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Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study: Predictions of Stormwater Contaminant Loads

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	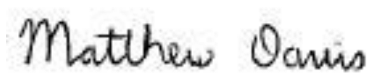
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Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study: Predictions of Stormwater Contaminant Loads

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PREFACE

The Manukau Harbour is comprised of tidal creeks, embayments and the central basin. The harbour receives sediment and stormwater chemical contaminant run-off from urban and rural land from a number of subcatchments, which can adversely affect the ecology. State of the environment monitoring in the Pahurehure Inlet showed increasing levels of sediment and stormwater chemical contaminant build up. However, previously little was known about the expected long-term accumulation of sediment and stormwater chemical contaminants in the inlet or adjacent portion of the Manukau Harbour. The South Eastern Manukau Harbour / Pahurehure Inlet Contaminant Study was commissioned to improve understanding of these issues. This study is part of the 10-year Stormwater Action Plan to increase knowledge and improve stormwater management outcomes in the region. The work was undertaken by the National Institute of Water and Atmospheric Research (NIWA).

The scope of the study entailed:

1. field investigation,
2. development of a suite of computer models for
    a. urban and rural catchment sediment and chemical contaminant loads,
    b. harbour hydrodynamics, and
    c. harbour sediment and contaminant dispersion and accumulation,
3. application of the suite of computer models to project the likely fate of sediment, copper and zinc discharged into the central harbour over the 100-year period 2001 to 2100, and
4. conversion of the suite of computer models into a desktop tool that can be readily used to further assess the effects of different stormwater management interventions on sediment and stormwater chemical contaminant accumulation in the central harbour over the 100-year period.

The study is limited to assessment of long-term accumulation of sediment, copper and zinc in large-scale harbour depositional zones. The potential for adverse ecological effects from copper and zinc in the harbour sediments was assessed against sediment quality guidelines for chemical contaminants.

The study and tools developed address large-scale and long timeframes and consequently cannot be used to assess changes and impacts from small subcatchments or landuse developments, for example. Furthermore, the study does not assess ecological effects of discrete storm events or long-term chronic or sub-lethal ecological effects arising from the cocktail of urban contaminants and sediment.

The range of factors and contaminants influencing the ecology means that adverse ecological effects may occur at levels below contaminant guideline values for individual chemical contaminants (i.e., additive effects due to exposure to multiple contaminants may be occurring).

Existing data and data collected for the study were used to calibrate the individual computer models. The combined suite of models was calibrated against historic sediment and copper and zinc accumulation rates, derived from sediment cores collected from the harbour.

Four scenarios were modelled: a baseline scenario and three general stormwater management intervention scenarios.

The baseline scenario assumed current projections (at the time of the study) of

- future population growth,
- future landuse changes,
- expected changes in building roof materials,
- projected vehicle use, and
- existing stormwater treatment.

The three general stormwater management intervention scenarios evaluated were:

1. source control of zinc from industrial areas by painting existing unpainted and poorly painted galvanised steel industrial building roofs;
2. additional stormwater treatment, including:
    - raingardens on roads carrying more than 20,000 vehicles per day and on paved industrial sites,
    - silt fences and hay bales for residential infill building sites and
    - pond / wetland trains treating twenty per cent of catchment area; and
3. combinations of the two previous scenarios.

International Peer Review Panel

The study was subject to internal officer and international peer review. The review was undertaken in stages during the study, which allowed incorporation of feedback and completion of a robust study. The review found:

- a state-of-the-art study on par with similar international studies,
- uncertainties that remain about the sediment and contaminant dynamics within tidal creeks / estuaries, and
- inherent uncertainties when projecting out 100 years.

Key Findings of the Study

Several key findings can be ascertained from the results and consideration of the study within the context of the wider Stormwater Action Plan aim to improve stormwater outcomes:

- The inner tidal creeks and estuary branches of the Pahurehure Inlet continue to accumulate sediment and contaminants, in particular in the eastern estuary of Pahurehure Inlet (east of the motorway).

- The outer Pahurehure Inlet/Southeastern Manukau bed sediment concentrations of copper and zinc are not expected to reach toxic levels based on current assumptions of future trends in landuse and activities.

- Zinc source control targeting industrial building roofs produced limited reduction of zinc accumulation rates in the harbour because industrial areas cover only a small proportion of the catchment area and most unpainted galvanised steel roofs are expected to be replaced with other materials within the next 25 to 50 years.

- Given that the modelling approach used large-scale depositional zones and long timeframes, differences can be expected from the modelling projections and stormwater management interventions contained within these reports versus consideration of smaller depositional areas and local interventions. As a consequence, these local situations may merit further investigation and assessment to determine the best manner in which to intervene and make improvements in the short and long terms.

Research and Investigation Questions

From consideration of the study and results, the following issues have been identified that require further research and investigation:

- Sediment and chemical contaminant dynamics within tidal creeks.

- The magnitude and particular locations of stormwater management interventions required to arrest sediment, copper and zinc accumulation in tidal creeks and embayments, including possible remediation / restoration opportunities.

- The fate of other contaminants derived from urban sources.

- The chronic / sub-lethal effects of marine animal exposure to the cocktail of urban contaminants and other stressors such sediment deposition, changing sediment particle size distribution and elevated suspended sediment loads.

- Ecosystem health and connectivity issues between tidal creeks and the central basin of the harbour, and the wider Manukau Harbour.

Technical reports

The study has produced a series of technical reports:

Technical Report TR2008/049
Southeastern Manukau Harbour / Pahurehure Inlet Harbour Contaminant Study. Landuse Analysis.

Technical Report TR2008/050
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Sediment Load Model Structure, Setup and Input Data.

Technical Report TR2008/051
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Sediment Load Model Evaluation.

Technical Report TR2008/052
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Sediment Load Model Results.

Technical Report TR2008/053
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Predictions of Stormwater Contaminant Loads.

Technical Report TR2008/054
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Harbour Sediments.

Technical Report TR2008/055
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Harbour Hydrodynamics and Sediment Transport Fieldwork.

Technical Report TR2008/056
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Hydrodynamic Wave and Sediment Transport Model Implementation and Calibration.

Technical Report TR2008/057
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Implementation and Calibration of the USC-3 Model.

Technical Report TR2008/058
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Predictions of Sediment, Zinc and Copper Accumulation under Future Development Scenario 1.

Technical Report TR2008/059
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Predictions of Sediment, Zinc and Copper Accumulation under Future Development Scenarios 2, 3 and 4.

Technical Report TR2009/110
Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Rainfall Analysis.

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1 Executive Summary

The main aim of the Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study is to model contaminant (zinc, copper) and sediment accumulation for the purposes of, amongst other things, identifying significant contaminant sources, and testing efficacy of stormwater treatment options.

This report describes the loads of TSS (total suspended solids), total zinc and total copper hindcast for the historical period (1940–2001) and predicted for the future period (2001–2100) for each of 11 consolidated harbour outfalls in the catchment of the Southeastern Manukau Harbour.

The development of the contaminant load model (CLM) used to perform the hindcasts/predictions is described in Timperley and Reed (2008a).

The four scenarios are:

1. Scenario 1 is the existing scenario and includes all existing stormwater treatment such as catchpits for all roads, all urban paved and all pervious surfaces; ponds for commercial and industrial construction sites; and specific installed devices.
2. Scenario 2 is the source-control scenario and includes the existing stormwater treatment from Scenario 1 plus painting of presently-unpainted galvanised steel roofs on industrial buildings.
3. Scenario 3 is the realistic-stormwater-treatment scenario and includes the existing stormwater treatment from Scenario 1 plus raingardens (in addition to catchpits) for all roads carrying >20,000 vpd; hay bales and silt fences (in addition to catchpits) for residential infill construction sites; raingardens or multimedia filters (in addition to catchpits) for industrial paved surfaces; and bottom-of catchment pond/wetland systems for treating 20% of the stormwater in each model unit.
4. Scenario 4 combines all of the above, that is: the existing treatment from Scenario 1, zinc source control of industrial areas from Scenario 2 and new realistic stormwater treatment from Scenario 3.

The model predictions show that source control of zinc applied to industrial galvanised roofs (Scenario 2) will achieve a very small reduction in zinc loads over a period of 15 years between 2010 and 2025 (≤ 7% per year). There are three reasons for this. Firstly, zinc source control is applied only to industrial galvanised roofs. Secondly, industrial land use constitutes a relatively small proportion of total urban land use (11.5%). Thirdly, industrial galvanised roofs that are mostly unpainted will be substantially replaced by 2025.

Additional stormwater treatment (Scenario 3) will achieve reductions of 25, 23 and 22% in the TSS, total zinc and total copper loads, respectively, by 2100. For all three contaminants the reductions are achieved almost entirely by bottom-of-catchment pond/wetland systems installed to treat 20% of the total stormwater discharge from

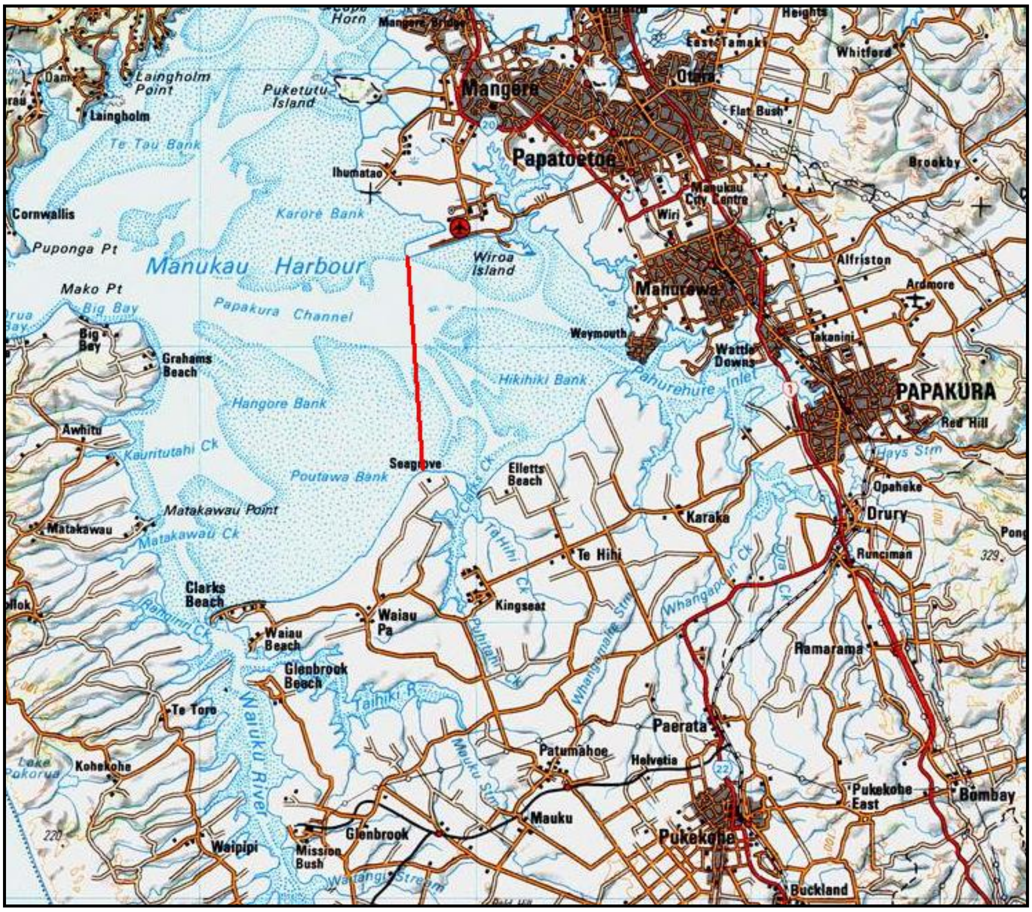
each catchment. On an individual catchment basis, load reductions due to stormwater treatment are in the ranges 20-39% (TSS), 16-28% (Zn) and 17-28% (Cu).

2 Introduction

2.1 Background

The main aim of the Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study is to model contaminant (zinc, copper) and sediment accumulation for the purposes of, amongst other things, identifying significant contaminant sources, and testing efficacy of stormwater treatment options. The study area extends westwards from Pahurehure Inlet to a line running approximately south from the western end of Auckland Airport (see Figure 2-1).

Figure 2-1.
Manukau Harbour, showing the study area to the east of the red line extending south from Auckland International Airport.



This part of the Manukau Harbour receives discharges from all or part of three separate territorial authorities (TAs): Manukau City Council (MCC), Papakura District Council (PDC) and Franklin District Council (FDC). Each of these TAs is currently planning or in the process of preparing Integrated Catchment Management Plans (ICMPs) to support stormwater network discharge consent applications. The ICMP process requires TAs to undertake an evaluation of the effects of contaminant delivery to receiving marine environments.

However, as a consequence of the cross-boundary distribution of contaminant sources to the South Eastern Manukau Harbour and its hydrodyamically complex nature, ARC has commissioned a single integrated study of contaminant accumulation in this receiving environment. The scope of the project is set out in the ARC's request for proposals (ARC, 2006) and the contractual agreement between ARC and NIWA. The essential requirements of the project are, for each 'inlet compartment' (or subestuary) of the study area:

- to predict trends over the period 1950 to 2100 of sediment deposition and copper and zinc concentrations for probable future population growth and urban development consistent with the Regional Growth Strategy, without either zinc source control of industrial areas or additional stormwater treatment;
- To predict trends in the accumulation of these contaminants with various combinations of zinc source control and stormwater treatment;
- To estimate the mass load contributions of sediment, copper and zinc from each subcatchment draining into the South Eastern Manukau Harbour; and
- To predict the year when sediment-quality guidelines will be exceeded.

2.2 Model suite

The Study centres on the application of a suite of models that are linked to each other:

- The GLEAMS sediment-generation model, which predicts sediment erosion from the land and transport down the stream channel network. Predictions of sediment supply are necessary because, ultimately, sediment eroded from the land dilutes the concentration of contaminants in the bed sediments of the harbour, making them less harmful to biota.
- The Contaminant Load Model (CLM)- a contaminant/sediment-generation model, which predicts sediment and contaminant concentrations (including zinc, copper) in stormwater at a point source, in urban streams, or at end-of-pipe where stormwater discharges into the receiving environment. Note the main distinction between the use of GLEAMS and CLM for estimating sediment generation in this study is that the former is largely used for rural areas and the latter for urban areas. Further details are given in Moores and Timperley (2008).
    - The USC-3 (Urban Stormwater Contaminant) contaminant/sediment accumulation model, which predicts sedimentation and accumulation of contaminants (including zinc, copper) in the bed sediments of the estuary.

Underlying the USC-3 model is yet another suite of models: the DHI Water and Environment MIKE3 FM HD hydrodynamic model, the DHI MIKE3 FM MT (mud) sediment transport model, and the SWAN wave model (Holthuijsen et al. 1993), which simulate harbour hydrodynamics and sediment transport. Combined, these three models can be used to simulate tidal propagation, tide- and wind-driven currents, freshwater mixing, waves, and sediment transport and deposition within a harbour."

2.3 This report

This report describes the estimation of loads of TSS (total suspended solids), total zinc and total copper hindcast for the historical period (1940–2001) and predicted for the future period (2001–2100) for 48 model units[1] (MUs) in the urban part[2] of the SE Manukau Harbour catchment and for 11 consolidated harbour outfall subcatchment[3] (Figures 2–2 and 2-3).

The contaminant load model (CLM) used in this study was developed and first applied in a similar study of the Central Waitemata Harbour (CWH). Development of the model is described in detail in Timperley and Reed (2008).

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[1] These are discrete spatial units determined from catchment topography, ICMP boundaries and council stormwater management units. The boundaries of each MU shown in Figure 2-3 are the same as one or more (aggregated) MU's described by Parshotam et al. (2008) in relation to the GLEAMS modelling component of this study, intersected by the MUL / Pukekohe urban boundary.

[2] Urban land is defined as all land lying within the Metropolitan Urban Limit (MUL) and those parts of Pukekohe zoned for urban land uses.

[3] While the study area comprises a total of fifteen consolidated harbour outfall subcatchments four of these contain no urban areas.

Figure 2-2:

The catchment of the South Eastern Manukau Harbour study area showing outfall subcatchments and extent of the urban area (grey hatching).

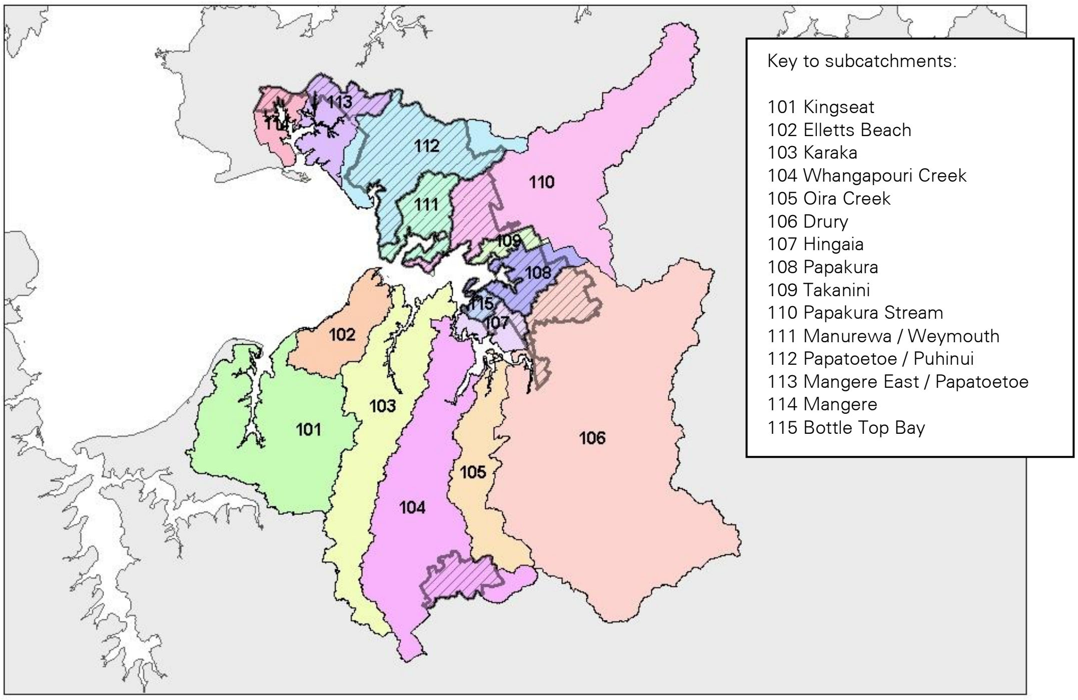
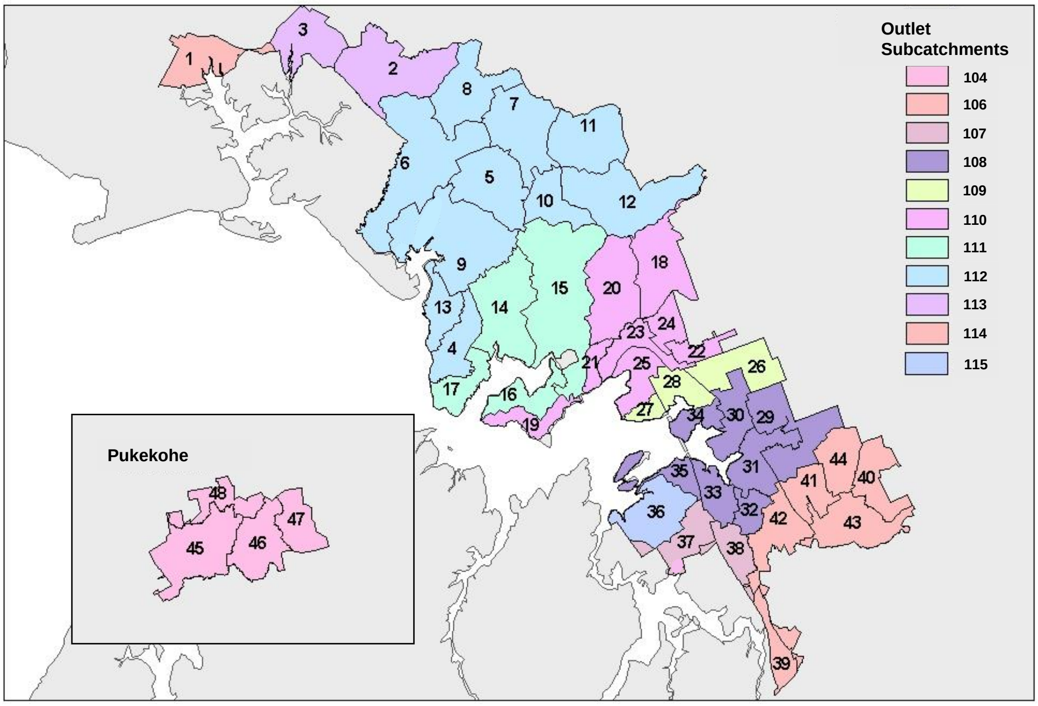


Figure 2-3:

CLM model units by subcatchment, South Eastern Manukau Harbour study area



3 Modelling procedure

The following description of the modelling procedure is from Timperley and Reed (2008a).

3.1 Future period (2001 – 2100)

1. For the first year of the prediction period, the area of each contaminant-generating source within each MU is either measured or estimated. The first year of the prediction period is 2001. An example of a contaminant-generating source is unpainted galvanised steel roofs. Subcatchments comprise one or more MUs
2. For every MU, new areas for each source are generated for years 2002 to 2100 according to trends. Trends for the majority of source areas are determined by fitting a curves to Auckland Regional Council (ARC) mid-range population projections. The exceptions are trends for motorways which are determined from MoT projections, and roofing materials which are based on market trends (Timperley and Reed, 2008a).
3. For each MU and each year, each source area is multiplied by a contaminant yield (g m^{-2} $year^{-1}$) to produce a corresponding annual contaminant load (g $year^{-1}$) for that source, MU and year. The derivation of contaminant yields is described by Timperley et al (2008).
4. In every MU, each annual contaminant load from each source is reduced according to (a) the efficiencies of stormwater treatment devices existing in 2001 and (b) the proportion of the MU area draining to those devices.
5. For MUs in which some stormwater is discharged to ground or is diverted to a combined system, the annual contaminant loads are reduced accordingly. The proportion of stormwater discharged to a combined system reduces over time according to a model user selected trend.
6. Source control of zinc in industrial areas is implemented, if required, in each MU by changing the contaminant yields for the source areas subject to zinc source control. For example, the reduction in the zinc load achieved by painting galvanised steel roofs is calculated in the model by replacing the zinc yield from that for unpainted roofs to that for painted roofs. The rate of implementation is varied by changing the area proportions over time according to a fixed trend parameter which achieves 50% zinc source control within 3 years and 90% within 10 years of the date of introduction of zinc source control measures.
7. In each MU new stormwater treatment is implemented if required by reducing the annual contaminant loads from each source according to (a) the efficiencies of the new stormwater treatment devices and (b) the proportion of the MU area draining

to the new devices. The rate of implementation is varied by changing the area proportions over time according to a fixed trend parameter which achieves 50% zinc source control within 10 years and 90% within 34 years of the date of introduction of new stormwater treatment measures.

8. For each MU and each contaminant, the annual loads from all sources are added to produce the annual contaminant load for that MU. The addition is performed after zinc source control of industrial areas and stormwater treatment are applied.
9. For every subcatchment and each contaminant, the annual loads from all MUs within the subcatchment are added to produce the annual load for that subcatchment. This load includes all sources in the subcatchment and has been adjusted for zinc source control of industrial areas and stormwater treatment.

3.2 Historical period (1940 – 2001)

Historical loads were calculated by running the CLM for the years 1940, 1959, 1996 and 2001.

Landuse information for years prior to 2001 is much less detailed than it is for 2001, which necessitated a somewhat simplified estimation of source areas. For example, road areas could not be calibrated against the Ministry of Transport vehicle fleet model (Timperley and Reed, 2008a).

The procedure for hindcasting the historical loads is as follows.

1. The total area of each MU was fixed at the 2001 value.
2. The areas of urban open space, residential, commercial and industrial landuse for the years 1940, 1959 and 1996 were extracted from aerial photographs and other GIS data by the Auckland Regional Council (ARC) and local councils (see Section 4.1).
3. Urban open space was added to residential pervious area after dividing the residential area into roofs, roads, paved and pervious surfaces, but before estimating areas of open stream channels.
4. Source areas in 2001 were derived as explained in the previous section.
5. The divisions of residential, commercial and industrial areas for the years 1940, 1959 and 1996 into roofs, roof materials, roads, road vehicle per day (vpd) categories, paved surfaces, pervious surfaces, stream channels, infill bare earth and other pervious surfaces were made according to a different set of area proportions for each of these three years. Details are given in Section 4.
6. Sediment and metal loads from infill bare earth were calculated using the same procedure that was used for 2001 and future years.
7. Sediment and metal loads from urban areas excluding vacant-land bare earth were calculated by multiplying source areas by source yields.

8. Sediment and metal loads for the years between 1940, 1959, 1996 and 2001 were calculated from smooth curves fitted to the loads hindcast for these four years.

9. Annual outfall loads were obtained by summing the loads for all MUs draining to the outfall.

10. Areas of bare earth on vacant-land subdivision and commercial/industrial construction sites in any year were estimated from the difference between the total urban areas in that year and in the previous year (Parshotam et al., 2008a). Note that this procedure is different from that used for years 2001 through 2100 (Timperley and Reed, 2008a).

11. Sediment loads for bare earth on vacant-land subdivision and commercial/industrial construction sites were derived using GLEAMS (Parshotam et al., 2008b). The reason for using this model rather than the CLM in this case is that for most MUs the areas of vacant-land bare earth prior to 2001 were much larger than they were in 2001 and will be in future years. GLEAMS produces more accurate estimates of bare-earth sediment loads than does the CLM. Bare-earth metal loads were estimated by multiplying sediment loads by natural metal concentrations (Timperley and Reed, 2008a).

4 Annual contaminant loads for 1940 to 2001

4.1 Source areas

In order to hindcast historic loads the CLM requires as input data the land area of residential, commercial, industrial, urban open space and motorways in each MU in the years 1940, 1959, 1996 and 2001. Rural land at each point in time is calculated as the balance of unaccounted for land within each MU.

Historical land use within the MUL was mapped at 1945, 1959, 1987 and 2001 by combining information from a number of GIS data layers (see also Parshotam et al., 2008a):

- LCDCB2 land cover database;
- Aerial photographs provided by ARC of all or part of the study area from 1959 and 2001; and
- Shapefiles provided by ARC of the extent of the urban area in 1945, 1987 and 2001.

Land use inside the MUL in 1940 was assumed to be the same as mapped land use in 1945 while that in 1996 was estimated by interpolation between 1987 and 2001 data.

Historical land use in urban zoned parts of Pukekohe was mapped from:

- LCDCB2 land cover database; and
- Aerial photographs provided by Franklin District Council (1942) and ARC (1968 and 2001).

The land use in Pukekohe in 1940 was assumed to be that present in the 1942 aerial photographs. Land use in 1959 and 1996 was estimated by interpolation between 1942, 1968 and 2001 data.

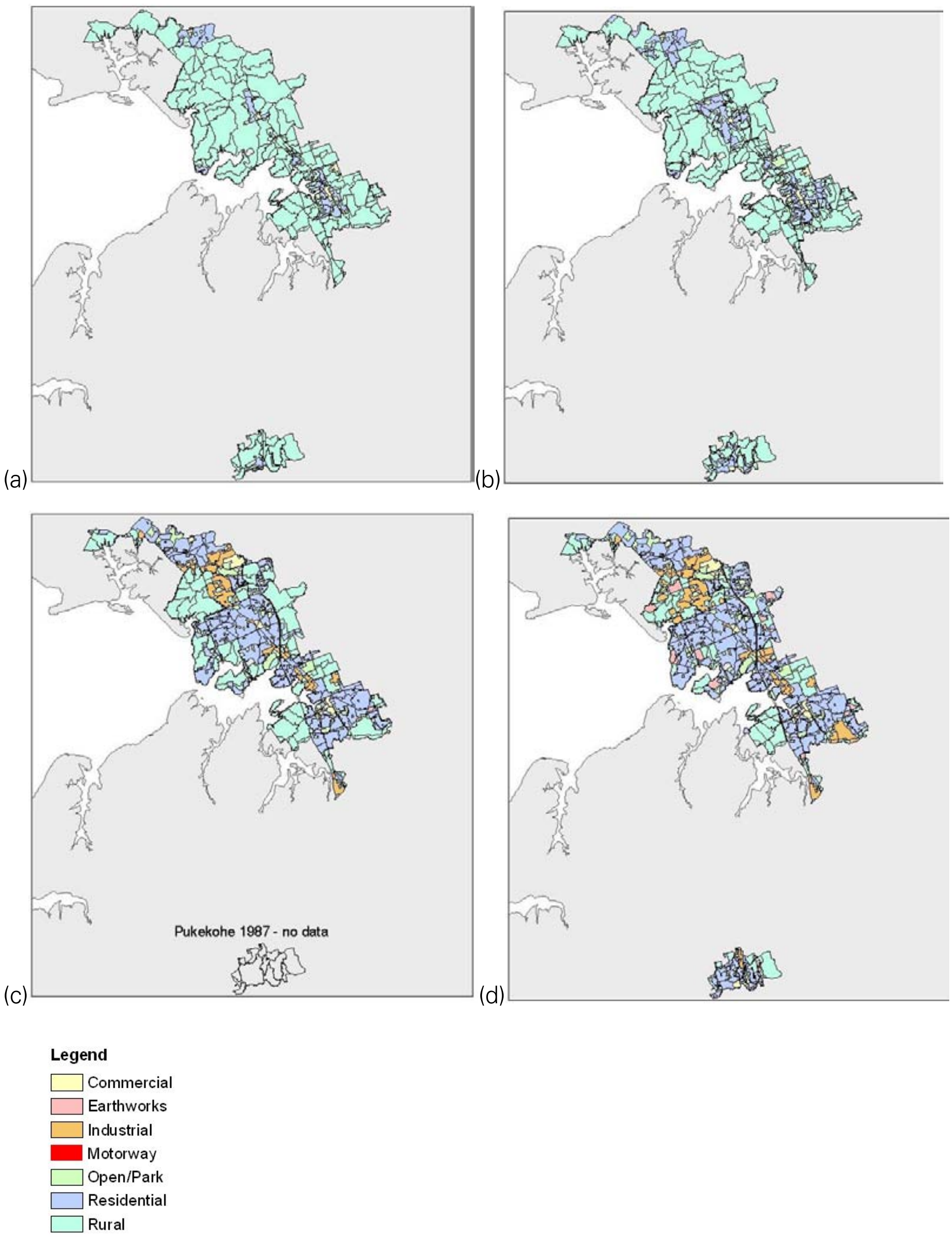
The mapped historic land use in each of the years 1945, 1959, 1987 and 2001 is shown in Figure 4-1. The estimated land use in each MU in the years 1940, 1959, 1996 and 2001 is detailed in Appendix 1.

4.2 Area Proportions

As described previously by Timperley and Reed (2008a), there have been no detailed analyses of the areas of roof materials, local roads, etc., in urban parts of the Auckland region for historic years. Hence, the area proportions for 1940 and 1959 are set at default values based on what are considered to be reasonable values from anecdotal knowledge of historic trends. Some of this knowledge derives from historic photographs. These show, for example, that galvanised roofs were the dominant roofing material in 1940, although some clay tiles were being used at that time and their use increased quite rapidly during the following decade. Similarly, there were apparently quite a lot of open stream channels used for stormwater conveyance in the years prior to the 1970s. Default area proportions assumed for the historical period are given in Appendix 2.

Figure 4-1

Land use within the area of the SE Manukau Harbour study catchment lying within the current MUL and urban-zoned land at Pukekohe in (a) 1945, (b) 1959, (c) 1987 and (d) 2001.



Information on the proportion of different sources (roofs, roads, paved surfaces etc) within residential, commercial and industrial land uses in 2001 was provided by Papakura District Council, GHD Limited and URS New Zealand Ltd (the latter two both on behalf of Manukau City Council). These proportions were used to distribute residential, commercial and industrial land use in each MU among different sources in both 1996 (historic model) and 2001 (historic and future models), although changes in the proportion of different road types between 1996 and 2001 was allowed for in proportion to CLM default fractions.

In the absence of other information, CLM default area proportions were used to distribute land use types between different source areas for all years in Pukekohe.

4.3 Source loads

An example of hindcast annual loads of TSS, total zinc and total copper is given in Figures 4-2, 4-3 and 4-4, respectively, for the urban area (excluding vacant-land subdivisions) in subcatchment 109 (Takanini). The dissolved forms of the metals have been distributed across the particulate fractions as described by Timperley and Reed (2008a). Smooth curves were fitted to the estimated loads in 1940, 1959, 1996 and 2001 in accordance with the approach adopted by Timperley and Reed (2008b).

For this outfall, the change in TSS reflects the expansion of the urban area throughout the period, with increasing imperviousness from the mid-1960s eventually leading to a reduction in the annual TSS load, reflecting the reduced availability of land for infill development .

The zinc load increases with increasing urbanisation because of extensive use of galvanised steel roofs. As explained in Timperley and Reed (2008a), almost all of the zinc and copper in roof runoff is in dissolved form, but this is assumed in the CLM to be attached to solids by the time the runoff reaches the outfalls. As also explained in Timperley and Reed (2008a), most of the zinc is attached to the finest particle size range because TSS in roof runoff originates mostly from atmospheric deposition.

The increasing trends for copper are driven almost entirely by increasing vehicle numbers over the period.

The TSS, total zinc and total copper loads for the 11 urban or part-urban outfalls to the South Eastern Manukau Harbour hindcast for the historical period are shown in Figures 4-5, 4-6 and 4-7.

The trends in TSS, zinc and copper are generally consistent with the size and different stages of urban development in the outfall catchments. The biggest loads are for outfall 112, which drains by far the largest subcatchment of the 11 outfalls (Papatoetoe / Puhinui). The hindcast loads rose throughout the hindcasting period in this subcatchment.

In subcatchments 108 (Papakura),109 (Takanini), 111 (Manurewa / Weymouth) and 113 (Mangere East / Papatoetoe) the TSS loads stablised or began to fall by the late 1980s/1990s as the rate of urban development in these catchments reduced.

The total zinc loads reflect the pattern of urban growth and the consequent increase in the area of galvanised steel roofs and vehicle numbers. The copper loads reflect the rapid increase in vehicle numbers since the late 1970s. The rate of increase in zinc and copper loads also slowed in the catchments experiencing a slow down in urban development. However, there was no decline in metal loads in any catchment reflecting the fact that, in the CLM, vehicle numbers continue to grow everywhere throughout the hindcasting period.

Figure 4-2:
Hindcast TSS loads for subcatchment 109 (Takanini).

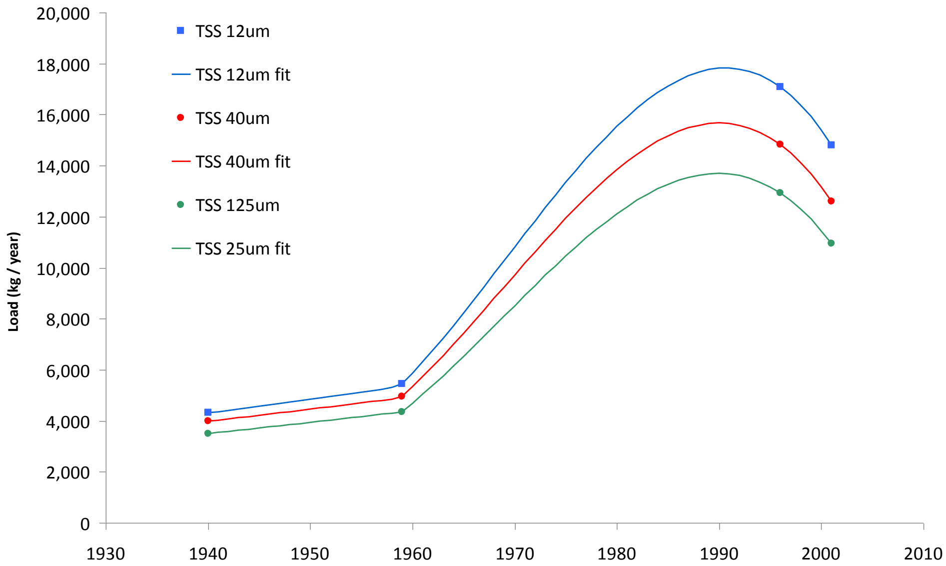


Figure 4-3:

Hindcast total zinc loads for subcatchment 109 (Takanini).

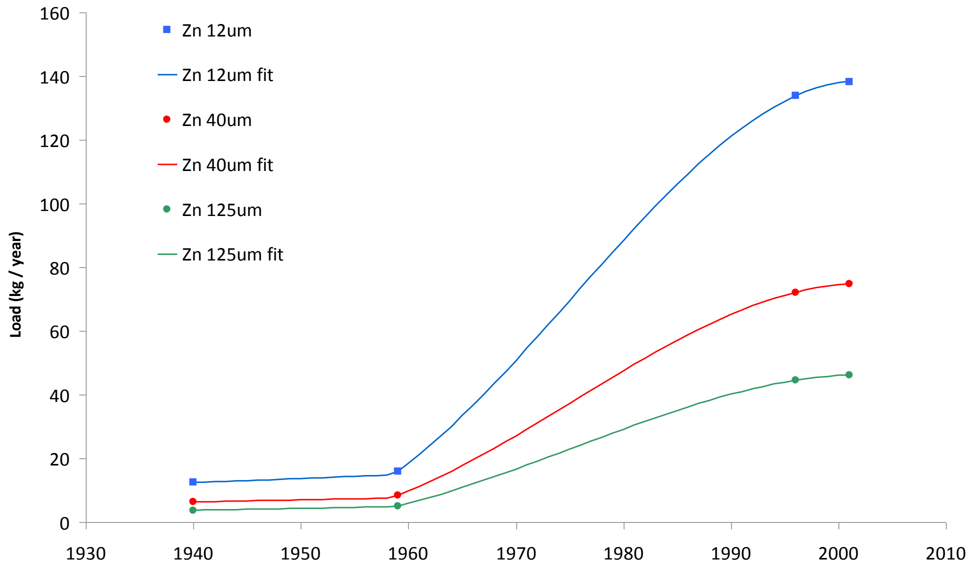


Figure 4-4:

Hindcast total copper loads for subcatchment 109 (Takanini).

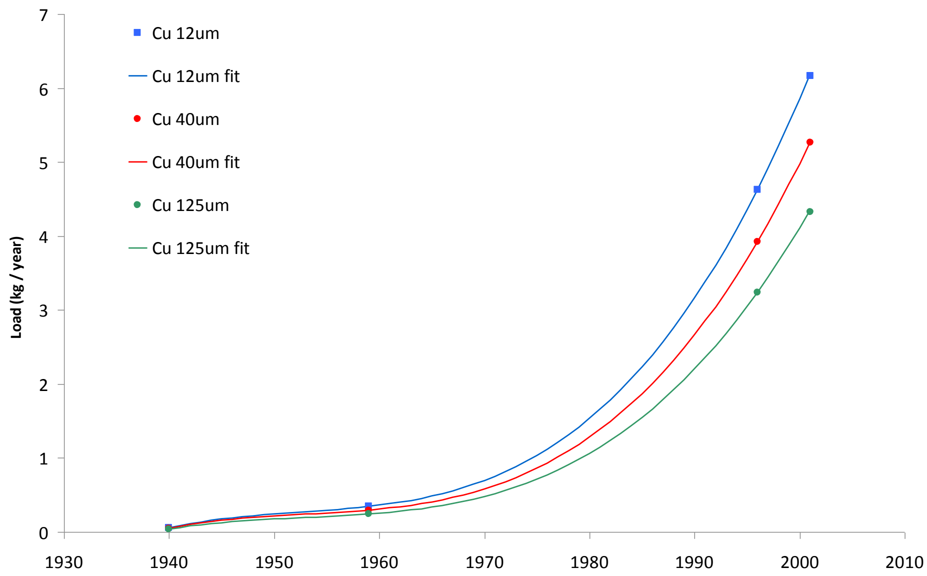


Figure 4-5:

Hindcast TSS loads for the 11 urban / part-urban outfalls to the South Eastern Manukau Harbour.

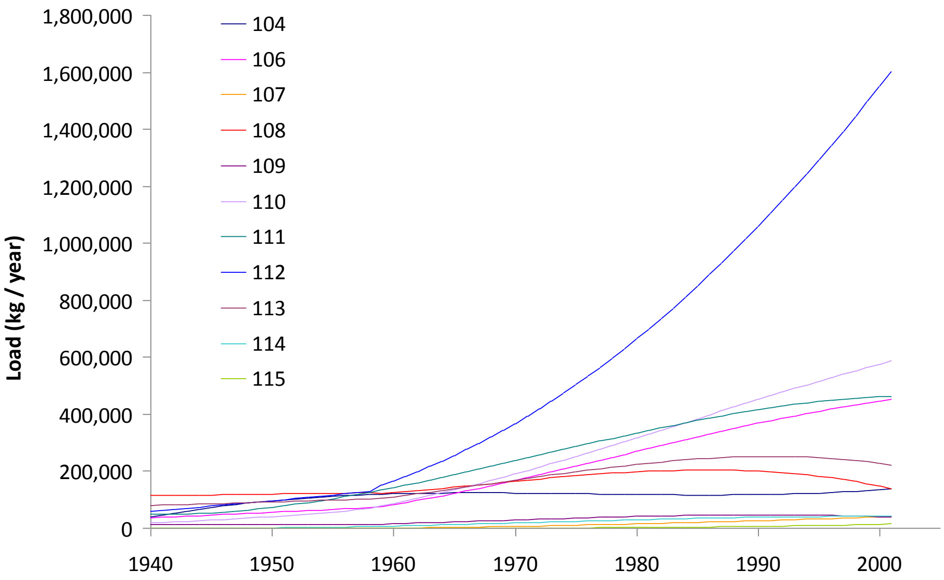


Figure 4-6:

Hindcast total zinc loads for the 11 urban / part-urban outfalls to the South Eastern Manukau Harbour.

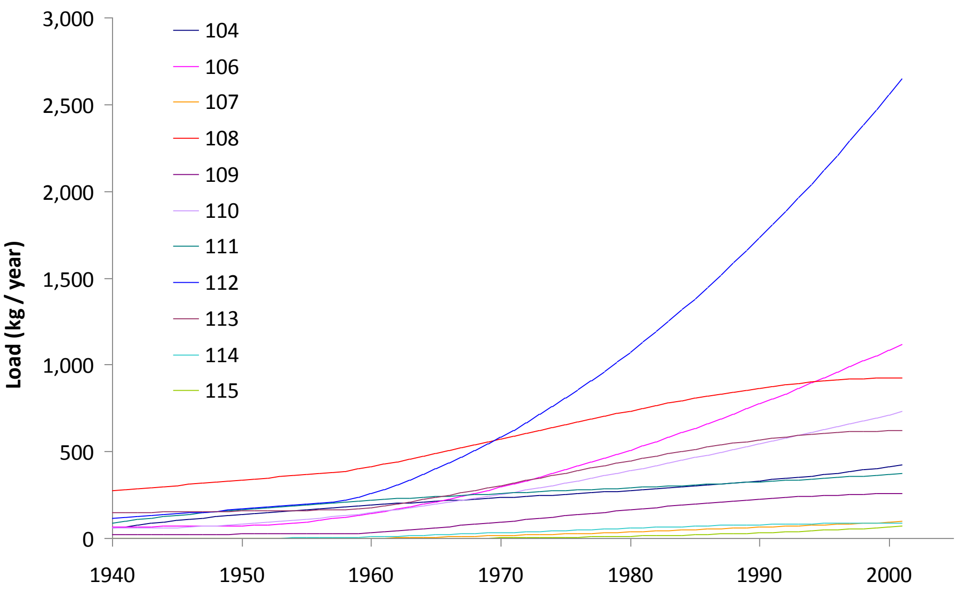
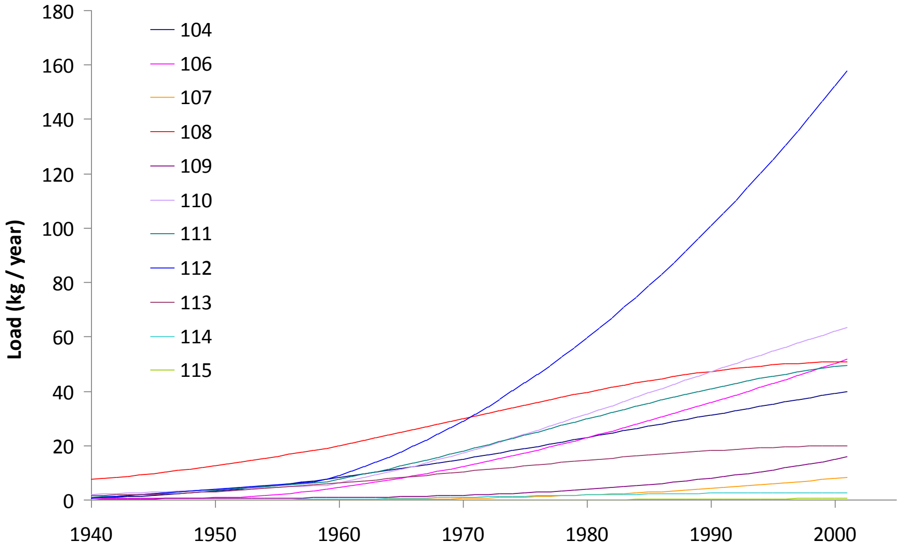


Figure 4-7:

Hindcast total copper loads for the 11 urban / part-urban outfalls to the South Eastern Manukau Harbour.



The cumulative loads for the 14 outfalls are shown in **Table 4-1**. The largest TSS, total zinc and total copper loads are for the catchments containing the greatest areas of urban development (remember that these loads do not include TSS and metals from vacant-land bare earth).

The metal/TSS load ratios provide a rough reality check on the loads. These ratios should be related, as explained below, to the metal concentrations measured on particulate matter carried in urban stormwater.

The hindcast ratios for zinc should be similar to the measured particulate concentrations in stormwater today because the proportions of galvanised steel roofs in urban areas has not changed greatly over the period 1940 to 1994.

The largest database of New Zealand stormwater quality is that collected by NIWA for Auckland City and Metrowater over the period 2001–2003. Stormwater was monitored in the network of eight subcatchments, five of which are predominantly residential. Just over 80% of the area of Auckland City is residential. The 10^{th},50^{th} and 90^{th} percentile concentrations of zinc on the TSS for the 757 samples collected from these five predominantly residential subcatchments were 578, 1,292 and 3,501 mg kg^{-1}, respectively. This compares with the median of 2,049 mg kg^{-1} and the range of 1,020–4,656 mg kg^{-1} hindcast for the outfalls.

Table 4-1:

Cumulative urban contaminant loads and metal/TSS load ratios hindcast for the period 1940–2001 and metal/TSS load ratios for 2001 for the 11 urban / part-urban outfalls to the South Eastern Manukau Harbour.

Outlet	Urban area (ha)	TSS (tonnes)	Zn (tonnes)	Cu (tonnes)	TZn/TSS		TCu/TSS	
					total period	2001	total period	2001
104 - Whangapouri Creek	616	6,905	14.7	1.06	2,136	3,059	154	288
106 - Drury Creek	776	12,524	25.2	1.08	2,008	2,483	87	115
107 - Hingaia	206	742	1.8	0.11	2,377	2,370	154	205
108 – Papakura	765	9,769	36.8	1.87	3,766	6,660	191	365
109 – Takanini	278	1,809	7.3	0.24	4,014	6,761	135	412
110 - Papakura Stream	882	14,647	19.0	1.47	1,299	1,243	100	108
111 - Manurewa / Weymouth	947	15,273	15.6	1.33	1,020	811	87	107
112 - Papatoetoe / Puhinui	2,381	33,611	54.9	2.98	1,633	1,651	89	98
113 - Mangere East / Papatoetoe	461	10,465	21.4	0.66	2,049	2,784	63	90
114 – Mangere	153	1,234	2.4	0.08	1,942	2,084	61	66
115 - Bottle Top Bay	177	187	0.9	0.01	4,656	4,656	44	44

Metal/TSS ratios calculated from loads estimated for representative residential, commercial and industrial catchments included in the Auckland City monitoring programme are 1,145, 4,438 and 15,720 mg kg^{-1} respectively (Timperley and Reed, 2005). The Zn/TSS ratios predicted here (see Table 4.1) are in reasonable agreement with these estimates, with relatively low Zn/TSS ratios in predominantly residential catchments (for instance Manurewa/Weymouth) and relatively high ratios in catchments with a high proportion of industrial land use (for instance Takanini). The estimated loads for 2001 are generally higher than that for the hindcasting period as a whole, reflecting the relatively greater increase in zinc loads compared to TSS resulting from urban development.

The agreement between the estimates presented here and these previous studies is close enough to confirm that the hindcast loads of TSS and zinc should be approximately correct. Both hindcast loads (i.e., TSS and zinc) could be proportionately too high or too low, of course, but given the different contributing sources of zinc and sediment, it is unlikely that this is the case.

The historical copper/TSS load ratios should be considerably lower than those measured in stormwater during the period 2001–2003 because of the much greater number of vehicles on the roads during recent times. (Vehicle brakes are considered to be the major source of copper in urban areas). As expected, for the 14 outfalls, the hindcast copper/TSS load ratios (median of 89 mg kg^{-1} and range of 44–191 mg kg^{-1}) are low compared to the 10^{th},50^{th} and 90^{th} percentiles for the measured concentrations of copper on stormwater TSS of 84, 198 and 405 mg kg^{-1}, while the estimates for 2001 (median of 108 mg kg^{-1} and range of 44–412 mg kg^{-1}) are in closer agreement with the measured concentrations.

5 Annual contaminant loads for 2001 to 2100

5.1 Source areas and area proportions

The calculation of land use areas for 2001 is explained in Section 4.1. As noted in Section 4.2, information on the areas of different sources within residential, commercial and industrial land uses in 2001 was provided by Papakura District Council and consultants for Manukau City Council (Papakura District Council, 2007; GHD, 2007a; GHD, 2007b; URS, 2007). These data were manipulated to estimate, for each MU:

- the fraction of residential, commercial and industrial areas occupied by roofs, roads, paved surfaces and pervious surfaces;
- the proportions of eight different categories of roofing material in residential, commercial and industrial areas;
- the proportions of four different categories of roads (based on the average number of vehicle per day) in residential, commercial and industrial areas; and
- the area of stream channels.

Default area proportions were used to distribute land use types between different source areas in Pukekohe. Source areas and other input parameters used in the CLM for each MU are given in Appendix 3.

5.2 Input parameters other than source areas

Table 5-1 lists the remaining input parameters together with their origins. The values of these input parametres for each MU are given in Appendix 3.

ARC provided GIS shapefiles of the areas of infill and vacant land available for development[4]. The area of these in each MU guided the setting of parameter values which split future population growth between the development of infill land, vacant land and apartments. In MUs with large areas of vacant land, up to 80% of future growth was allowed to occur by the development of vacant land.

The CLM estimates the growth of commercial and industrial land areas in relation to future population growth. The default commercial area growth rate of 5 m^2 $person^{-1}$ a^{-1} used by Timperley and Reed (2008b) was adopted for all MUs. Timperley and Reed (2008b) assumed no industrial growth. In the South Eastern Manukau Harbour study area industrial land is the predominant land use in a number of MUs and these MUs have relatively small or stable populations. In order to reflect the likelihood that future

[4] Vacant land is any parcel of land that contains no buildings and is zoned for residential or business activities. Infill (Vacant Potential) land is any parcel of land which is greater than 2,000m², has one or more residential buildings on it, but also has a portion of the land which is undeveloped or partially vacant.

urban development in these MUs will occur mainly through the expansion of the industrial area, it was necessary to allow for relatively high growth rates of up to 6000 m^2 $person^{-1}$ a^{-1} . Figure 5-1 provides an example of the way in which the use of a relatively high growth rate results in the prediction of industrial development in an MU despite only a moderate increase in population. Note that this approach is simply a mechanism for distributing likely future industrial development in those parts of the study area which already accommodate industrial activity. In contrast, the application of a uniform commercial growth rate reflects the likelihood of the development of local shops and services throughout the study area.

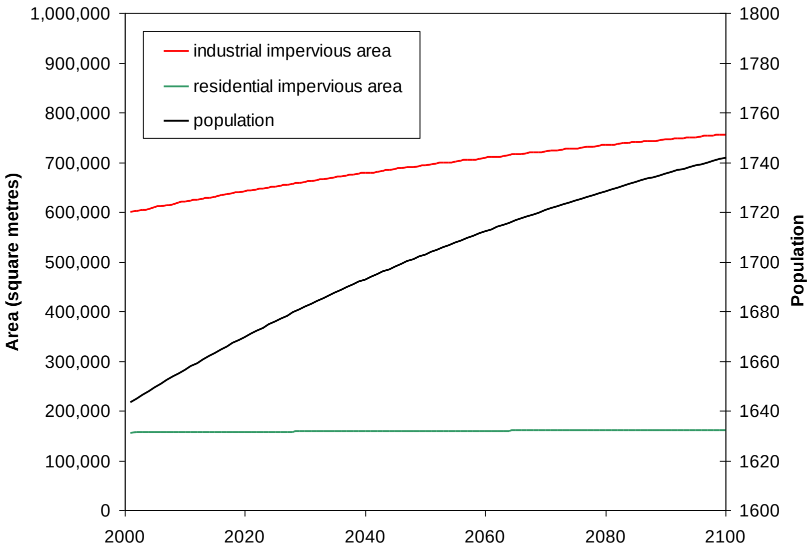
Table 5-1:

The origins of model input data other than source areas.

Parameter	Origin of data
Vacant and infill land available for development	**Auckland Regional Council**
GLEAMS bare-earth and grassland sediment yields (g m^{-2} a^{-1})	**Estimated from slope, soil properties and rainfall (Parshotam et al., 2008b)**
Natural soil Zn and Cu concentrations	**Values used by Timperley and Reed (2008b)[5]**
Area treated with wet ponds (ha)	**Auckland Regional Council, Papakura District Council**
Population projections	**Social and Economic Office, Auckland Regional Council**

Figure 5-1

Predicted changes in industrial and residential impervious surfaces in relation to population growth, model unit 43.



[5] Concentrations of 35 mg kg^{-1} Zn and 7 mg kg^{-1} Cu are consistent with concentrations at the base of sediment cores taken in the study area (Reed et al., 2008).

Available information on existing stormwater treatment was limited to wet ponds. Papakura DC provided information on the location of ponds, their catchment areas and an estimate of their efficiency. For the remainder of the study area, the locations of stormwater ponds were determined from ARC consent records, ARC shapefiles of ponds and dams and aerial photographs. A maximum pond efficiency of 75% TSS removal was assumed (consistent with Timperley and Reed, 2008b), with lower values adopted where there was evidence suggesting that a pond had not been specifically designed as a stormwater quality treatment device.

Other parameters which can be varied in the CLM include the area draining to soakage (i.e. to groundwater rather than to the reticulated pipe network) and combined stormwater/wastewater pipe networks. The TAs were unable to provide any quantitative data on these areas and indicated anecdotally that they represent, at most, only a small part of the total stormwater drainage system. For the purposes of this study the area of each MU draining to soakage or a combined system was assumed to be zero.

5.3 Scenarios modelled

Four scenarios, all with the same future projections of source areas but differing by zinc source control of industrial areas and/or additional stormwater treatment, were modelled. Details of the scenarios are given in Table 5-2. These are identical to the scenarios modelled in the Central Waitemata Harbour study (Timperley and Reed, 2008b).

5.4 Future trend parameters

Timperley and Reed (2008a) describe the way in which the CLM models changes in source areas over time. The change in the fraction of a particular source area is modelled as:

$$\text{Fraction}_{\text{year } i} = (\text{Fraction}_{\text{year } i\text{-}1} + A) \times (1\text{-}B)$$

where year i starts at 2002. Values of A and B used in the CLM for the future period 2002–2100 are given in Appendix 4. Population trends are fits to population projections derived from modelling (Social and Economic Office, ARC).

In some parts of the study area population is projected to fall. For the purposes of running the CLM, no change in population was assumed in these cases. Running the model with negative population growth results in a decrease in the area of impervious surfaces and a corresponding increase in the area of pervious surfaces, for instance representing the replacement of residential buildings by grassland. In reality, a gradual population decline is unlikely to result in the loss of built land. More likely is a reduction in the average number of persons per household, an associated fall in population density and stagnation in land use. Running the CLM with a zero population change results in no change in the area of most contaminant sources (although see Section 5.5) which is consistent with the likely outcome of population decline.

Table 5-2:

Details of the scenarios modelled.

Scenario	Zinc source control	Stormwater treatment
1	**None.**	**1. Local roads and motorways to catchpits, no change over time.** **2. Residential, industrial and commercial paved areas to catchpits, no change over time.** **3. Residential, industrial and commercial pervious areas to catchpits, no change over time.** **4. Residential bare earth to catchpits, no change over time.** **5. Commercial and industrial construction site bare earth to wet ponds, no change over time.** **6. Specific installed devices (Appendix 3), no change over time.**
2	**1. Painting of industrial unpainted and poorly painted galvanised roofs, starting in 2010, 50% complete in 3 years, 90% complete in 10 years.**	**1. As for Scenario 1.**
3	**None.**	**1. As for Scenario 1 except as changed below.** **2. Roads >20,000 vpd to raingardens, starting in 2010, 50% complete in 10 years, 90% complete in 34 years.** **3. Residential construction site bare earth to hay bales/silt fences starting in 2010, 50% complete in 10 years, 90% complete in 34 years.** **4. Industrial paved areas to raingardens/multimedia filters, starting in 2010, 50% complete in 10 years, 90% complete in 34 years.** **5. 20% of all MU stormwater to pond/wetland systems, starting in 2010, 50% complete in 10 years, 90% complete in 34 years.**
4	**As for Scenario 2.**	**As for Scenario 3.**

5.5 Annual outfall loads

The annual loads for the 11 outfall subcatchments predicted for the future period 2001–2100 under each of the 4 scenarios are shown in Appendix 5.

General comments on the predictions follow.

1. TSS.

   Source control of industrial areas for zinc has no effect on TSS loads and therefore the TSS loads for Scenarios 1 and 2 are the same, and likewise loads for Scenarios 3 and 4 are the same. Most outfall subcatchments show steadily decreasing TSS loads because of the increasing proportions of impervious surface resulting from increasing areas of urban development.

However, there are a number of exceptions to this. Sediment loads from subcatchments 107 (Hingaia), 108 (Papakura) and 109 (Takanini) increase slightly over the prediction period. These catchments each contain areas of stable population and, in the CLM, this contributes to an increase in TSS loads in the following way. Even with an unchanging population, the model predicts a change in the distribution of road types, with an increase in the total area of roads carrying >5,000 vpd and motorways carrying >100,000 vpd and a decrease in the total area of roads and motorways carrying lesser traffic volumes. This is not unreasonable: MUs are relatively small areas and likely to be subject to growth in the volumes of through-traffic from neighbouring MUs experiencing population growth.

In the model, TSS yields from busy roads and motorways are higher than those from lesser roads. As a result, the increased load from busy roads is greater than the load reduction from lesser roads and this gives a net increase in TSS over the prediction period. This increase in TSS loads from roads is actually predicted in all MUs but in most cases is less than the reduction in TSS from other sources (bare earth, grassland etc) giving a net reduction in total TSS. This is not the case in those MUs with stable population because, with no population growth, there is no change in the area of other sediment source areas.

Sediment loads from subcatchment 115 (Bottle Top Bay) first decrease, as a result of the development of vacant grassland which constitutes most of the catchment at the start of the prediction period, and then gradually increase from around 2040. This increase is again the result of the change in the distribution of road types.

Sediment loads from subcatchment 114 (Mangere) fall gradually until around 2050 at which point there is a much more marked reduction in loads. This corresponds with the time at which all vacant land in the subcatchment has been consumed, such that the discharge of sediment from vacant bare earth ceases.

2. Total zinc

The general trend in the zinc loads is a decrease over the next 15 to 20 years as existing galvanised roofs are replaced, followed by a slow increase as vehicles become the dominant source of zinc. The extent of the decrease relative to the later increase depends on the balance between the existing areas of galvanised roofs and the projected future vehicle use. Examples of subcatchments in which there is a relatively large initial fall in zinc loads are 106 (Drury Creek), 108 (Papakura), 109 (Takanini), 112 (Papatoetoe / Puhinui) and 113 (Mangere East/Papatoetoe). Each of these subcatchments contain large areas of industrial and/or commercial land, with substantial areas of galvanised roofs in these areas. The subsequent increase in zinc loads (relative to the initial fall) is most noticeable in catchments 107 (Hingaia), 111

(Manurewa / Weymouth) and 115 (Bottle Top Bay). These subcatchments comprise mainly residential or vacant land at the start of the prediction period, containing only small areas of galvanised roofs.

3. Total copper.

   The trends in future copper loads are generally similar for all subcatchments. Variations in the trends depend on the areas of high-use roads and motorways and of commercial areas which contain the major areas of copper roofs.

   There is a marked change in rate at which copper loads increase in subcatchment 114 (Mangere). This corresponds with the point at which all vacant land is consumed (noted in relation to TSS, above) resulting in a reduction in the rate at which the total area of roads grows. A change in the rate of increase in zinc loads also occurs at this point in time.

5.6 Effectiveness of zinc source control and stormwater treatment

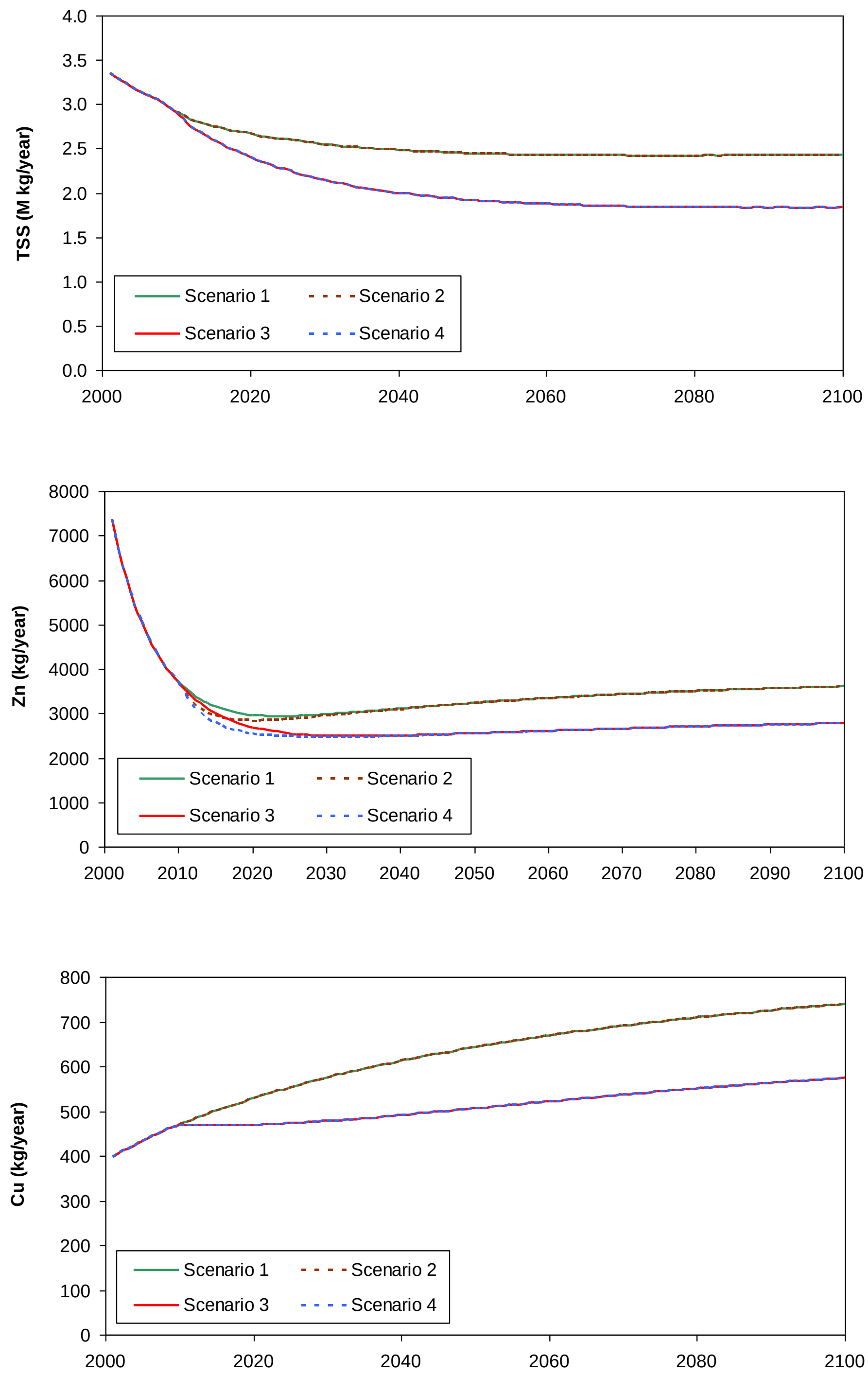
The predicted combined TSS, total zinc and total copper loads to the South Eastern Manukau Harbour are shown in Figure 5-2. Two key conclusions follow.

1. Source control of zinc applied to industrial galvanised roofs will achieve a very small reduction in zinc loads (maximum of 7% in any year) over a period of 15 years between 2010 and 2025. This is also true at the scale of the indivdual subcatchment, even in those subcatchments with relatively large areas of industrial land use. The largest reduction in annual zinc loads due to zinc source control is 11% in the years 2014 and 2015 in subcatchment 112 (Papatoetoe / Puhinui). The total reduction in zinc dervied from the study areas as whole due to zinc source control of industrial areas is 2,561 kg out of a total of 347,525 kg over the 100 year simulation period.
2. Additional stormwater treatment (incorporating any existing devices) will achieve reductions of 25, 23 and 22% in the TSS, total zinc and total copper loads, respectively, by 2100. For all three contaminants the reductions are achieved almost entirely by bottom-of-catchment pond/wetland systems installed to treat 20% of the total stormwater discharge from each catchment. On an individual subcatchment basis, load reductions due to stormwater treatment are in the ranges 20-39% (TSS), 16-28% (Zn) and 17-28% (Cu).

There are three reasons for the very small reductions in zinc loads achieved by zinc source control. Firstly, control is applied only to industrial galvanised roofs. Secondly, industrial land use constitutes a relatively small proportion of total urban land use (11.5%). Thirdly, industrial galvanised roofs that are mostly unpainted are assumed to be substantially replaced by 2025.

Figure 5-2:

Predicted combined (all outfalls) urban derived TSS, total zinc and total copper loads to the South Eastern Manukau Harbour.



Of all the additional methods of treatment assumed for Scenarios 3 and 4, only the bottom-of-MU pond/wetland systems would trap TSS from urban pervious surfaces (these contribute the largest proportion of urban-derived TSS), zinc from roofs (roof runoff is not required to be treated on-site) and zinc and copper from local roads <20000 vpd. Although these roads carry relatively low vehicle numbers, there are far greater areas of these roads than there are of higher-use roads, and in addition catchpits (which are the only on-site treatment assumed for roads <20,000 vpd) capture only about 11% and 15% of the zinc and copper throughput.

6 References

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7 Appendix 1

7.1 Source area data for 1940

Model Unit	Outlet subcatchment	TA	Area (square metres)						
			Total SMU area	Residential	Commercial	Industrial	Urban Open Space	Motorways	Rural
1	114	Manukau	1525268	0	0	0	0	0	1525268
2	113	Manukau	2982820	999629	55889	0	64395	0	1862907
3	113	Manukau	1621129	38196	0	0	0	0	1582933
4	112	Manukau	1260089	0	0	0	0	0	1260089
5	112	Manukau	2240652	0	0	0	0	0	2240652
6	112	Manukau	4255749	15846	0	0	0	0	4239903
7	112	Manukau	2401645	0	0	0	0	0	2401645
8	112	Manukau	2062837	719351	0	0	17315	0	1326171
9	112	Manukau	3951123	0	0	0	0	0	3951123
10	112	Manukau	1219079	179202	0	0	11491	0	1028386
11	112	Manukau	2177281	0	0	0	0	0	2177281
12	112	Manukau	3215419	0	0	0	0	0	3215419
13	112	Manukau	983289	0	0	0	0	0	983289
14	111	Manukau	2671794	0	0	0	0	0	2671794
15	111	Manukau	4798631	431256	18706	4719	30549	0	4313401
16	111	Manukau	993152	0	0	0	0	0	993152
17	111	Manukau	996984	219615	0	0	0	0	777370
18	110	Manukau	2112791	0	0	0	0	0	2112791
19	110	Manukau	758310	0	0	0	0	0	758310
20	110	Manukau	2355507	129448	74707	8351	4622	0	2138379
21	110	Manukau	398972	0	0	0	0	0	398972
22	110	Papakura	522783	36500	0	0	0	0	486283
23	110	Papakura	926531	44334	0	22609	0	0	859588
24	110	Papakura	707591	315	0	0	0	0	707276
25	110	Papakura	1023399	0	0	0	0	0	1023399
26	109	Papakura	1561262	74	0	0	0	0	1561188
27	109	Papakura	333103	0	0	0	0	0	333103
28	109	Papakura	878253	182425	0	0	524	0	695305
29	108	Papakura	2190855	155187	43707	1304	80107	0	1910550
30	108	Papakura	1202707	417378	0	24132	0	0	761196
31	108	Papakura	1367776	541274	228395	0	143196	0	454911
32	108	Papakura	601140	249748	0	0	14225	0	337166
33	108	Papakura	893743	16890	0	0	7212	0	869641
34	108	Papakura	607706	0	0	10975	0	0	596731
35	108	Papakura	779471	0	0	0	0	0	779471
36	115	Papakura	1767991	0	0	0	0	0	1767991
37	107	Papakura	1134208	0	0	0	0	0	1134208
38	107	Papakura	925924	1089	0	0	0	0	924834
39	106	Papakura	752072	0	0	9387	0	0	742685
40	106	Papakura	1269924	0	0	0	0	0	1269924
41	106	Papakura	1001816	131987	0	1636	63748	0	804444
42	106	Papakura	1730633	268347	0	0	29174	0	1433112
43	106	Papakura	1854847	966	0	0	0	0	1853881
44	106	Papakura	1161430	0	0	0	0	0	1161430
45	104	Franklin	2479438	285592	24116	0	0	0	2169731
46	104	Franklin	1614196	151031	0	0	0	0	1463166
47	104	Franklin	1096666	0	0	0	0	0	1096666
48	104	Franklin	967614	0	0	0	0	0	967614

7.2 Source area data for 1959

Model Unit	Outlet subcatchment	TA	Area (square metres) Total SMU area	Residential	Commercial	Industrial	Urban Open Space	Motorways	Rural
1	114	Manukau	1525268	69601	0	0	0	0	1455667
2	113	Manukau	2982820	1267612	55889	0	64395	0	1594925
3	113	Manukau	1621129	180841	0	0	47	0	1440241
4	112	Manukau	1260089	0	0	0	0	0	1260089
5	112	Manukau	2240652	44921	0	0	0	0	2195730
6	112	Manukau	4255749	197851	0	359	21	0	4057518
7	112	Manukau	2401645	0	0	0	0	0	2401645
8	112	Manukau	2062837	1337401	0	0	17634	0	707803
9	112	Manukau	3951123	96550	0	0	0	0	3854573
10	112	Manukau	1219079	349953	0	0	11491	0	857635
11	112	Manukau	2177281	0	0	0	0	0	2177281
12	112	Manukau	3215419	82932	0	0	0	0	3132487
13	112	Manukau	983289	0	0	0	0	0	983289
14	111	Manukau	2671794	11768	0	0	0	0	2660026
15	111	Manukau	4798631	1561137	18706	11922	131922	0	3074945
16	111	Manukau	993152	0	0	0	0	0	993152
17	111	Manukau	996984	260158	0	0	21	0	736805
18	110	Manukau	2112791	7606	0	0	0	0	2105185
19	110	Manukau	758310	0	0	0	0	0	758310
20	110	Manukau	2355507	883838	76227	8351	35771	0	1351319
21	110	Manukau	398972	3609	0	0	0	0	395362
22	110	Papakura	522783	64091	0	0	0	0	458692
23	110	Papakura	926531	51116	0	22609	0	0	852806
24	110	Papakura	707591	315	0	0	0	0	707276
25	110	Papakura	1023399	0	0	0	0	0	1023399
26	109	Papakura	1561262	1262	0	0	0	0	1560000
27	109	Papakura	333103	0	0	0	0	0	333103
28	109	Papakura	878253	234660	0	8543	1149	0	633901
29	108	Papakura	2190855	649675	271285	15505	80107	0	1174282
30	108	Papakura	1202707	423965	0	26440	0	0	752302
31	108	Papakura	1367776	602078	228395	0	143196	0	394107
32	108	Papakura	601140	259498	0	0	14225	0	327417
33	108	Papakura	893743	16890	0	0	7212	0	869641
34	108	Papakura	607706	3102	0	38978	0	0	565626
35	108	Papakura	779471	0	0	0	0	0	779471
36	115	Papakura	1767991	0	0	0	0	0	1767991
37	107	Papakura	1134208	0	0	0	0	0	1134208
38	107	Papakura	925924	1089	0	0	0	0	924834
39	106	Papakura	752072	68242	0	10959	0	0	672870
40	106	Papakura	1269924	0	0	0	0	0	1269924
41	106	Papakura	1001816	283492	0	15336	63809	0	639179
42	106	Papakura	1730633	449341	0	0	29174	0	1252118
43	106	Papakura	1854847	966	0	0	0	0	1853881
44	106	Papakura	1161430	242333	0	0	0	0	919097
45	104	Franklin	2479438	1123909	75470	0	58403	0	1221656
46	104	Franklin	1614196	343236	68061	0	0	0	1202899
47	104	Franklin	1096666	0	0	0	0	0	1096666
48	104	Franklin	967614	28890	0	0	0	0	938724

7.3 Source area data for 1996

Model Unit	Outlet subcatchment	TA	Area (square metres)						
			Total SMU area	Residential	Commercial	Industrial	Urban Open Space	Motorways	Rural
1	114	Manukau	1525268	629899	47319	168846	3294	0	675911
2	113	Manukau	2982820	2303121	84506	0	595193	0	0
3	113	Manukau	1621129	986749	0	148875	181881	0	303623
4	112	Manukau	1260089	689906	25812	0	92229	0	452142
5	112	Manukau	2240652	44426	0	1555147	259168	0	381911
6	112	Manukau	4255749	456930	0	998847	277667	0	2522304
7	112	Manukau	2401645	358468	744399	544931	711933	9553	32362
8	112	Manukau	2062837	1347522	0	547178	143903	0	24233
9	112	Manukau	3951123	1352115	18327	419871	92672	0	2068137
10	112	Manukau	1219079	552539	1030	85136	26956	0	553419
11	112	Manukau	2177281	966127	26474	0	259148	24491	901040
12	112	Manukau	3215419	1263658	28722	0	1257470	42072	623496
13	112	Manukau	983289	470762	0	0	66047	0	446480
14	111	Manukau	2671794	1704202	25544	17680	117990	0	806378
15	111	Manukau	4798631	3591060	93066	83340	475952	0	555213
16	111	Manukau	993152	164456	0	0	43585	0	785111
17	111	Manukau	996984	833027	0	0	46189	0	117767
18	110	Manukau	2112791	885537	0	4775	29456	19135	1173887
19	110	Manukau	758310	421711	0	0	90135	0	246464
20	110	Manukau	2355507	1780164	114618	215133	219750	12678	13163
21	110	Manukau	398972	210051	0	25829	92539	0	70553
22	110	Papakura	522783	417902	0	0	35825	0	69055
23	110	Papakura	926531	169731	0	154525	557355	13263	31657
24	110	Papakura	707591	21841	0	334129	0	0	351621
25	110	Papakura	1023399	715787	11360	0	155095	18537	122620
26	109	Papakura	1561262	57267	0	0	0	0	1503995
27	109	Papakura	333103	308172	0	0	11653	4888	8390
28	109	Papakura	878253	505025	0	286797	43414	7843	35174
29	108	Papakura	2190855	1224531	867995	0	75993	0	22335
30	108	Papakura	1202707	678478	4212	85273	56139	0	378605
31	108	Papakura	1367776	759081	392610	19963	170622	0	25500
32	108	Papakura	601140	395587	19986	0	185567	0	0
33	108	Papakura	893743	727056	7570	0	48894	23857	86365
34	108	Papakura	607706	152026	0	246499	48379	9019	151782
35	108	Papakura	779471	9750	0	0	0	0	769721
36	115	Papakura	1767991	70371	0	0	0	0	1697620
37	107	Papakura	1134208	7413	0	22659	0	12863	1091273
38	107	Papakura	925924	670369	18677	0	59969	1716	175193
39	106	Papakura	752072	103497	1338	401540	62907	0	182790
40	106	Papakura	1269924	688193	0	0	35209	0	546522
41	106	Papakura	1001816	740413	0	46979	214423	0	0
42	106	Papakura	1730633	1341125	14646	5969	78777	0	290115
43	106	Papakura	1854847	255009	0	730745	65019	0	804074
44	106	Papakura	1161430	1092698	0	0	24143	0	44589
45	104	Franklin	2479438	1715633	149870	91437	135782	0	386717
46	104	Franklin	1614196	657509	144384	0	163415	0	648888
47	104	Franklin	1096666	0	0	0	0	0	1096666
48	104	Franklin	967614	234120	0	92085	10339	0	631071

7.4 Source area data for 2001

Model Unit	Outlet subcatchment	TA	Area (square metres) Total SMU area	Residential	Commercial	Industrial	Urban Open Space	Motorways	Rural
1	114	Manukau	1525268	630918	47319	168846	5123	0	673062
2	113	Manukau	2982820	2303121	84506	0	595193	0	0
3	113	Manukau	1621129	996007	0	174270	185301	0	265551
4	112	Manukau	1260089	840021	40151	0	123398	0	256519
5	112	Manukau	2240652	44426	0	1584113	259168	0	352944
6	112	Manukau	4255749	457568	0	1202234	336102	0	2259844
7	112	Manukau	2401645	357592	746620	544931	711933	9553	31016
8	112	Manukau	2062837	1371755	0	547178	143902	0	0
9	112	Manukau	3951123	1385625	18328	712096	94557	0	1740517
10	112	Manukau	1219079	552434	1030	109252	26956	0	529406
11	112	Manukau	2177281	1185521	40832	0	319496	24492	606940
12	112	Manukau	3215419	1774881	28722	0	1257470	42073	112272
13	112	Manukau	983289	630941	0	0	83991	0	268356
14	111	Manukau	2671794	1806146	25674	27502	118166	0	694306
15	111	Manukau	4798631	3688070	93066	83340	517252	0	416903
16	111	Manukau	993152	205804	0	0	67662	0	719686
17	111	Manukau	996984	870306	0	0	50815	0	75863
18	110	Manukau	2112791	1191661	0	7428	35496	19136	859069
19	110	Manukau	758310	446179	0	0	126445	0	185685
20	110	Manukau	2355507	1793326	114618	215133	219750	12679	0
21	110	Manukau	398972	248625	0	25829	124518	0	0
22	110	Papakura	522783	462214	0	0	35825	0	24743
23	110	Papakura	926531	179568	0	158734	574965	13263	0
24	110	Papakura	707591	31050	0	451874	0	0	224667
25	110	Papakura	1023399	802467	11360	0	191035	18537	0
26	109	Papakura	1561262	57266	305000	0	0	0	1198995
27	109	Papakura	333103	315878	0	0	12337	4888	0
28	109	Papakura	878253	535402	0	286797	48210	7843	0
29	108	Papakura	2190855	1246866	867995	0	75993	0	0
30	108	Papakura	1202707	685452	4212	85273	59013	0	368756
31	108	Papakura	1367776	784581	392610	19963	170622	0	0
32	108	Papakura	601140	395587	19986	0	185567	0	0
33	108	Papakura	893743	781586	7570	0	48894	23857	31835
34	108	Papakura	607706	173934	0	248472	75257	9019	101024
35	108	Papakura	779471	9750	0	0	0	0	769721
36	115	Papakura	1767991	97681	0	0	0	0	1670310
37	107	Papakura	1134208	10542	52938	22659	0	12863	1035205
38	107	Papakura	925924	790014	29053	0	59969	1716	45172
39	106	Papakura	752072	144159	1703	401540	62907	0	141762
40	106	Papakura	1269924	937275	0	0	49586	0	283060
41	106	Papakura	1001816	740413	0	46979	214423	0	0
42	106	Papakura	1730633	1420601	14658	5970	78777	0	210626
43	106	Papakura	1854847	280184	0	1133238	91488	0	349937
44	106	Papakura	1161430	1135956	0	0	25474	0	0
45	104	Franklin	2479438	1821143	163156	107765	149599	0	237774
46	104	Franklin	1614196	713395	158013	0	192597	0	550190
47	104	Franklin	1096666	0	0	0	0	0	1096666
48	104	Franklin	967614	270713	0	108529	12185	0	576188

8 Appendix 2

8.1 Source area proportions assumed for years 1940, 1959 and 1996.

		1940			1959			1996		
Motorways	>100,000vpd	0.00			0.00			0.95		
	50,000-100,000vpd	1.00			1.00			0.05		
		residential	commercial	industrial	residential	commercial	industrial	residential	commercial	industrial
Roofs		0.100	0.200	0.200	0.120	0.220	0.220	0.150	0.250	0.250
Local roads		0.100	0.200	0.200	0.110	0.220	0.220	0.130	0.240	0.240
Paved		0.000	0.200	0.200	0.050	0.220	0.220	0.110	0.270	0.270
Pervious		0.800	0.400	0.400	0.720	0.340	0.340	0.610	0.240	0.240
Roof materials	Unpainted galvanised steel	0.400	0.400	0.900	0.200	0.200	0.900	0.100	0.120	0.870
	Poorly painted galvanised steel	0.200	0.200	0.100	0.200	0.200	0.100	0.150	0.200	0.041
	Well painted galvanised steel	0.100	0.100	0.000	0.100	0.100	0.000	0.080	0.090	0.019
	Coated galvanised steel	0.000	0.000	0.000	0.100	0.100	0.000	0.100	0.070	0.000
	Zinc-aluminium surfaced steel	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.040	0.000
	Coated zinc-aluminium surfaced steel	0.000	0.000	0.000	0.000	0.000	0.000	0.080	0.100	0.020
	Copper	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.000
	Other materials	0.300	0.300	0.000	0.400	0.400	0.000	0.484	0.375	0.050
Local roads	<1000vpd	0.900	0.800	0.800	0.700	0.600	0.600	0.500	0.300	0.300
	1000-5000vpd	0.100	0.200	0.200	0.200	0.300	0.300	0.400	0.400	0.400
	5000-20000vpd	0.000	0.000	0.000	0.100	0.100	0.100	0.100	0.300	0.300
	20000-50000vpd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pervious	Stream channels	0.010	0.010	0.010	0.010	0.010	0.010	0.007	0.005	0.005
	Bare earth (infill only)	0.000	n/a	n/a	0.000	n/a	n/a	0.010	n/a	n/a
	Other pervious	0.990	0.990	0.990	0.990	0.990	0.990	0.983	0.995	0.995

Note: 1940 and 1959 data apply to all MUs. 1996 data apply to Pukekohe MUs only. For all other MUs, 1996 proportions are as 2001 (see Appendix 3)

9 Appendix 3

9.1 Source area and other input data for 2001

Key for roof types

UG	Unpainted galvanised steel
PG	Poorly painted galvanised steel
WG	Well painted galvanised steel
CG	Coated galvanised steel
UZ	Zinc-aluminium surfaced steel
CZ	Coated zinc-aluminium surfaced steel
CU	Copper
OT	Other materials

Model Unit	Outlet subcatchment	TA	Area (square metres)											
			Total SMU area	Rural trees	Rural pasture	Motorways	Urban area	Urban Open Space	Urban built up area	Residential area inc. open space	Commercial area inc. open space	Industrial area inc. open space	Vacant area	Infill area
1	114	Manukau	1525268	16430	0	0	1508838	5123	1503715	1292673	47319	168846	977856	25664
2	113	Manukau	2982820	0	0	0	2982820	595193	2387627	2876657	106162	0	92127	161263
3	113	Manukau	1621129	25000	240912	0	1355217	185301	1169916	1180946	0	174270	205261	62679
4	112	Manukau	1260089	0	256267	0	1003822	123398	880424	963671	40151	0	91442	7676
5	112	Manukau	2240652	0	0	0	2240652	259168	1981484	561056	0	1679595	398824	4001
6	112	Manukau	4255749	0	0	0	4255749	336102	3919647	2883370	0	1372378	1616038	43968
7	112	Manukau	2401645	0	38700	9553	2353392	711933	1641460	268669	1539791	544931	152736	3771
8	112	Manukau	2062837	0	0	0	2062837	143902	1918935	1478317	0	584519	95736	135019
9	112	Manukau	3951123	0	0	0	3951123	94557	3856566	3220699	18328	712096	1207100	38267
10	112	Manukau	1219079	0	529406	0	689673	26956	662717	579391	1030	109252	42805	33222
11	112	Manukau	2177281	0	606941	24492	1545849	319496	1226352	1505016	40832	0	330104	19417
12	112	Manukau	3215419	0	112272	42073	3061074	1257470	1803604	3032352	28722	0	322204	24670
13	112	Manukau	983289	0	268356	0	714933	83991	630942	714933	0	0	103736	5626
14	111	Manukau	2671794	0	694305	0	1977488	118166	1859322	1924312	25674	27502	217349	24466
15	111	Manukau	4798631	0	416903	0	4381728	517252	3864476	4205322	93066	83340	101363	220892
16	111	Manukau	993152	0	0	0	993152	67662	925490	993151	0	0	725863	1676
17	111	Manukau	996984	0	75863	0	921121	50815	870306	921121	0	0	35290	68417
18	110	Manukau	2112791	0	859070	19136	1234586	35496	1199089	1227157	0	7428	511016	18917
19	110	Manukau	758310	0	185685	0	572625	126445	446180	572625	0	0	179996	3634
20	110	Manukau	2355507	0	0	12679	2342828	219750	2123078	2013077	114618	215133	82704	145116
21	110	Manukau	398972	0	0	0	398972	124518	274454	373143	0	25829	47124	3670
22	110	Papakura	522783	0	24629	0	498154	35825	462329	498153	0	0	96206	43242
23	110	Papakura	926531	0	0	13263	913267	574965	338302	754533	0	158734	53571	8377
24	110	Papakura	707591	0	0	0	707591	0	707591	255717	0	451874	313410	201
25	110	Papakura	1023399	0	0	18537	1004862	191035	813827	993501	11361	0	2547	5392
26	109	Papakura	1561262	0	1198995	0	362267	0	362267	57266	305000	0	0	1965
27	109	Papakura	333103	0	0	4888	328215	12337	315878	328215	0	0	769	2075
28	109	Papakura	878253	0	0	7843	870410	191035	679375	576665	0	293744	24789	25425
29	108	Papakura	2190855	0	0	0	2190855	75993	2114861	1322860	867994	0	18949	112189
30	108	Papakura	1202707	0	370042	0	832665	59013	773651	742612	4779	85273	18172	48881
31	108	Papakura	1367776	0	0	0	1367775	170622	1197153	925983	413396	28395	29654	46716
32	108	Papakura	601140	0	0	0	601139	185567	415573	581153	19986	0	2489	16173
33	108	Papakura	893743	0	31835	23857	838050	48894	789157	830479	7571	0	5970	10484
34	108	Papakura	607706	0	50512	9019	548175	75257	472918	299702	0	248472	145217	0
35	108	Papakura	779471	51721	0	0	727750	0	727750	727750	0	0	718000	0
36	115	Papakura	1767991	0	360311	0	1407680	0	1407680	1407679	0	0	1310000	9375
37	107	Papakura	1134208	0	0	12863	1121345	0	1121345	1045747	52938	22659	1035206	0
38	107	Papakura	925924	0	105141	1716	819066	59969	759098	790012	29053	0	42484	16688
39	106	Papakura	752072	0	0	0	752072	62907	689165	348828	1703	401541	167718	20358
40	106	Papakura	1269924	46678	0	0	1223246	49586	1173660	1223246	0	0	385728	13444
41	106	Papakura	1001816	0	0	0	1001816	214423	787393	954837	0	46979	29660	49224
42	106	Papakura	1730633	0	210931	0	1519702	78777	1440925	1499074	14658	5970	170169	87147
43	106	Papakura	1854847	78000	0	0	1776846	91488	1685358	643608	0	1133238	596547	23231
44	106	Papakura	1161430	0	0	0	1161430	25474	1135956	1161430	0	0	33606	76321
45	104	Franklin	2479438	0	237774	0	2241664	149599	2092065	1970743	163156	107765	173540	78829
46	104	Franklin	1614196	0	552349	0	1061847	192597	869250	903834	158013	0	260700	35710
47	104	Franklin	1096666	0	688666	0	408000	0	408000	408000	0	0	408000	0
48	104	Franklin	967614	0	0	0	967614	12185	955429	859086	0	108529	523400	11351

	Fractions of urban built up			Fractions of residential land use				Fractions of commercial land use				Fractions of industrial land use			
Model Unit	Residential fraction	Commercial fraction	Industrial fraction	roofs	roads	paved	pervious	roofs	roads	paved	pervious	roofs	roads	paved	pervious
1	0.857	0.031	0.112	0.099	0.053	0.033	0.815	0.198	0.104	0.068	0.630	0.198	0.104	0.068	0.629
2	0.964	0.036	0.000	0.250	0.079	0.067	0.603	0.253	0.077	0.461	0.209	0.200	0.200	0.250	0.350
3	0.871	0.000	0.129	0.280	0.108	0.067	0.545	0.300	0.200	0.160	0.340	0.280	0.108	0.247	0.365
4	0.960	0.040	0.000	0.138	0.140	0.141	0.581	0.158	0.160	0.162	0.520	0.200	0.200	0.250	0.350
5	0.250	0.000	0.750	0.013	0.013	0.013	0.961	0.300	0.200	0.160	0.340	0.143	0.145	0.146	0.566
6	0.678	0.000	0.322	0.023	0.023	0.023	0.931	0.300	0.200	0.160	0.340	0.187	0.186	0.193	0.435
7	0.114	0.654	0.232	0.272	0.275	0.278	0.174	0.068	0.069	0.069	0.794	0.159	0.161	0.162	0.518
8	0.717	0.000	0.283	0.108	0.109	0.110	0.674	0.300	0.200	0.160	0.340	0.119	0.120	0.121	0.641
9	0.815	0.005	0.180	0.050	0.051	0.051	0.848	0.122	0.123	0.124	0.631	0.235	0.238	0.240	0.287
10	0.840	0.001	0.158	0.178	0.180	0.181	0.461	0.180	0.182	0.184	0.453	0.180	0.182	0.184	0.454
11	0.974	0.026	0.000	0.156	0.158	0.160	0.526	0.191	0.193	0.194	0.422	0.200	0.200	0.250	0.350
12	0.991	0.009	0.000	0.119	0.120	0.121	0.641	0.229	0.232	0.234	0.305	0.200	0.200	0.250	0.350
13	1.000	0.000	0.000	0.152	0.154	0.155	0.539	0.300	0.200	0.160	0.340	0.200	0.200	0.250	0.350
14	0.973	0.013	0.014	0.150	0.222	0.110	0.517	0.157	0.233	0.116	0.494	0.176	0.261	0.129	0.434
15	0.960	0.021	0.019	0.121	0.180	0.089	0.610	0.138	0.205	0.102	0.555	0.138	0.205	0.102	0.555
16	1.000	0.000	0.000	0.052	0.052	0.052	0.843	0.300	0.200	0.160	0.340	0.200	0.200	0.250	0.350
17	1.000	0.000	0.000	0.121	0.179	0.089	0.612	0.300	0.200	0.160	0.340	0.200	0.200	0.250	0.350
18	0.994	0.000	0.006	0.205	0.180	0.137	0.478	0.300	0.200	0.160	0.340	0.236	0.214	0.177	0.372
19	1.000	0.000	0.000	0.254	0.231	0.191	0.324	0.300	0.200	0.160	0.340	0.200	0.200	0.250	0.350
20	0.859	0.049	0.092	0.189	0.172	0.142	0.497	0.215	0.195	0.161	0.428	0.215	0.195	0.161	0.428
21	0.935	0.000	0.065	0.186	0.169	0.139	0.506	0.300	0.200	0.160	0.340	0.281	0.255	0.210	0.254
22	1.000	0.000	0.000	0.212	0.200	0.133	0.455	0.300	0.200	0.160	0.340	0.200	0.200	0.250	0.350
23	0.826	0.000	0.174	0.033	0.078	0.046	0.842	0.300	0.200	0.160	0.340	0.068	0.260	0.100	0.572
24	0.361	0.000	0.639	0.018	0.019	0.013	0.950	0.300	0.200	0.160	0.340	0.189	0.260	0.148	0.403
25	0.989	0.011	0.000	0.183	0.160	0.134	0.524	0.186	0.270	0.330	0.214	0.200	0.200	0.250	0.350
26	0.158	0.842	0.000	0.218	0.160	0.105	0.516	0.016	0.049	0.138	0.797	0.200	0.200	0.250	0.350
27	1.000	0.000	0.000	0.229	0.160	0.159	0.452	0.300	0.200	0.160	0.340	0.200	0.200	0.250	0.350
28	0.663	0.000	0.337	0.157	0.160	0.152	0.531	0.300	0.200	0.160	0.340	0.199	0.260	0.206	0.335
29	0.604	0.396	0.000	0.200	0.160	0.129	0.511	0.024	0.012	0.095	0.869	0.200	0.200	0.250	0.350
30	0.892	0.006	0.102	0.119	0.160	0.102	0.619	0.314	0.000	0.105	0.581	0.290	0.260	0.410	0.040
31	0.677	0.302	0.021	0.231	0.160	0.122	0.487	0.249	0.270	0.273	0.208	0.217	0.260	0.327	0.196
32	0.967	0.033	0.000	0.153	0.160	0.104	0.583	0.153	0.270	0.104	0.473	0.200	0.200	0.250	0.350
33	0.991	0.009	0.000	0.209	0.160	0.145	0.485	0.226	0.270	0.330	0.174	0.200	0.200	0.250	0.350
34	0.547	0.000	0.453	0.191	0.160	0.134	0.515	0.300	0.200	0.160	0.340	0.236	0.267	0.237	0.260
35	1.000	0.000	0.000	0.006	0.002	0.001	0.991	0.300	0.200	0.160	0.340	0.200	0.200	0.250	0.350
36	1.000	0.000	0.000	0.035	0.011	0.008	0.946	0.300	0.200	0.160	0.340	0.200	0.200	0.250	0.350
37	0.933	0.047	0.020	0.001	0.004	0.002	0.993	0.472	0.189	0.189	0.150	0.132	0.177	0.265	0.426
38	0.965	0.035	0.000	0.156	0.160	0.102	0.581	0.149	0.103	0.379	0.369	0.200	0.200	0.250	0.350
39	0.464	0.002	0.534	0.077	0.099	0.066	0.758	0.117	0.235	0.294	0.354	0.117	0.249	0.324	0.310
40	1.000	0.000	0.000	0.126	0.122	0.087	0.665	0.300	0.200	0.160	0.340	0.200	0.200	0.250	0.350
41	0.953	0.000	0.047	0.153	0.155	0.104	0.589	0.300	0.200	0.160	0.340	0.174	0.260	0.128	0.438
42	0.986	0.010	0.004	0.172	0.161	0.120	0.547	0.270	0.270	0.330	0.130	0.290	0.000	0.333	0.377
43	0.362	0.000	0.638	0.081	0.092	0.069	0.758	0.300	0.200	0.160	0.340	0.141	0.260	0.128	0.471
44	1.000	0.000	0.000	0.170	0.160	0.121	0.550	0.300	0.200	0.160	0.340	0.200	0.200	0.250	0.350
45	0.879	0.073	0.048	0.190	0.160	0.110	0.540	0.290	0.270	0.330	0.110	0.290	0.260	0.333	0.117
46	0.851	0.149	0.000	0.190	0.160	0.110	0.540	0.290	0.270	0.330	0.110	0.200	0.200	0.250	0.350
47	1.000	0.000	0.000	0.000	0.000	0.000	1.000	0.300	0.200	0.160	0.340	0.200	0.200	0.250	0.350
48	0.888	0.000	0.112	0.063	0.053	0.036	0.849	0.300	0.200	0.160	0.340	0.290	0.260	0.333	0.117

	Fractions of residential roofs								Fractions of commercial roofs								Fractions of industrial roofs							
Model Unit	UG	PG	WG	CG	UZ	CZ	CU	OT	UG	PG	WG	CG	UZ	CZ	CU	OT	UG	PG	WG	CG	UZ	CZ	CU	OT
1	0.097	0.097	0.149	0.478	0.013	0.042	0.000	0.124	0.101	0.101	0.130	0.494	0.012	0.045	0.000	0.117	0.101	0.101	0.130	0.494	0.012	0.045	0.000	0.117
2	0.104	0.104	0.270	0.301	0.037	0.027	0.000	0.157	0.103	0.103	0.269	0.305	0.035	0.027	0.000	0.159	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
3	0.142	0.142	0.196	0.251	0.017	0.068	0.000	0.183	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.142	0.142	0.196	0.251	0.017	0.068	0.000	0.183
4	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
5	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
6	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
7	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.064	0.166	0.071	0.039	0.063	0.179	0.008	0.410	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
8	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
9	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.870	0.041	0.019	0.000	0.000	0.039	0.000	0.030
10	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
11	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
12	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
13	0.051	0.051	0.023	0.044	0.074	0.177	0.000	0.578	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
14	0.013	0.013	0.014	0.062	0.014	0.189	0.000	0.695	0.013	0.013	0.014	0.062	0.014	0.189	0.000	0.695	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
15	0.020	0.130	0.050	0.100	0.005	0.150	0.005	0.540	0.068	0.200	0.085	0.038	0.059	0.180	0.010	0.360	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
16	0.013	0.013	0.014	0.062	0.014	0.189	0.000	0.695	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
17	0.013	0.013	0.014	0.062	0.014	0.189	0.000	0.695	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
18	0.013	0.016	0.015	0.063	0.014	0.188	0.000	0.691	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
19	0.013	0.013	0.014	0.062	0.014	0.189	0.000	0.695	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
20	0.013	0.013	0.014	0.062	0.014	0.189	0.000	0.695	0.068	0.200	0.085	0.038	0.059	0.180	0.010	0.360	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
21	0.013	0.013	0.014	0.062	0.014	0.189	0.000	0.695	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
22	0.144	0.029	0.143	0.000	0.008	0.010	0.000	0.667	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
23	0.796	0.018	0.000	0.000	0.000	0.180	0.000	0.006	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.796	0.018	0.000	0.000	0.000	0.180	0.000	0.006
24	0.578	0.058	0.018	0.000	0.000	0.290	0.000	0.056	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.775	0.040	0.005	0.000	0.000	0.151	0.000	0.028
25	0.056	0.000	0.003	0.000	0.000	0.067	0.000	0.874	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.900	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
26	0.549	0.000	0.000	0.000	0.000	0.000	0.000	0.451	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
27	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.900	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
28	0.429	0.059	0.012	0.000	0.000	0.027	0.000	0.473	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.677	0.084	0.005	0.000	0.000	0.114	0.000	0.121
29	0.303	0.026	0.087	0.000	0.000	0.041	0.000	0.543	0.503	0.011	0.030	0.000	0.000	0.014	0.000	0.441	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
30	0.365	0.054	0.029	0.000	0.000	0.011	0.000	0.540	0.299	0.014	0.021	0.000	0.000	0.000	0.000	0.666	0.913	0.035	0.010	0.000	0.000	0.009	0.000	0.032
31	0.350	0.040	0.083	0.000	0.000	0.022	0.000	0.505	0.383	0.037	0.088	0.000	0.000	0.016	0.000	0.476	0.420	0.072	0.090	0.000	0.000	0.025	0.000	0.394
32	0.176	0.012	0.074	0.000	0.000	0.009	0.000	0.729	0.176	0.012	0.074	0.000	0.000	0.009	0.000	0.729	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
33	0.110	0.001	0.010	0.000	0.000	0.038	0.000	0.842	0.023	0.000	0.004	0.000	0.000	0.085	0.000	0.888	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
34	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.900	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.506	0.088	0.046	0.000	0.000	0.336	0.000	0.023
35	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
36	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
37	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
38	0.167	0.000	0.010	0.000	0.000	0.000	0.000	0.823	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
39	0.756	0.040	0.029	0.000	0.000	0.080	0.000	0.094	0.793	0.050	0.036	0.000	0.000	0.099	0.000	0.022	0.793	0.050	0.036	0.000	0.000	0.099	0.000	0.022
40	0.094	0.010	0.071	0.000	0.000	0.041	0.000	0.784	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
41	0.307	0.018	0.137	0.000	0.000	0.033	0.000	0.505	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.332	0.018	0.145	0.000	0.000	0.032	0.000	0.473
42	0.258	0.026	0.124	0.006	0.000	0.038	0.000	0.548	0.094	0.180	0.090	0.034	0.053	0.163	0.009	0.378	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
43	0.632	0.031	0.060	0.000	0.000	0.107	0.000	0.169	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.640	0.032	0.059	0.000	0.000	0.107	0.000	0.162
44	0.310	0.022	0.131	0.000	0.000	0.030	0.000	0.508	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
45	0.020	0.130	0.050	0.100	0.005	0.150	0.005	0.540	0.068	0.200	0.085	0.038	0.059	0.180	0.010	0.360	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032
46	0.020	0.130	0.050	0.100	0.005	0.150	0.005	0.540	0.068	0.200	0.085	0.038	0.059	0.180	0.010	0.360	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
47	0.038	0.173	0.067	0.147	0.008	0.173	0.001	0.394	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.869	0.042	0.019	0.000	0.000	0.038	0.000	0.033
48	0.020	0.130	0.050	0.100	0.005	0.150	0.005	0.540	0.124	0.243	0.054	0.030	0.038	0.163	0.010	0.338	0.870	0.041	0.019	0.000	0.000	0.038	0.000	0.032

Model Unit	Fractions of residential roads				Fractions of commercial roads				Fractions of industrial roads			
	< 1000 vpd	1000-5000 vpd	5000-20000 vpd	> 20000 vpd	< 1000 vpd	1000-5000 vpd	5000-20000 vpd	> 20000 vpd	< 1000 vpd	1000-5000 vpd	5000-20000 vpd	> 20000 vpd
1	0.677	0.238	0.084	0.000	0.668	0.234	0.098	0.000	0.668	0.234	0.098	0.000
2	0.412	0.359	0.230	0.000	0.381	0.373	0.245	0.000	0.100	0.300	0.500	0.100
3	0.367	0.345	0.288	0.000	0.100	0.300	0.500	0.100	0.367	0.345	0.288	0.000
4	0.584	0.011	0.261	0.144	0.584	0.011	0.261	0.144	0.100	0.300	0.500	0.100
5	0.584	0.011	0.261	0.144	0.100	0.300	0.500	0.100	0.584	0.011	0.261	0.144
6	0.584	0.011	0.261	0.144	0.100	0.300	0.500	0.100	0.539	0.012	0.289	0.159
7	0.584	0.011	0.261	0.144	0.584	0.011	0.261	0.144	0.584	0.011	0.261	0.144
8	0.584	0.011	0.261	0.144	0.100	0.300	0.500	0.100	0.584	0.011	0.261	0.144
9	0.584	0.011	0.261	0.144	0.584	0.011	0.261	0.144	0.582	0.011	0.262	0.144
10	0.584	0.011	0.261	0.144	0.584	0.011	0.261	0.144	0.584	0.011	0.261	0.144
11	0.584	0.011	0.261	0.144	0.584	0.011	0.261	0.144	0.100	0.300	0.500	0.100
12	0.584	0.011	0.261	0.144	0.584	0.011	0.261	0.144	0.100	0.300	0.500	0.100
13	0.584	0.011	0.261	0.144	0.100	0.300	0.500	0.100	0.100	0.300	0.500	0.100
14	0.726	0.057	0.205	0.012	0.726	0.057	0.205	0.012	0.726	0.057	0.205	0.012
15	0.726	0.057	0.205	0.012	0.726	0.057	0.205	0.012	0.726	0.057	0.205	0.012
16	0.726	0.057	0.205	0.012	0.100	0.300	0.500	0.100	0.100	0.300	0.500	0.100
17	0.726	0.057	0.205	0.012	0.100	0.300	0.500	0.100	0.100	0.300	0.500	0.100
18	0.771	0.032	0.185	0.011	0.100	0.300	0.500	0.100	0.780	0.033	0.175	0.011
19	0.781	0.033	0.175	0.011	0.100	0.300	0.500	0.100	0.100	0.300	0.500	0.100
20	0.781	0.033	0.175	0.011	0.781	0.033	0.175	0.011	0.780	0.033	0.175	0.011
21	0.781	0.033	0.175	0.011	0.100	0.300	0.500	0.100	0.781	0.033	0.175	0.011
22	0.749	0.201	0.050	0.000	0.100	0.300	0.500	0.100	0.100	0.300	0.500	0.100
23	0.746	0.000	0.254	0.000	0.100	0.300	0.500	0.100	0.637	0.000	0.363	0.000
24	1.000	0.000	0.000	0.000	0.100	0.300	0.500	0.100	0.772	0.228	0.000	0.000
25	0.868	0.132	0.000	0.000	1.000	0.000	0.000	0.000	0.100	0.300	0.500	0.100
26	0.673	0.327	0.000	0.000	1.000	0.000	0.000	0.000	0.100	0.300	0.500	0.100
27	0.905	0.095	0.000	0.000	0.100	0.300	0.500	0.100	0.100	0.300	0.500	0.100
28	0.675	0.325	0.000	0.000	0.100	0.300	0.500	0.100	0.607	0.065	0.327	0.000
29	0.528	0.189	0.283	0.000	0.326	0.674	0.000	0.000	0.100	0.300	0.500	0.100
30	0.902	0.092	0.000	0.006	0.994	0.001	0.004	0.001	0.639	0.000	0.361	0.000
31	0.713	0.236	0.051	0.000	0.209	0.493	0.298	0.000	0.000	0.136	0.864	0.000
32	0.570	0.376	0.054	0.000	0.537	0.463	0.000	0.000	0.100	0.300	0.500	0.100
33	0.714	0.173	0.113	0.000	0.755	0.245	0.000	0.000	0.100	0.300	0.500	0.100
34	1.000	0.000	0.000	0.000	0.100	0.300	0.500	0.100	0.819	0.045	0.136	0.000
35	1.000	0.000	0.000	0.000	0.100	0.300	0.500	0.100	0.100	0.300	0.500	0.100
36	0.680	0.320	0.000	0.000	0.100	0.300	0.500	0.100	0.100	0.300	0.500	0.100
37	0.250	0.250	0.500	0.000	0.200	0.200	0.600	0.000	0.250	0.250	0.500	0.000
38	0.362	0.638	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
39	0.566	0.000	0.434	0.000	0.000	0.000	1.000	0.000	0.450	0.450	0.100	0.000
40	0.783	0.217	0.000	0.000	0.100	0.300	0.500	0.100	0.100	0.300	0.500	0.100
41	0.403	0.398	0.199	0.000	0.100	0.300	0.500	0.100	0.263	0.491	0.246	0.000
42	0.587	0.186	0.227	0.000	0.154	0.299	0.464	0.083	0.100	0.300	0.500	0.100
43	0.664	0.336	0.000	0.000	0.100	0.300	0.500	0.100	0.283	0.309	0.408	0.000
44	0.731	0.135	0.135	0.000	0.100	0.300	0.500	0.100	0.100	0.300	0.500	0.100
45	0.436	0.358	0.207	0.000	0.250	0.284	0.466	0.000	0.645	0.196	0.160	0.000
46	0.714	0.131	0.154	0.000	0.273	0.117	0.609	0.000	0.100	0.300	0.500	0.100
47	0.560	0.290	0.120	0.030	0.100	0.300	0.500	0.100	0.100	0.300	0.500	0.100
48	0.680	0.110	0.210	0.000	0.100	0.300	0.500	0.100	1.000	0.000	0.000	0.000

	Fractions of residential pervious			Fractions of commercial pervious			Fractions of industrial pervious			GLEAMS yields		Existing treatment	
Model Unit	stream channels	bare earth	grassland	stream channels	bare earth	grassland	stream channels	bare earth	grassland	bare earth (g m^{-2} a^{-1})	grassland (g m^{-2} a^{-1})	Area treated (%)	Efficiency (%)
1	0.000	0.023	0.977	0.000	0.018	0.982	0.000	0.000	1.000	1608	67	41	75
2	0.008	0.018	0.975	0.023	0.030	0.947	0.000	0.000	1.000	826	25	0	0
3	0.007	0.000	0.993	0.000	1.000	0.000	0.011	0.000	0.989	1390	56	0	0
4	0.017	0.031	0.952	0.022	0.035	0.943	0.000	0.000	1.000	416	10	0	0
5	0.001	0.001	0.998	0.000	1.000	0.000	0.018	0.006	0.976	571	16	0	0
6	0.002	0.002	0.997	0.000	1.000	0.000	0.033	0.028	0.939	1048	43	3	75
7	0.112	0.053	0.835	0.006	0.000	0.994	0.022	0.000	0.978	675	19	10	50
8	0.011	0.005	0.984	0.000	1.000	0.000	0.013	0.000	0.987	571	14	41	50
9	0.004	0.009	0.986	0.014	0.043	0.943	0.059	0.046	0.895	936	37	3	75
10	0.031	0.021	0.948	0.028	0.510	0.462	0.028	0.000	0.972	815	26	100	50
11	0.021	0.039	0.940	0.032	0.035	0.934	0.000	0.000	1.000	3412	94	53	75
12	0.013	0.023	0.964	0.050	0.098	0.852	0.000	0.000	1.000	3798	54	100	50
13	0.020	0.085	0.895	0.000	1.000	0.000	0.000	0.000	1.000	396	9	0	0
14	0.011	0.033	0.956	0.012	0.050	0.938	0.015	0.000	0.985	512	13	0	0
15	0.008	0.004	0.989	0.009	0.013	0.977	0.009	0.000	0.991	735	22	6	75
16	0.005	0.044	0.951	0.000	1.000	0.000	0.000	0.000	1.000	917	26	39	75
17	0.007	0.010	0.982	0.000	1.000	0.000	0.000	0.000	1.000	755	25	0	0
18	0.024	0.095	0.881	0.000	1.000	0.000	0.026	0.000	0.974	2216	42	0	0
19	0.033	0.076	0.892	0.000	1.000	0.000	0.000	0.000	1.000	1061	32	0	0
20	0.016	0.003	0.981	0.021	0.005	0.974	0.021	0.000	0.979	995	37	0	0
21	0.015	0.030	0.955	0.000	1.000	0.000	0.046	0.000	0.954	1372	49	0	0
22	0.001	0.009	0.990	0.000	1.000	0.000	0.000	0.000	1.000	339	5	42	75
23	0.004	0.003	0.993	0.000	1.000	0.000	0.012	0.000	0.988	730	20	0	0
24	0.000	0.004	0.996	0.000	1.000	0.000	0.004	0.013	0.984	473	10	73	75
25	0.000	0.000	1.000	0.000	0.000	1.000	0.000	0.000	1.000	987	30	0	0
26	0.034	0.006	0.960	0.000	0.000	1.000	0.000	0.000	1.000	356	6	0	0
27	0.000	0.000	1.000	0.000	1.000	0.000	0.000	0.000	1.000	1109	39	0	0
28	0.000	0.005	0.995	0.000	1.000	0.000	0.000	0.000	1.000	666	17	0	0
29	0.000	0.000	1.000	0.002	0.000	0.998	0.000	0.000	1.000	532	12	51	54
30	0.004	0.004	0.992	0.000	0.042	0.958	0.130	0.000	0.870	621	19	69	55
31	0.000	0.000	1.000	0.000	0.000	1.000	0.000	0.000	1.000	792	26	49	45
32	0.000	0.000	1.000	0.000	0.000	1.000	0.000	0.000	1.000	710	21	0	0
33	0.000	0.000	1.000	0.000	0.000	1.000	0.000	0.000	1.000	698	22	0	0
34	0.000	0.013	0.987	0.000	1.000	0.000	0.000	0.000	1.000	760	22	49	57
35	0.002	0.008	0.990	0.000	1.000	0.000	0.000	0.000	1.000	340	8	0	0
36	0.002	0.011	0.988	0.000	1.000	0.000	0.000	0.000	1.000	262	5	0	0
37	0.001	0.003	0.996	0.201	0.008	0.791	0.071	0.000	0.929	425	12	0	0
38	0.000	0.000	1.000	0.000	0.000	1.000	0.000	0.000	1.000	663	20	0	0
39	0.010	0.000	0.990	0.039	0.008	0.953	0.045	0.039	0.916	598	19	0	0
40	0.003	0.030	0.967	0.000	1.000	0.000	0.000	0.000	1.000	4035	103	20	75
41	0.005	0.000	0.995	0.000	0.000	1.000	0.000	0.000	1.000	536	12	54	75
42	0.006	0.010	0.983	0.006	0.116	0.878	0.000	0.000	1.000	962	39	0	0
43	0.011	0.000	0.988	0.000	1.000	0.000	0.021	0.008	0.971	826	26	4	75
44	0.001	0.004	0.995	0.000	0.000	1.000	0.000	0.000	1.000	524	12	0	0
45	0.000	0.012	0.988	0.000	0.018	0.982	0.000	0.000	1.000	468	13	0	0
46	0.000	0.019	0.981	0.000	0.011	0.989	0.000	0.000	1.000	1859	99	49	50
47	0.000	0.037	0.963	0.000	1.000	0.000	0.000	0.000	1.000	2663	167	0	0
48	0.000	0.026	0.974	0.000	1.000	0.000	0.000	0.558	0.442	1062	47	0	0

	Population (medium growth rate)										Fraction of population growth			rate of non-residential growth	
Model Unit	2001	2006	2011	2016	2021	2026	2031	2036	2041	2046	apartments	infill	vacant	commercial (m^2 person)	industrial (m^2 person)
1	2368	2866	3346	3811	4259	4691	5109	5512	5902	6278	0.1	0.2	0.7	5	0
2	9232	9855	10447	11010	11546	12055	12539	13000	13438	13854	0.1	0.2	0.7	5	0
3	3996	3996	3996	3996	3996	3996	3996	3996	3996	3996	0.4	0.4	0.2	5	0
4	3510	4104	4669	5207	5718	6204	6666	7106	7524	7922	0.4	0.2	0.4	5	0
5	100	110	120	129	138	147	155	162	170	177	0.4	0.2	0.4	5	2750
6	1604	1767	1923	2073	2215	2352	2482	2606	2725	2839	0.4	0.2	0.4	5	500
7	1032	1115	1194	1269	1339	1404	1466	1525	1580	1632	0.4	0.2	0.4	5	0
8	3117	3371	3609	3834	4045	4244	4432	4608	4774	4931	0.4	0.4	0.2	5	0
9	6421	6881	7314	7722	8106	8467	8807	9128	9429	9713	0.1	0.1	0.8	5	100
10	1991	2173	2322	2446	2548	2631	2701	2757	2804	2843	0.4	0.2	0.4	5	0
11	3142	3706	4267	4825	5380	5933	6483	7030	7574	8116	0.1	0.1	0.8	5	0
12	4402	5167	5824	6389	6873	7290	7647	7954	8218	8444	0.1	0.1	0.8	5	0
13	3635	4233	4828	5420	6009	6595	7178	7758	8335	8910	0.1	0.1	0.8	5	0
14	9034	9574	9985	10299	10537	10719	10857	10963	11043	11104	0.1	0.1	0.8	5	0
15	12855	13407	13929	14424	14891	15334	15752	16149	16523	16878	0.4	0.4	0.2	5	0
16	500	1145	1719	2230	2685	3090	3450	3771	4057	4311	0.1	0.1	0.8	5	0
17	2403	2731	3054	3374	3690	4002	4309	4614	4914	5211	0.4	0.4	0.2	5	0
18	5218	6231	7216	8175	9107	10014	10897	11755	12590	13403	0.1	0.1	0.8	5	0
19	1375	1630	1877	2115	2345	2567	2781	2988	3188	3381	0.1	0.1	0.8	5	0
20	6049	6225	6380	6516	6634	6739	6830	6910	6980	7041	0.4	0.4	0.2	5	0
21	749	853	957	1061	1164	1266	1368	1469	1570	1671	0.1	0.1	0.8	5	0
22	285	334	384	433	482	531	579	627	675	723	0.2	0.2	0.6	5	0
23	574	617	654	686	714	738	759	777	793	807	0.2	0.2	0.6	5	0
24	106	124	142	160	177	195	212	230	247	264	0.1	0.1	0.8	5	650
25	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	0.4	0.4	0.2	5	0
26	170	207	244	282	321	360	400	440	481	523	0.5	0.5	0	5	0
27	663	663	663	663	663	663	663	663	663	663	0.4	0.4	0.2	5	0
28	1066	1126	1173	1211	1241	1265	1284	1299	1311	1320	0.4	0.3	0.3	5	0
29	3297	3297	3297	3297	3297	3297	3297	3297	3297	3053	0.4	0.4	0.2	5	0
30	1214	1310	1404	1497	1587	1675	1762	1847	1930	2012	0.4	0.4	0.2	5	0
31	2866	2866	2866	2866	2866	2866	2866	2866	2866	2866	0.4	0.4	0.2	5	0
32	1461	1461	1461	1461	1461	1461	1461	1461	1461	1461	0.4	0.2	0.4	5	0
33	2238	2238	2238	2238	2238	2238	2238	2238	2238	2238	0.4	0.4	0.2	5	0
34	166	204	242	280	318	355	393	431	469	506	0.1	0.1	0.8	5	0
35	156	263	369	474	578	680	782	883	983	1081	0.1	0.1	0.8	5	0
36	355	616	875	1131	1384	1635	1883	2129	2373	2614	0.1	0.1	0.8	5	0
37	165	224	282	339	396	451	506	560	613	665	0.1	0.1	0.8	5	0
38	2083	2083	2083	2083	2083	2083	2083	2083	2083	2083	0.4	0.2	0.4	5	0
39	42	45	49	52	54	56	58	60	61	62	0.4	0.2	0.4	5	6000
40	1619	1975	2164	2164	2164	2164	2164	2164	2164	2164	0.1	0.1	0.8	5	0
41	1598	1598	1598	1598	1598	1598	1598	1598	1598	1598	0.4	0.4	0.2	5	0
42	3330	3500	3613	3613	3613	3613	3613	3613	3613	3613	0.2	0.2	0.6	5	0
43	1643	1651	1658	1665	1671	1677	1683	1689	1694	1699	0.4	0.2	0.4	5	3000
44	3549	3671	3748	3796	3826	3826	3826	3826	3826	3826	0.4	0.4	0.2	5	0
45	2843	3135	3419	3695	3962	4222	4474	4718	4955	5185	0.2	0.2	0.6	5	0
46	1540	1712	1874	2029	2176	2316	2449	2576	2696	2811	0.1	0.1	0.8	5	0
47	20	284	501	681	828	950	1050	1133	1201	1257	0.1	0.1	0.8	5	0
48	323	650	916	1134	1311	1455	1573	1669	1747	1811	0.1	0.1	0.8	5	100

10 Appendix 4

10.1 Trend equation parameters: Population

Model Unit	A	B	Modelled population change
1	0.05	0.007	increase
2	0.024	0.01	increase
3	0	0	no change
4	0.045	0.01	increase
5	0.03	0.009	increase
6	0.03	0.009	increase
7	0.029	0.012	increase
8	0.029	0.012	increase
9	0.027	0.012	increase
10	0.06	0.038	increase
11	0.037	0.001	increase
12	0.069	0.03	increase
13	0.034	0.001	increase
14	0.07	0.053	increase
15	0.02	0.011	increase
16	0.3	0.023	increase
17	0.03	0.0025	increase
18	0.045	0.0055	increase
19	0.045	0.007	increase
20	0.033	0.026	increase
21	0.029	0.001	increase
22	0.036	0.001	increase
23	0.045	0.028	increase
24	0.035	0.001	increase
25	0	0	no change
26	0.04	-0.003	increase
27	0	0	no change
28	0.06	0.045	increase
29	0	0	no change
30	0.02	0.004	increase
31	0.01	0.01	no change
32	0	0	no change
33	0	0	no change
34	0.046	0.0002	increase
35	0.14	0.002	increase
36	0.15	0.002	increase
37	0.075	0.003	increase
38	0	0	no change
39	0.05	0.029	increase
40	0.2	0.12	increase to 2011
	0	0	no change after 2011
41	0.01	0.01	no change
42	0.1	0.08	increase to 2011
	0	0	no change after 2011
43	0.01	0.009	increase
44	0.108	0.09	increase to 2021
	0	0	no change after 2021
45	0.027	0.006	increase
46	0.033	0.01	increase
47	3	0.038	increase
48	0.27	0.04	increase

10.2 Trend equation parameters: Same for all MUs

Variable	A	B
Fraction apartments/total number of new dwellings	**0**	**0**
Fraction infill dwellings/total number of new dwellings	**0**	**0**
Total motor way area	**0.0695**	**0.03**
Motorways >100,000vpd area	**0.04**	**0.04**
Commercial roof area	**0.0025**	**0.005**
Commercial road area	**0.002**	**0.01**
Commercial paved area	**0.001**	**0.003**
Industrial roof area	**0**	**0**
Industrial road area	**0**	**0**
Industrial paved area	**0**	**0**
Residential unpainted galvanised steel roof area	**0**	**0.15**
Residential poorly painted galvanised steel roof area	**0**	**0.16**
Residential well painted galvanised steel roof area	**0**	**0.095**
Residential coated galvanised steel roof area	**0**	**0.07**
Residential unpainted zinc-aluminium surfaced steel roof area	**0.02**	**0.23**
Residential coated zinc-aluminium surfaced steel longrun and tiles roof area	**0.045**	**0.1**
Residential copper roof area	**0**	**0**
Commercial unpainted galvanised steel roof area	**0**	**0.15**
Commercial poorly painted galvanised steel roof area	**0**	**0.16**
Commercial well painted galvanised steel roof area	**0**	**0.095**
Commercial coated galvanised steel roof area	**0**	**0.07**
Commercial unpainted zinc-aluminium surfaced steel roof area	**0.025**	**0.15**
Commercial coated zinc-aluminium surfaced steel longrun and tiles roof area	**0.034**	**0.065**
Commercial copper roof area	**0.0005**	**0.02**
Industrial unpainted galvanised steel roof area	**0**	**0.15**
Industrial poorly painted galvanised steel roof area	**0**	**0.16**
Industrial well painted galvanised steel roof area	**0**	**0.095**
Industrial coated galvanised steel roof area	**0**	**0.07**
Industrial unpainted zinc-aluminium surfaced steel roof area	**0.12**	**0.14**
Industrial coated zinc-aluminium surfaced steel longrun and tiles roof area	**0.04**	**0.15**
Industrial copper roof area	**0**	**0**
Residential roads 1000-5000vpd area	**0.003**	**0.05**
Residential roads 5000-20000vpd area	**0.021**	**0.035**
Residential roads 20000-50000vpd area	**0.0135**	**0.04**
Commercial roads 1000-5000vpd area	**0.001**	**0.02**
Commercial roads 5000-20000vpd area	**0.007**	**0.01**
Commercial roads 20000-50000vpd area	**0.006**	**0.02**
Industrial roads 1000-5000vpd area	**0.001**	**0.015**
Industrial roads 5000-20000vpd area	**0.015**	**0.021**
Industrial roads 20000-50000vpd area	**0.005**	**0.025**
Residential stream channel area	**0.000001**	**0.04**
Commercial stream channel area	**0**	**0**
Industrial stream channel area	**0**	**0**

11 Appendix 5

11.1 TSS, total zinc and total copper loads for all outfalls for Scenarios 1, 2, 3 and 4.

Figure 11-1:

Annual TSS, total zinc and total copper loads for outfall 104 (Whangapouri Creek).

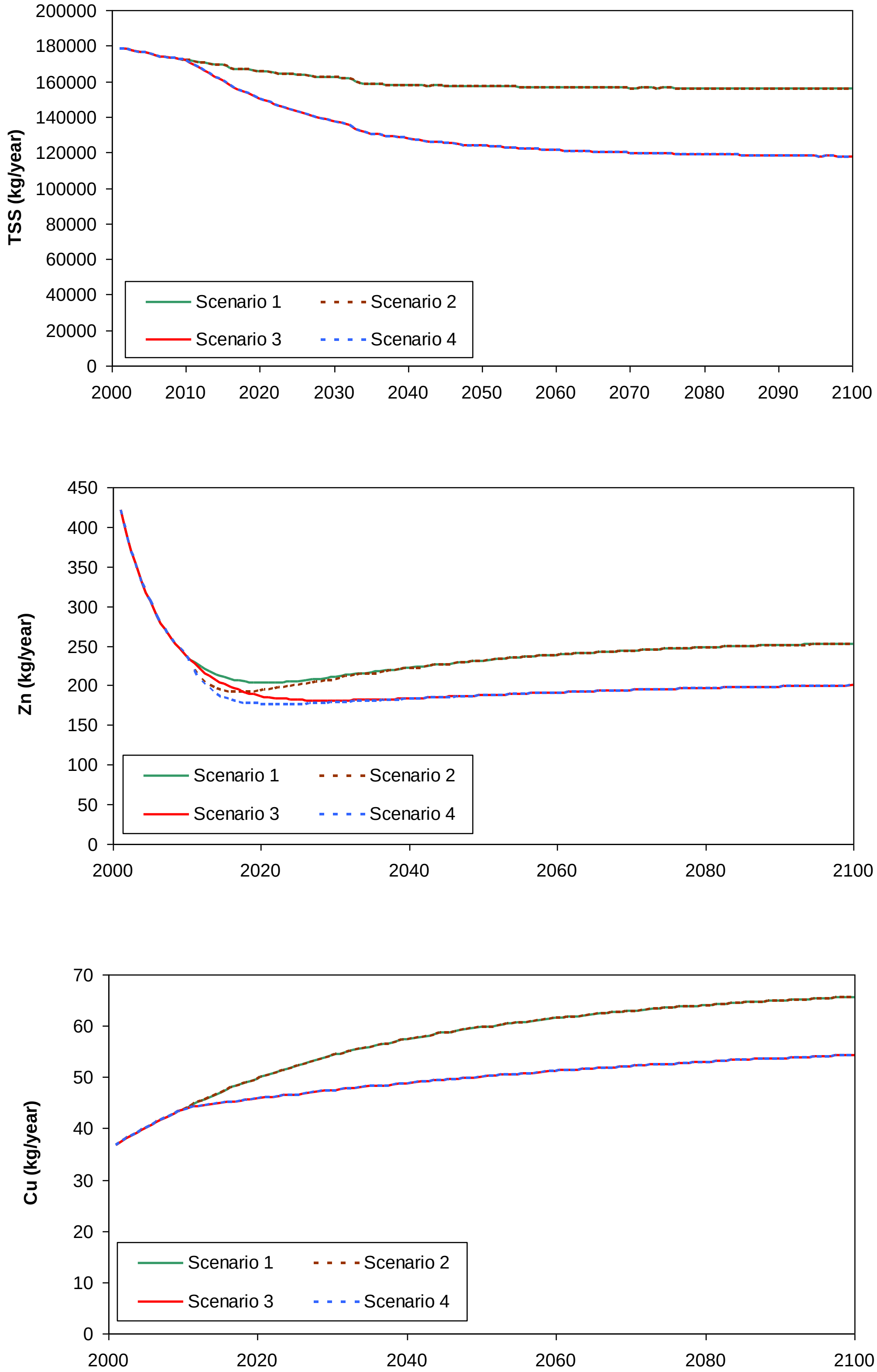
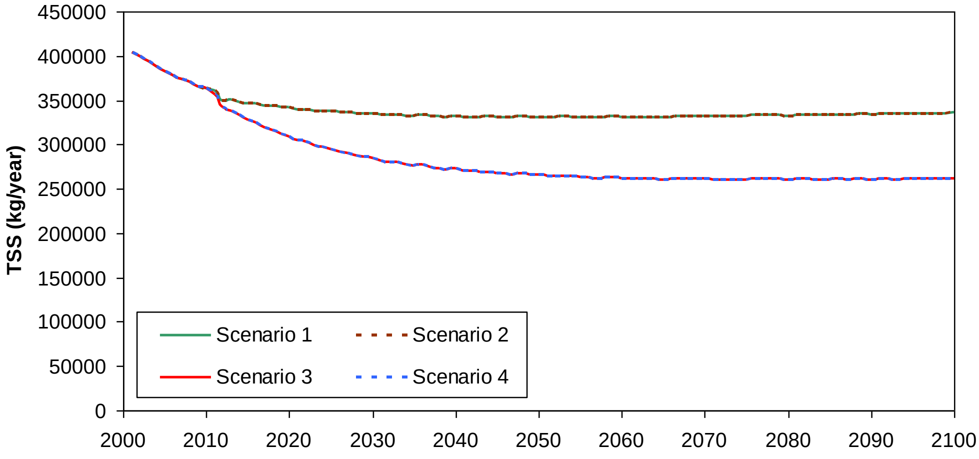
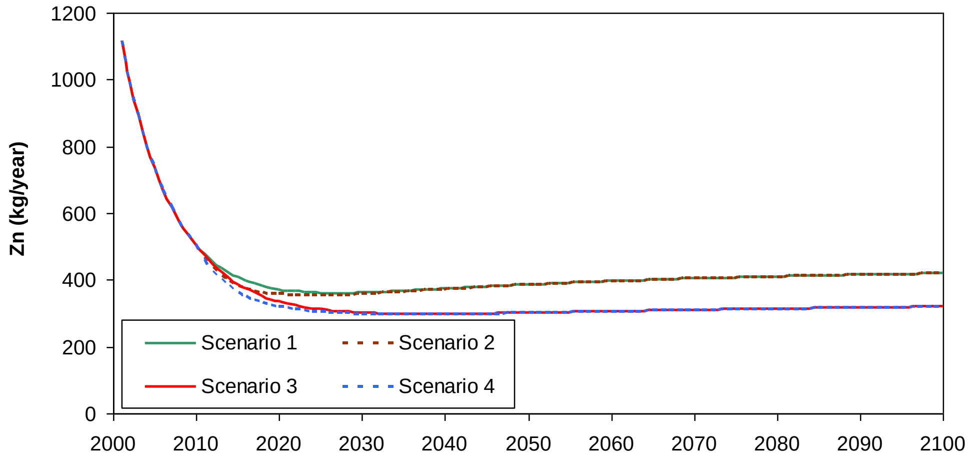


Figure 11-2:

Annual TSS, total zinc and total copper loads for outfall 106 (Drury Creek).





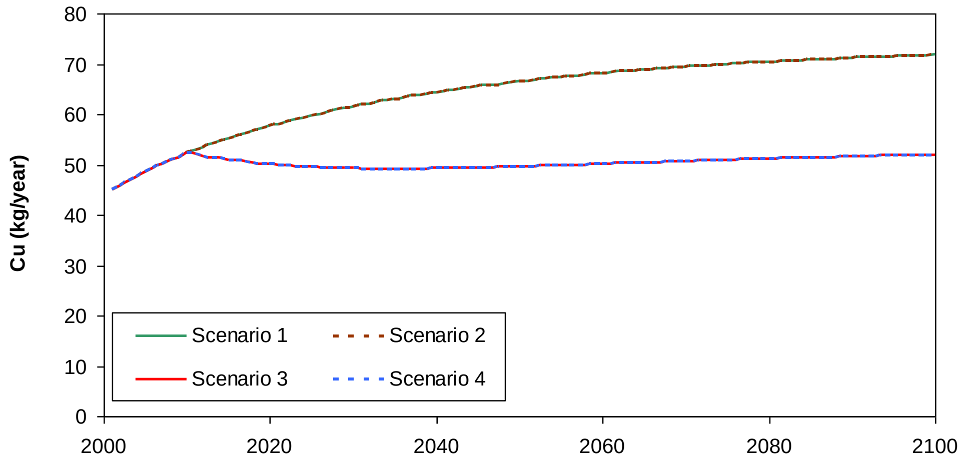


Figure 11-3:

Annual TSS, total zinc and total copper loads for outfall 107 (Hingaia).

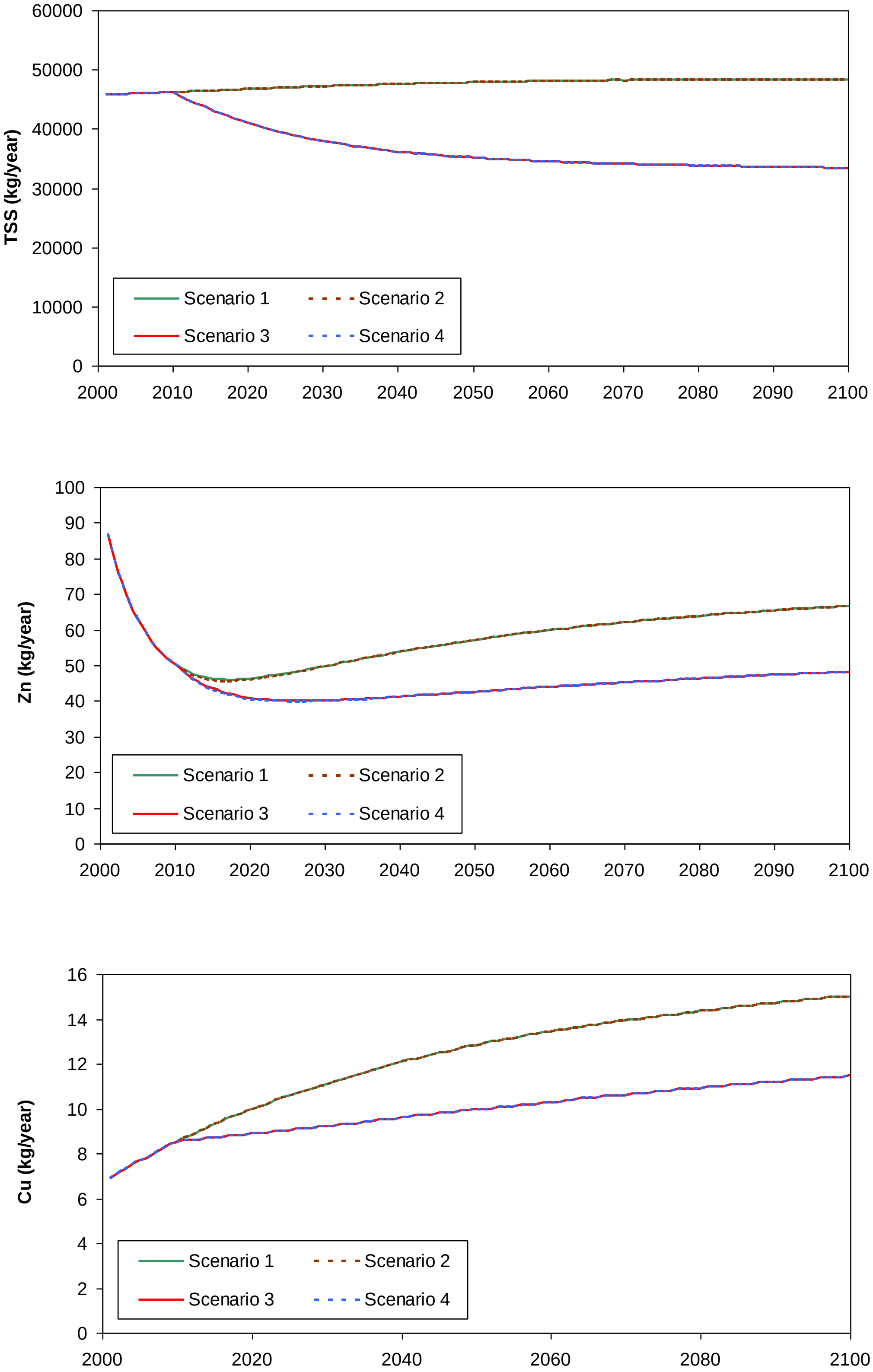


Figure 11-4:

Annual TSS, total zinc and total copper loads for outfall 108 (Papakura).

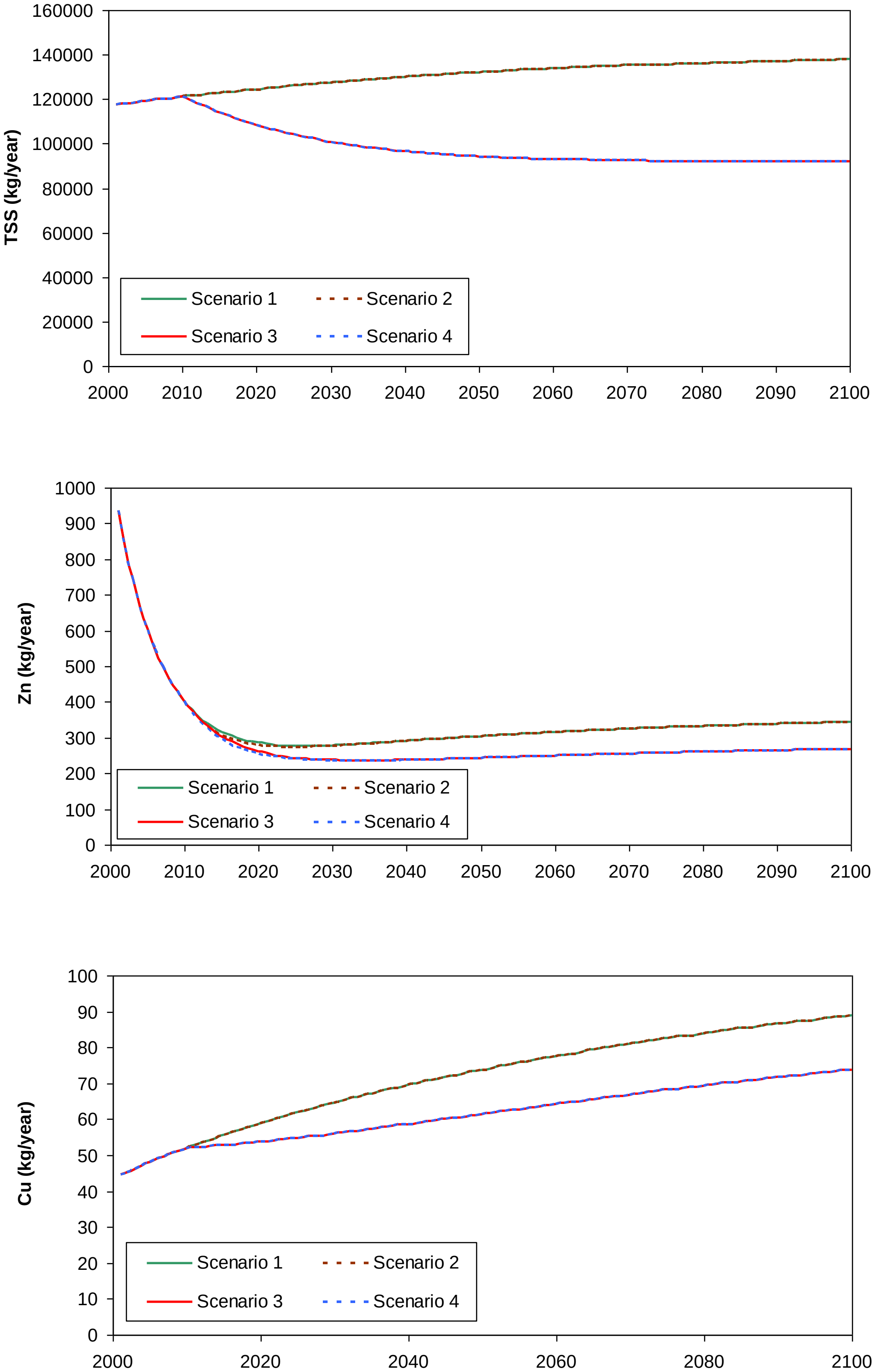
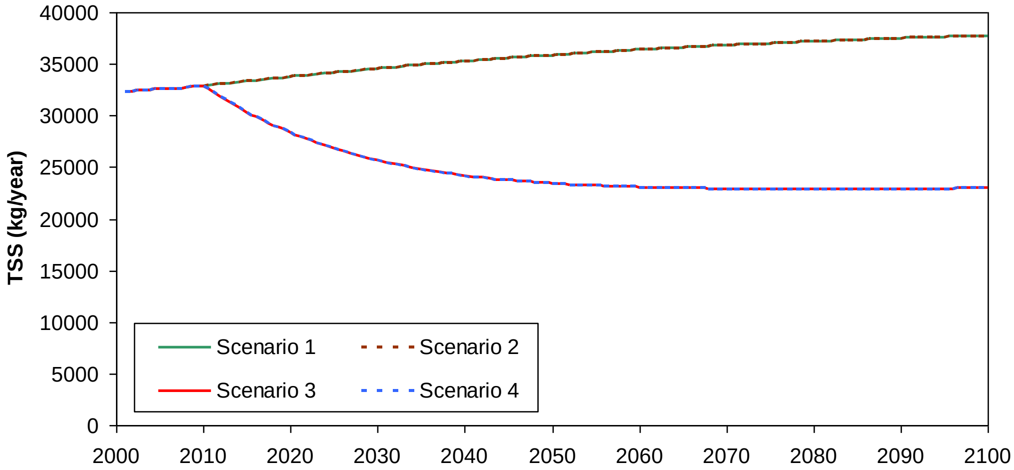
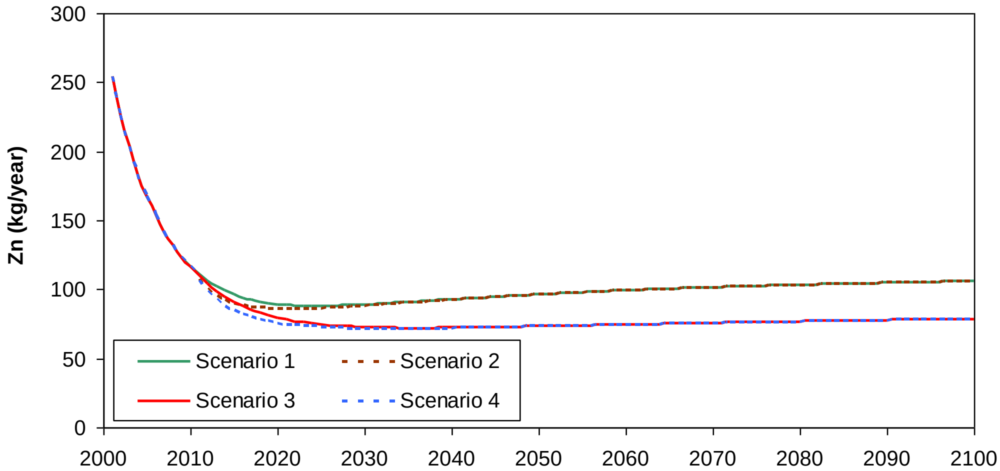


Figure 11-5:

Annual TSS, total zinc and total copper loads for outfall 109 (Takanini).





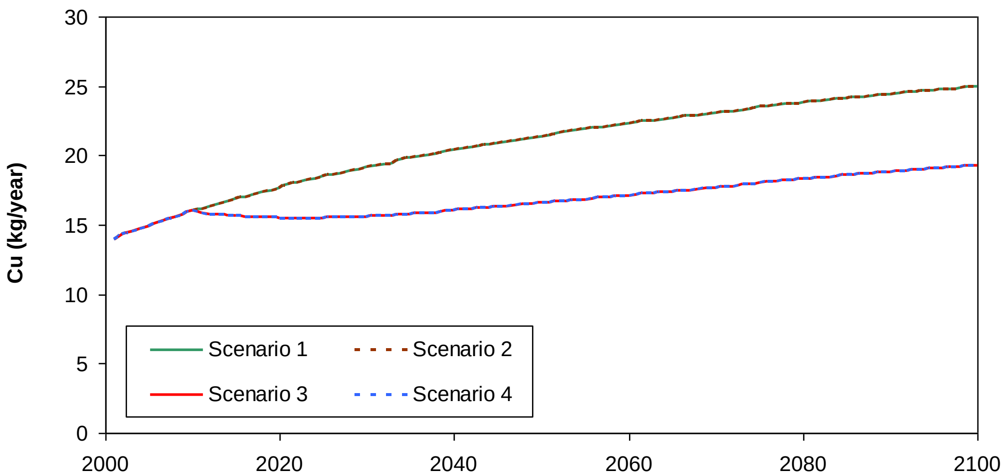
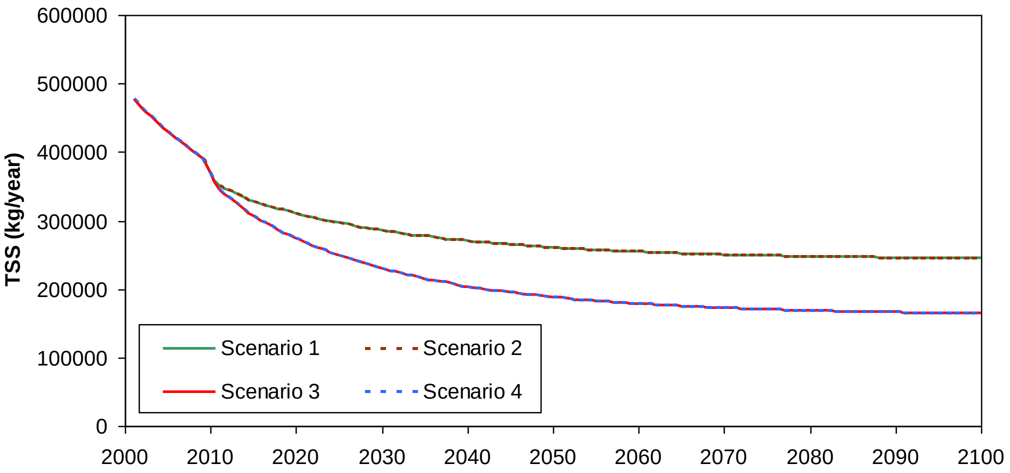
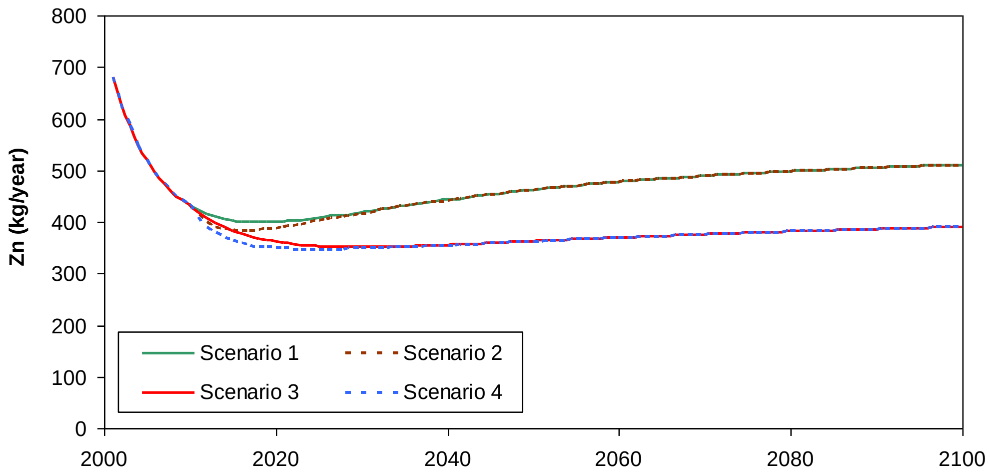


Figure 11-6:

Annual TSS, total zinc and total copper loads for outfall 110 (Papakura Stream).





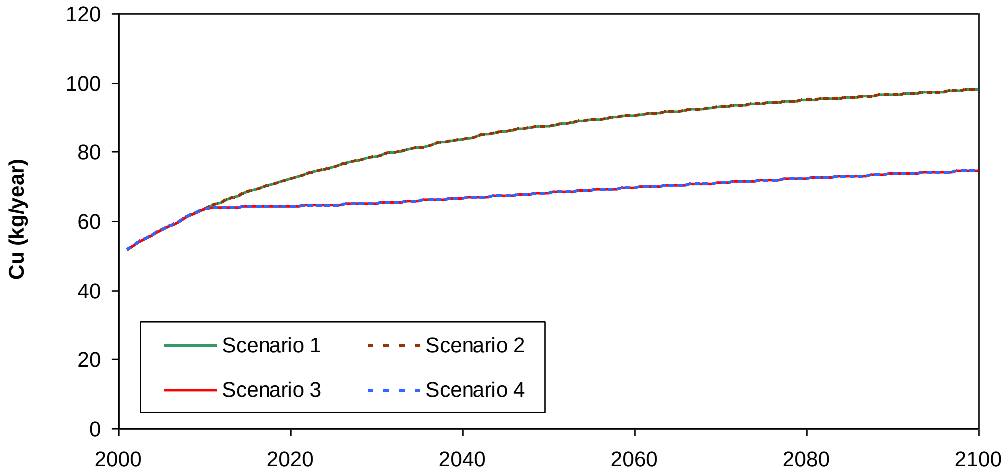


Figure 11-7:

Annual TSS, total zinc and total copper loads for outfall 111 (Manurewa / Weymouth).

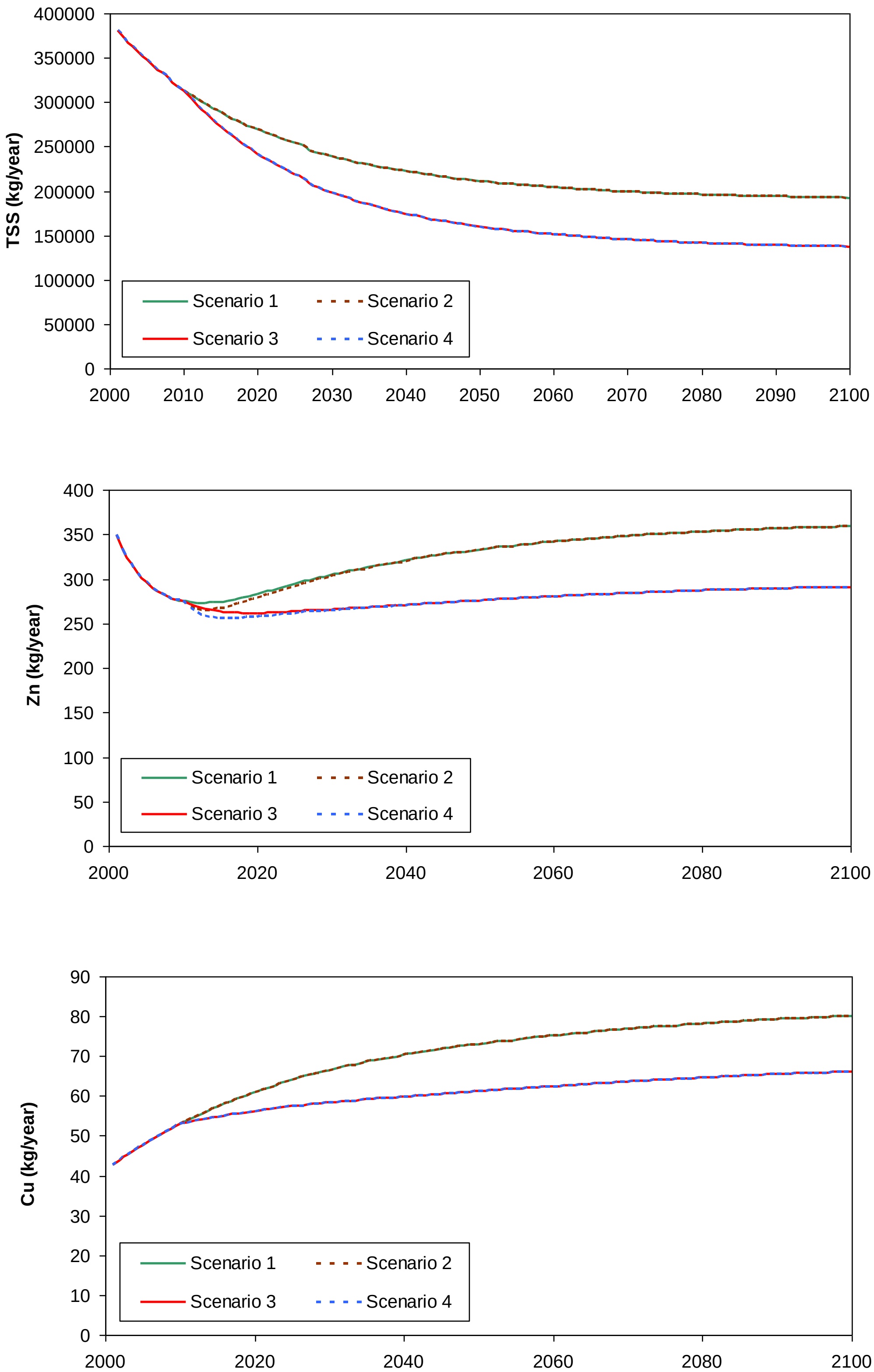


Figure 11-8:
Annual TSS, total zinc and total copper loads for outfall 112 (Papatoetoe / Puhinui).

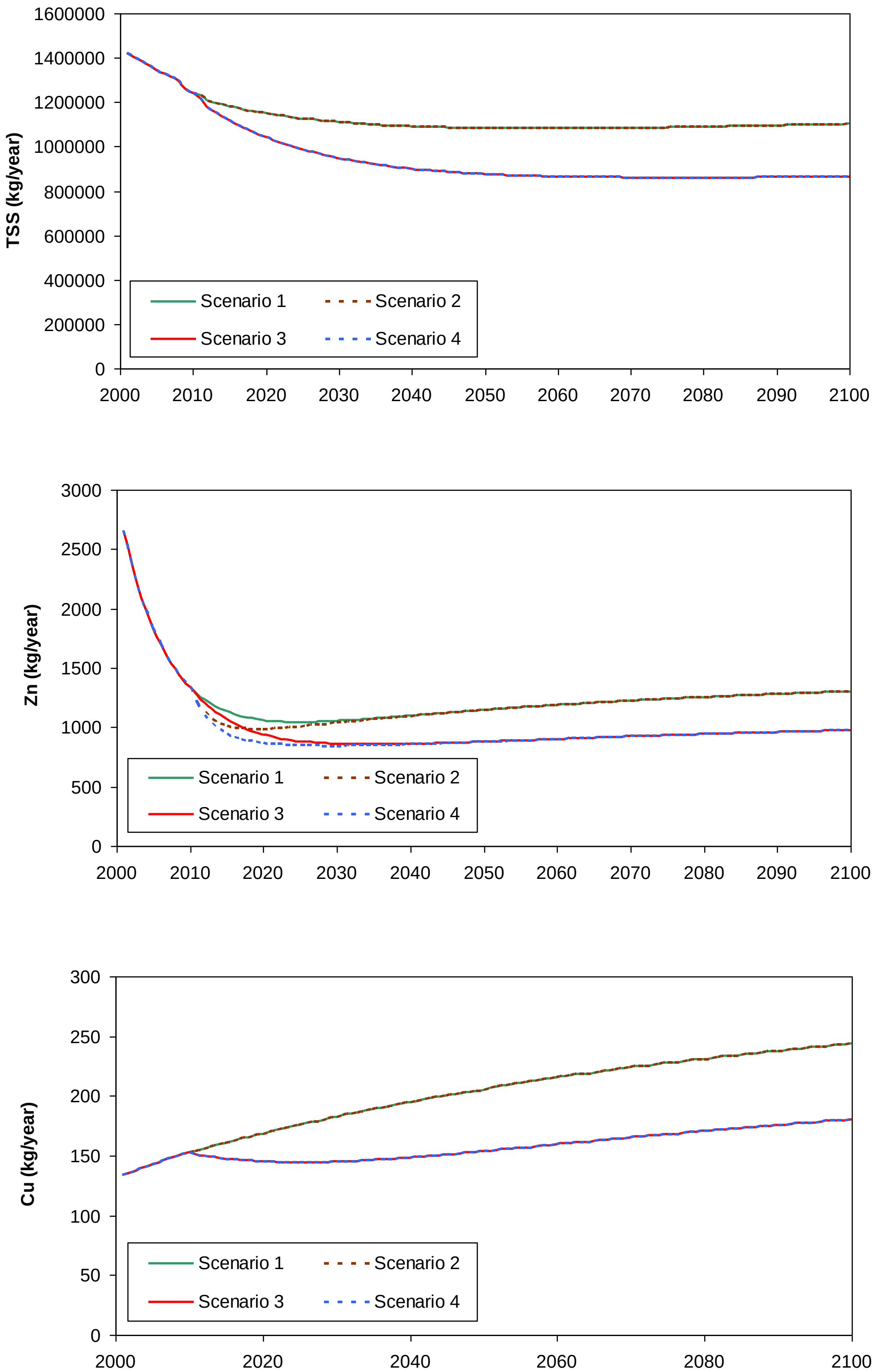


Figure 11-9:

Annual TSS, total zinc and total copper loads for outfall 113 (Mangere East / Papatoetoe).

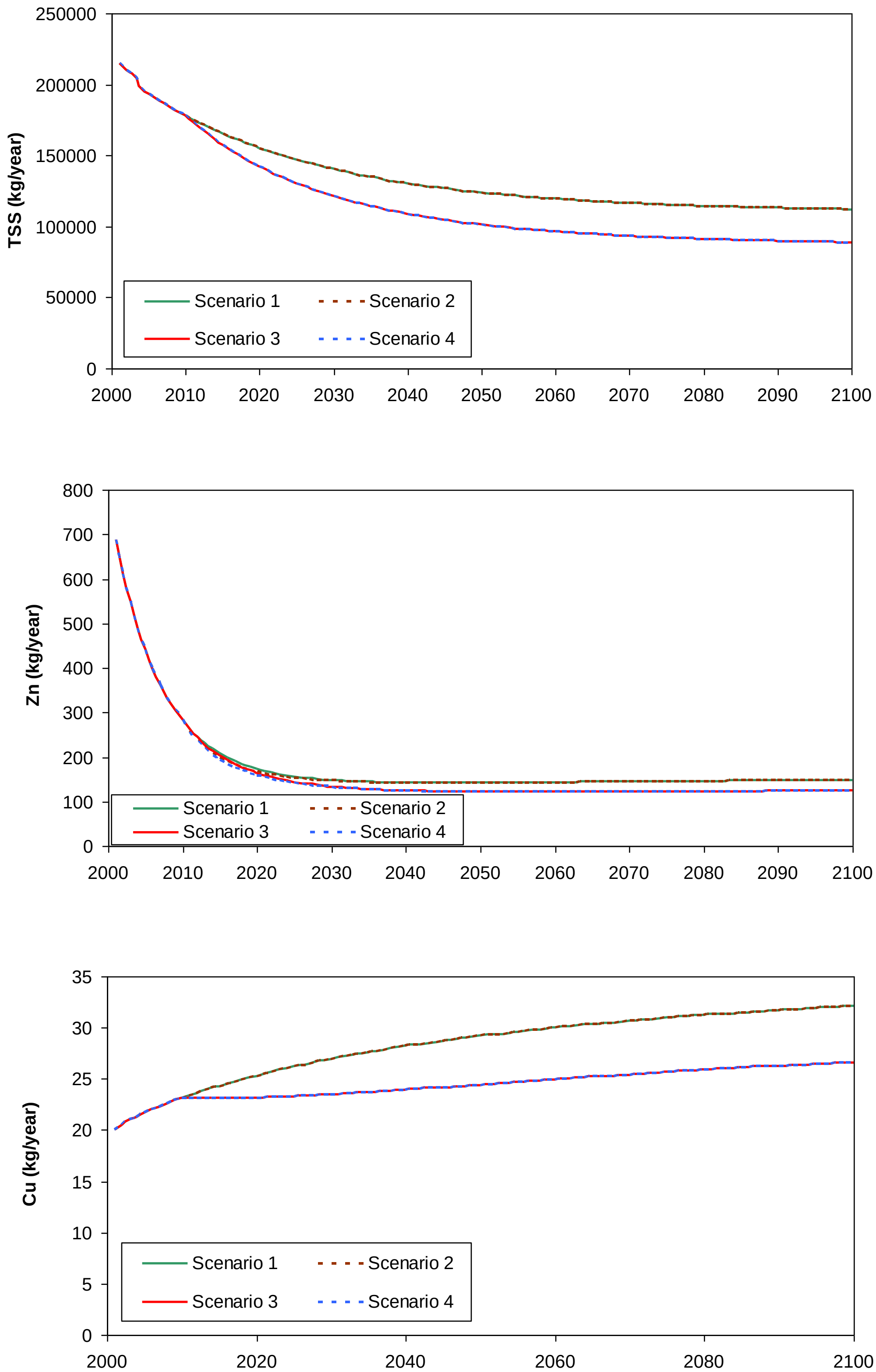


Figure 11–10:

Annual TSS, total zinc and total copper loads for outfall 114 (Mangere).

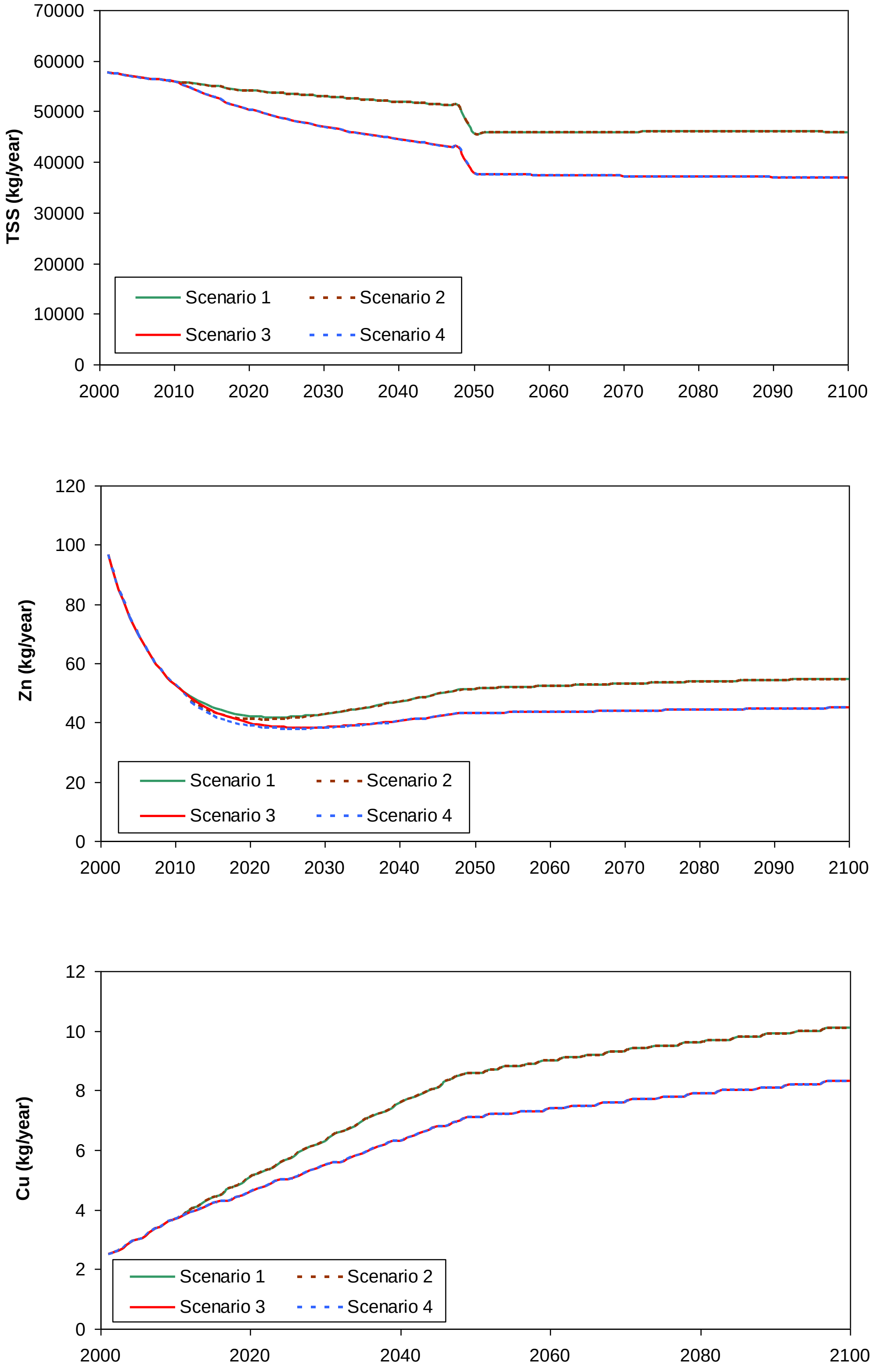


Figure 11-11:
Annual TSS, total zinc and total copper loads for outfall 115 (Bottle Top Bay).