BMT WBM

Port of Brisbane Monitoring Program – Assessment of Sediment from 2017 Maintenance Dredging Activities

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Synopsis:	**A report outlining sediment concentrations in plumes generated by maintenance dredging (Brisbane River) and disposal activities (Mud Island DMPA) in February 2017.**	

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Executive Summary

Background

The Port of Brisbane is a river port located in the lower Brisbane River. The lower Brisbane River is a depositional zone for terrigenous and reworked marine sediments, which are trapped in navigation channels, the swing basin and berth pockets. The Port of Brisbane Pty Ltd (PBPL) undertakes regular maintenance dredging of recently deposited sediments in these operational areas, using the trailing arm suction hopper dredge *Brisbane*. Dredged material then either placed at sea at the designated Mud Island Dredged Material Placement Area (DMPA), or in reclamation areas within the Future Port Expansion (FPE) area.

The dredging and ocean disposal generates plumes of suspended sediments (referred to as dredge plumes) in the water column. PBPL has undertaken monitoring of the characteristics and behaviour of dredge plumes since the 1990s. PBPL commissioned BMT WBM to monitor the plumes of suspended sediment created by the dredger *Brisbane* while undertaking dredging and offshore disposal activities in February 2017. A complementary numerical modelling exercise was also performed to predict the transport and advection of suspended sediments in plumes generated by dredging and offshore disposal. The results of this investigation, which are documented in this report, will be used by PBPL to manage potential risks associated with plumes of suspended sediment generated by their dredging operations.

Sampling Approach

Dredge plume monitoring was carried out at the swing basin, outer cutting and Mud Island DMPA using a combination of techniques, including:

- an Acoustic Doppler Current Profiler (ADCP) – this device uses sound wave reflections (backscatter) to determine the amount 'suspended sediments' through the water column. A boat based ADCP was used to measure a vertical cross-section of the sediment plume at varying stages of the plume creation and subsequent degradation.
- depth profiling of turbidity using a turbidity probe – Turbidity is a measure of water clarity or cloudiness. The turbidity probe was lowered through the water column to measure turbidity along depth profiles within and outside the plume.
- collection of samples for laboratory analysis of total suspended sediment and nutrient concentrations – water samples were collected through the water column.
- deployment of a drogue (i.e. surface drifter) to track the movement of currents that move the plume.

The relationship between backscatter (measured using ADCP), turbidity and TSS was statistically derived, which was used to derive two dimensional profiles of suspended sediment concentrations. The equation describing the statistical relationship between TSS and turbidity can also be used to calculate TSS values from turbidity measurements, which underpins modelling assessments.

Field Survey Findings

The dredged areas sampled in 2017 had higher concentrations of suspended sediments in dredge plumes compared to 2014 (mean TSS = 20 ± 5.1 in 2014, 59 ± 20.7 in 2017). This is expected to reflect differences in the in the characteristics of dredged material between years (i.e. likely higher proportion of silts in 2017).

Sediment plumes created by dredging and disposal were highly localised features that were detectable (above background) for short period of <2 hours. Both dredging and disposal created a surface sediment plume that rapidly settled to the seafloor, with the resulting near-bed plume dispersed by tidal currents. Sediment plumes in the dredge areas were largely confined within and directly adjacent to channels, and were not detectable (above background) in areas containing sensitive receptors such as reefs or seagrass meadows. The sediment plume generated by dredged material disposal had a lower intensity than that created by dredging. This plume was monitored as it migrated south-east with the current. After ~1.5 hours the disposal plume had visually disappeared (i.e. below background).

Increases (above background) in nutrient species were also detected in plumes generated by dredging and disposal. This occurs where the dredger disturbs the seabed, leading to the release of nutrients (contained in waters between sediment grains) into the water column. Nutrient concentrations exceeded the local WQO but did not approach the toxicity guideline value for ammonia. Dissolved and particle bound nutrients will be rapidly dispersed and diluted by currents, and in the case of bioavailable dissolved nutrients, rapidly taken up by phytoplankton.

These results are consistent with previous monitoring studies in the Brisbane River which indicate that sediment plumes created by dredging and offshore disposal are short-term, highly localised features, due to rapid dilution and dispersal by tidal currents.

Numerical Modelling

Field measurements provide multiple snap-shots of dredge plumes, which cannot fully resolve the spatial and temporal characteristics of plumes created by all dredge runs during a campaign. Hind-cast modelling was therefore undertaken to characterise the behaviour of sediment plumes created by dredging and ocean disposal during the February 2017 maintenance dredging campaign. Dredge related contributions were resolved in the hind-cast models (waves, currents, sediment transport models) and a comparison to both sampled turbidity data at the DMPA and ADCP transect data was made. The model provides a basis for assessing plume behaviour and potential risks to sensitive receptors.

Modelling has shown that sediment plumes created by dredging and disposal were short term, highly localised features, consistent with sediment plume measurement data. There is no evidence to suggest that multiple dredge and disposal runs resulted in significant cumulative sediment plumes at concentrations above background. Remnant plumes from previous dredging in other areas can be seen in the modelling. These are likely entrained in the higher current regions, though are well within background levels in this reach of the Brisbane River and are unlikely to be visible. Dredge plumes were dispersed in the direction of the dominant tidal current, and were not predicted to encroach onto sensitive receptor sites at concentrations above background (i.e. fringing reefs at Mud Island, seagrass meadows at Fisherman Islands).

Glossary and Abbreviations

ADCP	Acoustic Doppler Current Profiler
AHO	Australian Hydrographic Office
ANZECC/ARMCANZ	Australian and New Zealand Environment and Conservation Council, and Agriculture and Resource Management Council of Australia and New Zealand
DMPA	Dredge Material Placement Area
FPE	Future Port Expansion
FV	Finite-Volume
MSQ	Maritime Safety Queensland
NLSWE	Non-Linear Shallow Water Equations
NO_x	Nitrate and nitrite
NTU	Nephelometric Turbidity Units
PBPL	Port of Brisbane Pty Ltd
PSD	Particle Size Distribution
ST	Sediment Transport
TSHD	Trailing arm suction hopper dredge
TSS	Total Suspended Solids
WQO	Water quality objective

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1 Introduction

1.1 Background

The Port of Brisbane Pty Ltd (PBPL) is responsible for the maintenance of 90 km of navigational shipping channel stretching from the northern tip of Bribie Island, across Moreton Bay, and into the Brisbane River. Maintenance dredging between Fisherman Islands and the Hamilton Reach of the Brisbane River is also undertaken to enable safe passage of vessels visiting berths upstream. All dredging is conducted within approved navigation channels, berths and swing basins. The resultant dredged material is either placed within the Port of Brisbane Future Port Expansion (FPE) reclamation area or at the Mud Island Dredge Material Placement Area (DMPA), subject to specific approval. Refer to Figure 1-1 for a locality plan.

The creation of turbid plumes of suspended sediment is associated with the processes of dredging of marine sediments. Once disturbed by dredging activities, seabed sediments become entrained in the water column usually creating plumes of turbid water. The nature and extent of the plumes created depends on a range of factors including the type of dredge, the depth of dredging, the nature of the dredged material, the magnitude and direction of tidal currents, the surrounding bathymetry and the prevailing weather.

Monitoring of the characteristics of the plumes of suspended sediment created by the operations of PBPL's dredging fleet has been subject of numerous investigations (e.g. WBM Oceanics Australia 1995, 1997, 2002a, 2002b, 2004; BMT WBM 2008, 2011, 2014). In recent years, monitoring has been undertaken on a triennial basis, and the information gathered is used to guide the planning and management of dredging operations, particularly when working in locations that are in close proximity to sensitive receptors[1].

PBPL commissioned BMT WBM to monitor the plumes of suspended sediment created by the dredger *Brisbane* while undertaking dredging and offshore disposal activities in February 2017. A complementary numerical modelling exercise was also performed to predict the transport and advection of suspended sediments in plumes generated by dredging and offshore disposal. The results of this investigation, which are documented in this report, will be used by PBPL to manage potential risks associated with plumes of suspended sediment generated by their dredging operations.

1.2 Study Aim and Objectives

The aim of this study is to characterise the turbid plumes of suspended sediment generated by typical operations of the dredger *Brisbane*. The specific objectives of this study are to:

- Measure and quantify the behaviour, extent and intensities of plumes of suspended sediments generated by dredging at and adjacent to the loading sites and disposal operations at Mud Island DMPA

[1] Sensitive receptors are defined as marine plants or animals which may be affected by reduced light penetration or smothering resulting from sediment entrainment into the water column from dredging operations.

- Simulate the behaviour of suspended sediment plumes generated by dredging and offshore disposal during the 2017 Brisbane River maintenance dredging campaign
- Based on the above measurements and modelling, assess the potential exposure of existing sensitive receptors to sediment plumes nutrient concentrations.

1.3 Description of the Activity

1.3.1 The *Brisbane*

The *Brisbane* is the largest vessel in PBPL's dredging fleet, and is an 85 m long ocean-going trailing arm suction hopper dredge (TSHD). The *Brisbane* performs maintenance and capital dredging works within the Port of Brisbane for around three months of the year and contract maintenance dredging services for Central and North Queensland ports for the remainder.

The *Brisbane* is equipped with two trailing arm suction heads, on the port and starboard sides of the vessel, which are typically lowered and dragged along the seafloor, simultaneously dredging the bed sediments either side of the vessel as it progresses forward. The drag heads are lifted clear of the seabed when moving astern. To efficiently fill the hopper (volume 2,900 m^3) with dredged material, the vessel is usually operated in an overflowing mode whereby the dredged sediments are concentrated within the hopper over time. A telescoping weir within the centre of the hopper can be elevated to maximise the retention of dredged material before discharge from the hopper occurs. Excess water and suspended sediments are ultimately discharged from the hopper via the weir to the underside of the keel, approximately five metres below the water line.

Depending upon the nature of sediments to be dredged, dredging to effectively fill the dredge hopper generally lasts around one hour, typically without any overflow from the hopper occurring in the first 15 – 20 minutes. Subsequently, a dredging overflow plume of turbid water is usually obvious as the overflow water and suspended sediments discharged from the underside of the keel are entrained to the water surface by the action of the vessel's propellers operating near the stern of the vessel as it moves ahead. This results in an obvious surface plume of dredged sediment astern of the *Brisbane* for the remainder of the dredging duration.

Following end of dredging, the *Brisbane* typically delivers the material to the designated area, Mud Island DMPA. For offshore disposal at the DMPA, the dredge typically slows to a speed of a few knots where the dredged sediment within the hopper is released onto the placement area by opening a series of valves on the bottom of the hopper. This sediment is entrained into the water column before settling to the seafloor.

1.3.2 February 2017 Maintenance Dredge Campaign

Monitoring of the turbid plumes around the *Brisbane* took place during the 13th February 2017 whilst the vessel was performing the following duties:

- Maintenance dredging at the Inner Bar (9:00 – 10:25) - Flood Tide (high tide at 11:10, 2.47 m)
- Material placement at the Mud Island DMPA (11:00 – 12:17) of sediments from the Inner Bar – slack water/ebb tide
- Maintenance dredging at the swing basin – Pelican Banks (13:00 – 14:15) – ebb tide.

Modelling was carried out to incorporate maintenance dredging undertaken February 2017, specifically (i) areas subject to maintenance dredging during February 2017 in the Brisbane River area, and (ii) disposed of at Mud Island DMPA. This does not include dredging activities involving onshore disposal at the FPE area, i.e. dredging of offshore channels (Spitfire channel, North West channel). Further details on modelled dredge and disposal campaigns is provided in Section 4.

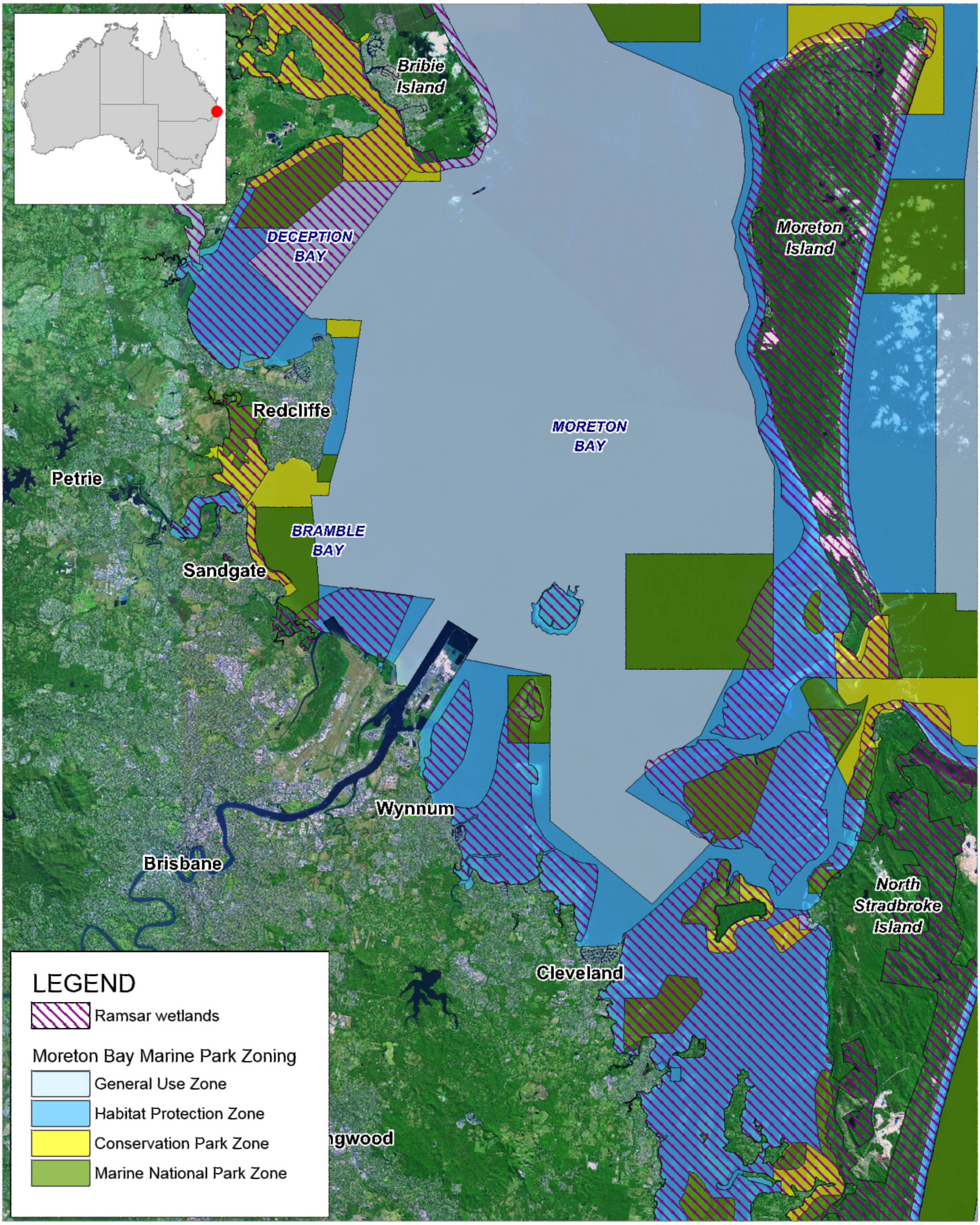
1.4 Study Area Context

The Port of Brisbane is located at Fisherman Islands (the study area), which is situated at the mouth of the Brisbane River on the western foreshore of Moreton Bay, Queensland.

Port facilities located at the Brisbane River mouth have been established on land reclaimed over a shallow sub-tidal river delta containing a series of low lying mangrove islands, collectively called the Fisherman Islands. The area was reserved for harbour purposes in the 1940’s. Reclamation commenced in the late 1960’s and the decision was made to re-locate port facilities from the city reaches in 1974. The Port of Brisbane is now Queensland’s largest container port facility and continues to expand by progressive filling within the existing perimeter bund.

Construction of the present day port facilities over intertidal and subtidal areas has resulted in extensive changes to the environmental attributes of the Fisherman Islands area. However, significant areas of mangrove, saltmarsh and seagrass have also been retained, and form part of the Fisherman Islands wetland complex on the south eastern side of the Port of Brisbane. Moreton Bay Marine Park is situated to the south and east of the FPE seawall, this area is thought to contain one of the largest semi-contiguous seagrass meadows in western Moreton Bay. A Ramsar listed wetland is situated only kilometres to the south of the Port facilities, comprising intertidal portions of the Fisherman Islands wetland complex (Figure 1-1). The seagrass and mudflats of this Ramsar area are recognised for their importance to dugong, marine turtles and migratory and resident shorebirds (BMT WBM 2008).

On the northern side of the Port of Brisbane, dredging occurs within the shipping channel through the Bar Cutting, the Swing Basin and berth areas, which are presently maintained to a declared depth of 14m (relative to Port Datum – Lowest Astronomical Tide, hereafter referred to as LAT). The Port facilities are situated at the mouth of the Brisbane River, which comprises the largest river catchment in Moreton Bay, and experiences freshwater flows and ongoing inputs of sediments and contaminants derived from human activities in its catchment. Two major sewage treatment plants also have their sewage discharges within kilometres of the Port facilities (Luggage Point and Wynnum North wastewater treatment plant). Control sites for the study are located adjacent to Manly and Cleveland on the western foreshore of Moreton Bay and to the south of the Fisherman Islands monitoring location (see Figure 2-2). At Manly, seagrass meadows extend from the intertidal areas adjacent to the Manly Boat Harbour and Fig Tree Point to the subtidal area close to Green Island. At Cleveland the seagrass habitat extends throughout the bay which is formed between Toondah Harbour and Coochiemudlo Island. Growing conditions at Manly and Cleveland are similar to those experienced at the Fisherman Islands site and in western Moreton Bay more generally.



Title:
Moreton Bay Ramsar Wetlands and Marine Park Zoning

Figure: 1-1

Rev: A

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0 5 10km
Approx. Scale

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2 Previous Dredge Plume Studies

2.1 Overview

Monitoring of dredge and disposal plumes has been carried out at the Port of Brisbane since the 1990s. As shown in Table 2-1, a wide variety of sampling techniques were used in the different studies, reflecting advancements in sampling technologies over time. The locations monitored are representative of the key dredge areas targeted in contemporary maintenance dredging campaigns. Monitoring of dredge plumes in the Brisbane River typically have targeted the ebbing tide, noting that plumes travelling into Moreton Bay are of most concern from an ecological perspective. Monitoring at the Mud Island DMPA has been carried out on an ebbing tide in 2014, whereas plume behaviour during a flooding tide remain unresolved.

2.2 Key Findings

2.2.1 Outer Bar Cutting

WBM Oceanics completed turbidity measurements within sediment plumes generated by the *Sir Thomas Hiley* in 2002 (WBM Oceanics Australia 2002a), and the *Brisbane* in 2004 (WBM Oceanics Australia 2004) and in 2014 (BMT WBM 2014) whilst dredging the Outer Bar Cutting of the Brisbane River.

Two dredge plumes were generated from each pass of the *Sir Thomas Hiley* dredger in 2002, and persisted for approximately one hour before becoming indistinguishable. The plumes moved northward in the direction of the ebb tide current and out of the navigation channel to the west into the shallow waters (6 m). Turbidity levels in surface waters ranged between 50 and 110 NTU compared to background levels of 5 to 7 NTU.

In 2004, the plumes generated by the Brisbane moved east to south-easterly, beyond the east margins of the channel in the first hour following operations, which may have been influenced by the prevailing northerly winds. The plume then returned to the channel and moved in a seaward (north-easterly) direction along the channel alignment. Background turbidity showed little variation between the water surface (2 NTU, 0 – 4 m), 2 – 3 NTU at mid-depth (4 – 9 m) and 3 – 4 NTU at the seabed (10 – 14 m). Following the hopper overflow, turbidity increased in surface and mid-depth turbidity (32 – 46 NTU, 8 – 32 NTU, respectively). Near-bed turbidity remained close to background levels (5.2 – 6.8 NTU). The plume dropped back close to background levels after 1 – 1.5 hours. These measurements were considerably lower than turbidity levels from the *Sir Thomas Hiley* in 2002. This could be due to vessel design changes to improve turbidity management between the *Sir Thomas Hiley* and the *Brisbane* (WBM Oceanics Australia 2002a).

In 2014, two plumes were generated by the *Brisbane*, one near the surface and one near the seabed. The plumes travelled south east, along and across the channel lasting more than 60 minutes and measured 350 m transverse the channel. TSS background concentrations were generally below 8 mg/L, and increased to approximately 40 mg/L at the surface, 60 mg/L at mid-depth, and 80 mg/L near the seabed. Again, these results showed that plumes were short term localised features.

Table 2-1 Previous dredging studies

Location	Survey Period	Tidal Stage	Sampling Methodology	Source
Swing Basin, Outer Bar Cutting, Mud Island DMPA (*Brisbane*) Manly Harbour (*Ken Harvey*) Swing Basin (*Alan M / Seahorse*)	10-12/04/2014 (*Brisbane* and *Ken Harvey*) 01/05/2014 (*Alan M / Seahorse*)	Ebb tide Flood tide (*Brisbane* operating in Outer Bar)	Campbell Scientific OBS-3A turbidity probe, Acoustic Doppler Current Profiler (ADCP), downward facing 1200kHz Teledyne RDI ADCP, drogue	BMT WBM (2014)
Fisherman Islands Berth 10 (*Amity*) Fisherman Islands foreshore (*Ken Harvey*) Maritime wharf, Hamilton Reach of Brisbane River (*Alan M*)	05/06/2007 (*Amity*) 31/08/2007 (*Ken Harvey* and *Alan M*)	Flood tide (1.0 m tidal range, *Amity* and *Ken Harvey*) Ebb tide (*Alan M*)	Oblique aerial photography (*Amity* only), drogues, turbidity profiles using YSI 6600, water samples collected using 2.2L Van Dorn water sampler	BMT WBM (2008)
Outer Bar Cutting near Coffee Pots	19/02/2004	Ebb tide (2.1 m tidal range)	Tow aerial photography flights, drogues, turbidity profiles using YSI 6600, Secchi disc, in-situ water samples for TSS	WBM Oceanics Australia (2004)
Outer Bar Cutting	11/01/2002	Ebb tide (1.8 m tidal range)	Turbidity profiler using Yeokal 611 water quality instrument, Secchi disc, drogue, aerial photography, in-situ water sample collection	WBM Oceanics Australia (2002a)
Incitec North Berth at Pinkenba	17/07/2002	Flood tide	Aerial photography (at 300 m), real-time measurements using towfish (three turbidity sensors at 1, 5 and 9 m, towed at 1-2 knots, recording at 10-second intervals), drogue, Van Veen grab for PSD, water samples for TSS	WBM Oceanics Australia (2002b)
Incitec North Berth (8 km upstream of Brisbane River mouth)	21/05/1997	Ebb tide	Drogue, turbidity profiler using Hydrolab H20 multiprobe water quality meter at 10, 50, 100 and 200 m downstream, sediment samples for PSD	WBM Oceanics Australia (1997)
Main Channel in Moreton Bay	28/02/1995	Ebb tide (1.9 m tidal range)	Turbidity profiler using Hydrolab H20 water quality instrument, drogues, in-situ water sample collection	WBM Oceanics Australia (1995)

2.2.2 Main Channel in Moreton Bay

WBM also surveyed the dredge plumes associated with the operation of vessel *Sir Thomas Hiley* in the Main Channel in Moreton Bay on 28 February 1995 (WBM Oceanics Australia 1995). The plume travelled approximately 3.5 km to the north-east for 1.25 hours before dropping back to background levels. The plume followed the same northly direction and appeared as turbid as the plumes observed in the Outer Bar Cutting in 2002. In-situ turbidity profiling showed peak levels behind the dredge of 20 (surface water) to 45 NTU (near the seabed) compared to background concentrations of 9 to 10 NTU. Suspended sediment concentrations peaked at 14 mg/L on background concentrations of 2 mg/L.

2.2.3 Swing Basin

Immediately following the 2014 operations by the dredger *Brisbane* at the Swing Basin (BMT WBM 2014), a single plume was observed travelling north-east down the channel, 50 – 100 m wide, extended 300 m transverse the channel and lasted more than 45 minutes. TSS concentrations were approximately 40 mg/L at the surface, 80 mg/L at mid-depth with increasing concentrations of 200 mg/L near the seabed. Background TSS concentrations was <10 mg/L above mid depth and <30 mg/L towards the bed. The turbid plumes generated by the bed levelling barge *Alan M* and its small complementing tug boat the *Seahorse*, was a single plume that extended over 100 m from the wharf face towards the centre of the Swing Basin. The TSS concentrations were approximately 30 mg/L and were distributed evenly throughout the water column.

2.2.4 Manly Harbour and Mud Island DMPA

In 2014, BMT WBM surveyed the turbid plumes generated by the Clam Shell Grab Dredger *Ken Harvey* while it performed maintenance dredging works at the entrance to Manly Harbour, and by the *Brisbane* at Mud Island DMPA (BMT WBM 2014). The single plume observed at Manly Harbour was within the channel and measured approximately 50 – 100 m in length (from the dredger). The duration of this plume was not measured. The plume has TSS concentrations up to 12 mg/L compared to background levels that were generally less than 3 mg/L.

A single turbid plume was created by the *Brisbane* dredger while disposing its dredged sediments at the Mud Island DMPA. The plume moved in a north-west direction, extended out to 2000 m and lasted 120 minutes following the disposal event. Background TSS concentrations were below 4 mg/L while concentrations within the plume at the seabed reached approximately 80 mg/L.

2.2.5 Fisherman Islands

In 2007, BMT WBM measured the distribution and extent of turbid plumes generated by the dredgers *Amity* and *Ken Harvey* and bed leveller *Alan M* (BMT WBM 2008). The plume that arose from *Amity* dredging operations was 80 – 100 m wide and moved 500 m – 1 km down current of the dredger, and dissipated after 2.5 hours. The turbid plume from *Ken Harvey* was visible 150 – 200 m downstream with a width of 12 – 15 m and turbidity measured between 10 to 120 NTU at the surface. The plume produced by *Alan M* formed narrow linear patches approximately 10 – 15 m wide and extended out 80 – 100 m towards the centreline of the Brisbane River that dissipated several hundred meters downstream.

2.2.6 Incitec North Berth

WBM Oceanics surveyed the Incitec North Berth in the Brisbane River in 1997 (WBM Oceanics Australia 1997) and 2002 (WBM Oceanics Australia 2002b). The turbid plume created by PBC dredger *Ken Harvey* in 1997 was relatively small, covering an area of ~100 m^2 and was confined to the surface layers (<1 m). The hopper discharge produced turbid water ~2 m wide and 100 m astern the dredge, and was confined to the top 1 m surface layers. Similar maximum turbidity levels were recorded for surface water and seabed (55.8 and 52 NTU, respectively). Background turbidity levels were also similar in concentrations between the surface and bed (23.8 and 31 NTU).

The turbid plume generated by bed levelling operations in 2002 was larger than the plume observed in 1997, having a maximum visible length of 120 – 150 m and an approximate width of 30 m. The plume extended downstream and dissipated after 25 minutes. Turbidity levels were five times lower near the surface water than 1997, peaking at 10 NTU and 70 NTU adjacent the seabed compared to background levels (5 and 10 NTU, respectively). The extent of the plume was influenced by nearby shop berthing operations, associated tug movements and drain discharges downstream of the Pinkenba Bulk Wharf.

3 Dredge Plume Monitoring

3.1 Methodology

3.1.1 Dredge Plume Measurements

All field measurements were conducted from BMT WBM's six metre research vessel *Resolution II* operating in the vicinity of the dredge operations. During the dredge plume monitoring, BMT WBM communicated and co-ordinated measurement and sampling activities with the dredging plant *via* mobile telephone or VHF marine radio.

The following field measuring instrumentation and techniques were employed during the course of the dredge plume monitoring:

- Water sampling for laboratory analysis of Total Suspended Solids (TSS) concentrations to be used in the calibration of the turbidity probe and in assessments of the dredge plumes. Selected samples were also analysed for Particle Size Distribution (PSD) and nutrient concentrations;
- Turbidity profiling, using a Campbell Scientific OBS-3A turbidity probe, within and beyond the extents of the dredge plumes for use in the calibration of the Acoustic Doppler Current Profiler (ADCP) and in assessments of the dredge plumes;
- Conducting transects of the dredge plumes with a vessel mounted downward facing 1200kHz Teledyne RDI ADCP to record the acoustic backscatter, providing an insight into the otherwise hidden plume characteristics across the various transects; and
- Deployment of a drogue into the plume to assist with the ADCP transects and turbidity profiling, thus ensuring that measurements were collected from where the concentrations of suspended sediments were highest.

3.1.2 Data Processing

Processed ADCP measurements were used to remotely measure the suspended sediment in the water column with a sufficient resolution to provide pictorial views of the suspended sediment associated with dredging.

ADCP measurements can be used to estimate suspended sediment concentrations throughout the water column, however an ADCP instrument does not directly measure TSS. The principle of ADCP operation is that a pulse of sound is propagated through the water column and is reflected / backscattered off suspended particles – such as suspended sediments. The Doppler shift of the backscattered acoustic signal is used to directly determine the water currents throughout the water column. The intensity of the backscattered echo can be translated into TSS values through a series of steps as detailed below.

Laboratory analysis of the TSS in water samples spanning a wide range of sediment concentrations provides the means to calibrate the handheld OBS turbidity profiling instrument. By pairing the TSS values with the Nephelometric Turbidity Units (NTU), recorded in the field by the OBS, the site and date specific NTU-TSS relationship can be determined.

The turbidity profiles measured with the OBS, once converted to TSS, are then used to derive a relationship between the ADCP acoustic signal backscatter intensity and TSS. The software package VISEA includes a built-in calibration module for this purpose which is based on acoustic theory. The calibration process requires information on water temperature and salinity at the site and various scaling factors and offsets for each of the four transducers.

Water samples were sent to the laboratories of Advanced Analytical Australia for analysis of the TSS and PSD.

3.1.3 Calibration

A relationship between turbidity and TSS was empirically derived using linear regression in Microsoft Excel. The calibration of backscatter to TSS was performed using the VISEA calibration module. Sufficient data were available to perform both site and day specific calibrations. The calibration parameters were consistent between the various monitoring efforts with no prevalent time, depth or concentration biases. The calibrations are deemed sufficient for the purposes of this study and observations made using the ADCP are consistent with those made using the OBS, the analysis of collected water samples and what was observed visually on each measurement day.

3.1.4 Presentation of Results

3.1.4.1 ADCP Data

Figure 3-1 is an example plot demonstrating how the sediment plume measurement results have been presented in this report. The plots are comprised of two components, an upper and a lower component. The upper component is a profile-view of the ADCP transect which depicts the TSS concentrations along the transect and through the water column. The lower component depicts the depth averaged plume concentrations in plan-view along the transect.

The coloured circles in the upper component of Figure 3-1 depict the OBS profile performed on the transect. The colour of the circles represents the TSS concentration returned by the OBS which align with those returned by the ADCP. The OBS profiles are plotted directly onto the elevation-chainage axes. As the OBS instrument is lowered down through the water column, a process which can take over a minute, the monitoring vessel often drifts with the wind/currents and hence the chainage along the transect increases with depth. Hence the OBS profiles do not appear vertical. Transects which were performed in an East to West direction have been reversed so the lower plan view plot links more intuitively with the upper profile view plot. In these transects the OBS profiles, plotted depth against chainage, will slope in the opposite direction to those conducted during transects extending from West to East. OBS profiles were not performed for every transect.

The red ‘x’ plotted in the lower component of Figure 3-1 identifies the start of the ADCP transect which extends from left to right in the upper profile-view component of the plot. All ADCP transects have been presented with the red ‘x’ on the most Westerly end point and have been reversed if necessary. The timing of the measurement within the tidal cycle is depicted in the upper right hand corner of the plot (date shown on x-axis).

The operations of the TSHD *Brisbane* are represented by small coloured squares in the lower component of Figure 3-1. They depict the *Brisbane’s* position at the time the transect was conducted and where and how the dredge had been operating for the past 60 minutes. In Figure 3-1, whilst the ADCP transect was conducted, the *Brisbane* was dredging (brown squares) the maintained channel before dredging with overflow (magenta squares). To see how the dredge was operating towards the beginning of the dredging cycle, refer to plots corresponding to transects conducted during this time. Since transects were often performed more than 60 minutes past the time at which the dredger created the plume, not all plots have the coloured squares.

TSS estimates are capped at a maximum value due to the uncertainty surrounding the backscatter–TSS relationship above that value. It should also be noted that due to its mounting and a measurement 'blanking-distance', the ADCP was only able to resolve TSS concentrations below a depth of approximately 1.5 m. The ADCP was also unable to estimate the TSS within approximately 1 m from the bed.

Background concentrations have not been removed from the data. Several of the data sets include a transect conducted before the dredge commenced operations and hence depict the background concentrations at that time. Where possible, the transects extend beyond the extents of the dredge plume and hence can be used to quantify the background concentrations at the time of the transect.

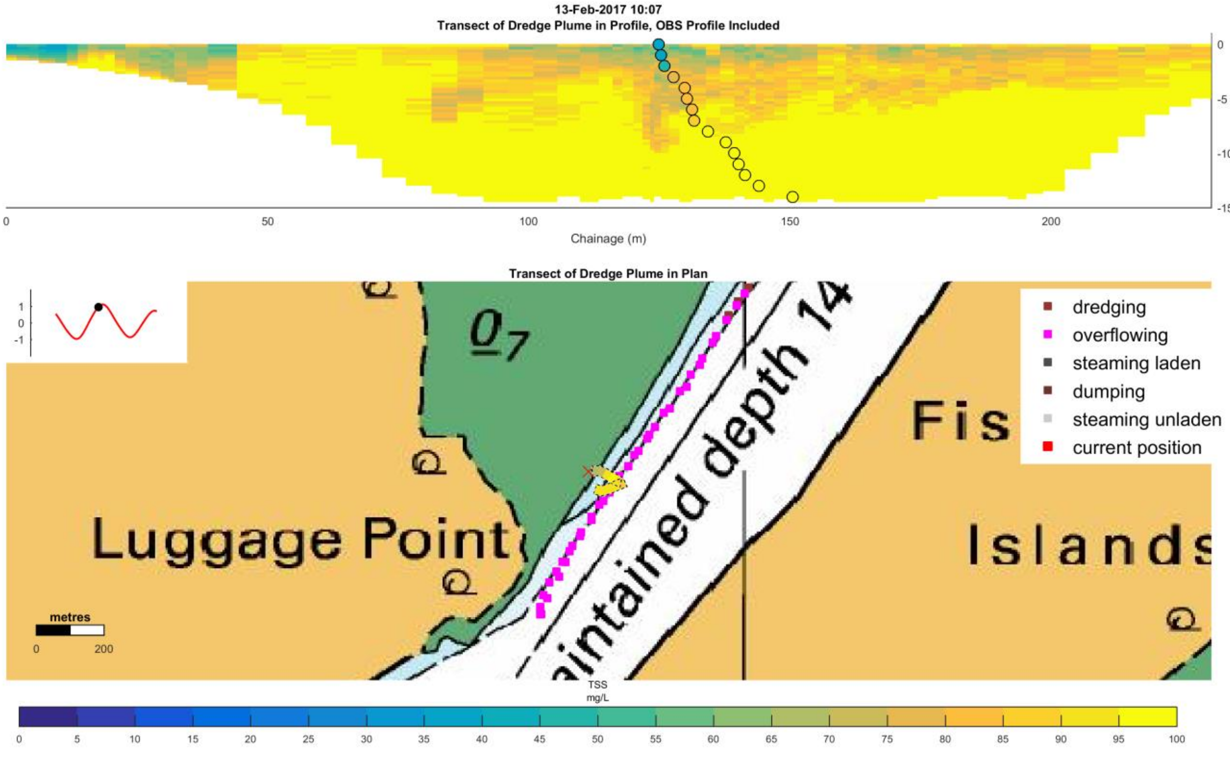

Figure 3-1 Example Figure 1

3.1.4.2 Potential Interferences

ADCP measurements of suspended sediment concentrations can occasionally be compromised by air bubbles generated by the dredger, other vessel traffic and waves. Fish and plankton will also interfere with the ADCP measurements. Air bubbles and fish reflect the acoustic signal emitted by the ADCP in the same manner as suspended sediments and hence can be erroneously interpreted as plumes of suspended sediments. To avoid any misinterpretation, plots depicting transects where air bubbles and/or fish have interfered with the acoustic signal have been stamped with a warning. The OBS instrument is far less susceptible to such interference.

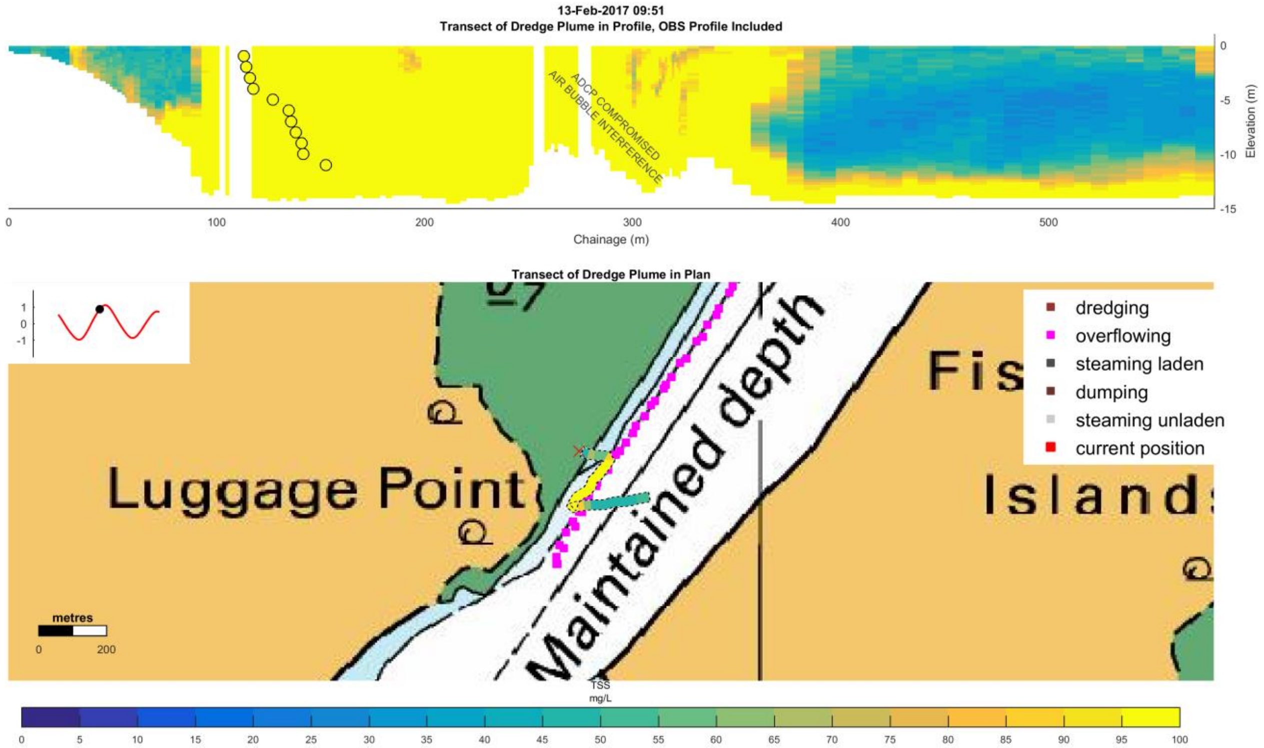

Figure 3-2 Example Figure 2

3.2 Results

3.2.1 TSS and Turbidity Relationship

Figure 3-3 shows the relationship between log turbidity and TSS from background and plume samples generated by TSHD *Brisbane*[2] collected at the loading site and Mud Island DMPA in 2014 and 2017. There was a significant ($p<0.05$) positive linear relationship between turbidity and TSS, with TSS explaining 71% and 98% of variation in 2014 and 2017, respectively. The conversion factor from turbidity to TSS differed between 2014 and 2017 studies as shown in Figure 3-3. The differences between years reflect both the broader range (i.e. higher concentrations) of TSS measured in 2017, and differences in dredged material properties between years (and related to this, different areas dredged).

[2] Note that samples collected for Alan M 2014 are not included here

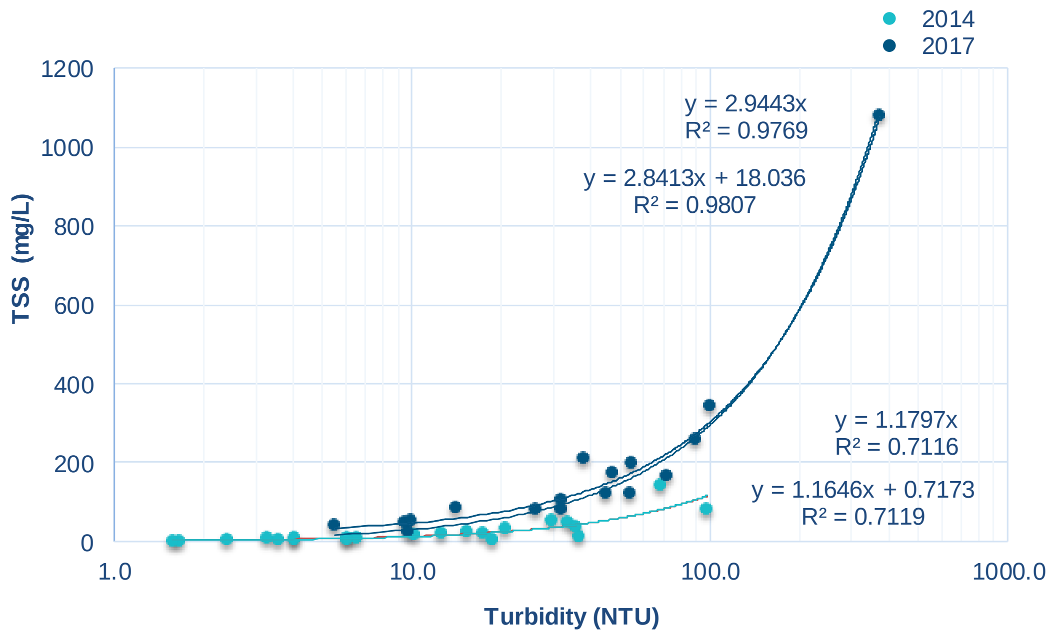

Figure 3-3 Relationship between log turbidity (NTU) and TSS (mg/L) from background and dredge plume samples (TSHD *Brisbane*) collected at the loading site and Mud Island DMPA – 2014 and 2017[3]

3.2.2 Spatial Patterns in Suspended Sediments in 2017

3.2.2.1 Channel Dredging 13/02/2017 09:30

A dredge plume was observed at a high intensity resulting from overflowing dredging of the north-western face of the dredged channel opposite to Fisherman Island. This plume was observed to quickly settle and move along the floor of the channel towards Luggage point. This path changed with the reversal of the tide and was then observed to be moving away from Luggage Point seawards towards the inner bar.

[3] Note that the maximum value recorded in2017 represents an outlier. The data follow the same linear relationship with or without this outlier

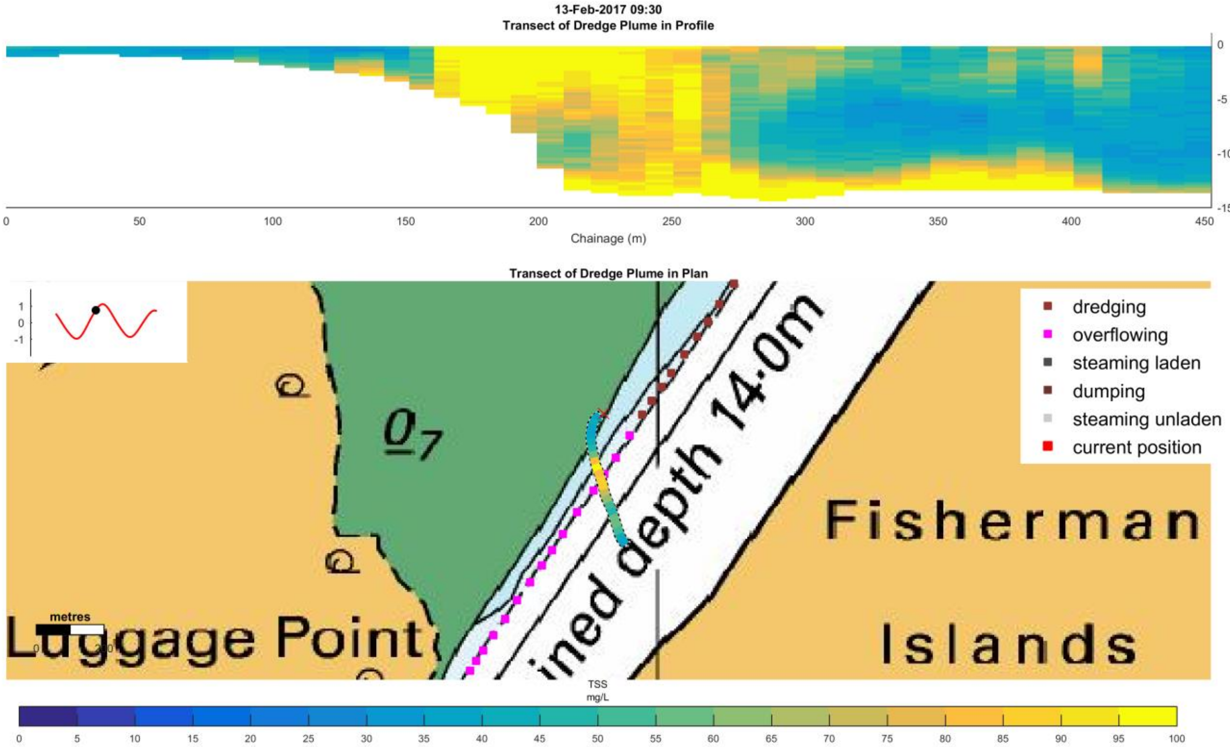

Figure 3-4 Channel Dredging Transect 1

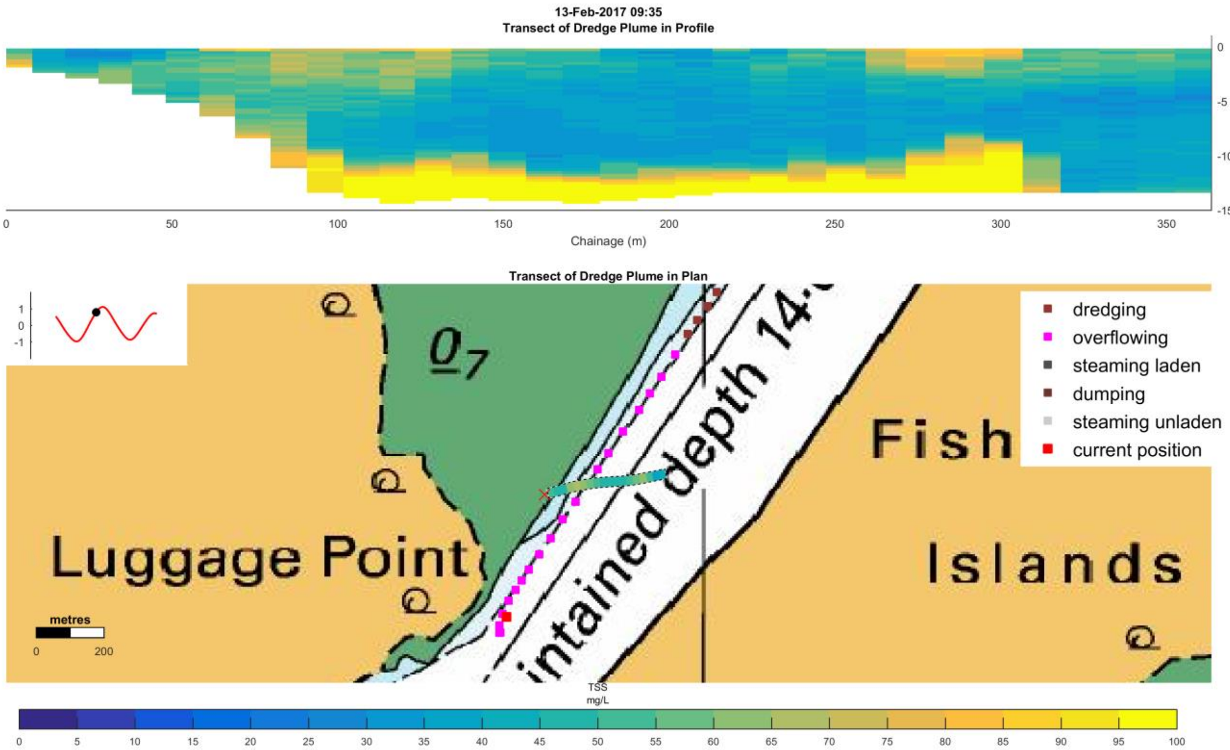

Figure 3-5 Channel Dredging Transect 2

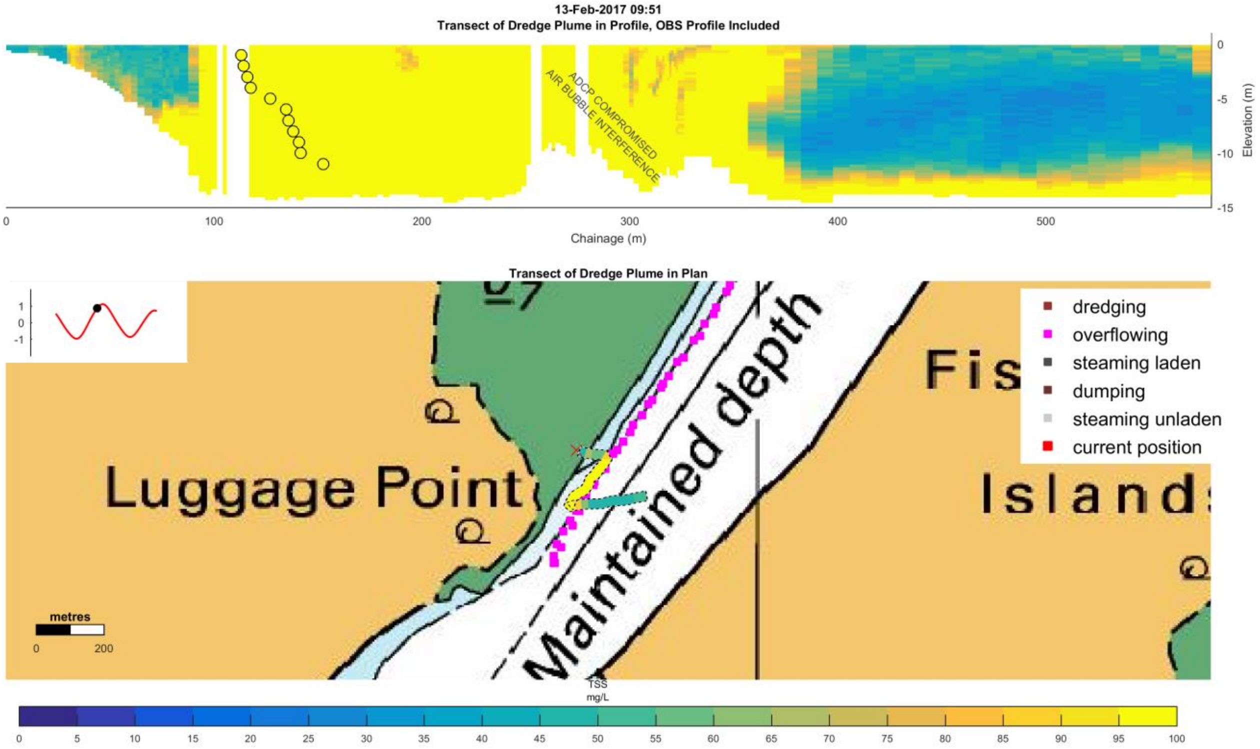

Figure 3-6 Channel Dredging Transect 3

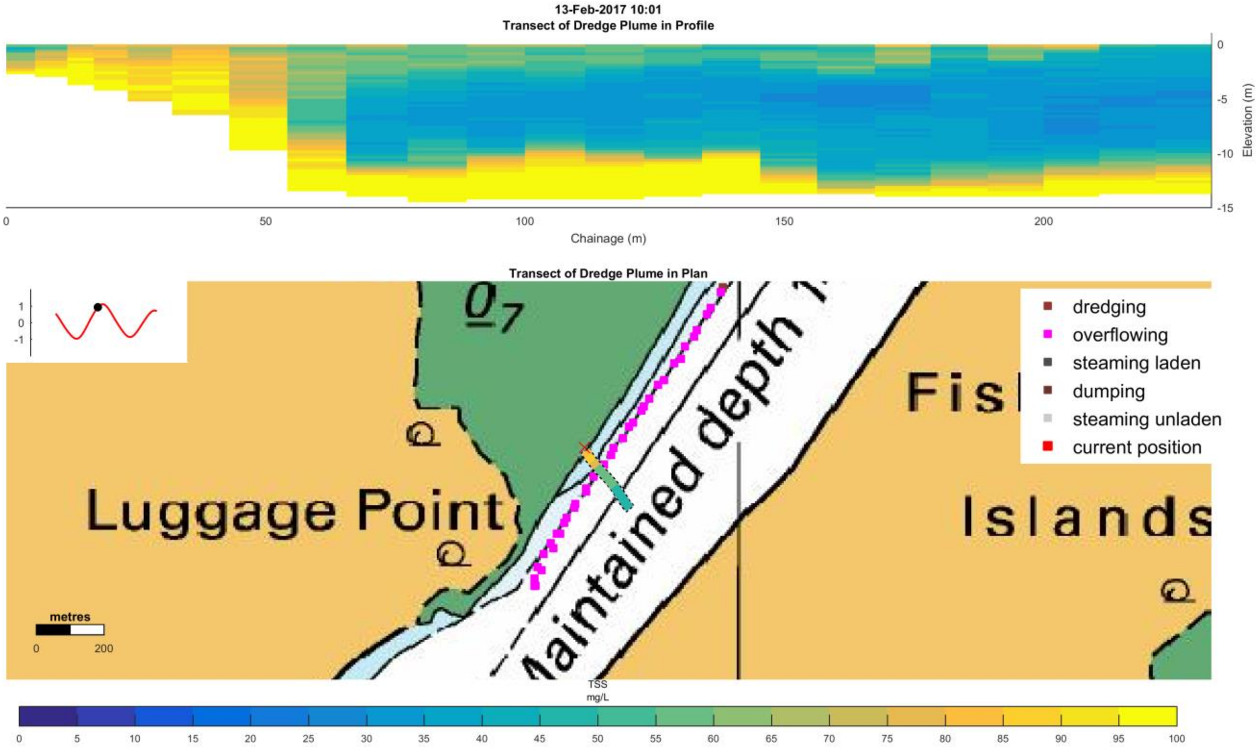

Figure 3-7 Channel Dredging Transect 4

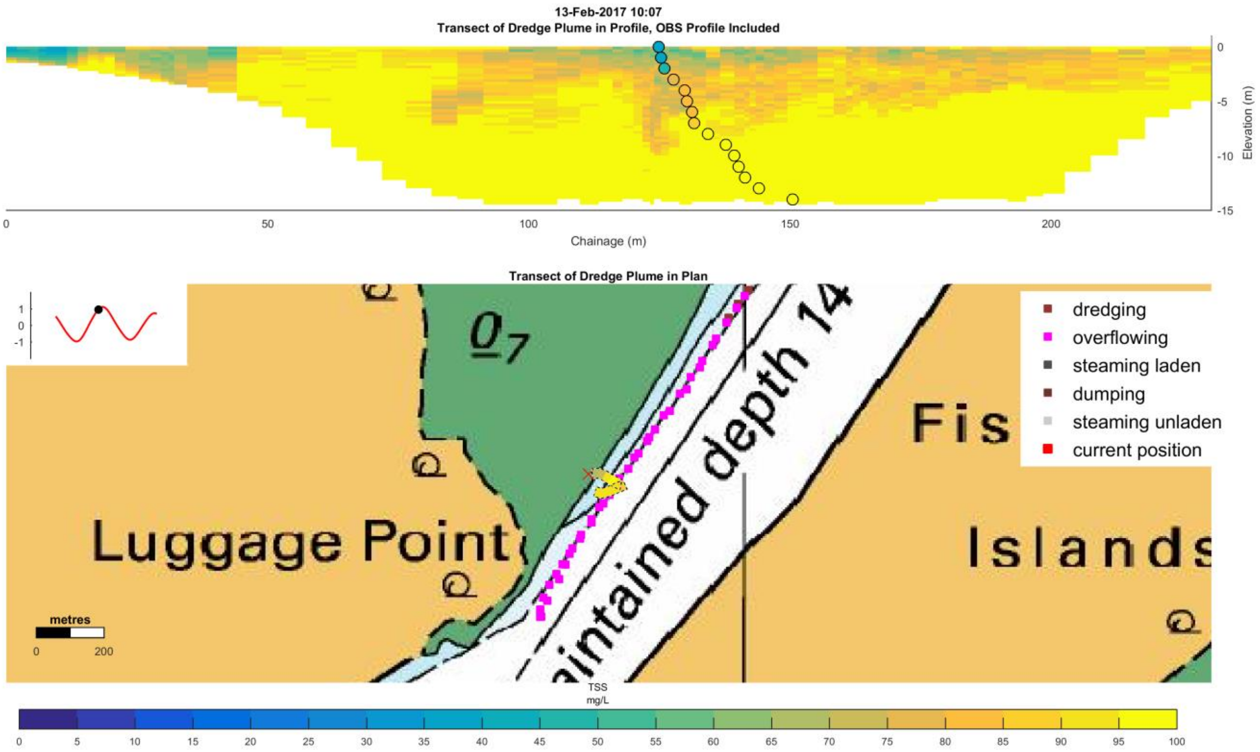

Figure 3-8 Channel Dredging Transect 5

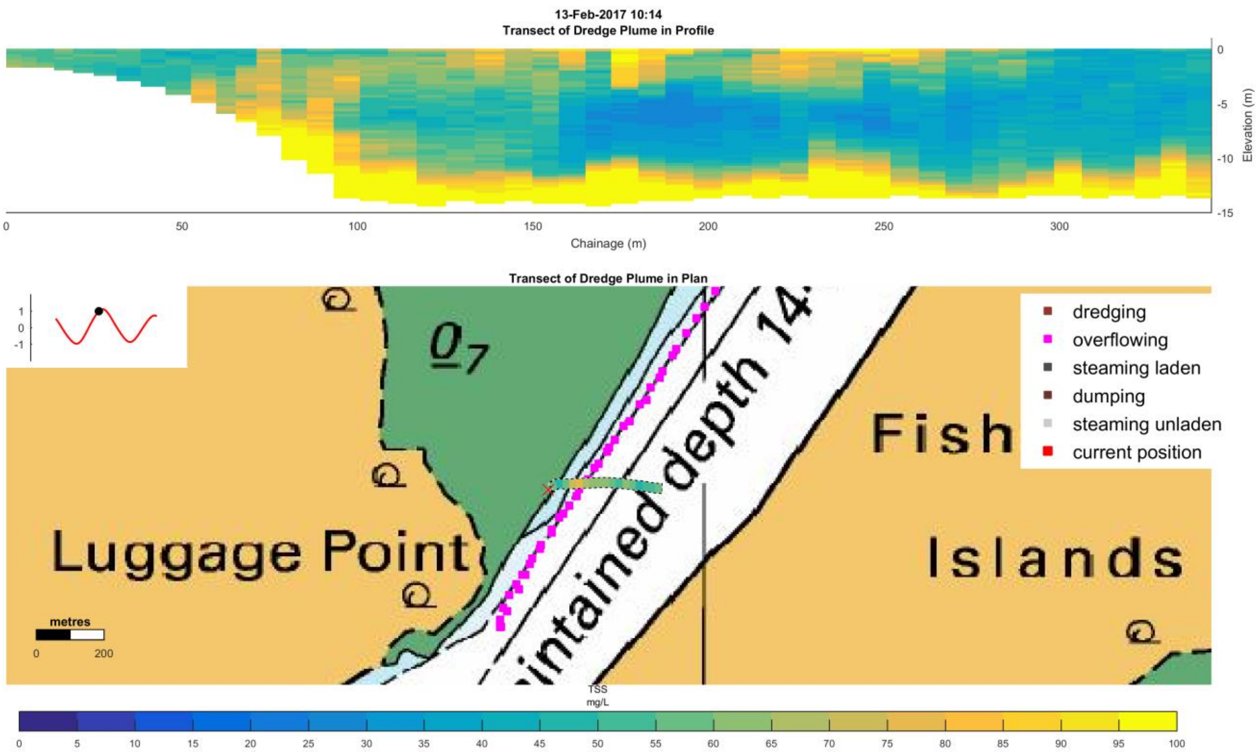

Figure 3-9 Channel Dredging Transect 6

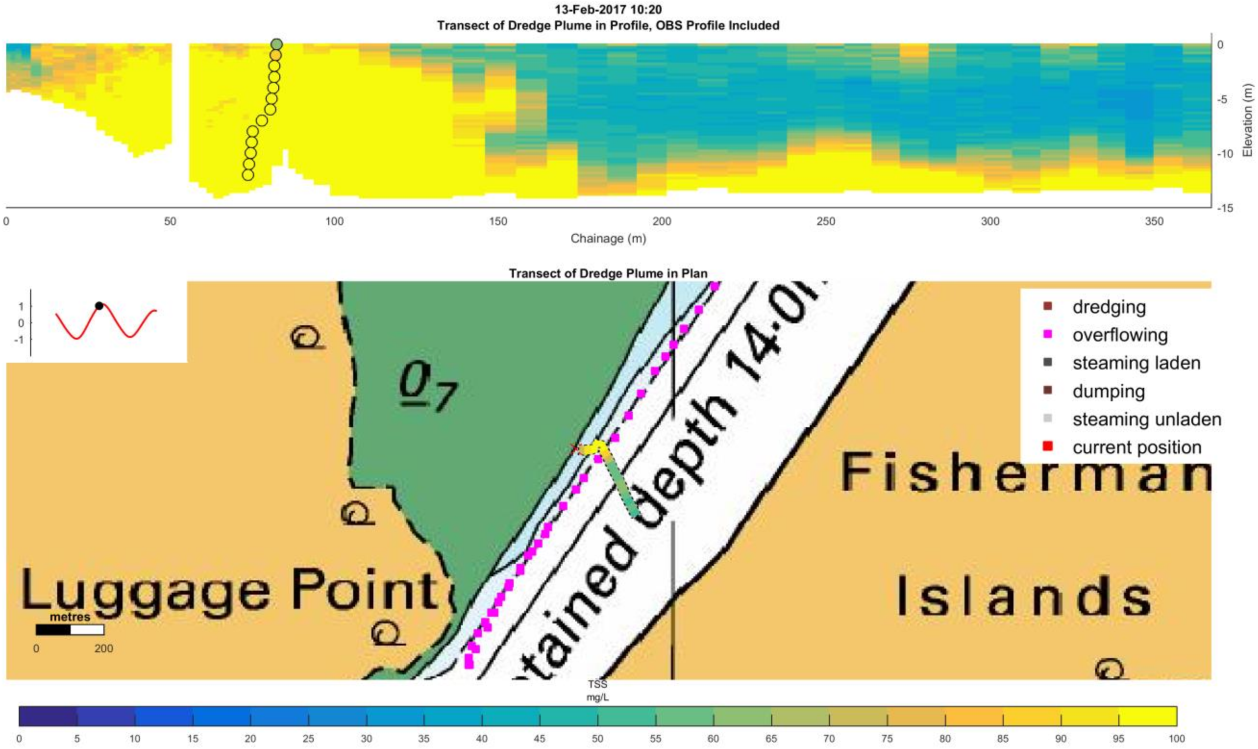

Figure 3-10 Channel Dredging Transect 7

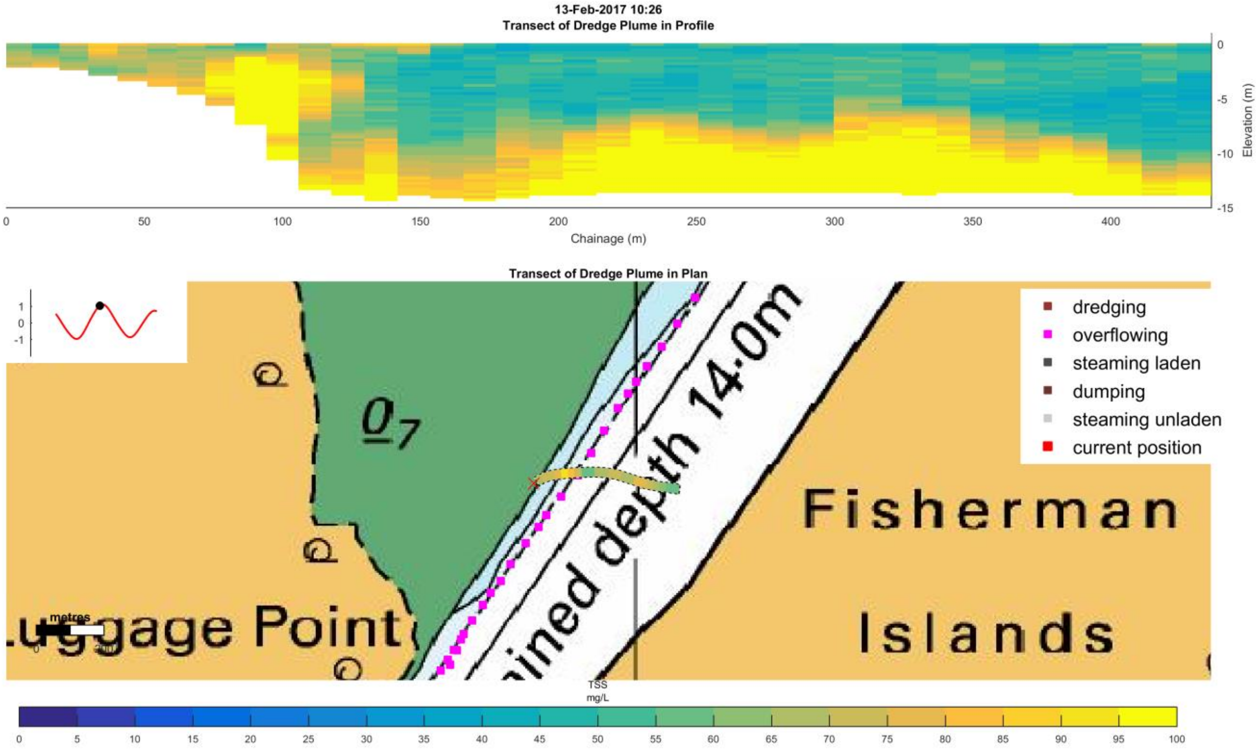

Figure 3-11 Channel Dredging Transect 8

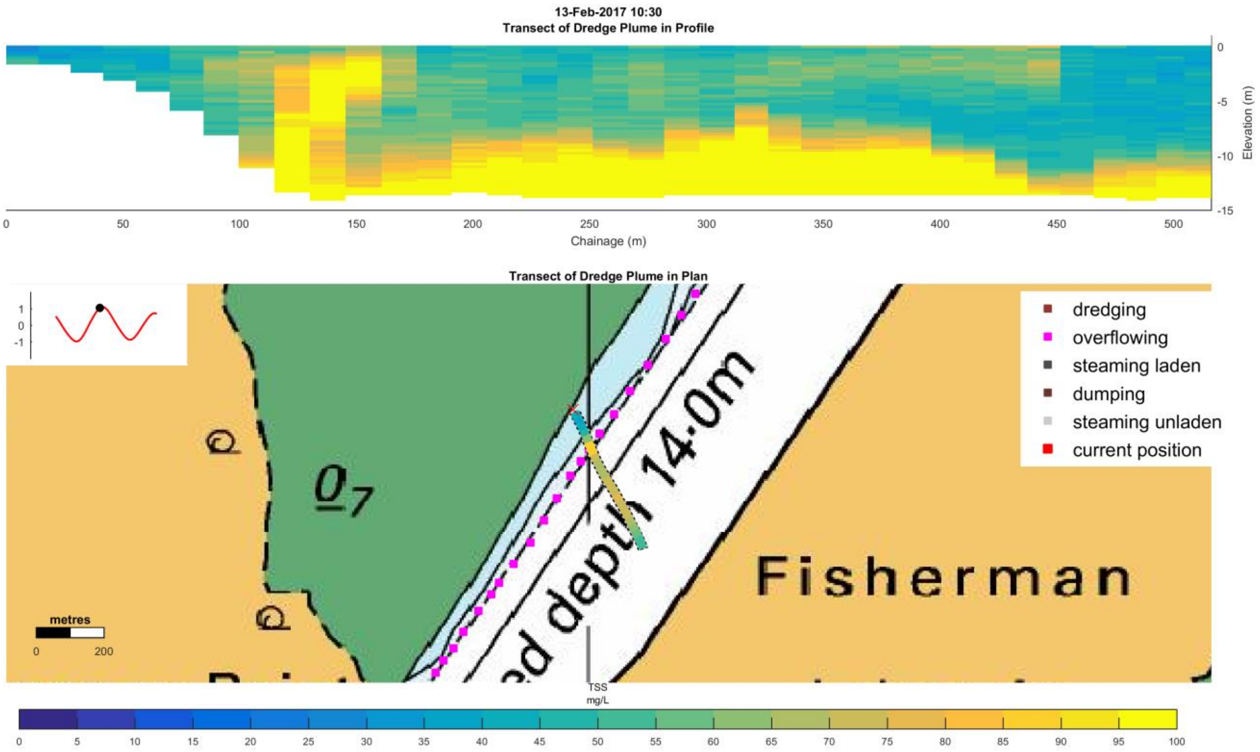

Figure 3-12 Channel Dredging Transect 9

3.2.2.2 DMPA Dumping 13/02/2017 11:00

Dredge discharge at DMPA, south of Mud Island, was monitored. The dredged sediment was observed to quickly settle to the bottom of the DMPA with a plume of lower intensity then inside the dredge channel being observed. This plume was monitored as it migrated south-east with the current. After ~1.5 hours the disposal plume had visually disappeared.

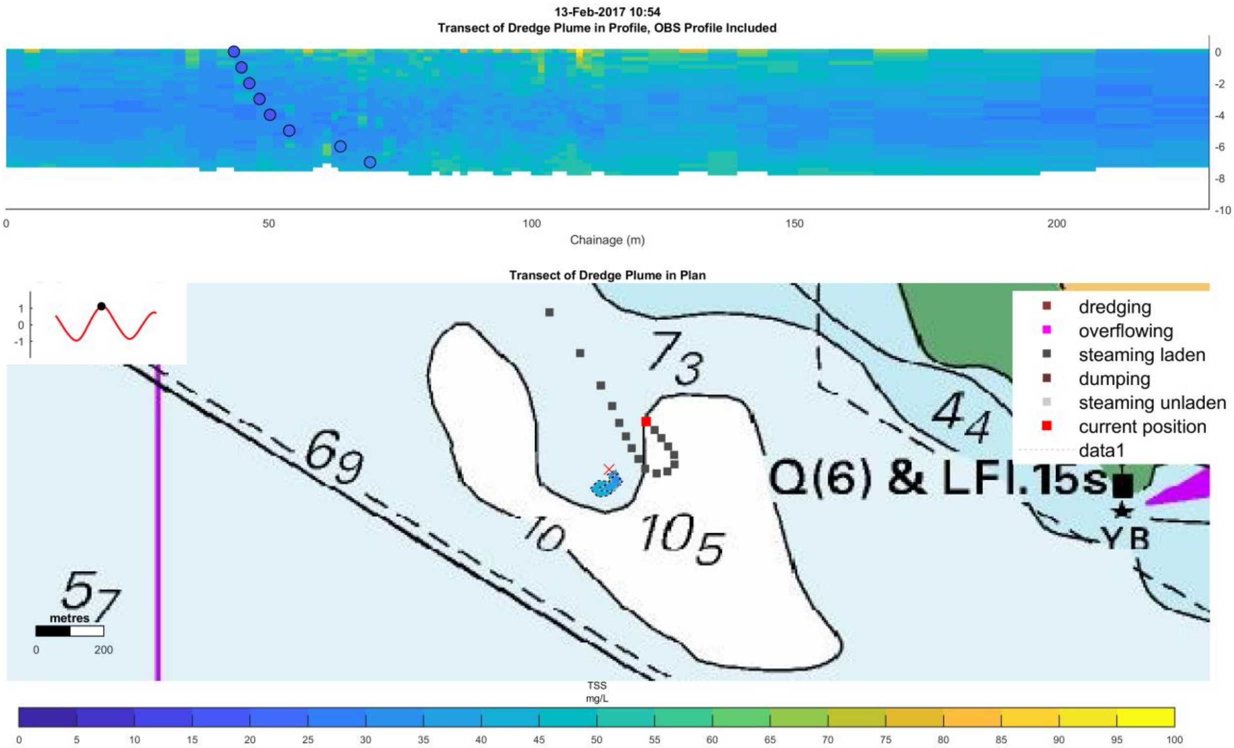

Figure 3-13 DMPA Disposal Transect 1

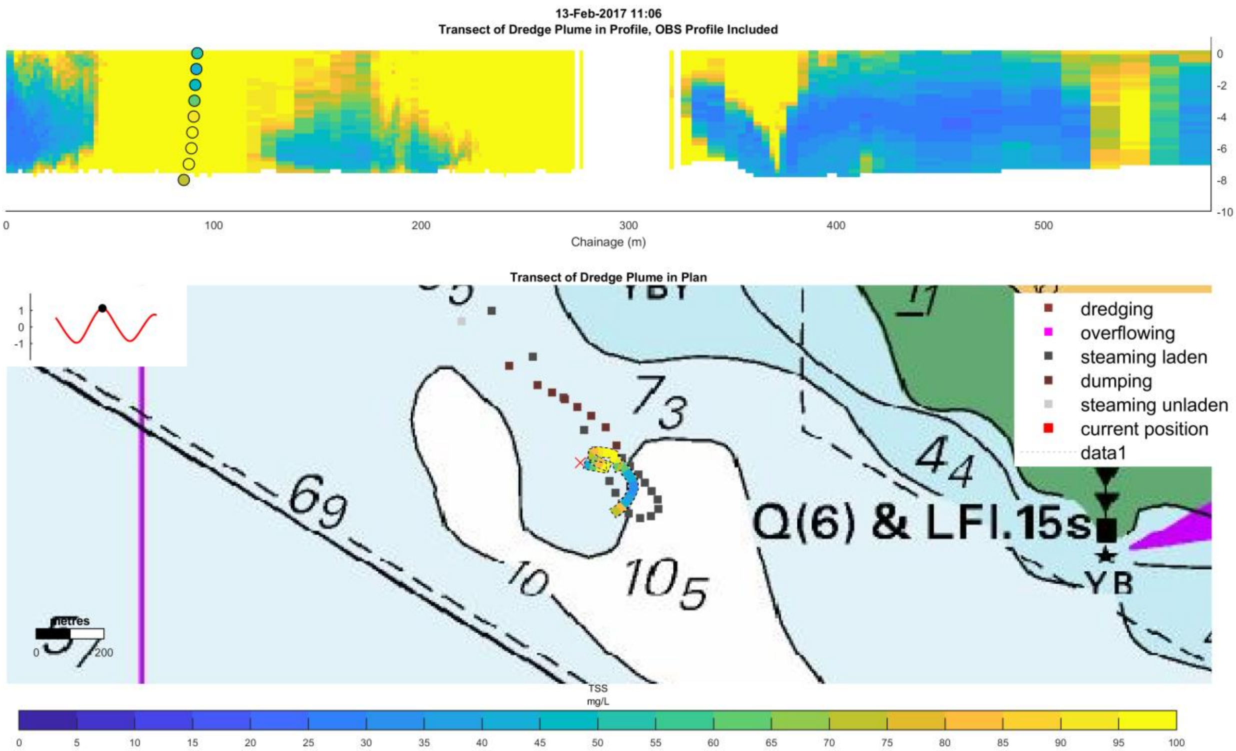

Figure 3-14 DMPA Disposal Transect 2

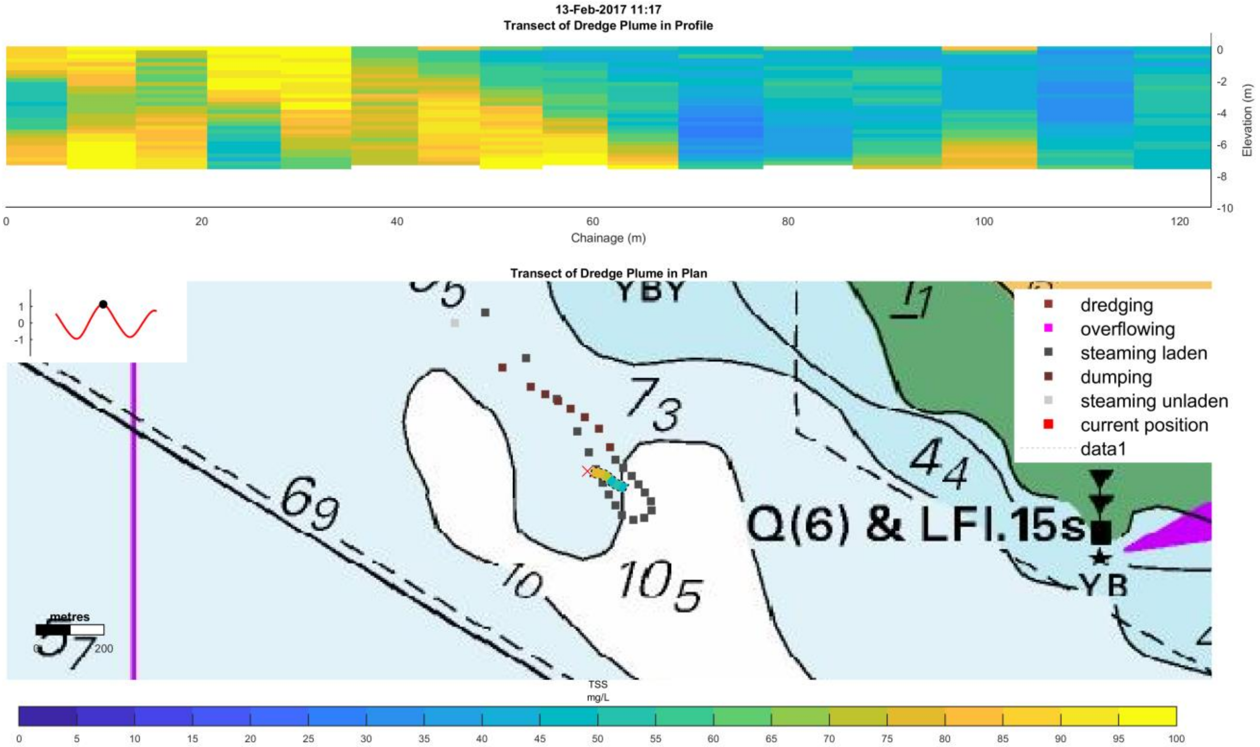

Figure 3-15 DMPA Disposal Transect 3

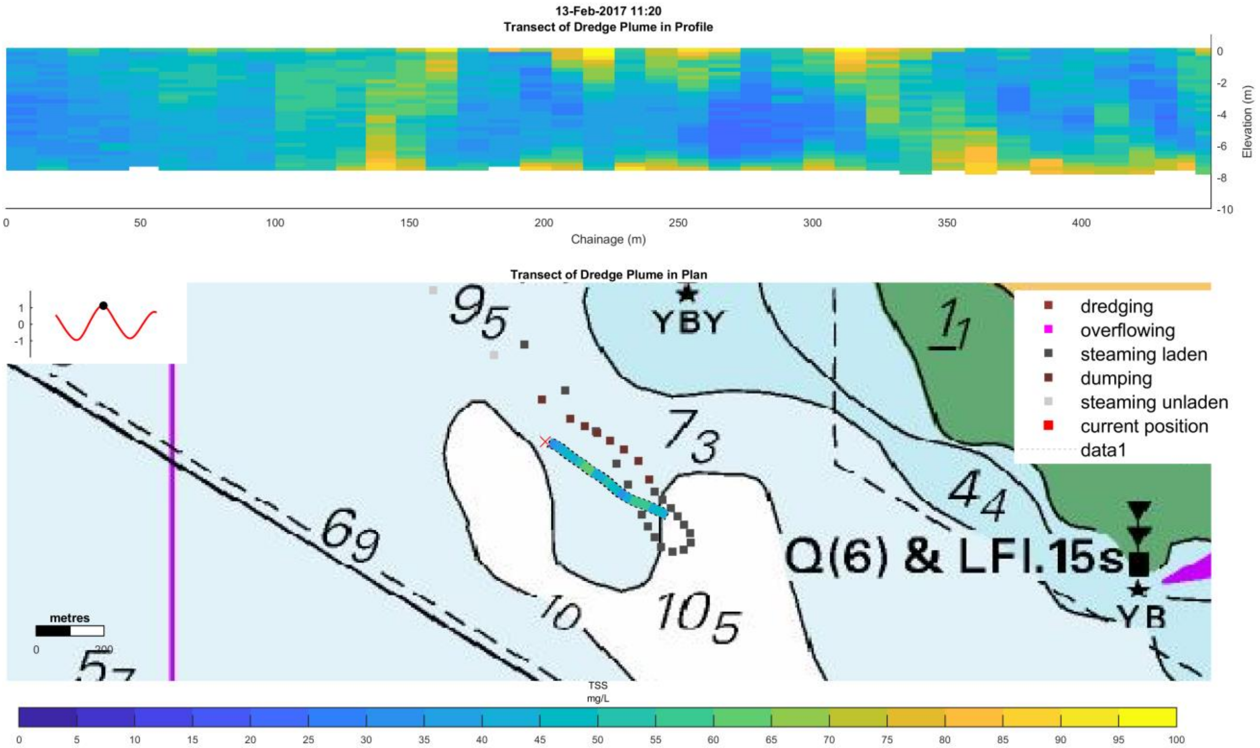

Figure 3-16 DMPA Disposal Transect 4

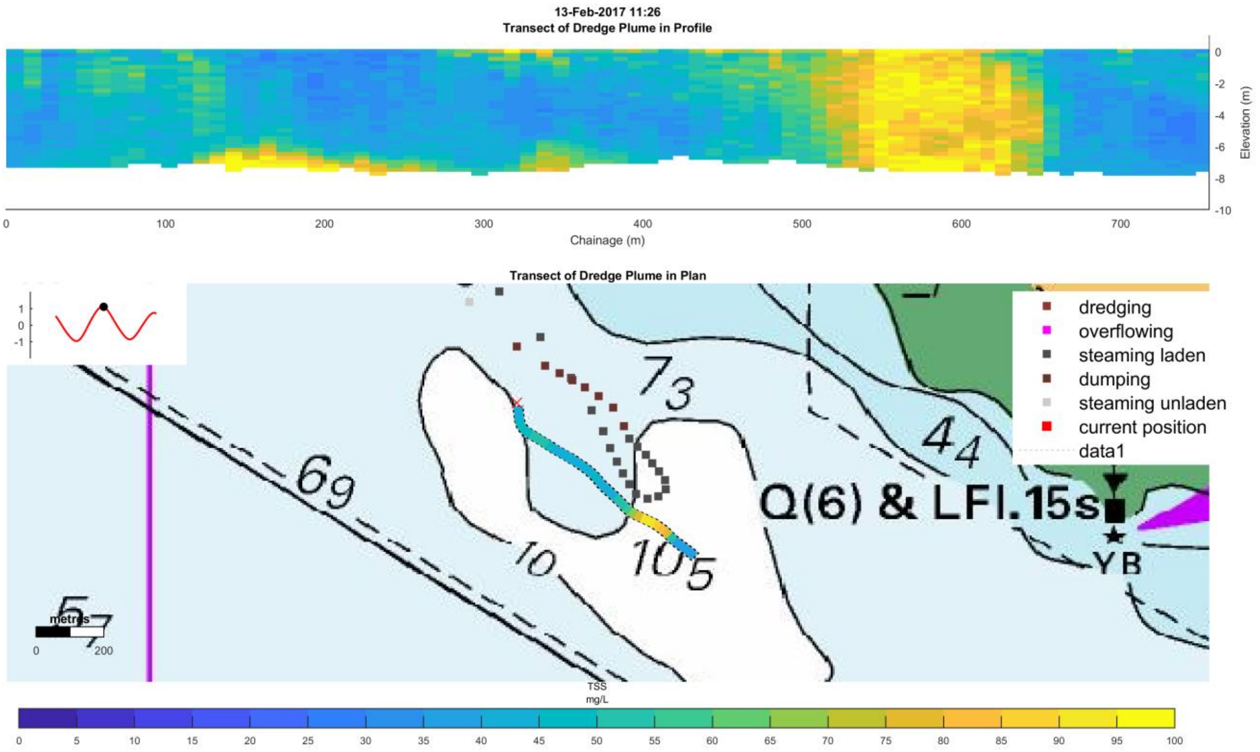

Figure 3-17 DMPA Disposal Transect 5

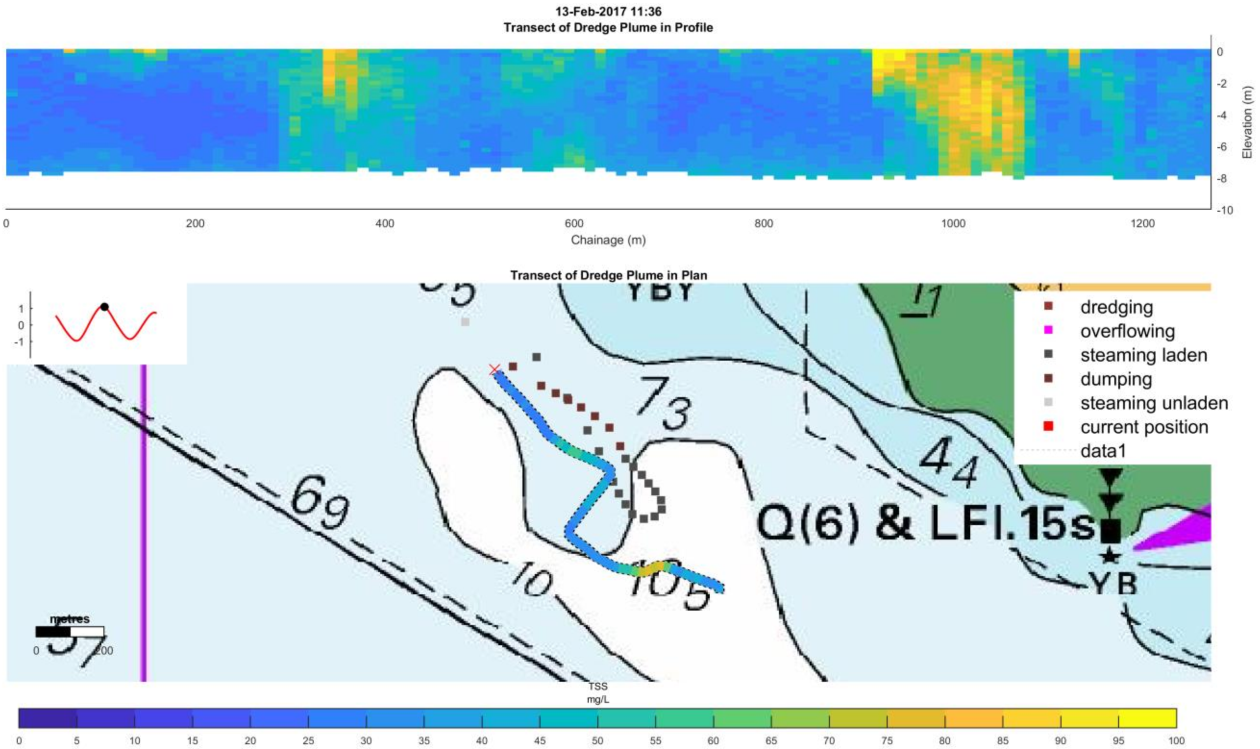

Figure 3-18 DMPA Disposal Transect 6

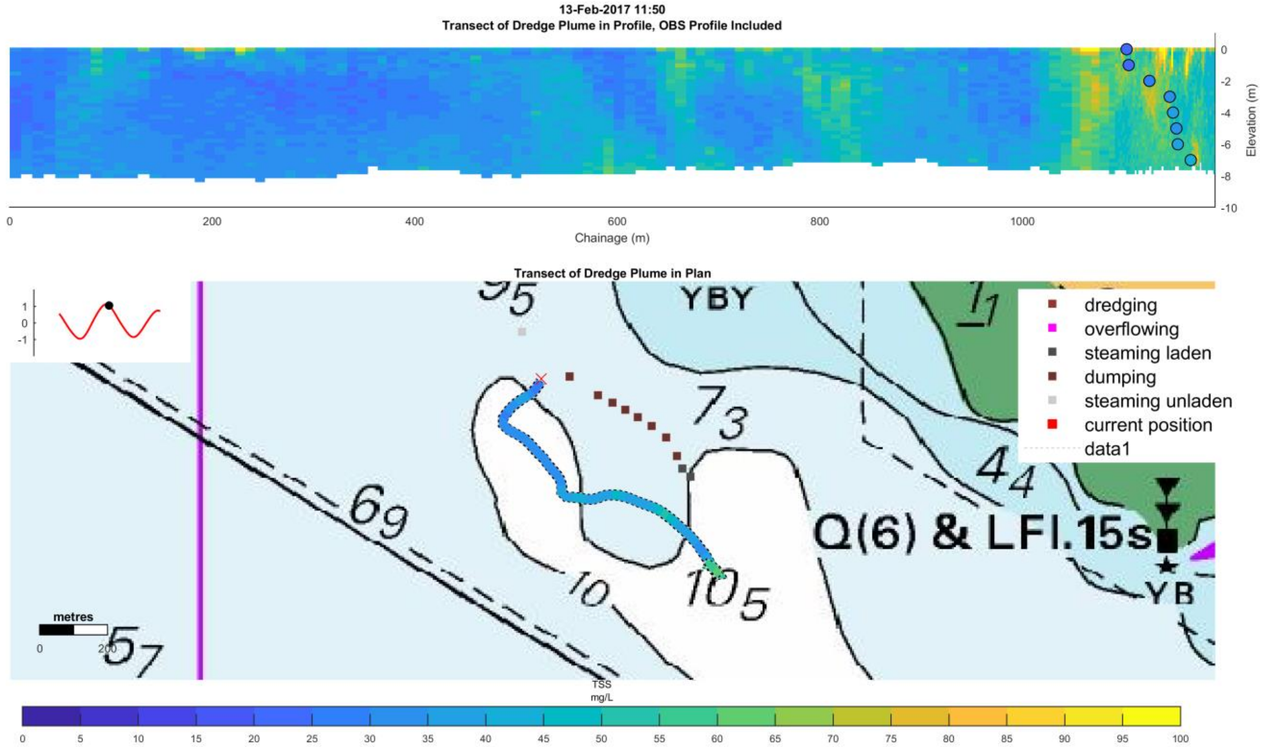

Figure 3-19 DMPA Disposal Transect 7

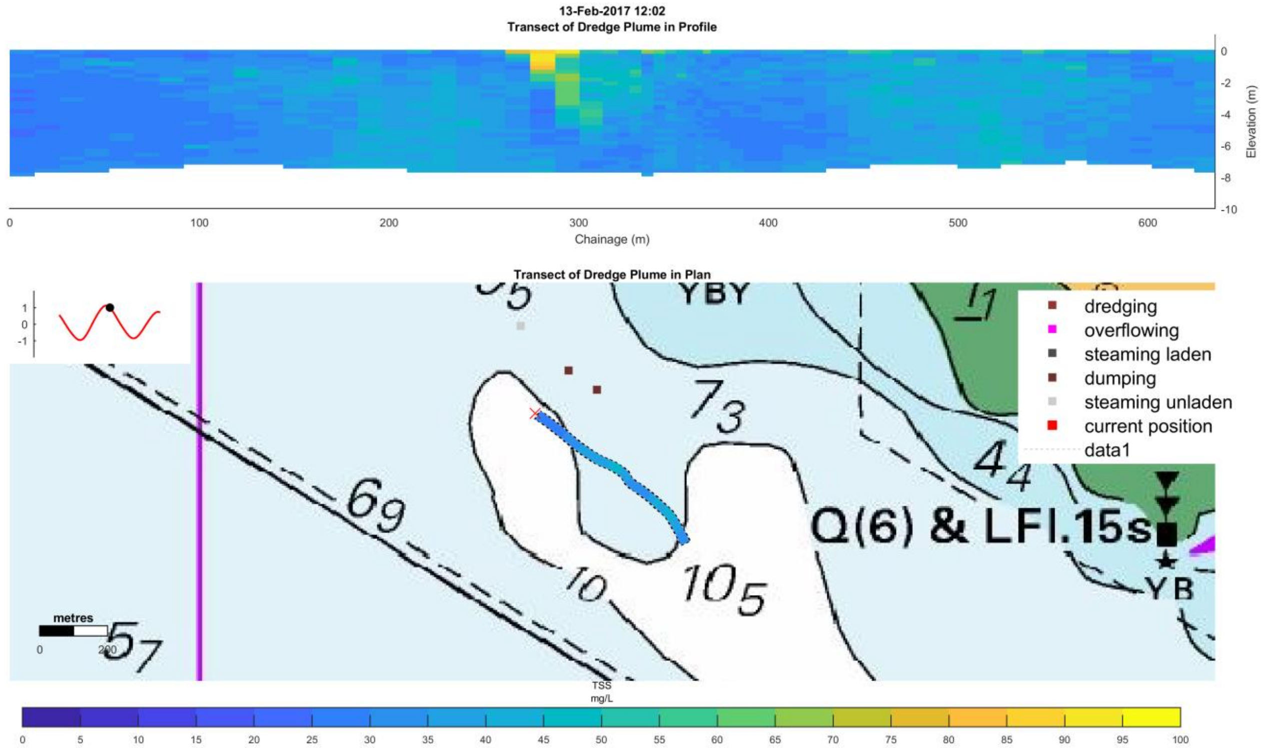

Figure 3-20 DMPA Disposal Transect 8

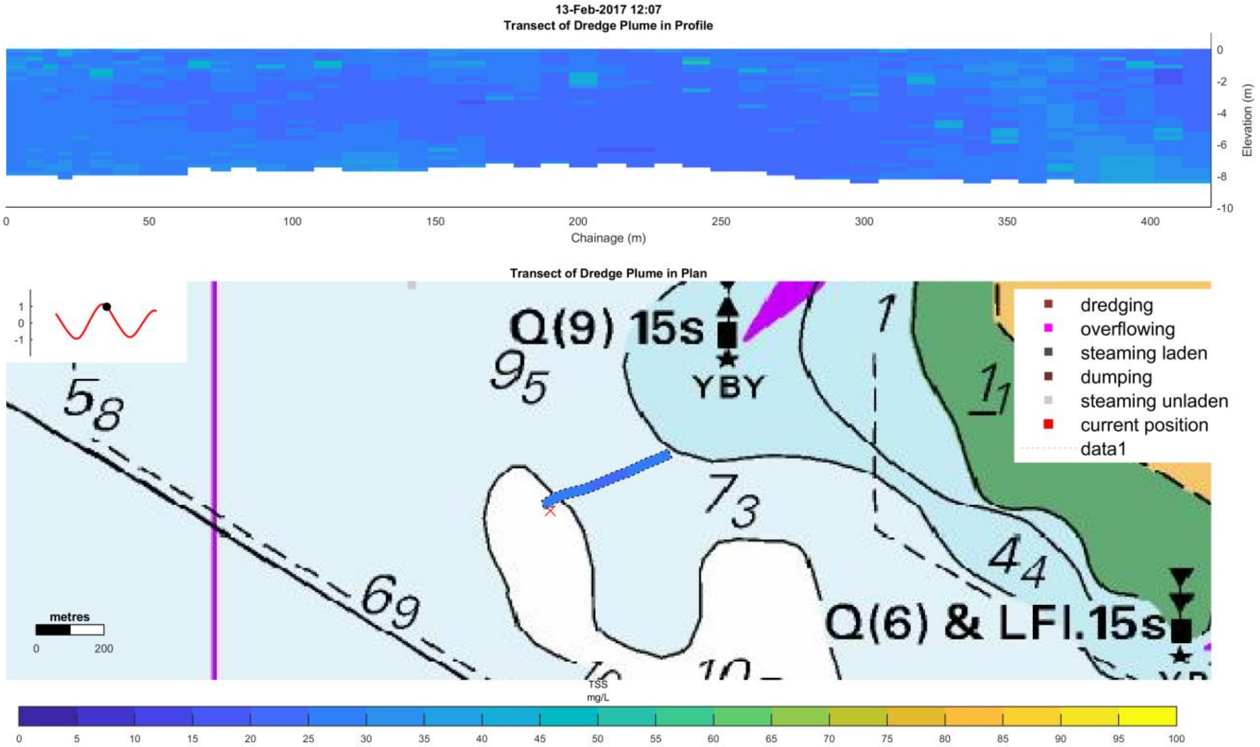

Figure 3-21 DMPA Disposal Transect 9

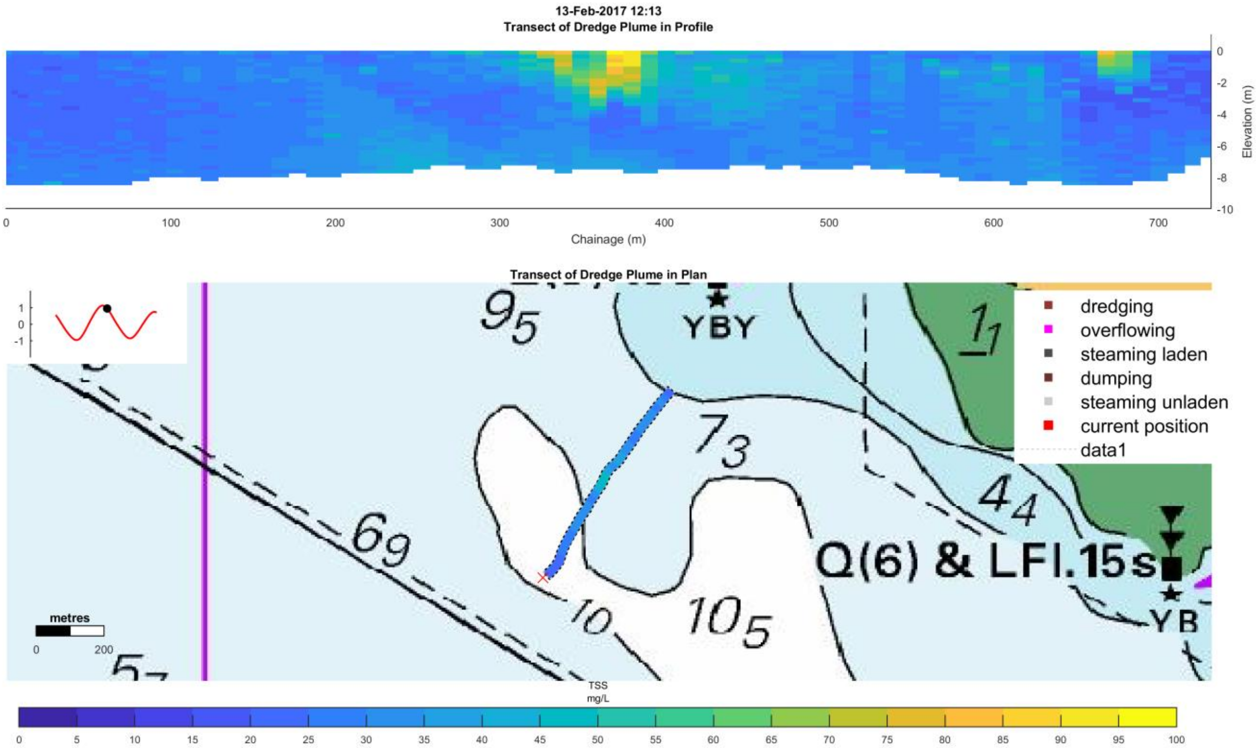

Figure 3-22 DMPA Disposal Transect 10

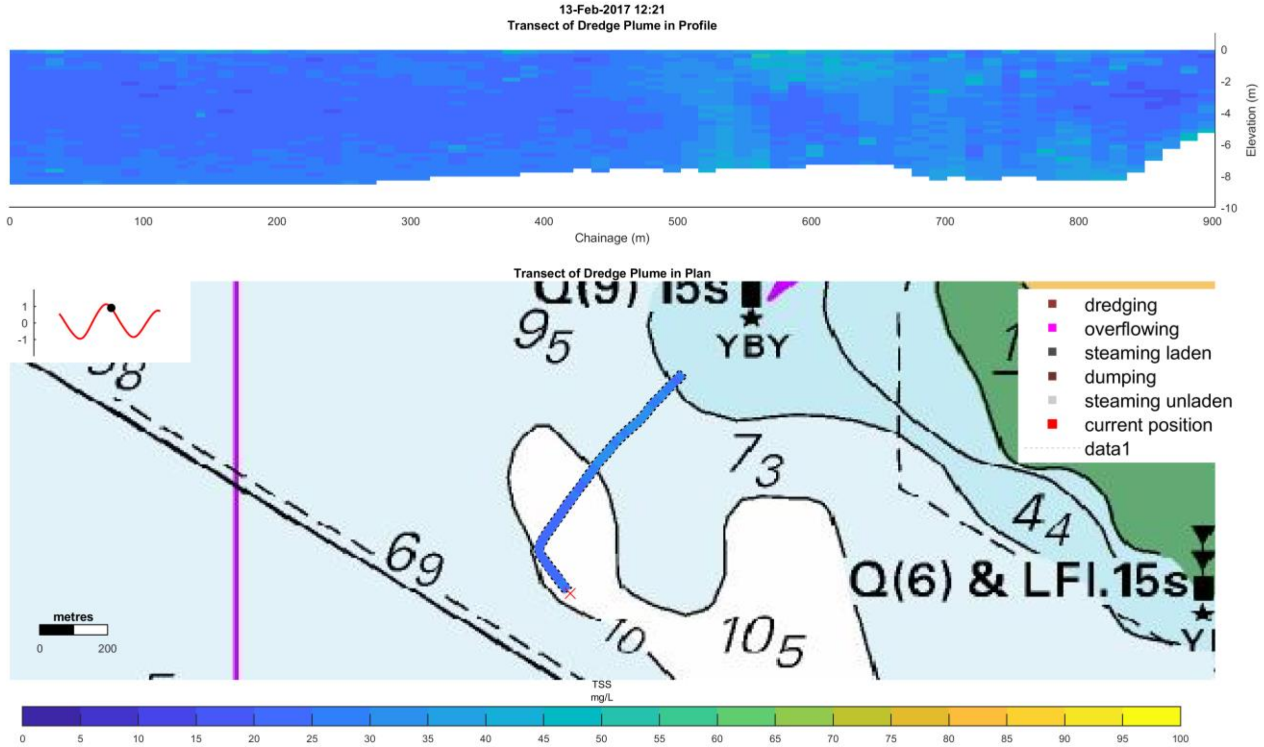

Figure 3-23 DMPA Disposal Transect 11

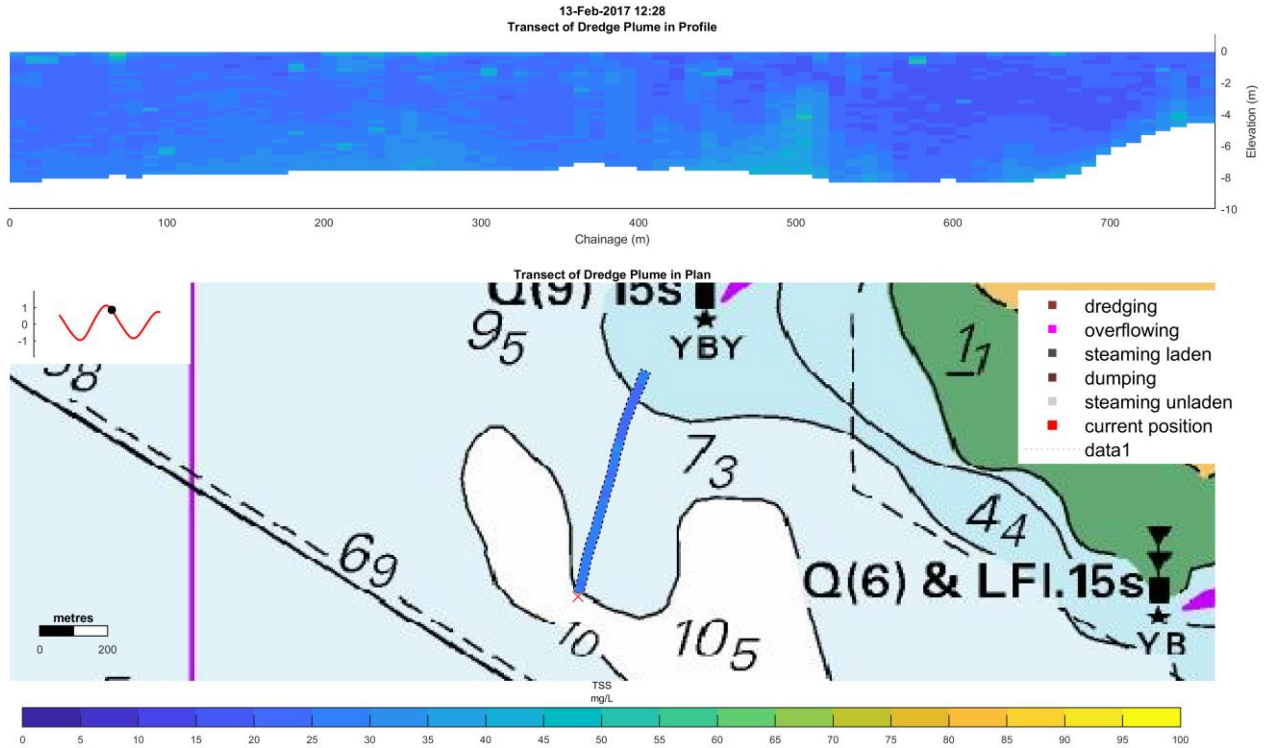

Figure 3-24 DMPA Disposal Transect 12

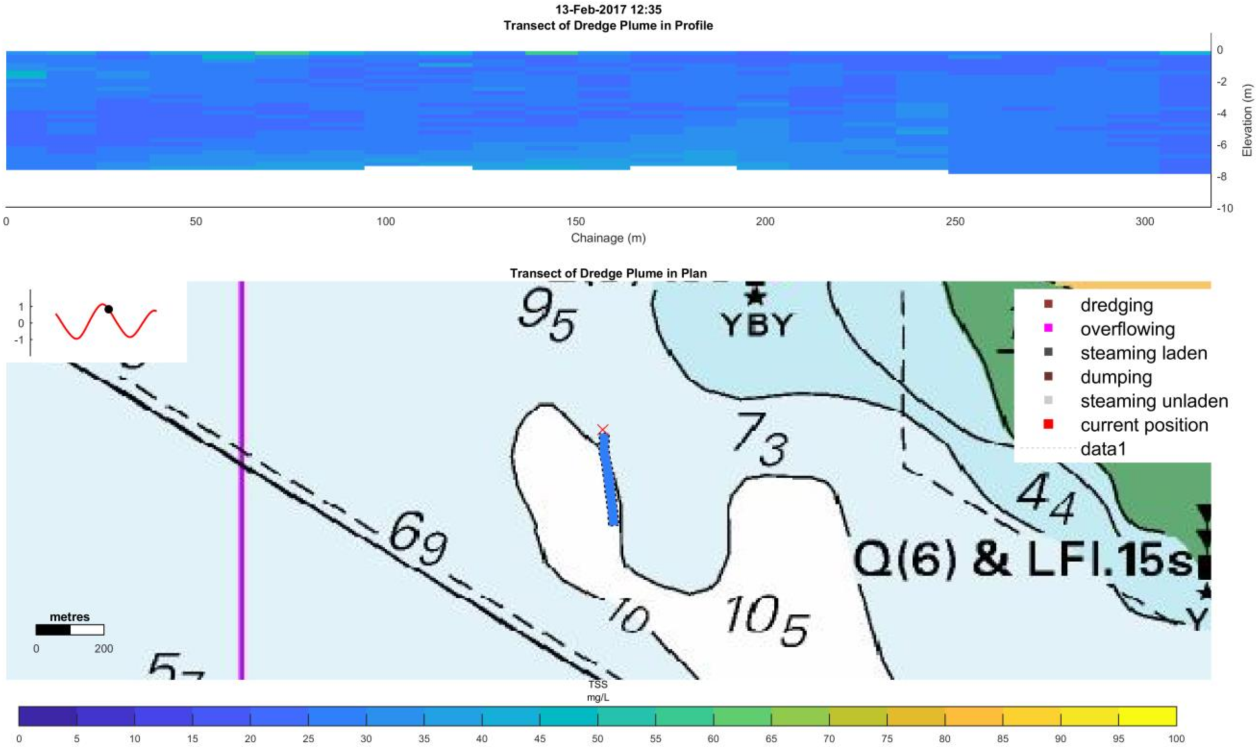

Figure 3-25 DMPA Disposal Transect 13

3.2.2.3 Channel Dredging 13/02/2017 13:00

Dredge plumes were monitored from inside the swing basin during operations adjacent to the Brisbane crew change wharf. Plumes at the surface resulting from overflow dredging were observed moving with the current towards luggage point. These plumes dispersed shortly after dredging stopped. Secondary plumes also detected at the floor of the channel; these were monitored moving seawards past Luggage Point.

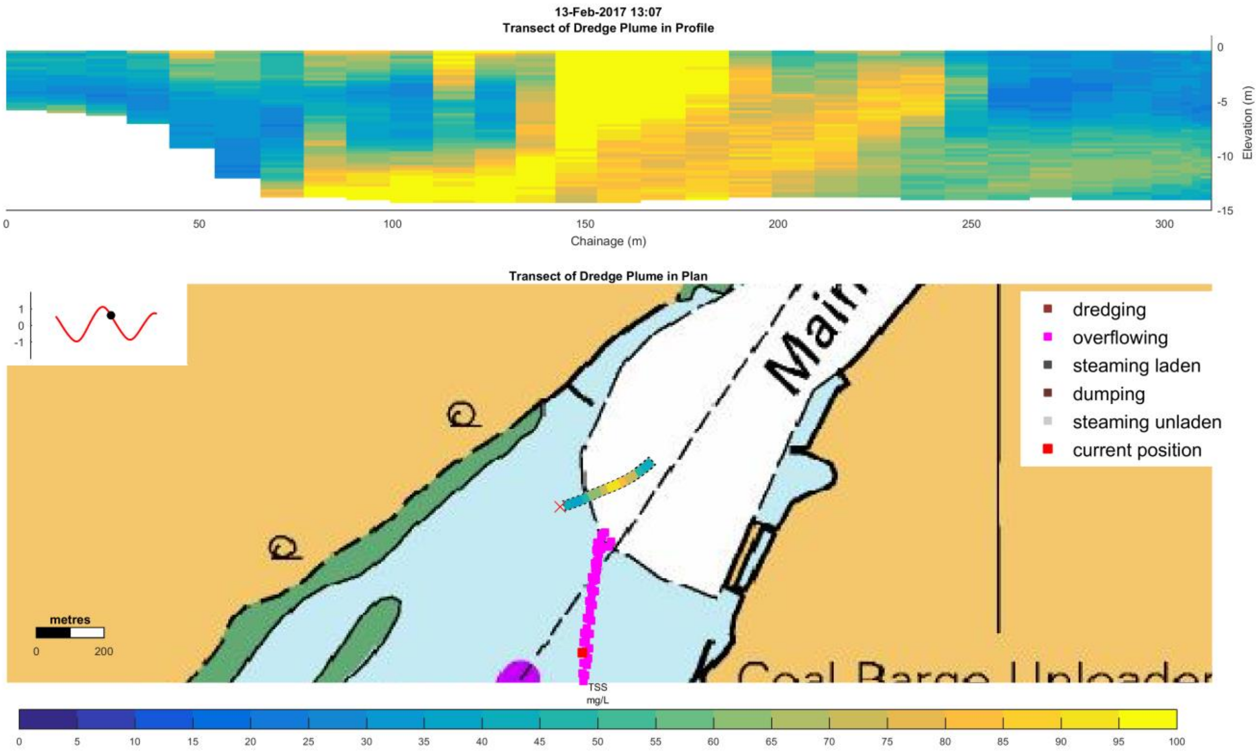

Figure 3-26 Swing Basin Dredging Transect 1

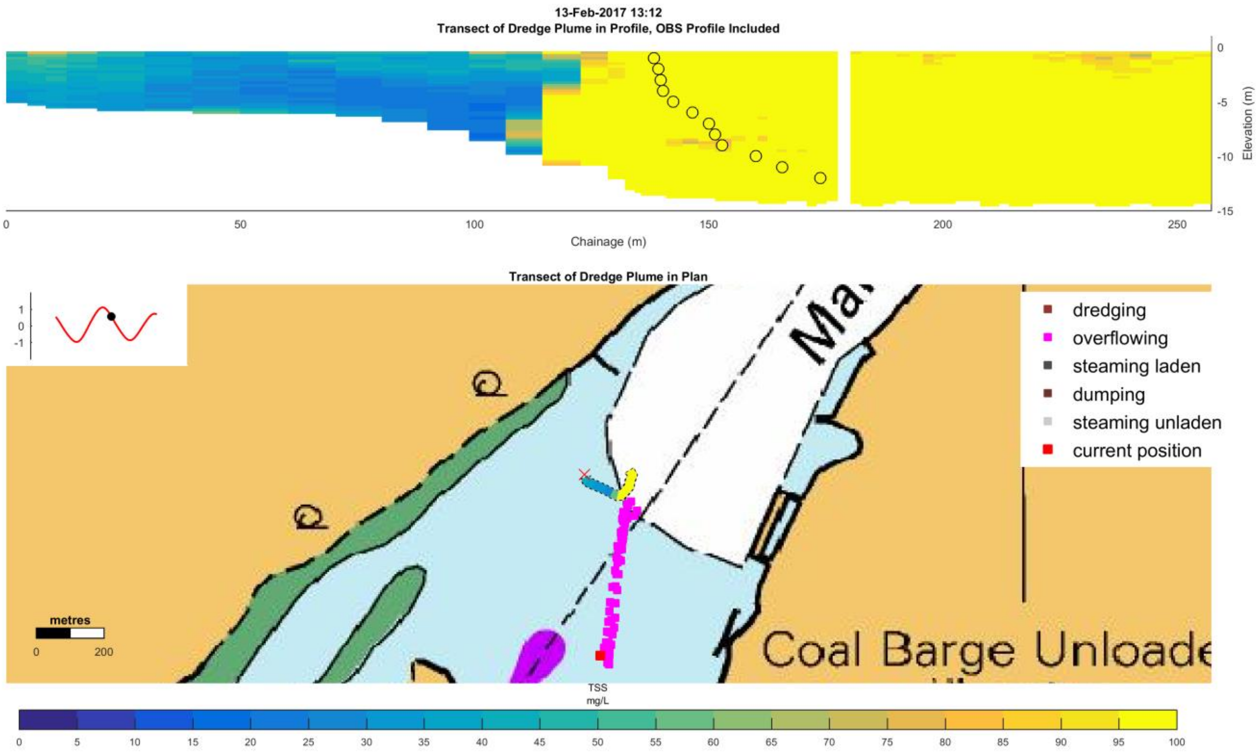

Figure 3-27 Swing Basin Dredging Transect 2

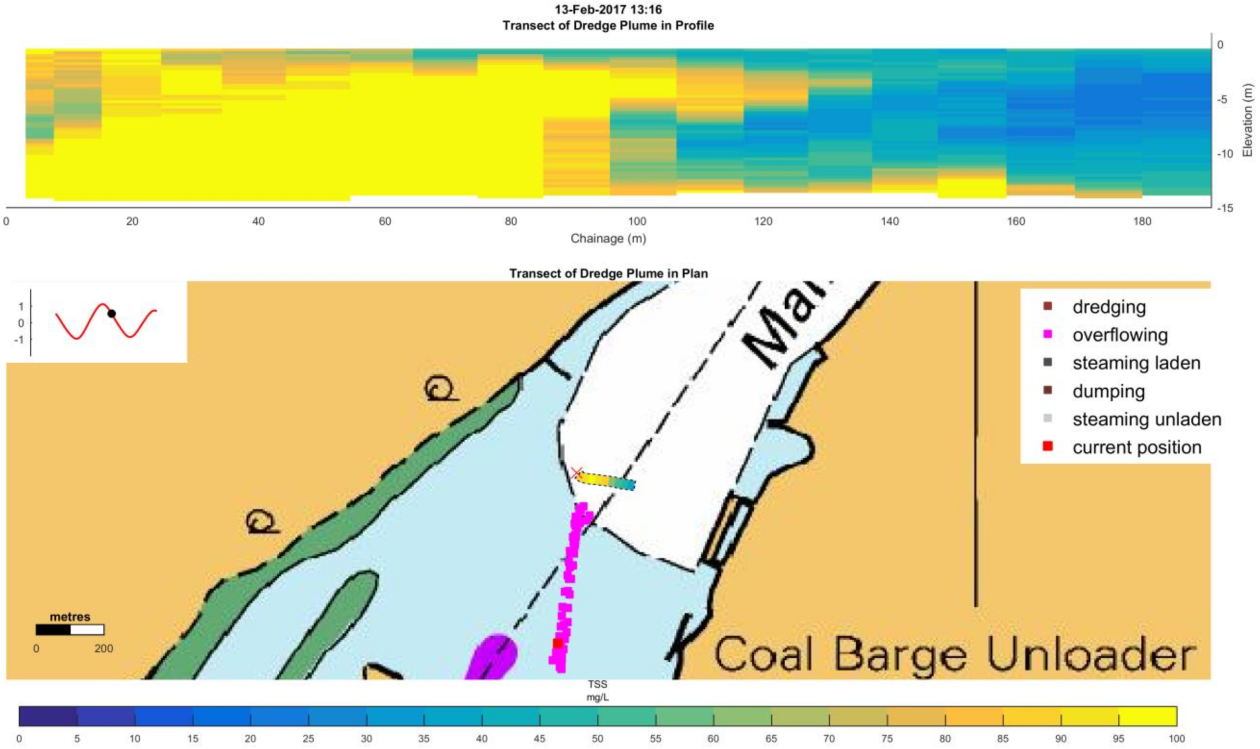

Figure 3-28 Swing Basin Dredging Transect 3

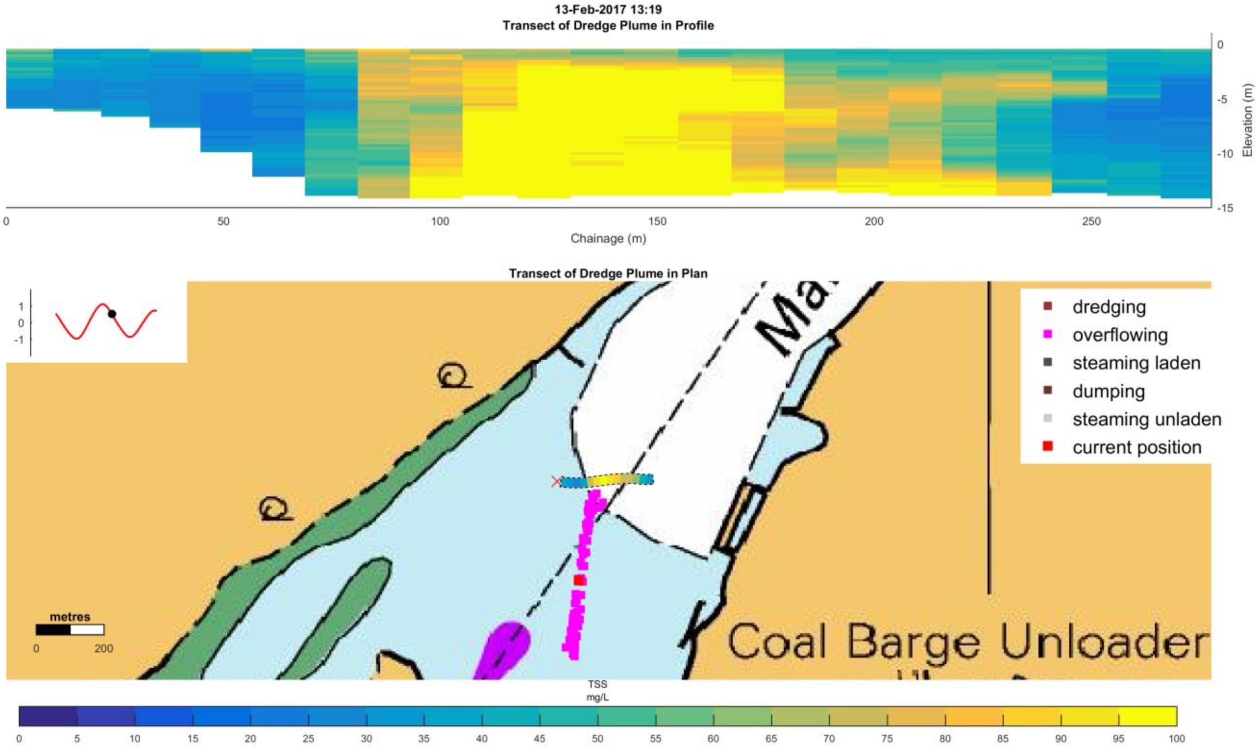

Figure 3-29 Swing Basin Dredging Transect 4

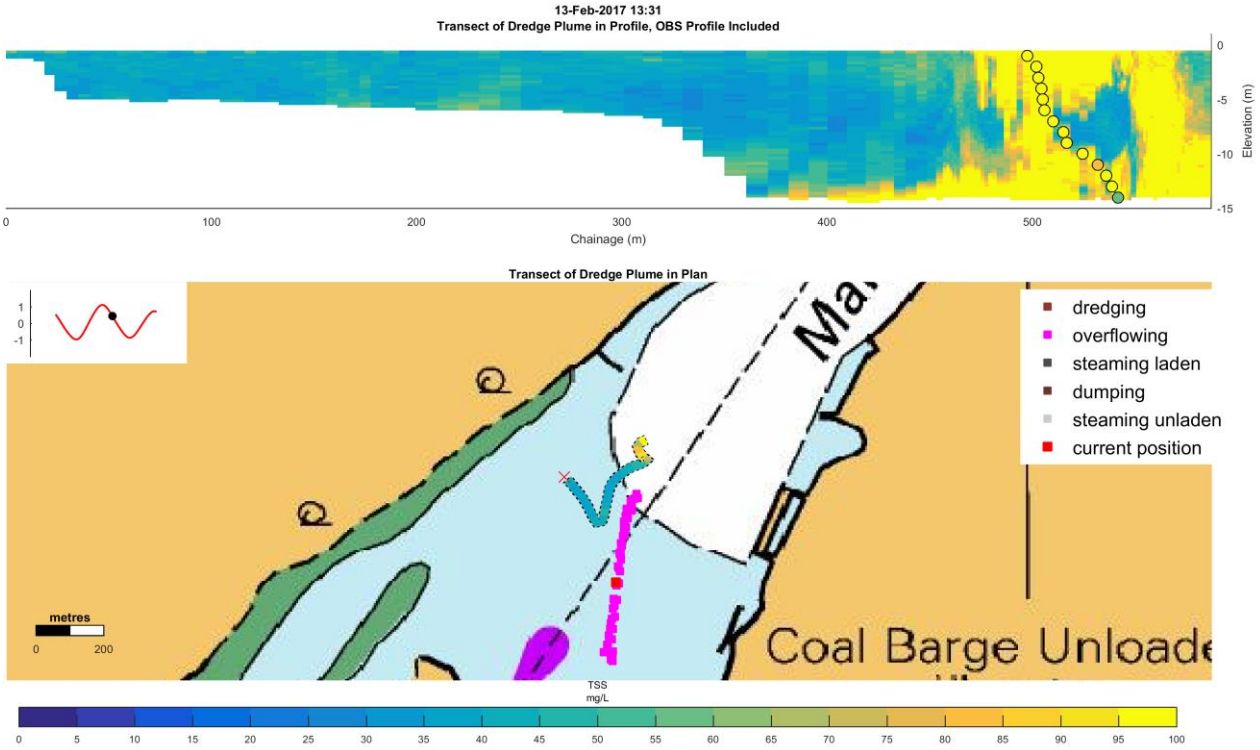

Figure 3-30 Swing Basin Dredging Transect 5

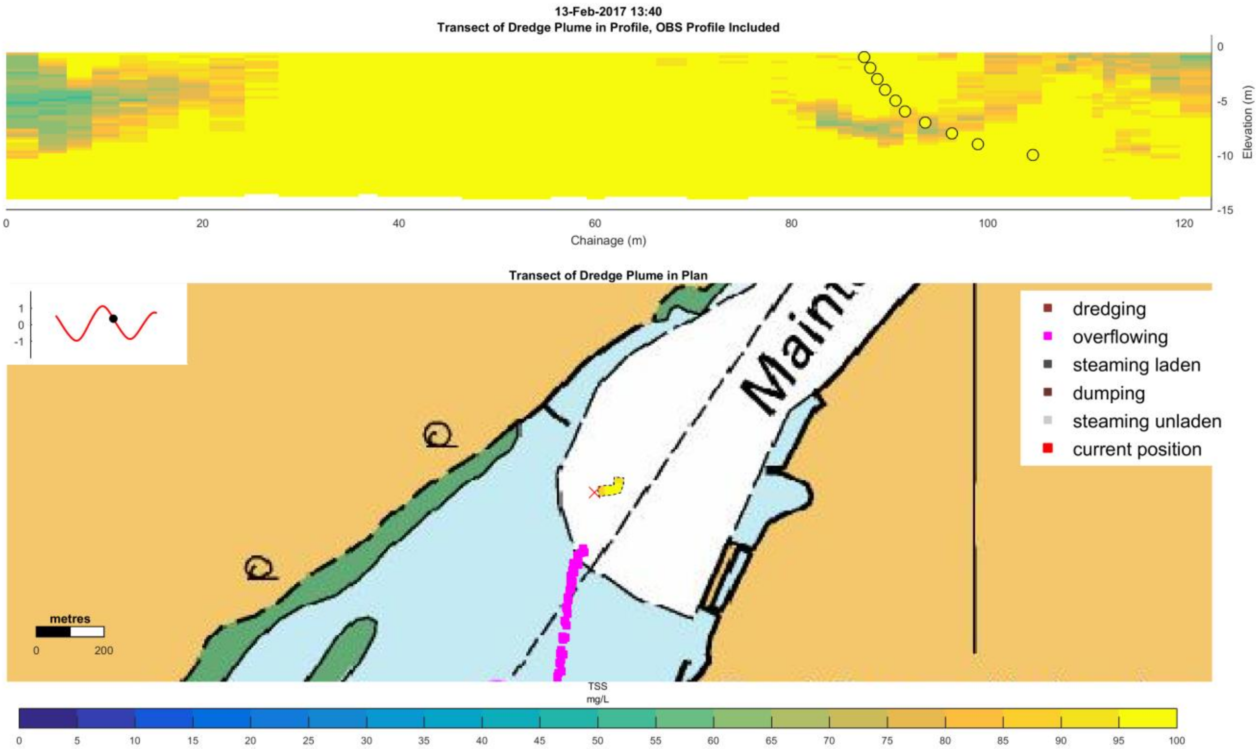

Figure 3-31 Swing Basin Dredging Transect 6

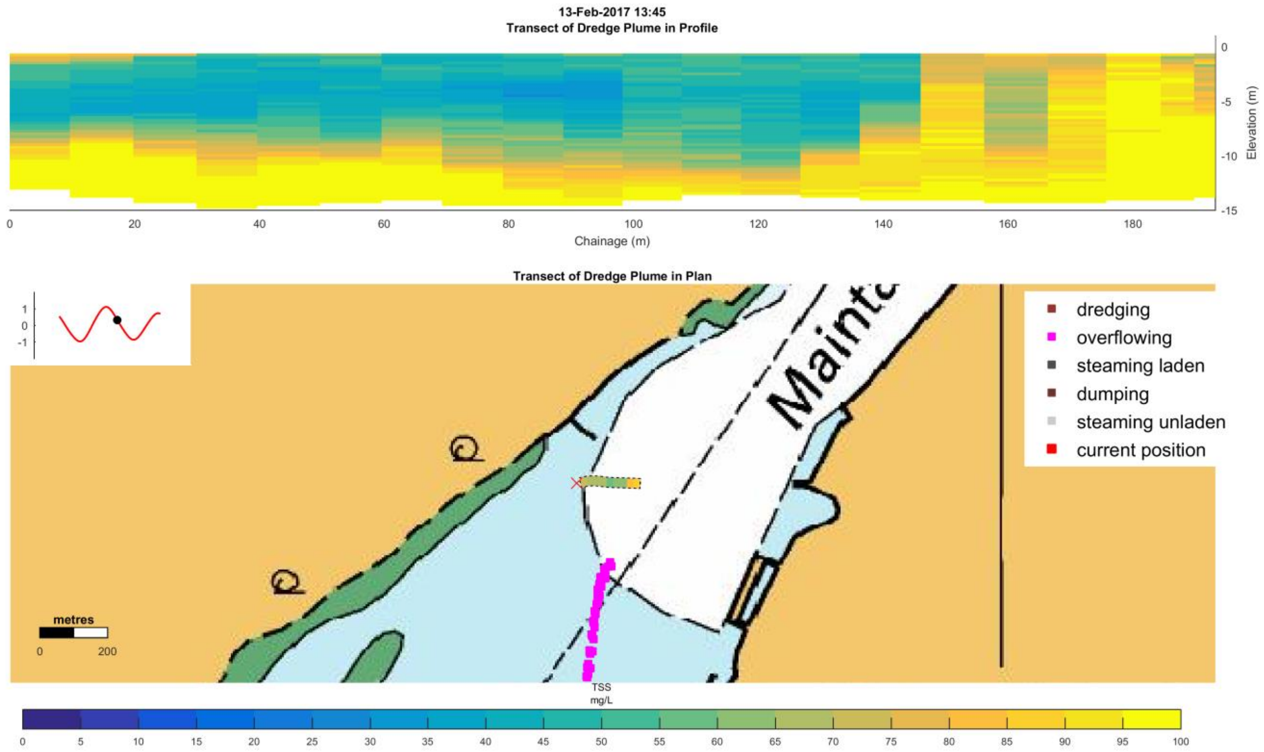

Figure 3-32 Swing Basin Dredging Transect 7

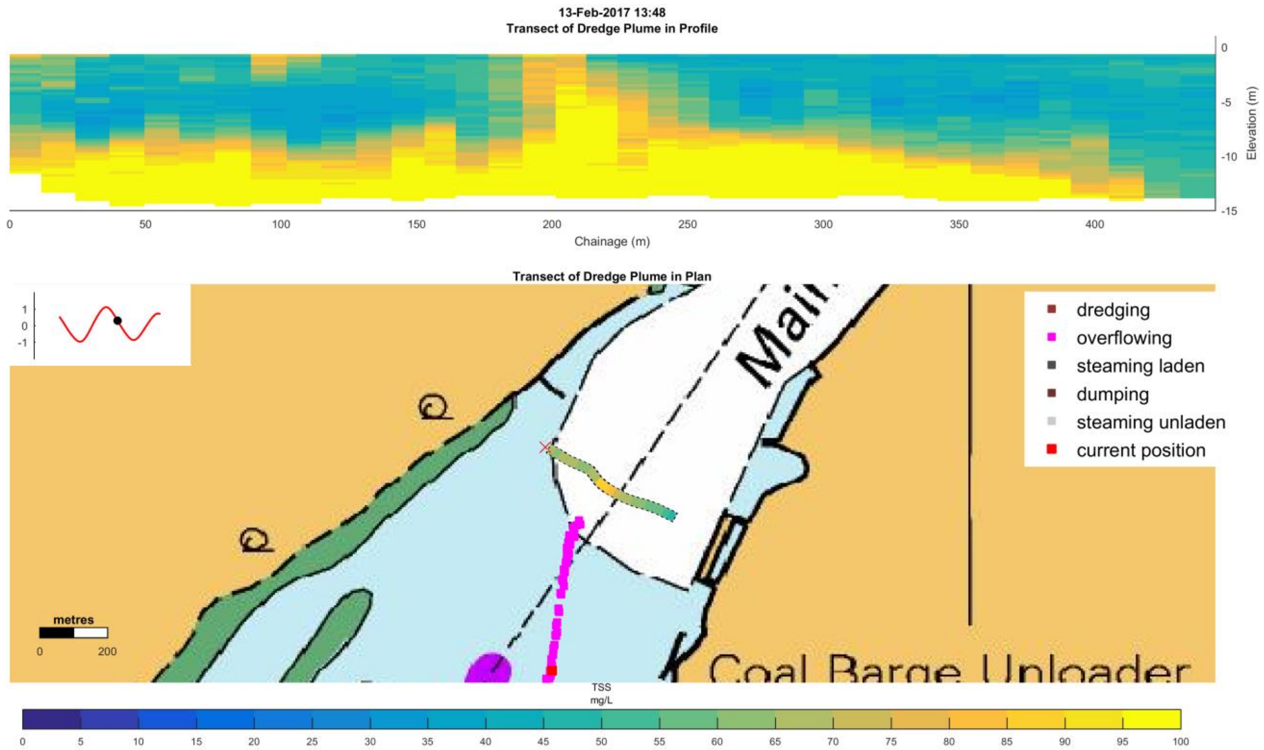

Figure 3-33 Swing Basin Dredging Transect 8

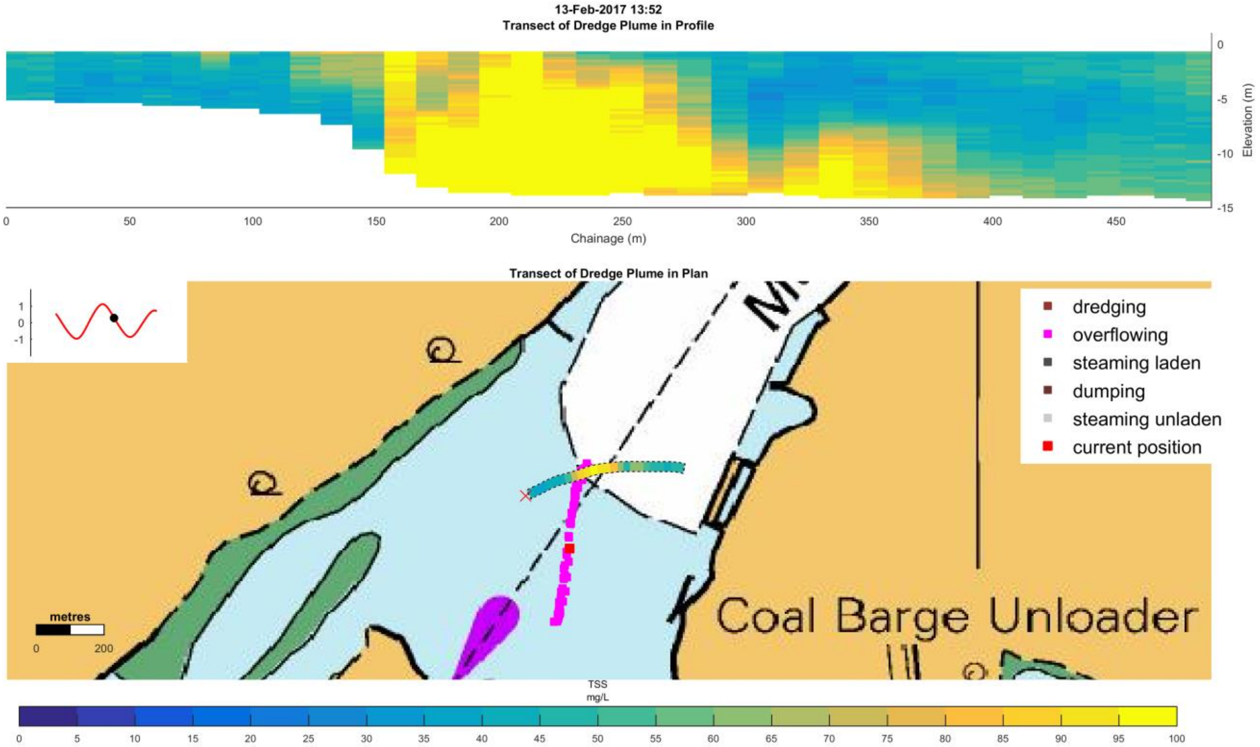

Figure 3-34 Swing Basin Dredging Transect 9

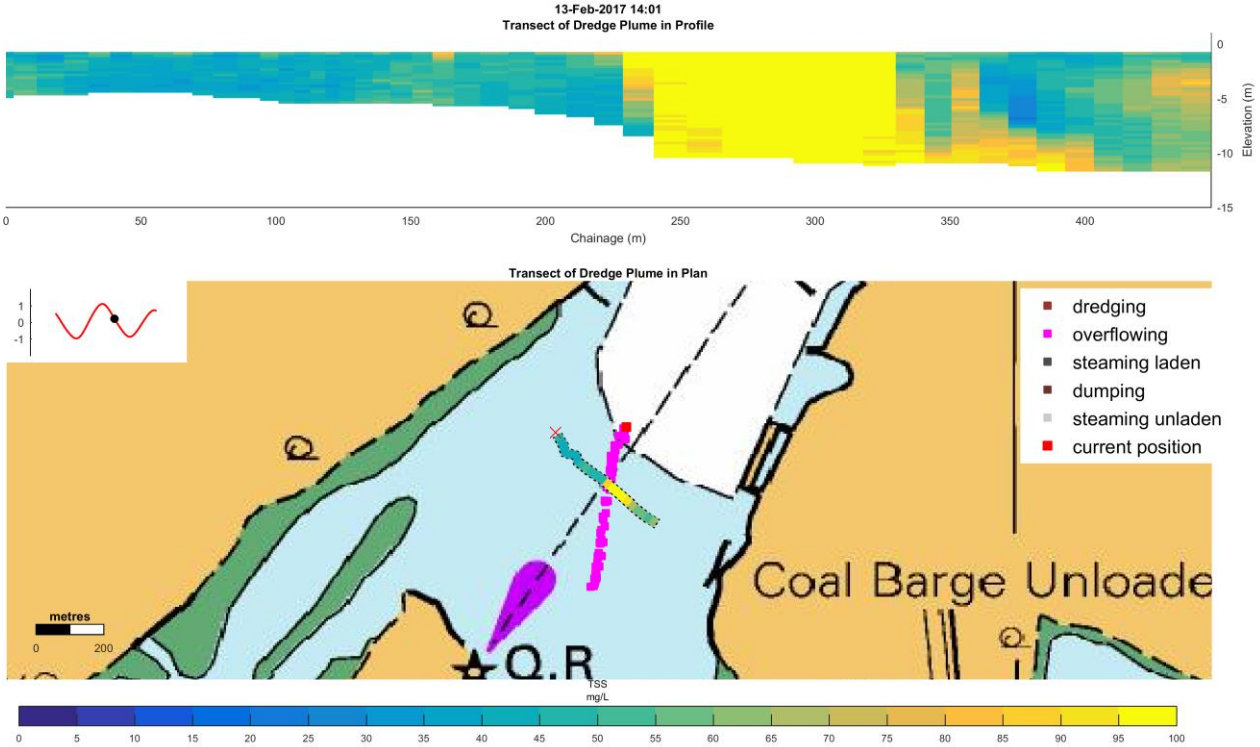

Figure 3-35 Swing Basin Dredging Transect 10

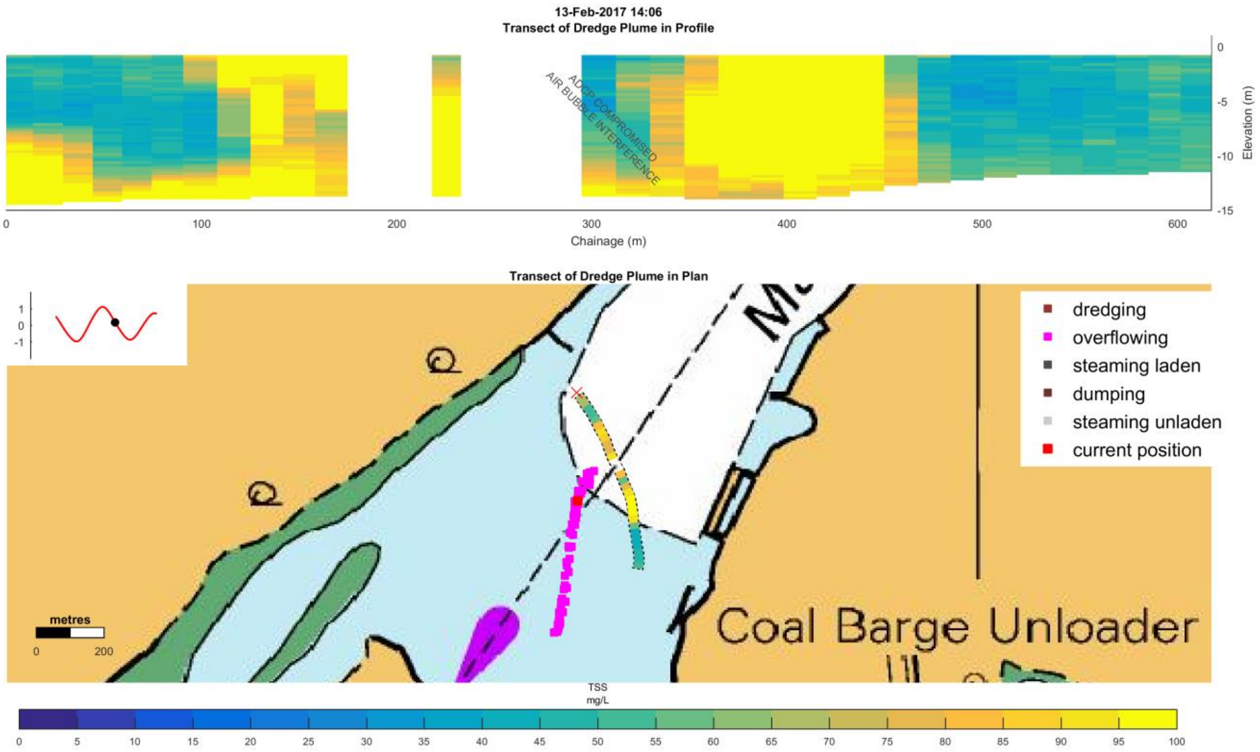

Figure 3-36 Swing Basin Dredging Transect 11

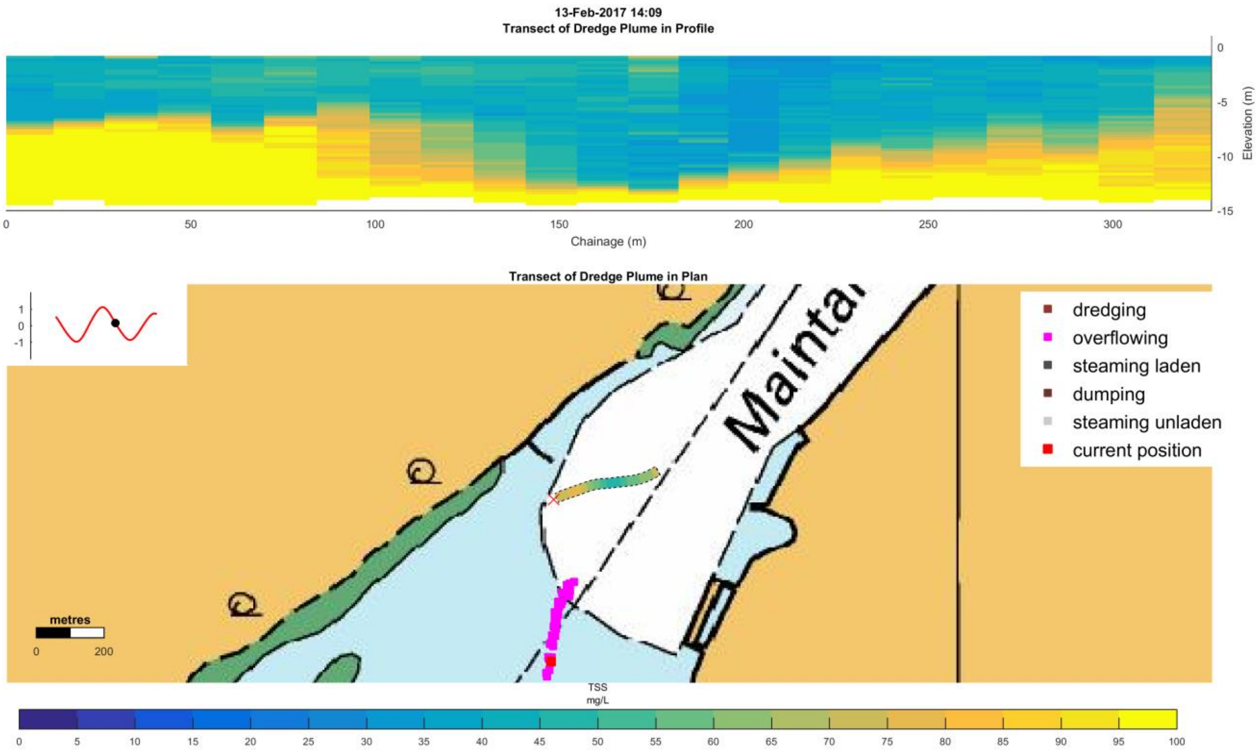

Figure 3-37 Swing Basin Dredging Transect 12

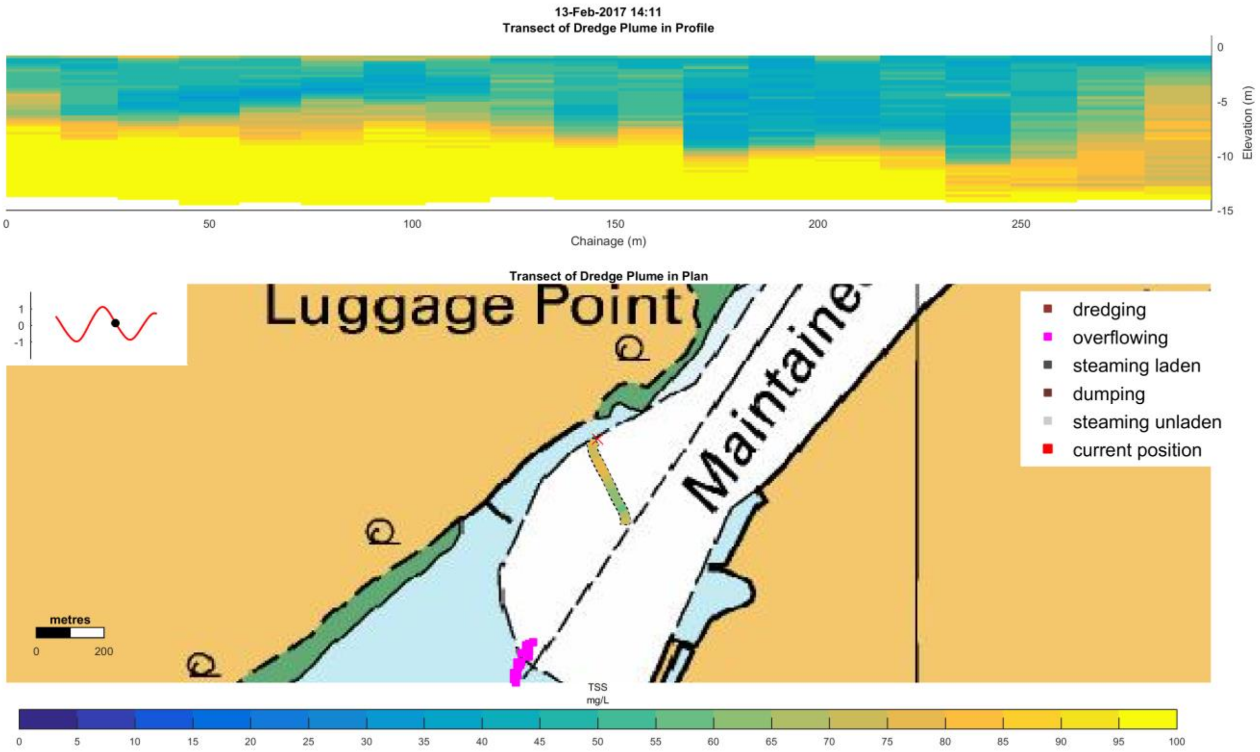

Figure 3-38 Swing Basin Dredging Transect 13

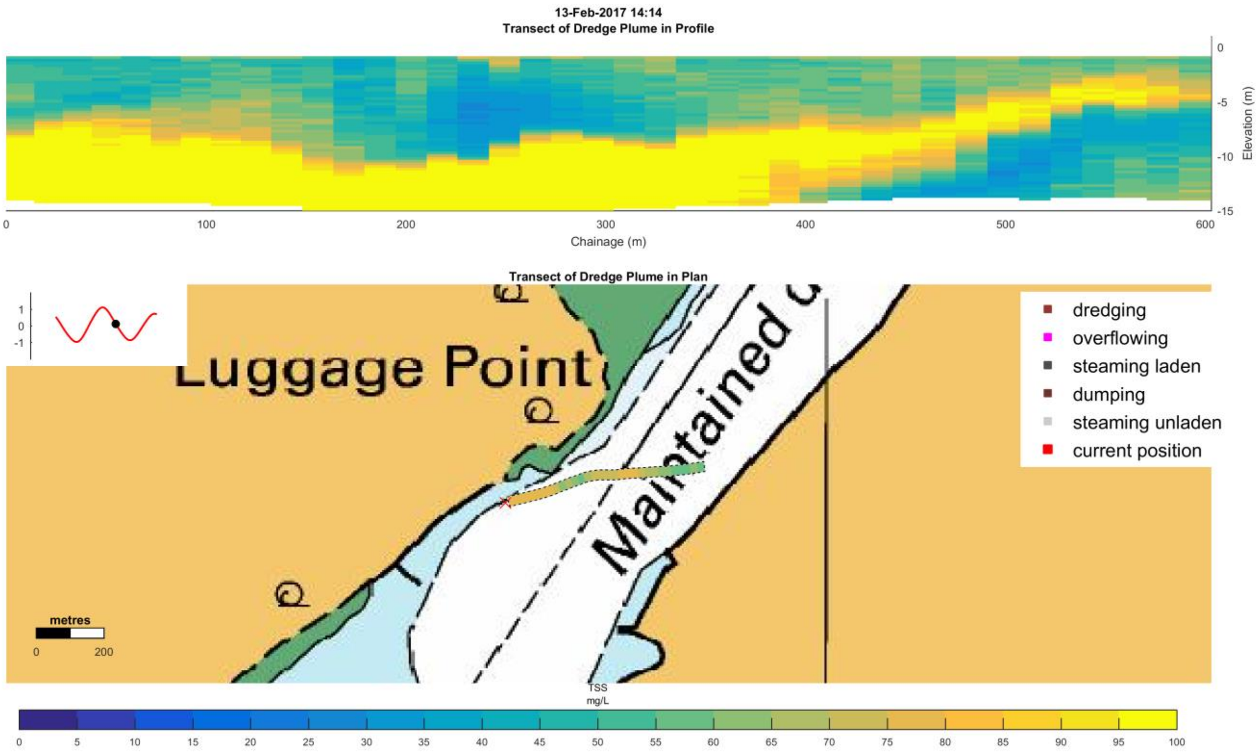

Figure 3-39 Swing Basin Dredging Transect 14

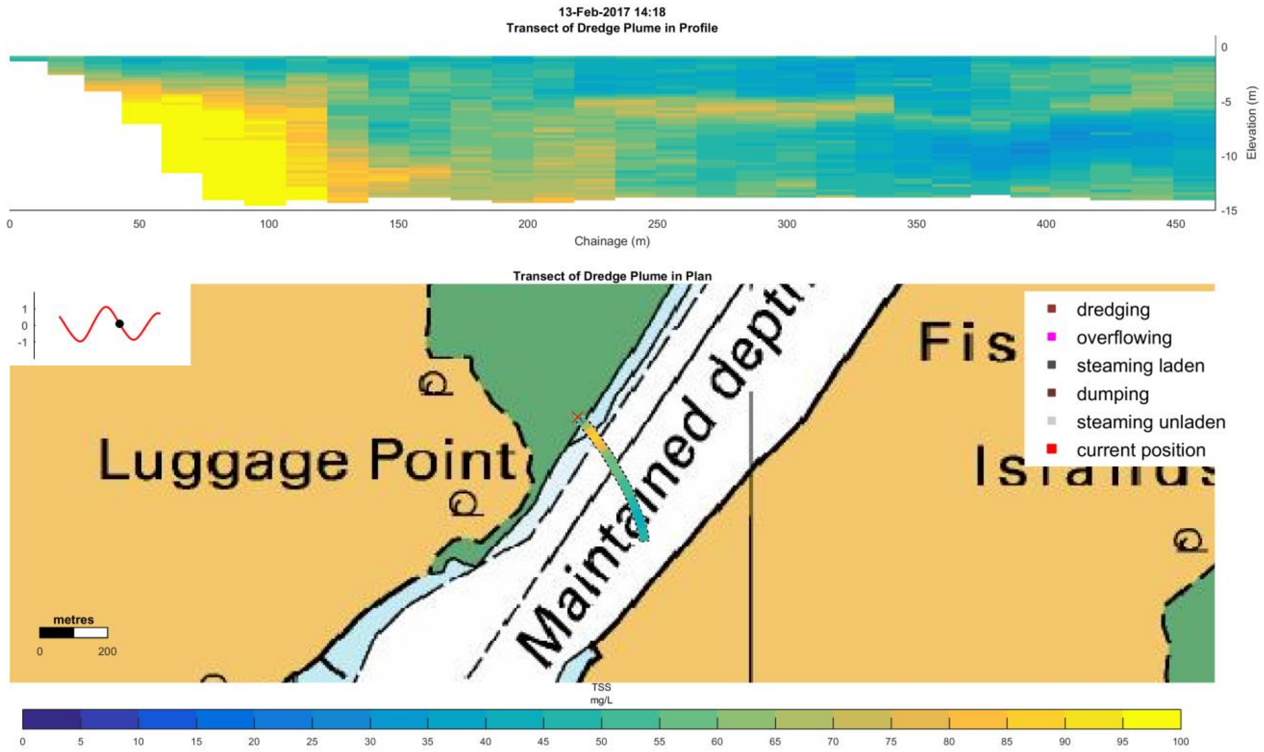

Figure 3-40 Swing Basin Dredging Transect 15

3.2.3 Nutrients

Figure 3-41 shows the concentration of TSS and nutrients in background and dredge and disposal plume samples. The results show:

- Particulate-bound nitrogen (organic nitrogen) and phosphorus were consistently higher than dissolved fractions (ammonia, nitrate, nitrite, reactive phosphorus) in background and plume samples.
- Total nitrogen and phosphorus concentrations were significantly positively correlated (Figure 3-41).
- TSS and most nutrients were higher in plumes generated by dredging, and to a lesser extent disposal, than background.
- At the loading site, TSS and particulate bound nutrients were higher near the bed compared to the surface, particularly at loading site 2 (Pelican Banks). At the DMPA, the surface plume had higher TSS and particulate bound nutrients than near the bed.
- Nitrate + nitrite (NO_x) was the dominant dissolved nitrogen species at the loading site in background and most plume samples, except at the near bed sample in the dredge plume at loading site 2 (Pelican Banks) where ammonia was highest.
- At the DMPA, NO_x was not detected at the DMPA site in background samples or the dredge plume, and ammonia was detected in the near bed sample in the dredge plume. Organic nitrogen

concentrations were similar between disposal plume and background samples, unlike at the loading sites where high organic nitrogen was recorded in near bed samples in the dredge plume.

- Ammonia concentrations ranged from 0.004 to 0.126 mg/L, and did not exceed the toxicity trigger value of 0.91 mg/L for 95% protection of species. All nutrients exceeded water quality objective (WQO) values in most samples, including background samples.

These results indicate that there was some nutrient enrichment at the loading site immediately adjacent to the dredger, particularly near the bed. Only mild enrichment was observed in the dredge plume at the disposal site, and this was mostly in the surface waters. Concentrations of ammonia were well below levels where toxic effects could occur.

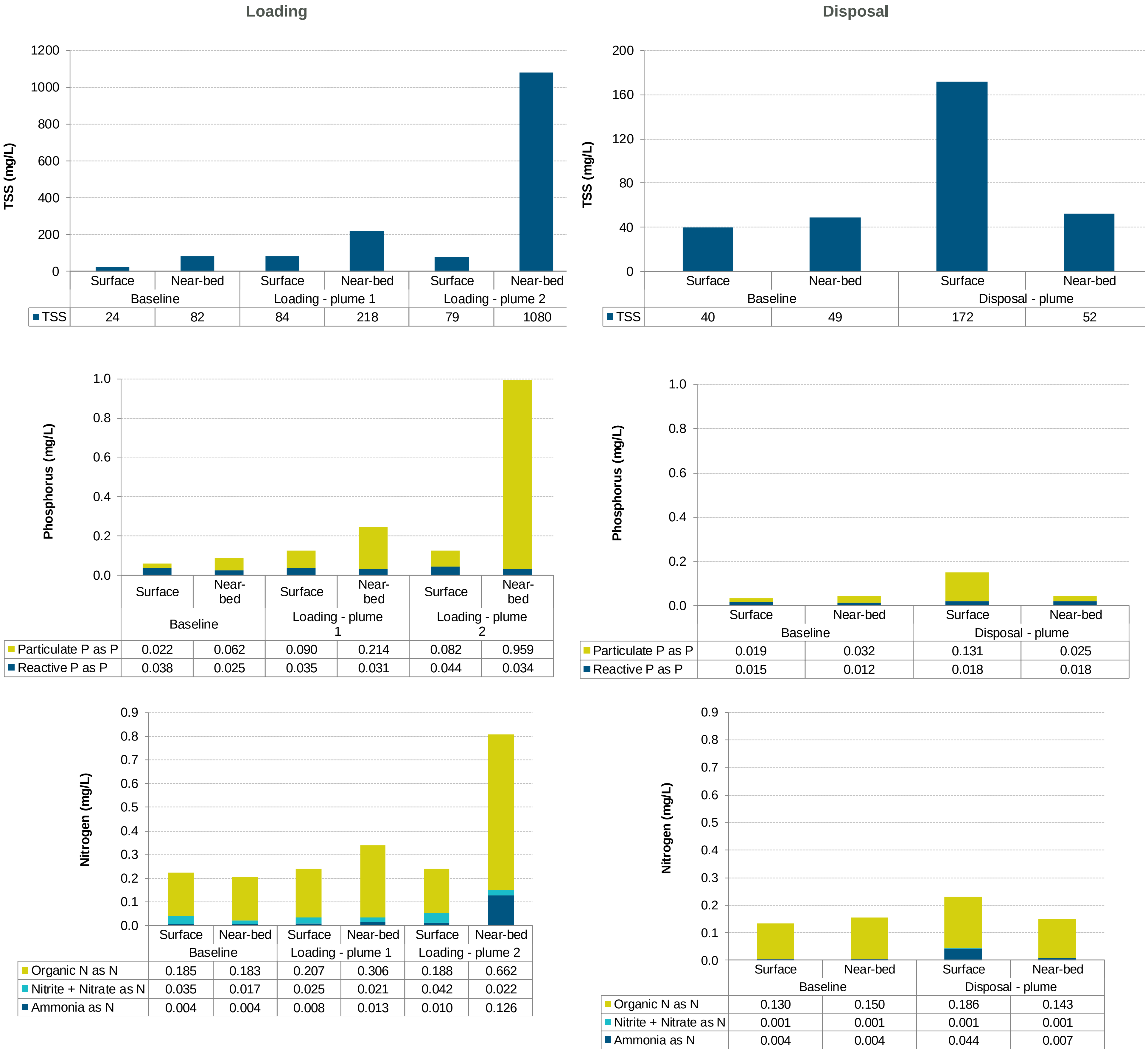

Figure 3-41 Concentration of TSS, phosphorus and nitrogen species (mg/L)

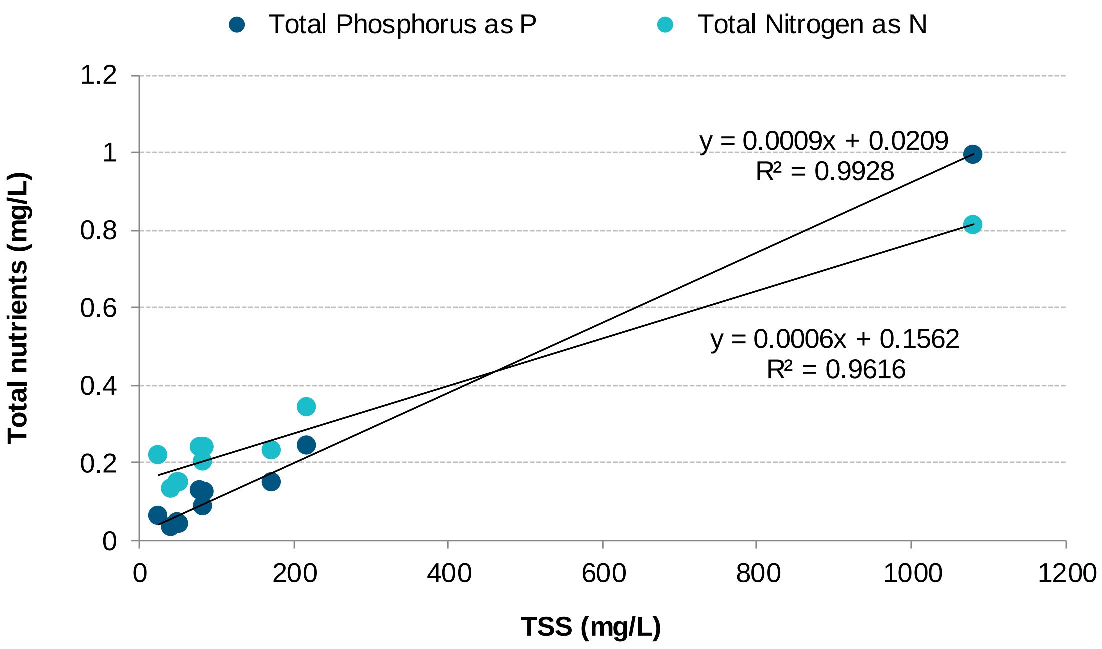

Figure 3-42 Relationship between TSS and total nutrients (nitrogen and phosphorus) in background and plume samples – February 2017

3.3 Discussion

3.3.1 Suspended Sediments

The measurements attained whilst monitoring the plumes generated by the *Brisbane* as it performed maintenance dredging within the Brisbane River and Mud Island DMPA could be successfully used to characterise the relevant plumes with respect to their intensity, movements and longevity.

Consistent with the results of previous studies, the disturbance of the seabed by the drag heads resulted in the generation of an initial plume near the seabed. The hopper gradually filled up and within seconds of the commencement of overflow from the hopper, a plume of sediment was visible at the water surface. This was the result of turbulence generated by the Brisbane's propellers mixing the sediments released at keel level from the hopper throughout the water column. The combination of the additional sediment released into the water column from the hopper and the inhibited settling due to the turbulence generated by the propellers resulted in a plume of sediments relatively evenly distributed throughout the water column and <100 metres in width. The sediments released from the hopper also contributed to the near bed plume which together with contributions from the drag heads reached concentrations that were typically less than 200 mg/L, but reached a maximum of 1080 mg/L in the swing basin.

With time both the near-bed plume and that of sediments initially mixed throughout the water column by the propellers were advected along the channel. The plumes were still discernible above background conditions for durations measured in tens of minutes to hours. Dredge plumes did not approach any sensitive receptor sites in Moreton Bay (i.e. seagrass meadows, reefs), and while passing close to intertidal shoals at Luggage Point, did not form persistent plumes that could result in impacts to intertidal fauna.

Dredged material disposal occurred at Mud Island DMPA at the top of the tide, and monitoring was conducted as the tide ebbed. Dredged sediment was observed to quickly settle to the bottom of the DMPA, with a plume of lower intensity than recorded at the dredge sites. This plume was monitored as it migrated with the current, and had disappeared (less than background) with ~1.5 hours of disposal. This plume was contained entirely within the bounds of the DMPA. Dredge plumes did not approach any sensitive receptor sites in Moreton Bay (i.e. seagrass meadows at Fisherman Island, reefs around Mud Island), consistent with results during 2014.

3.3.2 Nutrients

In the present study, increases (above background) in nutrient species were recorded in plumes generated by dredging and disposal. Increases in nutrient concentrations occur as a result of the following:

- Resuspension of particulate-bound nutrients by the dredge head at the dredge site
- Release of dissolved nutrients contained in pore waters as a result of disturbance of the seafloor by the dredge head
- Release of particulate-bound and dissolved nutrients in dredged sediments and waters from the dredge hopper into the disposal site.

The results of the present study found that most nitrogen and phosphorus in dredge plumes was particulate-bound forms contained in organic matter. Particulate forms are the lease bioavailable, but eventually break down over time to more readily bioavailable forms (e.g. ammonia). Organic matter degradation processes are not fundamentally altered by dredging and disposal. The degradation rates of organic matter to bioavailable nutrients in pore water depends on the form of the organic matter. Phytoplankton has high reactivity and is therefore broken down at timescales <1 year. Most organic matter in nearshore sediments (including dredged sediments) is terrestrial matter with low reactivity, with degradation half-life measured in years to millennia (Batley *et al.* 2015).

In a review of monitoring studies in Queensland and worldwide, Batley *et al.* (2015) suggested that increased concentrations of soluble ammonia associated with pore water release and desorption from particles was typically of most concern, whereas release of dissolved nitrite, nitrate and phosphate were generally minor and of least concern. The results of the present study confirm that ammonia was the dominant form of bioavailable nitrogen in dredge and disposal plumes.

Ammonia (and other nutrient) concentrations exceeded the local WQO but did not approach the toxicity guideline value for ammonia. Furthermore, ammonia and other bioavailable forms are highly unlikely to result in persistent water quality impacts. For example, monitoring of highly nutrient enriched dredged sediments (from Toondah Harbour) disposed of at Mud Island DMPA (BMT WBM 2008) found that ammonia concentrations in the water column were close or slightly above background concentrations within 10 minutes of dredged material placement, and had returned to background concentrations (often below laboratory detection limit of ~0.002 mg/L) within one hour of disposal. These results indicate that through dilution and biological uptake of nutrients in dredged sediments in the water column, ammonia was well below levels of potential concern.

4 Dredge Plume Modelling

The effects of dredging were assessed based on modelled hindcast of dredging operations from the TSHD Brisbane. Both ambient and dredge related signals have been resolved in the hindcast model and a comparison to both sampled turbidity data at the DMPA and ADCP transect data has been made. Details of the model parameterisation and calibration are presented in 4.1 to 4.3.

The model comparisons to the plume monitoring period are presented in 4.4. With additional commentary around the observations during this monitoring. A discussion of the entire maintenance campaign modelling has been presented in 4.5.

4.1 Hydrodynamic Modelling

The hydrodynamic modelling component of these assessments has been undertaken using the TUFLOW FV software, which is developed and distributed by BMT WBM (www.tuflow.com/Tuflow%20FV.aspx). TUFLOW FV is a numerical hydrodynamic model for the two-dimensional (2D) and three-dimensional (3D) Non-Linear Shallow Water Equations (NLSWE). The model is suitable for solving a wide range of hydrodynamic systems ranging in scale from open channels and floodplains, through estuaries to coasts and oceans. The Finite-Volume (FV) numerical scheme employed by TUFLOW FV is capable of solving the NLSWE on both structured rectilinear grids and unstructured meshes comprised of triangular and quadrilateral elements. The flexible mesh allows for seamless boundary fitting along complex coastlines or open channels as well as accurately and efficiently representing complex bathymetries with a minimum number of computational elements. The flexible mesh capability is particularly efficient at resolving a range of scales in a single model without requiring multiple domain nesting. Further details regarding the numerical scheme employed by TUFLOW FV are provided in the TUFLOW FV Science Manual (BMT WBM, 2015).

The hydrodynamic model domain is show in Figure 4-1, and extends from Mermaid Beach in the south to beyond Marcoola and includes the entire Moreton Bay, extending offshore 25km form Moreton Island to depths of ~200 m.

The model consists of 56,801 mesh cells with resolution varying from 2.5 km (mesh cell side length) at the offshore boundary and increasing to 50 m across shipping channels and around the dredging location.

Figure 4-1 and Figure 4-2 also show the model bathymetry (note with different bathymetry elevation colour schemes) which has been derived from the following sources:

- Maritime Safety Queensland (MSQ) Boating charts (www.msq.qld.gov.au/Boating-maps.aspx)
- Australian Hydrographic Office (AHO) nautical charts (www.hydro.gov.au/webapps/jsp/charts/chartlist.jsp).

The local hydrodynamics estimated by TUFLOW FV are influenced by boundary condition inputs. The model was forced with tidal water level predictions taken from the OSU Topex/Poseidon harmonic analysis (Egbert et al. 1994). Figure 4-3 and Figure 4-4 show a comparison of water level at the Brisbane Bar and the Gold Coast Seaway respectively.

4.2 Wave Modelling

The wave modelling component of these assessments has been undertaken using the spectral wave model SWAN.

SWAN (Delft University of Technology 2006) is a third-generation spectral wave model, which is capable of simulating the generation of waves by wind, dissipation by whitecapping, depth-induced wave breaking, bottom friction and wave-wave interactions in both deep and shallow water. SWAN simulates wave/swell propagation in two-dimensions, including shoaling and refraction due to spatial variations in bathymetry and currents. This is a global industry standard modelling package that has been applied with reliable results to many investigations worldwide.

For sediment resuspension and dispersion modelling the SWAN wave model was coupled with the 3D TUFLOW FV hydrodynamic and advection-dispersion models. This required the wave simulations to be completed separately, with the model output stored at hourly intervals on regular grids. During the subsequent sediment resuspension and dispersion simulations, the wave conditions were linearly interpolated spatially from the grids to the TUFLOW FV mesh.

A nested grid wave modelling approach has been adopted and is shown in Figure 4-5. The nested system comprises a region (500m grid resolution) model covering the extended coastline from Cape Byron to Double Island Point. Wave propagation and forces imposed on the seabed in the vicinity Moreton Bay have been assessed using a local sub-model (200m grid resolution).

The wave model bathymetry has been derived from the same sources adopted for hydrodynamics modelling.

Figure 4-6 shows the comparison of the significant wave height with observations made at the Moreton Bay Wave Rider Buoy.

4.3 Sediment Modelling

A system was developed for simulating the resuspension, advection-dispersion and deposition of sediment using the TUFLOW FV Sediment Transport (ST) module coupled with the aforementioned hydrodynamic and wave models. The ST model was configured to undertake coupled simulations of both ambient and dredging-related sediments. Three sediment size fractions were selected to simulate the ambient sediments, nominally separated into ‘clay’, ‘silt’ and ‘sand’ particle sizes. Three size fraction were adopted to simulate the dredging-related sediment contributions, modelling explicitly the plumes generated from the dredge cutter head, overflow and disposal.

A very important requirement for realistically predicting ambient sediment dynamics is to capture the significant spatial variability in sediment PSDs throughout the study domain. To this end, an initial rough segregation of the ambient sediment fractions was applied to the model, as shown in Figure 4-7. The model was then subjected to a prolonged ‘warm up’ simulation, which allowed a smoother spatial PSD to develop in accordance with the modelled sediment transport dynamics. The warmed-up sediment distribution is shown in Figure 4-8.

Bed shear stress is calculated in the ST model from the non-linear interaction of currents and waves using the procedure of Soulsby (1997). A Root-Mean-Square combined wave-current bed shear stress is used as the representative value in the sediment erosion and deposition calculations.

The modelled rate of sediment deposition, Q_d (g/m²/s), is a function of the near-bed sediment concentration (*TSS*), the still-water fall velocity and the bed shear stress (τ_b), according to the equation below. As such, sediment settling may be reduced below its still water value by the action of bed shear stress and associated mixing in the water column. Non-cohesive sediment fractions were modelled without a critical shear stress for deposition, meaning that they can potentially settle at all times regardless of the bed shear stress.

$$Q_d = w_s.TSS.\max\left(0, 1-\frac{\tau_b}{\tau_{cd}}\right)$$

The rate of erosion, Q_e (g/m²/s), is calculated according to the following equation. Erosion will occur in response to the combined wave-current driven bed shear stress (τ_b) when this exceeds a critical threshold (τ_{ce}).

$$Q_e = E.\max\left(0, \frac{\tau_b}{\tau_{ce}}-1\right)$$

The process of setting the key sediment model parameter values (E, w_s, τ_{ce}, τ_{cd}) would typically be undertaken through calibrating the predictions against in-situ time series measurements of hydrodynamic conditions and coincident suspended sediment concentrations (or turbidity as a proxy). These measurements are not presently available for Moreton Bay in the vicinity of Mud Island, therefore parameter values have been adopted based on typical literature values (Whitehouse et al. 2000) and other similar modelling studies. The adopted ST model parameters are tabulated below.

Table 4-1 Characteristics of simulated sediment classes

Parameters	*Silt*	*Clay*	*Sand*
Still Water Fall Velocity, W_s (m/s)	1 x10^{-3}	1 x10^{-4}	1 x10^{-2}
Critical Shear Stress Erosion, τ_{ce} *(Pa)*	0.2	0.2	0.2
Critical Shear Stress Deposition, τ_{cd} *(Pa)*	0.18	0.18	–
Erosion Rate Constant, E (g/m²/s)	0.15	0.15	0.15

4.3.1 Dredge Placement Modelling

Dredge placement activities of the TSHD Brisbane have been included in the model through the specification of spatially and temporally varying sediment source terms. These terms represent sediment entrained into the water column through; displacing material at the dredge drag head, overflowing from the dredge hopper and disposal of the material on the DMPA. The information to inform this boundary condition was derived from the on-board dredge log which contained information on the current dredge location and mass at one minute time intervals.

The boundary condition assumed a distribution of material in plumes consisting of 5% sand, 65% silts and 30% clays with the same sediment parameterisation as listed in Table 4-1. This distribution is consistent with previous sediment mapping of the (BMT WBM, 2015). Sediment source rates for the drag head, overflow and disposal of material were uses as 4kg/s, 250kg/s and 500 kg/s respectively. This is consistent with previous modelling of the TSHD Brisbane.

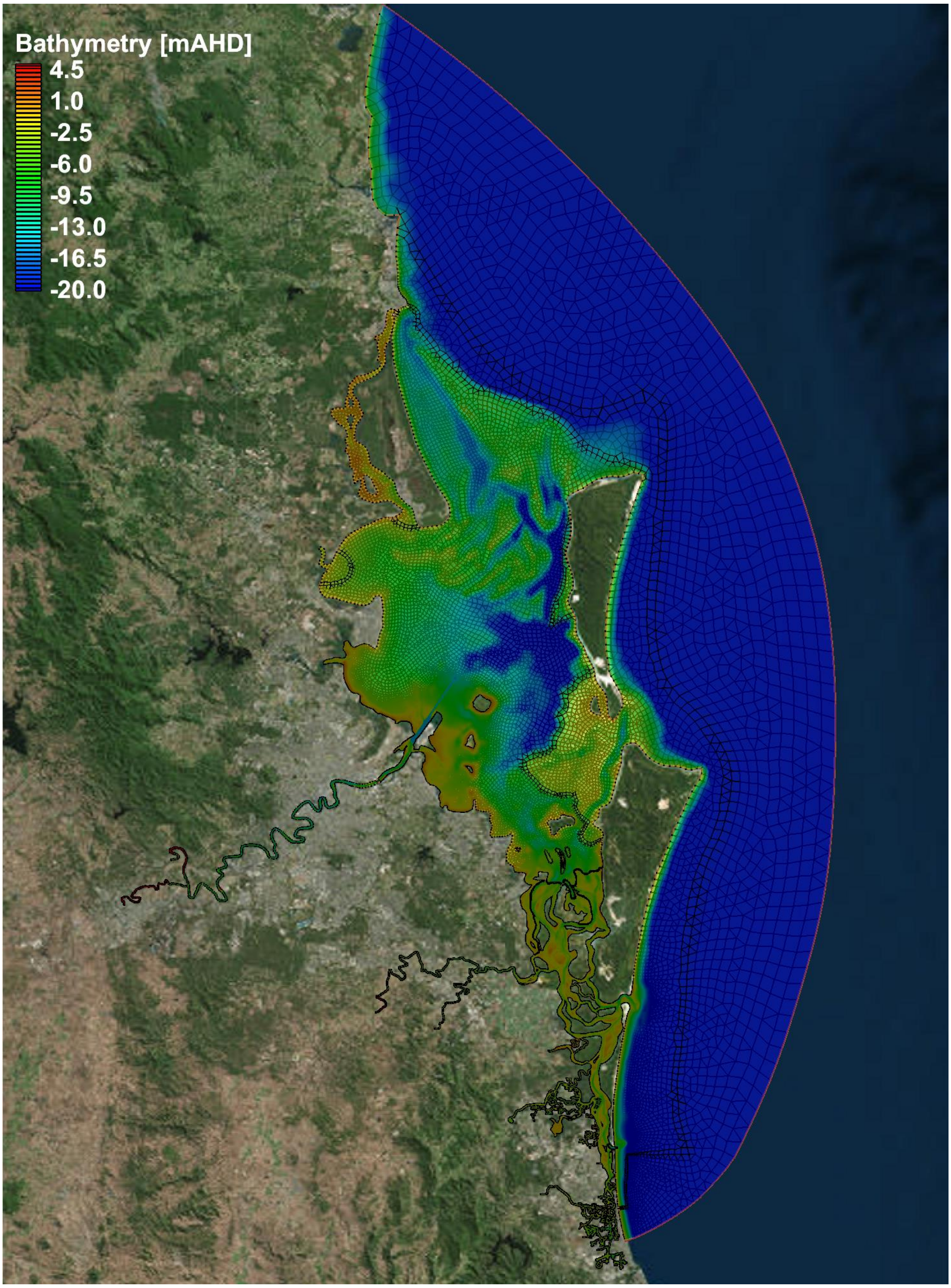

Figure 4-1 TUFLOW FV Model Mesh

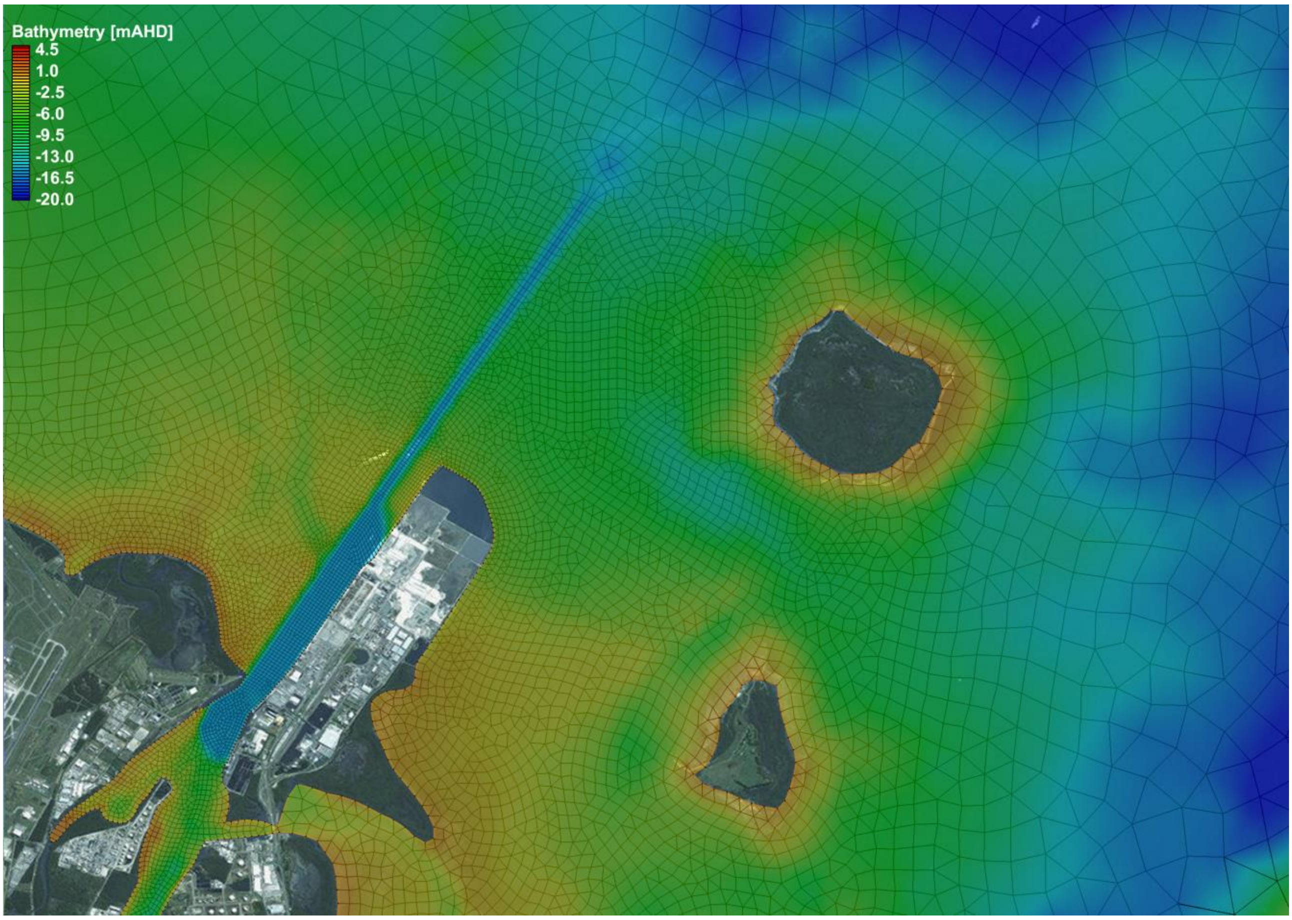

Figure 4-2 TUFLOW FV Model Mesh in the Dredged Area

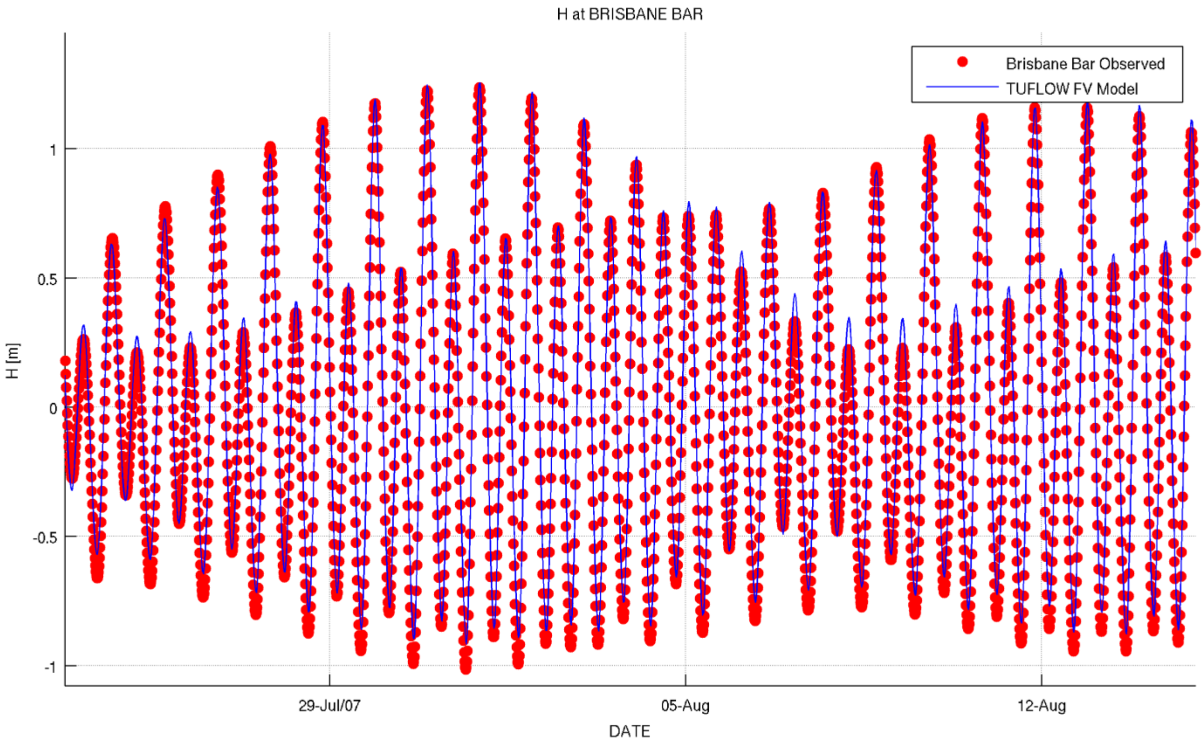

Figure 4-3 Water level comparison at Brisbane Bar

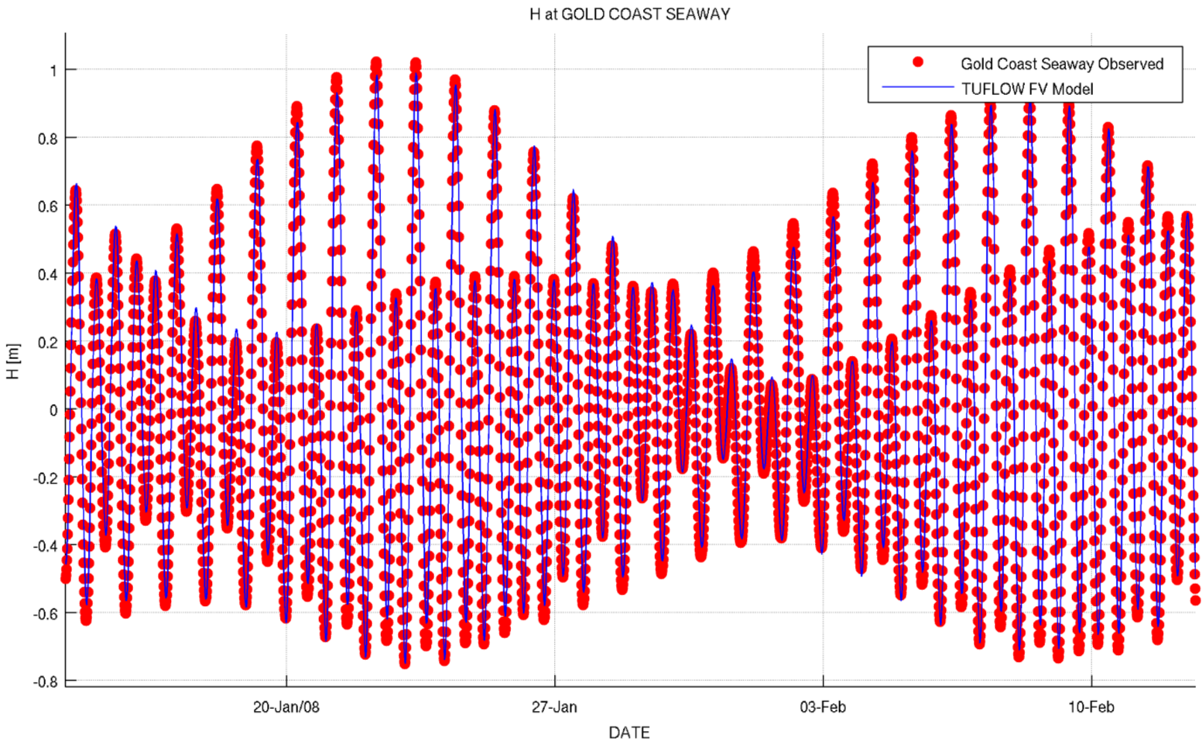

Figure 4-4 Water level comparison at Gold Coast Seaway

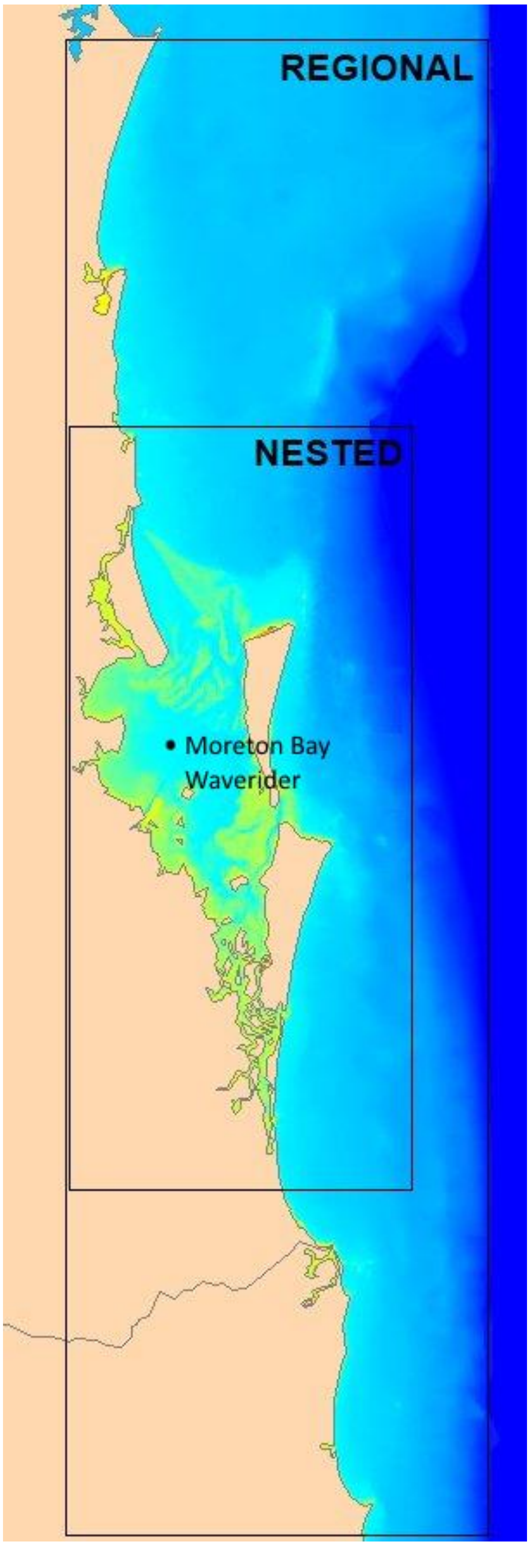

Figure 4-5 SWAN model domains

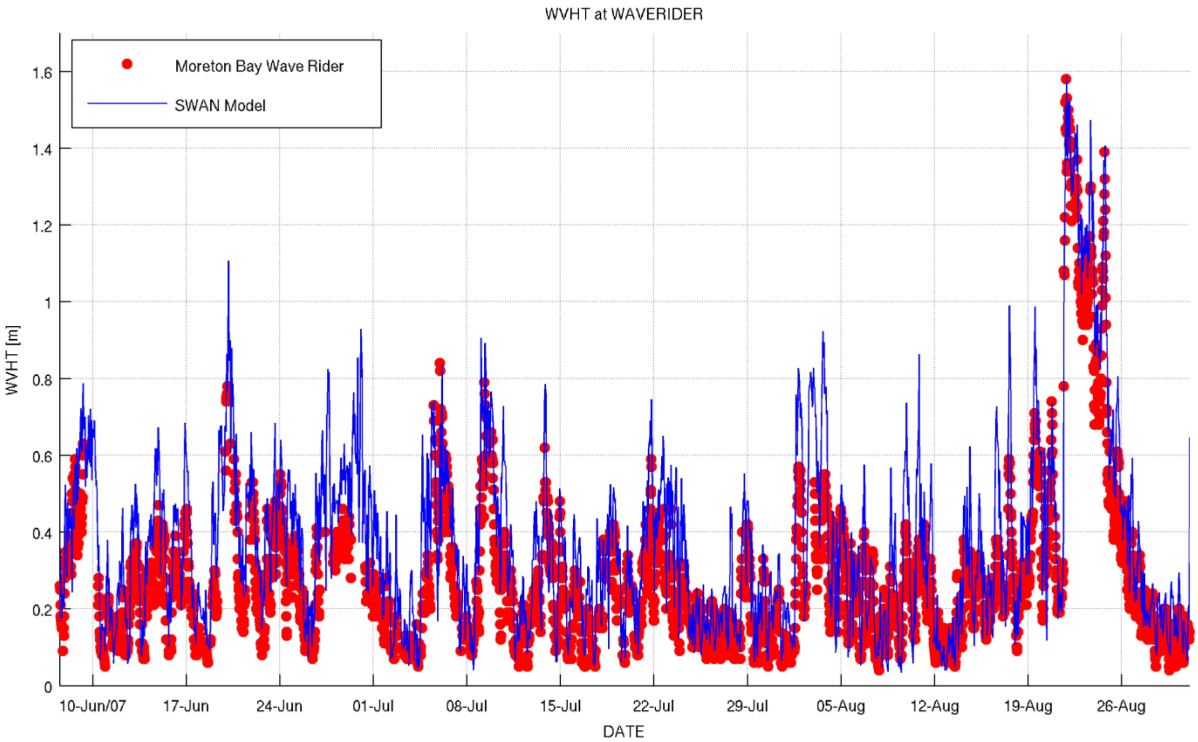

Figure 4-6 Significant wave height at Moreton Bay Wave Rider

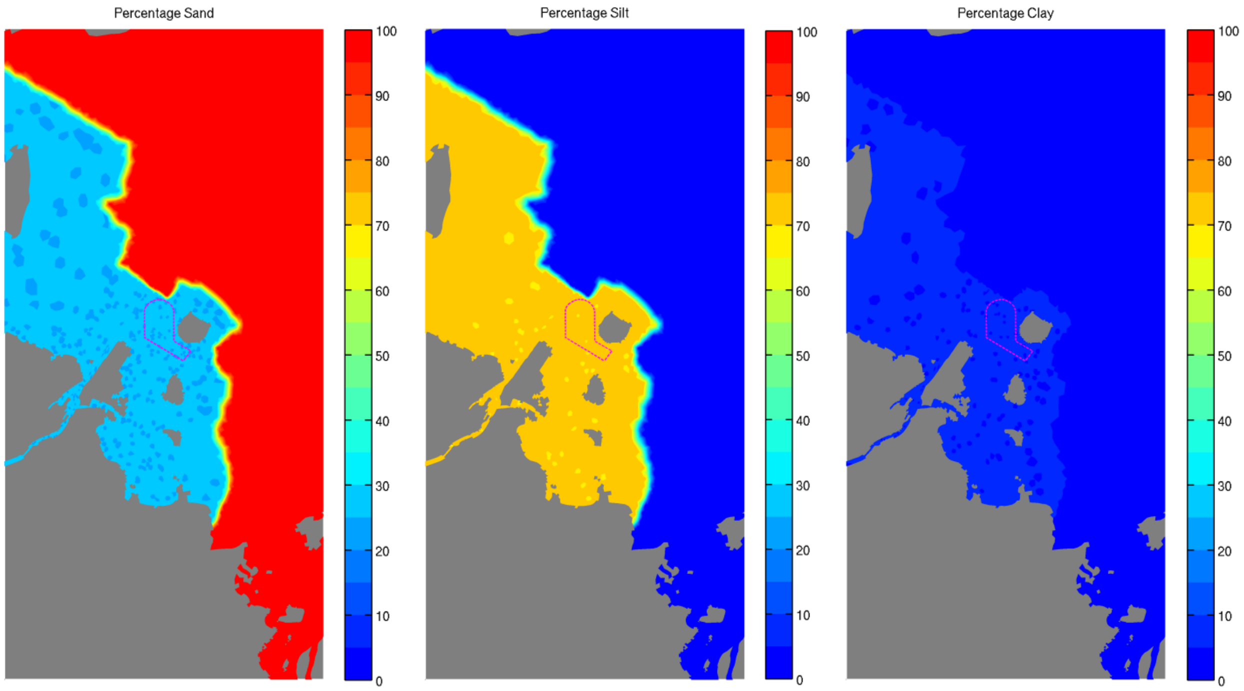

Figure 4-7 Pre-warm up sediment distributions

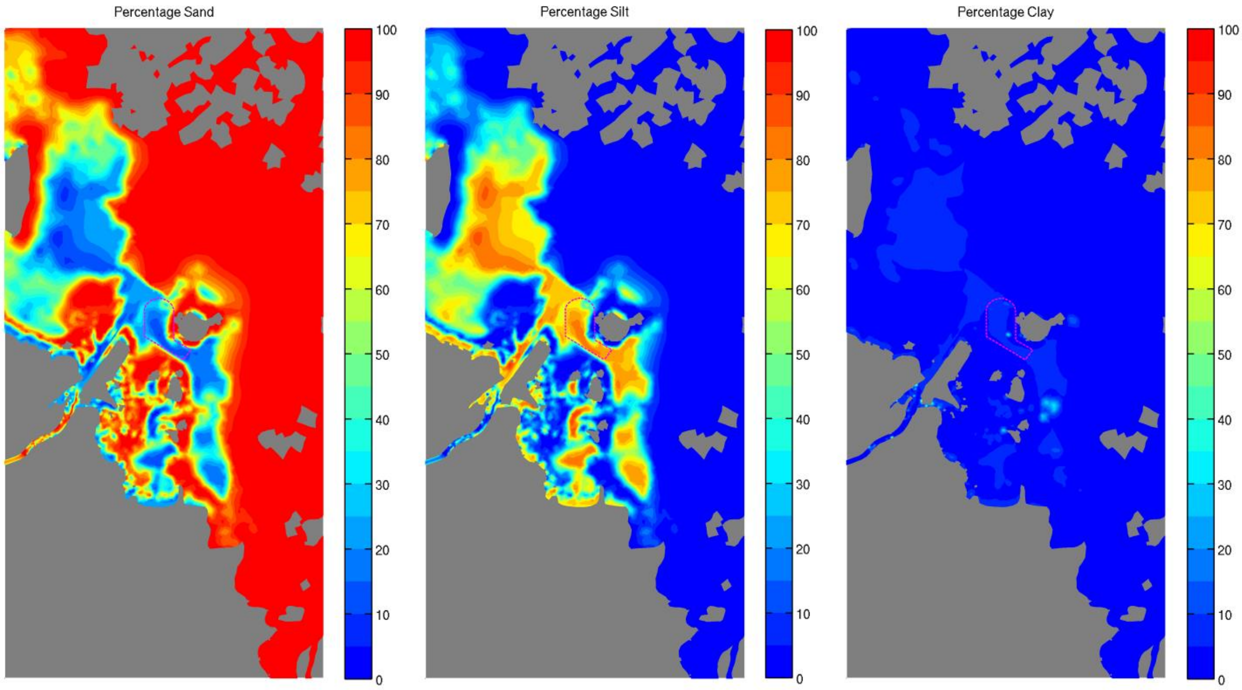

Figure 4-8 Post warm up sediment distributions

4.4 Plume Track Results

Plume tracks have been presented spatially as both a sheet plot and transect in this section. Both plots show the modelled results alongside the sampled data. In the case of the sheet plots depth averaged Total Suspended Solids (TSS, in mg/L) is presented along the sampled transect and over the modelled domain for the sampled and modelled plots respectively. These plots help to show spatial patterns both in the shape, extent and path of plumes as well as patterns in the ambient sediment. The transect plot shows the variation in sediment entrainment along the entire water column through the transect. This is useful to identify the mode in which a plume moves and intensity throughout the water column.

The instrument is able to resolve the water column at a far higher resolution than the model, typically with ~0.25 m vertical accuracy along ~2.5 m horizontal spacing. Contrast this with the model's mesh resolution of 20 – 30m and 2 m vertical 'bins'. The result is that the model will tend to 'smooth' the sediment concentrations over a larger volume, i.e. if the peak concentrations between the model and the observed look similar then the model likely has a higher amount of sediment in the water column (due to the same concentration in a larger volume).

4.4.1 Channel Dredging 13/02/2017 09:30 and 10:30

Model results for the channel dredging commencing at 9:30 am on the 13th February 2017 have been presented alongside data. Figure 4-9 shows how the depth averaged TSS changed as a result of overflow. This plot shows a sharp gradient in TSS with distance from the current dredging location along the dredge path. This reduction in intensity is a result of mixing in the water column and settling of the sediment. Figure 4-10 shows the TSS concentration shortly after dredging and overflow. As can be observed, the model predicts that most of the dredge material has settled out with the remaining dredge related sediment remaining in the lower half of the water column.

The large sediment plume to the west of the dredging location (adjacent to Luggage Point and visible in both figures) is a natural ambient resuspension event in these shallow areas. This highlights the relatively low contribution of dredged sediment plumes against the background turbidity levels.

4.4.2 DMPA Disposal 13/02/2017 11:20

Dredged material disposal at the DMPA, south of Mud Island, was monitored from 11:00 am 13th February 2017 for a period of two hours. Figure 4-11 shows a small plume immediately after disposal of relatively high concentration. The dredged sediment was observed to quickly settle to the bed of the DMPA with a plume of lower intensity then inside the dredge channel being observed. This plume was monitored as it migrated south-east with the current. After ~1.5 hours the disposal plume had visually disappeared. The modelling shows a slight tendency of the model to overpredict the peak concentration of the plume. The large plume south of the transect (shown in the plan view map) is a background resuspension plume during this period.

4.4.3 Channel Dredging 13/02/2017 13:00

Dredging operations by the swing basin were monitored and modelled for the operations being conducted from 1:00pm 13th February 2017. Similar spatial patterns to those observed in the maintained channel were observed in the swing basin with the dredge plume quickly settling from the water column. A strong ebbing tide meant that plumes were immediately pushed towards the outer bar. As can be seen in Figure 4-12 the plume has been drawn out seawards and diluted in the surrounding water. The model predicts the peak concentrations, though over a larger area suggesting a greater overall mass of sediment in the water column. This is a conservative result from a plume tracking perspective, and ensures that the model resolution will still capture the extent of the plume rather than diluting it too quickly in a coarse mesh.

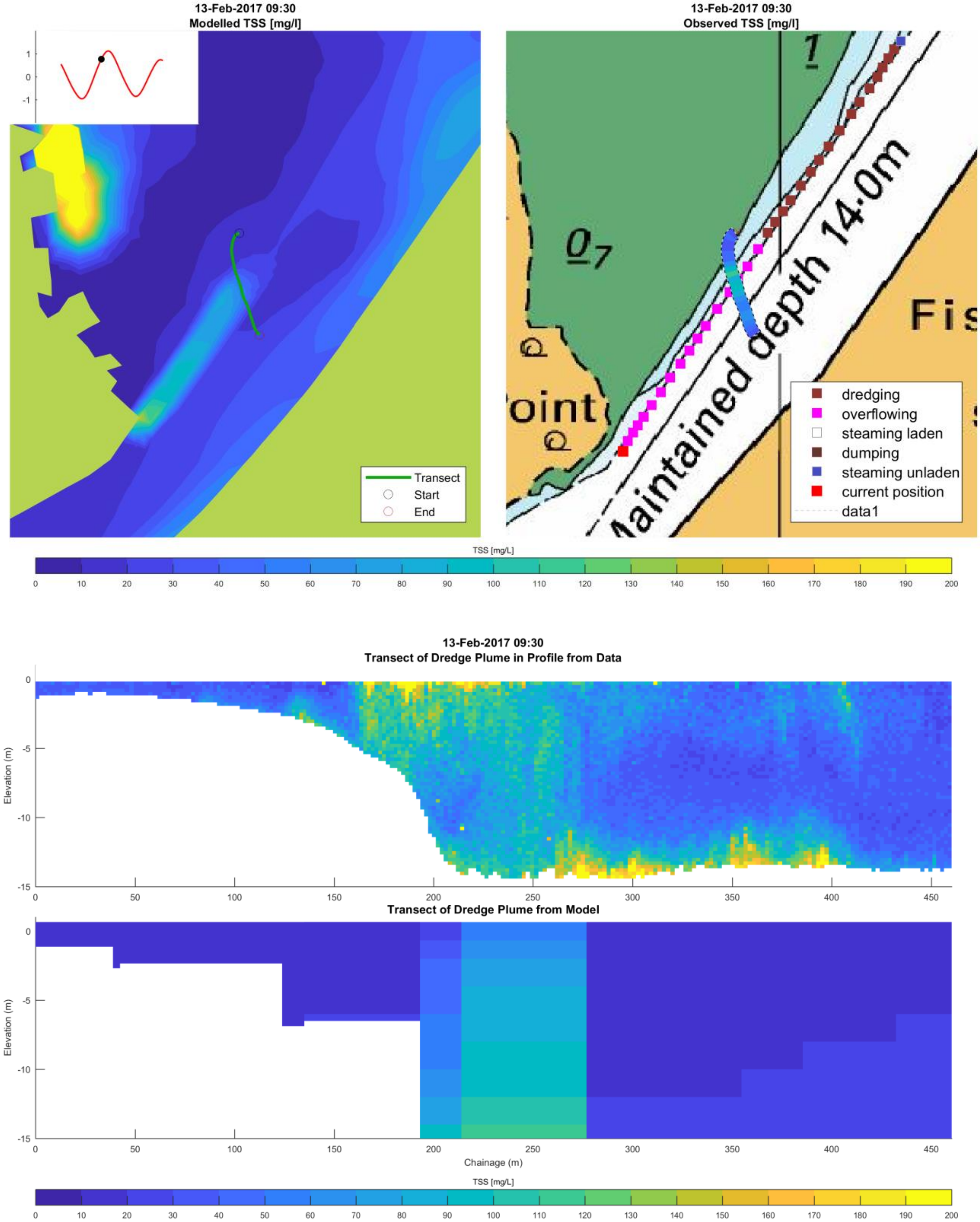

Figure 4-9 Channel Dredging During Overflow

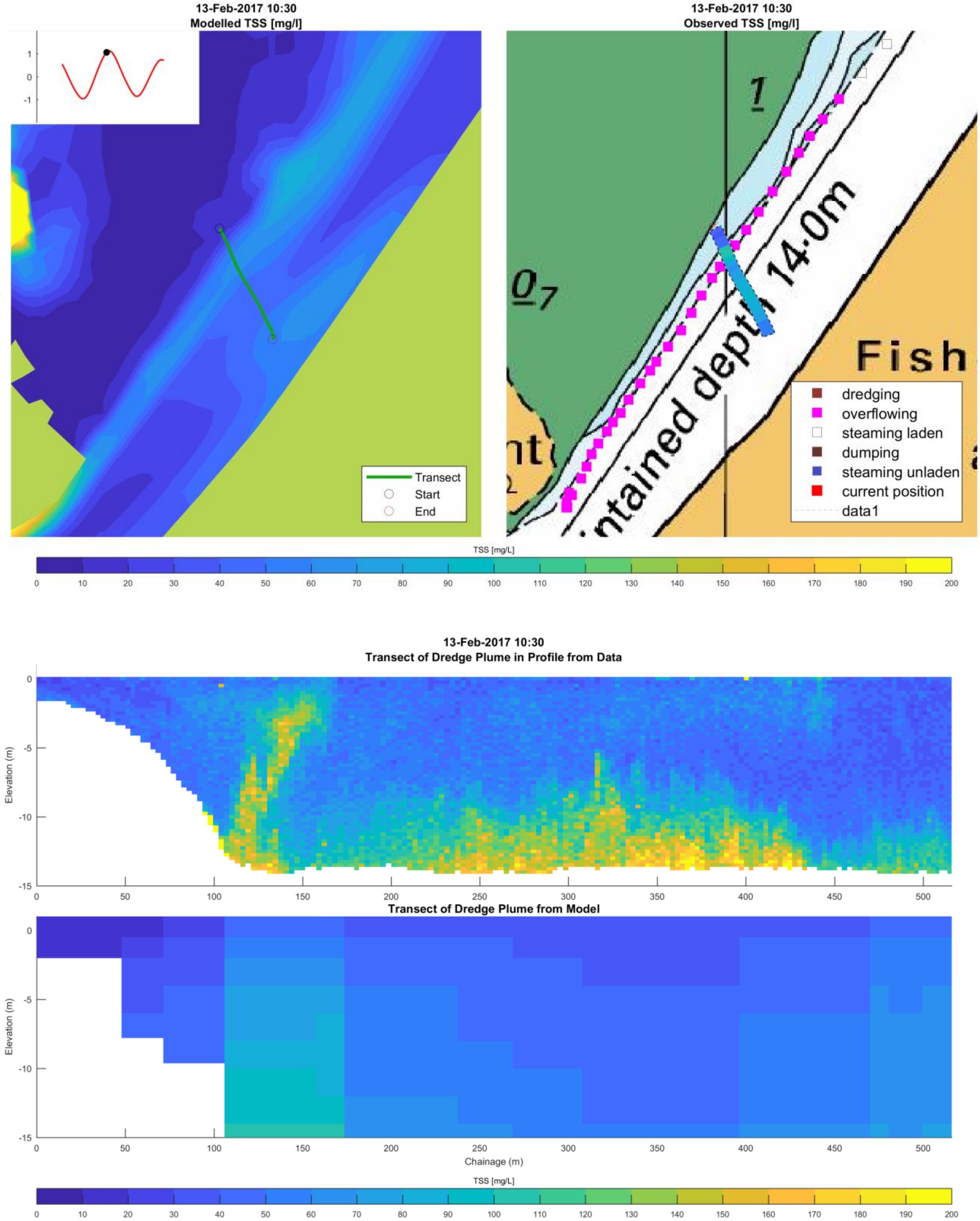

Figure 4-10 Channel Immediately After Dredging

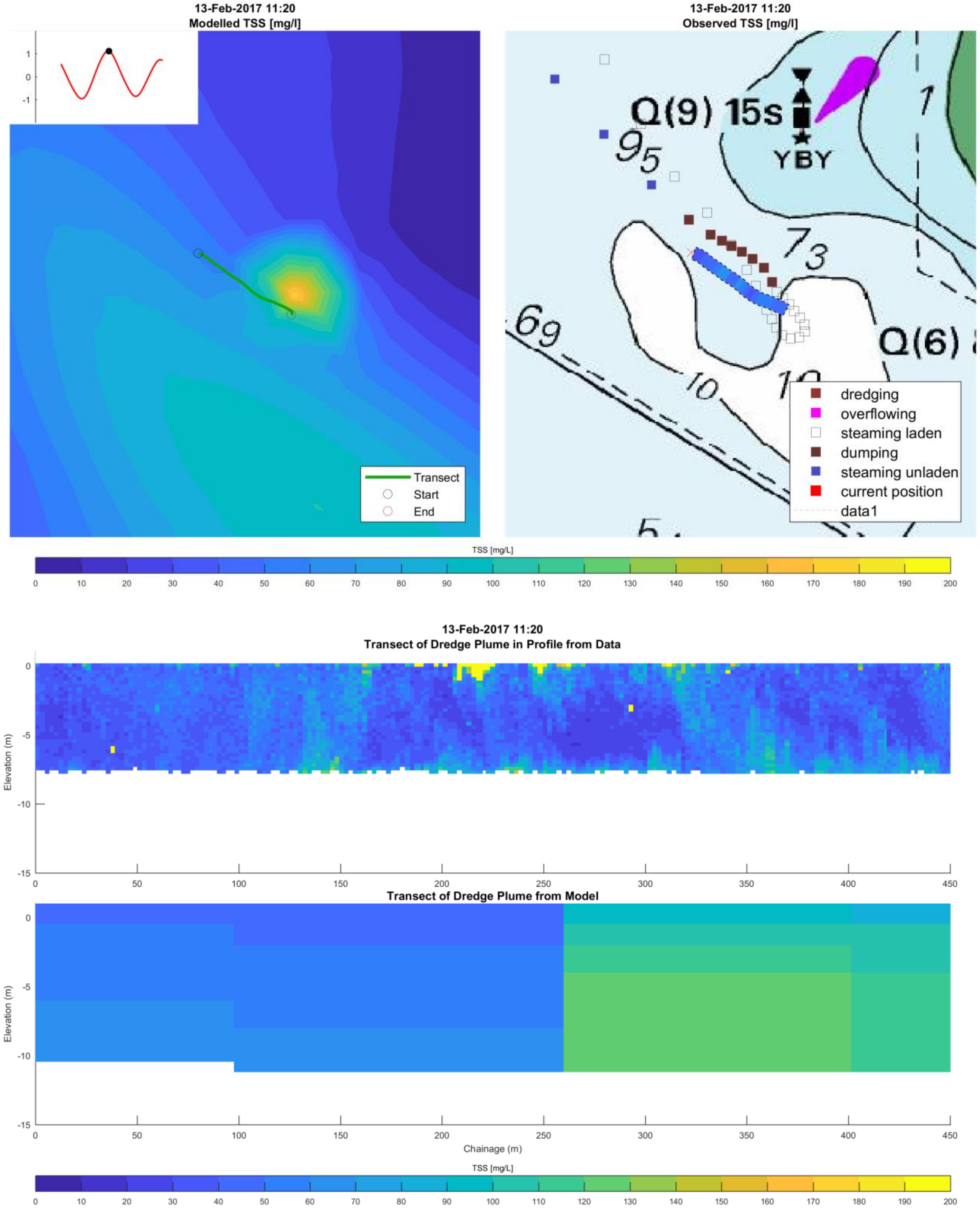

Figure 4-11 Dredge Plume Immediately After Disposal

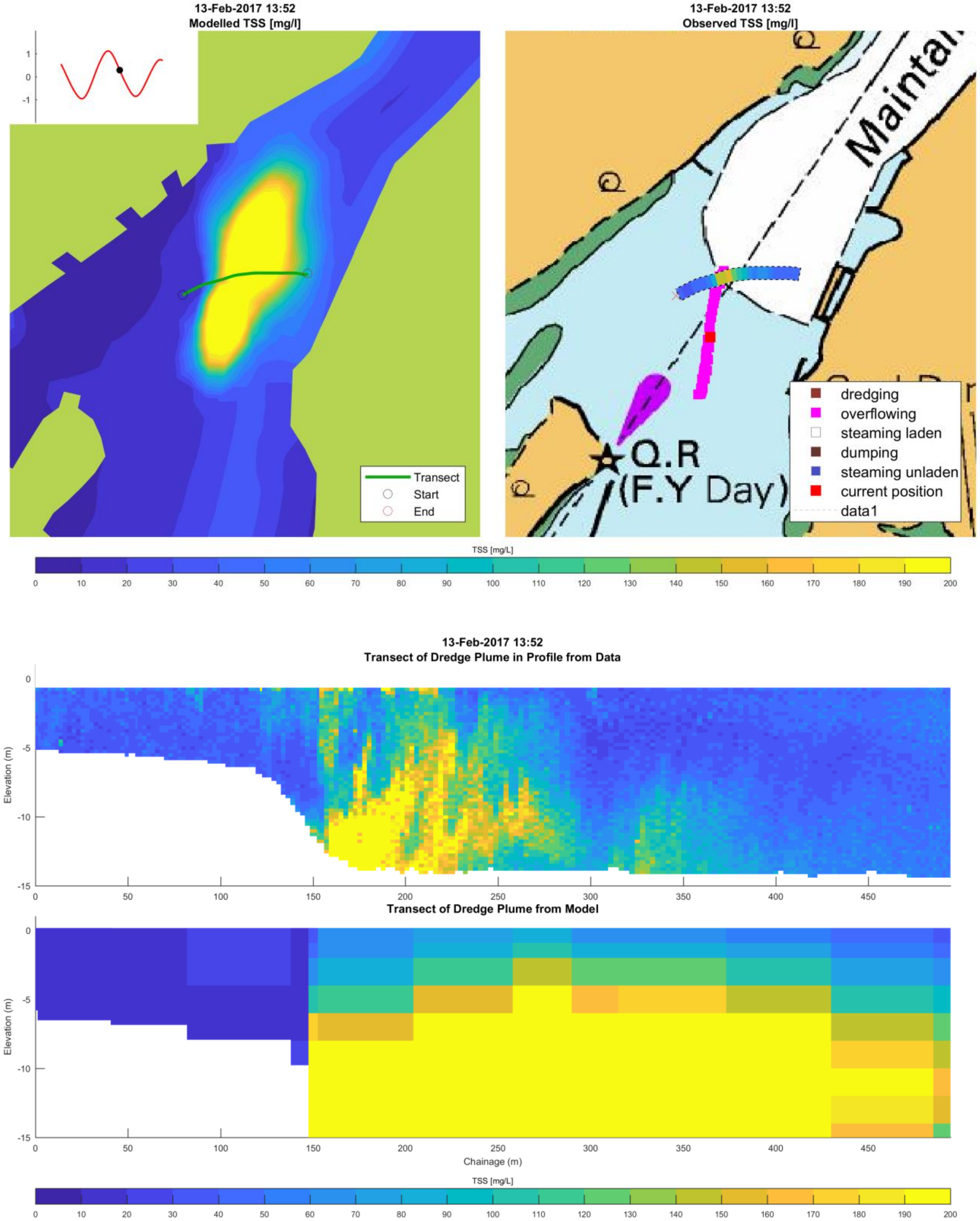

Figure 4-12 Plume Movement During Ebbing Tide

4.5 Maintenance Campaign Modelling Discussion

The modelled maintenance campaign extends for a month throughout February 2017. Maintenance dredging occurred in the channel and berths adjacent to Fisherman Islands, Bulwer Island, Pinkenba and Portside Wharf. Dredged material was placed at the Mud Island Dredge Material Placement Area (DMPA).

An animation showing the turbidity plumes generated by the actions of the dredge is presented in Figure 4-13 (snapshots from this are found in Figure 4-14 to Figure 4-21). Plumes are shown as coloured contours with any plumes below 5 NTU considered within background levels and are not shown. Vector arrows of the currents are overlain, as is the dredge position with colours according to the operational state. Note that these plots show only the contribution of dredged sediment and do not include ambient turbidity.

This animation shows that the plumes typically occur immediately adjacent to the dredge activity, and migrate a short distance from these areas. The disposal plumes typically dissipate (reduce to background levels) within three hours of placement. Plumes due to overflowing within the port areas remain entrained in the water column for longer, though do continue to fall out of suspension, minimising any cumulative impact. Primarily the dredge-related sediment plumes in the channel areas are entrained in the water column due to the current energy and follow the paths of these currents. Any plume that disperses beyond the areas of high current flow tends to fall out of suspension. Some wave-related resuspension events do occur, though there is a very high level of background resuspension during these events, minimising the impacts of the dredged material.

The snapshots (Figure 4-14 to Figure 4-21) show that over a range of dredging events, the behaviour of dredge plumes are consistent, regardless of the ambient condition or the location of dredging activity. The plumes do not tend to advect far from the site of dredging, even when dredging during large flooding or ebbing tide currents. However, as the model resolution reduces significantly upstream beyond Breakfast Creek, caution is advised when interpreting the model results in this region. Remnant plumes from previous dredging in other areas can be seen in the various snapshots. These are likely entrained in the higher current regions, though are well within background levels in this reach of the Brisbane River and are unlikely to be visible.

The peak increase over background levels within the port areas is ~50 NTU, which quickly dissipates to a slightly more persistent 20 NTU plume. Typical ambient turbidity levels around Fisherman Islands are ~20 NTU and range up to over 100 NTU during wave events. The model has not been validated to turbidity levels in the Brisbane River, and based on the comparisons to the plume transecting, is likely underpredicting the background levels there.

Figure 4-13 Animation of Dredging Activity and Associated Plumes (07/02/2017 – 10/02/2017)

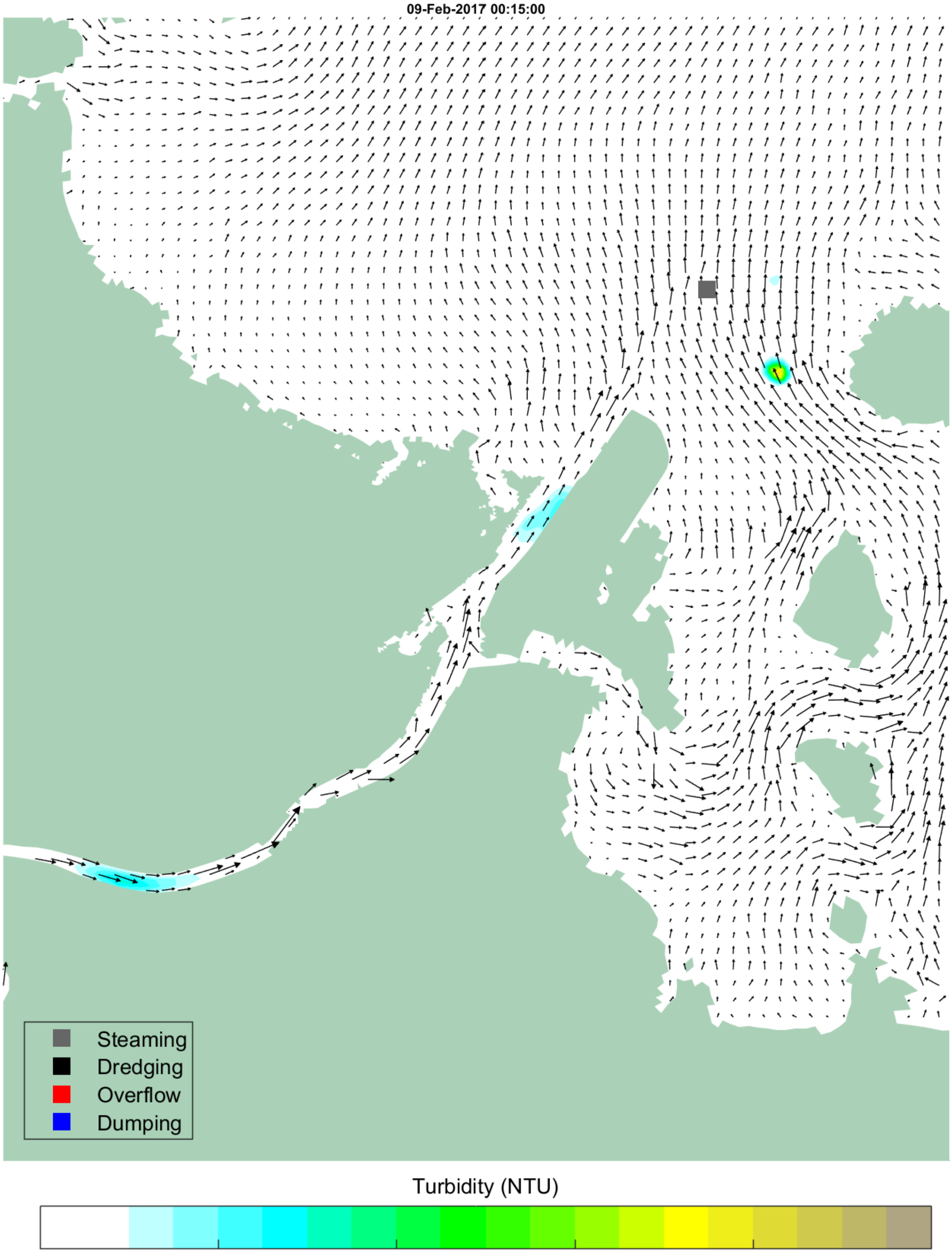

Figure 4-14 Snapshots of Dredge Activity (Disposal and ebbing tide)

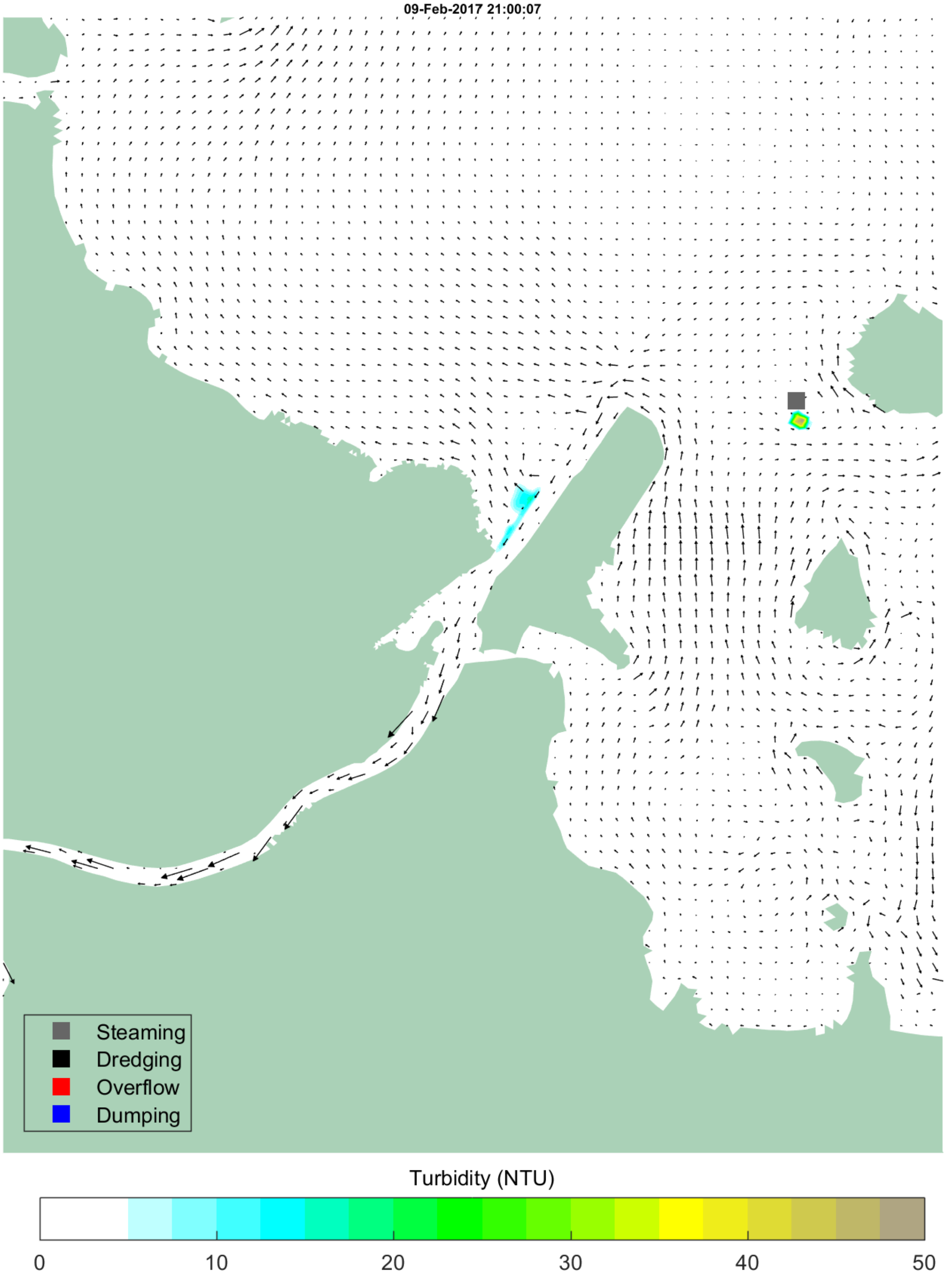

Figure 4-15 Snapshots of Dredge Activity (Disposal and flooding tide)

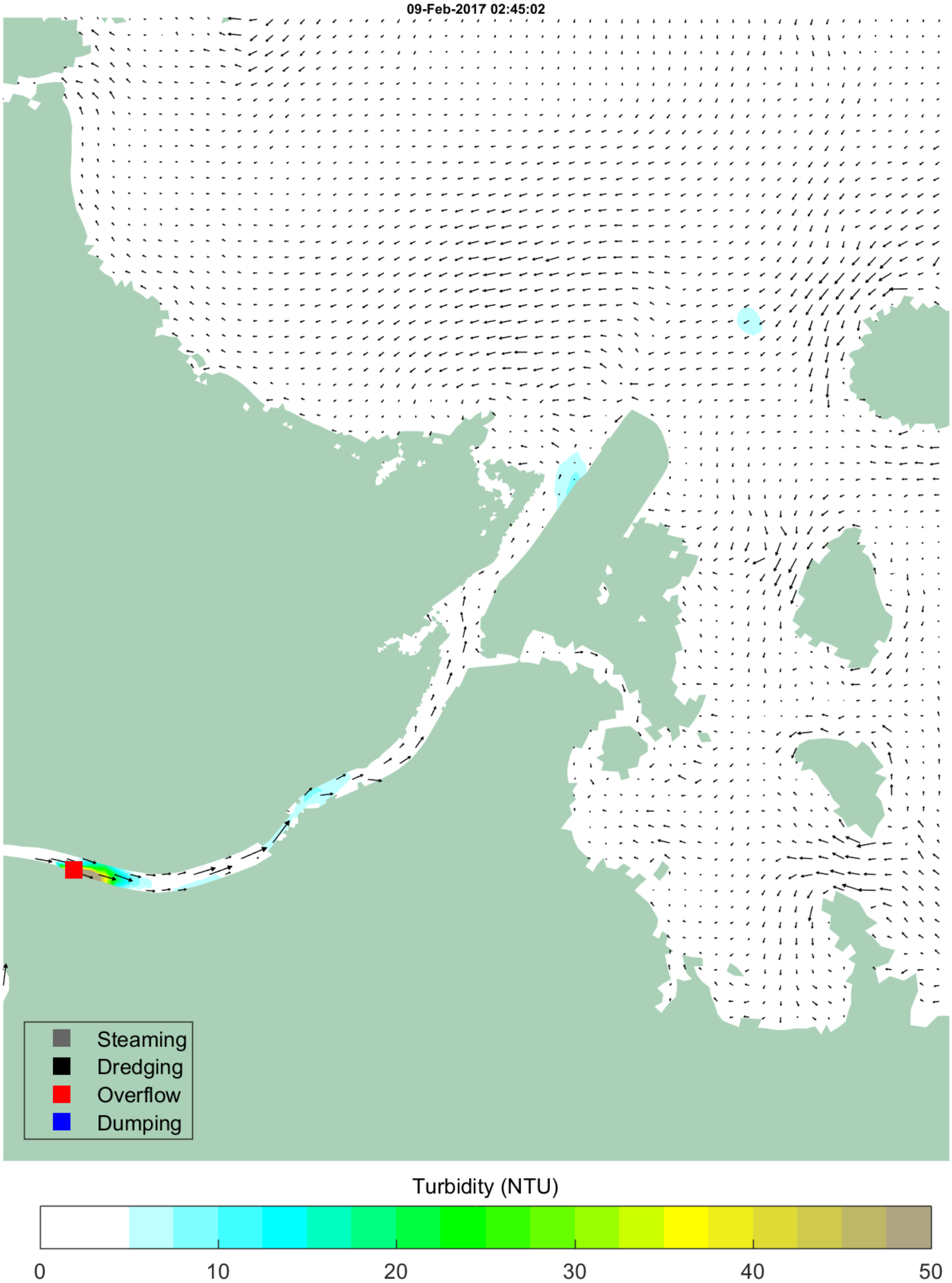

Figure 4-16 Snapshots of Dredge Activity (Overflowing during ebbing tide)

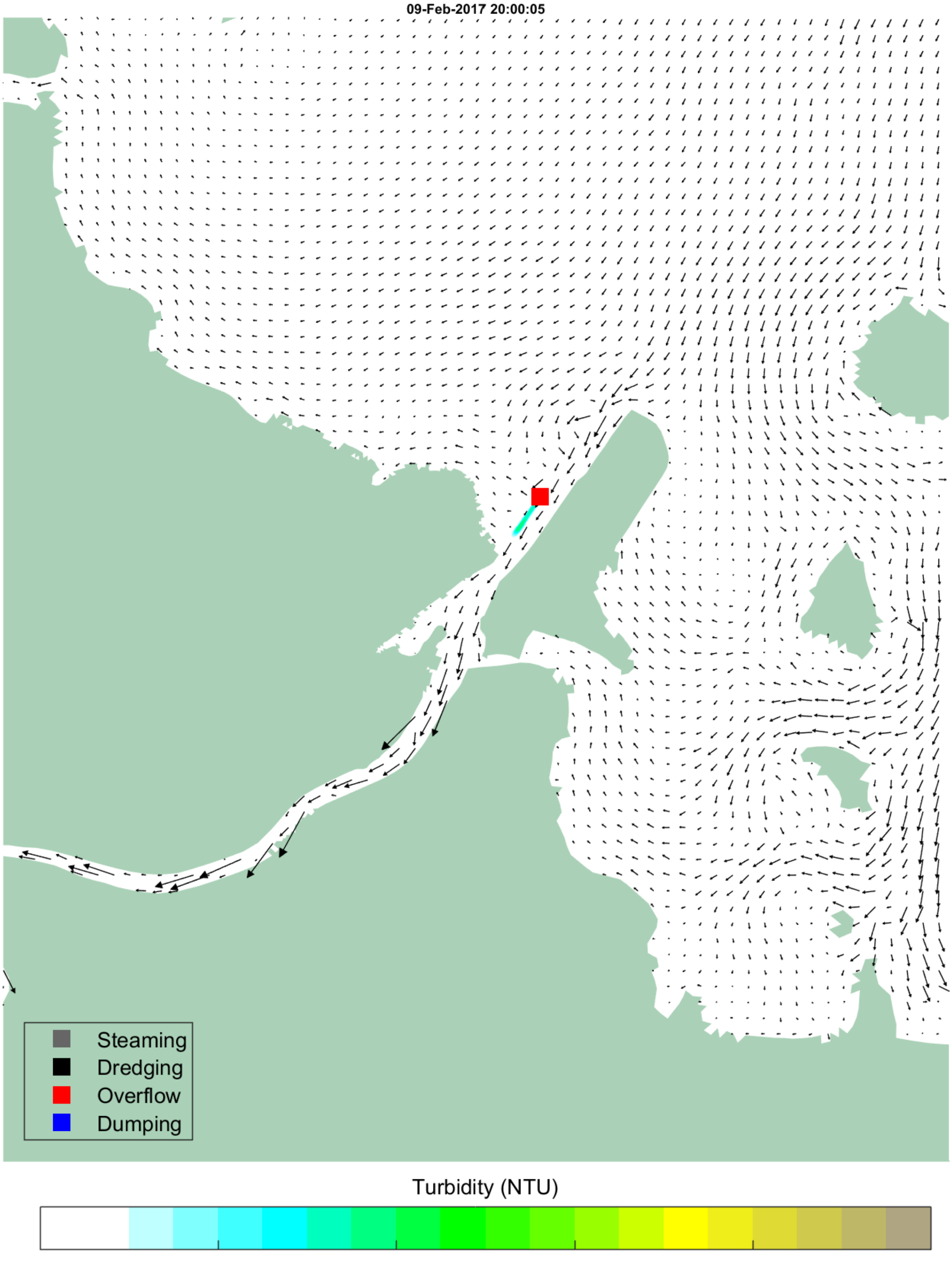

Figure 4-17 Snapshots of Dredge Activity (Overflowing during flooding tide)

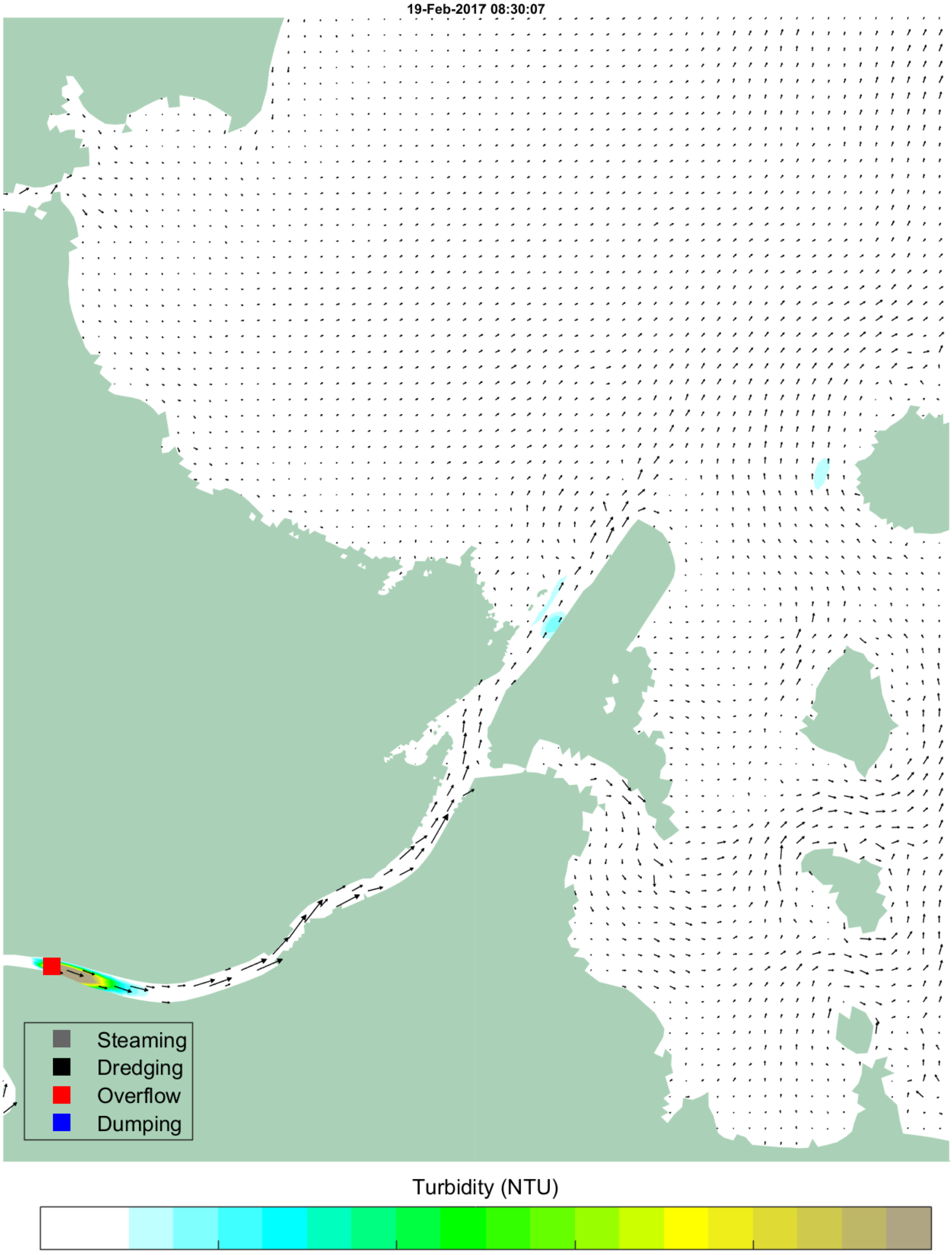

Figure 4-18 Snapshots of Dredge Activity (Overflow at Portside Wharf)

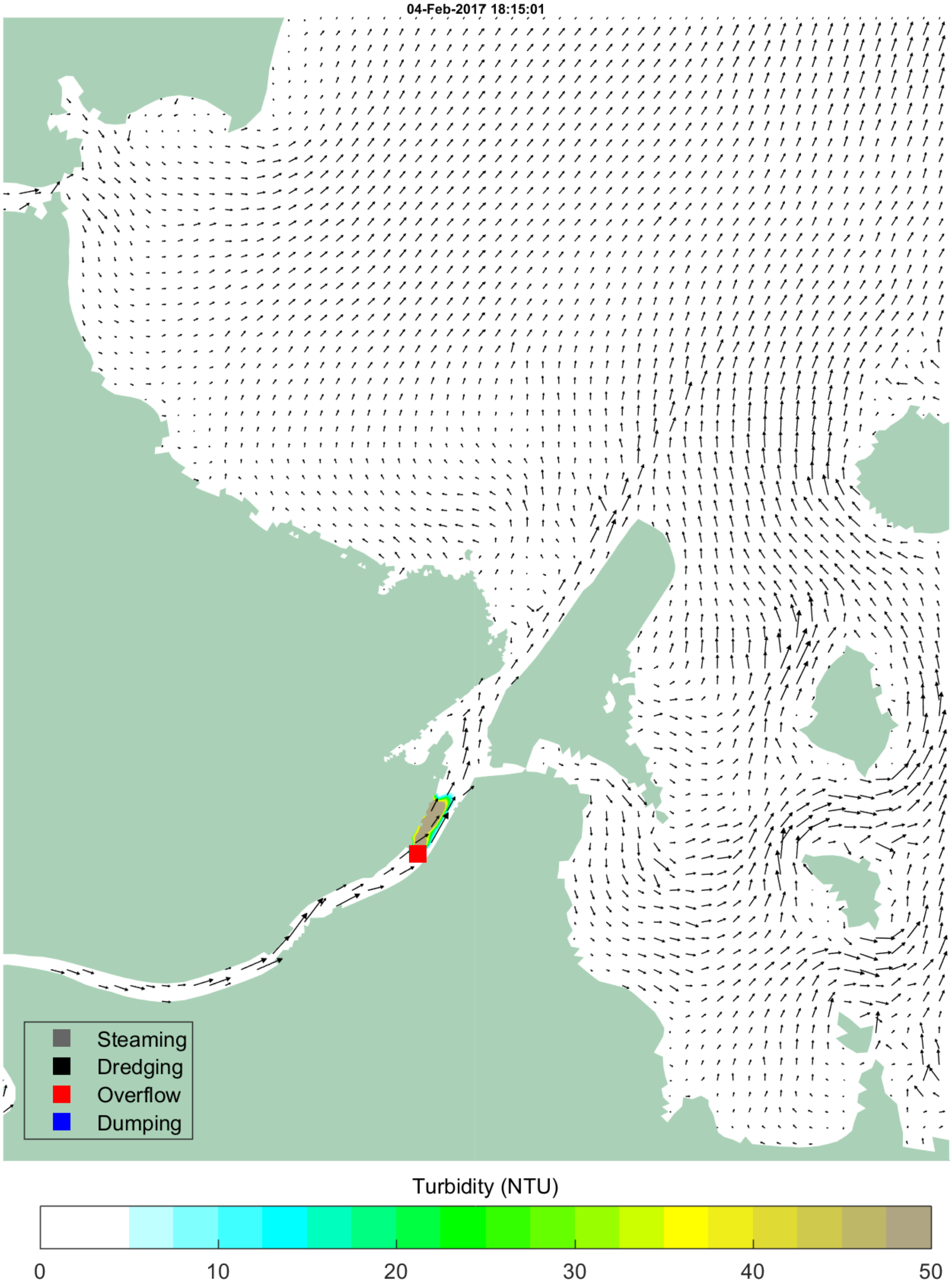

Figure 4-19 Snapshots of Dredge Activity (Overflow at Pinkenba)

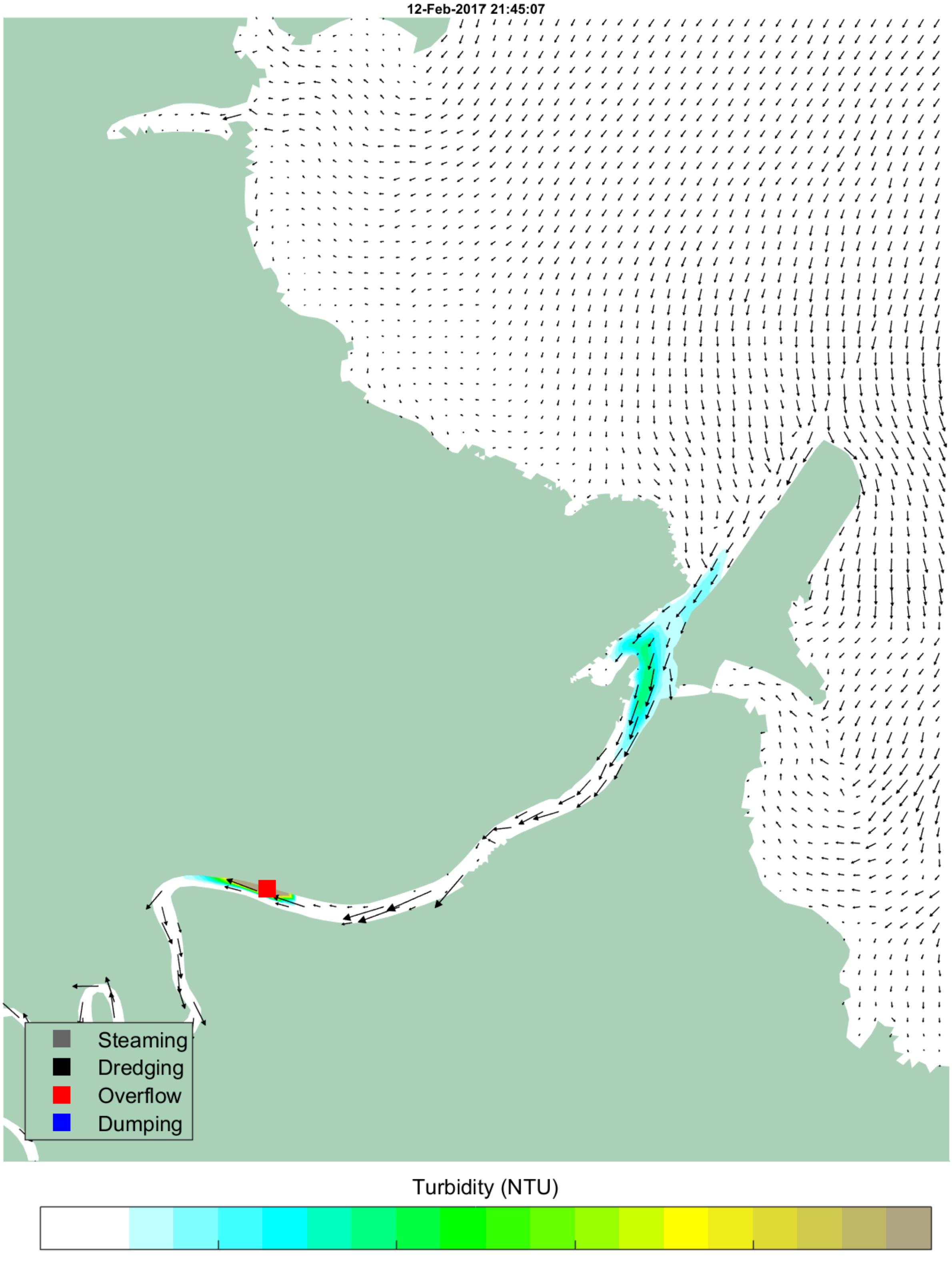

Figure 4-20 Snapshots of Dredge Activity (Dredging at Portside Wharf)

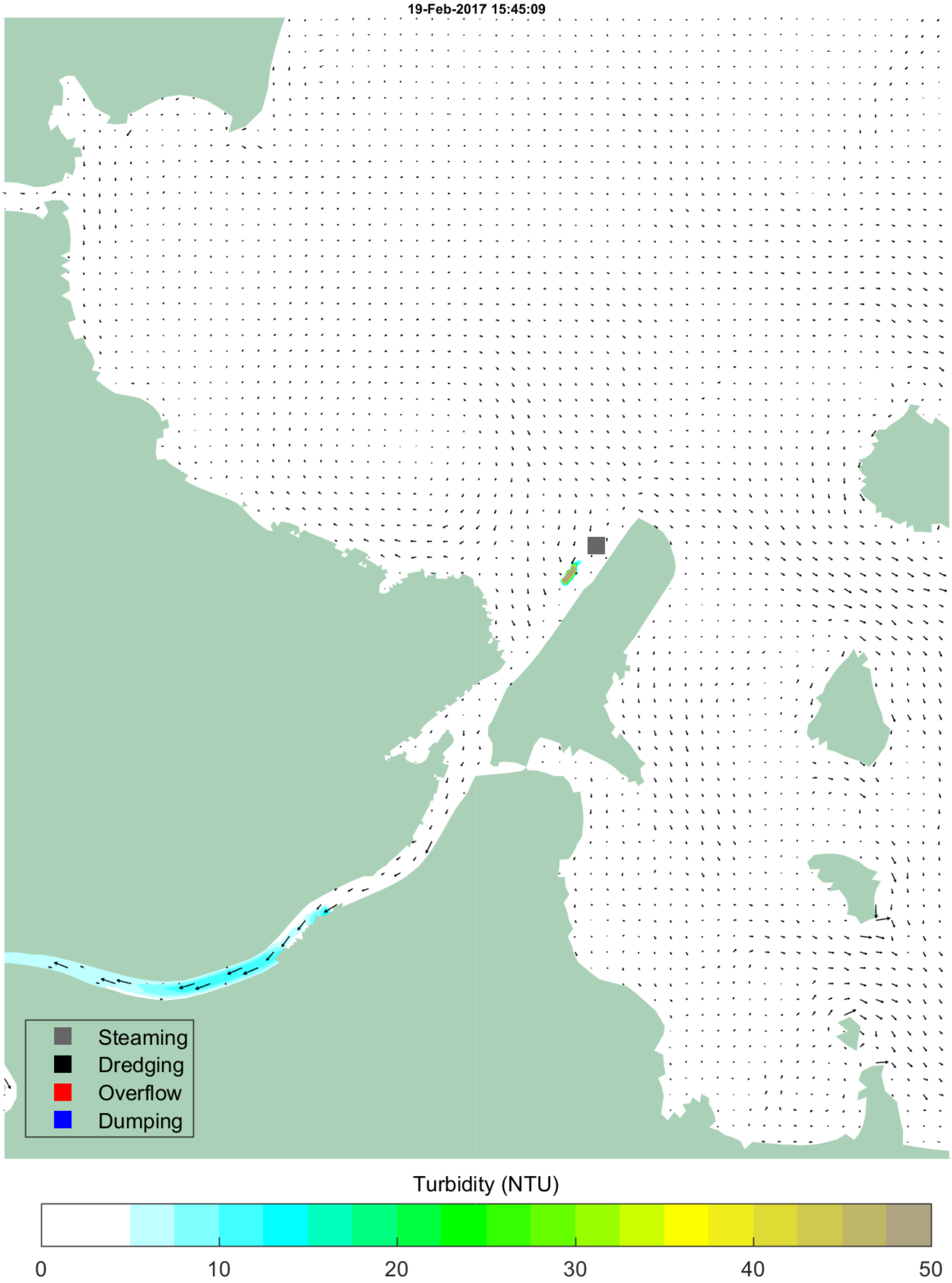

Figure 4-21 Snapshots of Dredge Activity (Dredging at Fisherman Islands)

5 Conclusions

The sediment plumes created by maintenance dredging activities at the Port of Brisbane are short-term, low intensity features (measured in hours). Monitoring of maintenance dredging shows visible plumes for up to an hour after dredge or disposal of dredged material localised around the areas of dredging activity and material placement. Modelling of the dredge campaign corroborates these observations, suggesting that the plumes return to well below background levels within a tidal cycle.

Fine materials that are suspended during dredging and overflow within the channel settles more slowly in the channel due to the high currents. These plumes typically fall out of suspension when they extend beyond the predominant current regions, limiting their influence to the channel.

The peak turbidity levels, as predicted by the modelling, are above the median ambient (background) turbidity levels. These peaks are within the peak ambient turbidity levels that are experienced during large wave-driven resuspension events, particularly in shoals on the eastern side of the channel towards Brisbane Airport.

Given the short-term nature of these plumes, and their constraint to the areas immediately adjacent to the dredging and disposal of dredged material, there is unlikely to be a cumulative impact of dredging, or a significant risk of these plumes migrating to sensitive regions. Moreover, the relative levels of the dredge-related turbidity in comparison to the overall background turbidity in areas dominated by fine sediments is unlikely to impact on sensitive receptors.

6 References

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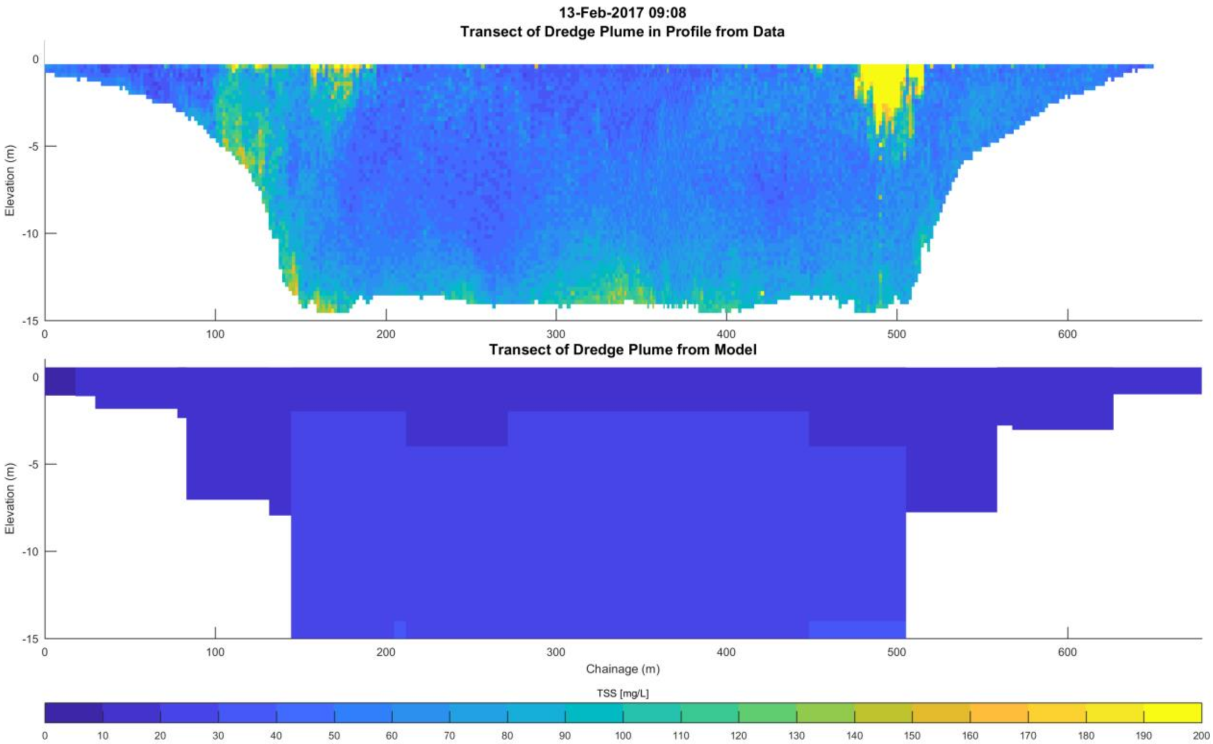
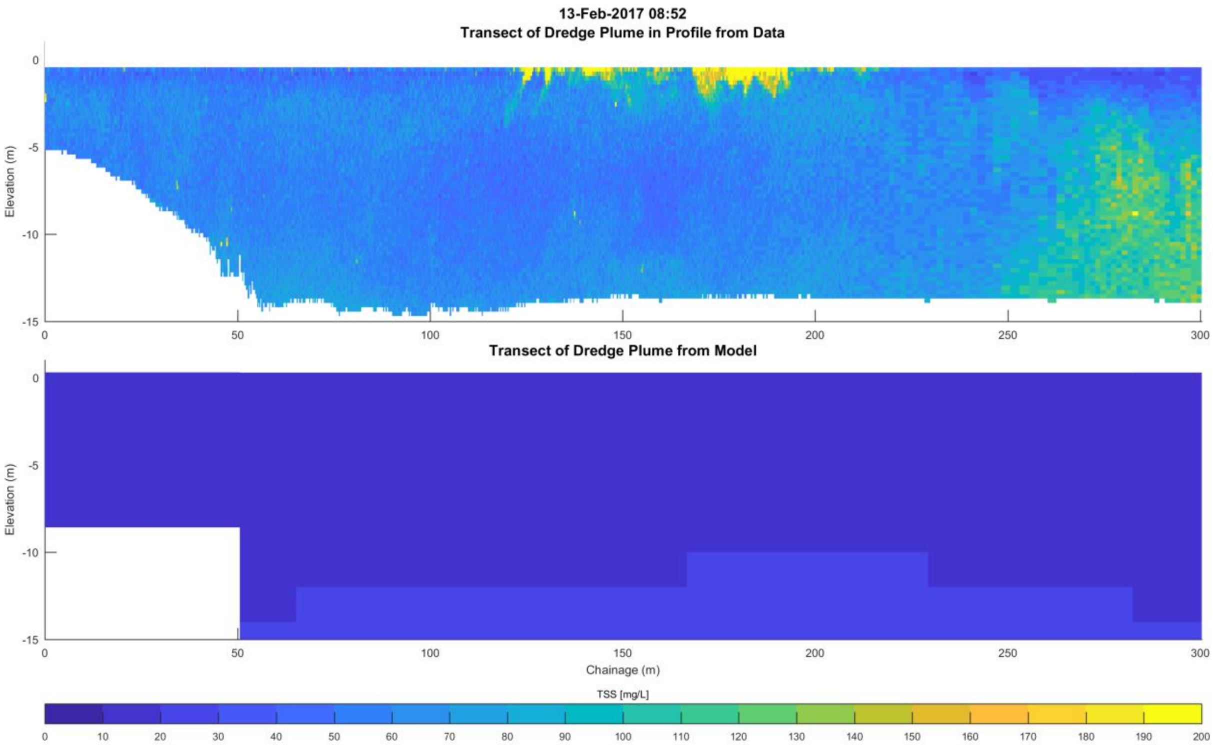
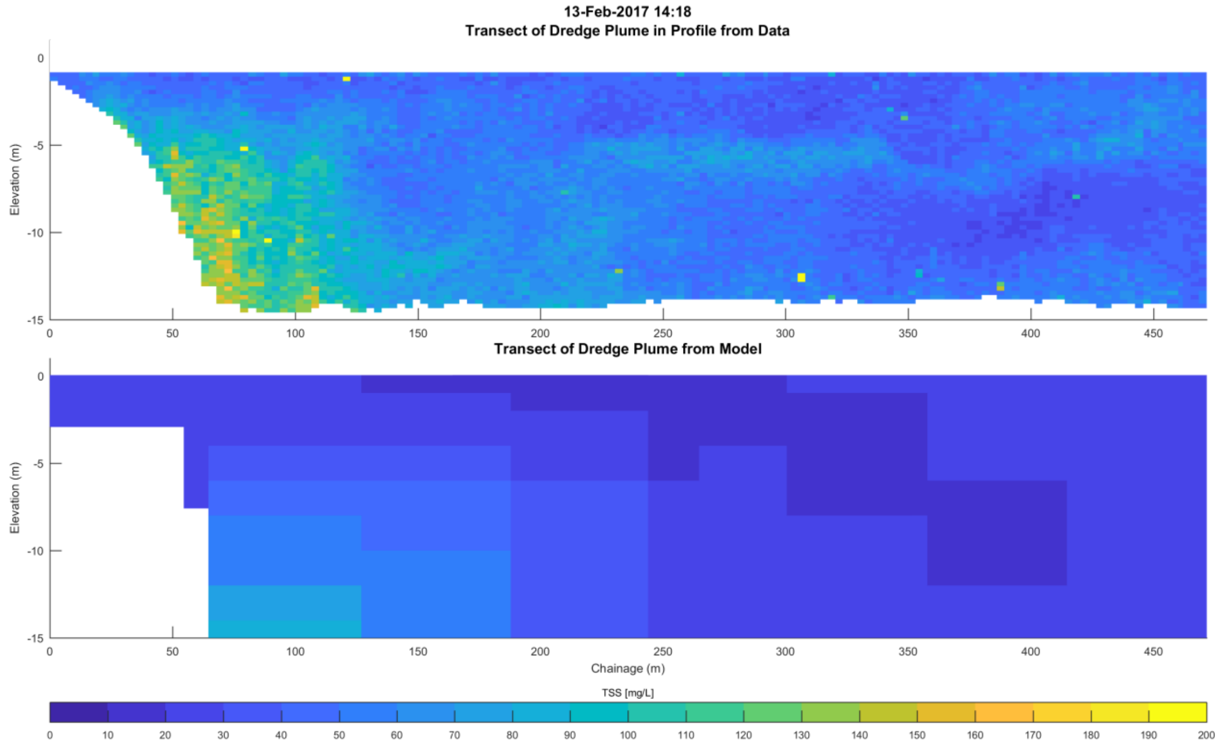
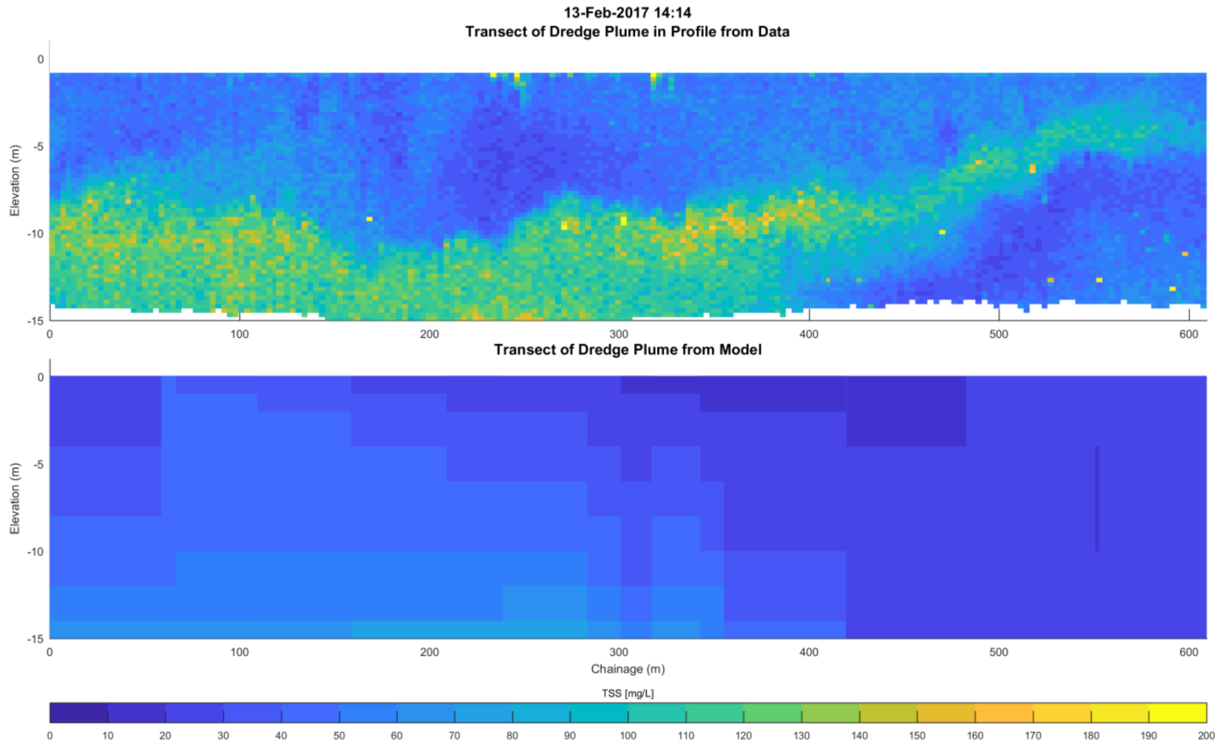
Appendix A Model Dredge Plume Transect Validation

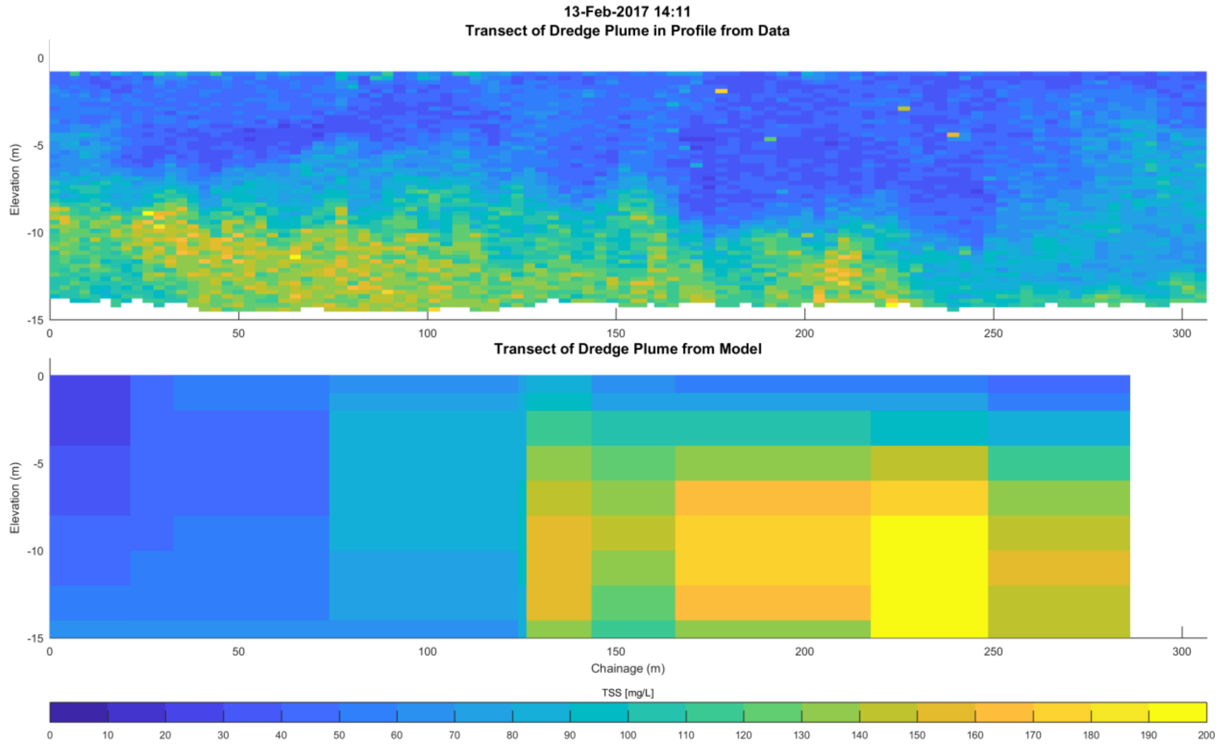


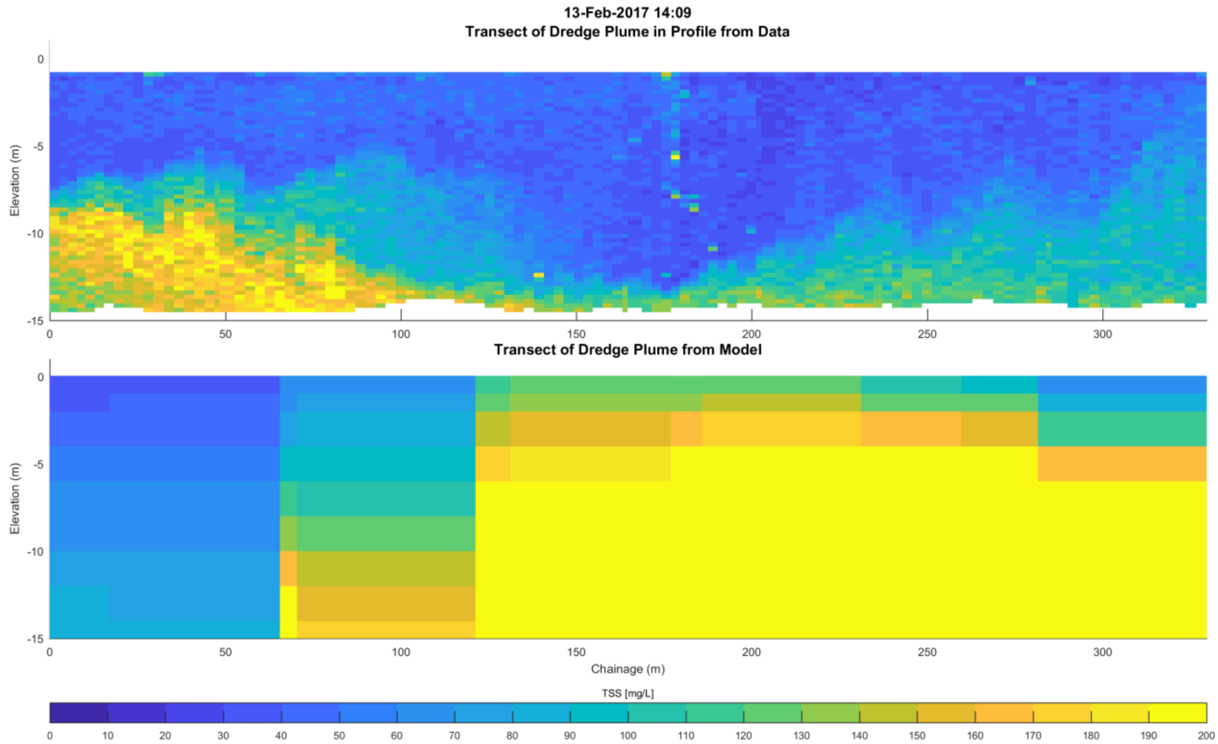



13-Feb-2017 14:18
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

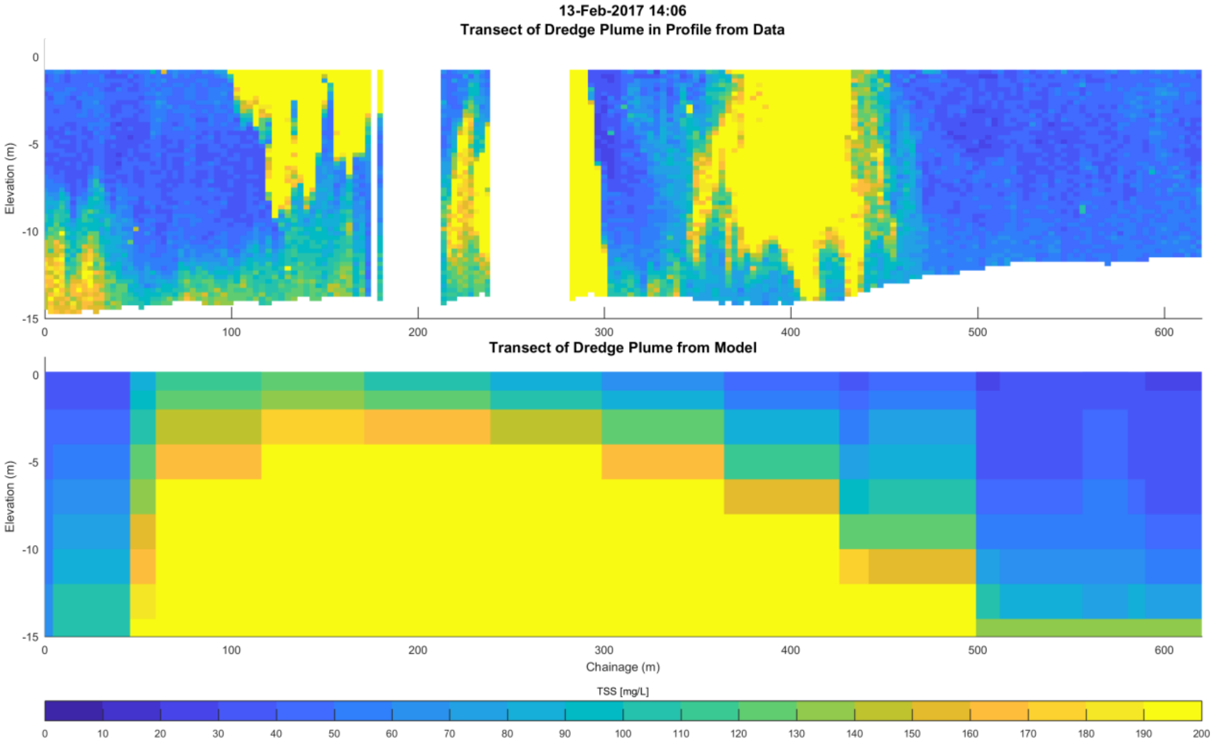

13-Feb-2017 14:14
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

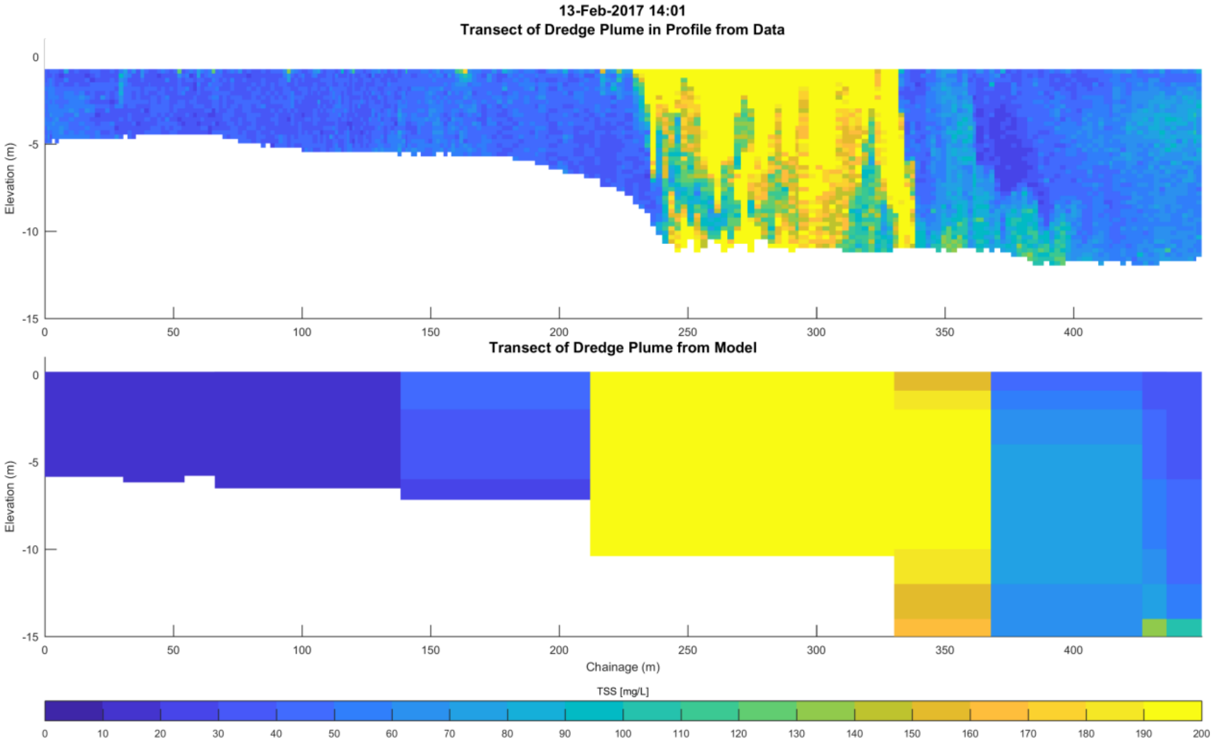
Model Dredge Plume Transect Validation

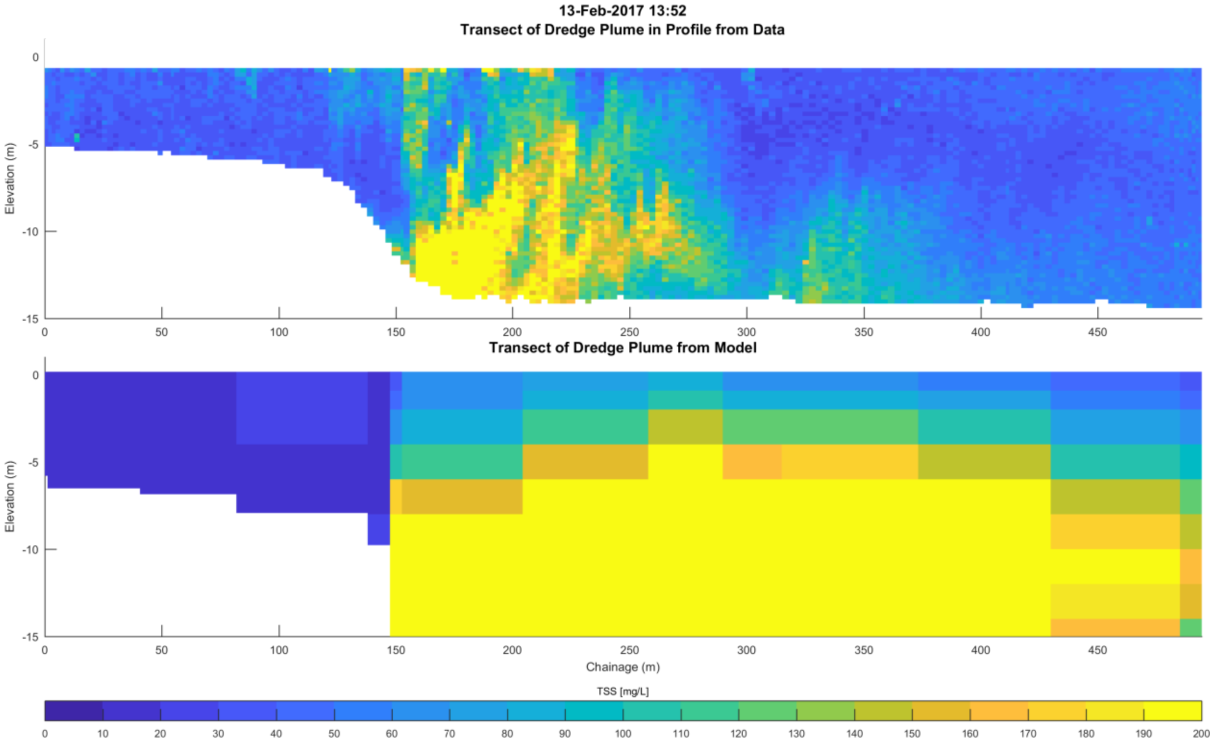




Model Dredge Plume Transect Validation



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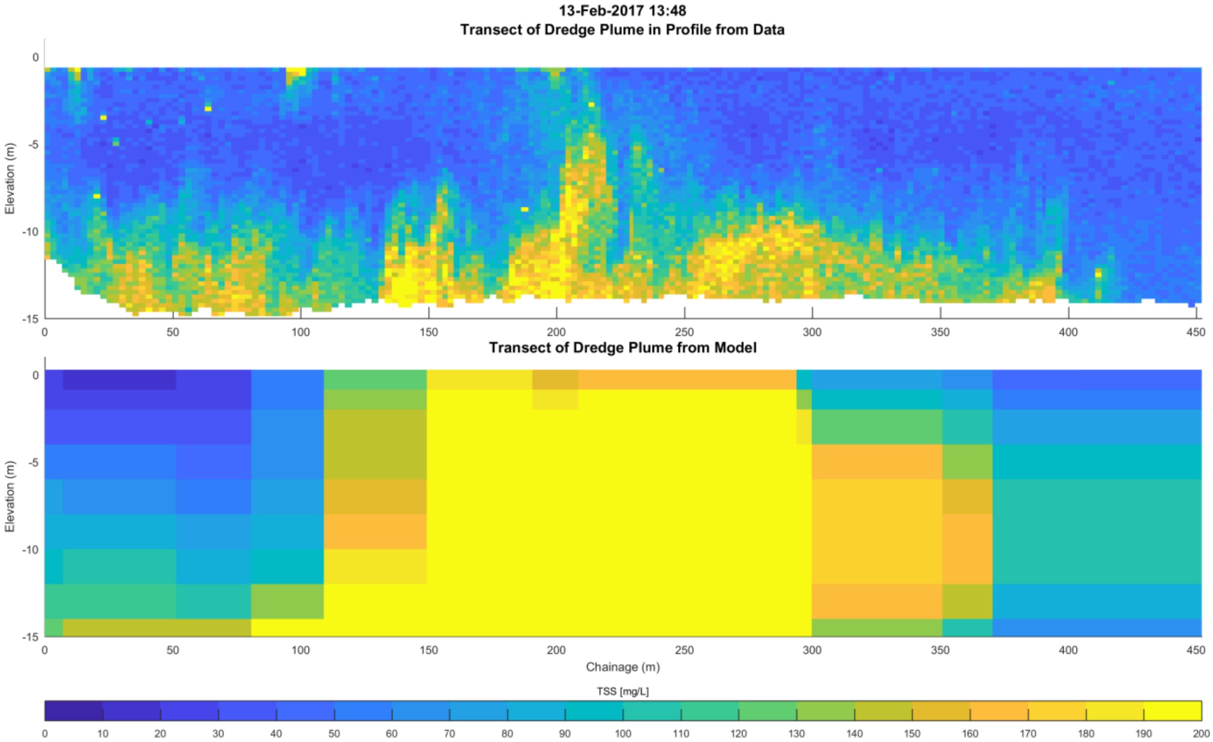
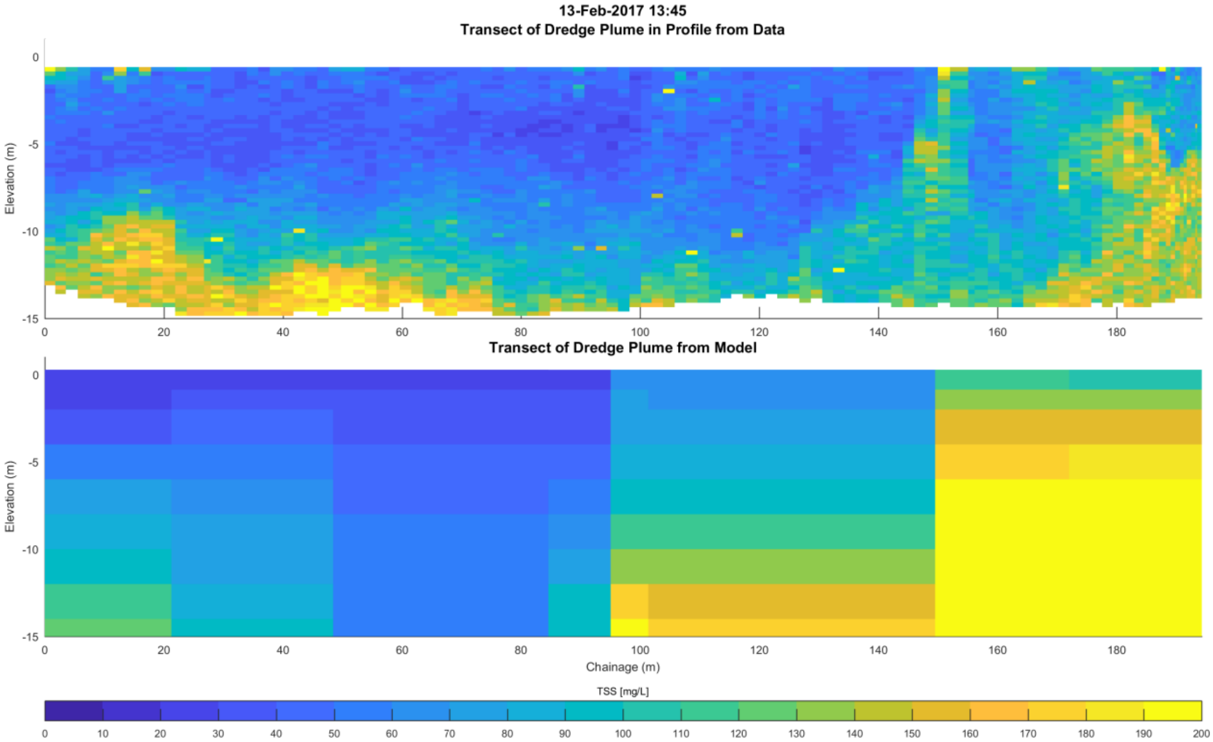
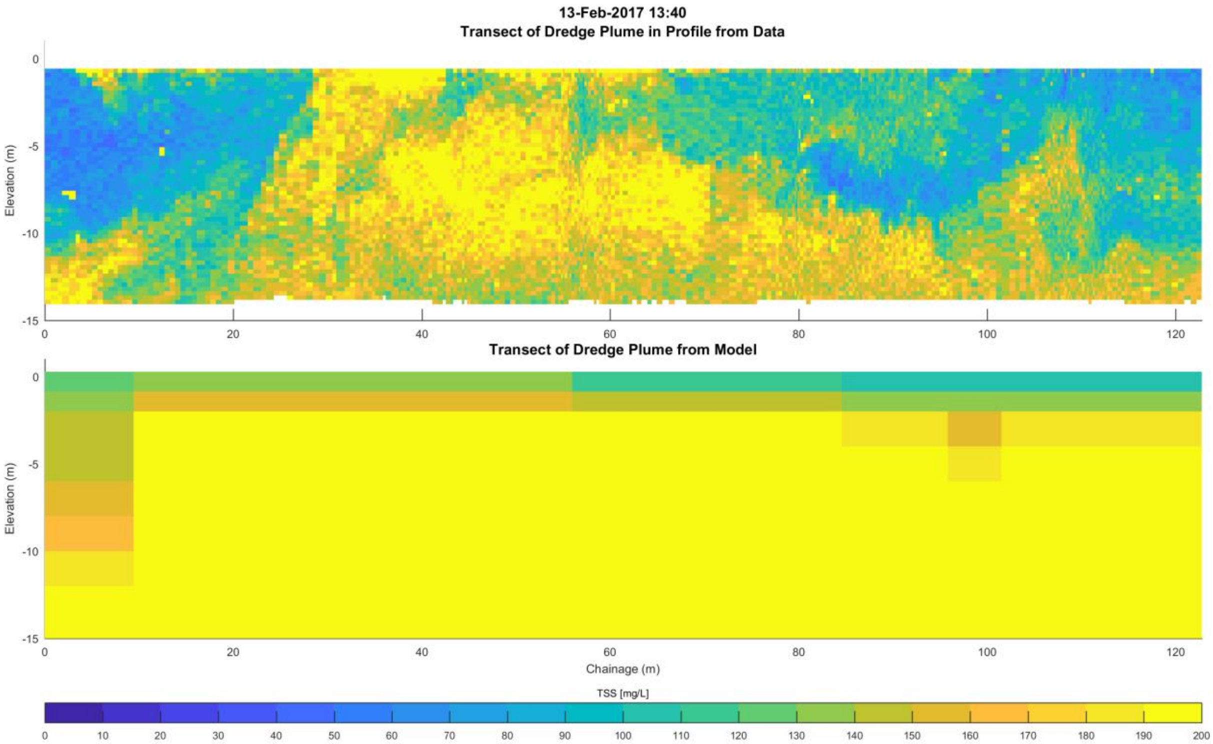
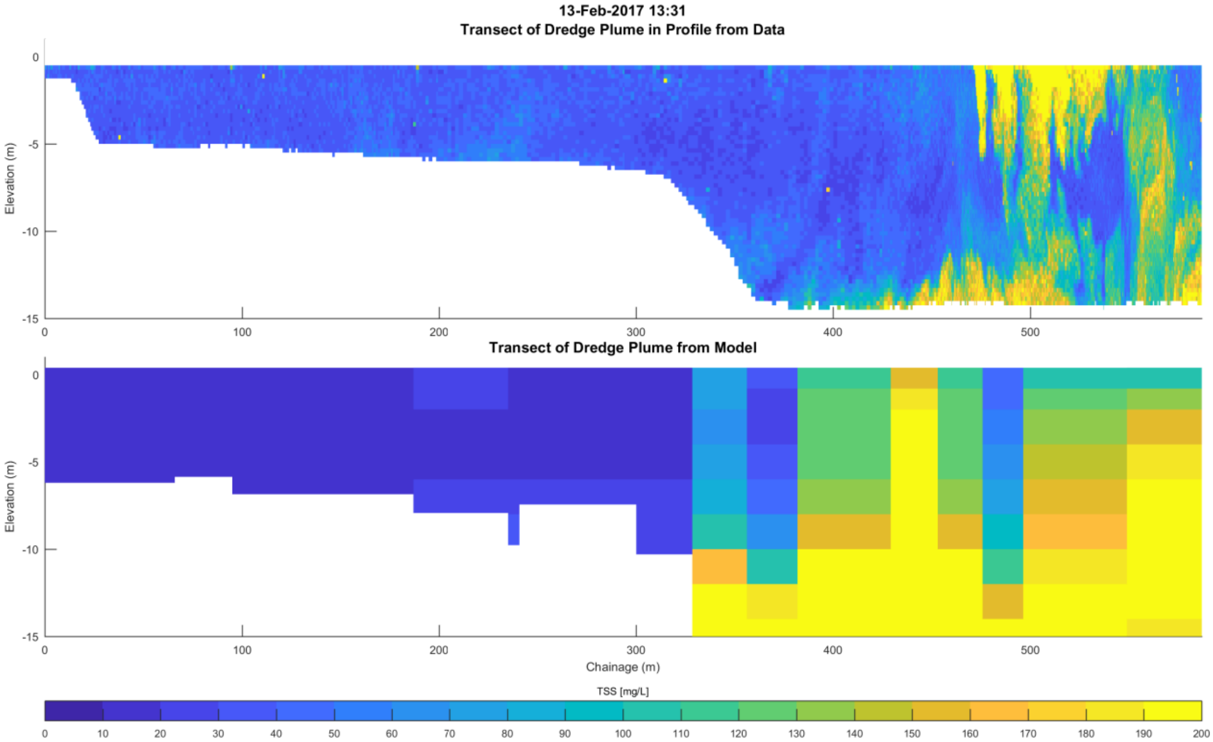
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

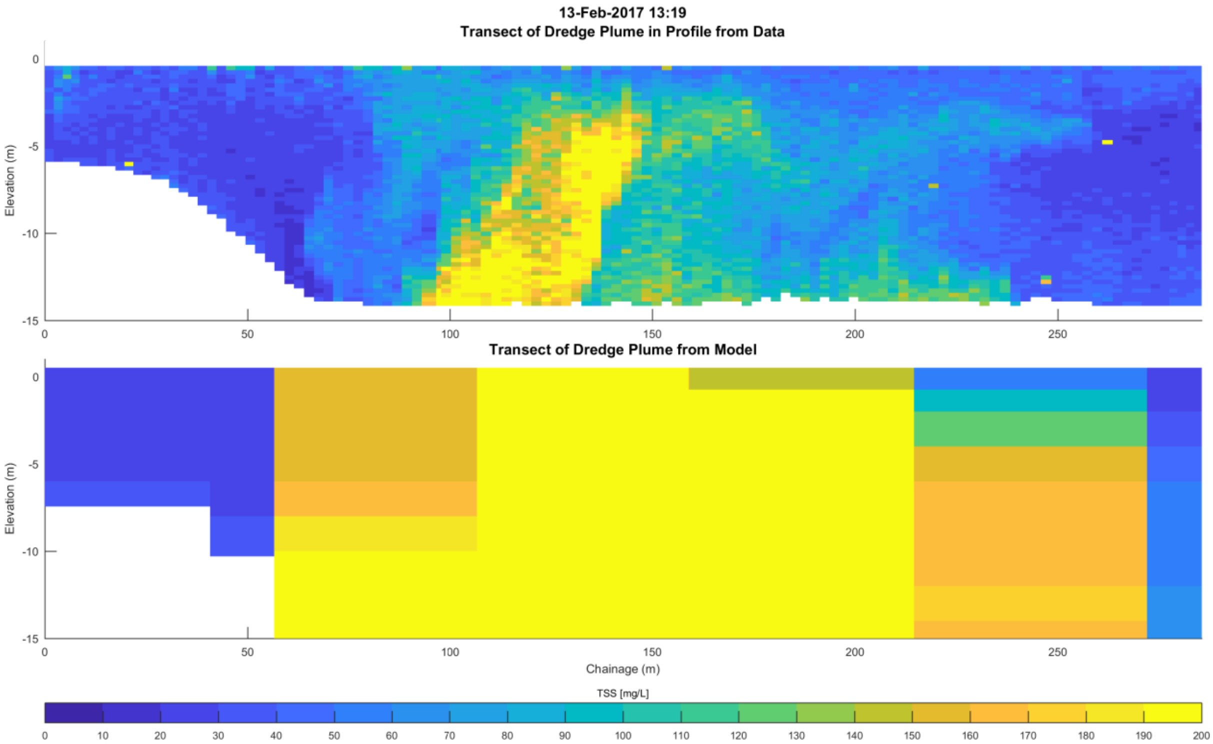

13-Feb-2017 13:48
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

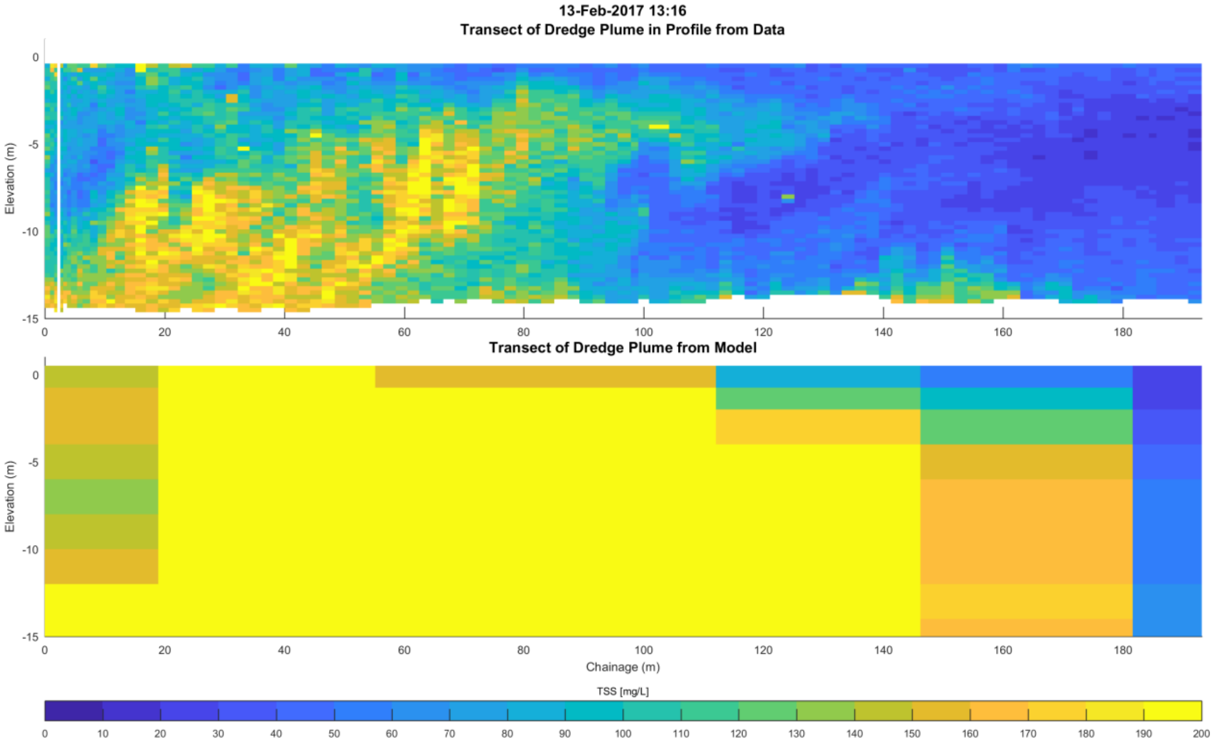
Model Dredge Plume Transect Validation

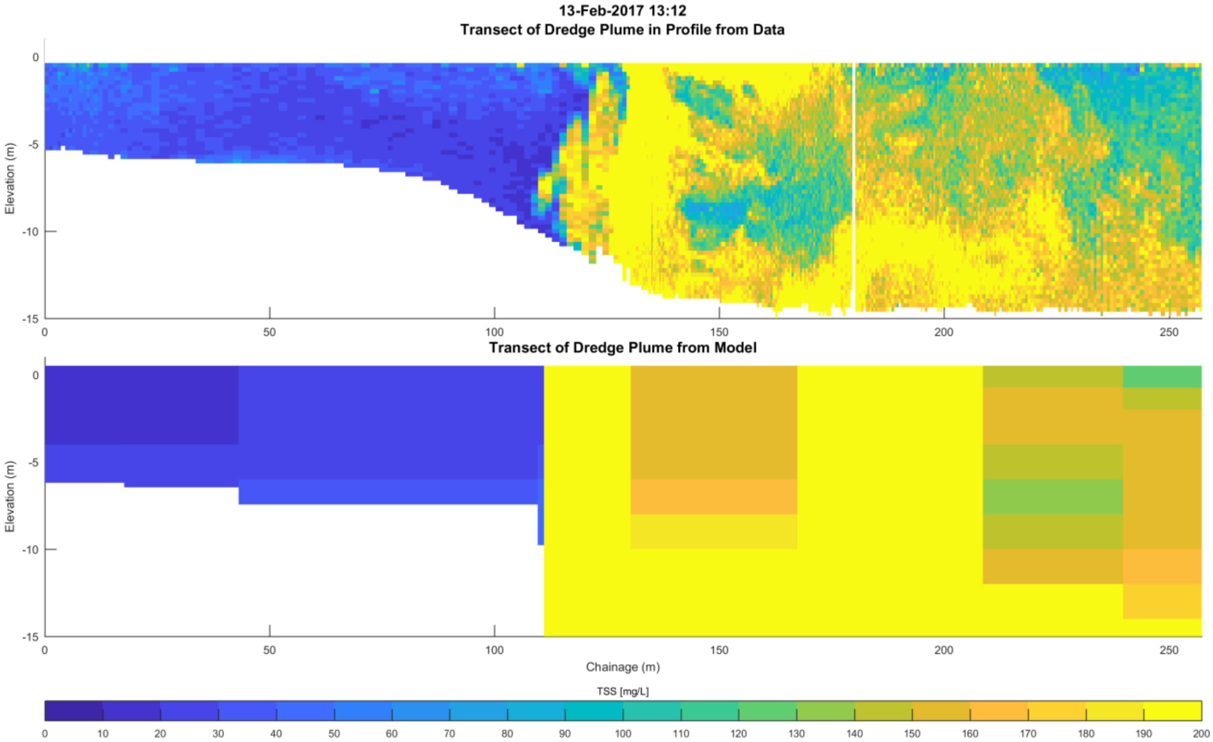




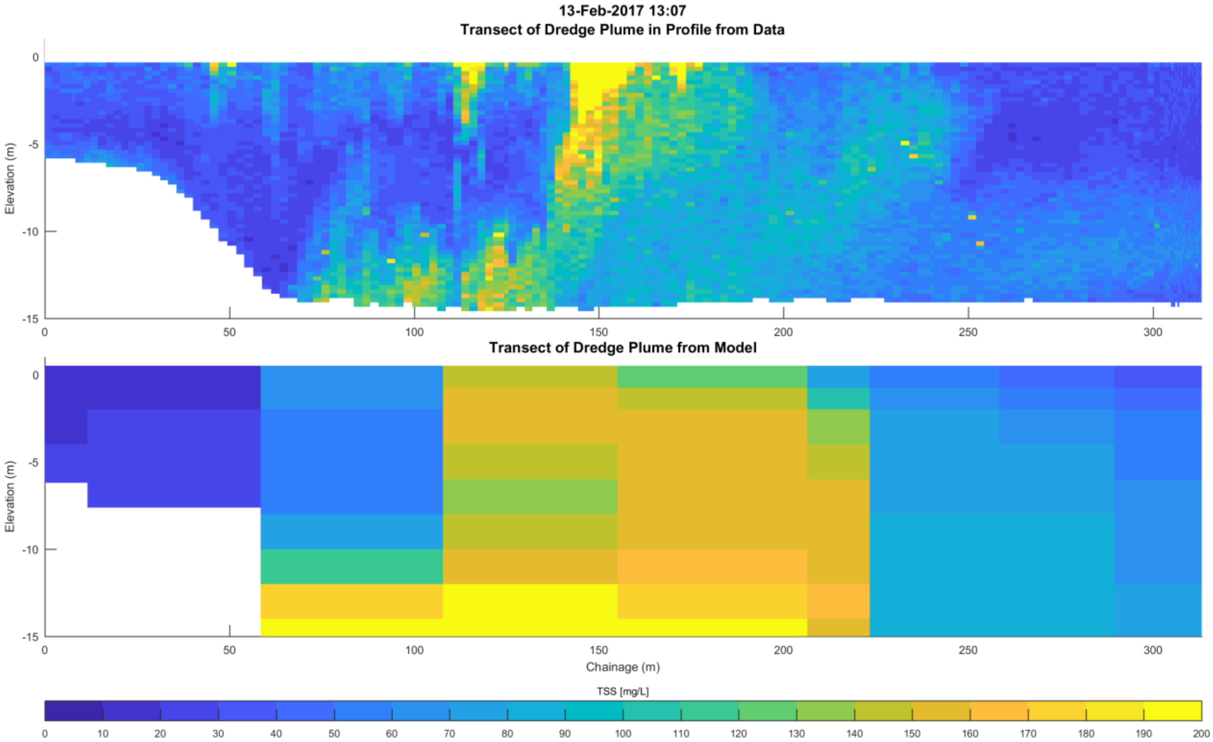

13-Feb-2017 13:31
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

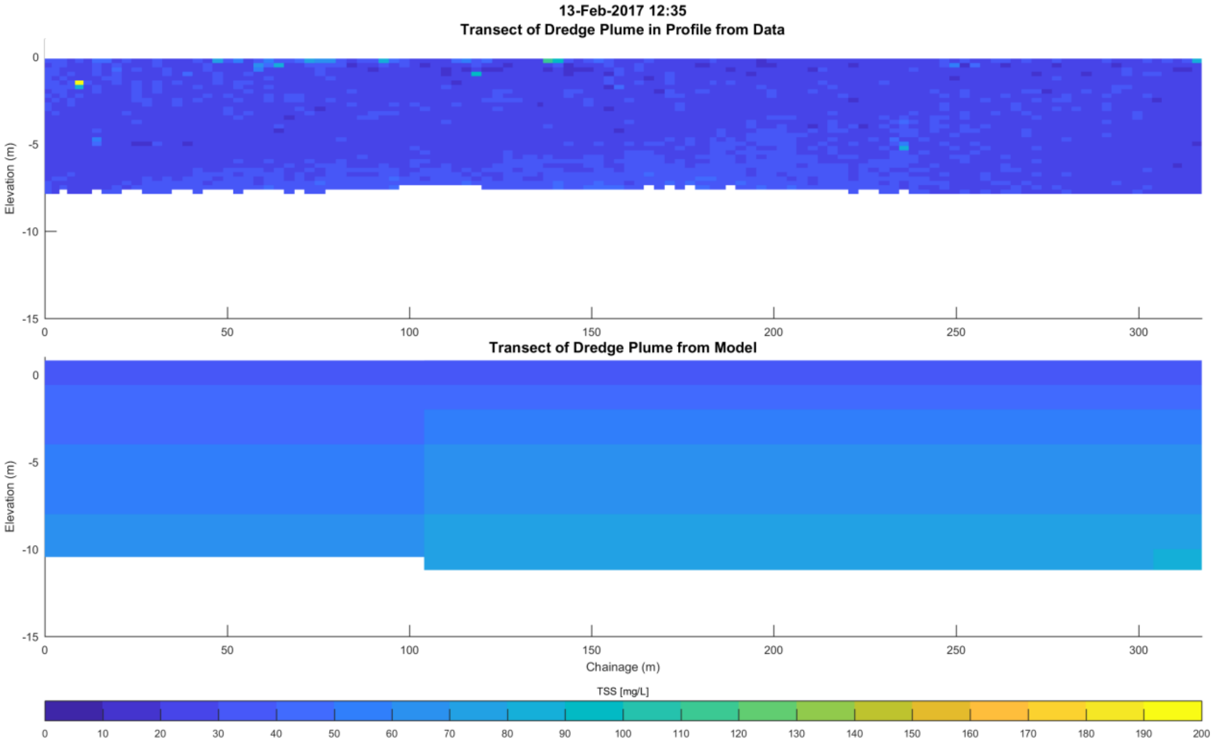

13-Feb-2017 13:19
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]


13-Feb-2017 13:16
Transect of Dredge Plume in Profile from Data
Elevation (m)
0
-5
-10
-15
0
20
40
60
80
100
120
140
160
180
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

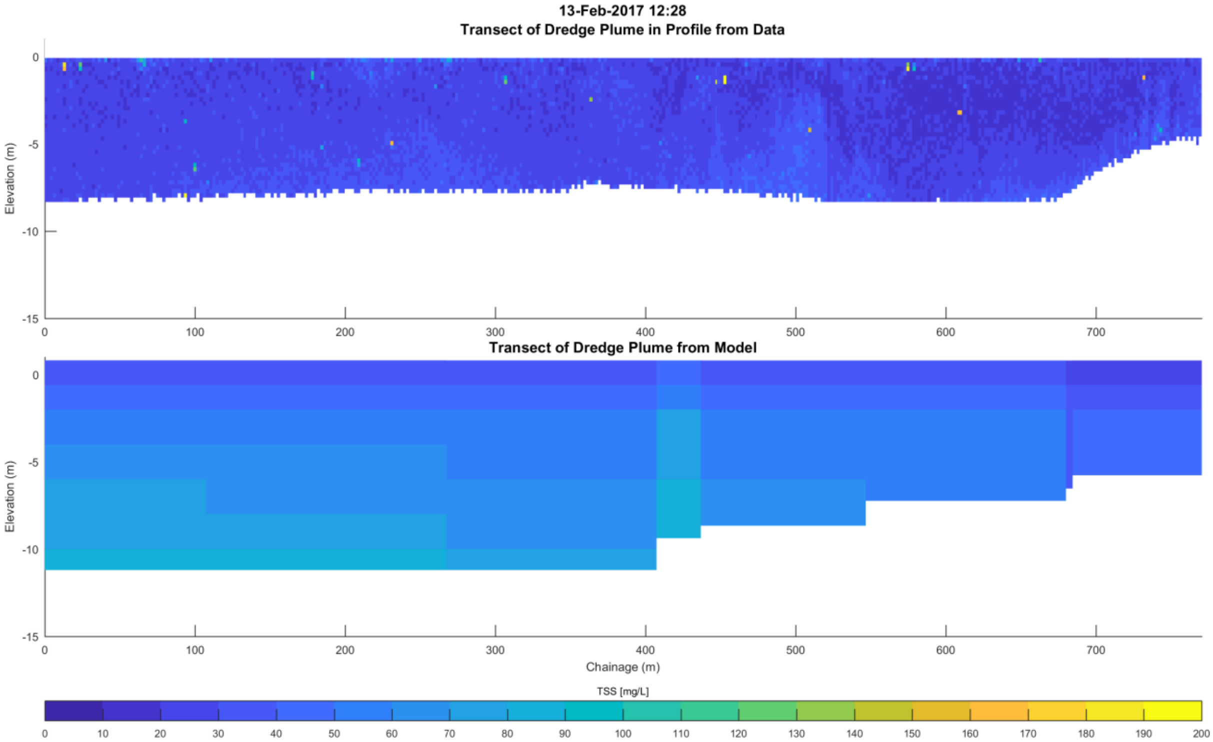

13-Feb-2017 13:12
Transect of Dredge Plume in Profile from Data
Elevation (m)
0
-5
-10
-15
0
50
100
150
200
250
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

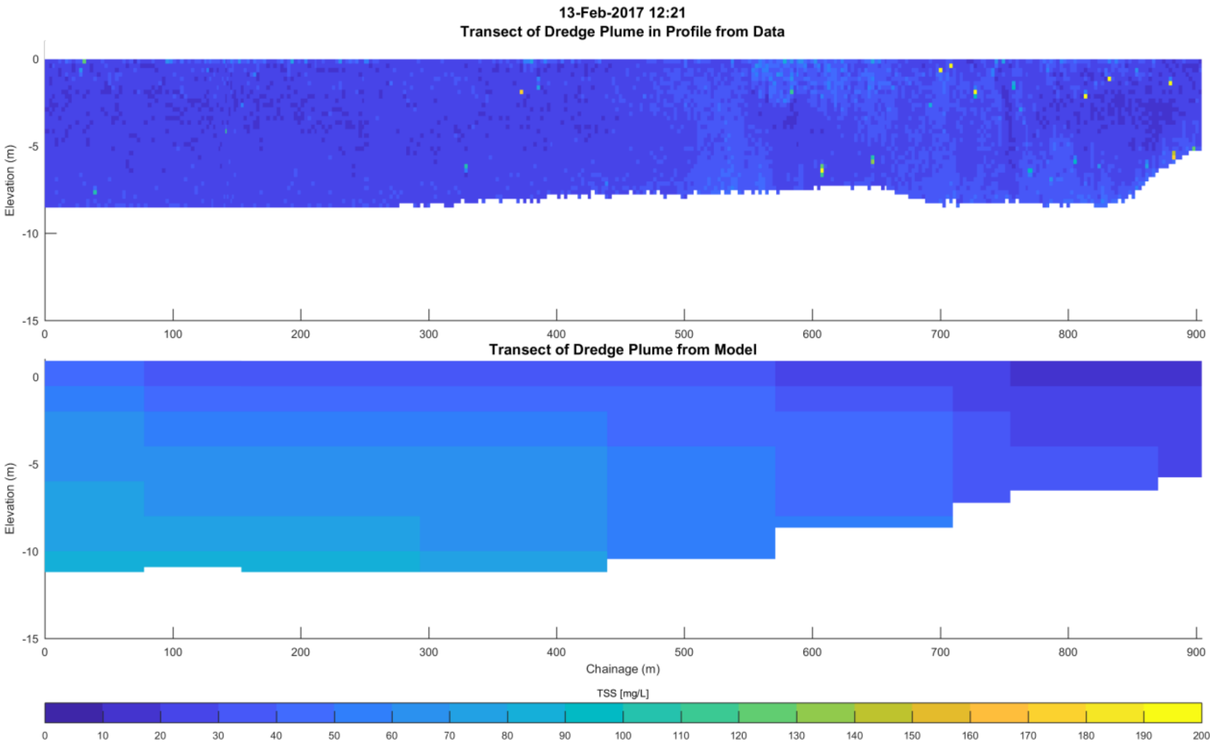
Model Dredge Plume Transect Validation



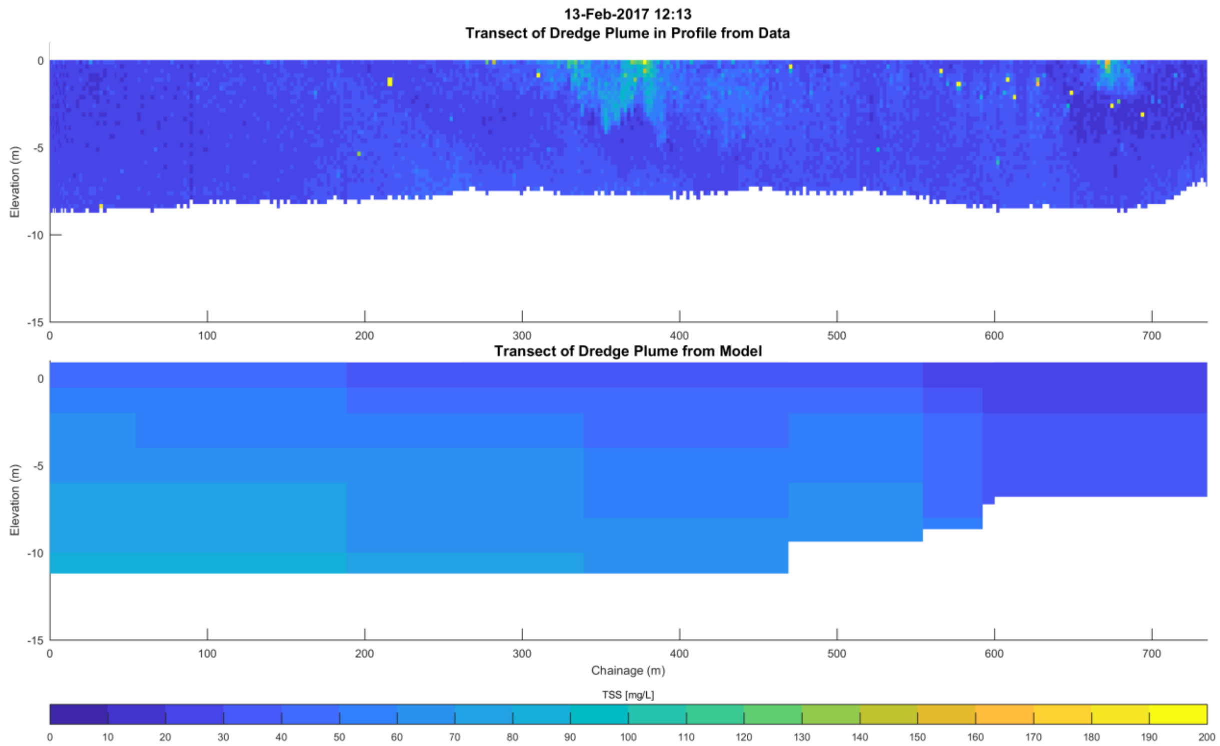


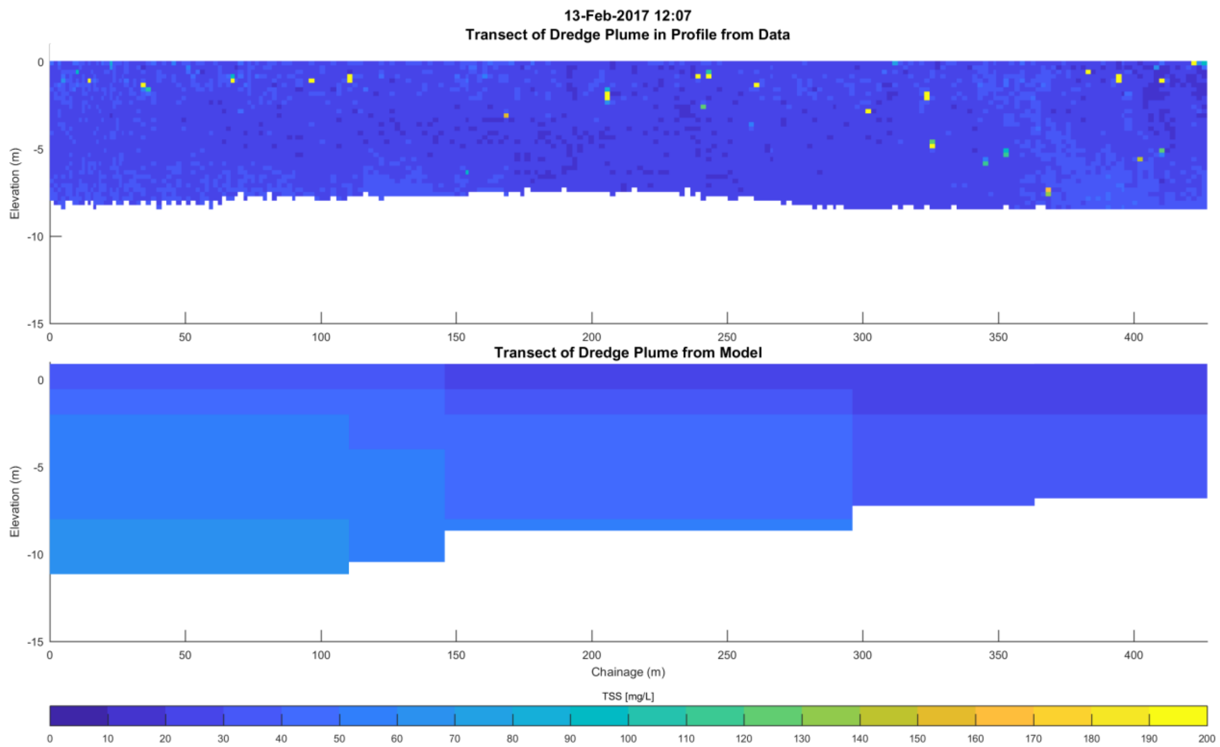
Model Dredge Plume Transect Validation

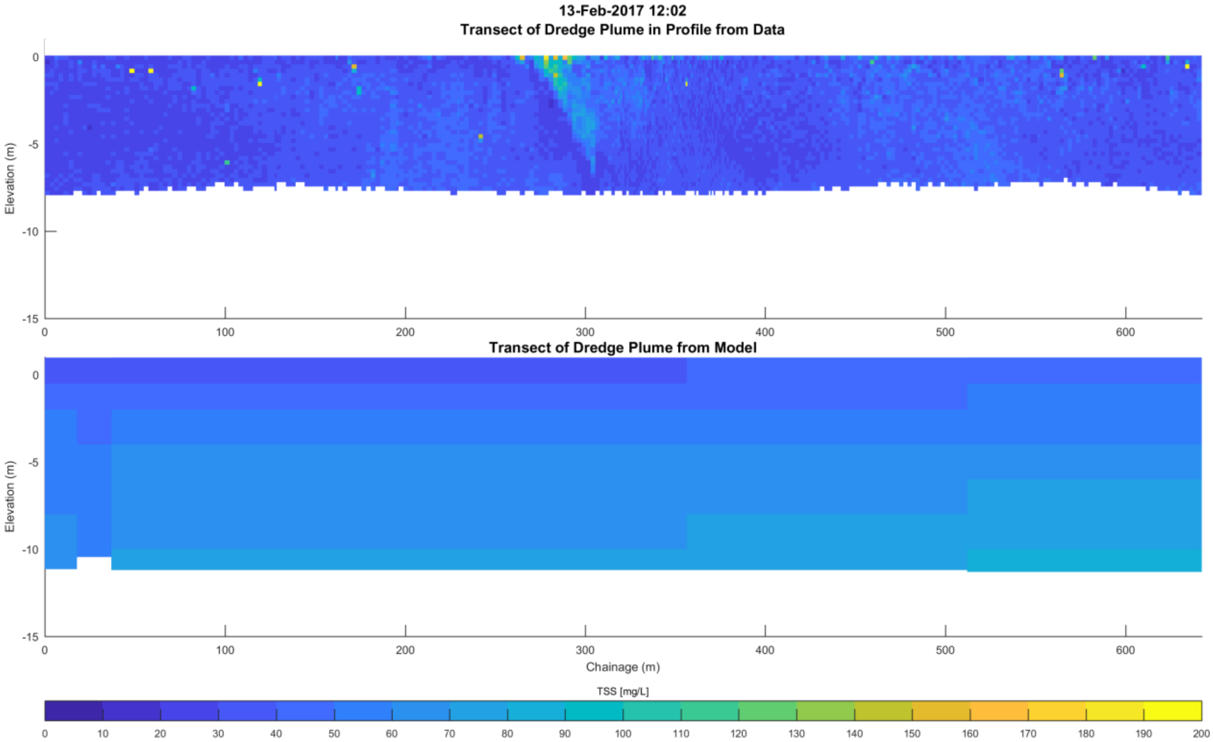


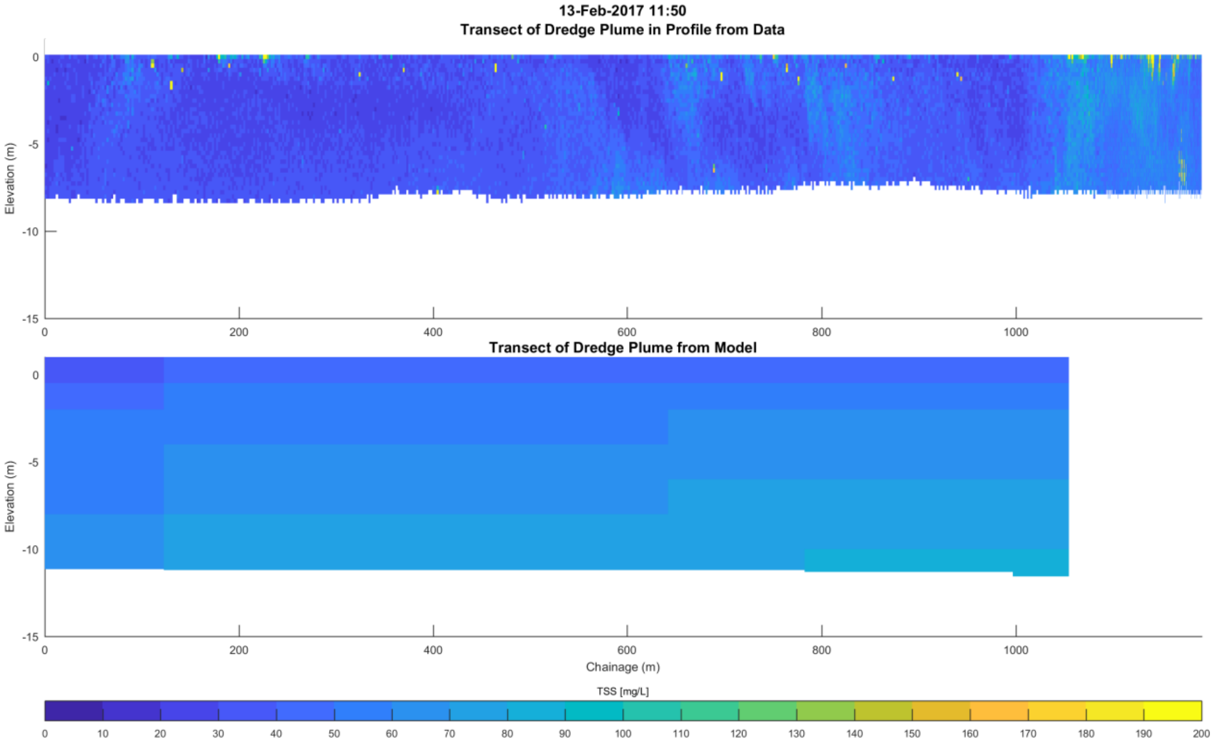


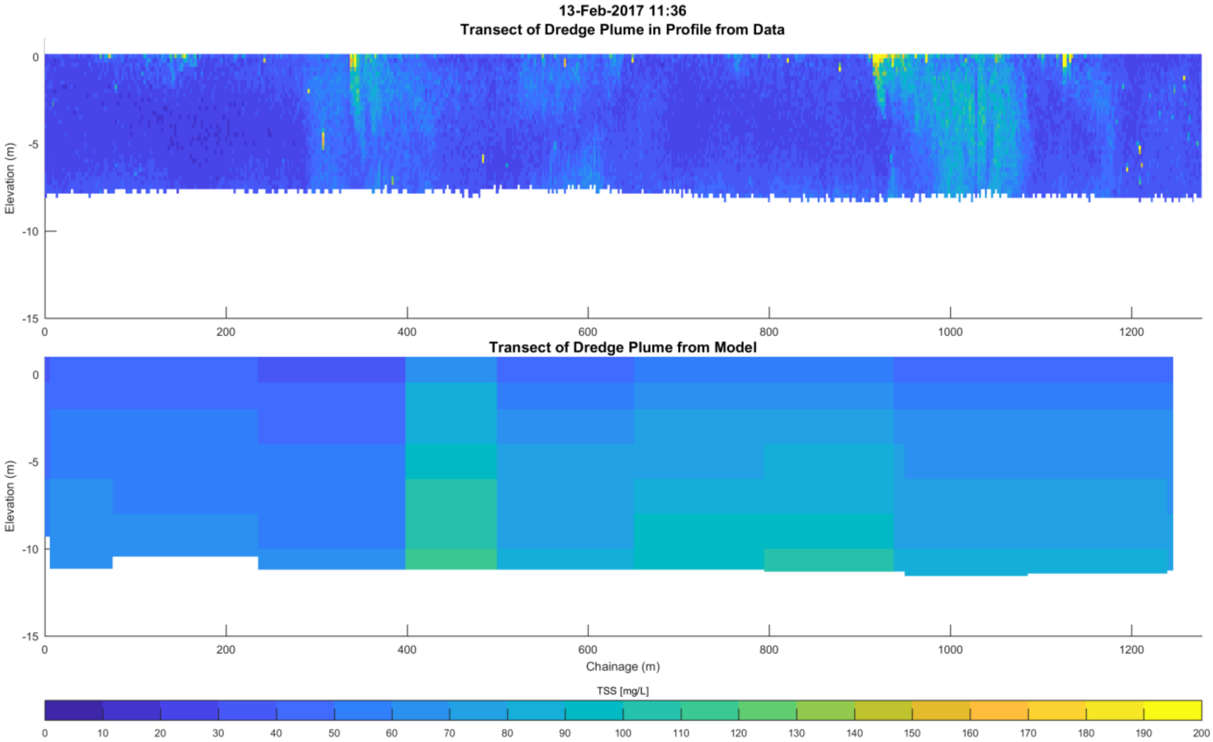
Model Dredge Plume Transect Validation

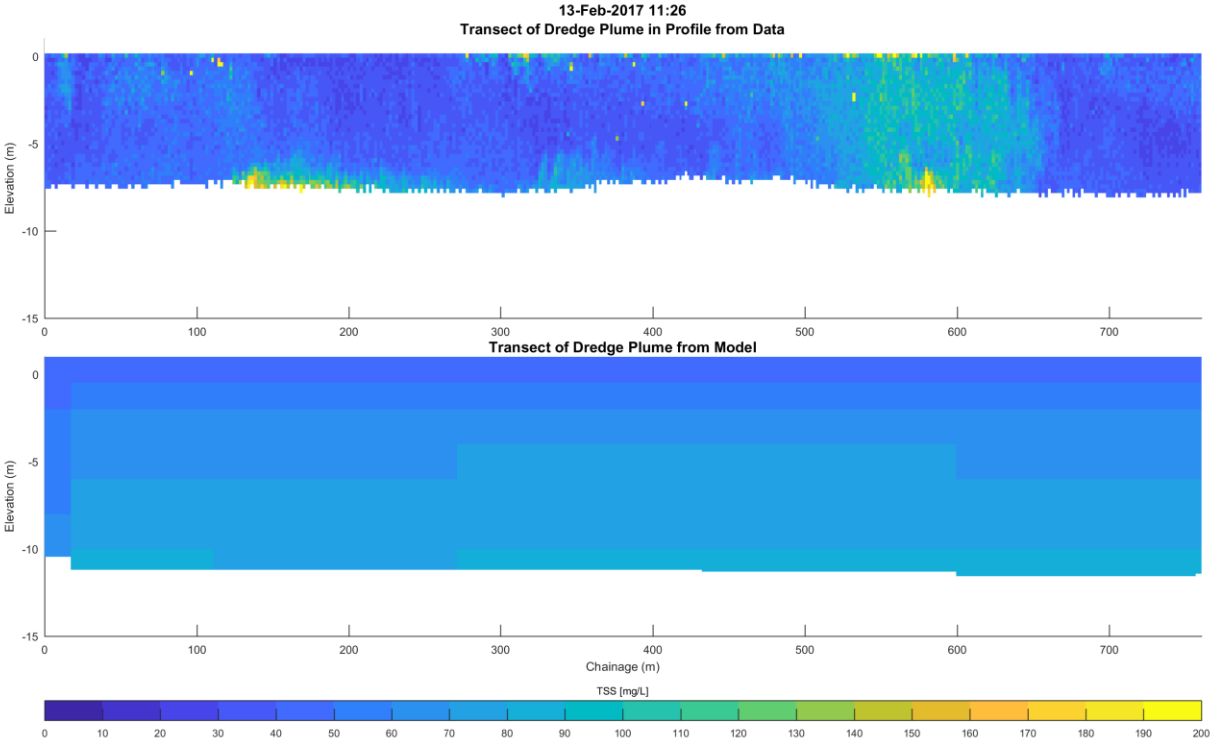


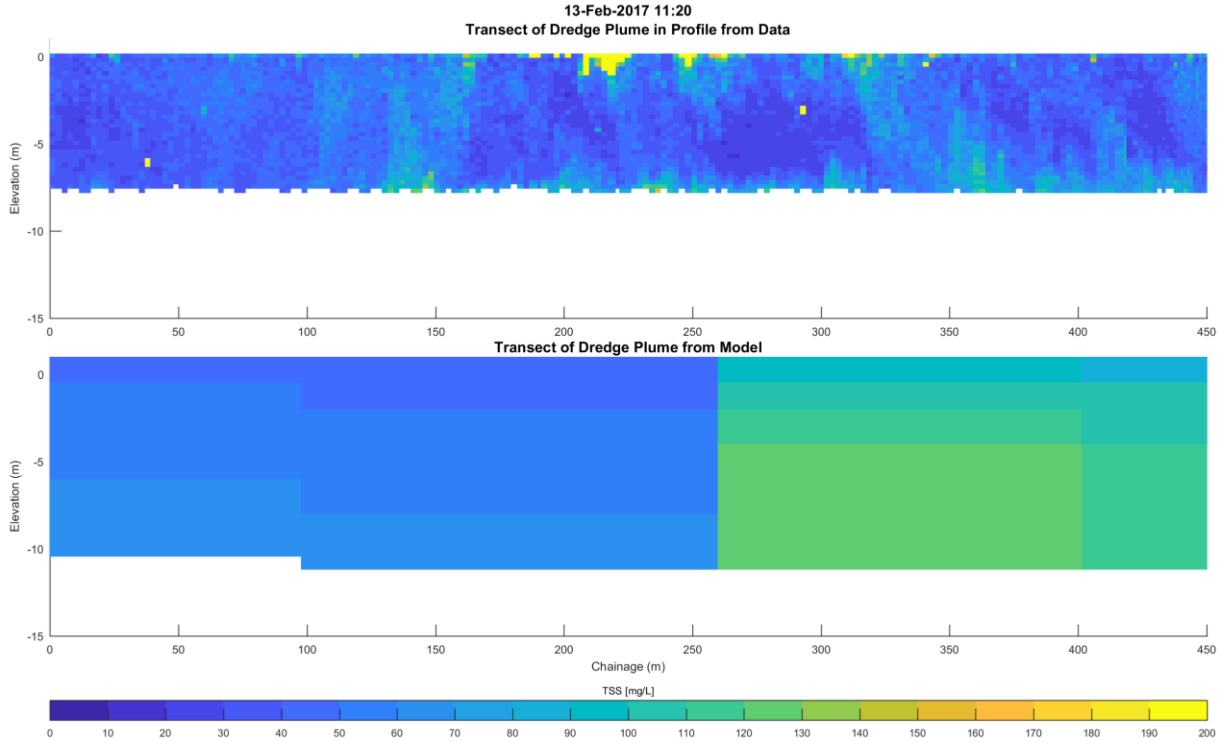


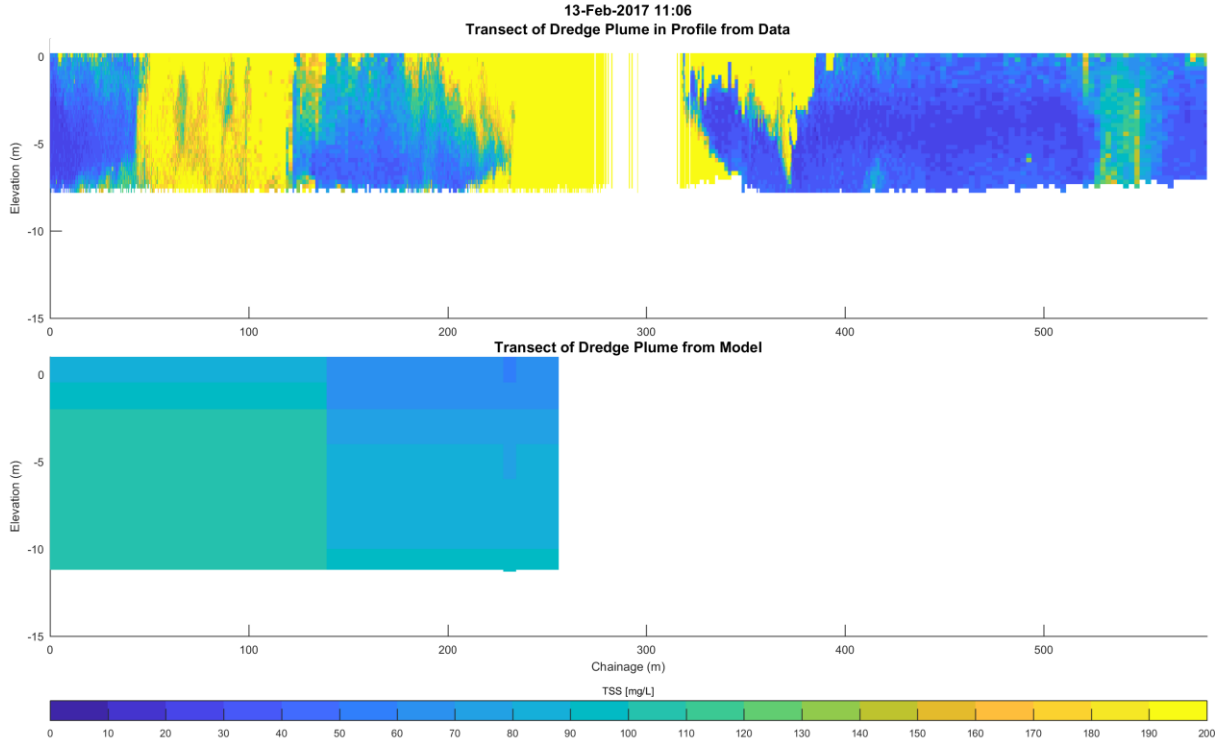

13-Feb-2017 12:02
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

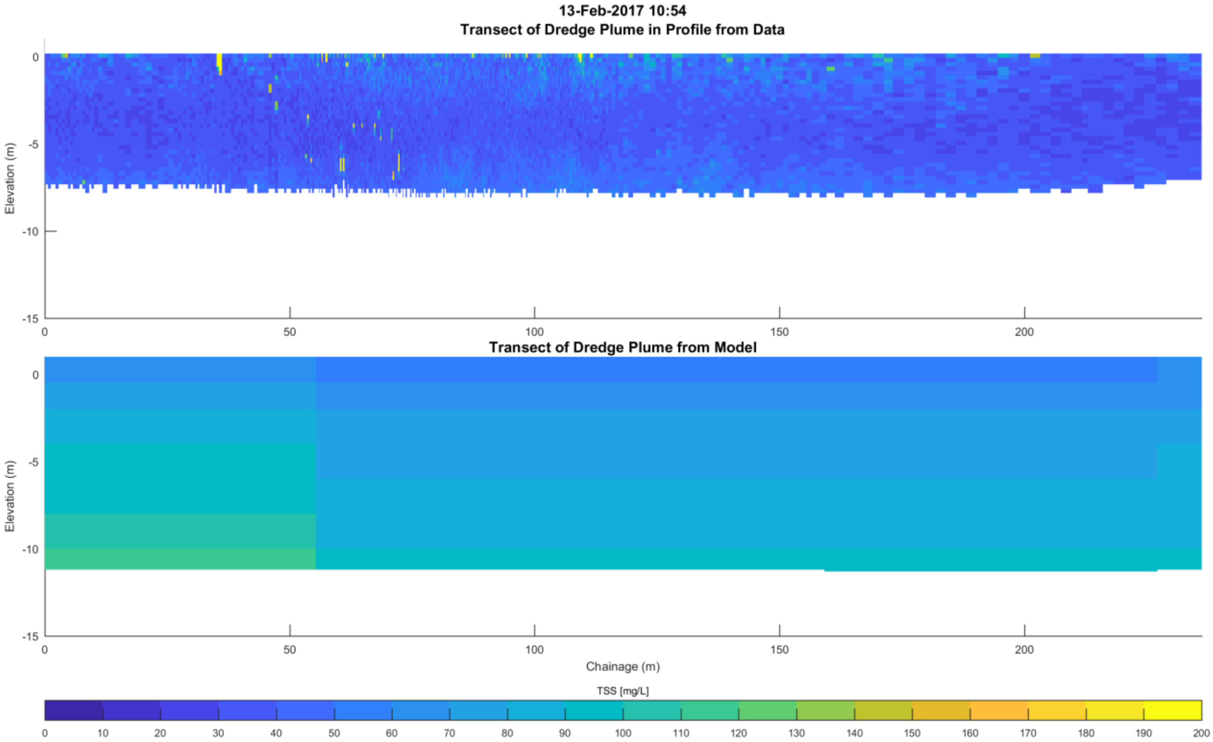

13-Feb-2017 11:50
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

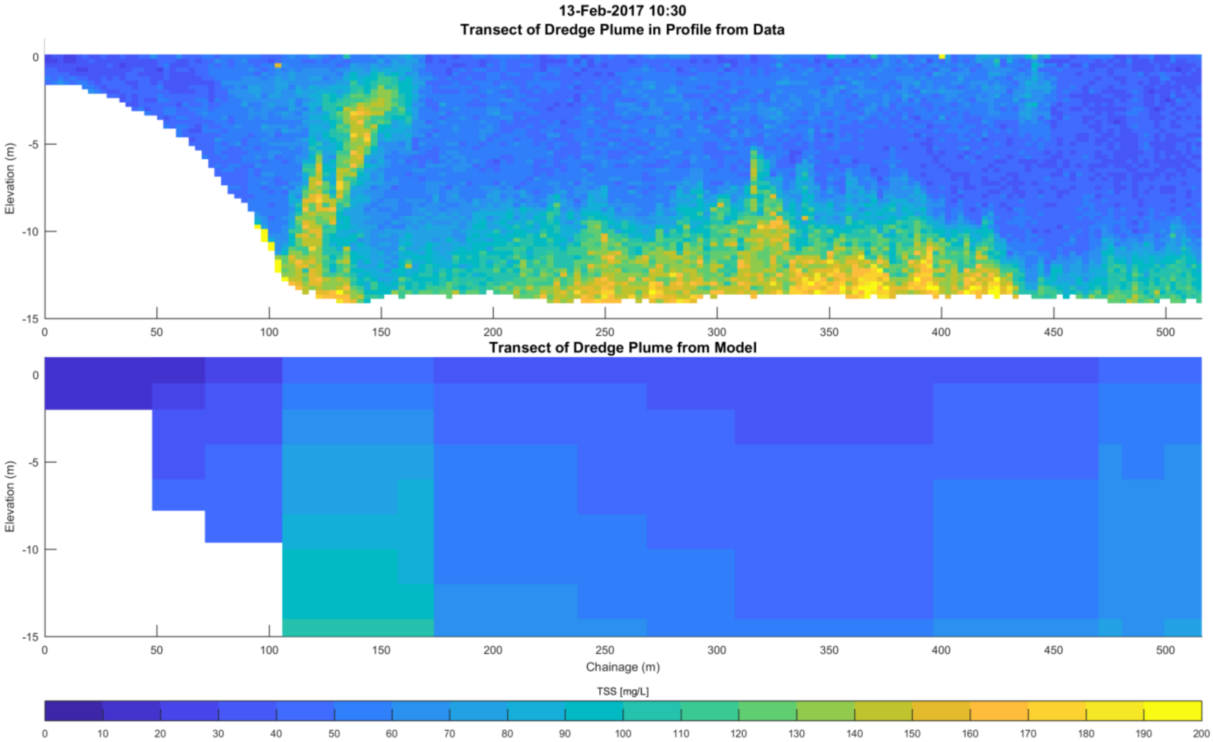

13-Feb-2017 11:36
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

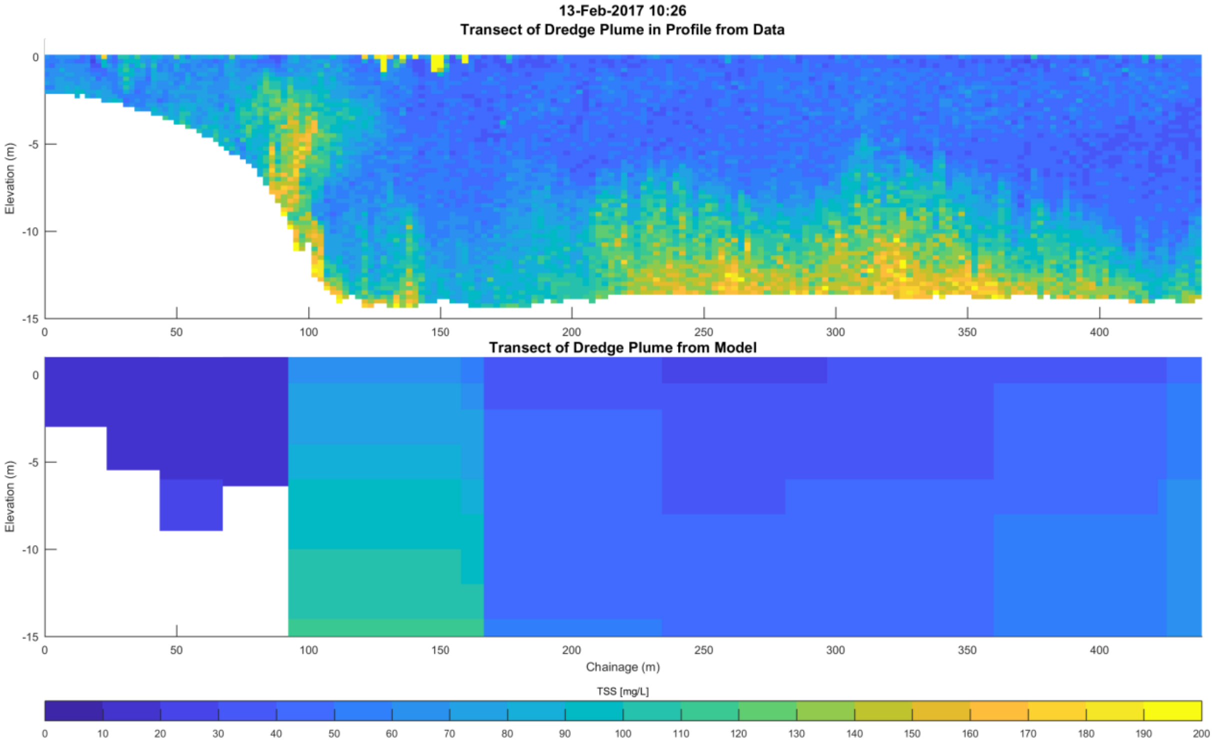

13-Feb-2017 11:26
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

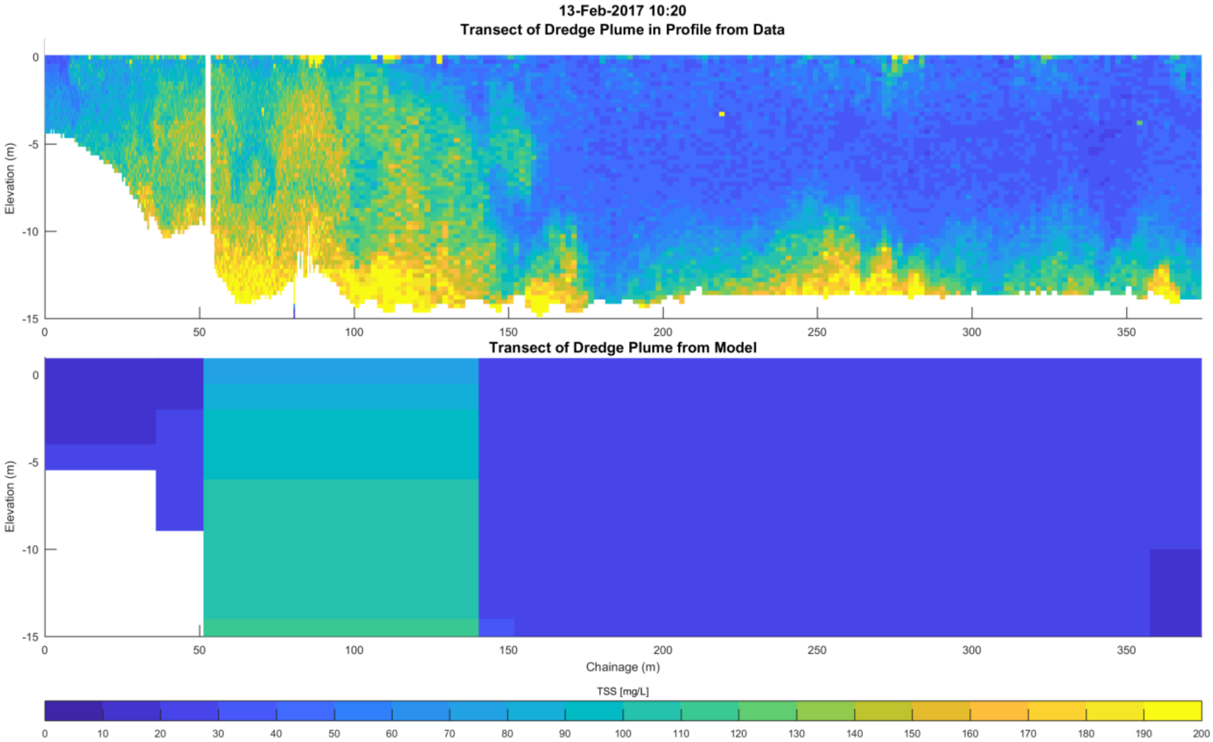

13-Feb-2017 11:20
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

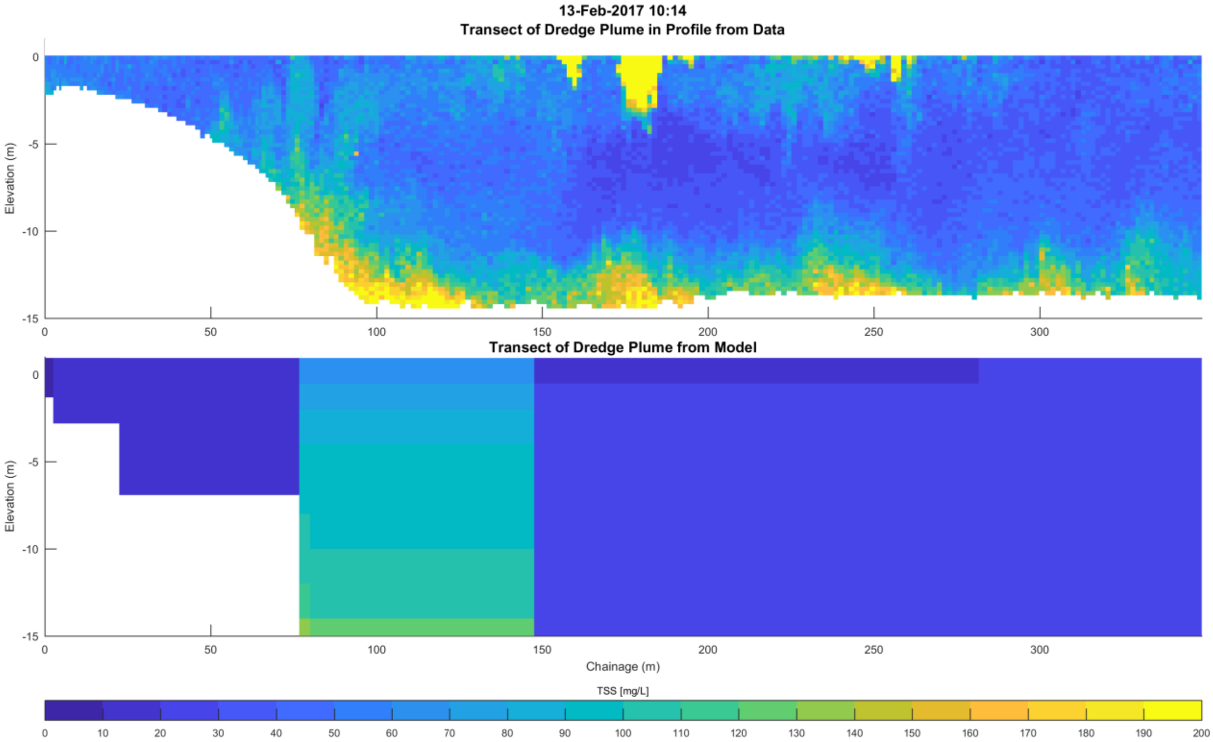

13-Feb-2017 11:06
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

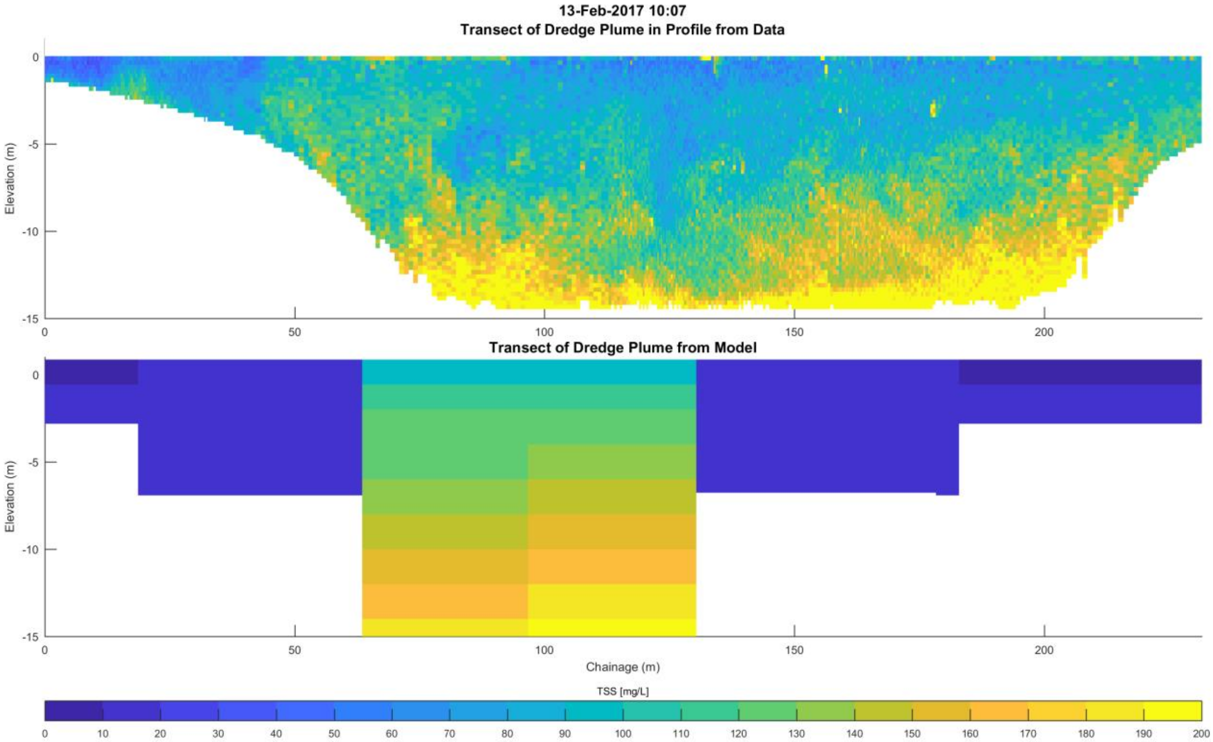

13-Feb-2017 10:54
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

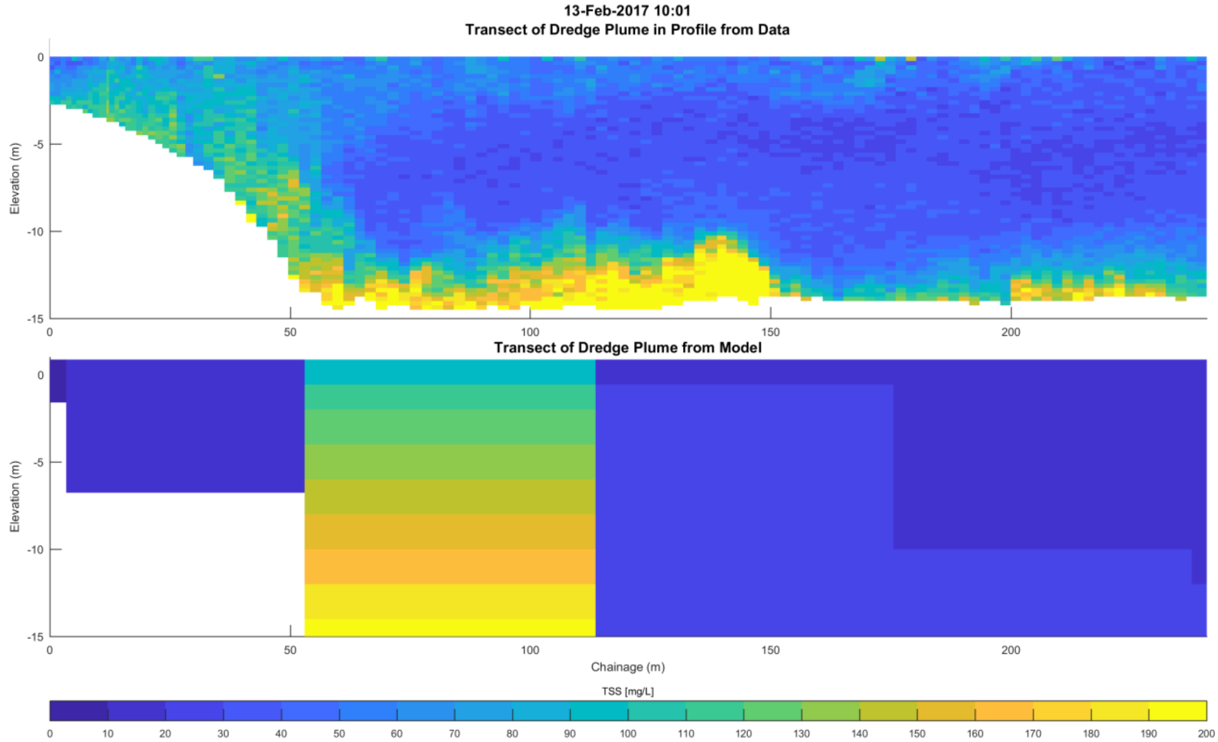

13-Feb-2017 10:30
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

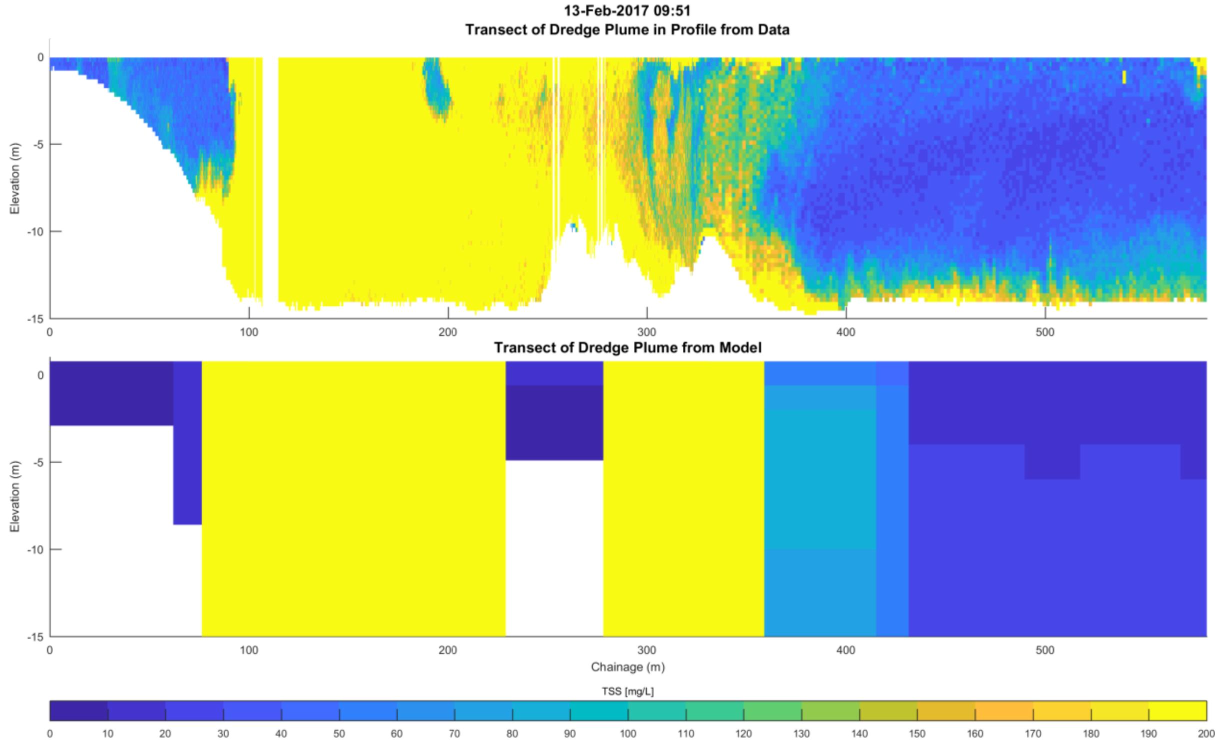

13-Feb-2017 10:26
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

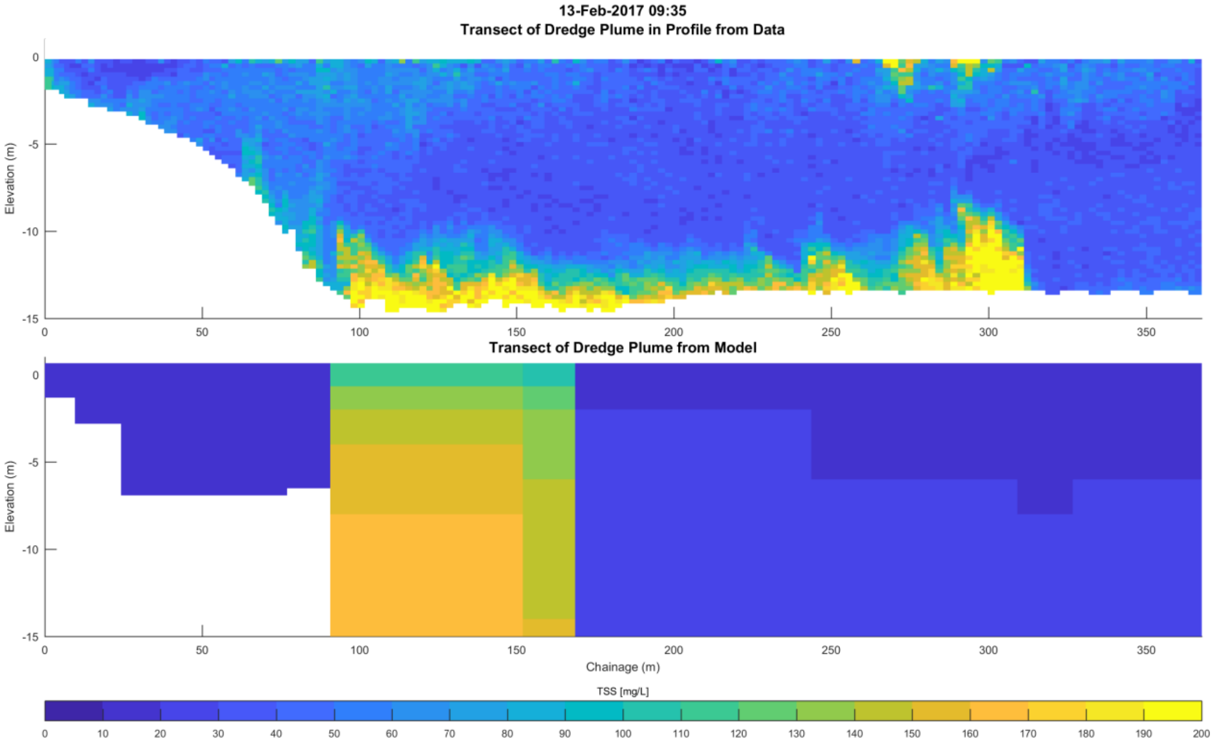

13-Feb-2017 10:20
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

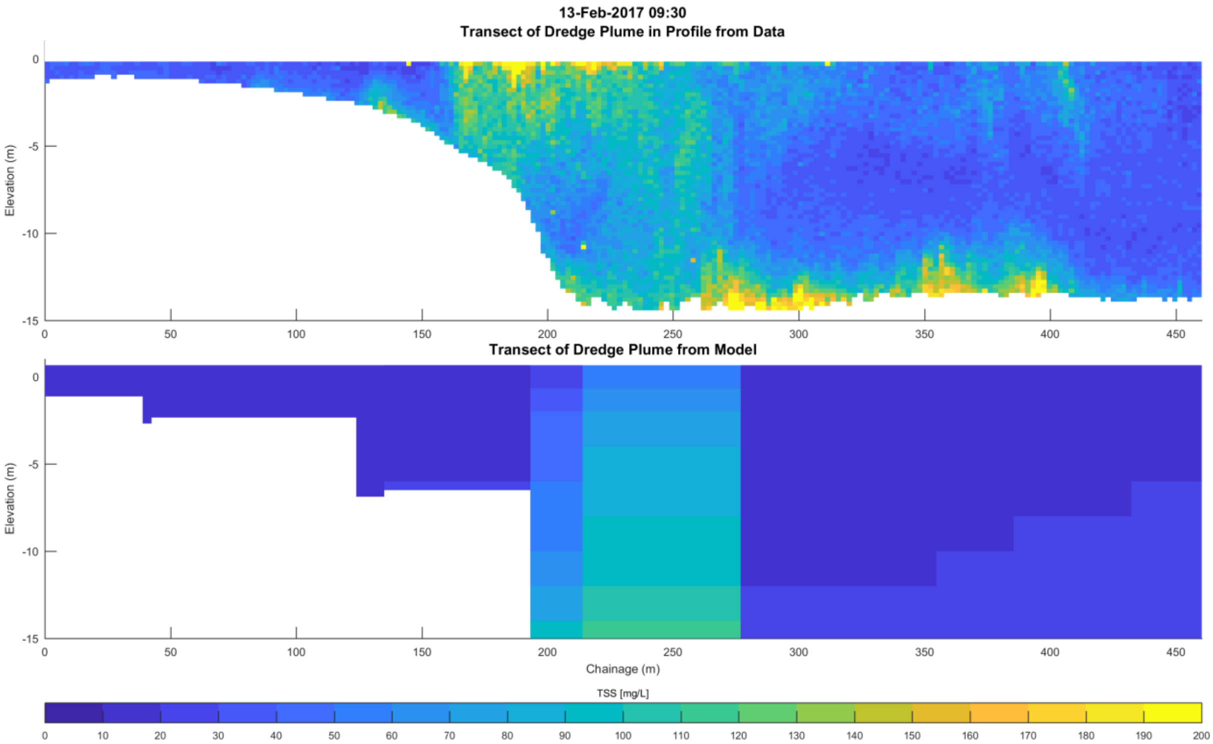

13-Feb-2017 10:14
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]


13-Feb-2017 10:07
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

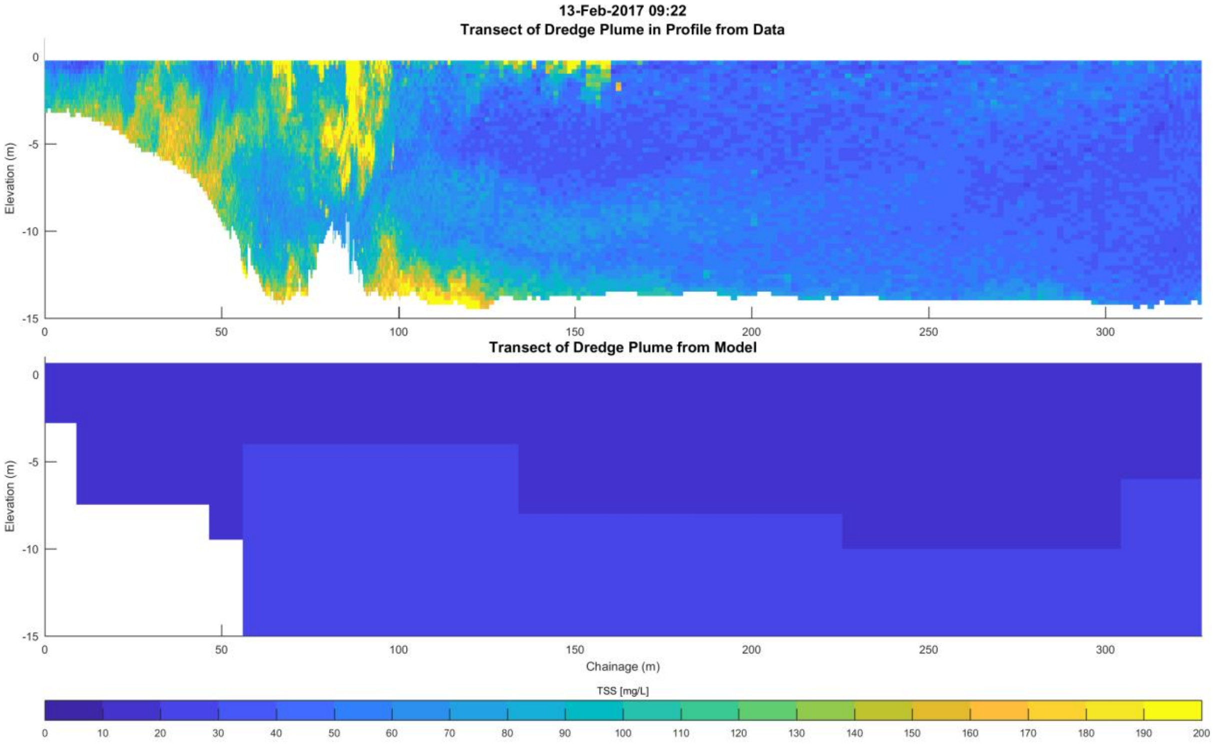

13-Feb-2017 10:01
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Chainage (m)
TSS [mg/L]

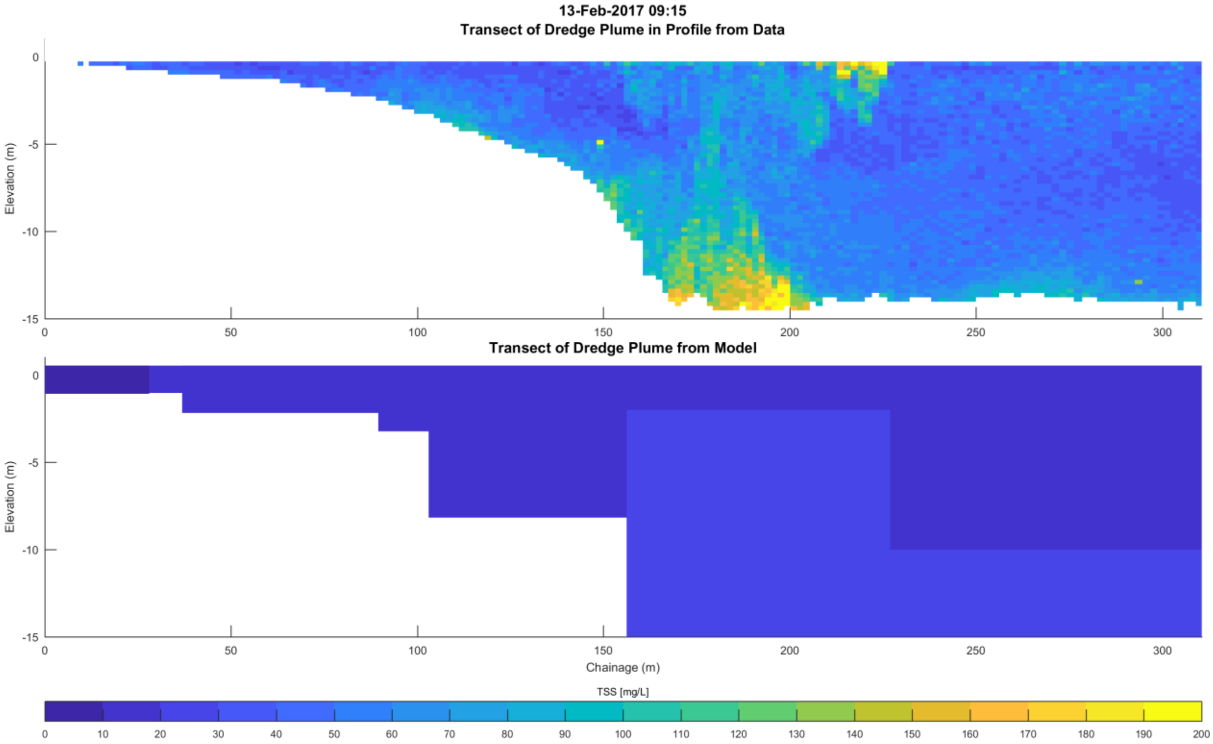

13-Feb-2017 09:51
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Chainage (m)
TSS [mg/L]


13-Feb-2017 09:35
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]


13-Feb-2017 09:30
Transect of Dredge Plume in Profile from Data
Elevation (m)
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]

BMT WBM


13-Feb-2017 09:22
Transect of Dredge Plume in Profile from Data
Elevation (m)
0
-5
-10
-15
0
50
100
150
200
250
300
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200


13-Feb-2017 09:15
Transect of Dredge Plume in Profile from Data
Elevation (m)
0
-5
-10
-15
0
50
100
150
200
250
300
Transect of Dredge Plume from Model
Elevation (m)
Chainage (m)
TSS [mg/L]
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

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