Appendix J:

Scour Event Modelling: Poverty Bay

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Scour event modelling

Report prepared for Gisborne District Council

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MetOcean SOLUTIONS

Document History

Versions

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Distribution

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1	25/02/2019	Wolfgang Kanz
1.1	14/05/2019	Wolfgang Kanz
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1. Introduction

The Gisborne District Council (GDC) is interested in understanding the dilution and discharge characteristics of contaminant from four discharge locations and how the dilution characteristics may affect nearby beaches within Poverty Bay. In order to understand these dilution characteristics GDC has commissioned MetOcean Solutions to undertake a numerical investigation into the expected discharge characteristics from different drain locations (Figure 1.1) for both the existing and upgraded stormwater network at 2 and 10 year Average Recurrence Intervals (ARI).

A range of numerical model simulations designed to bracket the likely dilution and discharge characteristics are needed.

This report is structured as follows. An introduction to the study background and rational is provided in Section 1, while methods applied, including numerical model definitions are provided in Section 2. Results are presented in Section 3 and a concise summary is provided in Section 4. References cited are given in Section 5.

Figure 1.1 Poverty Bay and discharge locations

2. Methodology

2.1 Modelling approach

Unplanned discharges are the result of emergency overflows and/or accidental discharges from pipeline failures or leakage. The outcome and timing of such releases is inherently non-deterministic (i.e. unknown) and is governed, in part, by variables such as currents, turbulences, wastewater network use, tidal stage, wind conditions and precipitation/fluvial discharges.

However, hydrodynamic conditions under different forcing conditions can be modelled; therefore, allowing the general geographical dispersion of the discharges to be determined. In the present study, a range of realistic simulations have been undertaken in order to bracket the expected dispersion and dilution characteristics of stormwater discharges from the four discharge points (see Figure 1.1) in the unlikely event of an unexpected discharge.

2.2 Hydrodynamic model

2.2.1 Model description

The 3D baroclinic hydrodynamics of Poverty Bay were modelled using the open-sourced hydrodynamic model SCHISM [1,2]. The benefit of using open-source science models is the full transparency of the code and numerical schemes, and the ability for other researchers to replicate and enhance any previous modelling efforts for a given environment.

SCHISM is a prognostic finite-element unstructured-grid designed to simulate 3D baroclinic, 3D barotropic or 2D barotropic circulation. The barotropic mode equations employ a semi-implicit finite-element Eulerian-Lagrangian algorithm to solve the shallow-water equations, forced by relevant physical processes (atmospheric, oceanic and fluvial forcing). A detailed description of the SCHISM model formulation, governing equations and numerics, can be found in Zhang and Baptista (2008).

The SCHISM model is physically realistic, in that well-understood laws of motion and mass conservation are implemented. Therefore, water mass is generally conserved within the model, although it can be added or removed at open boundaries (e.g. through tidal motion at the ocean boundaries) and water is redistributed by incorporating aspects of the real-world systems (e.g. bathymetric information, forcing by tides and wind). The model transports water and other constituents (e.g. salt, temperature, turbulence, tracers) using triangular volumes (connected 3-D polyhedrons).

The finite-element triangular grid structure used by SCHISM has resolution and scale benefits over other regular or curvilinear based hydrodynamic models. SCHISM is computationally efficient in the way it resolves the shape and complex bathymetry associated with estuaries, and the governing

[1] http://ccrm.vims.edu/schism/
[2] http://www.ccrm.vims.edu/w/index.php/Main_Page#SCHISM_WIKI

equations are similar to other open-source models such as Delft3D and ROMS. SCHISM has been used extensively within the scientific community[3],[4] where it forms the backbone of operational systems used to nowcast and forecast estuarine water levels, storm surges, velocities, water temperature and salinity[5].

2.2.2 Model domain and bathymetry

The model resolution was optimised to ensure replication of the salient hydrodynamic processes. The resolution ranged from 150 m at the boundary to 5 m in shallow water and inside the port/rivers and streams. The triangular elements of the model domain mesh are shown in Figure 2.1 and associated bathymetries are presented in Figure 2.2.

[3] http://www.stccmop.org/knowledge_transfer/software/selfe/publications
[4] http://ccrm.vims.edu/schism/schism_pubs.html
[5] https://tidesandcurrents.noaa.gov/ofs/creofs/creofs_info.html

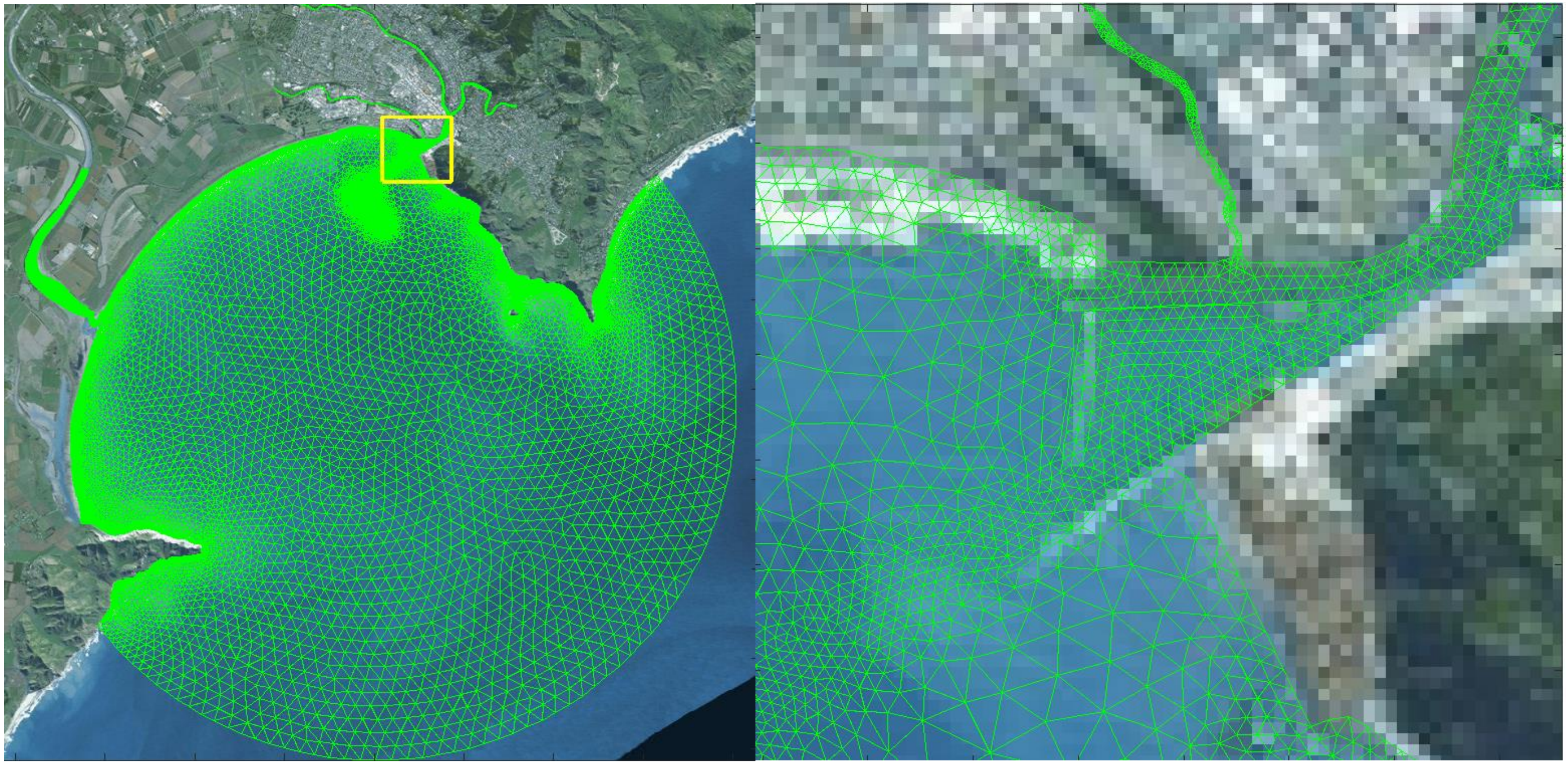

Figure 2.1 Poverty Bay model domain showing the Finite-Element triangular model mesh for the entire model domain (left) and in the vicinity of the Port (right)

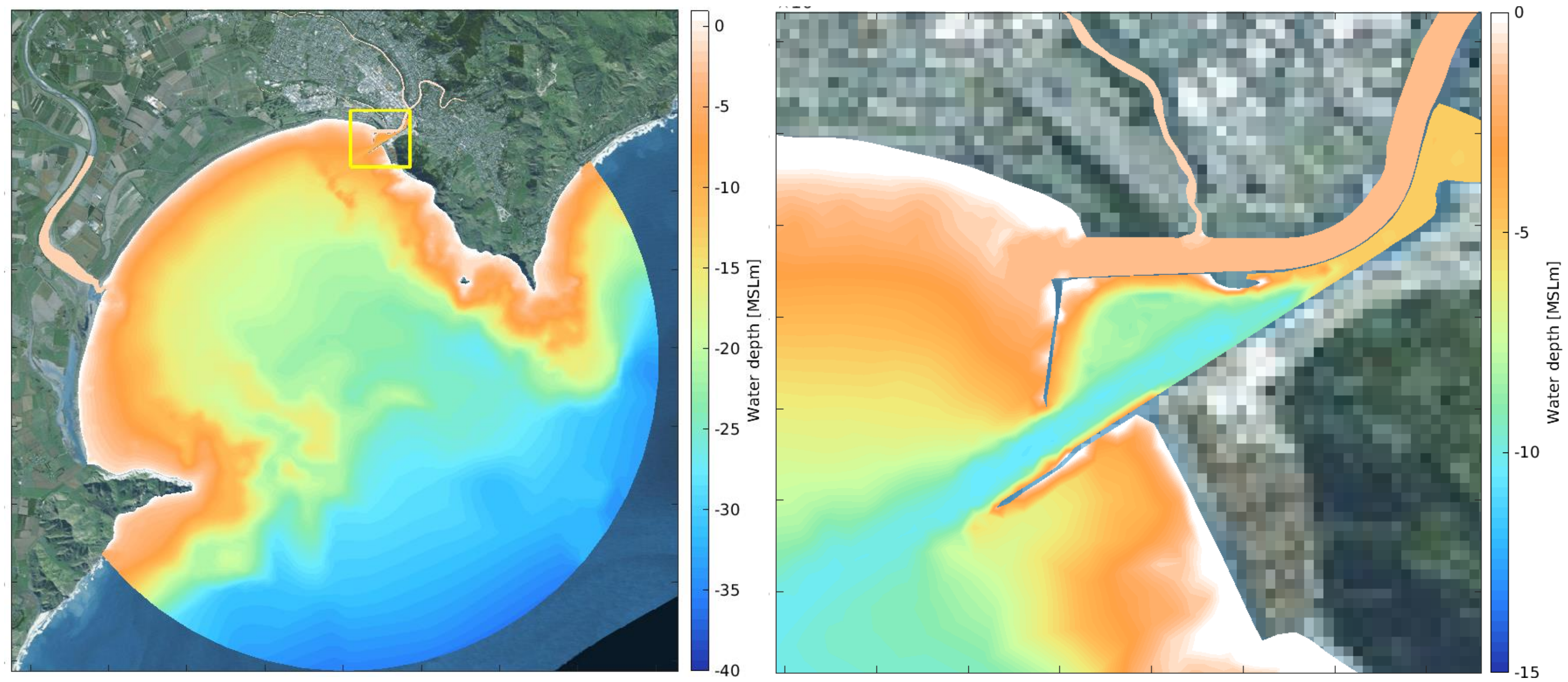

Figure 2.2 Poverty Bay model domain showing the model bathymetry of the whole domain (left) and near the Port (right). Depths are given to Mean Sea Level (MSL)

2.2.1 Vertical discretisation

For the 3D model simulations, the vertical discretisation of the water column consisted of a Localized Sigma Coordinate system with Shaved Cell (LSC^2), a type of terrain-following layers as described in Zhang et al., (2015). The model was configured with several sigma layers ranging from 4 in shallow waters to 12 in deep waters near the open boundary. A vertical section showing both the sigma layers and the water depths along the port navigation channel is presented in Figure 2.3

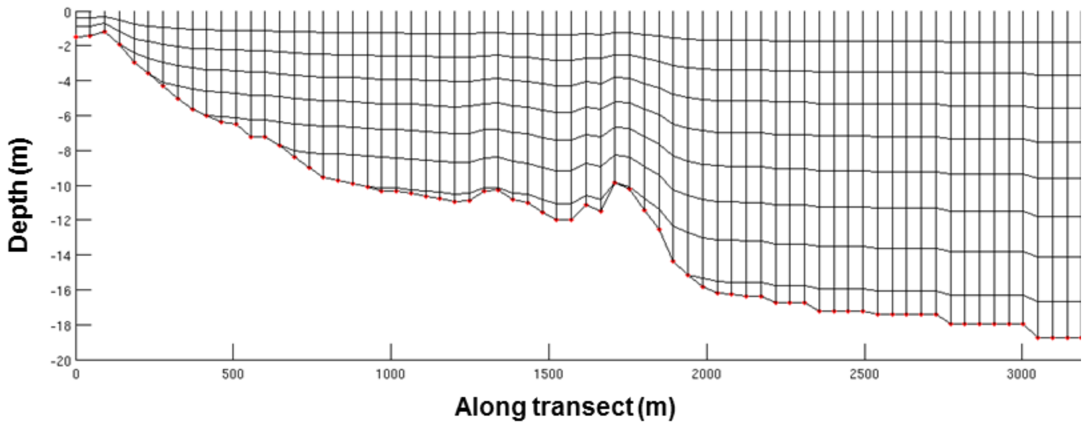

Figure 2.3 Section from the port entrance, and along the navigation channel showing the LSC2 grid used in this study.

2.2.2 Modelled scenarios

A range of scenarios have been modelled in order to describe the expected dispersion and dilution characteristics of stormwater discharges from the outfalls in the unlikely event of a discharge. Each of the simulations is unique in terms of the initial tidal state, forcing conditions and discharge rates, and represents 2 and 10-year ARI discharge scour events for the existing and upgraded stormwater network. Significantly, at the 2-year ARI level, the upgraded stormwater network is expected to be capable of storing the associated inputs, and no discharges are expected.

Different rivers forcing are applied depending on the 2 years and 10 years ARI events being simulated. Associated scour events (volume discharge and durations) depends on the current and future drain specification.

For each of those return periods, releases are modelled under four different wind state and start at two initial tidal states: Mean High Water Spring (MHWS) and Mean Low Water Spring (MLWS) as shown in Figure 2.4.

Wind used in these scenarios is representative of typical wind speed during storm event.

The conditions simulated are summarised in Table 2-1, while Table 2-2 and Table 2-3 detail the associated fluvial and accidental discharges respectively. Open boundary locations for each of the fluvial and stormwater discharges are shown in Figure 1.1.

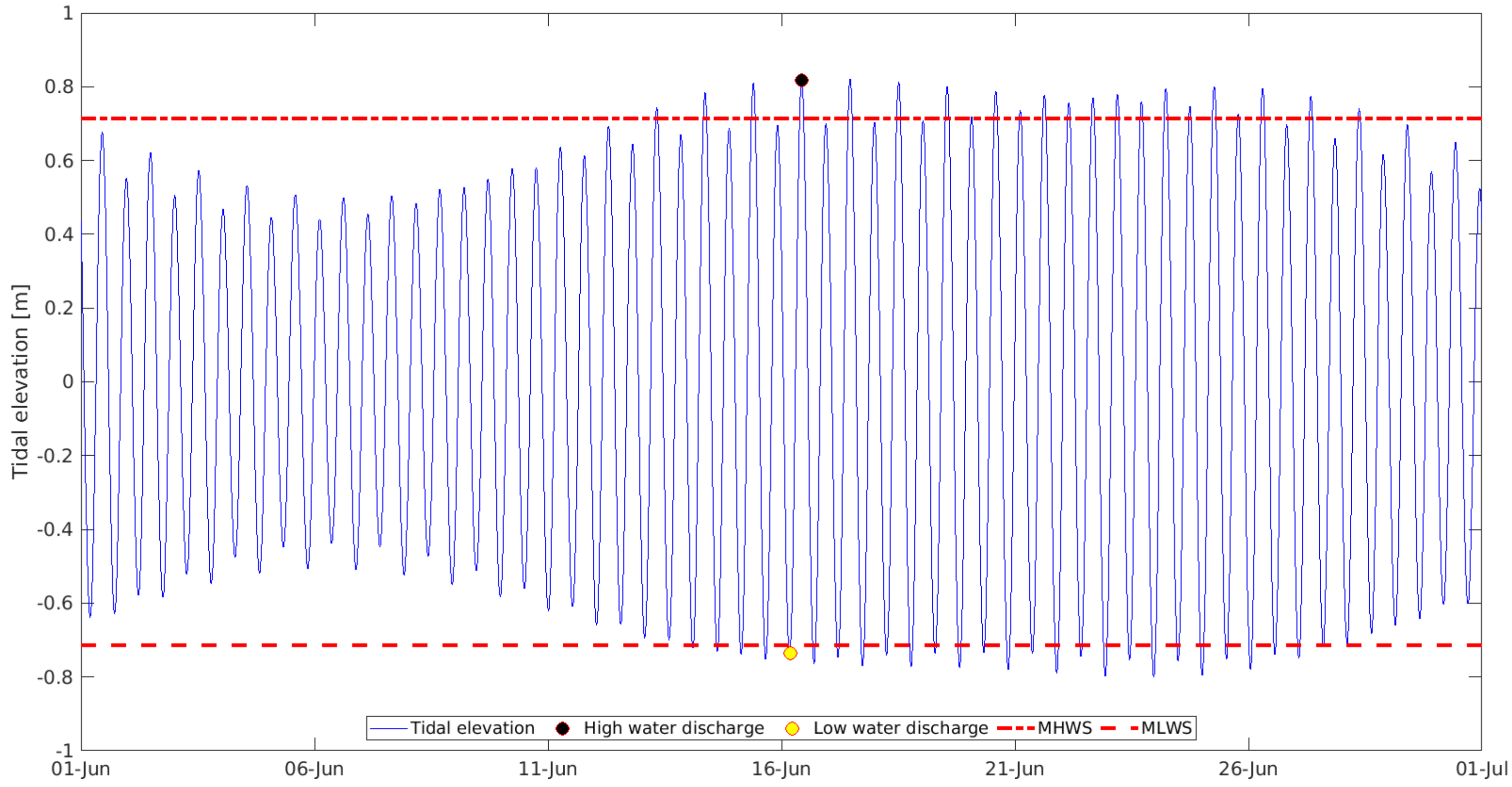

Figure 2.4 Time series of tidal elevation inside Poverty Bay showing the time of the high water discharge (black dot) and low water discharge (yellow dot) in relation to mean high water spring (MHWS), mean low water spring (MLWS).

Table 2-1 Model scenarios.

River flow conditions and scour name	Tide at start of the release	Wind velocity
2 years current Wainui street Seymour	MHWS	SE 15 $m.s^{-1}$
		SE 25 $m.s^{-1}$
		NW 15 $m.s^{-1}$
		NW 25 $m.s^{-1}$
	MLWS	SE 15 $m.s^{-1}$
		SE 25 $m.s^{-1}$
		NW 15 $m.s^{-1}$
		NW 25 $m.s^{-1}$
10 years current Wainui street Seymour Oak street Peel street	MHWS	SE 15 $m.s^{-1}$
		SE 25 $m.s^{-1}$
		NW 15 $m.s^{-1}$
		NW 25 $m.s^{-1}$
	MLWS	SE 15 $m.s^{-1}$
		SE 25 $m.s^{-1}$
		NW 15 $m.s^{-1}$
		NW 25 $m.s^{-1}$
10 years future Wainui street Peel street	MHWS	SE 15 $m.s^{-1}$
		SE 25 $m.s^{-1}$
		NW 15 $m.s^{-1}$
		NW 25 $m.s^{-1}$
	MLWS	SE 15 $m.s^{-1}$
		SE 25 $m.s^{-1}$
		NW 15 $m.s^{-1}$
		NW 25 $m.s^{-1}$

Table 2-2 Model scour conditions for each of the return periods

Discharging location	River flow conditions	Scour Flow (m^3)	Scour duration (Hrs)
Wainui street	2 year current	17643	46
	10 year current	17849	47
	10 year future	1545	28
Seymour	2 year current	914	21
	10 year current	1710	29
Oak street	10 year current	1358	29
Peel street	10 year current	25782	47
	10 year future	8010	28

Table 2-3 River flow conditions for each of the return periods

River name	Discharge 2-year ARI ($m^3.s^{-1}$)	Discharge 10-year ARI ($m^3.s^{-1}$)
Waipaoa	1185	2690
Taruheru	38	75
Shelly	4.2	9
Waimata	430	1000
Waikanae	10	17

3. Results

The outputs of each simulation of wastewater discharges were combined and post-processed to calculate dilution and concentration at each level through the water.

Timeseries of dilution and concentration were extracted from two key locations #4 #9 and #10 as example (See Figure 3.1).

Figure 3.1 Aerial image of Poverty Bay showing examples of locations where dilution time series can been extracted.

3.1 Dilution results

3.1.1 2-year ARI existing scenarios

Discharge rated for each of the sources are at the 2-year ARI level are provided in Table 2-2, while 2-year ARI fluvial discharges for each of the river/stream sources are defined in Table 2-3.

Dilution plots for persistent and relatively strong S-E wind events (15 and 25 $m.s^{-1}$) are presented in Figure 3.3 and Figure 3.5 for the MHWS and MLWS release respectively. For both initial tidal stage release times the strong onshore S-E winds hold the lowest dilution of the plume against the coast along Waikanae Beach and towards the Waipaoa River mouth. Dilution of 1:10,000 can be found up to 4 km from the Turanganui River mouth under SE 15 $m.s^{-1}$ winds, and 5 km under stronger SE 25 $m.s^{-1}$ winds at T+ 24 hours. At T+48 hours after the initial start of the accidental discharge dilution levels increase to > 1/10,000. At T+24 and T+48 the plume begins to extend over the northern Poverty Bay.

Dilution plots for persistent and relatively strong N-W wind events (15 and 25 $m.s^{-1}$) are presented in Figure 3.7 and Figure 3.9 for the MHWS and MLWS release respectively. For both initial tidal stage release times the strong offshore winds push the plume offshore and out into Poverty Bay along Kaiti Beach as the plume exits the Turanganui River and migrates southwards towards Tokomaru, Hawea and Te Moana Rocks. Dilution of 1/10000 can be found up to 1000 m from the mouth of the Turanganui River under N-W 15 $m.s^{-1}$ and 25 $m.s^{-1}$ after 24 hours form the start of the release respectively. At T+48 hours after the initial start of the accidental discharge dilution levels increase to > 1:10,000 with peak concentrations expected along Kaiti Beach and out towards Tuaheni Point.

Time-series of dilutions for each of the events simulated (i.e. varying release conditions and timing) are provided at location #4, #9 and #10 in Figure 3.10 and Figure 3.11.

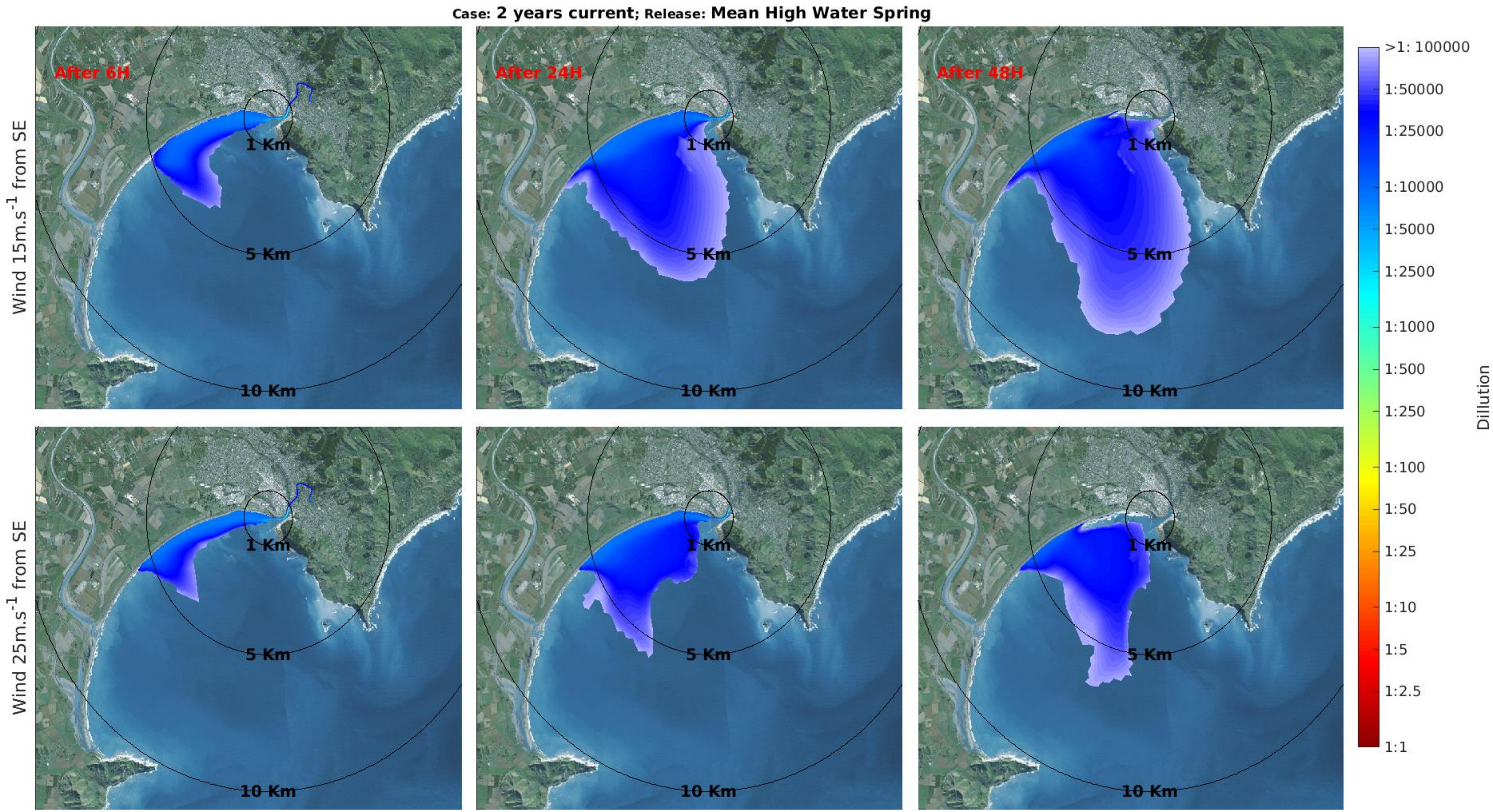

Figure 3.2 Poverty Bay view of the 2 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 m.s^{-1} (bottom) South-Easterly wind.

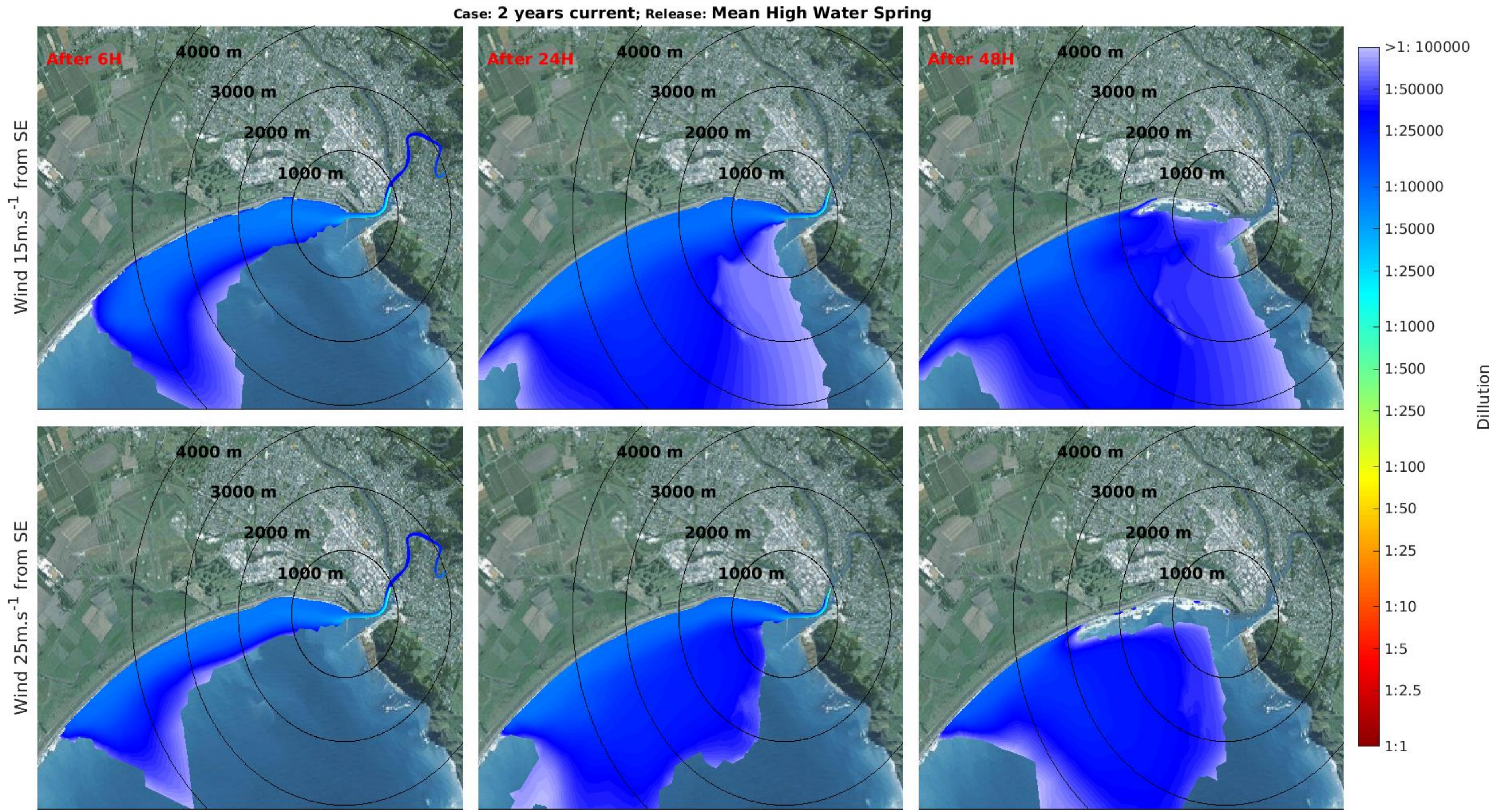

Figure 3.3 Close-up of the 2 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 $m.s^{-1}$ (bottom) South-Easterly wind.

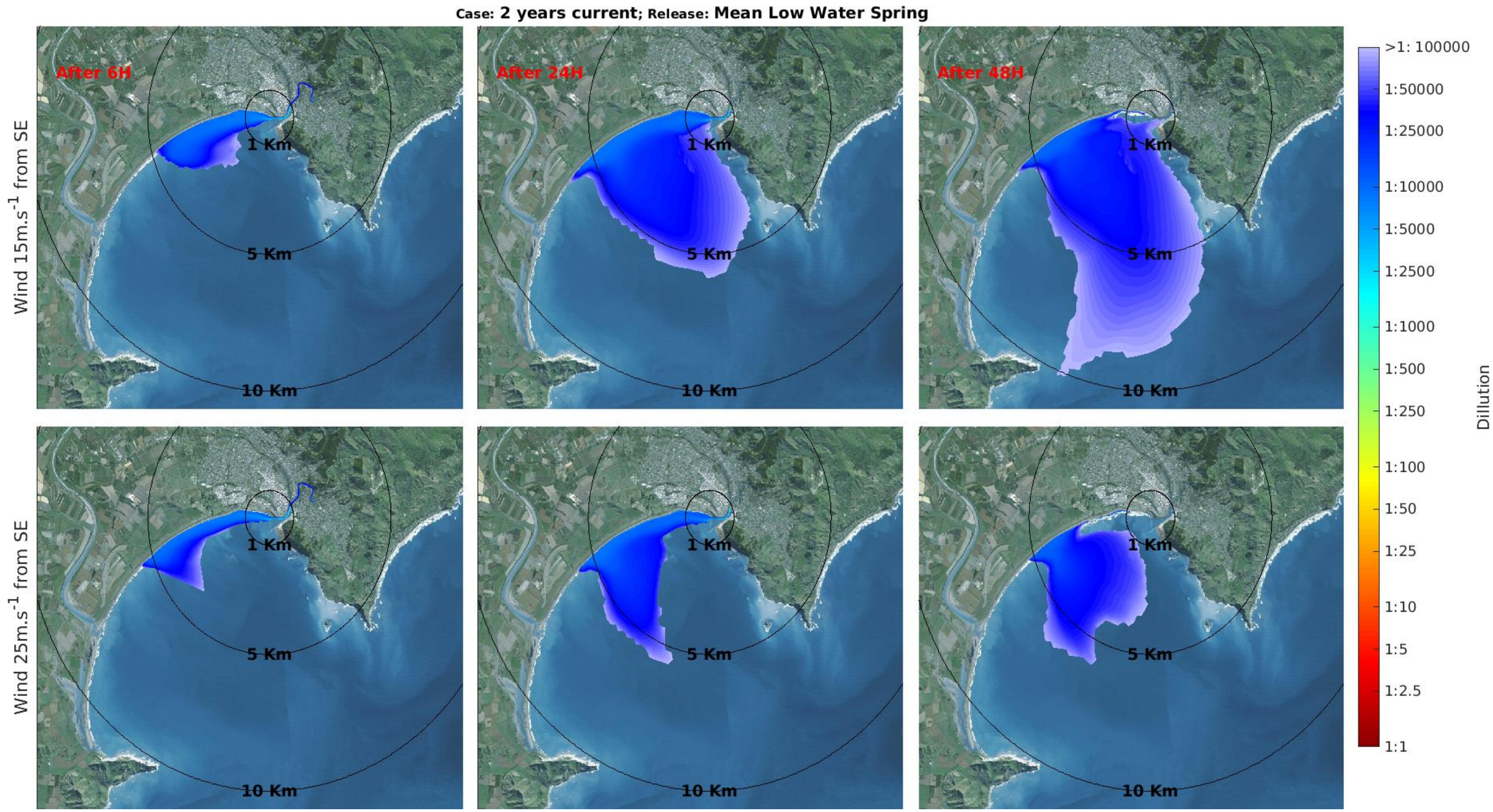

Figure 3.4 *Poverty Bay view of the 2 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 m.s^{-1} (bottom) South-Easterly wind*

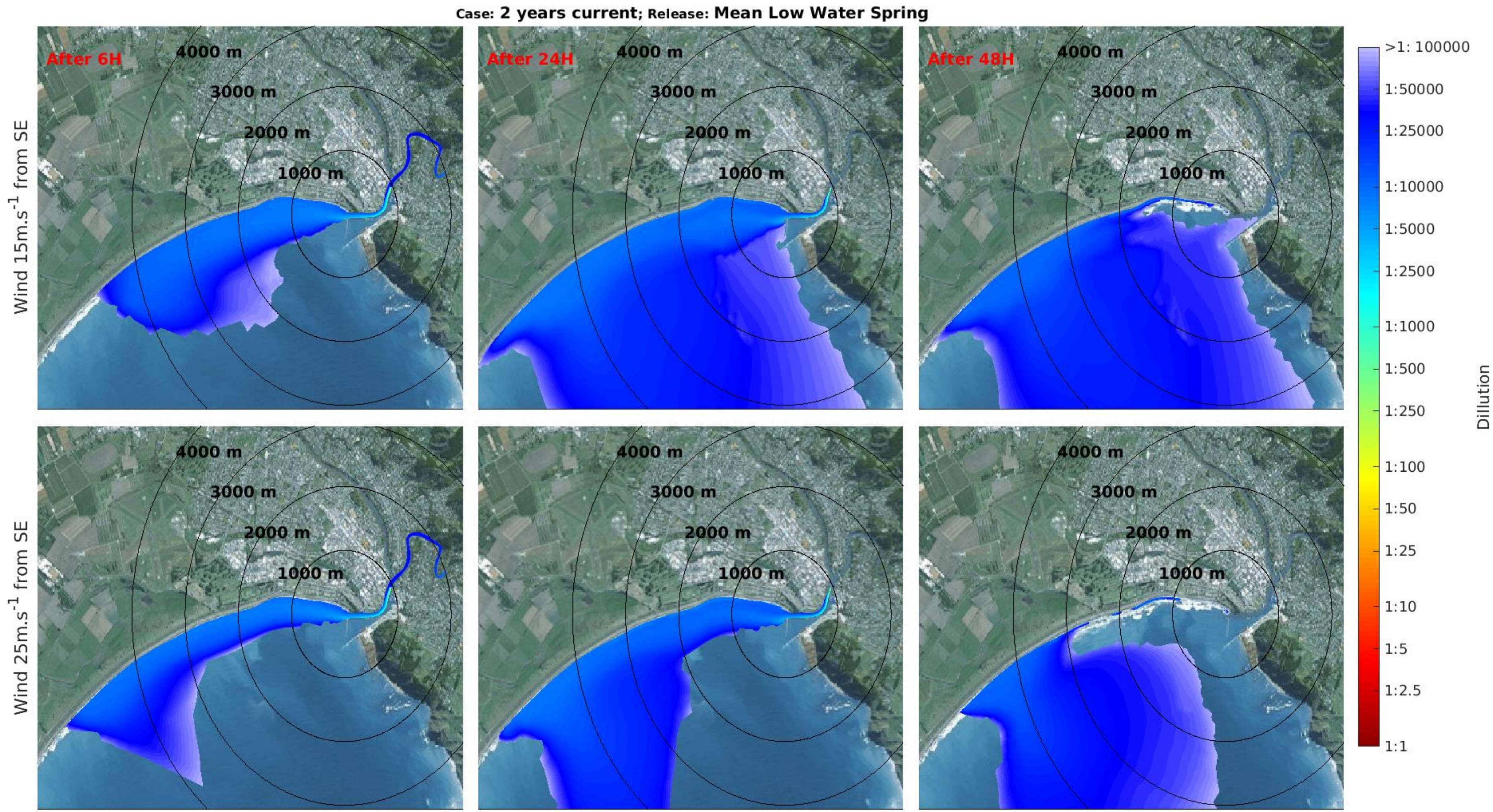

Figure 3.5 *Close-up of the 2 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 $m.s^{-1}$ (bottom) South-Easterly wind.*

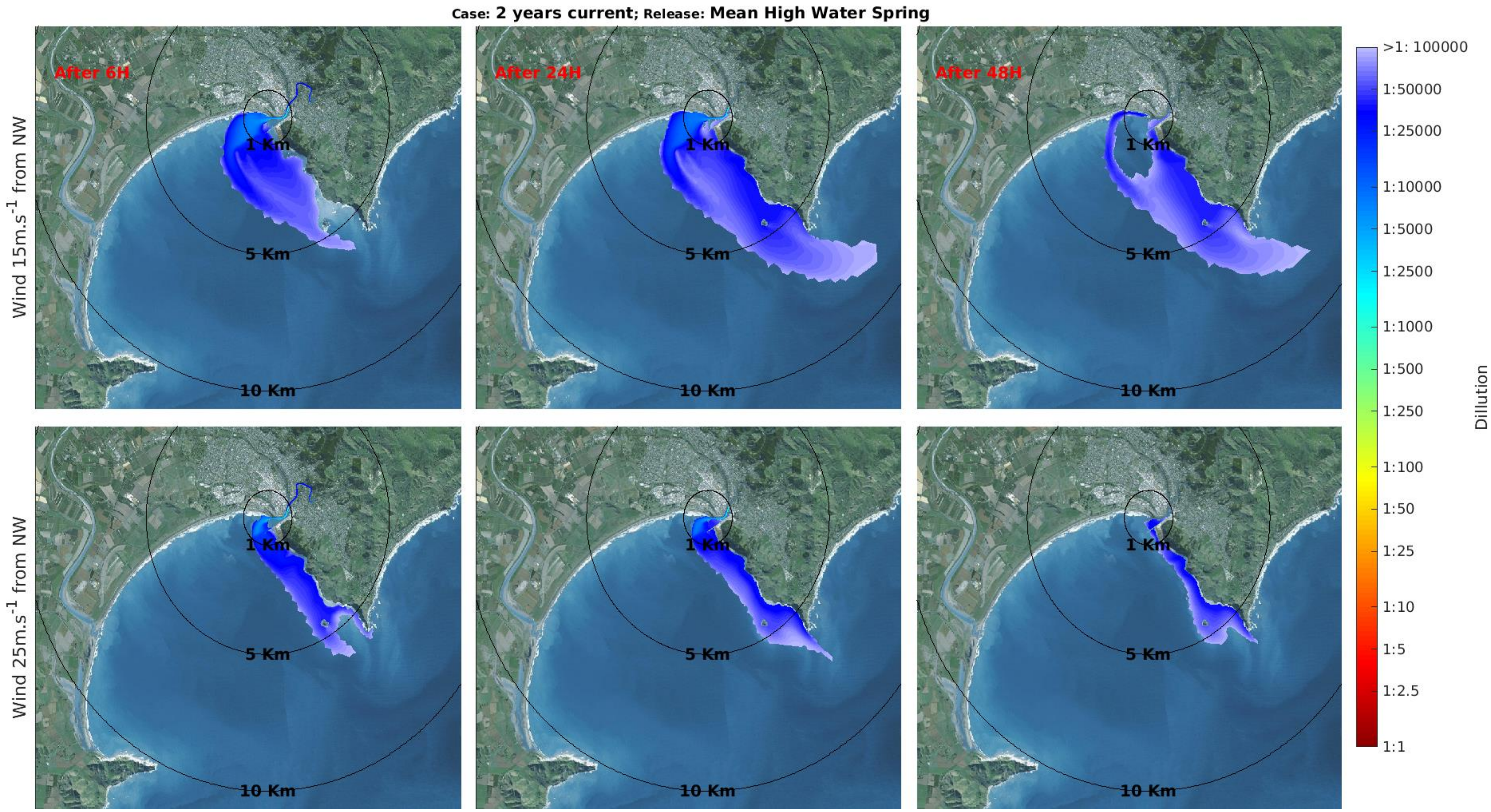

Figure 3.6 *Poverty Bay view of the 2 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 m.s^{-1} (bottom) North-Westerly wind.*

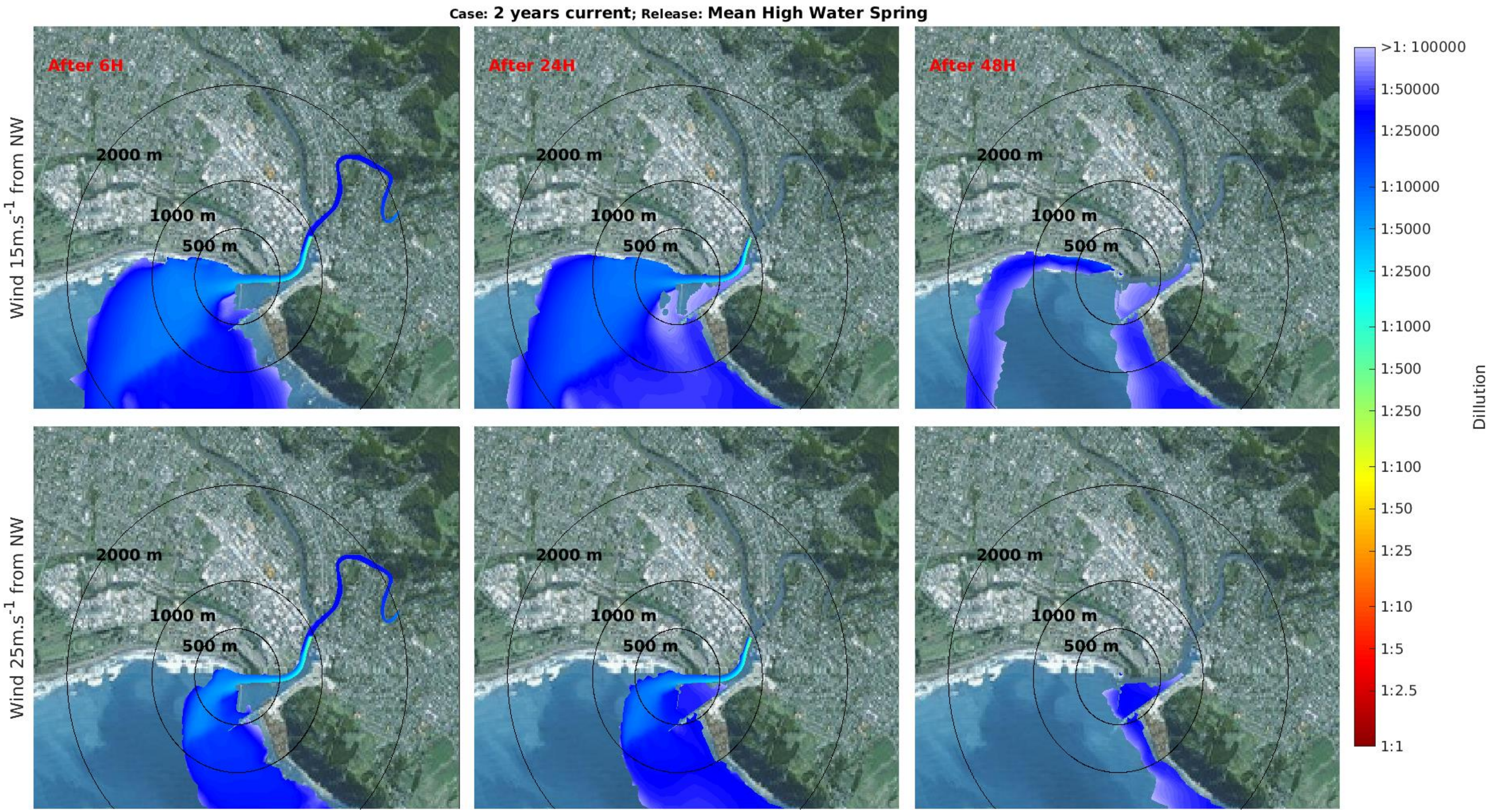

Figure 3.7 Close-up of the 2 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 $m.s^{-1}$ (bottom) North-Westerly wind.

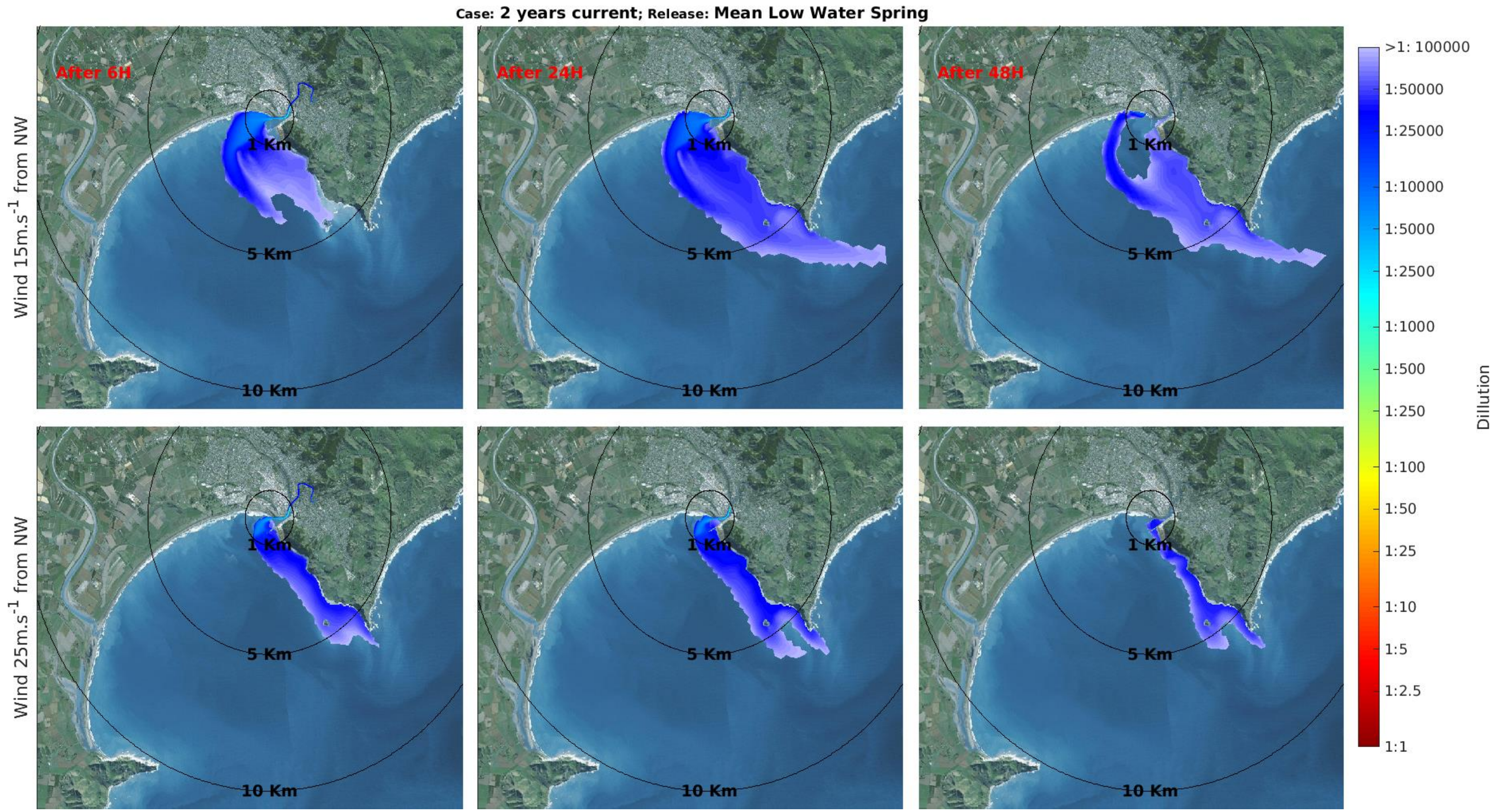

Figure 3.82 Poverty Bay view of the 2 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 m.s^{-1} (bottom) North-Westerly wind.

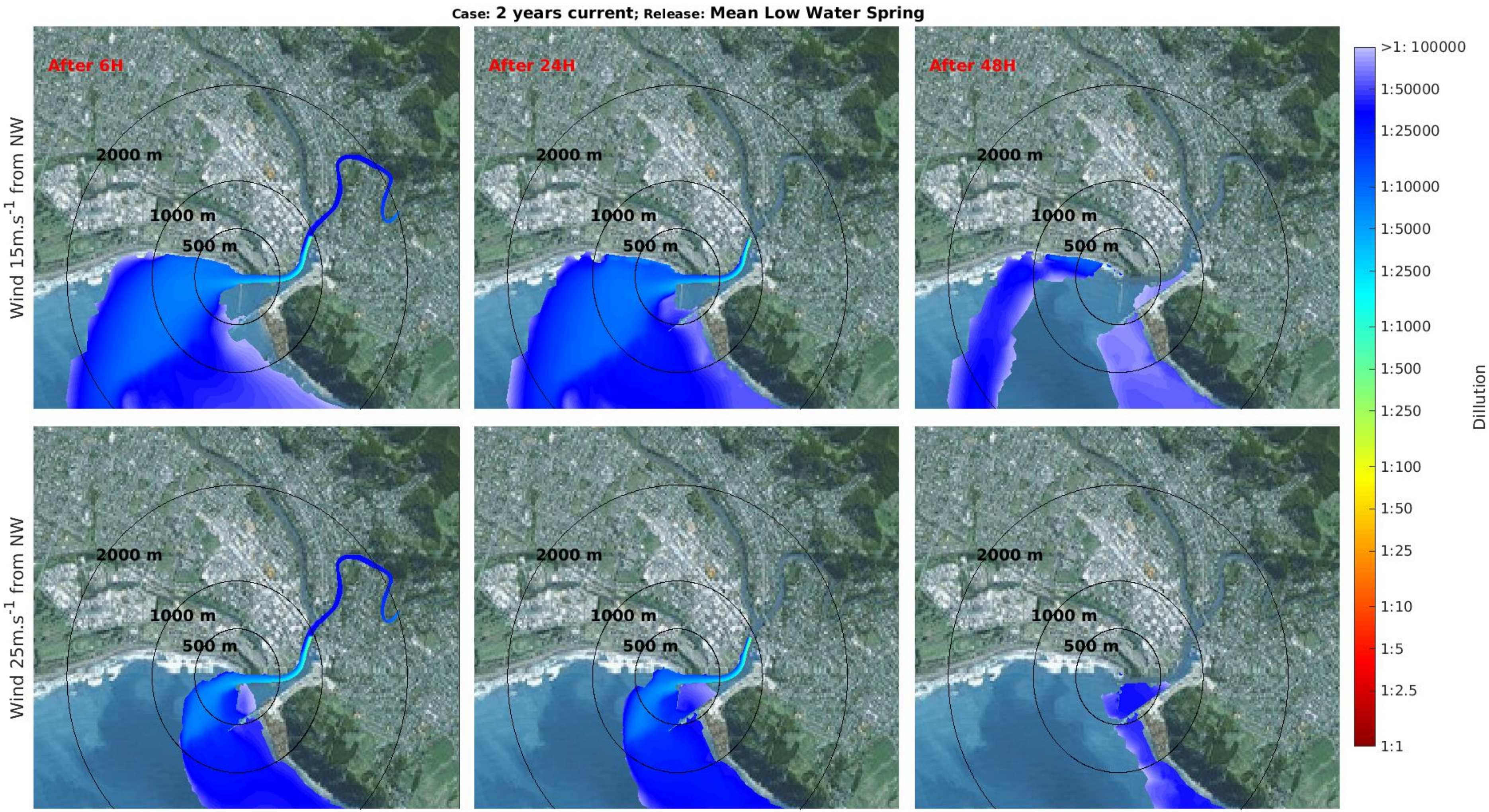

Figure 3.9 Close-up of the 2 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 $m.s^{-1}$ (bottom) North-Westerly wind.

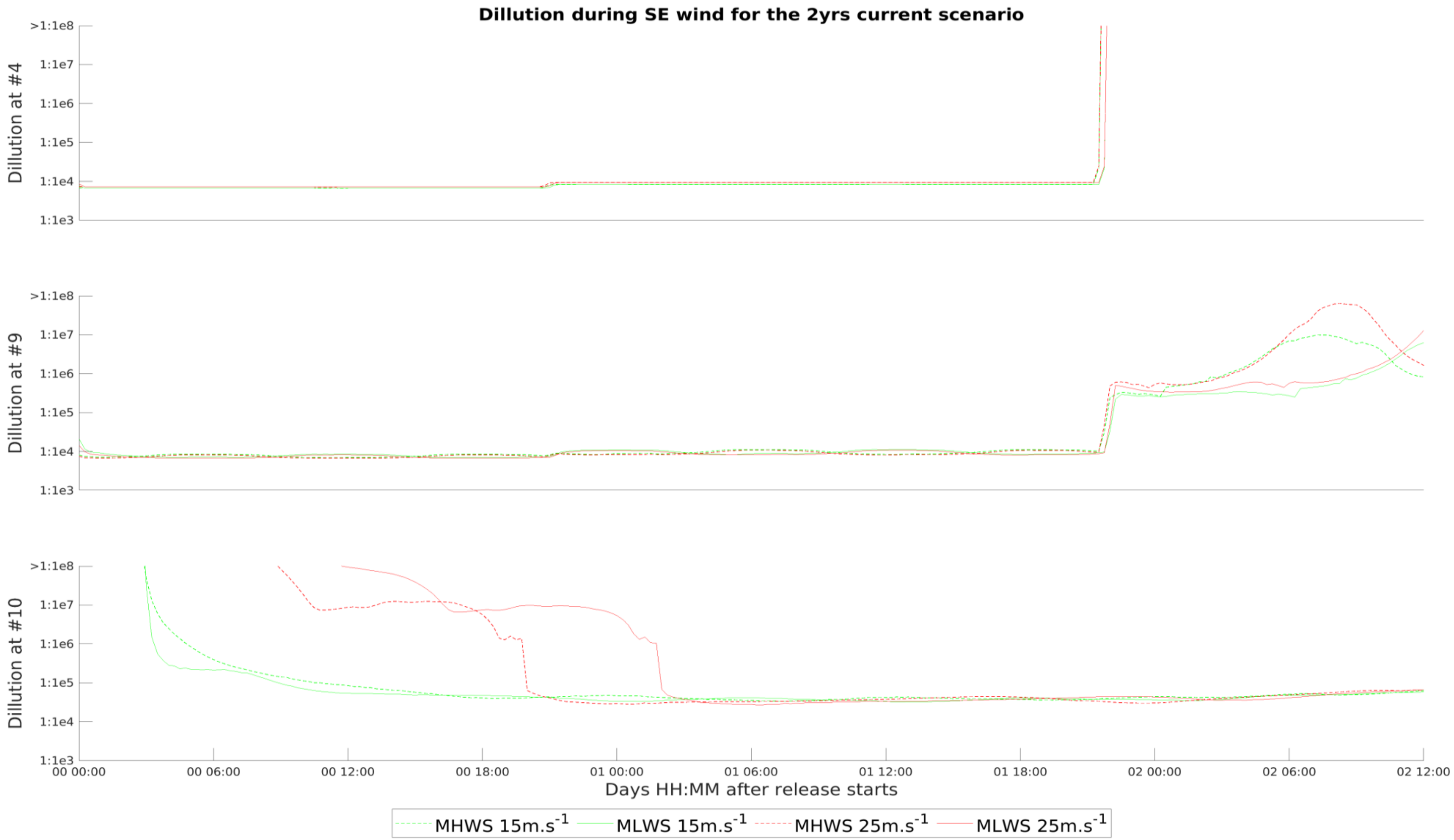

Figure 3.10 Dilution time series extracted at the four locations for the 2yrs current scenario under South-Easterlies condition. The solid line and the dot line represented the initial tidal state of the release (MHWS and MLWS respectively). The 15 m.s^{-1} wind speed is shown by the green colour and the 25 m.s^{-1} is represented by the red colour.

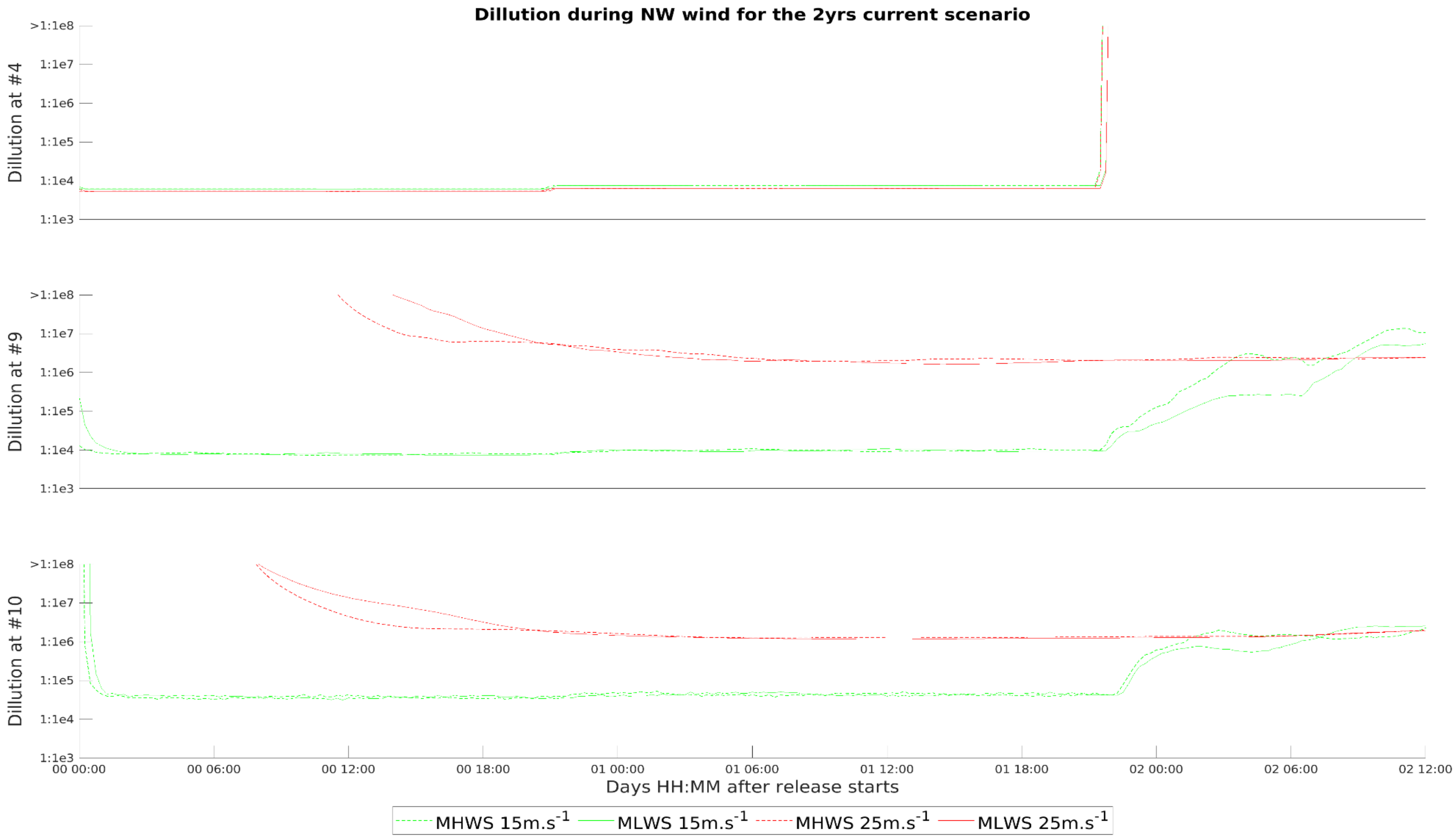

Figure 3.11 Dilution time series extracted at the four locations for the 2yrs current scenario under North-Westerlies condition. The solid line and the dot line represented the initial tidal state of the release (MHWS and MLWS respectively). The 15 m.s^{-1} wind speed is shown by the green colour and the 25 m.s^{-1} is represented by the red colour.

3.1.2 10-year ARI existing scenarios

Discharge rated for each of the sources are at the 10-year ARI level are provided in Table 2-2, while 10-year ARI fluvial discharges for each of the river/stream sources are defined in Table 2-3.

Dilution plots for persistent and relatively strong S-E wind events (15 and 25 $m.s^{-1}$) are presented in Figure 3.13 and Figure 3.15 for the MHWS and MLWS release respectively. For both initial tidal stage release times the strong onshore S-E winds hold the plume against the coast along Waikanae Beach and towards the Waipaoa River mouth. Dilution of 1:10000 can be found up to 6 km from the Turanganui River mouth under both S-E 15 and 25 $m.s^{-1}$. At T+48 hours after the initial start of the accidental discharge dilution levels along the coast still persist at levels > 1:10,000. At T+24 hr and T+48 hr the plume begins to extend over the northern Poverty Bay and begins to re-circulate back into southern Poverty Bay around Young Nicks Head, and potentially extends south beyond Young Nicks Head at T+48 hours.

Dilution plots for persistent and relatively strong N-W wind events (15 and 25 $m.s^{-1}$) are presented in Figure 3.17 and Figure 3.19 for the MHWS and MLWS release respectively. For both initial tidal stage release times the strong offshore winds push the plume offshore and out into Poverty Bay and along Kaiti Beach as the plume exits the Turanganui River and migrates southwards towards Tokomaru, Hawea and Te Moana Rocks. Dilution of 1/10000 can be found up to 1000 m from the mouth of the Turanganui River under N-W 15 $m.s^{-1}$ and 25 $m.s^{-1}$ at T+24 hours. At T+48 hours after the initial start of the accidental discharge dilution levels increase to > 1:10,000 as the plume mixes with the offshore waters, with peak concentrations expected along Kaiti Beach and out towards Tuaheni Point.

Time-series of dilutions for each of the events simulated (i.e. varying release conditions and timing) are provided at location #4, #9 and # in Figure 3.20 and Figure 3.21.

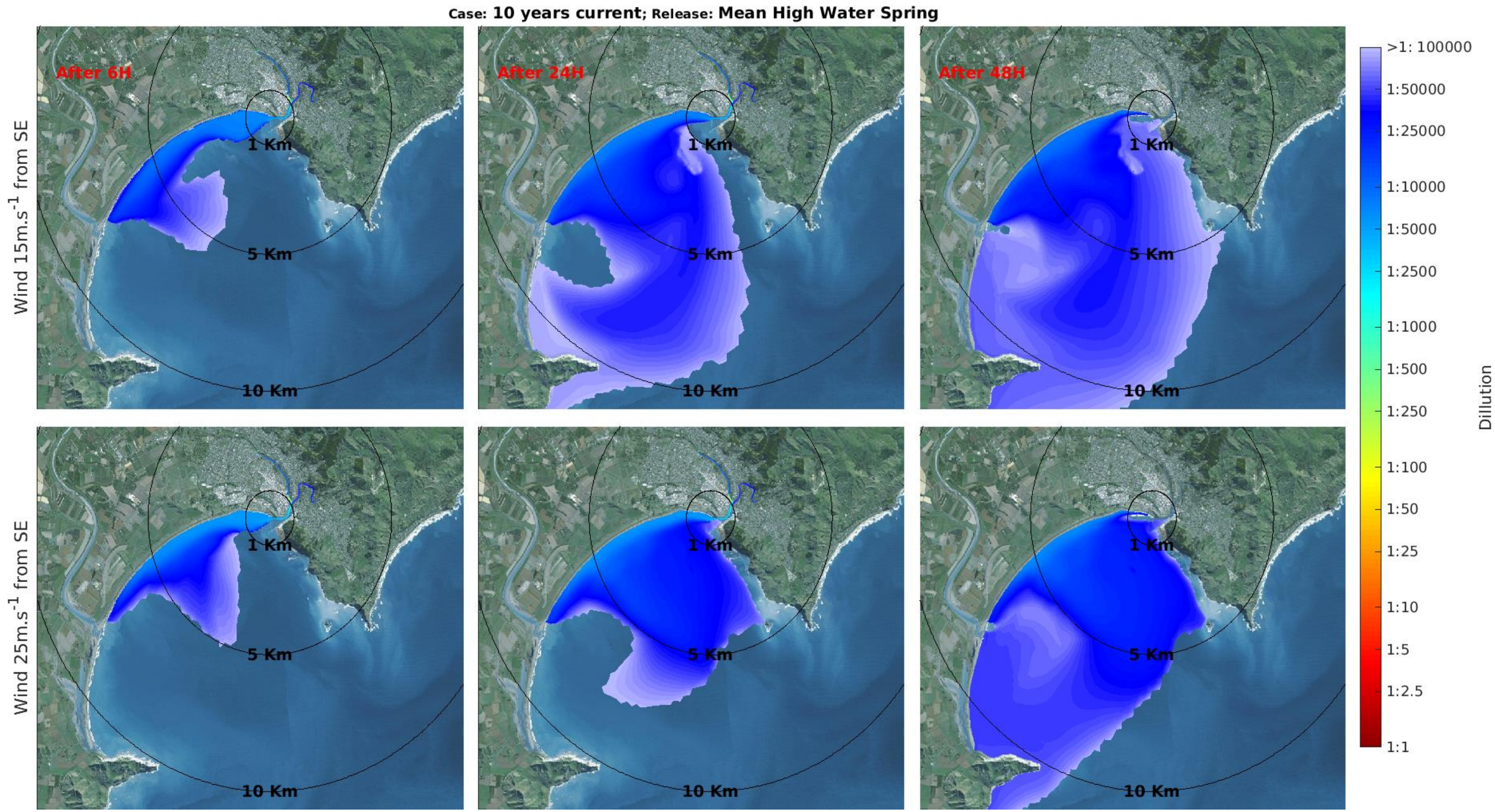

Figure 3.12 Poverty Bay view of the 10 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 m.s^{-1} (bottom) South-Easterly wind.

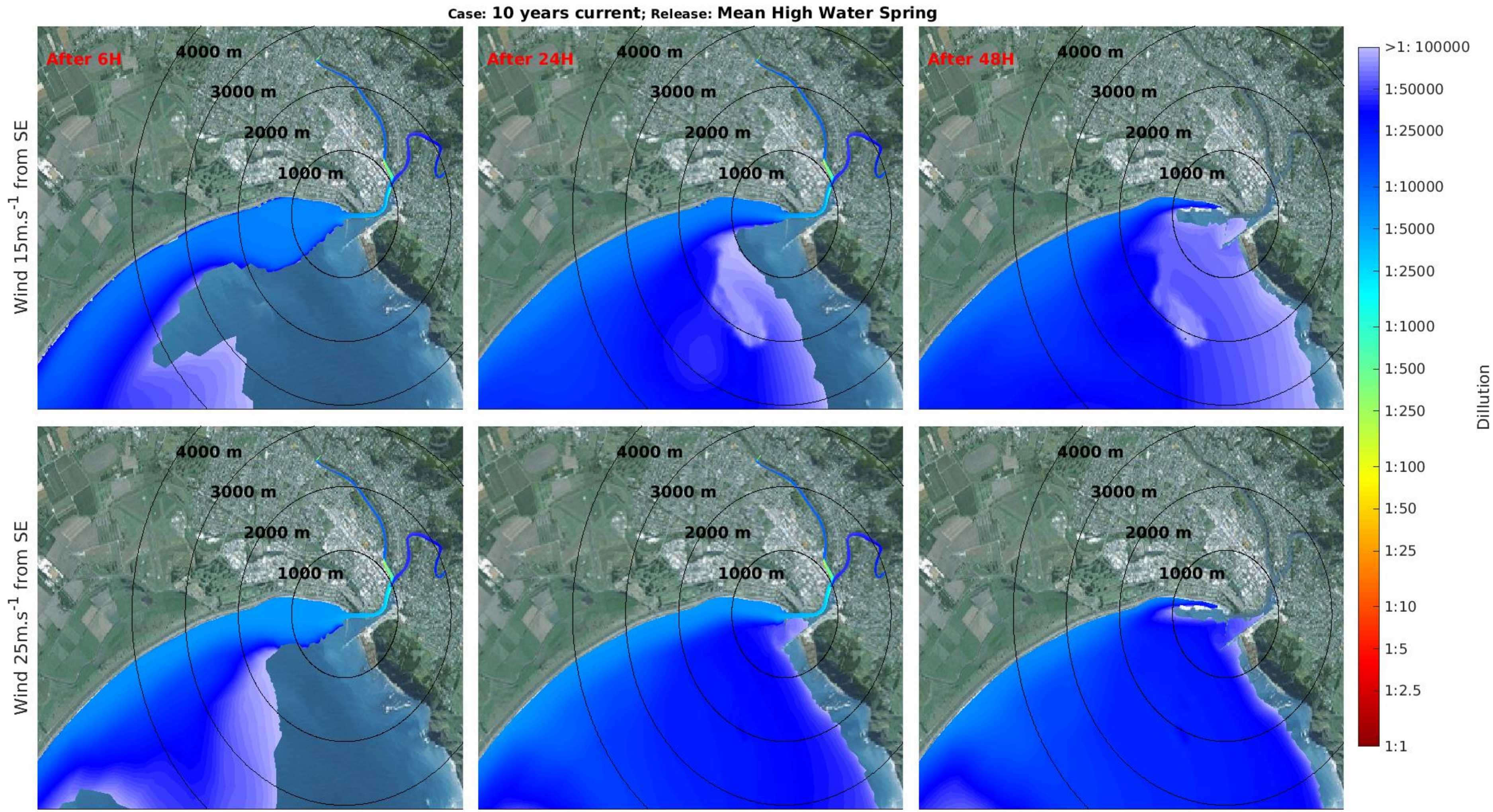

Figure 3.13 Close-up of the 10 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 $m.s^{-1}$ (bottom) South-Easterly wind.

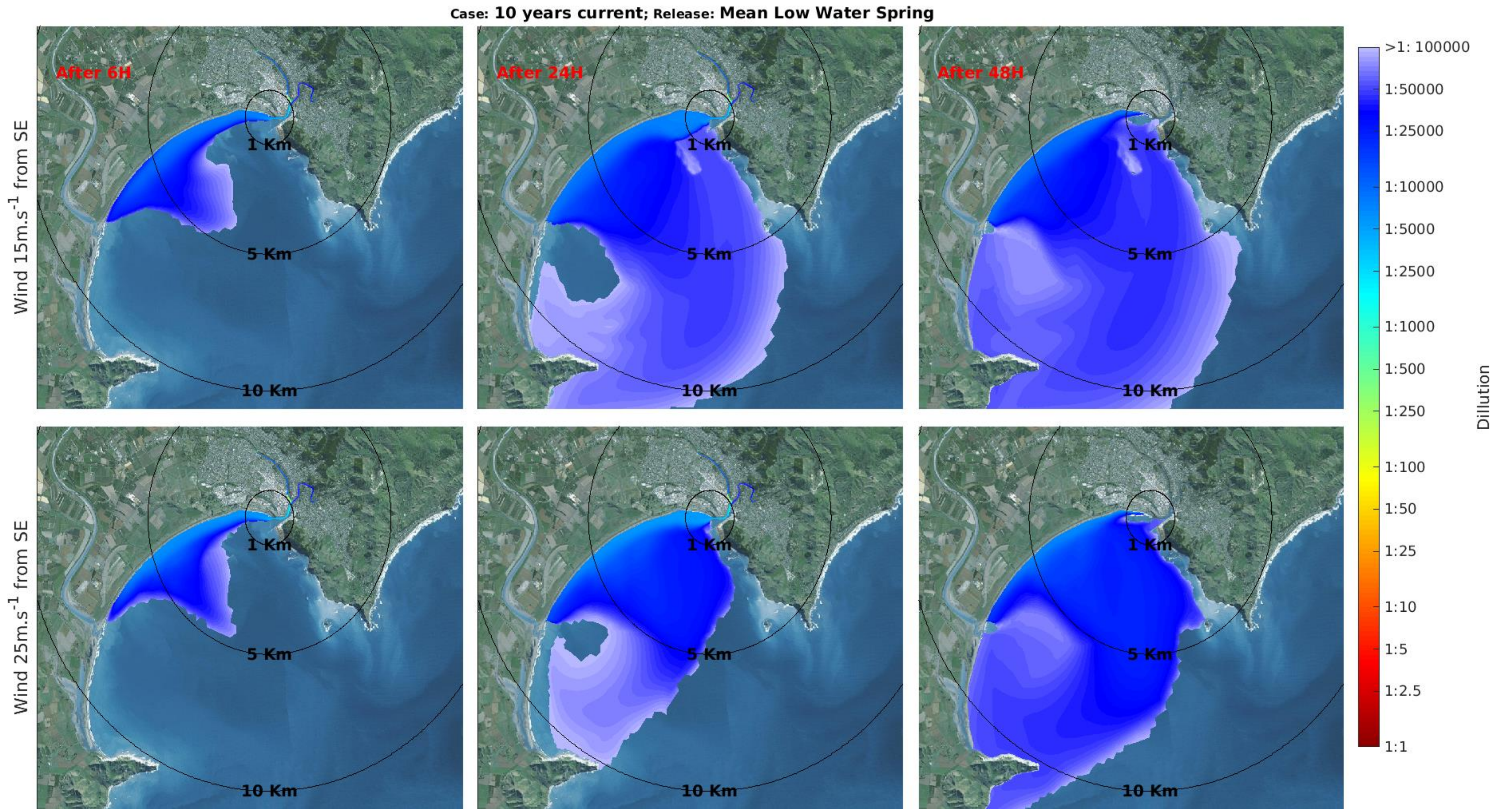

Figure 3.14 *Poverty Bay view of the 10 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 $m.s^{-1}$ (bottom) South-Easterly wind.*

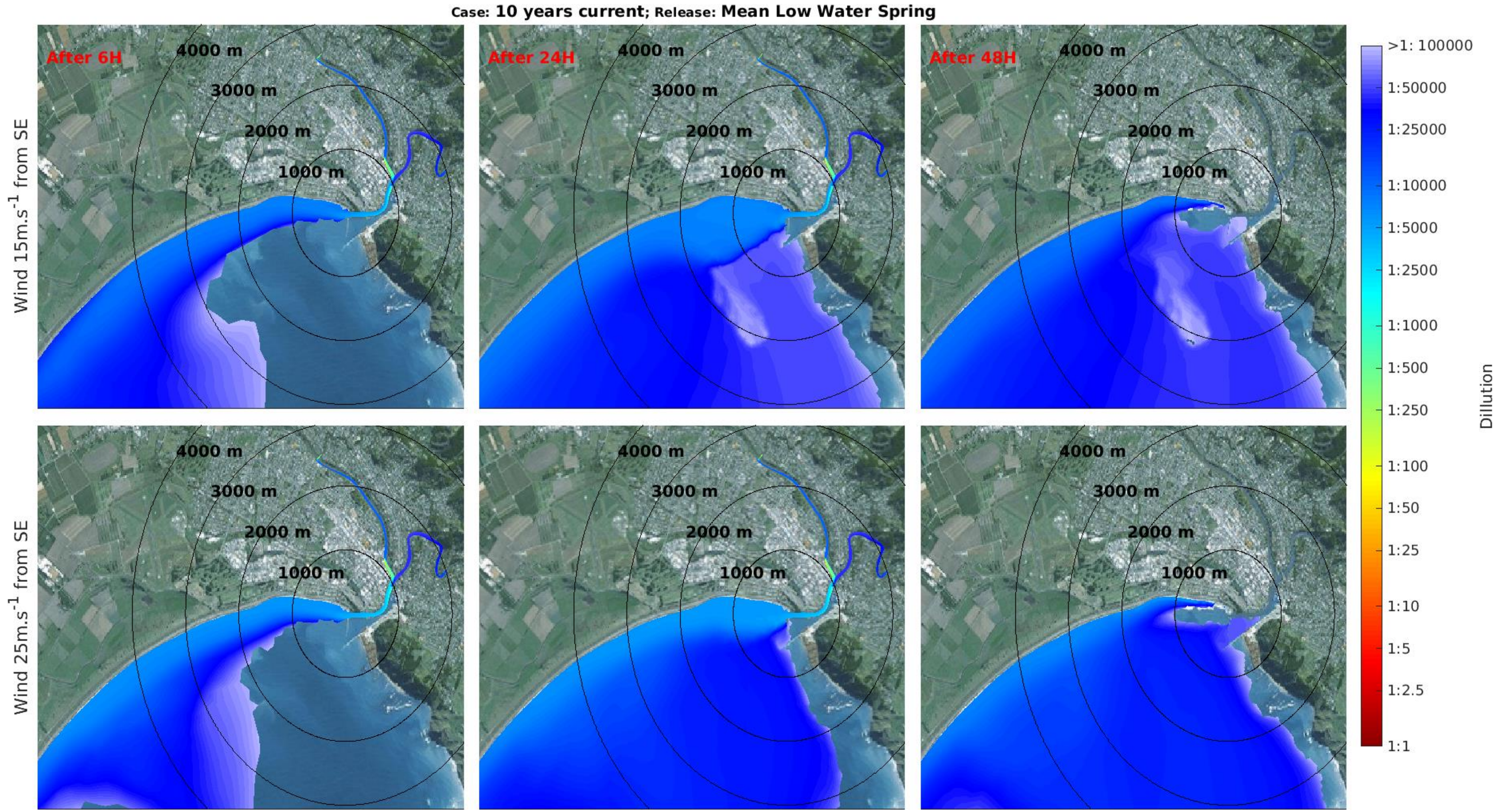

Figure 3.15 Close-up of the 10 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 m.s^{-1} (bottom) South-Easterly wind.

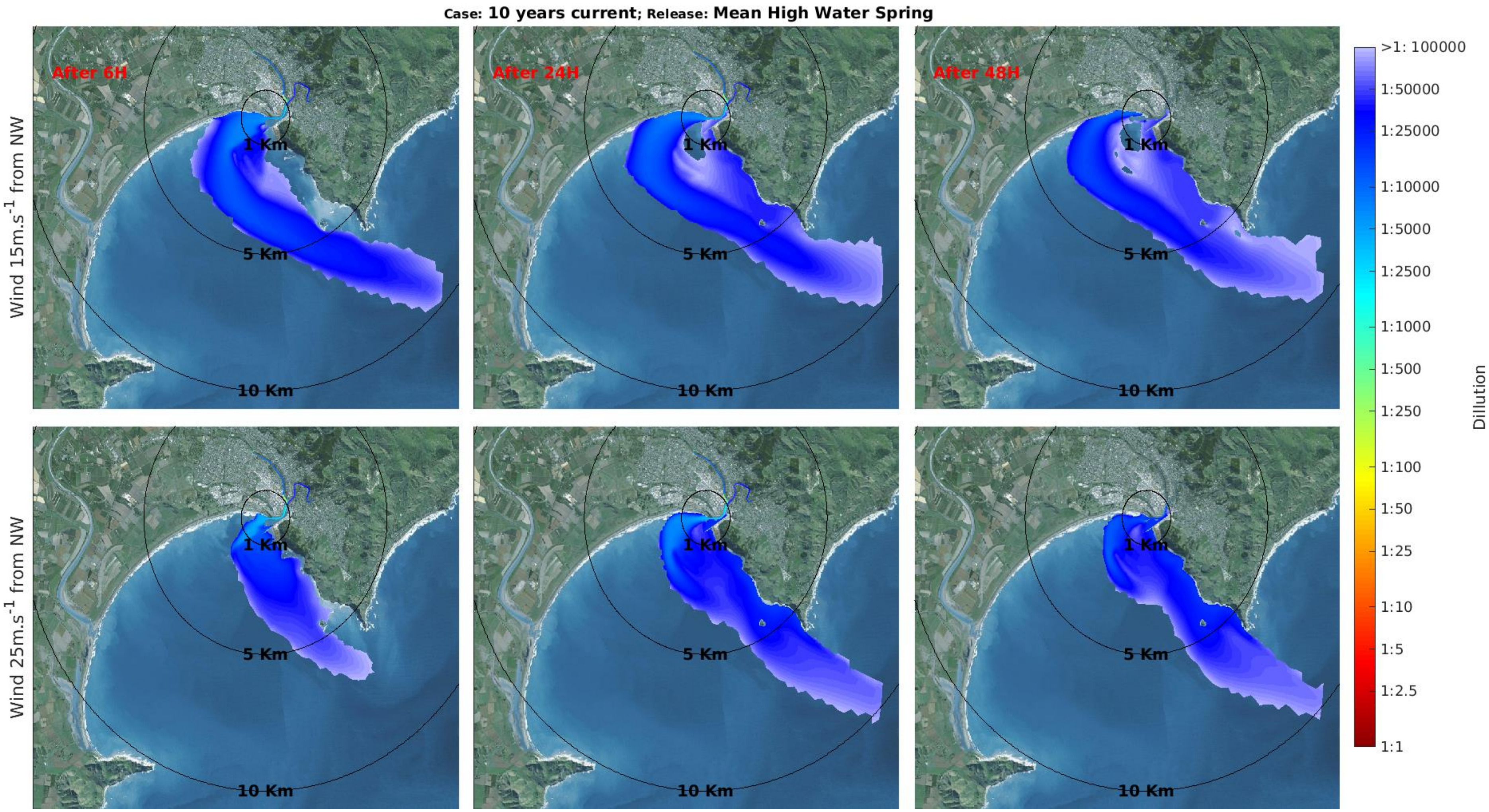

Figure 3.16 Poverty Bay view of the 10 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 m.s^{-1} (bottom) North-Westerly wind.

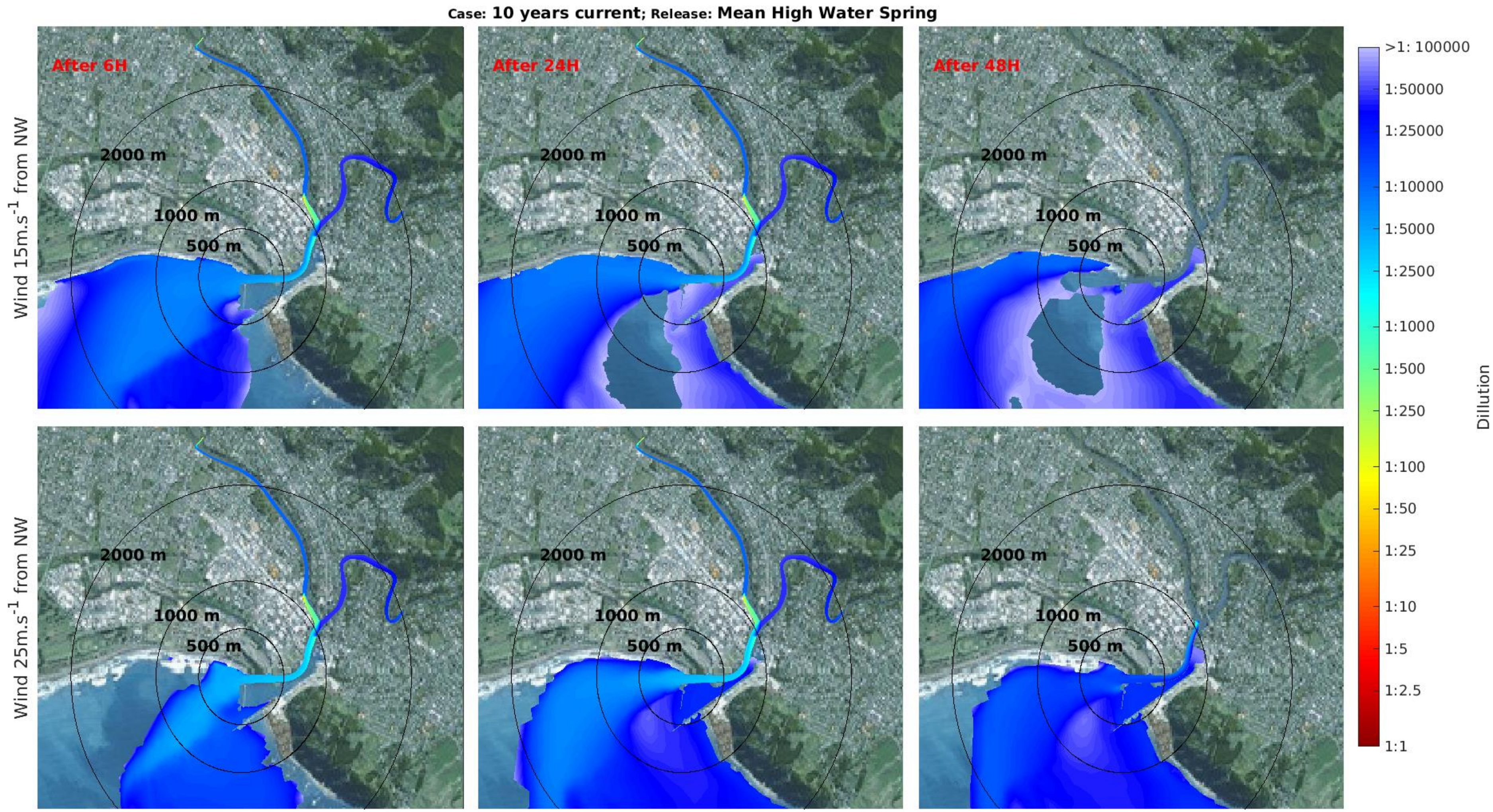

Figure 3.17 *Close-up of the 10 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 $m.s^{-1}$ (bottom) North-Westerly wind.*

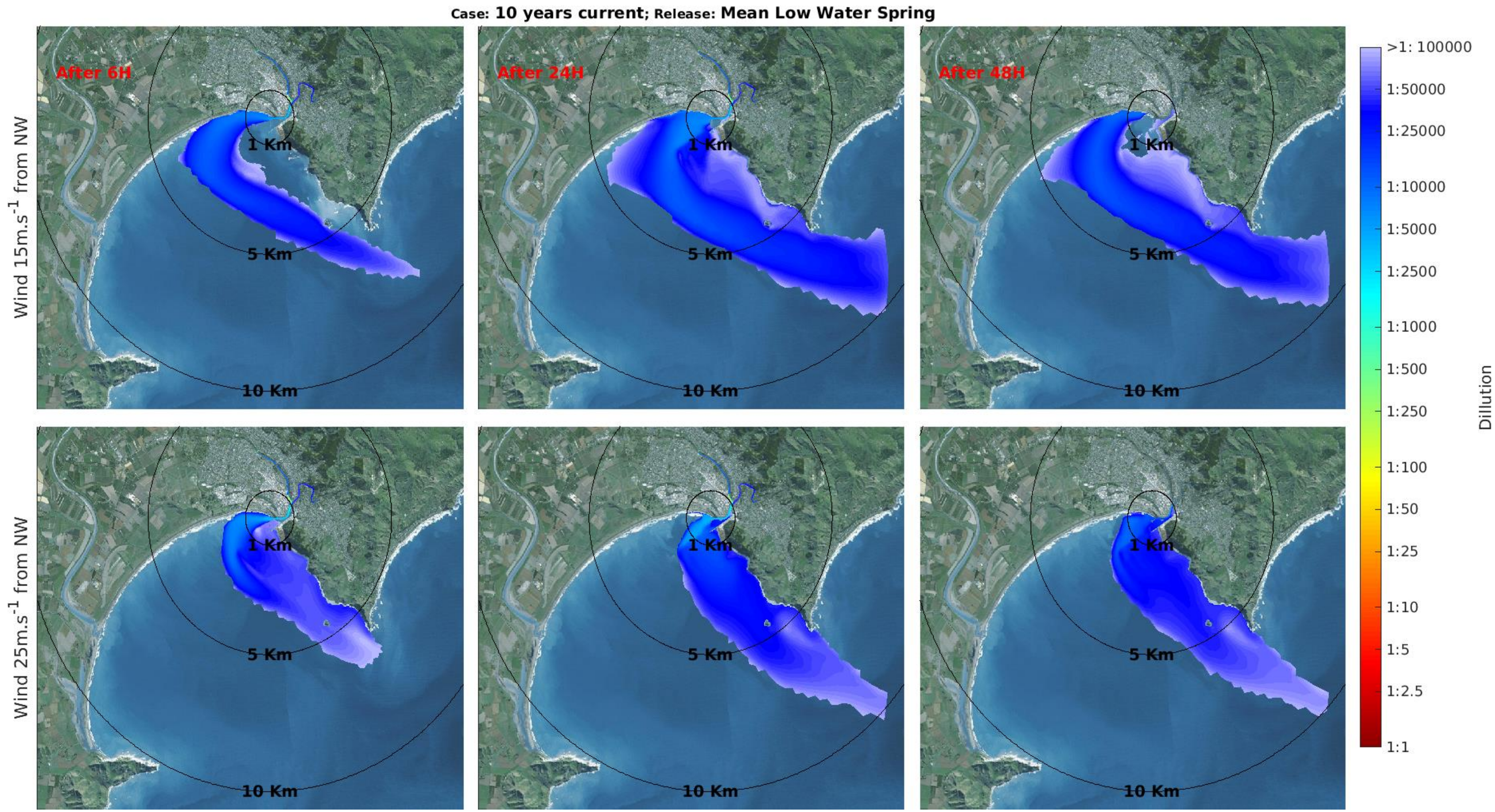

Figure 3.18 *Poverty Bay view of the 10 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 m.s^{-1} (bottom) North-Westerly wind.*

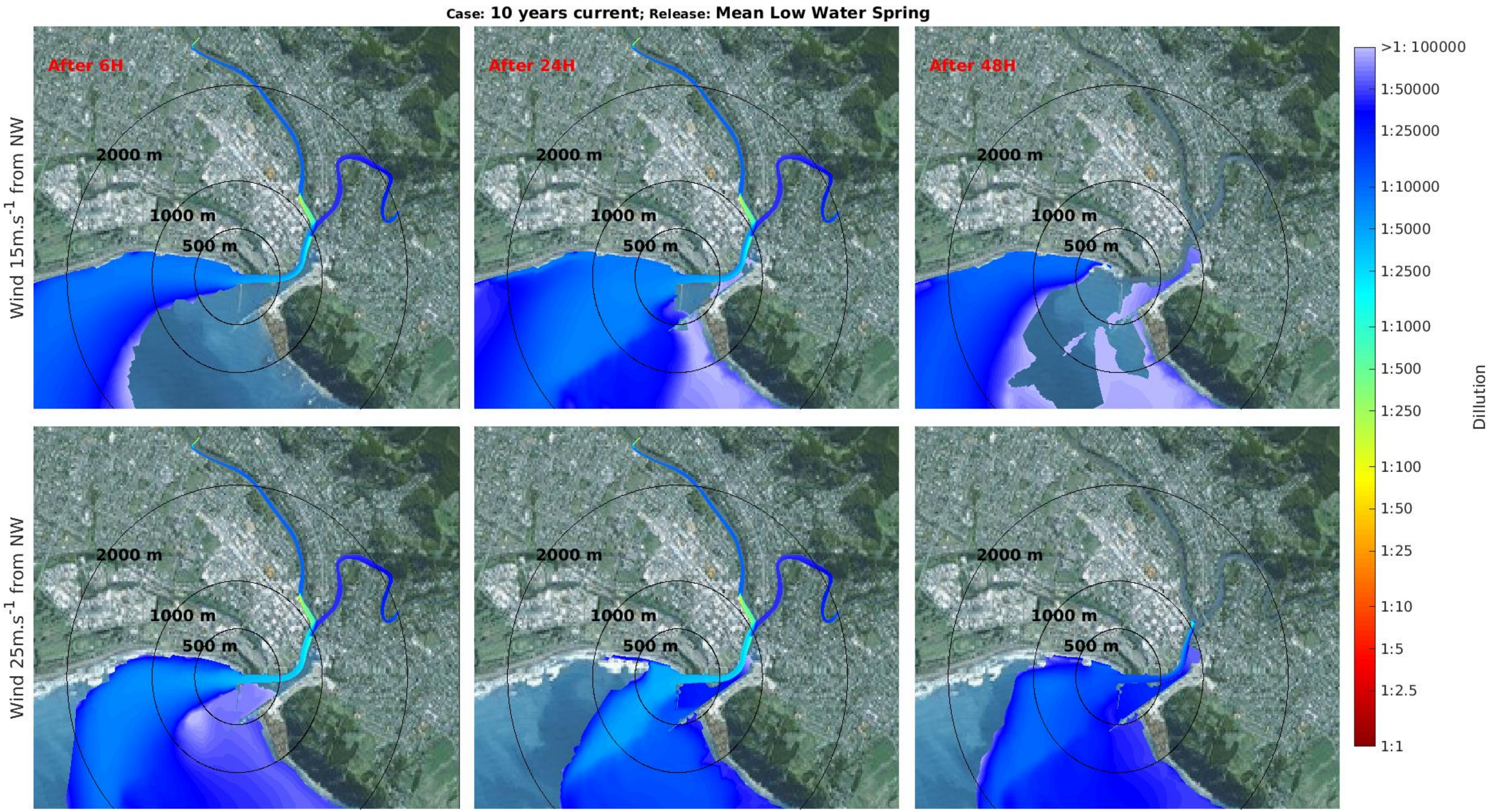

Figure 3.19 Close-up of the 10 year current scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 m.s^{-1} (bottom) North-Westerly wind.

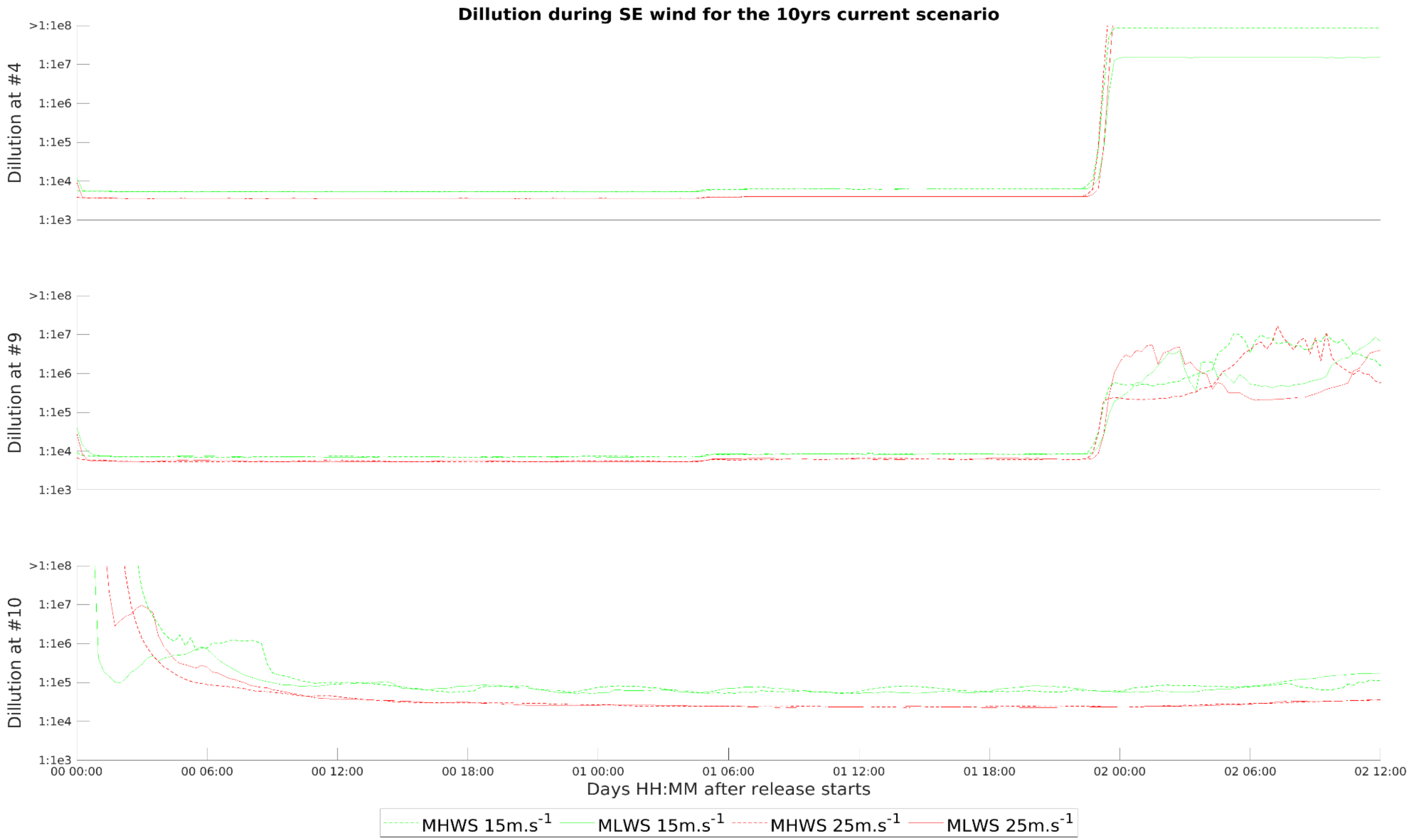

Figure 3.20 Dilution time series extracted at the four locations for the 10yrs current scenario under South-Easterlies condition. The solid line and the dot line represented the initial tidal state of the release (MHWS and MLWS respectively). The 15 m.s^{-1} wind speed is shown by the green colour and the 25 m.s^{-1} is represented by the red colour

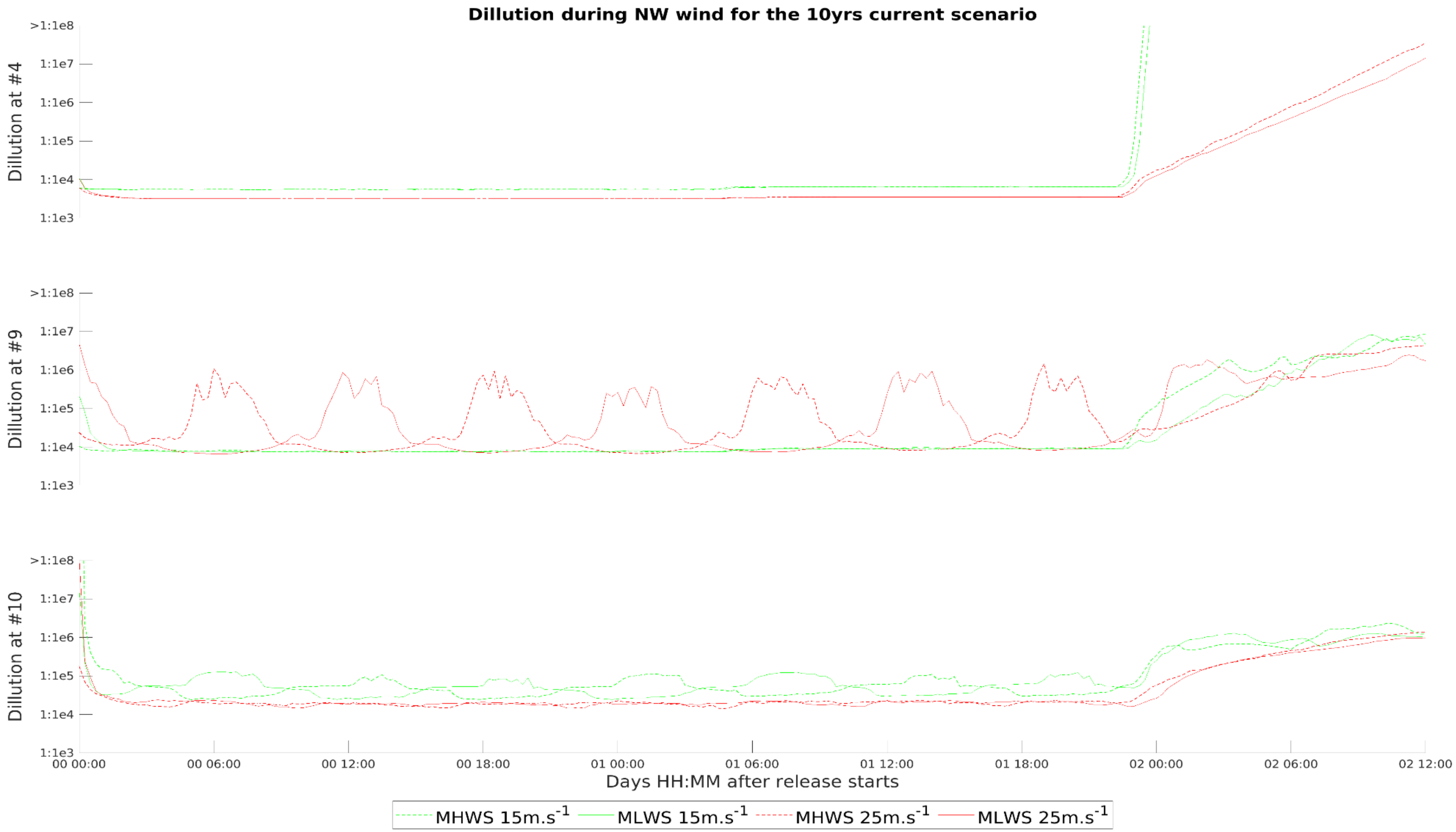

Figure 3.21 Dilution time series extracted at the four locations for the 10yrs current scenario under North-Westerlies condition. The solid line and the dot line represented the initial tidal state of the release (MHWS and MLWS respectively). The 15 m.s^{-1} wind speed is shown by the green colour and the 25 m.s^{-1} is represented by the red colour

3.1.3 10-year ARI future scenarios

Discharge rated for each of the sources are at the 10-year ARI level, assuming the infrastructure upgrade, are provided in Table 2-2, while 10-year ARI fluvial discharges for each of the river/stream sources are defined in Table 2-3.

Dilution plots for persistent and relatively strong S-E wind events (15 and 25 $m.s^{-1}$) are presented in Figure 3.23 and Figure 3.25 for the MHWS and MLWS release respectively, while dilution plots for persistent and relatively strong N-W wind events (15 and 25 $m.s^{-1}$) are presented in in Figure 3.27 and Figure 3.29 for the MHWS and MLWS release respectively.

Relative to the expected discharge rates for the existing network, the improved stormwater infrastructure results in a significant reduction in the expected discharge rate at the 10-year ARI level (Table 2-2,). Correspondingly, this results in a significant reduction in the dilution levels both at the immediate discharge point and within the broader environs, with dilution levels within Poverty Bay outside the mouth of the Turanganui River exceeding 1:10,000 and only limited plume expressions within the Turanganui, Taruheru and Waimata Rivers, and the Waikanea stream for all events modelled. Lowest dilutions rates are found along Waikanea and Midway Beaches under strong S-E winds, and along Kaiti Beach under strong N-W winds.

Time-series of dilutions for each of the events simulated (i.e. varying release conditions and timing) are provided at location #4, #9 and #10 in Figure 3.30 and Figure 3.31.

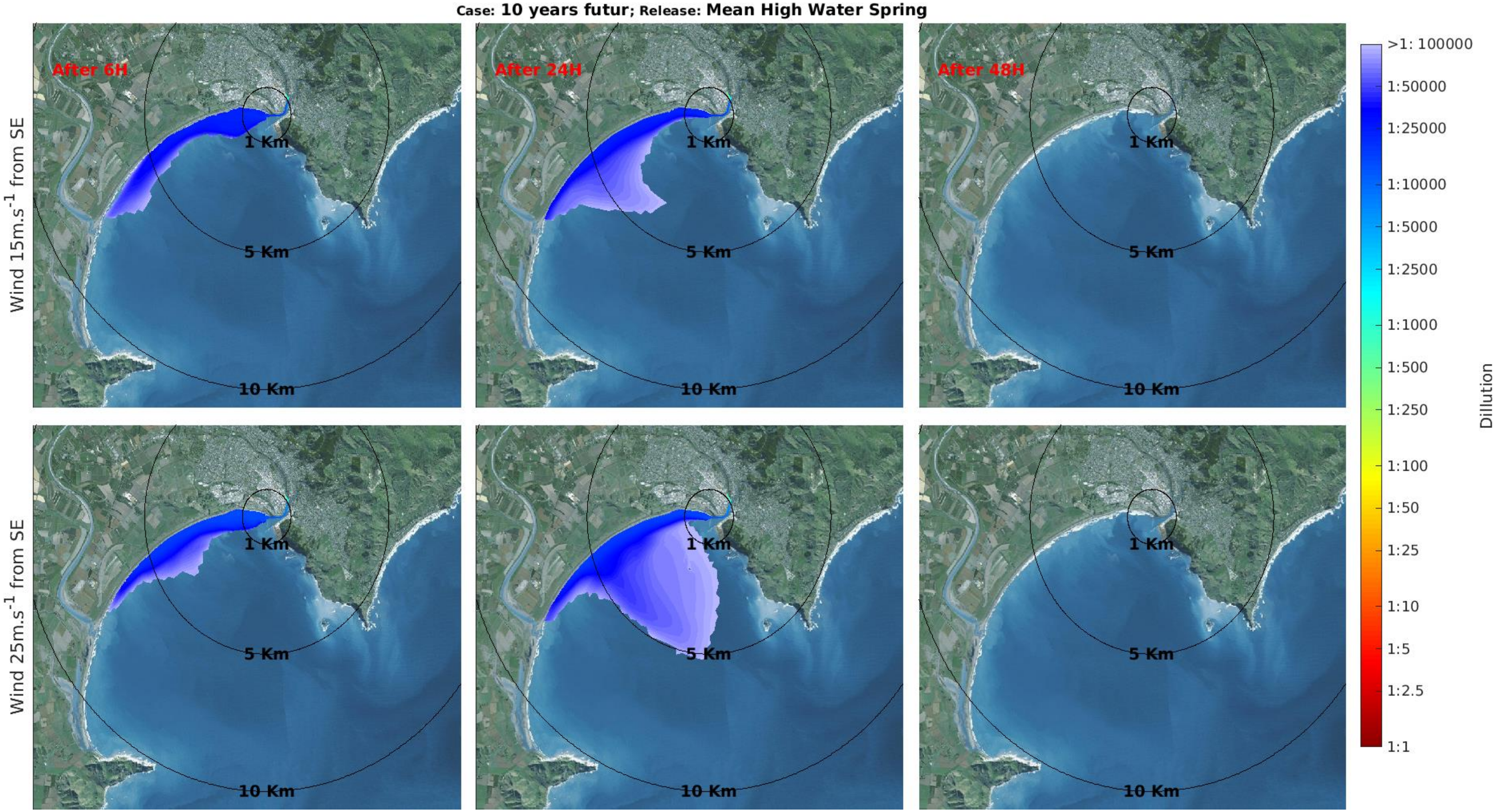

Figure 3.22 Poverty Bay view of the 10 year future scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 $m.s^{-1}$ (bottom) South-Easterly wind.

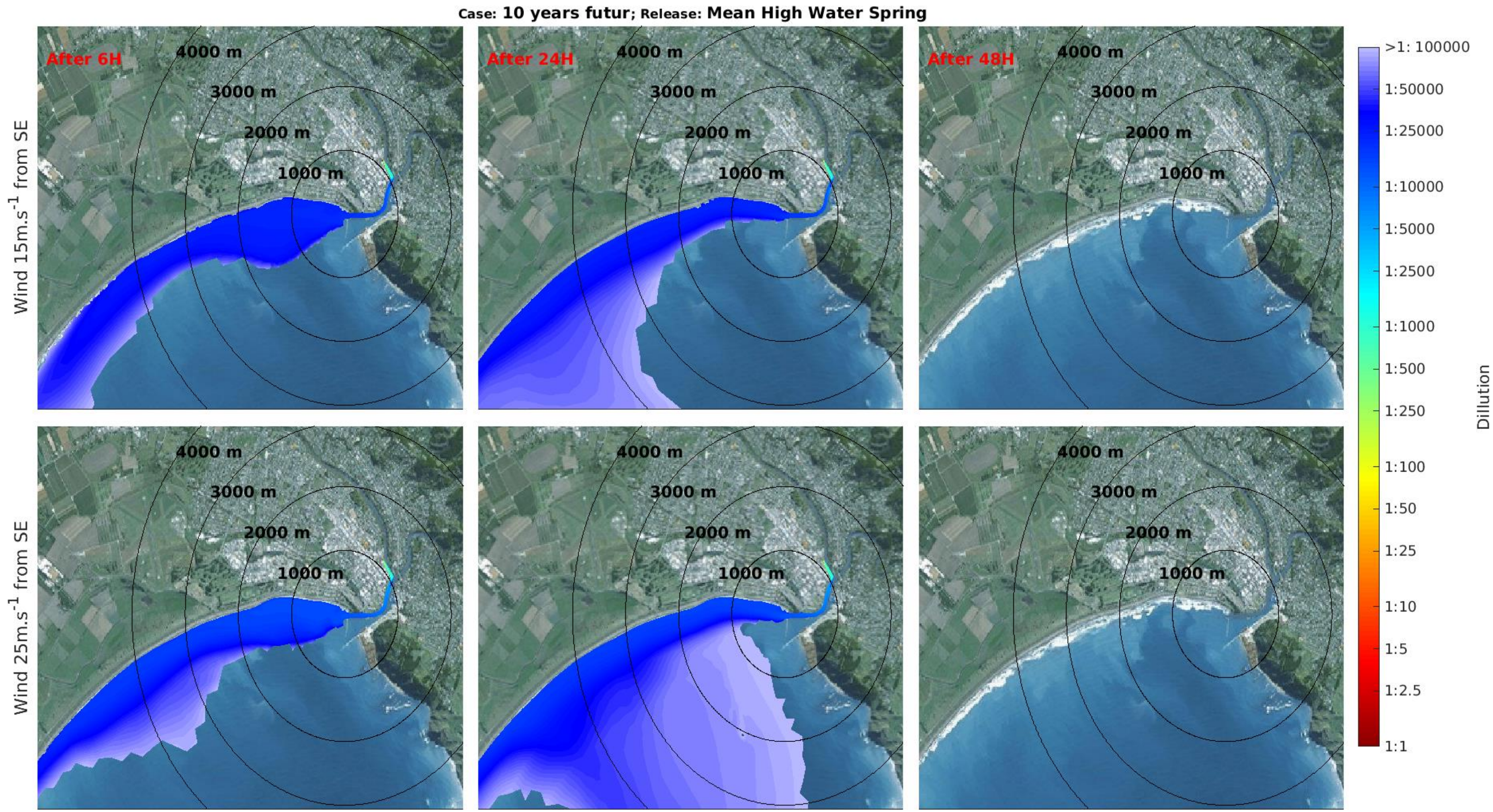

Figure 3.23 Close-up of the 10 year future scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 m.s^{-1} (bottom) South-Easterly wind.

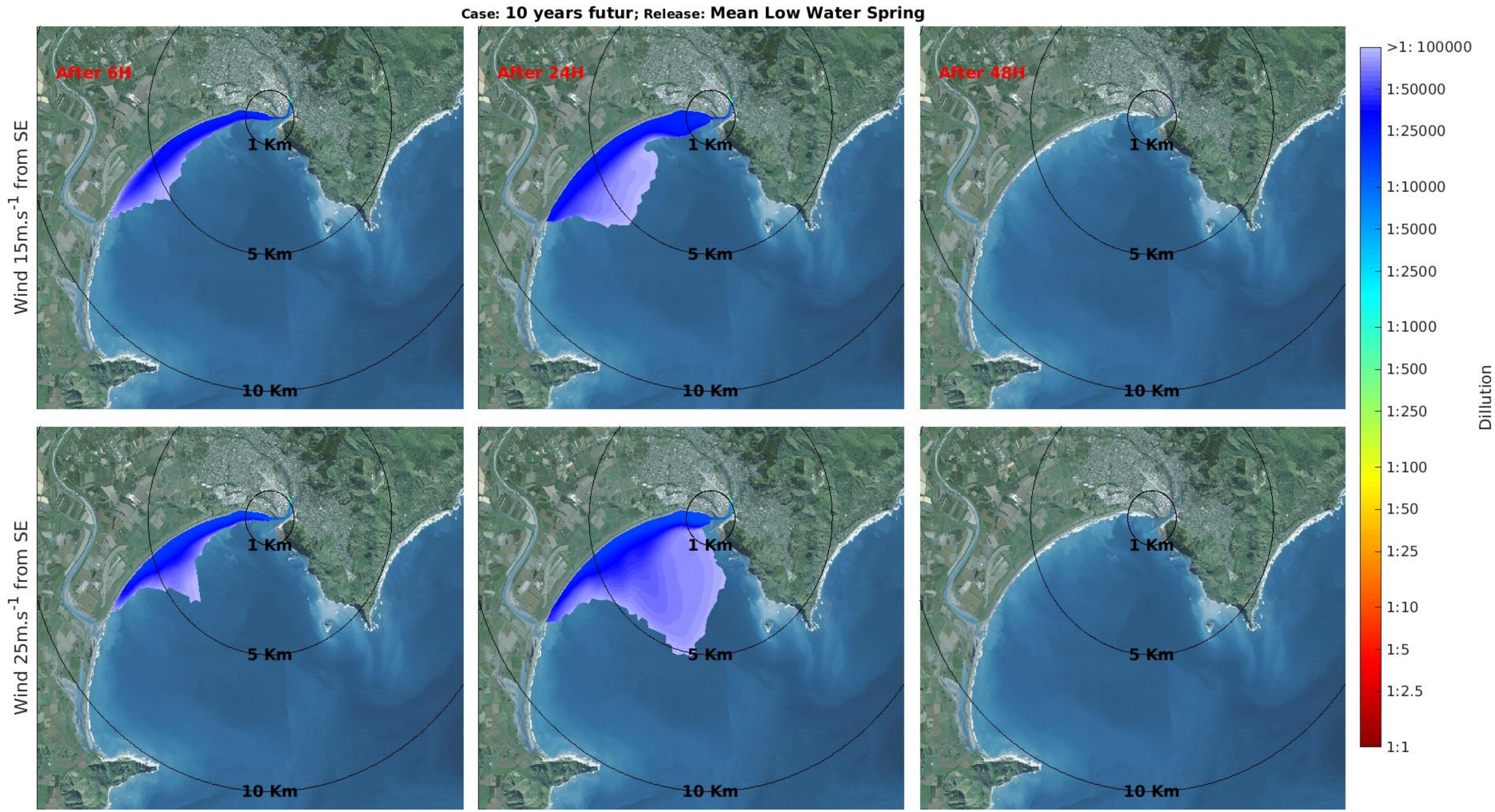

Figure 3.24 Poverty Bay view of the 10 year future scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 m.s^{-1} (bottom) South-Easterly wind.

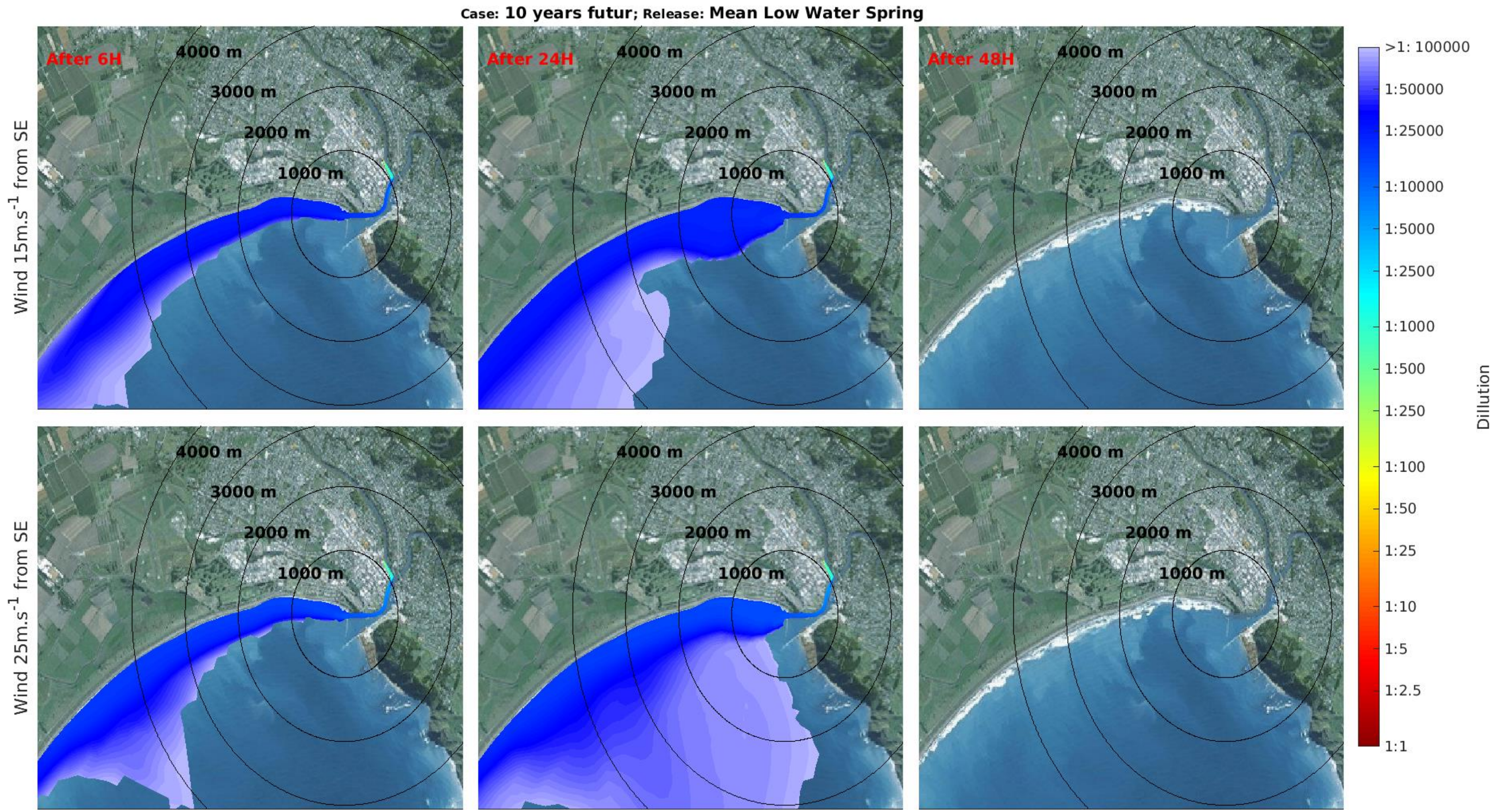

Figure 3.25 Close-up of the 10 year future scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 m.s^{-1} (bottom) South-Easterly wind.

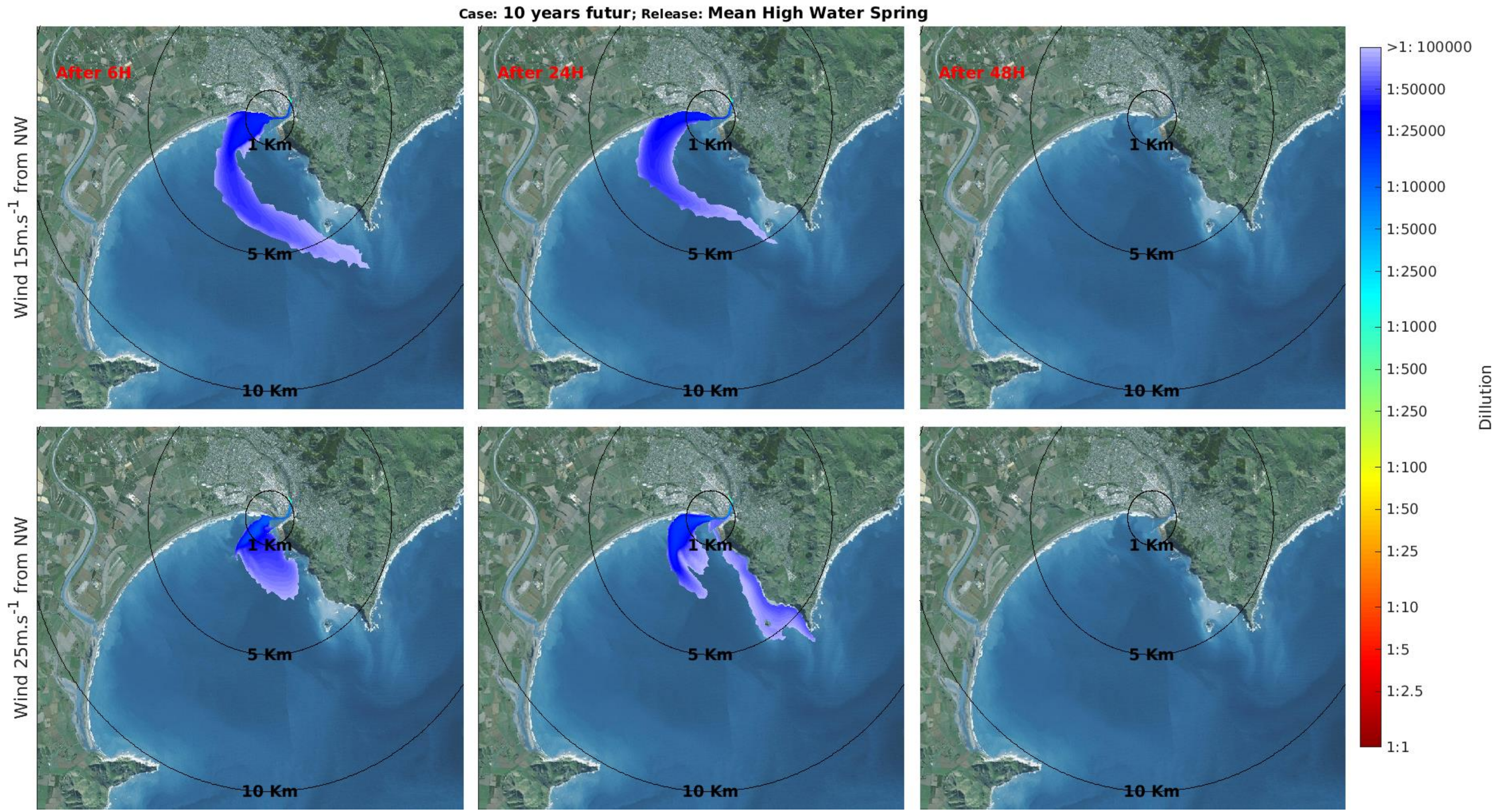

Figure 3.26 Poverty Bay view of the 10 year future scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 m.s^{-1} (bottom) North-Westerly wind.

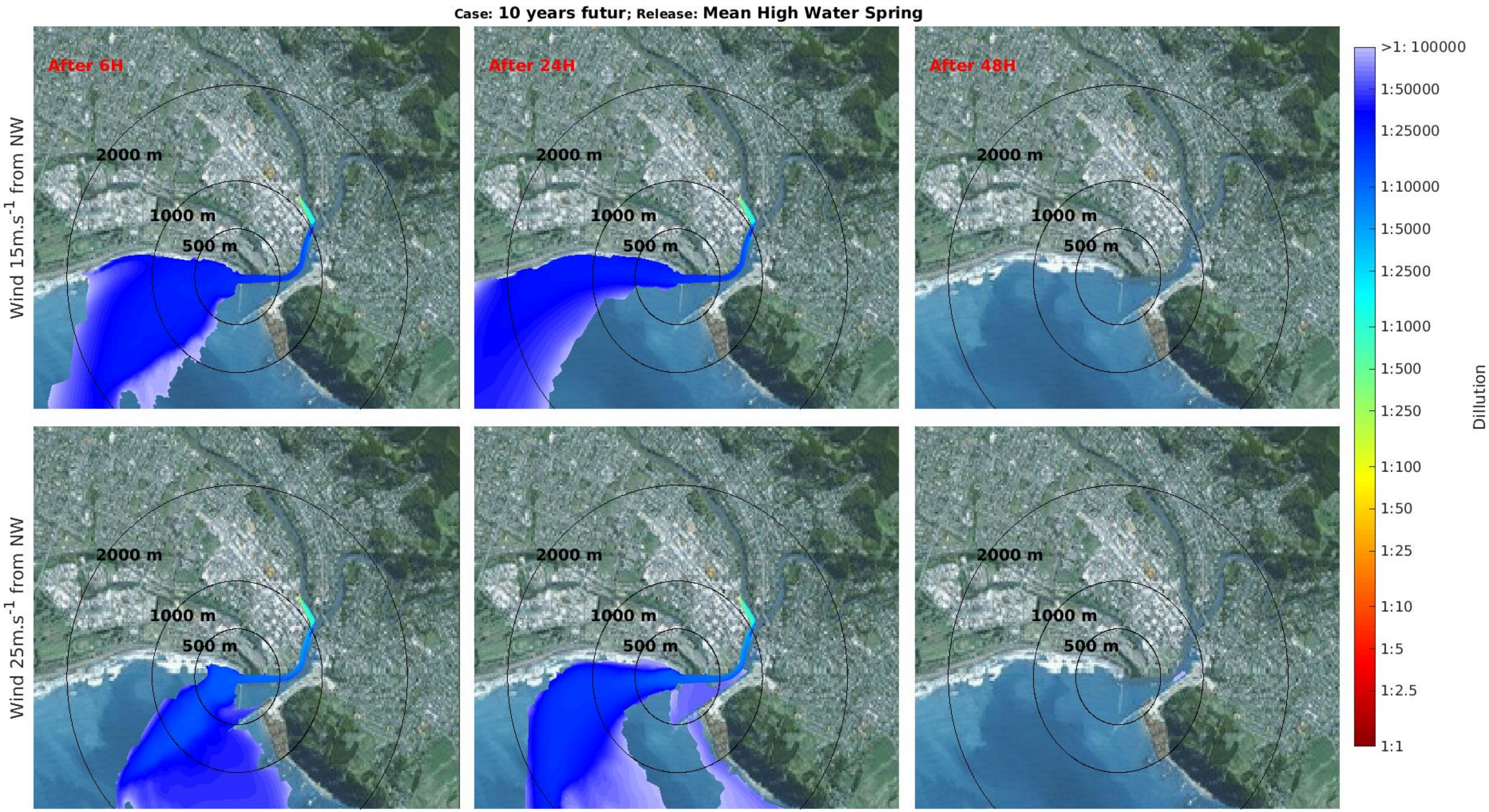

Figure 3.27 Close-up of the 10 year future scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MHWS release with 15 (top) and 25 m.s^{-1} (bottom) North-Westerly wind.

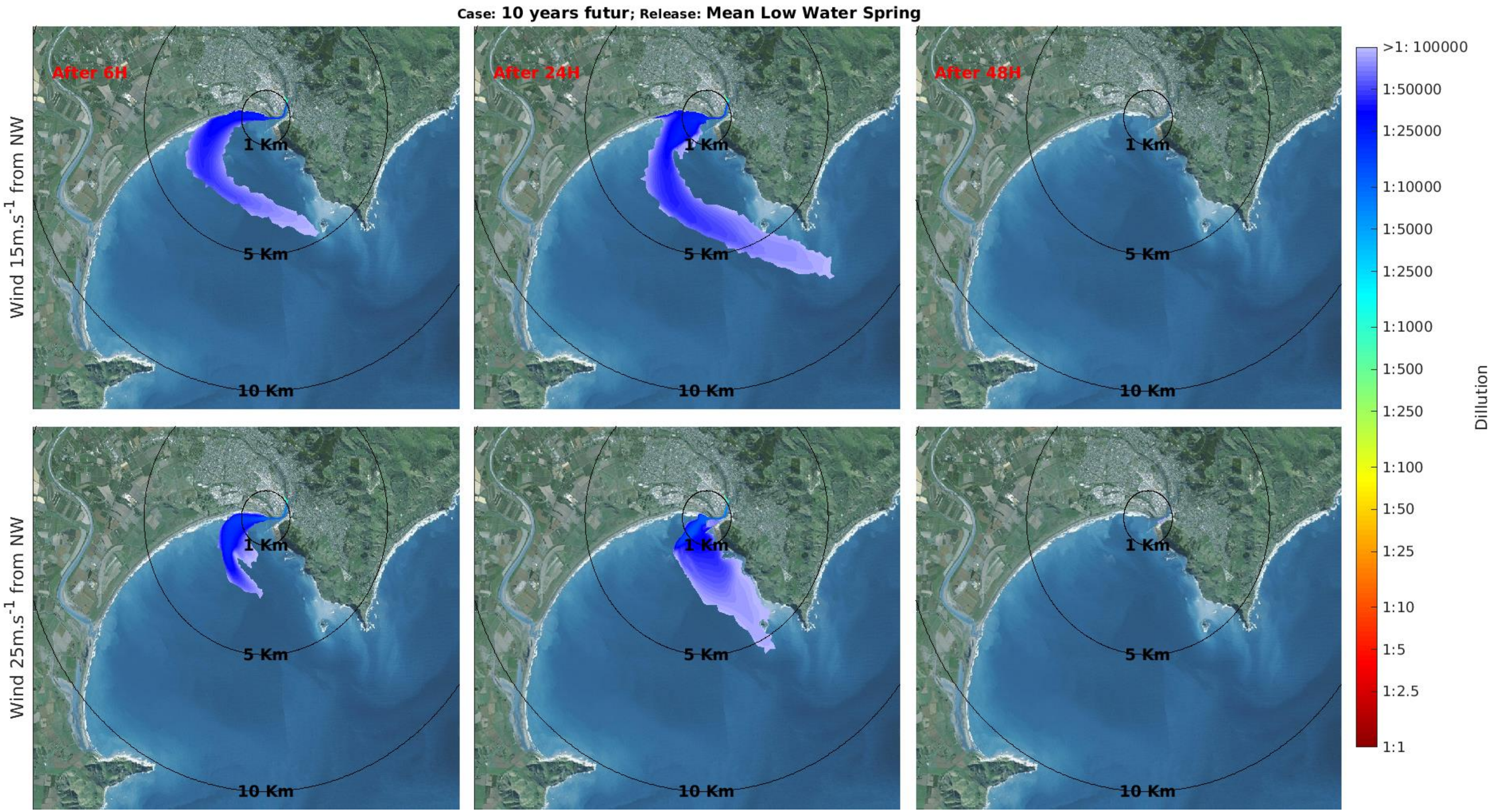

Figure 3.28 Poverty Bay of the 10 year future scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 m.s^{-1} (bottom) North-Westerly wind.

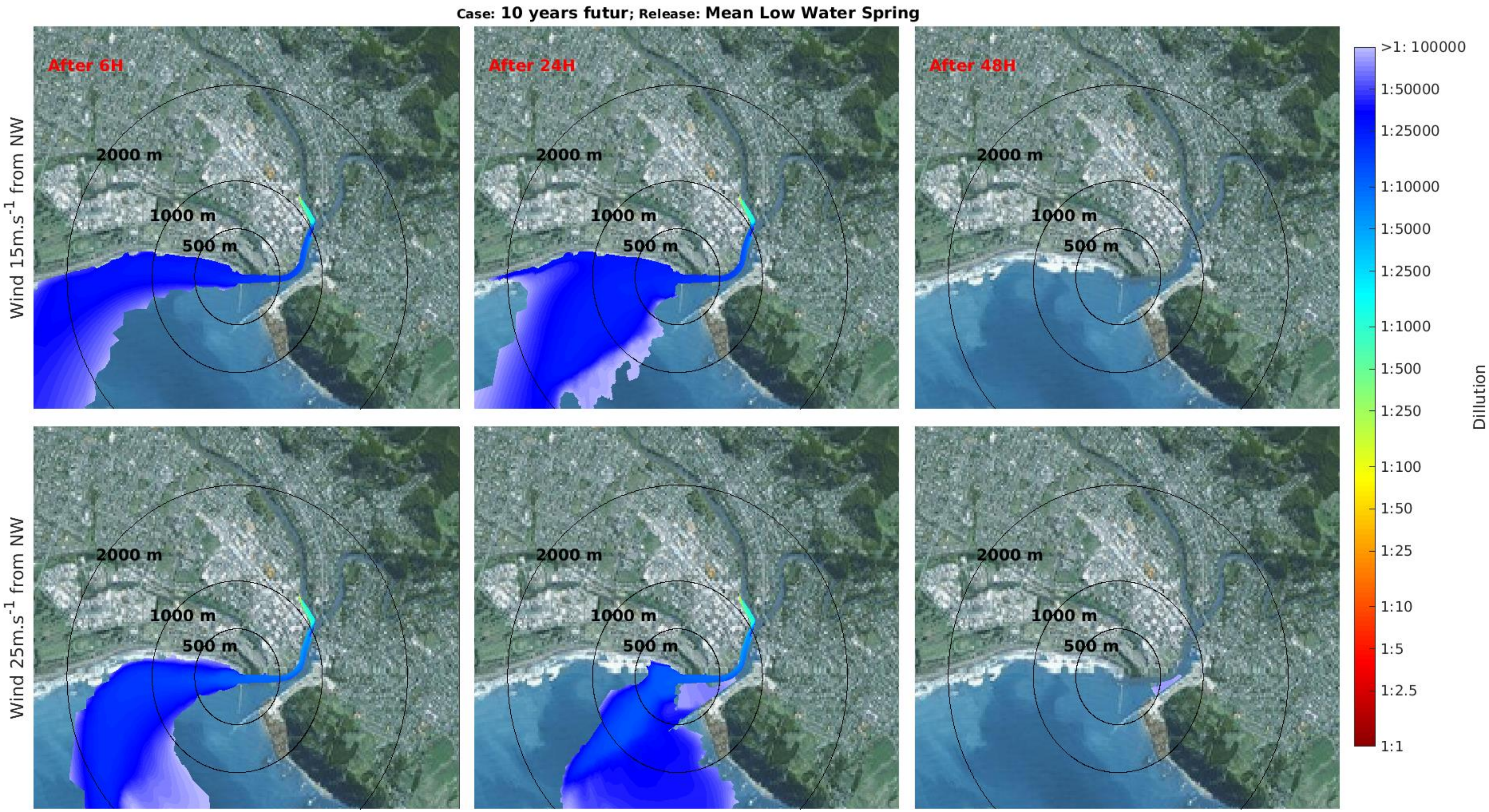

Figure 3.29 Close-up of the 10 year future scenario of minimum dilution field, after 6 (left), 24 (middle) and 48 (right) hours, from a MLWS release with 15 (top) and 25 m.s^{-1} (bottom) North-Westerly wind.

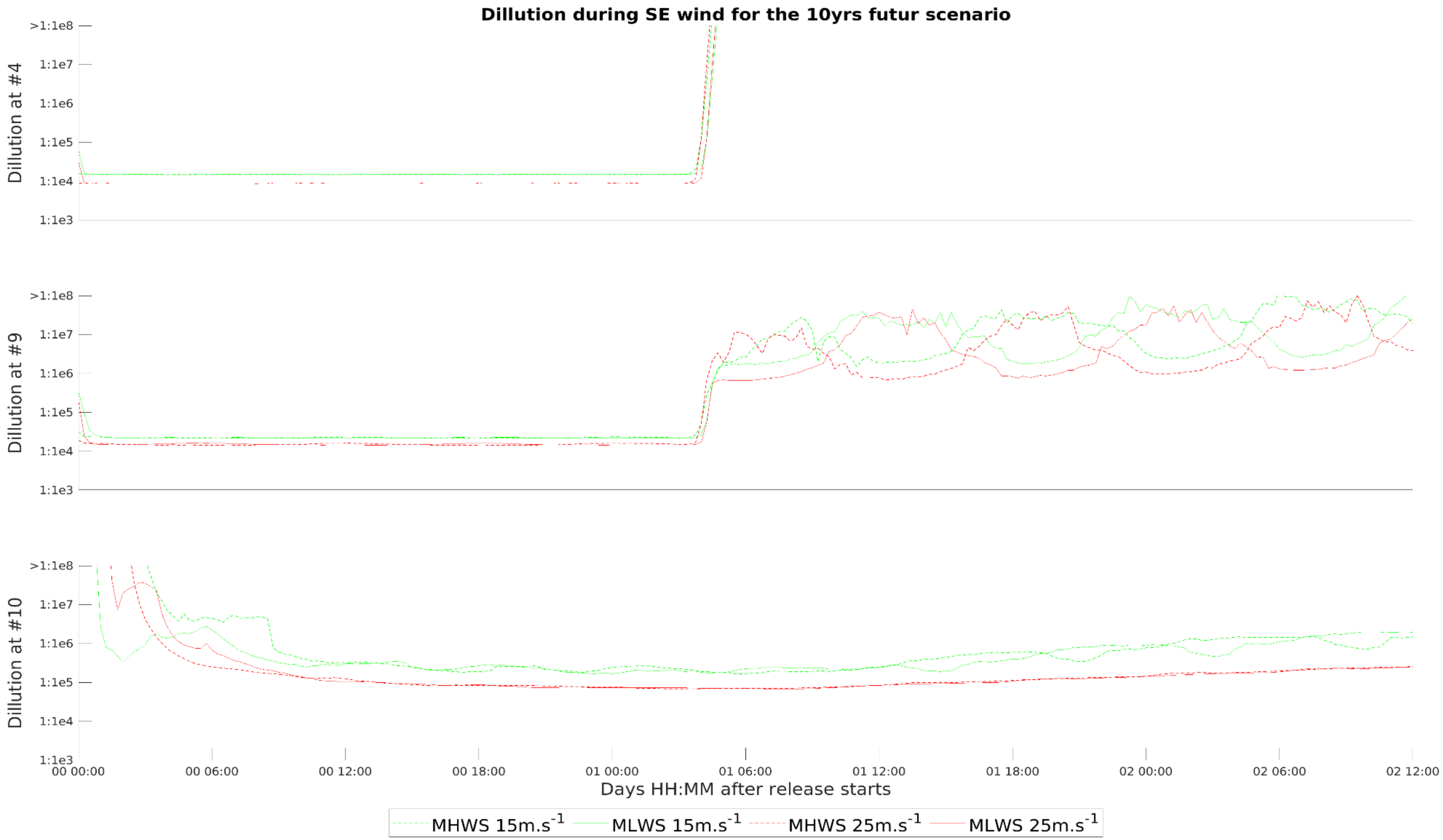

Figure 3.30 Dilution time series extracted at the four locations for the 10yrs future scenario under South-Easterlies condition. The solid line and the dot line represented the initial tidal state of the release (MHWS and MLWS respectively). The 15 $m.s^{-1}$ wind speed is shown by the green colour and the 25 $m.s^{-1}$ is represented by the red colour

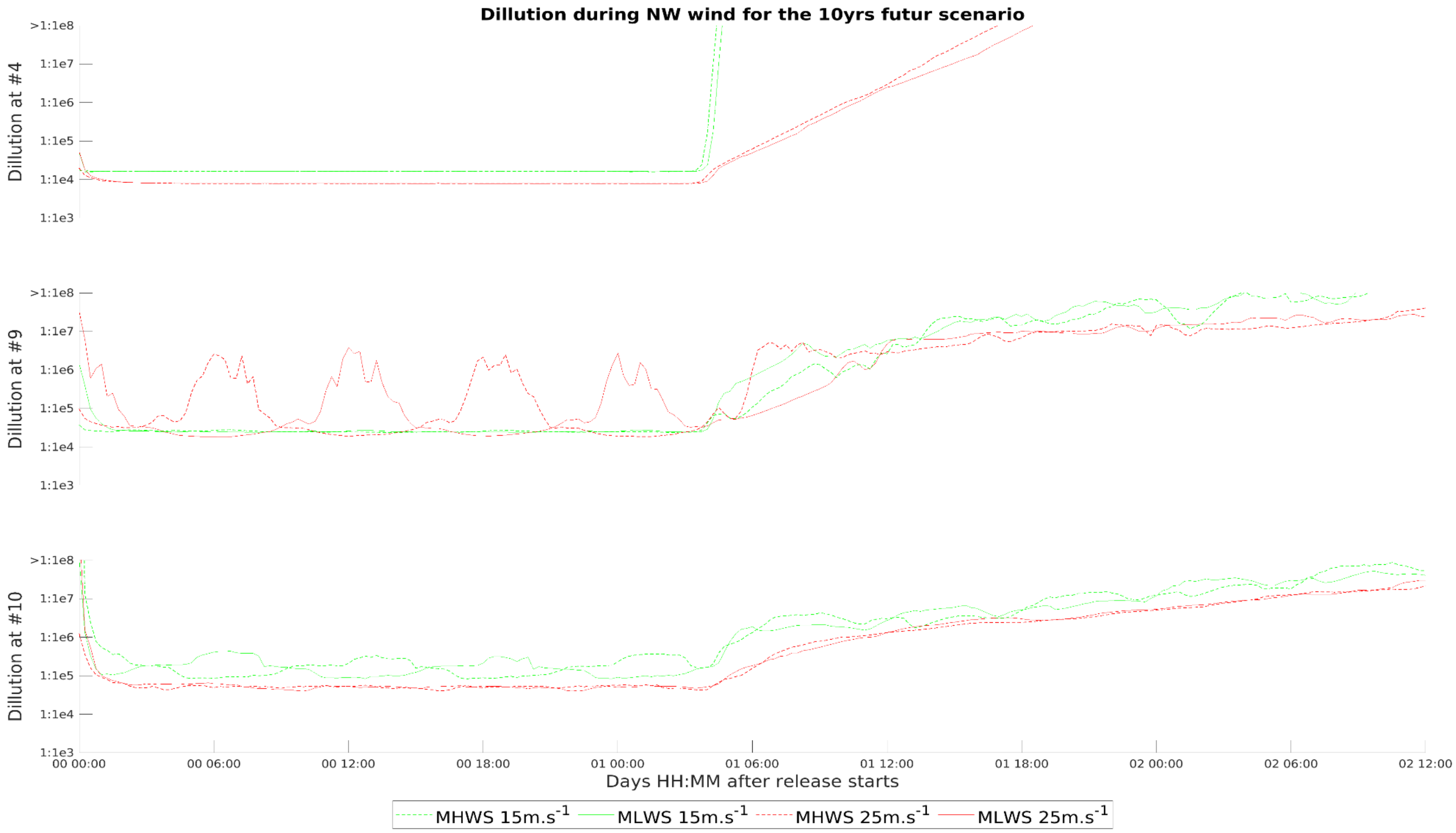

Figure 3.31 Dilution time series extracted at the four locations for the 10yrs future scenario under North-Westerlies condition. The solid line and the dot line represented the initial tidal state of the release (MHWS and MLWS respectively). The 15 m.s^{-1} wind speed is shown by the green colour and the 25 m.s^{-1} is represented by the red colour

3.2 Pollutant results

To characterize water quality, model results were scale with some of the pollutant concentration include in the Table 3-1. Only Enterococci results is shown in this section, viruses and parasites results can been seen in the appendix section

Additional contaminant dilution levels for Total Phosphate, virus loading and Total Suspended Solids, based on initial concentrations provided in Table 3-2, are provided in the Appendix

Table 3-1 Pollutant concentration used at the outfall location

Analyte	Concentration
Enterococci	2,500,000
Viruses/ Parasites	1,000

Table 3-2 Pollutant concentration used at the outfall location as provided in attached Appendices

Analyte	Concentration ($g.m^{-3}$)
Total P	5.05
Total Suspended Solids (TSS)	240

3.2.1 2-year ARI existing scenarios

Enterococci concentration plots for S-E wind events (15 and 25 $m.s^{-1}$) are presented in Figure 3.32 and Figure 3.34 for the MHWS and MLWS release respectively. Enterococci concentration plots for N-W wind events (15 and 25 $m.s^{-1}$) are presented in Figure 3.36 and Figure 3.38 for the MHWS and MLWS release respectively.

Time-series of Enterococci concentration for each of the events simulated (i.e. varying release conditions and timing) are provided at location #4, #9 and #10 in Figure 3.40 and Figure 3.41.