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Central Waitemata Harbour Contaminant Study

GLEAMS Model Results for Rural and Earthwork Sediment Loads from the Catchment

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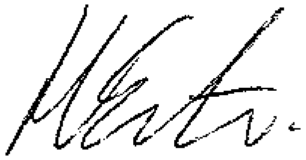	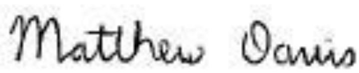
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Central Waitemata Harbour Contaminant Study. GLEAMS Model Results for Rural and Earthworks Sediment Loads from the Catchment

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Preface

The Waitemata 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. An earlier study examined long-term accumulation of sediment and stormwater chemical contaminants in the Upper Waitemata Harbour. However, previously little was known about the existing and long-term accumulation of sediment and stormwater chemical contaminants in the central harbour. The Central Waitemata Harbour 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 sedimentation 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 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:

- Henderson Creek (which drains the largest subcatchment and with the largest urban area, as well as substantial areas of rural land) contributes the largest loads of sediment, copper and zinc to the Central Waitemata Harbour. The second largest loads come from the Upper Waitemata Harbour.

- Substantial proportions of the subcatchment sediment, copper and zinc loads are accumulating in the Henderson, Whau, Meola and Motions tidal creeks and in the Shoal Bay, Hobson Bay and Waterview embayments.

- Central Waitemata Harbour bed sediment concentrations of copper and zinc are not expected to reach toxic levels based on current assumptions of future trends in urban 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. (For example, whereas the study addresses the Whau River as a whole, differences exist within parts of the Whau River that may merit a different magnitude or type of intervention than may be inferred from considering the Whau River and its long-term contaminant trends as a whole.) 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 Hauraki Gulf.

Technical reports

The study has produced a series of technical reports:

Technical Report TR2008/032
Central Waitemata Harbour Contaminant Study. Landuse Scenarios.

Technical Report TR2008/033
Central Waitemata Harbour Contaminant Study. Background Metal Concentrations in Soils: Methods and Results.

Technical Report TR2008/034
Central Waitemata Harbour Contaminant Study. Harbour Sediments.

Technical Report TR2008/035
Central Waitemata Harbour Contaminant Study. Trace Metal Concentrations in Harbour Sediments.

Technical Report TR2008/036
Central Waitemata Harbour Contaminant Study. Hydrodynamics and Sediment Transport Fieldwork.

Technical Report TR2008/037
Central Waitemata Harbour Contaminant Study. Harbour Hydrodynamics, Wave and Sediment Transport Model Implementation and Calibration.

Technical Report TR2008/038
Central Waitemata Harbour Contaminant Study. Development of the Contaminant Load Model.

Technical Report TR2008/039
Central Waitemata Harbour Contaminant Study. Predictions of Stormwater Contaminant Loads.

Technical Report TR2008/040
Central Waitemata Harbour Contaminant Study. GLEAMS Model Structure, Setup and Data Requirements.

Technical Report TR2008/041
Central Waitemata Harbour Contaminant Study. GLEAMS Model Results for Rural and Earthworks Sediment Loads.

Technical Report TR2008/042
Central Waitemata Harbour Contaminant Study. USC-3 Model Description, Implementation and Calibration.

Technical Report TR2008/043
Central Waitemata Harbour Contaminant Study. Predictions of Sediment, Zinc and Copper Accumulation under Future Development Scenario 1.

Technical Report TR2008/044
Central Waitemata Harbour Contaminant Study. Predictions of Sediment, Zinc and Copper Accumulation under Future Development Scenarios 2, 3 and 4.

Technical Report TR2009/109
Central Waitemata Harbour Contaminant Study. Rainfall Analysis.

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1 Executive Summary

The main aim of the Central Waitemata Harbour (CWH) Contaminant Study was to model contaminant (zinc, copper) and sediment accumulation within the CWH for the purposes of, amongst other things, identifying significant contaminant sources, and testing efficacy of stormwater treatment and industrial roof contaminant source control.

This report describes GLEAMS model predictions of rural sediment run-off from the catchment of the Central Waitemata Harbour for the historical period (1945 to 2001), the current time (2001), and the future period (2001 to 2100). The report also includes information on losses expected from earthworks in the urban area (such as construction on vacant lots).

The key outputs provided by the model are estimates of 1) sediment yields in the study area and their changes with time, 2) sub-catchment sediment loads and their changes with time, and 3) sediment yield assuming that the whole study area is fully covered with earthworks, a result used in the urban CLM model to derive yields from earthworks in the urban area (such as construction on vacant lots) at any given location, if required.

The key findings are:

- The overall decrease in sediment loads between 1945 and 2001 associated with the expansion of the urban area and corresponding reduction in the size of the rural area.
- The increase in overall annual sediment loads in 1964 compared to 1945 due to an increase in the rate of urbanisation in the 1960s.
- A decline in the amount of sediment generated in the catchment from greenfield earthworks sediment control practices in the 1990s.
- Before 2001, most of the rural sediment comes from the Henderson Creek sub-catchment. After 2001, the entire rural sediment load comes from the Henderson Creek sub-catchment.
- The gradual decrease in sediment loads between 1945 and 1987 associated with the expansion of the urban area and corresponding reduction in the size of the rural area, as well as reducing rates of urban earthworks.

2 Introduction

Modelling and empirical data indicate that stormwater contaminants are rapidly accumulating in the highly urbanised side branches of the Central Waitemata Harbour (CWH). However, there is no clear understanding of the fate of contaminants exported from these side branches into the main body of the harbour, or that of contaminants discharged directly into the harbour.

The main aim of the study is to model contaminant (zinc, copper) and sediment accumulation within the CWH for the purposes of, amongst other things, identifying significant contaminant sources, and predicting the efficacy of stormwater treatment and industrial roof contaminant source control.

2.1 Study aims

The study aims to:

- predict contaminant loads based on past, present and future land use and population growth for each sub-catchment discharging into the CWH, allowing for stormwater treatment and industrial roof contaminant source control;
- predict dispersal and accumulation (or loss) of sediment and stormwater contaminants in the CWH;
- calibrate and validate the dispersal/accumulation model;
- apply the various models to predict catchment contaminant loads and accumulation of copper, zinc and sediment in the CWH under specific scenarios that depict various combinations of projected land use/population growth, stormwater treatment efficiency, and industrial roof contaminant source control;
- determine from the model predictions the relative contributions of sediment and contaminant from individual sub-catchments and local authorities;
- provide an assessment of the environmental consequences of model outputs;
- provide technical reports on each component of the work;
- provide a desktop application suitable.

2.2 Model suite

The study centres on the application of three models that are linked to each other in a single suite:

- 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[1].

- The CLM 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.
- 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 model: an estuarine sediment-transport model, which simulates the dispersal of contaminants/sediments by physical processes such as tidal currents and waves.

2.3 Work plan

There are eight modules in the work plan:

- Module 1 – Implementation of the sediment-generation model.
- Module 2 – Implementation of the contaminant/sediment-generation model.
- Module 3 – Implementation of the contaminant/sediment-accumulation model.
- Module 4 – Calibration and validation of the model suite.
- Module 5 – Depiction of development scenarios, including stormwater treatment and industrial roof contaminant source control, as required.
- Module 6 – Execution of the model suite to produce predictions of contaminant build-up in bed sediments of the CWH.
- Module 7 – Evaluation of predictions with management.

This may lead to reconsideration of Module 5, and subsequent re-running of Module 6 until an acceptable development scenario can be found.

- Module 8 – Development of desktop application.

2.4 This report

This report presents GLEAMS model results for the historical period (1945 to 2001), the current time (taken to be 2001), and the future period (2001 to 2100).

Both the CLM contaminant/sediment-generation model and the USC-3 model use output from the GLEAMS sediment-generation model as input. Calibration of the USC-3 model is achieved by running the model for the historical period, with sediment and metal inputs from the catchment appropriate to that period, which in turn are hindcast

[1] We use the term "contaminant" herein to mean chemical contaminants such as zinc and copper, and we refer to "sediments" separately.

by the GLEAMS and CLM models. Predictions are made for the future period, which starts at the year 2001.

The emphasis in this report is on reporting results from GLEAMS which, in the CWH Contaminant Study, is used to hindcast/predict sediment run-off from the rural land of the catchment. The CLM model is used to hindcast/predict metal and sediment run-off from the urban parts of the catchment. This report focuses on GLEAMS results for the rural land in the study area.

GLEAMS was also run for urban earthworks, and the sediment yields so determined were used in the CLM model. The GLEAMS urban earthworks results are also reported herein.

The reader is referred to ARC Technical Reports TR2008/040 and TR2008/032 (ARC, 2008a and 2008b), who describe the GLEAMS model and its set up, and land use scenarios established for the CWH Contaminant Study. The model so implemented is called the "GLEAMS-CWH" model. The GLEAMS-CWH model is a field-scale physics-based mathematical model for predicting daily run-off of water and sediment. The primary information required by the model is the catchment characteristics, including climate, topography, soils and land use. A GIS interface is used to manage the spatial information required as input (eg, soil patterns, land use and topography).

Calibration of GLEAMS-CWH was not attempted in this study, and calibration was not in the study design, because we used parameter values which have been established based on previous applications of GLEAMS in the Auckland area, which included calibration.

The predicted sediment run-off is presented as 1) sediment yields (ie, loads per area per time) averaged over the rural area for every stormwater management unit (SMU), and 2) sediment loads at sub-catchment outlets. GLEAMS-CWH results are passed to the USC-3 model as daily time series of sediment run-off.

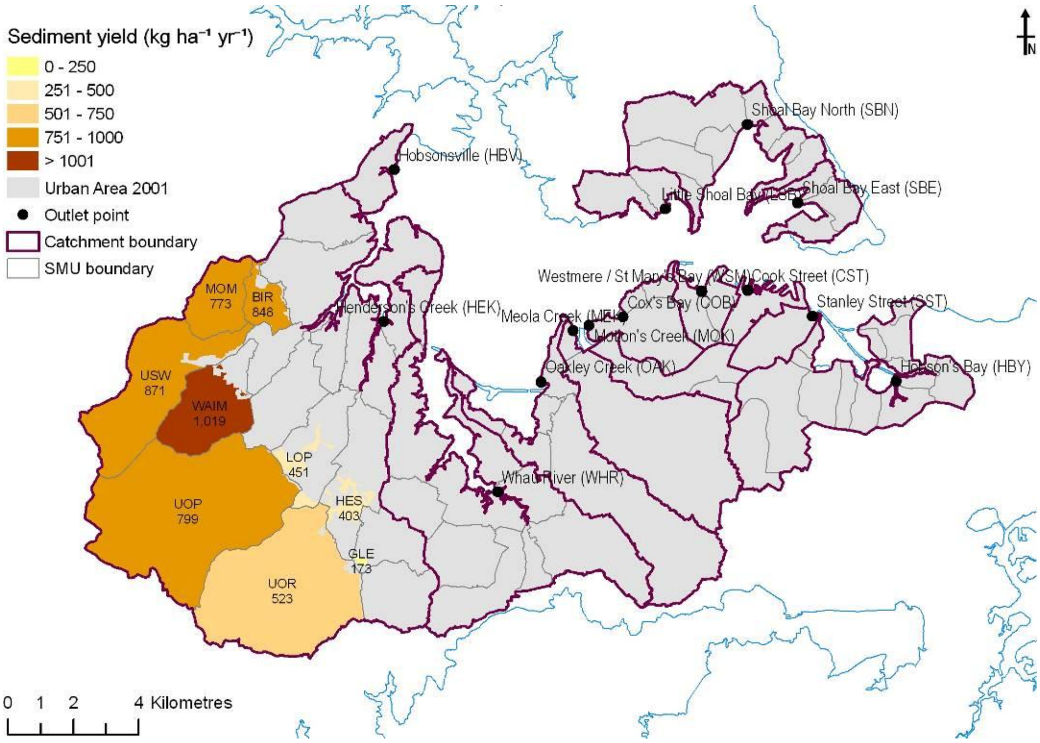
Estimates of sediment yields for urban earthworks are also presented. These estimates are used in the urban CLM model to derive yields from earthworks in the urban area (such as construction on vacant lots) for an arbitrary area within the urban boundary.

3 Current Time (2001)

3.1 Sediment yields by stormwater management unit (SMU)

Figure 1 shows current (2001) sediment yields averaged over the rural part of each SMU. Here "rural" refers to land beyond the ARC 2001 urban boundary and within the study area, and includes areas of urban earthworks and small residential areas outside the boundary. Note that the metropolitan urban limit (MUL) is used only for future scenarios. Differences in yield are attributed to variation in land use, soil type and slope angle. The predominantly "rural" Henderson Creek sub-catchment[2] is dominated by native and exotic forest found extensively in the Waitakere ranges. There is an increased yield from earthworks activity in the rural area at the urban fringe.

Figure 1
Current (2001) sediment yields (kg ha^{-1} yr^{-1}) averaged over the rural part of each SMU (land beyond the ARC 2001 urban boundary and within the study area).



Upon the same soil and slope, the predicted losses increase in the following sequence: native forest < pine forest < scrub, manuka/kanuka < grassland < earthworks. The estimates are reasonable compared with estimates in similar studies and with measured data (Senior et al., 2003; Collins, 2003).

[2] The term "sub-catchment" is used in the sense of a sub-catchment of the Central Waitemata Harbour.

Sediment yields for a given land use and slope increase according to soil types from lowest to highest in the following order: 1) Waitakere soil types (formed from andesite), 2) Cornwallis Hill soil types (formed from volcanic ash), 3) Warkworth soil types (formed from Waitemata formation [yellow brown earth]), 4) Whakapara soil types (formed from alluvium), 5) Apotu soil types (formed from basalt), 6) C1 complex soil types (formed from alluvium), 7) Kara soil types (formed from alluvium), and 8) Otonga soil types (formed from peat and alluvium).

3.2 Variation of sediment loads with rainfall

Figure 2 shows sediment loads (tonnes/day) as a function of daily rainfall (cm) from the rural land of the Henderson Creek (HEK) sub-catchment, the only sub-catchment that is fully rural beyond the ARC 2001 urban boundary, and still within the study area. The figure shows that an increased rainfall generally increases sediment load, although there is variability arising from soil types, slopes, land use, management practices, and prior rainfall events.

Figure 2
Model results for 2001 sediment loads (tonnes/day) as a function of daily rainfall (cm) from the rural land of the Henderson Creek (HEK) sub-catchment.

Figure 3 shows a time series (1954–2003) of predicted sediment load from the Henderson Creek (HEK) sub-catchment. The 50 years of data illustrate that individual rainfall events generate substantial sediment loads. The highest rainfall event of 24.76 cm on 17 February, 1966, contributed the greatest load (13,600 t) in the Henderson Creek sub-catchment. This amounts to 6 per cent of the total load of 223,500 t from this sub-catchment over 50 years (see Figure 4). Most sediment delivery is therefore delivered in large-sized events, and this is also true of the other sub-catchments under both existing and historical land use.

The mean annual load of 4470 t/year corresponds to a rainfall event of approximately 11.2 cm. This rainfall has a return interval of approximately six years.

The frequency distribution of rainfall event sizes by intensity is illustrated in Figure 5 and the frequency distribution of sediment event loads from these rainfall events is illustrated in Figure 6. These figures and Figure 4 show that while individual events can contribute large loads, they are also relatively rare, so that more frequent but smaller events make a substantial contribution to the sediment load.

Figure 3

Time series of rainfall (cm) used in this study (red line) and time series of predicted sediment loads (tonnes/day) from the rural part of the Henderson Creek sub-catchment. The highest rainfall is 24.76 cm on 17 February, 1966.

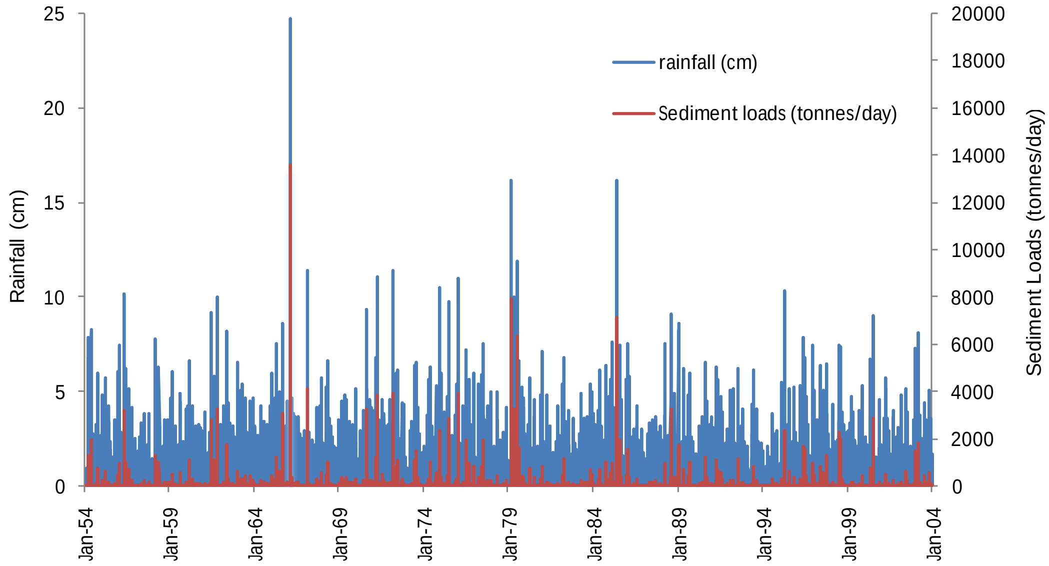


Figure 4

Cumulative fraction of total sediment load associated with daily sediment loads from the rural land of the Henderson Creek sub-catchment. For example, 50 per cent of the total sediment load is associated with events greater than 1460 t.

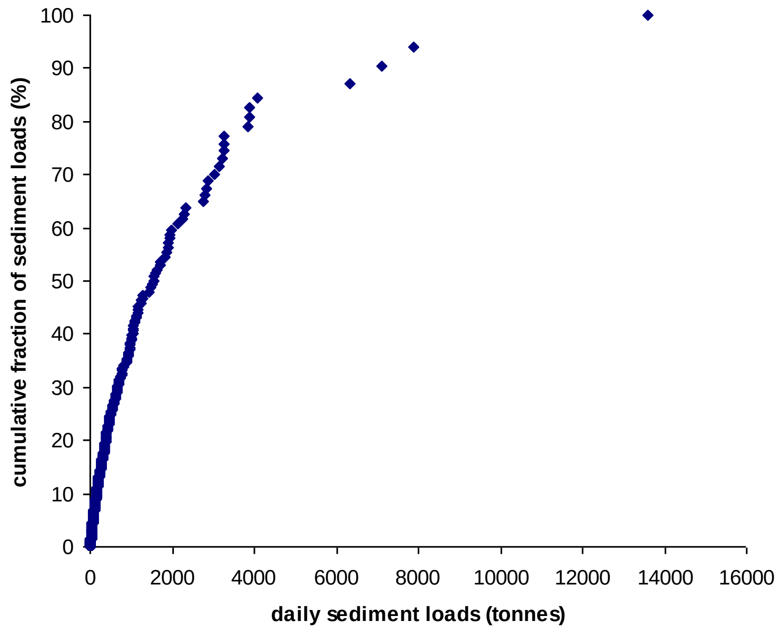


Figure 5

Histograms and cumulative percentage for mean daily rainfall showing the frequency distribution of rainfall events. The first bin covers the range from 0 to 1 cm/day.

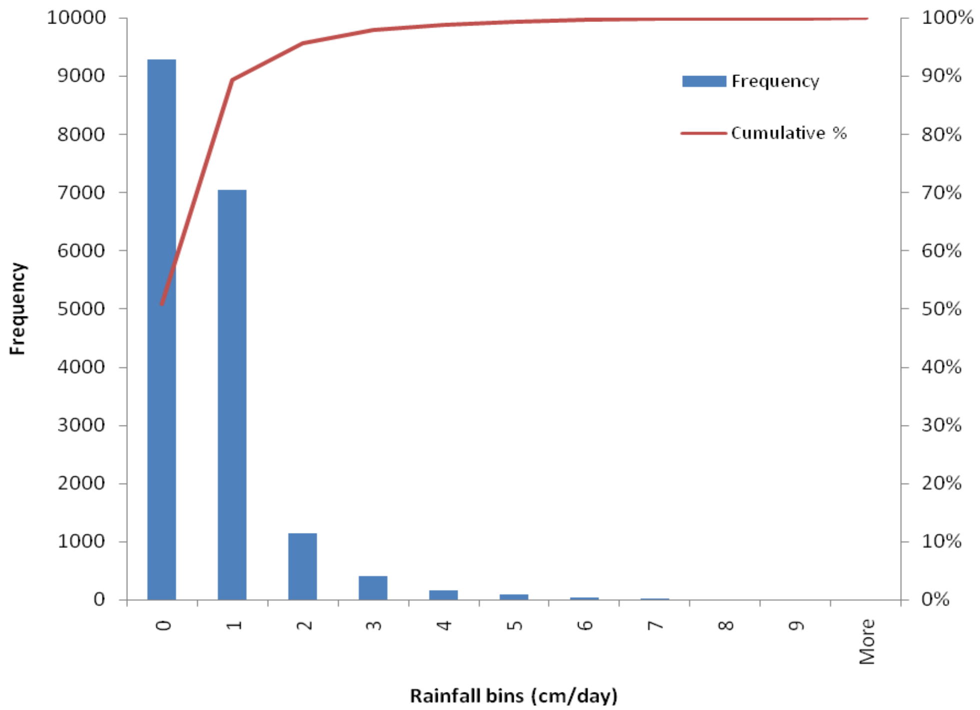
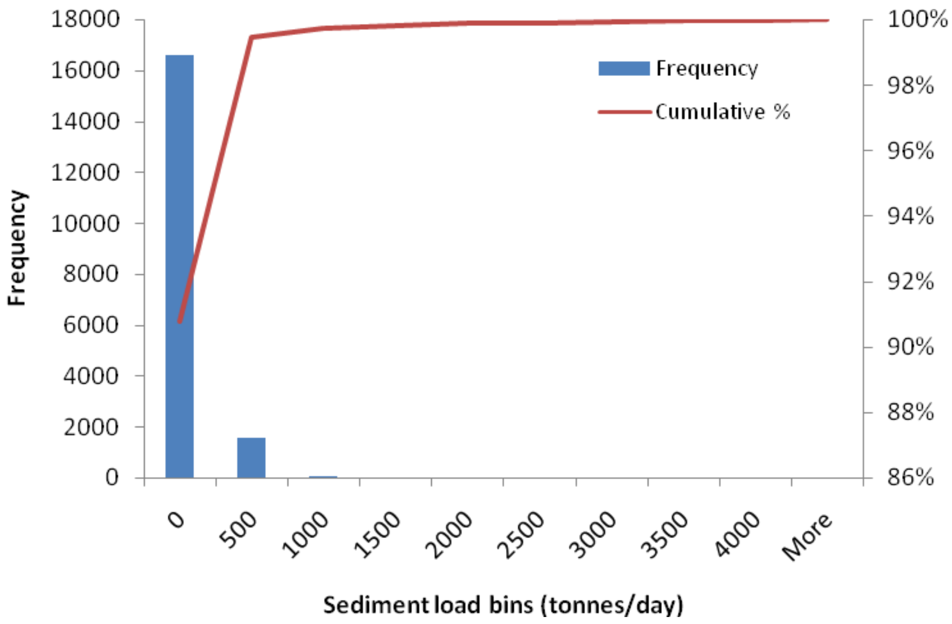


Figure 6

Histograms and cumulative percentage for mean daily sediment loads showing the frequency distribution of sediment load events. The first bin covers the range from 0 to 500 tonnes/day.

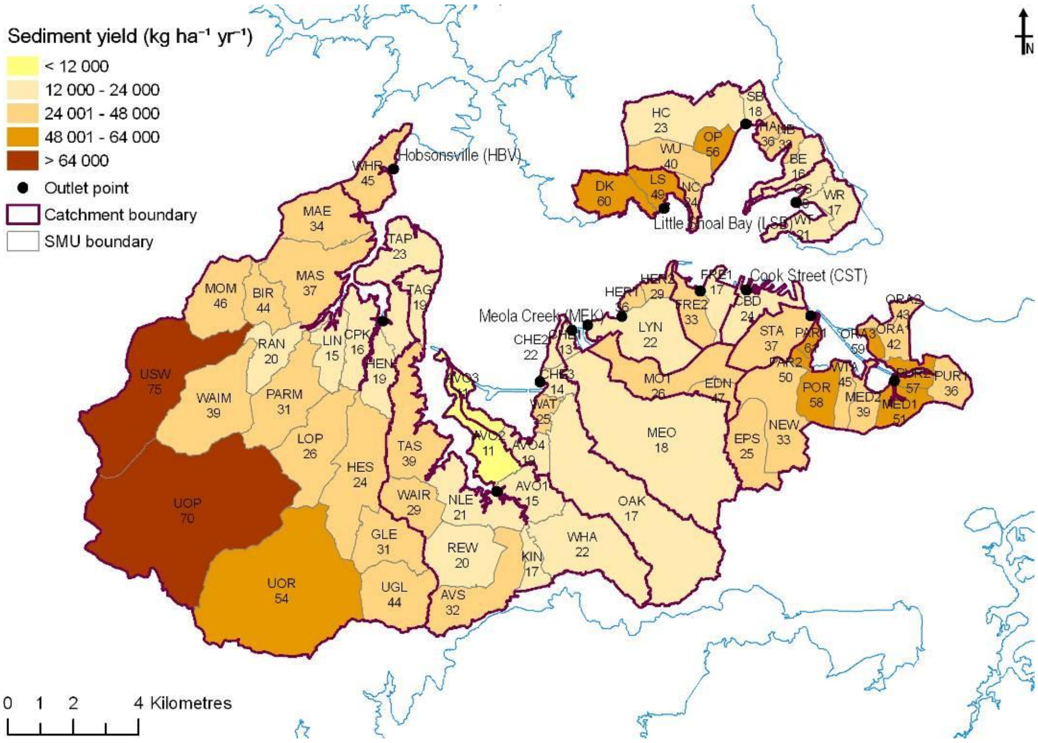


3.3 Sediment yields from greenfield earthworks areas within the urban boundary

The urban CLM model uses greenfield earthworks sediment yield data derived from GLEAMS for determining the loss of sediment from earthworks in the urban area (such as construction on vacant lots) at any given location. Since the particular location of earthworks within the urban part of an SMU is not known, average yields were determined for earthworks for each SMU. These yields were obtained by running GLEAMS with earthworks areas everywhere, and determining the average yield for each SMU (see Auckland regional Council 2008c, for further explanation of this approach). In this approach, there is no treatment of land by sediment ponds in GLEAMS, since treatment is taken care of within the CLM model. The resulting sediment yields for each SMU are given in Figure 7. The variation between SMUs is largely dependent on soil type and slope angles.

Figure 7

Sediment yields for earthworks areas (kg ha^{-1} yr^{-1}) for each SMU in the study area. This calculation assumes that whole catchment is earthworked (see text for further explanation).



The model greenfield earthworks yields lie within the range reported by Ng and Buckeridge (2000) in a review of sediment yields from construction sites within the Auckland region. Similar results have been prepared for grassland, and these are also used in the CLM model. The grassland estimates lie within between 100 and 3000 kg ha^{-1} yr^{-1} typically observed under pastoral land (eg, Van Roon, 1983).

We also note that we have derived annual yields for all seven major land uses for the Henderson Creek sub-catchment, and these predictions have been used in various other studies of sediment sources in the Henderson catchment (see Pinto et al., 2008).

4 Historical Period (1945-2001)

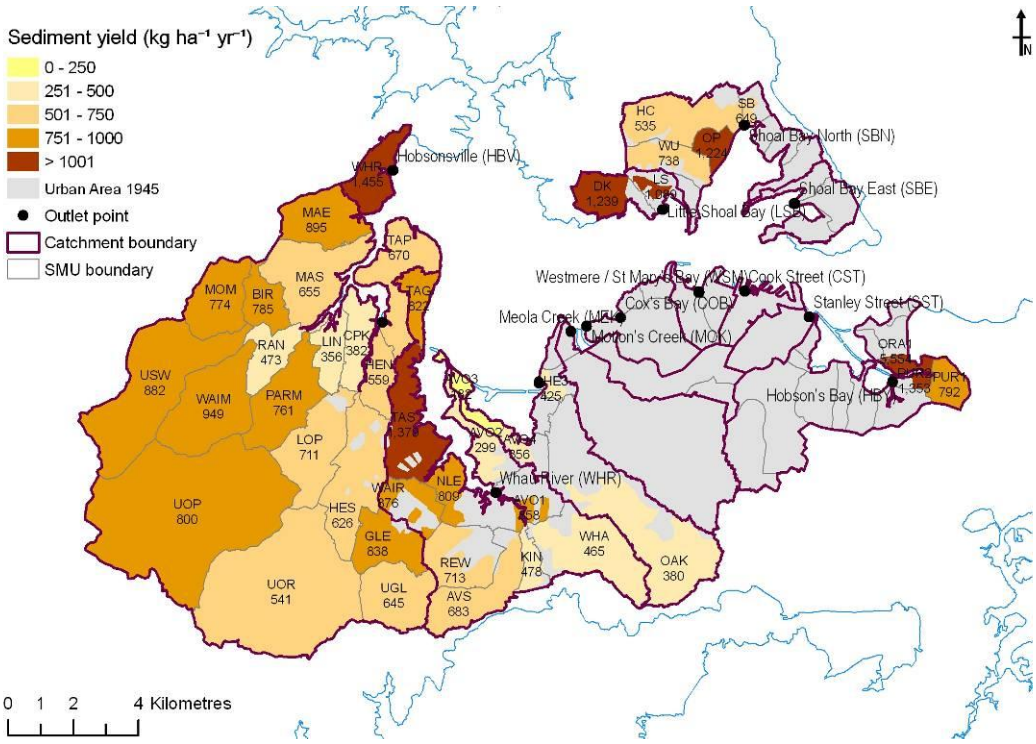
This section presents results of GLEAMS modelling for the historical period 1945–2001, from assumptions given by ARC Technical Reports TR2008/040 and TR2008/032 (ARC, 2008a and 2008b). These assumptions concern land use and greenfield earthworks area estimates, and the treatment of greenfield earthworks with sediment control practices.

Hindcasts are made for the years 1945, 1964, 1987 and 1996. For each of these years, areas within the ARC urban boundary that applied at the time were removed from the model. The year 1996 was simulated with the area within the 2001 ARC urban boundary removed.

4.1 Sediment generation: Year 1945

Figure 8 shows sediment yields from land beyond the ARC 1945 urban boundary and within the study area. These yields are averaged over the rural part of each SMU.

Figure 8
Sediment yields (kg ha^{-1} yr^{-1}) averaged over the rural land of each SMU (rural land beyond the ARC 1945 urban boundary and within the study area).



4.2 Sediment generation: Year 1964

Figure 9 shows sediment yields from rural land and averaged over the rural land beyond the ARC 1964 urban boundary. Note the higher yields that exist in areas where there is earthworks activity from urban growth in 1964.

Figure 10 shows a map of 1964 and 1945 sediment yield differences from rural land of each SMU. Only areas outside the 1964 urban area are shown in the figure. Note that the 1945 yield estimates by SMU are derived from, and averaged over a larger rural area in 1945 than 1964. Generally, high positive differences in sediment yields exist in those areas with earthworks activity in the rural area of an SMU in 1964 and little or no earthworks activity in the rural area of the same SMU in 1945. The relatively small negative differences in sediment yields exist in areas with earthworks activity in the rural area of an SMU in 1945 and no earthworks activity in the rural area of the same SMU in 1964. The figure shows a high increase in sediment yields at the outskirts of the 1964 boundary as a result of increased earthworks activity from urban growth. This same pattern can be seen in Figure 8. Apart from differences in yield estimates which occur as a result of a changing land use, differences also occur from averaging over areas with different slopes, soils and land use.

Figure 9

Sediment yields (kg ha^{-1} yr^{-1}) averaged over the rural land of each SMU (rural land beyond the ARC 1964 urban boundary and within the study area).

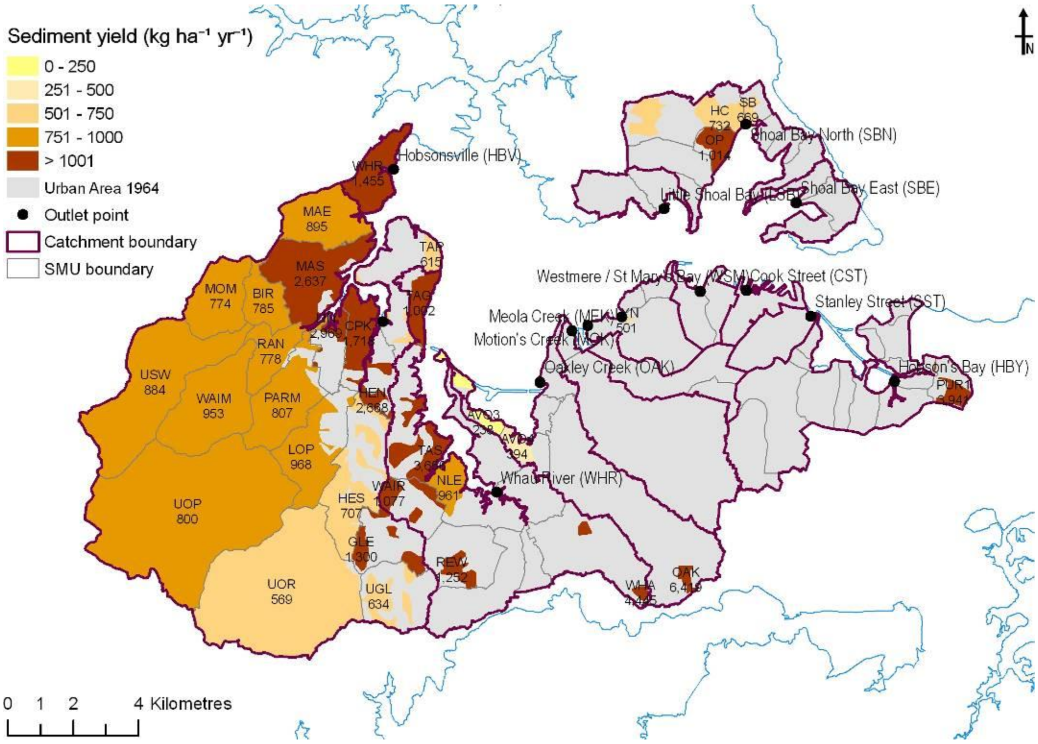
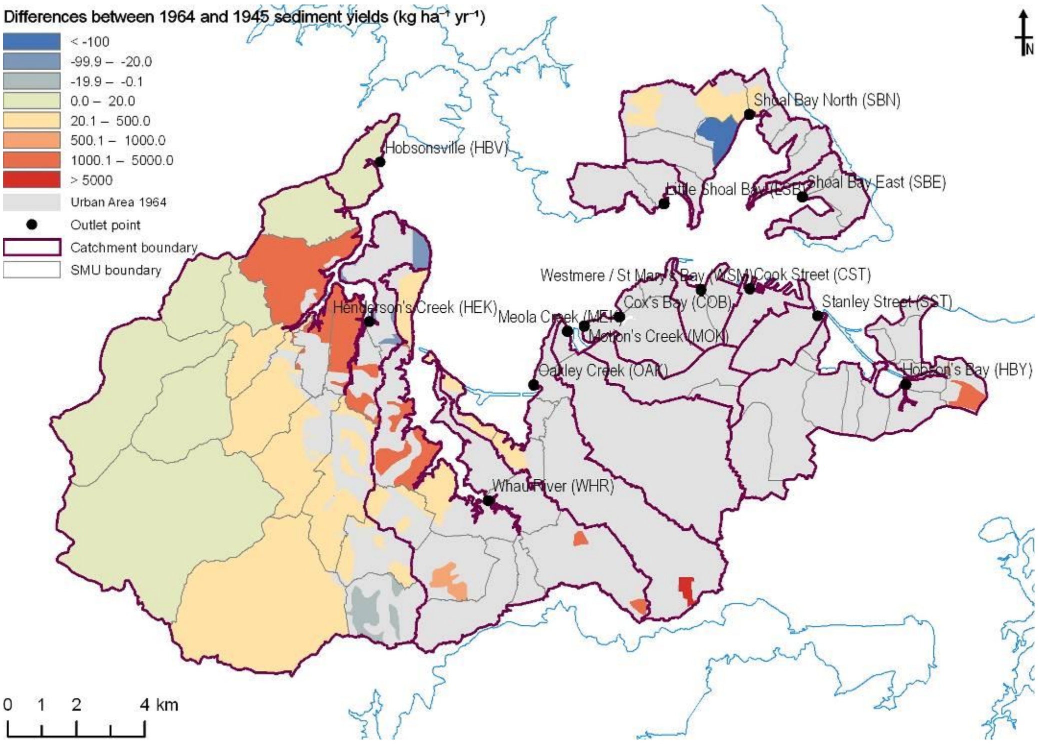


Figure 10

Differences between 1964 and 1945 sediment yields (kg ha^{-1} yr^{-1}) from the rural land of each SMU, overlayed with the 1964 urban area.



4.3 Sediment generation: Year 1975

Figure 11 shows sediment yields from rural land and averaged over the rural land beyond the ARC 1964 urban boundary. Note the higher yields that exist in areas where there is earthworks activity from urban growth in 1975. Figure 12 shows a map of 1975 and 1964 sediment yield differences from rural land of each SMU, overlayed with the 1975 urban area. Generally, high positive differences in sediment yields exist in those areas with earthworks activity in the rural area of an SMU in 1975 and little or no earthworks activity in the rural area of the same SMU in 1964.

Figure 11

Sediment yields (kg ha^{-1} yr^{-1}) averaged over the rural land of each SMU (rural land beyond the ARC 1975 urban boundary and within the study area).

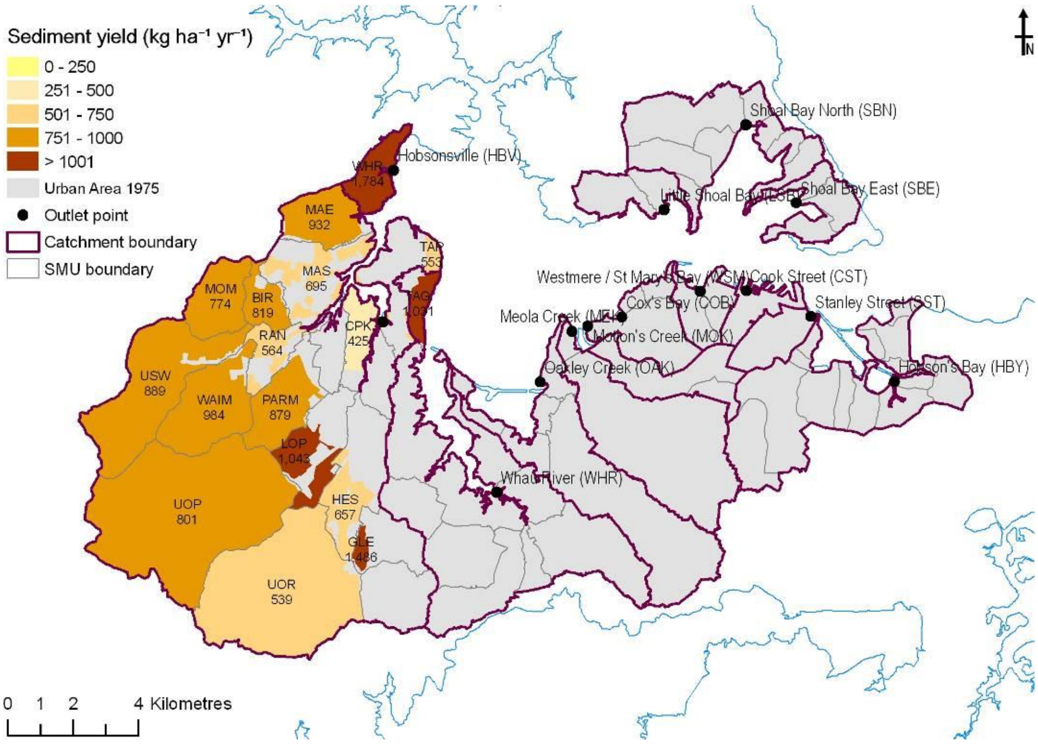
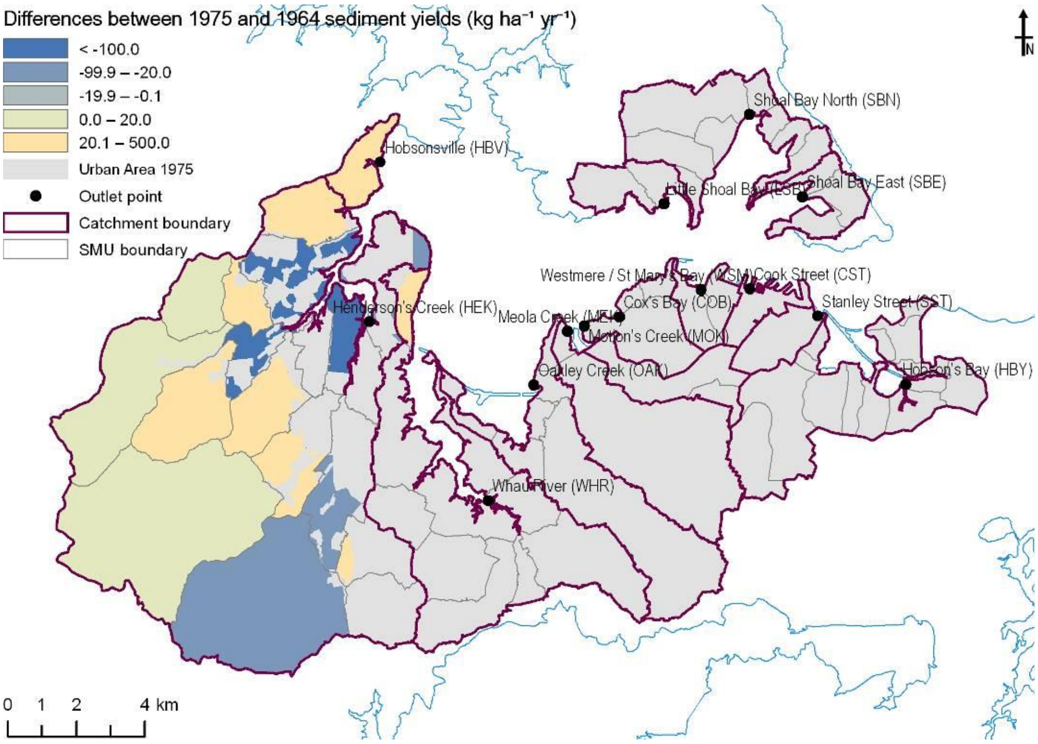


Figure 12
Differences between 1975 and 1964 sediment yields (kg ha^{-1} yr^{-1}) from the rural land of each SMU, overlayed with the 1975 urban area.



4.4 Sediment generation: Year 1987

Figure 13 shows sediment yields from rural land and averaged over the rural land beyond the ARC 1987 urban boundary. Note the higher yields that exist in areas where there is earthworks activity from urban growth in 1987. Figure 14 shows a map of 1987 and 1975 sediment yield differences from rural land of each SMU, overlayed with the 1987 urban area. Generally, high positive differences in sediment yields exist in those areas with earthworks activity in the rural area of an SMU in 1987 and little or no earthworks activity in the rural area of the same SMU in 1975.

Figure 13

Sediment yields (kg ha^{-1} yr^{-1}) averaged over the rural land of each SMU (rural land beyond the ARC 1987 urban boundary and within the study area).

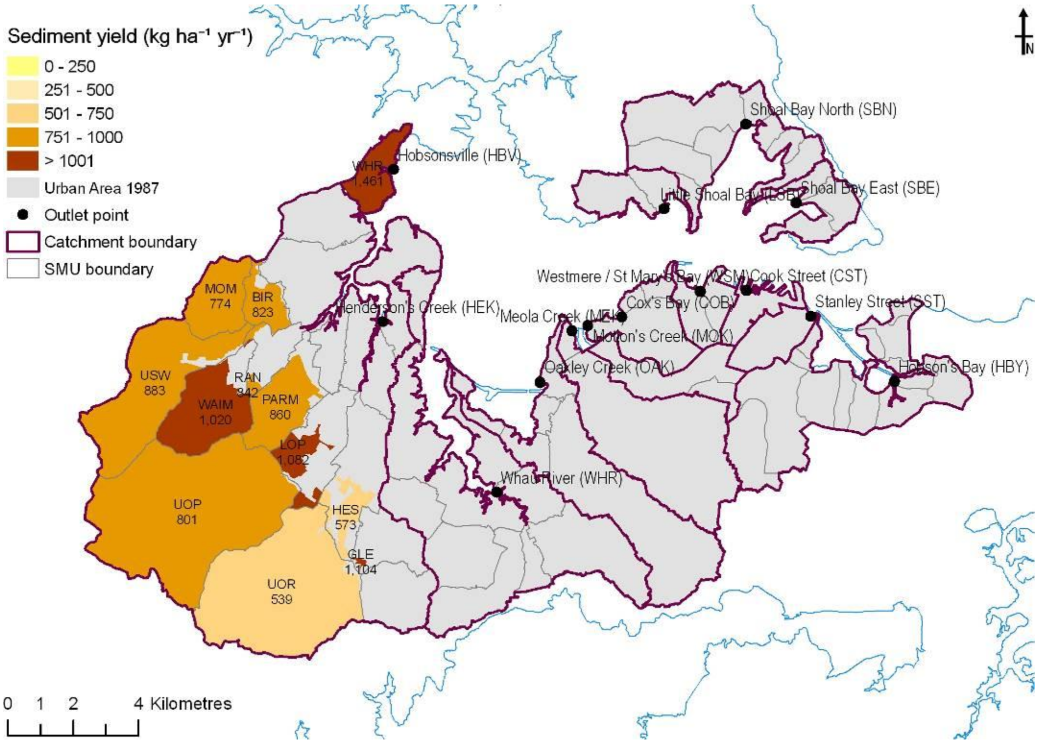
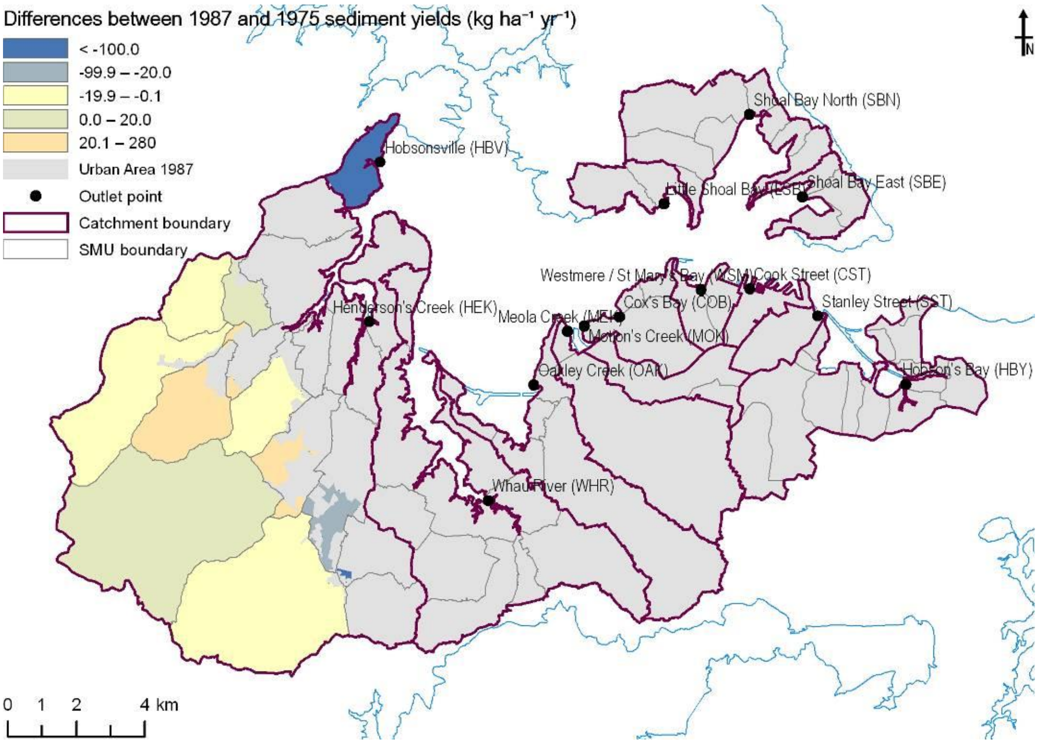


Figure 14
Differences between 1987 and 1975 sediment yields (kg ha^{-1} yr^{-1}) from the rural land of each SMU, overlayed with the 1987 urban area.



4.5 Sediment generation: Year 1996

Figure 15 shows sediment yields from rural land and averaged over the rural land beyond the ARC 2001 urban boundary. Figure 16 shows a map of 1996 and 1987 sediment yield differences from rural land of each SMU, overlayed with the 2001 urban area. Generally, high positive differences in sediment yields exist in those areas with earthworks activity in the rural area of an SMU in 1996 and little or no earthworks activity in the rural area of the same SMU in 1987.

Figure 15

Sediment yields (kg ha^{-1} yr^{-1}) averaged over the rural land of each SMU (rural land beyond the ARC 2001 urban boundary and within the study area).

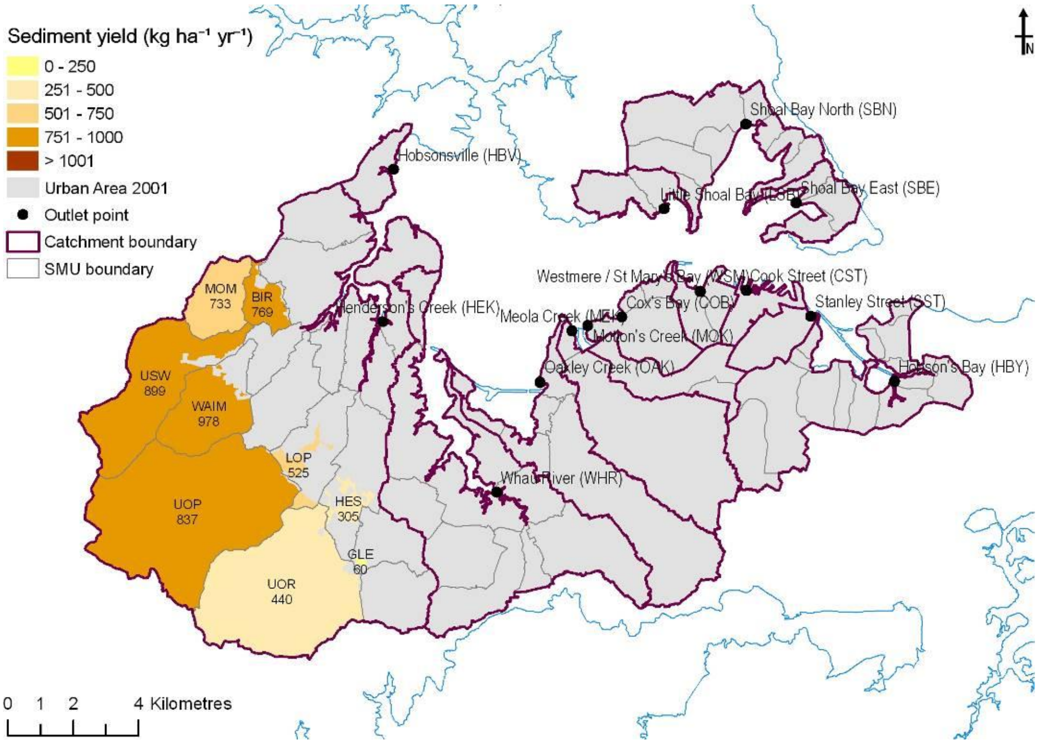
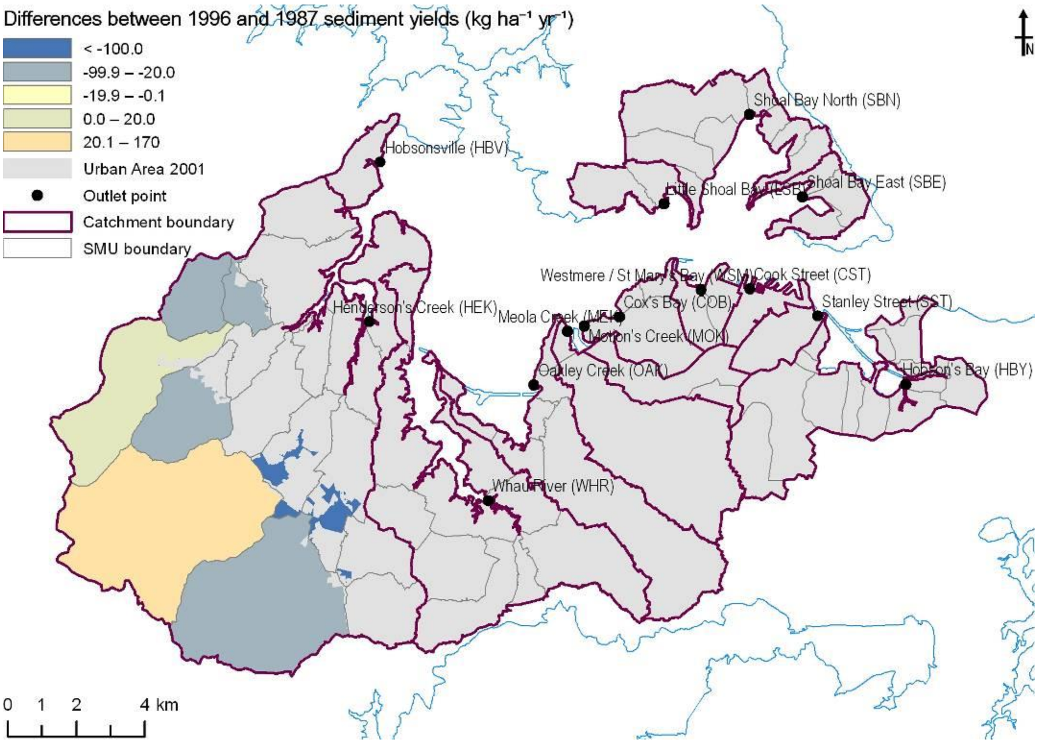


Figure 16

Differences between 1996 and 1987 sediment yields (kg ha^{-1} yr^{-1}) from the rural land of each SMU, overlayed with the 2001 urban area.



5 Future Period (2001-2100)

This section presents results of GLEAMS modelling for 2001 to 2100. The major assumption is that the metropolitan urban limit (MUL) is assumed to be fixed over the entire period (ARC, 2008a) and the future land use outside the MUL is assumed to remain the same as at present with no area of greenfields earthworks assumed. Note that areas within the MUL were removed from the GLEAMS-CWH model as loads from areas within the MUL are determined separately with the CLM model.

5.1 Sediment yields by stormwater management unit (SMU)

Figure 17 shows sediment yields from rural land beyond the MUL and averaged over the rural land beyond the MUL. Note the lower yields that exist in areas where there is earthworks activity from urban growth in 2001 that is not present in the future period.

Figure 17

Sediment yields (kg ha^{-1} yr^{-1}) averaged over the rural land of each SMU (rural land beyond the MUL and within the study area) for the future period.

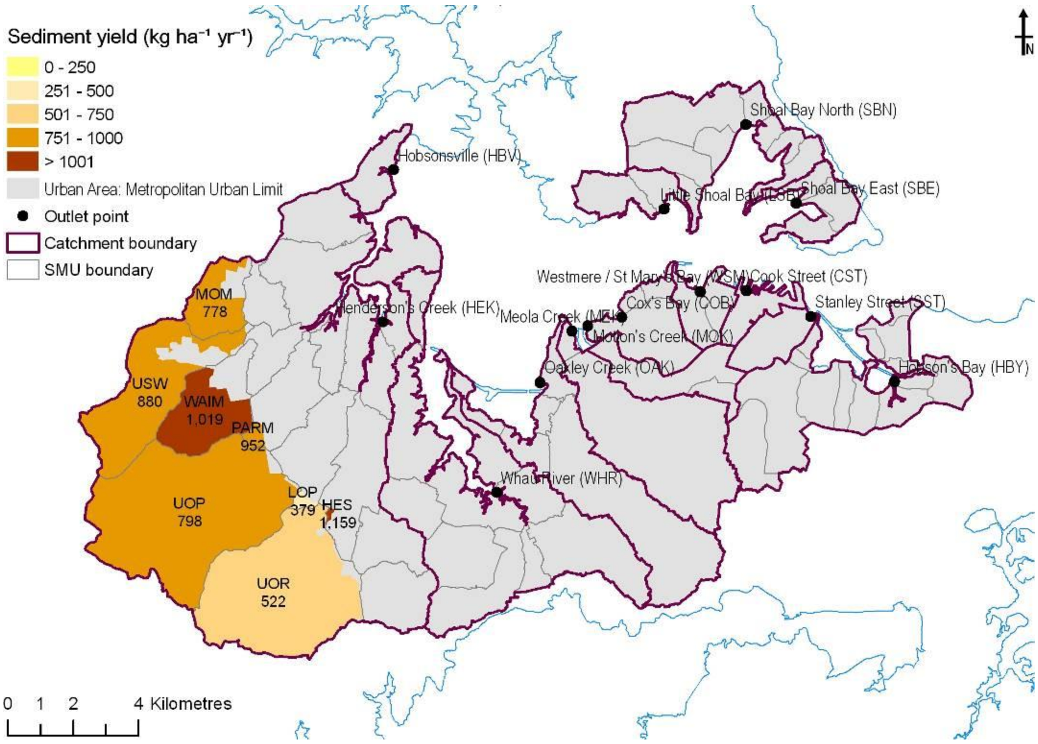
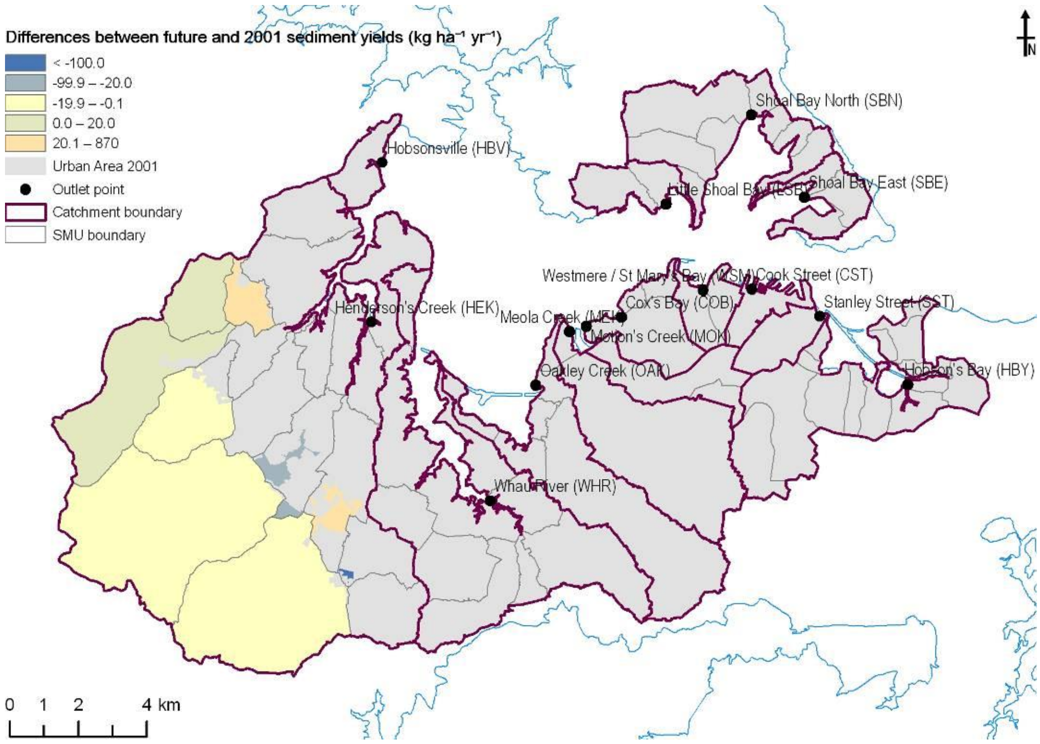


Figure 18 shows a map of future and 2001 sediment yield differences from rural land of each SMU, overlayed with the metropolitan urban limit. Note that the future yield estimates by SMU are derived from, and averaged over a larger rural area in 2001 than for future years. The relatively small negative difference in sediment yields exist in areas with earthworks activity in the rural area of an SMU in 2001 and no earthworks activity in the rural area of the same SMU in the future.

Figure 18

Differences between future and 2001 sediment yields (kg ha^{-1} yr^{-1}) from the rural land of each SMU, overlayed with the metropolitan urban area.



5.2 Sub-catchment sediment loads

Figure 19 shows sediment loads (tonnes/day) as a function of daily rainfall (cm) from rural land beyond the MUL from Henderson creek sub-catchment for the future period.

Figure 19
Model results of sediment loads (tonnes/day) as a function of rainfall (cm) from Henderson Creek (HEK) sub-catchment for the future period.

6 Summary of Trends Over Time

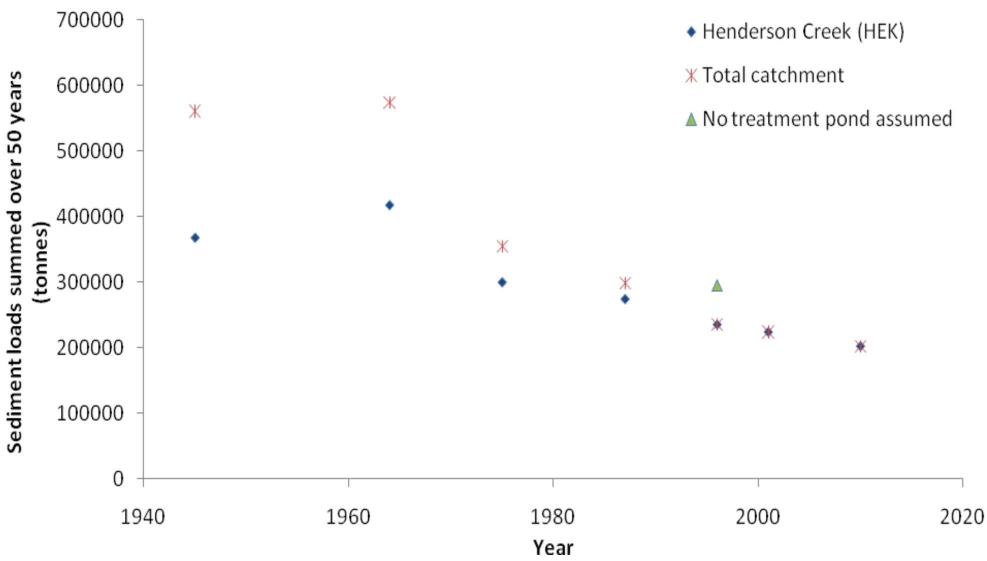
Figure 20 shows the total sediment load from rural and earthworks areas summed over 50 years as estimated by GLEAMS-CWH, for 1) the Central Waitemata Harbour catchment and 2) the Henderson Creek (HEK) sub-catchment. Note that there is no earthworks activity for the future period (shown in Figure 20 for year 2010).

The key points to note are:

- The overall decrease in sediment load between 1945 and 2001 associated with the expansion of the urban area and corresponding reduction in the size of the rural area.
- The increase in overall annual sediment load in 1964 compared to 1945 due to an increase in the rate of urbanisation in the 1960s.
- Greenfield earthworks sediment control practices in the 1990s have resulted in an appreciable decline in the amount of sediment generated in the catchment. This is shown in Figure 20 where no earthworks treatment ponds were assumed in the model for the year 1996.
- Before 2001, most of the rural sediment comes from the Henderson Creek (HEK) sub-catchment. After 2001, all the rural sediment load comes from the Henderson Creek sub-catchment, because other sub-catchments lie within the MUL. Note that there is a separate contribution of sediment from areas within the MUL, which is calculated by the urban CLM model.

Figure 20

Changes in total sediment load over time from the rural area of 1) the Central Waitemata Harbour catchment, and 2) the Henderson Creek (HEK) sub-catchment.



Figures 21 and 22 show the time progression of total sediment load estimates summed over 50 years from the rural part of sub-catchments other than the Henderson Creek sub-catchment, and excluding sub-catchments that are predominantly urban.

The key points to note are:

- The gradual decrease in sediment load between 1945 and 1987 is associated with the expansion of the urban area and corresponding reduction in the size of the rural area, as well as reducing rates of urban earthworks.
- Unlike the Henderson Creek sub-catchment, there was no peak in sediment load in the 1960s.

Figure 21

Changes in total sediment load estimates summed over 50 years from the rural area of all major sub-catchments other than the Henderson Creek sub-catchment.

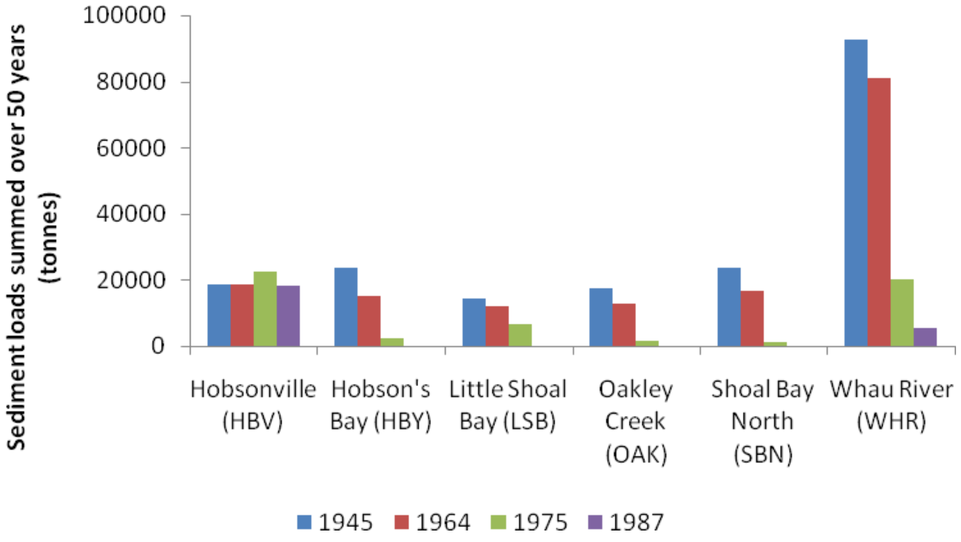
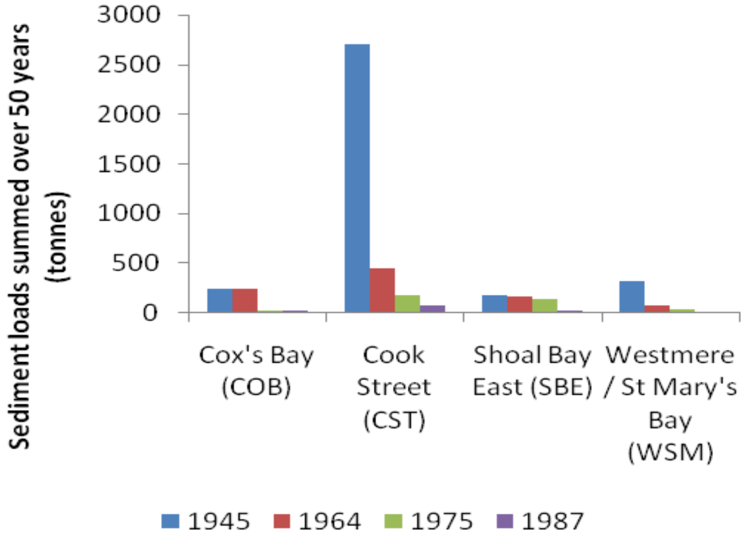


Figure 22

Changes in total sediment load estimates summed over 50 years from the rural area of minor sub-catchments.



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