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# Carmel River Lagoon Enhancement Project: Preliminary water quality report

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# Preface

This is a preliminary report to the California Department of Parks and Recreation. It describes water quality monitoring aspects of the Carmel River Lagoon Enhancement Project construction activities completed during Fall 2004. The report is intended for limited distribution to the agencies and other groups involved in the project. It is not intended for public distribution. A complete, public report will be published on the CCoWS web site in 2005.

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# 1 Introduction

## 1.1 Carmel Lagoon history

The Carmel Lagoon lies at the mouth of the Carmel River. The Lagoon is an important wetland habitat, in a region where such habitat has declined in historic times. It is habitat for two Federally Threatened species: the California Red Legged Frog, South Central Coast steelhead trout (an Evolutionary Significant Unit, ESU).

The Carmel River only flows to the ocean during the winter. It does so through a direct course running from east to west through the lagoon. At some point in the past a separate channel existed several hundred meters to the south, running alongside the steep granite bluffs to the south of the lagoon. The land area between these two channels was farmed for many years by the Odello family, and eventually acquired by California Department of Parks and Recreation (CDPR). In recent years, the south channel has existed as a remnant channel – a willow-dominated muddy habitat, only submerged during the highest lagoon stages, and during the largest floods.

## 1.2 Project background

In the summer of 2004, the CDPR implemented the construction phase of the Carmel River Lagoon Enhancement Project (CRLEP). The project significantly expanded the pre-existing lagoon by excavating the remnant south channel and adjacent former Odello farmland down to below sea level. Project plans were described in a Revegetation Mitigation and Monitoring Plan (RMMP) (CDPR, 2003).

The Watershed Institute and the Foundation of California State University Monterey Bay (CSUMB) was engaged to monitor water quality, habitat, and certain biological changes during the CRLEP. This report describes preliminary water quality monitoring results – and was completed 4 weeks after the cessation of major construction activities. Subsequent reports will provide a more comprehensive description.

## 1.3 Objectives relating to water quality and aquatic wildlife

The RMMP indicated a requirement that the CRLEP should not degrade lagoon water quality beyond the tolerance of steelhead trout, or beyond objectives provided by the Basin Plan maintained by the Regional Water Quality Control Board (RWQCB, 2004). Specifically, goals were set for cool water temperatures, high dissolved oxygen (or low biological oxygen demand), and low suspended sediment concentrations.

Some critical periods were identified for monitoring. Monitoring during construction activities was essential, since these activities had the potential to adversely affect the special status fish and frogs already living in the lagoon, and an adjacent pond. Monitoring during the first big storms of the 2005 winter is essential, since these have the potential to eroded the newly excavated banks into the lagoon creating sediment problems.

The RMMP indicated that steelhead trout habitat should increase as a result of increased acreage of deep and shallow water (after accounting for climate variability). Newly created open water areas were specified to be deeper than 70 cm.

## 1.4 Water quality parameters of interest

Water quality parameters of interest included:

- Temperature
- Salinity
- Dissolved Oxygen
- pH
- Carbon Dioxide
- Turbidity
- Suspended sediment concentration
- Hydrogen sulfide concentration

## 1.5 Report outline

This preliminary report presents much of the raw data collected to date. It contains the following major sections:

- Project timeline
- Review of water quality objectives
- Water quality sampling methods and objectives
- Site descriptions and monitoring schedule
- Hydrology results
- Key water quality results
- Detailed results (Appendices)

## 2 Project timeline

Water quality monitoring was conducted in several phases, as described in Table 2-1. 2 Phases have been designated according to construction activities and water quality monitoring regimes. The first Phase took place before any digging in existing habitat; the second Phase took place during digging in existing habitat through to the end of excavation in the lagoon.

In the original plan, the silt curtains were to be removed as soon as the water quality inside the silt curtains was sufficient not to endanger steelhead, though on the morning of the 21st October, 2004, the silt curtains were found dislodged from the left bank of the South Arm, concluding Phase 2c. On 22 October, final post-construction sampling was completed. Current sampling related to longer term restoration success is ongoing (not described in this report).

Table 2-2 summarizes the timeline of events during and around the construction phase of the project. These events are also depicted in the sequence of photographs in the following pages. A more extensive narrative of the timeline will be included in the next draft.

**Table 2-1. Phases of CRLEP according to construction and water quality monitoring activities.**

| | DATES | CONSTRUCTION ACTIVITIES | WQ MONITORING REGIME * |
|---|---|---|---|
| PHASE 1 | 20 July 04 – 10 September 04 | Construction of the new channel before removal of earth barrier separating this new channel from the existing lagoon. | Once daily |
| PHASE 2a | 13 September 04 – 30 September 04 | Excavation in South Arm. | 3 times daily |
| PHASE 2b | 1 – 5 October 04 | Removal of earth barrier. | 2 – 3 times daily |
| PHASE 2c | 12 – 22 October 04 | After removal of earth barrier and before removal of silt curtains. | 2 days: 12th and 15th October |

* 'daily' refers to weekdays when construction teams were working.

Table 2-2. Timeline of events significant to water quality.

| Phase | Date | Events |
|---|---|---|
| 1 | 20 Jul 04 | Water quality sampling begins. |
| 1 | 25 Jul 04 | CAWD release of water into the South Arm via small channel |
| 1 | 26 Jul 04 | CAWD release of water into the South Arm via small channel. |
| 1 | 27 Jul 04 | CAWD release of water into the South Arm via small channel. |
| 1 | 28 Jul 04 | 0.5 m dead steelhead found near South Arm pipe. Website containing WQ data started & updated daily. |
| 1 | 6 Aug 04 | Well water pumped into South Arm through corrugated pipe ~ 16 hrs. |
| 1 | 9 Aug 04 | Well water pumped into South Arm through corrugated pipe, pump was turned on a couple times during the 7th & 8th. |
| 1 | 10 Aug04 | Well water pumped into South Arm through corrugated pipe off & on. Water from excavated channel pumped & released onto earth barrier through sprinklers; intention was to have water runoff into the South Arm. |
| 1 | 11 Aug04 | Well water pumped into South Arm through corrugated pipe off & on. Water from excavated channel pumped & released onto earth barrier through sprinklers. |
| 1 | 12 Aug04 | Staff plate installed in the newly excavated channel. |
| 1 | 18 Aug04 | Silt curtain installed in mudflat of South Arm. |
| 1 | 20 Aug04 | Silt curtain installation in the newly excavated channel. |
| 1 | 24 Aug 04 | Silt curtains installed in South Arm next to frog pond. |
| 1 | 26 Aug04 | Health inspector out on pipe looking for mosquito larvae, sprayed surfactant in water. |
| 1 | 31 Aug 04 | Fish seined from outer edge of South Arm. |
| 1 | 1 Sep04 | Fish seined from outer edge of South Arm. |
| 1 | 9 Sep04 | Rock peninsula (temporary road) placed in South Arm. |
| 1 | 10 Sep 04 | Rock peninsula (temporary road) placed in South Arm. |
| 2a | 15 Sep04 | Excavation in South Arm. |
| 2a | 16 Sep04 | Excavation in South Arm. |
| 2a | 17 Sep 04 | Excavation in South Arm. |
| 2a | 20 Sep04 | Excavation in South Arm. |
| 2a | 27 Sep04 | Well water pumped into South Arm through corrugated pipe. |
| 2a | 28 Sep04 | Well water pumped into South Arm through corrugated pipe. |
| 2a | 29 Sep04 | Well water pumped into South Arm through corrugated pipe. |
| 2a | 30 Sep 04 | Well water pumped into South Arm through corrugated pipe. |
| 2b | 1 Oct04 | Excavated channel water pumped into South Arm to equalize water levels. Removal of earth barrier begins with a small channel. Silt curtains in excavated channel become dislodged. |
| 2b | 4 Oct 04 | Removal of earth barrier. |
| 2b | 5 Oct04 | Removal of earth barrier. |
| 2c | 21 Oct04 | Silt curtains in South Arm found dislodged; water level very high, stake holding curtain in place on left bank of South Arm went under water, water loosened dirt holding stake in place. |

Figure 2-1 Small channel feeding CAWD release into the South Arm, 26 July 04.

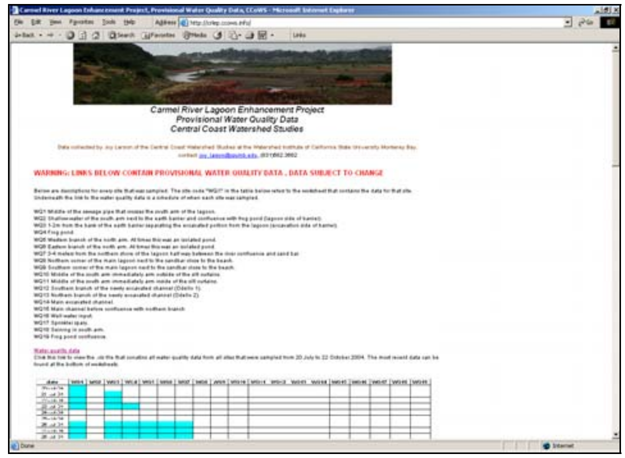


Figure 2-2 Water quality website, 28 July 2004

Figure 2-3 dead steelhead found next to the South Arm pipe, 28 July 2004.

Figure 2-4 Corrugated pipe feeding well water into the South Arm, 6 August 2004.

Figure 2-5 Sprinklers release water from the newly excavated channel onto the earth barrier, 10 August 2004.

Figure 2-6 Silt curtains in the newly excavated channel, 23 August 2004.

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Figure 2-8 Seining fish out of edge of South Arm, Chris Peregrin, Joel Casagrande, Julie Hager, and Dale Hameister, 31 August 2004.

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Figure 2-1 Excavator on temporary rock road, 9 September 2004.

Figure 2-2 Excavation in the South Arm next to the silt curtains, 15 September 2004.

Figure 2-18 Removal of the earth barrier begins with a small channel, 1 October 2004.

Figure 2-19 Water flowing from the newly excavated channel into the South Arm, 1 October2004.

Figure 2-20 View of silt curtains in South Arm during removal of the earth barrier, 1 October 2004.

Figure 2-21 Silt curtains dislodged in South Arm, 21 October 2004.

# 3 Water quality methods and objectives

The water quality parameters that were measured are temperature, salinity, dissolved oxygen (DO), pH, Carbon Dioxide ($CO_2$), turbidity, suspended sediment concentration (SSC), and hydrogen sulfide ($H_2S$); these are outlined below. This brief overview includes the field and laboratory methods used to measure each parameter.

Many parameters were measured *in situ* and some were taken from samples. The parameters measured *in situ* were taken with an YSI Environmental 556 MPS Multiprobe System in the form of depth profiles. Samples were collected from the surface and from a depth that was within one meter above the bottom using a horizontal alpha water sampler. Many measurements and samples were taken from a kayak; these are outlined in the site description section. For a more extensive overview of CCoWS laboratory procedures, see Protocols for Water Quality and Stream Ecology (Watson et al, 2002).

## 3.1 Temperature

Temperature directly effects fish metabolism, feeding, & survival (Morris, 1992). As the temperature increases, metabolic rates increase; as the temperature decreases, metabolic rates decrease. Spawning & egg hatching are geared to annual changes in environmental temperature. In streams, the ideal temperature of water for trout is around 17°C; temperature becomes potentially lethal for trout at about 26°C (Hunter, 1991). There is evidence that trout have higher temperature tolerances in lagoons, because the higher metabolic rate and food demand can be sustained by the abundant invertebrates typical of lagoons (mysids, amphipods etc.). Measurements were made *in situ* in depth profiles using an YSI Environmental 556 MPS Multiprobe System.

## 3.2 Salinity

Steelhead trout are born in freshwater streams, and migrate to the ocean as they become adults. Coastal lagoons are usually stratified, containing saltwater at depth, and fresher water at the surface. This provides a transitional environment with respect to salinity, that may facilitate the physiological smoltification process that steelhead undergo in order to move from freshwater to saltwater environments. Measurements were made *in situ* in depth profiles using an YSI Environmental 556 MPS Multiprobe System.

## 3.3 Dissolved Oxygen (DO)

Dissolved oxygen arises from two sources: direct diffusion at the air-water surface interface (Morris, 1992), and photosynthesis. DO levels that are less than 5mg/L have the potential to harm fish (Morris, 1992). This is the criterion used to evaluate the potential for harm that could come to fish in the lagoon as the construction proceeded. DO levels are highest in the late afternoon, as aquatic plants and algae have been photosynthesizing for most of the day. At night, photosynthesis ceases, algae and fish consume oxygen through respiration; so DO levels are lowest just averter dawn (Hargreaves, 1996). Casagrande and Watson (2004) documented diurnal DO minima in the Carmel Lagoon occurring typically around 9:00 AM.

Dissolved oxygen was specified to remain above 5 mg/L during the project, as directed by the NMFS Biological Opinion. Measurements were made *in situ* in depth profiles using an YSI Environmental 556 MPS Multiprobe System.

## 3.4 pH

pH was measured *in situ* in depth profiles using an YSI Environmental 556 MPS Multiprobe System.

## 3.5 Carbon Dioxide ($CO_2$)

Carbon dioxide concentrations are highest when DO concentrations are lowest (Hargreaves, 1996). In the daylight, $CO_2$ used during photosynthesis, and at night it is produced by respiration. $CO_2$ is released into water by almost all living aquatic organisms through respiration & decomposition. Some $CO_2$ bubbles to the surface, some dissolves in the water. It is this dissolved $CO_2$ that was measured from water samples.

High $CO_2$ concentrations are usually found near the bottom of the lagoon as dead organisms sink, in the autumn as dead algae and plants decompose (Morris, 1992). Evidence suggests that high $CO_2$ by itself is not harmful, but it becomes toxic when it is present in high concentrations in association with low DO (Morris, 1992). Surface waters normally contain less than 10 mg free $CO_2$ per liter (Clesceri et al., 1998). Water that supports fish populations generally has less then 5mg/L $CO_2$ (Morris, 1992).

$CO_2$ concentrations were measured from surface and column samples using a HACH Digital Titrator (Model 16900). In this method, the acidity due to $CO_2$ in a sample is titrated with sodium hydroxide to a phenolphthalein end point. This test was conducted in the lab as well as in the field, depending on the phase of the project. The range of this test is 10 – 1,000 mg/L as $CO_2$ (note: the lower detection limit of this test is at or below the criteria cited above).

## 3.6 Turbidity

Turbidity is the cloudiness of water – or the inverse of its transparency. In lagoon environments, turbidity is increased both by suspended mineral sediments, and by phytoplankton and other organic matter. Suspended solids include clay, silt, finely divided organic and inorganic matter, and plankton and other microorganisms (Clesceri et al, 1998).

Turbidity was measured from surface and column samples using a HACH Portable Turbidimeter (Model 2100P). Measurements made with this instrument have an accuracy of ±2% of reading plus stray light from 0-1000 Nephelometric Turbidity Units (NTU), a range of 0 – 1000 NTU, and a resolution of 0.01 NTU. This test was also conducted in the lab as well as in the field, depending on the phase of the project.

## 3.7 Suspended Sediment Concentration (SSC)

The water quality objective for SSC stated in the project contract is <50mg/L as suggested by the biological report completed by NMFS.

Many studies have examined impacts of suspended sediment on fish and aquatic invertebrates. Hager et al. (2003) reviewed the literature that is broadly applicable to the Central Coast Region. They arrived at the following guidelines, providing a baseline for comparison of turbidity levels (NTU) and SSC (mg/L) and the associated effects primarily on rainbow trout:

- Up to 2 NTU or 10 mg/L: not likely to adversely affect fish and invertebrates
- Up to 20 NTU or 100 mg/L: potential change in behavior and / or slight decrease in survival
- Up to 200 NTU or 1,000 mg/L: stress, physiological changes, and potentially lethal effects

SSC analysis was done on every sample collected by vacuum filtration in the lab. Note that this provides is a more complete characterization of suspended sediment levels than the simpler Total Suspended Solids (TSS) analytical technique.

## 3.8 Hydrogen Sulfide ($H_2S$)

Hydrogen sulfide ($H_2S$) is produced by anaerobic decay of organic matter (breakdown of sulfur-containing proteins; amino acid degradation) aided by bacteria. It is released during the decomposition of organic matter in bottom deposits (WHO, 1981; Mattson, 2000; ATSDR, 1999; Sand, 1997; and Smith & Oseid, 1972). It is soluble in water but its short residence time removes it rapidly from water (Smith & Oseid, 1972) as it is released into the atmosphere.

Since $H_2S$ is a gas, most toxicological information pertains to air pollution (WHO, 1981). It is considered to be a broad-spectrum poison (ATSDR, 1999) that affects the nervous and respiratory systems (Morris, 1992). When dissolved in water, H2S adversely affects fish in two ways. Firstly it is toxic to fish (Clesceri et al, 1998). Secondly, it reacts with dissolved oxygen, thus lowering dissolved oxygen levels (Van Handel, 1987). When bottom sediments are disturbed, $H_2S$ may be dispersed throughout the sediments and water column causing adverse impacts - particularly to invertebrate fish prey species and fish eggs and fry in the epibenthos (Smith & Oseid, 1972).

The National Water Quality Standard for $H_2S$ is based on the Criterion Continuous Concentration (CCC)[1] of 2.00 $\mu$g/L in both fresh water and salt water (EPA, 1976). This criterion is based on toxicities to a variety of species in aquatic communities. In particular, Smith and Oseid (1972) measured rainbow trout egg mortality, finding median tolerance levels ($TL_{50}$) between 55 and 80 $\mu$g/L over 72 hours, 49 $\mu$g/L over 96 hours. These authors also summarized that population maintenance would be greatly inhibited at levels approaching 25 $\mu$g/L (based on testing of walleye, sucker, trout, and northern pike). No studies were found documenting more temporally acute toxicity thresholds for juveniles and adults over relatively short time spans that would be relevant to the possible effects of construction activities.

Because of the instability of $H_2S$ in solution, samples were analyzed in the field within 45 minutes of collection. A mobile lab was set up to do this lab analysis on site (Fig. 3-1 and 3-2 ). For this reason, and because the only source of $H_2S$ in the lagoon was the disturbance of bottom sediments, surface and column samples were only tested for $H_2S$ while there was digging in the South Arm of the lagoon (at this time $CO_2$ and turbidity were also analyzed in the field lab); during Phase 2. A HACH ODESSEY Spectrophotometer DR/2500 was used to analyze samples for $H_2S$ using a methylene blue method. The range of this test is from 5 - 800 $\mu$g/L.

[1] CCC's are estimates of the highest concentration of a pollutant an aquatic community can be continuously exposed to without adverse effects. 'Aquatic community' is defined to include "the vast majority of aquatic communities in the U.S."

Figure 3-1 Mobile laboratory next to excavator in the South Arm. Photo was taken from the cross on 15 September 2004.

Figure 3-2 Sample analysis and data entry in the mobile lab. Thor Anderson and Joy Larson 16 September 2004.

# 4 Sampled Sites

To facilitate comparison of past and present data collected in specific parts of the lagoon, Casagrande et al. (2003) divided the lagoon into discrete sampling zones. These zones were adjusted for the present study to include the newly excavated portions of the lagoon. Figure 4-1 shows the layout of zones and the specific sampling sites used during the present study. The 'N' sites are in the North Arm zones, the 'R' sites are in the River zones, the 'S' sites are in the South Arm zones, and the 'O' sites are in the newly excavated Odello zones. Sites were selected in consultation with NOAA Fisheries (J. McKeon, pers. comm.). Detailed descriptions appear below.


Figure 4-1 Sampling zones and sites (red dots) at the Carmel River Lagoon (new excavation not shown).
Note: sites S4O and S4I are in the same spot.

## 4.1 S2: South Arm Section 2

The wastewater treatment plant outfall pipe that crosses the South Arm of the lagoon is a primary historic sampling site that is close to the construction (Fig. 4-1 and 4-2 ) A compilation of data from this site from previous studies will be included in the next report. Data were collected from this site at each visit to the lagoon from about the middle of the pipe. Aeration pumps were operating throughout the sampling period (Fig. 4-3 ). Surface grab samples were taken directly into storage bottles. In addition, from 30th August, an Alpha Sampling Bottle was used to collect samples within 1 m of the bottom (the lagoon is typically about 3 m deep at this point). A kayak was used at this site during Phase 2.

## 4.2 S4: South Arm Section 4

Beginning on the 28th of July for the duration of Phase 1, measurements were taken in the shallow water adjacent to the north side of the earth barrier separating the original lagoon from the new excavation, close to the frog pond confluence (Fig. 4-1 and 4-4 ). Samples from this location were subject to sediment released into the water by construction and monitoring crews walking through it for access to the silt curtains. YSI measurements were made at a single depth, since the water was too shallow for depth profiles.

## 4.3 FP: Frog pond

The pond just west of the earth barrier was a priority monitoring site because it supported California Red-legged Frogs, as well as tree frogs and bullfrogs (Fig. 4-1 and 4-5 ). Sampling in this frog pond began on the 23rd of Julyy and continued through Phases 2a and 2c. Samples were taken by wading into the deeper portion of the pond, which resulted in some sediment being disturbed. Suspended sediment samples were taken as surface grabs directly into storage bottles, visually avoiding apparent clouds of disturbed sediment.

## 4.4 N1: North Arm Section 1

While water levels in the lagoon were low, places other than the South Arm of the lagoon were sampled for viable steelhead habitat, specifically the north arm and the main lagoon. At the time these sites started to be sampled (26th of July), the North Arm was in two different ponds isolated from the main lagoon. This condition changed on the 25th of August when both ponds were connected to each other and the main lagoon.

N1 is in the western isolated pond of the North Arm (Fig. 4-1 ). This site was sampled throughout Phase 1, and on the 15th and 22nd of October (the 22nd was done from a kayak) (Fig.4-6 ).

## 4.5 N2: North Arm Section 2

N2 is in the eastern isolated pond of the North Arm (Fig. 4-1 ). This site was sampled throughout Phase 1, and on the 15th and 22nd of October (the 22nd was done from a kayak) (Fig 4-7 ).

Figure 4-2 View of S2 from beach access road off of Calle De Cruz, 20 October, 2004

Figure 4-3 Aeration pumps on at S2.

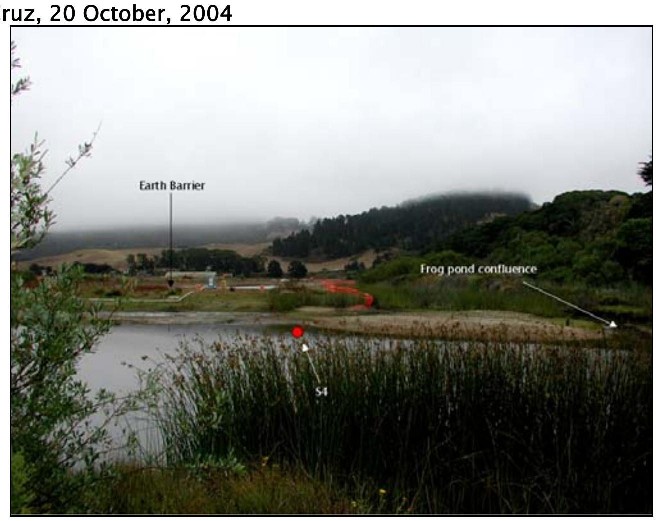


Figure 4-4 S4 taken from the right bank of the South Arm, 26 August 2004.

Figure 4-5 FP, 4 August 2004.

Figure 4-6 N1, looking up the western branch of the north arm. Photo was taken from the kayak, 22 October 2004.

Figure 4-7 N2, looking downstream from the eastern pond of the north arm, 22 October 2004.

## 4.6 R2: River Section 2

The main channel of the lagoon was also sampled in the same time period as N1 and N2. R2 was sampled 3-4 meters from the northern shore of the main lagoon halfway between the river confluence and the sand bar at the beach (Fig. 4-1 ). This site is exposed to continuous wind action and is therefore subject to more mixing than other places in the lagoon (Fig. 4-9 ).

## 4.7 R1N: River Section 1 North

Two sites immediately next to the sandbar in the lagoon were sampled to establish the quality of the water flowing through the sand bar to and from the ocean or from large wave events. R1N was a site in the northern corner of the sand bar (Fig. 4-1 ). This site was sampled throughout Phase 1.

## 4.8 R1S: River Section 1 South

The other site next to the sand bar close to the beach is in the southern corner of the main lagoon (Fig. 4-1 and 4-10 ). This site was also sampled throughout Phase 1.

## 4.9 S4O: South Arm Section 4, Outside of silt curtains

Four silt curtains were installed side by side in the South Arm starting 24 August 2004 to contain the poor water quality that resulted from excavation in the South Arm during Phases 2 and 3 (Fig 3-1 and4-1 ). These curtains were held in place by large chains that lined the bottom of each curtain and were submerged into the lagoon substrate. Samples were taken from either side of the curtains to document any transfer of poor water quality from inside the silt curtains to the outside.

At times the curtains bowed inward, as digging in the South Arm and removal of the earth barrier pulled the water toward the barrier where dirt under the water was being removed. At other times, particularly when ocean waves receded and lagoon water flowed out through the sandbar (see Watson & Casagrande, 2004), the curtains bowed outward. The top of the downstream curtain tended to submerge. On more than two occasions when water flowed from the excavation area into the original lagoon, the tops of all four curtains were submerged by the flow – allowing free exchange of water across the curtains. This was also influenced by wind speed and direction (Fig. 4-11 ).

All measurements and samples from these sites were taken from a kayak (Fig. 4-12 ). During phase 2, these sites were sampled 3 times each day. During Phase 3, these sites were sampled 2-3 times per day.

S4O was the sampling site outside of the silt curtains. Results from this site would give the first indication that the silt curtains were not working to block polluted water from entering potential habitat.

## 4.10 S4I: South Arm section 4, Inside of silt curtains

S4I was the sampling site inside the silt curtains. This water was expected to be very dirty as it was closest to the excavators (Fig. 4-13 ). Excavation began very close to the sampling point at the beginning of Phase 2 and receded back away from the curtains and the ocean as Phase 2 and 3 progressed.

## 4.11 OØ: New Odello waterway Section 0

Four main sampling sites were established in the newly excavated portion of the South Arm (Fig. 4-1 ). The first of these sites was immediately southeast of the earth barrier and was sampled throughout Phase 1 (Fig. 4-14 ).

### 4.12 O1: New Odello waterway Section 1

The main body of the newly excavated channel was sampled from the kayak on four separate dates (Fig. 4-1 and 4-15 ). The only relation of these sampling dates to the construction phases are on the 1st of October immediately prior to removal of the earth barrier, and on the 22nd of October after the entire South Arm and excavated channel were connected.

### 4.13 O2: New Odello waterway Section 2

O2 is in the north branch of the newly excavated channel (Fig. 4-1 ) and was sampled from a kayak (Fig. 4-16 ) on the same dates as O1.

### 4.14 O3: New Odello waterway Section 3

O3 is in the southern branch of the newly excavated (Fig. 4-1 and 4-17 ) channel and was sampled from a kayak on the same dates as O1 and O2.

Figure 4-8 O2 from the new shore, 18 August 2004.

Figure 4-9 R2 in the main lagoon, 26 August 2004.

Figure 4-10 R1S. Evidence of large wave event can be seen, 27 August 2004.

Figure 4-11 S4O and S4I. Bowed silt curtains (outward) with overflow, 21 September 2004.

Figure 4-12 Jon Detka sampling from the kayak at S4O, 15 September 2004

Figure 4-13 Sampling from the kayak at S4I while excavator is digging in the South Arm, 16 September 2004.

Figure 4-14 OØ, view from the earth barrier, 21 August 2004.

Figure 4-15 View of O1 from the kayak, 22 October 2004.

Figure 4-16 O2 from the kayak, 22 October 2004.

Figure 4-17 View of O3 from the kayak, 22 October 2004.

### 4.15 Sampling schedule

The following tables are summaries of when each site was sampled. Table 4-1 summarizes sites that were sampled during different phases of the project. Table 4-2 displays each day each site was visited.

**Table 4-1 Sites sampled during different construction phases.**

| | | DATES | SITES SAMPLED |
|---|---|---|---|
| **PHASE 1** | Construction in new waterway | 20 July 04 – 1 September 04 | S2, S4, O0, FP, N1, N2, R2, R1N, R1S |
| **PHASE 2a** | Excavation in South Arm | 13 September 04 – 30 September 04 | S2, FP, S4O, S4I |
| **PHASE 2b** | Removal of earth barrier | 1 – 5 October 04 | S2, S4O, S4I |
| **PHASE 2c** | Before removal of silt curtains | 12 – 22 October 04 | S2, O0, FP, N1, N2, S4O, S4I |

Table 4-2 Shaded boxes indicate when sites were sampled.

| date | S2 | S4 | O0 | FP | N1 | N2 | R2 | R1N | R1S | S4O | S4I | O3 | O2 | O1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20-Jul-04 | ■ | | | | | | | | | | | | | |
| 21-Jul-04 | ■ | | ■ | | | | | | | | | | | |
| 22-Jul-04 | ■ | | ■ | | | | | | | | | | | |
| 23-Jul-04 | ■ | | ■ | ■ | | | | | | | | | | |
| 24-Jul-04 | | | | | | | | | | | | | | |
| 25-Jul-04 | | | | | | | | | | | | | | |
| 26-Jul-04 | ■ | | ■ | ■ | ■ | ■ | ■ | | | | | | | |
| 27-Jul-04 | ■ | | ■ | ■ | ■ | ■ | ■ | | | | | | | |
| 28-Jul-04 | ■ | | ■ | ■ | ■ | ■ | ■ | | | | | | | |
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# 5 Hydrology

For the month of Julyy, the stage in the lagoon was lower than normal, raising concerns over available habitat for steelhead. There were many hypotheses to explain this phenomenon. The next report will include analysis of past stage data to add to the understanding of low stages during the month of July 2004.

Fig. 5-1 displays stage data along with wave height and mean sea level for the months of July, August, and September. Stage data are from the Monterey Peninsula Water Management District. Wave height data are from the NOAA buoy number 46042, 27 nautical miles west of Monterey Bay, accessed on 9 Nov 2004. Mean sea level data are from NOAA water level station 9413450, Monterey Harbor, accessed on 9 Nov 2004.

Water was discharged into the South Arm by releases from the Carmel Area Wastewater District (CAWD) via the small vegetated channel at the east end of the South Arm mud flats; and by pumping from old Odello groundwater wells via a pipe terminating just east of the north end of the silt curtains. The magnitudes of these releases have yet to be quantified, and so their effects on the water level in the lagoon have yet to be explored. The data displayed in Fig. 5-1, show that the lagoon stage increased when large waves coincided with high tidal magnitudes.

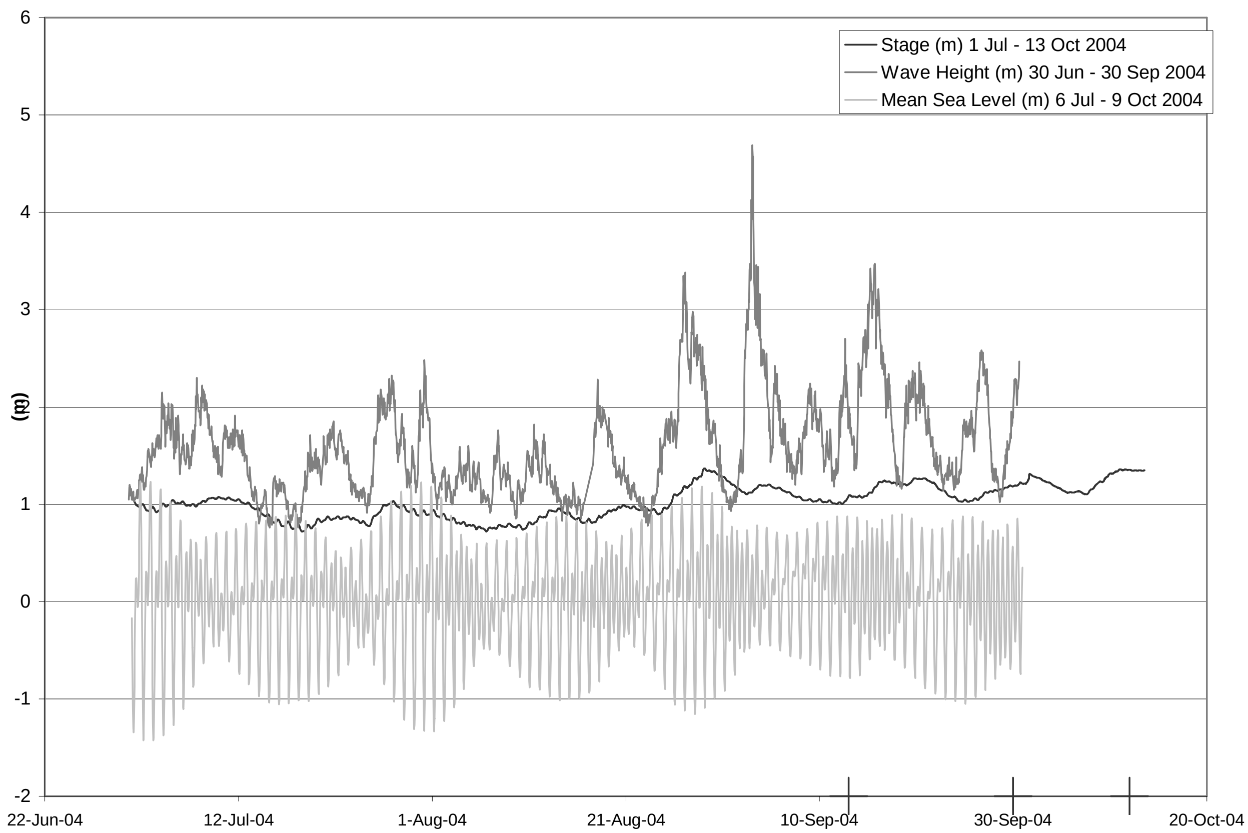


Figure 5-1 Lagoon stage, wave height, and mean sea level during the project period.

# 6 Water quality results

Due to the large amount of data that were collected, this section of the report will focus primarily on four water quality parameters at four sites for both Phases 1 and 2. The entire data set is presented in detail in Appendix 1.

The four water quality parameters highlighted in this section in the form of time series are SSC, DO, salinity, and $H_2S$. Three of these parameters have relatively clear numeric objectives that can be tracked over time (SSC, DO, and $H_2S$), and the fourth, salinity, is good indicator of the partitioning of the lagoon into vertical strata, and horizontal diffusion gradients. Surface measurements are given, since impairment of these would be an indication of widespread impairment of the lagoon's habitat. Corresponding data were recorded near the lagoon bottom. Time series for these will be summarized in the next report.

The four sites that are displayed together for each parameter are S2 – the primary historic site at the outfall pipe close to the excavation and with the most complete data set from the sampling regimes of this project, S4O and S4I – both sides of the silt curtains (Fig. 6-1 and 3-1 ), and R2 in the main body of the lagoon. Note that R2 was only sampled for Phases 1 and 2C, and that $H_2S$ was not measured here. Also, data from OØ was included in the salinity graph, to illustrate larger pattern of lateral salinity gradients.

In general, the excavation activities in the South Arm during Phase 2a generated the most exceedences of the water quality criteria at S2 and S4O. This could be because excavation during this phase was immediately next to the curtains. Excavation receded from the curtains as Phase 2 progressed.

## 6.1 SSC

During Phase 1, both S2 and R2 exceeded the water quality criterion of 50 mg/L (Fig. 6-2). This may be due to phytoplankton and other organic matter in the water column, rather than mineral sediments being suspended as a result of turbulence and bottom disturbance. S2 exceeded this criterion on the 14th and 23rd of September during Phase 2a as well. S2 exhibited a general decrease in SSC throughout the late summer and fall, which could be attributed to a seasonal reduction in photosynthesis.

Almost all of the samples collected from the surface inside the silt curtains (S4I) exceeded the criterion, whereas samples taken from outside the silt curtain only exceeded the criterion on two occasions. On the 15th September at 11:35 SSC spiked to 106 mg/L. This spike in SSC was followed by an immediate decrease to 17 mg/L at 15:45. The second spike in SSC occurred on the 5th of October at 12:35. At 15:50, SSC decreased from 88 mg/L to 69-mg/L. On the next sampling date 7 days later, SSC was 9mg/L.

## 6.2 DO

DO levels at the surface only fell below 5mg/L inside the silt curtain during Phase 2a (Fig. 6-3). Only once did DO levels fall to 5mg/L at R2 on the 13th August at 11:15 AM – presumably related to a natural low point in the diurnal balance of primary production and respiration.

## 6.3 Salinity

Water at the surface stayed relatively fresh at all sites for the duration of the sampling period (Fig. 6-4), although there was a season-long freshening trend from about 5 ppt down to less than 1 ppt, punctuated by brief influxes of salt associated with wave action. This is consistent with trends observed by Watson &

Casagrande (2004, pages 32-33). These authors discuss the freshening trend, suggesting continual groundwater replenishment as a possible cause.

There was a clear lateral gradient of increasing salinity from the new excavation area (OØ), through the earth barrier to the inside of the silt curtains (S4I), across the to the outside of the silt curtains (S4O), along open water to the outfall pipe (S2), and finally to the river mouth area (R2). The gradient was much steeper over the very short distance across the curtains from S4I to S4O. Thus, the curtains were effective in reducing not only the movement of suspended sediment, but also the dissolved solids that constitute salinity.

## 6.4 $H_2S$

Hydrogen sulfide concentrations consistently failed to meet the 25 μg/L water quality objective inside the silt curtains, but usually met objectives at sampling sites outside the curtains in the original lagoon area (Fig. 6-5). Concentrations inside the curtains increased whenever underwater excavation occurred, and gradually declined to safer concentrations in the hours and days thereafter. Concentrations immediately outside the curtains failed to meet the objective on a few occasions, more so when the silt curtains were bowed outward – possibly a consequence of reduced wave and tidal action leading to a reduction in water level in the original lagoon. Concentrations gradually decreased moving away from the outside of the curtains toward the outfall pipe and the River mouth area of the lagoon. The sharpest reduction in surface $H_2S$ occurred over the silt curtains themselves. Note that the 25 μg/L objective reviewed for $H_2S$ toxicity was based on 72-hour and 96-hour mortality tests on rainbow trout eggs. It is probable that smolts would tolerate higher concentrations, especially if they only lasted a few hours – as is the case for the data outside the silt curtains.

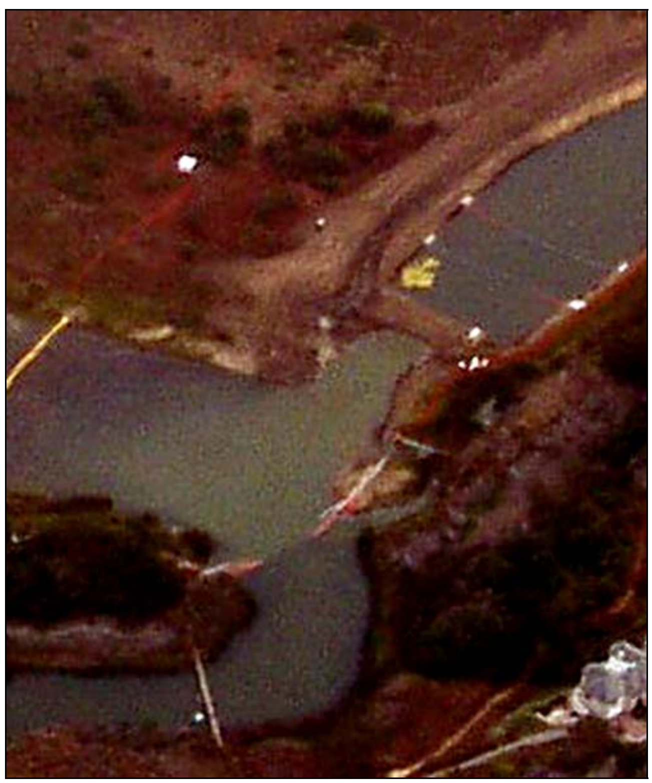

**Figure 6-1 Aerial photo showing both sides of the silt curtains (S4O is to the bottom right of the curtains, S4I is to the left) after excavation in the South Arm, 22 September 2004.**

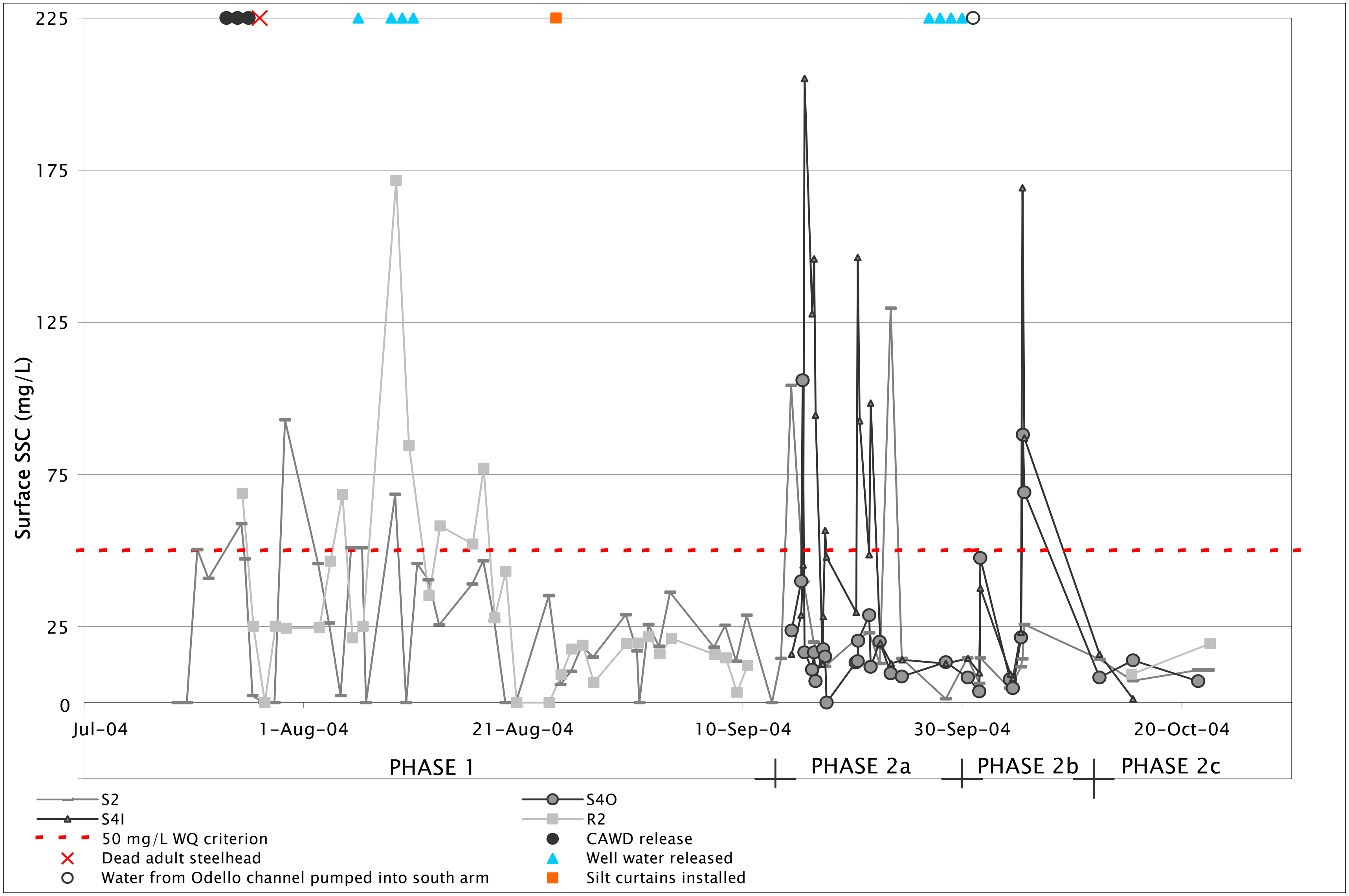


Figure 6-2 Time series of SSC from surface samples taken from S2, S4O, S4I, and R2.

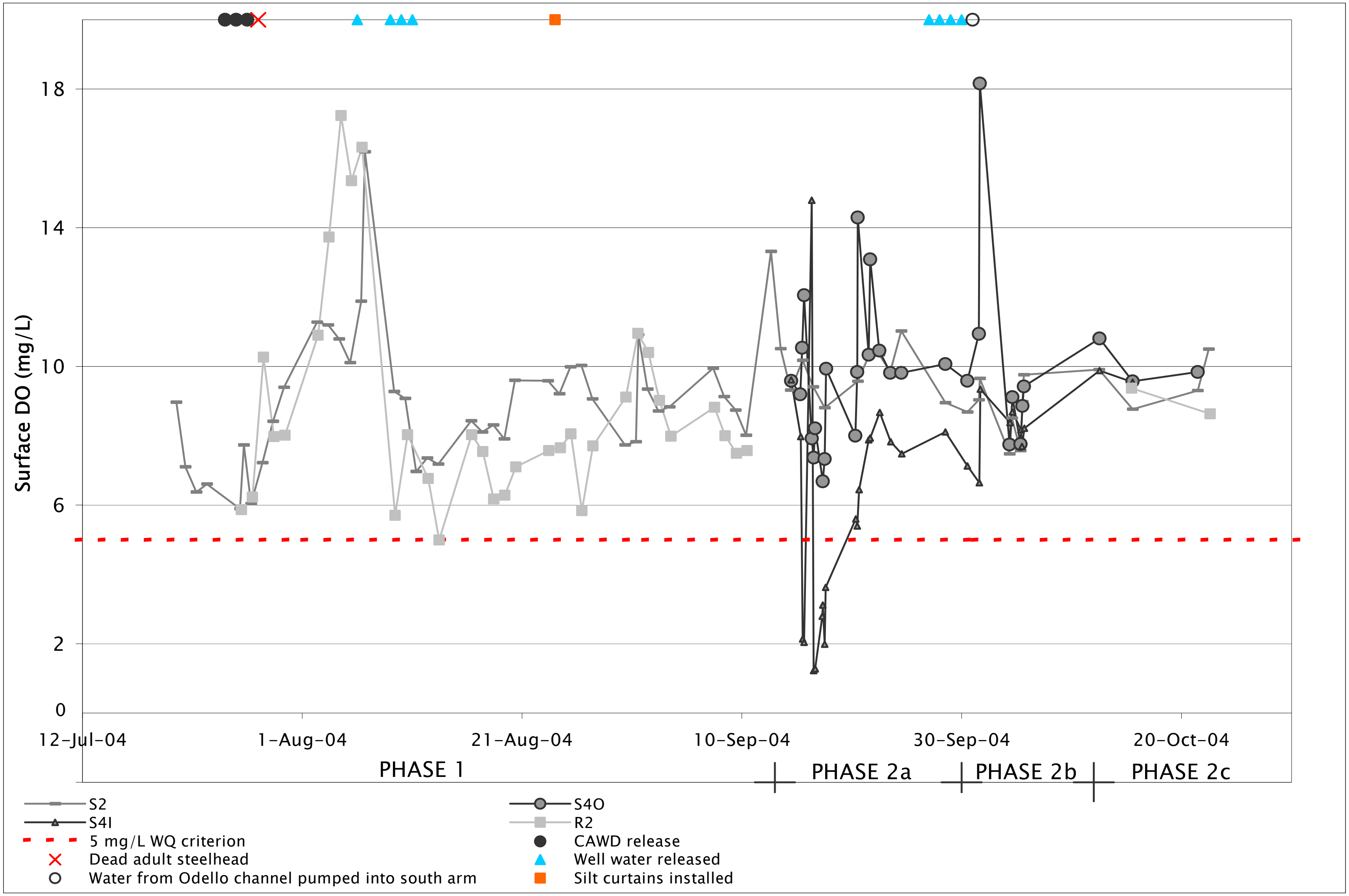


Figure 6-3 Time series of DO surface measurements taken from S2, S4O, S4I, and R2.

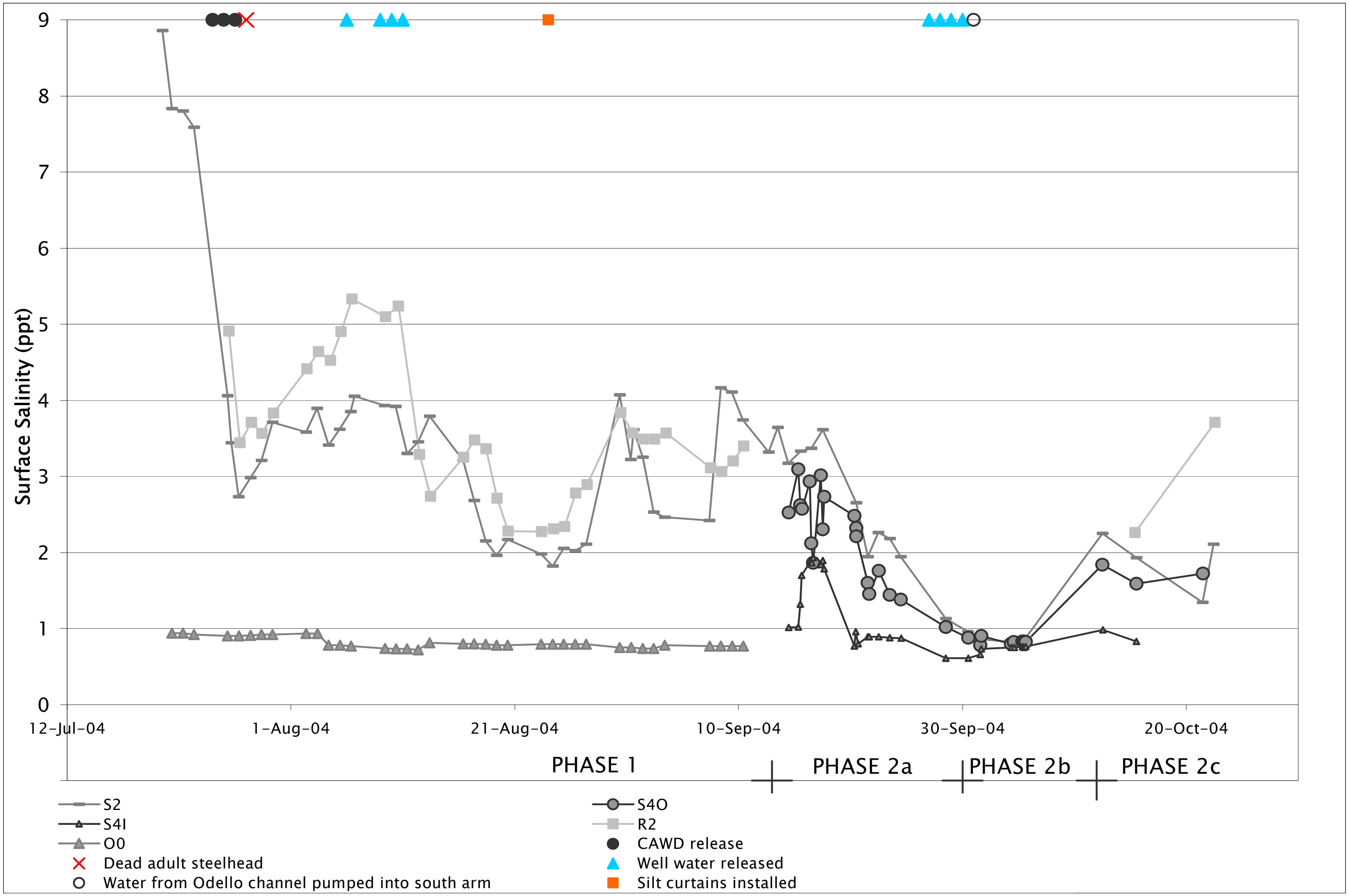


Figure 6-4 Time series of salinity surface measurements taken from S2, S4O, S4I, R2, and OØ.

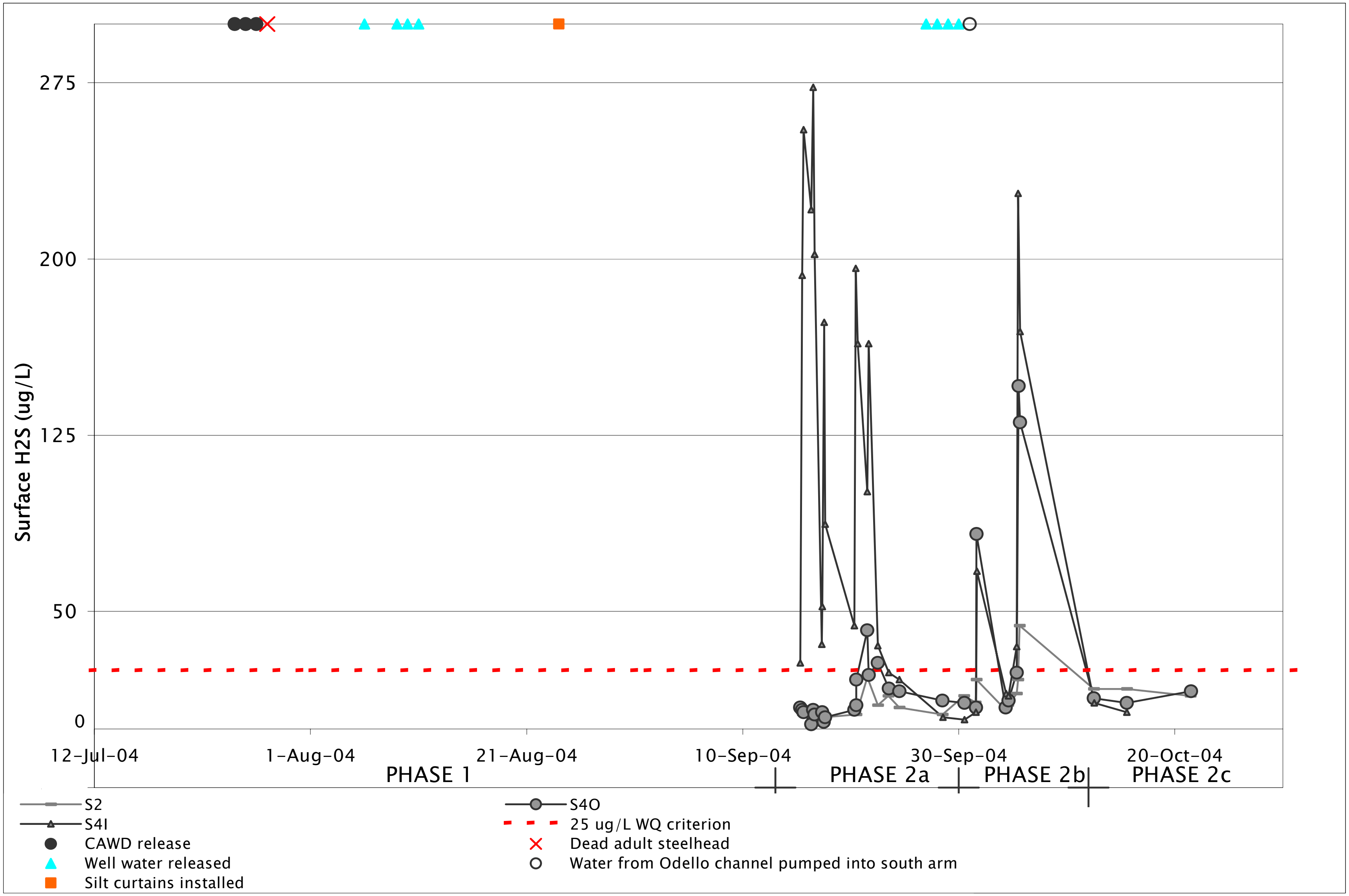


Figure 6-5 Time series of $H_2S$ surface measurements taken from S2, S4O, S4I, and R2.

# 7 Topics to be covered in following reports

This is a preliminary draft of water quality results during the construction and post construction phases of the enhancement project. The next report will include more thorough analysis of some of the topics not fully addressed in this report. These topics may include:

- Compilation of previous CCoWS Carmel River Lagoon data
- Detailed narrative of project timeline
- Time series of depth profiles of YSI measurements Fig 7-1 is an example of this time series.
- Review of stage data from the past 10 years
- Brief progress report on BMI sampling
- Brief progress report on underwater video
- YSI specs
- Time series of temperature dynamics at the South Arm pipe from temperature loggers. Fig 7-1 is an example of this time series.

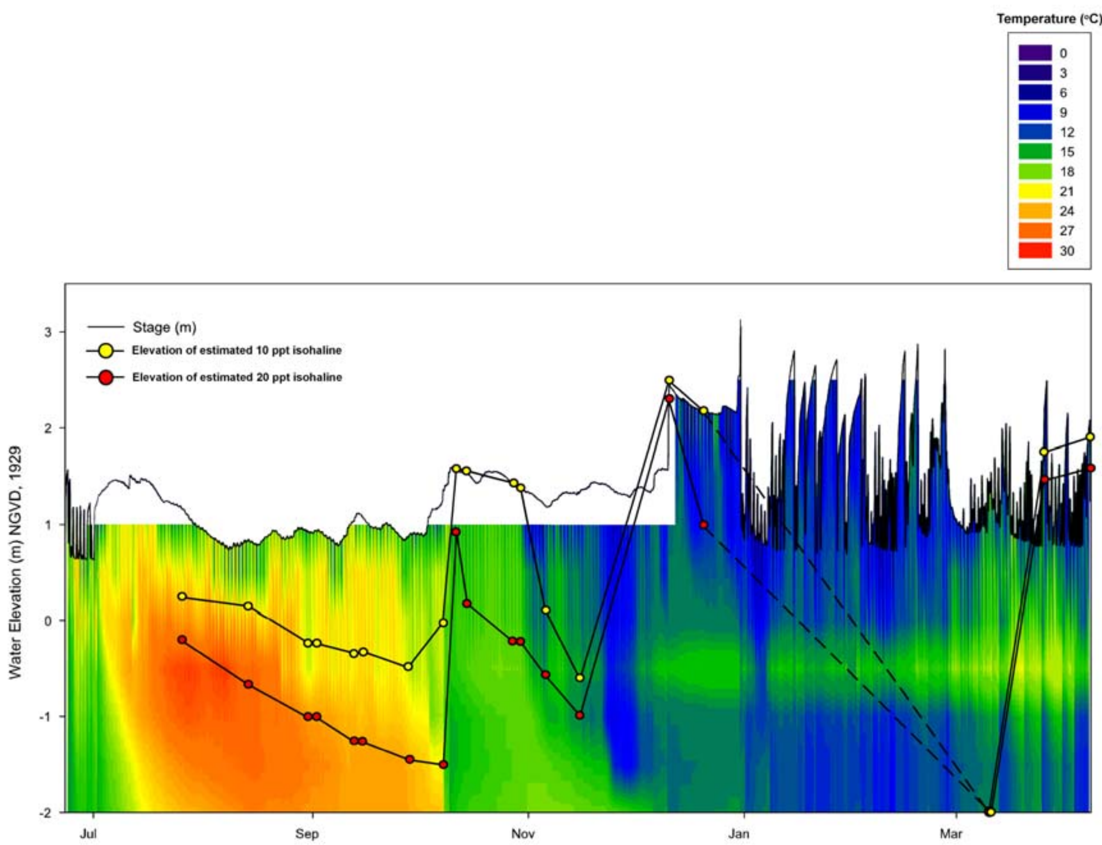


Figure 7-1 Example of a temperature time series of depth profiles, taken from Casagrande, 2003.

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# 9 Appendix 1: Detailed water quality results

These results are displayed by site. Each water quality parameters is presented in the two phases outlined in the timeline. Measurements taken with the YSI are in depth profiles. A time series of these parameters is difficult to interpret from these graphs. In the next report, these depth profiles will be displayed in a time series (Fig. 7-1 ). The general format for these depth profiles is as follows:

- PHASE 1 – Date in the legend in italics is the date a dead steelhead was found near S2. Dates that are in bold are dates that fish were seined from the edge of the South Arm in S5 and S6 (see Fig. 4-1 for location of S5 and S6). Dates that are in italics and bold are dates that the temporary rd was placed in the South Arm for excavation.

- PHASE 2 – Dates in the legend in italics are dates of excavation in the South Arm. Bold dates are dates that the earth barrier was removed. The date in bold and italics is the date the silt curtains were found dislodged.

Depth profiles were not taken from S4, as this site was too shallow. YSI measurements from S4 are presented in table form.

Data from samples are presented in time series for each parameter at each site for each phase.

S4O and S4I were only monitored for Phase 2. Depth profiles of YSI measurements from S4O and S4I are formatted similar to all other depth profiles, but turbidity, SSC, $CO_2$, and $H_2S$ from samples collected at these two sites are graphed together on the same time series to allow direct comparison of the data from either side of the silt curtains.

Since the north arm and main lagoon were only sampled twice during Phase 2, time series for turbidity, SSC, $CO_2$ were not created. These data are in table form as well.

R1N, R1S, & OØ were only sampled during Phase 1.

The Odello channel was not sampled according to phase. Monitoring in the newly excavated channel occurred on 4 separate dates, the date being 22October, after the entire channel was completely connected with the South Arm. Since there is only four sampling dates that are spread out over time, summaries of turbidity and SSC are not presented in time series, but in a table.

## 9.1 S2: South Arm pipe

### 9.1.1 Temperature

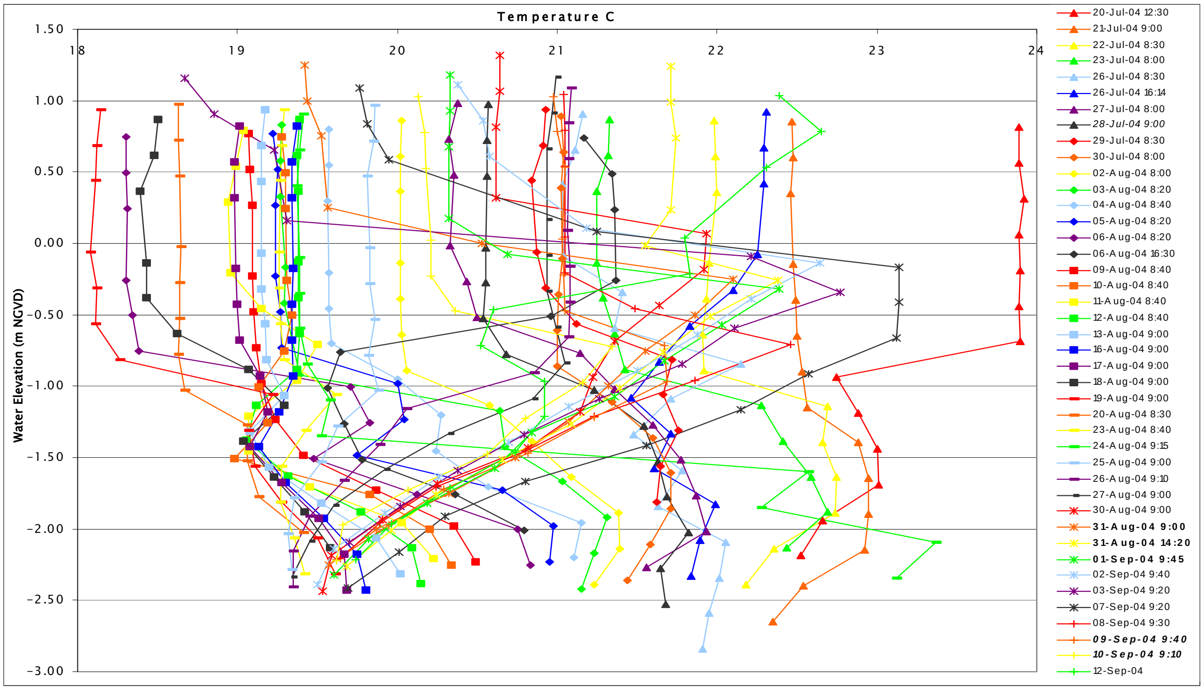


Figure 9-1 Depth profiles of temperature at S2 during Phase 1.

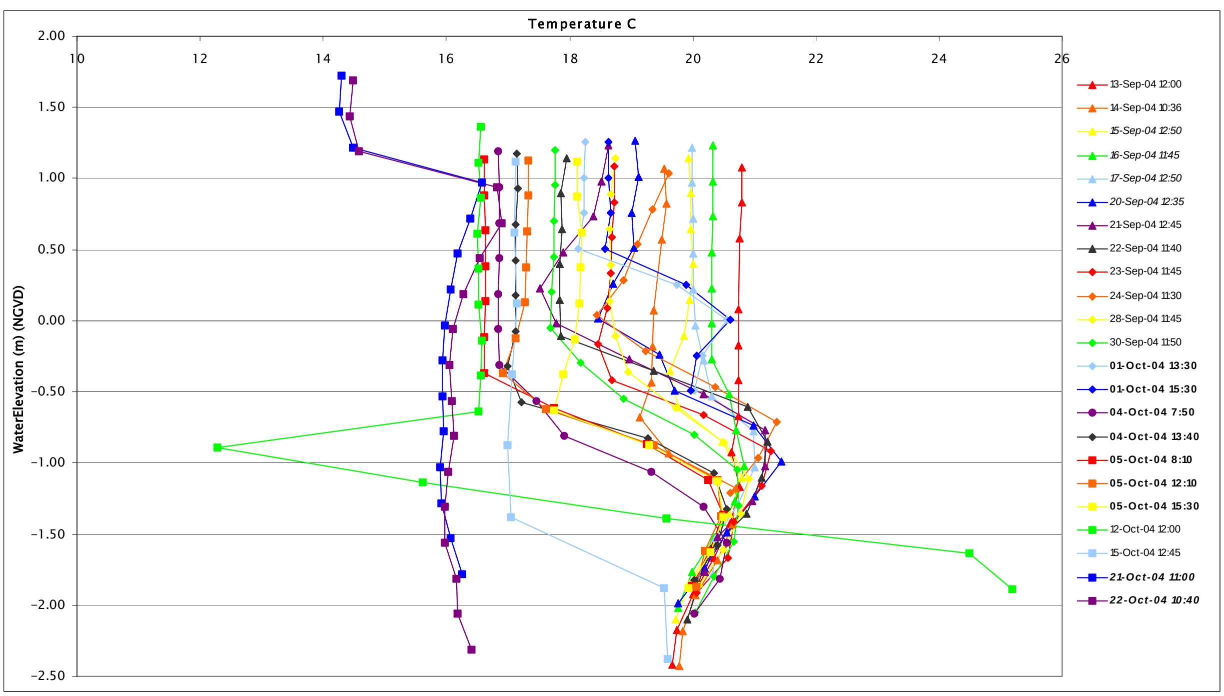


Figure 9-2 Depth profiles of temperature at S2 during Phase 2.

### 9.1.2 S2: Salinity

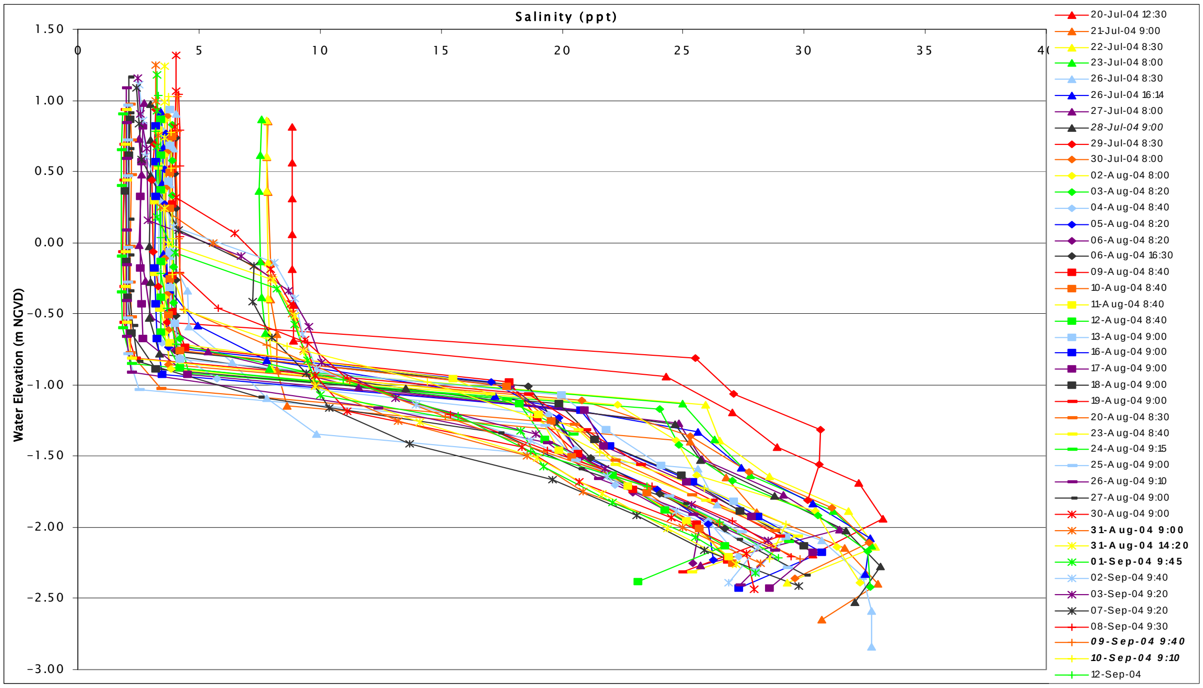


Figure 9-3 Depth profiles of salinity at S2 during Phase 1.

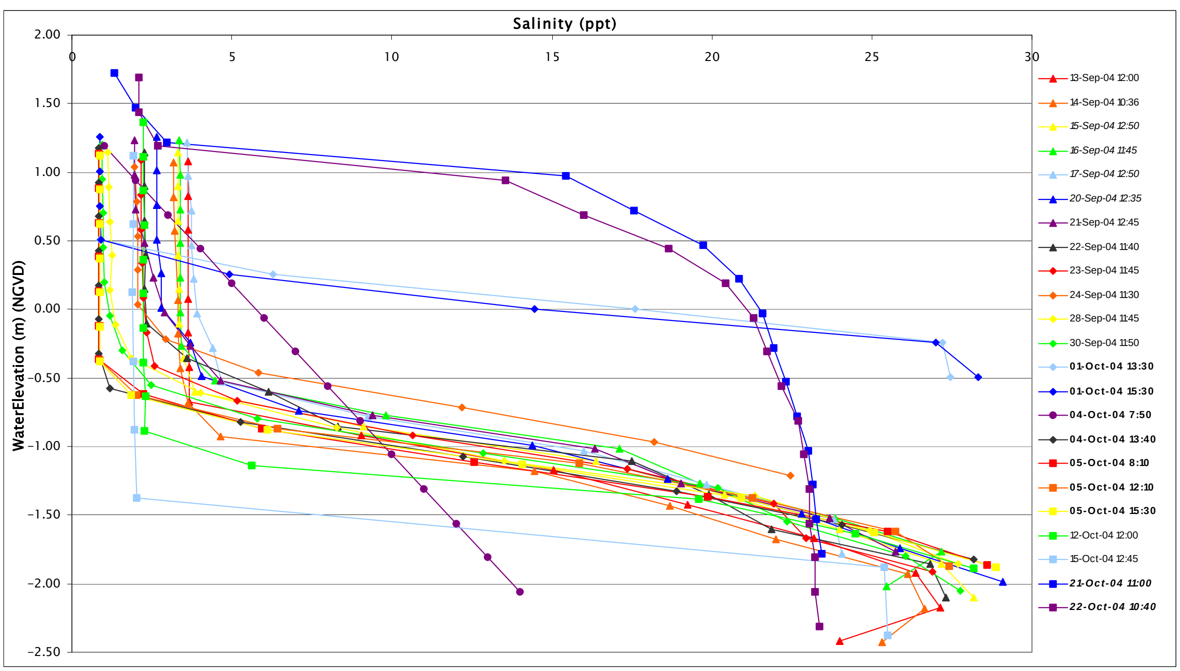


Figure 9-4 Depth profiles of salinity at S2 during Phase 2.

### 9.1.3 S2: Dissolved oxygen

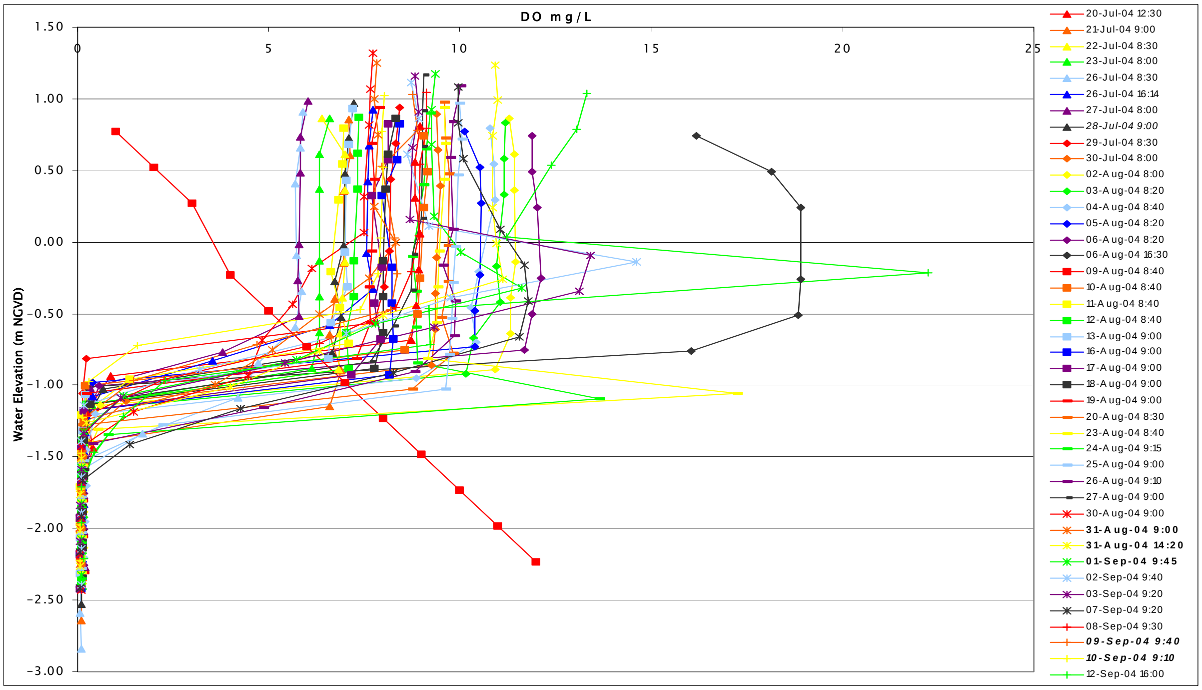


Figure 9-6 Depth profiles of DO at S2 during Phase 2.

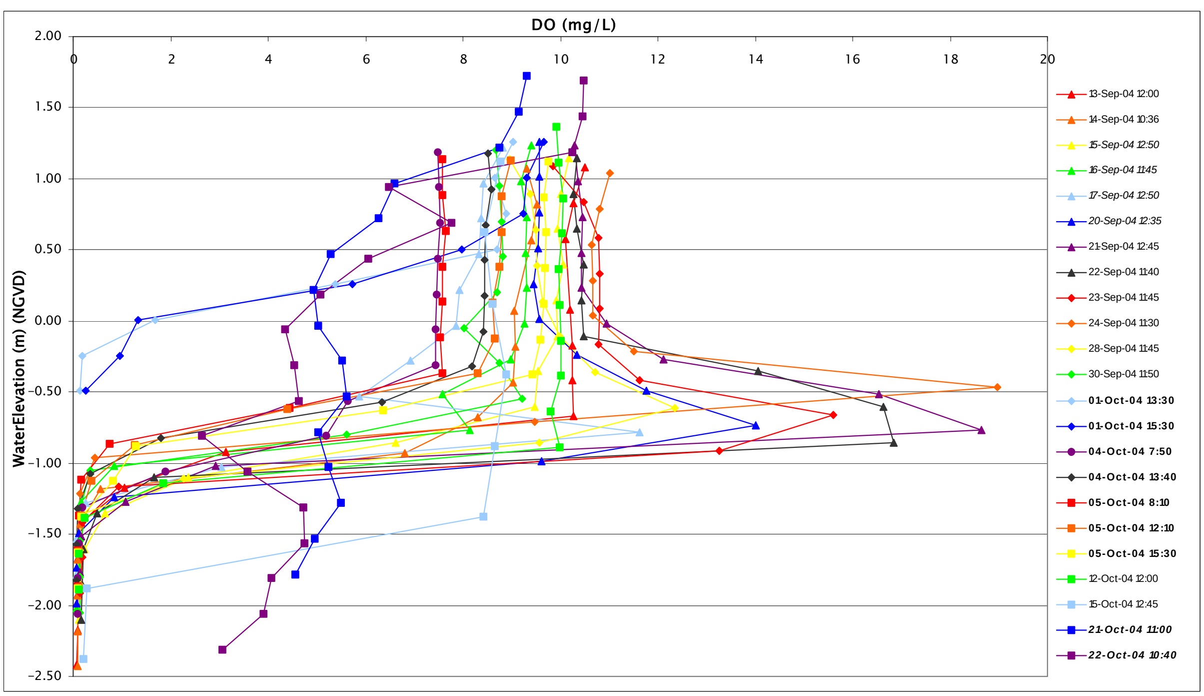


Figure 9-5 Depth profiles of DO at S2 during Phase 2.

### 9.1.4 S2: pH

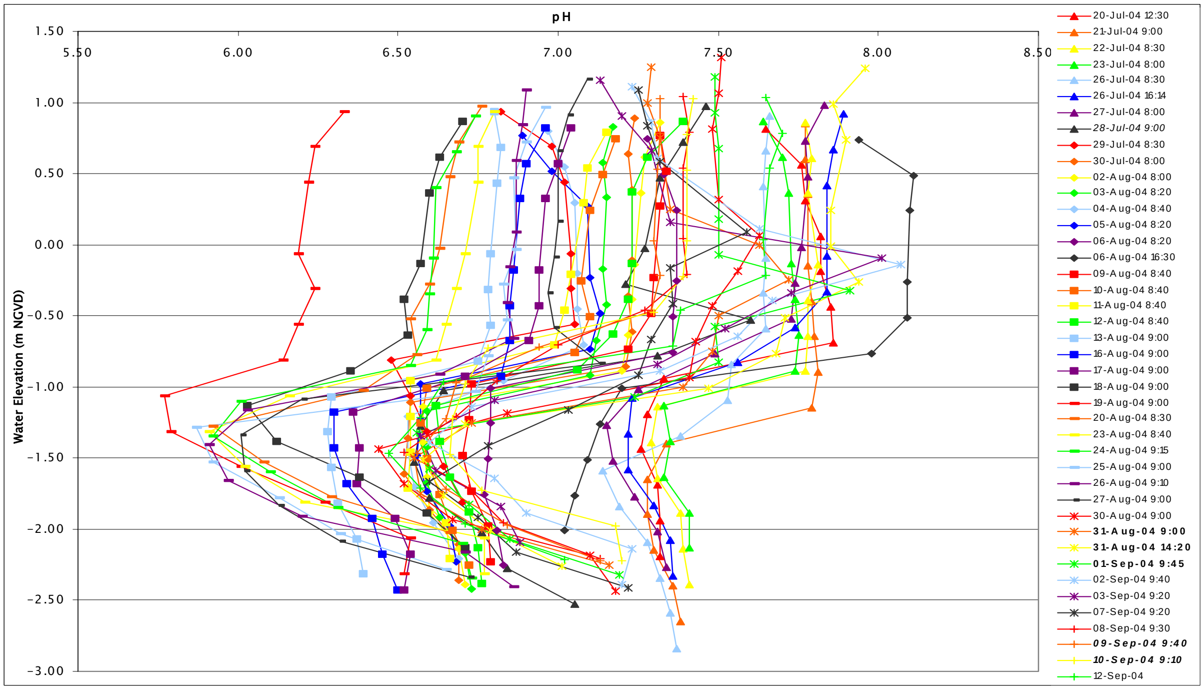


Figure 9-8 Depth profiles of pH at S2 during Phase 1.

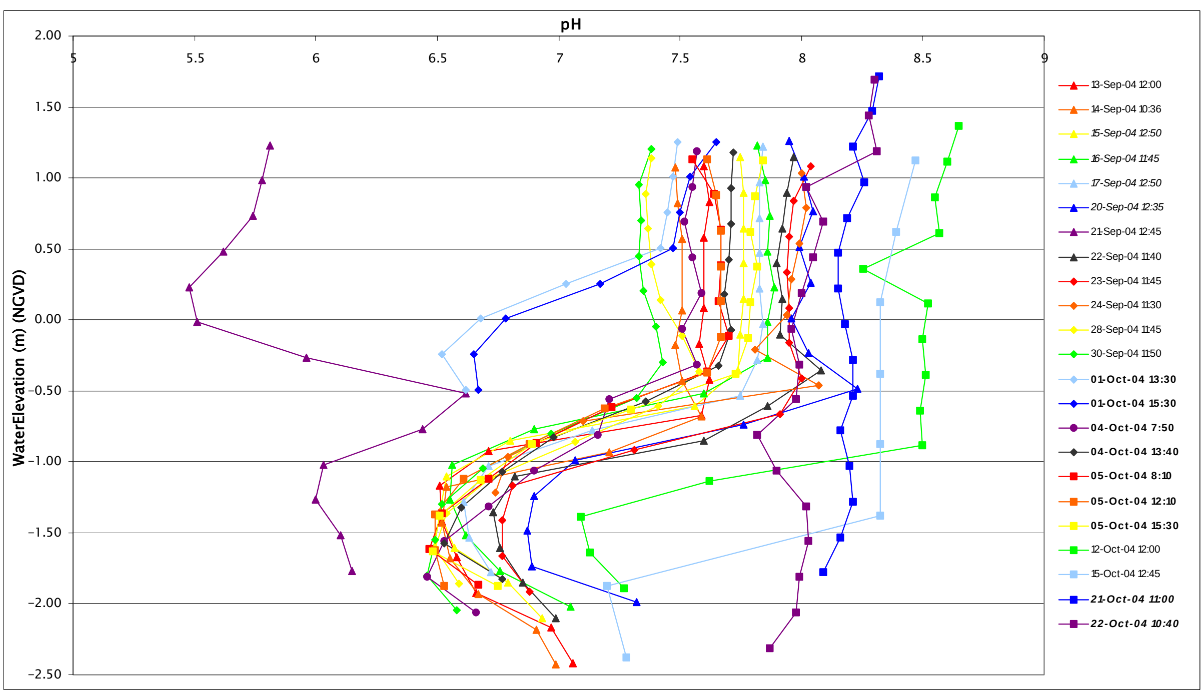


Figure 9-7 Depth profiles of pH at S2 during Phase 2.

### 9.1.5 S2: $CO_2$

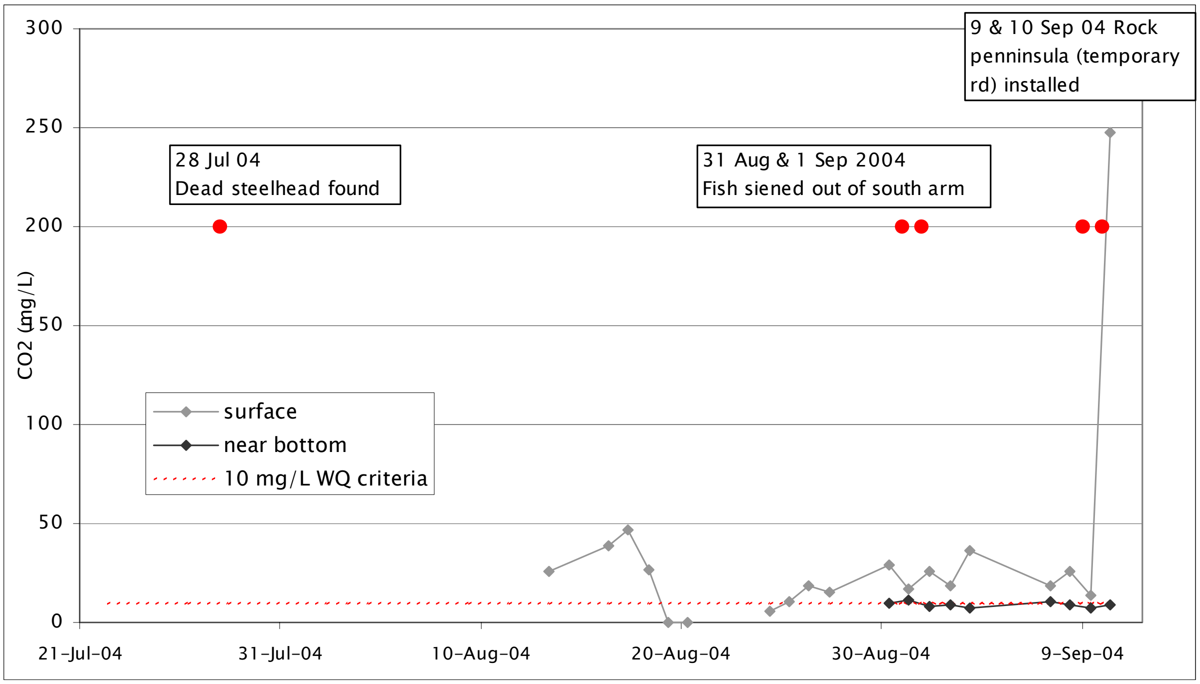


Figure 9-10 Time series of $CO_2$ at S2 during Phase 1.

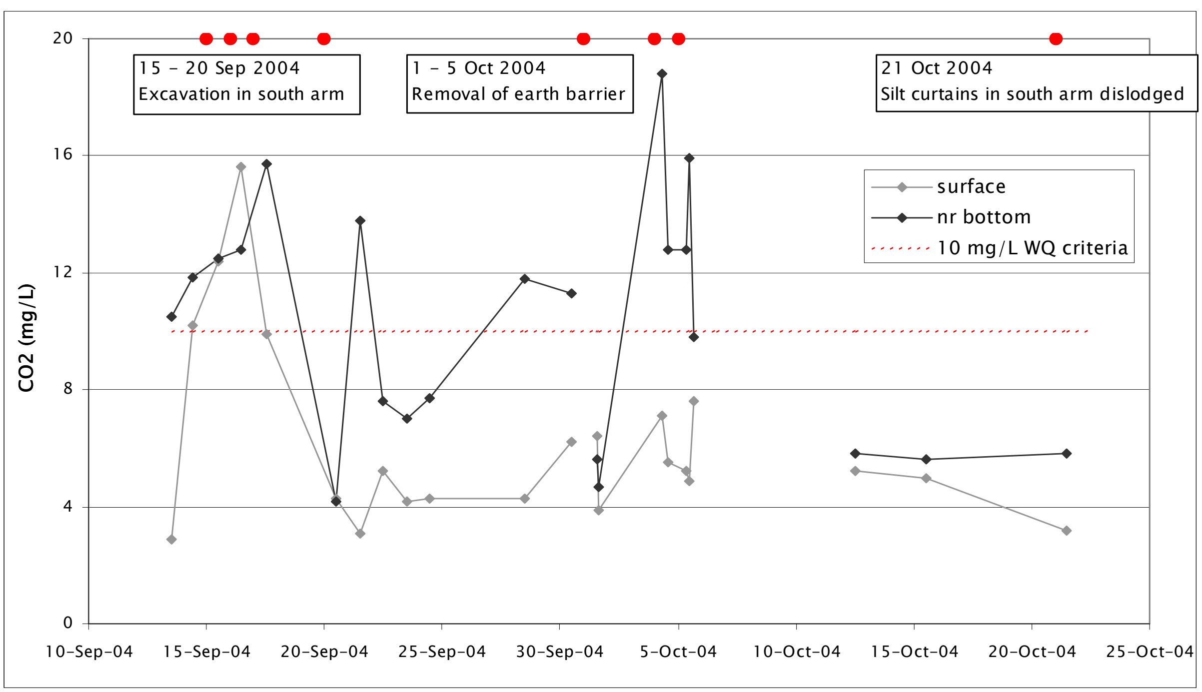


Figure 9-9 Time series of CO2 at S2 during Phase 2.

### 9.1.6 S2: Turbidity

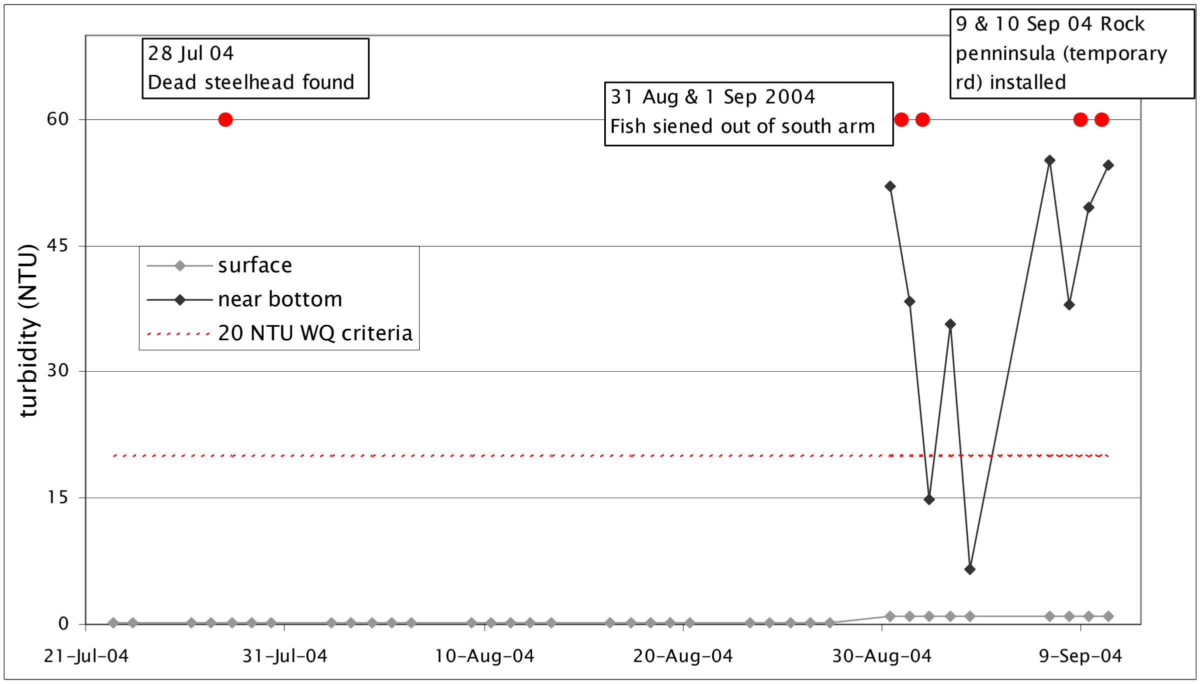


Figure 9-12 Time series of turbidity at S2 during Phase 1.

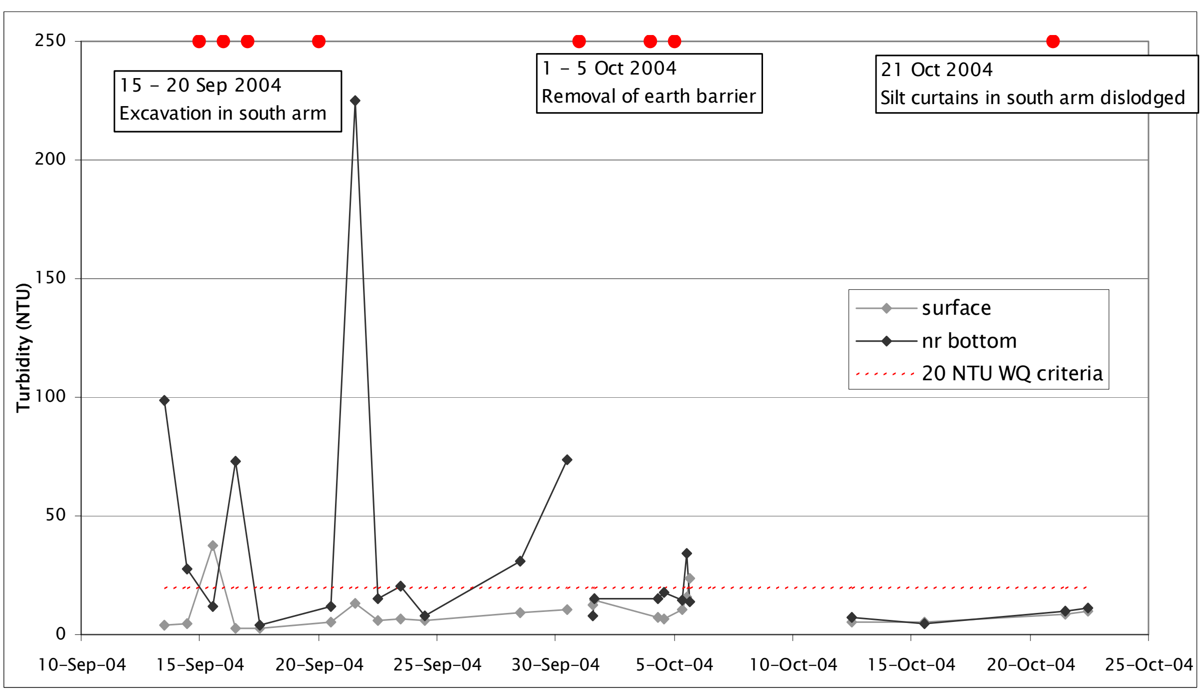


Figure 9-11 Time series of turbidity at S2 during Phase 2.

### 9.1.7 S2: SSC

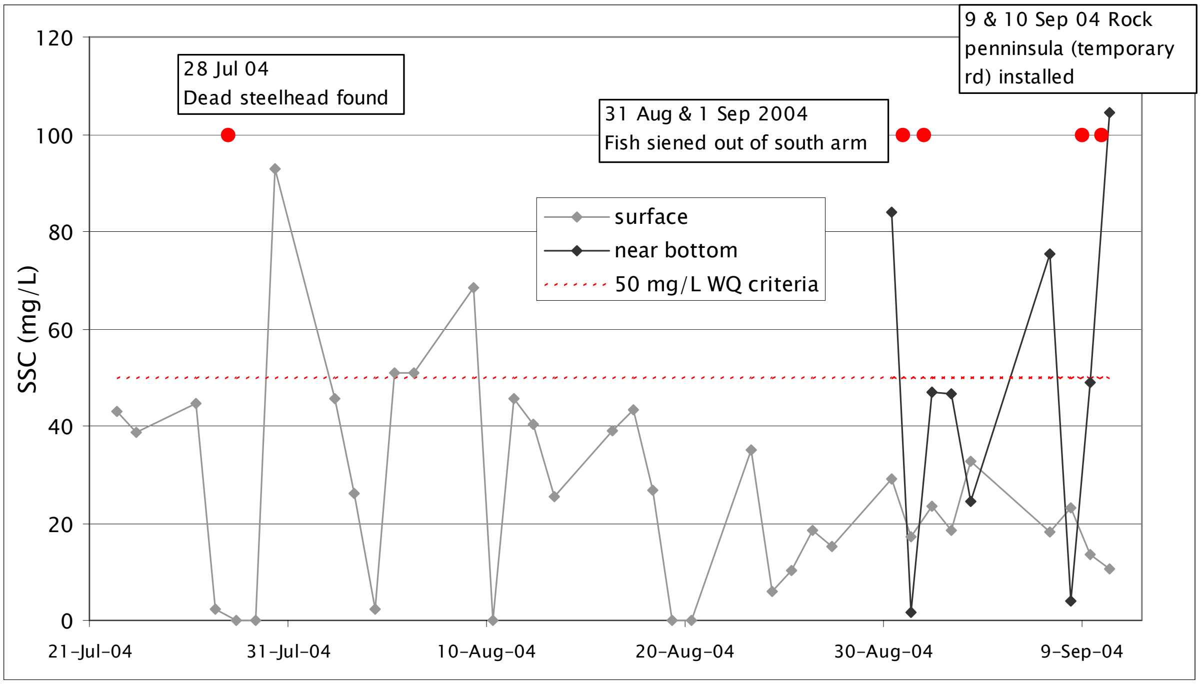


Figure 9-14 Time series of SSC at S2 during Phase 1.

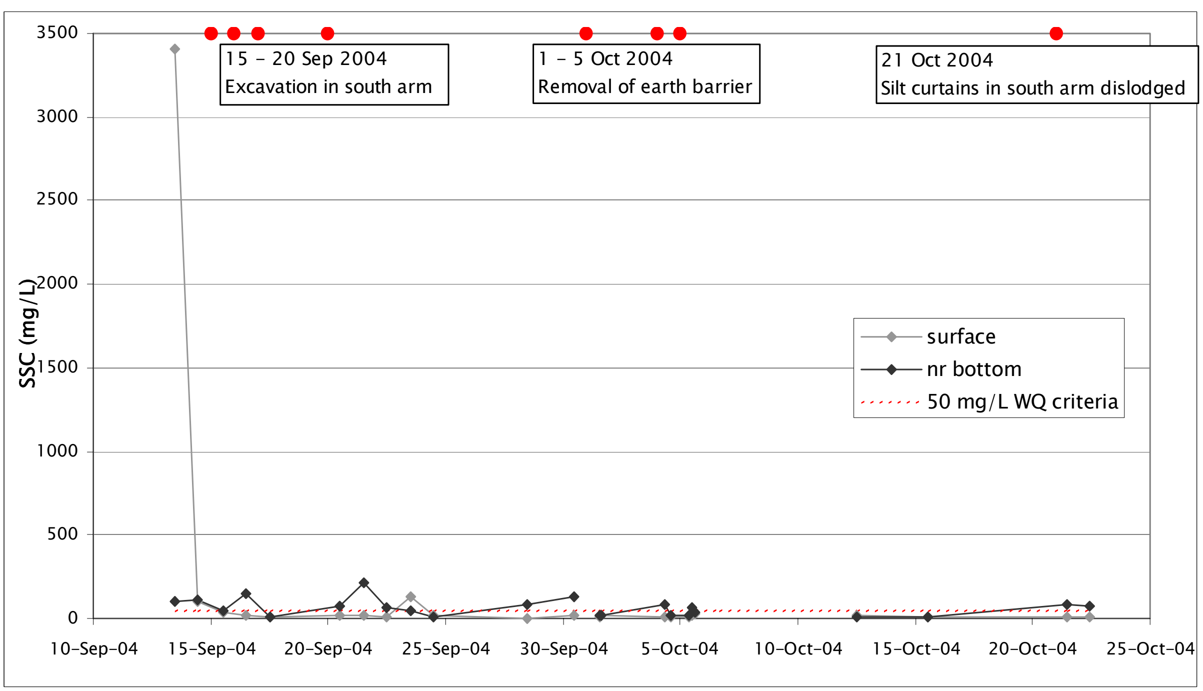


Figure 9-13 Time series of SSC at S2 during Phase 2.

### 9.1.8 S2: $H_2S$

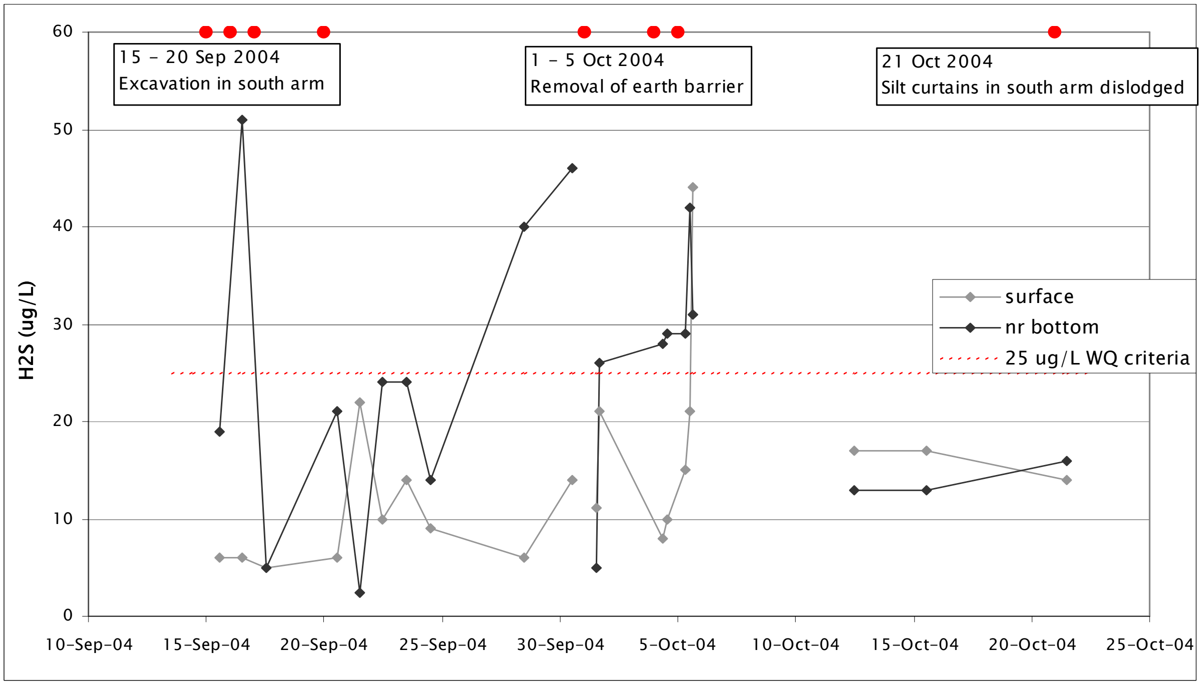


Figure 9-15 Time series of $H_2S$ at S2 during Phase 2.

## 9.2 S4: Existing lagoon side of earth barrier

### 9.2.1 Temperature, Salinity, DO, and pH

Table 9-1 Summary of temperature, salinity, DO and pH at S4 during Phase 1.

| date + time | Temp C | salinity (ppt) | DOconc (mg/L) | pH |
|---|---|---|---|---|
| *28-Jul-04 9:00* | 18.93 | 1.56 | 6.24 | 7.02 |
| 29-Jul-04 9:00 | 19.44 | 1.94 | 5.31 | 7.16 |
| 30-Jul-04 8:30 | 17.52 | 1.51 | 3.84 | 7.19 |
| 02-Aug-04 8:30 | 19.37 | 2.88 | 10.52 | 7.21 |
| 03-Aug-04 8:50 | 18.61 | 2.96 | 8.13 | 7.02 |
| 04-Aug-04 8:50 | 19.32 | 2.56 | 10.3 | 7.14 |
| 05-Aug-04 8:50 | 19.27 | 3.03 | 10.36 | 7.21 |
| 06-Aug-04 8:50 | 19.16 | 3.58 | 12.93 | 7.39 |
| 09-Aug-04 9:10 | 18.96 | 3.13 | 10.88 | 7.37 |
| 10-Aug-04 9:10 | 20.53 | 2.99 | 9.84 | 7.29 |
| 11-Aug-04 9:10 | 17.71 | 4.41 | 4.28 | 6.9 |
| 12-Aug-04 9:10 | 18.29 | 1.96 | 5.87 | 7.14 |
| 13-Aug-04 9:30 | 18.22 | 2.56 | 4.88 | 6.83 |
| 16-Aug-04 9:10 | 18.84 | 1.58 | 8.16 | 7.18 |
| 17-Aug-04 9:10 | 18.5 | 1.27 | 7.39 | 7.03 |
| 18-Aug-04 9:10 | 17.42 | 0.92 | 6.03 | 6.24 |
| 19-Aug-04 9:10 | 17.25 | 0.88 | 6.49 | 6.08 |
| 20-Aug-04 8:40 | 18.08 | 1.54 | 8.26 | 6.42 |
| 23-Aug-04 8:50 | 18.39 | 1.42 | 10.36 | 6.52 |
| 24-Aug-04 9:20 | 19.35 | 1.57 | 9.47 | 6.65 |
| 25-Aug-04 9:10 | 19.07 | 1.3 | 10.98 | 6.71 |
| 26-Aug-04 9:20 | 20.4 | 1.26 | 9.17 | 6.92 |
| 27-Aug-04 9:10 | 19.6 | 1.45 | 9.87 | 7.09 |
| 30-Aug-04 9:10 | 19.37 | 1.61 | 6.61 | 7.49 |
| 01-Sep-04 9:55 | 21.57 | 1.7 | 7.24 | 7.67 |
| 02-Sep-04 9:50 | 21.96 | 1.51 | 8.07 | 7.42 |
| 03-Sep-04 9:30 | 19.97 | 1.58 | 8.23 | 7.62 |
| 07-Sep-04 9:30 | 21.73 | 1.26 | 8.81 | 7.39 |
| 08-Sep-04 9:40 | 21.62 | 1.18 | 9.73 | 7.41 |
| *09-Sep-04 9:55* | 20.82 | 0.98 | 9.04 | 7.26 |
| *10-Sep-04 9:25* | 20.34 | 0.98 | 7.31 | 7.38 |

### 9.2.2 S4: $CO_2$

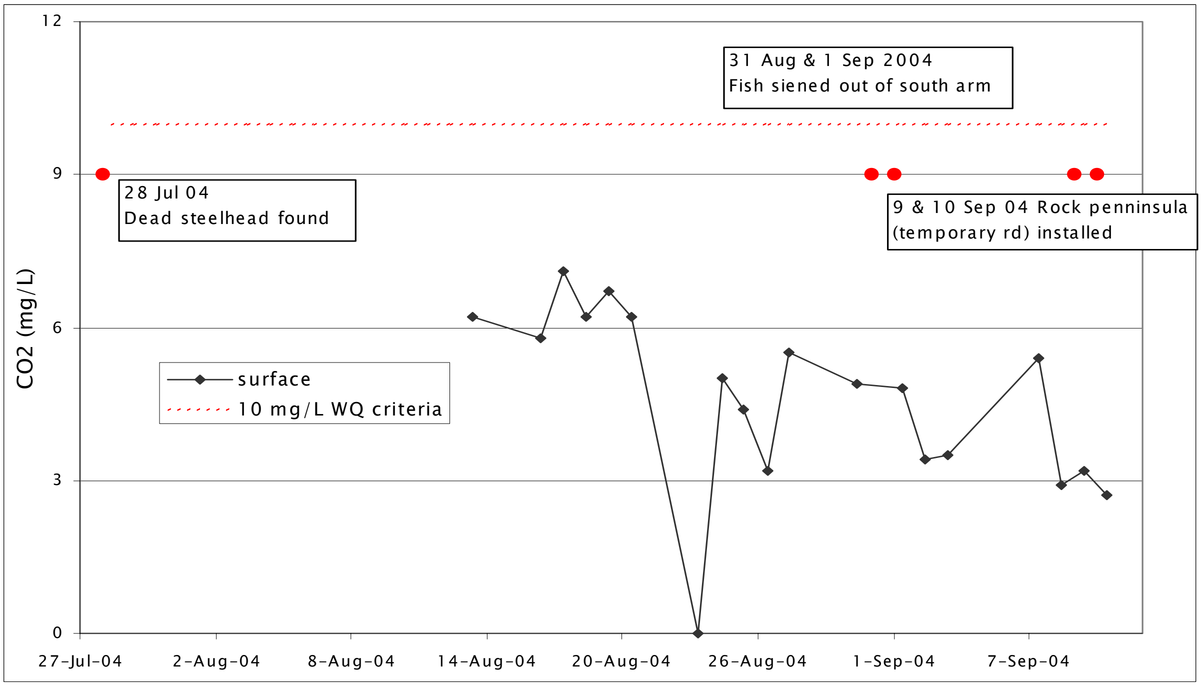


Figure 9-16Time series of CO2 at S4 during Phase 2.

### 9.2.3 S4: Turbidity

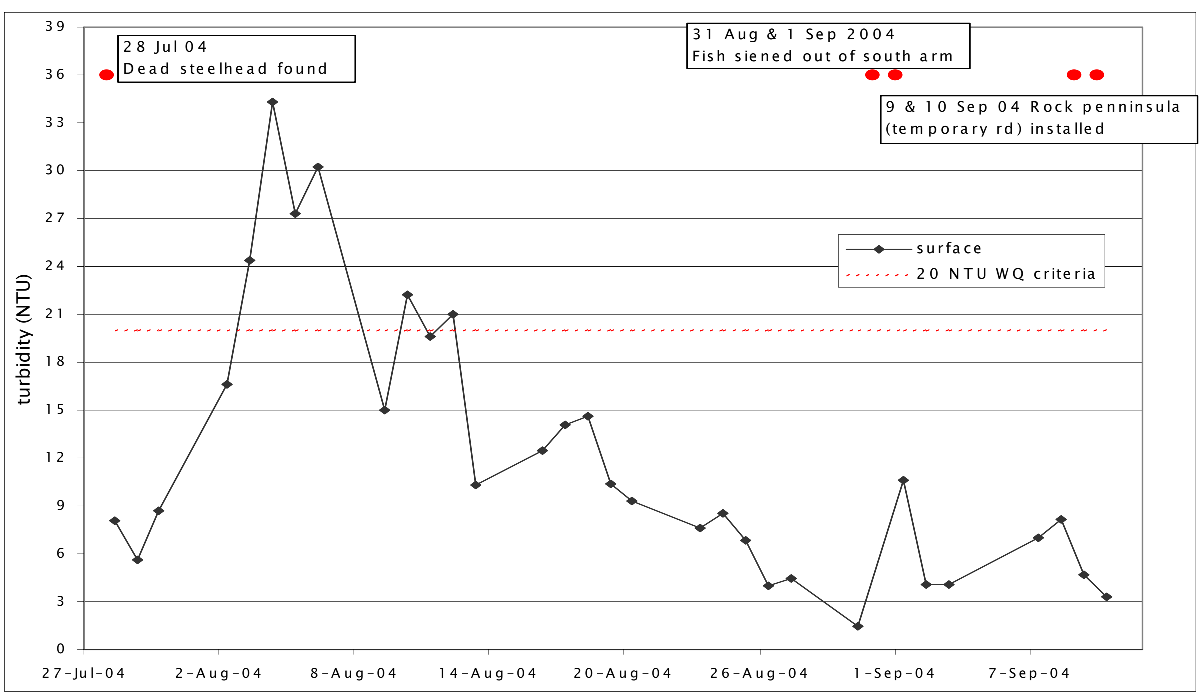


Figure 9-17 Time series of turbidity at S4 during Phase 1.

### 9.2.4 S4: SSC

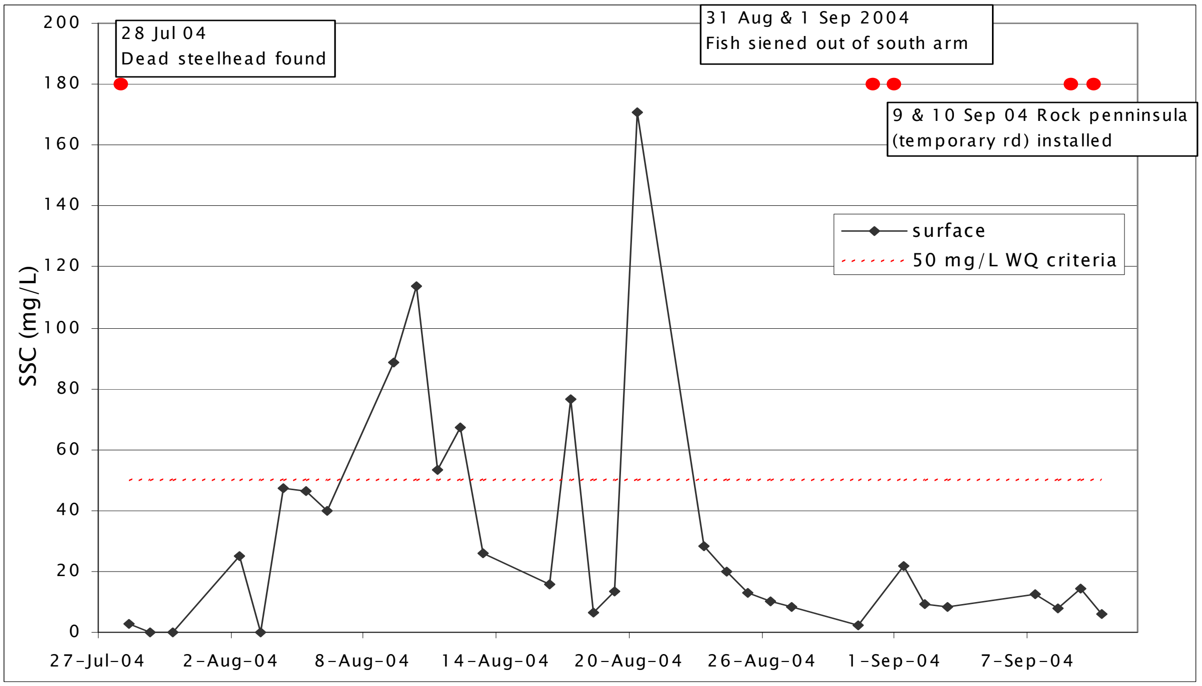


Figure 9-18 Time series of SSC at S4 during Phase 1.

## 9.3 FP: Frog pond

### 9.3.1 FP: Temperature

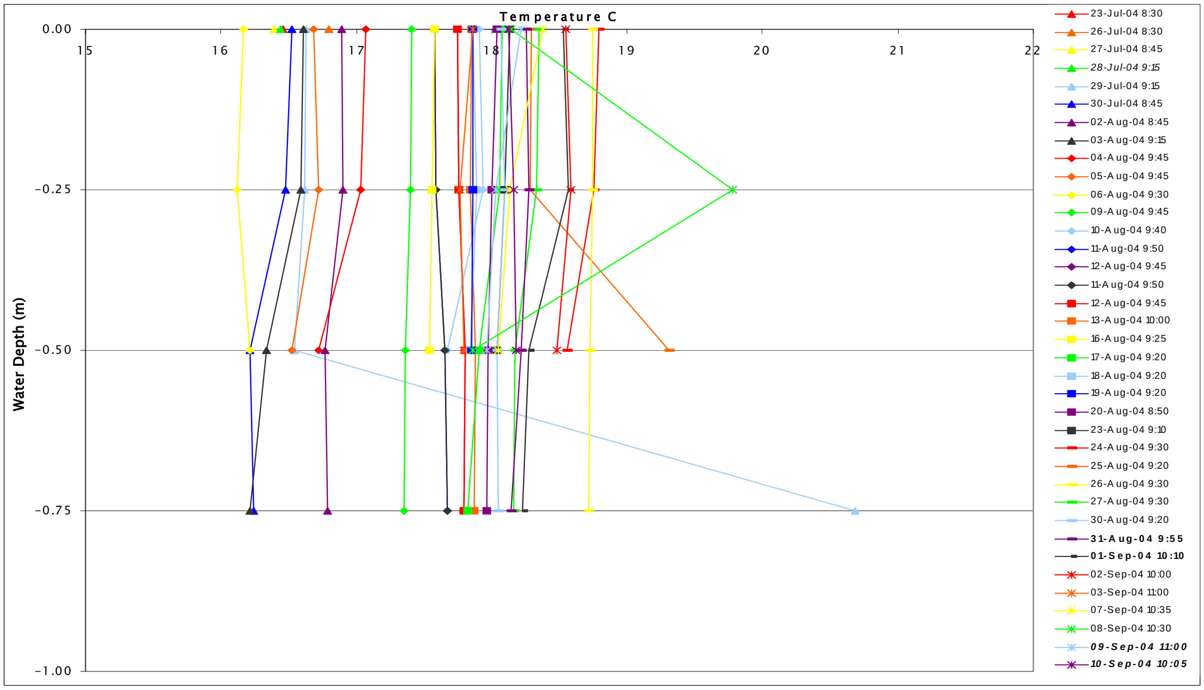


Figure 9-20 Depth profiles of temperature at FP during Phase 1.

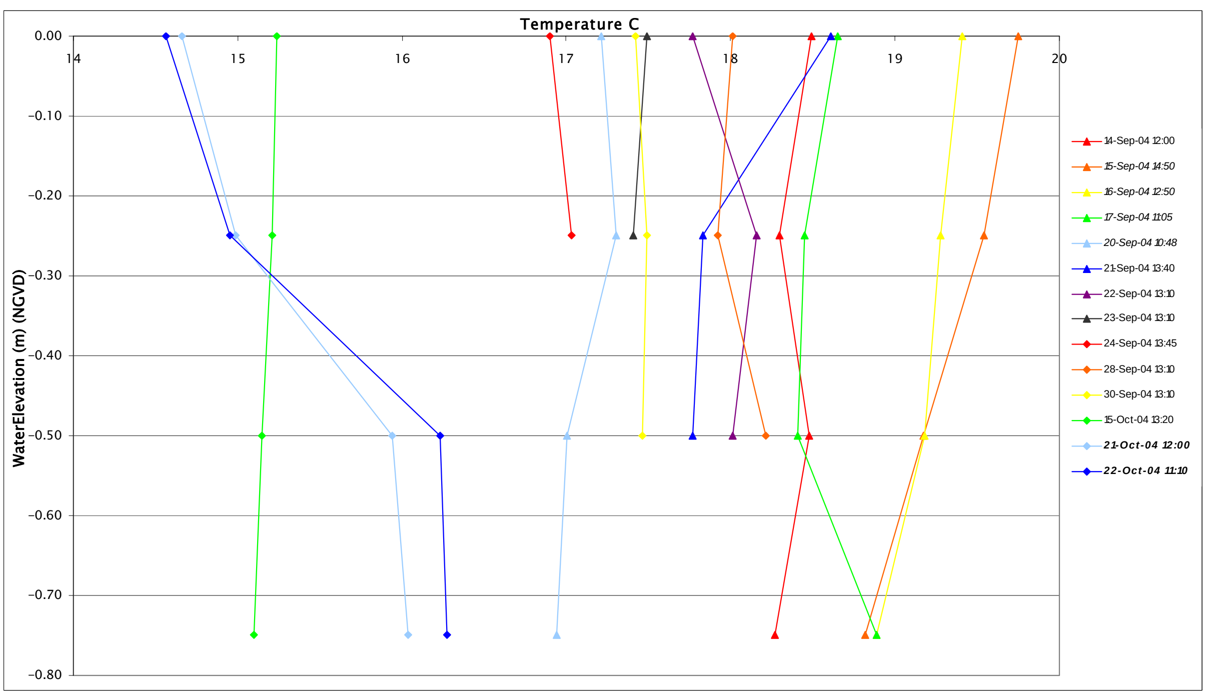


Figure 9-19 Depth profiles of temperature at FP during Phase 2.

### 9.3.2 FP: Salinity

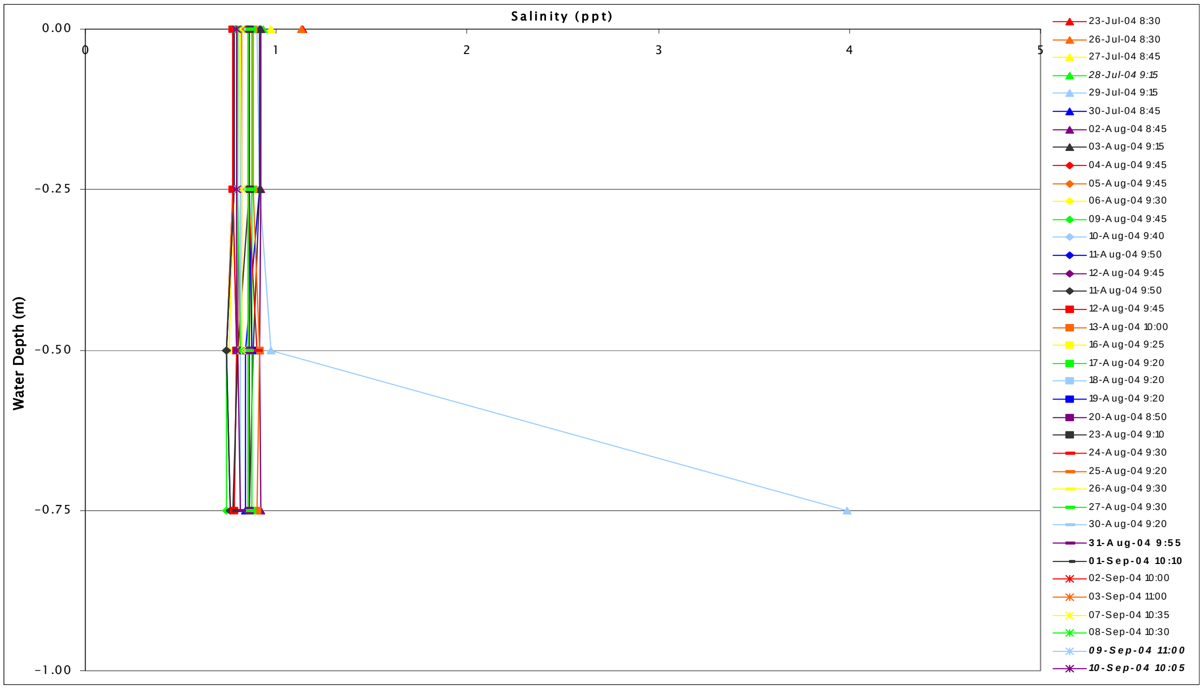


Figure 9-22 Depth profiles of salinity at FP during Phase 1.

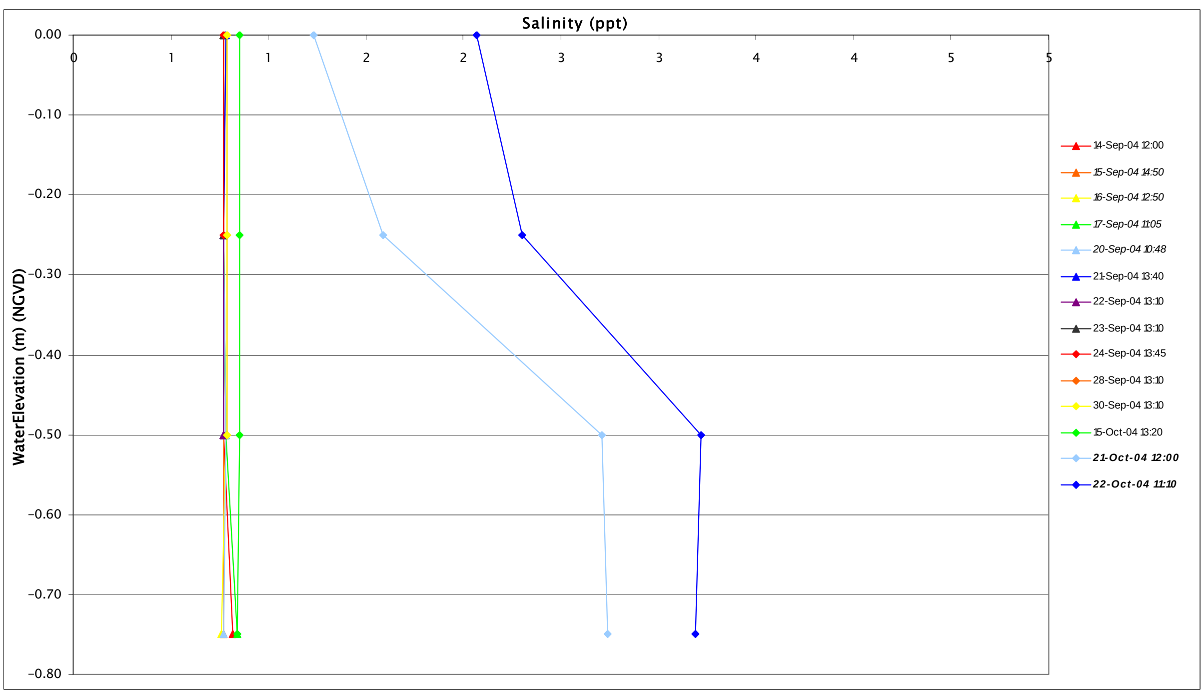


Figure 9-21 Depth profiles of salinity at FP during Phase 2.

### 9.3.3 FP: DO

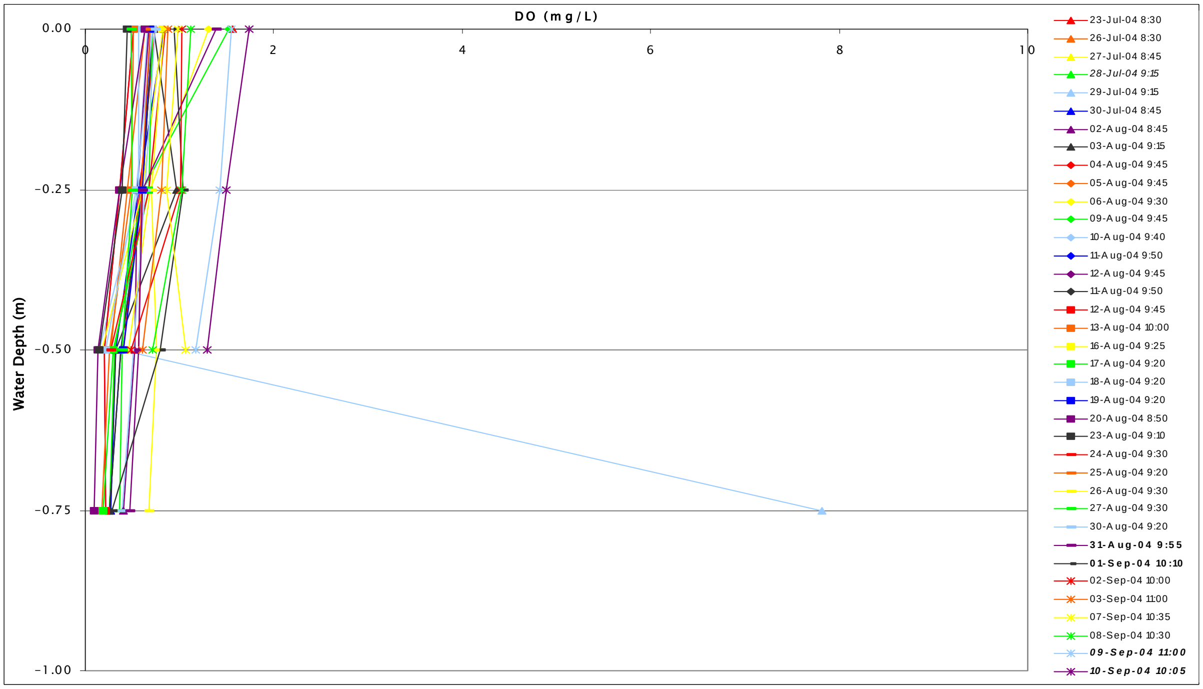


Figure 9-23 Depth profiles of DO at FP during Phase 1.

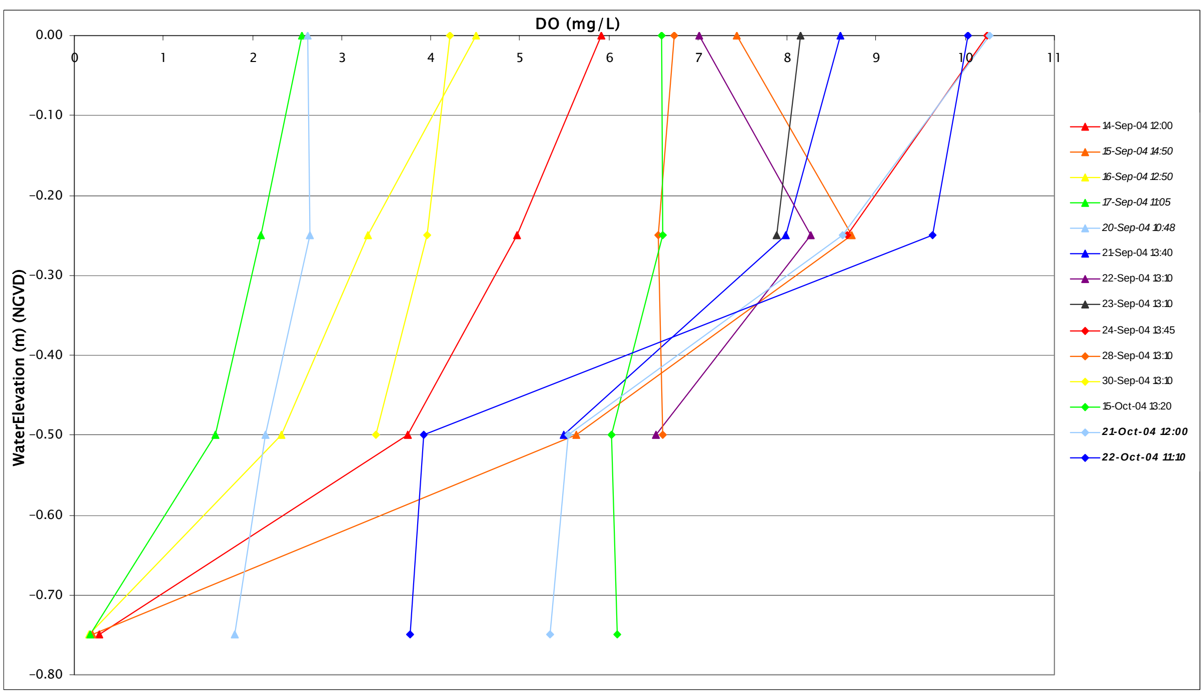


Figure 9-24 Depth profiles of DO at FP during Phase 2.

## 9.3.4 FP: pH

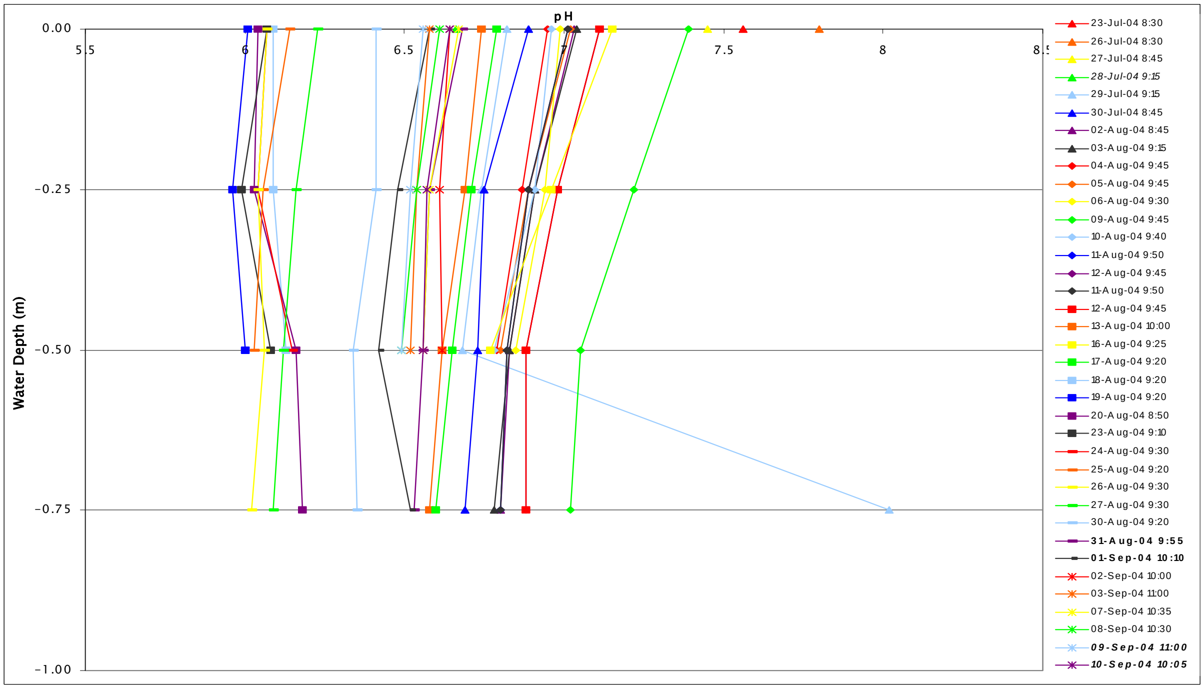


Figure 9-26 Depth profiles of pH at FP during Phase 1.

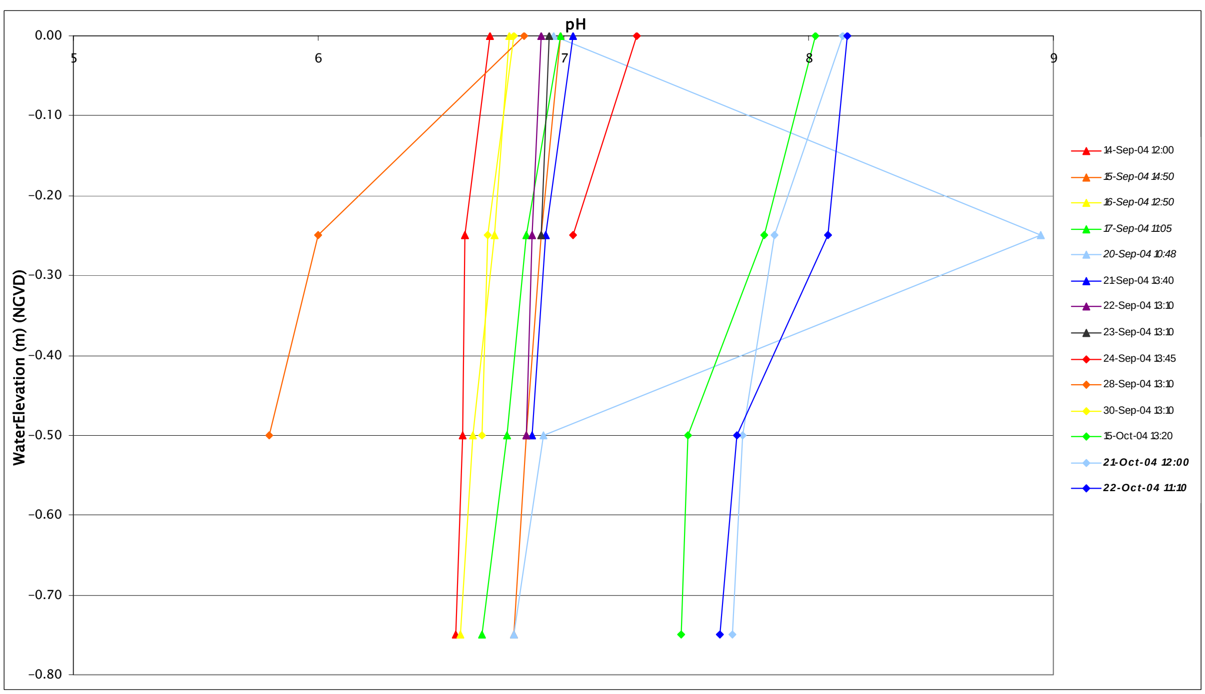


Figure 9-25 Depth profiles of pH at FP during Phase 2.

### 9.3.5 FP: $CO_2$

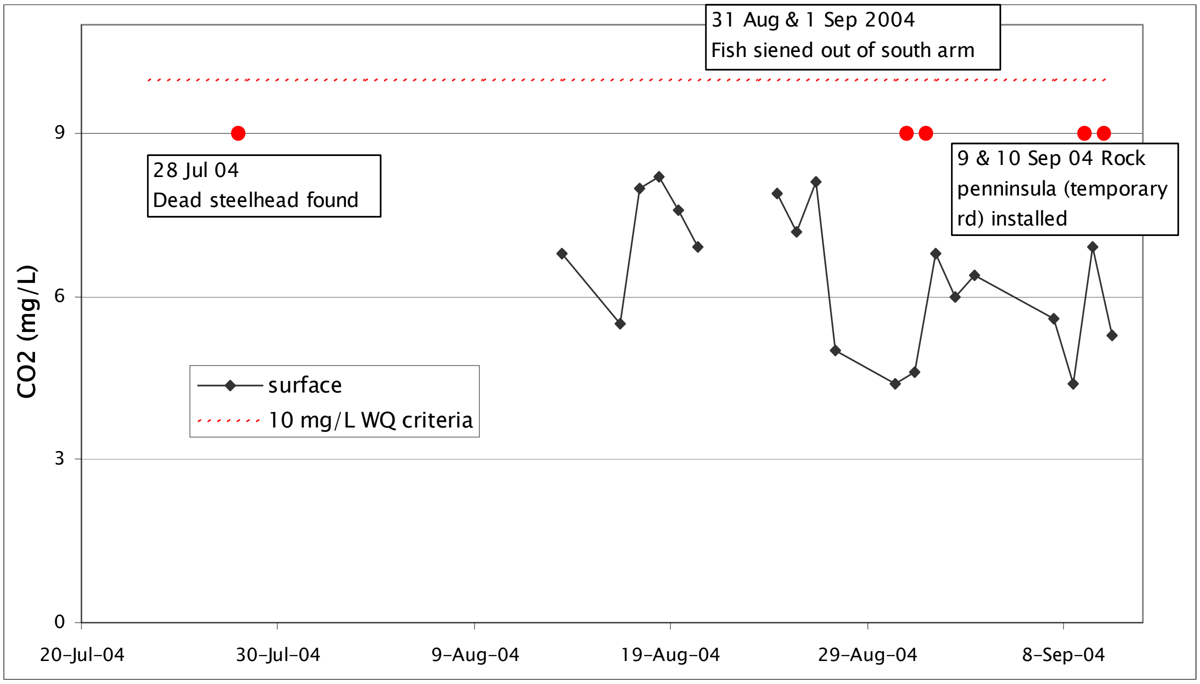


Figure 9-28 Time series of CO2 at FP during Phase 1.

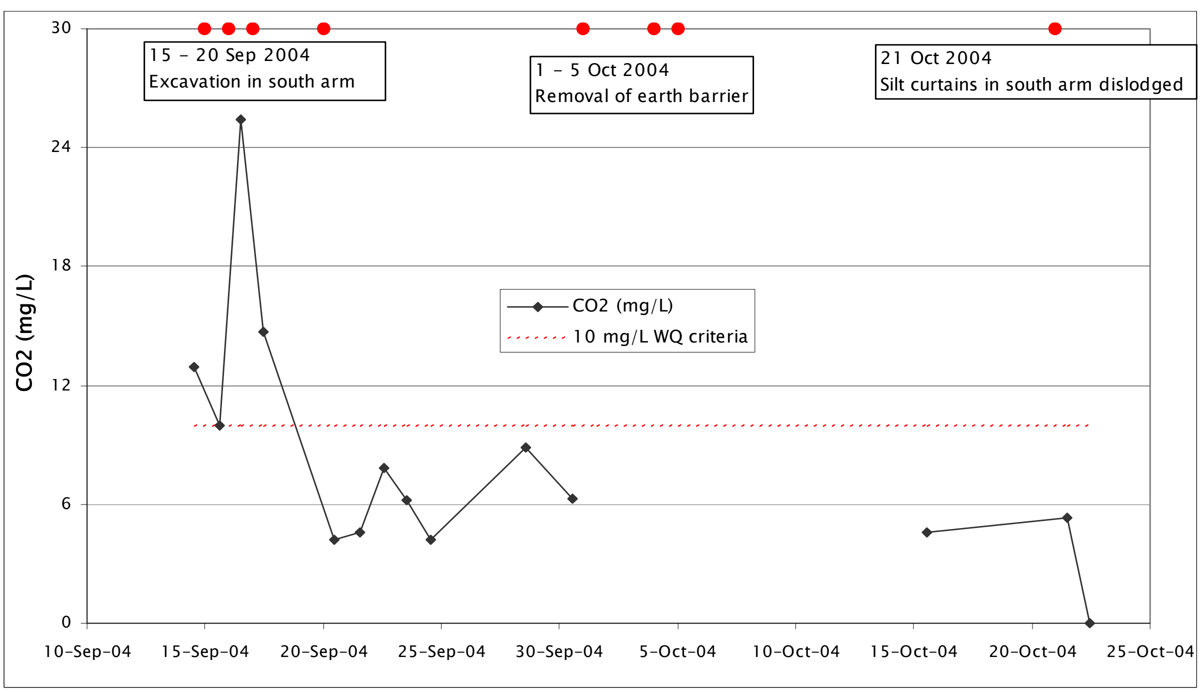


Figure 9-27 Time series of CO2 at FP during Phase 2.

### 9.3.6 FP: Turbidity

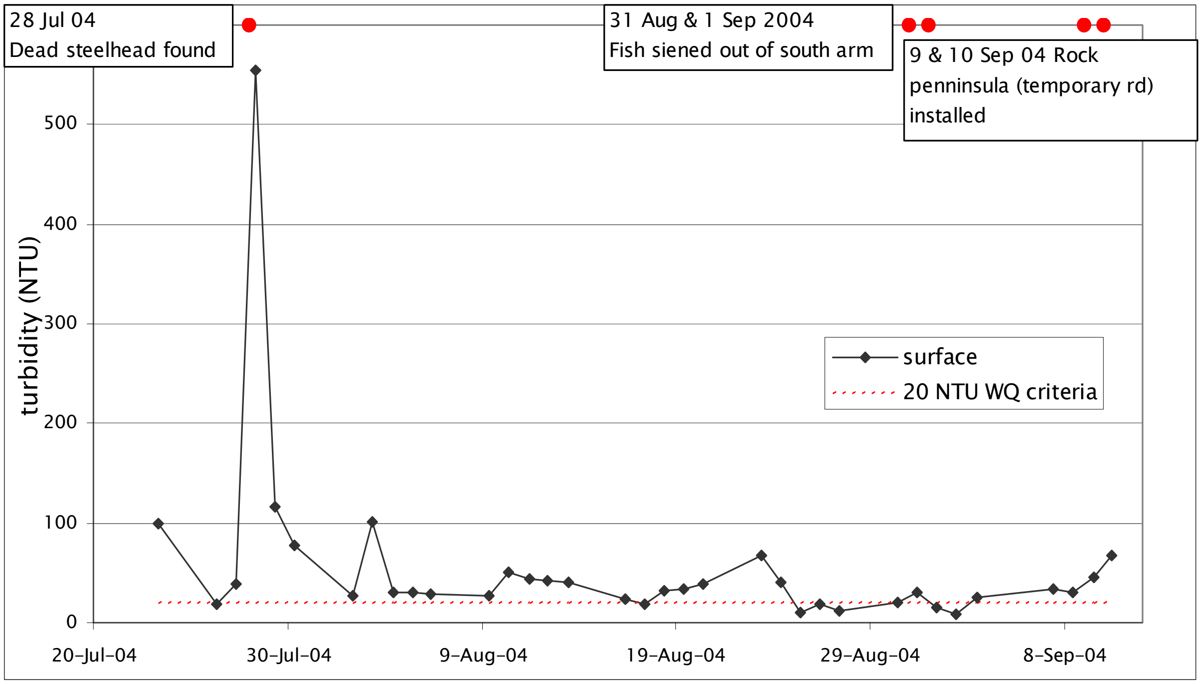


Figure 9-30 Time series of turbidity at FP during Phase 1.

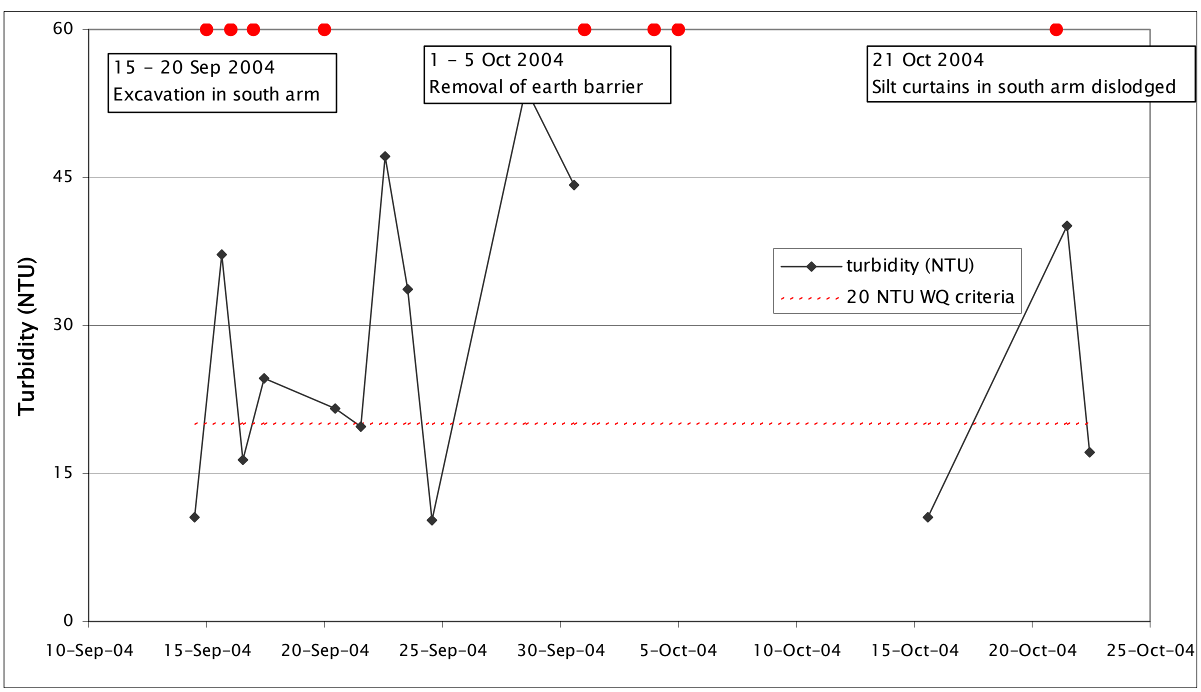


Figure 9-29 Time series of turbidity at FP during Phase 2.

### 9.3.7 FP: SSC

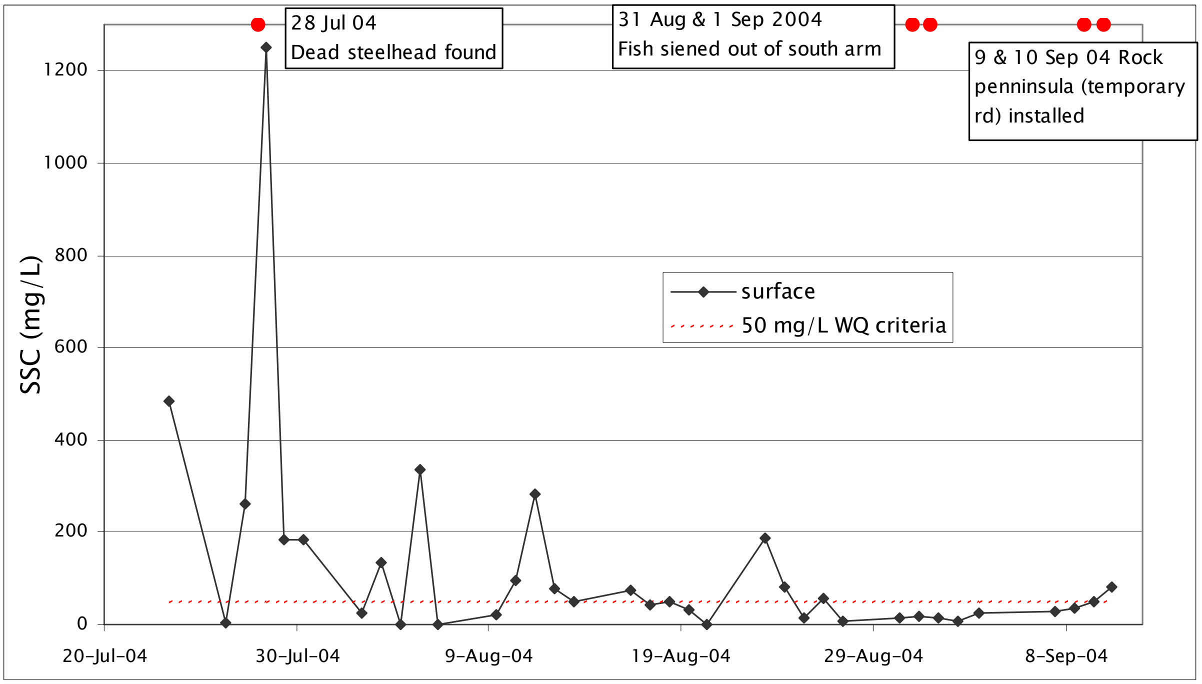


Figure 9-31 Time series of SSC at FP during Phase 1.

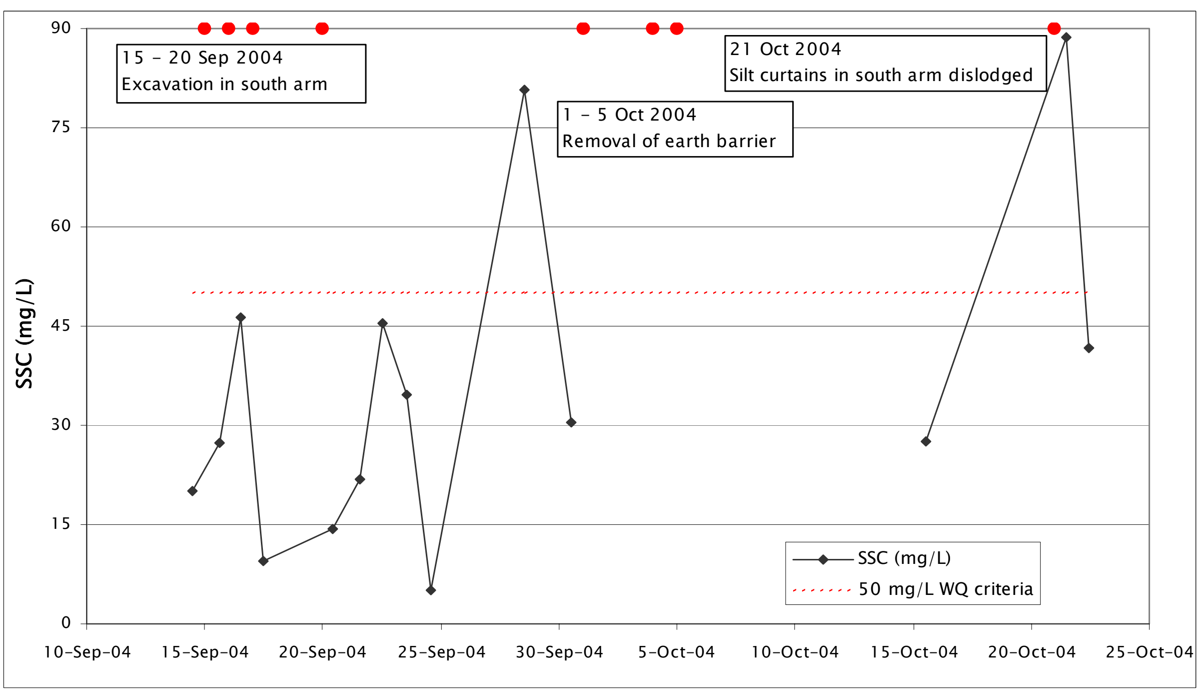


Figure 9-32 Time series of SSC at FP during Phase 1.

### 9.3.8 FP: $H_2S$

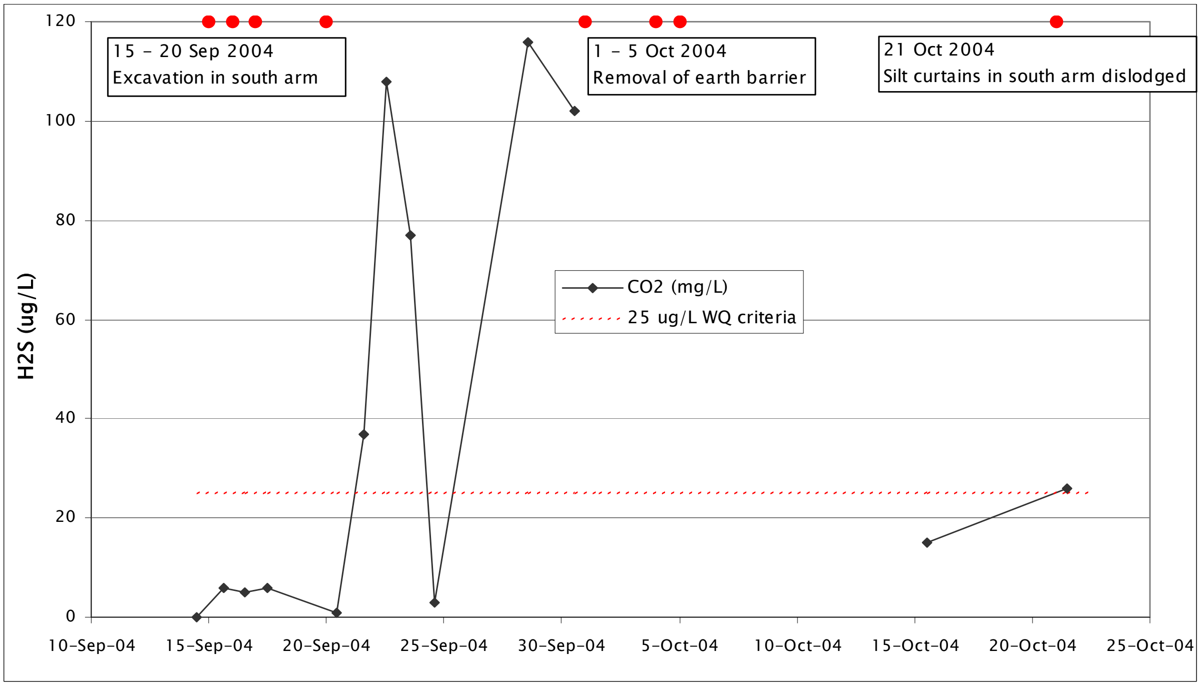


Figure 9-33 Time series of $H_2S$ at FP during Phase 2.

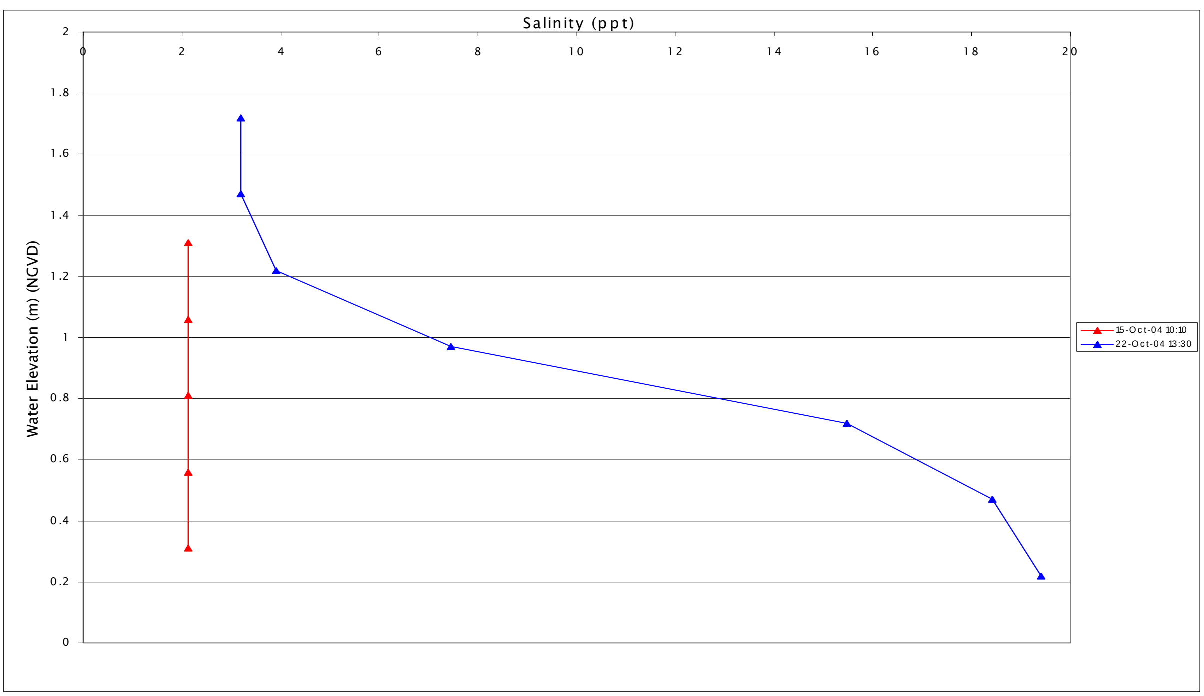


Figure 9-34 Depth profiles of salinity at N2 during Phase 2.

## 9.4 N1: Western branch of the north arm

### 9.4.1 Temperature

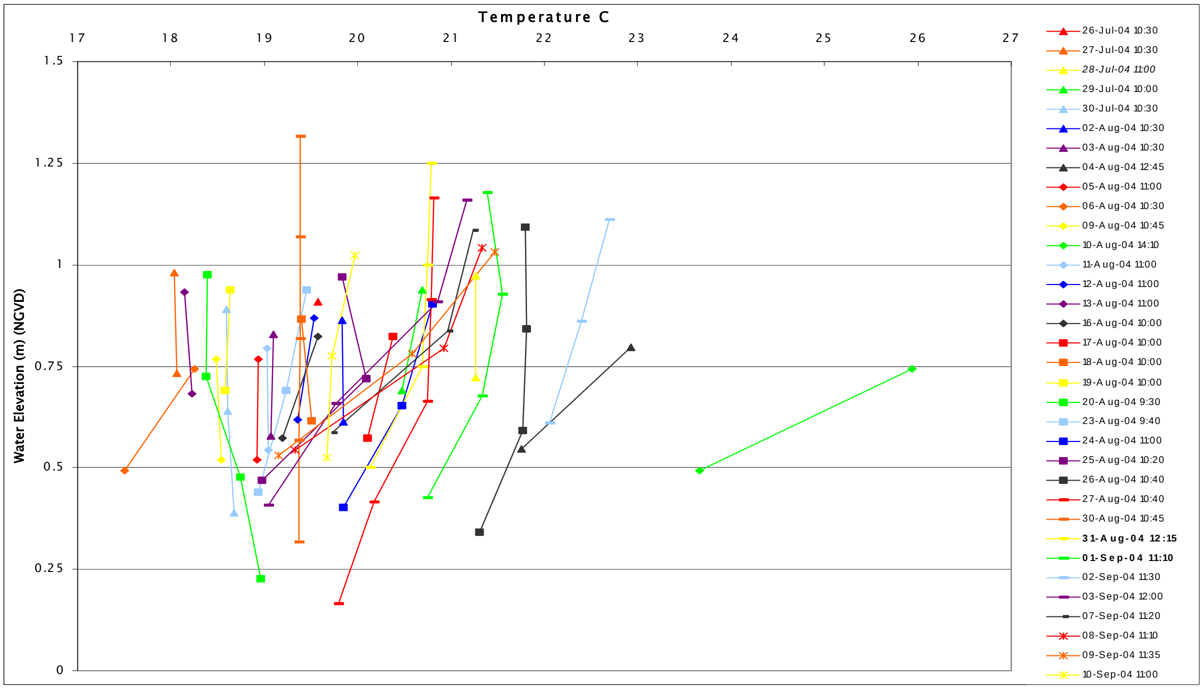


Figure 9-35 Depth profiles of temperature at N1 during Phase 1.

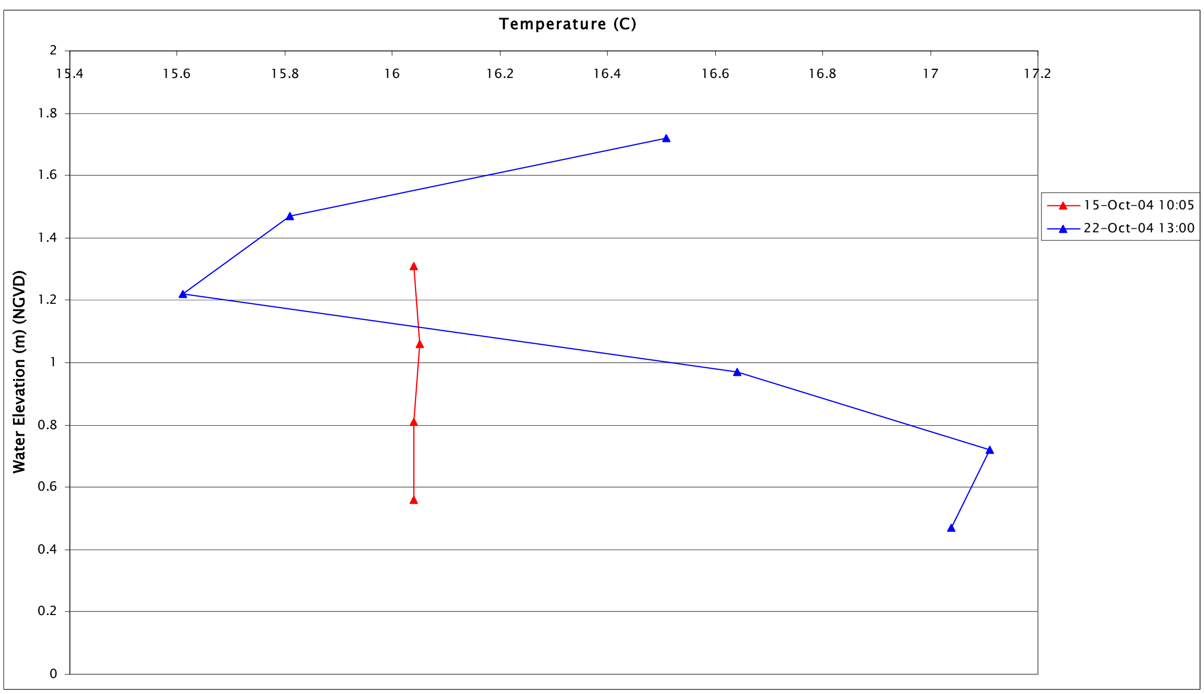


Figure 9-36 Depth profiles of temperature at N1 during Phase 2.

## 9.4.2 N1: Salinity

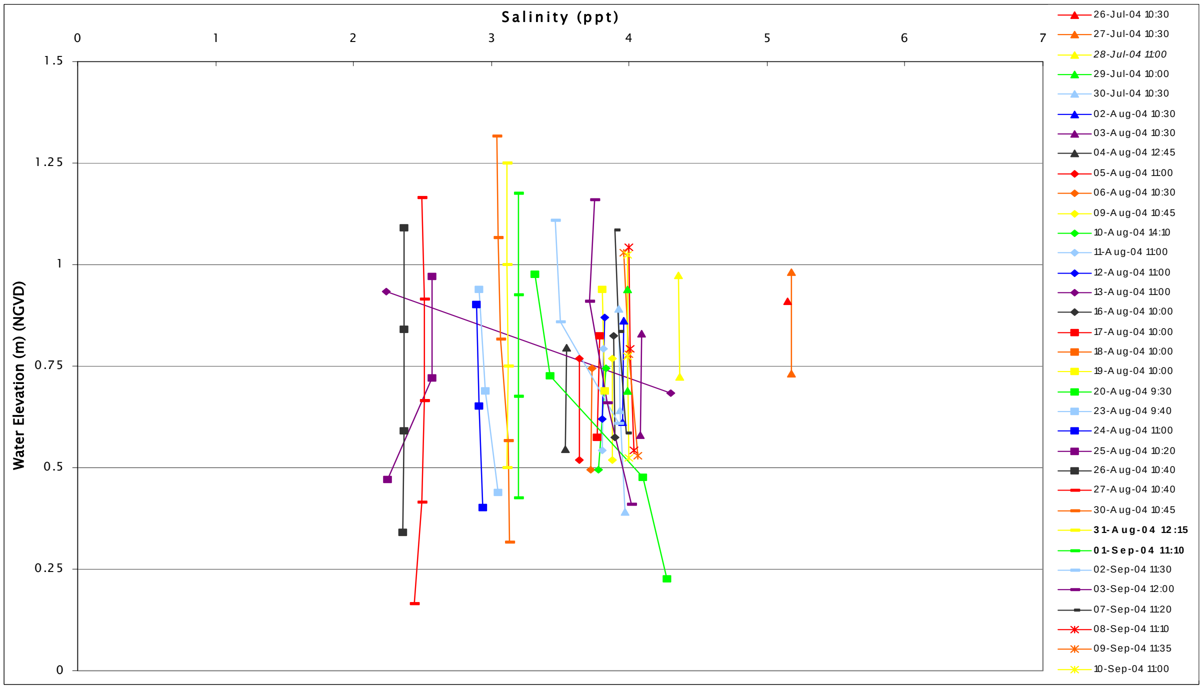


Figure 9-37 Depth profiles of salinity at N1 during Phase 1.

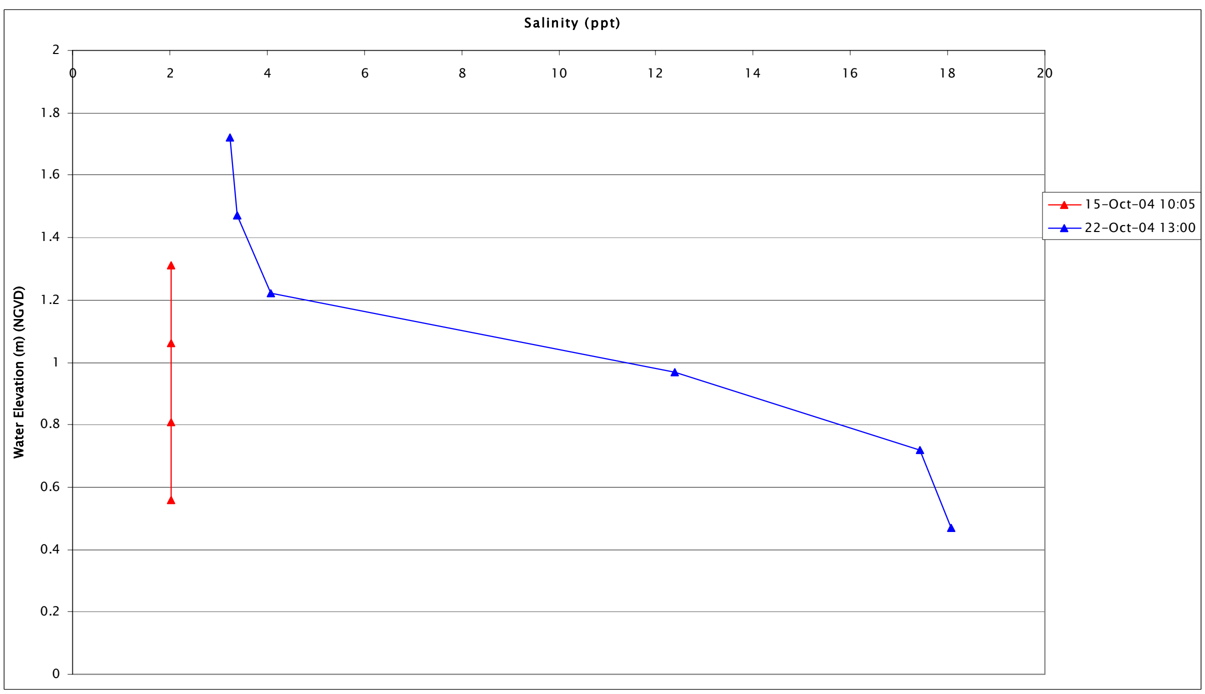


Figure 9-38 Depth profiles of salinity at N1 during Phase 2.

### 9.4.3 N1: DO

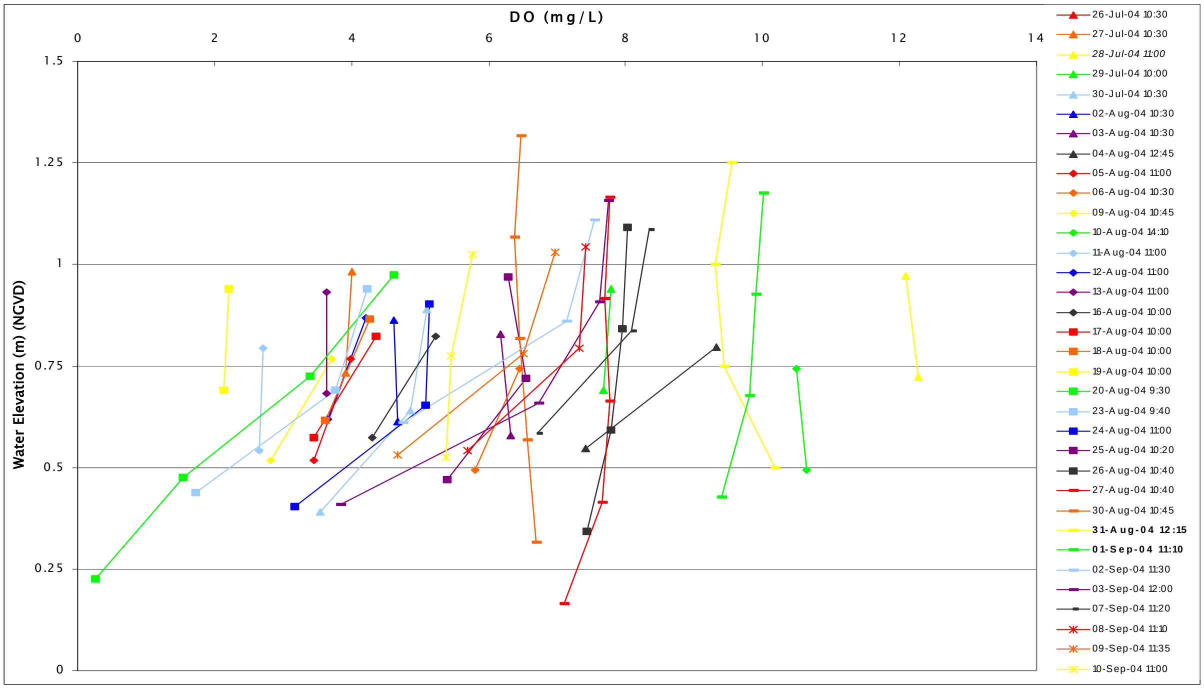


Figure 9-39 Depth profiles if DO at N1 during Phase 1.

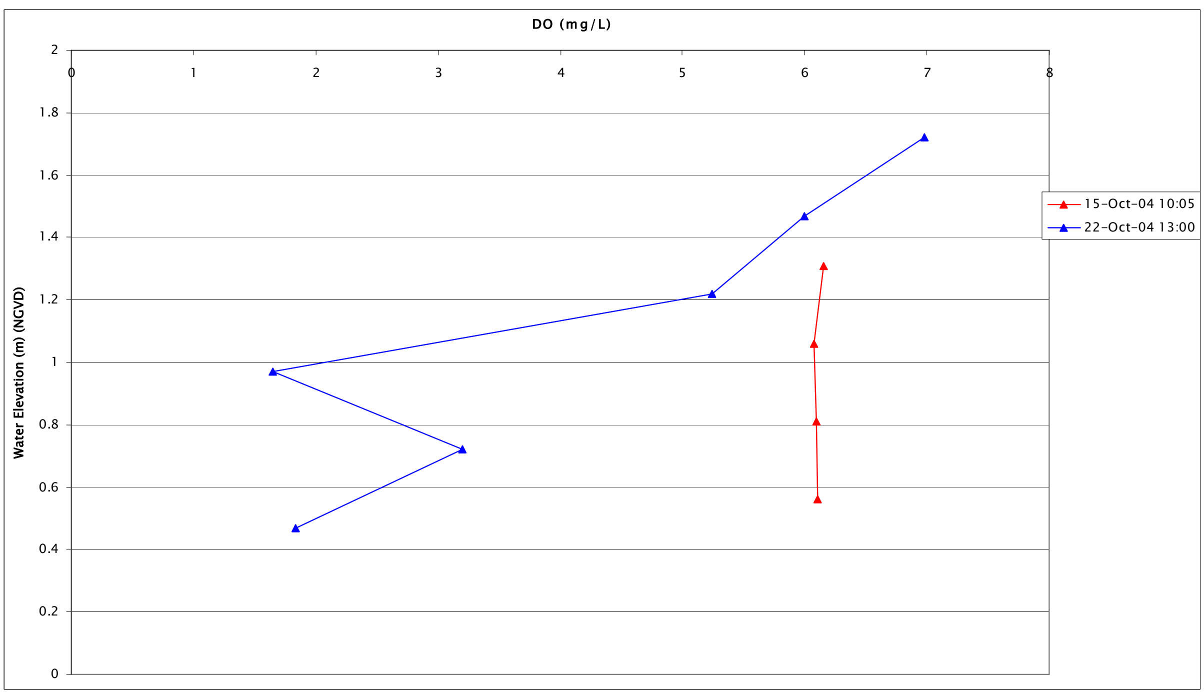


Figure 9-40 Depth profiles of DO at N1 during Phase 1.

### 9.4.4 N1: pH

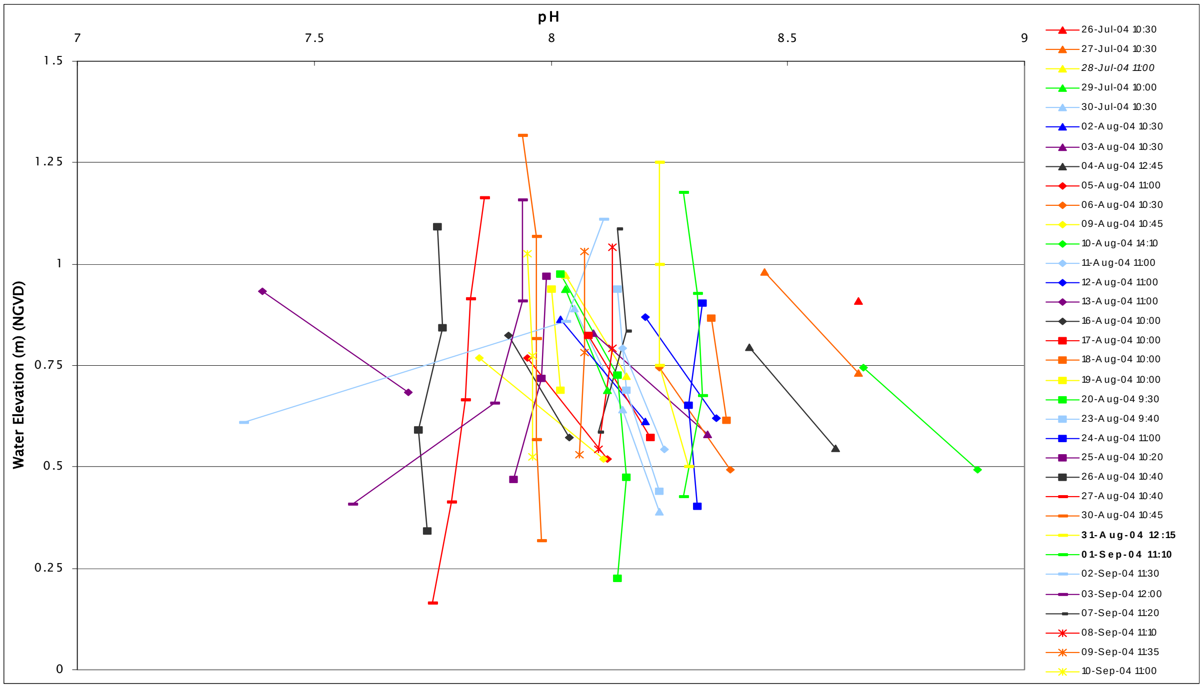


Figure 9-42 depth profiles of pH at N1 during Phase 1.

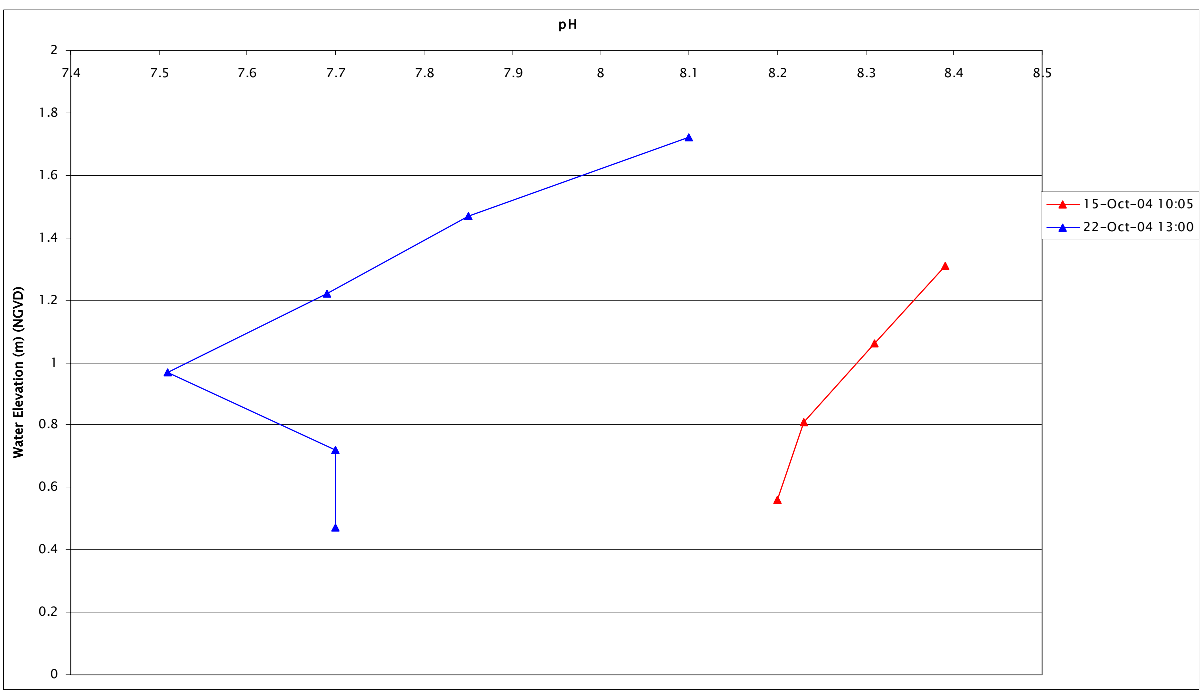


Figure 9-41 Depth profiles of pH at N1 during Phase 2.

### 9.4.5 N1: $CO_2$

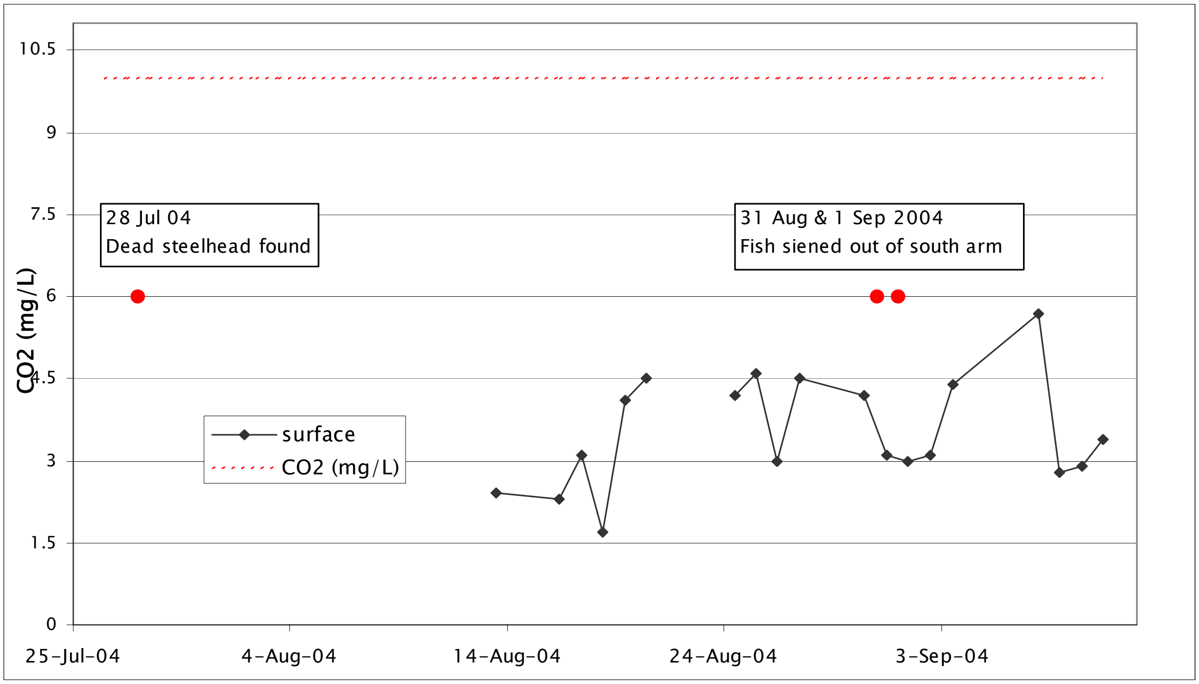


Figure 9-43 Time series of CO2 at N1 during Phase 1.

### 9.4.6 N1: Turbidity

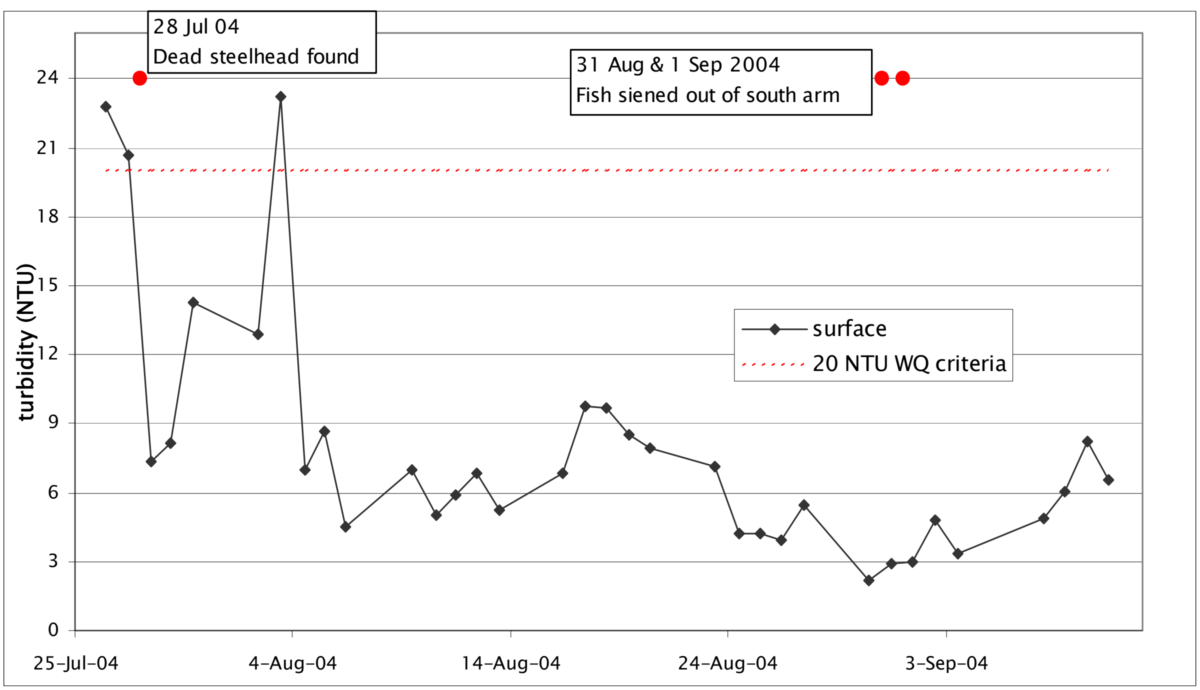


Figure 9-44 Time series of turbidity at N1 during Phase 1.

### 9.4.7 N1: SSC

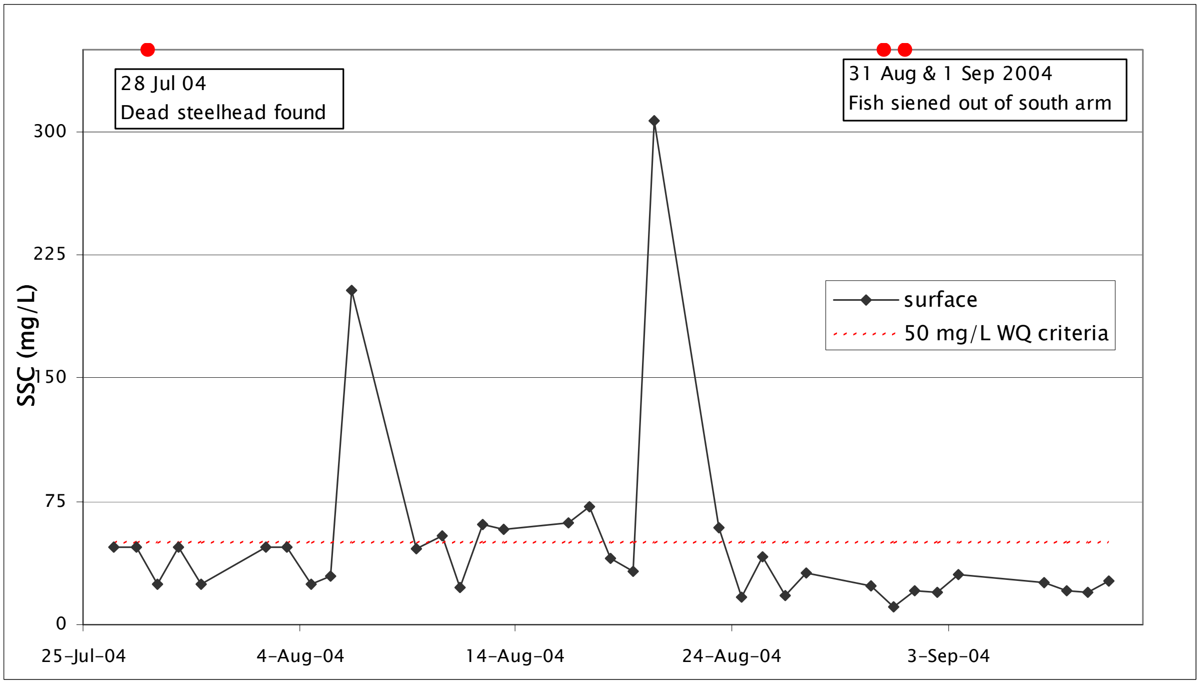


Figure 9-45 Time series of SSC at N1 during Phase 1.

### 9.4.8 N1: CO2, turbidity, and SSC Phase 2

Table 9-2 Summary of turbidity, SSC, and $CO_2$ at N1 during Phase 2.

| Date + Time | Stage (m) | Turbidity (NTU) | Suspended Solids Concentration (mg/L) | $CO_2$ (mg/L) |
|---|---|---|---|---|
| 15 Oct 04 | 1.31 | 7.34 | 11.88 | 4.8 |
| 22 Oct 04 | 1.72 | 7.34 | 16.57 | na |

## 9.5 N2: Eastern branch of the north arm

### 9.5.1 Temperature

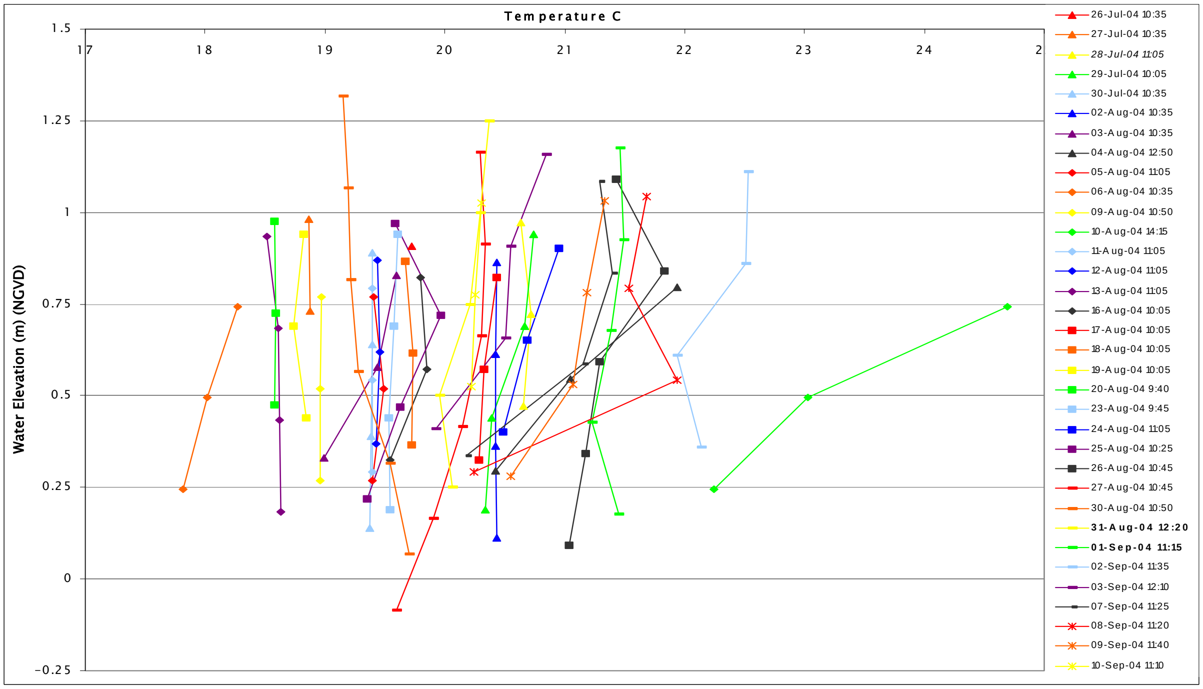


Figure 9-46 Depth profiles of temperature at N2 during Phase 1.

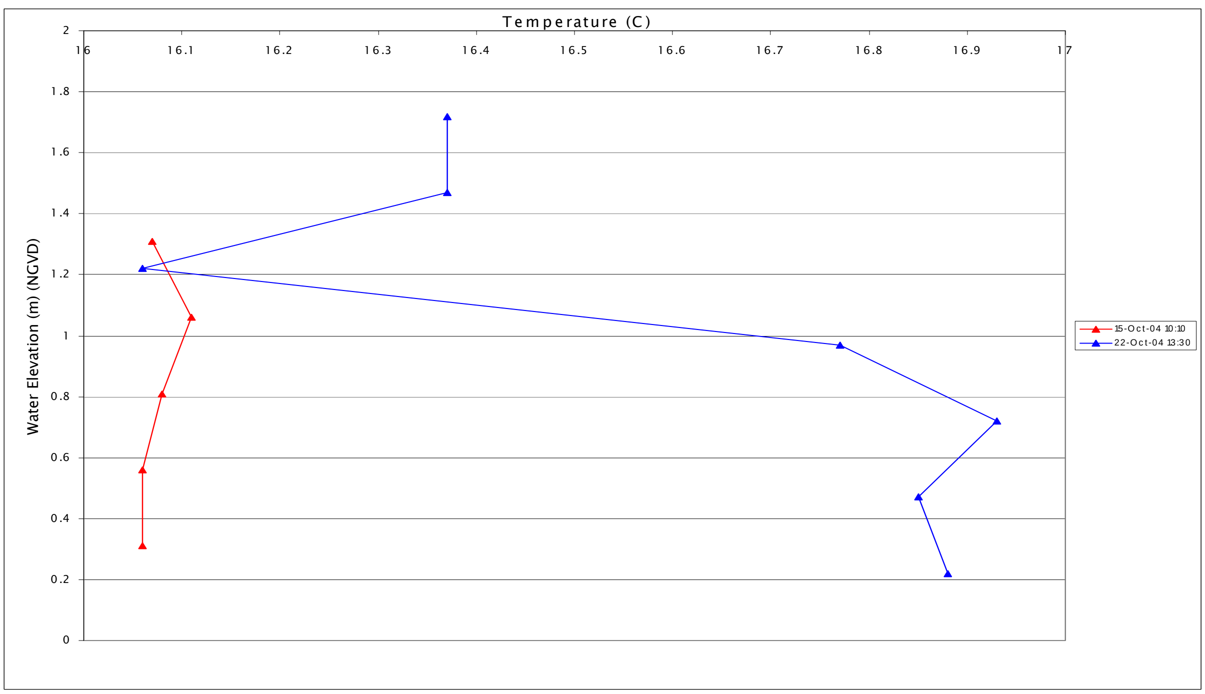


Figure 9-47 Depth profiles of temperature at N2 during Phase 2.

### 9.5.2 N2: Salinity

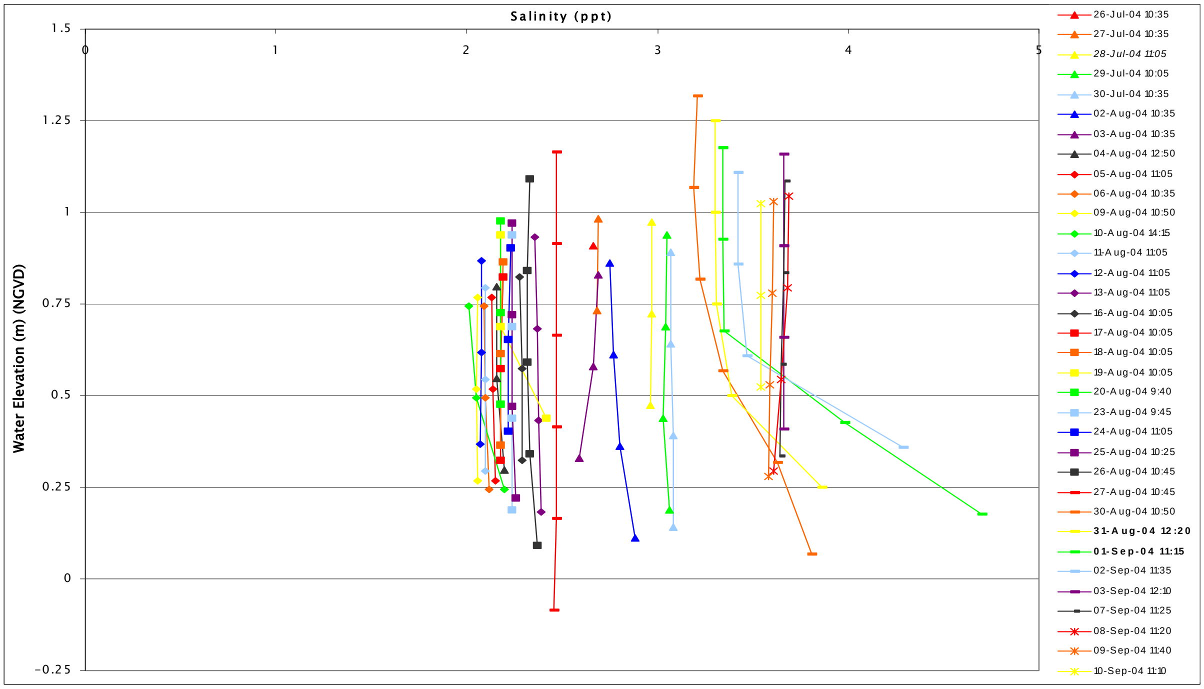


Figure 9-48 Depth profiles of salinity at N2 during Phase 1.

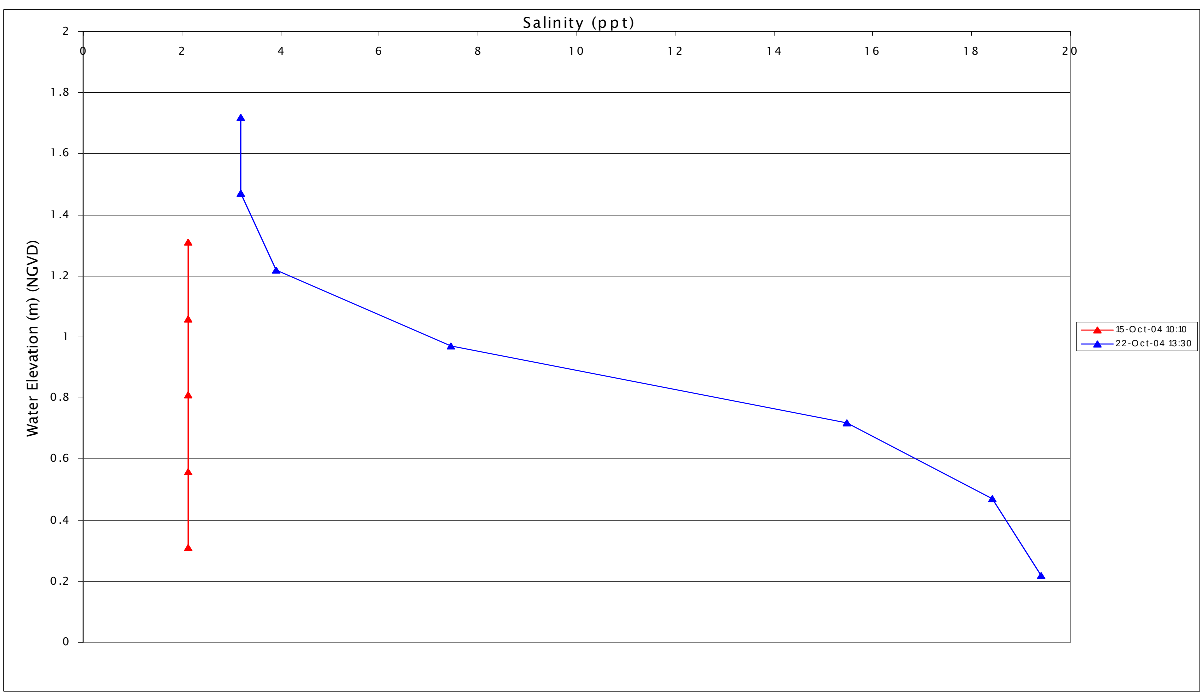


Figure 9-49 Depth profiles of salinity at N2 during Phase 2.

### 9.5.3 N2: DO

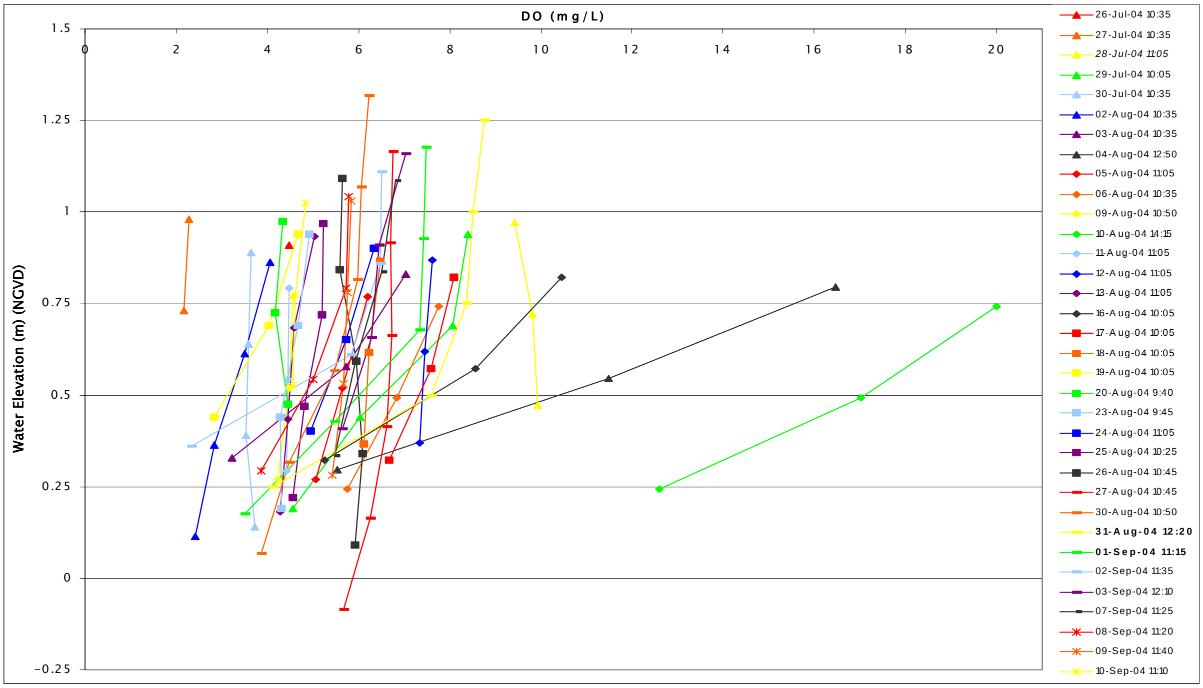


Figure 9-50 Depth profiles of DO at N2 during Phase 1.

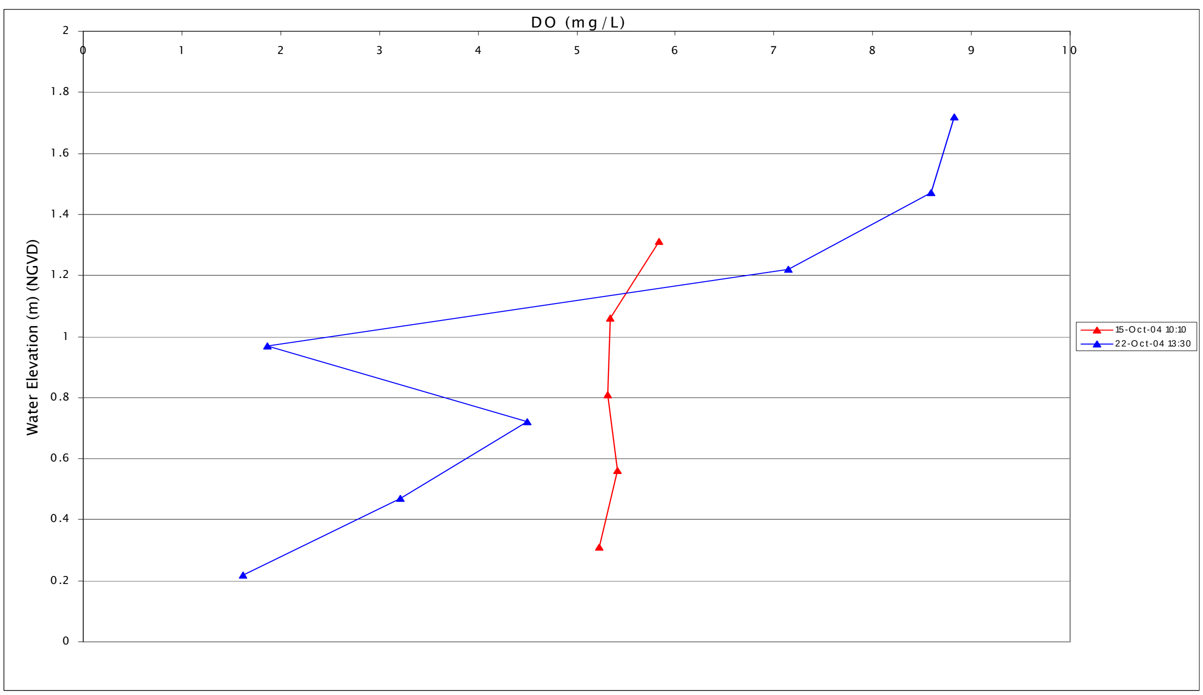


Figure 9-51 depth profiles of DO at N2 during Phase 2.

## 9.5.4 N2: pH

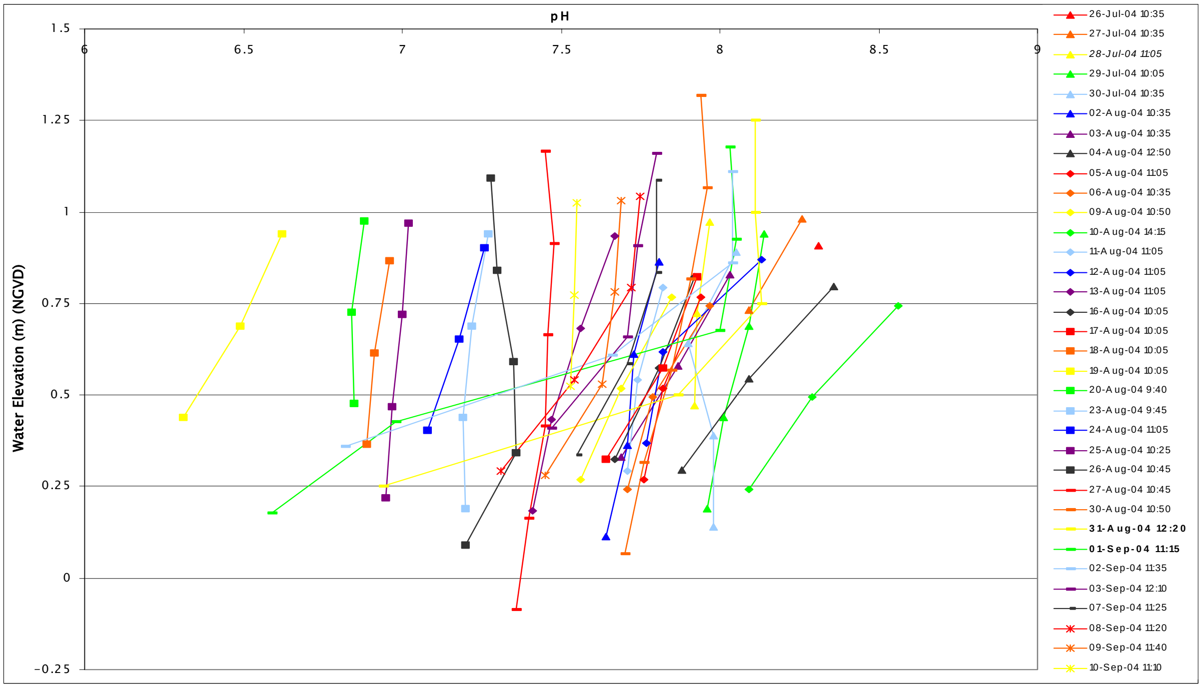


Figure 9-53 Depth profiles of pH at N2 during Phase 2.

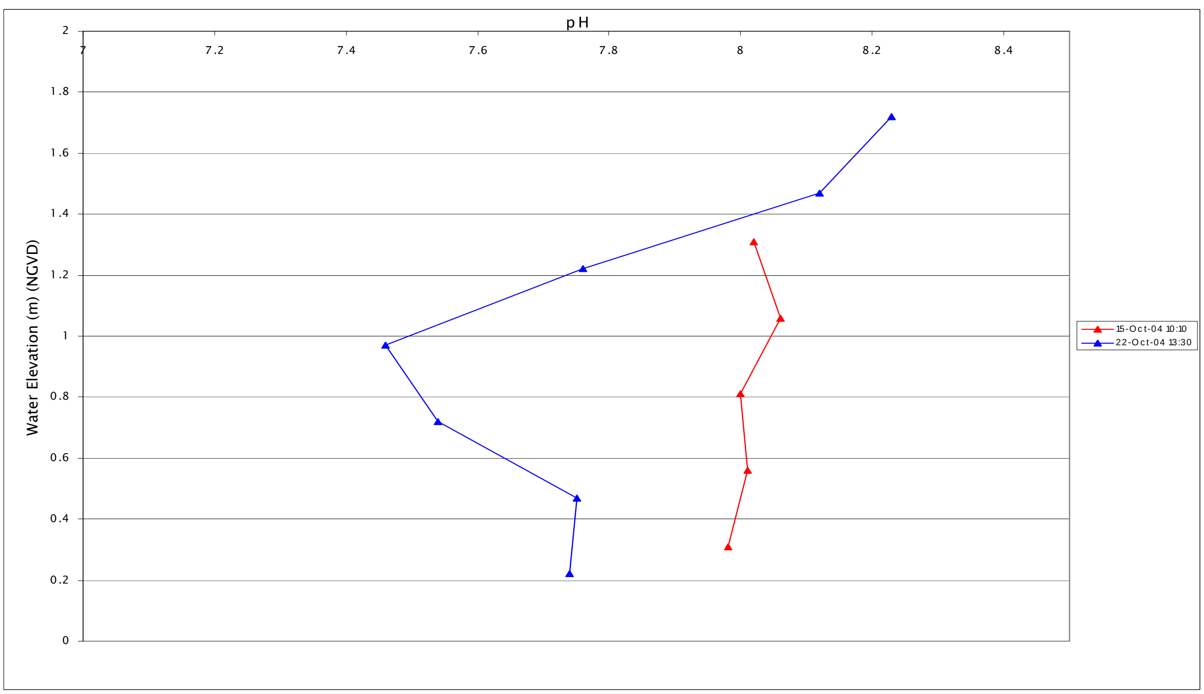


Figure 9-52 Depth profiles of pH at N2 during Phase 2.

### 9.5.5 N2: $CO_2$

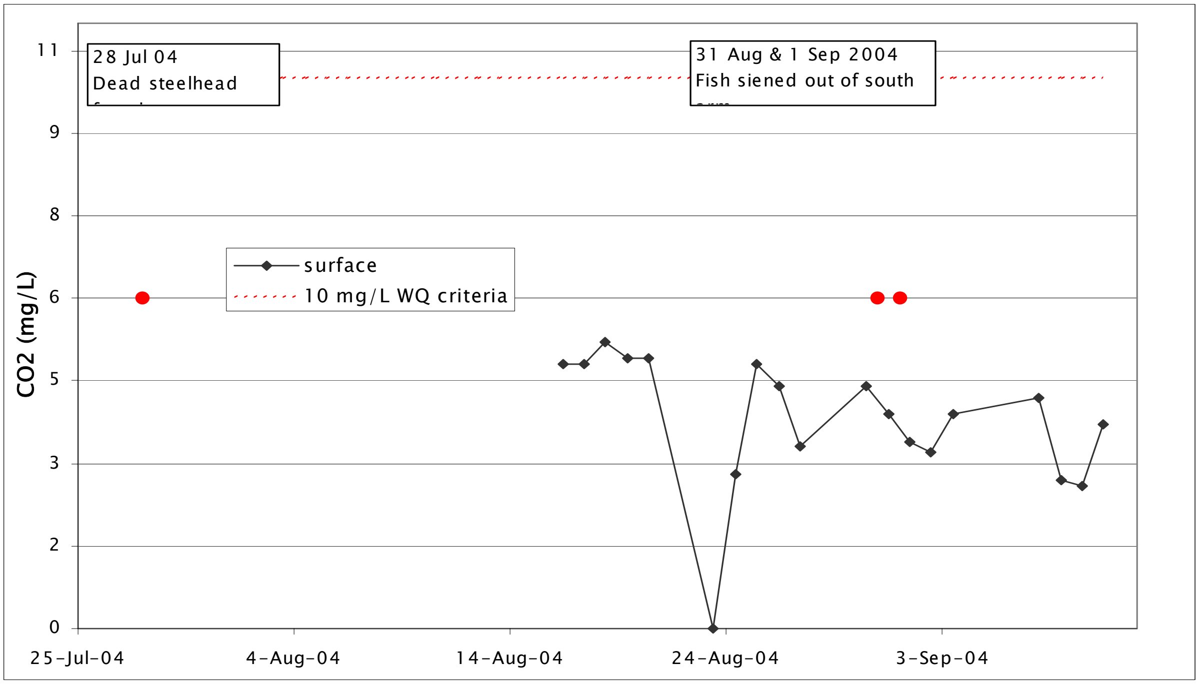


Figure 9-54 Time series of CO2 at N2 during Phase 1.

### 9.5.6 N2: Turbidity

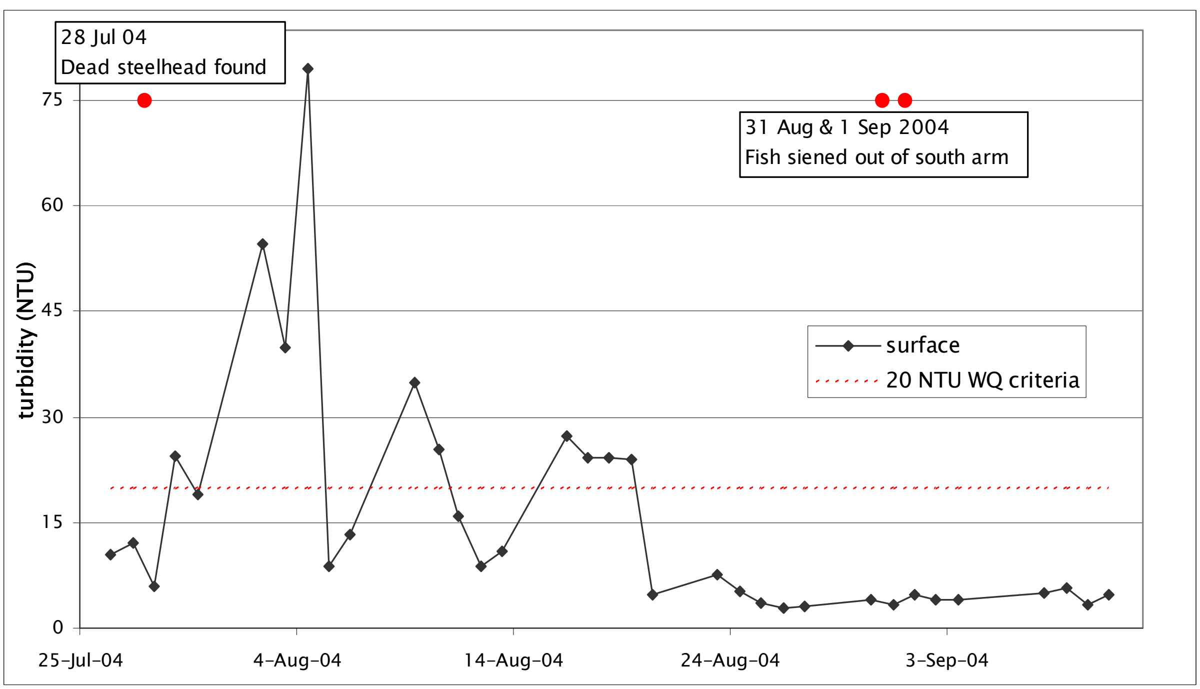


Figure 9-55 Time series of turbidity at N2 during Phase 1.

### 9.5.7 N2: SSC

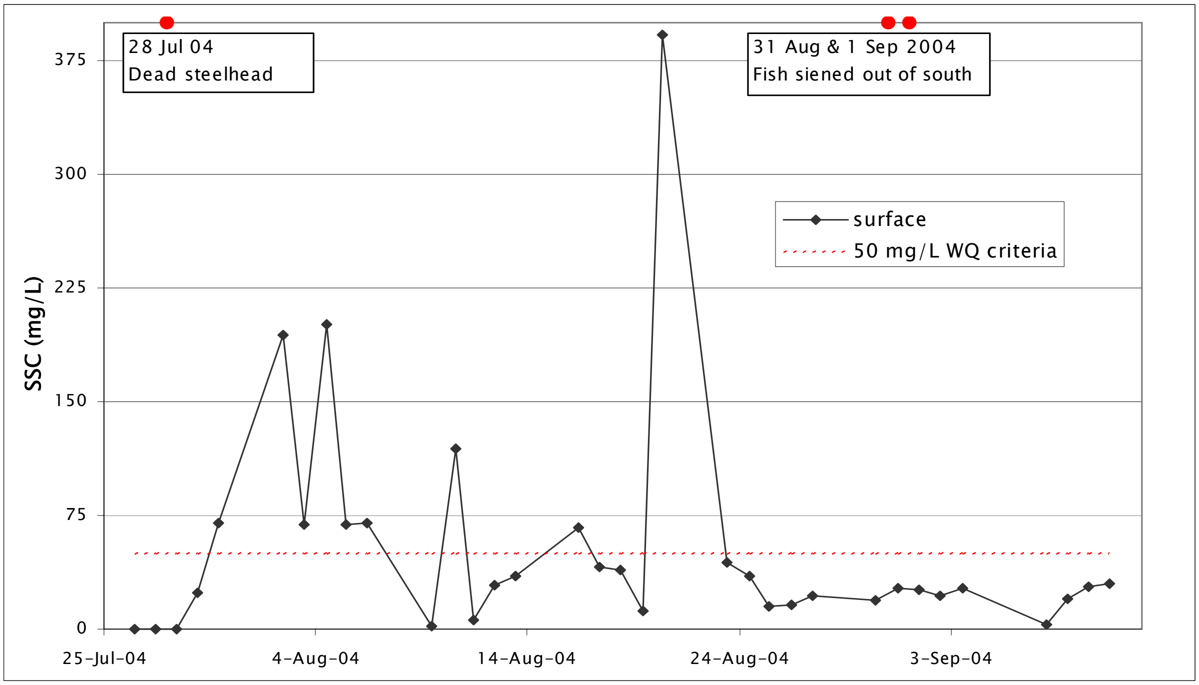


Figure 9-56 Time series of SSC at N2 during Phase 1.

### 9.5.8 N2: $CO_2$, turbidity, and SSC Phase 2

Table 9-3 Summary of turbidity, SSC and $CO_2$ at N2 during Phase 2.

| Date + Time | Stage (m) | Turbidity (NTU) | Suspended Solids Concentration (mg/L) | $CO_2$ (mg/L) |
|---|---|---|---|---|
| 15 Oct 04 | 1.31 | 8.73 | 0.00 | 4.4 |
| 22 Oct 04 | 1.72 | 8.73 | 16.63 | na |

## 9.6 R2: Main lagoon

### 9.6.1 Temperature

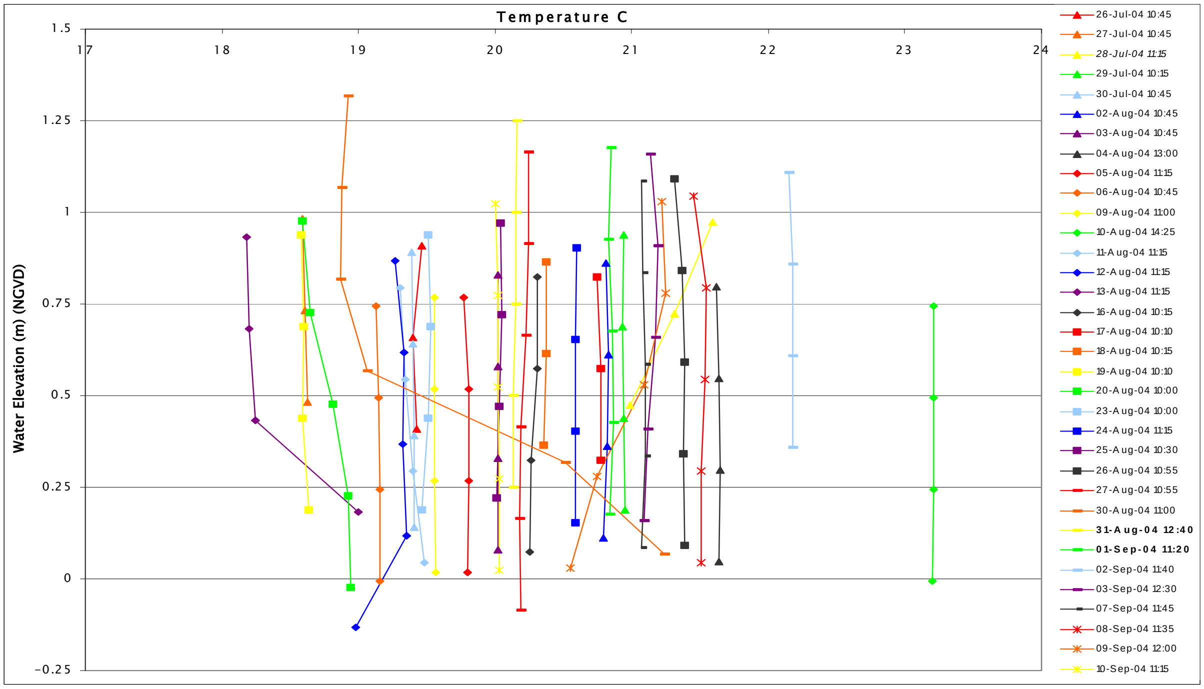


Figure 9-57 Depth profiles of temperature at R2 during Phase 1.

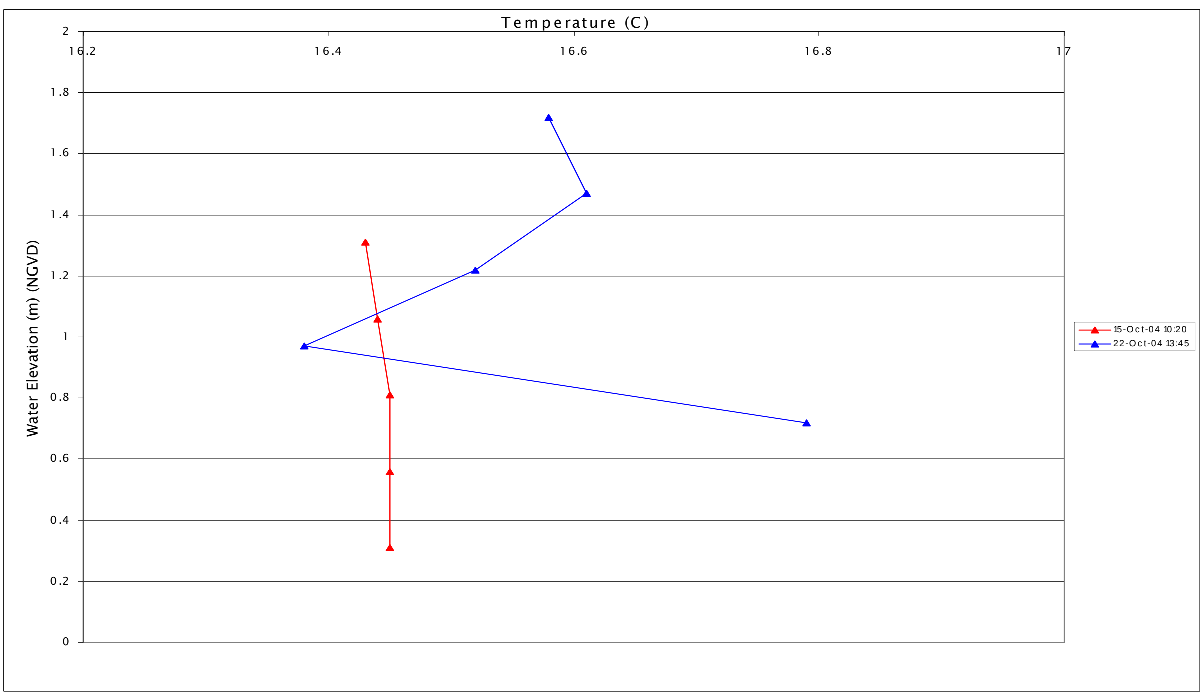


Figure 9-58 Depth profiles of temperature at R2 during Phase 2.

## 9.6.2 R2: Salinity

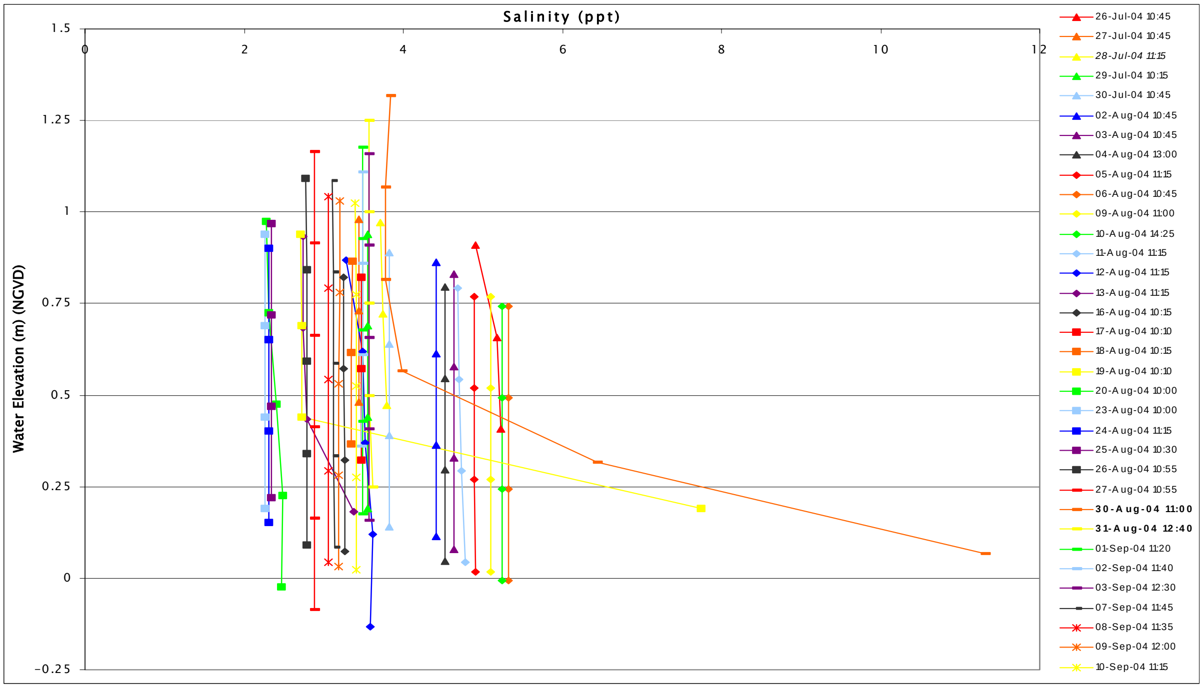


Figure 9-60 Depth profiles of salinity at R2 during Phase 1.

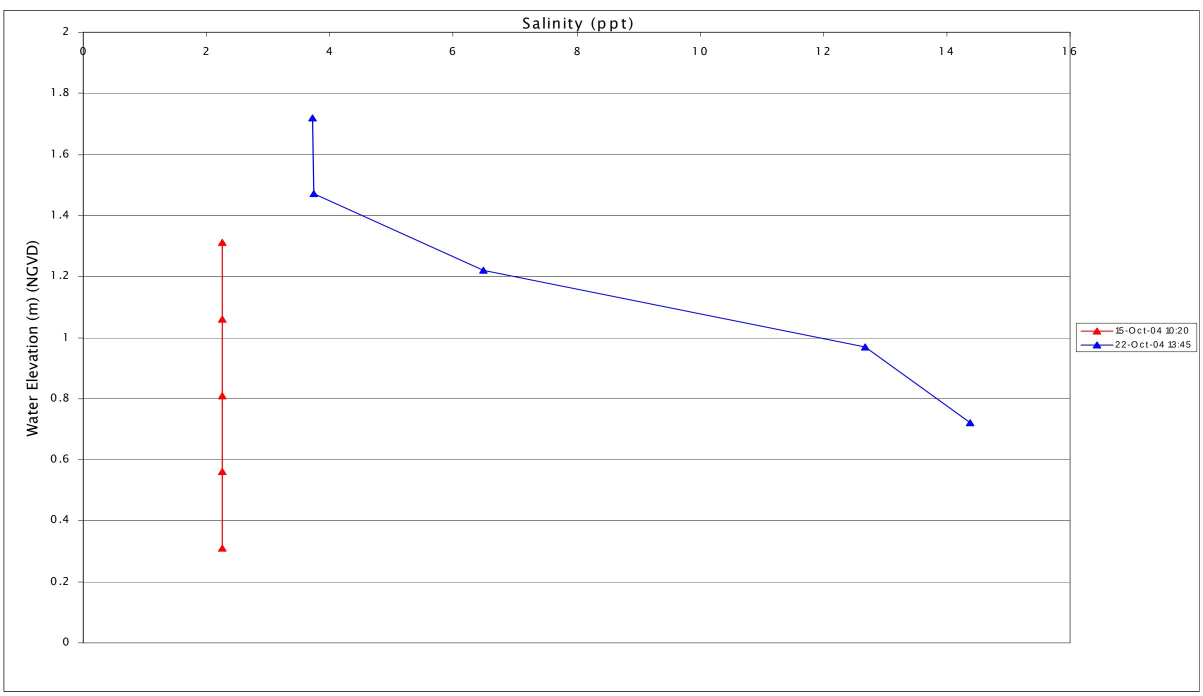


Figure 9-59 Depth profiles of salinity at R2 during Phase 2.

## 9.6.3 R2: DO

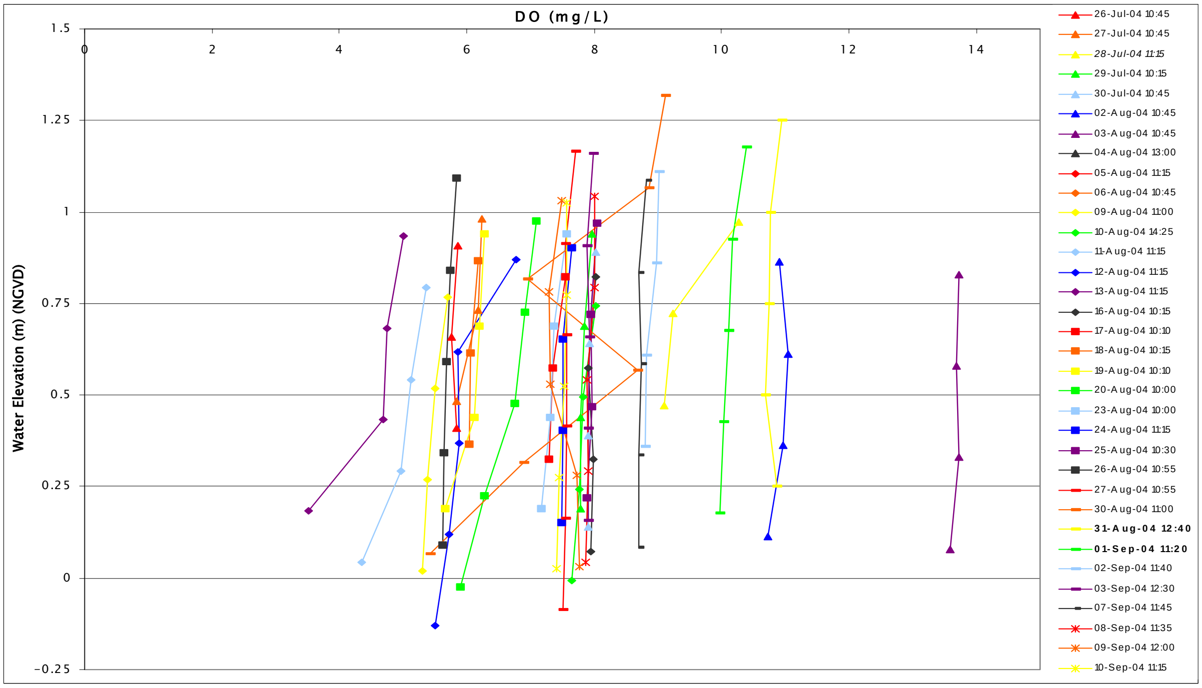


Figure 9-62 Depth profiles of DO at R2 during Phase 1.

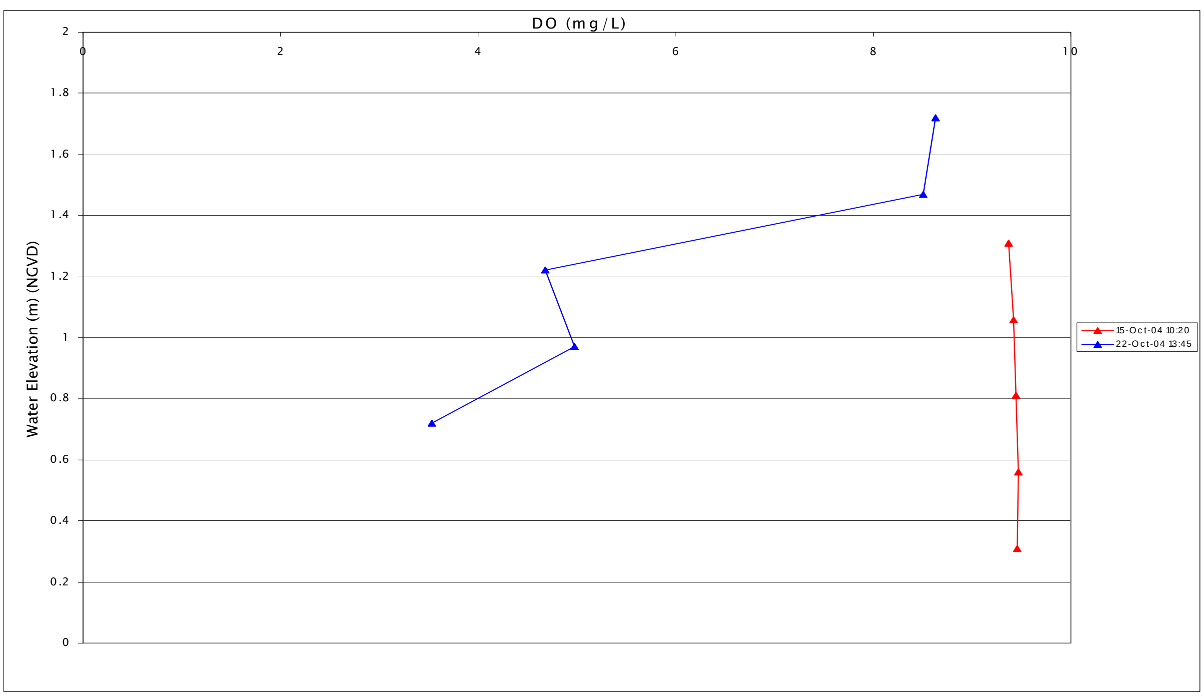


Figure 9-61 Depth profiles of salinity at R2 during Phase 2.

## 9.6.4 R2: pH

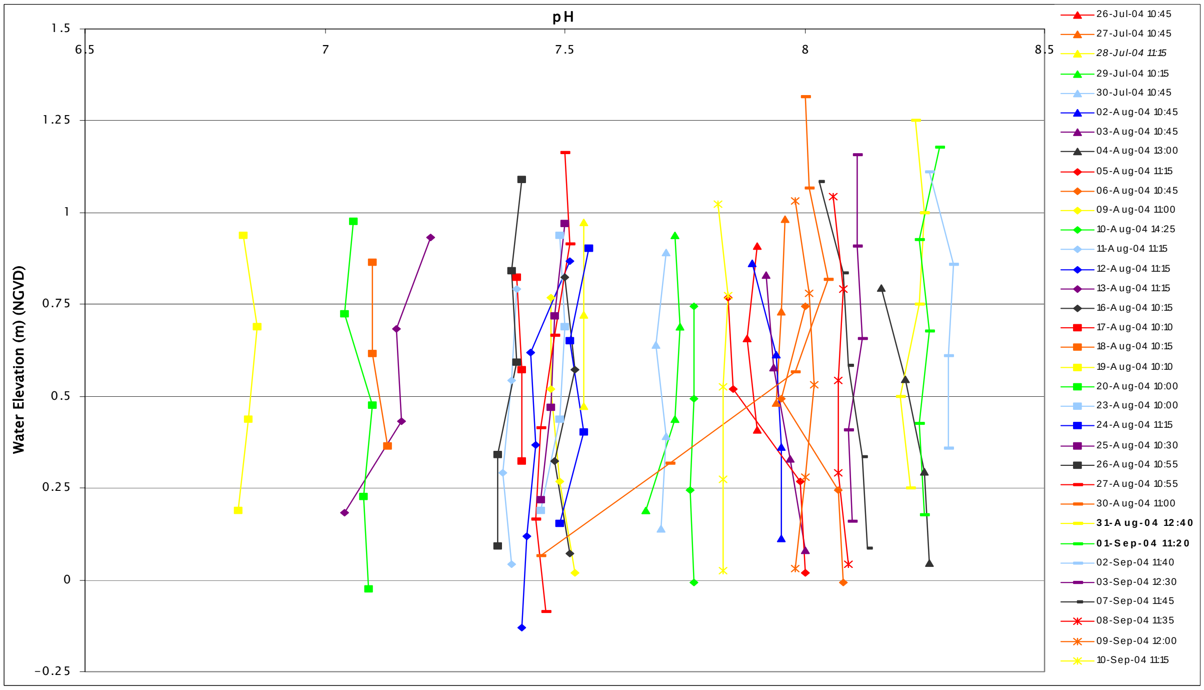


Figure 9-64 Depth profiles of pH at R2 during Phase 1.

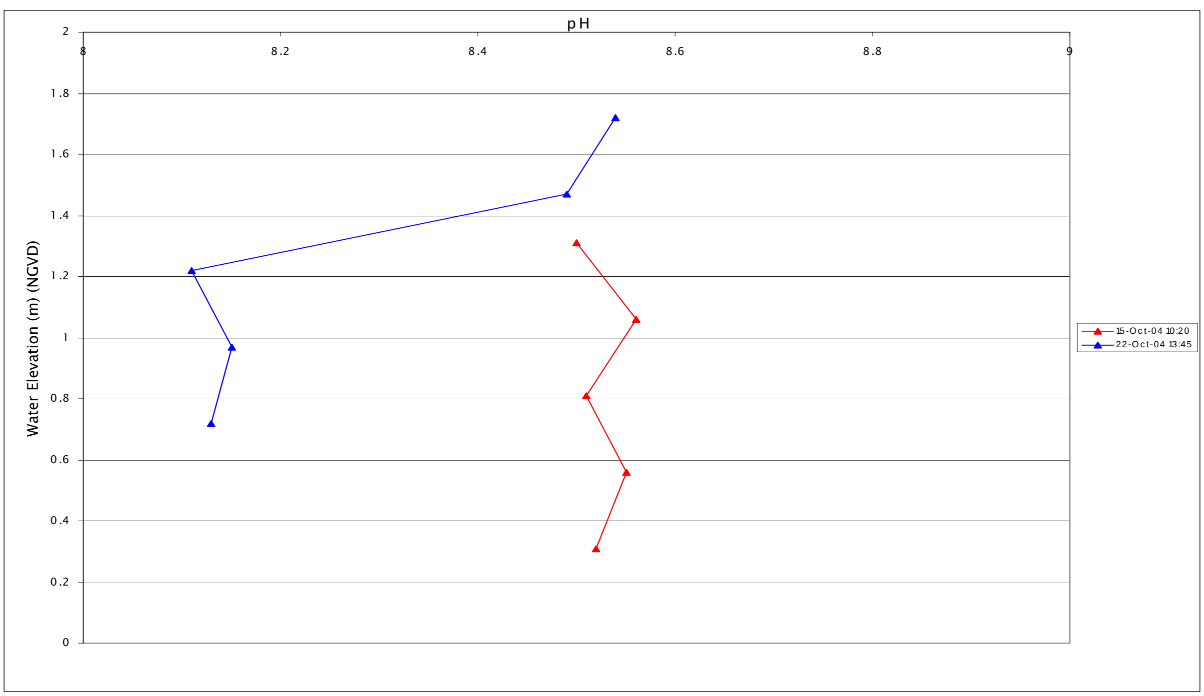


Figure 9-63 Depth profiles of pH at R2 during Phase 2.

### 9.6.5 R2: $CO_2$

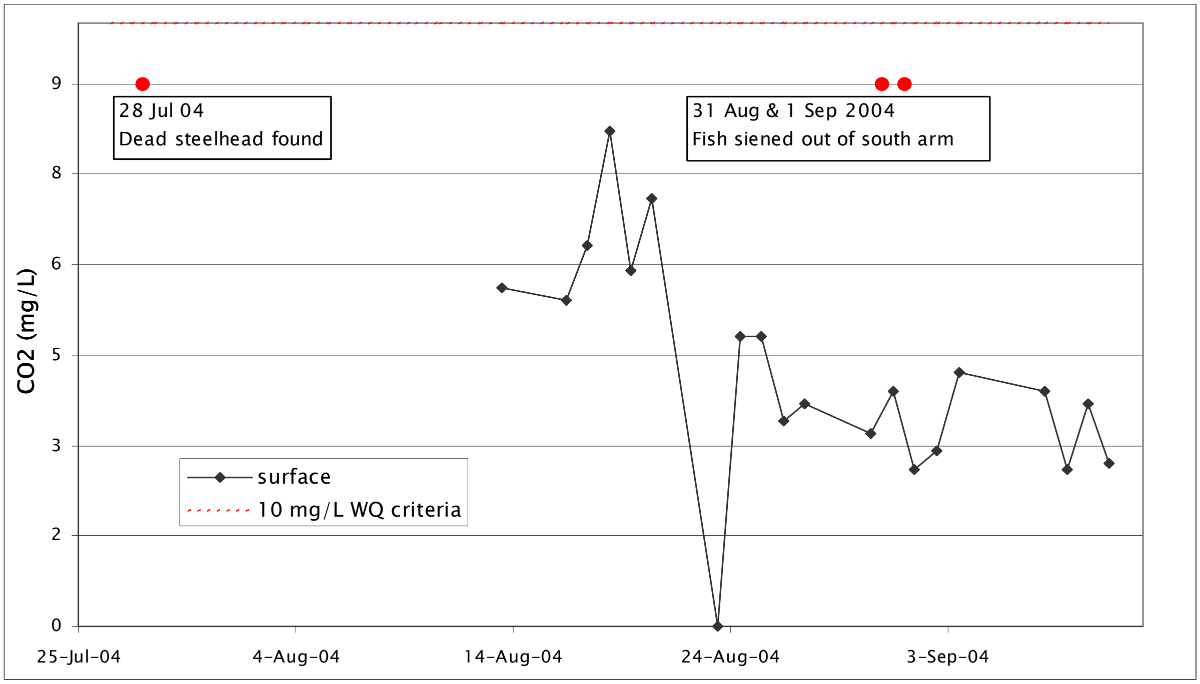


Figure 9-65 Time series of $CO_2$ at R2 during Phase 1.

### 9.6.6 R2: Turbidity

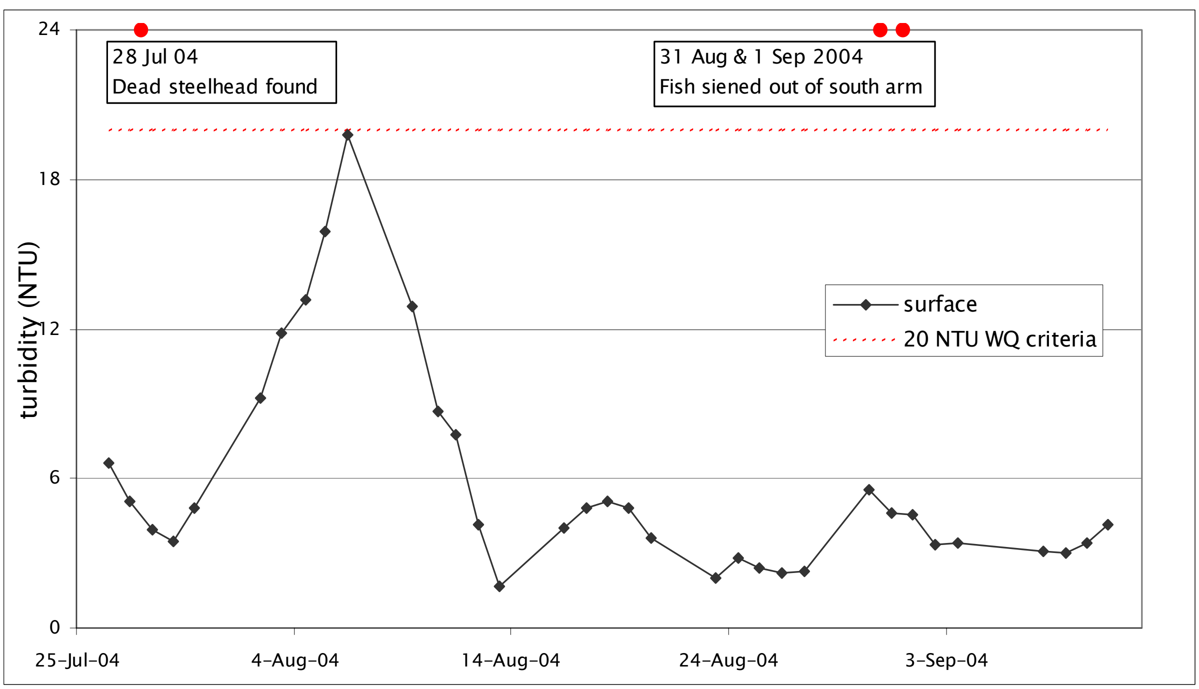


Figure 9-66 Time series of turbidity at R2 during Phase 1.

### 9.6.7 R2: SSC

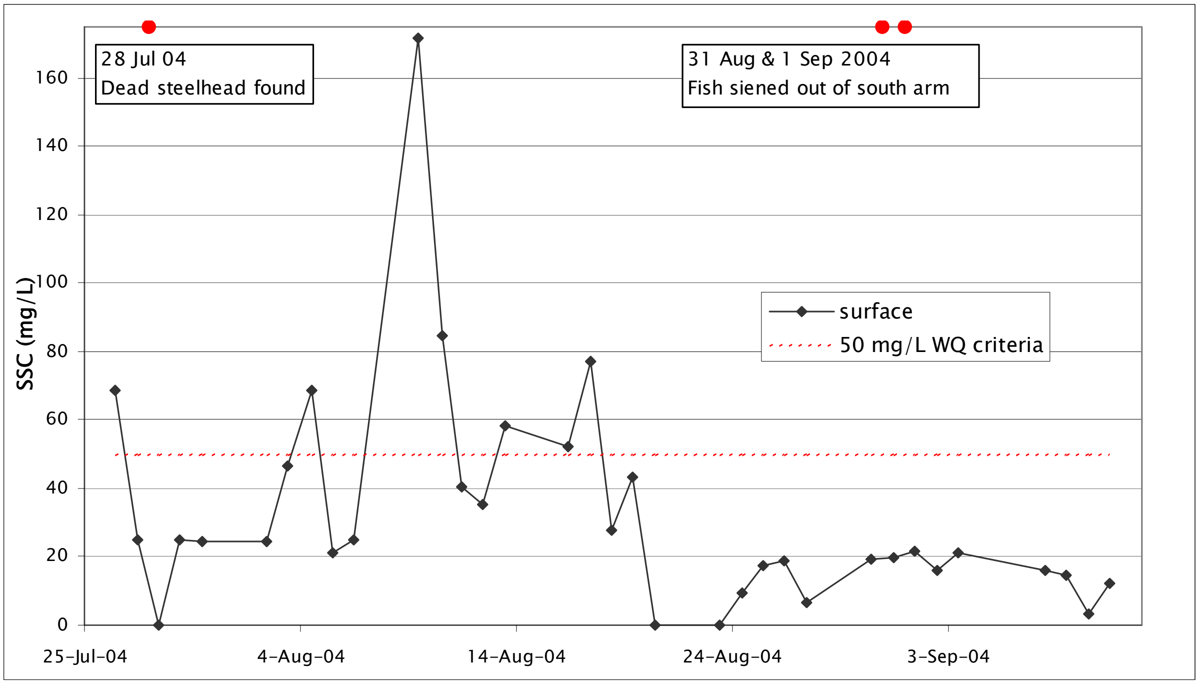


Figure 9-67 Time series of SSC at R2 during Phase 1.

### 9.6.8 R2: $CO_2$, turbidity, and SSC at R2 during Phase 2.

Table 9-4 Summary of turbidity, SSC, and $CO_2$ at R2 during Phase 2.

| Date + Time | Stage (m) | Turbidity (NTU) | Suspended Solids Concentration (mg/L) | $CO_2$ (mg/L) |
|---|---|---|---|---|
| 15 Oct 04 | 1.31 | 4.94 | 9.45 | 5.00 |
| 22 Oct 04 | 1.72 | 9.23 | 19.43 | na |

## 9.7 R1N: North corner next to sandbar

### 9.7.1 Temperature

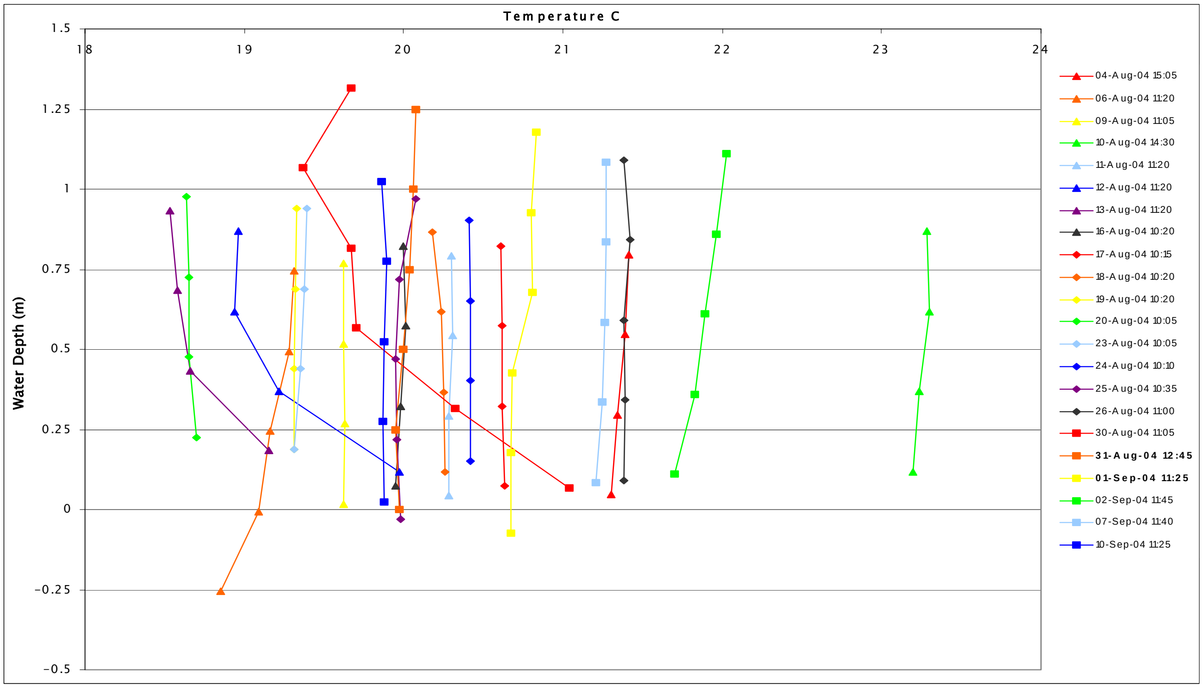


Figure 9-68 Depth profiles of temperature at R1N during Phase 1.

### 9.7.2 R1N: Salinity

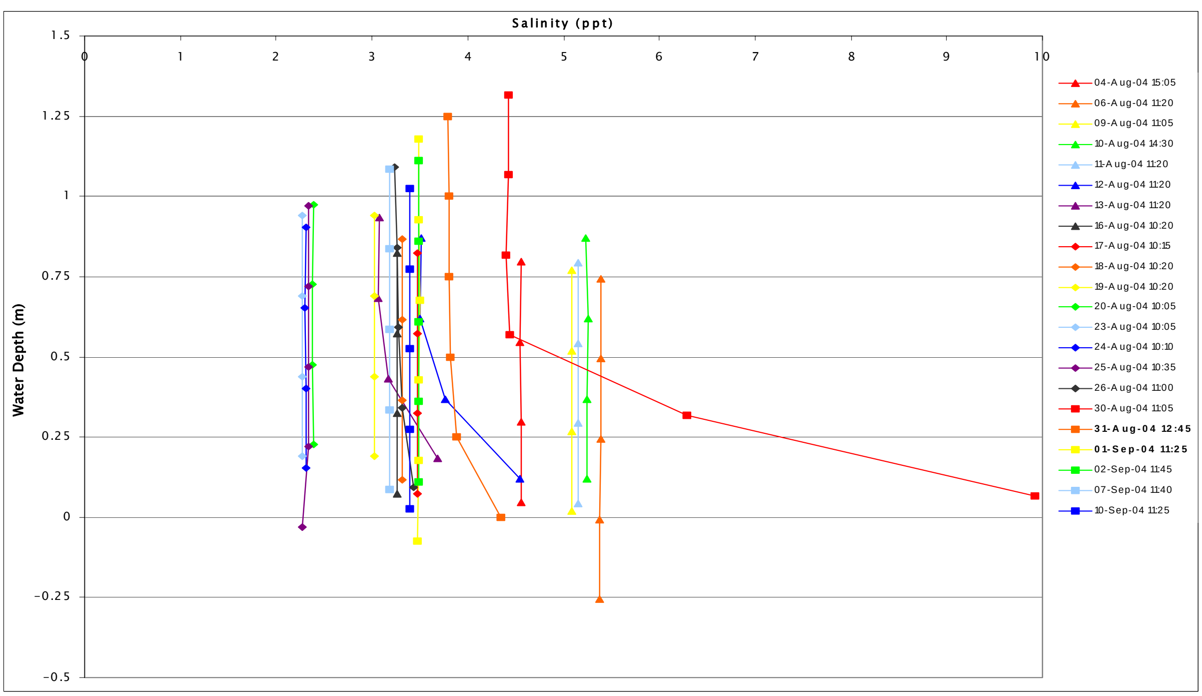


Figure 9-69 Depth profiles of salinity at R1N during Phase 1.

### 9.7.3 R1N: DO

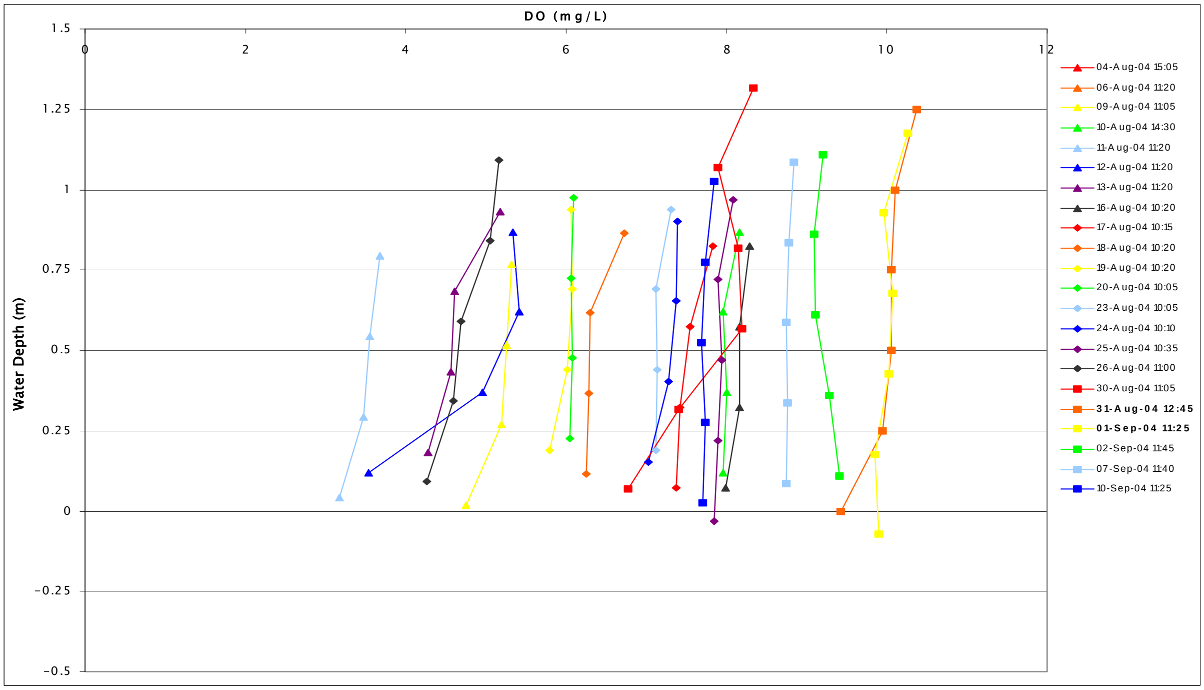


Figure 9-70 Depth profiles of DO at R1N during Phase 1.

### 9.7.4 R1N: pH

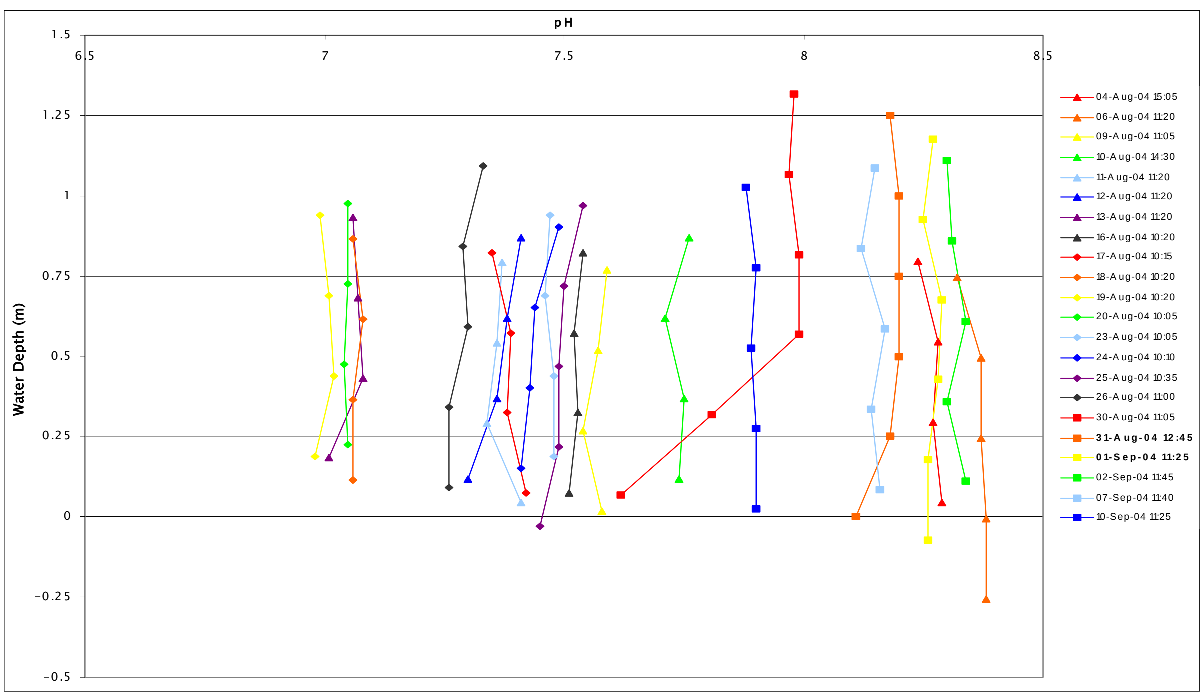


Figure 9-71 Depth profiles of pH at R1N during Phase 1.

### 9.7.5 R1N: $CO_2$

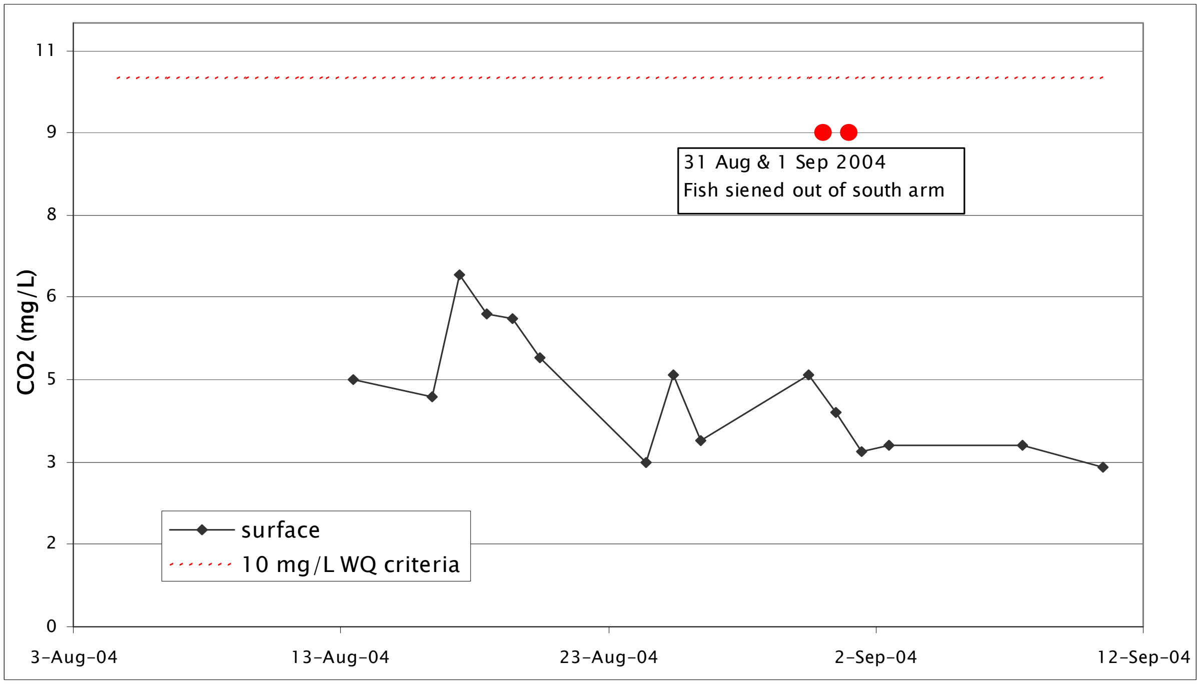


Figure 9-73 Time series of $CO_2$ at R1N during Phase 1.

### 9.7.6 R1N: Turbidity

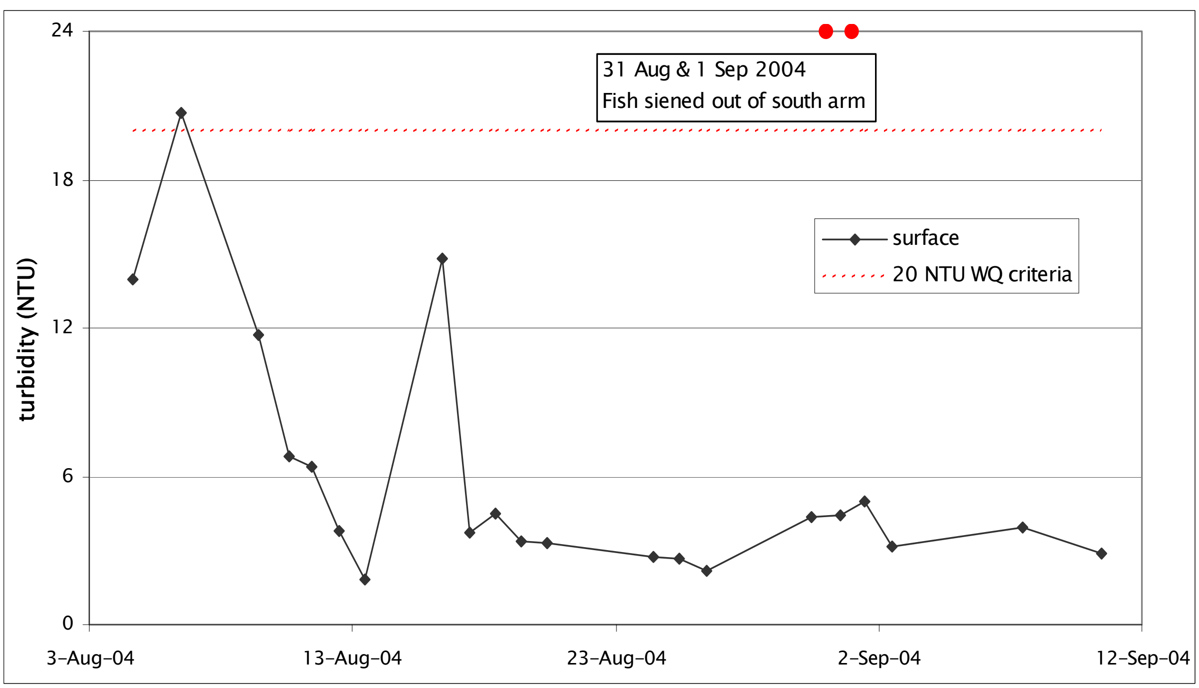


Figure 9-72 Time series of turbidity at R1N during Phase 1.

### 9.7.7 R1N: SSC

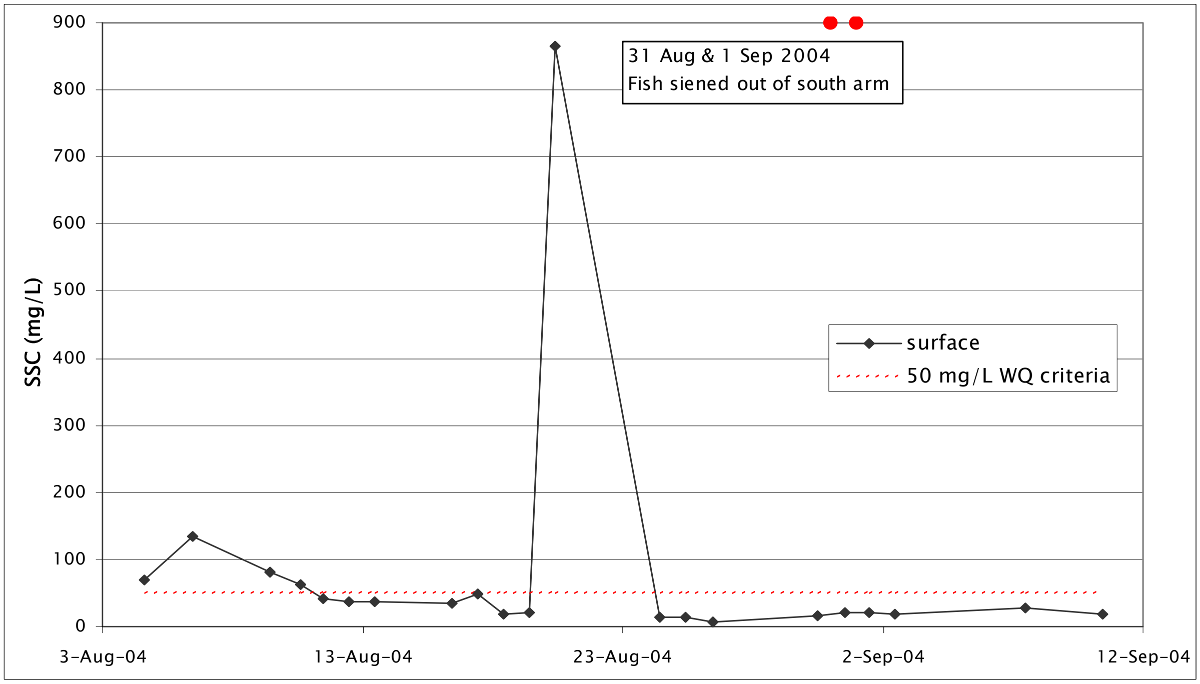


Figure 9-74 Time series of SSC at R1N during Phase 1.

## 9.8 R1S: south corner next to the sandbar.

### 9.8.1 Temperature

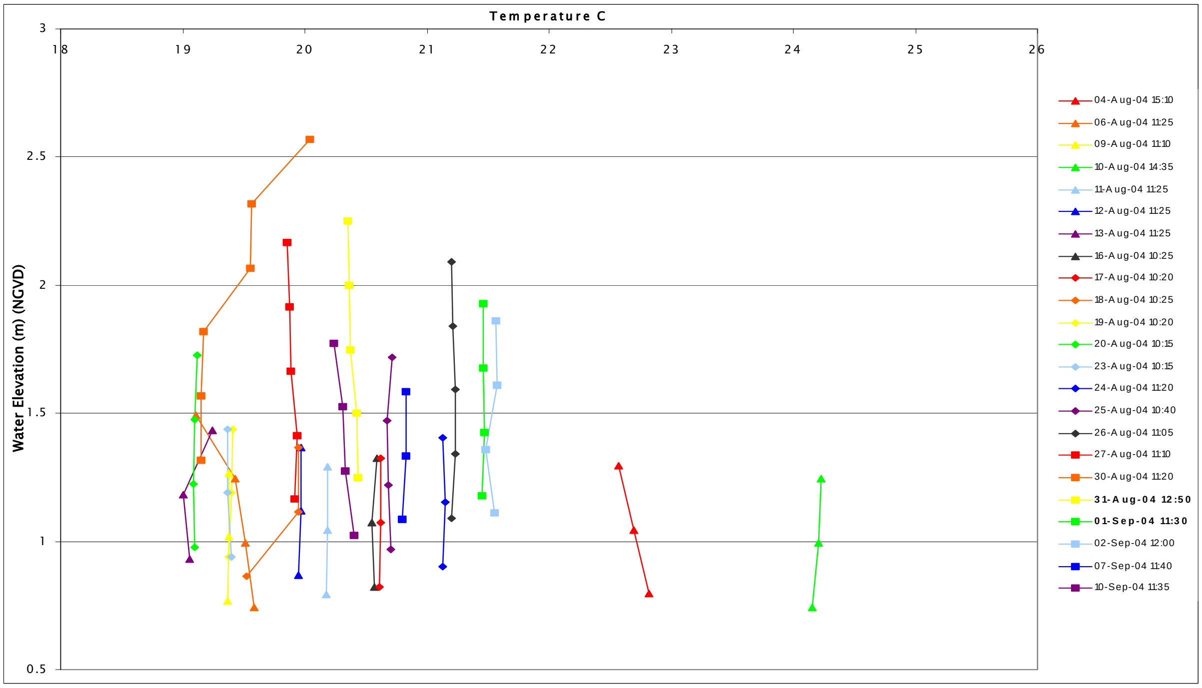


Figure 9-75 Depth profiles of temperature at R1S during Phase 1.

### 9.8.2 R1S: Salinity

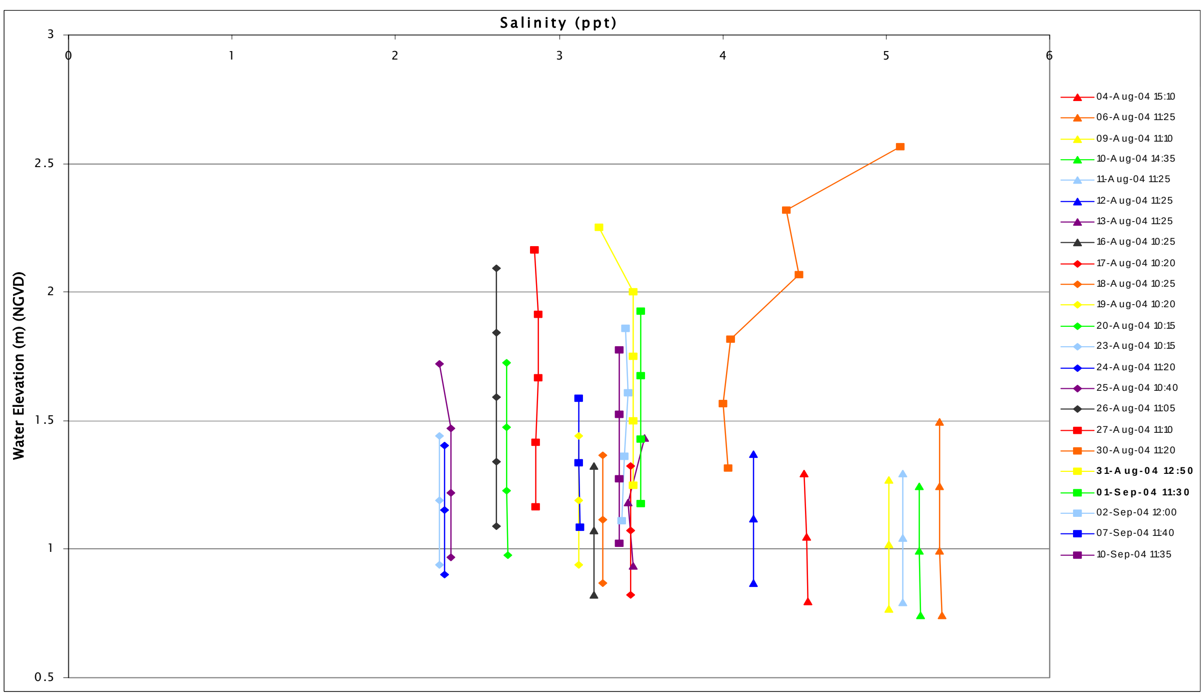


Figure 9-76 Depth profiles of salinity at R1S during Phase 1.

## 9.8.3 R1S: DO

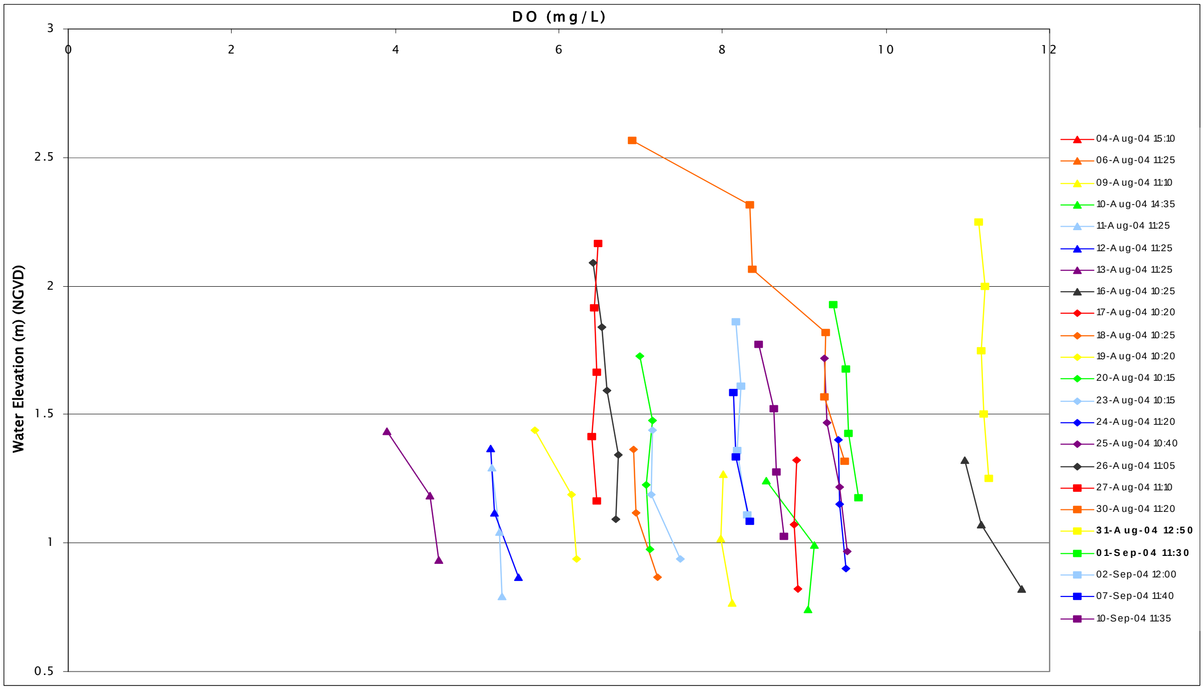


Figure 9-77 Depth profiles of DO at R1S during Phase 1.

## 9.8.4 R1S: pH

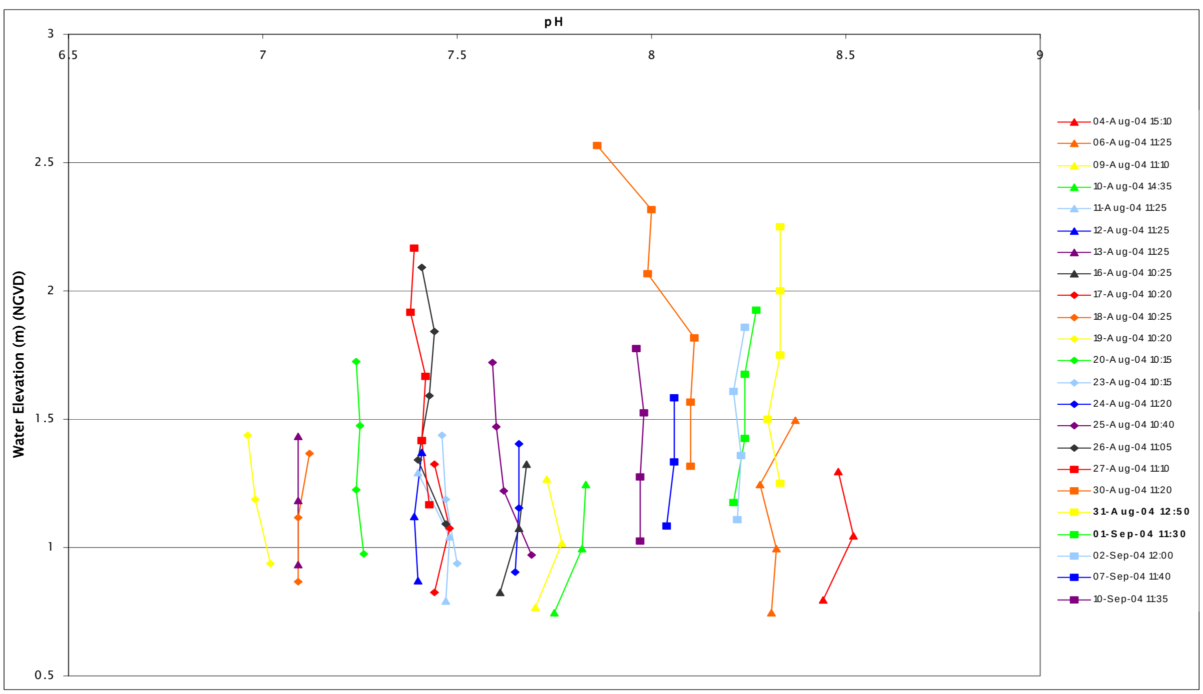


Figure 9-78 Depth profiles of pH at R1S during Phase 1.

### 9.8.5 R1S: $CO_2$

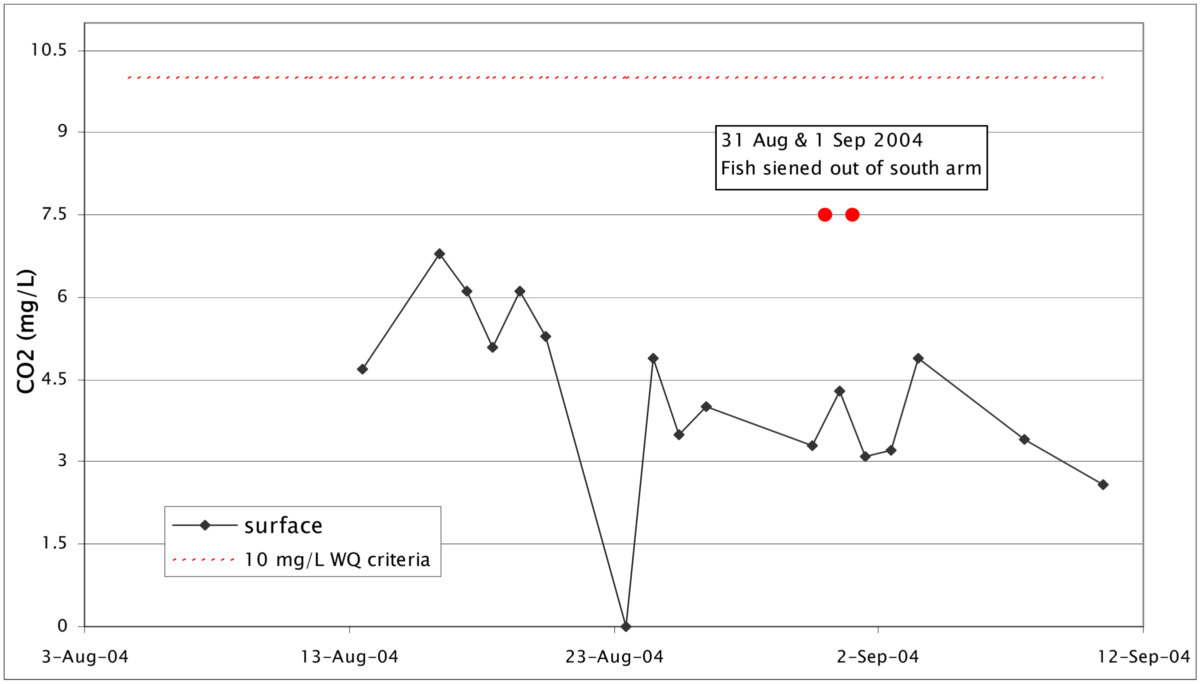


Figure 9-79 Time series of CO2 at R1S during Phase 1.

### 9.8.6 R1S: Turbidity

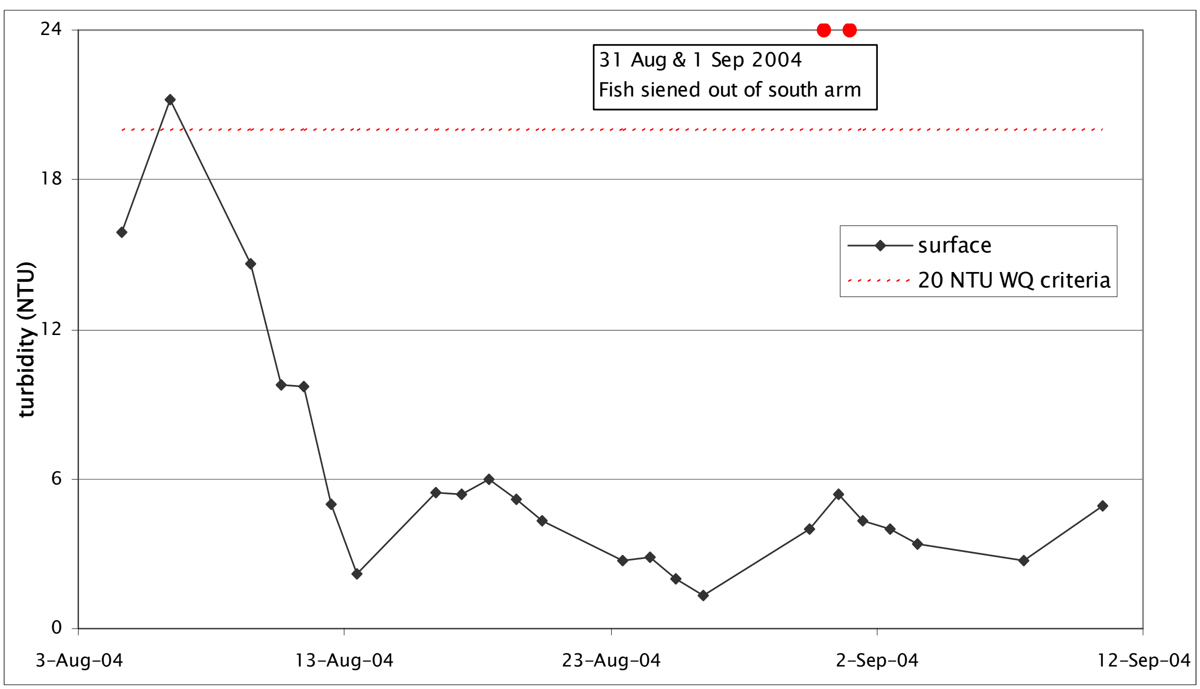


Figure 9-80 Time series of turbidity at R1S during Phase 1.

### 9.8.7 R1S: SSC

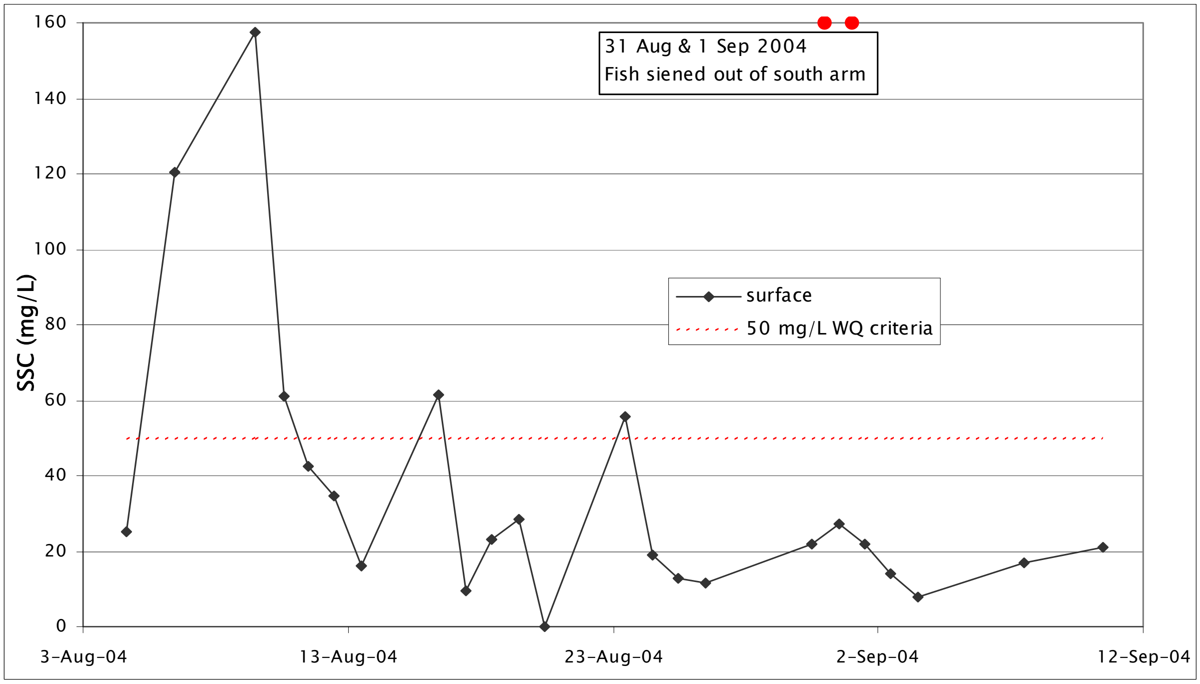


Figure 9-81 Time series of SSC at R1S during Phase 1.

## 9.9 S4O: Outside of silt curtains

### 9.9.1 Temperature

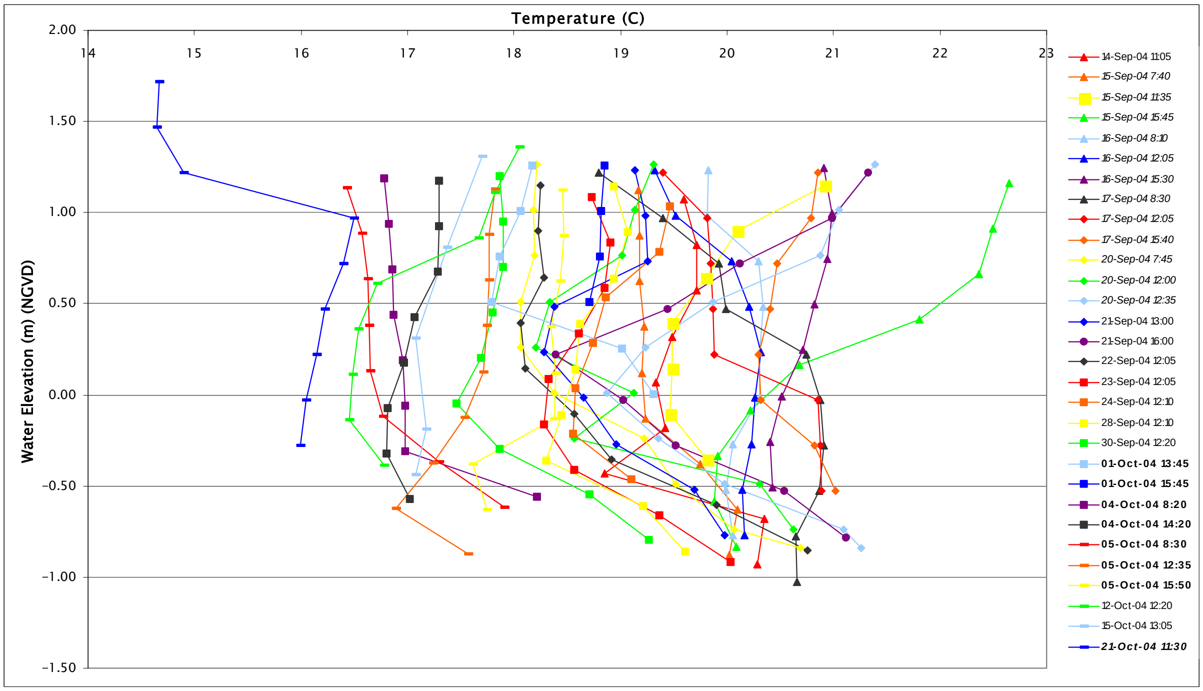


Figure 9-82 Depth profiles of temperature sat S4O during Phase 2.

### 9.9.2 Salinity

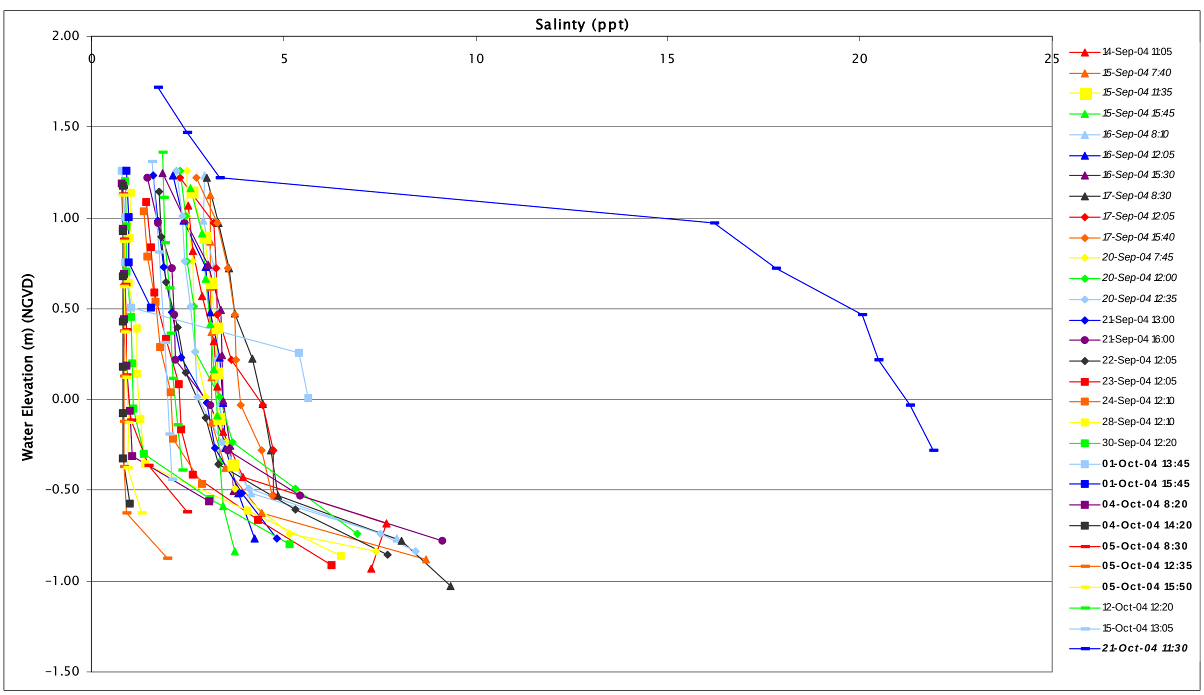


Figure 9-83 Depth profiles of salinity at S4O during Phase 2.

### 9.9.3 S4O: DO

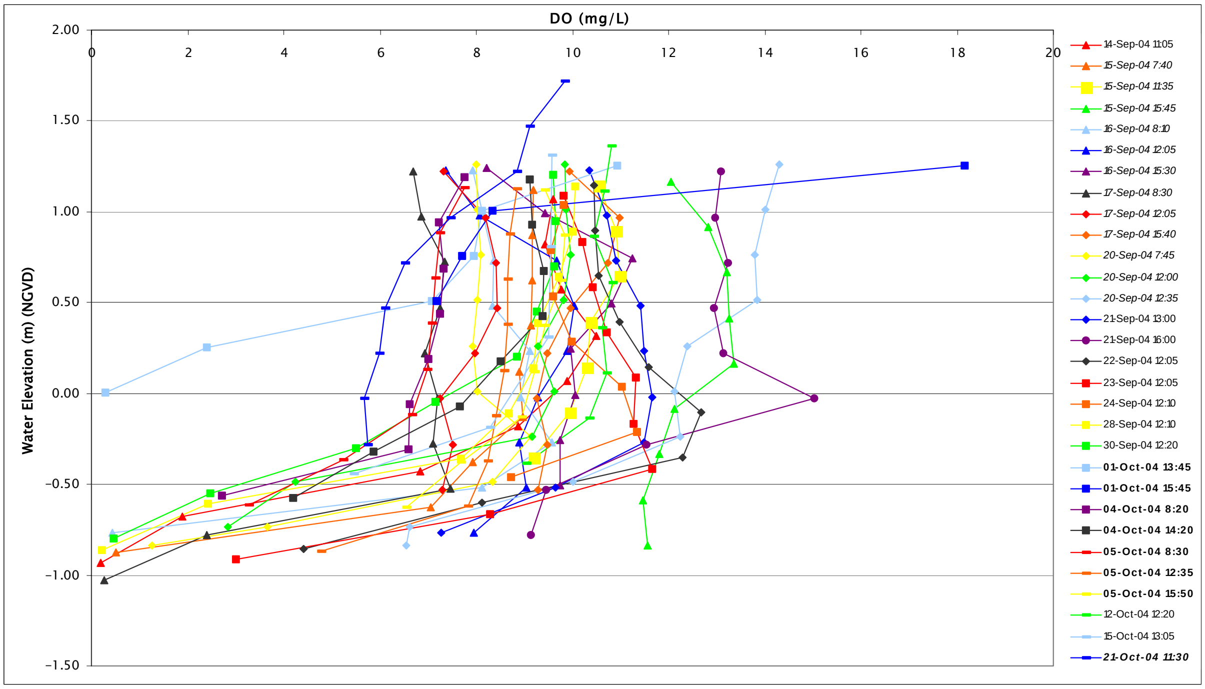


Figure 9-84 Depth profiles of DO at S4O during Phase 2.

### 9.9.4 S4O: pH

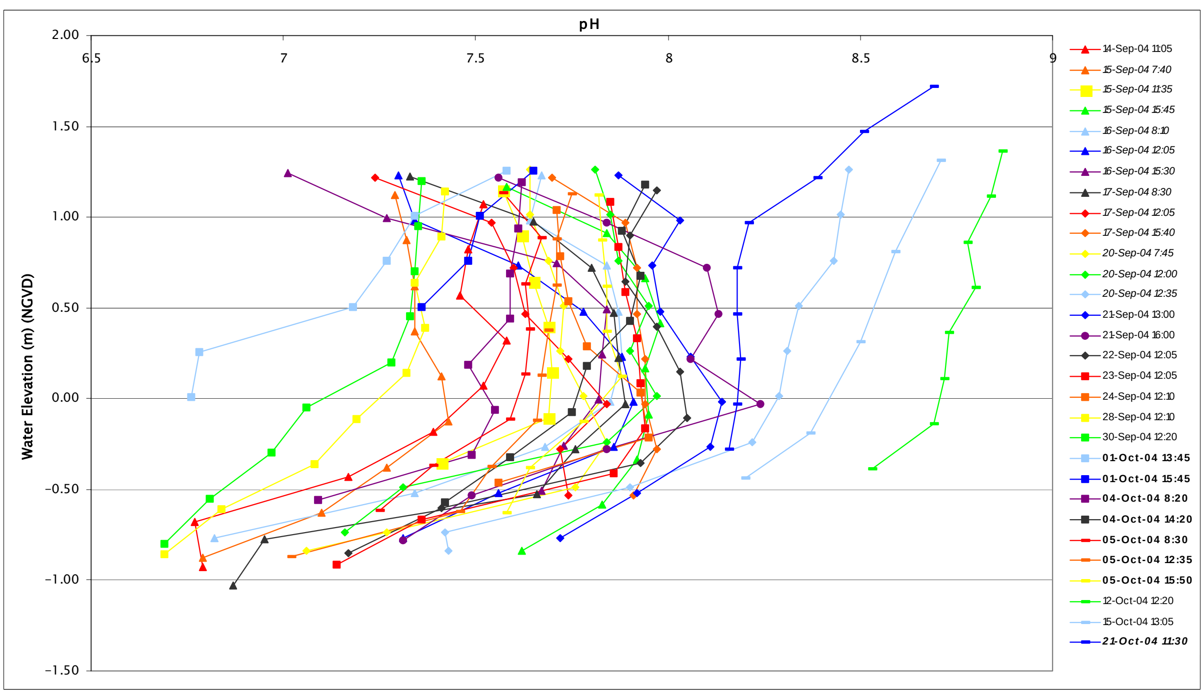


Figure 9-85 Depth profiles of pH at S4O during Phase 2.

## 9.10 S4I: Inside of the silt curtains

### 9.10.1 Temperature

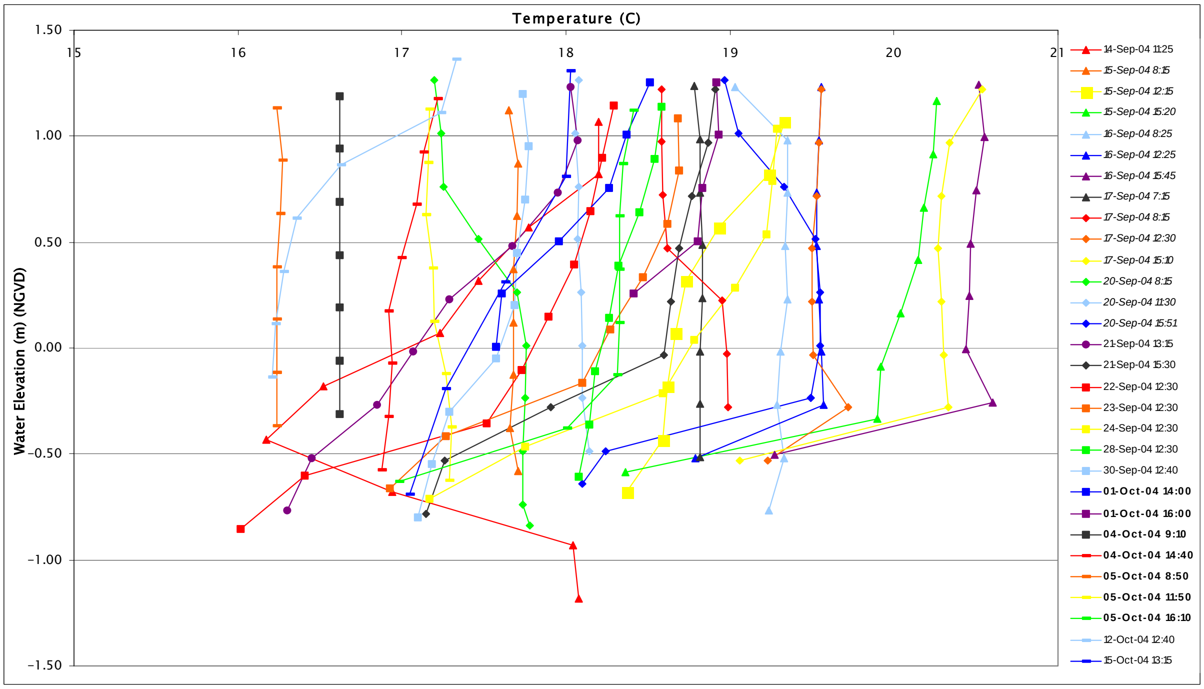


Figure 9-86 Depth profiles of temperature at S4I during Phase 2.

### 9.10.2 Salinity

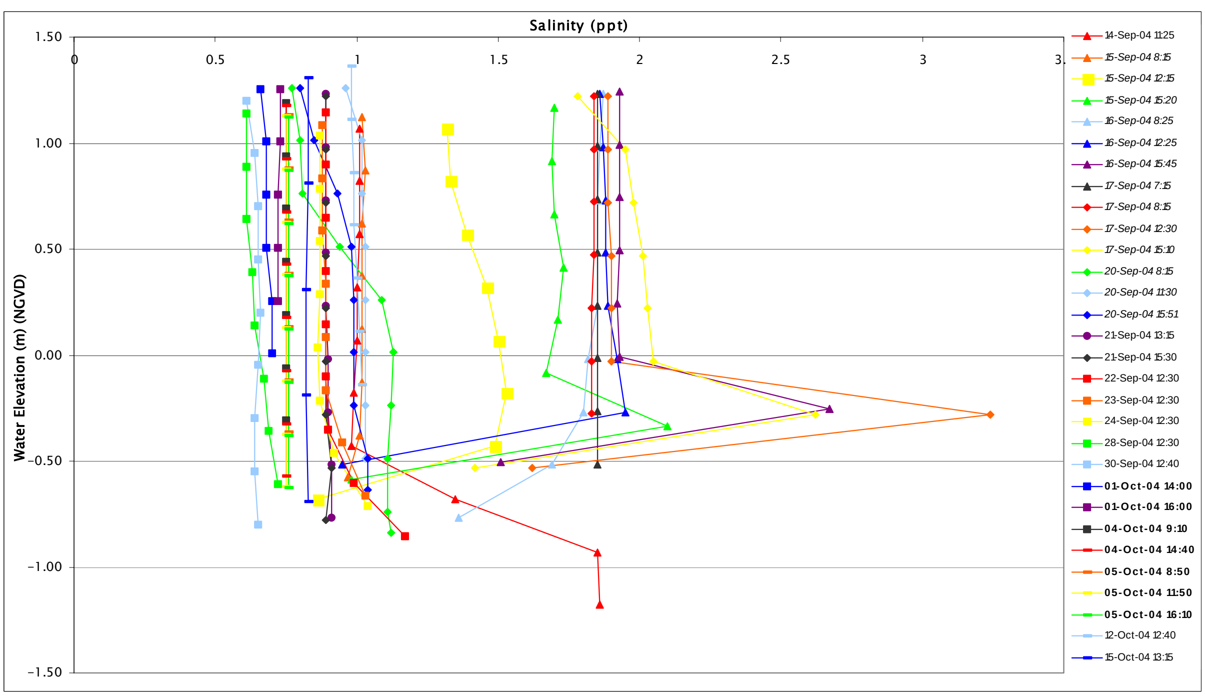


Figure 9-87 Depth profiles of salinity at S4I during Phase 2.

### 9.10.3 S4I: DO

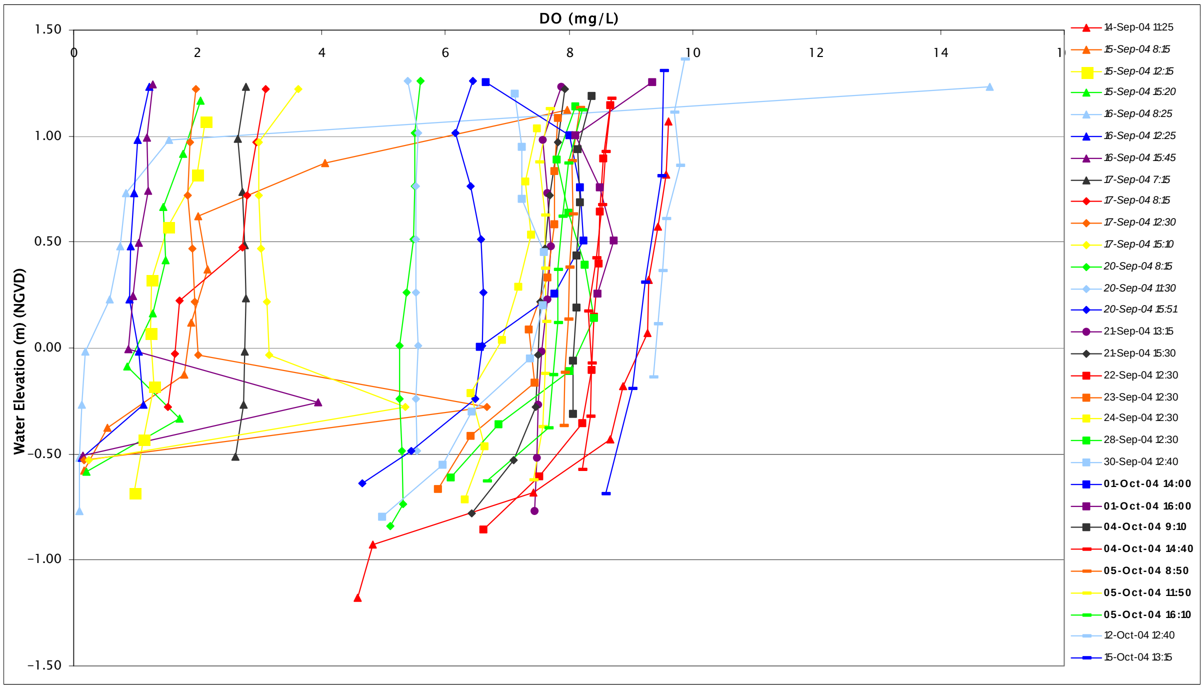


Figure 9-89 Depth profiles of DO at S4I during Phase 2.

### 9.10.4 S4I: pH

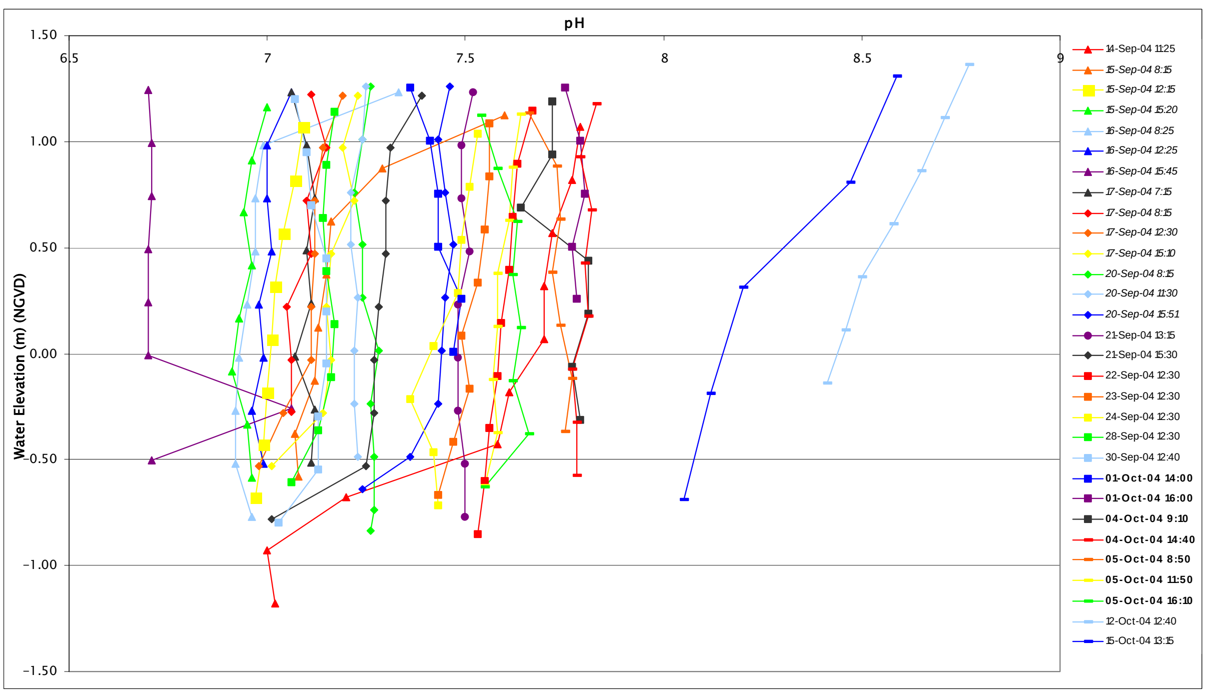


Figure 9-88 Depth profiles of pH at S4I during Phase 2.

## 9.11 S4O and S4I time series

### 9.11.1 $CO_2$

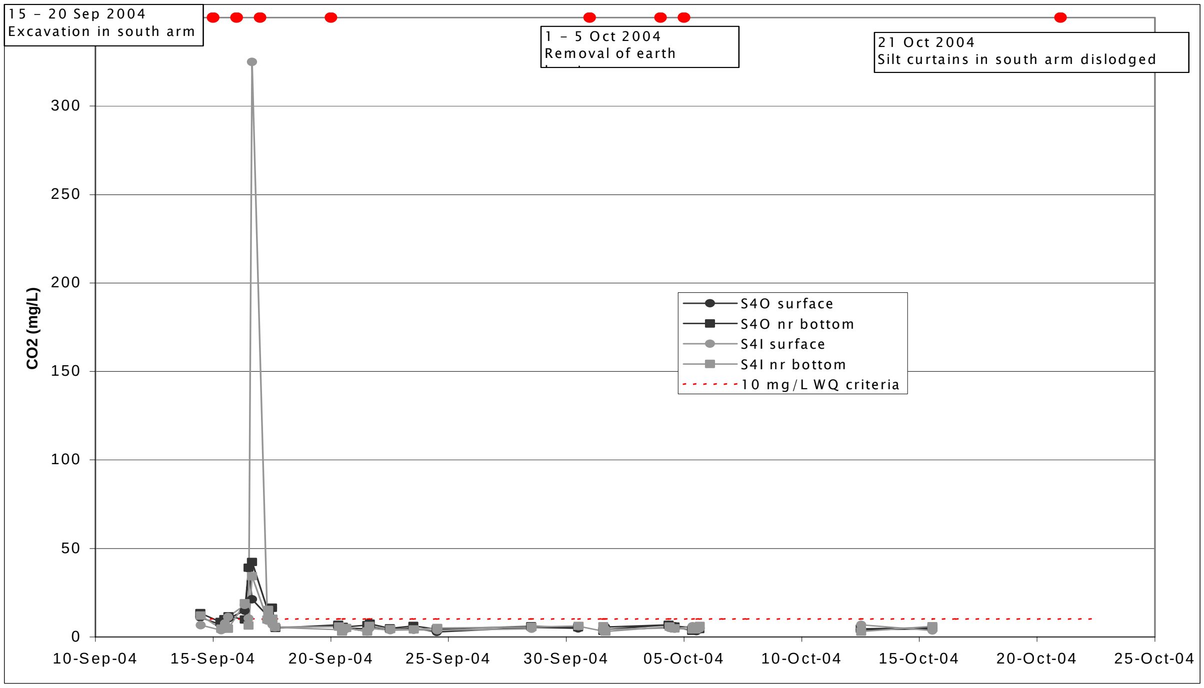


Figure 9-90 Time series of CO2 at S4O and S4I during Phase 2.

### 9.11.2 Turbidity

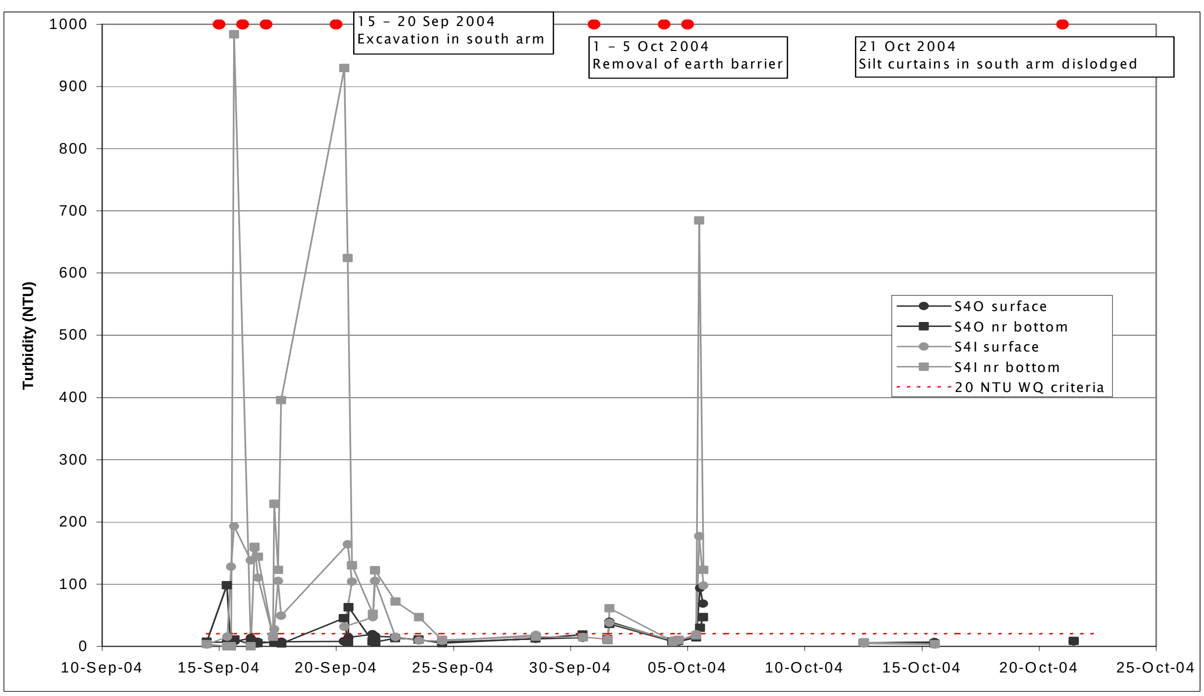


Figure 9-91 Time series of turbidity at S4O and S4I during Phase 2.

### 9.11.3 S4O and S4I: SSC

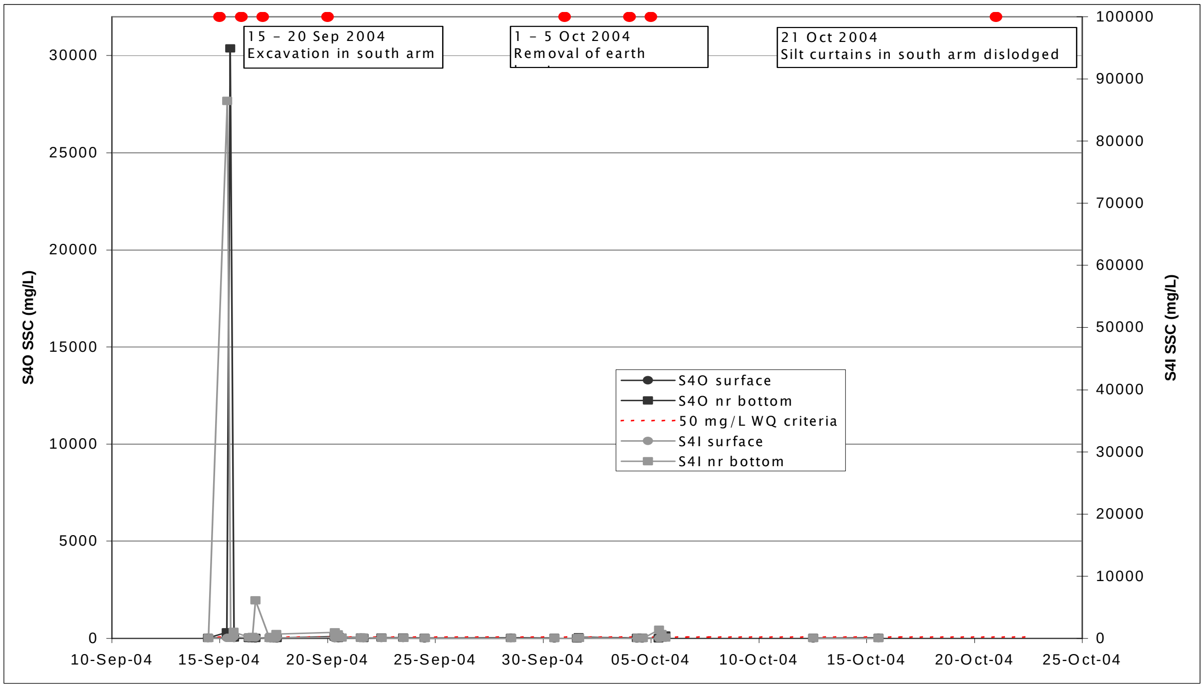


Figure 9-92 Time series of SSC at S4O and S4I.

### 9.11.4 S4O and S4I: $H_2S$

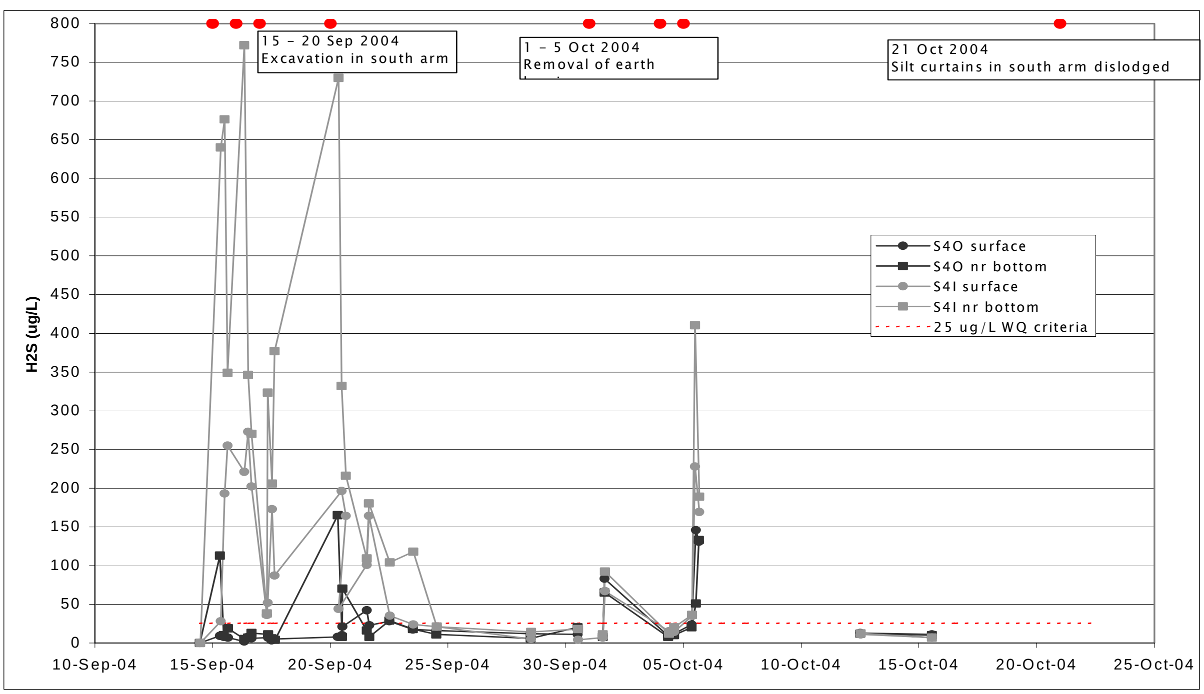


Figure 9-93 Time series of $H_2S$ at S4O and S4I during Phase 2.

## 9.12 OØ: Excavation side of earth barrier

### 9.12.1 Temperature

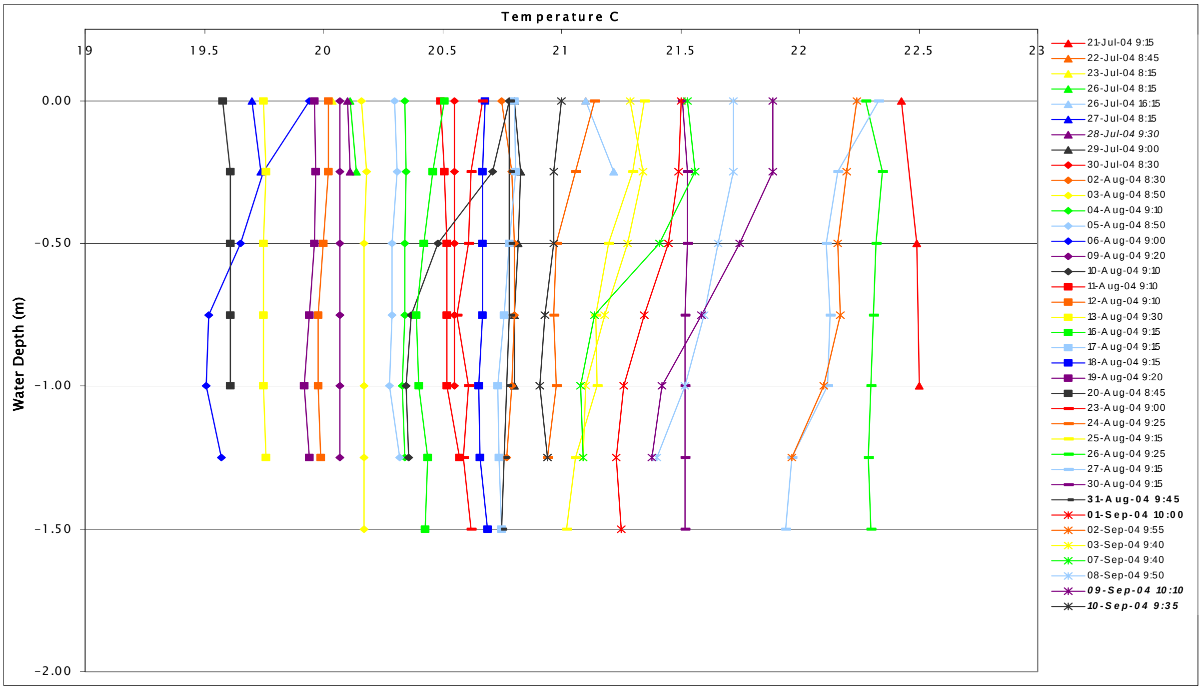


Figure 9-94 Depth profiles of temperature at OØ during Phase 1.

### 9.12.2 OØ: Salinity

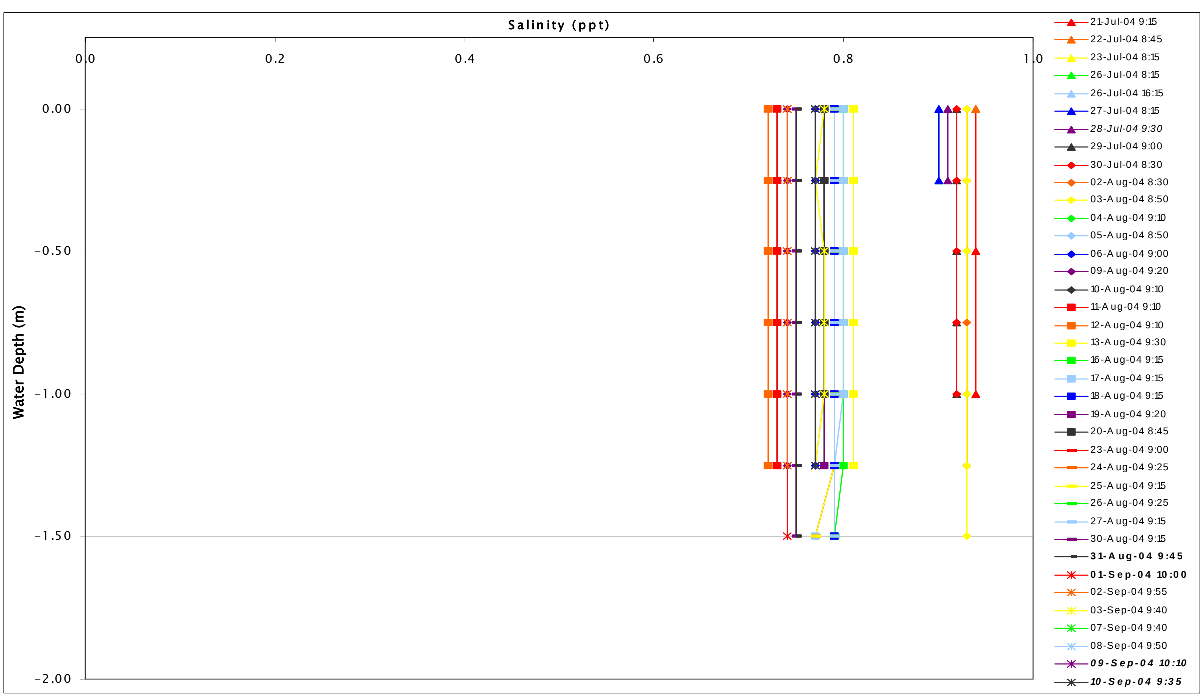


Figure 9-95 Depth profiles of salinity at OØ during Phase 1.

### 9.12.3 OØ: DO

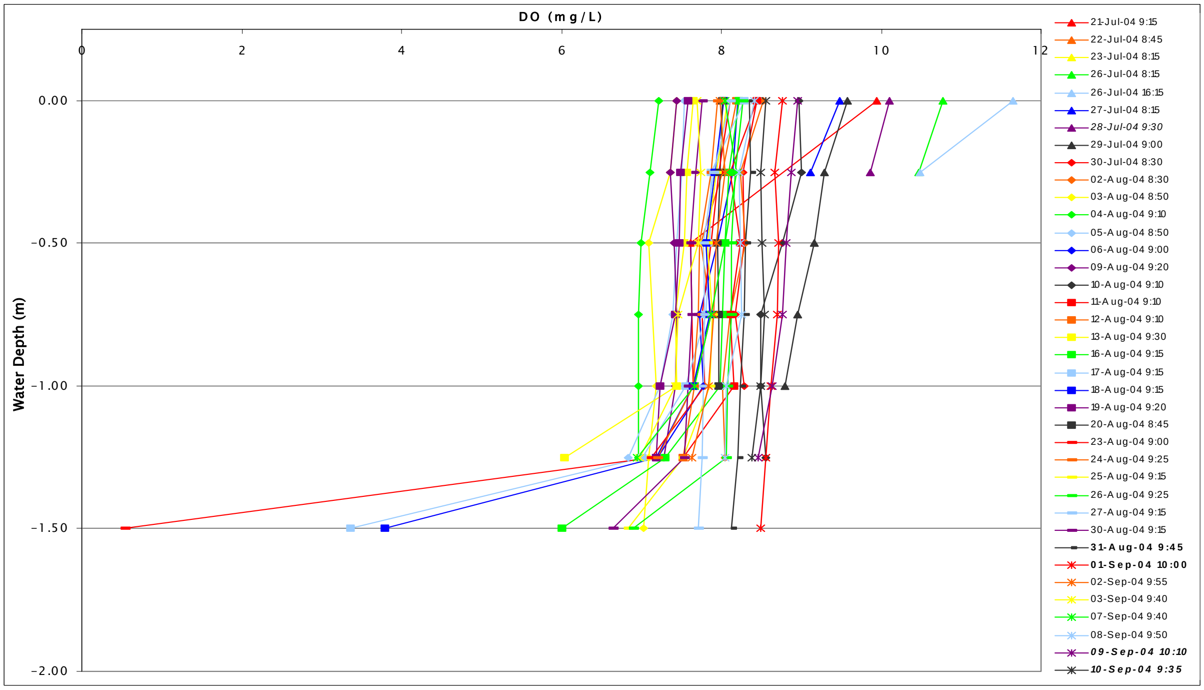

Figure 9-97 Depth profiles of DO at OØ during Phase 1.

### 9.12.4 OØ: pH

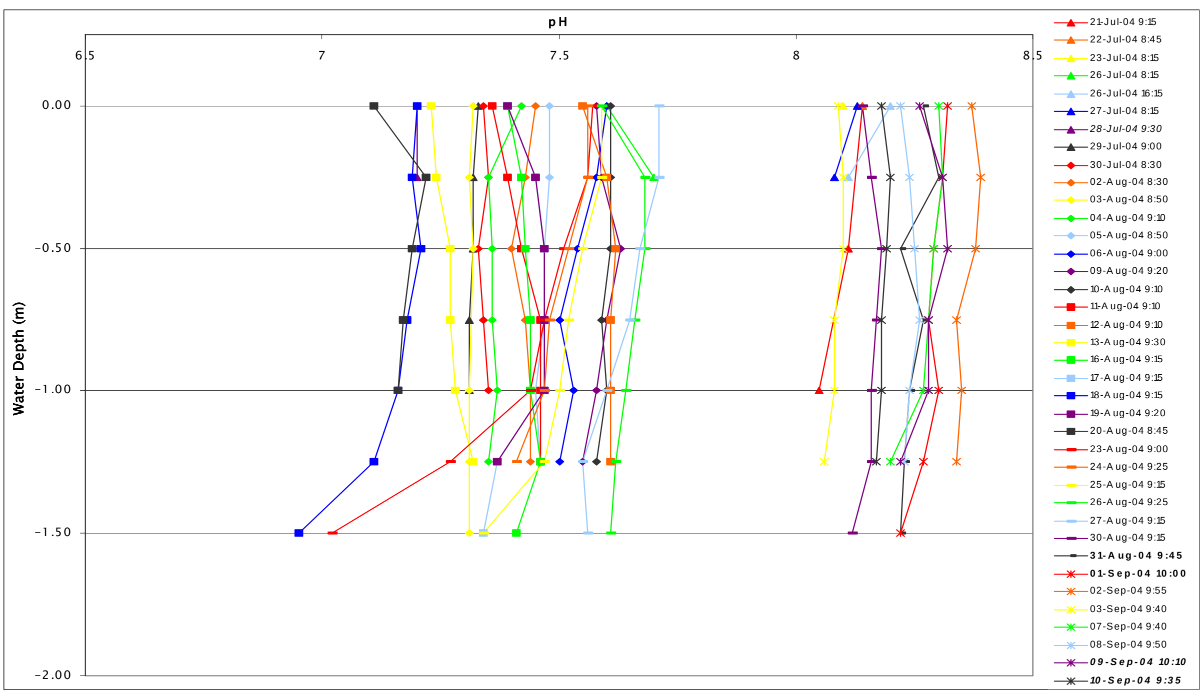

Figure 9-96 Depth profiles of pH at OØ during Phase 1.

### 9.12.5 OØ: $CO_2$

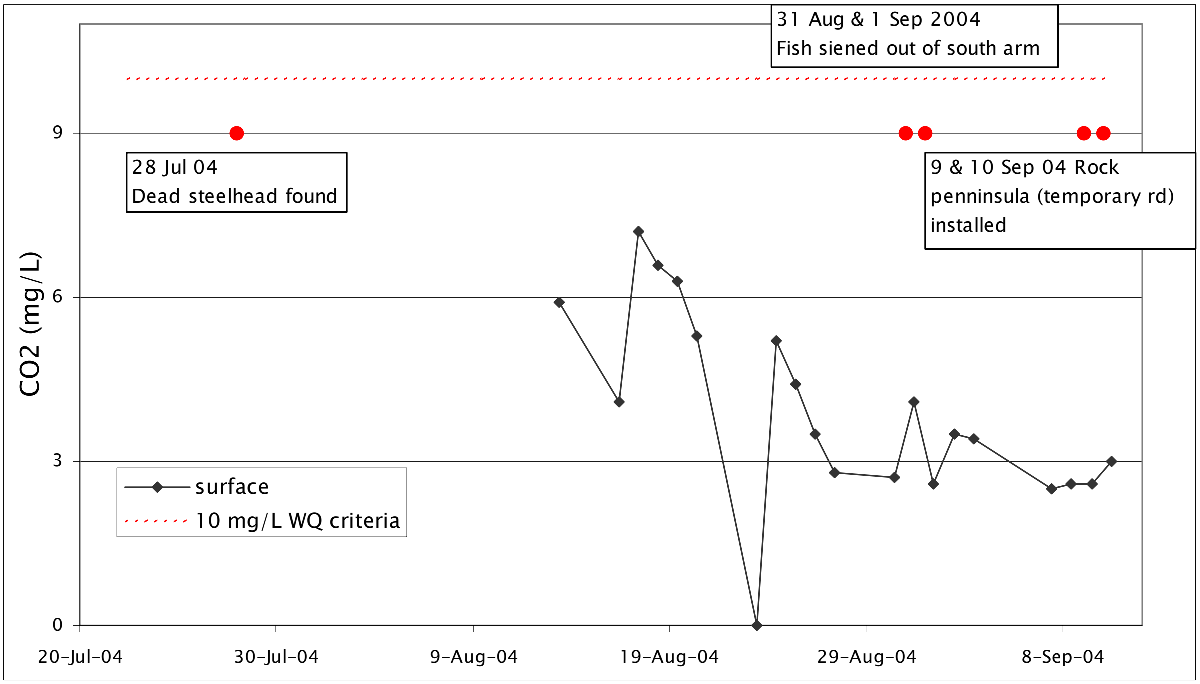


Figure 9-98 Time series of CO2 at O during Phase 1.

### 9.12.6 OØ: Turbidity

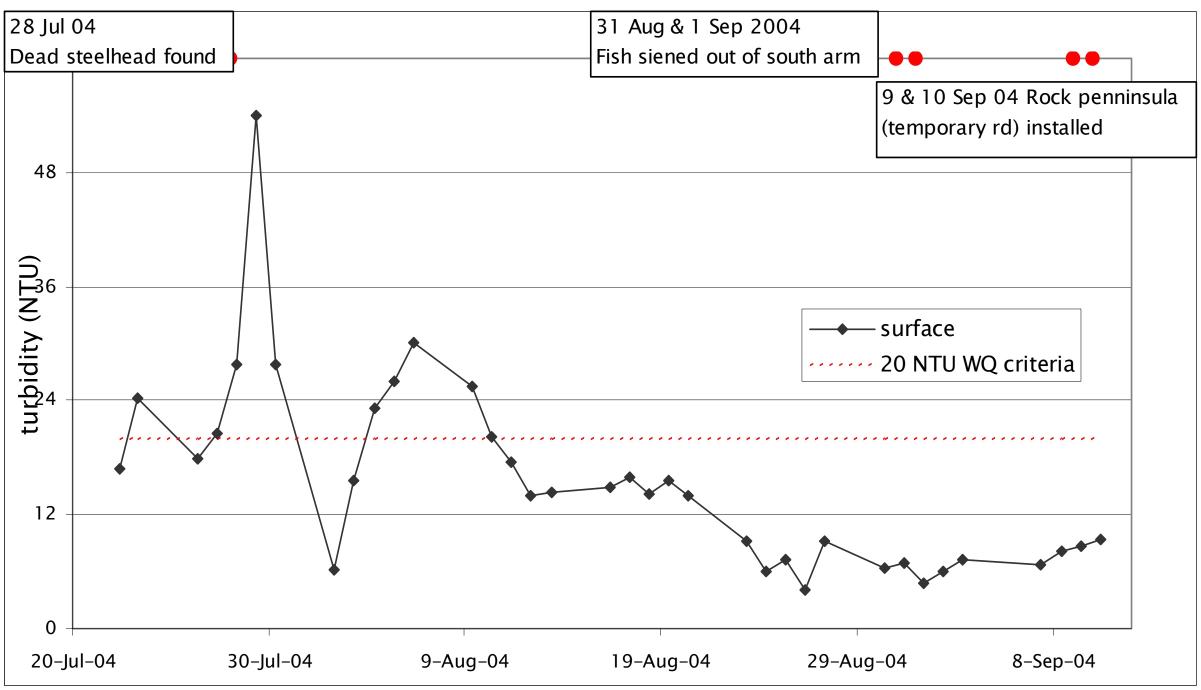


Figure 9-99 Time series of turbidity at O during Phase 1.

### 9.12.7 OØ: SSC

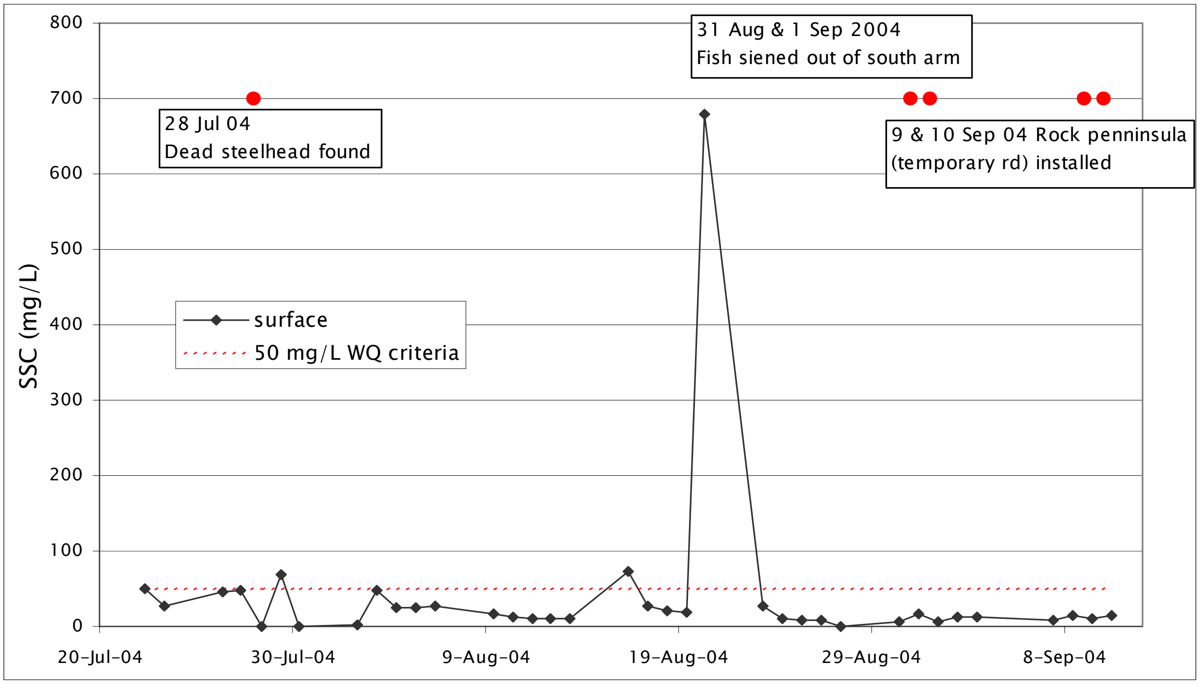


Figure 9-100 Time series of SSC at OØ during Phase 1.

## 9.13 O1: Main excavated channel

### 9.13.1 Temperature

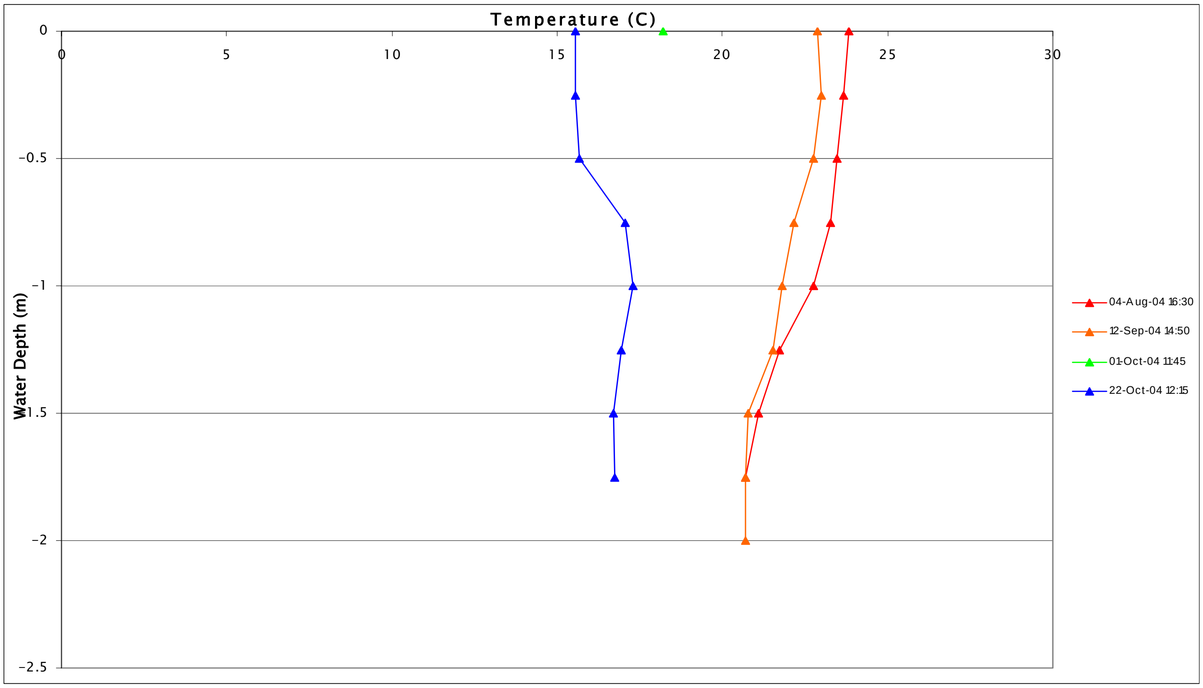


Figure 9-101 Depth profiles of temperature at O1.

### 9.13.2 O1: Salinity

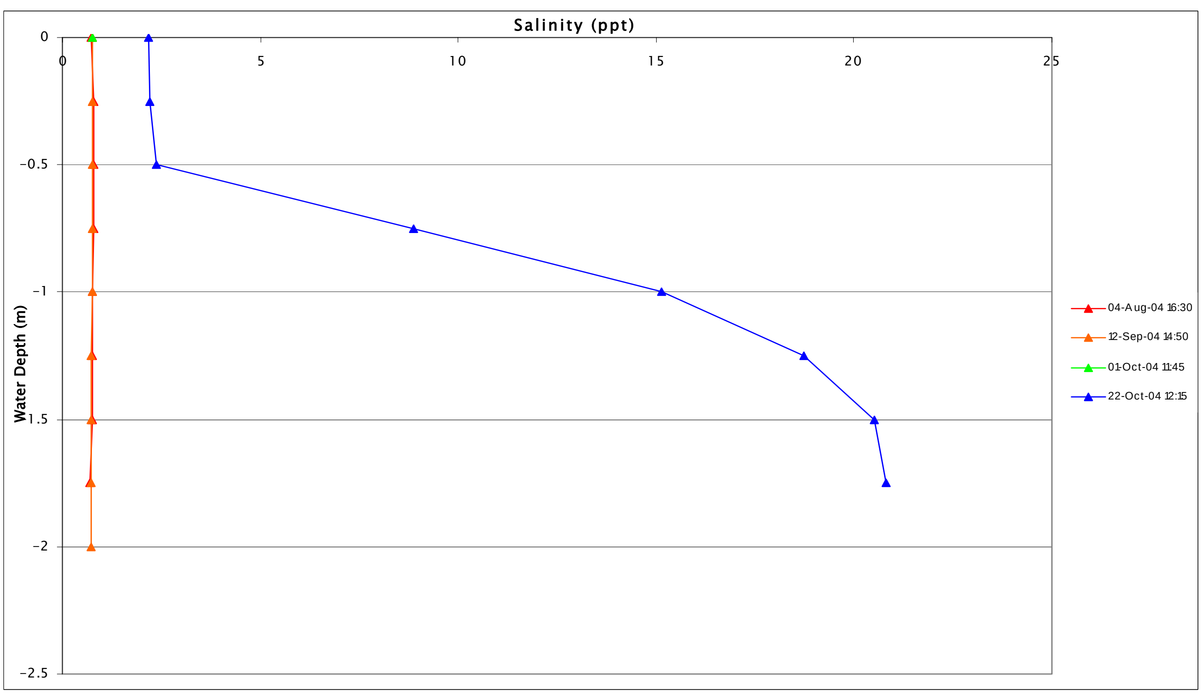


Figure 9-102 Depth profiles of salinity at O1.

### 9.13.3 O1: DO

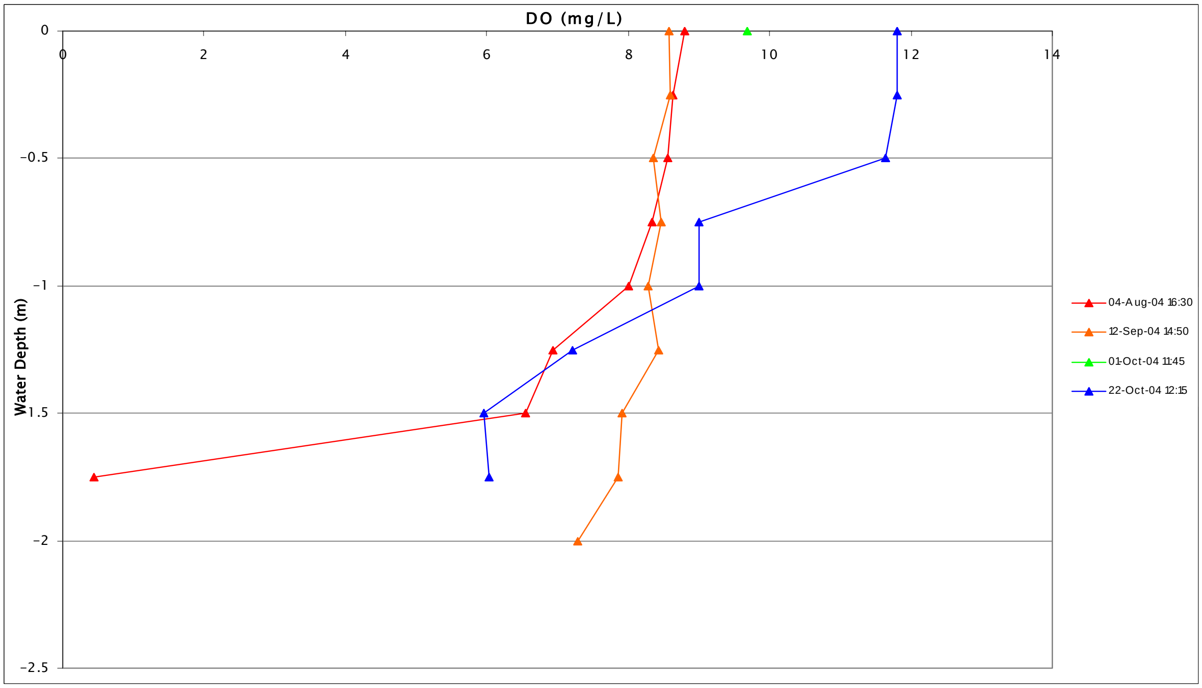


Figure 9-103 Depth profiles of DO at O1.

### 9.13.4 O1: pH

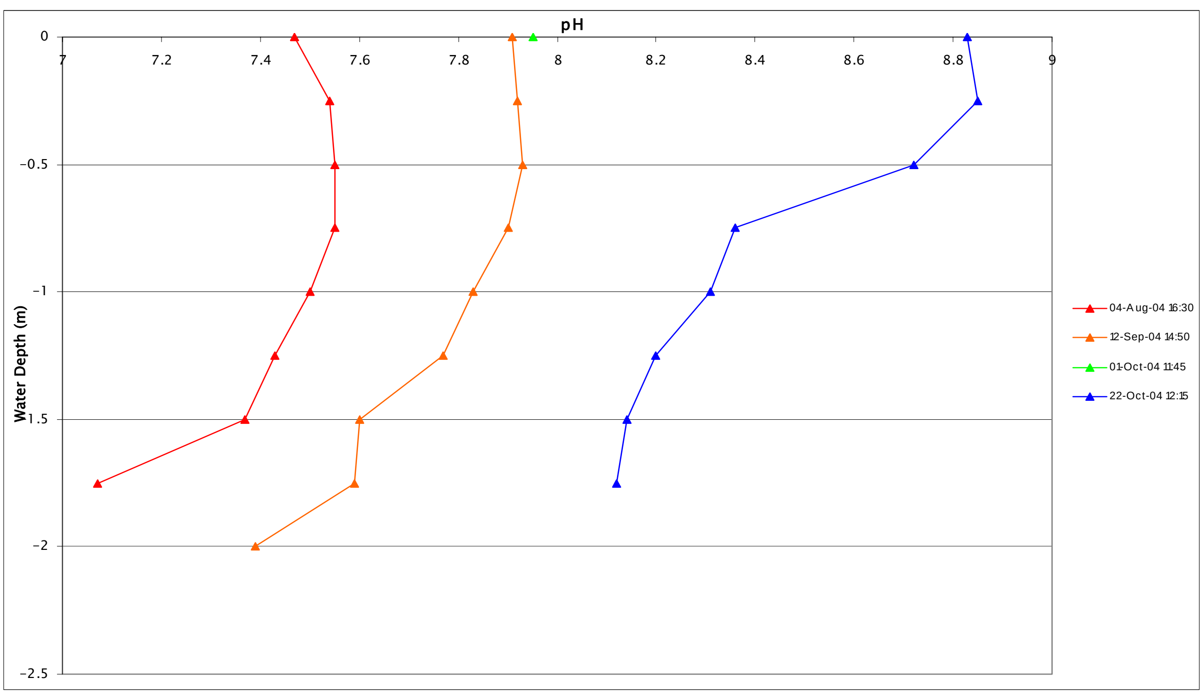


Figure 9-104 Depth profiles of pH at O1.

9.13.5 O1: Turbidity and SSC at O1.

Table 9-5 Summary of turbidity and SSC at O1.

| Date | Turbidity (NTU) | Suspended Solids Concentration (mg/L) |
|---|---|---|
| 4 Aug 04 | Na | Na |
| 12 Sep 04 | 8.97 | 9.01 |
| 1 Oct 04 | 5.34 | 8.82 |
| 22 Oct 04 | 8.52 | 12.67 |

## 9.14 O2: Northern branch of newly excavated channel

### 9.14.1 Temperature

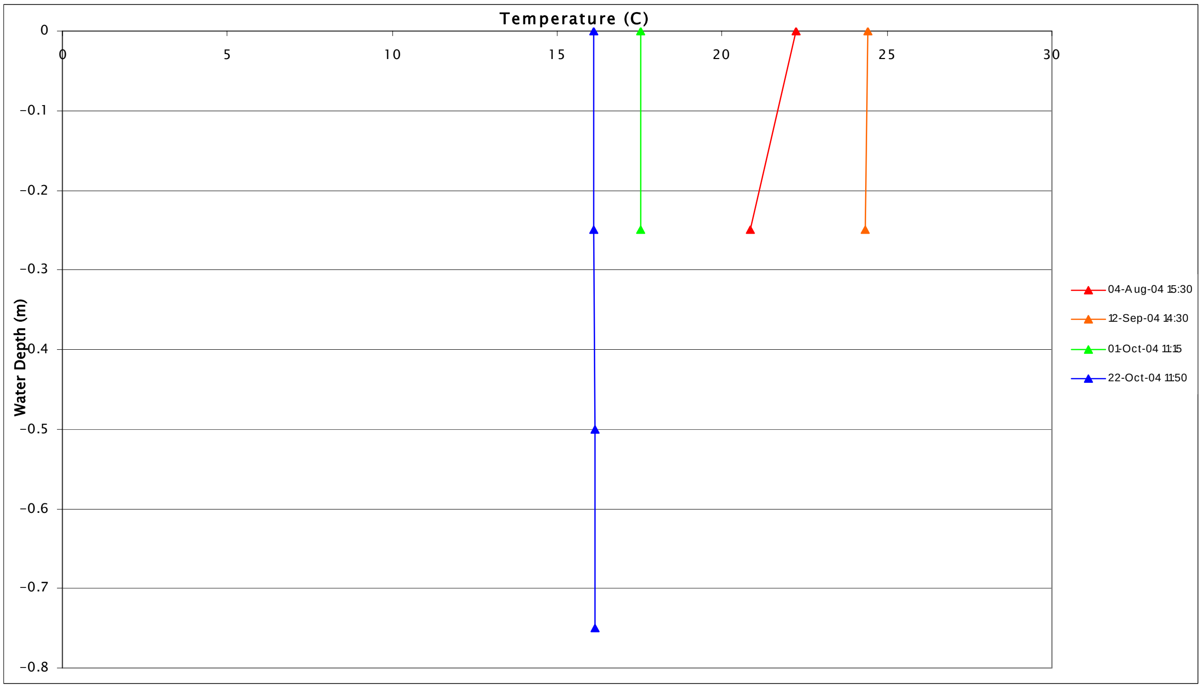


Figure 9-105 Depth profiles of temperature at O2.

### 9.14.2 Salinity

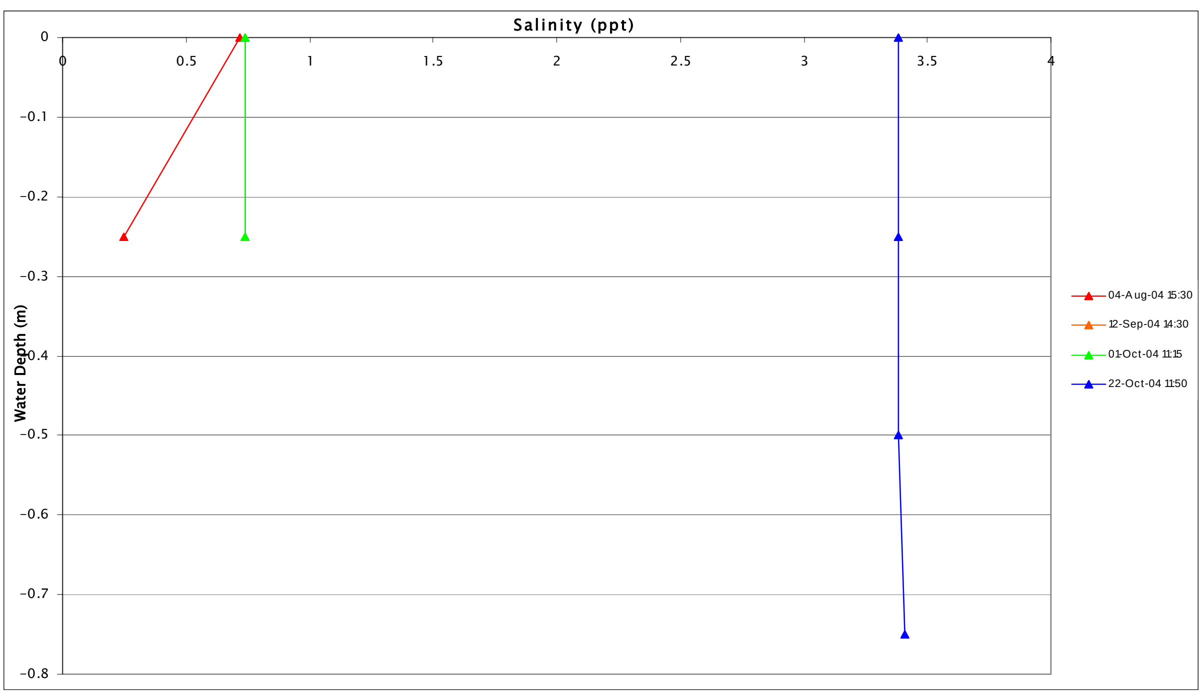


Figure 9-106 Depth profiles of salinity at O2.

### 9.14.3 O2: DO

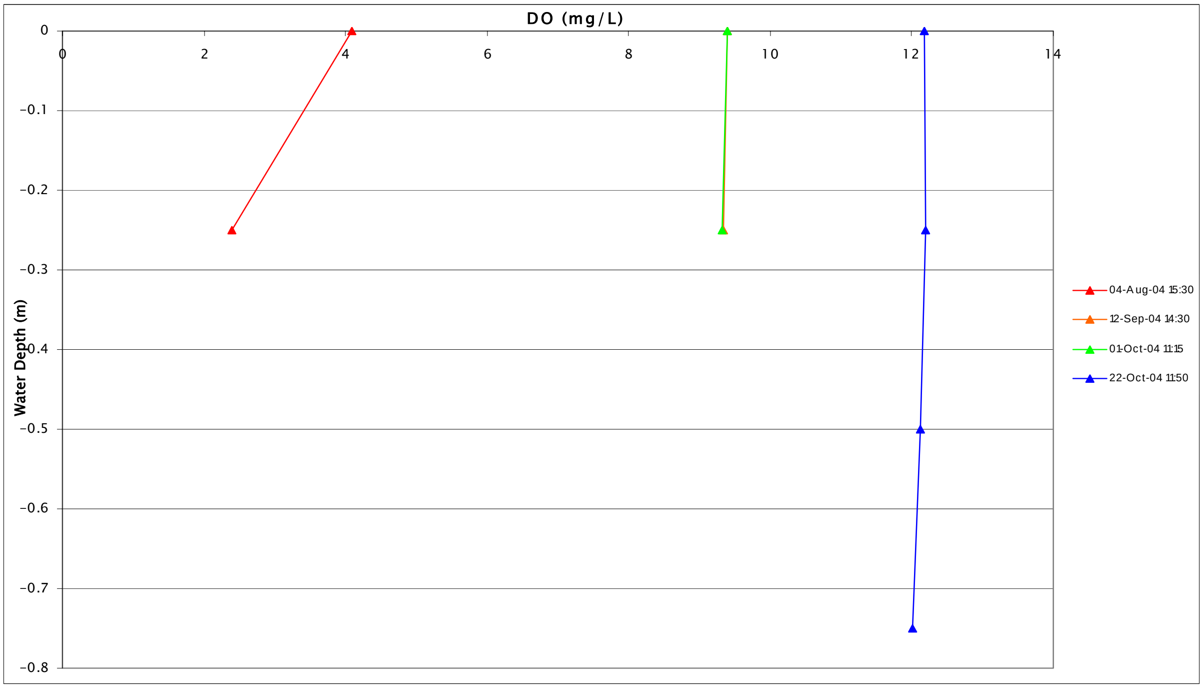


Figure 9-107 Depth profiles of DO at O2.

### 9.14.4 O2: pH

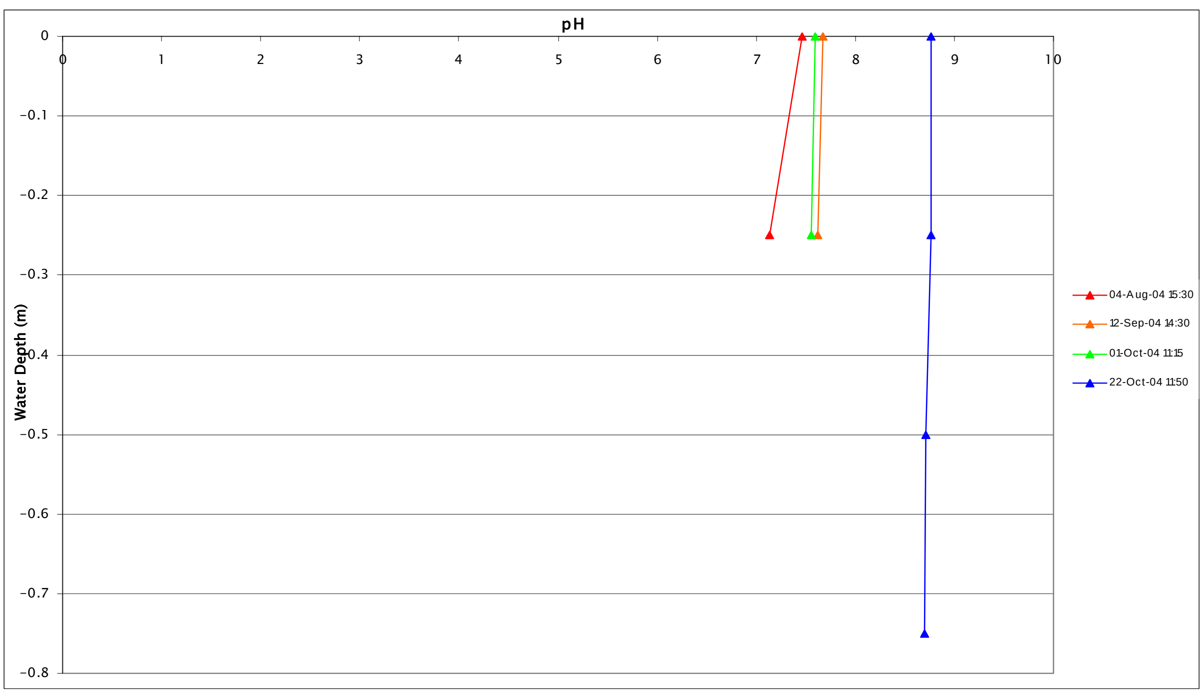


Figure 9-108 depth profiles of pH at O2.

### 9.14.5 O2: Turbidity and SSC at O1.

Table 9-6 Summary of turbidity and SSC at O2.

| Date | Turbidity (NTU) | Suspended Solids Concentration (mg/L) |
|---|---|---|
| 4 Aug 04 | Na | Na |
| 12 Sep 04 | 8.18 | 29.97 |
| 1 Oct 04 | 3.88 | 0.00 |
| 22 Oct 04 | 11.6 | 16.50 |

## 9.15 O3: Southern branch of newly excavated channel

### 9.15.1 Temperature

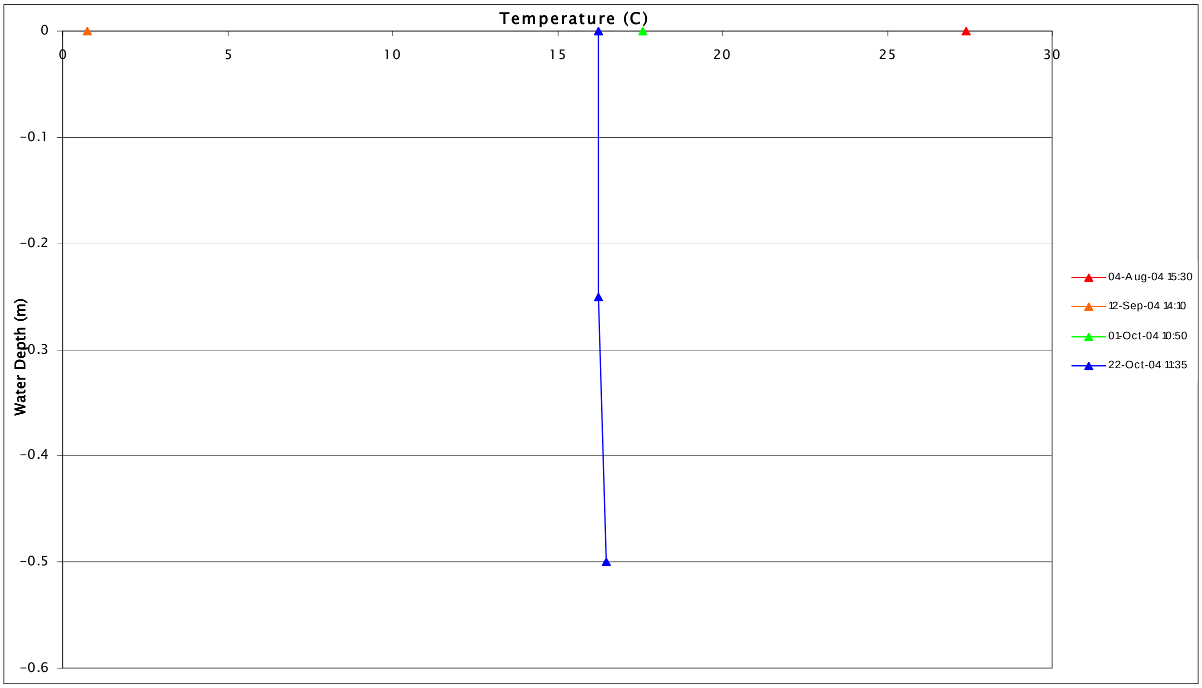


Figure 9-109Depth profiles of temperature at O3.

### 9.15.2 O3: Salinity

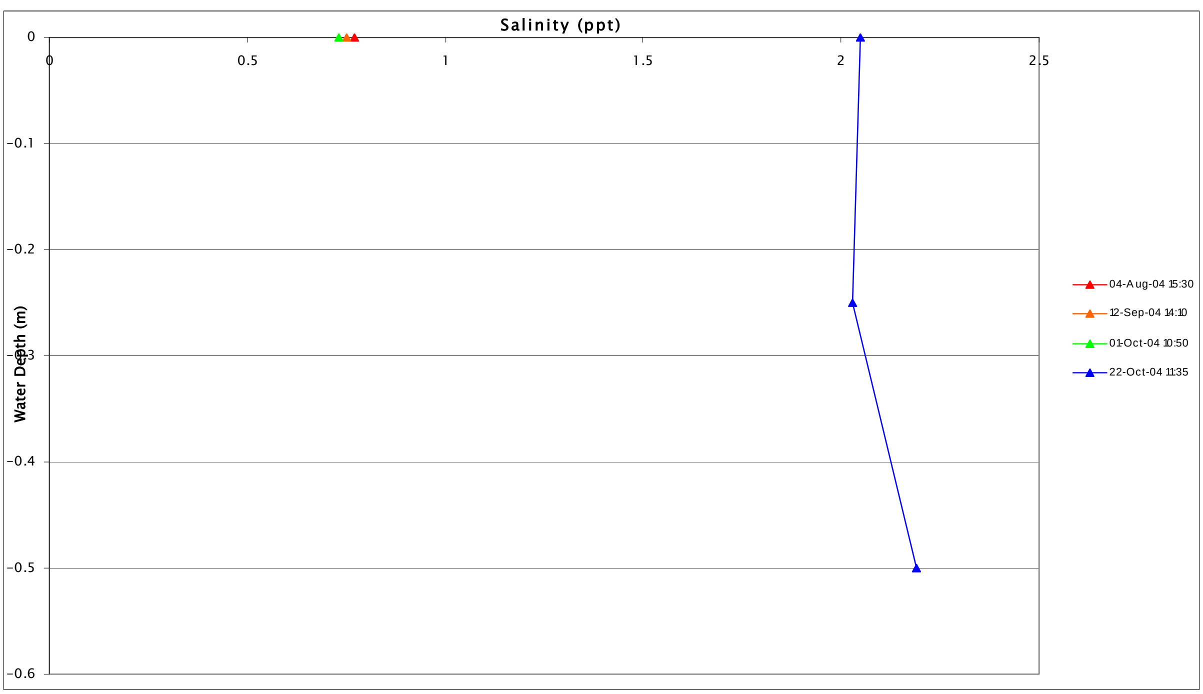


Figure 9-110 Depth profiles o salinity at O3.

### 9.15.3 O3: DO

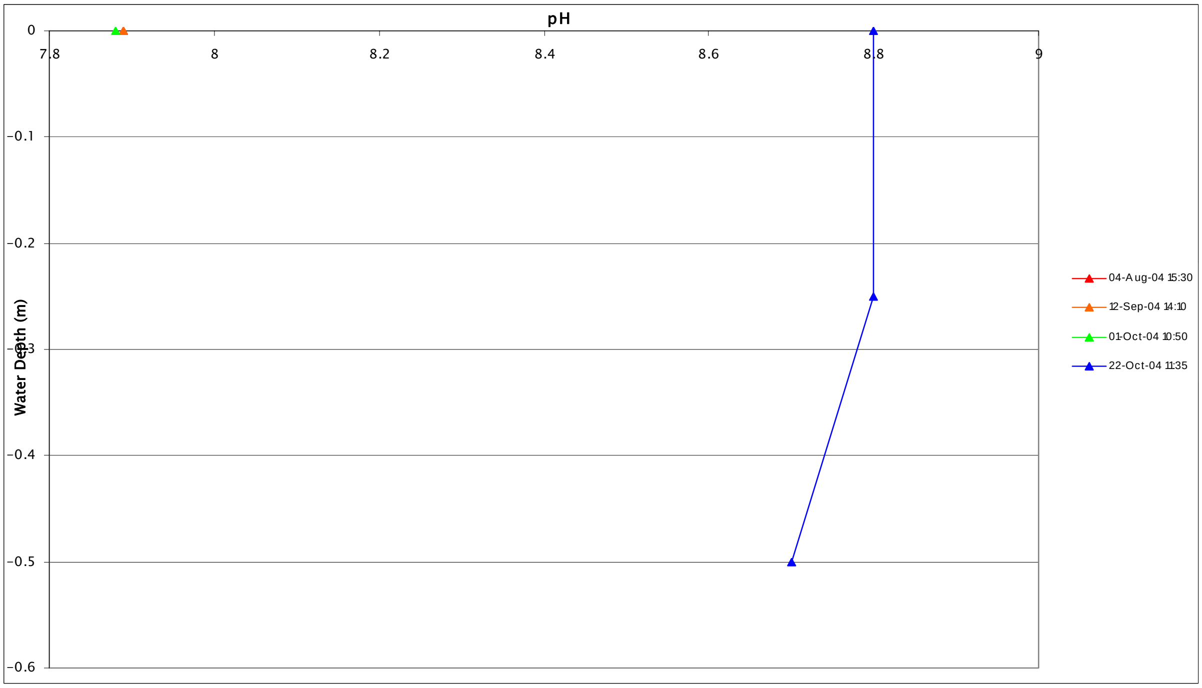


Figure 9-111 Depth profiles of pH at O3.

### 9.15.4 O3: pH

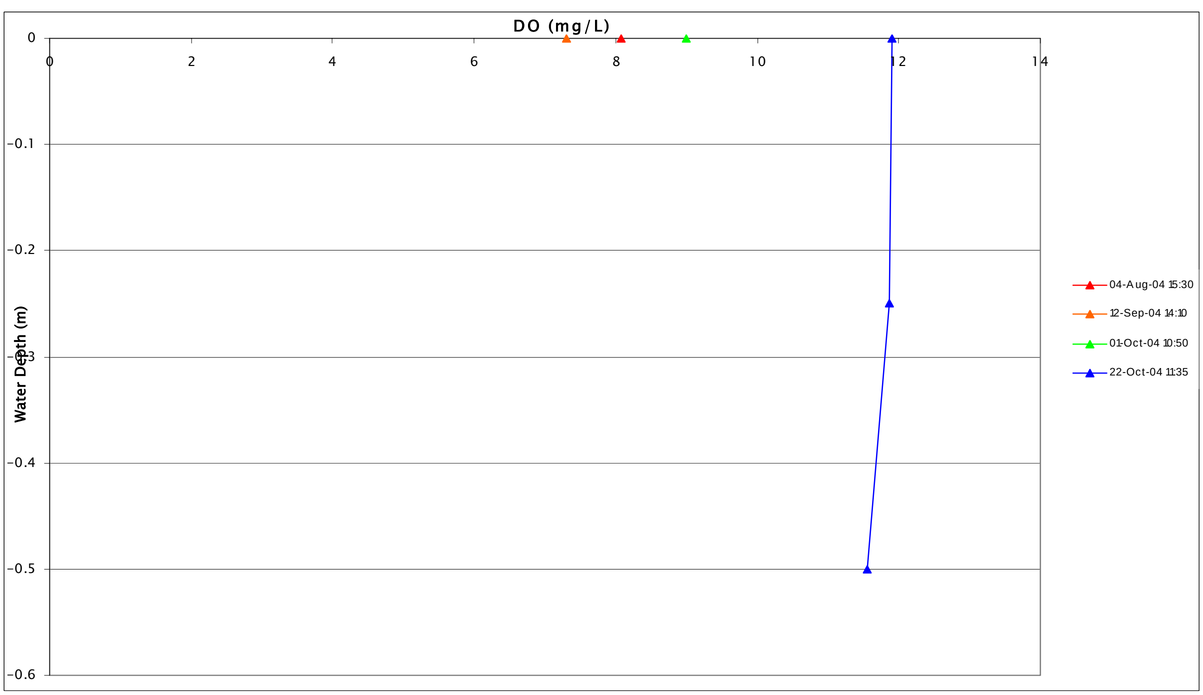


Figure 9-112 Depth profiles of DO at O3.

### 9.15.5 O3: Turbidity and SSC

Table 9-7 Summary of turbidity and SSC at O3.

| Date | Turbidity (NTU) | Suspended Solids Concentration (mg/L) |
|---|---|---|
| 4 Aug 04 | na | na |
| 12 Sep 04 | 11 | 20.01 |
| 1 Oct 04 | 7.46 | 8.96 |
| 22 Oct 04 | 8.26 | 11.83 |