CAWTHRON

REPORT NO. 3865

DISCHARGES TO THE MOTUWEKA / HAVELOCK ESTUARY

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Prepared for Marlborough District Council

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EXECUTIVE SUMMARY

Marlborough District Council (MDC) commissioned Cawthron to undertake a site visit to identify consented outfalls and produce a summary of the available information about the quality and quantity of direct aquatic inputs to the Motuweka / Havelock Estuary[1] (the 'Estuary'), the receiving environment for Te Hoiere / Pelorus River and Kaituna River and the residential and industrial areas of Havelock township.

This report presents the methods used for the site visit, and how the contributing discharges were identified, characterised and mapped. The main findings with respect to possible environmental and cumulative impacts were:

1. The identification of discharge contributors and discharge-specific compositional data. This suggested that the contributors may be adding to ecological or human health-related pressures within the Estuary and was the first key step to assessing cumulative effects to the Estuary.
2. Where data were available, many contributors frequently appear to be introducing discharges to the marine environment at concentrations higher than typical or guideline values for receiving waters.
3. The loading contribution from the riverine inputs was generally very high compared to other industry and municipal contributors.
4. The potential pressures to the Estuary identified from these contaminants include, broadly, eutrophication (nutrients, biochemical oxygen demand, total organic carbon), biological toxicity (metals), smothering of organisms (total suspended sediment) and human health-related effects (bacterial indicators / pathogens).

Several caveats and limitations were identified with the data used in this investigation, resulting in a medium to low level of data confidence. This was typically due to a lack of understanding around the discharge composition and / or volume. More developed knowledge of riverine contributor flows and water quality characteristics, consideration of other non-discharge-related Estuary stressors, and further contributor discharge compositional testing would improve this understanding.

[1] Referred to as the 'Motuweka / Havelock Estuary' on the LAWA website.

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1. INTRODUCTION

1.1. Background and scope

The Motuweka / Havelock Estuary (the 'Estuary') is the receiving environment for Te Hoiere / Pelorus River and Kaituna River and the residential and industrial areas of Havelock township. Despite signs of cumulative stress within the estuarine ecosystem (Robertson 2019a), there is limited information about the point-source discharges and their cumulative impacts on the Estuary. Marlborough District Council (MDC) commissioned the Cawthron Institute ('Cawthron') to undertake a site visit to identify consented outfalls and to produce a summary of the available information about the quality and quantity of direct aquatic inputs to the Estuary.

This report describes the methods used for the site visit, and how the contributing discharges (the 'contributors') were identified, characterised and mapped. Finally, we summarise the main findings with respect to possible environmental and cumulative impacts.

The specific deliverables / scope for this report were:

1. Undertake a site visit to identify consented coastal outfalls in the vicinity of Havelock township.
5. Produce an electronic summary table and geographic information system (GIS) map of the available information about the quality and quantity of direct aquatic inputs to the Estuary (i.e. contaminant concentrations and loadings).
6. Interpret the summary table results in relation to potential environmental effects, including cumulative effects, with specific focus on the following key physicochemical parameters of interest (as defined by MDC):
    - nutrients (nitrogen and phosphorous)
    - total organic carbon (TOC)
    - total suspended sediment (TSS)
    - bacteria – *E coli*, enterococci, faecal bacteria
    - biochemical oxygen demand (BOD)[2]
    - metals / metalloids – arsenic (As), mercury (Hg), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn).

[2] Dissolved oxygen (DO) was also identified at the project scoping phase as a contaminant of interest. However, given that DO levels in discharges are a point-in-time measurement and are contextual (dependent on time, dispersive potential, temp, pH, etc.), loading (mg/L) has not been calculated.

1.2. Caveats and limitations

As with many investigations compiling existing data, the data sources each have their own specific foibles, and were not originally intended to have continuity / comparability to one another. Given this, there are several limitations to this investigation that need to be considered in conjunction with any data interpretation:

- The data and information on the potential industry discharge contributors to the Estuary were obtained by interrogation of the MDC Smart Maps[3] and Open Data[4] web-based portals. We note that the two data sources did not always align, so that what was displayed on Smart Maps was not always available from Open Data, and vice versa. Cross-checking the data sources would improve the level of accuracy, but was beyond the scope and resources of the present study.
- To ensure we had included the key input contributors, we had the discharge contributor summary checked over by an MDC Environmental Protection Officer (Ally Perkins, pers. comm, 30 September 2022). However, we note that this approach was not part of the original scope, and greater input from the MDC consenting officers who are more familiar with the activities in the region would likely improve the level of accuracy of this assessment.
- The stormwater and wastewater geospatial data that were provided to us by MDC on the 29 August 2022 did not appear to be fully mapped (data were missing for coastal stormwater discharge points at the Havelock Marina). As per the disclaimer attached to the geospatial data (Tapper 2022), 'The accompanying material has been released by Council from its information repositories. Council does not accept any responsibility for the initial and ongoing accuracy to the material. It is the responsibility of the recipient to make such checks as the recipient considers appropriate to ensure accuracy. Services layers are schematic only and actual positions and level should be confirmed from Council's hard copy records.'
- The focus of this investigation was on identifying contaminant concentrations and loading from direct discharges. However, other diffuse inputs have also been identified here as they provide context and warrant consideration in determining potential cumulative effects.

The influence of the Marlborough Sounds tidal circulation on nutrient supply and contamination to the Estuary from other parts of the Marlborough Sounds and outer ocean has not been considered here (see Handley et al. 2017).

This report is a preliminary assessment of contaminant-related adverse effects from aquatic inputs and does not constitute a full environmental impact assessment or

[3] https://smartmaps.marlborough.govt.nz/smapviewer/?map=0c8c074302434a0b8ed0f0c18d77b372
[4] https://data-marlborough.opendata.arcgis.com

assessment of environmental effects. This project does not include or represent a substitute for pollution apportionment modelling or statistical analyses of receiving environment monitoring data that might show relationships between environmental quality and inputs. Ultimately, the quality of the data available dictated the level of confidence (LOC) in the overall findings (see discussion on LOC in Section 4.3).

2. METHODS

2.1. Site visit to identify consented discharges

A site visit to the Estuary was undertaken on 7 September 2022, around low tide (1.12pm NZDT, 1 MSL). The aim of the visit was to locate and describe (identify key features, photograph and record coordinates) any visible outfalls and obvious visual effects from inputs to the surrounding coastline. Following this, the easily identifiable asset management stormwater and wastewater drainage network outfalls were identified, and those outfalls not accounted for (possibility unconsented) under existing consents were highlighted.

2.2. Identifying inputs

Discharge inputs from consented industry, municipal and port / marina discharges were identified from spatial points available on the MDC Smart Maps and Open Data portals, as well as consent applications and consent decision documents. The portal data included a range of consent 'sub-types' that related to discharges near, or directly to, the Estuary:

- Coastal permit – discharge to seawater
- Land use – activity (Havelock Shell Processors)
- Certificate of compliance (e.g. Cloudy Bay Clams)
- Discharge permit – to land (e.g. landfill, petrol station, septic tanks, *Spartina* spraying, etc.)
- Land use – river surface or bed activity (e.g. sewage treatment ponds)
- Discharge permit – to water (e.g. fuel berth)
- Coastal permit – disturb foreshore or seabed (dredging)
- Coastal permit – reclaim or drain (island roost / dredging)
- Coastal permit – activity (e.g. civil works)
- Water permit – divert water (e.g. civil works / river protection).

River catchment inputs were also included in the assessment and were estimated using outputs from the Catchment Land Use for Environmental Sustainability model (NIWA 2022a). Te Hoiere / Pelorus River and the Kaituna River were identified as the largest riverine inputs into the Estuary and concentration and loading data for each were described separately. All other 11 river reaches draining into the Estuary were grouped together as 'other'. For limitations relating to the modelling of catchment run-off, the reader is referred to the CLUES user manual (Semadeni-Davies 2016).

2.3. Estimating contaminant loading

Discharge inputs were characterised individually (hereafter referred to as 'contributors') and were also grouped into broad categories: industrial discharges, municipal waste, urban stormwater, riverine inputs and 'other'. While a number of discharge input characteristics were identified, the focus of this report is on the key physicochemical parameters of interest (as defined by MDC, Section 1).

The full breadth of discharge inputs, raw data and associated information identified is provided as an electronic appendix (an Excel table, Appendix 1) and geospatially as an ArcMap package (Appendix 2). Only summary concentrations and loadings tables have been included in this report. Therefore, the reader is referred to electronic Appendix 1 for full data records and for the background context of each of the contributors' discharge characteristics.

Where available, consent-related data (e.g. maximum discharge volumes and concentration limits), data from assessments of effects / consent applications (e.g. discharge characteristics) and monitoring data (e.g. outfall volumes and concentrations) were extracted and collated from the publicly available documents saved in the MDC Smart Maps web portal. Additional data requests were made to the MDC water quality scientists for water quality parameters monitored in the river catchments (Steffi Henkel, MDC Water Quality Scientist, pers. comm., September 2022), and to MDC engineers and GIS staff, to obtain information on accidental wastewater overflows and the infrastructure layout (mapping) for stormwater and wastewater assets (Tapper 2022).

Where available, discharge contaminant concentrations (g/m^3) and volumes (m^3/day) were collated into an Excel table. In the case of riverine contaminants that were not CLUES outputs but for which MDC concentration data existed, flow rates[5] and total run-off estimates were obtained from the Land, Air, Water Aotearoa (LAWA)[6] and NIWA Hydro Web[7] portals to estimate volume per year (see Appendix 1 for further detail). Where no concentration or loading data existed, loading estimates were based on typical / representative contaminant concentrations and estimated flow rates / volumes for those inputs.

Estimates for the loading of each input were also made using the best available information at the time, with calculations described below.

[5] This flow data does not account for flood events, which are likely to be significant inputs.
[6] Te Hoiere / Pelorus River: https://www.lawa.org.nz/explore-data/marlborough-region/water-quantity/surface-water-zones/te-hoierepelorus-river/rai-river-at-rai-falls
Kaituna River: https://www.lawa.org.nz/explore-data/marlborough-region/water-quantity/monitoring-sites/kaituna-river-at-readers-road/
[7] https://hydrowebportal.niwa.co.nz

2.3.1. Stormwater loading calculations

The 'Simple Method' modified from Beca (2009, p. 13) and Stewart and Ryder (2005), and references therein, was used to determined stormwater contaminant loading in kilograms per year:

Contaminant loading (kg/yr) =

corrected rainfall volume (m^3/yr) × concentration of contaminant (g/m^3/yr) / 1,000 [8]

Where, corrected rainfall volume (m^3/yr) =

(surface area [9] × corrected annual rainfall [10]) × run-off coefficient [11] / 1,000 [12]

2.3.2. Wastewater loading calculations

Similarly, a simple method of determining wastewater contaminant loading (in kilograms per year) was used in cases where a discharge volume was available:

Discharge volume (m^3/yr) × concentration of contaminant (g/m^3/yr) / 1,000 [13]

The quality of the data available for this assessment (how much data was available for each contributor and how much of it was based on typical / representative concentrations and / or volumes) dictated the LOC assigned to each of the estimates in the summary table (discussed in Section 4.3 and presented in Appendix 1).

2.4. Mapping contaminant inputs from consented discharges

ArcMap Pro was used to define the location of the aquatic inputs to the Estuary. The electronic mapping package includes the location of all known inputs (as close as possible), the type of input, concentration / loading estimates for the key contaminants listed above, and any other contaminant data that existed. Comparative loading[14] (represented by points of graded colour, green to red) was mapped at the site of the discharge or the location of the consent (depending on what data were available).

[8] Divide by 1,000 for g to kg unit change.
[9] Site or catchment surface area (m^2).
[10] Multiply by correction factor of 0.85 for rainfall events that produce no run-off (mm).
[11] Higher or lower (0–1) depending on degree of site imperviousness.
[12] Divide by 1,000 for mm to m unit change.
[13] Divide by 1,000 for g to kg unit change.
[14] Note: this does not include a spatial extent or characterisation of associated discharge plumes.

For context, the mapping package also includes:

- the locations of the consents referred to in this report (points and polygons)
- stormwater infrastructure
- wastewater infrastructure
- site visit observations and notes.

2.5. Possible environmental impacts

The possible environmental impacts of the key contaminants and preliminary discussion around the potential cumulative impacts are presented in Section 5, with reference to previous monitoring findings and the findings of this investigation.

3. SITE VISIT TO IDENTIFY DISCHARGE OUTFALLS

During the Estuary site visit we located and described visible outfalls and obvious visual effects from inputs to the surrounding coastline. Thirty-five discharge outfalls or features were identified during the visit (Figure 1, waypoints 14–47), eight of which were partially or fully blocked (Table 1). Outfall pipes were of varying sizes (10–60 cm diameter, Table 1) and materials (PVC, plastic corrugated culvert, polythene pipe and concrete, Table 1). All outfall observations and photographs are provided in the Appendix 2 mapping package.

Cases where discharge consents could be matched to the observed outfalls (confirming they are consented discharges) are discussed in Section 3.1.

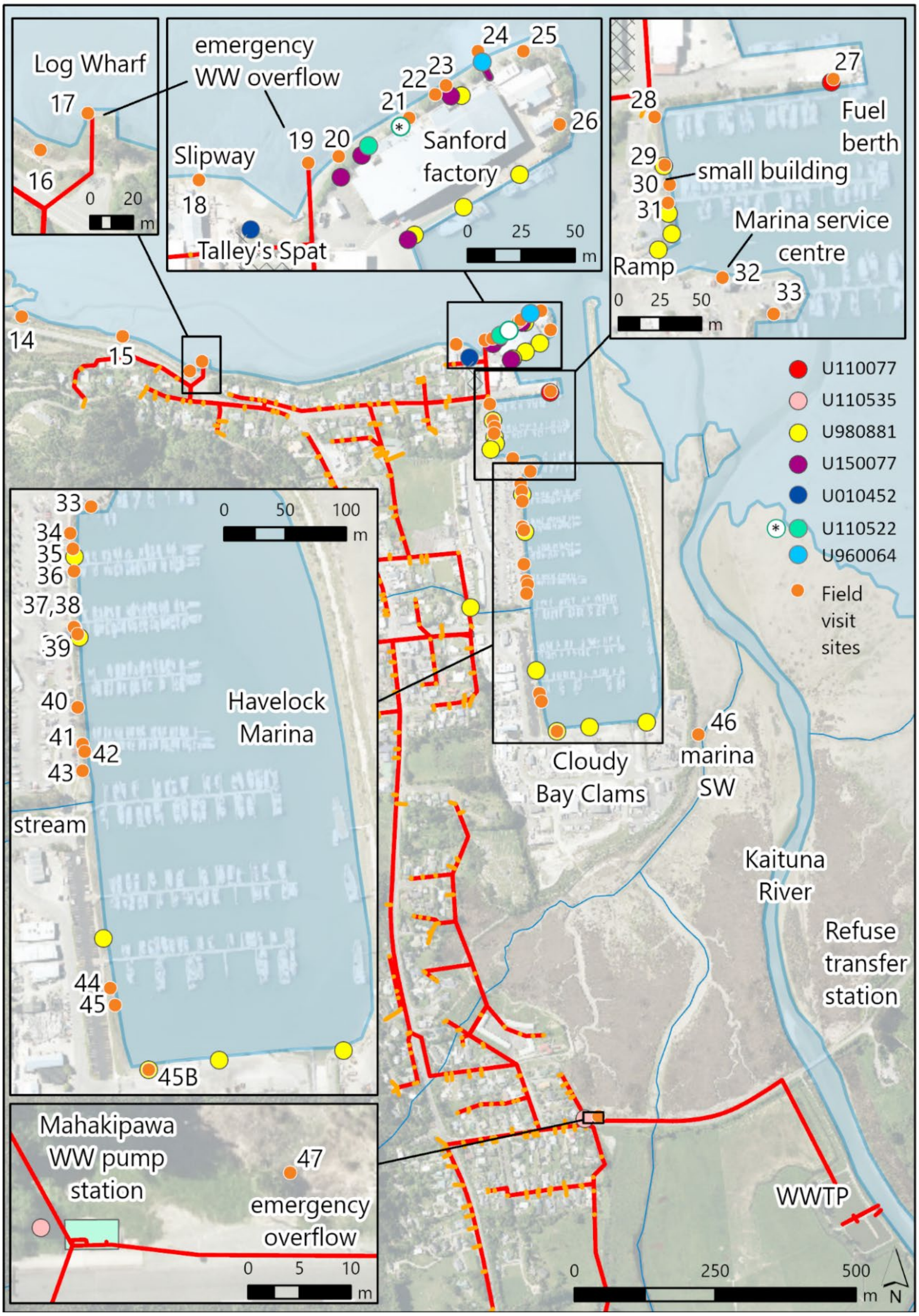

Figure 1. Site visit outfall locations (orange circles) mapped against consent point file data extracted from MDC Open Data.

Table 1. The site visit observations of outfalls and culverts in the coastal margins of Motuweka / Havelock Estuary used to identify consented discharge outlets. Photographs of each outfall / pipe observation are attached to the electronic mapping package (Appendix 2). The 'Consent match?' column shows where outfalls were observed and could be matched with their consents or where consents were lacking. The 'Further attention?' column suggests points for consideration. Note: 'amend consent data' has been used where it is possible that the MDC point data for stormwater (SW) outfalls need to be updated, as may be the case with the marina stormwater consent U980881. Abbreviations: FID = feature ID, Ind = indeterminate.

FID	Northing (NZTM)	Easting (NZTM)	Type of outfall / pipe	Material	Pipe diameter (cm)	Baseflow present?	Condition	Observations	Consent match?	Consent holder	Further attention?
14	5430534	1663571	Tidal waters	Concrete	50–60	Yes	OK	Clear baseflow from Estuary on other side of road. Prolific mussels, *Gracilaria* growing at outfall	No consent found	NZTA	Find consent
15	5430499	1663751	Tidal waters	Concrete	30–40	Yes	Partially blocked	Inundated with gravel. Small amount of *Gracilaria* and brown turfing algae, some mussels, slight green film on some stones. Clean baseflow	No consent found	NZTA	Find consent
16	5430437	1663870	Tidal waters	Concrete	50–60	Yes	Partially blocked	Partially blocked by large rock and gravels, submerged by baseflow. Baseflow slightly cloudy, with pine pollen on surface, no algae, small snails	No consent found	NZTA	Blocked Find consent
17	5430454	1663892	WW (overflow)	PVC	15	No	OK	Mounted on the side of the old logging wharf	No consent found	MDC	Find consent
18	5430484	1664343	WW (treated)	Metal / concrete	Not visible	Ind.	Ind.	Sump and drainage points for slipway, discharge point not visible	U100643	Havelock Slipway	Location of discharge outlet is not specified in consent and treated WW discharge point was not visible during the site visit
19	5430492	1664394	WW (overflow)	Concrete	Not visible	Ind.	Blocked	Appeared to be full of sediments, fouled with mussels and algae. Clearly old, with 1987(?) inscribed in concrete	No consent found	MDC	Blocked Find consent

FID	Northing (NZTM)	Easting (NZTM)	Type of outfall / pipe	Material	Pipe diameter (cm)	Baseflow present?	Condition	Observations	Consent match?	Consent holder	Further attention?
20	5430495	1664408	SW / WW (minor outfall?)	PVC	20–25	Drips	OK	Situated above or on the high-tide mark. Dripping slightly. Broken mature, green-lipped mussel shells at outlet, suggesting unconsented discharge of shell debris	U110522	Sanford	Check if consent allows shell debris in discharges
21	5430513	1664441	SW	PVC	15	No	OK	Situated above or on the high-tide mark. Surrounded by vegetation. No flow or drips	U150077	Sanford	
22	5430524	1664453	SW x2 pipes	PVC	15 and 10	No	Partially blocked	Situated above or on the high-tide mark. Two pipes side by side. Sticks inside large pipe	U150077	Sanford	
23	5430528	1664458	SW	PVC	15	No	Partially blocked	Situated above or on the high-tide mark. Partially blocked by large rock. Surrounded by vegetation. No flow or drips	U150077	Sanford	
24	5430544	1664473	WW (trade waste)	Concrete and large poly roading culvert	50–60	Yes	Good	Concrete pipe outlet extended into marine zone using a roading culvert. Discharging milky warm water, foams, mussel beard floating on water, large amounts of shell hash discharged in vicinity. Seabirds attracted to outlet	U960064 (and U110522 gets added to this discharge stream)	Sanford	Mussel beard floating on water
25	5430544	1664494	SW	PVC	15	Drips	OK	Situated above or on the high-tide mark	U150077	Sanford	
26	5430510	1664511	SW (erosion)	Blue / green poly pipe	15	No	Good	Situated above the high-tide mark in vegetation, appears to have caused some erosion to the coastal margin	U150077	Sanford	Possible erosion to the coastal margin
27	5430401	1664511	SW (treated SW / trade waste)	Grate / drain	N/A	No	OK	Exposed fuel lines to fuelling berth on the side of the jetty. No visible outfall from SW grate / drain, but consent shows an outfall at this location?	U110077	Port Marlborough (NZ) Limited	

FID	Northing (NZTM)	Easting (NZTM)	Type of outfall / pipe	Material	Pipe diameter (cm)	Baseflow present?	Condition	Observations	Consent match?	Consent holder	Further attention?
28	5430378	1664403	SW (marina and carpark)	PVC	15	No	OK	Footpath run-off	U980881? No match with U980881 MDC data. Looks like SW	Port Marlborough (NZ) Limited	Find / amend consent data
29	5430349	1664409	SW (marina and carpark)	Concrete	40	No	Partially blocked	Large rocks placed at opening, green algae on rocks (*Ulva*?). Under carpark, from town?	U980881	Port Marlborough (NZ) Limited	Possible urban stormwater from town?
30	5430337	1664412	SW (marina and carpark)	PVC	10	No	OK	Downpipes straight to ground, run-off to sea	U980881? No match with U980881 MDC data. Downpipe from building. Further investigation into building consent required	Port Marlborough (NZ) Limited	Find / amend consent data
31	5430326	1664411	SW (marina and carpark)	PVC	15	Drips	OK, cracked at end	Algae in pipe. Carpark SW?	U980881	Port Marlborough (NZ) Limited	
32	5430281	1664444	SW (marina and carpark)	PVC	15	No	OK	Marina service centre SW downpipe	U980881? No match with U980881 MDC data. Marine service centre downpipe, further investigation into building consent	Port Marlborough (NZ) Limited	Find / amend consent data
33	5430259	1664475	SW (marina and carpark)	PVC	15	No	OK	Carpark SW	U980881? No match with U980881 MDC data. Looks like carpark SW	Port Marlborough (NZ) Limited	Find / amend consent data
34	5430237	1664458	SW (marina and carpark)	PVC	15	No	OK	Carpark SW	U980881? No match with U980881 MDC data. Looks like carpark SW	Port Marlborough (NZ) Limited	Find / amend consent data
35	5430224	1664460	SW (marina and carpark)	Concrete	25	Yes	OK	Carpark SW? Baseflow, algae on inside / base of pipe. Moss growing underneath flow	U980881? Possible match with nearby point in U980881	Port Marlborough (NZ) Limited	Find / amend consent data

FID	Northing (NZTM)	Easting (NZTM)	Type of outfall / pipe	Material	Pipe diameter (cm)	Baseflow present?	Condition	Observations	Consent match?	Consent holder	Further attention?
									MDC data. Looks like carpark SW		
36	5430206	1664461	SW (marina and carpark)	PVC	15–25	No	OK	Carpark SW	U980881? No match with U980881 MDC data. Looks like carpark SW	Port Marlborough (NZ) Limited	Find / amend consent data
37	5430160	1664462	SW (town?)	Concrete	50–60	No	Partially blocked	Base of pipe (inside) filled with mussels, oysters and gravel. No baseflow	U980881? No match with U980881 MDC data. Looks like carpark SW or urban SW (due to size of culvert)	Port Marlborough (NZ) Limited	Partially blocked, possible urban SW from town? Find / amend consent data
38	5430160	1664461	SW (marina and carpark)	PVC	15	No	OK	Carpark SW	U980881? Possible match with nearby doubled up points in U980881 MDC data. Looks like carpark SW	Port Marlborough (NZ) Limited	Find / amend consent data
39	5430154	1664464	SW (town?)	Concrete	50–60	Yes	OK	Sides of pipe (inside) had some mussels and oysters (none on base). Baseflow discharging	U980881? Possible match with nearby doubled up points in U980881 MDC data. Looks like carpark SW	Port Marlborough (NZ) Limited	Possible urban SW from town? Find / amend consent data
40	5430094	1664464	SW (marina and carpark)	PVC	15–25	No	OK, cracked at end	Carpark SW	U980881? No match with U980881 MDC data. Looks like carpark SW	Port Marlborough (NZ) Limited	Find / amend consent data
41	5430064	1664468	SW (marina and carpark)	PVC	15	No	OK	Carpark SW	U980881? No match with U980881 MDC data. Looks like carpark SW	Port Marlborough (NZ) Limited	Find / amend consent data
42	5430058	1664470	SW (town?)	Concrete	50–60	No	OK	Carpark SW, linked to town?	U980881? No match with U980881 MDC data. Looks like carpark SW	Port Marlborough (NZ) Limited	Possible urban SW from town? Find / amend consent data

FID	Northing (NZTM)	Easting (NZTM)	Type of outfall / pipe	Material	Pipe diameter (cm)	Baseflow present?	Condition	Observations	Consent match?	Consent holder	Further attention?
43	5430042	1664468	SW (marina and carpark) – blocked, scouring	Concrete	15–25	No	Partially blocked	Carpark SW. Lower half of pipe blocked with debris and mud, and evidence of erosion / scouring on shoreline	U980881? No match with U980881 MDC data. Looks like carpark SW or urban SW (due to size of culvert)	Port Marlborough (NZ) Limited	Possible erosion to the coastal margin and blocked pipe Find / amend consent data
44	5429864	1664491	SW (marina and carpark)	PVC	15–25	No	OK	Carpark SW	U980881? No match with U980881 MDC data. Looks like carpark SW	Port Marlborough (NZ) Limited	Find / amend consent data
45	5429850	1664495	SW (marina and carpark) – fouled, damaged	Concrete	15–25	Ind.	Heavily fouled, possibly broken?	Carpark SW? Submerged at 20 mins to full low tide. Heavily fouled with mussels and oysters, brown algal slime and turf. Pointing down into water – broken?	U980881? No match with U980881 MDC data. Looks like carpark SW	Port Marlborough (NZ) Limited	Broken and partially blocked pipe Find / amend consent data
45B	5429797	1664522	SW (marina and carpark, industrial area)	PVC	15–25	No	OK	Carpark SW. Couldn't get to pipe location as inside factory compound	U980881? No match with U980881 MDC data. Looks like industrial area / carpark SW – there is a point for U980881 but it is 60 m away	Port Marlborough (NZ) Limited	Find / amend consent data
46	5429791	1664774	SW (marina and carpark) – damaged, scouring	Concrete	25–30	No	End disconnected	End has dropped off, possibly eroded bank underneath. No visible flow	U980881? Accounted for in consent picture, but no match with U980881 MDC data points	Port Marlborough (NZ) Limited	Broken and possible erosion to the coastal margin Find / amend consent data
47	5429114	1664597	SW and WW (overflow)	NA	Not visible	No	Roadside damage	PS overflow location overland into Estuary	U110535 (SW) / no consent found for WW overflow	MDC / MDC	Find / amend consent data

3.1. Consent matches

To determine whether the discharge outfalls we observed during the site visit were associated with specific consents (Table 1, Figure 1), the stormwater and wastewater infrastructure layers MDC Open Data discharge consent point data and MDC Smart Maps discharge consent point data were interrogated. On examination of the data sources (described in Section 2.1), it was evident that there is a disparity between the MDC Open Data discharge points for stormwater (6 points) in the marina area, those identified during the site visit (16 points) and those approved for consent in Port Marlborough's consent U980881 (25 points, Figure 1). Some discharge points were missing from the consent map and some that were observed during the site visit were not noted in the U980881 consent map. In addition, no coastal stormwater outlets could be identified from the infrastructure layer supplied by MDC (Tapper 2022). Stormwater infrastructure (pipework or flow directions / source tracing) was not available through the Open Data or Smart Maps web portals.

There were also a number of other observations that may warrant further investigation or action by MDC (see Table 1 for further details):

7. U100643 – Havelock Slipway. Location of the discharge outlet was not specified in publicly available consent records and the discharge point was not identified during the site visit.
8. U150077 – Sanford factory. Consent for six outfalls; the MDC Open Data and Smart Maps show four discharge points and one discharge line file. The number of outlets on MDC Open Data / Smart Maps matched the number of outfalls identified during the site visit (eight), but the locations differed (Figure 2).

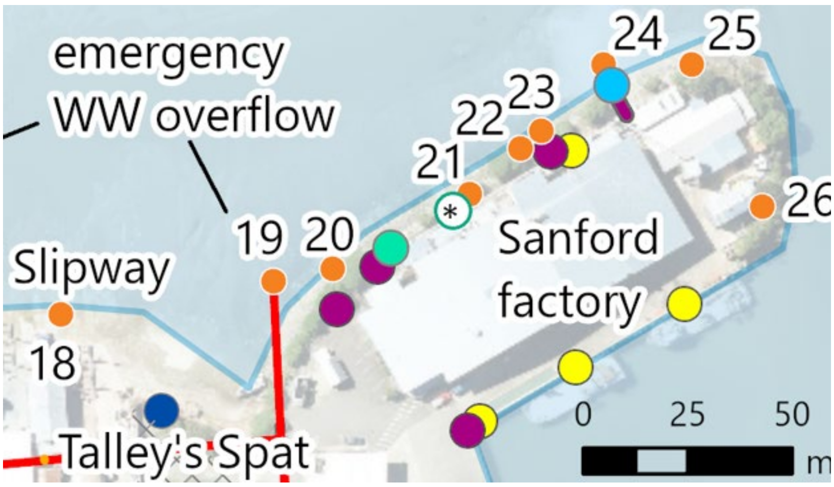

Figure 2. Comparison of Sanford factory site visit observations (orange points) and the available consent point data from MDC Open Data (full map in Figure 1). Sanford factory consents: purple circles = U150077, green circles = U110522 (outfall with asterisk is uncertain), light blue circle = U960064. Yellow circles = U980881 (Port Marlborough stormwater), dark blue circle = U010452 (Talley's spat outfall).

9. U150077 – Sanford factory. Possible erosion to the coastal margin at Site 26 (Figure 3).

Figure 3. Observation of possible coastal erosion (exposed black geotextile mat and cavity at the top of the seawall) at outfall Site 26. However, the location of this outfall was not matched on Open Data / Smart Maps.

10. U110522 – Sanford factory. Broken mature green-lipped mussel shells at outlet (Site 20), possible unconsented discharge of shell debris (Figure 4).

Figure 4. Observation of shell debris at outfall Site 20, possibly relating to consent U110522 (boiler water condensate, stormwater and factory water). No similar shells were observed in any other location along the shoreline searched.

11. U960064 (and U110522 is added to this discharge stream) – Sanford factory. Mussel beard floating on water and shell debris fan both observed (Figure 5).

Figure 5. Observation of shell debris and mussel beard at outfall Site 24, possibly relating to consent U960064 (wastewater from a shellfish processing plant) and consent U110522 (which is added to the U960064 discharge stream).

12. U980881 – Port Marlborough. Six potential outfalls showed possible erosion to the coastal margin and / or were blocked and / or were broken (Sites 19, 29, 37, 43, 45 and 46, Figure 6).

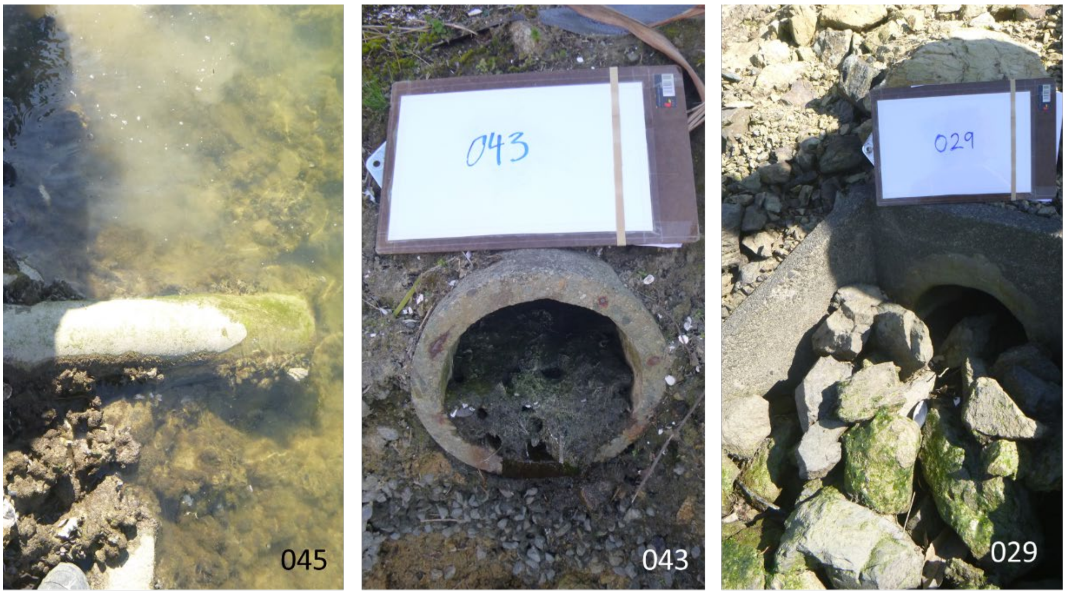

Figure 6. Representative images of blocked culverts from Sites 45, 43 and 29.

13. The wastewater overflow outfalls were identified from the infrastructure layer supplied by MDC (Table 1). While it is recognised that there may be a region-wide consent for wastewater overflows in Marlborough, no site-specific consents were found for any of the wastewater overflow sites. One of the wastewater overflow points was found to be blocked (Site 19).
14. The road culverts and causeway through the Estuary had no associated site-specific consent. This possibly pre-dates resource consent requirements. One Estuary causeway culvert was found to be partially blocked.
15. Two stormwater outfalls were observed to have baseflow during dry weather conditions (Sites 35 and 39, Figure 7). This may represent vessel wash-down water from the marina carpark.

Figure 7. Outfalls (Sites 35 and 39) were observed to have baseflow during the site visit (dry weather conditions).

4. CHARACTERISTICS OF INPUTS

4.1. Contributors

Seventeen coastal discharge contributors were identified through this project (Figures 8–10, Table 2, Appendix 1 and 2), some with multiple discharge consents (e.g. Sanford factory, urban stormwater and septic tanks).

The Sanford factory and the urban stormwater outfall locations were difficult to define / differentiate. This was largely due to disparities between the consent documents, the MDC Smart Maps / Open Data information, and the locations of outfalls observed during the site visit (see issues identified in Table 2).

Nine of the contributors (Table 2) had at least some discharge-specific compositional data to calculate loadings. Another four contributors could be assigned typical discharge concentrations from the literature (see references within Table 2). Discharge volumes could be obtained for all 13 of these contributors from either stormwater calculations, consent discharge limits or monitoring records (see Section 2.3 for methodological details).

In four cases, contributor loading inputs could not be calculated with any confidence due to a lack of information around the discharge composition and / or volume (Table 2).

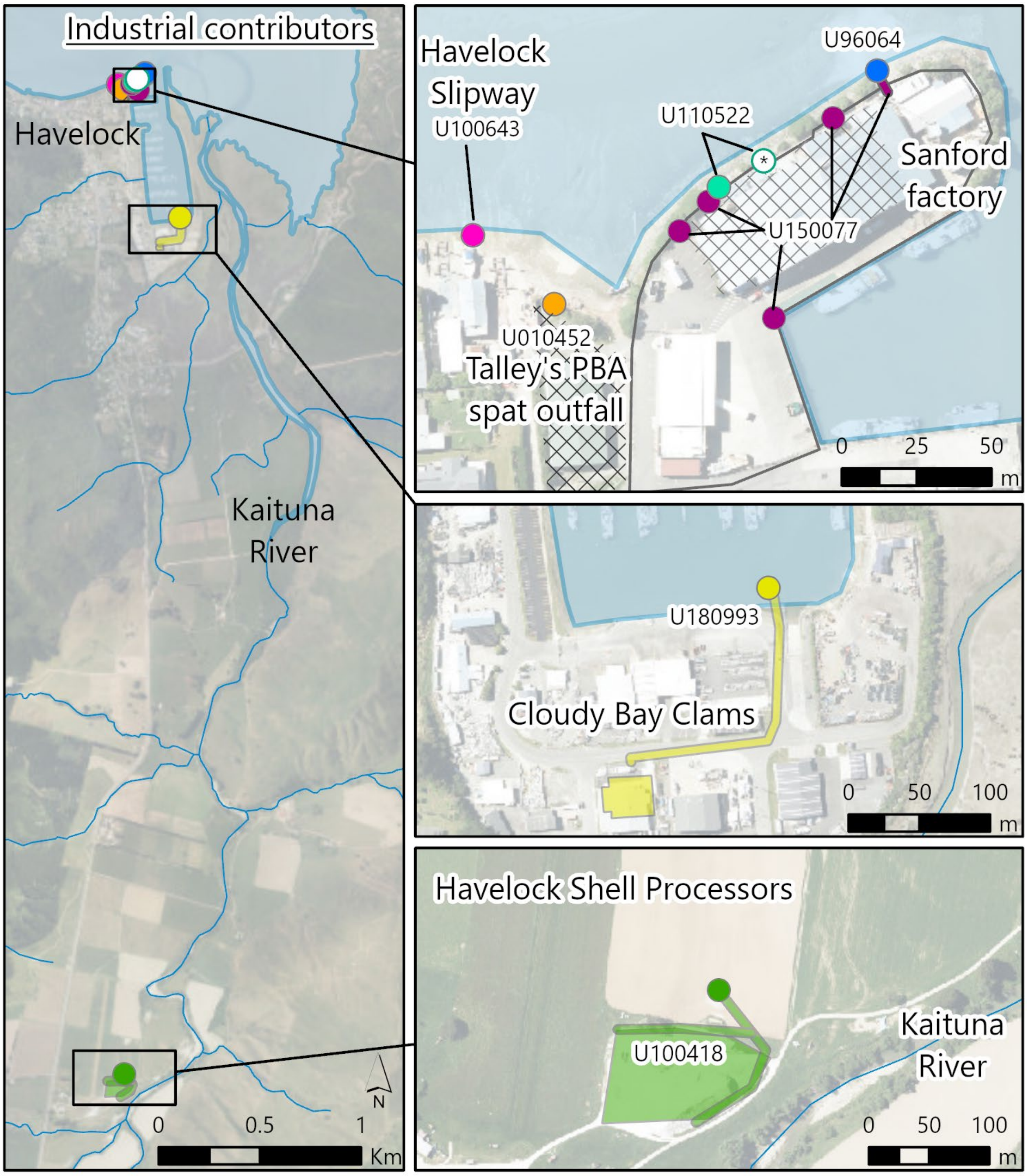

Figure 8. Industrial discharge contributors to Motuweka / Havelock Estuary.

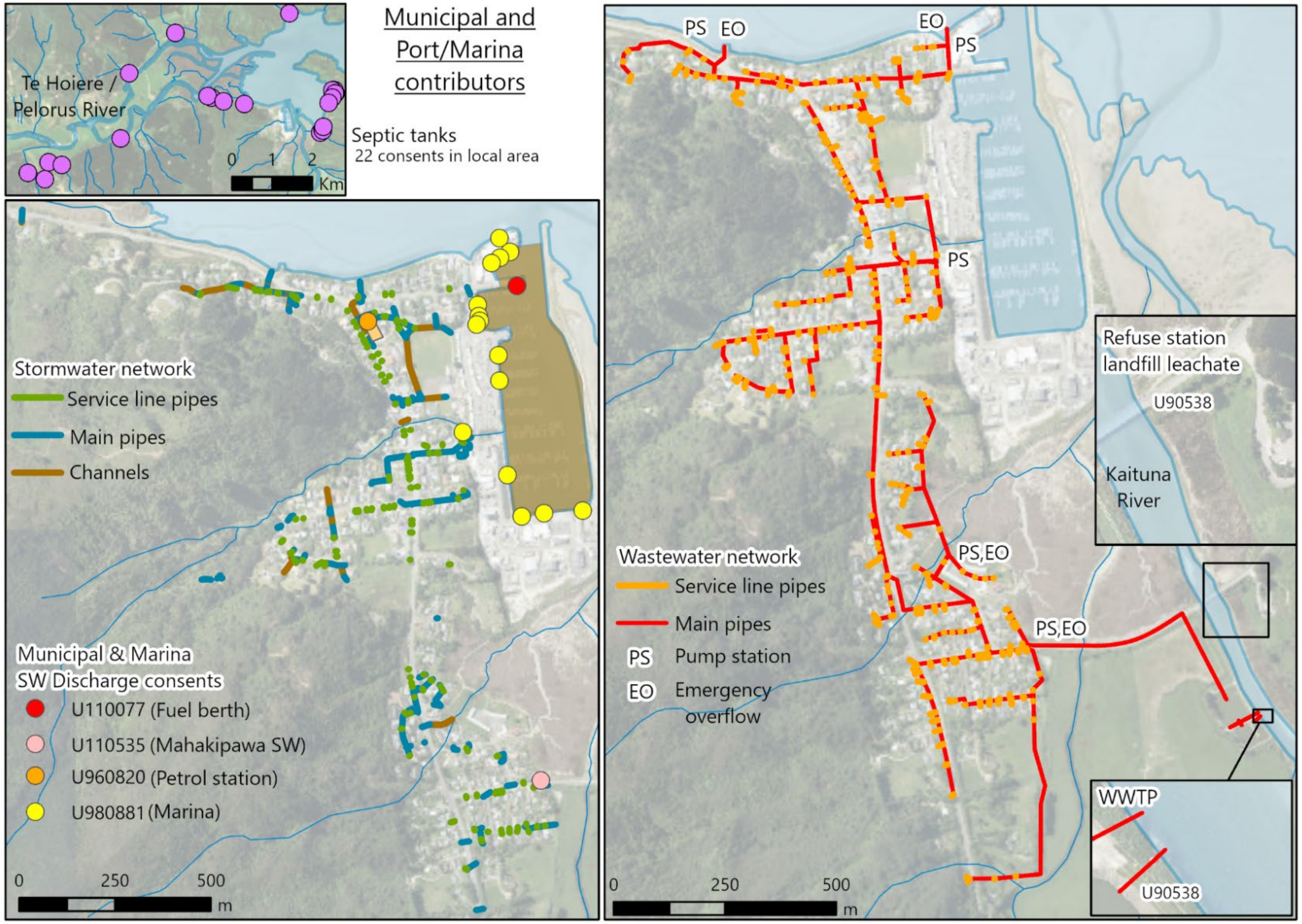

Figure 9. Municipal discharge contributors to Motuweka / Havelock Estuary.

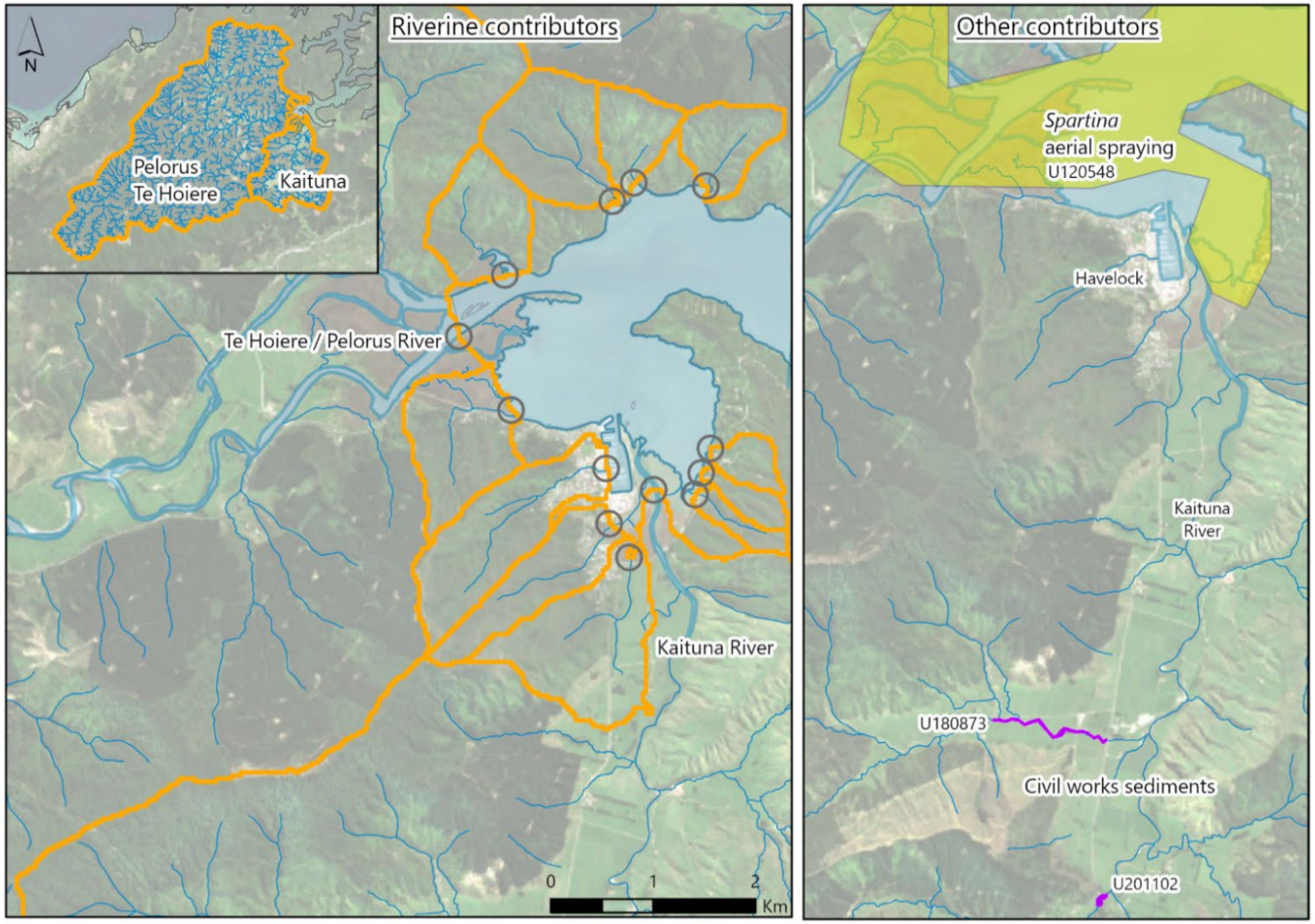

Figure 10. River catchment, *Spartina* spraying and civil works discharge contributors to Motuweka / Havelock Estuary Grey circles represent terminal river reaches (Semadeni-Davies 2016). White dots represent water quality monitoring sites (LAWA 2022a, 2022b) and yellow dots represent flow monitoring sites (LAWA 2022c; NIWA 2022b).

Table 2. Summary of the Motuweka / Havelock Estuary discharge contributors, with related consent numbers identified through this investigation and types of compositional and volumetric data available / used for the calculation of contaminant loading, as identified in Appendix 1. Data issues are noted in the description column. Text marked with an asterisk describes where outfalls were observed during the site visit (Section 3). Numbers in parentheses in the 'contaminant data' column are the total number of contaminant parameters available for determining loading calculations from each consent.

Contributor	Consent no.	Description	Compositional and volumetric data types	Contaminant data[a]
Sanford factory discharges	U110522, U960064, U150077	Three consents addressing boiler water, stormwater and factory / wastewater. Discharge consent outfalls were not clearly defined in consents or MDC Smart Maps / Open Data. For example: **U150077** – The consent specifies six outfalls, and MDC Open Data / Smart Maps shows four points and one line (five). **U960064** – One outfall specified in the consent, and one shown in MDC Open Data / Smart Maps. **U110522** – The consent shows two outfalls, and MDC Open Data / Smart Maps also shows two. We note that the U110522 consent specifies that part of the U110522 discharge is added to the U960064 discharge stream. Given this, one of the U110522 point locations appears to need amending on Open Data / Smart Maps, i.e. one of the U110522 outfall points should overlap with U960064. *Identified eight outfalls in the Sanford factory area during site visit.	Discharge monitoring data used for compositional concentrations. Maximum daily discharge volume used from consent for U110522 / U960064. Stormwater run-off equations (Section 2.3.1) used to estimate volume for U150077.	110522 and U960064 = TN, TP, nitrate, nitrite, TKN, TAN, DIN, VSS, TSS, EC, Entero, FC, BOD, COD (14 each). U150077, typical contaminants identified = TN, TP, nitrate, TAN, DRP, TSS, EC, copper, zinc, lead (10).
Havelock Shell Processors discharges	U100418	Stockpiling mussel shells for crushing on site and to discharge processed water run-off from the shell pile to land. Inputs may already be accounted for in the LAWA / flow rate derived loadings (given the LAWA samples are taken downstream of the shell processors). Leachate from shell pile discharged to paddocks adjacent to Kaituna River. Applied over many fields, not a single point as specified by MDC Open Data. *Not investigated during site visit.	Discharge monitoring data used for compositional concentrations. Discharge volume from land application monitoring reports used.	TN, TP, DIN, nitrate, nitrite, nitrate-nitrite, TKN, TAN, DRP, TOC, TSS, EC, FC, BOD, COD, copper, zinc, boron, nickel, magnesium, potassium, chloride, silica (23).

Contributor	Consent no.	Description	Compositional and volumetric data types	Contaminant data[a]
Talley's PBA spat outfall	U10452	Mussel spat processing facility discharging treated seawater through an outfall pipe. Discharge particle size and volume reported only. Note: Open Data says consent U990180 is still current, but it expired and was replaced by U10452. *Not recognised during the site visit but is identified in the consent diagram.	Not calculated. Discharge volume obtained but no specific compositional data of discharge nor any typical concentrations easily obtainable for this sort of discharge. Further investigation required.	Possible contaminants identified; no concentrations obtained.
Cloudy Bay Clams	U180993	Discharge of shellfish depuration water to marina coastal margin. Certificate of compliance issued, resource consent not required, but must comply with plan rules for water quality and discharges. No monitoring requirements. *Not investigated during site visit as we couldn't access this commercial area.	Nitrate concentration (only parameter considered) and maximum volume of discharge obtained from application.	Nitrate (1).
Havelock Slipway	U100643	To discharge treated water to sea from the slipway's sediment and fluid recovery system. Location of treated seawater discharge point not specified in consents or MDC Smart Maps / Open Data. Receiving environment sampling only, no discharge sampling. There is no information on the composition of the treated discharge to sea (in the decision document or the application), just that it is 'an improvement on the existing uncontrolled discharge'. *Outfall not recognised during the site visit but is described in the consent text.	No discharge composition or volume data. Discharge volume estimated from typical detention time for sand filters. Typical discharge concentrations used (EPA 2015).	Typical discharge concentrations used (EPA 2015): TSS, copper, zinc, lead, arsenic, tin / organotin compounds (6).
Landfill leachate and stormwater	U90538	To discharge landfill leachate and SW onto and into land in circumstances that it may enter groundwater and surface water, to discharge landfill gas to air, and to discharge leachate and stormwater within a coastal marine area, from the closed Havelock Landfill. *Was not recognised during the site visit but is identified in the consent diagram.	Compositional data of leachate obtained from ongoing monitoring, and for stormwater from historic stormwater data (no current stormwater monitoring). Stormwater and leachate volumes taken from application estimates (no maximum daily discharge volume in the consent).	Stormwater drain = nitrate, nitrite, TAN, TSS, copper, zinc, lead, boron, iron, chloride, TPH, BTEX (12). Leachate = TSS, COD, copper, zinc, lead, arsenic, boron,

Contributor	Consent no.	Description	Compositional and volumetric data types	Contaminant data[a]
				cadmium, chromium, iron, nickel, sulphide, sodium, chloride (14). Diffuse leachate (not captured), typical contaminant concentrations used (from leachate monitoring), copper, zinc, lead, arsenic, cadmium, chromium, nickel (7).
Sewage treatment pond	U170942	To discharge treated municipal wastewater to the Kaituna River through an existing outfall. Tested for a range of water quality parameters. The consent for one-off dye testing has not been considered here. *Was not recognised during the site visit, as we couldn't get access, but is identified in the consent.	Discharge monitoring data used for compositional concentrations. Maximum daily discharge volume used from consent.	TN, TP, nitrate, nitrite, nitrate-nitrite, TKN, TAN, DRP, TSS, EC, Entero, FC, BOD, COD (14).
Wastewater overflows	No consent	Overflows of wastewater to the marine environment due to pump failure or high rainfall events. No specific consent; may be covered under U170942. *Identified two outfalls that were for wastewater overflows, others not identified.	Observational overflow reports only. No monitoring data. Used volume data from overflow reports (reported on Smart Maps as part of treatment pond consent U170942). Typical discharge concentrations used (MfE 2020; Cawthron dataset[b]).	Typical WW contaminant concentrations used (MfE 2020; Cawthron 2022) = TN, TP, nitrate, nitrite, nitrate-nitrite, TKN, TAN, VSS, TSS, EC, BOD, COD, copper, zinc, lead, arsenic, boron, cadmium, chromium, nickel, mercury, sulphate, fluoride, TOG (24).
Urban stormwater	U960820, U980881, U110535	Urban stormwater run-off estimate. The stormwater infrastructure shapefiles supplied from MDC do not specify coastal outfalls / open drains, and do not appear to have a consent associated with them. Other consents MDC holds are for U110535 (overflow to marine environment at Lot 2 DP395873) and the Havelock Marina consent 980881 (a holding of MDC), of which not all was included in the Infrastructure shape files provided. One consent for stormwater from the Havelock petrol station is also included here, but the consent appears to have been surrendered and there is no easily located record of where the land application area is, thus its run-off contribution could not be calculated.	No monitoring data, typical discharge concentrations used (Gadd & Milne 2019). No total volumes provided in any consent documentation; stormwater volumes calculated using equations in Section 2.3.1.	Typical stormwater contaminant concentrations used (Gadd & Milne 2019) = TN, TP, nitrate, TAN, DRP, TSS, EC, copper, zinc, lead, organotin (11).

Contributor	Consent no.	Description	Compositional and volumetric data types	Contaminant data[a]
		*Identified 20 possible stormwater outfalls. However, these could not be cross-referenced to infrastructure plans or assigned a consent due to data issues described above.		
Septic tanks / land application	Multiple	Domestic septic tanks. Multiple consents (22, see GIS map for locations). Potential for septic tank system failure. All septic tanks were all listed as active, but it is not clear if they are compliant. No monitoring of how well the existing septic tanks and land application areas are performing could be found. *Not investigated during site visit as we couldn't access private areas to assess land application areas.	No MDC data. Representative septic tank contaminants and run-off used (MfE 2003a; ORC 2015). Assumes all septic tanks in the immediate Estuary area are poorly performing, are servicing three-bedroom houses and run-off is equal at all sites.	Typical contaminant concentrations used (MfE 2003a; ORC 2015) = TN, TP, TKN, TSS, FC, COD (6).
Fuel berth stormwater / spills	U110077	To discharge fuel facility stormwater to water from a bunded area. *Sump identified during site visit; outfall not identified.	Compositional data taken from sump sampling (consent monitoring). Volume calculated from stormwater run-off equations (Section 2.3.1).	TPH, PAH, BTEX (3).
Antifouling leachate	No consent	Leaching of antifouling-related contaminants to the marina and port. May be covered under the marina construction consent? *Not assessed during site visit.	No consent data, loadings obtained from comparable marina investigations (Gadd & Cameron 2012).	Typical contaminant loading used (Gadd & Cameron 2012) = copper (1).
Port / marina waste inputs	No consent	Accidental spills, leaks or rubbish from vessels in the marina. *Not assessed during site visit.	Not calculated. No discharge volumes and no specific compositional data of discharge available, and no typical concentrations easily obtainable for this sort of discharge. Further investigation required.	Possible contaminants identified; no concentrations obtained.
Dredging activities	U070402, U150715, U980881	Resuspension of sediments and contaminant from dredging activities. No current consent. *Not assessed during site visit.	Not calculated. No specific compositional data of discharge available, typical contaminants for this sort of discharge are available, but no easily obtainable information on the spatial scale / volume of inputs. Further investigation required.	Possible contaminants identified; no concentrations obtained.

Contributor	Consent no.	Description	Compositional and volumetric data types	Contaminant data[a]
River inputs	No consent	Contaminant inputs to the Estuary supplied from rivers. Flow rates not accurate for Te Hoiere / Pelorus River due to poor distribution of flow recorder in the catchment (LAWA 2022c; NIWA 2022b). Thus, input volumes (and subsequent loadings) underestimated for some parameters. CLUES loading estimates (Appendix 1) for suspended solids appear to be much lower than sediment accumulation studies suggest (Handley et al. 2017). Although not publicly available yet, the DOC Ngā Awa river project (DOC 2021; Tunnicliffe & Brierley 2021) may have some water quality and quantity data available in the future that could improve data accuracy for the Te Hoiere / Pelorus River inputs. *Not assessed during site visit.	Compositional data obtained from CLUES estimates, LAWA and MDC in-house data. River volumes obtained from LAWA, NIWA and MDC in-house data. Complete loading calculations from CLUES, where available.	TN, TP, DIN, nitrate, TAN, DRP, TON, TSS, EC, copper, zinc, arsenic (12).
Spartina aerial spraying	U120548	Hand-spraying of *Spartina* grass with Haloxfop™ herbicide in the Coastal Marine Zone in the Marlborough Sounds. *Not assessed during site visit.	Ammonium concentration calculated from consent Haloxfop™ limits. Volumes obtained from actual spray volumes described in consent.	Ammonium (1).
Civil works	Multiple – U180873, U201102, U080858	Civil works, such as slip clean-up, riverbank reinstatement, roadworks, etc. A couple of resource consents to discharge sediment-laden water were identified from Smart Maps, and one for flood repairs that is still active. *Not assessed during site visit.	Not calculated. No specific compositional data of discharge available. Typical contaminants for this sort of discharge are available, but no easily obtainable information on the spatial scale / volume of inputs. Further investigation required.	Possible contaminants identified; no concentrations obtained.

a. Contaminant abbreviations: TN = total nitrogen, TP = total phosphorus, DRP = dissolved reactive phosphorus, TKN = total Kjeldahl nitrogen, TAN = total ammoniacal nitrogen, VSS = volatile suspended solids, TSS = total suspended solids, EC = *E. coli*, Entero = enterococci, FC= faecal coliforms, BOD = biochemical oxygen demand, COD = chemical oxygen demand, TOG = total oil and grease, TPH = total petroleum hydrocarbons, PAH = polycyclic aromatic hydrocarbons, BTEX = benzene, toluene, ethylbenzene and xylene.
b. Cawthron effluent monitoring compositional dataset: Nelson pump stations (2022).

4.2. Contaminant concentrations and loading

With the exception of cadmium and mercury, the majority of contaminant inputs identified in Tables 3 and 4 were estimated to be introduced into the Estuary at concentrations higher than available ecological thresholds (ANZECC 2000; EPA 2001, 2006a; ANZG 2018) and contact recreational and shellfish-gathering thresholds (MfE 2003b). While it was outside the scope of this investigation to calculate the diluted contaminant concentration on mixing with receiving waters,[15] the findings do highlight where contributors may be adding to ecological or human health-related pressures within the Estuary.

Note that the loadings presented in Table 4 do not directly reflect the potential contaminant accumulation in the Estuary The final amount of contaminant accumulated in the Estuary will also depend on the dispersal characteristics and assimilative capacity[16] of the receiving environment (see Section 5.7 for further discussion on contaminant accumulation).

The highest contaminant loading contribution overall (where data existed) was from the river catchments, the most notable contributor being Te Hoiere / Pelorus River (Table 4).

Other notable contributors of nutrients (total nitrogen and total phosphorus) to the Estuary were estimated to be from the Sanford factory, the sewage treatment plant and urban stormwater.

Comparatively high loadings of copper were estimated from the Havelock Slipway and the leachate from the marina, with urban stormwater contributing to elevated zinc loading. Arsenic loading contributions from Te Hoiere / Pelorus River and the Kaituna River (concentration data obtained from the MDC water quality data, Steffi Henkel, MDC Water Quality Scientist, pers. comm., September 2022) were orders of magnitude higher than any other contributor listed.

Biochemical oxygen demand was particularly high from the Sanford factory discharge, and the sewage treatment plant outfall.

Eight of the 17 identified contributors had TSS concentration data, representing a combined TSS loading of 381,251 kg/yr (excluding the riverine inputs). In contrast, the riverine inputs were 1,000 times higher than this figure, with a total input of

[15] For relative context, the contaminant concentrations that are higher than receiving water guideline values have been highlighted in Table 3. However, receiving environment guideline values should not be directly compared to discharge concentrations without first calculating dilution / mixing with seawater (this was outside the scope of this investigation).

[16] The ability for pollutants to be absorbed by an environment without adverse effects.

341,605,500 kg/yr (including Te Hoiere / Pelorus River, Kaituna River and other minor tributaries).

The full list of all contaminant information (concentrations and loadings) is available in Appendix 1. Note that Appendix 1 also includes other contaminant information (outside of those parameters specified in the project scope) where data were available.

Table 3. Concentrations of key contaminants discharged to the Motuweka / Havelock Estuary by contributors. Additional contaminants are included in Appendix 1. The asterisk shows where analytical detection limits were occasionally used to calculate mean concentrations to obtain conservative estimates (e.g. MDC water quality data, Steffi Henkel, Water Quality Scientist, pers. comm., September 2022). For relative context, the contaminant concentrations that are higher than receiving water guideline values have been highlighted. However, receiving environment guideline values should not be directly compared to discharge concentrations without first calculating dilution / mixing with seawater (this was outside the scope of this investigation).

		Concentration															
Contributors		g/m^3													MPN/100 ml		
Industrial discharges	**Consent no.**	**TN**	**TP**	**TOC**	**TSS**	**BOD**	**Cu***	**Zn***	**Pb**	**As***	**Cd**	**Cr**	**Ni**	**Hg**	**EC**	**Entero**	**FC**
1. Sanford factory – WW and SW	110522	3.5	18.6		10.5	10.5									55	1,230	181
1. Sanford factory – WW	960064	79	11.6		119	613									1,275	1,987	2,475
1. Sanford factory – SW	150077	0.85	6.6		72		0.06	0.25	0.001						6,700		
2. Havelock Shell Processors leachate	100418	1,450	0.86	73	520	6	0.004	0.01					0.0005		135		135
3. Talley's PBA spat outfall	10452																
4. Cloudy Bay Clams	180993																
5. Havelock Slipway	100643				800		55	6	1.7	0.08							
Municipal waste																	
6. Landfill – SW drain					110		0.007	0.12	0.001								
6. Landfill – leachate pipe	90538				73		0.001	0.00985	0.00026	0.02	0.00005	0.0025	0.002				
6. Landfill – uncap. SW / leachate							0.001	0.00985	0.00026	0.02	0.00005	0.0025	0.002				
7. Sewage treatment ponds	170942	40	4.7		46	27									4,000	3,075	17,000

		Concentration															
Contributors		**g/m^3**													**MPN/100 ml**		
Industrial discharges	**Consent no.**	**TN**	**TP**	**TOC**	**TSS**	**BOD**	**Cu***	**Zn***	**Pb**	**As***	**Cd**	**Cr**	**Ni**	**Hg**	**EC**	**Entero**	**FC**
8. Wastewater overflows	NC	51	5.75		235	255	0.0385	0.115	0.00225	0.0031	0.00021	0.004	0.007	0.00008	10,000,000		
9. Urban stormwater	Multiple	0.85	6.6		72		0.06	0.25	0.001						6700		
10. Septic tanks / land application	Multiple	60	15		120	150											100,000
Port / marina discharges																	
11. Fuel berth SW sump & spills	110077																
12. Antifouling leachate	NIL																
13. Port / marina waste inputs	NIL																
14. Dredging activities	Multiple																
River catchments																	
15. Te Hoiere / Pelorus	NA	0.4	0.009		4		0.00058	0.001		0.001					37.5		
15. Kaituna	NA	0.9	0.11		16		0.00076	0.002		0.001					100		
15. Other terminal reaches	NA	0.2	0.02														
Other																	
16. *Spartina* aerial / spot spraying	120548																
17. Civil works (sediment)	Multiple																
Guideline values		0.0003[a]	0.000005[a]	0.15–1.8[b]	7.1[c]	5[d]	0.0013[e]	0.008[e]	0.004[e]	0.013[e]	0.001[+]	0.00014[++]	0.007[e]	0.0001[+++]	≤260[f]	≤40[f]	<14[f]

a. Table 3.3.2–3.3.3 South-east Australia (ANZECC 2000). Default trigger values for physical and chemical stressors.
b. EPA (2001). Concentrations of dissolved and particulate organic carbon in surface waters. https://www.epa.gov/sites/default/files/2018-10/documents/nutrient-criteria-manual-estuarine-coastal.pdf
c. Pelorus Sound / Te Hoiere marine monitoring site: PLS-1, SS value: 7.1 mg/L median value 2015–20 ('likely worsening' from 2011 to 2020). https://www.stats.govt.nz/indicators/coastal-and-estuarine-water-quality
d. EPA (2006a). Unpolluted natural water <5 mg/L. https://www.epa.gov/sites/default/files/2015-09/documents/2009_03_13_estuaries_monitor_chap9.pdf
e. ANZG (2018).
f. MfE (2003b). Microbiological water quality guidelines, *E. coli* and enterococci = Recreational Grade A value, and faecal coliforms = Recreational shellfish-gathering bacteriological guideline value (median value over season). Note: for marine water, the preferred indicator is enterococci. https://environment.govt.nz/assets/Publications/Files/microbiological-quality-jun03.pdf
\+ Freshwater default guideline value (DGV).
++ Chromium (CrVI) used as more conservative limit than chromium (CrIII) (0.0077 g/m^3).
+++ Mercury (inorganic).

Abbreviations: TN = total nitrogen, TP = total phosphorus, TOC = total organic carbon, TSS = total suspended solids, BOD = biochemical oxygen demand, Cu = copper, Zn = zinc, Pb = lead, As = arsenic, Cd = cadmium, Cr = chromium, Ni = nickel, Hg = mercury, EC = *E. coli*, Entero = enterococci, FC= faecal coliforms.

Table 4. Loading estimates of key discharge contaminants to the Motuweka / Havelock Estuary from contributors. Contaminant loads reflect the cumulative effect of discharge inputs over time. Additional contaminants are included in Appendix 1. The asterisk symbol shows where analytical detection limits were occasionally used to calculate mean concentrations to obtain conservative estimates (e.g. MDC water quality data, Steffi Henkel, Water Quality Scientist, pers. comm., September 2022).

		Loading per year															
Contributors		**kg/yr**													**MPN/yr***		
Industrial discharges	**Consent no.**	**TN**	**TP**	**TOC**	**TSS**	**BOD**	**Cu***	**Zn***	**Pb**	**As***	**Cd**	**Cr**	**Ni**	**Hg**	**EC**	**Entero.**	**FC**
1. Sanford factory – WW and SW	110522	2	9		5	5									2.6×10^{5}	5.8×10^{6}	8.6×10^{5}
1. Sanford factory – WW	960064	86,505	12,739		130,305	671,600									1.4×10^{10}	2.2×10^{10}	2.7×10^{10}
1. Sanford factory – SW	150077	3	25		275		0.23	0.956	0.004						2.6×10^{8}		
2. Havelock Shell Processors leachate	100418	9,882	6	498	3544	41	0.03	0.068					0.003		9.2×10^{6}		9.2×10^{6}
3. Talley's PBA spat outfall	10452																
4. Cloudy Bay Clams	180993																
5. Havelock Slipway	100643				2,307		158.59	17.301	4.902	0.231							
Municipal waste																	
6. Landfill – SW drain	90538				235		0.01	0.257	0.002								
6. Landfill – leachate pipe					682		0.01	0.092	0.002	0.187	0.0005	0.023	0.019				
6. Landfill – uncap. SW / leachate							0.01	0.000	0.000	0.000	0.0005	0.023	0.019				
7. Sewage treatment ponds	170942	35,040	4,117		40,296	23,652									3.5×10^{10}	2.7×10^{10}	1.5×10^{11}
8. Wastewater overflows	NC	48	5		222	241	0.15	0.109	0.002	0.003	0.0002	0.004	0.007	0.0001	9.5×10^{10}		
9. Urban stormwater	Multiple	2,395	18,595		202,860		0.23	704.37	2.82						1.9×10^{11}		
10. Septic tanks / land application	Multiple	260	65		520	650											4.3×10^{9}
Port / marina discharges																	
11. Fuel berth SW sump & spills	110077																

		Loading per year															
Contributors		kg/yr													MPN/yr*		
12. Antifouling leachate	NIL						780.00										
13. Port / marina waste inputs	NIL																
14. Dredging activities	Multiple																
River catchments																	
15. Te Hoiere /Pelorus	NA	376,535	106,331		2.9 x10^{8}*		316.25	545.26		545.26					5.9 x10^{15}		
15. Kaituna	NA	54,198	19,644		5.1 x10^{7}*		33.55	88.30		44.15					1.8 x10^{15}		
15. Other terminal reaches	NA	3,898	710		1.8 x10^{6}*		–	–		–					9.4 x10^{13}		
Other																	
16. *Spartina* aerial / spot spraying	120548																
17. Civil works (sediment)	Multiple																
Total load per year		568,765	162,246	498	3.4 x10^{8}	696,189	1,289	1,357	8	590	0.001	0.050	0.047	0.0001	7.8 x10^{15}	4.9 x10^{10}	1.8 x10^{11}

Abbreviations: TN = total nitrogen, TP = total phosphorus, TOC = total organic carbon, TSS = total suspended solids, BOD = biochemical oxygen demand, Cu = copper, Zn = zinc, Pb = lead, As = arsenic, Cd = cadmium, Cr = chromium, Ni = nickel, Hg = mercury, EC = *E. coli*, Entero = enterococci, FC= faecal coliforms.
* Rounded to one decimal place; see Appendix 1 for raw figures.

4.3. Level of data confidence

The overall level of confidence for the data collected for the loading estimates was between **low** and **medium** (Appendix 1). This relatively low level of confidence was largely attributable to the following factors.

- There is a lack of activity-specific discharge compositional data and hence the calculations relied on typical concentrations of similar discharges.
- Simple stormwater run-off calculations were used, derived from annual rainfall and imprecise surface area sizes and permeability estimates, rather than detailed stormwater modelling data.
- Discharge volume estimates for unconsented wastewater overflows were averaged by compiling reported overflow volumes. However, it is likely that these are underestimating / overestimating the annual volume. MDC may have an overflow record that they can use to improve this estimate.
- Industrial discharge volume estimates may be overestimated or underestimated because they were derived either from the maximum consented discharge volumes (e.g. for Sanford factory and Cloudy Bay Clams) or, where there were no discharge limits in their consents, from monitoring information (e.g. Havelock Shell Processors application rates and recorded volumes).
- The total loading estimates do not consider all the potential contributor contaminants, only those where contaminant data were available. Thus, they are not complete loading estimates. In some cases, there were no typical concentrations or discharge volumes available to determine the loading contribution (dredging, vessel wastewater spills and civil works); this was largely due to the unknown scale of the activities.
- Riverine loadings were heavily influenced by the lack of representative flow data for Te Hoiere / Pelorus River (see Appendix 1), and the limitations and inaccuracies associated with catchment run-off modelling (Semadeni-Davies 2016; NIWA 2022a). Although not yet publicly available, the DOC Ngā Awa river project (DOC 2021; Tunnicliffe & Brierley 2021) may have some water quality and quantity data that can be used in the future to improve data accuracy in relation to Te Hoiere / Pelorus River inputs.
- The influence of other catchment characteristics has not been considered in this assessment, such as (but not limited to) the location and condition of Hazardous Activities and Industries List (HAIL) sites,[17] soil type, land use (zoning), degree of permeability, seasons, forestry activities and farming schedules.
- Some contributor inputs for the Kaituna River may overlap with loadings derived from MDC water quality and flow rates (e.g. for arsenic, copper and zinc), given that the LAWA samples are taken downstream. This may lead to an

[17] It is noted that HAIL sites do exist in Havelock – e.g. the Havelock tennis courts are known to cap soil contaminated with heavy metals.

overestimation of inputs to the Estuary (e.g. the Havelock Shell Processors and civil works inputs).

5. POSSIBLE ENVIRONMENTAL IMPACTS

Summary of key contaminants and their potential impacts at the loadings and concentrations estimated are discussed in the following sections.

5.1. Nutrients

The nutrients most often responsible for water quality degradation are nitrogen and phosphorus, which can be found in the environment in several forms.[18] Sources of nutrients include sewage effluents, fertilisers, processing wastes (animal and food) and urban stormwater. Nutrients are essential for the growth of healthy aquatic communities (ANZECC 2000), but excess nutrients can cause excessive increases in the growth of aquatic weeds and algae (i.e. blooms), smothering the habitat used by aquatic fauna. In addition, the decomposition of excess weeds and algae can also lead to a reduction in dissolved oxygen. Waters that have high concentrations of nutrients are referred to as eutrophic. The adverse effects of high nutrient concentrations are particularly noticeable in waterbodies that have poor dispersion characteristics (e.g. some estuaries), where the nutrients are recycled through the same water and tend to gradually accumulate.

The most recent ecological monitoring of the Estuary, undertaken by Robertson (2019a, 2019b), reported that eutrophication issues are apparent in the Estuary. This was evidenced through the presence of areas of excessive macroalgal growth, as well as increased levels of muddiness and organically enriched, oxygen-depleted sediments throughout the intertidal Estuary.

Based on the findings from this investigation, high loads of total phosphorus (TP) and total nitrogen (TN) inputs contributing to the observed Estuary eutrophication are likely to be primarily from river catchment inputs, but with potential contributions from the Sanford factory, the sewage treatment plant and urban stormwater (Figure 11).

[18] For example, nitrogen present in water may be derived from plant or animal tissue, in which case it is referred to as 'organic' nitrogen. This nitrogen eventually breaks down into 'inorganic' forms such as nitrate (NO_3), nitrite (NO_2) or ammonia (NH_3). The relative proportions of these different nitrogen species suggest the possible sources of nutrient-rich contaminants, and/or the time since their discharge to the receiving water.

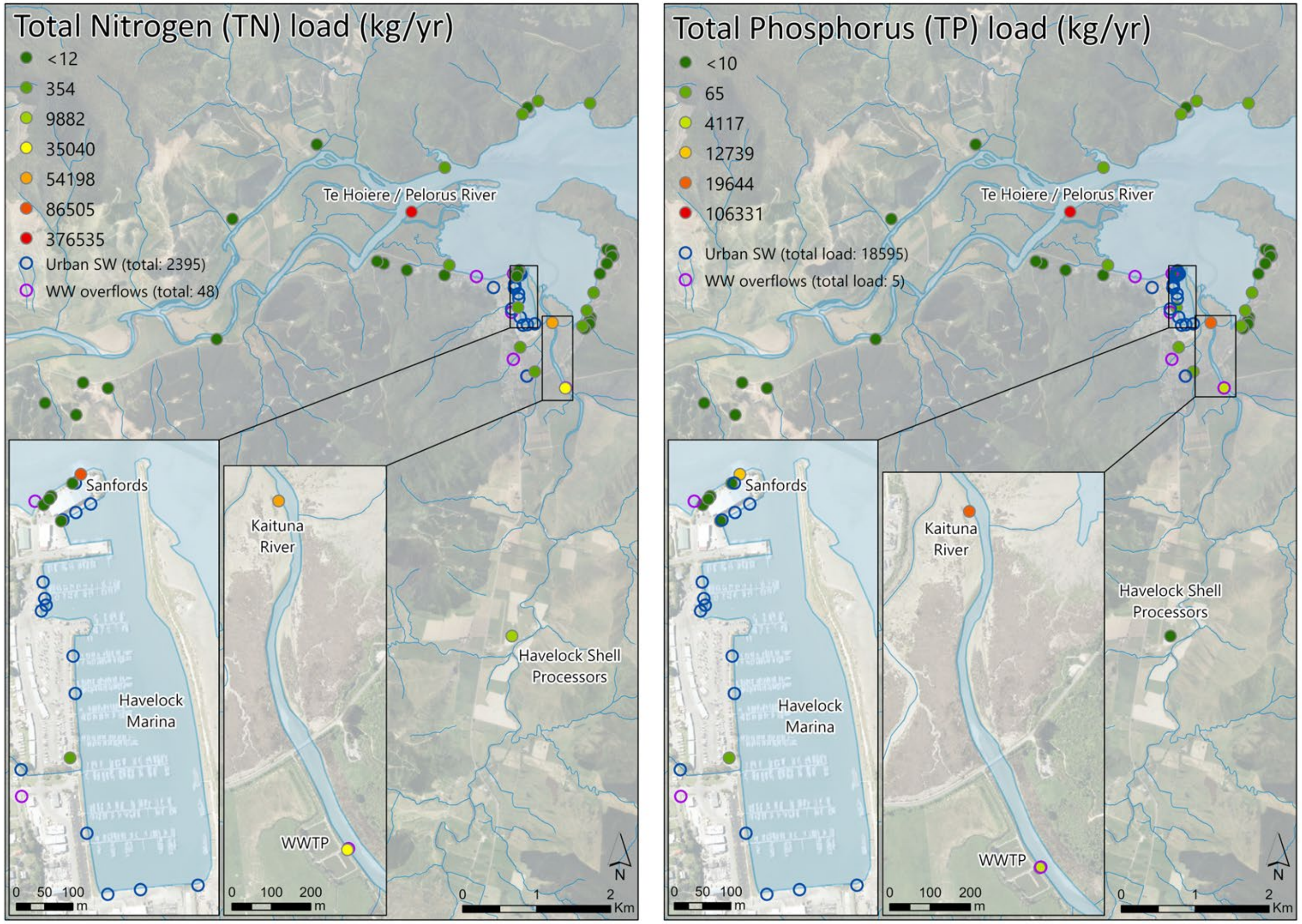

Figure 11. Relative total nitrogen (TN) and total phosphorus (TN) loading (kg/yr) from discharge contributors to Motuweka / Havelock Estuary. Refer to Section 4.1 for specific contributor descriptions. WWTP = wastewater treatment plant / sewage treatment ponds.

5.2. Total organic carbon

Total organic carbon (TOC) is the amount of carbon found in organic matter (ANZECC 2000). The rates of organic carbon production and decomposition, and the resulting microbial biomass, also influence eutrophication stress (EPA 2001). The more carbon or organic matter discharged to the receiving environment, the greater the risk of oxygen depletion caused by the growth of microorganisms. However, TOC is a measure only of organic carbon and does not take account of other oxygen-consuming materials, such as nitrogen, hydrogen and many inorganic compounds.[19]

TOC from contributor inputs in source waters comes from decaying natural organic matter (e.g. humic acid, fulvic acid, amines and urea) as well as synthetic sources (e.g. some detergents, pesticides, fertilisers, herbicides, industrial chemicals and chlorinated organics).

Sediment TOC (as opposed to water column TOC) is measured as part of the ongoing Estuary monitoring, and is likely to be positively correlated to the proportion of muddy sediments and eutrophic conditions found there (Robertson 2019a, 2019b). The TOC concentration / loading of discharges is also considered a useful measure for understanding the general quality of discharges and their potential to contribute to oxygen depletion / eutrophication in the Estuary. However, only one of the MDC consents for the identified contributors appeared to include this parameter (Havelock Shell Processors leachate). No other TOC concentrations or loads were found for other discharge contributors. Given this, little can be surmised about the characteristics of this specific input, although the organic content of the discharges will be captured, to a certain degree, through other test parameters, such as biological oxygen demand (BOD; see Section 5.5 for discussion).

5.3. Suspended sediment

Sediment in the water column (suspended sediment) largely consists of easily suspended fine clays and silts.[20] Most suspended sediments are made up of inorganic materials, although they can include anything drifting or floating in the water, from sediment, silt and sand to plankton and algae. Even organic particles from decomposing materials and chemical precipitates can contribute to the total suspended solids (TSS) concentration. When these fine sediments are in the water column, or settling out of suspension, they can adversely impact water quality characteristics and aquatic communities.

[19] TOC does not provide the same kind of information as BOD or chemical oxygen demand (COD), and should not be used to replace these methods (EPA 2001).

[20] TSS are particles that are larger than 2 microns found in the water column. Anything smaller than 2 microns (average filter size) is considered to be a dissolved solid.

With regard to water quality, high levels of TSS can increase water temperatures and decrease dissolved oxygen (DO) levels. This occurs because suspended particles absorb more heat from the sun than water molecules, and this is then conducted to the water. This causes DO concentration to drop, as warmer water does not hold as much DO as colder water, and, in turn, can lead to stratification (reduced mixing) of the body of water. This chain of events can cause the water layers near the seabed to become hypoxic (low in DO), making it difficult for organisms to survive. Increased levels of sediments can also increase turbidity, reduce clarity[21] and change the colour of the water. In this way, suspended sediments can influence aquatic plant growth, impact recreational activities and change the waterbody's aesthetic properties by affecting its appearance.

Suspended sediments have the potential to obstruct and injure fish gills and carry other pollutants into waterbodies. Nutrients and toxic chemicals such as trace metals may attach to soils, from where they are carried into surface waters. There, they may settle with the sediment or detach and become dissolved in the water column.

Sediments settling out of the water column can smother (suffocate) eggs and aquatic insect larvae on the bottom and modify the characteristics of the benthic substrate (e.g. filling in the spaces between gravel where fish lay eggs). High mud content of recently deposited sediments can also provide ideal habitat for the invasion of opportunists (both plant and animal), such as the introduced cordgrass (*Spartina townsendii*) and the Pacific oyster (*Crassostrea gigas*) (Robertson 2019a).

Natural run-off, water turbulence from storms, bottom-feeding animals and wave action can cause (re)suspension of sediments and increased water turbidity. In addition to natural[22] sources of sediment, there are a number of anthropogenic activities that can increase sediment inputs to aquatic environments (EPA 2006b). These include sediment run-off from agricultural fields, logging activities, run-off from construction sites and urban areas, and shoreline erosion from heavy boat traffic. Excessive algal growth due to the additions of nutrients into an estuary can also affect water turbidity and TSS (ANZECC 2000). High levels of turbidity over long periods can greatly weaken the health of an estuarine ecosystem (EPA 2006b).

Suspended sediment is measured as part of the MDC water quality monitoring[23] in the Marlborough Sounds. The median concentration value (from 2016 to 2020) of TSS

[21] Nephelometric turbidity is a measure of light scattering by suspended particles, and thus represents the level of suspended material in the water. Visual clarity (measured with a Secchi or black disc) provides an optical measurement with relevance to aesthetics, contact recreation and fish habitat. Typically, as the amount of sediment suspended in the water increases (increased turbidity), the water clarity can be expected to decrease.
[22] Although these are natural phenomena, the level of sediment introduced by these phenomena are influenced by human activities (e.g. changing land-use practices).
[23] https://www.stats.govt.nz/indicators/coastal-and-estuarine-water-quality

at the Pelorus Sound / Te Hoiere marine monitoring site (PLS-1, ~6 km from the Estuary) is 7.1 mg/L, and has been assigned the trend status 'likely worsening' (data ranging from 2011 to 2020).

TSS loading (kg/yr) for all non-riverine contributors identified in Table 4 was less than 1% of the annual contribution from the riverine tributaries (including Te Hoiere / Pelorus River, Kaituna River and other minor tributaries). This supports the conclusion from Robertson (2019a) attributing the freshwater riverine inputs as the main driver for the mud-dominated substrate in the Estuary (70% of intertidal flats are very soft or soft muds), where muddiness has been identified as a priority issue. The estimated current suspended sediment load (CSSL; Robertson 2019a) indicates that the current sedimentation rate is likely to exceed the natural rate and therefore contribute to sedimentation issues in the Estuary. It was outside the scope of this report to compare the monitored sedimentation rates (mm/yr) to the annual loading volumes (kg/yr) calculated here, but it was clear from the various sedimentation investigations interrogated that there is a high degree of variability in TSS loading calculations among sedimentation studies (Handley et al. 2017; LAWA 2022a, 2022b; NIWA 2022a).

5.4. Bacteria

The bacterial indicators *E. coli*, enterococci and faecal bacteria are applied in this context for assessing the public health risk of using marine recreational waters and collecting and consuming shellfish. For marine waters, the preferred indicator is enterococci; however, *E. coli* is a more appropriate indicator where the primary source of faecal contamination is a waste stabilisation pond, such as the Havelock sewage treatment ponds (MfE 2003b). Only standards that apply to receiving water concentrations of faecal indicator bacteria have been considered here (as opposed to shellfish tissue concentrations).

The greatest amount of bacteriological concentration data from the contributors was for *E. coli* concentrations (the Sandford factory, Havelock Shell Processors, septic tanks, the sewage treatment ponds, wastewater overflows, urban stormwater and rivers; Figure 12). While there were four contributors for faecal coliforms concentration data (the Sandford factory, Havelock Shell Processors, septic tanks and the sewage treatment ponds), only two of the contributors had any data relating to enterococci concentrations (the Sandford factory and the sewage treatment ponds). Of the available concentrations from contributors, almost all exceeded Recreational Grade A microbiological water quality guidelines (MfE 2003b) for *E. coli* and enterococci. In addition, the recreational shellfish-gathering bacteriological guideline (median value over season; MfE 2003b) was also exceeded for faecal coliforms.

The *E. Coli* concentration (Table 3) and loading (Table 4) figures from the rivers were at least four orders of magnitude higher than the other contributors (Figure 12). Although there were no enterococci and faecal coliforms concentration data available for the rivers, it can be assumed that riverine inputs of these bacterial indicators are also high relative to the other contributors.[24]

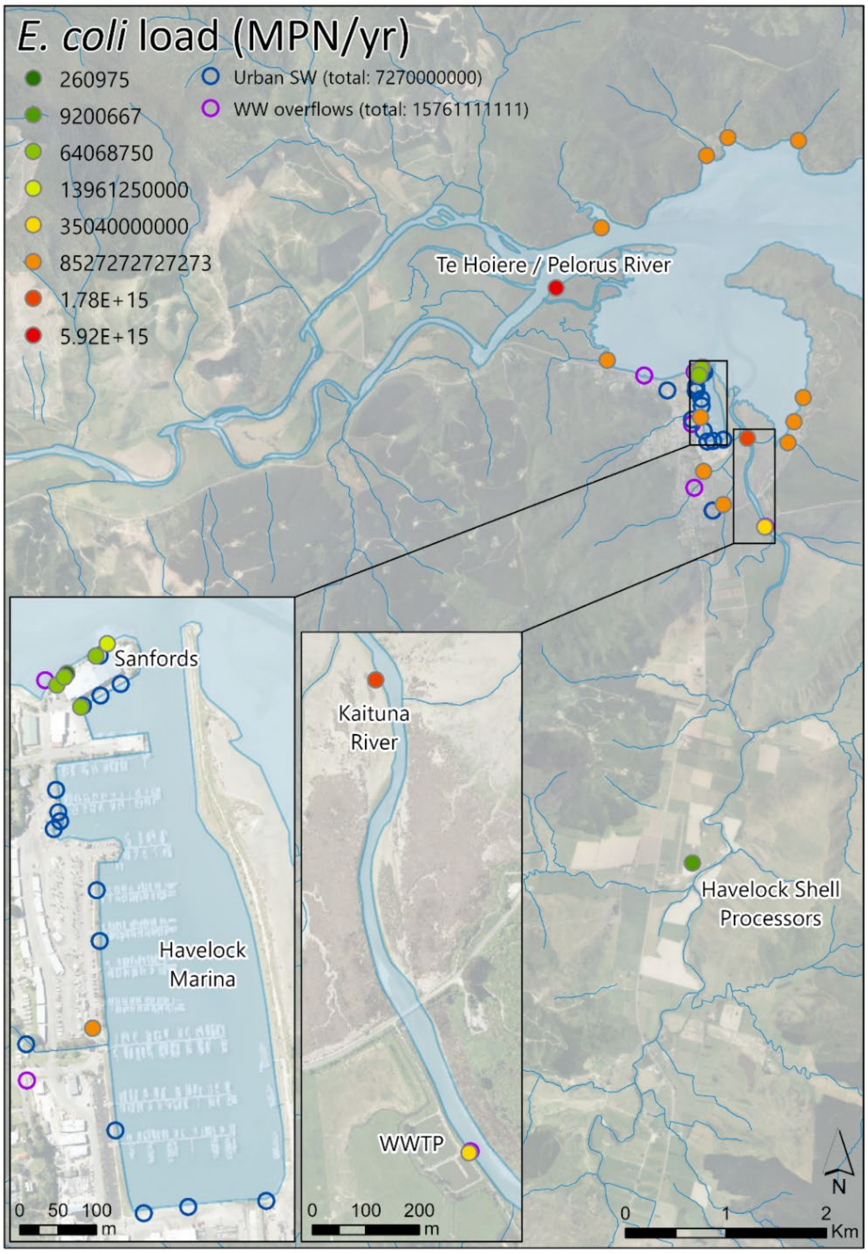

Figure 12. Relative *E.coli* loading from discharge contributors in Motuweka / Havelock Estuary. Refer to Section 4.1 for specific contributor descriptions. WWTP = wastewater treatment plant / sewage treatment ponds. MPN / yr = most probable number per year.

[24] MfE (2003a) provides an equation that estimates the number of enterococci from *E.coli* counts.

5.5. Biochemical oxygen demand

Biochemical oxygen demand (BOD) is a measure of the amount of dissolved oxygen (DO) consumed by aerobic biological organisms to break down organic material present in a water sample at a certain temperature over a specific time period (5 days; EPA 2006a). BOD is often used as a proxy for the degree of organic pollution of water.[25]

BOD in an estuary is affected by a number of variables, including temperature, types of microorganisms, and the type of organic and inorganic material in the water (EPA 2006a). BOD directly affects the amount of DO in estuaries, with increasing BOD levels causing decreasing DO levels. Thus, the impacts of high BOD are the same as those for low DO, where many aquatic organisms become stressed and suffocate.

There were four contributors that had BOD concentration data (Sanford factory, Havelock Shell Processors, the sewage treatment ponds and septic tanks). Of these, demand was particularly high from the Sanford factory discharge and the sewage treatment pond outfall. All four of the discharges exhibited BOD concentrations higher than the typical concentration of unpolluted natural waters (<5 g/m^3, Table 3).

Based on the limited contributor BOD data available, it is difficult to say what the highest BOD source is to the Estuary. However, given that the rivers are very large sources of nutrients, bacteria and TSS, it is reasonable to assume that they are also likely to be significant contributors of organic matter and, consequently, BOD to the Estuary.

5.6. Metals / metalloids

Trace metals / metalloids can have direct toxic effects on organisms (including, notably, in the early stages of fish development), and can persist in soft-sediment estuarine environments and organisms (bioaccumulate). They can also have adverse effects on human health (e.g. via eating contaminated shellfish). Heavy metal toxicity in water can be affected by pH, hardness, alkalinity, DO, temperature and turbidity (ANZECC 2000).

Contributor discharges most consistently had data for copper, zinc, lead and arsenic, whereas the other metals had little associated monitoring data, and those that were available had low concentration values. Riverine data for metals were available only for copper, zinc and arsenic (Table 3), each of which were at concentrations below their respective default guideline values (DGV) for slightly to moderately disturbed

[25] BOD analysis is similar in function to chemical oxygen demand (COD) analysis, in that both measure the amount of organic compounds in water. However, COD measures everything that can be chemically oxidised, rather than just amounts of biologically oxidisable organic matter.

ecosystems (ANZG 2018). Due to the high riverine discharge volume, however, they had the highest loading estimates of all contributors (Table 4).

High estimated loadings and concentrations (above DGV) of copper came from the Havelock Slipway and possibly the leachate from the marina. Urban stormwater potentially contributed considerably to zinc loading. Arsenic loadings from Te Hoiere / Pelorus River and Kaituna River were orders of magnitude higher than any other contributor (where data was available).

In contrast, long-term estuary monitoring (Robertson 2019a) showed that some sediment monitoring sites had nickel and chromium concentrations above the ANZECC (2000) ISQG-Low (now superseded by DGV; ANZG 2018), whereas cadmium, copper, mercury, lead, zinc and arsenic concentrations were all below their respective DGV levels. Robertson (2019a) attributed elevated nickel and chromium in the Estuary to naturally elevated inputs from catchment run-off. This potential for catchment supply is supported by the investigations of Cavanagh (2013), who showed that nickel and chromium are elevated in the soils in the Wakamarina River (lower Te Hoiere / Pelorus River) area. Unfortunately, we were not able to ascertain the contribution of these metals from the rivers, as neither nickel nor chromium are tested in the rivers as part of ongoing MDC monitoring (Steffi Henkel, MDC Water Quality Scientist, pers. comm., September 2022). However, given the sediment monitoring results (Robertson 2019a) and the high riverine TSS results (discussed in Section 5.3, which may include adsorbed metals), it is probable that the rivers contribute to the elevated nickel and chromium sediment concentrations.

5.7. Cumulative effects

Marine ecosystems today are under pressure from increasing levels of anthropogenic activity. It is therefore necessary to understand the potential for cumulative effects, which are the responses of an ecosystem to stressors that accumulate over space and time. Ecosystem responses are not usually simply additive (NIWA 2022c), but rather are typically either synergistic (the response to more than one stressor is greater than the sum of the individual stressors) or antagonistic (the response to more than one stressor is less than the sum of the individual stressors).

Depending on the timing and spatial overlap of accumulating ecosystem responses, there can be vastly different ecosystem outcomes (NSCSS 2020). Thus, an understanding of the spatial extent of accumulating ecosystem responses is important, including whether the stressor response footprints overlap (potentially creating synergistic or antagonistic responses) or not (creating an increasingly fragmented seascape). Consideration of the accumulating ecosystem responses in time is also important (NIWA 2022c), specifically whether the timing overlaps (increasing the magnitude of the stressor response) or not (the ecosystem may have time to recover).

Stressor response footprints (including the dilution and spatial extent of mixing of discharges) in the receiving environment have not been defined as part of this investigation, nor have other ecosystem stressors (e.g. increasing temperatures,[26] droughts,[27] sea-level rise,[28] floods,[29] storms,[30] wind changes,[31] physical disturbance, shellfish gathering, fishing pressures, etc.). In addition, only a limited range of contaminants were monitored for the contributor discharges investigated, and these were not consistent across all contributors. Therefore, the total loading estimates presented here, which assess the contributor inputs over space and time, are probably underestimating most contaminant inputs to the Estuary. This makes it difficult to surmise anything robust about the cumulative effects of the discharges. However, we have undertaken the key first step to assessing cumulative effects (NIWA 2022c) by identifying the key contributors of contaminants to the Estuary. Where data were available, we found that contributors appear to be introducing discharges to the marine environment at levels higher than background values and higher than guideline values for receiving waters. We can also say that the loading contribution from the riverine inputs was very high compared to the other contributors.

Although outside the scope of this investigation, the next steps for assessing cumulative effects (NIWA 2022c) are as follows:

1. determine whether stressor responses are going to overlap in either space or time
2. decide what responses are important to Estuary ecosystem function
3. determine whether stressor response interactions might occur.

It is also worth mentioning that a concerted effort is underway nationally to better understand cumulative effects to marine ecosystems, as part of the Sustainable Seas National Science Challenge projects (NSCSS 2020). Outputs from this project should provide more guidance for assessing cumulative effects in New Zealand.

[26] 'Compared to 1995, temperatures are likely to be 0.7˚C to 1.0˚C warmer by 2040 and 0.7˚C to 3.0˚C warmer by 2090' (MfE 2022).
[27] 'Droughts are expected to increase in frequency and intensity over time' (MfE 2022).
[28] 'New Zealand tide records show an average rise in relative mean sea level of 1.7 mm per year over the 20th century. Globally, the rate of rise has increased, and further rise is expected in the future. Coastal roads and infrastructure may face increased risk from coastal erosion and inundation, increased storminess and sea-level rise' (MfE 2022).
[29] The flow data used in this assessment do not account for flood event inputs, which are likely to be significant.
[30] 'Changes in rainfall will vary locally within the region. The largest changes will be for particular seasons rather than annually. Summer rainfall in Blenheim is projected to increase by up to 9 per cent by 2090. According to the most recent projections, extreme rainy days are likely to become more frequent in Marlborough by 2090 under the highest emissions scenario' (MfE 2022).
[31] 'The frequency of extremely windy days in Marlborough by 2090 is likely to increase by between 2 and 10 per cent. There may be an increase in westerly wind flow during winter, and north-easterly wind flow during summer' (MfE 2022).

Any improvements to catchment land-use practices that result in improvements to water quality (e.g. reducing TN, TP, TSS and arsenic concentrations in run-off), or reduce the volume and flow rate of water coming down rivers (e.g. by increasing or improving wetland areas and reducing channelisation), would likely reduce the annual loading figures calculated here. It is also clear that a better understanding the Te Hoiere / Pelorus River catchment (including more representative river flow gauges and wider understanding of the chemical characteristics of the waters[32]) is an important step towards understanding the impact of this stressor on the Estuary.

If no measures for river catchment improvement are taken, and if levels of rainfall and frequency of storm events in the region increase by 2090, as some models predict (MfE 2022), then the contribution of rivers to contaminant loading in the Estuary can be expected to increase.

[32] Including lead, cadmium, nickel, enterococci and faecal coliforms concentrations, to allow comparison with other contributor inputs and assessment of the overall loading to the Estuary.

6. SUMMARY

Seventeen coastal discharge contributors were identified through the MDC Smart Maps portal, some with multiple discharge consents (e.g. Sanford factory, urban stormwater and septic tanks). The locations of the Sanford factory and the urban stormwater outfalls were difficult to define. This was largely due to the limited documentation of the Havelock stormwater infrastructure, the disparities between the consent documents and the MDC Smart Maps / Open Data information, and the locations of the outfalls observed during the site visit.

Nine of the contributors had at least some discharge-specific compositional data to calculate loadings, although these were not consistent across all the contributors. Another four contributors could be assigned typical discharge concentrations from the literature. Discharge volumes could be obtained for all 13 of these contributors from either stormwater calculations, consent discharge limits or monitoring records. In the remaining four cases, contributor loading inputs could not be calculated with any confidence. Several caveats (Section 6) and issues (Section 4.3) with the data sources were identified. Overall, the level of confidence in the data for this assessment was medium to low. This was due either to a lack of understanding around the discharge composition, its volume, or both. Improved knowledge of riverine flows and water quality characteristics, consideration of other non-discharge-related Estuary stressors, and further contributor discharge compositional testing would improve this understanding.

The identification of discharge contributors, and discharge-specific information collated through this assessment, was the first key step to assessing cumulative effects to the Estuary and highlights where contributors may be adding to ecological or human health-related pressures within the Estuary. The identified pressures on the Estuary from these contaminants include, broadly, eutrophication (nutrients, BOD, TOC), biological toxicity (metals), smothering of organisms (TSS) and human health-related effects (bacterial indicators / pathogens). Where data were available, we found that contributors frequently appear to be discharging contaminants to the Estuary at concentrations higher than background values and higher than guideline values for receiving waters, and that the loading contribution from the riverine inputs was very high compared to the other contributors.

Once the contributor information gaps are filled (as discussed above), the following steps could be undertaken to assess cumulative effects to the Estuary:

1) determine whether stressor responses are likely to overlap in either space or time
2) decide what responses are important to Estuary ecosystem function
3) determine whether stressor response interactions might occur.

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8. APPENDICES

Appendix 1. Summary table of identified discharge contributors and contaminant concentrations and loading estimates to Motuweka / Havelock Estuary inputs.

Appendix 2. Summary map package of identified discharge contributors and contaminant loading estimates to Motuweka / Havelock Estuary inputs.

Note: both Appendix 1 and 2 have been supplied as separate electronic files.