Auckland
Regional Council
TE RAUHĪTANGA TAIAO

Central Waitemata Harbour Contaminant Study

Hydrodynamics and Sediment Transport Fieldwork

December TR 2008/036

Auckland Regional Council
Technical Report No.036 December 2008
ISSN 1179-0504 (Print)
ISSN 1179-0512 (Online)
ISBN 978-1-877483-77-6

Technical Report, first edition.

Reviewed by:	Approved for ARC publication by:
Name: Hayden Easton	Name: Matthew Davis
Position: Team Leader Stormwater Action Team	Position: Group Manager Partnerships & Community Programmes
Organisation: Auckland Regional Council	Organisation: Auckland Regional Council
Date: 12 December 2009	Date: 18 December 2009

Recommended Citation:

OLDMAN, J.; HANCOCK, N.; LEWIS, M., 2008. Central Waitemata Harbour Contaminant Study. Hydrodynamics and Sediment Transport Fieldwork. Prepared by NIWA Ltd for Auckland Regional Council. Auckland Regional Council Technical Report 2008/036

Central Waitemata Harbour Contaminant Study. Hydrodynamics and Sediment Transport Fieldwork

John Oldman
Nicole Hancock
Matt Lewis

Prepared for
Auckland Regional Council

NIWA Client Report: HAM2007-009
February 2007

NIWA Projects: ARC06217 and ARC07236

National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road, Hamilton
P O Box 11115, Hamilton, New Zealand
Phone: 07 856 7026 Fax: 07 856 0151
www.niwa.co.nz

Preface

The Waitemata 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. An earlier study examined long-term accumulation of sediment and stormwater chemical contaminants in the Upper Waitemata Harbour. However, previously little was known about the existing and long-term accumulation of sediment and stormwater chemical contaminants in the central harbour. The Central Waitemata Harbour 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 sedimentation 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 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:

- Henderson Creek (which drains the largest subcatchment and with the largest urban area, as well as substantial areas of rural land) contributes the largest loads of sediment, copper and zinc to the Central Waitemata Harbour. The second largest loads come from the Upper Waitemata Harbour.

- Substantial proportions of the subcatchment sediment, copper and zinc loads are accumulating in the Henderson, Whau, Meola and Motions tidal creeks and in the Shoal Bay, Hobson Bay and Waterview embayments.

- Central Waitemata Harbour bed sediment concentrations of copper and zinc are not expected to reach toxic levels based on current assumptions of future trends in urban 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. (For example, whereas the study addresses the Whau River as a whole, differences exist within parts of the Whau River that may merit a different magnitude or type of intervention than may be inferred from considering the Whau River and its long-term contaminant trends as a whole.) 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 Hauraki Gulf.

Technical reports

The study has produced a series of technical reports:

Technical Report TR2008/032
Central Waitemata Harbour Contaminant Study. Landuse Scenarios.

Technical Report TR2008/033
Central Waitemata Harbour Contaminant Study. Background Metal Concentrations in Soils: Methods and Results.

Technical Report TR2008/034
Central Waitemata Harbour Contaminant Study. Harbour Sediments.

Technical Report TR2008/035
Central Waitemata Harbour Contaminant Study. Trace Metal Concentrations in Harbour Sediments.

Technical Report TR2008/036
Central Waitemata Harbour Contaminant Study. Hydrodynamics and Sediment Transport Fieldwork.

Technical Report TR2008/037
Central Waitemata Harbour Contaminant Study. Harbour Hydrodynamics, Wave and Sediment Transport Model Implementation and Calibration.

Technical Report TR2008/038
Central Waitemata Harbour Contaminant Study. Development of the Contaminant Load Model.

Technical Report TR2008/039
Central Waitemata Harbour Contaminant Study. Predictions of Stormwater Contaminant Loads.

Technical Report TR2008/040
Central Waitemata Harbour Contaminant Study. GLEAMS Model Structure, Setup and Data Requirements.

Technical Report TR2008/041
Central Waitemata Harbour Contaminant Study. GLEAMS Model Results for Rural and Earthworks Sediment Loads.

Technical Report TR2008/042
Central Waitemata Harbour Contaminant Study. USC-3 Model Description, Implementation and Calibration.

Technical Report TR2008/043
Central Waitemata Harbour Contaminant Study. Predictions of Sediment, Zinc and Copper Accumulation under Future Development Scenario 1.

Technical Report TR2008/044
Central Waitemata Harbour Contaminant Study. Predictions of Sediment, Zinc and Copper Accumulation under Future Development Scenarios 2, 3 and 4.

Technical Report TR2009/109
Central Waitemata Harbour Contaminant Study. Rainfall Analysis.

Contents

Reviewed by:

Doug Ramsay, NIWA

Approved for release by:

Malcolm Green, NIWA

1 Executive Summary

The main aim of the Central Waitemata Harbour (CWH) Contaminant Study is to model contaminant accumulation (sediment, zinc, copper) within the harbour for the purposes of, amongst other things, identifying significant contaminant sources, and testing efficacy of stormwater treatment and industrial roof contaminant source control.

This report documents the fieldwork conducted in 2006 to acquire data needed to calibrate the model that will be used to simulate the dispersal of contaminants and sediments in the harbour by physical processes such as tidal currents and waves.

Fieldwork was carried out between 30 March and 24 July 2006.

Measurements of tides, currents, waves, conductivity and water temperature were made at a number of sites with moored instruments. In addition, conductivity-temperature-depth surveys were conducted from a survey vessel.

The tidal range is ~1.8 m during neap tides and ~3.0 m during spring tides. Highest tidal ranges were recorded within the middle reaches of the Whau and in Henderson Creek.

There is typically a strong tidal signal in suspended sediment concentration (SSC), with the highest SSC occurring during periods of wave activity or under peak currents on flooding and ebbing tides.

Only a limited number of wave events occurred during the deployment. Wave heights were typically less than 1 m and wave periods did not exceed 4.0 s. When they were present, waves enhanced SSC by as much as 0.25 kg/m^3 within the main body of the harbour.

Temperature and salinity data are used to quantify the degree of mixing that occurs between freshwater sources (eg, the Whau and Henderson Creek) and the more saline waters of the main body of the harbour. Large fluctuations in salinity (0-32 psu) were recorded in the upper reaches of both the Whau and Henderson Creek. In the main body of the harbour, fluctuations in salinity were much less, ranging between 25 and 32 psu.

2 Introduction

Modelling and empirical data indicate that stormwater contaminants are rapidly accumulating in the highly urbanised side branches of the Central Waitemata Harbour (CWH). However, there is no clear understanding of the fate of contaminants exported from these side branches into the main body of the harbour, or that of contaminants discharged directly into the harbour. This information is needed to ensure sustainability within the CWH.

The main aim of the study is to model contaminant (zinc, copper) and sediment accumulation within the CWH for the purposes of, amongst other things, identifying significant contaminant sources, and testing efficacy of stormwater treatment and industrial roof contaminant source control.

2.1 Study aims

The study aims to:

- predict contaminant loads based on past, present and future land use and population growth for each sub-catchment discharging into the CWH, allowing for stormwater treatment and industrial roof contaminant source control;
- predict dispersal and accumulation (or loss) of sediment and stormwater contaminants in the CWH;
- calibrate and validate the dispersal/accumulation model;
- apply the various models to predict catchment contaminant loads and accumulation of copper, zinc and sediment in the CWH under specific scenarios that depict various combinations of projected land use/population growth, stormwater treatment efficiency, and industrial roof contaminant source control;
- determine from the model predictions the relative contributions of sediment and contaminant from individual sub-catchments and local authorities;
- provide an assessment of the environmental consequences of model outputs;
- provide technical reports on each component of the work; and
- provide a desktop application suitable.

2.2 Model suite

The study centres on the application of three models that are linked to each other in a single suite:

- The GLEAMS sediment-generation model, which predicts sediment erosion from the land and transport down the stream channel network. Predictions of sediment supply are necessary because, ultimately, sediment eroded from the land dilutes the concentration of contaminants in the bed sediments of the harbour, making them less harmful to biota[1].

- The CLM contaminant/sediment-generation model, which predicts sediment and contaminant concentrations (including zinc, copper) in stormwater at a point source, in urban streams, or at end-of-pipe where stormwater discharges into the receiving environment.
- The USC-3 (Urban Stormwater Contaminant) contaminant/sediment accumulation model, which predicts sedimentation and accumulation of contaminants (including zinc, copper) in the bed sediments of the estuary. Underlying the USC-3 model is yet another model: an estuarine sediment-transport model, which simulates the dispersal of contaminants/sediments by physical processes such as tidal currents and waves.

2.3 Work plan

There are eight modules in the work plan::

- Module 1 – Implementation of the sediment-generation model.
- Module 2 – Implementation of the contaminant/sediment-generation model.
- Module 3 – Implementation of the contaminant/sediment-accumulation model.
- Module 4 – Calibration and validation of the model suite.
- Module 5 – Depiction of development scenarios, including stormwater treatment and industrial roof contaminant source control, as required.
- Module 6 – Execution of the model suite to produce predictions of contaminant build-up in bed sediments of the CWH.
- Module 7 – Evaluation of predictions with management.

This may lead to reconsideration of Module 5, and subsequent re-running of Module 6 until an acceptable development scenario can be found.

- Module 8 – Development of desktop application.

2.4 This report

This report documents the fieldwork conducted in 2006 to acquire data needed to calibrate the model that is used to simulate the dispersal of contaminants and sediments in the harbour by physical processes such as tidal currents and waves. This model comprises a hydrodynamics module, a sediment-transport module and a wave module. The data collected during the field programme will be used together with existing data to calibrate each module. Data to be used includes existing bathymetry, recently collected LIDAR bathymetry, archived tide and current-meter data, wave data and suspended-sediment data.

[1] We use the term "contaminant" herein to mean chemical contaminants such as zinc and copper, and we refer to "sediments" separately.

3 Field Programme

3.1 Instrument deployments

The consenting process for the field work began in mid-January with letters being sent to stakeholders that could be affected by activities. Appropriate iwi representatives were contacted by NIWA staff. Permission to carry out work in the Pollen Island Marine Reserve was granted by the Department of Conservation and the Maritime Safety Authority (MSA), and the relevant harbourmasters were informed of intentions. Formal consent for instrument deployments was then granted by the ARC.

Three four-week deployments between February and June 2006 were planned.

The first deployment of instruments commenced on March 30; the second on May 4; and the last on 13 June 2006. Instruments were retrieved on 24 July.

Ten DOBIE instrument packages for measuring water levels, waves and suspended-sediment concentration (SSC) were deployed at the locations shown in Figure 1 and Table 1. The DOBIEs at Sites 2, 3, 5, 7 and 8 also measured salinity and temperature.

In addition, an S4 current meter was deployed within the channel outside West Park Marina, Henderson Creek (Site 2, Figure 1), during three periods: 28 March to 2 May; 28 April to 19 June; 13 June to 27 July, 2006. The overlapping times arise as different current meters were deployed during the different periods, to prevent gaps in the record that would otherwise have arisen when a single current meter was out of the water being serviced.

Wind and rain data for the period of the instrument deployments were downloaded from the NIWA Climate Database for the station at Auckland Airport (Climate Database Agent Number 1962; latitude/longitude [WGS84] -37.007/174.789). Historic wind and rain data were also downloaded to derive long-term wind and rain statistics. The historic data were used to provide some context for the weather during the deployment period.

Analysis of the wind record from Auckland Airport shows that winds during the time of the deployment (Figure 2) were not dissimilar (in terms of wind strength and direction) to winds over the period 1980–2005 (Figure 3).

Rain fell on 75 days during the deployment period (63 per cent of the time) (Figure 4). During the period 1980–2005 rain fell in Auckland 40 per cent of the time. However, this precludes any consideration of seasonal variations; it is likely that analysis of the long-term record for the period March–July would show a much higher percentage of rain days.

The maximum recorded daily rainfall during the deployment period was 53 mm on 25 April and the average rainfall for all one-week periods during the deployment was 30 mm.

Figure 1

Locations of DOBIE instrument packages. All DOBIEs measured waves and water depth. DOBIEs at Sites 2, 3, 5, 7 and 8 (indicated by the black symbols on the map) also measured salinity and temperature. An S4 current meter was deployed at DOBIE Site 2, Henderson Creek.

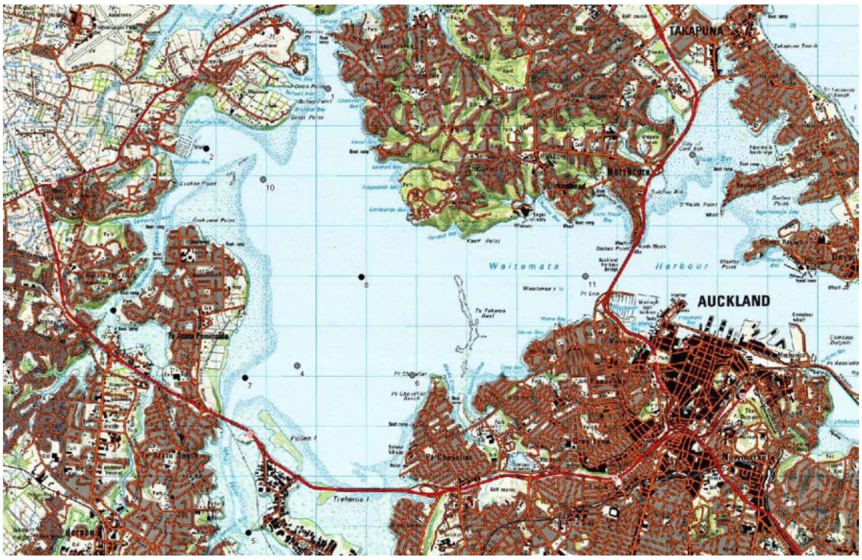


Table 1

Locations of DOBIE instrument packages.

Site	Longitude	Latitude	Description
1	-36.798850	174.679217	Entrance to Upper Waitemata Harbour
2	-36.811017	174.651933	Entrance to Henderson Creek
3	-36.839833	174.63215	Henderson Creek
4	-36.849650	174.673317	Approach channel to the Whau
5	-36.879950	174.663067	Upper Whau
6	-36.851000	174.699	Point Chevalier
7	-36.852083	174.66155	Entrance to the Whau
8	-36.833667	174.68167	Middle Harbour basin
9	-36.810733	174.760283	Shoal Bay
10	-36.816117	174.665333	Approach channel to Henderson Creek
11	-36.832383	174.738233	Harbour Bridge

Figure 2
Wind rose from Auckland Airport automated weather station data for deployment period 30 March – 28 July 2006.

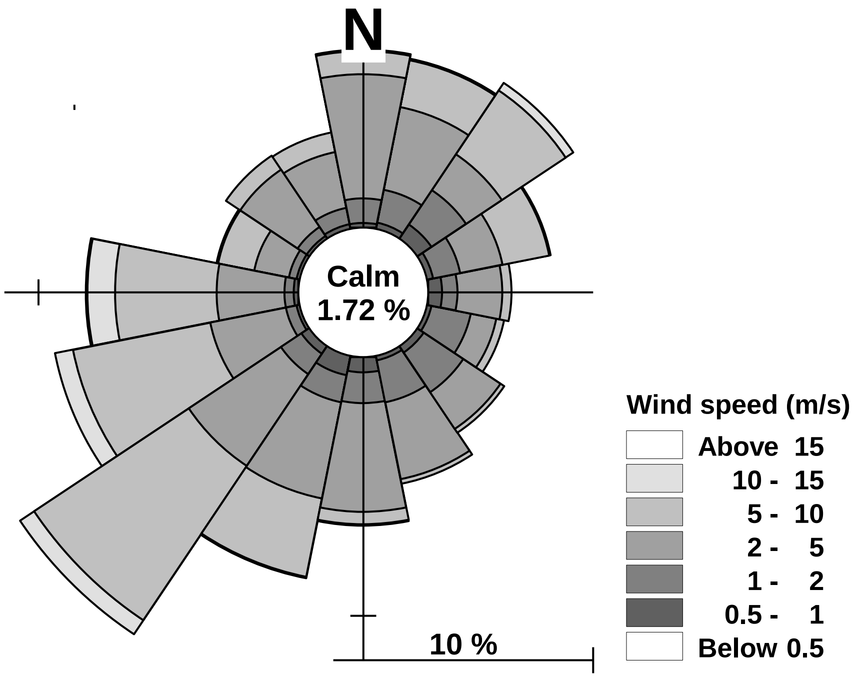


Figure 3
Wind rose from Auckland Airport automated weather station data for the period 1980-2005.

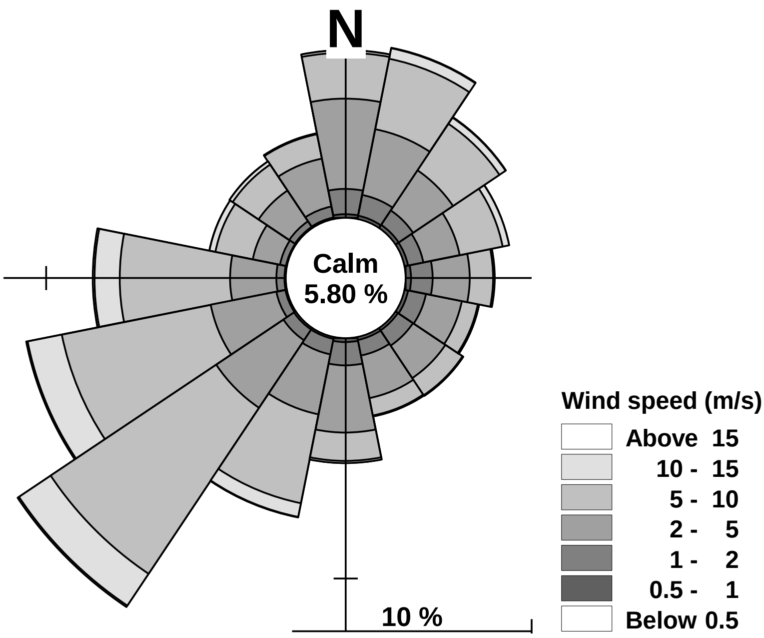
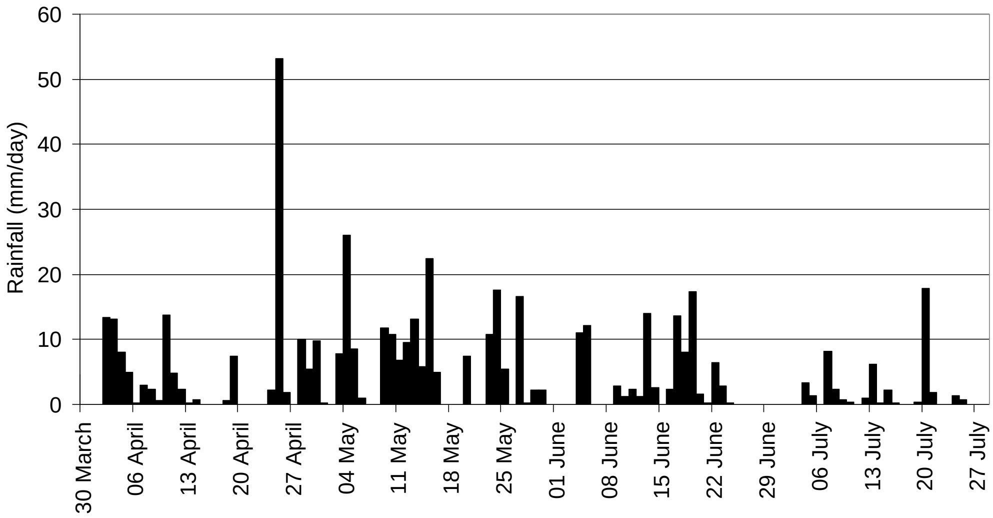


Figure 4
Daily rainfall from Auckland Airport automated weather station over the period of the instrument deployments (30 March – 28 July 2006).



3.2 Conductivity-temperature-depth (CTD) surveys

CTD (conductivity–temperature–depth) surveys were carried out between the June 14 – 17, 2006. Data from these surveys will be used to determine how freshwater from the Whau and from Henderson Creek mixes with the saline waters of the main body of the harbour on both incoming and outgoing tides.

The CTD survey sites are shown in Figure 5.

Figure 5
Sites for CTD surveys carried out between 14 and 16 June, 2006.

4 Data from Instrument Deployments

4.1 DOBIE instrument packages

The DOBIE instrument packages measure pressure, which is converted to water depth and estimates of wave parameters; infrared optical backscatter (OBS), which is converted to suspended-sediment concentration (SSC); and/or conductivity and temperature, from which salinity is calculated (Fofonoff and Millard, 1983).

Samples were acquired in bursts, with a 10-minute burst interval, 900 samples per burst, and a 10 Hz sampling rate. Hence, burst length was 90 s and there were six bursts per hour.

The DOBIEs were recovered, downloaded and redeployed on two occasions, and then recovered for a final time and downloaded at the end of the field programme. Start times for the first and last burst in each deployment period are given in Table 2a-c. The first deployment period did not yield data due to a problem with DOBIE's internal clock. A DOBIE was deployed at Site 6 during the first period, but not during the second and third periods. The DOBIE deployed at Site 1 during the third period was lost.

Some detail on the way pressure, optical backscatter, and conductivity-temperature data were processed is provided in Appendix 1, which includes listing of calibration coefficients.

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. These two independent estimates are reported in the following by reference to "gain setting 1" and "gain setting 2".

Table 2a

Dates and times of DOBIE deployments, and parameters measured at each site. P = pressure (water levels, waves), SSC = suspended-sediment concentration; CT = conductivity and temperature.

Site	Period 1 - start date	Period 1 - stop date	Parameters measured
1	30/03/2006 23:30	1/04/2006 22:00	P SSC
2	30/03/2006 23:30	1/04/2006 22:00	P SSC CT
3	30/03/2006 23:30	1/04/2006 22:00	P SSC CT
4	30/03/2006 23:30	1/04/2006 22:00	P SSC
5	30/03/2006 23:30	1/04/2006 22:00	P SSC CT
6	30/03/2006 23:30	1/04/2006 22:00	P SSC
7	30/03/2006 23:30	1/04/2006 22:00	P SSC CT
8	30/03/2006 23:30	1/04/2006 22:00	P SSC CT
9	30/03/2006 23:30	1/04/2006 22:00	P SSC
10	30/03/2006 23:30	1/04/2006 22:00	P SSC
11	30/03/2006 23:30	1/04/2006 22:00	P SSC

Table 2b

Dates and times of DOBIE deployments, and parameters measured at each site. P = pressure (water levels, waves), SSC = suspended-sediment concentration; CT = conductivity and temperature.

Site	Period 2 - start date	Period 2 - stop date	Parameters measured
1	3/05/2006 23:50	13/06/2006 10:00	P SSC
2	3/05/2006 23:50	29/05/2006 14:40	P SSC CT
3	3/05/2006 23:50	12/06/2006 13:40	P SSC CT
4	3/05/2006 23:50	3/06/2006 17:40	P SSC
5	3/05/2006 23:50	29/05/2006 14:40	P SSC CT
6	–	–	–
7	3/05/2006 23:50	13/06/2006 10:35	P SSC CT
8	3/05/2006 23:50	29/05/2006 14:40	P SSC CT
9	3/05/2006 23:50	3/06/2006 17:40	P SSC
10	3/05/2006 23:50	12/06/2006 13:40	P SSC
11	3/05/2006 23:50	3/06/2006 17:40	P SSC

Table 2c

Dates and times of DOBIE deployments, and parameters measured at each site. P = pressure (water levels, waves), SSC = suspended-sediment concentration; CT = conductivity and temperature.

Site	Period 3 - start date	Period 3 - stop date	Parameters measured
1	14/06/2006 23:55	–	P SSC
2	14/06/2006 23:55	10/07/2006 14:45	P SSC CT
3	14/06/2006 23:55	28/07/2006 10:55	P SSC CT
4	14/06/2006 23:55	15/07/2006 17:45	P SSC
5	14/06/2006 23:55	10/07/2006 14:45	P SSC CT
6	–	–	–
7	14/06/2006 23:55	28/07/2006 14:05	P SSC CT
8	14/06/2006 23:55	10/07/2006 14:45	P SSC CT
9	14/06/2006 23:55	15/07/2006 17:45	P SSC
10	14/06/2006 23:55	28/07/2006 10:55	P SSC
11	14/06/2006 23:55	15/07/2006 17:45	P SSC

4.2 S4 current meter

The S4 current meter measures current speed and direction and water depth. Samples were acquired in bursts, with a 5-minute burst interval, 512 samples per burst, and a 1-Hz sampling rate. Hence, burst length was 51.2 s and there were 12 bursts per hour.

Water depths were not recorded during the first and third deployment periods.

4.3 Results – DOBIE instrument packages

Water depth (m) and suspended-sediment concentration (kg/m^3) are reported at each site. For Sites 2, 3, 5, 7 and 8, salinity (psu) and water temperature (° C) are reported. Waves were not measured at sites which are either sheltered or to deep for pressure fluctuations to penetrate through the water column to the instrument. Where waves were measured, wave period(s) and significant wave height (m) are reported.

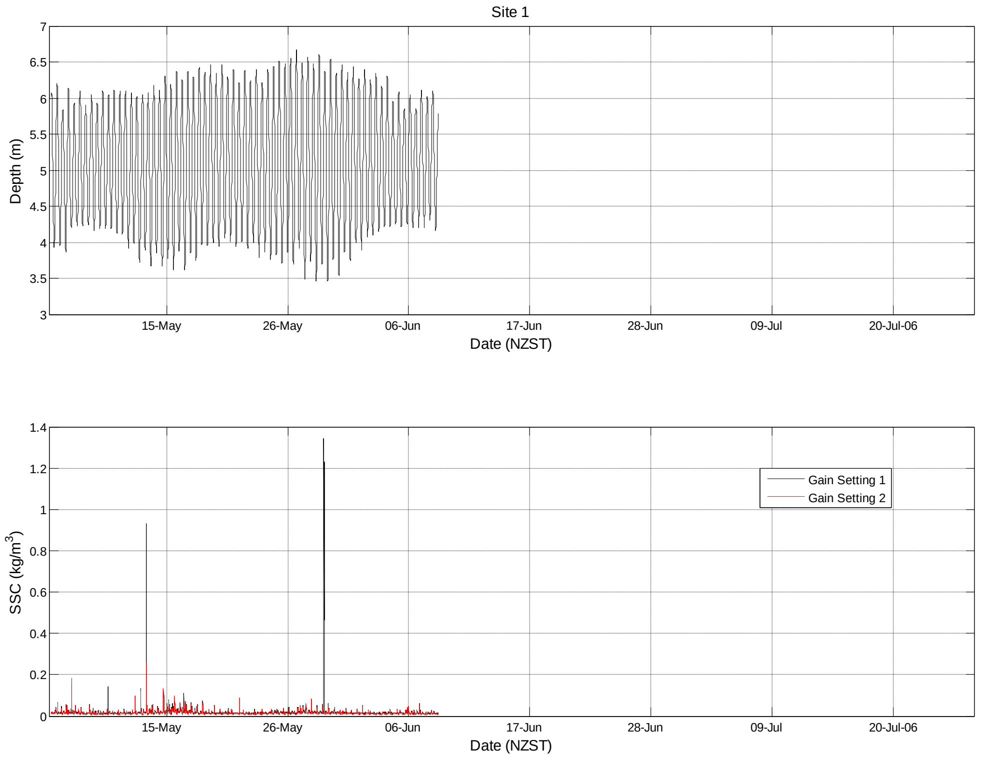
Gaps in the records are due to various causes including instruments emerging from the water, biofouling and sensor failure.

4.3.1 Site 1 (entrance to Upper Waitemata Harbour)

Parameters measured by the DOBIE at Site 1 are shown in Figure 6. The mean depth was 5.08 m with a range of ±1.6 m. The magnitude of the M_2 tidal component was 1.19 m and the magnitude of the S_2 component was 0.18 m. The instrument was located too far below the surface to detect any surface waves. SSC varied over the tidal cycle, and the maximum SSC was 1.34 kgm^{-3}. The 90th percentile SSC was 0.02 kgm^{-3}.

Figure 6

Parameters measured by the DOBIE at Site 1, 4 May – 27 July 2006.

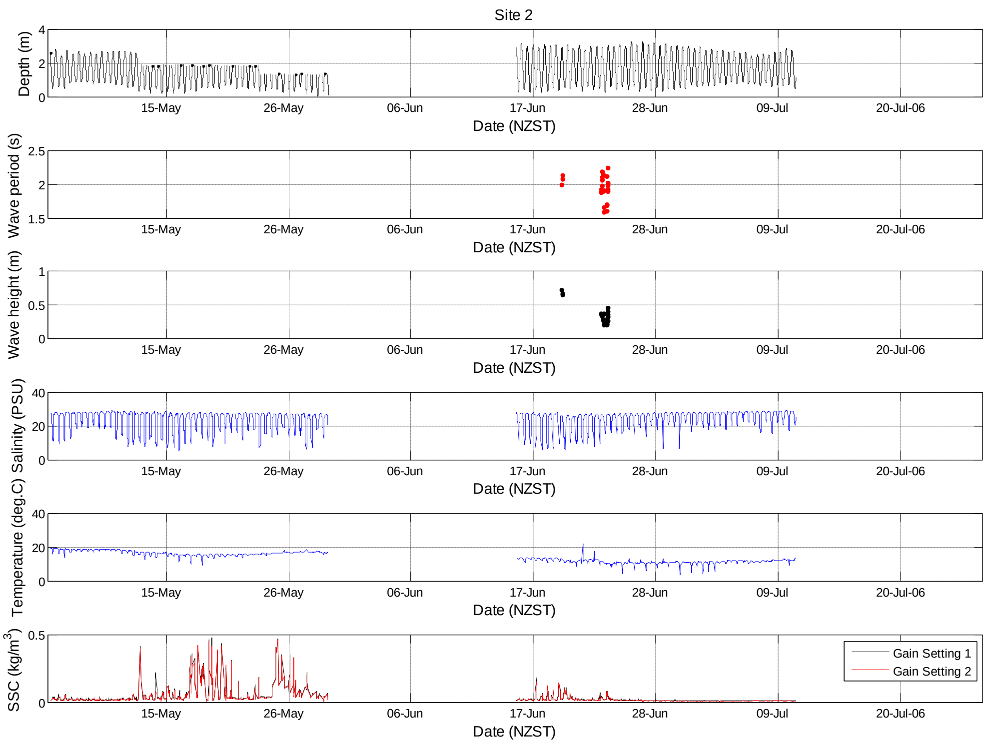


4.3.2 Site 2 (entrance to Henderson Creek)

Parameters measured by the DOBIE at Site 2 are shown in Figure 7. The DOBIE was found to have been moving on its mooring during the early part of the deployment, which resulted in loss of pressure data around mid-to-high tide. This resulted in data gaps in the record during the second deployment period (4 May to 13 June). As there was not a continuous depth record a complete tidal analysis could not be carried out. This site is relatively sheltered from waves, resulting in only a couple of recorded wave events, with a maximum wave period of 2.2 s and a maximum significant wave height of 0.7 m. Salinity varied over the tidal cycle in the range of 5 to 29 psu, and the mean water temperature was ~14° C. The maximum SSC was 0.47 kgm^{-3}, and the 90^{th} percentile SSC was 0.04 kgm^{-3}.

Figure 7

Parameters measured by the DOBIE at Site 2, 4 May – 27 July 2006.

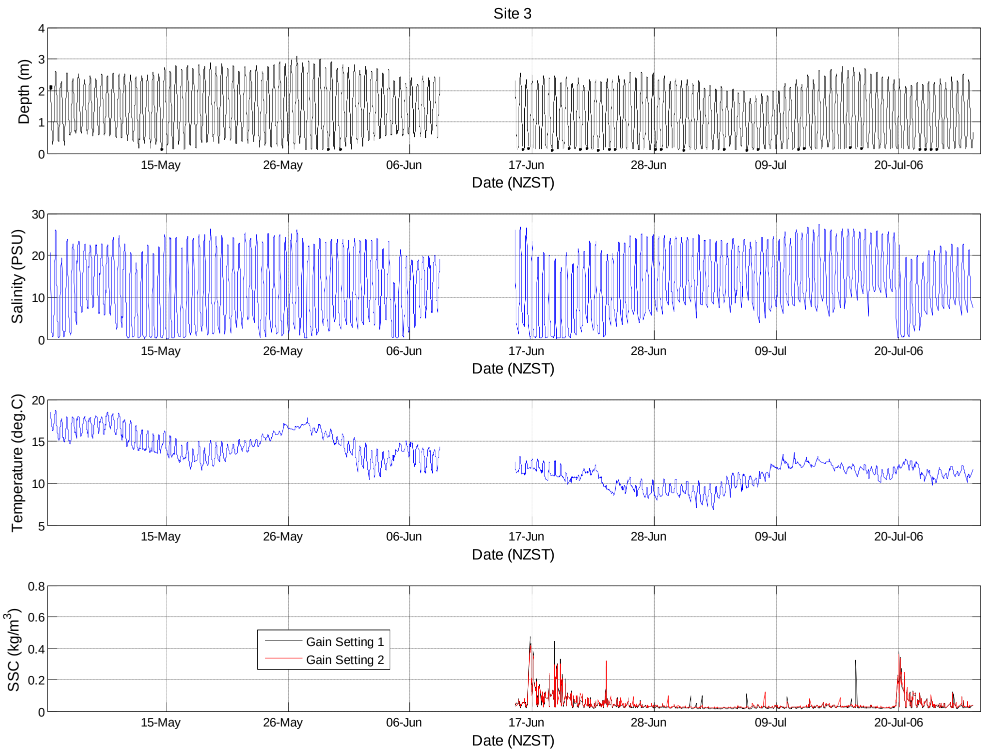


4.3.3 Site 3 (Henderson Creek)

Parameters measured by the DOBIE at Site 3 are shown in Figure 8. The instrument emerged from the water during spring tides during the last deployment period (14 June onwards). This resulted in an incomplete tide record and prevented a complete tidal analysis. No surface waves were detected as this site is very sheltered. Salinity varied over the tidal cycle in the range of 0–27 psu, and the mean water temperature was ~13° C. During the second deployment period (4 May to 3 June) a faulty cable connection resulted in unreliable OBS data. During the third deployment period (14 June onwards) SSC varied over the tidal cycle; the maximum SSC was 0.48 kgm^{-3}, and the 90th percentile SSC was 0.08 kgm^{-3}.

Figure 8

Parameters measured by the DOBIE at Site 3, 4 May – 27 July 2006.

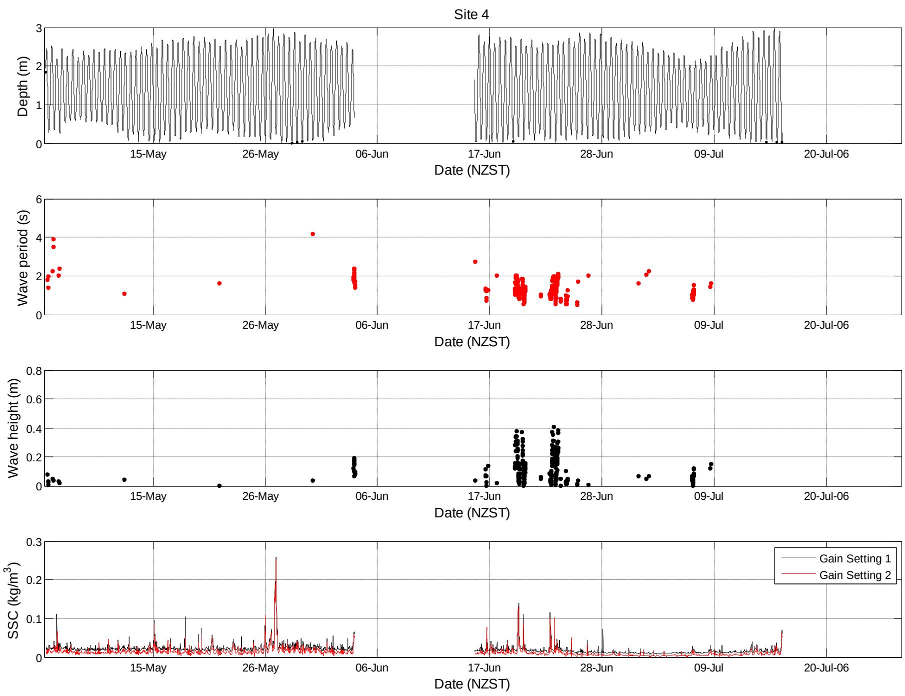


4.3.4 Site 4 (approach channel to the Whau)

Parameters measured by the DOBIE at Site 4 are shown in Figure 9. The instrument emerged from the water during spring low tides, thus preventing a complete tidal analysis being done. Several wave events were recorded: the maximum wave period was 4.0 s and the maximum significant wave height was 0.4 m. The maximum SSC was 0.25 kgm^{-3}, and the 90th percentile SSC was 0.03 kgm^{-3}. SSC varied over the tidal cycle and was also raised by wave activity.

Figure 9

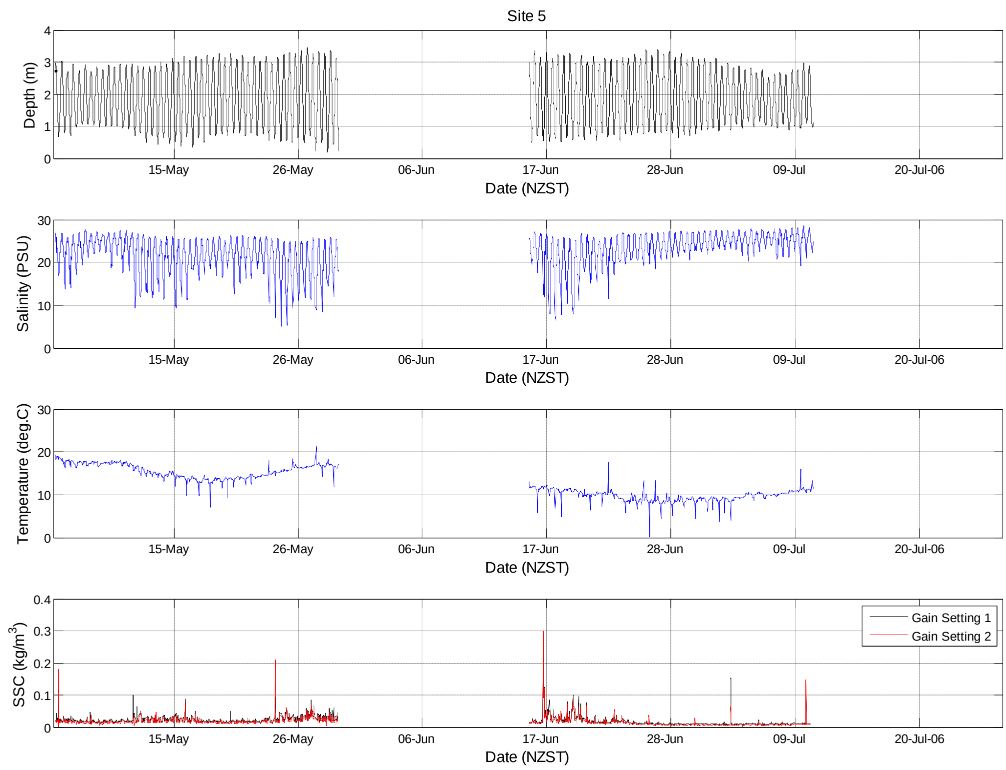
Parameters measured by the DOBIE at Site 4, 4 May – 27 July 2006.



4.3.5 Site 5 (Upper Whau)

Parameters measured by the DOBIE at Site 5 are shown in Figure 10. The mean depth was 1.87 m with a range of ±1.6 m. The magnitude of the M_2 tidal component was 1.19 m and the magnitude of the S_2 component was 0.19 m. No surface waves were detected as this site is sheltered. Salinity varied over the tidal cycle in the range of 5–29 psu, and the mean water temperature was ~13° C. The maximum SSC was 0.30 kgm^{-3}, and the 90^{th} percentile SSC was 0.03 kgm^{-3}.

Figure 10
Parameters measured by the DOBIE at Site 5, 4 May – 27 July 2006.

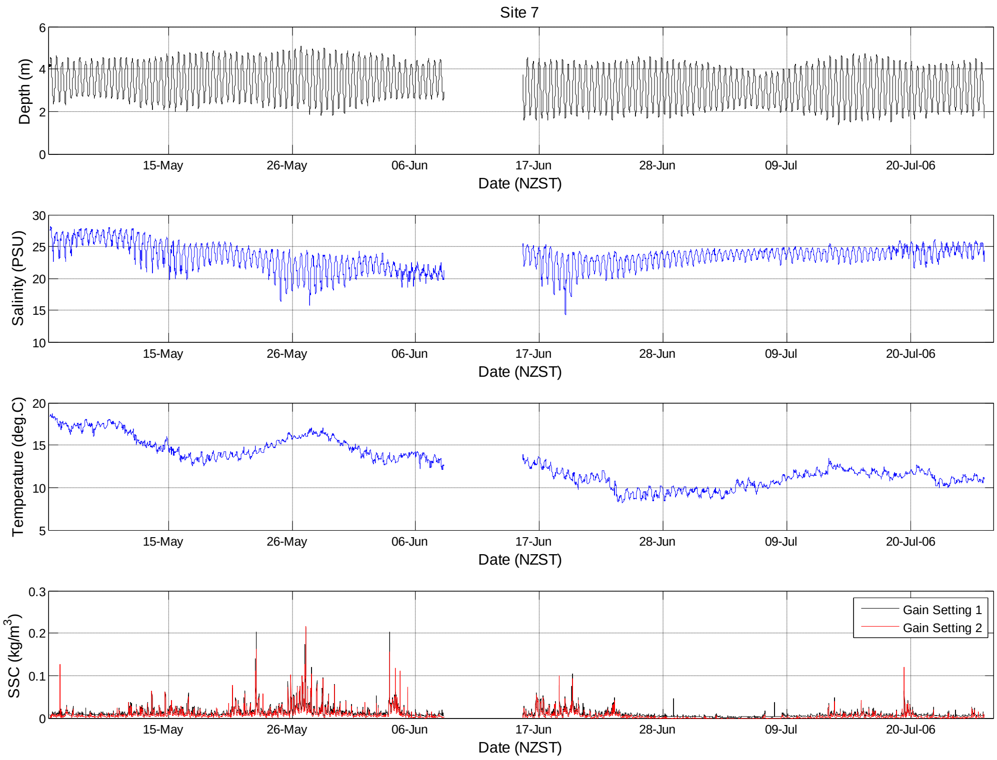


4.3.6 Site 7 (Entrance to the Whau)

Parameters measured by the DOBIE at Site 7 are shown in Figure 11. The mean depth was 3.28 m with a range of ±1.60 m. The magnitude of the M_2 tidal component was 1.18 m and the magnitude of the S_2 component was 0.18 m. The instrument was located too far below the water surface to detect surface waves. In addition, the site is sheltered. Salinity varied over the tidal cycle in the range of 14–28 psu, and the mean water temperature was ~13° C. The maximum SSC was 0.21 kgm^{-3}, and the 90th percentile SSC was 0.03 kgm^{-3}.

Figure 11

Parameters measured by the DOBIE at Site 7, 4 May – 27 July 2006.

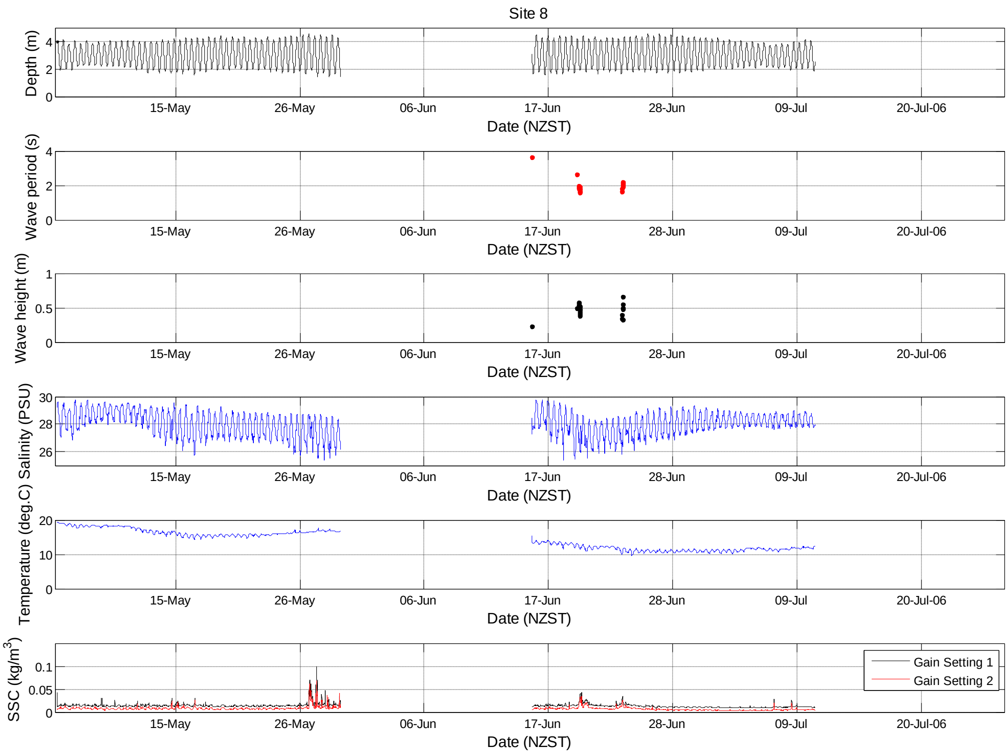


4.3.7 Site 8 (middle basin)

Parameters measured by the DOBIE at Site 8 are shown in Figure 12. The mean depth was 3.03 m with a range of ±1.6 m. The magnitude of the M_2 tidal component was 1.17 m and the magnitude of the S_2 component was 0.18 m. Waves were detected on a couple of occasions: the maximum wave period was 3.8 s and the maximum significant wave height was 0.7 m. Salinity varied over the tidal cycle in the range of 25–30 psu, and the mean water temperature was ~14° C. The maximum SSC was 0.10 kgm^{-3}, and the 90th percentile SSC was 0.02 kgm^{-3}.

Figure 12

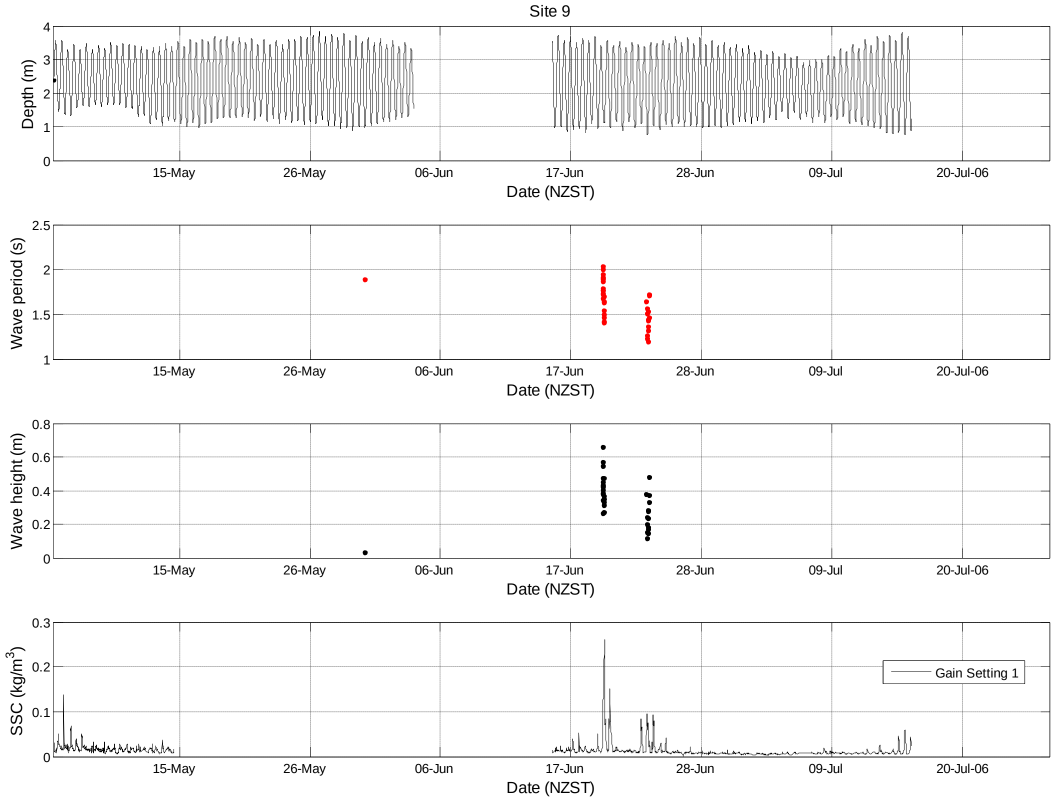
Parameters measured by the DOBIE at Site 8, 4 May – 27 July 2006.



4.3.8 Site 9 (Shoal Bay)

Parameters measured by the DOBIE at Site 9 are shown in Figure 13. The mean depth was 2.30 m with a range of ±1.5 m. The magnitude of the M_2 tidal component was 1.16 m and the magnitude of the S_2 component was 0.17 m. Waves were detected on a couple of occasions: the maximum wave period was 2.1 s and the maximum significant wave height was 0.7 m. The maximum SSC was 0.26 kgm^{-3}, and the 90th percentile SSC was 0.02 kgm^{-3}.

Figure 13
Parameters measured by the DOBIE at Site 9, 4 May – 27 July 2006.

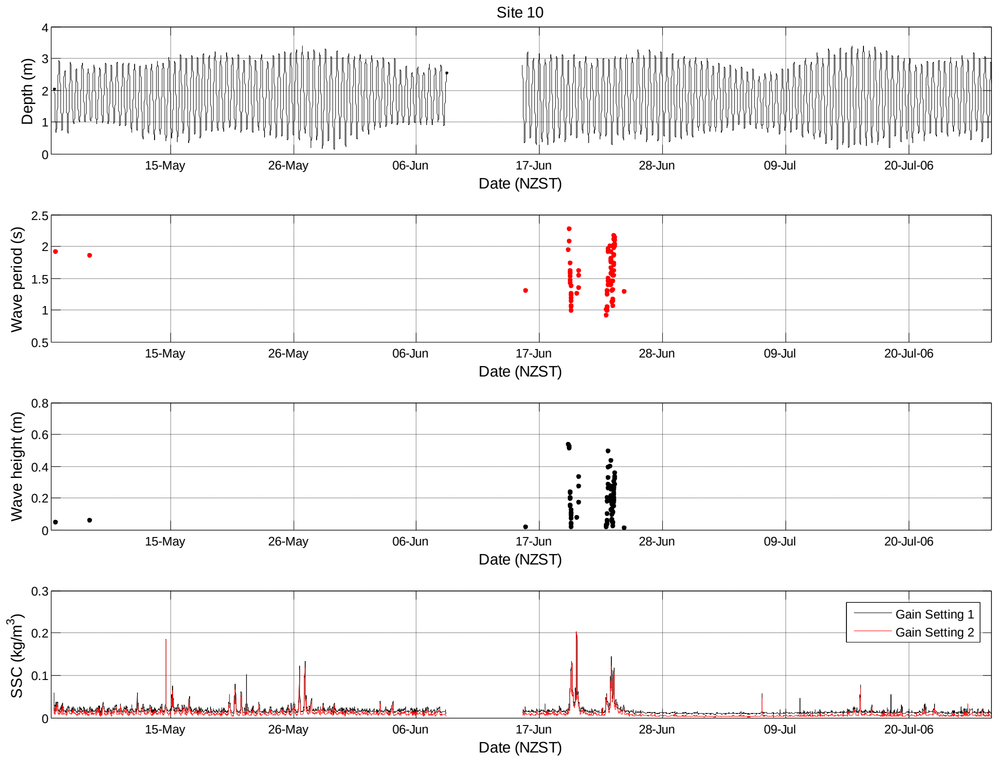


4.3.9 Site 10 (approach channel to Henderson Creek)

Parameters measured by the DOBIE at Site 10 are shown in Figure 14. The mean depth was 1.79 m with a range of ±1.6 m. The magnitude of the M_2 tidal component was 1.19 m and the magnitude of the S_2 component was 0.15 m. Waves were detected on a couple of occasions: the maximum wave period was 2.3 s and the maximum significant wave height was 0.5 m. The maximum SSC was 0.20 kgm^{-3}, and the 90th percentile SSC was 0.02 kgm^{-3}.

Figure 14

Parameters measured by the DOBIE at Site 10, 4 May – 27 July 2006.

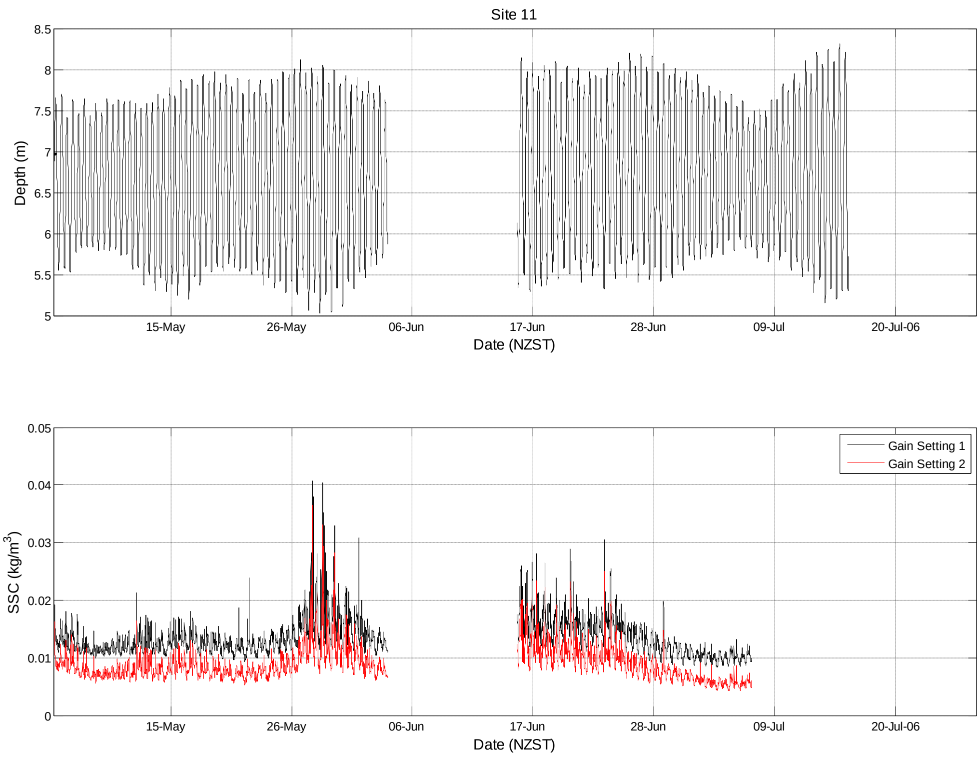


4.3.10 Site 11 (Harbour Bridge)

Parameters measured by the DOBIE at Site 11 are shown in Figure 15. The mean depth was 6.68 m with a range of ±1.6 m. The magnitude of the M_2 tidal component was 1.15 m and the magnitude of the S_2 component was 0.18 m. The instrument was located too far below the water surface to detect waves. Fouling of the OBS sensor during the latter part of the last deployment resulted in unreliable SSC data from early July. SSC varied over the tidal cycle; the maximum SSC was 0.04 kgm^{-3}. The 90th percentile SSC was 0.02 kgm^{-3}.

Figure 15

Parameters measured by the DOBIE at Site 11, 4 May – 27 July 2006.



4.4 Results – S4 current meter

Figure 16 shows mean water depth during the second deployment period, 28 April to 19 June, which spanned two complete spring–neap–spring tidal cycles. The mean depth was 2.02 m, the spring tidal range was 3.06 m, and the neap tidal range was 1.8 m.

Figure 17 shows current speeds during the three deployment periods. The mean current speed was 0.13 ms^{-1}. Peak current speed during spring tides reached 0.50 ms^{-1}, and during neap tides it was <0.20 ms^{-1}.

Current roses for each of the three deployment periods (Figure 18) show essentially rectilinear currents, with very little cross-channel flow. This is confirmed by the tidal analysis (Table 3), which shows that the M_2 tidal component has an inclination of ~45 ° relative to true North, which corresponds to the alignment of the channel at the deployment site. The tidal analysis also shows a small residual current (Z_0< cm^4s^{-1}), which arises from a combination of freshwater outflow from Henderson Creek and a small tidal asymmetry at this site.

Figure 16
Water depth measured by S4 current meter deployed at Henderson Creek, Site 2 (28 April to 19 June 2006).

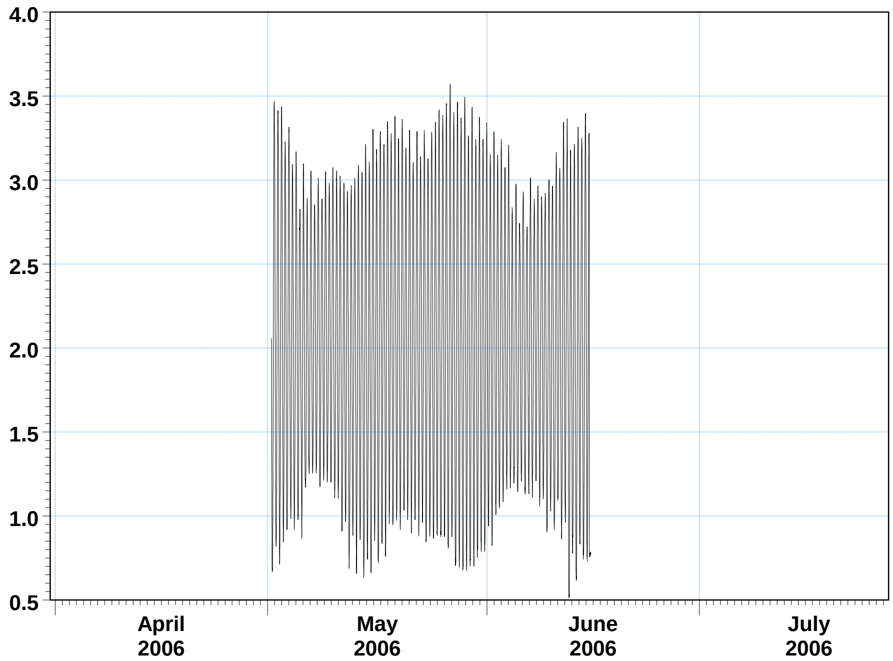


Figure 17

Current speed measured by S4 current meter deployed at Henderson Creek, Site 2, 28 March to 27 July 2006.

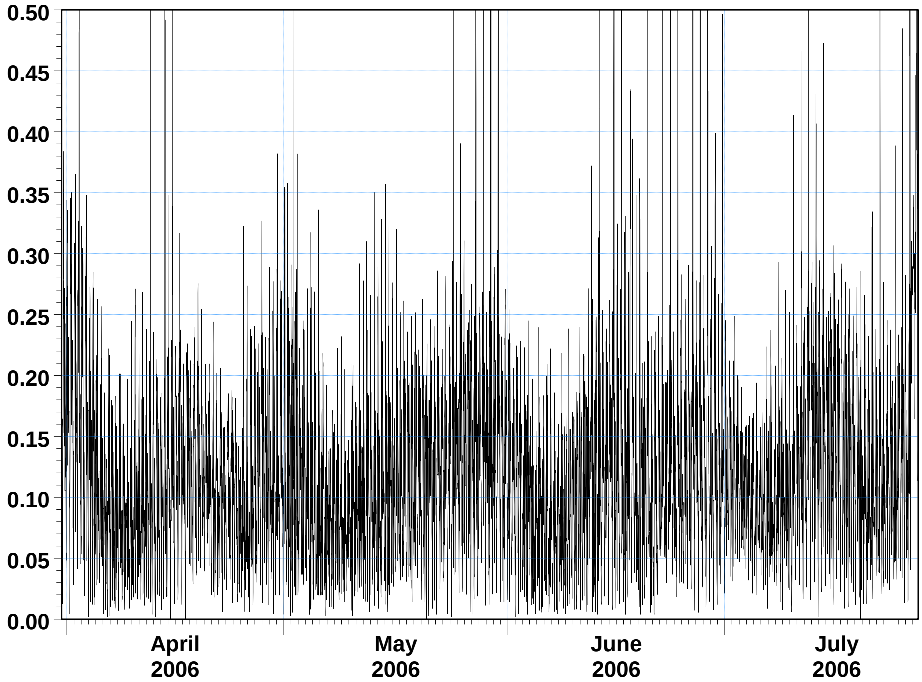
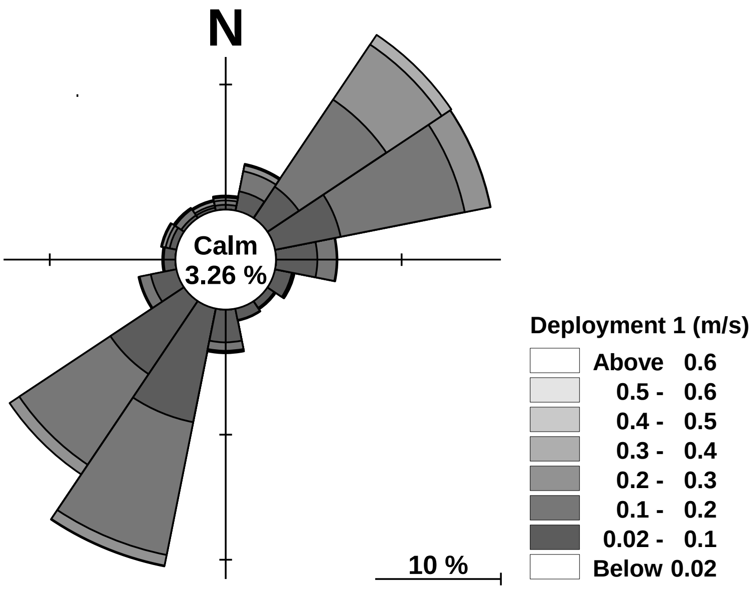
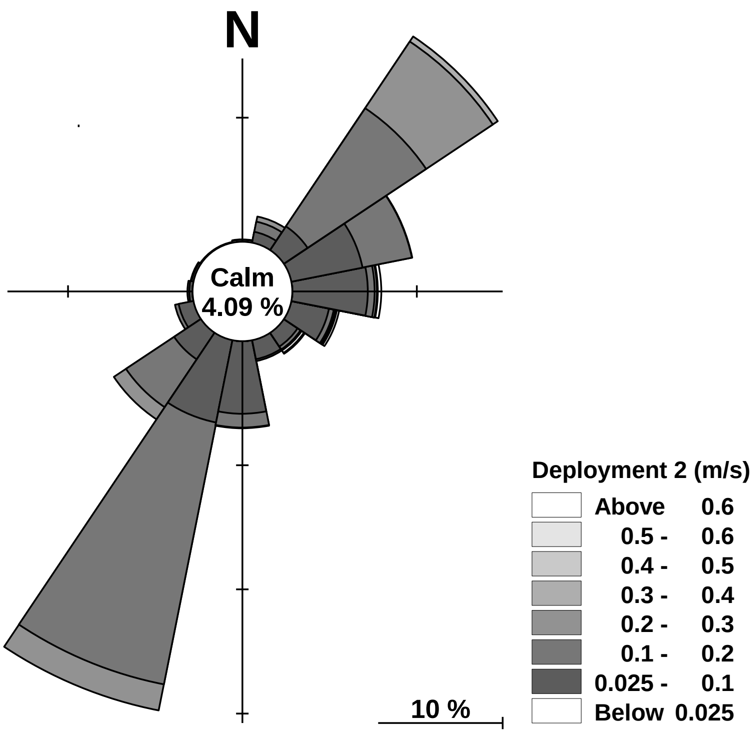


Figure 18

Current roses for the first (28 March to 2 May 2006), second (28 April to 19 June 2006) and third (13 June to 27 July) S4 current-meter deployments at Henderson Creek, Site 2.





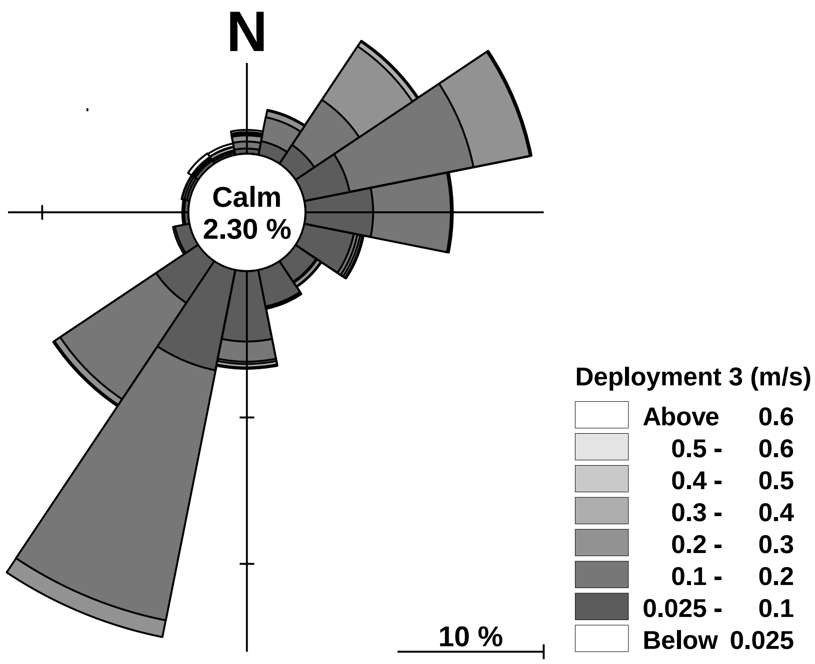

N
Calm
2.30 %
10 %
Deployment 3 (m/s)
Above 0.6
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
0.025 - 0.1
Below 0.025

Table 3

Major and minor current ellipse speeds (ms^{-1}) plus inclination of major axis (◦ relative to true north) and phase (relative to Greenwich Mean Time) of the tidal constituents from measured currents at Henderson Creek, Site 2. First deployment period was 28 March to 2 May 2006 second was 28 April to 19 June 2006 and third was13 June to 27 July 2006.

Constituent name	Deployment 1				Deployment 2				Deployment 3			
	Major speed (ms^{-1})	Minor speed (ms^{-1})	Inclination (° relative to true north)	Phase (° GMT)	Major speed (ms^{-1})	Minor speed (ms^{-1})	Inclination (° relative to true north)	Phase (° GMT)	Major speed (ms^{-1})	Minor speed (ms^{-1})	Inclination (° relative to true north)	Phase (° GMT)
M2	0.151	0.023	43.5	304.9	0.142	0.013	45.5	301.6	0.154	-0.012	52.1	308.3
N2	0.036	-0.007	66.3	312.5	0.036	0.002	36.4	262.1	0.042	-0.015	38.6	263.0
M4	0.036	0.026	72.0	346.6	0.020	0.017	93.4	346.0	0.039	-0.005	72.4	336.4
Z0	0.033	0.000	126.4	180.0	0.025	0.000	177.3	180.0	0.034	0.000	131.5	180.0
MM	0.023	0.015	48.5	347.1	0.006	0.001	151.1	120.9	0.016	0.002	10.2	76.1
L2	0.022	0.008	172.7	1.5	0.029	0.006	42.8	18.6	0.021	-0.003	153.8	132.0
S2	0.020	0.010	16.8	343.5	0.023	0.004	36.9	11.0	0.027	-0.007	22.8	31.0
M6	0.019	0.012	18.8	345.1	0.005	0.001	25.6	306.8	0.018	-0.013	88.5	315.9
MSF	0.016	0.001	161.4	57.3	0.012	0.005	10.3	249.8	0.014	-0.006	17.3	352.4
MU2	0.016	-0.001	10.9	172.8	0.005	0.003	84.4	226.1	0.023	-0.004	18.8	358.4
MN4	0.016	-0.003	106.5	330.5	0.015	0.008	50.1	291.4	0.013	-0.008	109.2	243.5
MS4	0.016	0.004	177.5	149.7	0.014	0.004	14.2	321.1	0.012	-0.004	22.0	85.8
M3	0.015	0.001	0.6	225.0	0.004	0.001	17.1	14.3	0.011	-0.006	140.4	242.8
2SM6	0.015	-0.002	157.1	220.5	0.007	-0.004	66.8	345.4	0.007	0.001	121.9	51.6

5 Data from CTD Surveys

5.1 CTD Site 1 (entrance to Henderson Creek)

Data at this site were collected around high tide on 14 June and on the falling tide on 16 June 2006 (Figure 19).

At high tide, salinity varied between 10 and 30 psu near the surface, increased to 30–32 psu at 0.5 m below the surface, and remained uniform from there to the bed (Figure 20). On the falling tide, the water column was well-mixed, with salinity ranging between 28 and 32 psu (Figure 21).

Figure 19
Measured tides and sampling times (o) for the CTD surveys at CTD Site 1 (entrance to Henderson Creek).

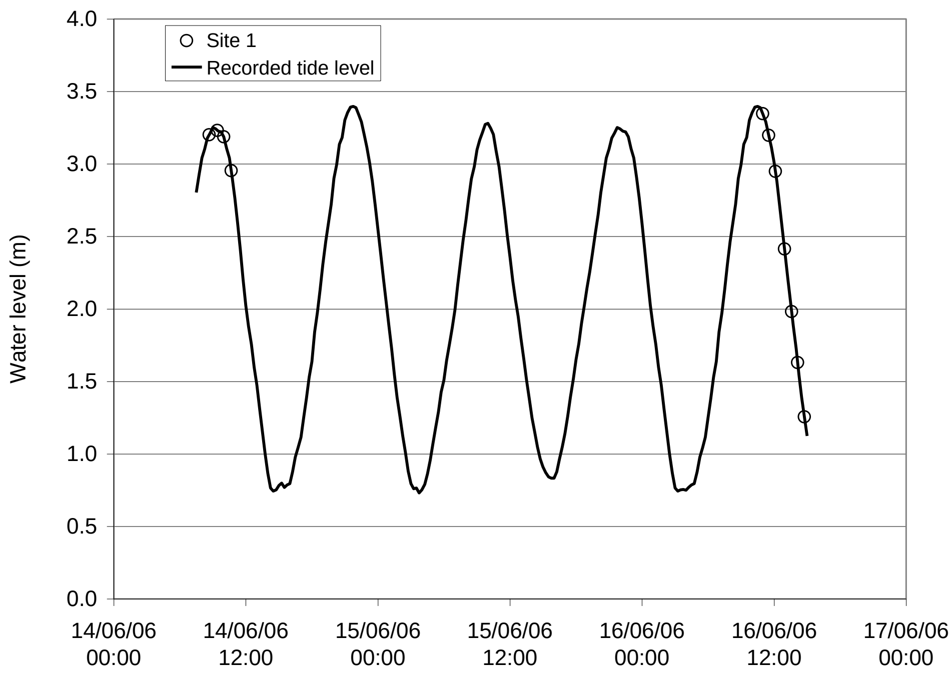


Figure 20

Measured salinity profiles at CTD Site 1 (entrance to Henderson Creek), high tide, 14 June 2006.

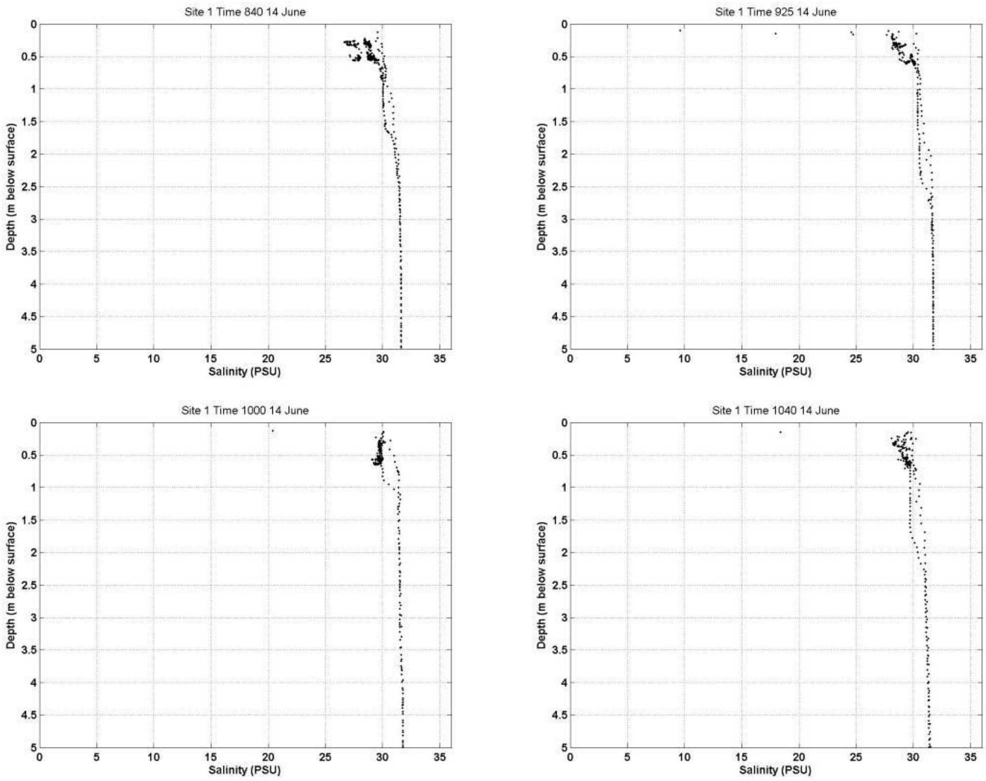
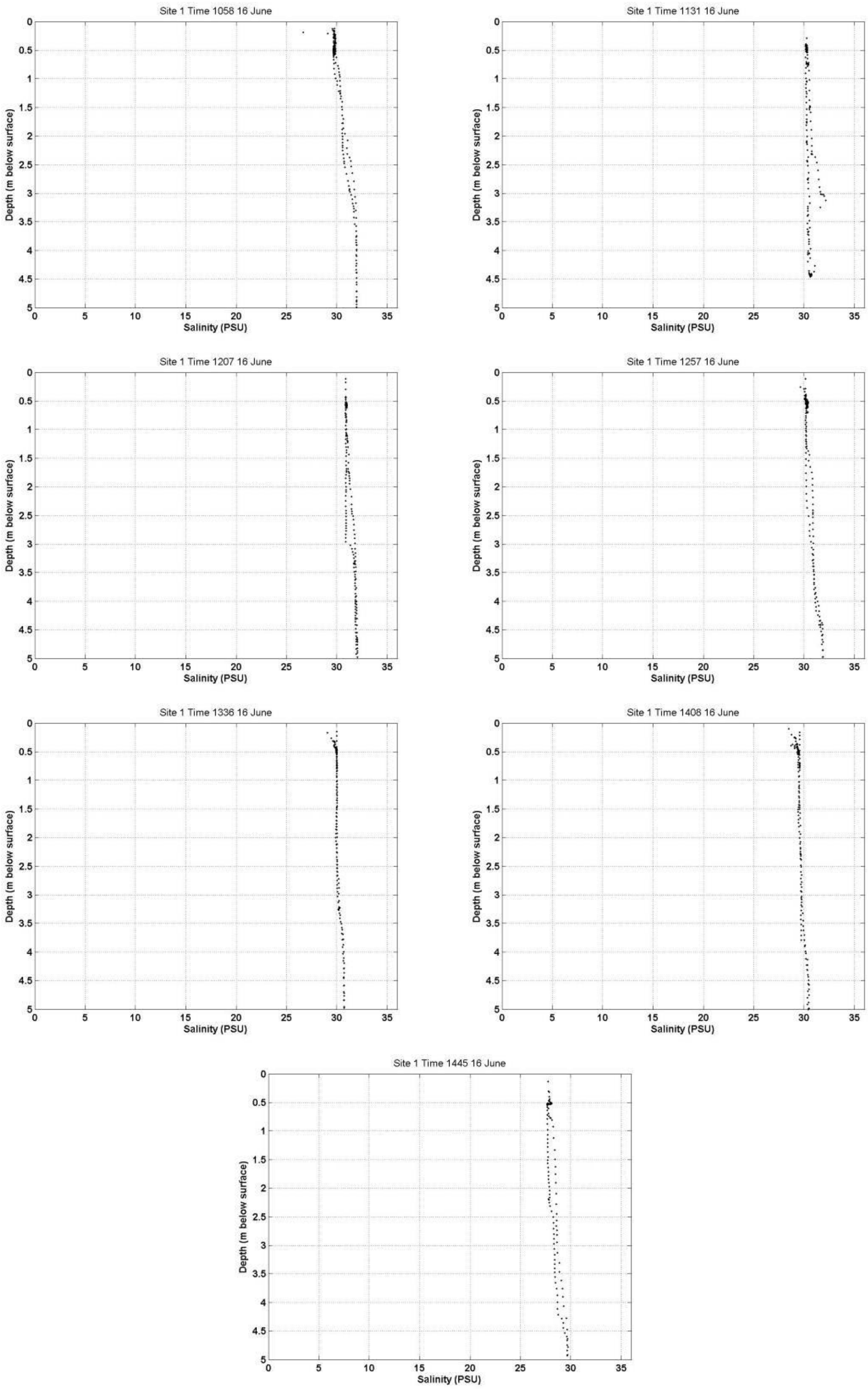


Figure 21

Measured salinity profiles at CTD Site 1 (entrance to Henderson Creek), falling tide, 16 June 2006.



5.2 CTD Site 2 (Henderson Creek)

Data at this site were collected around high tide on 14 June and on the falling tide on 16 June 2006 (Figure 22).

The water column was well-mixed at high tide, and salinity was ~28 psu (Figure 23).The last CTD cast (time 10:49) shows the influence of freshwater inflows. The water column was also well-mixed during the falling tide (Figure 24), with salinity ranging from 30 psu near high tide to 13 psu approaching low tide.

Figure 22

Measured tides and sampling times (o) for the CTD surveys at CTD Site 2 (Henderson Creek).

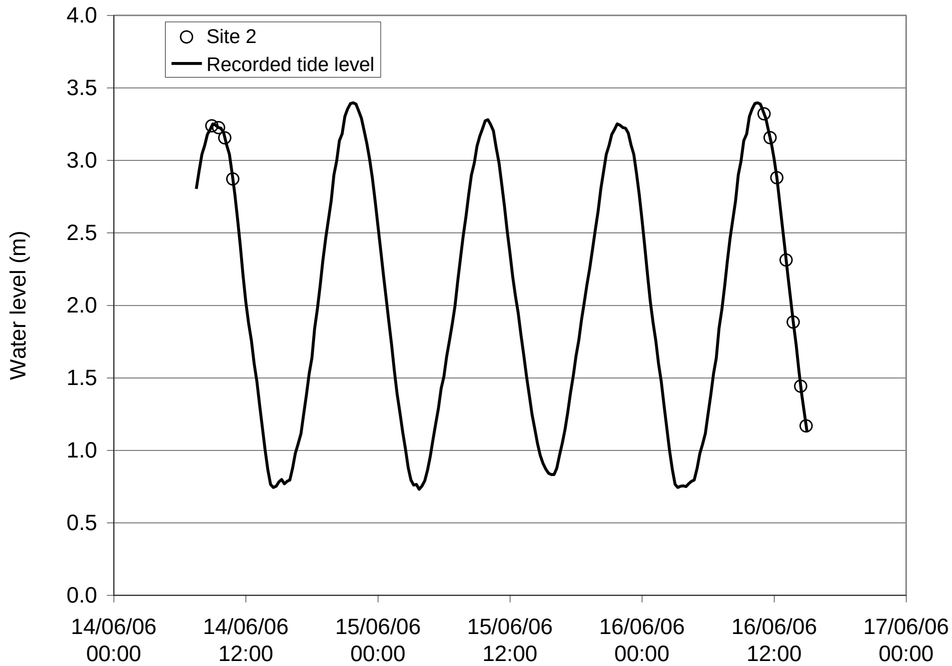


Figure 23

Measured salinity profiles at CTD Site 2 (Henderson Creek), high tide, 14 June 2006.

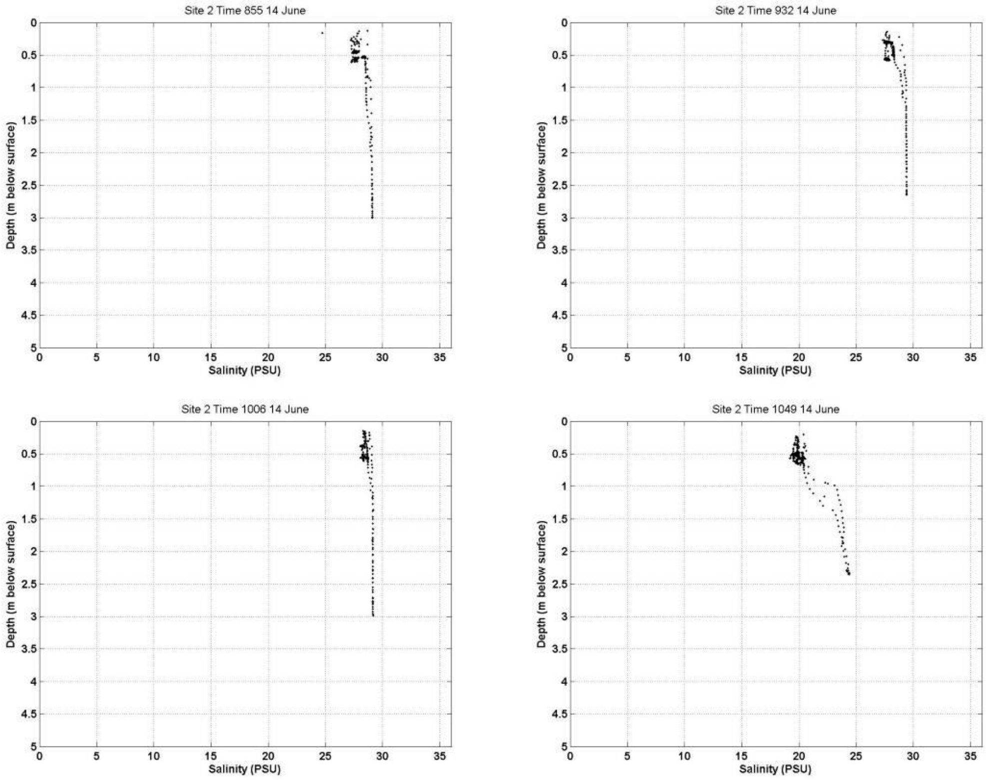
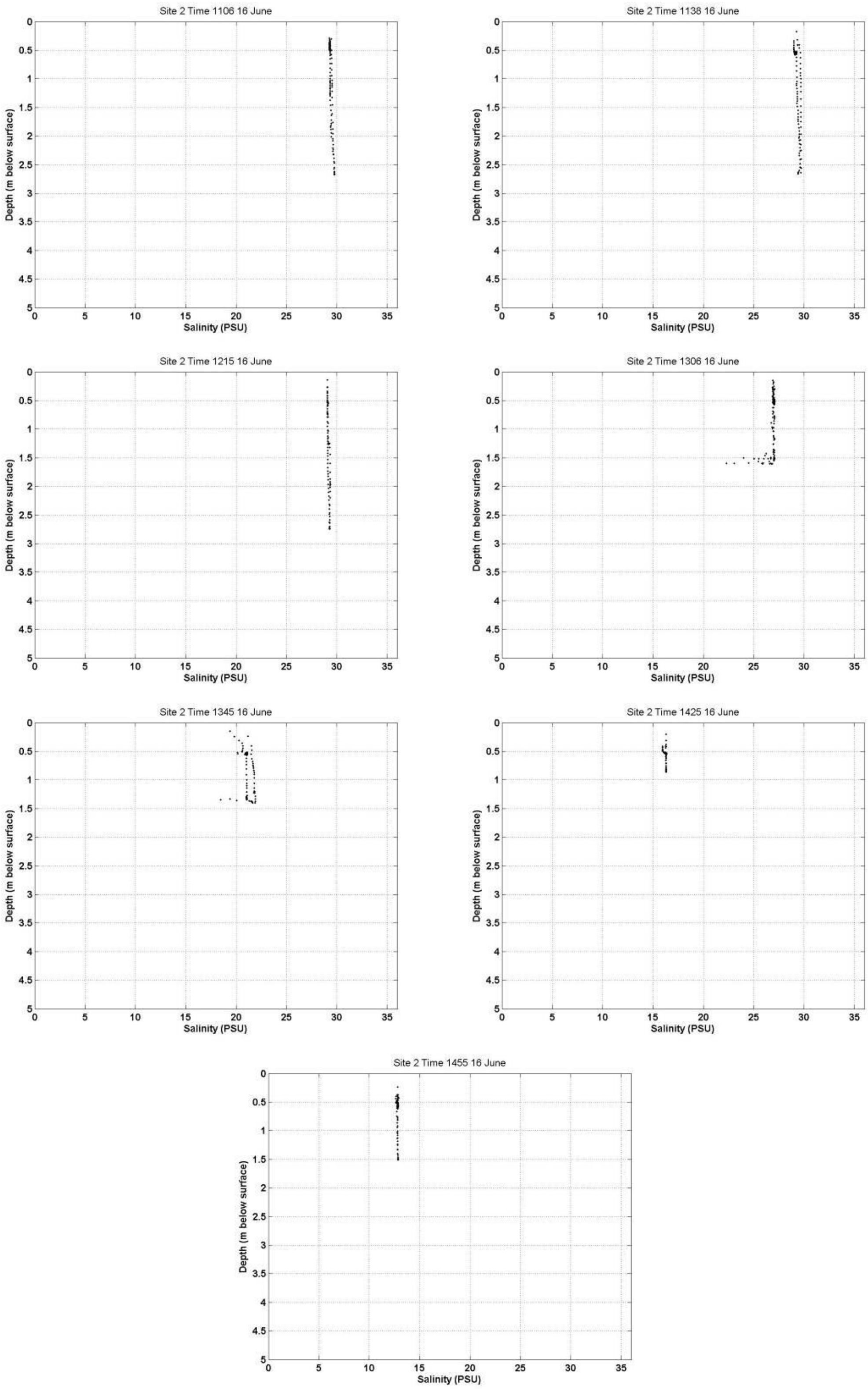


Figure 24

Measured salinity profiles at CTD Site 2 (Henderson Creek), falling tide, 16 June 2006.



5.3 CTD Site 3 (upper Henderson Creek)

Data at this site were collected around high tide on 14 June and on the falling tide on 16 June 2006 (Figure 25).

At high tide there was up to 18 psu salinity difference between the surface and underlying waters (Figure 26). There was also a significant reduction in the depth-averaged salinity during the first 90 minutes of the falling tide. For example, depth-averaged salinity at 9:05 was ~26 psu, which dropped to <8 psu by 10:56. During the falling tide on 16 June salinities ranged from 28 psu at high tide to 8 psu approaching low water (Figure 27). The water column was well-mixed at all times.

Figure 25

Measured tides and sampling times (o) for the CTD surveys at CTD Site 3 (upper Henderson Creek).

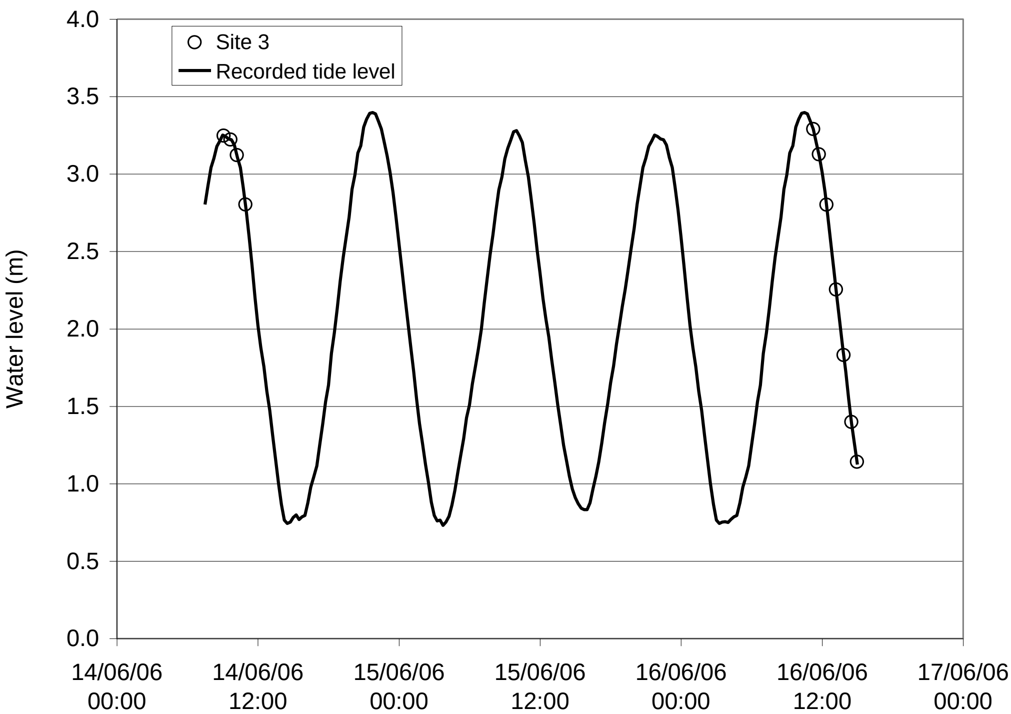


Figure 26

Measured salinity profiles at CTD Site 3 (upper Henderson Creek), high tide, 14 June 2006.

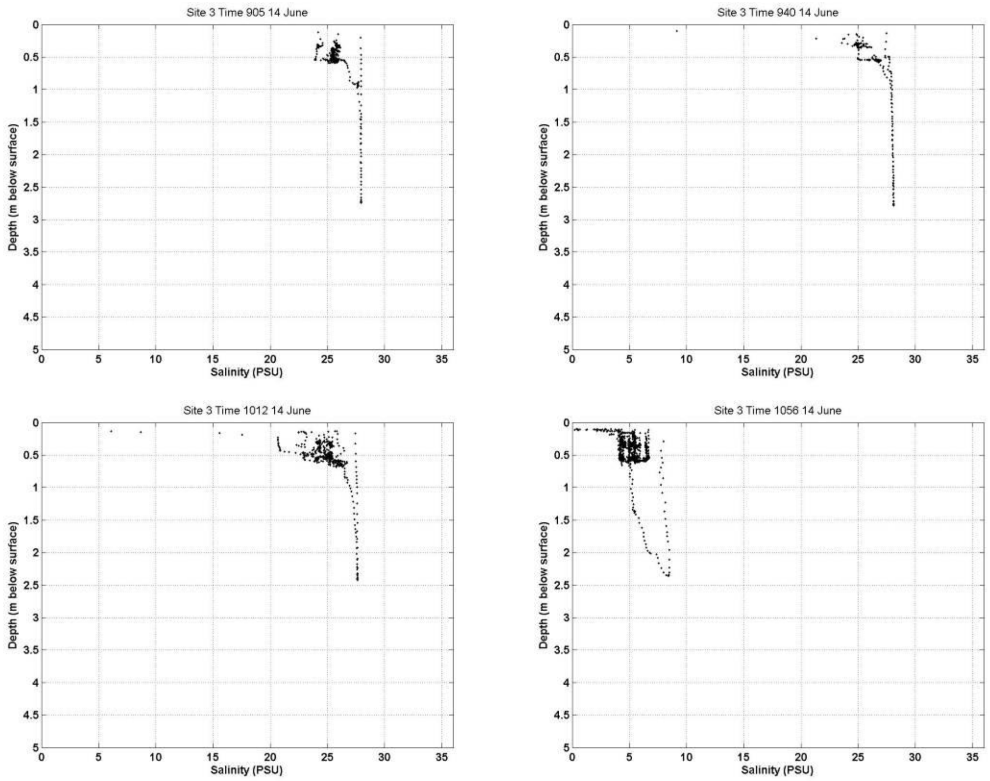
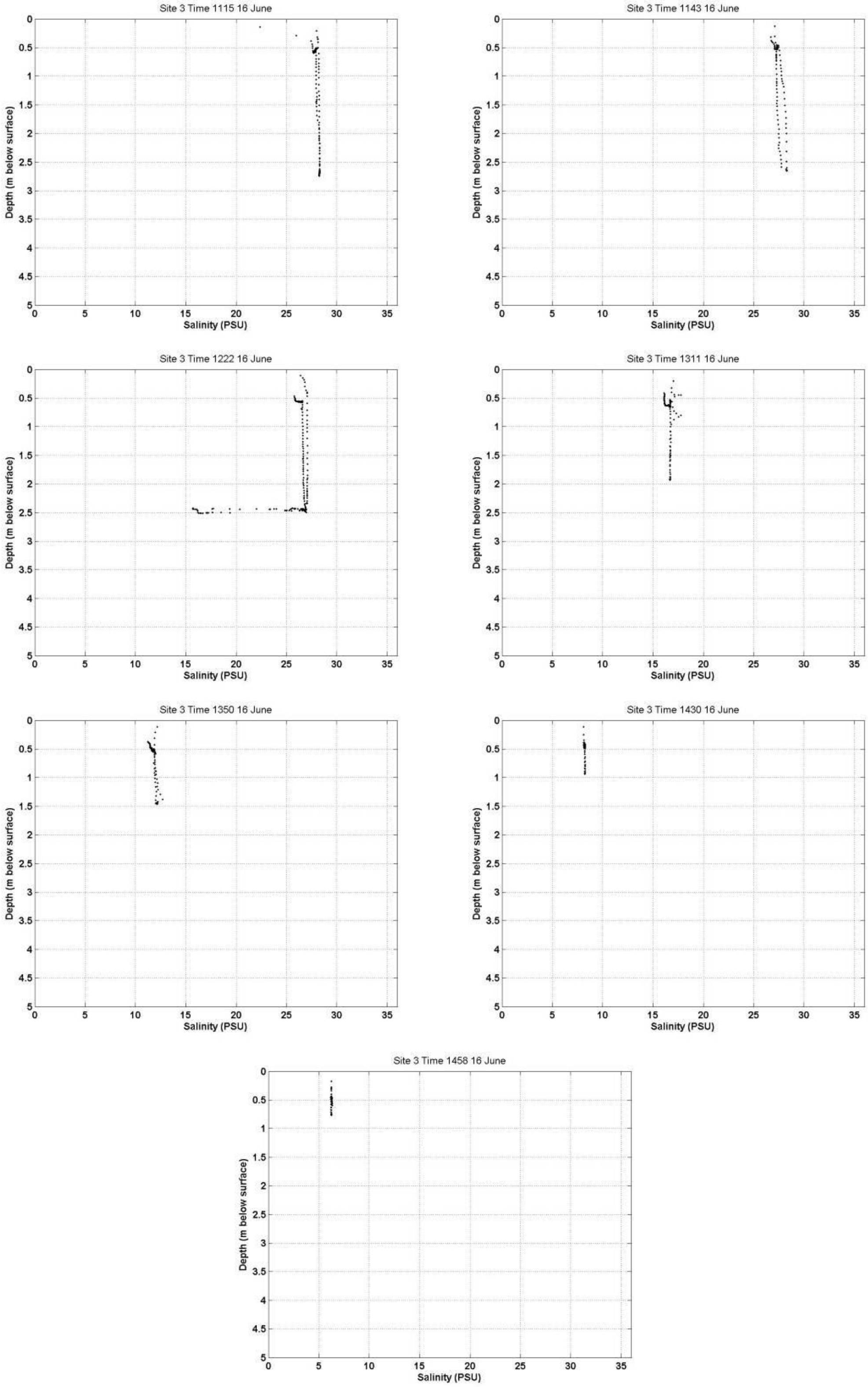


Figure 27

Measured salinity profiles at CTD Site 3 (upper Henderson Creek), falling tide, 16 June 2006.



5.4 CTD Site 4 (near head of Henderson Creek)

Data at this site were collected around high tide on 14 June and on the falling tide on 16 June 2006 (Figure 28).

At high tide there was a difference of 16 psu between the surface and underlying waters (Figure 29). There was also a significant reduction in the depth-averaged salinity during the first hour of the falling tide. For example, depth-averaged salinity at 9:15 was ~22 psu, which dropped to <7 psu by 10:23. The same pattern was seen during the survey carried out on 16 June (Figure 20). During peak currents (11:47–12:30) there was significant vertical structure in the water column, but at other times the water column was well-mixed.

Figure 28

Measured tides and sampling times (o) for the CTD surveys at CTD Site 4 (near head of Henderson Creek).

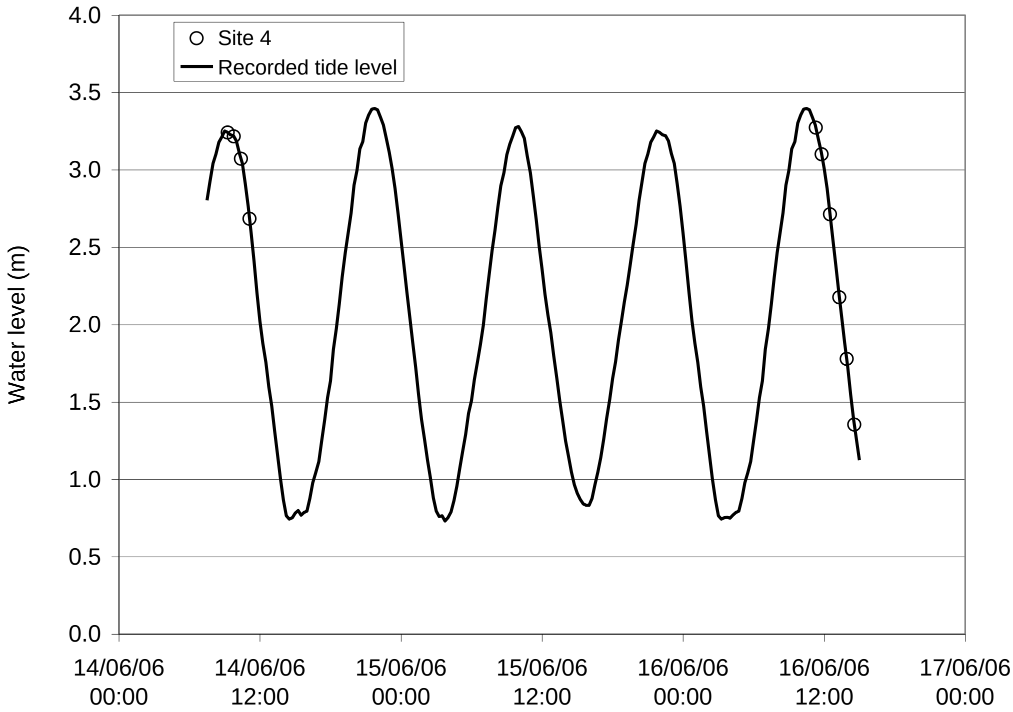


Figure 29

Measured salinity profiles at CTD Site 4 (near head of Henderson Creek), high tide, 16 June 2006.

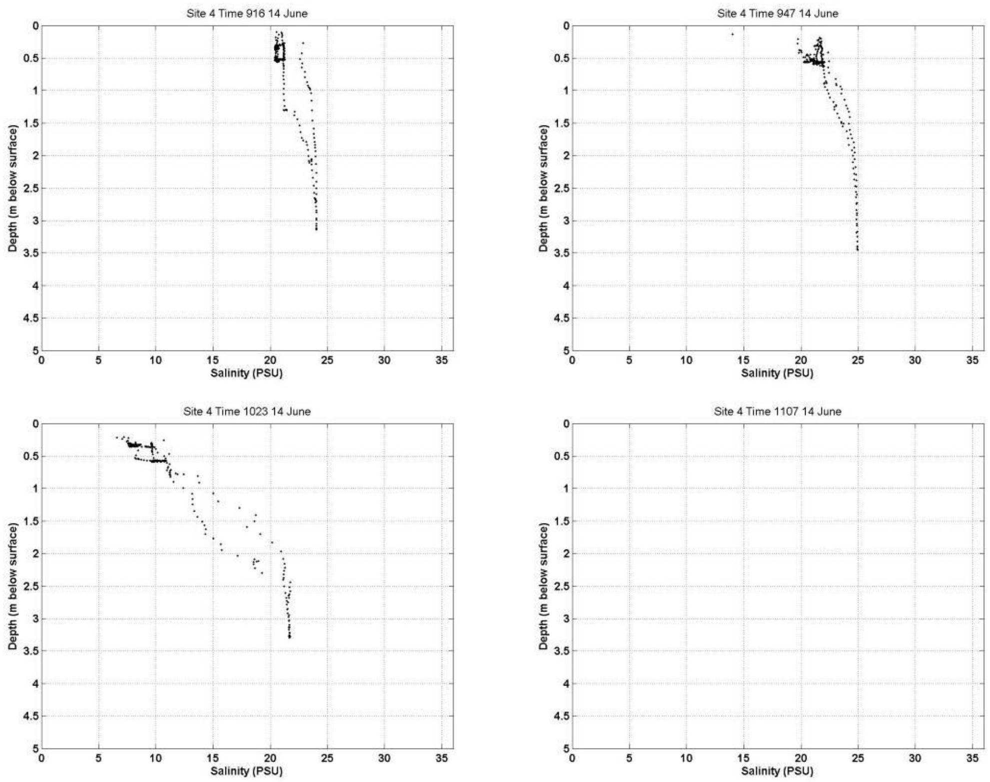
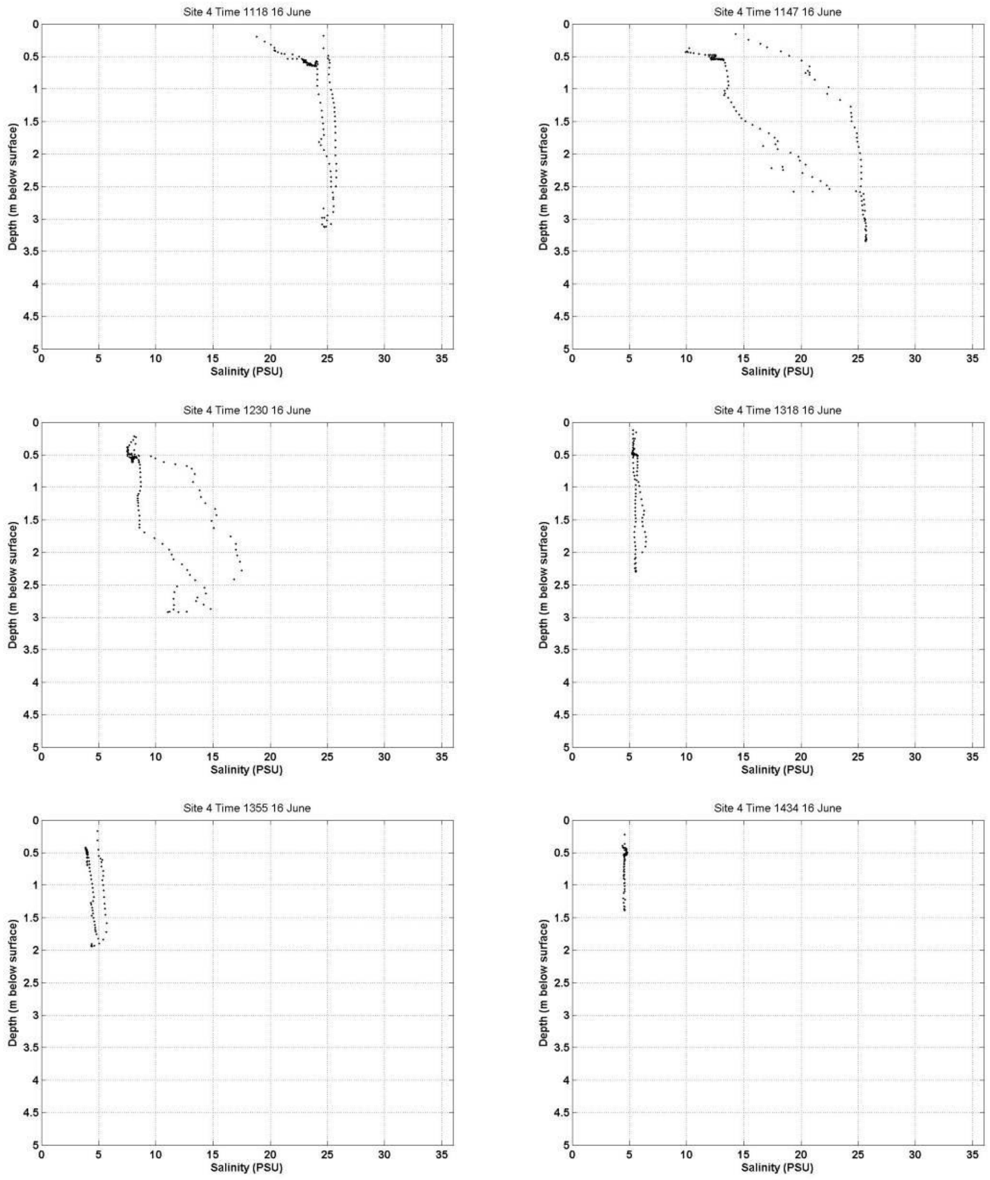


Figure 30

Measured salinity profiles at CTD Site 4 (near head of Henderson Creek), falling tide, 16 June 2006.



5.5 CTD Site 5 (entrance to the Whau)

Data at this site were collected on the falling tide on 15 June 2006 (Figure 31).

The water column was well-mixed at all times, and salinity fell below 30 psu approaching low tide (Figure 32a-b).

Figure 31
Measured tides and sampling times (o) for the CTD surveys at CTD Site 5 (entrance to the Whau).

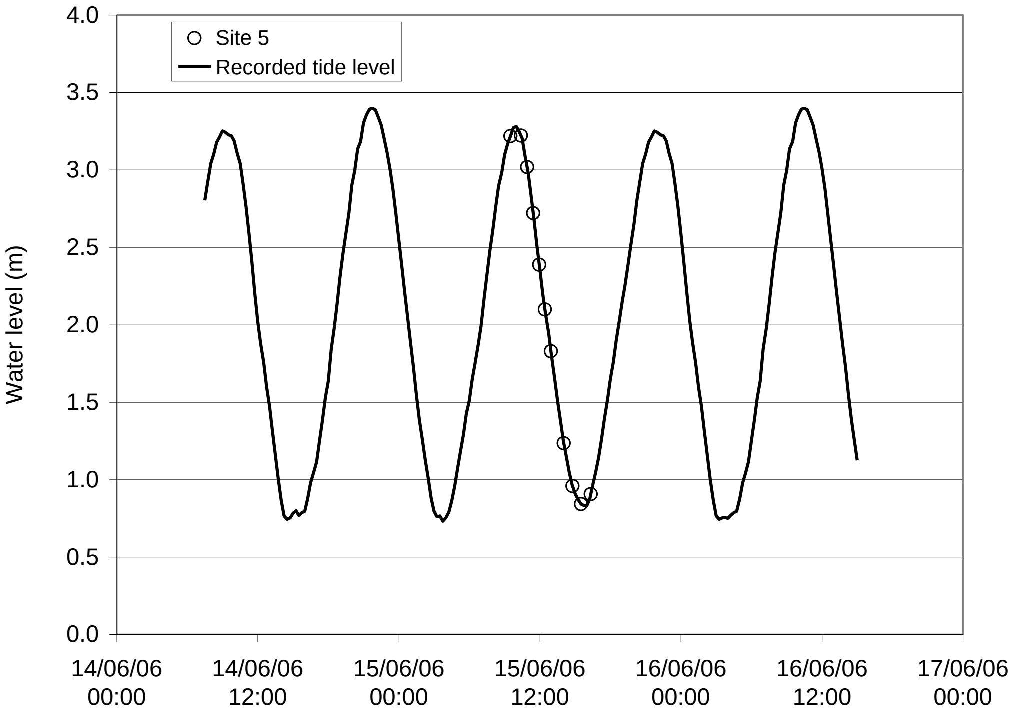


Figure 32a

Measured salinity profiles at CTD Site 5 (entrance to the Whau), falling tide, 15 June 2006.

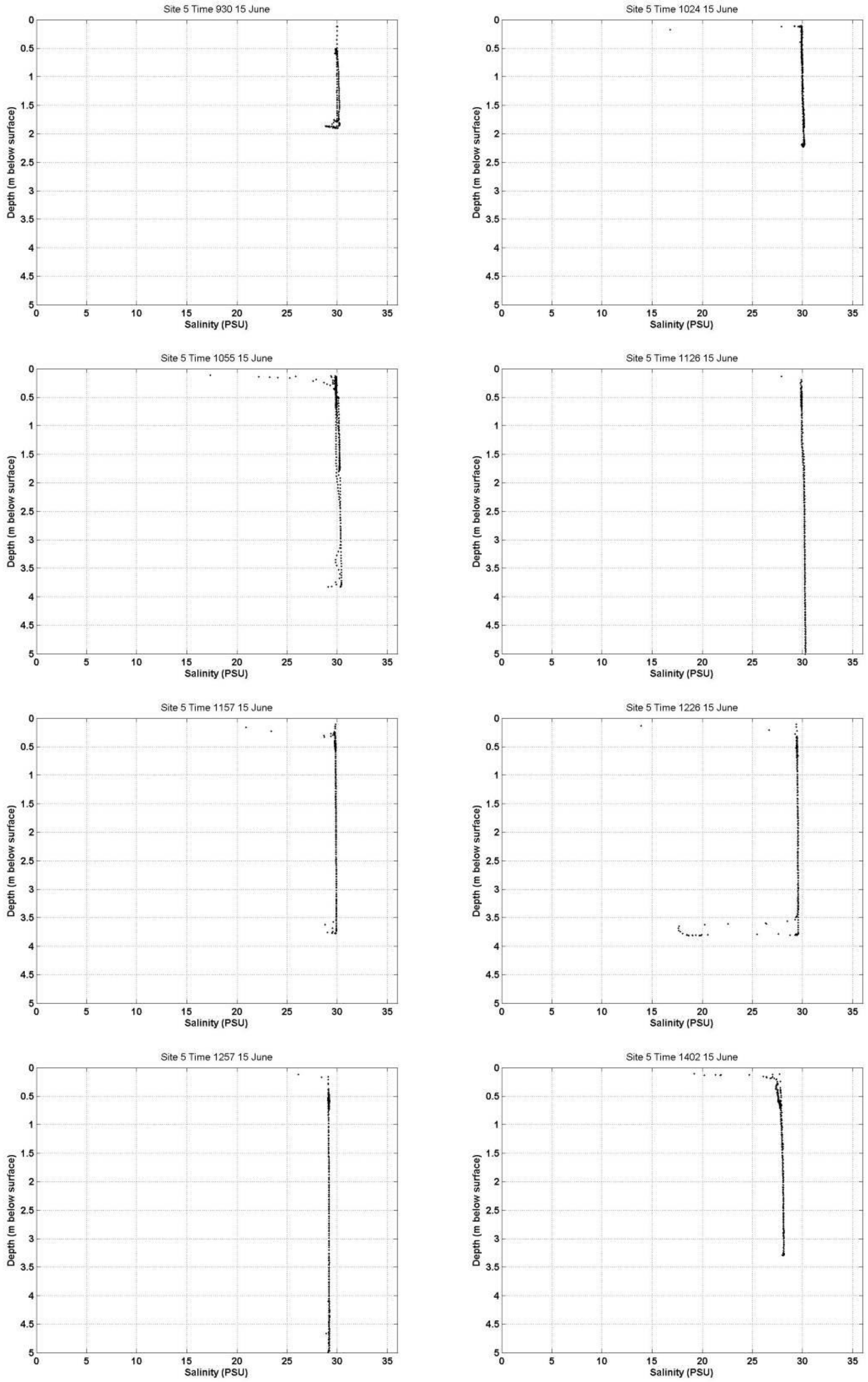
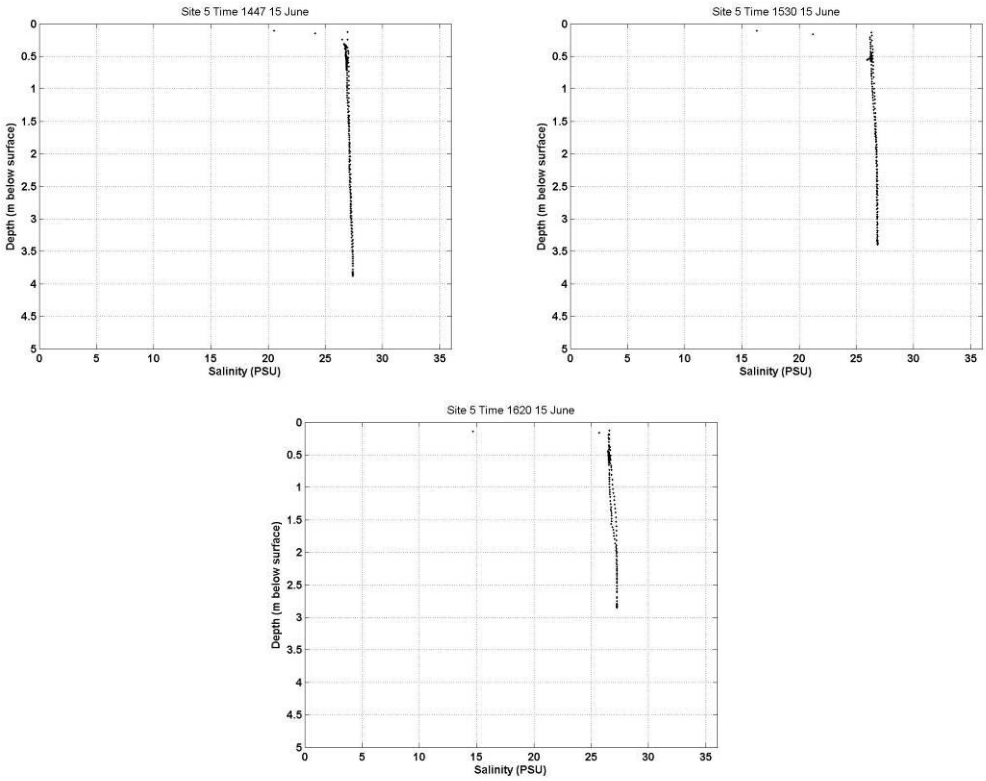


Figure 32b

Measured salinity profiles at CTD Site 5 (entrance to the Whau), falling tide, 15 June 2006.



5.6 CTD Site 6 (the Whau at the Eastern Motorway)

Data at this site were collected on the falling tide on 15 June 2006 (Figure 33).

The water column was well-mixed at all times, and salinity reduced approaching low tide (Figure 34a-b).

Figure 33

Measured tides and sampling times (o) for the CTD surveys at CTD Site 6 (the Whau at the Eastern Motorway).

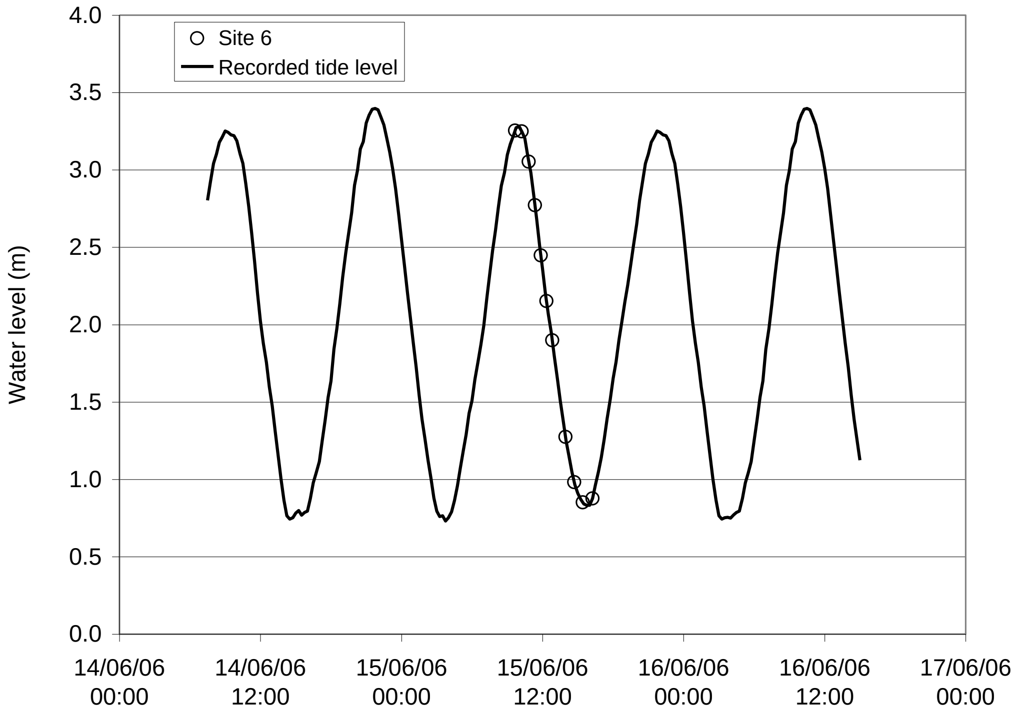


Figure 34a

Measured salinity profiles at CTD Site 6 (the Whau at the Eastern Motorway), falling tide, 15 June 2006.

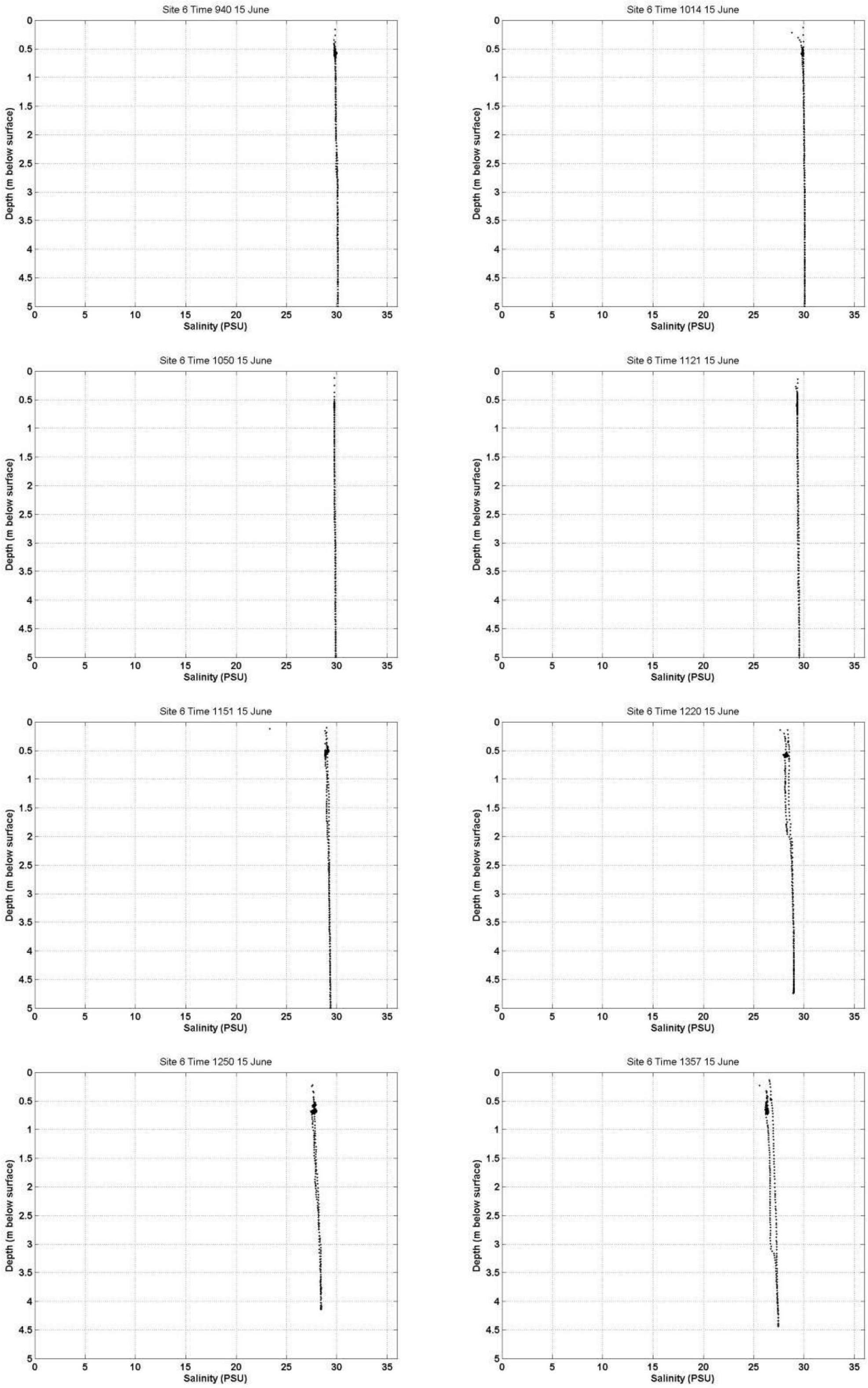
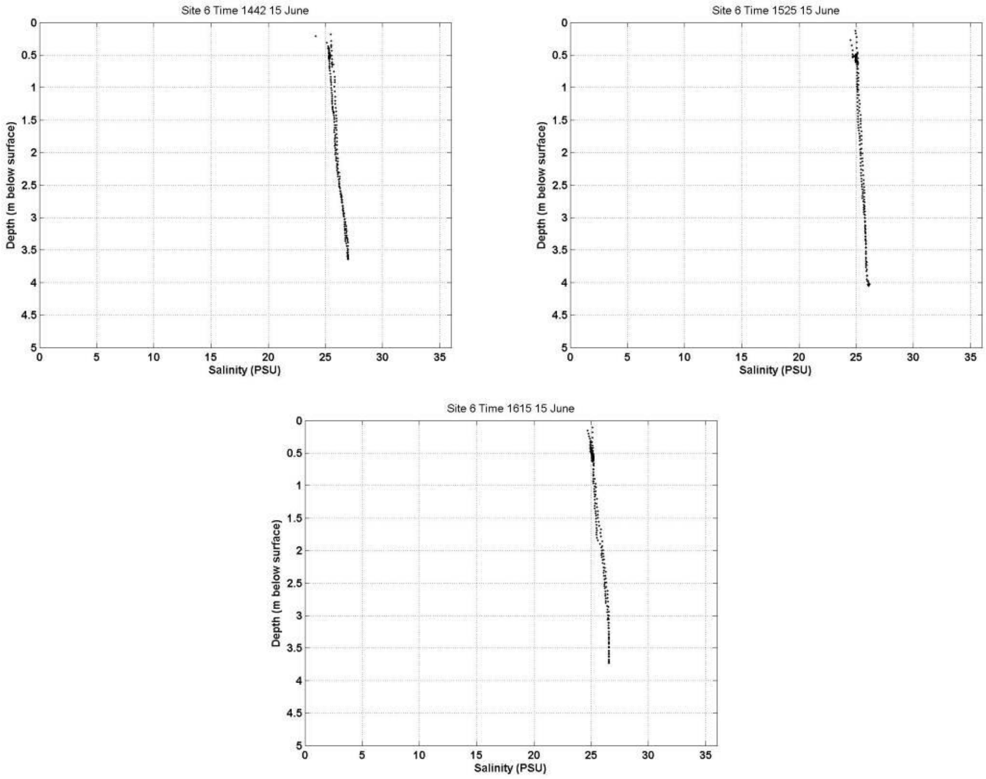


Figure 34b
Measured salinity profiles at CTD Site 6 (the Whau at the Eastern Motorway), falling tide, 15 June 2006.



5.7 CTD Site 7 (middle reaches of the Whau)

Data at this site were collected on the falling tide on 15 June 2006 (Figure 35).

The water column was well-mixed, and salinity reduced approaching low tide (Figure 36a-b). Towards low tide, vertical structure in the water column began to develop, with a 4–5 psu difference between the surface and underlying waters.

Figure 35

Measured tides and sampling times (o) for the CTD surveys at CTD Site 7 (middle reaches of the Whau).

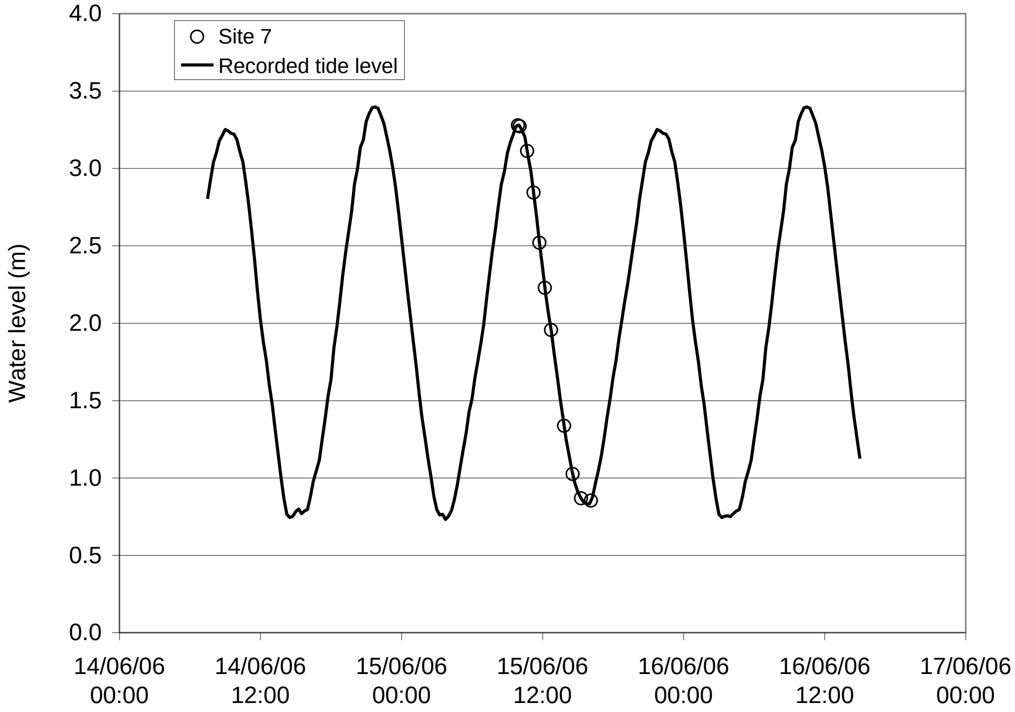


Figure 36a

Measured salinity profiles at CTD Site 7 (middle reaches of the Whau), falling tide, 15 June 2006.

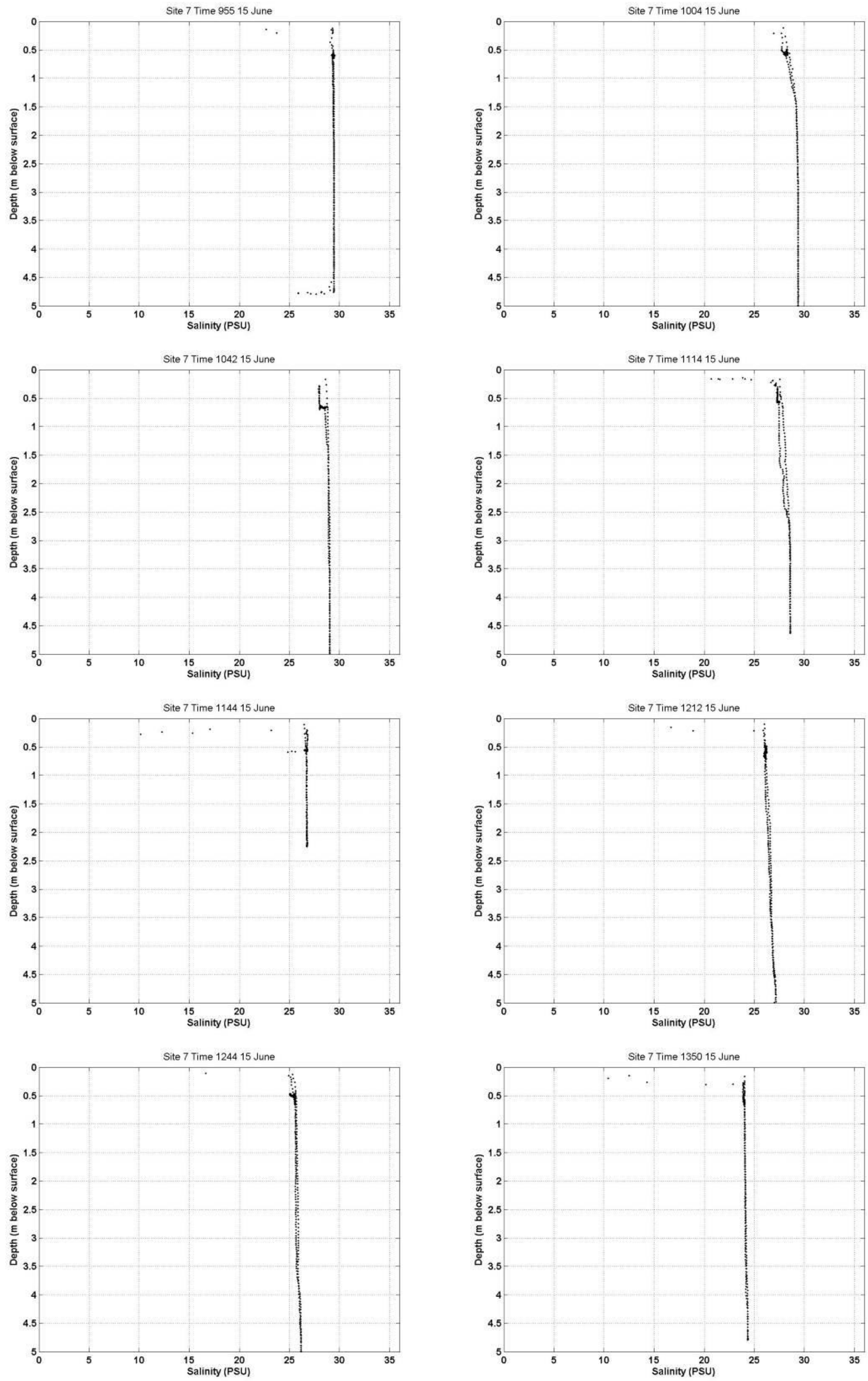
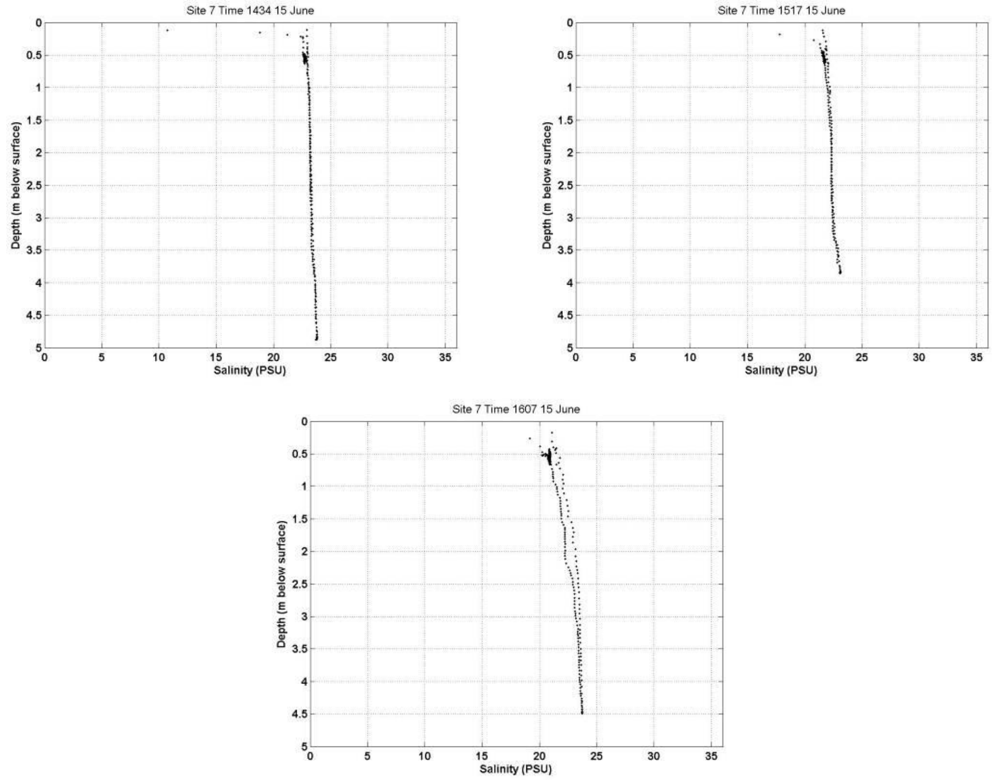


Figure 36b

Measured salinity profiles at CTD Site 7 (middle reaches of the Whau), falling tide, 15 June 2006.



5.8 CTD Site 8 (near the head of the Whau)

Data at this site were collected on the falling tide on 15 June 2006 (Figure 37).

The water column was well-mixed, and salinity reduced approaching low tide (Figure 38a-b). Towards low tide, vertical structure in the water column began to develop, with a >7 psu difference between the surface and underlying waters.

Figure 37

Measured tides and sampling times (o) for the CTD surveys at CTD Site 8 (near the head of the Whau).

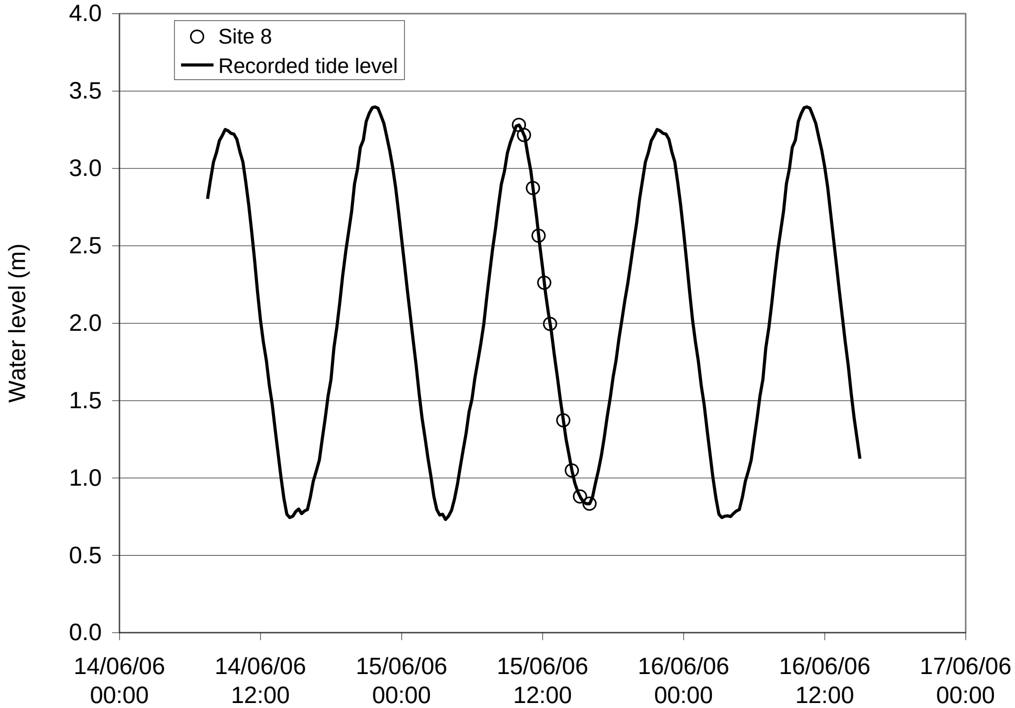


Figure 38a

Measured salinity profiles at CTD Site 8 (near the head of the Whau), falling tide, 15 June 2006.

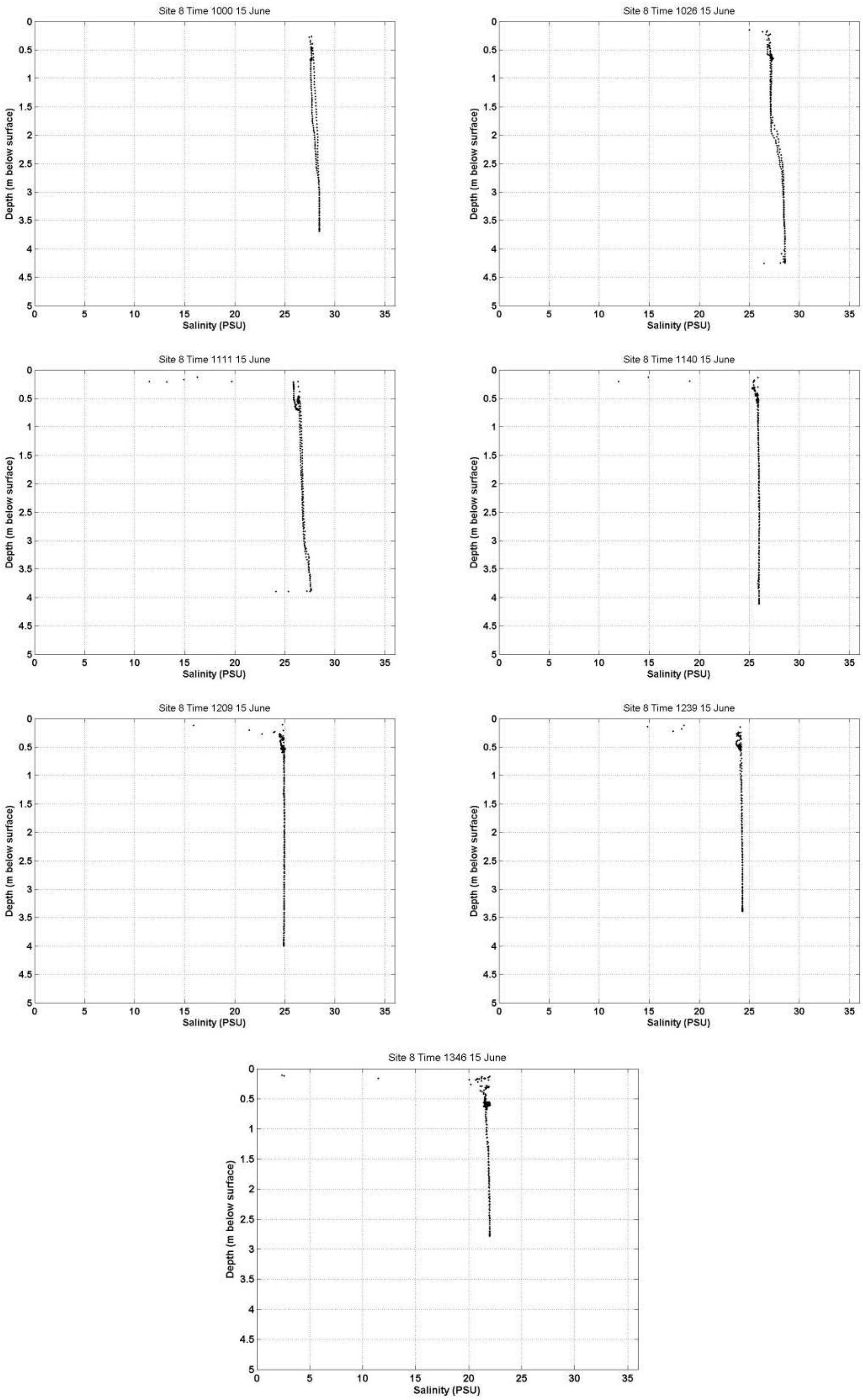
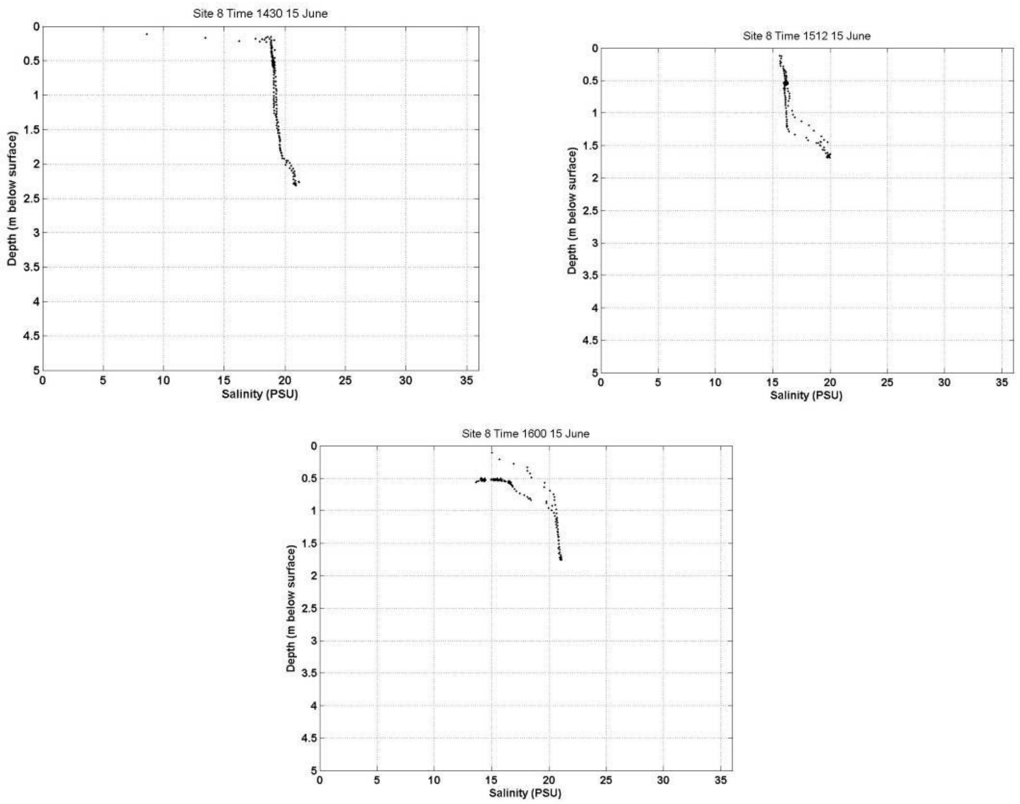


Figure 38b

Measured salinity profiles at CTD Site 8 (near the head of the Whau), falling tide, 15 June 2006.



6 Summary

Fieldwork involving the deployment of DOBIE instrument packages and S4 current meters, and surveys of conductivity, temperature and depth, has been carried out between 30 March and 24 July 2006, within the Waitemata Harbour.

Measurements of water levels, currents, waves, conductivity and water temperature were made at a number of sites. This data, along with previously collected field data, will be used to calibrate and validate the model that will be used to simulate the dispersal of contaminants and sediments in the harbour by physical processes such as currents and waves. Those simulations will underpin predictions of contaminant accumulation to be made by the Urban Stormwater Contaminant Model (Green, 2008).

The tidal range is ~1.8 m during neap tides and ~3.0 m during springs. Highest tidal ranges were recorded within the middle reaches of the Whau and in Henderson Creek.

There is typically a strong tidal signal in suspended sediment concentration (SSC), with highest SSC occurring during periods of wave activity or under peak currents on flooding and ebbing tides. Highest SSC between 0.30 -1 34 kgm^{-3} was recorded within the Whau and in Henderson Creek, and in the channel leading into the Upper Waitemata Harbour during periods of prolonged rainfall.

Only a limited number of wave events occurred during the deployment. Wave heights were typically less than 1 m and wave periods did not exceed 4.0 s. When they were present, waves enhanced SSC by as much as 0.25 kgm^{-3} within the main body of the harbour.

Temperature and salinity data will be used to quantify the degree of mixing that occurs between freshwater sources (eg, the Whau and Henderson Creek) and the more saline waters of the main body of the harbour. Large fluctuations in salinity (0-32 psu) were recorded in the upper reaches of both the Whau and Henderson Creek. In the main body of the harbour, fluctuations in salinity were much less, ranging between 25 and 32 psu.

Currents near the entrance to Henderson Creek were strong and aligned along the channel.

7 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.

GREEN, M., 2008. Central Waitemata Harbour Contaminant Study. USC-3 Model Description, Implementation and Calibration. Prepared by NIWA Ltd for Auckland Regional Council. Auckland Regional Council Technical Report 2008/044.

8 Appendix 1: Data Processing

8.1 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 pounds per square inch (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 4.

Table 4

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

Site	DOBIE serial number	Gain (psi/volt)	Offset (volts)
1	2312	11.6076	-0.5365
2	909	14.5503	0.0164
3	902	20.2985	0.1214
4	901	13.6763	0.8432
5	2110	14.5104	-0.0285
6	919	14.203	0.5164
7	917	14.5499	0.0177
8	906	14.4951	0.1574
9	914	20.2721	0.0865
10	908	14.5499	0.0177
11	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 kgm^{-3}.

All wave statistics were calculated using linear wave theory as implemented in the DOBIE's post processing software[2].

[2] www.niwascience.co.nz/rc/instrumentsystems/dobie.

8.2 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 mgL^{-1} per volt) and O is the sensor offset (units of mgL^{-1}).

The optical backscatter sensors have 4 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.

Sensor gain and offset were determined for each gain setting by calibrating each sensor in a turbidity tank against sediment from the Waitemata Harbour that was passed through a 63-micron sieve. SSC in the tank was raised from 0 to approximately 1000 mgL^{-1} in 200 mgL^{-1} increments, with five 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 5.

Table 5

Calibrated gains and offsets of the optical backscatter sensor on each DOBIE.

Site	DOBIE serial number	OBS serial number	Gain setting 1	Gain setting 2
1	2312	10596	SSC=536.65V - 0.382	SSC =108.06V + 0.6184
2	909	10597	SSC =585.07V - 1.6688	SSC =115.07V + 1.3071
3	902	10605	SSC =520.53V + 9.6202	SSC =98.94V + 17.97
4	901	1993	SSC =938.37V + 0.5766	SSC =187.03V - 1.9023
5	2110	10600	SSC =859.57V - 4.971	SSC =170.6V - 0.6781
6	919	10259	–	–
7	917	10601	SSC =681.52V - 8.2167	SSC =135.05V - 7.1148
8	906	10604	SSC =619.18V + 0.94	SSC =125.68V + 0.0907
9	914	10092	SSC =788.94V - 3.8785	SSC =152.92V + 2.9911
10	908	10599	SSC =627.43V + 0.5425.	SSC =125.33V - 0.6381
11	903	10602	SSC =723.48V - 3.2197	SSC =144.3V + 0.8335

8.3 Conductivity and temperature

Conductivity

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 $mScm^{-1}$ per volt) and O is the sensor offset (units of $mScm^{-1}$). 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 $mScm^{-1}$ to near 0 $mScm^{-1}$ in 10 mS/cm 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 6.

Temperature

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 6).

Table 6

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
1	2312	–	–	–
2	909	8495	C = 0.0012V - 0.1361	T = 0.0013V + 0.0477
3	902	22129	C = 0.0015V + 0.0411	T = 0.0013V - 0.0468
4	901	–	–	–
5	2110	15020	C =0.001436V - 0.502	T =0.001505V - 3.5654
6	919	–	–	–
7	917	22130	C = 0.0015V - 1.2789	T = 0.0013V - 1.4225
8	906	8494	C = 0.0012V - 0.0508	T = 0.0013V - 0.3079
9	914	–	–	–
10	908	–	–	–
11	903	–	–	–