Davidson Environmental Limited

Qualitative description of estuarine impacts in relation to sedimentation at three estuaries along the Abel Tasman coast

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Summary

Prior to European settlement, estuaries were dominated by sandy sediments and had low sedimentation rates (<1 mm/year). In the last 150 years, with catchment clearance, wetland drainage, and land development for agriculture and settlements, New Zealand's estuaries have begun to infill rapidly with fine sediments. Today, average sedimentation rates in our estuaries are typically 10 times or higher than before humans arrived. Further, changes in global weather patterns has meant extreme rainfall events occur more regularly and exacerbate the rate and severity of sediment related impacts. As such, many estuaries around New Zealand are being degraded by increased muddiness.

The present report provides a qualitative description of sedimentation at three selected estuaries along the Abel Tasman coast. All estuaries have catchments dominated by Separation Point granites, but each has a different range of human catchment activities. One estuary is representative of pre-human land cover, while the other two estuaries are subjected to a variety of historic and present day human land practices.

Unlike estuaries spread across the plains of Tasman and Golden Bays, the Abel Tasman estuaries are naturally dominated by coarse substratum composed of granule, coarse, medium and fine sands. This is due to the steep hillside catchments composed of Separation Point granites. Mud is naturally uncommon, with mud habitat occupying only 7% of the estuaries within the Abel Tasman National Park.

Despite silt and clays being a small component of the material arriving at the coast, mud has increased in Kaiteriteri and Otuwhero Estuaries. Recently, coarse substratum has been smothered by a layer of mud, while salt marsh and herb field habitats have been smothered and species assemblages altered. Smothering of estuarine vegetation in these ecologically important estuaries contravenes the NZCPS sections 11a and 11b. In contrast, Torrent Bay Estuary remains at pre-human sedimentation levels. There is no doubt that sedimentation effects at these estuaries is linked to human catchment activities.

It is recommended that a peer reviewed plan outlining management of the Separation Point granite catchments be initiated by Council and DOC. The primary aim of the Plan should be to reduce and minimise sedimentation before these ecologically important estuaries are further degraded.

1.0 Introduction

Fine sediment is New Zealand's most widespread water contaminant, degrading ecosystems, infilling dams and reservoirs and impairing recreational, cultural and aesthetic values in our rivers, estuaries and coastal seas (NIWA, 2017). This sediment also finds its way into subtidal marine systems where it degrades habitats and ultimately influences benthic habitats and fisheries (Morrison *et al*., 2009).

In a recent study, Gibbs and Woodward (2018) investigated sediment sources in the Moutere and Waimea Rivers. It was found that (a) native forest and mature pine forest plantations were found to produce very little sediment, (b) a substantial proportion of fine sediment was found to originate from forest harvesting, (c) harvested production forest that becomes colonised by gorse, broom and other weed species if not replanted are less efficient at protecting soil from rainfall than a closed canopy forest, (d) bank erosion is a major source of fine sediment, (e) the Waimea Estuary received a high proportion of legacy sediment from bank erosion but was also receiving sediment from harvested pine forest at various locations, and (f) Moutere Estuary received a high proportion of sediment directly attributable to pine forest harvesting. The authors stated that this sediment may be travelling through the Moutere River system rapidly and being flocced out at the river mouth when it contacts the more saline sea water (Gibbs and Woodward, 2018).

Weather can play a major contributing factor in the release of sediment into waterways and the coast. Recently, Cyclone Gita delivered a large rainfall event on 20th February 2018 (Figure 1). Motueka rainfall for the event was recorded at 133.6 mm, while Riwaka recorded 146.9 mm (Figure 2). The rivers and streams in the area flooded, delivering sediment and debris to the coastal environment. Numerous slips and subsidence's occurred in the catchments, exacerbating the amount of material transported into waterways (Plate 1). The present report provides a qualitative description of the estuarine impacts associated with the movement of sediment at three selected estuaries with Separation Point granite geology along the Abel Tasman coast. Estuaries investigated were:

1. Kaiteriteri Estuary: catchment dominated by pine forest in various stages of growth.
2. Otuwhero Estuary: catchment dominated by partially logged pine plantation, unlogged plantation and early regeneration scrub.
3. Torrent Bay Estuary: catchment dominated by mature native forest.

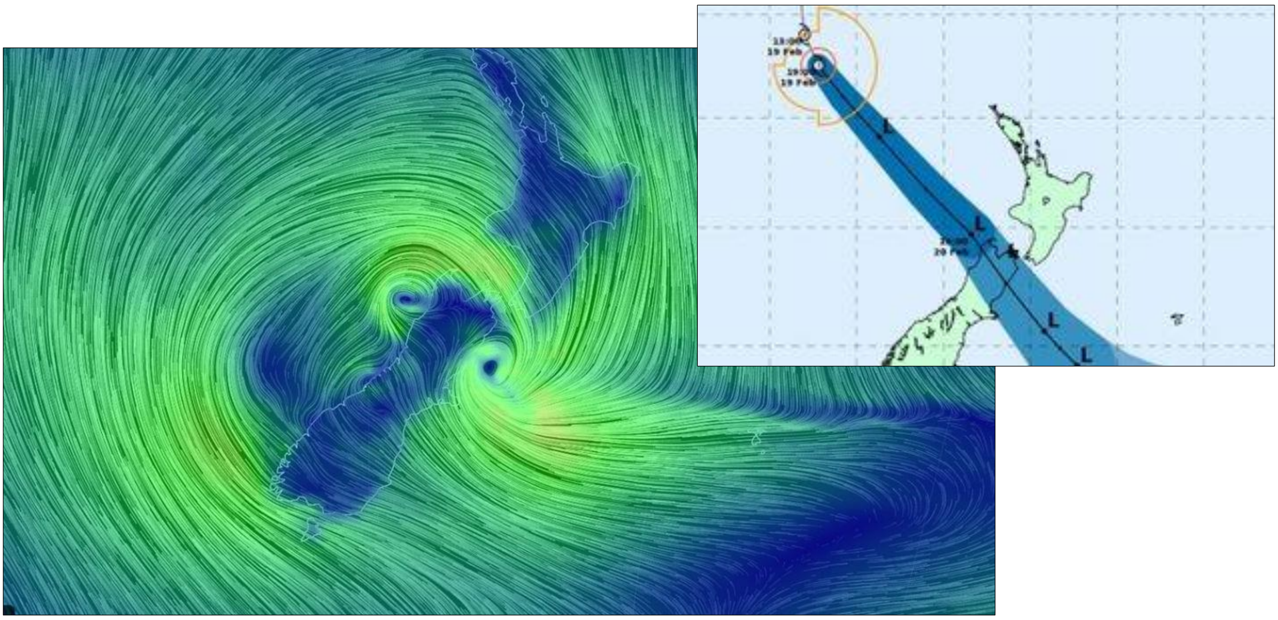

Figure 1. Weather representation of cyclone Gita.

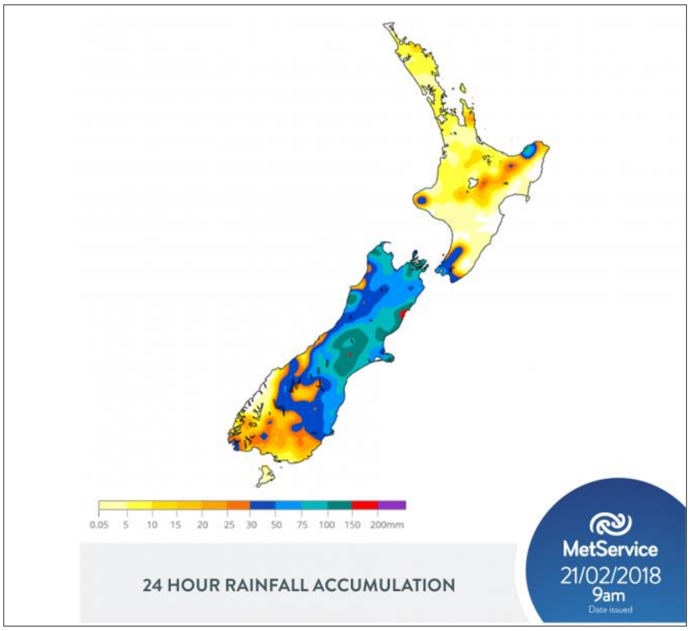

Figure 2. 24 hour accumulated rain during the Gita event.

Plate 1. One of many slips along the hillsides next to Otuwhero Estuary.

2.0 Background information

2.1 Study area

The three study estuaries are located along the Abel Tasman coastline with one estuary located inside the Abel Tasman National Park. All estuaries have comparable soil types; however, the land use, estuary and catchment size vary (approximate catchments sizes are Torrent Bay = 1544 ha, Otuwhero Estuary = 4446 ha and Kaiteriteri = 449 ha).

At Kaiteriteri, the valley floor is composed of a combination of housing, roads and two motor camps (Plate 2). Most of the hillsides are commercial forestry and 180 ha of pine forest has been developed as a mountain bike park. A health resort is also located on the southern side of the catchment (Kimi Ora). A small subdivision is presently under construction south of the Bethany Park motor camp (Plate 2). Approximately 20 ha of reserve clad in mature native forest abuts the estuary along its northern margins (Plate 3). One main stream and several tiny streams flow into the 22.2 ha estuary. The main stream is approximately 2-3 m wide with the bed dominated by granule and coarse sand material (Plate 4).

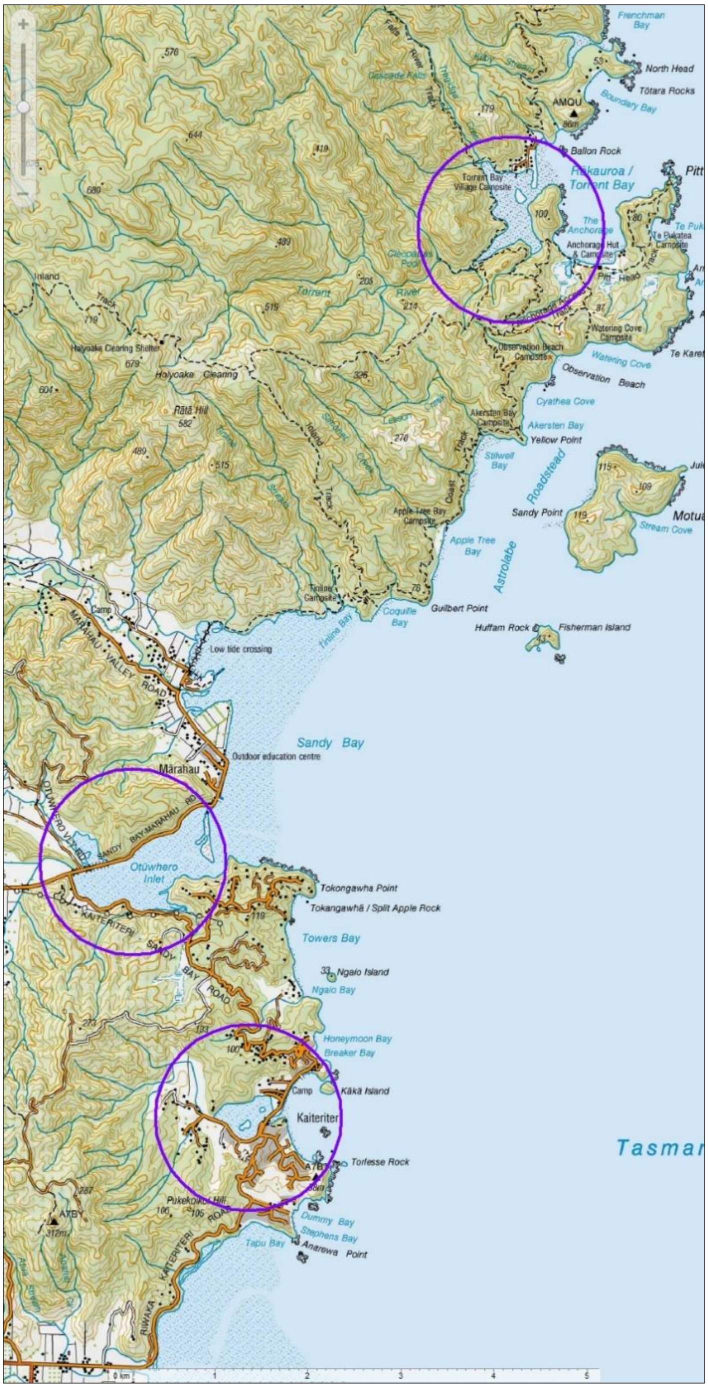

Figure 3. Estuary study sites along the Abel Tasman coast (purple circles).

Otuwhero Estuary valley floor is dominated by farms (pasture) with several roads and tracks. The hillsides are a combination of commercial forestry, pasture and regenerating scrub (Plate 5). Approximately 55 ha of reserve clad in mature native forest abuts the estuary along its northern margins (Plate 6). One main river and one main stream feed the 95 ha enclosed estuary as well as numerous small streams. The main river is approximately 10 m wide with the bed dominated by granule and coarse sand-sand material (Plate 7).

Torrent Bay Estuary valley floor is dominated by native vegetation and a small settlement at the base of a sand spit and beach (Plate 8). The Abel Tasman coastal track fringes the estuary and a low water walking route passes across the estuary. The hillsides are clad in mature forest (Plates 8 and 9). One main river as well as numerous small streams enter the 38 ha estuary. The main river is approximately 5-10 m wide with the bed dominated by cobbles, small boulders, granule and coarse sand material (Plate 10).

Plate 2. Kaiteriteri catchment with pine plantation and motor camp in the foreground.

Plate 3. Kaiteriteri Estuary Stream as it enters the estuary proper.

Plate 4. Kaiteriteri Stream as it enters the estuary.

Plate 5. Northern side of Otuwhero Estuary catchment. Note numerous slips on regenerating scrub hillsides.

Plate 6. Otuwhero River as it enters the estuary proper.

Plate 7. Otuwhero River as it enters the estuary above the main road bridge.

Plate 8. Torrent Bay Estuary and catchment taken from entrance.

Plate 9. Torrent Bay Estuary looking along the main river towards the entrance.

Plate 10. Torrent Bay Estuary River where it enters the estuary.

3.0 Historical reports and data

Relatively little biological work has occurred in the three estuaries.

Kaiteriteri Estuary

One historic biological study was found in relation to Kaiteriteri Estuary. Robertson and Stevens (2012) produced a habitat map (Figure 4) and evaluated the ecological status of Kaiteriteri Estuary. This work was conducted as part of a large study evaluating estuaries in the Tasman District.

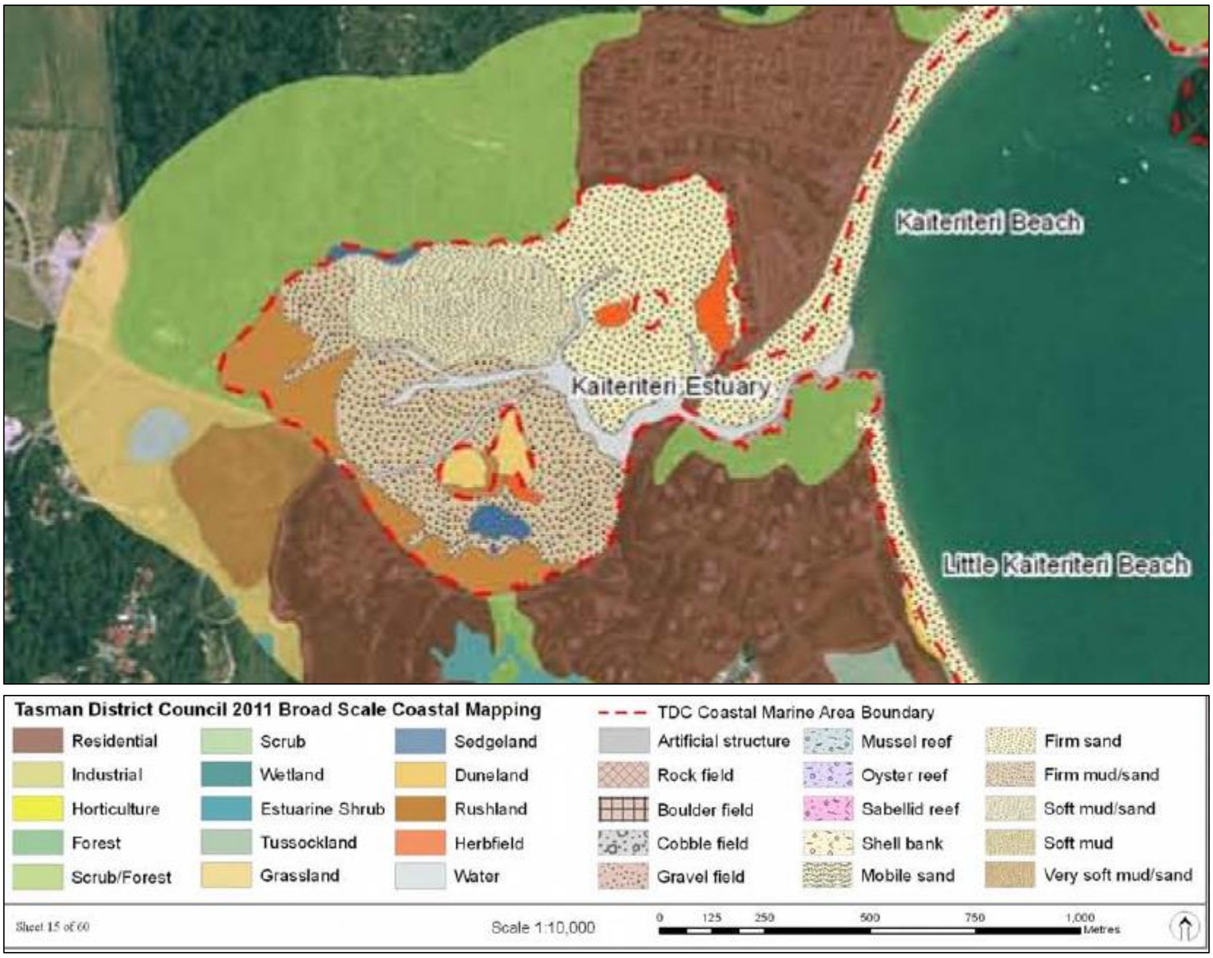

Figure 4. From Robertson and Stevens (2012). Major habitats from Kaiteriteri Estuary.

Robertson and Stevens (2012) stated “The Kaiteriteri Estuary is small, shallow, well-flushed tidal lagoon estuary that has a small freshwater inflow and is enclosed between the beach and the surrounding erosion-prone hills. Sediments are dominated by sands but areas of soft mud (17% of the estuary) and gravels are also present.” The authors stated the estuary was vulnerable to excessive muddiness caused primarily by catchment runoff from a steep and erosion-prone catchment that includes exotic forestry and intensive land use. They stated that sedimentation rates were 0.6 kt/year and ranked the estuary at a moderate level of stressor influence. The authors also suggested that sedimentation rates be monitored.

Otuwhero Estuary and Marahau sand flats

One historical study investigating Otuwhero Inlet was found. Robertson and Stevens (2012) produced a habitat map of Otuwhero Inlet (Figure 5) as part of a large study evaluating the ecological status of estuaries in the Tasman District.

In their assessment of the estuary, Robertson and Stevens (2012) stated “much of the estuary catchment is forest (primarily exotic 46%), with intensive pastoral use at 10%. The granite catchment is highly erodible and land disturbance has led to excessive sediment inputs to the estuary.” The authors stated the estuary was excessively muddy (10% soft mud) caused primarily by catchment runoff from intensive land use and exotic forestry (sediment only). Robertson and Stevens (2012) also stated that climate change (increased storms) was expected to exacerbate these issues. The authors suggested that sedimentation rates be monitored. They stated that suspended sediment rates were 24.2 kt/year and ranked the estuary at a moderate level of stressor influence, but fine sediment was ranked as a high stressor.

There have been a limited number of biological studies investigating the Marahau sand flats located on the seaward side of the Otuwhero Spit. Three studies were part of a sand relocation programme carried out between 2004 and 2005 (Davidson and Richards 2004a, 2004b, 2005).

Davidson and Richards (2004a, 2004b, 2005) sampled nine sand flat sites along the Marahau sand flats. Their site numbers 6 (south of access way) and sites 9 and 10 (north of access way) were located approximately 150 m away from the access way. Their sites 6 and site 9 were control sites described as sand, coarse sand substrata, while site 10 was described as an eelgrass bed. Sand-coarse sand sites supported four and three infaunal invertebrate species respectively at densities of 1799.5 and 106.7 individuals per m^2 respectively. At the eelgrass site (site 10), a total of 11 species of invertebrate were recorded at densities of 1548.3 individuals per m^2.

Counts of surface dwelling species by these authors showed that most sandy sites supported little species or individuals. Only eelgrass habitat supported a range of invertebrate species in significant densities.

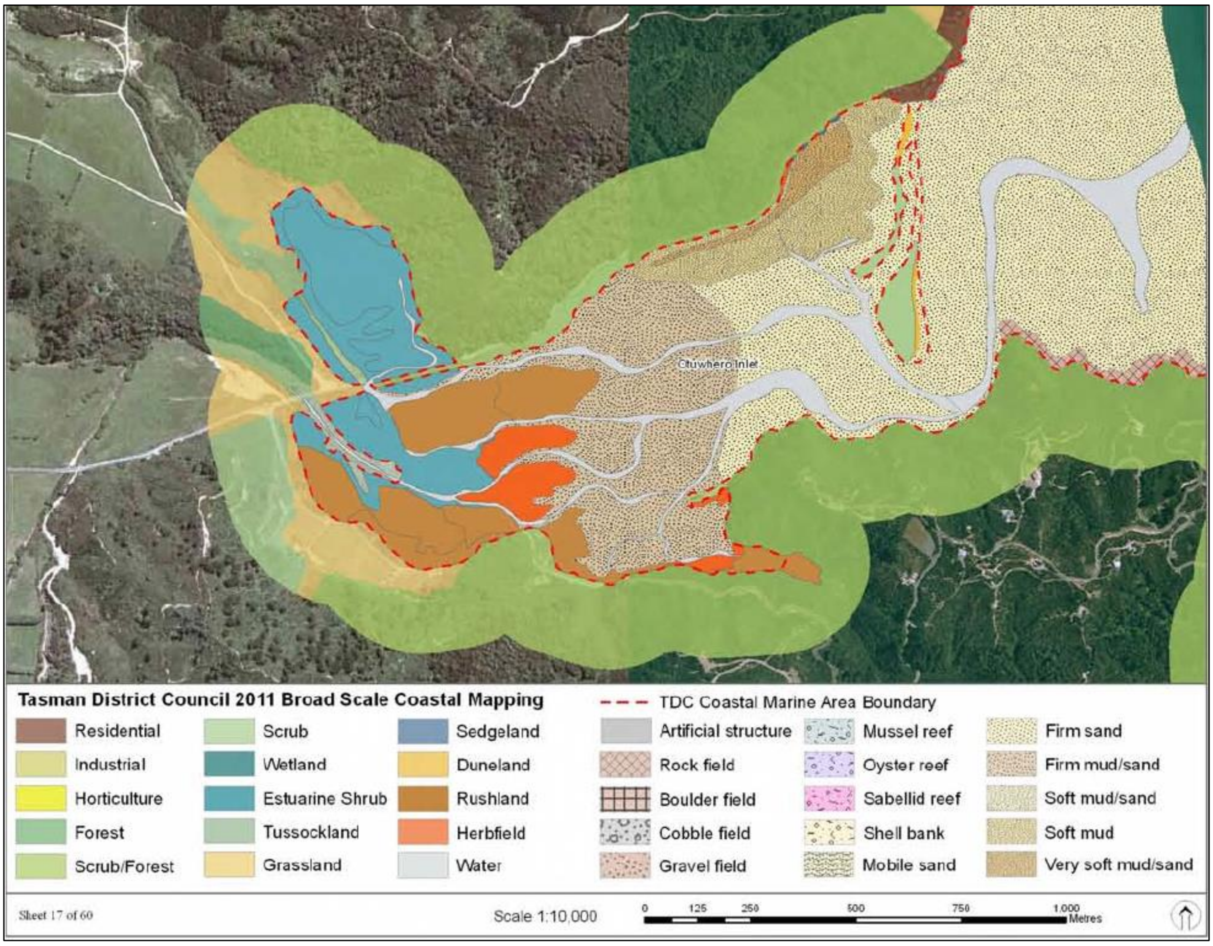

Figure 5. From Robertson and Stevens (2012). Major habitats from Otuwhero Inlet.

Overall, the authors consistently recorded highest species diversity from on top of and within eelgrass habitat; however, relatively high invertebrate numbers were also recorded from within the sediment at sandy sites. This was due to the presence of numerous juvenile pipi. The authors noted that not all sandy sites supported high numbers of these juveniles with some sites supporting relatively low numbers of invertebrates.

Davidson and Nister (2011) produced a baseline report for on-going photographic monitoring of the Marahau sand flats in relation to a Consent to launch boats (see monitoring protocol by Davidson and Richards, 2011).

Torrent Bay Estuary

Davidson (1991) conducted a biological survey along the Abel Tasman coast including the estuaries. Invertebrate cores were collected at four stations in Torrent Bay Estuary and a habitat map was produced. The map shows the estuary was dominated by coarse sand with some areas of cobbles, fine sand and one isolated area of mud covering an area of 1.13 ha or 2.9 % of the 38 ha estuary (Figure 6). Coarse sand and fine sand dominated the estuary at 83%.

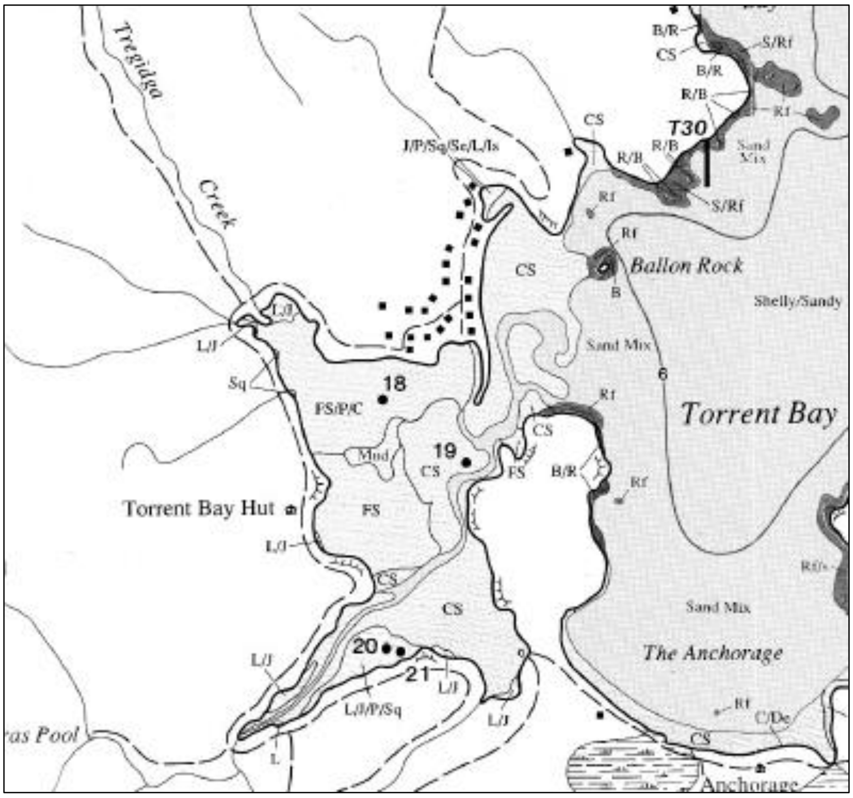

Figure 6. (From Davidson, 1992). Major habitats and substrata in Torrent Bay Estuary. CS = coarse sand, FS = fine sand, P = pebbles, C = cobbles, L, J, P, Sq= vegetation.

4.0 Methods

Field work was conducted on 29th March and 4th April 2018. For each estuary, a series of photo points were established with GPS coordinates and a compass bearing (Tables 1-3, Appendix 1-3). Notes were collected outlining observations of sediment, debris and habitat types.

Core samples (13 cm wide by 16 cm deep) were collected at 1-2 locations in each estuary. The core sample stations were selected in areas of the upper estuary at or close to mean high water (3.6 m). Each core was placed in a white tray and photographed. GPS coordinates were noted for each core station (Tables 1-3, Appendices 1-3).

5.0 Results

5.1 Kaiteriteri Estuary

A total of 27 photographs were collected from Kaiteriteri Estuary. Of those, 17 were established as photo points that can be used for future visual comparisons. Overall, the Estuary appears little impacted by the recent Cyclone Gita event. Coarse substrata are widespread in the small streams and was actively travelling downstream during field work (Plate 11).

Plate 11. New coarse sediment deposited at the foot of a small stream as it enters Kaiteriteri Estuary (photo 9).

At locations along the edges of the stream as it flowed through the estuary delta, silt and clay material were observed as a layer on top of coarse base sediments (Plate 12). This fine material was new, as few crab burrows were observed on this fine sediment layer. Core samples confirmed the base layer was composed of coarse sand material with no other layers or fine sediment down to 15 cm depth (Plate 13).

A core taken near mean high water away from the stream confirmed silt and clay was present but only as a thin layer compared to near the stream (Photo 61 in Appendix 1).

Plate 12. New fine sediment deposited over the top of coarse base sediment adjacent to the main stream near mean high water mark in Kaiteriteri Estuary (photo 18).

Plate 13. New fine sediment deposited over the top of coarse base sediment adjacent to the main stream near mean high water mark in Kaiteriteri Estuary (photo 55).

5.2 Otuwhero Inlet

A total of 24 photographs were collected from Otuwhero Estuary. Of those, 17 were established as photo points that can be used for future visual comparisons. Overall, the Estuary has been impacted by the recent Cyclone Gita event. Coarse and highly mobile substrata was widespread and up to 1 metre deep in the main river. This coarse material was observed actively travelling downstream during field work. Coarse substrata had also been deposited into the upper estuarine delta (Plate 14).

Plate 14. Coarse sediment deposited into the upper estuarine areas of Otuwhero Inlet (photo 33).

Along the stream edges, silt and clay had been deposited onto original estuarine coarse sediments (Plate 15). Collection of a core sample confirmed mud substrata was restricted to the surface layer over a base of coarse sand (Plate 16).

Plate 15. New fine sediment deposited over the top of coarse base sediment adjacent to the main stream near mean high water mark in Otuwhero Inlet (photo 37).

Plate 16. New fine sediment deposited over the top of coarse base sediment adjacent to the main stream near mean high water mark in Otuwhero Inlet (photo 52).

Further away from the stream, mud had also been deposited into and onto herb field communities. These plants had been partially or completely smothered (Plate 17).

Plate 17. New fine sediment deposited over and through herb-field communities adjacent to the main stream near mean high water mark in Otuwhero Inlet (photo 52).

On the inside of the Otuwhero Spit, an area of very fine and water-logged mud was observed (Plates 18 and 19). This area was previously characterised by mud; however, a new layer of very fine light brown mud had been recently deposited (Plate 18 and 19).

Plate 18. Extremely fine and waterlogged soupy sediment inside the Otuwhero Spit.

Plate 19. Area of fine and waterlogged sediment inside the Otuwhero Spit.

Around the margins of Otuwhero Inlet, adjacent land slips had deposited sediment into upper tidal areas completely smothering salt marsh habitat a several locations (Plate 20). Where this has raised the estuary above the maximum tidal limit for salt marsh and herb field species, exotic grasses will now grow. This represents a permanent loss of salt marsh habitat.

Plate 20. Smothered salt marsh around the upper edges of Otuwhero Inlet along the Marahau to Kaiteriteri Road.

5.3 Torrent Bay Estuary

A total of 10 photographs were collected from Torrent Bay Estuary. Of those, 9 were established as photo points that can be used for future visual comparisons. Overall, the Estuary appears unaffected by the recent Cyclone Gita event. The river bed at the head of the estuary was dominated by cobbles and boulders with some coarse sands (Plate 21). The estuary was characterised by coarse substrata with no indication of a silt layer (Plate 22). A core sample collected adjacent to the main river near mean high water showed no fine sediment bands and an absence of a mud surface layer (Plate 23).

Plate 21. Torrent River as it enters the head of Torrent Bay Estuary (photo 49).

Plate 21. Torrent Bay Estuary characterised by sandy substrata near its head (photo 45).

Plate 22. Core sample near mean high water adjacent to Torrent River channel (photo 50a).

Table 1. Photo point and core sample coordinates.

Photo number	Coordinates	Location	Photo description	Degrees
1 & 2	41 02.337,173 00.433	Kaiteriteri	Motorcamp stream	300
3	41 02.339,173 00.412	Kaiteriteri	Subdivision drain	292
4	41 02.332,173 00.439	Kaiteriteri	Main stream	154
5	41 02.330,173 00.437	Kaiteriteri	Main stream	342
6	41 02.324,173 00.433	Kaiteriteri	Main stream	140
7	41 02.348,173 00.469	Kaiteriteri	Combined stream	292
8	41 02.348,173 00.473	Kaiteriteri	Combined stream	112
9	41 02.375,173 00.523	Kaiteriteri	Subdivision drain in lagoon	278
10 & 11	41 02.358,173 00.527	Kaiteriteri	Combined stream looking upstream	287
	41 02.358,173 00.527	Kaiteriteri	Combined stream, looking downstream	96
12 & 13	41 02.352,173 00.552	Kaiteriteri	Salt marsh, looking upstream	259
		Kaiteriteri	Salt marsh, looking downtream	25
14 & 15	41 02.339,173 00.581	Kaiteriteri	Combined stream, looking downstream	50
	41 02.339,173 00.581	Kaiteriteri	Combined stream, looking upstream	234
16	41 02.327,173 00.614	Kaiteriteri	Combined stream, looking downstream	100
17 & 18	41 02.332,173 00.638	Kaiteriteri	Sediment closeup	
	41 02.332,173 00.638	Kaiteriteri	Sediment closeup	
19 & 20	41 02.340,173 00.673	Kaiteriteri	Combined stream, looking downstream	105
	41 02.332,173 00.638	Kaiteriteri	Combined stream, looking downstream	304
21 to 24	41 00.490,172 59.143	Otuwhero	Main stream	
	41 00.490,172 59.143	Otuwhero	Main stream	
	41 00.490,172 59.143	Otuwhero	Main stream	
	41 00.490,172 59.143	Otuwhero	Main stream	
25	41 00.520,172 59.151	Otuwhero	Main stream at bridge	0
26	41 00.512,172 59.150	Otuwhero	Main stream, looking upstream	272
27 & 28 & 29	41 00.748,172 59.363	Otuwhero	Main stream, looking upstream	314
	41 00.748,172 59.363	Otuwhero	Main stream, looking across stream	31
	41 00.748,172 59.363	Otuwhero	Main stream, looking down stream	81
30 & 31	41 00.905,172 59.526	Otuwhero	Main stream, upstream from bridge	300
	41 00.905,172 59.526	Otuwhero	Main stream, upstream and across from bridge	9
32	41 00.908,172 59.530	Otuwhero	Main stream, downstream from bridge	127
33 & 34	41 00.910,172 59.564	Otuwhero	Main stream, looking across saltmarsh	124
	41 00.910,172 59.564	Otuwhero	Main stream, looking downstream	320
35	41 00.919,172 59.577	Otuwhero	Sediment along stream edge	265
36	41 00.931,172 59.584	Otuwhero	Main stream, looking downstream	69
37 & 38	41 00.903,172 59.677	Otuwhero	Sediment along stream edge	69
	41 00.903,172 59.677	Otuwhero	Sediment along stream edge	69
39 & 40	41 00.839,172 59.858	Otuwhero	Sediment in estuary delta	296
	41 00.839,172 59.858	Otuwhero	Sediment in estuary delta	272
41	41 00.862,172 59.882	Otuwhero	Sediment in estuary delta	84
42 & 43	40 57.187,173 02.798	Torrent Bay Estuary	Lower delta looking downstream	59
	40 57.187,173 02.798	Torrent Bay Estuary	Lower delta looking upstream	237
44 & 45	40 57.249,173 02.671	Torrent Bay Estuary	Lower delta looking downstream	49
		Torrent Bay Estuary	Lower delta looking upstream	208
46	40 57.298,173 02.633	Torrent Bay Estuary	Saltmarsh near river edge	287
47 & 48	40 57.336,173 02.601	Torrent Bay Estuary	Torrent River looking downstream	55
		Torrent Bay Estuary	Torrent River looking upstream	240
49	40 57.345,173 02.603	Torrent Bay Estuary	Torrent River looking upstream	240
50	40 57.281,173 02.630	Torrent Bay Estuary	Core	
51	40 57.264,173 02.696	Torrent Bay Estuary	Saltmarsh looking downstream	42
52 & 53 & 54	41 00.879,172 59.692	Otuwhero Estuary	Core near stream edge	
	41 00.879,172 59.692	Otuwhero Estuary	Core near stream edge	
	41 00.879,172 59.692	Otuwhero Estuary	Core near stream edge	
55 - 59	41 02.329,173 00.635	Kaiteriteri Estuary	Core near stream edge	
	41 02.329,173 00.635	Kaiteriteri Estuary	Core near stream edge	
	41 02.329,173 00.635	Kaiteriteri Estuary	Core near stream edge	
	41 02.329,173 00.635	Kaiteriteri Estuary	Core near stream edge	
	41 02.329,173 00.635	Kaiteriteri Estuary	Core near stream edge	
60 & 61	41 02.374,173 00.633	Kaiteriteri Estuary	Core on estuary flats	

6.0 Conclusions

6.1 Background

Estuary sedimentation is a continual natural process (Black *et al.,* 2013). Prior to European settlement, estuaries were dominated by sandy sediments and had low sedimentation rates (<1 mm/year). In the last 150 years, with catchment clearance, wetland drainage, and land development for agriculture and settlements, New Zealand's estuaries have begun to infill rapidly with fine sediments. Today, average sedimentation rates in our estuaries are typically 10 times or higher than before humans arrived (e.g. see Abrahim, 2005; Gibb and Cox, 2009; Robertson and Stevens, 2007,2010; Swales and Hume, 1995; Handley, 2006; Handley *et al*., 2017). Monitoring of the Moutere Inlet for example, revealed the coverage of soft and very soft mud increased from 99 ha in 2006 to 274 ha in 2013, covering 38 per cent of the estuary (Stevens and Robertson, 2013). In the Waimea Inlet, the coverage of very soft mud increased from 10 ha in 1999 to 551 ha in 2014, with soft and very soft mud covering 40 per cent of the estuary (Stevens and Robertson, 2014).

Sources of sediment come from subdivision developments, bank erosion, farming, forestry, land clearance and roading activities. The contribution each catchment activity makes varies from catchment to catchment (Gibbs, 2008; Swales *et al*., 2012; 2013; Gibbs *et al*., 2014; Swales *et al.,* 2015; Handley *et al*., 2017). Handley *et al*. (2017) for example stated for Pelorus Sound that the major sediment sources were found to be derived from the 'Havelock inflow', pine, subsoil and bracken, with beech forest, ponga, native forest (other than beech), and sheep being only minor components. Further, at most sites, there were substantial proportions of sediment with a pine signature in the upper 2 cm. Handley *et al*. (2017) stated that this was consistent with the large areas of pine plantation forestry in the Pelorus Sound catchment and the potential for sediment relocation with the complex hydrodynamics associated with the large freshwater inflow at the head of the Sound and saline oceanic bottom water intrusions into the Sound. The authors concluded with a variety of recommendations mostly directed at improving catchment management practices (e.g. Urlich, 2015).

6.2 Abel Tasman Estuaries

Relatively little background data is available for these unique estuaries. Unlike estuaries spread across the plains of Tasman and Golden Bays, these small estuaries are surrounded by steep hillside comprised of Separation Point granites. As such, they are naturally dominated by coarse substratum composed of granules, coarse, medium and fine sands (Davidson, 1991). Mud is naturally uncommon in estuaries along the Abel Tasman coast (e.g. 2.9% cover in Torrent Bay Estuary and absent as a habitat from most estuaries). Davidson (1991) stated that overall mud habitat occupied 7% of the intertidal estuaries along the Abel Tasman National Park coast.

The Abel Tasman estuaries receive incoming sediment dominated by coarse material from the Separation Point granite catchments. Despite silt and clays being a small component of the material arriving at the coast, mud has increased in Kaiteriteri and Otuwhero Estuaries. Otuwhero has the largest of the three catchments and therefore receives more sediment, however, human activities in these catchments have increased sediment supply at both Kaiteriteri and Otuwhero Estuaries. Historic land clearance was likely the first activity that increased sedimentation rates for these estuaries. Since that time, the catchments have been modified by farming, roading, housing and forestry practices. Recent weather extremes have exacerbated this effect with regenerating hillsides subsiding during the Gita weather event.

In contrast, Torrent Bay Estuary shows little sign of the recent extreme rainfall event. Visual observations during the present study confirm mud remains uncommon in the estuary. Further, no layer of silt and clay was observed in and around the river delta. Where the Torrent River enters the estuary remains dominated by cobble and small boulder material. Torrent Bay Estuary has a relatively large catchment; however, there is little doubt the mature forest acts to stabilise the catchment and keep sediment at low levels. Handley *et al*. (2017) documented pre-human levels of sediment accumulation in inner Pelorus Sound (Kenepuru) at 0.2 to 1.2 mm/year. It is probable that sedimentation rates at Torrent Bay remain at pre-human levels.

6.3 Estuary condition

Robertson and Stevens (2012) and Stevens and Robertson (2013, 2014) documented an increase in muddiness in Moutere and Waimea Inlets. The increase in muddiness also relates to wider ecological impacts such as habitat loss, infilling, lowering light levels for seagrasses, smothering of habitats and communities, and community shifts to mud dwelling species. Overall, the authors stated that most of the estuaries in Tasman and Golden Bays are becoming muddier.

Robertson and Stevens (2012) and Stevens and Robertson (2013, 2014) have suggested increased monitoring and regular mapping of estuaries to monitor these negative effects.

Studying the decline of estuary values is valuable, however improving or solving the issue of increased sedimentation is the real challenge and requires immediate action.

6.4 Adverse impacts and catchment management

The TDC website states "***Land disturbance occurs when the soil and covering vegetation is removed or disturbed. Land disturbance may result in soil loss or damage, soil instability, sediment mobilisation and subsequent deposition and contamination of water ways (including underground cave systems). Such disturbances may adversely affect natural ecosystems or impact archaeological sites***." The TDC website also states "***Separation Point Granites are readily eroded when exposed. Particular care is needed during earthworks and with storm-water control. Because of the highly erodible nature of the Separation Point Granites particular care is needed when undertaking any form of land disturbance. In particular, all storm water needs to be appropriately controlled and any areas of exposed soils stabilised***."

The present investigation of three estuaries with Separation Point Granite soils confirms the two estuaries with modified catchments are being ecologically degraded. In Otuwhero Inlet, both Sections 11a and 11b of the New Zealand Coastal Policy Statement are contravened due to the adverse impacts documented during the present study. At Kaiteriteri Inlet, it is highly likely that adverse impacts will occur in the future when the catchment is disturbed during forestry harvesting activities coinciding with a major rainfall event.

To reduce further estuary degradation, carefully crafted integrated catchment management is required. Such a management Plan also requires "buy-in" from the catchment land owners. In particular, the Otuwhero catchment is large and will always carry significant sediment during large rainfall events, however, there are a number of activities exacerbating the sediment issue (e.g. forestry harvests). Catchment activities that destabilise or expose the erodible soils need to be assessed and, where appropriate, regulated or retired. Activities such as establishment of riparian strips, retirement of land from farming, replanting of native vegetation and sediment controls should be funded and encouraged (Urlich, 2015). Such measures are not an overnight fix and form part of long-term catchment management programme aimed to ensure the ecologically integrity of these ecologically important Abel Tasman estuaries are not further degraded.

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Appendix 1. Kaiteriteri Estuary photo points.

Photo 1 	*Photo 2* 	*Photo 3* 
Photo 4 	*Photo 5* 	*Photo 6* 
Photo 7 	*Photo 8* 	*Photo 9* 

Photo 10

Photo 11

Photo 12

Photo 13

Photo 14

Photo 15

Photo 16

Photo 17

Photo 18

Photo 19

Photo 20

Photo 5521 	*Photo 56* 	*Photo 57* 
Photo 58 	*Photo 22* 	*Photo 60* 
Photo 61 		

Appendix 2. Otuwhero Inlet photo points

Photo 23 	*Photo 23* 	*Photo 23* 
Photo 24 	*Photo 24* 	*Photo 25* 
Photo 27 	*Photo 28* 	*Photo 29* 
Photo 30 	*Photo 31* 	*Photo 32* 

Photo 33 	*Photo 34* 	*Photo 35* 
Photo 36 	*Photo 37* 	*Photo 38* 
Photo 39 	*Photo 40* 	*Photo 41* 
Photo 52 	*Photo 53* 	*Photo 54* 

Appendix 3. Torrent Bay photo points

Photo 42 	*Photo 43* 	*Photo 44* 
Photo 45 	*Photo 46* 	*Photo 47* 
Photo 48 	*Photo 49* 	*Photo 50a* 
Photo 50b 	*Photo 51*