Sediment plume dispersion modelling: Comparison of a larger dredger and the *New Era*

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Prepared for

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Executive Summary

As part of assessing environmental effects for Project Next Generation, Port Otago Ltd. commissioned NIWA in 2008 to carry out a comprehensive hydrodynamic, dispersion and sediment transport modelling investigation, which was reported by Bell et al. (2009). The 2009 report was submitted in 2010 to Otago Regional Council as a Technical Appendix to the Assessment of Environmental Effects (AEE) that accompanied the consents application.

As outlined in the Port Otago Ltd. applications and AEE, Port Otago will use their own small trailing suction hopper dredger *New Era*, for undertaking a substantial portion of the capital works dredging in Otago Harbour in the form of incremental dredging, progressively working towards the target depth over a longer period of time.

The 2009 NIWA report covered modelling simulations for the worst-case dredging operations, based around the use of a larger trailing suction hopper dredger (TSHD) of 10,800 m^3 capacity. In comparison, the capacity of the *New Era* is only 600 m^3.

This supplementary report compares the suspended-sediment concentrations (SSC) that would be generated during the dredging and disposal phases using the smaller *New Era* with previous model simulations for a larger TSHD. In the Harbour, the 14-day simulations for suspended sediment concentration and sediment deposition (Section 7.5 of the 2009 NIWA report) were all repeated based on the *New Era*, discharging conservatively at 1/13.3 times the larger TSHD sediment discharge rate but overflowing onto the water surface (rather than 5 m depth). Offshore, at the disposal area at A0, the repeated sediment plume simulations for the *New Era* were only undertaken for the scenarios where a hopper load of predominantly-silt dredged material is released at the landward side of the A0 disposal area offshore and at a higher elevation in the water column than the larger TSHD.

Harbour plume modelling (New Era)

Depth-averaged SSC in Otago Harbour for the repeated model simulations was then averaged over a 2 week spring-neap tide cycle to directly compare with the previous 2009 model simulations for a larger TSHD. Monitoring requirements for overseas dredging projects tend to also be expressed as a 2-week moving-average (covering a spring-neap tide cycle).

All simulations for *New Era*, based on a conservative 24/7 operation, show that 2-week average SSC in the main harbour channel reaches only 20–50 mg/L above background concentrations, with smaller patches from 50–100 mg/L where the dredge operates. On the intertidal areas, mostly the average SSC is predicted to only reach 20 mg/L with some limited areas adjacent to the channels of up to 50 mg/L. These concentrations are at least ten times less than those simulated for the larger TSHD.

Considering the silt component of discharges produced by *New Era* from either predominantly-silt versus predominantly-sand[1] areas, there is little difference in the spatial extent of the areas affected by the silt plumes from either dredging source. The SSC are only slightly higher in most cases for the longer overflows when dredging "sand" sources.

Virtually all of the eastern side of the Lower Harbour from Te Rauone Beach through to the eastern side of Portobello Bay would be largely unaffected by turbidity generated by *New Era*, with only a few small patches of SSC up to 10 mg/L above background. Similarly, the eastern side of the Upper Harbour from Grassy Point to Dunedin would be also largely unaffected.

Accumulated seabed deposition over each 14-day plume simulation is presented in mass of sediment per unit area of seabed (kg/m^2). These deposition values are generally conservative as no subsequent resuspension by competent tidal currents or wind-wave stirring was included in the plume model simulations, which will act to further spread and disperse some of the initially-settled material. The deposition plots show the following key results for seabed deposition over a 14-day neap/spring tide cycle with varying winds:

- deposition at or above a nominal 5 kg/m^2 upper level, or approximately 3.8 mm silt accumulation over a fortnightly period at a rate of 0.3 mm/day, is very confined to the immediate vicinity of the main shipping channel where *New Era* dredges. This is in contrast to the larger TSHD, where the same deposition level or rate occurred throughout the main shipping channel (from all discharge sources), and several other areas of the harbour

- most of the eastern parts of the Lower and Upper Harbours would be subject to negligible or no deposition, apart from the reach west of Latham Bay for discharges from the eastern side of the Turning Basin, where deposition may reach 0.5 kg/m^2 (0.4 mm) over 2 weeks or an accumulation rate of 0.03 mm/day)

- flanking mid-harbour intertidal flats, where most of the non-channel deposition will occur, will be at substantially lower deposition rates using *New Era* compared with the larger TSHD by about 10 times less, from 2–5 kg/m^2 (0.1–0.3 mm/day) down to 0.2–0.5 kg/m^2 (0.01–0.03 mm/day) for similar areas.

Offshore plume modelling (New Era)

The maximum excess SSC in the general vicinity of disposal area A0 using *New Era* will only be about 5–7% of the maximum SSC produced by a larger TSHD, based on three wind scenarios (light and moderate WSW winds at 7 and 14 m/s respectively and a light 3 m/s NNE wind). At the disposal area, the <u>near-surface layer</u> SSC concentrations for all silt classes from *New Era* are predicted to be in the range 7–11 mg/L (highest during the light NNE wind) above background concentrations. In the

[1] Where a small 2% fraction of silt has been assumed in the sands

more concentrated bottom layer, predicted SSC in the vicinity of A0 will be in the range 47–57 mg/L above background concentrations (highest for the moderate WSW wind).

The fringes of sediment plumes from the smaller *New Era* will reach the coastline north of Cornish Head, but the excess SSC combining all silt-size classes will be no higher than 0.05 mg/L for the different wind simulations (highest during light WSW winds). This is around ten times less than for the larger TSHD. During light NNE winds, the fringes of the sediment plumes will also reach Otago Heads, where the excess SSC for all silt classes will be no more than 0.6 mg/L.

The extent of the area influenced by the offshore sediment plume is similar for both dredge sizes during offshore-directed winds (WSW), but minor differences occur for the onshore or offshore fringes of the area affected, particularly to the north of the disposal area. In any case, the excess SSC in the fringes of the plume will be very low.

1. Introduction

1.1 Project Next Generation

Project Next Generation is an initiative by Port Otago Ltd. (POL) to expand the capability of Port Chalmers to handle larger container vessels of up to 8000 TEU capacity[2] through a substantial channel deepening capital works project. The main Harbour channel from Port Chalmers to Harington Bend (Figure 1.2) would need to be dredged to 15 m below Chart Datum to accommodate such vessels, but would need to be deepened to 17.5 m below Chart Datum in the offshore approach channel to accommodate vessel motions arising from a combination of waves, swell and currents.

As part of assessing environmental effects for Project Next Generation, Port Otago Ltd. commissioned NIWA in 2008 to carry out a comprehensive hydrodynamic, dispersion and sediment transport modelling investigation, which was reported by Bell et al. (2009). The modelling provides quantitative or comparative before-and-after information to underpin the assessments of the possible effects of dredging and disposal operations on both Otago Harbour and offshore-shelf environments. The 2009 report was submitted in 2010 to Otago Regional Council as a Technical Appendix to the Assessment of Environmental Effects (AEE) that accompanied the consents application.

1.2 This report

POL will use their own small trailing suction hopper dredge *New Era* (Figure 1.1), for undertaking the initial portions of the capital works dredging in Otago Harbour. This would be done over a much longer period of years (rather than months) to incrementally increase the draught of the channel. POL also wish to retain the flexibility to contract a larger dredge for part of the capital dredging project if the demand for larger TEU vessels rapidly increases in the future and the capital works require completion in a period of months.

The 2009 NIWA report covered modelling simulations for the worst-case dredging operations, based around the use of a trailing suction hopper dredger (TSHD) of 10,800 m^3 capacity. In comparison, the capacity of the *New Era* is much smaller at only 600 m^3 or 1/18 of the hopper capacity of the larger TSHD. Consequently, a number of plume-model simulations for harbour dredging and offshore disposal were

[2] Twenty-foot Equivalent Unit (or TEU) is an inexact unit of cargo capacity often used to describe the capacity of container vessels. It is based on the volume of a standard-size 20-foot (~6 m) long shipping container.

repeated using the smaller-scale discharges from *New Era*. This provides a quantitative comparison with the environmental effects that were extensively assessed for the larger TSHD.

This supplementary report compares the suspended-sediment concentrations that will be generated during the dredging and disposal operations using the smaller *New Era* with similar model simulations reported by Bell et al. (2009) for the larger TSHD. Accumulated deposition was also compared for the harbour modelling.

The 14-day harbour simulations repeat those carried out in the 2009 NIWA report (see Figures 7.4 to 7.13 of Bell et al., 2009) for all five representative source areas (see Figure 7.2, Bell et al., 2009). The outputs include plots of the spatial distribution of 2-week average suspended-sediment concentrations and the accumulated sediment deposition.

For the harbour modelling, a very conservative case was simulated with *New Era* working continuously (24/7). However, in reality this very unlikely to occur on a sustained and ongoing basis due to down-time or non-productive time the vessel may be dredging at other ports. In addition, a two-crew operation of *New Era* would only yield approximately 50% of this dredging intensity being available 90 hours per week out of 168 hours for 24/7 (Lincoln Coe, POL, pers. comm.)

Offshore, the simulations for both types of dredger assume the worst-case, where a hopper load of predominantly-silt dredged material is released at the landward side of the A0 disposal area offshore (see Figure 11.4 of Bell et al., 2009).

Figure 1.1: *New Era* passing Spit Jetty fully laden on passage to an offshore disposal site.

For ease of determining various Otago Harbour locations mentioned in this Report, Figure 1.1 from the 2009 NIWA report is reproduced in Figure 1.2.

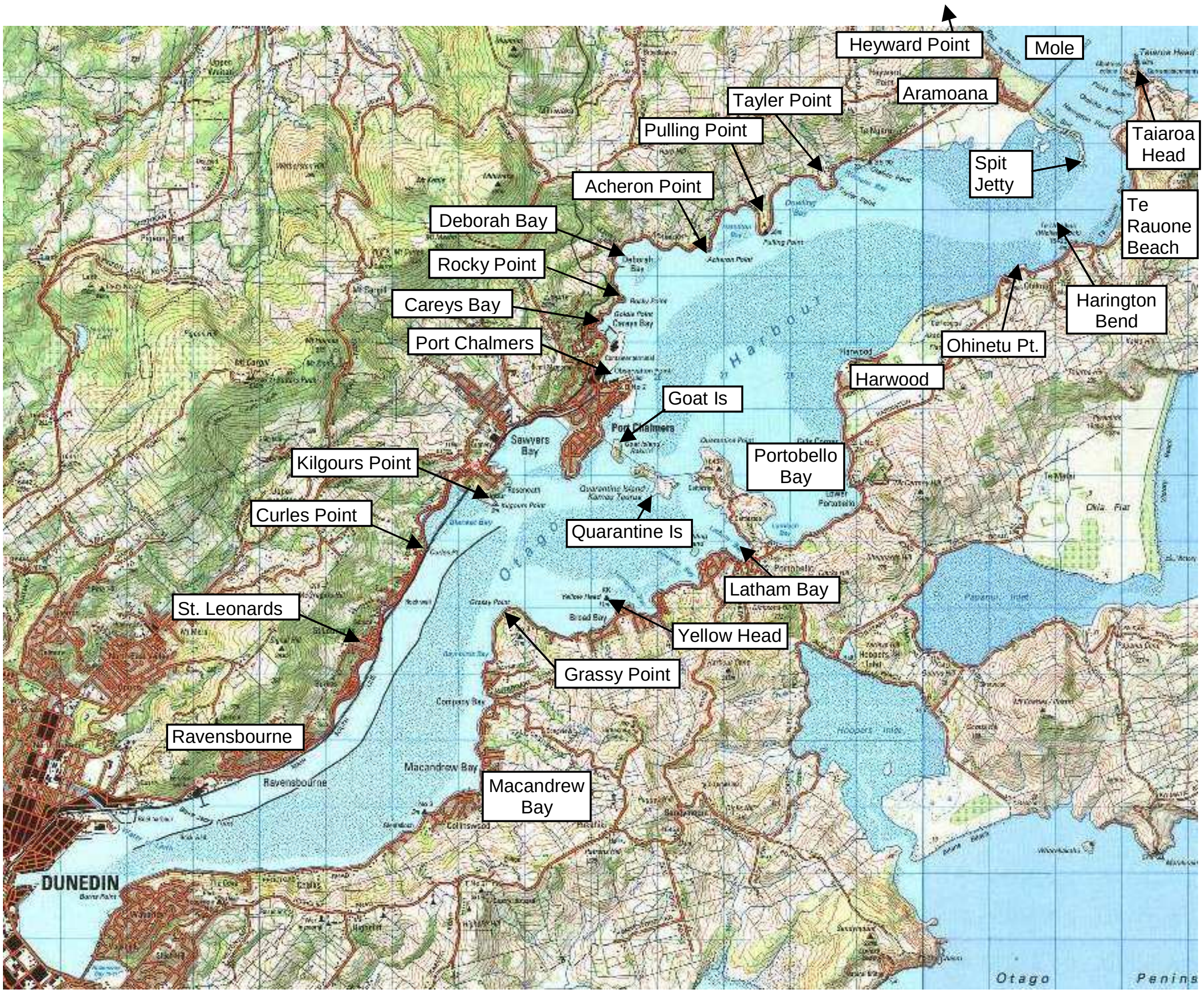


Figure 1.2: Geographical sites in Otago Harbour [*Source:* ©LINZ 1:50,000 topographic maps].

2. Set up of *New Era* simulations

2.1 Harbour sediment plume modelling

Sediment plume modelling in Otago Harbour for a larger TSHD was previously carried out using MIKE-21, which is a 2D (depth-averaged) hydrodynamic model setup on a regular square model grid of 30 m cells, and the MIKE PA module for the plume dispersion, which is 3D "particle-tracking" dispersion model with gravitational settling. In all, ten sets of 14-day sediment plume simulations were undertaken for dredging based at five representative source areas (Figure 2.1) and at each source area, for dredging predominantly-sand sediments (with a 2% silt content) and predominantly-silt sediments (with a distribution of silt size ranges based on seabed samples).

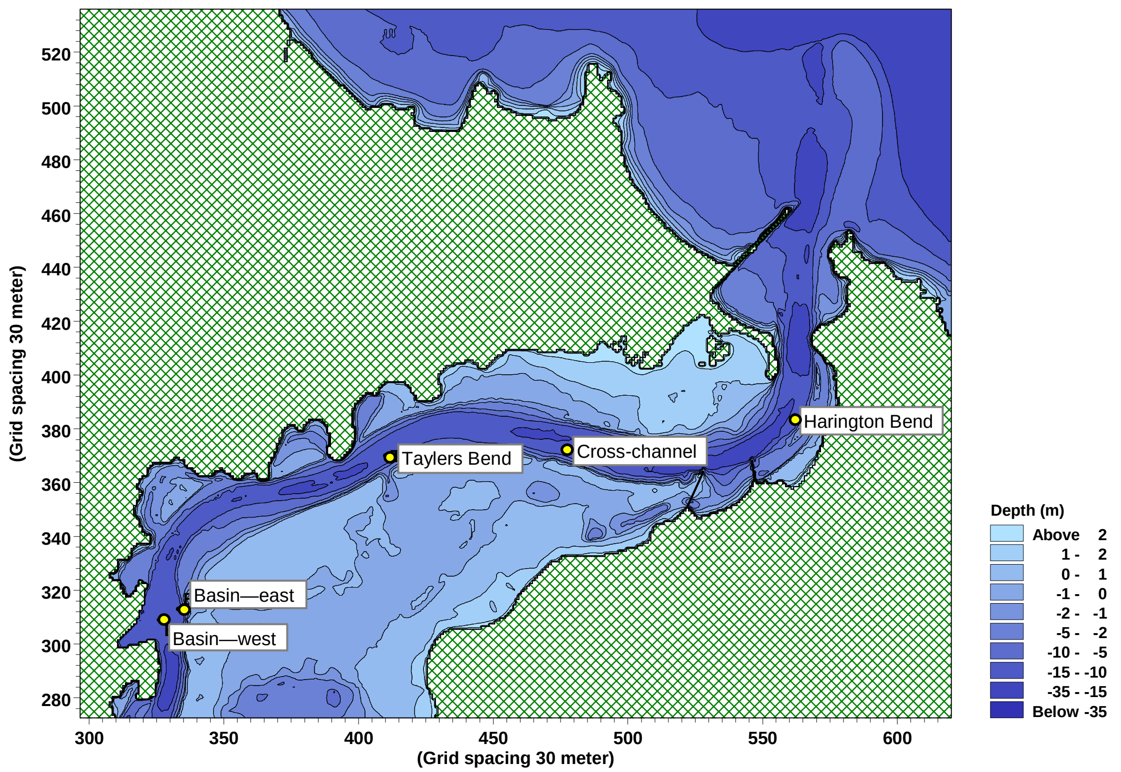


Figure 2.1: The five representative channel source-area sites used as the discharge source locations for dredged-cycle suspended-sediment plume simulations inside Otago Harbour.

These ten simulations were repeated using the smaller-scale *New Era* dredge. The model parameters used to set the sediment discharge rates and their depths for the *New Era* are listed in Table 2.1 (which can be compared with Table 7.1 in the 2009 NIWA

report for the larger TSHD). The main differences are the sediment discharge rates are about 1/15th of the larger TSHD modelled previously, the overflow for sands starts earlier at 10 minutes into the dredging cycle (20 minutes for the larger TSHD)*, and the overflow from *New Era* discharges directly onto the water surface (compared with 5 m depth for the larger TSHD).

Table 2.1: Source discharge rates for silt sizes to be used for the *New Era* for both near-bed suction-head disturbances and hopper overflow sources, time windows for these sources (t = 0 minutes at the start of pumping) for each sediment-source type. [*Source:* Lincoln Coe, POL].

Sediment source	Discharge height	Silt discharge rate (kg/s)	Timing (min)
"Sand" claims (2% silt)	1 m above bed	2	0–80 min
	0 m below surface	4	10–80 min
"Silt" claims	1 m above bed	2	0–24 min
	0 m below surface	75	20–24 min

*Note: the plots for predominantly-sand simulations in the 2009 NIWA report (bottom panels of Figs. 7.4 to 7.13) were mistakenly done for an overflow for the final 20 minutes of the 80 minute dredge cycle. These previous larger-TSHD simulations were repeated for the correct timing of the overflow starting 20 minutes after the start of the cycle and are displayed in Section 3 of this Report for comparison with the *New Era* simulations. The predominantly-silt simulations (top panels) were correct in the 2009 NIWA report. For assessing the effect of the revised predominantly-sand simulations on seabed deposition, compared to the earlier simulations in the 2009 NIWA report, see the comparison plots in Appendix A.

The dredge cycle times including turn-around times for *New Era* were left the same as for the previous simulations as listed in Table 7.2 of the 2009 NIWA report, including a conservative assumption of a 24/7 continuous dredging operation (which in reality will not occur on a sustained and ongoing basis due to downtime and non-productive time outside of the port). All other parameters, including settling velocity were also held to the same values as previously used.

Results are provided in plot showing the spatial distribution of a 2-week average of suspended-sediment concentrations in kg/m^3 (depth averaged and saturated-weight[3]

[3] Normally suspended-sediment concentrations are expressed in dry-weight of sediment, so these higher results based on saturated-weight will be more conservative.

basis as previously) and the accumulated sediment deposition after 2 weeks in kg per square metre of seabed. To convert to metres of deposition, these results would need to be divided by a conservative wet bulk sediment density of 1300 kg/m^3. The additional complex step of apportioning the deposition to several sub-areas of Otago Harbour (see Figure 7.3 of the 2009 NIWA report) and reporting on statistics was not re-done for this supplementary work, given the potentially long time of a few years that would be required to complete the dredging using *New Era*. However, the overall 14-day deposition plots show the main areas where sediments would preferentially settle under *New Era* dredging (with a surface overflow) compared to the larger TSHD overflowing at a greater depth.

2.2 Previous offshore sediment plume modelling

Previous modelling offshore for plume dispersal from the disposal site A0 was based on MIKE3-FM, which is a 3D layered hydrodynamic model on a flexible triangular mesh, and the MIKE3 PT module, which is a 3D "particle-tracking" dispersion model with gravitational settling (Bell et al., 2009).

The following plume model parameters were previously implemented in Bell et al. (2009) for the offshore disposal ground as described in Section 11.1.1 of that Report:

- sediment classes - Four sediment size fractions were simulated by "particles" in the discharge with their respective average settling velocity:
    - *Class 1* - fine silt with grain sizes of <0.00625 mm.
    - *Class 2* - medium silt with grain sizes between 0.00625 and 0.02 mm.
    - *Class 3* - coarse silt with grain sizes between 0.02 and 0.0625 mm.
    - *Class 4* - fine sand with grain sizes of >0.0625 mm.
- discharge height from bottom of hopper - set to 5 m below the water surface at the time, which is applicable to a larger trailing suction hopper dredger (TSHD)
- discharge sequence - based on an analysis of dredging operations by POL, the discharge at the disposal site was simulated as a 10-minute slug of sediment with a 2-hour turn-around window before the next disposal commenced and so on
- discharge location – the most landward sub-site #1 within the 2 km diameter A0 disposal area (see Figure 2.2 below)

- dredge hopper composition and discharge rates - two variants on the likely sediment composition of a hopper were simulated with their associated discharge rates in kg/s for each sediment class listed in Table 11.1 of Bell et al. (2009). The wet bulk density of sand in the hopper was assumed to be packed at 1800 kg/m^3 and for silts 1600 kg/m^3 based on dredging experience (Lincoln Coe, pers. comm.). The majority of the plume model runs in Bell et al. (2009) used an overall average sand/silt hopper composition, based on a dredging analysis by Port Otago Ltd. that incorporated geotechnical findings and sediment size grading curves. In terms of ascertaining peak suspended-sediment concentrations at the disposal site and surrounding area, some simulations were also performed for a hopper of predominantly silt (e.g., sourced from the Hamilton Bay reach between Beacons 18 and 20). It is these simulations for predominantly-silt hopper loads that are compared with using the *New Era* in this present Report.

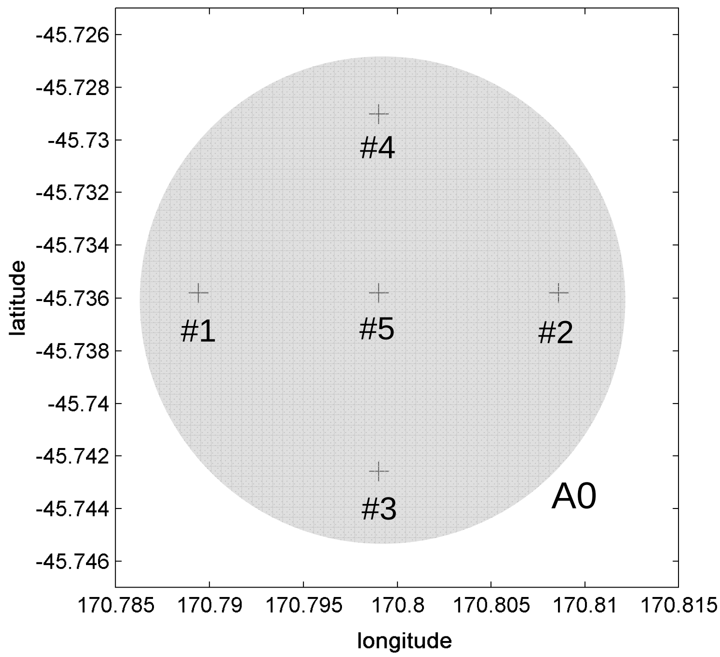


Figure 2.2: Relative location of the 5 sub-sites used as hopper-release locations within a 2-km diameter disposal site at A0 (central sub-site #5 is at –45.7358°N and 170.799°E).

2.3 *New Era* offshore plume simulations

The equivalent parameters for the *New Era* sediment-plume modelling runs were:

- *sediment classes* – used the same four sediment classes and settling velocities

- *discharge height* – the bottom of the hopper for the *New Era* when laden is 3.5 m below the water surface and 1.5 m when empty, so the sediment discharge height has been set at 2.0 m below the surface, slightly below the laden/empty average

- *discharge sequence* – the turnaround time of 2 hours is set the same as the larger TSHD but the discharge time is set at 4 minutes compared with 10 minutes for a larger TSHD

- *discharge location* – same as before

- *hopper composition and discharge rates* – the *New Era* hopper capacity is only 600 m^3 compared with 10,800 m^3 for the larger TSHD, otherwise the loading factors and wet bulk densities are assumed to be the same. Therefore the sediment volumes discharged from the *New Era* hopper are 5.56% of those for the larger TSHD (i.e., 600/10,800 = 0.0556), but the discharge time is only 4 minutes compared with 10 minutes for the larger TSHD so a factor of 10/4 has been applied to the volumes to determine the *New Era* discharge rates. A comparison of the sediment discharge rates for both TSHD is shown in Table 2.1.

Table 2.1: Sediment discharge rates (kg/s) on a saturated-weight basis used for the dredge hopper scenarios for each sediment size class covering a predominantly-silt hopper composition using a larger TSHD (10,800 m^3 capacity) compared with the *New Era* (600 m^3).

Hopper load scenarios (predominantly silt load)‡	**Larger TSHD**	***New Era***
Sediment-class discharge (kg/s)		
Class 1 (fine silt)	2,326	323
Class 2 (medium silt)	3,034	422
Class 3 (coarse silt)	3,236	450
Class 4 (fine sand)	1,517	211

‡Predominantly-silt hopper load for the larger TSHD dredge would be 3,790 m^3 assuming a lower hopper loading factor of 0.35 for mostly silts. The same loading factor was applied to the *New Era*. The lower loading factor arises from early cessation of dredging when the hopper starts to overflow and silts don't readily settle in the hopper like sands. A bulk density of 1600 kg/m^3 is assumed for both TSHD dredgers.

3. Results for the harbour plume modelling

The results are presented as a series of two sets of paired plots on facing pages of both the 2-week average SSC and the 2-week accumulated deposition.

The left-hand pages are the previous results from the larger TSHD shown in Figures 7.4 to 7.13 of the NIWA 2009 report (apart from the predominantly-sand simulations in the bottom panel which were re-run for an overflow starting 20 minutes into the dredging cycle). The right-hand pages are the equivalent simulations using the smaller *New Era*.

The same spatial coverage and the same suspended-sediment concentration or deposition scale palettes have been used in the plots, as those used in the 2009 NIWA report, to provide a ready comparison of the differences in average SSC and the 2-week accumulated deposition between using a larger dredger and the *New Era*.

Harbour sites mentioned are shown in Figure 1.2.

3.1 Comparisons for the 2-week average suspended-sediment concentrations

Suspended-sediment concentration (SSC) averaged over each 14-day plume simulation was calculated for each model grid cell (30 m × 30 m) and plotted in Figure 3.1 to Figure 3.10 for each of the five discharge sources. Concentrations are presented in kg/m^3, where 1 kg/m^3 is equivalent to 1000 mg/L and 0.1 kg/m^3 is equivalent to 100 mg/L. Average SSC over 2 weeks are provided to directly compare with the previous 2009 model simulations for a larger TSHD and monitoring requirements for overseas dredging projects tend to be expressed as a 2-week moving-average (covering a spring-neap tide cycle). Note: the modelled SSC excludes any background concentrations, which can vary considerably each day and throughout a tide cycle. So SSC is expressed as an excess concentration due to the dredging over and above any background concentration.

Concentrations from the MIKE-21 PA plume model are averaged over the entire depth of the water column at the time of calculation, so the 14-day SSC averages shown in the plots are also averages over the water depth (mid-tide to seabed level). However, because the sediments are discharged at depth and they preferentially settle (even though there will be some upwards vertical dispersion), the SSC will be distributed unevenly through the water column, skewed towards much higher-than-average SSC near the seabed compared to a lower-than-average SSC at the water surface. This

skewed distribution also occurs naturally with tidal current or wave stirring of bottom sediments, where the SSC is far greater just above the seabed than at the surface - more so the deeper the water column and the larger the grain size.

The plots (Figures 3.1–3.10) show the following key results:

- all simulations for a 24/7 operation based on *New Era* show that 2-week average SSC in the main channel reaches only 20–50 mg/L above background concentrations, with smaller patches from 50–100 mg/L where the dredge operates. On the intertidal areas, mostly the average SSC is predicted to only reach 20 mg/L with some limited areas up to 50 mg/L. These concentrations are at least ten times less than those simulated for the larger TSHD

- the *New Era* discharges in the Turning Basin (Figures 3.2 & 3.4) and Taylers Bend (Figure 3.6) would have the most influence on raising average SSC above background levels in the Upper Harbour. Outside the main channels, SSC would be up to 50 mg/L in small areas (mainly west of Portobello Peninsula for dredging in the eastern Turning Basin), and mostly below 10 mg/L above background concentrations

- the highest depth-average SSC values of up to 100 mg/L will occur in small patches in the main shipping channel where the *New Era* is operating. In subsidiary side channel north of Quarantine Island through to Portobello Peninsula (Figure 3.4), there will be patches with SSC up to 50 mg/L when the dredge is working the eastern Turning Basin

- considering the silt component of discharges produced by *New Era* from predominantly-silt (top panels) versus predominantly-sand[4] areas (bottom panels), there is little difference in the spatial extent of the areas affected by the respective silt plumes. The SSC are only slightly higher in most cases for the longer overflows when dredging predominantly-sand areas

- while there is only a short distance separating the two Turning Basin source locations (east and west on Figures 3.2 & 3.4), there will be a substantial divergence in areas affected by suspended-sediment plumes due to the strong flow divergence at Quarantine Island. From the “west” source location, discharge plumes would be transported up the Victoria Channel partway into the Upper Harbour (Figure 3.2), while plumes from the “east” source location (Figure 3.4) would be preferentially transported and dispersed to areas around

[4] Where a small 2% fraction of silt has been assumed in the sands

the Portobello Peninsula and into the Latham Bay to Yellow Head area of the Upper Harbour, predominantly only in the SSC range 5–10 mg/L above background but there are small patches with SSC up to 50 mg/L (for locations see Figure 1.1 of Bell et al., 2009)

- virtually all of the eastern side of the Lower Harbour from Te Rauone Beach through to the eastern side of Portobello Bay would be largely unaffected by turbidity generated by *New Era*, with only a few small patches of SSC up to 10 mg/L (Figure 3.10)

- the eastern side of the Upper Harbour from Grassy Point to Dunedin would be also largely unaffected by sediment discharges from *New Era*

- the 14-day average SSC will be negligible in the indistinct plume that emanates from the Mole to Taiaroa Head channel section for dredging claims in the Turning Basin, but will gradually increase up to a depth-average SSC of 10–20 mg/L for dredging at Harington Bend. These average SSC levels offshore from the Mole would reduce somewhat as the dredger works the Howlett claim (between Harington Point and the Mole) and further reduce in the Outer Channel claim as the silt content of the sandy seabed sediments reduces considerably to be negligible.

Also pertinent to these results on 2-week averages is the finding in the NIWA 2009 Report (Bell et al., 2009) that the % of time that the excess SSC is negligible is quite high outside the main channels—often 80% of the time or more. This occurs because the dredging discharges are not continuous, but cyclic with gaps of up to 1.8 hours and the tidal flows reverse every 6 to 6.5 hours, providing lengthy periods at "upstream" sites for silt-sized material to settle out.

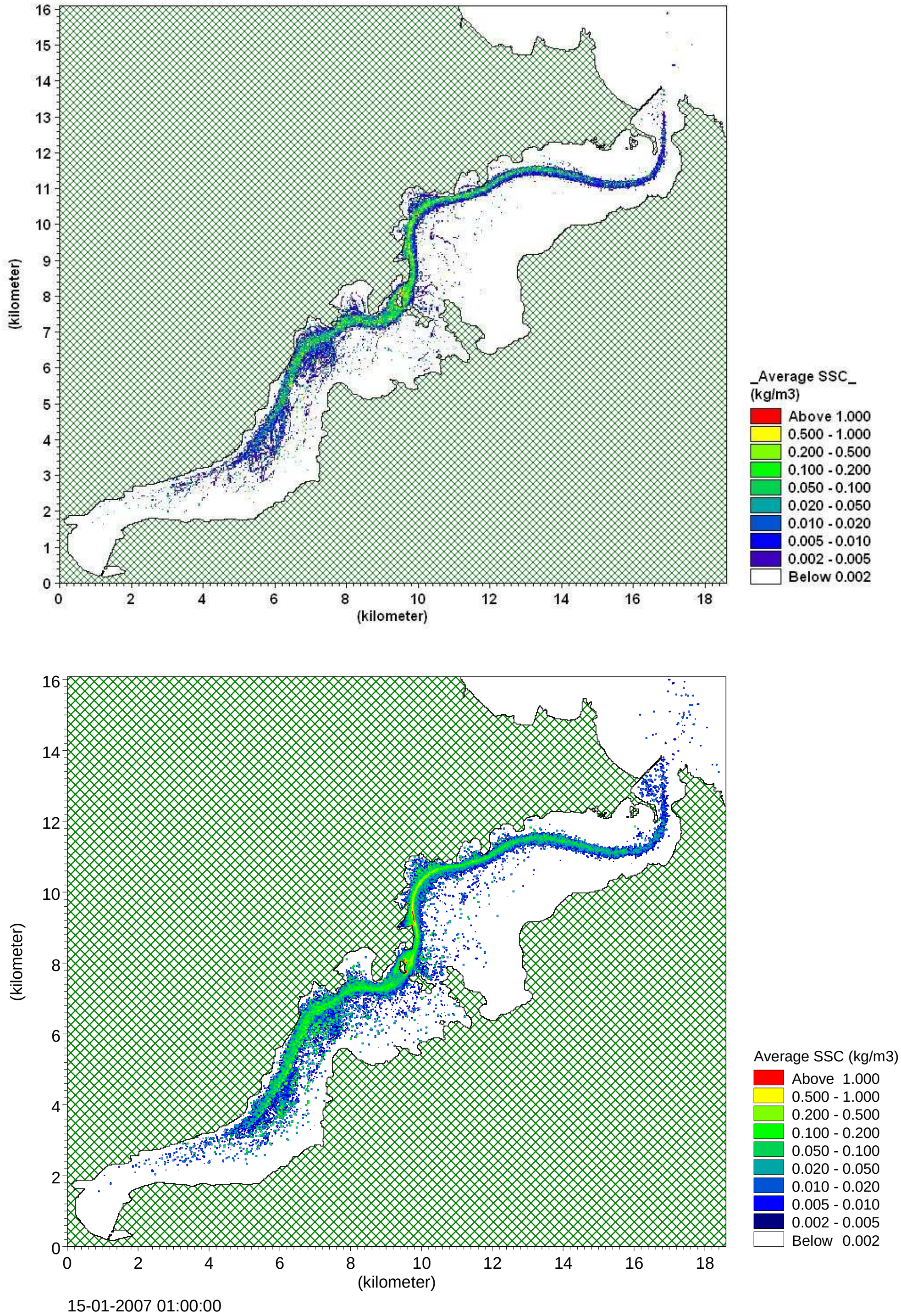
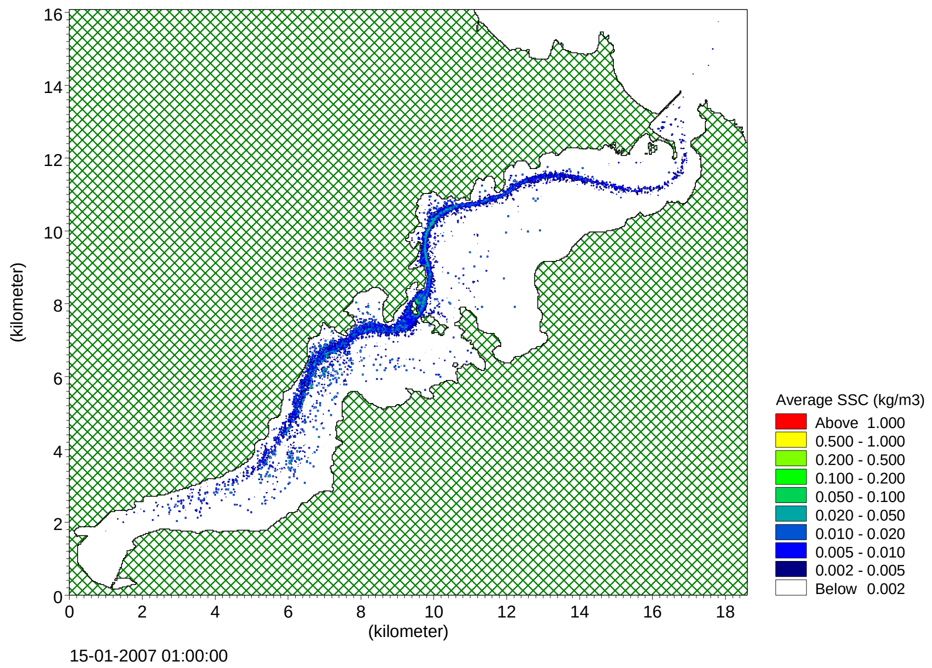


Figure 3.1: 14-day average SSC in kg/m^3 for a Basin–west discharge source for the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).



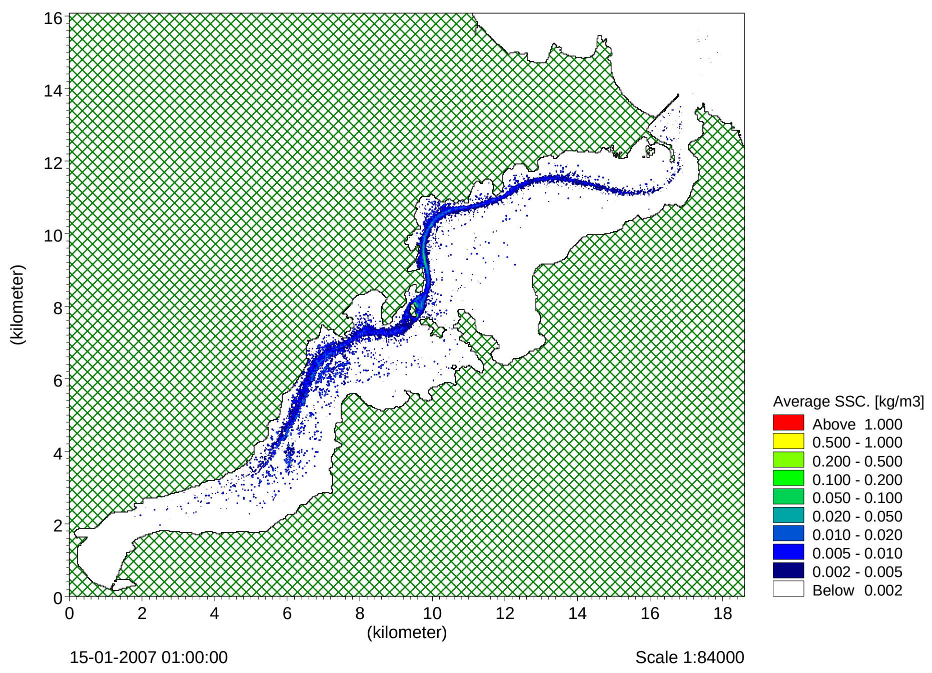


Figure 3.2: 14-day average SSC in kg/m^3 for a Basin–west discharge source for the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

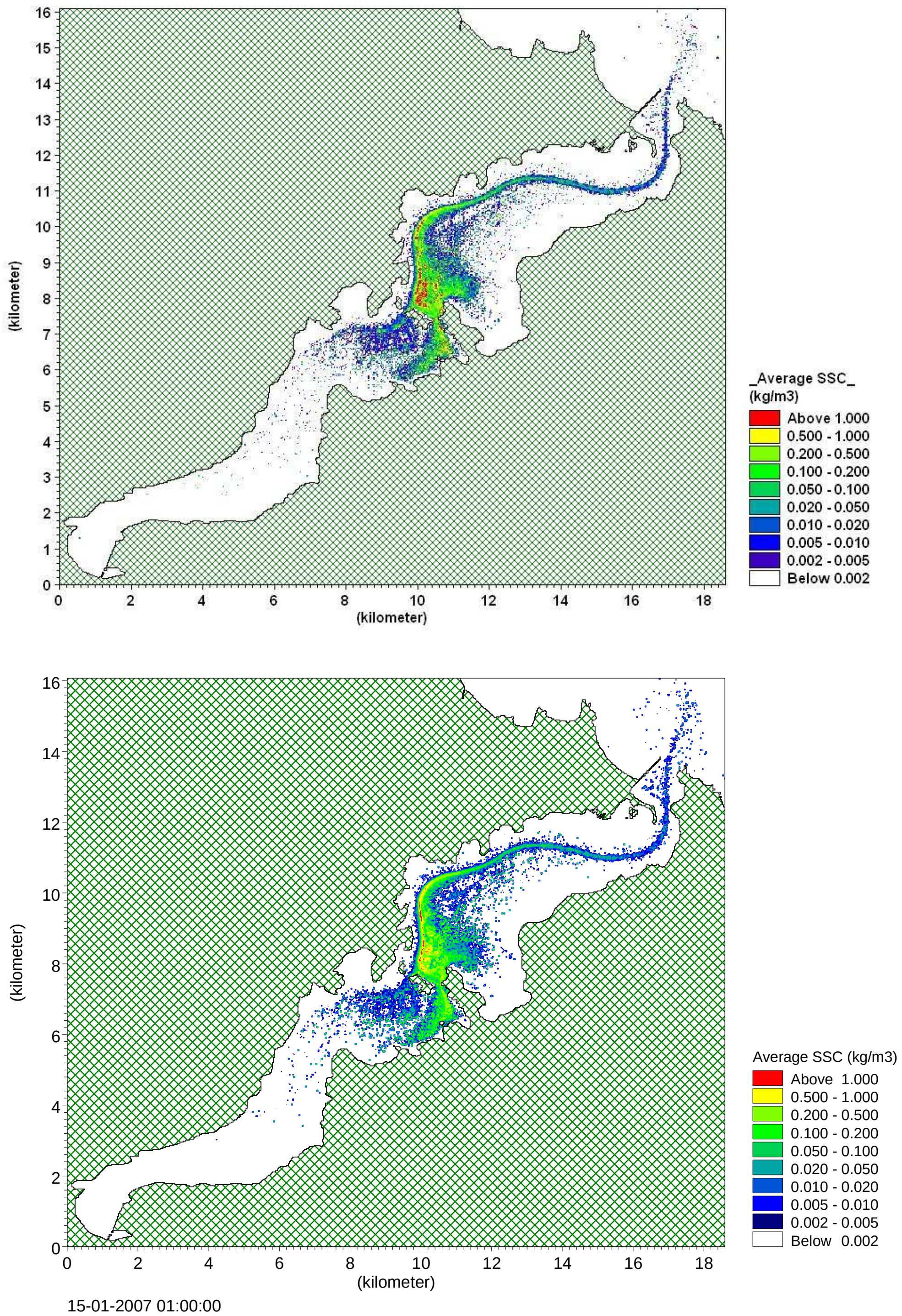
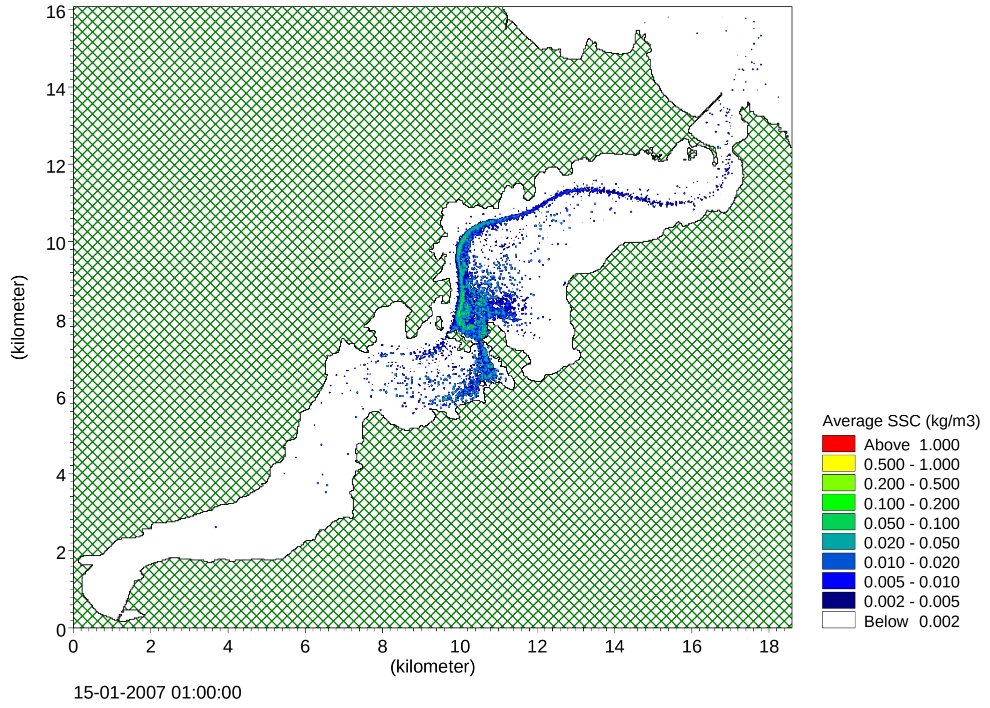


Figure 3.3: 14-day average SSC in kg/m^3 a Basin–east discharge source for the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).



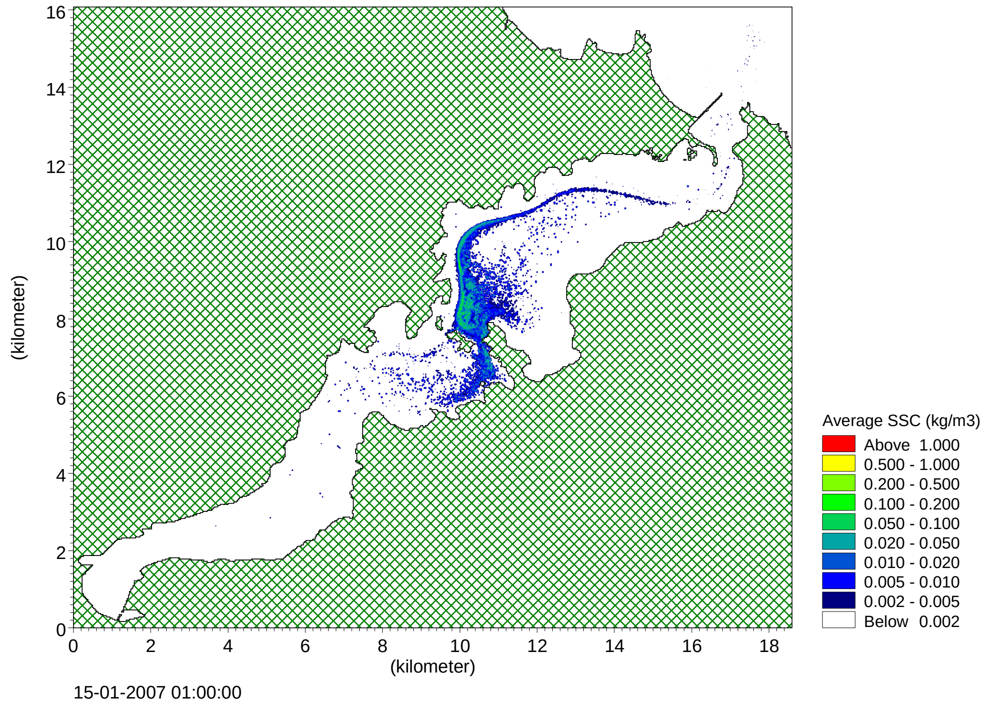


Figure 3.4: 14-day average SSC in kg/m^3 for a Basin–east discharge source for the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

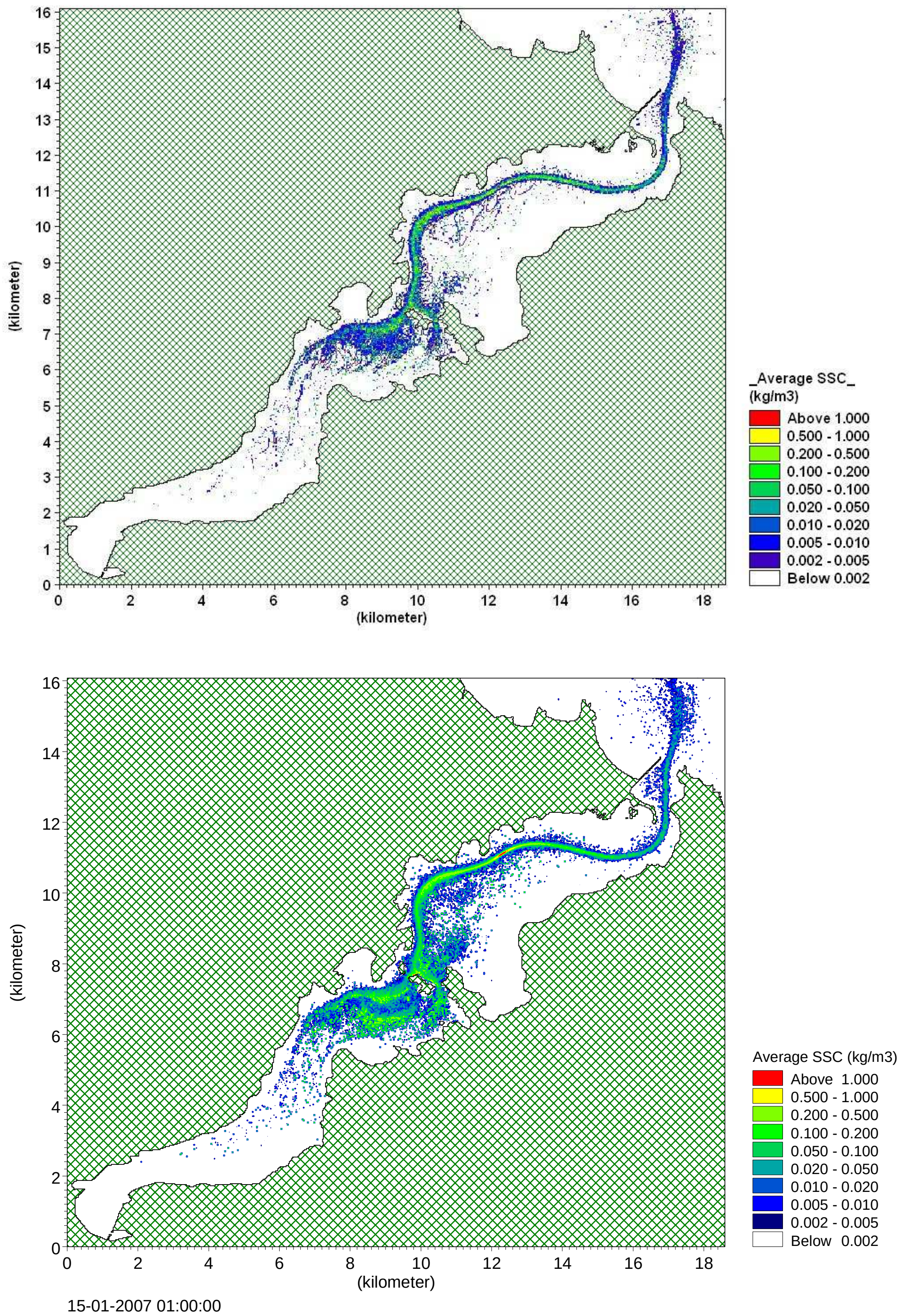
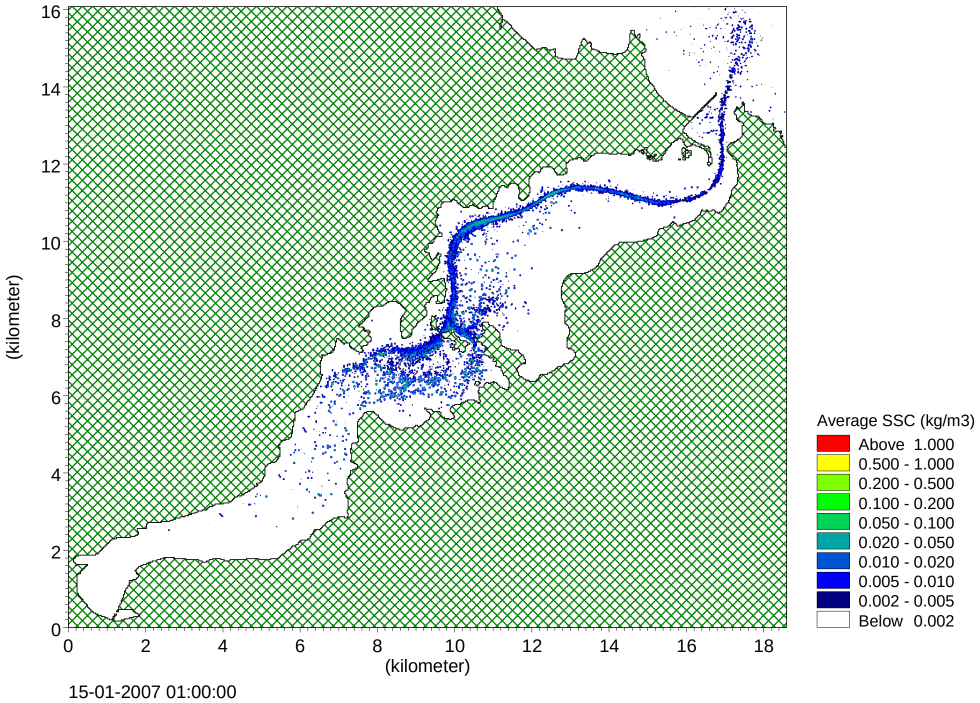


Figure 3.5: 14-day average SSC in kg/m^3 for a Taylers Bend discharge source for the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).



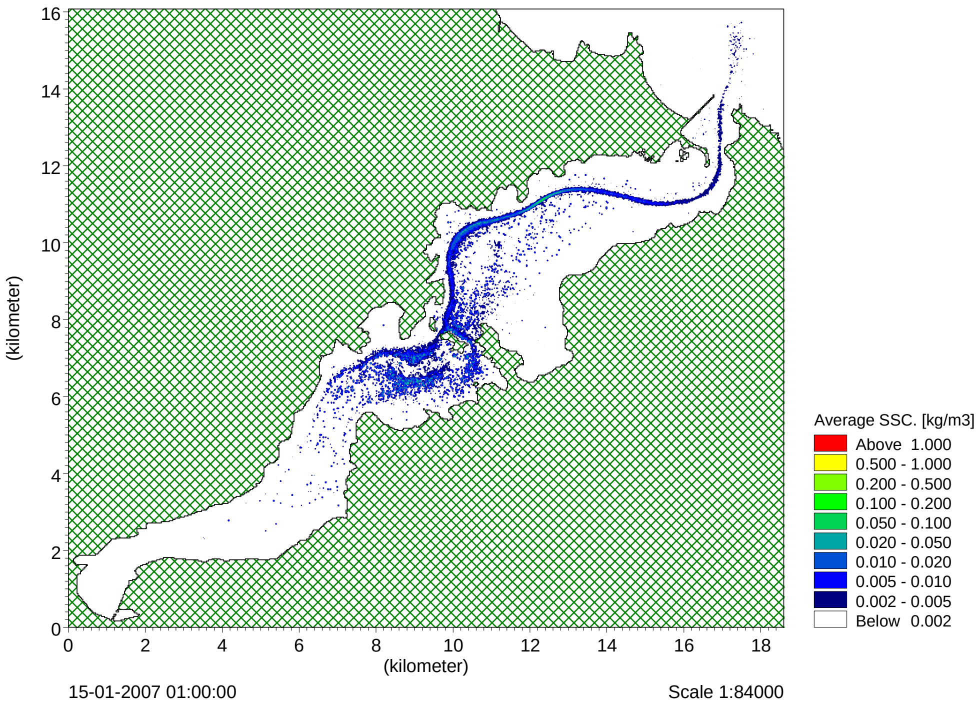


Figure 3.6: 14-day average SSC in kg/m^3 for a Taylers Bend discharge source for the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

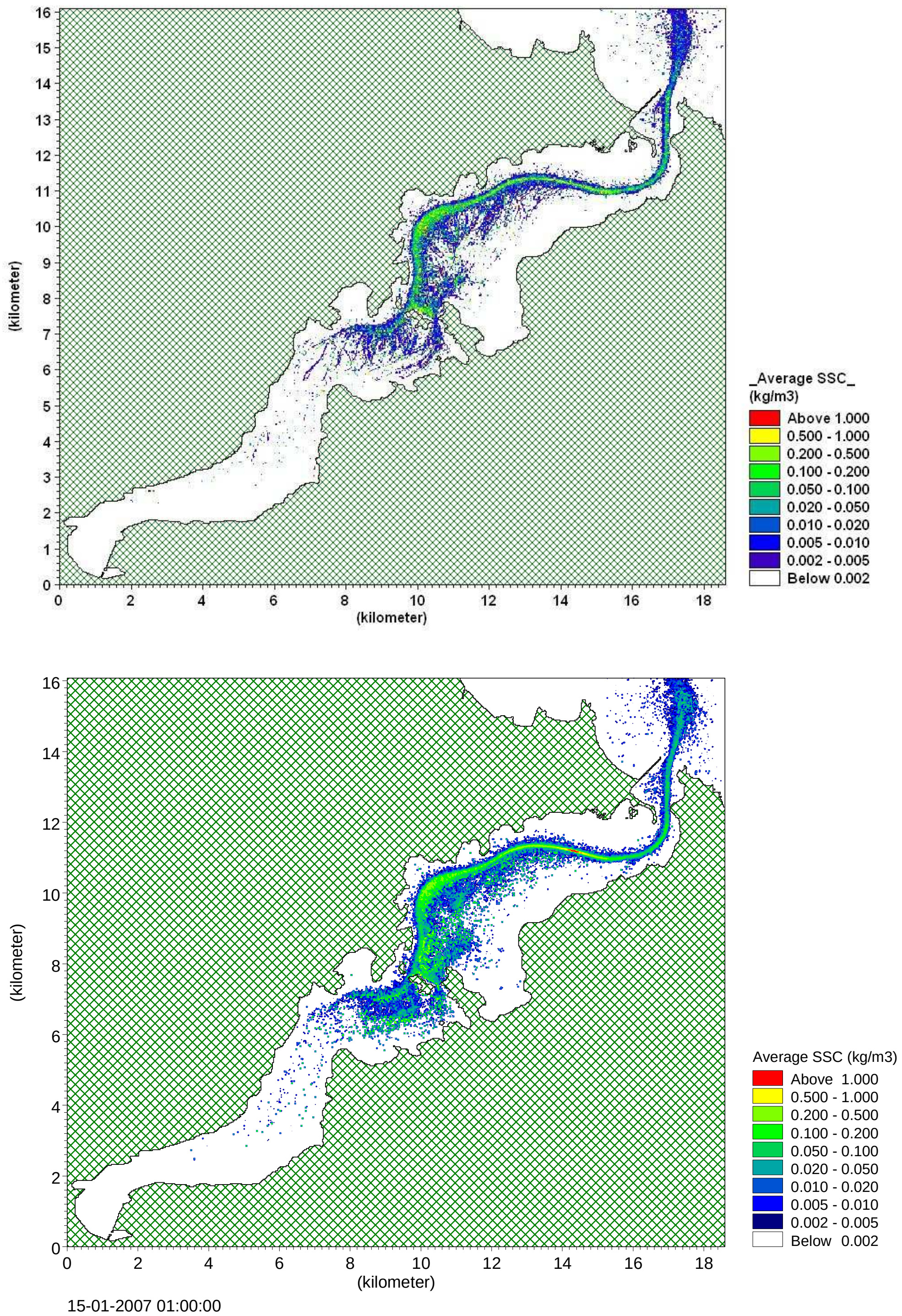


Figure 3.7: 14-day average SSC in kg/m^3 for a Cross-channel discharge source for the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

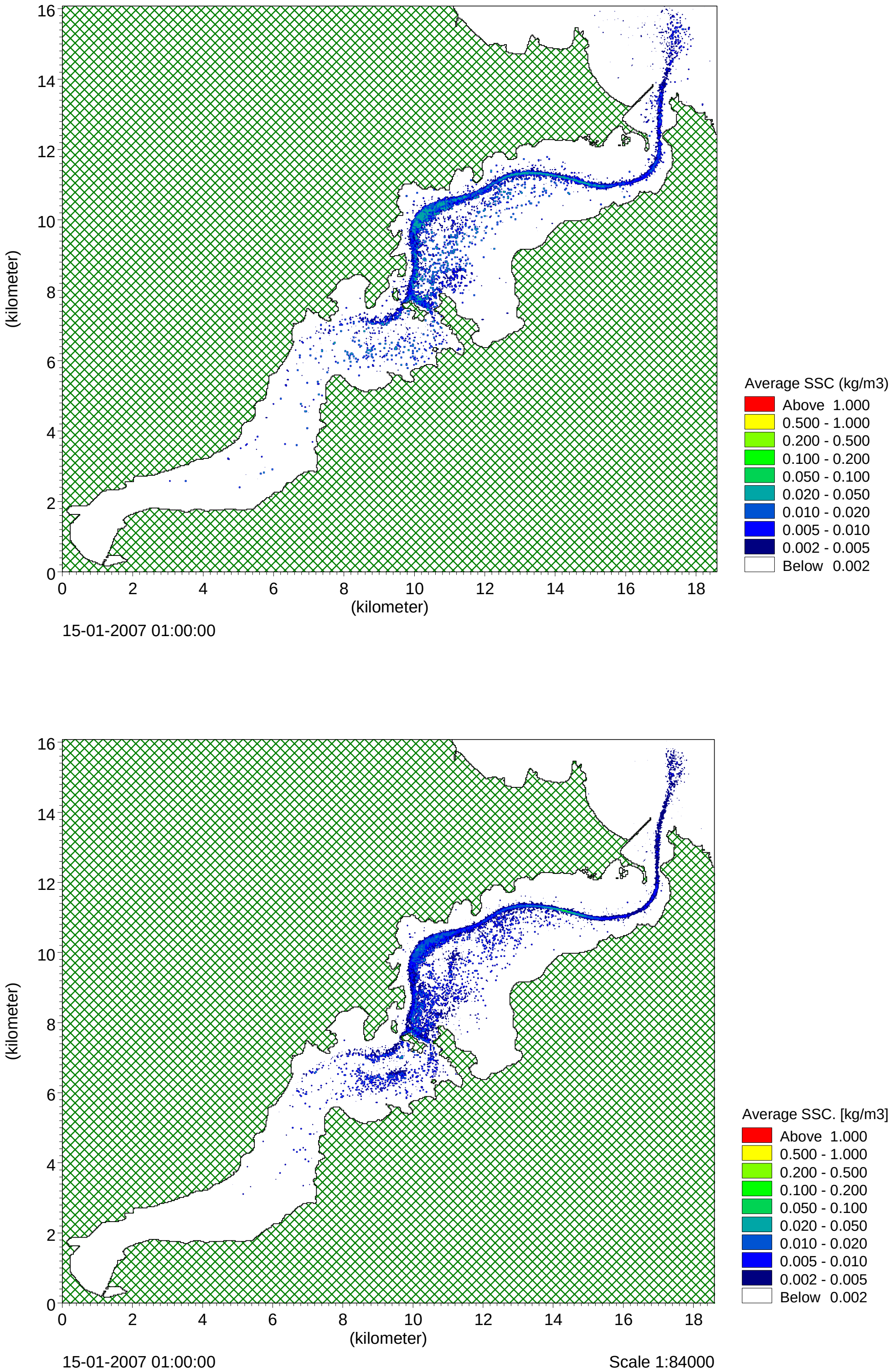
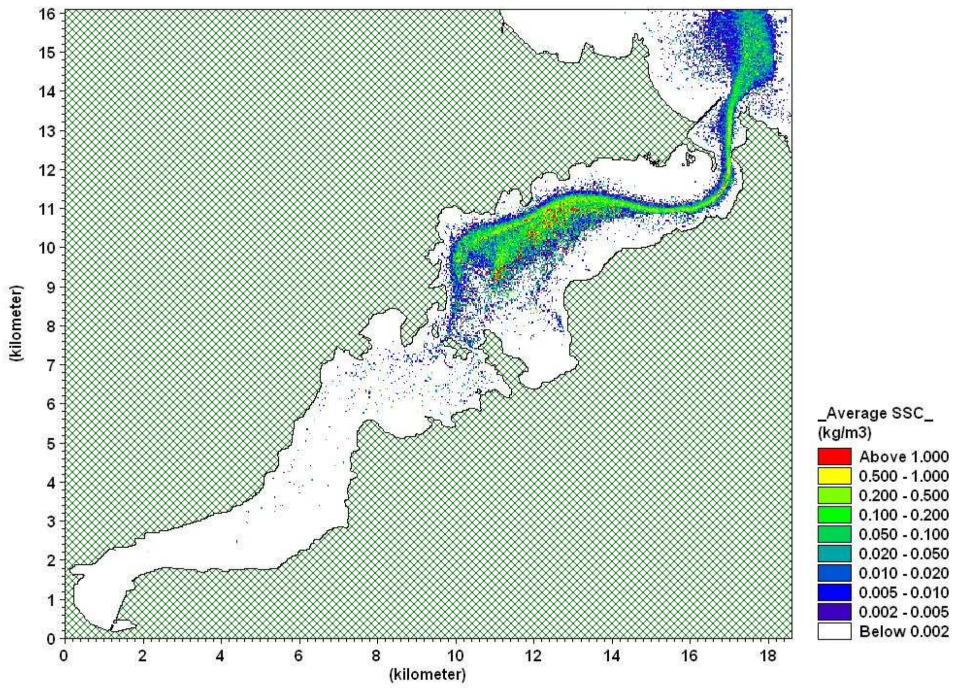


Figure 3.8: 14-day average SSC in kg/m^3 for a Cross-channel discharge source for the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).



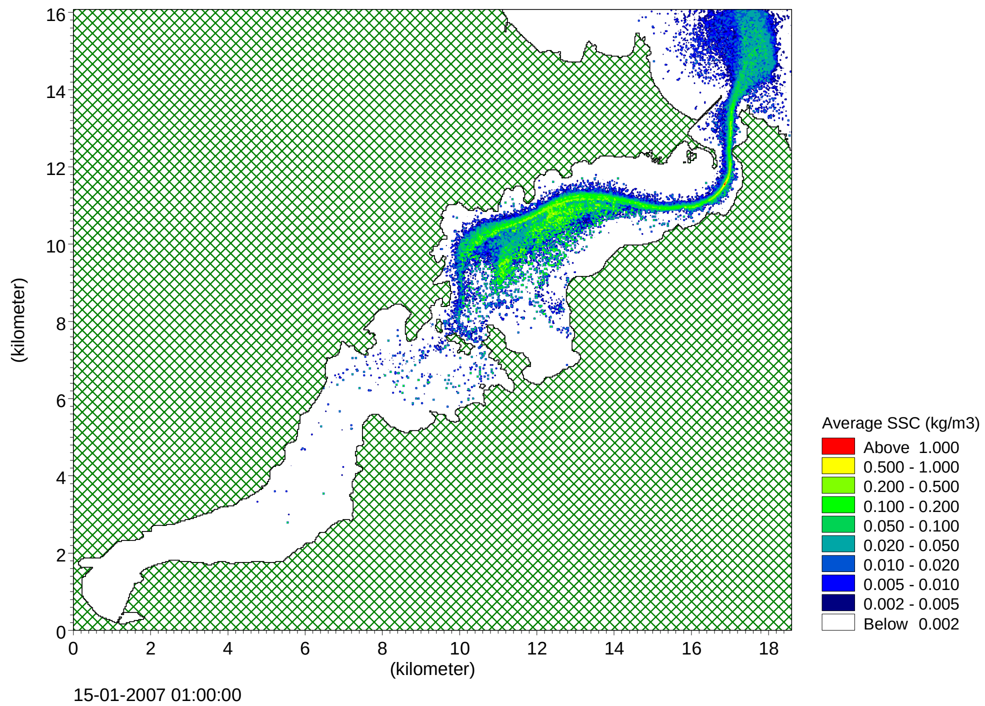


Figure 3.9: 14-day average SSC in kg/m^3 for a Harington Bend discharge source for the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

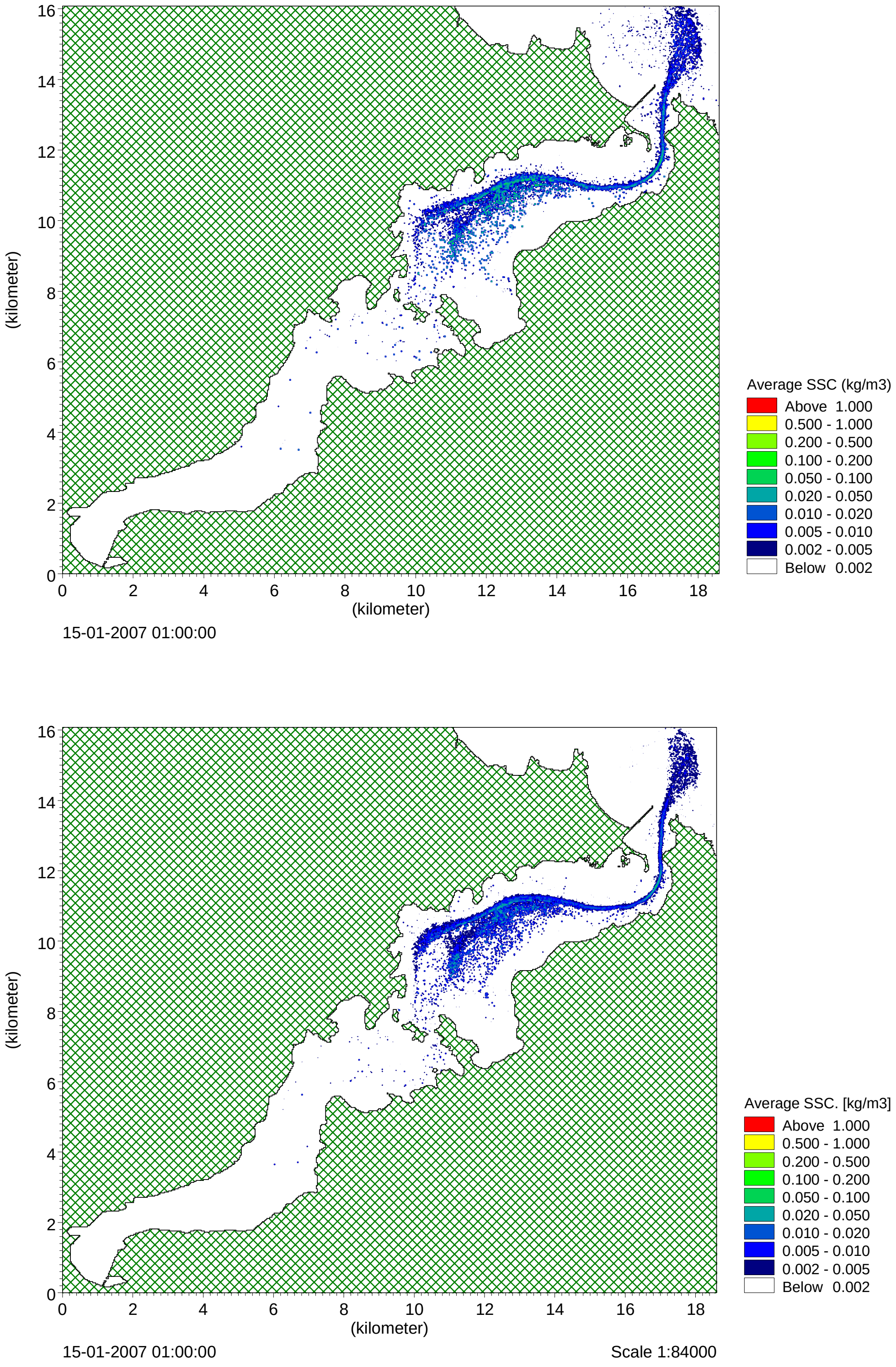
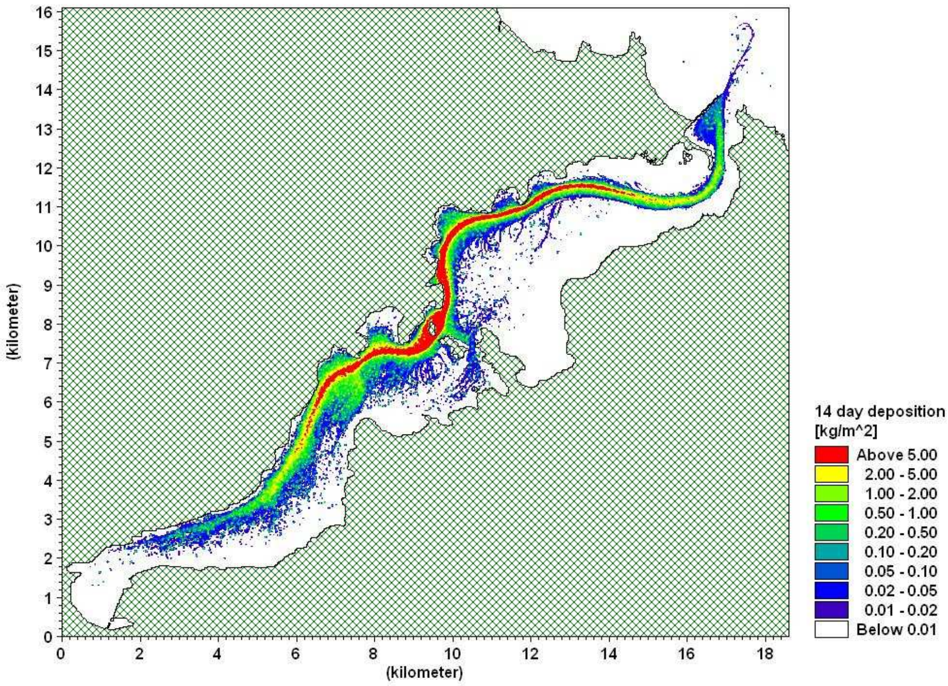


Figure 3.10: 14-day average SSC in kg/m^3 for a Harington Bend discharge source for the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

3.2 Comparisons for the 2-week accumulated seabed deposition

A similar sequence of plots is shown below (Figures 3.11 to 3.20) for the 2-week accumulated sediment deposition. Results are discussed at the end of the plots.



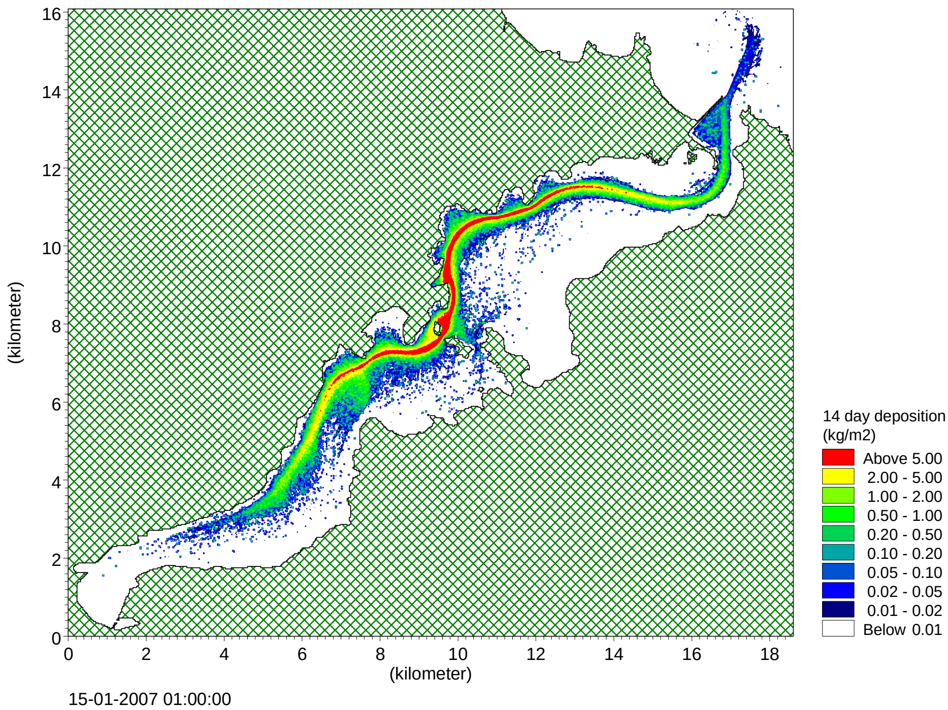
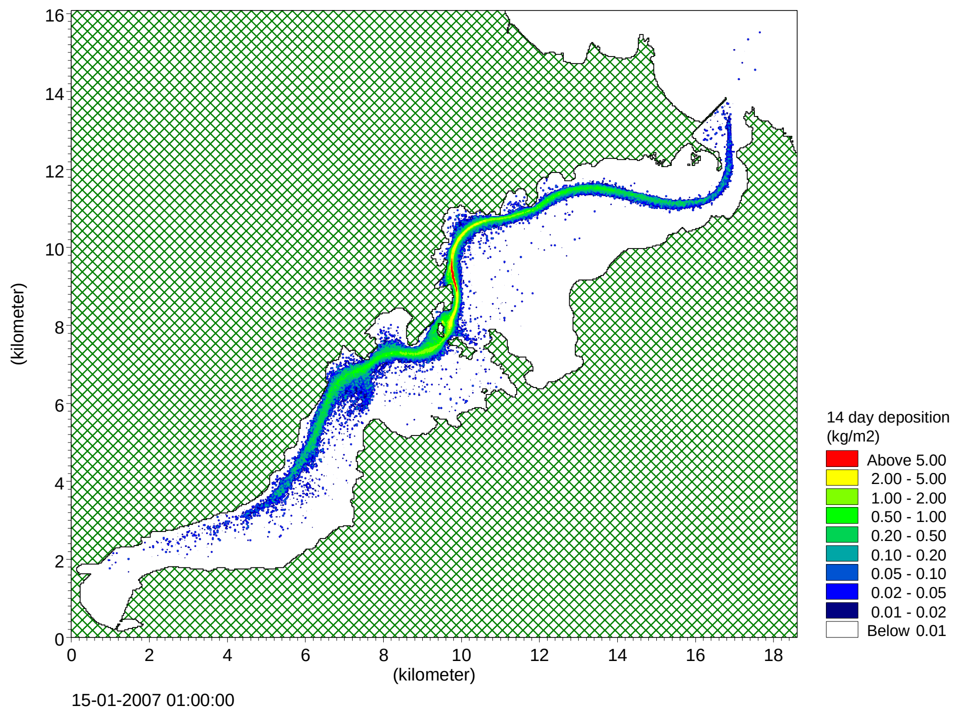


Figure 3.11: 14-day accumulated seabed deposition in kg/m^2 for a Basin–west discharge source from the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).



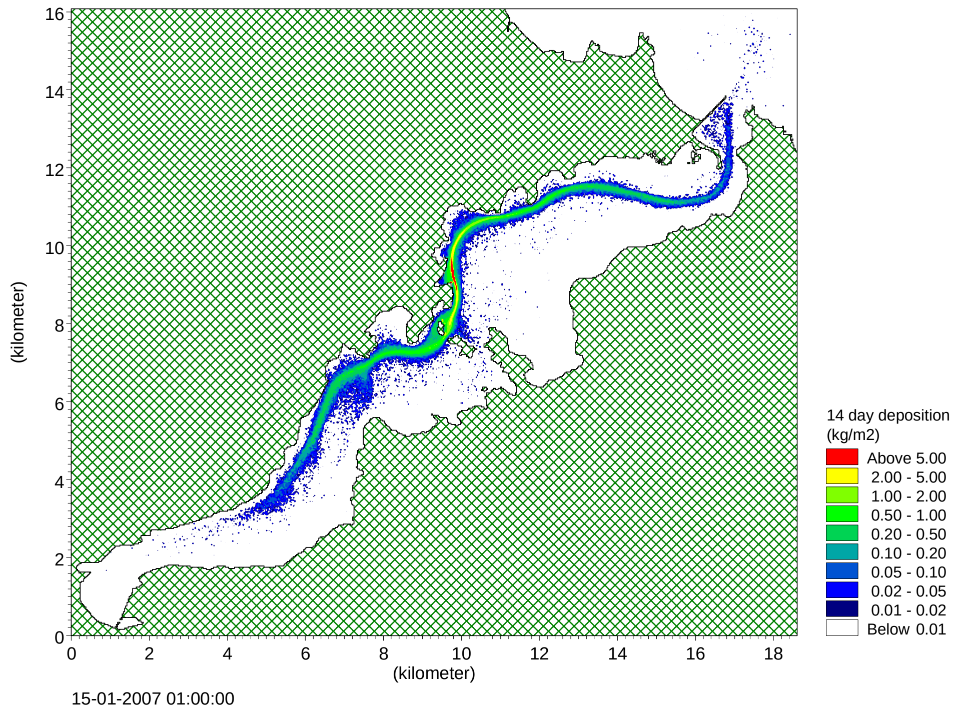
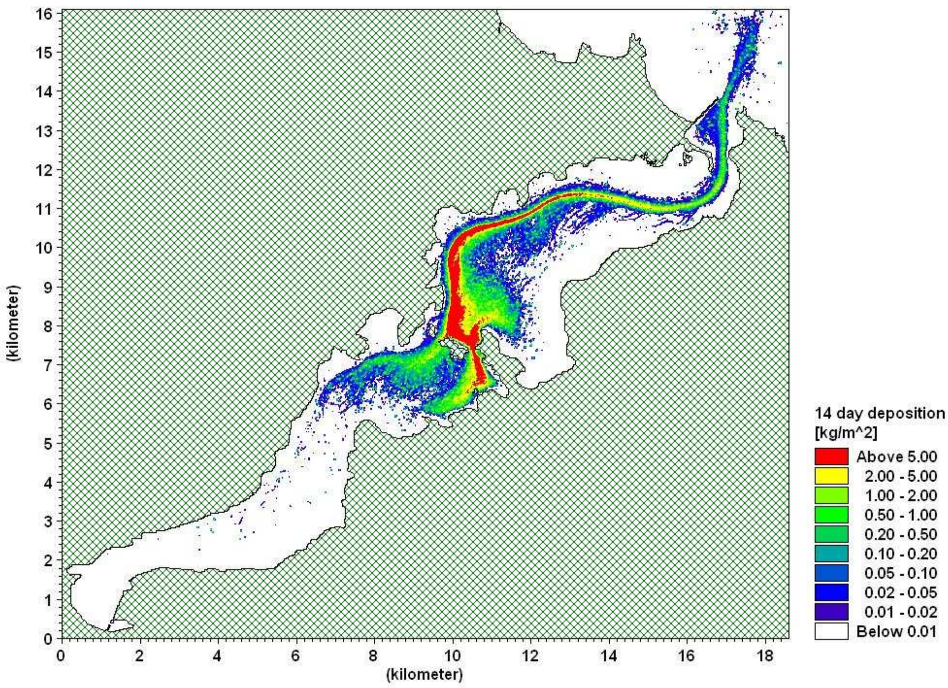


Figure 3.12: 14-day accumulated seabed deposition in kg/m^2 for a Basin–west discharge from the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).



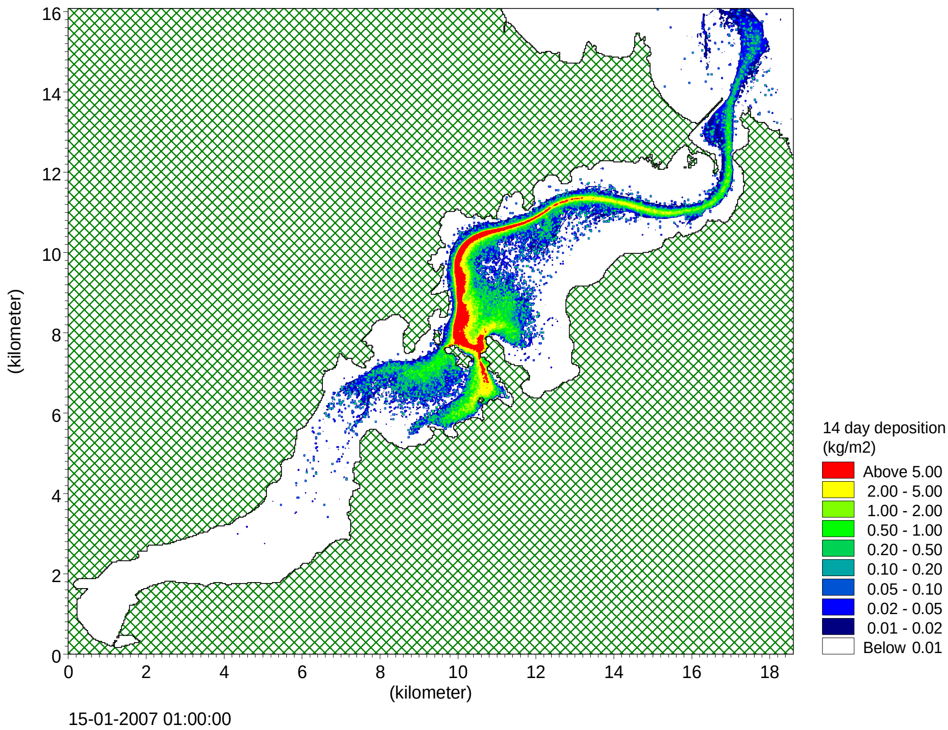


Figure 3.13: 14-day accumulated seabed deposition in kg/m^2 for a Basin–east discharge source from the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

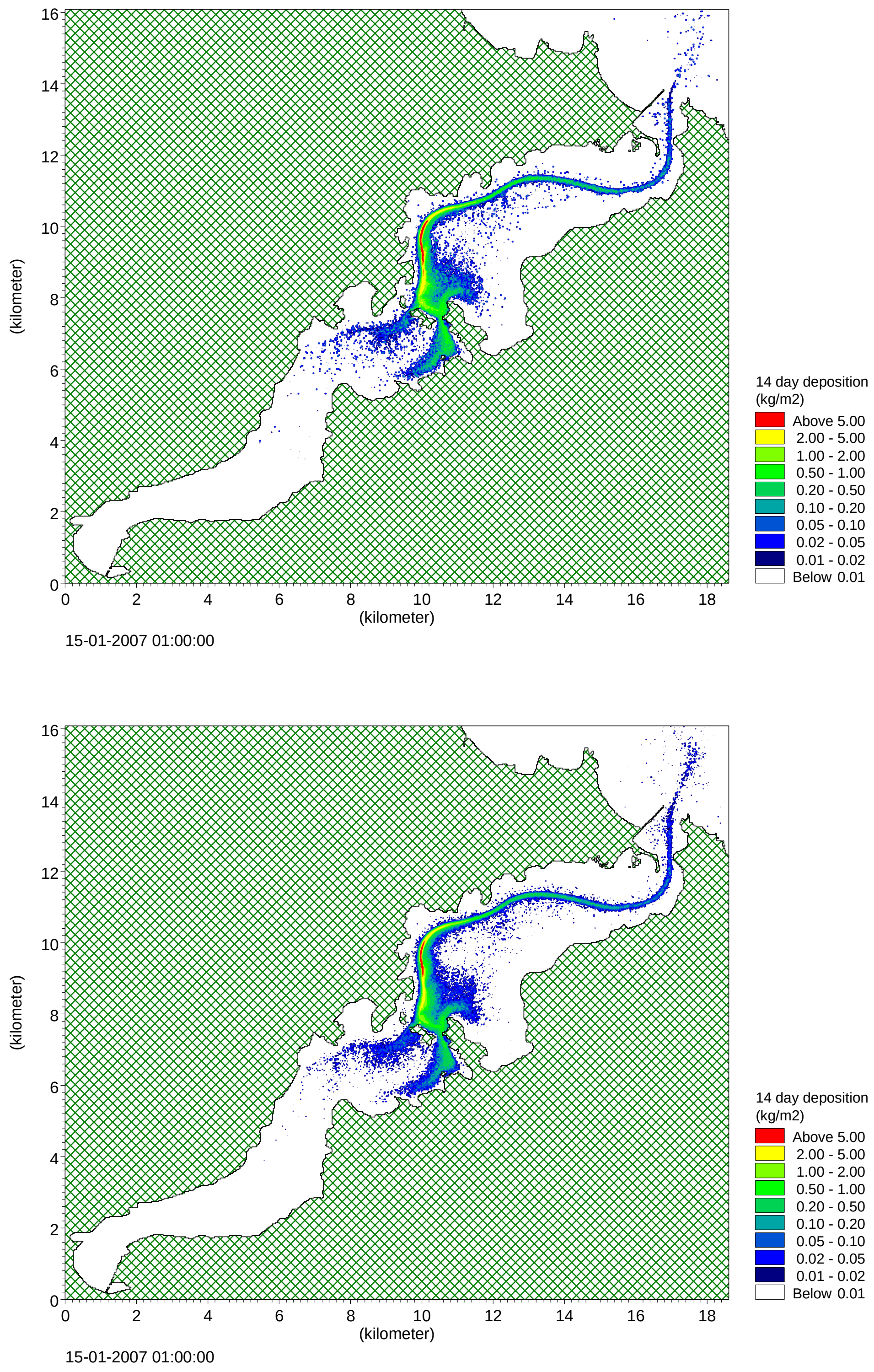


Figure 3.14: 14-day accumulated seabed deposition in kg/m^2 for a Basin–east discharge from the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

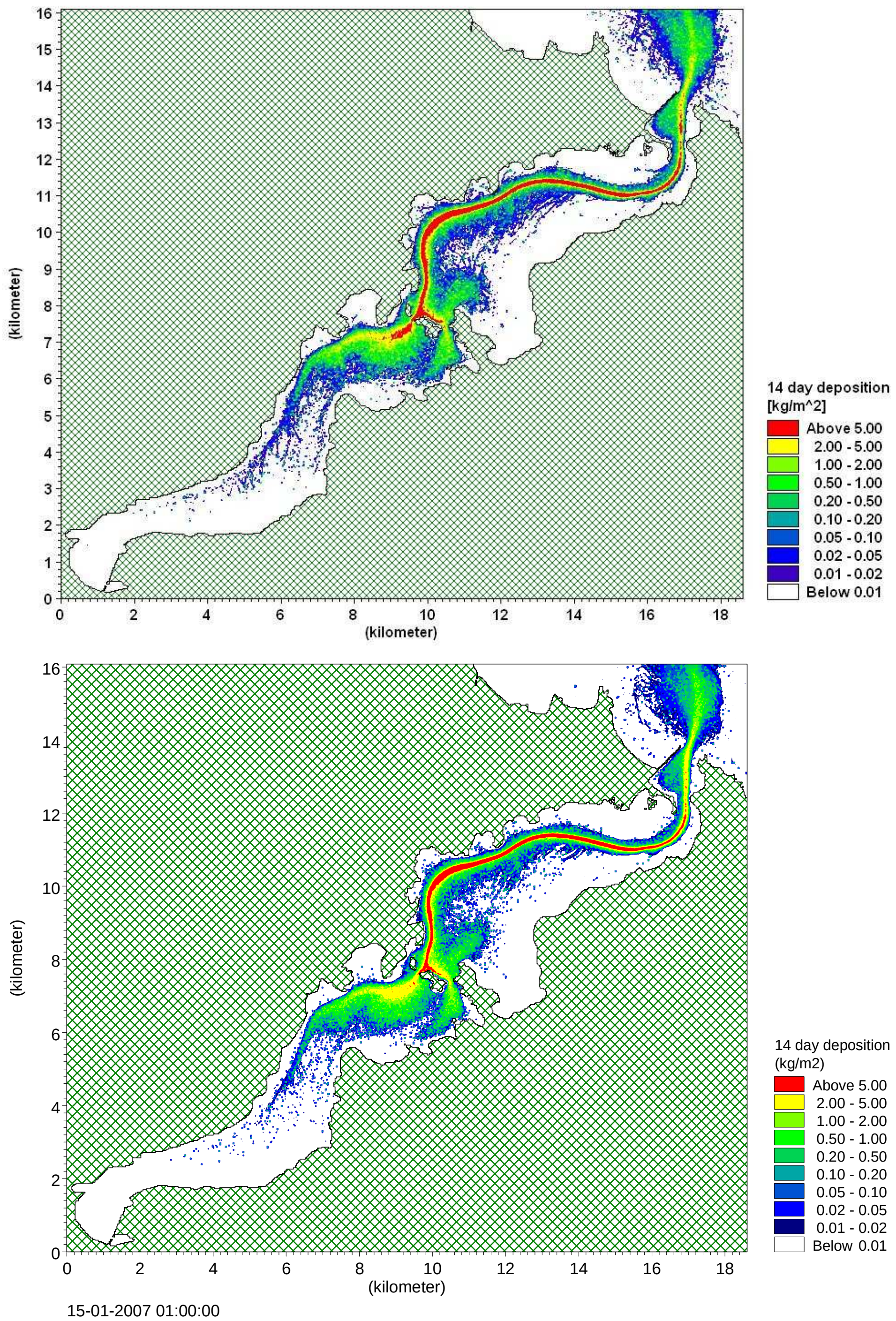
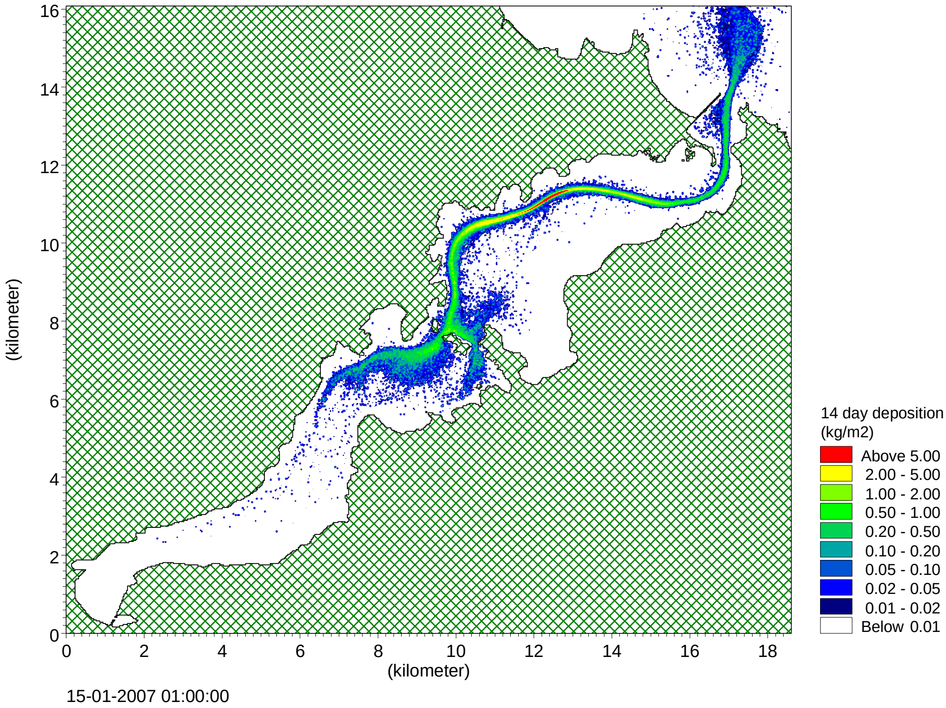


Figure 3.15: 14-day accumulated seabed deposition in kg/m^2 for a Taylers Bend discharge source from the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).



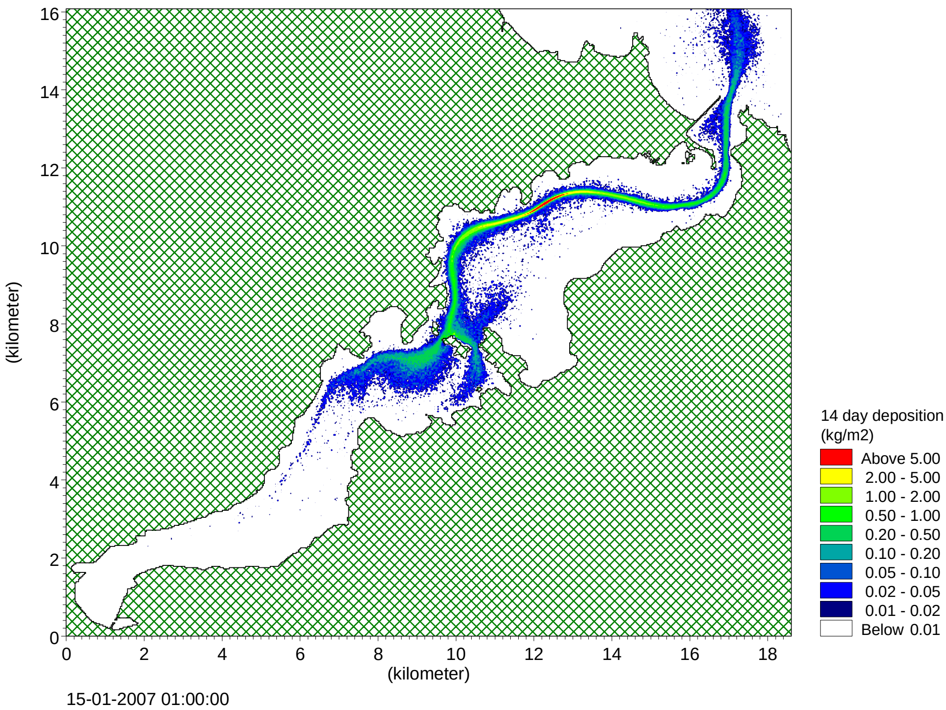


Figure 3.16: 14-day accumulated seabed deposition in kg/m^2 for a Taylers Bend discharge source from the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

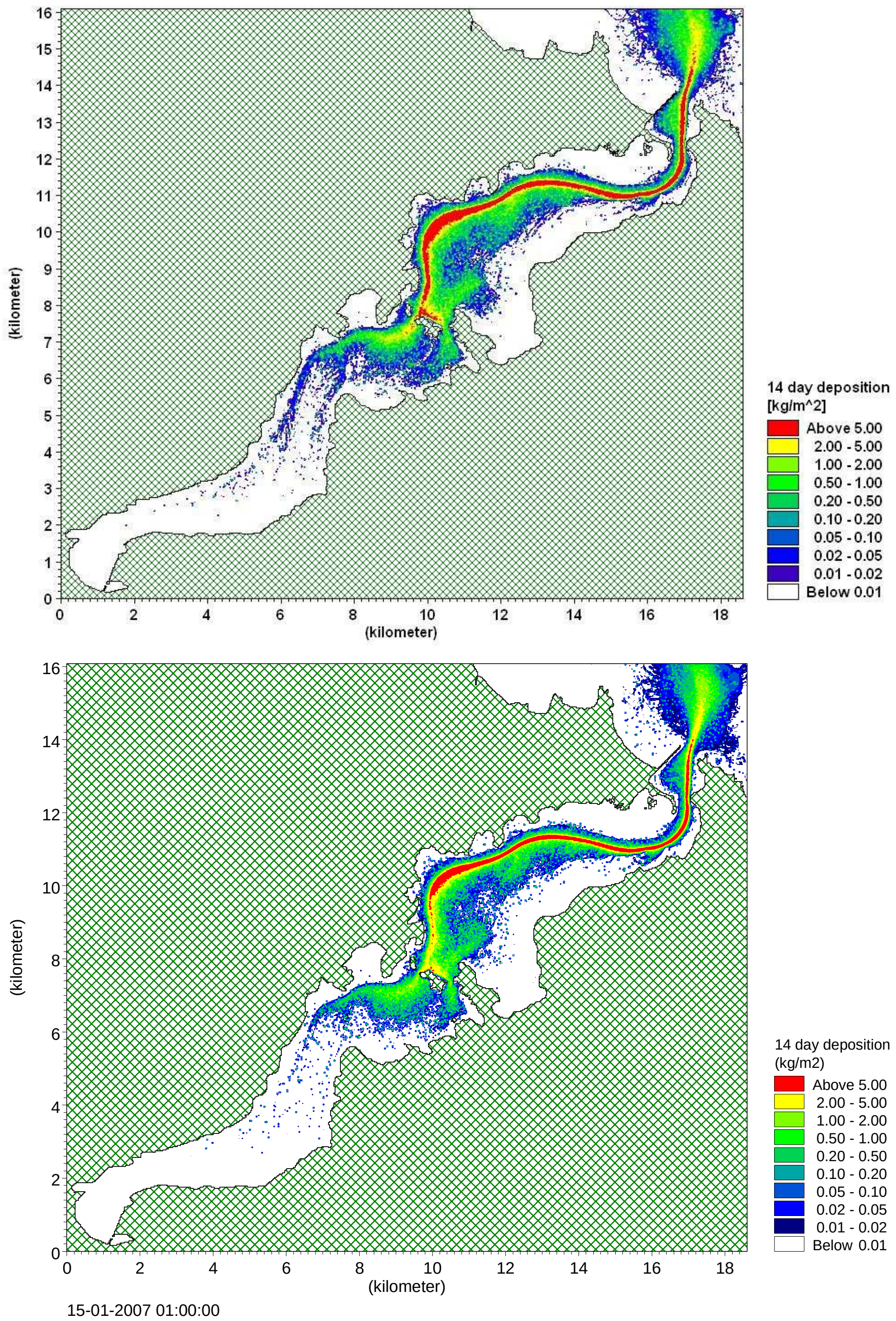
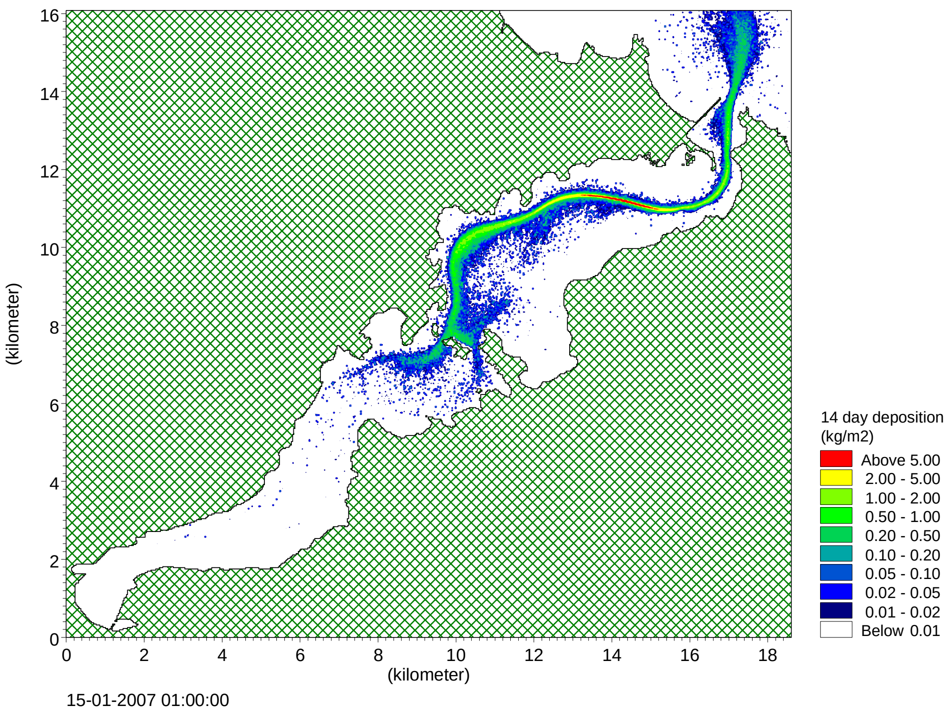


Figure 3.17: 14-day accumulated seabed deposition in kg/m^2 for a Cross-channel discharge source from the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).



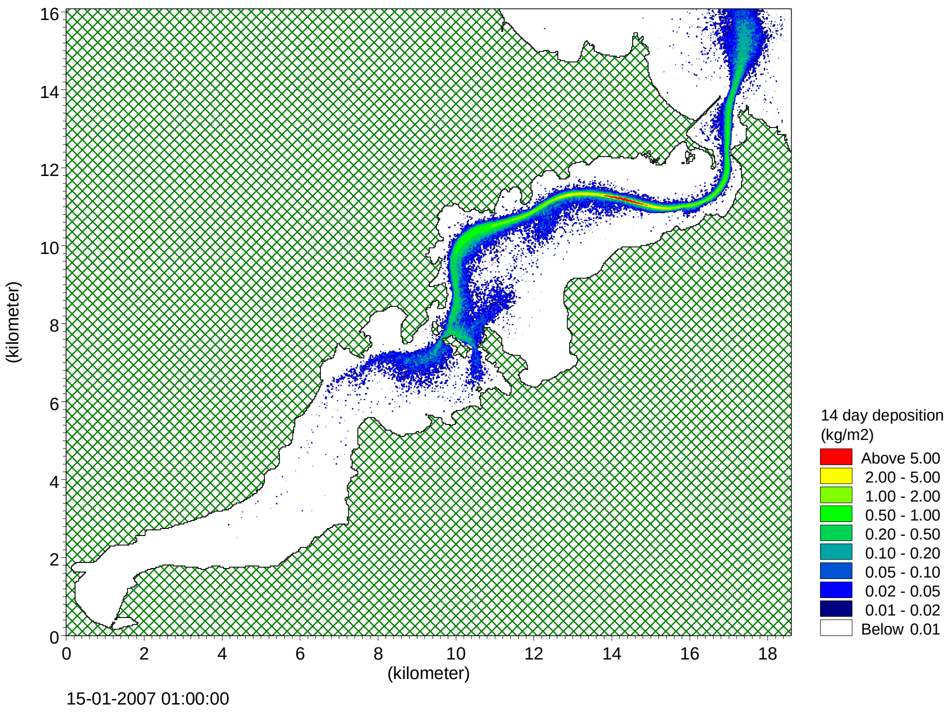


Figure 3.18: 14-day accumulated seabed deposition in kg/m^2 for a Cross-channel discharge source from the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

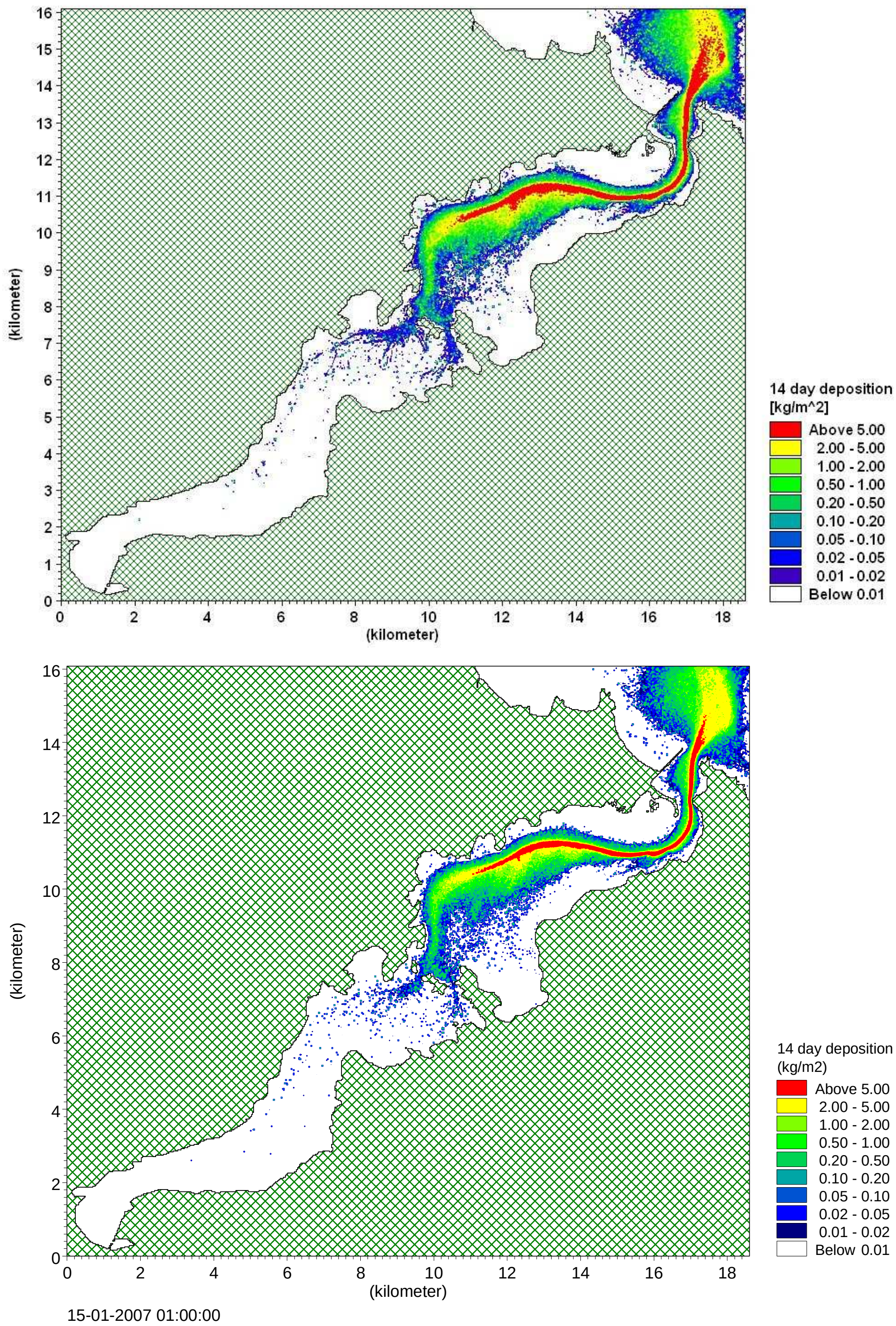


Figure 3.19: 14-day accumulated seabed deposition in kg/m^2 for a Harington Bend discharge source from the larger TSHD dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

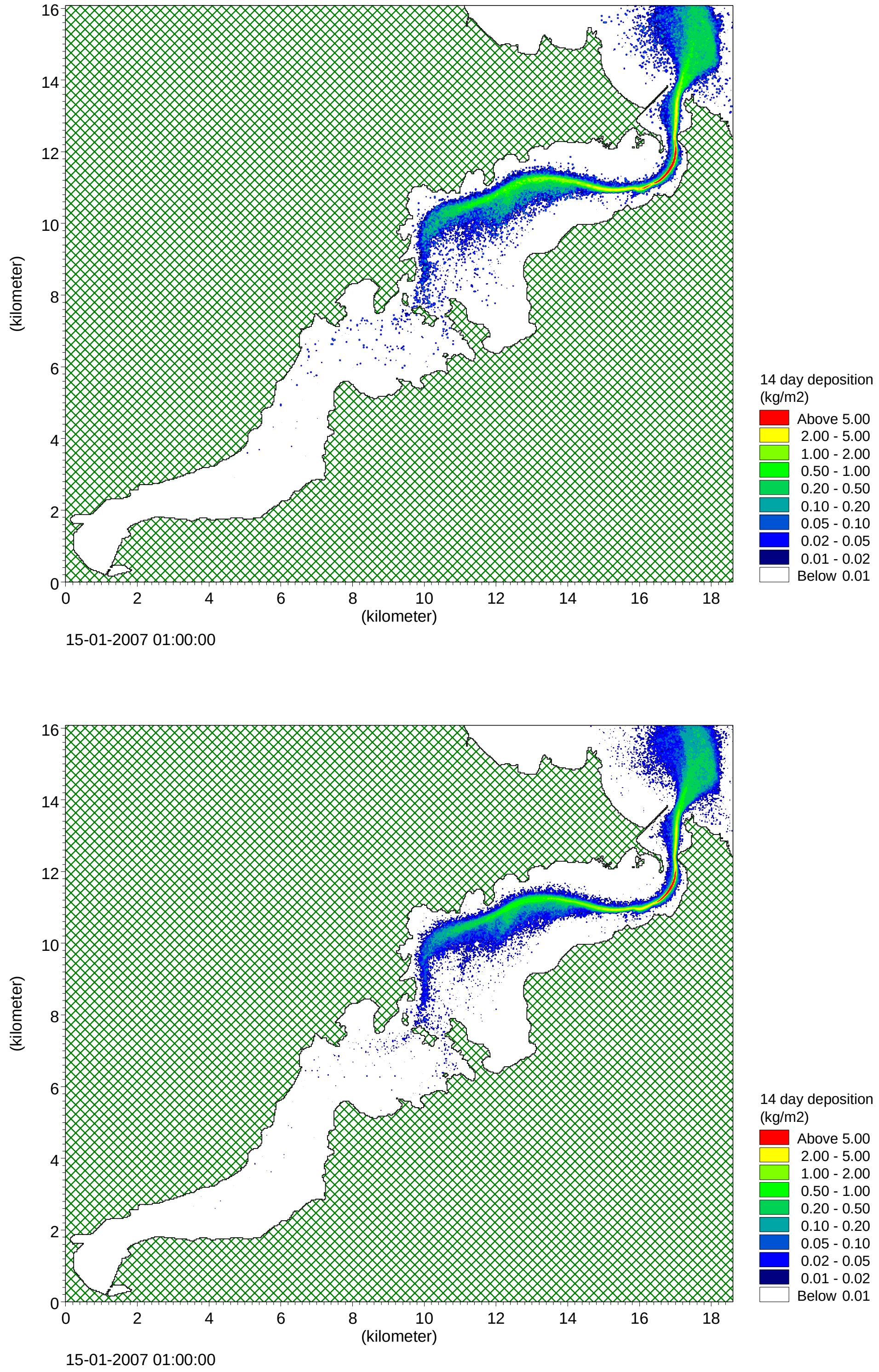


Figure 3.20: 14-day accumulated seabed deposition in kg/m^2 for a Harington Bend discharge source from the smaller *New Era* dredging predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM).

Accumulated seabed deposition over each 14-day plume simulation is presented in mass of sediment per unit area of seabed (kg/m^2). These deposition values are generally conservative as no subsequent resuspension by competent tidal currents or wind-wave stirring was included in the plume model simulations, which will act to further spread and disperse some of the initially-settled material.

To convert to the predicted thickness of deposition (mm), a settled wet bulk density has to be assumed. A wet bulk density for recently-settled sediments was assumed to be around 1300 kg/m^3 as used in the 2009 NIWA report. Consequently, the highest band of deposition above 5 kg/m^2 (red) in Figures 3.11–3.20 equates to a 3.8 mm thickness (dividing 5 by the density 1300) that would be accumulated over the 14-day simulation period, which converts to a rate of 0.3 mm per day.

The plots show the following key results for seabed deposition over a 14-day neap/spring tide cycle with varying winds:

- deposition at or above 5 kg/m^2 (red) or approximately 3.8 mm over a fortnightly period is very confined to the immediate vicinity of the main shipping channel where *New Era* dredges. This is in contrast to the larger TSHD, where the same deposition level occurred throughout the main shipping channel (all discharge sources), the subsidiary channel to the east from Quarantine Island, around Goat Island and up Victoria Channel to opposite St. Leonards for a discharge source at Turning Basin–west, and some of the flanking intertidal flats to these channels

- discharges from predominantly-silt claims (top panels in Figures 3.11–3.20) cause very similar deposition thicknesses (and daily deposition rates) to those from predominantly-sand claims (bottom panels)

- the Upper Harbour will have virtually no discernable seabed deposition arising from discharge sources at Harington Bend and further seaward (Fig. 3.20)

- most of the eastern parts of the Lower and Upper Harbours would be subject to negligible or no deposition, apart from the reach west of Latham Bay for discharges from the eastern side of the Turning Basin, where deposition may reach 0.5 kg/m^2 (0.4 mm) over 2 weeks or an accumulation rate of 0.03 mm/day)

- mid-harbour intertidal flats will have substantially lower deposition rates and extent of deposition using *New Era* compared with the larger TSHD by about 10 times less, from 2–5 kg/m^2 to 0.2–0.5 kg/m^2 for similar areas. With *New Era*, the main areas affected by up to accumulation of 0.5 kg/m^2 in 2 weeks or a rate of 0.03 mm/day will be: a) mid-harbour intertidal flats opposite Tayler and Pulling Points from dredging at Harington Bend; b) mid-harbour intertidal flats opposite Port Chalmers to Quarantine Island from dredging the eastern Turning Basin; and c) the inter-tidal bank south-west of Quarantine Island adjacent to the Victoria Channel from dredging Taylers Bend area.

4. Results for the offshore plume modelling

The results are presented as a series of paired plots of the envelopes of maximum suspended-sediment concentrations predicted at each location at any time during a 48-hour cycle of disposal from the larger TSHD (top plots) versus the *New Era* (bottom plots). These simulations cover the more conservative light-wind conditions simulated for the larger dredger and reported in Section 11.4.3 of Bell et al. (2009).

The same spatial coverage and concentration palette have been used in the plots to provide a true comparison of the differences in maximum suspended concentration between using a larger dredger and the *New Era*.

4.1 Light WSW winds

Figures 4.1a–c show the composites of maximum excess suspended-sediment concentration (SSC) during 48-hour periods for each of the smaller three size classes (excluding fine sand) in the bottom layer for wind scenario 1 (light WSW wind of 7 m/s). Figures 4.2a-c show the equivalent comparisons for the near-surface layer for the same wind scenario. Note: SSC from each of the three finer sediment classes is additive to get the total SSC leaving aside fine sand that settles much more quickly.

The top plot in each case shows the result from the predominantly-silt hopper load from a larger TSHD, and the bottom plot is the equivalent result for the *New Era*. Results are only for discharges at the most landward sub-site #1 in A0 (Figure 2.2).

The maximum SSC in the disposal area in the bottom layer using *New Era* will be about 6–7% of the maximum simulated SSC for a larger TSHD that was reported in Bell et al. (2009). For this light WSW wind condition, adding the maximum SSC in the disposal area from the three silt-size classes, the bottom layer will reach a maximum of 47 mg/L and the near-surface layer 8 mg/L using the *New Era*.

When the edge of the plume reaches the coastline north of Cornish Head, the excess SSC is very low reaching no higher than 0.5 mg/L (adding all 3 silt-size classes) in the bottom layer for the larger dredger under these wind conditions, while the *New Era* would produce concentrations of ten times less (<0.05 mg/L).

The extent of influence from the sediment plumes is similar for both sizes of dredge, with subtle differences, especially in the spread offshore for this light WSW wind scenario. These arise from differences in the hopper discharge depth.

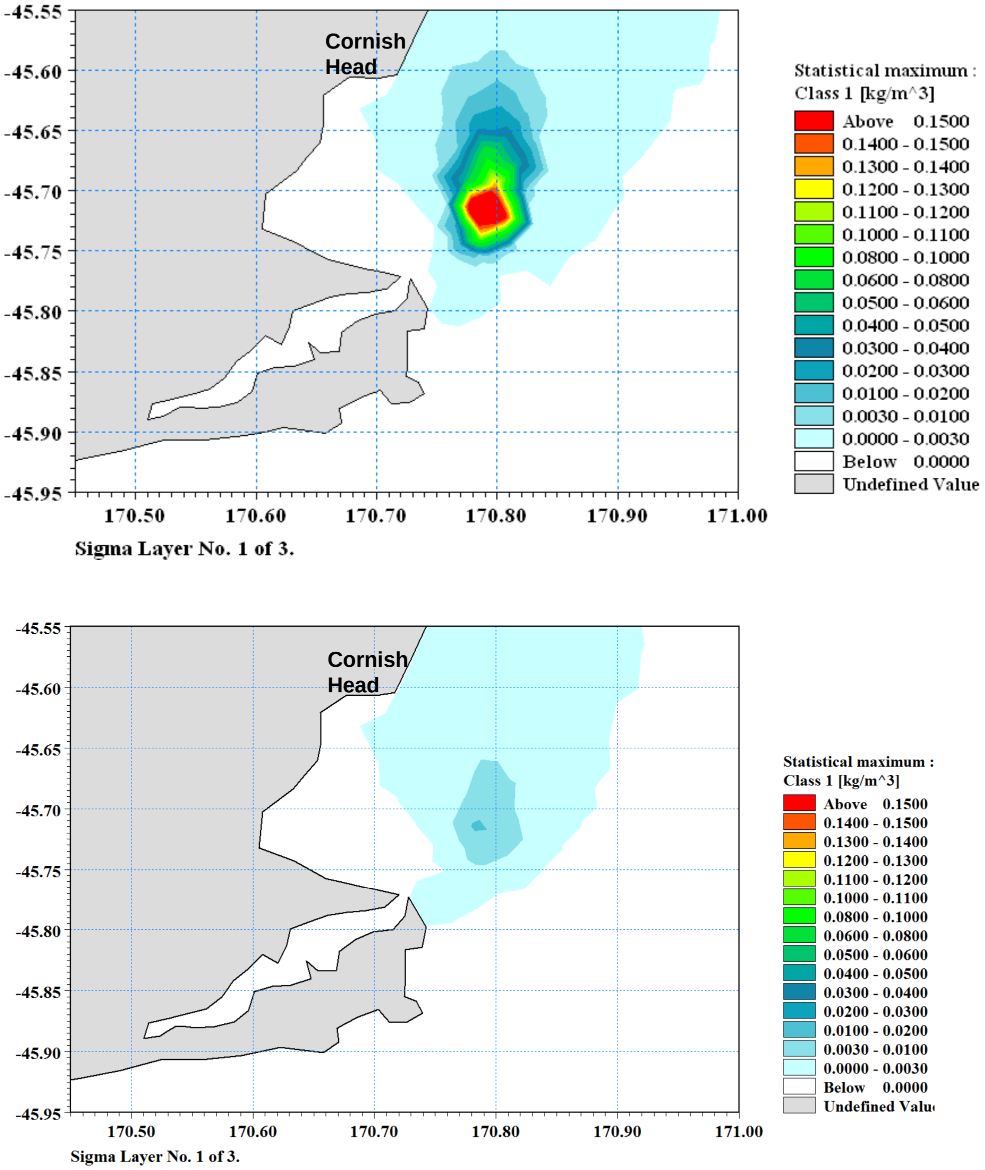


Figure 4.1a: <u>Max.</u> SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for <u>size class 1</u> in the <u>bottom layer (L1)</u> over 24 disposal cycles for <u>wind scenario 1 (light WSW wind)</u> at disposal sub-site #1. <u>Note:</u> maximum SSC for the top and bottom plots respectively is 160 mg/L and 11 mg/L (7%) and for coast north of Cornish Head, SSC will be 0.2–0.4 mg/L and 0.015–0.03 mg/L respectively.

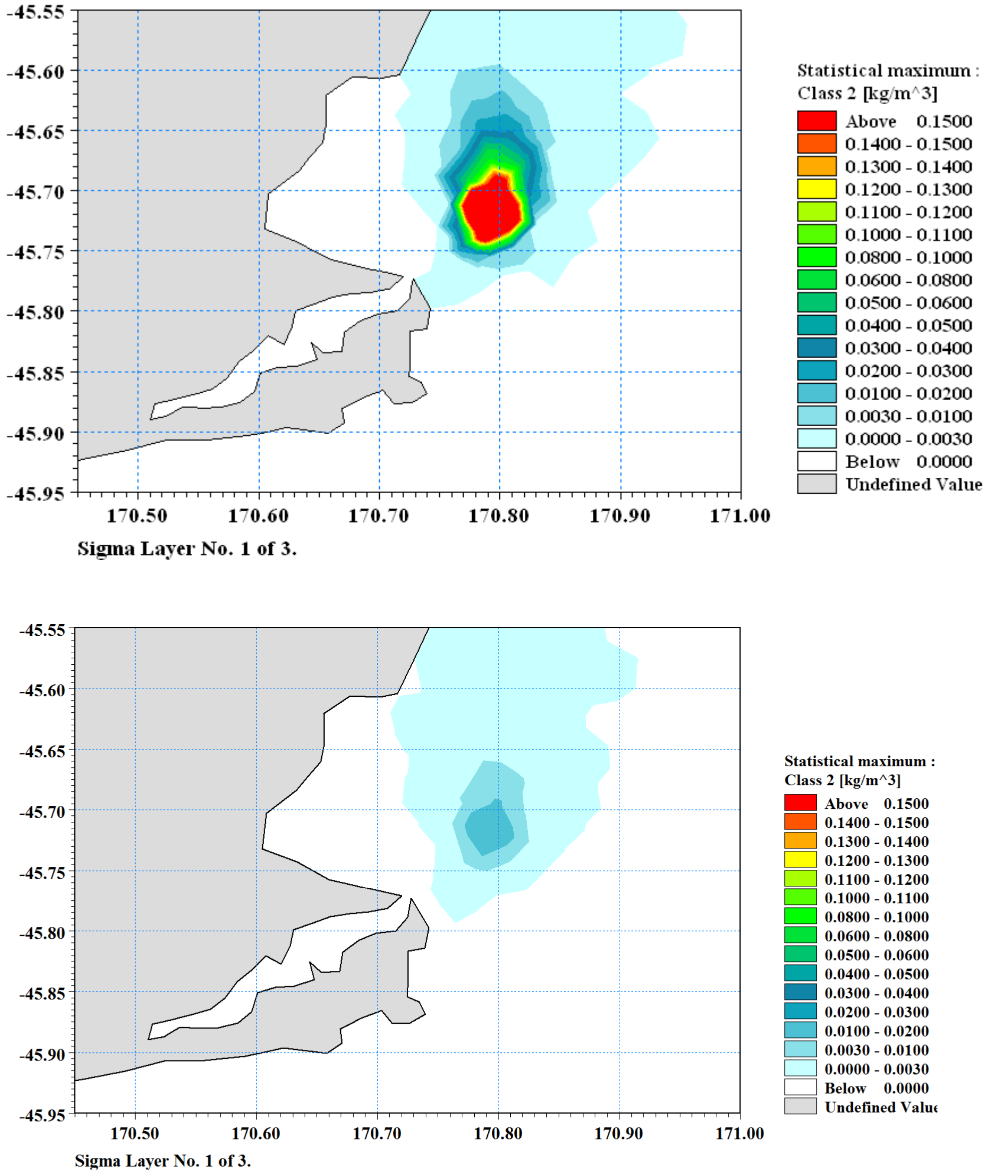


Figure 4.1b: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 2 in the bottom layer (L1) over 24 disposal cycles for wind scenario 1 (light WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 280 mg/L and 17 mg/L (6%) and for coast north of Cornish Head, SSC will be 0.002–0.04 mg/L and 0.002–0.01 mg/L respectively.

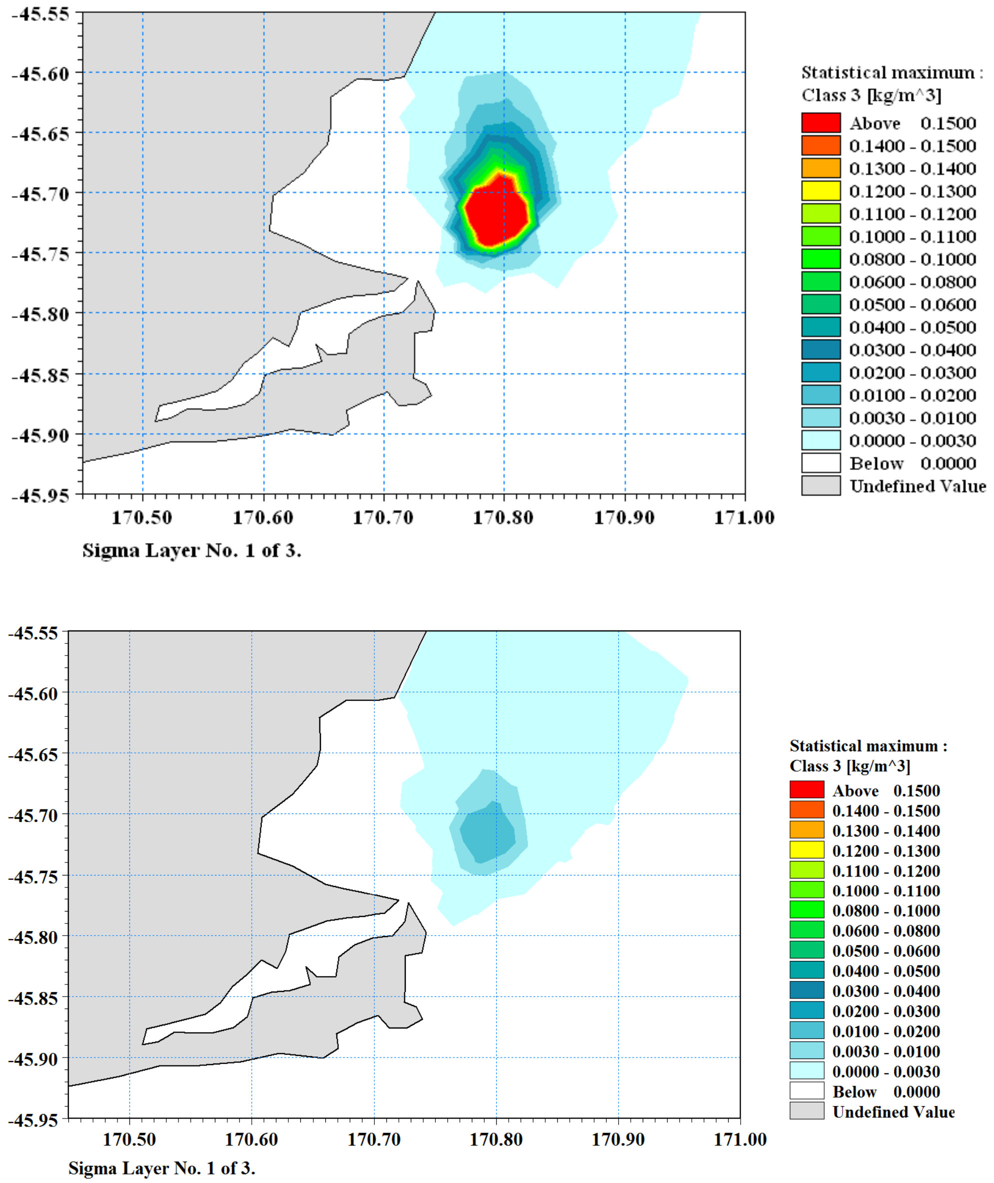


Figure 4.1c: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 3 in the bottom layer (L1) over 24 disposal cycles for wind scenario 1 (light WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 320 mg/L and 19 mg/L (6%) and for coast north of Cornish Head, SSC will be <0.011 mg/L and 0.001–0.003 mg/L respectively.

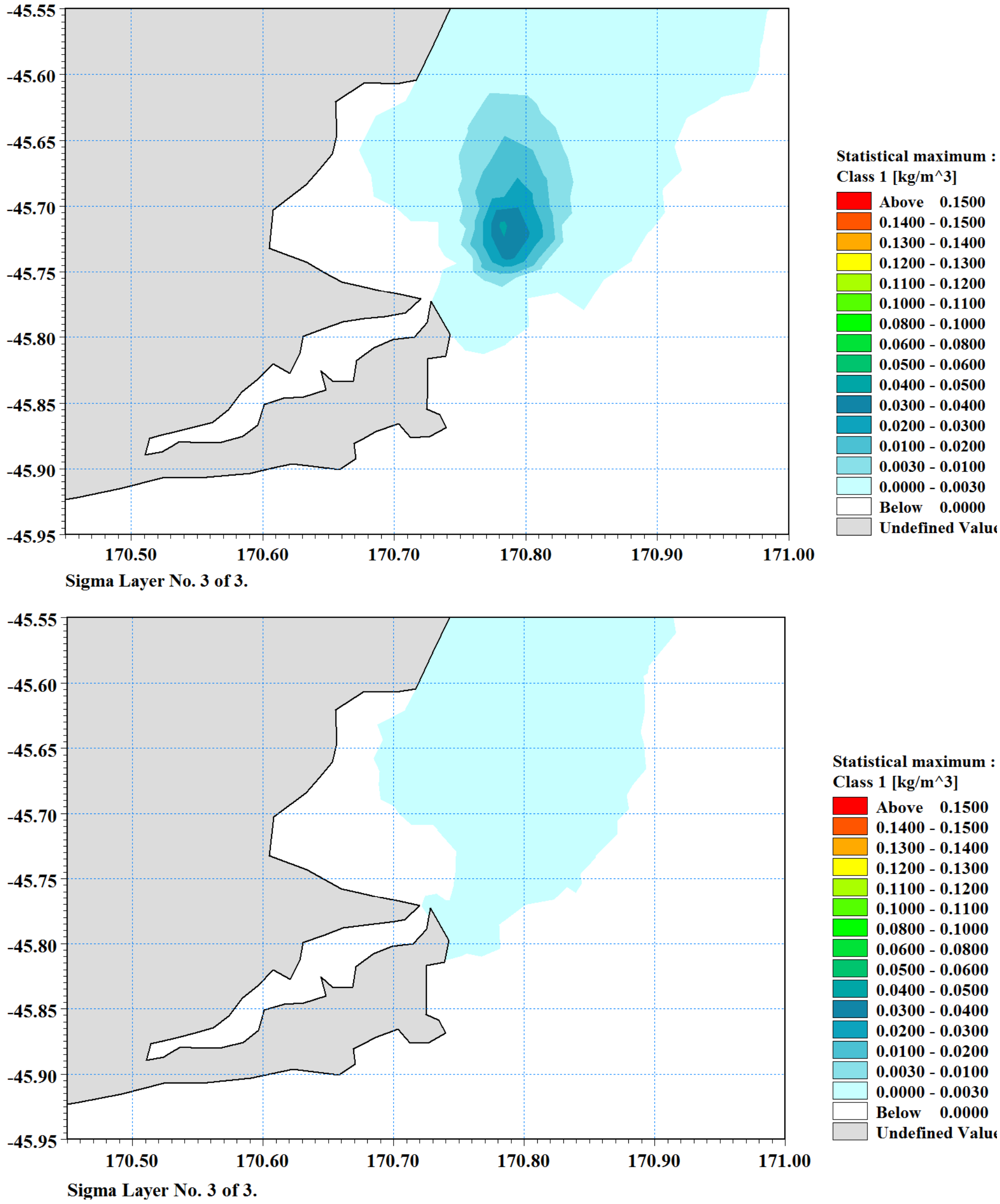


Figure 4.2a: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 1 in the near-surface layer (L3) over 24 disposal cycles for wind scenario 1 (light WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 42 mg/L and 2.5 mg/L (6%) and for coast north of Cornish Head, SSC will be 0.02–0.2 mg/L and 0.007–0.03 mg/L respectively.

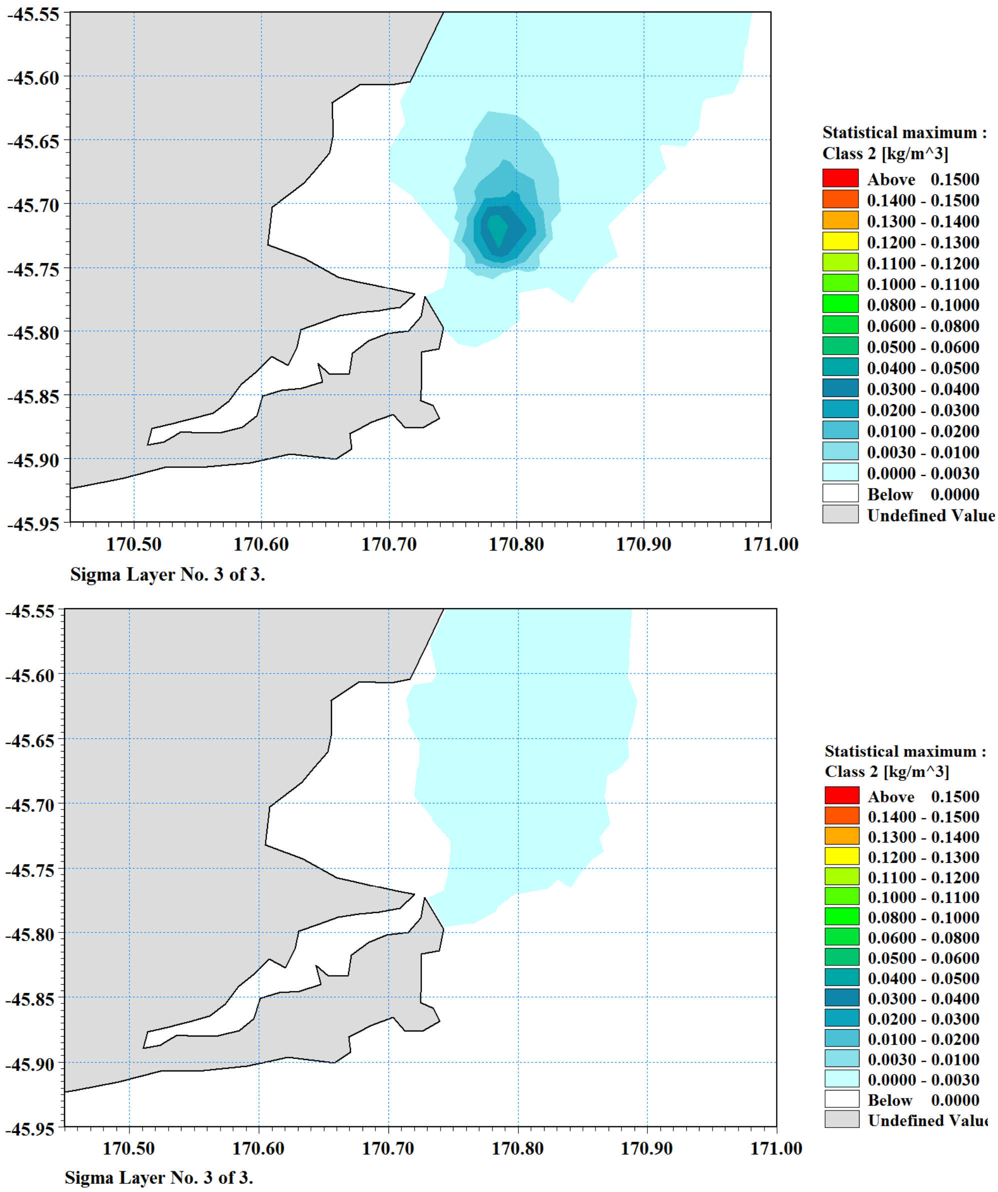


Figure 4.2b: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 2 in the near-surface layer (L3) over 24 disposal cycles for wind scenario 1 (light WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 46 mg/L and 2.7 mg/L (6%) and for coast north of Cornish Head, SSC will be 0.01–0.03 mg/L and 0.001–0.005 mg/L respectively.

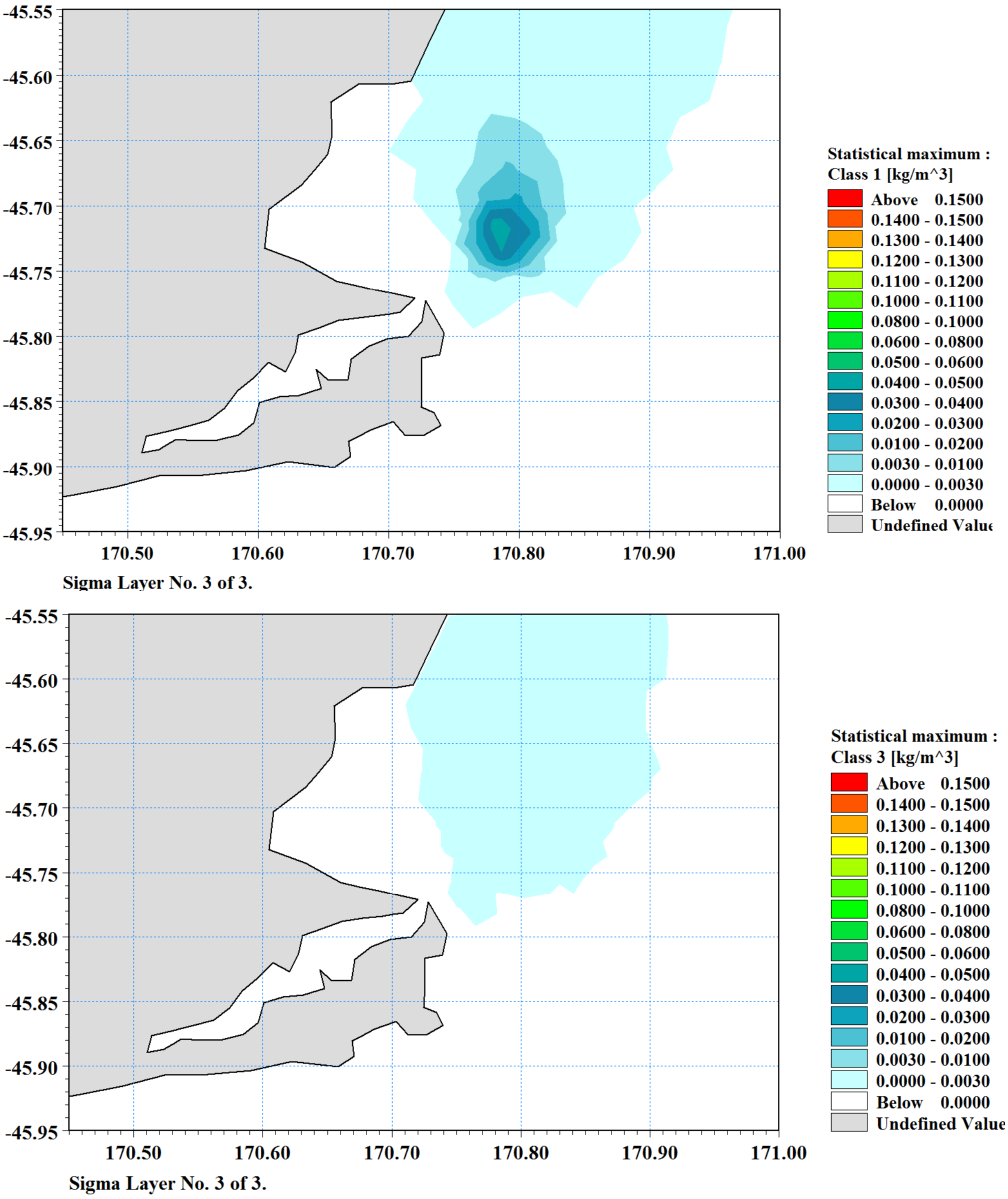


Figure 4.2c: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 3 in the near-surface layer (L3) over 24 disposal cycles for wind scenario 1 (light WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 46 mg/L and 2.7 mg/L (6%) and for coast north of Cornish Head, SSC will be 0.002–0.02 mg/L and 0.001–0.004 mg/L respectively.

4.2 Moderate WSW wind

Figure 4.3 shows a comparison of the composites of maximum excess suspended-sediment concentration (SSC) during 48-hour periods for just the finest silt-size class in the bottom layer for wind scenario 2 (moderate WSW wind of 14 m/s). Figure 4.4 shows the medium and coarse silt composites in the bottom layer for just the *New Era* simulations.

Figure 4.5 shows the equivalent comparison for fine silts between the larger TSHD and *New Era* for the near-surface layer for the same wind scenario. Figure 4.6 shows the maximum SSC composites for medium and coarse silts for just the *New Era*.

The top plot in Figures 4.3 & 4.5 show the result from the predominantly-silt hopper load from a larger TSHD, and the bottom plot is the equivalent result for the *New Era*. Results are only for discharges at the most landward sub-site #1 within the A0 disposal area (Figure 2.2).

The maximum SSC considering only fine silts (class 1) in the disposal area in the bottom layer using *New Era* will be about 5–6% of the maximum simulated SSC for a larger TSHD (Figure 4.3). If the edge of the plume reaches the coastline north of Cornish Head, the excess SSC for fine silts will be very low reaching no higher than 0.18 mg/L in the bottom layer for the larger dredger under these wind conditions. In comparison, the *New Era* would produce somewhat lower concentrations in the surface layer and ten time lower in the bottom layer.

Looking at all three silt fractions (and excluding fine sands that settle quickly), the maximum excess SSC in the bottom layer from *New Era* will be around 57 mg/L at the disposal area and along the coastline north of Cornish Head the maximum on the fringe of the plumes will be around 0.003–0.01 mg/L, with coarse silts not reaching the coast (Figure 4.4). In the near-surface layer, the maximum SSC from all silt classes would be 7 mg/L at the disposal area and no more than 0.01 mg/L along the coast north of Cornish Head, with medium and coarse silt plumes not reaching the coast (Figure 4.6).

The extent of influence from the sediment plumes is similar for both sizes of dredge (Figures 4.3 & 4.5), with only subtle differences due to the different hopper discharge depths.

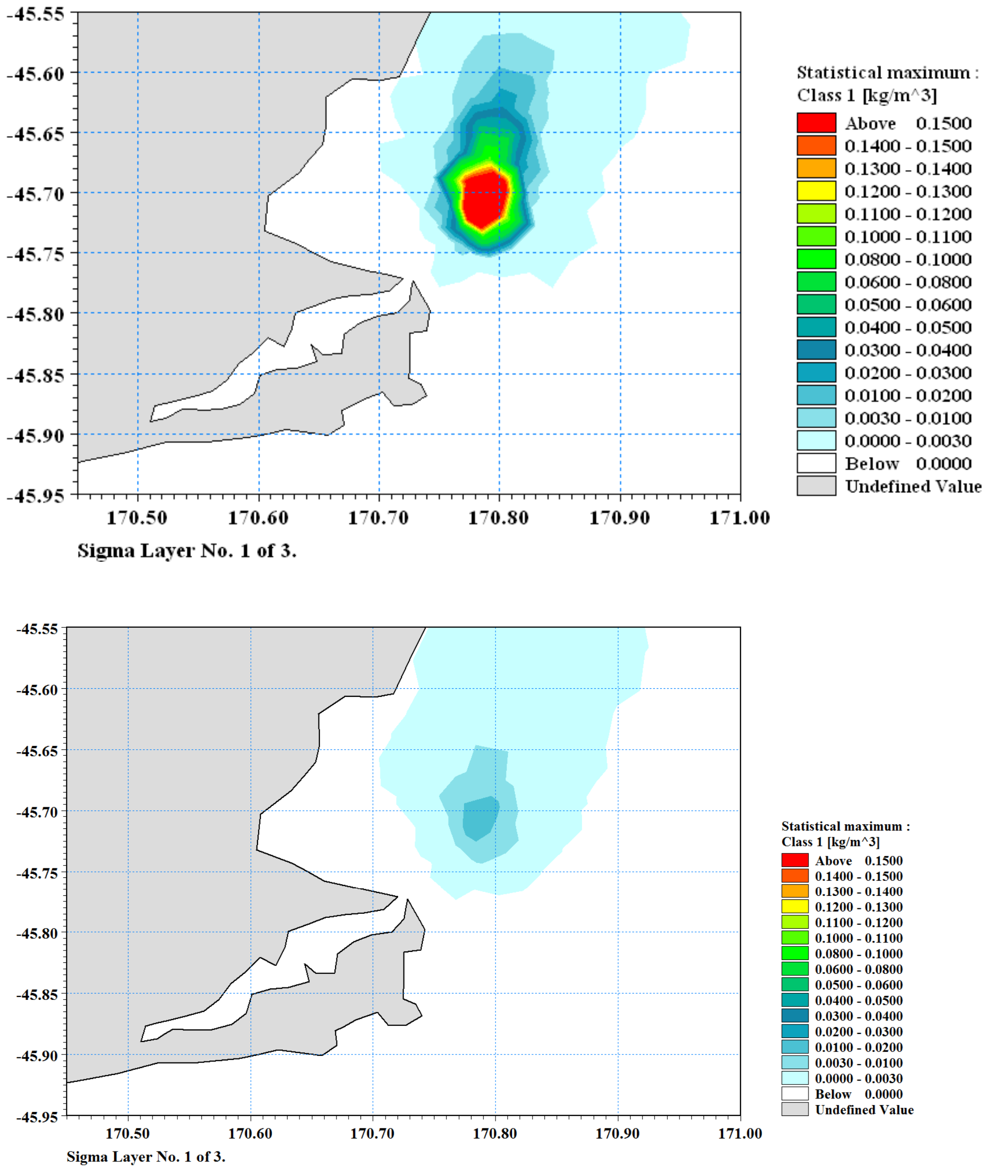


Figure 4.3: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for sediment size class 1 in the bottom layer (L1) over 24 disposal cycles for wind scenario 2 (moderate WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 260 mg/L and 14 mg/L (5%) and for coast north of Cornish Head, SSC will be 0.03–0.18 mg/L and 0.002–0.01 mg/L respectively.

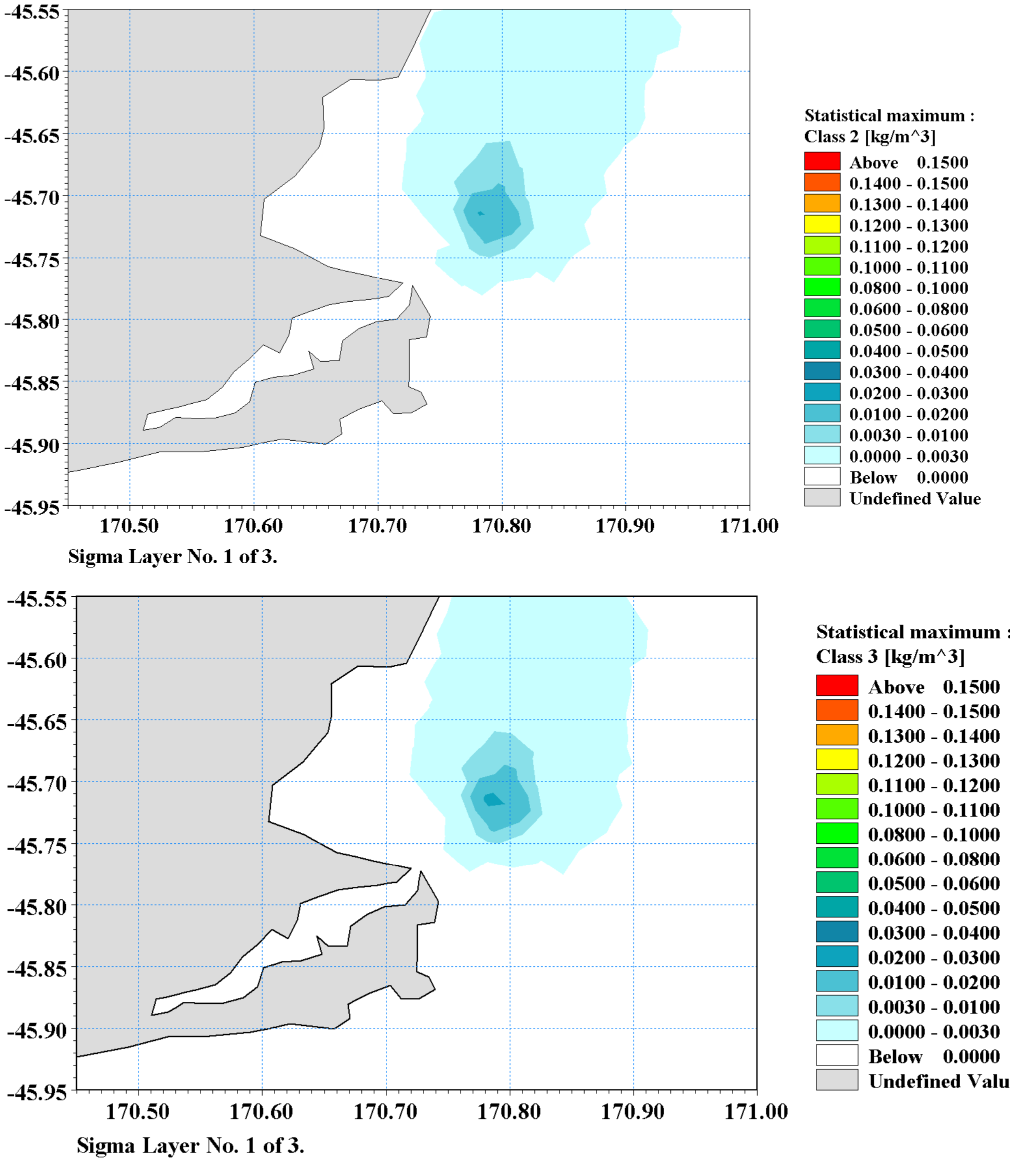


Figure 4.4: Max. SSC composite envelopes for just the *New Era* hopper discharges for medium silt (top) and coarse silt (bottom) in the bottom layer (L1) over 24 disposal cycles for wind scenario 2 (moderate WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 21 mg/L (medium silts) and 22 mg/L (coarse silts) and for coast north of Cornish Head, SSC will be ≤0.001 mg/L (medium silts) and 0 mg/L (coarse silts).

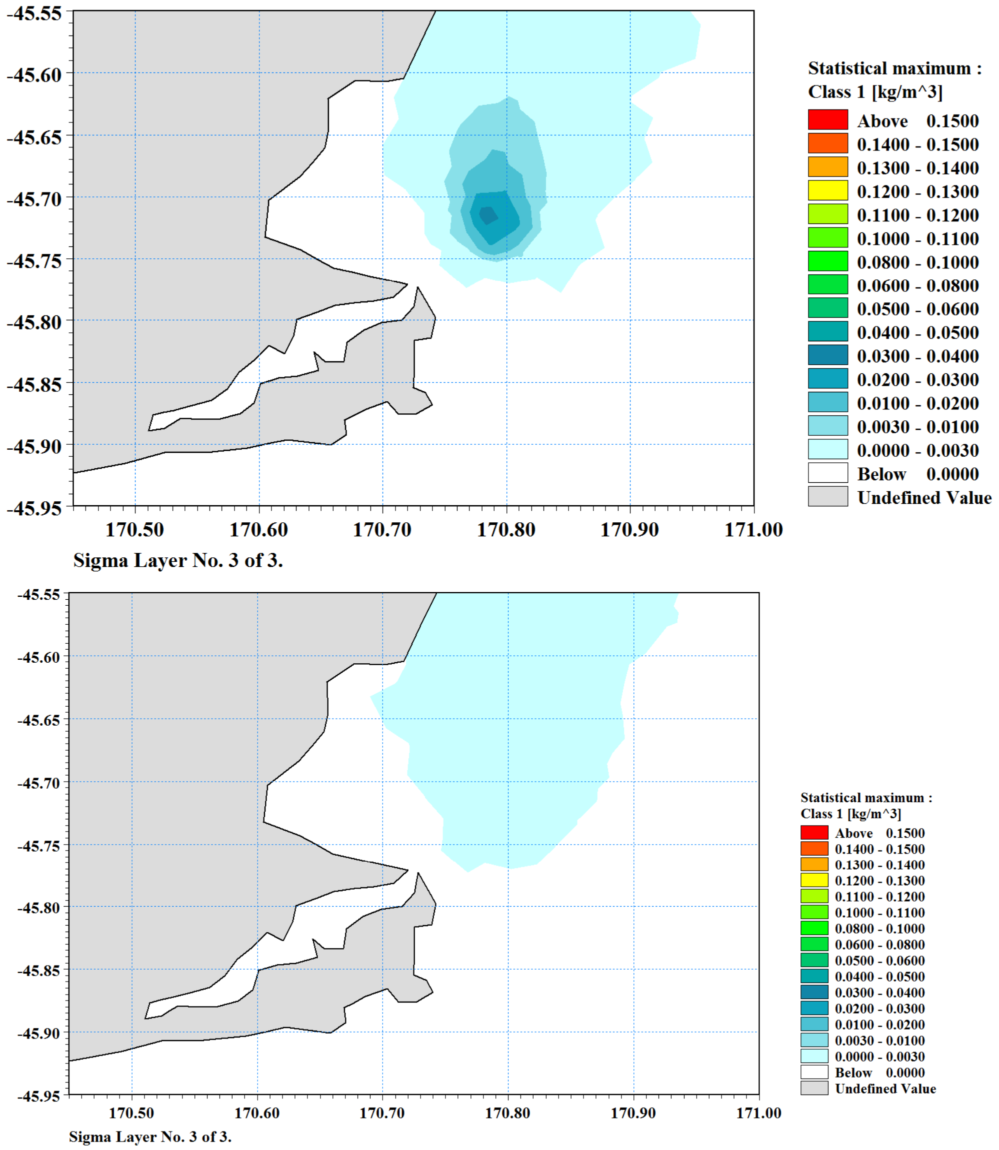


Figure 4.5: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for sediment size class 1 in the near-surface layer (L3) over 24 disposal cycles for wind scenario 2 (moderate WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 35 mg/L and 2 mg/L (6%) and for coast north of Cornish Head, SSC will be 0.003–0.05 mg/L and 0.002–0.02 mg/L respectively.

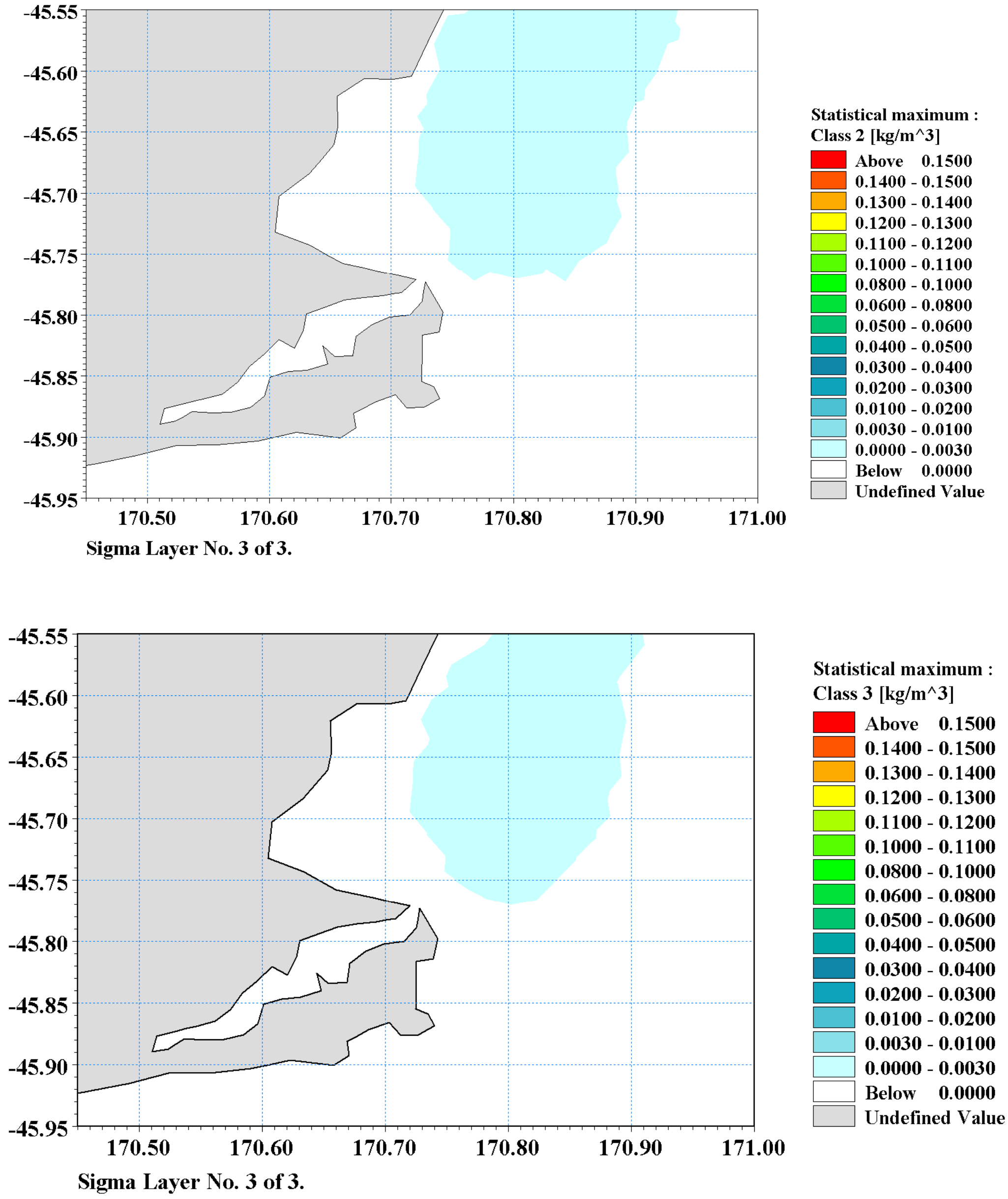


Figure 4.6: Max. SSC composite envelopes for just the *New Era* hopper discharges for medium silts (top) and coarse silts (bottom) in the near-surface layer (L3) over 24 disposal cycles for wind scenario 2 (moderate WSW wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 2.2 mg/L (medium silt) and 2.3 mg/L (coarse silt) and for coast north of Cornish Head, the excess SSC will be nil.

4.3 Light NNE winds

Figure 4.7 show the composites of maximum excess suspended-sediment concentration (SSC) during 48-hour periods for just the finest silt-size class in the bottom layer for wind scenario 4 (light NNE wind of 3 m/s). Figure 4.8 shows the medium and coarse silt composites in the bottom layer for just the *New Era* simulations.

Figure 4.9 shows the equivalent comparison between the larger TSHD and *New Era* for the near-surface layer for the same wind scenario. Figure 4.10 shows the medium and coarse silt composites in the near-surface layer for just the *New Era* simulations.

The top plot in Figures 4.7 & 4.9 show the result from the predominantly-silt hopper load from a larger TSHD, and the bottom plot is the equivalent result for the *New Era*. Results are only for discharges at the most landward sub-site #1 within the A0 disposal area (Figure 2.2).

The maximum SSC considering only fine silts (class 1) in the disposal area in both the bottom and near-surface layer using *New Era* will be about 5–6% of the maximum simulated SSC for a larger TSHD. If the edge of the plume reaches the coastline north of Cornish Head, the excess SSC for fine silts is very low reaching no higher than 0.1 mg/L in the near-surface layer for the larger dredger under these wind conditions. In comparison, the *New Era* would produce somewhat lower concentrations in the near-surface or bottom layer at no more than 0.004 mg/L (fine silts). A similar pattern of decreased SSC from a *New Era* discharge will occur off Otago Heads, with excess concentrations of no more than 0.3 mg/L (fine silt) compared with a maximum of 1.2 mg/L (fine silt) for the larger TSHD.

Across all three silt fractions (excluding fine sands that settle quickly), the maximum in the bottom layer from *New Era* will be around 50 mg/L at the disposal area. Along the coastline north of Cornish Head the maximum excess SSC on the fringe of the plumes from all silt classes will be ≤0.008 mg/L and along Otago Heads, ≤0.6 mg/L above background. In the near-surface layer, the maximum SSC from all silt classes would be 11 mg/L at the disposal area and no more than 0.03 mg/L along the coast north of Cornish Head, and along Otago Heads, ≤0.6 mg/L above background.

The extent of influence from the sediment plumes for both sizes of dredge shows subtle differences due to the different hopper discharge depths, which interacts with the 3-dimensional structure of the combined Southland Current flow and onshore NNE winds. The main difference is the reduced lateral spread of the plumes (both onshore and offshore) to the north for the *New Era* discharges.

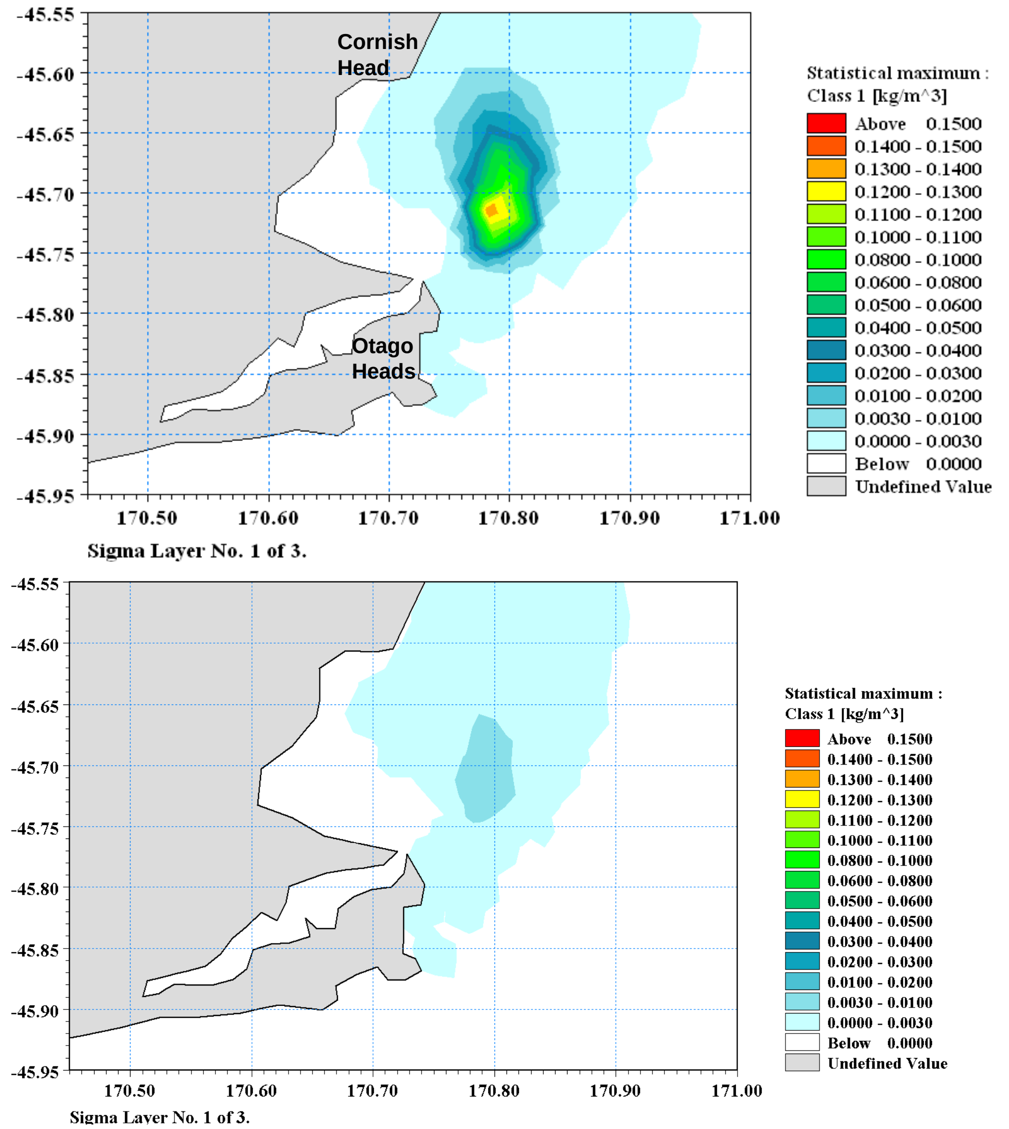


Figure 4.7: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 1 in the bottom layer (L1) over 24 disposal cycles for wind scenario 4 (light NNE wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 140 mg/L and 7 mg/L (5%). For the coast north of Cornish Head, SSC is predicted to be 0.01–0.06 mg/L compared with 0.001–0.004 mg/L (*New Era*) and off Otago Heads, 0.15–1 mg/L compared with 0.02–0.3 mg/L (*New Era*).

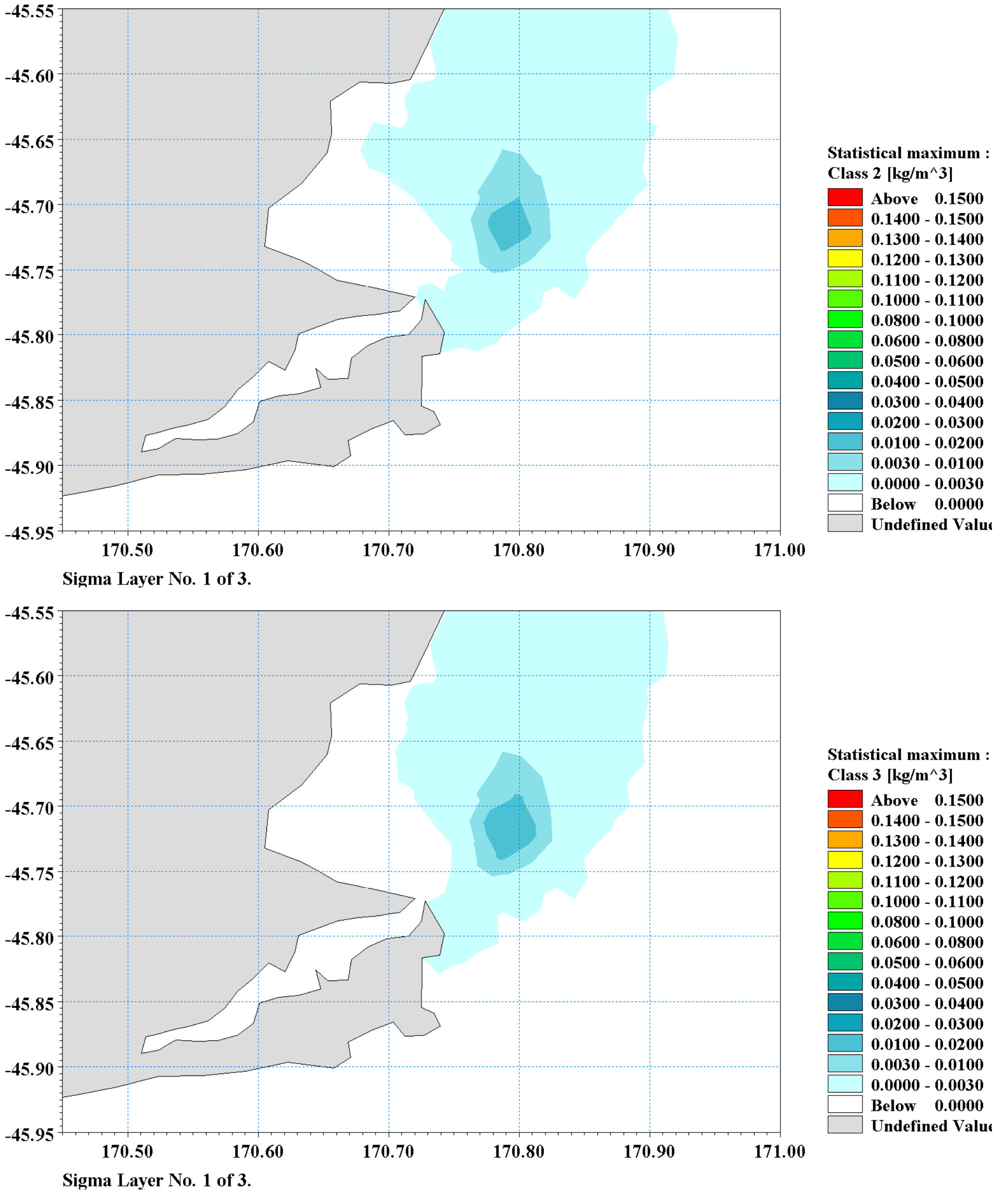


Figure 4.8: Max. SSC composite envelopes for just *New Era* hopper loads for medium silt (top) and coarse silt (bottom) in the bottom layer (L1) over 24 disposal cycles for wind scenario 4 (light NNE wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 13 mg/L (medium silts) and 16 mg/L (coarse silts). For the coast north of Cornish Head, SSC is predicted to be ≤0.002 mg/L (medium and coarse silts) and off Otago Heads, 0.01–0.05 mg/L (medium silts) and 0.02–0.26 mg/L (coarse silts).

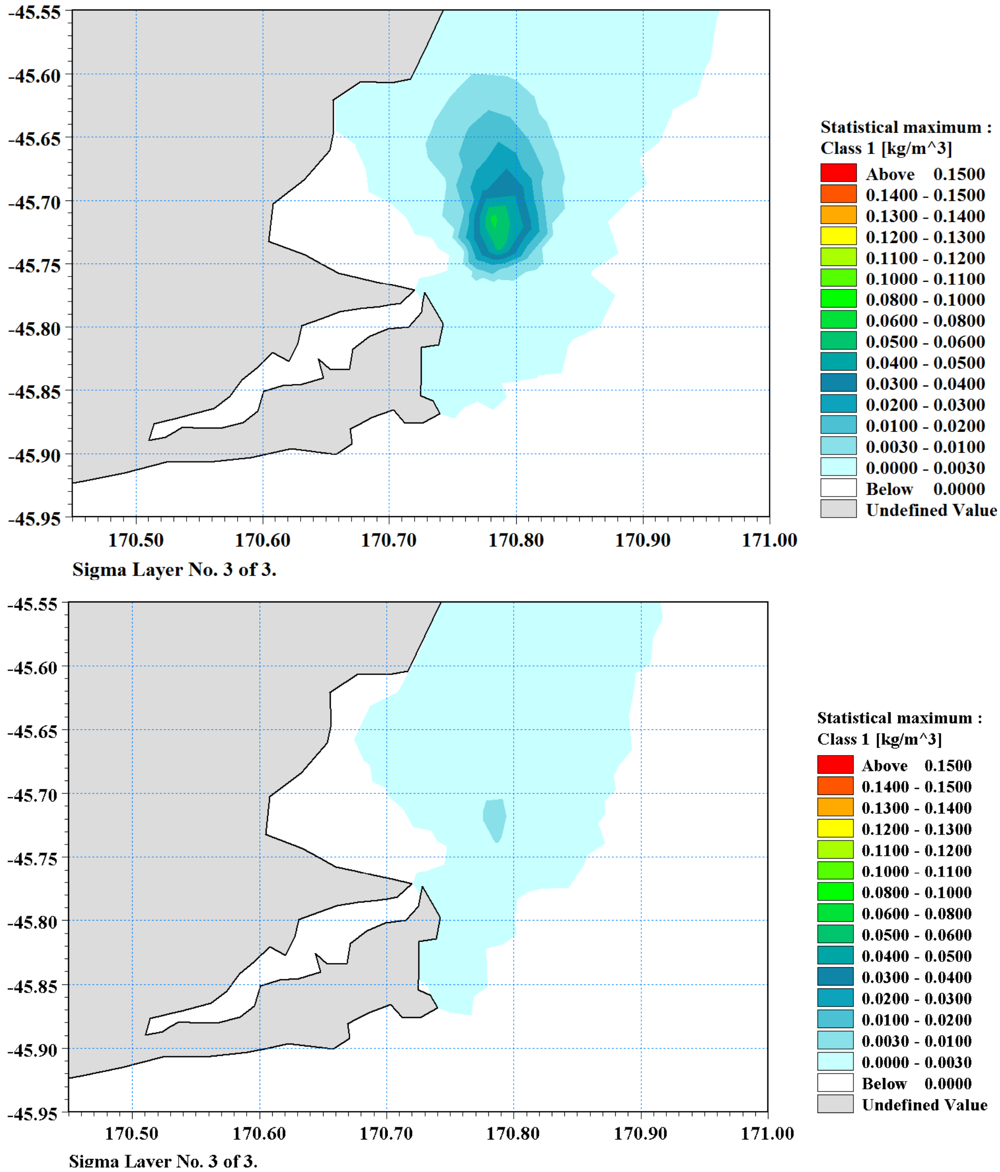


Figure 4.9: Max. SSC composite envelopes for larger TSHD loads (top) and the *New Era* hopper loads (bottom) for size class 1 in the near-surface layer (L3) over 24 disposal cycles for wind scenario 4 (light NNE wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 63 mg/L and 3.7 mg/L (6%). For the coast north of Cornish Head, SSC is predicted to be 0.04–0.1 mg/L compared with 0.001–0.003 mg/L (*New Era*) and off Otago Heads, 0.2–1.2 mg/L compared with 0.01–0.2 mg/L (*New Era*).

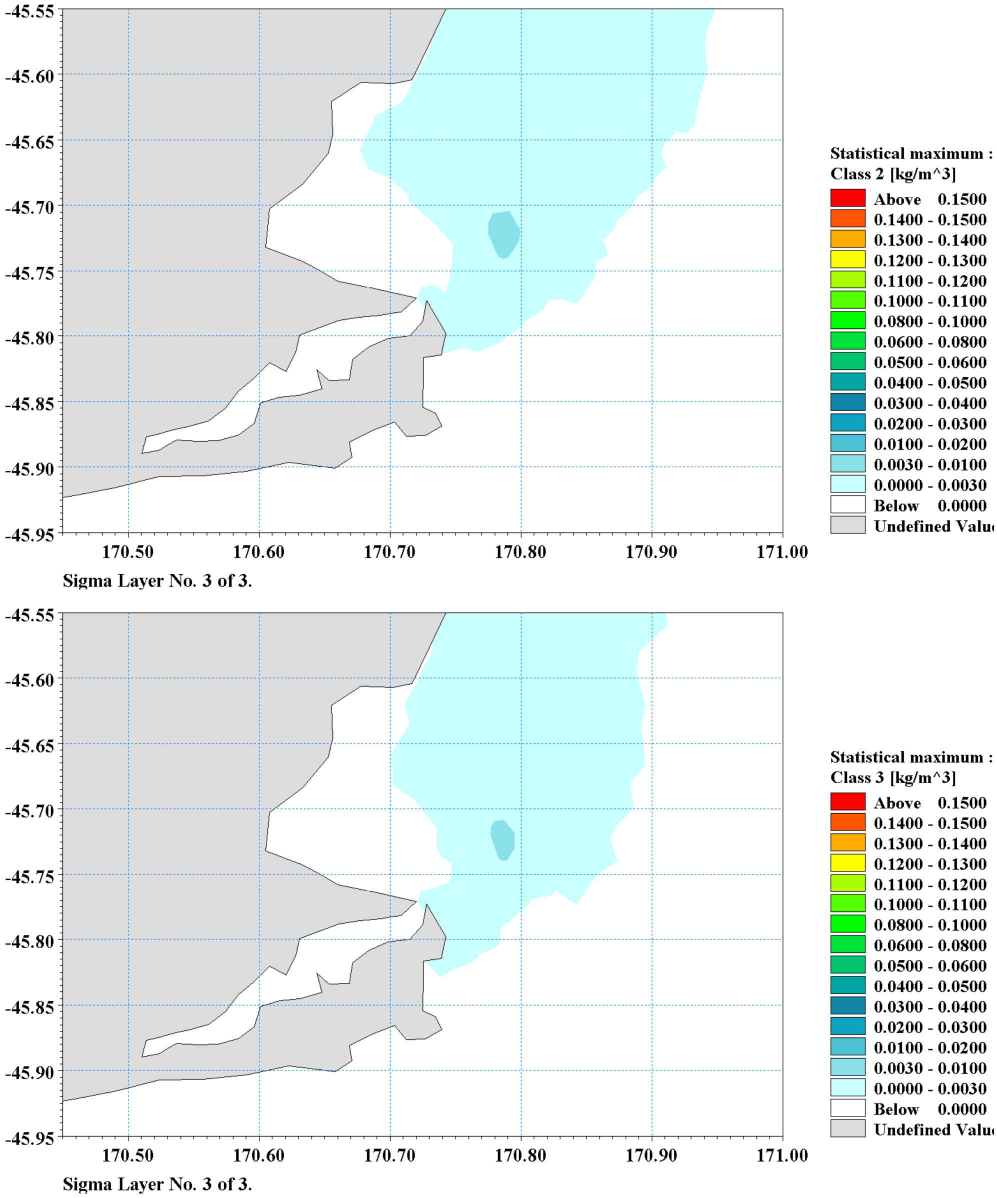


Figure 4.10: Max. SSC composite envelopes for just *New Era* hopper loads for medium silt (top) and coarse silt (bottom) in the near-surface layer (L3) over 24 disposal cycles for wind scenario 4 (light NNE wind) at disposal sub-site #1. Note: maximum SSC for the top and bottom plots respectively is 4 mg/L (medium silts) and 15 mg/L (coarse silts). For the coast north of Cornish Head, SSC is predicted to be ≤0.014 mg/L (medium and coarse silts) and off Otago Heads, 0.01–0.024 mg/L (medium silts) and 0.02–0.18 mg/L (coarse silts).

5. Conclusions

In summary, this supplementary report, based on further comparable modelling of conservative scenarios previously presented in the lodged Technical AEE Report for the smaller New Era dredge shows that:

- harbour suspended sediment concentrations and deposition rates will be around ten times less using *New Era* than a larger dredge (on which the previous modelling was based)

- offshore, the silt concentrations in the plume generated during disposal in the vicinity of A0 would be around 5–7% of those predicted for the larger dredge. On the fringes of the sediment plumes where the intersect the coast, *New Era* would produce much lower concentrations and in some cases ten times lower than the larger dredge.

5.1 Harbour plume modelling

Sediment plume modelling in Otago Harbour for a larger TSHD was previously carried out by NIWA in 2009 using MIKE-21 PA module which is depth-averaged (2D) model comprising a regular square grid. These ten sets of 14-day plume simulations were re-run for the case where the much smaller *New Era* undertakes the capital dredging, based on five representative source areas and at each source area, for dredging predominantly-sand sediments and predominantly-silt sediments.

5.1.1 2-week average SSC

Average SSC over 2 weeks are provided to directly compare with the previous 2009 model simulations for a larger TSHD and monitoring requirements for overseas dredging projects tend to be expressed as a 2-week moving-average (covering a spring-neap tide cycle). Concentrations from the MIKE-21 PA plume model are averaged over the entire depth of the water column at the time of calculation, so the 14-day SSC averages shown in the plots are also averages over the water depth (mid-tide to seabed level).

All simulations for a 24/7 operation based on *New Era* show that 2-week average SSC in the main channel reaches only 20–50 mg/L above background concentrations, with smaller patches from 50–100 mg/L where the dredge operates. On the intertidal areas, mostly the average SSC is predicted to only reach 20 mg/L with some limited areas up

to 50 mg/L. These concentrations are at least ten times less than those simulated for the larger TSHD.

Those *New Era* discharges in the Turning Basin and at Taylers Bend would have the most influence on raising average SSC above background levels in the Upper Harbour. Outside the main channels, SSC would be up to 50 mg/L in small areas (mainly west of Portobello Peninsula for dredging in the eastern Turning Basin), and mostly below 10 mg/L above background concentrations.

Considering silt discharges produced by *New Era* from predominantly-silt versus predominantly-sand[5] areas, there is little difference in the spatial extent of the areas affected by the silt plumes from either source. The SSC are only slightly higher in most cases for the longer predominantly-sand dredging cycles.

Virtually all of the eastern side of the Lower Harbour from Te Rauone Beach through to the eastern side of Portobello Bay would be largely unaffected by turbidity generated directly by *New Era*, with only a few small patches of SSC up to 10 mg/L above background levels. Similarly, the eastern side of the Upper Harbour from Grassy Point to Dunedin would be also largely unaffected by the direct transport and dispersion of suspended-sediment plumes generated by *New Era*.

The 14-day average SSC will be negligible in the indistinct plume that emanates from the Mole to Taiaroa Head channel section for dredging claims in the Turning Basin, but will gradually increase up to a depth-average SSC of only 10–20 mg/L for dredging at Harington Bend.

5.1.2 2-week accumulated deposition

Accumulated seabed deposition over each 14-day plume simulation is presented in mass of sediment per unit area of seabed (kg/m^2). These deposition values are generally conservative as no subsequent resuspension by competent tidal currents or wind-wave stirring was included in the plume model simulations, which will act to further spread and disperse some of the initially-settled material.

To convert to the predicted thickness of deposition (mm), the same settled wet bulk density of 1300 kg/m^3 was assumed, as used in the 2009 NIWA report.

The deposition plots show the following key results for seabed deposition over a 14-day neap/spring tide cycle with varying winds:

[5] Where a small 2% fraction of silt has been assumed in the sands

- deposition at or above 5 kg/m^2 or approximately 3.8 mm over a fortnightly period (0.3 mm/day) is very confined to the immediate vicinity of the main shipping channel where *New Era* dredges. This is in contrast to the larger TSHD, where the same deposition level or rate occurred throughout the main shipping channel (all discharge sources), the subsidiary channel to the east from Quarantine Island, around Goat Island and up Victoria Channel to opposite St. Leonards for a discharge source at Turning Basin–west, and some of the flanking intertidal flats to these channels

- discharges from predominantly-silt claims cause very similar deposition thicknesses (and daily deposition rates) to those from predominantly-sand claims

- the Upper Harbour will have virtually no discernable seabed deposition arising from discharge sources at Harington Bend and further seaward

- most of the eastern parts of the Lower and Upper Harbours would be subject to negligible or no deposition, apart from the reach west of Latham Bay for discharges from the eastern side of the Turning Basin, where deposition may reach 0.5 kg/m^2 (0.4 mm) over 2 weeks or an accumulation rate of 0.03 mm/day)

- flanking mid-harbour intertidal flats, where most of the non-channel deposition will occur, will be at substantially lower deposition rates using *New Era* compared with the larger TSHD by about 10 times less, from 2–5 kg/m^2 (0.1–0.3 mm/day) down to 0.2–0.5 kg/m^2 (0.01–0.03 mm/day) for similar areas.

5.2 Offshore plume modelling

Simulations for offshore disposal were undertaken for a more conservative predominantly-silt hopper load during light and moderate WSW winds of 7 m/s and 14 m/s respectively and a light 3 m/s NNE wind, when the very low concentration fringes of sediment plumes are most likely to reach the coast. The disposal in these simulations pertains to the landward side of the disposal area at A0.

SSC concentrations offshore during disposal operations for these scenarios will be substantially lower using the *New Era*. Generally, maximum SSC from the *New Era* in the general vicinity of 1–2 km around the disposal area will be around 5–7% of the maximum SSC produced by a larger TSHD.

At the disposal area, the near-surface layer SSC concentrations for all silt classes from *New Era*, for the three wind conditions simulated, are predicted to be in the range 7–11 mg/L (highest during the light NNE wind) above background concentrations. In the more concentrated bottom layer, predicted SSC will the range 47–57 mg/L above background concentrations (highest for the moderate 14 m/s WSW wind).

The fringes of sediment plumes from the smaller *New Era* will reach the coastline north of Cornish Head, but the excess SSC combining all silt-size classes will be no higher than 0.05 mg/L for the different wind simulations (highest during light WSW winds). During light NNE winds, the fringes of the sediment plumes will also reach Otago Heads, where the excess SSC for all silt classes will be no more than 0.6 mg/L. No contact with the Otago Heads coastline will occur for stronger NNE winds (see Figure 11.10b; Bell, et al., 2009).

In comparison with the larger TSHD, *New Era* would produce much lower concentrations and in most cases ten times lower on the fringes of the sediment plumes when they do intersect with the coast. These substantial reductions arise from a commensurate reduction in sediment loads from *New Era* compared with a larger TSHD. Concentrations simulated in the receiving waters are generally proportional to the rate of sediment volume discharged given the same disposal location and release height in the water column.

Patterns of plume dispersion and areal extent of influence are broadly similar between the two sizes of dredger. This is expected as the sediment material is released at the same location, from which the same environmental processes e.g., tides, winds, currents, turbulent eddies govern the dispersal characteristics of the plume. There are however subtle differences in the extent of influence, especially along the onshore and offshore fringes of the plumes. These differences arise from the shallower discharge (2 m depth) from the *New Era* compared with the larger TSHD (5 m depth), which means the plume from the *New Era* is initially influenced by near-surface water processes for a slightly longer period while sediment settles through the 3 m discharge height difference. The differences in extent of the plume are a little more noticeable for light onshore NNE winds.

6. References

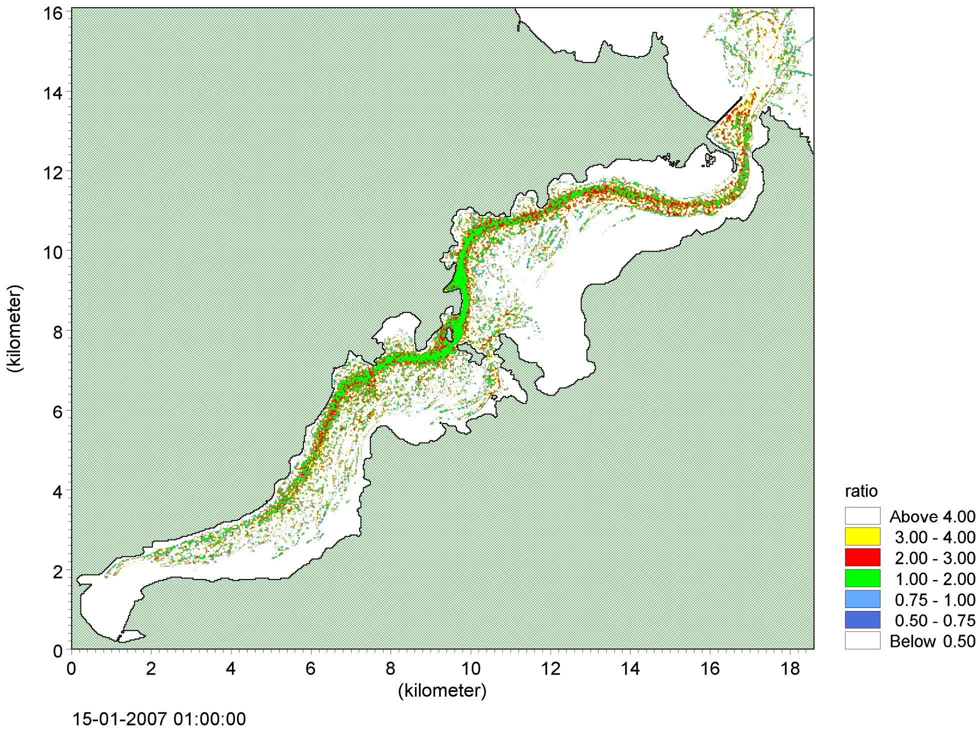
Bell, R.G.; Oldman, J.W.; Beamsley, B.; Green, M.O.; Pritchard, M.; Johnson, D.; McComb, P.; Hancock, N.; Grant, D.; Zyngfogel, R. (2009). Port of Otago dredging project: Harbour and offshore modelling. *NIWA Client Report HAM2008-179*, prepared for the Port Otago Ltd.

7. Appendix A: Ratio of seabed deposition for larger TSHD between 20-minute and a 60 minute overflow simulations for "sand" claims

The predominantly-sand plots in the 2009 NIWA report (bottom panels of Figs. 7.4 to 7.13) were mistakenly done for an overflow for the final 20 minutes of the 80 minute dredge cycle. These previous larger-TSHD simulations for "sand" claims were repeated in this present report (see Section 3) for the correct timing of the overflow starting 20 minutes after the start of the cycle for a 60-minute overflow.

For assessing the effect of the revised "sand" simulations on seabed deposition for the larger TSHD, compared to the earlier results in the 2009 NIWA report, the following plots show the ratio of the revised 14-day deposition to the earlier simulations with a 20-minute overflow e.g., a ratio of 2.0 means the longer 60-minute overflow simulations produce twice the deposition as the shorter 20-minute overflow for dredging "sand" areas.

In the main channel, the ratio is up to twice the deposition, while on the intertidal flanks of the channels, the ratio in places is up to three times higher for dredging in the critical swinging basin areas. This applies only to dredging by a larger TSHD in "sand" areas.



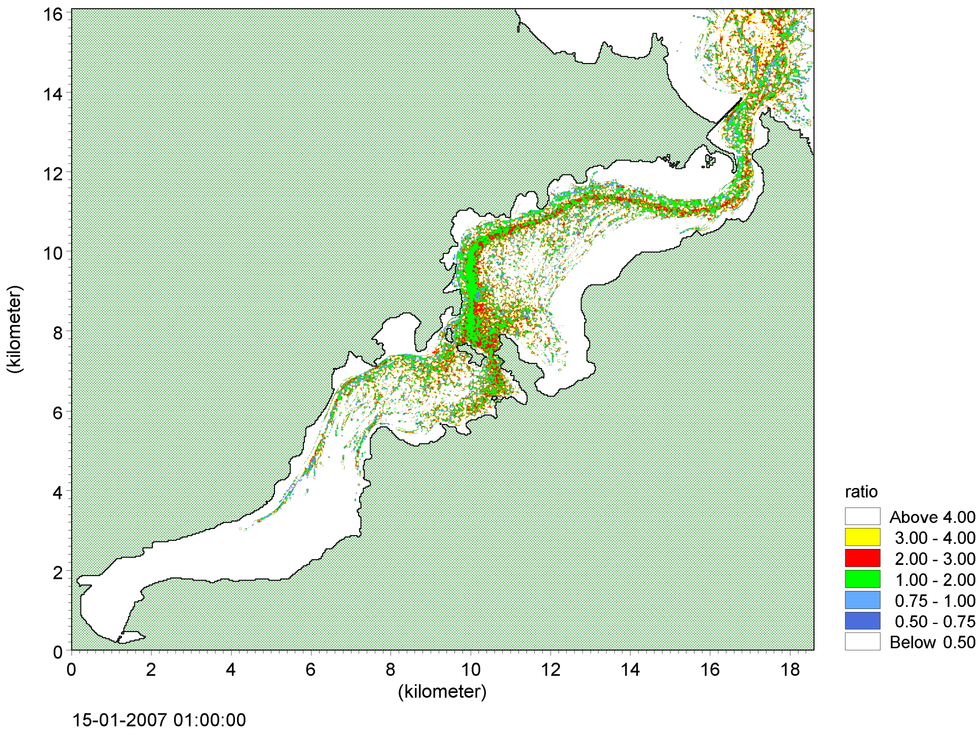


Figure A.1: Plots of the ratio of the seabed deposition for the longer 60-minute overflow to the previous 20-minute overflow simulations in the 2009 NIWA report for largely "sand" dredging in the swing basin–west (TOP) and swinging basin–east (BOTTOM) using the larger TSHD.