APPENDIX C

Dispersion Modeling

Modeling of Suspended Sediment During PEV Dredging

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Contents

CHAPTER 1 INTRODUCTION

It is proposed to dredge an estimated 180,000 m^3 of fine sediment in the South Arm of Sydney Harbour to allow the navigation and berthing of larger vessels to the Atlantic Canada Bulk Terminal Pier, south of the International Pier (Figure 1.1). The material will be disposed in a CDF inside the former Blast Furnace Cove. The present report summarizes results from modeling analyses to simulate the turbidity plume during dredging operations under various assumptions, based on the best information available at the time of the analyses.

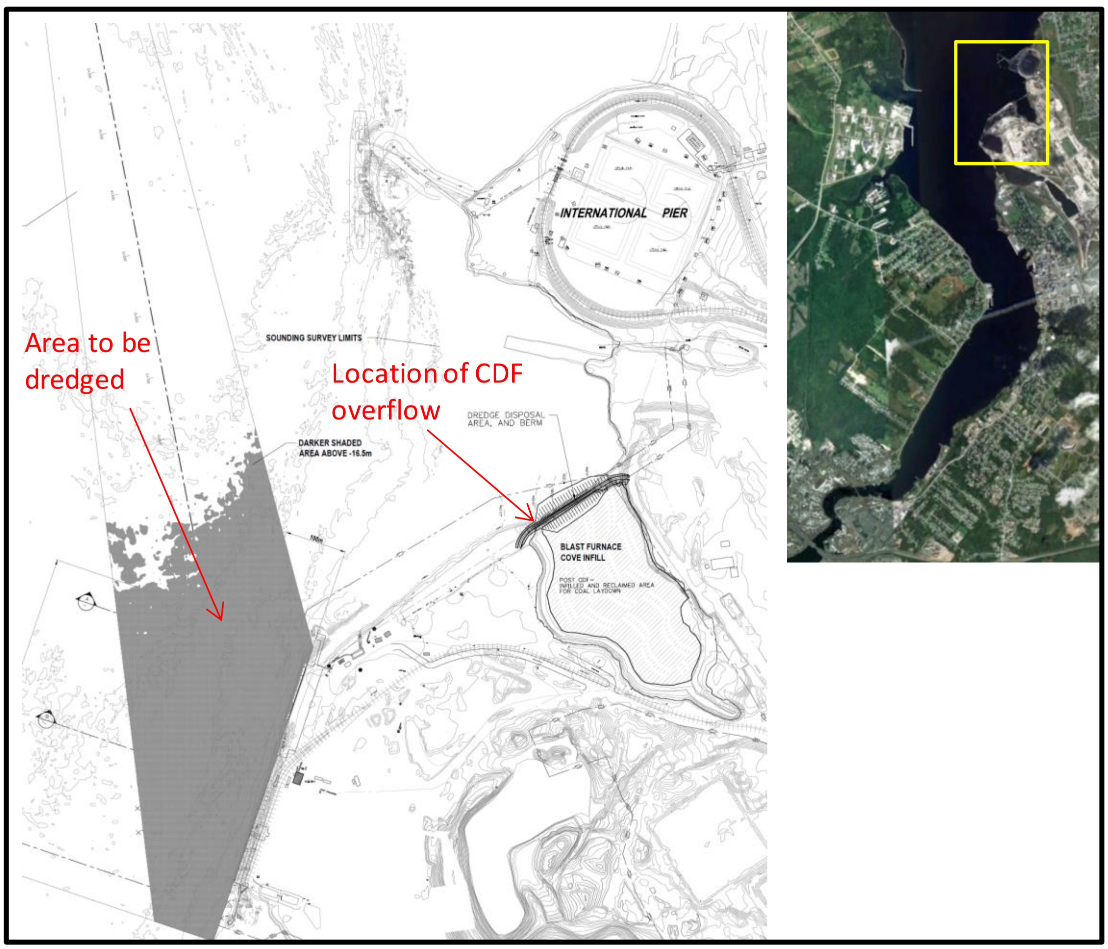

Figure 1.1 Project Site

CHAPTER 2 METHODOLOGY AND ASSUMPTIONS

2.1 Model Description

Numerical modeling was conducted using the Danish Hydraulic Institute's MIKE3 Hydrodynamic and Mud Transport (MT) modeling package. The model was initially developed and calibrated during the Environmental Assessment Phase of the Sydney Harbour Dredging Project (CBCL 2009), and a comparison of observations vs. model predictions is presented in section 2.3. The observed TSS values were well under worst-case model predictions, and model predictions averaged over the simulation period are comparable (in an order of magnitude sense) to the average of the TSS observations at each observation site. Therefore the model was considered the best tool available for assessing turbidity impacts in Sydney Harbour from this project.

In recognition of uncertainties in input parameters (sediment sizes and weather/hydrodynamic conditions notably), two sets of model runs were conducted, with (1) sediment settling, considered most likely, and (2) no-settling assumptions, in order to give a reasonable bracket of conditions to be expected. For the model runs that include settling, the results presented hereafter encompass 7 sediment classes input to the model as per Table 2.1, based on dredge material samples.

Table 2.1 Input sediment fractions settling velocities

		d50 mm	Median % finer	% per sediment class	Settling velocity [m/s]	Critical shear stress for deposition [N/m2]
< -1 Phi (2 mm)		2	100	5	3.54	
< 0 Phi (1 mm)	very coarse sand	1	95	4	0.89	
< +1 Phi (0.5 mm)	coarse sand	0.5	91	2	0.22	
< +2 Phi (0.25 mm)	medium sand	0.25	89	1.5	0.06	
Sediment fractions included in modeled resuspensed sediment source						
< +3 Phi (0.12 mm)	fine sand	0.12	87.5	1	0.01	0.17
< +4 Phi (0.062 mm)	very fine sand	0.062	86.5	2.5	0.003	0.12
< +5 Phi (0.031 mm)	coarse silt	0.031	84	8.5	0.001	0.1
< +6 Phi (0.016 mm)	medium silt	0.016	75.5	28	0.0002	0.05
< +7 Phi (0.0078 mm)	fine silt	0.0078	47.5	10	0.00005	0.02
< +8 Phi (0.0039 mm)	clay	0.0039	37.5	14	0.00001	0.01
< +9 Phi (0.0020 mm)	fine clay	0.002	23.5	23.5	0.000004	0.005

The simulated currents, which cover a range of representative tidal and estuarine flow conditions, were used to drive plume dispersion simulations using a moving source of suspended sediments (the dredge) over the dredging area, and another fixed source at the CDF for scenarios where an overflow is considered.

2.2 Dredging Scenarios

Two dredging scenarios were examined, using a Trailing Suction Hopper Dredge (TSHD) or a Clamshell dredge. Assumptions with both scenarios are listed in Table 2.2. With the TSHD option, excess water from the CDF is assumed to overflow through a weir in the berm that closes off the dredge disposal basin. No CDF overflow is expected with the clamshell option, which has a considerably lower output rate.

Table 2.2 Dredging scenarios modeled

	Scenario 1 Trailing Suction Hopper Dredge (TSHD)	Scenario 2 Clamshell dredge with environmental bucket
Dredging rate, m3/day	15,000	3,000
Loss rate as % of dredging rate	1.5%	3%
Re-suspension rate, kg/s	2.8	1.1
Project duration, days	12	60
Outflow at CDF, m3/s	0.2	0
TSS at CDF outflow, mg/l	500	N/A

Re-suspension rates of sediment were estimated by 2 methods:

Scenario1, TSHD - The Turbidity Generation Unit (TGU) method described by the USACE Technical Note DOER-E6 (Johnson 2000) and based on results by Nakai (1978). The TGU concept describes the mass of sediment re-suspended per unit volume dredged. It varies with sediment grain size distribution and dredge type. TGU values are based on empirical observations at other dredging projects. Based on Nakai's values for a hopper dredge and for comparable grain size distributions (10% sand and gravel, 64% silt, 26% clay), the local TGU for the TSHD is estimated at 17 kg per in-situ m^3 dredged. This leads to a re-suspension rate of **2.8 kg/s**.

Scenario 2, Clamshell- Material is typically being re-suspended at a rate between 0.5% (best practice, clean sites with no debris) and 10% (worst-case, using bucket dredging with no environmental controls) of the dredging rate. For clamshell dredges the literature reports an average value of 1%, which should be increased by a factor of 2 to 3 for capital dredging sites where debris may be encountered (USACE 2008). A worst-case loss rate of 3% was assumed, along with a seabed moisture content of 60% and a 3% percentage loss rate. The assumed re-suspension rate with the clamshell dredge was **1.1 kg/s.**

2.3 Model Validation with Sydney Harbour Dredging Project

2.3.1 TSS from CDF outflow

The model included a CDF outflow at Sydport Beach of 2 m^3/s at 500 mg/L (dredging rates during this project were much greater than those from dredges being considered for the PEV dock). Settling was not included, to be conservative. A comparison of modeled vs. observed TSS values near the surface in the vicinity of the CDF is given in Table 2.3. Observation sites are shown in the following figures. Modeled average TSS values above background are within the same range (3-8 mg/l) as observed average TSS, which has an estimated average background value of 5 mg/L during calm weather. Modeled maximum TSS (8 to 56 mg/l) are slightly less than observed (23-86 mg/l). This may be partly attributed to natural turbidity peaks during storm conditions, as evidenced by the observed maximum of 48 mg/l at background site 4. Overall, the comparison validates the model and its assumptions. It could even be argued that the no-settling assumption was too conservative, given that modeled *above background* values are similar to observed *total* values.

Table 2.3 Modeled vs. observed TSS ranges from CDF During Sydney Harbour Dredging

Near-surface TSS [mg/l]	**Observed total** Based on 216 samples from 2 Oct 2011 to 21 Jan 2012		**Modeled above background**	
Site	**Maximum**	**Average**	**Maximum**	**Average**
1	25	6	56	8
2	23	7	9	4
3	86	8	18	5
4	48	5	8	3

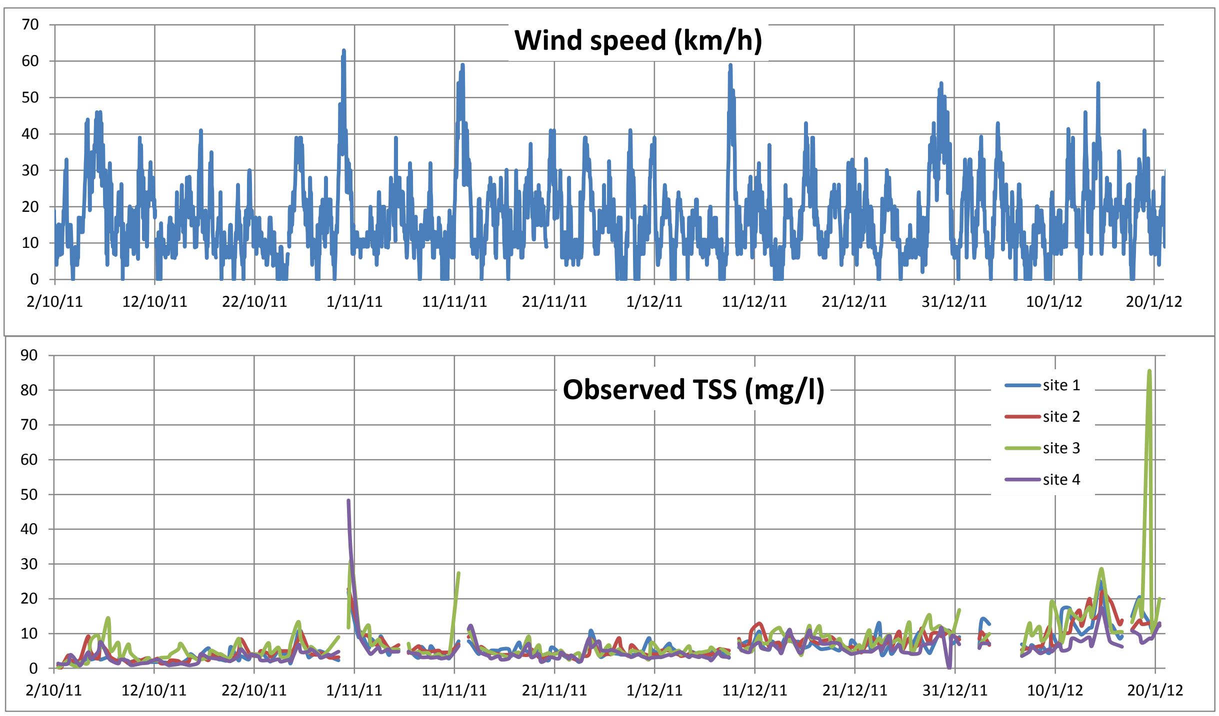

Figure 2.1 Time-series of observed TSS near CDF during Sydney Harbour Dredging

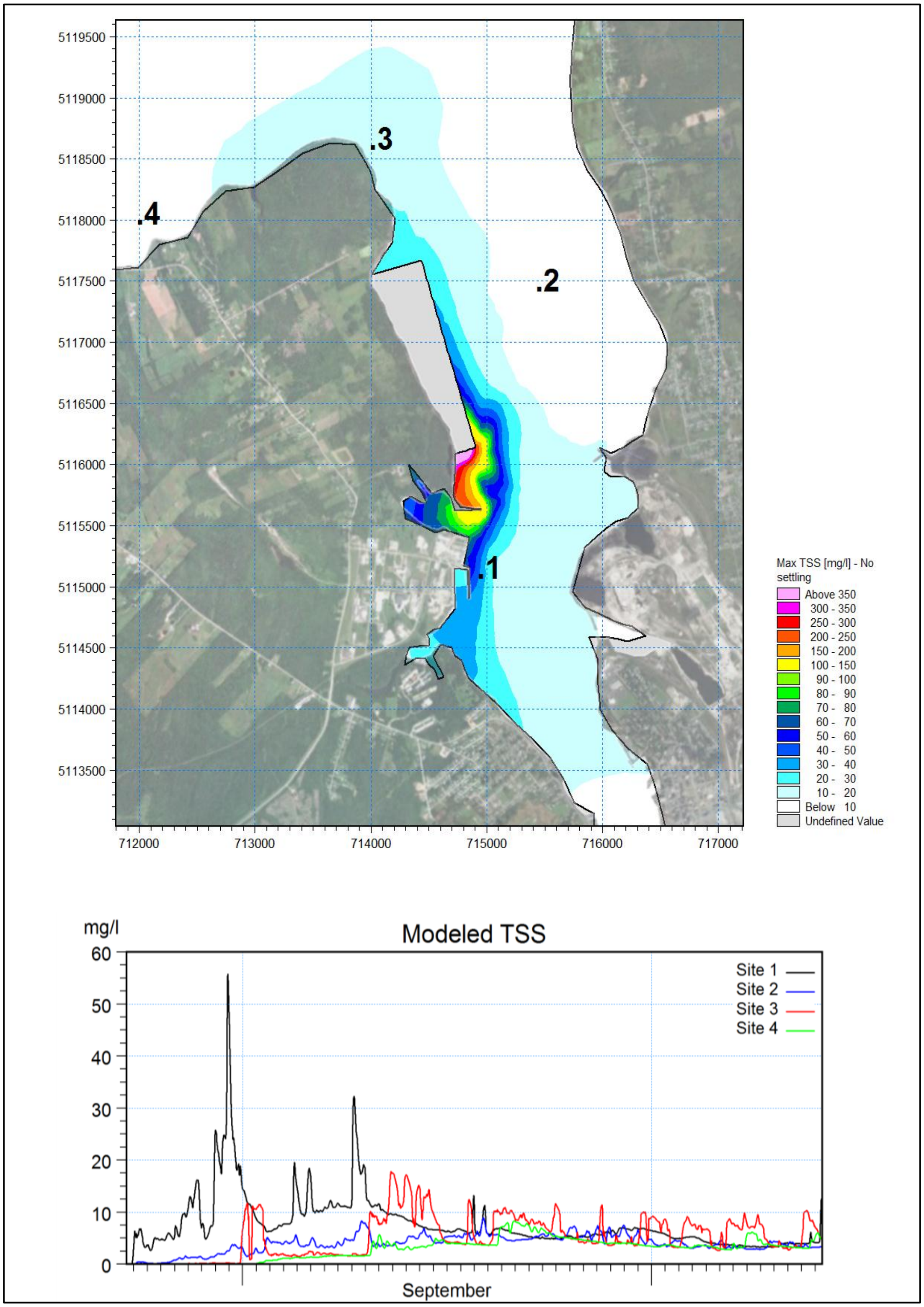

Figure 2.2 Modeled TSS values from Sydport CDF discharge with monitoring sites – Maximum (top) and timeseries (bottom)

2.3.2 TSS from resuspension during dredging

Samples were taken near the TSHD during channel dredging on October 6 and 19th. TSS values were converted from NTUs using a 2.3 scaling factor based on field calibration. The main observations are as follows:

- At a distance of 100 m behind the dredge, TSS ranged from 100 mg/l at 2 m deep to 900 mg/l near the bottom;
- At a distance of 200 m behind the dredge, near-surface TSS ranged from 10 to 100 mg/l, and values at 10 m depth ranged from 50 to 900 mg/l ;
- At a distance sideways from the dredge of 200 m or more, TSS values throughout the water column were less than 25 mg/l.

These observations indicate that the plume was narrow and confined behind the dredge, with much lesser turbidity near the surface. This is consistent with the model results initially presented and reproduced below. The dredge re-suspension model included settling of sediment re-suspended during TSHD dredging operations, at rates given by the contractor (which would not apply to PEV dredging, for which the contractor has not been chosen yet).

Composite image of modeled maximum TSS around TSHD during channel dredging

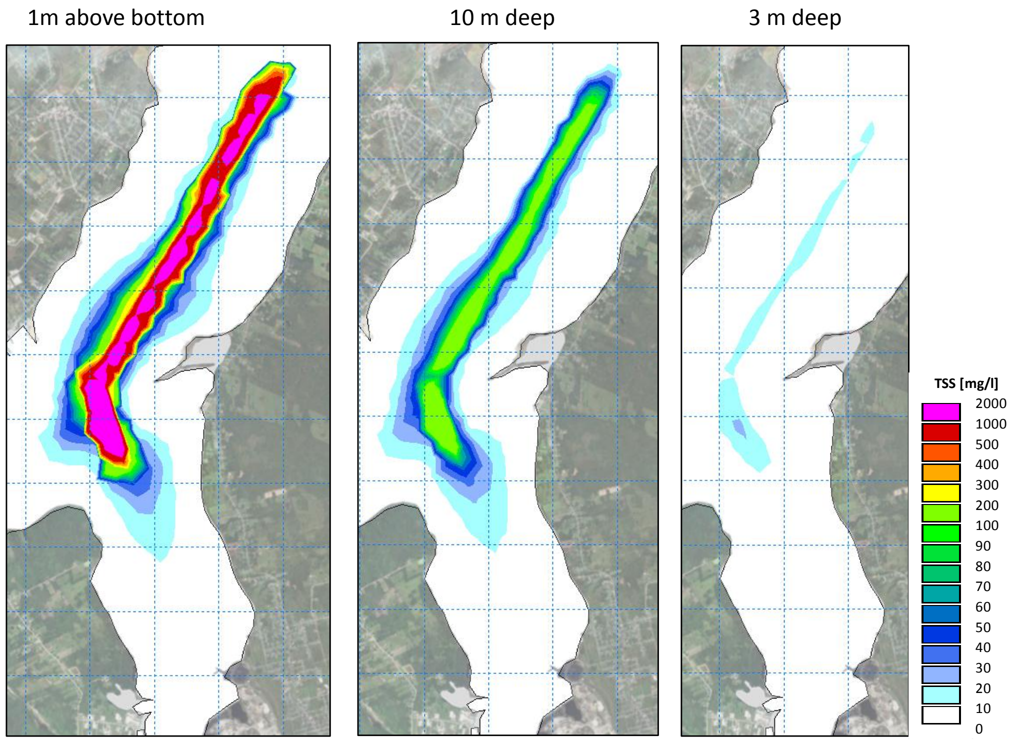

Figure 2.3 Modeled TSS values from sediment re-suspended during Sydney Harbour Channel Dredging by a TSHD

It is emphasized that re-suspension during dredging is very site- and sediment-specific. The potential turbidity during PEV dredging cannot be inferred from the channel dredging observations because sand was predominant in the channel, while fines prevail at the PEV wharf. This difference was accounted for in the PEV dredge model, for which the assumed resuspension rates could not be locally ground-truthed for similar dredging conditions.

CHAPTER 3 MODELED TSS LEVELS FROM PEV DREDGING OPERATIONS

Results are presented in section 3.1 for the TSHD scenario, and section 3.2 for the Clamshell dredge scenario. Proposed compliance monitoring sites are shown (#1 for bioassay at the CDF outflow, and # 2, 3, 4, 5 for TSS).

All concentrations shown represent above background values, and should be considered order-of-magnitude estimates.

Results are given for the 'no settling' and 'with settling' assumptions. The former represents worst-case conditions, to cover uncertainties in sediment size (i.e. if it is finer than expected) and weather conditions (i.e. stormier than usual). Results that include settling are considered more likely to represent actual conditions.

Finally, it is noted that Muggah Creek was assumed to be closed off from the Harbour by a cofferdam during the expected dredging period (summer-fall 2012), which coincides with the ongoing Tar Ponds Cleanup operations.

3.1 Clamshell Dredge Scenario

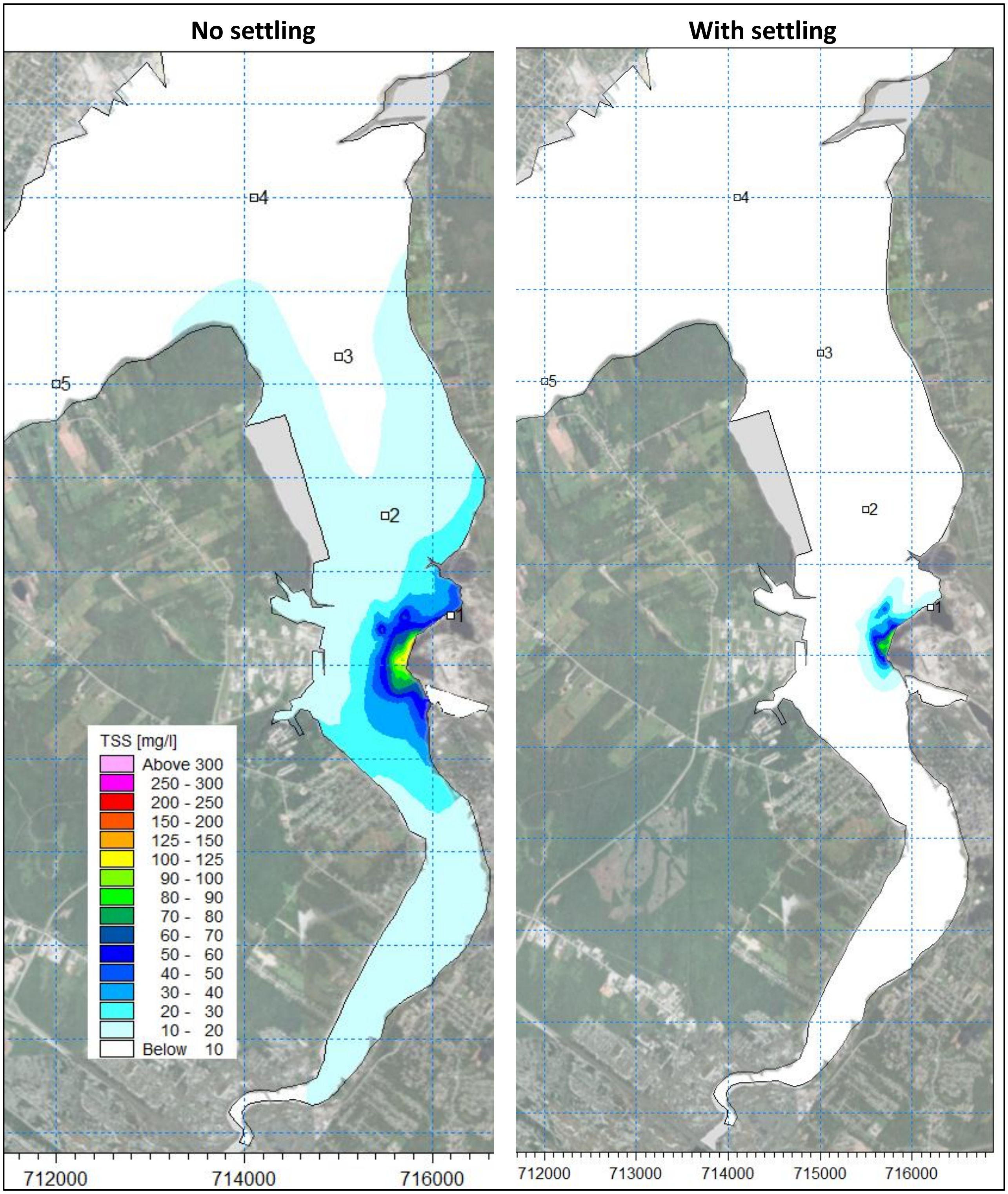

Figure 3.1 Clamshell dredging - <u>Maximum</u> concentrations over the 60 day simulation in surface layer

Note - This is a worst-case composite image, not a snapshot

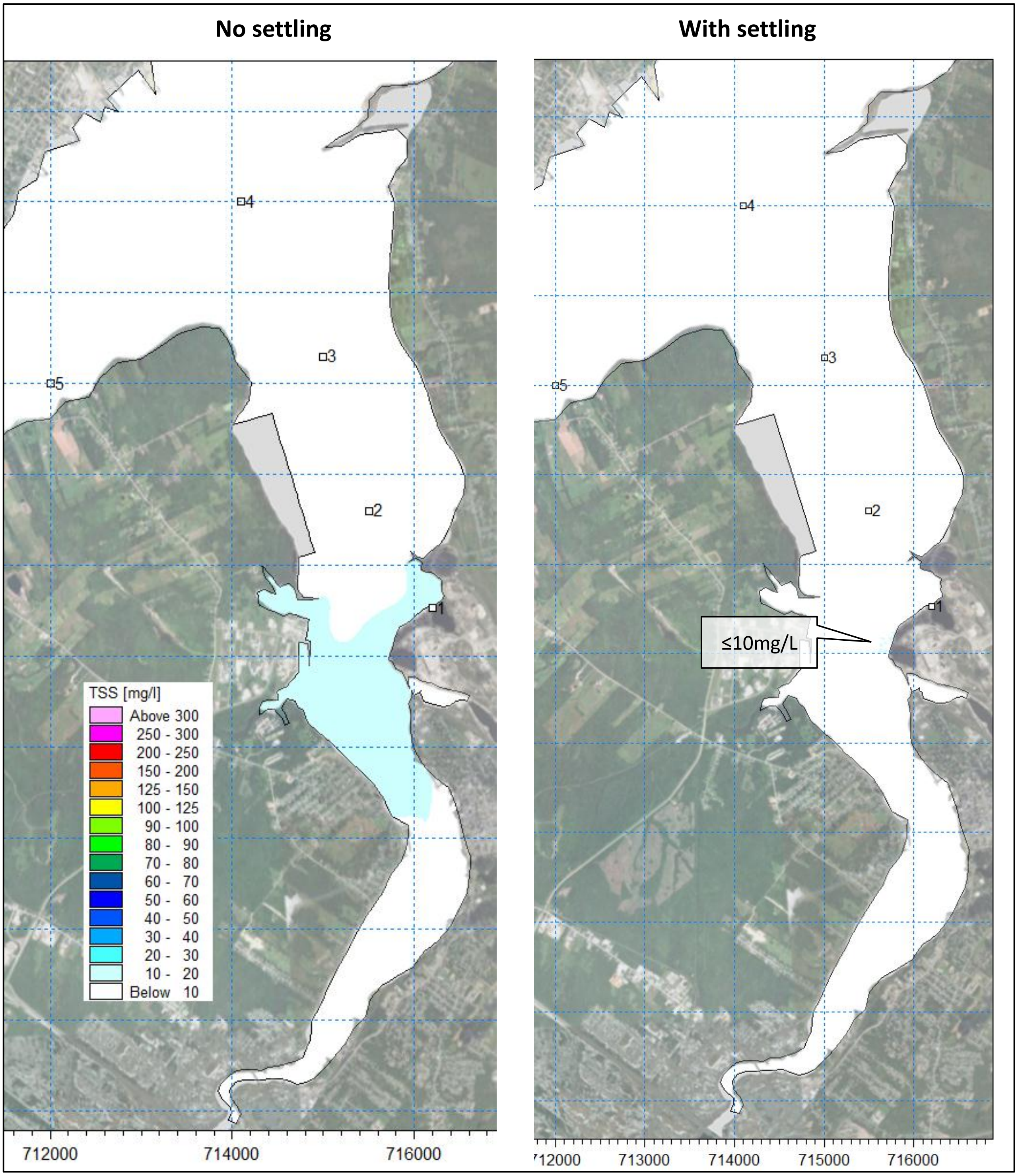

Figure 3.2 Clamshell dredging - <u>Average</u> concentrations over the 60 day simulation in surface layer

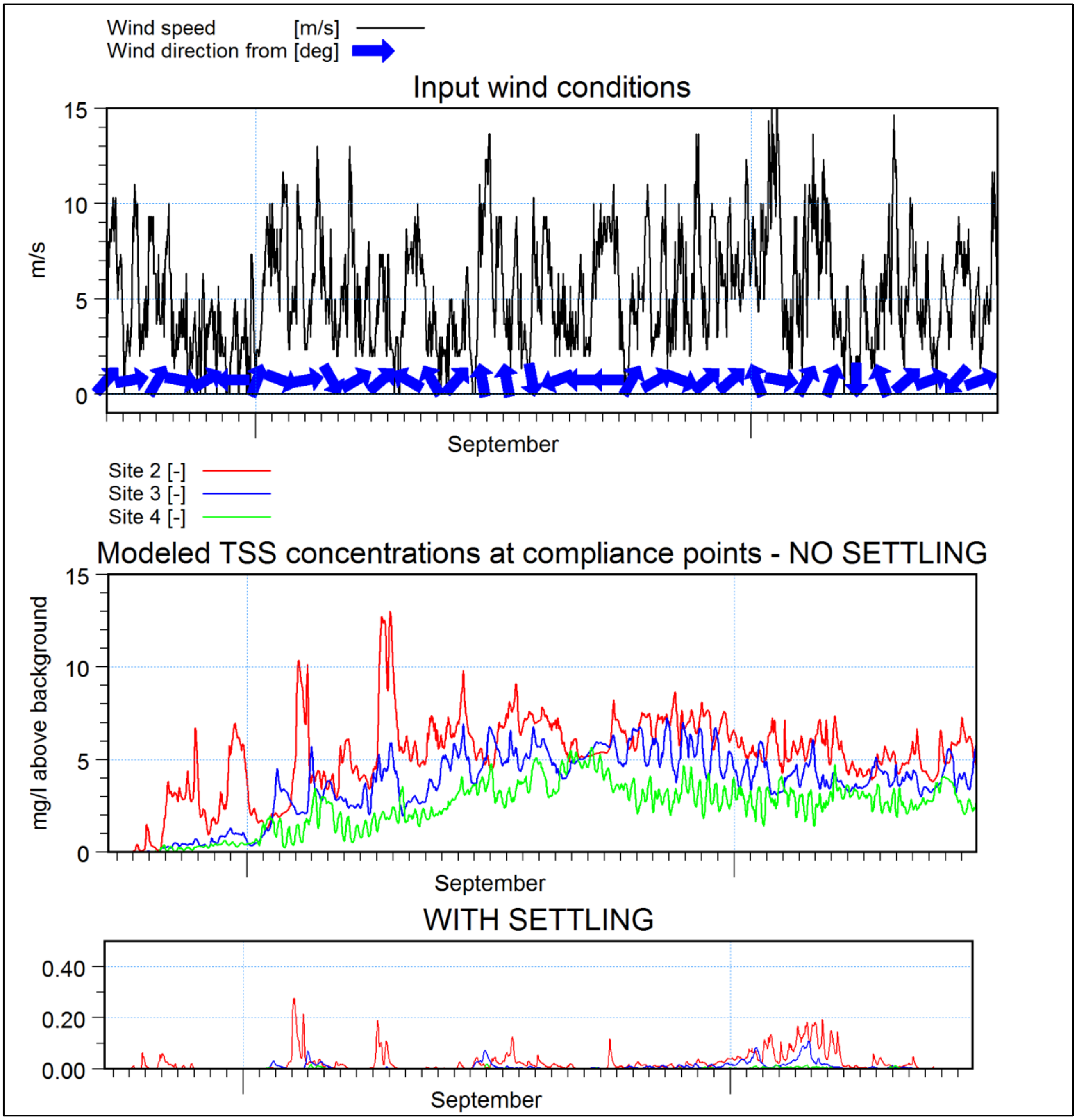

Figure 3.3 Clamshell dredging – Time-series of model inputs and modeled surface TSS concentrations at compliance points over the 60-day dredging period.

3.2 TSHD Scenario

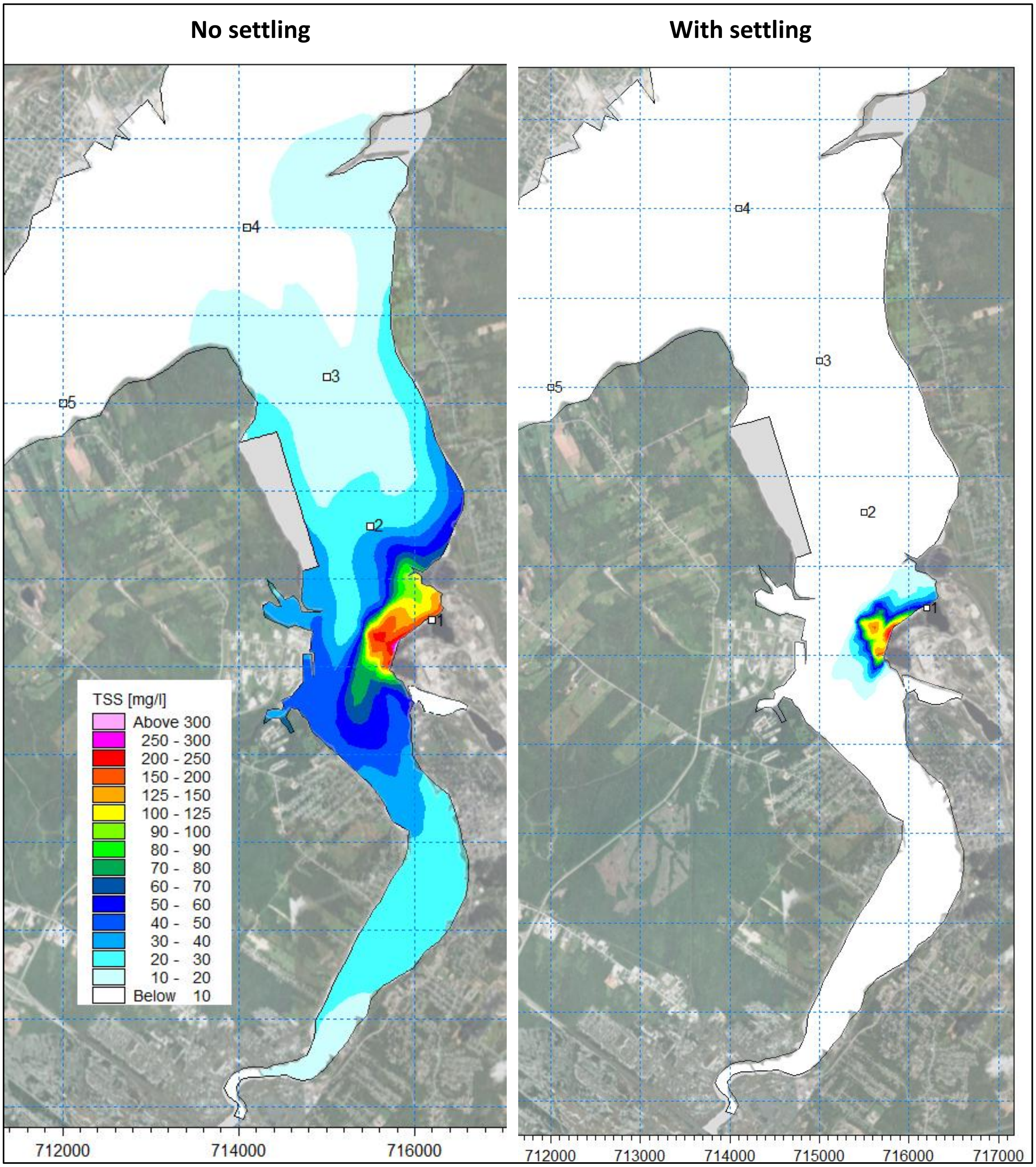

Figure 3.4 TSHD dredging - Maximum concentrations over the 12 day simulation in surface layer

Note - This is a worst-case composite image, not a snapshot

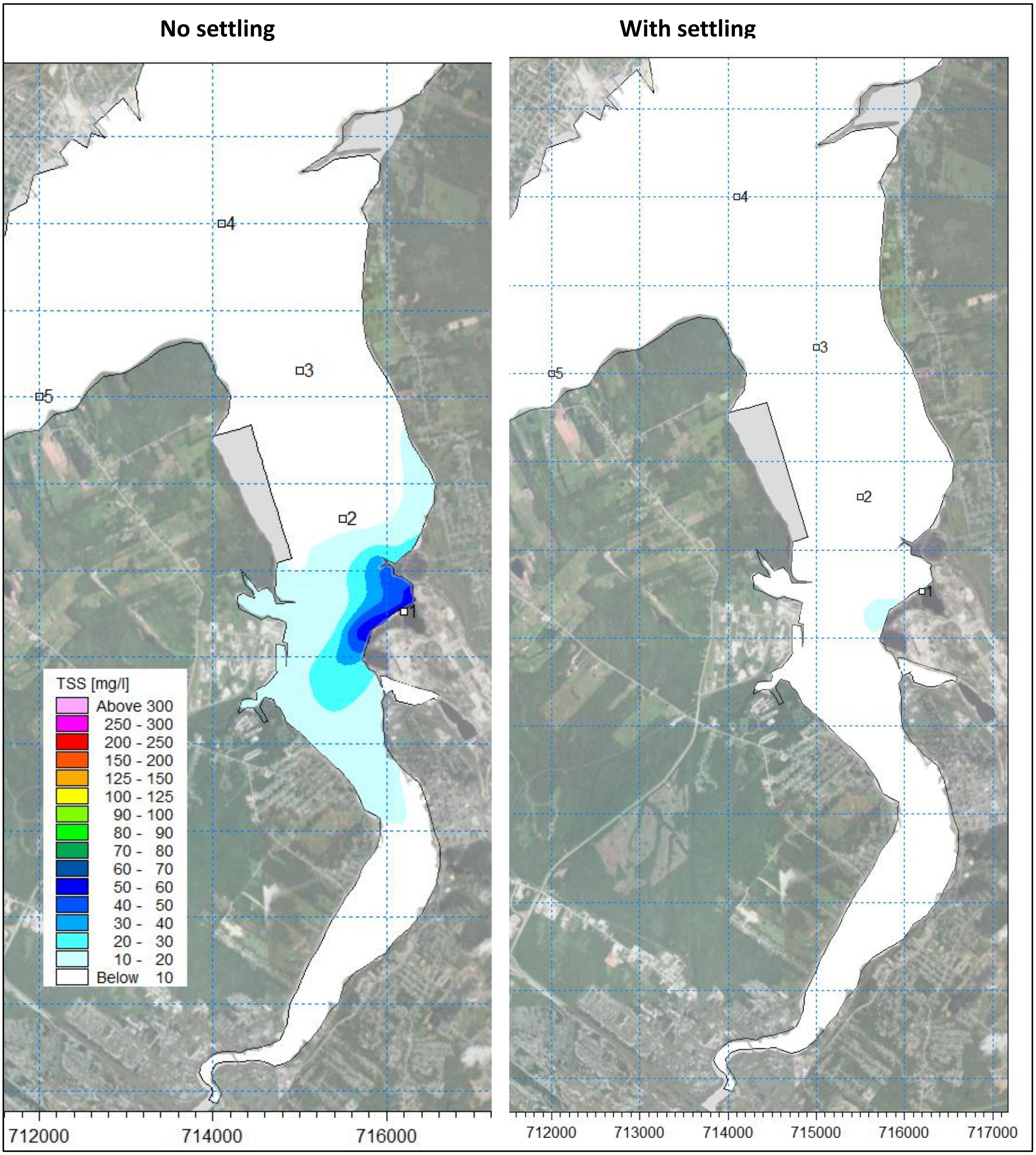

Figure 3.5 TSHD dredging - Average concentrations over the 12 day simulation in surface layer

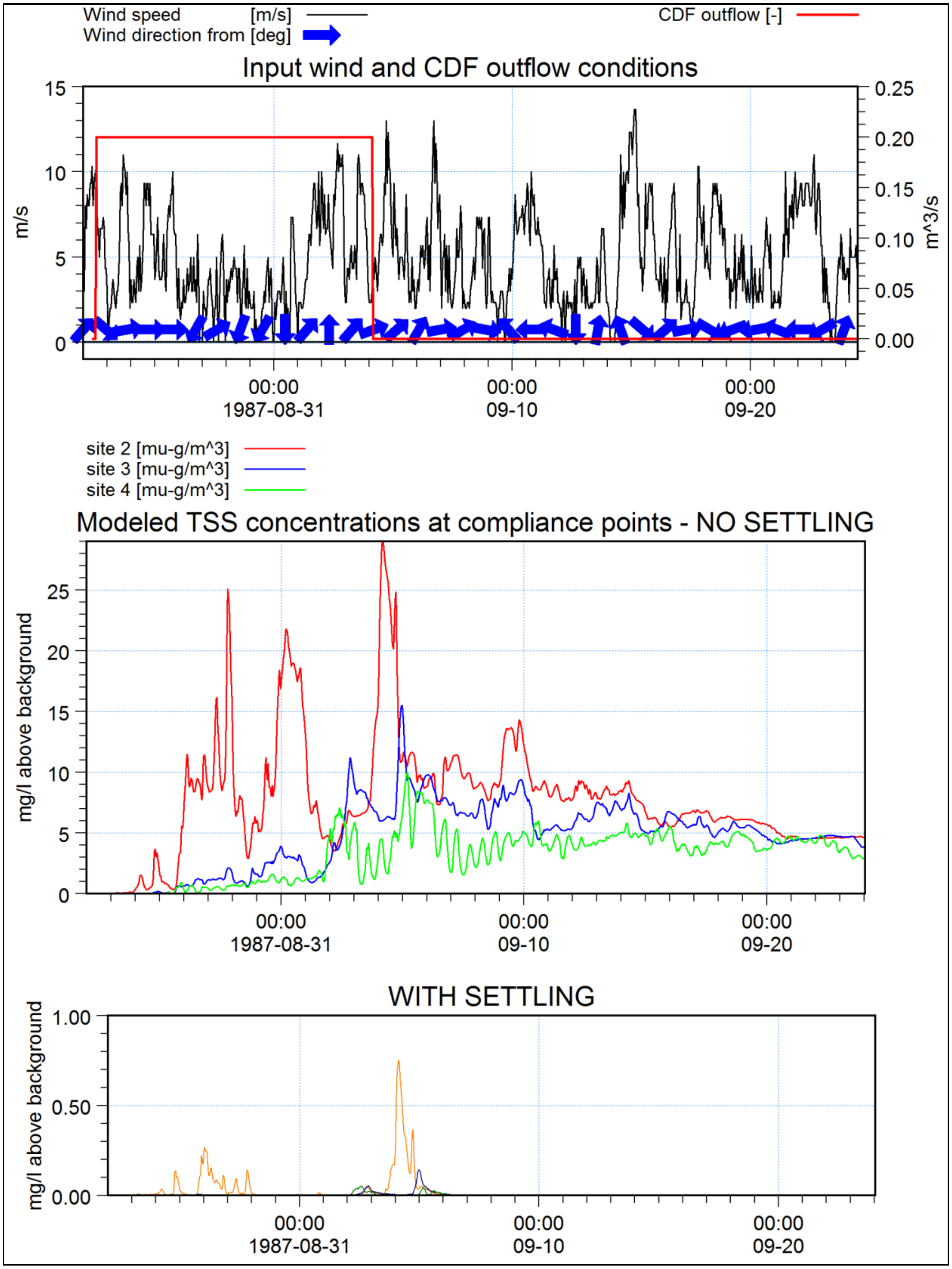

Figure 3.6 TSHD dredging – Time-series of model inputs and modeled surface TSS concentrations at compliance points.

3.3 Conclusions

In summary, the two main differences between dredging options are as follows:

- the re-suspension rate and associated TSS impacts are estimated to be twice as great with the TSHD, and
- the time to complete the work is 5 times longer with the clamshell dredge.

The impacts are summarized in Table 3.1, based on the most likely set of modeling results that included settling of the re-suspended sediment.

Table 3.1 Likely TSS impacts as indicated by modeling

Impacts	**Clamshell dredge**	**TSHD**
CDF outflow	None	Very likely
TSS plume extent – Will spread outside the South Arm?	Extremely unlikely	Unlikely
Maximum TSS - 300m away from PEV dock - At monitoring site 2	 50 mg/L ≤ 0.5 mg/L	 100 mg/L ≤ 1 mg/L
Average TSS	≤ 10 mg/L	≤ 10 mg/L
Project duration	60 days	12 days

CHAPTER 4 REFERENCES

CBCL Limited 2009. Sydney Harbour Hydrodynamic Coastal Study. Prepared for Sydney Ports Corporation Inc. Project 082466. April 2009

Johnson B.H, 2000. Estimating Dredging sediment Re-suspension Sources. USACE Technical Note DOER-E6, October 2000.

USACE 2008. Technical Guidelines for Environmental Dredging of Contaminated Sediments. US Army Corps of Engineers, Engineer Research and Development Center. ERDC/EL TR-08-29.