TABLED AT HEARING

Application: Lyttelton Port Co. hearing

Date: 2 May 2017

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Statement of evidence of Brett James Beamsley (sediment and plume modelling and surfing effects)

# SUMMARY

## Sediment and plume modelling, and surfing effects

- Modelling 101
- Plumes during dredging (Capital and Maintenance)
- Disposal plumes (Capital)
- Sediment behaviour post Capital disposal
- Disposal plumes (Maintenance)
- Sediment behaviour post Maintenance disposal
- Surfing effects

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## Sediment and plume modelling, and surfing effects

- **Modelling 101**
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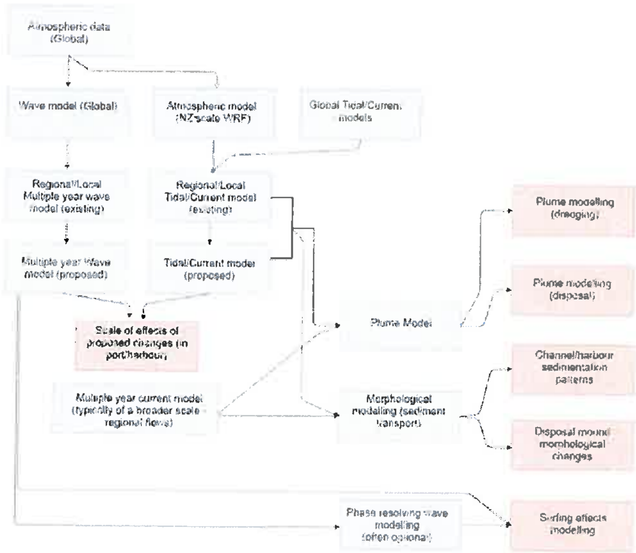
## Sediment and plume modelling, and surfing effects

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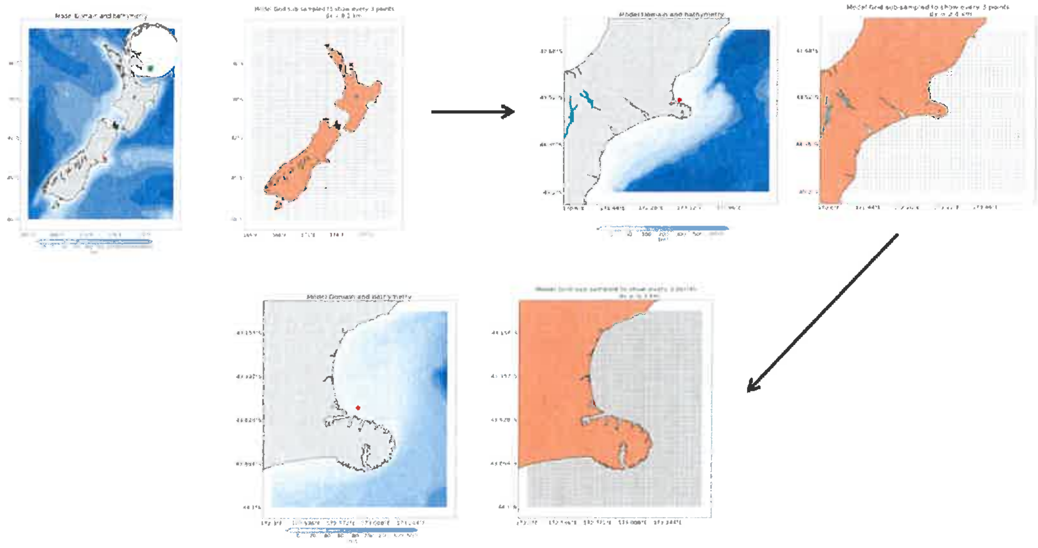
To understand the hydrodynamics and wave processes at the local scale we need to start at the global scale

To understand the scale of effects of a design or proposal we need to consider both the existing and proposed bathymetry

Depending on the model or what we are specifically interested in there is often a lot of sharing information from one model to another, i.e. Atmospheric data can influence both hydrodynamics and waves

## Sediment and plume modelling, and surfing effects



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Waves, currents and atmospheric forcings are stepped down in scale through nesting

This is an example of the nesting approach used to capture the hydrodynamics of the Pegasus Bay region. The model is ROMS.

A similar approach is used of waves using SWAN.

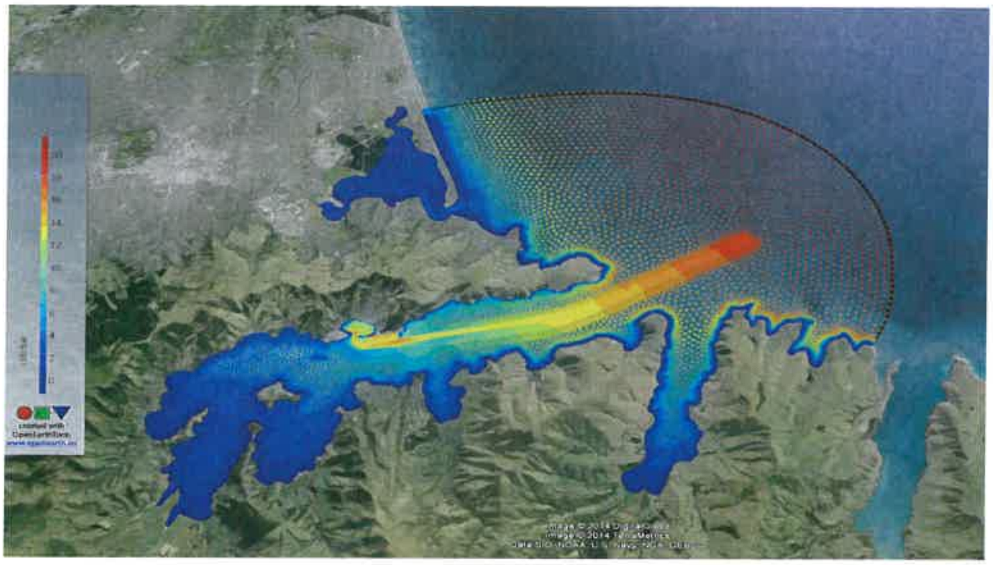
Started at a global scale and decreased to approximately 250-300 m resolution

This was necessary to ensure that we accurately captured the transfer of energy from the Southland Current into the eddy that forms in the Lee of Banks Peninsular

These models are industry standard and are used globally and is also used as part of operational forecast models internationally.

10 Years hindcast

## Sediment and plume modelling, and surfing effects



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Boundary conditions are passed from one domain to the next allowing high resolution domains that are designed to focus on the salient forcing mechanisms can be developed.

Here is an example of the domain used to simulate hydrodynamics in Lyttelton Harbour.

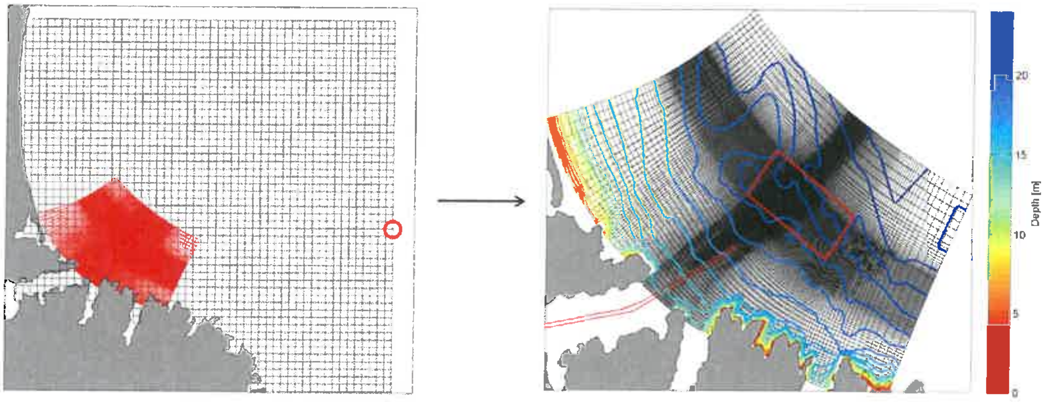
We used a finite element domain - which has a triangle grid with resolution decreasing to ~15 m in key areas

Numerics of these type of models are well understood and are essentially consistent irrespective of the model or who is applying it.

This is an industry standard model that is used globally and is also used as part of operational forecast models internationally.

Used to examine the salient hydrodynamics of Lyttetlon Harbour (tidal and seiche)

## Sediment and plume modelling, and surfing effects




Morphological models need to consider

- Waves
- Hydrodynamics, and
- Morphological or bathymetric changes

Boundary conditions come from the regional wave and hydrodynamic model

We have used the industry standard Delft3D model and applied it in an industry standard way in order to understand medium term morphological response.

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## Plumes during dredging (Capital and Maintenance)

- Sediment expected to be largely the same (4 different fractions considered, min $w_f$ = 1 mm/s).
- Exact timing of dredging (and hence forcing conditions) will be unknown – so a probabilistic approach has been taken.
- Source terms will be the same for both Capital and Maintenance (assuming a TSHD).
- Drag head (bottom 2 m @ 25 kg/s)
- Prop wash (bottom 4 m @ 25 kg/s), and
- Overflow consisting of
  - Sediment de-entrained from plume descent (through entire water column @ 25% of release rate), and
  - Sediment entrained following bed collapse of dynamic plume (bottom 2 m @ 25% of release rate)
  - Release rate of 1600 kg/s

HR Wallingford (2013) recommend surface loss of 50% for water depths less than 20m, but this decreases to 1% if a environmental or green valve is used (as will be the case here). Further, in the absence of evidence, HR Wallingford (2013) recommend de-entrainment be set to ZERO.

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Sediment largely the same based on sampling and coring

Fall velocity of 1 mm/s based on best practice for flocculated sediment

Trailer Suction Hopper Dredge proposed to be used for both Capital and Maintenance

Two modes of dredging (dredging and overflow or spill)

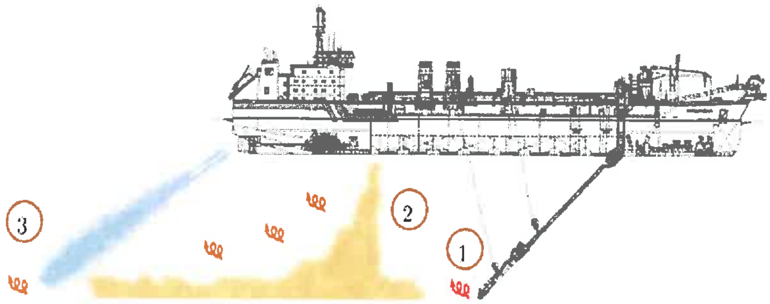
Overflow used to maximise amount of sediment in hopper

Overflow impact time dependant - 10 20 and 30 min

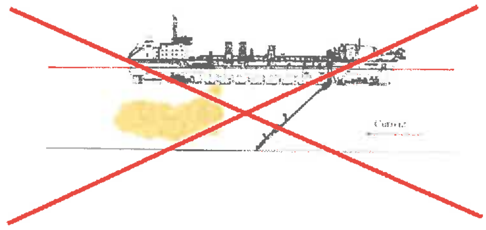
Modelled through **entire water** column

Maintenance dredging plumes expected to be smaller due to size of dredger

## Plumes during dredging (Capital and Maintenance)




- Overflow is time-dependant and have tested 10, 20 and 30 minutes.
  - Drag head (bottom 2 m @ 25 kg/s) - 1 above
  - Prop wash (bottom 4 m @ 25 kg/s) - 3 above, and
  - Overflow - 2 above



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Overflow actually occurs at base of hull, which is about 10m once the hopper is approaching being filled.

– so modelling through entire water column results in the sediment taking longer to settle and dispersed further.

- Calculations considering the water depth, overflow discharge characteristics and relative current velocities suggested that plume would fall as a dynamic plume to the seabed

## Plumes during dredging (Capital and Maintenance)

- Within Lyttelton Harbour the salient forcing mechanism expected to be tidal velocities (0.3-0.5 m/s)
- Seiche velocities provide a secondary forcing mechanism (3-4hr period @ ~0.1 m/s)
- Other potential forcing mechanisms, including wind induced currents expected to have minor to less than minor effect on plume dispersion (of order 5% of the tidal velocities at plume depths)

- Current velocities have been defined using a <u>calibrated</u> hydrodynamic model (both existing and proposed)
- Particles tracking simulations run for 28 days to provide probabilistic representation of plume
- Particles released at 12 different locations within the harbour

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Salient or the most important mechanism **<u>based on measured data</u>** is tidal velocities

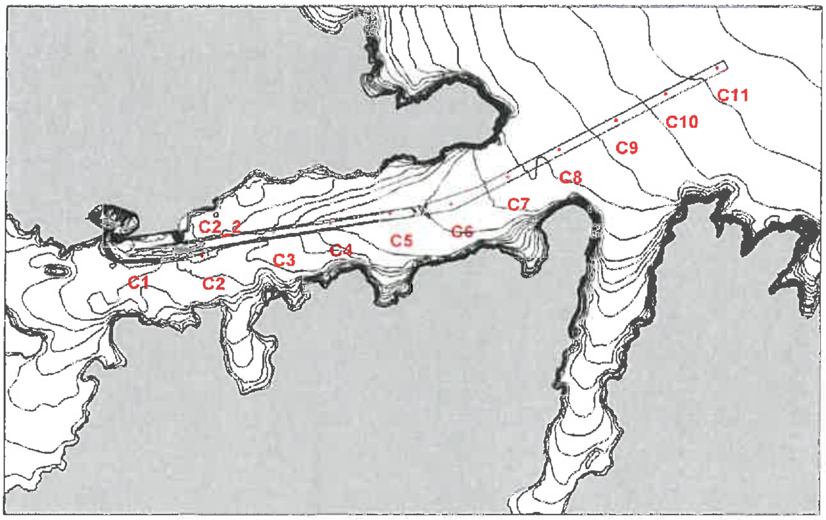
Seiche velocities with 3-4 hr period and ~0.1 m/s also considered

Other potential forcing mechanisms expected to be minor and of the order 5% to the salient velocities at plume depths

Hydrodynamic model is <u>calibrated</u>.

Running for 28 days allows probabilistic or statistical analysis of the expected plume extents

## Plumes during dredging (Capital and Maintenance)

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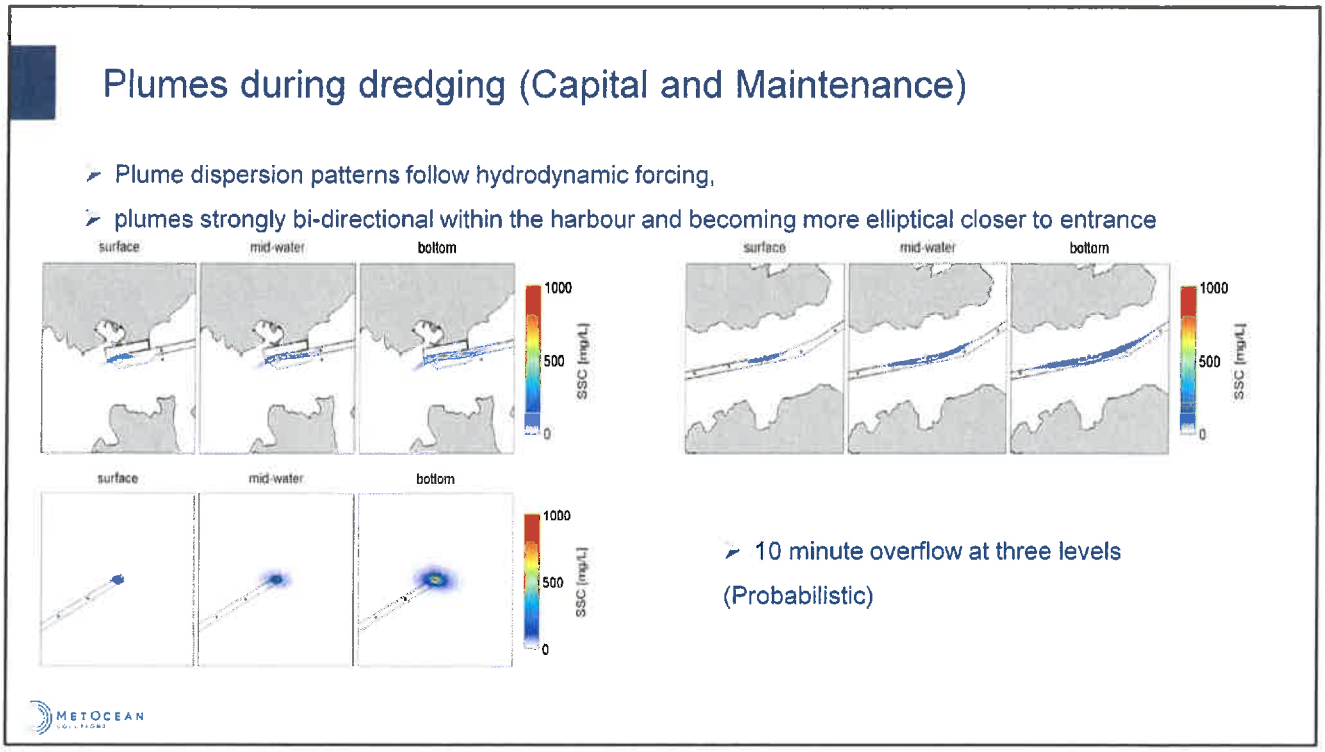
Both the existing and proposed harbour bathymetry were modelled and the plumes associated with both produced

12 sites




Plumes examined at three different depths

- Surface
- Mid water
- Bottom

Probabilistic over 28 days

Probabilistically extend less than 0.5 km in all layers for dredging only mode, and of the order 1-1.5 km at the most (in the bottom layer) for overflow mode

Dredging only phase concentrated in the bottom part of the water column

Overflow SSC can exceed 1000 mg/L in all layers but tends to be very limited in surface layer (50 m) extending to 100-200 m in bottom

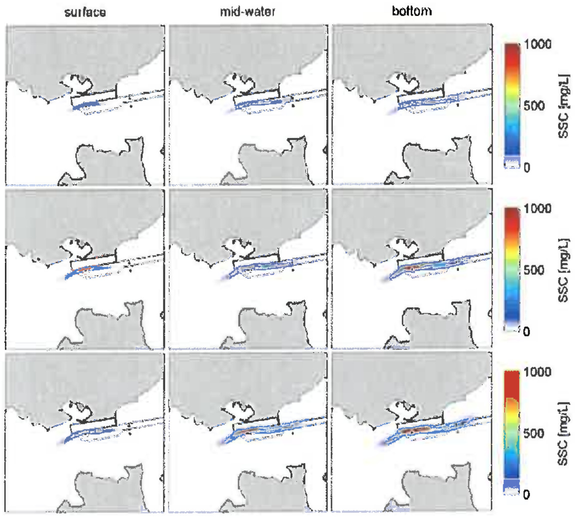
General pattern follows ambient hydrodynamic forcings.

probabilistically they typically extend less than 0.5 km in all layers for dredging only mode, and of the order 1-1.5 km at the most (in the bottom layer) for overflow mod

White in scale below ~10 mg/L

## Plumes during dredging (Capital and Maintenance)

- Different overflow durations (10, 20 and 30 min)




- 10 minute
- 20 minute
- 30 minute

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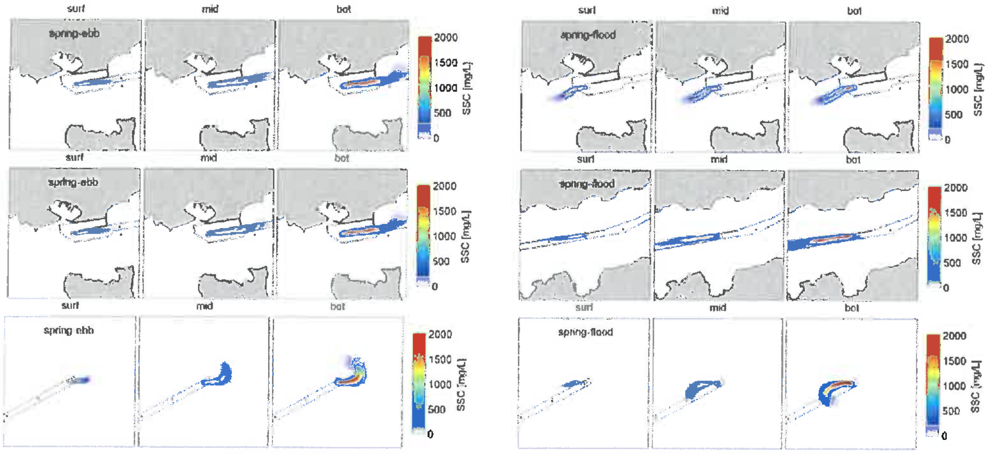
Overflow duration key to governing the extents of concentration magnitudes

Seiche velocities does not significantly change the distribution d.t. Phasing with tides and effect is only minor.

Difference between existing and proposed harbour configuration hydrodynamics is only minor in terms of plume excursions

## Plumes during dredging (Capital and Maintenance)

- Ebb and flood tidal conditions (peak flows)




- 10 minute overflow at three levels

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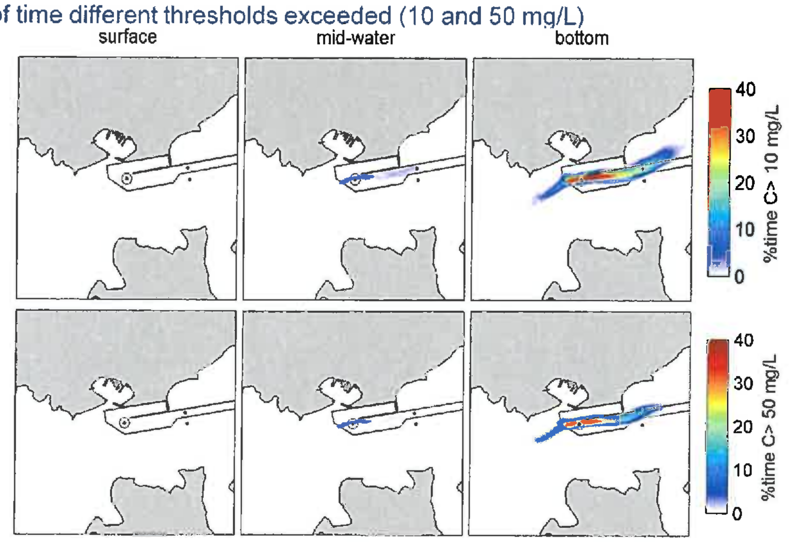
Plumes have relatively large excursion during peak flows but become relatively more diluted

## Plumes during dredging (Capital and Maintenance)

- % of time different thresholds exceeded (10 and 50 mg/L)




- 10 mg/L
- 50 mg/L

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Exceedence values

Assumed 25 min dredging, 10 min overflow and 85 min travel repeated over 28 days

Although surface concentrations can be elevated at times during overflow, represents a small percentage of time (1-2%)

Thresholds exceeded in mid and bottom about 30-40 % - spatially greater extent in bottom.

Largest exceedence times typically extend up to 500-100 m depending on the threshold

Offshore sites display a more elliptical shape due to the governing hydrodynamics

Greater dispersion in the harbour (due to stronger currents) leads to thresholds being exceeded less frequently.

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## Plumes during disposal (Capital)

- 4 different grain size fractions considered, min $w_f$ = 1 mm/s).
- Exact timing of dredging (and hence forcing conditions) will be unknown – so a probabilistic approach has been taken by considering 10-years of hindcast data from a calibrated and validated model.
- This does not assume dredging will take 10-yrs but is a way of accounting for the climatic variability
- Source terms .
  - Sediment de-entrained from plume decent, released at base of dredger (5% based on guidance from HR Wallingford)
  - Sediment entrained following bed collapse of dynamic plume (21% within bottom 2 m within 300m based on guidance from HR Wallingford)
  - Also considered 1% within the surface layer
  - Three different dredgers considered ranging 5,000 $m^3$ to 18,000 $m^3$ – 10,800 $m^3$ considered in more detail.

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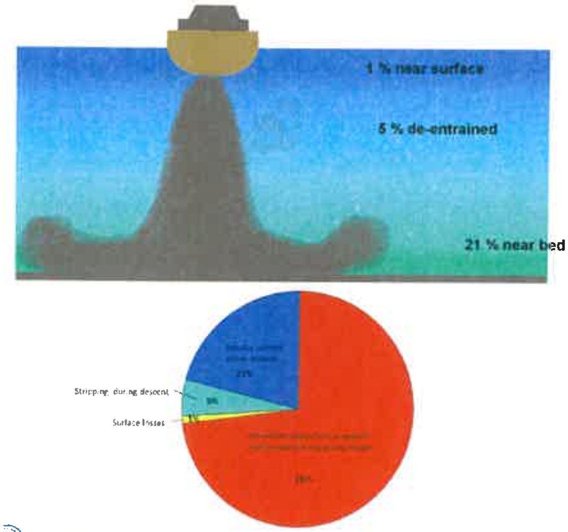
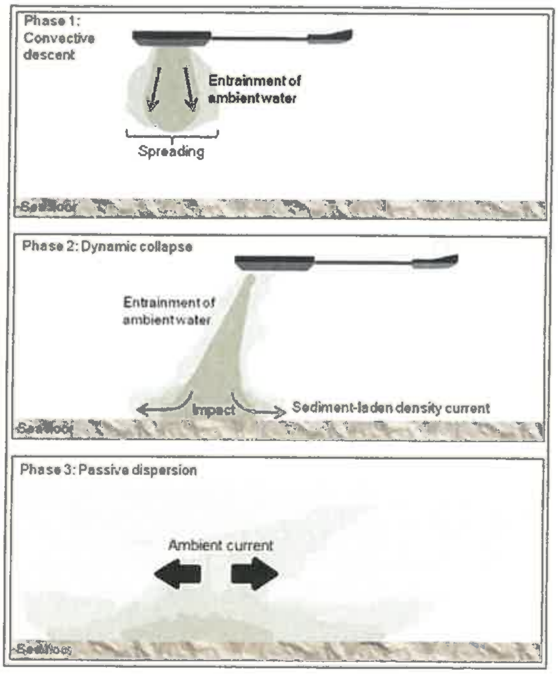
10 years of hydrodynamics – Calibrated and Validated model

Three different dredgers considered.

# Plumes during disposal (Capital)

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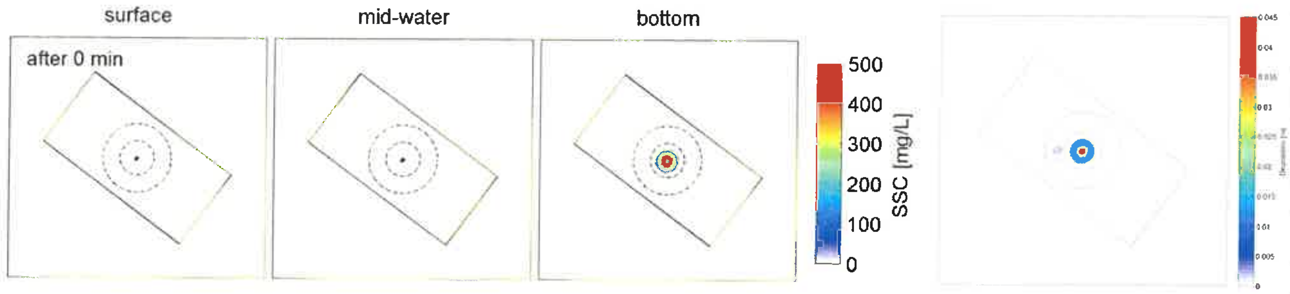
## Plumes during disposal (Capital)

- Discharges modelled at the centre and each corner of the proposed disposal ground
- 10-yrs of current were defined using a calibrated and validated hydrodynamic model (nested from NZ scale to Pegasus Bay scale)
- Discrete events within the hindcast were also examined – both calm and energetic

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Discrete events for calm and energetic conditions considered.

Calm event – three hopper loads at same site

Majority of sediment settles within 30 min

After 30 min plume essentially consists of sediment moving from higher in the water column through the layers.

Near bed SSC levels typically drop below 100-200 mg/L within 1km of disposal.

This is similar to near bed measurements being recorded during the monitoring program

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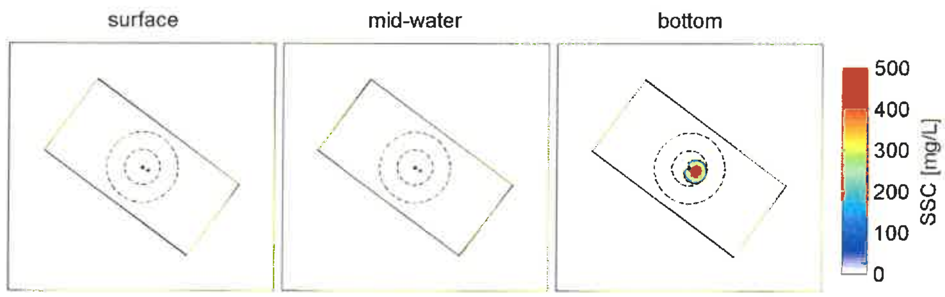


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Energetic event – three hopper loads at same site

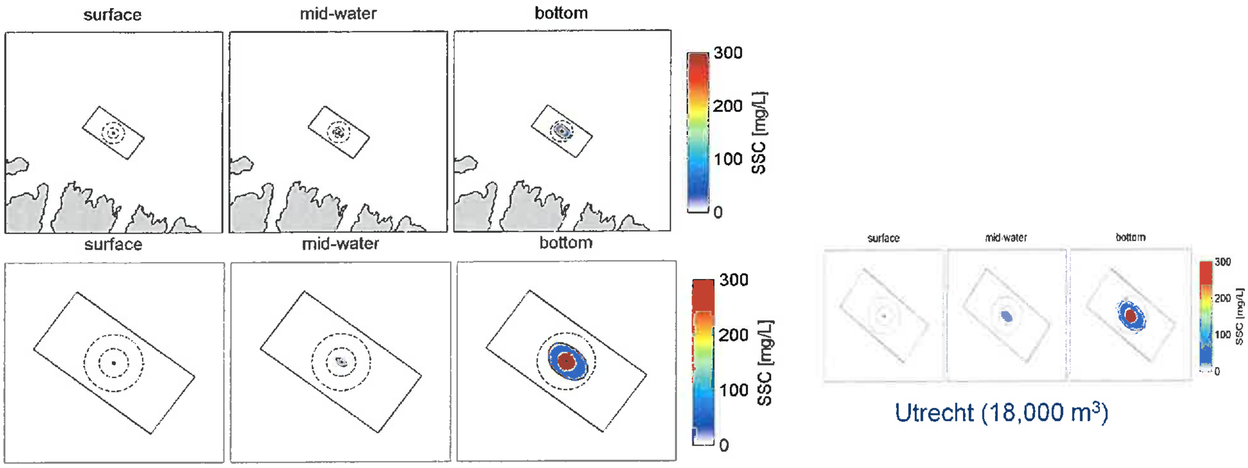
Most of sediment settles within 500 m in 30-45 minutes

After 45 min plume is very compact and essentially consists of sediment moving from higher in the water column through the layers.

At 120-180 no significant plume in surface or mid water

## Plumes during disposal (Capital)

- Based on 10-year climate hindcast – mean Suspended Sediment Concentration (*SSC*) of one hopper load of the Volvox Asia (10,800 $m^3$)

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Probabilistic maps produced for all 4 corners and a central site

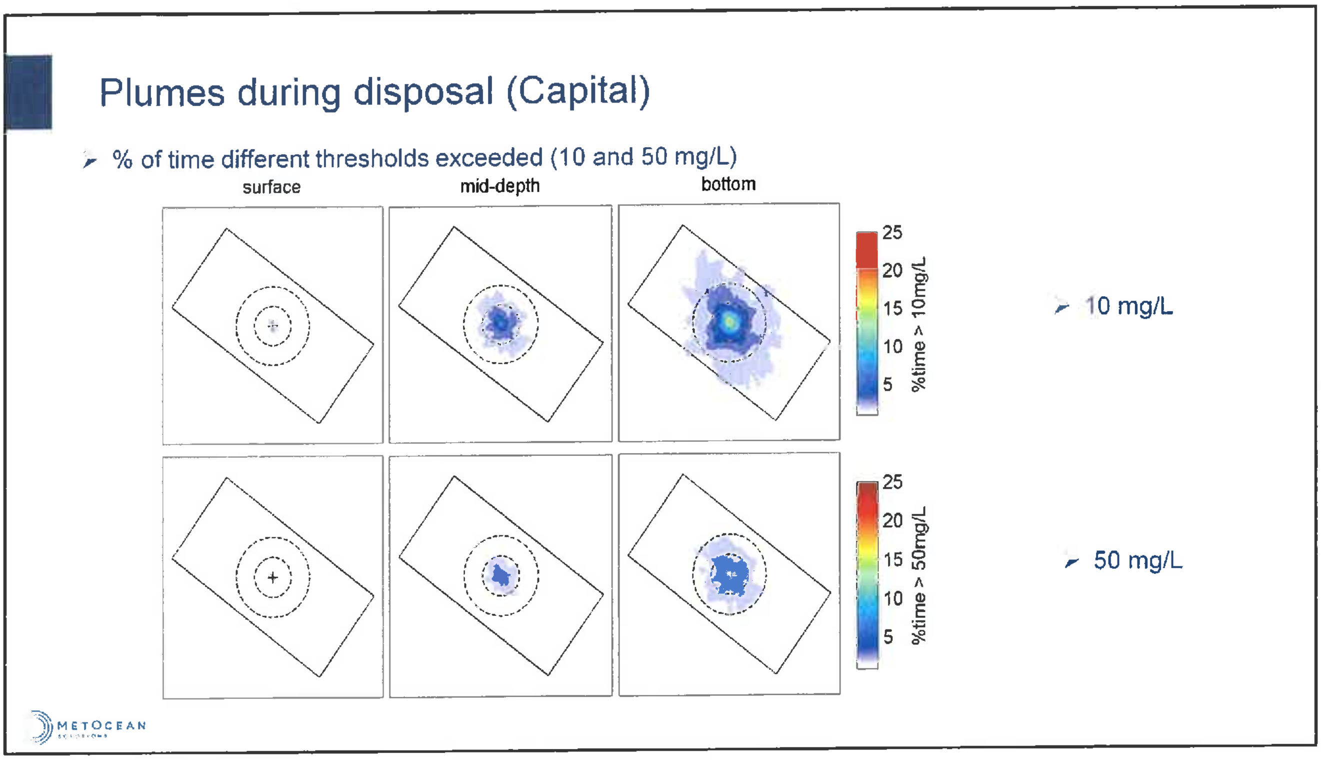
Relatively high SSC found within 300 m of discharge due to density current source term

Elliptical shape consistent with forcing mechanisms at disposal site

Larger dredgers result in the magnitude result in higher concentrations and increased spatial coverage – due to increased amount of sediment discharged into passive plume

SSC higher in mid water for smaller dredge due to size of dredge and draft

Even for the largest of the dredgers considered the 10 mg/L contour stays within 1-km of discharge location in bottom layer, and 0.5 km in mid-water.




Thresholds exceedances examined for two full months – Summer and Winter

near-bed layer the 10 mg.L$^{-1}$ threshold is typically exceeded 10-15 % of the time within a radius of ~300 m

exceedance times of order 5 % may extend up to ~1 km from the release position

mid-water, at the 10 mg.L$^{-1}$ level exceedances of up to 5 % are contained within a 500 m radius and become less than minor past the 1 km radius.

10 mg.L$^{-1}$ is very rarely exceeded in the surface layers

Even the low <1% exceedence contour remains 2-3 km from the closest shoreline point

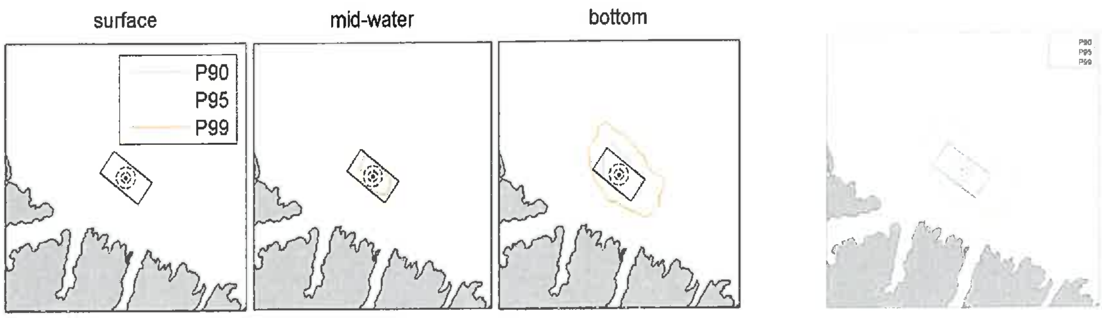
Consecutive disposals at the same location can increase the frequency of *SSC* exceeding the different thresholds (i.e. up to ~20-25% in the bottom layer)

## Plumes during disposal (Capital)

- Extreme particle dispersion

Approximately representative of the largest extend individual particles can potentially traverse

- Depositional footprint

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Extreme particle footprints from centre and all four corners

Combined to look at both the suspended and depositional footprint

Extreme particle excursions from release position are of the order of 2 km for the mid water plume and 4 km for the bottom plume

Elliptic shape

1% chance of an individual particle going beyond the 99th percentile contour

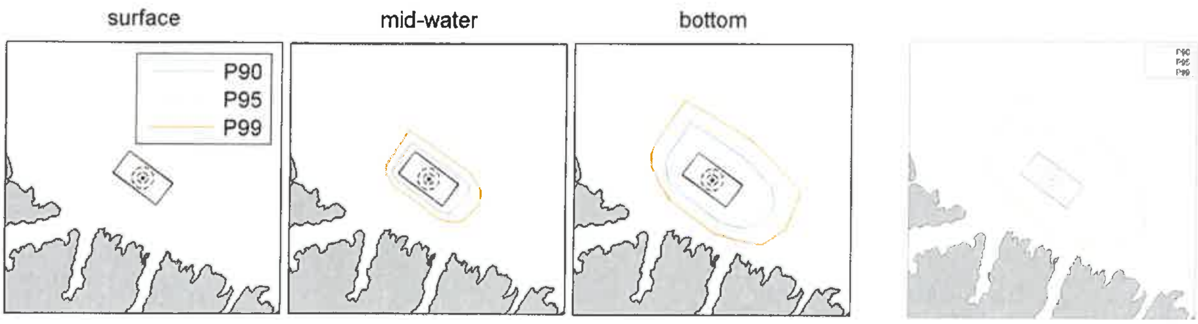
The majority of sediment settles immediately, this is only considering the % advected into the passive plume

# Plumes during disposal (Capital)

- Extreme particle dispersion

Approximately representative of the largest extend individual particles can potentially traverse

- Depositional footprint




Combined into an envelope by considering all 5 points

1% chance of an individual particle going beyond the 99th percentile contour

The majority of sediment settles immediately, this is only considering the % advected into the passive plume

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## Sediment and plume modelling, and surfing effects

- Plumes during dredging (Capital and Maintenance)
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- **Sediment behaviour post Capital disposal**
  - Medium term and Real time

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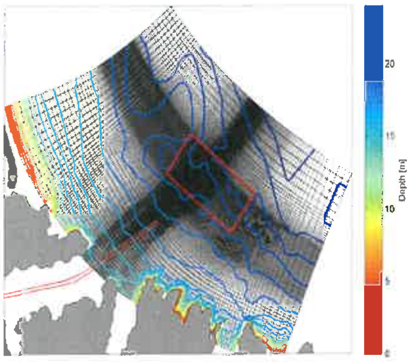
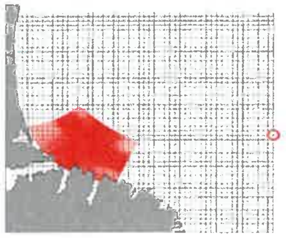
## Sediment behaviour post Capital disposal

- Delft-3D model nested in calibrated and validated hydrodynamic and wave models
- Input reduction technique used – limited number of representative forcing conditions (currents and waves)
- Only sediment in disposal ground considered (isolate effect of disposal)



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Delft -3d nested within the calibrated and validated hydrodynamic and wave models

Used as tools to understand governing processes

Key parameters in predicting entrainment of cohesive sediment is the Erosion parameter (M)

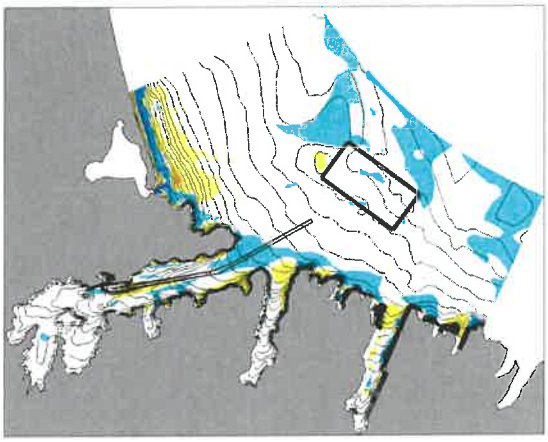
Expected to be within the range $1x10^{-3}$ and $1x10^{-7}$ $kg.m^{-2}.s^{-1}$.

Anecdotally evidence suggests that an Erosion Parameter of $1x10^{-6}$ more accurately represents what is seen within the environs, particularly within the entrance to Port Levy/Koukourārata.

Input reduction technique used – limited number of events modelled based on their representative forcing

Technique focuses on energetic conditions where critical thresholds are exceeded.

## Sediment behaviour post Capital disposal



Assuming 0.25 m of sediment available within entire domain and existing bathymetry

Under existing conditions slight erosion is predicted within Lyttelton Harbour, while sedimentation is expected in Port Levy

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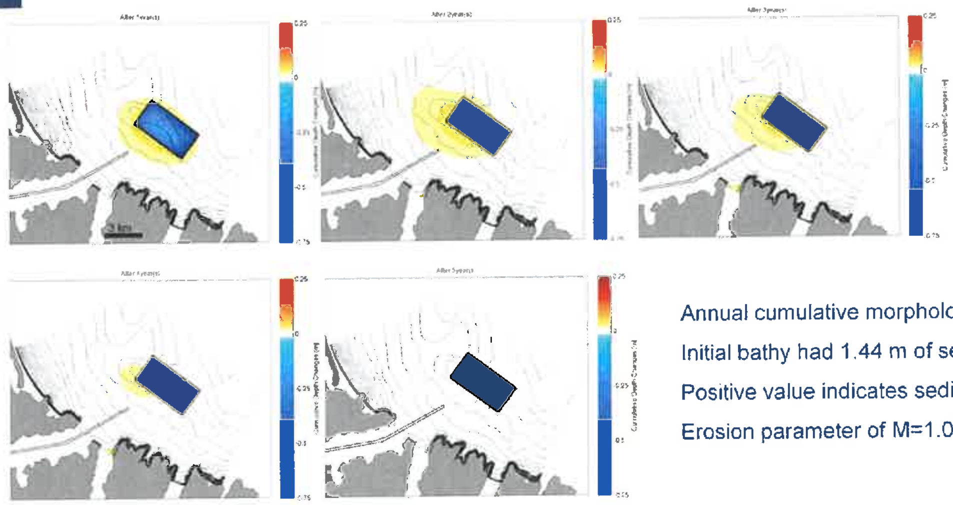
Assuming constant available sediment within the entire modelled environs the model predicts sedimentation with the entrance to Port Levy/Koukourārata, while erosion is predicted within the entrance to Lyttelton Harbour/Whakaraupō.

## Sediment behaviour post Capital disposal



Annual cumulative morphological changes over 5-yr.

Initial bathy had 1.44 m of sediment over entire ground

Positive value indicates sedimentation.

Erosion parameter of $M=1.0e^{-5}$ $kg.m^{-2}.s^{-1}$.

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Medium term simulations

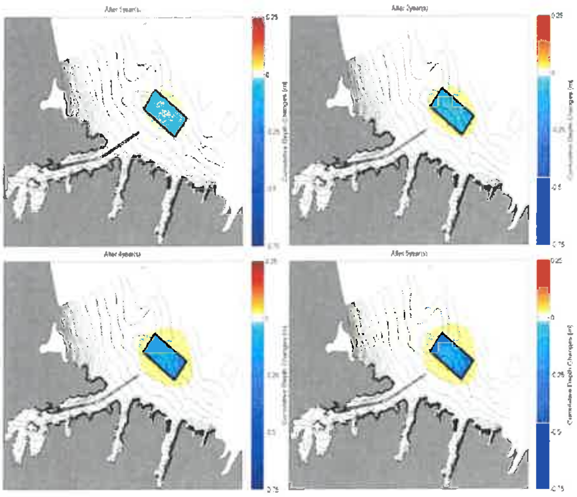
Only sediment in disposal ground

All sediment deposited at once, while in reality expected to be over two dredging campaigns of 9-14 mths each.

All sediment moved out of disposal ground after 5yrs for $M=1.0e^{-5}$ $kg.m^{-2}.s^{-1}$

Sediment transport fields and net circulation proportional to disposal sites exposure to wave energy.

## Sediment behaviour post Capital disposal



Annual cumulative morphological changes over 5-yr.

Initial bathy had 1.44 m of sediment over entire ground

Positive value indicates sedimentation.

Erosion parameter of $M=1.0e^{-6}$ $kg.m^{-2}.s^{-1}$.

Longer than 5-yrs to disperse from disposal ground

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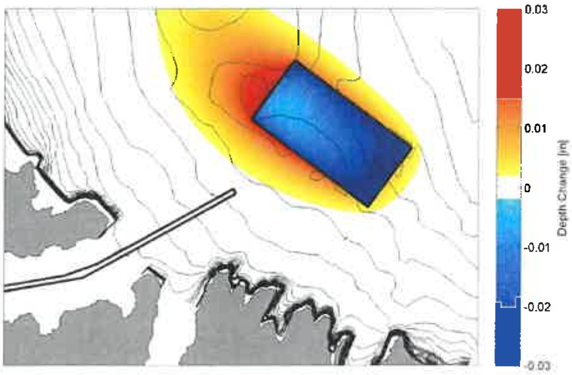
Medium term

Sediment takes longer to move out of disposal ground for $M=1.0e^{-5}$ $kg.m^{-2}.s^{-1}$

Sediment transport fields and net circulation proportional to disposal sites exposure to wave energy.

## Sediment behaviour post Capital disposal




- Morphological changes at end of 4-day event with NW residual currents (maximum bed shear stress of 0.4 N.m$^{-2}$)
- $H_s$ exceeded 2.5 m
- Westerly migration of sediment
- Note the scale goes from 0.03 to -0.03 m

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During energetic events

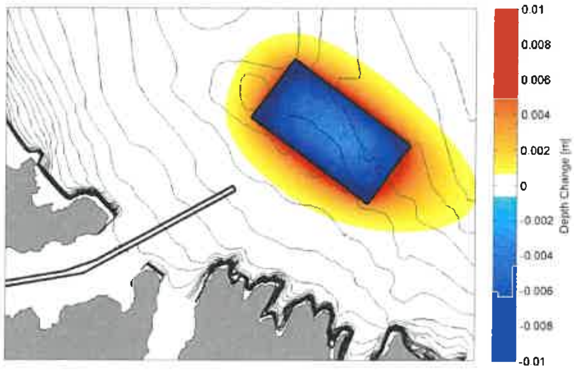
4-day period modelled, with velocity of ~0.20 m.s$^{-1}$ throughout the disposal ground.

This corresponds to an increase of the maximum bed shear stresses by up to 0.4 N.m$^{-2}$ within the disposal ground.

Sediment entrained over entire domain

Migration to the west

## Sediment behaviour post Capital disposal




- Morphological changes at end of 4-day event with SE residual currents (maximum bed shear stress of 0.4 N.m$^{-2}$)
- $H_s$ exceeded 2 m
- E-SE migration of sediment

Note the scale goes from 0.01 to -0.01 m

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SE event sediment moved towards the east

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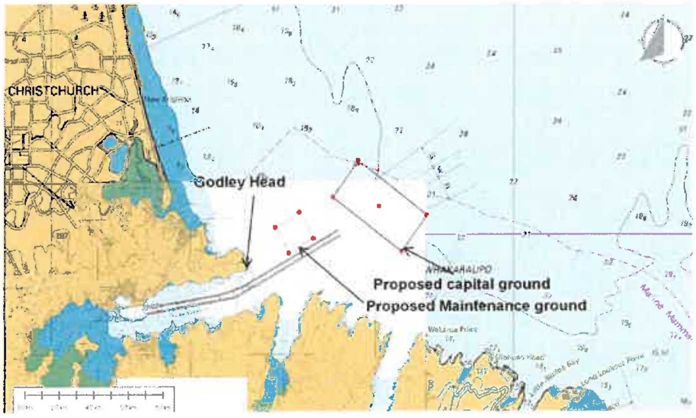
## Sediment and plume modelling, and surfing effects

- Plumes during disposal (Maintenance)

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Proposed site approximately 3-km off Godley Head

## Plumes during disposal (Maintenance)

- Same methodology as Capital disposal
- Discharges modelled at the centre and each corner of the proposed disposal ground
- 10-yrs of current were defined using a calibrated and validated hydrodynamic model (nested from NZ scale to Pegasus Bay scale)
- Discrete events within the hindcast were also examined – both calm and energetic
- Disposal cycle of 1.5 hrs, hopper size of 1840 $m^3$ with a draught of 4 m.

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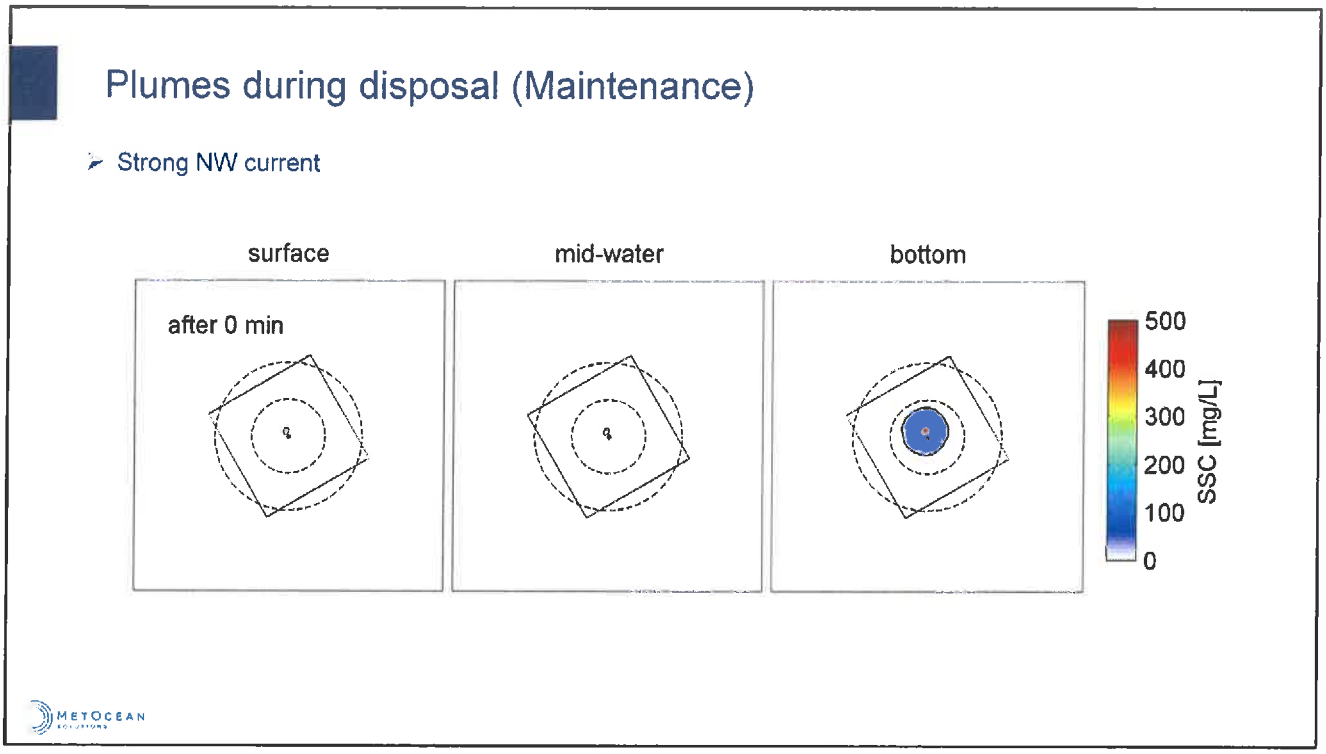
Same methodology as Capital disposal but

Specific differences include the hopper size (1840 $m^3$), the draught (4 metres) and the disposal cycle (1.5 hours).




During energetic events

bottom *SSC* plume spreads within a circular radius of ~300 m as prescribed by the near-field modelling undertaken by HR Wallingford

The smaller and more compact *SSC* plumes in the mid-water and surface layers are associated with the de-entrainment of sediment

dispersion directions are consistent with the ambient current forcing

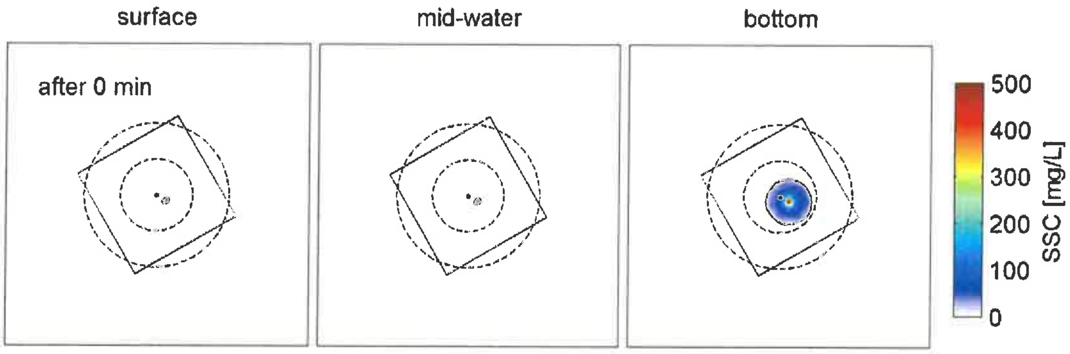
most of the circular near-bed *SSC* component of the passive plume will settle within 500 metres of the release site in the 30-45 minutes

After 45 minutes the *SSC* plumes are very compact in the three depth layers

The concentration fields at 120 and 180 minutes show less than minor *SSC* plumes in the surface or mid-water layers

## Plumes during disposal (Maintenance)

- Strong SE current

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During energetic events

bottom *SSC* plume spreads within a circular radius of ~300 m as prescribed by the near-field modelling undertaken by HR Wallingford

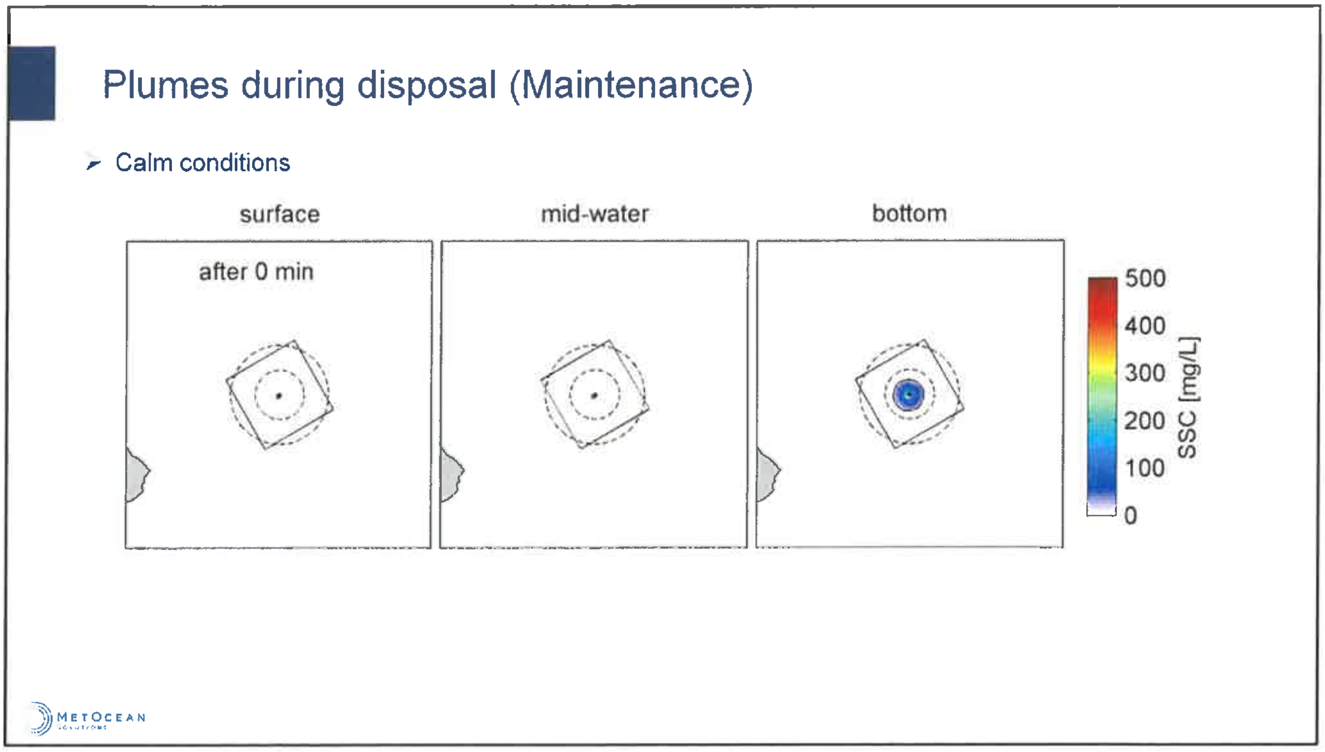
The smaller and more compact *SSC* plumes in the mid-water and surface layers are associated with the de-entrainment of sediment

dispersion directions are consistent with the ambient current forcing

most of the circular near-bed *SSC* component of the passive plume will settle within 500 metres of the release site in the 30-45 minutes

After 45 minutes the *SSC* plumes are very compact in the three depth layers

The concentration fields at 120 and 180 minutes show less than minor *SSC* plumes in the surface or mid-water layers




Calm conditions

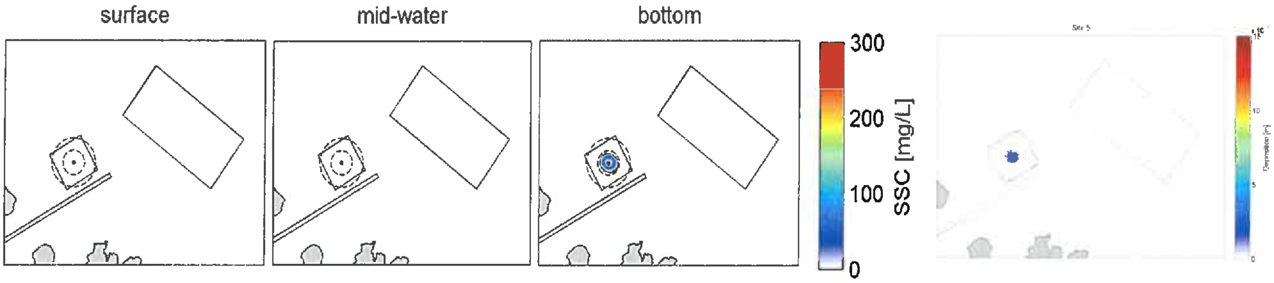
the majority of the initial bottom *SSC* plume settles to the seabed within ~30 minutes.

*SSC* levels in the bottom layers are then sequentially increased during transfer of suspended sediment from the surface and mid-depth layers to the bottom layer, or the next disposal event

The *SSC* plumes with the most significant extents and concentration magnitudes are consistently found in the bottom layer and in general *SSC* levels will typical drop below 100-200 $mg.L^{-1}$ within 1 km of the disposal location.

## Plumes during disposal (Maintenance)

- Based on 10-year climate hindcast – mean Suspended Sediment Concentration (*SSC*) and depositional footprint

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Examined disposal at both proposed Maintenance and Capital disposal grounds

4- corners and centre sites

Probabilistic approach taken

bottom *SSC* plume spreads within a circular radius of ~300 m as prescribed by the near-field modelling undertaken by HR Wallingford

The smaller and more compact *SSC* plumes in the mid-water and surface layers are associated with the de-entrainment of sediment

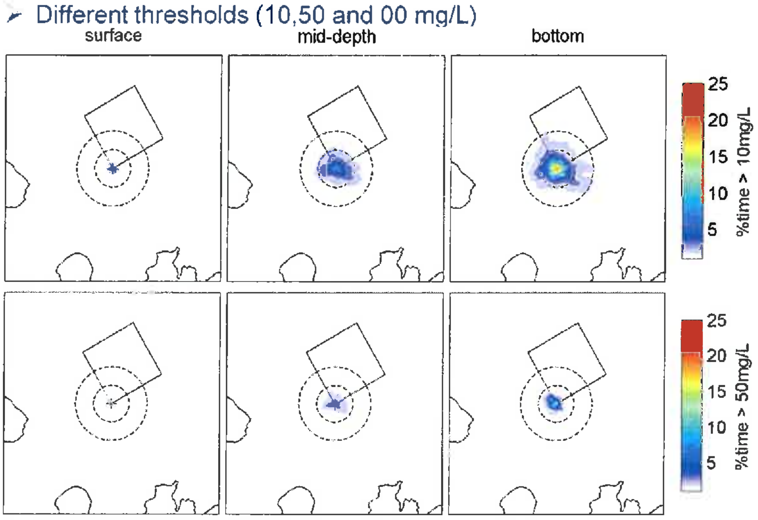
The overall shape of the statistically averaged plume extent ranges between almost circular (at the proposed Maintenance disposal ground) to elliptic in the northwest-southeast axis at the proposed Capital disposal ground

For all cases, and at both the proposed Maintenance and Capital disposal ground, the 10 mg.L$^{-1}$ contour generally stays within 1 km

For all cases and both disposal grounds, the 1 mm depositional contour is consistently contained within the 500 m radius around the release location.

# Plumes during disposal (Maintenance)

- Different thresholds (10,50 and 00 mg/L)




- 10 mg/L
- 50 mg/L

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Thresholds exceedances examined for two full months – Summer and Winter

near-bed layer the 10 $mg.L^{-1}$ threshold is typically exceeded 10-15 % of the time within a radius of ~300 m

exceedance times of order 5 % may extend up to ~1 km from the release position

mid-water, at the 10 $mg.L^{-1}$ level exceedances of up to 5 % are contained within a 500 m radius and become less than minor past the 1 km radius.

10 $mg.L^{-1}$ is very rarely exceeded in the surface layers

Even the low <1% exceedence contour remains 2-3 km from the closest shoreline point

Consecutive disposals at the same location can increase the frequency of *SSC* exceeding the different thresholds (i.e. up to ~20-25% in the bottom layer)

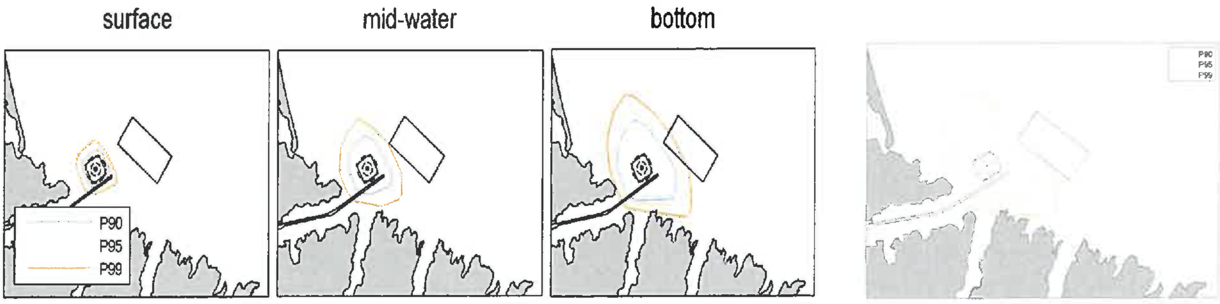
Dispersion slightly larger during winter months

## Plumes during disposal (Maintenance)

- Extreme particle dispersion

Approximately representative of the largest extend individual particles can potentially traverse

- Depositional footprint




Convex hull of individual particles  and depositional footprint

Worst case

General elliptic shape elongated in the direction northwest-southeast

near shore expressions of the depositional footprint between Godley Head and southeast of Port Levy / Koukourārata

Even though particle excursions approach the shoreline, sediments are not expected to settle in the highly dynamic nearshore environment, and it is my understanding that **Mr Shand** has discussed this in his evidence

1% chance of an individual particle going beyond the 99th percentile contour

The majority of sediment settles immediately, this is only considering the % advected into the passive plume

## Sediment and plume modelling, and surfing effects

- Modelling 101
- Plumes during dredging (Capital and Maintenance)
- Disposal plumes (Capital)
- Sediment behaviour post Capital disposal
- Disposal plumes (Maintenance)
- **Sediment behaviour post Maintenance disposal**
- Surfing effects

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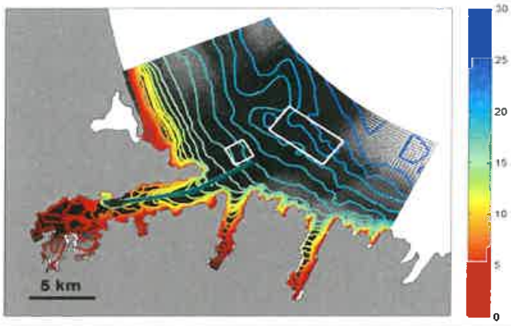
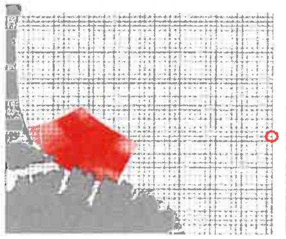
## Sediment behaviour post Maintenance disposal

- Delft-3D model nested in calibrated and validated hydrodynamic and wave models
- Input reduction technique used – limited number of representative forcing conditions (currents and waves)
- Only sediment in disposal ground considered (isolate effect of disposal)
- Both proposed Capital and Maintenance grounds considered
- Maintenance dredging of 0.9 M m3/yr considered



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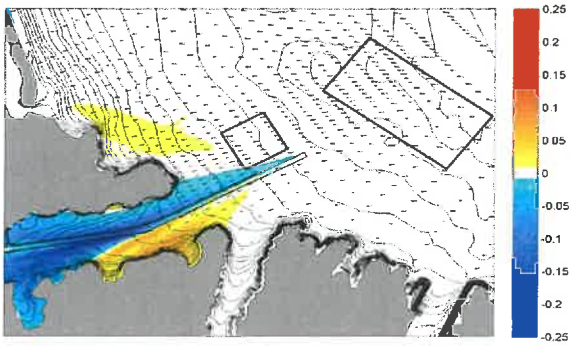
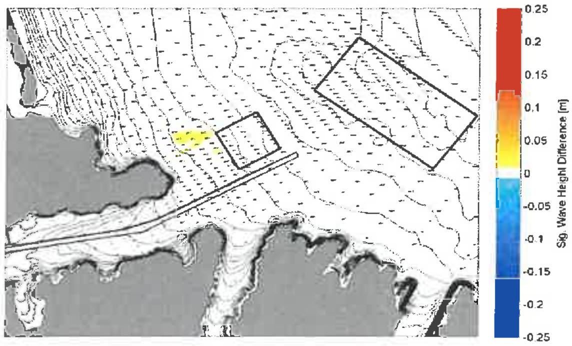
# Sediment behaviour post Maintenance disposal

Considering the proposed channel only results in a redirection of the incident wave energy towards the south side of the Harbour, while the north side is relatively shadowed (weighted mean)




The Maintenance ground focuses some additional wave energy towards the region from Godley Heads to Taylors Mistake. (weighted mean)

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Wave effects

Bathy changes

Channel only

Maintenance only (0.35 m over entire domain)

Capital only (1.44 m over entire domain) – both dredging campaigns – worst case

## Sediment behaviour post Maintenance disposal


Maintenance disposed of at the proposed offshore maintenance ground - annual

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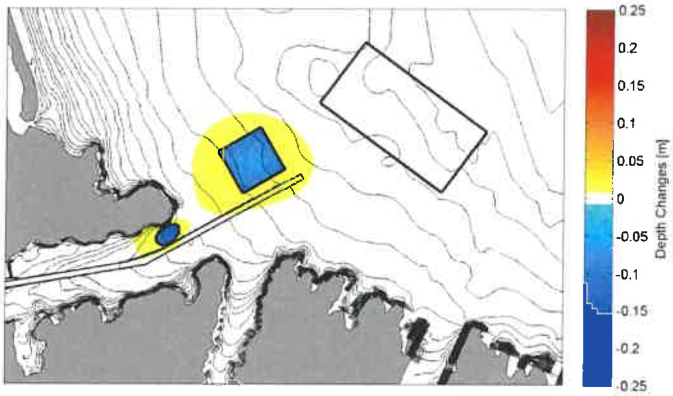
largest potential for sediment recirculation in the channel comes from the proposed Maintenance ground

## Sediment behaviour post Maintenance disposal

Maintenance split between the proposed offshore maintenance ground and the existing Godley head site

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Splitting the annual Maintenance volume between the proposed Maintenance ground and the existing Godley Heads

2 to 3 times more sedimentation in channel than when only the proposed offshore Maintenance ground is used

## Sediment and plume modelling, and surfing effects

- Modelling 101
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- Disposal plumes (Capital)
- Sediment behaviour post Capital disposal
- Disposal plumes (Maintenance)
- Sediment behaviour post Maintenance disposal
- **Surfing effects**

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## Surfing effects

- Analysis based on 10-year dataset
- Primarily swell-dominated considered and a range of representative wave heights, periods and directions modelled (12)
- Conditions chosen represent surfable conditions
- Effect of channel deepening and disposal mounds on locally generated short period waves expected to be less than effect on longer period swell
- Worst case mounds considered where all sediment is disposed of at once
- Both Capital and Maintenance grounds considered

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Range of events looked at in more detail (12)

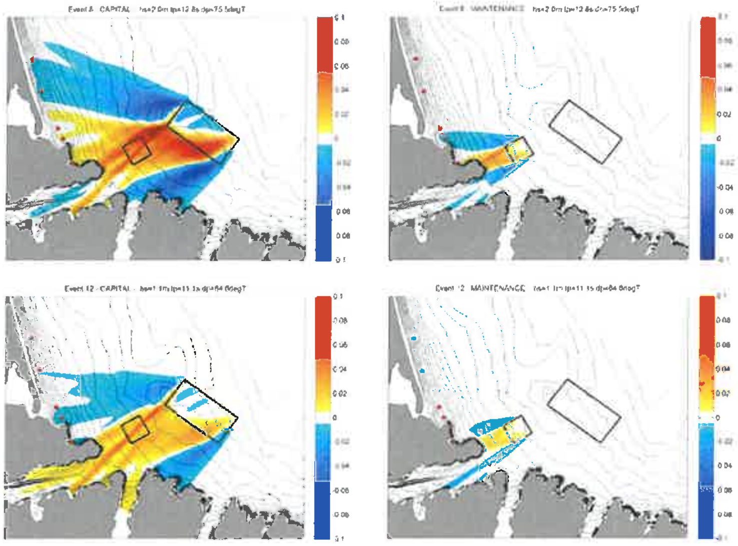
Swell dominated conditions considered – these are conditions that surfers prefer, but also will 'feel' the effects of the proposed modifications more than short period waves

This does not imply that shorter period conditions do not result in conditions that are surfable – Just that any bathymetric change effect will be highlighted more by swell dominated conditions than shorter period conditions

Worst case with entire disposal mound in place at once – spread evenly

I understand that an even distribution of the disposal is intended – rather than disposing of the sediment at the closest corner for example.

## Surfing effects



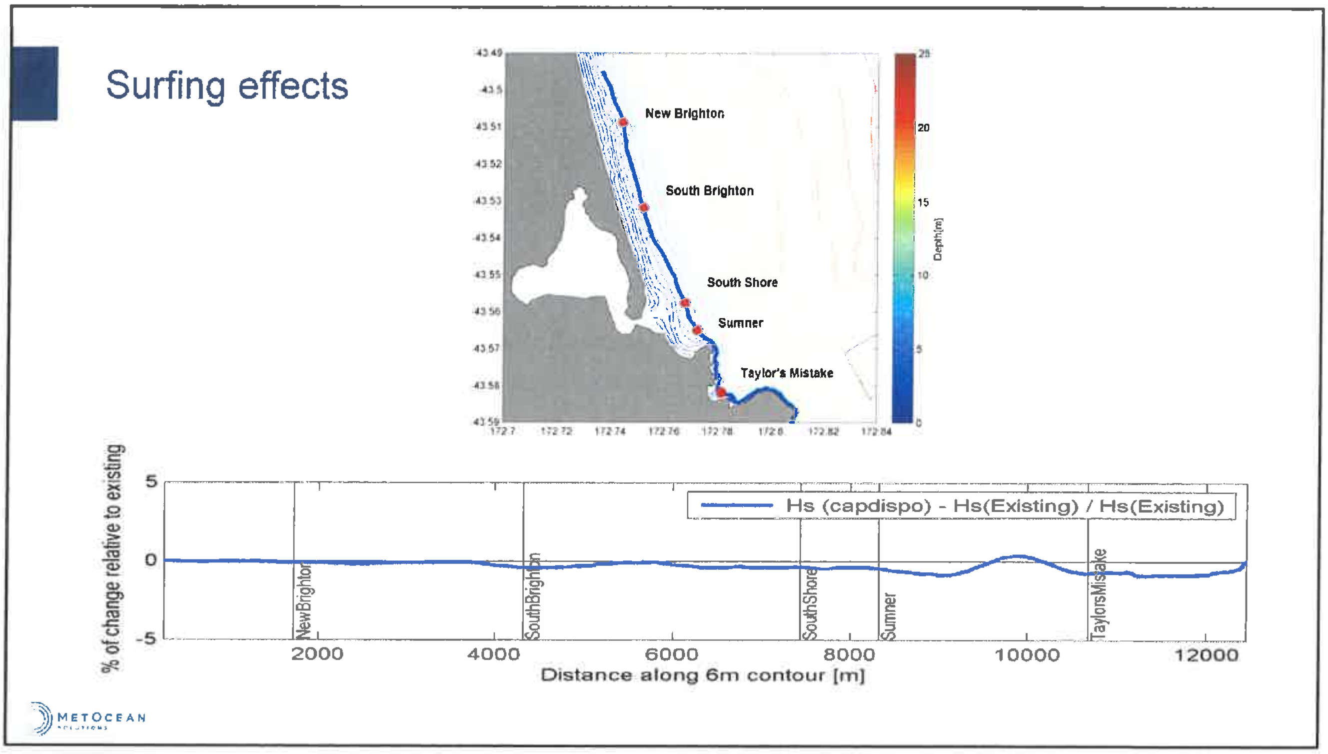
Wave height differences

localised increases in the incident wave heights over and in the lee of the mounds due to enhanced shoaling and refraction over the slightly shallower mound areas

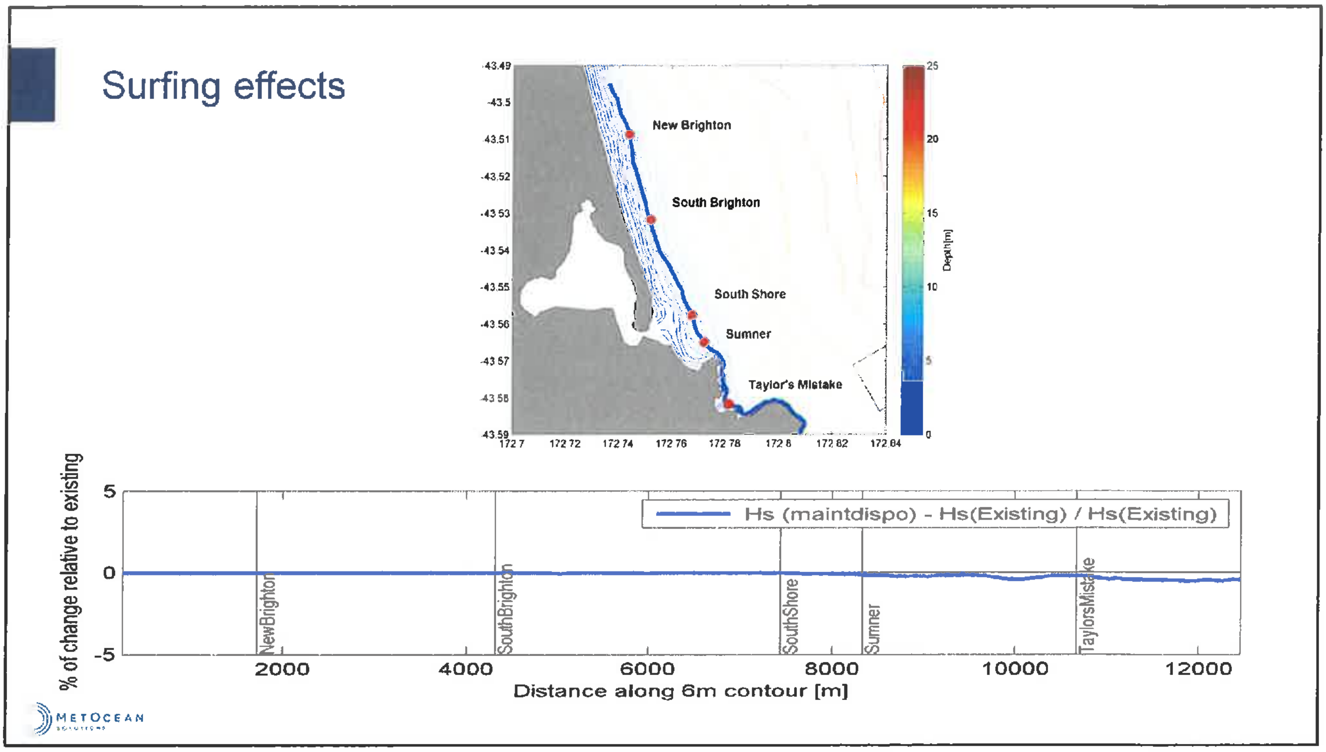
Lateral bands of relatively reduced wave heights are expected to either side of the disposal mounds

net effect on the nearshore wave heights is dependent on the incident wave direction

$H_s$ increases in the lee of the disposal mounds are expected (2%-5%), while reduced wave heights can be expected to either side (2%-5%); specific areas will depend on the incident wave directions.




absolute magnitudes of wave height change along the 6-m depth contour inshore of the disposal mounds are minor, with a change of the existing wave heights of less than 5% and 2% for the Capital and Maintenance disposal mounds respectively




absolute magnitudes of wave height change along the 6-m depth contour inshore of the disposal mounds are minor, with a change of the existing wave heights of less than 5% and 2% for the Capital and Maintenance disposal mounds respectively

## Surfing effects

Existing bathymetry


Maintenance ground bathymetry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Changes in crest patterns  are expected to have a less than minor effect on the incident wave crest patterns and conditions experienced by surfers inshore of the disposal mounds in the vicinity of the Christchurch surfing beaches

Differences in wave spectra likewise expected to be less than minor

Overall, the effect of the offshore disposal mounds, being in relatively deep water, is not expected to measurably or discernible change the conditions experienced with respect to surfing at beaches inshore of the disposal mounds.

## Surfing effects

Existing bathymetry


Capital ground bathymetry


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Changes in crest patterns  are expected to have a less than minor effect on the incident wave crest patterns and conditions experienced by surfers inshore of the disposal mounds in the vicinity of the Christchurch surfing beaches

Differences in wave spectra likewise expected to be less than minor

Overall, the effect of the offshore disposal mounds, being in relatively deep water, is not expected to measurably or discernible change the conditions experienced with respect to surfing at beaches inshore of the disposal mounds.