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Southeastern Manukau / Pahurehure Inlet Contaminant Study: Harbour Hydrodynamics and Sediment Transport Fieldwork

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Southeastern Manukau / Pahurehure Inlet Contaminant Study: Harbour Hydrodynamics and Sediment Transport Fieldwork

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Prepared for
Auckland Regional Council

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PREFACE

The Manukau Harbour is comprised of tidal creeks, embayments and the central basin. The harbour receives sediment and stormwater chemical contaminant run-off from urban and rural land from a number of subcatchments, which can adversely affect the ecology. State of the environment monitoring in the Pahurehure Inlet showed increasing levels of sediment and stormwater chemical contaminant build up. However, previously little was known about the expected long-term accumulation of sediment and stormwater chemical contaminants in the inlet or adjacent portion of the Manukau Harbour. The South Eastern Manukau Harbour / Pahurehure Inlet Contaminant Study was commissioned to improve understanding of these issues. This study is part of the 10-year Stormwater Action Plan to increase knowledge and improve stormwater management outcomes in the region. The work was undertaken by the National Institute of Water and Atmospheric Research (NIWA).

The scope of the study entailed:

1. field investigation,
2. development of a suite of computer models for
    a. urban and rural catchment sediment and chemical contaminant loads,
    b. harbour hydrodynamics, and
    c. harbour sediment and contaminant dispersion and accumulation,
3. application of the suite of computer models to project the likely fate of sediment, copper and zinc discharged into the central harbour over the 100-year period 2001 to 2100, and
4. conversion of the suite of computer models into a desktop tool that can be readily used to further assess the effects of different stormwater management interventions on sediment and stormwater chemical contaminant accumulation in the central harbour over the 100-year period.

The study is limited to assessment of long-term accumulation of sediment, copper and zinc in large-scale harbour depositional zones. The potential for adverse ecological effects from copper and zinc in the harbour sediments was assessed against sediment quality guidelines for chemical contaminants.

The study and tools developed address large-scale and long timeframes and consequently cannot be used to assess changes and impacts from small subcatchments or landuse developments, for example. Furthermore, the study does not assess ecological effects of discrete storm events or long-term chronic or sub-lethal ecological effects arising from the cocktail of urban contaminants and sediment.

The range of factors and contaminants influencing the ecology means that adverse ecological effects may occur at levels below contaminant guideline values for individual chemical contaminants (i.e., additive effects due to exposure to multiple contaminants may be occurring).

Existing data and data collected for the study were used to calibrate the individual computer models. The combined suite of models was calibrated against historic sediment and copper and zinc accumulation rates, derived from sediment cores collected from the harbour.

Four scenarios were modelled: a baseline scenario and three general stormwater management intervention scenarios.

The baseline scenario assumed current projections (at the time of the study) of

- future population growth,
- future landuse changes,
- expected changes in building roof materials,
- projected vehicle use, and
- existing stormwater treatment.

The three general stormwater management intervention scenarios evaluated were:

1. source control of zinc from industrial areas by painting existing unpainted and poorly painted galvanised steel industrial building roofs;
2. additional stormwater treatment, including:
    - raingardens on roads carrying more than 20,000 vehicles per day and on paved industrial sites,
    - silt fences and hay bales for residential infill building sites and
    - pond / wetland trains treating twenty per cent of catchment area; and
3. combinations of the two previous scenarios.

International Peer Review Panel

The study was subject to internal officer and international peer review. The review was undertaken in stages during the study, which allowed incorporation of feedback and completion of a robust study. The review found:

- a state-of-the-art study on par with similar international studies,
- uncertainties that remain about the sediment and contaminant dynamics within tidal creeks / estuaries, and
- inherent uncertainties when projecting out 100 years.

Key Findings of the Study

Several key findings can be ascertained from the results and consideration of the study within the context of the wider Stormwater Action Plan aim to improve stormwater outcomes:

- The inner tidal creeks and estuary branches of the Pahurehure Inlet continue to accumulate sediment and contaminants, in particular in the eastern estuary of Pahurehure Inlet (east of the motorway).

- The outer Pahurehure Inlet/Southeastern Manukau bed sediment concentrations of copper and zinc are not expected to reach toxic levels based on current assumptions of future trends in landuse and activities.

- Zinc source control targeting industrial building roofs produced limited reduction of zinc accumulation rates in the harbour because industrial areas cover only a small proportion of the catchment area and most unpainted galvanised steel roofs are expected to be replaced with other materials within the next 25 to 50 years.

- Given that the modelling approach used large-scale depositional zones and long timeframes, differences can be expected from the modelling projections and stormwater management interventions contained within these reports versus consideration of smaller depositional areas and local interventions. As a consequence, these local situations may merit further investigation and assessment to determine the best manner in which to intervene and make improvements in the short and long terms.

Research and Investigation Questions

From consideration of the study and results, the following issues have been identified that require further research and investigation:

- Sediment and chemical contaminant dynamics within tidal creeks.

- The magnitude and particular locations of stormwater management interventions required to arrest sediment, copper and zinc accumulation in tidal creeks and embayments, including possible remediation / restoration opportunities.

- The fate of other contaminants derived from urban sources.

- The chronic / sub-lethal effects of marine animal exposure to the cocktail of urban contaminants and other stressors such sediment deposition, changing sediment particle size distribution and elevated suspended sediment loads.

- Ecosystem health and connectivity issues between tidal creeks and the central basin of the harbour, and the wider Manukau Harbour.

Technical reports

The study has produced a series of technical reports:

Technical Report TR2008/049
Southeastern Manukau Harbour / Pahurehure Inlet Harbour Contaminant Study. Landuse Analysis.

Technical Report TR2008/050
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Sediment Load Model Structure, Setup and Input Data.

Technical Report TR2008/051
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Sediment Load Model Evaluation.

Technical Report TR2008/052
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Sediment Load Model Results.

Technical Report TR2008/053
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Predictions of Stormwater Contaminant Loads.

Technical Report TR2008/054
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Harbour Sediments.

Technical Report TR2008/055
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Harbour Hydrodynamics and Sediment Transport Fieldwork.

Technical Report TR2008/056
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Hydrodynamic Wave and Sediment Transport Model Implementation and Calibration.

Technical Report TR2008/057
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Implementation and Calibration of the USC-3 Model.

Technical Report TR2008/058
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Predictions of Sediment, Zinc and Copper Accumulation under Future Development Scenario 1.

Technical Report TR2008/059
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Predictions of Sediment, Zinc and Copper Accumulation under Future Development Scenarios 2, 3 and 4.

Technical Report TR2009/110
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Rainfall Analysis.

Contents

1 Executive Summary

The main aim of the Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study is to model contaminant (zinc, copper) and sediment accumulation for the purposes of, amongst other things, identifying significant contaminant sources, and testing efficacy of stormwater treatment options.

The harbour hydrodynamic and sediment transport model was implemented using the DHI MIKE3 FM HD and MT modelling suite. The model was then calibrated and validated using data collected from moored instruments that were deployed for two separate extended periods between mid February 2007 and the end of May 2007.

Moored instruments collected time series measurements of tidal elevations, currents, surface wave statistics and suspended sediment concentrations. The instruments used were: DOBIE wave gauges, optical backscatter sensors (OBS) and temperature/salinity probes; S4 current meters and an Acoustic Doppler Current Profiler (ADCP) current meter.

The weather through both deployment periods was dry, with relatively low wind speed conditions except on a few heavy showery gusty days. Only two significant rainfall events occurred during the whole duration of the fieldwork and instrument deployments.

Instrument recovery was complete with no instrument losses. Only a low proportion of the instrument data was compromised by bio-fouling and some transducer malfunctions. However, considering the exposed and vulnerable open harbour conditions, the data return from the instrument array was high.

These data along with ARC and NIWA archived data sets were then used to calibrate and validate both the MIKE3 FM modelling suite and a SWAN wave model. The results from numerous model scenarios which simulated the effects of different tidal, freshwater inputs and surface wave fields were then used to predict the dispersal and fate of sediment and stormwater contaminants through the inlet and inner harbour. This provided a regional estimate of sediment transport and deposition for use in an Urban Stormwater Contaminant (USC) model of the inlet and inner harbour.

2 Hydrodynamic and sediment transport fieldwork

2.1 Overview

The primary objective of the Pahurehure fieldwork was to collect: tidal and hydrographic data for the setup and calibration of the harbour/inlet DHI hydro-dynamical model; and wave statistics and suspended sediment loads to calibrate the DHI harbour/inlet sediment-transport model. The calibrated model would then be used to produce a series of weather (rain, wind) driven simulations of catchment derived sediment transport. The final (time integrated) results from these simulations produce predicted levels of suspended sediment load, sediment attenuation and a net-bed deposition for 3 sediment size fractions. These values are then post-processed into a form ready for use in the USC model.

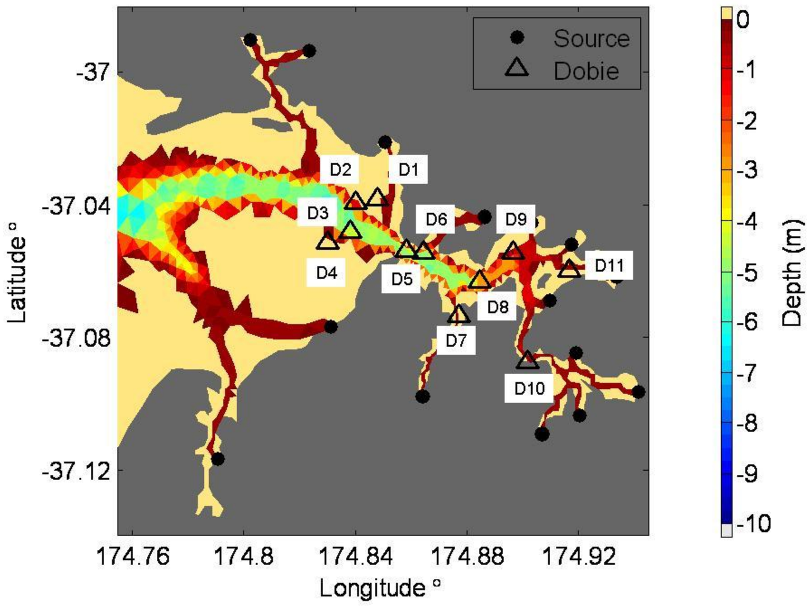
2.2 Field sites

Figure 1 and 2 shows a regional view of the Manukau Harbour and Pahurehure Inlet respectively. The bathymetric plot (Figure 2) identifies the network of tidal channels and specific catchment freshwater and/or sediment source inputs into the inlet. The mooring array was designed to capture freshwater and sediment fluxes into the inlet and regional surface wave statistics. Mooring sites were selected on the basis of the size of the instrument pool, optimal position, survivability and redundancy. The two sets of measurements could then be used to ascertain the extent of sediment re-suspension and transport both inside the inlet and in the inner Manukau harbour basin.

Figure 1:

Regional map of Manukau harbour and Pahurehure Inlet (outlined by red rectangle) shown in geographical perspective to the greater Auckland district.

Figure 2:
Detailed bathymetry (depth with respect to MSL) of the Pahurehure Inlet showing the extensive and complex network of tidal channels and mudflats. The figure shows position of freshwater and sediment source and the position of Dobie moorings.



2.3 Mooring array general description and instrumentation

The mooring geographical locations are shown in Figure 2 and Figure 3 and in Table 1a and 1b. Moorings consisted of RDI Acoustic Doppler Profiler (ADCP) and S4 Electromagnetic current meters and Dobie wave gauges (measuring pressure, optical backscatter, and conductivity/temperature sensors). These data were collected over two separate deployment periods that spanned two complete spring-neap tidal cycles (>29.7+ days). See Table A1 for instrument timeline.

For Deployment 1 (DP1) moorings were deployed and recovered in the Manukau Harbour and Pahurehure Inlet between 14 February 2007 and 26 March 2007. Specific mooring details are shown in Table 1a and 1b. The second series of mooring deployments for Deployment 2 (DP2) took place between 16 April 2007 and 29 May 2007. All moorings were deployed by NIWA diving teams from inshore craft and then anchored and buoyed in a U-type mooring configuration. Moorings and hardware were recovered complete at the end of both deployments.

Figure 3:
Regional view of the Pahurehure Inlet showing the positions of the current mooring during the two field deployments during 2007. Bathymetry is plotted with respect to MSL. CM = Current Meter.

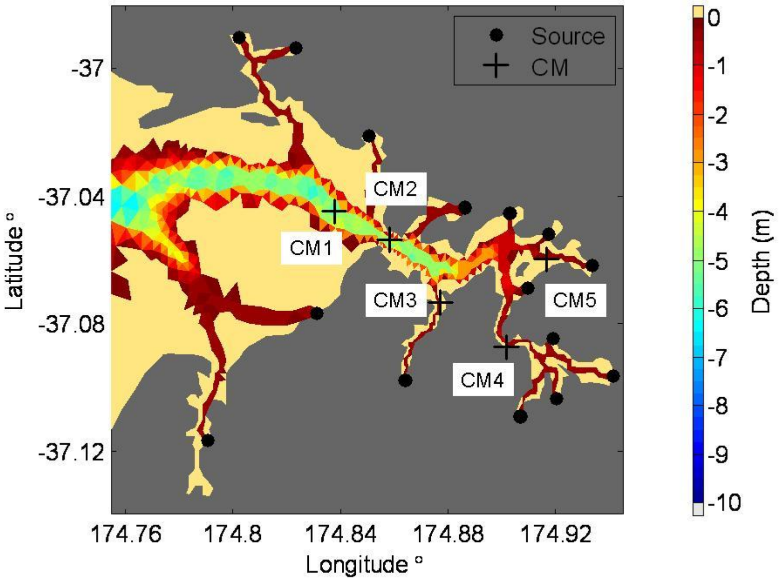


Table 1a:

Mooring ID and deployment details for all instrument sites during Deployment 1 for the period between 14/2/07 to 26/3/07.

Mooring ID	Latitude (S)	Longitude (E)	Instrument	MAB	Deployed	Recovered
D1	37.038	174.847	D/P/OBS	0.3	14/2/07	26/3/07
D2	37.039	174.840	D/P/OBS	0.3	14/2/07	26/3/07
D3 – CM1	37.048	174.838	D/P/OBS/CT/S4	0.3	14/2/07	26/3/07
D4	37.051	174.829	D/P/OBS	0.3	14/2/07	26/3/07
D5	37.054	174.865	D/P/OBS	0.6	14/2/07	26/3/07
D6 – CM2	37.054	174.858	D/P/OBS/CT/ADCP	0.6	15/2/07	26/3/07
D7 – CM3	37.073	174.877	D/P/OBS/CT/S4	0.6	15/2/07	26/3/07
D8	37.063	174.885	D/P/OBS	0.6	15/2/07	26/3/07
D9	37.054	174.897	D/P/OBS	0.3	14/2/07	26/3/07
D10 – CM4	37.087	174.902	D/P/OBS/CT/S4	0.6	15/2/07	26/3/07
D11 – CM5	37.060	174.917	D/P/OBS/CT/S4	0.6	15/2/07	26/3/07

S4 = S4 electromagnetic current meter; ADCP = Acoustic Doppler Current Profiles; D = Dobie; P= pressure (depth) sensor; OBS = Optical Backscatter Sensor; CT = Conductivity/Temperature.

Table 1b:

Mooring ID and deployment details for all instrument sites during Deployment 2 (DP2) for the period between 16/4/07 to 29/5/07.

S4 = S4 electromagnetic current meter; ADCP = Acoustic Doppler Current Profiles; D = Dobie; P= pressure (depth) sensor; OBS = Optical Backscatter Sensor; CT = Conductivity/Temperature.

Mooring ID	Latitude (S)	Longitude (E)	Instrument	MAB	Deployed	Recovered
D1	37.038	174.847	D/P/OBS	0.3	16/04/07	29/05/07
D2	37.039	174.840	D/P/OBS	0.3	16/04/07	29/05/07
D3 – CM1	37.048	174.838	D/P/OBS/CT/S4	0.3	16/04/07	29/05/07
D4	37.051	174.829	D/P/OBS	0.3	16/04/07	29/05/07
D5	37.054	174.865	D/P/OBS	0.6	16/04/07	29/05/07
D6 – CM2	37.054	174.858	D/P/OBS/CT/ADCP	0.6	16/04/07	29/05/07
D7 – CM3	37.073	174.877	D/P/OBS/CT/S4	0.6	16/04/07	29/05/07
D8	37.063	174.885	D/P/OBS	0.6	16/04/07	29/05/07
D9	37.054	174.897	D/P/OBS	0.3	16/04/07	29/05/07
D10 – CM4	37.087	174.902	D/P/OBS/CT/S4	0.6	16/04/07	29/05/07
D11 – CM5	37.060	174.917	D/P/OBS/CT/S4	0.6	16/04/07	29/05/07

2.4 Dobie moorings

The DOBIE instrument packages measure voltages from pressure, infrared optical backscatter (OBS), an OBS wiper to prevent bio-fouling and/or conductivity and temperature sensors. These data get converted through calibration constants to: pressure = water depth and wave statistics; OBS = suspended-sediment concentration (SSC); conductivity and temperature = salinity/density. See Appendix B for specific details on post processing calibration parameters.

Dobie sample rates were limited to a burst sample rate based on a compromise between deployment duration (battery power) and, the resolution of surface wave statistics through two full spring-neap tidal cycles. This equated to a 102.4 second 10 Hz burst every 1200 seconds. This provided 1024 stationary samples every 20 minutes.

2.5 S4 and ADCP current meter moorings

Four electromagnetic S4 current meters and one RDI-1200 Khz Acoustic Doppler Current Profiler (ADCP) were used to measure tidal and residual currents in the main sub-tidal channel network of the Pahurehure Inlet (see Figure 3). All S4 current meters provided current data in a Cartesian frame of reference with respect to the specific mooring. In addition, depending on the model used at a site, water depth above the instrument along with temperature and conductivity was also recorded by the instrument. Table 3 gives mooring specific details of each current meter deployed.

Table 3:

Mooring ID, instrument type, instrument sample rate and instrument height above seabed for both mooring deployments.

Mooring ID	Type	Sample Rate	Metres Above Bed (m)
CM1	S4	1min 2 Hz burst@5mins	0.75
CM2	ADCP	1min 1 Hz burst@2.55mins	0.50
CM3	S4	1min 2 Hz burst@5mins	0.75
CM4	S4	1min 2 Hz burst@5mins	0.75
CM5	S4	1min 2 Hz burst@30mins	0.40

3 Field conditions

Figures 4a and 4b along with Table 2 show time series and tabulated descriptive statistics of wind and rainfall spanning the duration of both field deployments as recorded at Auckland Airport. Wind was mainly directed from the easterly through to the westerly quadrants and predominately from a SSE direction. Speeds were generally low and below 5 m s^{-1}. This generally agrees with the longer period climatic trends of the region as discussed in subsequent reports on modelling regional input and wave scenarios. Rainfall was minimal with only two major rainfall events recorded during the entirety of the two deployment periods under consideration.

Table 2:

Descriptive statistics of wind and rainfall during both field deployments in the Southeastern Manukau and Pahurehure Inlet 2007.

	Deployment 1	Deployment 2
Wind Speed (m s^{-1})	4.5 ± 2.7 (mean ± sd)	3.4 ±2.4 (mean ± sd)
Maximum Wind Speed (m s^{-1})	14.9	14.4
Wind Direction (CW of N)	162 ± 91 (mean ± sd)	169 ± 91 (mean ± sd)
Number of Rain Days	2	9

Figure 4a:
Wind speed, wind direction and rainfall for Deployment 1 (14/2/07 - 26/3/07) period.

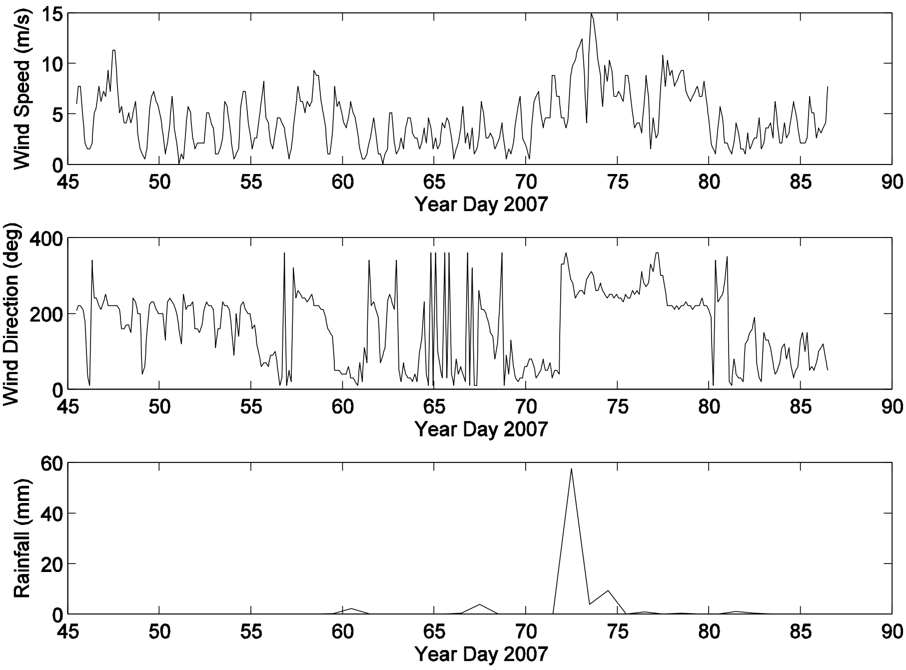
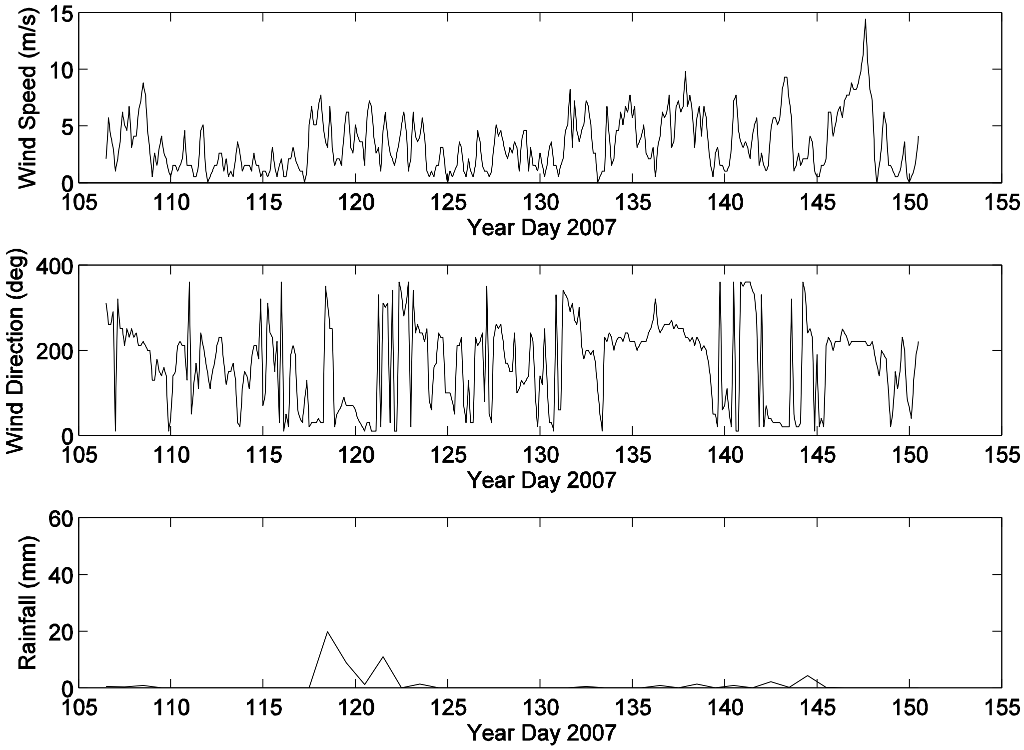


Figure 4b:

Wind speed, wind direction and rainfall for Deployment 2 (16/4/07-29/5/07) period.



4 Instrument performance and data return

During both deployment periods some minor problems were encountered with the instrumentation or integrity of the mooring position that compromised the quality or quantity of instrument data return. Nevertheless, the majority of data recovered from instrumentation was suitable for model calibration.

4.1 Dobie pressure transducer (PT)

Appendix A shows a series of time series plots for total water depth as computed from the burst average values from Dobie pressure transducers for deployments DP1 and DP2. Depths are not shown corrected to MSL.

Dobie D1 to D9 shown in Figures A1a and A1b were moored in inter-tidal sites. Hence, the PT shows depths as zero at times of local low water when the PT was out of the water. Data from these Dobies due to their shallow deployment depths were used in the computation of wave statistics for calibration of the SWAN model used to produce predicted wave statistics for the MIKE3 FM HD and MT models. With the exception of mooring D1, which failed after approximately 10-days into DP1 and again failed 4-days short of a complete record on DP2, all inter-tidal instruments recorded full PT records. Tests on the failed instrument found the PT to be faulty.

Figure A2a and A2b show burst average depth time series for Dobie instrument deployed in sub-tidal regions of the Manukau harbour and Pahurehure Inlet during DP1 and DP2. The Figures show complete recorded were recovered from all instruments with the exception of mooring D6 during DP2. The D6 mooring was later during post-recovery inspection found to be flooded.

Tidal ranges measured through the Southeastern Manukau and Pahurehure Inlet by the Dobie mooring were for all sites approximately 4.5 m on spring tides and 1.6 m on neap tides. The instruments were not surveyed in with respect to local datum as sea surface elevation is calibrated in the modeling.

4.2 Dobie and S4 conductivity/temperature (salinity) transducers

The salinity values on four of the sub-tidal Dobies (see Table 1a/1b and Figure 3) and one S4 current meter (CM5) were computed from conductivity, temperature and depth records through the UNESCO equation of state of seawater (Fofonoff and Millard, 1983). The salinity records for all moorings are displayed in Figure A3a and A3b in Appendix A. The Figures show complete time series recovered for moorings D3, D7 and D10 during both deployments. Mooring D6 records were complete for DP1 but during DP2 the instrument flooded. CM5 recorded a full record during D1 but failed through instrument memory problems during DP2 after only approximately 10 days into the deployment period.

Maximum salinities during both deployment periods of approximately 35 PSU were recorded at site D3. The minimum salinities of approximately 10.8 PSU were measured at Site D10. The salinity drop outs and spiking observed at CM5 were through the instrument being exposed to air at low water.

4.3 Dobie optical backscatter sensors (OBS) and suspended sediment concentration measurements

Individual Dobie OBS calibrations were carried out under laboratory conditions by methods described in Appendix B. Figure A4a and A4b show results from Dobies that recorded OBS measurements at the inter-tidal sites. Records show two failures both during DP1 at sites D2 and D5. The OBS on the Dobie at site D2 on recovery was found to be heavily fouled in addition to a rope being wrapped around the OBS wiper. Damage to the OBS wiper which was assumed to have happened unknowingly to mooring D5 during its deployment, was the cause of a short OBS data return from this instrument.

Data return from the sub-tidal mooring OBS's shown in Figures A5a and A5b was compromised on: Mooring D3 through Dobie internal logger problems during both deployments; D6 failed after about 5-days during DP1 through being tipped over and fouled and DP2 through instrument flooding; D11 failed after approximately 25-days during DP1 through OBS wiper failure. The OBS on mooring D10 failed after approximately 30-days in DP2 because of the OBS being fouled with a plastic bag.

SSC measurements were highly variable through both space and time during the two deployment periods. Baseline levels at sub tidal sites were measured at around 50 mg l^{-1}. These values increased during spring tides to approximately 100 mg l^{-1} at most of the sites. Intertidal moorings recorded the highest SSC values during the few short lived periods of wind waves.

4.4 Dobie wave statistics

Waves were computed from burst data collected at the shallow inter-tidal mooring sites D1, D2, D3, D4 and D9. The burst pressure data was post-processed through in-house software to resolve surface wave statistics from pressure measurements and linear wave theory. The results presented in Figure A6a and A6b for Figure A7a and A7b show time series from these computations for both the DP1 and DP2 deployment periods. Significant wave heights (H_s) and average wave period (T_{avg}) were extracted from all five inter-tidal moorings. However, after approximately 10 days into deployment period DP1, the pressure transducer on mooring D1 began to drift in a stepwise trend. This effectively rendered these data unusable for any future analysis.

Wave activity during both deployment periods was limited to the more exposed inter-tidal mooring sites in the SE Manukau due to greater exposure to the prevailing winds.

The suggestion of low frequency waves (~20s) in records is spurious and is only presented for completeness of the time series. These data form no part of any subsequent comparisons to SWAN modelling or analysis.

4.5 Current meter measurements

A total of 5 current meters were deployed in the Southeastern Manukau and Pahurehure Inlet. The mooring were positioned in deeper sub-tidal channels and where possible close to Dobie moorings. The raw S4 and ADCP data directional measurements were corrected for local magnetic declination (19.7 degrees). Figures A8a through to Figure A12b show the results from each mooring site through both deployment periods. Full data records were returned for all instruments with the exception of mooring CM5 which failed after approximately 10 days into deployment DP2 because of instrument memory problems.

Maximum current speeds of over 1.5 m s^{-1} were recorded at Site CM4 up in Drury Creek during both DP1 and DP2. Minimum speeds were observed out in the SE Manukau Harbour (Site CM1) where they rarely exceed 0.5 m s^{-1} during peak flow conditions.

5 Summary

Fieldwork in the Pahurehure Inlet and Southeastern Manukau Harbour involved the deployment of: 11 Dobie instrument packages; 4 S4 current meters and 1 ADCP between 15 February – 26 March 2007 and 16 April – 29 May 2007. Despite some failures through either instrument malfunction and/or mooring integrity, data return was high.

Time series measurements of water levels, currents, waves, conductivity and water temperature were made at a number of sites. These data are collated and used to calibrate and validate a DHI MIKE3 FM HD and MT model of the region. The model is used to simulate the dispersal of sediments in the inlet and harbour by physical processes such as currents, winds, freshwater inputs and waves. These simulations will underpin the predictions of contaminant accumulation made by the Urban Stormwater Contaminant (USC) Model.

The tidal ranges measured in sub-tidal regions of the harbour were in the range of 4.5 m during spring tides and 1.6 m during neap tides. Dobie suspended sediment concentration (SSC) measurements showed there was a typically low concentration with a strong tidal signal. The highest observed SSC at most sites (400 mg l^{-1}) was measured during wave activity and/or peak flood and ebb current. Despite one major rainfall event during DP1 there was no notable increase in SSC measured by the Dobie instrumentation during this time of increased freshwater input into the harbour.

Weather and wind conditions through both deployment periods were generally congenial with daily averaged wind speeds of below 5 m s^{-1}. Hence, through the deployments only a limited number of wave events occurred. During the few wind events, wave heights as recorded at the shallower inter-tidal sites were typically less than 0.5 m and wave periods generally were greater than 10 seconds.

The salinity data computed from the Dobie and S4 CT probes suggested during DP1 (with the exception of a period following the one major rainfall event) salinity was only modulated at semi-diurnal tidal frequencies in Pahurehure Inlet. The majority of this variability (5-15 PSU) in this signal was observed in Glassons (Site D7) and Drury Creek (Site D10). DP2 had one notable rainfall event (~20mm) where the largest variability in salinity was again observed in Glassons and Drury Creek.

The weather through both deployment periods was extremely dry, with only a few heavy showery gusty days. Only two notable rain fall events occurred during the whole duration of the fieldwork and instrument deployments.

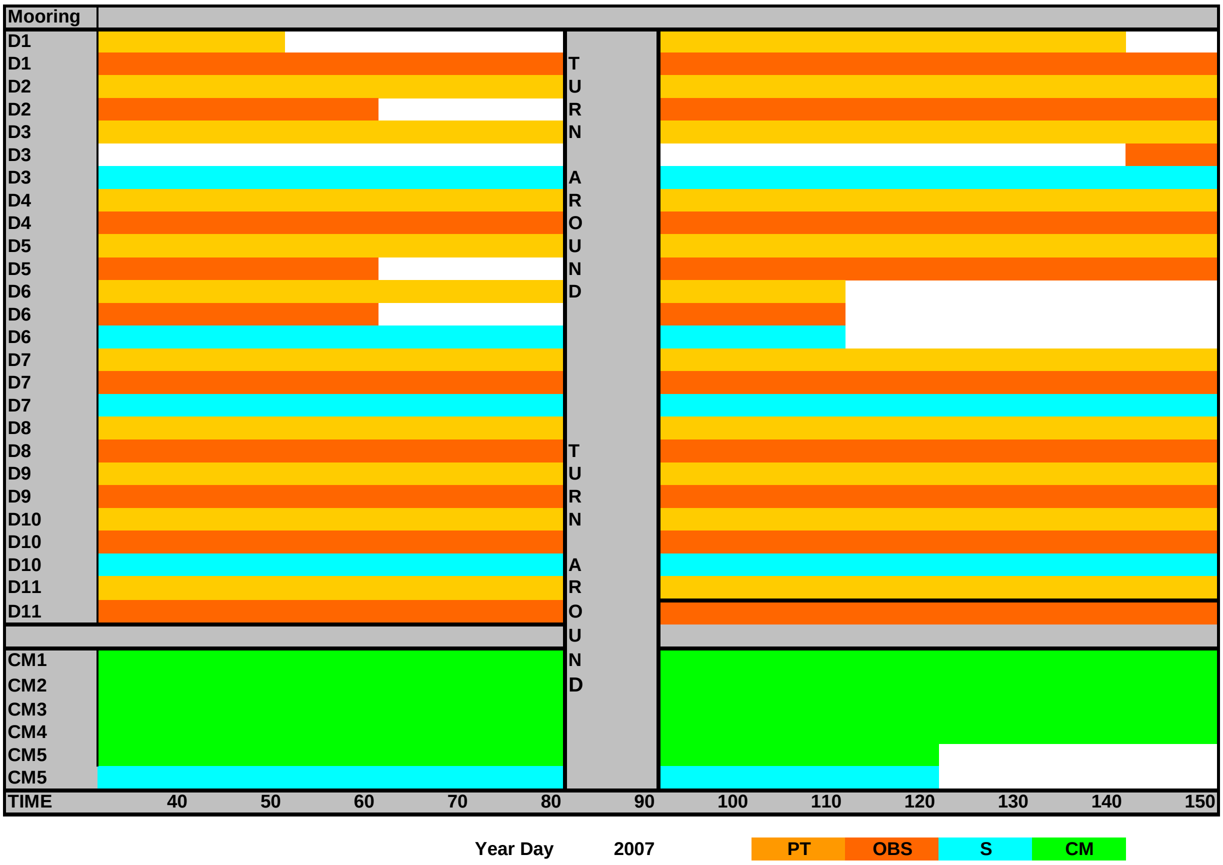
6 References

Fofonoff, P. & Millard, R.C. Jr (1983). Algorithms for computation of fundamental properties of seawater. Unesco Technical Papers in Marine Science 44, 53 pp.

7 Appendix

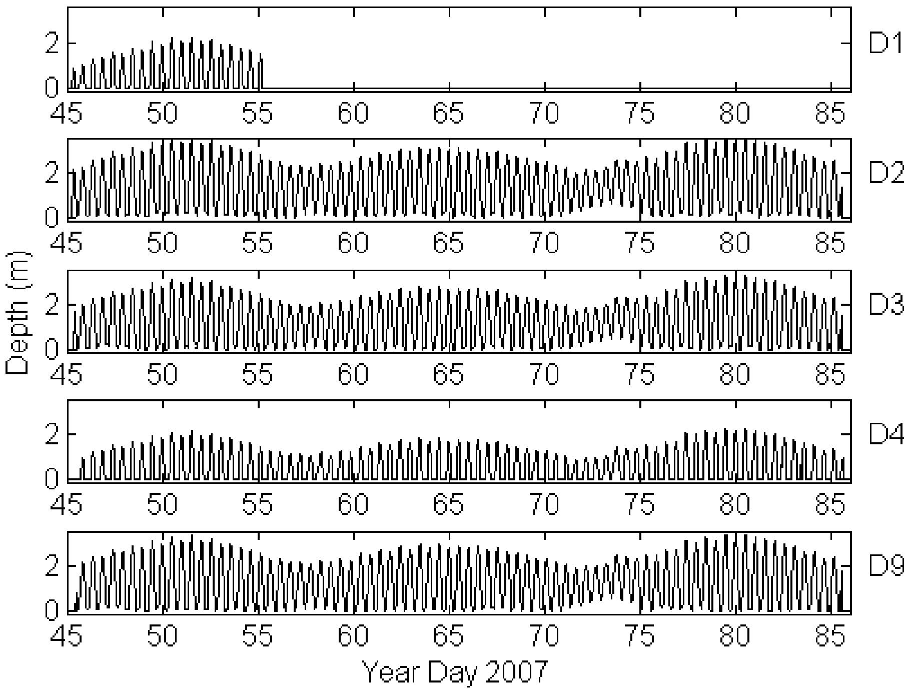
7.1 Appendix A

Table A1: Instrument deployment time line for both DP1 (15 February 2007–26 March 2007) and DP2 (16 April 2007–29 May 2007).



7.1.1 Pressure (Depth)

Figure A1a:
Sea surface height (m) above Dobie Pressure transducer at inter-tidal sites for Deployment Period 1 (DP1) between 15 February 2007–26 March 2007.



igure A1b:

Sea surface height (m) above Dobie Pressure transducer at inter-tidal sites for Deployment Period 2 (DP2) between 16 April 2007–29 May 2007.

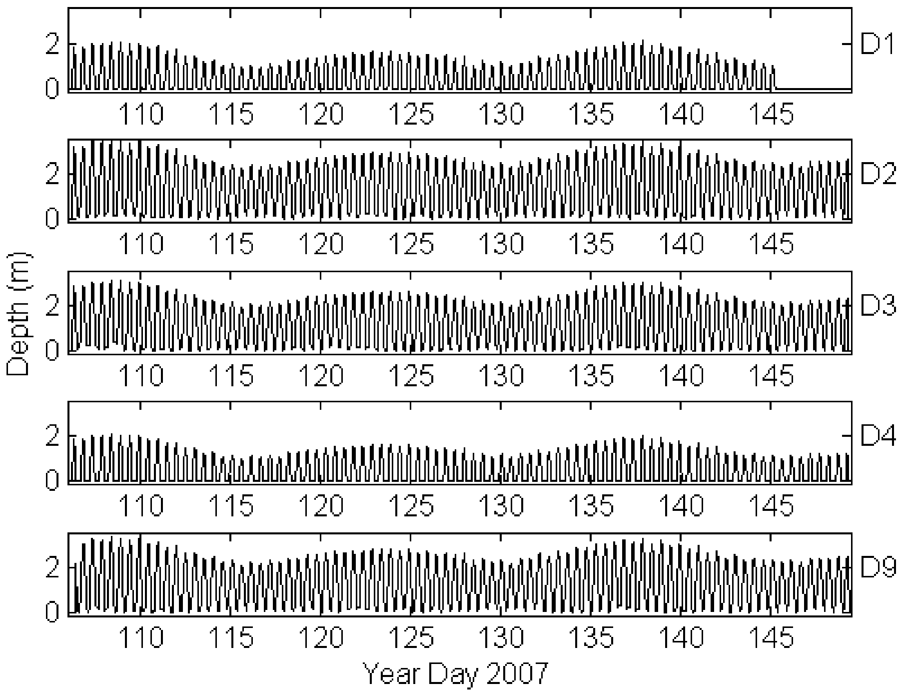


Figure A2a:

Sea surface height (m) above Dobie Pressure transducer at sub-tidal sites for Deployment Period 1 (DP1) between 15 February 2007–26 March 2007.

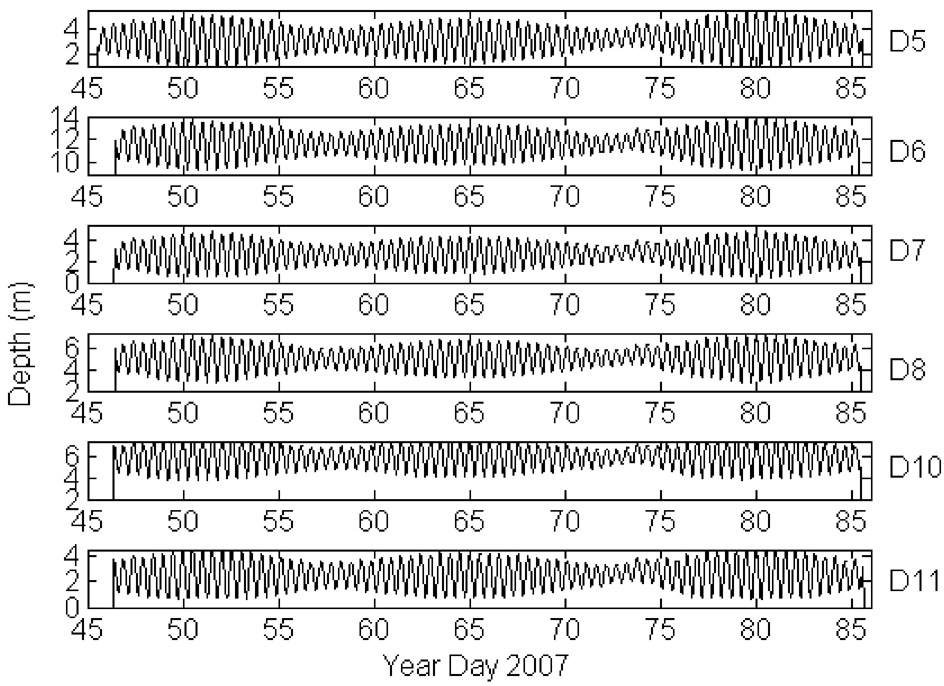
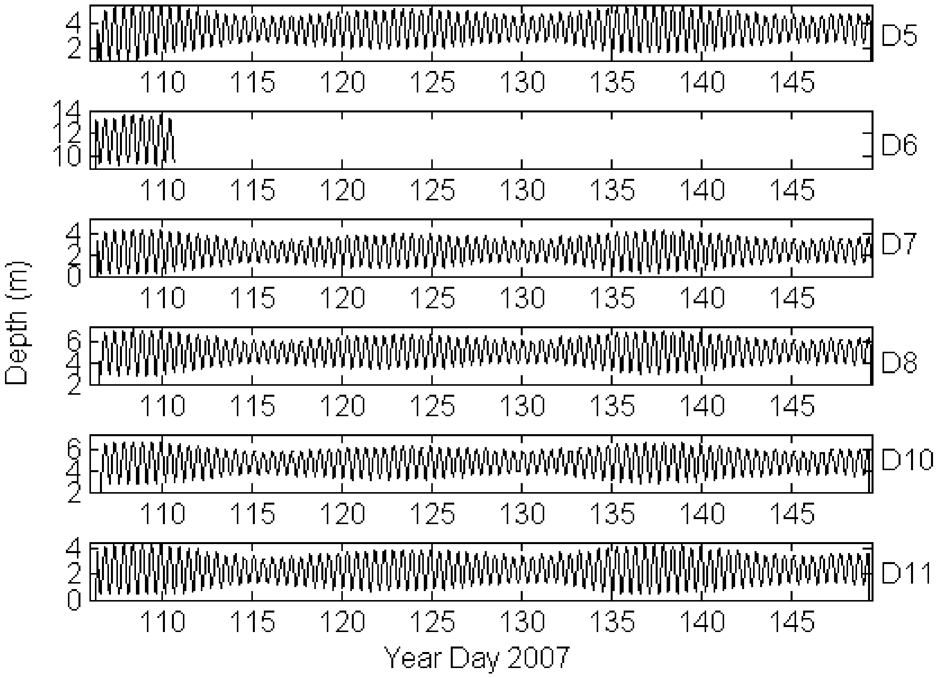


Figure A2b:

Sea surface height (m) above Dobie Pressure transducer at sub-tidal sites for Deployment Period 2 (DP2) between 16 April 2007–29 May 2007.



7.1.2 Salinity

Figure A3a:

Salinity recorded by Dobie CT transducer and S4 current meter at sub-tidal sites for Deployment Period 1 (DP1) between 15 February 2007–26 March 2007.

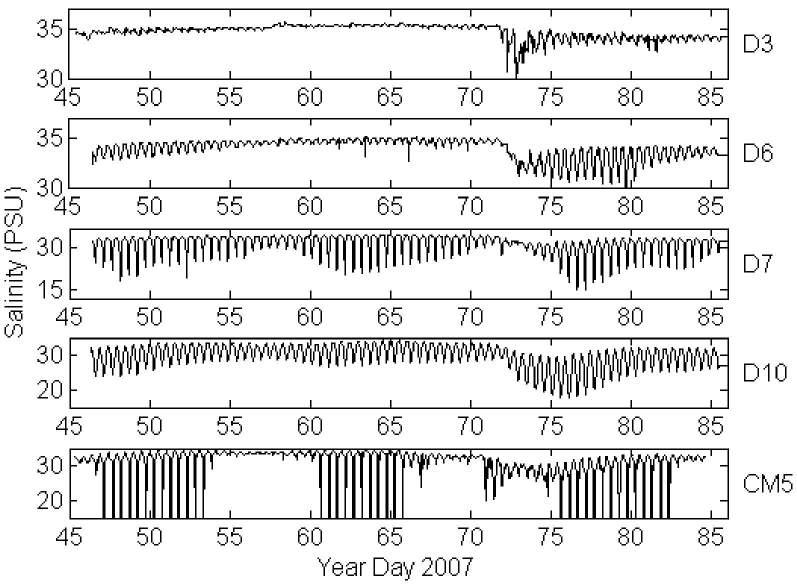
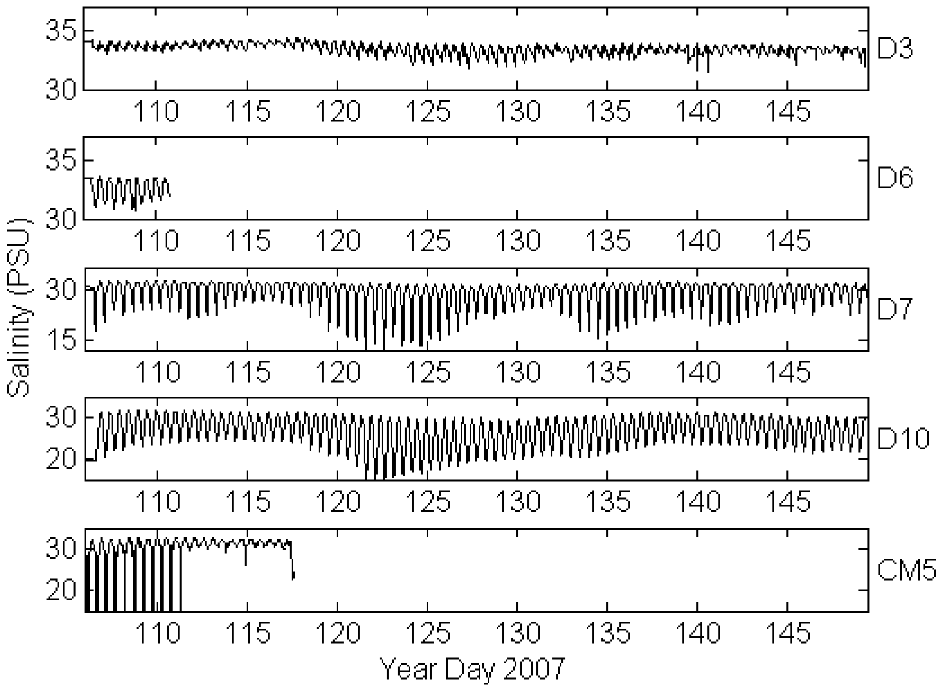


Figure A3b:

Salinity recorded by Dobie CT transducer and S4 current meter at sub-tidal sites for Deployment Period 2 (DP2) between 16April 2007–29May 2007.



7.1.3 Suspended sediment concentration (SSC)

Figure A4a:
SSC recorded by Dobie OBS transducer at inter-tidal sites for Deployment Period 1 (DP1) between 15 February 2007–26 March 2007.

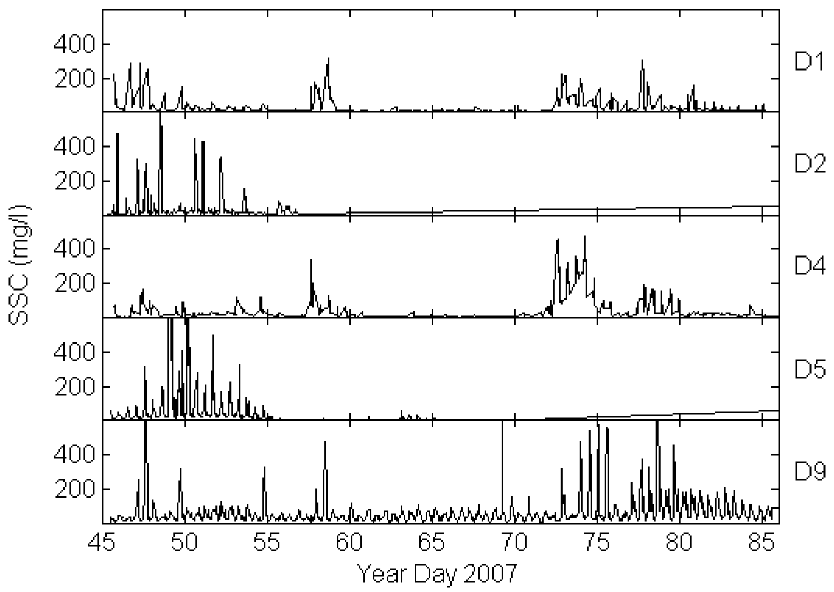


Figure A4b:
SSC recorded by Dobie OBS transducer at inter-tidal sites for Deployment Period 2 (DP2) between 16 April 2007–29 May 2007.

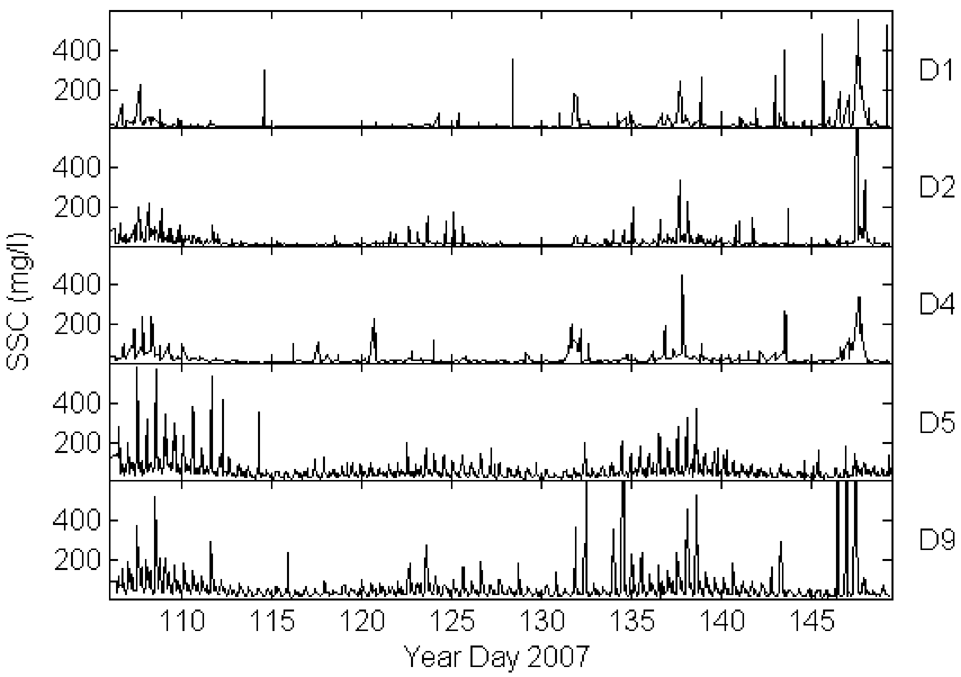


Figure A5a:
SSC recorded by Dobie OBS transducer at sub-tidal sites for Deployment Period 1 (DP1) between 15 February 2007–26 March 2007.

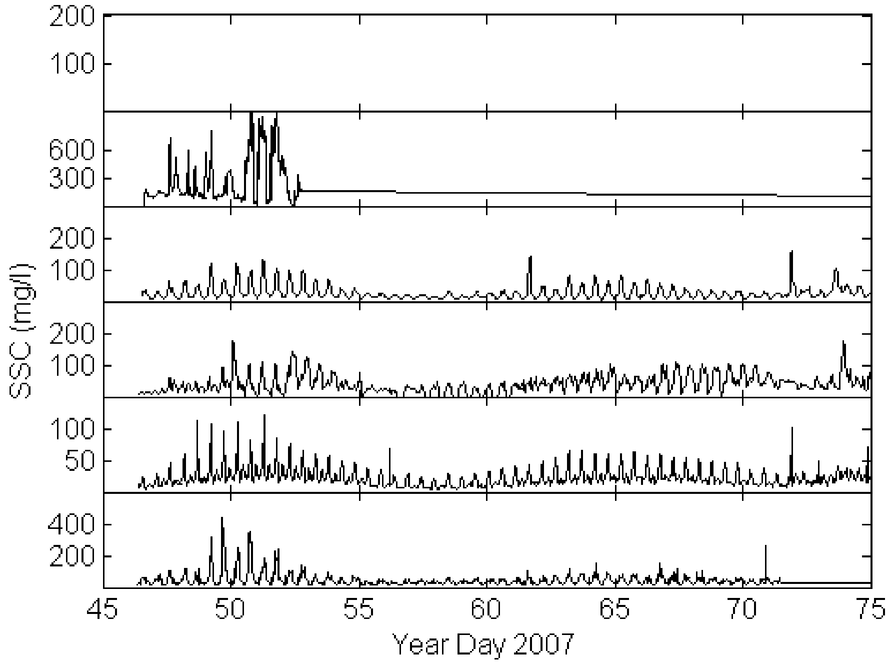
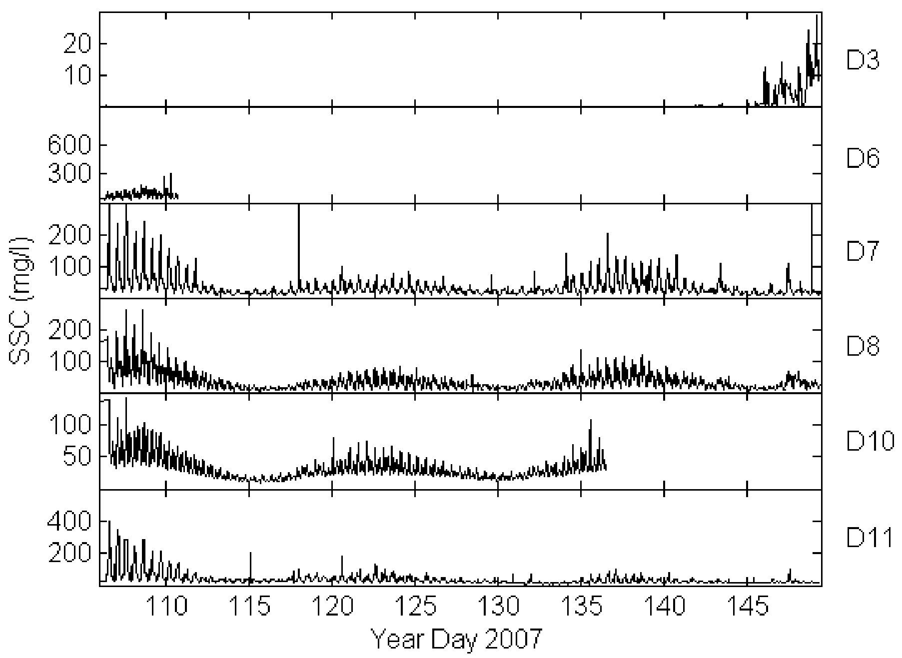


Figure A5b:
SSC recorded by Dobie OBS transducer at sub-tidal sites for Deployment Period 2 (DP2) between 16 April 2007–29 May 2007.



7.1.4 Wave statistics

Figure A6a:

Significant wave height (H_s) computed from Dobie pressure transducer at inter-tidal sites for Deployment Period 1 (DP1) between 15 February 2007–26 March 2007.

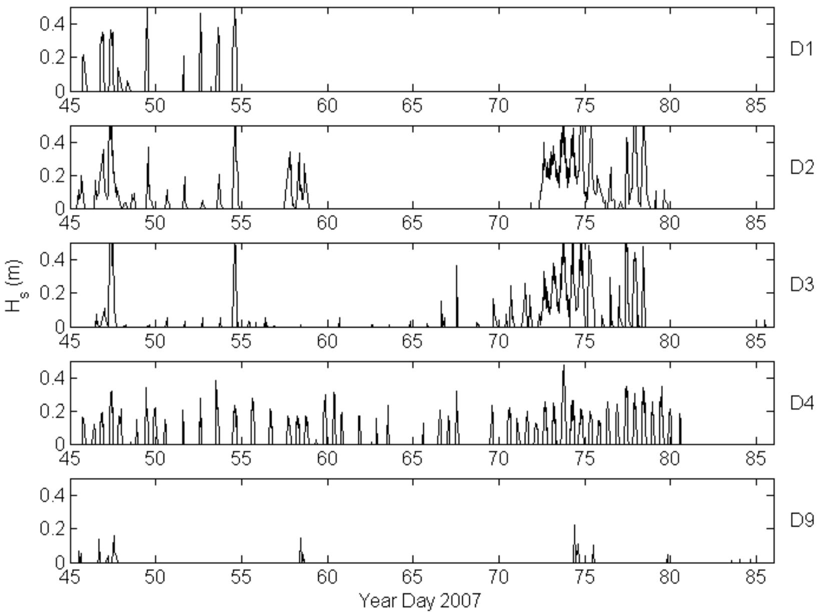


Figure A6b:

Significant wave height (H_s) computed from Dobie pressure transducer at inter-tidal sites for Deployment Period 2 (DP2) between 16 April 2007–29 May 2007.

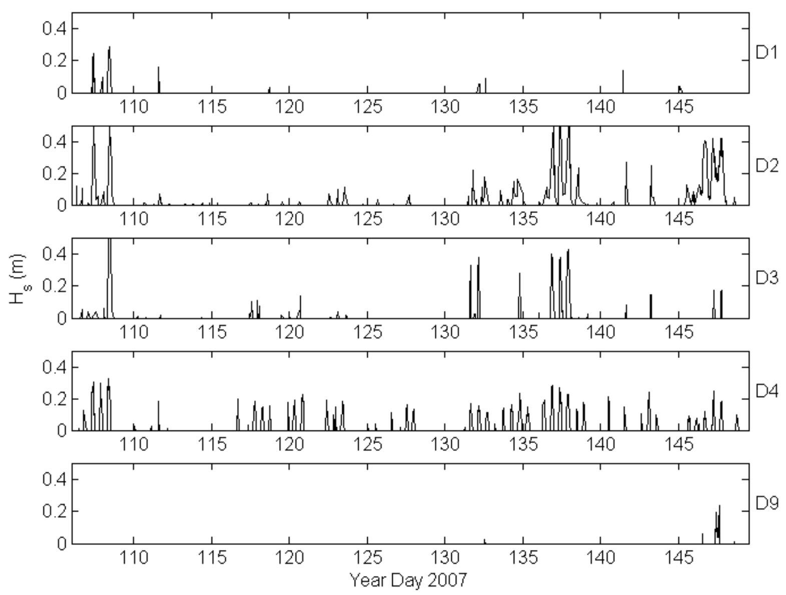


Figure A7a:

Average wave period (Tavg) computed from Dobie pressure transducer at inter-tidal sites for Deployment Period 1 (DP1) between 15 February 2007–26 March 2007. High T_{avg} are spurious.

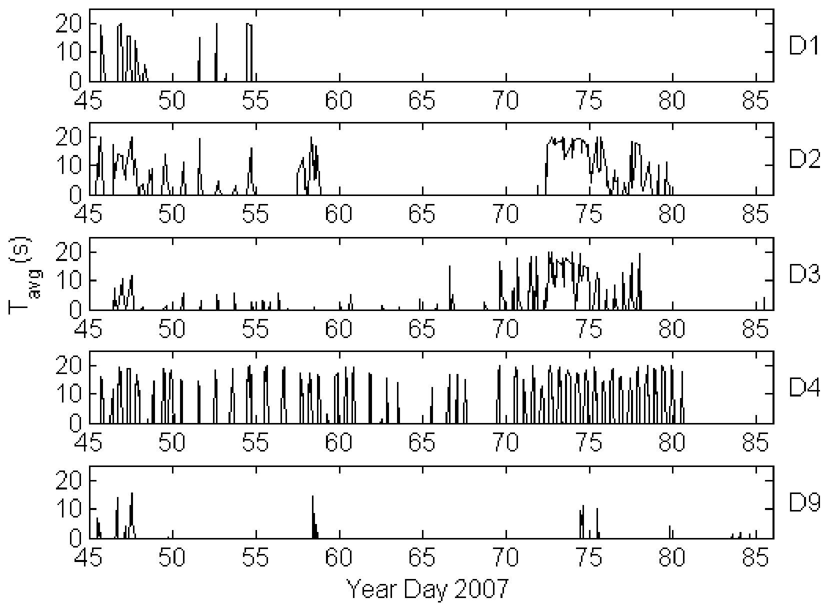
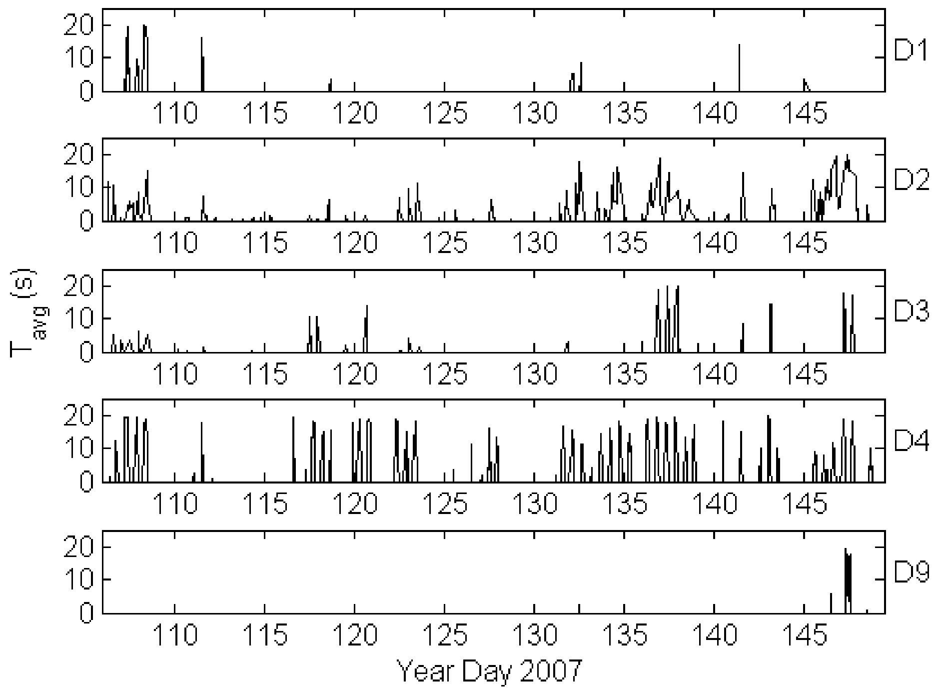


Figure A7b:

Average wave period (T_{avg}) computed from Dobie pressure transducer at inter-tidal sites for Deployment Period 2 (DP2) between 16April 2007–29May 2007 High T_{avg} are spurious.



7.1.5 Current meter measurements

Figure A8a:
Current speed and direction (true) measured during Deployment Period 1 (DP1) at site CM1 between 15 February 2007–26 March 2007.

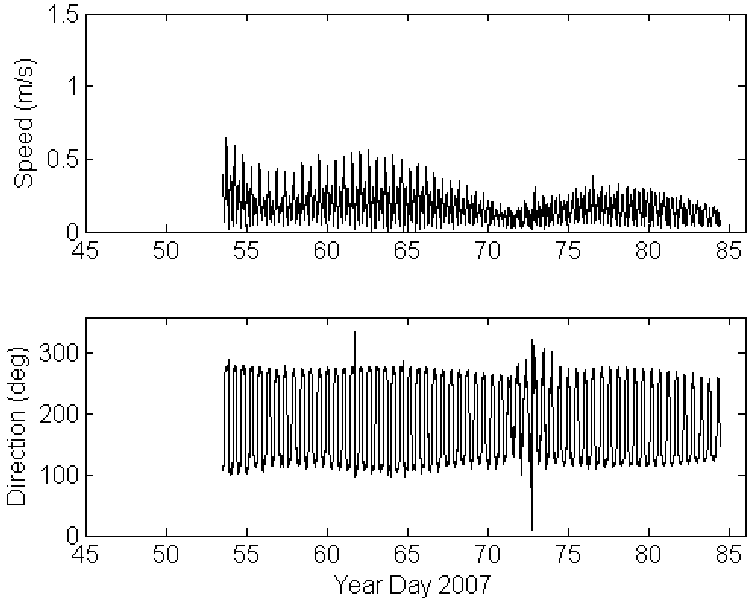


Figure A8b:
Current speed and direction (true) measured during Deployment Period 2 (DP2) at site CM1 between 16 April 2007–29 May 2007.

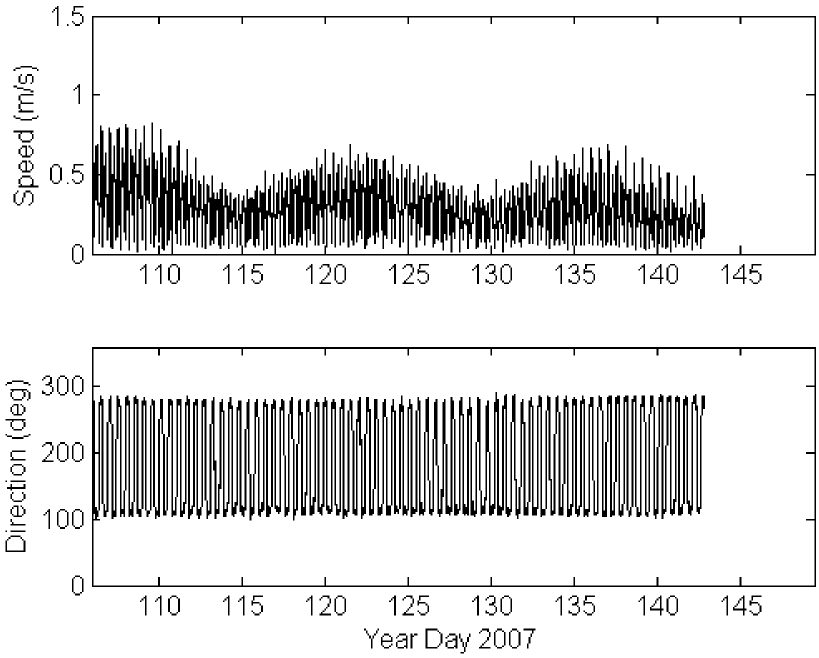


Figure A9a:

Current speed and direction (true) measured during Deployment Period 1 (DP1) at site CM2 between 15 February 2007–26 March 2007.

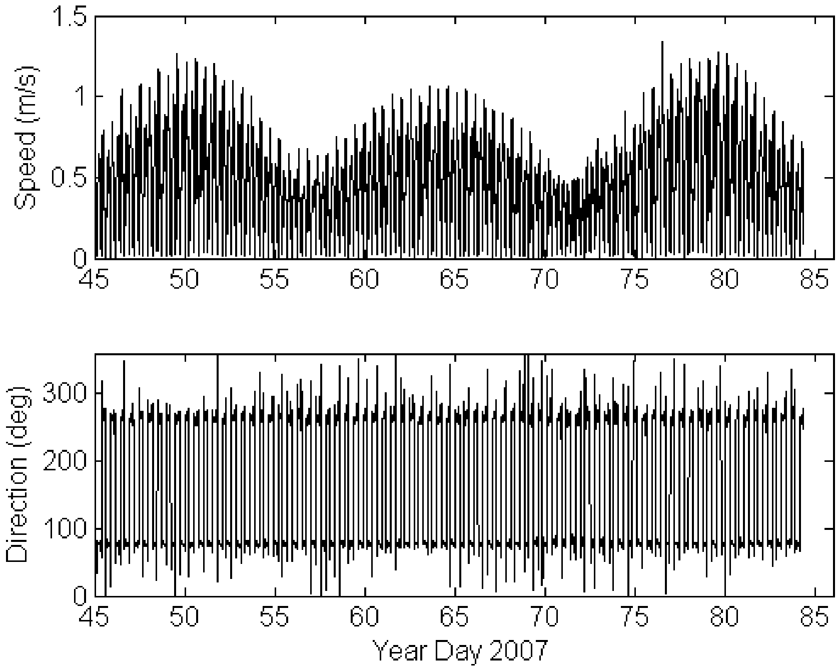


Figure A9b:

Current speed and direction (true) measured during Deployment Period 2 (DP2) at site CM2 between 16 April 2007–29 May 2007.

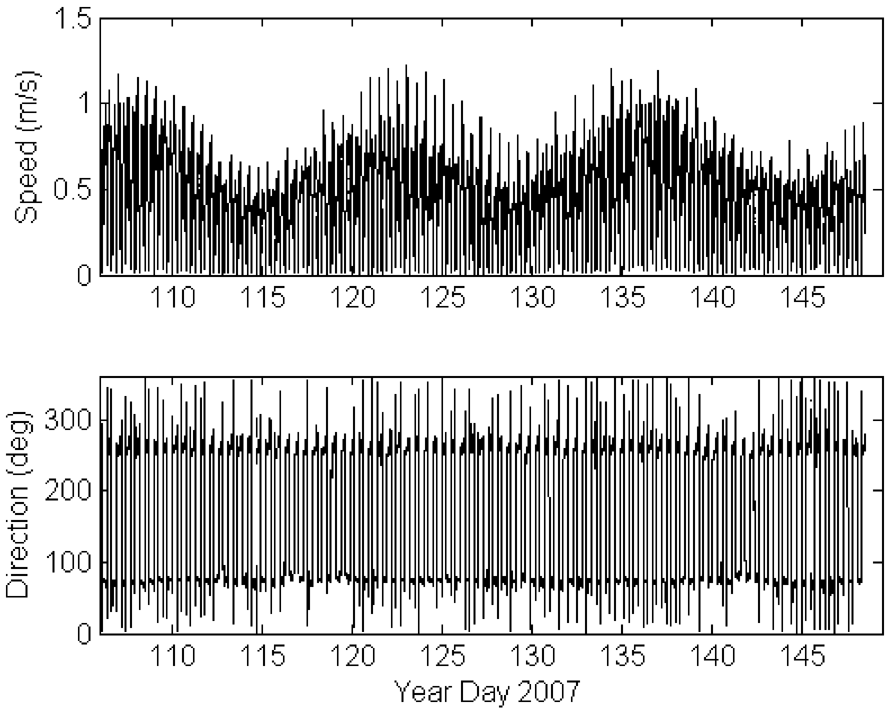


Figure A10a:

Current speed and direction (true) measured during Deployment Period 1 (DP1) at site CM3 between 15 February 2007–26 March 2007.

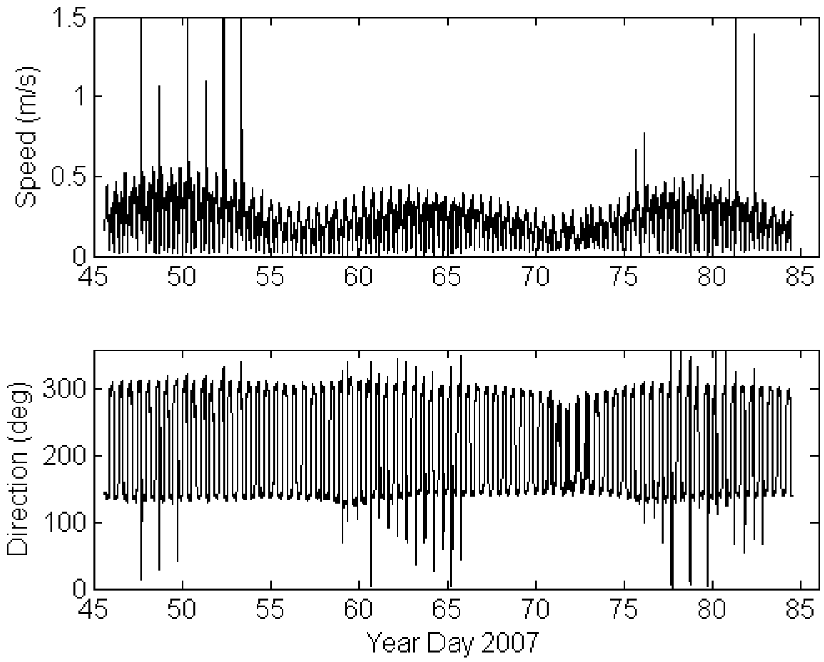


Figure A10b:
Current speed and direction (true) measured during Deployment Period 2 (DP2) at site CM3 between 16 April 2007–29 May 2007.

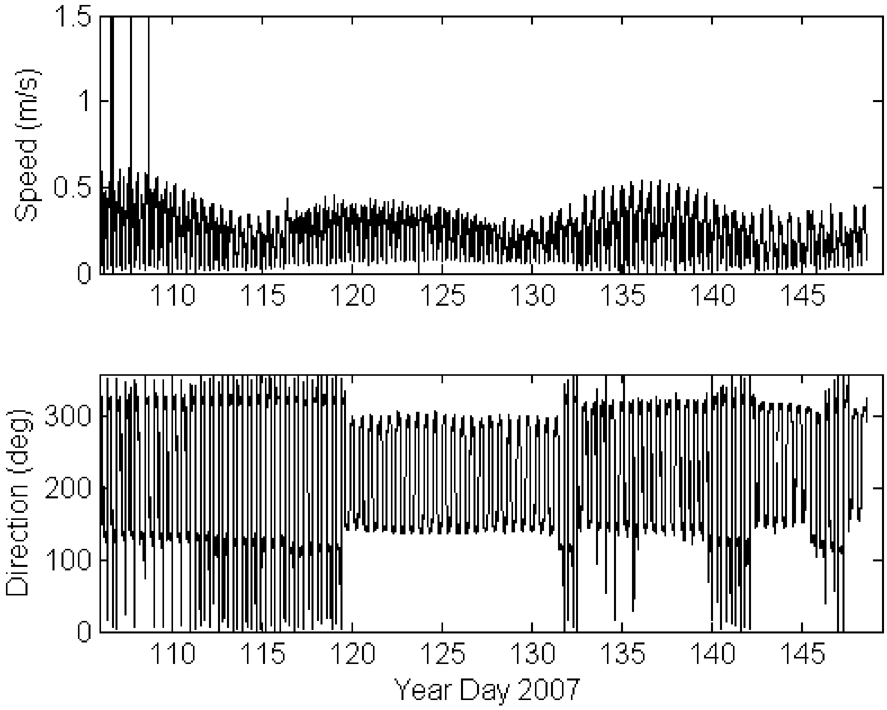


Figure A11a:
Current speed and direction (true) measured during Deployment Period 1 (DP1) at site CM4 between 15 February 2007–26 March 2007.

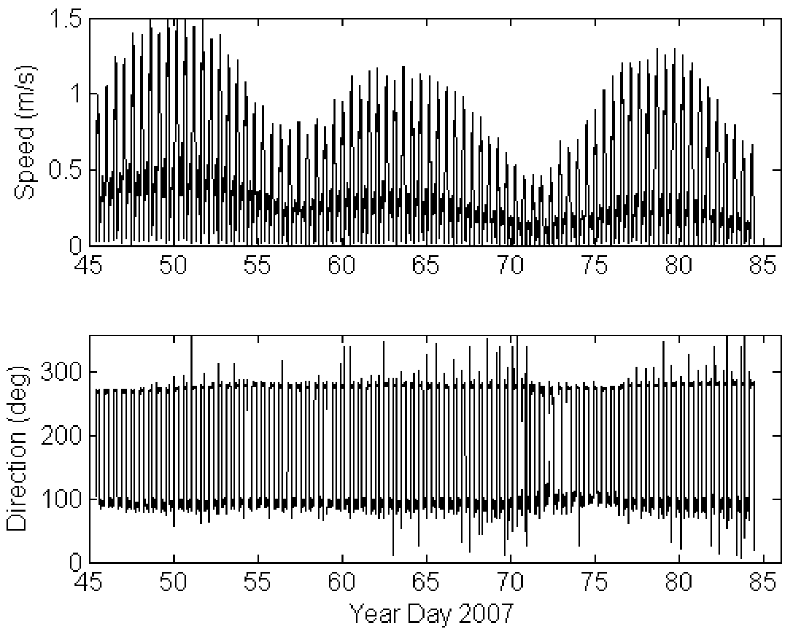


Figure A11b:

Current speed and direction (true) measured during Deployment Period 2 (DP2) at site CM4 between 16 April 2007–29 May 2007.

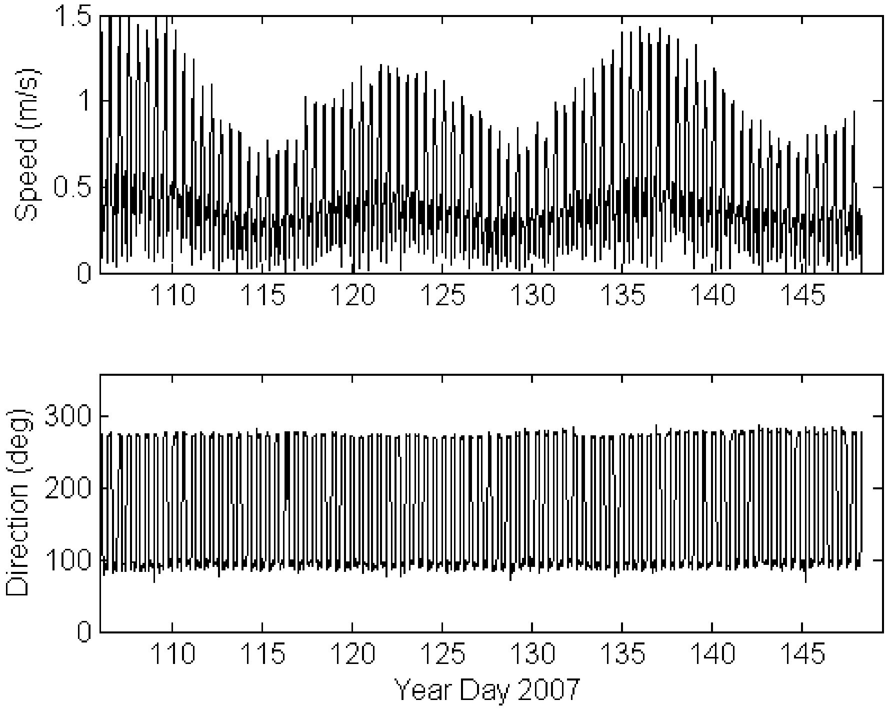


Figure A12a:

Current speed and direction (true) measured during Deployment Period 1 (DP1) at site CM5 between 15 February 2007–26 March 2007.

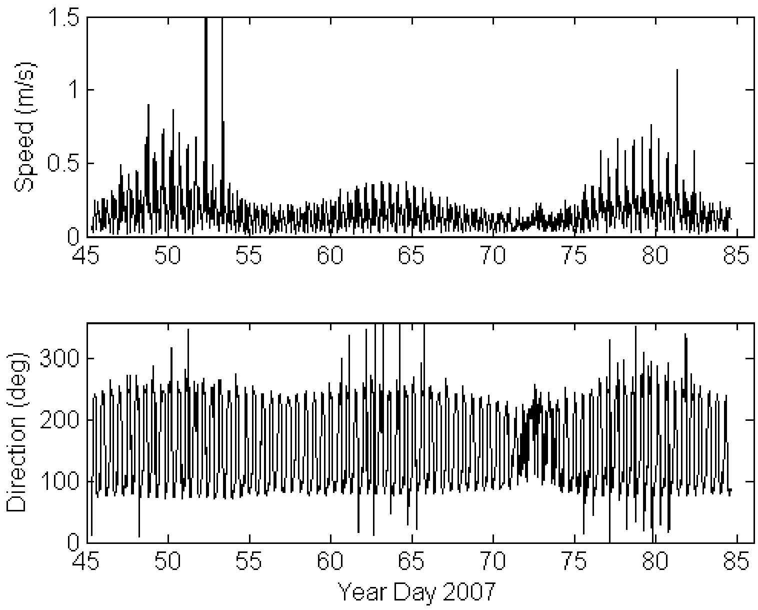
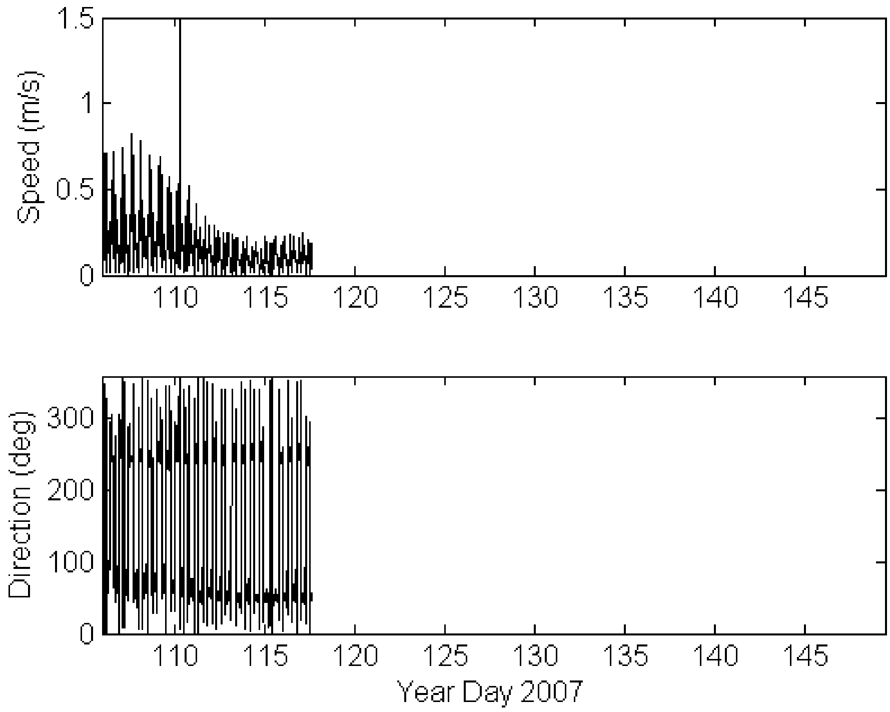


Figure A12b:
Current speed and direction (true) measured during Deployment Period 2 (DP2) at site CM5 between 16 April 2007–29 May 2007.



7.2 Appendix B

7.2.1 Pressure

The voltage output by the pressure sensor (*V*) is related to pressure (*p*) by a linear relationship:

$$p = G*(V - O)$$

where *G* is the sensor gain (units of psi per volt) and *O* is the sensor offset (units of volts). Sensor gain and offset were determined by calibrating each pressure sensor in a purpose-built pressure vessel. The pressure was raised in steps to 18, 20, 25, 30 and 40 psi, and the voltage output by the sensor at each step was recorded. The reference pressure was measured by a Paroscientific quartz-oscillator gauge attached to the vessel. A linear regression was fitted to the calibration dataset (sensor output versus reference pressure) to determine each sensor's gain and offset, which are shown in Table B.1.

Table B.1:

Calibrated gains and offsets for the pressure sensor on each DOBIE.

D4	2312	11.6076	-0.5365
D7	909	14.5503	0.0164
D3	902	20.2985	0.1214
D5	901	13.6763	0.8432
D10	2110	14.5104	-0.0285
D11	919	14.203	0.5164
D8	917	14.5499	0.0177
D6	906	14.4951	0.1574
D1	914	20.2721	0.0865
D9	908	14.5499	0.0177
D2	903	14.5765	0.1171

Total measured pressure was converted to water depth by using the hydrostatic equation with an assumed atmospheric pressure of 1 atm and a water density of 1025 kg m^{-3}.

All wave statistics were calculated using linear wave theory as implemented in the DOBIE's post processing software[1].

7.2.2 Optical backscatter

The voltage output by the optical backscatter sensor (*V*) is related to suspended-sediment concentration (*SSC*) by a linear relationship:

$$SSC = G*V - O$$

where *G* is the sensor gain (units of mg l^{-1} per volt) and *O* is the sensor offset (units of mg/L).

The optical backscatter sensors have four software-selectable gain settings. Each DOBIE was programmed to use two of these settings (gain setting 1 and gain setting 2) in each burst, with half of the burst recorded on one gain setting and the other half on the other gain setting. This ensures that an optimum tradeoff between sensor resolution and dynamic range is achieved. Analysis of the data takes the variable gain into account, which results in, essentially, two independent estimates of SSC for each burst.

OBS sensor calibrations using sediment samples collected from tidal creeks took place before the instrument was deployed in the field. Sensor gain and offset were determined for each gain setting by calibrating each sensor in a turbidity tank against sediment from the Pahurehure Inlet that was passed through a 63 µm sieve. SSC in the tank was raised from 0 to approximately 1,000 mg l^{-1} in 200 mg l^{-1} increments,

[1] http://www.niwascience.co.nz/rc/instrumentsystems/dobie

with 5 minutes allowed between readings to ensure proper mixing of the tank. Laboratory analysis of extracted samples was carried out to determine the reference concentration in the tank at each of the SSC levels. A linear regression was fitted to the calibration dataset (sensor output versus reference concentration) to determine each sensor's gain and offset, which are shown in Table B.2.

Table B.2:
Calibrated gains and offsets for the optical backscatter sensor on each DOBIE.

Site	DOBIE serial number	Gain setting 1	Gain setting 2
D1	914	SSC = 1158.05V - 15.000	SSC = 210.14V + 1.9279
D2	903	SSC = 1110.6V - 24.333	SSC = 206.83V - 7.3493
D3	902	SSC = 986.84V - 31.329	SSC = 178.81V - 0.0017
D4	2312	SSC = 896.65V - 30.047	SSC = 161.76V - 3.9681
D5	901	SSC = 1403.1V - 14.552	SSC = 255.51V - 4.1163
D6	906	SSC = 1014.4V - 39.022	SSC = 189.28V - 7.8714
D7	909	SSC = 928.61V - 29.055	SSC = 177.21V - 2.9899
D8	917	SSC = 987.28V - 23.079	SSC = 190.12V - 1.5117
D9	908	SSC = 996.69V - 27.932	SSC = 181.86V - 5.2377
D10	2110	SSC = 1339.4V - 18.524	SSC = 250.93V - 3.1536
D11	919	SSC = 1105.7V - 15.449	SSC = 208.38V - 0.2745

7.2.3 Conductivity and temperature

The voltage (*V*) output by the conductivity sensor is related to conductivity (*C*) by a linear relationship:

$$C = G * V - O$$

where *G* is the sensor gain (units of mS cm^{-1} per volt) and *O* is the sensor offset (units of mS cm^{-1}). Conductivity sensor gain and offset were determined by calibrating each sensor in a controlled-temperature (25° C) saline water bath. Conductivity in the water bath was lowered from approximately 50 mS cm^{-1} to near 0 mS cm^{-1} in 10 mS cm^{-1} increments by adding fresh water to the saline bath, with 10 minutes allowed between readings to ensure proper mixing and temperature stabilization of the tank water and sensors, then voltage output by the sensor at each step was recorded. The reference conductivity in the tank was measured by a Radiometer CDM83 conductivity meter. A linear regression was fitted to the calibration dataset (sensor output versus reference conductivity) to determine each sensor's gain and offset, which are shown in Table B.3.

The voltage (*V*) output by the temperature sensor is related to temperature (*T*) by a linear relationship:

$$T = G * V - O$$

where *G* is the sensor gain (units of degrees centigrade per volt) and *O* is the sensor offset (units of degrees centigrade). Temperature sensor gain and offset were determined by calibrating each sensor in a controlled-temperature water bath. Temperature in the water bath was raised in steps from 0° C to 5, 10, 15, 25 and 35° C, with 10 minutes allowed between readings to ensure temperature stabilization of the tank and sensors, then voltage output by the sensor at each step was recorded. The reference temperature in the tank was measured by a thermometer. A linear regression was fitted to the calibration dataset (sensor output versus reference temperature) to determine each sensor's gain and offset (Table A.3).

Table B.3:

Calibrated gains and offsets for the conductivity/temperature (CT) sensors on each Dobie.

Site	DOBIE serial number	CT sensor serial number	Conductivity calibration	Temperature calibration
D4	2312	–	–	–
D7	909	8495	C = 0.0012V - 0.1361	T = 0.0013V + 0.0477
D3	902	22129	C = 0.0015V + 0.0411	T = 0.0013V - 0.0468
D5	901	–	–	–
D10	2110	15020	C =0.001436V - 0.502	T =0.001505V - 3.5654
D8	917	–	–	–
D6	906	8494	C = 0.0012V - 0.0508	T = 0.0013V - 0.3079
D1	914	–	–	–
D9	908	–	–	–
D2	903	–	–	–
D11	919	–	–	–