NEW BRIDGEWATER BRIDGE

Hydrodynamic Modelling

10 November 2021

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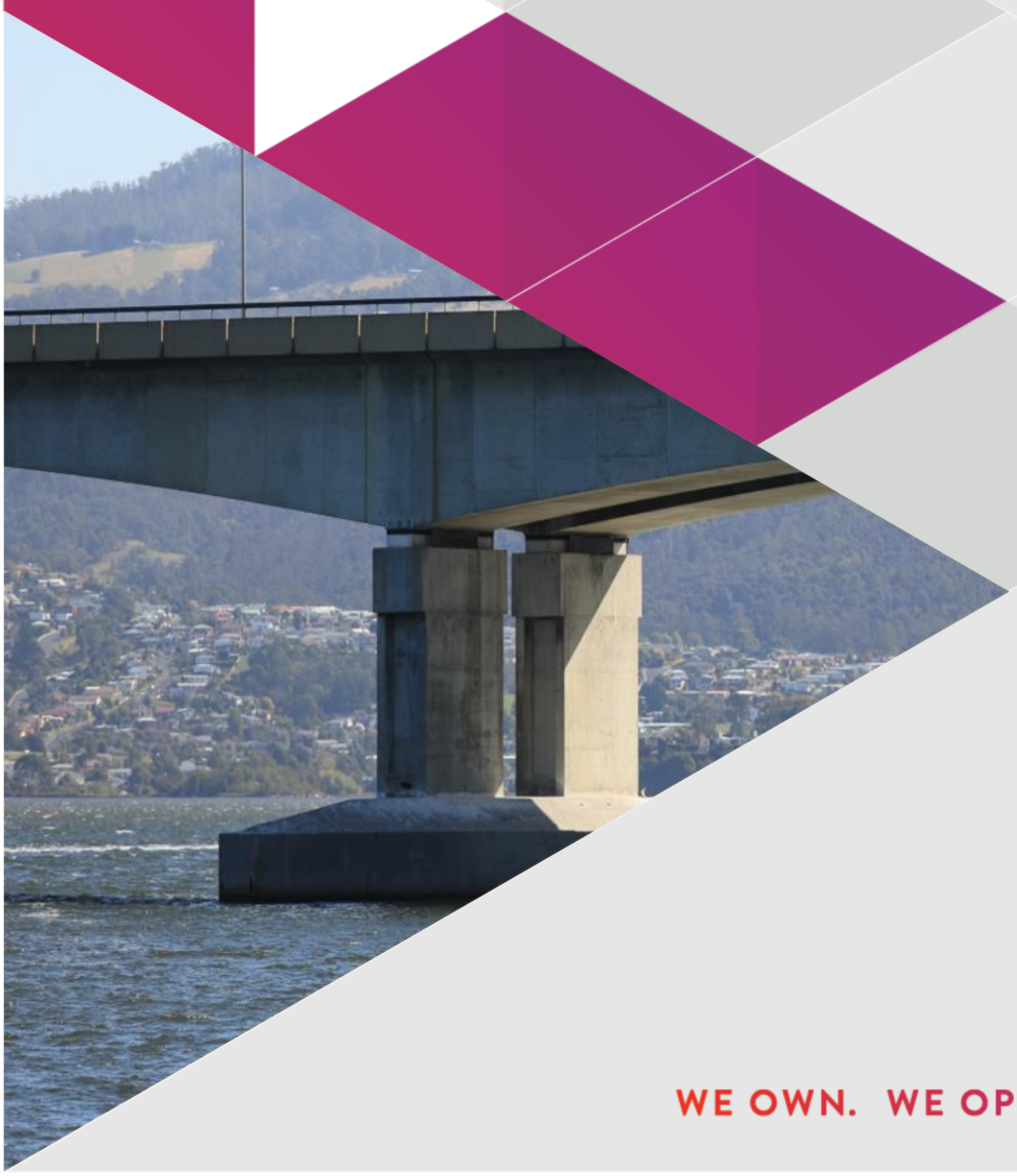

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Document information

Document title	New Bridgewater Bridge
	Hydrodynamic Modelling
Client organisation	Burbury Consulting
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ConsultDM number	E308893
Project Manager	Colin Terry
Project number	P517032

Revision history

Revision 2.1

Revision description			
Prepared by	Dr Colin Terry	Colin J. Terry	10 Nov 2021
Reviewed by	David Fuller		10 Nov 2021
Approved by	David Fuller		10 Nov 2021
	(name)	(signature)	(date)
Distributed to	Bryce Taplin (name)	Burbury Consulting (organisation)	10 Nov 2021 (date)

Revision 1.0

Revision description			
Prepared by	Dr Colin Terry	Colin J. Terry	24 July 2021
Reviewed by	David Fuller		28 July 2021
Approved by	David Fuller		28 July 2021
	(name)	(signature)	(date)
Distributed to	Bryce Taplin (name)	Burbury Consulting (organisation)	29 July 2021 (date)

Cover image: Looking upstream at the Bowen Bridge, River Derwent 4th April 2021 (Colin Terry)

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Executive summary

The report describes the development and validation of a hydrodynamic model for the River Derwent; and the application of this model to assess the mobilisation and distribution of sediment and zinc – a key contaminant within the sediment, during the construction and operation of the New Bridgewater Bridge. The model is also used to assess the potential for bed scouring and depositional changes post-construction.

Model results are to be used by others to assess the sediment and water quality impacts of the new bridge and in support of the development of the Major Project Impact Statement (MPIS).

As the final bridge design has yet to be determined, this assessment has been based on a bridge similar to reference design Option 2, with potential land reclamation on the northern and southern sides of the bridge alignment also considered. That is, a bridge that is supported by piles and separated from, and independent of the existing bridge. Noting the existing bridge is assumed to remain in place for the short-term but is noted to be removed for the longer term.

By disturbing the soft silty sediments, piling and other activities including the movement of equipment, barges and shipping associated with bridge building have the potential to release material into the water column. Accidental spills of removed silt could also occur. A range of conservative assumptions were made to develop plausible scenarios for the release of sediment and zinc into the water column at various locations across the works footprint. Modelling led to the following general conclusions:

- Heavier particles will settle out close to the source, while lighter particles and dissolved matter will be transported further.
- Material is likely to be transported a short distance upstream of the works but much further downstream, with concentrations reducing with distance from the source.
- Continuous or semi-continuous sources of material from extended works would waft back and forth on the tide near the source, and then drift further downstream creating a continuous plume of decreasing concentration.
- The shape of the plume is a function of the timing, concentration and location of the source of the matter, as well as river flow rates, tide and to a lesser extent atmospheric conditions (wind, temperature, solar radiation).
- Suspended sediment plumes may be visible during the construction period.
- With a plausible worst case scenario, modelled average zinc concentrations were found to be under 23 µg/L, except immediately near the worksite itself.
- Accidental spill of sediment into the water column for events up to 25 tonnes will create a slug of matter that dilutes as it is washed downstream. Poor water quality outcomes are likely in the immediate area of the spill. However, no significant far-field effects are expected.
- Post construction there is some potential for changes in the river bed associated with the completed works. The model indicates the changes are small under low flow conditions. However under larger events more significant changes may be expected locally in the main channel's central pier group. This is an issue to be considered during detailed design.
- Overall the effects of the works on water quality are confined to be close to the works, and mainly to the southern shore of the River Derwent downstream to the confluence with the Jordan River.
- Potential land reclamation causes local circulation changes, in particular a slowing of flow in the semi-enclosed space ("cove") at the southern site, resulting in approximately half the mean velocity compared to no reclamation (a third of the median velocity). Whilst there is still some flushing, this area could be prone to accumulation of floating debris or litter. Within the

sensitivity of the model, no changes in bed thickness were identified in the southern reclamation area during the two-month summer low flow scenario. However, some local erosion/deposition was modelled immediately around the northern reclamation area where there is faster moving water.

These conclusions are based on the assumptions made during modelling including the proposed design of the new bridge, disturbance caused by construction activities, any reclamation works being self-contained from the river from a water quality point of view, and the retention of the existing bridge and piers. Further modelling work may be required if substantive changes are made as part of the detailed design phase of the project.

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1. Introduction

Entura was engaged by Burbury Consulting to undertake hydrodynamic and contaminant transport modelling in support of the Major Project Impact Statement (MPIS) for the New Bridgewater Bridge.

The location of the proposed bridge is shown in Figure 1.1. The design of the bridge is yet to be finalised. For the purposes of this assessment the proposed bridge is assumed to be supported by piles with the potential for some limited reclamation. This is similar to the reference design Option 2, that is, a bridge separated from, and independent of, the existing causeway and bridge, which is assumed to remain in place for the short-term (and is left in for this modelling) but is noted to be removed for the longer term. The proposed bridge will be similar in character to the Bowen Bridge (see cover image).

Works within the river will involve the construction of the substructure such as piling and removal of sediment from inside the piles. The sediment will be transferred to barges and then removed from the project works for appropriate disposal. There would also be other activities within the river including temporary works, the movement of equipment, barges and shipping to support the bridge construction.

This report's focus is on the development and application of a computer model to support the assessment of the potential effects on water quality, effects from activities within the River Derwent during the construction and operation of the New Bridgewater Bridge. In particular, the model is used to estimate the mobilisation and transport of sediment and zinc (a key contaminant associated with the sediment), as well as the potential for bed scouring and depositional changes post-construction.

1.1 Scope

The Development Assessment Panel has included a section on water quality in the MPIS assessment criteria based on a submission by the Participating Regulator, the Environment Protection Authority (EPA) Tasmania. As water quality is naturally dependent on the hydrodynamics of the estuary, Entura and Marine Solutions were requested to work closely together to address these criteria (Table 1.1).

Entura's scope was therefore to:

- Develop a purely physical hydrodynamic model of the River Derwent that is capable of modelling the interaction between the bathymetry of the estuary with tides and catchment inflows, and the movement and deposition of suspended matter.
- The model was required to include recent and more detailed data on the bathymetry of the River Derwent than was available in earlier models. This included a survey near the Bridgewater Bridge.
- The model was required to quantify the key water quality effects of the proposed works.
- Model scenarios were to be developed in consultation with Burbury Consulting, Marine Solutions and other parties involved in the preparation of the MPIS.

The model was not required to model geochemical processes such as dissolved oxygen or nutrients, or biophysical processes such as the ingestion and concentration of heavy metals in biota.

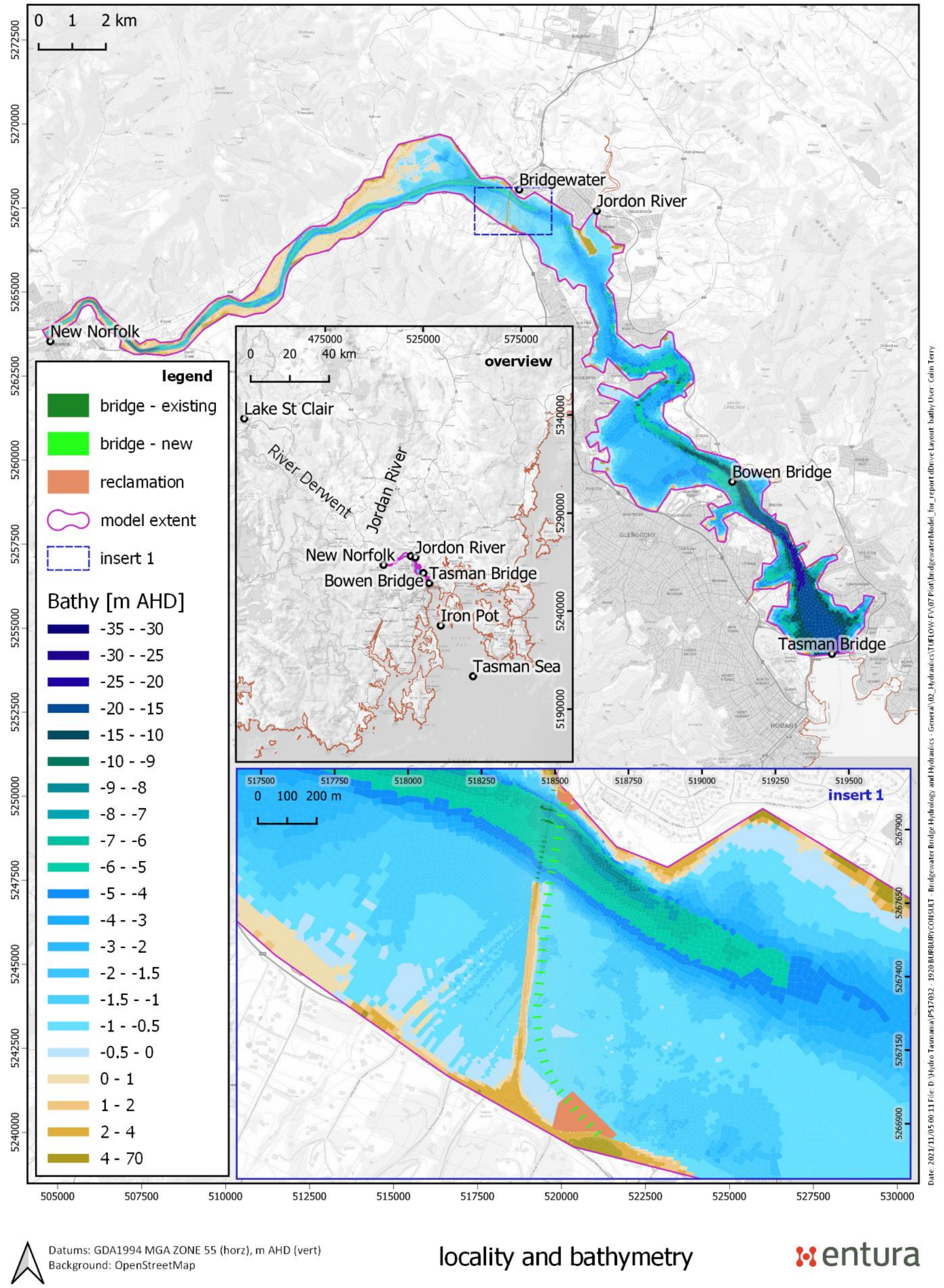


Figure 1.1: River Derwent and a potential new bridge alignment (pile groups shown)

Table 1.1: Entura's scope for addressing MPIS water quality assessment criteria

MPIS water quality assessment criteria	Response by
(a) describe the Derwent Estuary receiving environment (and other local water courses) for pollutants that may be released as a result of construction works and post-construction changes to water flow and sediment deposition, including:	
(i) identification of the full extent of the Estuary, both east and west of the Bridge, that may be impacted through the release of sediment and associated pollutants to the water column as a result of the proposal, or may be impacted by changes to water flows post construction;	Entura – **Sections 4, 5, 6**
(ii) a list all potential receptors and environmental values within the identified area of impact;	Marine Solutions
(iii) a description of estuarine hydrodynamics in the area of potential impact as relevant to the mobilisation and distribution of sediment and other potential contaminants; and	Entura – **Section 4.1**
(iv) a description of the physical and biological characteristics of the nearby macrophyte beds in relation to the potential for sediment entrapment, deposition, smothering and the effects of anoxic conditions;	Marine Solutions
(b) in addition to sediment load, identify contaminants of potential concern that may be released to the water column and water quality parameters that may be impacted and include a review of available historical information including previous contaminant assessments, land use history and contaminant transport modelling;	Entura – see **Section 2** and Marine Solutions
(c) provide details of monitoring programs and surveys established to assess impacts to water quality in relation to identified estuarine habitats and use, including impacts to the macrophyte beds in the vicinity of the Bridgewater Causeway, and provide:	Marine Solutions
(i) the results of sediment sampling undertaken in areas of potential disturbance along with a discussion that includes information regarding sediment physical characteristics, contaminant concentrations and the potential for acid sulphate soils;	Marine Solutions
(ii) survey results of aquatic habitats in the identified areas of potential impact; and	Marine Solutions
(iii) the results of baseline water quality monitoring for contaminants and parameters of concern that includes monitoring of existing sediment loads and turbidity at nearby receiving environments;	Marine Solutions
(d) assess potential impacts to receiving water quality and habitats, including:	
(i) provide the results of water flow investigations carried out that includes:	
a. an analysis of potential sediment mobilisation, transport, and deposition locations under a range of hydrologic circumstances including plausible worst-case scenarios;	Entura – **Sections 4**
b. references to any historical modelling;	Entura – **Sections 2**
c. analysis considering variable catchment flows and tides and a range of plausible construction scenarios; and	Entura – **Sections 3.2**
d. potential post construction changes to flows which may result in scouring and changes to sediment deposition location should be considered;	Entura – **Sections 3.4.3, 4.3**
(ii) subject to consideration of expected sediment control measures, determine potential sediment deposition rates and effects on estuarine habitats, using analysis based upon the results of:	Marine Solutions
a. monitoring programs of sediment characteristics and sediment deposition;	Marine Solutions
b. hydrodynamic analysis; and	Entura – **Sections 4.3**
c. consideration of the impact of smothering and anoxic condition on the macrophyte beds;	Marine Solutions
(iii) determine specific water quality guideline values for the project land for assessment of water quality impacts during and after construction, using guideline values determined by:	Marine Solutions
a. reference to National Water Quality Management Strategy Guidelines;	Marine Solutions
b. the results of monitoring and survey work;	Marine Solutions
c. other existing local water quality information available; and	Marine Solutions
d. analysis of potential sediment scouring and deposition impacts to habitats;	Marine Solutions
(iv) consider the near and far-field impacts that may result from release of nutrients to the water column; and	Marine Solutions
(v) consider the potential for metals and other contaminants contained within sediment to be desorbed, dissolved, or otherwise become chemically more or less bioavailable, in areas of disturbance and areas of potential sediment deposition;	Marine Solutions
(e) provide an outline of the proposed construction sediment management approach, that includes:	Marine Solutions
(i) detailed sediment control measures to be implemented during construction and the expected performance standards in relation to these control measures;	Marine Solution
(ii) detail of any construction sediment analysis, water quality monitoring programs and habitat monitoring proposed and the criteria against which impacts to water quality and receiving aquatic habitats will be assessed;	Marine Solutions
(iii) consideration of contingency measures to adapt to variations from predictions, poor performance or unforeseen changes during construction; and	Marine Solutions
(f) detail any post construction monitoring proposed to assess the potential longer term impacts to water quality and receiving habitats	Marine Solutions

In summary, Entura’ scope relates to the hydrodynamic components and Marine Solutions work focusses on the impact assessment on the marine environment.

This report

- Identifies the extent of the estuary likely to be affected by the release of sediment and a passive tracer representing dissolved pollutants to the water column as a result of the works, or may be impacted by changes to water flows post construction.
- Models and describes the estuarine hydrodynamics in the area of potential impact as relevant to the mobilisation and distribution of sediment and other potential contaminants.
- Provides a review of historical contaminant transport modelling and leverages off monitoring by the Derwent Estuary program.
- Provides an analysis of potential sediment mobilisation, transport and deposition under a range of hydrological conditions and construction scenarios; and identifies plausible worst-case scenarios.
- Assesses potential post-construction changes to flows which may result in scouring and changes to sediment deposition.
- Provides estimates of sediment deposition rates in support of the separate analysis of environmental impacts and sediment control measures.

2. The River Derwent

The New Bridgewater Bridge is proposed to make a new crossing of the River Derwent immediately downstream (east) of the existing causeway and bridge (Figure 1.1).

- Upstream of the project land the river flows from alpine catchments through Lake St Clair, passing through the rural Derwent Valley, through several run-of-the-river hydro-electric reservoirs, the township of New Norfolk and its bridge, and past a paper mill. Significant freshwater flows are generated from this catchment that discharge through the project land.
- Downstream of the project land, the river flows past the Jordan River, the Bowen Bridge at the City of Glenorchy, a zinc works, City of Hobart and the Tasman Bridge, and finally at the Iron Pot the river joins the Tasman Sea.

The River Derwent is comprised of upstream freshwater from the catchment, and the estuarine environment where fresh and saline waters mix. The upstream extent of the estuarine environment and tidal activity is around New Norfolk. There is a tide gauge near Battery Point in Hobart, 3 km downstream of the Tasman Bridge.

2.1 Previous modelling studies

The River Derwent has a history of heavy metal contamination and the upper and middle estuary typically display elevated nutrient levels. The river is monitored by the Derwent Estuary Program (Derwent Estuary Program, 2018; and Derwent Estuary Program, 2020) and has been comprehensively modelled by CSIRO (Margvelashvili, Herzfeld and Parslow, 2005; Herzfeld et al. 2005; Wild-Allen et al. 2009a; and Wild-Allen et al., 2009b). Some relevant findings from this work are listed below:

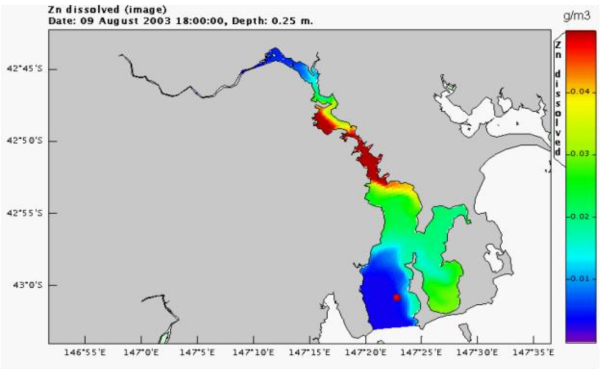
2.1.1 Circulation and hydrodynamics

- The Derwent Estuary behaves as a salt wedge estuary with marine flow in bottom waters directed upstream in the estuary and a fresh water surface flow heading downstream. The head of the salt wedge is located above Bridgewater under low flow and is pushed downstream under high flow conditions. Surface salinities may be less than 20 practical salinity units (psu) in the lower estuary under high flow.
- On diurnal timescales the tidal flow dominates the region, with flow directed up-river during the flood-tide, and vice versa during the ebb-tide. Under low flow conditions a surface reversal of the currents is seen in the upper and middle estuary during the tidal period but this is absent under high flow since the river discharge overwhelms the tidal flow.
- Herzfeld et al. (2005) noted that the calculation of flushing times can be subjective depending on the method used. Reported flushing times varied from less than 1 day for many of the side bays to approximately 11 days for the whole model domain from New Norfolk to the Tasman Sea. A flushing estimate for the whole domain based on the average time for neutrally buoyant particles to exit the domain was computed as approximately 12 days.

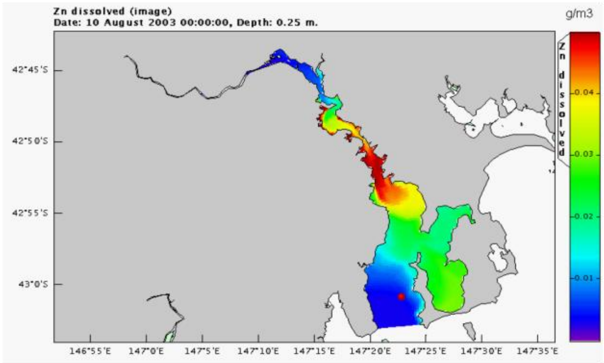
2.1.2 Sediment

- Under low and moderate flow conditions (less than 150 m^3/s), a net upstream flux of fine sediment was modelled in the Derwent estuary due to tidal resuspension and baroclinic (salt-wedge) circulation.
- During high flow events (greater than 500 m^3/s), enhanced resuspension of bottom sediments in the upper and middle estuary develops a plume of concentrated suspension that propagates downstream with fresh water. As this plume and its associated freshwater layer mix with the underlying salt wedge, sediments flocculate out and settle out onto the sea bed.

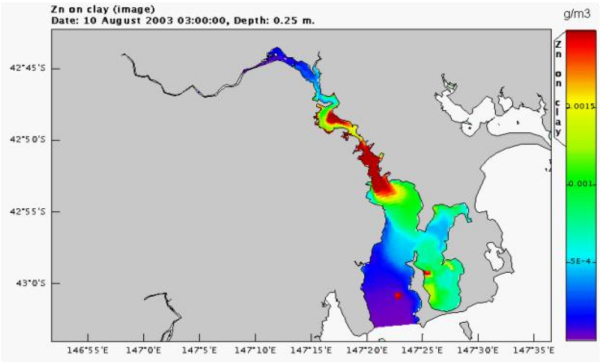
2.1.3 Zinc



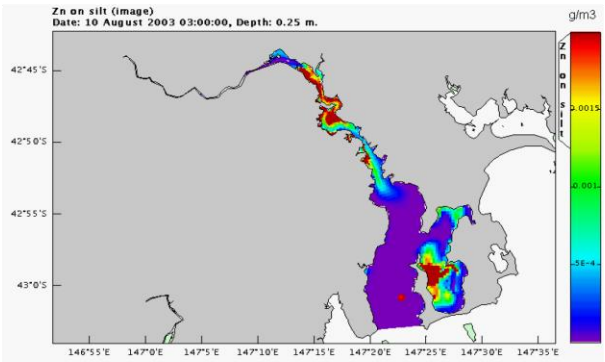
a) Dissolved zinc high spring tide



b) Dissolved zinc low spring tide



c) Attached zinc to clay



d) Attached zinc to silt

Figure 2.1: Modelled surface concentrations of dissolved and attached zinc in the Derwent Estuary (Source: Margvelashvili, Herzfeld and Parslow (2005))

- As a result of the circulation in the Derwent Estuary, combined with tidal mixing, zinc gradually spreads along the estuary out of the area of highest contamination, with the net fluxes directed upstream above Elwick Bay and downstream below Tasman Bridge.
- During flood events, the contaminant maximum in the water column is flushed downstream and diluted in the lower estuary. While the concentration of the dissolved zinc drops during runoff events, total zinc levels increase sharply, due to enhanced resuspension of zinc attached to sediments. Thus, particulate zinc, along with bottom sediments, are transported from the upper estuary downstream to the middle and lower estuary during flood events.
- The distribution of zinc in bottom sediments is controlled by a balance between low to moderate flow periods, during which some zinc is slowly transported upstream by the estuarine circulation, and high flow events during which sediments and attached zinc are transported downstream.

- A series of model runs were conducted by Margvelashvili, Herzfeld and Parslow (2005) to examine the ability of the model to reproduce observed distributions of dissolved and particulate zinc in the estuary water column under different assumptions about these parameters (Figure 2.1).

2.2 Key features to be modelled

For the purposes of the current project the focus is on the estuarine part of the River Derwent – from New Norfolk, to the Tasman Bridge which is the downstream extent of modelling.

The key features of the River Derwent are:

1. Estuarine environment with a mixture of fresh and salt water, with the balance depending on the river flow rate and tide levels
2. Normal semi-diurnal tide of ± 0.6 m around a mean of 0.05 m AHD[1], highest astronomical tide 0.86 m AHD and 1:100 annual exceedance probability (AEP) level of 1.44 m AHD with the current climate (CSIRO, 2019), with an expectation this will rise by 0.85 m over the next 80 years (McInnes *et al.*, 2016)
3. Depth is from 30 m near Tasman Bridge, 5 m near Cadburys, 5–10 m near Bridgewater in the main channel. The shallows either side of the causeway are 0.6–1 m deep (Figure 1.1)
4. A salt wedge that moves with the tide and flow regime. Saline water can reach New Norfolk under very low flows
5. Typical estuary wide background Total Suspended Solids (TSS)[2] is 3 mg/L (*pers comm*, Derwent Estuary Program)
6. Suspended sediment concentration increases with river flow for the River Derwent and Jordan River, with the Jordan River observed to have higher sediment concentrations
7. Macrophytes (seagrasses and macroalgae) are mainly just upstream and downstream of the existing Bridgewater Bridge and in Elwick Bay.

2.3 Existing sources of sediment

Waterways provide a natural pathway for the mobilisation and downstream transport of sediment and other material. Typically the highest concentrations of material are transported on the rising limb of flood waves. Material may be deposited within the waterways only to be remobilised during later events. Eventually most material finds its way to estuaries.

Figure 2.2 is a Google Earth™ satellite image from September 2009 that indicates sediment laden water (brown) from the Jordan River on the right hand two thirds of the of the image. The change in colouring on the left of the image is satellite imagery from a different date.

It is evident in Figure 2.2 that the sediment plume from the Jordan River hugs the eastern shore and is apparent downstream past the Bowen Bridge near Risdon. Near Faulkners Rivulet at Claremont there also appears to be sediment laden water in Windermere Bay on the western shore of the River Derwent. Sediment from sources just upstream of Bridgewater are also apparent as is a source near Granton that hugs the south/western shore (Figure 2.2).

[1] 1983 Tasmanian Australian Height Datum (AHD)

[2] Suspended solids retained on a 0.45 µm filter

Figure 2.2: Sediment plumes in the River Derwent and Jordan River

3. Methodology

A hydrodynamic model was used to help understand the state of the existing river, and then the river with the proposed New Bridgewater Bridge works. The focus of the computer model is water movement, sediment transport and movement of a passive tracer representing dissolved zinc. Zinc was chosen to represent matter released from sediments as a result of disturbance, as it was found to be the contaminant at the most toxic concentration in sediment elutriate samples from the project area (*pers. comm.* Marine Solutions). Passive dissolved zinc modelling therefore presents a conservative basis for modelling the effects of the works.

The nature of the proposed construction works is to disturb a relatively small area of the river cross section. More disruptive marine activities, such as dredging, are not proposed. Consequently, the methodology is considered appropriate from a risk and uncertainty point of view.

If extensive disturbance of sediments (e.g. dredging) were to be proposed then further investigation could be warranted.

Although the proposed disturbance is much less than would be expected from dredging, there are learnings that can be transferred from dredging plume studies. Research by CSIRO in Western Australia has developed a guideline for dredge plume modelling (Sun, Brabson and Mills, 2020). Figure 3.1 shows the indicative relationship between the mass of sediment in suspension and distance/time from source. Heavier sediments tend to drop out of the water column closer to the source.

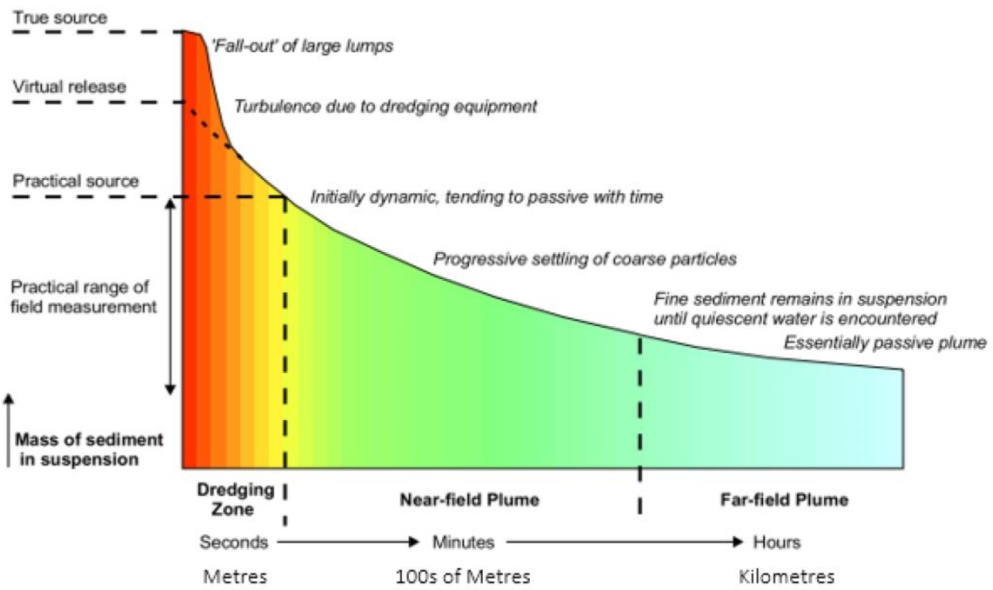


Figure 3.1: Development stages of dredge plumes and alternate source term definitions (Sun *et al.,* 2020)

A key challenge with this study was in establishing the local (near-field) hydrodynamic and water quality characteristics of the source of the effect that are an input to the far-field hydrodynamic model.

While there was no largescale field validation of the whole model, a qualitative comparison with a dye test by Marine Solutions gave confidence that the general circulation around the existing Bridgewater Bridge was well represented in the model. It is expected that:

- Further work may need to be undertaken once the final design and construction methodology has been further progressed
- Monitoring and an adaptive management approach will be adopted during construction to respond to actual river behaviour and unforeseen conditions.

At this stage of the project the detailed construction methodology from contractors is unknown. Therefore the modelling encompasses a range of standard industry construction practices that have varying effects on water quality, together with more or less favourable hydrological events. A combination of these factors produces a plausible worst case for water quality in the River Derwent.

3.1 Hydraulics

TUFLOW-FV software (BMT Group Ltd, 2020) was used for hydrodynamic modelling. TUFLOW-FV uses three-dimensional shallow water equation approximations of the Navier Stokes equations[3] and is suitable for modelling the circulation, water quality and sediment transport in lakes, estuaries, rivers and coastal regions. The model calculates spatially varying water velocity, surface levels, temperature, salinity, TSS[4], and sediment bed thickness as they vary with time from an initial condition.

The hydrodynamic model calculates the movement of water over time from an initial starting "model state" to a future "model state" under the influence of external "forcings". In this case:

- "Model state" means the velocity, depth, salinity, temperature, sediment concentration, etc for every point in the domain being modelled.
- "Forcings" are the wind, radiation, water levels, flow rates, sediment loading, etc applied at the edges of the model domain.

The initial state of the river is not known perfectly. To overcome this limitation, hydrodynamic modelling typically includes using a "warm up" dataset to create a stable starting point for a test simulation.

The extent of the hydraulic model was selected to be:

- Far enough from the site works that any inaccuracies in the boundary conditions would not have a measurable effect on the site circulation and water quality
- At locations where the water and water quality behaviour could be well defined
- Far enough from the site works that any effects at the extents would be minimal
- Not too large so that in the limited period for this assessment simulation runtimes would not be excessive when simulating a spatial scale to describe the site works.

[3] shallow water equations assume vertical momentum is zero

[4] Modelled TSS does not include organic material and is different from chemical analyses for TSS

The selected model extent covers 37.4 km of the River Derwent (Figure 3.2):

- Starting upstream at New Norfolk, which is the upper extent of the salt wedge under low flows; so water here could be assumed to be fresh.
- Ending downstream at Tasman Bridge, where there is a tide gauge and it is primarily seawater at a river cross section with a relatively simple circulation pattern.

Given the relatively small nature of the potential disturbance at the proposed bridge site, modelling beyond the Tasman Bridge was not considered appropriate.

The TUFLOW-FV model parameters are summarised in Appendix A.1.

The modelling process uses a finite volume discretisation on a flexible mesh, made horizontally of mainly quadrilaterals and some triangles. The size of the mesh varies from 3 m near the site to 100 m further downstream from the site. Vertically there is a hybrid co-ordinate system of flat z-layers[5] up to -2 m AHD and then five sigma levels that vary with depth above this. When the water is less than 0.5 m in depth it is modelled as two-dimensional flow.

Temperature and salinity control the water density within the model, which can create density driven flows such as the salt wedge. The river sediment concentration is low and would not have any material effect on density modelling. For this reason the model was set so that sediment concentration could not control water density.

Salinity is a scalar parameter in the model and is dominated by seawater adding salt to the model domain, and river water flushing the system with freshwater. Temperature is also controlled by sea and river heat inputs and is dominated by solar long and short wave radiation inputs. Wind at the surface introduces a shear stress and influences the upper levels of the water column; although in this assessment it did not have a noticeable effect on water quality outcomes. The Coriolis force is included forcing flow to the left[6], which means the flood-tide (inbound) hugs the west/south shore, and ebb-tide (outbound) the opposite shore.

Sediment erosion, transport, settling and deposition processes are modelled. For this assessment clay, silt and sand fractions are considered. Site sampling provided good data for the nearfield sediment properties, with literature values used for the far-field. The key model inputs are the 50th percentile particle diameter (d50), particle densities and bulk sediment densities.

Water eddy viscosity is calculated for mixing of scalars and momentum. The vertical viscosity uses an external add-in to TUFLOW-FV called the General Ocean Turbulence Model (GOTM) (2021). Horizontal eddy viscosity is from the Smagorinsky equation (BMT Group Ltd, 2013).

Final model runs simulated one month of river behaviour. Each run required approximately one day of actual time running on NVIDIA RTX 3090 graphical processor units.

While a small set of runs are presented in this report to describe the system behaviour and potential effects, over 200 test simulations were used to refine the model prior to these final runs.

[5] 1 m spacing -2 m AHD to -10 m AHD, 2 m spacing to -20 m AHD, and 5 m spacing to -35 m AHD

[6] as this is in the southern hemisphere (it would be the opposite in the northern hemisphere)

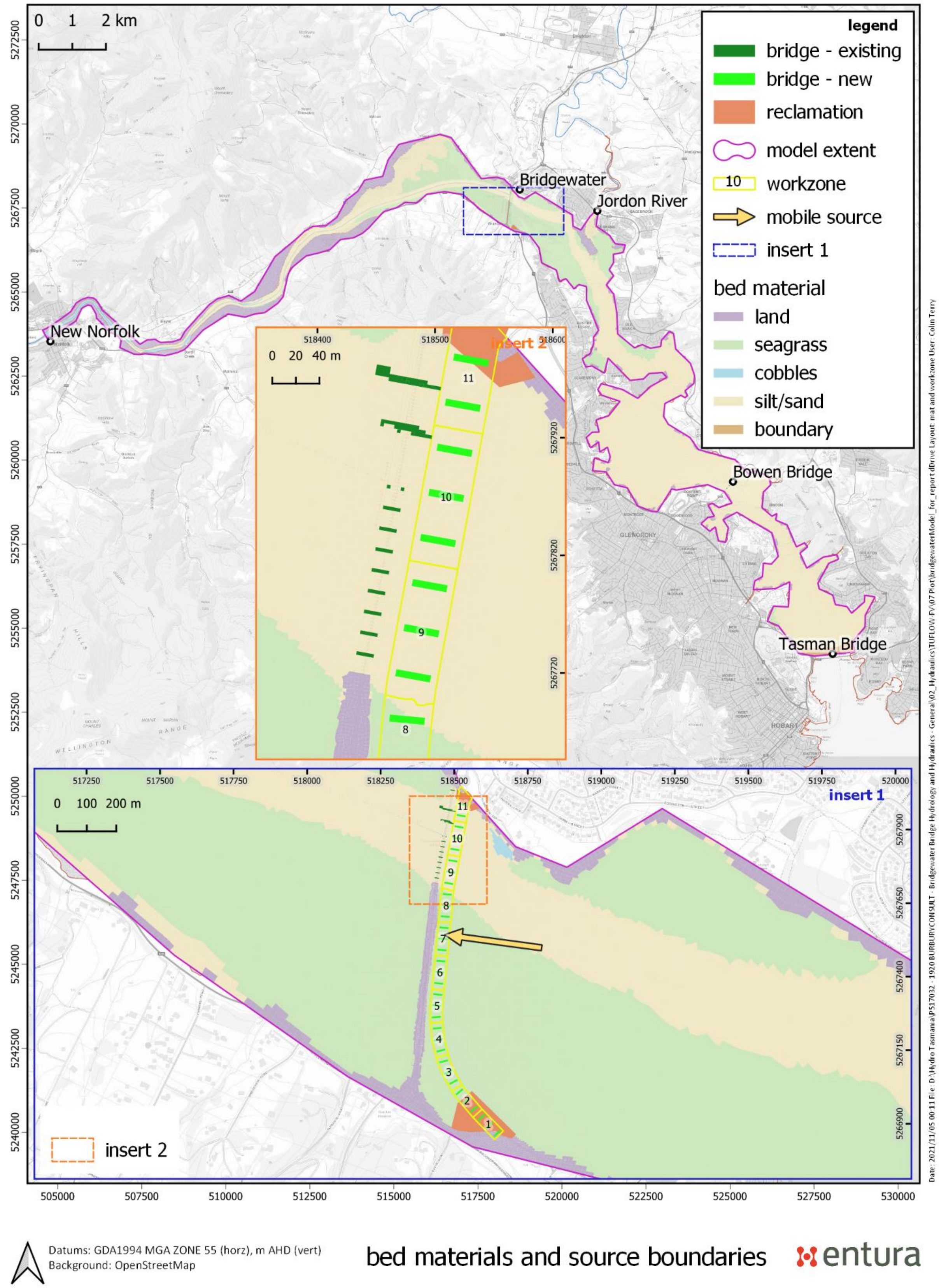


Figure 3.2: Hydrodynamic model set up, defined work zones and assumed “mobile source” location

Other key inputs to the hydraulic model are the bathymetry, bed roughness, initial condition and boundary conditions:

- Bathymetry was a combination of data from previous studies and project specific surveys downstream of the causeway and in the main river channel. The levels within the main channel were taken from a survey completed as part of the project by Jacobs. Shallow levels on the eastern side of the causeway were provided by Marine Solutions. Other model bathymetry was sourced from Mineral Resources Tasmania, survey and interpolation.
- Potential reclamation areas are assumed to have a conservative shape to highlight issues around changing circulation, with a small area on the northern bank of the River Derwent adjacent to the New Bridgewater Bridge and a larger area on the southern bank (Figure 3.2). Reclamation is assumed to be to a height of 1 m AHD (above the normal tidal range).
- Bed roughness values were taken from literature for the different zones (main channel sand/silt, shallow mud flats, cobbles and flood plains) and the mapping of these from the Tasmanian State Government's TheList layer *Derwent Habitat Atlas* (Tasmanian State Government, 2008).
- A model warmup sequence with a medium flow rate (see Section 3.2) for a month was used to initiate each model scenario. Typically January 2019 and Hobart Tide gauge was used for this purpose. This period was then reused for the comparison runs.
- Boundary conditions were derived from a flow hydrograph at the River Derwent (New Norfolk) and Jordan River (East Derwent Highway), water level at Tasman Bridge (using Hobart tide gauge data from 2019) and atmospheric forcing from ERA5 Reanalysis (2021). The study used an estimated Tasman Bridge water quality boundary (salinity[7] of 35 psu and temperature of 12°C). These assumed values were checked by modelling a test case with more accurate boundaries supplied by CSIRO. From testing with a medium flow scenario, the average results where similar enough to testing with the CSIRO boundaries to continue using the assumed boundary values.

The effects of the proposed New Bridgewater Bridge were modelled in the context of potential future scenarios (Section 3.4). Each scenario is described by a set of model inputs and represents a combination of hydrological, atmospheric, geometric and other model parameters.

3.2 Hydrology

Flow data is required as an input to the hydraulic model, to allow river and tailwater behaviour to be adequately modelled. This hydrological data is derived from measured and modelled inputs. The focus of the hydraulic analysis is on water quality processes which in this estuarine environment are dominated by the volume of river flow more than the peak flow rate.

River inflows at the River Derwent were derived from the analysis of river gauge data near Meadowbank Dam and at Macquarie Plains. Flows were adjusted by catchment area to account for the additional catchment between Meadowbank Dam and New Norfolk. There is limited gauged data for the Jordan River. As it provides a less important flow contribution, flows from the Jordan River were approximated by linear scaling with catchment areas of the River Derwent flow rates.

[7] practical salinity units (psu) is the same as parts per thousand (ppt) for this work

Two-month maximum and minimum rolling average volumes were calculated from the gauge data. This allowed a flood frequency analysis of the data to be calculated for three hydrological scenarios at different annual exceedance probabilities (AEP):

- **low** flow: lowest 2-month-volume 1:100 AEP
- **medium** flow: highest 2-month-volume median (1:2 AEP)
- **high** flow: highest 2-month-volume 1:100 AEP.

For each hydrological scenario, observed 2-month time series with the closest volume to the flood frequency analyses were used to disaggregate the estimates into a hydrograph (Figure 3.3).

- The high flow was from the Macquarie Plains gauge's 1928 event, with a peak flow of 1308 m^3/s.
- The low flow from a period in 1984 with approximately 30 m^3/s flow.
- The medium flow is a typical winter storm and then a typical Meadowbank power station controlled flow, from a period in 2001.

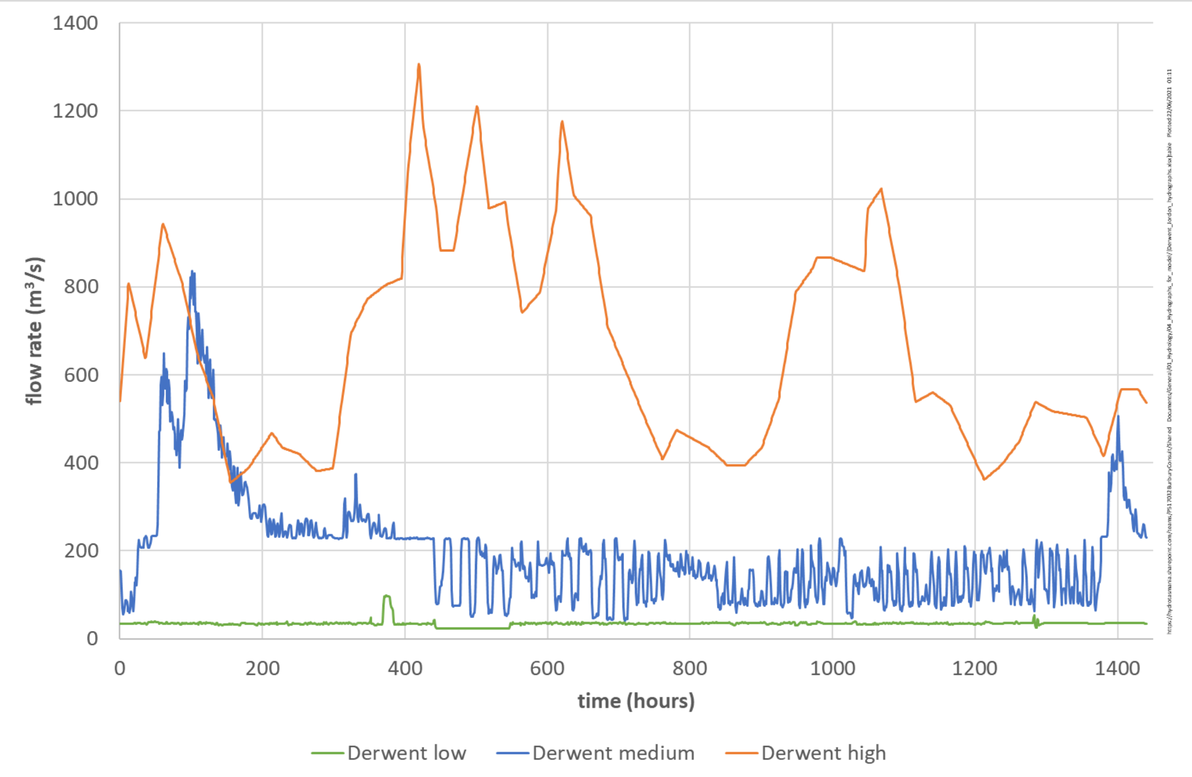


Figure 3.3: River Derwent hydrographs used as inputs to the hydraulic model

3.3 Water quality

The River Derwent water quality modelling in this study is focussed on the suspension and deposition of sediments, and the spatial and temporal changes in dissolved zinc concentrations. Zinc is the only heavy metal considered in this study. As explained previously, it is found at concentrations significantly higher than other contaminants in the sediment so is a good surrogate for potential toxicity concentrations resulting from sediment disturbance.

Suspended sediment, dissolved zinc, and the settled sediment have the potential to impact the environment and human health. The modelling results from this study will be used by others in assessing these impacts.

3.3.1 Source of water quality

The main source of sediment in the area modelled is the riverbed, with some from the River Derwent and some from the Jordan River. There is a thick layer of fine, soft sediment in the River Derwent in the vicinity of the proposed project area that is prone to dispersal when disturbed. Once mobilised in the water column, natural processes transport the sediment to near and far parts of the River Derwent, where it settles on the bed or is transported out to sea.

The sediment contains heavy metals, in particular zinc, which is partially dissolved into the water when the sediment is disturbed. There are natural processes such as adsorption of dissolved zinc onto sediment, and interactions with the environment which tend to reduce zinc's movement and bioavailability. As these processes are not considered in the passive contaminant modelling undertaken for this project, the dissolved zinc modelling results present a conservative assessment.

Disturbance of the sediments could occur from a range of activities. The scenarios considered in this assessment are where the river water is muddied by construction activity, and the release of sediment from piling operations. Examples of activities that may directly or indirectly stir up sediment include:

- Likely Construction Activities
    - Water vessel propellers near the bed in the shallows
    - Vessel wakes and wave action against their hulls
    - Dragging vessels through sediment
    - Vibration and impact on the bed from piling and temporary works
    - Removal of temporary work
- Emergency or Accident Scenarios
    - Release of sediment due to a vessel carrying sediment sinking
    - Losing a sediment filled skip overboard, or spillage of sediment being transferred into another vessel.

3.3.2 Quantifying the construction source concentration

The hydrodynamic model has computational cells, which are stacked through the water column. Within each cell the water parameters are assumed to be uniform. This means the detailed sediment processes within each cell are simplified or averaged, such that one value is given per cell. The horizontal and vertical sizes of the cells vary through the model domain, with the smallest cells at the proposed bridge location approximately 3 m across in plan and 0.5 m vertically. The behaviour within a cell or small group of cells is considered the "near-field", and the sediment in this group of cells will then be transported by the model as a plume to describe the behaviour of the "far-field".

The near-field/far-field concept is shown in Figure 3.4 for a dredging operation (Sun, Brabson and Mills, 2020).

The far-field plume is what this study models, and so an estimate of the near-field plume behaviour is required. The near-field processes are uncertain. Even in more researched areas, such as for dredging, heavy reliance is placed on empirical data to establish the near-field.

For this study the near-field behaviour is approximated by selecting sediment “generation” or “dosing” rates[8] based on the likelihood of marine vessels and construction activity disturbing the sediments. In addition, a dosing rate of a conservative tracer is used to model the potential effects associated with dissolved zinc.

In summary, the materials being dosed into the water column are:

- a sediment similar to the bed material in the shallows east and downstream side of the causeway (i.e. material with the same proportions of clay, silt and sand)
- a passive tracer, which does not decay with time, react or settle, and is therefore a conservative representation of a dissolved metal released from the sediment (i.e. zinc in this case).

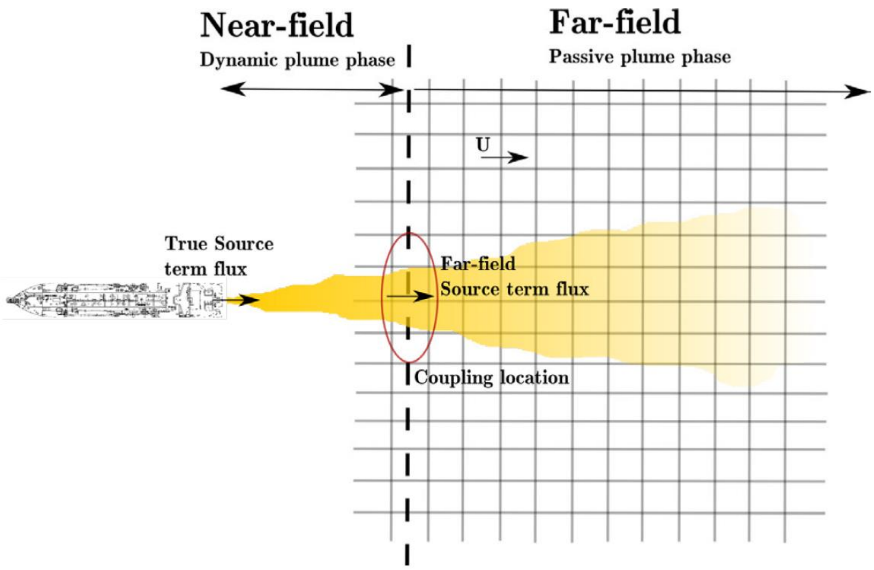


Figure 3.4: Schematic of dredge plume modelling indicating the near-field, far-field and coupling location (Source: Sun *et al.,* 2020)

As discussed in Section 3.4, the dosing rate, location and pattern represent a range of scenarios, including a small disturbance footprint with continuous inputs to the River; a large disturbance footprint with continuous inputs to the River; and transitory accidents.

Sediment is added to the model cells either in a continuous pattern (12 hours a day, 7 days a week) for typical work practices or as a transitory event (i.e. an accidental spill over one or two hours). Material is dosed evenly through the water column.

Laboratory testing arranged by Marine Solutions provided measurements of the dissolved zinc elutriate concentrations from the river sediment. Elutriate testing involved mixing sediment and water in a ratio of 1 part sediment to 4 parts of water by volume, agitation for 30 minutes,

[8] the sediment dosing rate is the residual material that has not settled after being disturbed or dropped into the water.

centrifuging and measurement of the dissolved metal content in the water. It is assumed that this process provides an adequately conservative representation of the processes likely to be associated with local water quality effects as the bridge construction progresses.

Different dissolved zinc concentrations were identified for sediments in the shallows and in the main channel. The 95th percentile elutriate concentrations sampled were 1061 µg/L in the shallows near the causeway (425 µg/L average, n = 17) and 114 µg/L in the main channel (61 µg/L average, n=5). The 95th percentile elutriate concentrations were adopted in the hydrodynamic model runs resulting in the presentation of a very conservative modelling results.

For the continuous dose modelling (i.e. likely construction activities) the material is dosed at the same rate (grams per second per square metre), with different work practices represented by changing the area over which the dosing occurs. The client provided the following levels of disturbance:

- **'Optimal' disturbance** – represented as a smaller but practical works footprint within a single work zone (approximately 10 m^2)
- **'Worst' disturbance** – represented as a larger but still practical works footprint (100 m^2) in each of three work zones simultaneously (i.e. a total works footprint of 300 m^2).

These disturbances are intended to represent an active workplace where the spatial location of disturbance moves around but the total area of disturbance remains constant. Section 3.4 discusses the selection of work zones where these disturbances are assumed to occur within the model.

A plausible rate of sediment and tracer dosing was estimated by engineering judgement then cross checked against another approach. This approach is consistent with modelling of dredging effects (Sun, Brabson and Mills, 2020), where a fraction of the dredging material mass flow rate as released back into the water.

For this project a lower fraction of material is expected to be returned to the marine environment compared with dredging. For example in a dredging operation, the cutter-head of a dredge may return 5% of the production rate immediately back to the water column, and the dredge hopper may have 30% of its production rate returned from overflow (Sun, Brabson and Mills, 2020). It is expected for this project most of the source sediment will be from ancillary actions (like propellers muddying the water) rather than a fraction of the main production (removal of sediment from the piles) – except if there is an accident.

Details of the dosing rate calculations for continuous modelling are given in Appendix A.2. The adopted continuous dosing rates are:

- Sediment 0.1 kg/s/m^2
- Tracer 1 mass-unit/s/computational cell.

Dissolved zinc concentration was inferred from the tracer based on a number of assumptions (Section 3.5).

3.4 Scenarios

Four groups of modelling scenarios were considered with a total of 22 model runs (see Table 3.1):

- **'Existing'** – the existing Bridgewater causeway and bridge without any construction. That is the current condition without any disturbance.
- **'Works'** – representing construction works in up to three work zones (nominated as zones 3, 7 and 10 as identified in Figure 3.2). Each work zone contains 3 pile groups.
- **'Constructed'** – post-construction conditions

Work zones 3, 7 and 10 were considered adequate to represent individual and cumulative effects associated with the bridge construction. They are located in the southern shallows, in the shallows at the end of the causeway, and in the middle of the main river channel respectively.

- **'Constructed reclamation'** – post-construction conditions with reclamation

As with 'Constructed' and includes the bathymetry lifted to 1 m AHD for the northern and southern reclamation areas shown in Figure 3.2.

3.4.1 Pre-construction modelling

Pre-construction (or 'Existing') condition model runs were used to establish a baseline of hydraulic conditions for comparison with post-construction ('Constructed') hydraulic conditions under low, medium and high flows. No dosing of contaminants was undertaken for these runs.

3.4.2 Construction modelling

During construction the new bridge structure is non-existent or partially constructed. There are temporary works within the river, and activity around the work in the river.

In addition to the dosing for these 'Works' scenarios, the three bridge piers in work zone 7 were raised during the first hour of the simulation by increasing the bed level at the pier locations from their existing levels to above the maximum water level. This simulated partial construction of the New Bridgewater Bridge.

The following scenarios were modelled:

- Worst disturbance area per work zone with all three zones being constructed at the same time under a mixture of flows and tides
- Optimal disturbance area in one work zone at a time, tested separately at three zones for a medium flow and normal tide, and in work zone 7 also at a high flow and normal tide
- Movement of a barge or similar across the shallows towards work zone 7.
- Accidental spills are modelled using three transitory scenarios, with model dosing occurring in a short time period at the start of a one month simulation:
    - **"A5" spill**: 2.8 kg/s/cell of sediment and 1 mass-unit/s/cell of tracer reducing to zero over an hour (total of 5 tonnes of sediment and 1,800 mass-units of tracer) at the edge of work zone 7
    - **"A25" spill**: 2.8 kg/s/cell of sediment and 5 mass-unit/s/cell of tracer constant over an hour (total of 25 tonnes of sediment and 9,000 mass-units of tracer) at the edge of work zone 7
    - a **Moving** barge scraping its bottom as a mobile source shown as an arrow that ends on the edge of work zone 7 in Figure 3.2 – 48 g/s/cell and 1 mass-unit/s/cell of tracer moving through the shallows over 2 hours.

Table 3.1: Definition of hydrodynamic modelling scenarios and model runs

Run	Work zone or Project stage	Flow	Tide	Scenario				
				Worst Continuous	Optimal Continuous	Spill	Moving	None
1	3,7,10	Low	High	●				
2	3,7,10	Low	Normal	●				
3	3,7,10	Med	Normal	●				
4	3,7,10	High	Normal	●				
5	7	Med	Normal		●			
6	10	Med	Normal		●			
7	3	Med	Normal		●			
8	7	High	Normal		●			
9	7 (A5)	Med	Normal			●		
10	7 (A25)	Med	Normal			●		
11	→ 7	Med	Normal				●	
12	→ 7	Low	Normal				●	
13	Existing	Med	Normal					●
14	Constructed	Med	Normal					●
15	Existing	High	Normal					●
16	Constructed	High	Normal					●
17	Existing	Low	Normal					●
18	Constructed	Low	Normal					●
19	Rec no-New no-Existing	Low	Normal					●
20	Rec no-New Existing	Low	Normal					●
21	Rec New no-Existing	Low	Normal					●
22	Rec New no Existing	Low	Normal					●

NOTES

1. Low flow is 1:100 AEP lowest 2-month volume
2. Med (medium) flow is 1:2 AEP highest 2-month volume
3. High flow is 1:100 highest 2-month volume
4. High (tide) is 2019 tide levels during January lifted so the peak levels reached 1.44 m AHD which is the 1:100 AEP current climate tide (a sea storm)
5. Worst is large scale disturbance footprint (100 m^2 per work zone)
6. Optimal is small scale disturbance footprint (10 m^2 per work zone)
7. Continuous is dosing 12 hour/day 7 day/week
8. Spill cases
   (a) A5 is accidental 5 tonnes release over 1 hour
   (b) A25 is accidental 25 tonnes release over 1 hour
9. Barge or other moving disturbance 300 m across shallows in 2 hours ending near zone 7 (indicated by → 7)
10. “Rec” is reclamation, “New” is New Bridgewater Bridge, “Existing” is existing bridge

3.4.3 Post-construction

Post-construction (“Constructed”) scenarios were modelled by raising the river bed below all of the pile groups shown in Figure 3.2, to above the water level. There were no additional water quality inputs like the construction loading scenarios. Based on the initial condition of 3 mg/L TSS (clay) and a bed thickness of 1 m, the sediment processes were modelled and bed thickness changes with time were estimated.

The model is tested with low, medium and high flow scenarios for a month. While this event based modelling does not directly give the full change possible over the life of the proposed works, it will generate typical bed shear to give an indication of the potential effects. Erosion is driven by threshold behaviours, with the passage of water volumes at high enough energy to trigger erosion. Comparing the low flow, medium flow (expected every year) and high flow (rare event) scenarios it is possible to gain an indication of how likely it is that significant erosion could be caused by the completed works.

The reclamation scenario is shown for the low flow, as this is the worst case for reduced circulation in the sheltered parts of the reclamation. The shape of the reclamation is similar to the general project description for reclamation and modified slightly to fit with the modelling environment and to conservatively reduce circulation within the trapped “cove” created on the west of the reclamation.

3.4.4 Post processing

To assess the potential effects of the works, comparisons were made of the model outputs for the cases with the proposed works and without the works. The model output is a time varying three-dimensional dataset for parameters such as suspended sediment, and a time varying two-dimensional dataset for bed thickness and water elevation.

Changes in bed thickness are cumulative for this site; therefore the greatest changes will be at the end of the simulation. Hence the effects will be calculated by comparing the final bed thickness values for the simulations of scenarios with and without works.

Comparing the three-dimensional parameters first requires some averaging. The water quality parameters are affected by the three-dimensional nature of the circulation, in particular the salt wedge’s density driven currents. This effect is predominantly in the main channel, while in the shallows the parameters are more uniform through the water column. While there is vertical variability in the water column, the dosing of sediment into the model at a location is done uniformly through the water column – so the initial distribution starts vertically uniform. The vertical plume distribution changes away from the source, often a centre weighted bell distribution.

Averaging water quality parameters is a useful representation of otherwise complex variability. To compare results between scenarios, water quality parameters were vertically averaged and then an average or maximum is calculated across the 30 day simulation.

3.5 Summary of modelling assumptions

A list of the key modelling assumptions used to establish the hydrodynamic model is provided below.

A. Input data

(1) Hydrological data is accurate and representative of the future inflows to the river and power station operation and sea state, including data from Meadowbank Dam and Macquarie Plains river gauges, and the Hobart tide gauge

(2) ERA-5 reanalysis data is representative of the atmospheric forcing, which gives hourly gridded historical wind, radiation and temperature

(3) Bathymetry of the estuary is well represented by the interpolation of upstream cross sections, local bridge channel survey by Jacobs, shallows east of causeway by Marine Solutions and downstream Mineral Resources Tasmania bathymetry

(4) Sediment data from Marine Solutions is representative of the river bed material

B. Hydrology

(5) Jordan River flow rate is a linear ratio of River Derwent flows scaled by catchment area

(6) Existing TSS concentrations in the River Derwent are the same as the 2015-17 survey by the Derwent Estuary Program

(7) Water temperature of the inflowing water is a moving one week average of the air temperatures in their catchment

(8) Sediment concentration of the River Derwent at New Norfolk[9] TSS [mg/L] = New Norfolk flow [m^3/s] × 0.01 + 0.27, with the Jordan River sediment concentration five times that of the River Derwent (based on a visual inspection of the 2009 Google Earth image showing the Jordan to be a major sediment source during floods Figure 2.2 and engineering judgment)

C. Hydraulics

(9) Meshing uses a mixture of quadrilaterals and triangles, with sizes from 3 m cells around the proposed bridge (which is detailed enough to capture the hydrodynamic behaviour at a planning stage), up to 100 m in the downstream far-field

(10) Hydraulic modelling software TUFLOW FV is accurate, based on its input data and setup (with a review of model setup undertaken by the software providers to check the software was being used correctly)

(11) Modelling one month of river behaviour is sufficient time to provide a representative tidal range (combinations of semi-diurnal variations and neap and spring tides) and allowance for bed erosion and transport of water quality parameters to present themselves

(12) Waves from wind or sea surge were not simulated

[9] based on a regression of Bryn Estyn sediment data from DEP 2015-2016 and catchment areas scaled flows from Meadowbank (with allowance for travel time) and conversion of turbidity to TSS from nearby River Derwent tributary DEP data (*pers comm*, 2021). The split of sediment fractions is assumed to be 70% clay, 25% silt and 5% sand based on judgment. Noting as a comparison to other units, the TSS (mg/L) in upstream tributaries is approximately 0.7 of turbidity (NTU)

D. Effects of project

(13) Ambient dissolved zinc is not included as part of the initial conditions of the model, this is due to the zinc being inferred from a passive tracer which is only introduced to the model as the construction work occurs

(14) An initial concentration of ambient TSS is included (uniformly across the model at 3 mg/L based on a DEP 2015-2016 data within the study area)

(15) Final shape of the bridge modelled is as per the assumed alignment in Figure 3.2 which is represented in the model by lifting the river bed levels for the whole plan area of each pile group to 5 m AHD; and as a sensitivity check, areas of potential permanent reclamation works as shown.

(16) Construction activity occurs from 6 am to 6 pm, seven days a week

(17) Construction activity disturbance of local material and addition of new material can be described by adding sediment, and a passive tracer to represent dissolved zinc to the model

(18) The dosing rate for the sediment is set by judgement as 1 kg/day/cell ("cell" is model computational cell located in plan and is 10 m^2 around the works, with sediment distributed evenly through the water column)

(19) The dosing rate for the tracer is set as 1 mass-unit/s/cell

(20) To convert the tracer concentration to dissolved zinc, the average concentration of tracer in the shallows over the 30 day simulation during a worst case construction disturbance area activity (100 m^2 area in three work zones) and a low flow scenario, is set as the laboratory 95th percentile elutriate concentration

(21) The ratio of tracer concentration to elutriate concentration, calculated from the previous assumption, will be applied to all continuous dosing scenarios (varying only for local variations in elutriate concentration for shallows versus main channel)

(22) For transitory scenarios a similar approach is used as for continuous scenarios, with the 5 tonne spill case assumed to give an elutriate concentration; and the ratio from this calculation used for the 25 tonne spill and mobile barge scenarios

(23) The passive tracer representing dissolved zinc does not have any decay (with time). This means adherence of zinc ions to clay or other particles and settling of zinc out of the water column is not modelled. As a result it is expected that the modelled dissolved zinc concentrations are higher than the actual concentrations likely to be observed

(24) Reclamation works involving soil disturbance are fully contained from the river flows, a breach scenario in their protection works is not considered in this study, and that any inert material (such as clean rock) is placed carefully with suitable silt screen to effectively remove this as a source of pollution.

Appendix A.1 gives the details of key model parameters.

Appendix A.2 provides information and calculations for the conversion of tracer concentrations to dissolved zinc concentrations.

4. Results

The hydraulic model was used to simulate a limited set of scenarios that give context to and quantify the potential effect of the proposed New Bridgewater Bridge on sediment and dissolved zinc transport.

The main set of model maps of average and maximum tracer, zinc and sediment for the 18 model runs is provided in Appendix B.

As discussed in Section 3.4.4, the model output is a time varying set of three-dimensional data, which requires post-processing to produce a simplified set of graphs and maps to present key aspects of the river behaviour. That is, each point in the graphs and maps represents either an average or maximum of the set of depth averaged results.

The following results are apparent:

4.1 General circulation

Water circulation within the River Derwent near the project site is dominated by the semi-diurnal tidal cycle. Superimposed on this is the River Derwent's flow rates. Circulation at the typical ebb and flood points in the tidal cycle is shown in Figure 4.1 (ebb tide) and Figure 4.2 (flood tide) respectively for typical flow conditions after construction of the new Bridgewater Bridge (i.e. Run 14, Table 3.1).

4.2 During Construction

4.2.1 Zinc

The zinc concentration is inferred from the modelled tracer and laboratory measured elutriate concentrations. The tracer at the source of expected construction activity is set to the Marine Solution's 95th percentile zinc elutriate concentration. This single ratio of tracer to zinc is applied for other continuous scenarios.

For the transitory scenarios, in which a 5 tonne accidental release of sediment into the river is assumed to occur, the dissolved zinc concentration is also assumed to achieve the 95th percentile elutriate concentration. This same ratio is used to scale the modelled tracer concentrations back to an inferred dissolved zinc concentration in the other transitory scenarios.

The concentration of the tracer, and hence zinc, varies during the simulation mainly from the semi-diurnal tide cycle. This variability is shown in time series graphs at four key locations (Figure 4.3) in Figure 4.4 to Figure 4.7 (scenarios defined in Table 4.1 and Appendix B).

Any sediment or tracer released into the water column near the project creates a plume which moves upstream and downstream of the release point on the tide; and is gradually washed downstream by the river flow. Under low flow scenarios (enhanced by high tide), the plume extends further upstream; until being washed downstream (this creates an adverse hydrological scenario for water quality outcomes near the site). Under high flow scenarios the plume is diluted and washed downstream faster. The location of the release has a local effect on the plume shape and dynamics, but these differences are less apparent further downstream.

While zinc concentrations vary dynamically, where there is a pattern, performing statistical calculations on these time series is a helpful way to simplify the pattern to enable comparisons between scenarios. The average and maximum zinc concentrations are shown in Table 4.1 and Table 4.2 respectively.

The selected construction methodology has a large effect on the zinc concentrations. The methodology is represented in the model by the area that is dosed (noting the centre of the dosing is the same between construction scenarios).

4.2.2 Sediment

Plumes of sediment behave dynamically in a similar way to the dissolved zinc plumes. The settling of larger sediment particles deposits them closer to the source, which reduces the distance affected compared to the passive tracer representing dissolved zinc.

The sediment plume moves on the tide and is also flushed downstream by the river flow. During flood events the background sediment from within the river, transported from upstream and stirred up by the flow will to some extent camouflage the effect of construction activities.

The figures in Appendix B indicate the changes due to the works in suspended sediment in the water column and the thickness of river bed (primarily from deposition of sediment). These figures show the difference of average modelled parameter values with and without the works for the same hydrological sequence.

- Figure B.49, Figure B.50, Figure B.51, and Figure B.52 show the average changes in clay, silt, sand and TSS concentrations for a medium flow and normal tide. These figures indicate an increase in the clay and silt plumes, but not the sand plume, downstream of the dosing source. The plume has up to 0.5 mg/L of extra clay and just over 0.5 mg/L of extra silt. Sand concentrations are only higher in the immediate vicinity of the dosing source. The TSS plume extends as far downstream as the confluence with the Jordan River. These are small amounts as the dosing is small, but the shape of the plume is indicative of range of other scenarios that could occur with larger dosing. The plume is persistent during the simulation downstream of the works, with some dynamic variations at the site and just upstream through the tidal cycle.
- Figure B.53 gives the change in bed thickness for medium flow and normal tide. While there is some modelling noise, there is no obvious change due to the small amount of sediment dosed in this scenario in the bed thickness. This indicates no measurable deposition of sediment on the river bed from the plume away from the immediate work area.

4.3 Post construction

Following completion of the works the potential effects of the bridge are investigated by looking for changed circulation and scouring around piers. Difference plots presented in Appendix B show local scouring around piers in the main river channel in medium and higher flows, but no significant far-field effects (Figure B.54–Figure B.56). The scouring occurred in the medium and high flow scenarios, but not in the low flow scenario.

There is no significant change to the overall circulation during average flow scenarios. There is localised slowing of the flow immediately around the pier groups.

For the reclamation case

- There is some slowing of the flow (to approximately half the mean velocity and to a third the median) in the triangular cove created by the reclamation's southern area. The sheltered area is still flushed, but could be susceptible to collecting floating debris and litter with its lower velocities. Figure 4.8 to Figure 4.11 show circulation plans during spring tides of February 2019, and at reporting points shown in Figure 4.12 with water levels, there are depth average velocity timeseries in Figure 4.13 to Figure 4.20. Note gaps in the timeseries are when that location dries out during a part of tidal cycle. The is no noticeable changes to circulation around the northern part of the reclamation option.

- There is no change to bed thickness near the southern shore in the 2-month simulation. It's possible there could be and these aren't showing up due to limitations in the model, but there is a limited source of sediment mobilised in that area (the slower moving water doesn't generate the higher sediment loads of the main channel). There are some very localised erosion/deposition around the northern shore reclamation given the higher velocities.

A separate Flood Hazard Assessment report has been prepared that assesses changes in water levels associated with the New Bridgewater Bridge with and without removal of the existing bridge and piers, and option of the reclamation works.

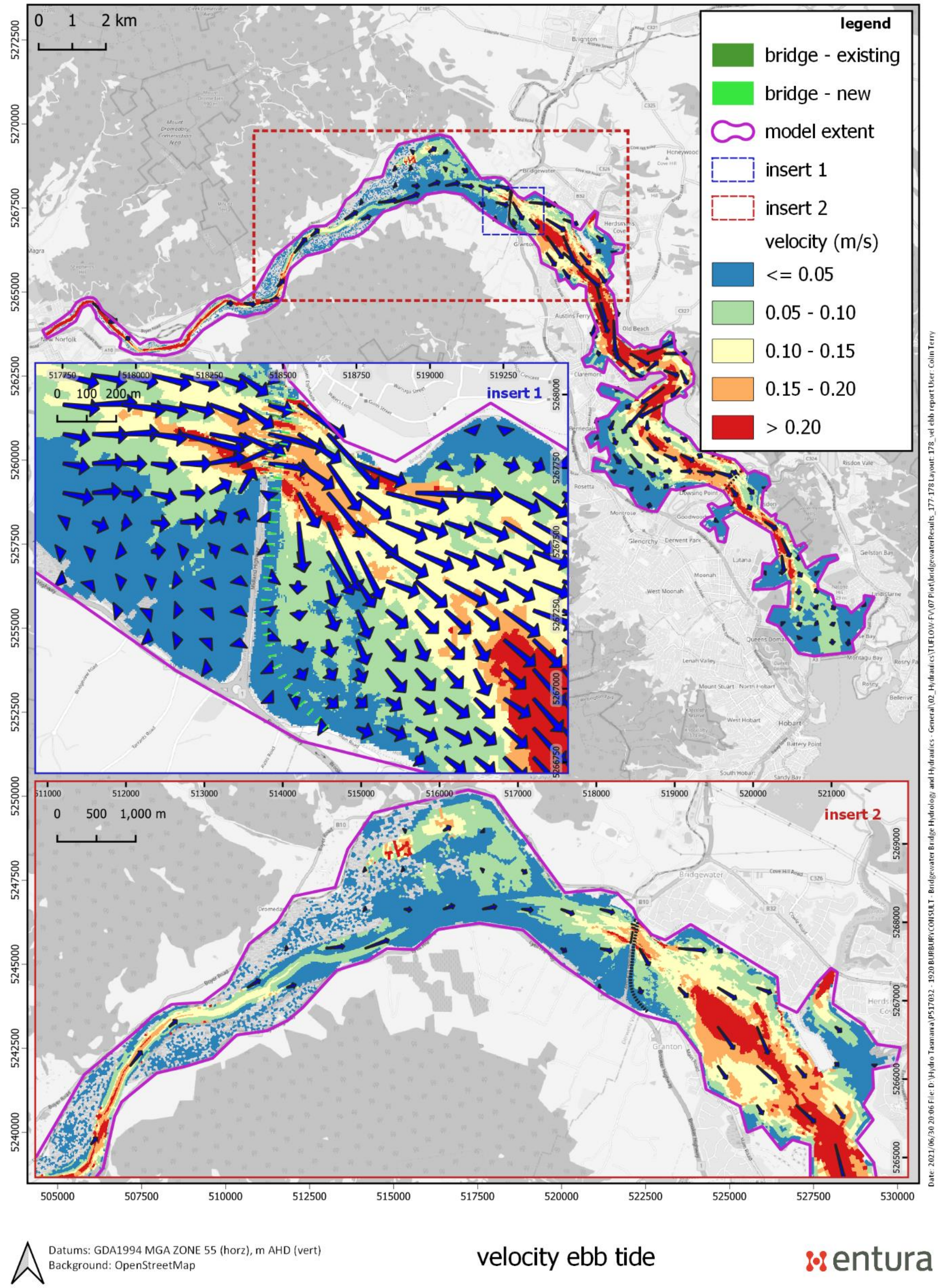


Figure 4.1: River Derwent post-construction circulation at Bridgewater during an ebb tide (Run 14)

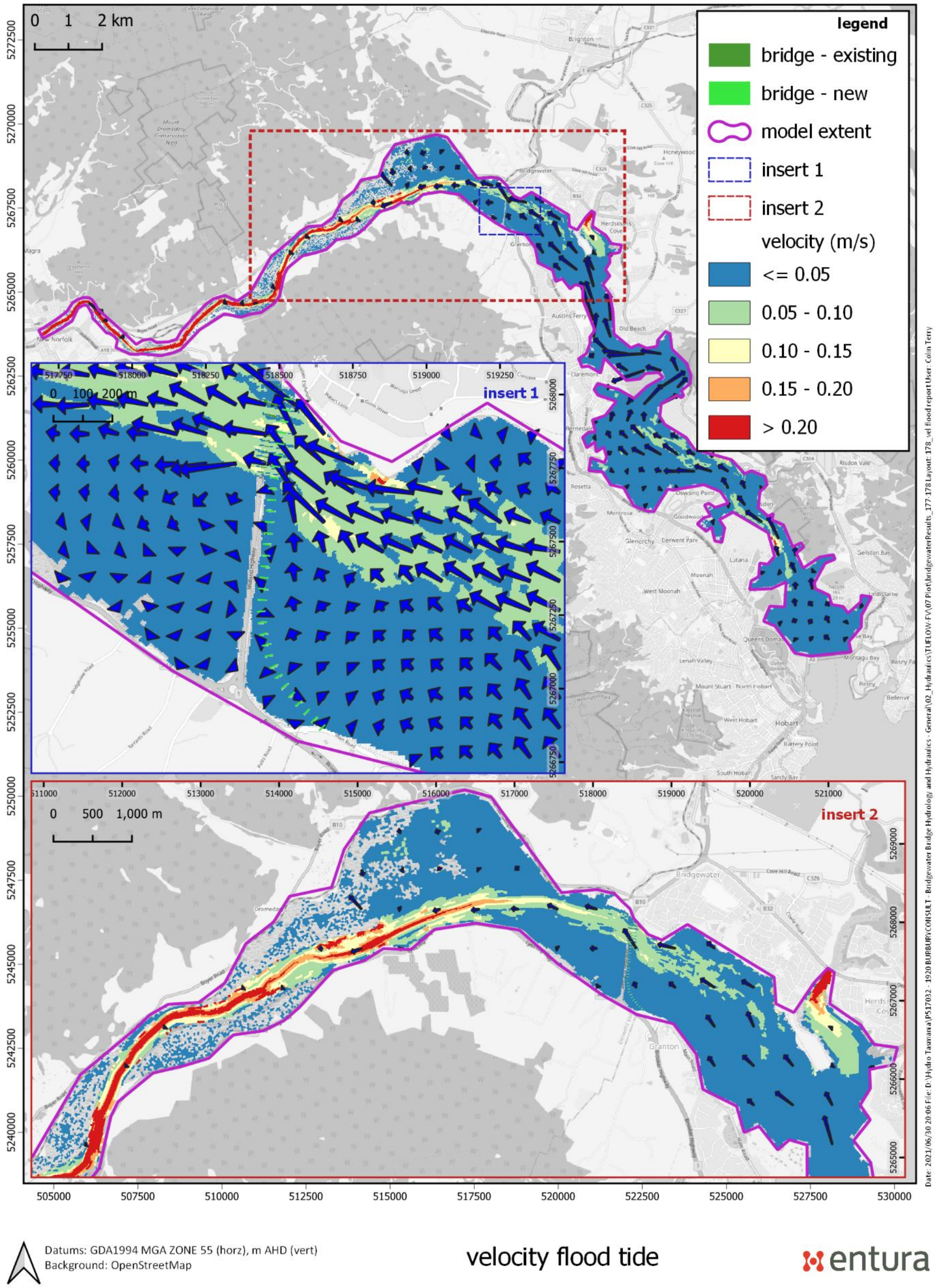
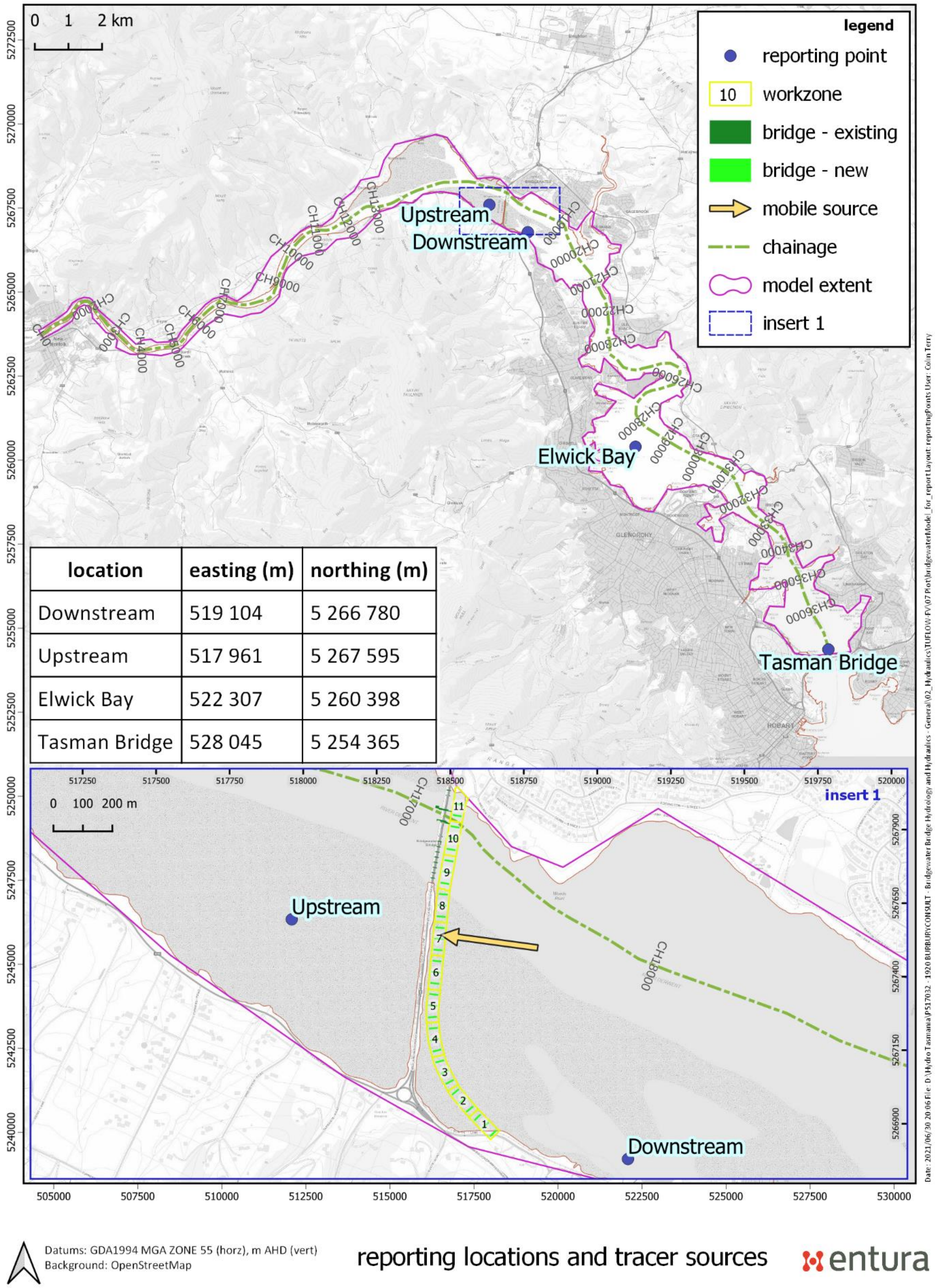


Figure 4.2: River Derwent post-construction circulation at Bridgewater during a flood tide (Run 14)



location	easting (m)	northing (m)
Downstream	519 104	5 266 780
Upstream	517 961	5 267 595
Elwick Bay	522 307	5 260 398
Tasman Bridge	528 045	5 254 365

Figure 4.3: Reporting locations for timeseries and tables

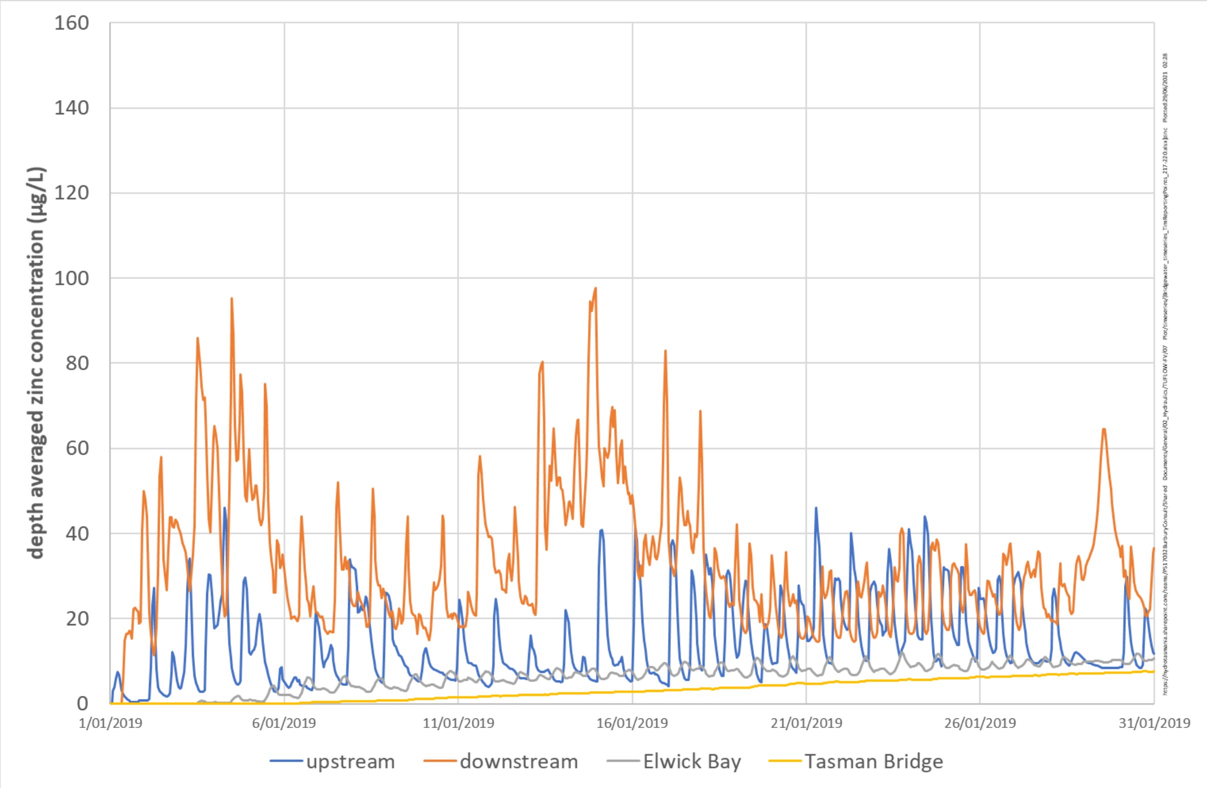


Figure 4.4: Zinc concentration timeseries, worst case disturbance, low flow, high tide (Run 1)

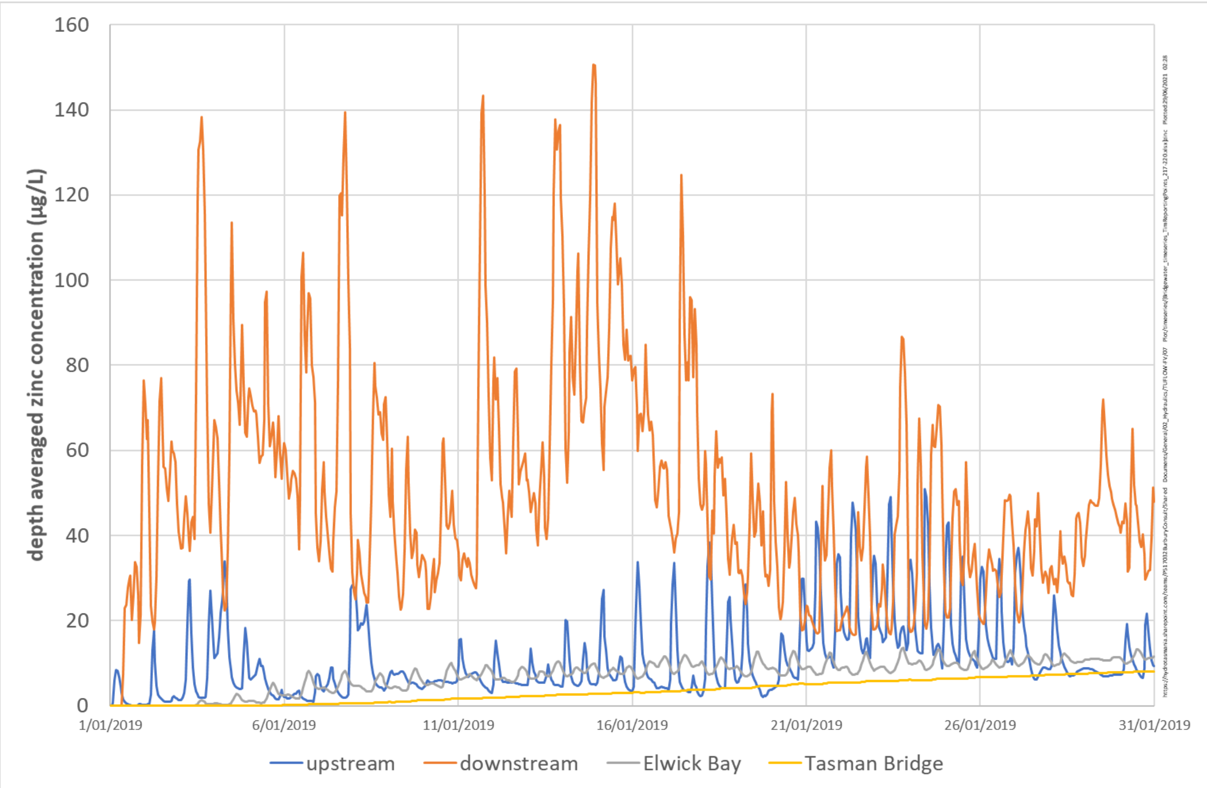


Figure 4.5: Zinc concentration timeseries, worst case disturbance, low flow, normal tide (Run 2)

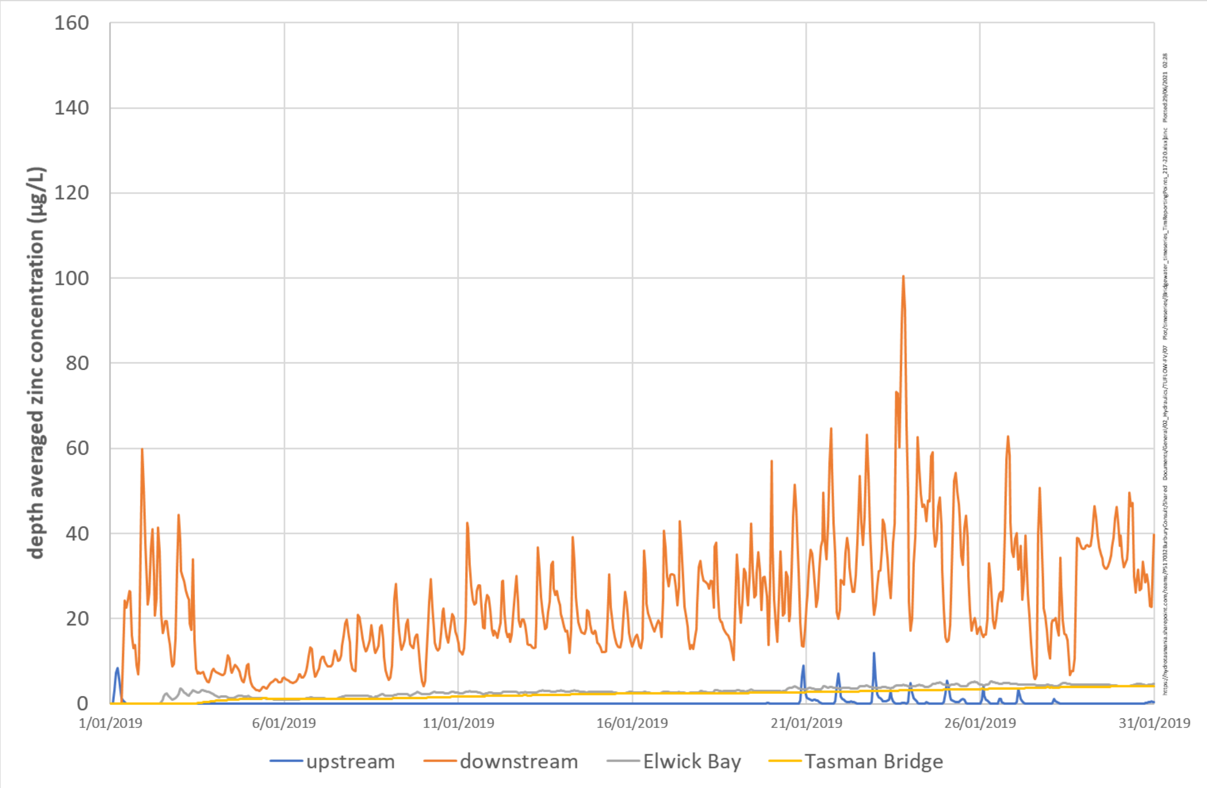


Figure 4.6: Zinc concentration timeseries, worst case disturbance, medium flow, normal tide (Run 3)

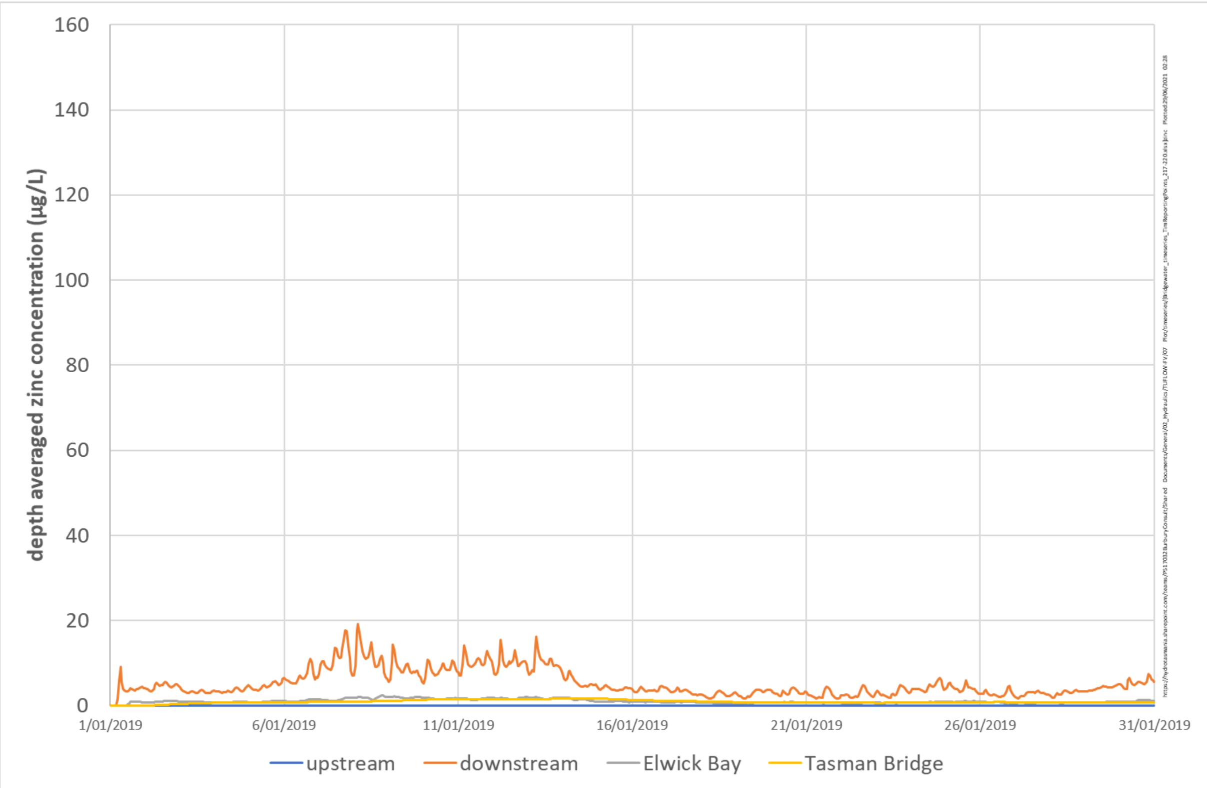


Figure 4.7: Zinc concentration timeseries, worst case disturbance construction, high flow, normal tide (Run 4)

Table 4.1: Estimated average Zinc concentration assuming elutriate source concentration

Model Scenario				Average[1] Dissolved Zinc Concentration (µg/L)			
Run	**Zone**	**Flow/tide[2]**	**Dosing[3]**	**Upstream**	**Downstream**	**Elwick Bay**	**Tasman Bridge**
1	3,7,10	Low/High	Worst	14.0	33.0	6.3	3.2
2	3,7,10	Low	Worst	11.0	52.0	7.2	3.4
3	3,7,10	Medium	Worst	0.26	24.0	2.9	2.2
4	3,7,10	High	Worst	0.0	5.5	1.1	0.95
5	7	Medium	Optimal	0.015	1.2	0.1	0.076
6	10	Medium	Optimal	0.001 1	0.006 5	0.011	0.008 2
7	3	Medium	Optimal	0.000 06	1.1	0.1	0.076
8	7	High	Optimal	0.0	0.28	0.038	0.033
9	7	Medium	Spill A5	0.000 66	0.000 36	0.000 05	0.000 032
10	7	Medium	Spill A25	0.003 3	0.001 8	0.000 25	0.000 16
11	→ 7	Medium	Moving	0.028	0.013	0.001 3	0.000 003 7
12	→ 7	Low	Moving	0.03	0.029	0.000 01	0.000 000 000 49

Notes:

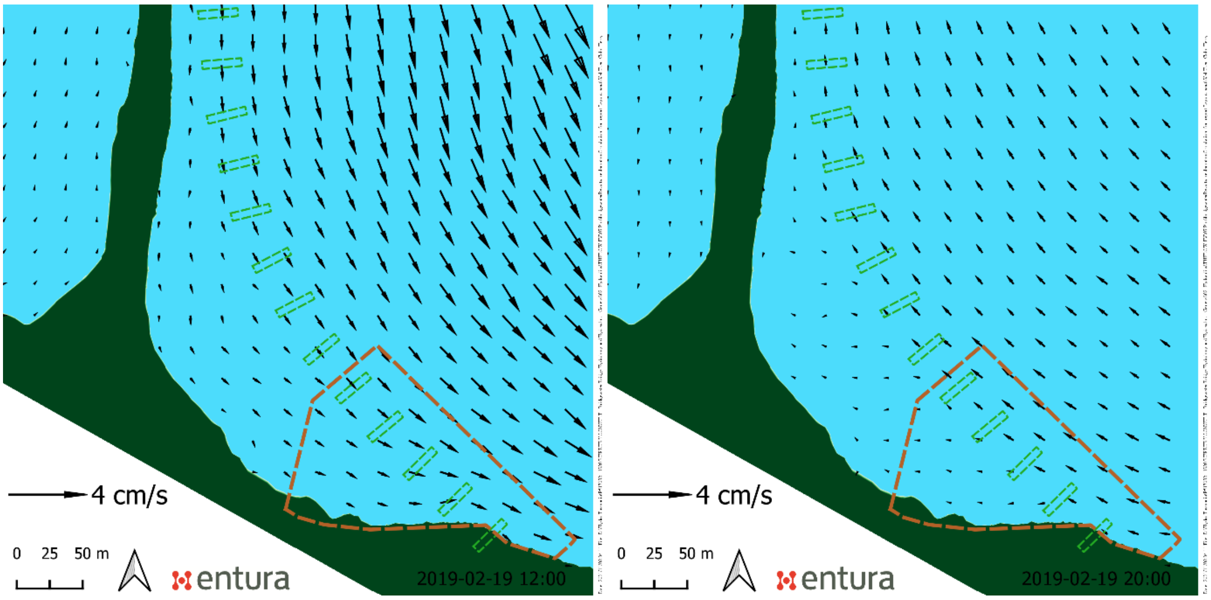
1. Averaging is vertically and averaging by time to create a single concentration for every plan location
2. Tide normal unless stated, low flow is 1:100 AEP lowest 2-month volume, medium is 1:2 AEP highest 2-month volume, high is 1:100 highest 2-month volume, high (tide) is 2019 tide levels during January lifted so the peak levels reached 1.44 m AHD which is the 1:100 AEP current climate tide (a sea storm)
3. Worst is large scale disturbance footprint (100 m² per work zone) and continuous dosing pattern of 12 hour/day 7 day/week
4. Optimal is small scale disturbance footprint (10 m² per work zone) and continuous dosing pattern of 12 hour/day 7 day/week
5. Spill A5 is accidental 5 tonnes release over 1 hour
6. Spill A25 is 25 tonnes release over 1 hour
7. Moving is Barge or similar moving 300 m across shallows in 2 hours ending near zone 7 (indicated by → 7)

Table 4.2: Estimated maximum dissolved Zinc concentration assuming elutriate source concentration

Model Scenario				Maximum[1] Dissolved Zinc Concentration (µg/L)			
Run	**Zone**	**Flow/Tide[2]**	**Dosing[3]**	**Upstream**	**Downstream**	**Elwick Bay**	**Tasman Bridge**
1	3,7,10	Low/High	Worst	46.0	99.0	12.0	7.6
2	3,7,10	Low	Worst	51.0	150.0	14.0	8.1
3	3,7,10	Medium	Worst	12.0	100.0	5.3	4.1
4	3,7,10	High	Worst	0.0	20.0	2.4	1.7
5	7	Medium	Optimal	1.0	5.3	0.2	0.14
6	10	Medium	Optimal	0.013	0.069	0.02	0.015
7	3	Medium	Optimal	0.008 6	4.9	0.2	0.14
8	7	High	Optimal	0.0	1.1	0.08	0.058
9	7	Medium	Spill A5	0.11	0.047	0.002 3	0.000 29
10	7	Medium	Spill A25	0.56	0.23	0.012	0.001 5
11	→ 7	Medium	Moving	0.29	0.11	0.007 2	0.000 073
12	→ 7	Low	Moving	0.28	0.096	0.000 1	0.000 000 022

Notes:

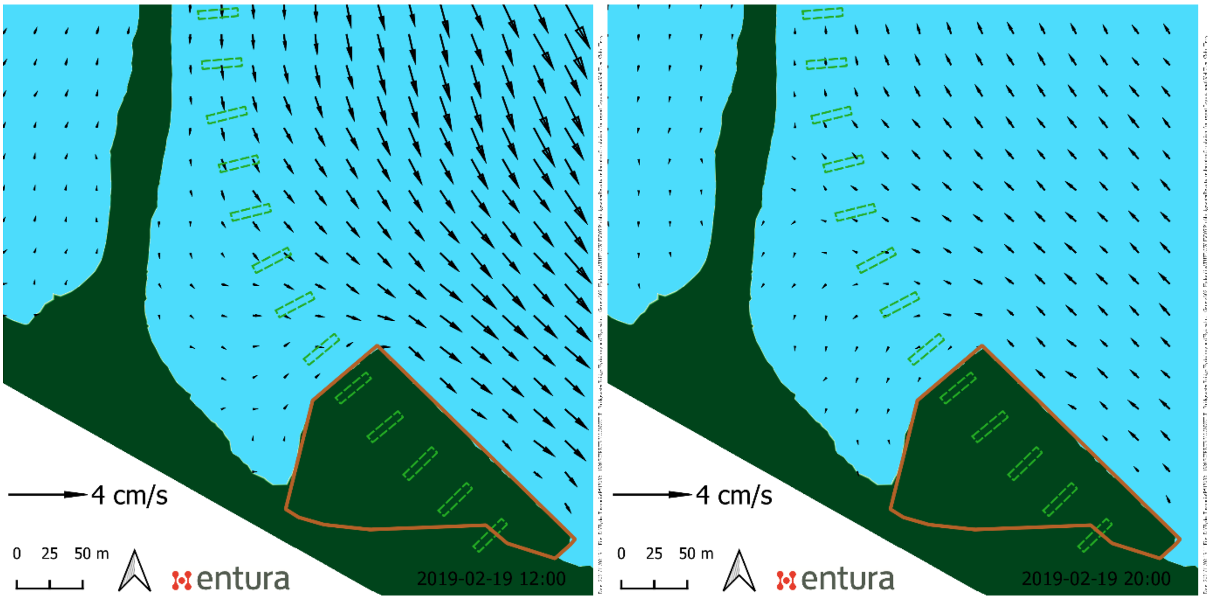
1. Averaging is vertically and averaging by time to create a single concentration for every plan location
2. Tide normal unless stated, low flow is 1:100 AEP lowest 2-month volume, medium is 1:2 AEP highest 2-month volume, high is 1:100 highest 2-month volume, high (tide) is 2019 tide levels during January lifted so the peak levels reached 1.44 m AHD which is the 1:100 AEP current climate tide (a sea storm)
3. Worst is large scale disturbance footprint (100 m^2 per work zone) and continuous dosing pattern of 12 hour/day 7 day/week
4. Optimal is small scale disturbance footprint (10 m^2 per work zone) and continuous dosing pattern of 12 hour/day 7 day/week
5. Spill A5 is accidental 5 tonnes release over 1 hour
6. Spill A25 is 25 tonnes release over 1 hour
7. Moving is Barge or similar moving 300 m across shallows in 2 hours ending near zone 7 (indicated by →7)



a) **Existing** ebb (outgoing) tide

b) **Existing** flood (incoming) tide

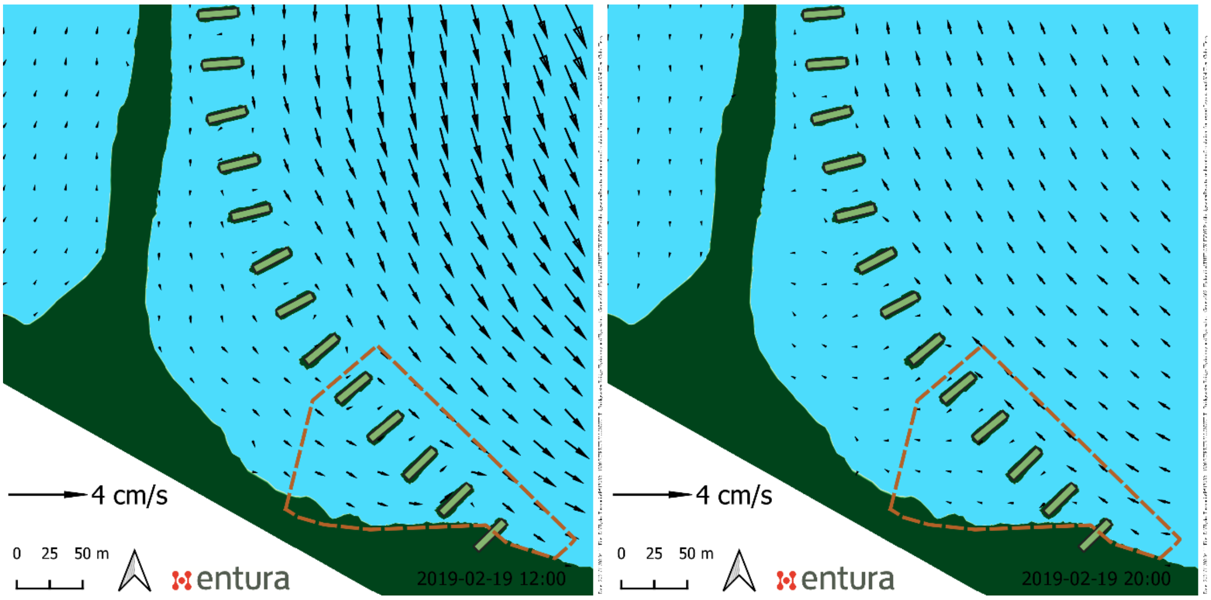
Figure 4.8: Depth averaged velocity on southern shore for existing system



a) **Reclamation only** ebb (outgoing) tide

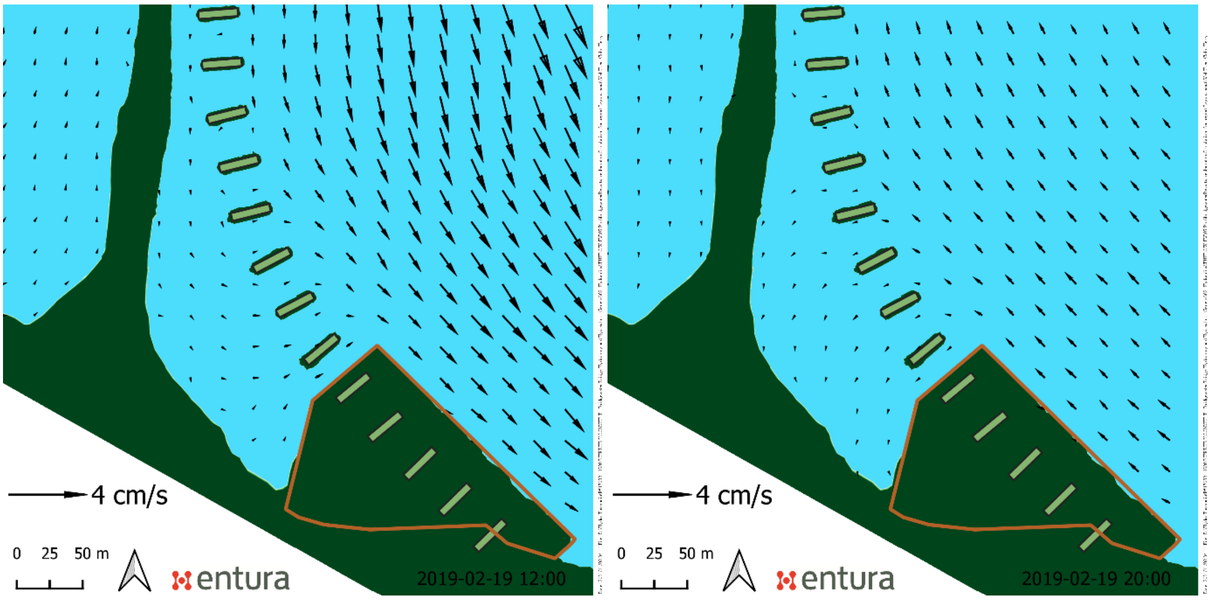
b) **Reclamation only** flood (incoming) tide

Figure 4.9: Depth averaged velocity on southern shore for reclamation and no new bridge



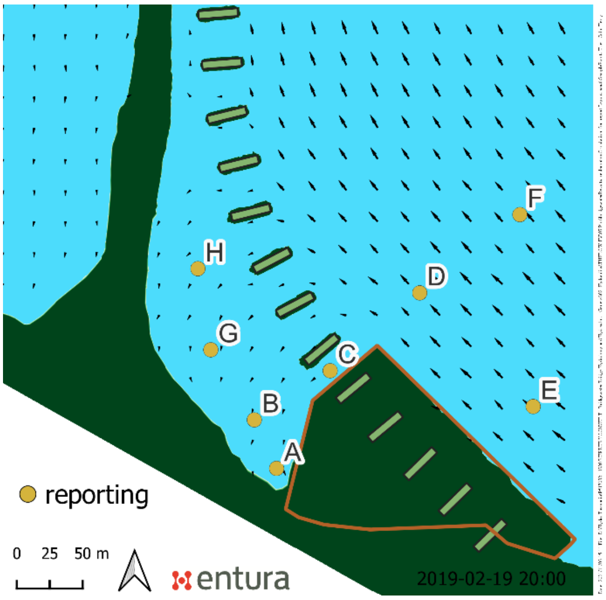
a) **New Bridgewater Bridge** ebb (outgoing) tide b) **New Bridgewater Bridge** flood (incoming) tide

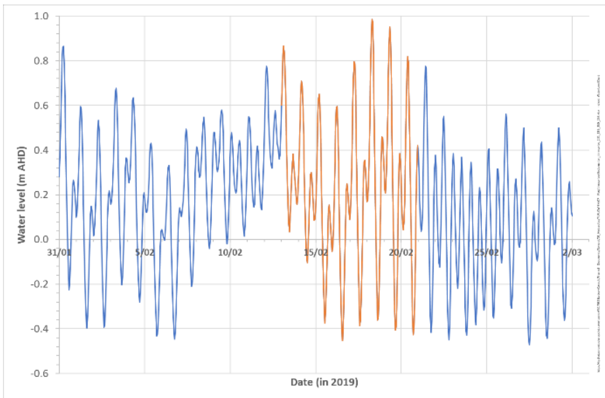
Figure 4.10: Depth averaged velocity on southern shore for New Bridgewater Bridge (no reclamation)



b) **Bridge and reclamation** ebb (outgoing) tide b) **Bridge and reclamation** flood (incoming) tide

Figure 4.11: Depth averaged velocity on southern shore for New Bridgewater Bridge and reclamation





a) reporting points on southern shore of River Derwent

b) water level during February 2019 with orange for reporting period

Figure 4.12: Reporting points around southern reclamation

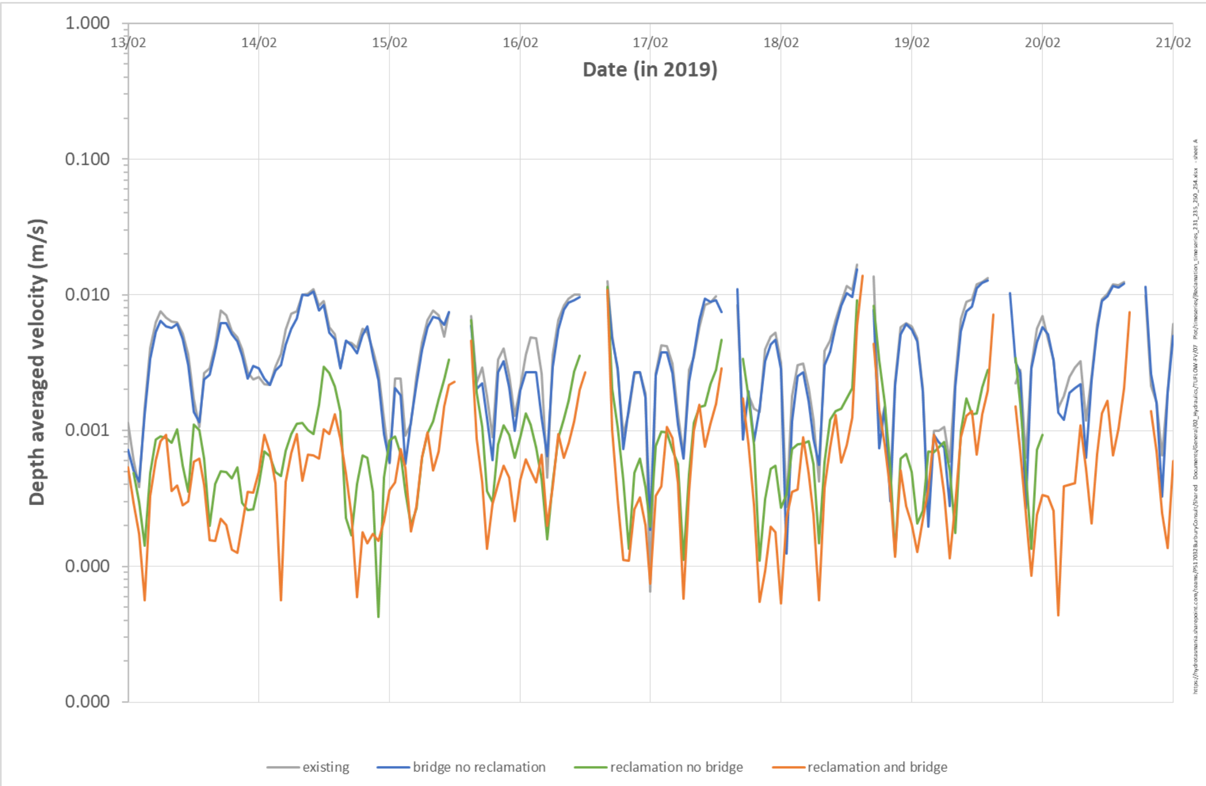


Figure 4.13: Depth averaged velocity reporting location A

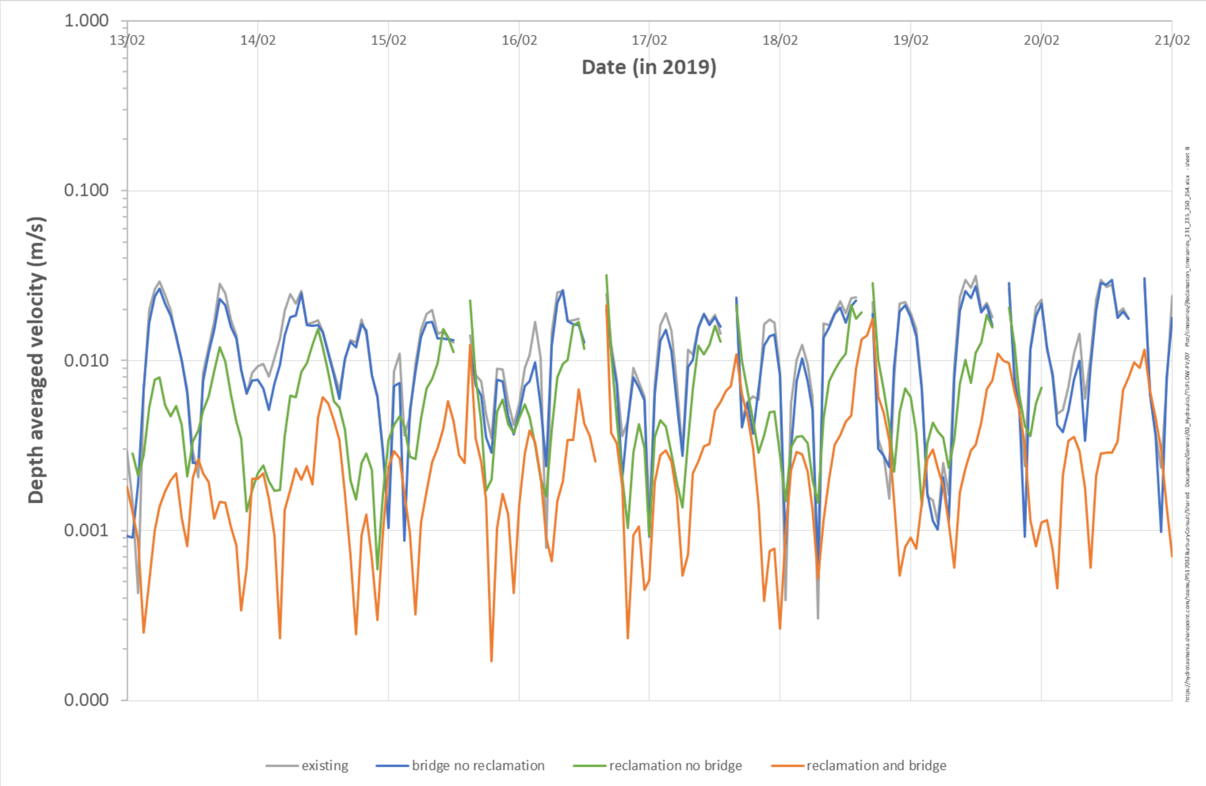


Figure 4.14: Depth averaged velocity reporting location B

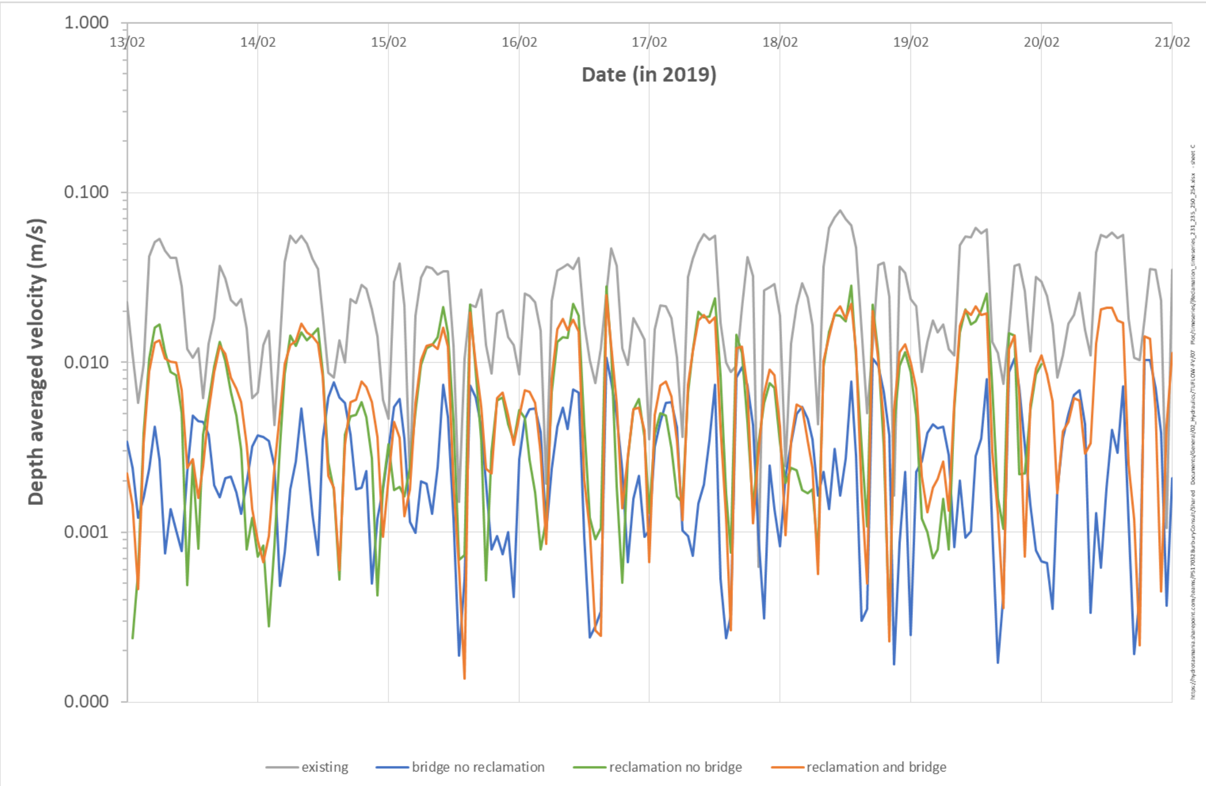


Figure 4.15: Depth averaged velocity reporting location C

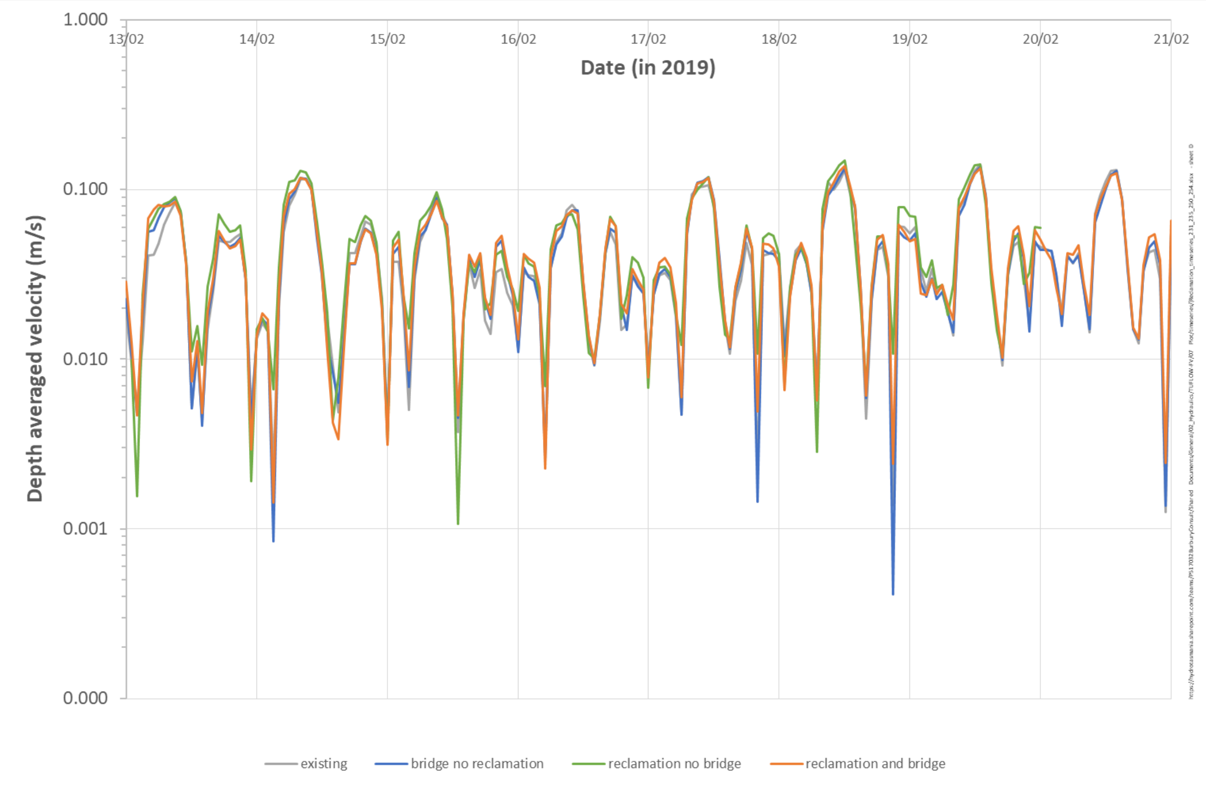


Figure 4.16: Depth averaged velocity reporting location D

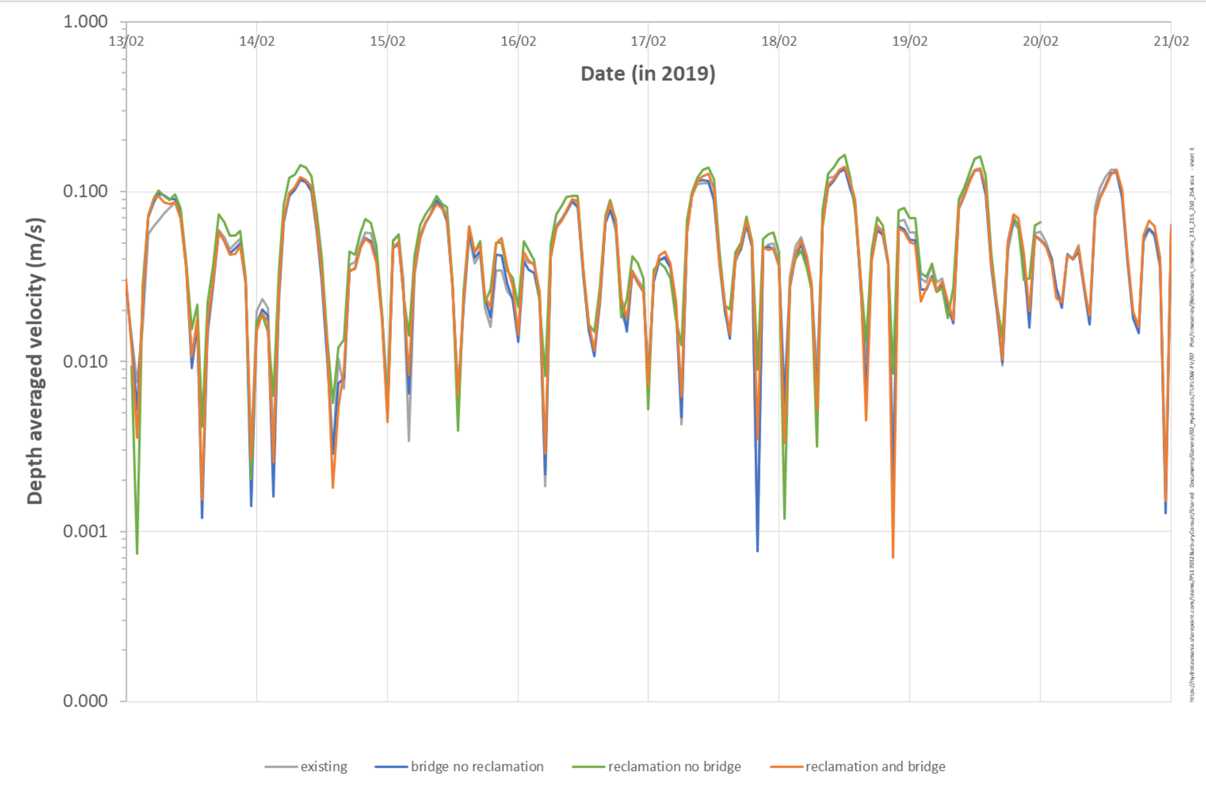


Figure 4.17: Depth averaged velocity reporting location E

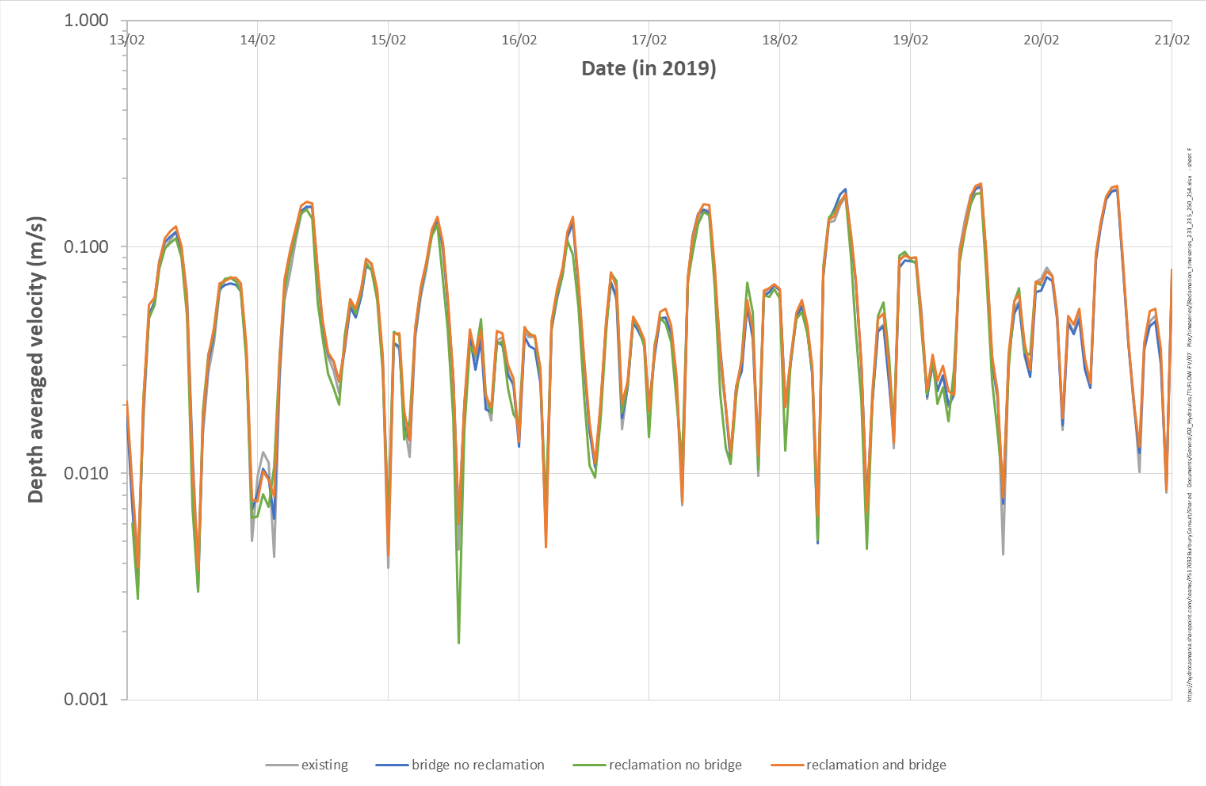


Figure 4.18: Depth averaged velocity reporting location F

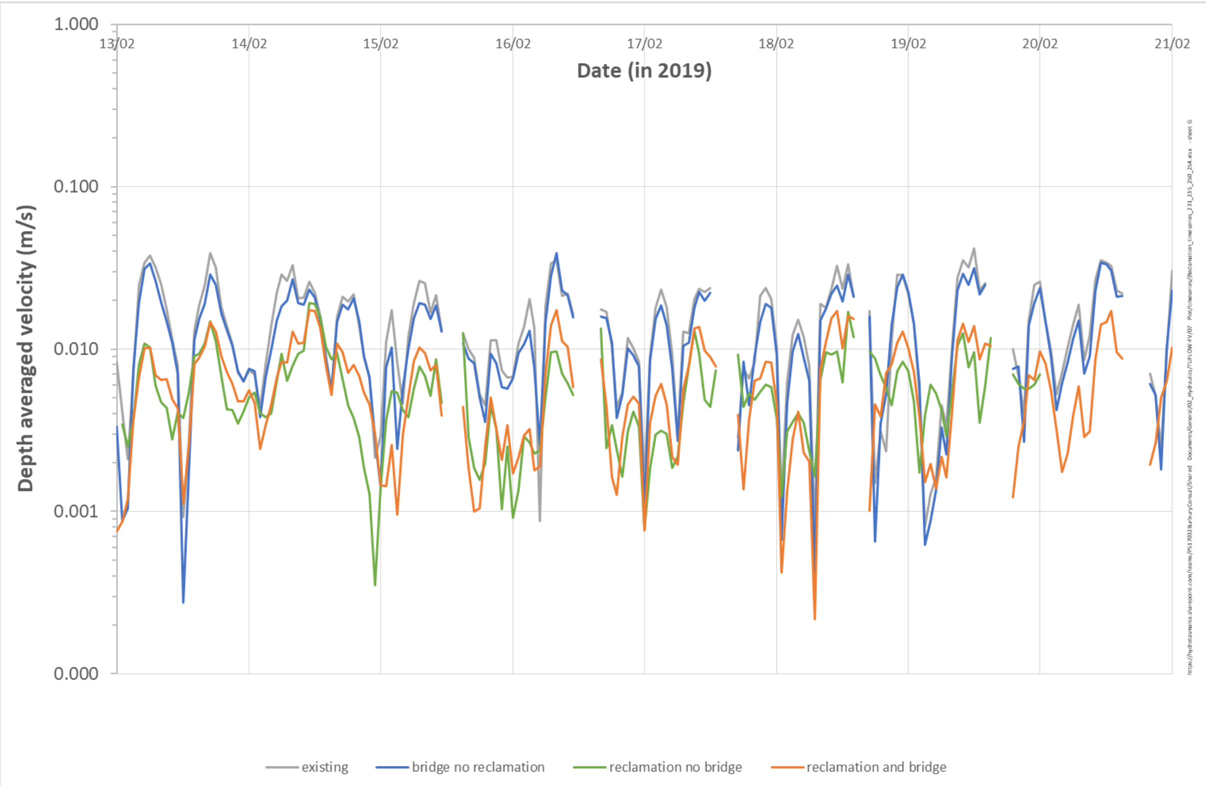


Figure 4.19: Depth averaged velocity reporting location G

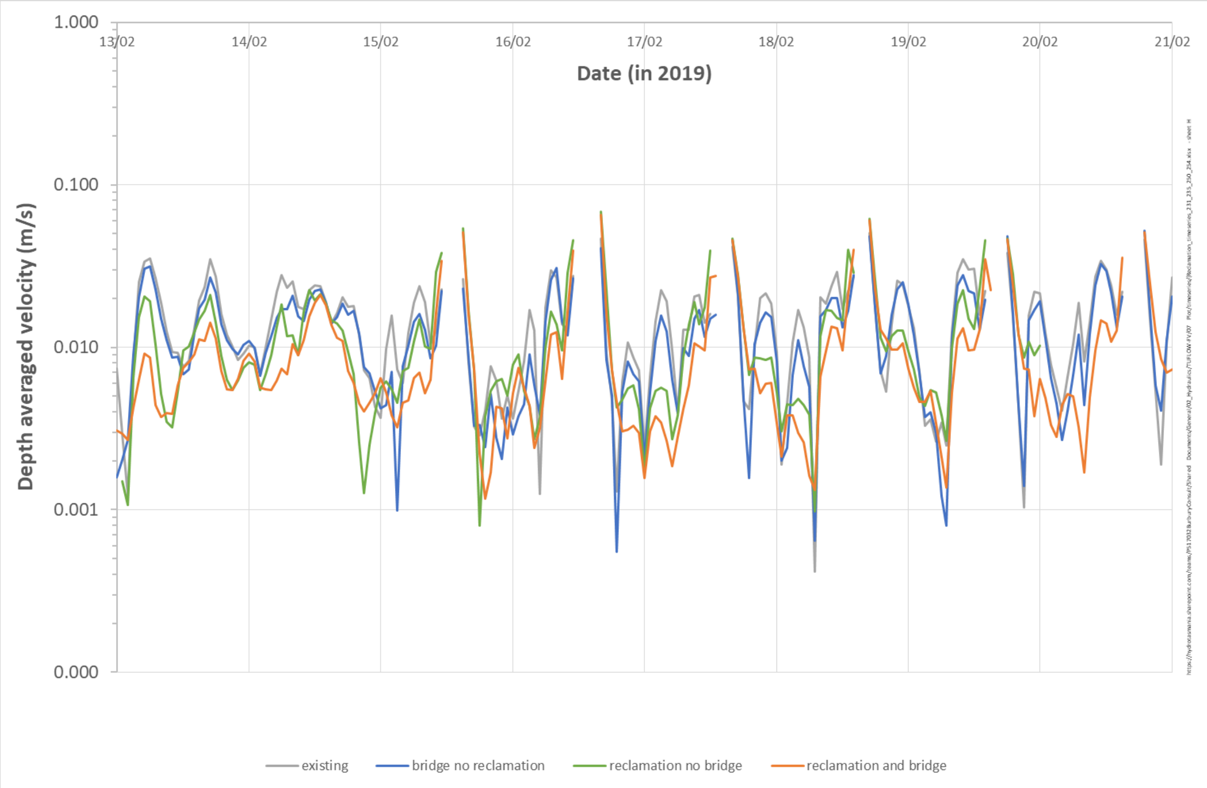


Figure 4.20: Depth averaged velocity reporting location H

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5. Discussion

5.1 Model certainty

The hydrodynamic model has been built using measured flow rates and tides, updated bathymetry and reasonable assumptions regarding environmental forcings to represent the large scale circulation patterns and behaviour that has previously been identified in the River Derwent. A qualitative comparison of the modelled sediment plumes with Marine Solutions' dye tracer test gives confidence the model is producing the general near-field distribution of pollution around the works area. Although no direct quantitative comparison with CSIRO modelling has been possible, the model is considered to adequately represent the near-field and far-field hydrodynamics of the River Derwent between New Norfolk and the Tasman Bridge for the purposes of assessing the effects of this project.

There is more certainty in the representation of circulation and water levels, compared to water quality results. The assumptions made about the quantum of water quality changes due to an uncertain construction process introduces uncertainty in the absolute level of sediment and zinc concentrations, but the mechanics of the hydrodynamic model provides confidence in the relative patterns of water quality dynamics. That is, while there is less certainty about the absolute changes in water quality, there is more confidence in the shape and location of the modelled plumes.

The laboratory elutriate tests provide confidence in the potential dissolved zinc concentrations arising from disturbed sediments. But assumptions about the area disturbed for a particular work practice and near-field processes, decrease the certainty. For example, while there was a laboratory test that gave a value for zinc concentration from a quantity of sediment, there was not a test to work out how much sediment was disturbed by a propeller moving through the soft sediment.

While the uncertainty of the modelling results cannot be quantified without considerable further work, these observations give context to the results:

- Using the 95th percentile rather than average elutriate concentration suggests the zinc levels are potentially conservatively high
- Calculations in Appendix A.2 comparing assumed aerial sediment dosing rate and elutriate concentrations, show some inconsistency between the two approaches, and that the sediment dosing is likely to be too low.

5.2 Zinc

The dynamic nature of the River Derwent water movement has been captured by the hydrodynamic modelling with the plausible worse case effects identified from the proposed New Bridgewater Bridge project. As context for the effects of the works, a dissolved zinc target used in proposed construction monitoring for the River Derwent by Marine Solutions is the default guideline value for highly disturbed marine environments from ANZG (2018), which is the 90th percentile species protection level of 23 µg/L (noting for highly disturbed marine environments the 80th percentile value of 43 µg/L could also have been adopted). Zinc is the focus of discussion because it is modelled to be more conservative and has effects further afield than the sediment which has more localised effects. Conservative here is in both senses of the word: chemical mass balance and from a risk point of view.

The plausible worst-case occurs with a worst disturbance construction footprint during low flows and to a lesser extent during high tides (runs 1–4).

- During these hydrological scenarios there is only a short time that dissolved zinc concentrations are at their maximum values (e.g. Figure 4.5), so it is expected the average values are more indicative of exposure over time. That said, the maximum over time (depth averaged) values for the plausible worst case are up to 51 µg/L away from the site (upstream reporting location), 150 µg/L at the downstream location and 8.1 µg/L at the Tasman Bridge. At the source the maximum (depth averaged) zinc concentration is up to 8,600 µg/L.

- The time and depth averaged dissolved zinc concentrations are expected to be 14 µg/L at the upstream reporting location, and 52 µg/L at the downstream reporting location. At the Tasman Bridge the zinc concentrations are expected to be at or below 3.4 µg/L. By the definition of how the tracer concentration was converted to a zinc concentration, at the dosing source the average zinc concentration is the 95th percentile elutriate concentration of 1,061 µg/L.

With the worst case disturbance construction, except close to the construction site, the average dissolved zinc concentrations are expected to be lower than the 23 µg/L target. If the turbid water is confined to a single cell in an ‘optimal’ small disturbance footprint construction approach (runs 5–8), then the average and maximum values are expected to be lower than 23 µg/L at all reporting locations. The accidental spill scenarios also produced low levels of zinc.

The average plume shapes for the transitory scenarios (runs 9–12) are affected by the tidal cycle at the start of the simulation when the accident occurs. The simulation starts on a flood tide, so the plume shapes were initially directed upstream. The transitory scenarios have lower concentration values than other scenarios and that initial direction of flow transfers the plume upstream before it is diluted to lower levels downstream.

5.3 Sediment

The plausible worst-case for suspended sediment also occurs with a worst disturbance construction footprint during low flows and to a lesser extent during high tides (runs 1–4).

Sediment plumes have similar patterns to the zinc plumes. Low river flows and to a lesser extent high tides, result in high modelled sediment concentrations. Highest river flows lead to the lowest modelled sediment concentrations. Given the settling effect of sediments, in particular silt and sand, and background levels of clay in the water column – the effect of sediments is less pronounced than for zinc. While the visibility of sediment has not been assessed directly, it is expected that construction work will produce visible plumes of sediment at and near the construction site. Noting also the comments in Section 5.1 about the sediment dosing potentially being too low, such that once construction practices are better defined there is value in undertaking further modelling to better quantify the sediment concentration and bed thickness effects from construction activities.

5.4 Post-construction scouring

The post-construction bed thickness maps in Appendix B show local scouring around the central pier group for the medium and high flow flood events. The cause of scouring is fast moving water flowing for a time over the bed. Water moves faster during flood events. Structures in the flow will locally accelerate and deaccelerate the flow.

In the modelled scenarios the existing bridge and its piers are retained. This could add some complexity to the modelled flow as it approaches the proposed bridge, just downstream of the existing structure.

While the model in this study has 3 m computation cells near the existing and new bridge, this is not detailed enough to resolve all the complex flow behaviours to provide accurate scour calculations. Modelling may under-represent the detailed scour near the piles. However, the modelling is suitable to indicate that scour effects are likely to be confined to a local area immediately near the bridge and within the main channel.

6. Conclusions

1. A 3D hydrodynamic model of the circulation and material transport for the River Derwent has been created. It extends 37.4 km from New Norfolk to the Tasman Bridge. This work builds on monitoring by the Derwent Estuary Program and modelling by CSIRO that has built a solid understanding of water quality in the River Derwent. The model is considered adequate to model the potential impacts associated with the New Bridgewater Bridge. It was used in this study to describe these effects for low, medium and high river flows. Water quality and sediment mobilisation and transport were also assessed for construction and the completed works. A comparison was made with and without the works.
2. The effects of construction of the proposed New Bridgewater Bridge will be higher at the construction site, and lower further away. Effects will be both upstream and downstream of the works site. There are potential effects from halfway between New Norfolk and the project site, to downstream of the Tasman Bridge, with significant effects only in the immediate vicinity of the works site. To a lesser extent these effects extend downstream along the southern shore to opposite the confluence with the Jordan River at Whitestone Point.
3. During construction, normal works activities and potentially accidents may release material into the river. The source of material is likely to be from the soft silty sediment in the works area. Fine suspended solids are likely to occur from mechanical activities, and dissolved matter is likely to be generated as silts are disturbed releasing zinc and other material.
   (a) Heavier particles will settle out closer to the source, while lighter particles and dissolved matter will be transported further afield.
   (b) Material would be transported a short distance upstream of the works but much further downstream, with concentrations reducing with distance from the source. A plume of suspended sediments associated with the works could be visible within the river.
   (c) The shape of the plume is a function of the timing, concentration and location of the source of the matter, as well as river flow rates, tide and to a lesser extent atmospheric conditions (wind, temperature, solar radiation).
   (d) Accidents would create a transitory slug of matter that dilutes as it is washed downstream. Continuous or semi-continuous sources of material would be associated with regular works practices and would waft back and forth on the tide near the source, and then drift further downstream creating a continuous plume of decreasing concentration.
   (e) Under a plausible worst case scenario, modelled average zinc concentrations were found to be under 23 µg/L, except near the immediate worksite.
   (f) Accidental spilling of sediment into the water column for events up to 25 tonnes would likely result in poor water quality outcomes in the immediate area of the spill, but are unlikely to have a significant effect in the far-field.

4. Post construction there is some potential for changes in the river bed associated with the completed works. Modelling indicates the changes are small under low flow conditions. However under larger events more significant changes may be expected locally in the main channel's central pier group. This is an issue to be considered during detailed design.

5. The potential area of reclamations on the northern and southern shores of the New Bridgewater Bridge alignment creates some changes to circulation on the southern area, with lower velocities in the cove created. The lack of source sediment material and being a protected area, means no measurable change in bed thickness for the 2-month simulation near the southern reclamation. But in the faster moving channel with more source material and energic flow, there was some localised minor erosion/deposition around the northern reclamation. No pollution was modelled for the reclamation during construction, and confirmation during detailed design would be required that construction practices could assure this to occur.

7. References

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Appendices

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A Model setup

A.1 Model parameters for TUFLOW FV

Sediment and material parameters [SI units]

Morphological coupling	off
Bed roughness coupling	off
bed roughness model	d50
bed roughness parameters	2.5, 1.0 mm
armouring	off
erosion depth limits	0.02, 0.1 m
deposition depth limits	0.02, 0.1 m
Clay Fraction	particle density, 2200 kg/m^3 d50, 1.0 × 10^{-6} m critical stress model, Soulsby_Egiazaroff settling model, VanRijn84 deposition model, ws0 erosion model, Mehta erosion parameters, 0.001 g/m^{2}s, 0.1 N/m^2, 1.5 bed load model, none
Silt fraction	particle density, 1820 kg/m^3 d50, 3 × 10^{-5} m settling model, VanRijn84 deposition model, ws0 erosion model, Mehta erosion parameters, 0.001 g/m^{2}s, 0.2 N/m^2, 1.5 bed load model, None
Sand fraction	particle density, 2690 kg/m^3 d50, 1 × 10^{-3} m critical stress model, Soulsby settling model, VanRijn84 deposition model, ws0 erosion model, Soulsby_VanRijn bed load model, MPM_Shimizu bed load parameters, 8, -1,1.5
Material properties for clay, silt, sand	Default Bed Load Scale 1.0 Suspended Load Scale 1.0 Dry density, 2000,1655,2445 kg/m^3 Initial mass, 0,827,1223 kg/m^2 Land Bed Load Scale, 1.0 Suspended Load Scale, 1.0 Dry density, 2000,1655,2445 kg/m^3 Initial mass, 0,827,1223 kg/m^2 Bottom roughness, 0.1

	Mud flats Bed Load Scale, 1.0 Suspended Load Scale, 1.0 Dry density, 1467,1213,1793 kg/m^3 Initial mass, 215,449,867 kg/m^2 Bottom roughness, 0.07 River channel cobbles Bed Load Scale, 1.0 Suspended Load Scale, 1.0 Dry density, 2000,1655,2700 kg/m^3 Initial mass, 0,0,2700 kg/m^2 Bottom roughness, 0.04 River channel silt/sand Bed Load Scale, 1.0 Suspended Load Scale, 1.0 Dry density, 2000,1655,2445 kg/m^3 Initial mass, 0,0,2445 kg/m^2 Bottom roughness, 0.03

Water parameters

Bottom drag model	Manning's n
CFL	0.6
Temperature, Salinity	on and affect density
Heat	on
Spatial order	first horizontally and second vertically
Cell wet/dry depths	0.005, 0.02 m
Coriolis	on
Latitude	-42.81°
Time step limits	0.02, 3 s
Turbulence	Momentum mixing model, Smagorinsky Global horizontal eddy viscosity factor, 0.7 Global horizontal eddy viscosity limits, 0.05, 100 m^2/s Scalar mixing model, Smagorinsky Global horizontal scalar diffusivity factor, 0.7 Global horizontal scalar diffusivity limits, 0.05, 100 m^2/s Vertical mixing model, GOTM turbulence update dt, 900 s Global vertical scalar diffusivity limits, 1×10^{-4}, 2 m^2/s
Vertical layers	Hybrid with sigma 5 layers, then z [m] layers -2, -3, -4, -5, -6, -7, -8, -9, -10, -12, -14, -16, -18, -20, -25, -30, -35
Cell 3D depth	0.5 m
Min Bottom Layer Thickness	0.2 m

A.2 Sediment dosing rates and conversion from tracer to zinc calculations

Calculation – base sediment dosing rate for continuous sources	**Result**
Input assumptions 1. over the approximate three year construction period up to 11,000 m^3 of material could be removed from the river bed 2. with an assumed bulk density of 1600 kg/m^3 3. a plausible amount of sediment to represent all the sediment added (dosed) to the far-field model with an expected intensity of work is 0.0005 of extraction rate (half a thousandths) 4. expected construction work will be 12 hours a day and 7 days a week (50% of the time) 5. a standard work area will be three lots of 100 m^2 (each working around a pile group). *Workings* 1. averaged over the construction period the sediment extraction rate is 10 m^3/day 2. applying the bulk density, this is 26 tonnes/day in total 3. the fraction entering the far-field is 0.0005 of 26 tonnes/day giving 13 kg/day 4. rounded up to 15 kg/day 5. over 300 m^2 this gives 0.05 kg/day/m^2 on average 6. twice that when only working half the time is 0.1 kg/day/m^2 7. with each model cell near the bridge being about 10 m^2, a rate of 1 kg/day/cell is adopted. With this total divided by the proportions of source material. *Notes* 1. the initial fraction (0.0005) was back calculated to give round final rate, and then sanity checked as one hundredth of a dredge suction cutter fraction (0.01–0.05)(Sun, Brabson and Mills, 2020) which is consistent with this project not intentionally disturbing the river bed 2. while this an estimate is based on professional judgement, it is not as important as the zinc concentration because zinc is the main parameter issued to assess the construction effects.	Base sediment dosing rate is 1 kg/day/cell applied (0.0116 g/s/cell) 12 hours per day and divided by source fraction (15% clay, 37% silt and 48% sand)

Calculation - tracer scaling factor for continuous sources	**Result**
Input assumptions 1. tracer is applied to model far-field at an arbitrary rate of 1 mass-unit/s/cell, and this calculation is to determine the scaling factor of the mass-unit to interpret the tracer results 2. 95th percentile elutriate concentrations are achieved in disturbed areas from construction in shallows with low flows during expected work practices 3. zinc 95th percentile elutriate concentration laboratory measurements for shallows are 1061 µg/L and in main channel 114 µg/L 4. average model tracer concentration in the shallows are 37 mass-units/m^3 in a dosing area (workzone 3 with 100 m^2), with an average velocity of 0.025 m/s and average depth of 0.89 m 5. elutriate concentrations take one part of sediment with four parts of water by volume 6. bulk density of sediment is 1600 kg/m^3 7. shallows are typically 0.7 m deep and main channel 7 m deep 8. base rate of sediment dosing (0.1 kg/day/m^2), which is 1.157×10^{-6} kg/s/m^2 *Workings* 1. consider a test area where the single cell is dosed at 1 mass-unit/s in the shallows 2. with the assumption this cell maintains the concentration achieved in elutriate testing (1061 µg/L), the cell's average tracer concentration of 37 mass-units/m^3 means to convert the model output from the tracer to µg/L the tracer values are multiplied by 1061 ÷ 37 = 29 3. in main channel the elutriate rate is lower, so the scaling factor is reduced, and is 114 ÷ 1061 × 29 = 3.1 As a check, now calculate the ratio of near-field to far-field sediment dosing to give the elutriate concentration (if externally added) 4. in the shallows in expected work area there is a volume of 100 m^3 and water is moving in low flows through this (0.025 m/s), so there is 0.025 × 100 × 0.89 = 2.2 m^3/s flow exchange (in and out) 5. elutriate volume of water to give elutriate concentration is 4 × sediment volume, so sediment volume = 2.2 ÷ 4 = 0.56 m^3/s 6. mass dosing to give elutriate concentration is 0.56 × 1.6 = 0.89 tonnes/s = 890 kg/s	To convert model tracer results (in mass-units/m^3) to µg/L, multiple by 29 for sediment from the shallows and by 3.1 for sediment from the main channel

7. relating back to unit area, with a cell of 100 m^2, is 890 ÷ 100 = 8.9 $kg/s/m^2$ (in the near-field) 8. As far-field dosing rate is 1.15×10^{-6} $kg/s/m^2$, the fraction of near-field to far-field is 8.9 ÷ 1.15×10^{-6} = 8 million *Notes* 1. These calculations make a number of assumptions about the near-field processes. The ratio of near-field to far-field sediment dosing of 8 million is on the high end, and could mean the sediment dosing mass rate is too low, the assumption that elutriate concentrations are achieved in the shallows is too conservative, or the elutriate concentrations are achieved primary through disturbance of local sediment rather than introduction of new sediment 2. Given the zinc concentration is a more important measure of effect than the sediment concentrations (as they relate more directly to environmental and human health), the potentially conservative approach is appropriate for this level of assessment	

Calculation - tracer scaling factor for transitory sources	**Result**
Input assumptions 1. for transitory sources the assumption that average source concentration is same as the elutriate level is not as good a model of the near-field mixing processes. Calculations are required to ensure the results can be compared with the continuous pattern sources. 2. transitory sources include 5 tonnes dosed over an hour in one location (starting at a rate of 10 tonnes/hour and reducing to zero), 25 tonnes dosed over one hour (constant rate) in one location, 1 cell dosed at base rate moving over 300 m over 2 hours from main channel into shallows 3. in the shallows the typical depths are 0.7 m, and in the main channel it is 7 m 4. sediment has an assumed bulk density of 1600 kg/m^3 5. in the laboratory the elutriate was created with 1 part sediment and 4 parts water by volume 6. increases in the soil mass will linearly increase dissolved zinc concentration 7. zinc elutriate concentration laboratory measurements for shallows are 1061 µg/L and in main channel 114 µg/L for a 5 tonne accident *Workings for accidental dump in one location*	To convert model tracer results (in mass-units/m^3) to µg/L for sediment from the shallows, multiply by 23

8. a 1 L sample of sediment has a mass of 1.6 kg, mixed with 4 L of water has final volume of approximately 5 L, and hence a density of 1.6 ÷ 5 = 0.32 kg/L 9. the sample mixture produces the elutriate concentration of zinc, that is the concentration of 0.32 kg/L of well mixed soil in water produces zinc concentrations in the shallows of 1061 µg/L and in main channel of 114 µg/L 10. the ratio of dissolved zinc to soil is 1061 µg ÷ 320 g = 3.3×10^{-6} for shallows and 114 µg ÷ 320 g = 0.36×10^{-6} for channel 11. in shallows 5 tonnes of sediment has the potential to produce $5\times10^{6} \times 3.3\times10^{-6}$ = 16.6 g of dissolved zinc, while in main channel this is 1.8 g 12. in the shallows the volume of water in a cell is 0.7 × 10 = 7 m^3, and in the main channel is 7 × 10 = 70 m^3 13. the sediment connection in the shallows from 5 tonnes of sediment is 5 000 ÷ 7 = 714 kg/m^3 = 0.714 kg/L, and in the main channel these number is a tenth, 0.071 kg/L 14. using the ratio of sediment concentration from step 2 and 4, the dissolved zinc concentration of 5 tonnes of sediment in the shallows is 0.714 ÷ 0.32 × 1061 = 2367 µg/L, but sediment is dosed over an hour 15. 5 tonnes of sediment released from shallows over 1 hour, is the release of 16.6 g × 5 of dissolved zinc = 83 g/hour = 0.023 g/s, while in the model the tracer was dosed at 1 mass-unit/s – hence 1 mass-unit is 0.023 g for a release of 5 tonnes 16. 5 tonnes of sediment released from main channel over 1 hour, is the release of 1.8 g × 5 of dissolved zinc = 9 g/hour = 0.0025 g/s, while in the model the tracer was dosed at 1 mass-unit/s – hence 1 mass-unit is 0.0025 g for a release of 5 tonnes 17. tracer output from the model is mass-units/m^3, which is mass-units ÷ 1000/L 18. to convert tracer output to µg/L for 5 tonne release in the shallows, multiplied by 0.023 ÷ 1000 × 10^6 = 23 19. to convert tracer output to µg/L for 5 tonne release in the channel, multiplied by 0.0025 ÷ 1000 × 10^6 = 2.5 *Workings for mobile release over 2 hours* 20. sediment release is 48 g/s/cell in the shallows, and the dissolved zinc from using step 10 is 48 g/s/cell × 3.3×10^{-6} = 158 µg/s/cell 21. model is dosing at 1 mass-unit/s/cell, and output is in mass-units/m^3 22. to convert tracer output to µg/L for mobile release in the shallows they should be multiplied by 158 ÷ 1000 = 0.158	

B Model output – 56 maps

The following maps are model output for the following runs ("run" being a 30 day model simulation of scenario). There are four sets of scenarios in the bands below, with the page number for each:

Scenario				Page Number				
				Tracer		Zinc		Sediment
Run	Work Zone[1]	Flow/Tide[2]	Dosing[3]	Average[4]	Max.	Average	Max.	Change
1	3,7,10	low/high	Worst	57	58	81	82	
2	3,7,10	Low	Worst	59	60	83	84	
3	3,7,10	Medium	Worst	61	62	85	86	105,106,107,10
4	3,7,10	High	Worst	63	64	87	88	
5	7	Medium	Optimal	65	66	89	90	
6	10	Medium	Optimal	67	68	91	92	
7	3	Medium	Optimal	69	70	93	94	
8	7	High	Optimal	71	72	95	96	
9	7	Medium	A5	73	74	97	98	
10	7	Medium	A25	75	76	99	100	
11	→ 7	Medium	Move	77	78	101	102	
12	→ 7	Low	Move	79	80	103	104	
13	Existing	Medium	Nil					
14	Constructed	Medium	Nil					110
15	Existing	High	Nil					
16	Constructed	High	Nil					111
17	Existing	Low	Nil					
18	Constructed	Low	Nil					112

Notes (further definitions over the page)

1. Work zone number during construction, "existing" for current, or "constructed" for completed works; work zones are shown in Figure 3.2
2. Tide normal unless stated, low flow is 1:100 AEP lowest 2-month volume, medium is 1:2 AEP highest 2-month volume, high is 1:100 highest 2-month volume, high (tide) is 2019 tide levels during January lifted so the peak levels reached 1.44 m AHD which is the 1:100 AEP current climate tide (a sea storm)
3. Dosing
    a. Worst is large scale disturbance footprint (100 m^2 per work zone)
    b. Optimal is small scale disturbance footprint (10 m^2 per work zone)
    c. continuous pattern of 12 hour/day 7 day/week, except for
        i. A5 is accidental 5 tonnes release over 1 hour; A25 = 25 tonnes release over 1 hour
        ii. Move is moving 300 m across shallows in 2 hours ending near zone 7
4. Averaging is vertically and then maximum or average by time to create a single concentration for every plan location, noting model output is saved every 3 hours so actual maximums may be missed.

Definitions for map titles and legends:

Average	Average of depth averaged values over the simulation period
Bed thickness	Vertical depth of the erodible river bed (starting with 1 m in this study)
Change	Values with proposed New Bridgewater Bridge works minus existing system values
Clay fraction	Sediment fraction with 50th percentile size of 1 µm
Concentration	Mass divided by volume
High flow	1:100 annual exceedance probability sequence with highest 2-month volumes
High tide	Normal tide increased to give 1:100 annual exceedance probability sea storm
Low flow	1:100 annual exceedance probability sequence with lowest 2-month volumes
Maximum	Maximum of depth averaged values over the simulation period
Medium flow	1:2 annual exceedance probability sequence with highest 2-month volumes
Normal tide	January 2019 from Hobart tide gauge
Optimum disturbance	Normal work practice over 10 m^2 at one work site for 12 hours, 7 days a week.
Sand fraction	Sediment fraction with 50th percentile size of 1000 µm (1 mm)
Sediment Concentration	Concentration in mg/L of a particular sediment fraction
Silt fraction	Sediment fraction with 50th percentile size of 30 µm
Simulation period	30 days from start of 1 January 2019
Total Suspended Solids (TSS)	Total of clay, silt and sand fractions sediment concentrations [mg/L]
Tracer	Conservative water quality variable that does not decay or settle
Worst disturbance	Normal work practice at 100 m^2 per work sites for 3 work sites, 12 hours, 7 days a week.
Zinc	Inferred dissolved zinc concentration due to the project based on assumptions about the source concentration. That is, it does not include the existing dissolved or attached zinc concentrations in the River Derwent.

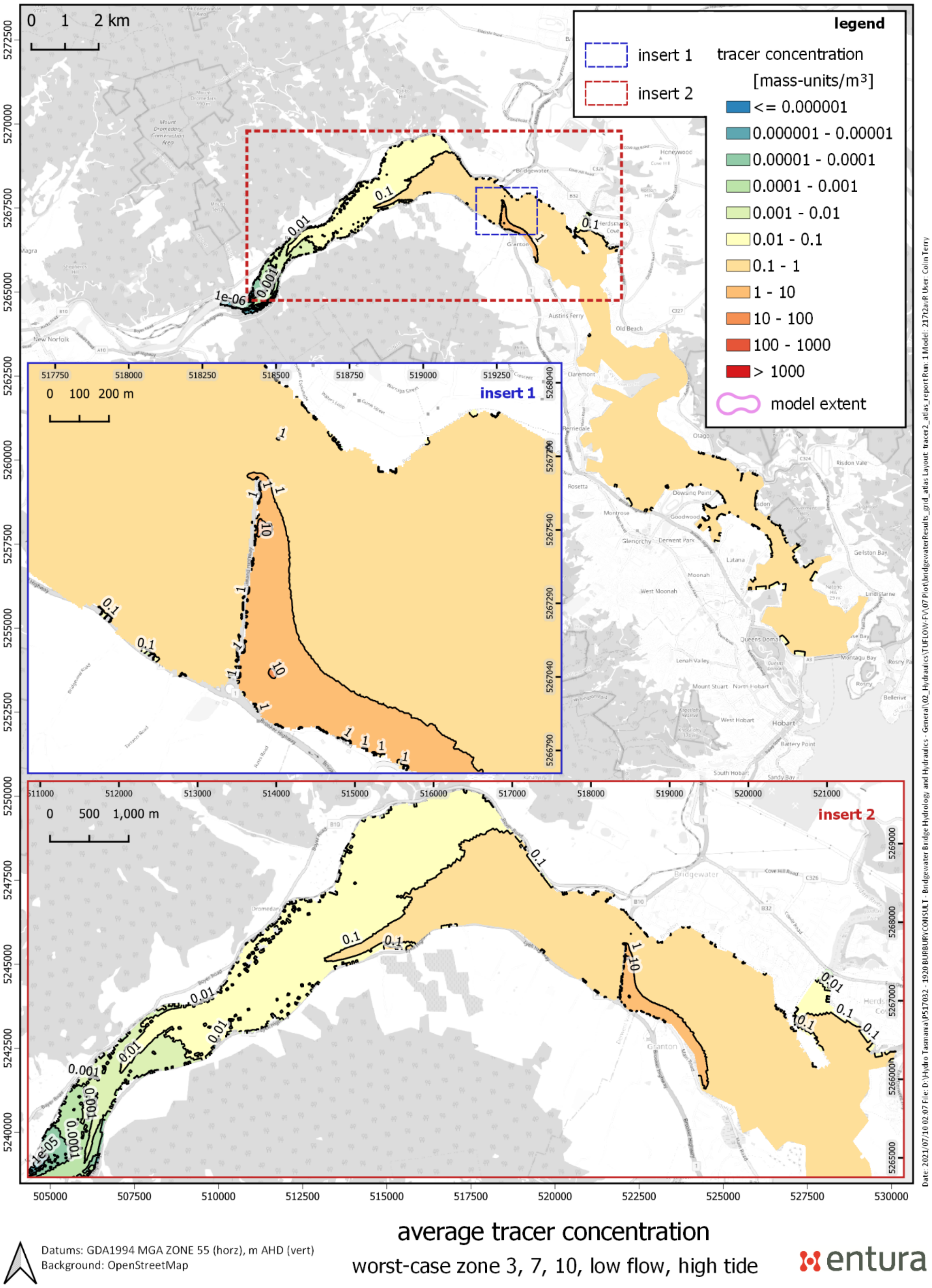

Figure B.1: Average tracer concentration, worst disturbance construction, low flow, high tide (Run 1)

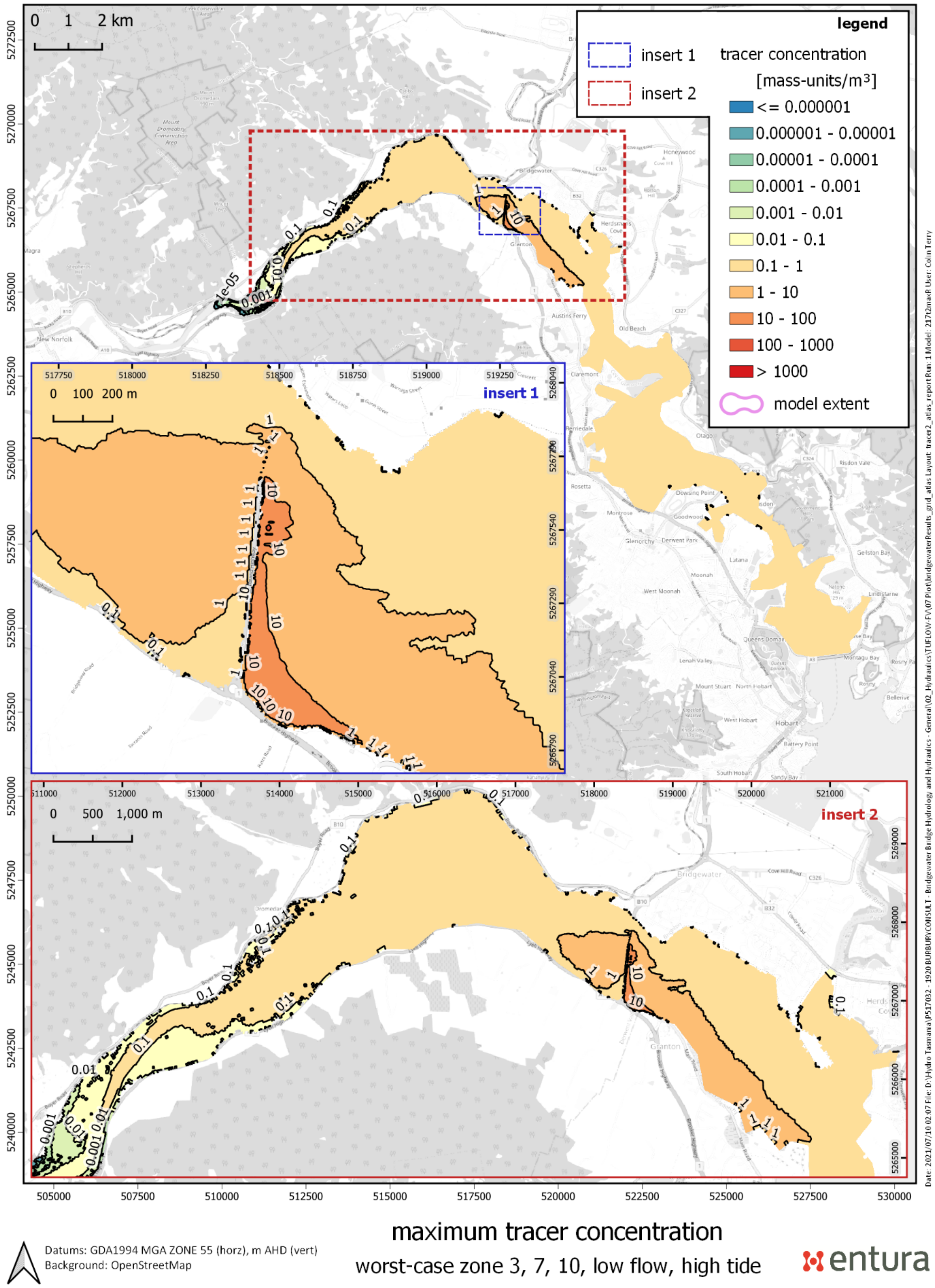

Figure B.2: Maximum tracer concentration, worst construction, low flow, high tide (Run 1)

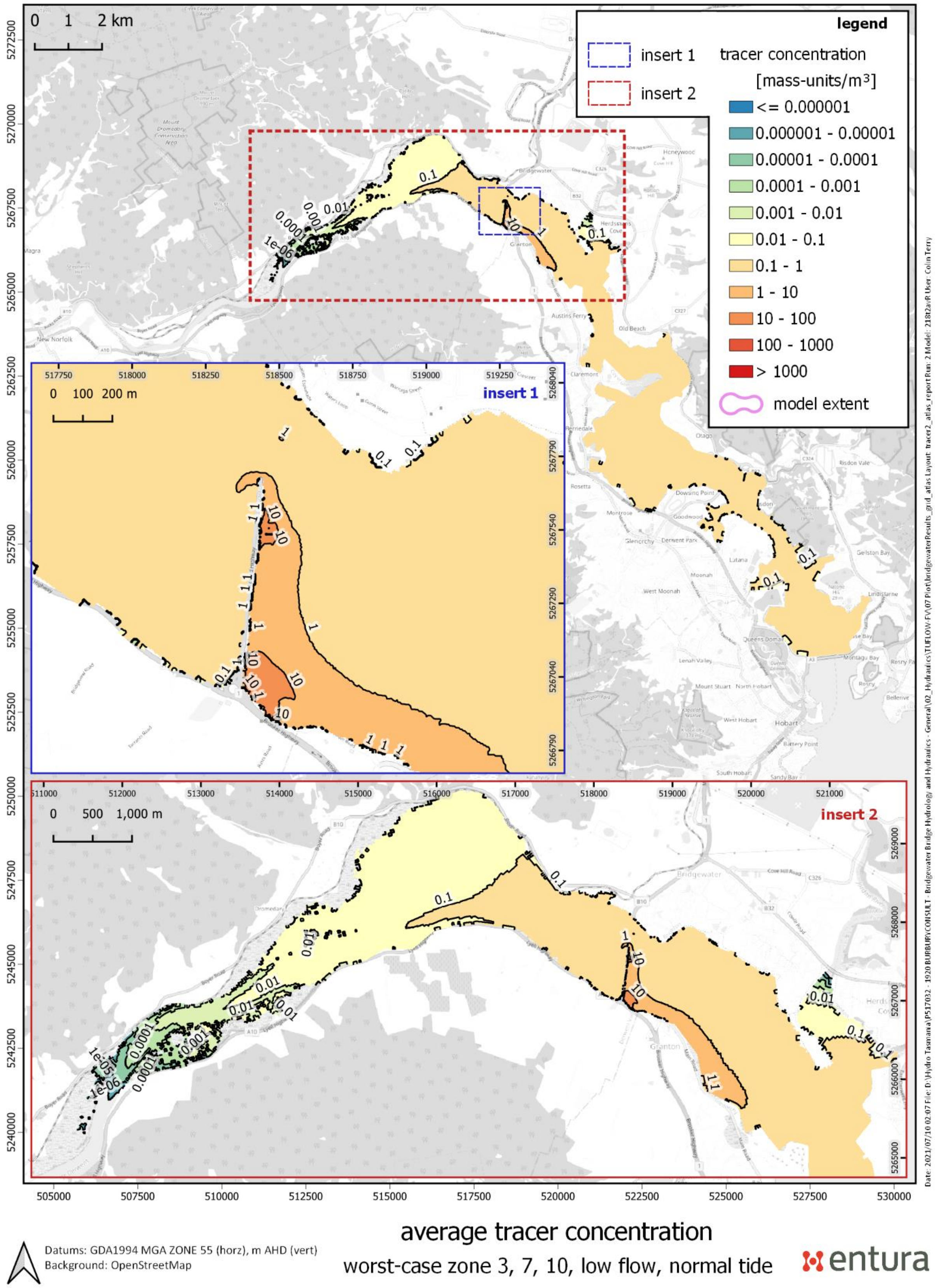

Figure B.3: Average tracer concentration, worst disturbance construction, low flow, normal tide (Run 2)

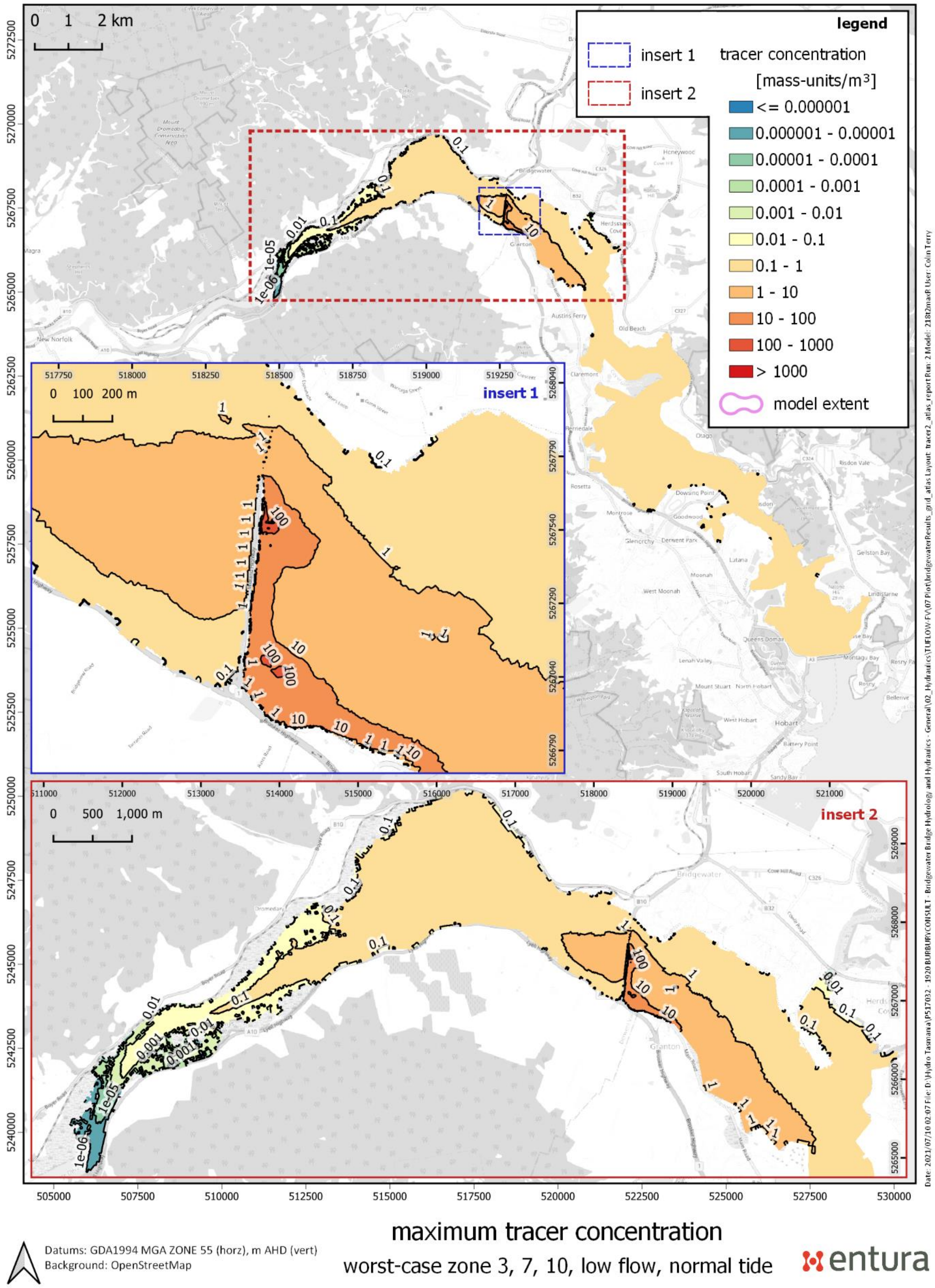

Figure B.4: Maximum tracer concentration, worst disturbance construction, low flow, normal tide (Run 2)

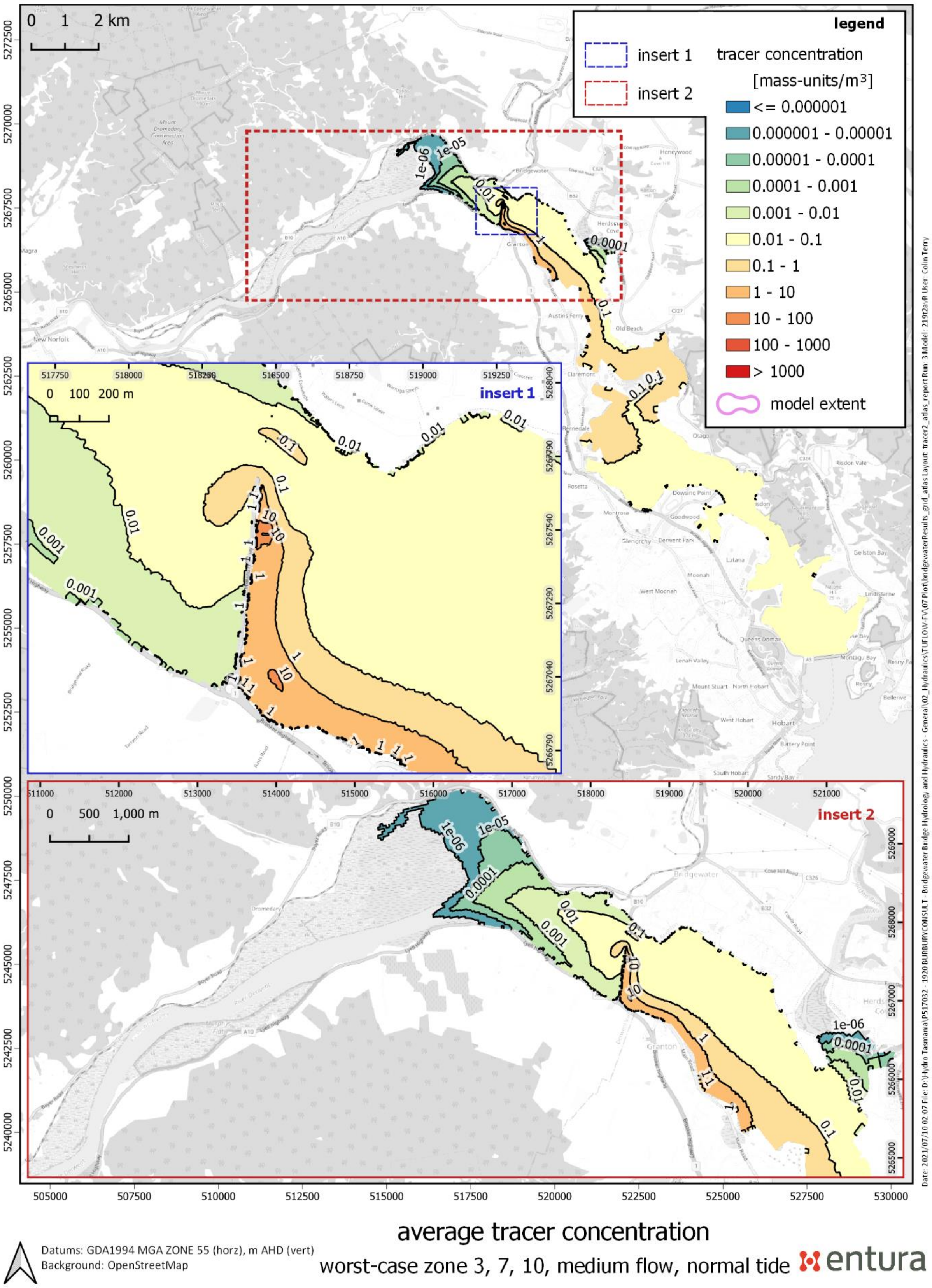

Figure B.5: Average tracer concentration, worst disturbance construction, medium flow, normal tide (Run 3)

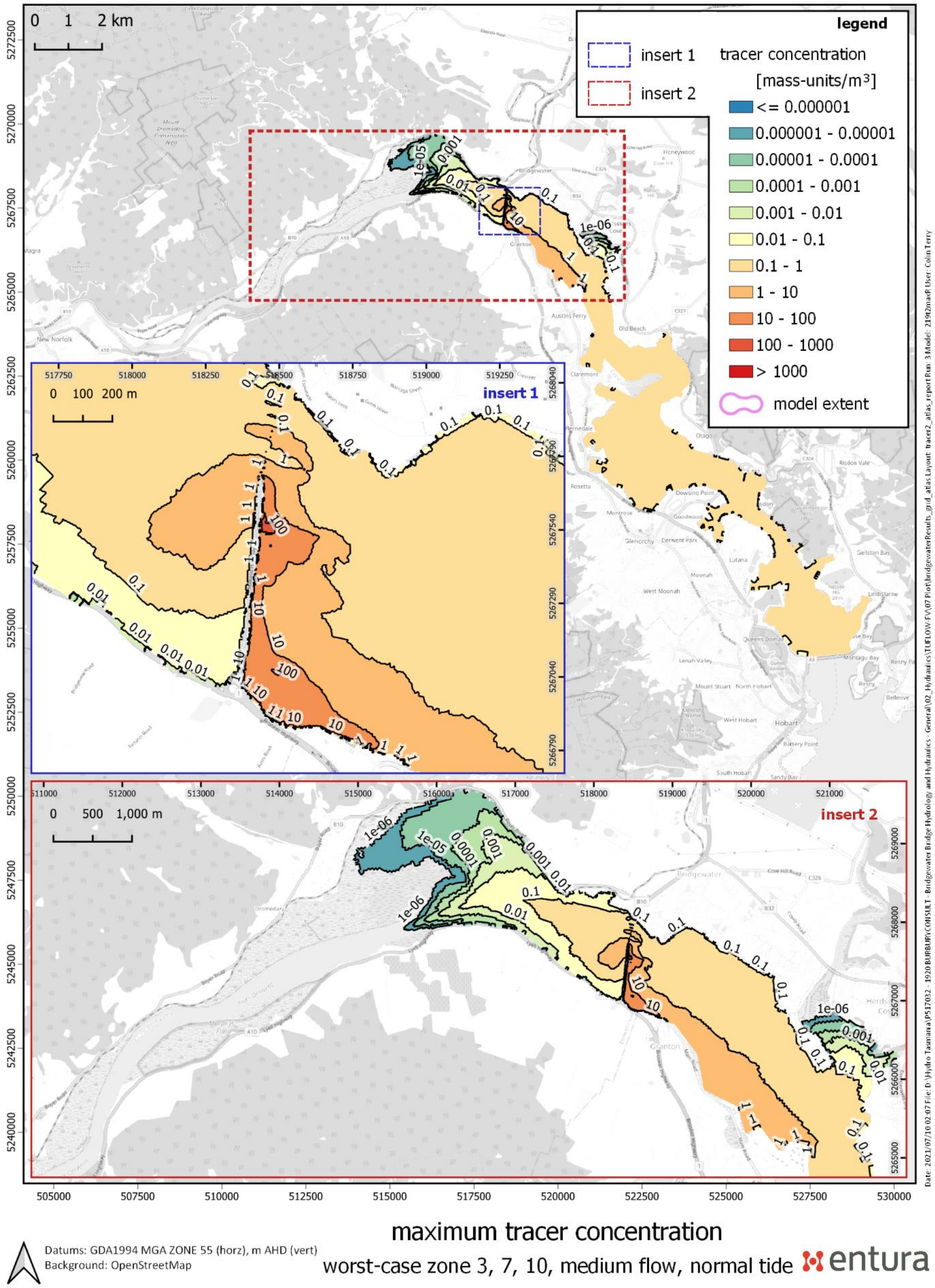

Figure B.6: Maximum tracer concentration, worst disturbance construction, medium flow, normal tide (Run 3)

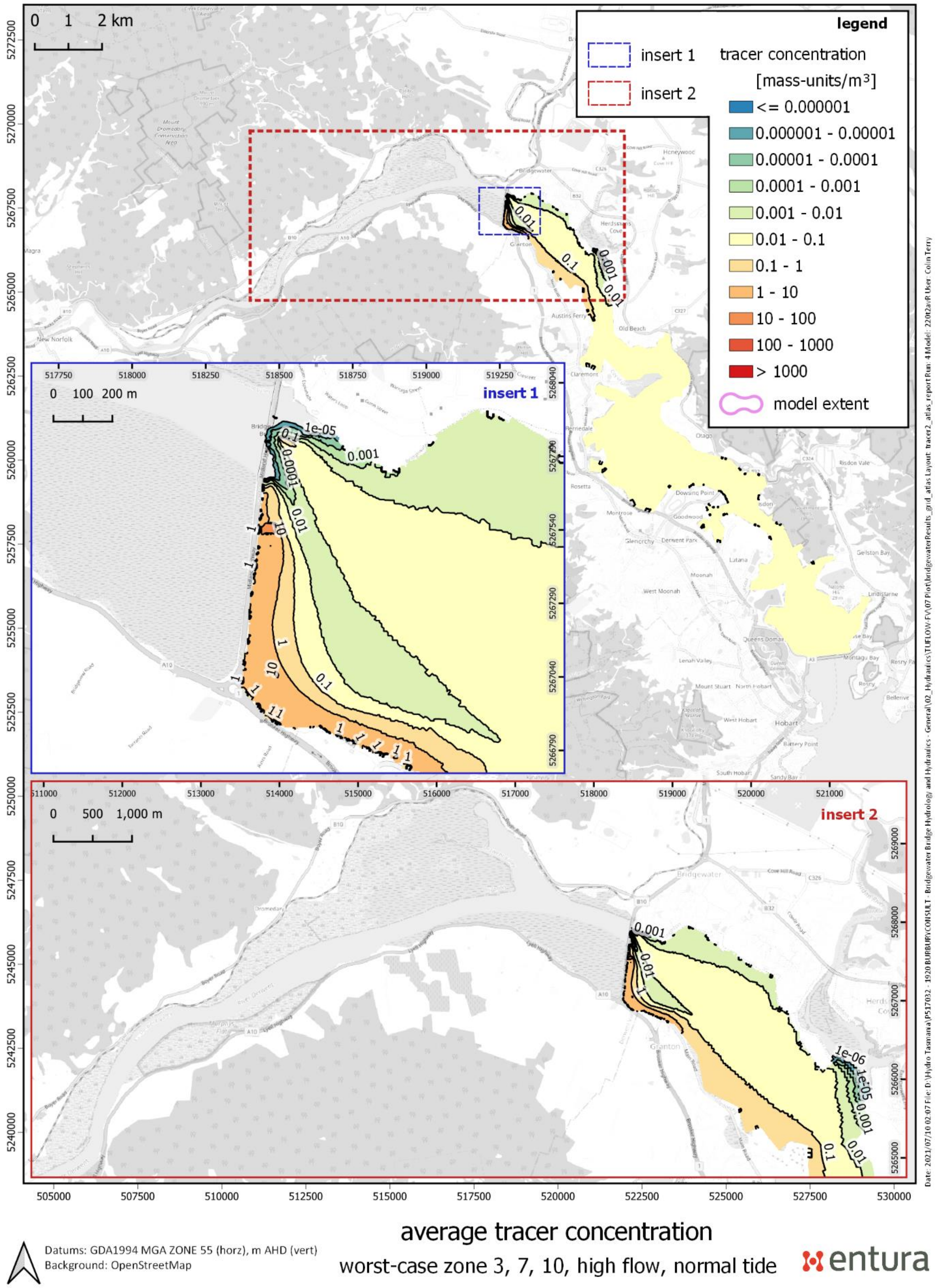

Figure B.7: Average tracer concentration, worst disturbance construction, high flow, normal tide (Run 4)

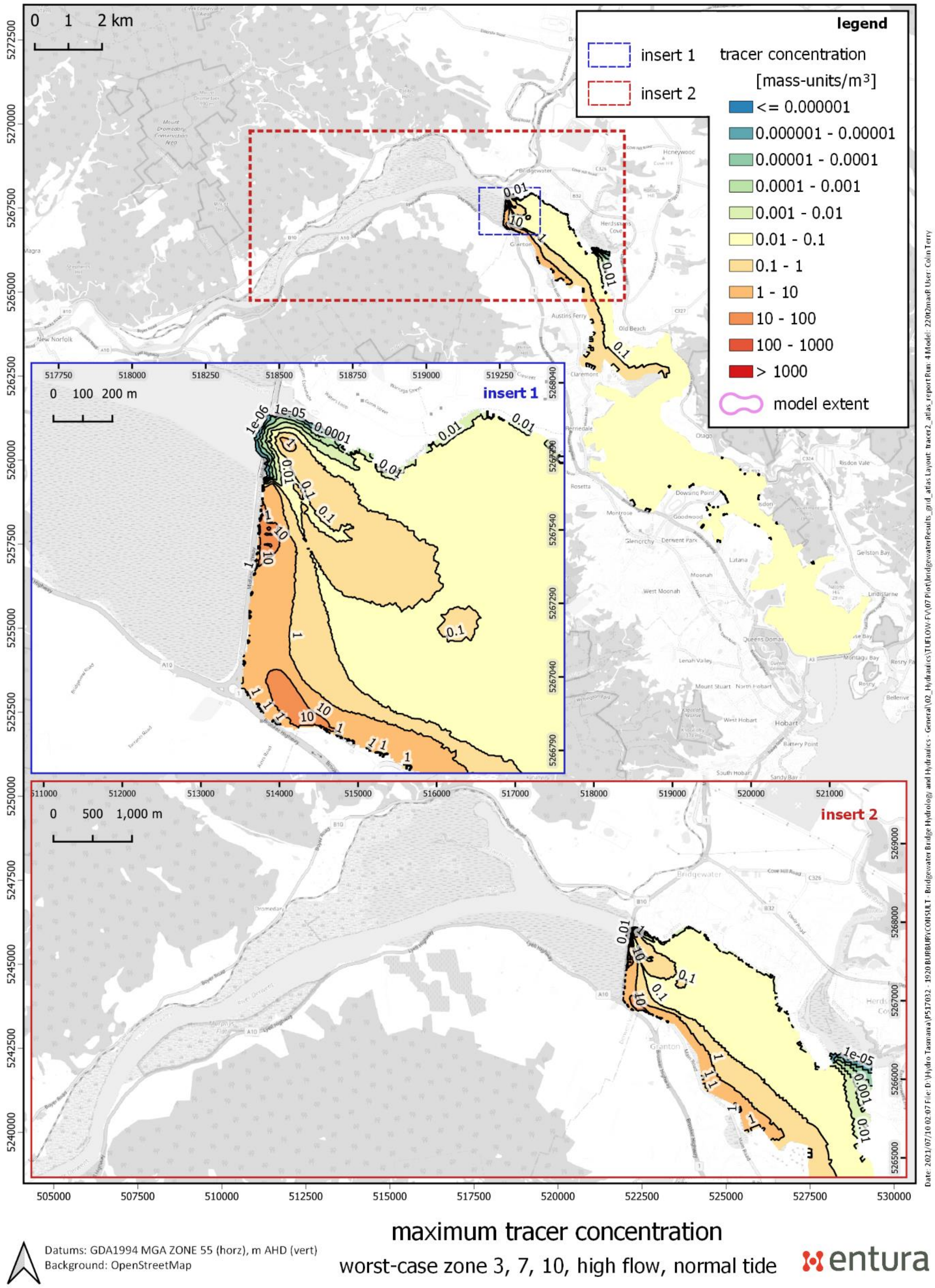

Figure B.8: Maximum tracer concentration, worst disturbance construction, high flow, normal tide (Run 4)

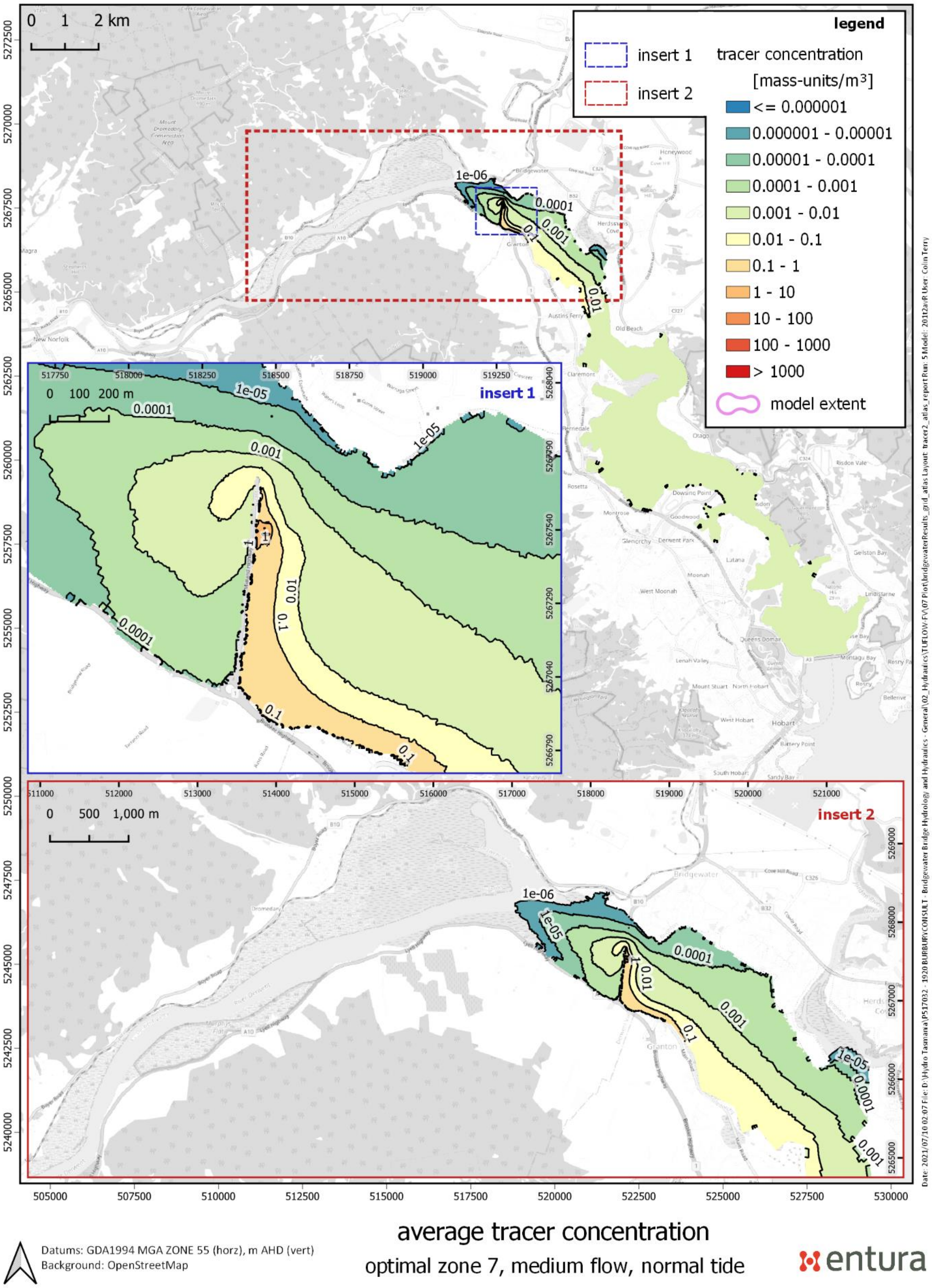

Figure B.9: Average tracer concentration, worst disturbance construction, medium flow, normal tide (Run 5)

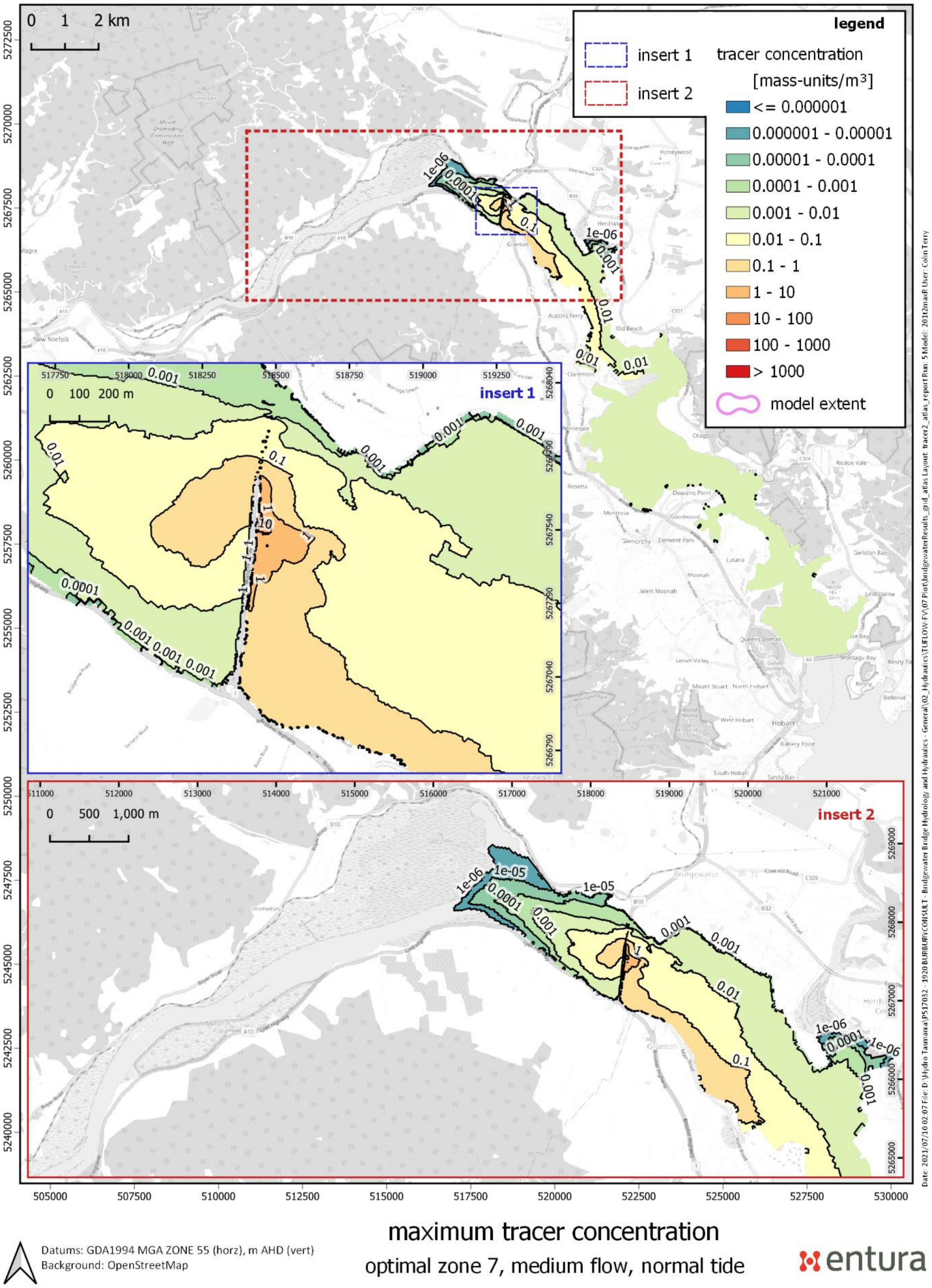

Figure B.10: Maximum tracer concentration, worst disturbance construction, medium flow, normal tide (Run 5)

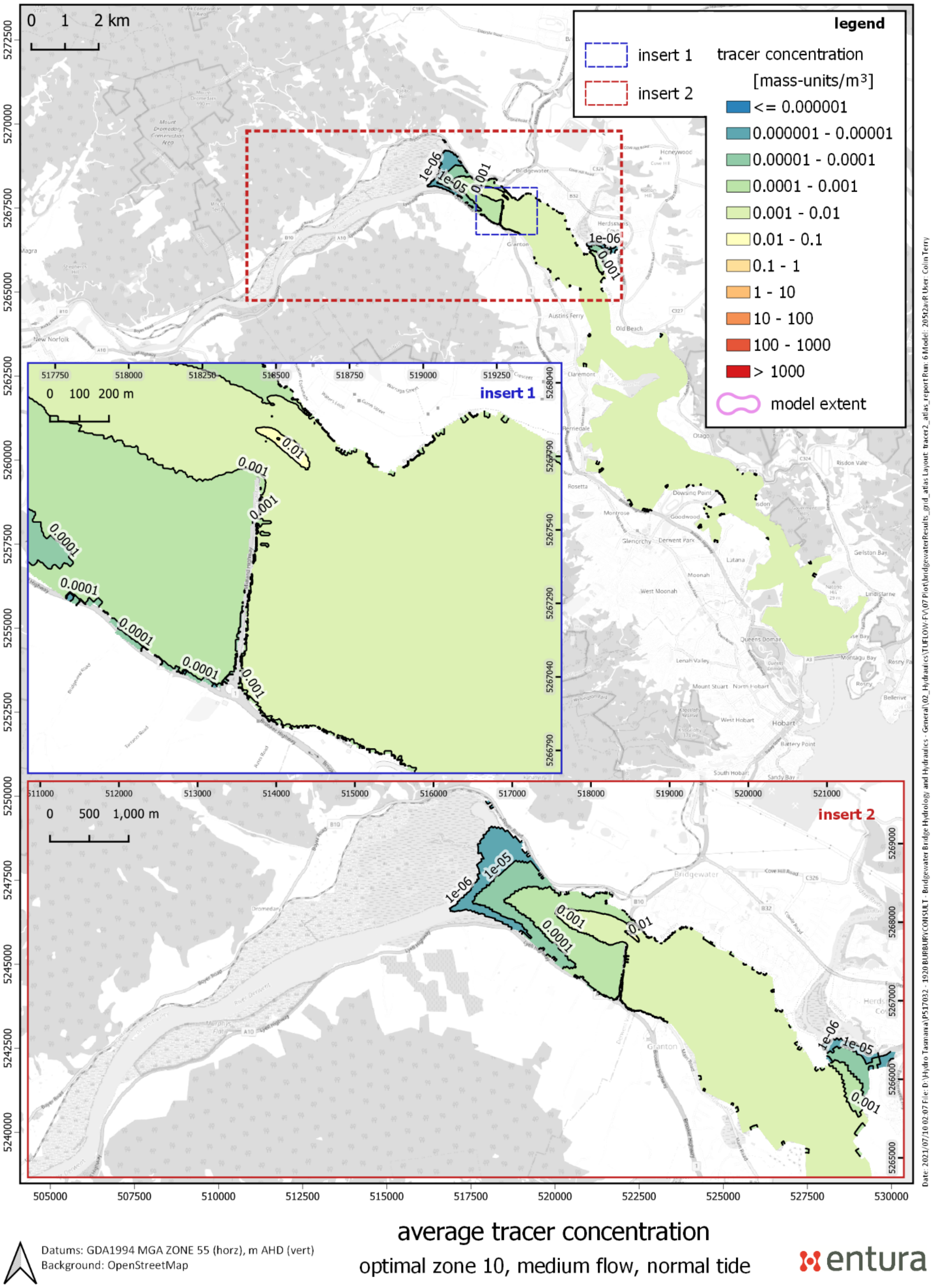

Figure B.11: Average tracer concentration, optimal disturbance zone 10 construction, medium flow, normal tide
(Run 6)

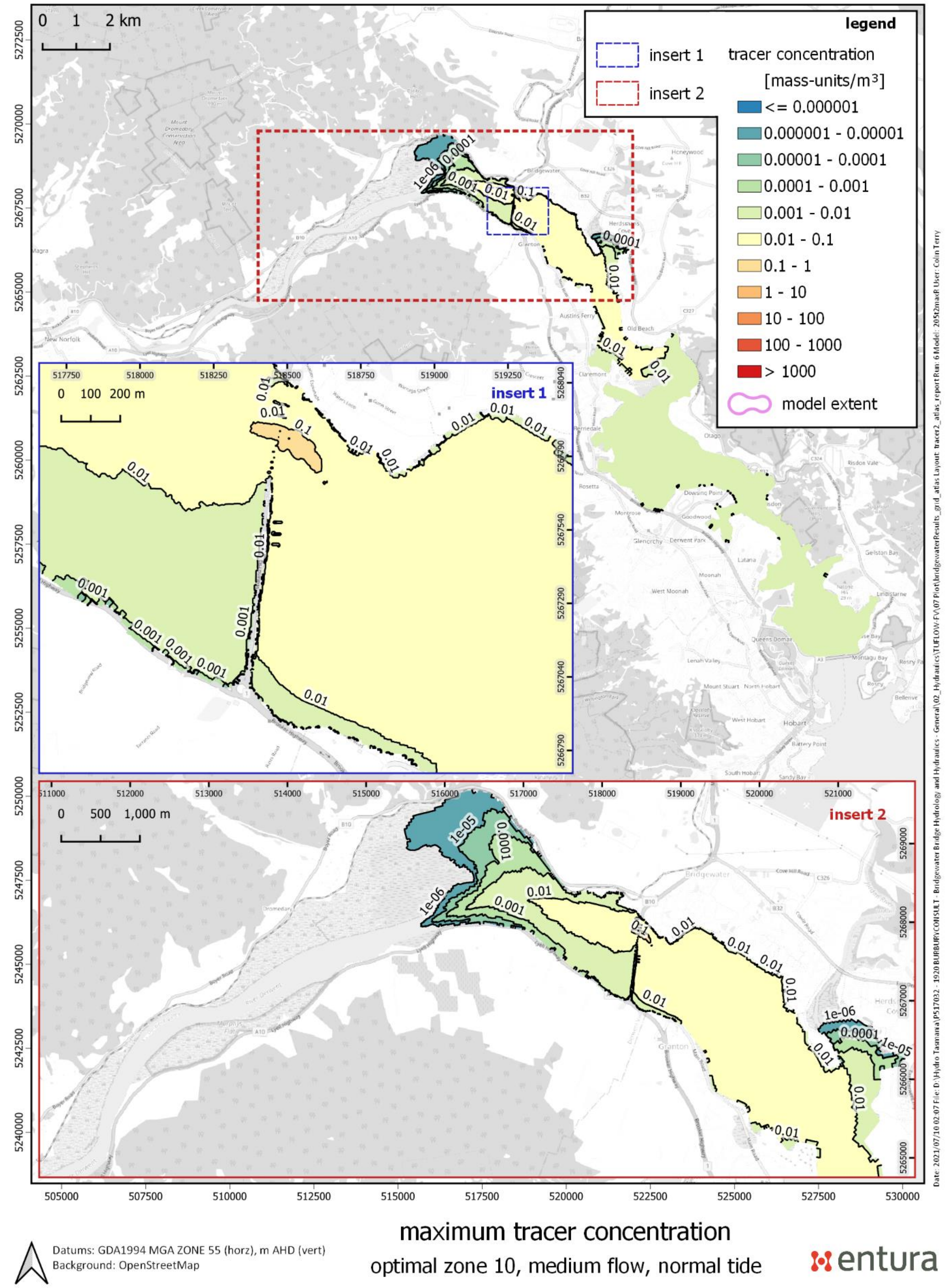

Figure B.12: Maximum tracer concentration, optimal disturbance zone 10 construction, medium flow, normal tide
(Run 6)

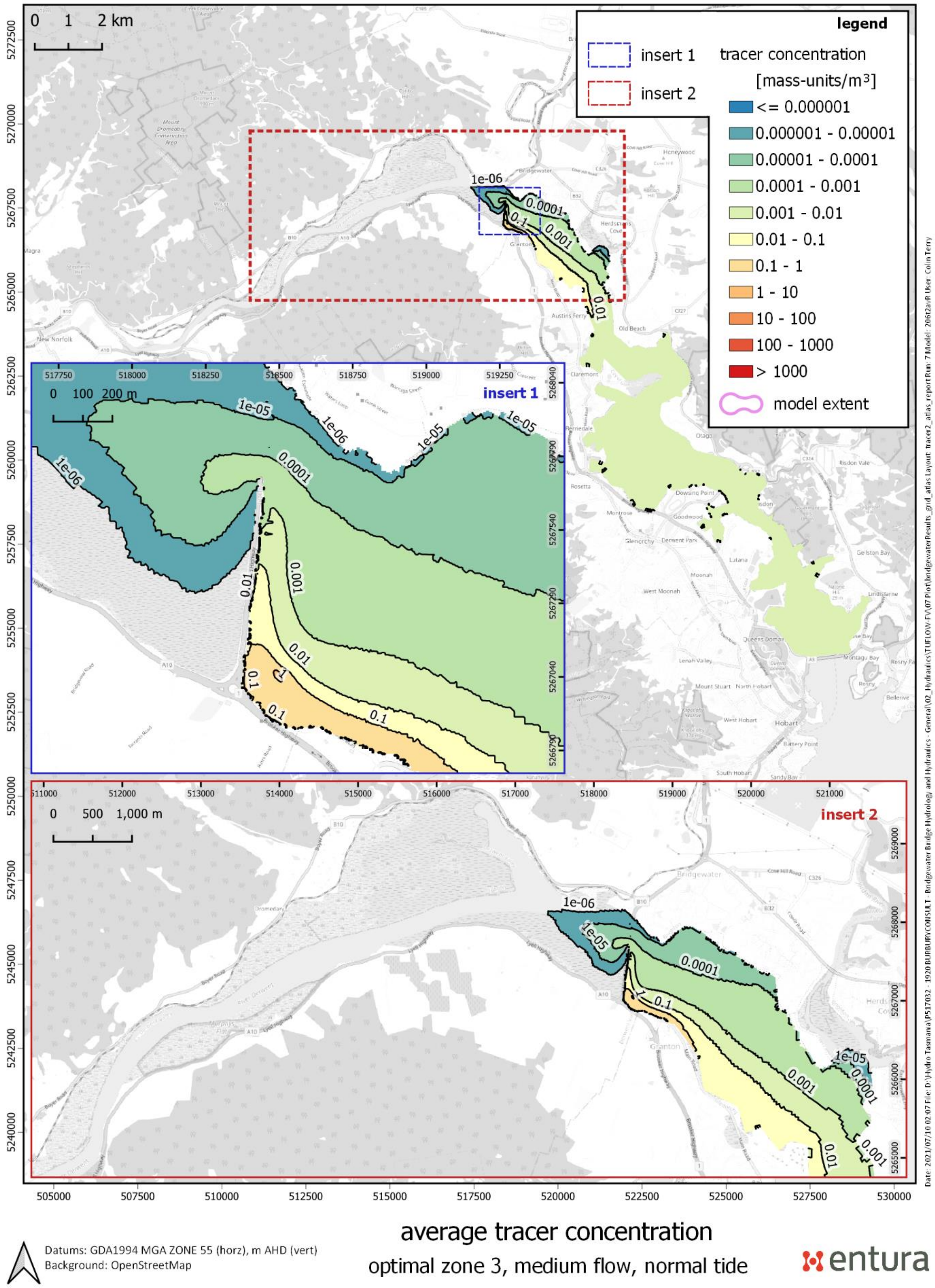

Figure B.13: Average tracer concentration, optimal disturbance zone 3 construction, medium flow, normal tide (Run 7)

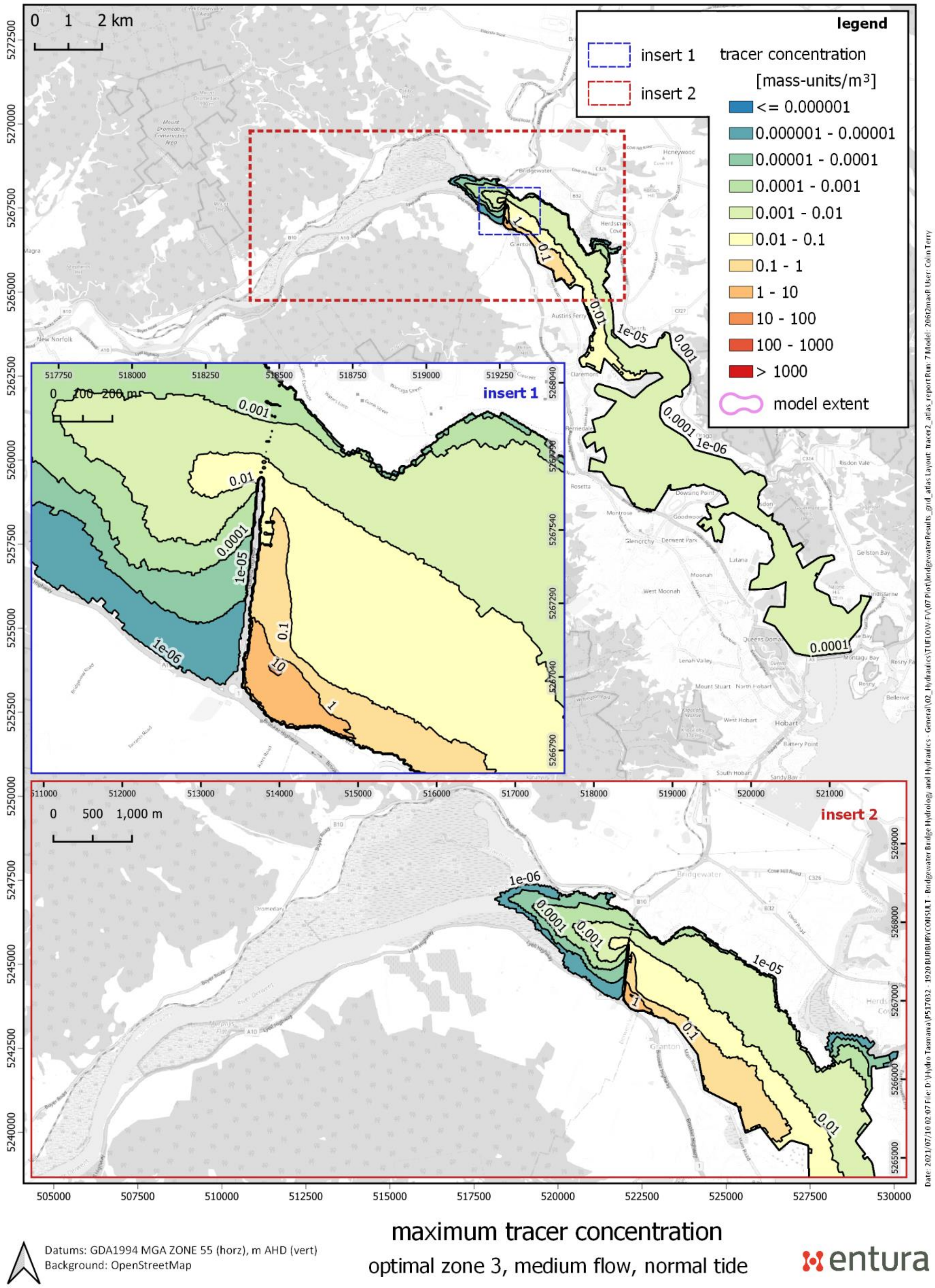

Figure B.14: Maximum tracer concentration, optimal disturbance zone 3 construction, medium flow, normal tide
(Run 7)

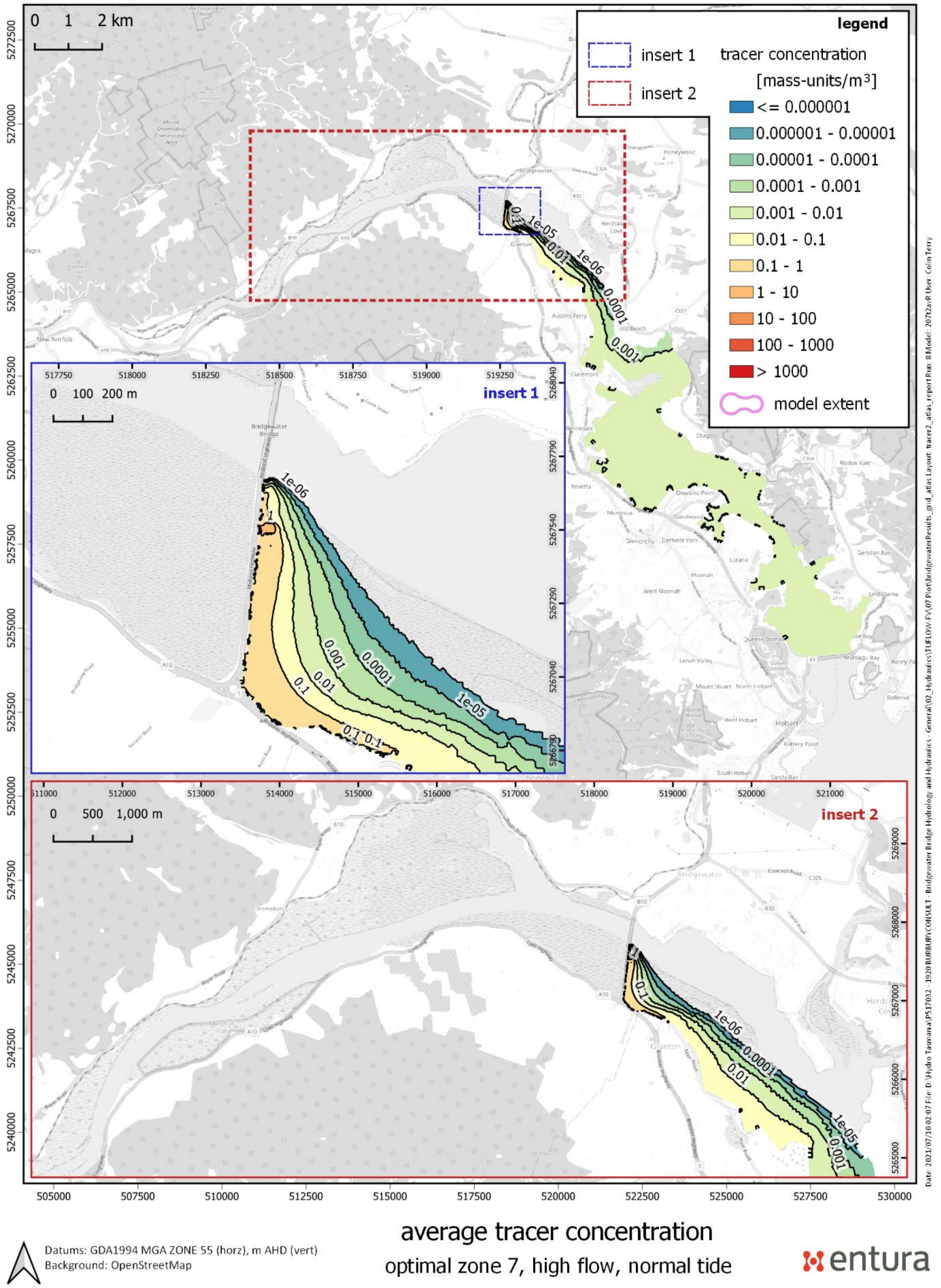

Figure B.15: Average tracer concentration, optimal disturbance zone 7 construction, high flow, normal tide (Run 8)

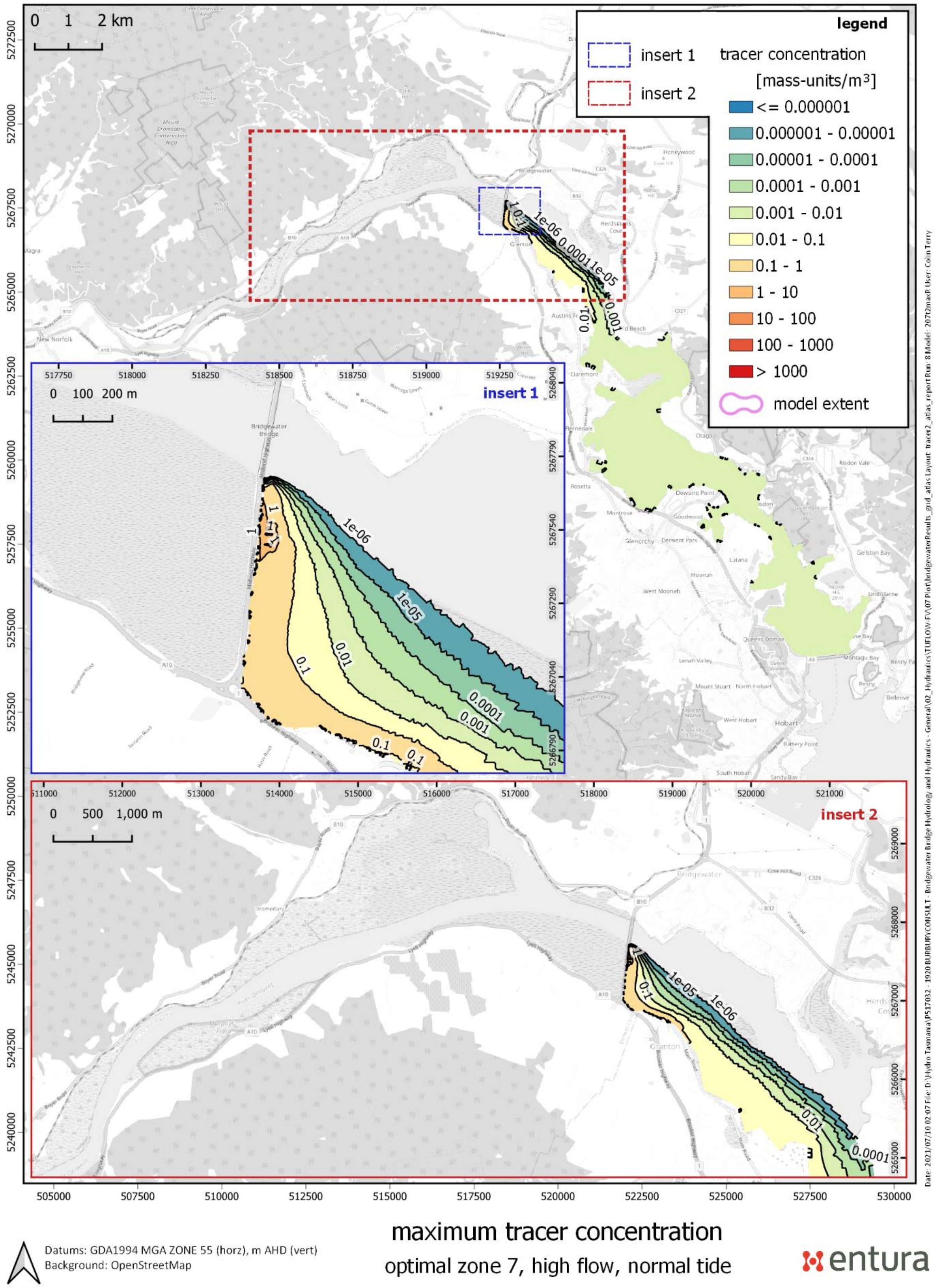

Figure B.16: Maximum tracer concentration, optimal disturbance zone 7 construction, high flow, normal tide (Run 8)

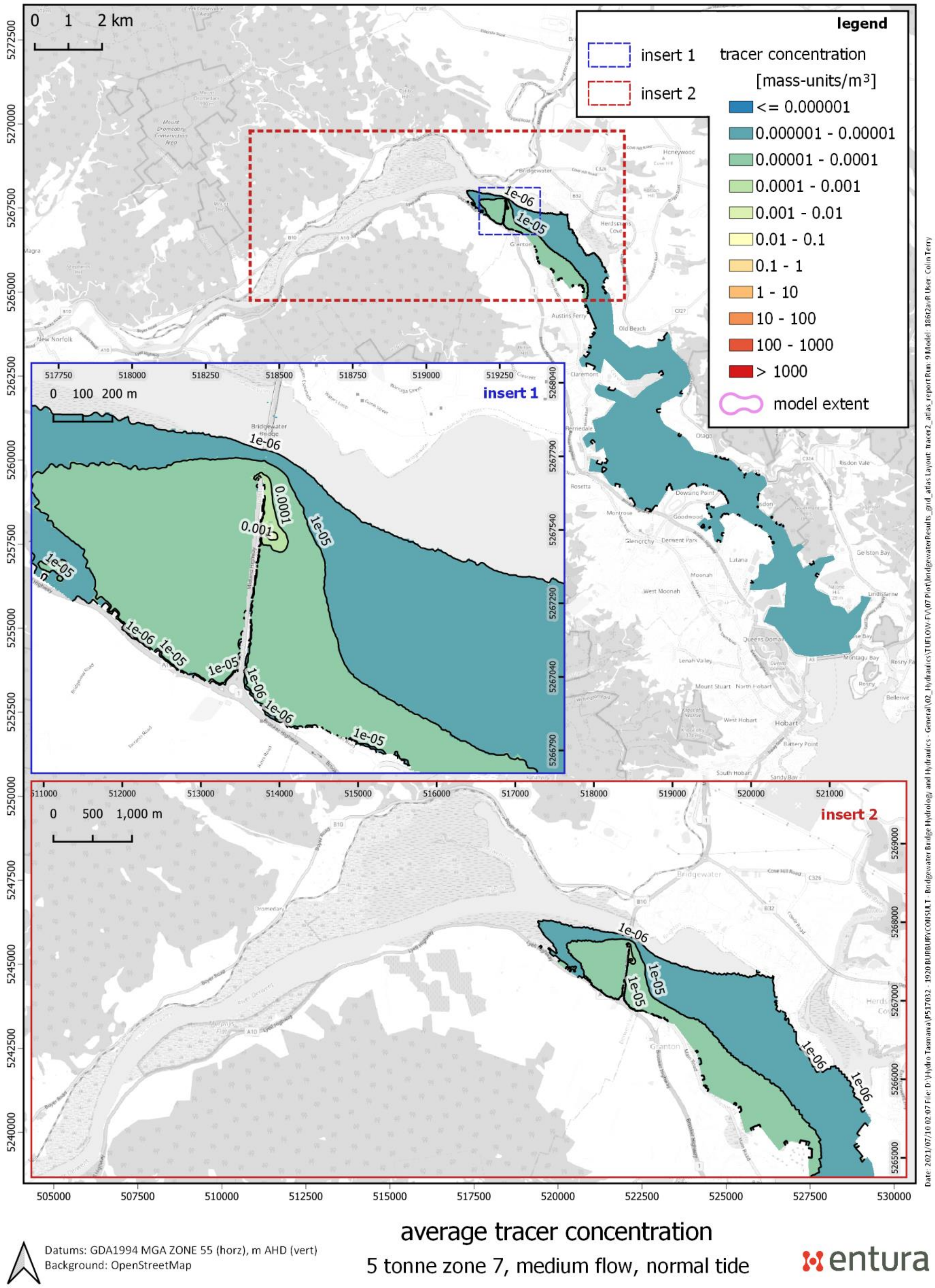

Figure B.17: Average tracer concentration, 5 tonne accident, medium flow, normal tide (Run 9)

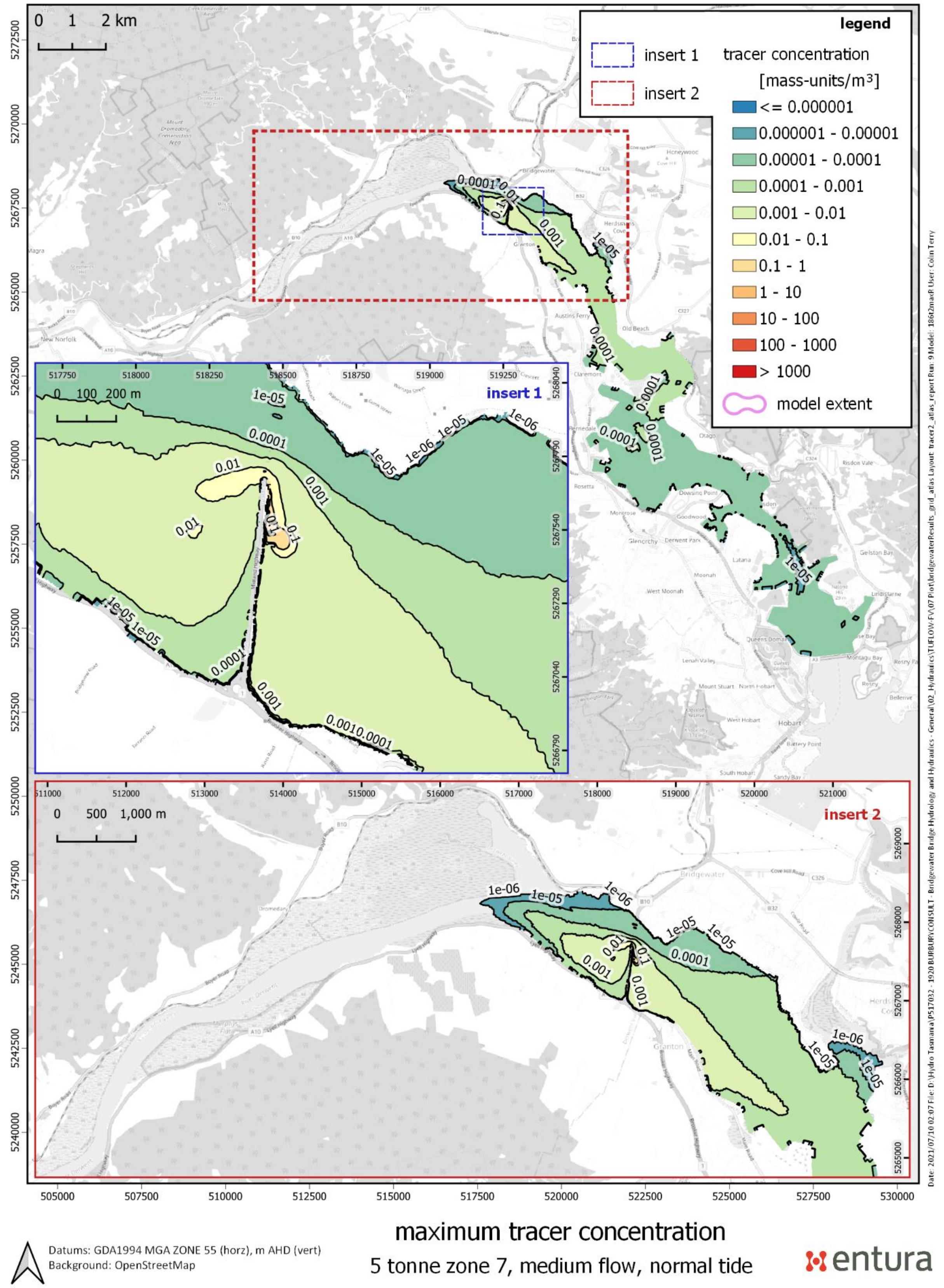

Figure B.18: Maximum tracer concentration, 5 tonne accident, medium flow, normal tide (Run 9)

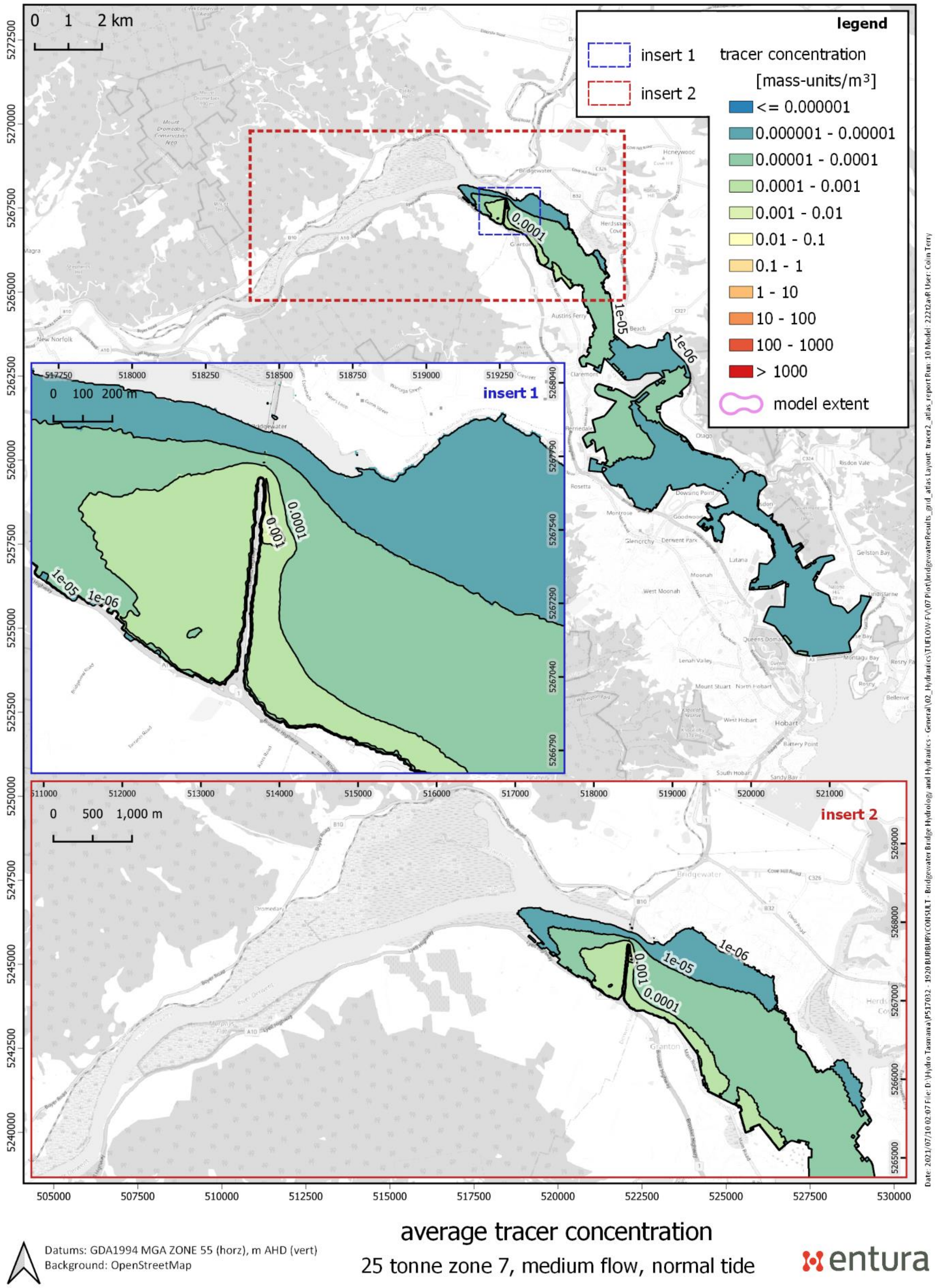

Figure B.19: Average tracer concentration, 25 tonne accident, medium flow, normal tide (Run 10)

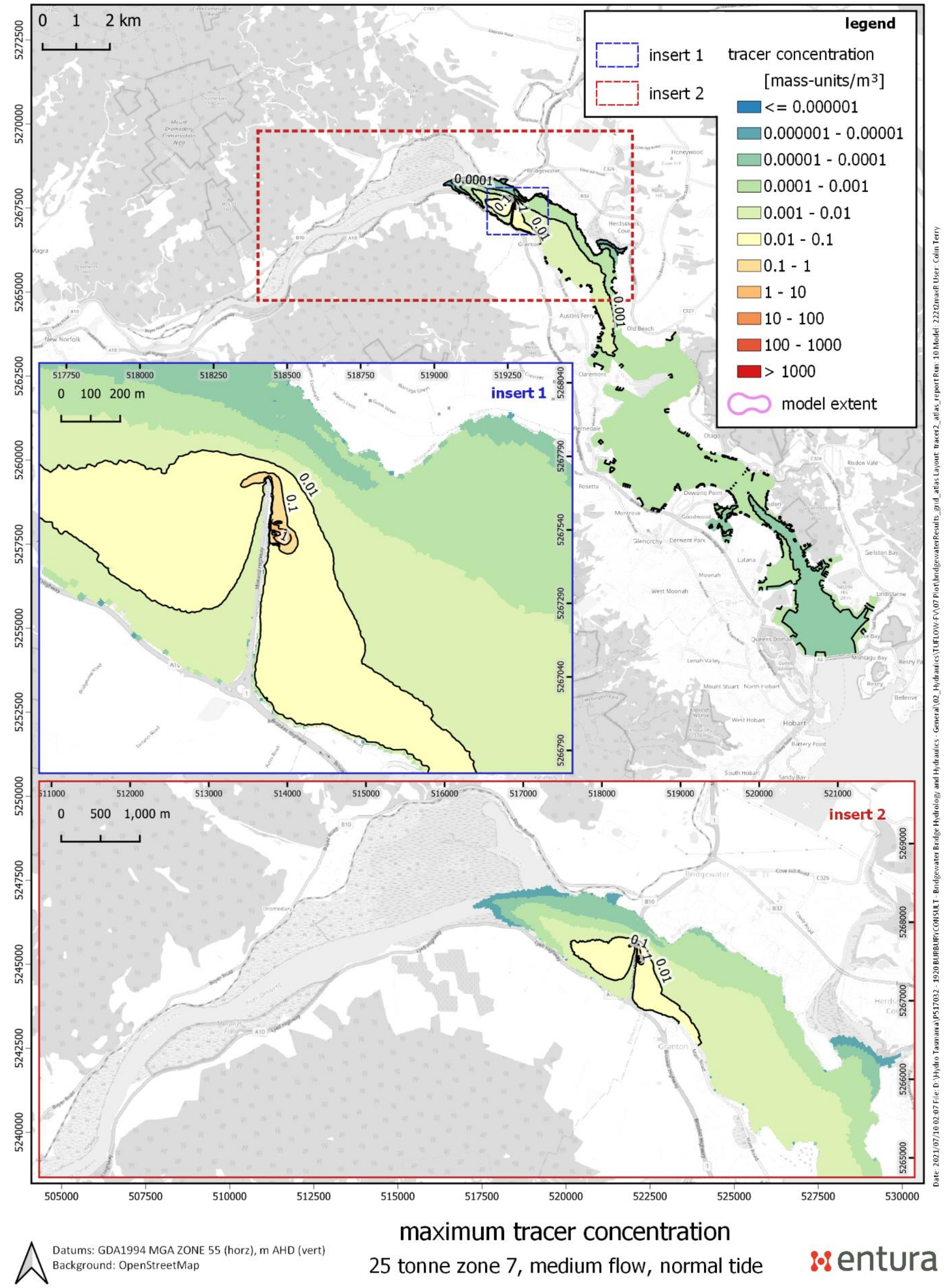

Figure B.20: Maximum tracer concentration, 25 tonne accident, medium flow, normal tide (Run 10)

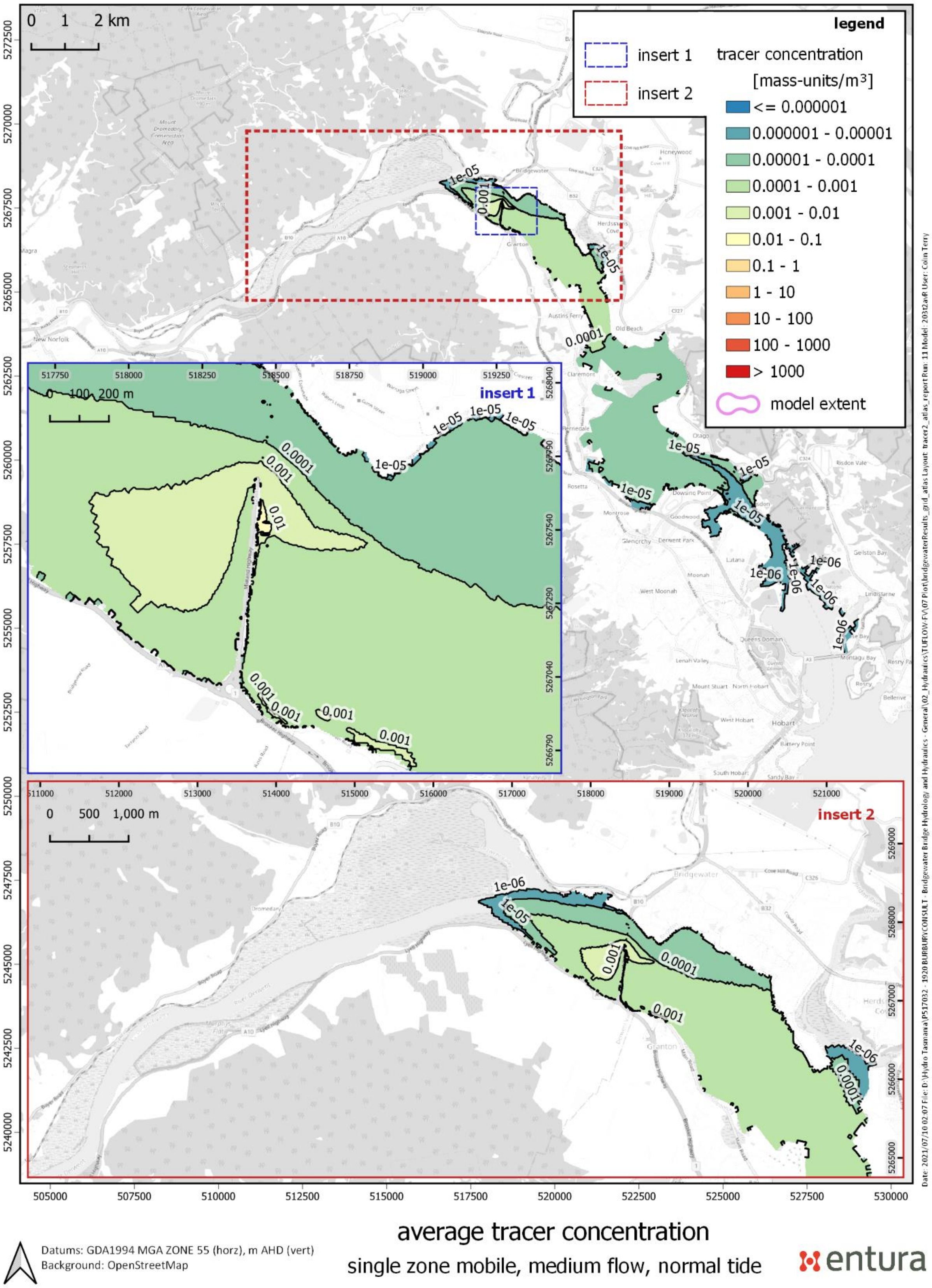

Figure B.21: Average tracer concentration, mobile source, medium flow, normal tide (Run 11)

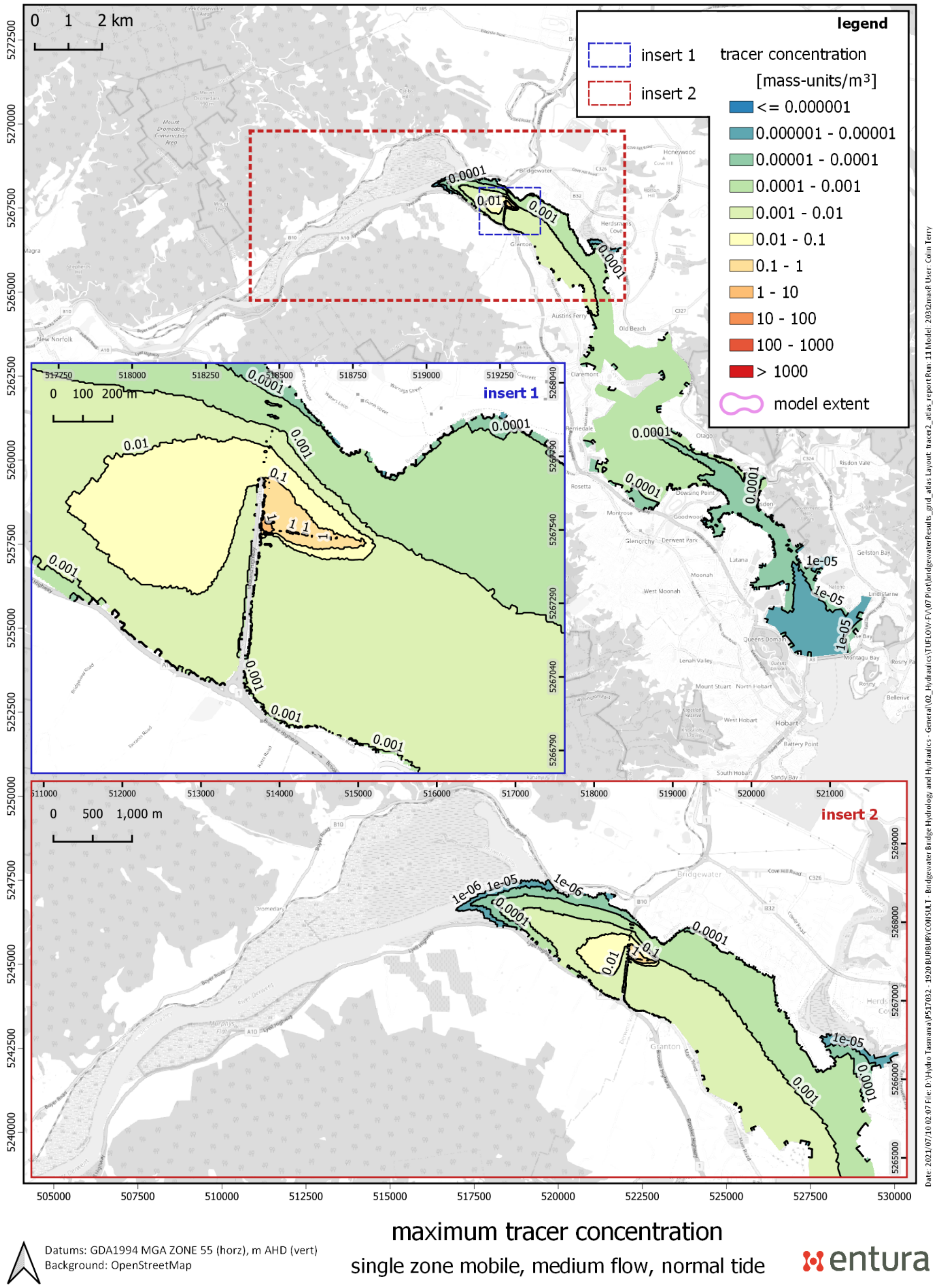

Figure B.22: Maximum tracer concentration, mobile source, medium flow, normal tide (Run 11)

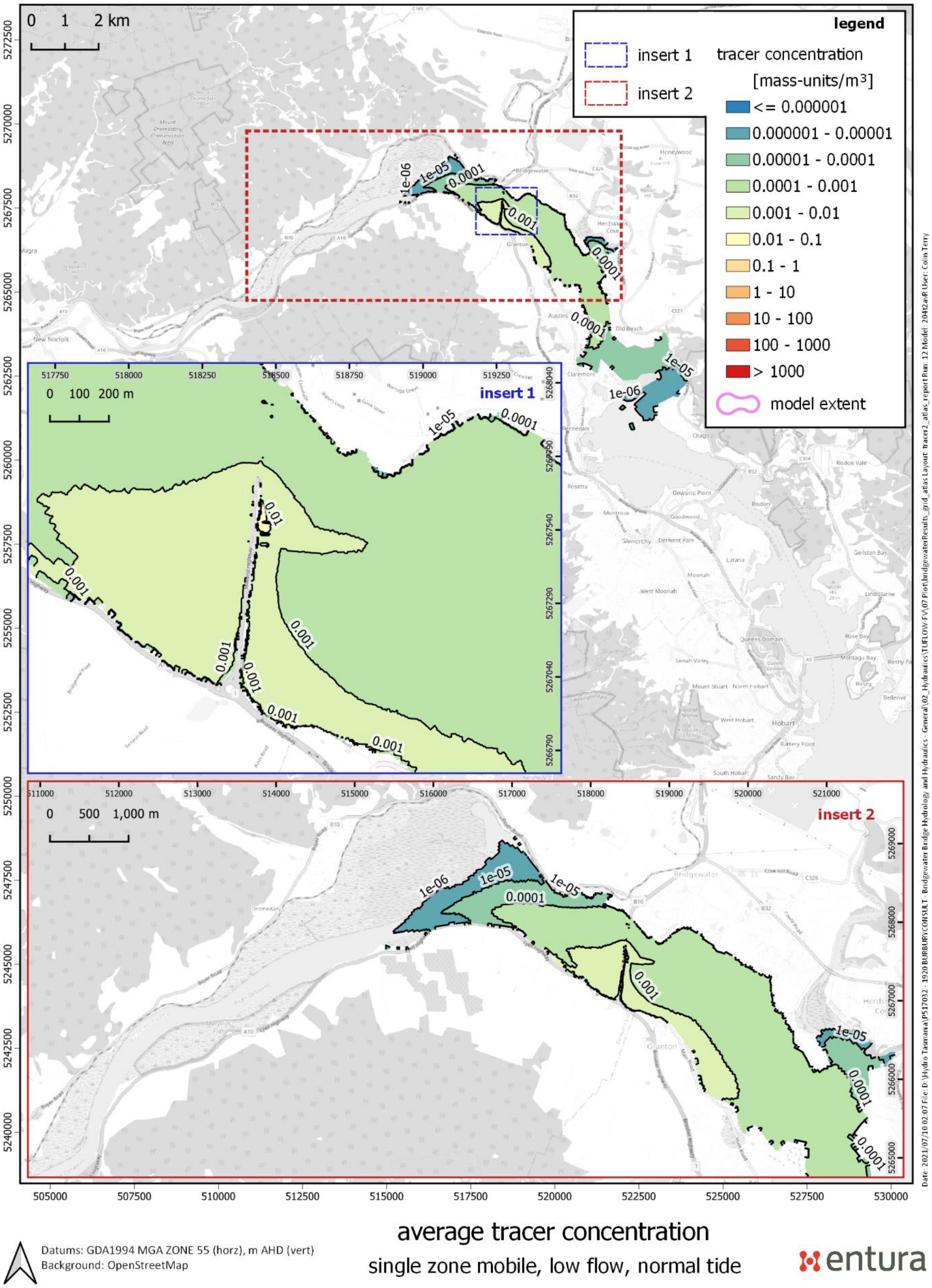

Figure B.23: Average tracer concentration, mobile source, low flow, normal tide (Run 11)

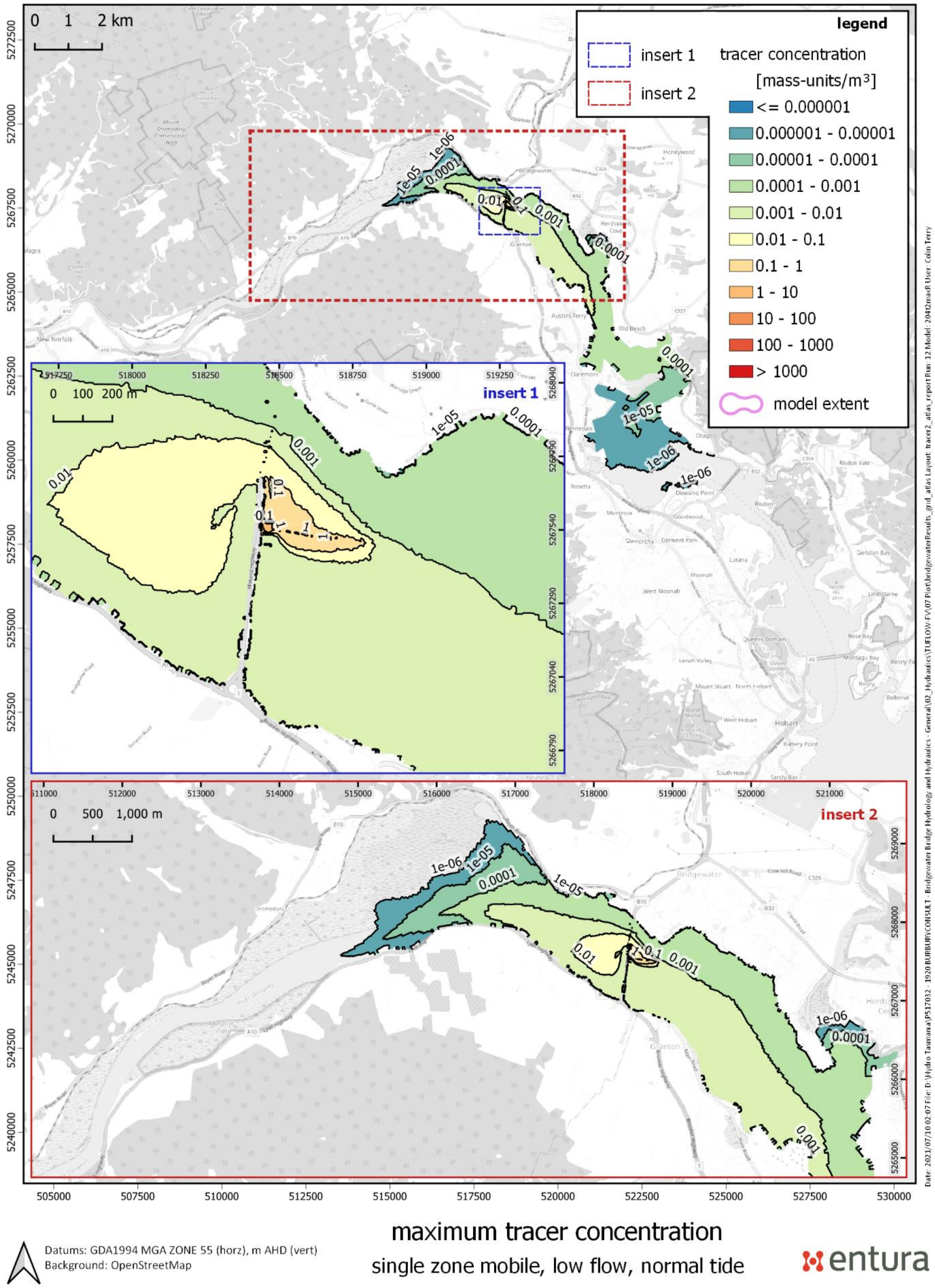

Figure B.24: Maximum tracer concentration, mobile source, low flow, normal tide (Run 12)

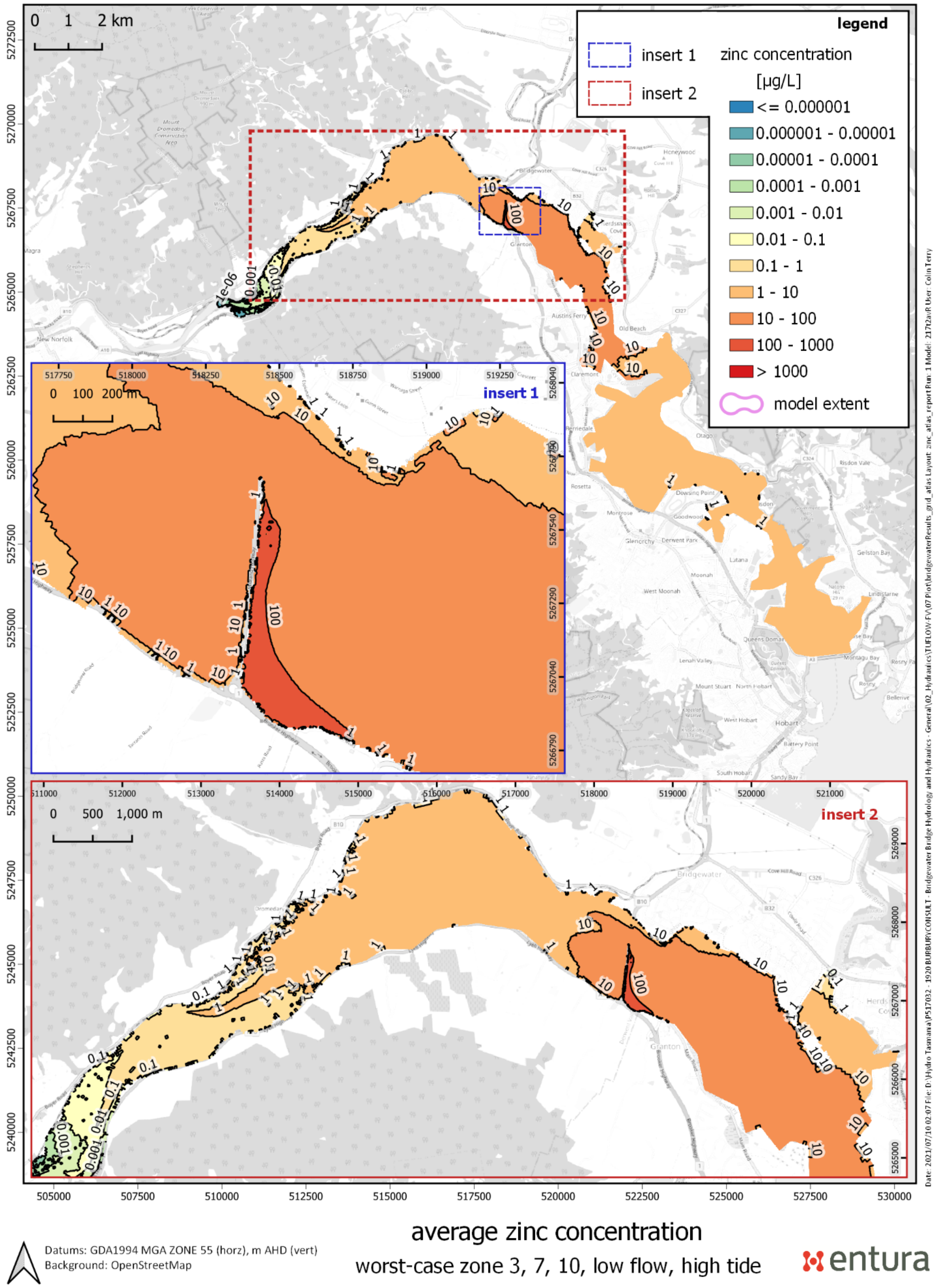

Figure B.25: Average zinc concentration, worst disturbance construction, low flow, high tide (Run 1)

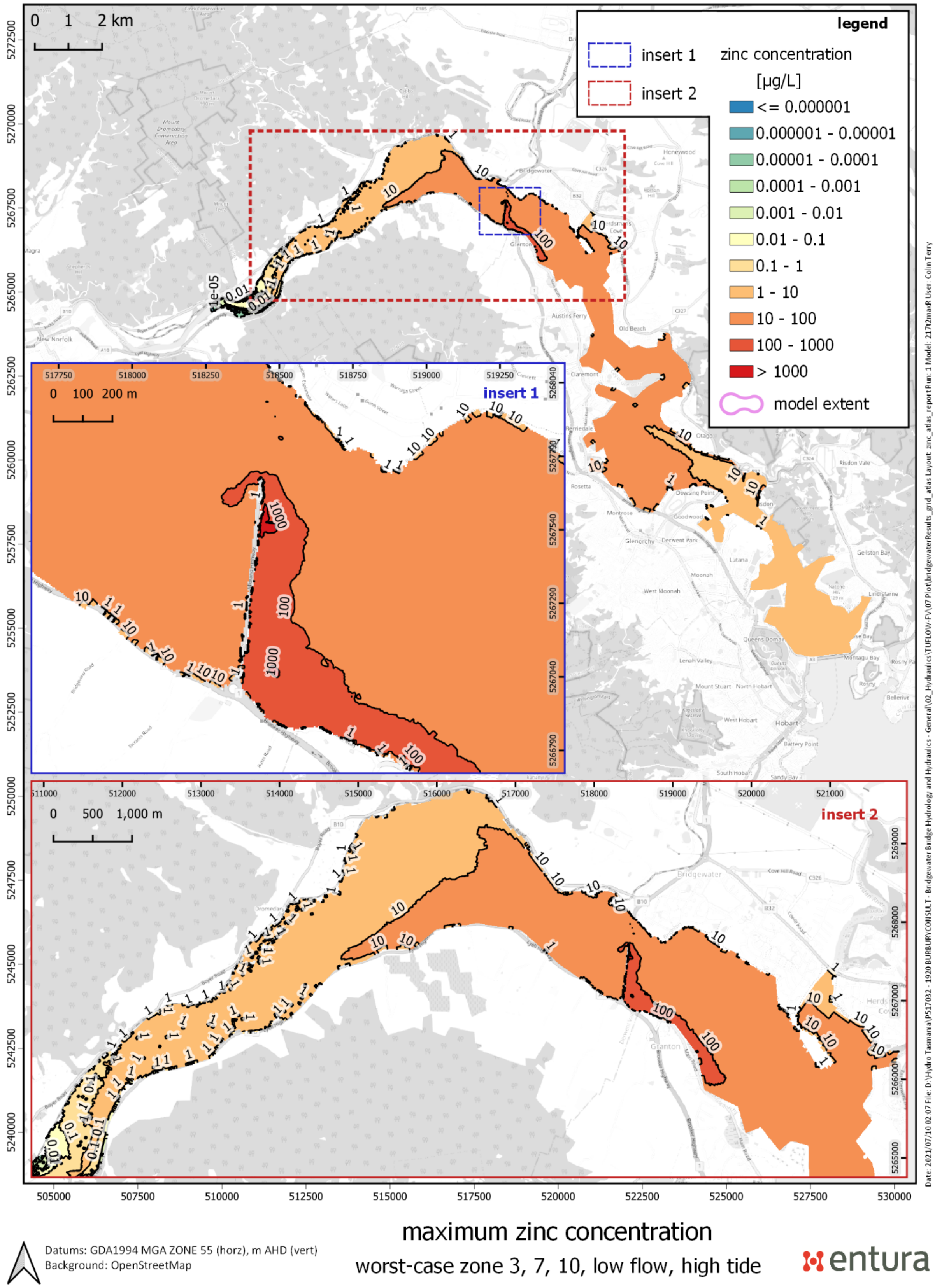

Figure B.26: Maximum zinc concentration, worst disturbance construction, low flow, high tide (Run 1)

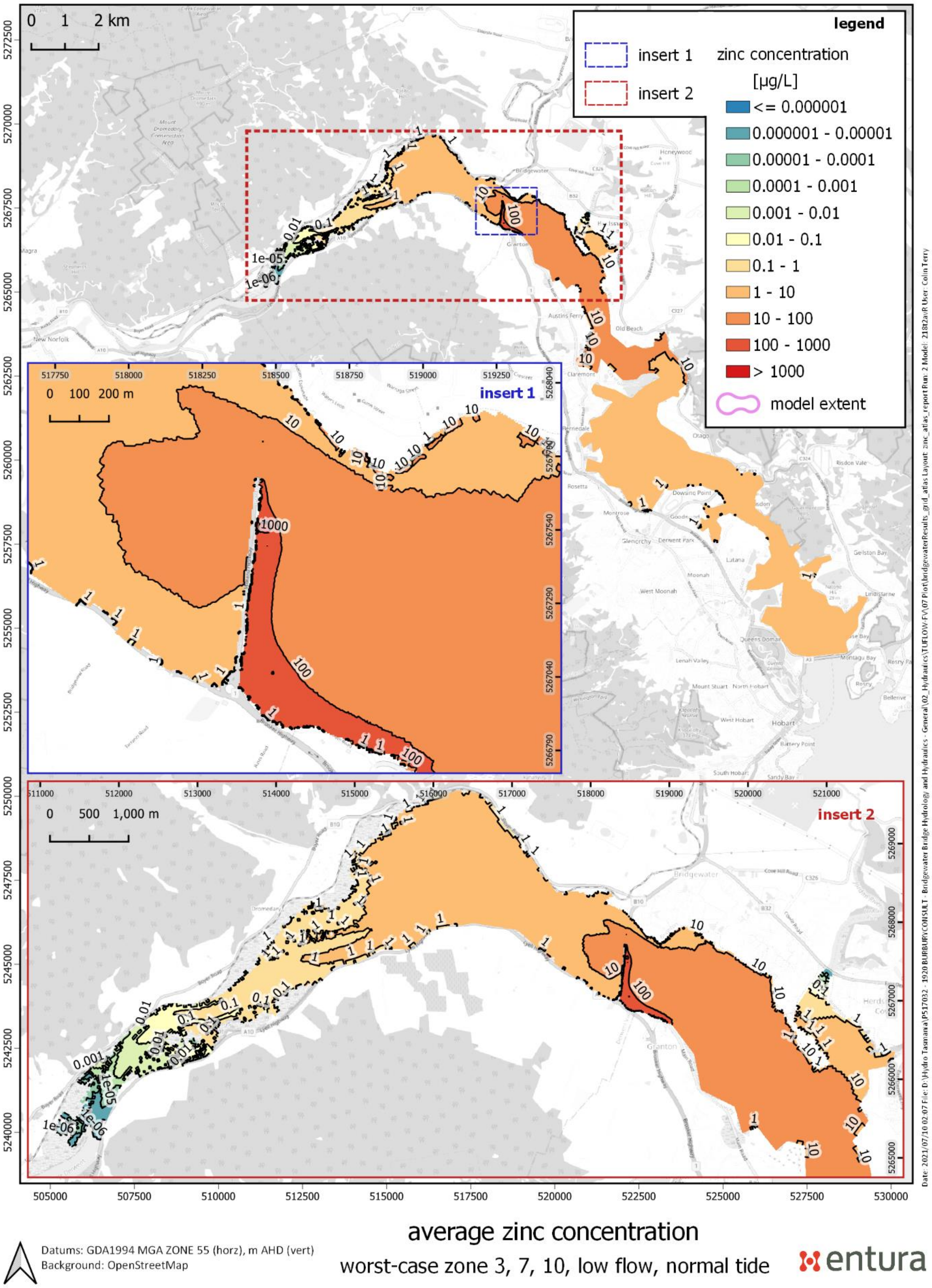

Figure B.27: Average zinc concentration, worst disturbance construction, low flow, normal tide (Run 2)

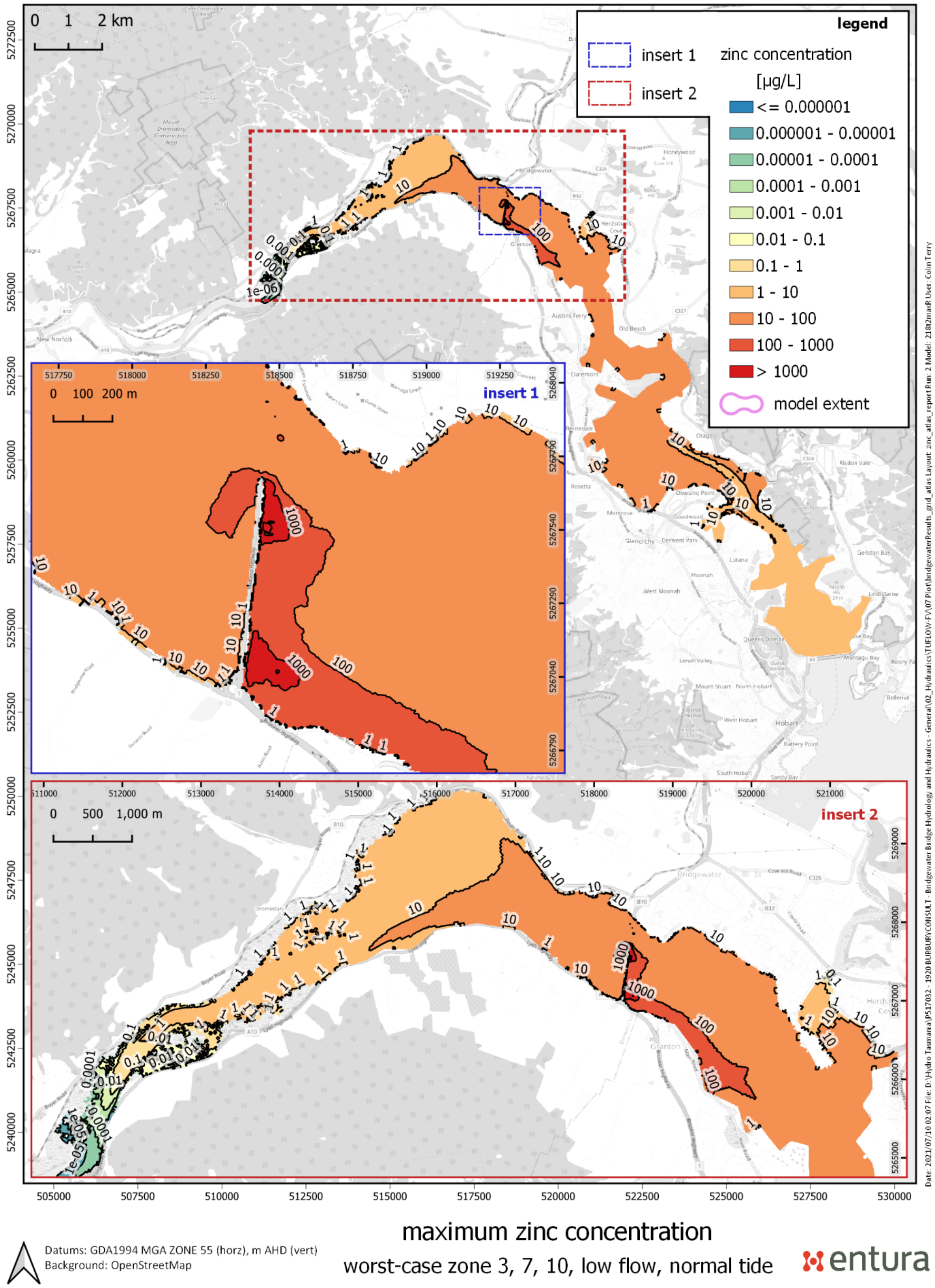

Figure B.28: Maximum zinc concentration, worst disturbance construction, low flow, normal tide (Run 2)

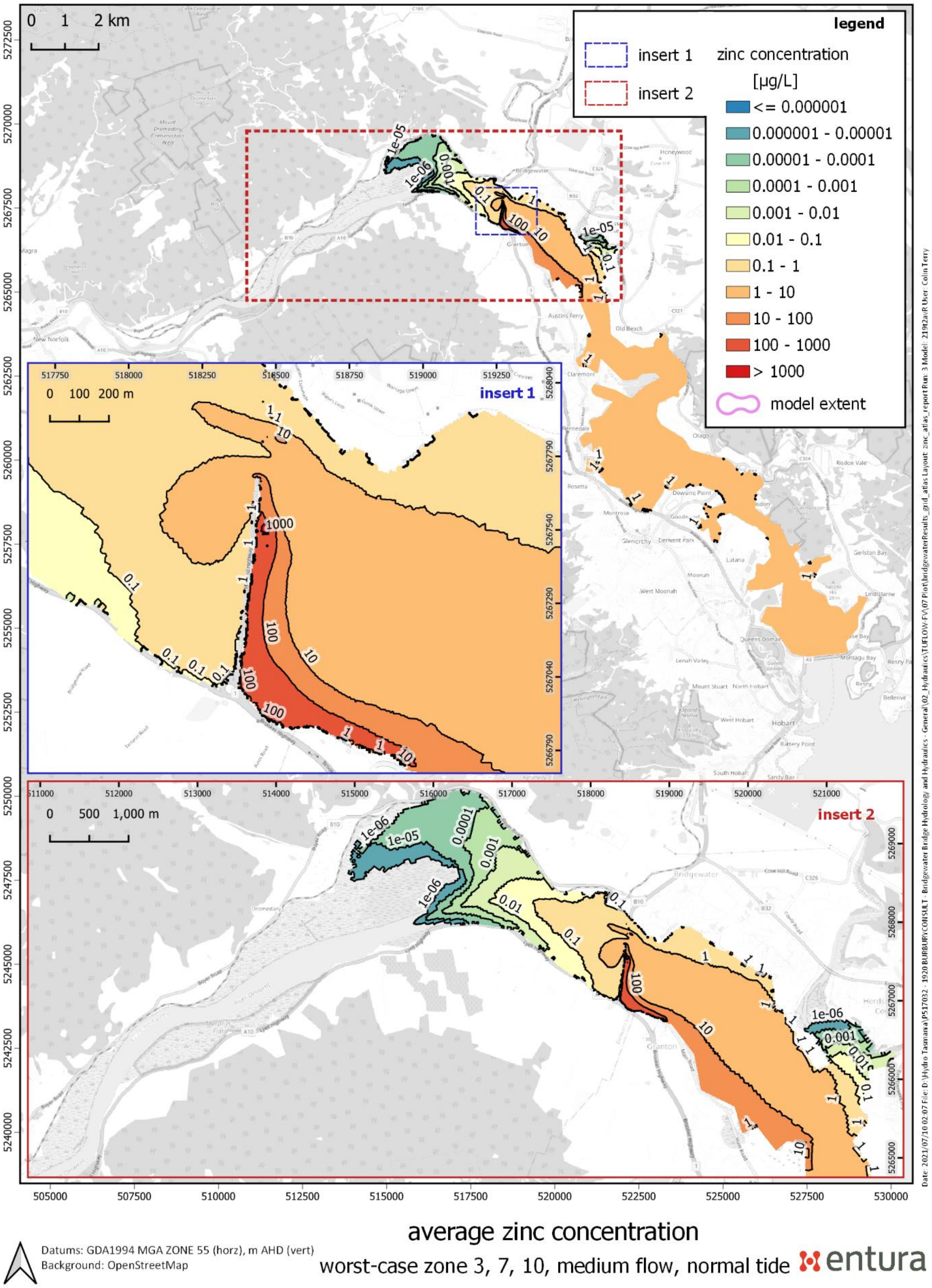

Figure B.29: Average zinc concentration, worst disturbance construction, medium flow, normal tide (Run 3)

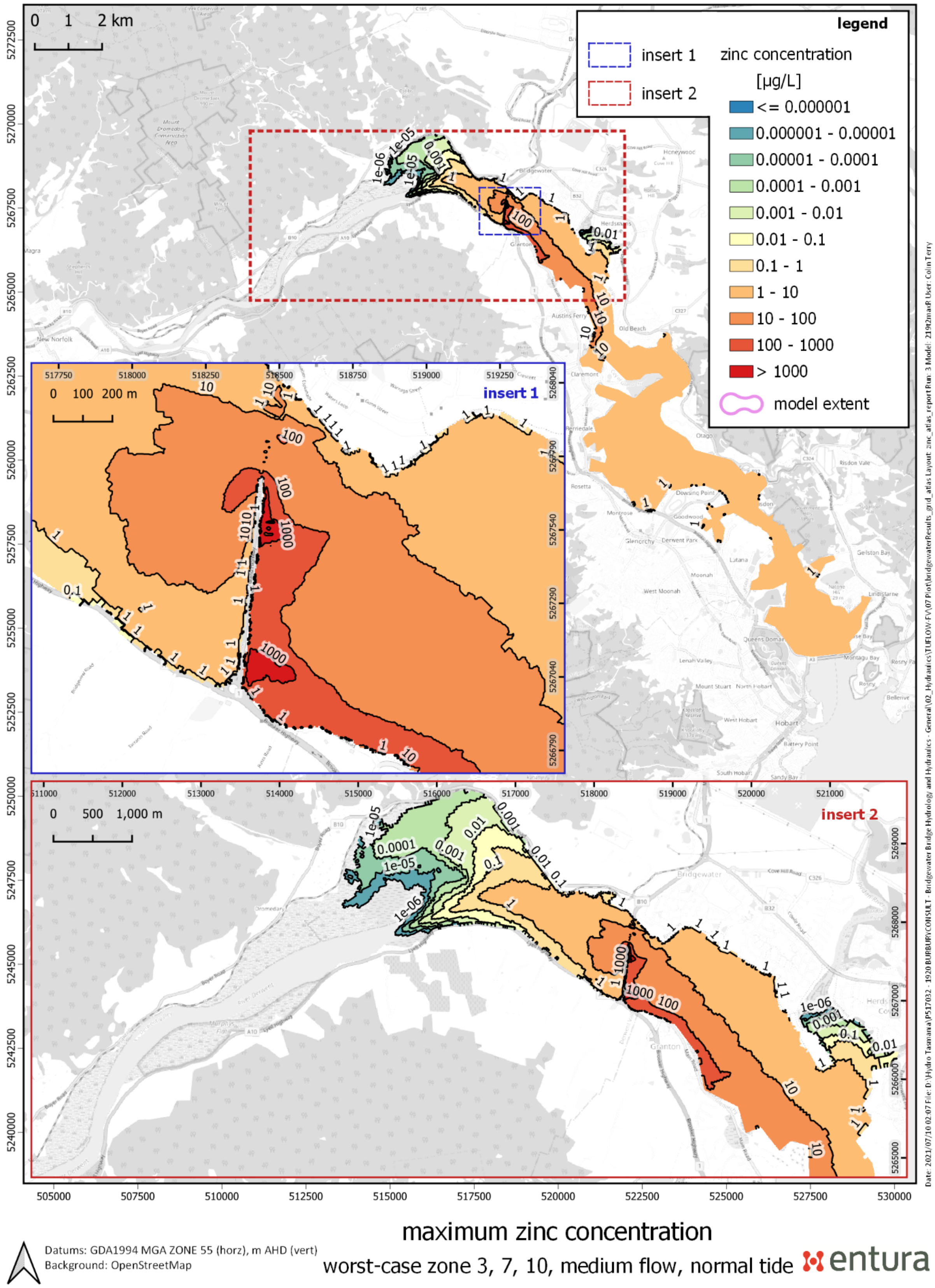

Figure B.30: Maximum zinc concentration, worst disturbance construction, medium flow, normal tide (Run 3)

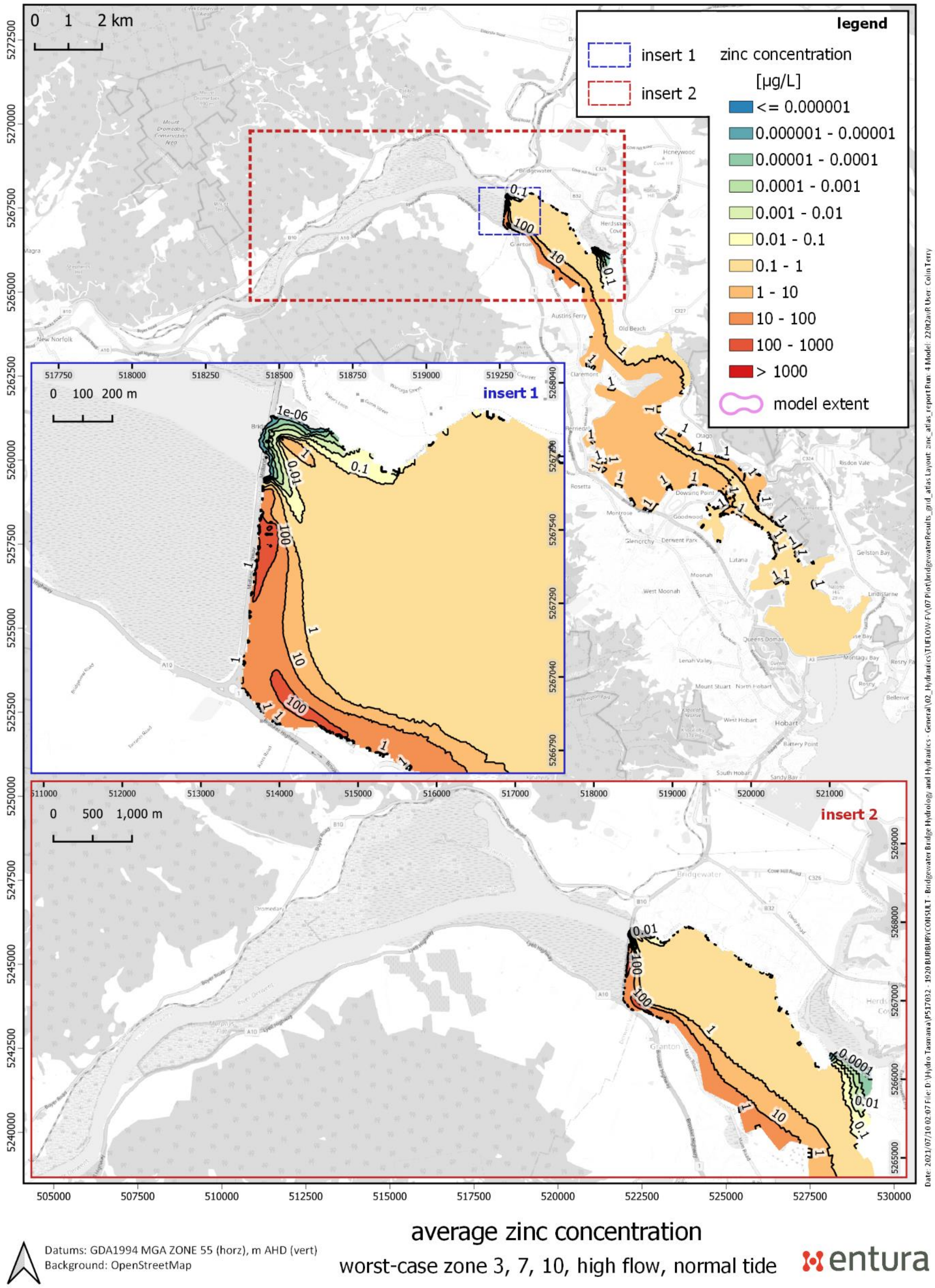

Figure B.31: Average zinc concentration, worst disturbance construction, high flow, normal tide (Run 4)

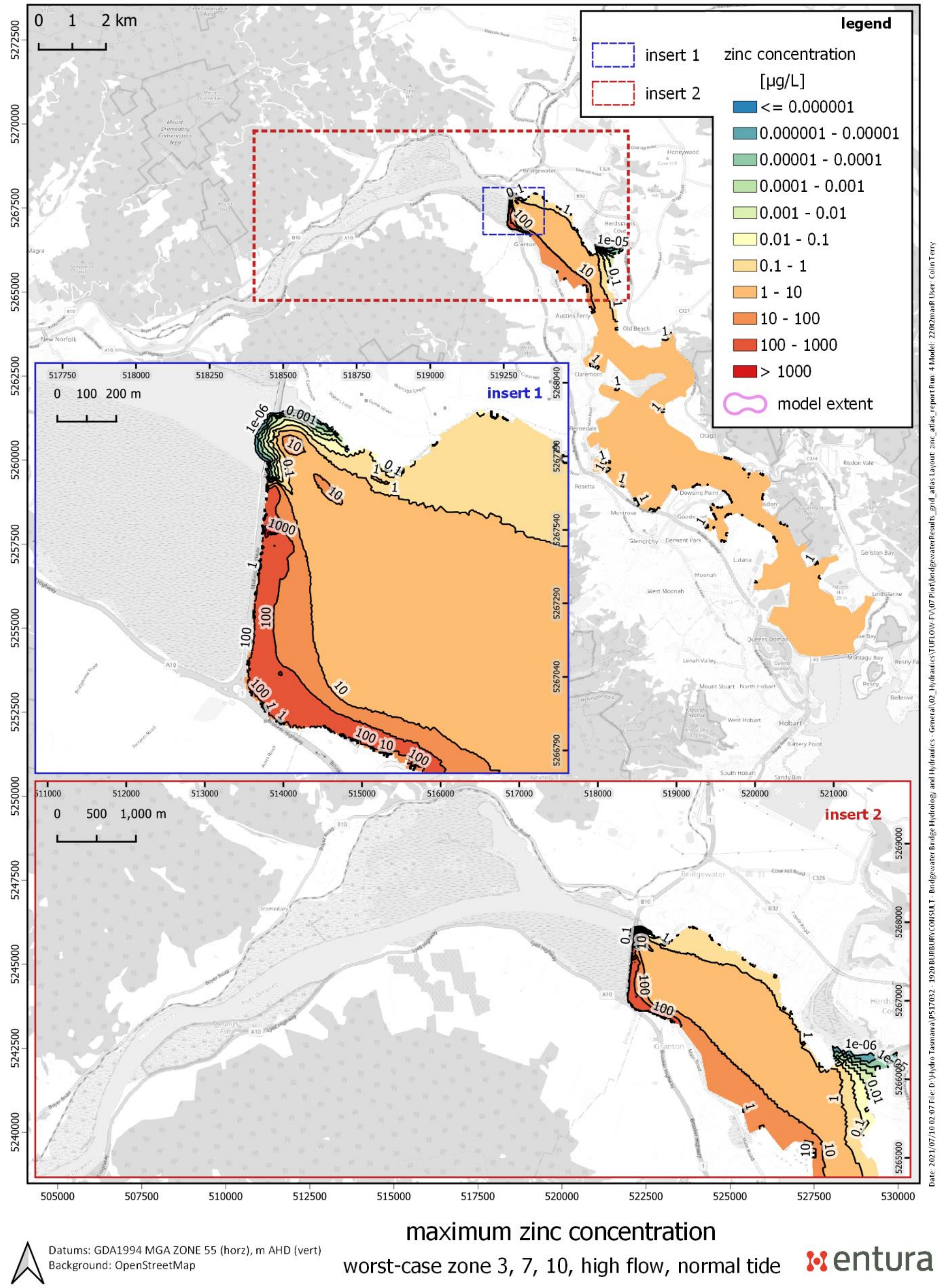

Figure B.32: Maximum zinc concentration, worst disturbance construction, high flow, normal tide (Run 4)

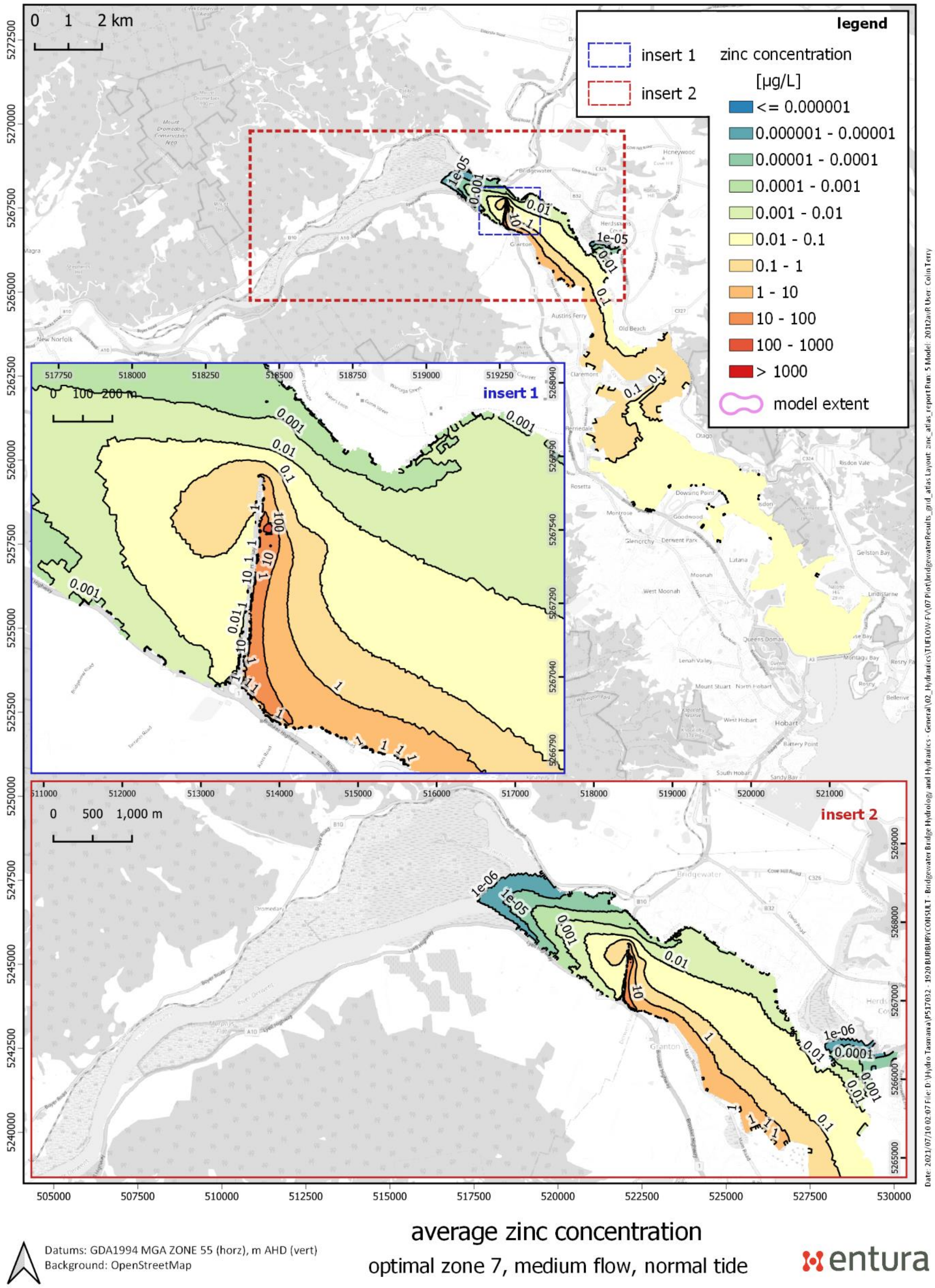

Figure B.33: Average zinc concentration, optimal disturbance zone 7 construction, medium flow, normal tide (Run 5)

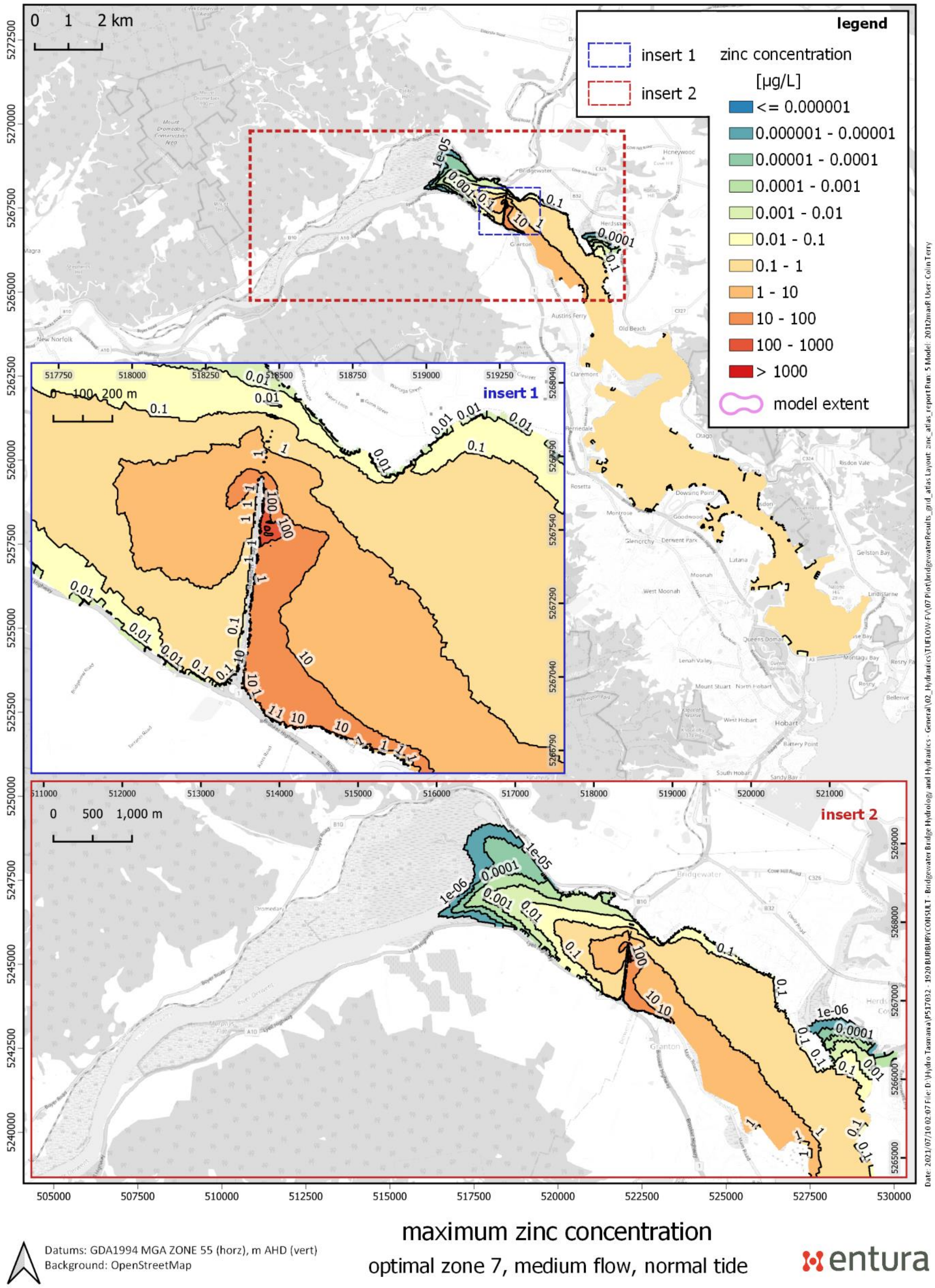

Figure B.34: Maximum zinc concentration, optimal disturbance zone 7 construction, medium flow, normal tide (Run 5)

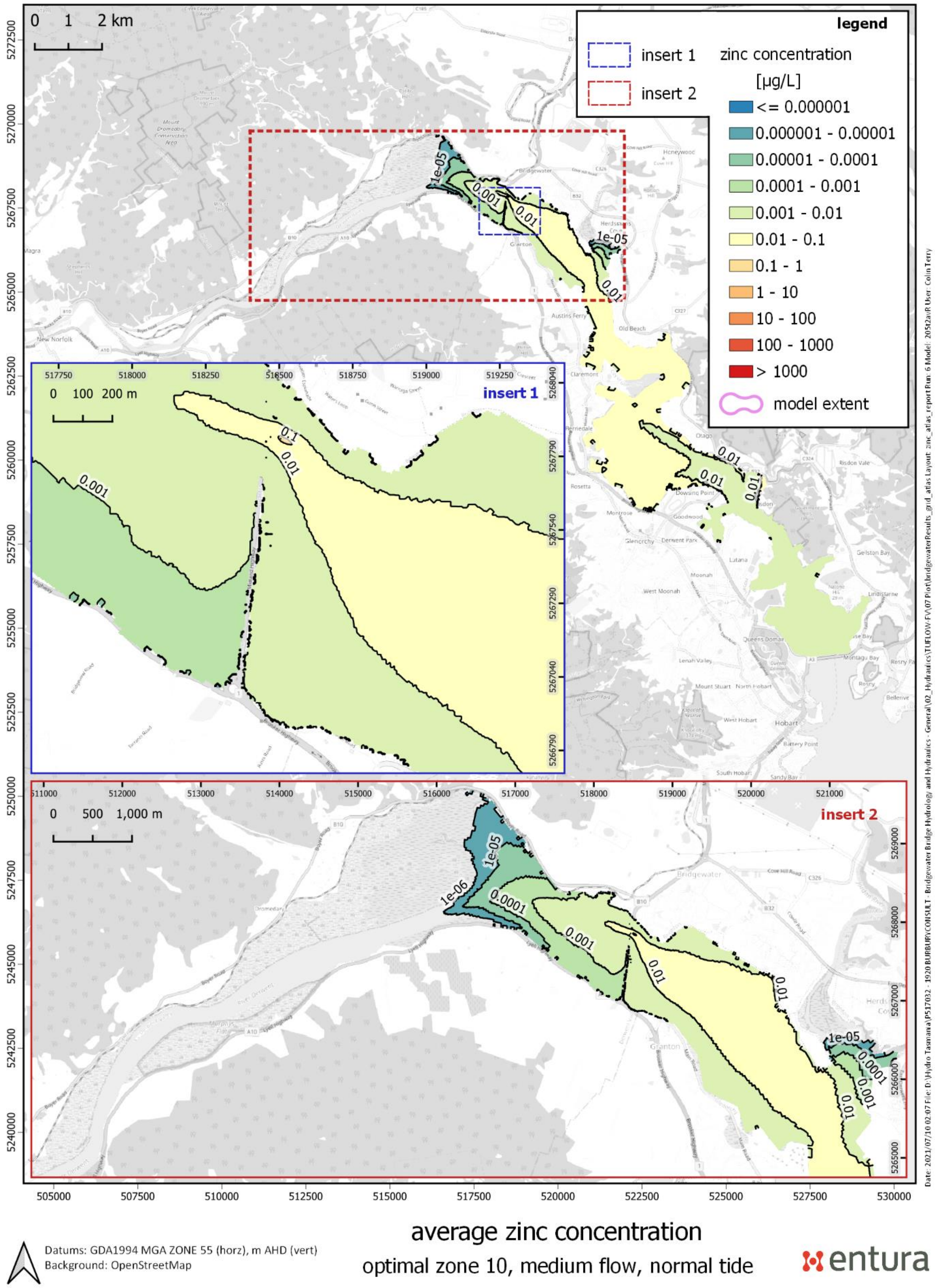

Figure B.35: Average zinc concentration, optimal disturbance zone 10 construction, medium flow, normal tide (Run 6)

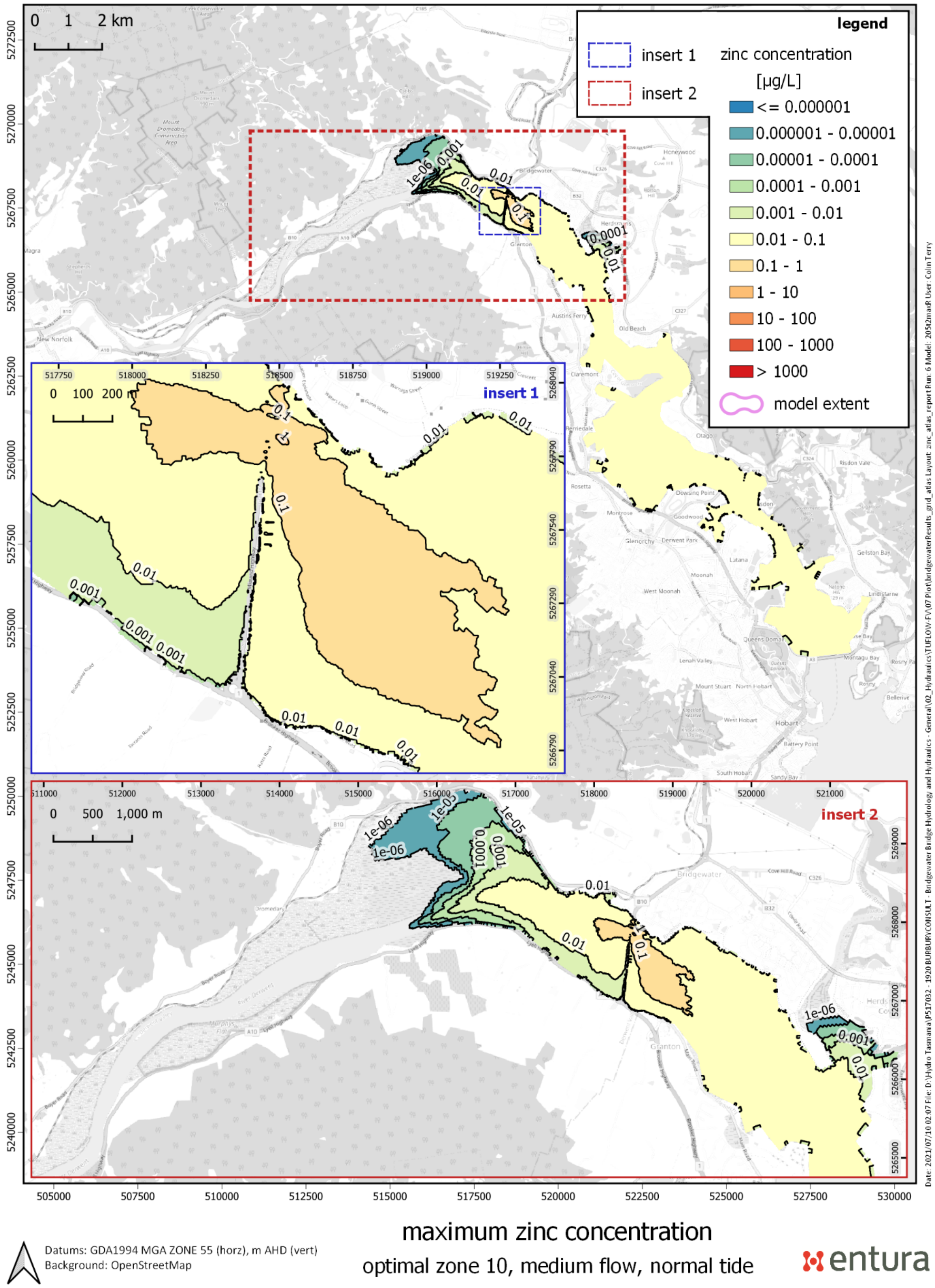

Figure B.36: Maximum zinc concentration, optimal disturbance zone 10 construction, medium flow, normal tide (Run 6)

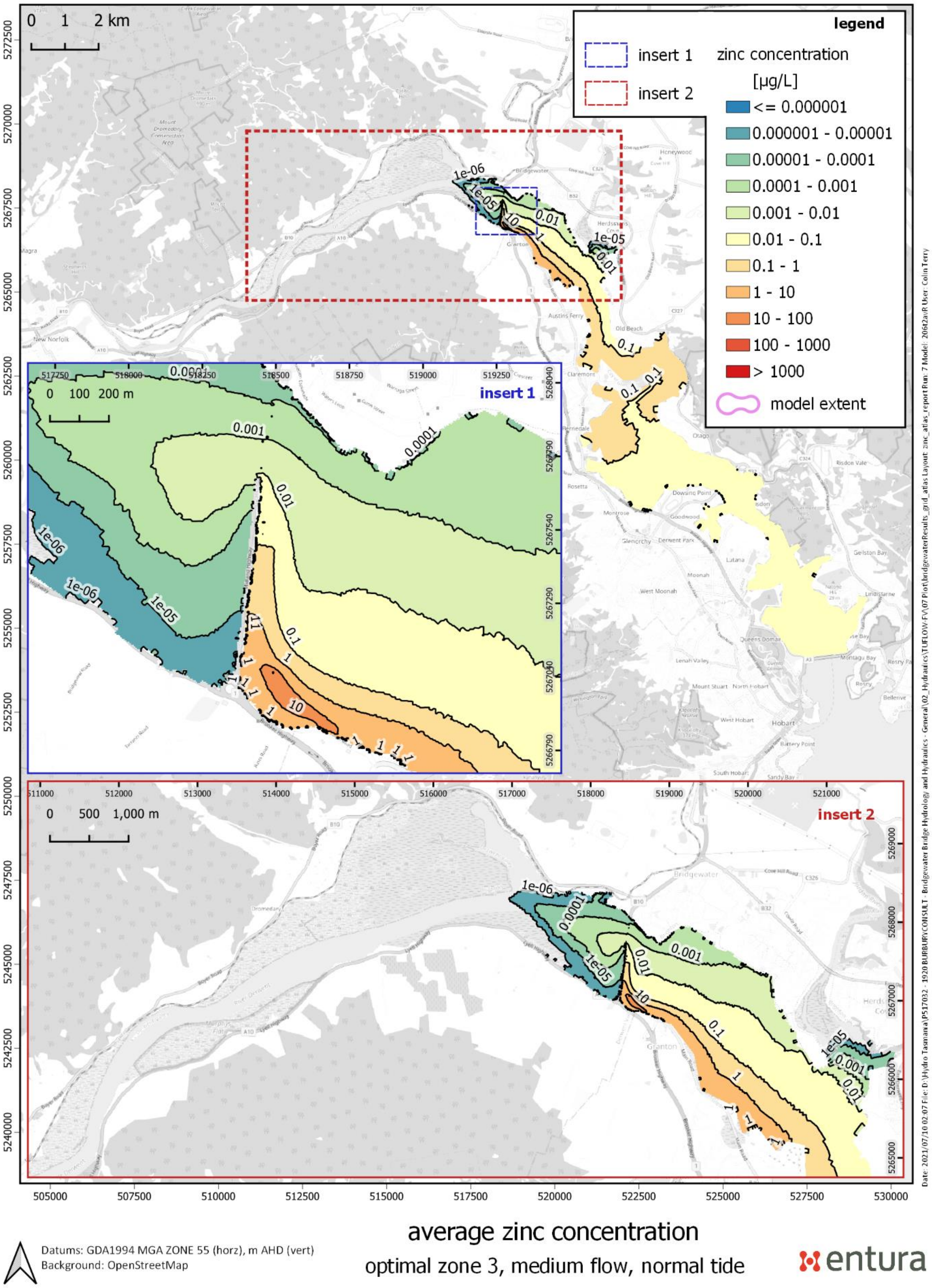

Figure B.37: Average zinc concentration, optimal disturbance zone 3 construction, medium flow, normal tide (Run 7)

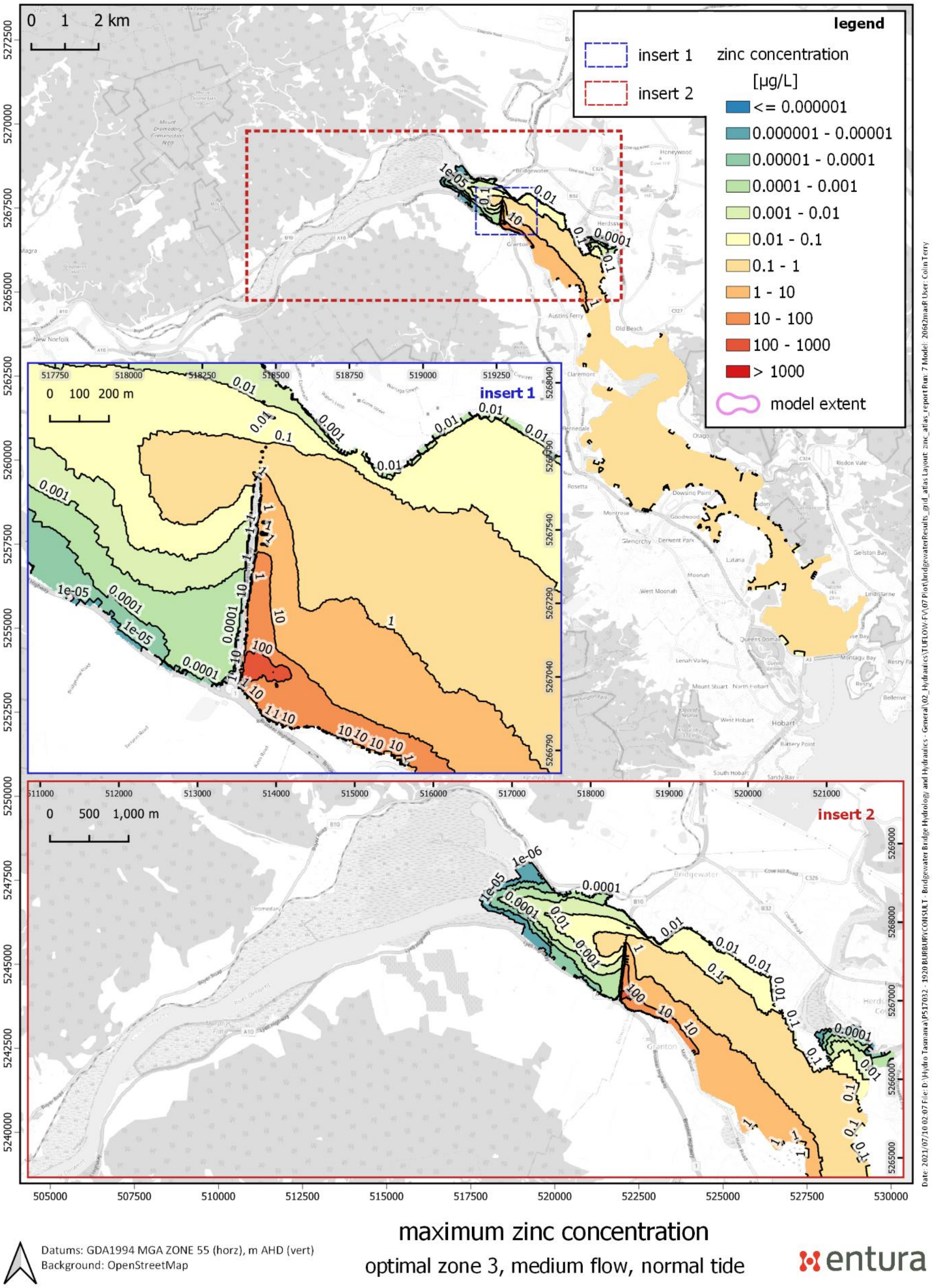

Figure B.38: Maximum zinc concentration, optimal disturbance zone 3 construction, medium flow, normal tide (Run 7)

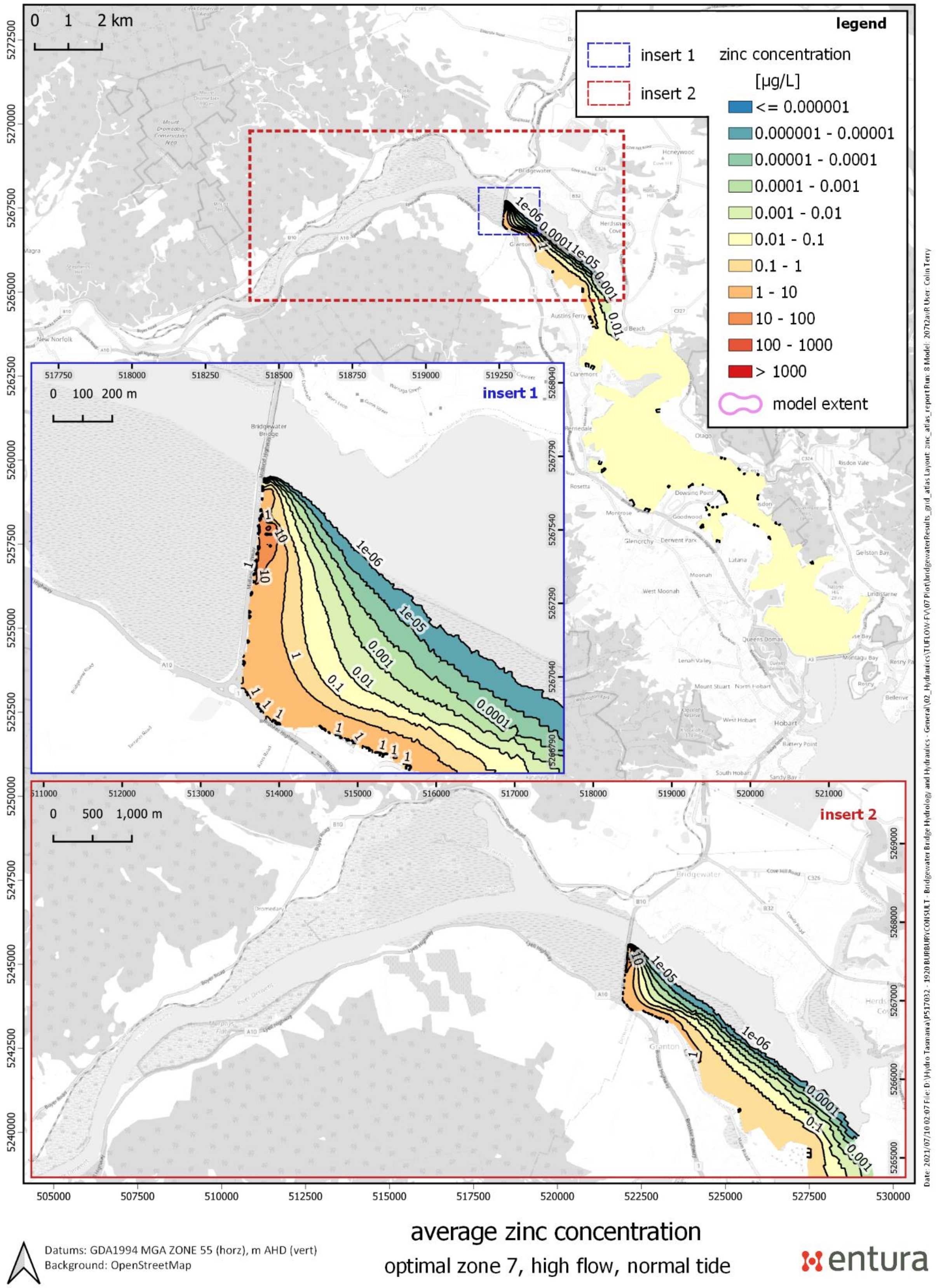

Figure B.39: Average zinc concentration, optimal disturbance zone 7 construction, high flow, normal tide (Run 8)

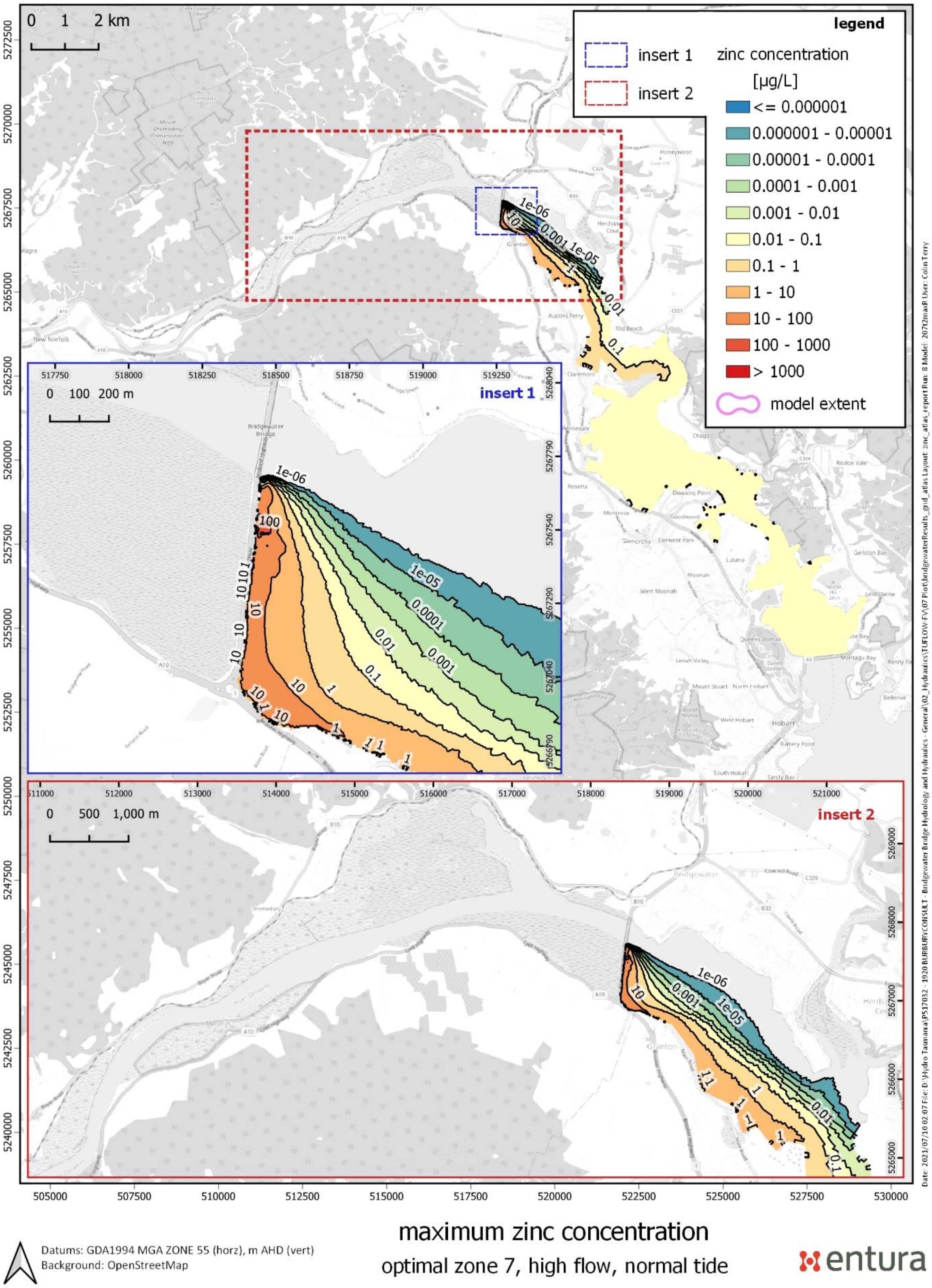

Figure B.40: Maximum zinc concentration, optimal disturbance zone 7 construction, high flow, normal tide (Run 8)

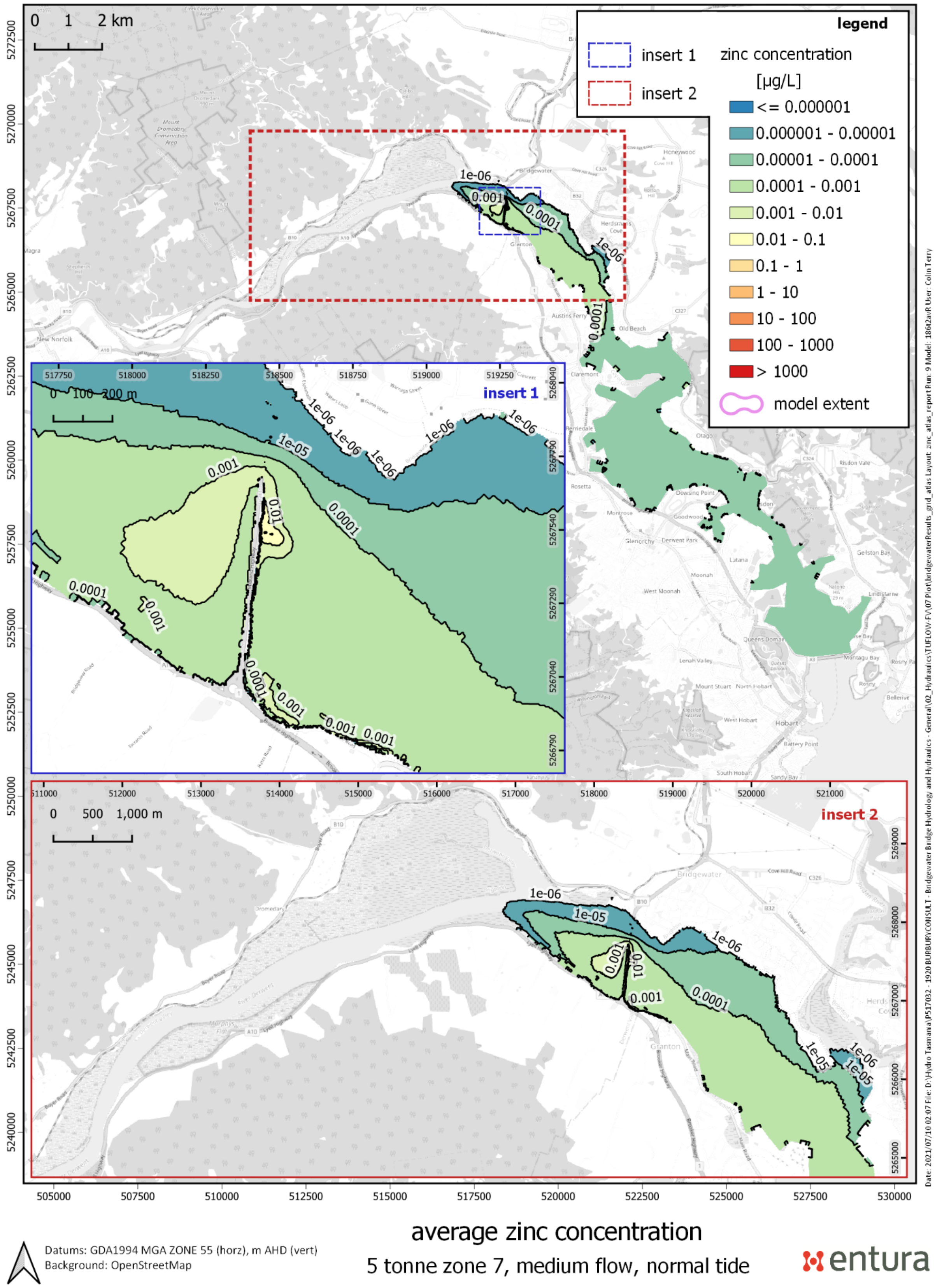

Figure B.41: Average zinc concentration, 5 tonne accident, medium flow, normal tide (Run 9)

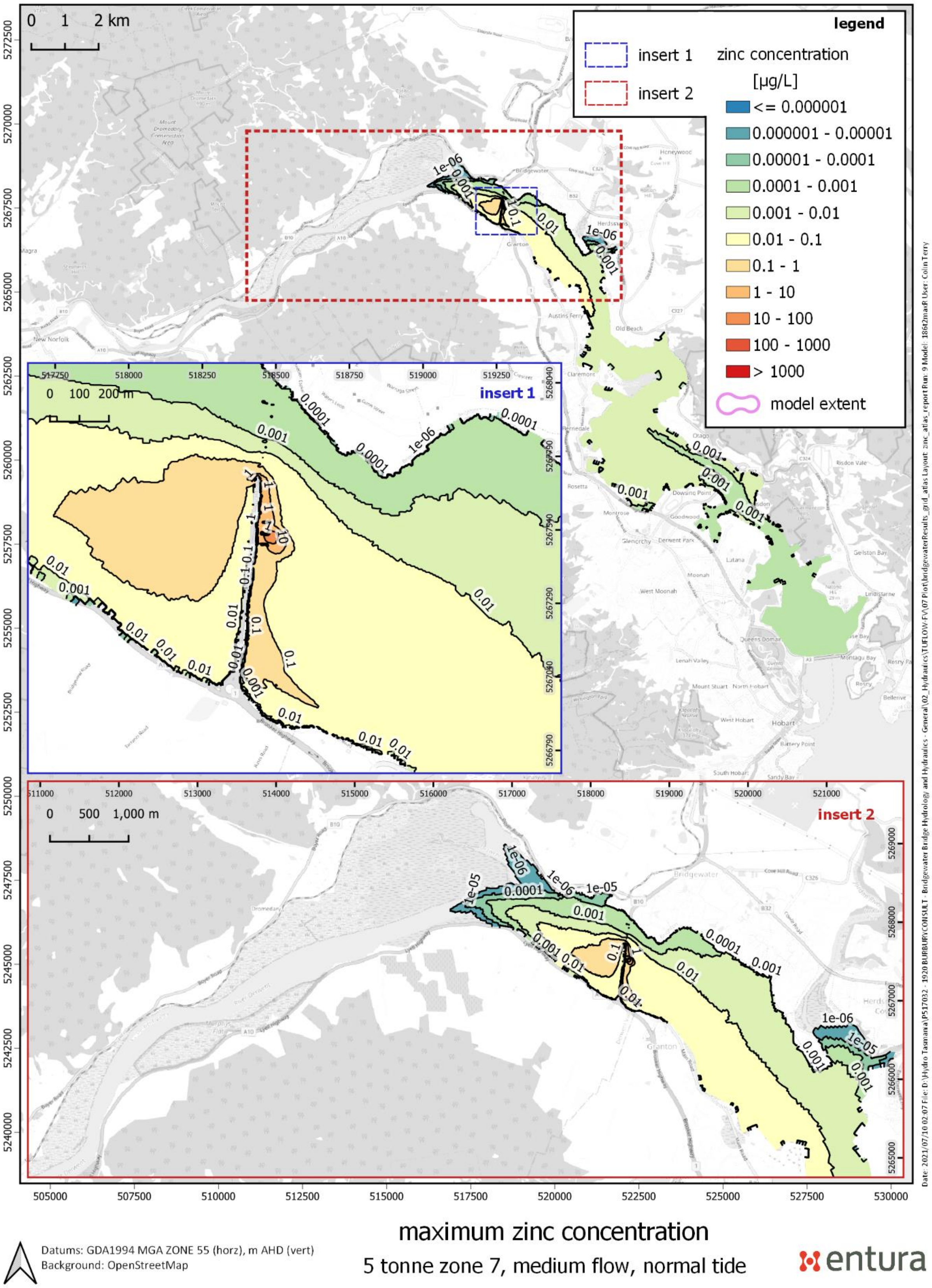

Figure B.42: Maximum zinc concentration, 5 tonne accident, medium flow, normal tide (Run 9)

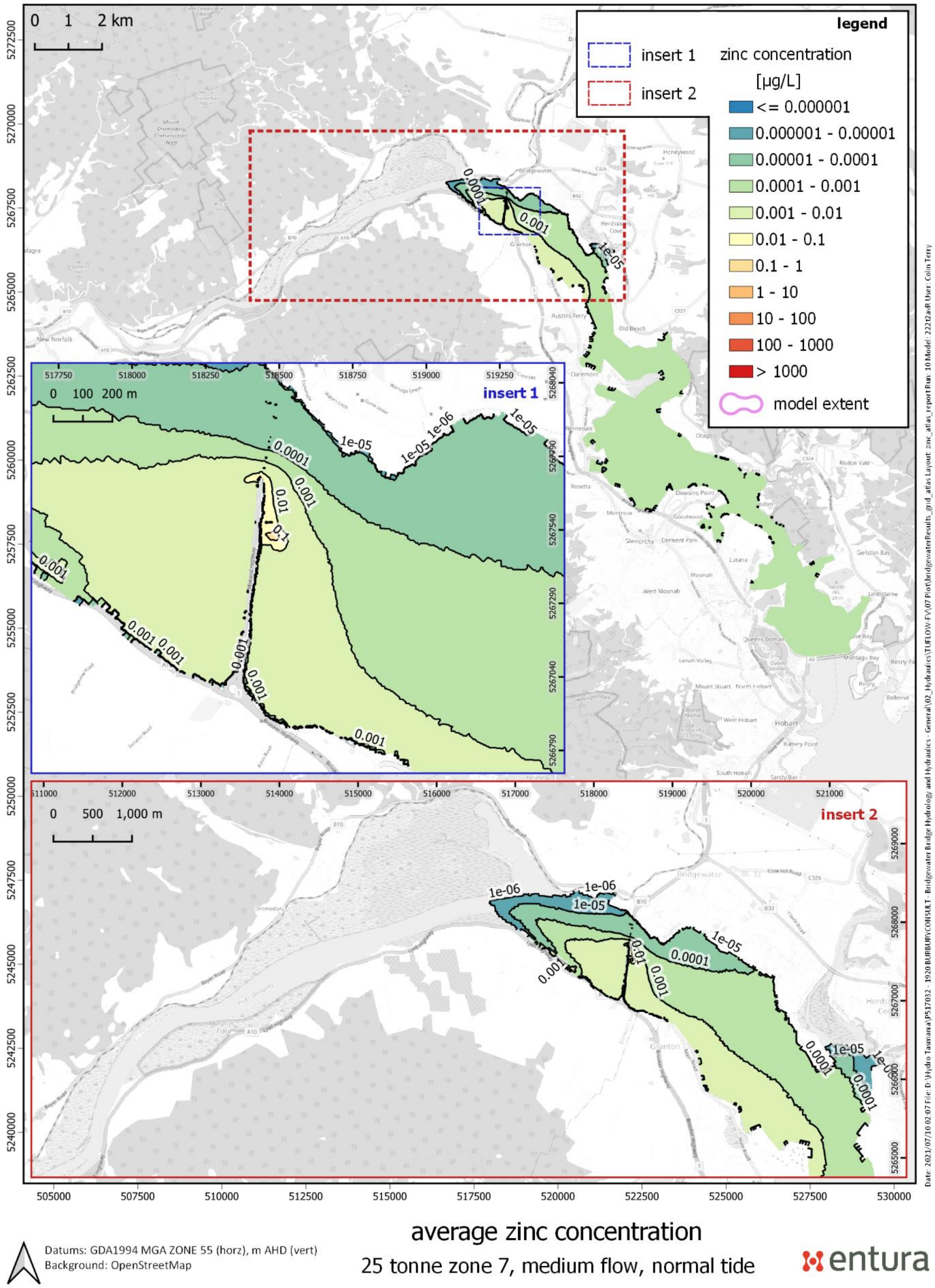

Figure B.43: Average zinc concentration, 25 tonne accident, medium flow, normal tide (Run 10)

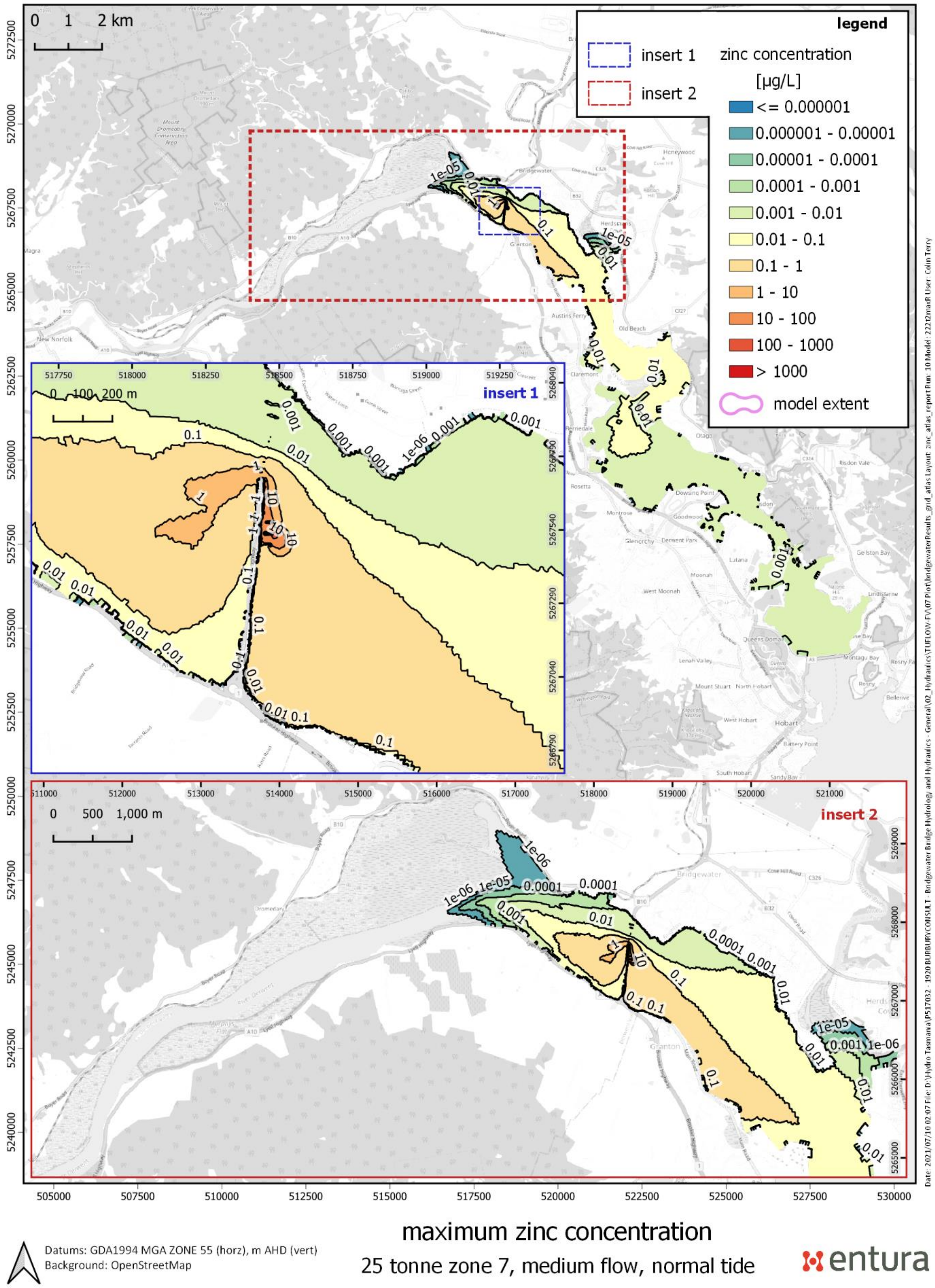

Figure B.44: Maximum zinc concentration, 25 tonne accident, medium flow, normal tide (Run 10)

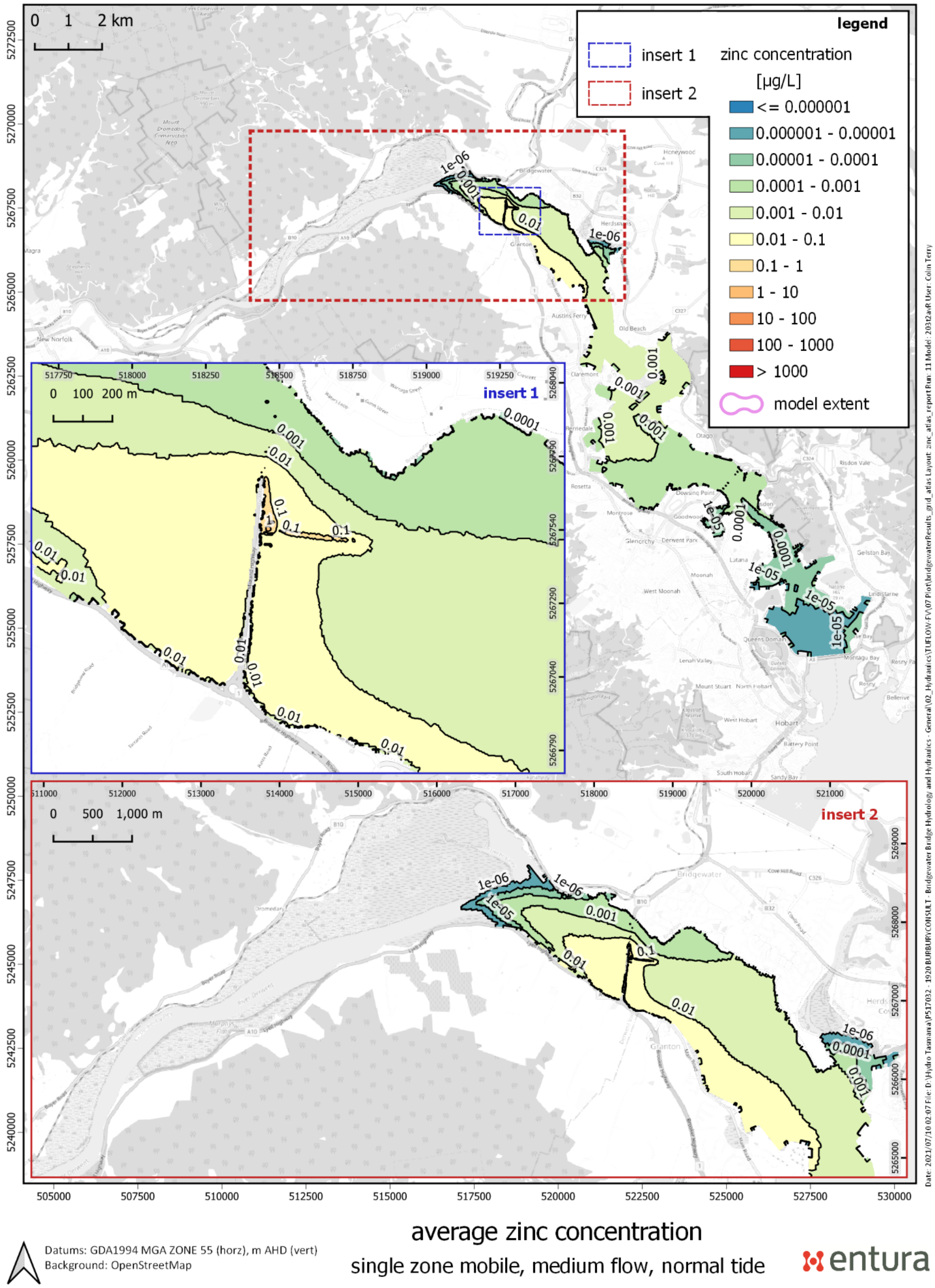

Figure B.45: Average zinc concentration, mobile source, medium flow, normal tide (Run 11)

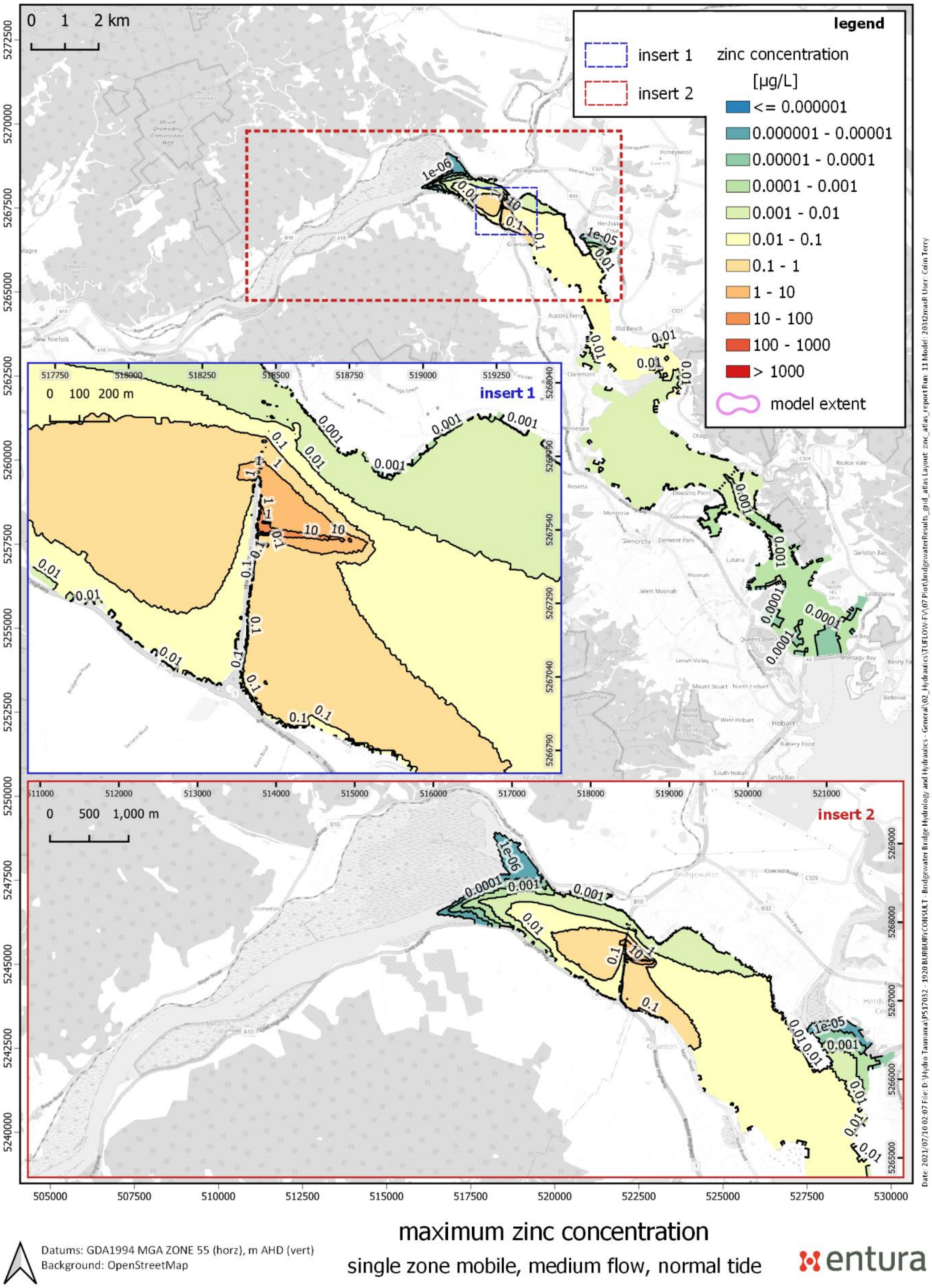

Figure B.46: Maximum zinc concentration, mobile source, medium flow, normal tide (Run 11)

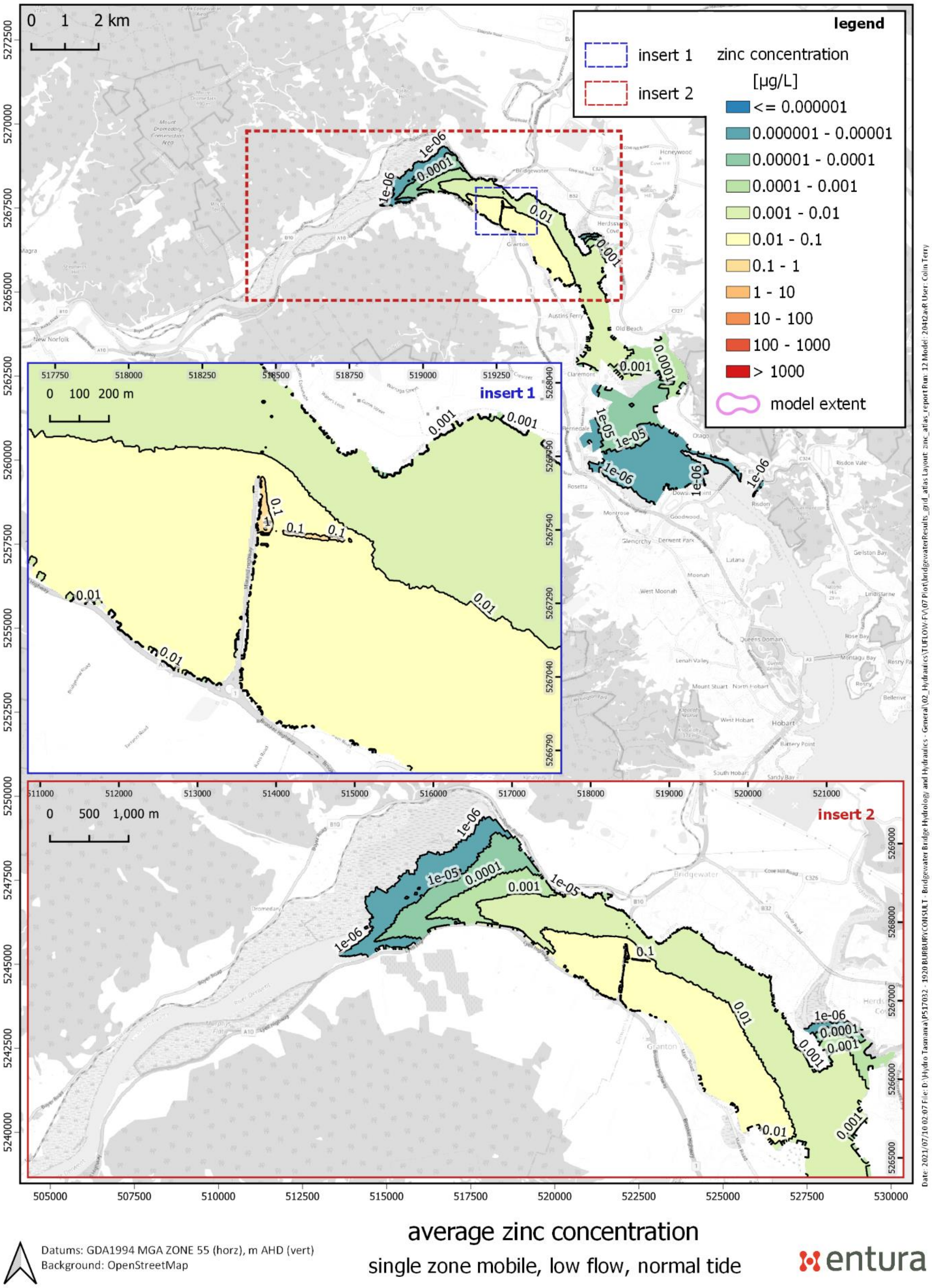

Figure B.47: Average zinc concentration, mobile source, low flow, normal tide (Run 12)

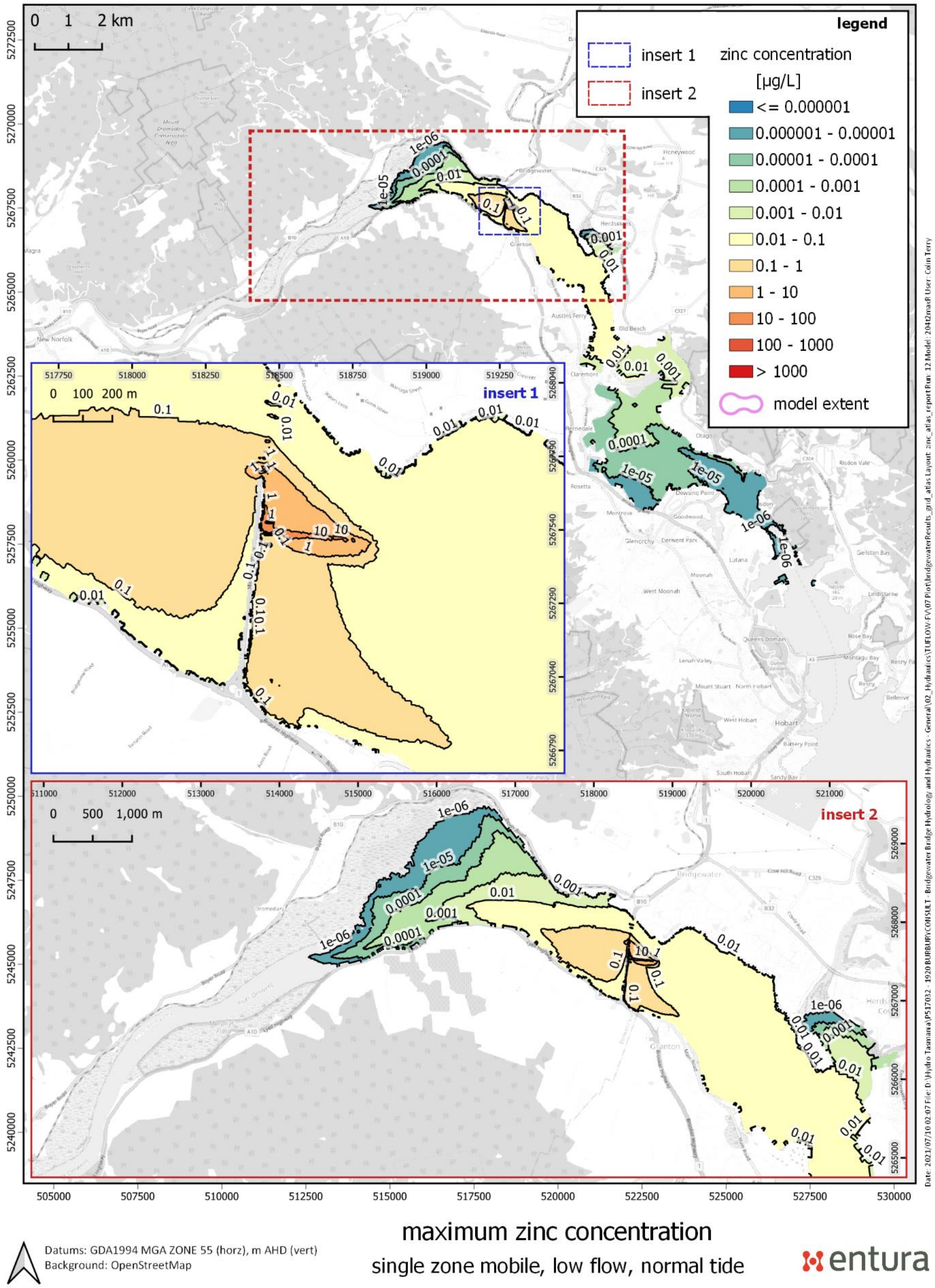

Figure B.48: Maximum zinc concentration, mobile source, low flow, normal tide
(Run 12)

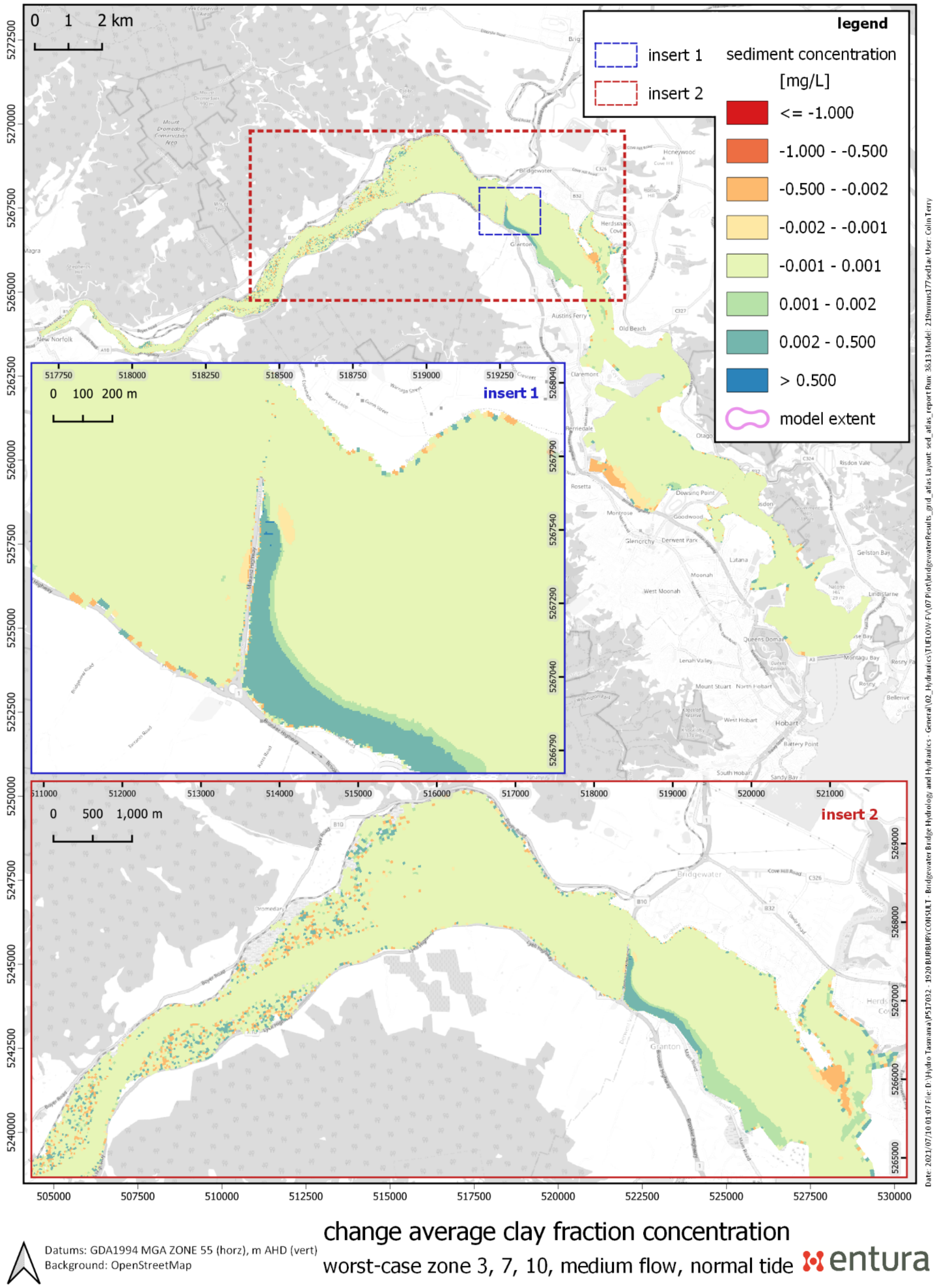

Figure B.49: Average clay concentration, worstdisturbanceconstruction, medium flow, normal tide (Run 3 minus 13)

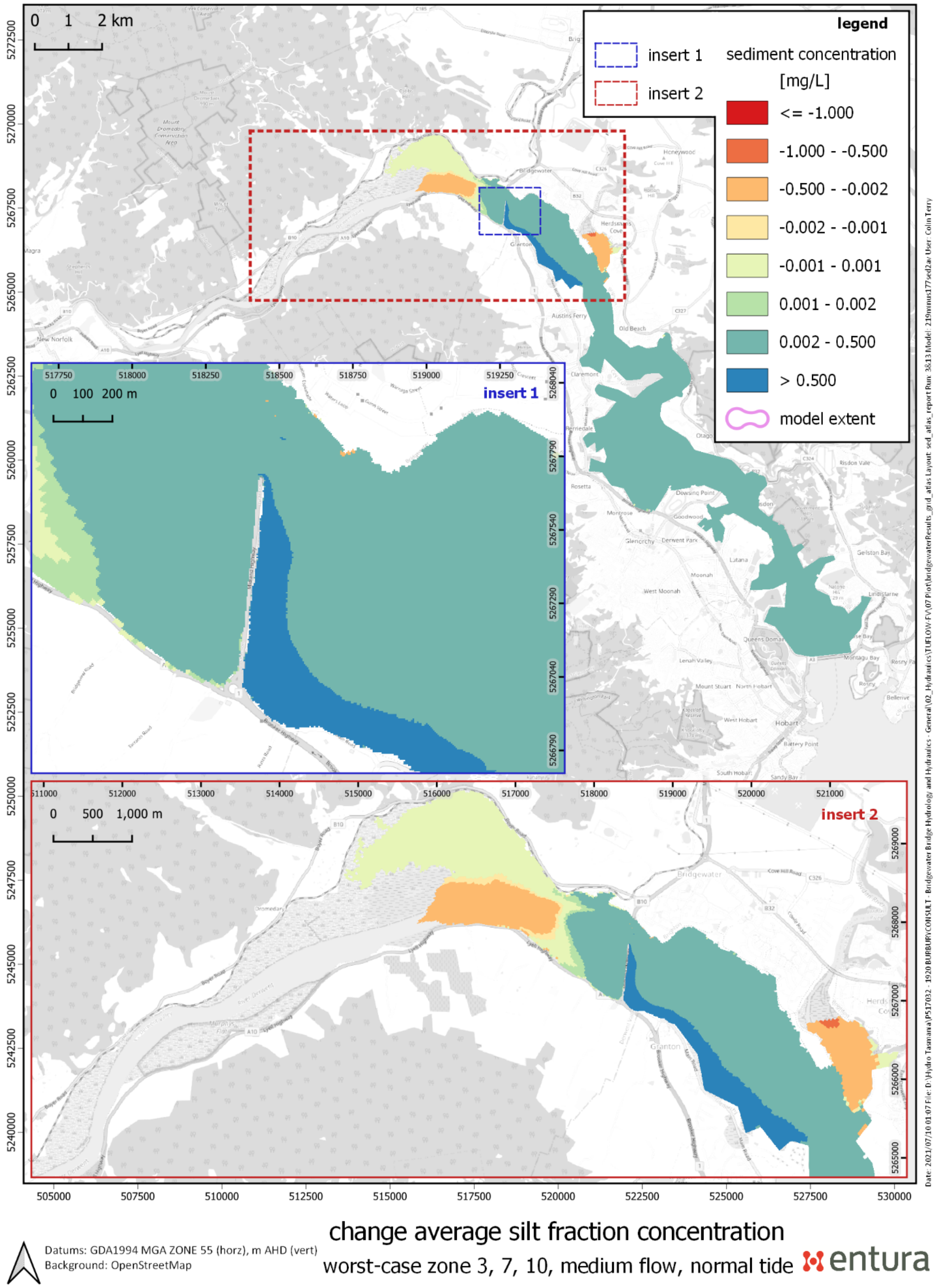

Figure B.50: Average silt concentration, worst disturbance construction, medium flow, normal tide (Run 3 minus Run 13)

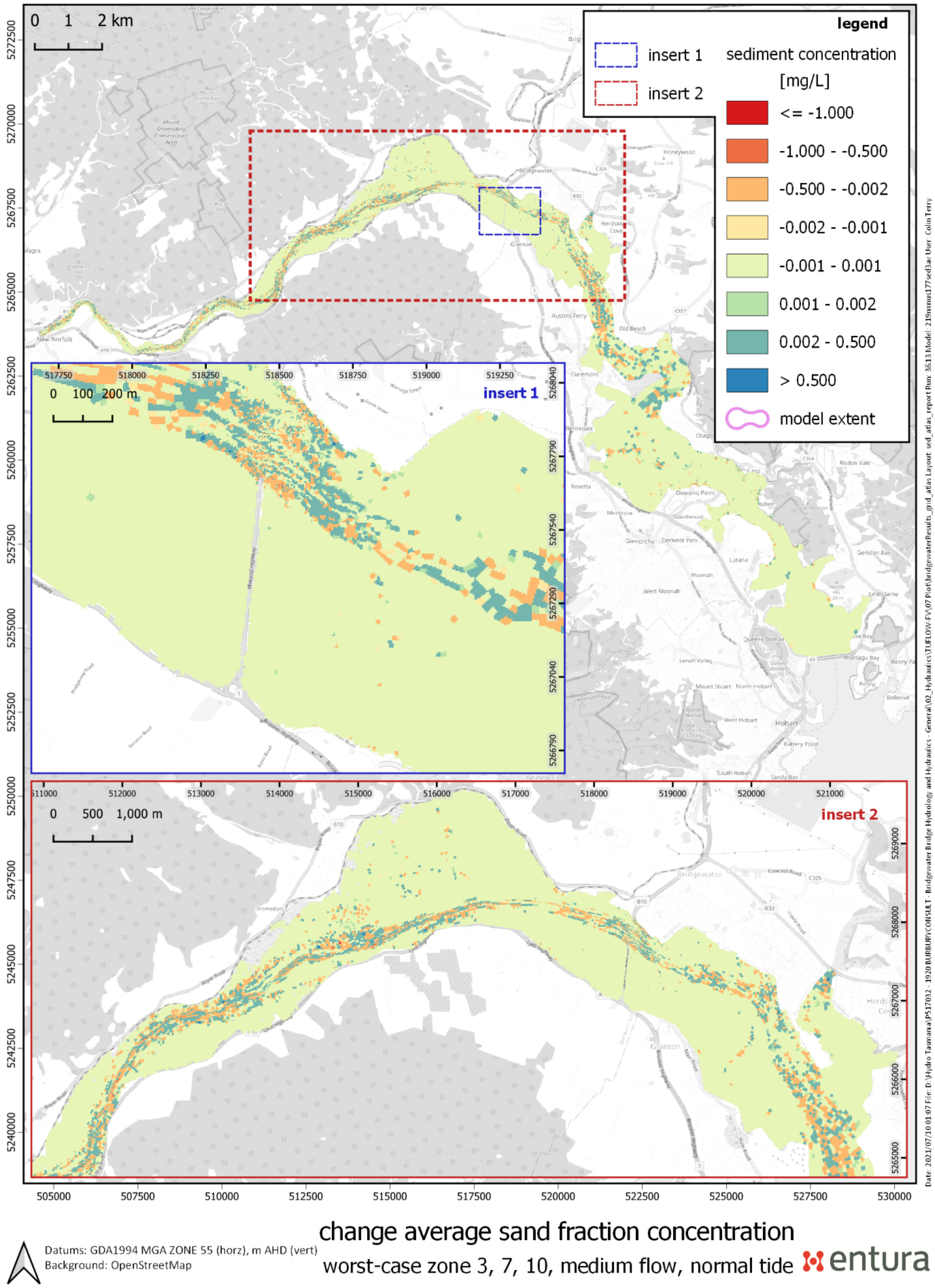

Figure B.51: Average sand concentration, worst disturbance construction, medium flow, normal tide (Run 3 minus Run 13)

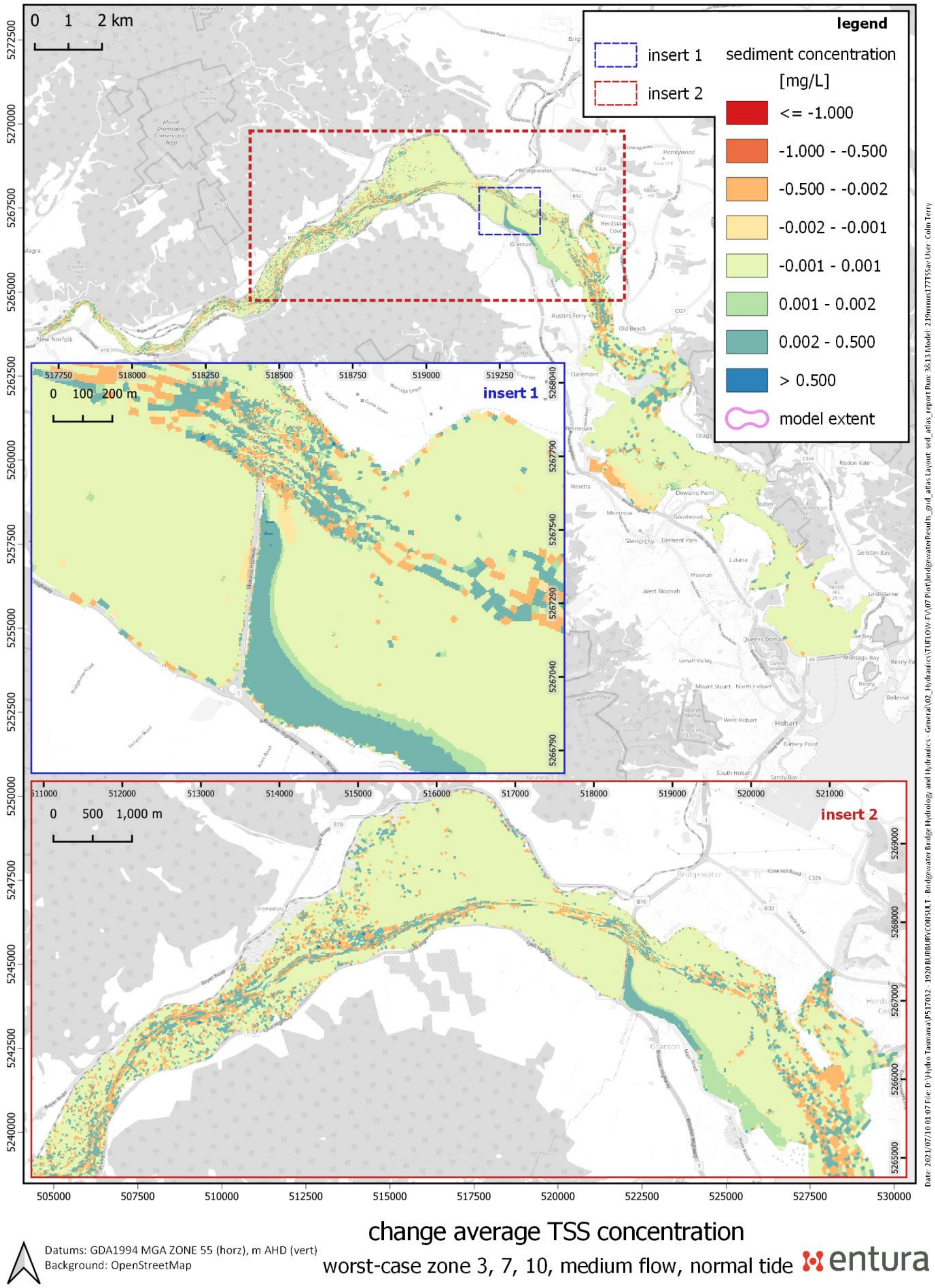

Figure B.52: Average TSS, worst disturbance construction, medium flow, normal tide (Run 3 minus Run 13)

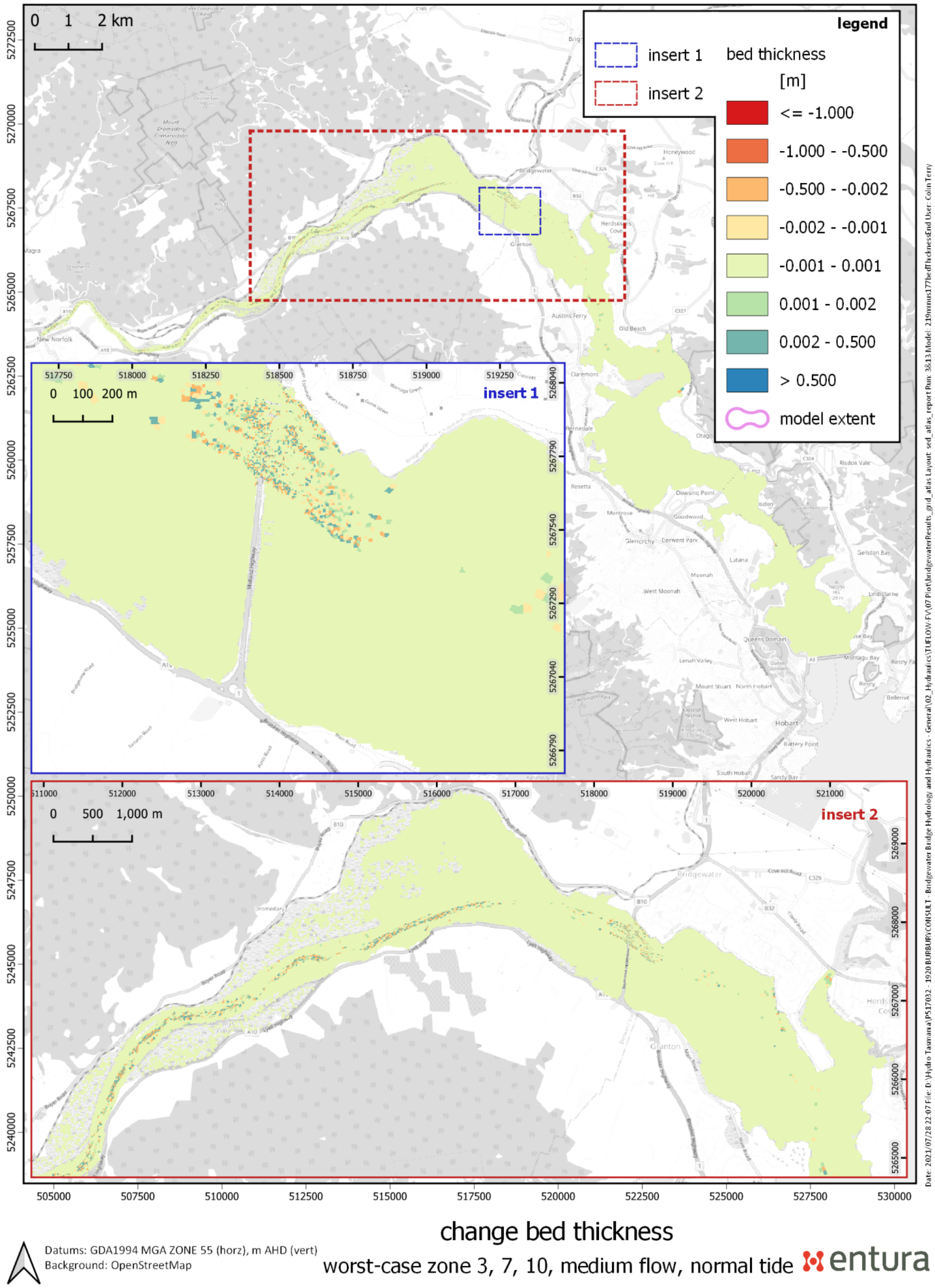

Figure B.53: Change in bed thickness, worst disturbance construction, medium flow, normal tide (Run 3 minus Run 13)

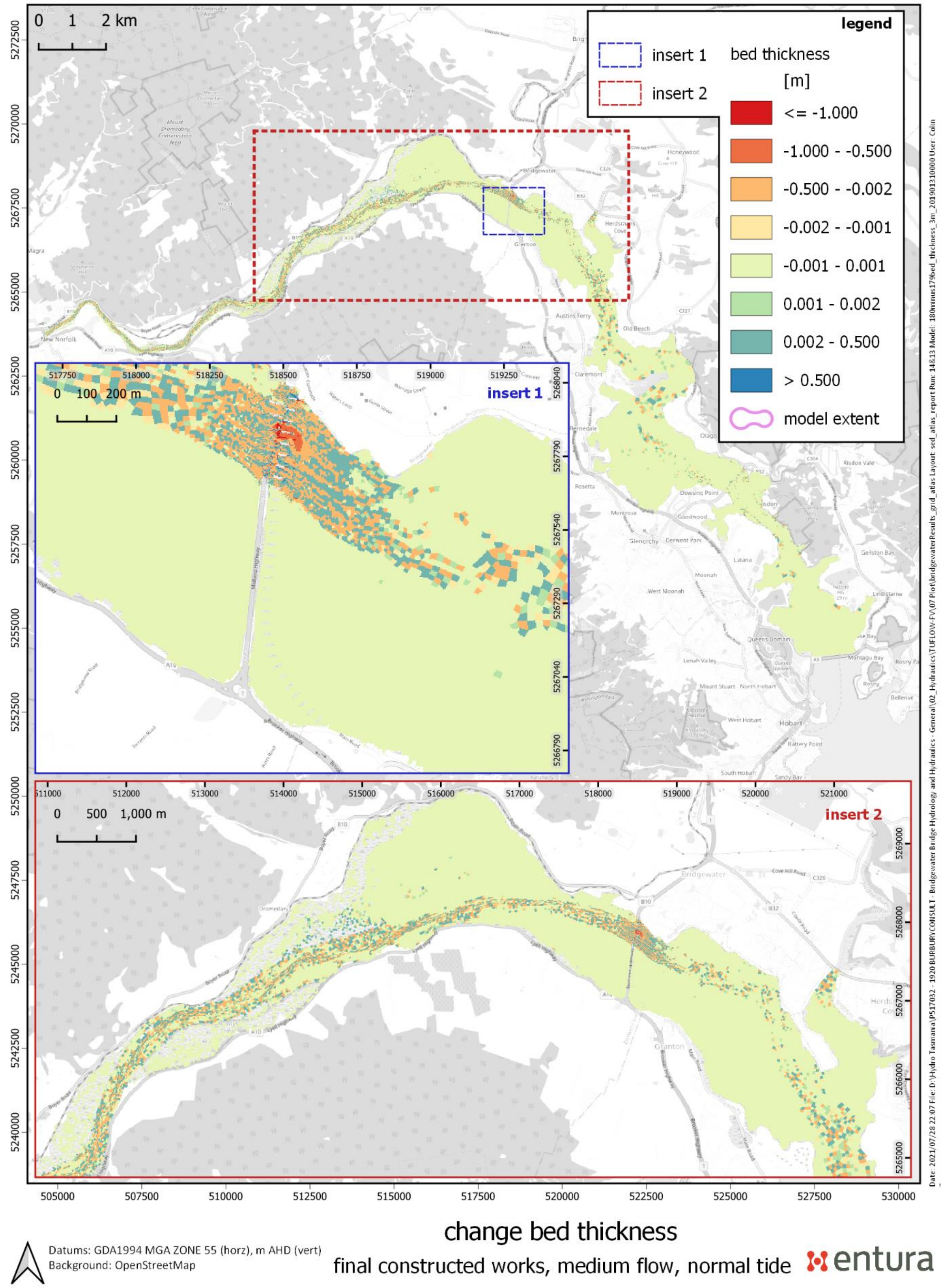

Figure B.54: Change in bed thickness, final constructed works, medium flow, normal tide (Run 14 minus Run 13)

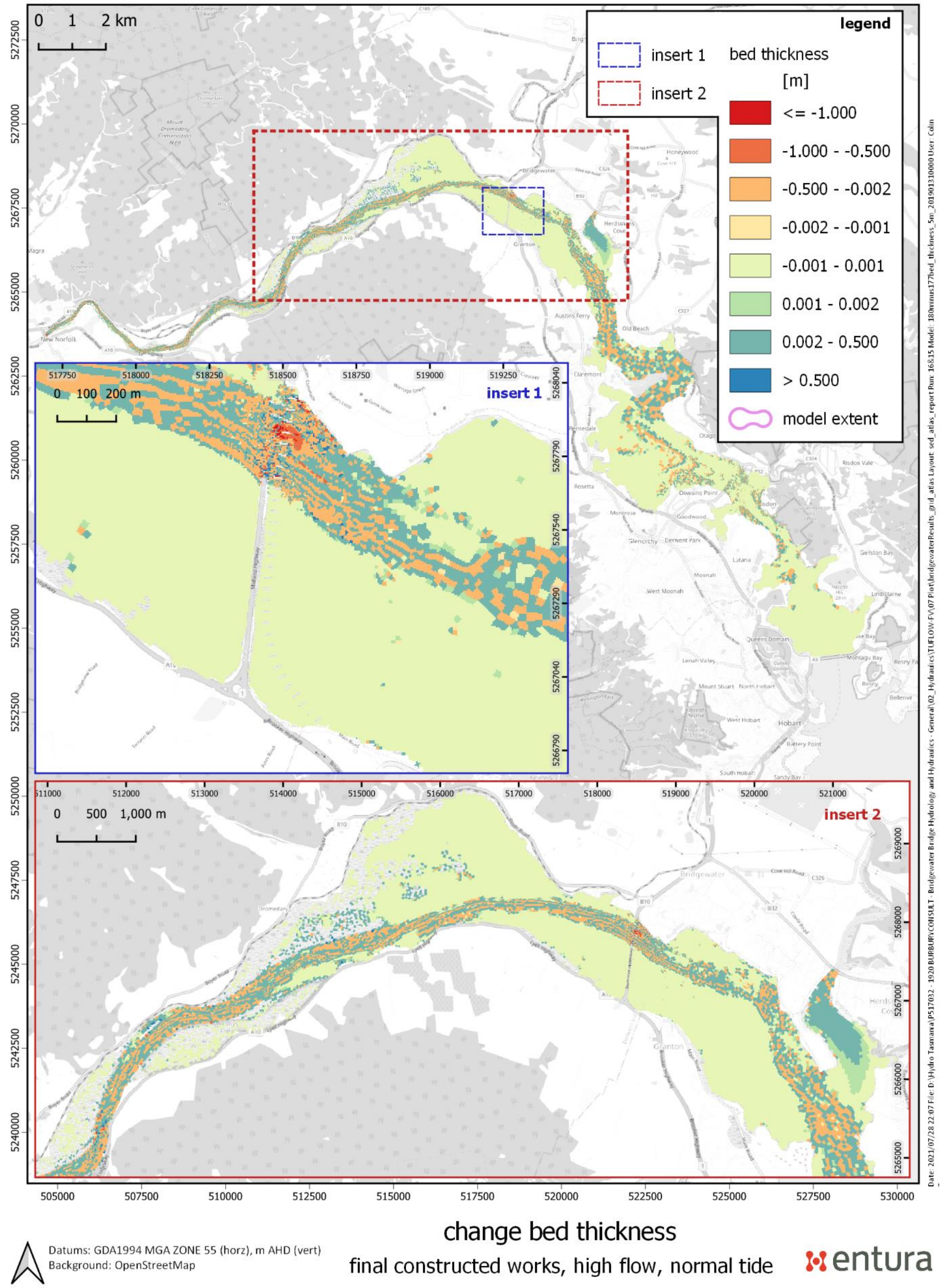

Figure B.55: Change in bed thickness, final constructed works, high flow, normal tide (Run 16 minus Run 15)

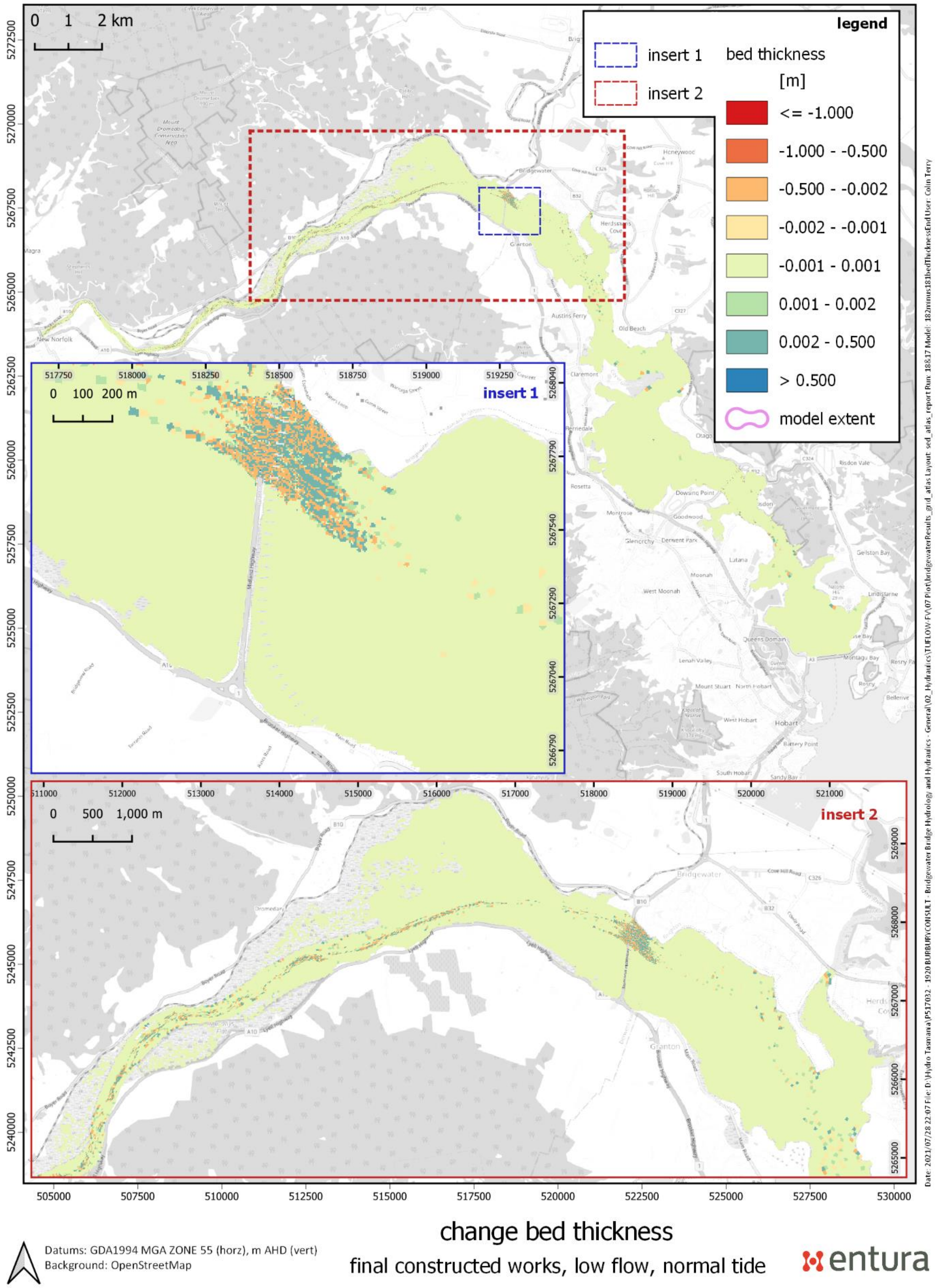

Figure B.56: Change in bed thickness, final constructed works, low flow, normal tide
(Run 18 minus Run 17)