INTRODUCING VERSION 4 OF THE ROAD STORMWATER SCREENING MODEL

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ABSTRACT

The Road Stormwater Screening Model (RSS) is a tool that has been developed for Waka Kotahi / New Zealand Transport Agency to assess risks to freshwater (streams and rivers) and coastal (including harbours and estuaries) receiving environments associated with the discharge of copper and zinc in road runoff and urban stormwater. It is a steady-state model that reflects average annual conditions for subcatchments in the River Environments Classification stream network. There are five risk levels rated from lowest to highest, and the level of risk is evaluated on a relative rather than absolute basis from the levels of zinc and copper in runoff and receiving environment sensitivity. Stream risk is assessed for each stream segment from the instream (cumulative) contaminant load for the segment from road and urban runoff and coastal risk is assessed on the basis of catchment contaminant loads delivered to the coast via terminal (coastal) stream segments.

In this paper, we describe the model and its further development since it was first presented at the 2016 Stormwater Conference (Gardiner and Moores 2016), including the field testing and sensitivity analysis undertaken in 2021 and 2022. We also summarize the outputs of a national run of the model. Field testing was done by comparing the estimated stream risk against the relative concentration of zinc and copper determined for streams neighbouring major roads. For the majority of sites, the contaminant strength predicted by the model was within the same category as contaminant strength calculated from measurements, or was higher than measured, indicating the model provides a conservative estimate of the risk. The sensitivity analysis varied model parameters and input data separately and together to determine how these changes affect risk estimates. The results show that the model is robust. National modelling found that most streams affected by roads are in the lowest risk level and those that do have a higher risk level are found in urban areas. In contrast, the risk level for streams in or immediately downstream of urban areas are consistently in the highest risk class. Like streams, the coastal risks are greatest for terminal segments downstream of urban areas. The highest coastal risk levels are associated with coastal towns and cities.

KEYWORDS

Streams, coast, stormwater, road runoff, zinc, copper, sensitivity, field testing

PRESENTER PROFILE

Dr. Annette Semadeni-Davies has been a member of NIWA's Urban Aquatics Group since 2006. Although her specialty is stormwater management, she has worked on projects ranging from environmental and climate change impact assessments to catchment modelling for both water quality and quantity. Annette is also skilled in geospatial analysis.

1 BACKGROUND

The Road Stormwater Screening Model (RSS) was developed for Waka Kotahi, the New Zealand Transport Agency, in 2015/16 by a team (Gardiner et al. 2016) from MWH NZ Ltd (now Stantec) and NIWA. The model assesses risks to freshwater (streams and rivers) and coastal (including harbours and estuaries) receiving environments associated with the discharge of copper and zinc in road runoff and urban stormwater. The purpose of the RSS model is to aid Waka Kotahi in work planning, existing operations and maintenance activities on the network.

The initial version of the model (RSS V.1) consisted of several loosely coupled spreadsheets and GIS (Geographic Information System) tools, each covering different aspects of the model including collation and formatting of input data, assessment of risks from roads and urban areas and output reporting. It was applied in a pilot study of the Te Awarua-o-Porirua Harbour catchment area. The model's initial development, assumptions, limitations and pilot application were presented at the 2016 Water NZ Stormwater Conference (Gardiner and Moores 2016) and are therefore only briefly described here. RSS V.2 integrated the model's various tools into a single spreadsheet version (Semadeni-Davies, A. et al. 2017). Version 3 of the model (Semadeni-Davies, A. and Moores 2020) was developed as a Python script that stream-lined model application and improved model run-times. RSS V.3 was set-up and applied nationally. The latest version, RSS V.4 (Semadeni-Davies, A et al. 2021) allows more flexible representation of the treatment of road and stormwater runoff. As part of its development, the predictions from RSS V.4 were compared to risks estimated from measured water quality data, and sensitivity analyses were undertaken to determine the model's sensitivity to model parameters and input data. In this paper, we briefly describe the updated model and present the outputs of the sensitivity analyses and field testing as well as the outputs of the national application.

2 MODEL DESCIPTION AND DATA SOURCES

RSS V.4 is a standalone Python tool that consists of a set of algorithms for determining contaminant loads and risk, a geodatabase containing all the spatial data required to run the model nationally, mitigation input tables for users to set the level of stormwater treatment by river reach or road runoff treatment by road and a user interface to set up model scenarios. The arrangement between these components is shown in Figure 2-1. Input data and the modelling method are summarised below.

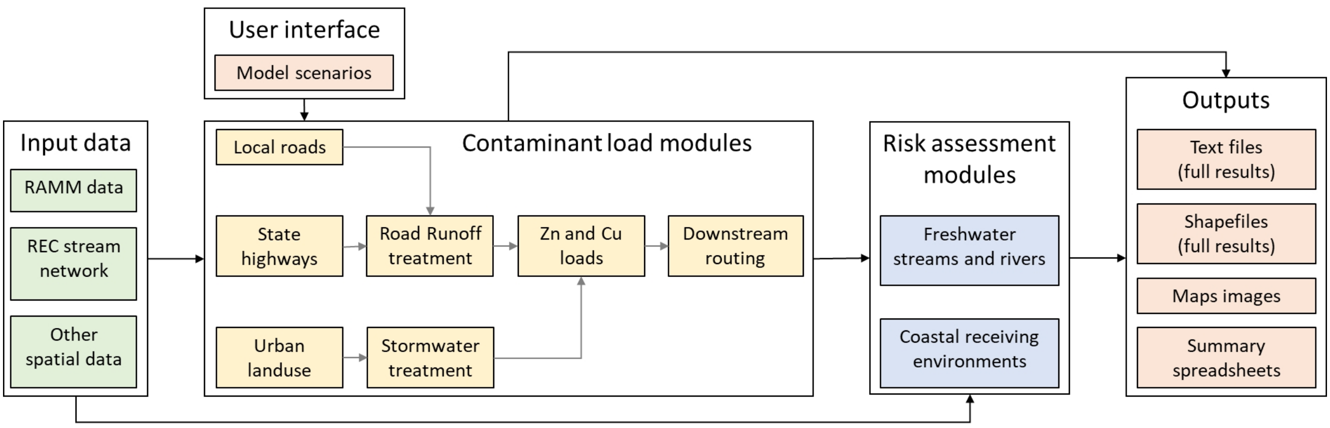

Figure 2-1: Schematic of the RSS model. Orange boxes show interaction between the user and the model

2.1 INPUT DATA

The RSS national geodatabase and its derivation are described in detail in Semadeni-Davies, A.,Moores (2020). The input data are listed below:

1. The drainage network and subcatchments from the River Environment Classification, REC[1] (Snelder, TH and Biggs 2002; Snelder, Ton et al. 2010). The REC subcatchments represent the smallest spatial units in the model.
2. Road centre-lines and traffic counts were taken from the Road Assessment and Maintenance Management (RAMM) database provided by Waka Kotahi. The roads in each REC sub-catchment were determined by intersecting the road centre lines with subcatchment boundaries in GIS.
3. Urban land cover from the Land Cover Data Base 4[2]. The proportion of the urban area in residential or commercial / industrial areas within each REC subcatchment was estimated from Census (2013) population data by mesh-block[3] and the LINZ building foot-print GIS dataset[4]. These datasets were chosen to be compatible with the RAMM dataset.
4. Soil drainage class is taken from the Fundamental Soil Layer (Newsome et al. 2008).
5. The location and characteristics of coastal hydrosystems (i.e., estuaries and harbours) from the NIWA Coastal Explorer database. The terminal (coastal) river segments discharging to each hydrosystems was determined using GIS.
6. Estimated mean annual flows for each REC stream segment come from Henderson et al. (2018).
7. Estimated Macroinvertebrate Community Index (MCI) scores for each REC stream segment come from Clapcott et al. (2013).
8. Sediment loads for each stream segment were estimated using the Catchment Land Use for Environmental Sustainability (CLUES; Elliott et al. 2016) model.

2.2 RISK ASSESSMENT METHOD

The full RSS modelling method is described in Gardiner et al. (2016). In brief, the RSS model provides a conservative method for screening the risk level to receiving waterbodies from road stormwater runoff, based on the copper and zinc contaminant loads from road traffic and non-road (urban) sources. It is a steady-state model that reflects annual average conditions and operates at the subcatchment scale. There are five risk classes ranging from lowest to highest. Risk class is evaluated on a relative rather than absolute basis, from the estimated levels of zinc and copper in runoff and receiving environment sensitivity. Stream risk is assessed for each stream segment from the instream (cumulative) contaminant load for the segment and coastal risk is assessed on the basis of catchment contaminant loads delivered to the coast via terminal (coastal) stream segments.

Contaminant loads and risks are calculated separately for each of three types of source (i.e., local roads, state highways and urban areas). These risks can also be reported for all roads (i.e., sum of local roads and state highways), and for urban and roads combined (i.e., total risk) to give an indication of the relative importance of each source.

The two key steps in the assessment of risk are as follows:

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[1] https://niwa.co.nz/freshwater/management-tools/river-environment-classification-0
[2] https://lris.scinfo.org.nz/layer/48423-lcdb-v41-deprecated-land-cover-database-version-41-mainland-new-zealand/
[3] https://koordinates.com/layer/7322-new-zealand-population-density-by-meshblock/
[4] https://koordinates.com/from/data.linz.govt.nz/layer/101290-nz-building-outlines/

1. **Estimation of contaminant loads and concentrations** are made for each REC subcatchment separately for roads and urban land use. Metal loads from rural sources (e.g., background levels from soil) are not included in the model.

Annual loads of copper and zinc from local roads and state highways within each REC subcatchment are estimated for each section of road as the product of vehicle kilometres travelled and vehicle emission factors. These loads are summed to give the total load from roads for the subcatchment.

Annual loads of copper and zinc from urban areas within each subcatchment are calculated as the product of the area of non-road impervious cover (roofing, carparks, other paved areas) and representative copper and zinc yields. The load calculations are made separately for residential and industrial/commercial land uses, respectively, and the results summed to give the total urban copper and zinc loads delivered to streams.

The zinc and copper loads generated by the separate and combined sources in each subcatchment are routed downstream to provide estimates of instream (cumulative) loads. Mean annual copper and zinc concentrations in stream water are calculated for each stream segment by dividing the instream copper and zinc load by the mean annual flow volume estimated for the stream from the mean annual flow. Mean annual copper and zinc concentrations in sediment delivered to the coast are calculated for terminal segments as the copper and zinc load for the segment divided by its estimated sediment load.

2. **Risk scores** are evaluated using a combination of a Contaminant Strength (CS) score and a Receiving Environment Sensitivity (RES) score, as shown in Table 2-1, with streams/rivers assessed by subcatchment segment and coasts/estuaries at their catchment outlets. For rivers and streams the CS score is based on comparison of the instream concentrations of copper and zinc in the water column against ANZECC (2000) guidelines while the RES score is based on the estimated MCI for the river segment. For coast and estuaries, the CS score is based on the concentrations of copper and zinc in sediments delivered to the receiving environment while the RES score is based on the extent to which depositional processes (sediment trapping) dominate in the receiving environment.

Table 2-1: Risk scores are a function of contaminant strength and receiving environment sensitivity.

		Contaminant Strength		
		Low	Medium	High
Receiving environment sensitivity	Excellent	Lowest	Higher	Highest
	Good	Lowest	Medium	Highest
	Poor	Lowest	Lower	Highest

2.3 REPRESENTATION OF STORMWATER AND ROAD RUNOFF TREATMENT

RSS V.4 allows users to apply water treatment using either global load reduction factors (LRFs), as in earlier versions of the model, or location-specific LRFs by subcatchment (urban stormwater and/or road runoff) or by road segment (road runoff). Users can set a customised LRF for each road segment and/or subcatchment by entering the LRFs in data entry templates that are saved as text files and read into the model. There are two templates, one each for roads and stormwater.

2.4 MODEL OUTPUTS

For each scenario run, the model calculates stream risks for stream segments that either have metal loads transported from upstream or that contain either roads or urban land use within their subcatchments. These segments are referred to as eligible stream segments. The outputs for each segment are the estimated zinc and copper loads generated by sources within the segment subcatchment (if there are no sources, the load is zero); the cumulative instream load and concentration (including loads from upstream subcatchments); and the risk scores associated with each source and source combination. The outputs for estuaries and harbour systems are the estimated zinc and copper concentrations discharged to the estuary or harbour and the risk scores associated with each source and source combination. While the model returns estimates of mean annual zinc and copper loads and concentrations, the model is not intended to be used as a predictive water quality model.

The full model outputs are saved as text files and shapefiles. For streams, the results are provided by REC stream segment, for coasts, the results are provided for REC terminal segments. Risks are calculated only for streams that have either a road or urban metal source within their subcatchment area or receive metals from upstream sources, these are referred to as eligible streams. The outputs are also summarised in an Excel spreadsheet summary file for each of stream and coastal risks. The risk summary spreadsheets have summary tabs for national and regional outputs. Risks are for streams by summing the number of stream segments and the total length (km) of streams within each risk class for each source. A screen shot of the national summary workbook for streams is shown in Figure 2-2. The layout of the coastal risk summary spreadsheet is very similar, this reports the number of eligible terminal segments in each risk level, the total number of terminal segments included in the summary and the eligible number of terminal segments (i.e., those segments with upstream sources).

3 NATIONAL APPLICATION

The national application of the RSS model (V.3) was undertaken in 2020 (Semadeni-Davies, A. and Moores 2020) and the results are summarised here. The application included no urban stormwater treatment and default treatment for road runoff – this assumes urban roads drain via catchpits while runoff from rural roads drains via infiltration in roadside soil.

3.1 STREAM RISK

The length of streams in each risk level for each source and the percentage of the eligible stream length are shown in Table 4-1. The eligible stream length and the percentage of these stream lengths in each of the risk levels varies for each of the sources. Only 2% of eligible stream lengths downstream of state highways (i.e., 646 km of 42461 km nationally) have the highest risk level due to state highways alone, compared to 45% of steams down stream of urban areas (i.e., 13772 km of 30512 km). Of eligible streams downstream of any source (i.e., combined risk), 9% of the eligible stream lengths have the highest risk level (i.e., 14008 km of 159459 km), and most of this risk is due to the metals loads from urban areas. When taken in combination with the other metal sources, some 17%[5] of the stream lengths downstream of state highways have the highest risk level. The difference between 2% and 17% is due to the metal loads from local roads and urban areas.

[5] Not shown in Table 4-1

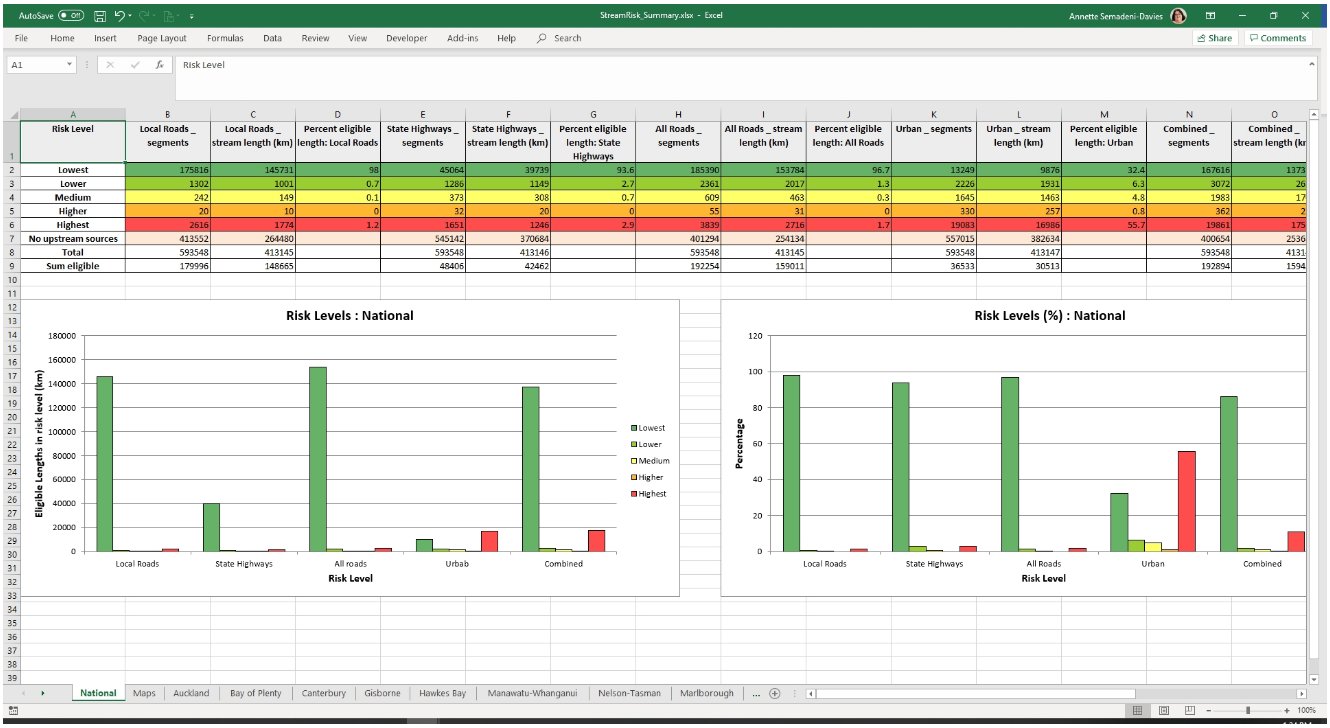

Figure 3-2 Screenshot of the stream risk summary workbook showing the National worksheet.

Table 3-1: Length of streams (km) in each risk level associated with each source. The percentage of eligible streams in each level are in parentheses.

Risk level	Local Roads	State Highways	All Roads	Urban	Combined
Lowest	146622 (99%)	40920 (96%)	155729 (98%)	13153 (43%)	141342 (89%)
Lower	739 (1%)	739 (2%)	1370 (1%)	1968 (6%)	2377 (2%)
Medium	88 (0%)	145 (0%)	243 (0%)	1388 (5%)	1488 (1%)
Higher	2 (0%)	11 (0%)	13 (0%)	231 (1%)	244 (0%)
Highest	1216 (1%)	646 (2%)	1658 (1%)	13772 (45%)	14008 (9%)
No upstream sources	264480	370684	254134	382634	253687
Total length of streams	413147	413145	413147	413146	413146
Sum of eligible stream lengths	148667	42461	159013	30512	159459

The level of posed risk by roads and urban areas varies around the country with the most populous regions having not only the greatest percentage of the total length classed as eligible for all of the metal sources, but also the greatest percentages of eligible streams with the highest risk level (Figure 4-1). The regional order largely reflects the relative area covered by urban land use compared to the total area and the stream density and location with respect to the metal sources. For example, the Auckland region, which is the most densely populated region, covers a relatively small area but has the greatest percentage of stream lengths in the highest risk level for all the metal sources. The total stream length in the region is 6637 km. The length of eligible streams downstream of a state highway in the region is 702 km, while the length of eligible streams downstream of any metal source is 4841 km. Roughly 20% of the state highway eligible stream lengths and 28% of stream lengths downstream of any metal source have the highest risk level.

In contrast, the sparsely populated West Coast (34963 total stream length) has the lowest percentage of eligible streams for either state highways (less that 1% of 2850 km eligible stream lengths) or combined sources (2% of 6410 km eligible stream lengths) in the high risk level.

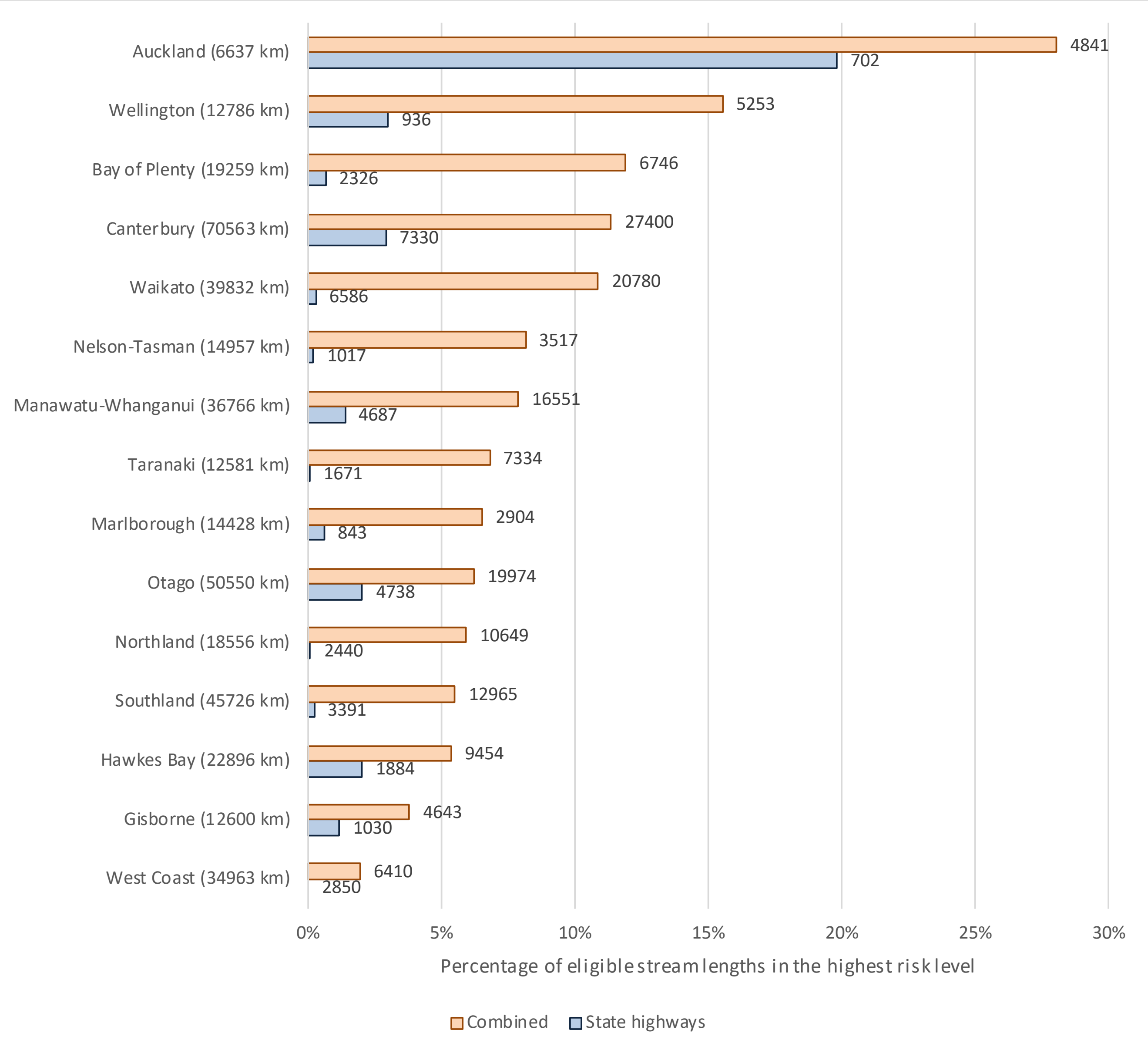

Figure 3-1: Regional percentage of eligible stream lengths downstream of state highways and combined sources that have the highest risk level. The bar labels are the length of eligible streams (km) for each source. The total stream length in the region is next to the region name in parentheses.

Nationally and regionally, the key findings are:

- Most streams affected by road runoff are in the lowest risk level and those that do have higher risk are generally found in and around urban areas. This is due to the combination of higher road density, traffic counts and congestion.
- The stream risk level associated with non-road urban stormwater is consistently high for both small towns and larger regional centres. Nationally, only 49% of streams

affected by urban areas are in the lower or lowest stream risk levels compared to 98% of streams affected by road runoff. However, urban areas affect fewer stream segments nationally than roads, which are more widely distributed across the country.

- The fact that the presence of urban land use frequently results in risk being assessed as 'highest' shows the importance of considering non-road sources of contaminants when investigating stormwater impacts on receiving water bodies. While the primary focus of the RSS model is to provide a screening tool for assessing the impacts of the road network, the inclusion of other non-road contaminant sources alerts users to locations where roads may, along with other sources, contribute to an elevated level of risk. To consider roads in isolation of other sources is likely to lead to a false sense of security over their potential influence on water quality in urban areas.

- Where there are no downstream metal sources, the stream risks associated with upstream sources dissipate with distance due to dilution effects. For roads, streams generally reach a low risk level after only a few downstream segments (i.e., <10 km). For urban areas, high stream risks can persist for tens of kilometres. This signals that the estimated metal concentrations from non-road urban sources in the model are greater than those estimated from roads, because they cover a much greater proportion of each urban subcatchment.

- Where there are contaminant loads from roads or urban areas discharging to sequential river segments along a stretch of river, the dilution effects are less pronounced. This is particularly noticeable for urban risks from inland towns as these tend to be located next to rivers. That is, while the urban risk associated with a specific town will decrease downstream, the risks will be increased again by the next town. This is clearly seen for the Waikato River, which shows high stream risks downstream of Taupo, Cambridge, Hamilton and Huntly. The Waikato River also receives urban metal loads from Te Awamutu (Waipa River) and Tokoroa (Pokaiwhenua Stream) via tributaries.

3.2 COASTAL RISK

The number of terminal segments in each risk level are shown in Table 3-2. Like the results from streams, the percentage of eligible terminal segments that have the highest risk level is greater downstream of urban areas compared to eligible terminal reaches down stream of either local roads or local highways. Only 3% of terminal segments downstream of state highways have the highest risk level from state highways along whereas 9% of terminal reaches downstream of any metal source have the highest risk level, mostly due to urban metal loads.

The regional results for terminal segments with the highest risk level are shown in Figure 3-2. While Auckland has the greatest percentage of eligible terminal reaches downstream of metal sources in the highest risk level, the order of the other regions is different to the order seen for streams. The difference in the regional order can be explained by the difference in how the risk levels are calculated and the number of terminals segments in each region that are downstream of roads and urban areas.

Table 3-2: Number of terminal segments in each risk level associated with each source. The percentage of eligible terminal segments in each level are in parentheses.

Risk level	Local Roads	State Highways	All Roads	Urban	Combined
Lowest	121 (2%)	91 (6%)	132 (2%)	74 (4%)	132 (2%)
Lower	4759 (93%)	1412 (88%)	5079 (92%)	744 (39%)	4261 (77%)

Medium	20	12 (1%)	30 (1%)	126 (7%)	137 (3%)
Higher	109 (2%)	53 (3%)	138 (3%)	470 (25%)	503 (9%)
Highest	98 (2%)	45 (3%)	120 (2%)	480 (25%)	496 (9%)
No upstream sources	6303	9797	5911	9516	5881
Total number of terminal segments	11410	11410	11410	11410	11410
Sum of eligible terminal segments	5107	1613	5499	1894	5529

For example, contrast the relative position of Auckland and Waikato in Figure 3-2. Around 67% of the terminal segments in Auckland and 60% of the terminal segments in Waikato are downstream of a metal source. Auckland has a higher percentage of those segments at the highest risk level with respect to both state highways and combined sources than Waikato. Auckland City's coastal location on an isthmus along with its high population and road density explains the region's top position. Auckland City is drained by a large number of medium to low order streams that drain directly to the coast and receive high metal loads from urban and road runoff (e.g., Motions Creek, Whau River, Oakley Creek, Lucas Creek). On the other hand, Waikato is largely drained by higher order river systems (namely the Waikato/Waipa, Piako and Waihou Rivers), and many of the larger towns and roads, including state highways, in this region are found in the river catchments of these rivers (e.g., SH1, Hamilton, Cambridge, Te Awamutu, Matamata). This means that these towns contribute to a small number of terminal segments and have a long distance between them and the coast. While there are coastal towns in the region (e.g., Thames, Raglan, Whitianga), they are relatively small and their impacts are localised to the rivers that flow through them.

4 SENSITIVITY ANALYSES

The outputs of the risk model reported nationally by Semadeni-Davies, A.,Moores (2020), summarised above were strongly driven by land use type. The distribution of risk scores for subcatchments downstream of urban areas are bimodal with the majority of river reaches classified as being either in the lowest or highest of the five risk classes used in the model. Subcatchments downstream of roads with no urban sources on the other hand were mostly in the lowest risk class. Semadeni-Davies, A et al. (2021) undertook parameter sensitivity analyses to investigate whether modification of the model parameters within their respective ranges results in a more even distribution of the risk scores across all risk classes, including those in the middle risk classes. The parameters were grouped into three groups for the analyses: 1. parameters that govern the metal yields from roads and urban surfaces; 2. parameters that set the thresholds used to classify the contaminant strength; 3. combinations of the modified parameters to give maximum and minimum risk score estimates. In all, 40 scenarios with changed parameters were run.

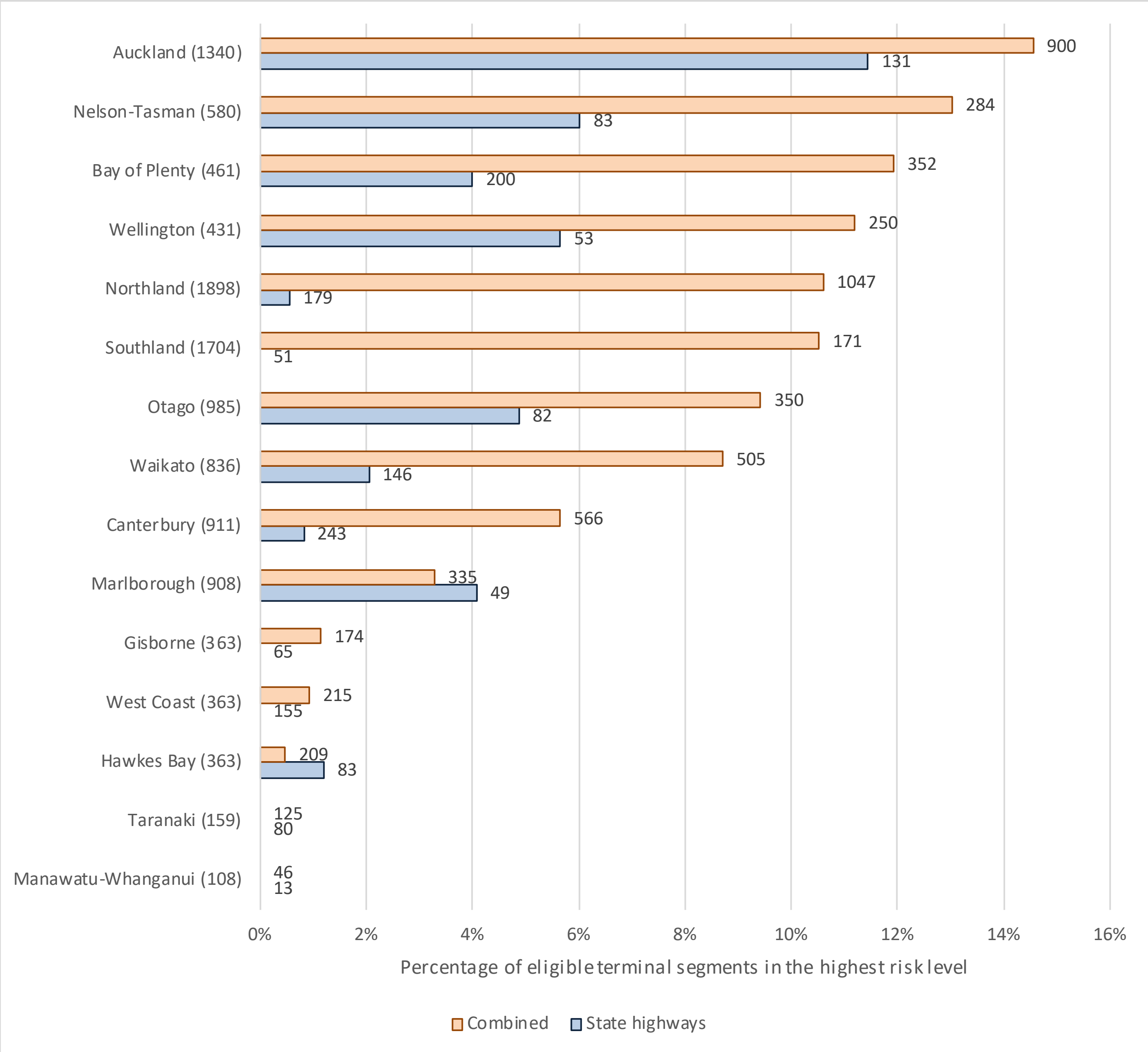

Figure 4-2: Regional percentage of eligible terminal segments downstream of state highways and combined sources that have the highest risk level. The bar labels are the number of eligible terminal reaches for each source. The total number of terminal segments in the region is next to the region name in parentheses.

4.1 SENSITIVITY ANALYSIS RESULTS

The parameter modification sensitivity analysis shows that the model consistently reproduces the bimodal distribution of result described above: i.e., most streams in subcatchments containing a metal source (road or urban) are either in the highest or lowest risk classes. The percentage of streams falling in the lowest risk class in subcatchments containing either a road or an urban area (or both) varies between 82% and 91% and the percentage falling in the highest risk class varies between 4% and 13%.

The results suggest that:

- For all the scenarios, the proportion of subcatchments containing urban areas that fall in the highest risks category is higher than the proportion of subcatchments containing just roads that fall in the highest risks category.

- For some scenarios, the change in instream metal concentrations due to changes in the metal load parameters is not enough to shift the risk from one class to another.

- For scenarios with significant changes in concentrations, the distribution is shifted either up or down the risk classes, but the bimodal distribution remains.

- Changing the CCU thresholds resulted in wider lower, medium and higher risk score bands (in terms of their absolute upper and lower thresholds), but not enough to change the bimodal distribution of the model output.

The results of the sensitivity analysis involving input data scenarios show that the model is robust and has fairly low sensitivity to changes in input data representing flow and MCI score. The distribution of risk scores was similar for all the scenarios modelled, with a difference of only a few percent in each of the risk classes compared to the default model risks.

5 GROUND TRUTHING

Semadeni-Davies, A et al. (2021) compared the model predictions to measured water quality data, using both existing and purpose-collected data.

5.1 EXISTING DATA

Existing data were collated from council State of the Environment monitoring programmes where dissolved copper and zinc have been measured in streams. This comparison showed that the model generally predicted higher concentrations than those measured – although this can be partly explained as the model predicts metals in the total form (i.e. dissolved and particulate forms combined). For the majority of sites, the contaminant strength predicted by the model was within the same category as contaminant strength calculated from measurements, or was higher than measured, indicating the model provides a conservative estimate of the risk.

5.2 PURPOSE COLLECTED DATA

Passive samplers were used to provide the purpose collected data over a period that included both wet and dry weather. We used diffusive gradients in thin film, or DGT samples, as described by Davison,Zhang (1994), to sample zinc and copper. DGTs are small, simple devices that have been used extensively in rivers and streams to measure metals (Österlund et al. 2016). DGTs accumulate metals over the deployment period to higher concentrations, and on retrieval the metals are extracted from this layer and analysed by routine laboratory methods. This enables the calculation of time-weighted average concentration in each waterbody over the period deployed.

The samplers were deployed at locations in Auckland (7 sites), Manawatu-Wellington (7 sites) and Canterbury (9 sites). Model outputs were mapped to identify streams with high, medium and low contaminant strength scores from roads, where the streams were outside of urban areas. Each potential site was then physically assessed using the following criteria:

- Stream size and flow. Streams had to have an estimated depths > 150 mm with permanently moving (i.e., not stagnant) water.

- Close proximity to the road with identifiable connectivity between the road and the stream (e.g, visible culverts or drainage channels) and no barriers such as wide riparian margins between the road and the stream.

- Site access and safety (including nearby parking away from traffic) and ease of installation.

The samplers were deployed according to the methods outlined in Gadd & Milne (2019) and were in situ for 3 to 4 weeks in April and June 2021. Three DGTs were installed at every site in an acrylic holder (Figure 5-1 left), which was mounted in line with the stream flow to optimise flow past the face of the DGTs and minimise sediment deposition, and at a depth to ensure the DGTs were always submerged (Figure 5-1 right). Water temperature was measured at the start and end of deployment and temperature loggers were deployed at selected sites to provide a continuous water temperature record.

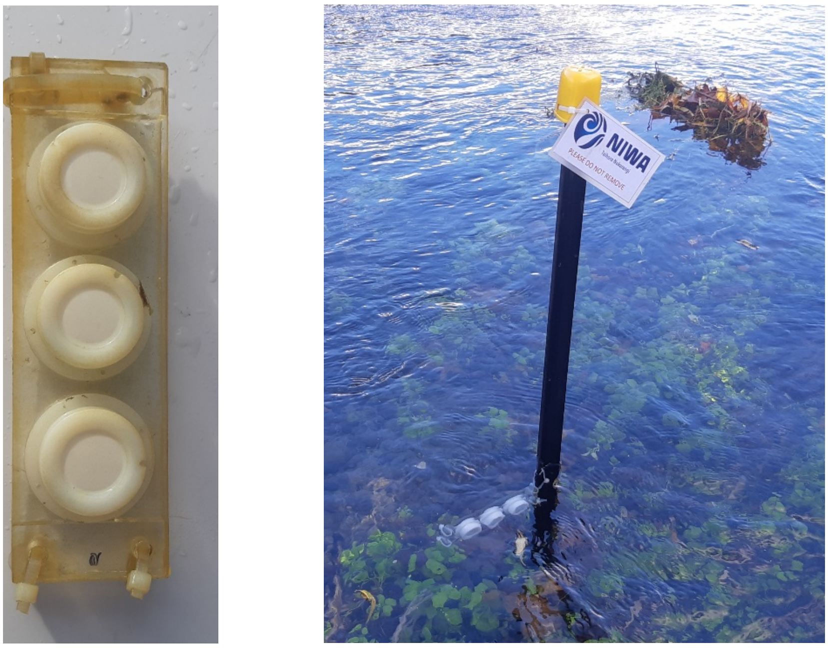

Figure 5-1: DGTs deployment methods. Left: DGTs contained within an acrylic plate holder. Right: Instream deployment with acrylic holder attached to waratah. Left photo taken after deployment.

5.2.1 PASSIVE SAMPLING RESULTS

The copper concentrations measured by the DGTs were invariably very low, less than 0.2 µg/L for all sites (minimum 0.01 µg/L). The zinc concentrations ranged from 0.1 to 1.9 µg/L. The concentrations were generally very low compared to the concentrations measured in streams by Councils, even compared to the sites located in rural areas. DGT metal concentrations were similar to those previously measured by DGTs in rural and control sites, though much lower than those measured in urban streams sites around New Zealand (Gadd and Milne 2019).

5.2.2 COMPARISON WITH MODELLED RISK OUTPUTS

The DGT metal concentrations are compared to those predicted from the RSS model in Figure 5-2. Compared with the DGT measured concentrations, there was a much greater range in the predicted copper and zinc concentrations (e.g., copper ranged from extremely low (<0.1 µg/L) to over 10 µg/L). For most of the sites, the predicted concentrations were higher than measured concentrations, in some cases, by 10-100-fold. This is not entirely surprising as the RSS model predicts the total concentration of metals, whereas DGTs measure labile metals (which excludes those bound to particulates, colloids and large dissolved compounds such as humic acids).

A comparison of the modelled CS and those calculated from the DGT data showed that the model over-predicts the contaminant strength for the majority of the sites. In all cases, the CS calculated from DGTs are low; whereas the model predicts a medium CS for 14 sites and a high CS for 11 sites. For 9 sites, the CS from the model falls into the same category as the measured CS – where both indicate low contaminant strength. In all cases, the model is conservative, that is, it predicts a higher contaminant strength than measured by DGTs, or the contaminant strength is in the low category for both predictions and measured data. The DGTs metal concentrations more closely reflect those that are bioavailable to aquatic organisms, lending further support to the model being conservative in its predictions.

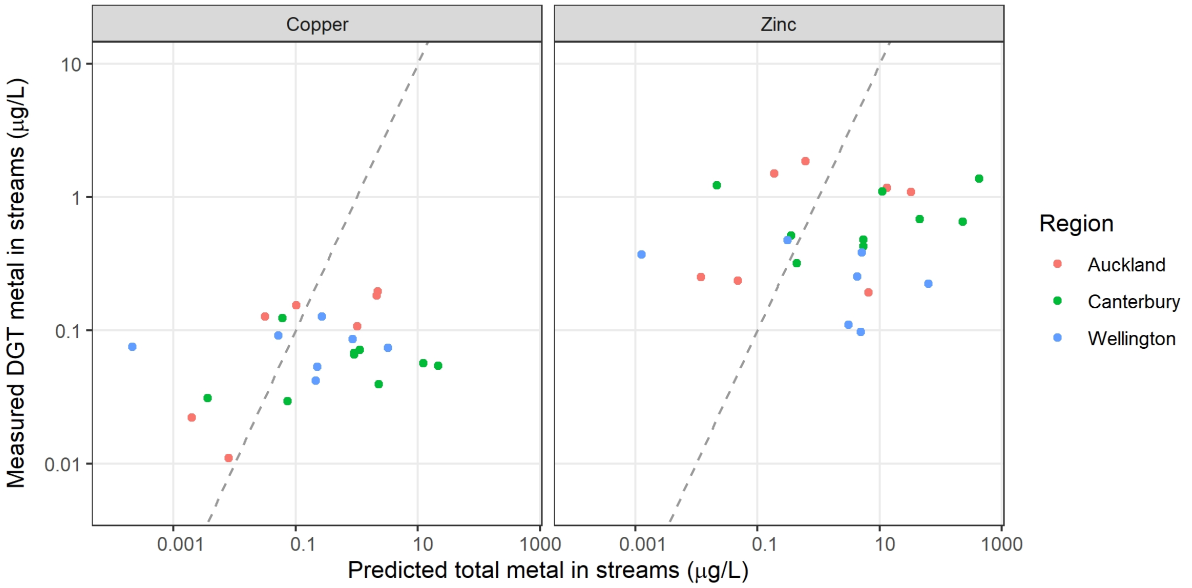

Figure 5-2: Comparison of copper and zinc measured by DGTs with copper and zinc predictions from the RSS model. Grey diagonal dashed line is 1:1 line, representing where data would fall if there was a perfect correlation. Many data points are below this line, indicating measured concentrations are lower than predicted.

6 LIMITATIONS AND ASSUMPTIONS

Key model limitations and sources of uncertainty are discussed in detail in Gardiner et al. (2016) and are summarised below:

- The RSS model was developed to address long-term risks to waterbodies from total annual loads of zinc and copper in stormwater runoff (i.e., chronic effects). Risk levels do not take account of variations in zinc and copper concentrations during storm events and their potential impacts (i.e., acute effects). Nor does the model take into account seasonal changes in contaminant load generation or flow rates.
- Spatial scaling to REC segments and their subcatchments results in the aggregation of spatial data and parameters and can be expected to lead to spatial smoothing in the model results.
- The model estimates total copper and zinc loads and concentrations and does not separate these into their particulate and dissolved fractions.
- The routing of metal and sediment loads does not include the effects of stream attenuation or losses.
- Estimation of non-road urban loads of copper and zinc uses broad representative yields for residential and industrial/commercial land uses, respectively. These were derived in the original RSS study (Gardiner et al. (2016) from land cover fractions and yields developed for Auckland Council's Contaminant Load Model (CLM;

Auckland Regional Council 2010). The screening method does not attempt to address uncertainty in yields adopted from the CLM.

- The separation of urban land cover into the 'residential' and 'commercial/industrial' classes was made on the basis of population and building density in lieu of detailed land use analysis or the availability of consistent nation-wide urban land use data.

- The model uses simplified default assumptions about the level of treatment for road runoff based on land cover and, in rural areas, soil drainage class. Similarly, the default assumes that there is no treatment of stormwater from non-road sources in urban areas. For this reason, the urban metal loads should be considered conservative estimates.

- The model uses the outputs of three other models as input data (Clapcott et al. 2013; Elliott et al. 2016; Henderson et al. 2018) and is therefore subject to the same limitations and assumptions as these models.

- The coastal risk assessment method involves calculation of concentrations of copper and zinc in suspended sediment and assumes that these reflect the likely relativity of risk associated with metal concentrations in deposited sediments. Physical, chemical and biological processes operating in receiving environments may result in result in metal concentrations in deposited sediments differing from those in suspended sediments.

- The model has only been subject to limited validation, this showed the model is generally conservative.

7 CONCLUSIONS

This paper provides an update on the development and testing of the Waka Kotahi RSS model that was first presented at the 2016 Water NZ Stormwater Conference. In that time the model has moved from a pilot version in Excel to a stand alone Python script to allow the model to be set up and run more effectively. The ability to model stormwater and road-runoff treatment more flexibly has also been added. The model has been applied nationally and we have undertaken both sensitivity analyses and ground truthing.

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