7 Metal loads in roof run-off

This section of the report describes the estimation of metal loads in roof run-off for the three urban catchments. Roof area and material data for the three study catchments combined with roof run-off quality data (Kingett Mitchell. 2003) were used to estimate the loads.

7.1 Roof areas

Auckland City has carried out a detailed examination of the nature of impervious surfaces in Auckland City. Kingett Mitchell (2003) summarized the contributions of roof area to total impervious surfaces in 38 City catchments. Table 5.1 from that report is reproduced below as Table 8.

The City catchments had roof impervious areas ranging from 30% to 57% (median 40%) of the total impervious area. For 30 of the 38 catchments the range was 36 to 45%. The median proportion of roof area to total catchment area was 19% (range 11 to 29%).

Roof areas for the 3 study catchments were measured directly from aerial photographs for which shape files were available from the previous Auckland City Council study. The catchment boundaries were delineated and all roof areas were identified with a unique number. The material from which each roof was constructed was identified by direct observation. The areas of roofs of the same material were then summed for each catchment. The catchment roof areas are shown in Figures 14, 15 and 16, and are listed in Table 9 according to roof type.

Table 8. Total, impervious and roof area for catchments in Auckland City (Reproduced from Kingett Mitchell 2003).

Catchment	Total Area (m²)	Total Impervious Area (m²)	Roof Area (m²)	% Roof Area of total impervious area (%)	% Roof area of total catchment
Avondale	6,847,357	3,365,604	1,423,218	42.3	20.78
Brentwood	790,802	431,458	184,931	42.9	23.39
Central Business District	2,062,549	1,759,463	599,414	34.1	29.06
Ellerslie/Waitarua	8,199,195	3,867,801	1,494,490	38.6	18.23
Epsom	2,997,973	1,636,354	688,794	42.1	22.98
Freemans Bay/St Marys	3,041,021	2,140,244	748,832	35.0	24.62
Glen Innes	7,344,985	2,417,270	928,786	38.4	12.65
Glendowie	4,273,056	1,597,948	637,833	39.9	14.93
Grey Lynn	4,479,270	2,512,744	1,090,240	43.4	24.34
Herne Bay	1,095,587	588,292	227,561	38.7	20.77
Hillsborough	4,018,552	1,154,693	442,850	38.4	11.02
Kinross/Lewis/Endeavour	2,195,808	805,756	335,258	41.6	15.26
Kohimarama	2,486,219	1,252,361	525,340	41.9	21.13
Meadowbank	3,368,399	1,393,143	588,305	42.2	17.47
Meola	15,101,708	7,386,467	3,169,905	42.9	20.99
Mission Bay	1,720,885	820,994	317,808	38.7	18.47
Motions/Westmere	4,234,972	2,228,356	816,092	36.6	19.27
Mt Wellington North	2,993,770	1,354,994	512,166	37.8	17.11
Mt Wellington South	1,549,078	849,681	367,844	43.3	23.75
Mt Wellington Southdown	9,469,025	5,356,322	2,200,523	41.1	23.24
Newmarket	4,572,942	2,553,450	1,007,639	39.5	22.04
Oakley	12,297,567	5,319,161	2,184,667	41.1	17.77
One Tree Hill	7,649,887	4,128,969	1,687,716	40.9	22.06
Onehunga	6,600,036	3,361,793	1,411,204	42.0	21.38
Orakei	2,038,160	743,783	241,721	32.5	11.86
Otahuhu East	4,587,942	2,178,215	882,008	40.5	19.22
Otahuhu West	1,588,100	1,023,496	414,843	40.5	26.12
Parnell	1,848,474	1,027,108	355,477	34.6	19.23
Point England	2,909,747	1217,629	365,002	30.0	12.54
Portland/Hapua	2,049,357	910,418	301,863	33.2	14.73
Pt Chevalier	1,746,635	802,974	459,395	57.2	26.26
Purewa	2,799,102	774,119	288,817	37.3	10.32
Royal Oak	4,081,447	1,798,215	779,711	43.6	19.10
St Heliers	1,856,075	912,452	352,246	38.6	18.98
Stanley	2,228,410	1,073,194	390,017	37.6	17.50
Waiata	1,010,522	463,721	175,271	37.8	17.34
Waterview/Fairland	646,234	285,471	117,039	41.0	18.11
Whau	6,097,367	2,592,073	1,086,889	41.9	17.83

Figure 14a. Roofs in the CBD western catchment.

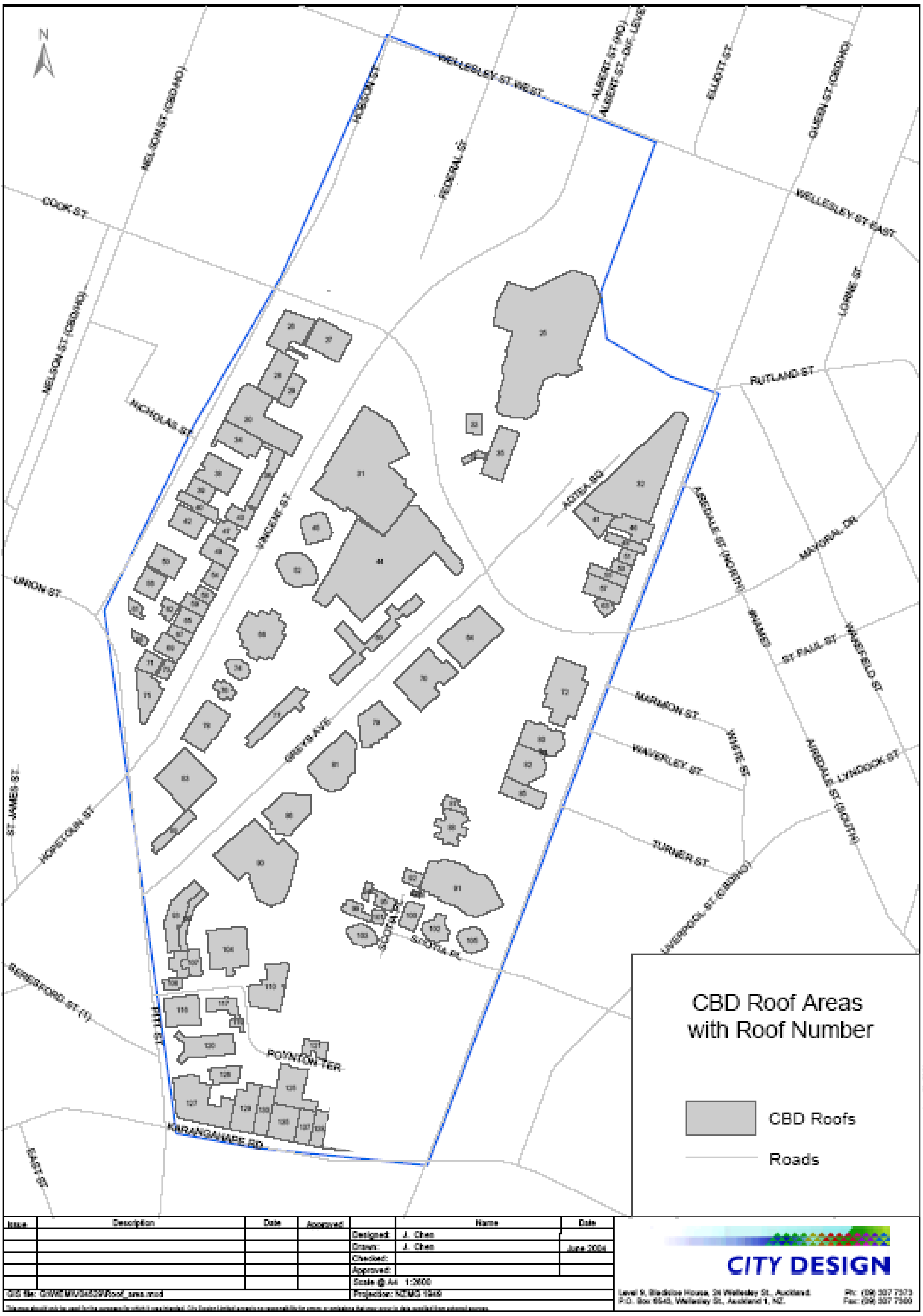

Figure 14b. Roofs in the CBD eastern catchment.

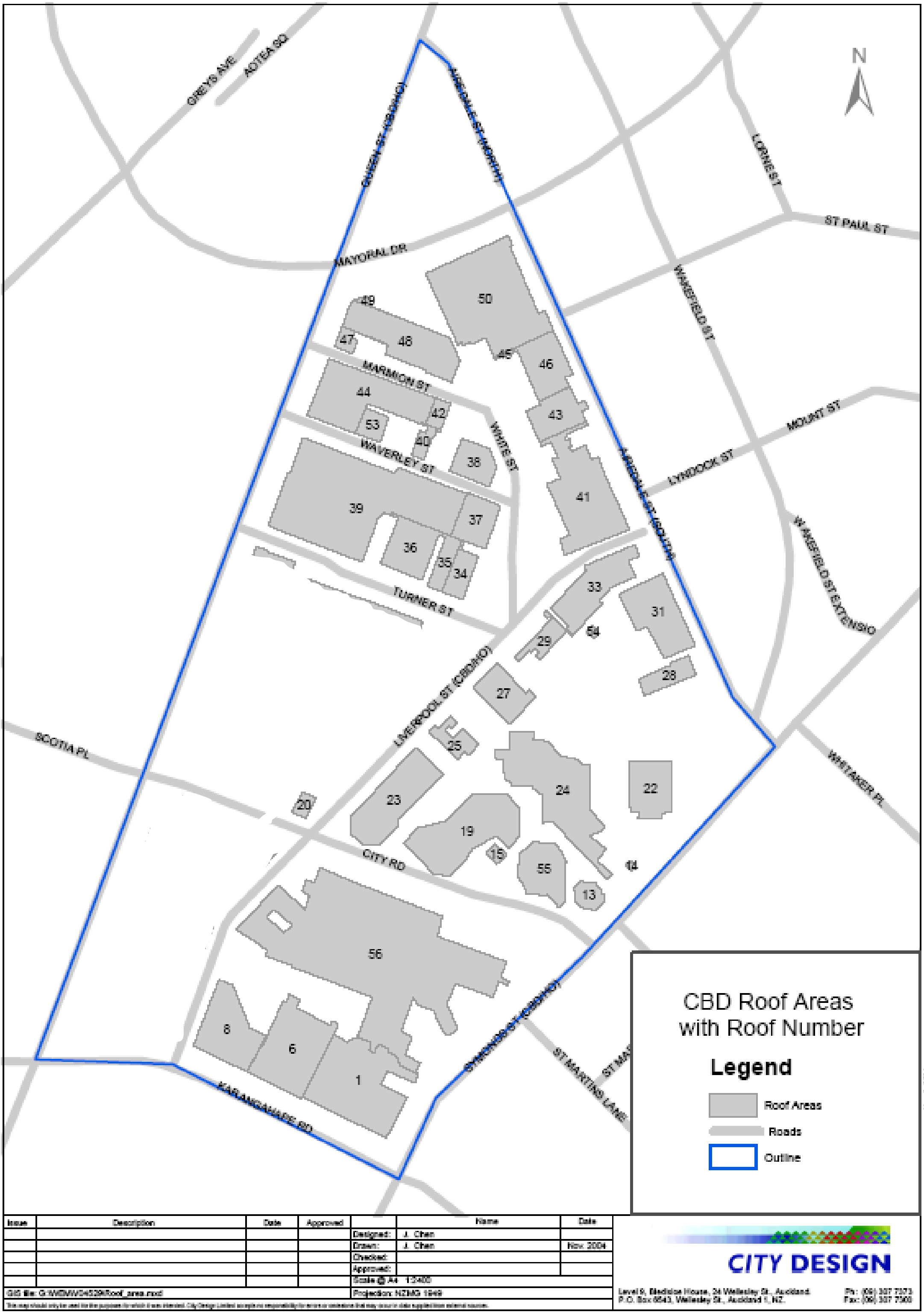

Figure 15. Roofs in the Mission Bay catchment.

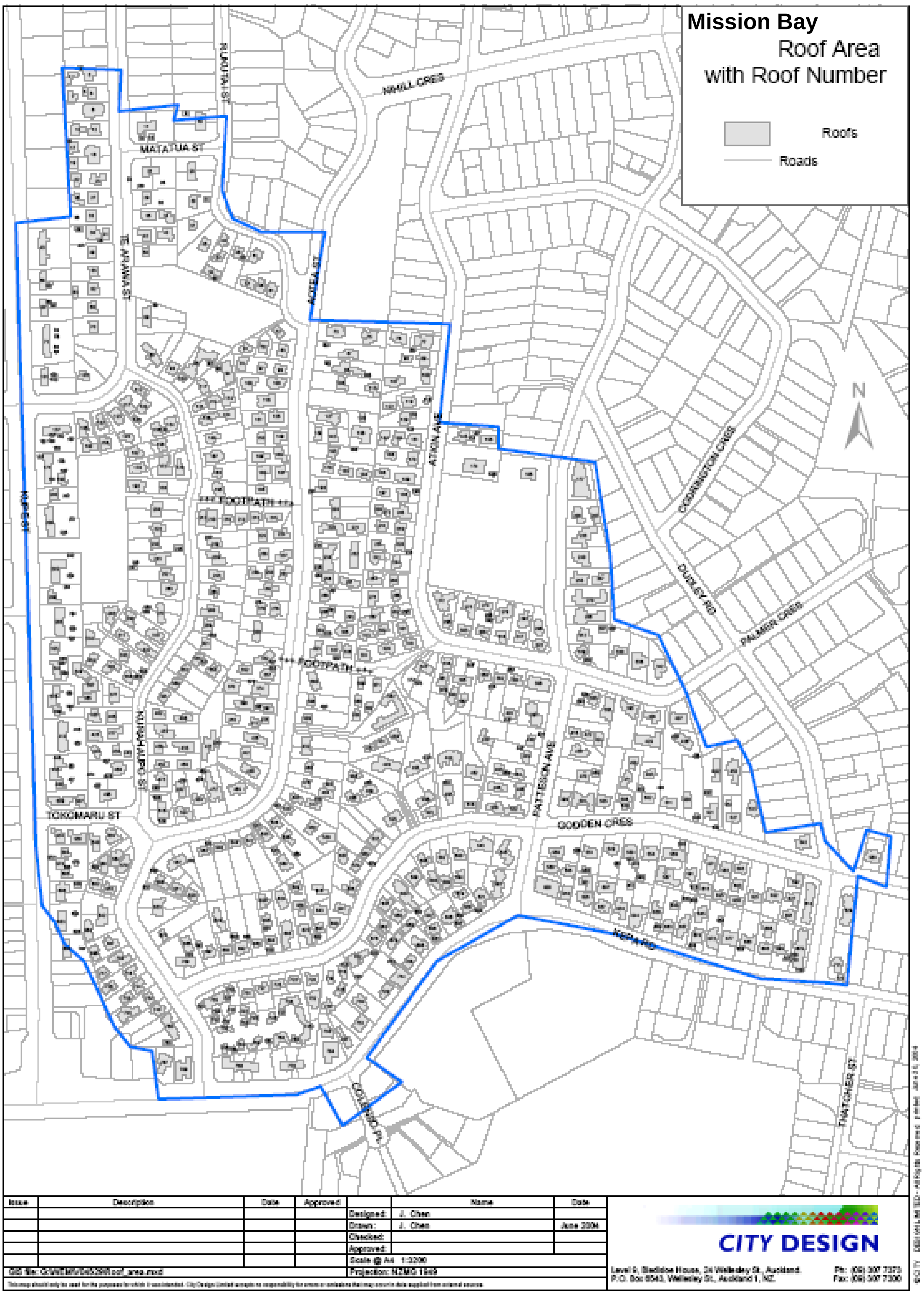

Figure 16. Roofs in the Mt Wellington catchment.

7.2 Roof types

The roofs in the CBD catchment were the most difficult to survey. Some were examined using high powered binoculars from the Sky Tower and the Wellesley St Post Office building. Individual roofs not visible from these vantage points were viewed at first hand after being granted access by the building supervisor. The material on some roofs was difficult to identify because either they were obscured, or permission to access the roof could not be obtained, or access was impossible. Some buildings had been demolished since the aerial photographs had been taken.

Parts of the stormwater network of the central CBD are very old and new information about the section of the network draining to the Aotea Square monitoring point became available during this study. Consequently, the roof survey conducted during the early stages of the study encompassed only 66% of the building roofs (the western catchment) eventually considered to drain to the monitoring point.

Most of the Mission Bay catchment was surveyed by observing the roof type and condition from the roads and driveways. Despite the relative ease of the survey in this catchment, the material on 6.7% of the roofs was not identified mainly because of the large number of individual roofs, the difficulty of seeing some roofs, the complexity of multiple roof materials in any one dwelling and the difficulty of locating owners to gain site access.

The Mt Wellington catchment was surveyed from Mt Wellington using high-powered binoculars followed by confirmation with ground surveys. The latter involved climbing onto the roof to observe the roof material and condition directly. This was by far the easiest catchment to survey because roofs were readily accessible.

It was not possible during the final stages of this study to extend the roof survey in the CBD to include the additional roofs identified in the catchment of the Aotea Square monitoring point. For the calculations of roof run-off loads in this catchment the results for the surveyed 66% of catchment roofs were extended to the remaining 33% of roofs on a pro-rata basis. The uncertainty introduced by this is discussed in the next section. This procedure was also applied to the unidentified roofs in the other two catchments although the uncertainties are quite small with only 0.8% unidentified roofs in the Mt Wellington catchment and 6.5% in the Mission Bay catchment.

In the previous study (Kingett Mitchell, 2003), a roof grading system related to roof condition and run-off quality was developed for galvanised iron roofs based on that used by Scholes (1997). However, in the present study, a simpler grading system was used because of the relatively large number of roofs to survey and the difficulties of getting close enough to observe roof type and condition. Table 10 summarises the grading system used, compared to the more complex system of Scholes (1997) and Kingett Mitchell (2003).

Table 9. Roof area and material in the three study catchments

Category	Mission Bay		Mt Wellington		CBD	
	Area (m^2)	% of total	Area (m^2)	% of total	Area (m^2)	%of total
Total Area	**84898**		**74782**		**102140**	
UNIDENTIFIED	**5463**	**6.5**	**568**	**0.8**	**33808**	**33.1**
sheds detached from main building	**3019**	**3.6**	**0**	**0.0**	**0**	**0.0**
Concrete	**24137**	**28.5**	**0**	**0.0**	**15711**	**15.4**
Colour steel (long run)	**17135**	**20.2**	**2788**	**3.7**	**10926**	**10.7**
Clay	**10932**	**12.9**	**0**	**0.0**	**967**	**1.0**
Colour steel tiles	**1484**	**1.8**	**0**	**0.0**	**996**	**1.0**
Decramastic	**8060**	**9.5**	**0**	**0.0**	**2490**	**2.4**
Bitumen (membrane and pebble)	**5555**	**6.6**	**0**	**0.0**	**1529**	**1.5**
Fibre cement	**480**	**0.6**	**2445**	**3.3**	**619**	**0.6**
GI1	**3438**	**4.1**	**1383**	**1.8**	**5594**	**5.5**
GI2	**2656**	**3.1**	**1369**	**1.8**	**6373**	**6.2**
GI3	**921**	**1.1**	**1727**	**2.3**	**6902**	**6.8**
GIU	**1088**	**1.3**	**64502**	**86.3**	**4493**	**4.4**
copper	**138**	**0.2**	**0**	**0.0**	**0**	**0**
zincalum	**182**	**0.2**	**0**	**0.0**	**3927**	**3.8**
glass	**0**	**0.0**	**0**	**0.0**	**924**	**0.9**
synthetic	**0**	**0.0**	**0**	**0.0**	**1742**	**1.7**
slate	**0**	**0.0**	**0**	**0.0**	**2919**	**2.86**

7.2.1 Comparison of roof types among catchments

The dominant roof types observed varied greatly among the catchments (Table 9, Figure 17). The residential catchment at Mission Bay was dominated by concrete tiles (28.5%), long run colour steel (20.2%) and clay tiles (12.9%). Total galvanized iron was <10% (9.6%). In direct contrast, the Mt Wellington catchment roof types were dominated by galvanised iron (92%), most of which were unpainted (86.3%).

The CBD had a high proportion of galvanized iron (36.8% of those surveyed) and this was evenly spread between the four categories. The proportions of concrete (20% of those surveyed) and long run colour steel (16.8% of those surveyed) were also high.

Decramastic, slate, bitumen and zincalum were significant in at least one of the catchments. Minor categories (<3%) were fibre cement, colour steel tiles, copper, synthetic and glass.

Table 10. Grading system for galvanised iron roofs.

Code used in this report	Scholes' code	Description of Paint Cover (from Scholes 1999)	Condition of Roof
GI1	GI-1	No paint deterioration, recent to newly painted	Excellent
GI2	GI-4	Visible oxidation of paint. Very minor flaking	Good
GI2	GI-3	Paint consistently oxidised. Visible flaking in patches	Moderate
GI3	GI-2	Areas of total paint loss. Most paint flaking or peeling	Deteriorating
GI3	GI-1	Large area of paint loss. All paint flaking or peeling. Possible patches of rust.	Poor
GIU	GIU	Unpainted galvanised iron	-

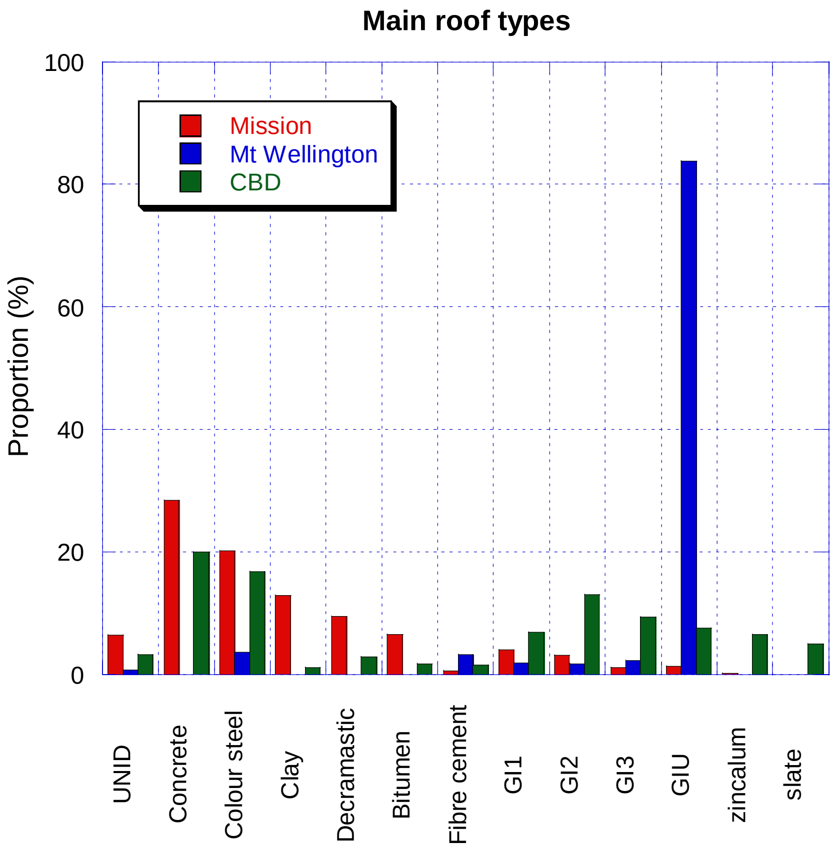

Figure 17. Roof types in the three study catchments. Only those roof types whose proportion is above 3% of the roofs surveyed in one or more catchments are shown. UNID=unidentified.

7.3 Metal concentrations in roof runoff

Concentrations of the main metals in the run-off from the different roof types are listed in Table 11 (Kingett Mitchell, 2003). The concentrations presented are the medians for the bulk samples collected from roofs of the specified type. Where there were no water quality data, e.g., for the uncommon roof types such as synthetic, we used the median metal concentrations for roof run-off from artificial roofs in residential areas for Mission Bay and the CBD, and the median concentrations for run-off in industrial areas for Mt Wellington.

Note that the study by Kingett Mitchell (2003) aimed to collect information from a large number of situations (roof type, land use, first flush etc), and so samples numbers for a given combination of factors are relatively small. Therefore there is a degree of uncertainty around the numbers listed in Table 11. Because of these low sample numbers, we use the median as the estimator of "typical" concentration, rather than the mean, which could be biased by excessively high or low numbers in the small data pool for each situation.

Note also that the median for zincalum in Kingett Mitchell (2003) was re-estimated after deletion of one site with a possibly damaged roof. Also note that the higher concentrations found in the industrial land use for Cu, Zn and Pb may be due to specific industrial discharges and hence may not be typical for all industrial areas.

Table 11. Concentrations (g m^{-3}) assumed for runoff from different roof types.

	Residential and Commercial			**Industrial**		
Category	**Cu**	**Pb**	**Zn**	**Cu**	**Pb**	**Zn**
Concrete	**0.0013**	**0.0005**	**0.020**	**0.003**	**0.0024**	**0.090**
Colour steel (long run)	**0.0008**	**0.0004**	**0.011**	**0.0025**	**0.0023**	**0.081**
Clay tiles	**0.0008**	**0.0004**	**0.015**	**0.0025**	**0.0023**	**0.085**
Colour steel tiles	**0.0008**	**0.0004**	**0.029**	**0.0025**	**0.0023**	**0.099**
Decramastic	**0.0017**	**0.0014**	**0.281**	**0.0034**	**0.0033**	**0.351**
Bitumen (membrane and pebbles)	**0.0008**	**0.0004**	**0.015**	**0.0025**	**0.0023**	**0.085**
Fibre cement	**0.0008**	**0.0004**	**0.015**	**0.0025**	**0.0023**	**0.085**
GI1	**0.0008**	**0.0008**	**0.151**	**0.0025**	**0.0027**	**0.221**
GI2	**0.0008**	**0.010**	**1.13**	**0.0025**	**0.0029**	**1.20**
GI3	**0.0008**	**0.015**	**1.36**	**0.0026**	**0.169**	**1.43**
GIU	**0.0008**	**0.0046**	**1.60**	**0.0025**	**0.0065**	**1.67**
copper	**3.00**	**0.0004**	**0.015**	**3.00**	**0.0023**	**0.085**
zincalum	**0.0008**	**0.0006**	**0.310**	**0.0025**	**0.0025**	**0.380**
glass	**0.0008**	**0.0004**	**0.015**	**0.0025**	**0.0023**	**0.085**
synthetic	**0.0008**	**0.0004**	**0.015**	**0.0025**	**0.0023**	**0.085**
slate	**0.0008**	**0.0004**	**0.015**	**0.0025**	**0.0023**	**0.085**

7.4 Uncertainties in the roof run-off loads

The assumed metal concentrations in roof run-off (Table 11) were derived from the results of the investigation reported in Kingett Mitchell (2003). Estimates of errors in these assumed values cannot be readily derived from the reported results but the authors discuss comparisons with other studies.

One comparison for zinc is informative. Karlen et al (2001) reported zinc run-off rates between 0.07 and 3.5 g m^{-2} $year^{-1}$ from roofs of various materials in Sweden. The rates reported by Kingett Mitchell (2003) were 0.02 to 1.92 g m^{-2} $year^{-1}$ for residential and commercial landuses and 0.12 to 2.25 g m^{-2} $year^{-1}$ for industrial land uses. Given that Karlen et al (2001) included pure zinc plate in their study whereas Kingett Mitchell (2003) did not, there is excellent agreement between the two studies on the zinc run-off rates.

The proportions of unidentified roof materials in the Mission Bay and Mt Wellington catchments were small, maximum 6.5%, so the error in the metal loads arising from these unidentified roofs must also be small.

Only 66% of the roofs in the CBD catchment were surveyed for roof type although all were surveyed for area. It was assumed that the proportions of different roof types in the unsurveyed roofs were the same as in those surveyed. For copper and lead, however, the concentrations in the run-off are almost the same for all roof types (Table 11). The material assumed for the unsurveyed roofs is, therefore, of no consequence for the copper and lead roof run-off loads and the errors introduced for these metals by the pro-rata assumption are negligible.

This is not necessarily the case for zinc, for which the run-off concentration varies with roof type (Table 10). An approximate indication of the possible size of the error introduced by this assumption can be obtained by assuming that the proportion of galvanised iron in the unsurveyed roofs could be either 20% higher or 20% lower than the observed proportion in the surveyed roofs. In both cases the areas of the other roof types are assumed to be distributed in the observed relative proportions. The higher area of galvanised roofs would increase the total catchment roof run-off load to 49.4 kg a^{-1} from the pro-rata value of 46.4 kg a^{-1} and the lower area would reduce the load to 44.0 kg a^{-1}, i.e. a total catchment roof run-off load of about 46.4 ± **3** kg a^{-1}.

7.5 Roof Runoff Loads

For the calculation of roof run-off loads we have assumed that all roofs have a runoff coefficient of 0.95, and that the annual rainfall is 1.2 m for Mission Bay and the CBD, and 1.35 m for Mt Wellington.

The calculated roof run-off loads for the 3 catchments are given in Table 12. As noted above, the loads from unidentified roofs have been included on a pro-rata basis.

Table 12. Loads from roof run-off in the three study catchments.

	Loads (kg a^{-1})		
	Zn	**Cu**	**Pb**
CBD	**46.4**	**0.11**	**0.27**
Mission Bay	**12.0**	**0.27**	**0.08**
Mt Wellington	**146**	**0.24**	**0.61**