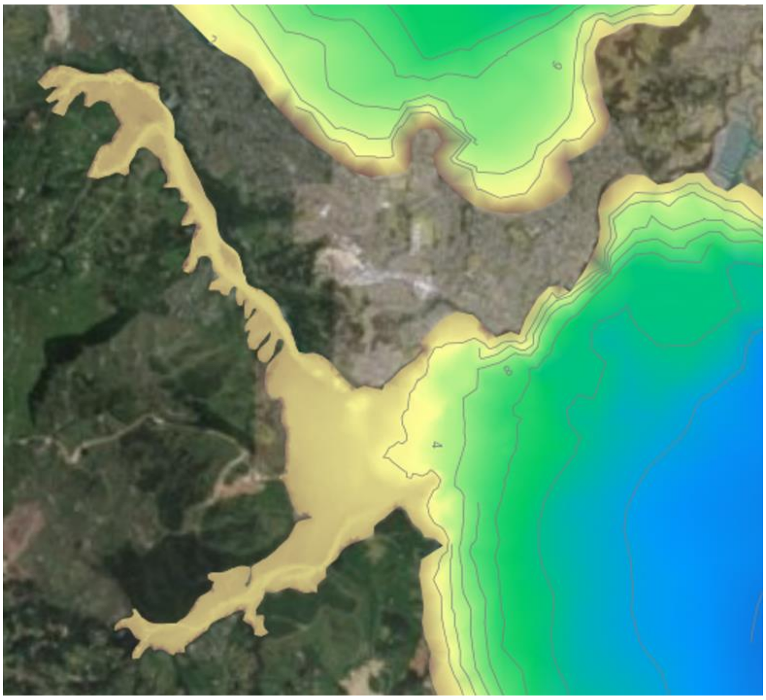
Okura Wēiti Marine Receiving Environment Modelling

Scenario Report



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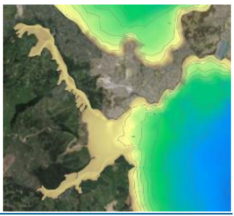
Scenario Report

Prepared for Auckland Council

Represented by Tom Porter



Karepiro Bay bathymetry.

Project manager	John Oldman

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CONTENTS

1 Executive Summary

There is potential for significant development within the catchments which surround the Wēiti and Okura estuaries. Of primary concern with such developments is the generation, transport and fate of catchment derived sediments and heavy metals and how they may impact the marine receiving environment.

To date there has been limited work to assess the potential for combined effects of future potential developments within these catchments on the marine receiving environment which includes the Long Bay-Okura Marine Reserve.

To address this, Auckland Council have developed a region wide land-based contaminant load and hydrological modelling (the Freshwater Management Tool - FWMT).

Outputs from the FWMT have been linked to a fully coupled hydrodynamic, wave, sediment and heavy metal transport models. This report provides an overview of the calibration of the models and how they have been used to assess the potential impacts on the marine receiving environment of a range of potential land use scenarios. These scenarios considered varying levels of development within different parts of the catchment. The scenarios only consider a fully developed state rather any staging of development through time.

The assessment of the scenarios includes quantifying the ultimate fate of catchment derived sediments in the marine receiving environment and providing an understanding of how suspended sediment concentrations vary due to the effect of winds, waves and tides. Based on an understanding of how particular catchments are connected to various sub-environments in the marine receiving environment and using metal load estimates from the FWMT estimates of future Zinc and Copper concentrations in surface sediments are summarised at a subestuary scale.

Existing bed sediments are resuspended off the seabed during wave events (and also in areas where stronger tidal currents occur). These wave events often correspond to periods when higher sediment loads are delivered from the catchment.

Thus, there is a combined effect of the resuspension of existing seabed sediments in deeper parts of the system during wave events, the transport of these resuspended seabed sediment into the Okura estuary and Wēiti river and the elevation of suspended sediment concentrations close to catchment outlets.

Over much of Karepiro Bay and the outer (seaward) sections of the Okura estuary and Wēiti river the dynamics of the existing bed sediment dominant over the effects of catchment derived sediments.

It is only in the upper and middle sections of the Okura estuary and Wēiti river where the delivery and subsequent transport of catchment derived sediments become important in determining the level of deposition and suspended sediment concentrations.

Different parts of the system can be classified in terms of how often deposition occurs, how often erosion occurs and the rate at which these two processes happen when they do occur.

For example, in the upper Okura estuary there is net deposition for nearly two-thirds of the time with limited erosion at other times (relating to the strength of tidal currents in this area).

In contrast, there is always net deposition in upper parts of the Wēiti river. Because of the stronger tidal currents in the middle sections of the Wēiti river erosion occurs for nearly two-thirds of the time.

Along Karepiro beach there is approximately the same amount of time when deposition or erosion is occurring but, because erosion is driven by wave processes, net erosion occurs here.

Understanding the dynamics and connectivity of the system allows the relative impacts of different catchment on different subestuaries to be quantified.

For example, the Long Bay catchment outlet contributes to 1.4% of the overall deposition seen in the marine receiving environment with the majority of deposition from this catchment outlet occurring in the wider Hauraki Gulf

The Redvale catchment contributes to just over 15% of the overall deposition seen in the marine receiving environment with the majority of the deposition from this catchment outlet occurring in the Upper and Mid Okura subcatchments but with some deposition also occurring within Wēiti subcatchments.

The Silverdale catchment contributes to just over 45% the overall deposition seen in the marine receiving environment with the majority of the deposited occurring in the Upper Wēiti subestuaries with lower levels of deposition occurring within the other Wēiti subestuaries and also the Upper Okura subestuary.

Less than 5% of the catchment derived sediments deposits in the wider Karepiro Bay with less than 2% being deposited within the Marine Reserve area.

The key sediment transport results drive the predicted levels of future metal concentrations. Importantly, the ratio of changes in sediment loads and metal loads under the different scenarios needs to be considered. Higher future metal concentrations will occur when metal loads alone are increased but concurrent reductions in sediment load will lead to further increases in future metal concentrations.

Areas of highest future metal concentrations occur in areas of highest deposition close to subcatchments with high metal loads - these areas are the upper parts of the Wēiti river and Okura estuary. Elsewhere, deposition rates are much lower and so over time the addition of new metal to existing seabed sediments does not result in metal concentrations exceeding Probable Effects Levels.

There is potential for significant development within the catchments which surround the Wēiti and Okura estuaries. Of primary concern is the generation, transport and fate of catchment derived sediments and heavy metals and how they may impact the marine receiving environment. Prior studies have focussed on development within the Okura catchment so there has been limited work to assess the potential for the combined effects of developments in the Long Bay, Okura, and Wēiti catchments.

To address this Auckland Council developed a region wide land-based contaminant load and hydrological modelling – the Freshwater Management Tool (FWMT). The FWMT has been used in this study to generate current state sediment and metal loads and flows from the Long Bay, Okura and Wēiti and catchments and to quantify the effects of potential development scenarios. Each of the scenarios considered assumes a fully developed state so does not include the staging of any land use development that would typically occur over a number of years.

DHI were commissioned to carry out a study that linked outputs from the Freshwater Management Tool (FWMT) to fully coupled hydrodynamic, wave, sediment and heavy metal transport models. The suite of marine receiving environment models has been used to quantify the impact that potential development scenarios within the Okura and Wēiti catchments may have within the marine receiving environment.

The FWMT modelling shows that greater than 60% of the sediment and ~50% of the metal loads entering the Long Bay/Okura marine receiving environment are derived from the Silverdale and Redvale subcatchments. The North Arm, Weiti South, Long Bay and Awaruku subcatchments each deliver around 5% of the total sediment and metal load entering the marine receiving environment.

Coupled hydrodynamic, wave and sediment transport models have been calibrated against field data and run for a representative period (January-July 2018) to provide estimates of suspended sediment concentrations and sediment deposition rates for a range of potential land use scenarios.

Predicted deposition rates from the sediment transport model and estimated metal loads from the FWMT have been used to estimate future (50 year) metal concentrations in the surface layer sediments at a subestuary level.

The key results with regard to the overall sediment dynamics of the system are as follows;

- within Karepiro Bay, the resuspension of existing seabed sediments by waves contribute significantly to elevated levels of suspended sediment concentrations.

- The predominant sinks for catchment derived sediments are the Upper Okura estuary and Wēiti river. This is due to the relatively low currents and proximity to the higher sediment loads from the Redvale and Silverdale and catchments respectively.

- Similarly, due to the relatively low currents and limited wave penetration that occurs in the Wēiti river, the embayment’s in the lower Wēiti River are deposition sinks.

- There is a strong gradient of deposition along axis of both the Okura estuary and Wēiti river.

- Sediments delivered directly to Long Bay are relatively widely dispersed within the Long Bay/Okura marine reserve.

- There is very little long-term deposition on Karepiro beach and the outer Okura estuary. This is driven by wave activity than can occur in these areas.

- Catchment derived sediments that are discharged to the open coast (e.g. Long Bay) are widely dispersed.

- Less than 5% of the catchment derived sediments deposits in the wider Karepiro Bay.

These key sediment transport results drive the predicted levels of future metal concentrations. Importantly, the ratio of changes in sediment loads and metal loads under the different scenarios needs to be considered. Higher future metal concentrations will occur when metal loads alone are increased but concurrent reductions in sediment load lead to further increases in future metal concentrations.

A combination of high deposition close to subcatchments with high metal loads lead to the highest future metal concentrations in the surface layer of sediments. These areas are the upper parts of the Wēiti River and Okura estuary. Applying metal load reductions to future land use development scenarios results in significant reductions in future metal concentrations in these areas which has the potential to offsets the effects of the land use development.

Elsewhere, deposition rates are much lower and so over time the addition of new metal to existing seabed sediments does not result in metal concentrations exceeding Probable Effects Levels. As such, changes in metal loads have little consequence in relation to future metal accumulation.

2 Introduction

This report provides a summary of results from the marine receiving environment models that have been setup and calibrated for the Wēiti river and Okura estuary and wider Karepiro Bay - including the Okura-Long Bay Marine Reserve.

Catchment inputs to the marine receiving environment model are derived from the Freshwater Management Tool (FWMT) being developed for the Auckland Council (as detailed in Morphum 2019). A total of 13 land use and future development options have been considered (Table 2-1). Scenarios 9 and 10 considered development within the Okura catchment. These scenarios have not been reported on. Table 2-2 provides a summary of the

The marine receiving environment models extend into the wider Hauraki Gulf with areas of higher resolution within Karepiro Bay, Okura Estuary and the Wēiti River (Figure 2-1) and include areas of high resolution within the Okura Estuary and Wēiti River

A previous report (DHI, 2019) detailed the calibration of the marine receiving environment models against field data collected specifically for this project and against available historic field data (DHI, 2018). The calibrated model used catchment inputs from the FWMT for Scenario 0 (Table 2-1) which corresponds to current land use and existing levels of development within the catchments surrounding the Okura estuary and Wēiti river prior to the recent developments in the Long Bay area.

The focus of the modelling was to understand the effect of land use change on the marine receiving environment. The dynamics of the offshore sediment are discussed in detail in the calibration report (DHI, 2019). The dynamics of these sediments will not change due to land use change. As such, all results presented in this report include just the input of catchment derived sediments to the system.

A summary of the mean annual catchment loads for sediment, Zinc, and Copper for each of the scenarios are shown in Table 2-1 along with the changes in loads for the comparative Scenario. For example, Scenario 1 (recent development in Long Bay) is compared to Scenario 0, and Scenario 4 (development in future growth areas) is compared to Scenario 1. This provides quantification of the impact of the land development being considered in each of the scenario. The catchment inputs are distributed across the 19 catchment outlets shown in Figure 2-2. Inputs for each of the catchment outlets are derived from Morphum data as summarised in Table 2-3.

Figure 2-4 shows the extent of the subestuaries, which have been defined in terms of describing sediment transport and metal accumulation in the marine receiving environment. As discussed in DHI (2019), an important outcome of the modelling is defining the connectivity of the system – how individual catchment outlets are connected to the marine receiving environment at a subestuary level. Table 2-4 shows the connectivity matrices for the individual catchment outlets and each of the subestuaries. This table shows the proportion of sediment deposited in each subestuary for each of the catchment outlets.

In the following sections of the report a detailed description of the changes in loads across the catchments are provided for each of the land use scenarios, along with a summary of the sediment transport and metal accumulation model predictions. Time series results at key sites, which are shown in Figure 2-5, are included.

Metal accumulation is predicted over the next 50 years which provide context in terms of long-term infrastructure planning timescales. Results are summarised at the subestuary level and in the context of the Probable Effects Levels (PEL) guidelines developed for the Auckland Region (Williamson et al. 2017) of 271 mg/kg for Zinc and 108 mg/kg for Copper. These values are higher than the ANZECC (2000) ISQC-Low values but, as discussed in Williamson et al. (2017), provide thresholds for metal concentrations above which adverse biological effects may be expected.

The time that suspended sediment concentrations above 80 mg/L are presented (0.08 kg/m^3) which, depending on the duration of elevated levels, may result in adverse effects on benthic organisms (e.g. Hewitt et al, 2001, Green 2016).

Table 2-1. Summary of scenarios considered, mean annual loads and differences in mean annual loads relative to the comparative scenario. Numbers in bracket are the change in load relative to the comparative scenario.

	Scenario description	Long Bay Structure Plan Development	Wēiti Bay Growth Area Development	Future Growth Area Development
Scenario 0	Land use prior to recent development within Long Bay	✗	✗	✗
Scenario 1	Completion of Long Bay Structure Plan development (2017-2018)	✓	✗	✗
Scenario 2	550 home Wēiti Bay Development	✓	550 home	✗
Scenario 3	1200 home Wēiti Bay Development	✓	1200 home	✗
Scenario 4	Future Growth Development	✓	✗	✓
Scenario 5	Future Growth + 550 Wēiti Bay Development	✓	550 home	✓
Scenario 6	Future Growth + 1200 Wēiti Bay Development	✓	1200 home	✓
Scenario 7	Scenario 6 with less Cu/Zn build-up wash-off	✓	1200 home	✓
Scenario 8	Scenario 6 more Cu/Zn build-up wash-off	✓	1200 home	✓
Scenario 11	Scenario 5 with inert roofing materials Wēiti Bay	✓	550 home	✓
Scenario 12	Scenario 6 with inert roofing materials Wēiti Bay	✓	1200 home	✓
Scenario 13	Scenario 5 with inert roofing materials Wēiti Bay and Future Growth	✓	550 home	✓
Scenario 14	Scenario 6 with inert roofing materials Wēiti Bay and Future Growth	✓	1200 home	✓

Table 2-2. Summary of scenarios considered, mean annual loads and differences in mean annual loads relative to the comparative scenario. Numbers in bracket are the change in load relative to the comparative scenario.

	Scenario description	Comparative Scenario	Mean annual sediment load (tonnes/yr)	Mean annual Zinc load (kg/yr)	Mean annual Copper load (kg/yr)
Scenario 0	Land use prior to recent development within Long Bay	-	2267	330	87
Scenario 1	Completion of Long Bay Structure Plan development (2017-2018)	Scenario 0	2274 (+7)	337 (+7)	87
Scenario 2	550 home Wēiti Bay Development	Scenario 1	2297 (+23)	351 (+14)	88 (1)
Scenario 3	1200 home Wēiti Bay Development	Scenario 2	2300 (+3)	352 (+1)	88
Scenario 4	Future Growth Development	Scenario 1	2095 (-179)	511 (+174)	88 (1)
Scenario 5	Future Growth + 550 Wēiti Bay Development	Scenario 2	2100 (-197)	526 (+175)	89 (1)
Scenario 6	Future Growth + 1200 Wēiti Bay Development	Scenario 3	2103 (-197)	526 (+174)	89 (1)
Scenario 7	Scenario 6 with less Cu/Zn build-up wash-off	Scenario 6	2105 (+2)	261 (-265)	45 (-44)
Scenario 8	Scenario 6 more Cu/Zn build-up wash-off	Scenario 6	2106 (+3)	1048 (522)	178 (+89)
Scenario 11	Scenario 5 with inert roofing materials Wēiti Bay	Scenario 5	2103 (+3)	520 (-6)	89
Scenario 12	Scenario 6 with inert roofing materials Wēiti Bay	Scenario 6	2106 (-3)	521 (-5)	89
Scenario 13	Scenario 5 with inert roofing materials Wēiti Bay and Future Growth	Scenario 5	2103 (+3)	383 (-143)	89
Scenario 14	Scenario 6 with inert roofing materials Wēiti Bay and Future Growth	Scenario 6	2106 (+3)	383 (-143)	89

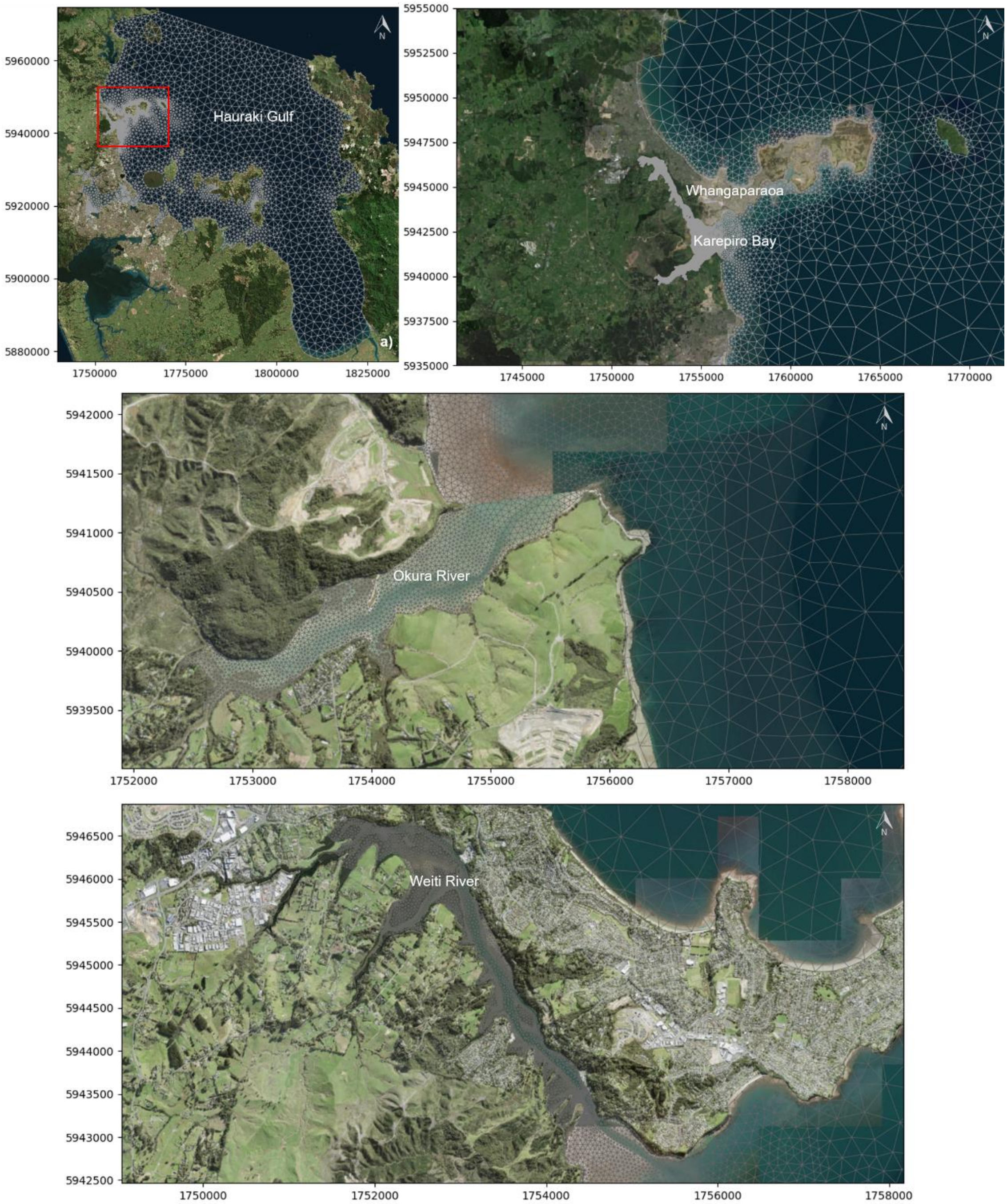


Figure 2-1. Detail of the model extent used for the wave, hydrodynamic, sediment transport and metal accumulation models that make up the marine receiving environment model. Top left panel shows full extent of grid, top right shows detailed grid around Long Bay/Whangaparaoa. Middle panel shows detailed grid within the Okura estuary and the bottom panel shows the detailed grid within the Wēiti River.

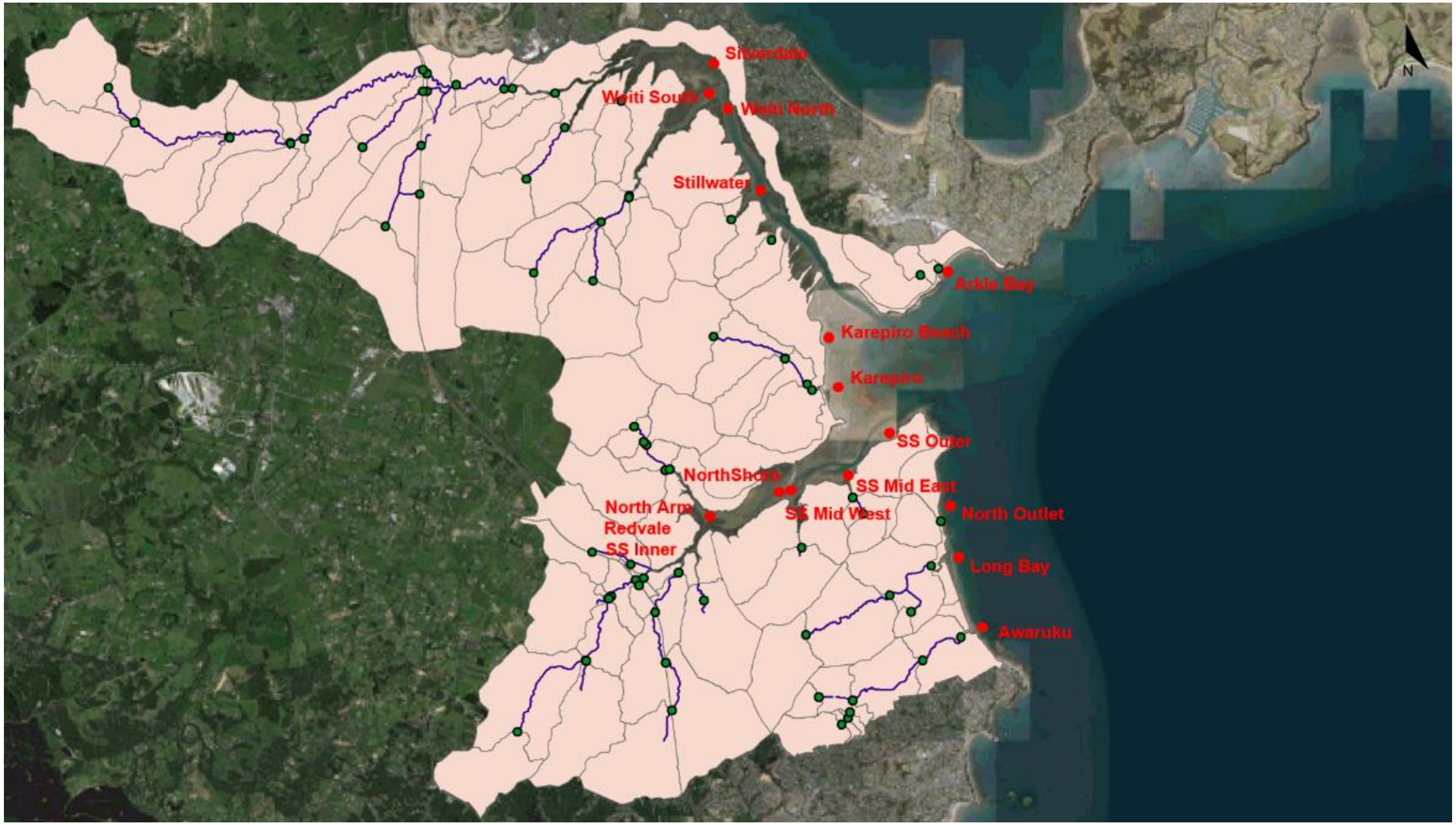


Figure 2-2. Location of the 19 catchment discharge points in Karepiro Bay, Okura Estuary and Wēiti River.

Table 2-3. Summary of linkages between the FWMT nodes (where loads and flows are calculated) and the marine receiving environment model catchment outlets shown in Figure 2-2.

Catchment Outlets (Figure 2-2)	FWMT node	Catchment Area (ha)	General Description
North Outlet	100283, 100284	82.6	Discharge directly to Marine Reserve (300.7 ha)
Awaruku	100291, 100292	97.2	
Long Bay	100285, 100286, 100290	120.9	
SS Outer	100282	69.3	Okura catchments (887.6 ha)
SS Mid-East	100279, 100280	93.8	
SS Mid-West	100278	93.3	
SS Inner	100277	105.1	
Redvale	100260, 100270, 100274, 100275, 100276	204.6	
North Arm	100251, 100252, 100257, 100258	235.6	
North Shore	100250	85.9	
Karepiro	100244, 100249	186.8	Discharge directly to Karepiro Bay (264.1 ha)
Karepiro Beach	100245	31.7	
Arkle Bay	100201, 100202	45.5	
Stillwater	100240, 100241, 100242, 100243	161.5	Wēiti catchments (980.2 ha)
Wēiti South	100233	44.9	
Silverdale	100205, 100206, 100225, 100226, 100227, 100228, 100230, 100231, 100232	451.5	
Whangaparaoa/Wēiti North	100204[1]	167.6	
Duck Creek	100239	154.7	

[1] River flows at the Whangaparaoa and Wēiti North catchment outlets were extracted from Site 100204 applying 50% of the FWMT river flow and load data.

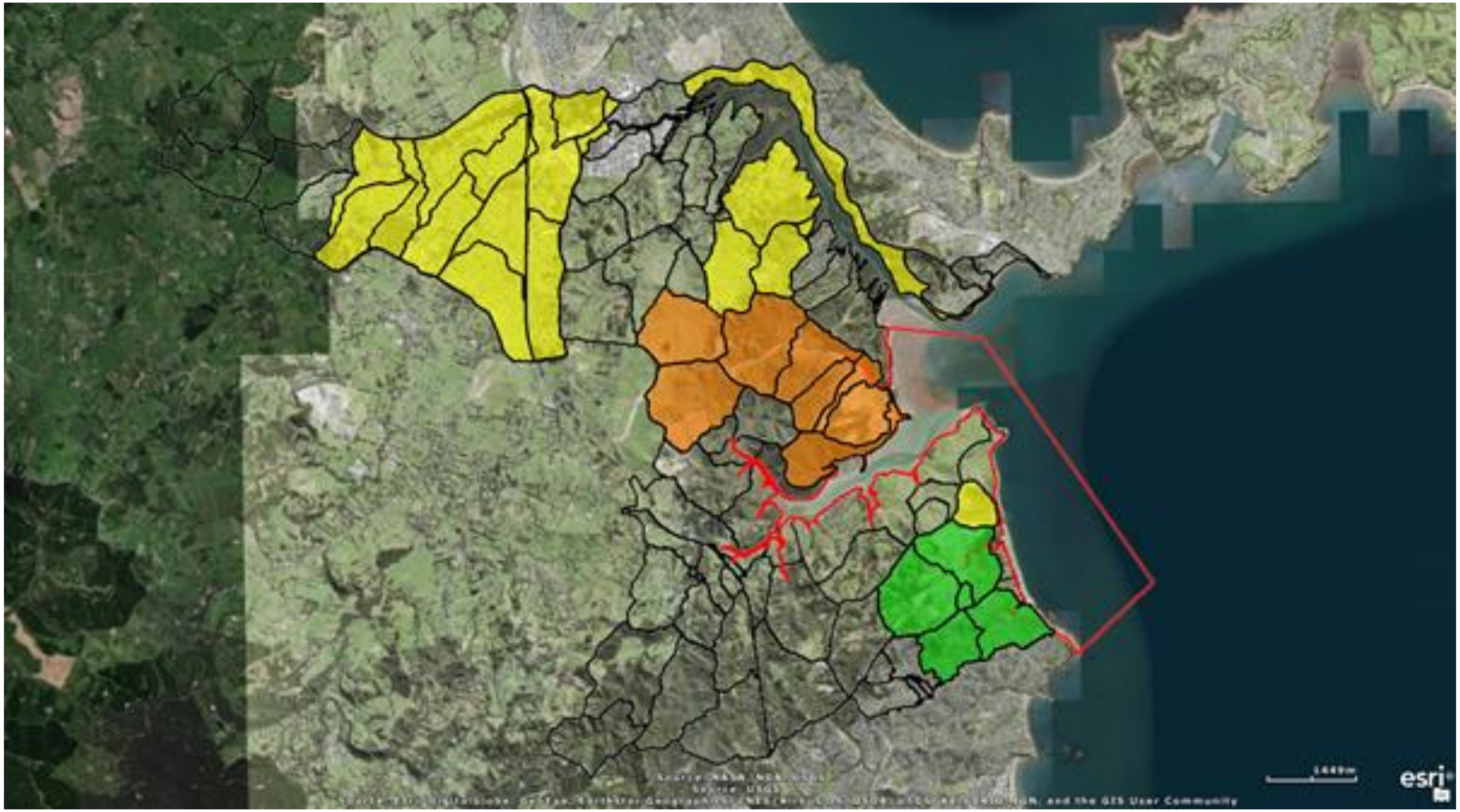


Figure 2-3. Extent of Long Bay-Okura Marine reserve (red) and Long Bay development area (green), Wēiti Bay Development area (orange) and Future Growth Areas (yellow).

Figure 2-4. Extent of the subestuaries within the Okura/Wēiti marine receiving environment.

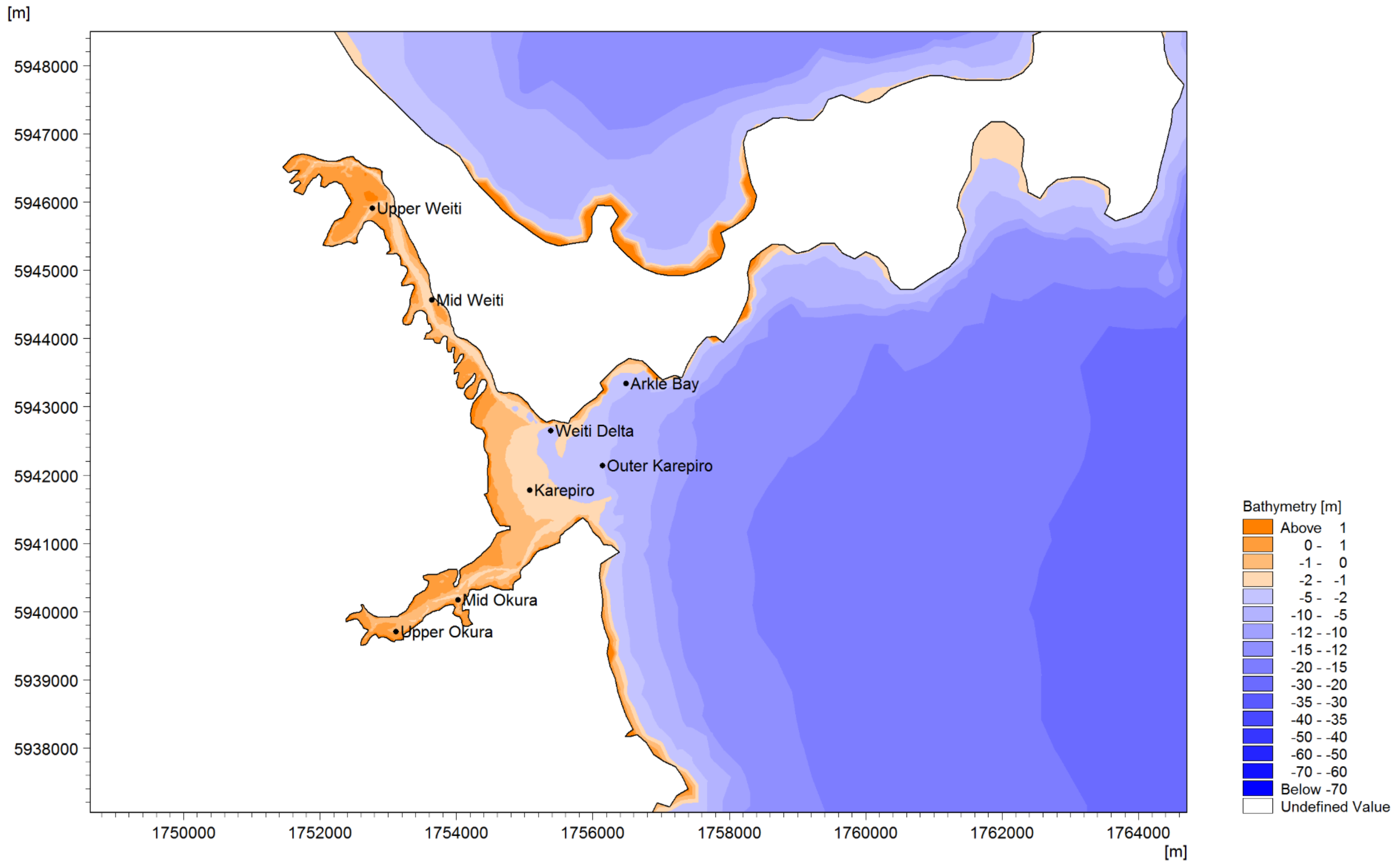


Figure 2-5. Key sites where bed level and suspended sediment concentrations are extracted for each scenario.

Table 2-4. Percentage of total predicted deposition attributable to a given catchment outlet (Figure 2-2) within each of the subestuaries shown in Figure 2-4. Colour coding indicates degree of connectivity for a given catchment outlet - red being highly connected to particular subestuary, intermediate connectivity is shown in yellow, and low connectivity in shown in green. Final column shows percentage of deposition attributable to a given catchment outlet. Final row shows percentage of total deposition in each subestuary.

Catchment Outlet	Subestuary													Percentage deposition from subcatchment
	Okura (Upper)	Okura (Mid)	Okura (Outer)	Karepiro (S)	Karepiro (N)	Wēiti (Upper)	Wēiti (Mid)	Wēiti (Outer)	Marine Reserve	Karepiro Bay	Whangaparaoa	Outer Karepiro Bay	Outer Gulf	
Awaruku	0.0071	0.0024	<0.0001	<0.0001	<0.0001	0.0080	0.0021	0.0013	0.0291	0.0061	0.0302	0.0392	0.7980	0.9
Long Bay	0.0326	0.0140	0.0010	<0.0001	<0.0001	0.0313	0.0087	0.0056	0.0330	0.0080	0.0408	0.0452	1.1853	1.4
SS Outer	0.1177	0.0524	<0.0001	<0.0001	0.0015	0.0434	0.0120	0.0080	0.0021	0.0016	0.0056	0.0045	0.0882	0.3
SS Mid East	0.3247	0.1564	0.0032	0.0013	0.0045	0.1218	0.0341	0.0222	0.0040	0.0038	0.0118	0.0076	0.1265	0.8
SS Mid-West	0.4051	0.1862	0.0029	0.0012	0.0033	0.1160	0.0309	0.0192	0.0029	0.0031	0.0091	0.0050	0.0774	0.9
SS Inner	0.6574	0.1349	0.0011	<0.0001	0.0013	0.0493	0.0128	0.0085	0.0015	0.0012	0.0047	0.0023	0.0382	0.9
Redvale	12.1227	1.9374	0.0143	0.0125	0.0168	0.7947	0.2037	0.1321	0.0230	0.0173	0.0741	0.0375	0.6251	16.0
North Arm	3.5346	0.5662	0.0036	0.0032	0.0042	0.1995	0.0510	0.0330	0.0061	0.0046	0.0188	0.0106	0.1859	4.6
NorthShore	0.2260	0.1406	0.0026	0.0010	0.0030	0.0924	0.0247	0.0154	0.0022	0.0026	0.0066	0.0029	0.0494	0.6
Karepiro	1.0901	0.5184	0.0023	0.0045	0.0047	0.4671	0.1169	0.0706	0.0236	0.0076	0.0414	0.0305	1.0745	3.5
Karepiro Beach	0.6712	0.3288	0.0050	0.0062	0.0444	1.0892	0.2365	0.1670	0.0105	0.0164	0.1022	0.0297	0.5877	3.3
Stillwater	0.2314	0.0930	<0.0001	<0.0001	0.0030	2.2632	0.7833	0.2617	0.0198	0.0073	0.0493	0.0264	0.9590	4.7
Wēiti South	0.2417	0.1000	<0.0001	0.0016	0.0052	7.9116	0.7663	0.2645	0.0177	0.0100	0.0641	0.0307	0.9349	10.3
Silverdale	1.0761	0.4482	0.0018	0.0082	0.0275	35.7864	3.4304	0.9739	0.0710	0.0451	0.2878	0.1379	4.0575	46.4
Arkle Bay	0.0939	0.0411	<0.0001	<0.0001	0.0018	0.2921	0.0761	0.0539	0.0137	0.0108	0.0760	0.0450	1.4516	2.2
Whangaparaoa	0.0444	0.0181	<0.0001	<0.0001	0.0021	0.4880	0.1016	0.0530	0.0028	0.0029	0.0170	0.0072	0.1766	0.9
Wēiti North	0.0297	0.0121	<0.0001	<0.0001	0.0012	0.7330	0.0831	0.0325	0.0018	0.0016	0.0096	0.0046	0.0939	1.0
North Outlet	0.0106	0.0048	<0.0001	<0.0001	<0.0001	0.0125	0.0035	0.0023	0.0050	0.0016	0.0078	0.0074	0.2101	0.3
Duck Creek	0.0236	0.0097	<0.0001	<0.0001	<0.0001	0.8376	0.0667	0.0232	0.0014	0.0013	0.0077	0.0033	0.0687	1.0
Percentage of total deposition in subestuary	20.94	4.76	0.04	0.04	0.13	51.34	6.04	2.15	0.27	0.15	0.86	0.48	12.79	

3 Scenario 0

This is the baseline scenario used for the calibration of the marine receiving environment models and represents a snapshot of land use in the catchment from 2012 (prior to the recent development in the Long Bay area) and has been simulated both with and without existing seabed sediments. This Scenario with the existing seabed sediments is the baseline scenario used for the calibration of the underlying models as detailed in DHI (2019).

The mean annual sediment load from all catchments is 2266.7 tonnes/yr with mean annual loads of 330.3 kg/yr of Total Zinc and 86.7 kg/yr of Total Copper.

The distribution of these loads across the catchments are shown in Table 3-2 along with details of the predicted runoff and source concentration (mg/kg) for Zinc and Copper – defined from the ratio of the metal to sediment load in the table.

3.1 Sediment Results – with existing seabed sediments

This section of the report provides results for Scenario 0 with existing seabed sediments. This allows the relative role of existing seabed sediments to be put in context of the impacts of catchment derived sediments.

Figures 3-1 to 3-3 show the predicted mid water column (layer 5) suspended sediment concentrations at the key sites.

As detailed in the calibration report (DHI, 2019), the area offshore of the Okura estuary and Wēiti river is dominated by the resuspension of existing seabed sediments during wave events which is highlighted in the time-series data for Karepiro Bay site (Figure 3-2) which shows the largest peaks in suspended sediment concentrations corresponding to the timing of the wave events.

The following show the maximum suspended sediment concentration that occurs at any time during the model simulation (January-July 2018) and the percentage of the model simulation time that a threshold of 80 mg/L is exceeded at the key sites.

Upper Okura
309.25 hours above 80 mg/L and maximum of 666 mg/L
Mid Okura
516.50 hours above 80 mg/L and maximum of 1885 mg/L
Upper Wēiti
704.00 hours above 80 mg/L and maximum of 1593 mg/L
Mid Wēiti
725.0 hours above 80 mg/L and maximum of 2988 mg/L
Karepiro
931.75 hours above 80 mg/L and maximum of 9271 mg/L
Wēiti Delta
889.25 hours above 80 mg/L and maximum of 4050 mg/L
Outer Karepiro
606.5 hours above 80 mg/L and maximum of 3582 mg/L
Arkle Bay
406.75 hours above 80 mg/L and maximum of 2459 mg/L
Long Bay
746.25 hours above 80 mg/L and maximum of 1157 mg/L

Figure 3-4 shows the predicted bed level change at the end of the model simulation for Scenario 0 with existing seabed sediments and Table 3-3 provides the total mass of sediment deposited and percentage of total mass change that occurs within each subestuary.

Figure 3-4 shows that the predominant areas of net erosion occur within the shallower waters within Long Bay, Karepiro and Whangaparaoa. Sediments from these areas are moved 1) offshore into deeper waters of Karepiro Bay and the Marine Reserve resulting in net deposition of the order of 10-30 mm or are transported into the Okura estuary and Wēiti river. In combination with the deposition from catchment derived sediments this results in deposition of the order of 50 mm in the upper parts of the Okura estuary and Wēiti river.

Areas of net erosion also occur in the outer section of the Okura estuary and within isolated parts of the upper Wēiti river.

Table 3-3 shows that the Wēiti river and Upper and Mid Okura subestuaries act as depostional sinks (for both catchment derived and existing seabed sediments) and that for other subestuaries the net rate of erosion far exceeds

Figures 3-5 to 3-7 show the predicted daily bed level change at the key sites. These plots show the range of daily deposition and erosion rates that can occur at the key sites and give a good indication of the combined effects of both existing seabed sediments and catchment derived sediments.

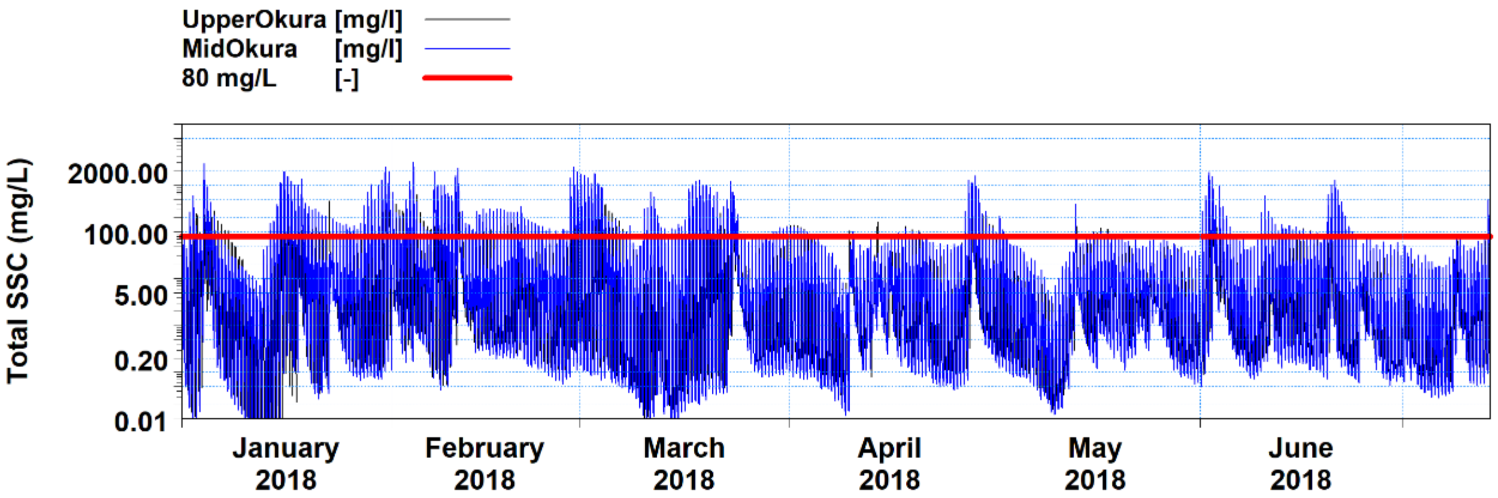
For example, at the upper Okura site (Figure 3-5) intermittent daily erosion of around 2 mm/day occurs during the first part of the production period (when sediment delivery from the catchment is lowest) followed by bed level changes (positive and negative) in the range of 5-10 mm/day during the second part of the production period. Overall this results in a net deposition of around 0.4 mm/day at this site.

In contrast, the mid Okura site has intermittent periods of deposition throughout the production period given the same overall result of net deposition but at a higher rate of 1.7 mm/day than at the upper Okura site.

The Upper Wēiti site (Figure 3-5) only shows periods of deposition (again resulting in net deposition of around 1.9 mm/day) whereas the mid Wēiti site has a number of days of relatively high deposition (> 10 mm/day) followed by periods of erosion resulting in a lower level of net deposition (~0.6 mm/day) over the period of the production run. These depositional events relate to both the arrival of existing seabed sediments and catchment derived sediments.

There is net erosion at the Karepiro sites (Figure 3-6) with a similar pattern at the Karepiro site to the Upper Okura site – given an indication of the relative role of catchment derived sediments and wave driven resuspension of existing seabed sediments which leads net erosion of around 1.7 mm/day. At the outer Karepiro site, net erosion is lower (~0.5 mm/day) and driven by a number of wave driven erosion events.

At the Wēiti delta site (Figure 3-6) a number of depostional events dominate the overall net deposition of 0.8 mm/day while at the Arkle Bay site the is no net change in bed level. At the Long Bay site (Figure 3-7) net erosion of around 0.5 mm/day occurs although there are periods of deposition that do occur during the production period.



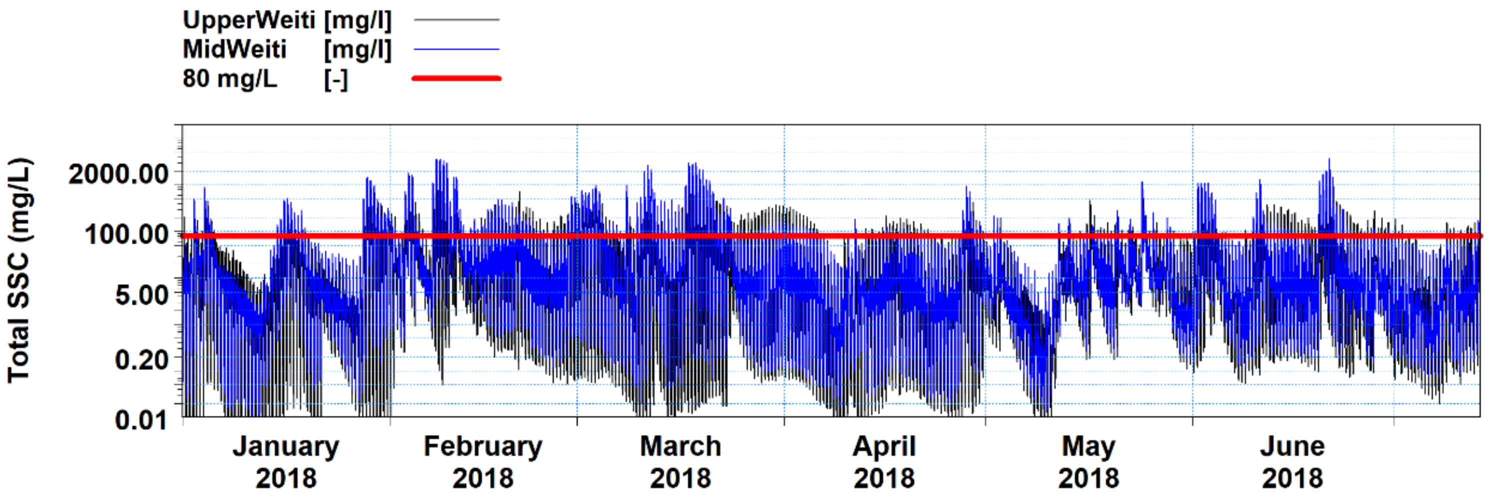


Figure 3-1. Total suspended sediment concentration at the Okura estuary and Wēiti river sites modelled under Scenario 0 with existing seabed sediments.

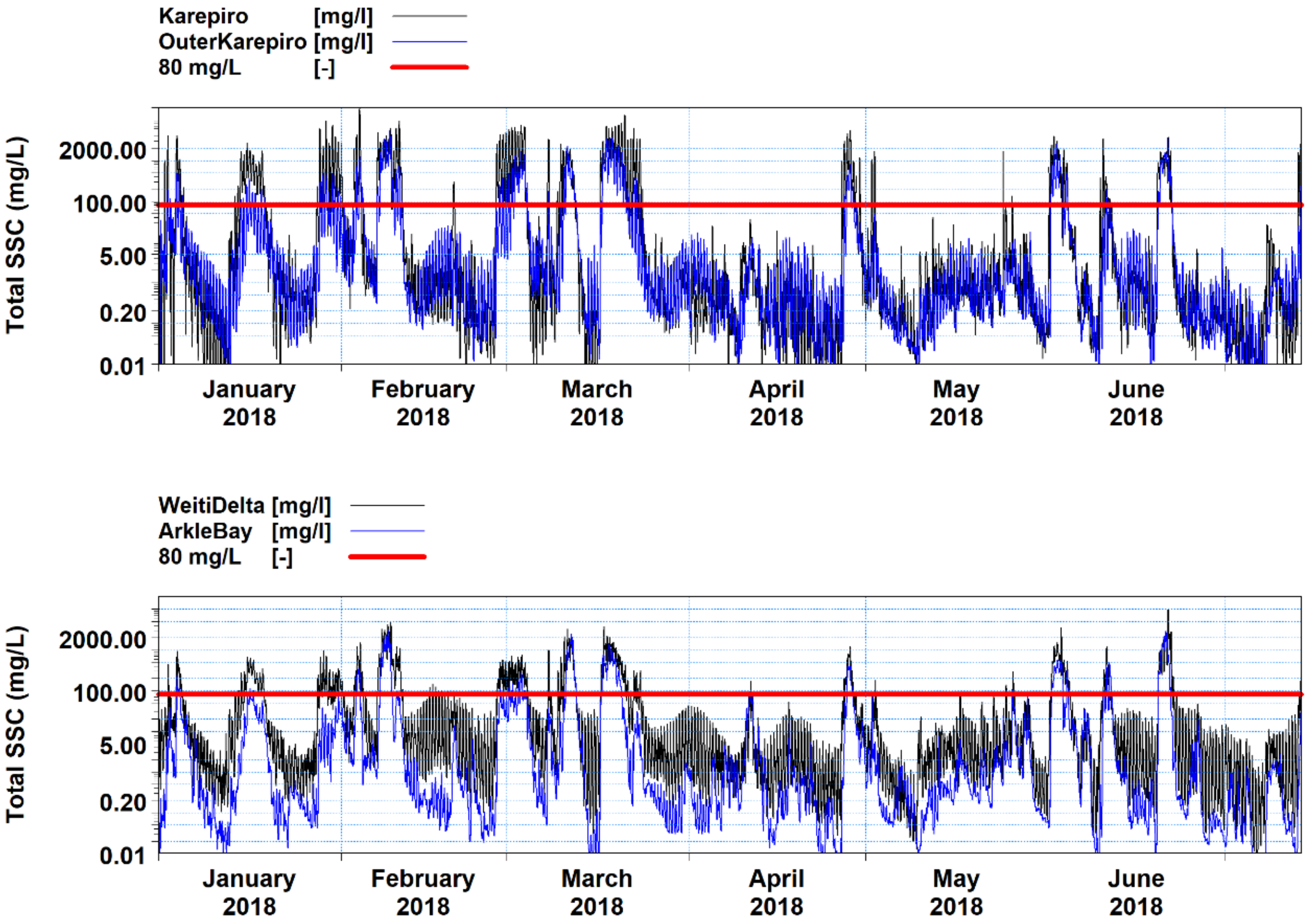


Figure 3-2. Total suspended sediment concentration at the Karepiro Bay sites under Scenario 0 with existing seabed sediments.

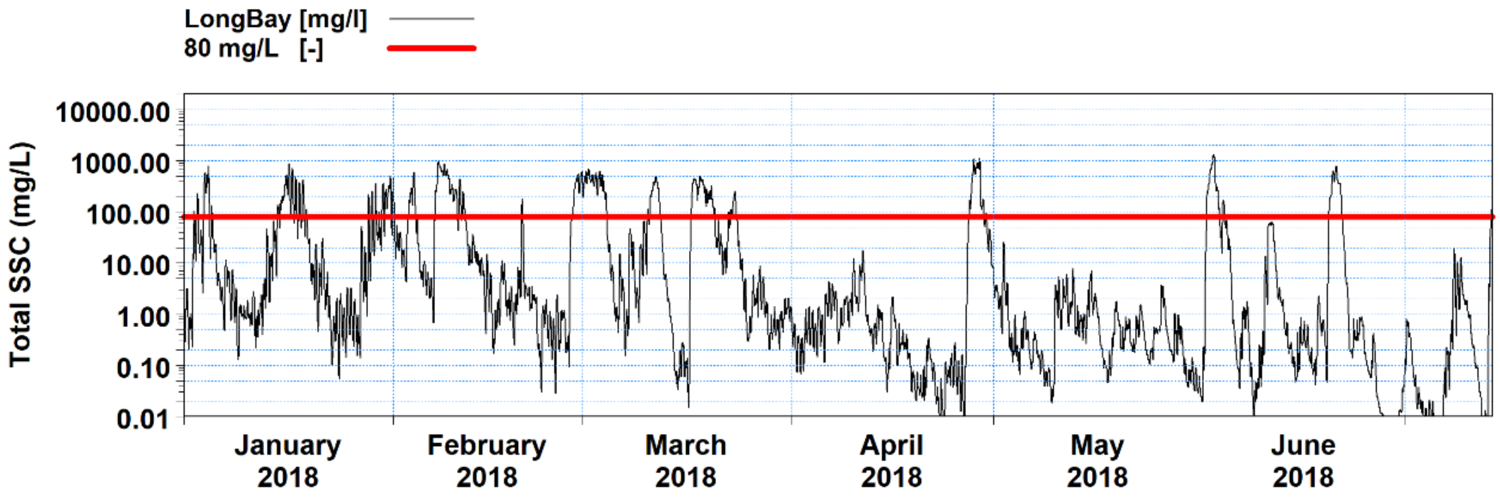


Figure 3-3. Total suspended sediment concentration at the Long Bay site under Scenario 0 with existing seabed sediments.

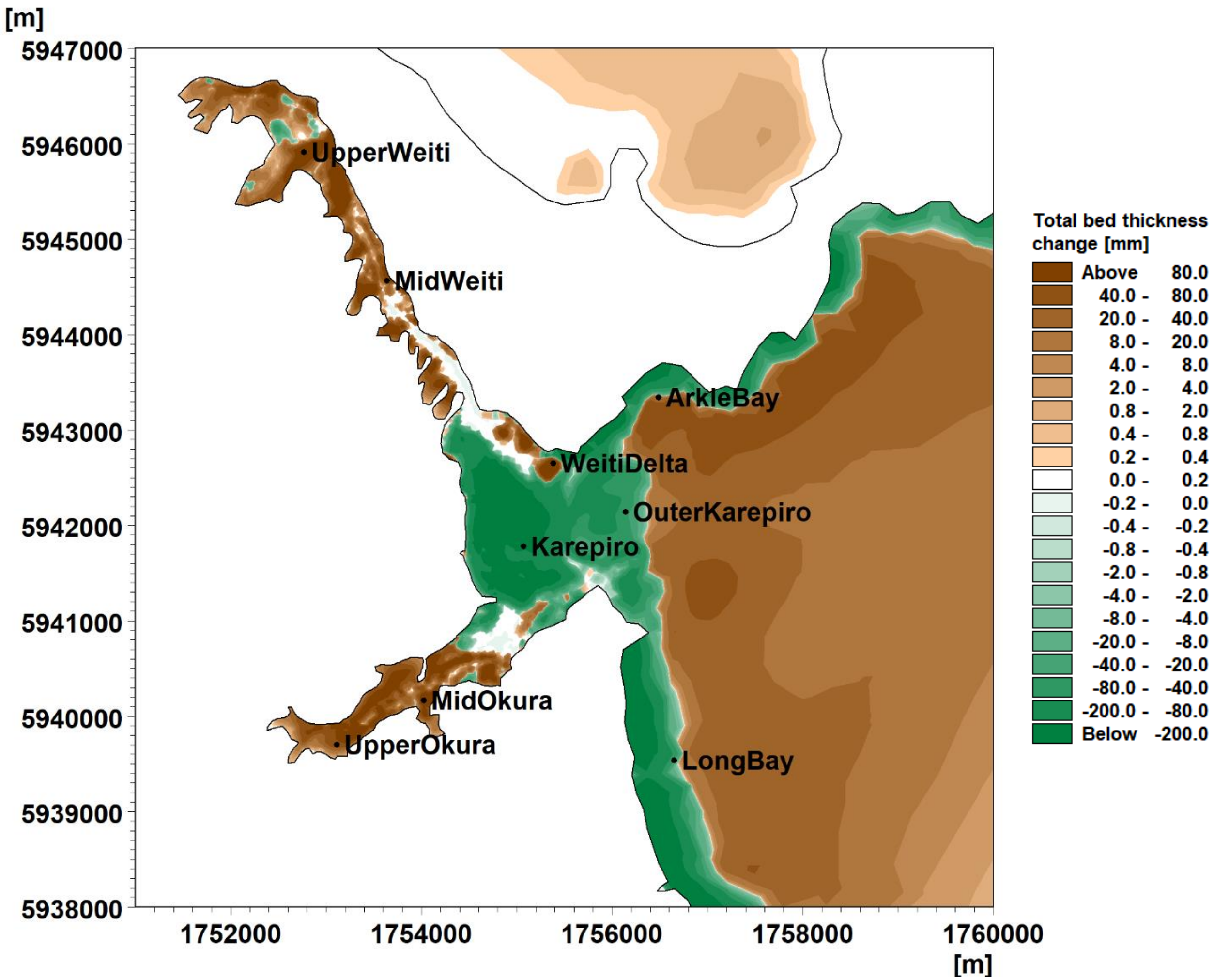


Figure 3-4. Predicted change in bed level (mm) at the end of the model simulation under Scenario 0 with existing seabed sediments. Labelled sites are the key sites where time-series data has been extracted from the model.

Table 3-1. Change in sediment (tonnes) at the end of the model simulation within each of the subestuaries (Figure 2-4) for Scenario 0 with existing bed sediments.

Subestuary	Net change in mass (tonnes) Scenario 0 with existing seabed sediments	Description
Upper Okura	9394	Depostional sink
Mid Okura	14335	
Outer Okura	-4035	Net erosion across subestuary
Karepiro (S)	-103601	Net erosion across subestuary
Karepiro (N)	-35924	
Upper Wēiti	15872	Depostional sink
Mid Wēiti	13084	
Outer Wēiti	5569	
Marine Reserve	-96026	Net erosion across subestuary
Outer Karepiro	-12607	
Whangaparaoa	86025	Depostional sink

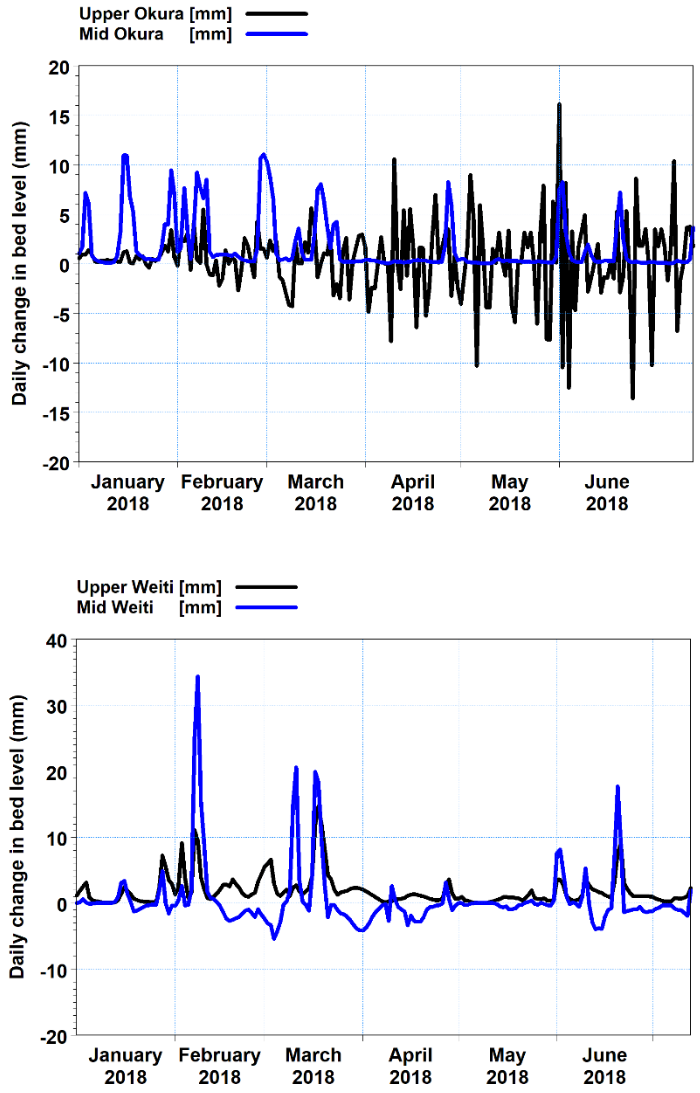


Figure 3-5. Predicted daily bed level change (mm) with the Okura estuary and Wēiti river sites (Figure 2-5) under Scenario 0 with existing bed sediments.

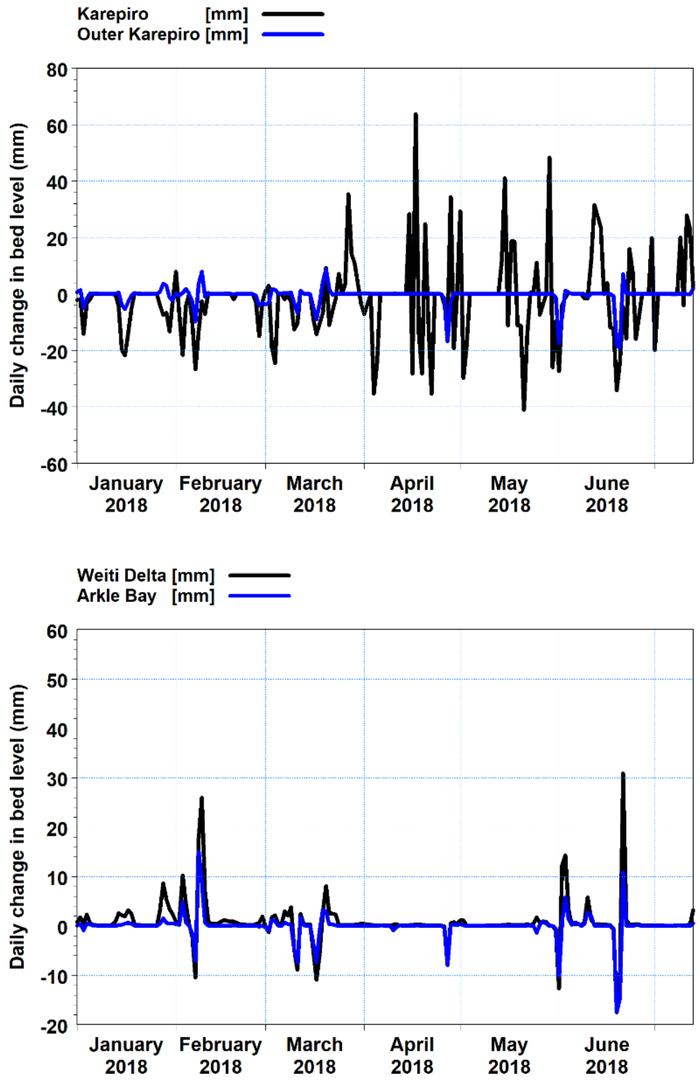


Figure 3-6. Predicted daily bed level change (mm) at the Karepiro Bay sites (Figure 2-5) under Scenario 0 with existing bed sediments.

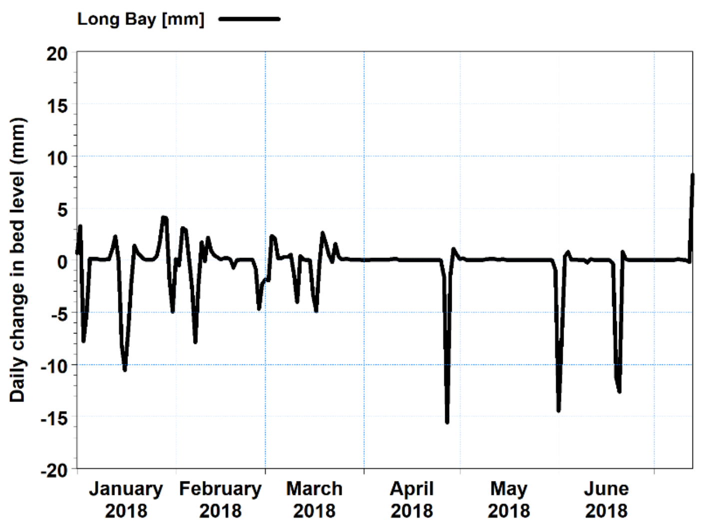


Figure 3-7. Predicted daily bed level change (mm) at the Long Bay site (Figure 2-5) under Scenario 0 with existing bed sediments.

3.2 Sediment Results – without existing seabed sediments

This section of the report provides results for Scenario 0 without existing seabed sediments. This provide benchmark data for comparison with other Scenarios.

Figures 3-8 to 3-10 show the predicted mid water column (layer 5) suspended sediment concentrations at the key sites.

Highest levels occur in the upper parts of the Okura estuary and Wēiti river with reduced levels elsewhere. As detailed in the calibration report (DHI, 2019), the area offshore of the Okura estuary and Wēiti river is dominated by the resuspension of existing seabed sediments during wave events. For the area offshore of Karepiro Bay, suspended sediment concentrations will be higher than those predicted by the model during wave events.

The following show the maximum suspended sediment concentration that occurs at any time during the model simulation (January-July 2018) and the percentage of the model simulation time that a threshold of 80 mg/L is exceeded at the key sites.

Upper Okura
18 hours above 80 mg/L and maximum of 428 mg/L
Mid Okura
17 hours above 80 mg/L and maximum of 378 mg/L
Upper Wēiti
44 hours above 80 mg/L and maximum of 603 mg/L
Mid Wēiti
34.25 hours above 80 mg/L and maximum of 955 mg/L
Karepiro
10.25 hours above 80 mg/L and maximum of 1444 mg/L
Wēiti Delta
7.25 hours above 80 mg/L and maximum of 122 mg/L
Outer Karepiro
0 hours above 80 mg/L and maximum of 16 mg/L
Arkle Bay
0 hours above 80 mg/L and maximum of 33 mg/L
Long Bay
0 hours above 80 mg/L and maximum of 8 mg/L

Figure 3-11 shows the predicted bed level change at the end of the model simulation for Scenario 0 and Table 3-3 provides the total mass of sediment deposited and percentage of total mass deposited within each subestuary.

Figures 3-12 to 3-14 show the predicted bed deposition at the key sites. These plots show how the deposition increases with time at the depostional sites (within Okura estuary and Wēiti river and at Long Bay) and the transitional nature of the deposition within Karepiro Bay.

3.3 Key Results – Sediments

The key results with regard to the overall sediment dynamics of the system are;

- The predominant sinks for catchment derived sediments are the Upper Okura estuary and Wēiti river,
- the embayment's on the Wēiti River are deposition sinks,
- there is a strong gradient of deposition along axis of the Okura estuary and Wēiti river,
- there is very little long-term deposition occurs on Karepiro beach and outer Okura estuary, and
- less than 5% of the catchment derived sediments deposits in Karepiro Bay with less than 2% of this being deposited in the Marine Reserve.
- The resuspension of existing seabed sediments has a significant impact on the overall sediment budget of the system. Near-shore sediments that do get resuspended during wave events contribute to deposition both within the Okura estuary and Wēiti river as well as being moved offshore to deeper parts of Karepiro Bay.
- The resuspension of existing seabed sediments greatly enhances the level of suspended sediment concentrations that occur. This results in both higher maximum predicted suspended sediment concentrations and thresholds being exceed for greater lengths of time compared to if only catchment derived sediments ae considered.

3.4 Zinc and Copper Results

Under this Scenario, the PEL limits for Zinc and Copper are not exceeded anywhere within the marine receiving environment (Figure 3-15 and Figure 3-16) and as summarised in Table 3-4.

Highest concentrations are predicted to occur in the upper parts of the Okura Estuary and Wēiti River, in the smaller embayment's fringing the south-west Wēiti River, the embayment just to the east of Okura township and the area landward of the spit opposite Okura Township.

These results incorporate the net effects of the connectivity of the system (i.e. how connected individual catchments are to different areas of the marine receiving environment), the ratio of metal to sediment load from the catchment outlets (which defines the catchment source concentration, Table 3-2) and the predicted level of deposition that occurs within the different parts of the marine receiving environment which define at what rate metal concentrations increase. Hence, we see highest metal concentrations in areas of highest deposition that are strongly linked to catchment sources which have a high metal to sediment load ratio.

Table 3-2. Summary of catchment inputs for each of the catchment outlets for Scenario 0 (Figure 2-2).

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa	Wēiti North	North Outlet	Duck Creek
Sediment (tonnes/yr)	53.1	129.3	16.9	35.8	26.7	27.1	589.9	186.1	10.1	26.1	29.9	28.2	205.7	801.7	23.7	12.9	12.9	17.7	32.9
Zn (kg/yr)	54.0	13.4	1.3	4.5	3.5	6.9	49.5	14.9	0.4	1.1	2.2	11.4	16.6	115.1	15.2	6.6	6.6	1.1	6.1
Cu (kg/yr)	7.9	3.9	0.6	1.3	1.0	1.4	15.0	5.4	0.2	0.6	0.9	1.8	6.1	33.8	2.2	1.2	1.2	0.6	1.7
Runoff (m^3 x 10^3/year)	1810	2042	369	477	428	463	6622	3327	379	930	1508	853	2970	13451	677	463	463	466	723
Zinc Concentration (mg/kg)	2209	364	195	282	243	541	154	212	53	54	111	511	238	333	1002	729	729	158	354
Copper Concentration (mg/kg)	322	106	82	83	69	111	47	77	26	27	46	79	87	98	142	128	128	78	98

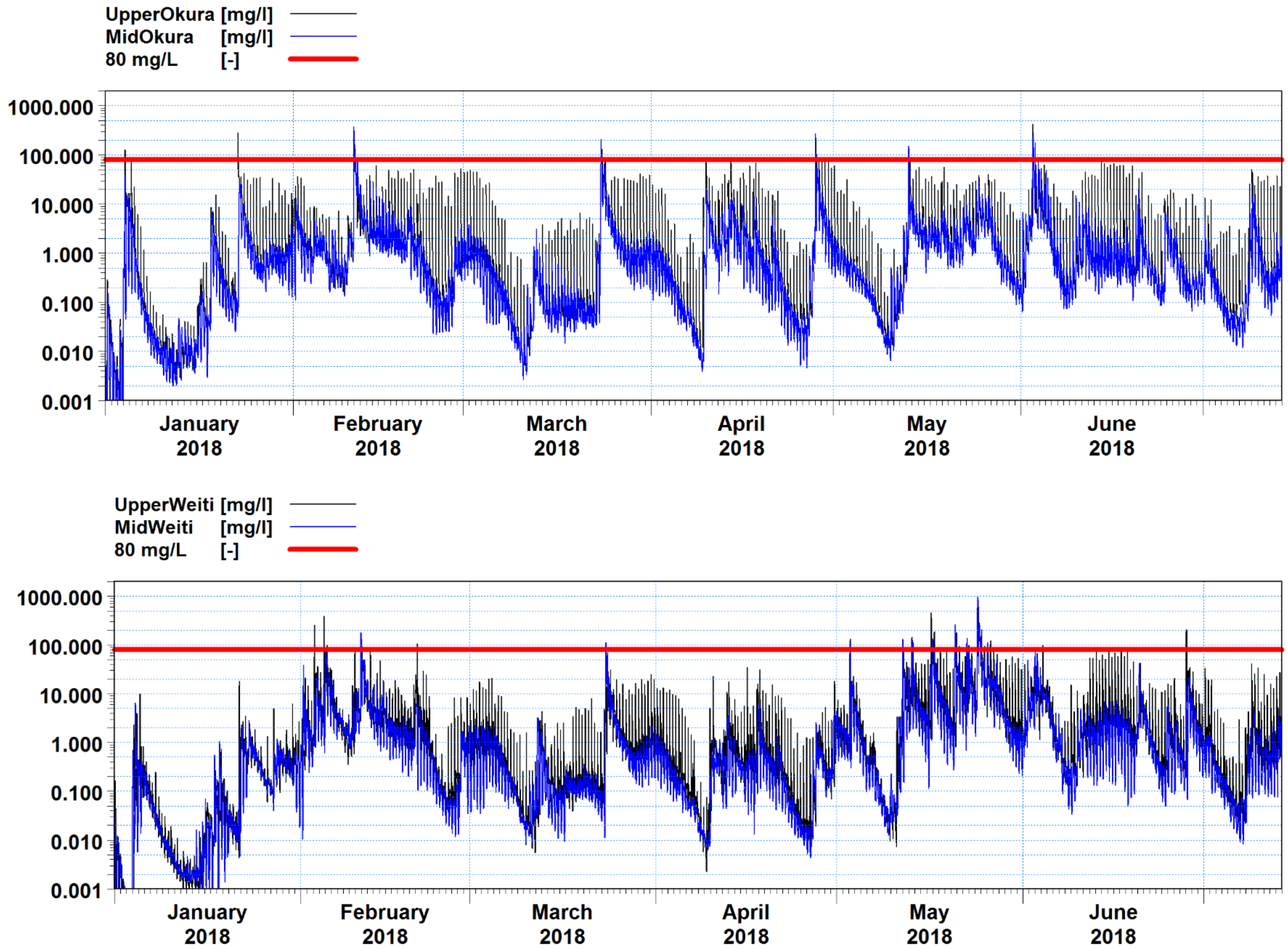


Figure 3-8. Total suspended sediment concentration at the Okura estuary and Wēiti river sites (Figure 2-5) under Scenario 0.

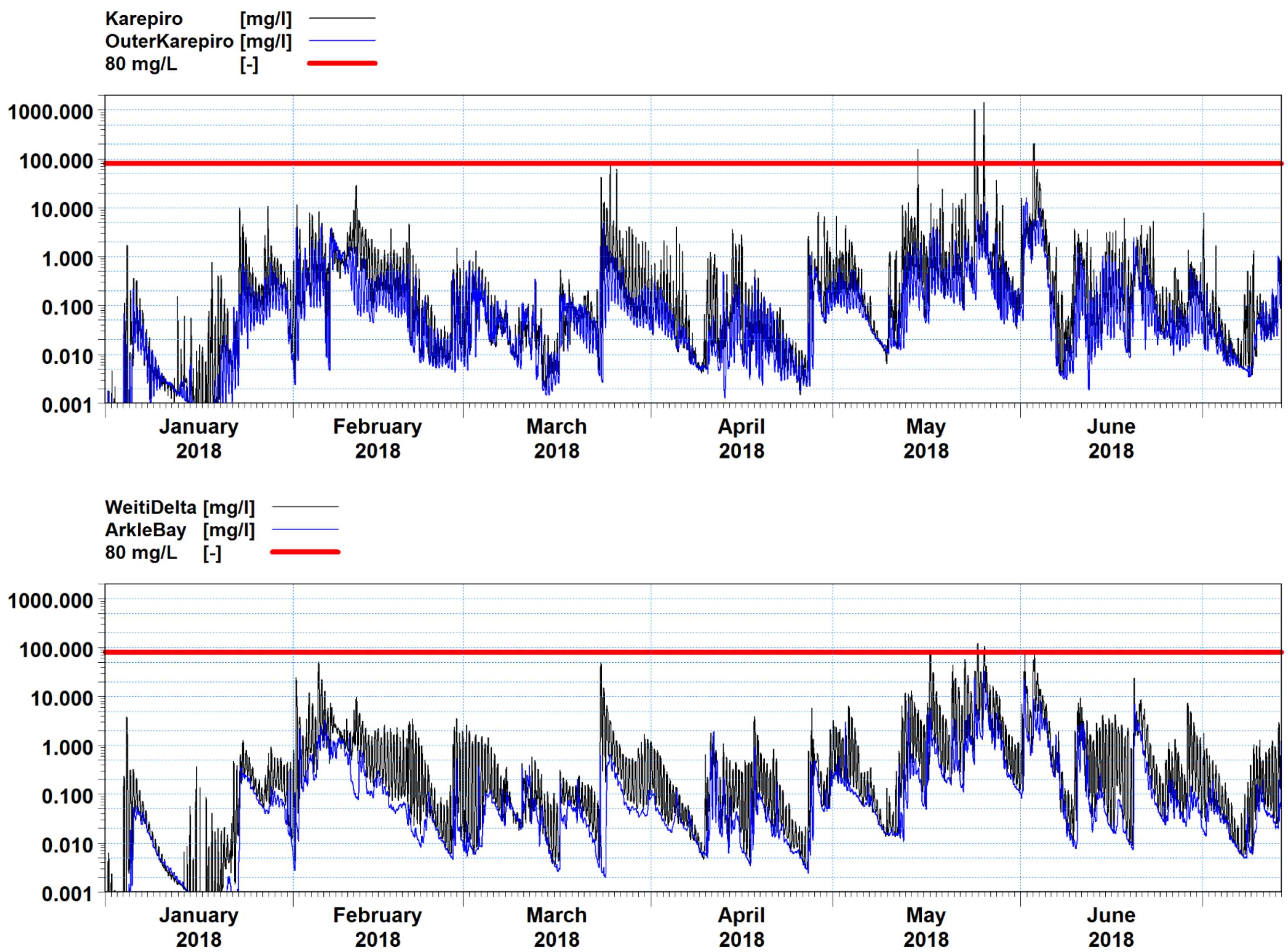


Figure 3-9. Total suspended sediment concentration at the Karepiro Bay sites (Figure 2-5) under Scenario 0.

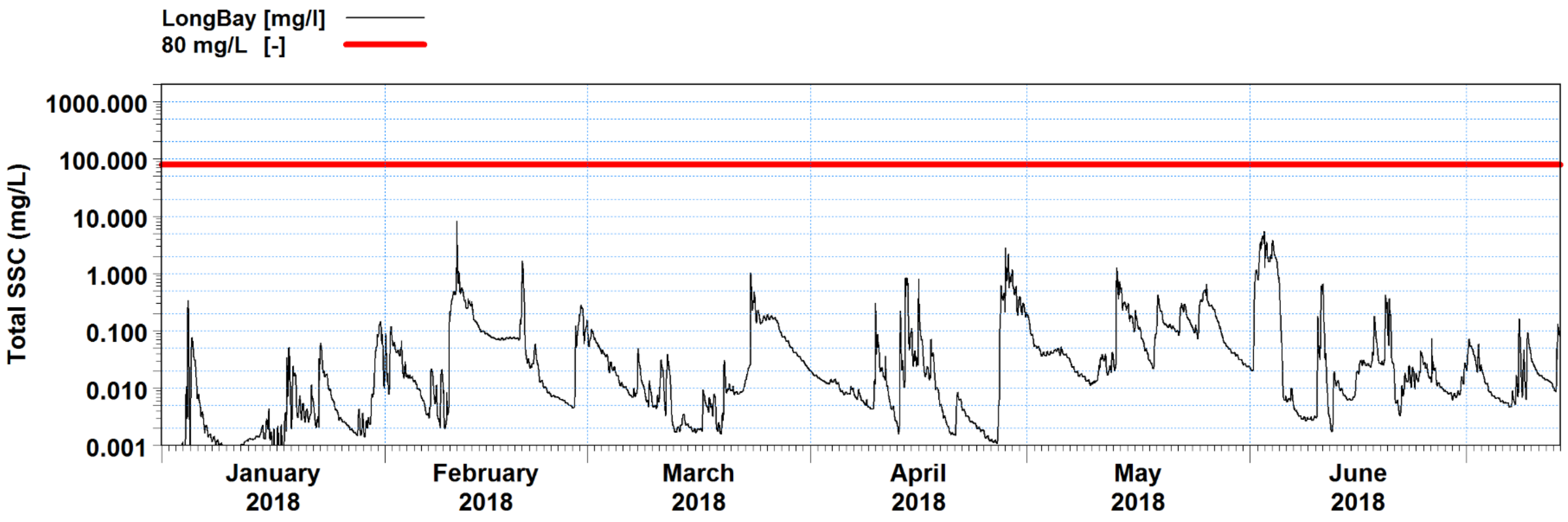


Figure 3-10. Total suspended sediment concentration at the Long Bay site (Figure 2-5) under Scenario 0.

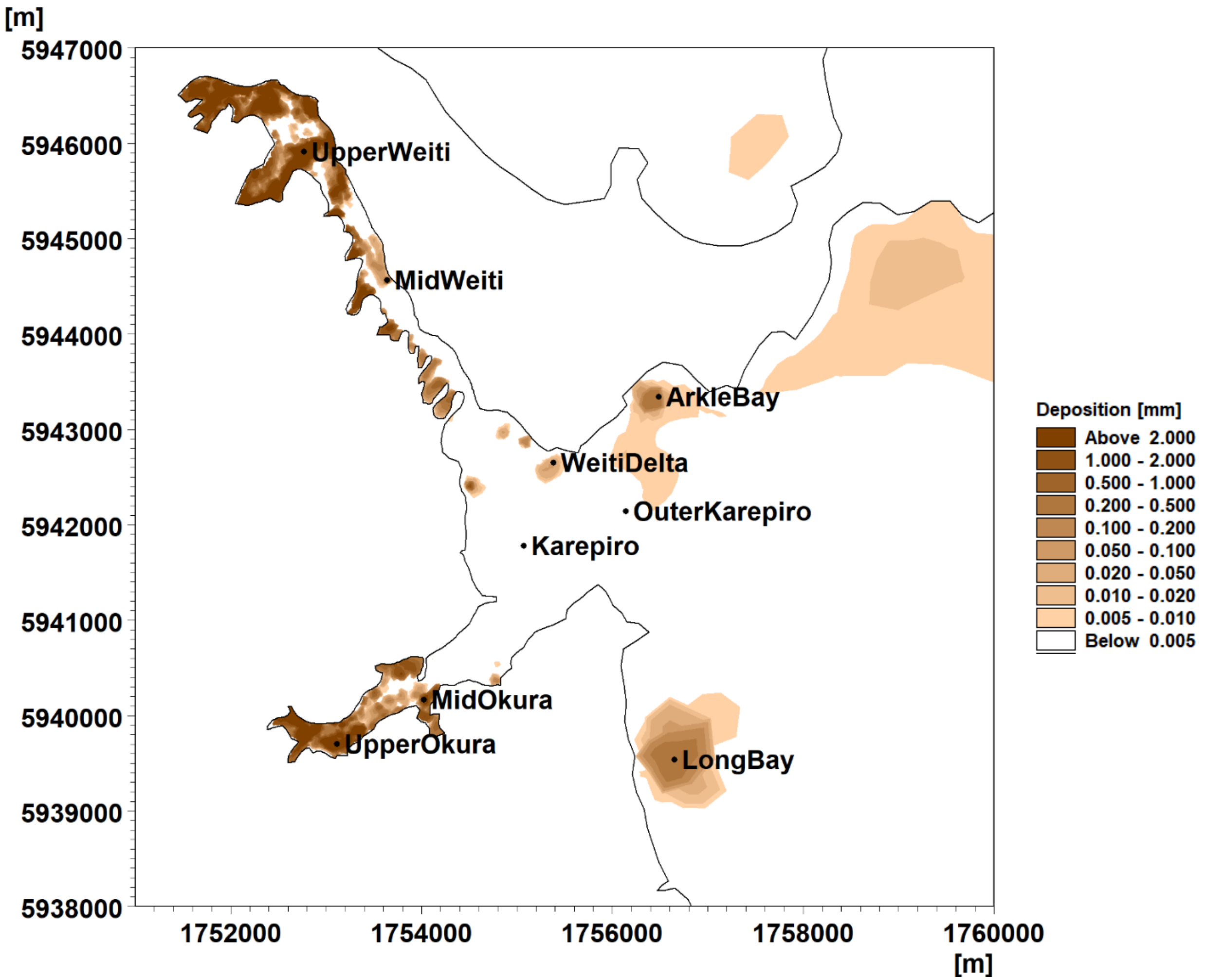


Figure 3-11. Predicted deposition (mm) at the end of the long term model simulation under Scenario 0. The period modelled (January-July 2018) consists of typical wind and rain conditions and a range of events which in total deliver 35% more catchment derived sediment than the long term annual average sediment load. Labelled sites are the key sites where time-series data has been extracted from the model.

Table 3-3. Total net sediment deposited (kg) at the end of the model simulation within each of the subestuaries (Figure 2-4) for Scenario 0.

Subestuary	Sediment deposited Scenario 0 (kg)	Percentage of total deposition
Upper Okura	382196	21.4%
Mid Okura	58499	3.3%
Outer Okura	171	<0.1%
Karepiro (S)	474	<0.1%
Karepiro (N)	3838	0.2%
Upper Wēiti	1110918	62.2%
Mid Wēiti	122430	6.9%
Outer Wēiti	27161	1.5%
Marine Reserve	36646	2.1%
Outer Karepiro	3859	0.2%
Whangaparaoa	38983	2.2%

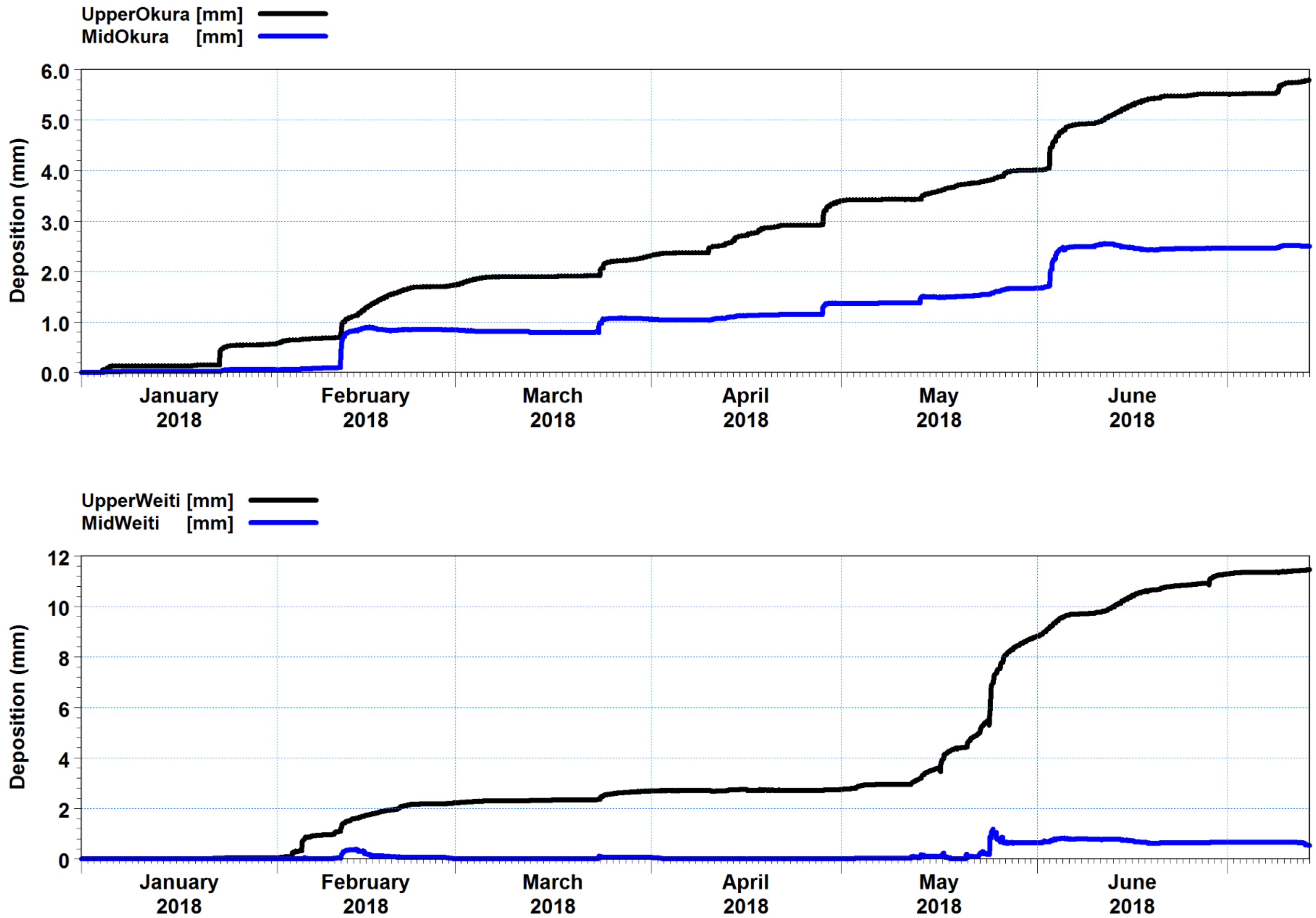


Figure 3-12. Predicted bed level change (mm) with the Okura estuary and Wēiti river sites (Figure 2-5) under Scenario 0.

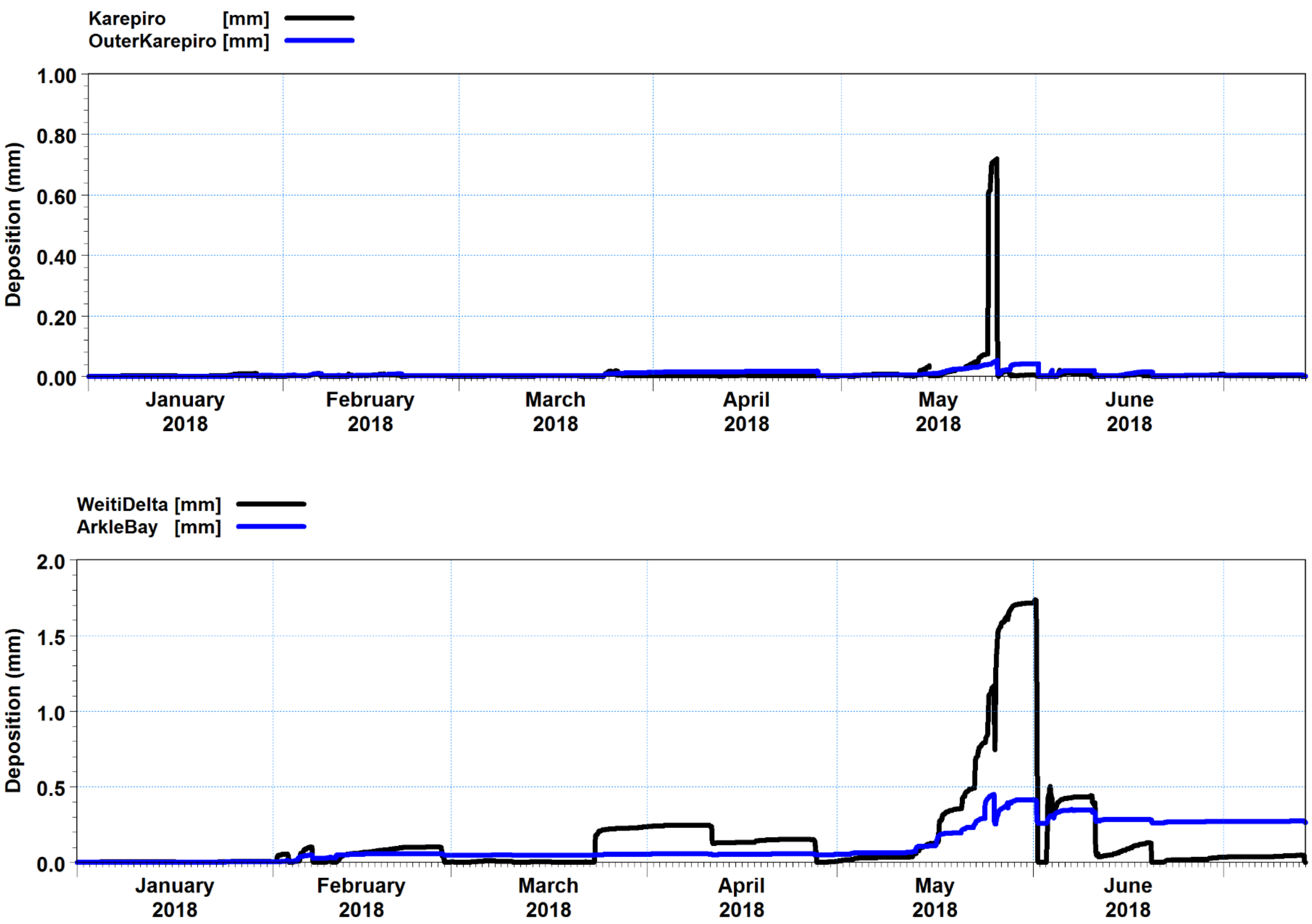


Figure 3-13. Predicted bed level change (mm) at the Karepiro Bay sites (Figure 2-5) under Scenario 0.

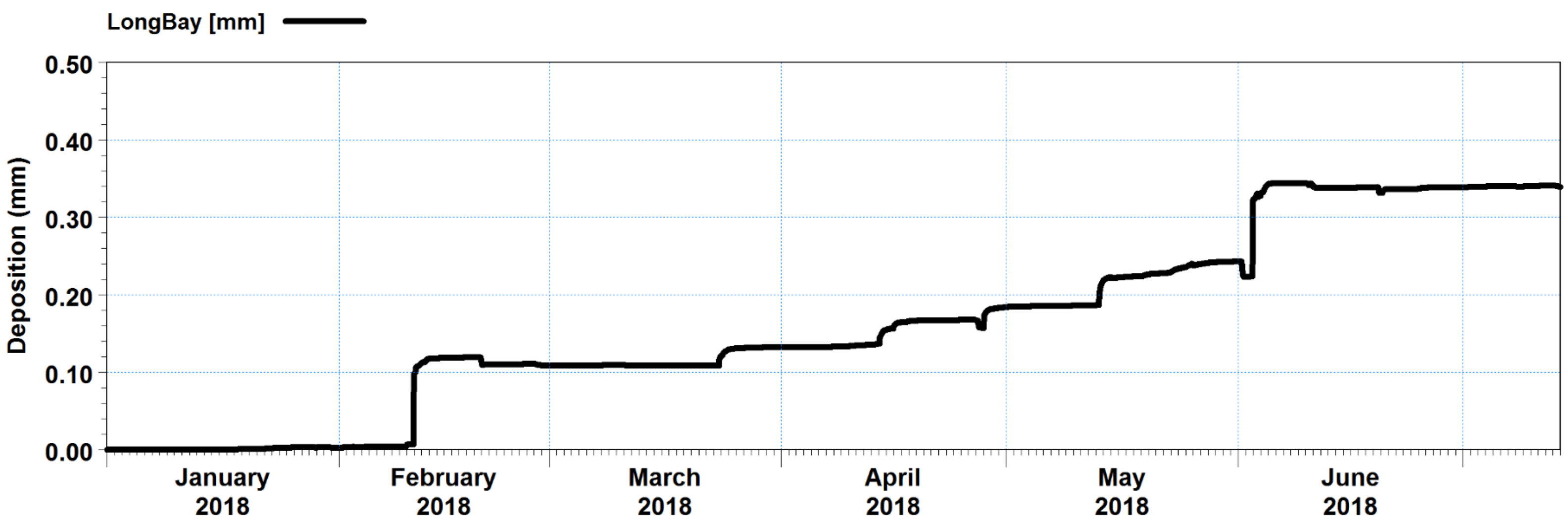


Figure 3-14. Predicted bed level change (mm) at the Long Bay site (Figure 2-5) under Scenario 0.

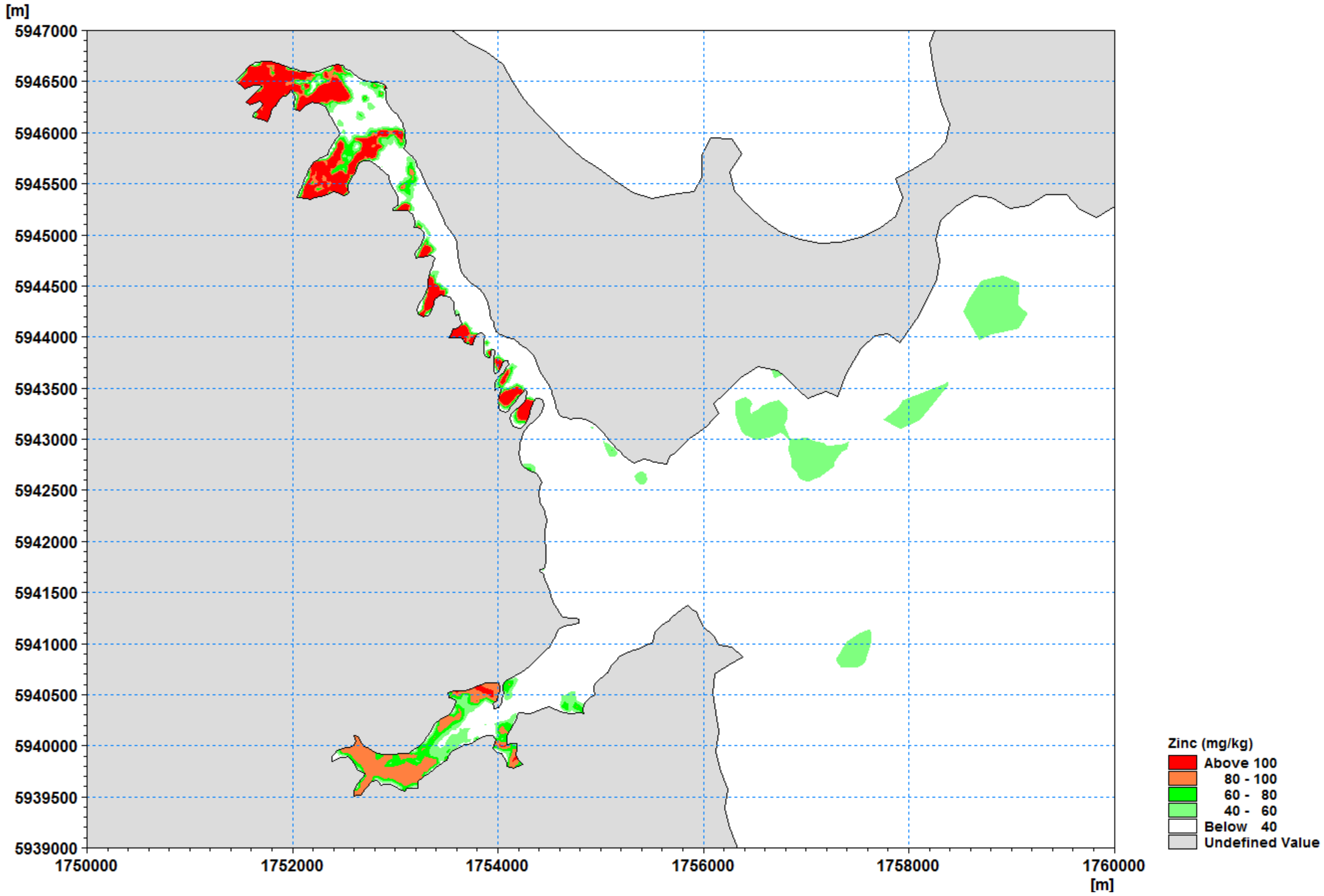


Figure 3-15. Zinc concentrations 50 years from present under Scenario 0.

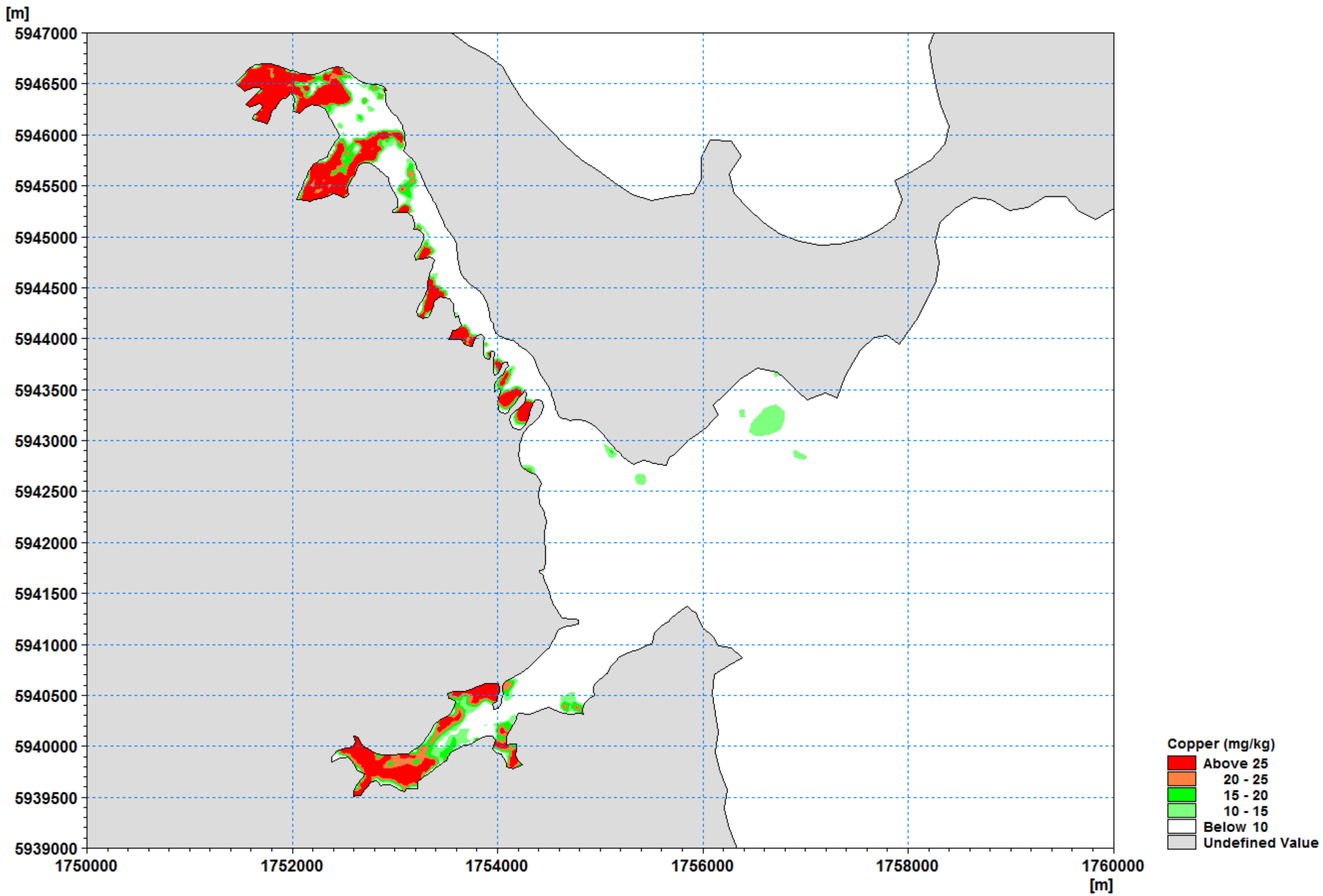


Figure 3-16. Copper concentrations 50 years from present under Scenario 0. planning timescales of 50

Table 3-4. Future subestuary metal concentration (mg/kg) under Scenario 0 along with the area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	**Future Copper (mg/kg)**
Upper Okura subestuary concentration	80.5	23.9
Mid Okura subestuary concentration	47.9	12.6
Lower Okura subestuary concentration	26.0	5.0
Karepiro (S) subestuary concentration	26.0	5.0
Karepiro (N) subestuary concentration	26.7	5.2
Upper Wēiti subestuary concentration	91.3	24.9
Mid Wēiti subestuary concentration	60.2	14.4
Lower Wēiti subestuary concentration	58.3	13.7
Marine Reserve subestuary concentration	26.5	5.0
Outer Karepiro subestuary concentration	26.6	5.0
Whangaparaoa subestuary concentration	29.6	5.8
Total area (ha) where PEL is exceeded		
	0.0	0.0
Maximum Concentration (mg/kg)		
	186.3	48.2

4 Scenario 1

This scenario adds in all the development within the Long Bay Structure Plan (due for completion in 2017-2018) as shown in Figure 2-3**.**

This scenario results in an increase in sediment and Zinc loads for the Awaruku and Long Bay catchment outlets, greater runoff from the Awaruku catchment outlet, and minor changes in Copper loads (Table 4-1).

The mean annual sediment load from all catchments is 2273.7 tonnes/yr with mean annual loads of 336.5 kg/yr of Total Zinc and 86.8 kg/yr of Total Copper.

The following are the maximum suspended sediment concentration that occurs at any time during the model simulation, the percentage of the model simulation time that a threshold of 80 mg/L is exceeded and the percentage change in mean SSC relative to Scenario 0 at the key sites (Figure 2-5).

Upper Okura
18 hours above 80 mg/L, maximum of 427 mg/L and 0.14 % change in SSC
Mid Okura
16.75 hours above 80 mg/L, maximum of 378 mg/L and 0.01 % change in SSC
Upper Wēiti
44.25 hours above 80 mg/L, maximum of 602 mg/L and 0.08 % change in SSC
Mid Wēiti
34.25 hours above 80 mg/L, maximum of 954 mg/L and 0.02 % change in SSC
Karepiro
10.25 hours above 80 mg/L, maximum of 1427 mg/L and 0.34 % change in SSC
Wēiti Delta
8 hours above 80 mg/L, maximum of 122 mg/L and 0.11 % change in SSC
Outer Karepiro
0 hours above 80 mg/L, maximum of 16 mg/L and 0.17 % change in SSC
Arkle Bay
0 hours above 80 mg/L, maximum of 33 mg/L and 0.17 % change in SSC
Long Bay
0 hours above 80 mg/L, maximum of 8 mg/L and 1.02 % change in SSC

Figure 4-1 shows the deposition under Scenario 1 and Figure 4-2 shows the difference in deposition under this Scenario as compared to Scenario 0. Small increases in deposition are predicted to occur offshore of Long Bay. There are minor changes in the predicted patterns of deposition in Wēiti river and Okura estuary but overall there are very small decreases in the mass of sediment deposited in the Okura estuary and Wēiti river (Table 4-2) and increases in the mass deposited within other subestuaries.

Figure 4-3 and Figure 4-4 show the predicted future Zinc and Copper concentrations under Scenario 1.

Because of the relatively small changes in deposition and the predicted increases and decreases in metal concentrations under this scenario (due to the relative changes in sediment and metal loads, Table 4-1) there are only minor increases compared to Scenario 0 in future Zinc concentrations in the upper Okura Estuary and the Marine Reserve (Table 4-3). Difference plots are not provided as changes in deposition are less than 0.10 mm.

Table 4-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 1. Number in brackets indicating magnitude of change compared to Scenario 0.

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa Wēiti North	North Outlet	Duck Creek
Sediment (tonnes/yr)	57.3 (4.1)	132.2 (2.9)	16.9	35.8	26.7	27.1	589.9	186.1	10.1	26.1	29.9	28.2	205.7	801.7	23.7	12.9	17.7	32.9
Zn (kg/yr)	55.5 (1.5)	18.1 (4.7)	1.3	4.5	3.5	6.9	49.5	14.9	0.4	1.1	2.2	11.4	16.6	115.1	15.2	6.6	1.1	6.1
Cu (kg/yr)	7.7 (-0.2)	4.2 (0.3)	0.6	1.3	1	1.4	15	5.4	0.2	0.6	0.9	1.8	6.1	33.8	2.2	1.2	0.6	1.7
Runoff (m^3 x 10^3/year)	2164 (354)	2075 (32)	369	477	428	463	6622	3327	379	930	1508	853	2970	13451	677	463	466	723
Zinc Concentration (mg/kg)	2073 (-136)	487 (123)	195	282	243	541	154	212	53	54	111	511	238	333	1002	729	158	354
Copper Concentration (mg/kg)	288 (-34)	114 (7)	82	83	69	111	47	77	26	27	46	79	87	98	142	128	78	98

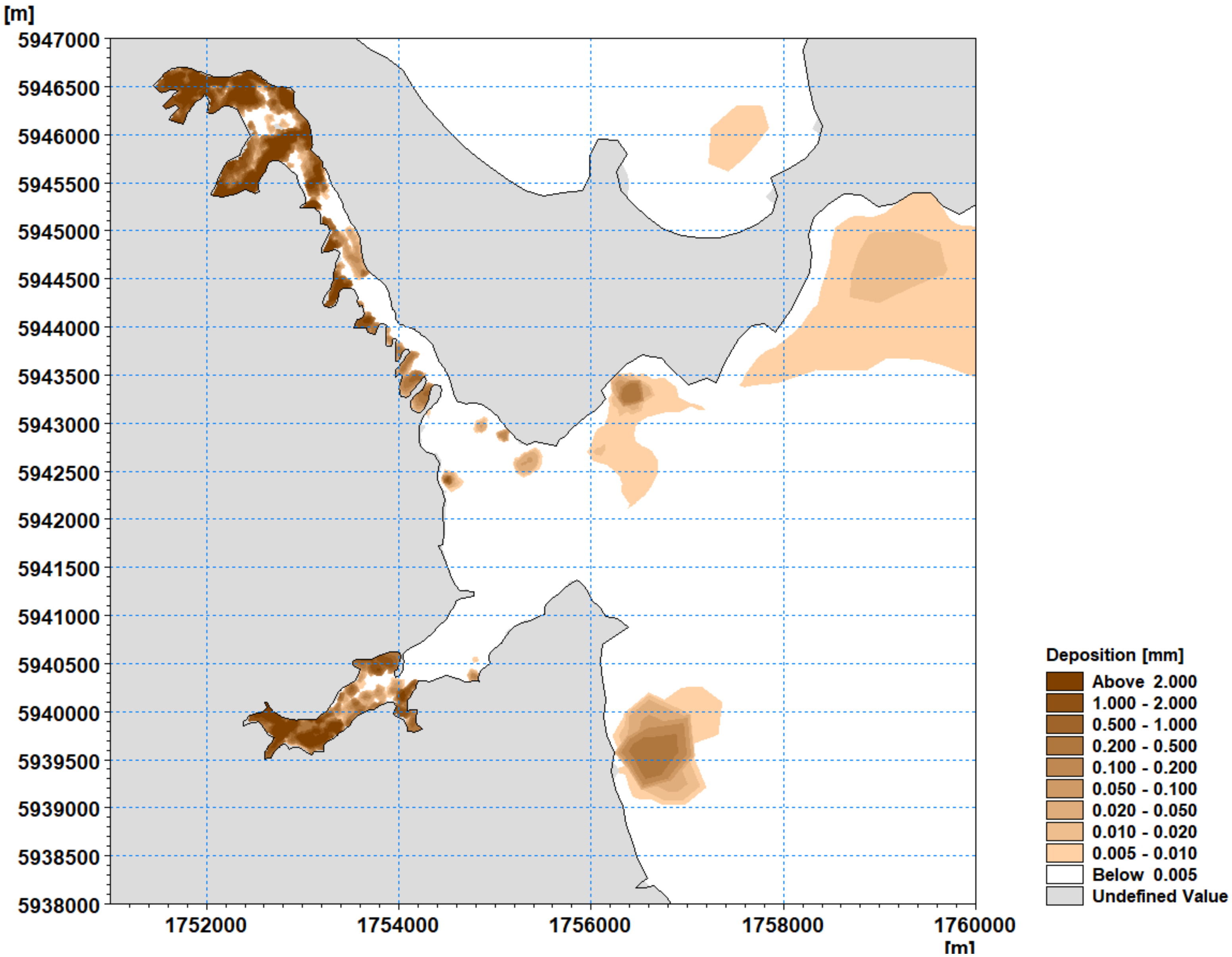


Figure 4-1. Predicted deposition (mm) at the end of the model simulation under Scenario 1. The period modelled (January-July 2018) consists of typical wind and rain conditions and a range of events which in total deliver 35% more catchment derived sediment than the long term annual average sediment load.

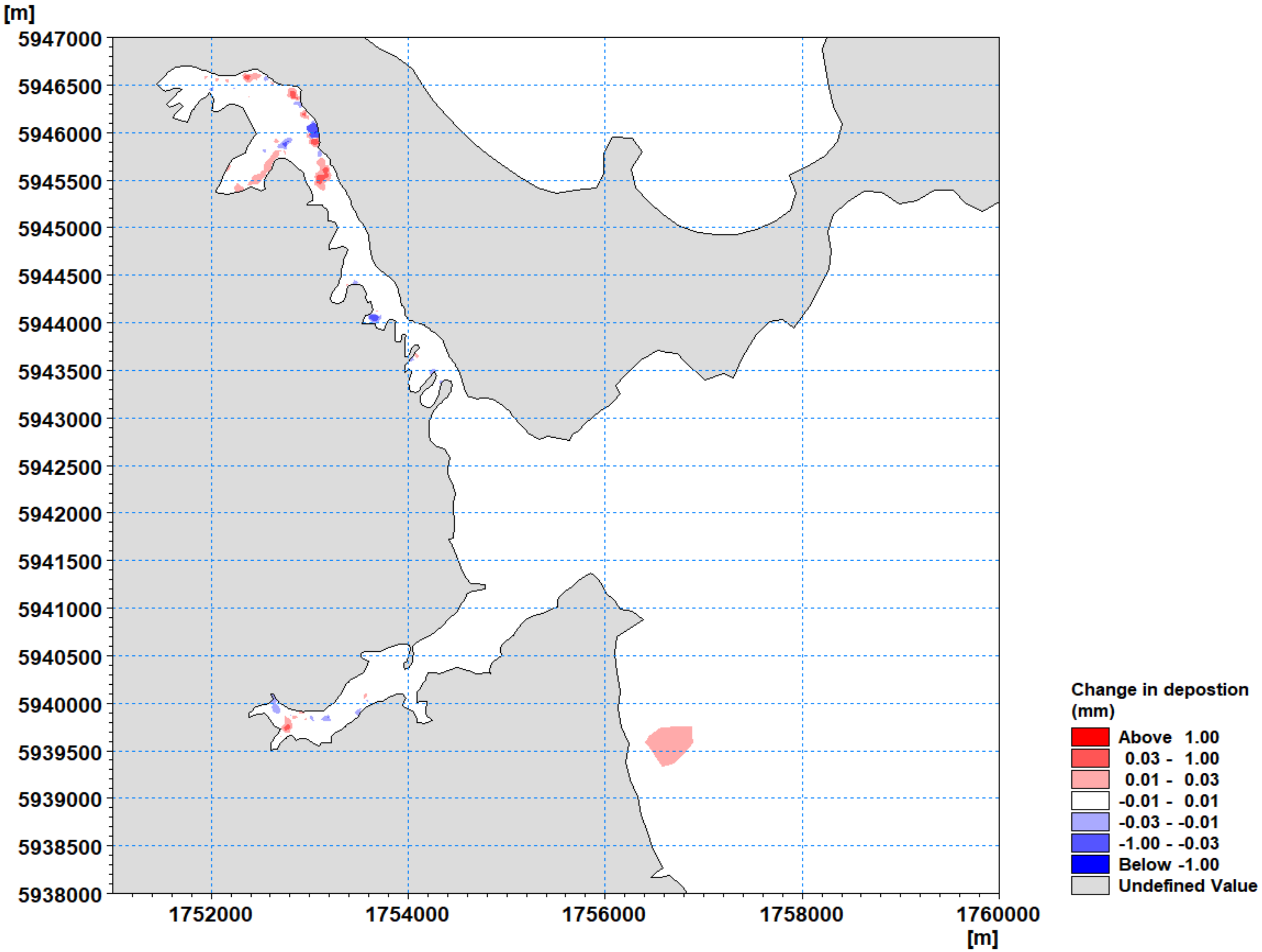


Figure 4-2. Predicted change deposition (mm) at the end of the model simulation under Scenario 1 compared to Scenario 0.

Table 4-2. Change in mass of sediment deposited (kg) at the end of the model simulation within each of the subestuaries (Figure 2-4) for Scenario 1 compared to Scenario 0.

Subestuary	Sediment deposited Scenario 0 (kg)	Change in sediment deposited compared to Scenario 1 (kg)	% Change
Upper Okura	382196	-12	-0.01%
Mid Okura	58499	-52	
Outer Okura	171	-2	
Karepiro (S)	474	6	1.35%
Karepiro (N)	3838	36	0.94%
Upper Wēiti	1110918	-659	-0.03%
Mid Wēiti	122430	423	
Outer Wēiti	27161	-192	
Marine Reserve	36646	1540	4.20%
Outer Karepiro	3859	17	0.43%
Whangaparaoa	38983	211	0.54%

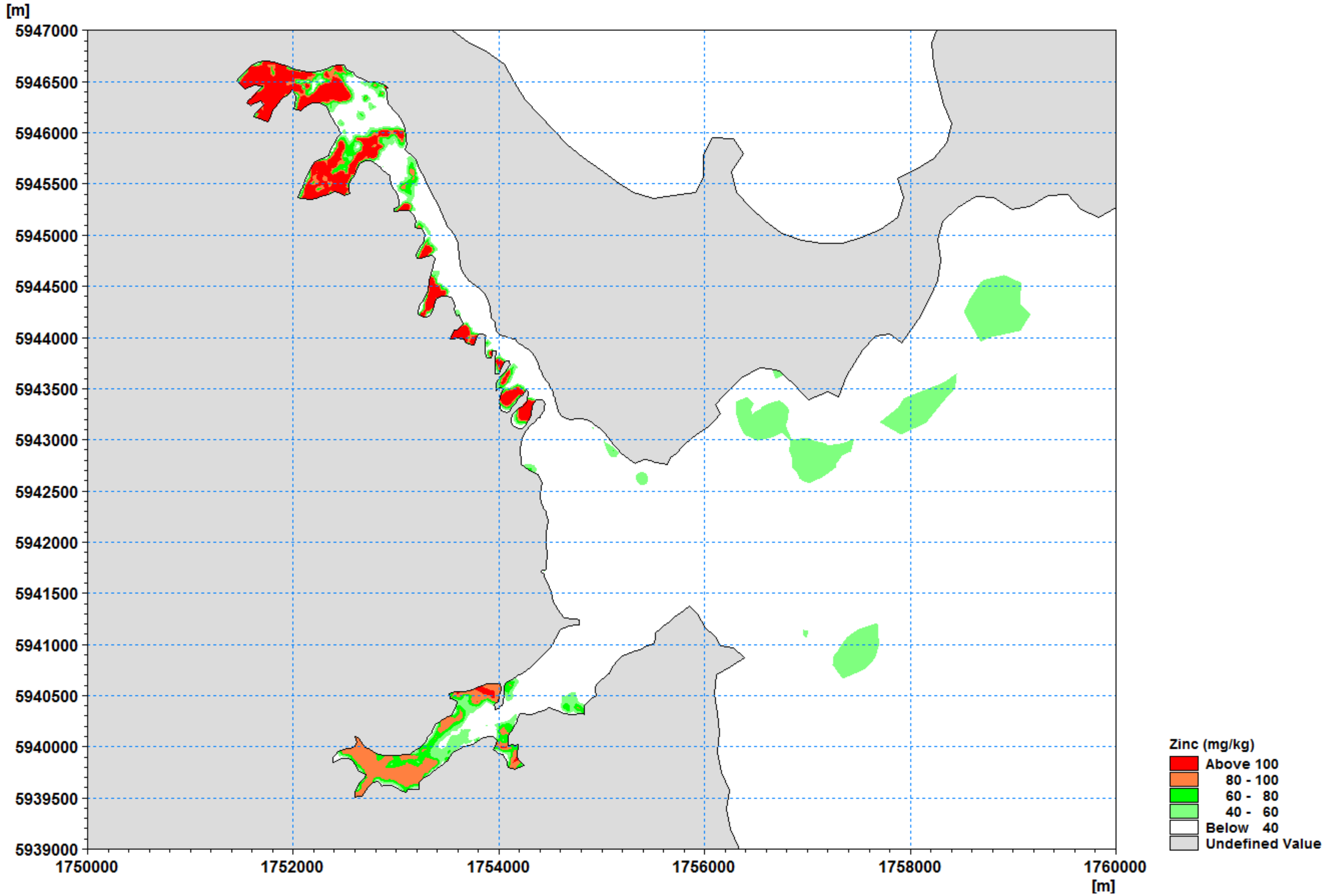


Figure 4-3. Zinc concentrations (mg/kg) 50 years from present under Scenario 1.

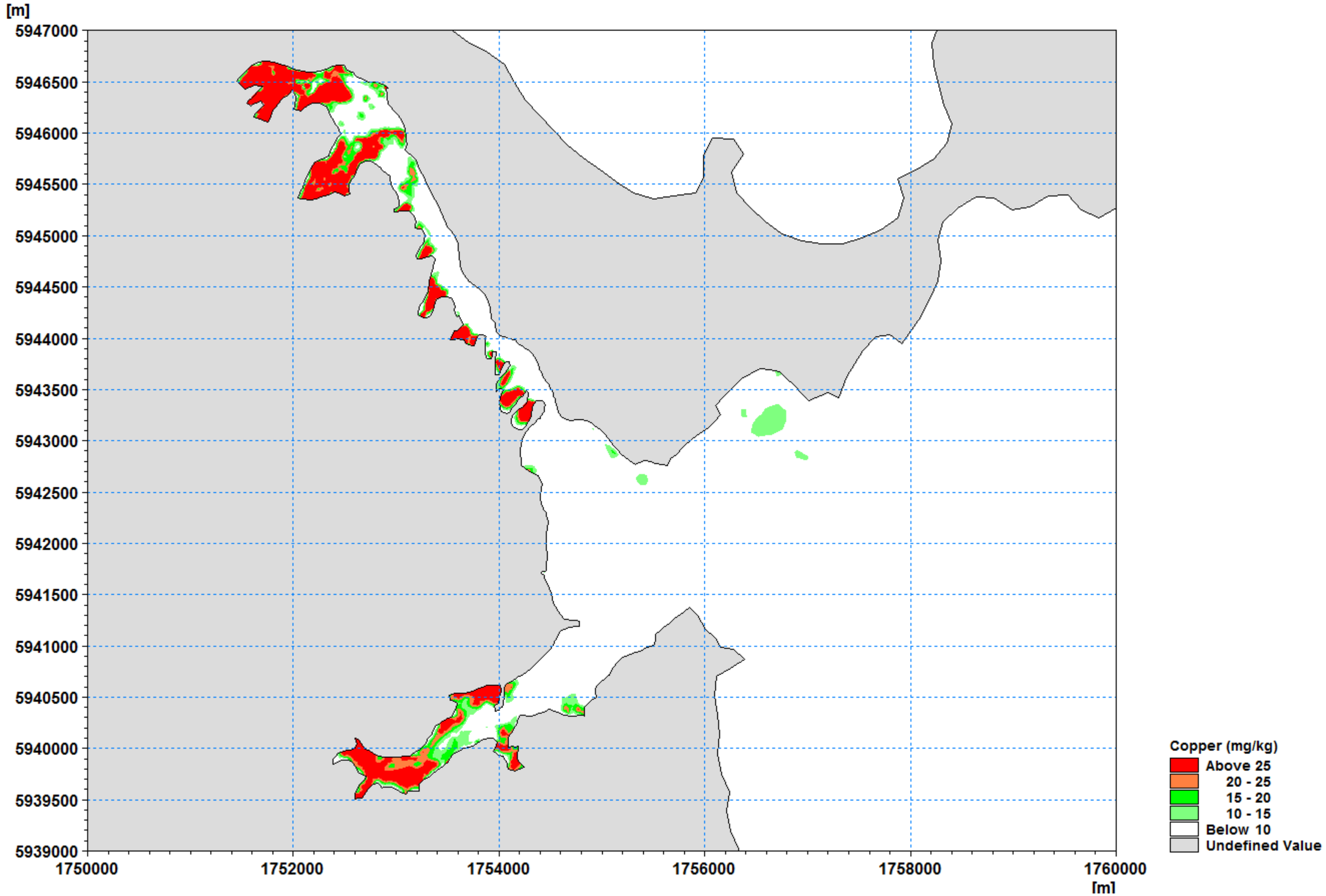


Figure 4-4. Copper concentrations 50 years from present Scenario 1.

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Table 4-3. Future subestuary metal concentration (mg/kg) under Scenario 1 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Numbers in brackets show the predicted change under this Scenario compared to Scenario 0. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	80.5 (0.1)	23.9
Mid Okura subestuary concentration	48.0 (0.1)	12.6
Lower Okura subestuary concentration	26.0	5.0
Karepiro (S) subestuary concentration	26.0	5.0
Karepiro (N) subestuary concentration	26.7	5.2
Upper Wēiti subestuary concentration	91.3	24.9
Mid Wēiti subestuary concentration	60.3	14.4
Lower Wēiti subestuary concentration	58.4	13.7
Marine Reserve subestuary concentration	26.6 (0.1)	5.0
Outer Karepiro subestuary concentration	26.6	5.0
Whangaparaoa subestuary concentration	29.6	5.8
Total area (ha) where PEL is exceeded		
	0.0	0.0
Maximum Concentration (mg/kg)		
	186.4	48.2

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5 Scenario 2

This scenario adds in a 550 home development within the Wēiti Bay area (Figure 2-3) in addition to the Long Bay Structure Plan developments (Scenario 1).

This scenario results in changes in loads and runoff for the North Arm, North Shore, Karepiro, Karepiro Beach and Wēiti South catchment outlets (Table 5-1), and increased sediment and metal loads to the marine receiving environment.

The mean annual sediment load from all catchments is 2296.9 tonnes/yr with mean annual loads of 351.4 kg/yr of Total Zinc and 88.2 kg/yr of Total Copper.

The following are the maximum suspended sediment concentration that occurs at any time during the model simulation, the percentage of the model simulation time that a threshold of 80 mg/L is exceeded and the percentage change in mean SSC relative to Scenario 0 at the key sites (Figure 2-5).

Upper Okura
18 hours above 80 mg/L, maximum of 427 mg/L and 0.14 % change in SSC
Mid Okura
16.75 hours above 80 mg/L, maximum of 378 mg/L and 0.01 % change in SSC
Upper Wēiti
44.25 hours above 80 mg/L, maximum of 602 mg/L and 0.08 % change in SSC
Mid Wēiti
34.25 hours above 80 mg/L, maximum of 954 mg/L and 0.02 % change in SSC
Karepiro
10.25 hours above 80 mg/L, maximum of 1427 mg/L and 0.34 % change in SSC
Wēiti Delta
8 hours above 80 mg/L, maximum of 122 mg/L and 0.11 % change in SSC
Outer Karepiro
0 hours above 80 mg/L, maximum of 16 mg/L and 0.17 % change in SSC
Arkle Bay
0 hours above 80 mg/L, maximum of 33 mg/L and 0.17 % change in SSC
Long Bay
0 hours above 80 mg/L, maximum of 8 mg/L and 1.02 % change in SSC

Figure 5-1 shows the deposition under Scenario 2 and Figure 5-2 shows the difference in deposition under this Scenario compared to Scenario 1. Increases in deposition occur near the Wēiti South catchment outlet resulting in large increases in overall deposition in the upper Wēiti river (Table 5-2) but reduced levels of deposition in the middle and outer Wēiti river. This change in pattern of deposition results from the decreased runoff from the Wēiti South catchment.

Similarly, there is a change in the distribution in deposition within Okura estuary with more deposited in the central part of the estuary and less in the upper estuary. This is due to the increased runoff from the North Arm catchment outlet and results in less overall sediment deposition within the Okura estuary (Table 5-2) and small changes elsewhere compared to Scenario 1.

Increases in metal concentrations are seen within the areas of highest deposition (Figure 5-2 and Figure 5-4) resulting in increases in future metal concentrations at a subestuary level within most subestuaries (Table 5-3) but PEL thresholds are not exceeded.

Table 5-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 2. Number in brackets indicating magnitude of change compared to Scenario 1.

	Awaruku	**Long Bay**	**SS Outer**	**SS Mid East**	**SS Mid West**	**SS Inner**	**Redvale**	**North Arm**	**North Shore**	**Karepiro**	**Karepiro Beach**	**Stillwater**	**Wēiti South**	**Silverdale**	**Arkle Bay**	**Whangaparaoa Wēiti North**	**North Outlet**	**Duck Creek**
Sediment (tonnes/yr)	57.3	132.2	16.9	35.8	26.7	27.1	589.9	194.2 (8.1)	10.9 (0.8)	28.2 (2.1)	32.7 (2.8)	28.2	215.1 (9.4)	801.7	23.7	12.9	17.7	32.9
Zn (kg/yr)	55.5	18.1	1.3	4.5	3.5	6.9	49.5	15 (0.1)	0.7 (0.3)	7.4 (6.3)	10.3 (8.1)	11.4	16.7 (0.1)	115.1	15.2	6.6	1.1	6.1
Cu (kg/yr)	7.7	4.2	0.6	1.3	1.0	1.4	15	5.4	0.2	1.2 (0.6)	1.7 (0.8)	1.8	6.1	33.8	2.2	1.2	0.6	1.7
Runoff (m^3 x 10^3/year)	2164	2075	369	477	428	463	6622	3571 (244)	379 (-1)	950 (21)	1538 (30)	853	2774 (-196)	13451	677	463	466	723
Zinc Concentration (mg/kg)	2073	487	195	282	243	541	154	204 (-8)	78 (25)	328 (274)	474 (363)	511	233 (-5)	333	1002	729	158	354
Copper Concentration (mg/kg)	288	114	82	83	69	111	47	73 (-3)	28 (2)	55 (28)	79 (33)	79	85 (-2)	98	142	128	78	98

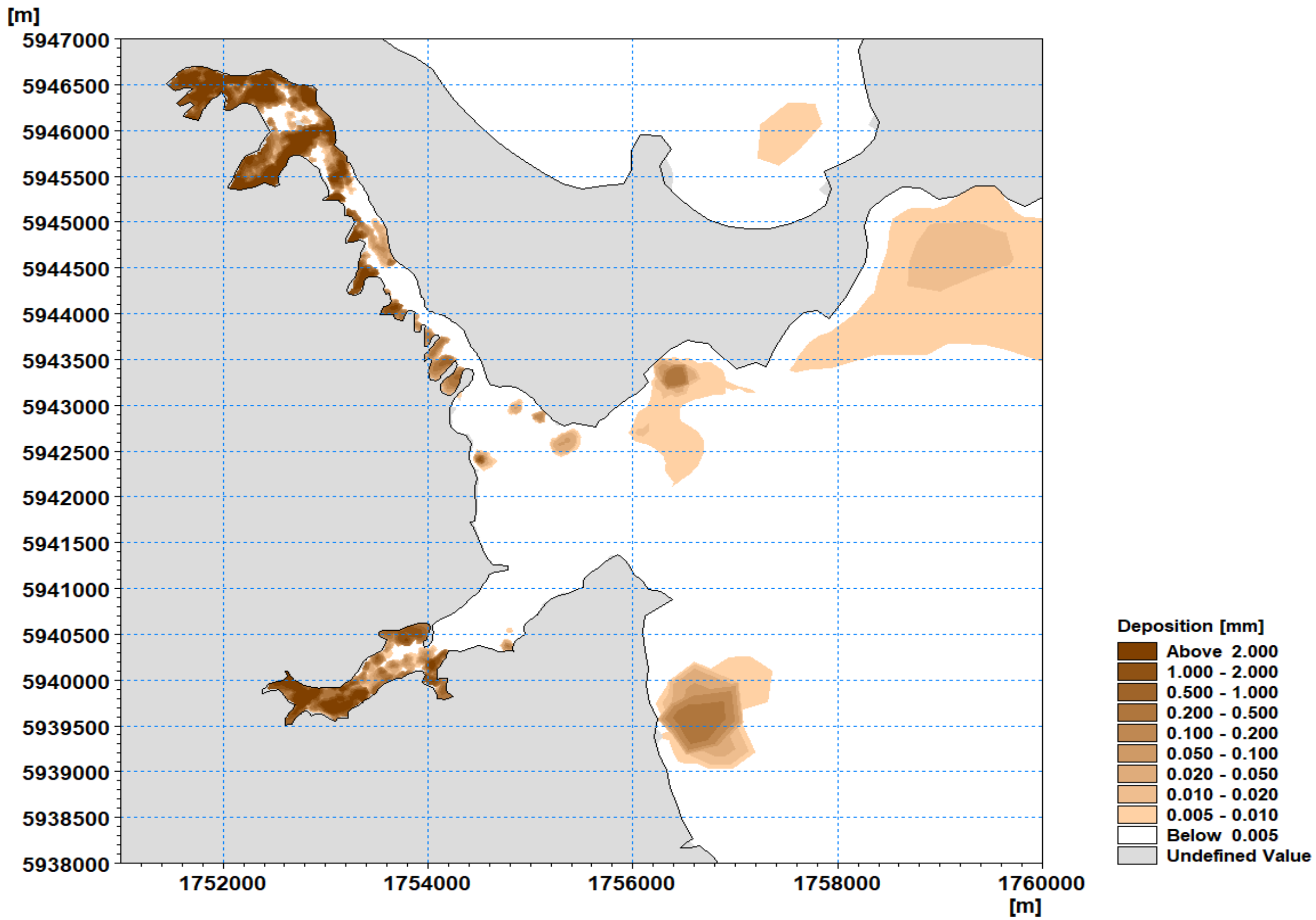


Figure 5-1. Deposition at the end of the model simulation for Scenario 2. The period modelled (January-July 2018) consists of typical wind and rain conditions and a range of events which in total deliver 35% more catchment derived sediment than the long term annual average sediment load.

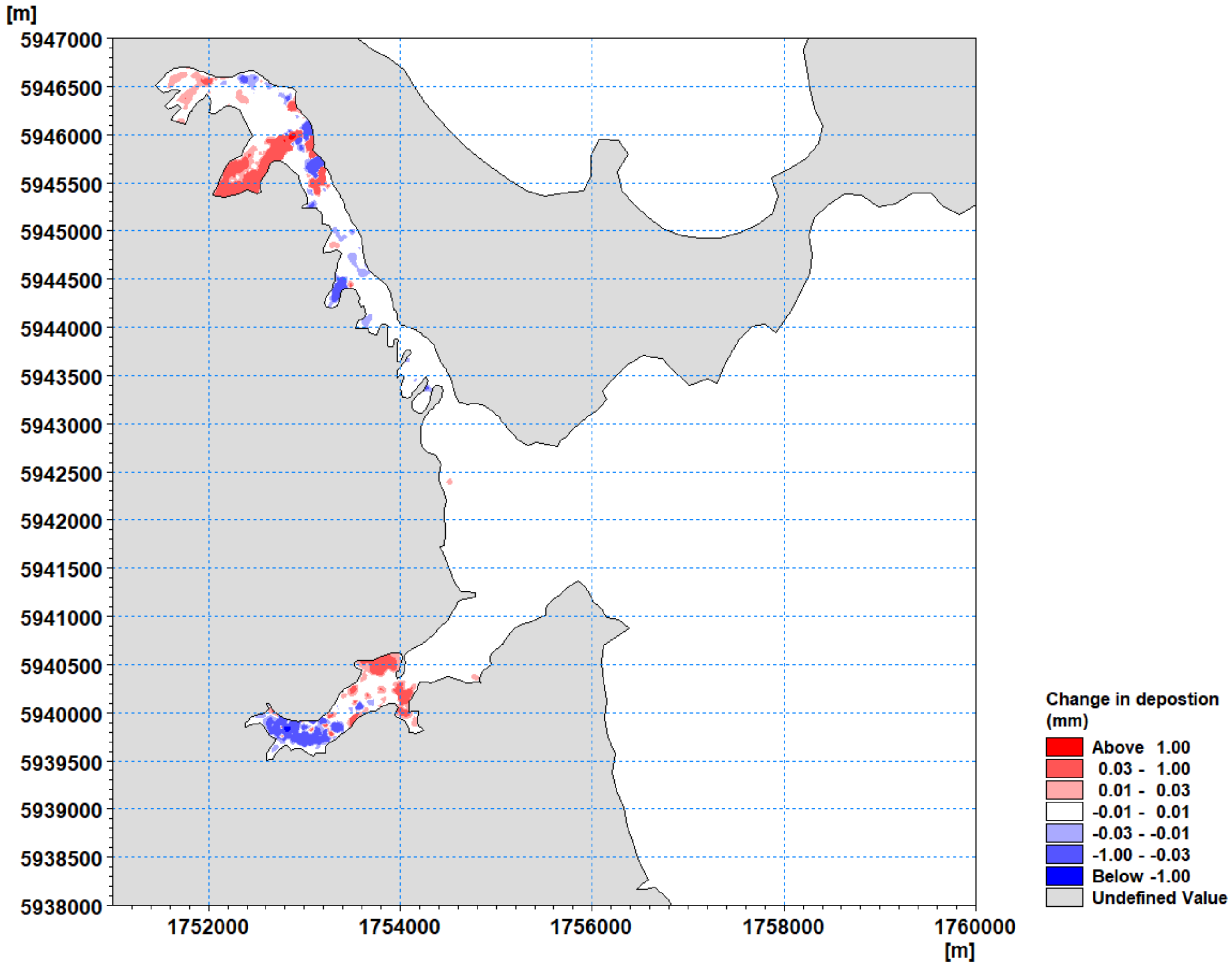


Figure 5-2. Predicted change in deposition at the end of the model simulation for Scenario 2 compared to Scenario 1.

Table 5-2. Change in mass of sediment deposited (kg) at the end of the model simulation within each of the subestuaries (Figure 2-4) for Scenario 2 compared to Scenario 1.

Subestuary	Sediment deposited Scenario 1 (kg)	Change in sediment deposited compared to Scenario 2 (kg)	% Change
Upper Okura	374048	-8136	-1.14%
Mid Okura	61575	3128	
Outer Okura	165	-4	
Karepiro (S)	479	-1	-0.29%
Karepiro (N)	3875	1	0.02%
Upper Wēiti	1132395	22136	1.60%
Mid Wēiti	121148	-1705	
Outer Wēiti	26694	-275	
Marine Reserve	38176	-10	-0.03%
Outer Karepiro	3867	-8	-0.22%
Whangaparaoa	39280	86	0.22%

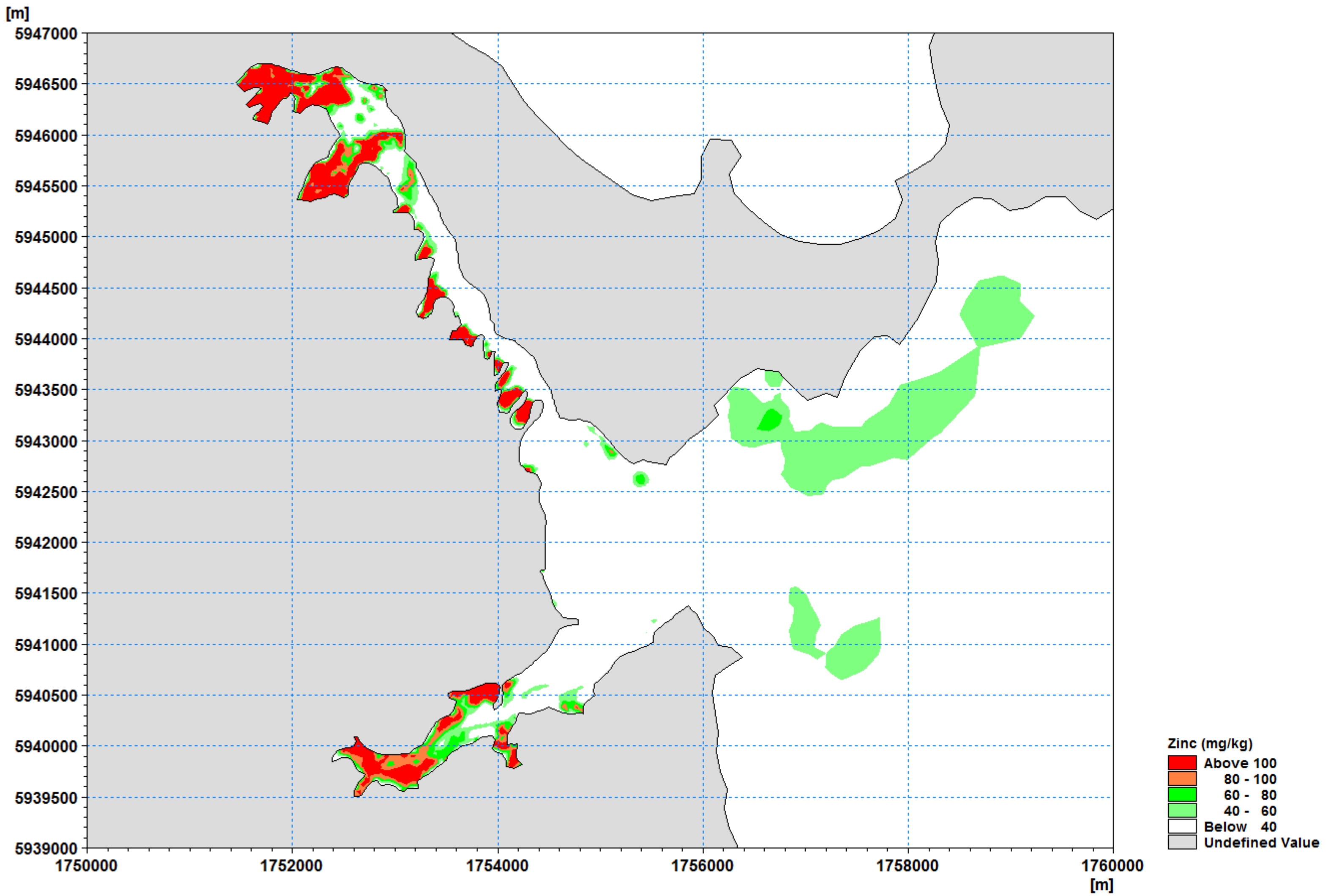


Figure 5-3. Zinc concentrations (mg/kg) 50 years from present under Scenario 2.

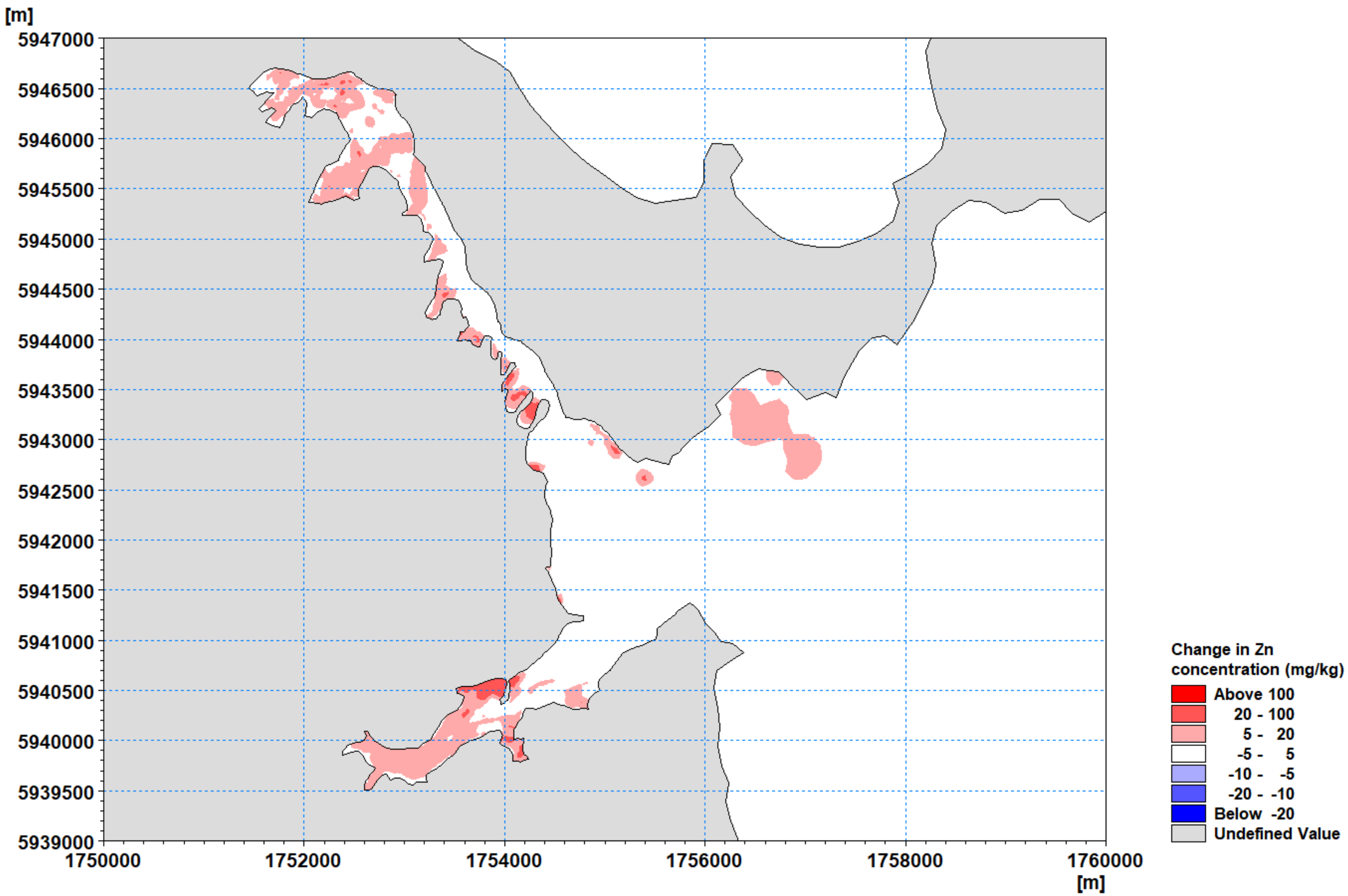


Figure 5-4. Changes in Zinc concentrations (mg/kg) 50 years from present under Scenario 2 (550 houses within the Wēiti Bay) compared to Scenario 1.

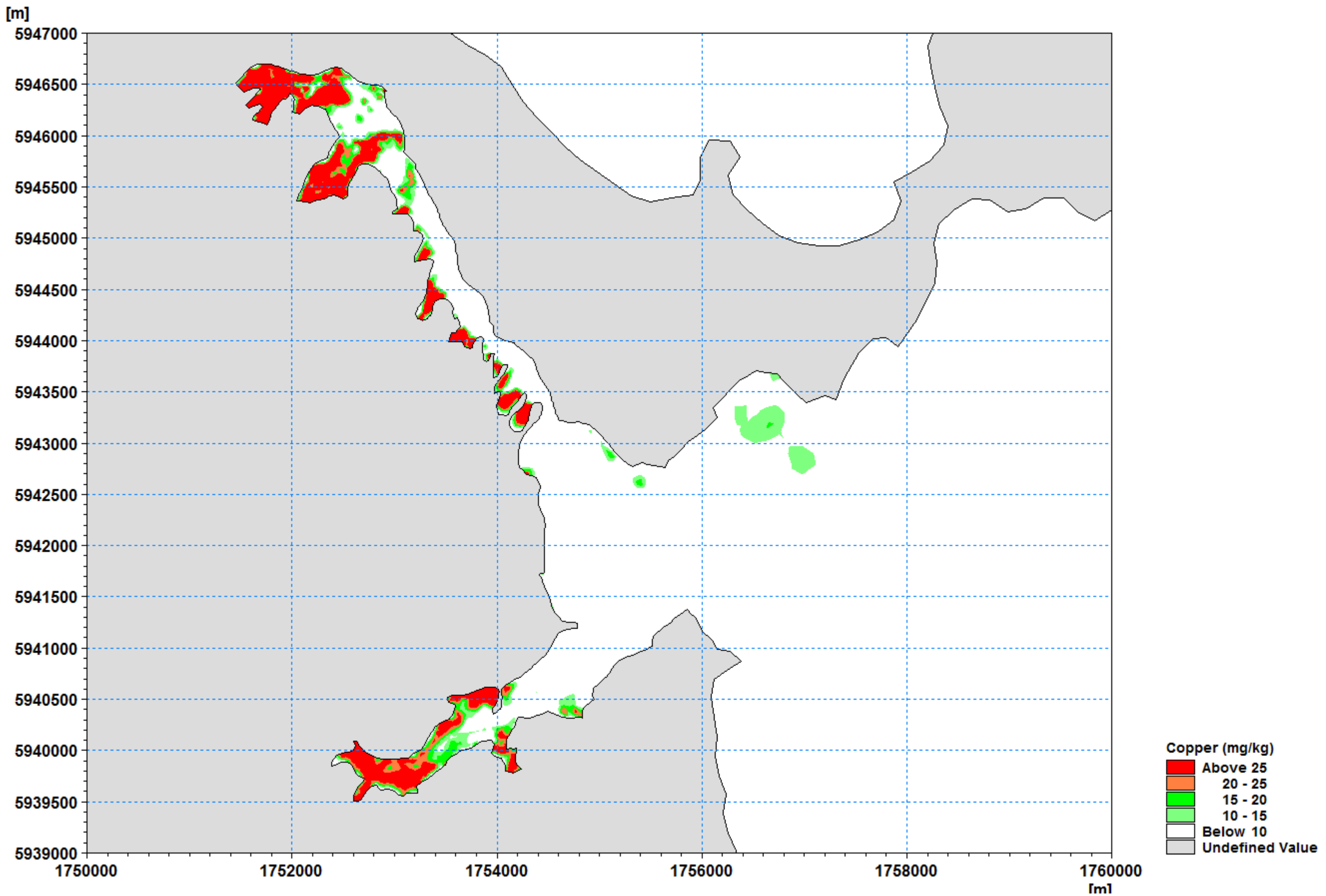


Figure 5-5. Copper concentrations (mg/kg) 50 years from present under Scenario 2.

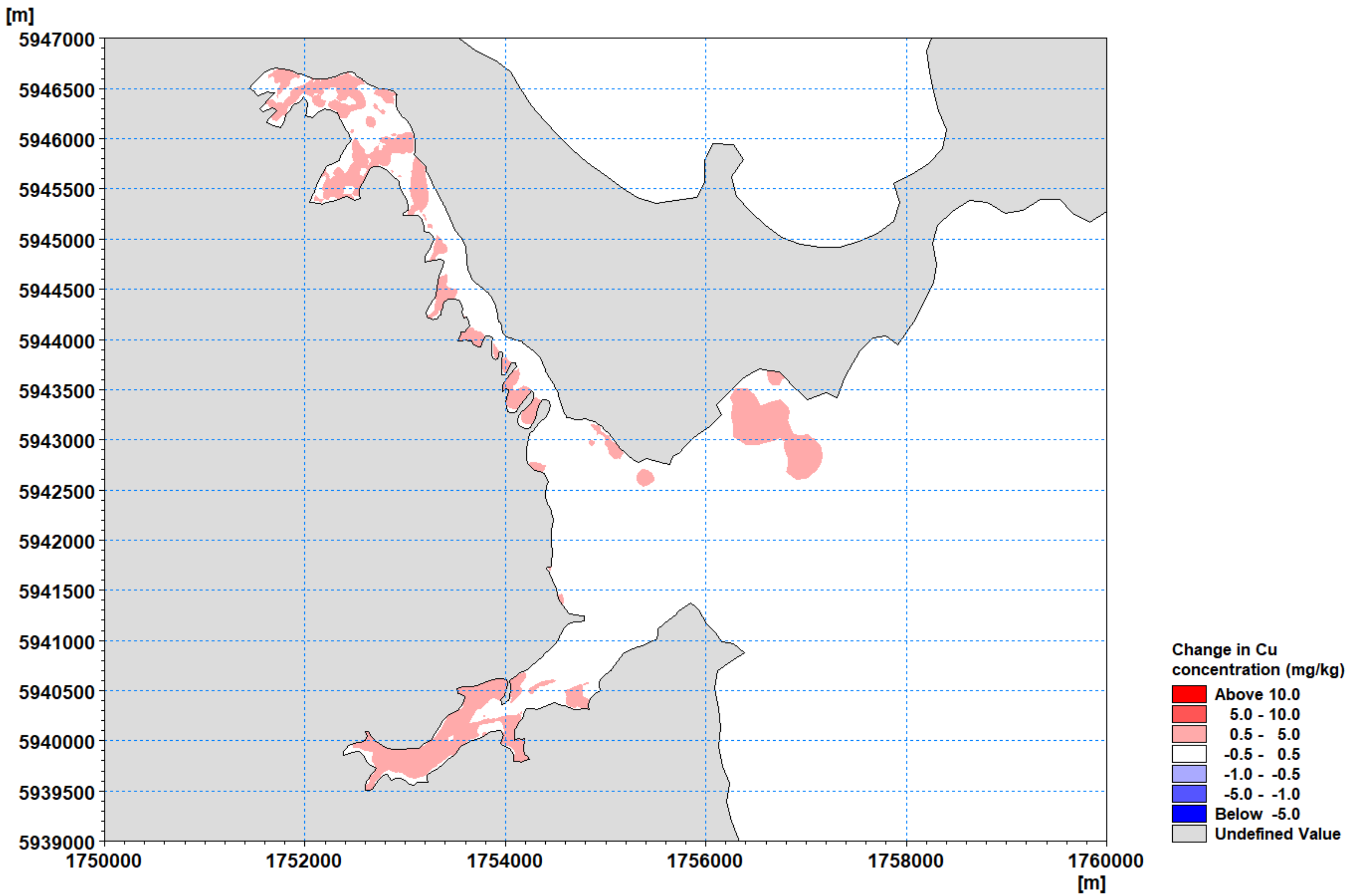


Figure 5-6. Changes in Copper concentrations (mg/kg) 50 years from present under Scenario 2 (550 houses within the Wēiti Bay) compared to Scenario 1.

Table 5-3. Future subestuary metal concentration (mg/kg) under Scenario 2 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Numbers in brackets show the predicted change under this Scenario compared to Scenario 1. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	92.0 (11.5)	24.9 (1.0)
Mid Okura subestuary concentration	57.2 (9.2)	13.4 (0.9)
Lower Okura subestuary concentration	26.4 (0.4)	5.0
Karepiro (S) subestuary concentration	26.8 (0.9)	5.1 (0.1)
Karepiro (N) subestuary concentration	28.1 (1.4)	5.4 (0.1)
Upper Wēiti subestuary concentration	98.6 (7.3)	25.6 (0.6)
Mid Wēiti subestuary concentration	65.3 (5.0)	14.8 (0.4)
Lower Wēiti subestuary concentration	65.1 (6.7)	14.3 (0.6)
Marine Reserve subestuary concentration	26.7 (0.1)	5.0
Outer Karepiro subestuary concentration	26.8 (0.2)	5.0
Whangaparaoa subestuary concentration	31.1 (1.5)	6.0 (0.1)
Total area (ha) where PEL is exceeded		
	0.0	0.0
Maximum Concentration (mg/kg)		
	194.4	48.3

6 Scenario 3

This scenario adds in a 1200 home development within the Wēiti Bay area (Figure 2-3) in addition to the Long Bay Structure Plan developments (Scenario 1).

This scenario results in increases in loads and runoff for the Karepiro and Karepiro Beach catchment outlets (Table 6-1).

The mean annual sediment load from all catchments is 2299.6 tonnes/yr with mean annual loads of 351.8 kg/yr of Total Zinc and 88.4 kg/yr of Total Copper.

The following are the maximum suspended sediment concentration that occurs at any time during the model simulation, the percentage of the model simulation time that a threshold of 80 mg/L is exceeded and the percentage change in mean SSC relative to Scenario 0 at the key sites (Figure 2-5).

Upper Okura
18 hours above 80 mg/L, maximum of 438 mg/L and -0.42 % change in SSC
Mid Okura
17.75 hours above 80 mg/L, maximum of 357 mg/L and 1.01 % change in SSC
Upper Wēiti
48.5 hours above 80 mg/L, maximum of 783 mg/L and 5.68 % change in SSC
Mid Wēiti
34 hours above 80 mg/L, maximum of 968 mg/L and 0.64 % change in SSC
Karepiro
10.75 hours above 80 mg/L, maximum of 1403 mg/L and 1.09 % change in SSC
Wēiti Delta
8.5 hours above 80 mg/L, maximum of 124 mg/L and 0.66 % change in SSC
Outer Karepiro
0 hours above 80 mg/L, maximum of 16 mg/L and 0.4 % change in SSC
Arkle Bay
0 hours above 80 mg/L, maximum of 33 mg/L and 0.58 % change in SSC
Long Bay
0 hours above 80 mg/L, maximum of 8 mg/L and 1.59 % change in SSC

There are very small changes in deposition in the upper parts of the Wēiti river and small changes in deposition within the Okura estuary (Figure 6-2) which result in minimal change in the overall mass of sediment deposited with the Wēiti river and Okura estuary (Table 6-2) and increased in deposition for other subestuaries except the Karepiro (S) subestuary. Overall these changes in deposition and small increases in metal loads (Table 6-1) have only a minor influence on future metal concentrations (Table 6-3) with just small reductions in metal concentrations in the upper Wēiti river reflecting the reduced metal source concentrations for the Karepiro Beach catchment outlet. Difference plots are not provided.

Table 6-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 3. Number in brackets indicating magnitude of change compared to Scenario 2.

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa Wēiti North	North Outlet	Duck Creek
Sediment (tonnes/yr)	57.3	132.2	16.9	35.8	26.7	27.1	589.9	194.2	10.9	28.2 (0.1)	35.3 (2.6)	28.2	215.1	801.7	23.7	12.9	17.7	32.9
Zn (kg/yr)	55.5	18.1	1.3	4.5	3.5	6.9	49.5	15	0.7	7.6 (0.2)	10.5 (0.2)	11.4	16.7	115.1	15.2	6.6	1.1	6.1
Cu (kg/yr)	7.7	4.2	0.6	1.3	1.0	1.4	15	5.4	0.2	1.3 (0.1)	1.8 (0.1)	1.8	6.1	33.8	2.2	1.2	0.6	1.7
Runoff (m^3 x 10^3/year)	2164	2075	369	477	428	463	6622	3571	379	952 (1)	1544 (5)	853	2774	13451	677	463	466	723
Zinc Concentration (mg/kg)	2073	487	195	282	243	541	154	204	78	336 (7)	443 (-31)	511	233	333	1002	729	158	354
Copper Concentration (mg/kg)	288	114	82	83	69	111	47	73	28	56 (1)	75 (-4)	79	85	98	142	128	78	98

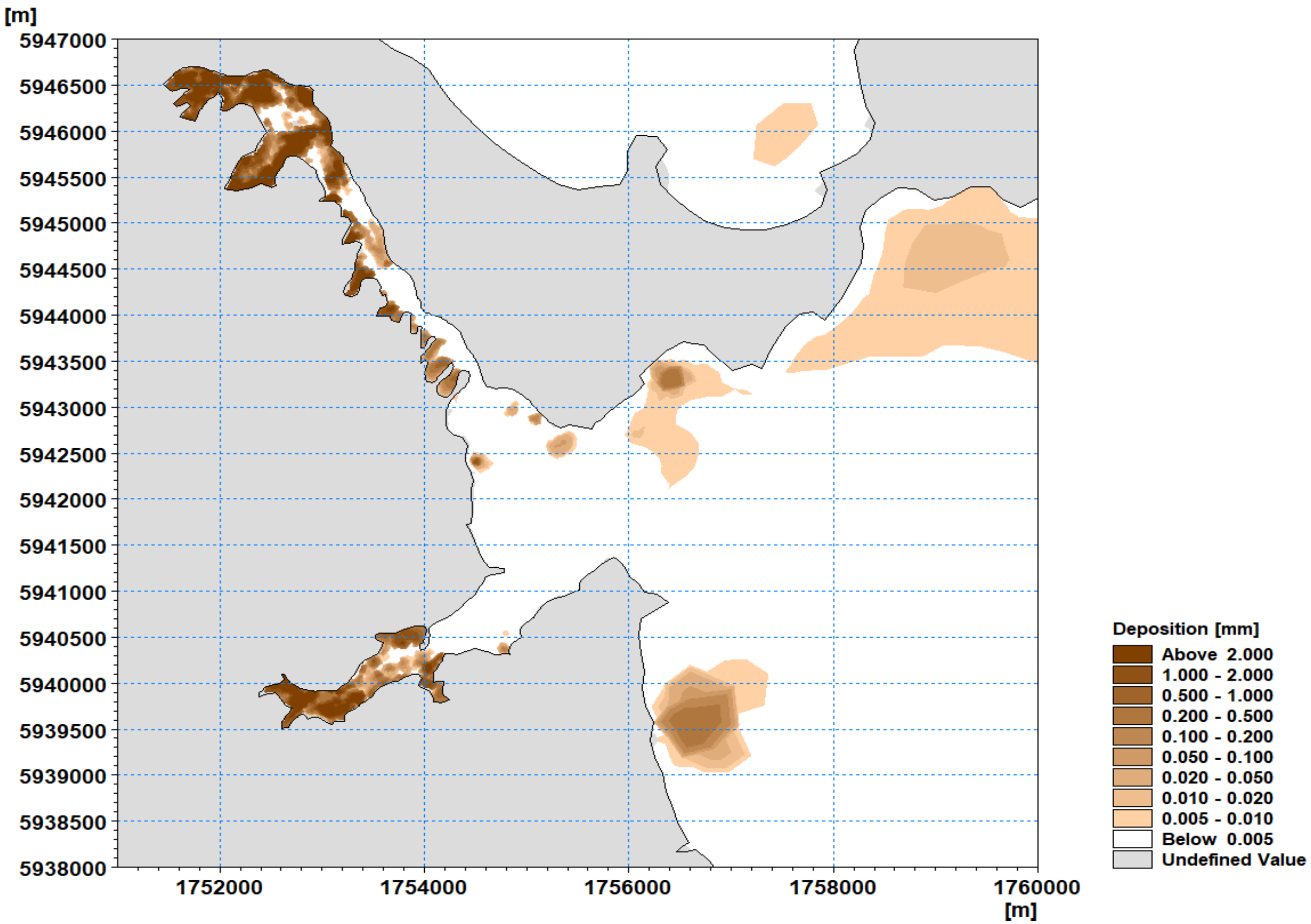


Figure 6-1. Deposition at the end of the model simulation for Scenario 3. The period modelled (January-July 2018) consists of typical wind and rain conditions and a range of events which in total deliver 35% more catchment derived sediment than the long term annual average sediment load.

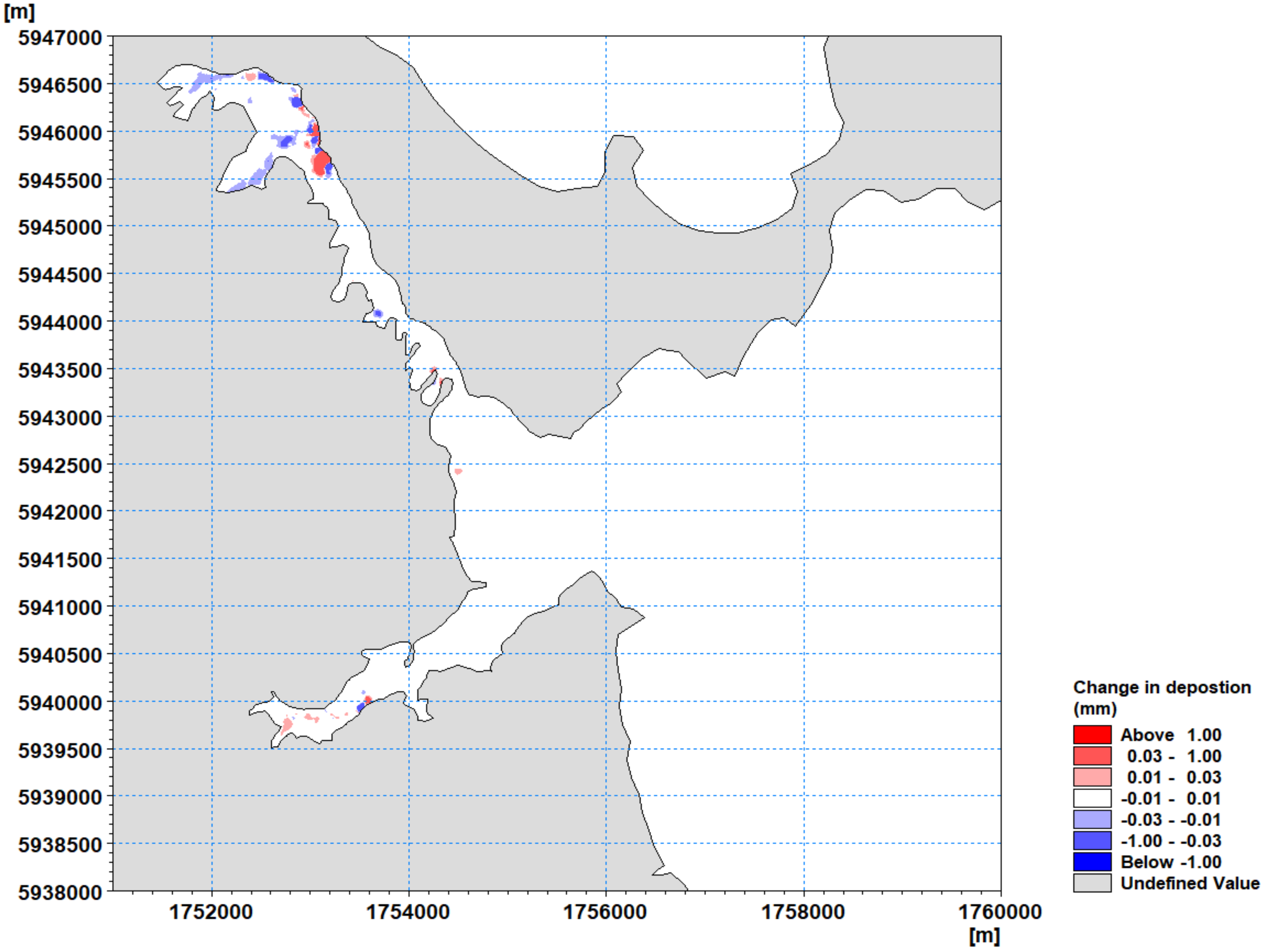


Figure 6-2. Predicted change in deposition at the end of the model simulation for Scenario 3 compared to Scenario 2.

Table 6-2. Change in mass of sediment deposited (kg) at the end of the model simulation within each of the subestuaries (Figure 2-4) for Scenario 3 compared to Scenario 2.

Subestuary	Sediment deposited Scenario 2 (kg)	Change in sediment deposited compared to Scenario 3 (kg)	% Change
Upper Okura	374273	224	0.09%
Mid Okura	61742	167	
Outer Okura	167	2	
Karepiro (S)	477	-2	-0.51%
Karepiro (N)	3919	44	1.14%
Upper Wēiti	1130880	-1515	-0.04%
Mid Wēiti	122187	1039	
Outer Wēiti	26691	-3	
Marine Reserve	38202	27	0.07%
Outer Karepiro	3876	9	0.23%
Whangaparaoa	39346	66	0.17%

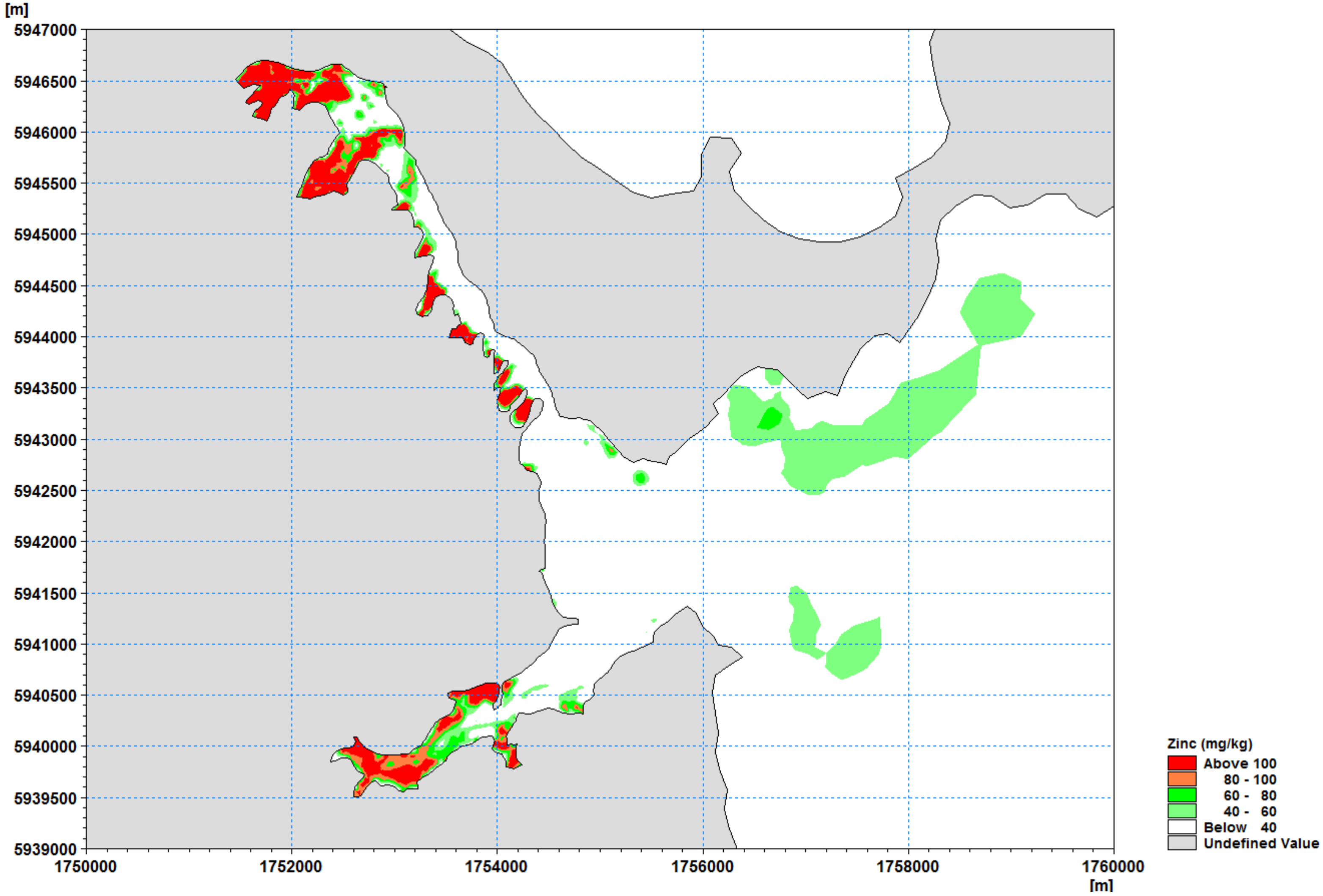


Figure 6-3. Zinc concentrations (mg/kg) 50 years from present under Scenario 3.

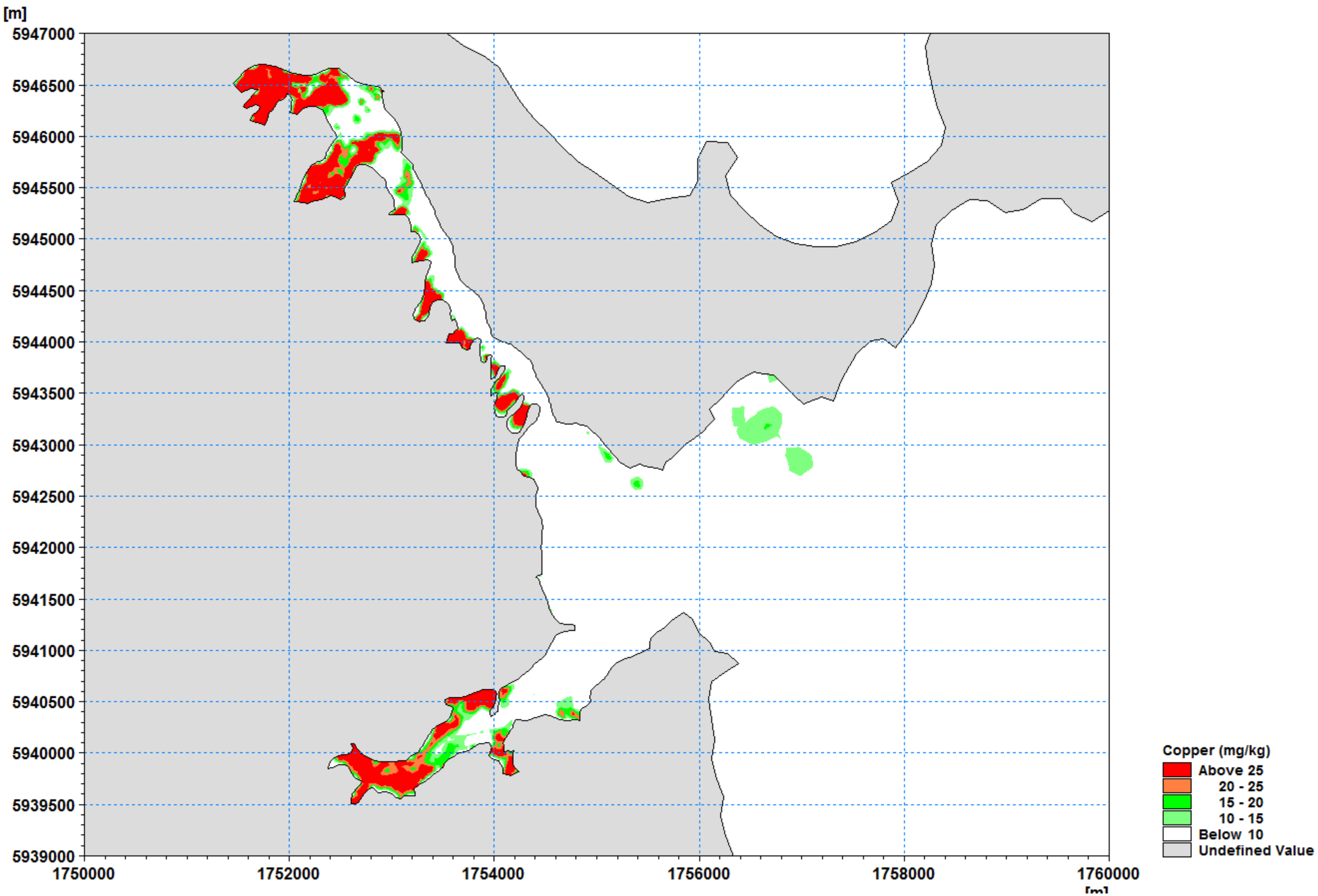


Figure 6-4. Copper concentrations (mg/kg) 50 years from present under Scenario 3.

Table 6-3. Future subestuary metal concentration (mg/kg) under Scenario 3 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Numbers in brackets show the predicted change under this Scenario compared to Scenario 2. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	92 .0	24.9
Mid Okura subestuary concentration	57.2	13.4
Lower Okura subestuary concentration	26.4	5.0
Karepiro (S) subestuary concentration	26.8	5.1
Karepiro (N) subestuary concentration	28.1	5.4
Upper Wēiti subestuary concentration	98.5 (-0.1)	25.5
Mid Wēiti subestuary concentration	65.2 (-0.1)	14.8
Lower Wēiti subestuary concentration	64.9 (-0.2)	14.3
Marine Reserve subestuary concentration	26.7	5
Outer Karepiro subestuary concentration	26.8	5
Whangaparaoa subestuary concentration	31.1	6
Total area (ha) where PEL is exceeded		
	0.0	0.0
Maximum Concentration (mg/kg)		
	194	48.2

7 Scenario 4

This scenario accounts for development in the Future Growth area (Figure 2-3) in addition to the Scenario 1 development. Compared to Scenario 1, this results in a reduced mean annual sediment load of 2094.8 tonnes/yr from all catchments. This is due to a combination of the reduction in sediment load from the Silverdale and Long Bay catchment outlets (Table 7-1) and increases for the North Arm, Stillwater, Wēiti South, Whangaparaoa, Wēiti North, North Outlet and Duck Creek catchment outlets.

Compared to Scenario 1, there is an increase in the mean annual load for Zinc (to 511.3 kg/yr) which is due to the significant increase in Zinc load from the Silverdale catchment outlet. There is a very small increase in Total Copper load. In addition, there are increases in runoff from the North Arm, Long Bay and Silverdale catchment outlets and decreases for the Wēiti South catchment outlet.

The following are the maximum suspended sediment concentration that occurs at any time during the model simulation, the percentage of the model simulation time that a threshold of 80 mg/L is exceeded and the percentage change in mean SSC relative to Scenario 0 at the key sites (Figure 2-5).

Upper Wēiti
38.25 hours above 80 mg/L, maximum of 609 mg/L and -10.21 % change in SSC
Mid Wēiti
26 hours above 80 mg/L, maximum of 620 mg/L and -20.31 % change in SSC
Karepiro
9.75 hours above 80 mg/L, maximum of 1379 mg/L and -5.94 % change in SSC
Wēiti Delta
4.75 hours above 80 mg/L, maximum of 101 mg/L and -15.14 % change in SSC
Outer Karepiro
0 hours above 80 mg/L, maximum of 15 mg/L and -12.44 % change in SSC
Arkle Bay
0 hours above 80 mg/L, maximum of 31 mg/L and -10.8 % change in SSC
Long Bay
0 hours above 80 mg/L, maximum of 8 mg/L and -7.44 % change in SSC

Figure 7-1 shows the deposition at the end of the simulation under this Scenario. The combined effect of this scenario in terms of deposition are reductions in deposition within the main depostional sinks with the Okura estuary and Wēiti river and offshore of Long Bay (Figure 7-2). Small areas of increased deposition are predicted within the middle section of the Okura estuary (attributable to the increased sediment load from the North Arm). Overall, there are reduced levels of deposition within each of the subestuaries (Table 7-2) except the northern Karepiro subestuary.

Future metal concentrations increase within the upper Wēiti river and landward of the spit opposite to Okura township (Figure 7-4 and Figure 7-6). Future Zinc concentrations also increase within the upper Okura estuary and offshore of Arkle Bay. There is 46.3 hectares of the Wēiti river where the PEL for Zinc is exceeded.

Table 7-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 4. Number in brackets indicating magnitude of change compared to Scenario 1.

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa Wēiti North	North Outlet	Duck Creek
Sediment (tonnes/yr)	57.3	121.5 (-10.7)	16.9	35.8	26.7	27.1	589.9	194.1 (8.0)	10.1	26.1	29.9	31.5 (3.2)	219.4 (13.8)	601 (-200.7)	23.7	14.6 (1.6)	18.4 (0.7)	36.3 (3.4)
Zn (kg/yr)	55.5	25 (6.9)	1.3	4.5	3.5	6.9	49.5	15 (0.1)	0.4	1.1	2.2	11.7 (0.3)	18.3 (1.7)	280.1 (165.0)	15.2	6.6	1.7 (0.6)	6.2 (0.1)
Cu (kg/yr)	7.7	4.6 (0.4)	0.6	1.3	1	1.4	15	5.4	0.2	0.6	0.9	1.8	6.4 (0.3)	33.8	2.2	1.2	0.6	1.7
Runoff (m^3 x 10^3/year)	2164	2549 (474)	369	477	428	463	6622	3573 (246)	379	930	1508	850 (-2)	2157 (-813)	15276 (1825)	677	462 (-1)	468 (2)	707 (-16)
Zinc Concentration (mg/kg)	2073	707 (221)	195	282	243	541	154	204 (-8)	53	54	111	473 (-39)	249 (11)	1054 (721)	1002	651 (-78)	224 (66)	319 (-35)
Copper Concentration (mg/kg)	288	130 (16)	82	83	69	111	47	73 (-3)	26	27	46	74 (-5)	87	127 (30)	142	114 (-14)	83 (5)	86 (-11)

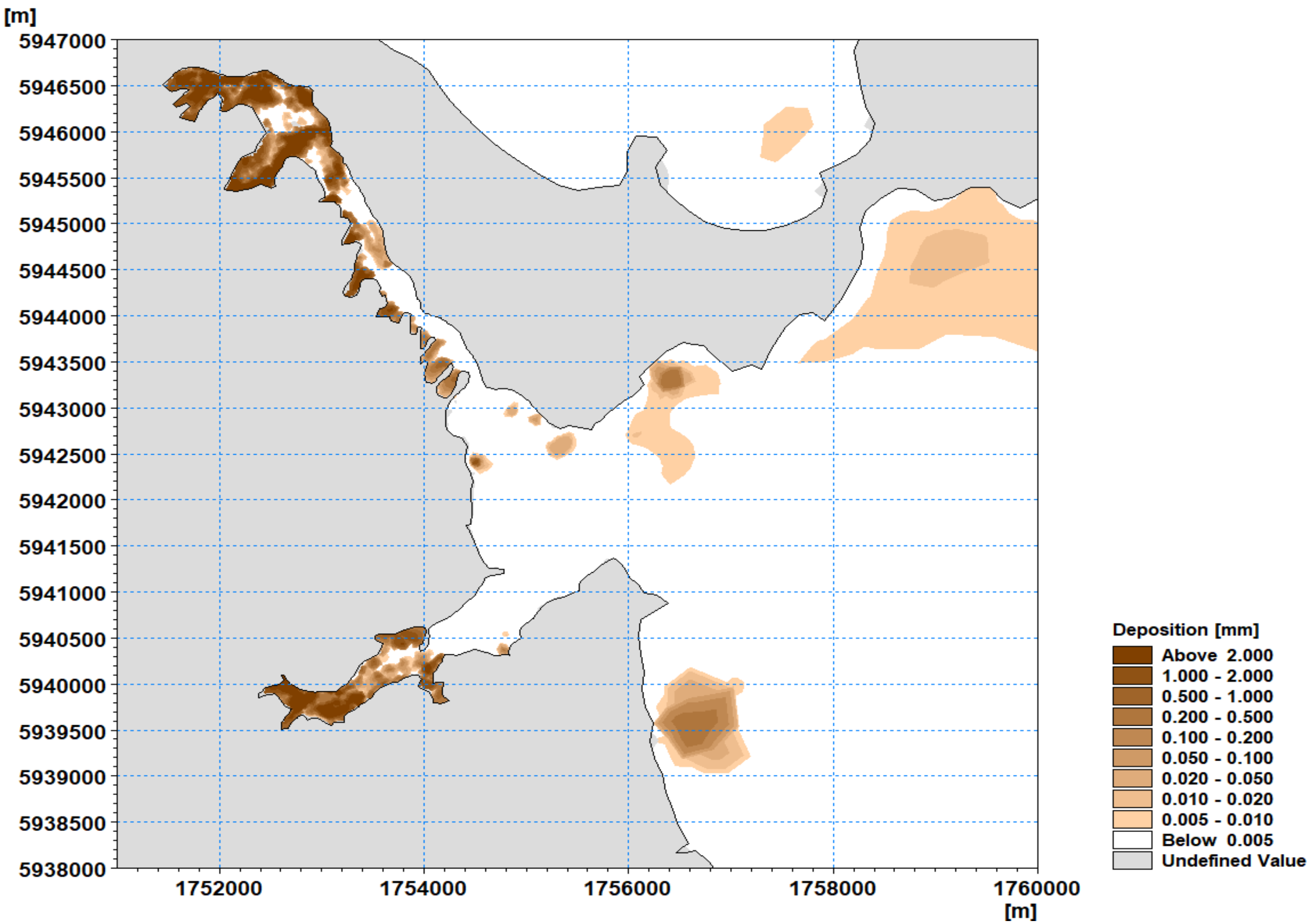


Figure 7-1. Deposition at the end of the model simulation for Scenario 4. The period modelled (January-July 2018) consists of typical wind and rain conditions and a range of events which in total deliver 35% more catchment derived sediment than the long term annual average sediment load.

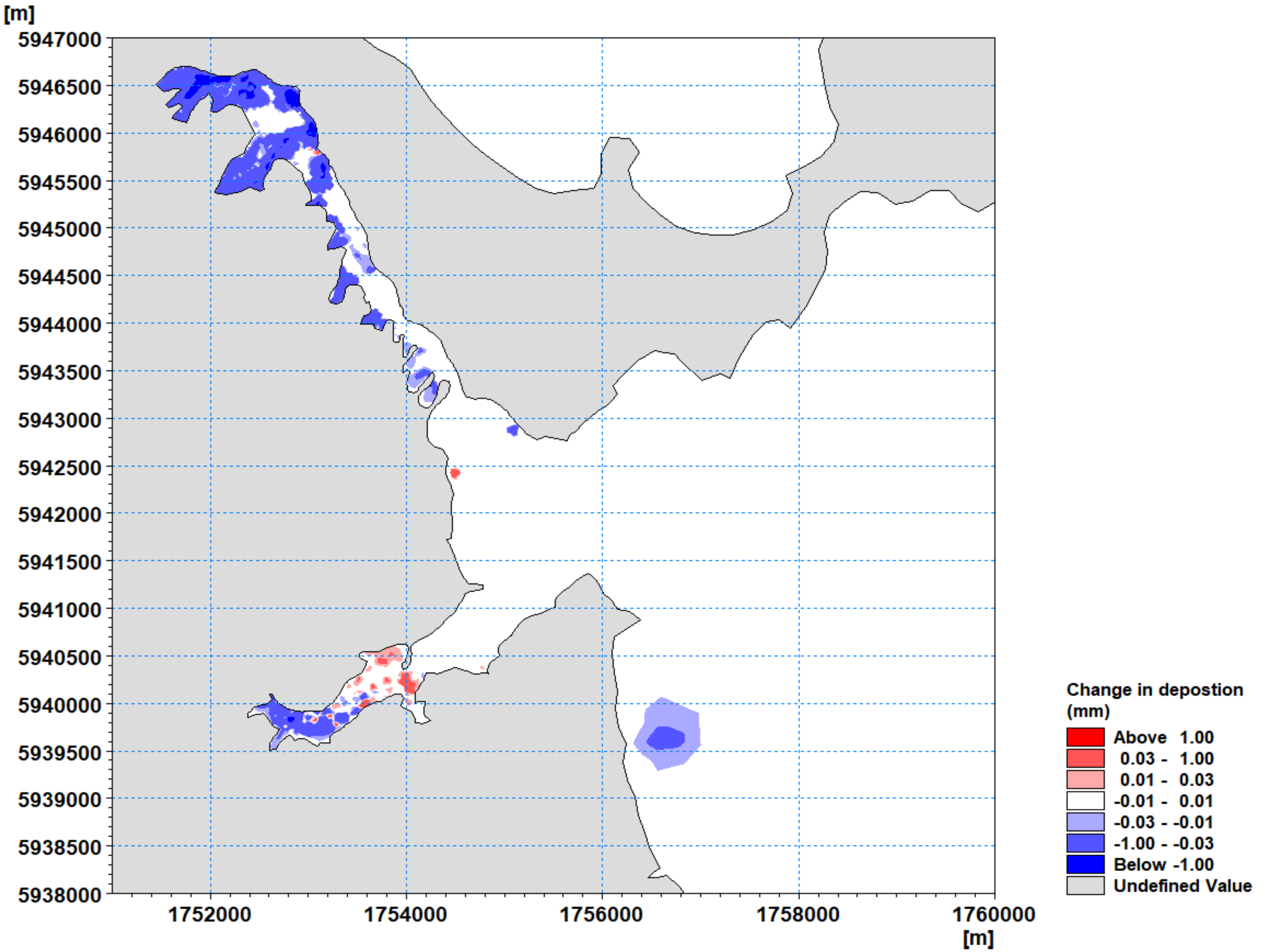


Figure 7-2. Predicted change in deposition (mm) at the end of the model simulation for Scenario 4 compared to Scenario 1.

Table 7-2. Change in mass of sediment deposited (kg) at the end of the model simulation within each of the subestuaries (Figure 2-4) for Scenario 4 compared to Scenario 1.

<table>
<tr><th>Subestuary</th><th>Sediment deposited Scenario 1 (kg)</th><th>Change in sediment deposited compared to Scenario 4 (kg)</th><th>% Change</th></tr>
<tr><td>Upper Okura</td><td>371290</td><td>-10895</td><td rowspan="3">-2.09%</td></tr>
<tr><td>Mid Okura</td><td>60141</td><td>1694</td></tr>
<tr><td>Outer Okura</td><td>165</td><td>-4</td></tr>
<tr><td>Karepiro (S)</td><td>471</td><td>-10</td><td>-2.06%</td></tr>
<tr><td>Karepiro (N)</td><td>4023</td><td>148</td><td>3.83%</td></tr>
<tr><td>Upper Wēiti</td><td>911175</td><td>-199083</td><td rowspan="3">-18.12%</td></tr>
<tr><td>Mid Wēiti</td><td>96996</td><td>-25857</td></tr>
<tr><td>Outer Wēiti</td><td>23617</td><td>-3352</td></tr>
<tr><td>Marine Reserve</td><td>32530</td><td>-5656</td><td>-14.81%</td></tr>
<tr><td>Outer Karepiro</td><td>3644</td><td>-232</td><td>-5.98%</td></tr>
<tr><td>Whangaparaoa</td><td>37216</td><td>-1978</td><td>-5.05%</td></tr>
</table>

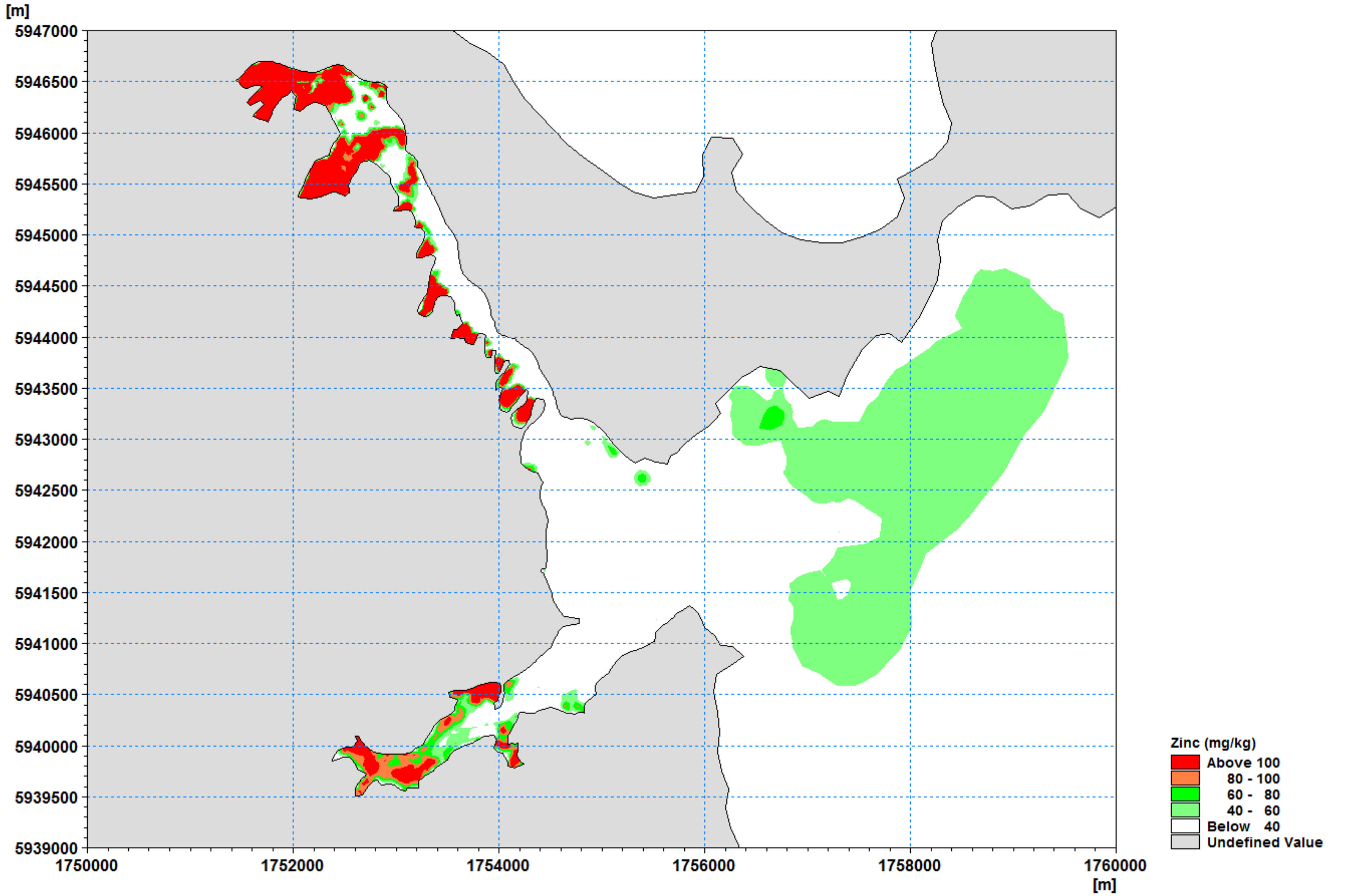


Figure 7-3. Zinc concentrations (mg/kg) 50 years from present under Scenario 4.

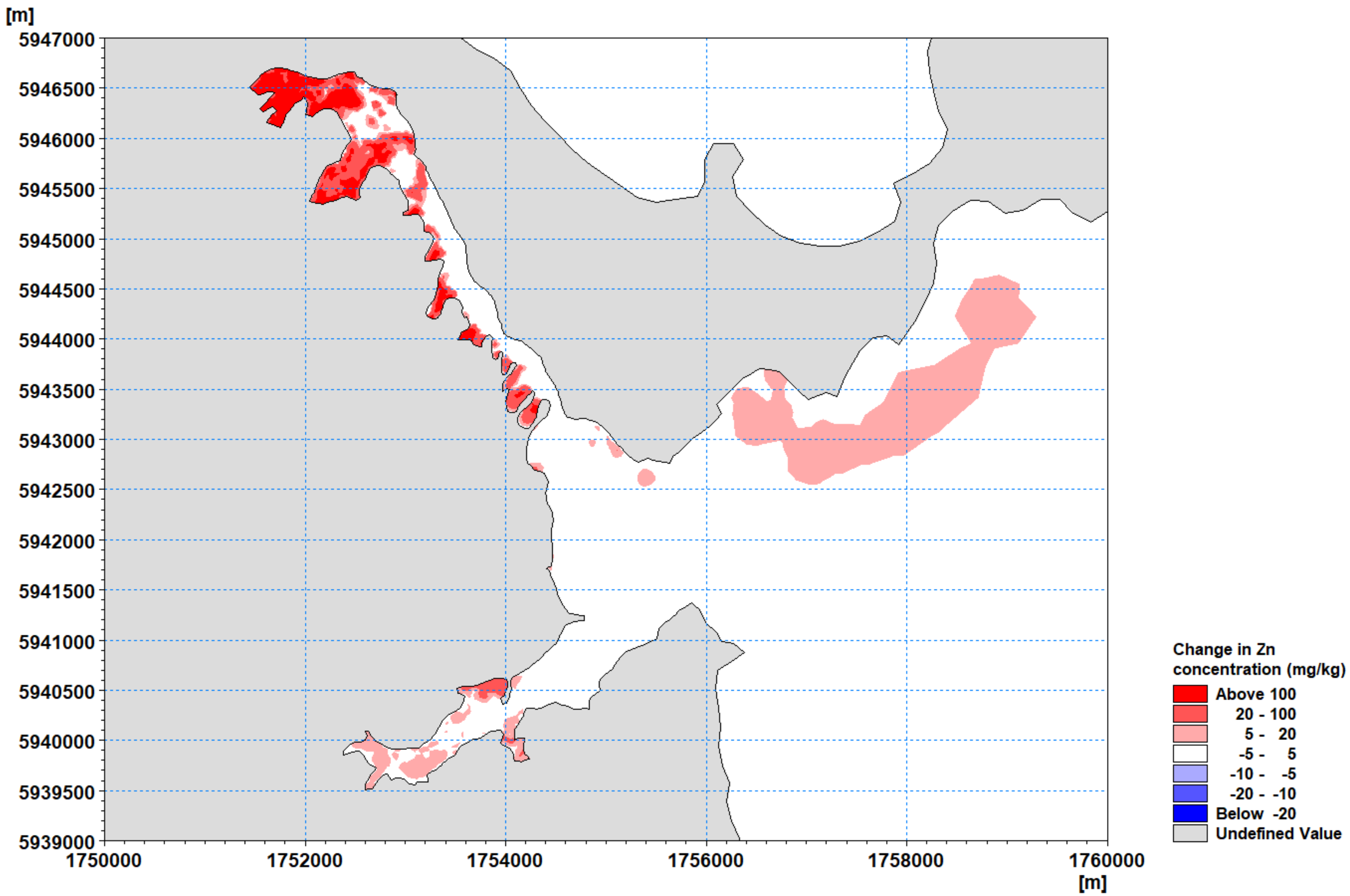


Figure 7-4. Changes in Zinc concentrations (mg/kg) 50 years from present under Scenario 4 (future growth development) compared to Scenario 1.

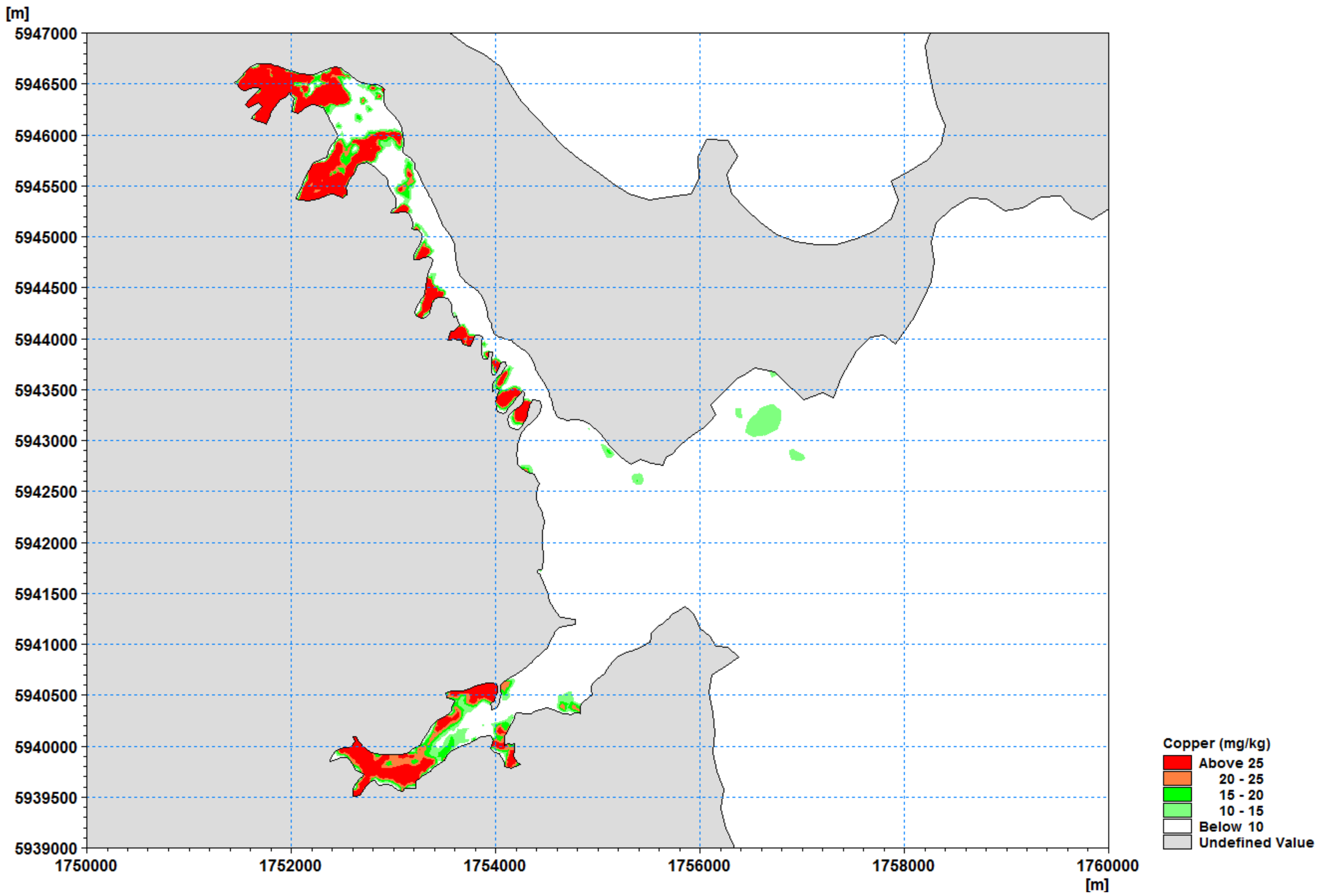


Figure 7-5. Copper concentrations (mg/kg) 50 years from present under Scenario 4.

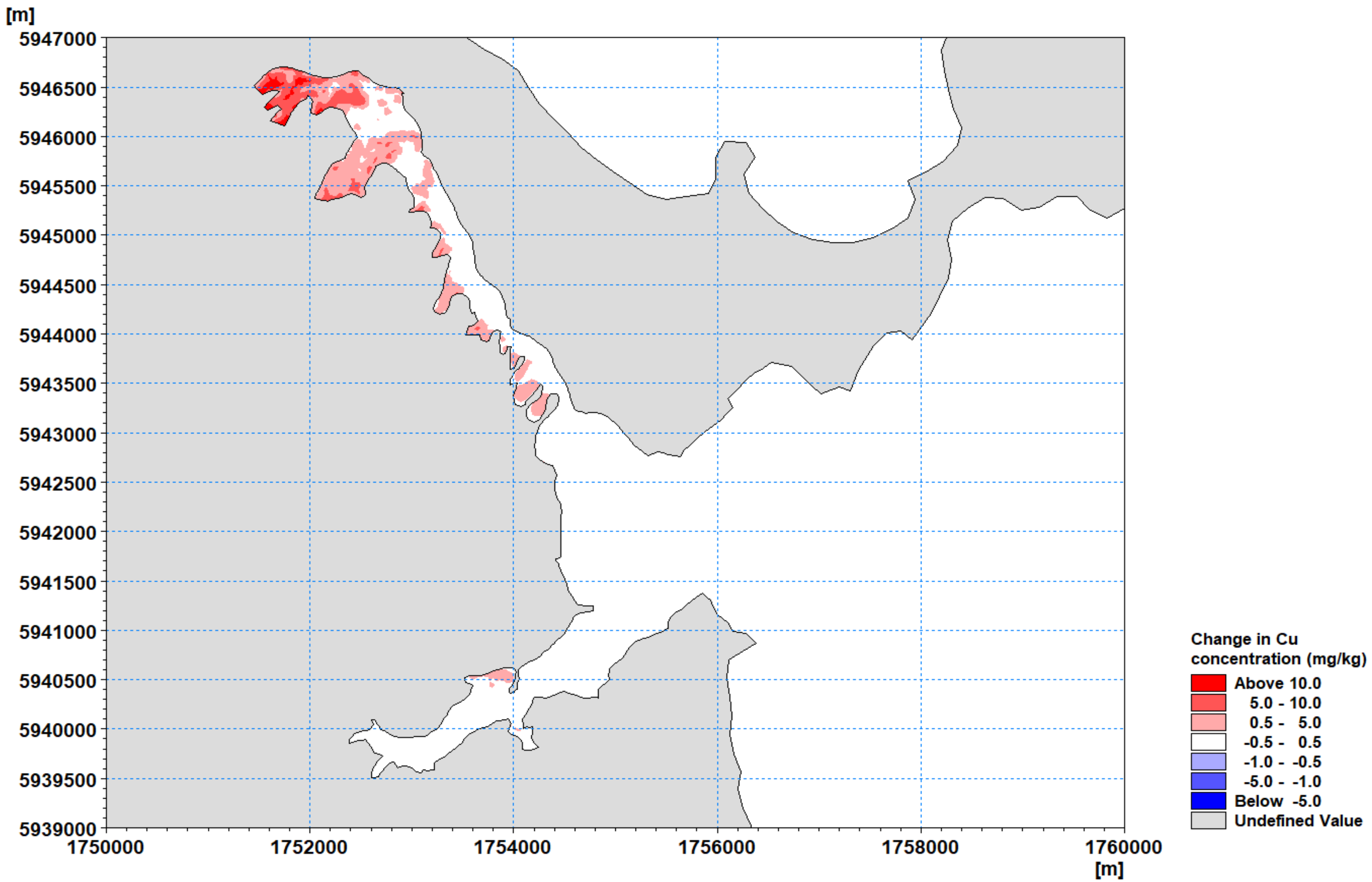


Figure 7-6. Changes in Copper concentrations (mg/kg) 50 years from present under Scenario 4 (future growth development) compared to Scenario 1.

Table 7-3. Future subestuary metal concentration (mg/kg) under Scenario 4 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Numbers in brackets show the predicted change under this Scenario compared to Scenario 1. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	87.4 (6.9)	23.9
Mid Okura subestuary concentration	53.5 (5.6)	12.7 (0.1)
Lower Okura subestuary concentration	26.2 (0.2)	5
Karepiro (S) subestuary concentration	26.4 (0.5)	5
Karepiro (N) subestuary concentration	27.5 (0.8)	5.2
Upper Wēiti subestuary concentration	190.9 (99.6)	28.4 (3.5)
Mid Wēiti subestuary concentration	96.3 (36)	15.6 (1.1)
Lower Wēiti subestuary concentration	84.6 (26.2)	14.4 (0.7)
Marine Reserve subestuary concentration	27 (0.4)	5
Outer Karepiro subestuary concentration	27.1 (0.5)	5
Whangaparaoa subestuary concentration	31.7 (2.2)	5.9
Total area (ha) where PEL is exceeded		
	46.3	0.0
Maximum Concentration (mg/kg)		
	464.7	59.7

8 Scenario 5

This scenario adds in development within the Future Growth area (Figure 2-3 **in addition to the 550 home development within the Wēiti Bay area and the Long Bay Structure Plan developments (Scenario 2).**

This scenario results in a reduced mean annual sediment load of 2100.4 tonnes/yr from all catchments. This is due to a combination of the reduction in sediment load from the Silverdale and Long Bay catchment outlets (Table 8-1) and increases for the North Arm, Stillwater, Wēiti South, Whangaparaoa, Wēiti North, North Outlet and Duck Creek catchment outlets.

Compared to Scenario 2, there is an increase in the mean annual load for Zinc (to 526.0 kg/yr) which is due to the significant increase in Zinc load from the Silverdale catchment outlet and a very small increase in Total Copper load.

The following are the maximum suspended sediment concentration that occurs at any time during the model simulation, the percentage of the model simulation time that a threshold of 80 mg/L is exceeded and the percentage change in mean SSC relative to Scenario 0 at the key sites (Figure 2-5).

Upper Okura
18 hours above 80 mg/L, maximum of 438 mg/L and -1.74 % change in SSC
Mid Okura
17.75 hours above 80 mg/L, maximum of 356 mg/L and -1.76 % change in SSC
Upper Wēiti
38.25 hours above 80 mg/L, maximum of 613 mg/L and -9.93 % change in SSC
Mid Wēiti
26 hours above 80 mg/L, maximum of 622 mg/L and -20.23 % change in SSC
Karepiro
10 hours above 80 mg/L, maximum of 1359 mg/L and -5.2 % change in SSC
Wēiti Delta
4.75 hours above 80 mg/L, maximum of 102 mg/L and -14.95 % change in SSC
Outer Karepiro
0 hours above 80 mg/L, maximum of 15 mg/L and -12.26 % change in SSC
Arkle Bay
0 hours above 80 mg/L, maximum of 31 mg/L and -10.77 % change in SSC
Long Bay
0 hours above 80 mg/L, maximum of 8 mg/L and -7.14 % change in SSC

Figure 8-1 shows the deposition at the end of the simulation under this Scenario. The combined effect of this scenario in terms of deposition are reductions in deposition within the main depostional sinks within the Okura estuary and Wēiti river and offshore of Long Bay (Figure 8-2) and small pockets of increased deposition within the Okura estuary and near the Karepiro Beach catchment outlet. At a subestuary level, there are reduced levels of deposition within each of the subestuaries except the northern Karepiro subestuary (Table 8-2).

Future Zinc concentrations increase within the main depostional zones in the Wēiti river, Okura estuary and offshore of Arkle Bay (Figure 8-4) while future Copper concentrations increase within the Wēiti river and in the middle sections of the Okura estuary, landward of the spit opposite Okura township (Figure 8-6). These results are driven primarily by the large increases in metal Zinc concentrations for the Silverdale and Long Bay catchment outlets. This occurs because of the decreases in sediment loads and increases in metal loads (Table 8-1).

There are 46.3 hectares of the Wēiti river where the PEL for Zinc is exceeded (Table 8-3).

Table 8-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 5. Number in brackets indicating magnitude of change compared to Scenario 2.

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa Wēiti North	North Outlet	Duck Creek
Sediment (tonnes/yr)	57.3	121.5 (-10.7)	16.9	35.8	26.7	27.1	589.9	194.1 (-0.1)	10.9	28.2	32.7	31.5 (3.2)	219.4 (4.3)	601 (-200.7)	23.7	14.6 (1.6)	18.4 (0.7)	36.3 (3.4)
Zn (kg/yr)	55.5	25 (6.9)	1.3	4.5	3.5	6.9	49.5	15	0.7	7.4	10.3	11.7 (0.3)	18.3 (1.6)	280.1 (165)	15.2	6.6	1.7 (0.6)	6.2 (0.1)
Cu (kg/yr)	7.7	4.6 (0.4)	0.6	1.3	1	1.4	15	5.4	0.2	1.2	1.7	1.8	6.4 (0.3)	33.8	2.2	1.2	0.6	1.7
Runoff (m^3 x 10^3/year)	2164	2549 (474)	369	477	428	463	6622	3573 (2)	379	950	1538	850 (-2)	2157 (-617)	15276 (1825)	677	462 (-1)	468 (2)	707 (-16)
Zinc Concentration (mg/kg)	2073	707 (221)	195	282	243	541	154	204	78	328	474	473 (-39)	249 (16)	1054 (721)	1002	651 (-78)	224 (66)	319 (-35)
Copper Concentration (mg/kg)	288	130 (16)	82	83	69	111	47	73	28	55	79	74 (-5)	87 (2)	127 (30)	142	114 (-14)	83 (5)	86 (-11)

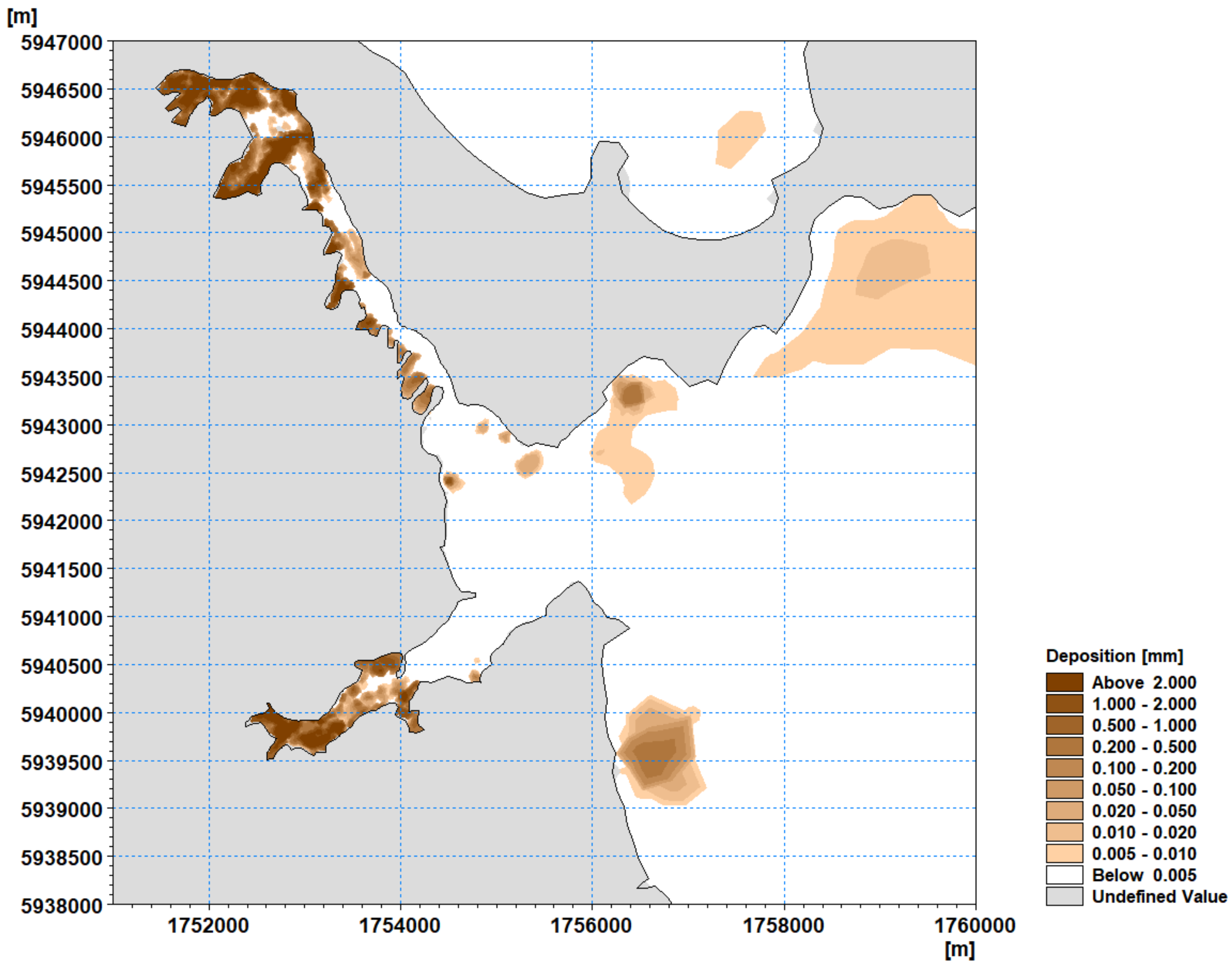
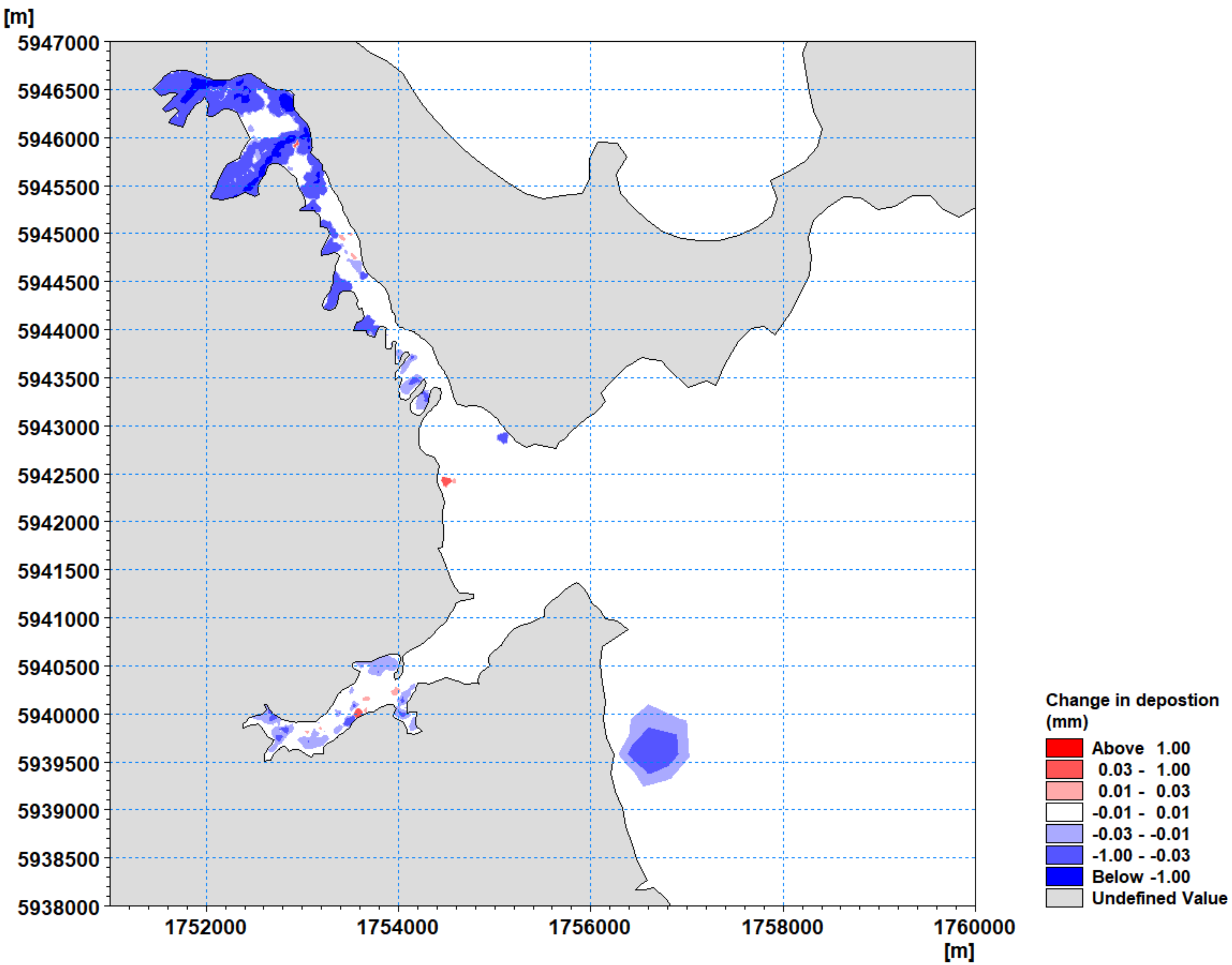


Figure 8-1. Deposition at the end of the model simulation for Scenario 5. The period modelled (January-July 2018) consists of typical wind and rain conditions and a range of events which in total deliver 35% more catchment derived sediment than the long term annual average sediment load.



[m]
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1758000
1760000
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Change in depostion (mm)
Above 1.00
0.03 - 1.00
0.01 - 0.03
-0.01 - 0.01
-0.03 - -0.01
-1.00 - -0.03
Below -1.00
Undefined Value

Figure 8-2. Predicted change in deposition at the end of the model simulation for Scenario 5 compared to Scenario 2.

Table 8-2. Change in mass of sediment deposited (kg) at the end of the model simulation within each of the subestuaries (Figure 2-4) for Scenario 5 compared to Scenario 2.

Subestuary	Mass deposited Scenario 2 (kg)	Change in sediment deposited compared to Scenario 5 (kg)	% Change
Upper Okura	372381	-1667	-0.57%
Mid Okura	60753	-822	
Outer Okura	166	1	
Karepiro (S)	477	-2	-0.47%
Karepiro (N)	4157	282	7.29%
Upper Wēiti	909560	-222835	-19.36%
Mid Wēiti	99147	-22001	
Outer Wēiti	23720	-2974	
Marine Reserve	32524	-5652	-14.81%
Outer Karepiro	3662	-205	-5.30%
Whangaparaoa	37203	-2078	-5.29%

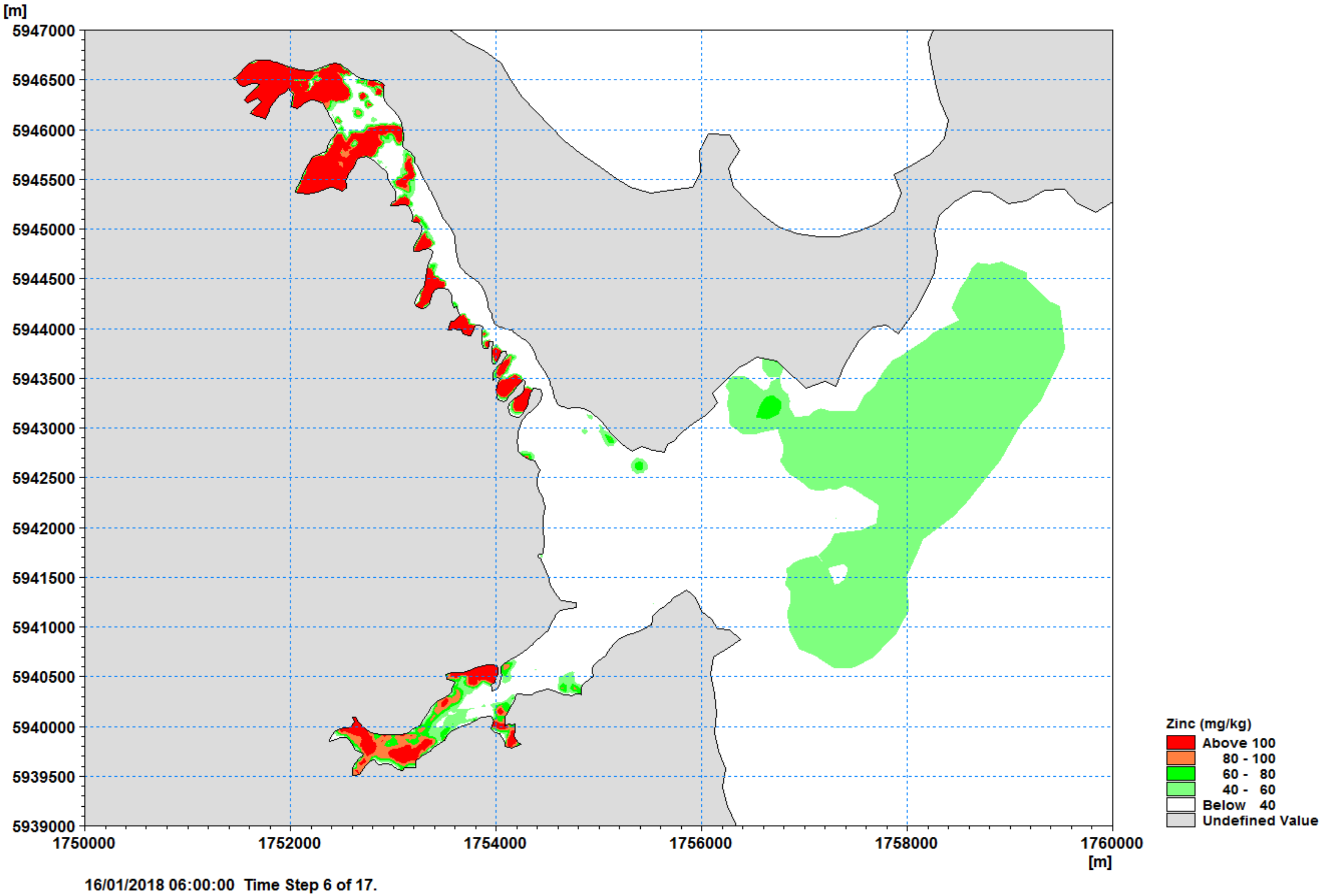

Figure 8-3. Zinc concentrations (mg/kg) 50 years from present under Scenario 5.

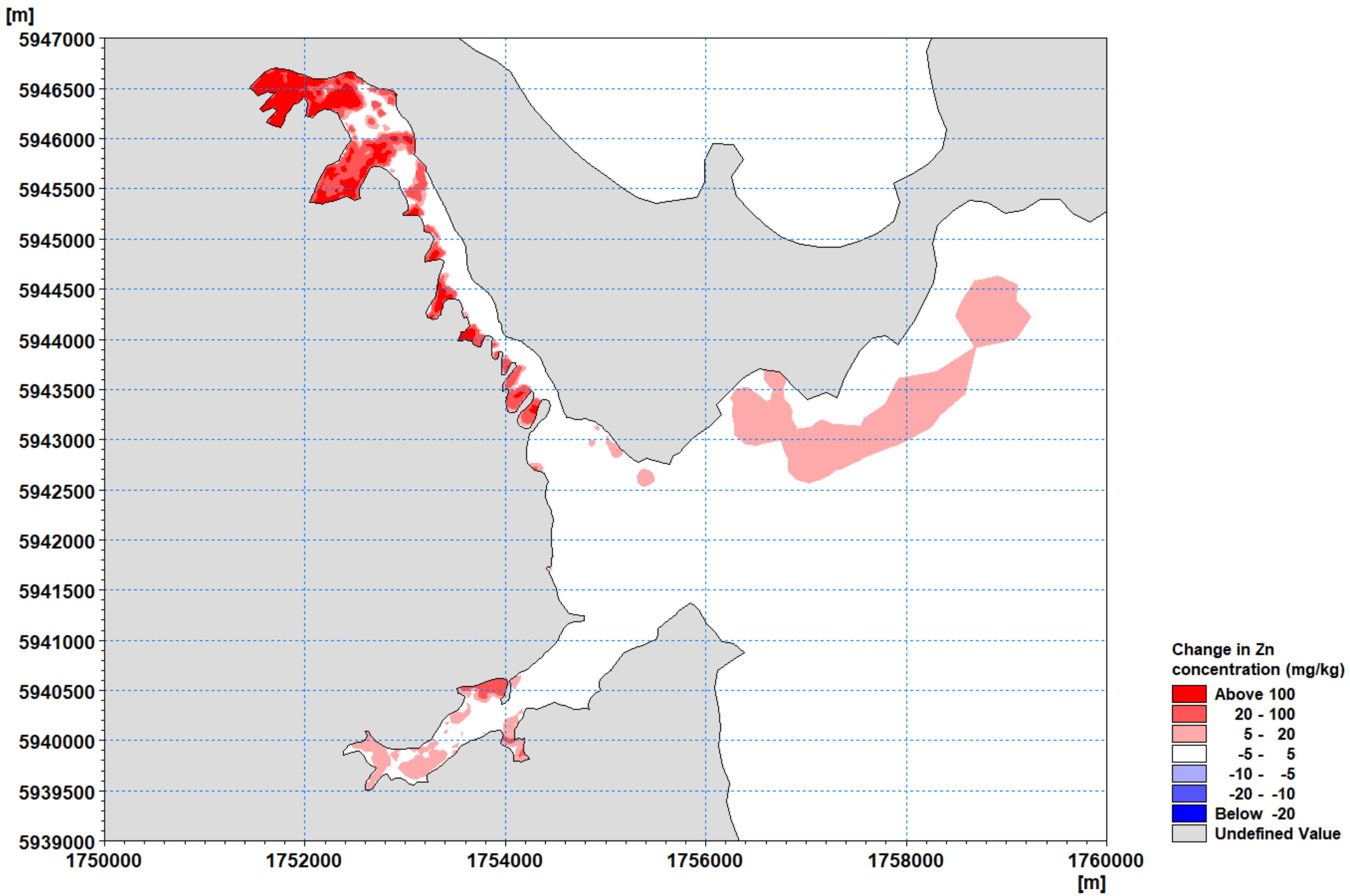

Figure 8-4. Changes in Zinc concentrations (mg/kg) 50 years from present under Scenario 5 compared to Scenario 2.

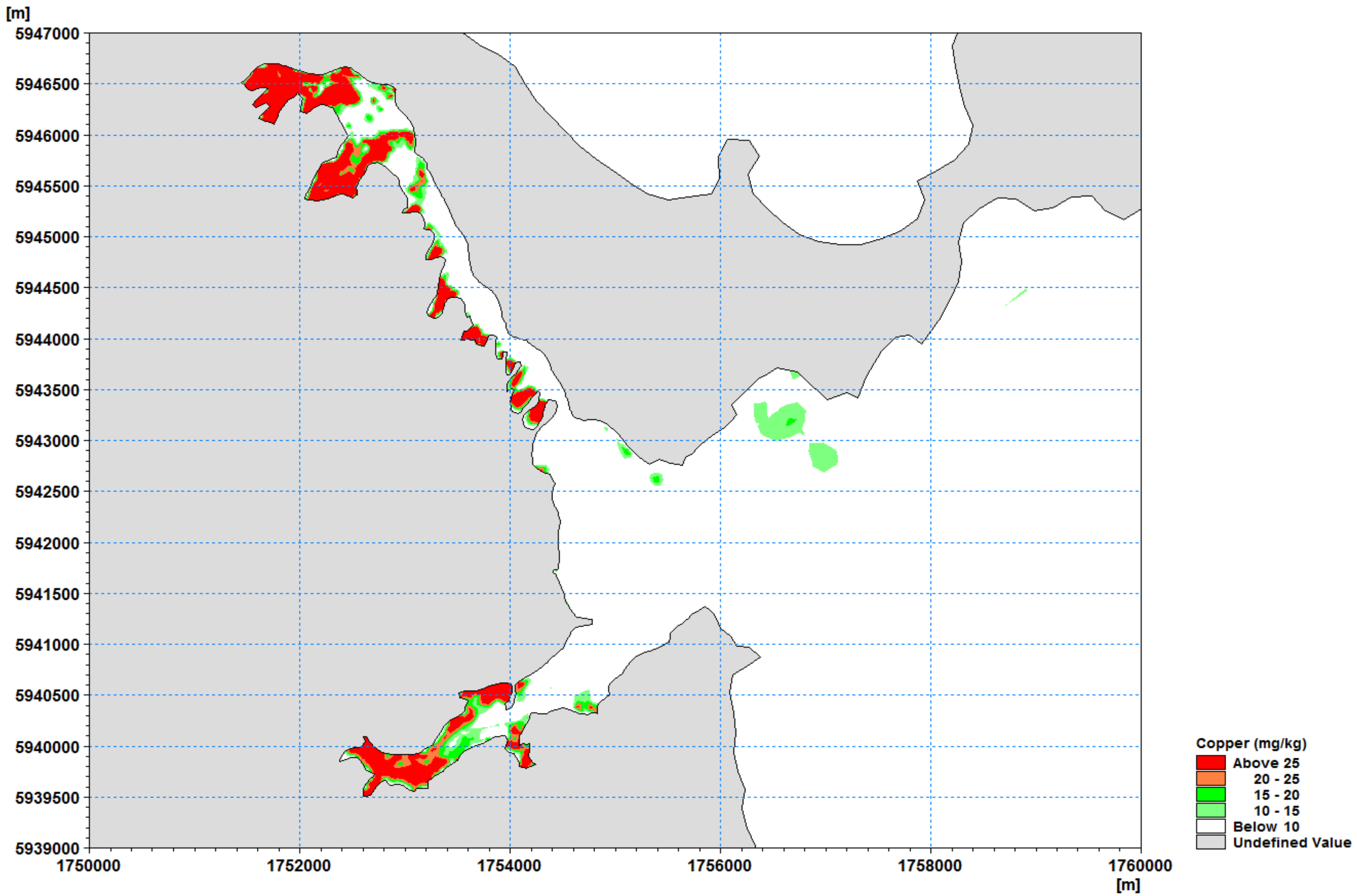

Figure 8-5. Future Copper concentration (mg/kg) 50 years from present under Scenario 5.

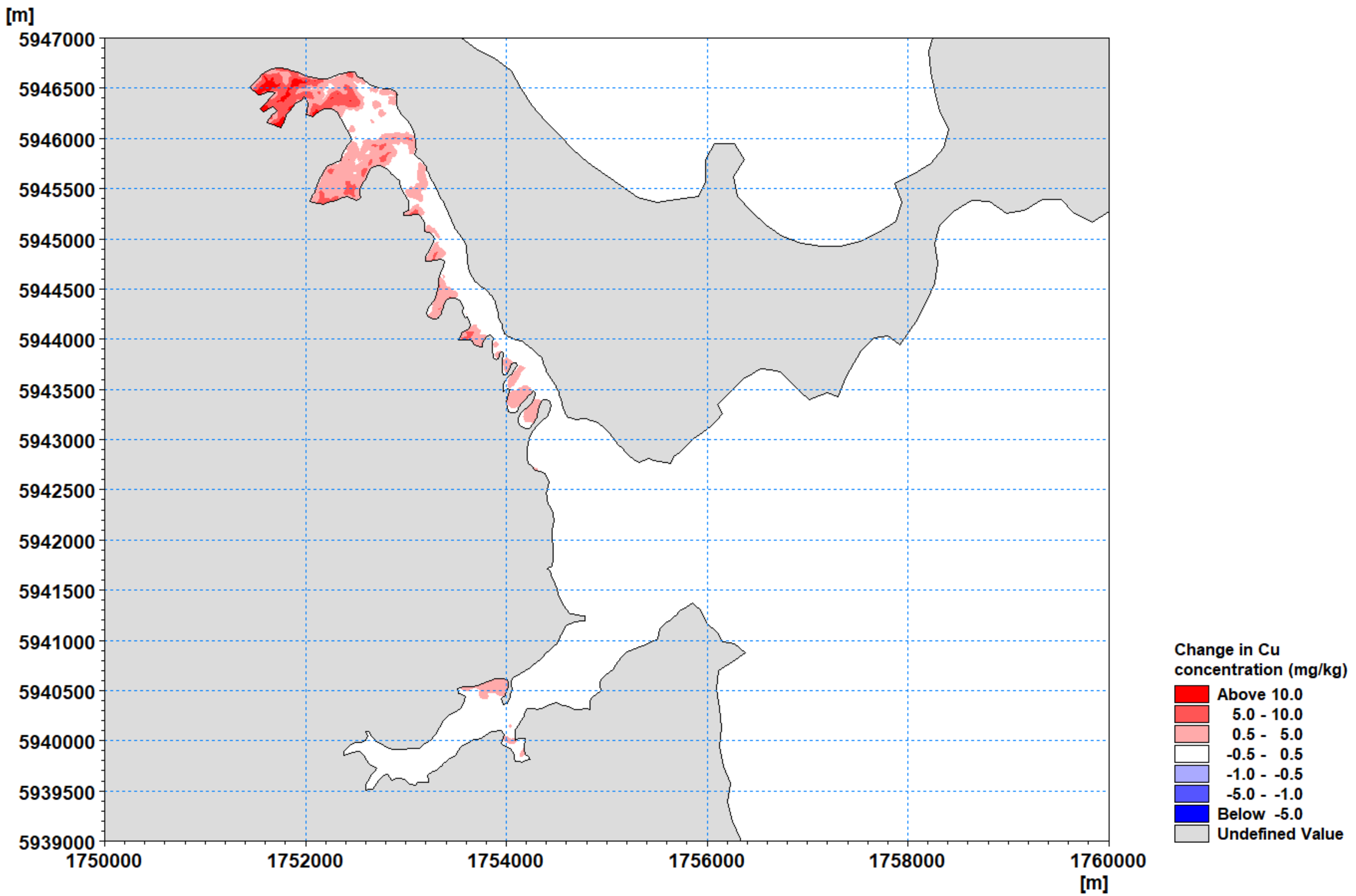

Figure 8-6. Changes in Copper concentrations (mg/kg) 50 years from present under Scenario 5 compared to Scenario 2.

Table 8-3. Future subestuary metal concentration (mg/kg) under Scenario 5 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Numbers in brackets show the predicted change under this Scenario compared to Scenario 2. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	99.4 (7.3)	25 (0.2)
Mid Okura subestuary concentration	62.9 (5.7)	13.6 (0.1)
Lower Okura subestuary concentration	26.6 (0.2)	5.0
Karepiro (S) subestuary concentration	27.3 (0.5)	5.1
Karepiro (N) subestuary concentration	28.9 (0.8)	5.4
Upper Wēiti subestuary concentration	198.5 (99.9)	29.1 (3.6)
Mid Wēiti subestuary concentration	101.4 (36.2)	16.0 (1.2)
Lower Wēiti subestuary concentration	91.4 (26.3)	15.1 (0.8)
Marine Reserve subestuary concentration	27.1 (0.4)	5.0
Outer Karepiro subestuary concentration	27.2 (0.5)	5.0
Whangaparaoa subestuary concentration	33.3 (2.2)	6.0
Total area (ha) where PEL is exceeded		
	46.3	0.0
Maximum Concentration (mg/kg)		
	464.7	59.9

9 Scenario 6

This scenario adds in development within the Future Growth area (Figure 2-3 **in addition to the 1200 home development within the Wēiti Bay area and the Long Bay Structure Plan developments (Scenario 3).**

This scenario results in a reduced mean annual sediment load of 2103 tonnes/yr from all catchments. This is due to a combination of the reduction in sediment load from the Silverdale, North Arm and Long Bay catchment outlets (Table 9-1) and increases for the Stillwater, Wēiti South, Whangaparaoa, Wēiti North, North Outlet and Duck Creek catchment outlets.

Compared to Scenario 3, there is an increase in the mean annual load for Zinc (to 526.4 kg/yr) which is due to the significant increase in Zinc load from the Silverdale catchment outlet and a very small increase in Total Copper load.

The following are the maximum suspended sediment concentration that occurs at any time during the model simulation, the percentage of the model simulation time that a threshold of 80 mg/L is exceeded and the percentage change in mean SSC relative to Scenario 0 at the key sites (Figure 2-5).

Upper Okura
18.25 hours above 80 mg/L, maximum of 438 mg/L and -1.75 % change in SSC
Mid Okura
17.5 hours above 80 mg/L, maximum of 357 mg/L and -1.8 % change in SSC
Upper Wēiti
38 hours above 80 mg/L, maximum of 610 mg/L and -9.94 % change in SSC
Mid Wēiti
26.25 hours above 80 mg/L, maximum of 616 mg/L and -20.24 % change in SSC
Karepiro
10 hours above 80 mg/L, maximum of 1388 mg/L and -5.32 % change in SSC
Wēiti Delta
4.75 hours above 80 mg/L, maximum of 102 mg/L and -15.03 % change in SSC
Outer Karepiro
0 hours above 80 mg/L, maximum of 15 mg/L and -12.17 % change in SSC
Arkle Bay
0 hours above 80 mg/L, maximum of 31 mg/L and -10.71 % change in SSC
Long Bay
0 hours above 80 mg/L, maximum of 8 mg/L and -6.99 % change in SSC

The combined effect of this scenario in terms of deposition are reductions in deposition within the main depostional sinks with the Okura estuary and Wēiti river and offshore of Long Bay Figure 9-2) with small areas of increased deposition in the upper section of the Okura estuary. At a subestuary level, there are reduced levels of deposition within each of the subestuaries (Table 9-2).

As for Scenario 5, future Zinc concentrations increase within the main depostional zones in the Wēiti river, Okura estuary and offshore of Arkle Bay (Figure 9-4) while future Copper concentrations increase within the Wēiti river and in the middle sections of the Okura estuary (Figure 9-6). These results are driven primarily by the large increases in metal Zinc concentrations for the Silverdale and Long Bay catchment outlets. This occurs because of the decrease in sediment loads and increase in metal loads under this Scenario (Table 9-1). There are 48.3 hectares of the Wēiti river where the PEL for Zinc is exceeded (Table 9-3).

Table 9-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 6. Number in brackets indicating magnitude of change compared to Scenario 3.

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa Wēiti North	North Outlet	Duck Creek
Sediment (tonnes/yr)	57.3	121.5 (-10.7)	16.9	35.8	26.7	27.1	589.9	194.1 (-0.1)	10.9	28.2	35.3	31.5 (3.2)	219.4 (4.3)	601 (-200.7)	23.7	14.6 (1.6)	18.4 (0.7)	36.3 (3.4)
Zn (kg/yr)	55.5	25 (6.9)	1.3	4.5	3.5	6.9	49.5	15	0.7	7.6	10.5	11.7 (0.3)	18.3 (1.6)	280.1 (165.0)	15.2	6.6	1.7 (0.6)	6.2 (0.1)
Cu (kg/yr)	7.7	4.6 (0.4)	0.6	1.3	1	1.4	15	5.4	0.2	1.3	1.8	1.8	6.4 (0.3)	33.8	2.2	1.2	0.6	1.7
Runoff (m^3 x 10^3/year)	2164	2549	369	477	428	463	6622	3573	379	952 (1)	1544 (5)	850	2157	15276	677	462	468	707
Zinc Concentration (mg/kg)	2073	707 (221)	195	282	243	541	154	204	78	336	443	473 (-39)	249 (16)	1054 (721)	1002	651 (-78)	224 (66)	319 (-35)
Copper Concentration (mg/kg)	288	130 (16)	82	83	69	111	47	73	28	56	75	74 (-5)	87 (2)	127 (30)	142	114 (-14)	83 (5)	86 (-11)

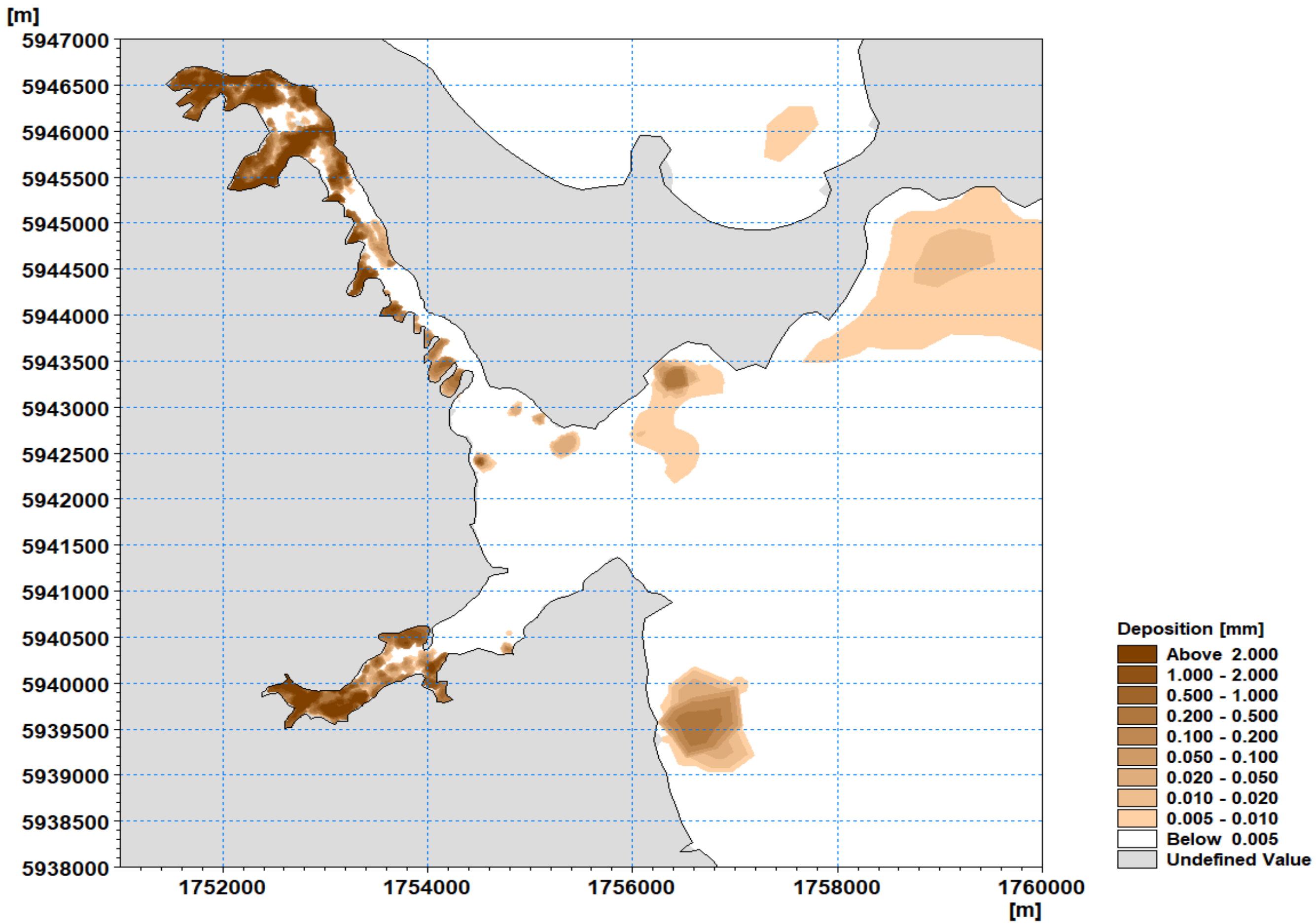

Figure 9-1. Deposition at the end of the model simulation for Scenario 6. The period modelled (January-July 2018) consists of typical wind and rain conditions and a range of events which in total deliver 35% more catchment derived sediment than the long term annual average sediment load.

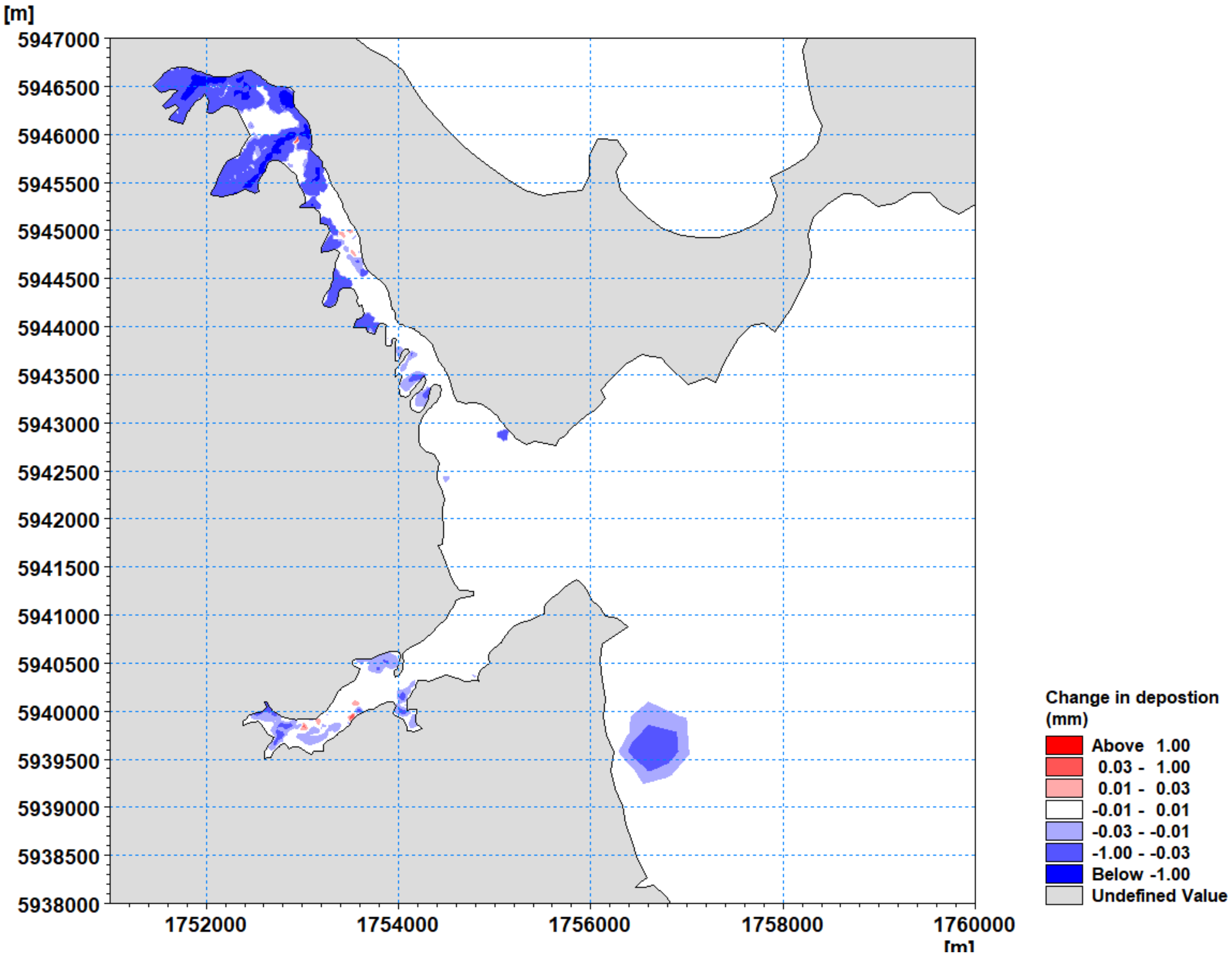

Figure 9-2. Predicted change in deposition at the end of the model simulation for Scenario 6 compared to Scenario 3.

Table 9-2. Change in sediment deposited (kg) at the end of the model simulation within each of the subestuaries (Figure 2-4) for Scenario 6 compared to Scenario 3.

<table>
<tr><th>Subestuary</th><th>Mass deposited Scenario 3 (kg)</th><th>Change in sediment deposited compared to Scenario 6 (kg)</th><th>% Change</th></tr>
<tr><td>Upper Okura</td><td>372881</td><td>-1392</td><td rowspan="3">-0.58%</td></tr>
<tr><td>Mid Okura</td><td>60607</td><td>-1135</td></tr>
<tr><td>Outer Okura</td><td>162</td><td>-6</td></tr>
<tr><td>Karepiro (S)</td><td>472</td><td>-5</td><td>-1.09%</td></tr>
<tr><td>Karepiro (N)</td><td>3524</td><td>-395</td><td>-10.08%</td></tr>
<tr><td>Upper Wēiti</td><td>910975</td><td>-219905</td><td rowspan="3">-19.27%</td></tr>
<tr><td>Mid Wēiti</td><td>98319</td><td>-23868</td></tr>
<tr><td>Outer Wēiti</td><td>23800</td><td>-2891</td></tr>
<tr><td>Marine Reserve</td><td>32553</td><td>-5650</td><td>-14.79%</td></tr>
<tr><td>Outer Karepiro</td><td>3678</td><td>-198</td><td>-5.11%</td></tr>
<tr><td>Whangaparaoa</td><td>37299</td><td>-2047</td><td>-5.20%</td></tr>
</table>

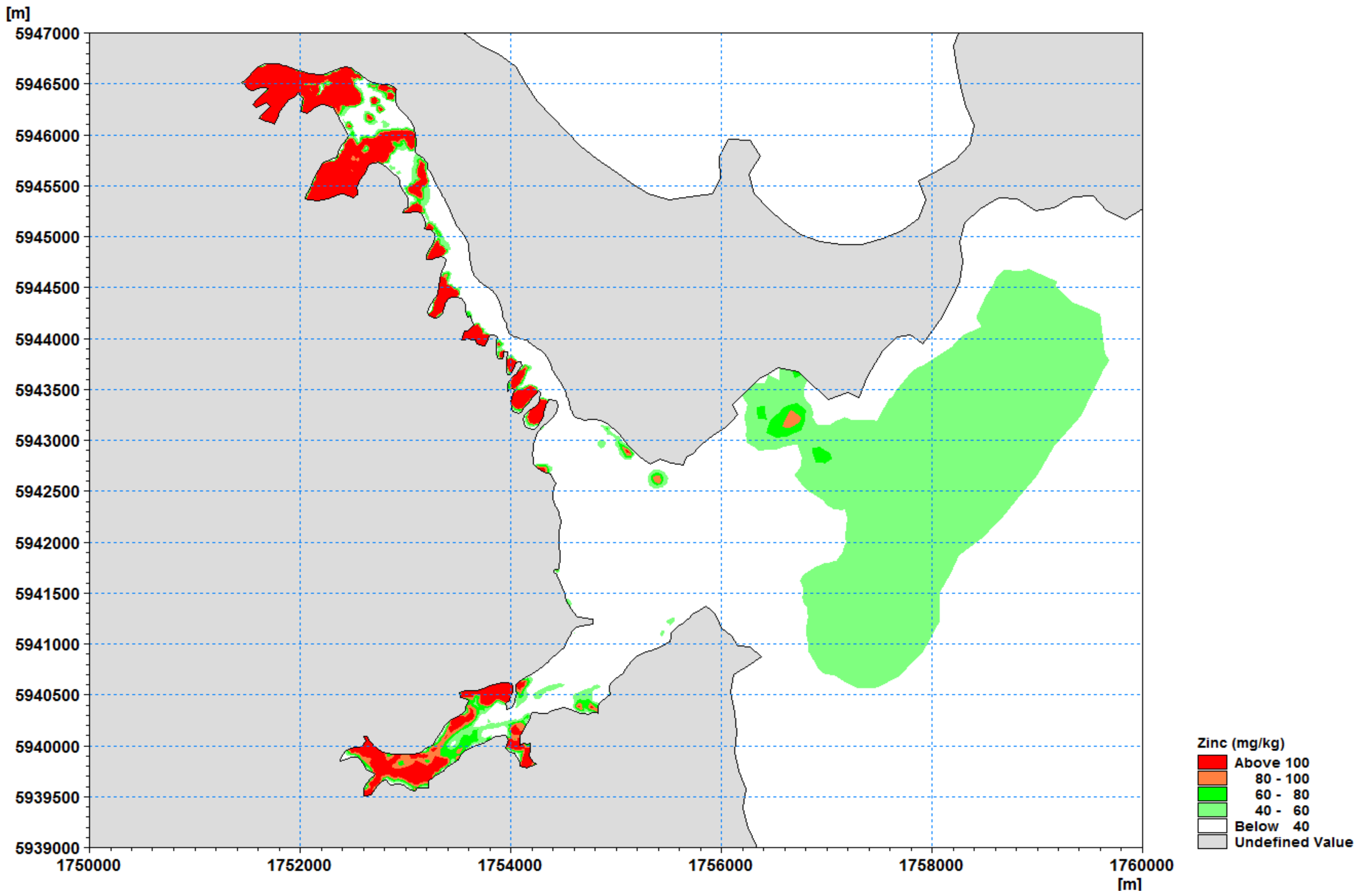

Figure 9-3. Zinc concentrations (mg/kg) 50 years from present under Scenario 6.

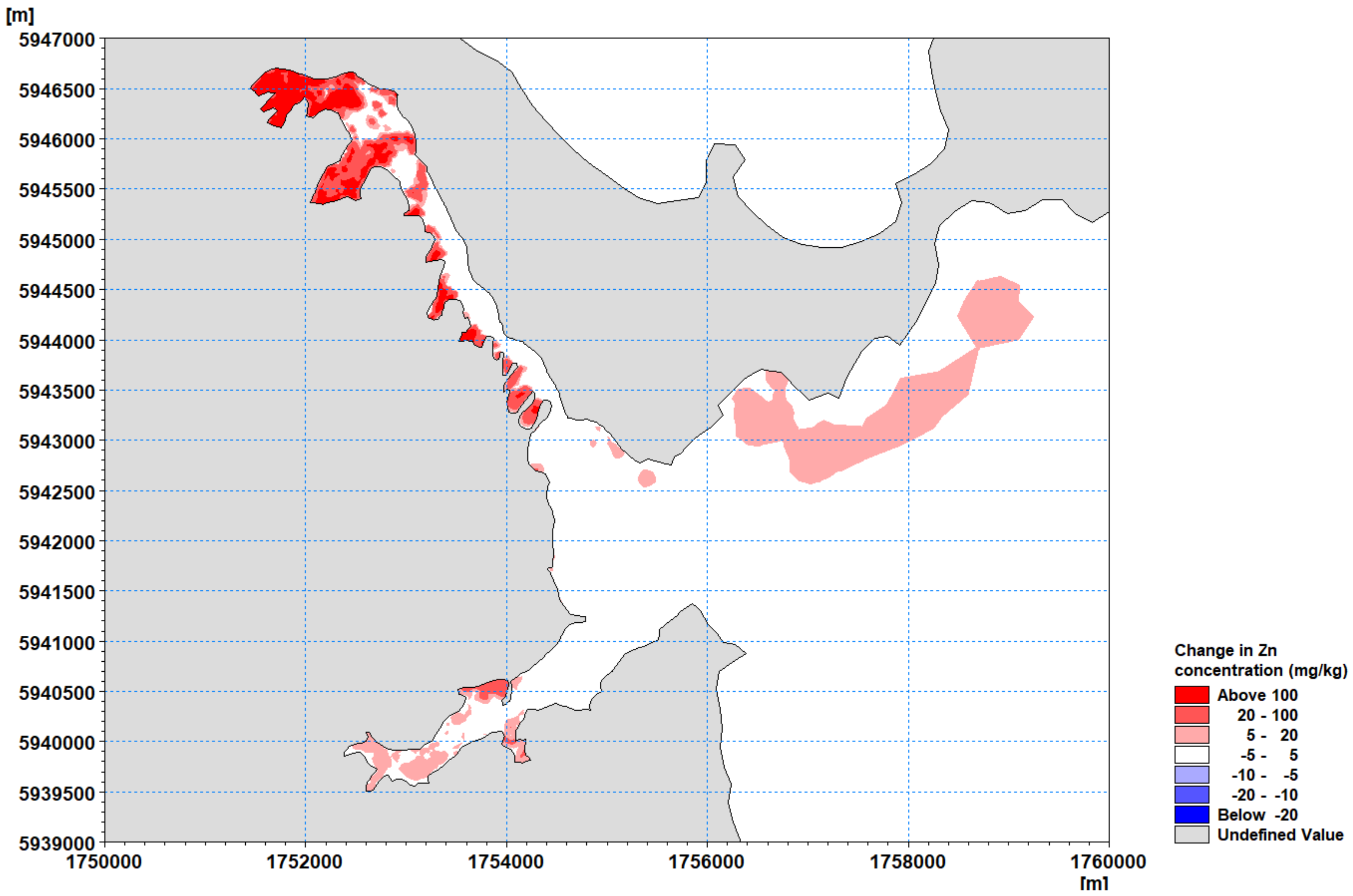

Figure 9-4. Changes in Zinc concentrations (mg/kg) 50 years from present under Scenario 6 compared to Scenario 3.

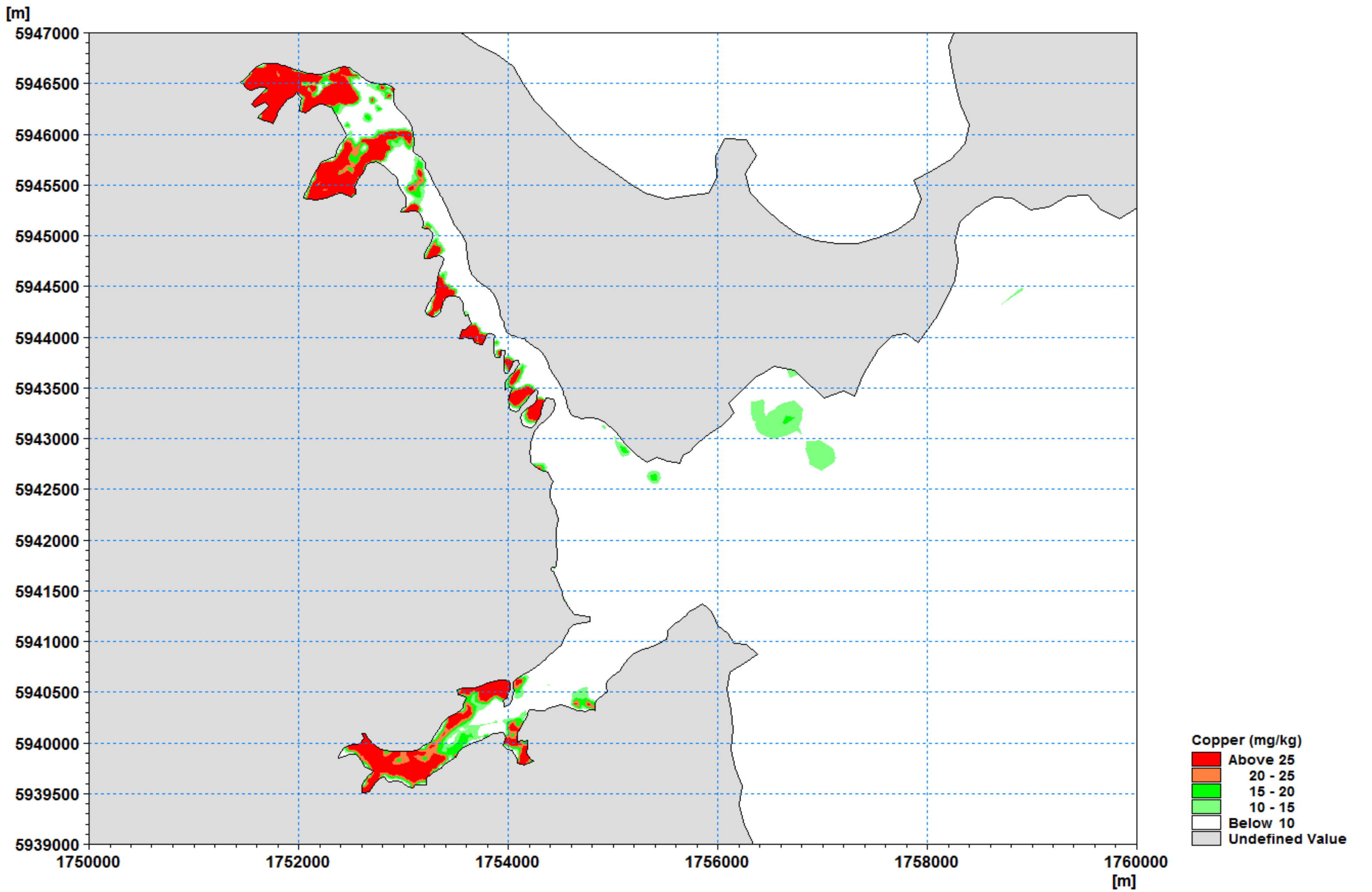

Figure 9-5. Copper concentration (mg/kg) 50 years from present under Scenario 6.

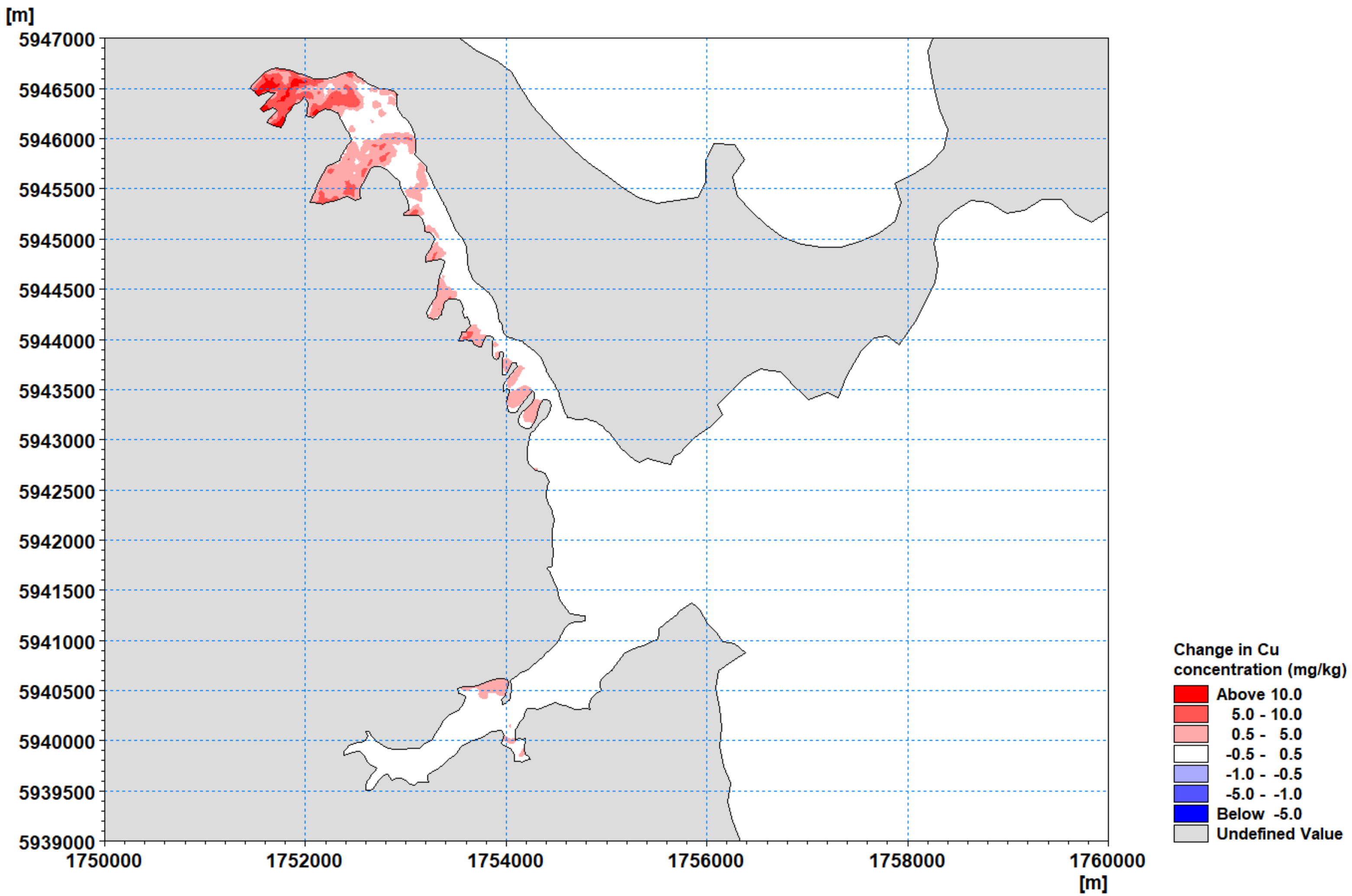

Figure 9-6. Changes in Copper concentrations (mg/kg) 50 years from present under Scenario 6 compared to Scenario 3.

Table 9-3. Future subestuary metal concentration (mg/kg) under Scenario 6 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Numbers in brackets show the predicted change under this Scenario compared to Scenario 5. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	99.3 (7.3)	25 (0.2)
Mid Okura subestuary concentration	62.9 (5.7)	13.6 (0.1)
Lower Okura subestuary concentration	26.6 (0.2)	5.0
Karepiro (S) subestuary concentration	27.3 (0.5)	5.1
Karepiro (N) subestuary concentration	28.9 (0.8)	5.4
Upper Wēiti subestuary concentration	198.1 (99.5)	29.1 (3.6)
Mid Wēiti subestuary concentration	101.2 (35.9)	16 (1.2)
Lower Wēiti subestuary concentration	91.1 (26)	15 (0.8)
Marine Reserve subestuary concentration	27.1 (0.4)	5.0
Outer Karepiro subestuary concentration	27.2 (0.5)	5.0
Whangaparaoa subestuary concentration	33.3 (2.2)	6.0
Total area (ha) where PEL is exceeded		
	48.3	0.0
Maximum Concentration (mg/kg)		
	466.6	59.8

10 Scenario 7

This scenario applies a global reduction in Zinc and Copper and the sediment loads associated with Scenario 6 (Future Growth plus 1200 home development within the Wēiti Bay area and Long Bay Structure Plan development).

This results in the mean annual sediment load from all catchments is 2105.3 tonnes/yr with reductions in mean annual loads to 260.9 kg/yr for Total Zinc and 44.7 kg/yr for Total Copper.

Compared to Scenario 6, Zinc and Copper loads decrease for all catchment outlets (Table 10-1).

The following are the maximum suspended sediment concentration that occurs at any time during the model simulation, the percentage of the model simulation time that a threshold of 80 mg/L is exceeded and the percentage change in mean SSC relative to Scenario 0 at the key sites (Figure 2-5).

Upper Okura
18.25 hours above 80 mg/L, maximum of 438 mg/L and -1.66 % change in SSC
Mid Okura
17.5 hours above 80 mg/L, maximum of 357 mg/L and -1.59 % change in SSC
Upper Wēiti
37.5 hours above 80 mg/L, maximum of 611 mg/L and -10.23 % change in SSC
Mid Wēiti
26 hours above 80 mg/L, maximum of 622 mg/L and -20.24 % change in SSC
Karepiro
10 hours above 80 mg/L, maximum of 1391 mg/L and -4.99 % change in SSC
Wēiti Delta
4.75 hours above 80 mg/L, maximum of 102 mg/L and -15.02 % change in SSC
Outer Karepiro
0 hours above 80 mg/L, maximum of 15 mg/L and -12.08 % change in SSC
Arkle Bay
0 hours above 80 mg/L, maximum of 31 mg/L and -10.59 % change in SSC
Long Bay
0 hours above 80 mg/L, maximum of 8 mg/L and -6.84 % change in SSC

There are only small changes deposition within the Okura estuary and Wēiti river (Figure 10-2) and minor changes to deposition elsewhere.

Because of the significant reduction on metal loads, there are widespread reductions in future metal concentrations (Figure 10-4 and Figure 10-6) across all the subestuaries (Table 10-3). The PEL thresholds are not exceeded.

Table 10-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 7. Number in brackets indicating magnitude of change compared to Scenario 6.

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa Wēiti North	North Outlet	Duck Creek
Sediment (tonnes/yr)	57.3	121.5	16.9	35.8	26.7	27.1	589.9	194.1	10.8	30.5 (2.3)	36.2 (0.9)	31.5	219.4	599.9 (-1.0)	23.7	14.6	18.4	36.3
Zn (kg/yr)	27.8 (-27.7)	12.5 (-12.5)	0.7 (-0.6)	2.3 (-2.2)	1.7 (-1.8)	3.4 (-3.5)	24.7 (-24.8)	7.5 (-7.5)	0.2 (-0.5)	3.0 (-4.6)	5.1 (-5.4)	5.9 (-5.8)	9.2 (-9.1)	138.8 (-141.3)	7.6 (-7.6)	3.3 (-3.3)	0.8 (-0.9)	3.1 (-3.1)
Cu (kg/yr)	3.9 (-3.8)	2.3 (-2.3)	0.3 (-0.3)	0.7 (-0.6)	0.5 (-0.5)	0.7 (-0.7)	7.5 (-7.5)	2.7 (-2.7)	0.1 (-0.1)	0.6 (-0.7)	0.9 (-0.9)	0.9 (-0.9)	3.2 (-3.2)	17.0 (-16.8)	1.1 (-1.1)	0.6 (-0.6)	0.3 (-0.3)	0.8 (-0.9)
Runoff (m^3 x 10^3/year)	2164	2549	369	477	428	463	6622	3573	379	948 (-4)	1543	850	2157	15262 (-14)	677	462	468	707
Zinc Concentration (mg/kg)	1036 (-1036)	354 (-354)	98 (-98)	141 (-141)	121 (-122)	270 (-271)	77 (-77)	102 (-102)	24 (-54)	122 (-214)	208 (-236)	238 (-235)	124 (-125)	523 (-531)	501 (-501)	326 (-325)	112 (-112)	160 (-159)
Copper Concentration (mg/kg)	144 (-144)	65 (-65)	41 (-41)	41 (-41)	35 (-35)	55 (-55)	23 (-24)	37 (-37)	12 (-17)	24 (-32)	37 (-39)	38 (-37)	44 (-44)	64 (-63)	71 (-71)	57 (-57)	42 (-42)	43 (-43)

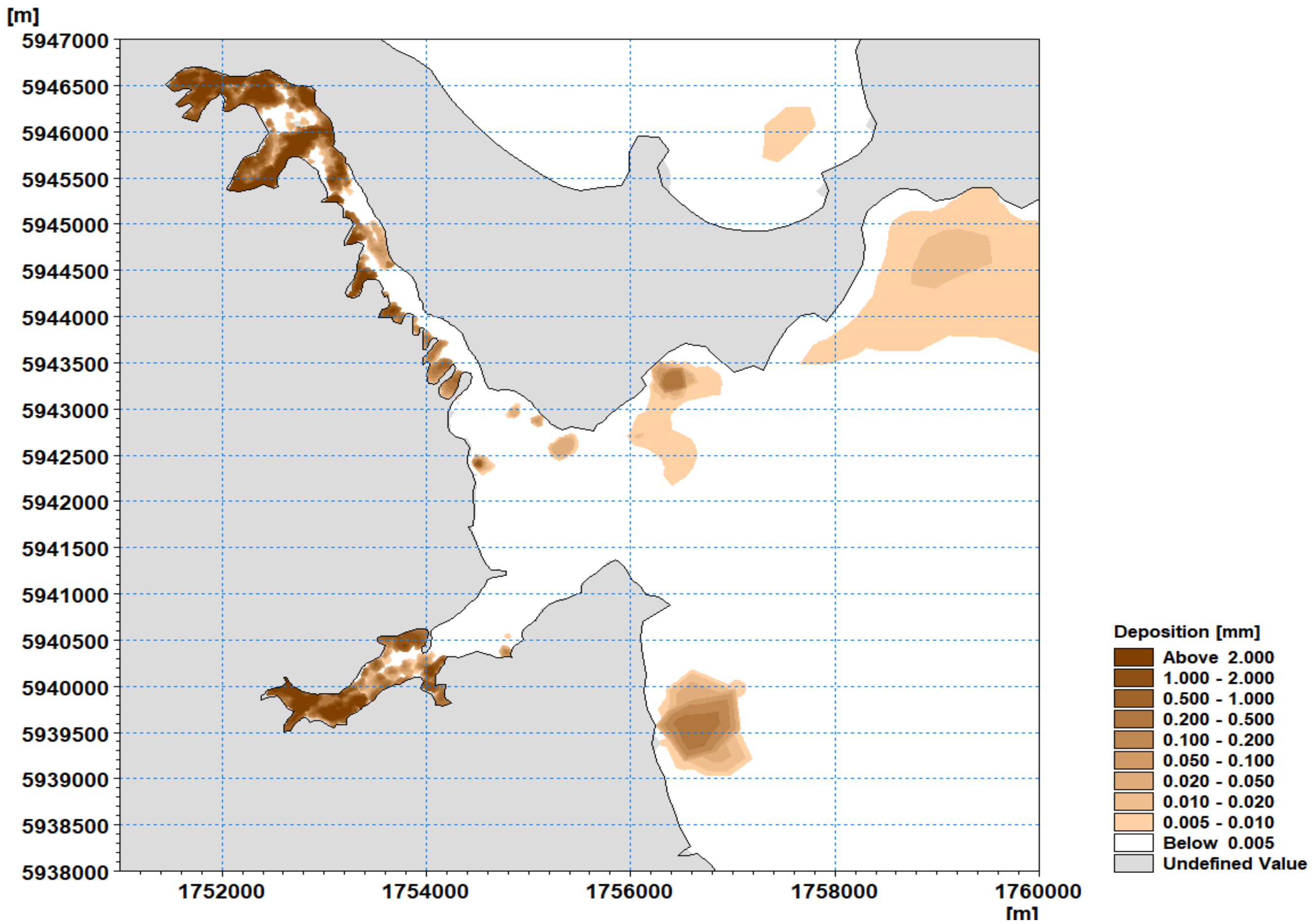

Figure 10-1. Deposition at the end of the model simulation for Scenario 7. The period modelled (January-July 2018) consists of typical wind and rain conditions and a range of events which in total deliver 35% more catchment derived sediment than the long term annual average sediment load.

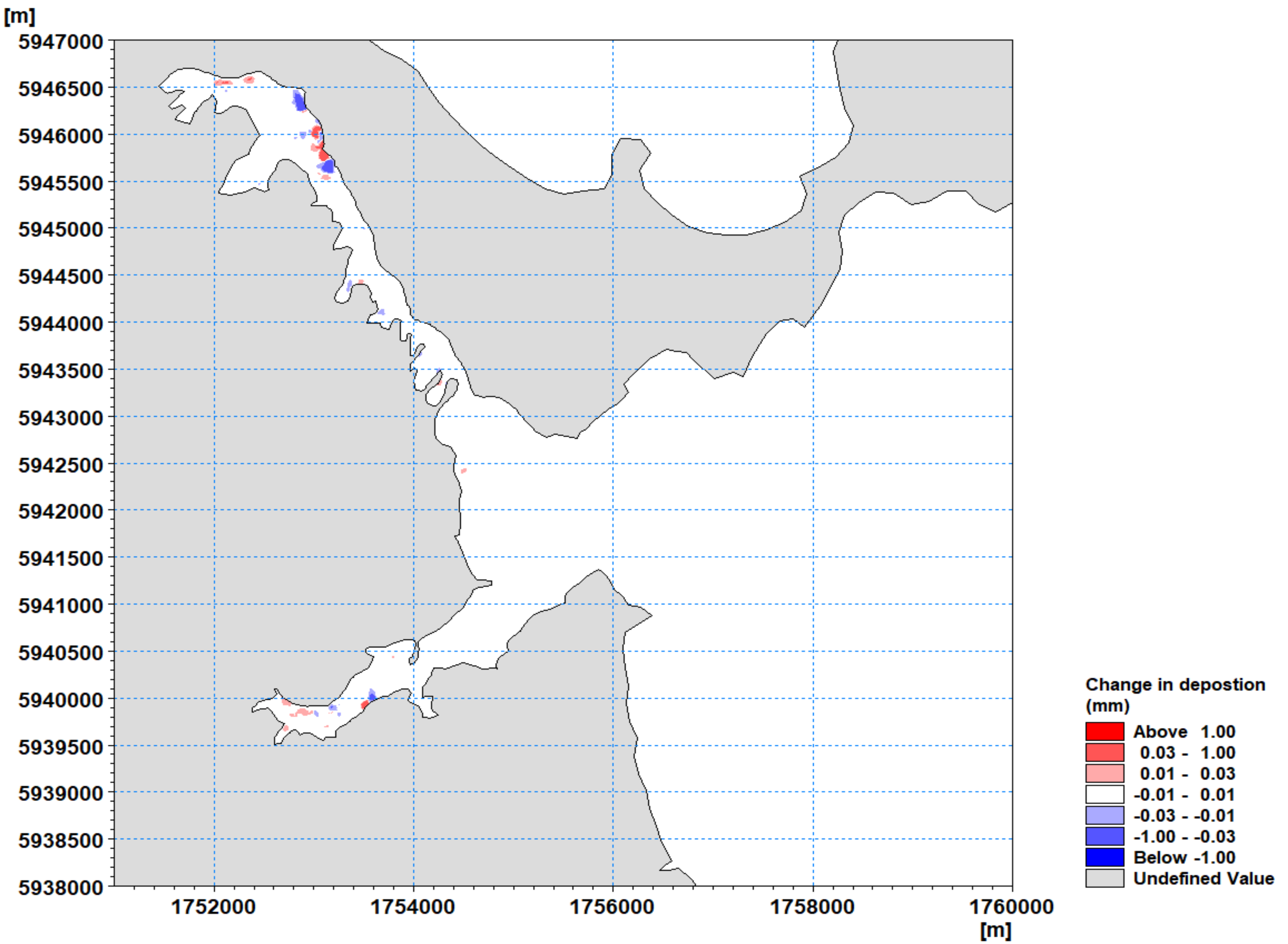

Figure 10-2. Predicted change in deposition at the end of the model simulation for Scenario 7 compared to Scenario 6.

Table 10-2. Change in sediment deposited (kg) at the end of the model simulation within each of the subestuaries (Figure 2-4) for Scenario 7 compared to Scenario 6.

Subestuary	Mass deposited Scenario 6 (kg)	Change in sediment deposited compared to Scenario 7 (kg)	% Change
Upper Okura	373168	287	0.11%
Mid Okura	60776	168	
Outer Okura	170	8	
Karepiro (S)	466	-5	-1.07%
Karepiro (N)	3552	28	0.81%
Upper Wēiti	910998	23	-0.03%
Mid Wēiti	97955	-364	
Outer Wēiti	23801	1	
Marine Reserve	32563	10	0.03%
Outer Karepiro	3656	-22	-0.59%
Whangaparaoa	37362	63	0.17%

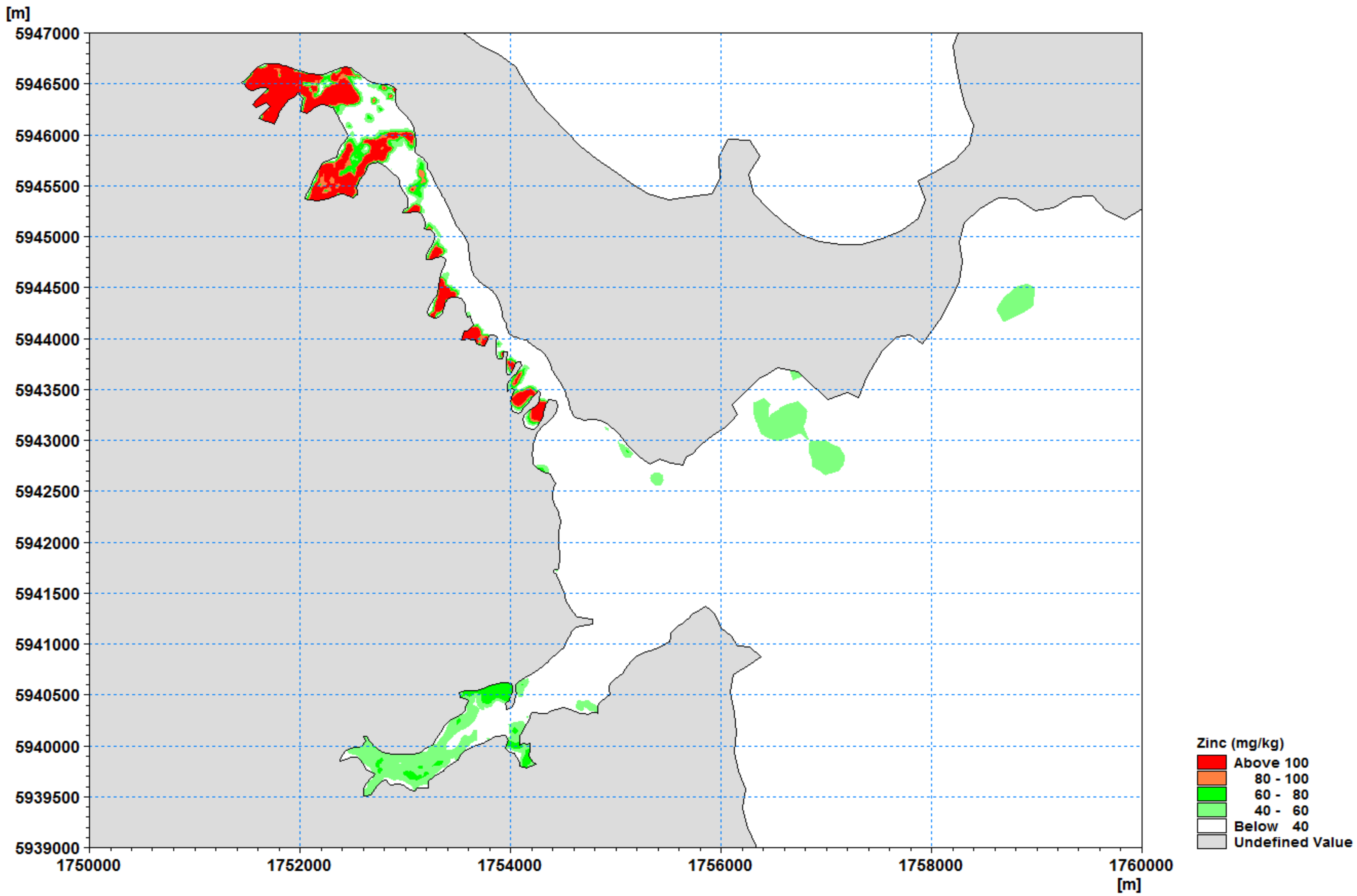

Figure 10-3. Zinc concentrations (mg/kg) 50 years from present under Scenario 7.

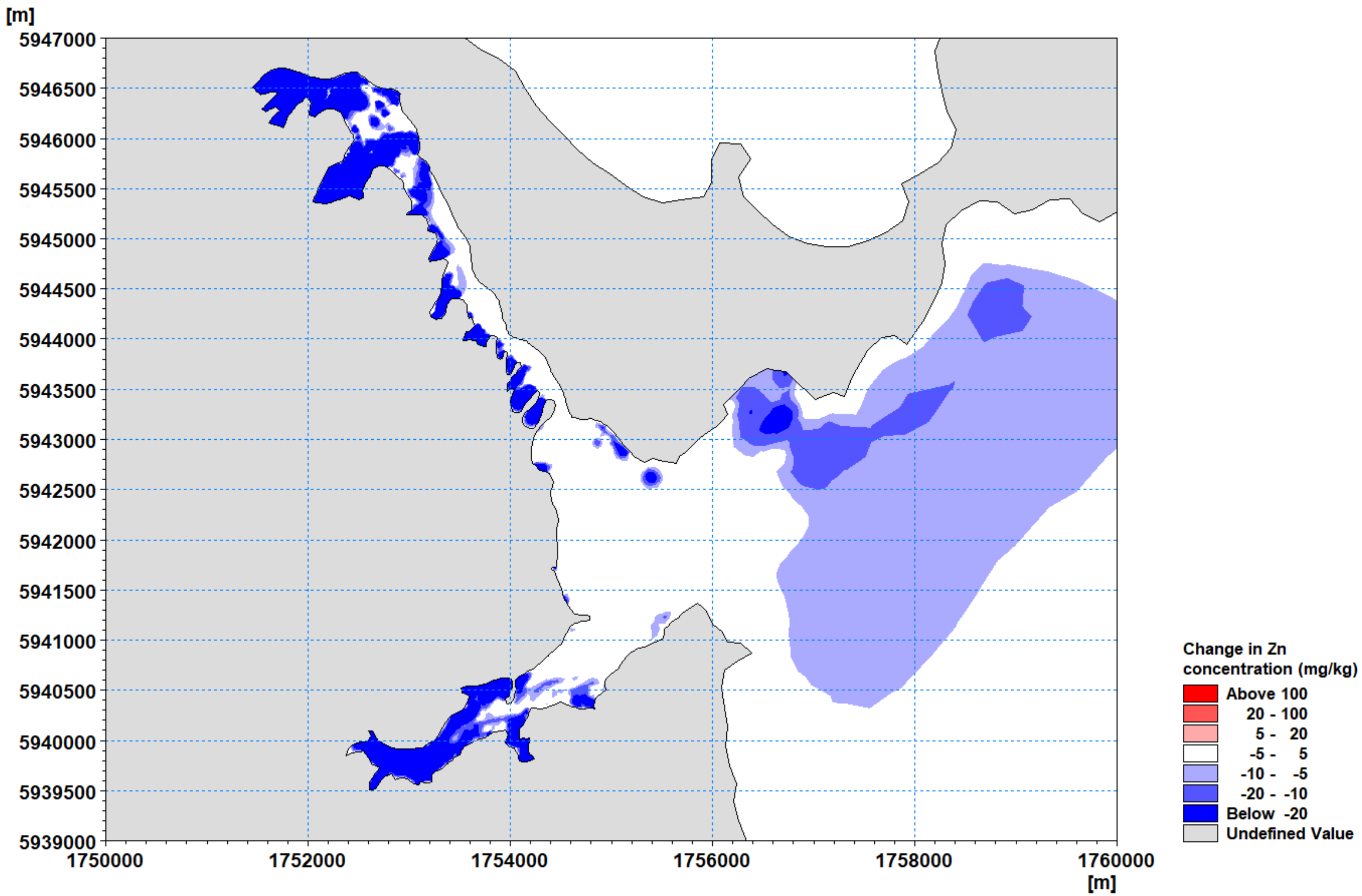

Figure 10-4. Changes in Zinc concentrations (mg/kg) 50 years from present under Scenario 7 compared to Scenario 6.

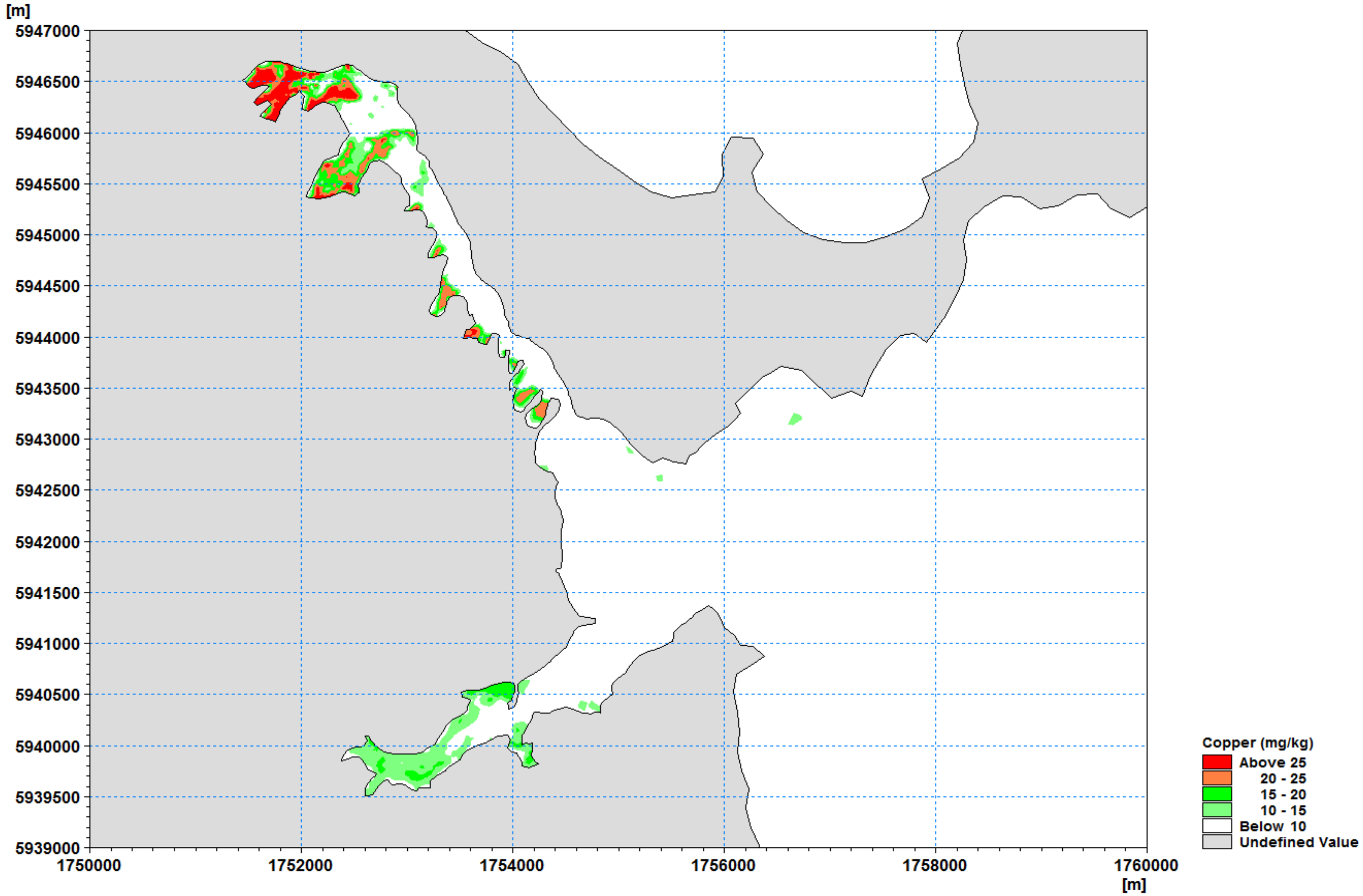

Figure 10-5. Copper concentration (mg/kg) 50 years from present under Scenario 11.

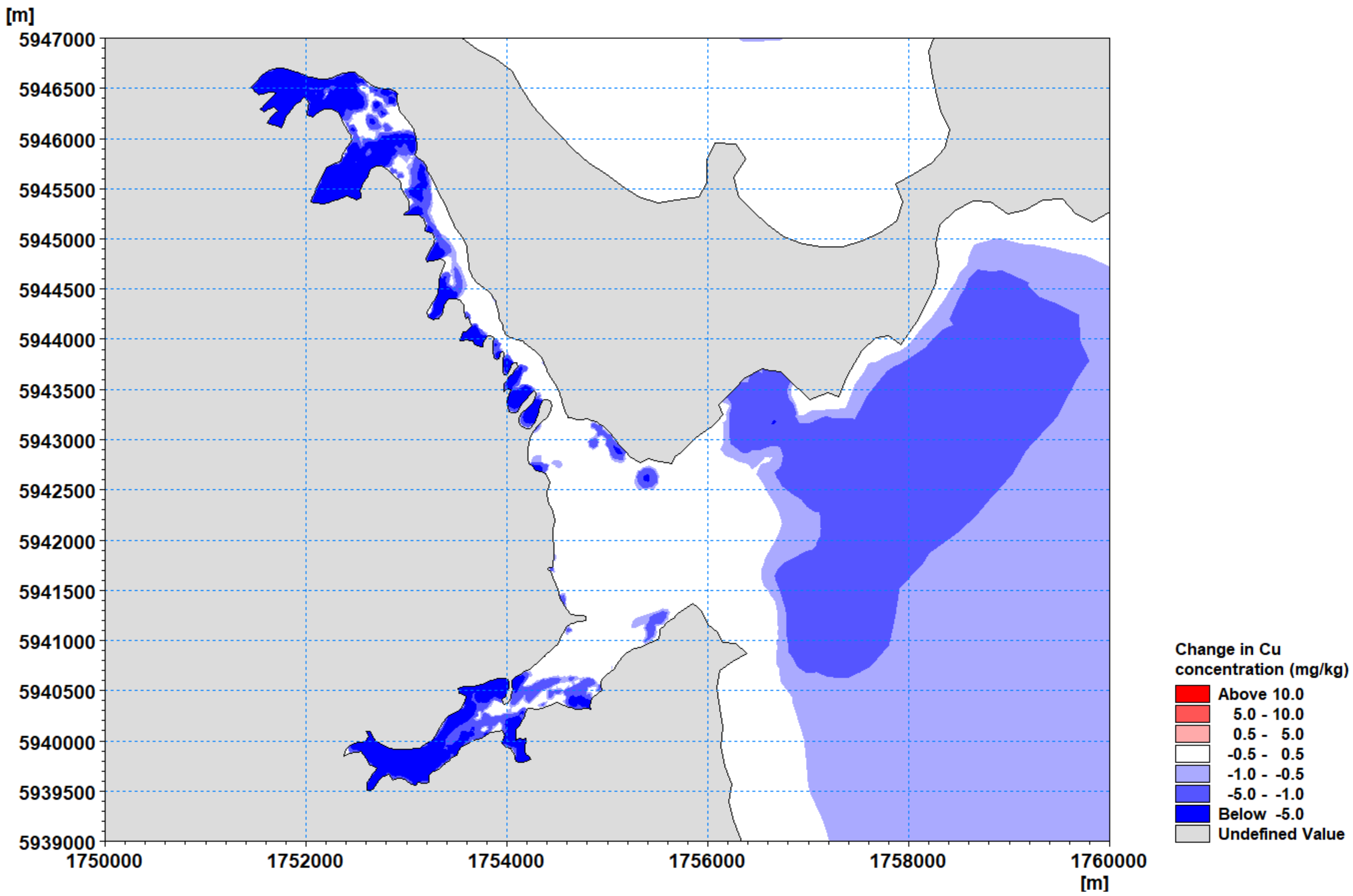

Figure 10-6. Changes in Copper concentrations (mg/kg) 50 years from present under Scenario 7 compared to Scenario 6.

Table 10-3. Future subestuary metal concentration (mg/kg) under Scenario 7 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Numbers in brackets show the predicted change under this Scenario compared to Scenario 6. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	51.5 (-47.8)	13.1 (-11.9)
Mid Okura subestuary concentration	39.5 (-23.4)	8.5 (-5.1)
Lower Okura subestuary concentration	25.7 (-0.9)	4.8 (-0.2)
Karepiro (S) subestuary concentration	26 (-1.3)	4.9 (-0.2)
Karepiro (N) subestuary concentration	26.8 (-2.1)	5 (-0.4)
Upper Wēiti subestuary concentration	105.4 (-92.7)	16.1 (-13)
Mid Wēiti subestuary concentration	59.7 (-41.5)	9.9 (-6.1)
Lower Wēiti subestuary concentration	55 (-36)	9.5 (-5.6)
Marine Reserve subestuary concentration	26.1 (-1.0)	4.9 (-0.2)
Outer Karepiro subestuary concentration	26.2 (-1.0)	4.8 (-0.2)
Whangaparaoa subestuary concentration	29.2 (-4.0)	5.4 (-0.6)
Total area (ha) where PEL is exceeded		
	0.0	0.0
Maximum Concentration (mg/kg)		
	231.4	30.1

11 Scenario 8

This scenario applies a global increase in Zinc and Copper and the sediment loads associated with Scenario 6 (Future Growth plus 1200 home development within the Wēiti Bay area and Long Bay Structure Plan development).

This results in the mean annual sediment load from all catchments is 2106.3 tonnes/yr with increases in mean annual loads to 1047.7 kg/yr for Total Zinc and 177.8 kg/yr for Total Copper.

Compared to Scenario 6, Zinc and Copper loads increase for all catchment outlets (Table 11-1).

The following are the maximum suspended sediment concentration that occurs at any time during the model simulation, the percentage of the model simulation time that a threshold of 80 mg/L is exceeded and the percentage change in mean SSC relative to Scenario 0 at the key sites (Figure 2-5).

Upper Okura
18 hours above 80 mg/L, maximum of 438 mg/L and -1.65 % change in SSC
Mid Okura
17.5 hours above 80 mg/L, maximum of 357 mg/L and -1.6 % change in SSC
Upper Wēiti
37.75 hours above 80 mg/L, maximum of 611 mg/L and -10.12 % change in SSC
Mid Wēiti
26 hours above 80 mg/L, maximum of 622 mg/L and -20.2 % change in SSC
Karepiro
10 hours above 80 mg/L, maximum of 1391 mg/L and -4.93 % change in SSC
Wēiti Delta
4.75 hours above 80 mg/L, maximum of 101 mg/L and -14.88 % change in SSC
Outer Karepiro
0 hours above 80 mg/L, maximum of 15 mg/L and -12.06 % change in SSC
Arkle Bay
0 hours above 80 mg/L, maximum of 31 mg/L and -10.54 % change in SSC
Long Bay
0 hours above 80 mg/L, maximum of 8 mg/L and -6.81 % change in SSC
There are only small changes in deposition within the Okura estuary and Wēiti river (Figure 11-2) and minor changes to deposition elsewhere.

Because of the significant increase on metal loads there are widespread increases in future metal concentrations (Figure 11-4 and Figure 11-6) across all the subestuaries (Table 11-3). The PEL threshold for Zinc is exceed in 67.7 hectares including the area just landward of the spit opposite Okura township and the PEL for Copper is exceeded in 21.2 hectares in the upper Wēiti river.

Table 11-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 8. Number in brackets indicating magnitude of change compared to Scenario 6.

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa Wēiti North	North Outlet	Duck Creek
Sediment (tonnes/yr)	57.3	121.5	16.9	35.8	26.7	27.1	589.9	194.1	10.8	30.5 (2.3)	36.2 (0.9)	31.5	219.4	601	23.7	14.6	18.4	36.3
Zn (kg/yr)	111.1 (55.6)	49.9 (24.9)	2.7 (1.4)	9 (4.5)	7 (3.5)	13.8 (6.9)	98.9 (49.4)	30 (15)	0.8 (0.1)	12 (4.4)	20.2 (9.7)	23.4 (11.7)	36.7 (18.4)	559.5 (279.4)	30.4 (15.2)	13.3 (6.7)	3.4 (1.7)	12.4 (6.2)
Cu (kg/yr)	15.4 (7.7)	9.2 (4.6)	1.1 (0.5)	2.6 (1.3)	2.0 (1.0)	2.8 (1.4)	30.1 (15.1)	10.8 (5.4)	0.4 (0.2)	2.3 (1.0)	3.6 (1.8)	3.7 (1.9)	12.8 (6.4)	67.4 (33.6)	4.3 (2.1)	2.3 (1.2)	1.3 (0.7)	3.4 (1.7)
Runoff (m^3 x 10^3/year)	2164	2549	369	477	428	463	6622	3573	379	948 (-4)	1543	850	2157	15276	677	462	468	707
Zinc Concentratio n (mg/kg)	4145 (2072)	1415 (707)	390 (195)	564 (282)	486 (243)	1082 (541)	309 (154)	408 (204)	95 (17)	487 (152)	830 (387)	943 (470)	498 (249)	2105 (1051)	2005 (1003)	1302 (651)	448 (224)	638 (319)
Copper Concentratio n (mg/kg)	575 (288)	260 (130)	165 (82)	165 (83)	139 (69)	221 (111)	94 (47)	147 (73)	47 (19)	95 (40)	146 (71)	148 (73)	174 (87)	254 (126)	285 (142)	228 (114)	167 (83)	173 (86)

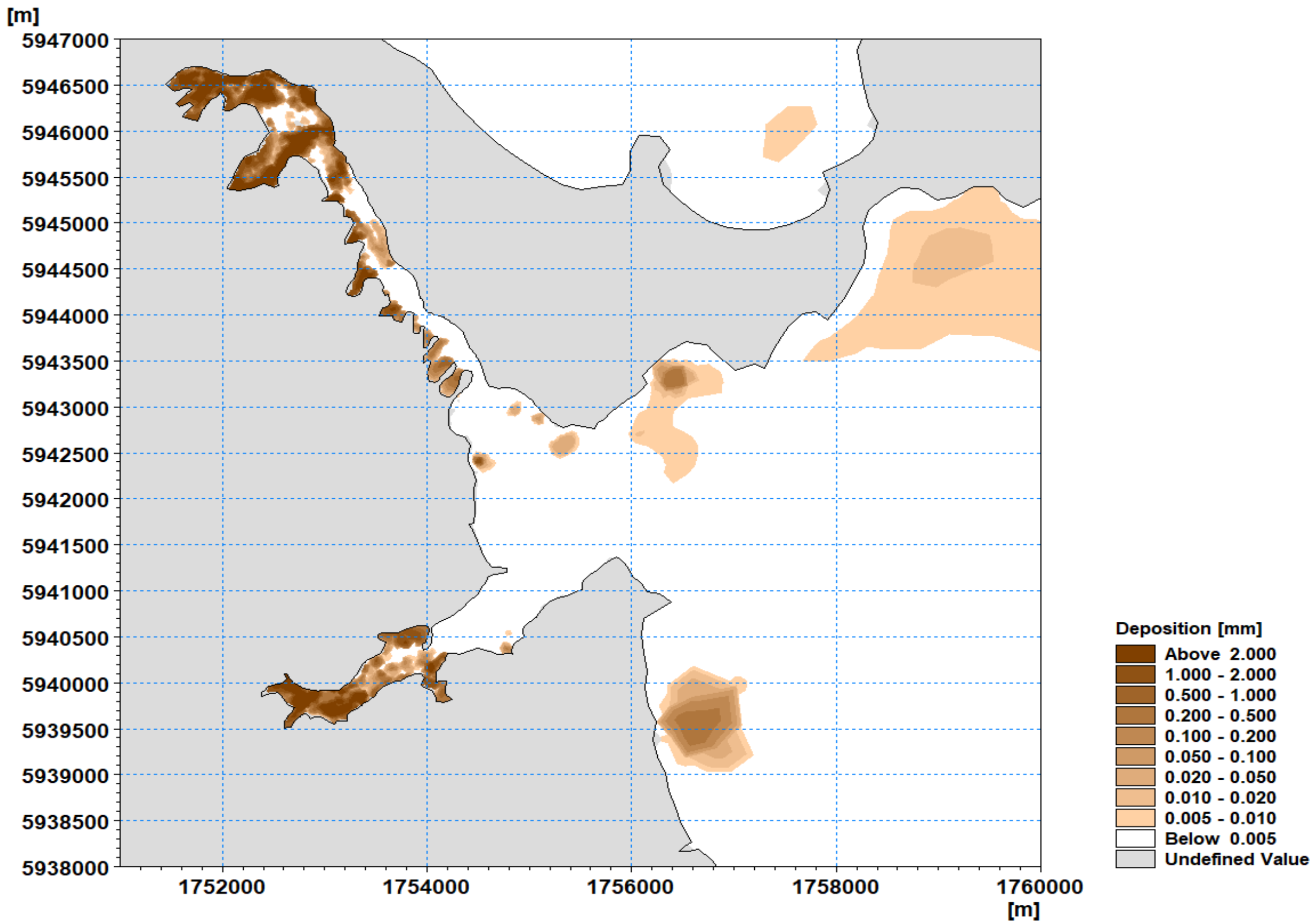

Figure 11-1. Deposition at the end of the model simulation for Scenario 8. The period modelled (January-July 2018) consists of typical wind and rain conditions and a range of events which in total deliver 35% more catchment derived sediment than the long term annual average sediment load.

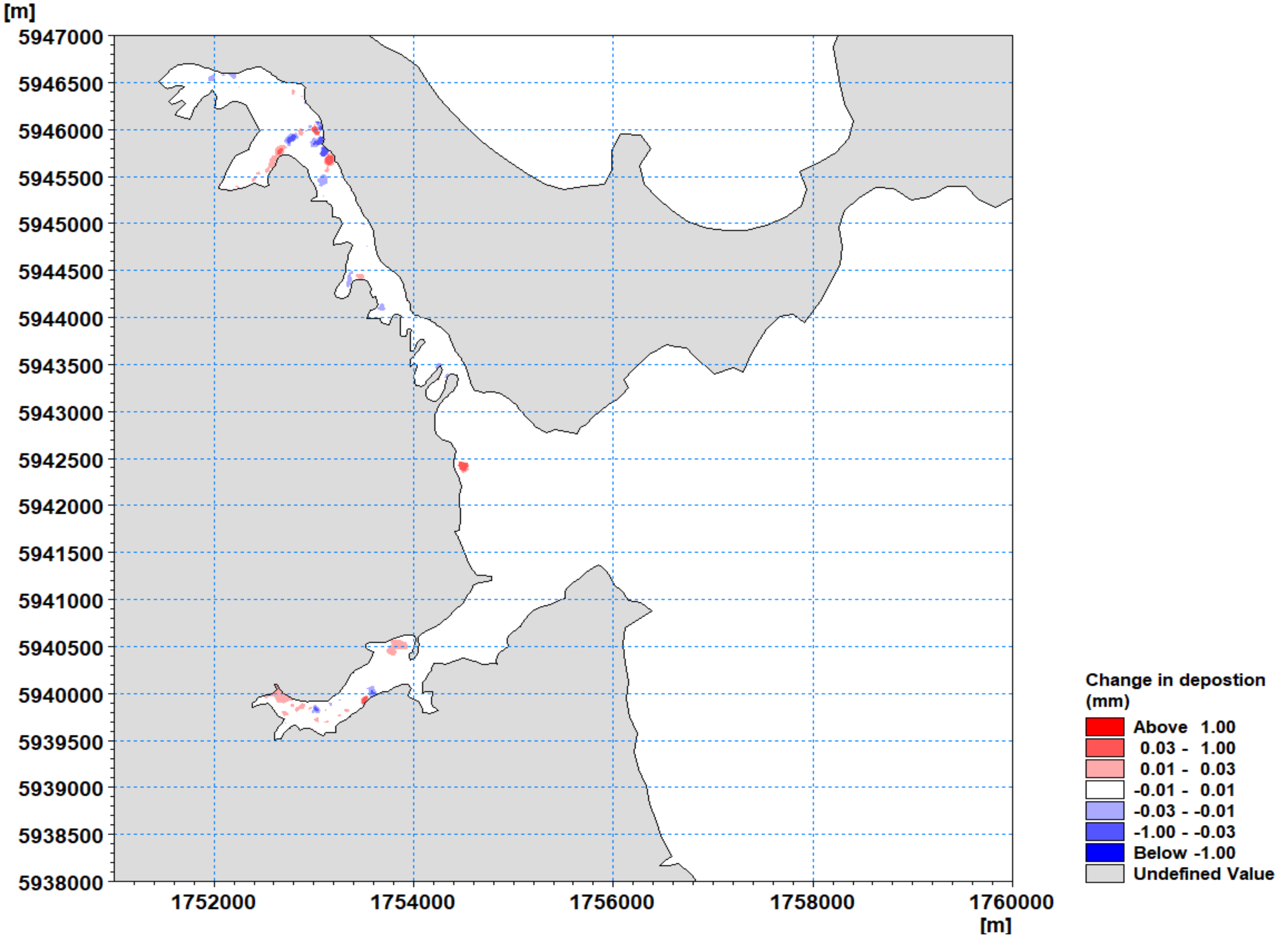

Figure 11-2. Predicted change in deposition at the end of the model simulation for Scenario 8 compared to Scenario 6.

Table 11-2. Change in sediment deposited (kg) at the end of the model simulation within each of the subestuaries (Figure 2-4) for Scenario 8 compared to Scenario 6.

Subestuary	Mass deposited Scenario 6 (kg)	Change in sediment deposited compared to Scenario 8 (kg)	% Change
Upper Okura	373318	437	0.18%
Mid Okura	60942	334	
Outer Okura	168	7	
Karepiro (S)	466	-6	-1.21%
Karepiro (N)	4198	674	19.12%
Upper Wēiti	910660	-315	-0.01%
Mid Wēiti	98486	167	
Outer Wēiti	23797	-3	
Marine Reserve	32575	22	0.07%
Outer Karepiro	3675	-3	-0.08%
Whangaparaoa	37339	41	0.11%

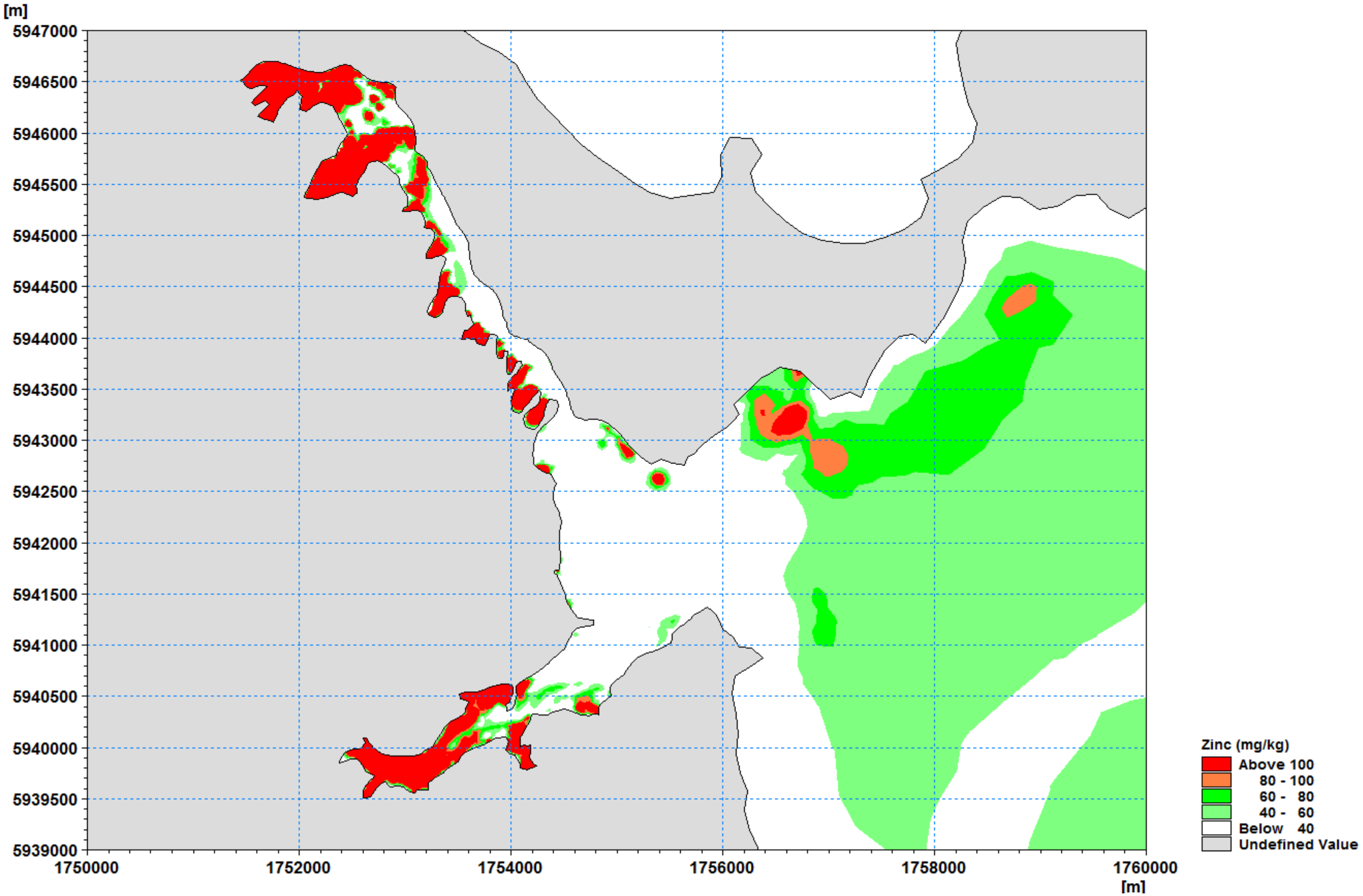

Figure 11-3. Zinc concentrations (mg/kg) 50 years from present under Scenario 8.

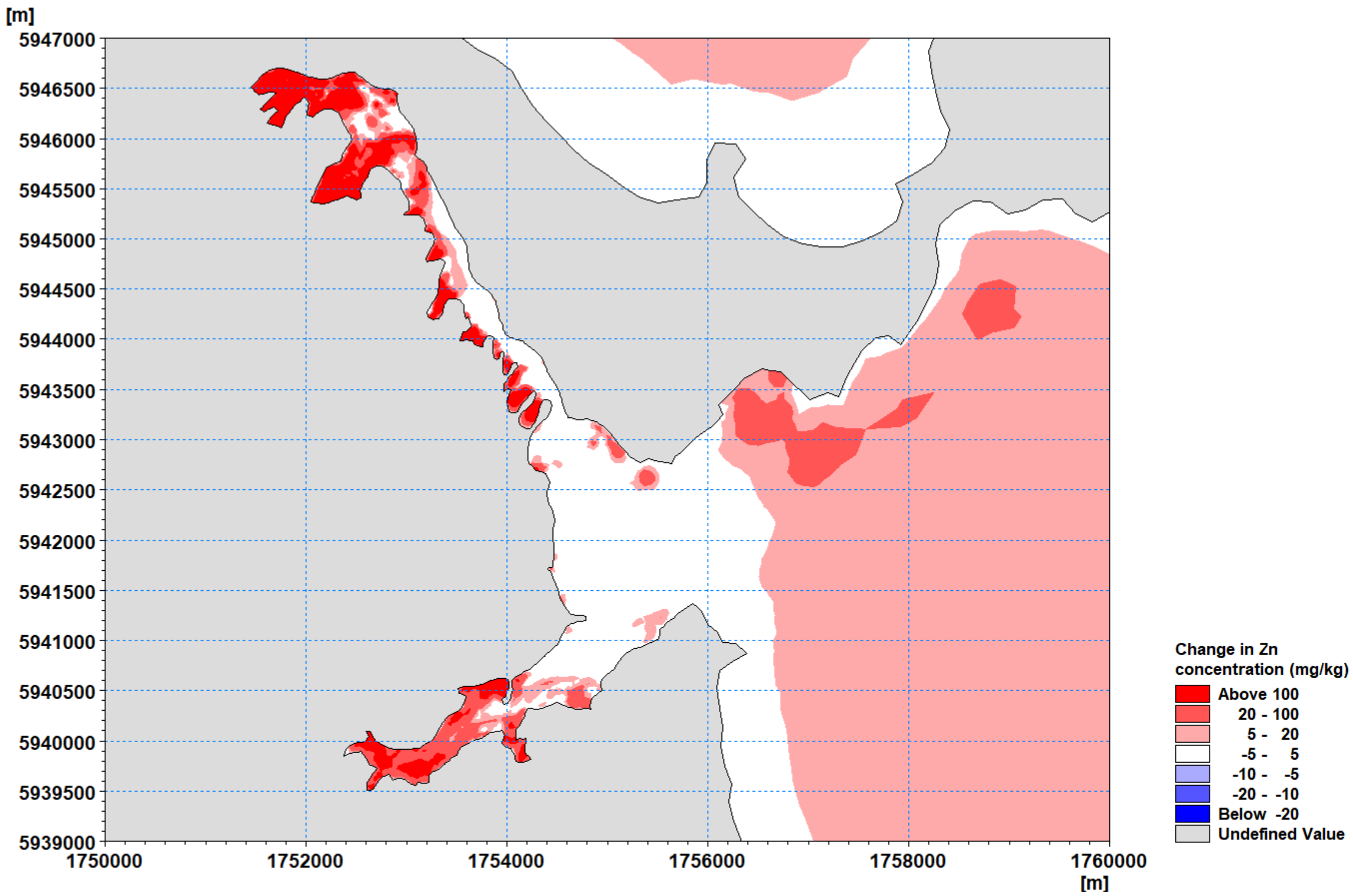

Figure 11-4. Changes in future Zinc concentration (mg/kg) 50 years from present under Scenario 8 compared to Scenario 6.

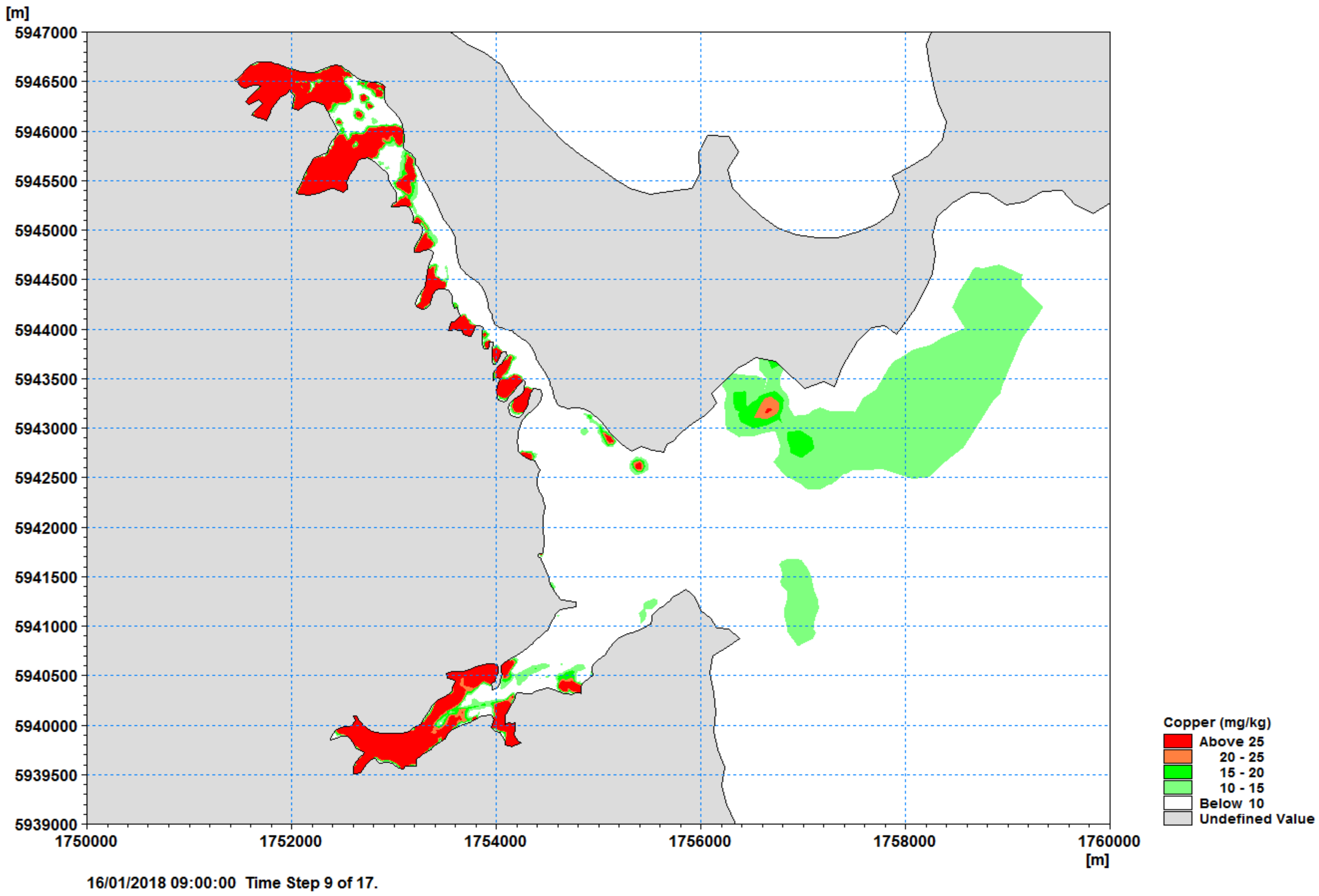

Figure 11-5. Copper concentrations (mg/kg) 50 years from present under Scenario 8.

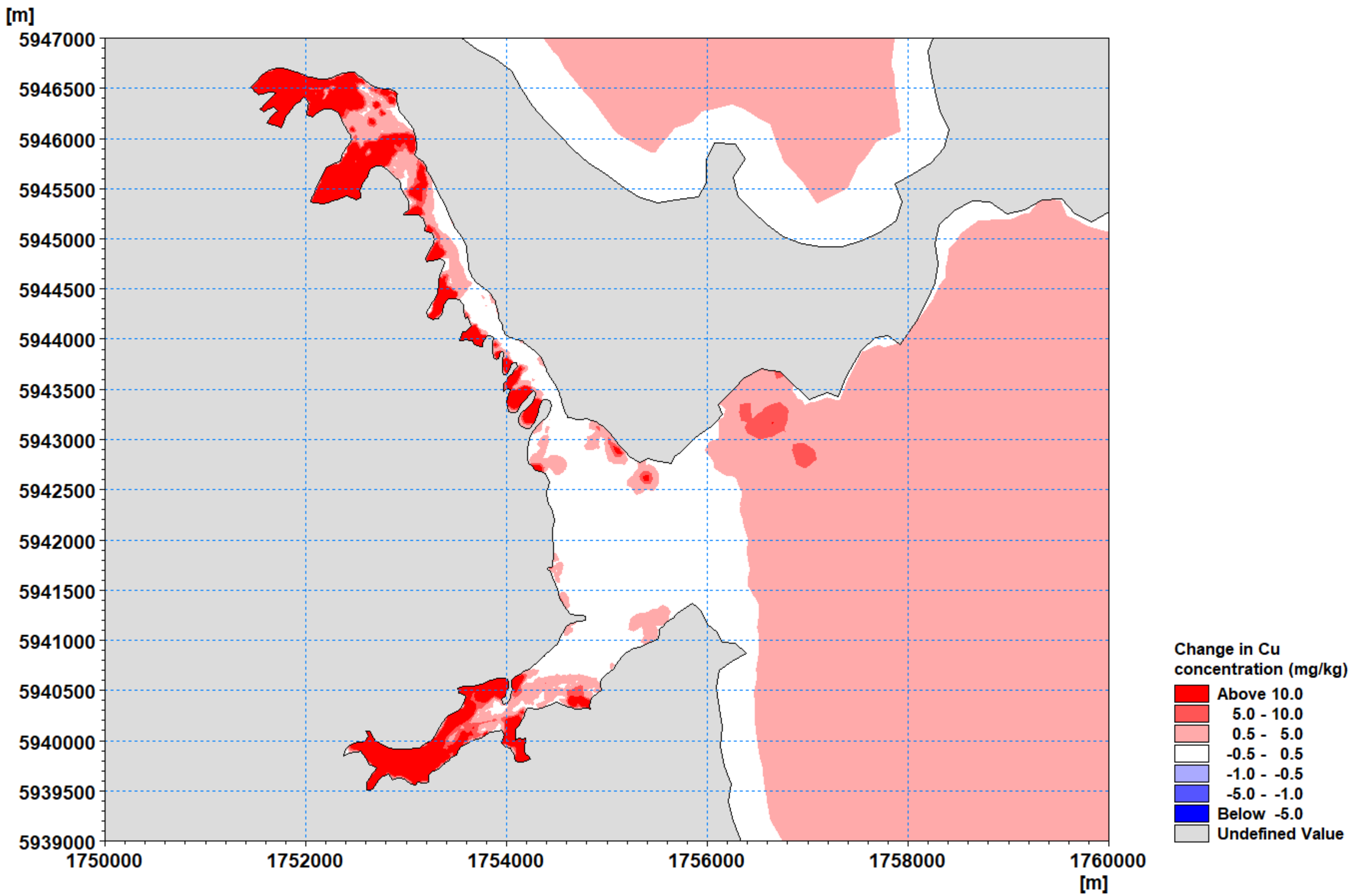

Figure 11-6. Changes in future Copper concentration (mg/kg) 50 years from present under Scenario 8 compared to Scenario 6.

Table 11-3. Future subestuary metal concentration (mg/kg) under Scenario 8 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Numbers in brackets show the predicted change under this Scenario compared to Scenario 6. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	188.2 (88.9)	48.2 (23.2)
Mid Okura subestuary concentration	104 (41.1)	23.2 (9.6)
Lower Okura subestuary concentration	28.3 (1.6)	5.4 (0.4)
Karepiro (S) subestuary concentration	29.5 (2.2)	5.5 (0.4)
Karepiro (N) subestuary concentration	32.8 (3.9)	6.1 (0.7)
Upper Wēiti subestuary concentration	379 (180.9)	54.8 (25.7)
Mid Wēiti subestuary concentration	181.2 (80)	28.1 (12.1)
Lower Wēiti subestuary concentration	159.5 (68.4)	25.9 (10.8)
Marine Reserve subestuary concentration	29 (1.9)	5.3 (0.3)
Outer Karepiro subestuary concentration	29.2 (2.0)	5.3 (0.3)
Whangaparaoa subestuary concentration	41 (7.7)	7.2 (1.2)
Total area (ha) where PEL is exceeded		
	67.7	21.2
Maximum Concentration (mg/kg)		
	930.7	119.1

12 Scenario 11

This scenario introduces the use of inert roofing materials for a 500 home development in the Wēiti Bay area with development in the Future Growth area (Scenario 5).

The mean annual sediment load from all catchments is 2013.1 kg/yr and is only slightly more than for Scenario 5 (2100.4 tonnes/yr). The majority of the reductions relate to Zinc with the mean annual loads for Total Zinc and Copper of 520.5 kg/yr and 88.8 kg/yr respectively (compared to the loads for Scenario 5 of 526.0 kg/yr and 89.1 kg/yr).

Sediment results are not presented for this scenario as they are very similar to Scenario 5.

This scenario results in reductions in Zinc accumulation within the upper parts of the Okura estuary and the intertidal embayment's within the Wēiti river (Figure 12-2). There is a slight reduction in Copper accumulation within the Okura estuary to the landward side of the spit opposite Okura township (Figure 12-4, Table 12-2) as a results of the relatively small reductions in copper loads (and hence copper source concentrations, Table 12-1) from the North Shore, Karepiro and Karepiro Beach outlets.

Compared to Scenario 5, a similar area of the marine receiving environment exceeds the PEL for Zinc because there are no reductions in metal loads from the Wēiti catchments (Table 12-1) that contribute significantly to the high Zinc levels in the upper part of the Wēiti river.

Table 12-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 11. Number in brackets indicating magnitude of change compared to Scenario 5.

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa Wēiti North	North Outlet	Duck Creek
Zn (kg/yr)	55.5	25	1.3	4.5	3.5	6.9	49.5	15	0.4 (-0.3)	4.7 (-2.7)	7.5 (-2.8)	11.7	18.3	280.1	15.2	6.6	1.7	6.2
Cu (kg/yr)	7.7	4.6	0.6	1.3	1	1.4	15	5.4	0.2	1.1 (-0.1)	1.7	1.8	6.4	33.8	2.2	1.2	0.6	1.7
Zinc Concentration (mg/kg)	2073	707	195	282	243	541	154	204	47 (-31)	191 (-137)	341 (-133)	473	249	1054	1002	651	224	319
Copper Concentration (mg/kg)	288	130	82	83	69	111	47	73	23 (-5)	47 (-8)	78 (-2)	74	87	127	142	114	83	86

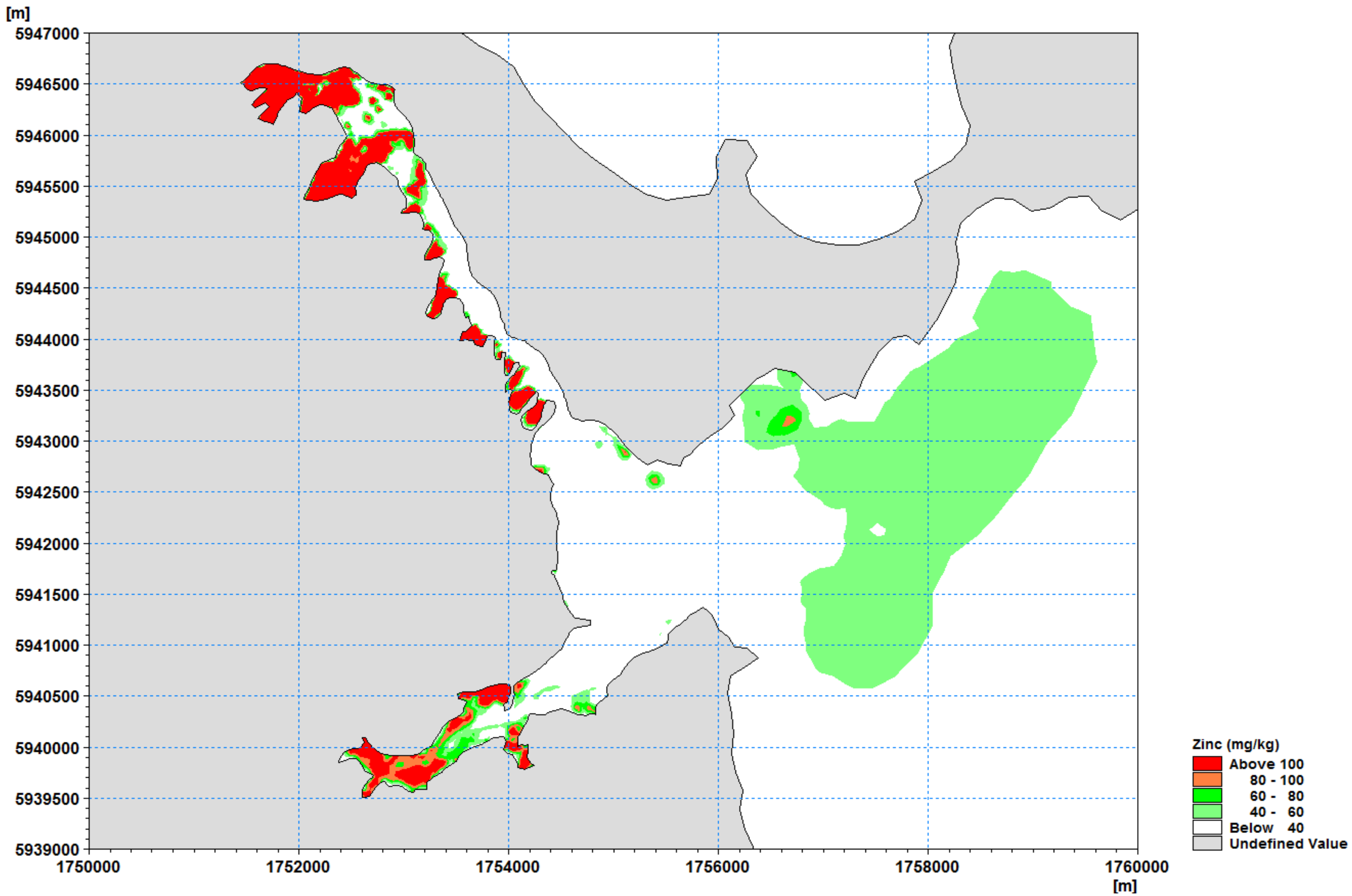

Figure 12-1. Zinc concentrations (mg/kg) 50 years from present under Scenario 11.

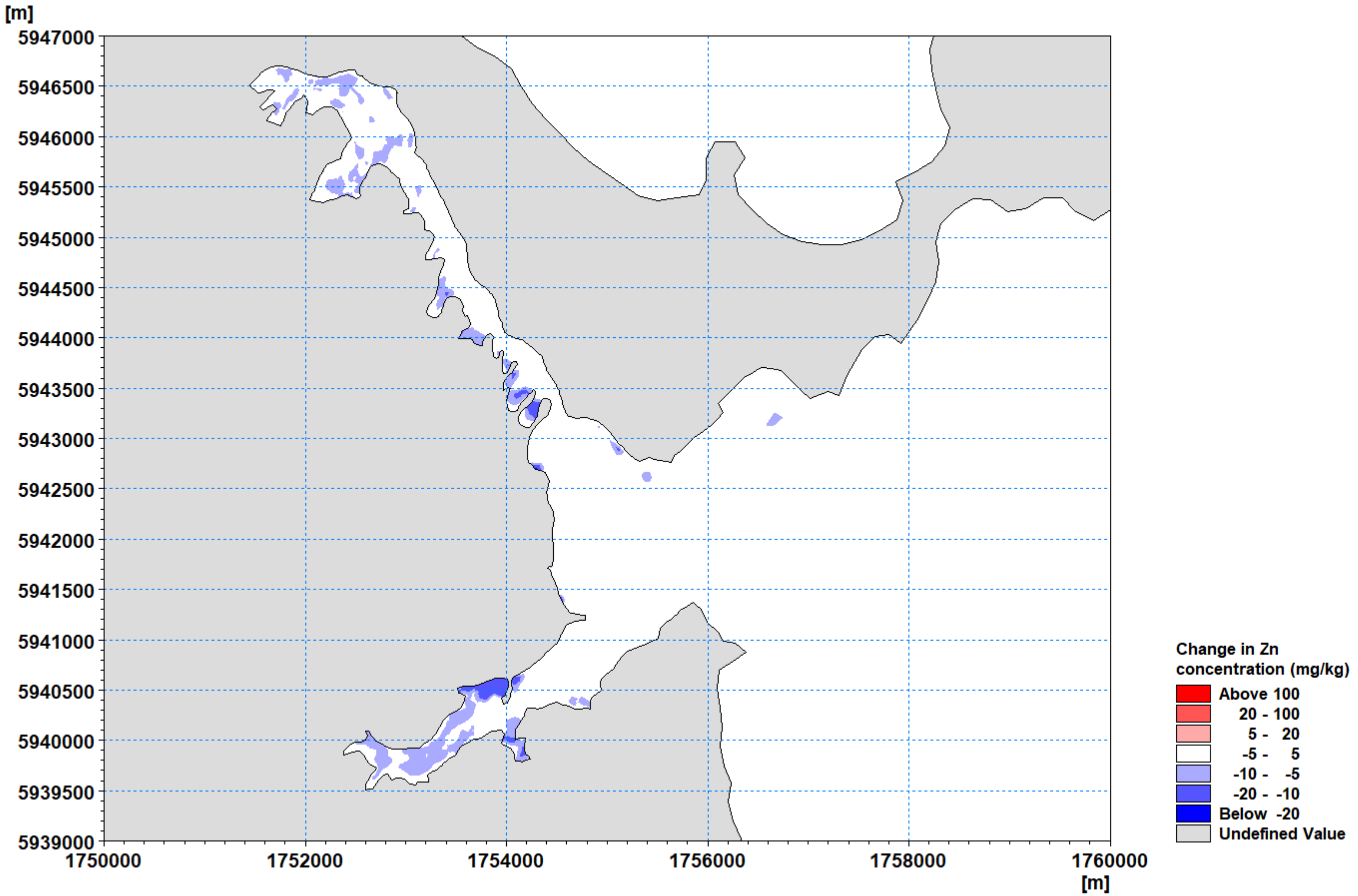

Figure 12-2. Changes in Zinc concentrations (mg/kg) 50 years from present under Scenario 11 (inert roofing across for Wēiti development) compared to Scenario 5.

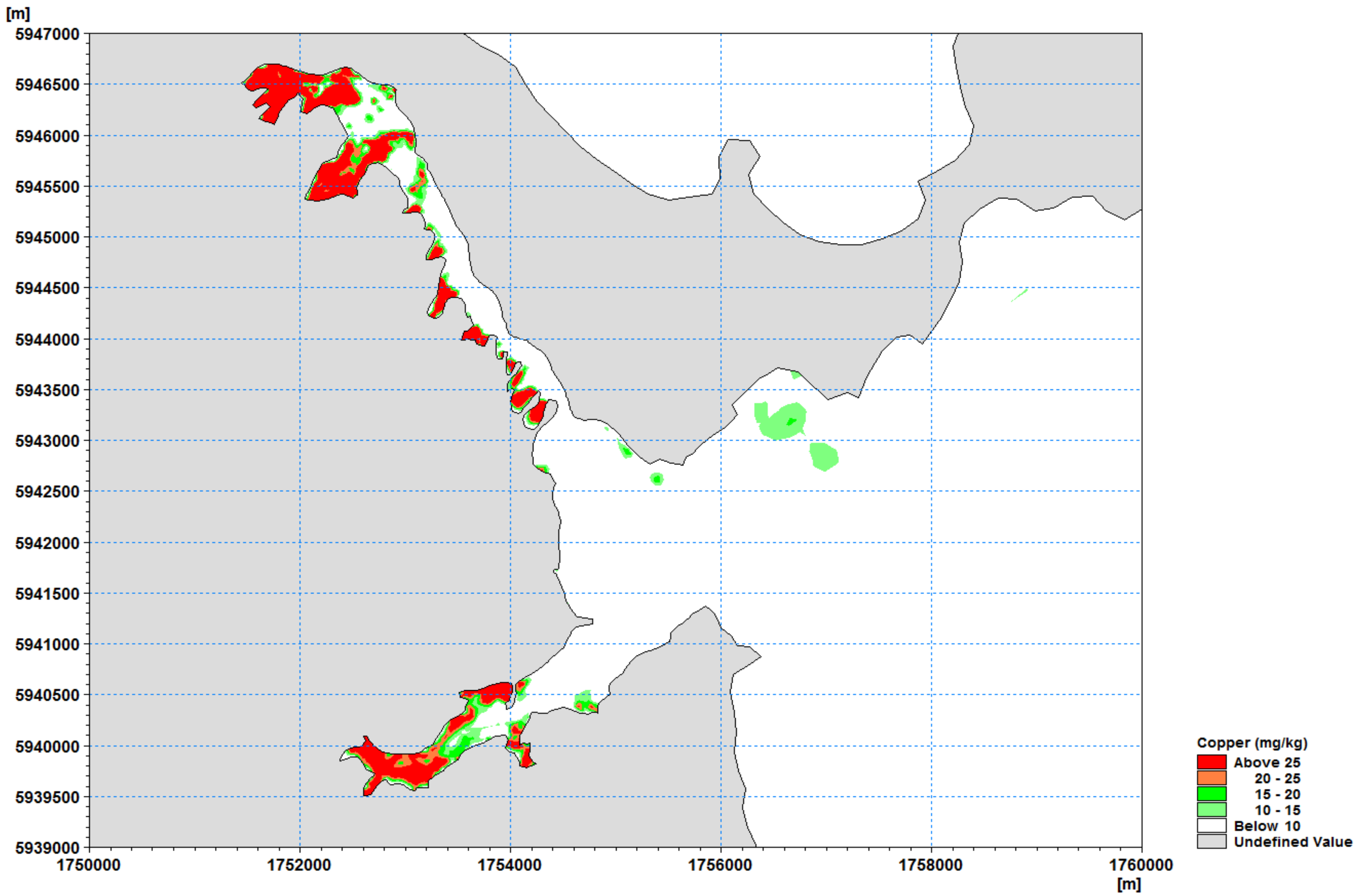

Figure 12-3. Copper concentrations (mg/kg) 50 years from present under Scenario 11.

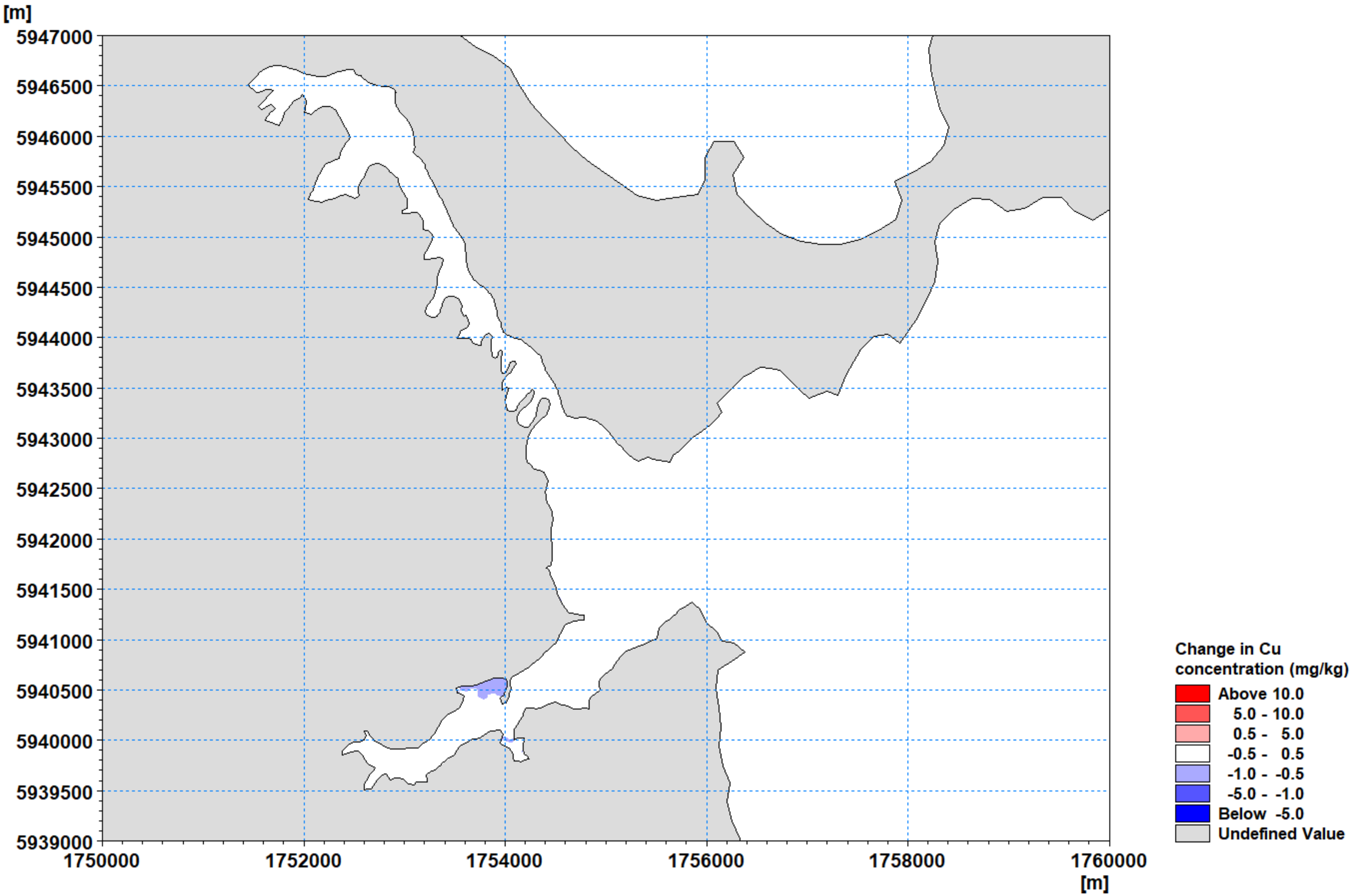

Figure 12-4. Changes in Copper concentrations (mg/kg) 50 years from present under Scenario 11 (inert roofing across for Wēiti development) compared to Scenario 6.

Table 12-2. Future subestuary metal concentration (mg/kg) under Scenario 11 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Numbers in brackets show the predicted change under this Scenario compared to Scenario 5.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	94.1 (-5.2)	24.8 (-0.2)
Mid Okura subestuary concentration	58.7 (-4.2)	13.4 (-0.2)
Lower Okura subestuary concentration	26.4 (-0.2)	5.0
Karepiro (S) subestuary concentration	26.9 (-0.3)	5.1
Karepiro (N) subestuary concentration	28.4 (-0.5)	5.4
Upper Wēiti subestuary concentration	195.3 (-3.2)	29.1 (-0.1)
Mid Wēiti subestuary concentration	99.2 (-2.3)	16.0 (-0.1)
Lower Wēiti subestuary concentration	88.4 (-3)	15 (-0.1)
Marine Reserve subestuary concentration	27.1 (-0.1)	5.0
Outer Karepiro subestuary concentration	27.2 (-0.1)	5.0
Whangaparaoa subestuary concentration	32.7 (-0.6)	6.0
Total area (ha) where PEL is exceeded		
	47.4	0.0
Maximum Concentration (mg/kg)		
	465.6	59.8

13 Scenario 12

This scenario introduces the use of inert roofing materials for a 1200 home development in the Wēiti Bay area with development in the Future Growth area (Scenario 6).

The mean annual sediment load from all catchments is 2106.3 tonnes/yr which is very similar to Scenario 6 (2103.6 tonnes/yr). The mean annual loads for Zinc and Copper are reduced to 520.5.8 kg/yr and 89.0 kg/yr respectively compared to the loads for Scenario 6 of 526.4 kg/yr and 89.1 kg/yr.

Sediment results are not presented for this scenario as very similar to Scenario 6.

Compared to Scenario 6 this Scenario results in similar changes in Zinc and Copper concentrations as Scenario 11. Reductions in Zinc accumulation occur within the upper parts of the Okura estuary and the intertidal embayment’s within the Wēiti river (Figure 13-2). There is a slight reduction in Copper accumulation within the Okura estuary to the landward side of the spit opposite Okura township (Figure 13-4, Table 13-2) as a results of the relatively small reductions in copper loads (and hence copper source concentrations, Table 12 1) from the North Shore, Karepiro and Karepiro Beach outlets.

Just over 47 hectares of the marine receiving environment exceed the PEL for Zinc (compared to just over 48 hectares under Scenario 6).

Table 13-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 12. Number in brackets indicating magnitude of change compared to Scenario 6.

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa Wēiti North	North Outlet	Duck Creek
Zn (kg/yr)	55.5	25	1.3	4.5	3.5	6.9	49.5	15	0.4 (-0.3)	4.8 (-2.8)	7.7 (-2.8)	11.7	18.3	280.1	15.2	6.6	1.7	6.2
Cu (kg/yr)	7.7	4.6	0.6	1.3	1	1.4	15	5.4	0.2	1.2 (-0.1)	1.8	1.8	6.4	33.8	2.2	1.2	0.6	1.7
Zinc Concentration (mg/kg)	2073	707	195	282	243	541	154	204	47 (-31)	197 (-139)	314 (-129)	473	249	1054	1002	651	224	319
Copper Concentration (mg/kg)	288	130	82	83	69	111	47	73	23 (-5)	48 (-8)	73 (-2)	74	87	127	142	114	83	86

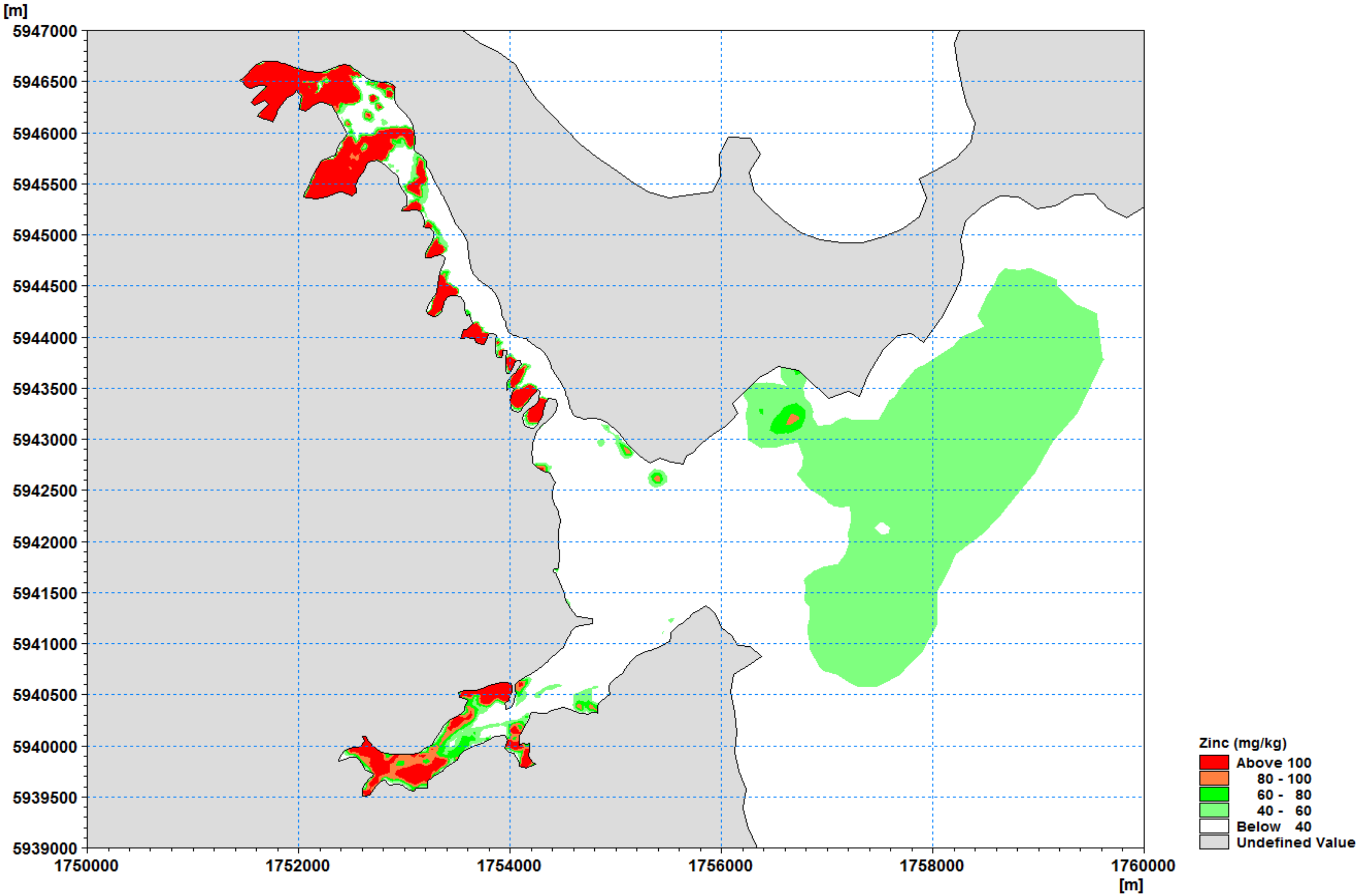

Figure 13-1. Zinc concentrations (mg/kg) 50 years from present under Scenario 12.

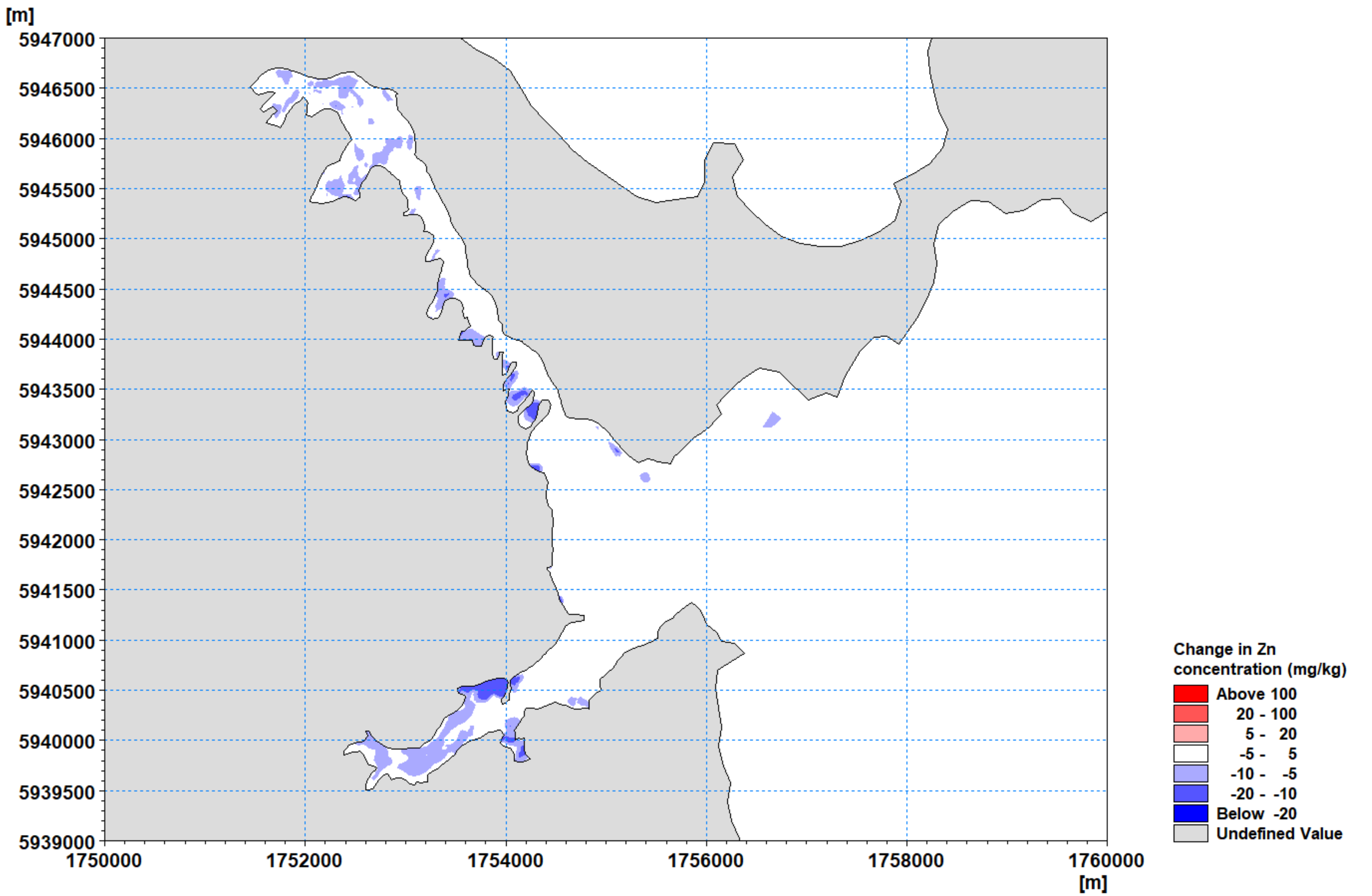

Figure 13-2. Changes in Zinc concentrations (mg/kg) 50 years from present under Scenario 12 (inert roofing Wēiti development) compared to Scenario 6.

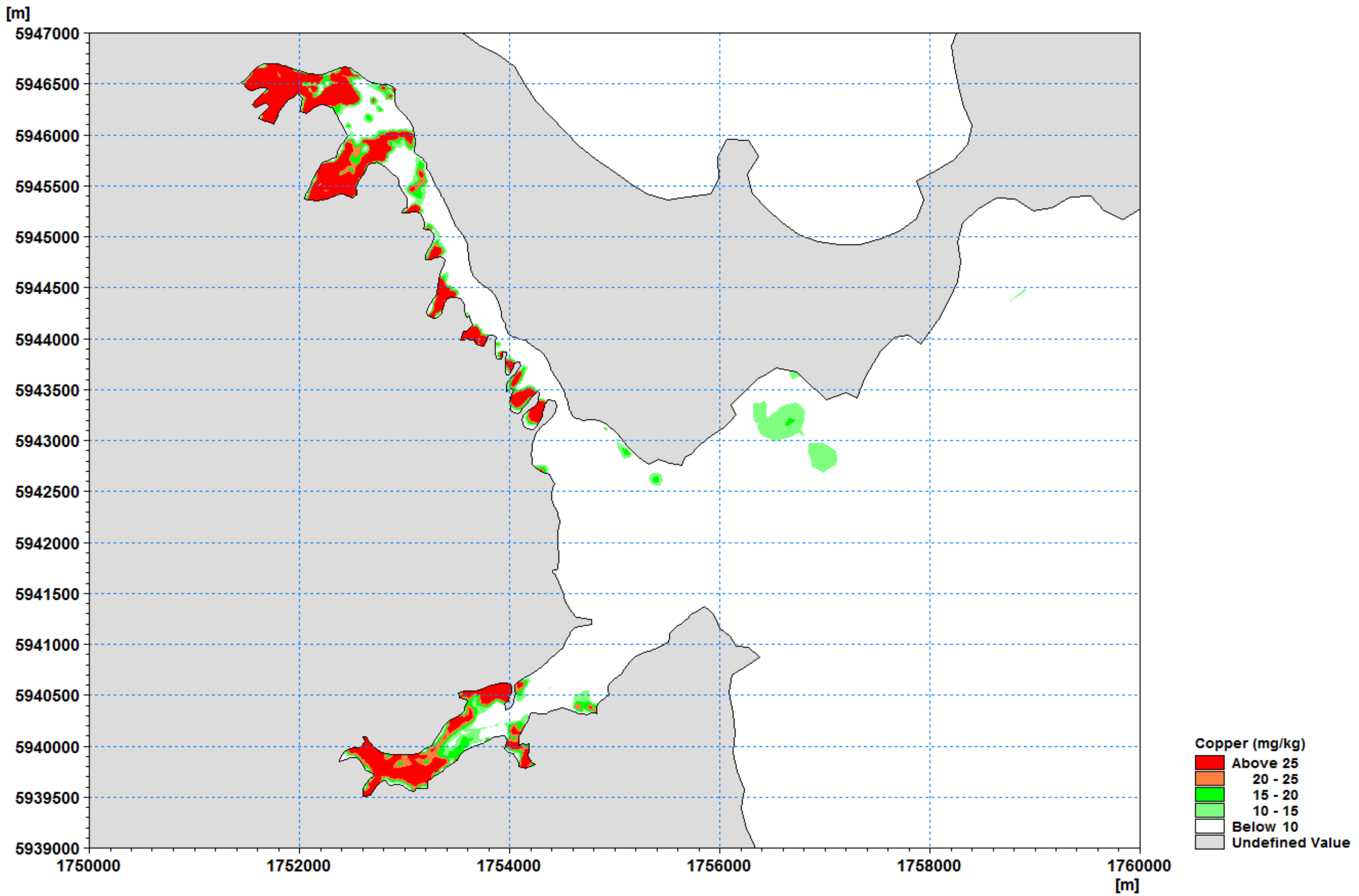

Figure 13-3. Copper concentrations (mg/kg) 50 years from present under Scenario 12.

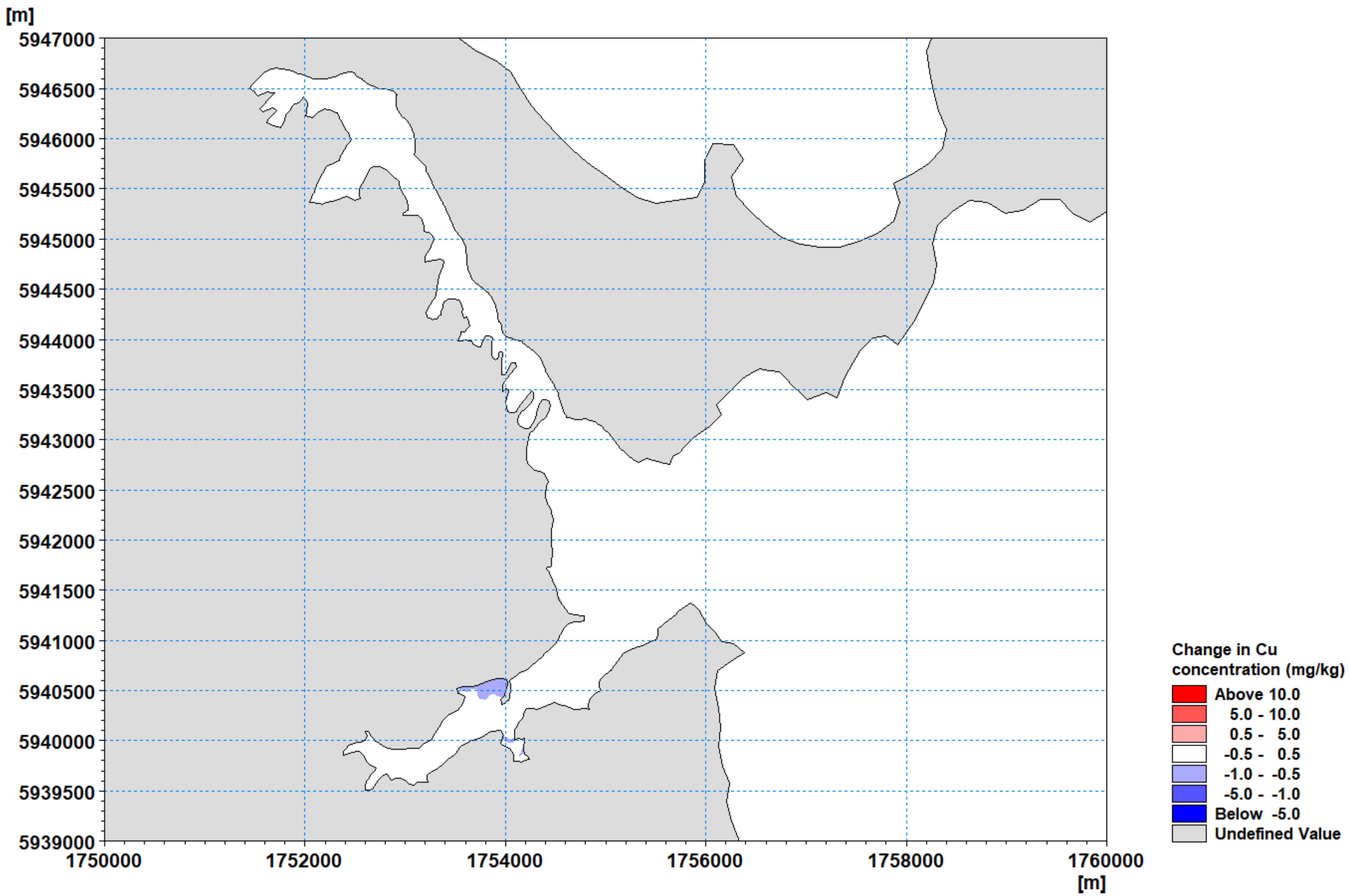

Figure 13-4. Changes in Copper concentrations (mg/kg) 50 years from present under Scenario 12 (inert roofing Wēiti development) compared to Scenario 8.

Table 13-2. Future subestuary metal concentration (mg/kg) under Scenario 12 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Numbers in brackets show the predicted change under this Scenario compared to Scenario 8. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	94.0 (-5.3)	24.8 (-0.2)
Mid Okura subestuary concentration	58.6 (-4.3)	13.4 (-0.2)
Lower Okura subestuary concentration	26.4 (-0.2)	5.0
Karepiro (S) subestuary concentration	26.9 (-0.4)	5.1
Karepiro (N) subestuary concentration	28.4 (-0.5)	5.4
Upper Wēiti subestuary concentration	194.7 (-3.4)	29 (-0.1)
Mid Wēiti subestuary concentration	98.8 (-2.4)	16 (-0.1)
Lower Wēiti subestuary concentration	87.9 (-3.1)	15 (-0.1)
Marine Reserve subestuary concentration	27.1 (-0.1)	5.0
Outer Karepiro subestuary concentration	27.2 (-0.1)	5.0
Whangaparaoa subestuary concentration	32.7 (-0.6)	6.0
Total area (ha) where PEL is exceeded		
	47.2	0.0
Maximum Concentration (mg/kg)		
	465.1	59.8

14 Scenario 13

This scenario introduces the use of inert roofing materials for a 550 home development in the Wēiti Bay area and in the Future Growth area (Scenario 5).

The mean annual sediment load from all catchments is 2103.1 tonnes/yr and is similar to load associated with Scenario 5 (2100.4 tonnes/yr). The majority of the reductions relate to Zinc with the mean annual loads for Total Zinc and Copper of 382.5 kg/yr and 88.8 kg/yr respectively (compared to the loads for Scenario 5 of 526.0 kg/yr and 89.1 kg/yr).

Sediment results are not presented for this scenario as they are very similar to Scenario 5.

This scenario results in significant reductions in Zinc accumulation within the upper parts of the Okura estuary and Wēiti river but also in the area just offshore of Arkle Bay (Figure 14-2 and Table 14-2). There is a slight reduction in Copper accumulation within the Okura estuary to the landward side of the spit opposite Okura township (Figure 14-4, Table 14-2).

Just over 1 hectare of the Wēiti river exceeds the PEL for Zinc (compared to over 48 hectares under Scenario 5).

Table 14-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 13. Number in brackets indicating magnitude of change compared to Scenario 5.

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa Wēiti North	North Outlet	Duck Creek
Zn (kg/yr)	48.7 (-6.8)	19.5 (-5.5)	1.3	4.5	3.5	6.9	49.5	15	0.4 (-0.3)	4.7 (-2.7)	7.5 (-2.8)	11.5 (-0.2)	18.3	156.3 (- 123.8)	15.2	6 (-0.6)	6.0 (-0.6)	1.6 (-0.1)
Cu (kg/yr)	7.7	4.6	0.6	1.3	1	1.4	15	5.4	0.2	1.1 (-0.1)	1.7	1.8	6.4	33.8	2.2	1.2	1.2	0.6
Zinc Concentration (mg/kg)	1819 (-254)	553 (-154)	195	282	243	541	154	204	47 (-31)	191 (-137)	341 (-133)	464 (-9)	249	588 (-466)	1002	583 (-68)	208 (-16)	318 (-1)
Copper Concentration (mg/kg)	288	130	82	83	69	111	47	73	23 (-5)	47 (-8)	78 (-2)	74	87	127	142	114	83	86

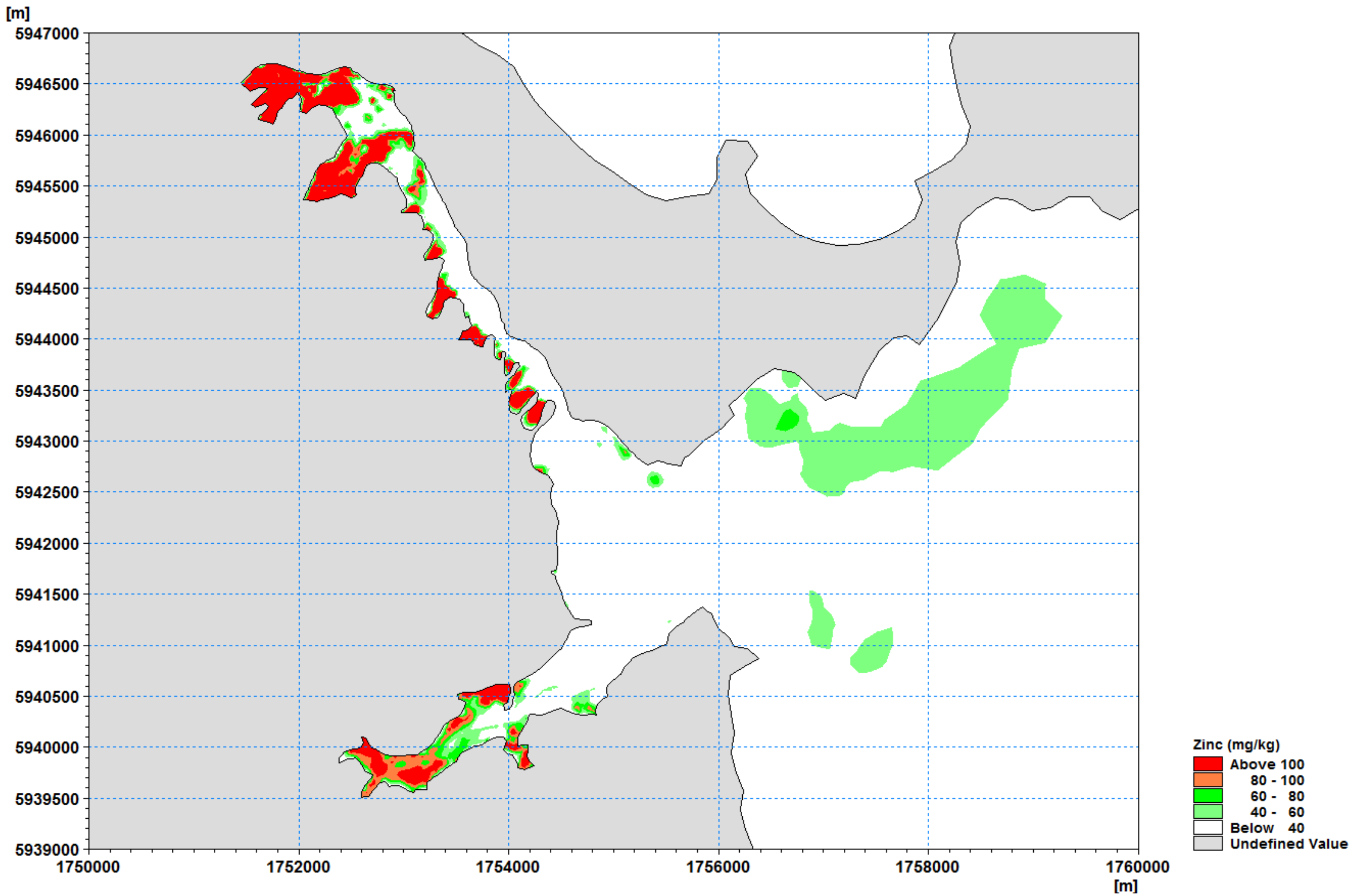

Figure 14-1. Zinc concentrations (mg/kg) 50 years from present under Scenario 13.

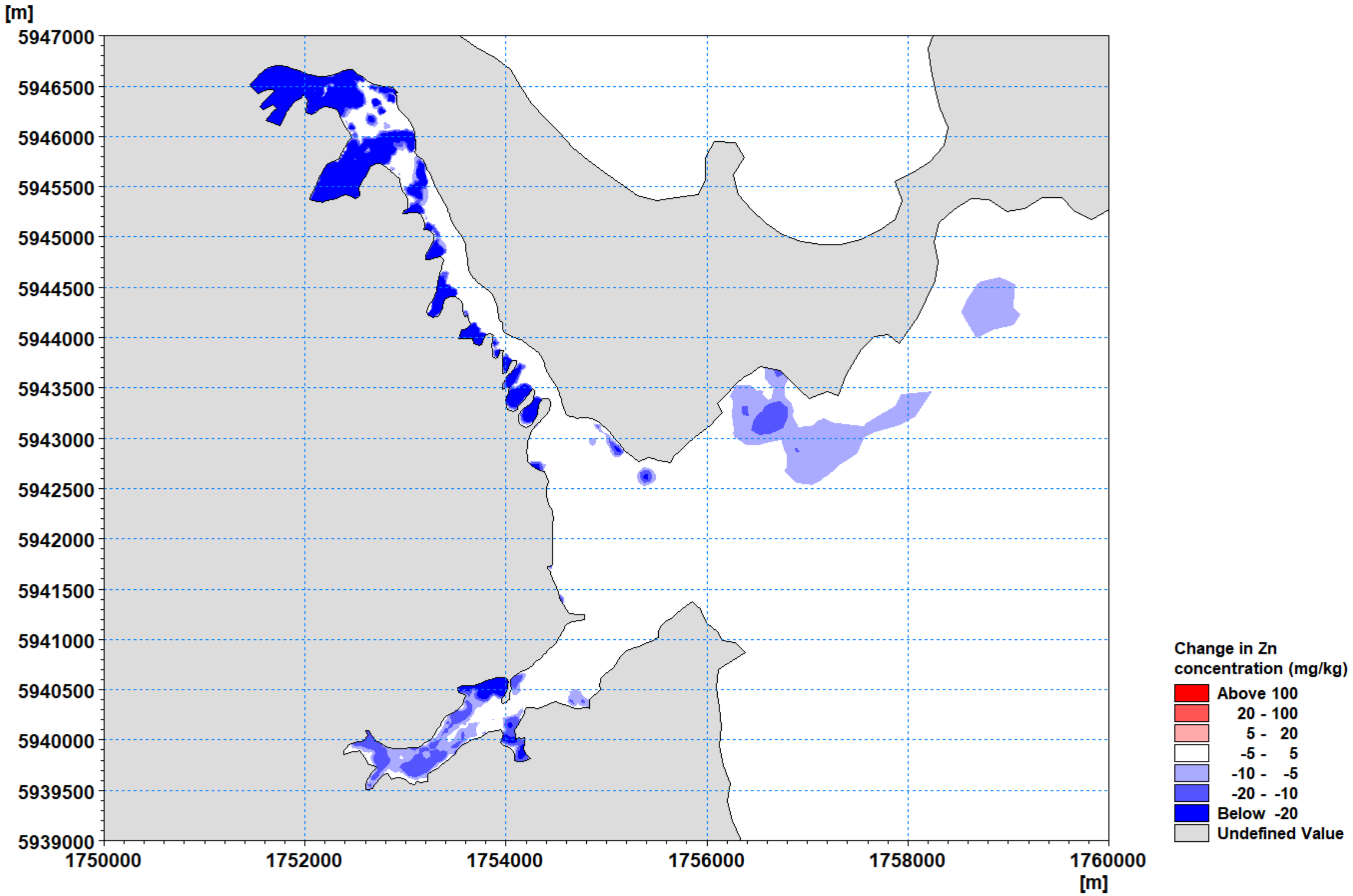

Figure 14-2. Changes in Zinc concentrations (mg/kg) 50 years from present under Scenario 13 (inert roofing across all development areas) compared to Scenario 5.

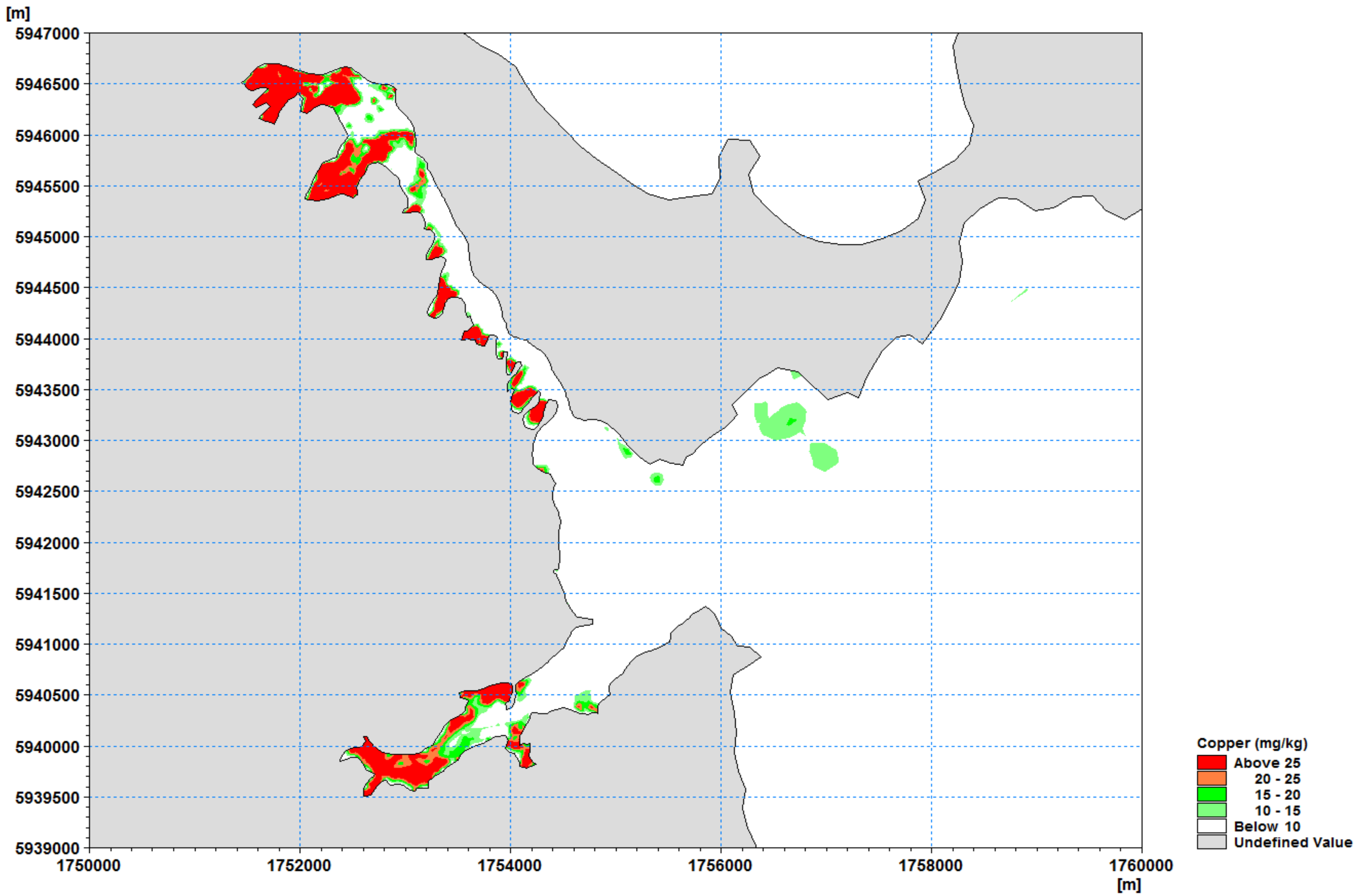

Figure 14-3. Copper concentrations (mg/kg) 50 years from present under Scenario 13.

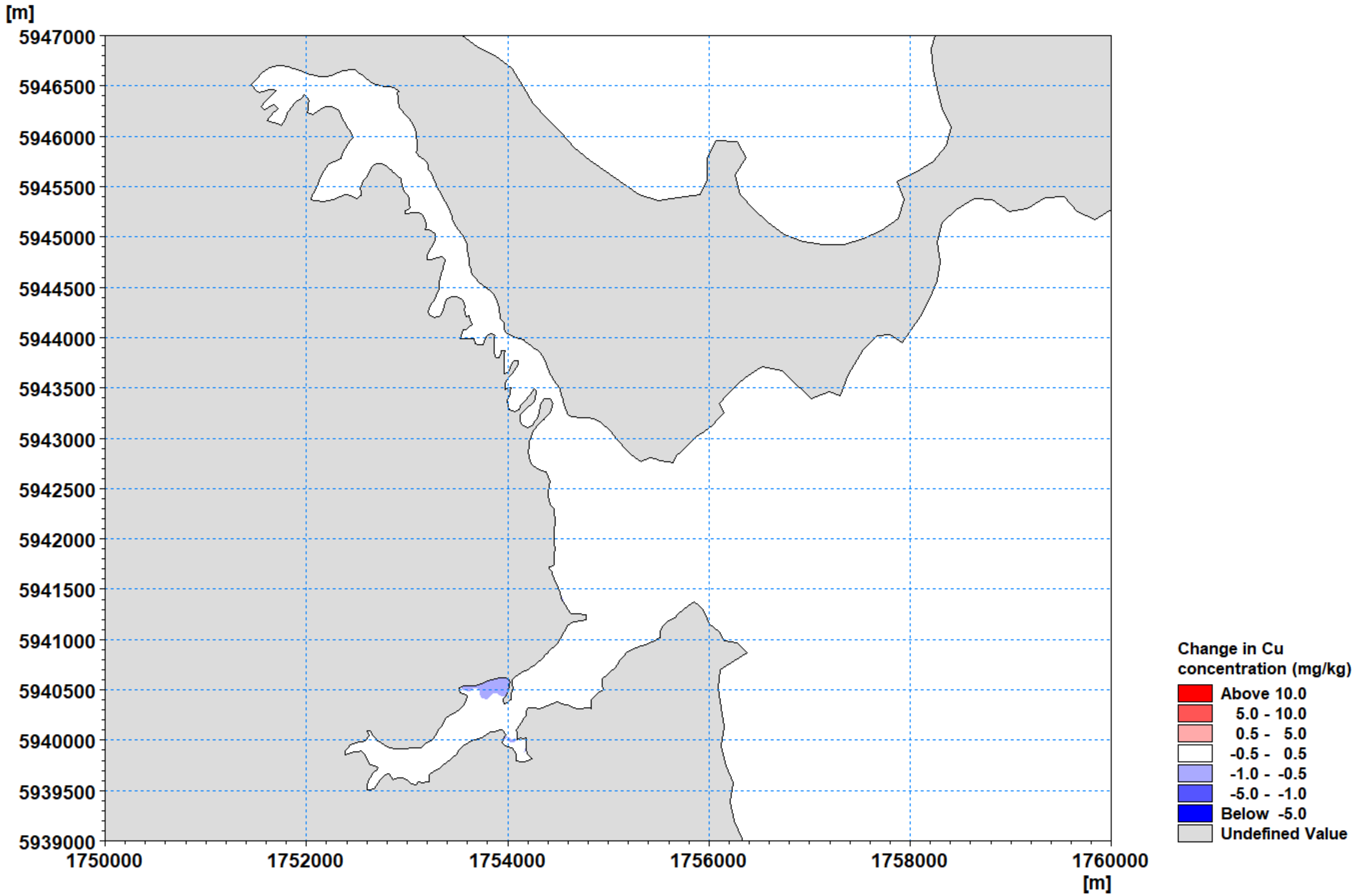

Figure 14-4. Changes in Copper concentrations (mg/kg) 50 years from present under Scenario 13 (inert roofing across all development areas) compared to Scenario 6.

Table 14-2. Future subestuary metal concentration (mg/kg) under Scenario 13 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Numbers in brackets show the predicted change under this Scenario compared to Scenario 6. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	89 (-10.4)	24.8 (-0.2)
Mid Okura subestuary concentration	54.8 (-8.1)	13.4 (-0.2)
Lower Okura subestuary concentration	26.3 (-0.3)	5.0
Karepiro (S) subestuary concentration	26.6 (-0.7)	5.1
Karepiro (N) subestuary concentration	27.8 (-1.1)	5.4
Upper Wēiti subestuary concentration	129.6 (-68.9)	29.1 (-0.1)
Mid Wēiti subestuary concentration	75.2 (-26.2)	16 (-0.1)
Lower Wēiti subestuary concentration	70.6 (-20.8)	15.0 (-0.1)
Marine Reserve subestuary concentration	26.7 (-0.4)	5.0
Outer Karepiro subestuary concentration	26.8 (-0.4)	5.0
Whangaparaoa subestuary concentration	31.1 (-2.1)	6.0
Total area (ha) where PEL is exceeded		
	1.3	0.0
Maximum Concentration (mg/kg)		
	274.1	59.8

15 Scenario 14

This scenario introduces the use of inert roofing materials for a 1200 home development in the Wēiti Bay area and in the Future Growth area (Scenario 6).

The mean annual sediment load from all catchments is 2106.3 tonnes/yr and is very similar to load associated with Scenario 6 (2106.3 tonnes/yr). The mean annual loads for Zinc and Copper are reduced to 382.8 kg/yr and 89 kg/yr respectively compared to the loads for Scenario 6 of 526.4 kg/yr and 89.1 kg/yr.

Sediment results are not presented for this scenario as very similar to Scenario 6.

Compared to Scenario 6 this Scenario results in similar changes in Zinc and Copper concentrations as Scenario 13. Significant reductions in Zinc accumulation occur within the upper parts of the Okura estuary and Wēiti river but also in the area just offshore of Arkle Bay (Figure 15-2 and Table 15-2). There is a slight reduction in Copper accumulation within the Okura estuary to the landward side of the spit opposite Okura township (Figure 15-4, Table 15-2).

Just over 1 hectare of the upper Wēiti river exceeds the PEL for Zinc (compared to just under 48 hectares under Scenario 6).

Table 15-1. Summary of catchment inputs for each of the catchment outlets (Figure 2-2) for Scenario 14. Number in brackets indicating magnitude of change compared to Scenario 6.

	Awaruku	Long Bay	SS Outer	SS Mid East	SS Mid West	SS Inner	Redvale	North Arm	North Shore	Karepiro	Karepiro Beach	Stillwater	Wēiti South	Silverdale	Arkle Bay	Whangaparaoa Wēiti North	North Outlet	Duck Creek
Zn (kg/yr)	57.3	121.5	16.9	35.8	26.7	27.1	589.9	194.1	10.8	30.5 (2.3)	36.2 (0.9)	31.5	219.4	601	23.7	14.6	18.4	36.3
Cu (kg/yr)	48.7 (-6.8)	19.5 (-5.5)	1.3	4.5	3.5	6.9	49.5	15	0.4 (-0.3)	4.8 (-2.8)	7.7 (-2.8)	11.5 (-0.2)	18.3	156.3 (-123.8)	15.2	6.0 (-0.6)	1.6 (-0.1)	6.2
Zinc Concentration (mg/kg)	1819 (-254)	553 (-154)	195	282	243	541	154	204	47 (-31)	197 (-139)	314 (-129)	464 (-9)	249	588 (-466)	1002	583 (-68)	208 (-16)	318 (-1)
Copper Concentration (mg/kg)	288	130	82	83	69	111	47	73	23 (-5)	48 (-8)	73 (-2)	74	87	127	142	114	83	86

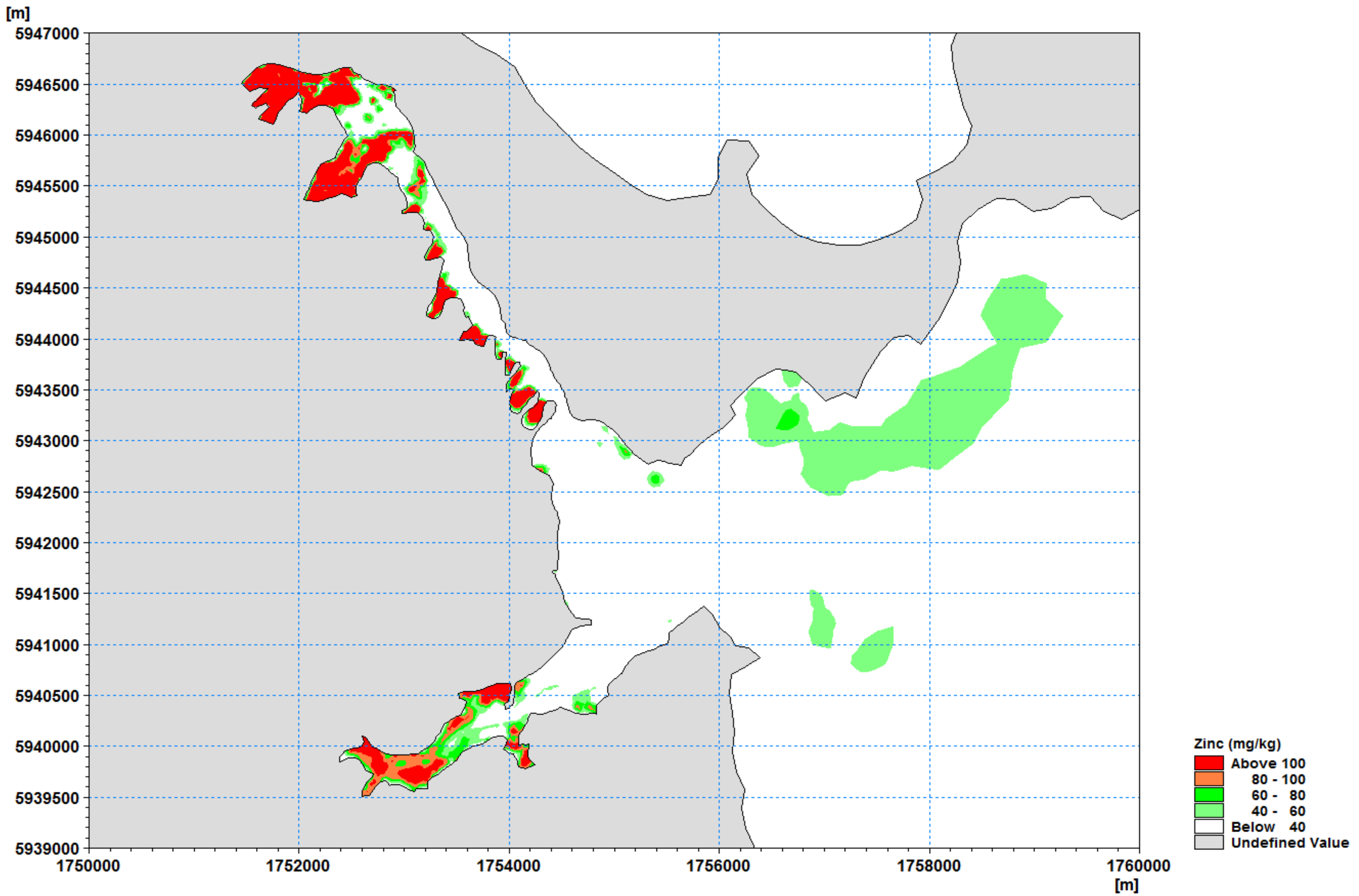

Figure 15-1. Zinc concentrations (mg/kg) 50 years from present under Scenario 14.

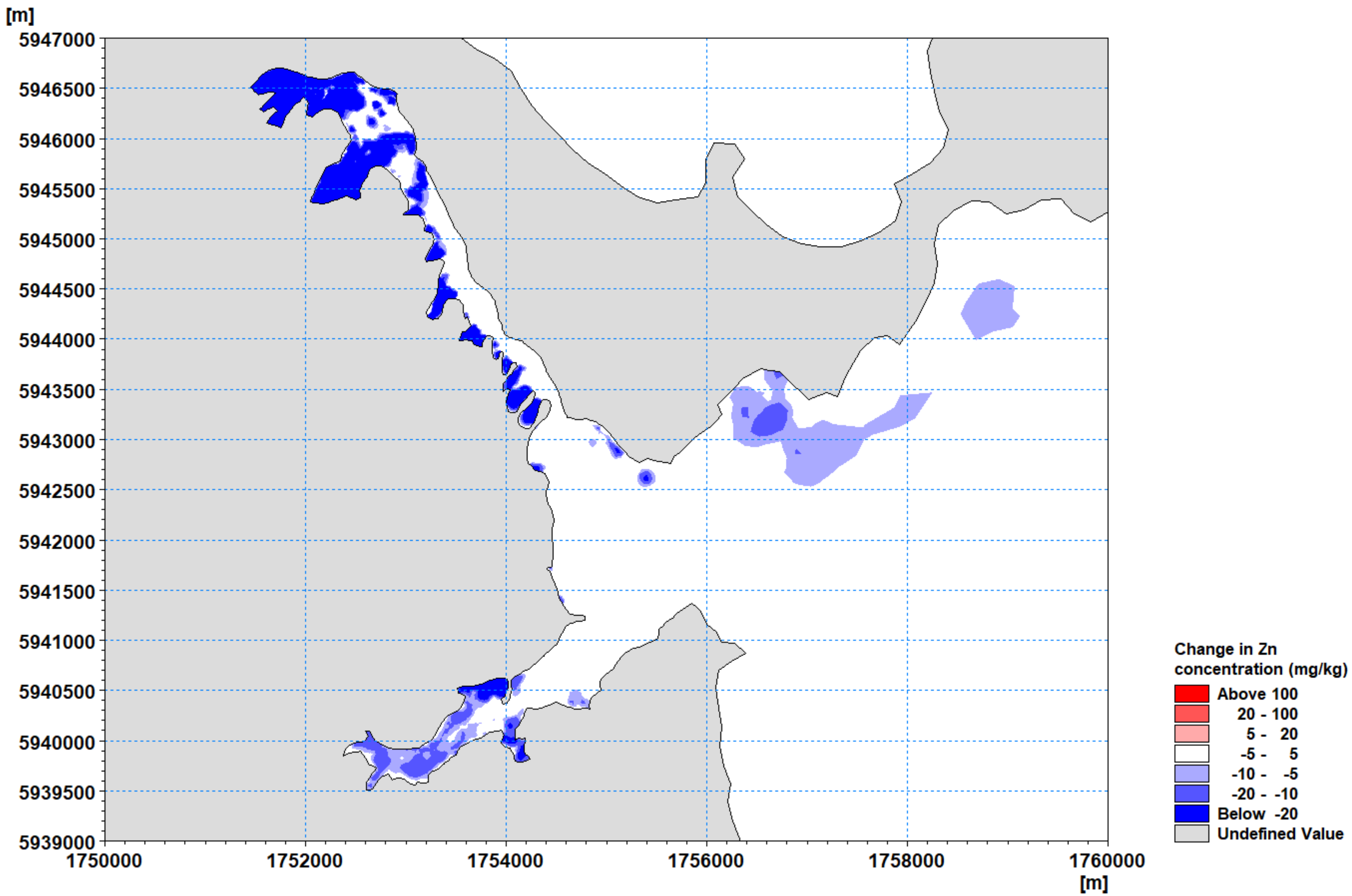

Figure 15-2. Changes in Zinc concentrations (mg/kg) 50 years from present under Scenario 14 (inert roofing across all development areas) compared to Scenario 6.

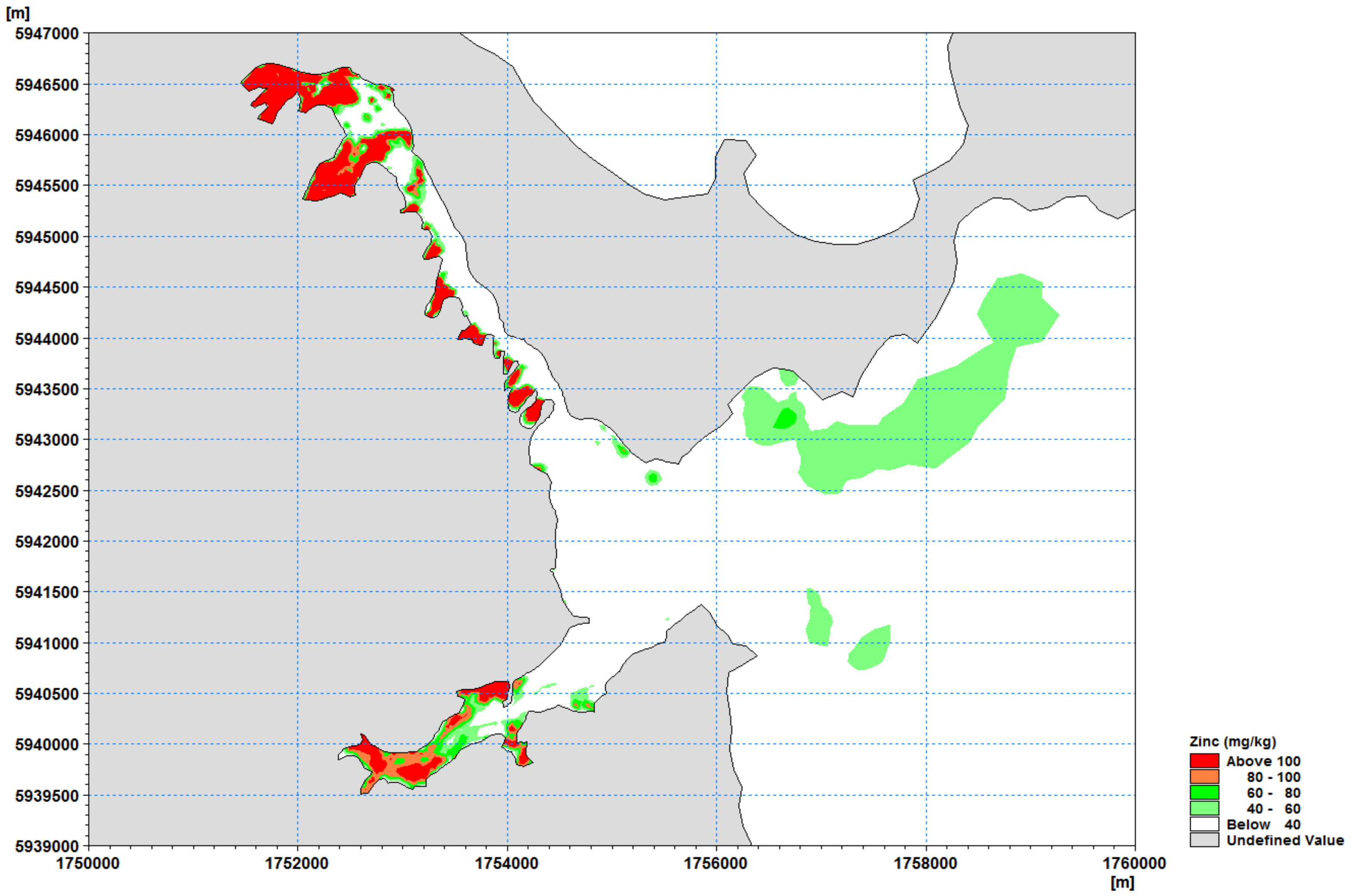

Figure 15-3. Copper concentrations (mg/kg) 50 years from present under Scenario 14.

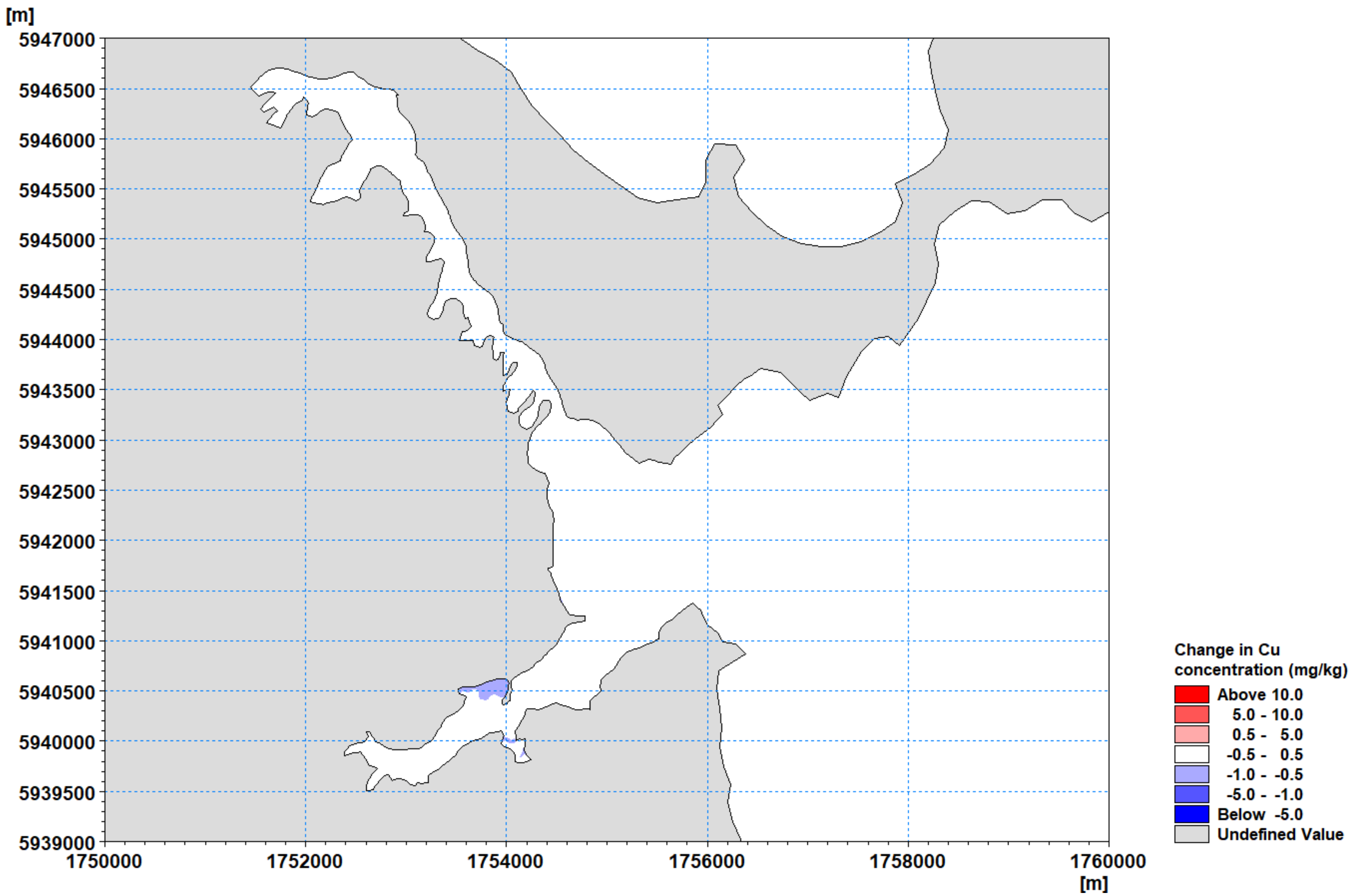

Figure 15-4. Changes in Copper concentrations (mg/kg) 50 years from present under Scenario 14 (inert roofing across all development areas) compared to Scenario 8.

Table 15-2. Future subestuary metal concentration (mg/kg) under Scenario 14 along with area where PEL thresholds of 271 mg/kg for Zinc and 108 mg/kg for Copper are exceeded and the maximum predicted concentrations. Figures in brackets show the change in concentration compared to Scenario 6. Predictions are for 50 years from present day.

	Future Zinc (mg/kg)	Future Copper (mg/kg)
Upper Okura subestuary concentration	88.9 (-10.4)	24.8 (-0.2)
Mid Okura subestuary concentration	54.7 (-8.2)	13.4 (-0.2)
Lower Okura subestuary concentration	26.3 (-0.3)	5.0
Karepiro (S) subestuary concentration	26.6 (-0.7)	5.1
Karepiro (N) subestuary concentration	27.8 (-1.1)	5.4
Upper Wēiti subestuary concentration	129.3 (-68.8)	29 (-0.1)
Mid Wēiti subestuary concentration	75 (-26.2)	16.0 (-0.1)
Lower Wēiti subestuary concentration	70.3 (-20.8)	15.0 (-0.1)
Marine Reserve subestuary concentration	26.7 (-0.4)	5.0
Outer Karepiro subestuary concentration	26.8 (-0.4)	5.0
Whangaparaoa subestuary concentration	31.1 (-2.2)	6.0
Total area (ha) where PEL is exceeded		
	1.1	0.0
Maximum Concentration (mg/kg)		
	273.8	59.8

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