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SEDIMENT CONCENTRATION MEASUREMENT

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Abstract

Sydney Harbour is an important port and recreational region for the City of Sydney. A study of water clarity is reported here. Water turbidity is influenced by the urban and industrial wastes that drain from the watershed and the flushing of the estuary by clear oceanic water.

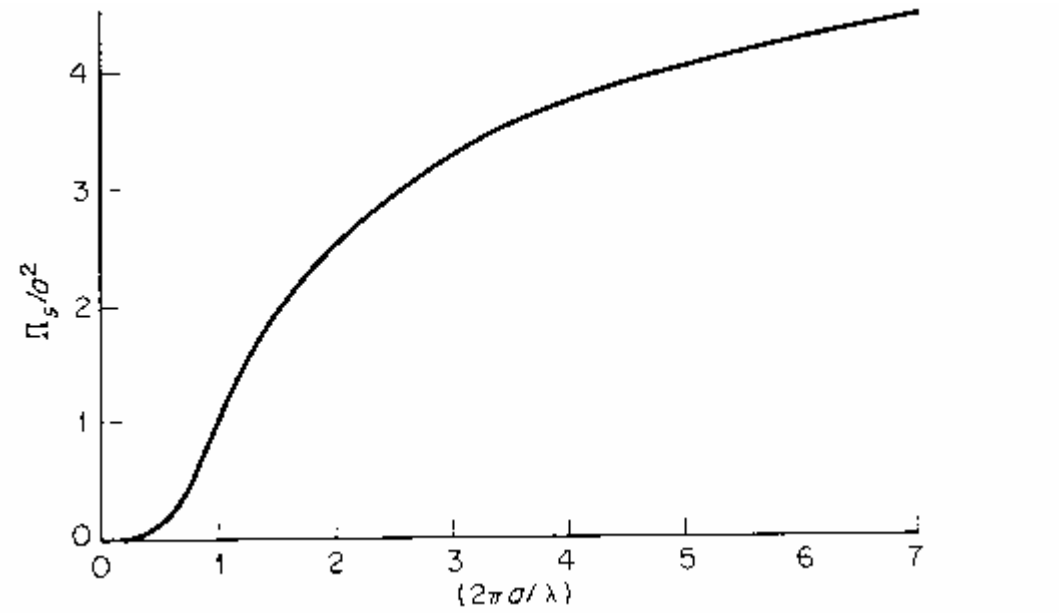
In order to contrast the imaging of objects underwater by light or sound, it is necessary to understand the role played by the scatterers in the water that cause turbidity. Using five reference sites, the grain size, the number of grains per litre and the turbidity have been compared before and after rain. Three Sydney area estuaries have been observed to have similar turbidity increases with increasing distance from the sea.

Contents

Introduction

Optical visibility is typically poor in ports and harbours restricting activities such as salvage or explosive mine clearance. To overcome this difficulty the underwater imaging program described in Jones (1996) was commenced. It is based on the reduced scattering of sound over that of light. Measurements have been carried out in three NSW ports to help understand the scattering and absorption of underwater signals, i.e. light and sound.

When the particles in the water are smaller than the wave length of the incident energy, λ, the deflected energy is termed Rayleigh scattering e.g. see Morse and Ingard (1968) from which the figure below is reproduced.



Scattered energy Π_s as a function of a spherical grain of diameter a.

The scattering energy is normalised by the grain cross section. Thus as the wavelength increases the scatter from grains of a given size decreases providing the motivation to image with sound rather than light.

As well as being scattered, wave energy can be absorbed in the water. Coloured pigments that result from organic matter attenuate light. Also, some molecular processes will absorb acoustic energy.

Procedure

Measurements were made at what we will designate as reference sites and in addition simpler measurements were carried out at auxiliary sites. At reference sites, listed in Table 1, two readings separated by order 100m were often made. Little difference was

observed between these two observations and they were averaged, when available, to produce a single result for each site. The sites are shown in Fig 1.

Table 1 Reference Sites

DSTO Pyrmont HMAS Penguin Spectacle Island HMAS Waterhen Garden Island Newcastle	 "dockyard #4" near Dyke Point

The principle of the Nephelometer Turbidity Unit is discussed in Hamilton et al (1998). The Horiba U-10 turbidity sensor was calibrated on 20 October 2001 and again on 18 December 2001 against a Formazin suspension. The calibration constant remained the same. This device compares the transmission of infra red light with the forward scattered signal. A simple test of adding blue ink to a Formazin solution showed that such a design is relatively insensitive to strong discolouration of the water sample. The influence of micron sized bubbles, studied for example by Mulhearn (1981) was not examined.

The Galai CIS particle sizer was calibrated with glass beads on 14 November 2001. This device counts the number of particles per litre. Some of the statistical measures it provides are described in Appendix B.

Turbidity

Turbidity was determined by either a Secchi disk or an optical back scattering device. The Secchi disk is a long-standing device for measuring the depth in the ocean at which one can no longer see a white disk. The first measurements by such a device at Port Jackson was in Feburary1824. Jones (1992) reported that a depth of 12m was observed.

In the open ocean the Secchi depth usually exceeds 10m but in estuaries it can be much less. Near the coast Mulhearn (1993) often found Secchi depths less than 5m. The shortest distance reported here is 1.5m (Newcastle) but this would not be the smallest depth in the estuaries studied. The Ocean Technology Group carried out a survey along the "centre" of Port Jackson in 1997 and found the variation in Secchi disk depth shown in Fig 2. Values ranged from 16m near the heads to 3 meters near Gladesville, some 15km inland. Gladesville is located between Hen and Chicken Bay and Iron Cove. Near Fort Denison the 1997 results were similar to the 1824 observation.

The turbidity was measured using the River Cat on Sunday 9 December between 10 am and 11 am. The results are shown in Fig 3 and illustrate a clear increase in turbidity as one moves upstream from the Harbour Bridge to Rydalmere. Care was taken to avoid measuring in the vessel wake. Salinity decreased from about 35ppt to 22ppt at Rydalmere. The change in turbidity can be attributed to the settling of suspended sediments as the water travels down the estuary and the dilution of the inflow water from storm water drains and tributaries by sea water. Typical seawater has a turbidity of less than 1 NTU.

This trend of decreasing turbidity as one moves from the head of the estuary towards the sea can be recognised in Fig 4 where the results obtained in three estuaries are shown. There is also, as expected, a correlation between turbidity and Secchi disk depth. This is illustrated in Fig 5. Previous studies by Golding et al (1999) in the Darwin area found turbidities up to 11 NTU.

Other turbidities were measured with the OBS-3a sensor, which relies on backscattered IR light. Its sensitivity to discolouration in the water was not determined.

Rain

The time of sampling was classified pre and post rain. This is not a clear criterion as can be seen from Fig 6 where rain events for December 2001 are shown. Here the total rain in an event is shown. By event we mean a day or a continuous series of days on which there was rain.

To gain some understanding of the influence of rain we chose a point to monitor that was neither at the head of an embayment or on the main channel of the Port Jackson estuary. This was Pyrmont Park, a spot not far from the DSTO reference site. The turbidity was monitored for 9 days after a “minor rain event”. This is illustrated in Fig 7 where the daily rainfall for Sydney City area is shown. The turbidity was measured some two weeks earlier and shown with error bars of ± 0.5 NTU, a value which we believe is related to the uncertainty of a single the turbidity reading.

There is anecdotal evidence of turbidity changes in the head of embayments after rain. However for this to be of significant extent may require a large storm event. Following the experiments there was a large deposition of dust over Sydney from bush fires. Then on 4 Feburary, 2002 there was rainfall of 130mm; more than any total event during the experiment. The Pyrmont Park sampling site had a turbidity of 5 NTU on Sunday 10 Feb, 6 days after the day of high rainfall. This was the highest value of turbidity seen during this experiment at that site and is a different response to that in Fig 7 (a more usual event) where no impact can be seen 6 days after a much smaller event. It seems that turbidity is not much changed by “usual” rain events over

the broad areas of the estuary that Pyrmont Park is representative of. The reference station DSTO#1 was also examined after the storm event of 4 Feb and the results shown in Appendix D. The turbidity was much higher than usual and had a response time (e^{-1}) of about 4 days. Appendix E contains a narrative of the response to rain of another estuary. The water, during the high turbidity period, was significantly fresher than the dry weather values of about 35 parts per thousand indicating that the storm water that flowed into the head of the embayment had not been mixed by the tidal flows. Possibly turbidity is controlled to a large extent by tidal mixing of storm water/river input with clear oceanic water.

The above conclusion is supported by a comparison of turbidity at the five reference sites before rain with the same sites after 'usual" rain. The turbidity was measured at two depths at the reference sites before and after rain as defined in Fig 6. If the uncertainty is accepted as 0.5 NTU, then no clear trend in turbidity between pre rain and post rain emerges from Fig 8. Post-rain is three days after the storm event finished but longer from the day of heaviest rainfall.

Salinity is a measure of the mixing of the fresh river and storm water input. At the five reference sites salinity varied between 35.0 ppt to 33.4 ppt. Thus the bulk of the water when the reference sites were sampled was seawater. Knowledge of the flushing time would help understand the impact of rain on turbidity.

Particle Sizes

The particles within each water sample were analysed using a Galai CIS 100 laser particle sizer A focused laser beam rotating at a constant velocity scans the moving particles in the sample. The size of each particle can be calculated from the angular velocity of the laser beam and the duration of beam obscuration. The results obtained are shown in Appendix A. Probability values are for the volume of particles within a given range of diameters. To calculate some quantities used later, the probability of the number of particles within each size class derived from such results. Some of the quantities in Appendix A are defined in Appendix B.

The data in Appendix A is expressed graphically in Fig 9. The concentration of 'large' particles is shown grouped into before and after rain. The vertical scale is logarithmic. Some samples had too few particles per litre for us to count reliably. They are shown as arrows. In the pre rain samples the big particles has a higher concentration 1 meter above the sea floor than 1 meter below the surface. After rain this was mostly reversed.

The most dramatic conclusion however is that there were many more large particles after rain than before. Table 2 is provided to assist in understanding this change.

Table 2 number of particles

	# particles per ml				Mean diameter based on cross section μm			
SITE	pre top	post top	pre bottom	post bottom	pre top	post top	pre bottom	post bottom
DSTO#1	low		4780				4.0	
DSTO#2	low	4580	low			5.2		
PENGUIN#1	low	4830	19000	6880		6.7	3.4	4.5
PENGUIN#2	6560				3.7			
SPEC I.#1	16800	12000	24500	8130	3.6	4.8	3.7	5.4
SPEC I.#2		6540		12600		6.2		7.5
WATERHEN#1	7210	7330	12500	5560	3.2	6.1	3.5	4.2
WATERHEN#2		7050		14600		5.2		4.2
GARDEN#1	7630		7440		3.4		3.7	
GARDEN#2	low		4390		3.6		5.0	
NEWC#1	16100		24400		4.5			
NEWC#2	9860		10600		5.2		6.3	

Settling time for large particles is less than for small particles of the same density. Settling times for spherical shaped particles are shown in Fig 10. From this we conclude that, as expected, the large particles swept into the harbour by the large rain event settled more rapidly than the small and after enough time the concentration became typical of the pre rain value.

At one site the bottom sediments at the water interface were sampled and the distribution shown in Fig 11. This distribution which resulted from settling of particles in the past years was quite similar to the distribution of particles in the water after rain. The larger grains seem more strongly represented as the site was near to an entry point for storm water.

Composition of particles

Microscopic analysis showed most of the particles appeared to be of terrigenous origin. Dust on a Sydney street was collected in Glebe, an area from which storm water drains into the harbour up stream of Pyrmont Park. To consider this further the probability of the number of grains of given size (NB not the distribution by volume as in the other figures) is shown in Fig 12. Distributions by number of grains peak in general at lower diameters than distributions by volume.

Suspended sediment concentrations

Hamilton (1998) suggested that the measured NTU value might approximate to the total suspended solids in mgL^{-1} within a factor of 1 or 2. To examine this we first plotted the turbidity against the number of particles per litre in Fig 13. The correlation is poor at the reference sites. The data when separated into pre and post rain showed no improvement. We would guess that staining of the water is not so important for backscatter and so can provide little explanation. Could it be microbubbles? Two additional points, added to Fig 13 and shown in red, suggest that over a wider range of turbidities there will be a trend and that environmental noise overwhelmed any trends at the reference site.

By assuming a density of the suspended material, which is mostly terrigenous, and using the volume fraction of suspended sediments in Appendix A, an estimate of the total weight of suspended solids can be produced. The suspended solids fraction is shown in Fig 14. The solid line assumes the grains have a density of 2.6 and that turbidity is 1 times the total suspended sediment in mg/L. The two Newcastle turbidity appears not to follow this simple formula.

There were greater numbers of particles per litre in the 1998 study of Darwin (which used the same instrument for analysis). A histogram of the particle numbers is shown in Fig 15 using the data in Golding et al (1998). Since the turbidity was generally also higher, this seems reasonable. Using data supplied by Ian Jones of the turbidities during the 1998 experiment within 0.5 m depth and within 30 minutes of taking the water sample, the turbidity with respect to the number of grains per unit volume is shown in Appendix C. They lie above the expression of Fig 13.

We made a comparison between the weight of suspended sediments by filtering through a 0.45 micron filter and drying of a Newcastle #2 sample and the value from the assuming density. The weight of suspended sediment calculated from the number of grains was 1.6 mg/L compared with that by evaporation of 1.1 mg/L. Because of the small weights involved in the filtered material, this was considered satisfactory agreement.

Optical transmission

Optical transmission of two samples were measured in order to calibrate the Secchi disk results. Glass cells of 5 cm path length were used.

At Garden Island the light attenuation was 40% per m when the Secchi depth was 3m.

Conclusions

Turbidities measured in the Sydney estuary, the Botany Bay estuary and the Hunter River were all broadly similar to the previous studies in Darwin. Turbidities can be expected in the range 1 to 10. Particles of diameter greater than 50 micron settle to the sea floor rather quickly and in number were not frequently found. By volume, they are more important after rain (see Fig 9).

A measure of the optical scattering strength can be computed for particles large compared with the optical wavelength. This measure is the cross sectional area of all the grain divided by their volume. This measure was not well correlated with the turbidity. Since the range of turbidities at the reference sites was relatively small this might not be a good test of a general trend. However the discrepancies in Fig 16 seem more than can be attributed to experimental error alone.

To help clarify this issue a sample was taken at DSTO #1 at the surface after a 16 day period without rain. As well the sample from the Hunter river site shown in Fig 4 was analyzed. Between these two samples we have a big spread of turbidities. The result is shown in Fig 16.

The impact of rain on turbidity seems to be controlled by mixing of the fresh sediment laden storm water and the clear sea water and the settling of large particles. At the head of the DSTO site embayment, the flushing time was estimated as 4 days.

References

Golding, J A Cole and ISF Jones (1999) Suspended Sediment Characteristics of Darwin Harbour. Ocean Sciences Report, TR 80, University of Sydney, Sydney, ISSN 0815-3175

Hamilton, L J (1998) Calibration and interpretation of acoustic backscatter measurements of suspended sediment concentration profiles in Sydney Harbour. Acoustics Australia, 26, 87-93.

Hamilton, LJ, Z Shi and S Y Zhang (1998) Acoustic backscatter measurements of estuarine suspended cohesive sediment concentration profiles. J. Coastal Res., 14, 1213-1224.

Jones, ISF and JE Jones (1992) Oceanography in the Days of Sail, Hale and Iremonger, Sydney.

Jones, ISF (1996) Underwater Acoustic Imaging Innovation Program. DSTO Tech Note TN-0065

Morse, P M and K U Ingard (1968) Theoretical Acoustics. McGraw Hill, NY.

Mulhearn, P J (1993) Distribution of turbidity in Australian tropical waters. DSTO Rep. MRL-TN-638, Melbourne

Mulhearn, P J (1981) Bubbles. Journal of Geophysical Research, 86, 6429.

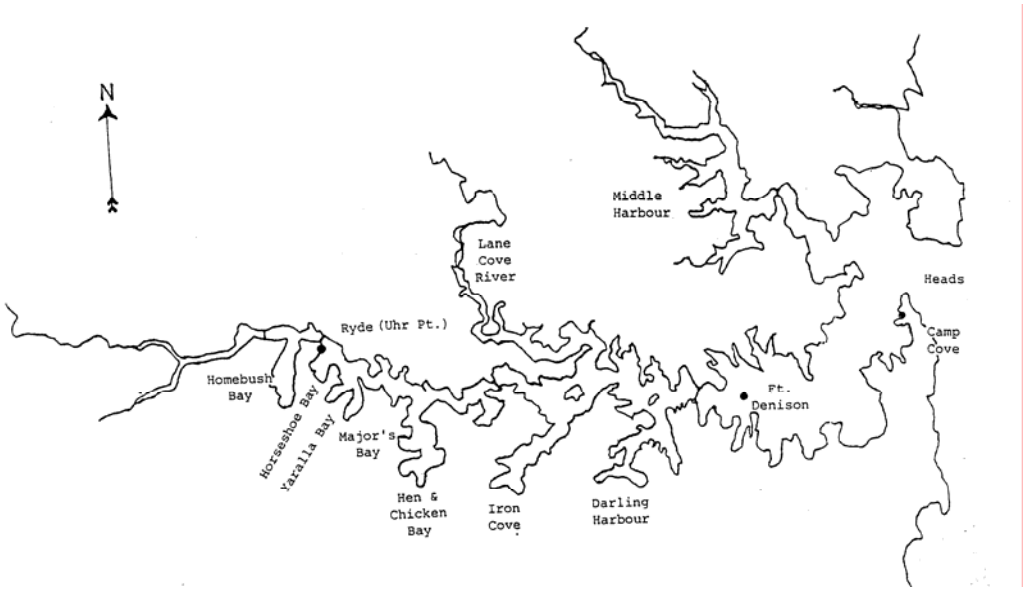


Fig 1 reference sites

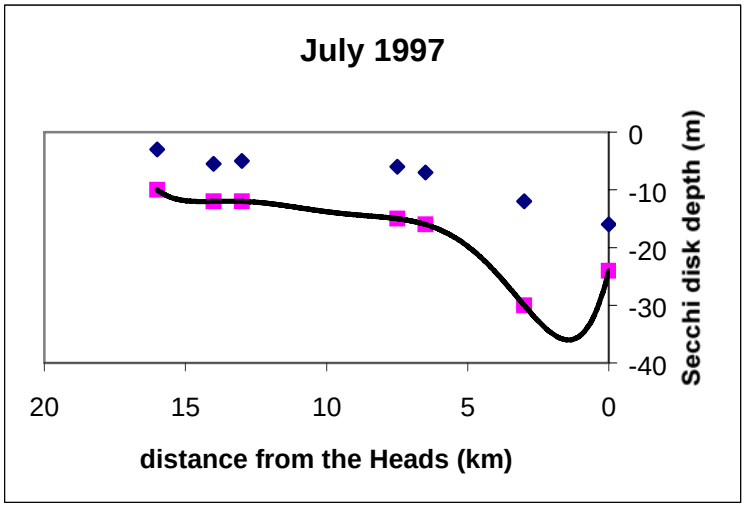


Fig 2 Secchi disk depth from Sydney Heads to Gladesville bridge. Aug/1997. Harbour depths shown as red squares.

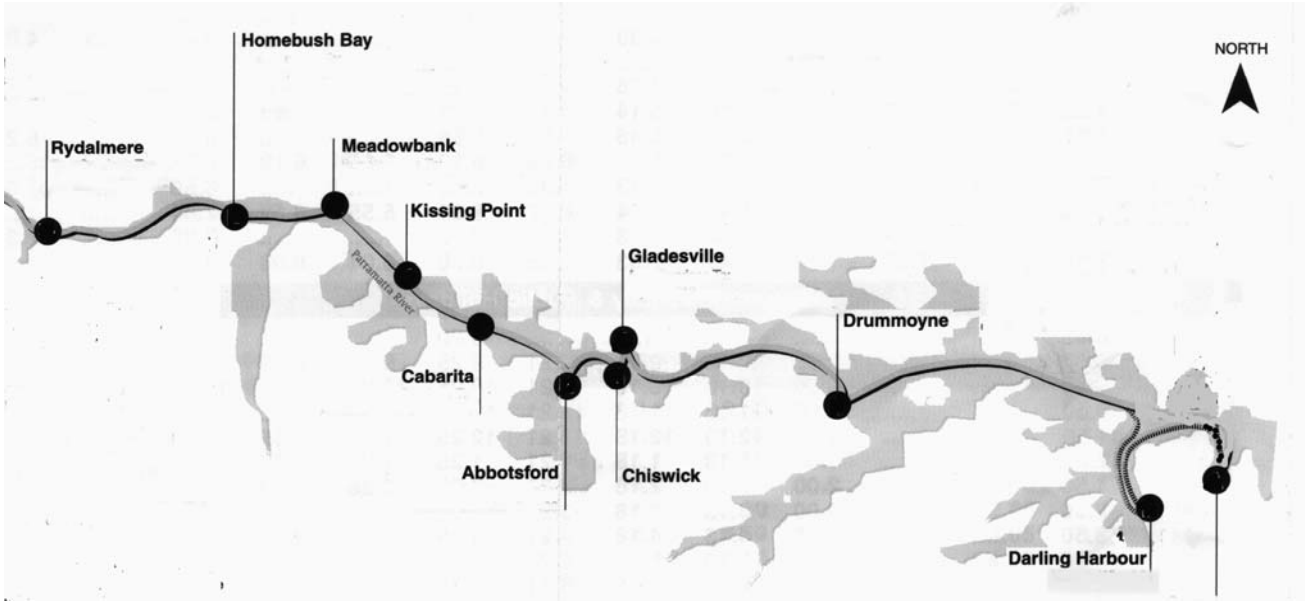


Fig 3 Turbidity measured 9 Dec 2001. NTU units

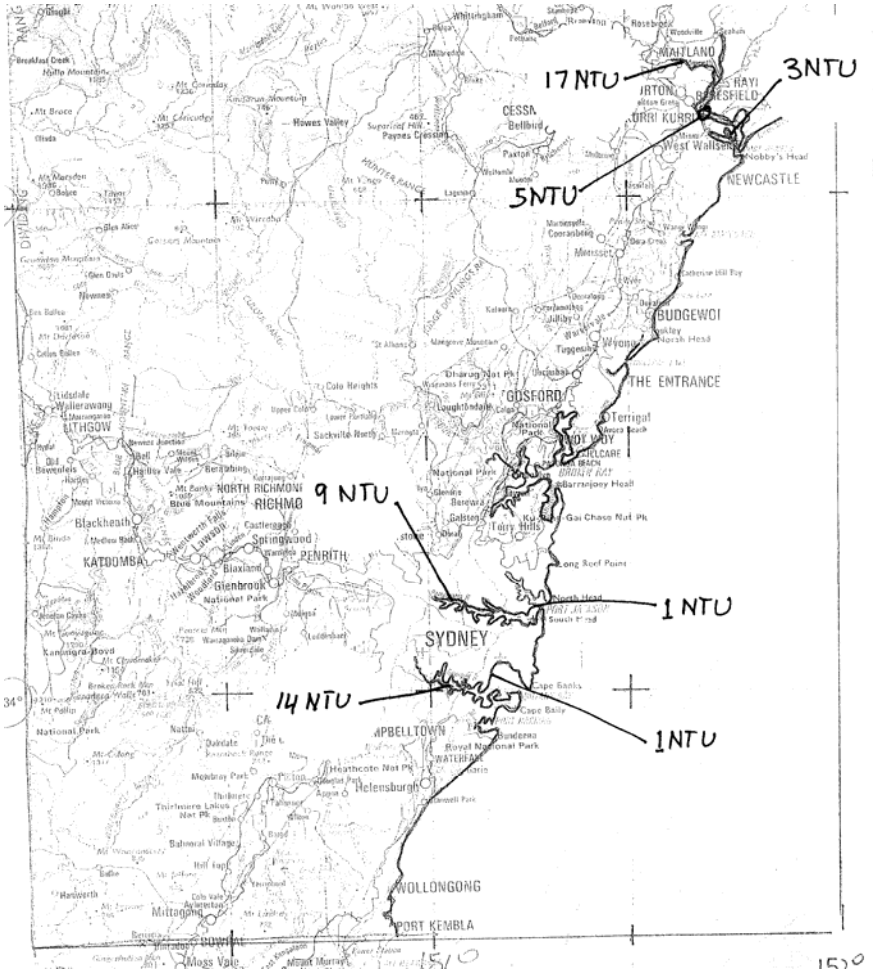


Fig 4 Three estuaries showing greater turbidity towards the head of the estuary.

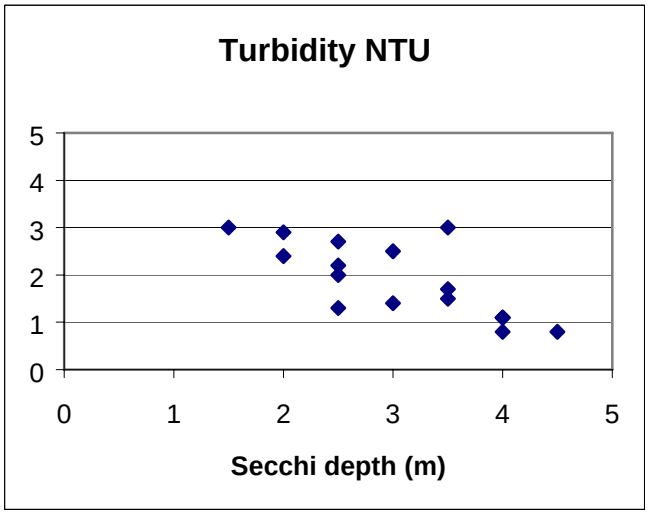


Fig 5 Correlation between Secchi depth and nephelometer turbidity units at a depth of 1 metre below the water surface.

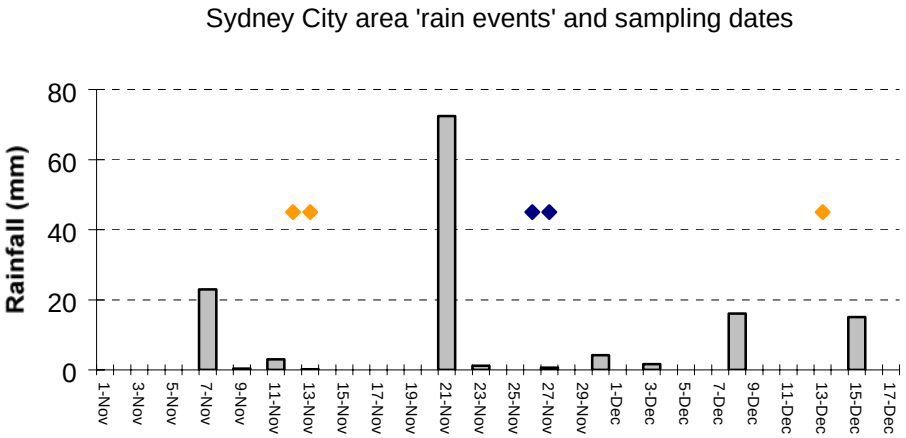


Fig 6 One major rain event during the data collection period. Period marked in blue designated “post rain” while periods in orange are designated “pre rain”.

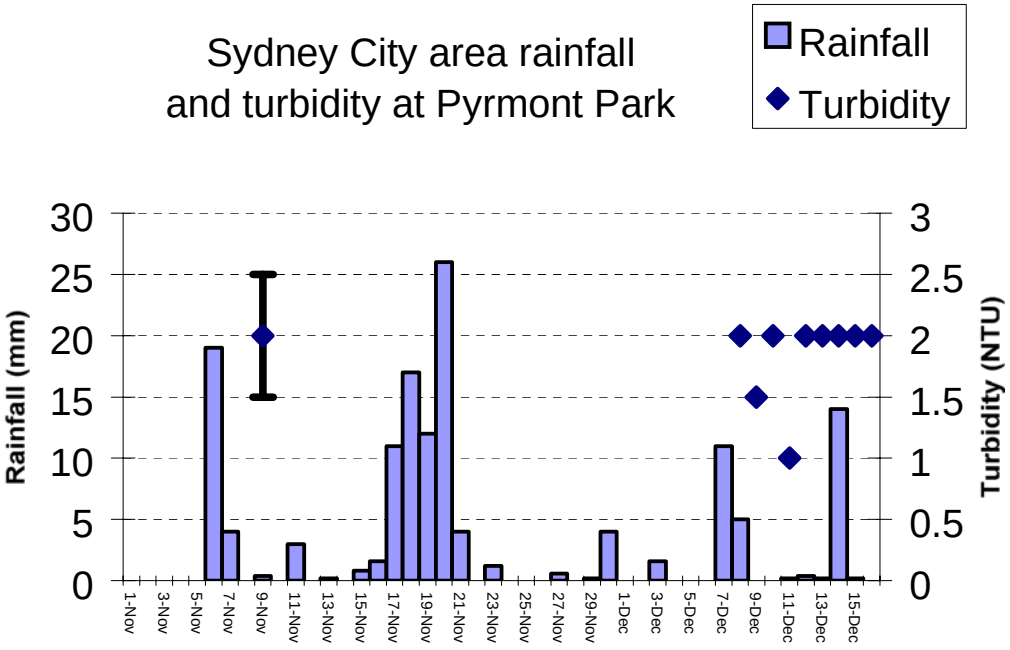


Fig 7 Turbidity at Pyrmont Park and daily rainfall measured from 9am on the day shown till 9am the following day.

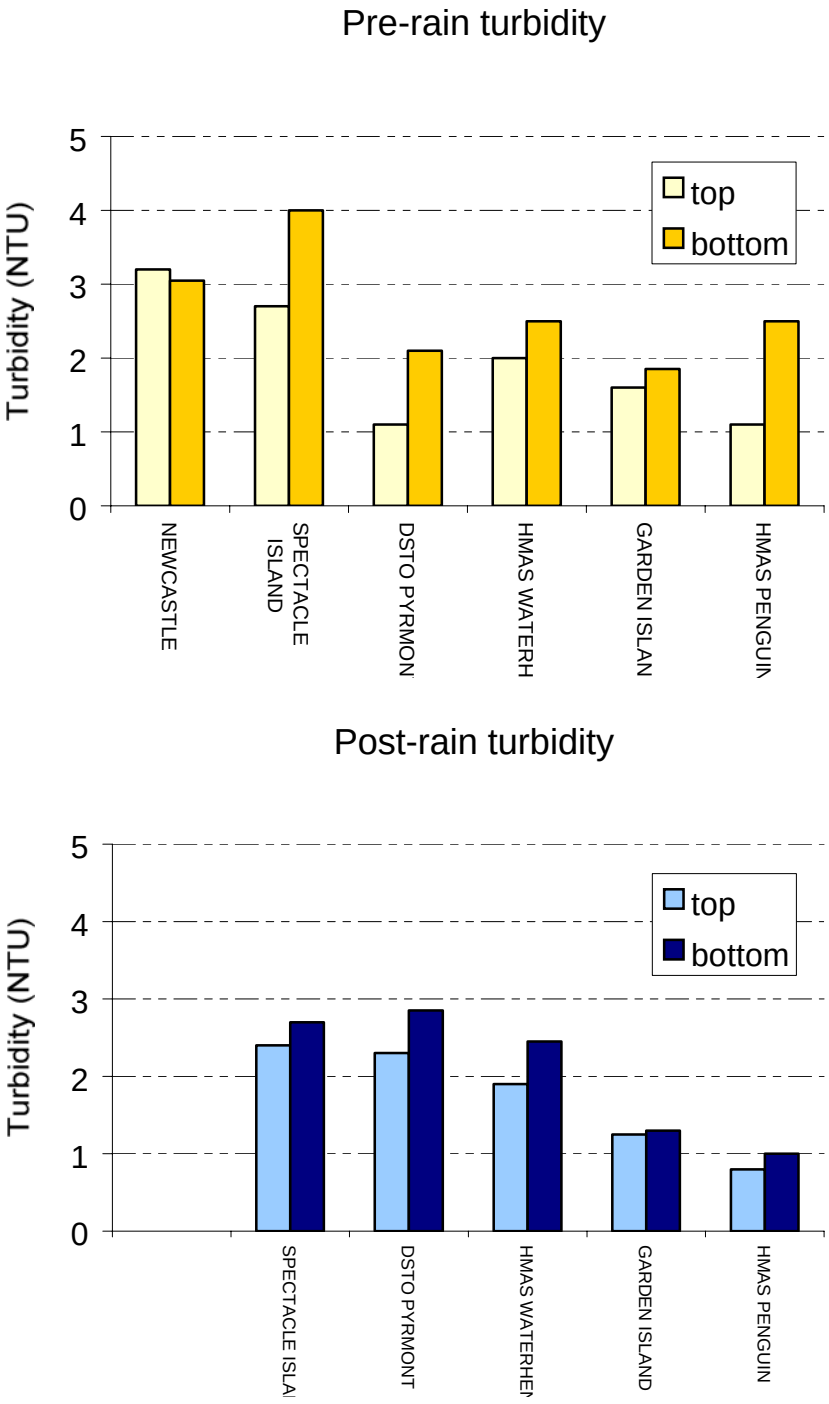


Fig 8 Turbidity at each of the study sample sites.

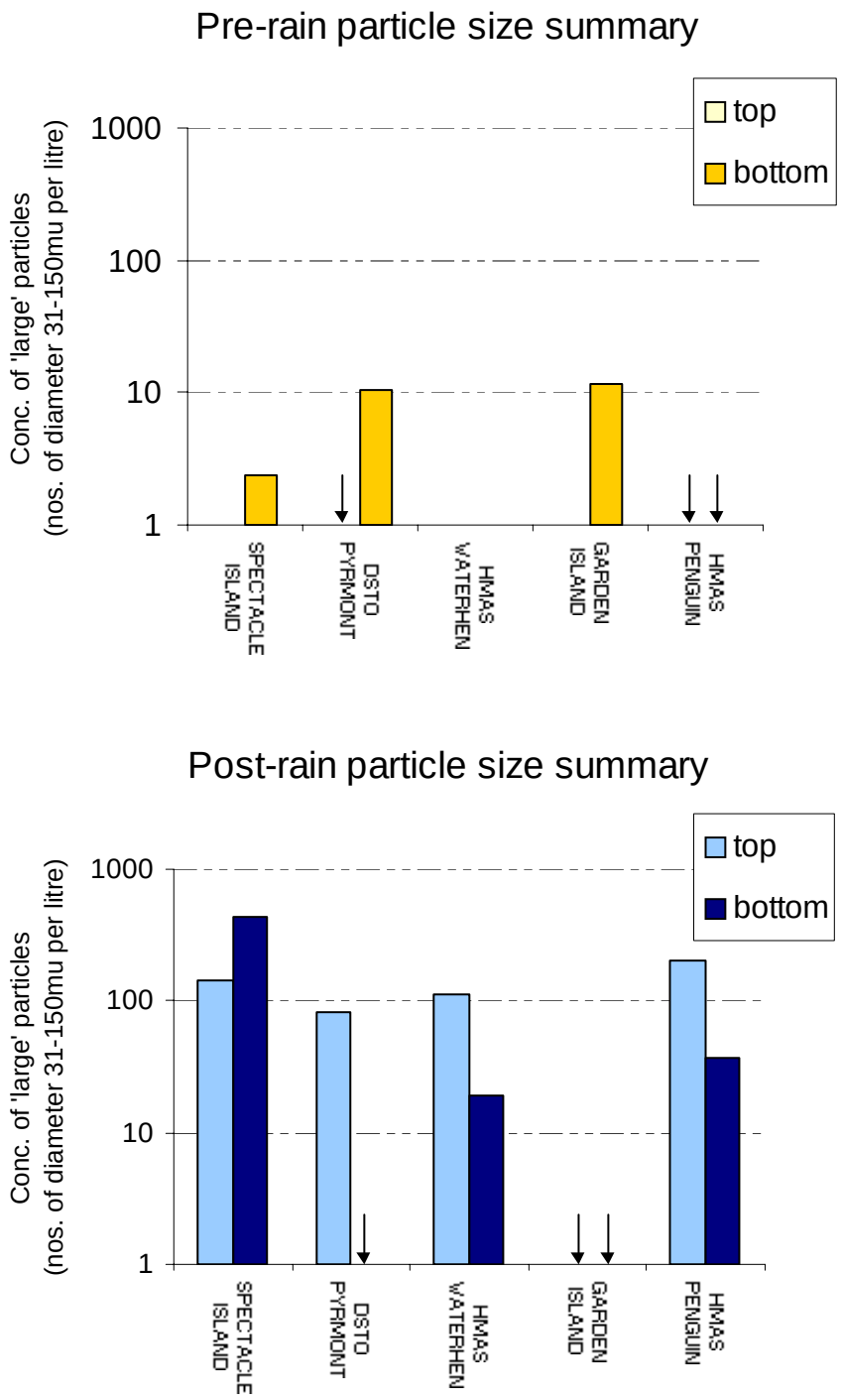


Fig 9A comparison of the number of particles per litre before and after rain.

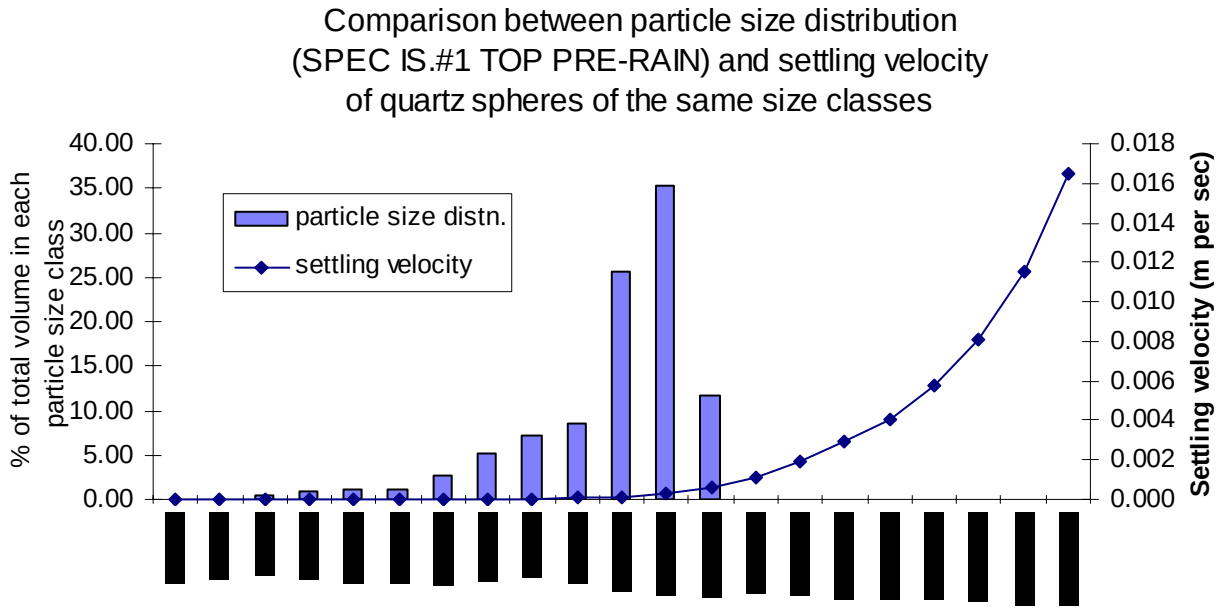


Fig 10 Settling velocity of spherical particles together with the probability by volume og grains of a given diameter in microns.

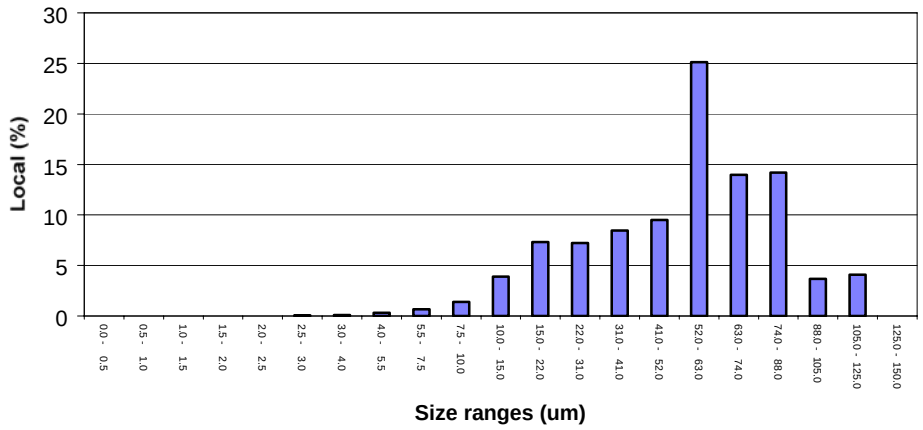


Fig 11 The grain size distribution (by volume) of sea floor sediments at the DSTO site.

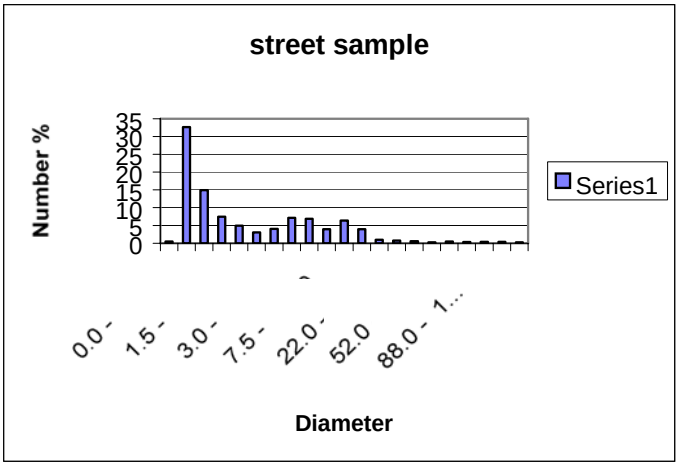


Fig 12 Probability of the number of grain of a given diameter.

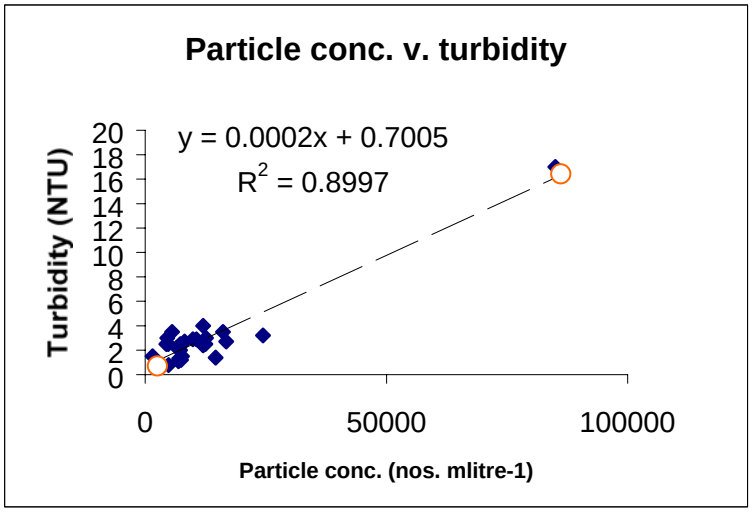


Fig 13 Turbidity as a function of number of particles per litre. The broken line joins the two additional points discussed in the text.

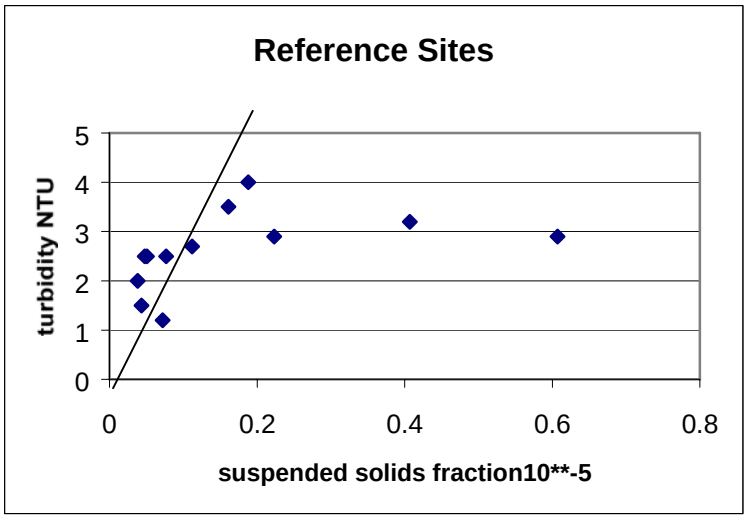


Fig 14 Turbidity as a function of total suspended solids. Solid line is expression discussed in the text. The two largest suspended solids points are from Newcastle.

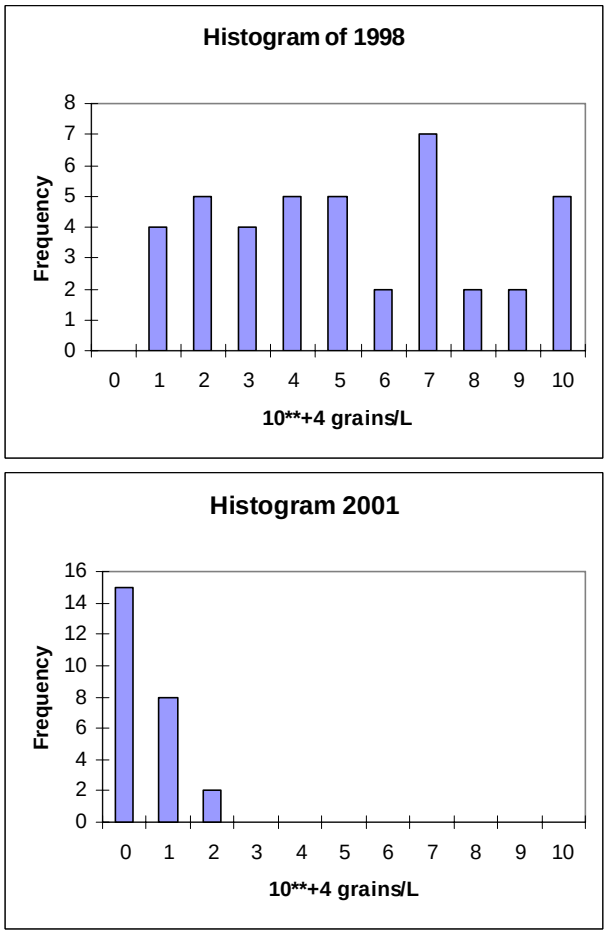


Fig 15 Number of particles per litre in units of 10,000 grains/litre. The top histogram is for Darwin, the lower histogram is all the reference sites. Notice the bar between 1 and 2 represents the number of samples below 1.

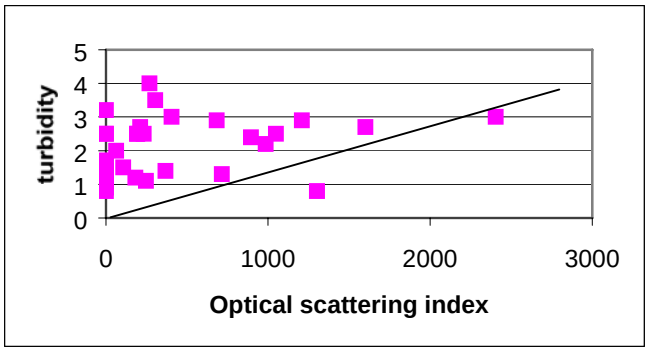


Fig 16 Comparison between turbidity and a measure of scattering. Solid line is a hypothesis.

Appendix A

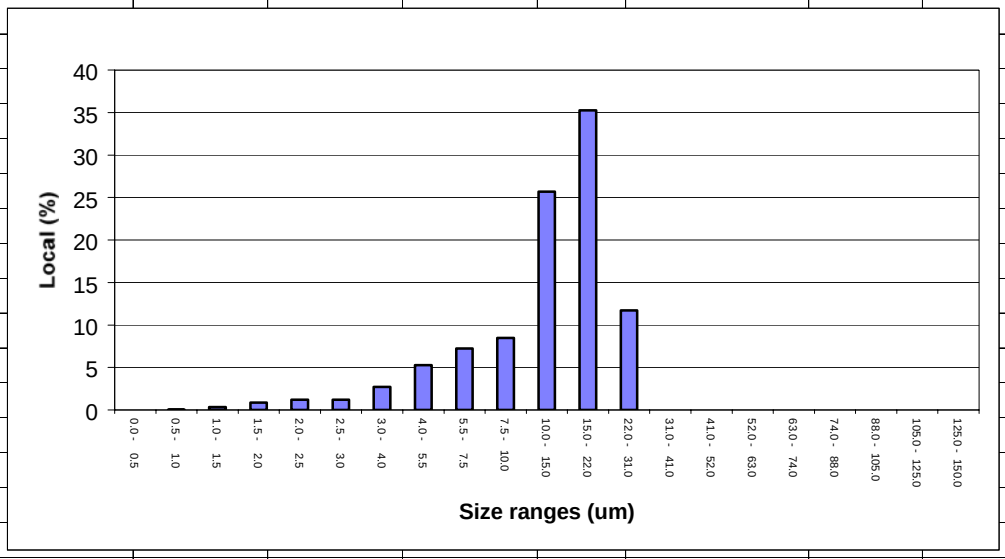
Grain size analysis results

The following sites had too few grains to allow a statistically acceptable result from the Galai laser particle sizer. It uses an indicator, the Signal Normalisation Factor (SNF) to make this judgement.

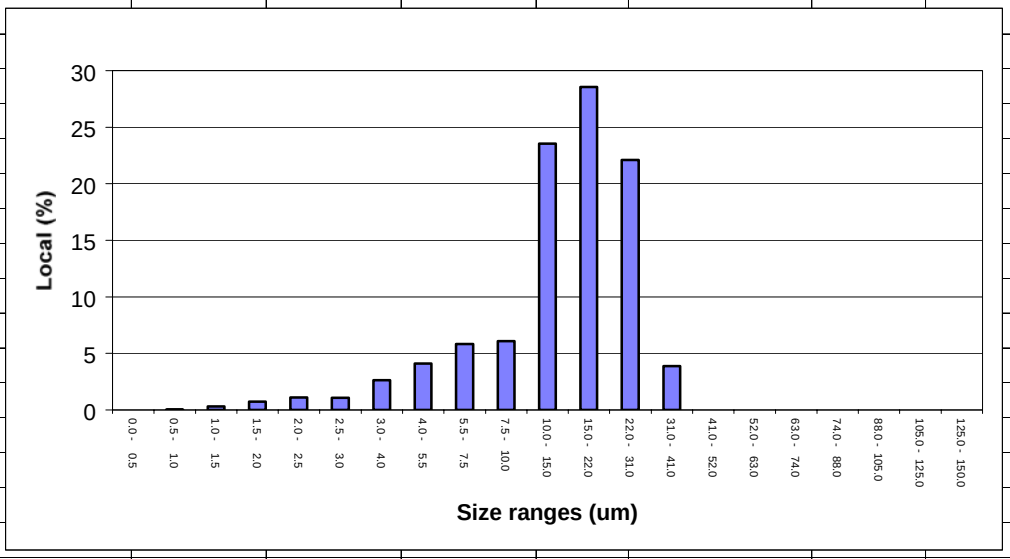
DSTO#1	pre top
DSTO#2	pre top
DSTO#2	pre bottom
PENGUIN#1	pre top
PENGUIN#1	pre bottom
GARDEN IS#2	pre top

Samples able to provide adequate statistics are shown below. The histograms show the percentage by volume of particles in a given range of diameters.

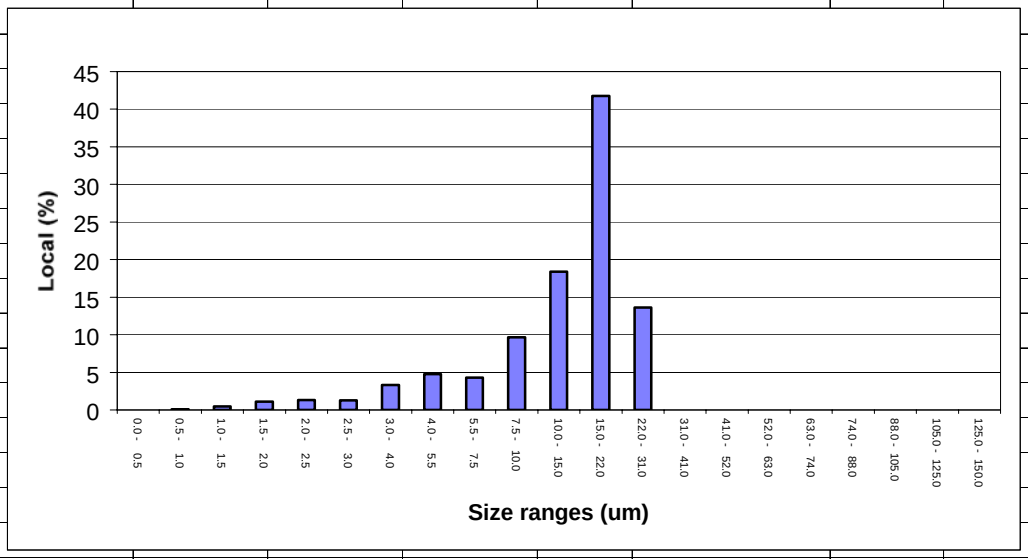
SPECTACLE ISLAND#1 TOP					12/11 "PRE-RAIN"				
STATISTICS					Volume ranges				
File Name : COLLECTING					Size(microns)	Local(%)	Under (%	Over(%)	
Date & Time : Tue Nov 13 2001 11:41:51					0.0 - 0.5	0	0	100	
Sample Name : 12/11/01spec1top					0.5 - 1.0	0.05	0.05	99.96	
----------					1.0 - 1.5	0.34	0.39	99.61	
Configuration : 1 (0.5A)					1.5 - 2.0	0.86	1.25	98.75	
Cell Type : Liquid Flow					2.0 - 2.5	1.19	2.44	97.56	
Sample Type : Special					2.5 - 3.0	1.21	3.65	96.35	
Acqui. Range : 0 - 150					3.0 - 4.0	2.71	6.36	93.64	
Acqui. Mode : Sample Size (2)					4.0 - 5.5	5.26	11.62	88.38	
Acqui. Time : 535					5.5 - 7.5	7.24	18.86	81.14	
----------					7.5 - 10.0	8.48	27.34	72.66	
Mean (µm) Standard Deviation(µm)					10.0 - 15.0	25.7	53.04	46.96	
Number, Length : 2.59 2.54					15.0 - 22.0	35.25	88.29	11.71	
Number, Area : 3.63 2.75					22.0 - 31.0	11.71	100	0	
Number, Volume : 5.04 3.53					31.0 - 41.0	0	100	0	
Length, Area : 5.08 4.86					41.0 - 52.0	0	100	0	
Length, Volume : 7.04 5.24					52.0 - 63.0	0	100	0	
Area, Volume : 9.74 6.60					63.0 - 74.0	0	100	0	
Volume, Moment : 14.22 6.44					74.0 - 88.0	0	100	0	
					88.0 - 105.0	0	100	0	
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)					105.0 - 125.0	0	100	0	
Number : 0.87 1.84 4.87 1.25 99.29					125.0 - 150.0	0	100	0	
Area : 2.19 8.23 19.27 2.25 70.01									
Volume : 5.05 14.34 22.29 19.25 86.94									



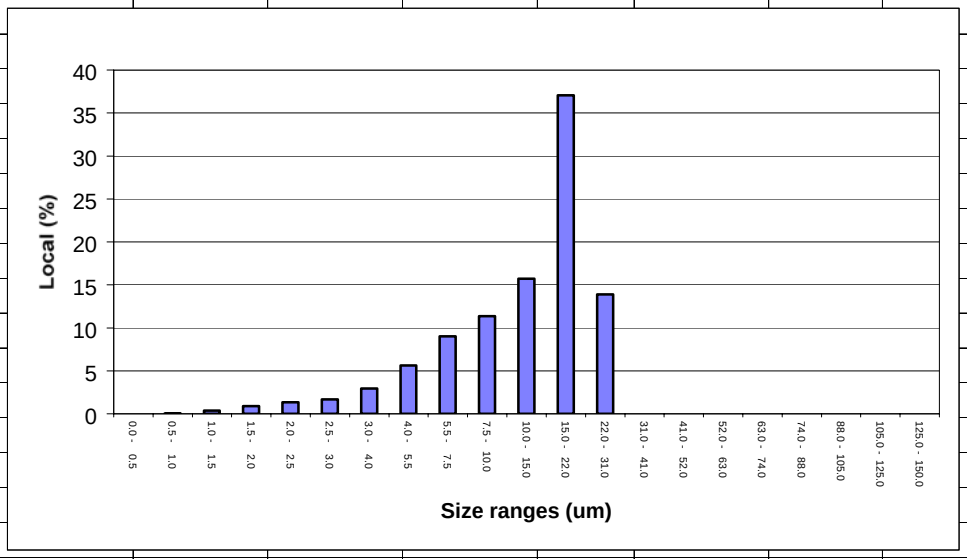
SPECTACLE ISLAND#1 BOTTOM					12/11 "PRE-RAIN"				
STATISTICS					Volume ranges				
File Name : COLLECTING					Size(microns)	Local(%)	Under(%	Over(%)	
Date & Time : Tue Nov 13 2001 12:20:44					0.0 - 0.5	0	0	100	
Sample Name : 12/11/01spec1top					0.5 - 1.0	0.04	0.04	99.96	
----------					1.0 - 1.5	0.31	0.34	99.66	
Configuration : 1 (0.5A)					1.5 - 2.0	0.74	1.08	98.92	
Cell Type : Liquid Flow					2.0 - 2.5	1.09	2.17	97.83	
Sample Type : Special					2.5 - 3.0	1.08	3.24	96.76	
Acqui. Range : 0 - 150					3.0 - 4.0	2.62	5.86	94.14	
Acqui. Mode : Sample Size (2)					4.0 - 5.5	4.11	9.97	90.03	
Acqui. Time : 348					5.5 - 7.5	5.84	15.82	84.18	
----------					7.5 - 10.0	6.09	21.91	78.09	
Mean (µm) Standard Deviation(µm)					10.0 - 15.0	23.54	45.45	54.55	
Number, Length : 2.58 2.63					15.0 - 22.0	28.57	74.02	25.98	
Number, Area : 3.69 2.85					22.0 - 31.0	22.11	96.13	3.88	
Number, Volume : 5.27 3.76					31.0 - 41.0	3.88	100	0	
Length, Area : 5.26 5.38					41.0 - 52.0	0	100	0	
Length, Volume : 7.53 5.84					52.0 - 63.0	0	100	0	
Area, Volume : 10.76 7.75					63.0 - 74.0	0	100	0	
Volume, Moment : 16.34 7.88					74.0 - 88.0	0	100	0	
					88.0 - 105.0	0	100	0	
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)					105.0 - 125.0	0	100	0	
Number : 0.88 1.85 4.74 1.25 99.07					125.0 - 150.0	0	100	0	
Area : 2.22 9.03 22.58 2.25 65.83									
Volume : 5.51 15.65 27.43 17.75 84.44									



HMAS WATERHEN#1 TOP					12/11 "PRE-RAIN"				
STATISTICS					Volume ranges				
File Name : COLLECTING					Size(microns)	Local(%)	Under(%	Over(%)	
Date & Time : Tue Nov 13 2001 12:58:50					0.0 - 0.5	0	0	100	
Sample Name : 12/11/01spec1top					0.5 - 1.0	0.08	0.08	99.92	
----------					1.0 - 1.5	0.46	0.54	99.46	
Configuration : 1 (0.5A)				| Counts : 34392	1.5 - 2.0	1.1	1.64	98.36	
Cell Type : Liquid Flow				| S.N.F. : 0.56	2.0 - 2.5	1.3	2.94	97.06	
Sample Type : Special				| S.D.U. : 41	2.5 - 3.0	1.27	4.21	95.79	
Acqui. Range : 0 - 150				| Solids : 3.82e-005 %	3.0 - 4.0	3.31	7.52	92.48	
Acqui. Mode : Sample Size (2) | Concent. : 7.21e+003 #/ml					4.0 - 5.5	4.78	12.3	87.7	
Acqui. Time : 1355				| Sp. Area : 0.70 cm²/ml	5.5 - 7.5	4.28	16.58	83.42	
----------					7.5 - 10.0	9.66	26.25	73.75	
	Mean (µm)		Standard Deviation(µm)		10.0 - 15.0	18.38	44.63	55.37	
Number, Length :	2.27		2.32		15.0 - 22.0	41.76	86.38	13.62	
Number, Area :	3.24		2.51		22.0 - 31.0	13.62	100	0	
Number, Volume :	4.66		3.33		31.0 - 41.0	0	100	0	
Length, Area :	4.64		4.81		41.0 - 52.0	0	100	0	
Length, Volume :	6.68		5.22		52.0 - 63.0	0	100	0	
Area, Volume :	9.62		6.79		63.0 - 74.0	0	100	0	
Volume, Moment :	14.41		6.37		74.0 - 88.0	0	100	0	
					88.0 - 105.0	0	100	0	
D10(µm)	D50(µm)	D90(µm)	MODE(µm)	CONF.(%)	105.0 - 125.0	0	100	0	
Number : 0.59	1.66	4.00	1.25	99.69	125.0 - 150.0	0	100	0	
Area : 1.95	8.28	19.47	1.75	68.70					
Volume : 4.76	15.68	22.47	17.25	87.87					



HMAS WATERHEN#1 BOTTOM						12/11 "PRE-RAIN"				
STATISTICS						Volume ranges				
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)	
Date & Time : Tue Nov 13 2001 13:49:07						0.0 - 0.5	0	0	100	
Sample Name : 12/11/01spec1top						0.5 - 1.0	0.04	0.04	99.96	
----------						1.0 - 1.5	0.39	0.43	99.57	
Configuration : 1 (0.5A)						1.5 - 2.0	0.91	1.34	98.66	
Cell Type : Liquid Flow						2.0 - 2.5	1.35	2.69	97.31	
Sample Type : Special						2.5 - 3.0	1.66	4.35	95.65	
Acqui. Range : 0 - 150						3.0 - 4.0	2.95	7.3	92.7	
Acqui. Mode : Sample Size (2)						4.0 - 5.5	5.64	12.94	87.06	
Acqui. Time : 675						5.5 - 7.5	9.01	21.95	78.05	
----------						7.5 - 10.0	11.35	33.3	66.7	
Mean (µm) Standard Deviation(µm)						10.0 - 15.	15.73	49.03	50.97	
Number, Length : 2.58 2.41						15.0 - 22.	37.06	86.09	13.91	
Number, Area : 3.53 2.60						22.0 - 31.	13.91	100	0	
Number, Volume : 4.89 3.34						31.0 - 41.	0	100	0	
Length, Area : 4.84 4.68						41.0 - 52.	0	100	0	
Length, Volume : 6.73 5.05						52.0 - 63.	0	100	0	
Area, Volume : 9.36 6.88						63.0 - 74.	0	100	0	
Volume, Moment : 14.42 7.25						74.0 - 88.	0	100	0	
						88.0 - 105	0	100	0	
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)						105.0 - 12	0	100	0	
Number : 0.94 1.88 4.87 1.25 99.54						125.0 - 15	0	100	0	
Area : 2.15 7.14 19.43 2.75 68.02										
Volume : 4.74 15.20 24.01 17.75 82.68										



GARDEN ISLAND#1 TOP 12/11 "PRE-RAIN"

STATISTICS

File Name : COLLECTING

Date & Time : Tue Nov 13 2001 14:57:46

Sample Name : 12/11/01spec1top

Configuration : 1 (0.5A) | Counts : 44410

Cell Type : Liquid Flow | S.N.F. : 0.47

Sample Type : Special | S.D.U. : 48

Acqui. Range : 0 - 150 | Solids : 4.32e-005 %

Acqui. Mode : Sample Size (2) | Concent. : 7.63e+003 #/ml

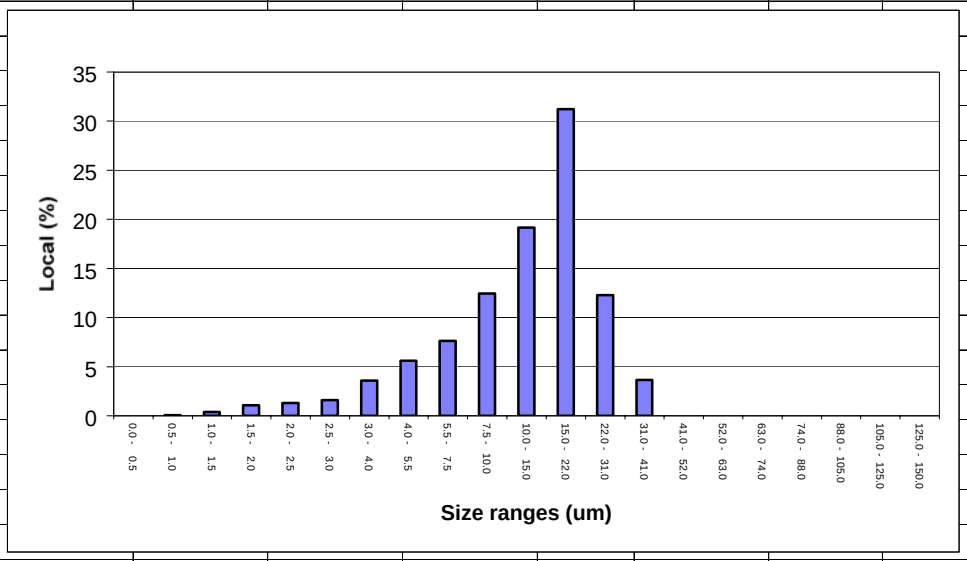
Acqui. Time : 1185 | Sp. Area : 0.72 cm²/ml

	Mean (µm)	Standard Deviation(µm)
Number, Length :	2.50	2.33
Number, Area :	3.42	2.51
Number, Volume :	4.76	3.25
Length, Area :	4.68	4.62
Length, Volume :	6.57	4.99
Area, Volume :	9.23	7.13
Volume, Moment :	14.74	8.02

	D10(µm)	D50(µm)	D90(µm)	MODE(µm)	CONF.(%)
Number :	0.88	1.84	4.69	1.25	99.66
Area :	2.07	7.00	19.86	1.75	66.32
Volume :	4.60	14.81	25.66	14.75	79.16

Volume ranges

Size(micro	Local(%)	Under(%	Over(%)
0.0 - 0.5	0	0	100
0.5 - 1.0	0.05	0.05	99.95
1.0 - 1.5	0.4	0.45	99.55
1.5 - 2.0	1.07	1.52	98.48
2.0 - 2.5	1.31	2.83	97.17
2.5 - 3.0	1.59	4.42	95.58
3.0 - 4.0	3.6	8.03	91.97
4.0 - 5.5	5.61	13.64	86.36
5.5 - 7.5	7.61	21.25	78.75
7.5 - 10.0	12.45	33.7	66.3
10.0 - 15.	19.17	52.87	47.13
15.0 - 22.	31.21	84.07	15.93
22.0 - 31.	12.28	96.35	3.65
31.0 - 41.	3.65	100	0
41.0 - 52.	0	100	0
52.0 - 63.	0	100	0
63.0 - 74.	0	100	0
74.0 - 88.	0	100	0
88.0 - 105	0	100	0
105.0 - 12	0	100	0
125.0 - 15	0	100	0



GARDEN ISLAND#1 BOTTOM 12/11 "PRE-RAIN"

STATISTICS

File Name : COLLECTING
Date & Time : Tue Nov 13 2001 15:21:50
Sample Name : 12/11/01spec1top

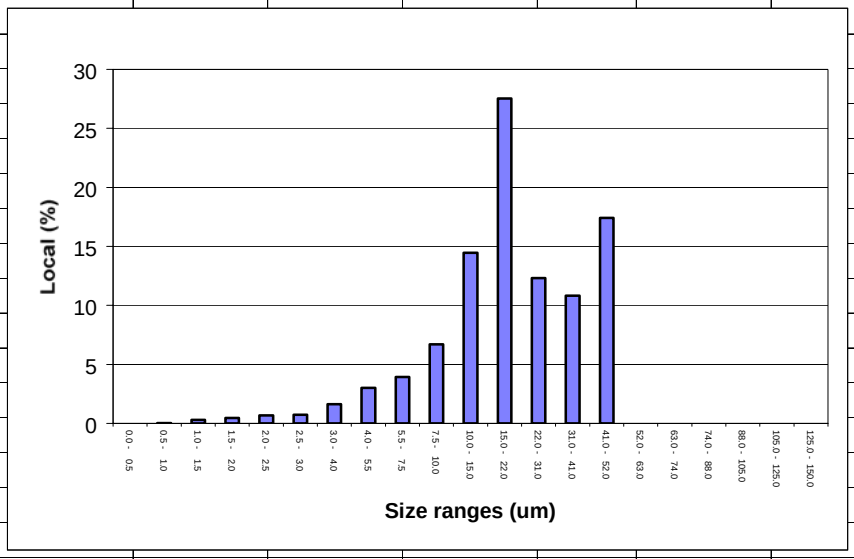
Configuration : 1 (0.5A) | Counts : 69458
Cell Type : Liquid Flow | S.N.F. : 0.68
Sample Type : Special | S.D.U. : 85
Acqui. Range : 0 - 150 | Solids : 7.18e-005 %
Acqui. Mode : Sample Size (2) | Concent. : 7.44e+003 #/ml
Acqui. Time : 1276 | Sp. Area : 0.65 cm²/ml

	Mean (µm)	Standard Deviation(µm)
Number, Length :	2.44	2.80
Number, Area :	3.72	3.08
Number, Volume :	5.69	4.29
Length, Area :	5.65	6.60
Length, Volume :	8.69	7.26
Area, Volume :	13.35	11.42
Volume, Moment :	23.12	14.04

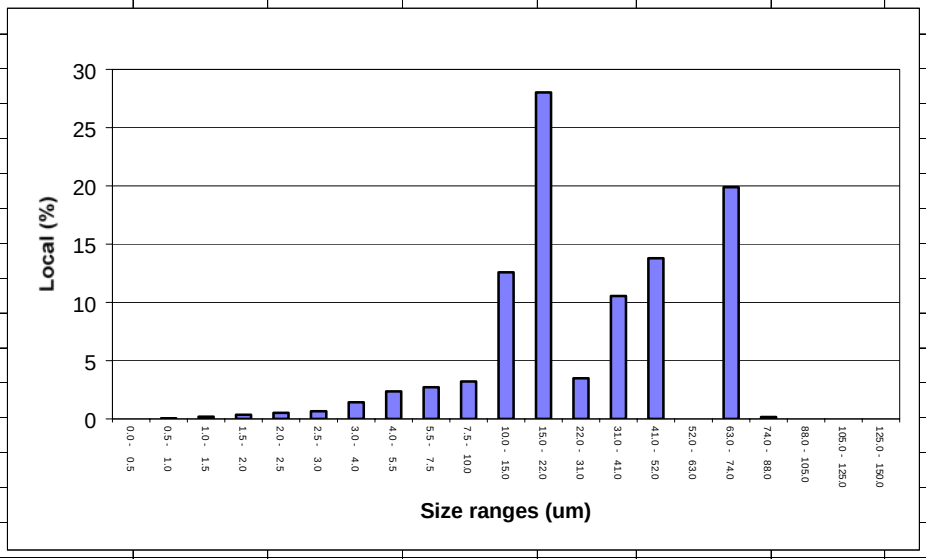
	D10(µm)	D50(µm)	D90(µm)	MODE(µm)	CONF.(%)
Number :	0.59	1.62	4.49	1.25	98.55
Area :	2.32	10.37	28.56	2.25	57.66
Volume :	7.05	20.00	46.23	46.25	74.04

Volume ranges

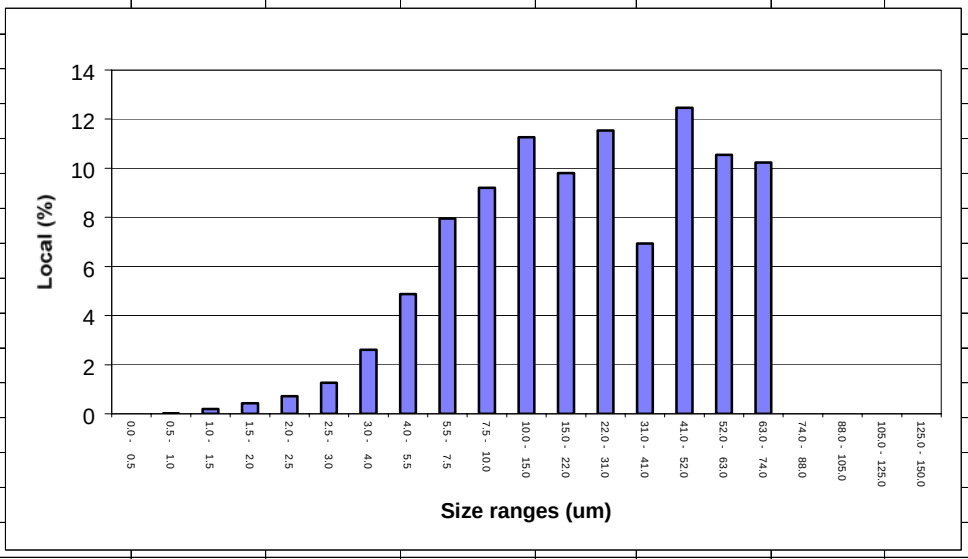
Size(micro	Local(%)	Under(%	Over(%)
0.0 - 0.5	0	0	100
0.5 - 1.0	0.04	0.04	99.96
1.0 - 1.5	0.29	0.33	99.67
1.5 - 2.0	0.46	0.79	99.21
2.0 - 2.5	0.69	1.48	98.52
2.5 - 3.0	0.74	2.22	97.78
3.0 - 4.0	1.63	3.85	96.15
4.0 - 5.5	3	6.85	93.15
5.5 - 7.5	3.92	10.77	89.23
7.5 - 10.0	6.7	17.47	82.53
10.0 - 15.	14.46	31.93	68.07
15.0 - 22.	27.54	59.46	40.54
22.0 - 31.	12.31	71.77	28.23
31.0 - 41.	10.81	82.57	17.43
41.0 - 52.	17.42	100	0
52.0 - 63.	0	100	0
63.0 - 74.	0	100	0
74.0 - 88.	0	100	0
88.0 - 105	0	100	0
105.0 - 12	0	100	0
125.0 - 15	0	100	0



GARDEN ISLAND#2 BOTTOM				12/11 "PRE-RAIN"					
STATISTICS				Volume ranges					
File Name : COLLECTING				Size(micro	Local(%)	Under(%	Over(%)		
Date & Time : Tue Nov 13 2001 15:50:45				0.0 - 0.5	0	0	100		
Sample Name : 12/11/01spec1top				0.5 - 1.0	0.06	0.06	99.94		
----------				1.0 - 1.5	0.2	0.27	99.73		
Configuration : 1 (0.5A)				1.5 - 2.0	0.36	0.63	99.38		
Cell Type : Liquid Flow				2.0 - 2.5	0.53	1.15	98.85		
Sample Type : Special				2.5 - 3.0	0.67	1.83	98.17		
Acqui. Range : 0 - 150				3.0 - 4.0	1.43	3.26	96.74		
Acqui. Mode : Sample Size (2)				4.0 - 5.5	2.35	5.61	94.39		
Acqui. Time : 1978				5.5 - 7.5	2.72	8.32	91.68		
----------				7.5 - 10.0	3.21	11.53	88.47		
Mean (µm) Standard Deviation(µm)				10.0 - 15.	12.59	24.12	75.88		
Number, Length : 2.20 2.79				15.0 - 22.	28.02	52.15	47.85		
Number, Area : 3.56 3.10				22.0 - 31.	3.48	55.62	44.38		
Number, Volume : 5.91 4.64				31.0 - 41.	10.54	66.16	33.84		
Length, Area : 5.74 7.80				41.0 - 52.	13.78	79.95	20.05		
Length, Volume : 9.68 8.73				52.0 - 63.	0	79.95	20.05		
Area, Volume : 16.32 16.24				63.0 - 74.	19.88	99.83	0.17		
Volume, Moment : 32.48 21.85				74.0 - 88.	0.17	100	0		
				88.0 - 105	0	100	0		
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)				105.0 - 12	0	100	0		
Number : 0.33 1.43 4.04 0.75 97.55				125.0 - 15	0	100	0		
Area : 2.34 13.61 40.81 18.25 47.21									
Volume : 8.75 21.70 68.02 68.25 64.94									



DSTO PYRMONT#1 BOTTOM						15/11 "PRE-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Wed Nov 21 2001 10:57:21						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.01	0.01	99.99
----------						1.0 - 1.5	0.19	0.2	99.8
Configuration : 1 (0.5A)						1.5 - 2.0	0.43	0.63	99.37
Cell Type : Liquid Flow						2.0 - 2.5	0.72	1.35	98.65
Sample Type : Special						2.5 - 3.0	1.27	2.62	97.38
Acqui. Range : 0 - 150						3.0 - 4.0	2.61	5.23	94.77
Acqui. Mode : Sample Size (2)						4.0 - 5.5	4.87	10.1	89.9
Acqui. Time : 1641						5.5 - 7.5	7.95	18.05	81.95
----------						7.5 - 10.0	9.2	27.25	72.75
	Mean (µm)	Standard Deviation(µm)				10.0 - 15.	11.26	38.5	61.5
Number, Length :	2.99	2.68				15.0 - 22.	9.8	48.3	51.7
Number, Area :	4.02	2.87				22.0 - 31.	11.53	59.84	40.16
Number, Volume :	5.87	3.93				31.0 - 41.	6.93	66.76	33.24
Length, Area :	5.39	6.20				41.0 - 52.	12.46	79.23	20.77
Length, Volume :	8.21	6.81				52.0 - 63.	10.54	89.77	10.23
Area, Volume :	12.52	14.09				63.0 - 74.	10.23	100	0
Volume, Moment :	28.38	20.53				74.0 - 88.	0	100	0
						88.0 - 105	0	100	0
D10(µm)	D50(µm)	D90(µm)	MODE(µm)	CONF.(%)		105.0 - 12	0	100	0
Number : 1.04	2.31	5.69	1.25	98.95		125.0 - 15	0	100	0
Area : 2.57	7.18	31.16	2.75	45.68					
Volume : 5.47	23.59	56.35	52.25	65.61					



HMAS PENGUIN#1 TOP

26/11 "POST-RAIN"

STATISTICS

File Name : COLLECTING

Date & Time : Wed Nov 28 2001 13:27:06

Sample Name : WCIS-100 Version 1.22

Configuration : 1 (0.5A) | Counts : 148546

Cell Type : Liquid Flow | S.N.F. : 0.80

Sample Type : Special | S.D.U. : 140

Acqui. Range : 0 - 150 | Solids : 4.57e-004 %

Acqui. Mode : Sample Size (2) | Concent. : 4.84e+003 #/ml

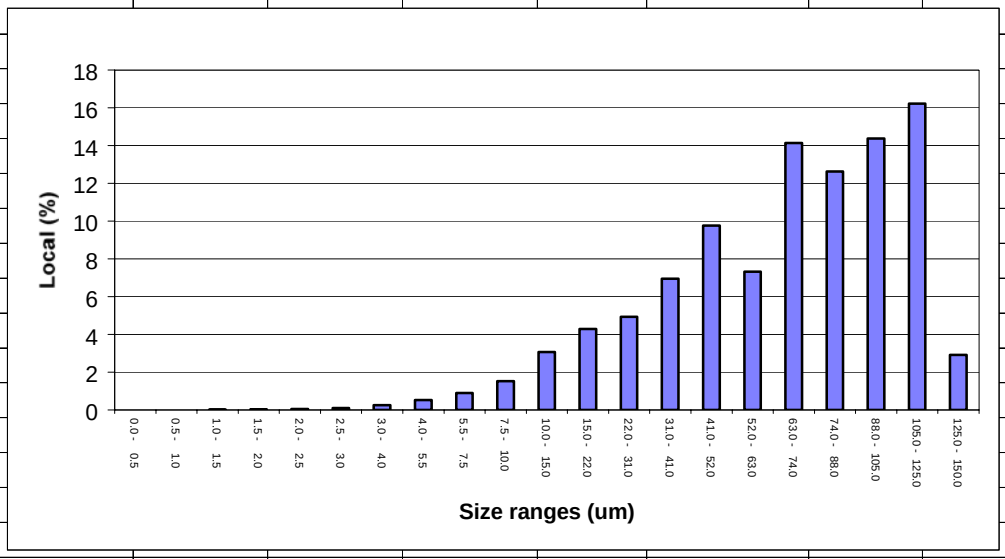
Acqui. Time : 1521 | Sp. Area : 0.55 cm²/ml

	Mean (µm)	Standard Deviation(µm)
Number, Length :	3.62	5.62
Number, Area :	6.68	6.40
Number, Volume :	12.17	10.23
Length, Area :	12.33	18.59
Length, Volume :	22.31	21.10
Area, Volume :	40.37	34.65
Volume, Moment :	70.11	33.44

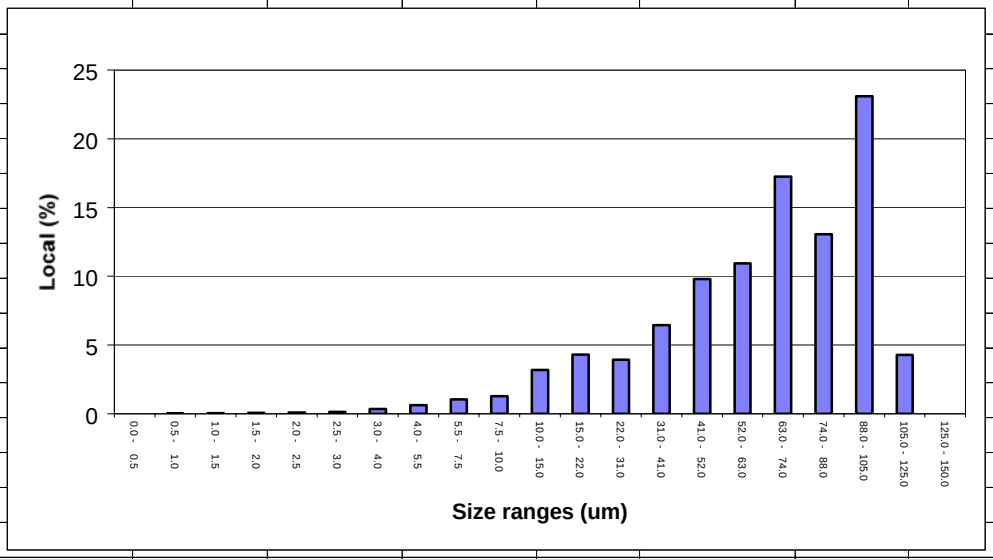
	D10(µm)	D50(µm)	D90(µm)	MODE(µm)	CONF.(%)
Number :	0.48	2.12	7.61	0.75	77.72
Area :	5.14	29.61	92.22	10.25	57.50
Volume :	21.00	71.59	119.12	106.75	84.88

Volume ranges

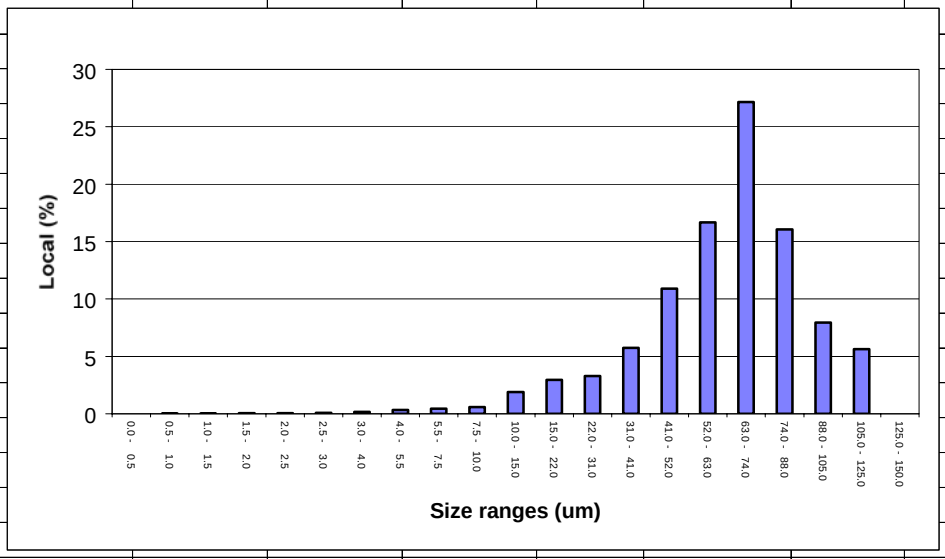
Size(microns	Local(%)	Under(%	Over(%)
0.0 - 0.5	0	0	100
0.5 - 1.0	0	0	100
1.0 - 1.5	0.02	0.02	99.98
1.5 - 2.0	0.03	0.05	99.94
2.0 - 2.5	0.05	0.1	99.9
2.5 - 3.0	0.1	0.2	99.8
3.0 - 4.0	0.25	0.45	99.55
4.0 - 5.5	0.52	0.98	99.02
5.5 - 7.5	0.89	1.87	98.13
7.5 - 10.0	1.52	3.39	96.61
10.0 - 15.0	3.07	6.46	93.54
15.0 - 22.0	4.29	10.75	89.25
22.0 - 31.0	4.94	15.69	84.31
31.0 - 41.0	6.95	22.64	77.36
41.0 - 52.0	9.77	32.4	67.6
52.0 - 63.0	7.33	39.74	60.26
63.0 - 74.0	14.13	53.87	46.13
74.0 - 88.0	12.62	66.49	33.51
88.0 - 105.0	14.37	80.86	19.14
105.0 - 125.(	16.22	97.07	2.93
125.0 - 150.(	2.92	100	0



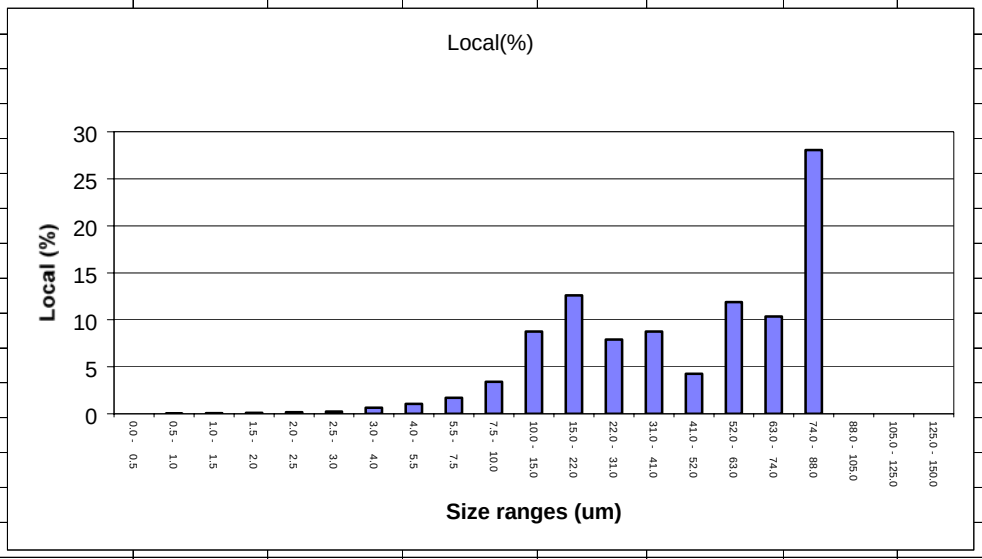
HMAS PENGUIN#1 BOTTOM						26/11 "POST-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(microns	Local(%)	Under(%	Over(%)
Date & Time : Wed Nov 28 2001 14:01:23						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.02	0.02	99.98
----------						1.0 - 1.5	0.05	0.07	99.93
Configuration : 1 (0.5A)						1.5 - 2.0	0.07	0.14	99.86
Cell Type : Liquid Flow						2.0 - 2.5	0.1	0.25	99.75
Sample Type : Special						2.5 - 3.0	0.13	0.38	99.62
Acqui. Range : 0 - 150						3.0 - 4.0	0.36	0.74	99.26
Acqui. Mode : Sample Size (2)						4.0 - 5.5	0.62	1.36	98.64
Acqui. Time : 2870						5.5 - 7.5	1.04	2.39	97.61
----------						7.5 - 10.0	1.28	3.68	96.32
Mean (µm) Standard Deviation(µm)						10.0 - 15.0	3.18	6.86	93.14
Number, Length : 2.21 3.89						15.0 - 22.0	4.31	11.18	88.82
Number, Area : 4.47 4.49						22.0 - 31.0	3.93	15.1	84.9
Number, Volume : 9.12 7.92						31.0 - 41.0	6.45	21.56	78.44
Length, Area : 9.03 16.16						41.0 - 52.0	9.81	31.37	68.63
Length, Volume : 18.51 18.73						52.0 - 63.0	10.94	42.31	57.69
Area, Volume : 37.93 32.32						63.0 - 74.0	17.25	59.56	40.44
Volume, Moment : 65.47 28.56						74.0 - 88.0	13.05	72.61	27.39
						88.0 - 105.0	23.09	95.71	4.29
D10(µm)	D50(µm)	D90(µm)	MODE(µm)	CONF.(%)		105.0 - 125.	4.29	100	0
Number : 0.25	1.22	4.37	0.75	92.20		125.0 - 150.	0	100	0
Area : 3.54	27.51	91.25	69.75	57.82					
Volume : 19.96	69.75	100.24	69.75	88.35					



DSTO PYRMONT#2 TOP						26/11 "POST-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micron	Local(%)	Under(%	Over(%)
Date & Time : Wed Nov 28 2001 14:57:51						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.02	0.02	99.98
----------						1.0 - 1.5	0.03	0.05	99.95
Configuration : 1 (0.5A)						1.5 - 2.0	0.05	0.09	99.91
Cell Type : Liquid Flow						2.0 - 2.5	0.06	0.15	99.85
Sample Type : Special						2.5 - 3.0	0.08	0.23	99.77
Acqui. Range : 0 - 150						3.0 - 4.0	0.18	0.41	99.59
Acqui. Mode : Sample Size (2)						4.0 - 5.5	0.33	0.74	99.26
Acqui. Time : 2280						5.5 - 7.5	0.45	1.19	98.81
----------						7.5 - 10.0	0.58	1.77	98.23
Mean (µm) Standard Deviation(µm)						10.0 - 15.0	1.89	3.66	96.34
Number, Length : 2.21 4.69						15.0 - 22.0	2.96	6.62	93.38
Number, Area : 5.19 5.55						22.0 - 31.0	3.29	9.91	90.09
Number, Volume : 10.63 9.64						31.0 - 41.0	5.74	15.65	84.35
Length, Area : 12.15 19.88						41.0 - 52.0	10.89	26.54	73.46
Length, Volume : 23.30 22.80						52.0 - 63.0	16.67	43.21	56.79
Area, Volume : 44.70 29.27						63.0 - 74.0	27.16	70.37	29.63
Volume, Moment : 63.86 23.56						74.0 - 88.0	16.05	86.42	13.58
						88.0 - 105.0	7.95	94.38	5.62
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)						105.0 - 125	5.62	100	0
Number : 0.24 1.15 3.92 0.75 85.57						125.0 - 150	0	100	0
Area : 4.86 46.28 81.24 64.25 70.42									
Volume : 31.37 65.14 91.96 73.75 93.66									



SPECTACLE ISLAND#1 TOP						27/11 "POST-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Wed Nov 28 2001 09:42:40						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.02	0.02	99.98
----------						1.0 - 1.5	0.06	0.09	99.91
Configuration : 1 (0.5A)						1.5 - 2.0	0.11	0.2	99.8
Cell Type : Liquid Flow						2.0 - 2.5	0.18	0.38	99.62
Sample Type : Special						2.5 - 3.0	0.25	0.63	99.37
Acqui. Range : 0 - 150						3.0 - 4.0	0.64	1.27	98.73
Acqui. Mode : Sample Size (2)						4.0 - 5.5	1.05	2.31	97.69
Acqui. Time : 741						5.5 - 7.5	1.69	4.01	95.99
----------						7.5 - 10.0	3.42	7.43	92.57
Mean (µm) Standard Deviation(µm)						10.0 - 15.	8.75	16.18	83.82
Number, Length : 2.77 3.89						15.0 - 22.	12.6	28.78	71.22
Number, Area : 4.78 4.38						22.0 - 31.	7.9	36.68	63.32
Number, Volume : 8.23 6.71						31.0 - 41.	8.76	45.44	54.56
Length, Area : 8.24 11.55						41.0 - 52.	4.26	49.71	50.29
Length, Volume : 14.19 12.99						52.0 - 63.	11.88	61.58	38.42
Area, Volume : 24.43 24.30						63.0 - 74.	10.34	71.93	28.07
Volume, Moment : 48.59 28.32						74.0 - 88.	28.07	100	0
						88.0 - 105.	0	100	0
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)						105.0 - 12	0	100	0
Number : 0.37 1.58 5.79 0.75 92.13						125.0 - 15	0	100	0
Area : 3.47 14.66 65.32 13.75 50.89									
Volume : 11.77 57.55 85.79 86.25 75.99									



SPECTACLE ISLAND#1 BOTTOM

27/11 "POST-RAIN"

STATISTICS

File Name : COLLECTING

Date & Time : Wed Nov 28 2001 09:59:37

Sample Name : WCIS-100 Version 1.22

Configuration : 1 (0.5A) | Counts : 235096

Cell Type : Liquid Flow | S.N.F. : 0.95

Sample Type : Special | S.D.U. : 187

Acqui. Range : 0 - 150 | Solids : 4.10e-004 %

Acqui. Mode : Sample Size (2) | Concent. : 8.13e+003 #/ml

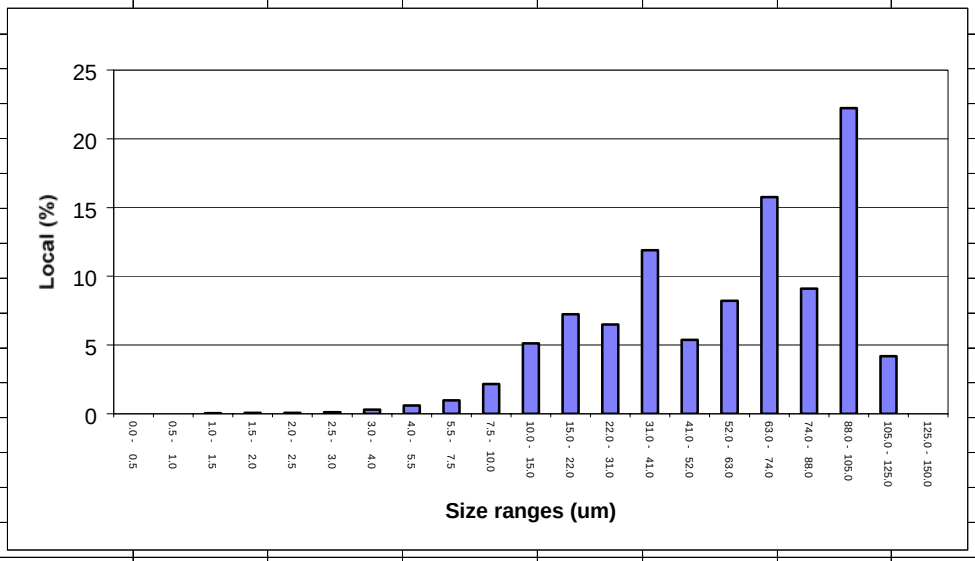
Acqui. Time : 1152 | Sp. Area : 0.55 cm²/ml

	Mean (µm)	Standard Deviation(µm)
Number, Length :	2.84	4.62
Number, Area :	5.42	5.29
Number, Volume :	9.88	8.42
Length, Area :	10.36	15.23
Length, Volume :	18.42	17.23
Area, Volume :	32.75	29.52
Volume, Moment :	59.36	31.16

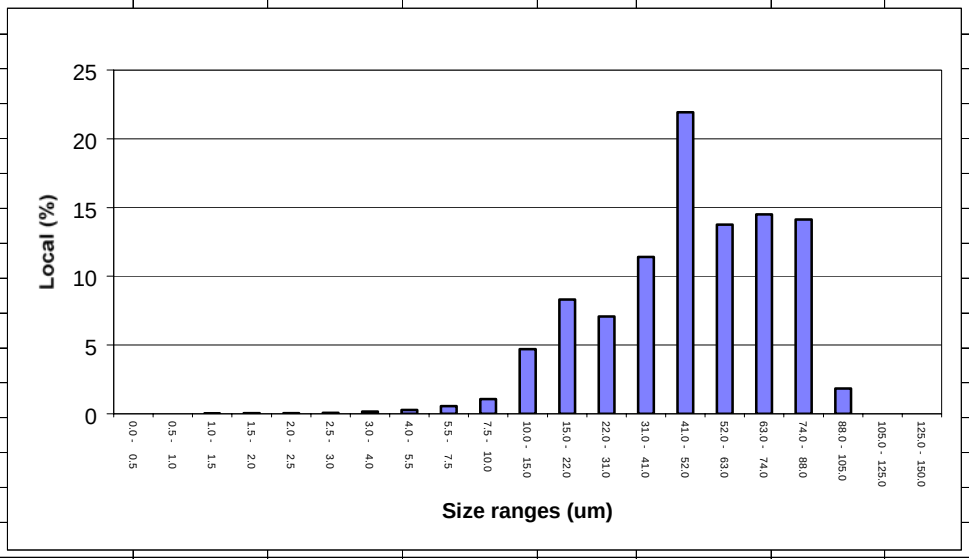
	D10(µm)	D50(µm)	D90(µm)	MODE(µm)	CONF.(%)
Number :	0.32	1.44	6.13	0.75	86.16
Area :	4.52	20.28	77.85	9.75	55.25
Volume :	15.31	63.22	99.72	109.75	80.79

Volume ranges

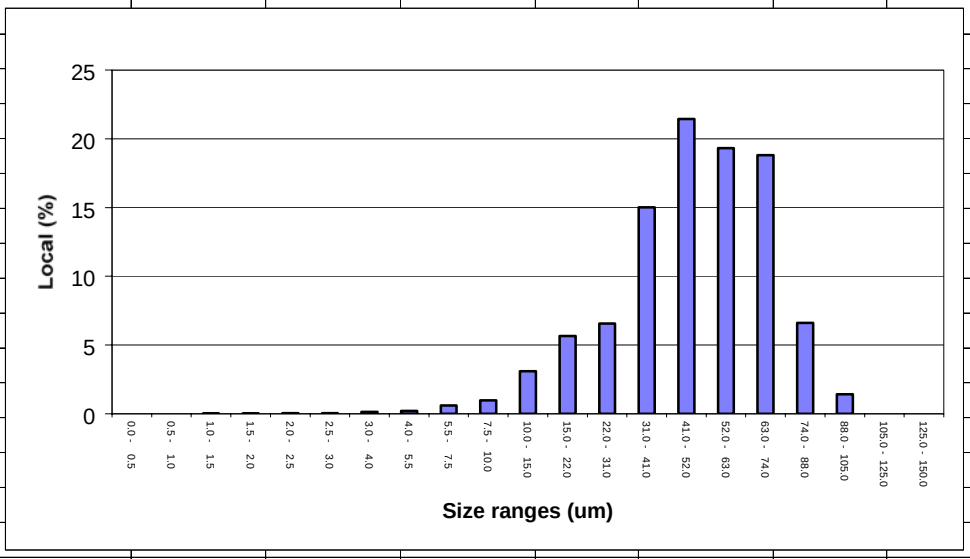
Size(micro	Local(%)	Under(%	Over(%)
0.0 - 0.5	0	0	100
0.5 - 1.0	0.01	0.01	99.99
1.0 - 1.5	0.04	0.05	99.94
1.5 - 2.0	0.06	0.12	99.88
2.0 - 2.5	0.08	0.2	99.8
2.5 - 3.0	0.12	0.32	99.68
3.0 - 4.0	0.31	0.63	99.37
4.0 - 5.5	0.6	1.23	98.77
5.5 - 7.5	0.98	2.2	97.8
7.5 - 10.0	2.17	4.38	95.63
10.0 - 15.	5.12	9.49	90.51
15.0 - 22.	7.25	16.74	83.26
22.0 - 31.	6.5	23.24	76.76
31.0 - 41.	11.89	35.12	64.88
41.0 - 52.	5.38	40.51	59.49
52.0 - 63.	8.21	48.72	51.28
63.0 - 74.	15.77	64.49	35.51
74.0 - 88.	9.11	73.59	26.41
88.0 - 105	22.23	95.82	4.18
105.0 - 12	4.18	100	0
125.0 - 15	0	100	0



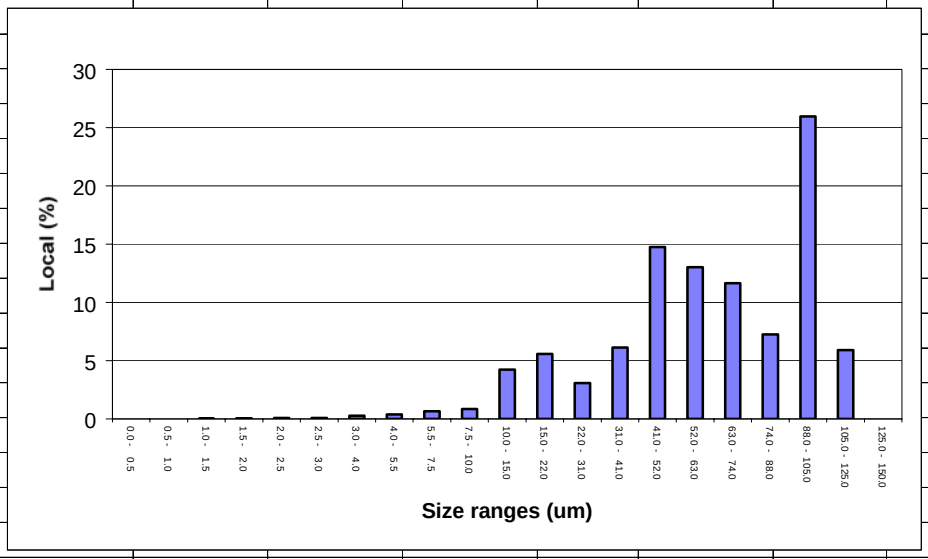
SPECTACLE ISLAND#2 TOP						27/11 "POST-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Wed Nov 28 2001 10:40:16						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.01	0.01	99.99
----------						1.0 - 1.5	0.03	0.04	99.96
Configuration : 1 (0.5A)						1.5 - 2.0	0.05	0.1	99.9
Cell Type : Liquid Flow						2.0 - 2.5	0.05	0.15	99.85
Sample Type : Special						2.5 - 3.0	0.08	0.24	99.76
Acqui. Range : 0 - 150						3.0 - 4.0	0.16	0.4	99.6
Acqui. Mode : Sample Size (2)						4.0 - 5.5	0.29	0.69	99.31
Acqui. Time : 1331						5.5 - 7.5	0.57	1.25	98.75
----------						7.5 - 10.0	1.08	2.34	97.66
Mean (µm) Standard Deviation(µm)						10.0 - 15.	4.71	7.05	92.95
Number, Length : 2.91 5.43						15.0 - 22.	8.31	15.36	84.64
Number, Area : 6.16 6.33						22.0 - 31.	7.07	22.43	77.57
Number, Volume : 10.86 9.62						31.0 - 41.	11.4	33.83	66.17
Length, Area : 13.03 16.42						41.0 - 52.	21.93	55.76	44.24
Length, Volume : 20.96 18.23						52.0 - 63.	13.75	69.51	30.49
Area, Volume : 33.72 23.11						63.0 - 74.	14.5	84.01	15.99
Volume, Moment : 49.56 21.87						74.0 - 88.	14.14	98.15	1.85
						88.0 - 105	1.85	100	0
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)						105.0 - 12	0	100	0
Number : 0.28 1.34 6.07 0.75 79.28						125.0 - 15	0	100	0
Area : 6.91 29.72 69.42 58.75 68.21									
Volume : 17.50 48.64 78.71 58.75 87.92									



SPECTACLE ISLAND#2 BOTTOM						27/11 "POST-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Wed Nov 28 2001 11:06:27						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.01	0.01	99.99
----------						1.0 - 1.5	0.02	0.02	99.98
Configuration : 1 (0.5A)						1.5 - 2.0	0.03	0.05	99.95
Cell Type : Liquid Flow						2.0 - 2.5	0.04	0.09	99.91
Sample Type : Special						2.5 - 3.0	0.05	0.14	99.86
Acqui. Range : 0 - 150						3.0 - 4.0	0.14	0.27	99.73
Acqui. Mode : Sample Size (2)						4.0 - 5.5	0.2	0.47	99.53
Acqui. Time : 610						5.5 - 7.5	0.61	1.09	98.91
----------						7.5 - 10.0	0.97	2.05	97.95
Mean (µm) Standard Deviation(µm)						10.0 - 15.	3.1	5.15	94.85
Number, Length : 3.58 6.63						15.0 - 22.	5.66	10.81	89.19
Number, Area : 7.54 7.73						22.0 - 31.	6.57	17.38	82.62
Number, Volume : 12.70 11.28						31.0 - 41.	15.02	32.4	67.6
Length, Area : 15.88 17.89						41.0 - 52.	21.43	53.83	46.17
Length, Volume : 23.92 19.61						52.0 - 63.	19.31	73.13	26.87
Area, Volume : 36.04 21.57						63.0 - 74.	18.81	91.94	8.06
Volume, Moment : 48.95 19.05						74.0 - 88.	6.62	98.57	1.43
						88.0 - 105	1.43	100	0
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)						105.0 - 12	0	100	0
Number : 0.31 1.44 8.22 0.75 69.79						125.0 - 15	0	100	0
Area : 8.30 35.84 65.92 45.25 74.73									
Volume : 21.08 49.28 72.12 78.75 92.15									



HMAS WATERHEN#1 TOP						27/11 "POST-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Wed Nov 28 2001 11:21:31						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.01	0.01	99.99
----------						1.0 - 1.5	0.03	0.04	99.96
Configuration : 1 (0.5A)						1.5 - 2.0	0.06	0.09	99.91
Cell Type : Liquid Flow						2.0 - 2.5	0.07	0.17	99.83
Sample Type : Special						2.5 - 3.0	0.09	0.26	99.74
Acqui. Range : 0 - 150						3.0 - 4.0	0.28	0.54	99.46
Acqui. Mode : Sample Size (2)						4.0 - 5.5	0.38	0.92	99.08
Acqui. Time : 1115						5.5 - 7.5	0.67	1.59	98.41
----------						7.5 - 10.0	0.86	2.45	97.55
Mean (µm) Standard Deviation(µm)						10.0 - 15.	4.23	6.68	93.32
Number, Length : 3.09 5.21						15.0 - 22.	5.58	12.26	87.74
Number, Area : 6.06 6.00						22.0 - 31.	3.07	15.33	84.67
Number, Volume : 11.27 9.70						31.0 - 41.	6.14	21.47	78.53
Length, Area : 11.89 17.94						41.0 - 52.	14.74	36.21	63.79
Length, Volume : 21.52 20.37						52.0 - 63.	13.02	49.22	50.78
Area, Volume : 38.98 31.50						63.0 - 74.	11.64	60.87	39.13
Volume, Moment : 64.43 29.60						74.0 - 88.	7.26	68.12	31.88
						88.0 - 105	25.95	94.08	5.92
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)						105.0 - 12	5.92	100	0
Number : 0.48 1.72 6.02 0.75 81.08						125.0 - 15	0	100	0
Area : 4.84 33.17 93.52 15.25 60.31									
Volume : 17.77 63.78 102.27 101.25 86.38									



HMAS WATERHEN#1 BOTTOM

27/11 "POST-RAIN"

STATISTICS

File Name : COLLECTING

Date & Time : Wed Nov 28 2001 11:52:53

Sample Name : WCIS-100 Version 1.22

Configuration : 1 (0.5A) | Counts : 121387

Cell Type : Liquid Flow | S.N.F. : 0.96

Sample Type : Special | S.D.U. : 151

Acqui. Range : 0 - 150 | Solids : 1.04e-004 %

Acqui. Mode : Sample Size (2) | Concent. : 5.56e+003 #/ml

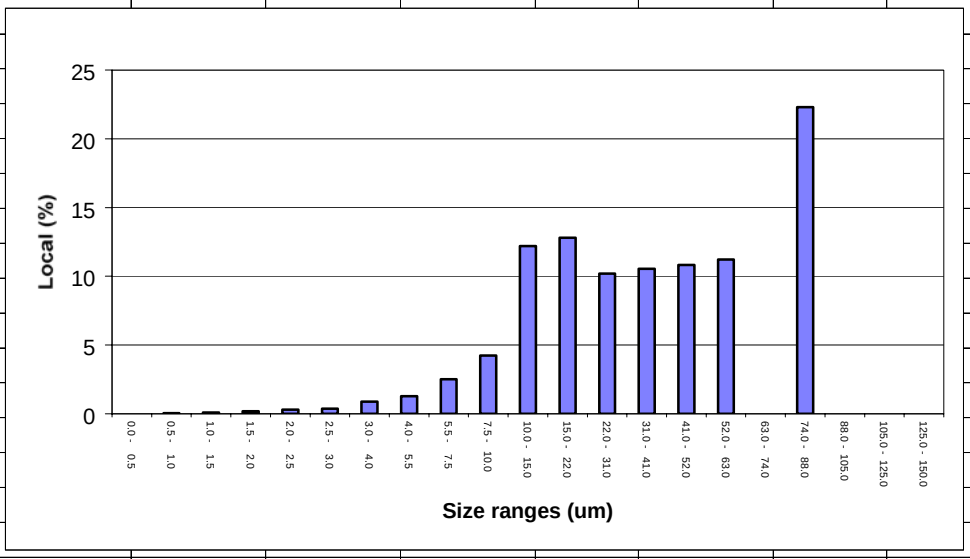
Acqui. Time : 1686 | Sp. Area : 0.59 cm²/ml

	Mean (µm)	Standard Deviation(µm)
Number, Length :	2.52	3.39
Number, Area :	4.22	3.80
Number, Volume :	7.10	5.70
Length, Area :	7.09	9.59
Length, Volume :	11.92	10.74
Area, Volume :	20.05	20.11
Volume, Moment :	40.22	25.94

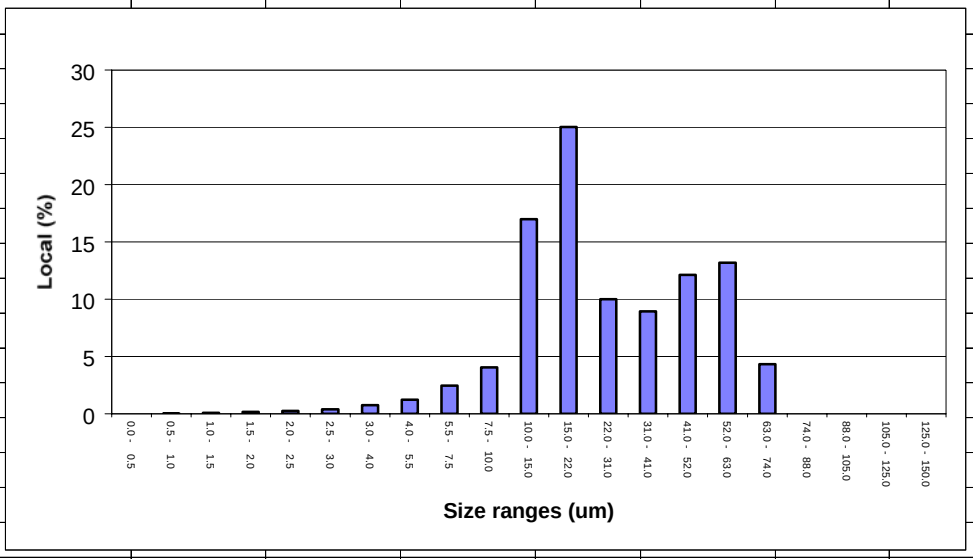
	D10(µm)	D50(µm)	D90(µm)	MODE(µm)	CONF.(%)
Number :	0.33	1.48	5.05	0.75	95.65
Area :	2.97	13.34	51.34	15.25	50.52
Volume :	10.04	38.03	82.10	74.75	71.15

Volume ranges

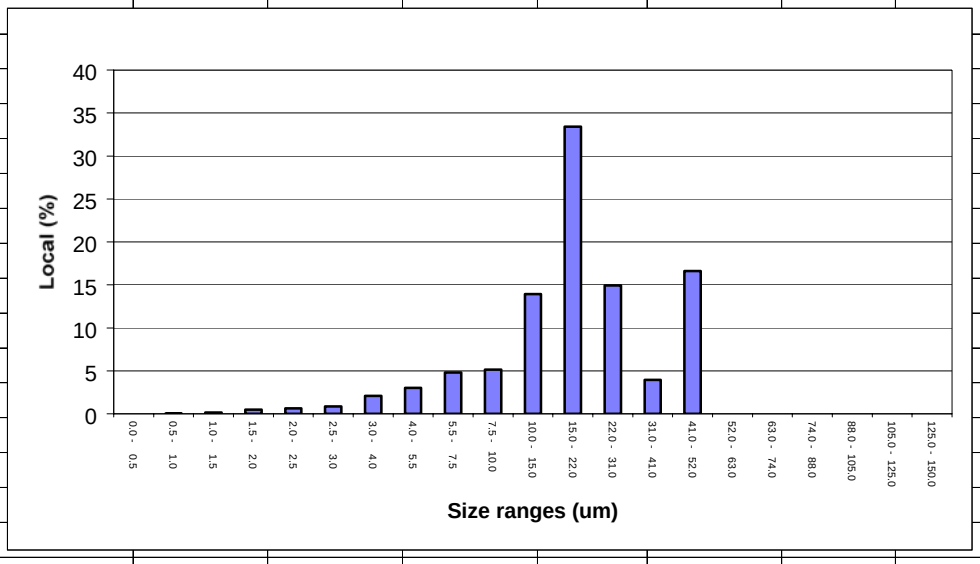
Size(micro	Local(%)	Under(%	Over(%)
0.0 - 0.5	0	0	100
0.5 - 1.0	0.04	0.04	99.96
1.0 - 1.5	0.1	0.14	99.86
1.5 - 2.0	0.18	0.32	99.68
2.0 - 2.5	0.3	0.62	99.38
2.5 - 3.0	0.38	1	99
3.0 - 4.0	0.89	1.89	98.11
4.0 - 5.5	1.28	3.17	96.82
5.5 - 7.5	2.51	5.68	94.32
7.5 - 10.0	4.24	9.92	90.08
10.0 - 15.	12.19	22.11	77.89
15.0 - 22.	12.81	34.92	65.08
22.0 - 31.	10.19	45.11	54.89
31.0 - 41.	10.55	55.66	44.34
41.0 - 52.	10.82	66.47	33.53
52.0 - 63.	11.22	77.69	22.31
63.0 - 74.	0	77.69	22.31
74.0 - 88.	22.31	100	0
88.0 - 105	0	100	0
105.0 - 12	0	100	0
125.0 - 15	0	100	0



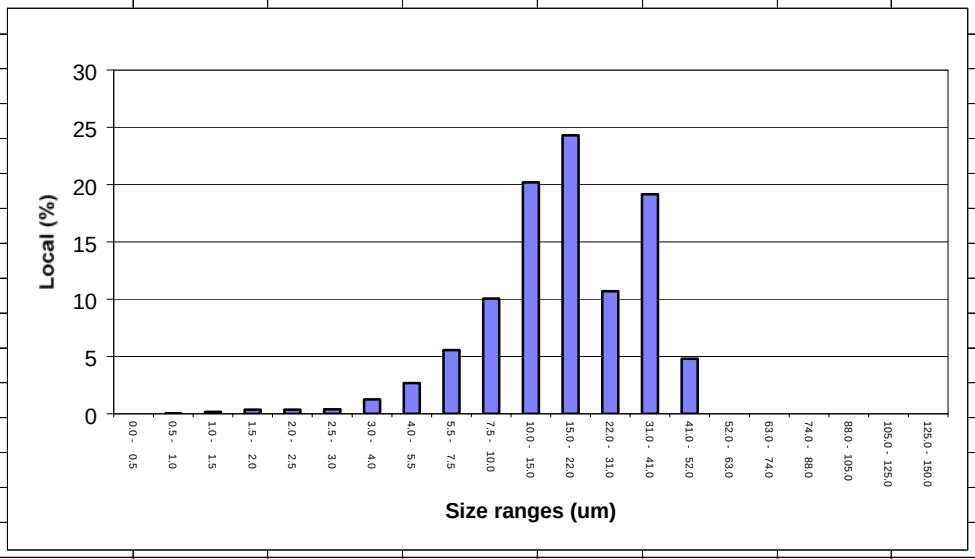
HMAS WATERHEN#2 TOP						27/11 "POST-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Wed Nov 28 2001 12:25:28						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.02	0.02	99.98
----------						1.0 - 1.5	0.08	0.09	99.91
Configuration : 1 (0.5A)						1.5 - 2.0	0.17	0.26	99.74
Cell Type : Liquid Flow						2.0 - 2.5	0.26	0.52	99.47
Sample Type : Special						2.5 - 3.0	0.38	0.9	99.1
Acqui. Range : 0 - 150						3.0 - 4.0	0.75	1.66	98.34
Acqui. Mode : Sample Size (2)						4.0 - 5.5	1.23	2.89	97.11
Acqui. Time : 1106						5.5 - 7.5	2.47	5.35	94.65
----------						7.5 - 10.0	4.06	9.41	90.59
	Mean (µm)	Standard Deviation(µm)				10.0 - 15.	16.98	26.39	73.61
Number, Length :	3.23	4.05				15.0 - 22.	25.02	51.42	48.58
Number, Area :	5.18	4.50				22.0 - 31.	10.01	61.42	38.58
Number, Volume :	7.78	6.09				31.0 - 41.	8.95	70.38	29.62
Length, Area :	8.32	8.76				41.0 - 52.	12.11	82.48	17.52
Length, Volume :	12.08	9.53				52.0 - 63.	13.19	95.67	4.33
Area, Volume :	17.53	14.10				63.0 - 74.	4.33	100	0
Volume, Moment :	28.88	17.78				74.0 - 88.	0	100	0
						88.0 - 105	0	100	0
D10(µm)	D50(µm)	D90(µm)	MODE(µm)	CONF.(%)		105.0 - 12	0	100	0
Number : 0.59	1.90	7.20	0.75	90.88		125.0 - 15	0	100	0
Area : 3.70	14.49	40.84	14.75	60.53					
Volume : 10.23	21.46	55.21	64.25	73.38					



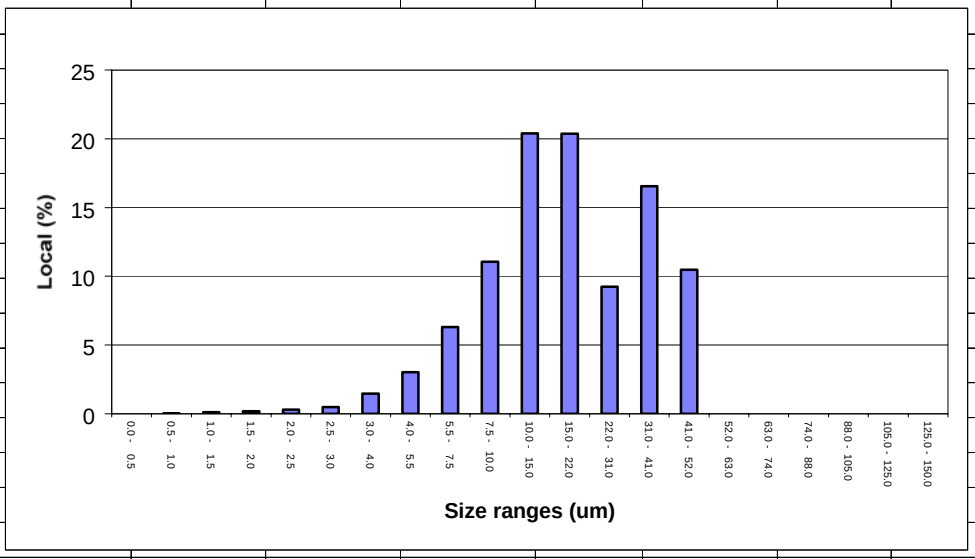
HMAS WATERHEN#2 BOTTOM						27/11 "POST-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Wed Nov 28 2001 12:47:53						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.02	0.02	99.98
----------						1.0 - 1.5	0.16	0.17	99.83
Configuration : 1 (0.5A)						1.5 - 2.0	0.48	0.65	99.35
Cell Type : Liquid Flow						2.0 - 2.5	0.64	1.29	98.71
Sample Type : Special						2.5 - 3.0	0.86	2.15	97.85
Acqui. Range : 0 - 150						3.0 - 4.0	2.08	4.23	95.77
Acqui. Mode : Sample Size (2)						4.0 - 5.5	3	7.22	92.78
Acqui. Time : 527						5.5 - 7.5	4.8	12.03	87.97
----------						7.5 - 10.0	5.14	17.17	82.83
Mean (µm) Standard Deviation(µm)						10.0 - 15.	13.93	31.1	68.9
Number, Length : 2.93 3.05						15.0 - 22.	33.42	64.52	35.48
Number, Area : 4.23 3.31						22.0 - 31.	14.92	79.45	20.55
Number, Volume : 6.18 4.45						31.0 - 41.	3.94	83.38	16.62
Length, Area : 6.10 6.57						41.0 - 52.	16.62	100	0
Length, Volume : 8.97 7.17						52.0 - 63.	0	100	0
Area, Volume : 13.19 10.82						63.0 - 74.	0	100	0
Volume, Moment : 22.06 13.45						74.0 - 88.	0	100	0
						88.0 - 105	0	100	0
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)						105.0 - 12	0	100	0
Number : 0.94 2.04 5.42 1.75 97.53						125.0 - 15	0	100	0
Area : 2.59 10.82 25.26 17.25 59.61									
Volume : 6.52 18.77 46.75 17.25 73.85									



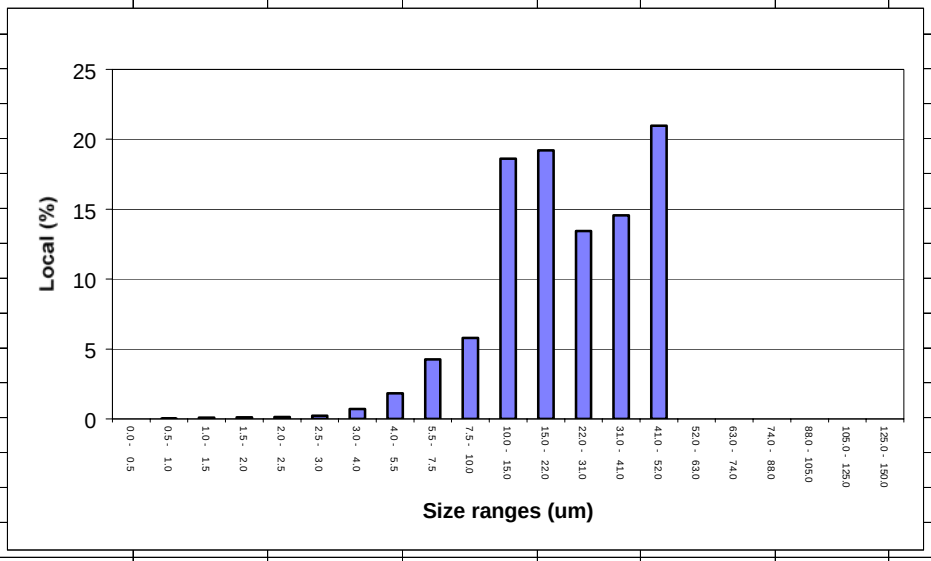
NEWCASTLE#1 TOP				7/12 "PRE-RAIN"			
STATISTICS				Volume ranges			
File Name : COLLECTING				Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Tue Dec 11 2001 13:16:13				0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22				0.5 - 1.0	0.03	0.03	99.97
----------				1.0 - 1.5	0.17	0.2	99.8
Configuration : 1 (0.5A)			| Counts : 102299	1.5 - 2.0	0.35	0.56	99.44
Cell Type : Liquid Flow			| S.N.F. : 0.59	2.0 - 2.5	0.35	0.91	99.09
Sample Type : Special			| S.D.U. : 139	2.5 - 3.0	0.38	1.29	98.71
Acqui. Range : 0 - 150			| Solids : 1.61e-004 %	3.0 - 4.0	1.27	2.56	97.44
Acqui. Mode : Sample Size (2) | Concent. : 1.17e+004 #/ml				4.0 - 5.5	2.67	5.22	94.78
Acqui. Time : 719			| Sp. Area : 0.70 cm²/ml	5.5 - 7.5	5.55	10.78	89.22
----------				7.5 - 10.0	10.05	20.82	79.18
Mean (µm)		Standard Deviation(µm)		10.0 - 15.	20.19	41.01	58.99
Number, Length :	2.95	3.36		15.0 - 22.	24.31	65.32	34.68
Number, Area :	4.48	3.69		22.0 - 31.	10.71	76.03	23.97
Number, Volume :	6.41	4.82		31.0 - 41.	19.16	95.19	4.81
Length, Area :	6.78	6.57		41.0 - 52.	4.81	100	0
Length, Volume :	9.44	7.08		52.0 - 63.	0	100	0
Area, Volume :	13.14	9.59		63.0 - 74.	0	100	0
Volume, Moment :	20.13	11.18		74.0 - 88.	0	100	0
				88.0 - 105	0	100	0
D10(µm)	D50(µm)	D90(µm)	MODE(µm) CONF.(%)	105.0 - 12	0	100	0
Number : 0.61	1.74	6.75	1.25 95.82	125.0 - 15	0	100	0
Area : 3.24	10.47	27.44	9.75 65.20				
Volume : 7.27	18.37	38.27	18.75 78.22				



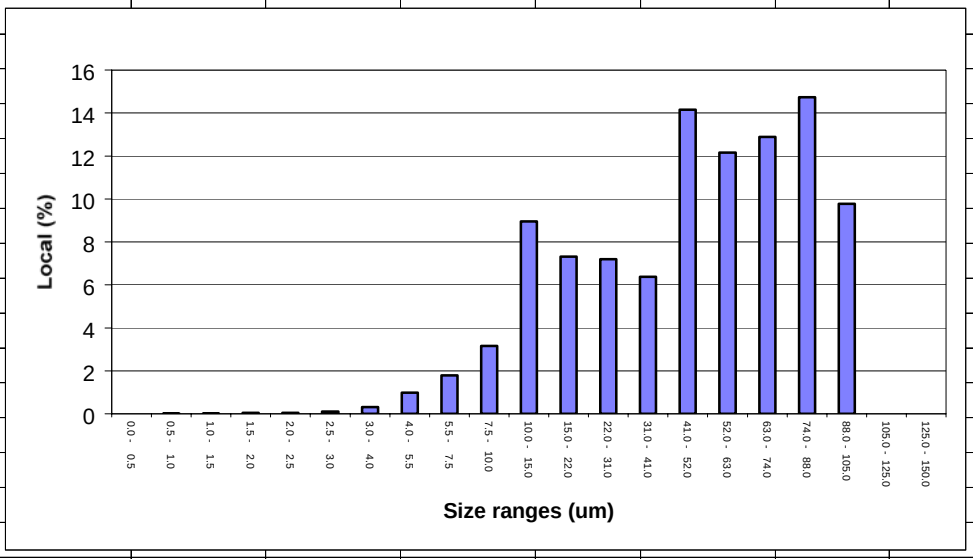
NEWCASTLE#1 BOTTOM						7/12 "PRE-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Tue Dec 11 2001 13:37:54						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.02	0.02	99.98
----------						1.0 - 1.5	0.12	0.14	99.86
Configuration : 1 (0.5A)						1.5 - 2.0	0.19	0.33	99.67
Cell Type : Liquid Flow						2.0 - 2.5	0.31	0.64	99.36
Sample Type : Special						2.5 - 3.0	0.5	1.13	98.86
Acqui. Range : 0 - 150						3.0 - 4.0	1.46	2.59	97.41
Acqui. Mode : Sample Size (2)						4.0 - 5.5	3.03	5.62	94.38
Acqui. Time : 317						5.5 - 7.5	6.31	11.93	88.07
----------						7.5 - 10.0	11.05	22.98	77.03
	Mean (µm)	Standard Deviation(µm)				10.0 - 15.	20.4	43.38	56.62
Number, Length :	3.46	3.54				15.0 - 22.	20.36	63.74	36.26
Number, Area :	4.95	3.84				22.0 - 31.	9.25	72.99	27.01
Number, Volume :	6.83	4.88				31.0 - 41.	16.54	89.53	10.47
Length, Area :	7.07	6.48				41.0 - 52.	10.47	100	0
Length, Volume :	9.59	6.95				52.0 - 63.	0	100	0
Area, Volume :	13.01	10.25				63.0 - 74.	0	100	0
Volume, Moment :	21.09	13.11				74.0 - 88.	0	100	0
						88.0 - 105	0	100	0
	D10(µm)	D50(µm)	D90(µm)	MODE(µm)	CONF.(%)	105.0 - 12	0	100	0
Number :	0.84	2.28	7.66	1.25	94.71	125.0 - 15	0	100	0
Area :	3.53	10.03	28.87	11.75	61.51				
Volume :	6.81	16.54	41.18	11.75	72.93				



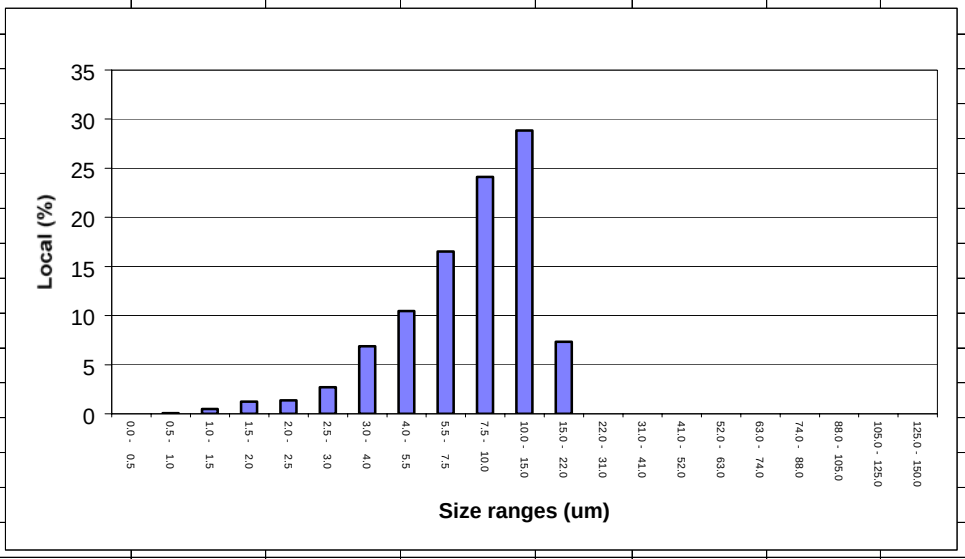
NEWCASTLE#2 TOP				7/12 "PRE-RAIN"			
STATISTICS				Volume ranges			
File Name : COLLECTING				Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Tue Dec 11 2001 13:46:33				0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22				0.5 - 1.0	0.03	0.03	99.97
----------				1.0 - 1.5	0.09	0.12	99.88
Configuration : 1 (0.5A)			| Counts : 169539	1.5 - 2.0	0.11	0.23	99.77
Cell Type : Liquid Flow			| S.N.F. : 0.95	2.0 - 2.5	0.13	0.36	99.64
Sample Type : Special			| S.D.U. : 201	2.5 - 3.0	0.24	0.6	99.4
Acqui. Range : 0 - 150			| Solids : 2.23e-004 %	3.0 - 4.0	0.72	1.32	98.68
Acqui. Mode : Sample Size (2)			| Concent. : 9.86e+003 #/ml	4.0 - 5.5	1.84	3.16	96.84
Acqui. Time : 840			| Sp. Area : 0.68 cm²/ml	5.5 - 7.5	4.26	7.41	92.59
----------				7.5 - 10.0	5.79	13.2	86.8
Mean (µm)		Standard Deviation(µm)		10.0 - 15.	18.62	31.82	68.18
Number, Length :	3.22	4.04		15.0 - 22.	19.21	51.03	48.97
Number, Area :	5.17	4.49		22.0 - 31.	13.44	64.47	35.53
Number, Volume :	7.56	5.93		31.0 - 41.	14.56	79.03	20.97
Length, Area :	8.30	8.10		41.0 - 52.	20.97	100	0
Length, Volume :	11.59	8.74		52.0 - 63.	0	100	0
Area, Volume :	16.20	12.06		63.0 - 74.	0	100	0
Volume, Moment :	25.18	13.98		74.0 - 88.	0	100	0
				88.0 - 105	0	100	0
D10(µm)	D50(µm)	D90(µm)	MODE(µm) CONF.(%)	105.0 - 12	0	100	0
Number : 0.37	1.55	7.64	0.75 90.97	125.0 - 15	0	100	0
Area : 4.37	12.82	38.90	10.75 64.20				
Volume : 8.61	21.71	42.92	42.25 78.24				



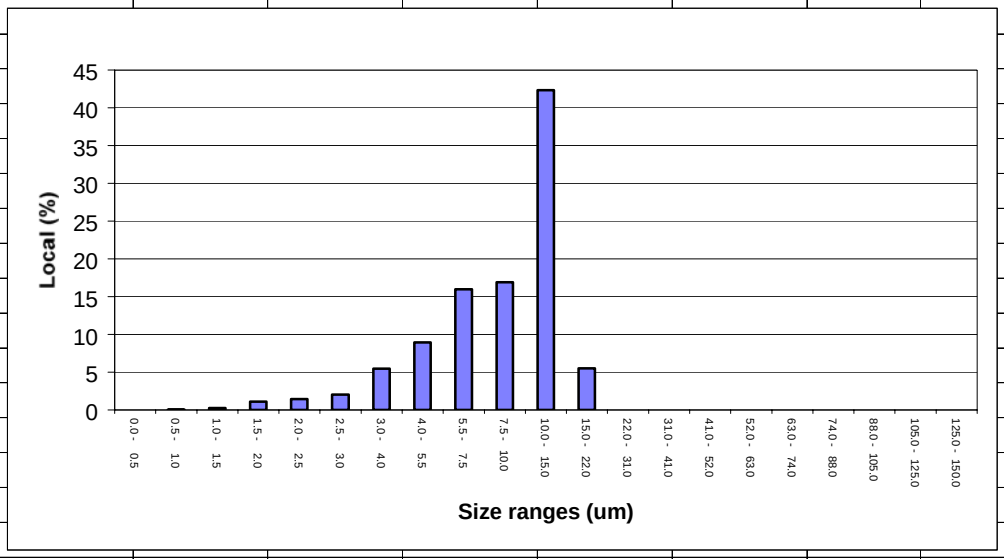
NEWCASTLE#2 BOTTOM						7/12 "PRE-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Tue Dec 11 2001 14:09:31						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.01	0.01	99.99
----------						1.0 - 1.5	0.02	0.04	99.96
Configuration : 1 (0.5A)					| Counts : 123982	1.5 - 2.0	0.04	0.07	99.93
Cell Type : Liquid Flow					| S.N.F. : 0.95	2.0 - 2.5	0.05	0.13	99.87
Sample Type : Special					| S.D.U. : 213	2.5 - 3.0	0.11	0.23	99.76
Acqui. Range : 0 - 150					| Solids : 6.07e-004 %	3.0 - 4.0	0.31	0.55	99.45
Acqui. Mode : Sample Size (2)					| Concent. : 1.06e+004 #/ml	4.0 - 5.5	0.99	1.54	98.46
Acqui. Time : 764					| Sp. Area : 0.61 cm²/ml	5.5 - 7.5	1.79	3.32	96.68
----------						7.5 - 10.0	3.16	6.49	93.51
	Mean (µm)		Standard Deviation(µm)			10.0 - 15.	8.95	15.44	84.56
Number, Length :	3.73		5.07			15.0 - 22.	7.31	22.75	77.25
Number, Area :	6.29		5.68			22.0 - 31.	7.19	29.93	70.07
Number, Volume :	10.29		8.29			31.0 - 41.	6.38	36.32	63.68
Length, Area :	10.62		13.40			41.0 - 52.	14.16	50.47	49.53
Length, Volume :	17.10		14.89			52.0 - 63.	12.15	62.62	37.38
Area, Volume :	27.54		25.28			63.0 - 74.	12.88	75.5	24.5
Volume, Moment :	50.75		27.69			74.0 - 88.	14.73	90.24	9.76
						88.0 - 105	9.77	100	0
D10(µm)	D50(µm)		D90(µm)	MODE(µm)	CONF.(%)	105.0 - 12	0	100	0
Number : 0.33	1.96		8.73	0.75	82.32	125.0 - 15	0	100	0
Area : 5.07	15.40		65.82	11.25	54.42				
Volume : 11.80	51.81		86.45	79.75	79.04				



HMAS PENGUIN#1 BOTTOM						13/12 "PRE-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Wed Dec 19 2001 14:09:55						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.06	0.06	99.93
----------						1.0 - 1.5	0.49	0.55	99.45
Configuration : 1 (0.5A)						1.5 - 2.0	1.24	1.8	98.2
Cell Type : Liquid Flow						2.0 - 2.5	1.37	3.17	96.83
Sample Type : Special						2.5 - 3.0	2.71	5.88	94.12
Acqui. Range : 0 - 150						3.0 - 4.0	6.86	12.74	87.26
Acqui. Mode : Sample Size (1)						4.0 - 5.5	10.46	23.2	76.8
Acqui. Time : 161						5.5 - 7.5	16.52	39.72	60.28
----------						7.5 - 10.0	24.11	63.83	36.17
Mean (µm) Standard Deviation(µm)						10.0 - 15.	28.83	92.66	7.34
Number, Length : 2.70 2.13						15.0 - 22.	7.34	100	0
Number, Area : 3.44 2.25						22.0 - 31.	0	100	0
Number, Volume : 4.29 2.65						31.0 - 41.	0	100	0
Length, Area : 4.38 3.17						41.0 - 52.	0	100	0
Length, Volume : 5.41 3.33						52.0 - 63.	0	100	0
Area, Volume : 6.67 3.99						63.0 - 74.	0	100	0
Volume, Moment : 9.06 4.38						74.0 - 88.	0	100	0
						88.0 - 105	0	100	0
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)						105.0 - 12	0	100	0
Number : 0.91 1.99 5.15 1.25 93.68						125.0 - 15	0	100	0
Area : 2.25 5.96 12.38 3.75 67.79									
Volume : 3.65 8.74 14.76 10.25 63.34									

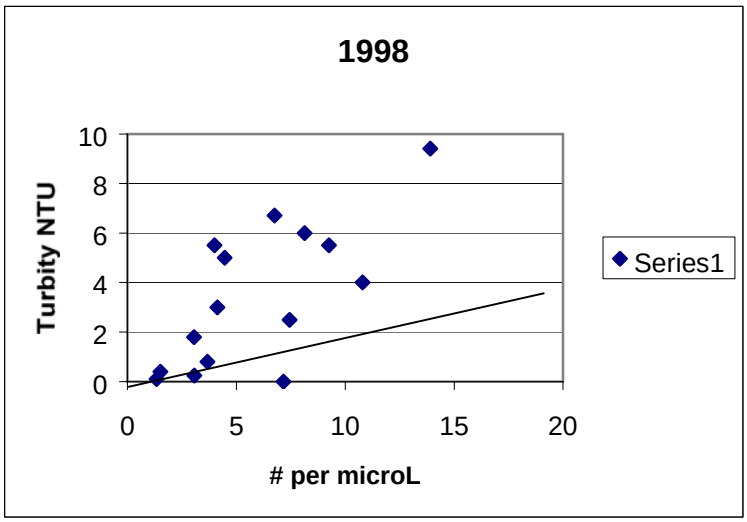


HMAS PENGUIN#2 TOP						13/12 "PRE-RAIN"			
STATISTICS						Volume ranges			
File Name : COLLECTING						Size(micro	Local(%)	Under(%	Over(%)
Date & Time : Wed Dec 19 2001 14:25:55						0.0 - 0.5	0	0	100
Sample Name : WCIS-100 Version 1.22						0.5 - 1.0	0.05	0.05	99.95
----------						1.0 - 1.5	0.24	0.29	99.71
Configuration : 1 (0.5A)						1.5 - 2.0	1.11	1.4	98.6
Cell Type : Liquid Flow						2.0 - 2.5	1.43	2.84	97.17
Sample Type : Special						2.5 - 3.0	2.05	4.89	95.11
Acqui. Range : 0 - 150						3.0 - 4.0	5.46	10.35	89.65
Acqui. Mode : Sample Size (1)						4.0 - 5.5	8.96	19.31	80.69
Acqui. Time : 388						5.5 - 7.5	15.98	35.29	64.71
----------						7.5 - 10.0	16.92	52.21	47.79
Mean (µm) Standard Deviation(µm)						10.0 - 15.	42.31	94.51	5.49
Number, Length : 2.92 2.32						15.0 - 22.	5.49	100	0
Number, Area : 3.73 2.46						22.0 - 31.	0	100	0
Number, Volume : 4.64 2.89						31.0 - 41.	0	100	0
Length, Area : 4.77 3.38						41.0 - 52.	0	100	0
Length, Volume : 5.85 3.55						52.0 - 63.	0	100	0
Area, Volume : 7.17 3.96						63.0 - 74.	0	100	0
Volume, Moment : 9.35 3.86						74.0 - 88.	0	100	0
						88.0 - 105	0	100	0
D10(µm) D50(µm) D90(µm) MODE(µm) CONF.(%)						105.0 - 12	0	100	0
Number : 0.90 2.19 5.79 1.75 91.09						125.0 - 15	0	100	0
Area : 2.39 6.56 12.58 11.25 68.22									
Volume : 3.94 9.71 14.52 11.25 69.37									



Appendix C

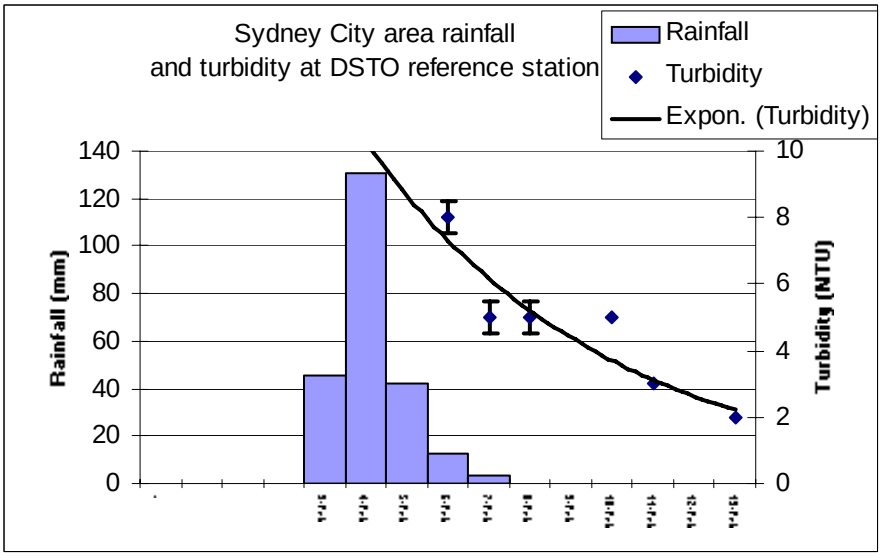
Darwin results



The approximate turbidity measured in the Darwin estuary compared with the number particles per micro litre. The solid line is reproduced from Fig 13.

Appendix D

Response to rain



The turbidity after a major rain event. The typical dry weather turbidity is shown as a broken line. The measurements were taken at 1 meter depth and always during the lower half of the tide cycle.

Appendix E

Hinchinbrook Results

A recent experiment was conducted in the Hichinbrook Channel, an estuary open at both ends and fed by the Herbert River. After rain fall the turbidity was measured. Near surfaces values changed with the time after substantial rain. The turbidity in the fresh surface water was order 50 NTU on the first day of measurement, 30 NTU on the second and third day of measurement, 20 NTU on the fourth day and 10 NTU on the fifth.

During the five days the deeper water became more turbid, rising from 20 NTU to 40NTU, presumably as suspended solids settled from the surface river water into saltier subsurface water. These most recent results are generally consistent with the results in Appendix D.