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Memorandum

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Subject	**Contaminant Load Model development**	**Project Name**	Whaitua te Whanganui-a-Tara
Attention	James Blyth, Mark Heath	**Project No.**	IZ130500
From	Stuart Easton, Oliver Hopkinson		
Date	7 February 2020		
Copies to	**Brent King, Tim Sharp, John Phillips**		

1. Overview

This memo describes the data sources, spatial development, and initial results of a customised Contaminant Load Model (CLM) developed for whaitua te Whanganui-a-Tara.

The CLM is a spreadsheet-based model developed by Auckland Council and customised for the Wellington region as part of the previous Porirua Whaitua modelling package (Moores et al. 2017). The customised model estimates diffuse losses of Total Suspended Solids (TSS), Total Zinc, Total Copper, Total Phosphorus (TP), Total Nitrogen (TN), and *E. coli* from urban land uses.

The contaminant loss rates of the customised CLM (Moores et al. 2017) have been applied to a detailed land cover map developed for whaitua te Whanganui-a-Tara to identify patterns of diffuse contaminant sources and loading to receiving waterbodies. It is intended that the spatial model will be visualised as an interactive ESRI web map and dashboard, and the landcover map utilised as an input into an eWater Source hydrological and dSedNet sediment yield and transport model (currently under development). The developed CLM provides the ability to modify land uses or apply stormwater mitigation to allow for scenario exploration.

2. Model development

2.1 Land cover mapping

CLM land covers were mapped using data derived various sources which are given in Table 1. The Land Cover Database (LCDB) version 4.1 forms the base dataset, on top of which detailed land covers were mapped using a variety of sources and methodologies. The following sub-sections describe the mapping methods for each land cover.

Table 1: CLM data sources

Land cover	Sub-categories	Data sources
Roof	Residential Commercial Industrial	• LINZ building outlines[1] • Territorial Authority Zoning information (WCC, HCC, UHCC)

[1] https://data.linz.govt.nz/layer/101290-nz-building-outlines/

Land cover	Sub-categories	Data sources
		• Corelogic roof material and condition information
Roads (Vehicles per day)	<1000 VPD 1000-5000 VPD 5000-20000 VPD 20000-50000 VPD 50000-100000 VPD >100000 VPD	• LINZ road centrelines • Jacobs' SATURN Wellington Regional traffic model
Paved Surfaces	Residential Commercial Industrial	• Classified LINZ regional aerial imagery (2012-13) • Wellington Water impervious surfaces spatial data • Territorial Authority Zoning information (WCC, HCC, UHCC)
Urban grasslands and trees	Slope < 5 5 < Slope < 10 10 < Slope	• LCDB v4.1[2] • Classified LINZ regional aerial imagery (2012-13) • NZ School of Surveying DEM (15m)[3]
Parks	Golf course Sports field Racecourse	• LCDB v4.1[2] • Visual assessment to assign sub-category
Rural Land uses (Exotic production forest, Stable forest, Farmed pasture, Retired pasture, Horticulture)	Slope < 10 10 < Slope < 20 20 < Slope	• LCDB v4.1[2]

2.1.1 Roofs

Roof area is estimated as equal to building footprint area (LINZ building outlines[1]). Roof material information at the resolution of the original CLM categories is not readily available for whaitua Te Whanganui-a-Tara. Instead, and consistent with the approach for the Porirua whaitua, is to categorise roofs as either residential, commercial, or industrial based on local authority zoning information. Where not defined, roofs were assumed to be residential. Contaminant yields within these categories have been calculated as the weighted average from a representative sample of 2,816 roofs across 105 suburbs in the Hutt Valley, Porirua, and Johnsonville / North-West harbour suburbs from Corelogic data matched to the original CLM roof categories.

2.1.2 Roads

Spatial road data is derived from LINZ road centrelines. Some manual data cleaning was required to ensure adequate road surface mapping. Vehicle Per Day (VPD) categories have been estimated using the Jacobs Wellington Regional SATURN traffic model.

[2] https://lris.scinfo.org.nz/layer/48423-lcdb-v41-land-cover-database-version-41-mainland-new-zealand/
[3] https://koordinates.com/layer/3743-16-wellington-15m-dem-nzsosdem-v10/

2.1.3 Parks

Parks have been defined as equivalent to the LCDB category 'Urban Parkland/Open Space'. Sub-categories have been defined based on visual assessment of each spatial polygon defined as a Park to aerial imagery.

2.1.4 Paved surfaces

The delineation of paved surfaces other than roads used an impervious surfaces dataset provided by Wellington Water for the Wellington city area. For the Hutt Valley, 0.3 metre resolution imagery captured in 2012 and 2013 and supervised aerial imagery classification processing was used. Image classification was constrained within the area defined by the LCDB as either 'Built-up area' or 'Transport Infrastructure'. Some manual data cleaning and quality assurance against aerial imagery was also necessary to ensure adequate paved surface mapping. Zoning of defined paved surfaces between residential, commercial, and industrial is based on WCC, HCC, and UHCC zoning information.

2.1.5 Urban grasslands and Trees

Within the urban area defined by the the LCDB as either 'Built-up area' or 'Transport Infrastructure', landcover not classified as paved surfaces was defined as urban grassland and trees. Slope categories have been defined using the NZ School of Surveying Digital Elevation Model (DEM).

2.1.6 Rural land uses

The rural land uses of Exotic production forest, Stable forest, Farmed pasture, Retired pasture, and Horticulture have been defined using the LCDB following Table 2. Slope categories have been defined using the NZ School of Surveying DEM.

Table 2: CLM Rural land cover mapping

CLM Land cover	LCDB Classes
Exotic production forest	Exotic Forest
Stable forest	Broadleaved Indigenous Hardwoods, Deciduous Hardwoods, Indigenous Forest
Farmed pasture	High Producing Exotic Grassland, Low Producing Grassland
Retired pasture	Fernland, Forest – Harvested, Gorse and/or Broom, Manuka and/or Kanuka, Matagouri or Grey Scrub, Mixed Exotic Shrubland, Sub Alpine Shrubland, Tall Tussock Grassland
Horticulture	Orchard, Vineyard or Other Perennial Crop
Other	Gravel or Rock, Herbaceous Freshwater Vegetation, Herbaceous Saline Vegetation, Lake or Pond, Landslide, River, Sand or Gravel

2.1.7 Data collation

Following the mapping of each land cover, data sets were combined to remove overlaps and allow catchment and sub-catchment analysis. Data combination was based on a hierarchy determined by visual assessment of data accuracy. Where two spatial datasets overlapped, priority was as follows:

1. Roofs
2. Roads
3. Parks

4. Paved surfaces other than roads
5. Urban grasslands and trees
6. Rural categories

2.1.8 Changes to Porirua Whaitua customised CLM

In addition to the customised CLM land cover categories, urban parks were mapped, and assigned a subcategory of either sports field, golf course, or race course. Mapping of urban parks was undertaken to understand their contribution of Total Nitrogen to groundwater using the leaching rates estimated in Kelly (2015). For the contaminants modelled by the customised CLM, urban parks have been assigned the CLM loss rates of urban grasslands and trees.

In agreement with Greater Wellington Regional Council, land cover mapping for whaitua te Whanganui-a-Tara did not include construction sites, as whaitua water quality assessment did not require quantification of the impact of transient construction sites.

2.2 Contaminant yields

The development of the customised CLM contaminant yields is described in Moores et al. (2017). Values are given in the Appendix.

3. Results and interpretation

The final CLM land cover map for the full whaitua Te Whanganui-a-Tara extent is shown in Figure 1. Contaminant load results are given in this section for the urban area only, as defined by the LCDB as ‘Urban Parkland/Open Space’, ‘Built-up area’, or ‘Transport Infrastructure’ (Figure 2). Land cover grouping of sub-categories follows Table 1.

It is envisaged that use of the CLM for whaitua te Whanganui-a-Tara will be at the sub-catchment scale, so that all land covers that contribute runoff to a given water body are accounted for. At the time of writing, whaitua reporting locations are yet to be determined. The results given in this section are therefore illustrative only.

Table 3 provides aggregated CLM results. Of the total urban area of 11,500 ha, approximately 50% is classified as either urban grasslands and trees or parks, 20% as roads, 20% as paved surfaces other than roads, and 10% as roofs (Figure 3).

TSS loads are dominated by urban grasslands and trees, which contribute three-quarters of the total (Figure 4). For Zinc, two-thirds of the total load is produced by roofs, which make up just one-tenth of the total urban area (Figure 5). Similarly, Copper loads are dominated by paved surfaces other than roads, which contribute three-quarters of the load from one-fifth of the area (Figure 6). TP loads are largely derived from urban grasslands and trees. For TN and *E. coli* loads, proportionality mirrors the area proportionality, as yields are not differentiated between urban land covers.

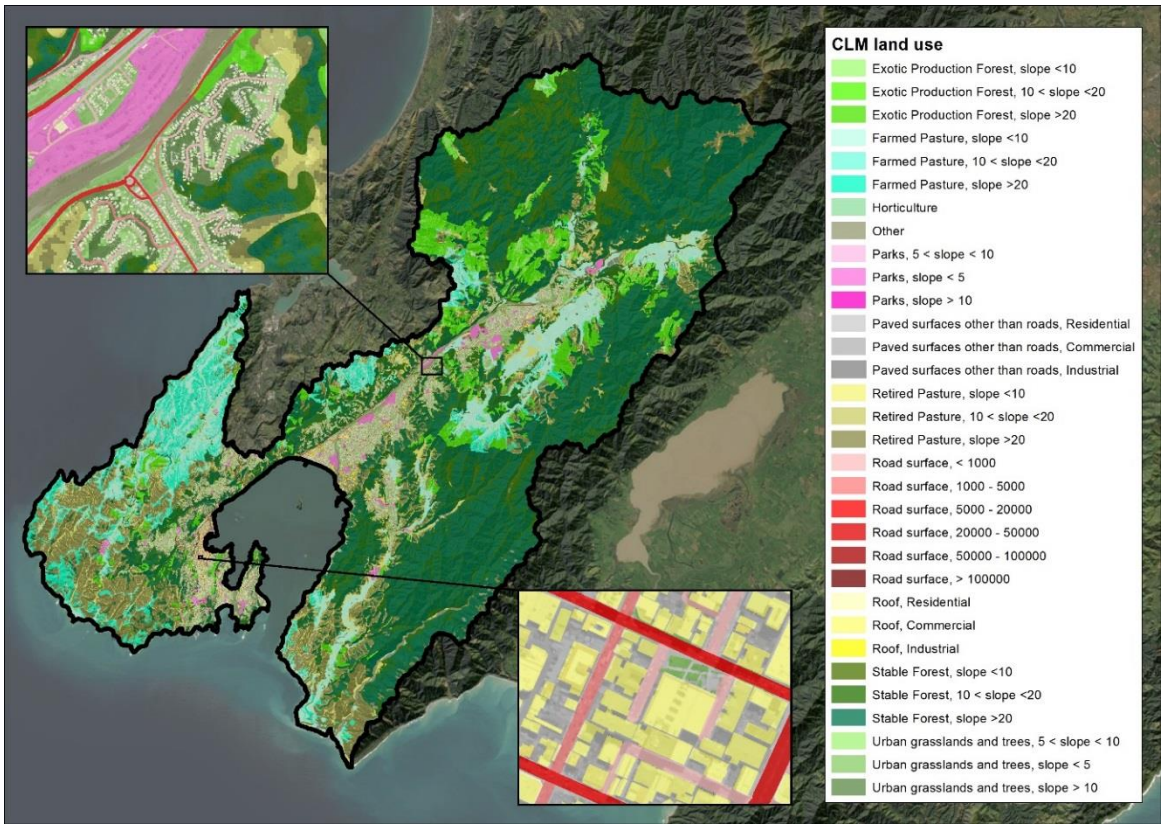

Figure 1 Developed CLM land cover map for Whaitua Te Whanganui-a-Tara – full extent

Table 3 CLM results for the urban area only. Proportion of total area/load provided in brackets.

Group	Area (ha)	TSS (kg)	Zinc (kg)	Copper (kg)	TP (kg)	TN (kg)	*E. coli* (000,000's)
Parks	991 (8.6%)	532,953 (7.2%)	28 (0.1%)	5 (0.3%)	2,143 (8.9%)	14,858 (8.6%)	792,401 (8.6%)
Paved surfaces other than roads	2,240 (19.4%)	681,427 (9.2%)	5,709 (28.1%)	1,046 (75.4%)	3,926 (16.3%)	33,607 (19.4%)	1,792,377 (19.4%)
Roads	1,360 (11.8%)	485,517 (6.5%)	840 (4.1%)	168 (12.1%)	2,040 (8.5%)	20,402 (11.8%)	1,088,122 (11.8%)
Urban grasslands and trees	4,818 (41.7%)	5,555,814 (74.8%)	292 (1.4%)	490 (3.5%)	14,505 (60.1%)	72,273 (41.7%)	3,854,552 (41.7%)
Roofs	2,152 (18.6%)	170,311 (2.3%)	13,462 (66.2%)	120 (8.7%)	1,507 (6.2%)	32,287 (18.6%)	1,721,973 (18.6%)
Total	11,562	7,426,022	20,330	1,387	24,121	173,427	9,249,425

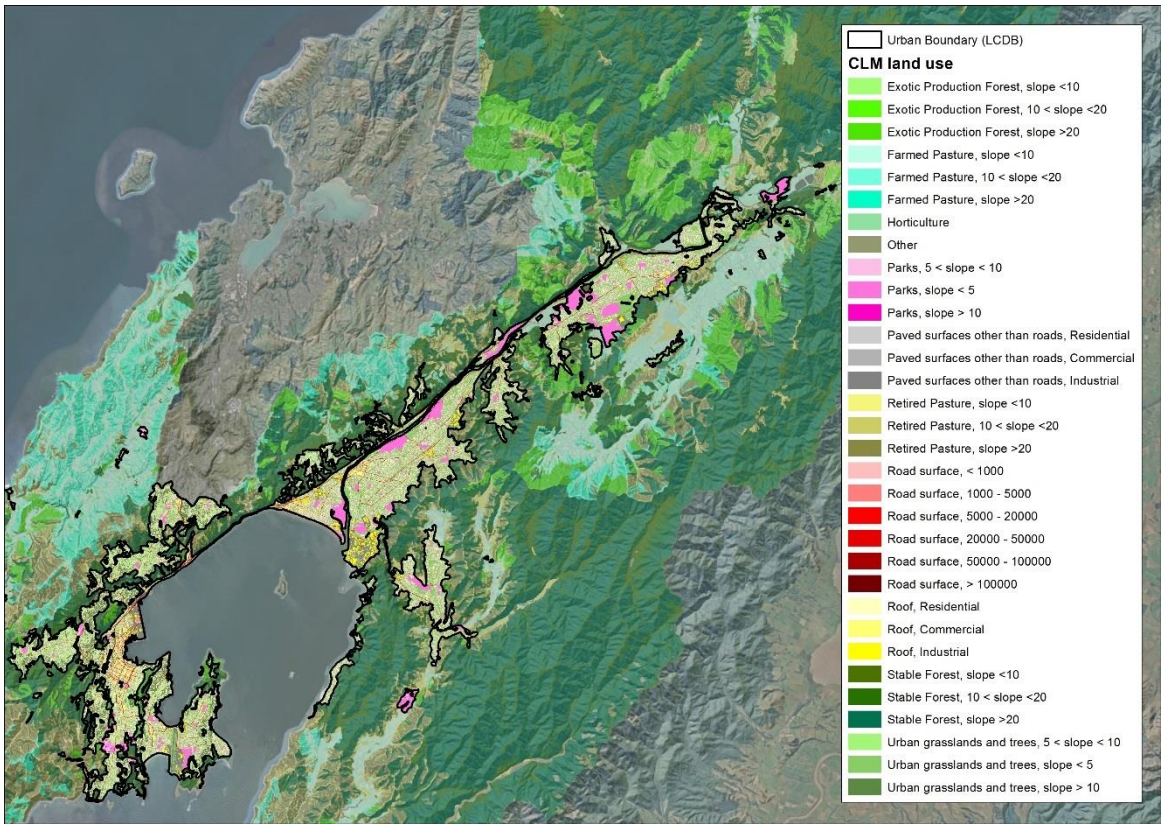

Figure 2 Developed CLM land cover map for Whaitua Te Whanganui-a-Tara urban area

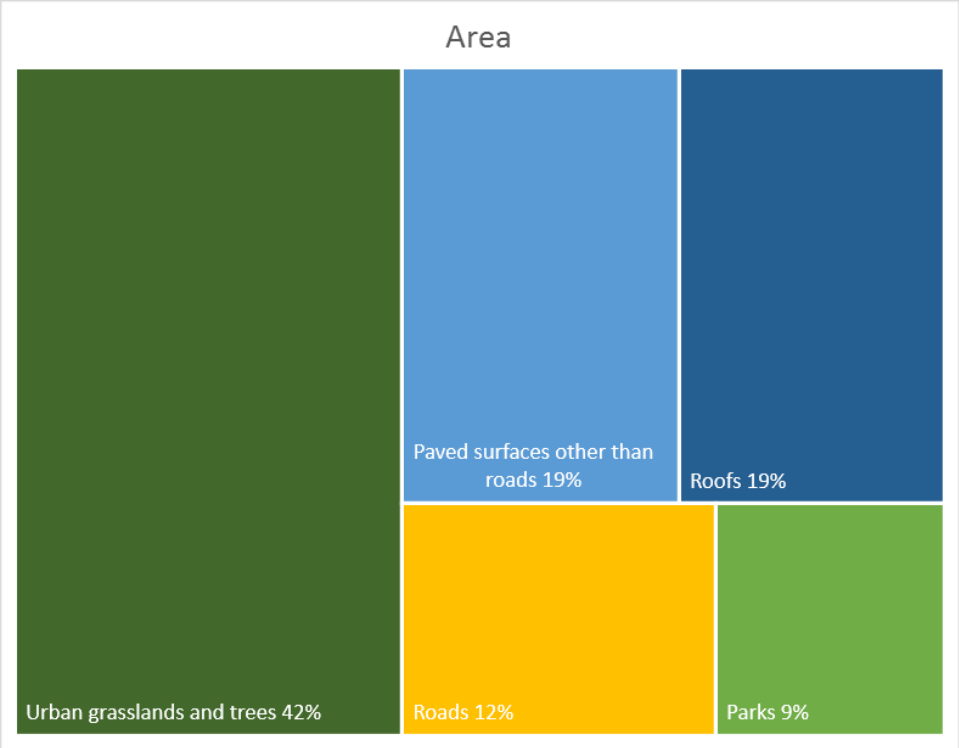

Figure 3 Urban area land cover proportion

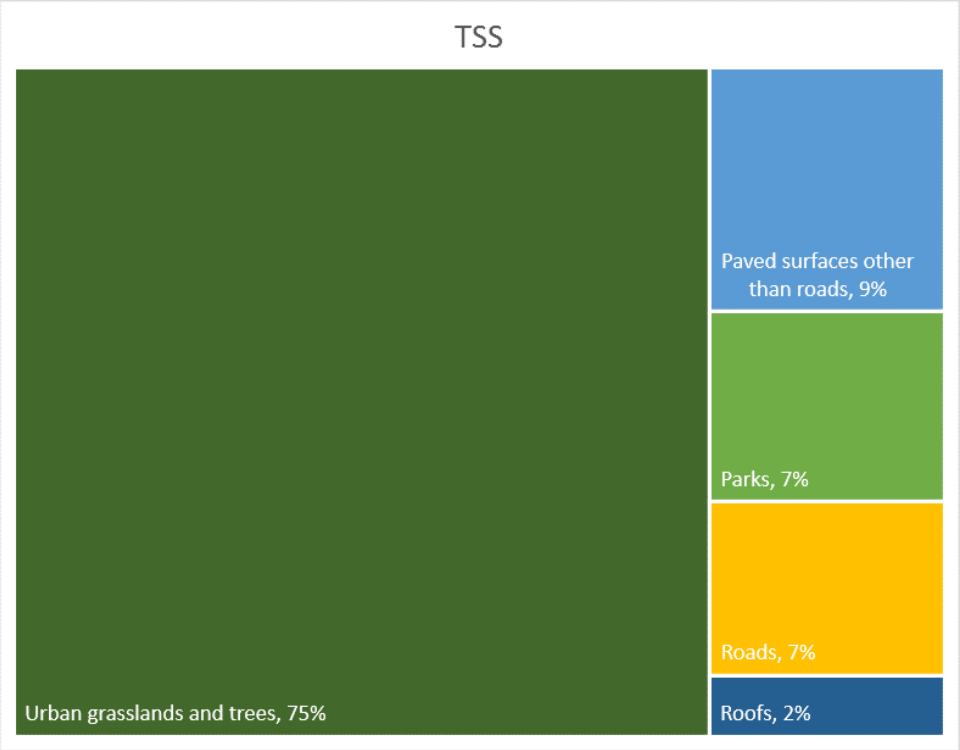

Figure 4 Urban area TSS load proportion

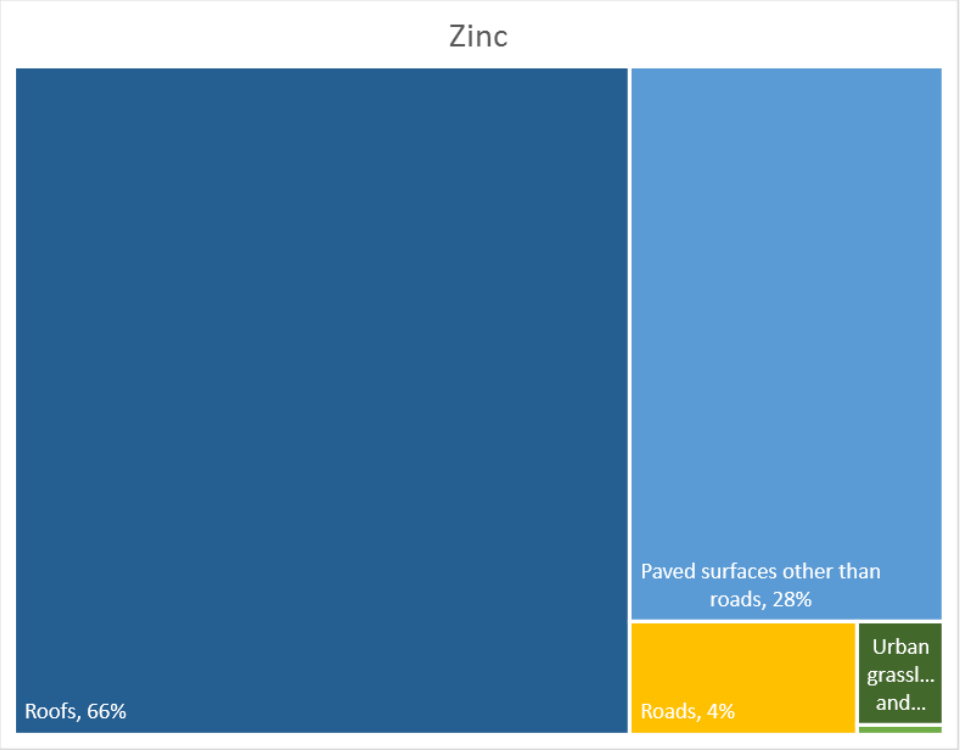

Figure 5 Urban area Zinc load proportion

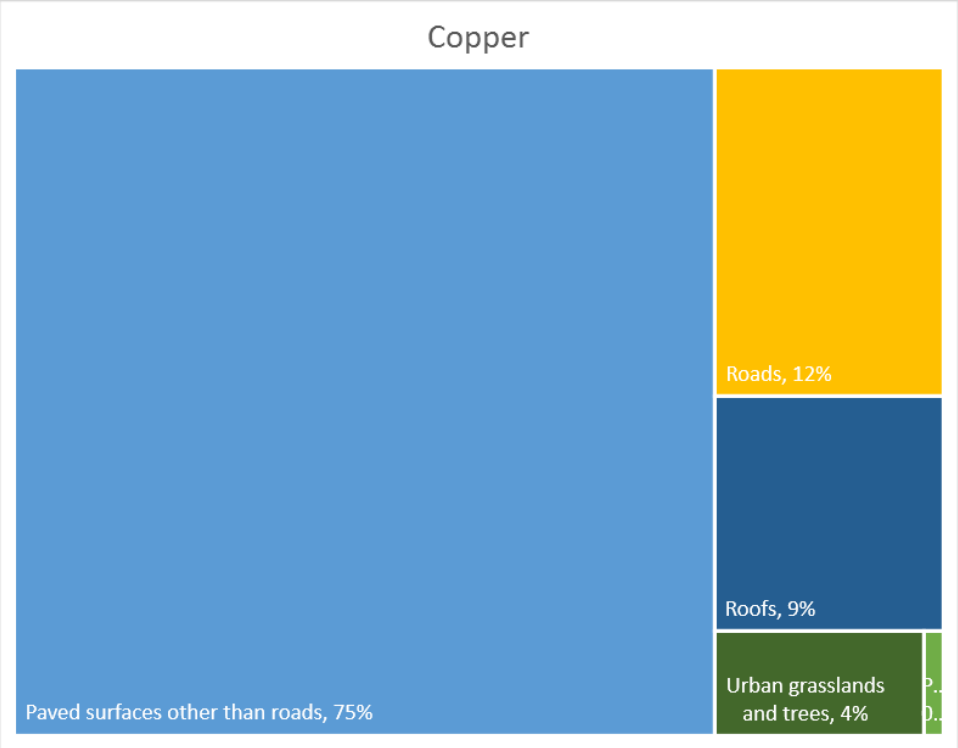

Figure 6 Urban area Copper load proportion

3.1 Limitations

The land cover mapping as described in this memo uses best available data, however does not aim to achieve an exact representation of a given land use or cover. The developed CLM is designed to provide a consistent estimate of the relative proportion of land use categories within a catchment or sub-catchment, rather than exact mapping of a given feature.

3.1.1 Land cover mapping

The external data sets utilised (Table 1) are presumed to be accurate, and comprehensive quality control on their accuracy has not been carried out as part of the CLM development.

In the case of the aerial image classification used to differentiate paved and vegetated surfaces, multi-spectral imagery was not readily available which has resulted in minor artefacts in the land cover mapping. For example, red surface pixels (e.g. tile roofs, red coloured vehicles) are in some cases mis-classified as vegetation, and bare earth or brown vegetation pixels (e.g. browned-off grass) are in some cases mis-classified as paved surfaces.

3.1.2 CLM contaminant yields

Contaminant yields in the CLM have been derived from several sources. The original CLM yields are predominantly from stormwater runoff studies in Auckland, which were then customised for the Wellington region in Moores et al. (2017). Yields are therefore based on limited data and subject to various sources of uncertainty; they may not be representative of the range activities that occur on or within a given land cover type.

The conference paper describing the development of version 2 of the CLM (Timperly et al., 2011) provides the caveat that the CLM has not been calibrated for catchments containing significant rural land due to lack of monitored data for rural catchments. Furthermore, contaminant yields for rural land

uses are based on Auckland soil and rainfall properties as they were not customised for the Wellington region as part of the Porirua whaitua modelling project. Therefore, the TSS loads estimated by the CLM for such catchments will be more uncertain than will be the loads estimated for fully urban catchments. Timperly et al. (2011) suggest that to minimise error for catchments containing both urban and rural land, the CLM model should only be applied to areas where the total area of rural land is less than about 20% of the total catchment area.

4. References

Kelly, L. 2015. The Hutt River and urban nutrient sources: a study of Upper Hutt land use and its impact on groundwater nutrients. Summer Scholarship Report 2014/2015.

Moores, J., Easton, S., Gadd, H., and Sands, M. 2017. Te Awarua-o-Porirua Collaborative Modelling Project: Customisation of urban contaminant load model and estimation of contaminant loads from Sources excluded from the core models.

Timperley, M., Jayaratne, R., Davis, M., Skeen, M. 2011. An Overview of version 2 of the Contaminant Load Model. New Zealand Stormwater Conference Proceedings 2011.

5. Appendix

Table 4 Customised CLM yield table

Land Cover	Land Cover Type	TSS (g/m^2)	Zinc (g/m^2)	Copper (g/m^2)	TP (g/m^2)	TN (g/m^2)	*E. coli** ($000's/m^2$)
Roofs	Residential	8.130	0.510	0.002	0.07	1.5	80,000
	Commercial	7.484	0.605	0.035	0.07	1.5	80,000
	Industrial	6.767	1.512	0.001	0.07	1.5	80,000
Roads (VPD)	<1000	21	0.0044	0.00088	0.15	1.5	80,000
	1000-5000	28	0.0266	0.00532	0.15	1.5	80,000
	5000-20000	53	0.1296	0.02593	0.15	1.5	80,000
	20000-50000	96	0.3012	0.06023	0.15	1.5	80,000
	50000-100000	158	0.5512	0.11024	0.15	1.5	80,000
	>100000	234	0.8534	0.17068	0.15	1.5	80,000
Paved surfaces other than roads	Residential	32	0.195	0.036	0.18	1.5	80,000
	Industrial	22	0.59	0.107	0.15	1.5	80,000
	Commercial	32	0.162	0.0294	0.18	1.5	80,000
Urban grasslands and trees	Slope < 5	37	0.0019	0.0003	0.19	1.5	80,000
	5 < Slope < 10	108	0.0057	0.001	0.32	1.5	80,000
	10 < Slope	260	0.0137	0.0023	0.49	1.5	80,000
Construction site open for 12 months/year	Slope < 5	2800	0.147	0.0252	1.1	4.5	-
	5 < Slope < 10	8291	0.4353	0.0746	3.3	13.3	-
	10 < Slope	19305	1.0135	0.1737	7.7	30.9	-
Exotic production forest**	Slope < 10	35	0.0012	0.0002			
	10 < Slope < 20	104	0.0036	0.0007			
	Slope > 20	208	0.0073	0.0015			
Stable forest**	Slope < 10	14	0.0005	0.0001			
	10 < Slope < 20	42	0.0015	0.0003			
	Slope > 20	83	0.0029	0.0006			
Farmed pasture**	Slope < 10	152	0.0053	0.0011			

Land Cover	Land Cover Type	TSS (g/m^2)	Zinc (g/m^2)	Copper (g/m^2)	TP (g/m^2)	TN (g/m^2)	*E. coli** ($000's/m^2$)
	10 < Slope < 20	456	0.016	0.0032			
	Slope > 20	923	0.032	0.0065			
Retired pasture**	Slope < 10	21	0.0007	0.0001			
	10 < Slope < 20	63	0.0022	0.0004			
	Slope > 20	125	0.0044	0.0009			
Horticulture**	Volcanic soil	50	0.0018	0.0004			
	Sedimentary soil	100	0.0035	0.0007			
	Unknown soil type	100	0.0035	0.0007			

*Assuming stormwater is contaminated with wastewater from cross-connections etc. Where wastewater contamination is absent, a lower *E. coli* yield of 18,000,000 m2/a is proposed.

** Rural land use yields not customised for the Porirua Whaitua project.