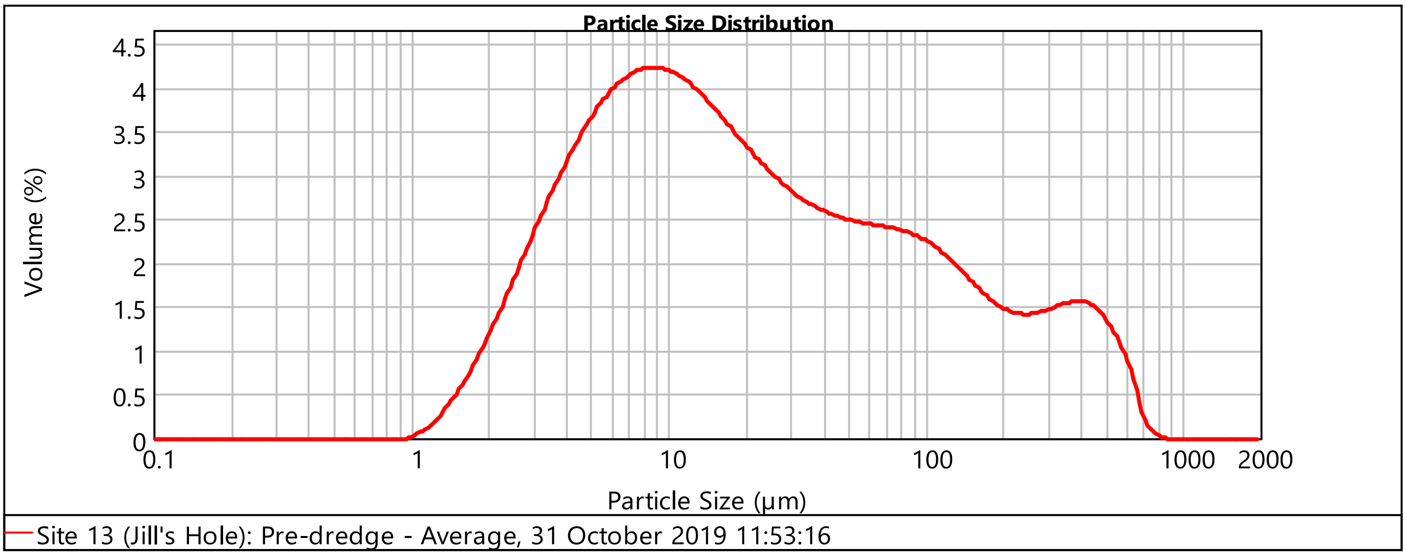
d(0.1): 3.637 µm **d(0.5): 17.739 µm** d(0.9): 222.420 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	19 %	31 %	20 %	16 %	10 %	1 %

Frequency Curve



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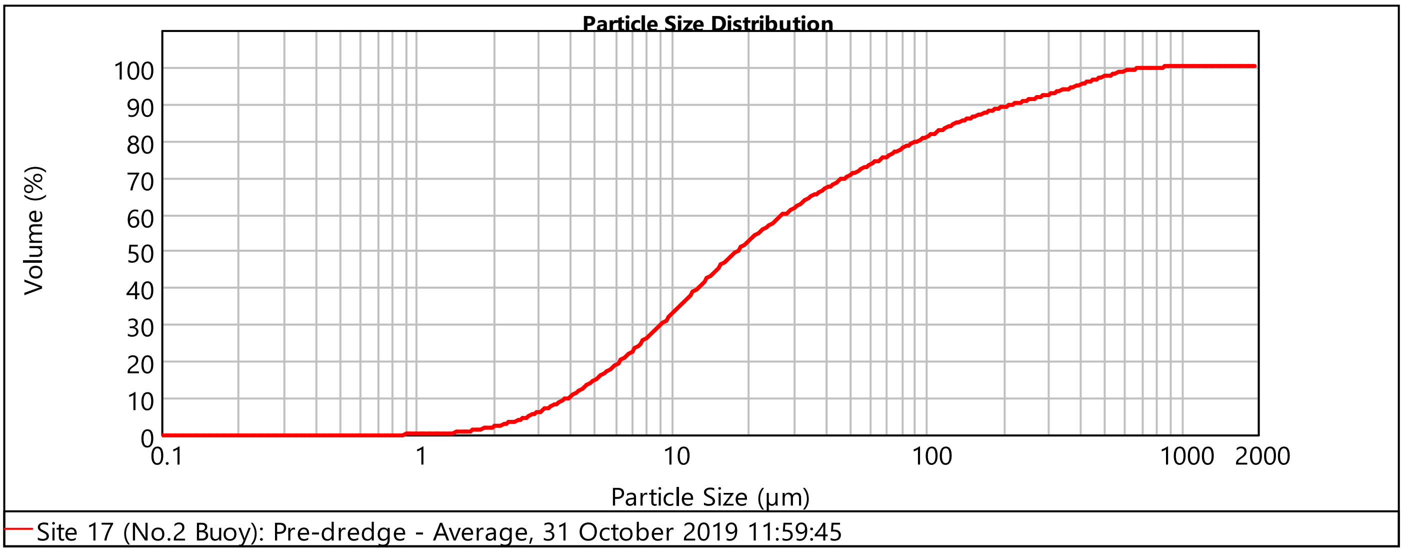
Particle Size Analysis Report

Sample Name:	Site 17 (No.2 Buoy): Pre-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	13.31 %
Sample Collected:		Weighted Residual:	0.745 %

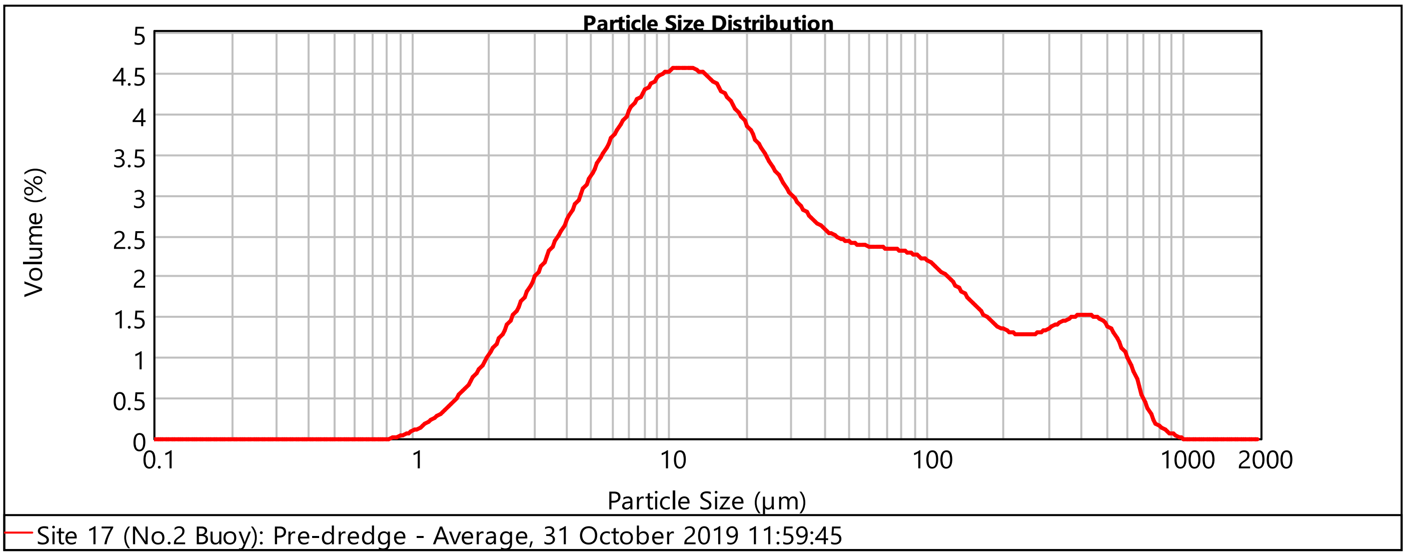
d(0.1): 3.926 µm **d(0.5): 18.183 µm** d(0.9): 224.300 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	17 %	34 %	21 %	16 %	10 %	1 %

Frequency Curve



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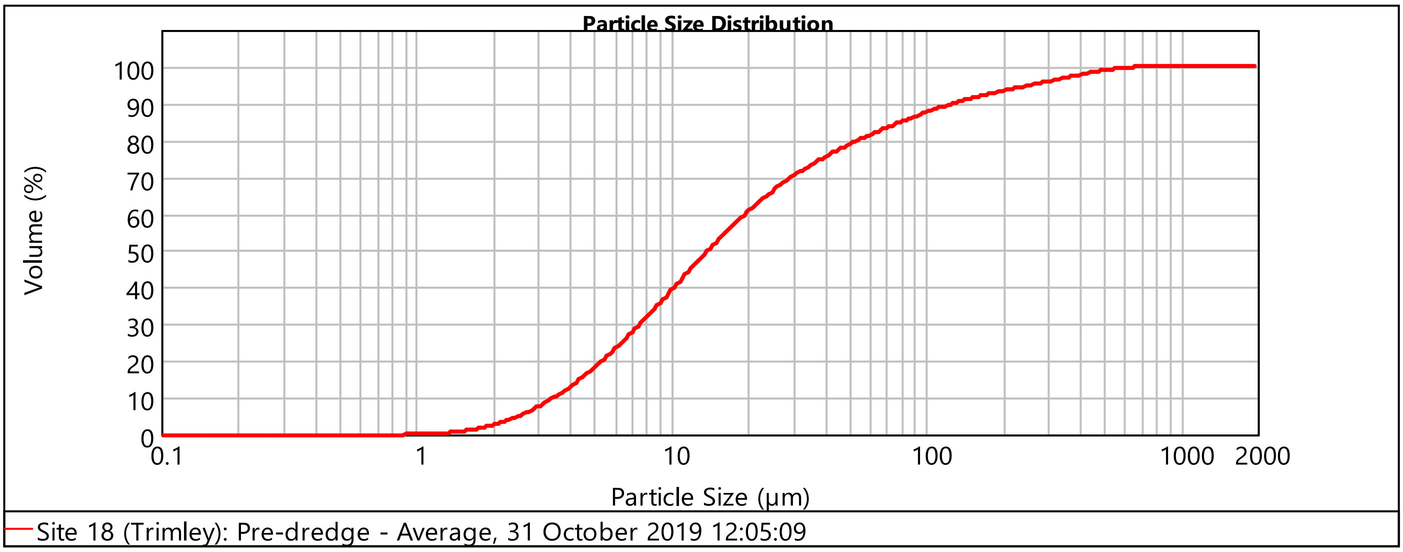
Particle Size Analysis Report

Sample Name:	Site 18 (Trimley): Pre-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	15.63 %
Sample Collected:		Weighted Residual:	0.905 %

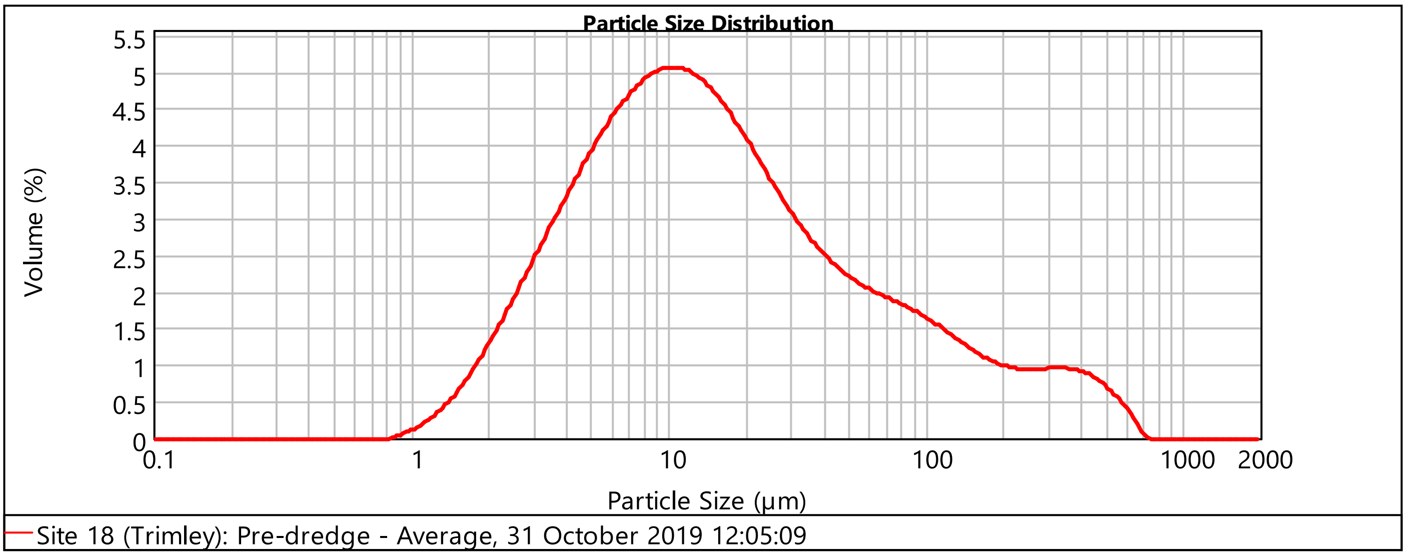
d(0.1): 3.452 µm   **d(0.5): 13.915 µm**   d(0.9): 126.820 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
3 %	20 %	38 %	21 %	12 %	6 %	0 %

Frequency Curve



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Particle Size Analysis Report

Sample Name: UKD Orca (IGT Load 2) - Average

Sample Source: Ipswich

Sample Collected:

Measured by: IDavidson on 31 October 2019

Obscuration: 12.51 %

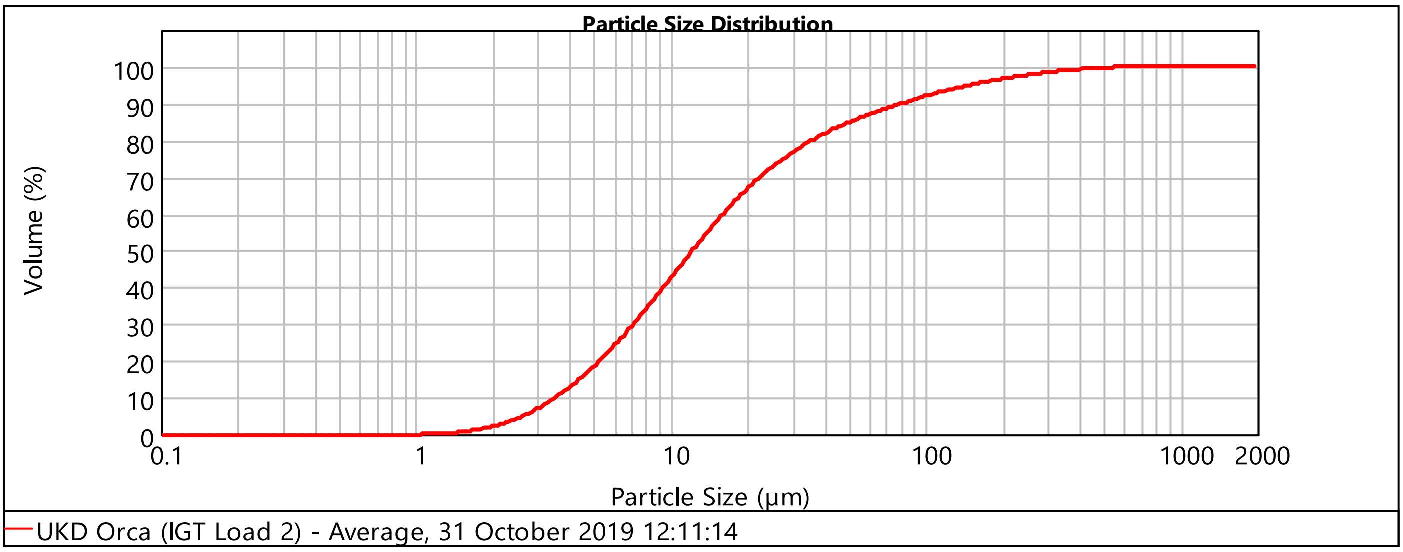
Weighted Residual: 0.782 %

d(0.1): 3.519 μm

d(0.5): 12.132 μm

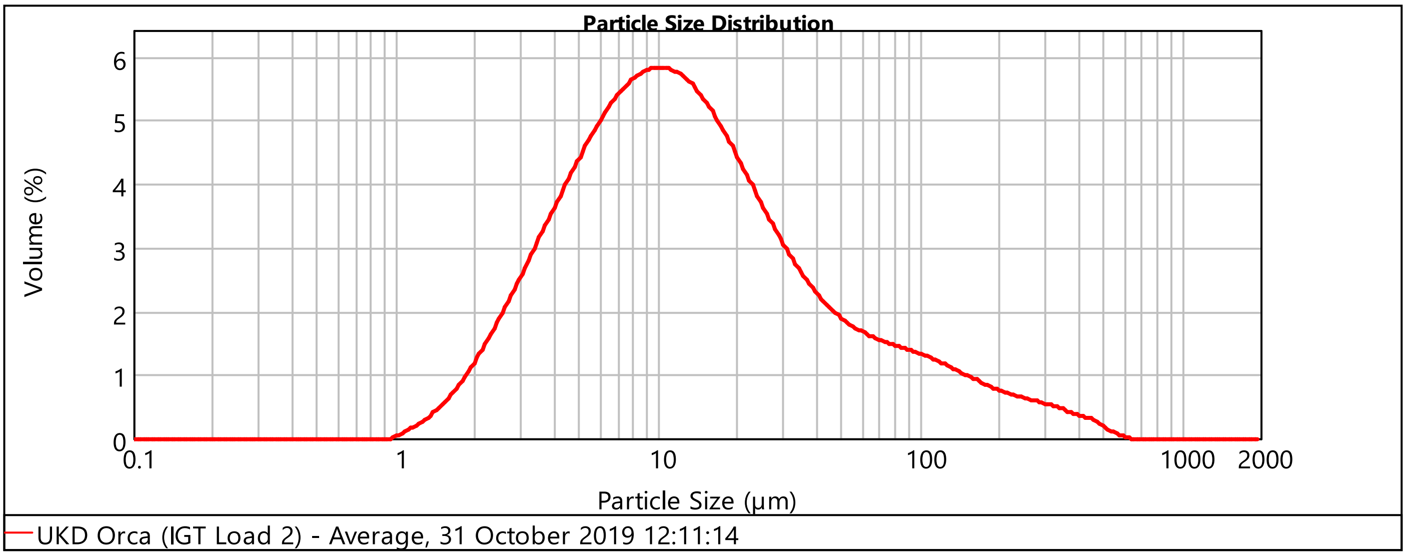
d(0.9): 79.668 μm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	22 %	43 %	20 %	10 %	3 %	0 %

Frequency Curve



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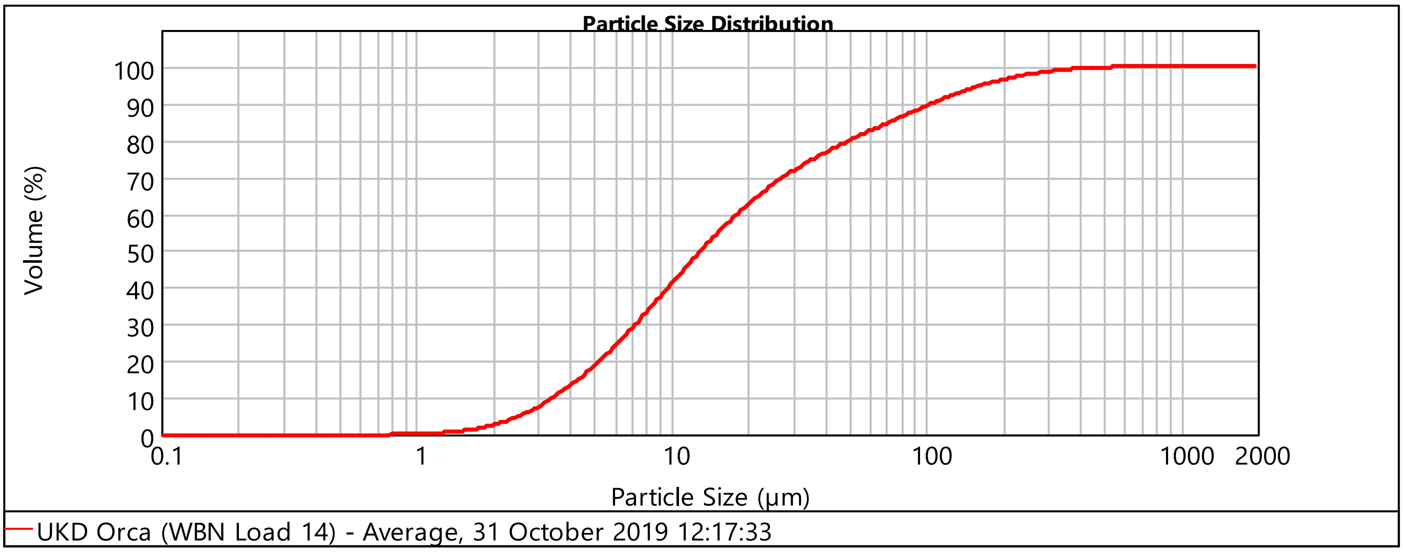
Particle Size Analysis Report

Sample Name:	UKD Orca (WBN Load 14) - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	14.43 %
Sample Collected:		Weighted Residual:	0.805 %

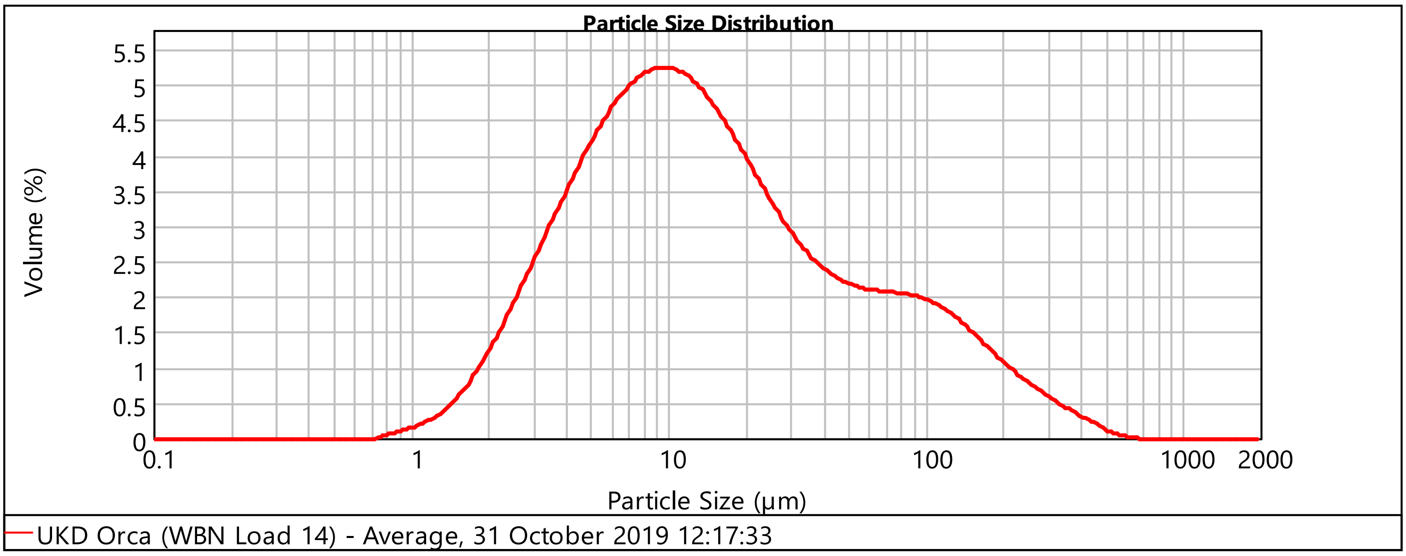
d(0.1): 3.449 µm **d(0.5): 13.079 µm** d(0.9): 104.974 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
3 %	21 %	39 %	20 %	14 %	3 %	0 %

Frequency Curve



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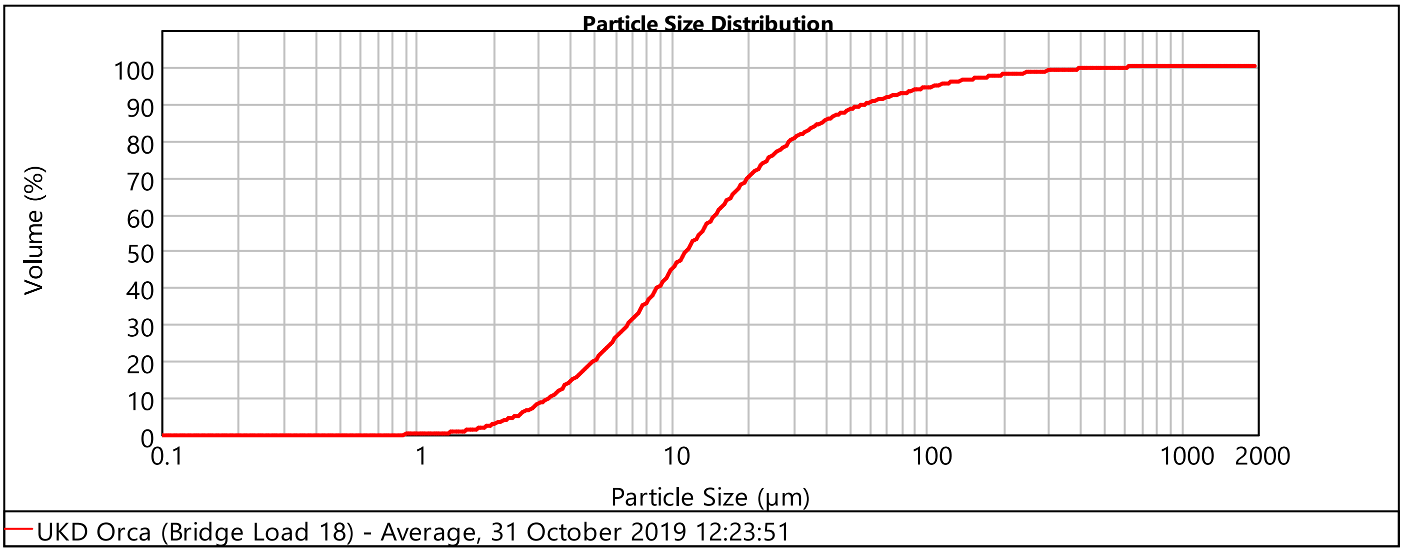
Particle Size Analysis Report

Sample Name:	UKD Orca (Bridge Load 18) - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	14.92 %
Sample Collected:		Weighted Residual:	0.611 %

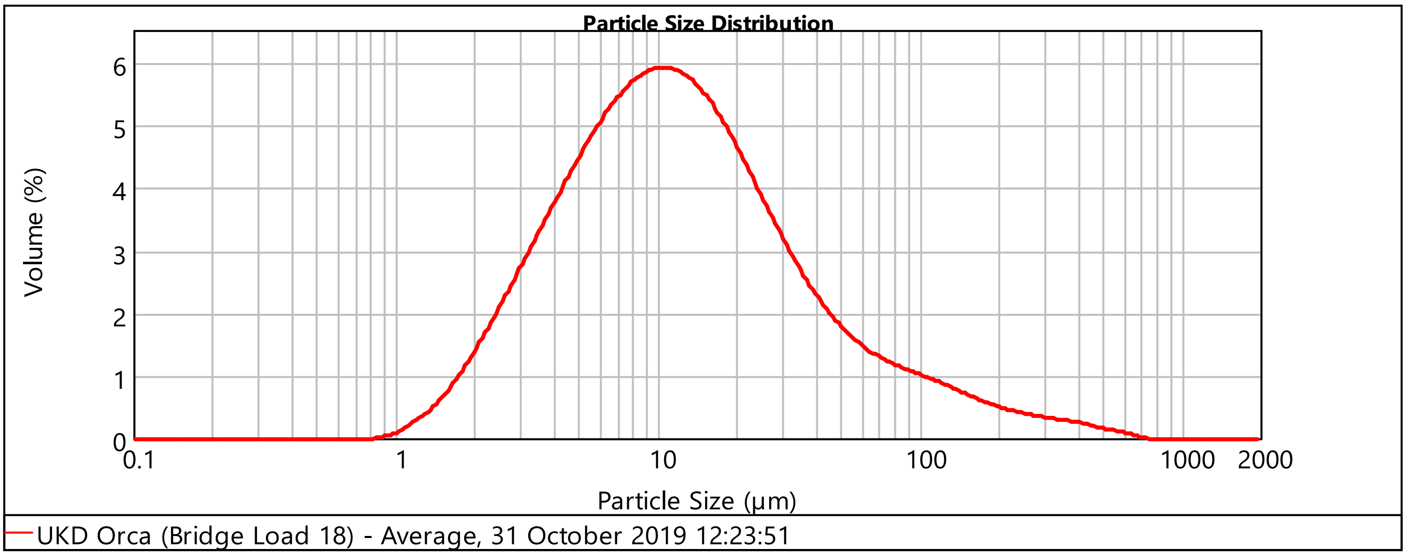
d(0.1): 3.304 μm **d(0.5): 11.491 μm** d(0.9): 58.419 μm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
3 %	23 %	44 %	21 %	8 %	2 %	0 %

Frequency Curve



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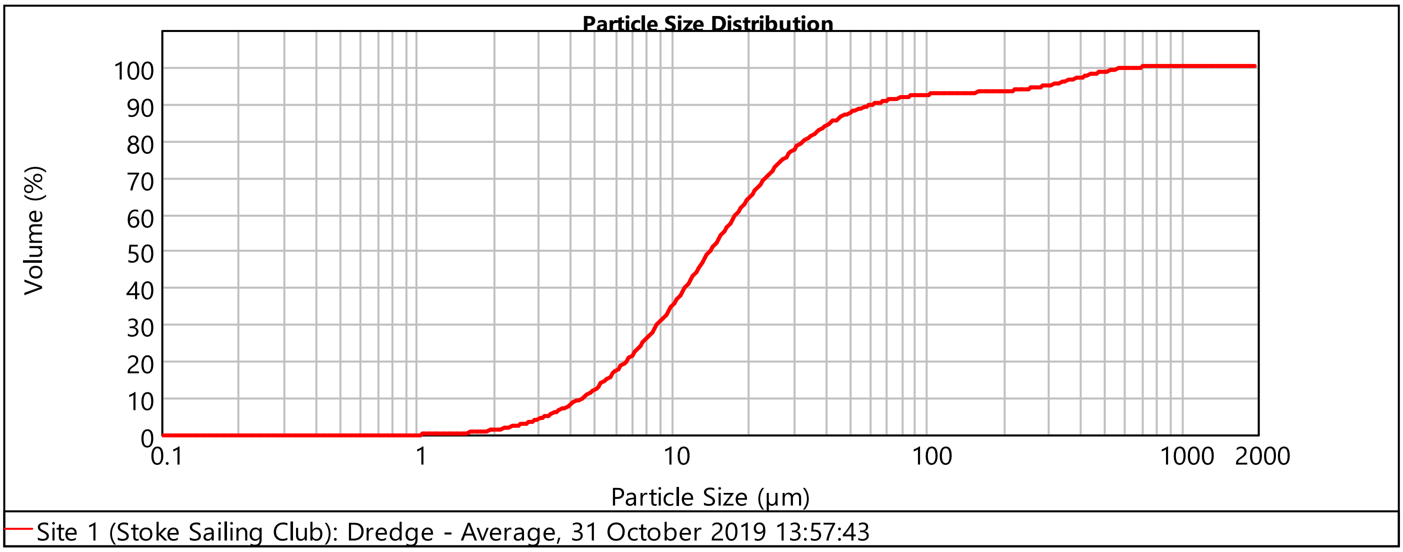
Particle Size Analysis Report

Sample Name:	Site 1 (Stoke Sailing Club): Dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	11.76 %
Sample Collected:		Weighted Residual:	0.764 %

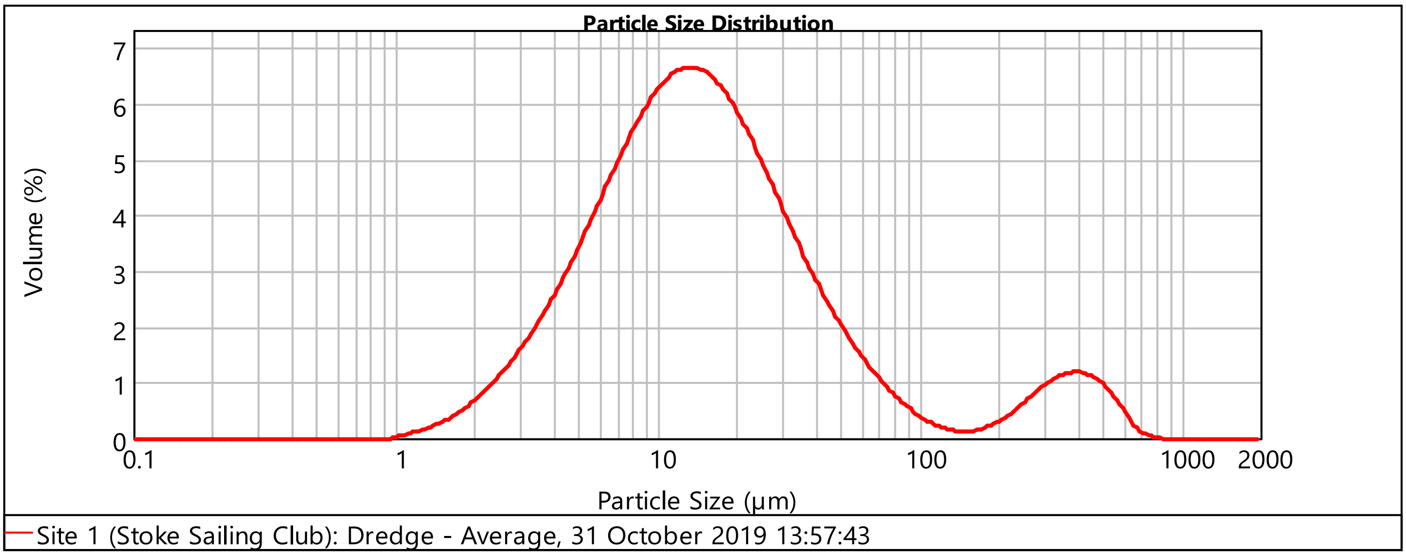
d(0.1): 4.468 µm **d(0.5): 14.282 µm** d(0.9): 63.149 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	16 %	47 %	26 %	4 %	6 %	0 %

Frequency Curve



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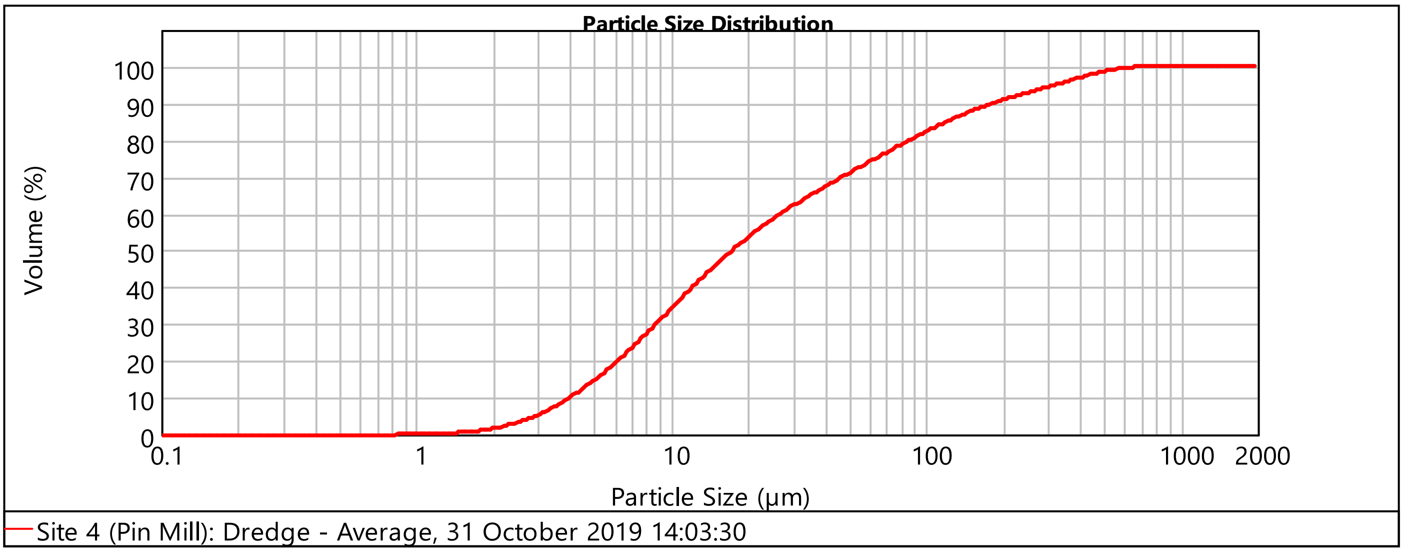
Particle Size Analysis Report

Sample Name:	Site 4 (Pin Mill): Dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	13.86 %
Sample Collected:		Weighted Residual:	0.835 %

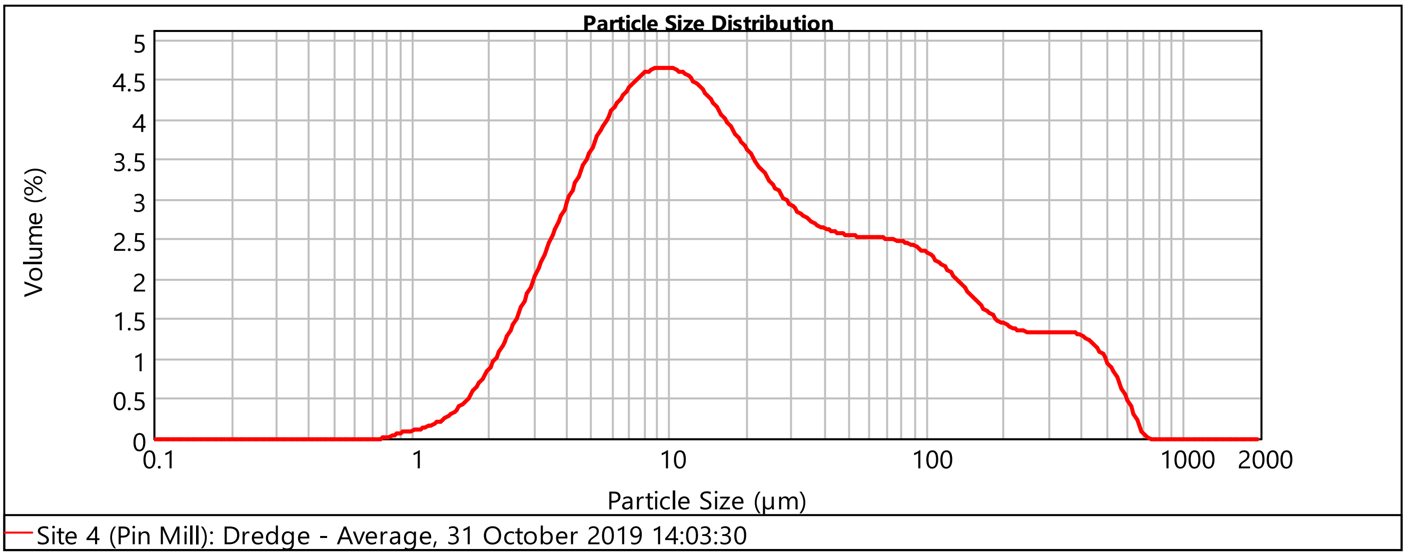
d(0.1): 4.009 µm   **d(0.5): 17.313 µm**   d(0.9): 181.007 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	18 %	34 %	21 %	17 %	9 %	0 %

Frequency Curve



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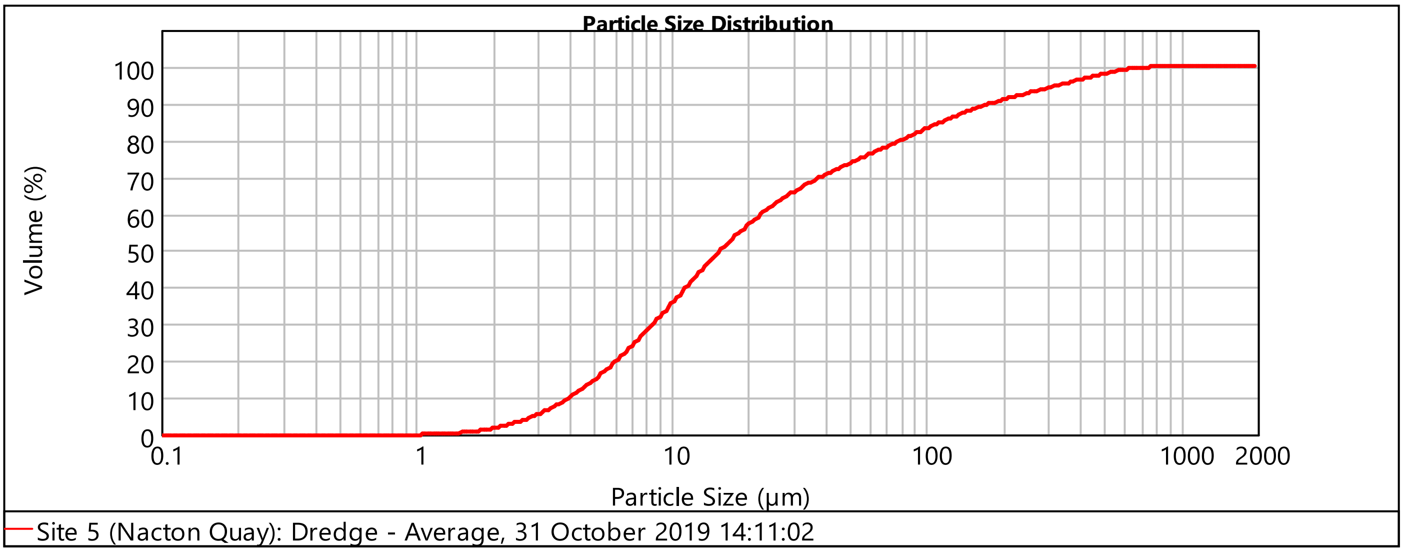
Particle Size Analysis Report

Sample Name:	Site 5 (Nacton Quay): Dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	18.23 %
Sample Collected:		Weighted Residual:	0.542 %

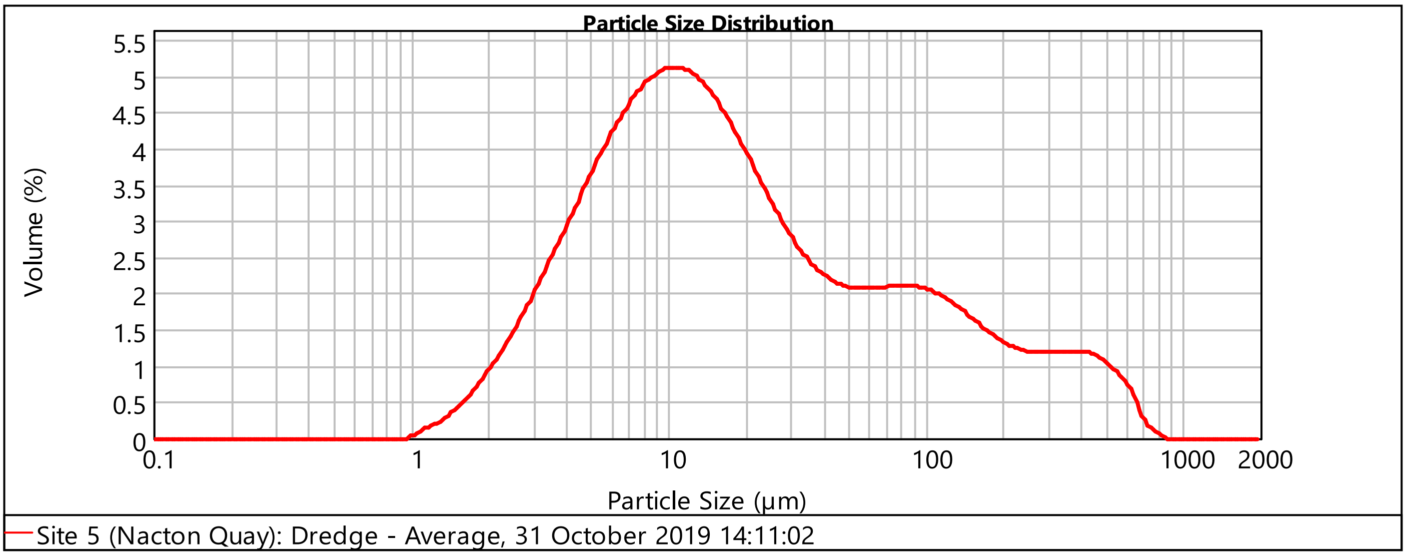
d(0.1): 3.973 µm **d(0.5): 15.606 µm** d(0.9): 178.725 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	18 %	37 %	19 %	15 %	8 %	1 %

Frequency Curve



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Particle Size Analysis Report

Sample Name: Site 9 (Hares Creek): Dredge - Average

Sample Source: Ipswich

Sample Collected:

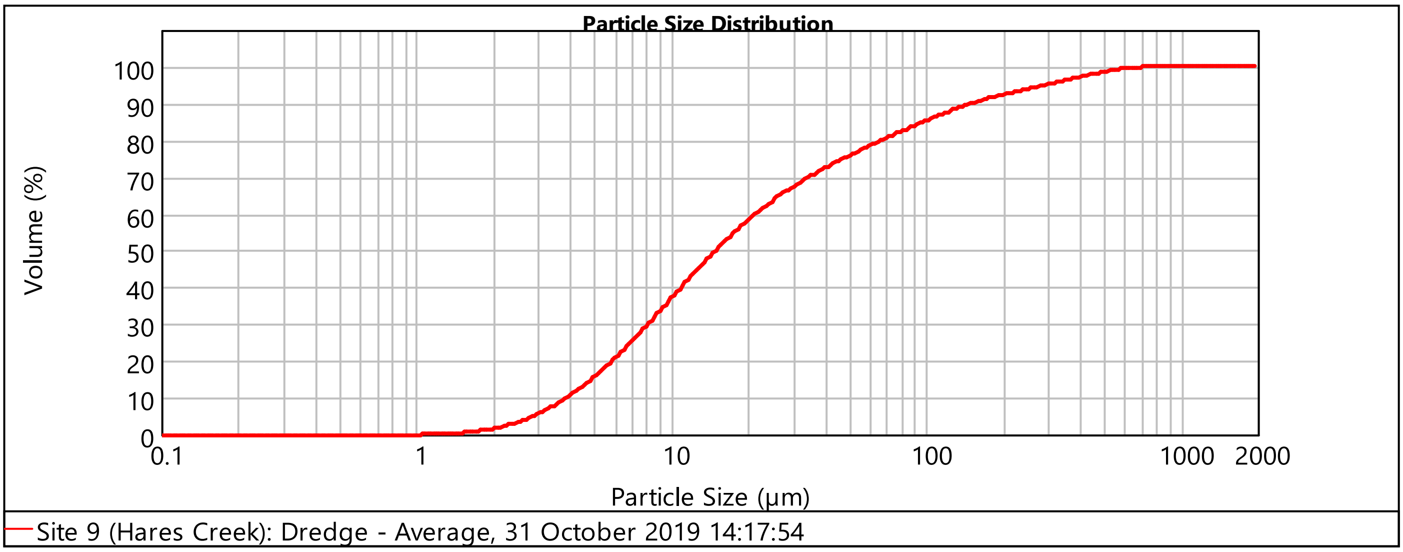
Measured by: IDavidson on 31 October 2019

Obscuration: 12.52 %

Weighted Residual: 0.673 %

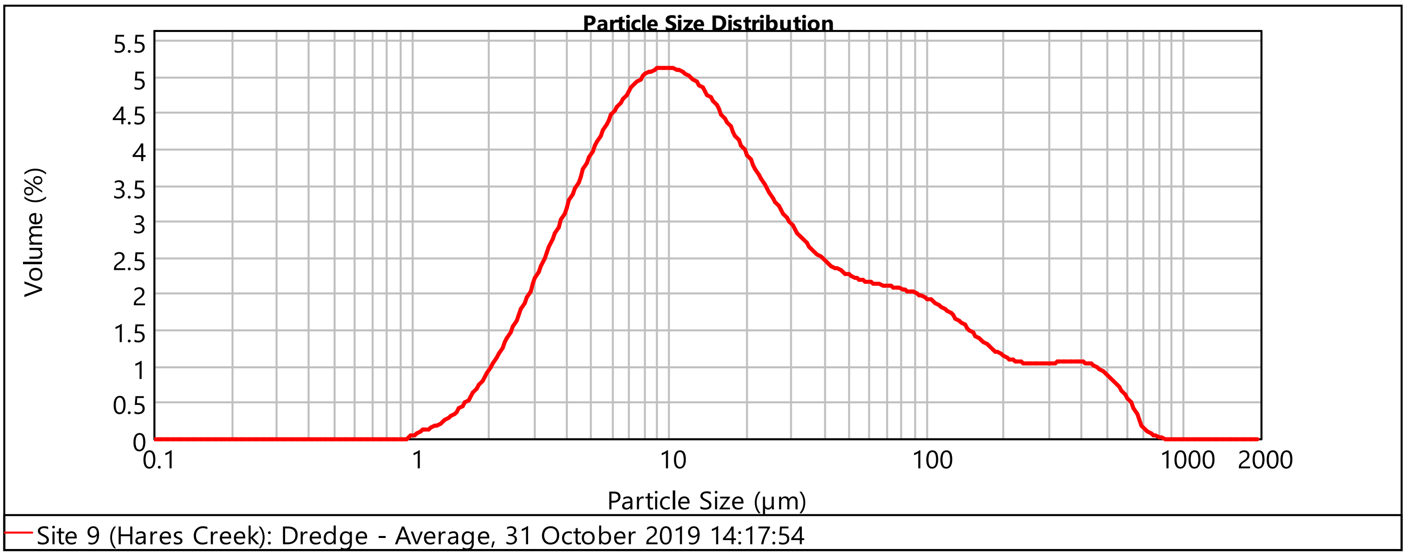
d(0.1): 3.889 µm d(0.5): 14.901 µm d(0.9): 150.157 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	19 %	38 %	20 %	14 %	7 %	0 %

Frequency Curve



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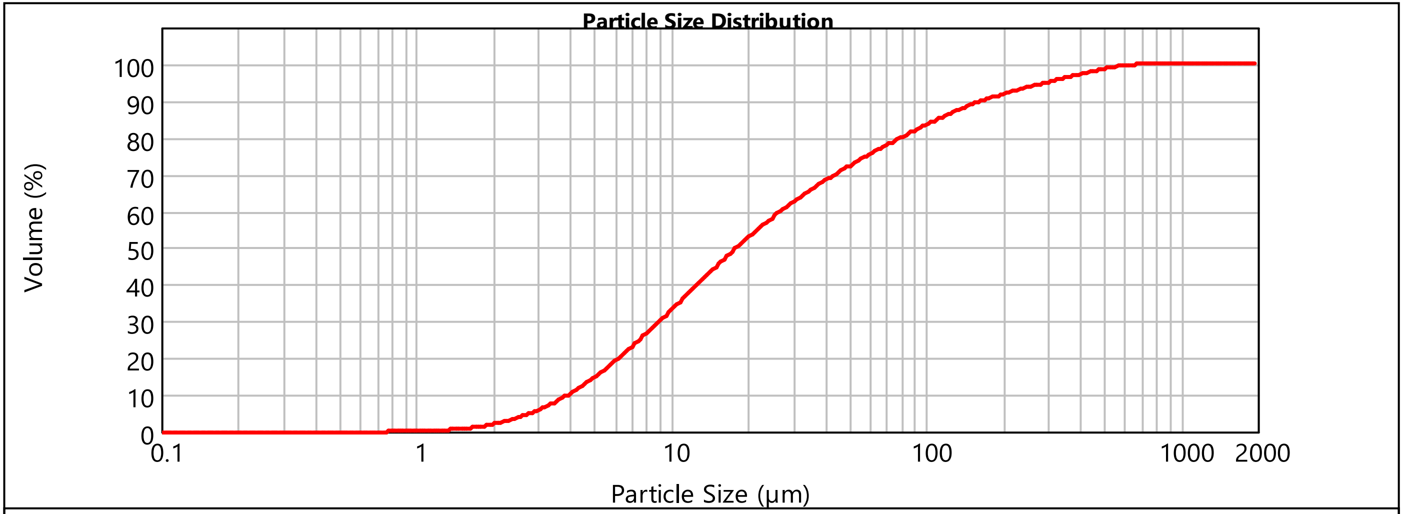
Particle Size Analysis Report

Sample Name:	Site 11 (Levington): Dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	14.43 %
Sample Collected:		Weighted Residual:	0.764 %

d(0.1): 3.934 µm   **d(0.5): 17.985 µm**   d(0.9): 164.644 µm

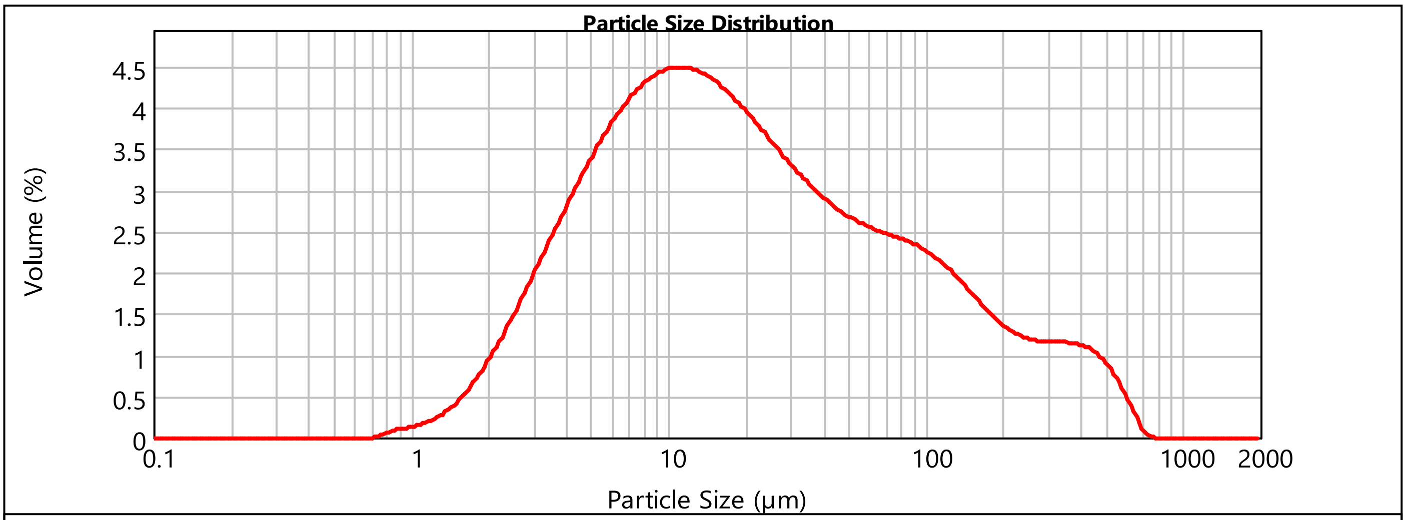
Cumulative Frequency Plot



Site 11 (Levington): Dredge - Average, 31 October 2019 14:23:42

Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	17 %	34 %	23 %	16 %	8 %	0 %

Frequency Curve



Site 11 (Levington): Dredge - Average, 31 October 2019 14:23:42

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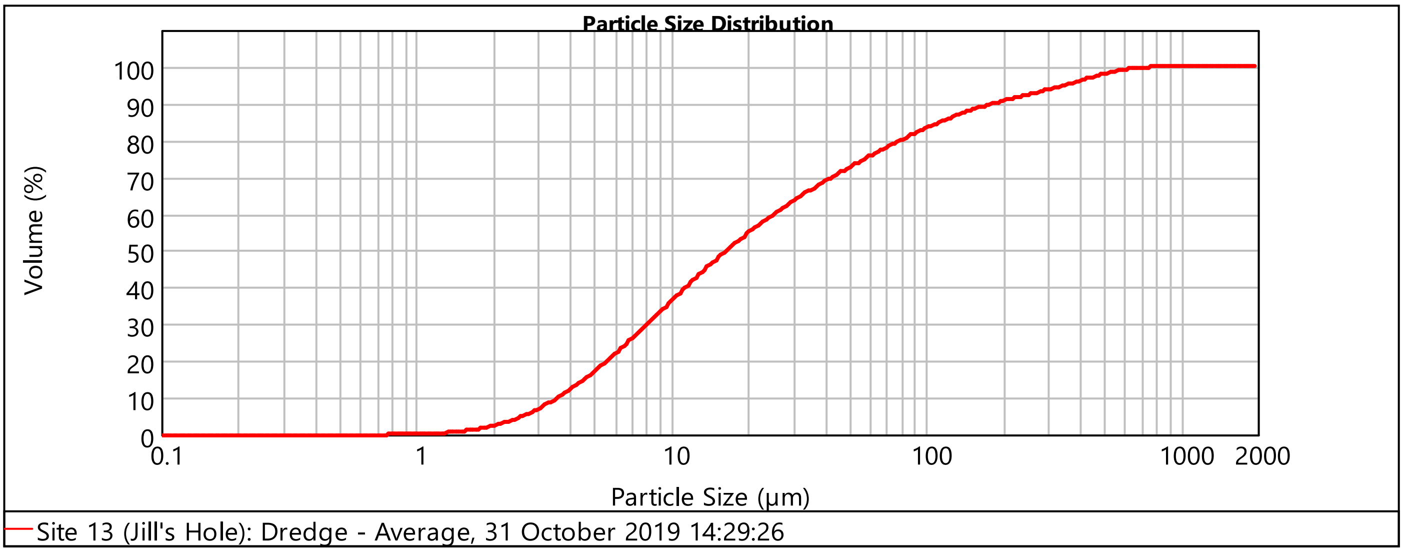
Particle Size Analysis Report

Sample Name:	Site 13 (Jill's Hole): Dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	14.00 %
Sample Collected:		Weighted Residual:	0.783 %

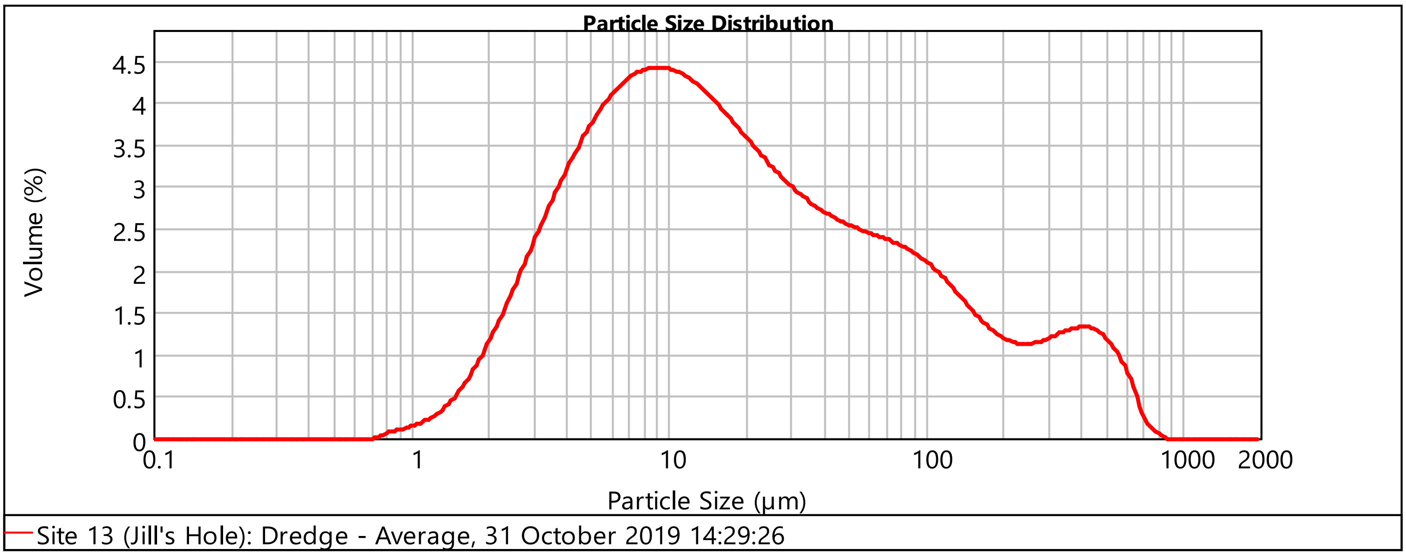
d(0.1): 3.586 µm   **d(0.5): 16.443 µm**   d(0.9): 181.881 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	19 %	33 %	21 %	15 %	9 %	1 %

Frequency Curve



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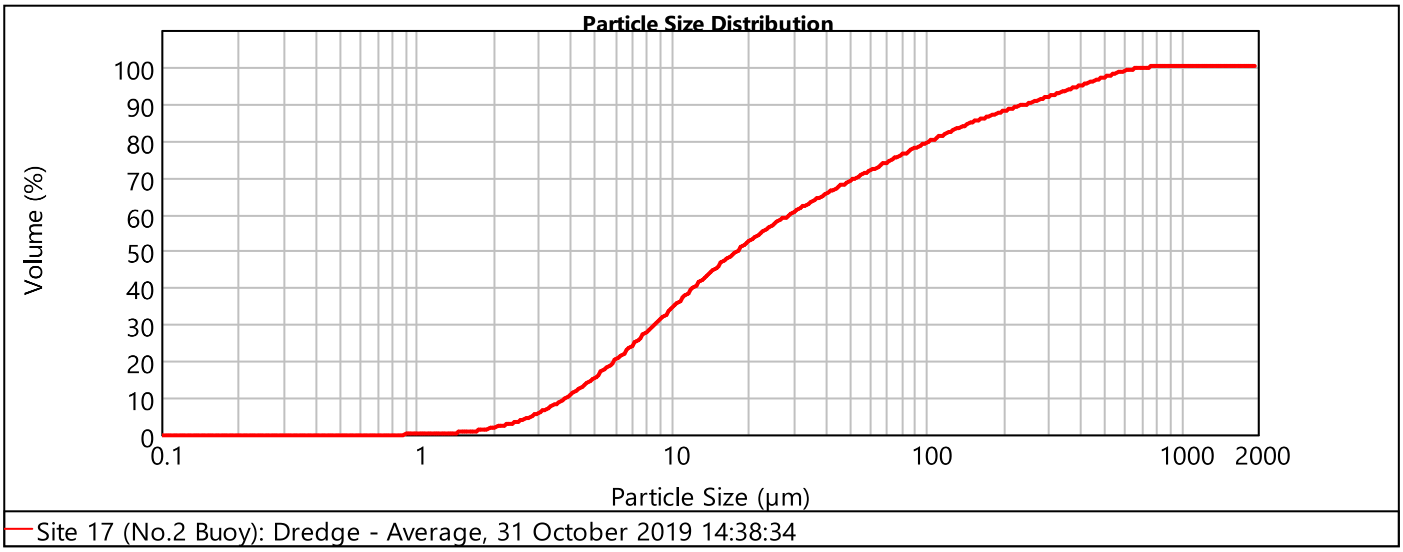
Particle Size Analysis Report

Sample Name:	Site 17 (No.2 Buoy): Dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	11.68 %
Sample Collected:		Weighted Residual:	0.927 %

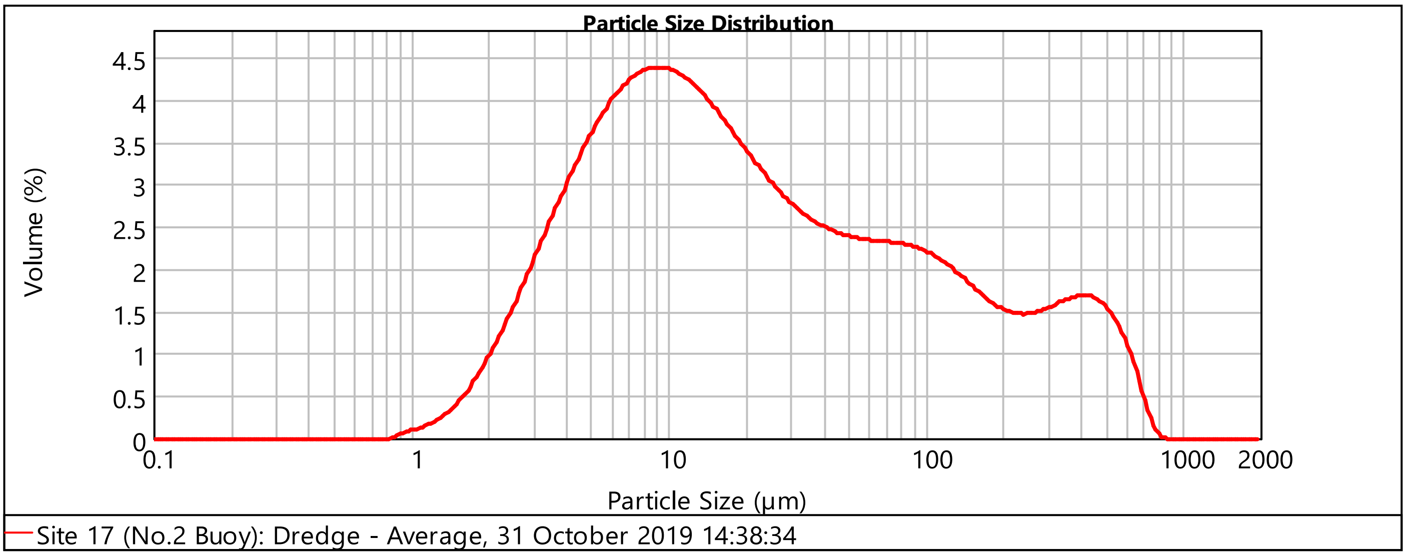
d(0.1): 3.873 µm **d(0.5): 18.153 µm** d(0.9): 249.686 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	18 %	32 %	19 %	16 %	11 %	1 %

Frequency Curve



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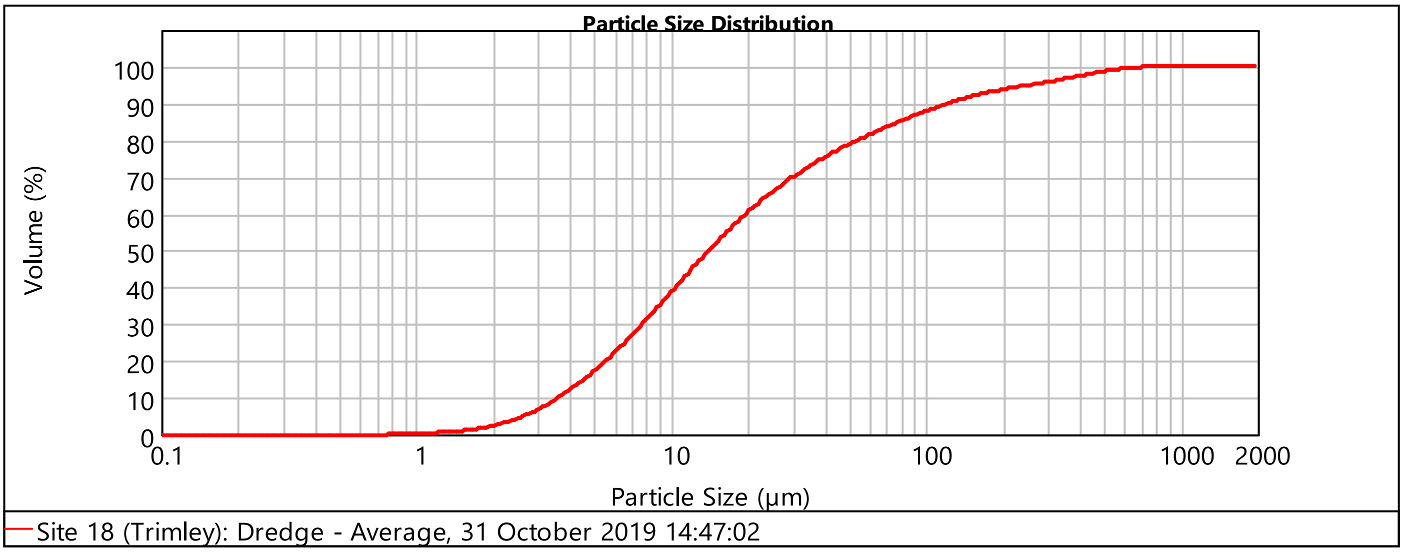
Particle Size Analysis Report

Sample Name:	Site 18 (Trimley): Dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	10.51 %
Sample Collected:		Weighted Residual:	0.847 %

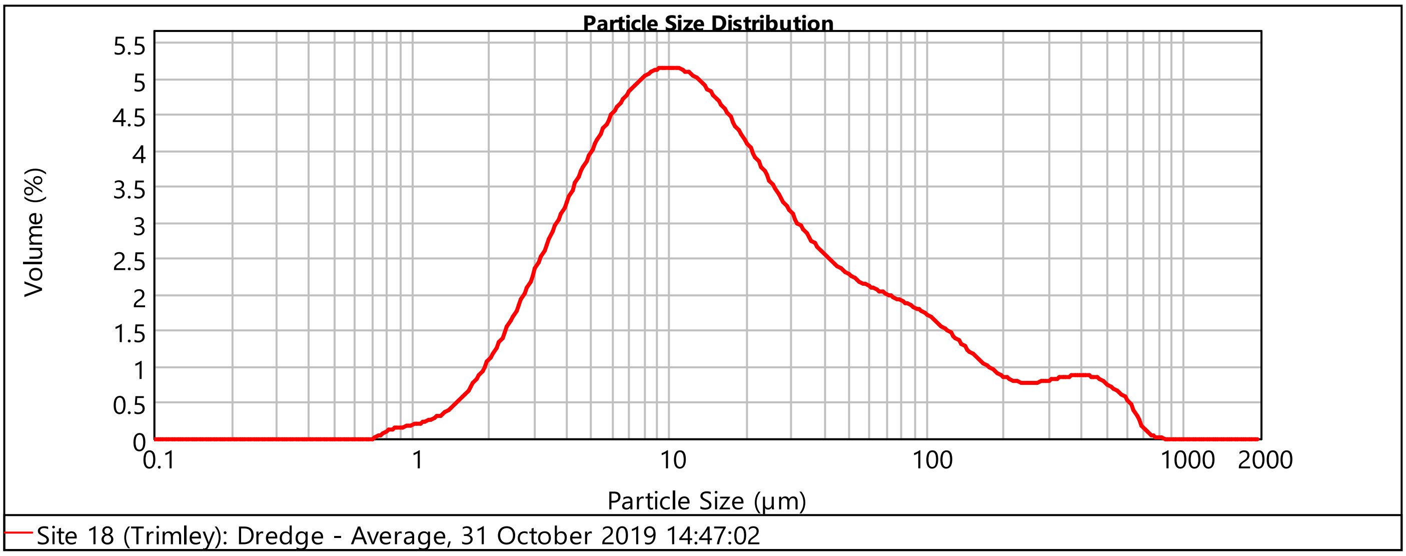
d(0.1): 3.617 µm **d(0.5): 14.025 µm** d(0.9): 120.348 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	20 %	38 %	21 %	12 %	6 %	0 %

Frequency Curve



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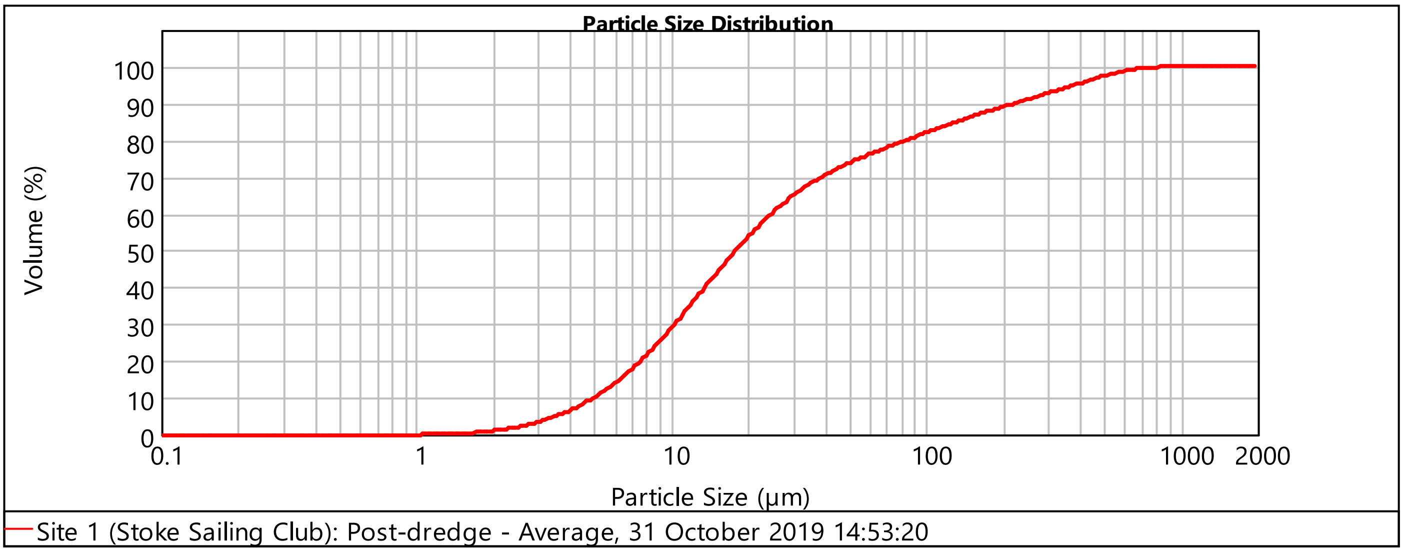
Particle Size Analysis Report

Sample Name:	Site 1 (Stoke Sailing Club): Post-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	12.57 %
Sample Collected:		Weighted Residual:	0.578 %

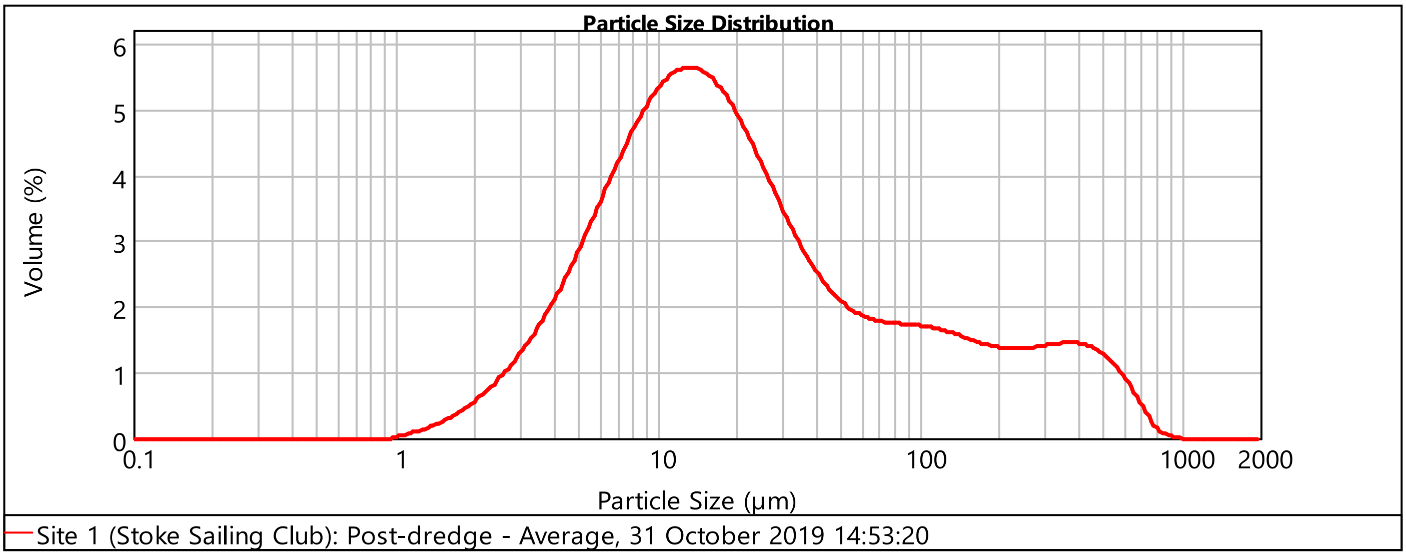
d(0.1): 4.964 µm   **d(0.5): 17.907 µm**   d(0.9): 219.665 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	13 %	40 %	23 %	13 %	10 %	1 %

Frequency Curve



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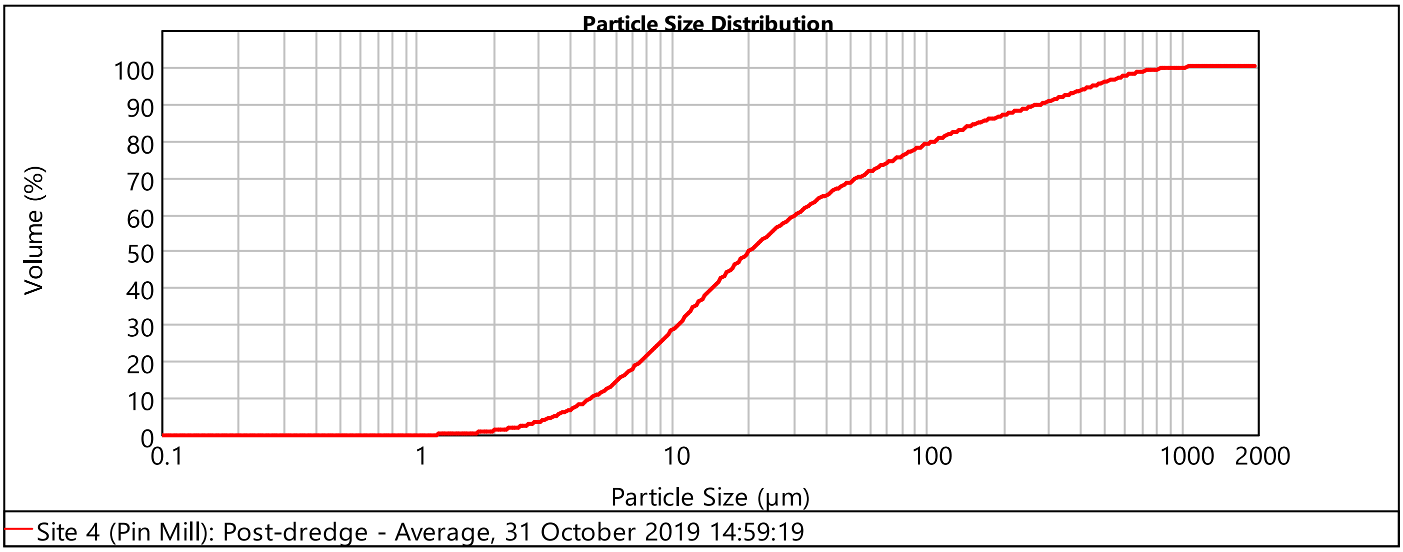
Particle Size Analysis Report

Sample Name:	Site 4 (Pin Mill): Post-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	11.12 %
Sample Collected:		Weighted Residual:	0.419 %

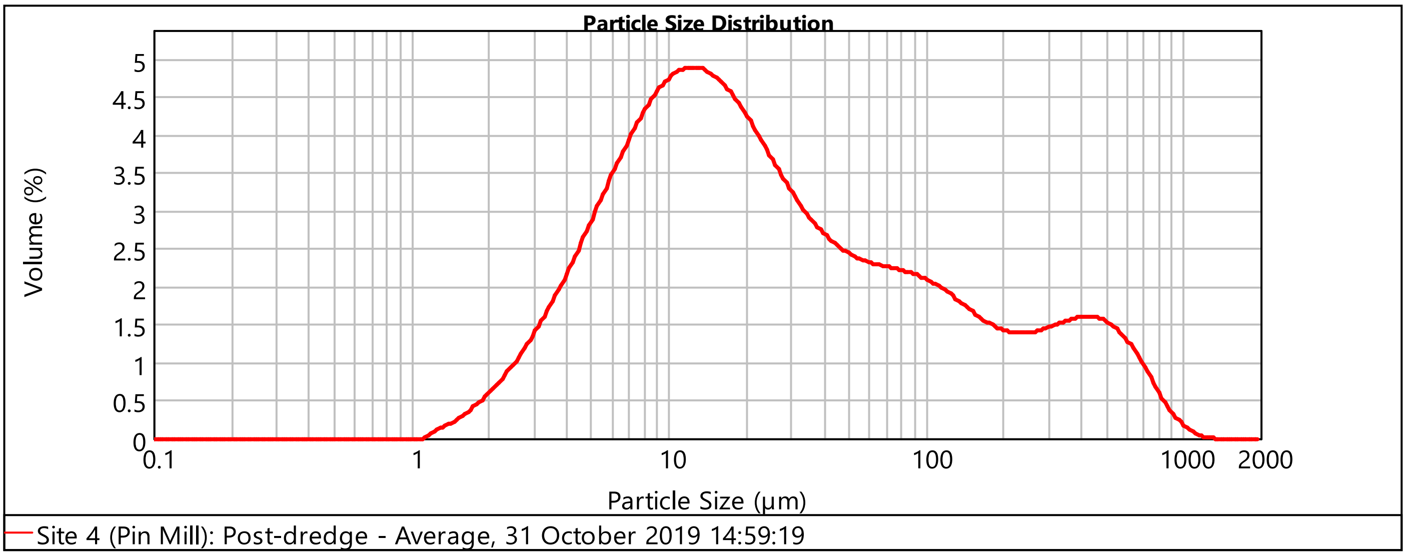
d(0.1): 4.896 µm **d(0.5): 20.425 µm** d(0.9): 282.950 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	13 %	35 %	22 %	15 %	11 %	3 %

Frequency Curve



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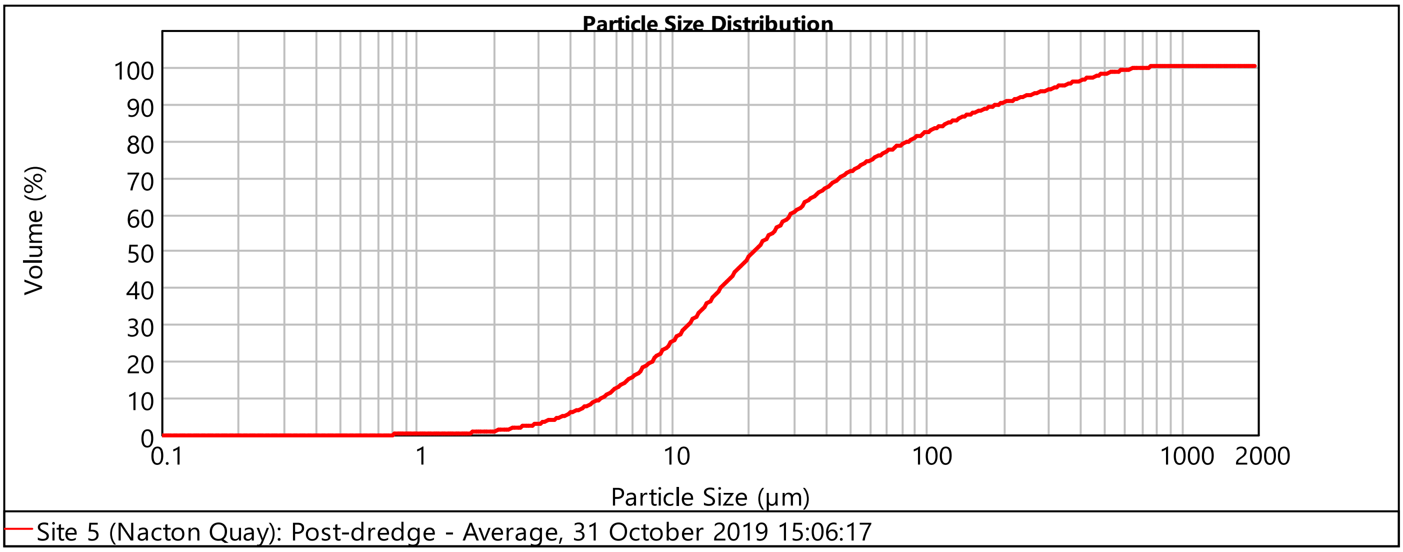
Particle Size Analysis Report

Sample Name:	Site 5 (Nacton Quay): Post-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	13.26 %
Sample Collected:		Weighted Residual:	0.555 %

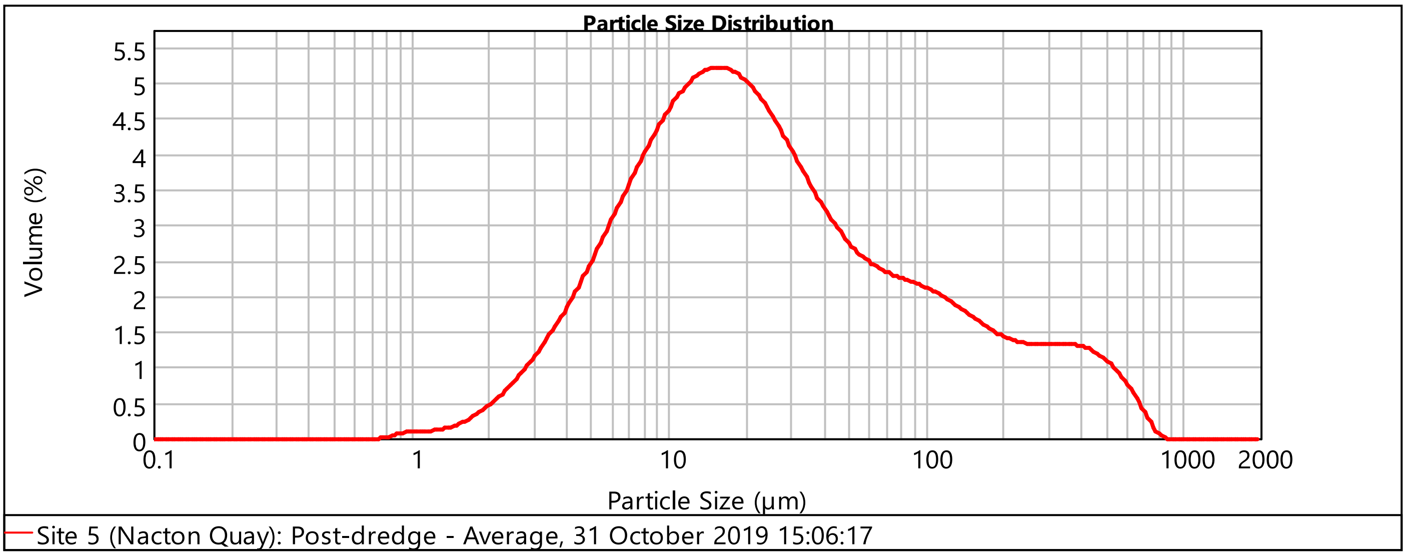
d(0.1): 5.353 µm **d(0.5): 21.304 µm** d(0.9): 195.782 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	11 %	36 %	27 %	16 %	9 %	1 %

Frequency Curve



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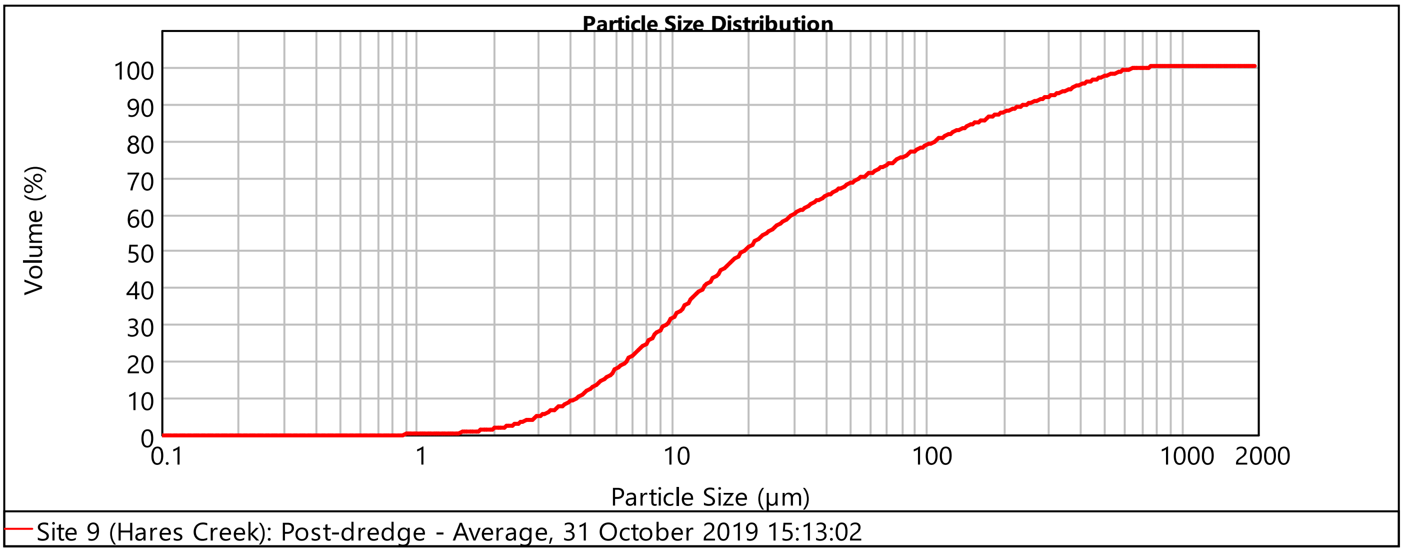
Particle Size Analysis Report

Sample Name:	Site 9 (Hares Creek): Post-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	14.06 %
Sample Collected:		Weighted Residual:	0.754 %

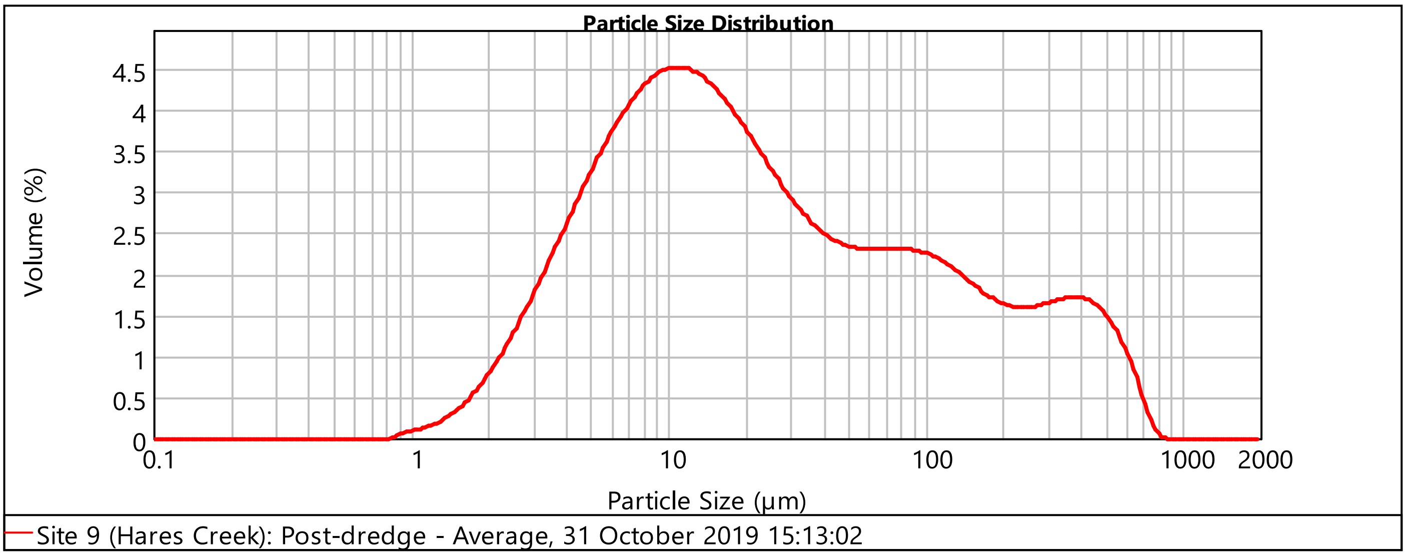
d(0.1): 4.249 µm   **d(0.5): 19.355 µm**   d(0.9): 252.780 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	16 %	33 %	20 %	17 %	11 %	1 %

Frequency Curve



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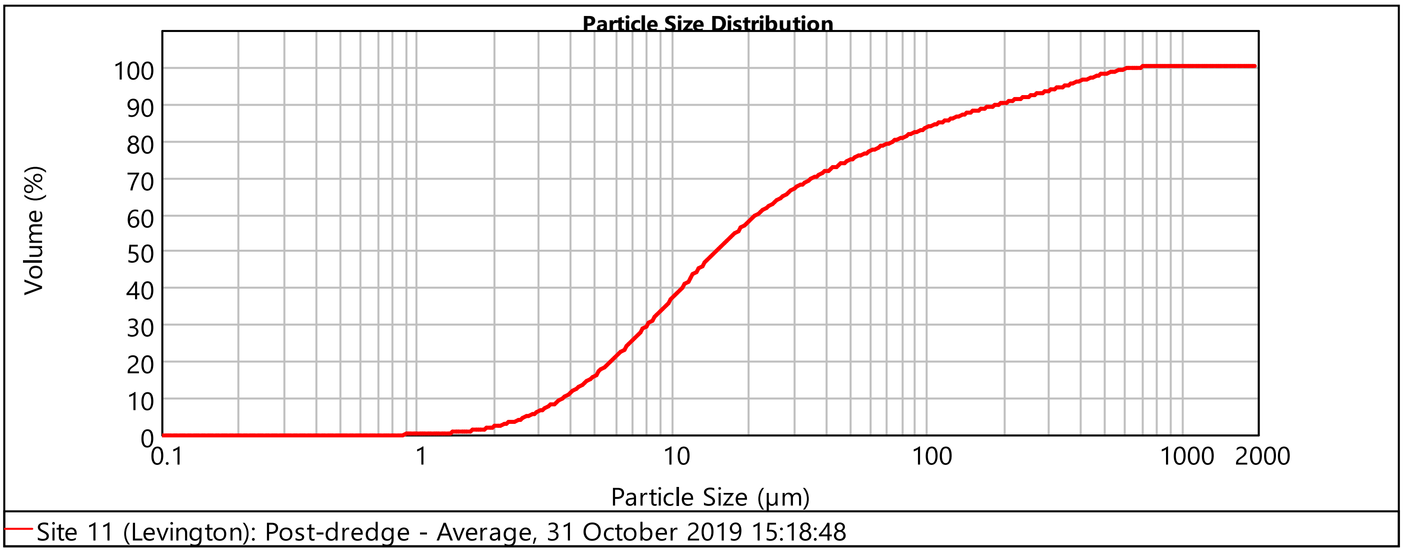
Particle Size Analysis Report

Sample Name:	Site 11 (Levington): Post-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	13.33 %
Sample Collected:		Weighted Residual:	0.794 %

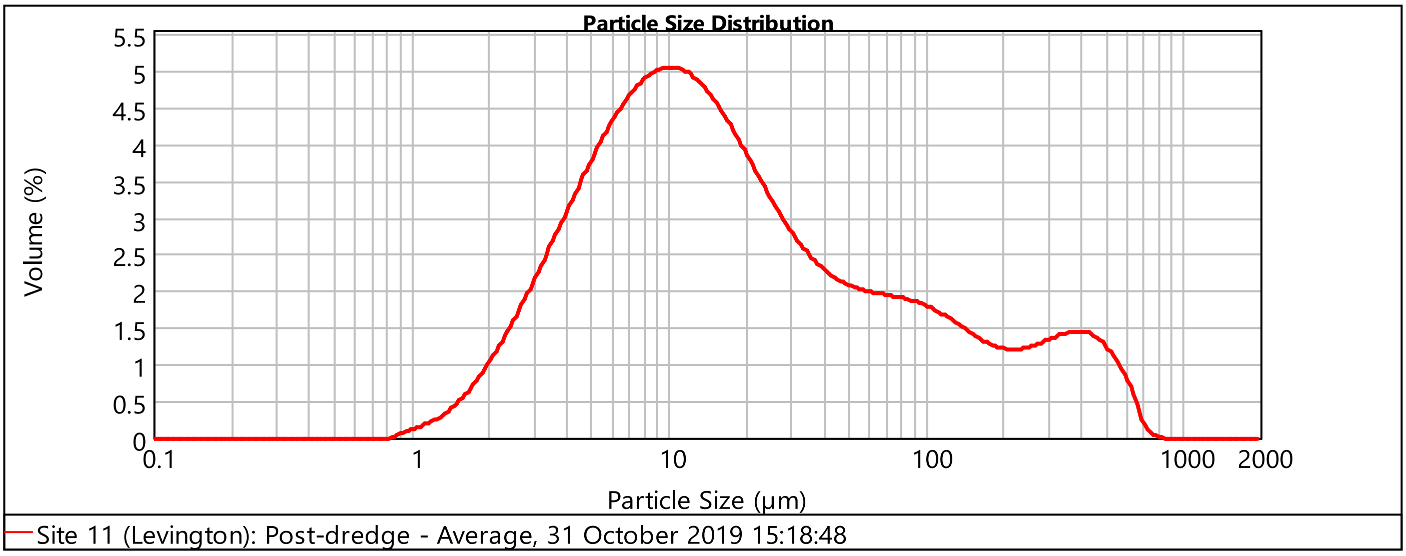
d(0.1): 3.792 µm | **d(0.5): 15.111 µm** | d(0.9): 196.627 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	19 %	37 %	19 %	13 %	9 %	1 %

Frequency Curve



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Particle Size Analysis Report

Sample Name: Site 13 (Jill's Hole): Post-dredge - Average

Sample Source: Ipswich

Sample Collected:

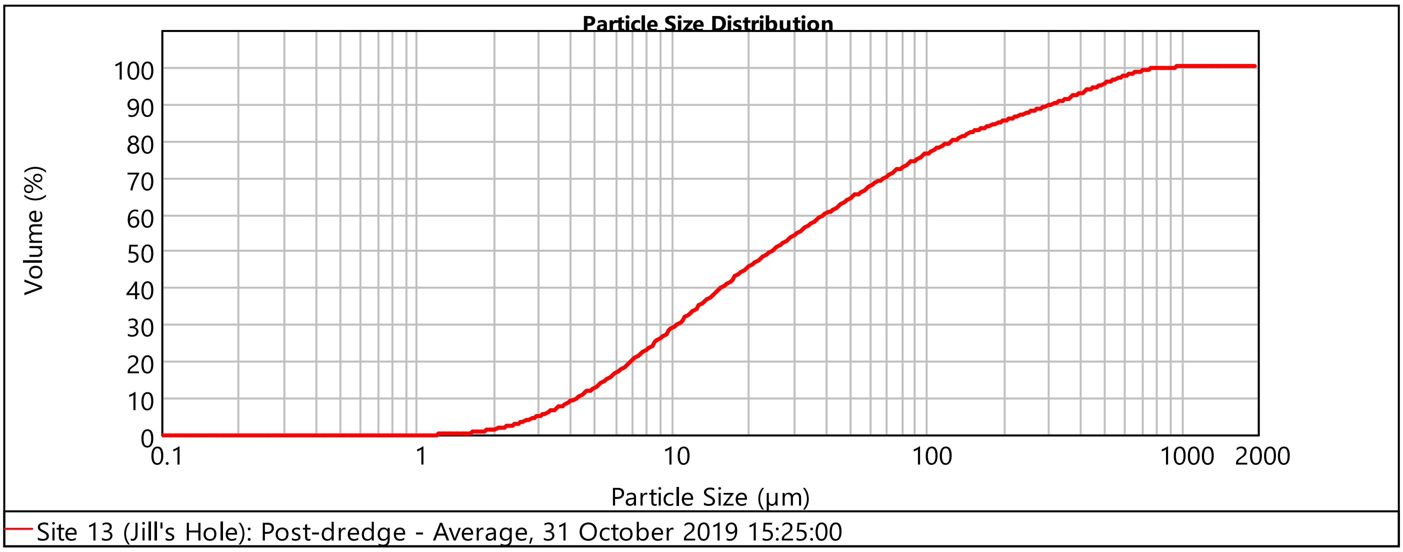
Measured by: IDavidson on 31 October 2019

Obscuration: 20.81 %

Weighted Residual: 0.428 %

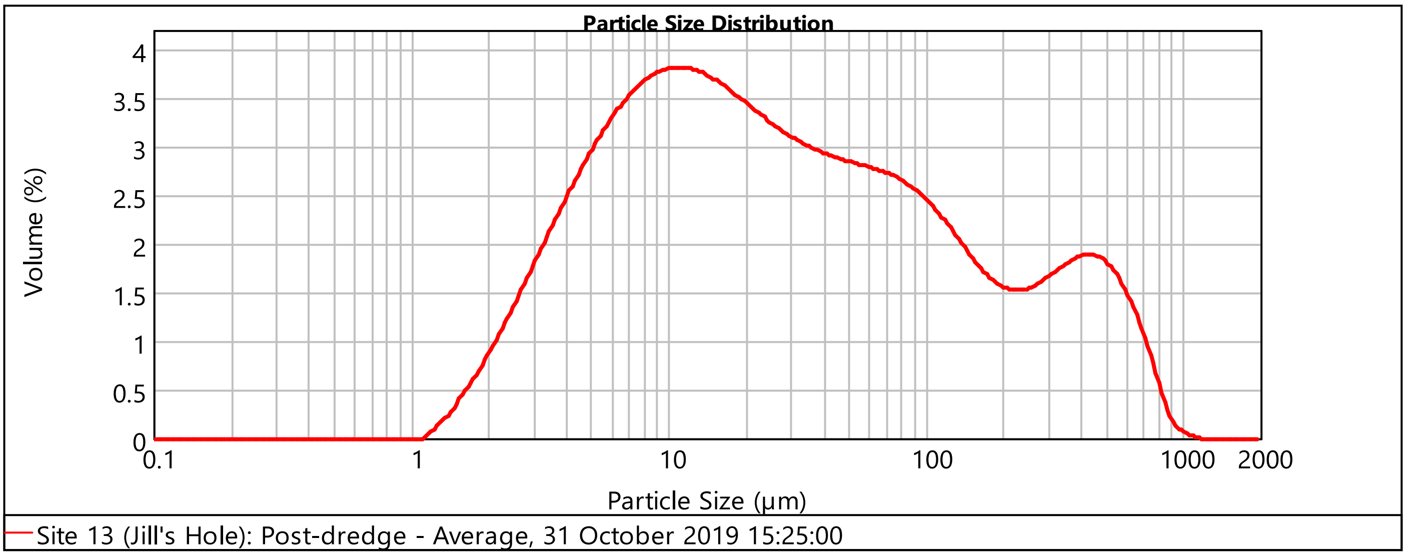
d(0.1): 4.271 µm | **d(0.5): 24.596 µm** | d(0.9): 316.587 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	15 %	29 %	22 %	18 %	12 %	2 %

Frequency Curve



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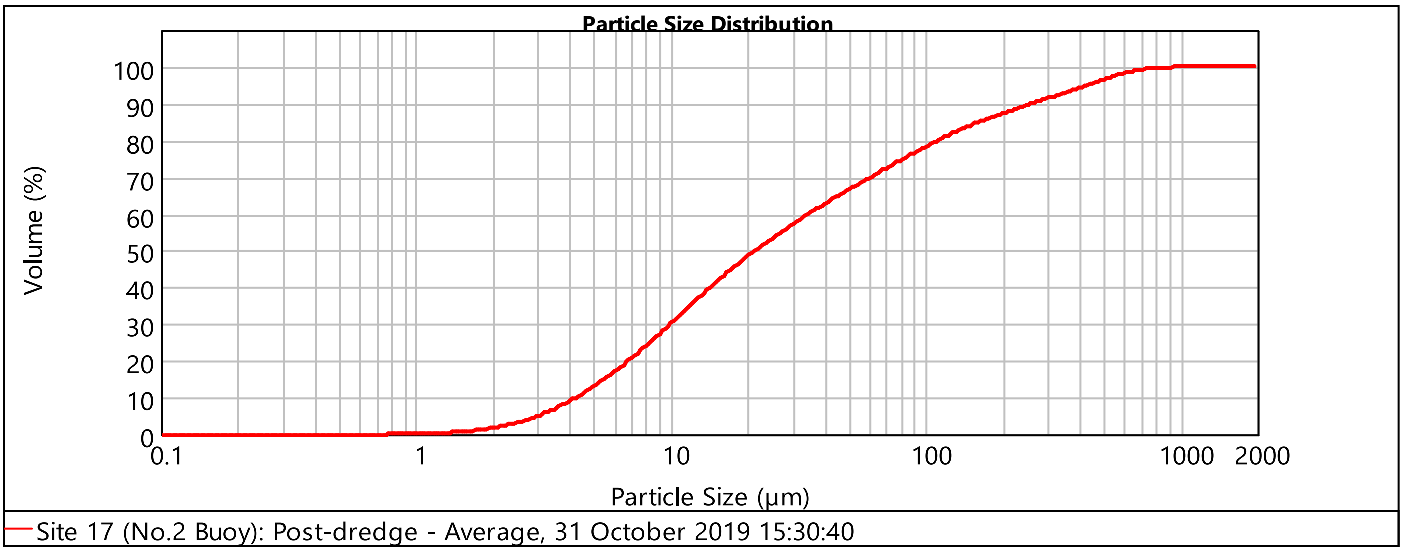
Particle Size Analysis Report

Sample Name:	Site 17 (No.2 Buoy): Post-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	15.04 %
Sample Collected:		Weighted Residual:	0.556 %

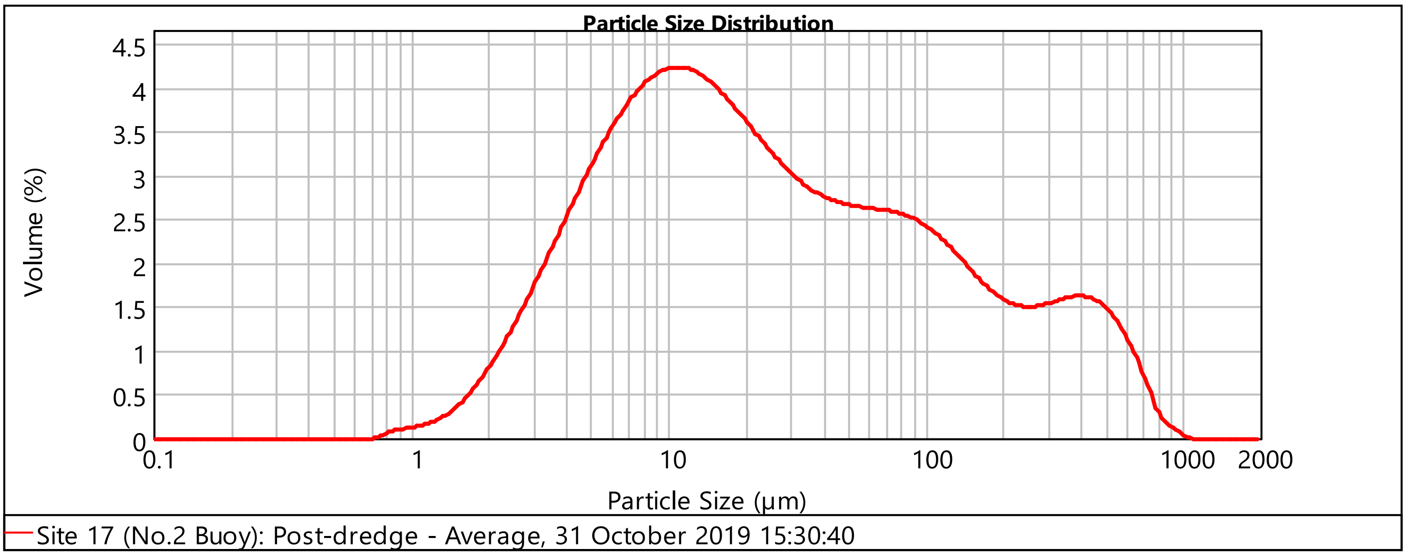
d(0.1): 4.239 µm **d(0.5): 21.287 µm** d(0.9): 259.201 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	15 %	31 %	21 %	18 %	11 %	2 %

Frequency Curve



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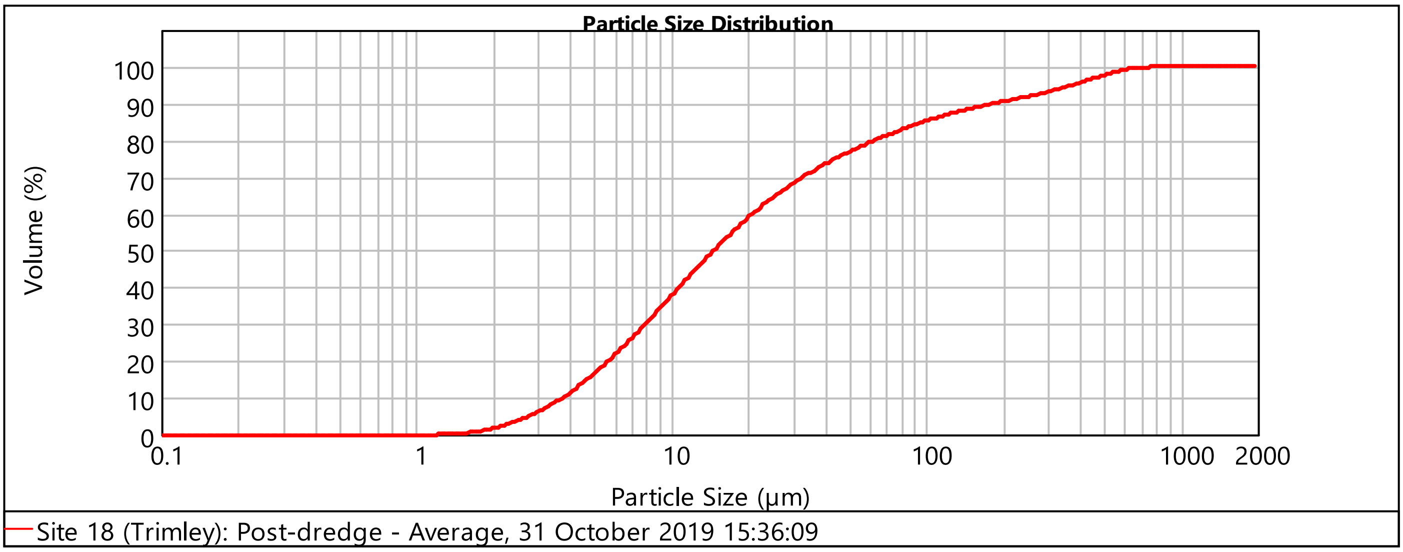
Particle Size Analysis Report

Sample Name:	Site 18 (Trimley): Post-dredge - Average	Measured by:	IDavidson on 31 October 2019
Sample Source:	Ipswich	Obscuration:	15.68 %
Sample Collected:		Weighted Residual:	0.779 %

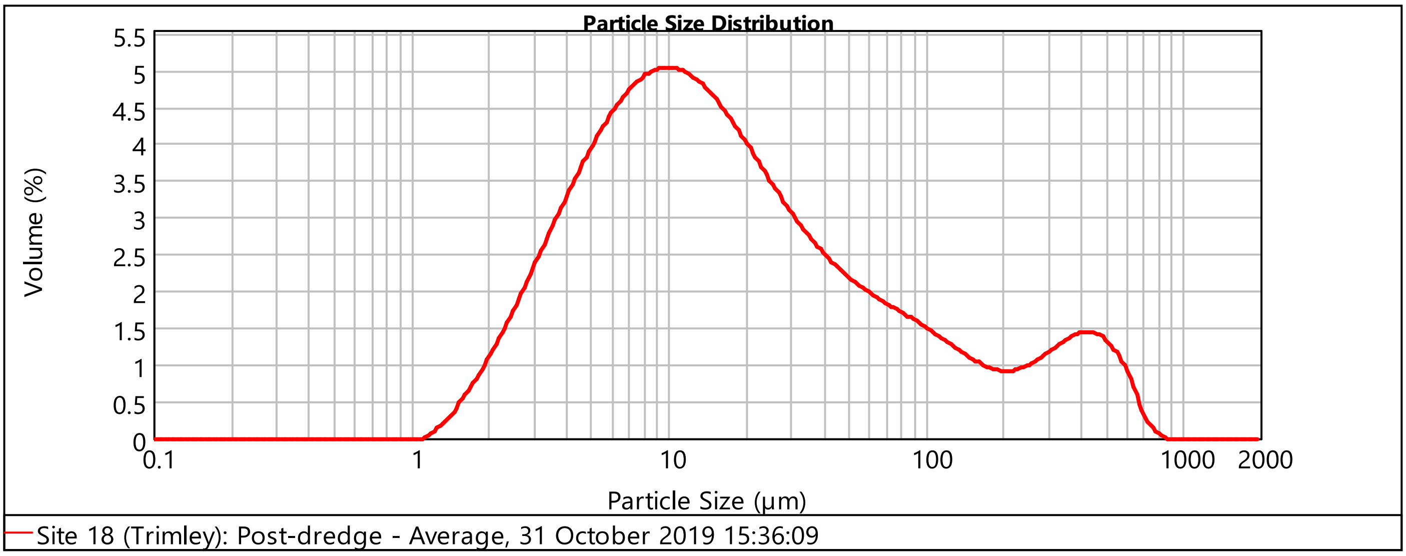
d(0.1): 3.737 µm   **d(0.5): 14.643 µm**   d(0.9): 182.146 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	20 %	37 %	21 %	11 %	9 %	1 %

Frequency Curve



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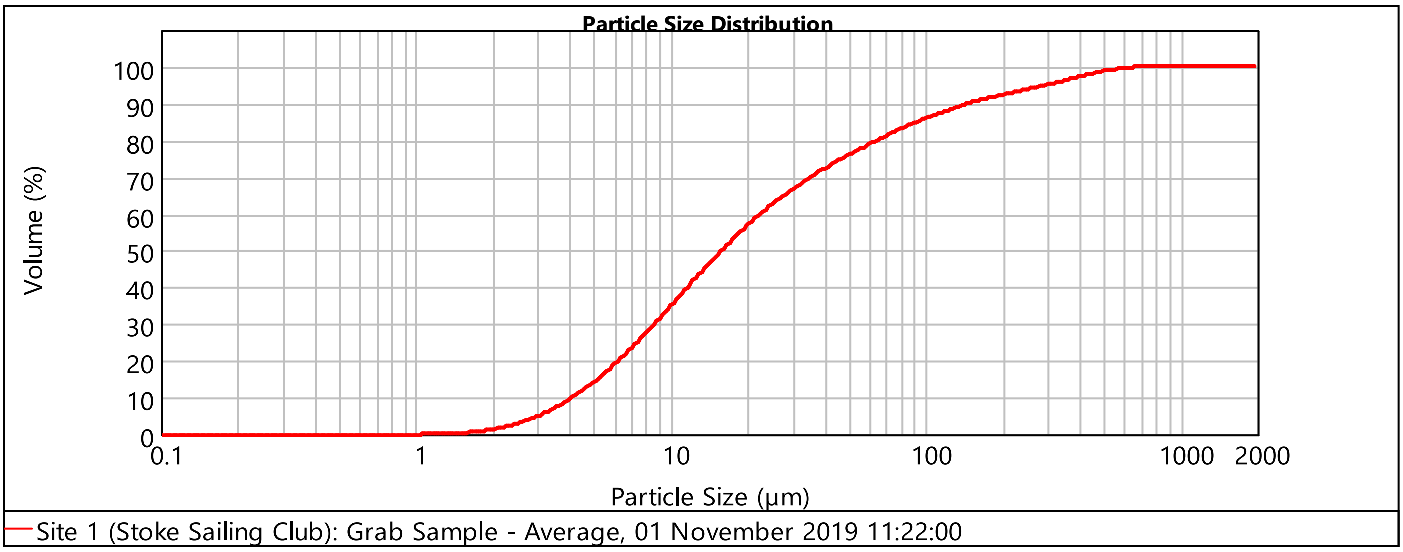
Particle Size Analysis Report

Sample Name:	Site 1 (Stoke Sailing Club): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	13.81 %
Sample Collected:		Weighted Residual:	0.712 %

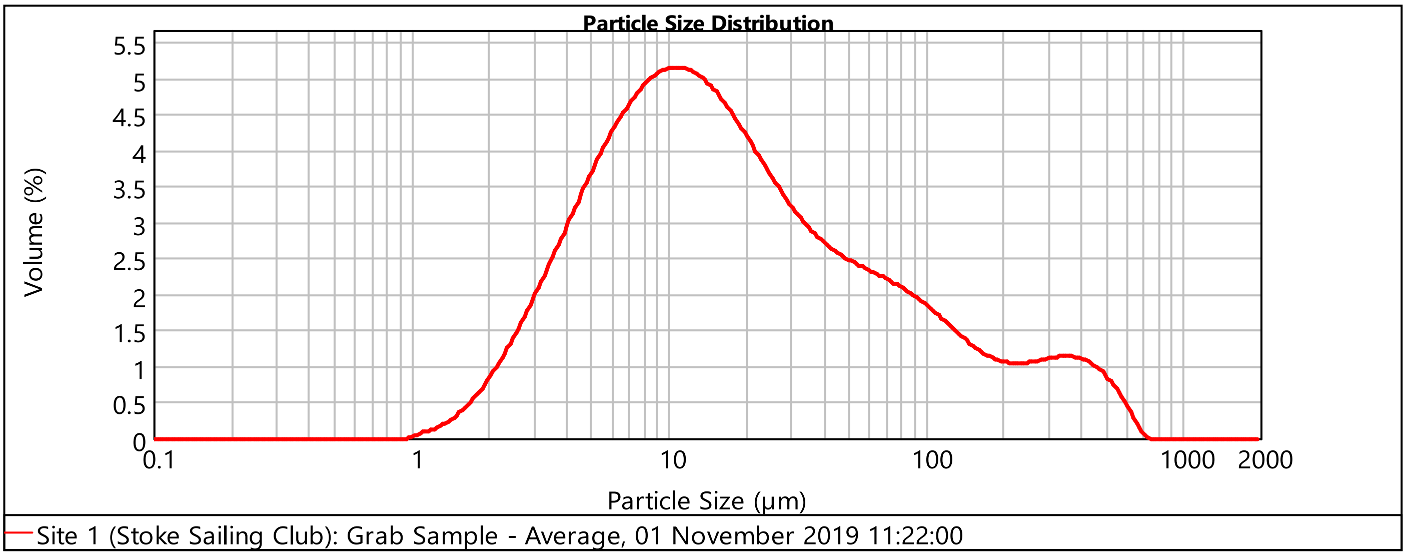
d(0.1): 4.101 µm **d(0.5): 15.764 µm** d(0.9): 144.965 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	18 %	38 %	22 %	13 %	7 %	0 %

Frequency Curve



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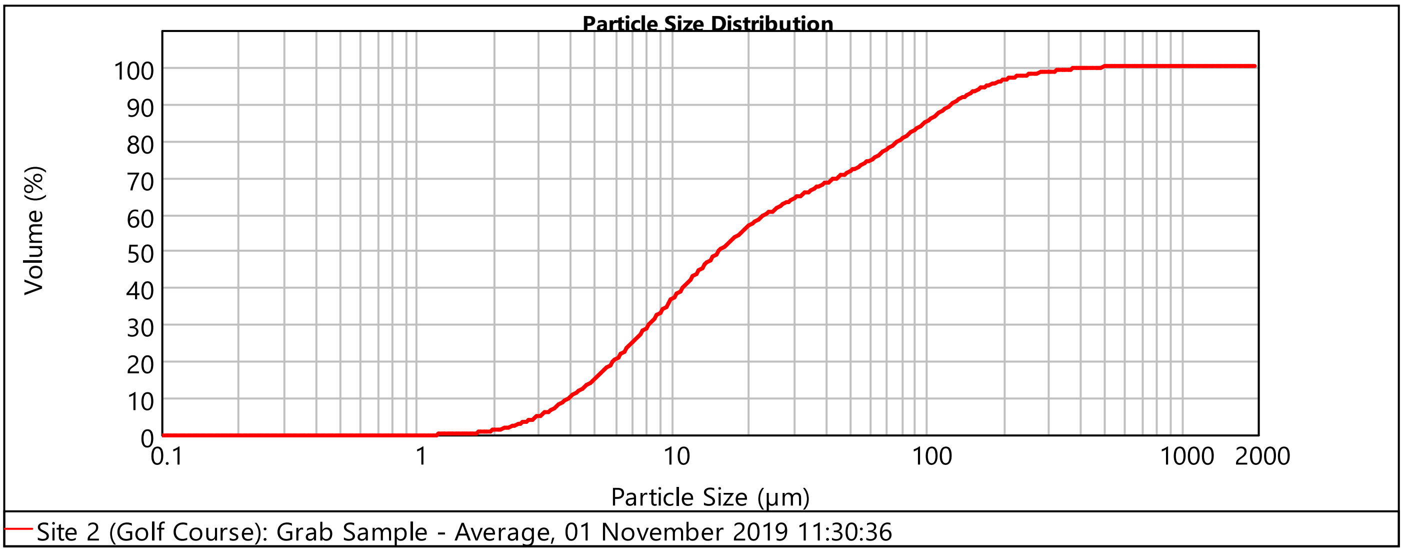
Particle Size Analysis Report

Sample Name:	Site 2 (Golf Course): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	13.08 %
Sample Collected:		Weighted Residual:	0.989 %

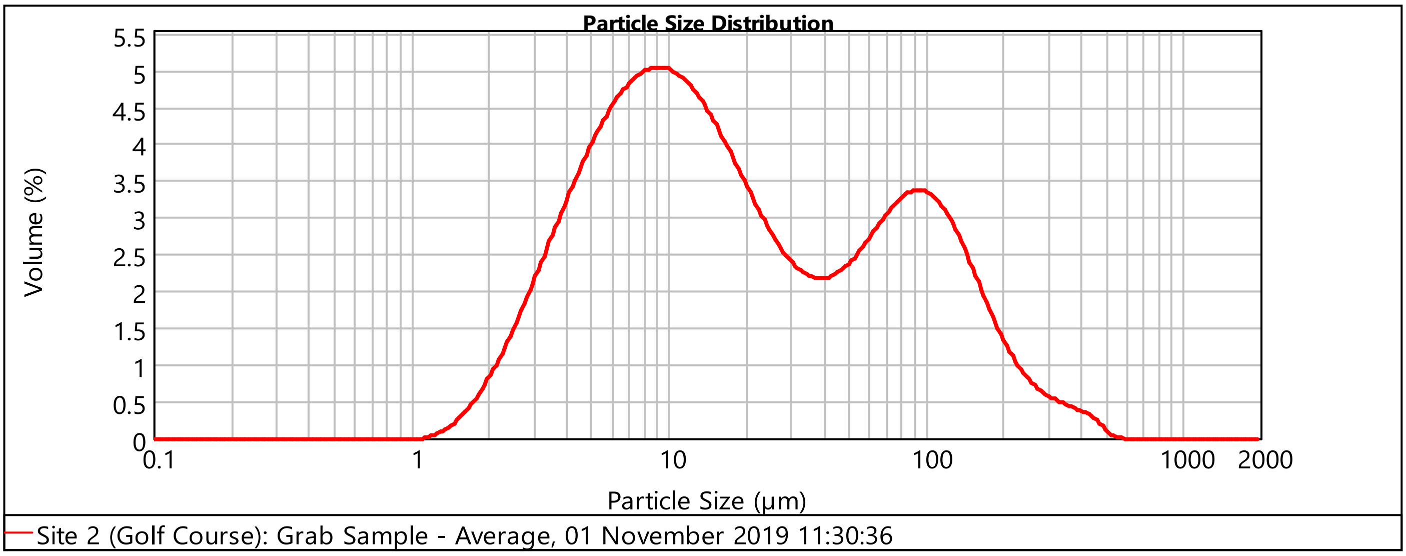
d(0.1): 4.022 µm **d(0.5): 15.506 µm** d(0.9): 127.046 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	19 %	36 %	18 %	22 %	4 %	0 %

Frequency Curve



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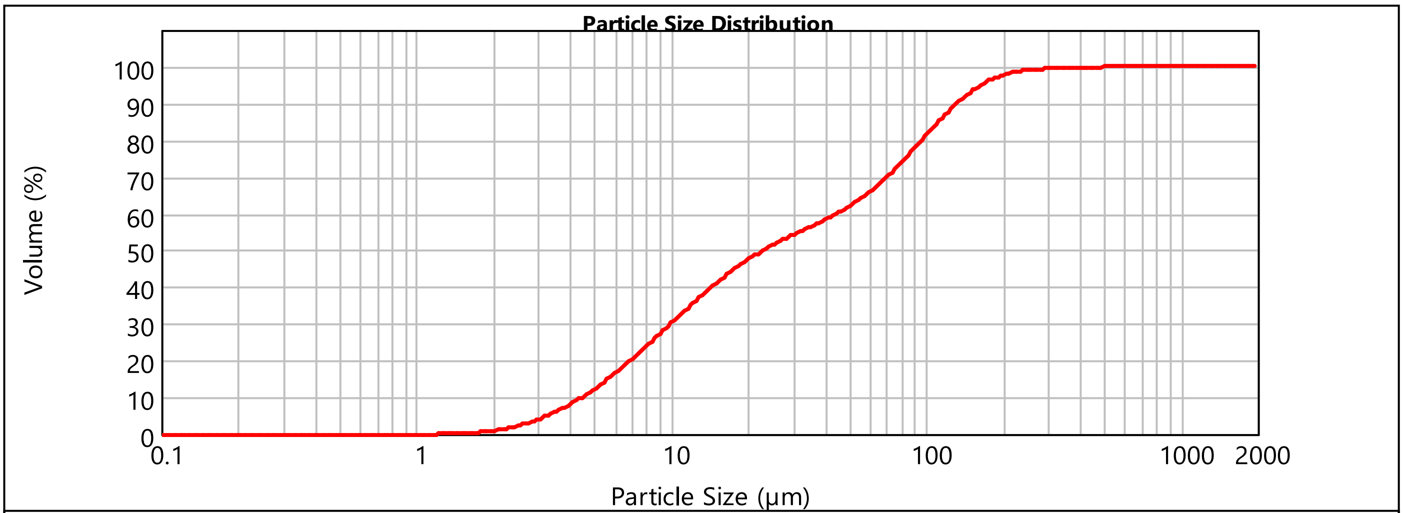
Particle Size Analysis Report

Sample Name:	Site 3 (Woolverstone): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	15.04 %
Sample Collected:		Weighted Residual:	0.793 %

d(0.1): 4.454 μm | **d(0.5): 22.918 μm** | d(0.9): 131.488 μm

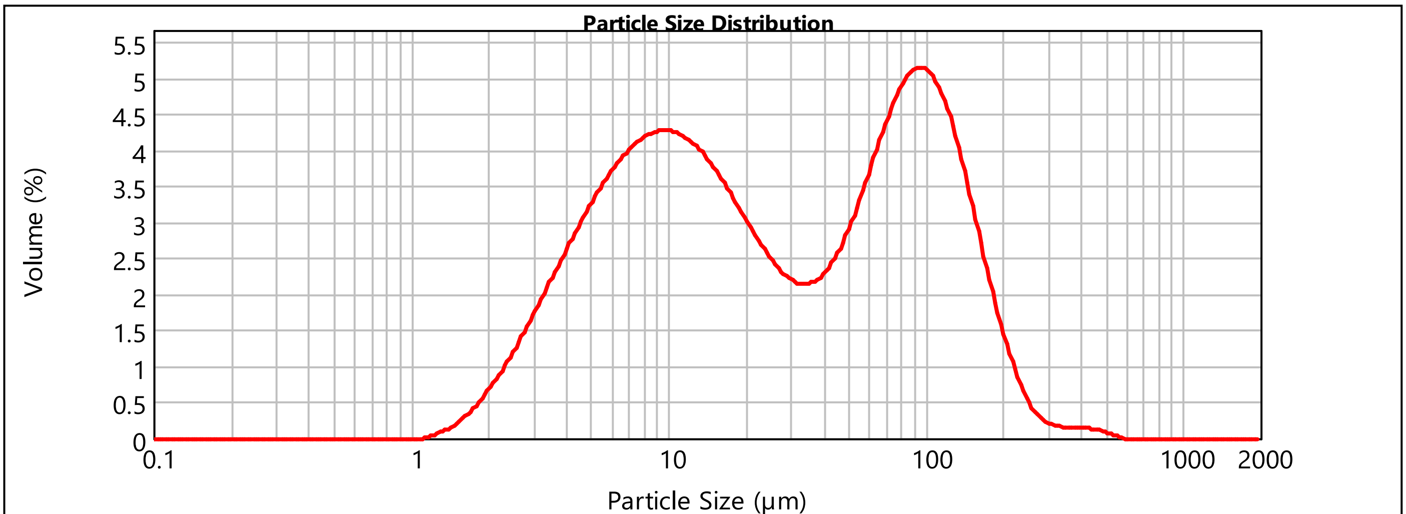
Cumulative Frequency Plot



Site 3 (Woolverstone): Grab Sample - Average, 01 November 2019 11:38:41

Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	16 %	31 %	18 %	32 %	2 %	0 %

Frequency Curve



Site 3 (Woolverstone): Grab Sample - Average, 01 November 2019 11:38:41

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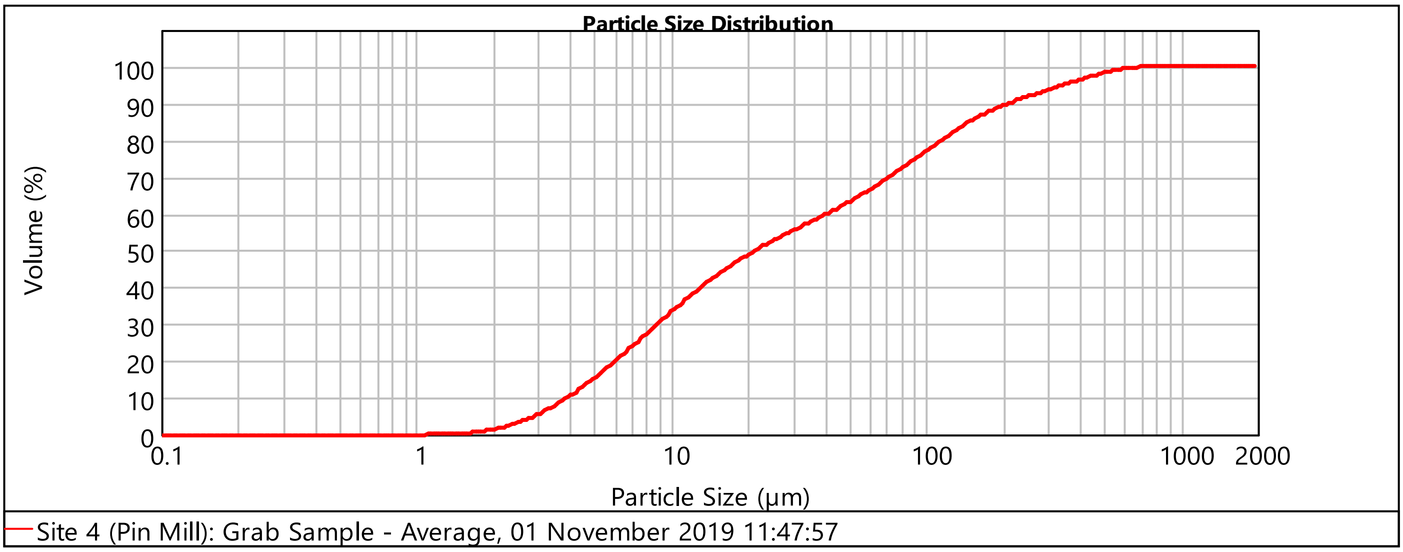
Particle Size Analysis Report

Sample Name:	Site 4 (Pin Mill): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	14.61 %
Sample Collected:		Weighted Residual:	0.560 %

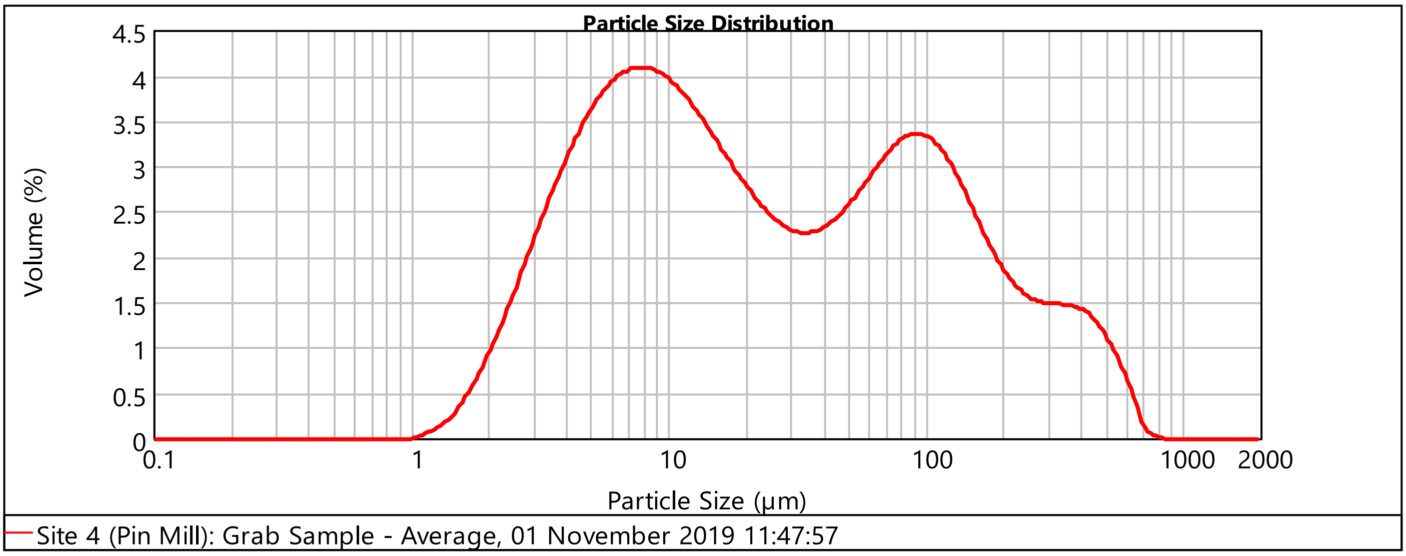
d(0.1): 3.917 µm d(0.5): 21.314 µm d(0.9): 209.405 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	18 %	29 %	18 %	23 %	10 %	0 %

Frequency Curve



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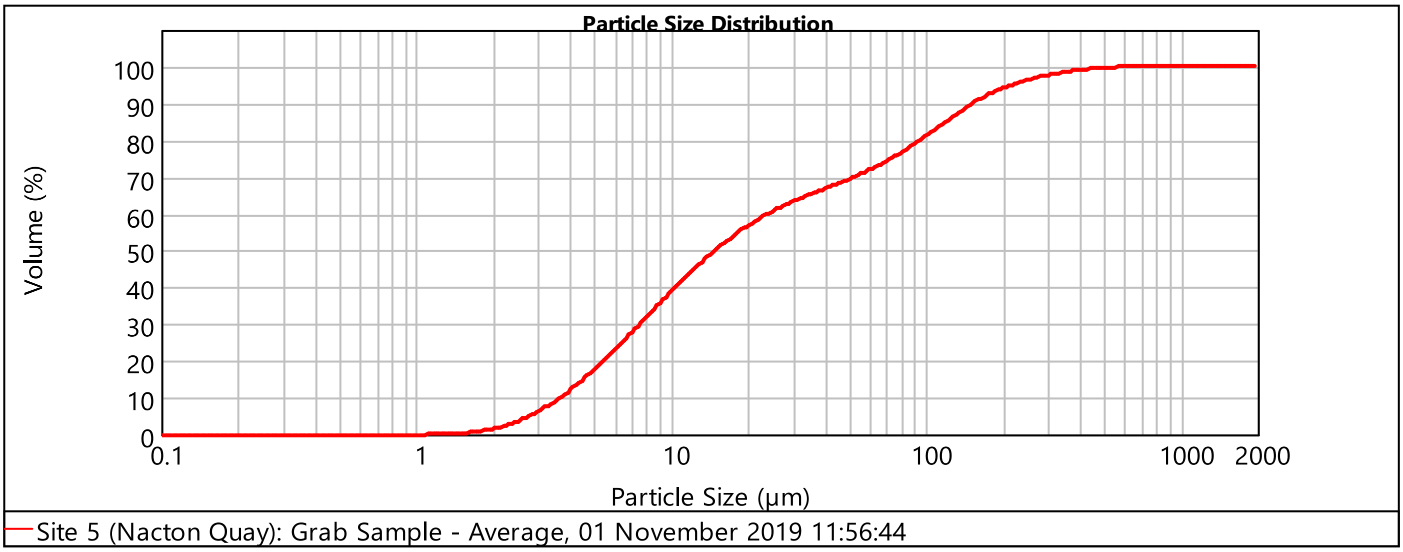
Particle Size Analysis Report

Sample Name:	Site 5 (Nacton Quay): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	13.01 %
Sample Collected:		Weighted Residual:	0.955 %

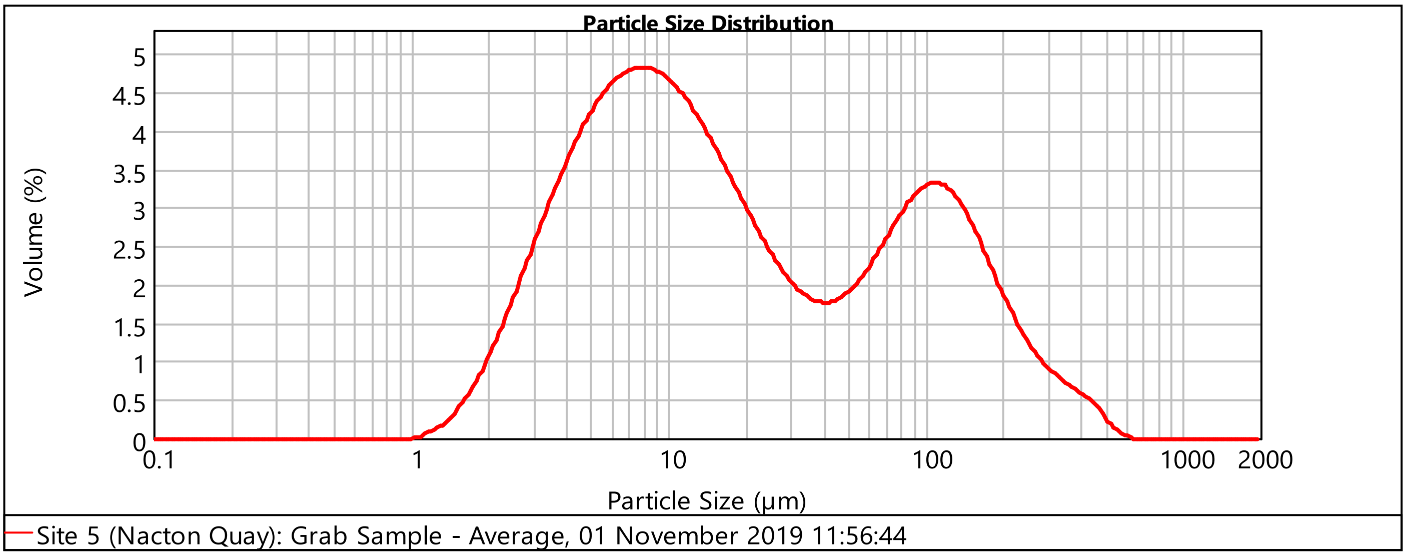
d(0.1): 3.657 µm **d(0.5): 14.782 µm** d(0.9): 151.525 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	21 %	34 %	15 %	22 %	6 %	0 %

Frequency Curve



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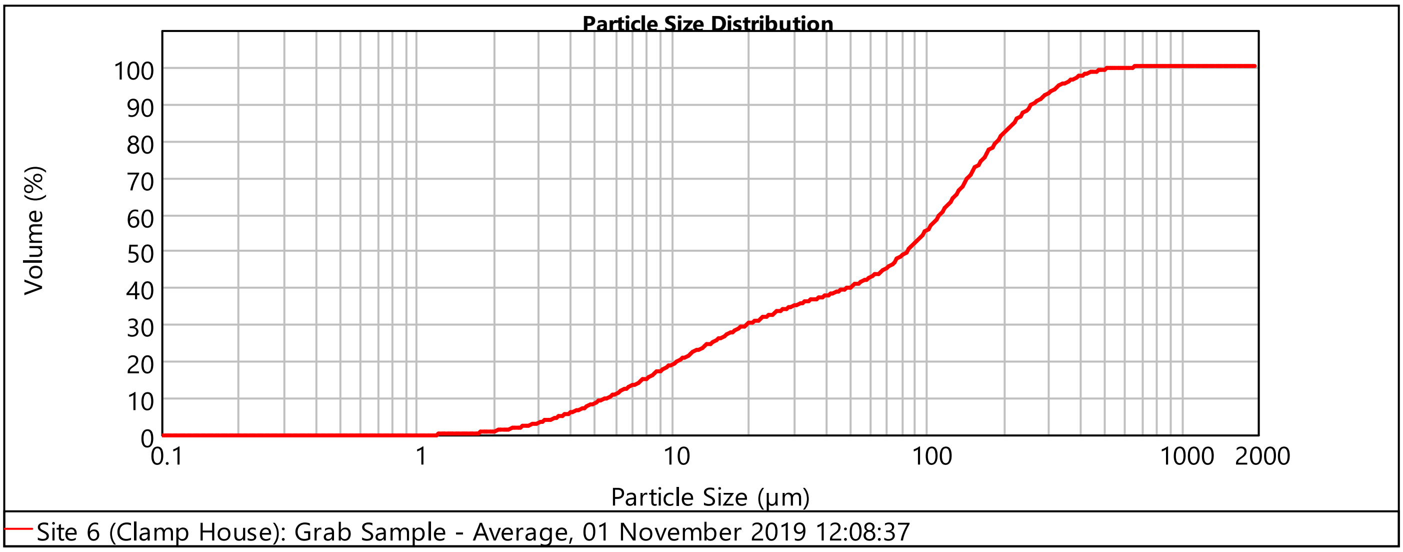
Particle Size Analysis Report

Sample Name:	Site 6 (Clamp House): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	16.26 %
Sample Collected:		Weighted Residual:	0.470 %

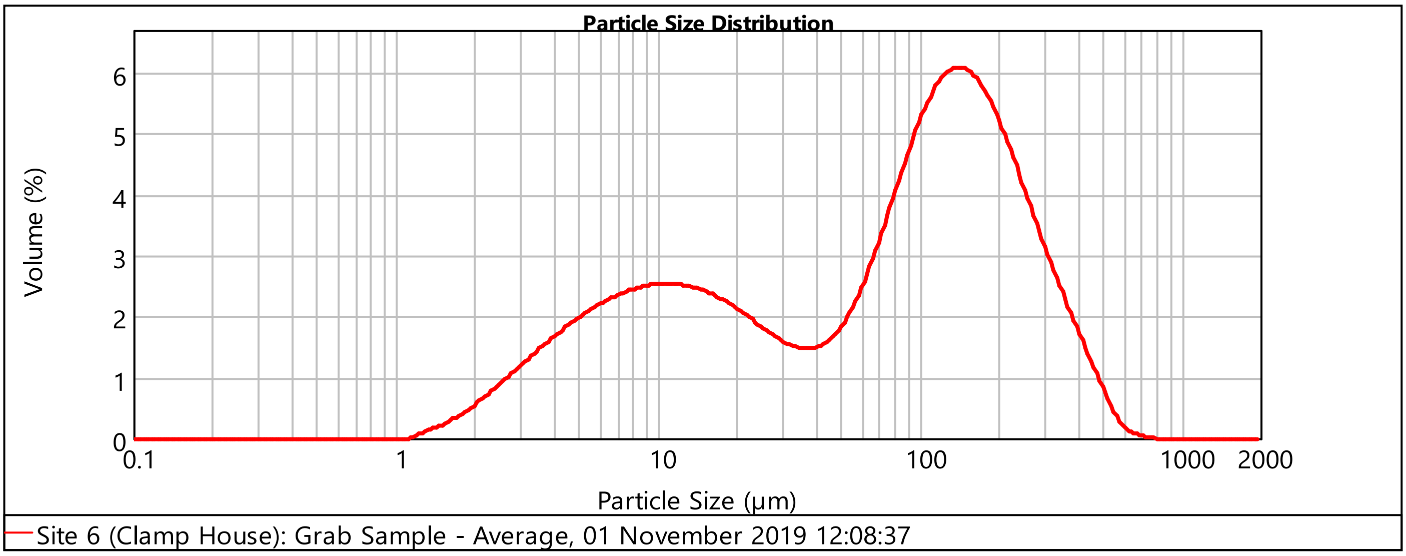
d(0.1): 5.591 µm — **d(0.5): 84.302 µm** — d(0.9): 265.367 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	10 %	19 %	13 %	39 %	18 %	0 %

Frequency Curve



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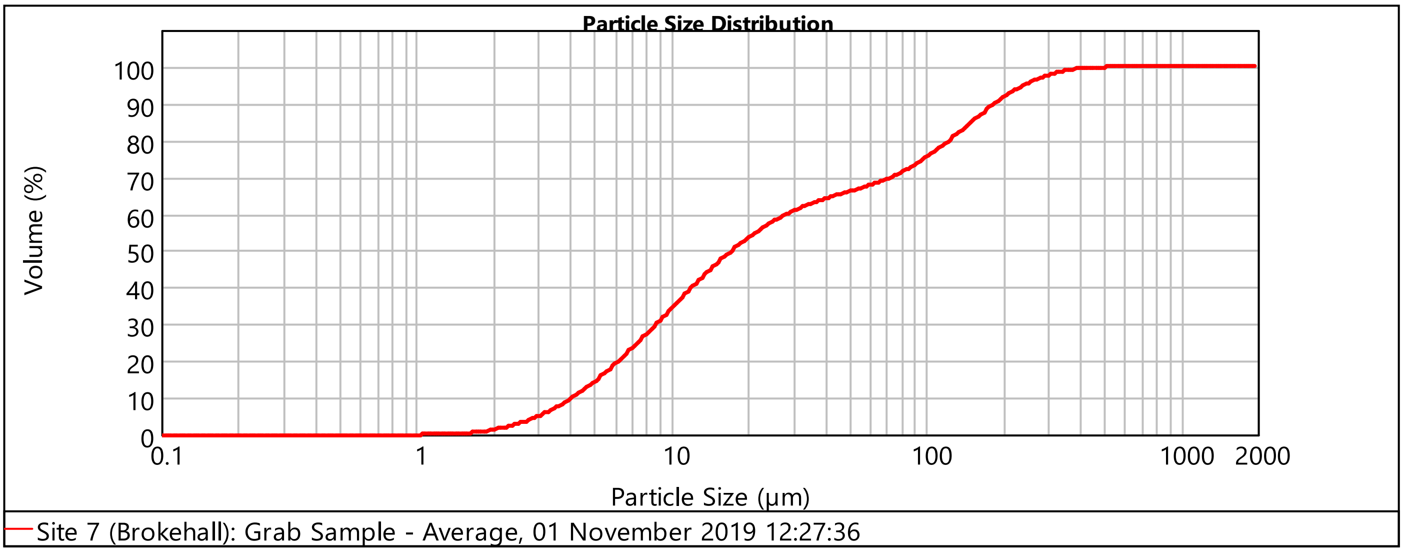
Particle Size Analysis Report

Sample Name:	Site 7 (Brokehall): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	13.92 %
Sample Collected:		Weighted Residual:	0.599 %

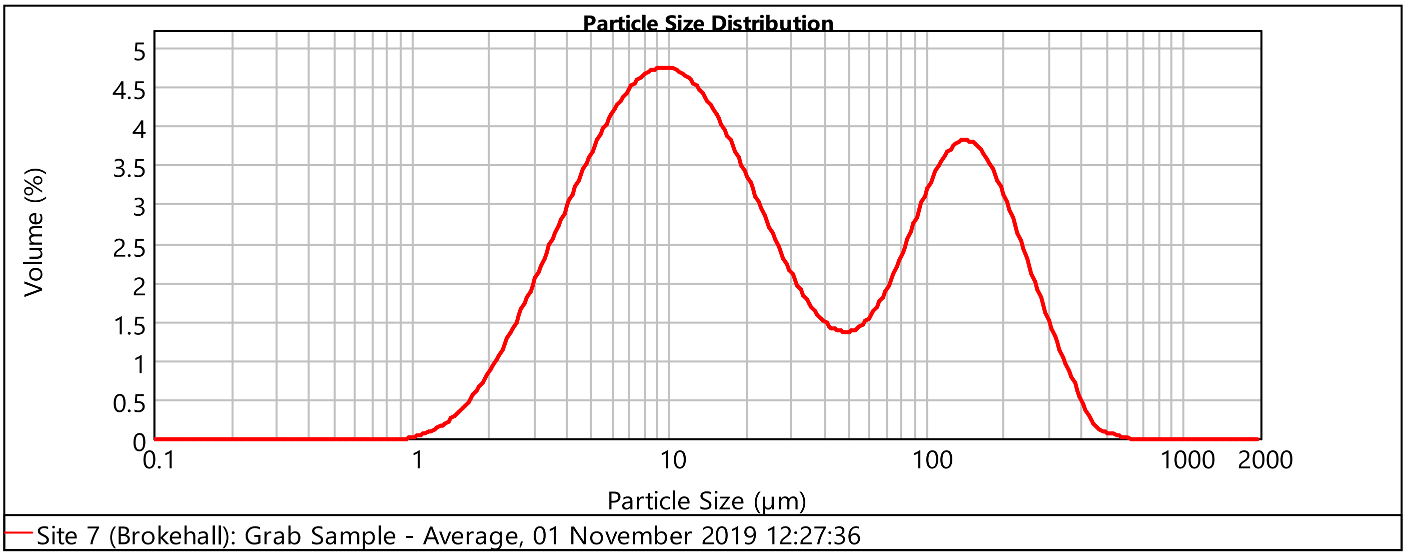
d(0.1): 4.084 µm   **d(0.5): 17.257 µm**   d(0.9): 185.933 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
1 %	18 %	34 %	14 %	24 %	8 %	0 %

Frequency Curve



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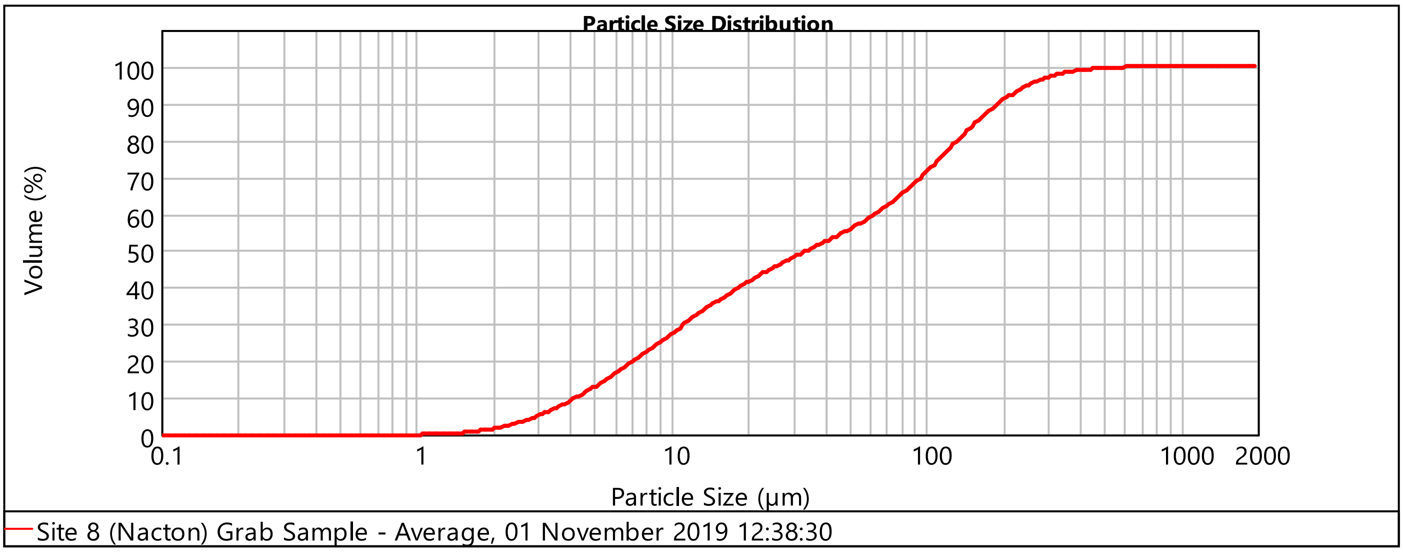
Particle Size Analysis Report

Sample Name:	Site 8 (Nacton) Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	13.33 %
Sample Collected:		Weighted Residual:	0.568 %

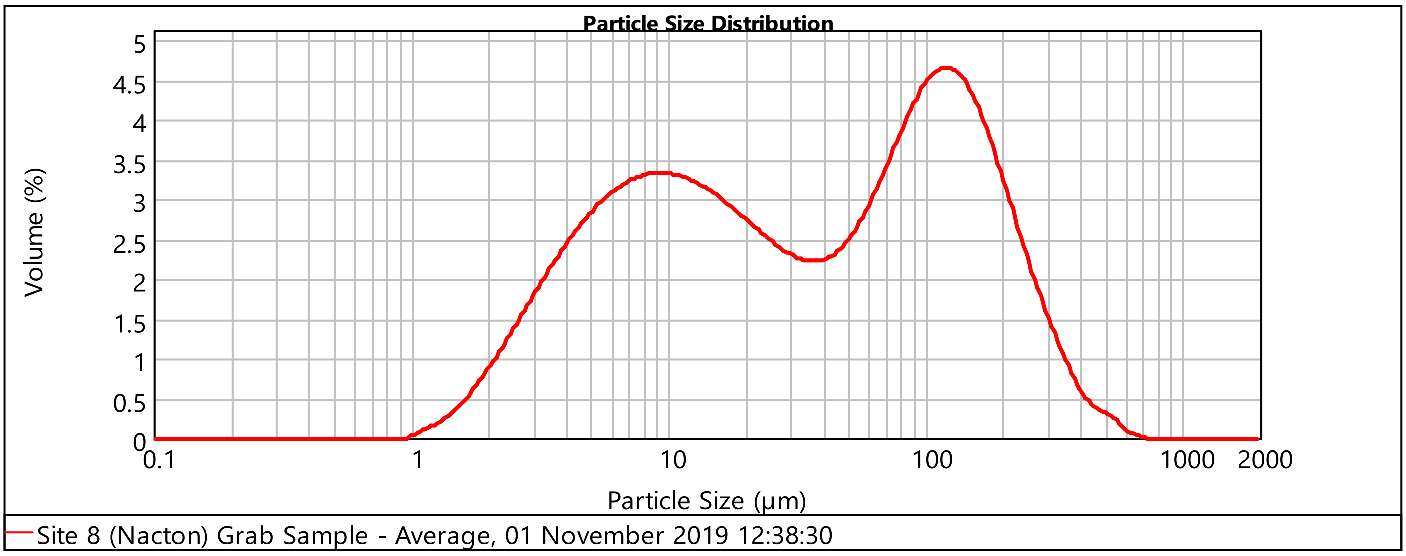
d(0.1): 4.225 µm **d(0.5): 33.929 µm** d(0.9): 192.203 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	15 %	25 %	17 %	32 %	9 %	0 %

Frequency Curve



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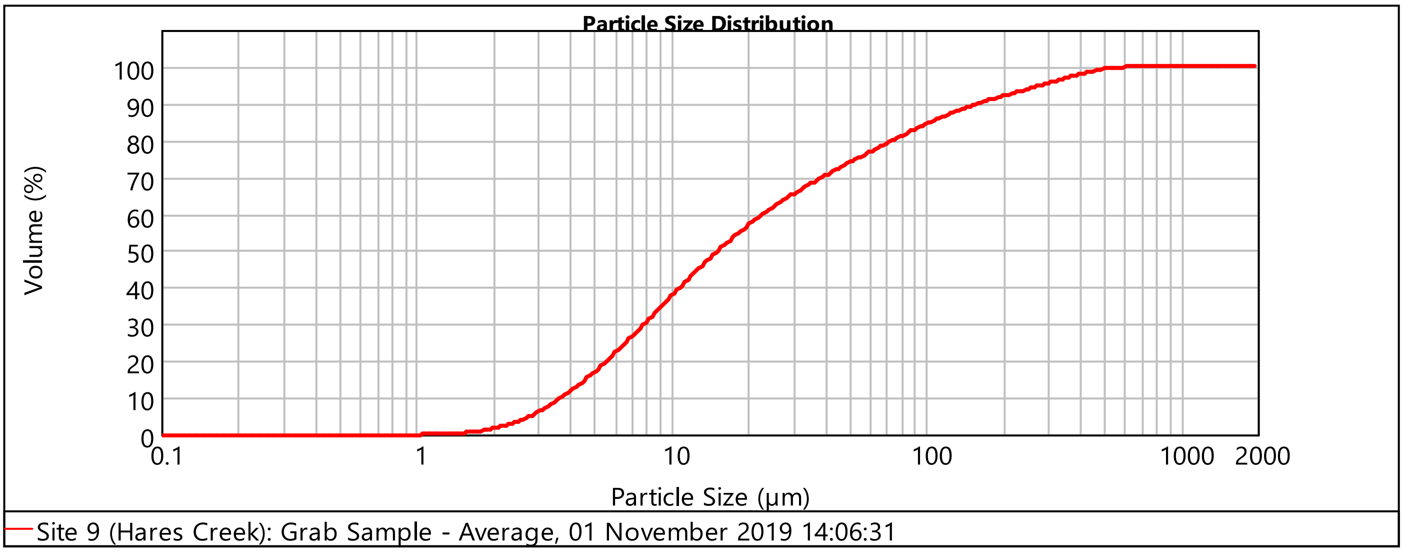
Particle Size Analysis Report

Sample Name:	Site 9 (Hares Creek): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	13.84 %
Sample Collected:		Weighted Residual:	0.956 %

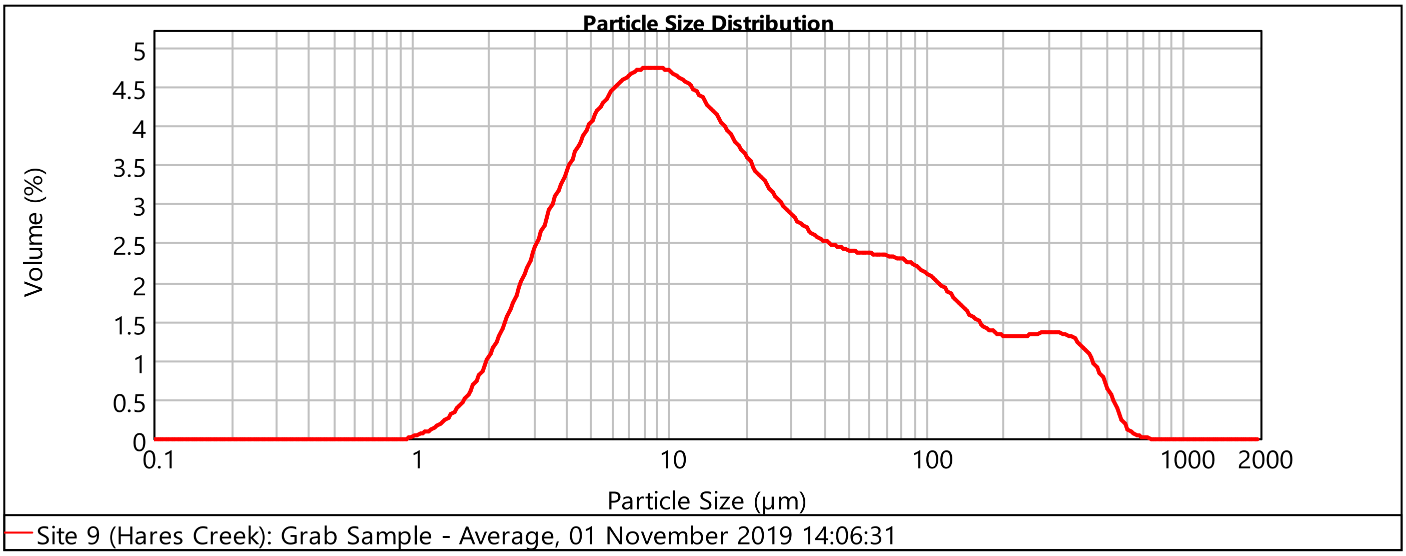
d(0.1): 3.721 µm **d(0.5): 15.287 µm** d(0.9): 159.797 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	20 %	35 %	20 %	15 %	8 %	0 %

Frequency Curve



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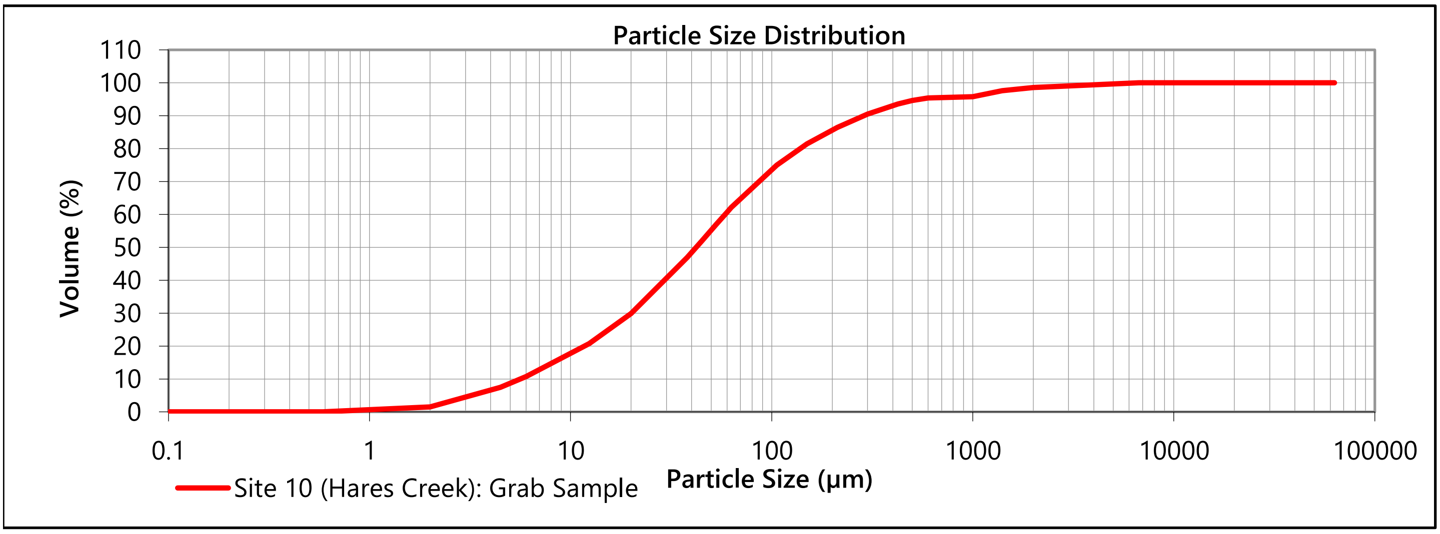
Particle Size Analysis Report

Sample Name:	Site 10 (Hares Creek): Grab Sample	**Measured by:**	IDavidson
Sample Source:	Ipswich		
Sample Collected:			4158

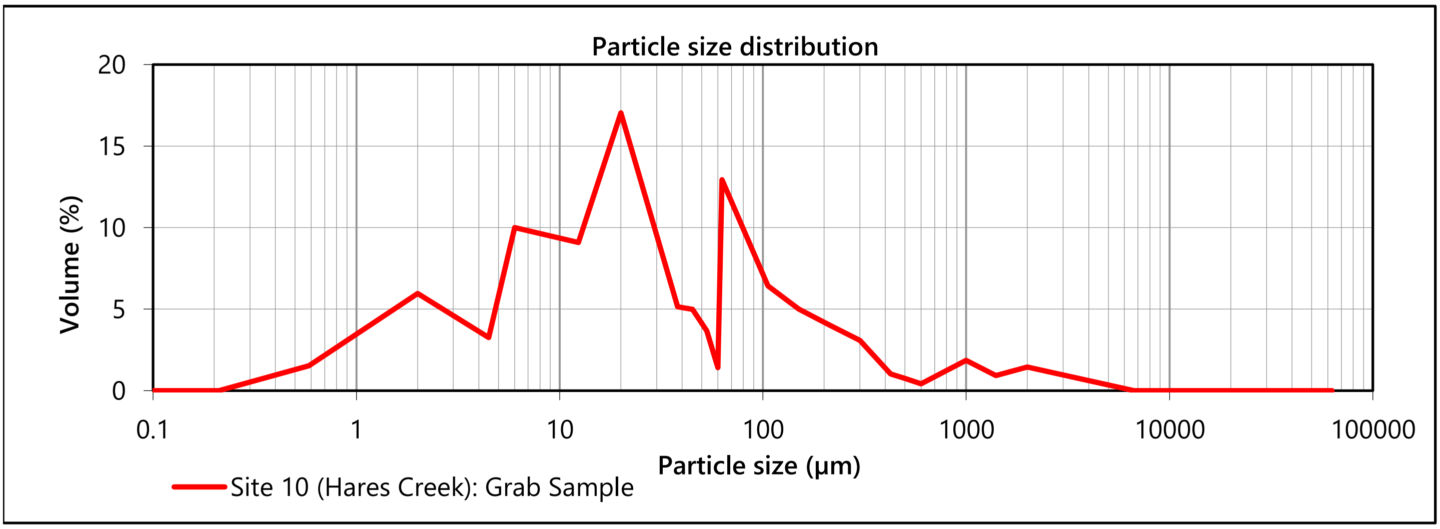
d(0.1):	5.6	µm	**d(0.5):**	**42.2**	**µm**	d(0.9):	289.6	µm

Cumulative Frequency Plot



Clay (%)	Silt (%)			Sand (%)			Gravel (%)			Cobble (%)
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	
1.5	9.2	19.1	30.8	25.8	8.9	3.2	1.4	0.0	0.0	0.0

Frequency Curve



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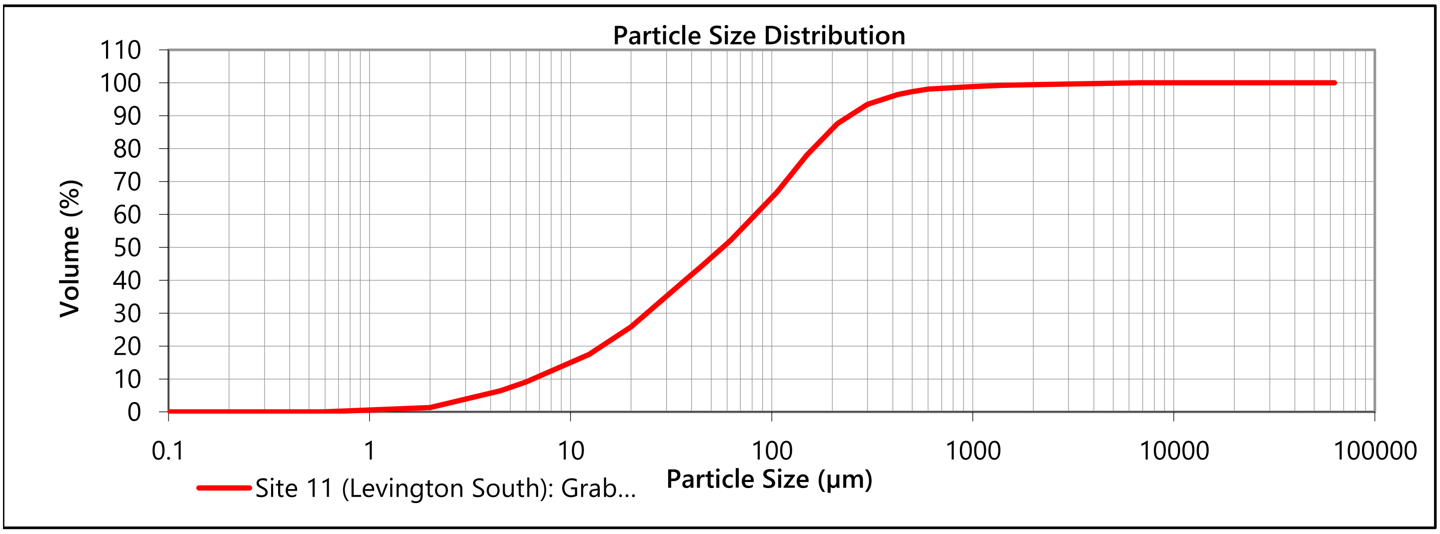
Particle Size Analysis Report

Sample Name:	Site 11 (Levington South): Grab Sample	**Measured by:**	IDavidson
Sample Source:	Ipswich		
Sample Collected:			4158

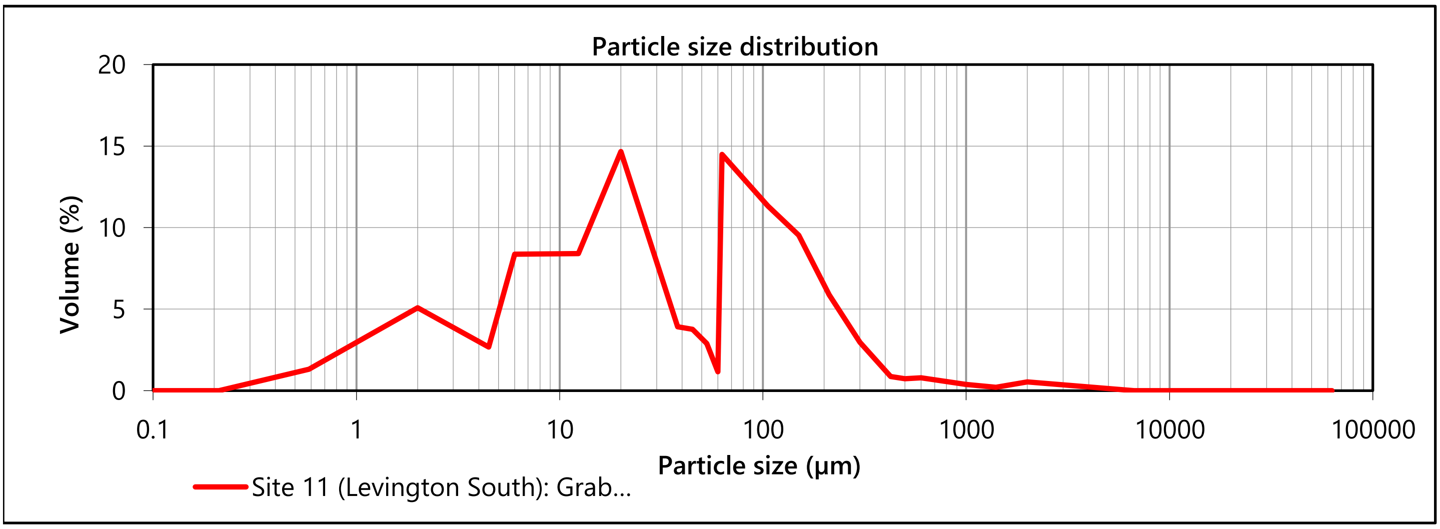
d(0.1):	6.7	µm	**d(0.5):**	**57.4**	**µm**	d(0.9):	247.7	µm

Cumulative Frequency Plot



Clay (%)	Silt (%)			Sand (%)			Gravel (%)			Cobble (%)
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	
1.3	7.8	16.8	25.2	36.5	10.5	1.4	0.5	0.0	0.0	0.0

Frequency Curve



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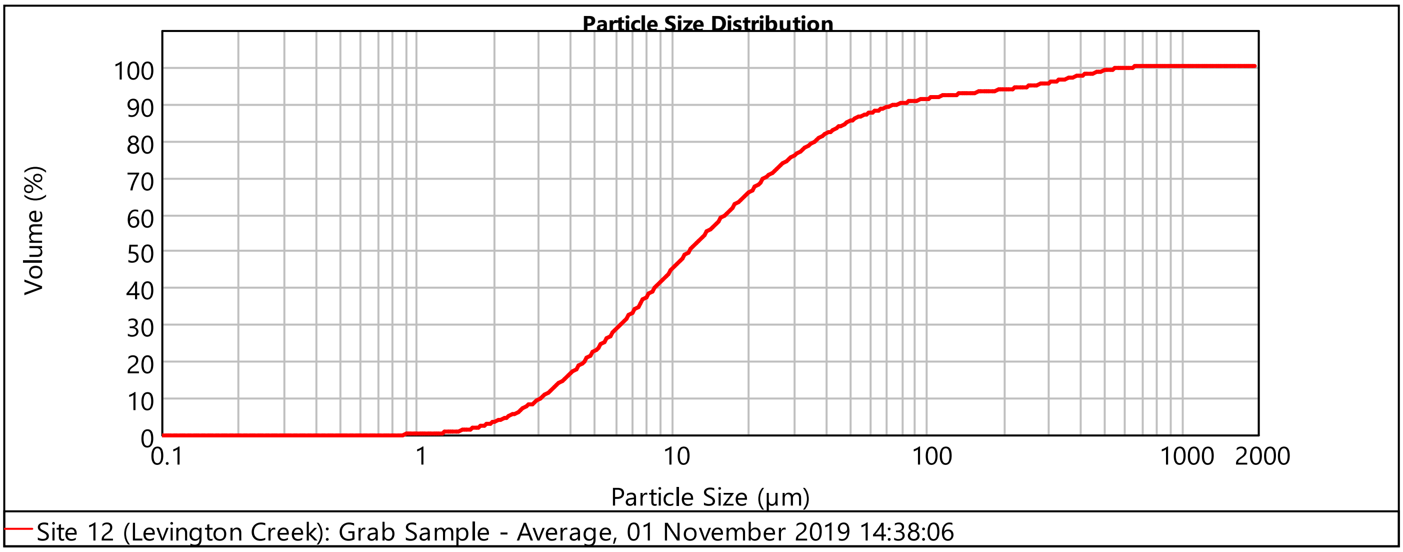
Particle Size Analysis Report

Sample Name:	Site 12 (Levington Creek): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	11.62 %
Sample Collected:		Weighted Residual:	0.811 %

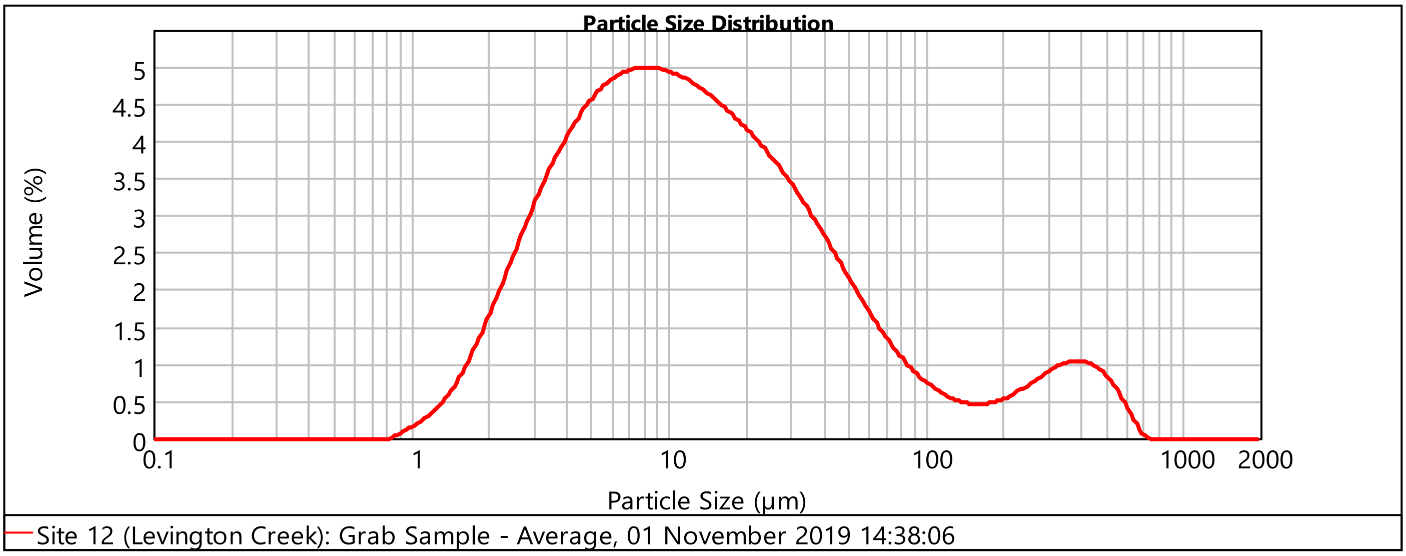
d(0.1): 3.064 µm **d(0.5): 11.805 µm** d(0.9): 79.383 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
3 %	25 %	37 %	22 %	6 %	6 %	0 %

Frequency Curve



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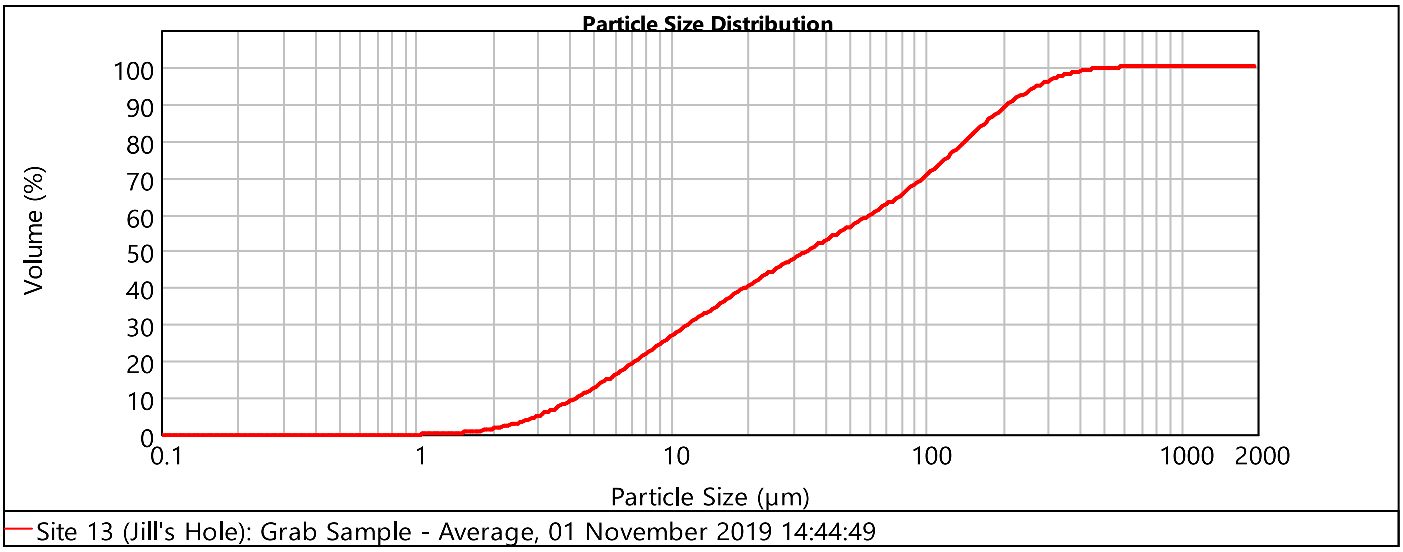
Particle Size Analysis Report

Sample Name:	Site 13 (Jill's Hole): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	13.31 %
Sample Collected:		Weighted Residual:	0.613 %

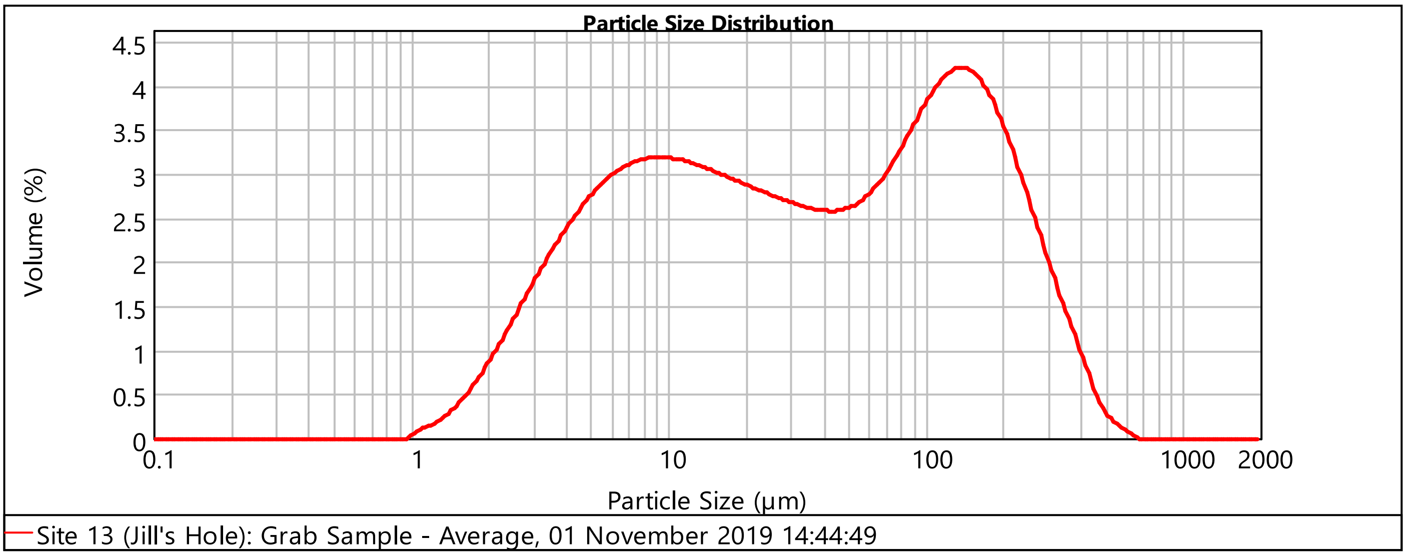
d(0.1): 4.269 µm   **d(0.5): 34.175 µm**   d(0.9): 212.274 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	15 %	24 %	19 %	29 %	11 %	0 %

Frequency Curve



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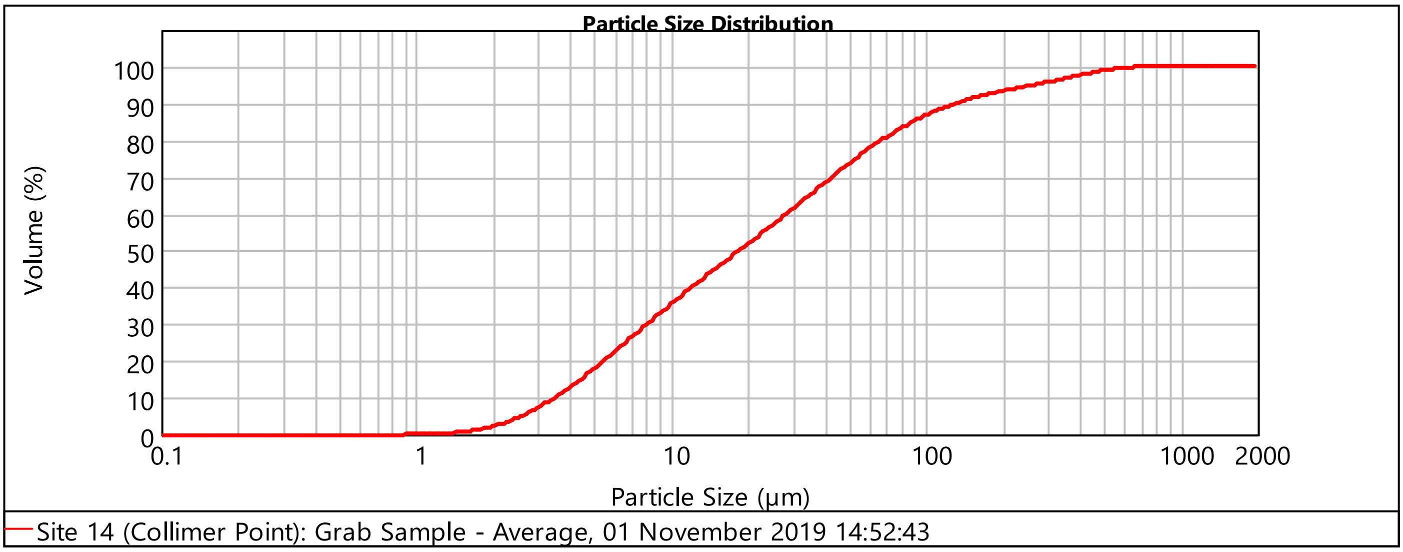
Particle Size Analysis Report

Sample Name:	Site 14 (Collimer Point): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	12.76 %
Sample Collected:		Weighted Residual:	0.821 %

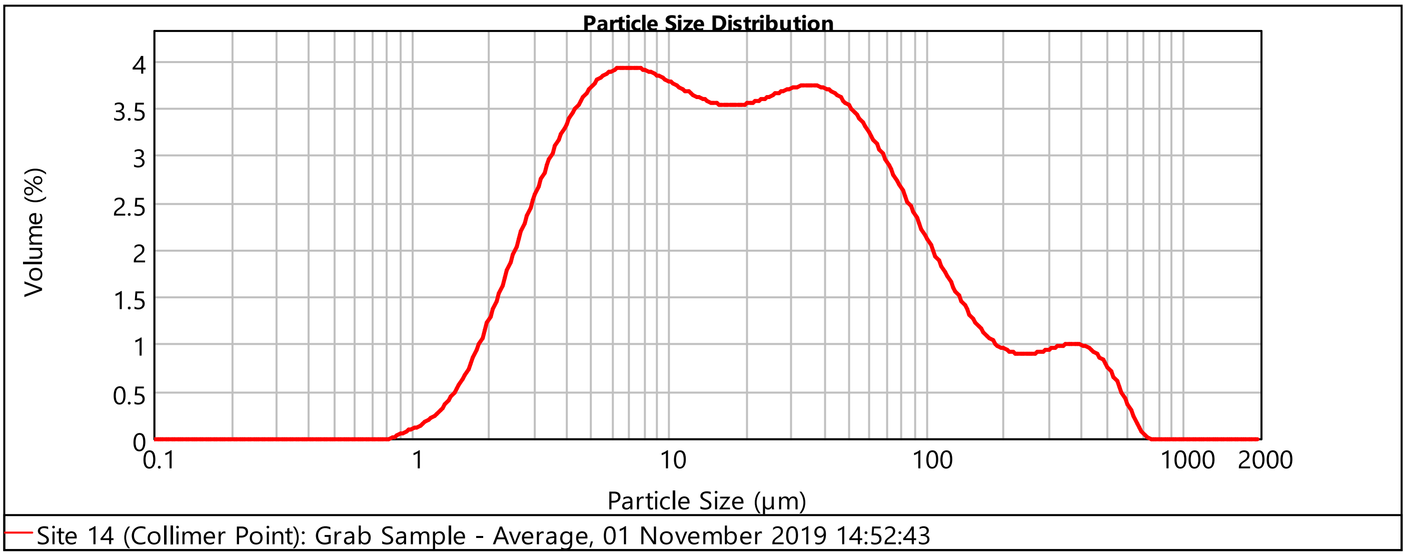
d(0.1): 3.486 μm **d(0.5): 18.460 μm** d(0.9): 129.236 μm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	20 %	29 %	26 %	16 %	6 %	0 %

Frequency Curve



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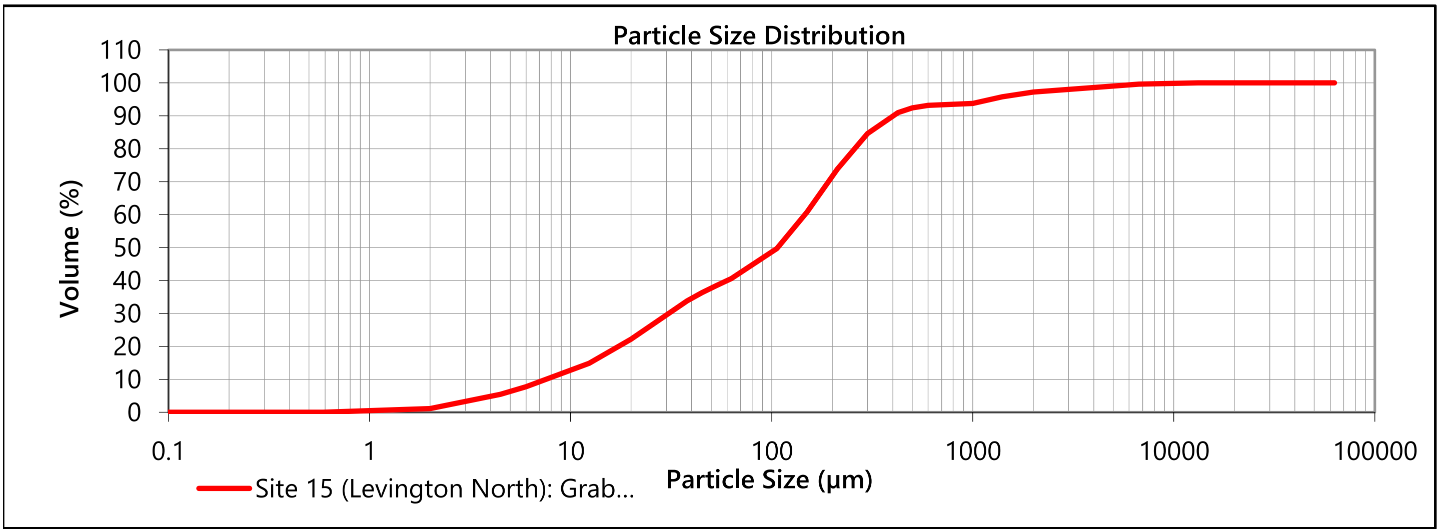
Particle Size Analysis Report

Sample Name:	Site 15 (Levington North): Grab Sample	**Measured by:**	IDavidson
Sample Source:	Ipswich		
Sample Collected:			4158

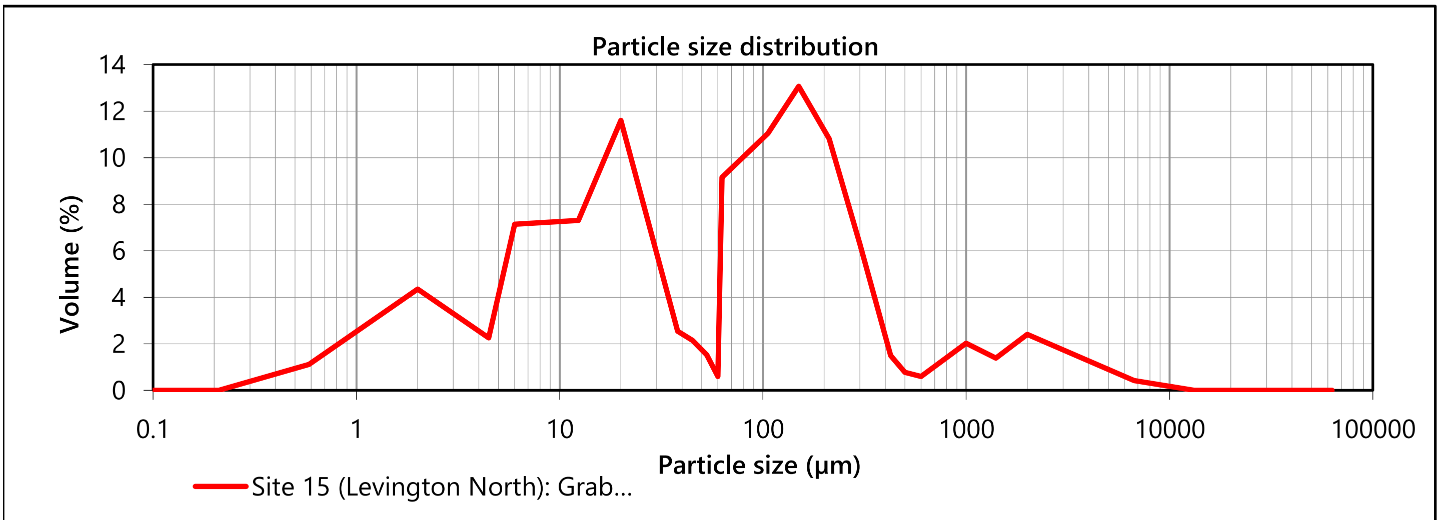
d(0.1):	8.0	µm	**d(0.5):**	**107.1**	**µm**	d(0.9):	406.7	µm

Cumulative Frequency Plot



Clay (%)	Silt (%)			Sand (%)			Gravel (%)			Cobble (%)
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	
1.1	6.6	14.4	17.8	33.8	19.4	4.0	2.4	0.4	0.0	0.0

Frequency Curve



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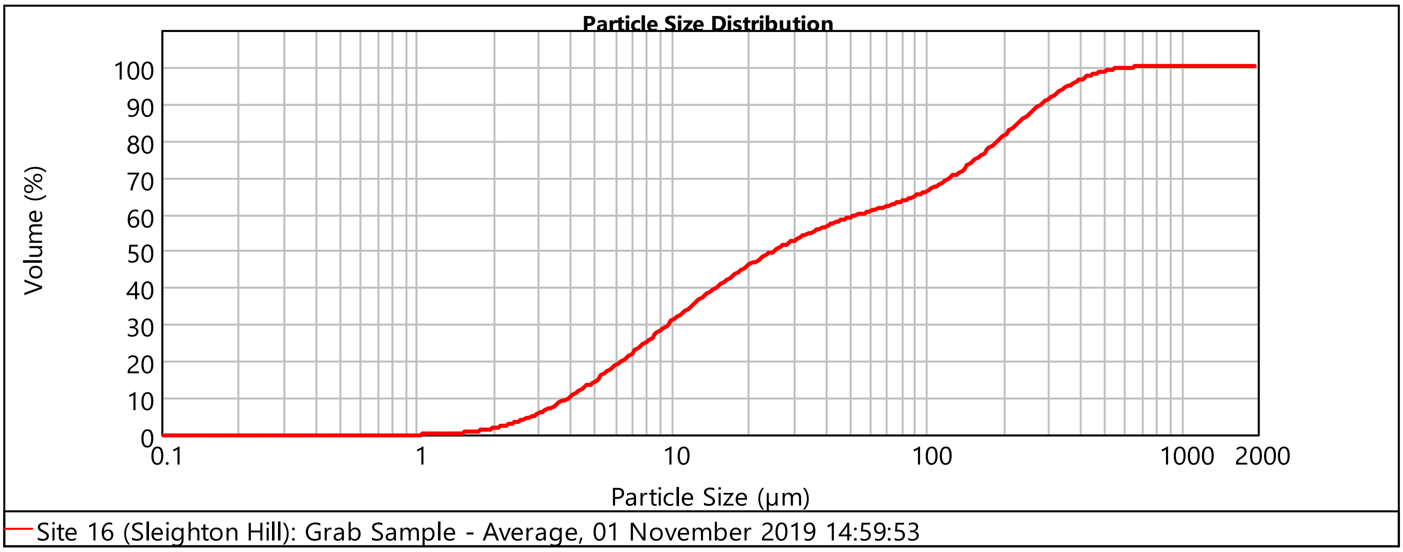
Particle Size Analysis Report

Sample Name:	Site 16 (Sleighton Hill): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	14.57 %
Sample Collected:		Weighted Residual:	0.744 %

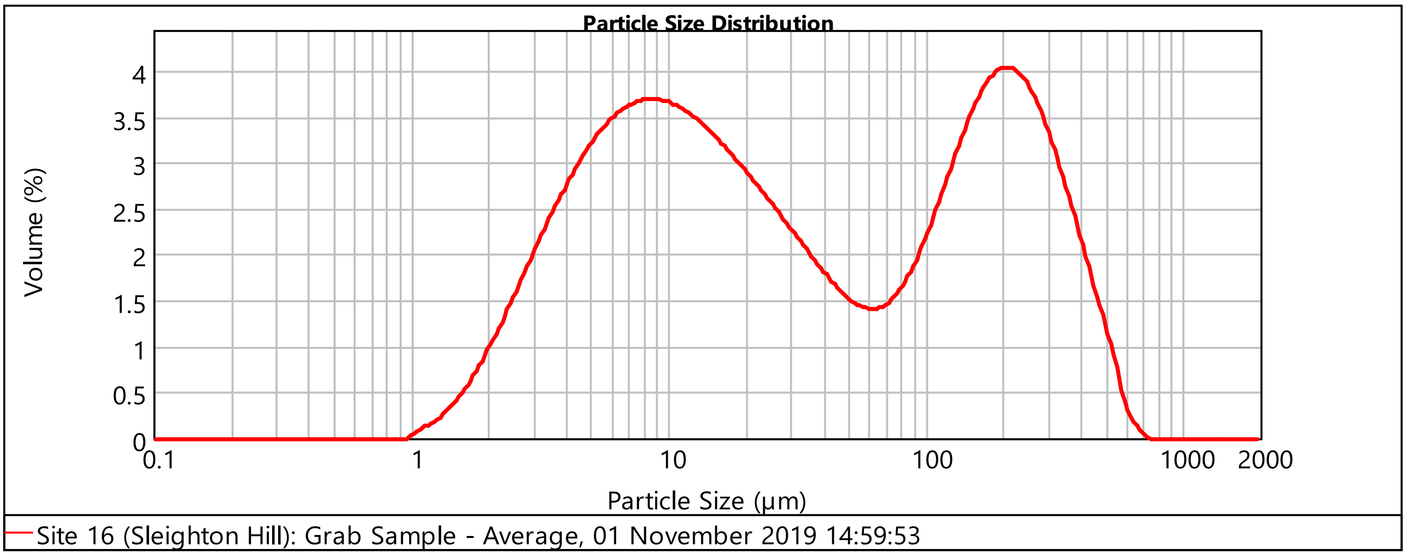
d(0.1): 3.958 µm   **d(0.5): 25.276 µm**   d(0.9): 284.980 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	17 %	27 %	15 %	20 %	19 %	0 %

Frequency Curve



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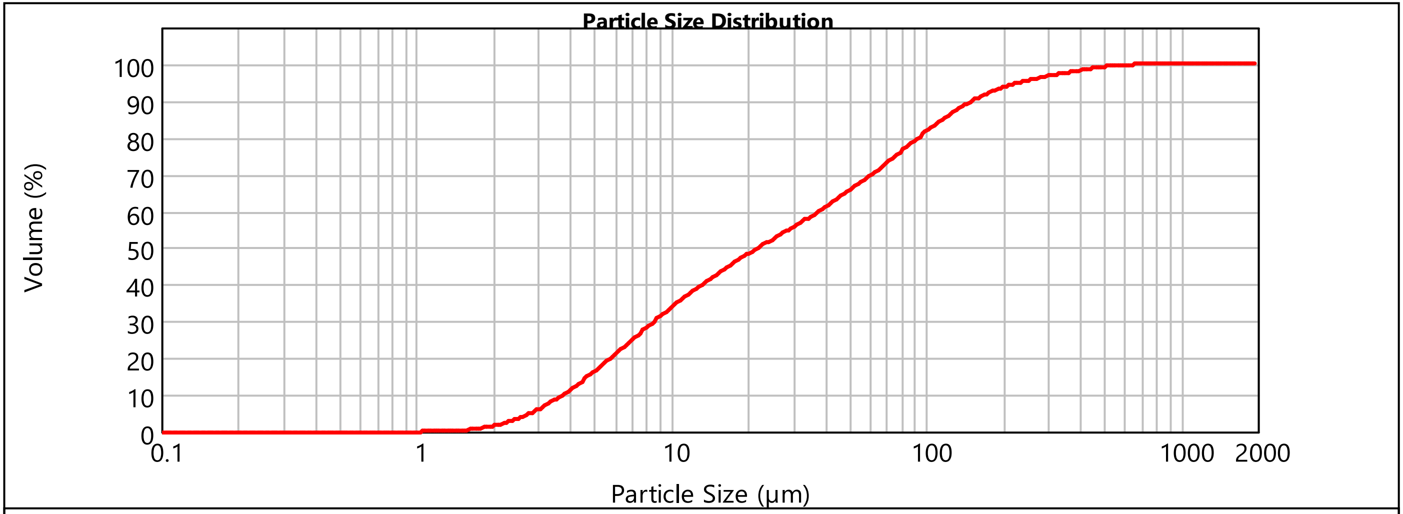
Particle Size Analysis Report

Sample Name:	Site 17 (No.2 Buoy): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	13.14 %
Sample Collected:		Weighted Residual:	0.628 %

d(0.1): 3.751 µm | **d(0.5): 21.846 µm** | d(0.9): 150.954 µm

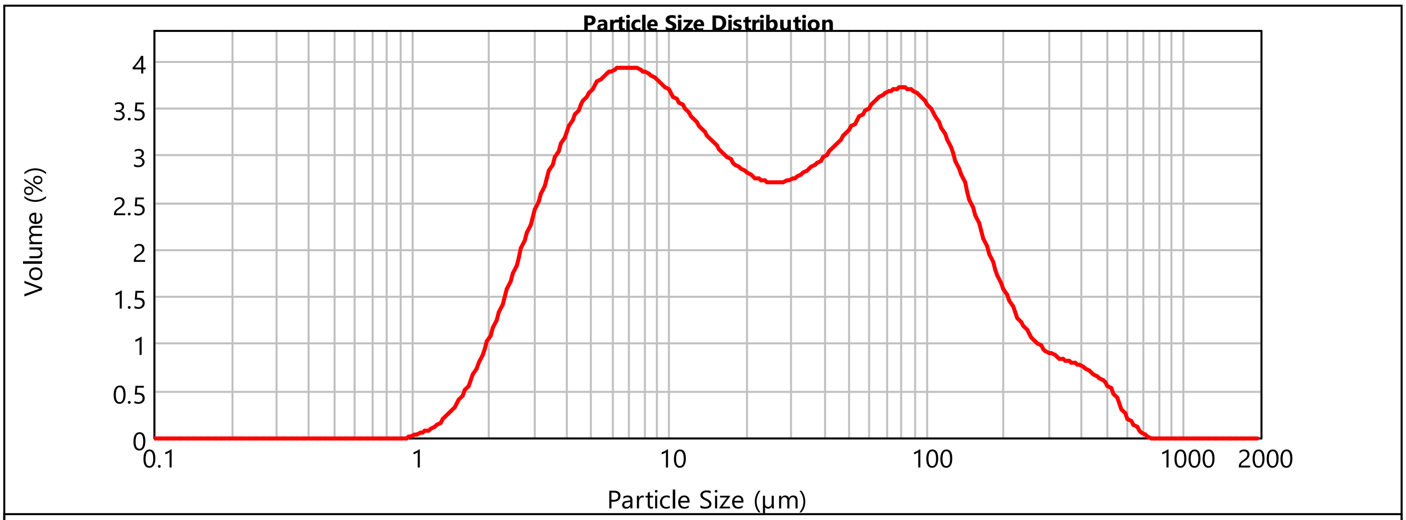
Cumulative Frequency Plot



Site 17 (No.2 Buoy): Grab Sample - Average, 01 November 2019 15:07:05

Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
2 %	19 %	27 %	21 %	24 %	6 %	0 %

Frequency Curve



Site 17 (No.2 Buoy): Grab Sample - Average, 01 November 2019 15:07:05

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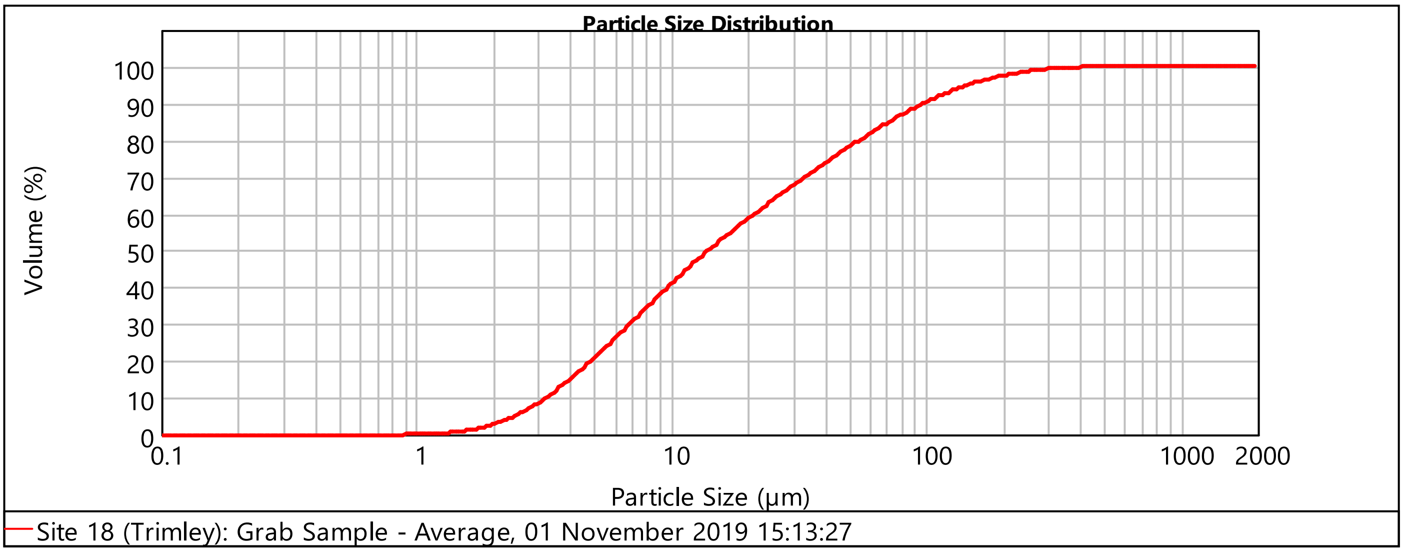
Particle Size Analysis Report

Sample Name:	Site 18 (Trimley): Grab Sample - Average	Measured by:	IDavidson on 01 November 2019
Sample Source:	Ipswich	Obscuration:	11.68 %
Sample Collected:		Weighted Residual:	0.797 %

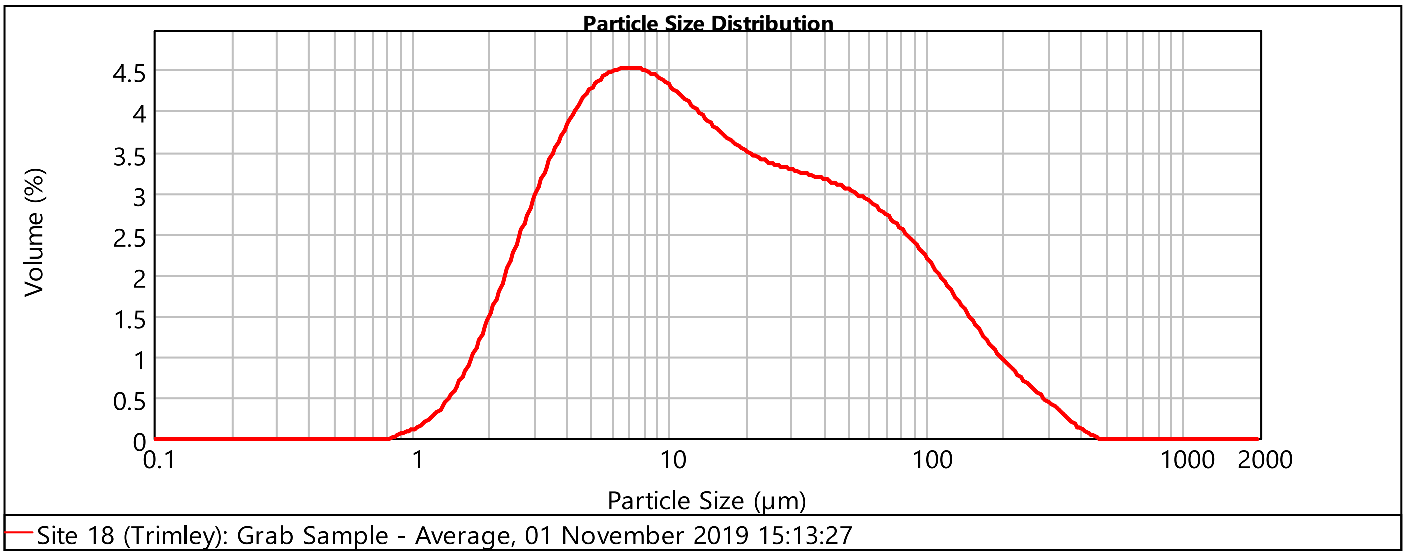
d(0.1): 3.225 µm **d(0.5): 13.963 µm** d(0.9): 97.055 µm

Cumulative Frequency Plot



Clay	Silt			Sand		
	Fine	Medium	Coarse	Fine	Medium	Coarse
3 %	23 %	33 %	23 %	16 %	2 %	0 %

Frequency Curve



C Measuring Stakes

Year	Monitoring Period	Dates
2013	Spring	Between 6-7 March 2013 (stake deployment) and 20-21 May 2013 (spring)
	Pre-disposal	Between 20-21 May 2013 (Spring) and 28-29 May 2013 (Pre-disposal)
	During disposal	Between 28-29 May 2013 (Pre-disposal) and 03-04 June 2013 (During disposal)
	Post disposal	Between 03-04 June 2013 (During disposal) and 10-11 June 2013 (Post disposal)
	Summer/ Autumn	Between 10-11 June 2013 (Post disposal) and 14-16 October 2013 (Autumn)
2014	Autumn to Spring	Between 14-16 October 2013 (Autumn) and 16-17 April 2014 (Spring)
	Pre-disposal	Between 16-17 April 2014 (Spring) and 24-25 April 2014 (Pre-disposal)
	During disposal	Between 24-25 April 2014 (Pre-disposal) and 1-2 May 2014 (During disposal)
	Post disposal	Between 1-2 May 2014 (During disposal) and 7-8 May 2014 (Post disposal)
	Summer/ Autumn	Between 7-8 May 2014 (Post disposal) and 29-30 October 2014 (Autumn)
2015	Pre-disposal	Between 29-30 October 2014 (Autumn) and 28-29 April (Pre-disposal)
	During disposal	Between 28-29 April 2015 (Pre-disposal) and 8 May 2015 (During disposal)
	Post disposal	Between 8 May 2015 (During disposal) and 12-13 May 2015 (Post disposal)
	Summer/ Autumn	Between 12-13 May 2015 (Post disposal) and 5-6 November 2015 (Autumn)
2016	Winter / Spring	Between 5-6 November 2015 (Winter) and 21-22 April 2016 (Spring)
	Pre-disposal	Between 21-22 April 2016 (Spring) and 28-29 April 2016 (Pre-disposal)
	During disposal	Between 28-29 April 2016 (Pre-disposal) and 13 May 2016 (During disposal)
	Post disposal	Between 13 May 2016 (During disposal) and 20 May 2016 (Post disposal)
	Summer / Autumn	Between 20 May 2016 (Post disposal) and 10-11 November 2016 (Autumn)

Year	Monitoring Period	Dates
2017	Winter / Spring	Between 10-11 November 2016 (Winter) and 12-13 April 2017 (Spring)
	Pre-disposal	Between 12-13 April 2017 (Spring) and 18-19 April (Pre-disposal)
	During disposal	Between 18-19 April (Pre-disposal) and 24-25 April (During disposal)
	Post disposal	Between 24-25 April (During disposal) and 3-4 May (Post disposal)
	Summer / Autumn	Between 3-4 May (Post disposal) and 25-26 November 2017 (Autumn).
2018	Winter / Spring	Between 25-26 November 2017 (Autumn). 19-20 April and 24-25 May (Spring)
	Pre-disposal	Between 19-20 April and 24-25 May (Spring) and 23-24 July (Pre-disposal)
	During disposal	Between 23-24 July (Pre-disposal) and 29 July-01 August (During disposal)
	Post disposal	29 July-01 August (During disposal) and 02-04 August (Post disposal)
	Summer / Autumn	02-04 August (Post disposal) and 29-30 November
2019	Winter / Spring	Between 29-30 November 2018 (Autumn). 12-13 March (Spring)
	Pre-disposal	Between 12-13 March (Spring) and 10-11 April (Pre-disposal)
	During disposal	Between 10-11 April (Pre-disposal) and 16-17 April (During disposal)
	Post disposal	16-17 April (During disposal) and 23-24 April (Post disposal)
	Summer / Autumn	23-24 April (Post disposal) and 31 October and 1 November

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