Porirua Harbour's sediment problem: causes and solutions

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The origin of Porirua Harbour

22,000 years ago, at the last glacial maximum and with sea level 150 m lower than it is today, Pauatahanui Inlet was a gravel outwash plain built by rivers flowing from the central volcanic plateau. The Onepoto arm of the harbour was a freshwater swamp.

Sea level rose as the glaciers melted, and around 8,000 years ago the Pauatahanui and Porirua river valleys began to flood with seawater.

By 6,000 years ago, sea level had reached the present level and since then, the drowned river valleys have been filling in with sediment.

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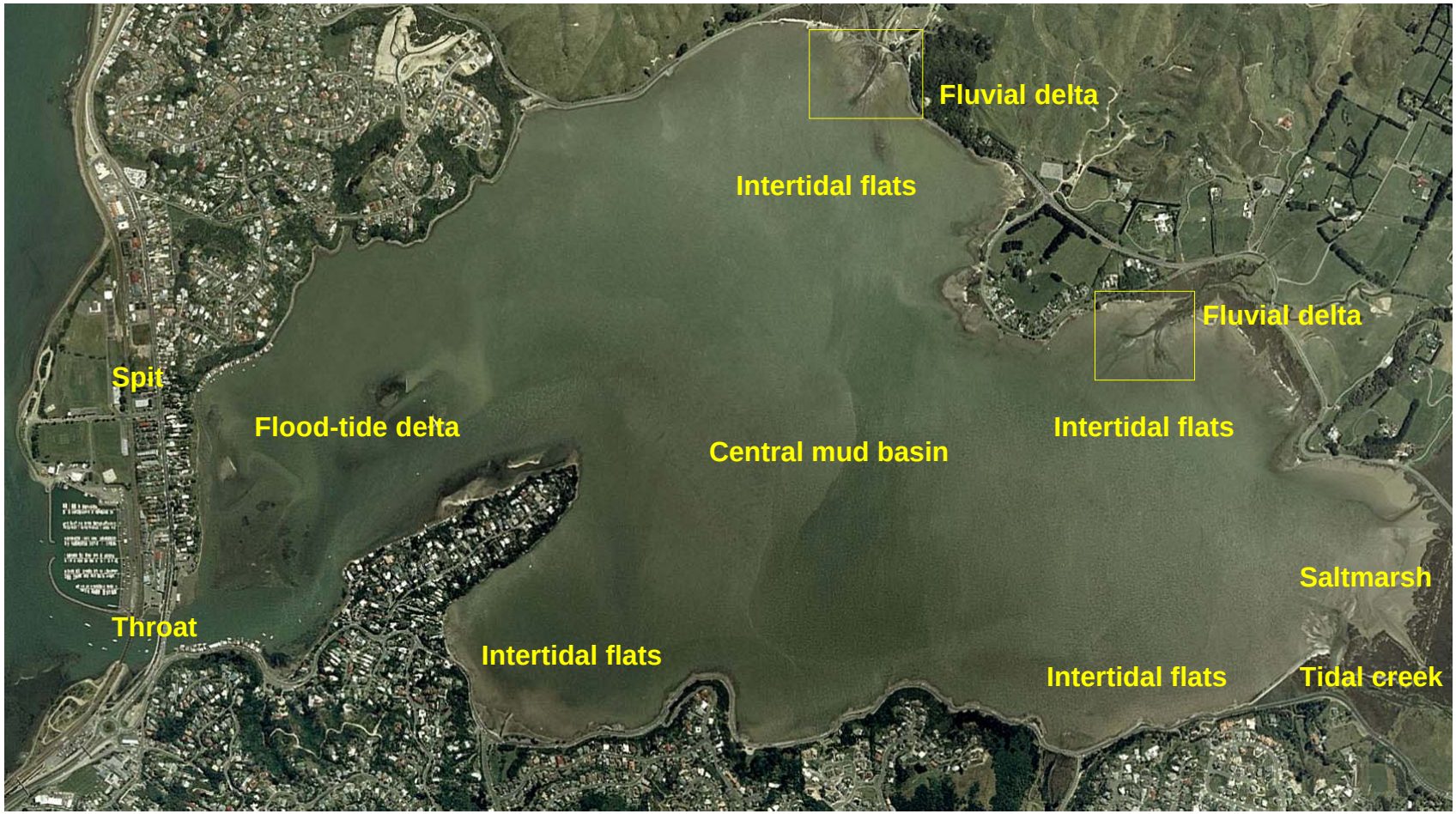
The origin of Porirua Harbour

Marine sediments

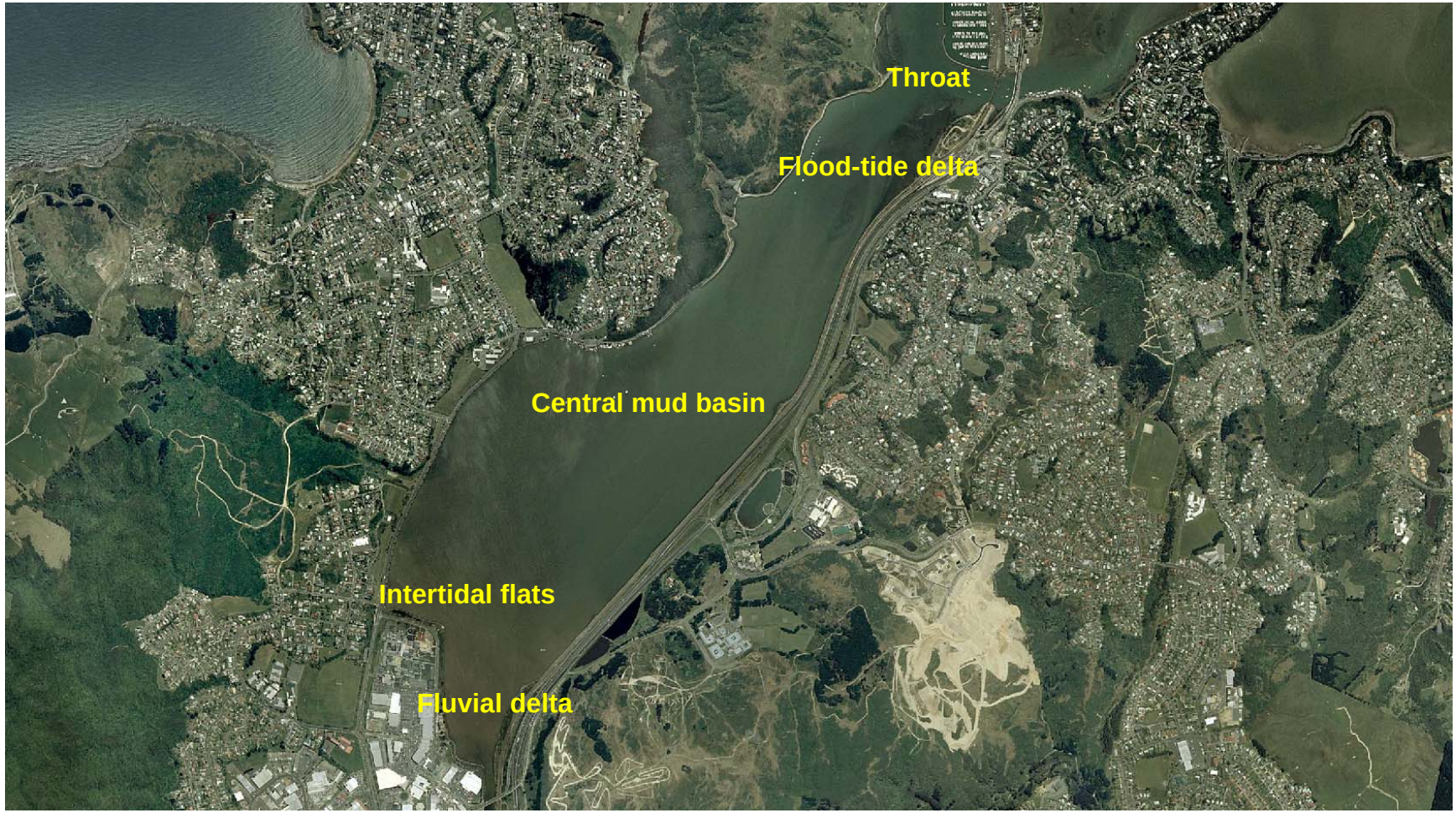
Image: Google.

Terrestrial sediments

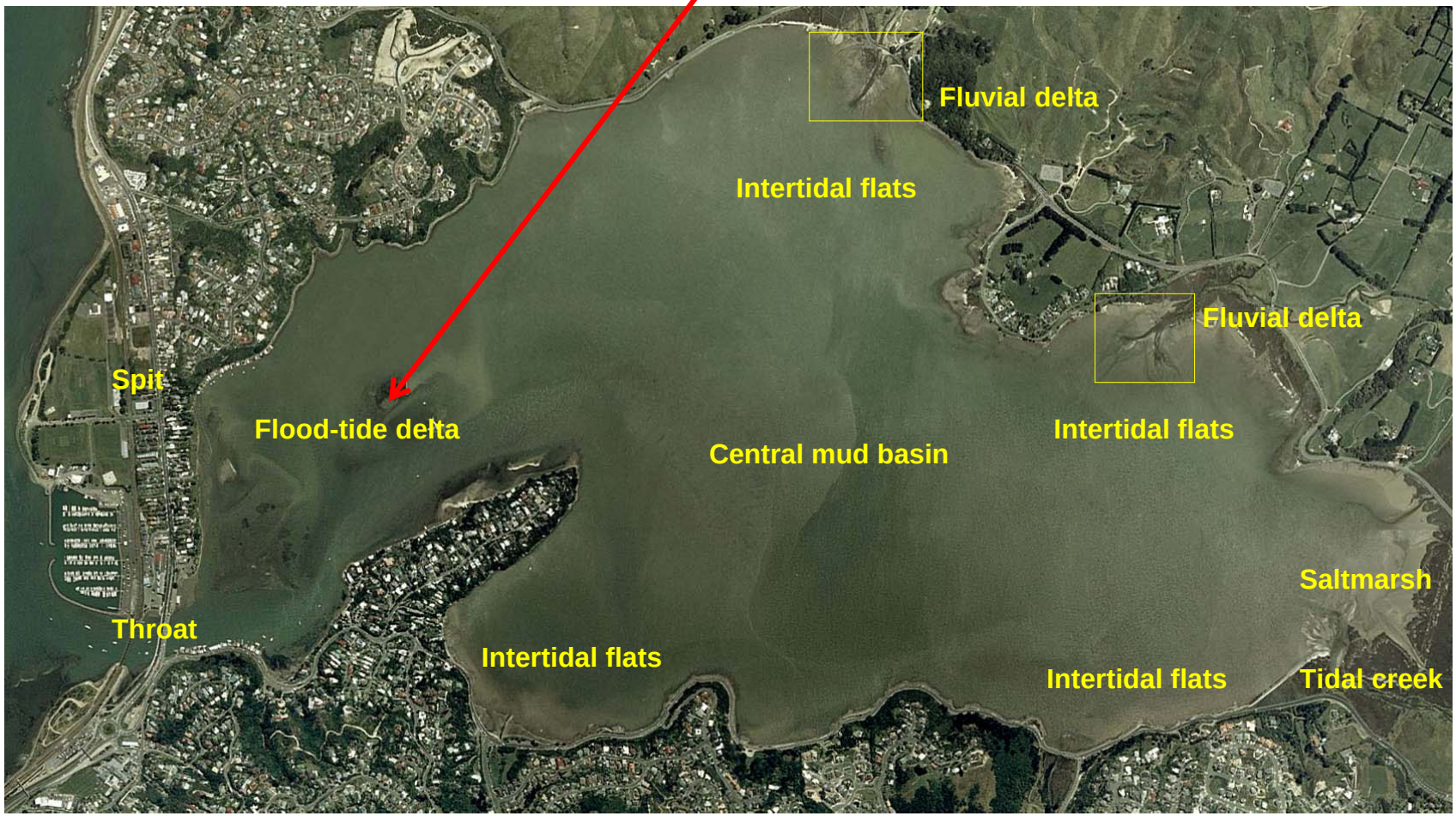
The components of Pauatahanui Inlet



The components of Onepoto



The problem (1)



The problem (2)

Terrestrial sediment inputs have got bigger

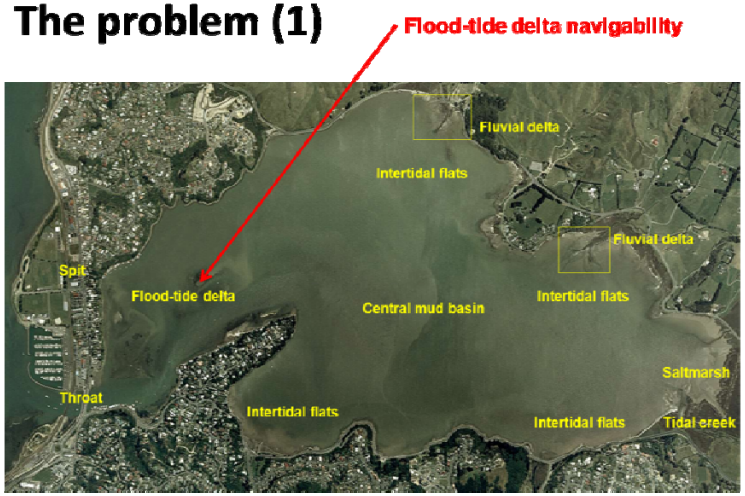
Marine sediments

Image: Google.

Terrestrial sediments

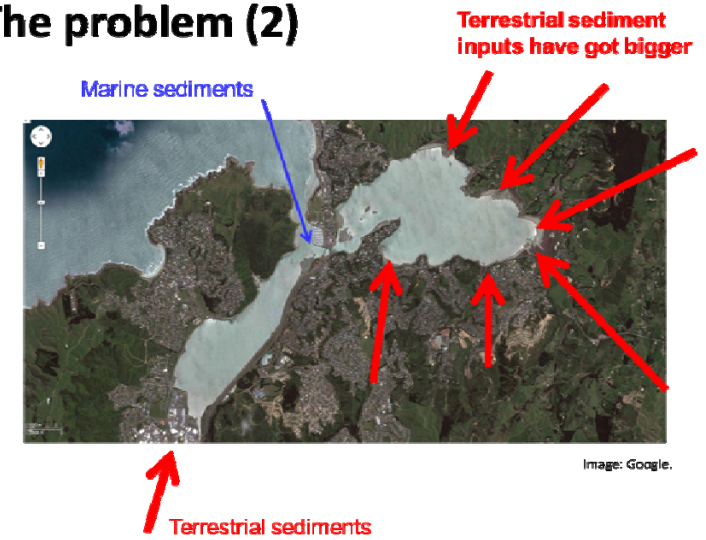
Two quite different problems

The problem (1)



This one is essentially about the natural variability of the flood-tide delta …

The problem (2)



… but this one concerns a long-term trend

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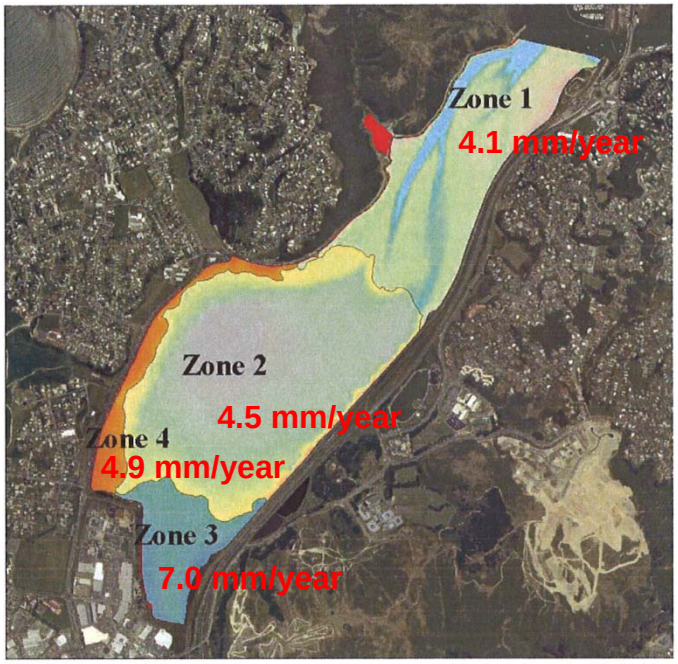
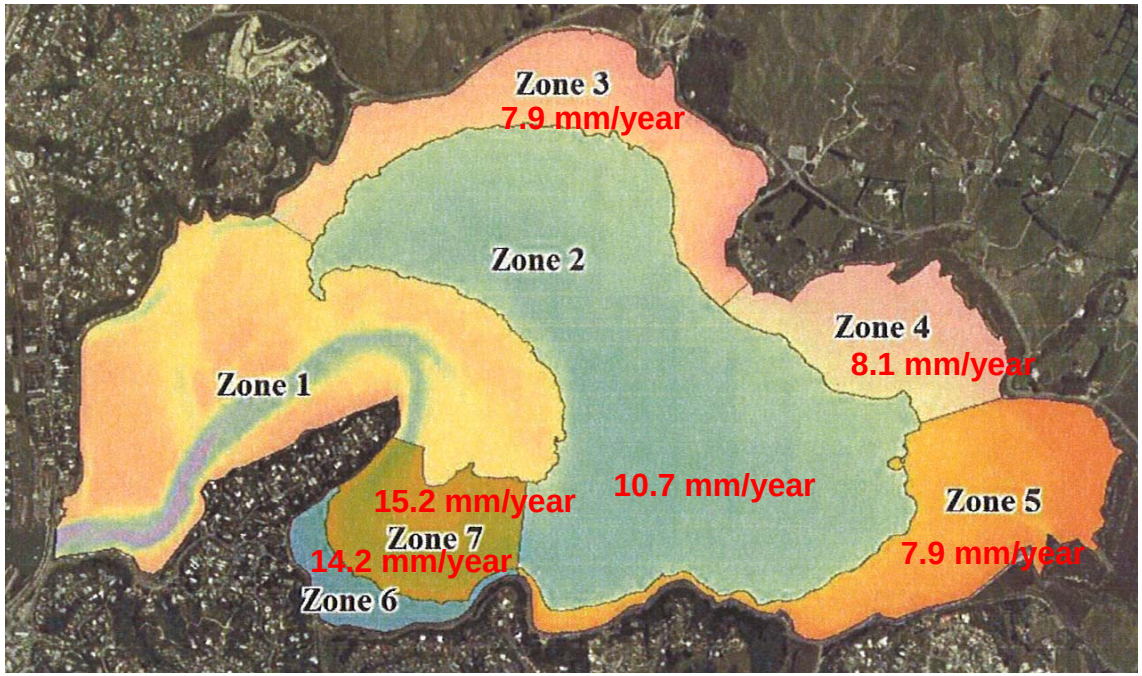
The pace of change

Pre-catchment-disturbance sedimentation rate 0.1-1 mm/year

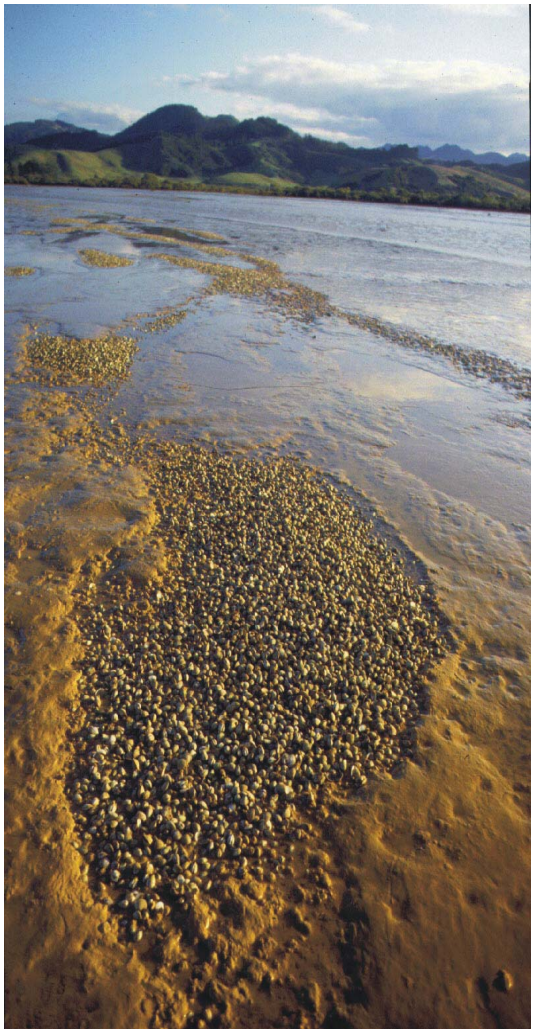




Sedimentation rate over the period 1974 to 2009, estimated from bathymetric surveys. Gibb and Cox, 2009; 2011.

Solutions

1.Do nothing



and continue to suffer the ecological consequences, loss of human amenity, and ultimately the premature infilling of the harbour

Solutions

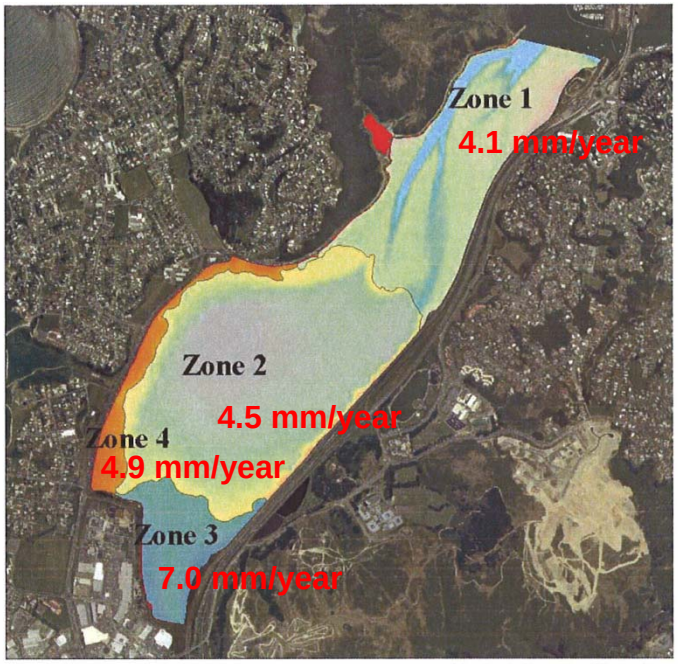
2. Reduce sediment runoff from the catchment

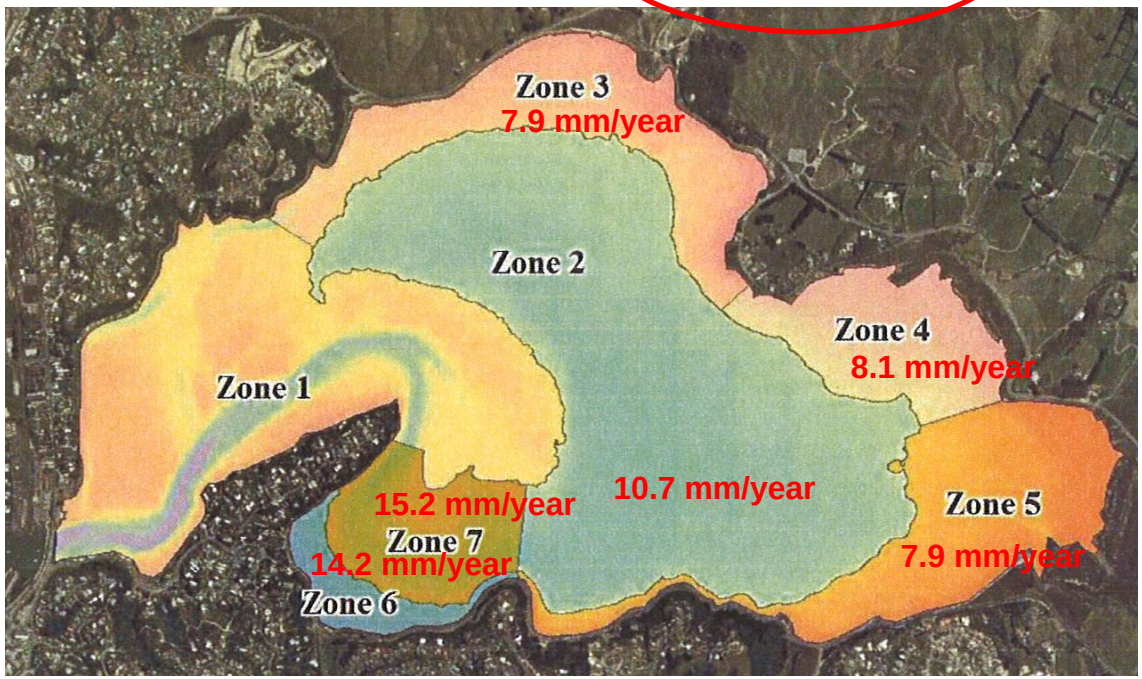
and deal with the root cause of the problem.

We can try to reduce sediment runoff with no clear goal in mind, or we can set a target and try to achieve it…

A good sedimentation target is probably around 1 mm/year.

Pre-catchment disturbance sedimentation rate 0.1-1 mm/year





Sedimentation rate over the period 1974 to 2009, estimated from bathymetric surveys. Gibb and Cox, 2009; 2011.

How much of a reduction in sediment runoff does this correspond to?

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We can answer this question the easy way or the hard way…

Easy way

For instance, assuming we want to achieve a reduction in sedimentation throughout the harbour of 90% then we could simply aim to reduce sediment runoff from every subcatchment by 90%.

However, that could be a highly inefficient solution.

Hard way

We need a way to find more efficient solutions, and for this we need a source-to-sink model of Porirua Harbour…

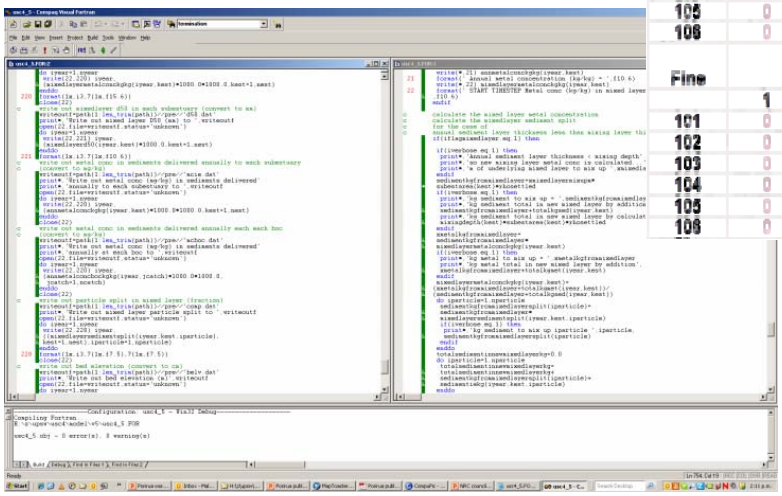
Source-to-sink model:

Freshwater runoff

Catchment sediment runoff

Sediment dispersal and reworking by tidal currents, waves and wind-driven currents

Sedimentation in the harbour

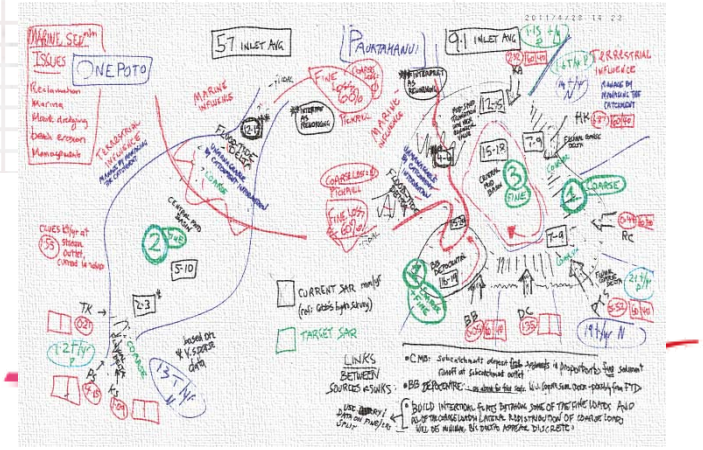


Coarse

	1	2	3	4	5	6	7	8	
101	0	0.1	0.9	0	0	0	0	0	1.00
102	0	0.1	0.15	0.5	0.25	0	0	0	1.00
103	0	0.1	0.15	0.25	0.5	0	0	0	1.00
104	0	0.1	0.05	0.15	0.6	0.1	0	0	1.00
105	0	0.1	0	0	0.7	0.1	0.1	0	1.00
106	0	0	0	0	0	0.8	0.2	0	1.00

Fine

	1	2	3	4
101	0	0.94	0.06	0
102	0	0.704	0	0.016
103	0	0.6	0	0
104	0	0.56	0	0
105	0	0.544	0	0
106	0	0	0	0



Inverting – or running backwards – the source-to-sink model:

Freshwater runoff

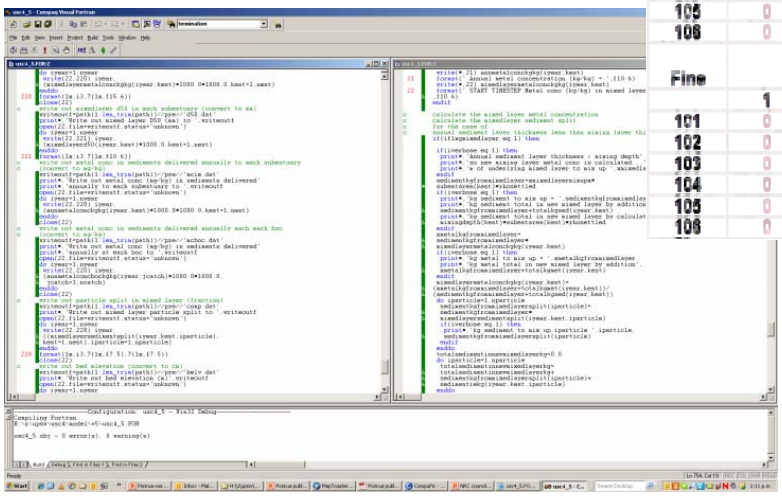
Catchment sediment runoff

Catchment sediment load limits

Sediment dispersal and reworking by tidal currents, waves and wind-driven currents

Sedimentation in the harbour

Sedimentation target



Coarse									
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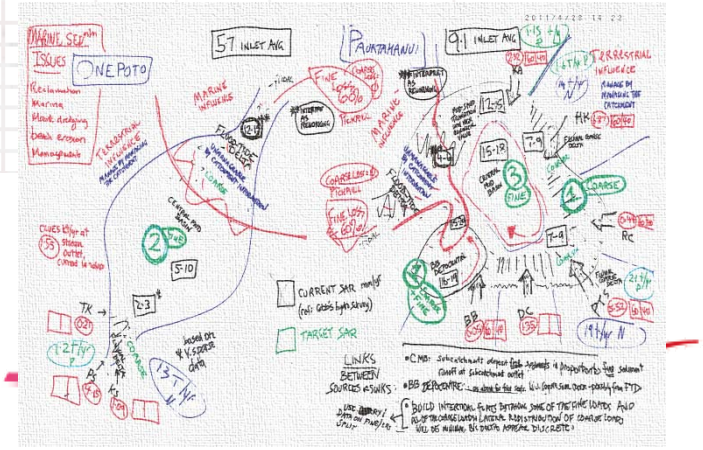
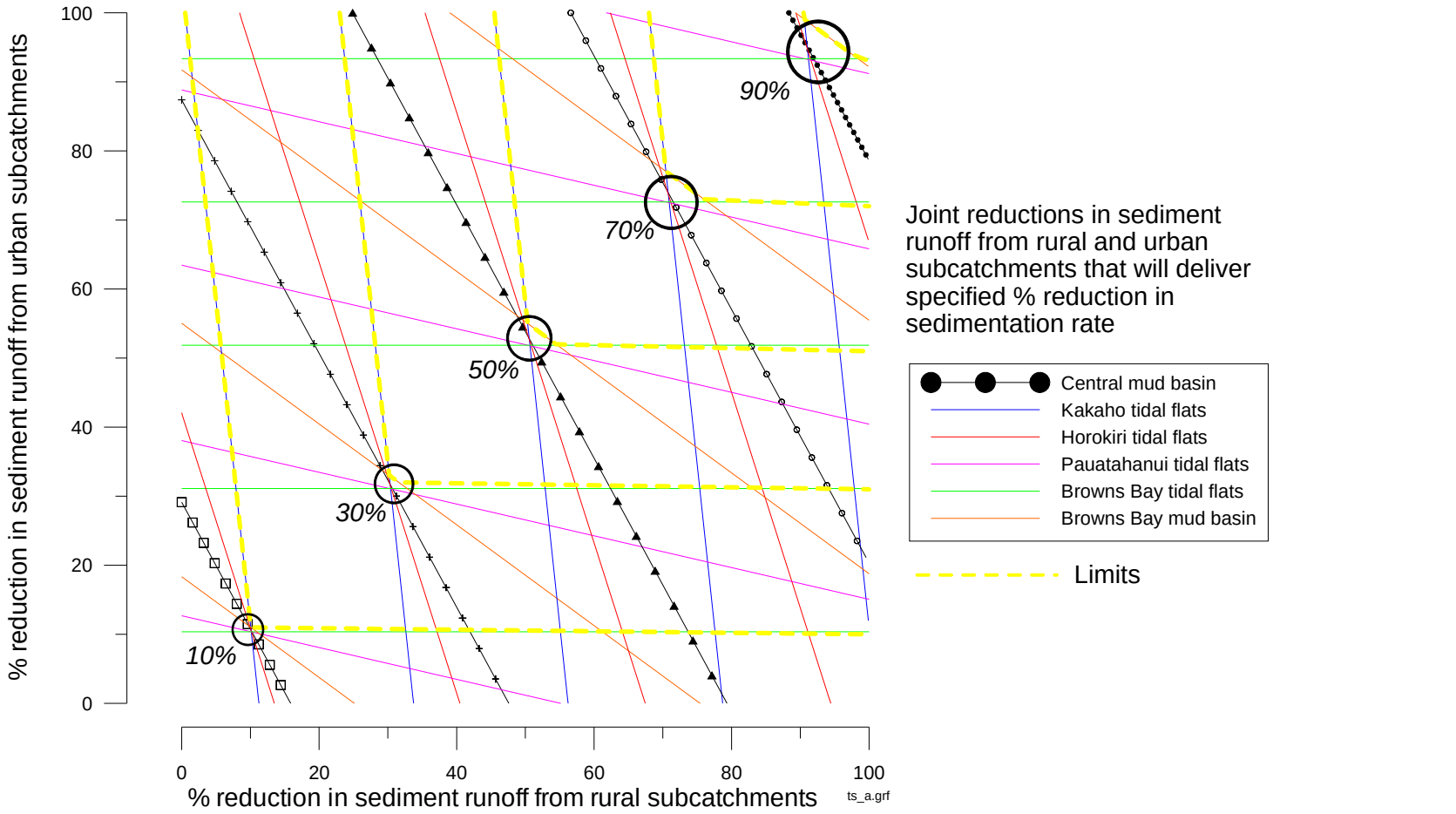
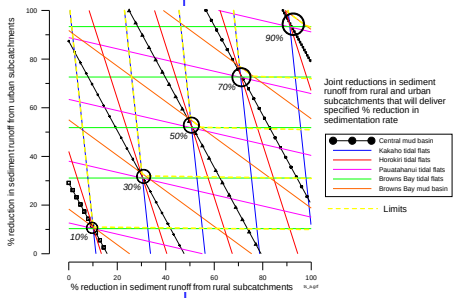


Using the model, we can identify all of the ways to reduce sediment runoff in the catchment that will deliver any set of sedimentation targets in the harbour



Aim is to find sediment runoff reductions that are achievable and that are affordable and that will deliver the sedimentation targets.

Sedimentation targets



Find new catchment sediment load limits

Too costly

Economic analysis → Do it

Affordable

Catchment sediment load limits

Catchment Land Use for Environmental Sustainability

Cannot do it

Achievable

Mitigation in the catchment

A strategy for measuring progress towards (1) achievement of the runoff-reduction targets and (2) the improvements in the harbour that are expected to come along on the back of the target 1-mm/year sedimentation rate is being developed.

Solutions

3. Dredge

- physically remove the problem fine sediments
- increase the tidal prism, causing an increase in tidal flushing
- change circulation patterns
- improve navigability over the flood-tide delta

Solutions

3. Dredge

(a) physically remove the problem fine sediments

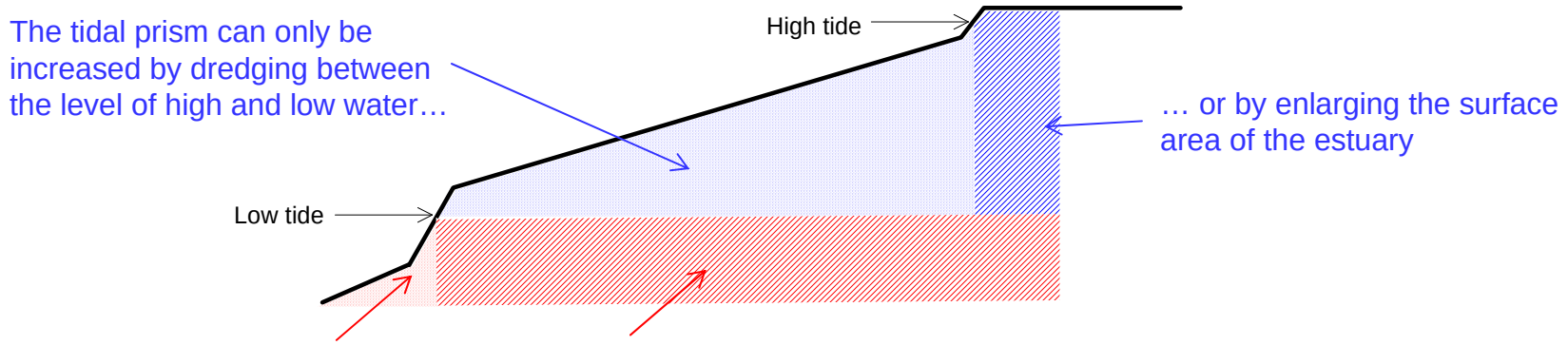
expensive, massive ecological impacts, need a place to dispose of material, very unlikely to get resource consent, the problem will return

Solutions

3. Dredge

(b) increase the tidal prism, causing an increase in tidal flushing

- the tidal prism is roughly the volume of water contained in an estuary between the low and high tide levels
- the bigger the tidal prism relative to the total volume of water contained in the estuary, the bigger the tidal flushing



Could it work?

•Remove the entire flood-tide delta down to MLWS: increase tidal prism by **2%**

•Remove intertidal flats down to MLWS: increase tidal prism by **13%**

These are quite massive interventions, but even they are unlikely to result in much of an increase in the tidal prism

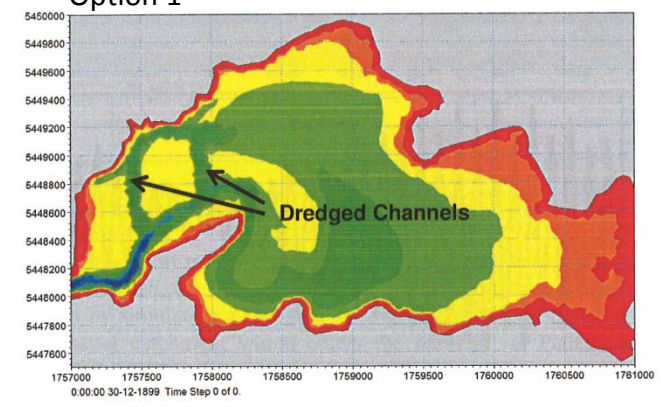
Solutions

3. Dredge

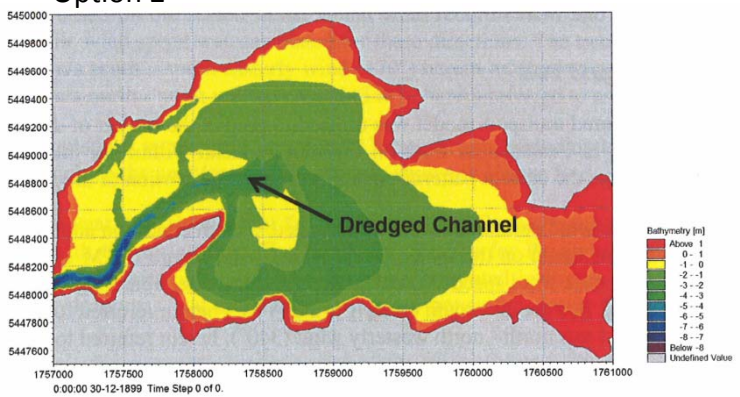
(c) change circulation patterns

Two options investigated by DHI Water & Environment and neither very effective at either flushing mud from the central mud basin or increasing the loss to sea of fine sediment discharged from rivers and streams during floods

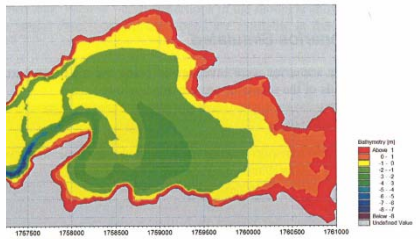
Option 1



Option 2



Current bathymetry



DHI Water & Environment, 2011

Solutions

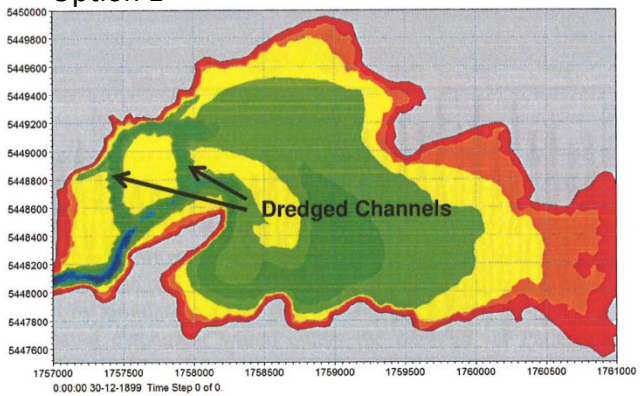
3. Dredge

(d) dredge the flood-tide delta to improve navigability

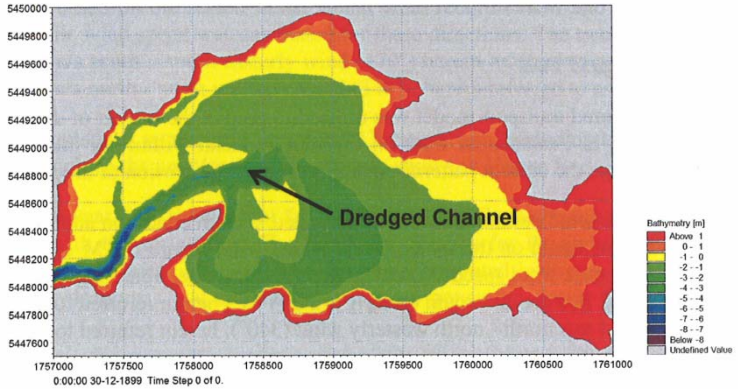
Option 2 investigated by DHI Water & Environment may be sustainable and have additional benefit of reducing intrusion of flood-tide delta into Browns Bay

Option 1 not sustainable

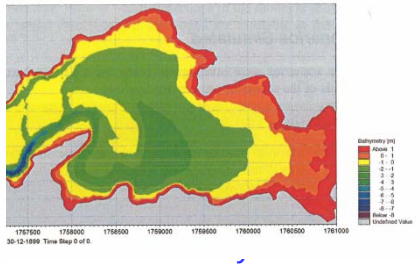
Option 1



Option 2



Current bathymetry



DHI Water & Environment, 2011

Solutions Summary

1.Do nothing

2. Reduce sediment runoff from the catchment

3. Dredge

(a) physically remove the problem fine sediments

(b) increase the tidal prism, causing an increase in tidal flushing

(c) change circulation patterns

(d) improve navigability over the flood-tide delta

Option 1

Option 2

Image: Google.