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SedNetNZ to estimate sediment sources from the TANK, South Coast, and Porangahau catchments

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SedNetNZ modelling to estimate sediment sources from the TANK, South Coast, and Porangahau catchments

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Summary

Project and Client

Landcare Research was funded by Hawke's Bay Regional Council (HBRC) to undertake an analysis of the Tutaekuri, Ahuriri, Ngaruroro, Karamu (TANK), South Coast, and the Porangahau catchments to identify areas of high-risk hillslope sediment generation and stream bank erosion. After quantifying erosion, scenario modelling was undertaken to assess remedial work required to reduce sediment loads in the river and stream network.

Objectives

- using the Highly Erodible Land (HEL) model, evaluate high risk areas of hillslope sediment generation
- using SedNetNZ, provide a quantitative analysis of sediment generation and undertake an assessment of stream bank erosion
- undertake scenario modelling to assess reductions in sediment loads through potential mitigation strategies.

Methods

Land at risk of landslide erosion was identified using the HEL model, using slope thresholds defined by erosion terrain and vegetation cover, to determine whether the sediment is likely to be delivered to streams. HEL also identifies land at risk of earthflow and gully erosion based on previous mapping and distinguishes between moderate and severe earthflow risk.

To provide an indication of where fine sediments across the TANK, South Coast, and the Porangahau catchments are potentially coming from, we used the soil particle size (*PS* field) from the Fundamental Soil Layers. Soil particle size provides an estimation of the dominant particle size class of the soil profile to c. 1 m. The classes were grouped into clay-, silt-, and sand-dominated particle sizes.

The SedNetNZ model was used to provide estimates of spatial variation in sediment load (t a^{-1}) and yield (t km^{-2} a^{-1}) across the TANK, South Coast, and the Porangahau catchments. Output from SedNetNZ was intersected with farm boundaries from AgriBase to estimate the potential sediment reduction through adoption of soil conservation farm plans, assuming a 70% reduction in sediment where farm plans were fully implemented. This methodology was used to calculate the potential reduction in sediment generation by focusing on farms that have the largest areas of highly erodible land.

The SedNetNZ model was further used to calculate stream and river bank erosion from bank height, mean annual flood, and bank migration rate. Bank erosion was summed across stream links (small hydrologically connected subcatchments) to provide overall stream bank erosion. The potential reduction in bank erosion from stock exclusion and fencing in the riparian area was also calculated assuming a reduction in stream bank erosion of 80 percent.

HBRC provided information on the current status of fencing and potential stock exclusion from stream and river riparian margins across the TANK catchments. The proportion of fenced river channels was assumed to be the same for the South Coast, and the Porangahau catchments. An analysis was undertaken to estimate stream bank erosion with current fencing and where an additional 25%, 50%, and 100% of streams were assumed to be fenced on both sides of the river or stream.

Results

In the TANK catchments, 1.8% was classed as HEL, with 3995 ha at risk of landsliding with potential of delivery to streams, and a further 1478 ha are classed as at risk of landsliding but non-contributing. The HEL occurs mostly on the steeper headwaters of the western tributaries. There is also some land with a severe earthflow risk (811 ha) within the TANK catchment. Areas identified as being highly susceptible to erosion by the HEL map were intersected with the FSL *PS* field to identify those areas of HEL more likely to deliver clay and silt size material to the river and stream network. Overall, 208 ha (<0.1% of catchment area) of HEL were associated with clay dominant particle size distribution, while around 5670 ha (1.6%) were associated with silt-dominated particle sizes.

The area of the South Coast catchment associated with HEL is relatively large (22.7% of catchment area), with 2662 ha at risk of landsliding with potential to delivery to streams, and a further 1168 ha classified as at risk of landsliding but non-contributing. Land with moderate (3205 ha) and severe earthflow risk (3769 ha) is also significant. Land identified as having gully erosion risk was 694 ha. Areas identified as being highly susceptible to erosion by the HEL map were intersected with the FSL *PS* field in an effort to identify those areas of HEL more likely to deliver clay and silt size material to the river and stream network. Overall, 4109 ha (8.3%) of HEL were associated with clay-dominant particle size distribution, while around 6577 ha (13.2%) were associated with silt-dominated particle sizes.

The area associated with highly erodible land for the Porangahau catchment is largest of the three catchments (29.3% of catchment area), with 1247 ha at risk of landsliding with potential to delivery to streams and a further 350 ha classified as at risk of landsliding but non-contributing. Land with moderate (19 315 ha) and severe earthflow risk (4798 ha) is significant within the Porangahau catchment. Areas identified as being highly susceptible to erosion by the HEL map were intersected with the FSL *PS* field in an effort to identify those areas of HEL more likely to deliver clay and silt size material to the river and stream network. Overall, only 80 ha (< 1%) of HEL was associated with clay-dominant particle size distribution, while 25 512 ha (34.0%) was associated with silt-dominated particle sizes.

SedNetNZ divides large catchments into many subcatchments (stream links) and a sediment budget is calculated, quantifying where sediment sources are associated with main erosion processes. When data are converted to a sediment load basis (t a^{-1}), the Upper Ngaruroro, Taruarau, and the Mangaone subcatchments of the TANK catchment have the highest sediment loads, with 229 620 t a^{-1}, 187 585 t a^{-1}, and 171 884 t a^{-1}, respectively. The Ngaruroro Corridor, Tutaekuri Corridor, and the Poporangi, Upper Tutaekuri, and Mangatutu subcatchments also have relatively high sediment loads, ranging from 80 099 to 50 554 t a^{-1}. Across the South Coast catchments the Mangakuri, Maraetotara, and Pourerere subcatchments have the highest sediment loads, with 81 757 t a^{-1}, 55 932 t a^{-1}, and 32 434 t a^{-1}, respectively. For the Porangahau catchment the Turaekaitai, Mangaorapa, and Lower Porangahau subcatchments have the greatest sediment loads, with 193 281 t a^{-1}, 100 418 t a^{-1}, and 82 230 t a^{-1}, respectively.

Using SedNetNZ and AgriBase, a scenario model was developed to investigate on-farm sediment reduction through mitigation strategies (farm plans). The model focuses on farms in the TANK, South Coast, and Porangahau catchments that have the greatest area of HEL, and assumes a 70% reduction in sediment is achieved where farm plans were fully implemented. Currently, SedNetNZ calculates a reduction in sediment load from mitigation strategies (farm plans) of around 645 000 t a^{-1} (35%) for the TANK, around 101 000 t a^{-1} (67%) for the South Coast, and 195 000 t a^{-1} (50%) for the Porangahau catchments targeting the worst HEL areas for 100 farms, based on AgriBase polygons. This approach enables mitigation strategies to be applied on farms identified by AgriBase and HEL for targeted farms and mitigation strategies.

The results of the SedNetNZ model were also used to develop stream bank erosion scenarios within the TANK, South Coast, and Porangahau catchments. The stream bank sediment load (t a^{-1}) was modelled for three different scenarios of 25% and 50% additional fencing, and 100% fencing on both sides of rivers and streams in addition to the current fencing status as identified by HBRC. Results from SedNetNZ bank erosion model estimate a reduction (compared to current sediment load) from 222 000 t a^{-1} to 51 000 t a^{-1} for the TANK catchment, from 8900 t a^{-1} to 2200 t a^{-1} for the South Coast catchments, and from 32 000 t a^{-1} to 7800 t a^{-1} for the Porangahau catchment (100% fencing on both sides of the rivers and streams).

Conclusions

The area of HEL identified in the TANK catchments is low at 1.8% of total catchment area, with half of the erosion area at risk from landslides (5473 ha), and the remainder being at risk from severe earthflow erosion (811 ha). The areas of HEL occur mostly in the steeper headwaters of the western tributaries. The area of HEL in the South Coast catchment at 22.7% (10 804 ha) with one third of the area at risk of landslides (3830 ha), but the largest contributor was from moderate and severe earthflow (6974 ha). The area of HEL identified in the Porangahau catchment is the highest at 25 711 ha (29.3%). For the Porangahau catchment HEL identifies the largest erosion risk as moderate and severe earthflow (24 113 ha), followed by high landslide risk (1598 ha).

Using the SedNetNZ model for the TANK catchments, the Upper Ngaruroro, Taruarau, and the Mangaone subcatchments have the highest sediment loads, with 229 620 t a^{-1}, 187 585 t a^{-1}, and 171 884 t a^{-1}, respectively. The Ngaruroro Corridor, Tutaekuri Corridor, Poporangi, Upper Tutaekuri, and the Mangatutu subcatchments also have relatively high sediment loads, ranging from 80 099 t a^{-1} to 50 554 t a^{-1}. In the South Coast catchments the Mangakuri, Maraetotara, and the Pourerere subcatchments have the highest sediment loads, with 81 757 t a^{-1}, 55 932 t a^{-1}, and 32 434 t a^{-1}, respectively. For the Porangahau catchment the Turaekaitai, Mangaorapa, and Lower Porangahau subcatchments have the greatest sediment loads, with 193 281 t a^{-1}, 100 418 t a^{-1}, and 82 230 t a^{-1}, respectively.

By combining SedNetNZ and AgriBase, a scenario model was developed to investigate on-farm sediment reduction through mitigation strategies (farm plans) by identifying farms with the greatest area of HEL, and thereby the greatest potential to erosion risk. SedNetNZ calculates reductions in sediment load of around 228 000t a^{-1} (23%) for the TANK, around 204 000t a^{-1} (67%) for the South Coast, and 194 000 t a^{-1} (50%) for the Porangahau catchments from the 100 farms identified from Agribase with the largest area of HEL.

SedNetNZ predicts that if all remaining stream banks were fully fenced and stock excluded, bank erosion could be reduced from 255,000 t a^{-1} to 83,000 t a^{-1} for the TANK, from 11,000 t a^{-1} to 3,600 t

a^{-1} for the South Coast, and from 39,000 t a^{-1} to 13,000 t a^{-1} for the Porangahau catchments (assuming 100% fencing on both sides of the rivers and streams).

1 Introduction

The Tutaekuri, Ahuriri, Ngaruroro, and Karamu (TANK) catchments cover around 350 000 ha, draining the eastern flanks of the Kaweka Range, the intensively farmed inland steeplands and hills, and the lowland coastal fringe west of Napier. The catchments drain to Hawke Bay at Clive where the Ngaruroro, Tutaekuri and Clive Rivers converge (Fig. 1). The South Coast catchment stretches from the Cape Kidnappers in the north to Aramoana and Blackhead in the south. The catchments of the South Coast cover around 49, 800 ha and comprises lower order rivers and streams that drain directly to the sea. The Porangahau catchment is larger, at around 88 000 ha, draining to the east beyond the town of Porangahau. An overview of the catchments and the river and stream network is shown in Figure 1.

Like much of New Zealand's North Island hill country, the TANK, South Coast, and the Porangahau catchments were converted from indigenous forest to pastoral agriculture since settlement by Europeans (Guthrie-Smith 1969). The consequence of native vegetation removal includes accelerated erosion, slope failures, and river bed aggradation.

Landcare Research was funded by Hawke's Bay Regional Council (HBRC) to undertake an analysis of the TANK, South Coast, and the Porangahau catchments to (1) identify areas at high risk of hill slope sediment generation, (2) identify areas at high risk of stream bank erosion, and (3) undertake an assessment of the erosion mitigation required to reduce suspended sediment loads in the stream and river network.

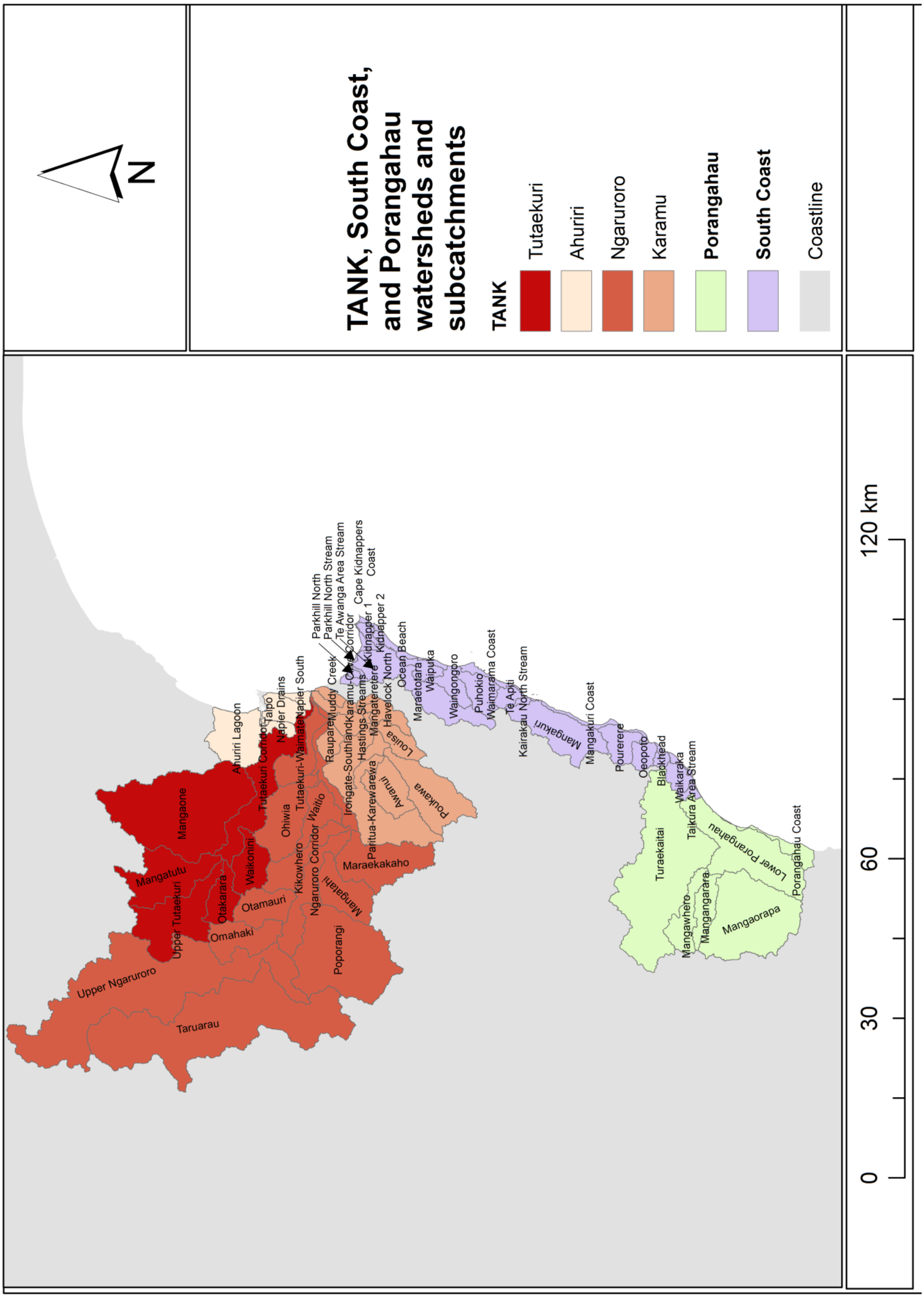

Figure 1 The Tutaekuri, Ahuriri, Ngaruroro, Karamu (TANK), Porangahau, and South Coast catchments and subcatchments, as defined by the Hawke's Bay Regional Council.

2 Background

The Tutaekuri and Ngaruroro Rivers originate on the slopes of the Kaweka Range. The South Coast has a relatively long and narrow catchment where rivers are minimal, and for the most part streams terminate at the coast. The Porangahau River has a larger more substantial catchment. Because the Tutaekuri and Ngaruroro Rivers originate from the higher elevated regions of the Kaweka Range, increased precipitation rates in the ranges and surrounding foothills is the source of much of the river's water. Six major catchments and 61 subcatchments are recognised in this study (as defined by Hawke's Bay Regional Council). Identifying sediment sources from these catchments is a key objective to reducing the sediment load to their rivers.

Table 1 Area of the catchments and subcatchments within the (A) Tutaekuri, Ahuriri, Ngaruroro, Karamu (TANK), (B) South Coast, and (C) Porangahau catchments (see Fig. 1 for spatial extent)

Catchment	Subcatchment	Area (ha)
(A) Tutaekuri	Upper Tutaekuri	13,455
	Mangatutu	12,103
	Otakarara	4713
	Mangaone	33,903
	Waikonini	5846
	Tutaekuri Corridor	13,086
	Total	83,105
(A) Ahuriri	Ahuriri Lagoon Tributaries	8917
	Napier Drains	3276
	Napier South	1110
	Taipo	1260
	Total	14,564
(A) Ngaruroro	Upper Ngaruroro	52,601
	Taruarau	49,545
	Poporangi	25,680
	Mangatahi	7686
	Omahaki	7408
	Otamauri	6251
	Kikowhero	6569

	Maraekakaho	12,241
	Waitio	5196
	Ohiwia	10431
	Tutaekuri-Waimate	5468
	Ngaruroro Corridor	12,171
	Total	201,246
(A) Karamu	Poukawa	11,044
	Paritua-Karewarewa	12,005
	Awanui	6165
	Louisa	3483
	Irongate-Southland	6213
	Havelock North Streams	2742
	Hastings Streams	2106
	Raupare	2367
	Mangateretere	597
	Karamu-Clive Corridor	3683
	Muddy Creek	1058
	Total	51,462
(B) South Coast	Maraetotara	11,794
	Pourerere	3708
	Oeopoto	2105
	Blackhead	670
	Waikaraka	2049
	Taikura Area Stream	689
	Kidnapper 1	886
	Kidnapper 2	360
	Waipuka	1852
	Waingongoro	2504

	Puhokio	4180
	Te Apiti	1557
	Kairakau North Stream	338
	Mangakuri	10,472
	Parkhill Road Stream	309
	Te Awanga Area Stream	271
	Parkhill North	536
	Waimarama Coast	1105
	Blackhead Coast	981
	Cape Kidnappers Coast	1103
	Mangakuri Coast	1011
	Ocean Beach	1278
	Total	49,759
(C) Porangahau	Turaekaitai	36,221
	Mangawhero	5239
	Mangangarara	4233
	Mangaorapa	22,026
	Lower Porangahau	17,753
	Porangahau Coast	2518
	Total	87,989

Long-term suspended sediment loads across New Zealand are given by in Hicks et al. (2011 - see Table 2). The Waiapu and the Waipaoa on the East Coast are the largest contributing rivers with sediment loads of 28 276 986 and 13 864 903 t a^{-1}, respectively. The Tukituki River at Red Bridge is recorded as contributing 1 033 230 t a^{-1}, one third of the load of the Manawatu River (3 197 368 t a^{1}), and about 20% less than the Mohaka (1 341 544 t a^{-1}), and Ngaruroro Rivers (1 317 380 t a^{-1}). Interestingly, on a suspended sediment load basis, the Tukituki River (424 t km^{-2} a^{-1}) is about 50% of the Manawatu River (817 t km^{-2} a^{-1}), and 65–75% of the Ngaruroro (658 t km^{-2} a^{-1}) and Mohaka (566 t km^{-2} a^{-1}) Rivers.

Table 2 Measured sediment load and suspended sediment load of selected North Island rivers; from Hicks et al. (2011). Note, for comparison with Table 1,

River	Site	Region	Area (km^2)	Measured Sediment Load ($t\ a^{-1}$)	Suspended Sediment yield ($t\ km^{-2}\ a^{-1}$)
Waiapu	Rotokautuku	Gisborne	1374	28 276 986	20 577
Waipaoa	Matawhero	Gisborne	1922	13 864 903	7216
Manawatū	Teachers College	Manawatu	3911	3 197 368	817
Mohaka	Raupunga	Hawkes Bay	2371	1 341 544	566
Ngaruroro	Chesterhope Bridge	Hawkes Bay	2001	1 317 380	658
Tukituki	Red Bridge	Hawkes Bay	2438	1 033 230	424
Esk	Waipunga Bridge	Hawkes Bay	253	348 257	1379
Waipa	Whatawhata	Waikato	2822	184 002	65

Land uses in the TANK, South Coast, and the Porangahau catchments are summarised in Table 3 using Agribase[1]. Sheep and beef are the largest land use contributor across the TANK catchment, at 129 424 ha. TANK also has substantial native vegetation (84 300 ha), forestry (22 434 ha), beef (21 762 ha), horticulture (16 643 ha), sheep (10 199 ha), and dairy (7568) components. The South Coast catchment land cover is comprised primarily of sheep and beef (36 037 ha), beef (4323 ha), and forestry (842 ha). Note that dairying is absent from this catchment. The Porangahau catchment follows a similar trend, with main land uses being sheep and beef (65 609 ha), undefined (6719 ha), sheep (6570 ha), beef (4623 ha), and forestry (2368 ha). The South Coast region also has a substantial amount of undefined (2456 ha) land cover.

For the most part, sediment is derived from only small parts of the landscape. The critical source areas have spatially distinct zones of generation and transport that vary greatly according to geology (rock type and composition), degree of deformation, uplift rates, land management, and land use. Models such as SedNetNZ and the highly erodible land (HEL) model (Dymond et al. 2006) can be used to target these critical source areas and predict the impact of erosion on water quality and quantity under current and future land management regimes (Elliott et al. 2006; Elliott & Basher 2011). Setting realistic targets for the reduction in sediment loads can also be evaluated using SedNetNZ by evaluating contemporary sediment loads in relation to natural or background levels.

[1] We used the most recent version of Agribase available to Landcare Research (2015)

Table 3 Land use types and area within the subcatchments of the TANK, South Coast, and Porangahau (derived from Agribase 2015)

Description	Catchment		
	TANK (ha)	South Coast (ha)	Porangahau (ha)
Sheep and beef	129,424	36,037	65,609
Native	84,300	108	80
Undefined	40,365	2,456	6,719
Forestry	22,434	842	2,368
Beef	21,762	4,323	4,623
Horticulture	16,643	407	-
Sheep	10,199	1,769	6,570
Dairy	7,568	-	304
Support	5,766	485	698
Other	4,704	546	52
Deer	4,072	287	523
Lifestyle	3,739	349	138
Total	350,976	47,607	87,684

The HEL model identifies land at risk of severe mass-movement erosion (landslide, earthflow, and gullying), assesses the risk of sediment delivery to streams, but does not provide quantitative estimates of erosion. HEL identifies land susceptible to landsliding using three main datasets: slope derived from a Digital Elevation Model (DEM); rock type derived from the New Zealand Land Resource Inventory (NZLRI, Newsome et al. 2000); and a land cover map (Land Cover Database version 4 derived from satellite imagery from 2102/13, https://lris.scinfo.org.nz/layer/423-lcdb-v41-land-cover-database-version-41-mainland-new-zealand/).

Land at risk of landslide erosion is defined by slope thresholds that are related to rock type and land cover (Dymond et al. 2006). Using a 15-m cell size resolution slope map we can estimate whether the threshold is exceeded for each rock/regolith type. If a cell exceeds the slope threshold, and does not have protective woody vegetation (determined from the satellite-derived land cover map) then the land is identified as susceptible to landsliding. Land at risk from landsliding is further classified as connected to a stream channel or not connected. The flow path downstream is traversed across a 15-m cell size resolution DEM using flow direction and accumulative flow algorithms, to determine whether a cell at that location can deliver sediment to a stream. If the modelled sediment flow path encounters more than two consecutive cells of low slope (i.e. <5 degrees), the cell is termed 'non-contributing', if not, the cell is determined as 'contributing'. Land susceptible to earthflow and gully erosion is derived from the erosion data in the New Zealand Land Resource Inventory.

Current empirical erosion models developed for New Zealand relate specific suspended sediment yield (t km^{-2} a^{-1}) to mean annual rainfall and an 'erosion terrain' classification. Erosion terrains[2] (Dymond et al. 2010) were developed from 1:50 000 NZLRI data. These empirical models are calibrated using long-term load estimates from approximately 200 rivers across New Zealand. The models include (1) Suspended Sediment Load Estimator (Hicks & Shankar 2003; Hicks et al. 2011), (2) SPARROW (Elliot et al. 2008), and (3) NZeem® (Dymond et al. 2010). NZeem® and SPARROW both use the influence of land cover to modify sediment source contribution based on vegetation. The NZeem® model assumes that herbaceous land cover and bare ground erode at 10 times the rate of woody cover. Using the SPARROW model, Elliott et al. (2008) found pasture had 4.5 times the erosion rate of the base land cover of trees and shrubs. In both models the vegetation source contribution modifier is applied uniformly across the landscape and ignores differences in the effect of inherent erosion susceptibility on responses to vegetation cover change. SPARROW further includes source modification terms for mean catchment slope, while NZeem® modifies sediment delivery dependent on slope-dependent connectivity between the hillslope and channel, as described for the HEL model. The SPARROW model is included as part of the NIWA CLUES water quality modelling system (Woods et al. 2006). None of these models provides information on the contribution of different erosion processes to sediment load. The New Zealand landscape is characterised by a wide range of erosion processes, from overland flow to shallow landslide and stream bank erosion (Eyles 1983). An assessment of erosion process contribution is essential for better targeting of erosion mitigation.

The SedNet modelling approach was developed in Australia (Wilkinson et al. 2004) and calculates process-based sediment budgets on an average annual basis. It provides an improvement on lumped empirical erosion models (such as NZeem®), by using a relatively simple physical representation of erosion and deposition processes that has realistic calibration data requirements. It has been developed for application in New Zealand (De Rose & Basher 2011a; Dymond et al. 2016) by incorporating landslides, earthflows, large-scale gully erosion, and streambank erosion typical of parts of New Zealand (this is referred to as SedNetNZ).

This report is divided into three main sections:

- Section 1 uses the Highly Erodible Land (HEL) model to define spatially the land at greatest risk from landsliding, gully and earthflow erosion.
- Section 2 uses SedNetNZ to provide a quantitative spatial picture of sediment sources.
- Section 3 uses HEL to identify areas at high risk of erosion and SedNetNZ to undertake scenario modelling to assess the likely reduction in suspended sediment loads across the TANK, South Coast, and Porangahau catchments from mitigation strategies.

[2] An erosion terrain is a land type with a characteristic combination of topography, rock type, rainfall and associated erosion processes and erosion rates. They reflect the intrinsic susceptibility of land to erosion.

3 Objectives

- Assess high risk areas for hillslope sediment generation using the HEL model
- Provide a quantitative analysis of spatial variation in sediment generation using SedNetNZ
- Undertake an assessment of the work required to reduce suspended sediment loads to the TANK, South Coast, and Porangahau stream networks.

4 Methods

4.1 Highly Erodible Land (HEL)

Highly erodible land (Dymond et al. 2008) is defined as land at risk of severe erosion (landsliding, earthflow, and gullying) where protective woody vegetation (i.e. shrubs or forest) is absent. To be at risk of landslide erosion, a slope threshold must be exceeded. Risk of earthflow and gully erosion is derived from Land Use Capability and erosion data in the NZLRI following procedures described in Page et al. (2005). If the land has protective woody vegetation (i.e. indigenous forest, exotic forest, or scrub) then it is considered not at risk of severe landslide erosion, earthflow or gully erosion. The distribution of woody vegetation from which HEL is identified is derived from the Land Cover Database version 4 (LCDB4, with a nominal date of 2012/13). Particle-size variation within HEL is also examined by intersecting HEL with particle size class from the Fundamental Soils Layer.

4.1.1 The modelling approach used by HEL

The program Erdas Imagine was used to undertake the spatial modelling of HEL. The modelling approach used to define the classes of HEL at risk of landslide erosion uses a slope threshold defined for each erosion terrain (Table 4). All pixels in a 15-m cell size resolution DEM above the threshold defined by the cell's erosion terrain were assigned to "high landslide risk". All "high landslide risk" cells were examined to see if they were connected to a watercourse. Land was considered capable of delivering sediment if it was possible to traverse down a flowpath (streamline) until a watercourse was reached without encountering two consecutive cells of low slope (i.e. <5 degrees). If "high landslide risk" can deliver sediment to a watercourse then it is classified as "high landslide risk – delivery to stream". Otherwise it is classified as "high landslide risk – non-delivery to stream". Cells mapped as moderate earthflow land in the NZLRI were assigned to "moderate earthflow risk", whereas cells in severe earthflow land were assigned to "severe earthflow risk". Cells occurring in gully land were assigned to "gully risk".

Table 4 The (A) TANK, (B) Porangahau, and (C) the Southern Coast erosion terrains,, and their slope thresholds (°) above which land is at risk of landsliding if there is no protective woody vegetation (modified from Dymond et al. 2008)

Catchment			Erosion terrain	Description	Slope threshold (°)
				Active flood plains	
A	B	C	1.1.1	Undifferentiated alluvium from modern overbank depositional events. Parts may be peaty. Includes non-peaty wetlands	90
				Sand Country	
	B	C	2.1.1	Recent fresh dune sand	90
				Peatland	
A			3.1.1	Organic soils on deep peat	90
				Terraces, low fans, laharic aprons (most slopes <8°)	
A	B	C	4.1.1	Loess	90
A			4.1.2	Young tephra, mostly pumiceous (Waimihia and younger)	90
A			4.1.3	Basins infilled with Taupo tephra flow deposits - intensely gullied	90
A	B	C	4.3.1	Gravelly soils on alluvial terrace gravels or on gravelly laharic aprons-above the level of modern flood plains	90
				Downland (most slopes 8–15°)	
A	B	C	5.1.1	Loess	90
A			5.1.2	Young tephra (Waimihia and younger), over older tephra	90
A		C	5.1.3	Mid-aged (late Pleistocene/early Holocene) tephra, older tephra, or tephric loess	90
A	B		5.3.1	Weathered sedimentary and non-tephric igneous rocks	90
				Hill country (most slopes 16–25°)	
A		C	6.1.1	Loess	26
A			6.1.2	Young tephra (Waimihia and younger), usually over older tephra - shallow (0.3 - 1.0 m)	26
A	B	C	6.3.1	Weak to very weak Tertiary-aged mudstone	24
	B	C	6.3.2	Crushed Tertiary-aged mudstone, sandstone; argillite, or ancient volcanic rock with moderate earthflow	90
A	B	C	6.3.3	Crushed mudstone or argillite with severe earthflow-dominated erosion	24
A	B	C	6.4.1	Cohesive, generally weak to moderately strong Tertiary-aged sandstone	28
A	B	C	6.5.1	Limestone	90
A	B		6.6.1	Unweathered to moderately weathered greywacke/argilite	28
	B		6.6.2	Unweathered to slightly weathered white argillite	90
				Hilly steeplands (most slopes >25°)	
A	B	C	7.3.1	Weak to very weak Tertiary-aged mudstone	24
A	B	C	7.4.1	Cohesive, generally weak to moderately strong Tertiary-aged sandstone	28
A	B	C	7.5.1	Limestone	90
A			7.6.1	Unweathered to moderately weathered greywacke/argillite	28
	B		7.6.2	Unweathered to slightly weathered white argillite	26
				Upland plains and plateaux	
A			8.1.1	Upland plains and plateaux with tephra covers	90
				Mountain steeplands	
A			9.1.1	Greywacke/argillite or younger sedimentary rocks of the main ranges prone to landslide erosion	45
A			9.1.2	Greywacke/argillite or younger sedimentary rocks of the main ranges prone to sheet/wind/scree erosion	45

Note: A slope threshold of 90° is considered a stable landscape, i.e. no landslide erosion.

All HEL was examined to determine if protective woody vegetation was present using LCDB4, with imagery representing the 2012–2013 period. If woody vegetation was present, then land was labelled as "woody vegetation". In other words, land is not highly erodible when there is protective woody vegetation. The Highly Erodible Land algorithm produces 5 categories of highly erodible land:

- High landslide risk – delivery to stream
- High landslide risk – non-delivery to stream
- Moderate earthflow risk
- Severe earthflow risk
- Gully risk

4.2 Particle size analysis

Improving the water clarity of the rivers and tributaries from the TANK, South Coast, and the Porangahau catchments may require targeting land areas that produce the finest-grain size sediments, rather than those areas that produce a higher load of coarser particle sizes. In an attempt to identify these areas we extracted information on soil particle size class (*PS* field) from the Fundamental Soil Layers (FSL) (Newsome et al. 2000). This provides an estimate of the dominant particle size class of the soil profile to c. 1 m. To simplify the map we amalgamated the *PS* classes clayey, loamy over clayey, and silty over clayey into clay-dominant particle sizes; loamy, loamy over sandy, silty, and silty over sandy into silt-dominant particle sizes; and sandy and sandy over silty into sand-dominant particle sizes. This amalgamation distinguishes soils dominated by clay size particles from those dominated by silt and sand-size particles. The rationale for this analysis was to overlay risk of erosion identified from the highly erodible land (HEL) model onto particle size with the view to highlighting subcatchments with not only high risk of erosion, but also with finer particle size characteristics of the TANK, South Coast, and the Porangahau catchments and their tributaries.

4.3 The SedNetNZ model description

SedNet is a spatially distributed, time-averaged (decadal to century) model that routes sediment through the river network, based on a relatively simple physical representation of hillslope and channel processes at the reach scale, accounting for losses in water bodies (reservoirs, lakes) and deposition on floodplains and in the channel. The basic element in this model is the stream link (Fig. 2). Each link has an internal catchment area (stream link) that drains overland flow and delivers sediment to that link.

The main outputs from the model are predictions of mean annual suspended sediment loads in each stream link, throughout the tributary network. Because source erosion is spatially linked to sediment loads, it is also possible to examine the proportionate contribution that specific areas of land make to downstream export of sediment. By adjusting input data and model parameters it is possible to simulate river loads for natural conditions (pre-European) and examine the consequences of future land use scenarios. If discharge-sediment concentration flow rating curves are known, then mean annual suspended sediment concentrations for indicative discharge events can be back-calculated from predicted loads.

SedNetNZ has three main components – (1) an erosion submodel, (2) a hydrological submodel, and (3) a sediment-routing submodel – each submodel having its own model algorithms. SedNetNZ is a relatively straightforward model to execute and run; however, data preparation and getting the data into the required format before running the model can be time consuming. A brief description of the model development and parameterisation for the calculation of stream bank erosion follows.

4.3.1 The river and stream link network and sediment budget

To be consistent between spatial datasets the SedNetNZ stream link network for the TANK, South Coast, and the Porangahau catchments used the River Environment Classification (REC) version 2. The catchment boundaries of TANK, South Coast, and Porangahau were derived based on REC-2 subcatchments to maintain connectivity between stream links (see Fig. 2). The boundaries of the study areas, particularly along the coastline, are therefore not perfectly congruous with the subcatchments provided by HBRC as displayed in Fig. 1. This has to do with the minimum catchment area (1 km^2) required for REC-2 stream initiation. All results related to the highly erodible land, SedNetNZ, and particle size data are based on the REC-2 derived catchment area. However, the results are also aggregated to subcatchments provided by HBRC in Tables 5, 7 and 8.

Sediment budgets were constructed for each individual stream link in a river with each stream link connecting tributary junctions that have a subcatchment draining directly into them. This resulted in TANK, South Coast, and Porangahau having 7656, 1108, and 1988 stream links, respectively, and the same number of corresponding sediment budgets. The sediment sources to each stream link are surficial erosion (i.e. sheet and rill erosion limited to the top 50 cm of soil), gully erosion (i.e. large gully erosion – Herzig et al. (2011)), landslide erosion, and earthflow erosion, from the hills, and riverbank erosion along the stream link. The stream link has a sink of sediment if it has a floodplain in the directly-draining stream link. The sediment load at the downstream end of the link is the sum of these sources with the load of the input tributaries minus the floodplain deposition, and this provides the sediment input to the next downstream link. The sediment budget was reduced by 85% at major lakes where sediment was likely to be trapped. These budgets represent mean annual fluxes of soil, or sediment, in tonnes per year ($t\ a^{-1}$).

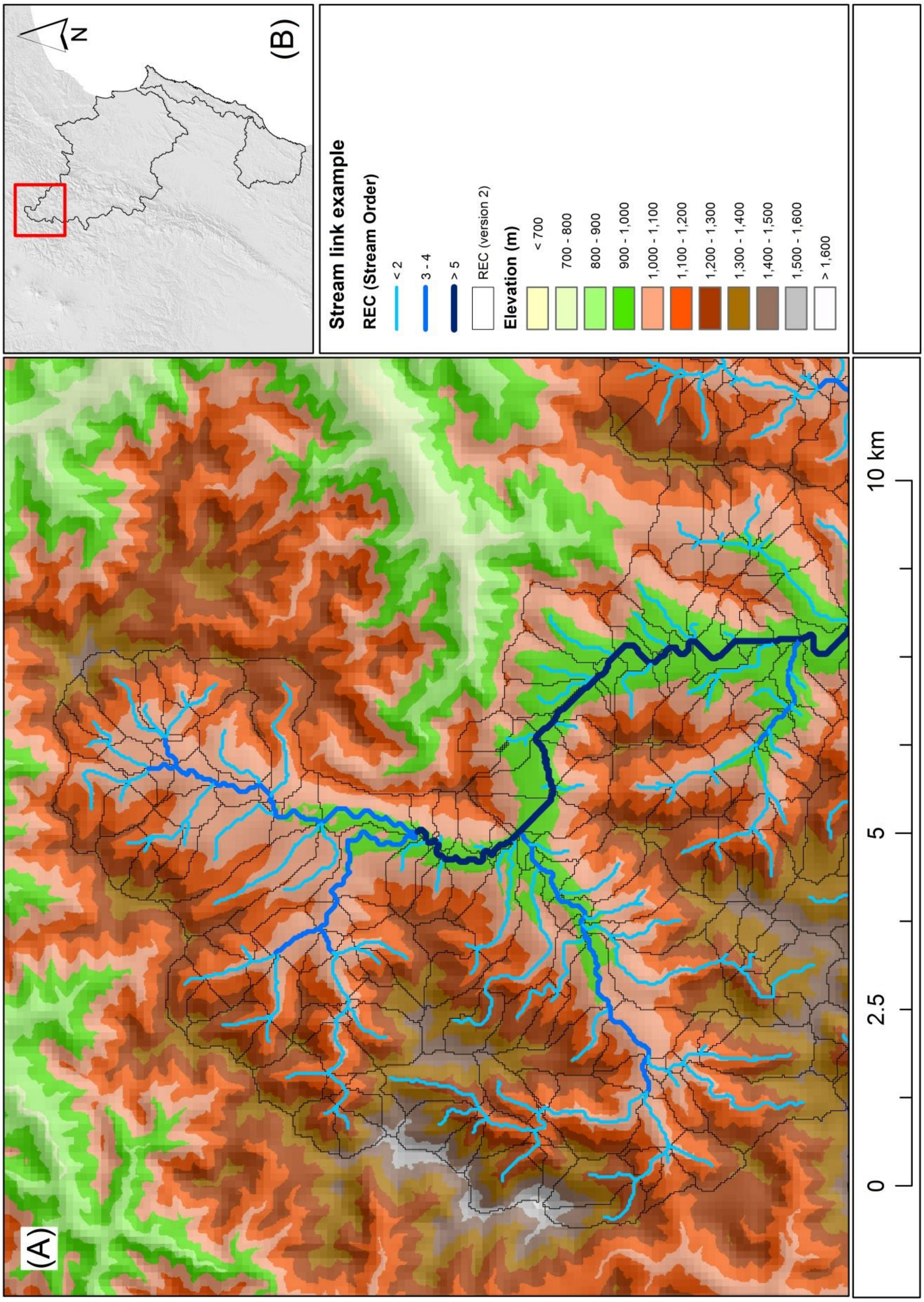

Figure 2 View of (A) River Environment Classification (REC) stream orders, stream links, and elevation for (B) a selected example location within the TANK catchment. The red box in the upper right hand insert indicates example location (main graphic) in the TANK catchment.

4.3.2 Landslide erosion

In New Zealand hill country shallow landslides are considered the most common form of erosion (Eyles, 1983). Typically, these failures are seldom greater than 2 m depth, and individually are of small areal extent (50–500 m^2). They usually have a debris tail of deposited sediment below their source that often reaches a stream (about half the time – Dymond et al. (1999)). Landslide occurrence is considered highly correlated with slope angle, with most failures occurring above 26 degrees, but landslides can occur on slopes as low as 15 degrees (De Rose 2013). The expected mass of soil lost per square kilometre, in a year, due to landslide erosion, and the connection with a stream, is given by *LE*.) by

$$\mathrm{LE} = \rho\ SDR\ d_l\ f(s)$$

where
ρ is the bulk density of soil (t m^{-3}),
SDR is the sediment delivery ratio,
d_l is the mean depth of landslide failure (m), and
f(s) is the expected area of landslide scars per km per year at slope angle s (m^2 km^{-2} a^{-1}).

Landslide erosion is estimated in those erosion terrains identified as being susceptible to landslide erosion.

SDR is set to 0.50 for hill country and 0.1 for mountainous areas (from consideration of published data). d_l is set to 1m (from published data). *f(s)* is determined from analysis of historical aerial photographs where the average proportion of eroded bare ground is determined for different slope classes (Dymond et al., 2016).

4.3.3 Earthflow erosion

Slow moving earthflows (~ 1 m per year) are common in erosion terrains underlain by crushed mudstone and argillite lithologies (Dymond et al. 2010). The delivery of sediment to streams is through the undercutting of the earthflow toe. The mass of soil delivered to streams by earthflows in t km^{-2} a^{-1} is denoted by *EE* and is estimated as

$$EE = \rho\ d_e\ v\ ED$$

where
ρ is the bulk density of soil (t m^{-3}),
d_e is the mean depth of earthflows,
v is the mean speed of earthflows (m a^{-1}), and
ED is the mean length of stream touching earthflow toes in a square kilometre (m km^{-2}).

d_e is set to 3 m (through field observation). v is set to 0.1 m a^{-1} (from published data). *ED* is set to 1000 m km^{-2} (from digitising stream lengths on digitised aerial photographs – Dymond et al., 2016).

4.3.4 Gully erosion

A gully initiates at a channel head usually formed by water flow. Once initiated they can continue to grow over long time periods (~ decades) and attain large proportions (~ 200 m × 50 m). The mass of soil delivered to streams by gullies in t km^{-2} a^{-1} is denoted by *EG* and is estimated by

$$EG = \frac{\rho\ A_g\ GD}{T}$$

where
ρ is the bulk density of soil (t m^{-3}),
A_g is the mean cross sectional area of gullies (m^2),
GD is the length of gullies in a square kilometre (m km^{-2}), and
T is the time since gully initiation (a).

A_g is set to 900 m^2 (from field observations). GD is set to 220 m (from digitising gully lengths on digitised aerial photographs).

4.3.5 Surficial erosion

Surficial erosion comes from sheetwash, rill, and inter-rill processes. The NZUSLE model (Dymond 2010) is used to estimate surficial erosion, in t km^2 a^{-1}. Surficial erosion is given as ES and is estimated by

$$ES = a\ P^2\ K\ (\frac{L}{22})^{0.5}\ F_s\ C$$

where
a is a constant,
P is mean annual rainfall (mm),
K is a soil erodibility factor (=0.25 for loam soil),
L is slope length (m),
F_s is a slope factor given by $0.065 + 4.56\ \mathrm{s} + 65.41\ \mathrm{s}^2$ where s is slope gradient, and
C is a vegetation cover factor (1.0 for bare ground, .01 for pasture, 0.005 for forest).

4.3.6 Bank erosion

The mass of soil eroded by bank erosion in a stream segment is estimated from the product of the bank migration rate, bank height, and stream segment length. Bank erosion is given as B_j and is estimated from

$$B_j = \rho\ M_j\ H_j\ L_j$$

where
B_j is the total mass of soil eroded by bank erosion in the *j*th stream segment, in t a^{-1},
ρ is the bulk density of soil, in t m^{-3},
M_j is the bank migration rate of the *j*th stream segment, in m a^{-1},
H_j is the mean bank height of the *j*th stream segment, in m, and
L_j is the length of the *j*th stream segment, in m.

More specifically, the volumetric rate of erosion per unit channel length (m^3 m^{-1} a^{-1}) is given by the product of $M \times H$, where *H* is bank height, and *M* is the bank migration rate in m a^{-1}. For conversion of volume erosion to mass erosion we assume a bulk density of unity. A preliminary dataset of bank migration rate in (m a^{-1}) on 26 New Zealand river reaches has been compiled and these are positively correlated with the Water Resources Explorer New Zealand (WRENZ) (NIWA, 2007) modelled annual flood discharge (Fig. 3). The exponent in the regression model ($x^{0.469}$) is within the range of reported values elsewhere.

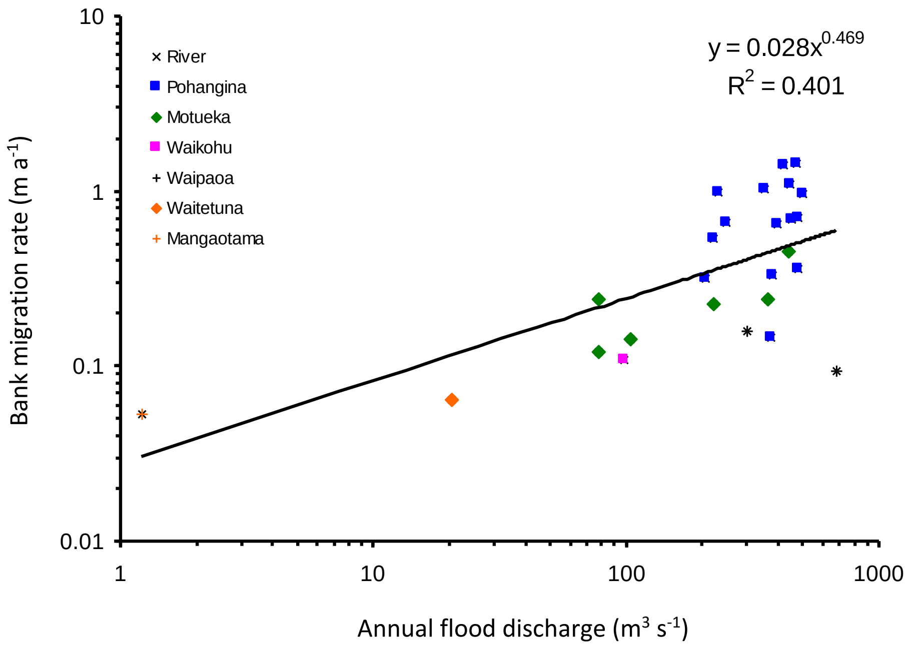

Figure 3 Average channel migration in relation to mean annual flood discharge (WRENZ-modelled) for New Zealand rivers.

The stream bank migration (B_m) was calculated using the equation:

$$B_m = 0.028\ F^{0.469} \quad (2)$$

Where F is the mean annual flood.

The mean annual flood for each gauged subcatchment (Q_f) in the catchments was related to the measured mean discharge ($\bar{q}$) using:

$$Q_f = 30\bar{q} \quad (3)$$

The mean discharge for each of the stream links in the SedNetNZ model was determined by first estimating the mean runoff in mm (estimated from the national Watyield model) and then multiplying by stream link area to determine the volume of runoff in a year. The SedNet accumulation routine was run to calculate the total mean discharge down the stream network. The mean annual flood was then estimated using Equation (3) for each stream link using a relationship derived for the Tukituki catchment (Fig. 4).

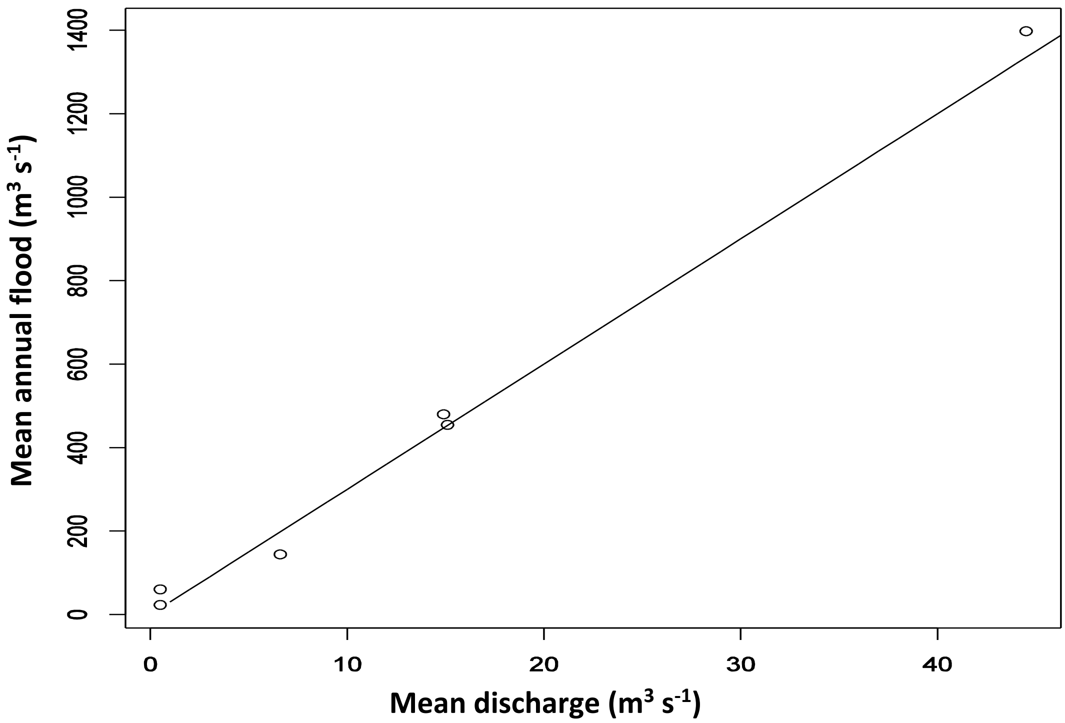

Figure 4 Relationship between mean annual flood and mean discharge for the main tributaries of the Tukituki River. Data from Waipawa at RDS/SH2, Porangahau at Oruawhara Rd, Mangatarata at Farm Road, Tukituki at Tapairu and Red Bridge, and Makaroro at Burnt Bridge.

The bank migration rate for each subcatchment was estimated using the relationship between the mean annual flood and bank migration rate shown in Figure 3. Currently the riparian vegetation is assumed to be primarily grass.

The mass of soil eroded by bank erosion also relies on estimating bank heights (*H*) across the catchment tributaries. Although numerous long-term cross-sections of streams and rivers are available for this region, the majority of these surveys relate to lower river branches of higher stream order and are therefore of limited use in modelling bank height. The second issue is that information needed to develop a robust bank height model is not available for the upper reaches of these catchments (e.g. fine resolution DEM). Because fine resolution LiDAR or derived Digital Elevation Model (DEM) data is not available for the development of bank height relationships in the upper tributaries, we have developed methodologies using the Ruamahanga catchment as a proxy (as it also has greywacke ranges in the west and soft-rock hill country in the east). The success of this proxy for the Porangahau and South Coast catchments, which don't have greywacke ranges, should be checked in future with field work.

High resolution LiDAR coverage is available for the Greater Wellington region and the Ruamahanga catchment. To be representative of the modelled catchments, seven subcatchments draining from the soft rock hill country in the east of the Ruamahanga, along with another seven subcatchments draining from greywacke country to the west were selected. ArcGIS was used to view the LiDAR data and its shaded relief, and the stream discharge layer. Using these datasets, a sample point was placed in the stream-river channel, and a second paired point placed on the adjacent stream bank, providing a total of 300 observations. These data were converted to a shapefile and the elevations extracted for these sites. Height differences were calculated and stream discharge values extracted for the stream-river observations. These data were converted to a spreadsheet where multivariate analysis using linear regression of the two study sites was undertaken. Observations were used to develop the relationship between bank height and mean discharge. As a result, the bank height was estimated using the relationship where Log10*H* = 0.3 + 0.2Log10(discharge) (R^2 0.27) (Fig. 5).

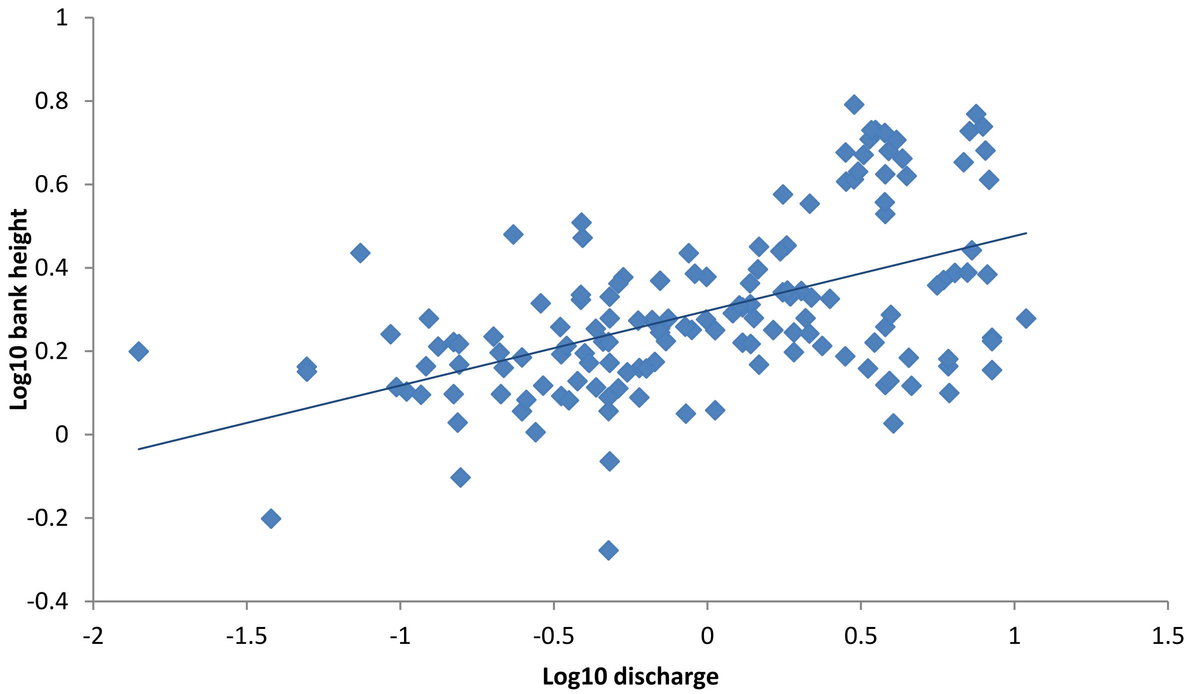

Figure 5 Relationship between discharge and bank height for the Ruamahanga catchment.

The final bank erosion as a total for each stream link was derived from the product of bank migration rate, bank height, and stream length.

4.3.7 Floodplain deposition

The mass of sediment deposited on floodplains adjacent to the major tributaries is estimated as a proportion of total sediment load in the tributary. The proportion is determined by examining historical measurements of water discharge and sediment discharge and estimating the proportion of sediment discharge occurring above bankfull discharge (i.e. 1.5 times mean annual discharge). The mass of sediment deposited on floodplains is spread evenly around tributary floodplains.

$$F_i = p_i \, SY_i / A_i$$

where

F_i is the floodplain deposition in t km^{-2} a^{-1},

p_i is the proportion of sediment load deposited on floodplains,

SY_i is the sediment load of the ith tributary in t a^{-1}, and

A_i is the area of flood plains in the ith tributary (as determined from erosion terrains).

4.4 Scenario modelling and mitigation strategies for bank erosion

A riparian study of the TANK catchment was undertaken by the HBRC that provided information on vegetation and stock disturbance class for River Environment Classification (REC) stream orders 2–4. We selected the 'excellent' class from the riparian class field and used this to define where fencing and stock exclusion occurred as the baseline for the bank erosion scenarios. For TANK the actual location of fencing was used to calculate current bank erosion rates. However, for South Coast and Porangahau catchments because the actual location of fencing was not known it was assumed that a similar proportion of all stream links in the catchment (23.8%) were fenced.

Using these data, we assumed that excluding stock from riparian margins will allow woody vegetation to fully colonise the banks and reduce the magnitude of bank erosion by up to 80% (Wilkinson et al. 2004). Using modelled SedNetNZ net bank erosion sediment load, an analysis was undertaken to estimate current stream bank erosion incorporating the effect of the 'excellent' riparian class (as the baseline), and adding a further 25%, 50%, and 100% additional fencing of both sides of streams and rivers. This was calculated using a vegetation factor for each stream segment that is multiplied by the bank erosion sediment load to calculate the final bank erosion rate for the segment. The vegetation factor E_b is given by

$$E_b = (1–0.8*P_f)$$

where P_f is the fraction (i.e. percentage/100) of stream bank fenced. The 0.8 value is a conservative value for the reduction in stream bank erosion set in the Australian SedNet model (Wilkinson et al. 2004) at 0.9.

4.5 Scenario modelling using SedNetNZ for farms identified with the greatest areas of HEL

Further analysis was undertaken to investigate the potential reduction in sediment using SedNetNZ for farms identified with the greatest area of HEL. AgriBase 2015 was used to define farm boundaries. In this analysis land owned by the Department of Conservation, schools and district and city councils, and land with no farm ID was removed from the Agribase-defined farm polygons. Using raster-based zonal means, statistics were calculated for SedNetNZ sediment load for each AgriBase farm type polygon identified across the TANK, Coastal Hawke's Bay, and the Porangahau catchments. Only hillslope processes (landslide, earthflow, gully and surficial erosion) were included in the analysis since these are the relevant processes for on-farm mitigation of soil erosion. The distribution of HEL and SedNetNZ sediment loads were attached to the original AgriBase geodatabase unique identifier to enable sorting of farm polygons with the greatest area of HEL. We assumed that if a farm plan was put in place a potential sediment reduction of 70% was possible (Dymond et al. 2016). This approach allows the identification of farms with the most highly erodible land and the calculation of sediment reduction (SedNetNZ sediment loss prevented) should a farm plan be applied, providing a mitigation planning tool for HBRC.

5 Results and Discussion

5.1 Highly Erodible Land (HEL) model

The HEL model was masked to the TANK, South Coast, and Porangahau, catchment boundaries derived from REC-2. This HEL model utilises woody vegetation from the most modern available coverage of LCDB4. The TANK catchment has 1.8% HEL the South Coast 23%, and Porangahau 29%. The HEL model for the TANK (Fig. 6) identified 3995 ha (1.1%) of land at risk of landsliding with potential of delivery to streams, and a further 1478 ha (0.4%) classed as not contributing to streams (see Table 5). Land with a severe earthflow risk (811 ha, 1.4%) occurs mostly in the middle section of the TANK catchment just east of the forested uplands.

The HEL model for the South Coast catchments (Fig. 6) identified 2662 ha (5.6%) of land at risk of landsliding with potential of delivery to streams, and a further 1168 ha (2.5%) classed as not contributing to streams (see Table 5). Land with moderate (3205 ha, 6.7%) and severe earthflow risk (3769 ha, 7.9%) occurs mostly in the mid-southern region of the South Coast catchments.

The HEL for the Porangahau catchment (Fig. 6) identified 1248 ha (1.4%) of land at risk of landsliding with potential of delivery to streams, and a further 350 ha (0.4%) classed as not contributing to streams (see Table 5). Land with moderate (19 315 ha, 22%) and severe earthflow risk (4798 ha, 5.5%) is relatively high, occurring predominately in the western and eastern regions of the Porangahau catchment.

It is worth noting that in the HEL model woody vegetation provides protection from erosion and, if cleared, the land is at increased erosion risk. In contrast to the overview illustrated in Figure 6, of the distribution of HEL in the TANK, South Coast, and Porangahau catchments, Figure 7 illustrates its distribution for a selected area of TANK.

For the TANK catchment, the largest areas of erosion risk identified by HEL are high landslide risk – delivery to stream, followed by landslides with non-delivery to streams, 1.1% and 0.4%, respectively. The largest percentages of area erosion identified by HEL as having a high risk of erosion are the Mangatahi (9.3%), Mangaone (4.3%), Mangatutu (4.0%), Tutaekuri Corridor (3.9%), Poporangi (3.4%), Waikonini (3.1%), and Ahuriri Lagoon tributaries (3%). , All remaining subcatchments have <2% HEL (Table 5, Fig. 1).. Although TANK subcatchments have relatively low HEL percentages compared with the South Coast and Porangahau, standout areas of high landslide risk – delivery to stream are the Mangaone, Mangatutu, Waikonini, Poporangi, and Mangatahi subcatchments, with 3.5%, 3.2%, 2.7%, 2.3% and 2.1%, respectively. The Mangatahi subcatchment also has a higher portion of severe earthflow risk at 9.3% (Table 5).

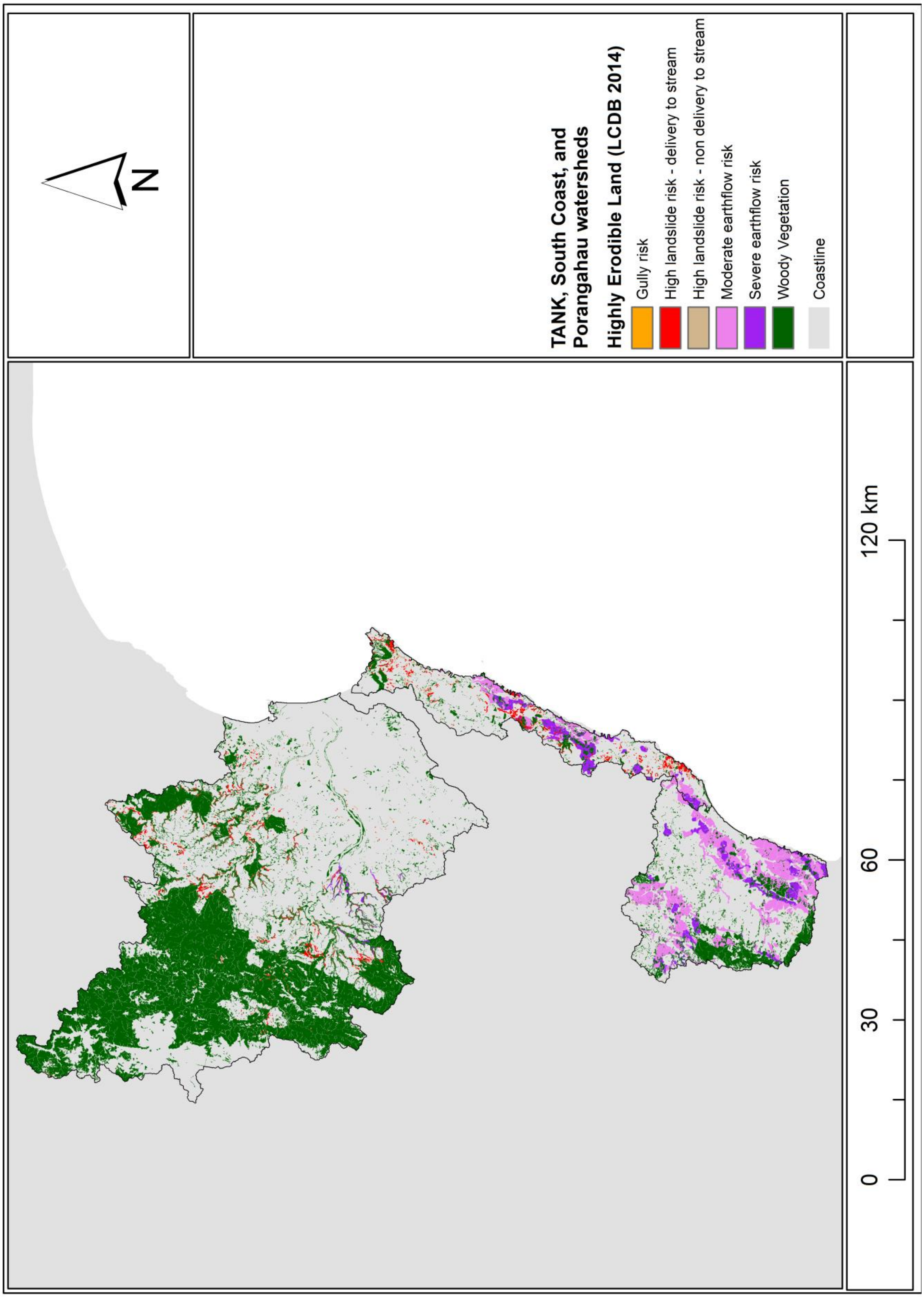

Figure 6 Distribution of Highly Erodible Landin the TANK, South Coast, and Porangahau catchments (using LCDB4). Grey area is land not classified as HEL.

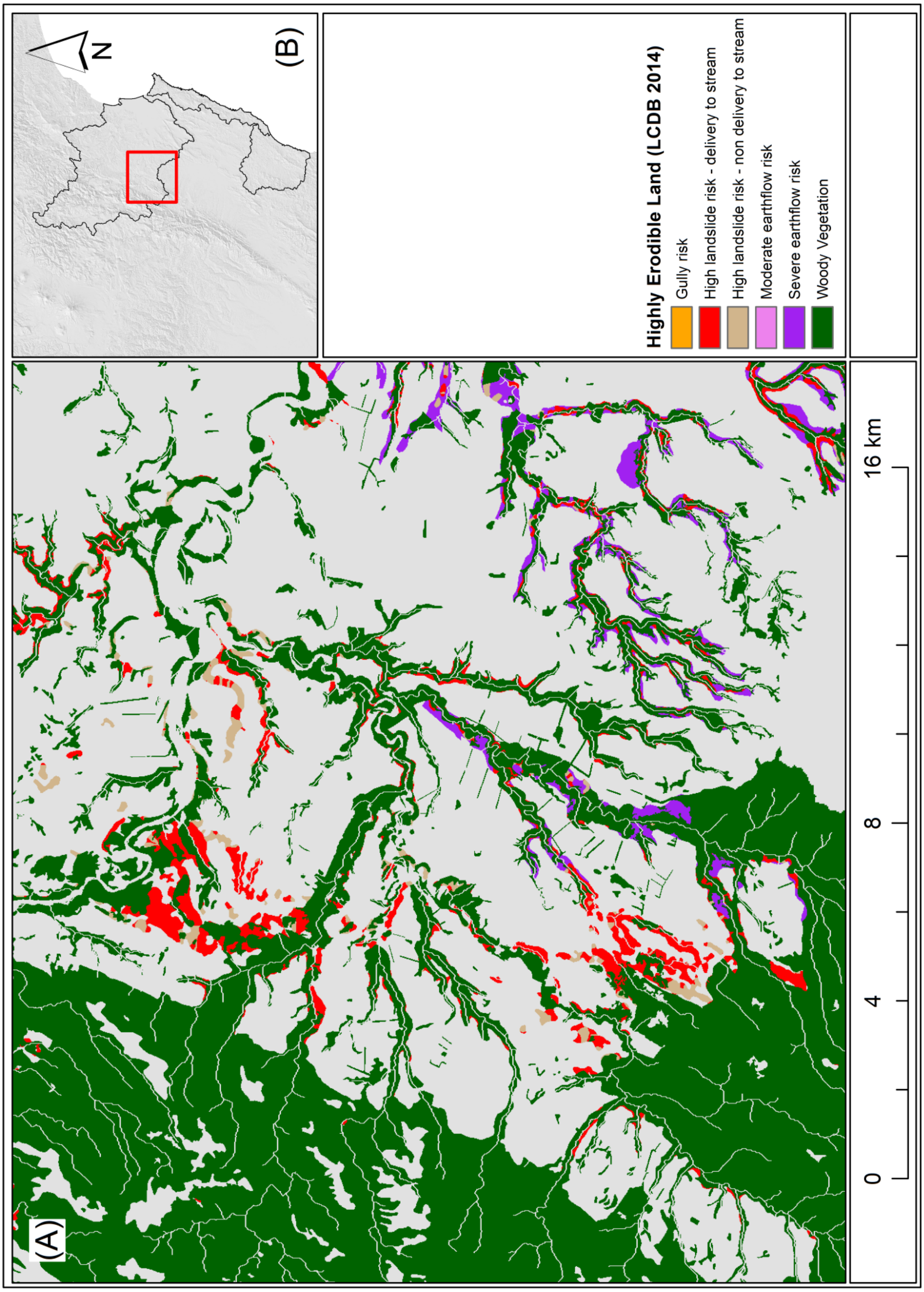

Figure 7 A close up view of the highly erodible land (A) and its location within part of the TANK catchment (B). Grey area is land not classified as HEL.

The South Coast catchment has a considerable area of HEL erosion identified at risk (23%). The largest category of erosion risk identified by HEL was severe earthflow, followed by moderate earthflow and high landslide – delivery to streams with 7.9%, 6.7%, and 5.6%, respectively. For the South Coast, the subcatchments identified as having the greatest percentage HEL erosion were the Waimarama Coast (64%), Kidnapper 2 (50.2%), Mangakuri Coast (47.4%), Waikaraka (45.4%), Te Apiti (45.1%), Taikura Area Stream (44.3%), Blackhead (43.3%), and Blackhead Coast (41.8%) (Table 5, Fig. 1). Significant areas of HEL erosion also occur in the Mangakuri (38.3%), Puhokio (29.3%), Ocean Beach (20.3%), Pourere (18.9%), Oepoto (17.5%), Kairakau North Stream (16.9%), Kidnapper 1 (11.1%) and Cape Kidnappers Coast (10.4%) subcatchments. In the South Coast subcatchments HEL severe earthflow risk is high for the Mangakuri Coast (41.6%), Taikura Area Stream (26.5%), Te Apiti (23.9%), and Mangakuri (19.5%) subcatchment. South Coast subcatchments identified with HEL high landslide risk with potential delivery to stream were Kidnapper 2 (40.3%), Blackhead Coast (31.7%), Te Apiti (19.5%), Blackhead (19.0%), Kairakau North Stream (13.2%), Waimarama Coast (12.8%), and Oeopoto (10.2%).

The Poranaghau catchment has relatively large area of HEL with 29% of its area at risk. The largest areas of erosion risk identified by HEL were moderate and severe earthflow, with 22% and 5.5% respectively. The Porangahau subcatchments with the highest risk of HEL erosion were Porangahau Coast (68.4%), the Lower Porangahau (56.7%), Turaekaitai (23.7%), and Mangwhero (23.0%). HEL identifies the Porangahau Coast and Mangwhero subcatchments as having significant severe earthflow risk and all subcatchments as having moderate earthflow risk.

Earthflow erosion risk is important to consider because these areas are likely to be older landscape features that historically made relatively small contributions to sediment loads, but now post-deforestation make large contributions.

Table 5 Highly Erodible Land and woody vegetation as a percentage of area (%) summed by subcatchments and total (A) TANK, (B) South Coast, and (C) Porangahau, catchment percentages

(A) TANK	High landslide risk (%)		Earthflow risk (%)		Total HEL (%)
	Delivery to stream	Non-delivery to stream	Moderate	Severe	
Ahuriri Lagoon Tributaries	1.6	1.4		0.0	3.0
Awanui	0.0	0.0		0.0	0.0
Hastings Streams	0.0	0.0		0.0	0.0
Havelock North Streams	0.0	0.0		0.0	0.0
Irongate-Southland	0.0	0.5		0.0	0.5
Karamu-Clive Corridor	0.0	0.0		0.0	0.0
Kikowhero	0.1	0.0		0.0	0.1
Louisa	0.0	0.0		0.0	0.0
Mangaone	3.5	0.8		0.0	4.3
Mangatahi	2.1	0.5		6.7	9.3
Mangateretere	0.0	0.0		0.0	0.0
Mangatutu	3.2	0.7		0.0	4.0
Maraekakaho	0.6	0.1		1.3	2.0
Muddy Creek	0.0	0.0		0.0	0.0
Napier Drains	0.0	0.0		0.0	0.0
Napier South	0.0	0.0		0.0	0.0
Ngaruroro Corridor	1.7	1.2		0.0	2.9
Ohiwia	1.1	0.2		0.0	1.3
Omahaki	1.2	0.6		0.0	1.8
Otakarara	1.1	0.0		0.0	1.1
Otamauri	1.6	0.2		0.0	1.9
Paritua-Karewarewa	1.0	0.8		0.0	1.7
Poporangi	2.3	0.6		0.5	3.4
Poukawa	0.0	0.0		0.0	0.0
Raupare	0.0	0.0		0.0	0.0
Taipo	0.0	1.7		0.0	1.7
Taruarau	0.3	0.1		0.0	0.4
Tutaekuri Corridor	2.0	1.9		0.0	3.9
Tutaekuri-Waimate	0.1	0.5		0.0	0.5
Upper Ngaruroro	0.2	0.0		0.0	0.2
Upper Tutaekuri	0.6	0.3		0.0	0.8
Waikonini	2.7	0.4		0.0	3.1
Waitio	0.2	0.3		0.0	0.5
Total	1.1	0.4		0.2	1.8

(B) South Coast	High landslide risk (%)		Earthflow risk (%)		Total HEL (%)
	Delivery to stream	Non-delivery to stream	Moderate	Severe	
Blackhead	19.0	10.5	8.6	5.2	43.3
Blackhead Coast	31.7	10.1	0.0	0.1	41.8
Cape Kidnappers Coast	6.1	4.3	0.0	0.0	10.4
Kairakau North Stream	13.2	3.7	0.0	0.0	16.9
Kidnapper 1	8.0	3.1	0.0	0.0	11.1
Kidnapper 2	40.3	9.9	0.0	0.0	50.2
Mangakuri	5.1	1.2	12.4	19.5	38.3
Mangakuri Coast	3.4	0.2	2.2	41.6	47.4
Maraetotara	3.9	2.6	0.0	0.0	6.5
Ocean Beach	3.1	15.4	1.4	0.4	20.3
Oeopoto	10.2	4.1	0.0	3.2	17.5
Parkhill North	0.0	0.0	0.0	0.0	0.0
Parkhill Road Stream	0.0	0.0	0.0	0.0	0.0
Pourerere	4.5	2.1	0.0	12.3	18.9
Puhokio	3.0	1.2	19.9	5.2	29.3
Taikura Area Stream	0.2	0.6	17.0	26.5	44.3
Te Apiti	19.5	1.3	0.4	23.9	45.1
Te Awanga Area Stream	0.0	0.0	0.0	0.0	0.0
Waikaraka	2.5	2.8	27.5	12.7	45.4
Waimarama Coast	12.8	0.9	42.4	7.9	64.0
Waingongoro	0.3	0.3	0.0	0.0	0.7
Waipuka	3.2	1.9	0.1	0.0	5.3
Blackhead	19.0	10.5	8.6	5.2	43.3
Total	5.6	2.5	6.7	7.9	22.7

(C) Porangahau	High landslide risk (%)		Earthflow risk (%)		Total HEL (%)
	Delivery to stream	Non-delivery to stream	Moderate	Severe	
Lower Porangahau	0.6	0.3	45.9	9.9	56.7
Mangangarara	0.1	0.0	11.2	0.0	11.3
Mangaorapa	3.4	0.4	11.1	3.4	18.4
Mangawhero	0.3	0.2	11.7	10.7	23.0
Porangahau Coast	0.6	0.9	40.2	26.7	68.4
Turaekaitai	1.0	0.5	19.0	3.2	23.7
Total	1.4	0.4	22.0	5.5	29.3

The distribution of particle size in approximately the top 1 m in the TANK, South Coast, and Porangahau catchments from the Fundamental Soil Layer are shown in Figure 8. Those areas of HEL identified as being highly susceptible to erosion were intersected with the FSL *PS* field to identify the areas more likely to deliver clay- and silt-size material to the river system. Overall, the TANK catchment has 208 ha of the HEL modelled as a dominant clay-particle-size distribution, while 5667 ha were associated with silt-dominated particle sizes (Tables 6 and 7). For the South Coast catchment 4109 ha of the HEL model has a dominant clay-particle-size distribution, while 6577 ha were associated with silt-dominated particle sizes. Porangahau exhibited 80 ha of the HEL model has a dominant clay-particle-size distribution and 25,512 ha associated with silt-dominated particle sizes.

Table 6 provides the area considered being at risk of landslide, earthflow, and gully erosion based on the HEL model and their associated dominant particle size (note statistics only consider silt and clay areas within HEL). Noteworthy is that the high landslide – delivery to stream class (and non-delivery to stream) is the dominant HEL erosion type for TANK, whereas moderate and severe earthflow are the main HEL erosion types for the South Coast catchment. Moderate earthflow stands out as the main silt contributor for the HEL model across the Porangahau catchment (Table 6).

Table 6 Area of Highly Erodible Land by erosion type and associated dominant particle size across the (A) TANK, (B) South Coast and (C) the Porangahau catchments

(A) TANK HEL erosion	Clayey (ha)	Silty (ha)	Total (ha)
High landslide risk - delivery to stream	146	3513	3659
High landslide risk - non delivery to stream	62	1347	1409
Moderate earthflow risk			
Severe earthflow risk	0	807	807
Total	208	5667	5874

(B) South Coast HEL erosion	Clayey (ha)	Silty (ha)	Total (ha)
High landslide risk - delivery to stream	443	2167	2611
High landslide risk - non delivery to stream	151	1004	1154
Moderate earthflow risk	1884	1291	3175
Severe earthflow risk	1631	2116	3747
Total	4109	6577	10686

(B) Porangahau HEL erosion	Clayey (ha)	Silty (ha)	Total (ha)
High landslide risk - delivery to stream	45	1199	1244
High landslide risk - non delivery to stream	32	315	346
Moderate earthflow risk	2	19,262	19,264
Severe earthflow risk	1	4736	4737
Total	80	25,512	25,591

The analysis of the HEL model (Fig. 6) intersected with the FSL *PS* field (Fig. 8) showed that across the TANK, the Mangaone (1460 ha), Poporangi (786 ha), and Mangatahi (713 ha) subcatchments have the greatest areas of erosion associated with mostly silt and some clay dominated particles sizes (Table 7). Across the South Coast catchment, the Mangakuri (3946 ha), Puhokio (1219 ha), and the Waikaraka (919 ha) subcatchments have the greatest areas of clay and silt dominated particles sizes. For the Porangahau catchment, the Lower Porangahau (9980 ha), Turaekaitai (8522 ha), and the Mangaorapa (4036 ha) subcatchments have the greatest areas of clay and silt dominated particles sizes. Although spatial analysis of dominant particle size provides a picture of which subcatchments are likely to have erosion types associated with finer sediments, it should be remembered that there is no way of assessing prediction certainty related to the original particle size spatial layer. Therefore it is recommended that this assessment be utilised only as a generalised particle size assessment of subcatchment pattern.

Table 7 Area of Highly Erodible Land associated with clay and silt dominant particle size class within (A) TANK, (B) South Coast, and (C) Porangahau subcatchments

Catchment	Subcatchment	Clayey	Silty	Total
(A) TANK	Ahuriri Lagoon Tributaries	-	266	266
	Awanui	1	-	1
	Hastings Stream	-	-	-
	Havelock North Streams	-	-	-
	Irongate-Southland	-	32	32
	Karamu-Clive Corridor	-	-	-
	Kikowhero	-	8	8
	Louisa	-	-	-
	Mangaone	54	1406	1460
	Mangatahi	-	713	713
	Mangateretere	-	-	-
	Mangatutu	-	477	477
	Maraekakaho	-	234	234
	Muddy Creek	-	-	
	Napier Drains	-	-	

	Napier South	-	-	
	Ngaruroro Corridor	3	148	151
	Ohiwia	-	138	138
	Omahaki	-	131	131
	Otakarara	-	53	53
	Otamauri	15	102	117
	Paritua-Karewarewa	114	94	207
	Poporangi	1	785	786
	Poukawa	-	-	-
	Raupare	-	-	-
	Taipo	-	22	22
	Taruarau	-	178	178
	Tutaekuri Corridor	9	507	515
	Tutaekuri-Waimate	-	29	29
	Upper Ngaruroro	-	43	43
	Upper Tutaekuri	-	109	109
	Waikonini	11	169	179
	Waitio	-	25	25
Total		208	5667	5874
(B) South Coast	Blackhead	-	287	287
	Blackhead Coast	-	241	241
	Cape Kidnappers Coast	15	44	59
	Kairakau North Stream	22	34	56
	Kidnapper 1	42	53	96
	Kidnapper 2	2	177	179
	Mangakuri	1790	2156	3946
	Mangakuri Coast	103	22	126
	Maraetotara	112	630	742
	Ocean Beach	48	155	203
	Oeopoto	-	359	359
	Parkhill North	-	-	-
	Parkhill Road Stream	-	-	-
	Pourerere	1	690	691
	Puhokio	1046	172	1219
	Taikura Area Stream	-	290	290
	Te Apiti	450	243	692
	Te Awanga Stream	-	-	-
	Waikaraka	-	919	919
	Waimarama Coast	465	3	468
	Waingongoro	-	17	17
	Waipuka	14	83	97

Total		4109	6577	10686
Porangahau	Lower Porangahau	-	9980	9980
	Mangangarara	-	478	478
	Mangaorapa	49	3987	4036
	Mangawhero	-	1207	1207
	Porangahau Coast	-	1369	1369
	Turaekaitai	31	8491	8522
Total		80	25512	25591

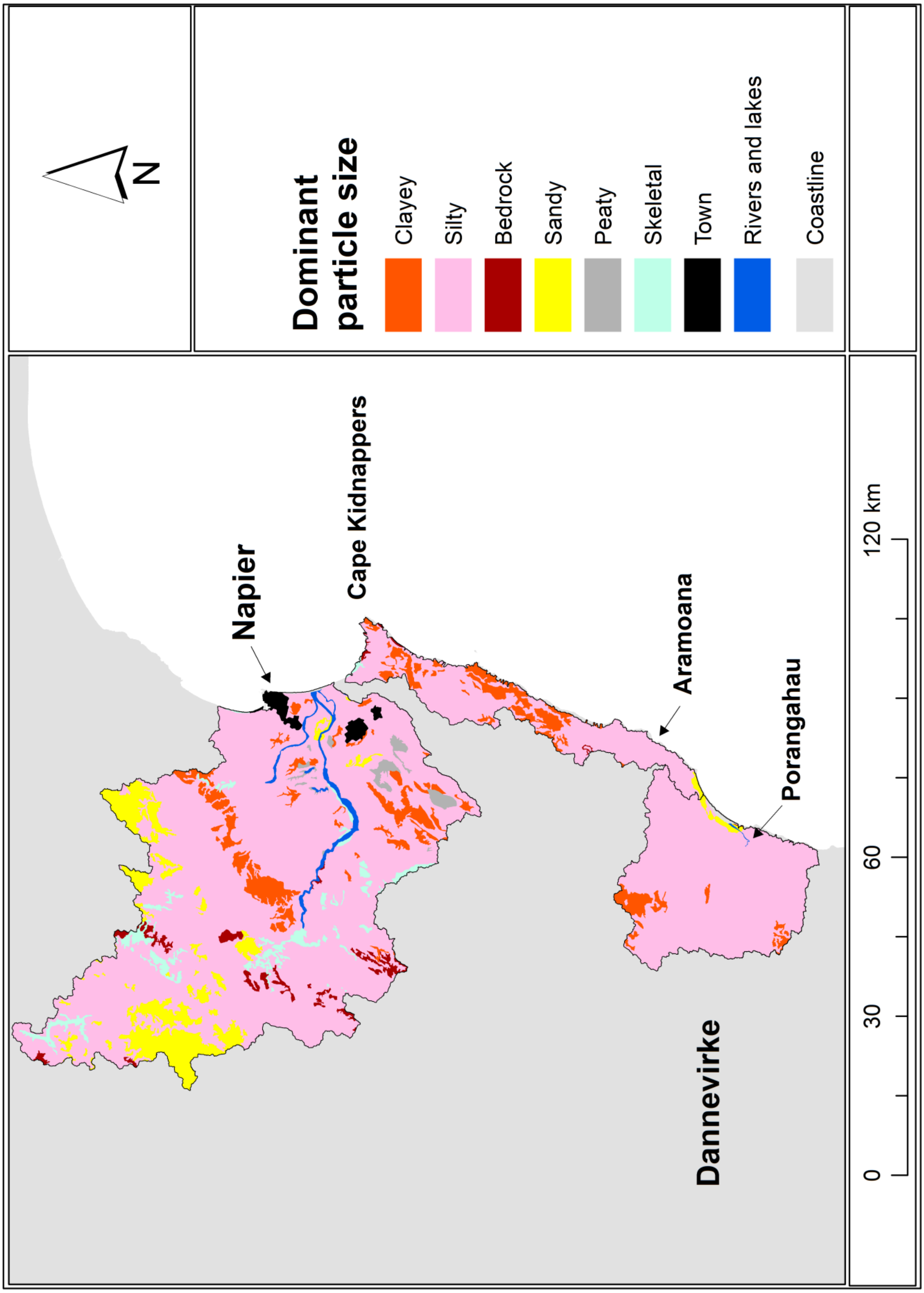

Figure 8 Dominant particle size across the TANK, South Coast, and Porangahau catchments from the FSL.

5.2 SedNetNZ modelling of erosion rates and sediment yield and load

SedNetNZ is a spatially distributed, time-averaged (decadal to century) model that routes sediment through the river network providing a quantitative assessment of sediment load and yield. The process is based on relatively simple physical representation of hillslope and channel processes at the reach scale, accounting for losses in water bodies (reservoirs, lakes) and deposition on floodplains and in the channel. Figure 9 is a map of sediment yield from the SedNetNZ model in t km^{-2} a^{-1}. For the TANK catchment the highest sediment yields of over 1000 t km^{-2} a^{-1} generally occur along the river margins and to the north east. Highest sediment yields for the South Coast catchments occur in its north (towards Cape Kidnappers), and the central to southern areas of the catchment. Highest sediment yieldsfor the Porangahau catchment occur more towards its eastern boundaries. Figure 10 illustrates the spatial distribution of sediment load (t a^{-1}) for each stream link and its contributing REC-2 subcatchment across the TANK, South Coast, and Porangahau catchments using the SedNetNZ model. This provides a spatial pattern that allows visualisation and quantification of the stream links with the greatest sediment load. Overall the stream links with the greatest sediment loads for the TANK catchments are along the river margins, and also the northeast and the far west, but not clearly defined spatially because the load depends both on the sediment yield and catchment area. Highest sediment loads for the South Coast and Porangahau catchments are also not clearly defined spatially, again because it depends both on the sediment yield and catchment area.

To provide a generalised overview of SedNetNZ erosion, sediment load (t a^{-1}) was summed to the TANK, South Coast, and Porangahau subcatchments (Fig. 11). Sediment load at the subcatchment level provides a more general indication of erosion within each subcatchment (Table 8). In the TANK catchment the Upper Ngaruroro, Mangaone, and the Taruarau subcatchments have the highest sediment loads, with 229 620 t a^{-1}, 171 884 t a^{-1}, and 187 585 t a^{-1}, respectively. The Ngaruroro Corridor (80 099 t a^{-1}), Tutaekuri Corridor (71 635 t a^{-1}), Poporangi (67 796 t a^{-1}), Upper Tutaekuri (51 569 t a^{-1}), and the Mangatutu (50 554 t a^{-1}) are also shown to have high sediment loads on a subcatchment basis. Although the South Coast catchment sediment loads are generally low, the Mangakuri, Maraetotara, and to a lesser degree the Pourerere subcatchment have the highest sediment loads, with 81 757 t a^{-1}, 55 932 t a^{-1}, and 32 434 t a^{-1}, respectively (Table 8). The Porangahau catchment has relatively high sediment loads with the Turaekaitai, Mangaorapa, and the Lower Porangahau subcatchments having modelled loads of 193 281 t a^{-1}, 100 418 t a^{-1}, and 82 230 t a^{-1} respectively (Table 8).

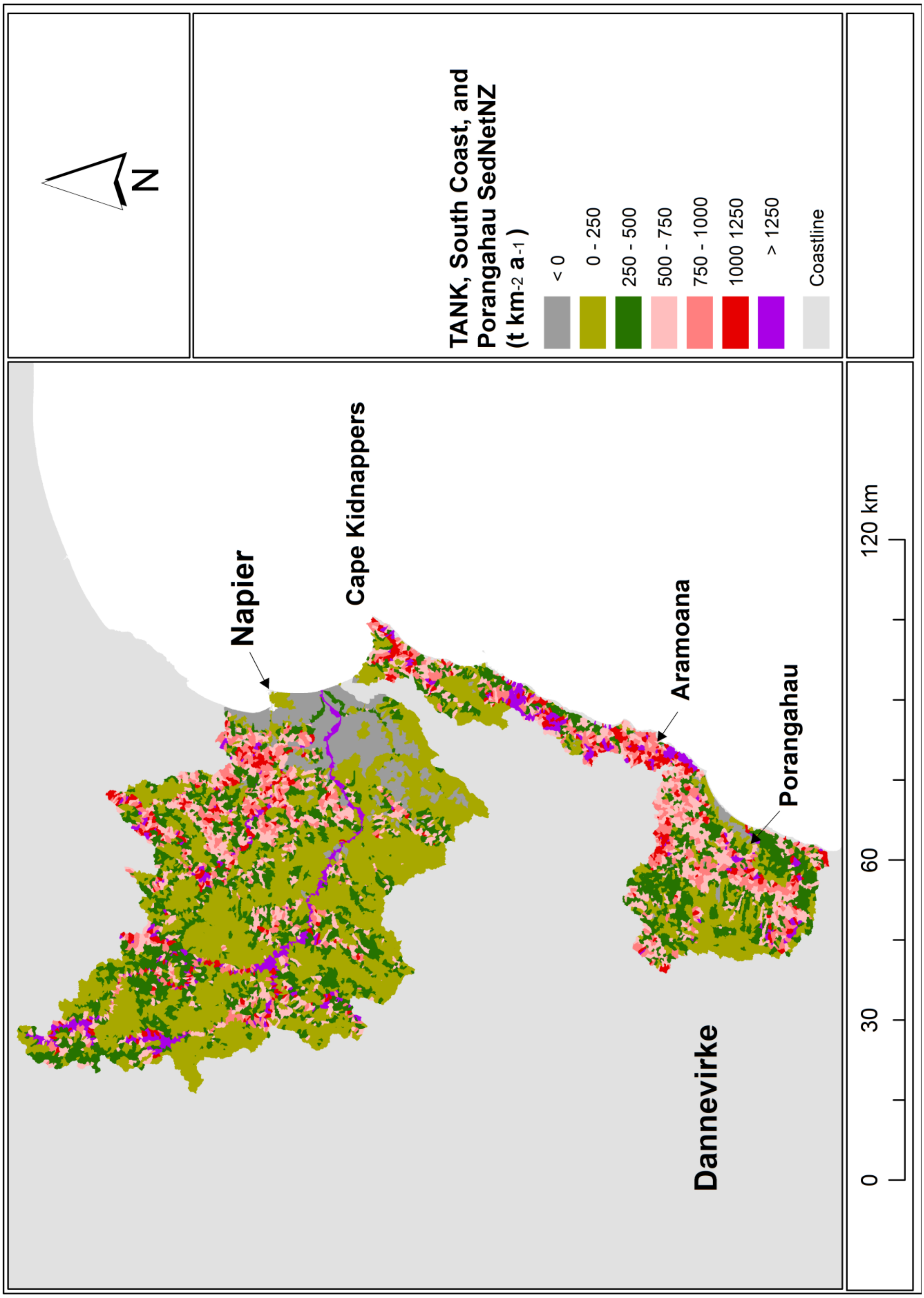

Figure 9 TANK, South Coast, and Porangahau catchments erosion distribution for stream links from SedNetNZ in t km^{-2} a^{-1}.

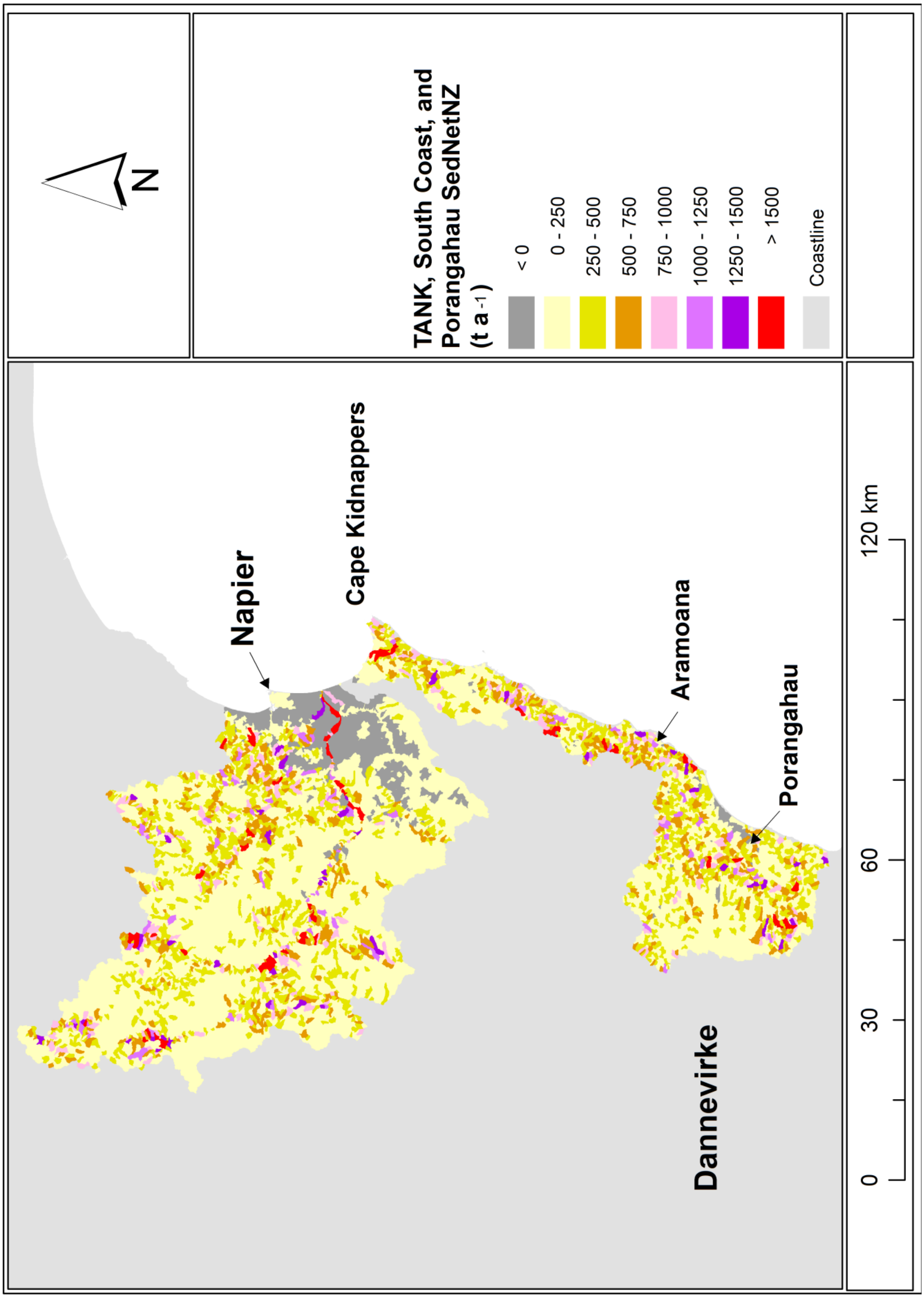

Figure 10 TANK, South Coast, and Porangahau catchments sediment load (t a^{-1}) distribution for each stream link and its contributing REC-2 subcatchment from SedNetNZ.

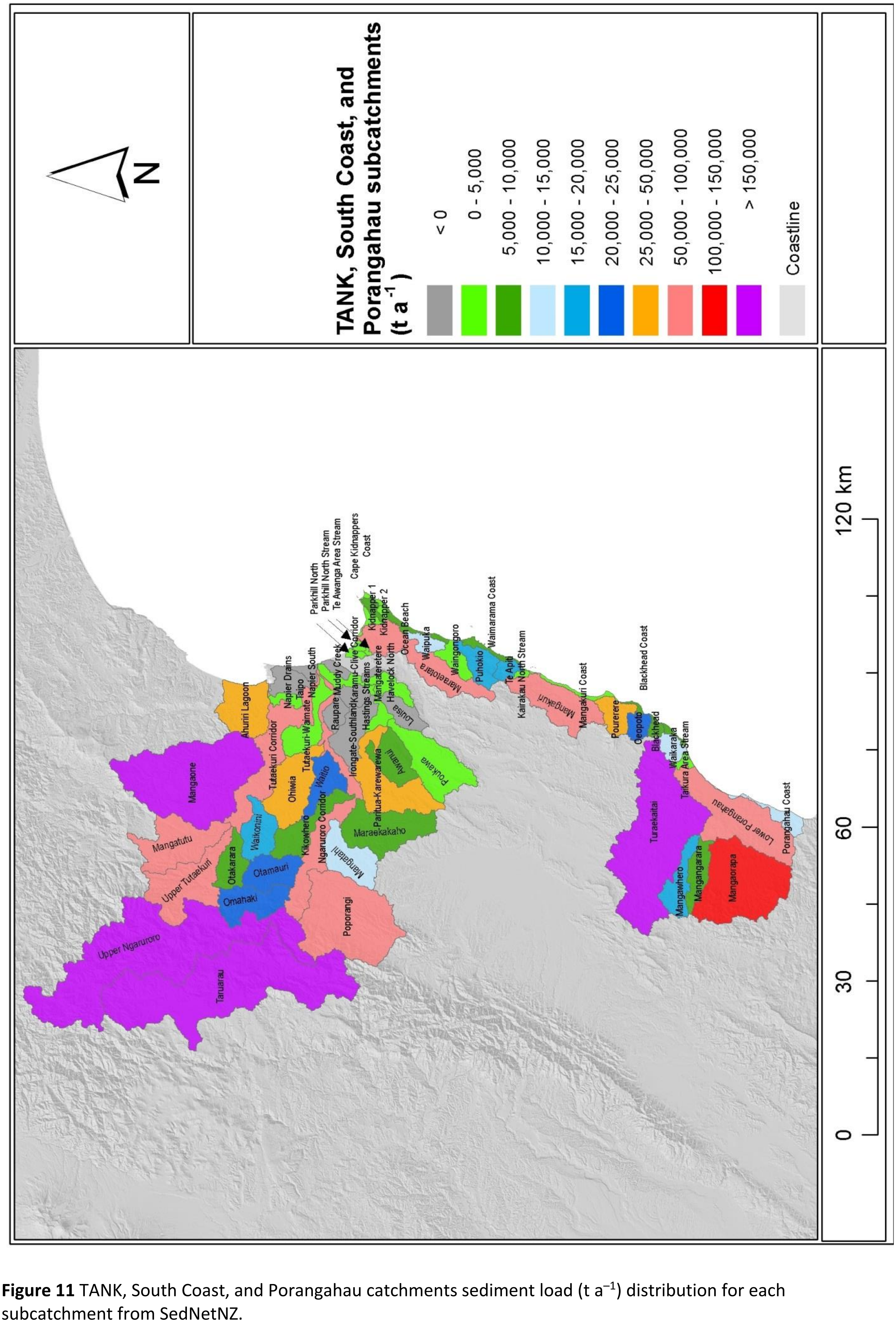

Figure 11 TANK, South Coast, and Porangahau catchments sediment load (t a^{-1}) distribution for each subcatchment from SedNetNZ.

Table 8 TANK, South Coast, and Porangahau catchment and subcatchment sediment loads (summed across REC-2 stream links)

Catchment	Subcatchment	Load (t a^{-1})
TANK (Tutaekuri)	Mangaone	171,884
TANK (Tutaekuri)	Mangatutu	50,554
TANK (Tutaekuri)	Otakarara	9,072
TANK (Tutaekuri)	Tutaekuri Corridor	71,635
TANK (Tutaekuri)	Upper Tutaekuri	51,569
TANK (Tutaekuri)	Waikonini	17,578
TANK (Tutaekuri)	Total	372,292
TANK (Ahuriri)	Ahuriri Lagoon Tributaries	45,379
TANK (Ahuriri)	Napier Drains	-3,436
TANK (Ahuriri)	Napier South	-474
TANK (Ahuriri)	Taipo	4,011
TANK (Ahuriri)	Total	45,480
TANK (Ngaruroro)	Kikowhero	9,824
TANK (Ngaruroro)	Mangatahi	14,855
TANK (Ngaruroro)	Maraekakaho	8,497
TANK (Ngaruroro)	Ngaruroro Corridor	80,099
TANK (Ngaruroro)	Ohiwia	39,114
TANK (Ngaruroro)	Omahaki	21,289
TANK (Ngaruroro)	Otamauri	20,646
TANK (Ngaruroro)	Poporangi	67,796
TANK (Ngaruroro)	Taruarau	187,585
TANK (Ngaruroro)	Tutaekuri-Waimate	632
TANK (Ngaruroro)	Upper Ngaruroro	229,620
TANK (Ngaruroro)	Waitio	24,283
TANK (Ngaruroro)	Total	704,240
TANK (Karamu)	Awanui	5,807
TANK (Karamu)	Hastings Streams	-2,398
TANK (Karamu)	Havelock North Streams	3,328
TANK (Karamu)	Irongate-Southland	-521
TANK (Karamu)	Karamu-Clive Corridor	1,058
TANK (Karamu)	Louisa	-238
TANK (Karamu)	Mangateretere	-148
TANK (Karamu)	Muddy Creek	-1,726
TANK (Karamu)	Paritua-Karewarewa	27,293
TANK (Karamu)	Poukawa	4,748
TANK (Karamu)	Raupare	-4,201
TANK (Karamu)	Total	33,001

TANK	Total	1,155,013
South Coast	Blackhead	8,217
South Coast	Blackhead Coast	7,639
South Coast	Cape Kidnappers Coast	3,384
South Coast	Kairakau North Stream	3,031
South Coast	Kidnapper 1	6,320
South Coast	Kidnapper 2	4,563
South Coast	Mangakuri	81,757
South Coast	Mangakuri Coast	2,490
South Coast	Maraetotara	55,932
South Coast	Ocean Beach	7,334
South Coast	Oeopoto	20,926
South Coast	Parkhill North	13
South Coast	Parkhill Road Stream	49
South Coast	Pourerere	32,434
South Coast	Puhokio	19,248
South Coast	Taikura Area Stream	3,247
South Coast	Te Apiti	19,219
South Coast	Te Awanga Area Stream	311
South Coast	Waikaraka	14,048
South Coast	Waimarama Coast	6,370
South Coast	Waingongoro	2,461
South Coast	Waipuka	11,303
South Coast	Total	310,294
Porangahau	Lower Porangahau	82,230
Porangahau	Mangangarara	8,107
Porangahau	Mangaorapa	100,418
Porangahau	Mangawhero	18,487
Porangahau	Porangahau Coast	13,973
Porangahau	Turaekaitai	193,281
Porangahau	Total	416,497

As a comparison, modelled SedNetNZ sediment loads for the TANK catchment above the Fernhill gauging site were compared with measured long-term sediment loads from the Fernhill (site number 23 102) site ~ 14 km upstream from the ocean. SedNetNZ modelled a sediment load of 689 000 t a^{-1}, whereas the Fernhill site measured long-term sediment load as 1 084 000 t a^{-1} (data collected from November 1958 to March 1988).This is approximately within the error limits of the estimate of the measured load (±1.26).

5.3 Scenario modelling using SedNetNZ and Highly Erodible Land (HEL) models

Using SedNetNZ and AgriBase data a scenario model was developed to estimate the on-farm sediment reduction through mitigation strategies (farm plans). The rationale was to focus on farms in the TANK, South Coast, and Porangahau catchments that have the greatest areas of HEL. In the model we assumed a 70% reduction in sediment load was achieved where farm plans were fully implemented. SedNetNZ modelled the current sediment load (total of hillslope erosion processes) for the TANK catchment as 989 553 t a^{-1}, South Coast as 304 235 t a^{-1}, and Porangahau as 390 419 t a^{-1} (Table 9). With the implementation of farm plans on the 100 farms identified by the HEL model with the greatest erosion risk, sediment load for the TANK could be reduced by 23%, the South Coast by 67%, and Porangahau by 50%.

Table 9 Scenario modelling using SedNetNZ and AgriBase for the TANK, South Coast, and Porangahau catchments. Modelled current - total sediment load from hillslope erosion processes in each catchment; modelled reduction - estimate of sediment load reduction through mitigation strategies (farm plans) for the 100 highest ranked farms identified using the HEL model.

Catchment	Modelled current sediment load (t a^{-1})	Modelled reduction in sediment load (t a^{-1})	Percentage reduction (%)
TANK	989,553	228,078	23
South Coast	304,235	203,645	67
Porangahau	390,419	194,469	50

5.4 SedNetNZ stream bank erosion scenario modelling

The SedNetNZ model was used to undertake an assessment of stream bank erosion occurring within the TANK, South Coast, and Porangahau catchments. Table 10 shows the stream bank sediment load (t a^{-1}) modelled for (A) the current status of bank erosion (about 24% of the length of streams fenced), (B) 25% additional fencing, (C) 50% additional fencing, and (D) 100% fencing on both sides of rivers and streams within the TANK, South Coast, and Porangahau catchments. Figure 12 shows the same scenarios expressed as sediment load per unit length of stream channel (t m^{-1} a^{-1}) which provides an overview of comparative rates of sediment generation from bank erosion. The current fencing status was estimated from the HBRC riparian assessment. Our analysis assumed that the *excellent* class in the riparian class field of the HBRC data represents adequate fencing to withhold cattle from river or stream margins and allow woody vegetation to fully colonise the banks. Because at this time a riparian assessment of the South Coast and Porangahau catchments was not available, we used the same current proportion of fenced stream lengths as found for the TANK catchments to calculate current sediment load from bank erosion. In terms of total stream length fenced, the scenarios are equivalent to 24%, 43%, 62%, and 100% for the current, 25%, 50% and 100% scenarios respectively.

Using SedNetNZ bank erosion sediment loads for the TANK, South Coast, and Porangahau catchments, a respective reduction of 171 500 t a^{-1} , 6700 t a^{-1}, and 23 900 t a^{-1} is potentially possible by fully 'cattle proof' fencing rivers and streams (Table 10 and Fig. 12). Soil eroded by bank erosion enters the river, but not all of this sediment exits the catchments. Some sediment will redeposit as bank accretion. At present SedNetNZ assumes 80% of gross bank erosion is redeposited, based on a study of bank erosion in the Waipaoa River (De Rose & Basher 2011b).

Table 10 Scenario modelling using SedNetNZ to estimate the total stream bank sediment load for the TANK, South Coast, and Porangahau catchments where the impact of riparian management (fencing both sides of the river and stream banks) is modelled as (A) current fencing, (B) 25% additional fencing, (C) 50% additional fencing, and (D) 100% fencing. The percentage reduction is calculated using current status as the baseline.

Catchment	Management regime	SedNetNZ net bank sediment load (t a^{-1})	Percentage reduction (%)
TANK[1]	Current status	222,426	
	25% fencing	179,548	19
	50% fencing	136,671	39
	100% fencing	50,916	77
South Coast	Current status	8866	
	25% fencing	7197	19
	50% fencing	5528	38
	100% fencing	2191	75
Porangahau	Current status	31,707	
	25% fencing	25,739	19
	50% fencing	19,771	38
	100% fencing	7834	75

[1] Current status identified by Hawkes's Bay Regional Council

[2] Assumed relationship with TANK data

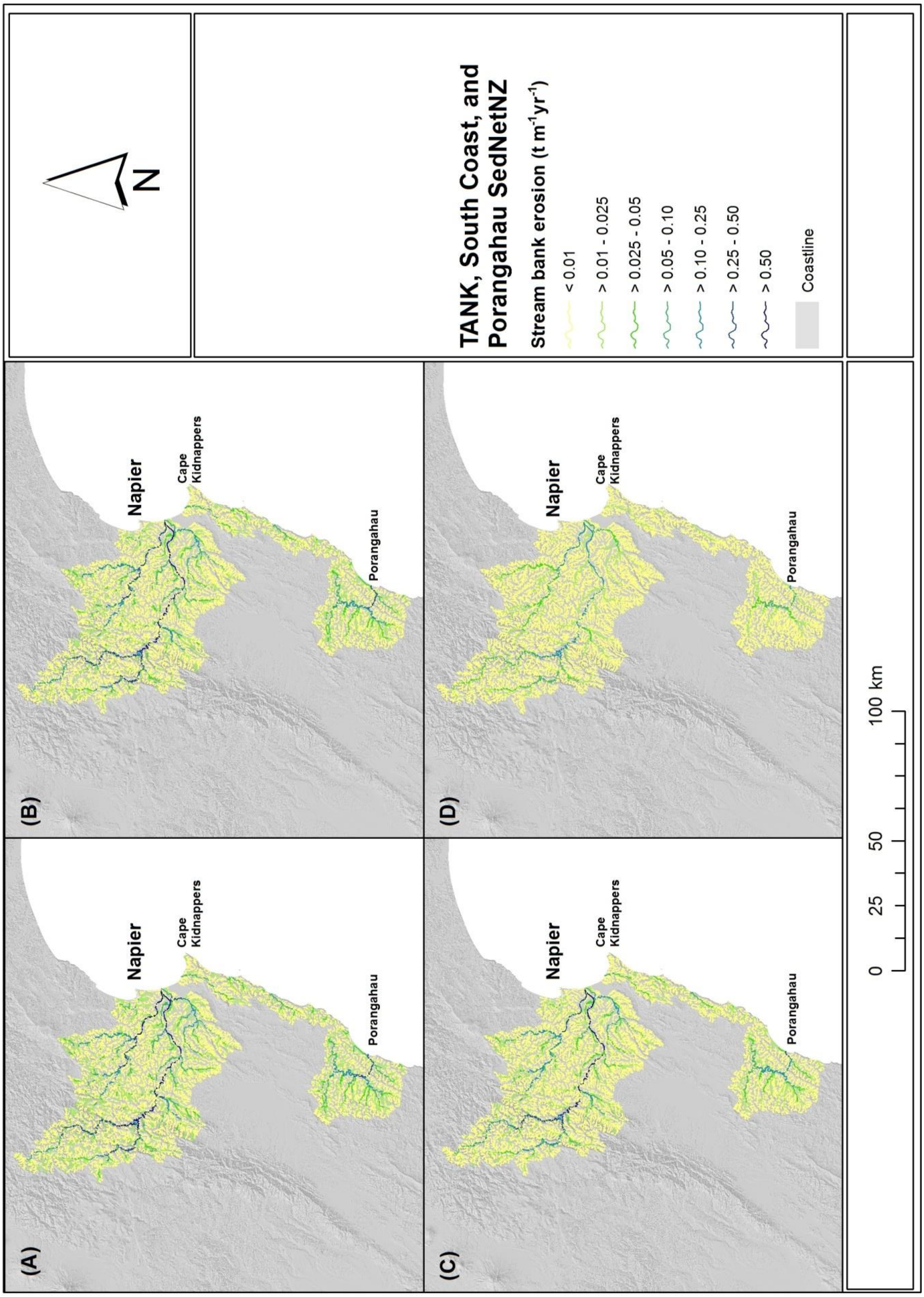

Figure 12 Scenario modelling using SedNetNZ to estimate the total stream bank sediment yield (t m^{-1} a^{-1}) for the TANK, South Coast, and Porangahau catchments where the impact of riparian management (% fencing both sides of the river and stream banks) is assessed as an addition to the (A) current fencing, (B) 25% fencing, (C) 50% fencing, and (D) 100% fencing

6 Conclusions

The area associated with highly erodible land for the TANK catchment is ~6300 ha (1.8%) of the ~350 000 ha TANK catchment. Of the HEL land 90% is at risk from landsliding (1.5% of catchment area), and the remainder at risk from earthflow erosion (0.2% of catchment area). The HEL areas are mostly in the steeper headwaters of the western and northern tributaries. The HEL model identified 3995 ha of TANK land at risk of landsliding with potential of delivery to streams, and a further 1478 ha are classed as at risk of landsliding but not contributing to streams. Land with a severe earthflow risk (811 ha) is minor. Areas identified as being highly susceptible to erosion by the HEL map were intersected with the FSL *PS* field in an effort to identify those areas of HEL more likely to deliver clay and silt size material to the river and stream network. Overall, 208 ha (<0.1% of catchment area) of HEL was associated with clay-dominant particle size distribution, while around 5700 ha (1.6% of catchment area) was associated with silt-dominated particle sizes.

The area associated with highly erodible land for the South Coast catchment is ~10 804 ha (22.7% of the South Coast catchments). Of the HEL 40% of the area is at risk from landsliding (8.1% of catchment area), and 60% is at risk from earthflow erosion (14.6% of catchment area). The HEL land is mostly in the steeper regions of the mid and southern regions of the catchment. The HEL model identified 2662 ha of South Coast land at risk of landsliding with potential of delivery to streams, and a further 1168 ha are classed as at risk of landsliding but not contributing to streams. Land with a moderate (3205 ha) and severe earthflow risk (3769 ha) is also substantial. Areas identified as being highly susceptible to erosion by the HEL map were intersected with the FSL *PS* field in an effort to identify those areas of HEL more likely to deliver clay and silt size material to the river and stream network. Overall, 4109 ha (8.3% of catchment area) of HEL was associated with clay-dominant particle size distribution, while around 6580 ha (13.2% of catchment area) was associated with silt-dominated particle sizes.

The area associated HEL for the Porangahau catchment is the largest of the three catchments (~25 711 ha (29.3%) of the catchment area). Of the HEL only a small percentage is at risk from landsliding (1.8%), while HEL at risk of earthflow erosion is substantial (27.5%). The HEL is mostly in the steeper coastal regions and the north west of the catchment. The HEL model identified 1248 ha of Porangahau land at risk of landsliding with potential of delivery to streams, and a further 350 ha are classed as at risk of landsliding but not contributing to streams. Land with a moderate (19 315 ha) and severe earthflow risk (4798 ha) is also substantial. Areas identified as being highly susceptible to erosion by the HEL map were intersected with the FSL *PS* field in an effort to identify those areas of HEL more likely to deliver clay and silt size material to the river and stream network. Overall, only 80 ha (< 0.1% of catchment area) of HEL was associated with clay-dominant particle size distribution, while 25 512 ha (29.0% of catchment area) was associated with silt-dominated particle sizes.

SedNetNZ divides large catchments into many subcatchments (stream links) and a sediment budget is calculated, quantifying where sediment sources are associated with main erosion processes. When data are converted to a sediment load basis (t a^{-1}), within the TANK catchment the Upper Ngaruroro, Taruarau, and the Mangaone subcatchments have the highest sediment loads, with 229 620 t a^{-1}, 187 585 t a^{-1}, and 171 884 t a^{-1}, respectively. The Ngaruroro Corridor, Tutaekuri Corridor, and the Poporangi, Upper Tutaekuri, and Mangatutu subcatchments also have relatively high sediment loads, ranging from 50 554 to 80 099 t a^{-1}. Across the South Coast catchments the Mangakuri, Maraetotara, and Pourerere subcatchments have the highest sediment loads, with 81 757 t a^{-1}, 55 932 t a^{-1}, and 32 434 t a^{-1}, respectively. For the Porangahau catchment the Turaekaitai, Mangaorapa, and Lower Porangahau subcatchments have the greatest sediment loads, with 193 281 t a^{-1}, 100 418 t a^{-1}, and 82 230 t a^{-1}, respectively.

Scenario modelling using SedNetNZ and AgriBase calculates that an on-farm reduction in sediment through mitigation strategies (farm plans) of 228 000 t a^{-1} (23%) for the TANK, 101 000 t a^{-1} (67%) for the South Coast, and 195 000 t a^{-1} (50%) for the Porangahau catchments related to the 100 farms with the greatest area of HEL is possible (based on AgriBase polygons). This approach enables mitigation strategies to be applied on farms identified by AgriBase and HEL for targeted farm plan and mitigation strategies.

SedNetNZ predicts that if all remaining stream banks were fenced and stock excluded, bank erosion could be reduced from 180 000 t a^{-1} to 51 000 t a^{-1} for the TANK, from 9 000 t a^{-1} to 2200 t a^{-1} for the South Coast, and from 32 000 to 8 000 t a^{-1} for the Porangahau catchments (100% fencing on both sides of the rivers and streams).

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