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Review of historical land use and nitrogen leaching: Waikato and Waipa catchments

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Technical Leaders Group of the Healthy Rivers/Wai Ora Project

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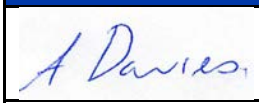
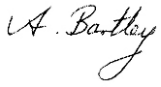
	Reviewed by:	Annette Semadeni-Davies
	Formatting checked by:	Alison Bartley
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Executive summary

A main objective of the "Healthy Rivers: Plan for Change / Wai Ora: He Rautaki Whakapaipai" project is restoration and protection of the health of the Waikato and Waipa Rivers. The plan change will identify measures that, over time, will help reduce inputs of sediment, bacteria and nutrients (nitrogen and phosphorus) to water bodies (including groundwater) in the Waikato and Waipa River catchments.

This report, commissioned by the Technical Leaders Group, describes what was done to estimate historical changes in nitrogen leaching losses. This information will be used to:

- provide an understanding of drivers of trends in nitrogen in streams and rivers
- provide input to assessments of the degree to which current water quality has adjusted to changes in catchment sources
- provide information for catchment models that predict the likely consequences of meeting a water quality improvement target on farm and regional economics.

Historical land use data derived from several sources were collated in a geospatial framework and analysed to provide information regarding land use change over time. Several techniques were used to infill land use data that were missing for various periods. As a result, estimates of land use were obtained across the 74 Healthy Rivers/Wai Ora sub-catchments for the years 1972, 1986, 1996, 2002, 2008 and 2012. Linear interpolation techniques were used to estimate land use at decadal intervals for a period commencing in 1972. A consistent set of 10 land uses was derived that could be used to classify all land uses over the 74 sub-catchments over time.

Having access to accurate leaching losses is important when estimating the yield of nitrogen at land parcel, sub-catchment or catchment scale. Nitrogen leaching loss (or load) is the product of land area used for a particular land use multiplied by a nitrogen yield (kg per ha) that is representative of that land use. Nitrogen yields for some land uses are relatively uniform and may be applied reasonably widely – estimates for forestry (native and exotic) fall into this category. For other land uses (for example pastoral farming), the selection of representative yields is important for several reasons:

- the areas subject to these land uses are changing rapidly across much of the Waikato River catchment
- pastoral farming is the dominant land use across many of the Healthy Rivers/Wai Ora sub-catchments, and
- nitrogen losses from pastoral land use (particularly dairy) tend to be large relative to other land uses.

Several methods were explored to estimate **historical nitrogen leaching yields** for land used for dairy and sheep and beef farming operations. Many estimates of nitrogen loss have been published. Most of these are the net loss; the loss observed after various attenuation processes have exerted an influence. To overcome this limitation, nitrogen yield estimates were sought from the literature where the OVERSEER® model was used to estimate nitrogen loss from pastoral land uses in the Waikato and Bay of Plenty Regions. Several reports were identified where the OVERSEER® model had been used to estimate nitrogen losses either at individual farm or at sub-catchment scale over a

period of time. Data derived from OVERSEER® for nitrogen losses from dairy, and sheep and beef operations indicated a linear increase in leaching rates for these land uses over time. Data for dairy, and sheep and beef farming were fitted to identify separate linear relationships. These estimates were then scaled so that nitrogen loss for dairy, and sheep and beef farming in 2012 became reference values, similar to those that were being used in other Healthy Rivers/Wai Ora projects. We present both absolute and relative leaching rate estimates.

Nitrogen leaching losses for other land uses were obtained from separate work-streams within the Healthy Rivers/Wai Ora project. Leaching losses for various land uses were combined with areas of land use within individual sub-catchments to provide estimates of nitrogen loads on a sub-catchment basis. Separate sub-catchment yields were obtained for decadal and other time steps. These yields were also accumulated in a downstream direction, to describe how nitrogen losses contribute to the increase in load along the Waikato River. Annual nitrogen losses for selected land use classes are summarised in the table below for the entire Healthy Rivers catchment area:

Trend in total nitrogen losses over the entire Healthy Rivers catchment, 1972-2012.

Year	Nitrogen loss by land use type (kt/y)					
	Total	Dairy	Intensive Sheep and Beef	Hill Sheep and Beef	Pasture Total	Non-Pasture
1972	9.24	3.95	1.64	1.90	7.49	1.75
1982	10.65	4.83	1.93	1.88	8.64	2.01
1992	12.00	5.64	2.24	1.86	9.74	2.27
1996	12.53	5.95	2.37	1.84	10.16	2.37
2002	13.51	7.74	2.27	1.52	11.52	1.99
2008	14.87	8.28	2.39	1.78	12.44	2.43
2012	15.35	9.62	2.93	1.09	13.64	1.71

Analysis of these estimates identified the follow points:

- Nitrogen losses summed over the entire Waikato River catchment have increased gradually since 1972, with nitrogen losses 66% larger in 2012 than they were in 1972.
- Nitrogen losses from dairy land use have increased 240% since 1972, driven by an increase in nitrogen yield (a factor of 2.1), as well as an increase in the total area used for dairy.
- The relative contribution of dairy to catchment nitrogen yield increased from 43% in 1972 to 63% of the total in 2012.
- Estimated losses from non-dairy pastoral land use increased by 4% over the period 1972 to 2012.

Although these predicted nitrogen losses do not take attenuation in groundwater, lakes and streams into account, the **relative increases** are likely to be largely independent of attenuation. The trends in nitrogen loss predicted for individual sub-catchments are generally consistent with what is evident in the water quality record.

Several individual sub-catchments indicate more pronounced trends. For example:

- in the Little Waipa sub-catchment, nitrogen losses have increased 322% since 1972, while
- nitrogen losses from the Kirikiriroa sub-catchment were predicted to decrease over this period – this decrease has been associated with improved management of leachate from a closed landfill site, and is corroborated by changes in water quality leaving the catchment.

Although inaccuracies in assignments of land use and the areas associated with specific land uses at discrete time steps exist because the method used for determining land use varied between different time periods, overall trends in land use and nitrogen leaching losses are considered adequate for the objectives of the Healthy Rivers/Wai Ora Plan Change. These trends in land use and nitrogen leaching losses will provide valuable information for the catchment models that have been developed for the Healthy Rivers/Wai Ora Plan Change, and also provide a sound foundation for the creation of a more elaborate dynamic catchment model.

1 Background and scope

1.1 Background

Waikato and Waipa River iwi and the Waikato Regional Council (WRC) are partners in a project "Healthy Rivers: Plan for Change / Wai Ora: He Rautaki Whakapaipai" (HRWO). The project aims to change the Waikato Regional Plan to help restore and protect the health of the Waikato and Waipa Rivers. These changes and their objectives have been set out in settlement and co-management legislation for the Waikato and Waipa Rivers. The measures that will be implemented through the plan change will, over time, help to reduce inputs of sediment, bacteria and nutrients (nitrogen and phosphorus) to water bodies (including groundwater) in the Waikato and Waipa River catchments. This report is one of a series commissioned by the Technical Leaders Group of the HRWO Project to better understand the sources of nitrogen in the Waikato/Waipa catchment and its transport from land to surface waters.

Transport of nitrogen from the base of the soil profile through the subsurface (vadose zone, shallow and deep groundwater) creates the potential for temporary storage of nitrogen. This introduces a time delay or lag period between the time when nitrogen is lost from the soil surface to when it re-emerges in surface water (streams and lakes). If N leaching rates increase more rapidly than the residence time of the subsurface system there is potential for a "load to come", where water quality in the streams and lakes may not yet reflect the ultimate condition. This is particularly pertinent to parts of the Upper Waikato catchment where there are known long groundwater storage times (reflected in the measured age of groundwater) and increased N leaching due to intensification of current land use and conversion of land to more intensive uses such as dairy (from uses such as exotic forestry).

A complete representation of the evolution of future response to past changes in land use requires characterisation of leaching losses over time, consideration of the dynamic response of the subsurface system, and estimation of attenuation processes that would dampen the N response observed in surface waters.

This report addresses the first of these three aspects, providing an estimate of leaching losses over the period 1972 to 2012. Other aspects of the overall task, such as identifying groundwater response times, estimating attenuation and modelling the overall system, are addressed in separate projects under the Healthy Rivers programme. The emphasis in this study is provision of an independent estimate of historical leaching rates. This information was further developed to provide estimates of leaching rates **relative** to current levels, as well as absolute leaching rates. The relative leaching rate estimates are provided to demonstrate how the estimates derived from this work compare with leaching rates estimates provided by other parties.

In the short term, this information is being used to interpret current stream nutrient concentrations, the degree to which they reflect current leaching rates, and associated attenuation of nitrogen as it moves from the land to surface water. For example, if historical leaching rates have been stable and response times are short, then the attenuation of nitrogen can be estimated from the difference between the source loads and the loads observed in streams. In other cases, where the lags are significant in relation to changes in leaching, then the attenuation cannot be estimated in this way, and there may be significant load to come. Alternatively, if attenuation of leached Nis high, there may not be significant "load to come".

In the longer term, the assessment of historical leaching rates presented in this report may be incorporated into more sophisticated dynamic models that explicitly represent the transient response to changes in leaching.

When considered within a context of land use (nitrogen input), soil properties and hydrogeology (groundwater lag times), and the subsurface electrochemical environment (an indicator of the likelihood of nitrogen attenuation), key information is obtained to guide model development.

1.2 Scope of this investigation

This report describes an assessment of nitrogen (N) leaching losses likely to prevail in the Waikato River catchment from the outlet of Lake Taupo to Port Waikato, inclusive of the Waipa River catchment. These estimates are provided for each of 74 sub-catchments, the boundaries of which were delineated in other projects on the basis of monitoring sites for which water quality data exist (Semadeni-Davies et al. 2015a). The sub-catchments are shown in Figure 1-1 and listed in Table 1-1.

This report comprises three key components:

- Estimating the areas within each catchment associated with specific types of land use at specific times - decadal intervals were selected for the period 1972 – 2012.
- Estimating trends in leaching rate for two key land use types (dairying, and sheep and beef farming) that were likely to have occurred over the same period of time.
- Combining the land use at decadal intervals with the leaching rate estimates at the same time intervals to provide an estimate of nitrogen loss over time.

The historical leaching estimates were based on reviews of existing literature, rather than detailed modelling of progression of factors such as stocking rates and production, farm management, and fertiliser application.

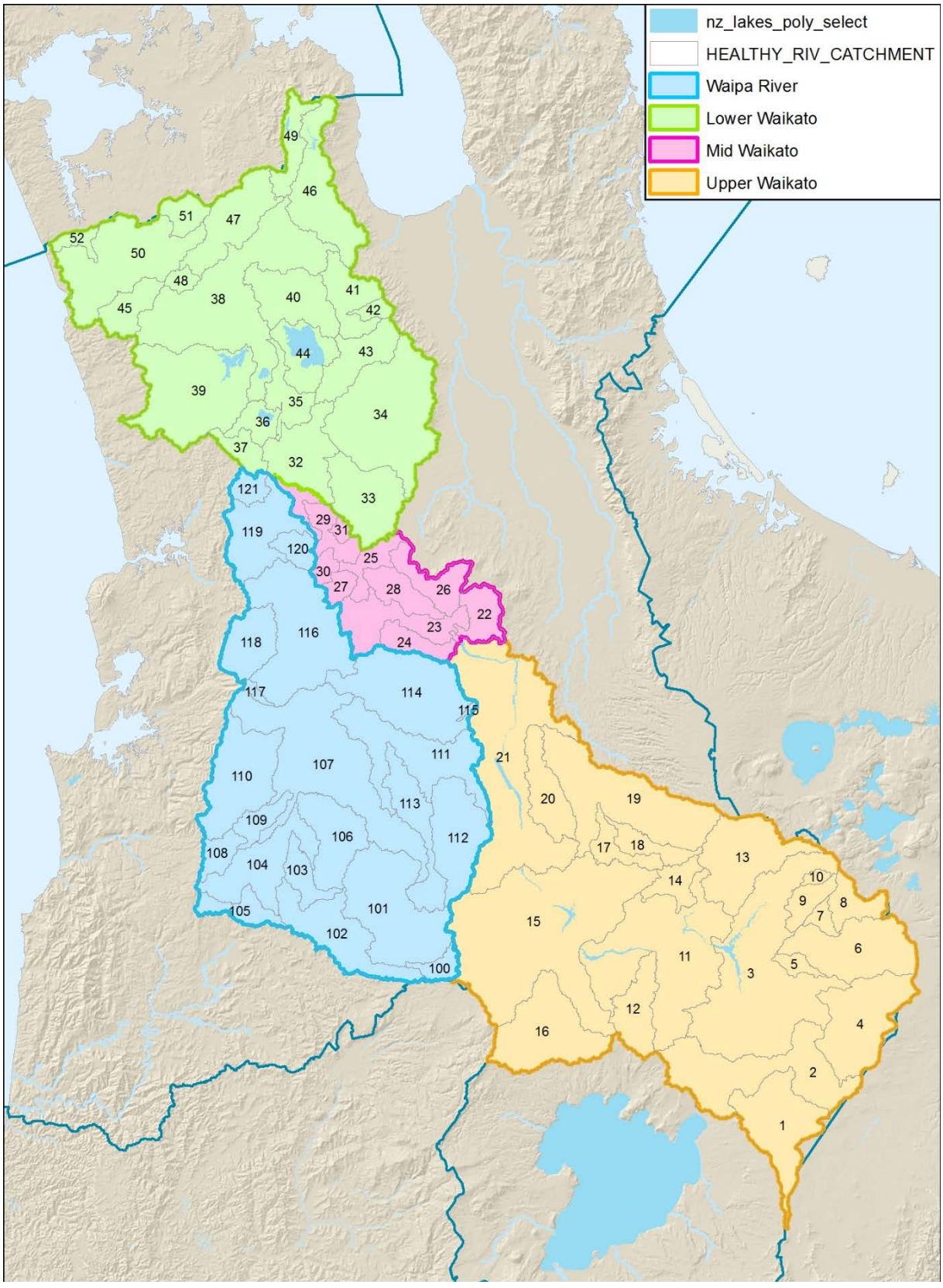


Figure 1-1: Sub-catchments in the upper, mid and lower Waikato River and Waipa River catchments. Labels refer to "Map ID" values in Table 1-1.

Table 1-1: List of sub-catchments in the Waipa, and upper and lower Waikato River catchments.

Map ID	Sub-catchment	Area (ha)
1	Pueto	20029
2	Waikato at Ohaaki	29009
3	Waikato at Ohakuri	53139
4	Torepatutahi	21721
5	Mangakara	2235
6	Waiotapu at Homestead	20478
7	Kawaunui	2134
8	Waiotapu at Campbell	6079
9	Otamakokore	4573
10	Whirinaki	1080
11	Waikato at Whakamaru	44665
12	Waipapa	10049
13	Tahunaatara	20816
14	Mangaharakeke	5415
15	Waikato at Waipapa	69392
16	Mangakino	22186
17	Mangamingi	5175
18	Whakauru	5302
19	Pokaiwhenua	32701
20	Little Waipa	10649
21	Waikato at Karapiro	53969
22	Karapiro	6741
23	Waikato at Narrows	12987
24	Mangawhero	5347
25	Waikato at Bridge St Br	5072
26	Mangaonua	8096
27	Mangakotukutuku	2708
28	Mangaone	6760
29	Waikato at Horotiu Br	5405
30	Waitawhiriwhiri	2223
31	Kirikiriroa	1233
32	Waikato at Huntly-Tainui Br	17322
33	Komakorau	16399
34	Mangawara	35884
35	Waikato at Rangiriri	6853
35	Waikato at Rangiriri	6853
36	Awaroa (Rotowaro) at Harris/Te Ohaki Br	4730
37	Awaroa (Rotowaro) at Sansons Br	4561
38	Waikato at Mercer Br	45168
39	Whangape	31767
40	Whangamarino at Island Block Rd	14365
41	Whangamarino at Jefferies Rd Br	9701
42	Waerenga	1959
43	Matahuru	10637
44	Waikare	10418
45	Opuatia	7067
46	Mangatangi	19452
47	Waikato at Tuakau Br	15178
48	Ohaeroa	2033
49	Mangatawhiri	6808
50	Waikato at Port Waikato	28148
51	Whakapipi	4648
52	Awaroa (Waiuku)	2506
100	Waipa at Mangaokewa Rd	3221
101	Waipa at Otewa	28665
102	Mangaokewa	17419
103	Mangarapa	5443
104	Mangapu	16170
105	Mangarama	5528
106	Waipa at Otorohanga	13889
107	Waipa at Pirongia-Ngutunui Rd Br	43607
108	Waitomo at Tumutumu Rd	4318
109	Waitomo at SH31 Otorohanga	4393
110	Moakurarua	20630
111	Puniu at Bartons Corner Rd Br	22785
112	Puniu at Wharepapa	16853
113	Mangatutu	12269
114	Mangapiko	28069
115	Mangaohoi	431
116	Waipa at SH23 Br Whatawhata	31506
117	Mangauika	978
118	Kaniwhaniwha	10259
119	Waipa at Waingaro Rd Br	15484
120	Ohote	4041
121	Firewood	3372

2 Methods

2.1 Land use change over time

Land use data from various sources for various periods was obtained to assess land use change over time. Land use data were available for the base years 1972, 1996, 2002, 2008 and 2012. All land use data were provided by WRC:

- Land uses for the years 1996, 2002 and 2008 were derived from land use modelling undertaken by Motu Research (Motu).
- 2012 land use data estimates were provided by WRC.

Several processes were used to create an historical land use file:

- The data from Motu was received in digital format as asci files; these data covered the whole country.
- In ArcMap, these files were converted into polygon shape files, which were clipped to select the Waikato catchment area alone.
- Land use data for 2012 was obtained from Waikato Regional Council in electronic format; these data were used as-received.
- It was necessary to combine land use data for 1972 and 1958 because the coverage of the Healthy Rivers catchments were incomplete in the hardcopy maps available for each period.
  - Hardcopy maps produced by Department of Lands and Survey (for the years 1972 and 1958) were obtained.
  - To estimate land use in 1972, the 1972 and 1958 maps were digitised and georeferenced separately in ArcMap, then merged together to provide full coverage of land use in the Waikato catchment.
  - Careful inspection of the resulting file revealed that land use data were incomplete for the northern most part of the catchment. This area was limited to approximately 5% of the entire HR/WO catchment area. Land use from the 1996 polygon shape file was used to fill this data gap and provide a complete land use map for 1972. This was done because the 1996 land use file was the closest in time to 1972 that had the data required, and was regarded an appropriate solution because of the relatively small area involved.
- When necessary, corrections were made to other files. These corrections involved re-classifying each of the land use categories in the supplied maps, to ensure that consistent land use categories were applied across all maps.
- For the land use data supplied by Motu, all land use that was originally classified as 'DoC and Public Land', was replaced with the 2012 land use in the same area. This was to correct a reclassification error, which would over-estimate the area of 'Native Forest and Scrub' during those years.

At the conclusion of this process, shapefiles of land use data were available for selected base years.

- The project required estimates of land use at decadal scale. Land use for intermediate years (1982, 1992 and 2002) were obtained by linear interpolation applied to the base data using facilities provided in the ArcGIS software package (ESRI).

Specific reclassifications that were undertaken to provide consistent land uses and land use assignments are detailed in Sections 2.3 and 2.4.

2.2 Nitrogen leaching yields over time

Nitrogen leaching data were obtained for the main land uses from the New Zealand literature. Emphasis was given to pastoral land uses, specifically dairy, and sheep and beef farming, because these land uses are the dominant land uses in the Waikato region. It is recognised that other land uses, such as commercial vegetable growing and arable crop production may have larger nitrogen leaching rates (i.e., when expressed as kg N lost per ha per year), but they represent relatively minor land uses in terms of total land area and data regarding historical leaching rates has been problematic to attain.

With the data available, it was difficult to estimate the extent of all land uses over time. For example, maize appears as a specific land use only intermittently over time in available land use records. Areas of land subject to intermittent land uses of this nature were allocated to dairy and intensive sheep and beef land uses, in proportion to the extent of the latter land uses in each sub-catchment. We regard this as a pragmatic approach because crops such as maize are cultivated to directly support more intensive pastoral farming.

Historical estimates were sought to determine trends in nitrogen leaching over time. These historical leaching losses were applied to the decadal land use data to estimate the trend in sub-catchment nitrogen yield over the past 40 years. The review and process followed to estimate leaching yields are described in Sections 2.5 and 2.6 respectively.

2.3 Current (2012) land use and classes of land use

Regional land use data for 2012 was supplied for this project by WRC as a polygon shape file with the same land use classes as those used in the Catchment Land Use for Environmental Sustainability (CLUES) model. The year 2012 was taken as the current land use for the purpose of this project, because this was the latest year for which complete data were available. It is worth noting however that land use conversions are still in progress, and anecdotally it is estimated that between 5,000 and 8,000 ha have been converted from commercial forestry to drystock and dairying land uses since 2010.

The CLUES classes were reclassified to classes agreed with WRC (to be consistent with an independent strand of work associated with the Farm Cost Model (FCM) (Doole et al. 2015a, b), detailed in Table 2-1. These land uses were then reclassified into 10 broader land use categories to be compatible with the classes in the right hand column of Table 2-1. Since high-country sheep and beef occupied less than 1% of the catchment, this class was combined with Hill Sheep and Beef.

The land use layer supplied by WRC was overlaid by the 74 Healthy Rivers sub-catchments layer to enable the proportional area of each land use within each sub-catchment.

Table 2-1: Reclassification of the CLUES 2012 land use classes.

ID	CLUES	Reclassified class name	Reclassified class code
1	DAIRY	Dairy	1
2	SBHIGH	Sheep and Beef - Hill and High	2
3	SBHILL	Sheep and Beef - Hill and High	2
4	SBINTEN	Sheep and Beef - Intensive	3
5	PLANT_FOR	Forestry	4
6	MAIZE	Maize	5
7	ONIONS	Horticulture	6
8	POTATOES	Horticulture	6
9	NAT_FOR	Native Forest & Scrub	7
10	SCRUB	Native Forest & Scrub	7
11	DEER	Other Animal	8
12	OTHER_ANIM	Other Animal	8
13	URBAN	Urban	9
14	APPLES	Miscellaneous	10
15	GRAPES	Miscellaneous	10
16	KIWIFRUIT	Miscellaneous	10
17	OTHER	Miscellaneous	10
18	TUSSOCK	Miscellaneous	10
19	UNGR_PAST	Miscellaneous	10

2.4 Land use before 2012

Land use areas were estimated for 1972 using digitised land-use maps that were originally developed as part of the National Resources Survey (Town and Country Planning Division Ministry of Works 1973). While most of the study area was covered by a map corresponding to 1972, additional areas were covered as follows:

- part of a map representing land use in 1958 was used for the south eastern corner of the HRWO study area (Town and Country Planning Branch 1962), and
- part of the map for 1996 needed to be infilled where data were missing in the northernmost fringes of the catchment. The processed used to infill the 1996 data is described below.

Land use categories were consistent over the three map areas. Following digitisation, the sub-catchment boundaries were overlaid on the land use map and areas of the map that fell within the catchment boundaries were selected for further analysis. Land-use categories for the 1972 and 2012 maps were related using the land use codes and names summarised in Table 2-2:

Table 2-2: Reclassification of land uses for 1972.

Original 1972 name	Reclassified class name	Reclassified class code
Indigenous forest	Native forest and scrub	7
Exotic forest	Forestry	4
Unproductive land	Miscellaneous	10
Dairying	Dairy	1
Beef	Sheep and Beef	2 and 3
Intensive Sheep	Sheep and Beef	2 and 3
Extensive Sheep	Sheep and Beef	2 and 3
Mixed livestock	Sheep and Beef	2 and 3
National Parks	Native forest and scrub	7
Urban Areas	Urban	9
River/Lake	Miscellaneous	10
Other	Miscellaneous	10

The combined sheep and beef areas were then split into a) Intensive or lowland and b) Hill and High, using landscape classifications from Land Environments of New Zealand (Leathwick 2002), as described in the original CLUES model documentation (Woods et al. 2006). Since there is only a small fraction of high country sheep and beef in the HRWO area, hill and high country sheep and beef were amalgamated into a single category.

Land uses for the years 1996, 2002 and 2008 were based on data provided by WRC. These data were in turn provided by Motu Research (Motu), based on their land use modelling. The classes from Motu land use were reclassified as detailed in Table 2-3. The Motu classes included Department of Conservation (DoC) and public land as a class. In most cases, this was actually native forest and scrub, but some (in the Kaingaroa Forest area) the public land was exotic forest. The DoC land was allocated to the two relevant classes based on the 2012 land use.

Table 2-3: Reclassification of land use classes for the periods 1996, 2002 and 2008.

LU_name_1996	Reclassified Class Name	Reclassified Class Code
Dairy	Dairy	1
Sheep and beef	Sheep and beef	2 and 3
Plantation	Forestry	4
Scrub	Native forest and scrub	7
Horticulture	Horticulture	6
Non-productive	Miscellaneous	10
Urban	Urban	9
Other animal and lifestyle	Other animal	8
Indigenous forest	Native forest and scrub	7
Pasture on public land	Sheep and beef	2 and 3
DoC and public land	Various	Various

The combined sheep and beef class from the Motu layers was split into two classes, as for the 1972 class. The project scope called for decadal change in land use, whereas reasonable quality land use data and information were available for 1972, 1996, 2002 and 2012 only. The extent of land use for the years required to provide decadal estimates were calculated by linear interpolation between dates where data were available.

The process used for infilling data for years where land use data are not available is regarded as the most cost-effective method that makes best use of the available data. While it may be possible to improve the estimation of land use over time, or improve the assignment of land use between classification systems, considerable additional time and expense would be required. For example, when estimating historical land use for the Lake Rotorua catchment (a considerably smaller area), several weeks of intensive work was required for the task. It was necessary to access data from Ministry of Agriculture (MAF, now Ministry for Primary Industries, MPI), Statistics NZ and the University of Waikato, compile the data and then make sense of it. Despite careful investigation of potential data and information sources, numerous stages remained at which land uses had to be re-assigned using expert judgement[1].

2.5 Review of historical leaching

We estimated historical yields (kg/ha) associated with different land uses from literature values, with particular emphasis on studies that provided historical estimates. We focused on dairy, and sheep and beef land uses because they comprise the greatest proportion of all land use in the Healthy Rivers catchments (61%, Table 3-1) and are associated with measurable nutrient yields. It has been demonstrated that these land uses have the potential to impair water quality as a consequence of nutrient losses to surface and groundwater (e.g., Quinn and Stroud 2002; Wilcock et al. 2006; Betteridge et al. 2011). Current and historical N yields have been estimated in the sub-catchments of Lake Rotorua (Rutherford et al. 2011b). In the Lake Rotorua catchments, however, greater emphasis was given to estimating stock numbers, in preference to areas of land use. Although each method may provide some advantage over the other for certain purposes, the relationship between stock numbers and land use (through stocking rate) ensures that similar results may be anticipated. However, the compilation of plausible historical stocking rates done for the Lake Rotorua catchment from historical census data took several weeks of intensive effort[2]: time that was not available for this project. Use of "land use" rather than "stocking rate" to estimate N loading to pasture is considered adequate for the current task. Sources of uncertainty that were considered during the review process (and responses to minimise them) included:

- We make use of historical estimates of nitrogen leaching that take historical stocking rates and management practices into account.
- Land parcels have natural limitations in terms of carrying capacity, related to slope, soil type and natural fertility.
- Several other sources of uncertainty exist which are likely to have a greater impact on the estimates of nitrogen leaching (e.g., soil drainage characteristics, limited understanding of catchment hydrogeology etc.).

[1] Dr Chris Palliser, NIWA, pers. comm.
[2] Dr Chris Palliser, NIWA, pers. comm.

Research has indicated that stocking rate may be a poor indicator of leaching under some circumstances, and that losses are determined by the combined influences of stocking rate, soil drainage, rainfall, slope and pasture and enterprise management.

Assessment and documentation of N yields (kg/ha/yr) from diffuse sources (i.e., land uses) was undertaken following a review of readily available published literature. Key data sources include:

- technical reports prepared for regional councils by NIWA and other Crown Research Institutes (CRIs)
- reports prepared by agricultural consultants available in the public domain
- manuscripts published in conference proceedings, and
- peer-reviewed journal articles.

The relationships between nitrogen leaching and land use has been investigated in New Zealand over decades – for example, nutrient management in grazed pastures was reviewed by Monaghan et al (2007). More recently, however, information regarding nutrient dynamics derived from soil sampling and routine monitoring has been combined to create the OVERSEER® modelling framework[3] (Cichota and Snow 2009). The latter allows whole-of-farm nutrient planning and management, taking account of nutrient transfers onto and within the farm. OVERSEER® currently allows estimation of N (and P) loss from a farming enterprise.

Use of OVERSEER® therefore allows N losses to be estimated from farming enterprises under recent conditions. With use of estimates of historical nitrogen application rates, animal numbers, grazing areas and stocking rates, it is possible to estimate N losses from historical farming enterprises as well. Combining these historical N loss estimates with information regarding local hydrogeological and geomorphological conditions, allows estimation of lags times and N "loads to come". Moreover, when used as input to suitable models, the estimates can be used to predict future surface water quality conditions.

Many leaching yield estimates recorded in the New Zealand technical literature obtained at small plot or paddock scale, others at sub-catchment scale. Some studies provide catchment yields. Leaching losses may also be estimated using models such as OVERSEER®, SPASMO[4], and LUCI[5] (reviewed briefly by Cichota and Snow 2009). It is important to recognise an important difference between leaching losses derived from models such as OVERSEER®, and measured loads derived from paddock or sub- catchment scale studies:

- **OVERSEER® estimates** represent the mass of nitrogen lost from the soil profile below the root zone.
  - This nitrogen is likely to be subject to further transport (e.g., to shallow and deeper groundwater, or lateral flow which may remerge in surface water further downstream).
  - OVERSEER® estimates do not account for attenuation, such as denitrification.

[3] http://overseer.org.nz/

[4] "Soil-Plant-Atmosphere System Model" is a detailed process-orientated model developed by HortResearch (now Plant and Food Research), described by Green et al. 2003a, 2004b.

[5] "Land Use Change and Intensification" model is a framework for simulating changes in drainage, and N leaching from different land uses and management systems, at a paddock scale (Jamieson et al. 2006b; Zyskowski et al. 2007).

- OVERSEER® provides estimates of nitrogen loss from the root zone – the actual mass of nitrogen lost to surface water is likely to be less than the OVERSEER® estimate, determined ultimately by the extent of attenuation and in the interim by attenuation and travel time.

- Estimates of nitrogen loss derived from **sub-catchment or paddock-scale investigations** represent the net mass of material lost from the various land uses after various attenuation processes have had an effect.

  - These direct estimates of nitrogen loss should be used with caution - they reflect the interaction between many different soil, climate and farming system differences that will be associated with each land parcel.

  - They are useful however, because they present the net paddock or catchment yield following attenuation. They also provide a direct indication of the variability in leaching rates that exist across a range of farms and farming systems that may ostensibly share a common land use.

The review had regard for metadata relating to input data for models such as OVERSEER® (when this information was available), including the location of the sites assessed, biophysical information associated with the various assessment sites, and the nature of the enterprise that was being assessed. Emphasis was given to assessments that involved application of OVERSEER® in the Waikato and Bay of Plenty regions; wherever possible the version of OVERSEER® was recorded.

2.6 Synthesis of historical trends in leaching yields

The information on yields from the literature was synthesised into a time series of yields for each land use. This involved extracting trends from individual studies and combining the information to derive an overall representative trend. This required some judgement to reconcile various sources and interpolate and extend the data. An additional objective was to derive yields relative to 2012 values, because absolute yields for 2012 were available from other components of the Healthy Rivers/Wai Ora project.

2.7 Estimate of historical nitrogen yields

There have been relatively few studies in NZ on land use intensification and resulting nitrogen leaching. This creates uncertainty regarding the "actual" leaching losses that occur in response to land use change. In this study, we chose a leaching loss estimate derived from two studies where leaching losses had been estimated for a pastoral land uses over a period of time. Two examples exist where OVERSEER® has been used to provide long-term (years to decades) estimates of N leaching losses:

i. estimates of leaching from dairy and sheep and beef farms in the Rotorua Lake catchment by Rutherford et al (2009), and

ii. assessment of leaching losses from representative Waikato dairy, sheep and beef, and deer farms (Judge and Ledgard 2004, 2009).

For both dairy, and sheep and beef, N leaching yields in the Waikato Region are increasing at a greater rate than in Rotorua according to the above assessments. While use of an average value may be questioned, we consider this is acceptable because:

- "true" leaching losses are unknown, and leaching losses will vary considerably across all sub-catchments and farms due to differences in biophysical characteristics, attenuation, and land management factors,
- we are considering both absolute and relative leaching losses and
- even though the OVERSEER®-derived estimates of nitrogen loss extend over periods of decades, these data do not extend to 1972 for the Waikato region.

Absence of leaching loss data for pastoral farming in the Waikato Region prior to the mid-1990s was overcome by applying a linear regression to the data available for both the Waikato Region and Lake Rotorua catchment data, and hindcasting to 1970. This provided a yield estimate that was effectively an average for the two regions.

The nitrogen yield may be calculated for the dominant pastoral land uses according to calendar years using Equation 2-1 and Equation 2-2:

$$\text{Dairy nitrogen yield (kg/ha/yr)} = 0.392 \times \text{calendar year} - 758.2 \qquad \textbf{Equation 2-1}$$

$$\text{Sheep and Beef nitrogen yield (kg/ha/yr)} = 0.0452 \times \text{calendar year} - 80.119 \qquad \text{Equation 2-2}$$

2.8 Trends in total leaching loss

Estimation of trends in leaching losses of nitrogen was approached from two perspectives:

- calculation of nitrogen leaching losses, and
- normalising these estimates, so that they were comparable with those from other strands of work, or for input into other models.

2.8.1 Calculation of leaching yields

The estimated historical leaching yields for each land use were combined with the estimates of areas of each land use at each time step to calculate leaching losses at each time step. The sum of the product of leaching rate for each land use (t/ha/y) and the area of each land use (ha) within each sub-catchment provides an estimate of the total leaching loss (t/y) for the sub-catchment. Analysis of the change in these values over time allows the progression of leaching loss (t/y) over time, for each sub-catchment to be assessed. Trends in land use in each sub-catchment over time are summarised in Appendix A, while Appendix B provides estimates of nitrogen leaching loss at decadal intervals (1972-2012) for each of the 74 Healthy Rivers catchments.

2.8.2 Normalisation of leaching yields

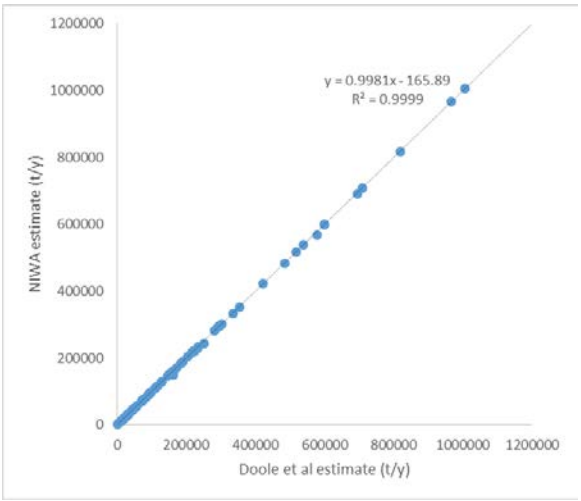
The **current** leaching yield for each sub-catchment and land use was determined from values used in the catchment nitrogen model, as provided by Professor Graeme Doole[6] and Olubade-Awosola et al (2014), to ensure that the current overall leaching loss is compatible with the values estimated in the catchment nitrogen model. The catchment nitrogen model included a more detailed assessment of the effects of location and farm practices, so it was appropriate to adopt those values as a benchmark for current conditions. To achieve this compatibility, maize (which appears only in some years) was allocated to dairy and intensive sheep and beef, in proportion to the extent of those land

[6] Dr Graeme Doole, University of Waikato, Pers comm (June 2015).

uses in each sub-catchment. This is consistent with assumptions used in the nitrogen component of the catchment economic model. For dairy areas, Doole had provided separate yields for areas used as the dairy platform and for dairy support. We combined these to get a combined leaching yield for dairy (from an area-weighted average of the separate leaching rates). "Other Animals" was allocated to intensive sheep and beef, which differed from the approach followed by Doole, where "Other Animals" was integrated with the "Miscellaneous" land use category. This difference in classification will have insignificant impact on load estimates because of the small proportion of land use of the total catchment area (<3% for all decadal periods). For sheep and beef enterprises, Doole provided a single leaching estimate. We split the combined sheep and beef into an "intensive" and "hill" component. To achieve this split, we assumed that the yield from intensive sheep and beef is the product of a specified factor and the yield of hill sheep and beef. We then adjusted the yield for intensive sheep and beef to achieve the same average yield as the value provided in Doole, for each sub-catchment.

Initially we used a factor of 1 (equal yields for pasture land uses) but also investigated a factor of 1.5 to assess sensitivity of leaching estimates to this factor. Trends in leaching were not sensitive to the factor, and a value of 1 was chosen as it is more consistent with our interpretation of small effects of sheep and beef type based on spatial variations in losses from Doole. For the remaining land uses, the leaching rates were taken directly from the values provided by Doole. The validity of scaling the NIWA estimates of nitrogen loss to match those of Doole et al was tested by linear regression of the estimates across the 74 HR/WO sub-catchments. The relationship between these estimates is summarised in Figure 2-1 A and B, which indicate good correspondence between the estimates, a close match with the 1:1 line and non-random distribution of residuals. Although the latter indicates that the regression model could be improved, we concluded that it was appropriate to "anchor" our results to those of Doole, using 2012 as a base year. It should also be remembered that there are uncertainties inherent in the data underlying both estimation methods – these uncertainties do not, however invalidate their use to meet the objectives of the HR/WO project.

A



B

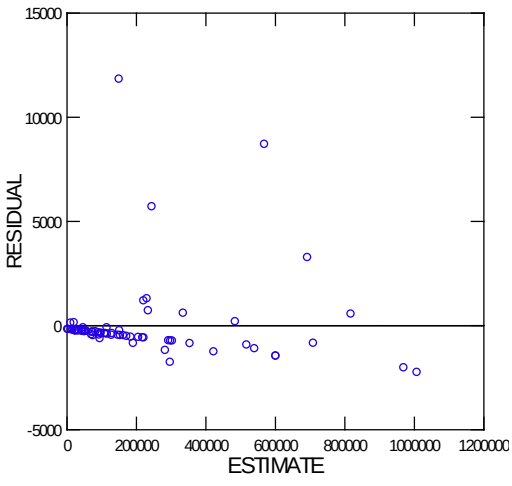


Figure 2-1: Relationship between NIWA and Doole N-loss estimates for 2012. A) Linear regression and B) plot of errors associated with the regression model.

3 Results: Land use

3.1 Current (2012) land use

The current dominant land uses in the study area are dairy, sheep and beef (together comprising 61% of land use), along with native forest and forestry (Table 3-1). The maize and other animals land use classes each comprise around 1% of the area, while the "miscellaneous" land use class comprises approximately 3% of the area. The latter land use classes collectively comprise approximately 5% of overall land use; these may therefore be regarded relatively minor land use classes (in terms of overall extent). As a consequence, these land uses have been amalgamated for display in Figure 3-1, which shows the distribution of land uses across the HRWO study area. Dairy dominates central Waikato in the Waipa and Lower Waikato catchments. Native and plantation forest is mainly located in the south-eastern Upper Waikato catchment. Urban areas account for 3%, with Hamilton being the largest centre; the potential exists that urban land use may be overestimated in the vicinity of Pukekohe, due to some inaccuracies in the land-use data available to and provided by WRC

Table 3-1: Land use and classes and corresponding CLUES classes; the areal coverage of each land use class is indicated for the entire study area for 2012. From Table 2-3, Semadeni-Davies et al (2014).

Reclassified class name	Proportion of cover (%)	Area (km^2)
Dairy	28	3053
Intensive (lowland) sheep and beef	22	2426
Hill and high country sheep and beef	11	1249
Other stock	<1	17
Forestry	15	1695
Native forest and scrub	16	1727
Maize	1	56
Horticulture	1	62
Urban	3	350
Miscellaneous	4	388
Total area		**11022**

*not present in study area

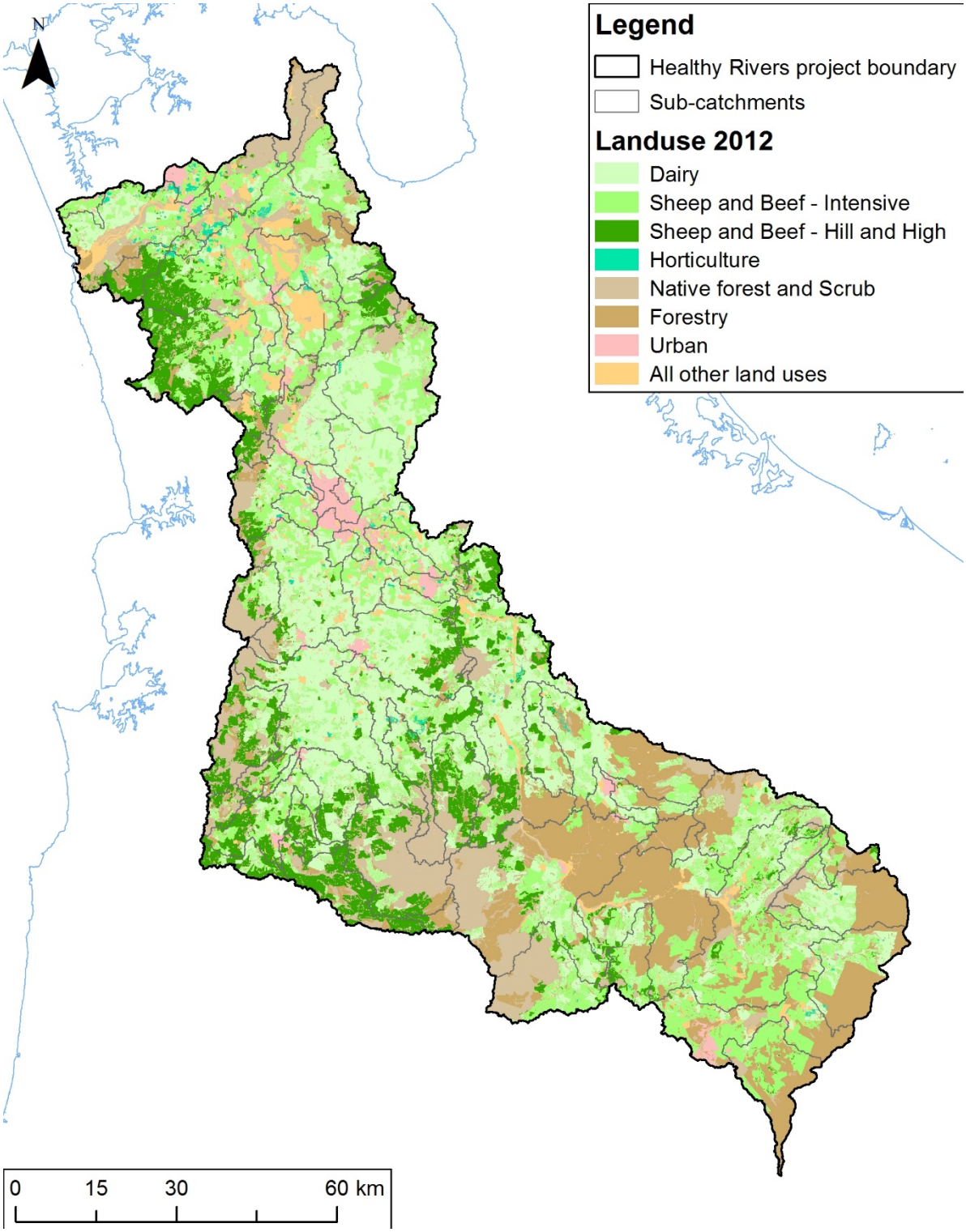


Figure 3-1: Land use from WRC classified into classes for 2012. Maize, other animals, horticulture and miscellaneous land use classes have been amalgamated for display. Hill country sheep and beef includes a small area of high country sheep and beef.

3.2 Change in land use over time

The change in land use over time is summarised for the periods for which reasonable quality data exist in Appendix A. Figure A-1 and Figure A-2 summarise the areas and proportion of land associated with each land use category by decade respectively. Figure A-3 through Figure A-12 indicate the change in area associated with each land use and FMU by decade. Maps of historical land use are provided in Figure 3-3 to Figure 3-6.

The interpolated decadal changes in the proportion of dairy and overall pasture land use over time is summarised in Table 3-2 (change in area) and Table 3-3 (proportion of area in each land use). The change in proportion of land use at key years is shown graphically in Figure 3-2 for selected land uses. The area of dairy land use has increased steadily since 1996, from 22.5% of the catchment to 27.9% of the catchment. The proportion of the catchment in dairy in 1972 was greater than in 1996. This was somewhat surprising, and seems to be related to intensive sheep and beef replacing dairy in some sub-catchments (for example, the Ohote sub-catchment to the west of Hamilton, where there was 43% 'reverse' conversion, and other sub-catchments primarily in the lower Waikato). There may also be inaccuracies in the original maps.

Overall, the proportion of the catchment in pastoral land use has been fairly stable. There was an increase in exotic forest from 1972 to 1996, amounting to ca. 5.1% of the catchment area. This is primarily due to the widespread occurrence of patchy forest, although a significant proportion of the Waipa at Mangaokewa catchment was converted to forestry from scrub in that period. Since 1996, the amount of exotic forest has decreased slightly over the catchment overall. There is an apparent drop in the area of hill and high country sheep and beef from 2008 to 2012. This is likely due to differences in the methodology for splitting hill sheep and beef from intensive sheep and beef between the two studies. There is also an increase in the proportion of the catchment that is not in pasture or exotic forest from 2008 to 2012 (increase of 3.1% of the catchment), which is likely to be an artefact of the methodology used.

Temporal variations in land use are more pronounced for individual sub-catchments (Appendix A). For example, in the Little Waipa sub-catchment, dairy increased from 27% in 1996 to 60% in 2012, due in large part to conversion of forest to pasture. Increases in dairying in the order of 15%-20% of the catchment occurred for the Puniu, Waipapa, Whakauru, and Waipa at Otorohanga sub-catchments over the period 1996-2012. In other areas, forestry was established over that period (e.g., about 20% of the catchment was converted to forestry). In the Kirikiriroa sub-catchment to the northeast of Hamilton, and in the Waikato at Horotiu (Flagstaff), a significant area of the sub-catchment has been urbanised. The apparent decrease in pasture in the Tuakau catchment seems to be an error in the 2012 land use. The increases and decreases in pasture approximately balance catchment-wide.

Table 3-2: Change in land use areas over time for dominant land use categories in the Healthy River catchments. Pasture includes "dairy", "sheep and beef" (intensive and hill country) and "other animals" categories. "Miscell." includes "horticulture", "maize", "miscellaneous" and "urban" land use classes.

Year	Land use area (km^2)							
	Dairy	Sheep and Beef - Intensive	Sheep and Beef - Hill and High	Pasture	Forestry	Native Forest & Scrub	Miscell.	Total
1972	2748	1711	2635	7094	1452	1154	1285	10985
1982*	2632	1910	2489	7031	1681	1310	954	10976
1992*	2516	2110	2344	6970	1910	1467	623	10970
1996	2470	2190	2286	6946	2002	1529	490	10967
2002	2852	2054	1828	6734	2077	1593	567	10971
2008	2794	2099	2100	6993	1917	1525	533	10968
2012	3080	2472	1249	6801	1695	1727	801	11024

*Interpolated land use.

Table 3-3: Change in proportion of land use areas over time for dominant land use categories in the Healthy River catchments. Pasture includes "dairy", "sheep and beef" (intensive and hill country) and "other animals" categories. "Miscell." includes "horticulture", "maize", "miscellaneous" and "urban" land use classes.

Year	Proportion of land use (%)						
	Dairy	Sheep and Beef - Intensive	Sheep and Beef - Hill and High	Pasture	Forestry	Native Forest & Scrub	Miscell.
1972	25	15.6	24	64.6	13.2	10.5	11.7
1982*	24	17.4	22.7	64.1	15.3	11.9	8.7
1992*	22.9	19.2	21.4	63.5	17.4	13.4	5.7
1996	22.5	20	20.8	63.3	18.3	13.9	4.5
2002	26	18.7	16.7	61.4	18.9	14.5	5.2
2008	25.5	19.1	19.1	63.8	17.5	13.9	4.9
2012	27.9	22.4	11.3	61.7	15.4	15.7	7.3

*Interpolated land use.

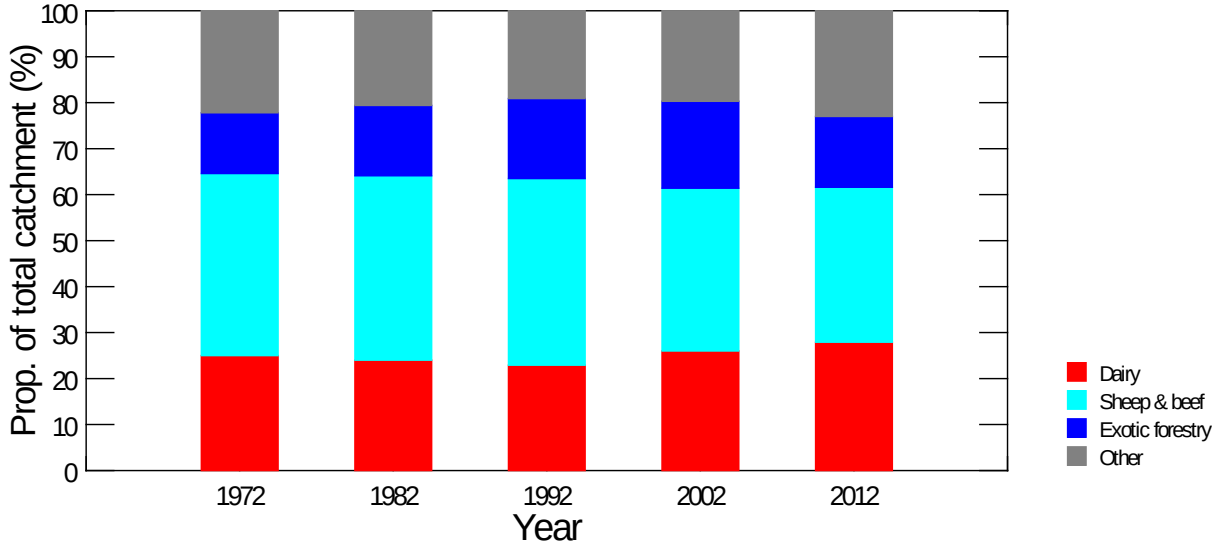


Figure 3-2: Proportion of the Healthy Rivers catchment in different land uses from 1972 to 2012.

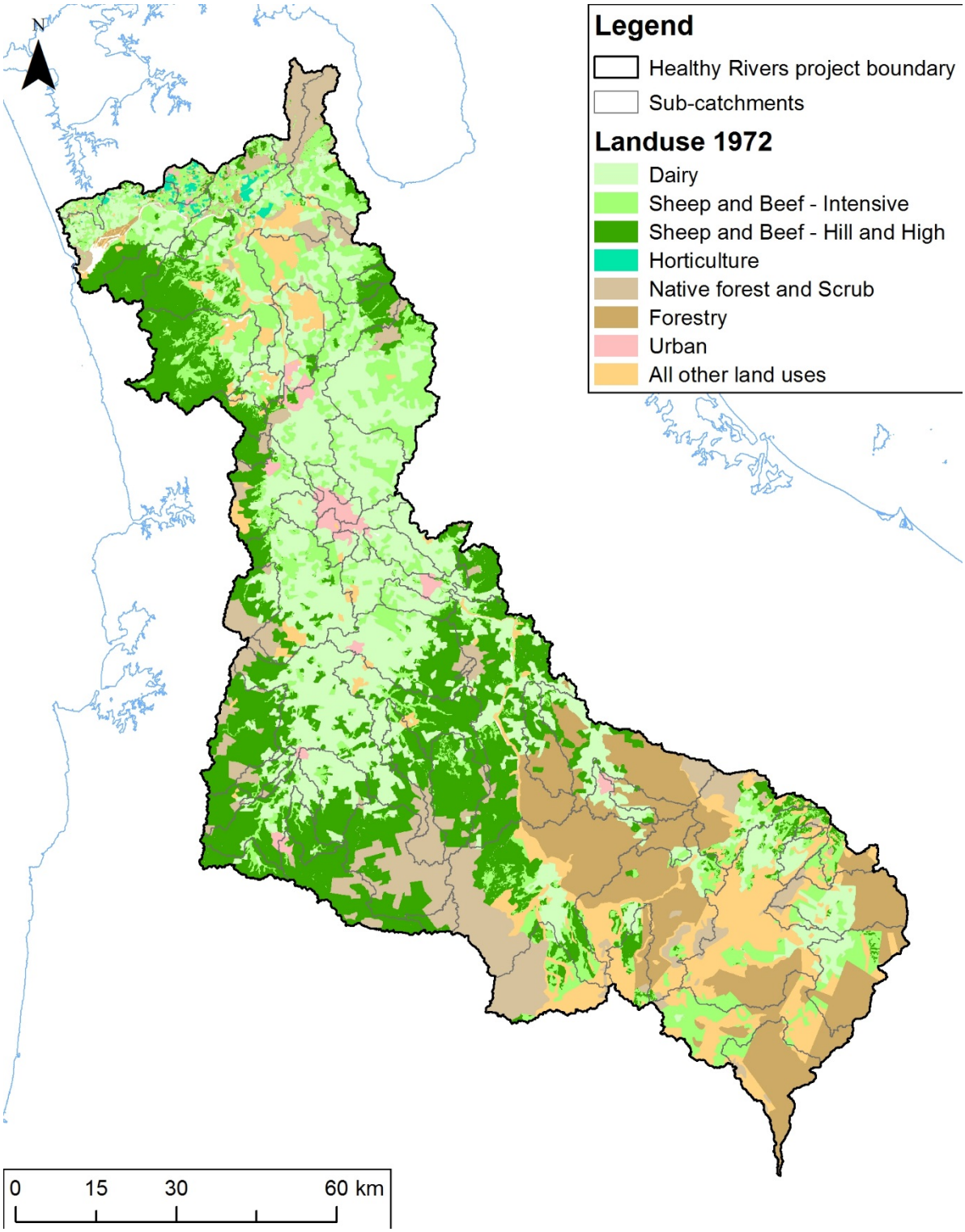


Figure 3-3: Land use for 1972.

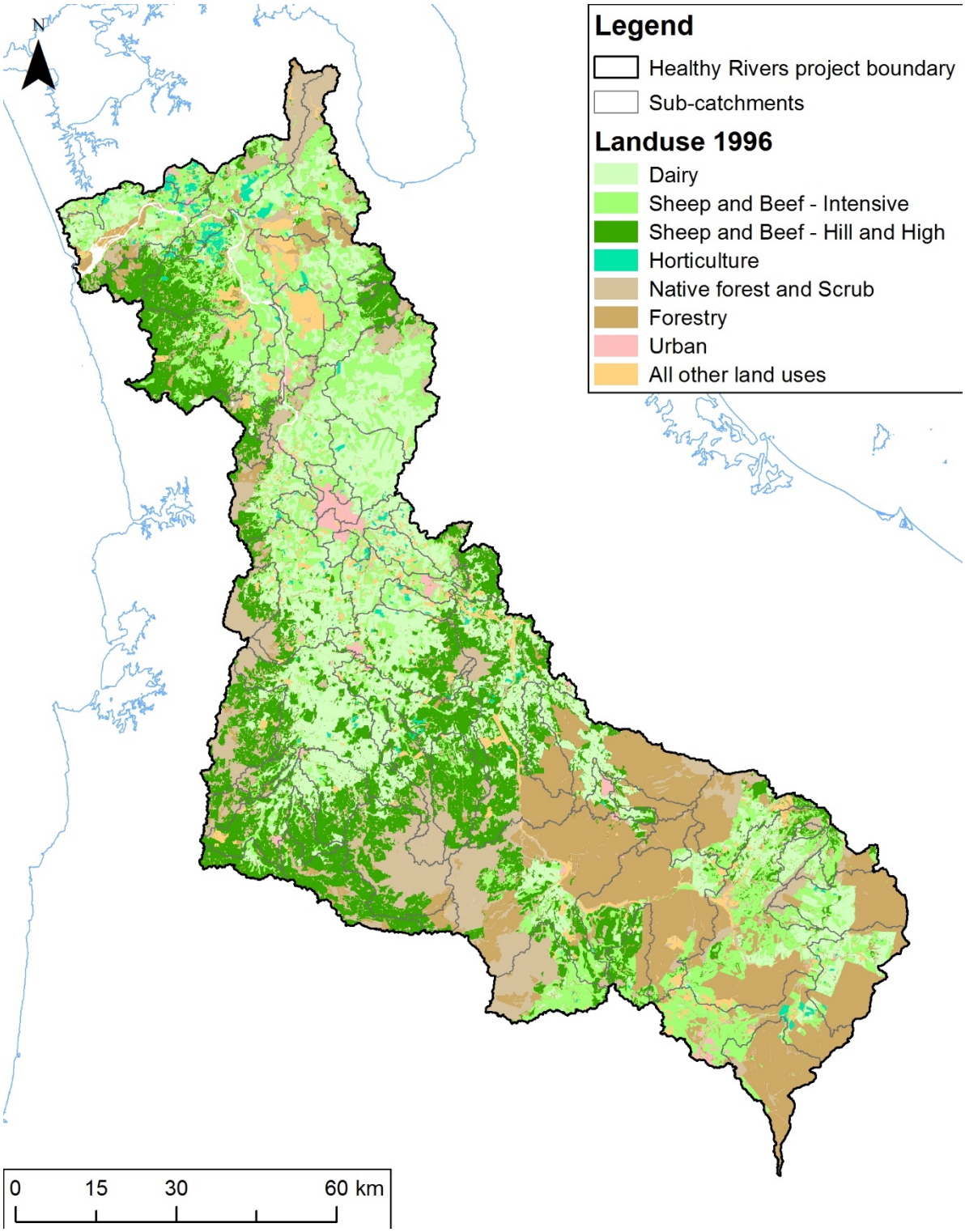


Figure 3-4: Land use for 1996.

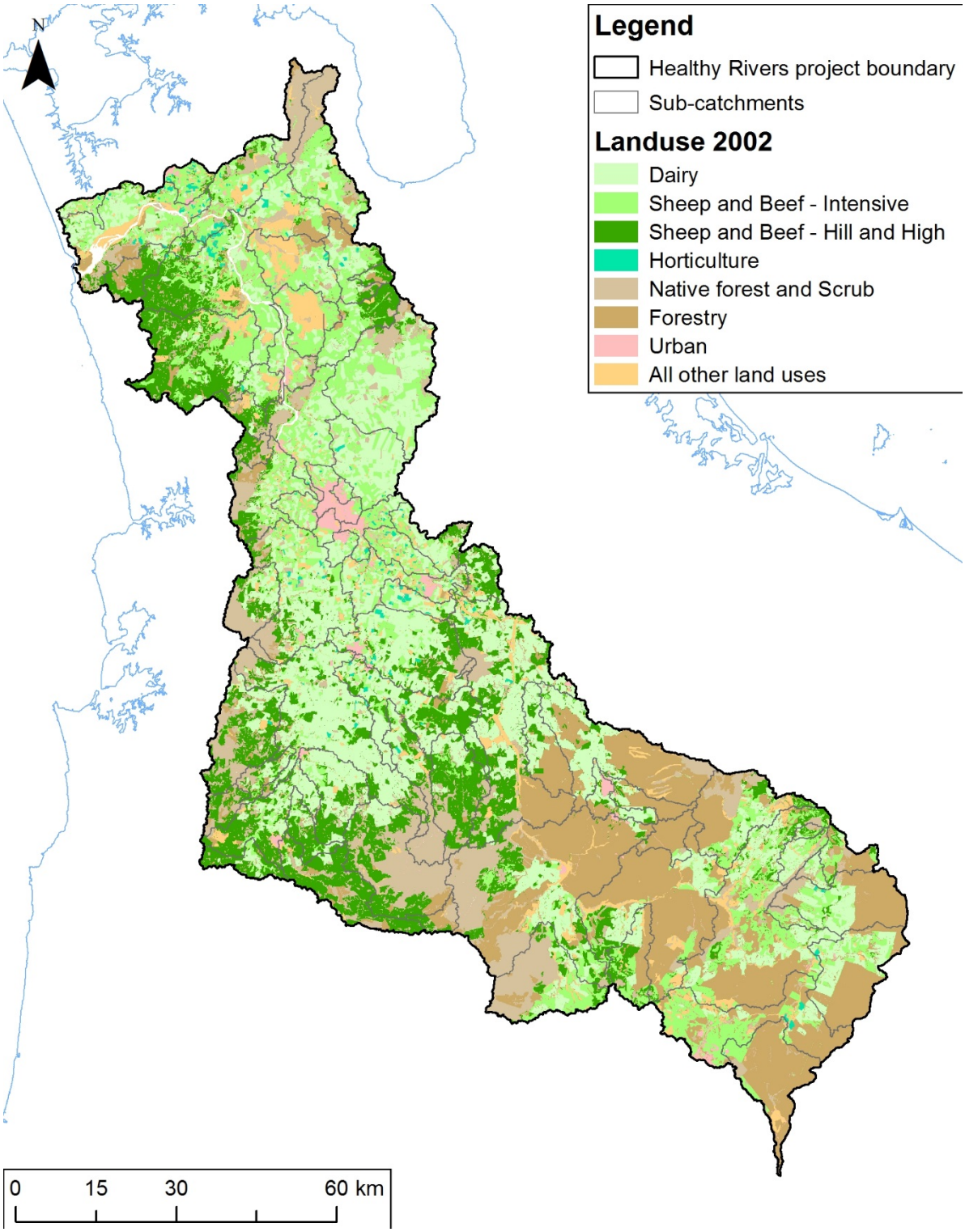


Figure 3-5: Land use for 2002.

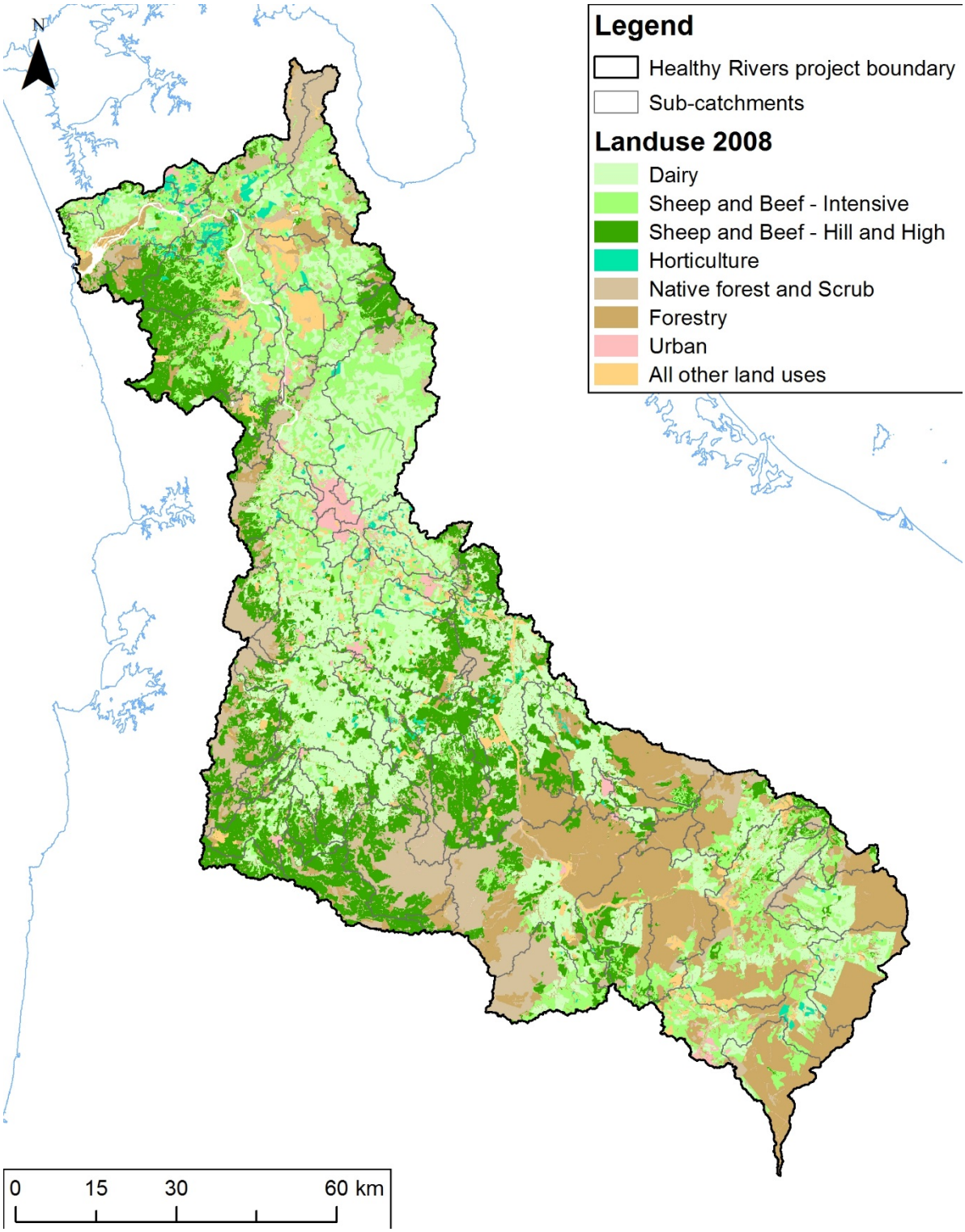


Figure 3-6: Land use for 2008.

4 Results: Trends in nitrogen loss

4.1 Review of leaching yield estimates

Two reviews have summarised measured and estimated nitrogen leaching yields (kg/ha) in New Zealand, these are:

1. McDowell and Wilcock (2008) summarised measured values for contaminants discharged from pastoral lands (N, P, sediment and *E. coli*). Data represented sheep, deer, mixed stock (not defined further) and dairying land use across New Zealand, across a selection of elevation, slope and rainfall conditions. The data derived from this compilation are reproduced in Table C-1 (Appendix C), with a summary in Table C-2. These data are included to indicate the range of net N loss values that have been measured in New Zealand. The variability associated with these values confirm the influence that sub-catchment or site-specific factors (specifically mitigation measures and natural attenuation) may have on contaminant transport processes.

2. Watkins and Shepherd (2014) describe a series of pasture farmlet experiments where sufficient data exist to undertake OVERSEER® modelling. Were OVERSEER® modelling to be undertaken, it would be possible to compare measured and modelled leaching rates. Watkins and Shepherd caution users of these data to be aware of the scale at which these data were obtained (farm block vs. whole farm), and the inherent limitations associated with the field measurements (impact of soil type, use of suction cups vs. lysimeters to measure soil moisture, or hydrologically isolated plots). The latter limitations apply to all directly measured leaching rates. The authors also draw attention to factors which should be considered when utilising OVERSEER® nutrient loss estimates for sub-catchment nutrient yield estimations:

   - "practical and theoretical challenges of comparing data from farmlet experiments with whole farm system modelled data"
   - "a paucity of data at the grazed paddock/block level"
   - "the limited number of farmlet experiments that can be used to evaluate farm nutrient management models, such as OVERSEER®"
   - "the limited number of soil types and climatic conditions" represented.

One cause of uncertainty when using OVERSEER® to estimate nitrogen leaching yields are the different values obtained when different versions of OVERSEER® are used to undertake these estimates. We are aware of the significant difference between estimates of leaching yield derived from OVERSEER® v5 (which was the latest version available at the time these estimates were made) and OVERSEER® v6. OVERSEER® v6 provides much larger nitrogen yields than v5 because it better represents the impact of factors such as increased N loss from higher-permeability soils and areas of higher rainfall. For the current study, only estimates derived from OVERSEER® v5 were included in this review and subsequent calculations.

Using OVERSEER® v5.4, Dymond et al. (2013) combined animal numbers and estimates of nitrate release per animal for 100 soil and climate combinations to estimate nitrogen yields. Input data required to run OVERSEER® are summarised in Table 4-1. The national estimate of nitrate leaching per stock unit (SU) is shown in Table 4-2 as an example of the study output.

Table 4-1: Sources of input data for the OVERSEER® model runs (version 5.4) and assumptions for horticulture, shallow soils and irrigated land. (Dymond et al. 2013).

Stocking rate	Stock-carrying capacity from NZLRI
Fertiliser	P required to maintain stock carrying capacity from NZLRI
Irrigated dairy land	Annual rainfall set to 1000 mm (if <1000 mm)
Soil type	From Fundamental Soil Layers
Annual rainfall	From LENZ climate layers
Horticulture	Twice nitrate leaching at stock carrying capacity
Shallow soils	Nitrate leaching doubled on shallow soils (profile available water <80 mm)

Table 4-2: Average national estimates of nitrate leaching per stock unit by soil type for wet conditions (Dymond et al. 2013). For dairy, the nitrate leaching rate per cow is 10x the nitrate leaching per stock unit (sheep) shown in the original table.

NZSC order	Brown/Sedimentary	Pallic/Yellow grey earth	Organic/Peats	Recent/Sedimentary
OVERSEER® soil group	(Hilly wet conditions)	(Hilly dry conditions)	(Flat wet conditions)	(Flat dry conditions)
N Leached (kg N/ha/yr)	24	15	16	20

Temporal trends were calculated by Dymond et al (*ibid*) at the regional scale over the period 1990-2011 by multiplying regional stock numbers by regional leaching rates per animal. This approach assumed that the leaching rates per animal were independent of stock number, and that farming practices have not altered appreciably over the estimation period. Regional leaching rates were presented graphically; with many areas in the Waikato having leaching rates greater than 30 kg N/ha/yr. There was a generally increasing trend in regional-scale nitrogen leaching rates in the Waikato. No estimate of uncertainty was provided. After comparing leachate concentration (obtained by dividing the mass of nitrate-N leached annually by the catchment water yield) with river concentrations for locations where water quality is sampled, it was demonstrated that approximately 50% of nitrogen leached from agriculture is attenuated in the landscape and river upstream of the sampling location.

Perrin Ag (2012) used OVERSEER® to estimate nitrogen losses at the whole farm (total area) level for a series of farms in the Lake Rotorua catchment. For the sheep & beef operations, the sheep to cattle ratio averaged 55:45. The farms used an average of 19 kg fertiliser N/ha/yr. Annual N losses averaged 13 kg N/ha/year (range 10-25.9kg N/ha/year), with losses from the effective pastoral area averaging 16 kg N/ha/year. Details for the "model" Sheep and Beef (S&B) farm are presented in Table 4-3.

Perrin Ag (*ibid*) classified sheep and beef enterprises into hill (>15°) and non-hill (≤15°) classes. Three sheep and beef farm case studies were identifiable according to topography and operating policies as being either intensive non-hill ("Flat to easy") or extensive hill ("Hill"); case study N losses were used to assign the *status quo* N losses to the respective topographical categories. Although these classifications differ from those we have used in the current study, they illustrate the impact that slope has on nutrient loss. On an area-weighted basis, the average N loss from the effective farming

area was 16 kg N/ha/year, identical to that which had been assumed in ROTAN[7]. Estimates of yields according to land use and dominant slope class are summarised in Table 4-4.

Table 4-3: Summary of key data regarding model sheep and beef farm for Rotorua catchment. From Perrin Ag (2012).

Key indicator	Units	Value
Total area	ha	725
Total area in Rotorua catchment	ha	725
Total effective area	ha	562
Total effective area in catchment	ha	562
Stock units	SU	6706
Stocking rate	SU/ha	12
Live weight wintered/ha	kg/ha	617
Net kg product /ha	kg /ha	297
Proportion cattle	%	45
Total N applied/ha	kg/ha	19
Current N loss /ha	kg N/ha/year	13
Current N loss / effective grazing hectare	kg N/ha/year	16

Table 4-4: Nitrogen leaching rate for sheep and beef operations in the Lake Rotorua catchment according to slope class. From Perrin Ag (2012).

Sheep and beef type	Area	No. parcels	Topo class	Proportion in topo class (%)	N-loss (kg N/ha/yr)
Dairy grazers	858	105	Flat to easy	70	25.9
Other cattle intensive	646	216	Flat to easy	100	25.9
Other cattle extensive	677	21		100	11
Sheep and beef intensive	4650	749	Flat to easy	100	25.9
Sheep and beef extensive	8764	570	Hill	99	11

The dairy sample group had an average stocking rate of 2.8 cows/ha (range 2.3-3.2 cows/ha), with all replacement animals grazed-off the milking platform and about half of all cows wintered-off for eight weeks. None of the sample group fully wintered on the milking platform. External supplement usage averaged 1.3 t DM/ha (range 0. 9-1.8 t DM/ha) and on average, 135 kg/ha of fertiliser N (range 45-218 kg N/ha/year) was used.

Current whole farm (including forestry and contiguous run-off) N loss averaged 30.8 kg N/ha/year (range 16.9 kg-56.5 kg N/ha/year), with N-losses just from the milking platform of 41 kg N/ha/year,

[7] ROtorua and TAupo Nitrogen model, developed by NIWA (e.g., Rutherford, K., Palliser, C., Wadhwa, S. (2009) Nitrogen exports from the Lake Rotorua catchment - calibration of the ROTAN model. *BOP08225*. NIWA, Hamilton: 62.)

which was biased high by the results for one enterprise. Key performance and N leaching data are summarised in Table 4-5:

Table 4-5: Summary of key data regarding model dairy farm for Rotorua catchment. From Perrin Ag (2012).

Key indicator	Units	Value
Total area	ha	365
Total area in Rotorua catchment	ha	241
Total effluent application area	ha	219
Total effluent application area in catchment	ha	188
Peak cows	n	612
Milk production	kg MS	220327
Per cow	kg MS/cow	360
Per hectare	kg MS/ha	1008
Stocking rate	cows/ha	2.8
Imported supplement fed	kg DM/ha/yr	1364
Total N applied/ha	kg/ha	135
Annual N loss/ha	kg N/ha/year	31
per effective milking platform	kg N/ha/year	41

Judge and Ledgard (2004; 2009) used OVERSEER® to prepare annual nutrient budgets for Waikato dairy farms over the period 1997–2007 (10 years), and for sheep and beef, and deer farms over the period 1995–2006 (12 years). For sheep and beef, and deer farms:

- A Class 3 farm is defined as North Island Hard Hill Country, which is steep hill country and low fertility soils, with most farms carrying six to ten SU/ha. While some stock are finished, a significant proportion are sold in store condition.
- Class 4 is North Island Hill Country, which is easier hill country and more fertile soils than Class 3, mostly carrying between eight and thirteen SU/ha. A high proportion of sale stock sold is in forward store or prime condition.
- Class 5 is North Island Intensive Finishing farms, which is easy contour farmland with the potential for high production, with most farms carrying between eight and fourteen SU/ha. A high proportion of stock is sent to slaughter and replacements are often brought in.

Assumptions and deficiencies in the input data for sheep and beef, and deer farms included:

- Soil groups were assumed to be Sedimentary for Class 3 and Volcanic for Classes 4 and 5.
- Only the effective area was used to model farms (area used for pastoral farming) – areas on the farm used for agroforestry, forestry and undeveloped land was not included in the modelling.

- Soil test data was only provided for 2006/07. Where no soil test data were available, typical soil test values for Volcanic soils were used from those included in the OVERSEER® model; these were based on aggregated data derived from analysis of soil samples submitted to NZ Labs and its predecessors.
- All stock was grazed on-farm during winter months.
- Distance from the coast was 50 km (the model is relatively insensitive to this parameter after this distance).
- Best practice fertiliser application was assumed. Where N and P fertiliser was applied, it was assumed that none was applied during the at-risk winter months.
- No wetland or dicyandiamide (DCD) data were provided, so these categories were not entered in OVERSEER®.
- The pasture development status "developed" was assumed for all farms.
- No supplementary feed information was given except for the 2006/07 year, where it was assumed that supplements were fed to beef cattle on paddocks.
- After discussions with Ian Power (AgResearch) about previous work with average Waikato sheep and beef farms, it was assumed that 20% of cattle were male.
- Insufficient information was provided to use the advanced stock calculation form in OVERSEER®, but stock units were supplied for each animal type, so these were used.
- The topography was assumed to be that of the largest category for each farm class type, namely: Class 3 – steep, Class 4 – easy hill and Class 5 – rolling. OVERSEER® does not provide estimates of N concentration in drainage for easy hill and steep categories.

Table 4-6: Estimates of nitrogen leaching rates derived from OVERSEER® for Waikato sheep and beef, and deer farms (1995-2006). (Judge and Ledgard 2004; Judge and Ledgard 2009)

Year	Estimated nitrogen leaching rate (kg N/ha/yr)		
	Class 3	Class 4	Class 5
1995	10	13	16
1996	10	13	15
1997	10	13	15
1998	10	13	17
1999	10	13	16
2000	9	13	16
2001	9	13	16
2002	9	14	15
2003	9	14	17
2004	10	14	17
2005	10	14	17
2006	10	14	16

The dairy farms selected were used in MAF monitor programme and listed in the Dexcel ProfitWatch database, and were regarded as representative of farms in an area that extended from Franklin to Taupo and included the Waitomo, Otorohanga and Ruapehu areas, but excluded Rotorua. The farms selected represented lower quartile, median and upper quartile milk solids production. The data used for the simulations represented between 55 and 144 farms. Assumptions and deficiencies in the input data for dairy farms are as follows:

- Only the effective area was used to model farms; agroforestry, forestry and undeveloped land were not included.
- The average long term rainfall value of 1250 mm for the Waikato region was used for all years and for all farm categories (which may under-estimate N leaching loss from high rainfall areas).
- As per best practice, it was assumed that dairy effluent was applied to 15% of the farm area. Effluent blocks were assumed to receive the same rates of fertiliser application as the rest of the farm.
- The pasture development status of developed was assumed for all farms.
- It was assumed that the soil group was Volcanic and the topography rolling. Where no soil test data were provided, typical soil test values for Volcanic soils were used from the OVERSEER® model database based on means for an average farm obtained from aggregated data from soil samples submitted to NZ Labs and its predecessors.
- It was assumed that the stock comprised Friesian x Jersey cows with:
  - replacements being grazed off the farm after 9 months of age
  - all milking dairy cows wintered on the farm.
- Distance from the coast was assumed to be 50 km. The model is relatively insensitive to this parameter after this distance.
- Where nitrogen (N) and phosphorus (P) fertiliser was applied, it was assumed that none was applied during the at-risk winter months as per best practice.
- No information was provided regarding application of lime on any farms.
- No wetland or DCD data was provided, so these categories were not entered in OVERSEER®.
- Supplementary feed was assumed to be of average quality, and was separated into hay and silage, and maize silage.
- It was assumed that no cropping occurred on farms.

Table 4-7: Estimates of nitrogen leaching rates derived from OVERSEER® for Waikato dairy farms (1996-2008). (Judge and Ledgard 2004; Judge and Ledgard 2009).

Year	Estimated nitrogen leaching rate (kg N/ha/yr)		
	Lower quartile	Average	Upper quartile
1997	26	32	39
1998	25	31	39
2000	25	34	42
2001	30	38	51
2002	32	39	48
2003	31	39	49
2004	32	39	49
2005	34	41	44
2006	37	45	60
2007	33	38	47

Ledgard and Power (2006) estimated nutrient losses from "average" Waikato farms to waterways as part of an assessment of likely effects of best management practices. The focus of this work was on the lower Waikato River catchment. OVERSEER® version 5.2.4.0 was used to prepare nutrient budgets for three scenarios:

1. Average dairy farm characteristics were derived from the Livestock Improvement Corporation (LIC) database, with average dairy farm information was based on the MAF (now MPI) sheep and beef farm monitoring report.

2. Best management farms practice scenarios assumed practices that would provide environmental benefits at low net cost, or might increase farm profitability.

3. Potential farm, which included practices likely to significantly reduce N and P losses, but which would incur additional cost (e.g., winter feed pads etc.).

Assumptions associated with the OVERSEER® modelling by Ledgard and Power are summarised in Table 4-8:

Table 4-8: Assumptions used in the OVERSEER® nutrient budget model to estimate nitrogen and phosphorus losses (kg/ha/year) from "average" Waikato farms to waterways. From Ledgard and Power (2006).

Variable	Dairy	Sheep and Beef
Stocking rate	3.0 cows/ha	Sheep: 7.4 SU/ha Cattle: 5.5 SU/ha (40% male)
Production	920 kg MS/ha/yr	25 kg wool/ha/yr
Effluent block area	15% of farm	N/A
Contour	Flat	Rolling
Rainfall	1200 mm/yr	1200 mm/yr
Soil type	Volcanic (ash)	Volcanic (ash)
Olsen P	43	16
Fertiliser	114 kg N/ha/yr 49 kg P/ha/yr	20 kg N/ha/yr 24 kg P/ha/yr

Nitrogen and phosphorus losses estimated by Ledgard and Power (ibid) from average Waikato farms to surface waters are summarised in Table 4-9:

Table 4-9: Estimates of nitrogen and phosphorus losses from scenarios based on conditions representative of the average Waikato farm. From Ledgard and Power (2006).

Scenario	Nutrient loss by farm type (kg/ha/yr)			
	Dairy		Sheep & beef	
	N	P	N	P
Average	36	0.5	13	0.3
Best practices	33	0.3	10	0.3
Potential practices	20	0.2	8	0.2

Ledgard and Power made the note that “a wide variation in biophysical properties and management practices are used on individual farms”. Consequently the N and P losses from individual farms will vary widely around the values for the "average" farm presented in Table 4-9 (as will the efficacy of practices implemented to reduce N and P losses from farms to waterways). Although not stated explicitly, we assume that the nutrient loss values provided in Table 4-9 are net losses, after implementation of mitigation practices such as winter feed/stand-off pads and riparian management.

OVERSEER® modelling (which assumes best practice) was used extensively by Rutherford et al (Rutherford et al. 2009; Rutherford et al. 2011a) to estimate current and historical N leaching rates from farmland in the Lake Rotorua catchment. These leaching rate estimates were combined with surface and groundwater hydrogeology information for the various catchments draining into Lake Rotorua to:

- estimate “loads to come”, and
- to determine the range and extent of mitigation that would be required to reduce the load of N entering Lake Rotorua to achieve future water quality objectives.

Their estimates of historical nitrogen yield from dairy and drystock pasture are summarised in Table 4-10 and Table 4-11 respectively. The procedure followed included consideration of leaching losses by an "expert panel", experienced agricultural consultants, researchers and practitioners, who identified a series of leaching losses on the basis of their expert judgement.

Table 4-10: Estimates of nitrogen yield from dairy pasture over time (kg N/ha/y). From Rutherford et al (2011).

Source of estimate	1940	1958	1974	1986	1996	2001	2003	2005	2010
OVERSEER® prediction	30	32	40	46	51	52	57	58	58
Expert group	30	32	40	46	51	52	56	56	56
Expert group plus effects of land conversion	34.6	34.6	42.1	46	51	53.5	56	56	56
Fertiliser application rate	0	0	50	100	140	160	180	180	180

Notes:

- Bay of Plenty Region, deep, well-drained pumice soils, annual rainfall 2000 mm.
- Earlier estimates (Rutherford et al 2009) indicated 20 – 55 kg N/ha/yr (north of Rotorua, 1958 – 2003), and 15 – 35 kg N/ha/yr (south of Rotorua).
- Expert group estimates were an outcome of the consultation process – these included views of farmers regarding their actual estimates.

Table 4-11: Estimates of nitrogen yield from drystock pasture. Estimated by the expert panel, revised using agricultural statistics, and revised to include effects of 'land conversion', which included clearance of gorse. From Rutherford et al (2011).

Source of estimate	Estimates of nitrogen yield and trend in stocking rate								
	1940	1958	1974	1986	1996	2001	20013	2005	2010
Expert panel	7	11	12	13	14	14	16	16	16
Agricultural statistics	12.1	13.4	16.8	17.4	18.5	17	16	16	16
Land conversion	13.8	17.0	17.8	17.4	18.5	17	16	16	16
Stocking rate (SU/ha)	4	6.6	8	8.8	9.2	9.6	12	12	12

Olubode-Awosolo et al. (2014) published estimates of N leaching from drystock and dairy support farms in the Waikato. These estimates were obtained during development of the economic model developed during the second Economic Impact Joint Venture project in the Waikato region (Waikato Regional Council 2015). The process they followed included analysis of farm case studies, which suggested that five 'typical' dry stock farms would provide adequate estimates of average N leaching rates and the range of leaching rates that were likely. These were considered to represent the diversity of among drystock farm systems captured during the data collection exercise.

In this study, the drystock data captured at farm-level were scaled up to catchment level using a range of regional agricultural statistics and other industry databases (FarmsOnline database, Beef+Lamb economic survey data sets, Agribase, Statistics NZ agricultural census data , etc. See Olubade-Awosola et al. 2014). Key steps in the process included:

- Waikato Regional Council survey of 450 drystock farms in the region.
- Selection of 20 farms for case studies, covering the region spatially and the farm systems clusters identified in the 450 farms survey.
- Collection of farm level information such as animal transactions information, from the case study sample.
- Extrapolation of regional climate and financial data for the purpose of generalisation.
- Data from 13 case study farms were complete and used to represent five 'typical' farm systems across the region.
- The data typify empirical data which contain qualitative information, lacking statistical properties. The data were subsequently complemented with appropriate data-validating techniques such as literature and expert knowledge from farmers, rural consultants and scientists in a group discussion workshop.
- Feedback from industry representatives provided insights regarding the typical farm types and corresponding mitigations options and scenarios.
- The farm level data were scaled to catchment level:
  - by approximation in terms of pastoral area, number of drystock farms and the farm size distribution in the districts that make up the catchment, considering…
  - a range of regional agricultural statistics and other information derived from industry databases.

Further detail regarding the upscaling process is included as Appendix D. Estimates of N leaching rates derived from their assessment are summarised in Table 4-12.

Results from other field scale trials are included in Appendix E. Key findings from selected studies include:

- Leaching rates were highly dependent on the presence of grazing animals, and could be reduced substantially by removal of stock during the winter period. Leaching increased during wet conditions irrespective of land use (Betteridge et al. 2007).
- Increased nitrogen leaching may be anticipated following pasture to pasture renovation, most likely because of increased mineralisation of pasture residues and soil organic matter. This suggested that were the effects of pasture renovation to be included in OVERSEER®, farmers would need to reduce stock numbers to comply with nutrient limits, which may reduce the viability of pastoral farming. (Betteridge et al. 2011).

An alternate approach used to estimate nutrient losses from agriculture was developed by Lilburn et al. (2010) and is briefly summarised in Appendix F. This method involves application of fairly coarse

leaching rate values according to land use, soil types, stock management and irrigation practice to provide plausible estimates of nitrogen yields that were adequate for the development of land and water management policy.

Table 4-12: Summary of N leaching rates for five representative drystock operations in Waikato region. From Olubode-Awosolo et al. (2014). N leaching rates rounded to single decimal place.

Classification	Description	Assumption/enterprise description	N leaching rate (kg N/ha/yr)
I	Small lamb finishing farms, with some beef finishing	Average farm size 50-100 ha Sheep: cattle ratio 70:30 Stocking rate 10-13 (SU/ha)	11.5
II	Traditional hill country with lamb finishing	Average farm size 165-450 ha Sheep: cattle ratio 70:30 Stocking rate 8.5 (SU/ha) Male: female cattle 70:30 Steep slope – 10% of effective area	7.8
IIIa	Hill country with maize silage cropping for dairy support	Average farm size 35-250 ha All cattle Stocking rate 8.6 Male: female cattle 80:20 Wintering dry dairy cows/dairy heifer grazing Beef breeding with dairy support operation	27.9
IIIb	Hill country with pasture-based dairy support	Average farm size 5-250 ha All cattle Stocking rate 8.6 Male: female cattle 80:20 Wintering dry dairy cows/dairy heifer grazing Mainly beef breeding with dairy support operation	10.1
IV	Bull and prime beef finishing	Average farm size 35-250 ha Mostly beef cattle Stocking rate 11.75 100% male cattle Wintering dry dairy cows/dairy heifer grazing Mainly finishing operation, with purchase of replacement stock rather than bred	12.3

4.2 Derivation of historical N leaching yields for use in the HR/WO project

4.2.1 Absolute historical N leaching yield estimates

The review of technical material summarised in Section 4.1 and Appendix C and Appendix E highlighted that considerable variability in N leaching yields may be expected regionally and within individual sub-catchments. This variability arises from site specific conditions such as climate, soil type and farm management practice. One way of effectively minimising and estimating this variability is use of OVERSEER® to estimate leaching losses at farm scale using enterprise-level information derived from a large sample of representative farm types. Data from selected studies

are summarised in in Table 4-13, which was used to provide the two regression equations described in Section 2.7.

Table 4-13: Estimates of leaching from representative dairy and sheep and beef farms in Waikato and the Bay of Plenty region. Blue text are for Rotorua (Rutherford et al. 2012), and red text are for Waikato studies (Judge and Ledgard (2004, 2009).

Year	Nitrogen leaching rate estimated per land use category using OVERSEER® (kg N/ha/yr)					Reference
	Dairy	Sheep and beef intensive	Sheep and beef extensive	Other intensive	Other extensive	
2014[a]		11.5-12.3	7.8-10.1[e]	27.9[d]		A
2013[b]	16-24					B
2012[c]	25.9	25.9	11	25.9	11	C
2010[c]	**56-58**		**16**			**D**
2007[a]	33-38-47[f]					E
2006[a]	37-45-60		10-16			E
2006[a]	33-36		10-13			F
2005[c]	**56-58**		**16**			**D**
2005[a]	34-41-44		10-17			E
2004[a]	32-39-49		10-17			E
2003[c]	**56-57**		**16**			**D**
2003[a]	31-39-49		9-17			E
2002[a]	32-39-48		9-15			E
2001[c]	**52-53.5**		**14-17**			**D**
2001[a]	30-38-51		9-16			E
2000[a]	25-34-42		9-16			E
1999[a]			10-16			E
1998[a]	25-31-39		10-17			E
1997[a]	26-32-39		10-15			E
1996[c]	**51**		**14-18.5**			**D**
1996[a]			10-15			E
1995[a]			10-16			E
1986[c]	**46**		**13-17.4**			**D**
1974[c]	**40-42.1**		**12-17.8**			**D**
1958[c]	**32-34.6**		**11-17**			**D**

Notes		References	
[a]	Waikato region	A	Olubode-Awosolo et al (2014)
[b]	National average	B	Dymond et al (2013)
[c]	Rotorua region	C	PerrinAg (2011)
[d]	Includes maize silage production	D	Rutherford et al (2011)
[e]	Traditional hill country, lamb finishing	E	Judge and Ledgard (2004, 2009)
[f]	Range of estimates, with average	F	Ledgard and Power (2006)

While the leaching loss estimates used for the current study are considered adequate for the purposes of this report, they will be adjusted in future as more detailed information becomes available, and as model sophistication increases. Although the absolute leaching loss estimates and resulting sub-catchment leaching losses have uncertainty, they represent the best data currently

available, and when these values are considered together with estimated land use change and observed trends in surface water quality, the overall impact of land use and land use change on surface water quality is evident.

4.2.2 Relative historical N leaching yield estimates

This report also scaled the leaching loss data to provide relative leaching loss estimates. This was done for several reasons:

- Doole et al. (2015) independently estimated leaching losses for each of the Healthy River/Wai Ora sub-catchments, using different information to estimate nitrogen leaching losses from pastoral land uses.
- The current work (this report) was likely to provide different absolute leaching loss estimates from those of Doole et al.

The existence of different leaching loss estimates may lead to debates regarding "which estimate is 'correct'?", diverting attention from the more important issues ("Which sub-catchments are responsible for the greatest nitrogen loss?", "Where has nitrogen loss increased most over time?", and "Where should mitigation strategies be implemented to improve surface water quality?").

Although this report provides both absolute and relative leaching loss estimates, it is important to remember that the key issues are related to land use and intensification *change*, *trends* in water quality, and identifying *where* resource management intervention is required.

Data from Rutherford et al. (2011a) and Judge and Ledgard (2004; 2009) are summarised in Table 4-13. These data were used to calculate decadal estimates of nitrogen loss using Equation 2-1 and Equation 2-2, which were subsequently re-scaled so that N leaching yield estimates in 2012 have a value of 1. These re-scaled, decadal estimates are summarised in Table 4-14.

Table 4-14: Summary of estimated and relative leaching yield for selected years, with the reference year of 2012.

Year	Dairy yield		Sheep and Beef yield	
	Estimated (kg/ha/y)	Proportion of 2012 yield	Estimated (kg/ha/y)	Proportion of 2012 yield
2012	30.6	1	10.8	1
2008	29	0.948	10.6	0.983
2002	26.6	0.871	10.4	0.958
1996	24.3	0.794	10.1	0.933
1992	22.7	0.742	9.9	0.916
1982	18.8	0.613	9.5	0.875
1972	14.8	0.484	9	0.833

4.3 Trends in total nitrogen leaching loss

The process used to estimate nitrogen leaching yields relative to current estimates was described in Section 2.8. Leaching losses for the entire Healthy Rivers catchment are summarised in Table 4-15 and Figure 4-1, with a breakdown by key land uses. These leaching losses for key pastoral land use

categories are summarised as a series of maps in Figure 4-2 through Figure 4-4, which indicate the magnitude of leaching loss at decadal step across all 74 Healthy Rivers/Wai Ora sub-catchments.

Losses estimated for each sub-catchment are detailed in Appendix B. Appendix B provides:

- total leaching loss for all land uses for the Wai Ora/Healthy Rivers project area according to freshwater management unit and decade (Figure B-1), and
- total leaching loss for all land uses for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment (Figure B-2).

This information is further detailed in Appendix G, which includes:

- Nitrogen leaching loss by catchment and year for each land use (Table G-1).
- Total leaching loss for the Wai Ora/Healthy Rivers project area according to land use, freshwater management unit, and decade (Figure G-1).
- Proportion of total leaching loss for the Wai Ora/Healthy Rivers project area according to land use, freshwater management unit, and decade (Figure G-2),
- Nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for various land uses (Figure G-3 - Figure G-10).
- Proportion of nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for various land uses (Figure G-11 - Figure G-18).

Nitrogen losses are estimated to have increased gradually since 1972, culminating with 2012 having a 66% increase relative to 1972 estimates. This increase has been driven both by an increasing proportion of the catchment that is in dairy land use, and intensification of existing land uses.

Losses from dairy in 2012 are estimated to be 2.4 times the 1972 values. This has been driven largely by the increase in leaching yield by a factor of 2.1, and in part by an increase in the area of dairy (by a factor of 1.12). In 1972 the losses from dairy were 43% of the total; now they are 63% of the total. The estimated rate of increase accelerated from 1992. In comparison, using data based on national and regional-scale estimates of nitrogen inputs to and outputs from pastoral land use, Parfitt et al (2012) estimated that the loss of nitrogen in Waikato region increased from 16,000 t in 1990 to 24,000 t in 2010. This equates to an increase from 6.5 kg/ha to 9.8 kg/ha (over the Waikato region, 24,500 km^2). At regional scale, Dymond et al (2013) estimated that nitrate-N loss increased from 13.3 to 14.8 kg/ha/year over the period 1990-2010. Examination of the leaching rate maps (displayed at North and South Island scale) produced by Dymond et al (2013) indicates that nitrate-N leaching losses across much of the Waikato River catchment in 2011 occurred at rates in the range of 15 kg/ha/year - >40 kg/ha/year, which are consistent with the estimates summarised in Table 4-14.

The estimated losses from non-dairy pasture increased by about 4% over the period from 1972 to 2012. The area of non-dairy pasture decreased by about 14% over that time, but this was offset by a corresponding increase in leaching yield by about 20%. The impact of these changes in pastoral land use on nitrogen leaching losses are evident in Figure 4-2 through Figure 4-4.

- Figure 4-2 indicates how intensification of dairy land use has increased the nitrogen loss across all FMUs.
  - High losses of nitrogen commenced relatively early in some sub-catchments in the Waipa River FMU (from 1992).
  - Nitrogen losses from sub-catchments subject to increasingly intensive dairying have increased in the lower and upper Waikato FMUs noticeably since 2002.
  - There are relatively few sub-catchments where nitrogen losses associated with dairy land use have not increased since 1972.
- The contribution of sheep and beef (high and hill) land use to nitrogen loss (Figure 4-3) has decreased over time. This decrease is evident both in:
  - the magnitude of nitrogen loss, and in
  - the area of land subject to this land use.
  - This change in land use (and impact on nitrogen leaching loss) is particularly evident in the upper Waipa River and upper Waikato River FMU.
- The contribution of sheep and beef (intensive) land use to nitrogen loss (Figure 4-4) have increased over time in similar fashion to the dairying land use.
  - Where contributions related to sheep and beef intensive land use appear to have decreased, they are usually associated with increased losses from dairying land use (e.g., in the mid- and lower subcatchments of the Waipa FMU).

Consideration of Figure 4-2 through Figure 4-4 indicates a shift in intensification of pastoral land use – dairying is increasingly occurring in areas previously used for intensive sheep and beef, while intensive sheep and beef land use has tended to replace sheep and beef (high and hill) land use. This intensification in land use has been accompanied by a predicted increase in nitrogen loss.

It should be noted that the predicted total losses leaving the root zone do not take into account attenuation in groundwater, streams or lakes. Although such attenuation will reduce the total N loads below the values discussed above, the relativities between land uses and the overall trends are likely to remain similar after attenuation.

These results assume that intensive sheep and beef have the same yield as hill sheep and beef. If instead it is assumed that the yield from intensive sheep and beef is 1.5 times the yield from hill sheep and beef, then the overall trends are similar. The losses for 1972 are marginally lower, because there was a greater proportion of hill sheep and beef to total sheep and beef in 1972 compared with 2012. The ratio of hill sheep and beef losses to total sheep and beef is sensitive to the assumed ratio of leaching yield. It is difficult to be definitive about the split between these two land uses, because the ratio of yields is uncertain and because the split of total sheep and beef into hill and intensive components is uncertain (for example, the WRC 2012 land use layer made this split in a different way, resulting in an apparent increase in intensive sheep and beef from 2008 to 2012 which is an artefact of changing methodology).

For individual sub-catchments there are some pronounced trends. The most extreme case was the Little Waipa, where estimated losses increased by a factor of 3.22 from 1972 to 2012, and by 58%

from 1992 to 2012. The Kirikiriroa Stream had a reduction in predicted load over time associated with urbanisation and de-intensification. Interestingly, water quality records show a dramatic decline in TN concentrations from about 3.5 g/m^3 in 1995 to about 1.5 g/m^3 currently, which is a stronger reduction than suggested by the modelling; this reduction is related to a regulatory intervention which effectively eliminated leachate discharge a Hamilton City Council landfill which closed in 1998[8].

Table 4-15: Trend in total nitrogen losses over the entire Healthy Rivers catchment, 1972-2012.

Year	Total nitrogen loss (kt/y)	Nitrogen loss by land use type (kt/y)				
		Dairy	Intensive Sheep and Beef	Hill Sheep and Beef	Pasture Total	Non-Pasture
1972	9.24	3.95	1.64	1.90	7.49	1.75
1982	10.65	4.83	1.93	1.88	8.64	2.01
1992	12.00	5.64	2.24	1.86	9.74	2.27
1996	12.53	5.95	2.37	1.84	10.16	2.37
2002	13.51	7.74	2.27	1.52	11.52	1.99
2008	14.87	8.28	2.39	1.78	12.44	2.43
2012	15.35	9.62	2.93	1.09	13.64	1.71

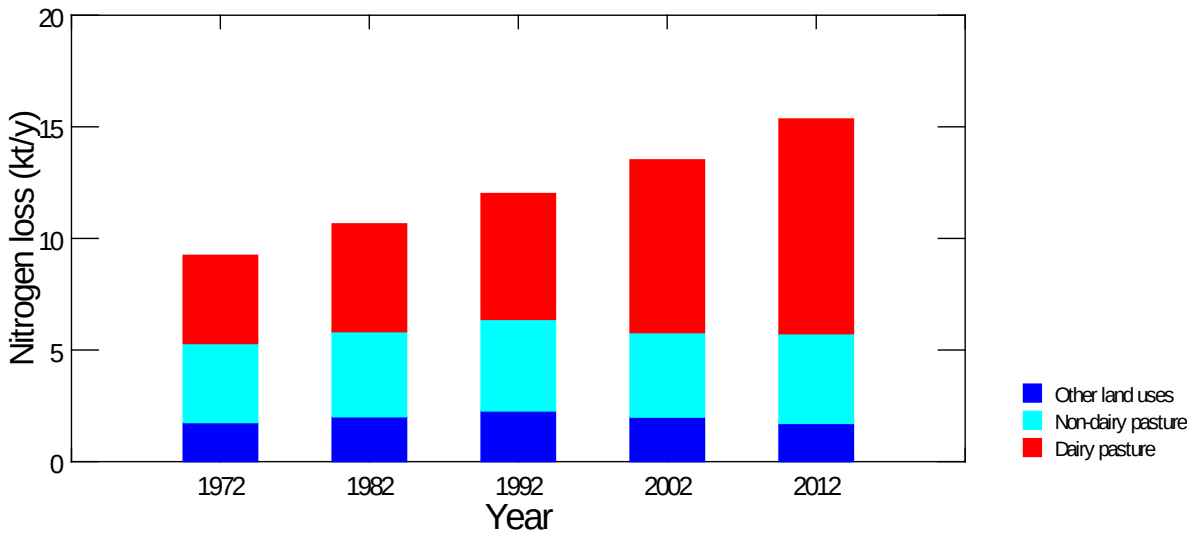


Figure 4-1: Trend in nitrogen loss according to consolidated land use classes over the entire Healthy Rivers catchment, 1972-2012.

[8] Dr Bill Vant, Waikato Regional Council. E-mail to N. Hudson, 10/11/2015.

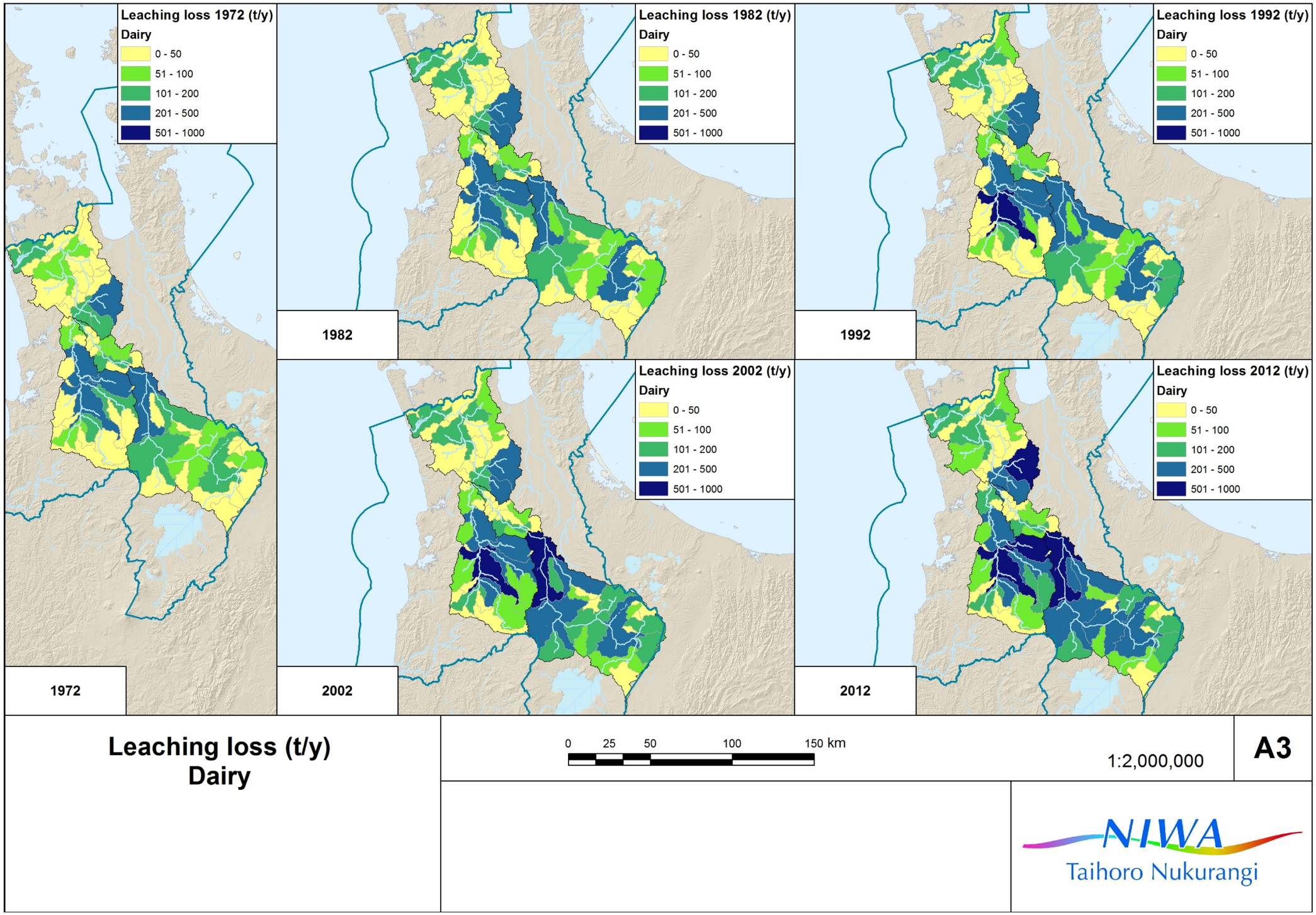


Figure 4-2: Trend in nitrogen leaching loss from land used for dairy by sub-catchment, 1972-2012.

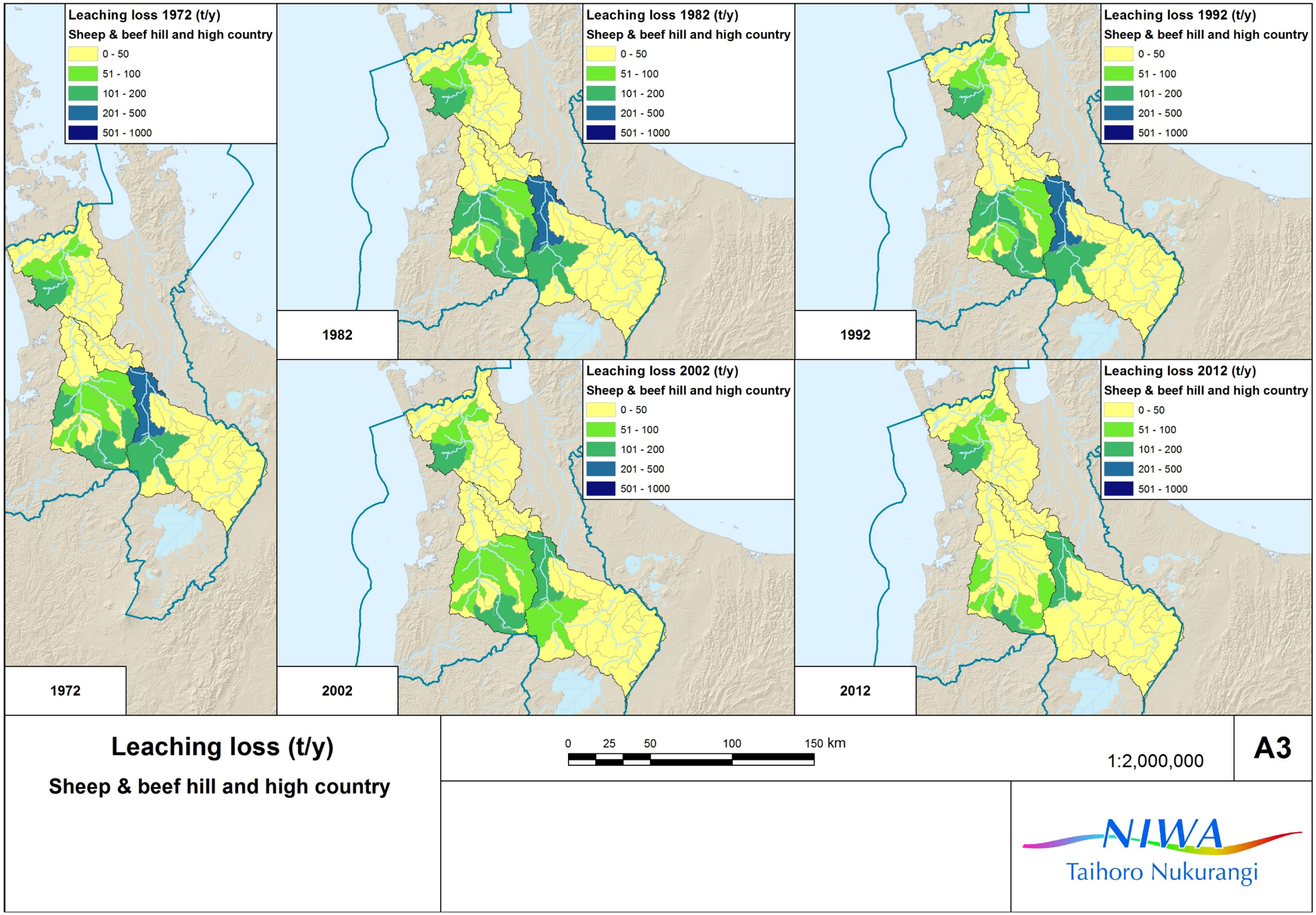


Figure 4-3: **Trend in nitrogen leaching loss from land used for sheep and beef (hill and high country) by sub-catchment, 1972-2012.**

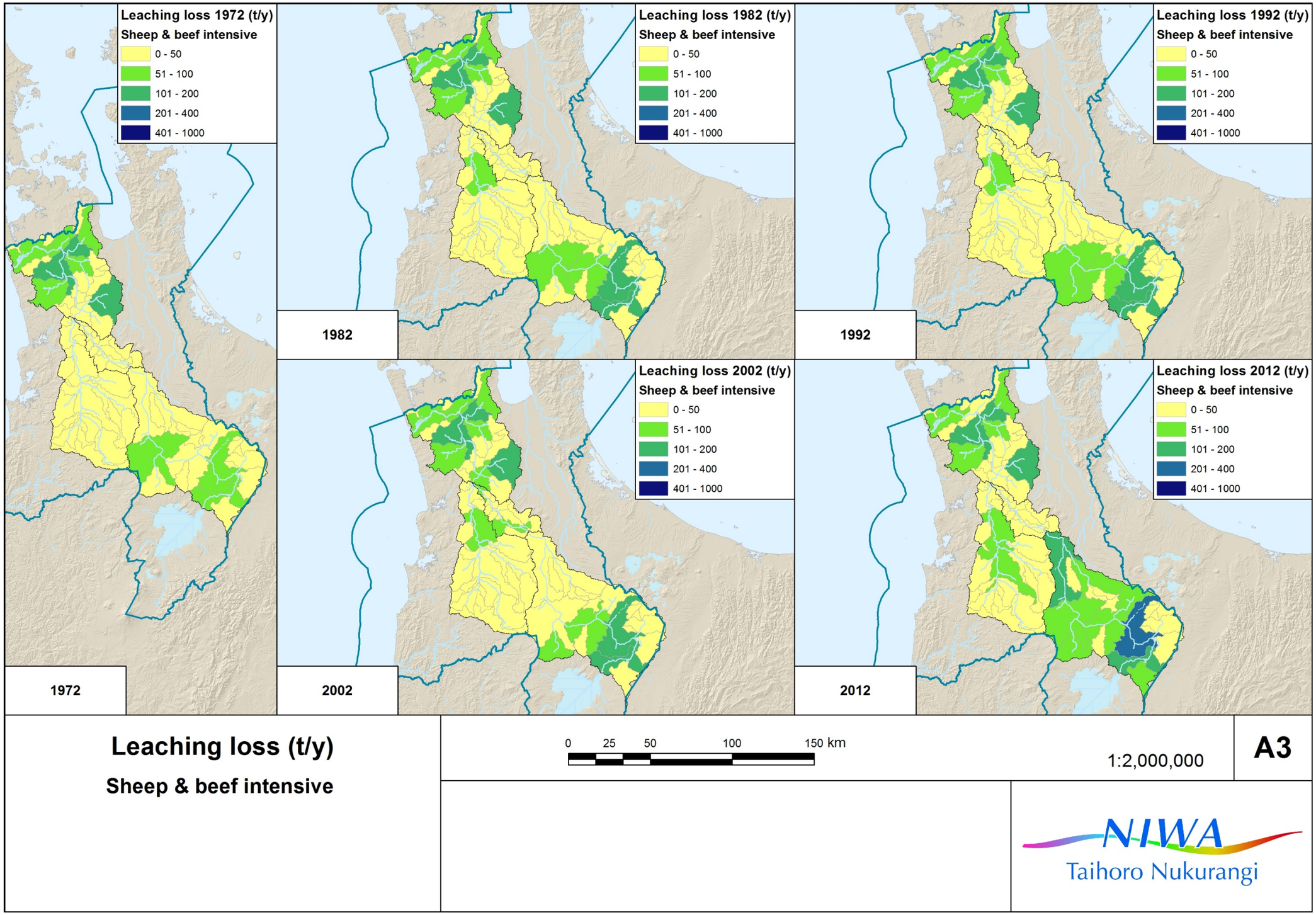


Figure 4-4: Trend in nitrogen leaching loss from land used for sheep and beef (intensive) by sub-catchment, 1972-2012.

The predicted increases in losses are broadly consistent with increasing TN concentrations in many streams in the catchment. An example is the Kawaunui Stream (Figure 4-5 A). In some sub-catchments, the stream may not yet reflect past changes in loading due to lags in catchment response, and this is of importance for estimating future water quality (Semadeni-Davies et al. 2015b).

The trend in TN concentration is also evident at the Waikato at Bridge St Bridge site (Hamilton) (Figure 4-5 B). The cumulative loss is estimated to have increased from 5381 t/y in 1996 to 6902 t/y in 2012, or by 28%. The concentrations have increased by approximately 17% over that period, generally consistent with the increase in loading. The difference may be attributed in part to time lags in the upper catchment and to errors in the estimation of historical leaching.

Cumulative losses, that is, the total losses for the local sub-catchment and all upstream catchments, are shown for each sub-catchment in Appendix B, Table B-2. These total losses are intended for comparison with water quality trends, which reflect the total upstream catchment.

A **B**

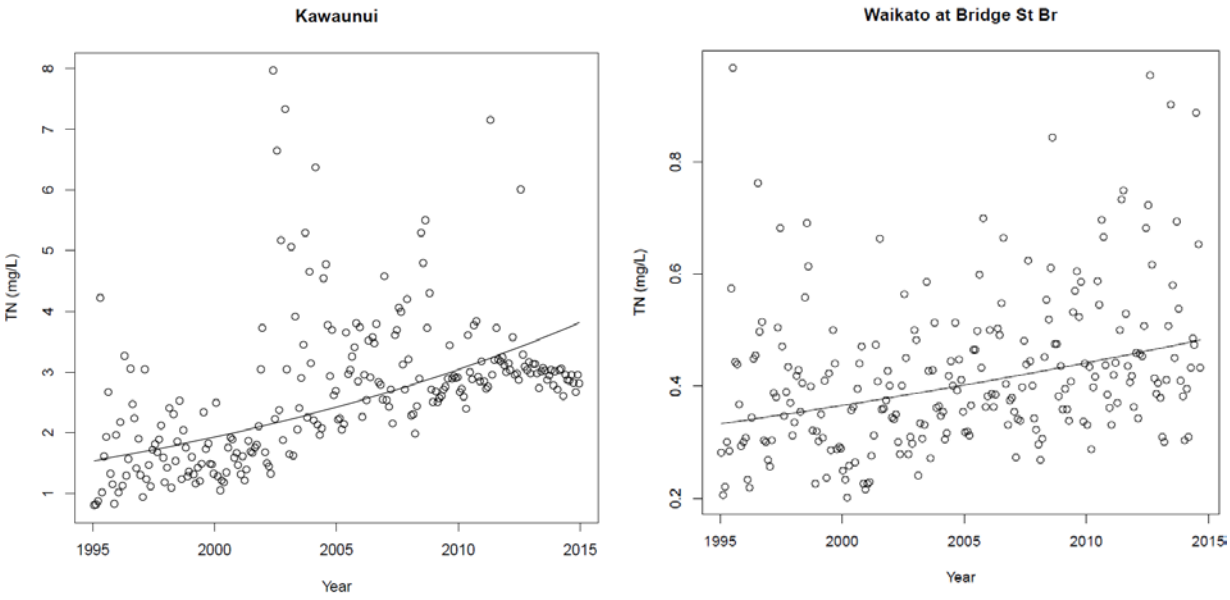


Figure 4-5: Example of increasing TN concentrations in a sub-catchment where estimated loadings have increased (Kawaunui Stream, A), and at a site representing a larger sub-catchment (Waikato at Bridge St Br, B). In both cases the line is an exponential model fit.

5 Key findings, limitations and future work

There have been slight overall changes in land use since 1972. Areas of dairying decreased to 1996 then increased to 2012. Areas of dairying have increased since then. In some catchments, the changes in land use have been more pronounced and variable, with considerable introduction of dairying in the upper catchment since the late 1990s.

Leaching yields (kg/ha) are estimated to have increased substantially since 1972. This is particularly so for dairying, where the yield was estimated to have increased by a factor of 2.1 since 1972. The trends are broadly consistent with increases in TN concentrations observed in streams in the catchment since 1995.

The estimates of trends in nitrogen leaching were based on assessment of literature values to derive historical yields. In the Methods section (Section 2), several sources of uncertainty were identified. Although these may determine the accuracy of these estimates, we consider the overall trends to be fit for the purposes of this study. They clearly indicate changes in land use and land use intensity over time and, as a result, estimate that nitrogen leaching losses have trended upwards. These trends are supported by the results of surface water quality monitoring for the catchment, which generally indicate increasing concentrations of nitrogen over time.

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Appendix A Land use in each sub-catchment over time

Table A-1: Land use by sub-catchment at discrete time steps. Data for 1982 and 1992 derived from linear interpolation from other data. Blue shading indicates decadal time steps.

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1972	Pueto	1	0	15245	0	2753.9	714.1	0.2	1315.7	0	20028.9
1972	Waikato at Ohaaki	2	168.8	7444.1	0	12019.8	399.6	9.4	8951.6	0	28993.3
1972	Waikato at Ohakuri	3	7537.8	9663	0	24291.5	1699.3	2416	7487.9	0	53095.5
1972	Torepatutahi	4	3247.2	10874	0	2730.6	0	363.3	4505.8	0	21720.4
1972	Mangakara	5	327.3	0	0	1146	247.9	0.2	513.5	0	2234.9
1972	Waiotapu at Homestead	6	5528.1	9805	0	1658.9	1623.8	51.6	1809.7	0	20477.1
1972	Kawaunui	7	2.8	0	0	1070	266.2	13.4	779.4	0	2131.8
1972	Waiotapu at Campbell	8	76.6	2023	0	1612.8	132	554.5	1655.6	0	6054.5
1972	Otamakokore	9	2157.6	0	0	1593.9	64.1	77.8	677.7	0	4571.1
1972	Whirinaki	10	58.2	0	0	440.1	148.3	215.9	217.1	0	1079.6
1972	Waikato at Whakamaru	11	2543.9	21543	0	11375.4	3672	1678.3	3827.6	0	44640.5
1972	Waipapa	12	504.2	2683.9	0	3678	276.2	1843.6	1062.2	0	10048.1
1972	Tahunaatara	13	2604	3895.2	0	4086.2	4296.3	2648.3	3272.1	0	20802.1
1972	Mangaharakeke	14	643.5	4462.8	0	0	0	1.3	307.7	0	5415.3
1972	Waikato at Waipapa	15	5621.9	19885	0	7697.9	16703.5	13399.3	6055.5	0	69363.4
1972	Mangakino	16	357.6	0	0	5872.1	10938	1886.4	3130.7	0	22184.8
1972	Mangamingi	17	2660.5	1480.6	0	0	0	258.1	88.3	687.6	5175.1
1972	Whakauru	18	1354.2	3694.2	0	0	0	74.3	1.6	178.2	5302.5
1972	Pokaiwhenua	19	7677.4	17435	0	277.4	2446.3	4643.5	217.5	1.2	32697.9
1972	Little Waipa	20	2112.8	5690.8	0	0	0	2760.1	83.3	0	10647
1972	Waikato at Karapiro	21	11817.1	7488	0	2427.2	2759.5	26982.9	2009.4	0	53484.1
1972	Karapiro	22	1725.7	0	0	0	341	4391.2	278.8	0	6736.7
1972	Waikato at Narrows	23	8452.7	0	0	465.9	22.8	586.4	2297.2	1108.8	12933.8

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1972	Mangawhero	24	3154.1	0	0	0	0	653.2	1465.3	74.7	5347.3
1972	Waikato at Bridge St Br	25	3590	0	0	0	0	18.6	563.7	882	5054.3
1972	Mangaonua	26	5700.6	0	0	182.3	158.7	1400.5	653.7	0	8095.8
1972	Mangakotukutuku	27	1173.4	0	0	161.2	0	9.2	755.1	608.9	2707.8
1972	Mangaone	28	4963.7	0	0	37.2	0	1.3	1494.9	263.1	6760.2
1972	Waikato at Horotiu Br	29	2273.3	0	0	0	0	1.2	537.3	2571.7	5383.5
1972	Waitawhiriwhiri	30	731.2	0	0	50.7	0	0	194.8	1245.9	2222.6
1972	Kirikiriroa	31	588.9	0	0	0	0	0	351.6	293	1233.5
1972	Waikato at Huntly-Tainui Br	32	10087.8	0	0	92.1	991	880.9	3531.8	1703.4	17287
1972	Komakorau	33	12301.5	0	0	0	0	0	4096.1	0	16397.6
1972	Mangawara	34	17013.3	0	0	155.7	1877.7	1975.3	14855.3	0	35877.3
1972	Waikato at Rangiriri	35	3284.7	0	0	696.6	0	507	1017.6	1271.3	6777.2
1972	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	2065.2	0	0	989.4	0	497.2	1090.1	3.1	4645
1972	Awaroa (Rotowaro) at Sansons Br	37	339.1	0	0	384.5	270.4	3232.8	326.2	0	4553
1972	Waikato at Mercer Br	38	9703.8	102.1	522.6	6272	2873.7	10328.9	15062.2	46.8	44912.1
1972	Whangape	39	2278.5	0	0	1687.7	0	18838.7	8661.2	0	31466.1
1972	Whangamarino at Island Block Rd	40	3366.4	0	0	4101.4	844.8	6.4	6015.9	0	14334.9
1972	Whangamarino at Jefferies Rd Br	41	2647	0	0	0	1392.3	1747	3912.2	0	9698.5
1972	Waerenga	42	39.2	0	0	0	0	1426.9	493.1	0	1959.2
1972	Matahuru	43	2727.3	0	0	7.6	512.5	3660.2	3722.7	0	10630.3
1972	Waikare	44	3384.8	0	0	3578.5	55.6	63.3	3224.9	0	10307.1
1972	Opuatia	45	613.8	0	0	38.1	0	6161.6	253.1	0	7066.6
1972	Mangatangi	46	3948.3	141.7	9.2	123	6463.9	1118.8	7631.3	4.8	19441
1972	Waikato at Tuakau Br	47	2807.2	487.5	1033.4	121.5	2401.8	1582.9	6411.5	67.3	14913.1
1972	Ohaeroa	48	877.5	0	0	0	0	675	477.9	0	2030.4
1972	Mangatawhiri	49	293.2	2.6	8.7	0	6028.8	19.8	451.3	3.5	6807.9

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1972	Waikato at Port Waikato	50	9199	1028.8	1141.8	964.3	1674.5	4814.2	7595	146.5	26564.1
1972	Whakapipi	51	255.6	49.1	991.9	31.8	357.8	254.8	2255.2	448.7	4644.9
1972	Awaroa (Waiuku)	52	894.3	29.7	111.5	1.6	53.2	18.8	1343.7	52.2	2505
1972	Waipa at Mangaokewa Rd	100	0	0	0	0	2057.9	1159.2	0	0	3217.1
1972	Waipa at Otewa	101	964.8	0	0	0	13230.5	14273.4	159	0	28627.7
1972	Mangaokewa	102	83.5	0	0	0	3248.3	13389.5	130.3	564	17415.6
1972	Mangarapa	103	1049.4	0	0	0	0	3954.1	437.5	0	5441
1972	Mangapu	104	4515.7	0	0	0	66.8	9697.4	1363.8	517.1	16160.8
1972	Mangarama	105	405.6	0	0	0	27.6	4353	738.9	0	5525.1
1972	Waipa at Otorohanga	106	7046.5	0	0	0	126	5815	575.6	319.6	13882.7
1972	Waipa at Pirongia-Ngutunui Rd Br	107	26600.9	0	0	20.4	3121.5	11652.6	1987.7	206.4	43589.5
1972	Waitomo at Tumutumu Rd	108	149.5	0	0	137.5	498.9	3530.5	0	0	4316.4
1972	Waitomo at SH31 Otorohanga	109	1357.1	0	0	4	922.4	1737.5	367.2	3.5	4391.7
1972	Moakurarua	110	1470.9	0	0	131.6	3139.9	15611.5	273.4	0	20627.3
1972	Puniu at Bartons Corner Rd Br	111	8376.7	0	0	1155	117.7	11505	1615.4	1.2	22771
1972	Puniu at Wharepapa	112	884.9	0	0	0	2244.5	12542.9	1164.5	0	16836.8
1972	Mangatutu	113	2225.7	0	0	164.1	4459.1	4873.7	544.5	0	12267.1
1972	Mangapiko	114	14557	0	0	174.3	813.6	8585.9	3437.8	499.3	28067.9
1972	Mangaohoi	115	0	0	0	0	367.2	63.6	0	0	430.8
1972	Waipa at SH23 Br Whatawhata	116	17001.2	0	0	1880.6	1965.9	4918.3	5675.3	0	31441.3
1972	Mangauika	117	17.4	0	0	0	693.9	265.1	0	0	976.4
1972	Kaniwhaniwha	118	2415.2	0	0	40.8	3469.4	3893.4	439.2	0	10258
1972	Waipa at Wainaro Rd Br	119	4792.4	0	0	1494.9	1353.3	4285.9	2788.2	709.7	15424.4
1972	Ohote	120	3416.8	0	0	61.7	0	3.2	427	132.2	4040.9
1972	Firewood	121	22.6	0	0	0	728.3	2594.5	9.7	16.7	3371.8
1982	Pueto	1	21.7	15680	28.2	1618.5	914.6	3.3	1698.7	62.8	20027.8
1982	Waikato at Ohaaki	2	577.4	8913	324.1	7208.1	781.6	44.4	10656.1	466.5	28971.2

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1982	Waikato at Ohakuri	3	8066.4	12392	32.8	14700.7	2686.3	2880.6	12269.2	37.5	53064.9
1982	Torepatutahi	4	4447	11030	68	1605.5	169.5	246.8	4122.8	27.8	21717.8
1982	Mangakara	5	302.3	85.9	0	668.5	321.1	7.9	849.1	0	2234.8
1982	Waiotapu at Homestead	6	5264	10034	44.3	981.9	1685.3	166.8	2272.3	25	20473.4
1982	Kawaunui	7	361.3	54.1	0.8	624.6	331.6	21.5	738	0.7	2132.6
1982	Waiotapu at Campbell	8	234.6	2015.8	0	956.7	368.1	669.3	1808	8.9	6061.4
1982	Otamakokore	9	2178.1	58.9	0.3	930.9	282.7	100.1	1009.7	10.8	4571.5
1982	Whirinaki	10	105.9	14.5	0	256.7	201.9	244.5	256	0	1079.4
1982	Waikato at Whakamaru	11	2764	24114	8.2	7045.7	2930.5	2847.2	4869.9	52.8	44632.3
1982	Waipapa	12	429.9	2938.9	13.2	2149.1	368.5	2517.7	1630.3	0.3	10048
1982	Tahunaatara	13	2774.3	5337.2	0	2387.5	4158.3	2426.8	3715.4	3.5	20803.1
1982	Mangaharakeke	14	543.8	4463.3	0	0	59.3	17.3	320.5	11	5415.3
1982	Waikato at Waipapa	15	5807.8	23225	9.3	4779.4	17333.5	11935.1	6027.6	245	69363
1982	Mangakino	16	544	734.6	17.5	3447.9	10675.8	2188.3	4573.1	1.9	22183.1
1982	Mangamingi	17	2371.5	1345.3	22.1	7.3	4.3	609	126	688.1	5173.6
1982	Whakauru	18	1213.5	3573.9	0	2.2	12.1	265.1	58	177.8	5302.5
1982	Pokaiwhenua	19	7879.8	18049	4.6	165.5	2291.9	3933.6	341.5	32.5	32698.7
1982	Little Waipa	20	2418	5326.2	0	0.3	37	2783.7	79.8	1.9	10646.8
1982	Waikato at Karapiro	21	12770.5	7441.6	256.3	2187.2	4094.3	24311.1	2455.9	98.2	53615.1
1982	Karapiro	22	1634.7	41.1	6.1	13.5	369.3	4245.7	426.6	0	6737.1
1982	Waikato at Narrows	23	7011.1	85	63.8	374.4	238.9	609.6	3494.1	1061.3	12938.1
1982	Mangawhero	24	2891	5.3	99.6	0	71.7	547.7	1671.5	60.5	5347.3
1982	Waikato at Bridge St Br	25	3103.9	13.6	166.8	43.3	77.1	21.3	814.3	815	5055.1
1982	Mangaonua	26	4982.1	25.6	53.5	107.3	394	1399.2	1122	12.1	8095.6
1982	Mangakotukutuku	27	1271.3	6	13.1	96	17.6	7.7	734.7	561.1	2707.6
1982	Mangaone	28	4273.5	43.5	160.7	26.5	54.2	3	1949.2	238.1	6748.7
1982	Waikato at Horotiu Br	29	1810.9	6.1	24.9	55.4	22	2	796.1	2669.7	5387.2

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1982	Waitawhiriwhiri	30	604.2	6.8	0	51.5	6.5	0	358	1195.7	2222.7
1982	Kirikiriroa	31	486	0	11.4	0.1	17.4	0	369.2	349.3	1233.5
1982	Waikato at Huntly-Tainui Br	32	8804.2	91.3	28.8	187.8	1649.2	807.5	4294.8	1253.4	17116.8
1982	Komakorau	33	12208.5	11.3	82.5	1.5	16.4	0	4057	21	16398.1
1982	Mangawara	34	16659.9	169.3	58.1	108.4	2958.9	1538.7	14362.3	19.1	35874.6
1982	Waikato at Rangiriri	35	2488	70.8	1.3	542.3	451	332.6	1696.2	946.2	6528.3
1982	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	1780.1	28.7	0	842	158.6	554.7	1261.7	37.7	4663.5
1982	Awaroa (Rotowaro) at Sansons Br	37	321.4	65.7	0	428.9	524.6	2879.6	313	2	4535.3
1982	Waikato at Mercer Br	38	8854.1	1464.5	1145.9	4542.3	2825.7	10016.2	15600.5	103	44552
1982	Whangape	39	2156.4	318.9	4.8	1495.2	1090.7	17692.4	8798.1	8.6	31565.1
1982	Whangamarino at Island Block Rd	40	3226.2	597.9	115.1	3593.1	986	6.2	5777.1	36.7	14338.1
1982	Whangamarino at Jefferies Rd Br	41	2816.5	630.8	0	2.8	1070.5	1520.8	3648.5	8.5	9698.3
1982	Waerenga	42	73.7	10.5	0	0	71.1	1359.1	444.8	0	1959.2
1982	Matahuru	43	2441	113.9	0	10.2	597.3	3643.5	3820.5	4.6	10631
1982	Waikare	44	2433.9	12.8	53.3	3740.7	222.6	46.3	3783.5	46	10339.1
1982	Opuatia	45	486.1	390.5	24.4	23.1	302.6	5519.2	316.6	4.2	7066.6
1982	Mangatangi	46	4032.8	474.4	23.1	137.9	6560.3	849.7	7358.8	5.6	19442.5
1982	Waikato at Tuakau Br	47	2588.7	538.7	1317.9	135.4	2504.2	1492.4	6229.8	75.4	14882.4
1982	Ohaeroa	48	594.8	16.7	104.7	0.8	79	662.7	569.8	2.3	2030.8
1982	Mangatawhiri	49	293.2	174.8	8.7	50.8	5782.8	22.8	465.3	4.4	6802.8
1982	Waikato at Port Waikato	50	8507.1	1781.9	1260.1	941.5	2280.5	3768.4	7649.8	165.4	26354.7
1982	Whakapipi	51	255.6	49.2	1004	32.1	313.1	254.8	2257.5	478.6	4644.9
1982	Awaroa (Waiuku)	52	894.3	29.7	111.5	2.7	50.4	18.8	1344.5	53.1	2505
1982	Waipa at Mangaokewa Rd	100	0	514.9	0	9	1595.7	1092.4	0	4	3216.1
1982	Waipa at Otewa	101	836.8	575.9	0	35.5	13650.5	13369.4	131.6	35.7	28635.4
1982	Mangaokewa	102	175.8	544.5	0	25.8	3149.2	12998.3	148.8	373.7	17416.1

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1982	Mangarapa	103	943.1	32.3	0	0.3	167	3905.4	393.2	0	5441.3
1982	Mangapu	104	4244.3	102.1	13.6	47.7	569.3	9200	1549.6	435.1	16161.7
1982	Mangarama	105	483.7	51.2	0	3.2	118.9	4224.9	642.5	1	5525.5
1982	Waipa at Otorohanga	106	6505.5	50	8.9	16.1	379.2	5864.3	785.3	269.9	13879.2
1982	Waipa at Pirongia-Ngutunui Rd Br	107	25066.3	202.3	116.2	82.3	3668.3	11964.7	2260	221.7	43581.7
1982	Waitomo at Tumutumu Rd	108	89.3	160.4	0	81.4	955.2	3022.5	3.5	4.2	4316.5
1982	Waitomo at SH31 Otorohanga	109	1005.5	46.6	0	7.4	1003.3	1904.8	415.3	8.5	4391.3
1982	Moakurarua	110	1515.9	285.2	0	82.9	4626	13709.6	375.8	32.6	20627.8
1982	Puniu at Bartons Corner Rd Br	111	8786.2	195.3	115.6	696.8	177	10811.5	1877.7	111.6	22771.5
1982	Puniu at Wharepapa	112	978.8	127.9	0	2.3	2987.5	11606.5	1128.7	6.8	16838.5
1982	Mangatutu	113	2221.8	54.9	71.6	96.7	4736.1	4359.5	697.4	28	12266.1
1982	Mangapiko	114	14301.2	101.8	104	108.2	1210.5	8095.7	3584.9	561.9	28068.2
1982	Mangaohoi	115	12	0	0	0	368.9	49.6	0.3	0	430.8
1982	Waipa at SH23 Br Whatawhata	116	15731.4	352.5	104.7	1229.9	2476.1	4864.1	6531.8	152.3	31442.7
1982	Mangauika	117	15.2	11.9	0	0.7	753	195	0.9	0.5	977.2
1982	Kaniwhaniwha	118	2196.1	19	0	24.2	3823.7	3513.3	672.2	9.6	10258.1
1982	Waipa at Wainaro Rd Br	119	4326.8	480.5	64.7	980.2	2169.4	3827.7	3068.5	517.9	15435.7
1982	Ohote	120	2690.6	19.2	25	55.5	19.3	6.8	1079.9	143.4	4039.7
1982	Firewood	121	16	68.4	0	6	936.7	2295.2	31.9	17.7	3371.8
1992	Pueto	1	43.3	16115	56.3	483.2	1115	6.5	2081.6	125.5	20026.7
1992	Waikato at Ohaaki	2	986	10382	648.3	2396.3	1163.7	79.3	12360.7	933	28949.1
1992	Waikato at Ohakuri	3	8595.1	15120	65.7	5109.8	3673.3	3345.2	17050.4	75	53034.3
1992	Torepatutahi	4	5646.8	11187	136	480.4	339	130.2	3739.8	55.6	21715.2
1992	Mangakara	5	277.3	171.8	0	191	394.2	15.6	1184.8	0	2234.7
1992	Waiotapu at Homestead	6	4999.9	10263	88.6	304.8	1746.7	281.9	2735	49.9	20469.7
1992	Kawaunui	7	719.8	108.2	1.7	179.2	397	29.6	696.7	1.3	2133.3
1992	Waiotapu at Campbell	8	392.6	2008.6	0	300.6	604.2	784.1	1960.4	17.8	6068.3

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1992	Otamakokore	9	2198.5	117.8	0.6	267.9	501.3	122.5	1341.7	21.7	4571.9
1992	Whirinaki	10	153.5	28.9	0	73.4	255.5	273.1	294.9	0	1079.2
1992	Waikato at Whakamaru	11	2984.1	26685	16.3	2716	2189.1	4016.1	5912.3	105.7	44624.2
1992	Waipapa	12	355.5	3194	26.4	620.2	460.9	3191.9	2198.5	0.6	10047.9
1992	Tahunaatara	13	2944.7	6779.3	0	688.8	4020.4	2205.2	4158.8	6.9	20804
1992	Mangaharakeke	14	444.1	4463.9	0	0	118.6	33.3	333.4	22	5415.2
1992	Waikato at Waipapa	15	5993.7	26565	18.7	1860.8	17963.5	10470.9	5999.8	489.9	69362.6
1992	Mangakino	16	730.4	1469.2	35	1023.8	10413.6	2490.2	6015.5	3.8	22181.3
1992	Mangamingi	17	2082.6	1210	44.2	14.6	8.5	959.9	163.7	688.7	5172.2
1992	Whakauru	18	1072.7	3453.5	0	4.4	24.2	456	114.4	177.4	5302.6
1992	Pokaiwhenua	19	8082.2	18664	9.2	53.7	2137.5	3223.8	465.5	63.8	32699.4
1992	Little Waipa	20	2723.1	4961.6	0	0.6	74.1	2807.3	76.2	3.8	10646.6
1992	Waikato at Karapiro	21	13723.9	7395.3	512.5	1947.3	5429.2	21639.2	2902.4	196.4	53746.1
1992	Karapiro	22	1543.8	82.3	12.3	27.1	397.5	4100.1	574.5	0.1	6737.5
1992	Waikato at Narrows	23	5569.5	169.9	127.7	282.9	455.1	632.7	4691	1013.7	12942.5
1992	Mangawhero	24	2627.9	10.7	199.3	0	143.3	442.2	1877.7	46.3	5347.4
1992	Waikato at Bridge St Br	25	2617.8	27.2	333.5	86.5	154.2	24	1065	747.9	5056
1992	Mangaonua	26	4263.5	51.2	107	32.3	629.3	1397.8	1590.2	24.2	8095.5
1992	Mangakotukutuku	27	1369.2	12	26.3	30.9	35.3	6.3	714.4	513.2	2707.4
1992	Mangaone	28	3583.4	87.1	321.4	15.8	108.3	4.6	2403.5	213.2	6737.3
1992	Waikato at Horotiu Br	29	1348.6	12.3	49.8	110.8	44.1	2.8	1055	2767.6	5390.9
1992	Waitawhiriwhiri	30	477.1	13.5	0	52.3	13.1	0.1	521.2	1145.5	2222.8
1992	Kirikiriroa	31	383.2	0	22.8	0.3	34.8	0	386.9	405.7	1233.5
1992	Waikato at Huntly-Tainui Br	32	7520.6	182.6	57.5	283.4	2307.3	734.1	5057.8	803.4	16946.7
1992	Komakorau	33	12115.4	22.6	165.1	2.9	32.8	0	4017.9	41.9	16398.6
1992	Mangawara	34	16306.5	338.5	116.3	61	4040	1102.1	13869.2	38.3	35871.8
1992	Waikato at Rangiriri	35	1691.2	141.6	2.6	387.9	902	158.2	2374.9	621.1	6279.4

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1992	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	1495	57.3	0	694.6	317.3	612.1	1433.3	72.4	4681.9
1992	Awaroa (Rotowaro) at Sansons Br	37	303.8	131.4	0	473.3	778.7	2526.4	299.9	4.1	4517.5
1992	Waikato at Mercer Br	38	8004.3	2826.9	1769.2	2812.6	2777.6	9703.4	16138.8	159.2	44191.9
1992	Whangape	39	2034.3	637.8	9.6	1302.7	2181.4	16546.1	8935	17.2	31664.1
1992	Whangamarino at Island Block Rd	40	3085.9	1195.8	230.2	3084.7	1127.2	5.9	5538.3	73.3	14341.3
1992	Whangamarino at Jefferies Rd Br	41	2986.1	1261.6	0	5.6	748.6	1294.5	3384.9	16.9	9698.2
1992	Waerenga	42	108.3	20.9	0	0	142.3	1291.3	396.4	0	1959.2
1992	Matahuru	43	2154.7	227.8	0	12.9	682.1	3626.8	3918.2	9.3	10631.6
1992	Waikare	44	1483.1	25.5	106.7	3902.8	389.6	29.4	4342.2	91.9	10371.1
1992	Opuatia	45	358.5	781	48.8	8.1	605.2	4876.9	380	8.3	7066.7
1992	Mangatangi	46	4117.2	807.1	37	152.8	6656.7	580.6	7086.2	6.4	19444
1992	Waikato at Tuakau Br	47	2370.1	589.8	1602.4	149.3	2606.6	1402	6048.2	83.5	14851.8
1992	Ohaeroa	48	312	33.3	209.3	1.7	158.1	650.4	661.7	4.7	2031.2
1992	Mangatawhiri	49	293.2	346.9	8.7	101.7	5536.8	25.9	479.2	5.3	6797.7
1992	Waikato at Port Waikato	50	7815.3	2535.1	1378.4	918.6	2886.4	2722.6	7704.7	184.3	26145.3
1992	Whakapipi	51	255.6	49.4	1016.2	32.4	268.3	254.8	2259.7	508.5	4644.8
1992	Awaroa (Waiuku)	52	894.3	29.7	111.5	3.9	47.5	18.8	1345.3	54	2504.9
1992	Waipa at Mangaokewa Rd	100	0	1029.8	0	18.1	1133.4	1025.6	0	8.1	3215
1992	Waipa at Otewa	101	708.7	1151.8	0	71.1	14070.6	12465.4	104.2	71.3	28643
1992	Mangaokewa	102	268.2	1089.1	0	51.5	3050.1	12607.2	167.4	183.3	17416.7
1992	Mangarapa	103	836.8	64.7	0	0.6	334	3856.8	348.8	0	5441.7
1992	Mangapu	104	3973	204.2	27.2	95.4	1071.7	8702.7	1735.4	353.2	16162.6
1992	Mangarama	105	561.9	102.4	0	6.4	210.3	4096.8	546.1	2.1	5525.9
1992	Waipa at Otorohanga	106	5964.6	100.1	17.8	32.3	632.3	5913.6	995	220.2	13875.8
1992	Waipa at Pirongia-Ngutunui Rd Br	107	23531.7	404.6	232.3	144.2	4215.2	12276.9	2532.3	236.9	43573.9
1992	Waitomo at Tumutumu Rd	108	29.2	320.8	0	25.3	1411.4	2514.5	7.1	8.4	4316.6

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1992	Waitomo at SH31 Otorohanga	109	653.9	93.2	0	10.8	1084.2	2072.1	463.4	13.4	4391
1992	Moakurarua	110	1560.8	570.3	0	34.1	6112.2	11807.7	478.2	65.2	20628.4
1992	Puniu at Bartons Corner Rd Br	111	9195.7	390.6	231.2	238.5	236.4	10117.9	2139.9	222	22772.1
1992	Puniu at Wharepapa	112	1072.7	255.8	0	4.5	3730.6	10670.2	1092.8	13.5	16840.1
1992	Mangatutu	113	2218	109.8	143.2	29.4	5013.2	3845.4	850.3	56	12265.2
1992	Mangapiko	114	14045.4	203.7	207.9	42.1	1607.4	7605.4	3732.1	624.5	28068.5
1992	Mangaohoi	115	24.1	0	0	0	370.6	35.5	0.5	0.1	430.8
1992	Waipa at SH23 Br Whatawhata	116	14461.5	704.9	209.3	579.3	2986.2	4809.8	7388.4	304.6	31444.1
1992	Mangauika	117	13.1	23.8	0	1.3	812.2	124.9	1.8	0.9	977.9
1992	Kaniwhaniwha	118	1977	38.1	0	7.6	4178	3133.2	905.1	19.3	10258.2
1992	Waipa at Wainaro Rd Br	119	3861.2	961	129.3	465.5	2985.5	3369.6	3348.9	326	15447
1992	Ohote	120	1964.4	38.4	50	49.4	38.6	10.4	1732.8	154.6	4038.6
1992	Firewood	121	9.4	136.8	0	12	1145.1	1995.9	54	18.8	3371.9
1996	Pueto	1	52	16289	67.6	29	1195.2	7.7	2234.8	150.6	20026.2
1996	Waikato at Ohaaki	2	1149.4	10970	777.9	471.6	1316.5	93.3	13042.5	1119.6	28940.3
1996	Waikato at Ohakuri	3	8806.5	16211	78.8	1273.5	4068.1	3531	18962.9	90	53022.1
1996	Torepatutahi	4	6127.3	11250	163.2	30.4	406.8	83.6	3587	66.7	21715.1
1996	Mangakara	5	267.3	206.1	0	0	423.5	18.7	1319	0	2234.6
1996	Waiotapu at Homestead	6	4894.2	10355	106.3	34	1771.3	328	2920	59.9	20468.2
1996	Kawaunui	7	863.2	129.8	2	1	423.1	32.8	680.1	1.6	2133.6
1996	Waiotapu at Campbell	8	455.8	2005.7	0	38.2	698.6	830	2021.4	21.3	6071
1996	Otamakokore	9	2206.7	141.3	0.7	2.7	588.7	131.4	1474.5	26	4572
1996	Whirinaki	10	172.6	34.7	0	0	276.9	284.5	310.4	0	1079.1
1996	Waikato at Whakamaru	11	3072.1	27713	19.6	984.1	1892.5	4483.6	6329.2	126.8	44620.9
1996	Waipapa	12	325.8	3296	31.7	8.6	497.8	3461.5	2425.7	0.7	10047.8
1996	Tahunaatara	13	3014.7	7356.1	0	9.3	3965.2	2116.6	4338.4	8.3	20808.6
1996	Mangaharakeke	14	404.2	4464.1	0	0	142.3	39.7	338.5	26.4	5415.2

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1996	Waikato at Waipapa	15	6068.1	27901	22.4	693.4	18215.5	9885.2	5988.6	587.9	69362.4
1996	Mangakino	16	805	1763	42	54.1	10308.7	2610.9	6592.4	4.5	22180.6
1996	Mangamingi	17	1967	1155.9	53	17.5	10.2	1100.3	178.8	688.9	5171.6
1996	Whakauru	18	1016.4	3405.4	0	5.3	29	532.3	137	177.2	5302.6
1996	Pokaiwhenua	19	8163.2	18910	11	8.9	2075.7	2939.8	515.1	76.3	32699.7
1996	Little Waipa	20	2845.2	4815.7	0	0.7	88.9	2816.7	74.8	4.5	10646.5
1996	Waikato at Karapiro	21	14105.2	7376.7	615	1851.3	5963.1	20570.5	3081	235.7	53798.5
1996	Karapiro	22	1507.4	98.7	14.7	32.5	408.8	4041.9	633.6	0.1	6737.7
1996	Waikato at Narrows	23	4994.5	203.9	153.2	246.3	541.5	642	5171.1	994.7	12947.2
1996	Mangawhero	24	2522.7	12.8	239.1	0	172	400	1960.2	40.6	5347.4
1996	Waikato at Bridge St Br	25	2423.6	32.6	400.2	103.8	185	25.1	1165.3	721.1	5056.7
1996	Mangaonua	26	3976.1	61.4	128.4	2.3	723.4	1397.3	1777.5	29	8095.4
1996	Mangakotukutuku	27	1408.3	14.4	31.5	4.8	42.3	5.7	706.2	494.1	2707.3
1996	Mangaone	28	3325.7	104.5	385.7	11.5	130	5.3	2594.2	203.2	6760.1
1996	Waikato at Horotiu Br	29	1163.6	14.7	59.8	133	52.9	3.1	1158.5	2806.8	5392.4
1996	Waitawhiriwhiri	30	426.3	16.2	0	52.6	15.7	0.1	586.5	1125.4	2222.8
1996	Kirikiriroa	31	342	0	27.3	0.3	41.8	0	393.9	428.2	1233.5
1996	Waikato at Huntly-Tainui Br	32	7008	219.1	69	321.7	2570.6	704.7	5363.6	623.4	16880.1
1996	Komakorau	33	12078.2	27.1	198.1	3.5	39.4	0	4002.2	50.3	16398.8
1996	Mangawara	34	16165.1	406.2	139.5	42.1	4472.5	927.4	13672	45.9	35870.7
1996	Waikato at Rangiriri	35	1372.5	169.9	3.1	326.2	1082.4	88.4	2646.3	491	6179.8
1996	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	1381	68.8	0	635.6	380.7	635.1	1501.9	86.2	4689.3
1996	Awaroa (Rotowaro) at Sansons Br	37	296.7	157.7	0	491	880.4	2385.1	294.6	4.9	4510.4
1996	Waikato at Mercer Br	38	7665.3	3371.8	2018.5	2120.7	2758.4	9578.3	16356	181.7	44050.7
1996	Whangape	39	1985.5	765.3	11.5	1225.7	2617.7	16087.6	8989.8	20.6	31703.7
1996	Whangamarino at Island Block Rd	40	3031.5	1434.9	276.2	2881.4	1183.7	5.8	5445.6	88	14347.1

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1996	Whangamarino at Jefferies Rd Br	41	3053.9	1513.9	0	6.7	619.9	1204	3279.4	20.3	9698.1
1996	Waerenga	42	122.1	25.1	0	0	170.7	1264.2	377.1	0	1959.2
1996	Matahuru	43	2040.2	273.3	0	13.9	716	3620.1	3957.3	11.1	10631.9
1996	Waikare	44	1102.7	30.6	128	3967.7	456.4	22.6	4565.6	110.3	10383.9
1996	Opuatia	45	307.4	937.2	58.5	2.1	726.2	4619.9	405.4	10	7066.7
1996	Mangatangi	46	4151	940.2	42.6	158.8	6695.2	472.9	6977.2	6.7	19444.6
1996	Waikato at Tuakau Br	47	2292	610.3	1716.2	154.8	2647.5	1365.8	5998.8	86.7	14872.1
1996	Ohaeroa	48	198.9	40	251.2	2	189.7	645.5	698.5	5.6	2031.4
1996	Mangatawhiri	49	293.2	415.8	8.7	122	5438.4	27.1	484.8	5.6	6795.6
1996	Waikato at Port Waikato	50	7538.5	2836.3	1425.7	909.5	3128.8	2304.3	7726.6	191.8	26061.5
1996	Whakapipi	51	255.6	49.4	1021	32.5	250.4	254.8	2260.6	520.5	4644.8
1996	Awaroa (Waiuku)	52	894.3	29.7	111.5	4.3	46.4	18.8	1345.6	54.3	2504.9
1996	Waipa at Mangaokewa Rd	100	0	1235.8	0	21.7	948.5	998.9	0	9.7	3214.6
1996	Waipa at Otewa	101	657.5	1382.1	0	85.3	14238.6	12103.8	93.2	85.6	28646.1
1996	Mangaokewa	102	305.1	1306.9	0	61.8	3010.4	12450.7	174.8	107.2	17416.9
1996	Mangarapa	103	794.3	77.6	0	0.7	400.8	3837.3	331.1	0	5441.8
1996	Mangapu	104	3864.4	245	32.6	114.5	1272.7	8503.7	1809.7	320.4	16163
1996	Mangarama	105	593.1	122.9	0	7.7	246.8	4045.6	507.5	2.5	5526.1
1996	Waipa at Otorohanga	106	5748.2	120.1	21.3	38.7	733.6	5933.3	1078.9	200.3	13874.4
1996	Waipa at Pirongia-Ngutunui Rd Br	107	22917.8	485.5	278.8	168.9	4433.9	12401.7	2641.2	243	43570.8
1996	Waitomo at Tumutumu Rd	108	5.1	384.9	0	2.8	1593.9	2311.3	8.5	10.1	4316.6
1996	Waitomo at SH31 Otorohanga	109	513.3	111.8	0	12.2	1116.5	2139	482.6	15.4	4390.8
1996	Moakurarua	110	1578.8	684.4	0	14.6	6706.6	11046.9	519.1	78.2	20628.6
1996	Puniu at Bartons Corner Rd Br	111	9360.8	468.7	277.4	55.2	260.1	9840.5	2245.1	266.1	22773.9
1996	Puniu at Wharepapa	112	1110.3	307	0	5.4	4027.8	10295.6	1078.5	16.2	16840.8
1996	Mangatutu	113	2217.9	131.8	171.8	2.4	5124	3639.7	911.9	67.2	12266.7
1996	Mangapiko	114	13943.1	244.4	249.5	15.7	1766.2	7409.3	3790.9	649.5	28068.6

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
1996	Mangaohoi	115	28.9	0	0	0	371.3	29.9	0.6	0.1	430.8
1996	Waipa at SH23 Br Whatawhata	116	13957.4	845.9	251.2	319	3190.3	4788.1	7732.8	365.5	31450.2
1996	Mangauika	117	12.2	28.5	0	1.6	835.8	96.9	2.1	1.1	978.2
1996	Kaniwhaniwha	118	1889.3	45.7	0	0.9	4319.7	2981.2	998.3	23.1	10258.2
1996	Waipa at Wainaro Rd Br	119	3675	1153.2	155.2	259.6	3311.9	3186.3	3461	249.3	15451.5
1996	Ohote	120	1673.9	46.1	60	46.9	46.3	11.8	1994	159.1	4038.1
1996	Firewood	121	6.7	164.1	0	14.4	1228.4	1876.2	62.9	19.2	3371.9
2002	Pueto	1	50.5	15900	33	565.1	1152.7	0.1	2173.2	150.1	20024.4
2002	Waikato at Ohaaki	2	2329.3	11540	309.3	556.4	1251	91.8	11914.9	986.6	28979.6
2002	Waikato at Ohakuri	3	11449.3	17941	51.1	1986.3	4358.3	2834.6	14347	89.2	53056.7
2002	Torepatutahi	4	6543.9	11309	93.2	70.3	385.4	51.3	3195.3	66.6	21715.1
2002	Mangakara	5	308.6	307.5	0	0	427.9	18.3	1172.6	0	2234.9
2002	Waiotapu at Homestead	6	5146.9	10401	84.5	34	1772.6	327.6	2641.4	60.1	20468.2
2002	Kawaunui	7	987.8	168.4	2	1	418.5	30.6	523.7	1.6	2133.6
2002	Waiotapu at Campbell	8	514.8	2707.7	0	50.9	692.6	652.4	1433.8	21.3	6073.5
2002	Otamakokore	9	2241.3	174.5	0	208.5	576.9	127.3	1217.9	25.8	4572.2
2002	Whirinaki	10	173.2	62.4	0	0	249.5	283.5	310.4	0	1079
2002	Waikato at Whakamaru	11	5259	28030	0	1542.7	1852.3	2820.7	5007.9	127	44639.7
2002	Waipapa	12	1561	3189.9	0	282.7	474	2423	2113.5	3.9	10048
2002	Tahunaatara	13	3227.4	7424	0	232.2	3945	1795.5	4176.9	8.3	20809.3
2002	Mangaharakeke	14	435.2	4533.7	0	0	196.8	40	183.4	26.3	5415.4
2002	Waikato at Waipapa	15	8665.5	29416	0	2193.5	17653.4	6776.8	4074.6	587.1	69367.3
2002	Mangakino	16	2841.7	1729.1	0	570.8	10297.8	2054.3	4682.5	4.5	22180.7
2002	Mangamingi	17	2354.3	1165.7	0	21.5	84.5	684	173.6	688.6	5172.2
2002	Whakauru	18	1138.7	3429.6	0	7.9	5.7	405.8	137.8	176.9	5302.4
2002	Pokaiwhenua	19	9648.6	17952	6.3	953.3	2105.4	1526.3	432.9	76.3	32701.1
2002	Little Waipa	20	4305.8	4911.8	0	0.7	94.9	1266.4	63.8	4.5	10647.9

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
2002	Waikato at Karapiro	21	20549.5	7627.3	250.1	2513.8	6147.5	13799.1	2729	262.3	53878.6
2002	Karapiro	22	2256	257	21.5	37.2	411.6	3161.5	592.8	0.1	6737.7
2002	Waikato at Narrows	23	4963	378.6	269.8	266.4	687.2	338.3	4970.2	1081.4	12954.9
2002	Mangawhero	24	2698.2	14.2	376.3	0	236	208	1771.7	42.9	5347.3
2002	Waikato at Bridge St Br	25	1187.7	31.7	229.6	156.2	271.3	15.1	2406.8	762.2	5060.6
2002	Mangaonua	26	3421.8	70.8	81.5	2.3	920.9	1196.4	2347.7	54	8095.4
2002	Mangakotukutuku	27	1533.7	9.8	19.5	13.4	44.6	3.3	581.2	501.7	2707.2
2002	Mangaone	28	1897.9	105.5	229.3	7.6	286.1	5.3	3893.3	335.3	6760.3
2002	Waikato at Horotiu Br	29	733.8	19.4	22.7	196.5	144	3.1	1257.2	3016.2	5392.9
2002	Waitawhiriwhiri	30	426.3	9.5	0	68.9	14.2	0	573.5	1130.2	2222.6
2002	Kirikiriroa	31	210.8	0	3.9	3.1	46.2	0	294.1	675.2	1233.3
2002	Waikato at Huntly-Tainui Br	32	6033.5	232.5	48.8	338.7	2876.8	680.6	6008.2	656.7	16875.8
2002	Komakorau	33	10895.7	31.6	177.8	3.5	536.7	0	4692.3	61.2	16398.8
2002	Mangawara	34	17938.4	440	0	42.5	5720.8	700.9	10983.6	45.9	35872.1
2002	Waikato at Rangiriri	35	1267.5	167.5	2	393	1152.7	97	2646.2	493.8	6219.7
2002	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	1381	72.5	35	655.4	384.2	624.8	1465	86.6	4704.5
2002	Awaroa (Rotowaro) at Sansons Br	37	296.1	281.4	0	579.7	987	2123.2	285.5	4.9	4557.8
2002	Waikato at Mercer Br	38	8100.5	3250.7	866.1	2780.8	3225.9	9355.2	16383.2	191.7	44154.1
2002	Whangape	39	2040.7	1191.8	7	1581.4	2673.4	15556.9	8656.2	21.1	31728.5
2002	Whangamarino at Island Block Rd	40	2611.5	948.7	122.9	3738.9	1373	5.8	5455.6	92.4	14348.8
2002	Whangamarino at Jefferies Rd Br	41	3060.2	1609.5	131.3	9.1	846	1130.7	2889.9	21.4	9698.1
2002	Waerenga	42	122.7	353.7	0	0	185	1011.7	286.1	0	1959.2
2002	Matahuru	43	2042.2	325.7	0	150.9	737.2	3473.7	3891.2	11.1	10632
2002	Waikare	44	810.3	122.6	0.9	3978.7	651.3	22.6	4695.6	109.4	10391.4
2002	Opuatia	45	353.6	1429.5	30	2.1	708.5	4122	410.7	10.3	7066.7
2002	Mangatangi	46	4229.4	994.5	31.8	161.7	6880.3	453.7	6686.8	6.7	19444.9

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
2002	Waikato at Tuakau Br	47	2435.6	518.7	646.5	1067.3	2603.5	1211.1	6310.2	82.8	14875.7
2002	Ohaeroa	48	220.9	84.5	54.4	1.6	172	621.2	870.8	5.5	2030.9
2002	Mangatawhiri	49	301.4	417.8	0	138.6	5428.5	25.3	479.2	4.8	6795.6
2002	Waikato at Port Waikato	50	7636	2289.9	600.7	2564.4	3319.6	1782.1	7664.8	214.9	26072.4
2002	Whakapipi	51	260	54.3	423.7	42.8	259.4	272.3	2814.5	517.7	4644.7
2002	Awaroa (Waiuku)	52	896.6	29.8	42.6	6.5	49	17.8	1334.3	128.5	2505.1
2002	Waipa at Mangaokewa Rd	100	0	1221.5	0	35.4	946.8	995.5	0	15.4	3214.6
2002	Waipa at Otewa	101	2145.9	1502.9	0	350.5	14183.3	10311.2	67	86.6	28647.4
2002	Mangaokewa	102	708	1276.8	0	327.6	3042.4	11802.8	152.1	107.2	17416.9
2002	Mangarapa	103	1604.8	127.6	0	0.7	454.8	2950.4	303.7	0	5442
2002	Mangapu	104	5043.1	492.3	14.6	181.9	1319.3	7005	1780.7	326.9	16163.8
2002	Mangarama	105	974.5	140.6	0	7.7	272	3636.6	492.1	2.6	5526.1
2002	Waipa at Otorohanga	106	7478.7	186.5	5.9	83.3	783.7	4084	1049.1	204.5	13875.7
2002	Waipa at Pirongia-Ngutunui Rd Br	107	27243.3	675.4	245.8	260.1	4712.7	7649.3	2539.7	242.2	43568.5
2002	Waitomo at Tumutumu Rd	108	5.1	530.1	0	3.7	1539.5	2219.6	8.5	10.1	4316.6
2002	Waitomo at SH31 Otorohanga	109	1156.2	325.7	0	12.7	1142.6	1292.5	444.9	16.4	4391
2002	Moakurarua	110	3449.4	1016.8	49.3	99.1	6714.1	8714.8	505.3	80	20628.8
2002	Puniu at Bartons Corner Rd Br	111	11412.1	646.6	209.5	63.3	334.3	7632.1	2207.2	269.7	22774.8
2002	Puniu at Wharepapa	112	2499.8	351.6	0	5.4	4015.9	9104.5	847.9	16.2	16841.3
2002	Mangatutu	113	3350.9	199.8	74.5	178.8	5206	2345.9	844.2	67.2	12267.3
2002	Mangapiko	114	14750.3	603.7	436.2	21.6	1845.8	6103.5	3611.7	696	28068.8
2002	Mangaohoi	115	47	0	0	0	371.5	11.6	0.6	0.1	430.8
2002	Waipa at SH23 Br Whatawhata	116	14402.7	927.2	328.3	319.9	3907.9	3986.3	7153.2	427.2	31452.7
2002	Mangauika	117	37.9	28.5	0	15.4	837.1	56.1	2.1	1.1	978.2
2002	Kaniwhaniwha	118	2575.9	79.8	1	0.9	4424.4	2200.1	952.4	23.9	10258.4
2002	Waipa at Wainaro Rd Br	119	2852.3	1274.8	26	264.3	3845.4	2798	4075.3	293.8	15429.9
2002	Ohote	120	1441.1	59.8	23	46.7	224.1	7.7	2019.8	215.9	4038.1

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
2002	Firewood	121	2.1	322.3	0	15.1	1242.7	1703.2	67.3	19.2	3371.9
2008	Pueto	1	1498.1	14181	66.8	29.7	1119.2	80	2891.6	159.9	20026.6
2008	Waikato at Ohaaki	2	4746.7	9747	775.6	467.5	1397.2	94.3	10517.6	1206.4	28952.3
2008	Waikato at Ohakuri	3	12453.7	15469	79	1276.2	3984	2883.2	16796.6	89.5	53031.5
2008	Torepatutahi	4	6613.8	11173	163.6	30.4	406.3	48	3212.8	66.8	21715
2008	Mangakara	5	308.6	307.6	0	0	426.9	18.3	1173.5	0	2234.9
2008	Waiotapu at Homestead	6	5122.2	10241	106.3	34	1767	327.7	2809.5	60.2	20468.1
2008	Kawaunui	7	981	191	2	1	362.4	34.6	560	1.6	2133.6
2008	Waiotapu at Campbell	8	515.8	2713.7	0	38.7	696.3	653.4	1432.9	21.3	6072.1
2008	Otamakokore	9	2354.6	195	0.7	2.6	588.7	127.5	1276.9	26	4572
2008	Whirinaki	10	174.6	62.7	0	0	249.5	283.5	308.7	0	1079
2008	Waikato at Whakamaru	11	5834.4	26360	20.4	994	1899.6	3192.6	6194.7	129	44624.9
2008	Waipapa	12	1695	2621.9	32.1	8.6	553.9	2524	2589.4	23.4	10048.3
2008	Tahunaatara	13	3475.7	6755.8	0	9.6	3824	1996.9	4738.3	8.3	20808.6
2008	Mangaharakeke	14	435.2	4446	0	0	83.5	98.4	325.2	27	5415.3
2008	Waikato at Waipapa	15	9483.4	27610	22.4	691.7	18093.8	8741.6	4132.3	587.7	69362.9
2008	Mangakino	16	3001.5	1803.8	42	56.5	10331.1	2067.4	4873.8	4.5	22180.6
2008	Mangamingi	17	2352.4	1121.1	53	17.5	9.9	756.9	172.3	688.9	5172
2008	Whakauru	18	1139.5	2174.9	0	2.1	5.4	1163.9	639.6	177	5302.4
2008	Pokaiwhenua	19	9592.5	14241	249.9	9.4	2249.4	5128.2	1142.4	84.9	32697.5
2008	Little Waipa	20	4251.9	2200.1	0	0.7	84.9	4042.1	63.6	3.4	10646.7
2008	Waikato at Karapiro	21	17764.8	7505.4	739.6	1856.3	6075.6	16826.9	2778.3	266.3	53813.2
2008	Karapiro	22	1609.5	260.9	68.7	37.2	421.5	3790.8	549.1	0.1	6737.8
2008	Waikato at Narrows	23	5045.6	301.9	152.1	263.9	559.8	528.1	5001.2	1098.9	12951.5
2008	Mangawhero	24	2463	14.2	321.3	0	180.4	381.6	1939.7	47.2	5347.4
2008	Waikato at Bridge St Br	25	2532.7	31.4	494	103.5	183.7	20.5	900.5	793.8	5060.1
2008	Mangaonua	26	4038.8	69.1	127.9	2.3	722	1378.4	1696	61	8095.5

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
2008	Mangakotukutuku	27	1629.3	5.8	32.3	4.8	44.7	3.2	476.7	510.4	2707.2
2008	Mangaone	28	3269	105.4	450.5	13.5	130.9	5.2	2302.9	482.6	6760
2008	Waikato at Horotiu Br	29	1342.8	16.4	46.8	145.4	52.9	0.5	529.4	3259.8	5394
2008	Waitawhiriwhiri	30	427.7	16.2	0	52.6	15.7	0	561.2	1149.2	2222.6
2008	Kirikiriroa	31	380.4	0	4.5	1.1	47.7	0	50.6	749	1233.3
2008	Waikato at Huntly-Tainui Br	32	7277.2	228.7	210.9	330.5	2347.1	832.4	4939.7	715.4	16881.9
2008	Komakorau	33	12366.9	29	224.6	3.5	38	0	3664.3	72.6	16398.9
2008	Mangawara	34	15933.8	481.8	181.2	44.3	4480.2	915.2	13786.3	47.8	35870.6
2008	Waikato at Rangiriri	35	1403.9	169.9	3.1	324.8	978.1	135.6	2667.3	497.2	6179.9
2008	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	1382	74.8	0	635.9	374.2	636.8	1498.2	87.5	4689.4
2008	Awaroa (Rotowaro) at Sansons Br	37	286.2	273.5	0	737.9	799.9	2119.3	288.9	4.9	4510.6
2008	Waikato at Mercer Br	38	6138.7	3575	2187.6	2185.1	2744.9	9897.5	17111.2	215.3	44055.3
2008	Whangape	39	1660	1192.9	39.7	1228.2	2570.3	15934.4	9058.2	21.1	31704.8
2008	Whangamarino at Island Block Rd	40	3187.8	1530.6	310.9	2888.1	1225.5	5.8	5096.9	102.3	14347.9
2008	Whangamarino at Jefferies Rd Br	41	3058.2	1609.4	4.5	6.7	623.4	1133.3	3241.1	21.3	9697.9
2008	Waerenga	42	122.5	353.7	0	0	172.9	1012.6	297.6	0	1959.3
2008	Matahuru	43	2038.3	334.4	0	13.9	699.7	3605.5	3929	11.1	10631.9
2008	Waikare	44	1162.5	114.3	155.8	3972.4	450.7	23.8	4378.4	126.6	10384.5
2008	Opuatia	45	8.6	1429.9	178.3	2.1	661	4284	492.6	10.3	7066.8
2008	Mangatangi	46	3657.5	995	43.6	161.5	6665.7	516.3	7397.4	6.7	19443.7
2008	Waikato at Tuakau Br	47	1635.9	762.7	1747.5	165.5	2675.3	1372.2	6426.3	86.6	14872
2008	Ohaeroa	48	35.5	79.5	278.1	2	187.5	638.3	805.1	5.2	2031.2
2008	Mangatawhiri	49	187	417.4	8.7	122	5443.6	37.2	574	5.6	6795.5
2008	Waikato at Port Waikato	50	5369.4	3423.9	1559.8	920.1	3122.7	2265.5	9174.1	222.5	26058
2008	Whakapipi	51	214.6	50.5	1015.6	37.6	252	258.6	2232.8	583.3	4645
2008	Awaroa (Waiuku)	52	579.3	29.4	111.6	4.4	45.6	116.1	1489.4	128.9	2504.7

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
2008	Waipa at Mangaokewa Rd	100	0	1227.4	0	21.7	948.5	1001.9	0	15.1	3214.6
2008	Waipa at Otewa	101	1465.8	1536.9	0	85.7	14306	11097.6	68.8	86.7	28647.5
2008	Mangaokewa	102	459.6	1371	0	61.7	3025	12219.6	167.8	112.2	17416.9
2008	Mangarapa	103	1130.9	139.7	0	0.7	452.2	3399.2	319.2	0	5441.9
2008	Mangapu	104	4378.3	472.6	32.6	114.8	1265.3	7775.5	1799.2	325.8	16164.1
2008	Mangarama	105	716.4	140.7	0	7.7	270.1	3893.2	495.4	2.5	5526
2008	Waipa at Otorohanga	106	6844.9	179.5	21.3	38.7	779.3	4738.6	1064.9	207.4	13874.6
2008	Waipa at Pirongia-Ngutunui Rd Br	107	25880.5	680.8	278.5	171	4462.2	9238.8	2607.5	252.6	43571.9
2008	Waitomo at Tumutumu Rd	108	5.1	521.7	0	3.7	1539.7	2227.9	8.5	10.1	4316.7
2008	Waitomo at SH31 Otorohanga	109	808.2	322.8	0	12.2	1103.3	1657.2	471	16.4	4391.1
2008	Moakurarua	110	2722.8	1332	2	16.5	6741.2	9223.9	508	82.3	20628.7
2008	Puniu at Bartons Corner Rd Br	111	10096	577.1	359.2	59.6	286.6	8888.7	2219	288	22774.2
2008	Puniu at Wharepapa	112	1529.8	352.7	0	5.8	4018	9909.9	1008.4	16.2	16840.8
2008	Mangatutu	113	2934.6	253.1	282.7	3.8	5170.2	2719	837	67	12267.4
2008	Mangapiko	114	14025.4	591.4	252.2	15.7	1728.6	6947.1	3788.1	720.3	28068.8
2008	Mangaohoi	115	32.4	0	0	0	371.3	26.4	0.6	0.1	430.8
2008	Waipa at SH23 Br Whatawhata	116	14167.7	921.8	249.4	319	3168.9	4534.5	7622.9	467	31451.2
2008	Mangauika	117	31.5	28.5	0	1.6	835.8	77.6	2.1	1.1	978.2
2008	Kaniwhaniwha	118	1933	75.3	6.5	0.9	4394.9	2833.7	990.1	23.9	10258.3
2008	Waipa at Wainaro Rd Br	119	3995.3	1422.4	155.6	261.1	3374.5	2876.3	3019.5	347	15451.7
2008	Ohote	120	1950.6	53.1	59.7	46.9	47.1	11.7	1639.9	229.4	4038.4
2008	Firewood	121	6.7	372.6	0	14.4	1126.1	1766	62.9	23.2	3371.9
2012	Pueto	1	202.6	10173	11.4	84.4	1266.2	195.4	7954	140	20026.6
2012	Waikato at Ohaaki	2	2729.8	8006.2	130.5	1393.4	1974	40.6	12795.2	1938.1	29007.8
2012	Waikato at Ohakuri	3	11549.6	10385	35.5	1883.3	4445.5	1303.8	22986.5	549.7	53139.3
2012	Torepatutahi	4	5217.2	11270	99.8	40.5	619.7	30	4248.9	188.6	21714.8
2012	Mangakara	5	302.5	310.1	0	1	491.5	13.8	1095.2	20.7	2234.8

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
2012	Waiotapu at Homestead	6	5724	10356	20.9	56.2	1892.5	64.1	2160.1	203.3	20477.2
2012	Kawaunui	7	783	199	0	3.1	439.7	0	703.7	5.6	2134.1
2012	Waiotapu at Campbell	8	392.6	2878.6	0	54.6	751.9	225.2	1725.6	49.4	6077.9
2012	Otamakokore	9	1815.9	135.2	0	82.7	708.5	108	1665.6	56.8	4572.7
2012	Whirinaki	10	168.7	45.2	0	0	247.9	173.6	440.5	3.7	1079.6
2012	Waikato at Whakamaru	11	6421.5	24690	20.1	1250.2	2336.9	1493.7	8097.7	355.6	44665.4
2012	Waipapa	12	2055.7	2579.7	24.9	6.1	517	1085.4	3698	82.5	10049.3
2012	Tahunaatara	13	4679	5937.7	0	207.7	4259	248.6	5350.8	132.5	20815.3
2012	Mangaharakeke	14	570.5	4323.7	0	0	92.5	0	370.6	58	5415.3
2012	Waikato at Waipapa	15	10152.4	26890	13	1031.4	18747.9	3031.2	8377.8	1128.4	69372.4
2012	Mangakino	16	2524.4	1593.2	28	147.3	10636.8	1196.2	5940.4	115.9	22182.2
2012	Mangamingi	17	2253.4	1106.5	0	233.1	16.9	74.6	752.5	737.9	5174.9
2012	Whakauru	18	1794.9	1757.2	0	66.2	18.9	54	1262.6	348.6	5302.4
2012	Pokaiwhenua	19	10594.3	12313	161	111.8	2422.3	585.8	6153	359.8	32701.1
2012	Little Waipa	20	6392.4	1283.5	0	30	209.8	844.8	1770.9	117.5	10648.9
2012	Waikato at Karapiro	21	19713.2	6549.6	322.7	2630.5	6711	8590.5	8680.7	770.4	53968.6
2012	Karapiro	22	1617	277	36	102	414.6	2742.3	1484.1	68.4	6741.4
2012	Waikato at Narrows	23	4969.4	172.7	123.7	963.1	747	389.4	4018.6	1602.7	12986.6
2012	Mangawhero	24	2809	10	46	137.7	186.1	354.8	1660.4	143.3	5347.3
2012	Waikato at Bridge St Br	25	1525.8	10.1	200.2	384.6	220.1	1	1731.8	998.8	5072.4
2012	Mangaonua	26	3223.4	55.1	90.3	496.3	718.5	638.6	2711.1	162.5	8095.8
2012	Mangakotukutuku	27	1455.5	5.8	1	111.4	51	0	581.3	501.8	2707.8
2012	Mangaone	28	2263.9	38.9	113.2	610.9	215.7	0	2303	1214.5	6760.1
2012	Waikato at Horotiu Br	29	925.1	9.4	2	204.9	58	0	422.2	3783.5	5405.1
2012	Waitawhiriwhiri	30	574.4	15.6	0	61.1	23	0	351.5	1197.1	2222.7
2012	Kirikiriroa	31	259.1	0	5	31.3	57.4	0	80.4	800.2	1233.4
2012	Waikato at Huntly-Tainui Br	32	8748.8	135.9	77.5	1218.2	2626.6	698.5	2418.9	1397.9	17322.3

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
2012	Komakorau	33	13183.2	26.8	23	239.6	80	0	2611	235.2	16398.8
2012	Mangawara	34	18818	458.5	85	151	4625.5	629.1	10716.3	400.1	35883.5
2012	Waikato at Rangiriri	35	1874.6	119.8	0	1033.8	1131.3	110.8	1985.1	597.4	6852.8
2012	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	999.7	35.6	0	832.2	486.5	429.8	1833.7	112	4729.5
2012	Awaroa (Rotowaro) at Sansons Br	37	257	770.3	0	651.1	712.4	1701.3	398.6	70.1	4560.8
2012	Waikato at Mercer Br	38	8398.1	2430.9	976.9	4267	4604	7797.4	15542.3	1151.6	45168.2
2012	Whangape	39	4062.9	1083	22	1411.3	3082.7	13677.1	8044.5	383.1	31766.6
2012	Whangamarino at Island Block Rd	40	2384.2	917.5	204.2	3219.7	2038.4	4	5147.9	448.7	14364.6
2012	Whangamarino at Jefferies Rd Br	41	3639.7	1581.1	29.8	65.9	712.2	1015.8	2507	149.8	9701.3
2012	Waerenga	42	119.1	366.9	0	1	189	970.9	295.9	16.4	1959.2
2012	Matahuru	43	2151.9	315.7	0	33.6	1499.1	2589	3884.6	163.4	10637.3
2012	Waikare	44	2270.5	109.7	72	4260.1	607.7	24.1	2757.1	316.8	10418
2012	Opuatia	45	256.1	1449.9	93.8	68	608.8	3975.5	531.3	83.6	7067
2012	Mangatangi	46	4405.1	1099.8	6	282.2	6733.8	322	6434.7	168.2	19451.8
2012	Waikato at Tuakau Br	47	1422.3	349.9	684.4	1004.7	5854.7	337.9	4834.1	688	15176
2012	Ohaeroa	48	358	60.4	123.1	20.5	281.1	199.5	942.8	47.3	2032.7
2012	Mangatawhiri	49	2.1	419.6	5.6	125	5859	18	358.2	7.3	6794.8
2012	Waikato at Port Waikato	50	7903.1	2065.4	950.3	3720.6	5003.9	1050.7	6572.3	877.7	28144
2012	Whakapipi	51	163.8	39.8	434.6	430.6	213.5	78.3	1737.3	1548.2	4646.1
2012	Awaroa (Waiuku)	52	552.4	25.6	26.8	111.6	40.2	13.3	1488.4	247.9	2506.2
2012	Waipa at Mangaokewa Rd	100	0	1208.1	0	21	1017.6	944.8	5	20.2	3216.7
2012	Waipa at Otewa	101	2687.9	1524.3	0	106.7	15081.9	7370.8	1601.8	292.1	28665.5
2012	Mangaokewa	102	1160.2	1483.6	0	63.6	3641.4	10136.2	585.3	346	17416.3
2012	Mangarapa	103	1156.7	123	0	9.2	569.6	2245.1	1278.1	61.3	5443
2012	Mangapu	104	4123.9	419.9	5	297.5	1325.4	5006.3	4335.7	656.2	16169.9
2012	Mangarama	105	1062.4	91.4	0	11	381.8	3110.5	821.7	49.5	5528.3

Year	Catchment	Id	Land area per land use per sub-catchment (ha)								Total area/ decade (ha)
			Dairy	Forestry	Horticulture	Misc.	Native Forest & Scrub	Sheep and Beef Hill and High	Sheep and Beef Intensive	Urban	
2012	Waipa at Otorohanga	106	7768.7	173	12	61	913	2703.8	1811.2	446.2	13888.9
2012	Waipa at Pirongia-Ngutunui Rd Br	107	26620.4	547.2	156	357.8	5019.8	3677.6	6288	940.3	43607.1
2012	Waitomo at Tumutumu Rd	108	279.5	544.9	0	5.5	1730.7	1365.8	307.5	83.7	4317.6
2012	Waitomo at SH31 Otorohanga	109	558.9	312.9	0	42	1259.9	1085.7	1056	77.5	4392.9
2012	Moakurarua	110	2994.5	1440.6	0	66	7281.3	6949	1504.7	394	20630.1
2012	Puniu at Bartons Corner Rd Br	111	14125.9	526.5	303.2	142.9	316.2	2775.2	4088.5	507	22785.4
2012	Puniu at Wharepapa	112	3844.1	326.7	0	15	4218.2	5916.7	2325.7	206.3	16852.7
2012	Mangatutu	113	3363.9	243.5	193.5	64	5443.1	1395.5	1369.1	196.6	12269.2
2012	Mangapiko	114	16029.1	651.3	33.6	292.9	1815.1	3593.8	4499.8	1153.8	28069.4
2012	Mangaohoi	115	10.5	0	0	0	373.7	36.1	8.4	2.1	430.8
2012	Waipa at SH23 Br Whatawhata	116	17189.5	745.2	122.1	879.3	3450	2232	5686	1201.9	31506
2012	Mangauika	117	57.9	28.8	0	2.1	854.5	0	27.9	6.9	978.1
2012	Kaniwhaniwha	118	2301.7	70.2	5.9	95.3	4702.8	1562.2	1394.4	126.8	10259.3
2012	Waipa at Wainaro Rd Br	119	3528.3	1359.8	106.2	472.4	3670.1	2023.4	3515.4	808.7	15484.3
2012	Ohote	120	1333	18	12.3	222.5	75.7	2.7	1986.1	390.5	4040.8
2012	Firewood	121	180	399.8	0	37.2	1031	1634.5	37.5	52.2	3372.2

Table A-2: Land use across the Wai Ora/Healthy River project area at discrete time steps. Data for 1982 and 1992 derived from linear interpolation from other data.

Year	Area of land associated with each land use in the Healthy Rivers/Wai Ora catchments (ha)									
	Dairy	Forestry	Hort	Misc.	Native Forest and Scrub	S&B Hill	S&B Intensive	Urban	Pasture	Total area
1972	274836.4	145154.1	3819.1	110139.7	115360.3	263455.7	171125.6	14632.4	709417.7	1098523
1982	263203.3	168099.3	7398.1	72903.8	131013.2	248923.9	191043.5	15127.7	703170.7	1097711.2
1992	251570.5	191045.8	10977.3	35668	146666.2	234392.2	210962.2	15622.6	696924.9	1096900
1996	246958.8	200223.7	12408.2	20772.9	152926.5	228578.7	218972.7	15819.8	694510.2	1096661
2002	285176.4	207654.6	6719.2	33074.9	159341.9	182839.7	205429.3	16855.8	673445.4	1097092.4
2008	279355.5	191671.7	14012.7	21200.5	152541	210002.4	209886.9	18050.6	699244.8	1096722.4
2012	308007.8	169477.8	6250	38829.4	172661	124896.1	247150.5	34966.3	680054.4	1102239.2

Table A-3: Proportion of land across the Wai Ora/Healthy River project area associated with each land use at discrete time steps. Data for 1982 and 1992 derived from linear interpolation from other data.

Year	Proportion of land associated with each land use in the Healthy Rivers/Wai Ora catchments (%)								
	Dairy	Forestry	Hort	Misc.	Native Forest and Scrub	S&B Hill	S&B Intensive	Urban	Pasture
1972	25	13.2	0.3	10	10.5	24	15.6	1.3	64.6
1982*	24	15.3	0.7	6.6	11.9	22.7	17.4	1.4	64.1
1992*	22.9	17.4	1	3.3	13.4	21.4	19.2	1.4	63.5
1996	22.5	18.3	1.1	1.9	13.9	20.8	20	1.4	63.3
2002	26	18.9	0.6	3	14.5	16.7	18.7	1.5	61.4
2008	25.5	17.5	1.3	1.9	13.9	19.1	19.1	1.6	63.8
2012	27.9	15.4	0.6	3.5	15.7	11.3	22.4	3.2	61.7

Table A-4: Proportion of selected pastoral land uses of estimated total pasture land use in the Healthy Rivers/Wai Ora catchments. Data for 1982 and 1992 derived from linear interpolation from other data.

Year	Proportion of land use of total pasture land use (%)		
	Dairy	S&B Hill	S&B Intensive
1972	38.7	37.2	24.1
1982*	37.4	35.4	27.1
1992*	36.1	33.7	30.2
1996	35.5	32.9	31.6
2002	42.3	27.2	30.5
2008	40	29.9	29.9
2012	45.2	18.3	36.3

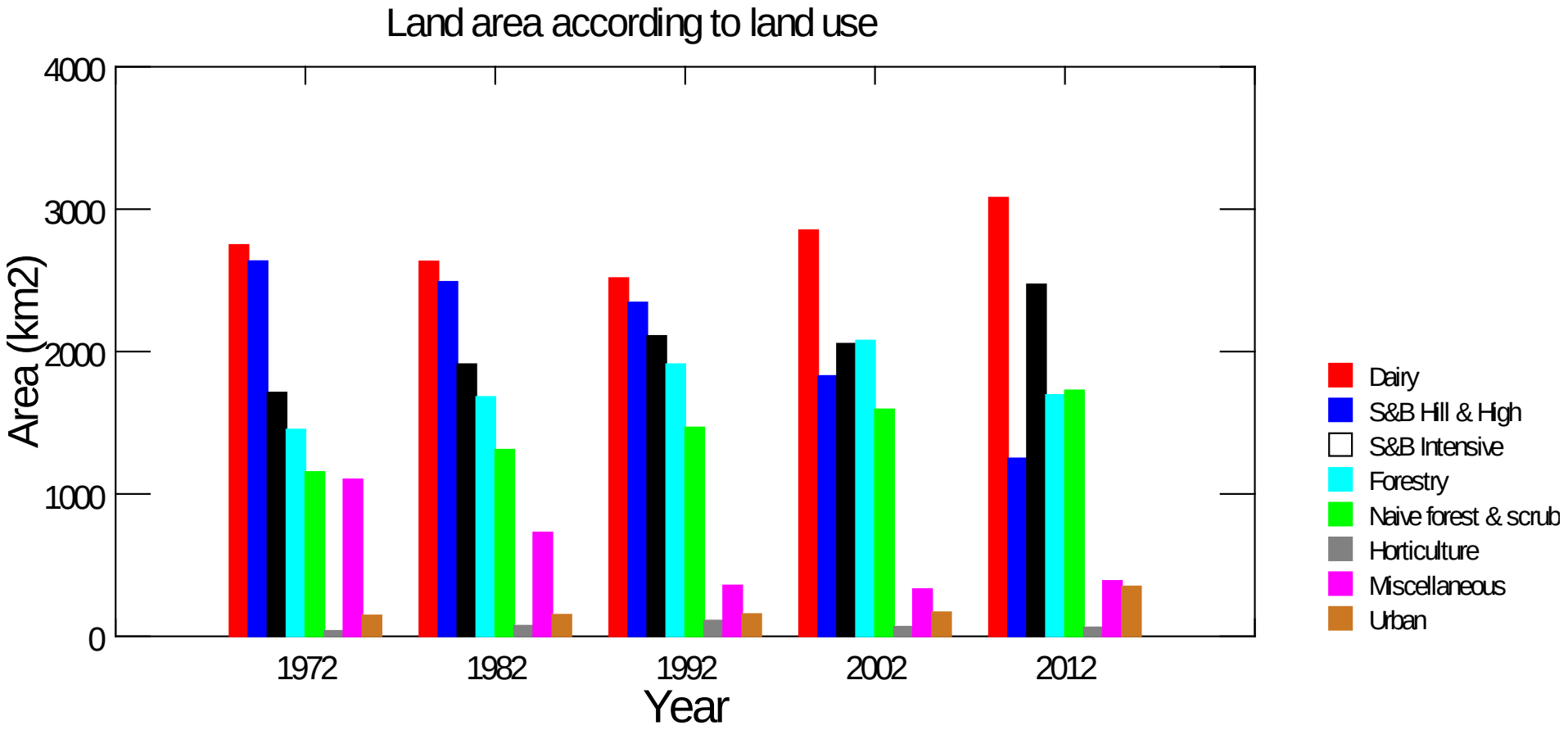


Figure A-1: Area of land associated with categories of land use by decade.

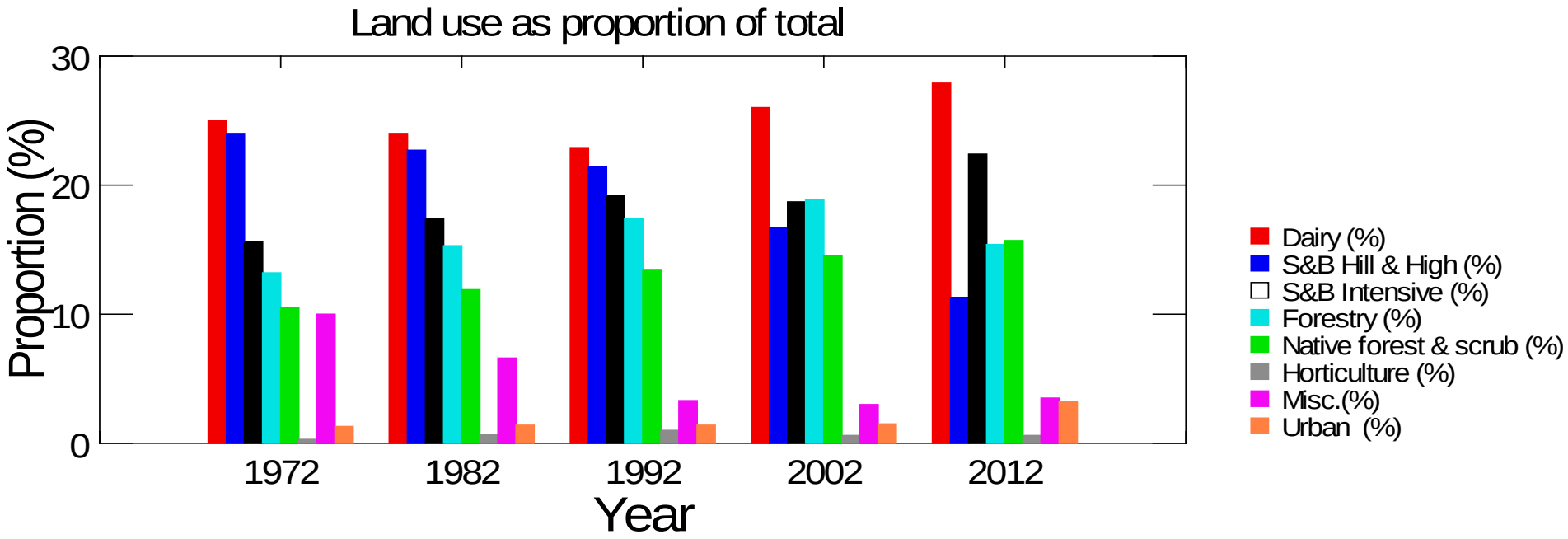


Figure A-2: Proportion of land area associated with categories of land use by decade.

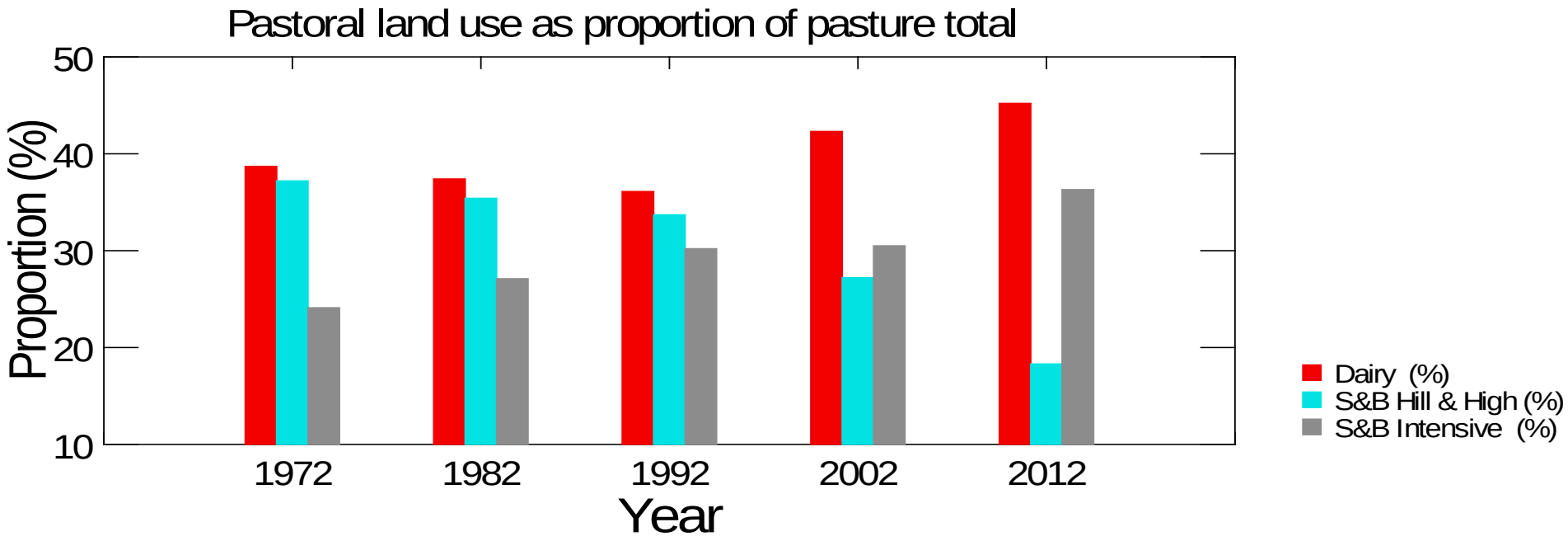
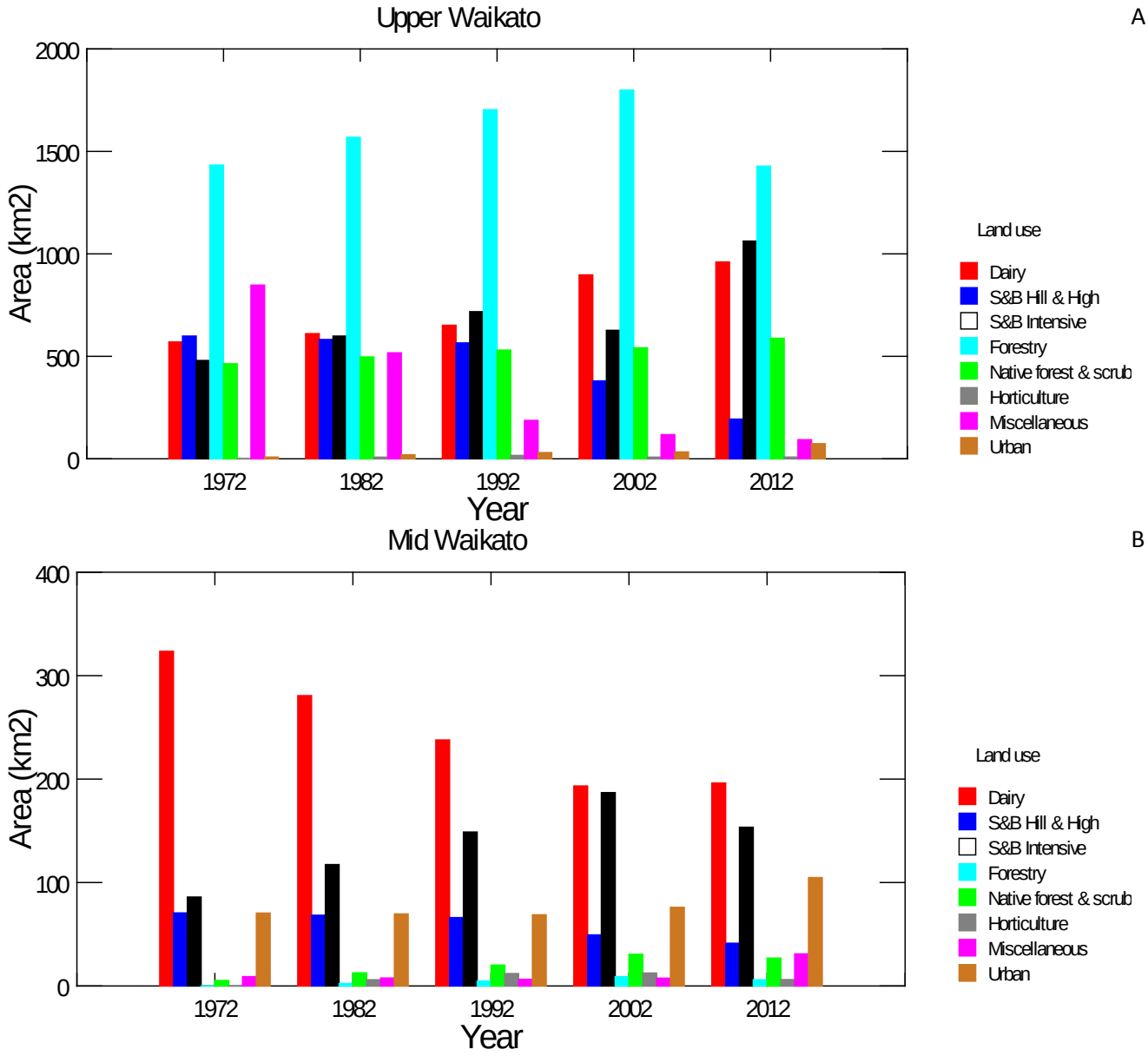


Figure A-3: Area of land associated with three key pastoral land uses as proportion of total pastoral land use by decade.


Upper Waikato
A
Area (km2)
2000
1500
1000
500
0
1972
1982
1992
2002
2012
Year
Land use
Dairy
S&B Hill & High
S&B Intensive
Forestry
Native forest & scrub
Horticulture
Miscellaneous
Urban
Mid Waikato
B
Area (km2)
400
300
200
100
0
1972
1982
1992
2002
2012
Year
Land use
Dairy
S&B Hill & High
S&B Intensive
Forestry
Native forest & scrub
Horticulture
Miscellaneous
Urban

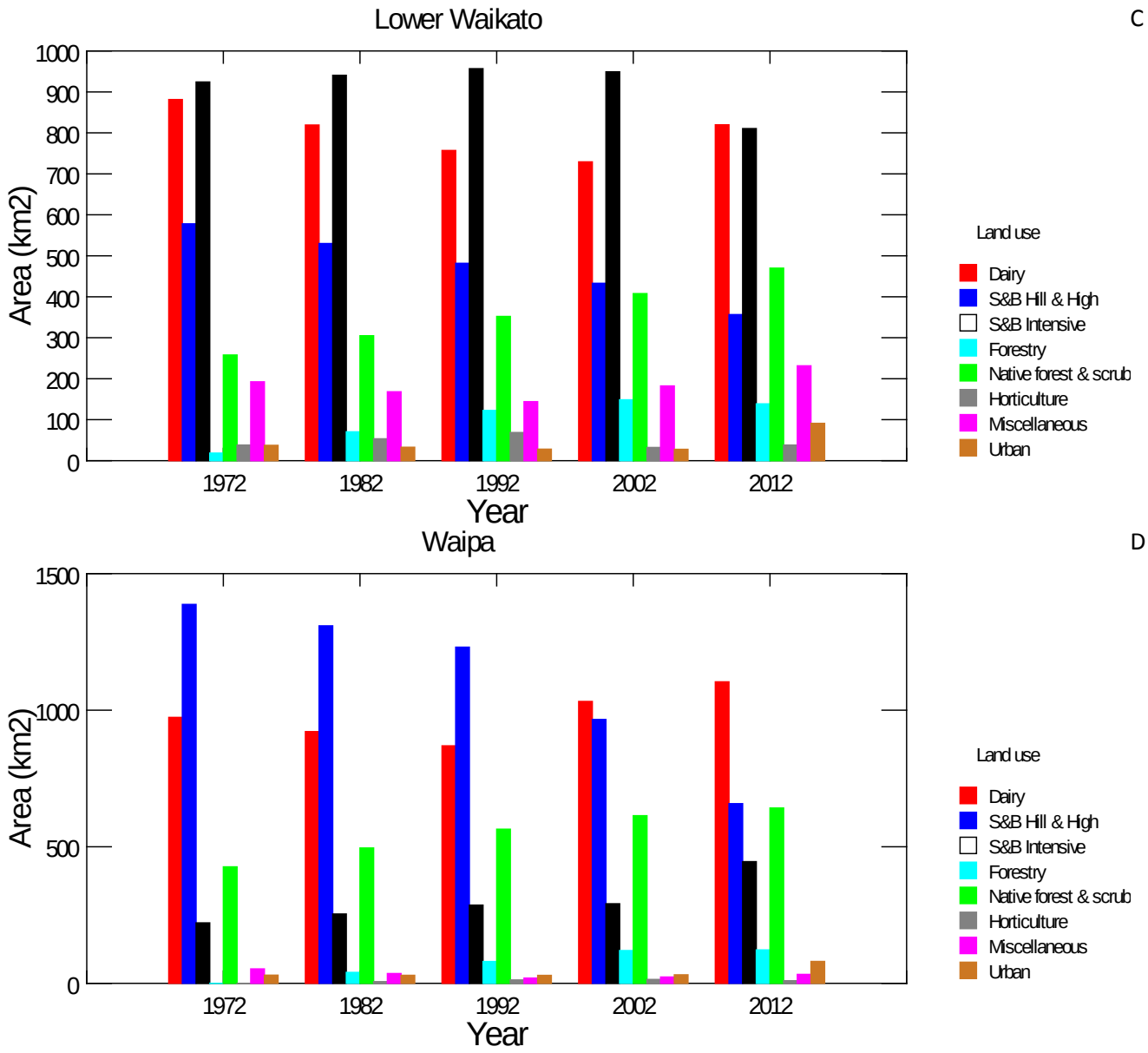
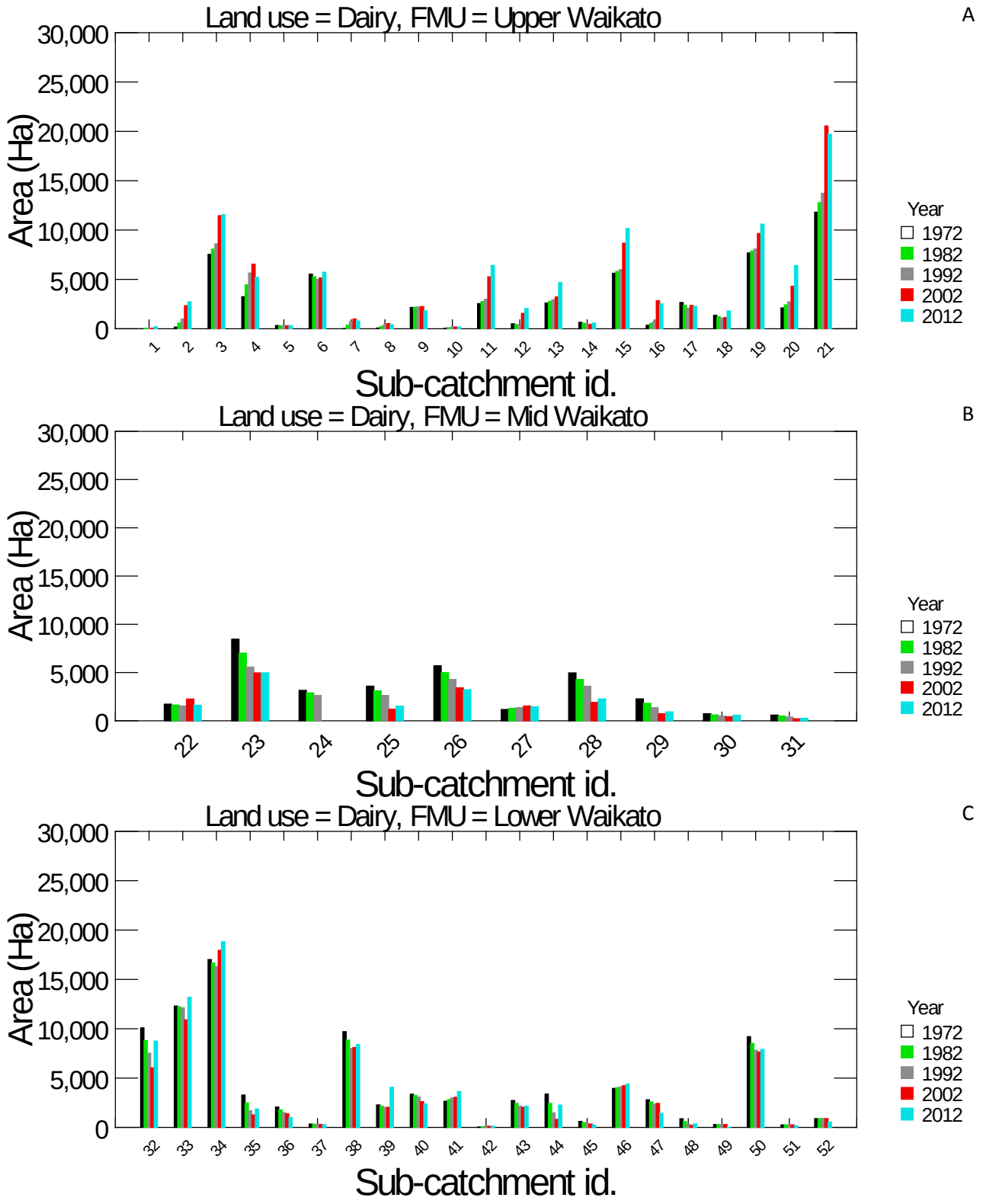


Figure A-4: Area of land associated with pastoral land uses by FMU and decade.


A
Land use = Dairy, FMU = Upper Waikato
Area (Ha)
30,000
25,000
20,000
15,000
10,000
5,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012
B
Land use = Dairy, FMU = Mid Waikato
Area (Ha)
30,000
25,000
20,000
15,000
10,000
5,000
0
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012
C
Land use = Dairy, FMU = Lower Waikato
Area (Ha)
30,000
25,000
20,000
15,000
10,000
5,000
0
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

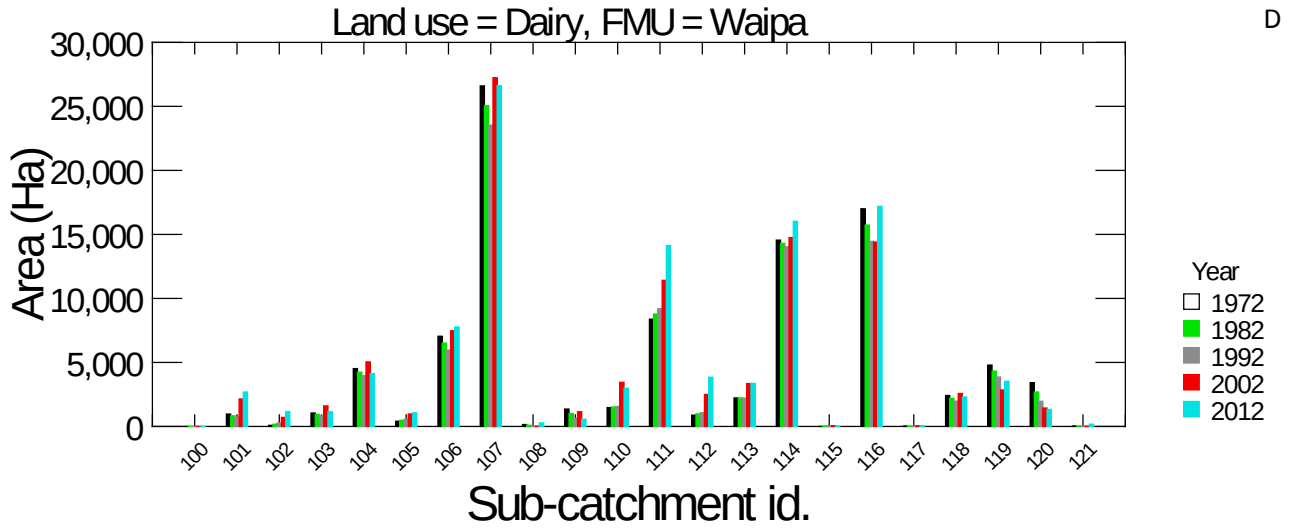
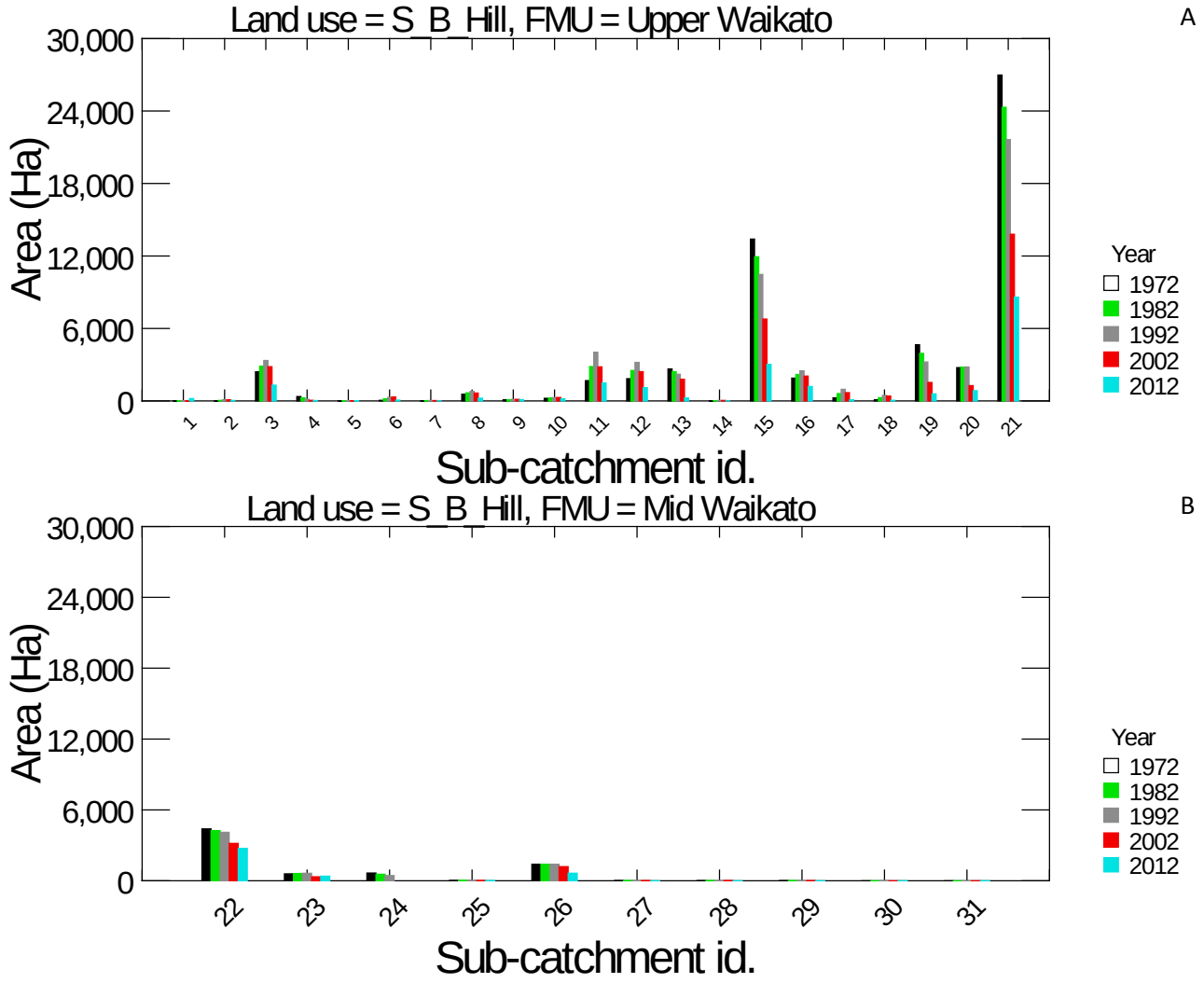


Figure A-5: Area of land associated with dairy land uses by FMU and decade.



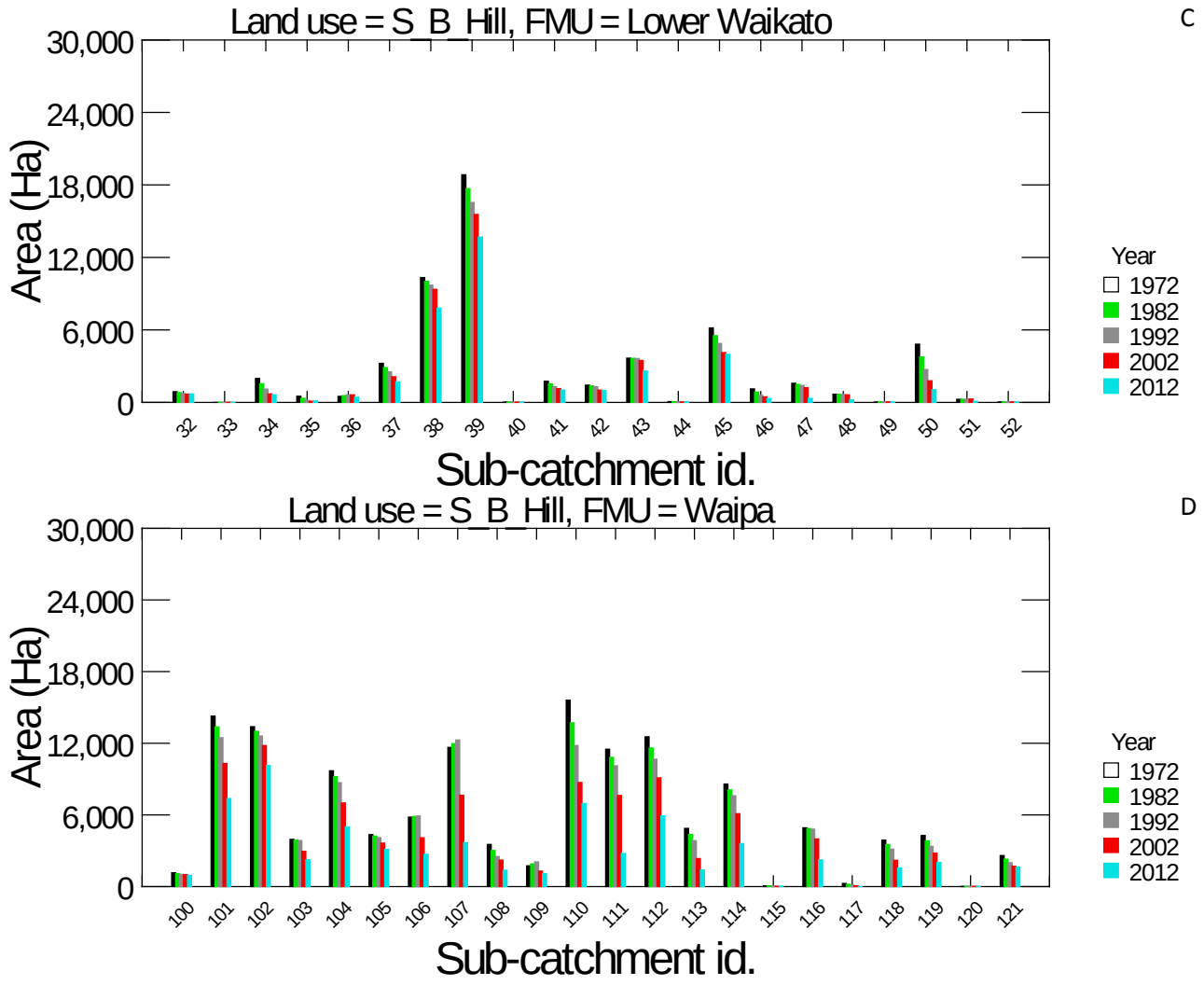
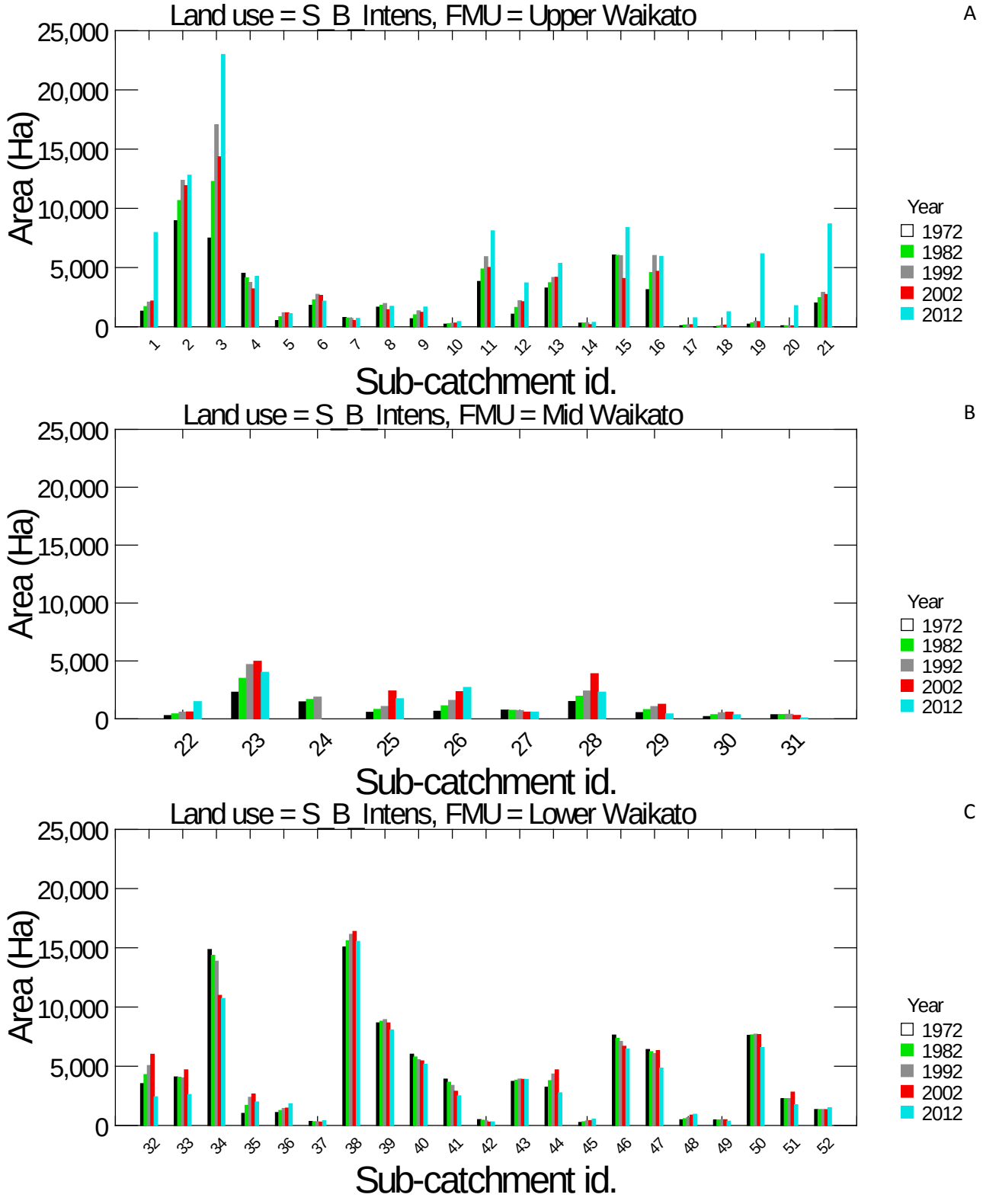


Figure A-6: Area of land associated with sheep and beef, hill and high land uses by FMU and decade.


Land use = S_B_Intens, FMU = Upper Waikato
A
Area (Ha)
25,000
20,000
15,000
10,000
5,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012
Land use = S_B_Intens, FMU = Mid Waikato
B
Area (Ha)
25,000
20,000
15,000
10,000
5,000
0
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012
Land use = S_B_Intens, FMU = Lower Waikato
C
Area (Ha)
25,000
20,000
15,000
10,000
5,000
0
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

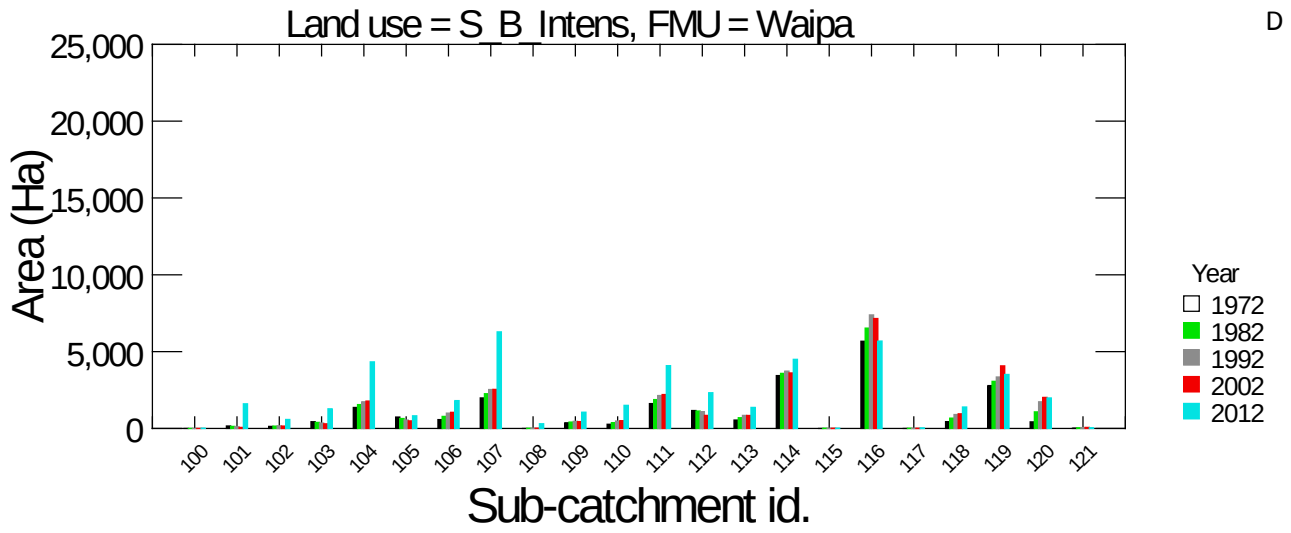
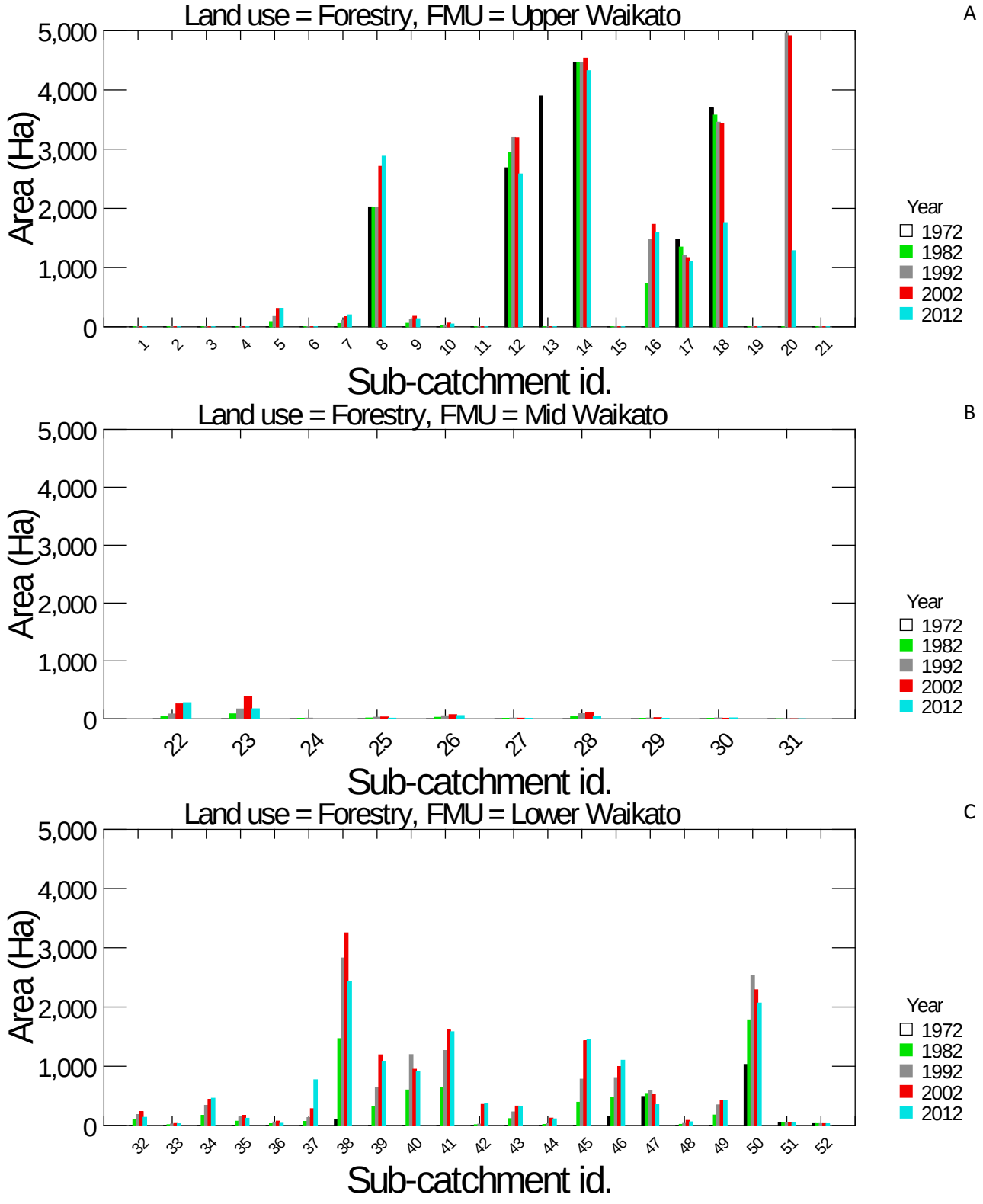


Figure A-7: Area of land associated with sheep and beef intensive land uses by FMU and decade.


A
Land use = Forestry, FMU = Upper Waikato
Area (Ha)
5,000
4,000
3,000
2,000
1,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012
B
Land use = Forestry, FMU = Mid Waikato
Area (Ha)
5,000
4,000
3,000
2,000
1,000
0
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012
C
Land use = Forestry, FMU = Lower Waikato
Area (Ha)
5,000
4,000
3,000
2,000
1,000
0
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

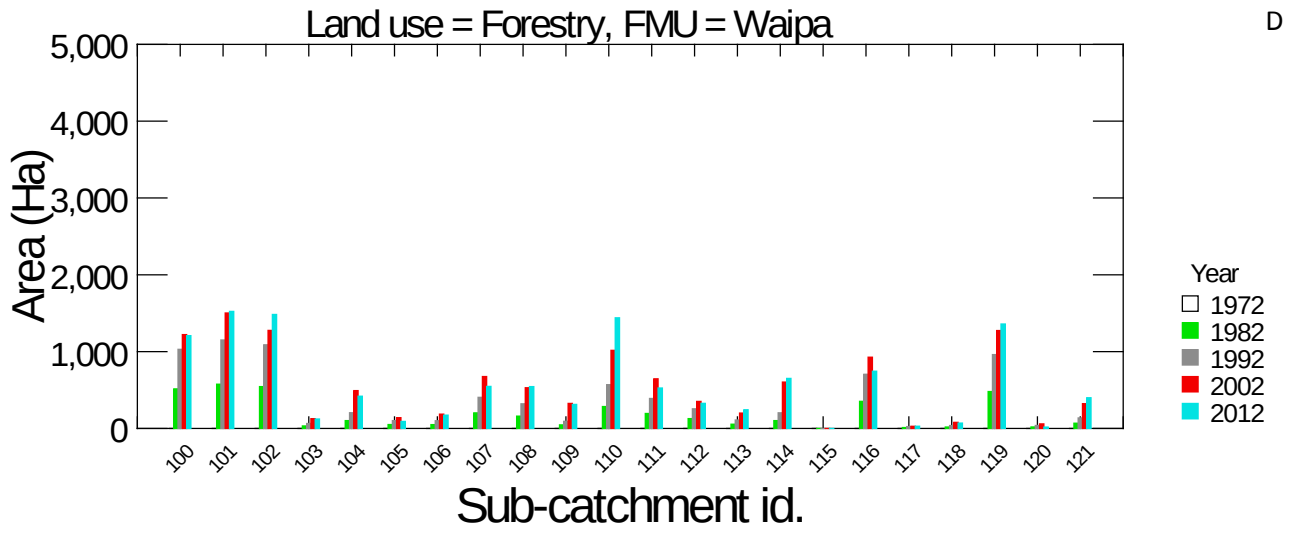
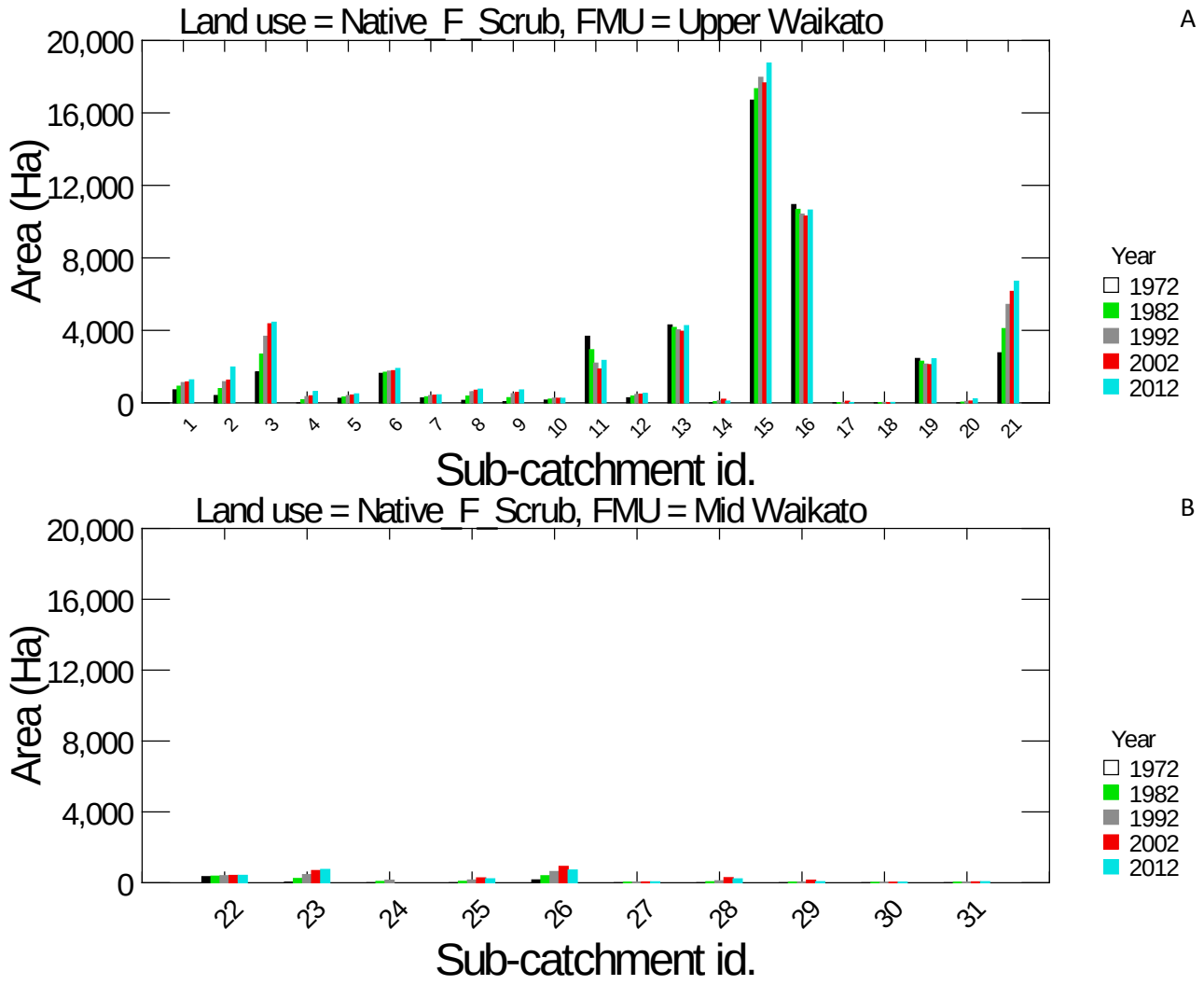


Figure A-8: Area of land associated with forestry land uses by FMU and decade.



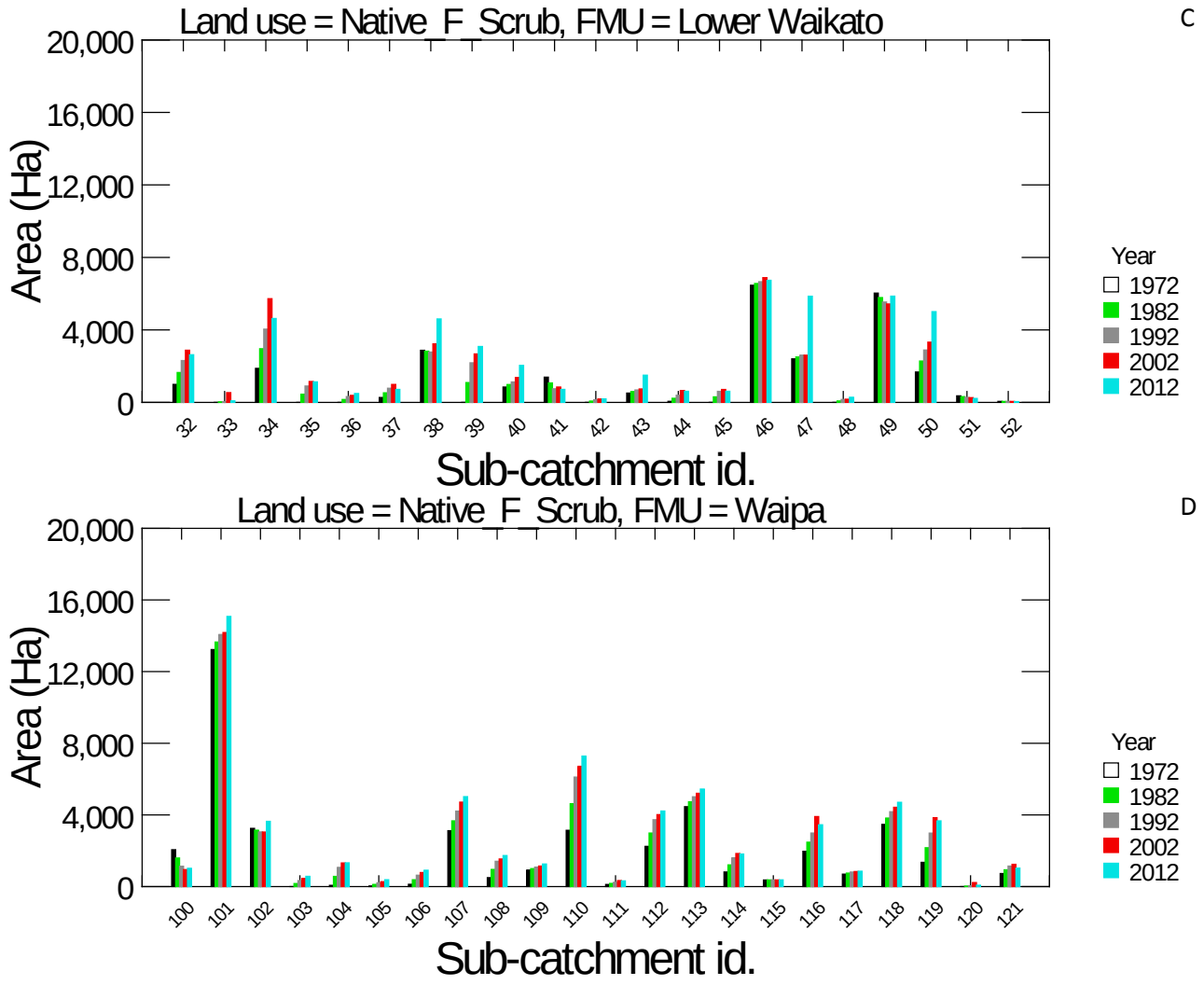
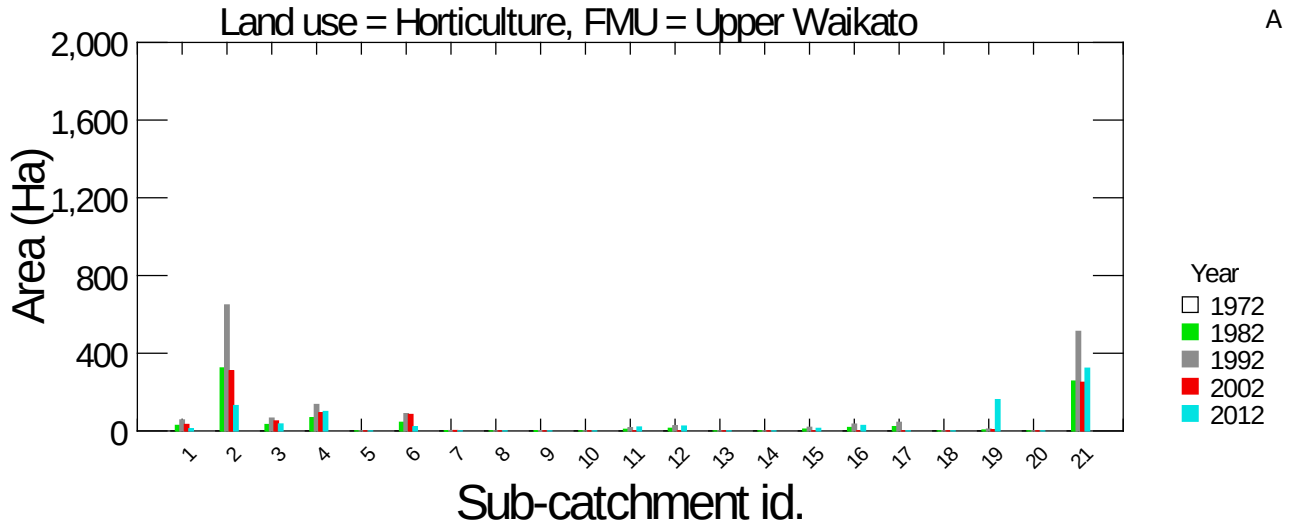


Figure A-9: Area of land associated with native forest and scrub land uses by FMU and decade.



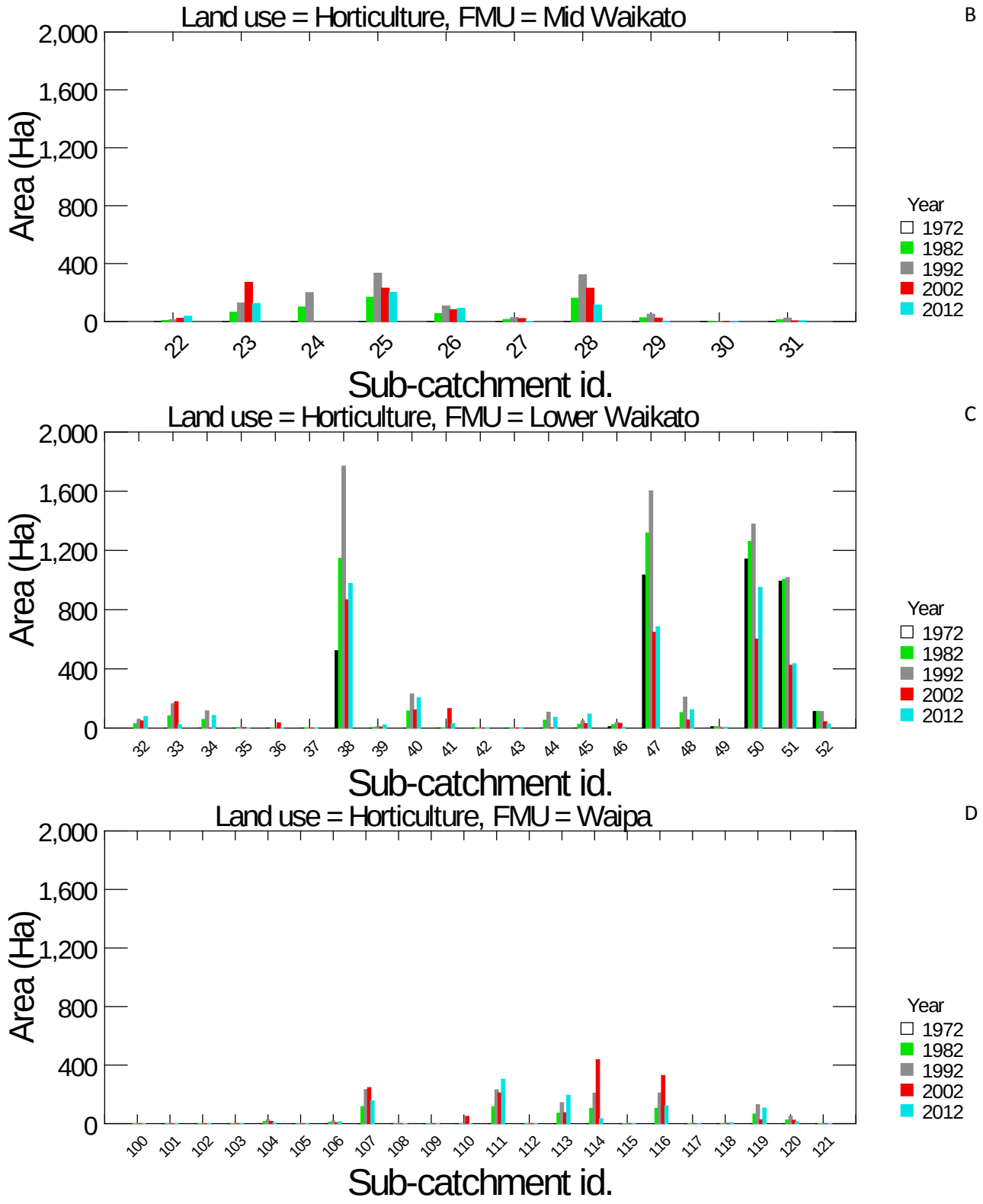
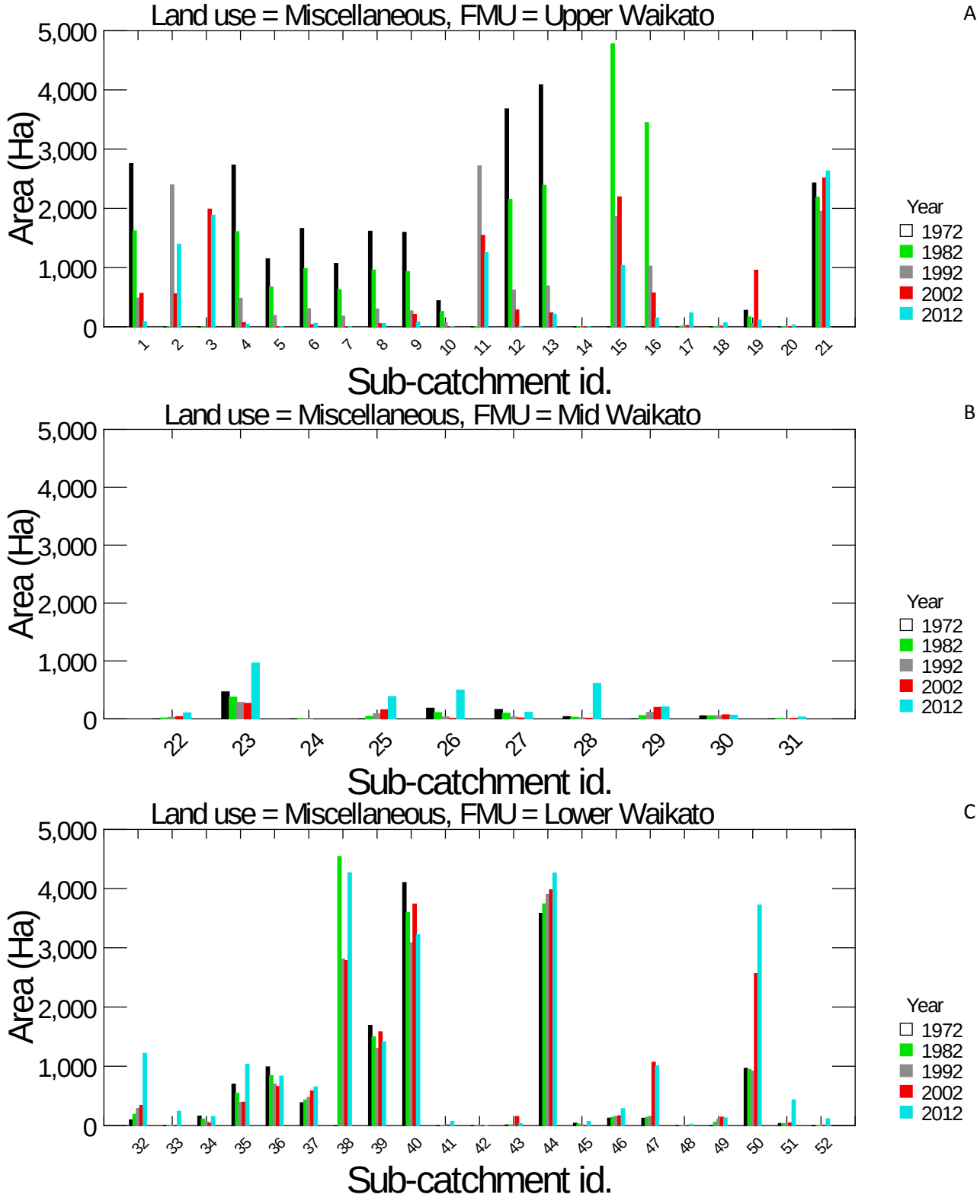


Figure A-10: Area of land associated with horticulture land uses by FMU and decade.


A
Land use = Miscellaneous, FMU = Upper Waikato
Area (Ha)
5,000
4,000
3,000
2,000
1,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012
B
Land use = Miscellaneous, FMU = Mid Waikato
Area (Ha)
5,000
4,000
3,000
2,000
1,000
0
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012
C
Land use = Miscellaneous, FMU = Lower Waikato
Area (Ha)
5,000
4,000
3,000
2,000
1,000
0
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

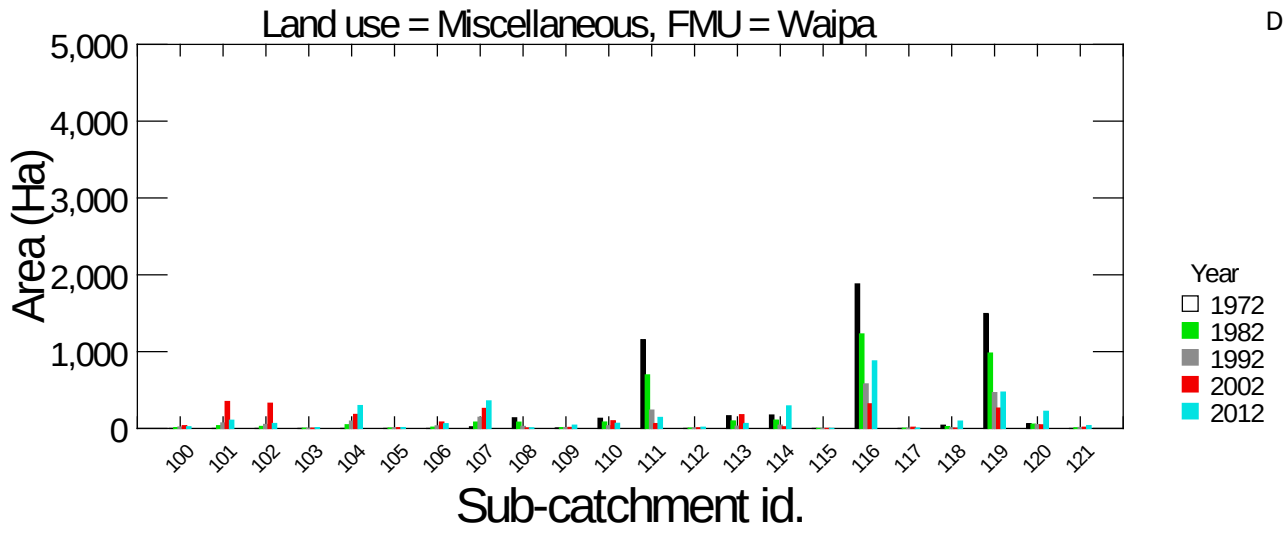
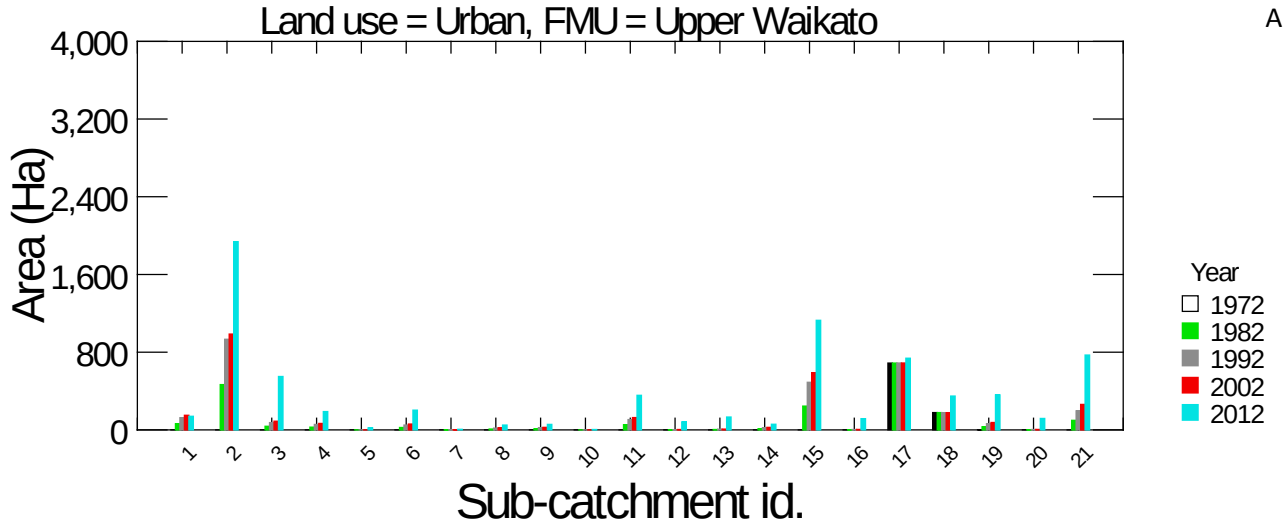
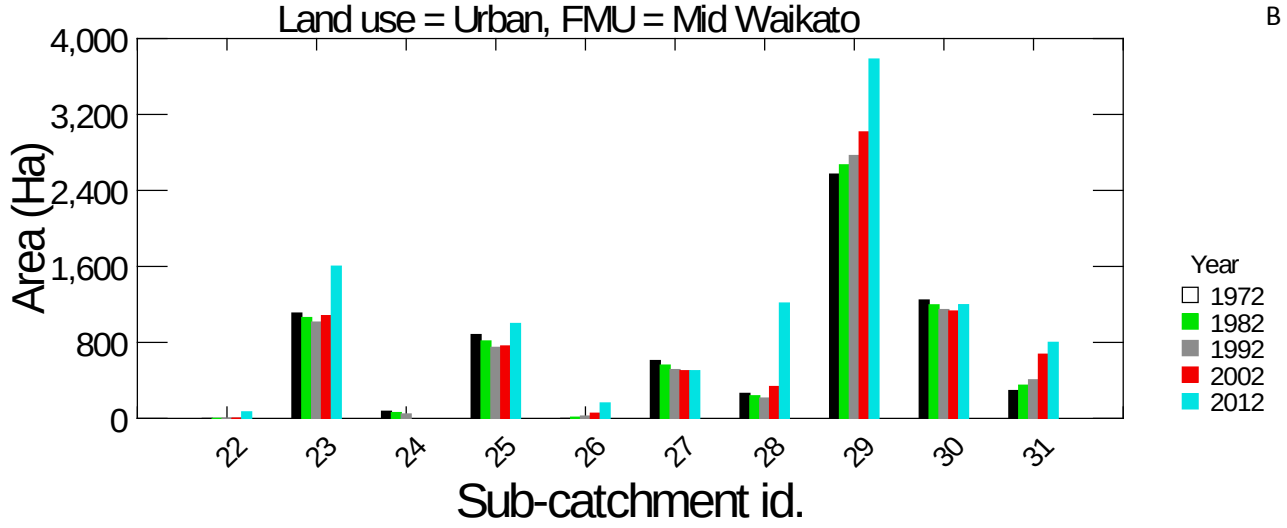


Figure A-11: Area of land associated with miscellaneous land uses by FMU and decade.





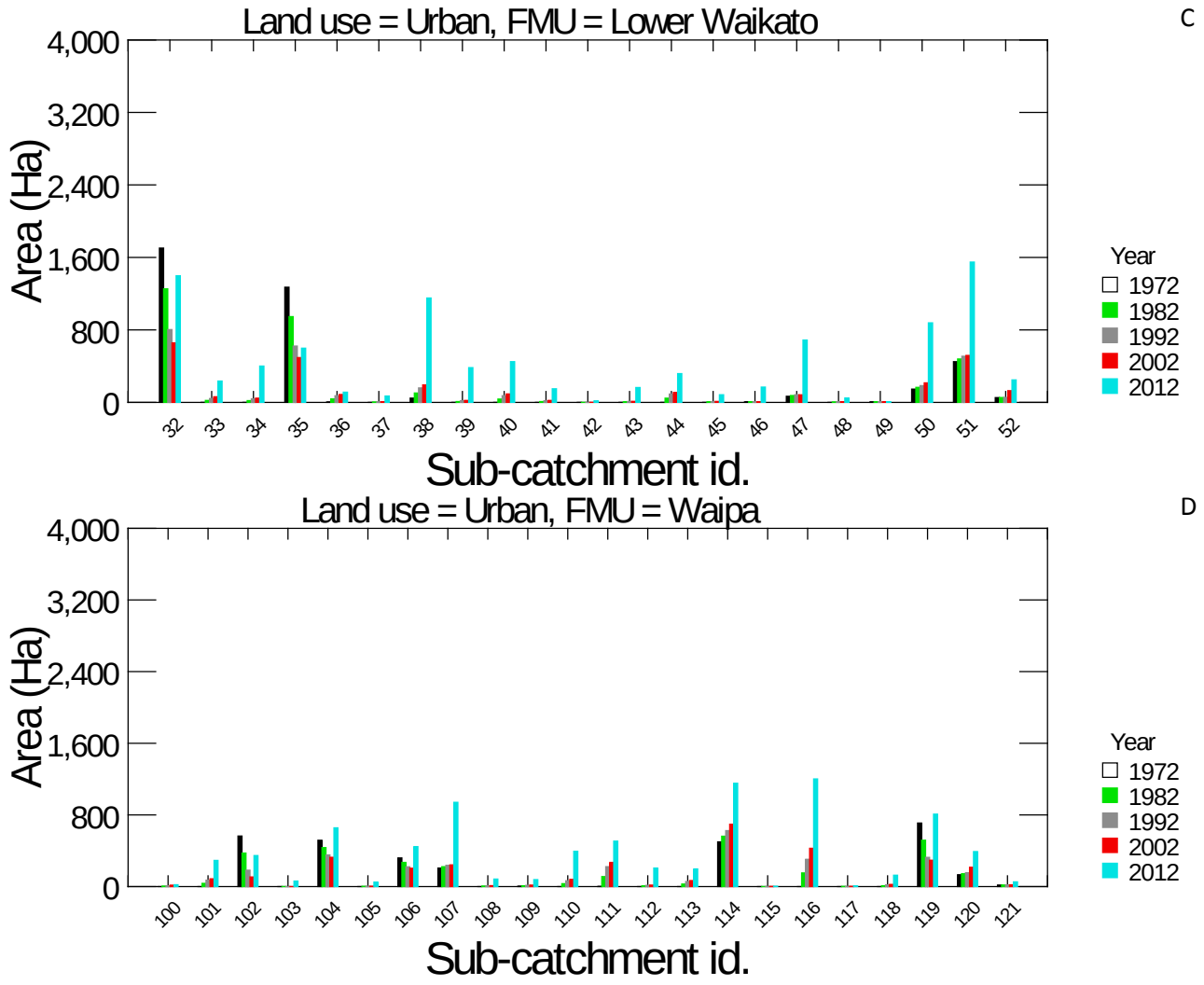


Figure A-12: Area of land associated with urban land uses by FMU and decade.

Appendix B Estimates of nitrogen leaching losses at decadal intervals (1972-2012) for 74 Healthy Rivers catchments

Nitrogen loss per sub-catchment

Table B-1: Estimated nitrogen loss per sub-catchment at decadal interval. Id = catchment identification code.

Sub-catchment	Id	Nitrogen leaching loss per sub-catchment (t/y)						
		1972	1982	1992	1996	2002	2008	2012
Pueto	1	82.5	89	95.9	98.9	96.2	140.1	146.9
Waikato at Ohaaki	2	149.7	197	248.9	271.1	265.9	349.7	282.1
Waikato at Ohakuri	3	349.7	453.2	567.2	616	692.1	790.1	818.5
Torepatutahi	4	142.1	174.6	215.2	233.8	249.2	270.4	250.5
Mangakara	5	13	16.8	20.9	22.5	23.3	24.3	24.1
Waiotapu at Homestead	6	140.8	165.5	188.8	197.8	211.2	225.2	235
Kawaunui	7	11.1	16.7	24.8	28.8	32.2	34.8	32.2
Waiotapu at Campbell	8	34.8	40.5	47.6	50.9	48.5	50.2	47.2
Otamakokore	9	41	52.4	64.3	69.3	72.9	81.6	74.9
Whirinaki	10	6.5	8.2	10.3	11.2	11.8	12.4	12.8
Waikato at Whakamaru	11	228	270.6	317.7	337.9	396.2	448.7	484.9
Waipapa	12	59.1	72.4	86.1	91.7	121.3	138.8	153.7
Tahunaatara	13	146	170.4	196.7	208	222.3	249.1	292.2
Mangaharakeke	14	33.6	35.1	35.6	35.5	36.7	39.8	45.3
Waikato at Waipapa	15	441.1	478.6	516.3	531.7	598.5	675.4	708.7
Mangakino	16	98.3	122.6	150.6	162.9	211.1	232.4	222.5
Mangamingi	17	63.6	75.5	84.7	87.7	100	111.6	108.6
Whakauru	18	42.7	48.5	53	54.4	60.8	74.1	96.9
Pokaiwhenua	19	275.1	319.2	364.9	383.7	444.9	521.9	577.7
Little Waipa	20	92.4	111.4	133.6	143.5	188	221.1	297.8
Waikato at Karapiro	21	537.3	626.7	722.7	763.4	918.1	949	1005.6
Karapiro	22	65.6	72.7	79.1	81.6	93.4	93	93.1
Waikato at Narrows	23	133.2	156.2	170.9	174.7	188.9	196	190.4
Mangawhero	24	58.5	73.4	86.7	91.6	106.1	106.3	97.6
Waikato at Bridge St Br	25	59.5	78.5	93.9	99.1	75.6	117.3	82.5
Mangaonua	26	89.5	106.6	119.4	123.4	121.4	141	128.5
Mangakotukutuku	27	25.5	32.4	40	43.2	47.5	53.4	50.2
Mangaone	28	74.6	95.9	113.1	119.3	99.1	134.1	94.5
Waikato at Horotiu Br	29	44.4	49.6	51.6	51.4	42.8	55.7	42.7
Waitawhiriwhiri	30	15.6	17.6	18.9	19.1	20.2	21.2	24.2
Kirikiriroa	31	12.6	14.3	15.1	15.3	10.8	13.6	11.2
Waikato at Huntly-Tainui Br	32	185.5	211.5	228.5	232.9	231.4	280.6	302.9
Komakorau	33	211.2	263.8	315.5	336.2	340.7	400.3	421.8
Mangawara	34	392.4	457.4	518.8	542.6	595.3	621.8	696.1
Waikato at Rangiriri	35	54.3	58.4	58.1	56.9	58.3	64.3	71.8

Sub-catchment	Id	Nitrogen leaching loss per sub-catchment (t/y)						
		1972	1982	1992	1996	2002	2008	2012
Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	39	44	47.6	48.7	53.6	54.6	50
Awaroa (Rotowaro) at Sansons Br	37	36.1	36.1	35.6	35.3	34.8	35.7	34.3
Waikato at Mercer Br	38	374.6	445.3	511.4	536.8	488.4	567.4	517
Whangape	39	266.8	278.5	288.3	291.9	296.8	307.4	335.7
Whangamarino at Island Block Rd	40	95.1	111.3	126.6	132.5	122.1	146.3	129.8
Whangamarino at Jefferies Rd Br	41	76.5	84.7	93.3	96.9	107.6	107.8	116
Waerenga	42	16.9	17.4	17.9	18.1	16.7	17.3	17.2
Matahuru	43	89.1	96.9	103.4	105.7	109.1	115.1	111.8
Waikare	44	68.4	76.5	80.3	80.8	72.5	87.7	89.9
Opuatia	45	67	68.3	68.1	67.7	65.8	70.7	70.5
Mangatangi	46	127.3	138.8	150.1	154.6	160.4	166.5	171.5
Waikato at Tuakau Br	47	176.5	202	225.9	235.5	177	240.3	151.3
Ohaeroa	48	19.6	26.7	32.1	33.8	23.6	34.6	29.2
Mangatawhiri	49	22.3	23.5	24.8	25.3	25.3	25.6	21
Waikato at Port Waikato	50	294.3	320.5	341.6	348.8	308.8	359.1	353.5
Whakapipi	51	91.9	94.5	97.1	98.1	65.5	99	56.5
Awaroa (Waiuku)	52	29.3	32.6	35.8	37.1	34.6	36.8	31
Waipa at Mangaokewa Rd	100	15	15.8	16.6	16.9	17.1	17.4	17.2
Waipa at Otewa	101	170.6	173.5	174.4	174.3	203	198.3	221.1
Mangaokewa	102	125.9	132	138.4	141.2	150.2	151.6	162.1
Mangarapa	103	53.4	57.2	60	60.9	77.5	72.8	74.5
Mangapu	104	163.5	181	195.9	201.3	230.9	234.2	232
Mangarama	105	49.6	53.4	57.5	59.4	68.4	66.7	75.1
Waipa at Otorohanga	106	163	187.5	207.9	215	259.2	267.4	295.8
Waipa at Pirongia-Ngutunui Rd Br	107	529.4	628.9	716.3	748.3	878.4	924.3	967.8
Waitomo at Tumutumu Rd	108	33.9	32	29.2	27.8	28	28.6	32.6
Waitomo at SH31 Otorohanga	109	40.9	42.9	42.2	41.1	52.9	49.6	44.2
Moakurarua	110	165.8	168.2	169.3	169.5	209.4	201.6	205.8
Puniu at Bartons Corner Rd Br	111	242.5	293.9	348.1	370.8	427.3	440.5	539.4
Puniu at Wharepapa	112	135.8	140.8	145.6	147.6	177.5	166.8	217.7
Mangatutu	113	91.6	105.2	118.4	123.7	142.5	156.1	162.2
Mangapiko	114	327.5	392	454.1	478.5	536.9	551.2	600
Mangaohoi	115	1.5	1.6	1.9	2	2.3	2.2	1.8
Waipa at SH23 Br Whatawhata	116	335.9	396.6	448.5	467.1	506.3	537.8	600
Mangauika	117	4.3	4	3.6	3.5	3.9	4	4.4

Sub-catchment	Id	Nitrogen leaching loss per sub-catchment (t/y)						
		1972	1982	1992	1996	2002	2008	2012
Kaniwhaniwha	118	82	89.1	94.2	95.8	112.7	107.4	115.3
Waipa at Wainaro Rd Br	119	136.4	153.9	167.8	172.4	157.2	194.7	183.5
Ohote	120	41.9	49.8	53.9	54.6	51.8	64	53.7
Firewood	121	24.6	24	23.1	22.7	22.1	23.2	26.9
Annual total		**9236.5**	**10653.8**	**12001.7**	**12529.9**	**13510.7**	**14871.7**	**15345**

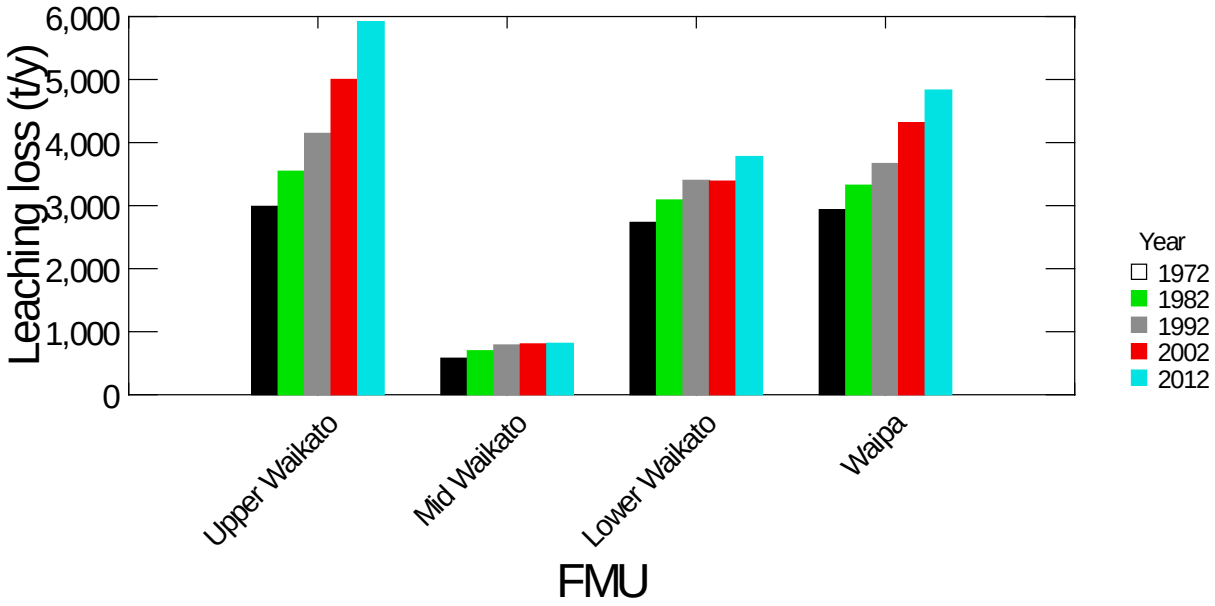
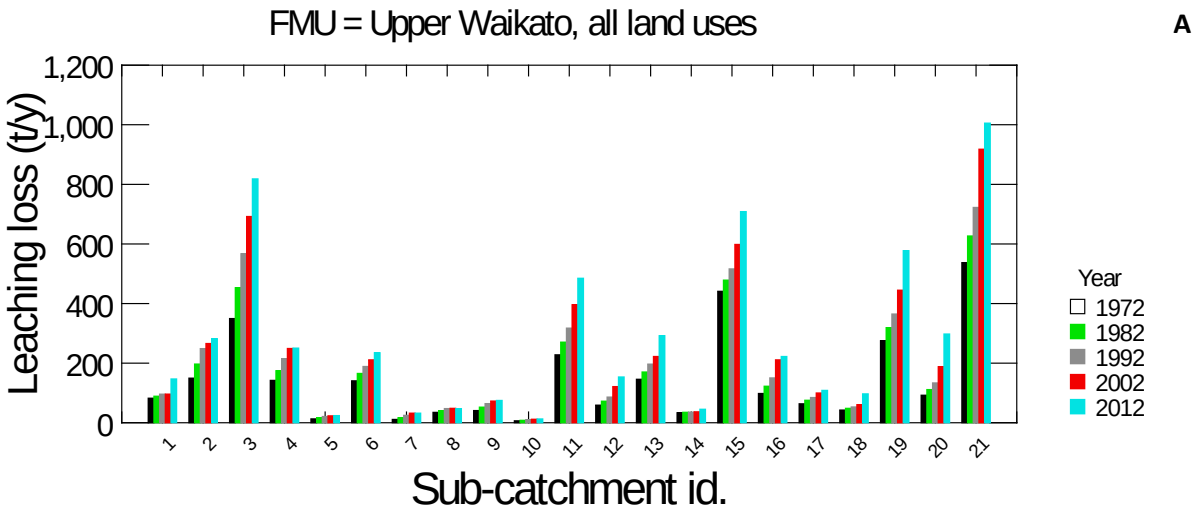


Figure B-1: Total leaching loss for all land uses for the Wai Ora/Healthy Rivers project area according to freshwater management unit and decade.



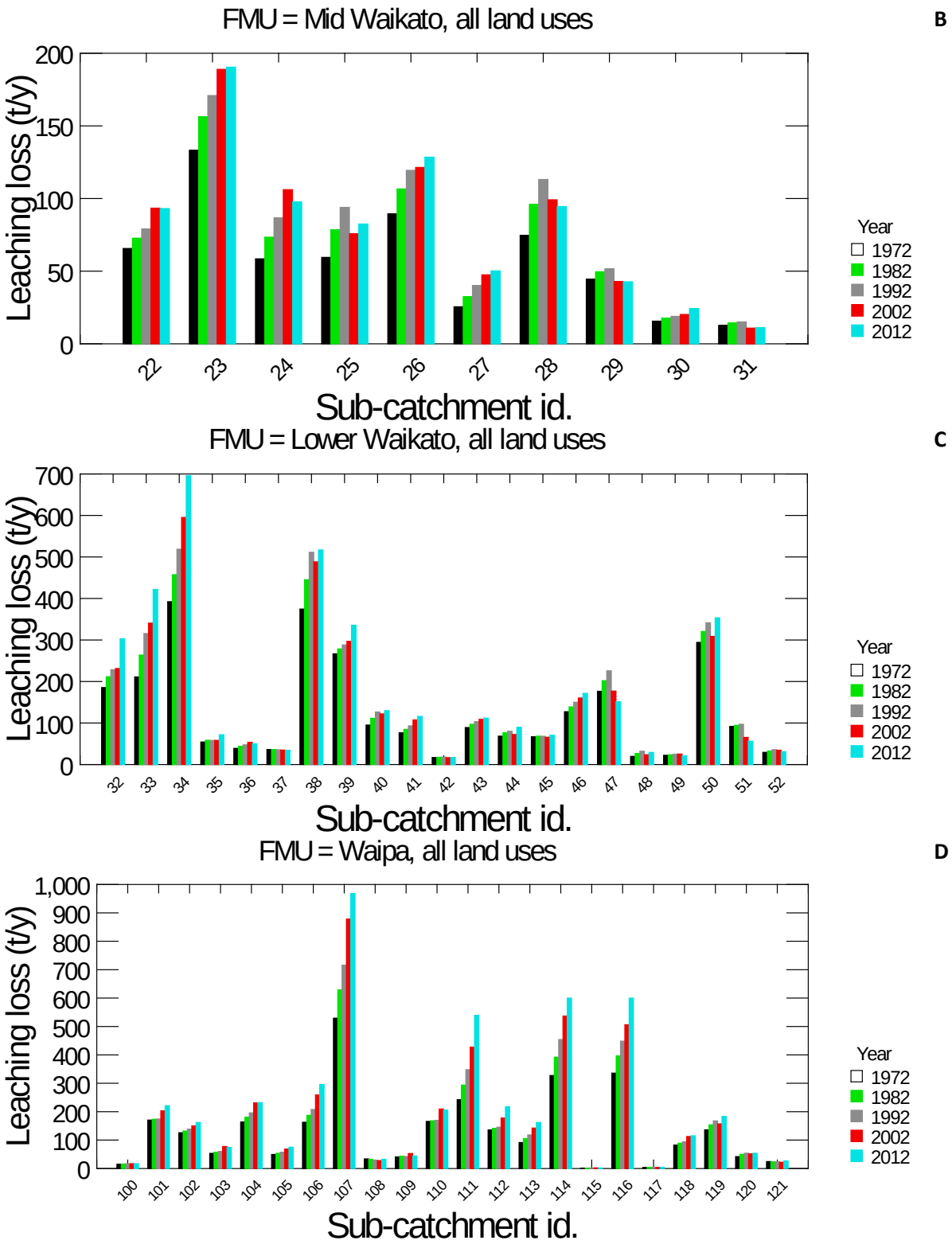


Figure B-2: Total leaching loss for all land uses for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment.

Cumulative nitrogen leaching loss per sub-catchment

Table B-2: Estimated cumulative nitrogen leaching loss per sub-catchment at decadal interval. "Id" is catchment identification code and "DS id" is the code of the sub-catchment into which the sub-catchment of concern discharges. Cumulative leaching loss is the total N leaching loss for all contributing subcatchments upstream of each respective site. The cumulative nitrogen loss includes 247 t/y from Lake Taupo (which enters the catchment in sub-catchment 2 "Waikato at Ohaaki".

Sub-catchment	Id	DS Id	Cumulative nitrogen loss per sub-catchment (t/y)						
			1972	1982	1992	1996	2002	2008	2012
Pueto	1	2	82.5	89	95.9	98.9	96.2	140.1	146.9
Waikato at Ohaaki	2	3	479.3	533	591.8	616.9	609.1	736.8	676
Waikato at Ohakuri	3	11	1218.2	1460.8	1730.8	1847.3	1950.3	2225.8	2171.1
Torepatutahi	4	3	142.1	174.6	215.2	233.8	249.2	270.4	250.5
Mangakara	5	6	13	16.8	20.9	22.5	23.3	24.3	24.1
Waiotapu at Homestead	6	3	199.7	239.5	282.1	300	315.1	334.5	338.5
Kawaunui	7	6	11.1	16.7	24.8	28.8	32.2	34.8	32.2
Waiotapu at Campbell	8	6	34.8	40.5	47.6	50.9	48.5	50.2	47.2
Otamakokore	9	3	41	52.4	64.3	69.3	72.9	81.6	74.9
Whirinaki	10	3	6.5	8.2	10.3	11.2	11.8	12.4	12.8
Waikato at Whakamaru	11	15	1684.9	2009.3	2366.9	2520.4	2726.7	3102.1	3147.2
Waipapa	12	11	59.1	72.4	86.1	91.7	121.3	138.8	153.7
Tahunaatara	13	11	146	170.4	196.7	208	222.3	249.1	292.2
Mangaharakeke	14	11	33.6	35.1	35.6	35.5	36.7	39.8	45.3
Waikato at Waipapa	15	21	2224.3	2610.5	3033.8	3215	3536.3	4010	4078.4
Mangakino	16	15	98.3	122.6	150.6	162.9	211.1	232.4	222.5
Mangamingi	17	19	106.3	124	137.7	142.2	160.9	185.7	205.5
Whakauru	18	17	42.7	48.5	53	54.4	60.8	74.1	96.9
Pokaiwhenua	19	21	381.5	443.2	502.6	525.9	605.8	707.6	783.2
Little Waipa	20	21	92.4	111.4	133.6	143.5	188	221.1	297.8
Waikato at Karapiro	21	23	3235.4	3791.8	4392.7	4647.8	5248.2	5887.8	6165
Karapiro	22	23	65.6	72.7	79.1	81.6	93.4	93	93.1
Waikato at Narrows	23	25	3492.6	4094.1	4729.4	4995.6	5636.6	6283.1	6546.2
Mangawhero	24	23	58.5	73.4	86.7	91.6	106.1	106.3	97.6
Waikato at Bridge St Br	25	29	3741.8	4407.4	5095.7	5380.7	5980.2	6728.9	6902
Mangaonua	26	25	89.5	106.6	119.4	123.4	121.4	141	128.5
Mangakotukutuku	27	25	25.5	32.4	40	43.2	47.5	53.4	50.2
Mangaone	28	25	74.6	95.9	113.1	119.3	99.1	134.1	94.5
Waikato at Horotiu Br	29	32	3814.3	4488.9	5181.3	5466.5	6054	6819.5	6980.1
Waitawhiriwhiri	30	29	15.6	17.6	18.9	19.1	20.2	21.2	24.2
Kirikiriroa	31	29	12.6	14.3	15.1	15.3	10.8	13.6	11.2
Waikato at Huntly-Tainui Br	32	35	7538.5	8745	9910.8	10372.4	11536.8	12582.6	13233.9

Sub-catchment	Id	DS Id	Cumulative nitrogen loss per sub-catchment (t/y)						
			1972	1982	1992	1996	2002	2008	2012
Komakorau	33	32	211.2	263.8	315.5	336.2	340.7	400.3	421.8
Mangawara	34	32	392.4	457.4	518.8	542.6	595.3	621.8	696.1
Waikato at Rangiriri	35	38	7667.8	8883.4	10052.2	10513.3	11683.5	12737.1	13389.9
Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	35	75.1	80.1	83.3	84	88.4	90.3	84.2
Awaroa (Rotowaro) at Sansons Br	37	36	36.1	36.1	35.6	35.3	34.8	35.7	34.3
Waikato at Mercer Br	38	47	8849.6	10201.2	11491.6	11998.4	13123	14323.4	14949.4
Whangape	39	38	266.8	278.5	288.3	291.9	296.8	307.4	335.7
Whangamarino at Island Block Rd	40	38	346.1	386.9	421.5	434	428	474.2	464.8
Whangamarino at Jefferies Rd Br	41	40	93.4	102.1	111.2	115	124.3	125	133.2
Waerenga	42	41	16.9	17.4	17.9	18.1	16.7	17.3	17.2
Matahuru	43	44	89.1	96.9	103.4	105.7	109.1	115.1	111.8
Waikare	44	40	157.5	173.4	183.8	186.5	181.6	202.8	201.7
Opuatia	45	38	67	68.3	68.1	67.7	65.8	70.7	70.5
Mangatangi	46	38	127.3	138.8	150.1	154.6	160.4	166.5	171.5
Waikato at Tuakau Br	47	50	9067.9	10453.3	11774.3	12292.9	13348.8	14623.9	15150.9
Ohaeroa	48	47	19.6	26.7	32.1	33.8	23.6	34.6	29.2
Mangatawhiri	49	47	22.3	23.5	24.8	25.3	25.3	25.6	21
Waikato at Port Waikato	50	200	9483.5	10900.8	12248.7	12776.9	13757.7	15118.7	15592
Whakapipi	51	50	91.9	94.5	97.1	98.1	65.5	99	56.5
Awaroa (Waiuku)	52	50	29.3	32.6	35.8	37.1	34.6	36.8	31
Waipa at Mangaokewa Rd	100	101	15	15.8	16.6	16.9	17.1	17.4	17.2
Waipa at Otewa	101	106	185.6	189.3	191	191.2	220.1	215.7	238.3
Mangaokewa	102	104	125.9	132	138.4	141.2	150.2	151.6	162.1
Mangarapa	103	104	53.4	57.2	60	60.9	77.5	72.8	74.5
Mangapu	104	107	392.3	423.5	451.9	462.8	527.1	525.3	543.8
Mangarama	105	104	49.6	53.4	57.5	59.4	68.4	66.7	75.1
Waipa at Otorohanga	106	107	348.6	376.9	398.9	406.2	479.3	483.1	534.1
Waipa at Pirongia-Ngutunui Rd Br	107	116	1980.9	2212.3	2419.7	2497.7	2922.4	2975.9	3247.5
Waitomo at Tumutumu Rd	108	109	33.9	32	29.2	27.8	28	28.6	32.6
Waitomo at SH31 Otorohanga	109	107	74.8	74.9	71.3	68.9	80.9	78.2	76.8
Moakurarua	110	107	165.8	168.2	169.3	169.5	209.4	201.6	205.8
Puniu at Bartons Corner Rd Br	111	107	469.9	539.9	612.1	642.1	747.3	763.4	919.2
Puniu at Wharepapa	112	111	135.8	140.8	145.6	147.6	177.5	166.8	217.7
Mangatutu	113	111	91.6	105.2	118.4	123.7	142.5	156.1	162.2

Sub-catchment	Id	DS Id	Cumulative nitrogen loss per sub-catchment (t/y)						
			1972	1982	1992	1996	2002	2008	2012
Mangapiko	114	116	329	393.7	455.9	480.4	539.2	553.4	601.8
Mangaohoi	115	114	1.5	1.6	1.9	2	2.3	2.2	1.8
Waipa at SH23 Br Whatawhata	116	119	2732.1	3095.7	3421.9	3544.5	4084.4	4178.5	4569
Mangauika	117	116	4.3	4	3.6	3.5	3.9	4	4.4
Kaniwhaniwha	118	116	82	89.1	94.2	95.8	112.7	107.4	115.3
Waipa at Wainaro Rd Br	119	32	2935.1	3323.4	3666.7	3794.1	4315.6	4460.4	4833.1
Ohote	120	119	41.9	49.8	53.9	54.6	51.8	64	53.7
Firewood	121	119	24.6	24	23.1	22.7	22.1	23.2	26.9

Appendix C New Zealand estimates of catchment yields of agricultural contaminants

Table C-1: Catchment studies in New Zealand with data for contaminant loads arranged by stock class. All loads in kg/ha/year except *E. coli* (cfu/ha/year), where cfu = 'colony forming units'. From McDowell and Wilcock (2008).

Stock	Major land use	Slope class [a]	Elevation (m [b])	Rain (mm/y)	Area (ha)	Contaminant yields (kg/ha/yr)						Region	Reference
						P fert. applied	N fert. applied	P loss	N loss	Sediment loss	*E. coli* loss (cfu/ha/yr)		
Sheep	Rangeland	Easy	800	690	4,800	0.1						Otago	Caruso (2000)
Sheep	Pasture	Easy	200	1,200	16	25		1.3	7	700		Waikato	Cooke (1988); Cooke and Cooper (1988)
Sheep	Pasture	Easy	300	1,200	1.5	65		0.7	9	1,220		Manawatu	Lambert et al. (1985)
Sheep	Pasture	Easy	200	1,448	<1	0.1		0.8				Wellington	McColl and Gibson (1979)
Sheep	Pasture	Rolling	95	1,453	1.4	56		1.1				Northland	Mc Coll et al. (1975)
Sheep	Pasture	Easy	200	1,295	4	30		0.3	1.3			Wellington	McColl et al. (1977)
Sheep	Pasture	Easy	150	690	300	25		0.1	2	97	$8.6x10^9$	Otago	McDowell and Paton (2004)
Sheep	Pasture	Easy	200	1,401	<1	45		0.8	4	374		Waikato	Smith (1987)
Mixed [c]	Pasture	Steep	260	1,000	180	27		1.6	5	1,400		Manawatu	Bargh (1978)
Mixed	Pasture	Easy	410	1,500	11	25		1.7	12	22		Bay of Plenty	Cooper and Thomsen (1988)
Mixed	Mixed [c]	Rolling	250	1,500	7,500	–		0.8	8			Bay of Plenty	Hoare(1984)
Mixed	Pasture	Steep	160	1,600	259	21		1.5	10	988		Waikato	Quinn and Stroud (2002)
Mixed	Mixed	Steep	160	1,600	266	21		1.3	7	2,632		Waikato	
Mixed	Mixed	Rolling	250	1,923	7,330	0.6		7	128			Bay of Plenty	Williamson et al. (1996)
Mixed	Native	Rolling	100	3,000	2,100			2.1	22			Westland	Davies-Colley and Nagels (2002)
Mixed	Pasture	Easy	300	1,200	1.2	65		1.5	12	2,740		Manawatu	Lambert et al. (1985)
Mixed	Pasture	Flat	40	1,006	10,500	35	35	0.3	18	183		Southland	Thorrold et al. (1997)
None	Native forest	Easy	60	3,000	1,800			0.6	7			Westland	Davies-Colley and Nagels (2002)
None	Native forest	Easy	200	1,295	11			0.2	0.01			Wellington	McColl et al. (1977)
None	Native forest	Easy	200	1,295	5			0.1	1.4			Wellington	
None	Exotic forest	Easy	200	1,295	4			0.07	0.04			Wellington	
None	Native forest	Steep	160	1,600	300			0.6	2	320		Waikato	Quinn and Stroud (2002)

Stock	Major land use	Slope class [a]	Elevation (m [b])	Rain (mm/y)	Area (ha)	Contaminant yields (kg/ha/yr)						Region	Reference
						P fert. applied	N fert. applied	P loss	N loss	Sediment loss	*E. coli* loss (cfu/ha/yr)		
None	Native forest	Easy	420	1,500	28			0.01	4	27		Bay of Plenty	Cooper and Thomsen (1988)
None	Exotic	Easy	400	1,500	34			0.01	1			Bay of Plenty	
Deer	Pasture	Easy	200	687	4	25		0.9	6	4,480	$3.41x10^{10}$	Otago	McDowell (2007)
Deer	Pasture	Rolling	80	944	36	35		3	3	3,950	$9.79x10^{9}$	Otago	
Deer	Pasture	Easy	200	687	4	25		1.4	5	3,356	$4.7x10^{11}$	Otago	McDowell (2008)
Deer	Pasture	Flat	90	1,100	32	31		0.6	7	158	$1.07x10^{10}$	Otago	McDowell et al. (2006)
Deer	Pasture	Easy	180	1,300	120	30		1.8	850			Otago	McDowell et al. (2008);+unpub.
Deer	Pasture	Rolling	260	800	25	25		1.4	19	2,068	$1.31x10^{11}$	Southland	McDowell et al. (2008);+unpub.
Deer	Pasture	Easy	270	800	24	25		0.6	14	398	$5.52x10^{11}$	Southland	
Deer	Winter crop	Rolling	240	800	<1	60	45	2	3	1,012	$5.1x10^{10}$	Southland	McDowell and Stevens (2008); +unpub.
Dairy	Pasture	Flat	40	3,000	3,400			1.5	13			Westland	Davies-Colley and Nagels (2002)
Dairy	Pasture	Flat	30	3,000	5,000			10	48			Westland	
Dairy	Pasture	Rolling	40	3,000	1,600			10.5	50			Westland	
Dairy	Mixed	Rolling	80	1,100	27,000			0.2	9			Waikato	
Dairy	Pasture	Flat	20	1,100	105,000			0.4	27			Waikato	
Dairy	Pasture	Flat	60	1,000	<1	49	72	0.3	28			Manawatu	Houlbrooke et al. (2003)
Dairy	Pasture	Flat	60	1,000	<1	38	72	0.9	31			Manawatu	
Dairy	Pasture	Flat	60	1,000	<1	38	135	1.7	31			Manawatu	Houlbrooke et al. (2008)
Dairy	Pasture	Flat	60	1,000	<1	31	154	2.6	37			Manawatu	
Dairy	Mixed	Rolling	220	780	4	58	78	1.5	1,250		$2.5x10^{10}$	Otago	McDowell (2006b)
Dairy	Pasture	Flat	40	1,000	<1	50		0.4	29			Southland	Monaghan et al. (2000)
Dairy	Pasture	Flat	40	1,000	<1	50	100	0.1	34			Southland	
Dairy	Pasture	Flat	40	1,000	<1	50	200	0.2	46			Southland	
Dairy	Pasture	Flat	40	1,000	<1	50	400	0.4	54			Southland	

Stock	Major land use	Slope class [a]	Elevation (m [b])	Rain (mm/y)	Area (ha)	Contaminant yields (kg/ha/yr)					*E. coli* loss (cfu/ha/yr)	Region	Reference
						P fert. applied	N fert. applied	P loss	N loss	Sediment loss			
Dairy	Pasture	Flat	70	1,132	1,512	78	65	1.2	35	142		Waikato	Wilcock et al. (1999b)
Dairy	Pasture	Flat	100	850	2,480	48	95	0.4	8	58	$1.3x10^{11}$	Southland	Monaghan et al. (2007b)
Dairy	Pasture	Flat	70	1,132	1,512	60	80	0.7	13	67		Waikato	Wilcock et al. (2006)
Dairy	Pasture	Flat	70	1,160	1,580	61	83	1.2	15	38	$1.01x10^{11}$	Waikato	Wilcock et al. (year) Davies-Colley et al. (2007)
Dairy	Pasture	Flat	100	1,250	2,090	65	99	0.7	26	149		Taranaki	
Dairy	Pasture	Flat	60	1,330	4,100	60	62	0.9	8	72		Canterbury	
Dairy	Pasture	Flat	98	4,830	600	50	100	5	23	883		Westland	
Dairy	Pasture	Flat	70	900	2,480	68	37	0.3	7	32		Southland	

Notes:

[a] Slope class is defined as: ≤° = flat; 8–15° = rolling; 16–25° = easy; >25° = steep.

[b] Metres above sea level.

[c] Refers to catchment with a mix of stock types, but largely sheep-and-beef or a catchment with a mix of land uses, but largely pasture.

fert. = fertiliser applied; + unpub. = and unpublished data; ns = no significant difference.

Table C-2: Mean loads derived from catchment studies in New Zealand presented for each stock class. All loads in kg/ha/year except *E. coli* (cfu/ha/year). From McDowell and Wilcock (2008). For superscripts, refer to notes in Table C-1. The F-statistic and LSD [b] at the p<0.05 level (LSD_{05}).

Stock	Slope class [a]	Elevation (m [b])	Rain (mm)	Contaminant loads (kg/ha/yr)					*E. coli* loss (cfu/ha/yr)
				P fert.	N fert.	P loss	N loss	Sediment loss	
Stock type									
Sheep	Easy	268	1,172	41		0.6	3	598	$8.6x1^{09}$
Mixed	Easy	214	1,592	32	35	1.3	11	1,156	
None	Easy	234	1,641			0.2	2	174	
Deer	Rolling	190	890	32	45	1.5	8	2,034	$1.8x10^{11}$
Dairy	Flat	67	1,480	53	108	1.9	27	299	$8.54x10^{10}$
F-statistic [a]	<0.001	<0.001	ns	ns	ns	ns	<0.001	<0.05	ns
LSD_{05}	1 class	151	1,029	22	214	2.6	14	1,394	$4.52x10^{11}$

[a] Significance of difference between stock class

[b] Least significant difference

Appendix D Procedure used for upscaling case study data to catchment level estimates of leaching rates[9]

The following information was sent as an email from WRC to further explain the process followed to estimate nitrogen yields from case-study farms and up-scale these estimates to provide yield estimates for the 74 Healthy Rivers catchments:

> *"The scaling up process built on FarmsOnline (FOL) database (MPI, 2013) clipped to the Waikato extent (defined as the area covered by the sub-catchments) where a definition query was applied by MPI, to select some land use categories including the drystock farming. LCDB (Landcare research, v4.0, 2014) was clipped to the Waikato extent. The area covered by the FarmsOnline categories were erased from LCDB, so LCDB would fill just the gaps in FOL. These two datasets were merged to give one land use dataset for the Waikato, with the above FOL categories having priority, and gaps filled by LCDB categories. This was intersected with the sub-catchment boundaries. The data was cleaned to remove overlaps and a pivot table used to get land use breakdowns for the sub-catchments.*
>
> *To build on the data from previous paragraph, we considered a map showing 66 sub-catchments, the districts and 4 management zones boundaries to have idea of how sub-catchments are distributed by districts and management zones. In terms of how the 66 sub-catchments are distributed by district and catchment, land area under drystock farming are visually assigned to the catchments and zones using a map showing the 66 sub-catchments, the catchments and districts. Such that the lower Waikato Catchment approximately consists of 70% of Waikato District and 5% of Matamata-Piako District land areas. The Central Waikato Catchment approximately consists of 100% Hamilton City, 45% of Waipa District and 5% of Waikato district land areas. The Waipa Catchment approximately consists of 60% of Otorohanga district, 35% of Waipa District, 5% of Waikato District and 20% of Waitomo district land areas. The Upper Waikato Catchment approximately consists of 40% of Taupo district, 45% of Rotorua district, 60% of South Waikato District, 10% of Otorohanga district and 25% of Waipa district land areas.*
>
> *In addition, we considered where relatively large and or small farms are concentrated; likewise where farm systems are concentrated. For example, the agribase database gives us idea of sheep and beef farm systems distribution by area across the region. We also looked at the distribution of farm units by TAs from the NZ Statistics' Agricultural survey data sets. Also, the Kaine (2013) study suggests that more of flat lands are under beef cows, beef cattle & dairy heifer systems farming. More of mainly rolling and some steep are under sheep dominated systems while mainly steep land is fairly distributed across all enterprises but least in dairy heifers and beef cows systems.*
>
> *In summary, the case study farms were approximately related to these sets of information using a number of approximations to match the farm areas given by MPI with some margin of error assumed to be a difference between effective areas and total farm area."*

[9] Dr Femi Olubode-Awosolo, WRC, pers comm (email to N Hudson (NIWA) 20/05/2015).

Appendix E Other leaching rate information derived from on-farm trials

Betteridge et al (2007) investigated nitrate leaching for farming options in the Lake Taupo catchment. The plot-scale trials were located on the west side of Lake Taupo on moderately rolling, deep very free-draining Oruanui Sand (Podzolic Orthic Pumice). Soil water samples were collected in ceramic suction cups once 40 mm of drainage had occurred; drainage volumes were estimated from a water balance model. Removing cattle from the pasture between May and August (no winter grazing) reduced N-leaching from 13 to 5 kg nitrate-N/ha/year (average over three years, 2002 – 2005). No grazing land use leached less than 2 kg nitrate-N/ha/year over this period. The trial indicated that leaching rates were highly dependent on the presence of grazing animals, and could be reduced substantially by removal during the winter period. Leaching increased during wetter conditions irrespective of land use.

Betteridge (2011) compared leaching losses from similar soil and land forms than in the previous trial. The trials differed in terms of pasture type – in the second trial, pasture was replaced with a variety with a high sugar: protein ratio, intended to improve nitrogen use efficiency relative to conventional pasture (the control). This trial highlighted that increased nitrogen leaching may be anticipated following pasture to pasture renovation. This likely arises from increased mineralisation of pasture residues and soil organic matter. Leaching rates from renovated pasture was 63 and 25 kg/ha/yr in 2007/8 and 2008/9 respectively, whereas it was 8 and 22 kg/ha/yr respectively from the control during these periods. The authors suggest that were the effects of pasture renovation to be included in OVERSEER®, farmers would need to reduce stock numbers to comply with nutrient limits, which may reduce the viability of pastoral farming.

Results from trials undertaken to estimate nitrogen leaching from East Coast hill country (Wairarapa) were reported by Crofoot et al (2010). N-leaching rates were measured in plot-scale trials using shallow lysimeter arrays (300 mm depth) installed on low, medium, and high slope areas, which included Taihape steepland and Atua silt loam on easier topography. A single application of urea occurred in mid-winter at rates of 0, 60 and 120 kg N/ha. Rainfall was 1026 mm, mainly in autumn and winter. Leaching rates were determined over a three-year period. Stocking rates were managed so that pasture condition matched that of adjacent farmland. The leaching rate from the 120 kg N/ha treatment was about three time greater than the control and twice that of the 60 kg N/ha treatment (79 kg N/ha /yr vs. 24 and 40 kg N/ha yr respectively). Volume-weighted concentrations of nitrate-N were higher for lower and medium slopes than high slopes for all treatments, although the ranges of concentrations for all slopes and treatments were large. These results indicate that loss of nitrogen may managed by differential application of nutrient (higher application rates on steeper slopes, accompanied by stock movement to maximise use of greater feed growth).

Appendix F An alternate method for estimating nitrogen yields

This appendix summarises an alternative method for estimating N yields that was applied to Canterbury by Lilburn et al (2010). The summary is provided to indicate how an alternate approach may be worth investigating when estimating leaching yields in the Waikato Region in future.

Many difficulties are associated with estimating nitrate-N leaching rates for the main land uses on different soils and rainfall zones, including the rarity of good long term measured data, which means that models cannot be reliability calibrated for Canterbury conditions. An expert approach was used to extend the Lincoln University Dairy Farm data to a range of soils, climates and other land uses. Lilburn et al (2010) produced a series of look-up tables that related land use, soil type, stock type and stocking rate and climate factors to allow estimation of N leaching rates for Canterbury conditions.

After review of the literature, and results from the Lincoln University dairy farm, it was concluded that leaching under the same stocking rate for dairy farms can be modelled with a constant nitrate-N concentration, irrespective of drainage volume within the modelled range of drainage. This conclusion is based on:

i) Bidwell et al. (2003) who reviewed leaching data for a number of land uses and estimated nitrate-N concentration to increase with stocking rate and to have an annual average nitrate-N concentration of 13.9 mg N/L at 4 cows per hectare.

ii) Di et al. (2005), who also reviewed leaching data for a range of land uses in Canterbury, estimated that 'Dairy grassland' has an average annual nitrate-N concentration of 13 mg N/L.

iii) Analysis of the data from the Lincoln University Dairy Farm (a highly efficient farming enterprise) for 4 cows/ha winter off, showed that the best mathematical relationship between nitrate leached (kg N/ha) and amount of drainage (mm) collected in the lysimeters was a straight line.

This dataset is the best available information on leaching under dairy farming in Canterbury and represents seven years of lysimeter leaching data collected from a moderately deep and a stony soil under field conditions. Annual drainage varied from 50 to 600 mm/y (depending on winter rainfall). Values exclude any reductions due to an eco-n effect. The drainage-weighted average nitrate concentration from all the data is 12.5 mg N/L. These results mean that the nitrate concentration in drainage from pastoral land use is assumed to be constant for all values of drainage, and that this constant value is 12.5 mg N/L for the base case of the best practice dairy farms with 4 cows/ha winter off). These nitrate-N load values then formed the 'base' data, from which nitrate-N loads for all the other land uses were then derived according to the assumptions from the Caucus Workshop.

Table F-1: Derivation of the nitrate-N leached values for different farm types. Table 3.1 from Lilburn et al (2010).

Land use/management	Relative ratio	Assumptions
Base = nitrate-N load (mass) of 4 cows/ha winter off		From Lincoln University Dairy Farm data and expected concentration trend
3 cows/ha winter off	75% of base	25% less leaching than 4 cows/ha winter off
3 cows/ha winter on	= base	25% less leaching than 4 cows/ha but with winter on approx = base
4 cows/ha winter on	= base + 25%	The winter on practice adds 25%
5 cows/ha winter off[3]	= base + 15%	The additional stock adds 15%
Beef 100% (irrigated)	= base	Same as 3 dairy cows/ha winter on
Sheep 100% (irrigated)	50% of base	Half the leaching of 4 cows/ha winter off
Deer 100% (irrigated)	60% of base	Sheep + 20%
Dairy Support (irrigated)	= base + 25%	Stock is there only part of the year but are concentrated in a smaller area. Add 25%
Dairy support (dryland)	= base + 25%	Same as irrigated as it involves winter grazing
Pigs (dryland)	= base	Report by LEL (2001) equates an annual nitrogen load limit of 150 kg/ha (pig) to 200 kg/ha (dairy) in terms of permitted activity rules so this leads to pigs = base + 33% The Pork industry argues that pigs should have the same leaching threshold as cows in the regional rules. So it is assumed that pigs = base
Arable		LUCI modelling results (med values, best management practice) Brown & Zyskowski (2009)
Vegetables		Horticulture NZ are commissioning further modelling (C Keenan pers comm.) .
Fruit trees, Lifestyle & Golf		SPASMO modelling results for best management practice (Green & Clothier 2009)
Exotic and native forestry		SWatBal modelling results (Davis & Watts 2008)

Table F-2: Look-up tables used to estimate nitrate-N leached values for different farm types according to irrigation techniques and soil types. From Lilburn et al (2010).

Land use	Concentration (mg N/L)	Irrigation	Area	Drainage (mm/y)											
				Lincoln				Darfield				Hororata			
			Soil	XL	VL	L	M & H	XL	VL	L	M & H	XL	VL	L	M & H
3 cows/ha winter off	9.4	Spray irrigation		400	325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
3 cows/ha winter on	12.5	Spray irrigation			325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
4 cows/ha winter off	12.5	Spray irrigation		400	325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
4 cows/ha winter on	16.3	Spray irrigation	400		325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
5 cows/ha winter off	14.4	Spray irrigation		400	325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
100% beef	12.5	Dryland	400		140	120	80	180	160	140	100	200	180	160	120
		Spray irrigation			325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
100% sheep	6.3	Dryland		160	140	120	80	180	160	140	100	200	180	160	120
		Spray irrigation		400	325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
100% Deer	7.5	Dryland			140	120	80	180	160	140	100	200	180	160	120
		Spray irrigation			325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
Dairy Support	15.6	Dryland		160	140	120	80	180	160	140	100	200	180	160	120
		Spray irrigation		400	325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
50% beef; 50% sheep	11.5	Dryland			140	120	80	180	160	140	100	200	180	160	120
		Spray irrigation			325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
20% Beef; 80% Sheep	9.8	Dryland		160	140	120	80	180	160	140	100	200	180	160	120
		Spray irrigation		400	325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
10% Beef; 90% Sheep	8.6	Dryland			140	120	80	180	160	140	100	200	180	160	120
		Spray irrigation			325	250	150	450	350	255	180	500	375	260	210
		Border Dyke		1060	690	610	610	1150	760	670	660	1200	820	740	710
Pigs	12.5	Dryland		160	140	120	80	180	160	140	100	200	180	160	120

Land use	Concentration (mg N/L)	Irrigation	Area	Nitrate mass (kg N/ha/y)											
				Lincoln				Darfield				Hororata			
			Soil	XL	VL	L	M & H	XL	VL	L	M & H	XL	VL	L	M & H
3 cows/ha winter off	9.4	Spray irrigation		38	30	23	14	42	33	24	17	47	35	24	20
		Border Dyke		99	65	57	57	108	71	63	62	113	77	69	67
3 cows/ha winter on	12.5	Spray irrigation		50	41	31	19	56	44	32	23	63	47	33	26
		Border Dyke			86	76	76	144	95	84	83	150	103	93	89
4 cows/ha winter off	12.5	Spray irrigation		50	41	31	19	56	44	32	23	63	47	33	26
		Border Dyke		133	86	76	76	144	95	84	83	150	103	93	89
4 cows/ha winter on	16.3	Spray irrigation	133	65	53	41	24	73	57	41	29	81	61	42	34
		Border Dyke		172	112	99	99	187	124	109	107	195	133	120	115
5 cows/ha winter off	14.4	Spray irrigation		58	47	36	22	65	50	37	26	72	54	37	30
		Border Dyke		152	99	88	88	165	109	96	95	173	118	106	102
100% beef	12.5	Dryland		20	18	15	10	23	20	18	13	25	23	20	15
		Spray irrigation		50	41	31	19	56	44	32	23	63	47	33	26
		Border Dyke			86	76	76	144	95	84	83	150	103	93	89
100% sheep	6.3	Dryland		10	9	8	5	11	10	9	6	13	11	10	8
		Spray irrigation		25	20	16	9	28	22	16	11	31	23	16	13
		Border Dyke		66	43	38	38	72	48	42	41	75	51	46	44
100% Deer	7.5	Dryland		12	11	9	6	14	12	11	8	15	14	12	9
		Spray irrigation		30	24	19	11	34	26	19	14	38	28	20	16
		Border Dyke		80	52	46	46	86	57	50	50	90	62	56	53
Dairy Support	15.6	Dryland		25	22	19	13	28	25	22	16	31	28	25	19
		Spray irrigation		63	51	39	23	70	55	40	28	78	59	41	33
		Border Dyke		166	108	95	95	180	119	105	103	188	128	116	111
50% beef; 50% sheep	11.5	Dryland		18	16	14	9	21	18	16	12	23	21	18	14
		Spray irrigation		46	37	29	17	52	40	29	21	58	43	30	24
		Border Dyke		122	79	70	70	132	87	77	76	138	94	85	82
20% Beef; 80% Sheep	9.8	Dryland		16	14	12	8	18	16	14	10	20	18	16	12
		Spray irrigation		39	32	25	15	44	34	25	18	49	37	25	21
		Border Dyke		104	68	60	60	113	74	66	65	118	80	73	70
10% Beef; 90% Sheep	8.6	Dryland		14	12	10	7	15	14	12	9	17	15	14	10
		Spray irrigation		34	28	21	13	39	30	22	15	43	32	22	18
		Border Dyke		91	59	52	52	98	65	57	56	103	70	63	61
Pigs	12.5	Dryland		20	18	15	10	23	20	18	13	25	23	20	15

Appendix G Estimates of nitrogen leaching losses for 74 Healthy Rivers sub-catchments by land use

Estimates at decadal intervals and selected additional years for the period 1972-2012:

Table G-1: Nitrogen leaching loss (t/y) by catchment and year for each land use.

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1972	Pueto	1	0	61	0	6.9	1.8	0	12.9	0	82.5
1972	Waikato at Ohaaki	2	2.4	29.8	0	30	1	0.1	86.4	0	149.7
1972	Waikato at Ohakuri	3	149	38.7	0	60.7	4.2	23.7	73.4	0	349.7
1972	Torepatutahi	4	44.1	43.5	0	6.8	0	3.6	44.1	0	142.1
1972	Mangakara	5	4.4	0	0	2.9	0.6	0	5	0	13
1972	Waiotapu at Homestead	6	75.1	39.2	0	4.1	4.1	0.5	17.7	0	140.8
1972	Kawaunui	7	0	0	0	2.7	0.7	0.1	7.6	0	11.1
1972	Waiotapu at Campbell	8	1	8.1	0	4	0.3	5.3	16	0	34.8
1972	Otamakokore	9	29.3	0	0	4	0.2	0.8	6.8	0	41
1972	Whirinaki	10	0.8	0	0	1.1	0.4	2.1	2.1	0	6.5
1972	Waikato at Whakamaru	11	50.3	86.2	0	28.4	9.2	16.4	37.5	0	228
1972	Waipapa	12	10	10.7	0	9.2	0.7	18.1	10.4	0	59.1
1972	Tahunaatara	13	51.5	15.6	0	10.2	10.7	26	32.1	0	146
1972	Mangaharakeke	14	12.7	17.9	0	0	0	0	3	0	33.6
1972	Waikato at Waipapa	15	111.1	79.5	0	19.2	41.8	130.5	59	0	441.1
1972	Mangakino	16	7.1	0	0	14.7	27.3	18.5	30.7	0	98.3
1972	Mangamingi	17	52.6	5.9	0	0	0	2.5	0.9	1.7	63.6
1972	Whakauru	18	26.8	14.8	0	0	0	0.7	0	0.4	42.7
1972	Pokaiwhenua	19	151.7	69.7	0	0.7	6.1	44.7	2.1	0	275.1
1972	Little Waipa	20	41.8	22.8	0	0	0	27.1	0.8	0	92.4
1972	Waikato at Karapiro	21	212.1	30	0	6.1	6.9	262.7	19.6	0	537.3

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1972	Karapiro	22	21	0	0	0	0.9	41.2	2.6	0	65.6
1972	Waikato at Narrows	23	102.7	0	0	1.2	0.1	5.4	21.1	2.8	133.2
1972	Mangawhero	24	38.3	0	0	0	0	6.2	13.8	0.2	58.5
1972	Waikato at Bridge St Br	25	51.8	0	0	0	0	0.2	5.4	2.2	59.5
1972	Mangaonua	26	69.3	0	0	0.5	0.4	13.2	6.2	0	89.5
1972	Mangakotukutuku	27	16.4	0	0	0.4	0	0.1	7.1	1.5	25.5
1972	Mangaone	28	60.3	0	0	0.1	0	0	13.5	0.7	74.6
1972	Waikato at Horotiu Br	29	32.8	0	0	0	0	0	5.1	6.4	44.4
1972	Waitawhiriwhiri	30	10.5	0	0	0.1	0	0	1.8	3.1	15.6
1972	Kirikiriroa	31	8.5	0	0	0	0	0	3.4	0.7	12.6
1972	Waikato at Huntly-Tainui Br	32	140.6	0	0	0.2	2.5	7.6	30.4	4.3	185.5
1972	Komakorau	33	177.5	0	0	0	0	0	33.8	0	211.2
1972	Mangawara	34	245.4	0	0	0.4	4.7	16.7	125.2	0	392.4
1972	Waikato at Rangiriri	35	36.2	0	0	1.7	0	4.4	8.8	3.2	54.3
1972	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	22.8	0	0	2.5	0	4.3	9.4	0	39
1972	Awaroa (Rotowaro) at Sansons Br	37	3.7	0	0	1	0.7	27.9	2.8	0	36.1
1972	Waikato at Mercer Br	38	99.8	0.4	34.5	15.7	7.2	88.2	128.7	0.1	374.6
1972	Whangape	39	25.1	0	0	4.2	0	162.7	74.8	0	266.8
1972	Whangamarino at Island Block Rd	40	30.9	0	0	10.3	2.1	0.1	51.8	0	95.1
1972	Whangamarino at Jefferies Rd Br	41	24.3	0	0	0	3.5	15.1	33.7	0	76.5
1972	Waerenga	42	0.3	0	0	0	0	12.3	4.3	0	16.9
1972	Matahuru	43	24	0	0	0	1.3	31.6	32.1	0	89.1
1972	Waikare	44	31	0	0	8.9	0.1	0.5	27.8	0	68.4
1972	Opuatia	45	8.6	0	0	0.1	0	56.1	2.3	0	67

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1972	Mangatangi	46	34.2	0.6	0.6	0.3	16.2	9.7	65.8	0	127.3
1972	Waikato at Tuakau Br	47	31	2	68.2	0.3	6	13.6	55.3	0.2	176.5
1972	Ohaeroa	48	9.7	0	0	0	0	5.8	4.1	0	19.6
1972	Mangatawhiri	49	2.5	0	0.6	0	15.1	0.2	3.9	0	22.3
1972	Waikato at Port Waikato	50	101.4	4.1	75.4	2.4	4.2	41.3	65.2	0.4	294.3
1972	Whakapipi	51	2.8	0.2	65.5	0.1	0.9	2.2	19.1	1.1	91.9
1972	Awaroa (Waiuku)	52	9.9	0.1	7.4	0	0.1	0.2	11.6	0.1	29.3
1972	Waipa at Mangaokewa Rd	100	0	0	0	0	5.1	9.9	0	0	15
1972	Waipa at Otewa	101	14.7	0	0	0	33.1	121.5	1.4	0	170.6
1972	Mangaokewa	102	1.3	0	0	0	8.1	114	1.1	1.4	125.9
1972	Mangarapa	103	16	0	0	0	0	33.7	3.7	0	53.4
1972	Mangapu	104	68.8	0	0	0	0.2	81.7	11.5	1.3	163.5
1972	Mangarama	105	6.2	0	0	0	0.1	37.1	6.3	0	49.6
1972	Waipa at Otorohanga	106	107.4	0	0	0	0.3	49.6	4.9	0.8	163
1972	Waipa at Pirongia-Ngutunui Rd Br	107	405.3	0	0	0.1	7.8	98.9	16.9	0.5	529.4
1972	Waitomo at Tumutumu Rd	108	2.3	0	0	0.3	1.2	30.1	0	0	33.9
1972	Waitomo at SH31 Otorohanga	109	20.7	0	0	0	2.3	14.8	3.1	0	40.9
1972	Moakurarua	110	22.4	0	0	0.3	7.8	132.9	2.3	0	165.8
1972	Puniu at Bartons Corner Rd Br	111	127.6	0	0	2.9	0.3	97.9	13.8	0	242.5
1972	Puniu at Wharepapa	112	13.5	0	0	0	5.6	106.8	9.9	0	135.8
1972	Mangatutu	113	33.9	0	0	0.4	11.1	41.5	4.6	0	91.6
1972	Mangapiko	114	221.8	0	0	0.4	2	72.8	29.2	1.2	327.5
1972	Mangaohoi	115	0	0	0	0	0.9	0.6	0	0	1.5
1972	Waipa at SH23 Br Whatawhata	116	236.9	0	0	4.7	4.9	41.5	47.9	0	335.9

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1972	Mangauika	117	0.3	0	0	0	1.7	2.3	0	0	4.3
1972	Kaniwhaniwha	118	36.8	0	0	0.1	8.7	32.8	3.7	0	82
1972	Waipa at Wainaro Rd Br	119	66.8	0	0	3.7	3.4	36.8	23.9	1.8	136.4
1972	Ohote	120	37.7	0	0	0.2	0	0	3.7	0.3	41.9
1972	Firewood	121	0.3	0	0	0	1.8	22.4	0.1	0	24.6
1982	Pueto	1	0.4	62.7	1.9	4	2.3	0	17.5	0.2	89
1982	Waikato at Ohaaki	2	10.3	35.7	21.4	18	2	0.4	108.1	1.2	197
1982	Waikato at Ohakuri	3	201.9	49.6	2.2	36.8	6.7	29.7	126.3	0.1	453.2
1982	Torepatutahi	4	76.5	44.1	4.5	4	0.4	2.5	42.4	0.1	174.6
1982	Mangakara	5	5.2	0.3	0	1.7	0.8	0.1	8.7	0	16.8
1982	Waiotapu at Homestead	6	90.6	40.1	2.9	2.5	4.2	1.7	23.4	0.1	165.5
1982	Kawaunui	7	6.2	0.2	0.1	1.6	0.8	0.2	7.6	0	16.7
1982	Waiotapu at Campbell	8	4	8.1	0	2.4	0.9	6.8	18.3	0	40.5
1982	Otamakokore	9	37.5	0.2	0	2.3	0.7	1	10.6	0	52.4
1982	Whirinaki	10	1.8	0.1	0	0.6	0.5	2.5	2.6	0	8.2
1982	Waikato at Whakamaru	11	69.2	96.5	0.5	17.6	7.3	29.3	50.1	0.1	270.6
1982	Waipapa	12	10.8	11.8	0.9	5.4	0.9	25.9	16.8	0	72.4
1982	Tahunaatara	13	69.4	21.3	0	6	10.4	25	38.2	0	170.4
1982	Mangaharakeke	14	13.6	17.9	0	0	0.1	0.2	3.3	0	35.1
1982	Waikato at Waipapa	15	145.4	92.9	0.6	11.9	43.3	122.1	61.7	0.6	478.6
1982	Mangakino	16	13.6	2.9	1.2	8.6	26.7	22.5	47.1	0	122.6
1982	Mangamingi	17	59.4	5.4	1.5	0	0	6.3	1.3	1.7	75.5
1982	Whakauru	18	30.4	14.3	0	0	0	2.7	0.6	0.4	48.5
1982	Pokaiwhenua	19	197.2	72.2	0.3	0.4	5.7	39.8	3.5	0.1	319.2

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1982	Little Waipa	20	60.5	21.3	0	0	0.1	28.7	0.8	0	111.4
1982	Waikato at Karapiro	21	290.3	29.8	16.9	5.5	10.2	248.7	25.1	0.2	626.7
1982	Karapiro	22	25.2	0.2	0.4	0	0.9	41.8	4.2	0	72.7
1982	Waikato at Narrows	23	107.9	0.3	4.2	0.9	0.6	5.9	33.7	2.7	156.2
1982	Mangawhero	24	44.5	0	6.6	0	0.2	5.4	16.5	0.2	73.4
1982	Waikato at Bridge St Br	25	56.7	0.1	11	0.1	0.2	0.2	8.1	2	78.5
1982	Mangaonua	26	76.7	0.1	3.5	0.3	1	13.9	11.1	0	106.6
1982	Mangakotukutuku	27	22.4	0	0.9	0.2	0	0.1	7.3	1.4	32.4
1982	Mangaone	28	65.8	0.2	10.6	0.1	0.1	0	18.5	0.6	95.9
1982	Waikato at Horotiu Br	29	33.1	0	1.6	0.1	0.1	0	8	6.7	49.6
1982	Waitawhiriwhiri	30	11	0	0	0.1	0	0	3.4	3	17.6
1982	Kirikiriroa	31	8.9	0	0.8	0	0	0	3.7	0.9	14.3
1982	Waikato at Huntly-Tainui Br	32	155.4	0.4	1.9	0.5	4.1	7.3	38.8	3.1	211.5
1982	Komakorau	33	223.1	0	5.4	0	0	0	35.1	0.1	263.8
1982	Mangawara	34	304.4	0.7	3.8	0.3	7.4	13.6	127.2	0	457.4
1982	Waikato at Rangiriri	35	34.7	0.3	0.1	1.4	1.1	3	15.4	2.4	58.4
1982	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	24.9	0.1	0	2.1	0.4	5	11.4	0.1	44
1982	Awaroa (Rotowaro) at Sansons Br	37	4.5	0.3	0	1.1	1.3	26.1	2.8	0	36.1
1982	Waikato at Mercer Br	38	115.3	5.9	75.6	11.4	7.1	89.9	140	0.3	445.3
1982	Whangape	39	30.1	1.3	0.3	3.7	2.7	160.5	79.8	0	278.5
1982	Whangamarino at Island Block Rd	40	37.5	2.4	7.6	9	2.5	0.1	52.3	0.1	111.3
1982	Whangamarino at Jefferies Rd Br	41	32.7	2.5	0	0	2.7	13.8	33	0	84.7
1982	Waerenga	42	0.8	0	0	0	0.2	12.3	4	0	17.4
1982	Matahuru	43	27.2	0.5	0	0	1.5	33	34.7	0	96.9

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1982	Waikare	44	28.3	0.1	3.5	9.4	0.6	0.4	34.2	0.1	76.5
1982	Opuatia	45	8.6	1.6	1.6	0.1	0.8	52.7	3	0	68.3
1982	Mangatangi	46	44.2	1.9	1.5	0.3	16.4	7.7	66.7	0	138.8
1982	Waikato at Tuakau Br	47	36.1	2.2	87	0.3	6.3	13.5	56.4	0.2	202
1982	Ohaeroa	48	8.3	0.1	6.9	0	0.2	6	5.2	0	26.7
1982	Mangatawhiri	49	3.2	0.7	0.6	0.1	14.5	0.2	4.2	0	23.5
1982	Waikato at Port Waikato	50	118.8	7.1	83.2	2.4	5.7	34	68.9	0.4	320.5
1982	Whakapipi	51	3.6	0.2	66.3	0.1	0.8	2.3	20.1	1.2	94.5
1982	Awaroa (Waiuku)	52	12.5	0.1	7.4	0	0.1	0.2	12.2	0.1	32.6
1982	Waipa at Mangaokewa Rd	100	0	2.1	0	0	4	9.8	0	0	15.8
1982	Waipa at Otewa	101	16.1	2.3	0	0.1	34.1	119.5	1.2	0.1	173.5
1982	Mangaokewa	102	3.4	2.2	0	0.1	7.9	116.2	1.3	0.9	132
1982	Mangarapa	103	18.2	0.1	0	0	0.4	34.9	3.5	0	57.2
1982	Mangapu	104	81.9	0.4	0.9	0.1	1.4	81.4	13.7	1.1	181
1982	Mangarama	105	9.3	0.2	0	0	0.3	37.8	5.7	0	53.4
1982	Waipa at Otorohanga	106	125.5	0.2	0.6	0	0.9	52.5	7	0.7	187.5
1982	Waipa at Pirongia-Ngutunui Rd Br	107	483.7	0.8	7.7	0.2	9.2	106.6	20.1	0.6	628.9
1982	Waitomo at Tumutumu Rd	108	1.7	0.6	0	0.2	2.4	27	0	0	32
1982	Waitomo at SH31 Otorohanga	109	19.4	0.2	0	0	2.5	17	3.7	0	42.9
1982	Moakurarua	110	29.3	1.1	0	0.2	11.6	122.6	3.4	0.1	168.2
1982	Puniu at Bartons Corner Rd Br	111	169.6	0.8	7.6	1.7	0.4	96.7	16.8	0.3	293.9
1982	Puniu at Wharepapa	112	18.9	0.5	0	0	7.5	103.8	10.1	0	140.8
1982	Mangatutu	113	42.9	0.2	4.7	0.2	11.8	39	6.2	0.1	105.2
1982	Mangapiko	114	276	0.4	6.9	0.3	3	72.1	31.9	1.4	392

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1982	Mangaohoi	115	0.2	0	0	0	0.9	0.5	0	0	1.6
1982	Waipa at SH23 Br Whatawhata	116	277.6	1.4	6.9	3.1	6.2	43.1	57.9	0.4	396.6
1982	Mangauika	117	0.3	0	0	0	1.9	1.7	0	0	4
1982	Kaniwhaniwha	118	42.4	0.1	0	0.1	9.6	31.1	5.9	0	89.1
1982	Waipa at Wainaro Rd Br	119	76.4	1.9	4.3	2.5	5.4	34.5	27.7	1.3	153.9
1982	Ohote	120	37.6	0.1	1.7	0.1	0	0.1	9.8	0.4	49.8
1982	Firewood	121	0.3	0.3	0	0	2.3	20.8	0.3	0	24
1992	Pueto	1	0.9	64.5	3.7	1.2	2.8	0.1	22.4	0.3	95.9
1992	Waikato at Ohaaki	2	21.3	41.5	42.8	6	2.9	0.8	131.2	2.3	248.9
1992	Waikato at Ohakuri	3	260.4	60.5	4.3	12.8	9.2	36	183.7	0.2	567.2
1992	Torepatutahi	4	117.6	44.7	9	1.2	0.8	1.4	40.3	0.1	215.2
1992	Mangakara	5	5.8	0.7	0	0.5	1	0.2	12.8	0	20.9
1992	Waiotapu at Homestead	6	104.1	41.1	5.8	0.8	4.4	3	29.5	0.1	188.8
1992	Kawaunui	7	15	0.4	0.1	0.4	1	0.3	7.5	0	24.8
1992	Waiotapu at Campbell	8	8.2	8	0	0.8	1.5	8.3	20.8	0	47.6
1992	Otamakokore	9	45.8	0.5	0	0.7	1.3	1.3	14.7	0.1	64.3
1992	Whirinaki	10	3.2	0.1	0	0.2	0.6	2.9	3.2	0	10.3
1992	Waikato at Whakamaru	11	90.4	106.7	1.1	6.8	5.5	43.3	63.7	0.3	317.7
1992	Waipapa	12	10.8	12.8	1.7	1.6	1.2	34.4	23.7	0	86.1
1992	Tahunaatara	13	89.2	27.1	0	1.7	10.1	23.8	44.8	0	196.7
1992	Mangaharakeke	14	13.5	17.9	0	0	0.3	0.4	3.6	0.1	35.6
1992	Waikato at Waipapa	15	181.6	106.3	1.2	4.7	44.9	112.1	64.3	1.2	516.3
1992	Mangakino	16	22.1	5.9	2.3	2.6	26	26.8	64.8	0	150.6
1992	Mangamingi	17	63.1	4.8	2.9	0	0	10.3	1.8	1.7	84.7

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1992	Whakauru	18	32.5	13.8	0	0	0.1	4.9	1.2	0.4	53
1992	Pokaiwhenua	19	244.9	74.7	0.6	0.1	5.3	34.1	4.9	0.2	364.9
1992	Little Waipa	20	82.5	19.8	0	0	0.2	30.3	0.8	0	133.6
1992	Waikato at Karapiro	21	377.6	29.6	33.8	4.9	13.6	231.7	31.1	0.5	722.7
1992	Karapiro	22	28.8	0.3	0.8	0.1	1	42.3	5.9	0	79.1
1992	Waikato at Narrows	23	103.8	0.7	8.4	0.7	1.1	6.4	47.3	2.5	170.9
1992	Mangawhero	24	49	0	13.2	0	0.4	4.6	19.4	0.1	86.7
1992	Waikato at Bridge St Br	25	57.9	0.1	22	0.2	0.4	0.3	11.1	1.9	93.9
1992	Mangaonua	26	79.4	0.2	7.1	0.1	1.6	14.5	16.5	0.1	119.4
1992	Mangakotukutuku	27	29.2	0	1.7	0.1	0.1	0.1	7.4	1.3	40
1992	Mangaone	28	66.8	0.3	21.2	0	0.3	0	23.9	0.5	113.1
1992	Waikato at Horotiu Br	29	29.8	0	3.3	0.3	0.1	0	11.1	6.9	51.6
1992	Waitawhiriwhiri	30	10.6	0.1	0	0.1	0	0	5.2	2.9	18.9
1992	Kirikiriroa	31	8.5	0	1.5	0	0.1	0	4.1	1	15.1
1992	Waikato at Huntly-Tainui Br	32	160.7	0.7	3.8	0.7	5.8	7	47.9	2	228.5
1992	Komakorau	33	267.9	0.1	10.9	0	0.1	0	36.4	0.1	315.5
1992	Mangawara	34	360.6	1.4	7.7	0.2	10.1	10.2	128.6	0.1	518.8
1992	Waikato at Rangiriri	35	28.6	0.6	0.2	1	2.3	1.5	22.5	1.6	58.1
1992	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	25.3	0.2	0	1.7	0.8	5.8	13.6	0.2	47.6
1992	Awaroa (Rotowaro) at Sansons Br	37	5.1	0.5	0	1.2	1.9	24	2.8	0	35.6
1992	Waikato at Mercer Br	38	126.2	11.3	116.8	7	6.9	91.1	151.6	0.4	511.4
1992	Whangape	39	34.4	2.6	0.6	3.3	5.5	157.1	84.8	0	288.3
1992	Whangamarino at Island Block Rd	40	43.4	4.8	15.2	7.7	2.8	0.1	52.5	0.2	126.6
1992	Whangamarino at Jefferies Rd Br	41	42	5	0	0	1.9	12.3	32.1	0	93.3

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1992	Waerenga	42	1.4	0.1	0	0	0.4	12.3	3.8	0	17.9
1992	Matahuru	43	29.1	0.9	0	0	1.7	34.4	37.2	0	103.4
1992	Waikare	44	20.8	0.1	7	9.8	1	0.3	41.1	0.2	80.3
1992	Opuatia	45	7.7	3.1	3.2	0	1.5	48.8	3.8	0	68.1
1992	Mangatangi	46	54.6	3.2	2.4	0.4	16.6	5.5	67.2	0	150.1
1992	Waikato at Tuakau Br	47	40.1	2.4	105.8	0.4	6.5	13.3	57.3	0.2	225.9
1992	Ohaeroa	48	5.3	0.1	13.8	0	0.4	6.2	6.3	0	32.1
1992	Mangatawhiri	49	3.9	1.4	0.6	0.3	13.8	0.2	4.6	0	24.8
1992	Waikato at Port Waikato	50	132.1	10.1	91	2.3	7.2	25.7	72.7	0.5	341.6
1992	Whakapipi	51	4.3	0.2	67.1	0.1	0.7	2.4	21.1	1.3	97.1
1992	Awaroa (Waiuku)	52	15.1	0.1	7.4	0	0.1	0.2	12.7	0.1	35.8
1992	Waipa at Mangaokewa Rd	100	0	4.1	0	0	2.8	9.6	0	0	16.6
1992	Waipa at Otewa	101	16.6	4.6	0	0.2	35.2	116.7	1	0.2	174.4
1992	Mangaokewa	102	6.3	4.4	0	0.1	7.6	118	1.6	0.5	138.4
1992	Mangarapa	103	19.5	0.3	0	0	0.8	36.1	3.3	0	60
1992	Mangapu	104	92.8	0.8	1.8	0.2	2.7	80.6	16.1	0.9	195.9
1992	Mangarama	105	13.1	0.4	0	0	0.5	38.3	5.1	0	57.5
1992	Waipa at Otorohanga	106	139.3	0.4	1.2	0.1	1.6	55.4	9.3	0.6	207.9
1992	Waipa at Pirongia-Ngutunui Rd Br	107	549.7	1.6	15.3	0.4	10.5	114.5	23.6	0.6	716.3
1992	Waitomo at Tumutumu Rd	108	0.7	1.3	0	0.1	3.5	23.5	0.1	0	29.2
1992	Waitomo at SH31 Otorohanga	109	15.3	0.4	0	0	2.7	19.4	4.3	0	42.2
1992	Moakurarua	110	36.5	2.3	0	0.1	15.3	110.5	4.5	0.2	169.3
1992	Puniu at Bartons Corner Rd Br	111	214.8	1.6	15.3	0.6	0.6	94.7	20	0.6	348.1
1992	Puniu at Wharepapa	112	25.1	1	0	0	9.3	99.9	10.2	0	145.6

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1992	Mangatutu	113	51.8	0.4	9.4	0.1	12.5	36	8	0.1	118.4
1992	Mangapiko	114	328.1	0.8	13.7	0.1	4	70.9	34.8	1.6	454.1
1992	Mangaohoi	115	0.6	0	0	0	0.9	0.4	0	0	1.9
1992	Waipa at SH23 Br Whatawhata	116	308.9	2.8	13.8	1.4	7.5	44.6	68.6	0.8	448.5
1992	Mangauika	117	0.3	0.1	0	0	2	1.2	0	0	3.6
1992	Kaniwhaniwha	118	46.2	0.2	0	0	10.4	29	8.4	0	94.2
1992	Waipa at Wainaro Rd Br	119	82.5	3.8	8.5	1.2	7.5	31.8	31.6	0.8	167.8
1992	Ohote	120	33.2	0.2	3.3	0.1	0.1	0.1	16.5	0.4	53.9
1992	Firewood	121	0.2	0.5	0	0	2.9	18.9	0.5	0	23.1
1996	Pueto	1	1.2	65.2	4.5	0.1	3	0.1	24.5	0.4	98.9
1996	Waikato at Ohaaki	2	26.6	43.9	51.3	1.2	3.3	1	141	2.8	271.1
1996	Waikato at Ohakuri	3	285.5	64.8	5.2	3.2	10.2	38.8	208.1	0.2	616
1996	Torepatutahi	4	136.6	45	10.8	0.1	1	0.9	39.3	0.2	233.8
1996	Mangakara	5	6	0.8	0	0	1.1	0.2	14.5	0	22.5
1996	Waiotapu at Homestead	6	109.1	41.4	7	0.1	4.4	3.6	32.1	0.1	197.8
1996	Kawaunui	7	19.2	0.5	0.1	0	1.1	0.4	7.5	0	28.8
1996	Waiotapu at Campbell	8	10.2	8	0	0.1	1.7	9	21.8	0.1	50.9
1996	Otamakokore	9	49.2	0.6	0	0	1.5	1.5	16.5	0.1	69.3
1996	Whirinaki	10	3.8	0.1	0	0	0.7	3.1	3.4	0	11.2
1996	Waikato at Whakamaru	11	99.6	110.9	1.3	2.5	4.7	49.2	69.4	0.3	337.9
1996	Waipapa	12	10.6	13.2	2.1	0	1.2	38	26.6	0	91.7
1996	Tahunaatara	13	97.7	29.4	0	0	9.9	23.2	47.6	0	208
1996	Mangaharakeke	14	13.1	17.9	0	0	0.4	0.4	3.7	0.1	35.5
1996	Waikato at Waipapa	15	196.7	111.6	1.5	1.7	45.5	107.8	65.3	1.5	531.7

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1996	Mangakino	16	26.1	7.1	2.8	0.1	25.8	28.7	72.4	0	162.9
1996	Mangamingi	17	63.8	4.6	3.5	0	0	12.1	2	1.7	87.7
1996	Whakauru	18	33	13.6	0	0	0.1	5.8	1.5	0.4	54.4
1996	Pokaiwhenua	19	264.7	75.6	0.7	0	5.2	31.7	5.6	0.2	383.7
1996	Little Waipa	20	92.3	19.3	0	0	0.2	30.9	0.8	0	143.5
1996	Waikato at Karapiro	21	415.3	29.5	40.6	4.6	14.9	224.3	33.6	0.6	763.4
1996	Karapiro	22	30.1	0.4	1	0.1	1	42.4	6.7	0	81.6
1996	Waikato at Narrows	23	99.6	0.8	10.1	0.6	1.4	6.6	53.1	2.5	174.7
1996	Mangawhero	24	50.3	0.1	15.8	0	0.4	4.2	20.7	0.1	91.6
1996	Waikato at Bridge St Br	25	57.4	0.1	26.4	0.3	0.5	0.3	12.4	1.8	99.1
1996	Mangaonua	26	79.3	0.2	8.5	0	1.8	14.8	18.8	0.1	123.4
1996	Mangakotukutuku	27	32.2	0.1	2.1	0	0.1	0.1	7.5	1.2	43.2
1996	Mangaone	28	66.3	0.4	25.5	0	0.3	0.1	26.2	0.5	119.3
1996	Waikato at Horotiu Br	29	27.5	0.1	3.9	0.3	0.1	0	12.4	7	51.4
1996	Waitawhiriwhiri	30	10.1	0.1	0	0.1	0	0	6	2.8	19.1
1996	Kirikiriroa	31	8.1	0	1.8	0	0.1	0	4.2	1.1	15.3
1996	Waikato at Huntly-Tainui Br	32	160.2	0.9	4.6	0.8	6.4	6.8	51.7	1.6	232.9
1996	Komakorau	33	285.8	0.1	13.1	0	0.1	0	36.9	0.1	336.2
1996	Mangawara	34	382.5	1.6	9.2	0.1	11.2	8.8	129.1	0.1	542.6
1996	Waikato at Rangiriri	35	24.8	0.7	0.2	0.8	2.7	0.9	25.6	1.2	56.9
1996	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	25	0.3	0	1.6	1	6.1	14.5	0.2	48.7
1996	Awaroa (Rotowaro) at Sansons Br	37	5.4	0.6	0	1.2	2.2	23.1	2.8	0	35.3
1996	Waikato at Mercer Br	38	129.3	13.5	133.2	5.3	6.9	91.6	156.5	0.5	536.8
1996	Whangape	39	35.9	3.1	0.8	3.1	6.5	155.6	86.9	0.1	291.9

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1996	Whangamarino at Island Block Rd	40	45.6	5.7	18.2	7.2	3	0.1	52.5	0.2	132.5
1996	Whangamarino at Jefferies Rd Br	41	45.9	6.1	0	0	1.5	11.6	31.7	0.1	96.9
1996	Waerenga	42	1.7	0.1	0	0	0.4	12.2	3.6	0	18.1
1996	Matahuru	43	29.5	1.1	0	0	1.8	35	38.3	0	105.7
1996	Waikare	44	16.6	0.1	8.4	9.9	1.1	0.2	44	0.3	80.8
1996	Opuatia	45	7	3.7	3.9	0	1.8	47.1	4.1	0	67.7
1996	Mangatangi	46	58.9	3.8	2.8	0.4	16.7	4.6	67.4	0	154.6
1996	Waikato at Tuakau Br	47	41.5	2.4	113.3	0.4	6.6	13.2	57.9	0.2	235.5
1996	Ohaeroa	48	3.6	0.2	16.6	0	0.5	6.2	6.8	0	33.8
1996	Mangatawhiri	49	4.2	1.7	0.6	0.3	13.6	0.3	4.7	0	25.3
1996	Waikato at Port Waikato	50	136.3	11.3	94.1	2.3	7.8	22.1	74.2	0.5	348.8
1996	Whakapipi	51	4.6	0.2	67.4	0.1	0.6	2.4	21.5	1.3	98.1
1996	Awaroa (Waiuku)	52	16.2	0.1	7.4	0	0.1	0.2	13	0.1	37.1
1996	Waipa at Mangaokewa Rd	100	0	4.9	0	0.1	2.4	9.5	0	0	16.9
1996	Waipa at Otewa	101	16.4	5.5	0	0.2	35.6	115.4	0.9	0.2	174.3
1996	Mangaokewa	102	7.6	5.2	0	0.2	7.5	118.7	1.7	0.3	141.2
1996	Mangarapa	103	19.9	0.3	0	0	1	36.6	3.2	0	60.9
1996	Mangapu	104	96.6	1	2.2	0.3	3.2	80.3	17.1	0.8	201.3
1996	Mangarama	105	14.8	0.5	0	0	0.6	38.6	4.8	0	59.4
1996	Waipa at Otorohanga	106	143.7	0.5	1.4	0.1	1.8	56.7	10.3	0.5	215
1996	Waipa at Pirongia-Ngutunui Rd Br	107	572.9	1.9	18.4	0.4	11.1	117.9	25.1	0.6	748.3
1996	Waitomo at Tumutumu Rd	108	0.1	1.5	0	0	4	22	0.1	0	27.8
1996	Waitomo at SH31 Otorohanga	109	12.8	0.4	0	0	2.8	20.4	4.6	0	41.1
1996	Moakurarua	110	39.5	2.7	0	0	16.8	105.3	4.9	0.2	169.5

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
1996	Puniu at Bartons Corner Rd Br	111	234	1.9	18.3	0.1	0.7	93.8	21.4	0.7	370.8
1996	Puniu at Wharepapa	112	27.8	1.2	0	0	10.1	98.2	10.3	0	147.6
1996	Mangatutu	113	55.4	0.5	11.3	0	12.8	34.7	8.7	0.2	123.7
1996	Mangapiko	114	348.5	1	16.5	0	4.4	70.4	36	1.6	478.5
1996	Mangaohoi	115	0.7	0	0	0	0.9	0.3	0	0	2
1996	Waipa at SH23 Br Whatawhata	116	319.1	3.4	16.6	0.8	8	45.3	73.1	0.9	467.1
1996	Mangauika	117	0.3	0.1	0	0	2.1	0.9	0	0	3.5
1996	Kaniwhaniwha	118	47.2	0.2	0	0	10.8	28.1	9.4	0.1	95.8
1996	Waipa at Wainaro Rd Br	119	84	4.6	10.2	0.6	8.3	30.6	33.3	0.6	172.4
1996	Ohote	120	30.3	0.2	4	0.1	0.1	0.1	19.4	0.4	54.6
1996	Firewood	121	0.2	0.7	0	0	3.1	18.1	0.6	0	22.7
2002	Pueto	1	1.3	63.6	2.2	1.4	2.9	0	24.5	0.4	96.2
2002	Waikato at Ohaaki	2	59	46.2	20.4	1.4	3.1	1	132.3	2.5	265.9
2002	Waikato at Ohakuri	3	407.2	71.8	3.4	5	10.9	31.9	161.7	0.2	692.1
2002	Torepatutahi	4	160	45.2	6.2	0.2	1	0.6	36	0.2	249.2
2002	Mangakara	5	7.5	1.2	0	0	1.1	0.2	13.2	0	23.3
2002	Waiotapu at Homestead	6	125.8	41.6	5.6	0.1	4.4	3.7	29.8	0.2	211.2
2002	Kawaunui	7	24.1	0.7	0.1	0	1	0.3	5.9	0	32.2
2002	Waiotapu at Campbell	8	12.6	10.8	0	0.1	1.7	7.2	15.9	0.1	48.5
2002	Otamakokore	9	54.8	0.7	0	0.5	1.4	1.5	14	0.1	72.9
2002	Whirinaki	10	4.2	0.2	0	0	0.6	3.2	3.5	0	11.8
2002	Waikato at Whakamaru	11	187	112.1	0	3.9	4.6	31.8	56.4	0.3	396.2
2002	Waipapa	12	55.5	12.8	0	0.7	1.2	27.3	23.8	0	121.3
2002	Tahunaatara	13	114.8	29.7	0	0.6	9.9	20.2	47.1	0	222.3

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
2002	Mangaharakeke	14	15.5	18.1	0	0	0.5	0.5	2.1	0.1	36.7
2002	Waikato at Waipapa	15	308.2	117.7	0	5.5	44.1	75.9	45.6	1.5	598.5
2002	Mangakino	16	101.1	6.9	0	1.4	25.7	23.2	52.8	0	211.1
2002	Mangamingi	17	83.7	4.7	0	0.1	0.2	7.7	2	1.7	100
2002	Whakauru	18	40.5	13.7	0	0	0	4.6	1.6	0.4	60.8
2002	Pokaiwhenua	19	343.2	71.8	0.4	2.4	5.3	16.9	4.8	0.2	444.9
2002	Little Waipa	20	153.1	19.6	0	0	0.2	14.3	0.7	0	188
2002	Waikato at Karapiro	21	663.6	30.5	16.5	6.3	15.4	154.5	30.6	0.7	918.1
2002	Karapiro	22	49.3	1	1.4	0.1	1	34.1	6.4	0	93.4
2002	Waikato at Narrows	23	108.6	1.5	17.8	0.7	1.7	3.6	52.4	2.7	188.9
2002	Mangawhero	24	59	0.1	24.8	0	0.6	2.3	19.2	0.1	106.1
2002	Waikato at Bridge St Br	25	30.8	0.1	15.2	0.4	0.7	0.2	26.3	1.9	75.6
2002	Mangaonua	26	74.8	0.3	5.4	0	2.3	13	25.5	0.1	121.4
2002	Mangakotukutuku	27	38.5	0	1.3	0	0.1	0	6.3	1.3	47.5
2002	Mangaone	28	41.5	0.4	15.1	0	0.7	0.1	40.4	0.8	99.1
2002	Waikato at Horotiu Br	29	19	0.1	1.5	0.5	0.4	0	13.8	7.5	42.8
2002	Waitawhiriwhiri	30	11.1	0	0	0.2	0	0	6	2.8	20.2
2002	Kirikiriroa	31	5.5	0	0.3	0	0.1	0	3.2	1.7	10.8
2002	Waikato at Huntly-Tainui Br	32	151.3	0.9	3.2	0.8	7.2	6.7	59.5	1.6	231.4
2002	Komakorau	33	282.8	0.1	11.7	0	1.3	0	44.5	0.2	340.7
2002	Mangawara	34	465.7	1.8	0	0.1	14.3	6.8	106.5	0.1	595.3
2002	Waikato at Rangiriri	35	25.1	0.7	0.1	1	2.9	1	26.3	1.2	58.3
2002	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	27.4	0.3	2.3	1.6	1	6.2	14.5	0.2	53.6
2002	Awaroa (Rotowaro) at Sansons Br	37	5.9	1.1	0	1.4	2.5	21.1	2.8	0	34.8

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
2002	Waikato at Mercer Br	38	149.9	13	57.2	7	8.1	91.9	161	0.5	488.4
2002	Whangape	39	40.5	4.8	0.5	4	6.7	154.5	86	0.1	296.8
2002	Whangamarino at Island Block Rd	40	43.1	3.8	8.1	9.3	3.4	0.1	54	0.2	122.1
2002	Whangamarino at Jefferies Rd Br	41	50.5	6.4	8.7	0	2.1	11.2	28.6	0.1	107.6
2002	Waerenga	42	1.9	1.4	0	0	0.5	10	2.8	0	16.7
2002	Matahuru	43	32.4	1.3	0	0.4	1.8	34.5	38.6	0	109.1
2002	Waikare	44	13.4	0.5	0.1	9.9	1.6	0.2	46.5	0.3	72.5
2002	Opuatia	45	8.9	5.7	2	0	1.8	43.1	4.3	0	65.8
2002	Mangatangi	46	65.9	4	2.1	0.4	17.2	4.5	66.3	0	160.4
2002	Waikato at Tuakau Br	47	48.3	2.1	42.7	2.7	6.5	12	62.5	0.2	177
2002	Ohaeroa	48	4.4	0.3	3.6	0	0.4	6.2	8.6	0	23.6
2002	Mangatawhiri	49	4.7	1.7	0	0.3	13.6	0.3	4.8	0	25.3
2002	Waikato at Port Waikato	50	151.5	9.2	39.6	6.4	8.3	17.6	75.6	0.5	308.8
2002	Whakapipi	51	5.2	0.2	28	0.1	0.6	2.7	27.5	1.3	65.5
2002	Awaroa (Waiuku)	52	17.8	0.1	2.8	0	0.1	0.2	13.2	0.3	34.6
2002	Waipa at Mangaokewa Rd	100	0	4.9	0	0.1	2.4	9.7	0	0	17.1
2002	Waipa at Otewa	101	58.8	6	0	0.9	35.5	100.9	0.7	0.2	203
2002	Mangaokewa	102	19.4	5.1	0	0.8	7.6	115.5	1.5	0.3	150.2
2002	Mangarapa	103	44	0.5	0	0	1.1	28.9	3	0	77.5
2002	Mangapu	104	138.3	2	1	0.5	3.3	67.9	17.3	0.8	230.9
2002	Mangarama	105	26.7	0.6	0	0	0.7	35.6	4.8	0	68.4
2002	Waipa at Otorohanga	106	205.1	0.7	0.4	0.2	2	40	10.3	0.5	259.2
2002	Waipa at Pirongia-Ngutunui Rd Br	107	747	2.7	16.2	0.7	11.8	74.6	24.8	0.6	878.4
2002	Waitomo at Tumutumu Rd	108	0.1	2.1	0	0	3.8	21.7	0.1	0	28

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
2002	Waitomo at SH31 Otorohanga	109	31.7	1.3	0	0	2.9	12.7	4.4	0	52.9
2002	Moakurarua	110	94.6	4.1	3.3	0.2	16.8	85.3	4.9	0.2	209.4
2002	Puniu at Bartons Corner Rd Br	111	312.9	2.6	13.8	0.2	0.8	74.7	21.6	0.7	427.3
2002	Puniu at Wharepapa	112	68.5	1.4	0	0	10	89.1	8.3	0	177.5
2002	Mangatutu	113	91.9	0.8	4.9	0.4	13	23	8.3	0.2	142.5
2002	Mangapiko	114	404.5	2.4	28.8	0.1	4.6	59.5	35.2	1.7	536.9
2002	Mangaohoi	115	1.3	0	0	0	0.9	0.1	0	0	2.3
2002	Waipa at SH23 Br Whatawhata	116	361.2	3.7	21.7	0.8	9.8	38.7	69.4	1.1	506.3
2002	Mangauika	117	1	0.1	0	0	2.1	0.5	0	0	3.9
2002	Kaniwhaniwha	118	70.6	0.3	0.1	0	11.1	21.3	9.2	0.1	112.7
2002	Waipa at Wainaro Rd Br	119	71.5	5.1	1.7	0.7	9.6	27.6	40.3	0.7	157.2
2002	Ohote	120	28.6	0.2	1.5	0.1	0.6	0.1	20.2	0.5	51.8
2002	Firewood	121	0.1	1.3	0	0	3.1	16.9	0.7	0	22.1
2008	Pueto	1	41.3	56.7	4.4	0.1	2.8	0.9	33.4	0.4	140.1
2008	Waikato at Ohaaki	2	130.9	39	51.2	1.2	3.5	1.1	119.8	3	349.7
2008	Waikato at Ohakuri	3	482.1	61.9	5.2	3.2	10	33.3	194.2	0.2	790.1
2008	Torepatutahi	4	176	44.7	10.8	0.1	1	0.6	37.1	0.2	270.4
2008	Mangakara	5	8.2	1.2	0	0	1.1	0.2	13.6	0	24.3
2008	Waiotapu at Homestead	6	136.3	41	7	0.1	4.4	3.8	32.5	0.2	225.2
2008	Kawaunui	7	26.1	0.8	0.1	0	0.9	0.4	6.5	0	34.8
2008	Waiotapu at Campbell	8	13.7	10.9	0	0.1	1.7	7.4	16.3	0.1	50.2
2008	Otamakokore	9	62.7	0.8	0	0	1.5	1.5	15	0.1	81.6
2008	Whirinaki	10	4.6	0.3	0	0	0.6	3.3	3.6	0	12.4
2008	Waikato at Whakamaru	11	225.9	105.4	1.3	2.5	4.7	36.9	71.6	0.3	448.7

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
2008	Waipapa	12	65.6	10.5	2.1	0	1.4	29.2	29.9	0.1	138.8
2008	Tahunaatara	13	134.6	27	0	0	9.6	23.1	54.8	0	249.1
2008	Mangaharakeke	14	16.8	17.8	0	0	0.2	1.1	3.8	0.1	39.8
2008	Waikato at Waipapa	15	367.1	110.4	1.5	1.7	45.2	100.5	47.5	1.5	675.4
2008	Mangakino	16	116.2	7.2	2.8	0.1	25.8	23.9	56.4	0	232.4
2008	Mangamingi	17	91.1	4.5	3.5	0	0	8.7	2	1.7	111.6
2008	Whakauru	18	44.1	8.7	0	0	0	13.4	7.4	0.4	74.1
2008	Pokaiwhenua	19	371.3	57	16.5	0	5.6	58.3	13	0.2	521.9
2008	Little Waipa	20	164.6	8.8	0	0	0.2	46.8	0.7	0	221.1
2008	Waikato at Karapiro	21	624.4	30	48.8	4.6	15.2	193.3	31.9	0.7	949
2008	Karapiro	22	38.3	1	4.5	0.1	1.1	41.9	6.1	0	93
2008	Waikato at Narrows	23	120.1	1.2	10	0.7	1.4	5.7	54.1	2.7	196
2008	Mangawhero	24	58.6	0.1	21.2	0	0.5	4.2	21.6	0.1	106.3
2008	Waikato at Bridge St Br	25	71.6	0.1	32.6	0.3	0.5	0.2	10.1	2	117.3
2008	Mangaonua	26	96.1	0.3	8.4	0	1.8	15.3	18.9	0.2	141
2008	Mangakotukutuku	27	44.5	0	2.1	0	0.1	0	5.3	1.3	53.4
2008	Mangaone	28	77.8	0.4	29.7	0	0.3	0.1	24.5	1.2	134.1
2008	Waikato at Horotiu Br	29	37.9	0.1	3.1	0.4	0.1	0	6	8.1	55.7
2008	Waitawhiriwhiri	30	12.1	0.1	0	0.1	0	0	6.1	2.9	21.2
2008	Kirikiriroa	31	10.7	0	0.3	0	0.1	0	0.6	1.9	13.6
2008	Waikato at Huntly-Tainui Br	32	198.6	0.9	13.9	0.8	5.9	8.5	50.2	1.8	280.6
2008	Komakorau	33	349.4	0.1	14.8	0	0.1	0	35.6	0.2	400.3
2008	Mangawara	34	450.2	1.9	12	0.1	11.2	9.1	137.2	0.1	621.8
2008	Waikato at Rangiriri	35	30.3	0.7	0.2	0.8	2.4	1.4	27.2	1.2	64.3

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
2008	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	29.8	0.3	0	1.6	0.9	6.5	15.3	0.2	54.6
2008	Awaroa (Rotowaro) at Sansons Br	37	6.2	1.1	0	1.8	2	21.6	2.9	0	35.7
2008	Waikato at Mercer Br	38	123.6	14.3	144.4	5.5	6.9	99.8	172.5	0.5	567.4
2008	Whangape	39	35.8	4.8	2.6	3.1	6.4	162.4	92.3	0.1	307.4
2008	Whangamarino at Island Block Rd	40	57.2	6.1	20.5	7.2	3.1	0.1	51.8	0.3	146.3
2008	Whangamarino at Jefferies Rd Br	41	54.9	6.4	0.3	0	1.6	11.5	33	0.1	107.8
2008	Waerenga	42	2.1	1.4	0	0	0.4	10.3	3	0	17.3
2008	Matahuru	43	35.2	1.3	0	0	1.7	36.7	40	0	115.1
2008	Waikare	44	20.9	0.5	10.3	9.9	1.1	0.2	44.5	0.3	87.7
2008	Opuatia	45	0.2	5.7	11.8	0	1.7	46	5.3	0	70.7
2008	Mangatangi	46	62	4	2.9	0.4	16.7	5.3	75.3	0	166.5
2008	Waikato at Tuakau Br	47	35.3	3.1	115.3	0.4	6.7	14	65.4	0.2	240.3
2008	Ohaeroa	48	0.8	0.3	18.4	0	0.5	6.5	8.2	0	34.6
2008	Mangatawhiri	49	3.2	1.7	0.6	0.3	13.6	0.4	5.9	0	25.6
2008	Waikato at Port Waikato	50	116	13.7	102.9	2.3	7.8	22.9	92.9	0.6	359.1
2008	Whakapipi	51	4.6	0.2	67	0.1	0.6	2.6	22.4	1.5	99
2008	Awaroa (Waiuku)	52	12.5	0.1	7.4	0	0.1	1.2	15.1	0.3	36.8
2008	Waipa at Mangaokewa Rd	100	0	4.9	0	0.1	2.4	10.1	0	0	17.4
2008	Waipa at Otewa	101	43.7	6.1	0	0.2	35.8	111.5	0.7	0.2	198.3
2008	Mangaokewa	102	13.7	5.5	0	0.2	7.6	122.7	1.7	0.3	151.6
2008	Mangarapa	103	33.8	0.6	0	0	1.1	34.1	3.2	0	72.8
2008	Mangapu	104	130.7	1.9	2.2	0.3	3.2	77.3	17.9	0.8	234.2
2008	Mangarama	105	21.4	0.6	0	0	0.7	39.1	5	0	66.7
2008	Waipa at Otorohanga	106	204.3	0.7	1.4	0.1	1.9	47.7	10.7	0.5	267.4

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			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
2008	Waipa at Pirongia-Ngutunui Rd Br	107	772.4	2.7	18.4	0.4	11.2	92.5	26.1	0.6	924.3
2008	Waitomo at Tumutumu Rd	108	0.2	2.1	0	0	3.8	22.4	0.1	0	28.6
2008	Waitomo at SH31 Otorohanga	109	24.1	1.3	0	0	2.8	16.7	4.7	0	49.6
2008	Moakurarua	110	81.3	5.3	0.1	0	16.9	92.7	5.1	0.2	201.6
2008	Puniu at Bartons Corner Rd Br	111	301.3	2.3	23.7	0.1	0.7	89.3	22.3	0.7	440.5
2008	Puniu at Wharepapa	112	45.7	1.4	0	0	10	99.5	10.1	0	166.8
2008	Mangatutu	113	87.6	1	18.7	0	12.9	27.3	8.4	0.2	156.1
2008	Mangapiko	114	418.6	2.4	16.6	0	4.3	69.5	37.9	1.8	551.2
2008	Mangaohoi	115	1	0	0	0	0.9	0.3	0	0	2.2
2008	Waipa at SH23 Br Whatawhata	116	386.7	3.7	16.5	0.8	7.9	45.2	75.9	1.2	537.8
2008	Mangauika	117	0.9	0.1	0	0	2.1	0.8	0	0	4
2008	Kaniwhaniwha	118	57.7	0.3	0.4	0	11	28.1	9.8	0.1	107.4
2008	Waipa at Wainaro Rd Br	119	109	5.7	10.3	0.7	8.4	29.1	30.6	0.9	194.7
2008	Ohote	120	42.1	0.2	3.9	0.1	0.1	0.1	16.8	0.6	64
2008	Firewood	121	0.2	1.5	0	0	2.8	18	0.6	0.1	23.2
2012	Pueto	1	5.9	40.7	0.8	0.2	3.2	2.3	93.6	0.4	146.9
2012	Waikato at Ohaaki	2	79.4	32	8.6	3.5	4.9	0.5	148.3	4.8	282.1
2012	Waikato at Ohakuri	3	471.6	41.5	2.3	4.7	11.1	15.3	270.4	1.4	818.5
2012	Torepatutahi	4	146.4	45.1	6.6	0.1	1.5	0.4	49.9	0.5	250.5
2012	Mangakara	5	8.5	1.2	0	0	1.2	0.2	12.9	0.1	24.1
2012	Waiotapu at Homestead	6	160.7	41.4	1.4	0.1	4.7	0.8	25.4	0.5	235
2012	Kawaunui	7	22	0.8	0	0	1.1	0	8.3	0	32.2
2012	Waiotapu at Campbell	8	11	11.5	0	0.1	1.9	2.6	20	0.1	47.2
2012	Otamakokore	9	51	0.5	0	0.2	1.8	1.3	19.9	0.1	74.9

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			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
2012	Whirinaki	10	4.7	0.2	0	0	0.6	2	5.2	0	12.8
2012	Waikato at Whakamaru	11	262.2	98.8	1.3	3.1	5.8	17.6	95.2	0.9	484.9
2012	Waipapa	12	83.9	10.3	1.6	0	1.3	12.8	43.5	0.2	153.7
2012	Tahunaatara	13	191.1	23.8	0	0.5	10.6	2.9	62.9	0.3	292.2
2012	Mangaharakeke	14	23.3	17.3	0	0	0.2	0	4.4	0.1	45.3
2012	Waikato at Waipapa	15	414.6	107.6	0.9	2.6	46.9	35.4	98	2.8	708.7
2012	Mangakino	16	103.1	6.4	1.8	0.4	26.6	14.1	69.9	0.3	222.5
2012	Mangamingi	17	92	4.4	0	0.6	0	0.9	8.8	1.8	108.6
2012	Whakauru	18	73.3	7	0	0.2	0	0.6	14.8	0.9	96.9
2012	Pokaiwhenua	19	432.6	49.3	10.6	0.3	6.1	6.8	71.2	0.9	577.7
2012	Little Waipa	20	261	5.1	0	0.1	0.5	9.9	20.8	0.3	297.8
2012	Waikato at Karapiro	21	730.9	26.2	21.3	6.6	16.8	100.4	101.5	1.9	1005.6
2012	Karapiro	22	40.6	1.1	2.4	0.3	1	30.9	16.7	0.2	93.1
2012	Waikato at Narrows	23	124.8	0.7	8.2	2.4	1.9	4.3	44.2	4	190.4
2012	Mangawhero	24	70.5	0	3	0.3	0.5	4	18.8	0.4	97.6
2012	Waikato at Bridge St Br	25	45.5	0	13.2	1	0.6	0	19.8	2.5	82.5
2012	Mangaonua	26	80.9	0.2	6	1.2	1.8	7.2	30.7	0.4	128.5
2012	Mangakotukutuku	27	41.9	0	0.1	0.3	0.1	0	6.6	1.3	50.2
2012	Mangaone	28	56.9	0.2	7.5	1.5	0.5	0	25	3	94.5
2012	Waikato at Horotiu Br	29	27.6	0	0.1	0.5	0.1	0	4.8	9.5	42.7
2012	Waitawhiriwhiri	30	17.1	0.1	0	0.2	0.1	0	3.9	3	24.2
2012	Kirikiriroa	31	7.7	0	0.3	0.1	0.1	0	0.9	2	11.2
2012	Waikato at Huntly-Tainui Br	32	251.9	0.5	5.1	3	6.6	7.2	25	3.5	302.9
2012	Komakorau	33	392.9	0.1	1.5	0.6	0.2	0	25.8	0.6	421.8

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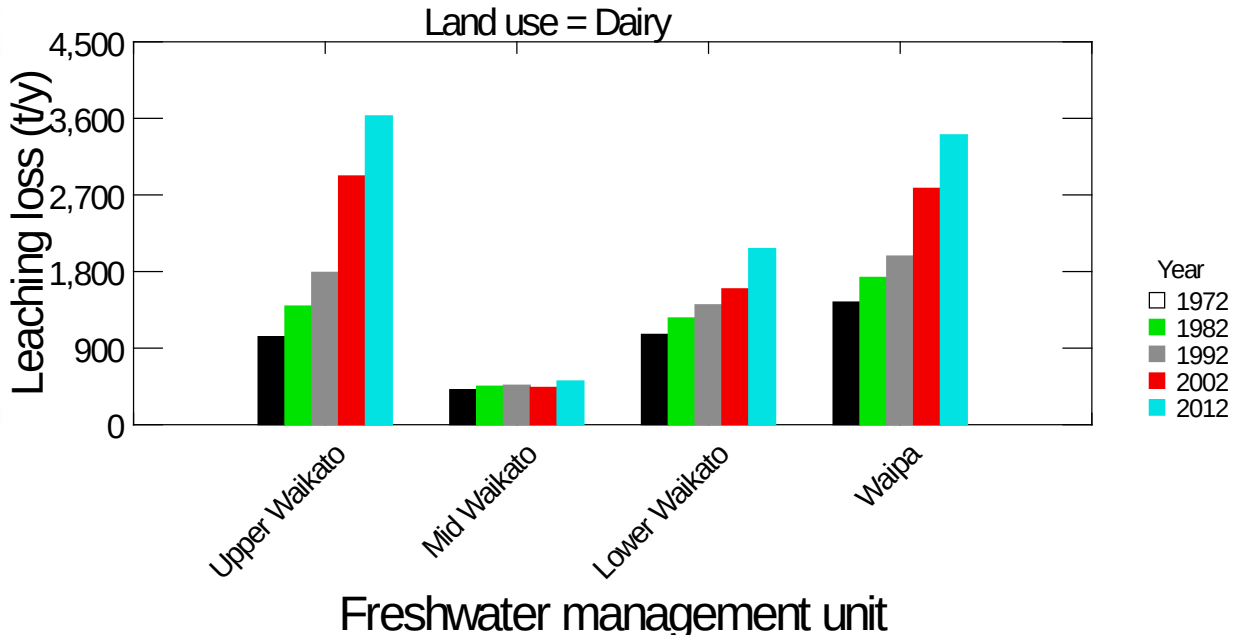
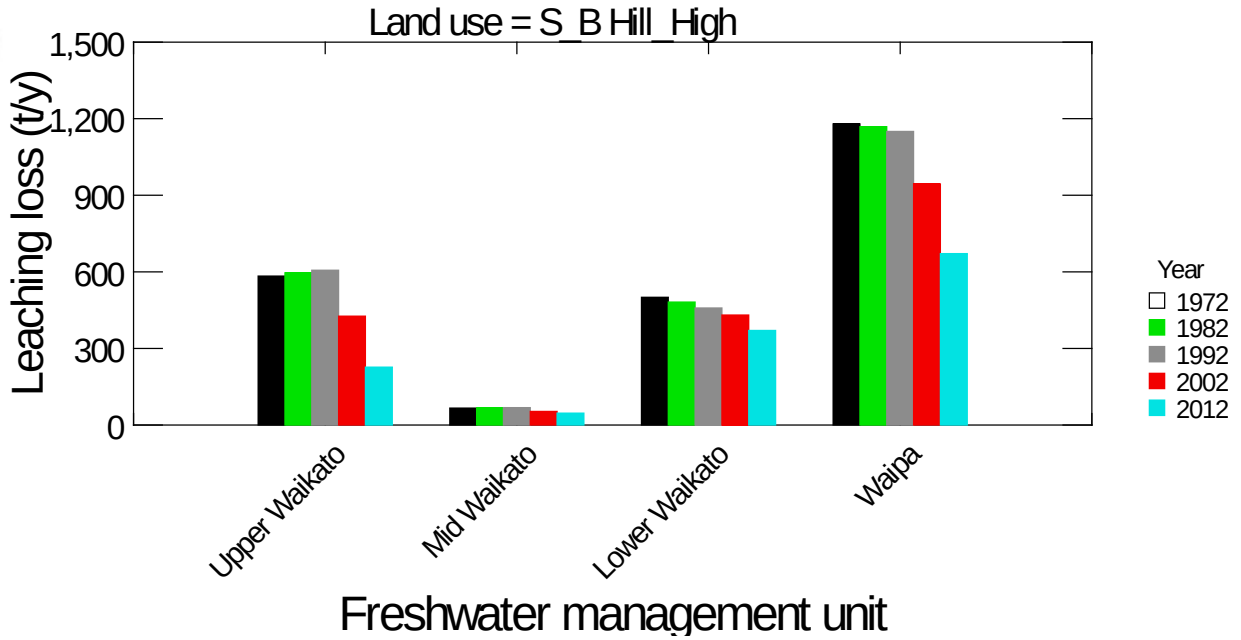
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
2012	Mangawara	34	560.9	1.8	5.6	0.4	11.6	6.4	108.5	1	696.1
2012	Waikato at Rangiriri	35	42.7	0.5	0	2.6	2.8	1.1	20.6	1.5	71.8
2012	Awaroa (Rotowaro) at Harris/Te Ohaki Br	36	22.8	0.1	0	2.1	1.2	4.5	19	0.3	50
2012	Awaroa (Rotowaro) at Sansons Br	37	5.9	3.1	0	1.6	1.8	17.6	4.1	0.2	34.3
2012	Waikato at Mercer Br	38	178.4	9.7	64.5	10.7	11.5	80	159.4	2.9	517
2012	Whangape	39	92.6	4.3	1.5	3.5	7.7	141.8	83.4	1	335.7
2012	Whangamarino at Island Block Rd	40	45.2	3.7	13.5	8	5.1	0	53.2	1.1	129.8
2012	Whangamarino at Jefferies Rd Br	41	68.9	6.3	2	0.2	1.8	10.5	25.9	0.4	116
2012	Waerenga	42	2.1	1.5	0	0	0.5	10.1	3.1	0	17.2
2012	Matahuru	43	39.2	1.3	0	0.1	3.7	26.8	40.3	0.4	111.8
2012	Waikare	44	43	0.4	4.8	10.7	1.5	0.2	28.5	0.8	89.9
2012	Opuatia	45	7.4	5.8	6.2	0.2	1.5	43.4	5.8	0.2	70.5
2012	Mangatangi	46	78.8	4.4	0.4	0.7	16.8	3.3	66.6	0.4	171.5
2012	Waikato at Tuakau Br	47	32.4	1.4	45.2	2.5	14.6	3.5	50	1.7	151.3
2012	Ohaeroa	48	8.2	0.2	8.1	0.1	0.7	2.1	9.8	0.1	29.2
2012	Mangatawhiri	49	0	1.7	0.4	0.3	14.6	0.2	3.7	0	21
2012	Waikato at Port Waikato	50	180	8.3	62.7	9.3	12.5	10.8	67.7	2.2	353.5
2012	Whakapipi	51	3.7	0.2	28.7	1.1	0.5	0.8	17.7	3.9	56.5
2012	Awaroa (Waiuku)	52	12.6	0.1	1.8	0.3	0.1	0.1	15.4	0.6	31
2012	Waipa at Mangaokewa Rd	100	0	4.8	0	0.1	2.5	9.7	0.1	0.1	17.2
2012	Waipa at Otewa	101	84.6	6.1	0	0.3	37.7	75.3	16.4	0.7	221.1
2012	Mangaokewa	102	36.5	5.9	0	0.2	9.1	103.6	6	0.9	162.1
2012	Mangarapa	103	36.4	0.5	0	0	1.4	22.9	13.1	0.2	74.5
2012	Mangapu	104	129.8	1.7	0.3	0.7	3.3	50.6	43.9	1.6	232

Year	Catchment	Id	Nitrogen leaching loss by year and subcatchment per land use (t/y)								Total leaching loss per sub catchment (t/y)
			Dairy	Forestry	Hort.	Miscell.	Native Forest & Scrub	Sheep and Beef - Hill and High	Sheep and Beef - Intensive	Urban	
2012	Mangarama	105	33.4	0.4	0	0	1	31.8	8.4	0.1	75.1
2012	Waipa at Otorohanga	106	244.6	0.7	0.8	0.2	2.3	27.7	18.5	1.1	295.8
2012	Waipa at Pirongia-Ngutunui Rd Br	107	838	2.2	10.3	0.9	12.5	37.5	64	2.4	967.8
2012	Waitomo at Tumutumu Rd	108	8.8	2.2	0	0	4.3	14	3.1	0.2	32.6
2012	Waitomo at SH31 Otorohanga	109	17.6	1.3	0	0.1	3.1	11.1	10.8	0.2	44.2
2012	Moakurarua	110	94.3	5.8	0	0.2	18.2	71	15.4	1	205.8
2012	Puniu at Bartons Corner Rd Br	111	444.7	2.1	20	0.4	0.8	28.4	41.8	1.3	539.4
2012	Puniu at Wharepapa	112	121	1.3	0	0	10.5	60.5	23.8	0.5	217.7
2012	Mangatutu	113	105.9	1	12.8	0.2	13.6	14.3	14	0.5	162.2
2012	Mangapiko	114	504.6	2.6	2.2	0.7	4.5	36.6	45.8	2.9	600
2012	Mangaohoi	115	0.3	0	0	0	0.9	0.4	0.1	0	1.8
2012	Waipa at SH23 Br Whatawhata	116	494.9	3	8.1	2.2	8.6	22.6	57.6	3	600
2012	Mangauika	117	1.8	0.1	0	0	2.1	0	0.3	0	4.4
2012	Kaniwhaniwha	118	72.5	0.3	0.4	0.2	11.8	15.8	14.1	0.3	115.3
2012	Waipa at Wainaro Rd Br	119	101.6	5.4	7	1.2	9.2	20.9	36.2	2	183.5
2012	Ohote	120	30.4	0.1	0.8	0.6	0.2	0	20.7	1	53.7
2012	Firewood	121	5.2	1.6	0	0.1	2.6	16.9	0.4	0.1	26.9

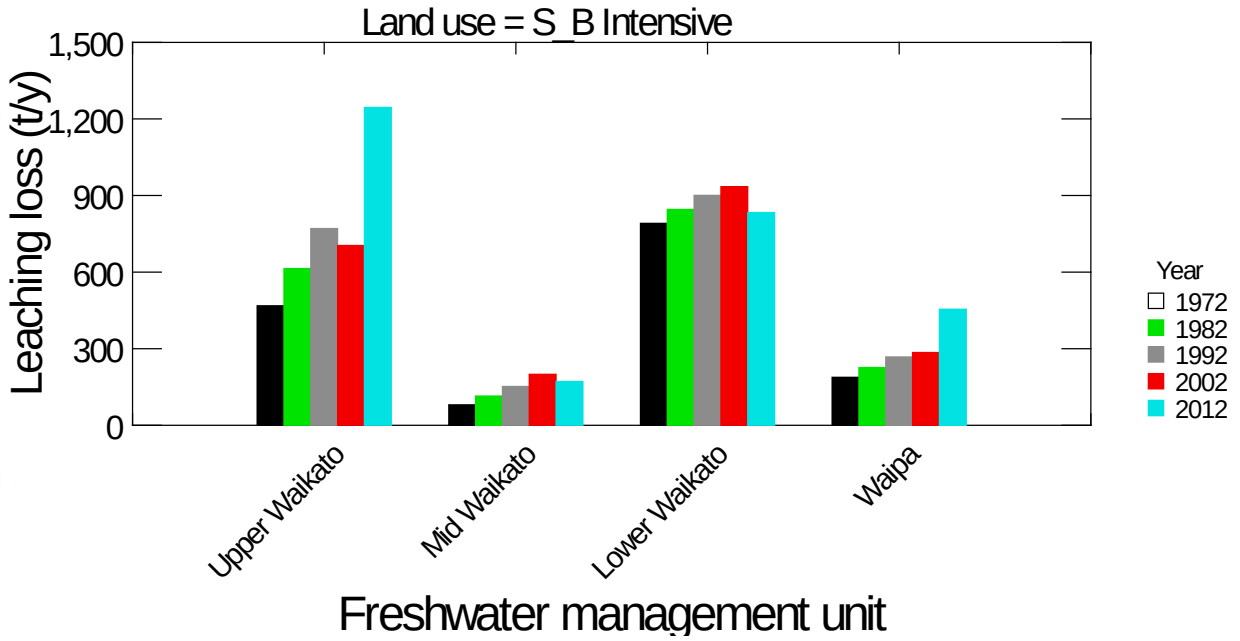
A


Land use = Dairy
Leaching loss (t/y)
4,500
3,600
2,700
1,800
900
0
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit
Year
1972
1982
1992
2002
2012

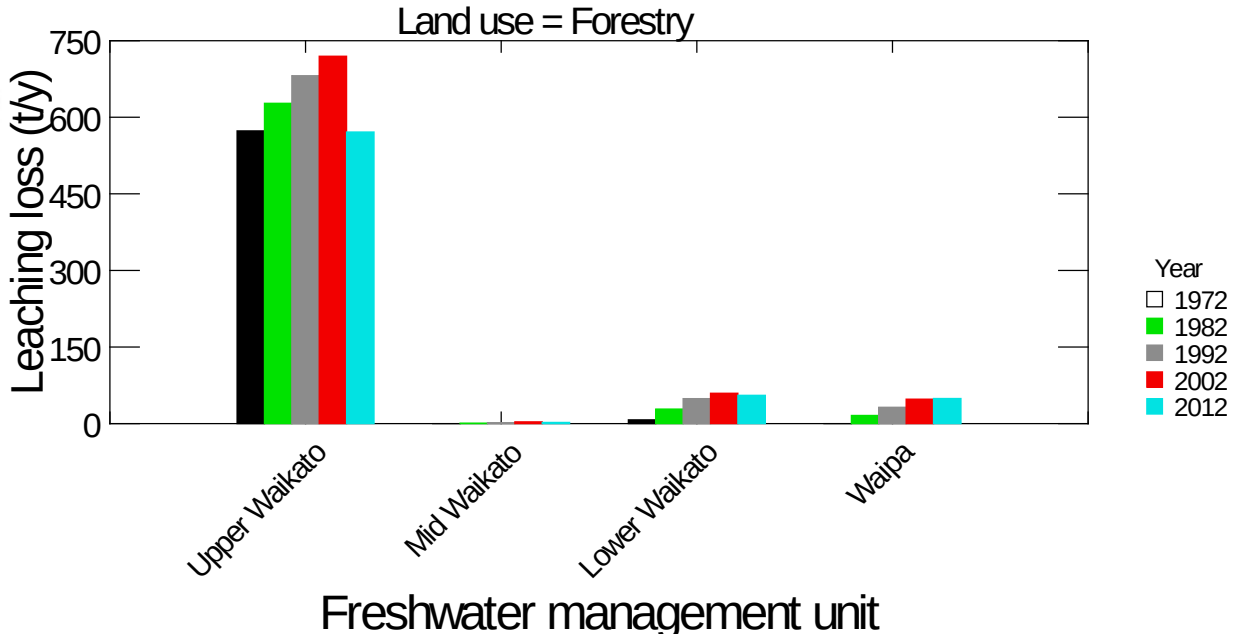
B

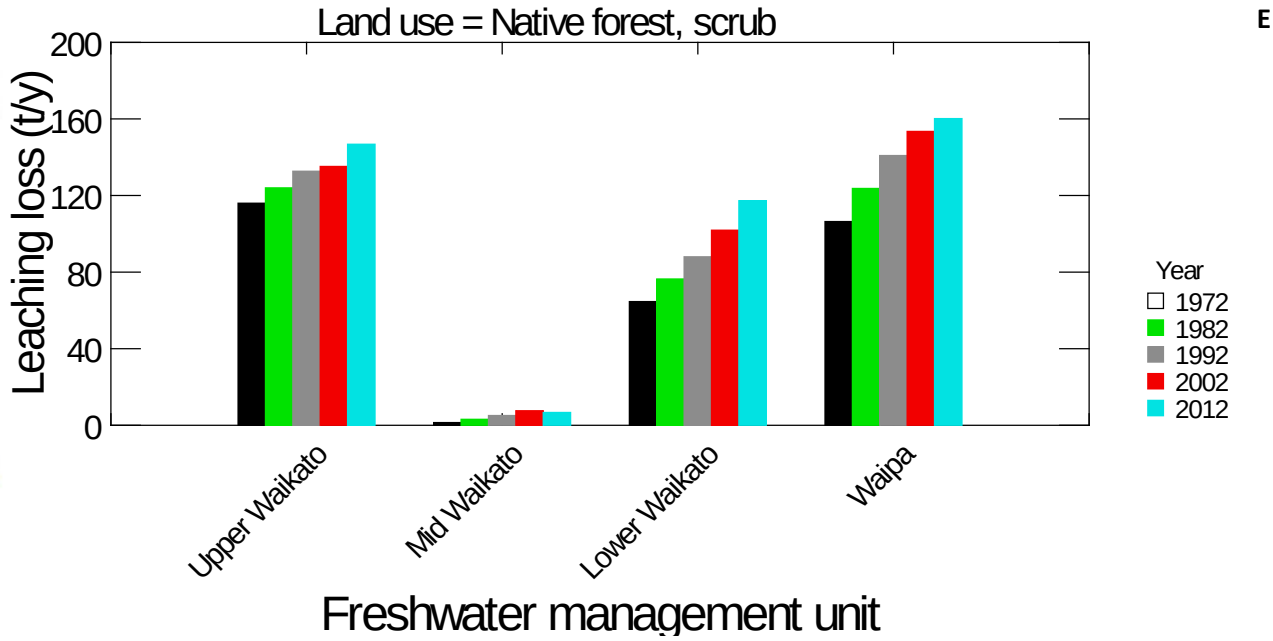

Land use = S_B Hill_High
Leaching loss (t/y)
1,500
1,200
900
600
300
0
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit
Year
1972
1982
1992
2002
2012

C

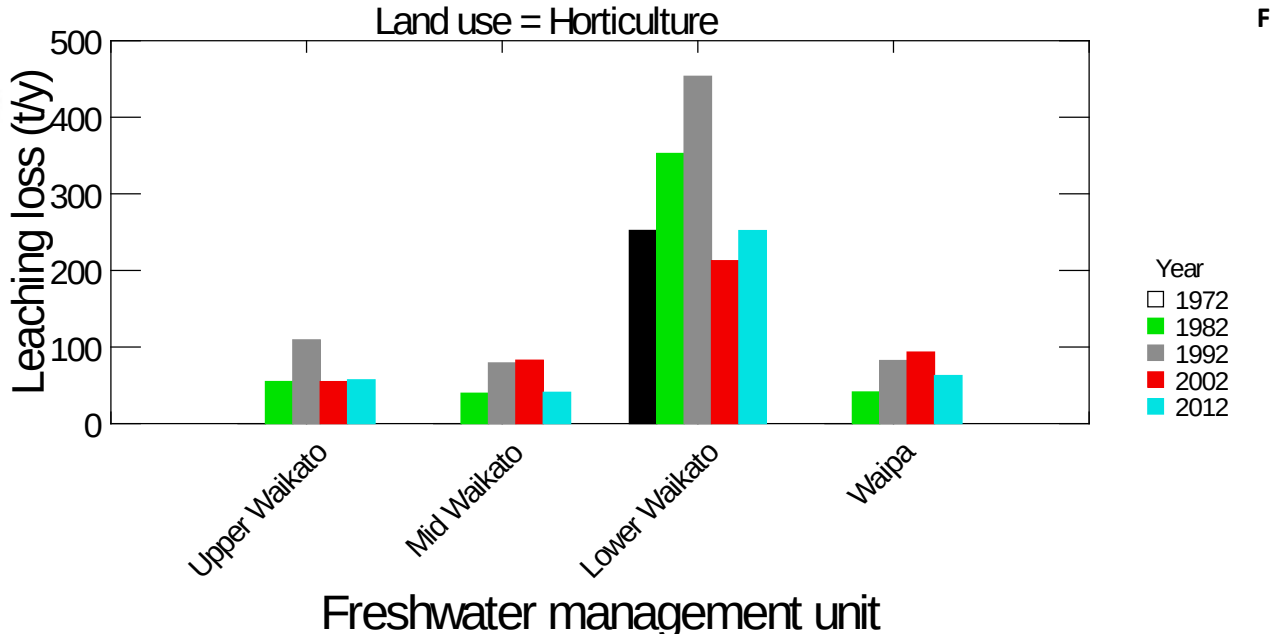

Land use = S_B Intensive
Leaching loss (t/y)
1,500
1,200
900
600
300
0
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit
Year
1972
1982
1992
2002
2012

D


Land use = Forestry
Leaching loss (t/y)
750
600
450
300
150
0
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit
Year
1972
1982
1992
2002
2012


Land use = Native forest, scrub
Leaching loss (t/y)
200
160
120
80
40
0
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit
Year
1972
1982
1992
2002
2012

E


Land use = Horticulture
Leaching loss (t/y)
500
400
300
200
100
0
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit
Year
1972
1982
1992
2002
2012

F

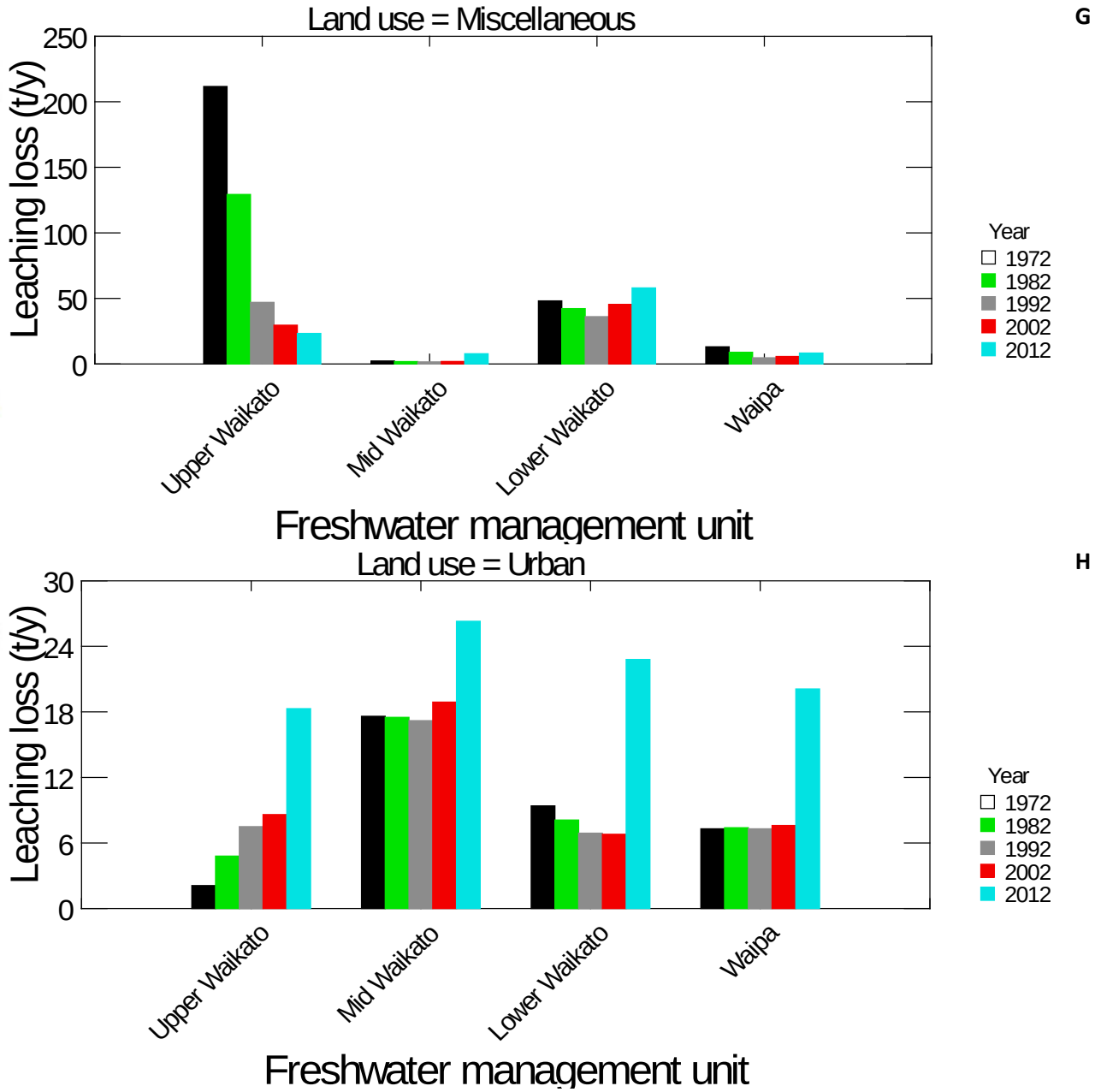
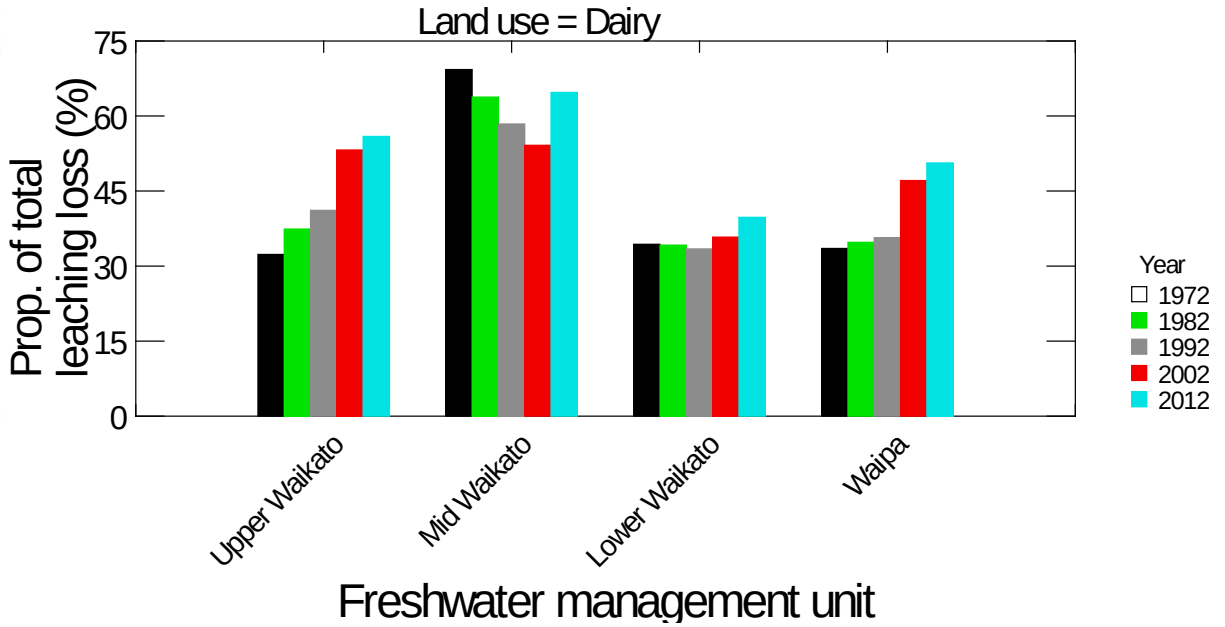
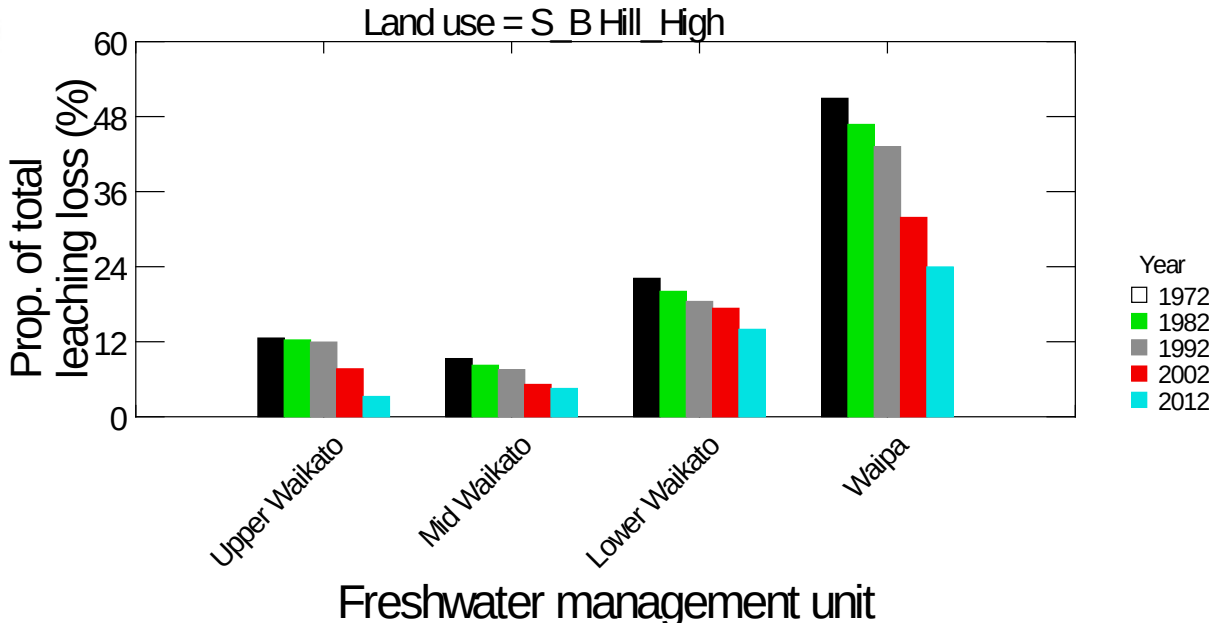
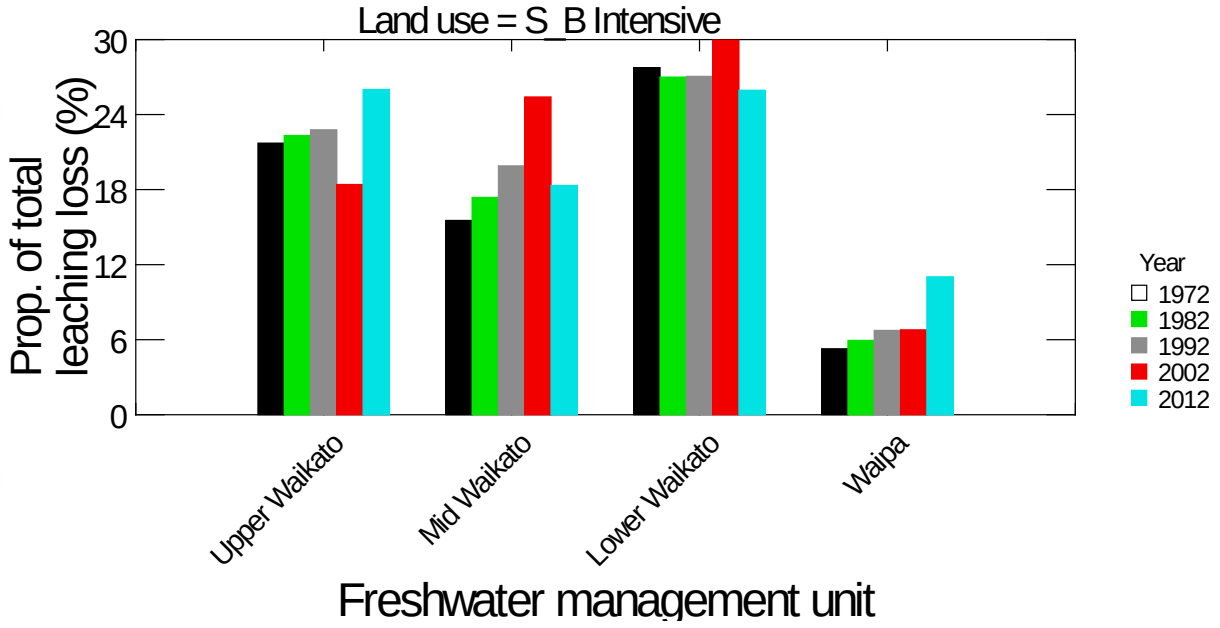


Figure G-1: Total leaching loss for the Wai Ora/Healthy Rivers project area according to land use, freshwater management unit, and decade.

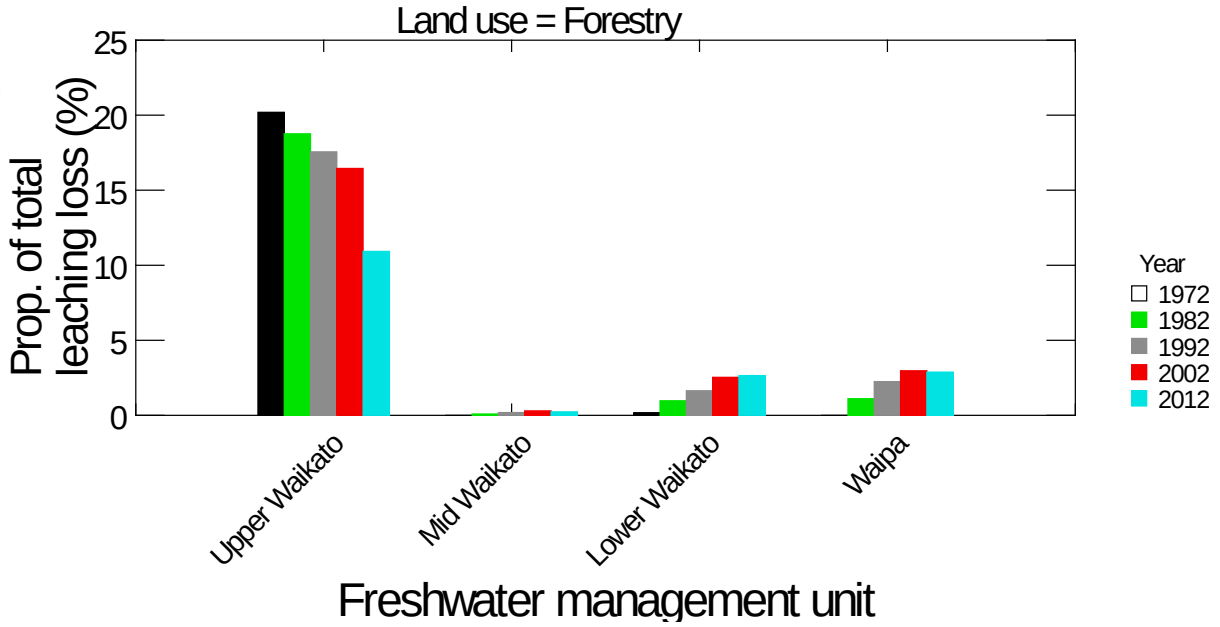

Land use = Dairy
A
Prop. of total leaching loss (%)
75
60
45
30
15
0
Year
1972
1982
1992
2002
2012
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit


Land use = S_B Hill_High
B
Prop. of total leaching loss (%)
60
48
36
24
12
0
Year
1972
1982
1992
2002
2012
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit

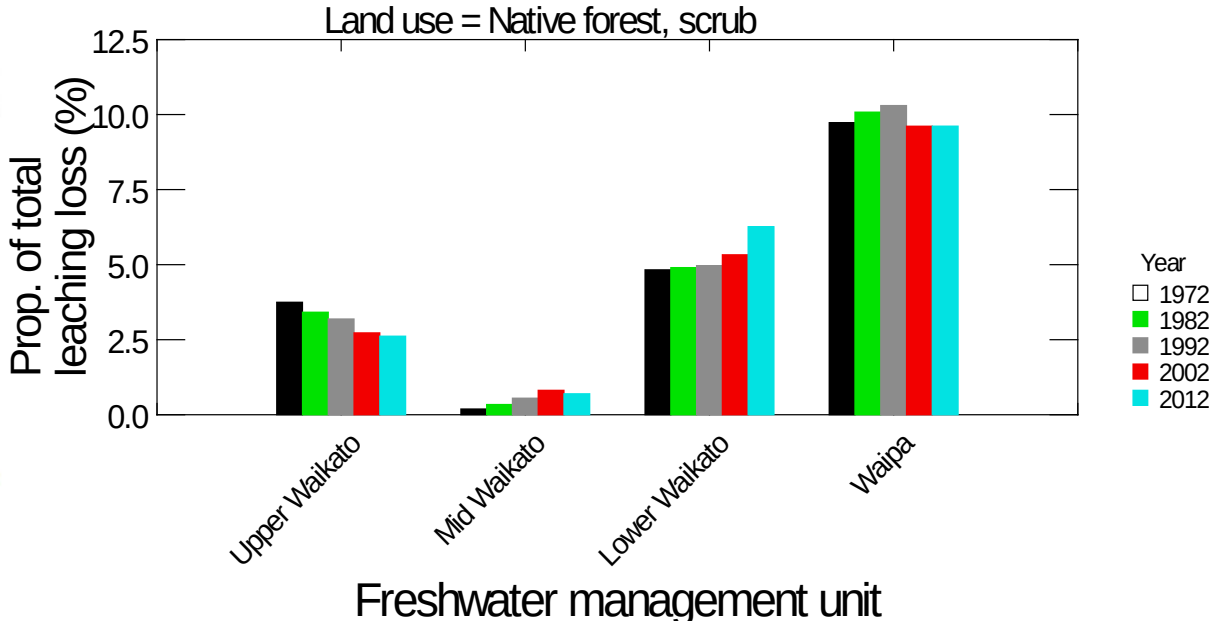
C


Land use = S_B Intensive
Prop. of total leaching loss (%)
0
6
12
18
24
30
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit
Year
1972
1982
1992
2002
2012

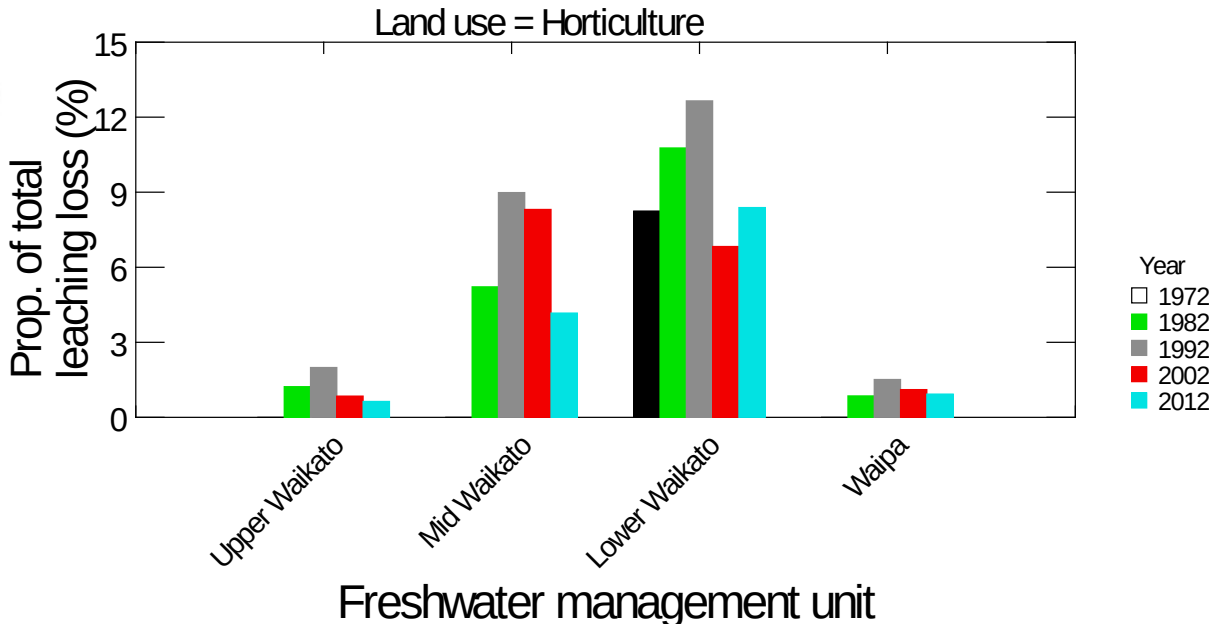
D


Land use = Forestry
Prop. of total leaching loss (%)
0
5
10
15
20
25
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit
Year
1972
1982
1992
2002
2012

E


Land use = Native forest, scrub
Prop. of total leaching loss (%)
12.5
10.0
7.5
5.0
2.5
0.0
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit
Year
1972
1982
1992
2002
2012

F


Land use = Horticulture
Prop. of total leaching loss (%)
15
12
9
6
3
0
Upper Waikato
Mid Waikato
Lower Waikato
Waipa
Freshwater management unit
Year
1972
1982
1992
2002
2012

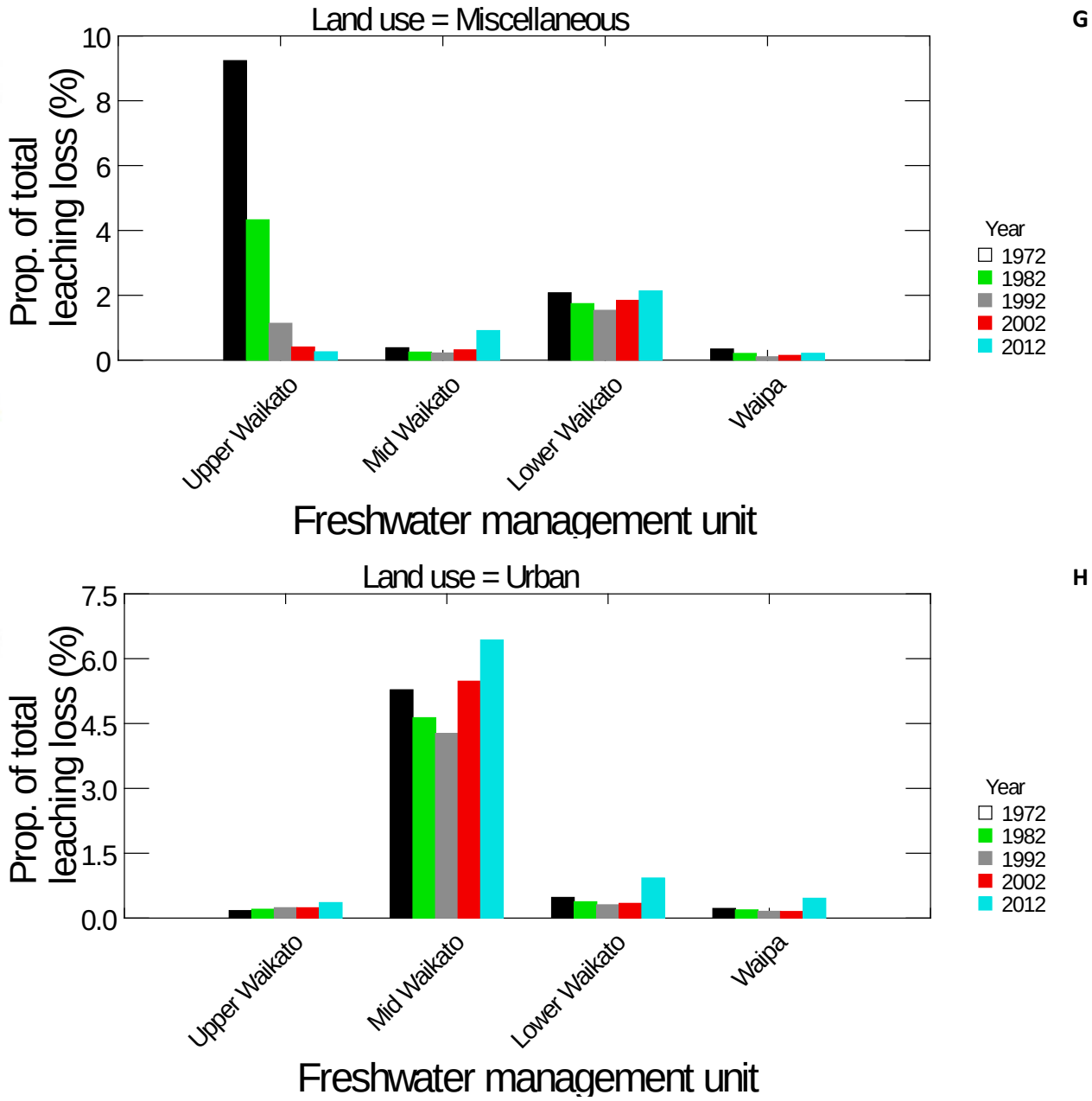
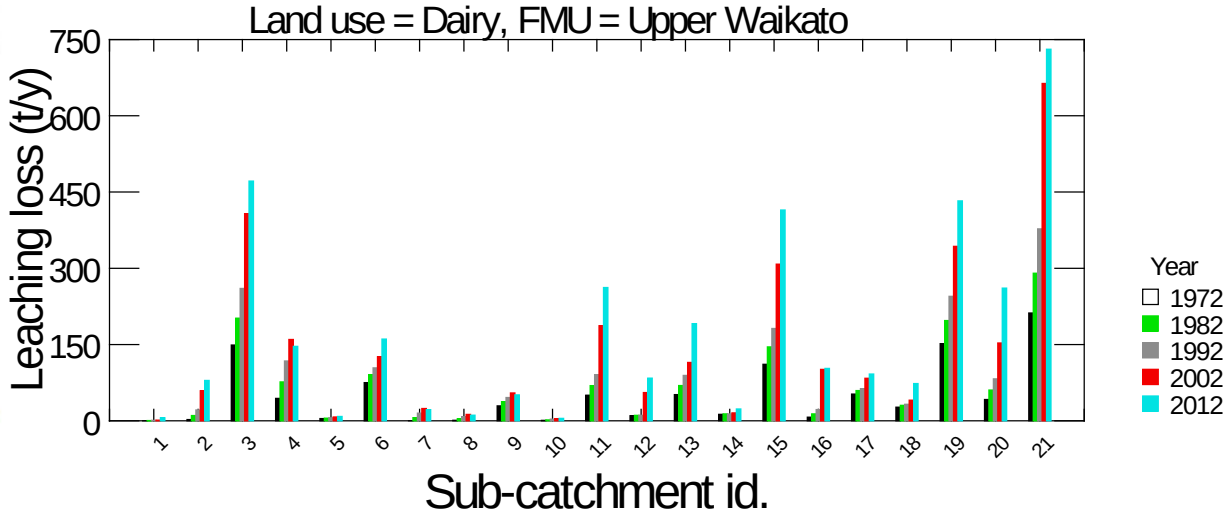
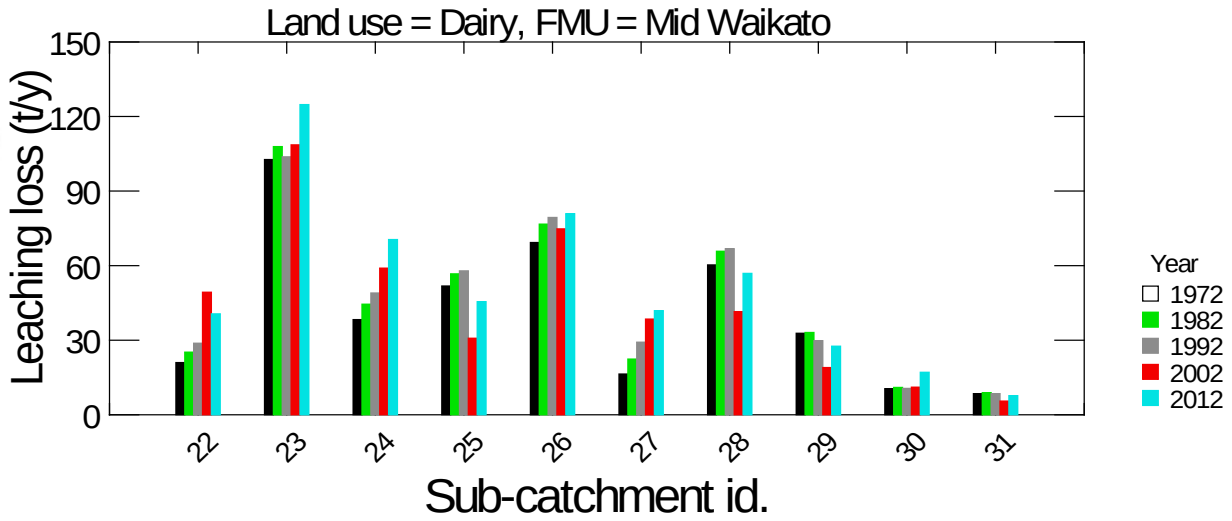


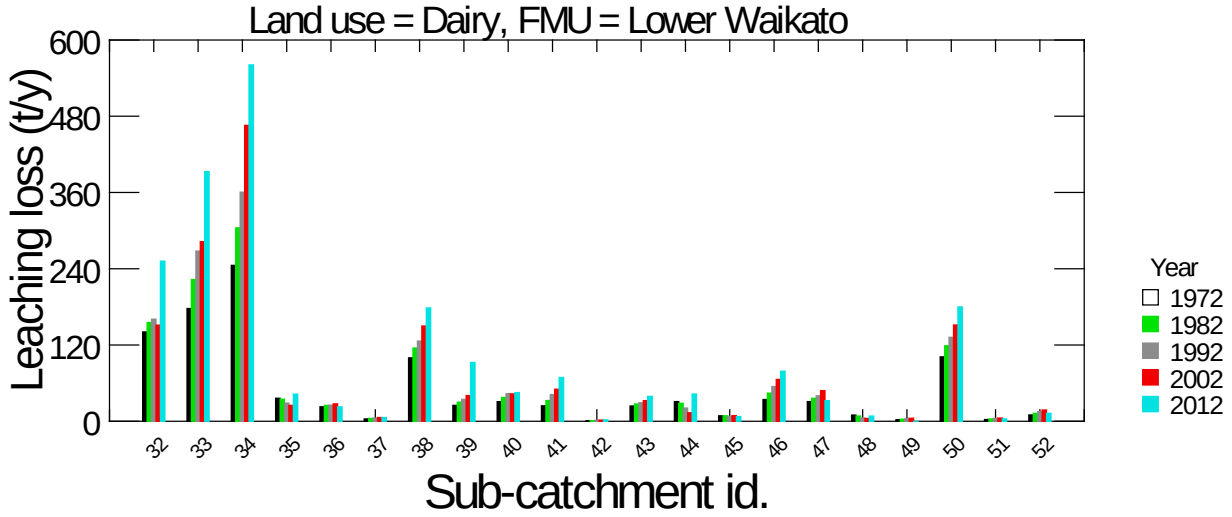
Figure G-2: Proportion of total leaching loss for the Wai Ora/Healthy Rivers project area according to land use, freshwater management unit, and decade.


Land use = Dairy, FMU = Upper Waikato
Leaching loss (t/y)
750
600
450
300
150
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012

A


Land use = Dairy, FMU = Mid Waikato
Leaching loss (t/y)
150
120
90
60
30
0
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012

B


Land use = Dairy, FMU = Lower Waikato
Leaching loss (t/y)
600
480
360
240
120
0
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

C

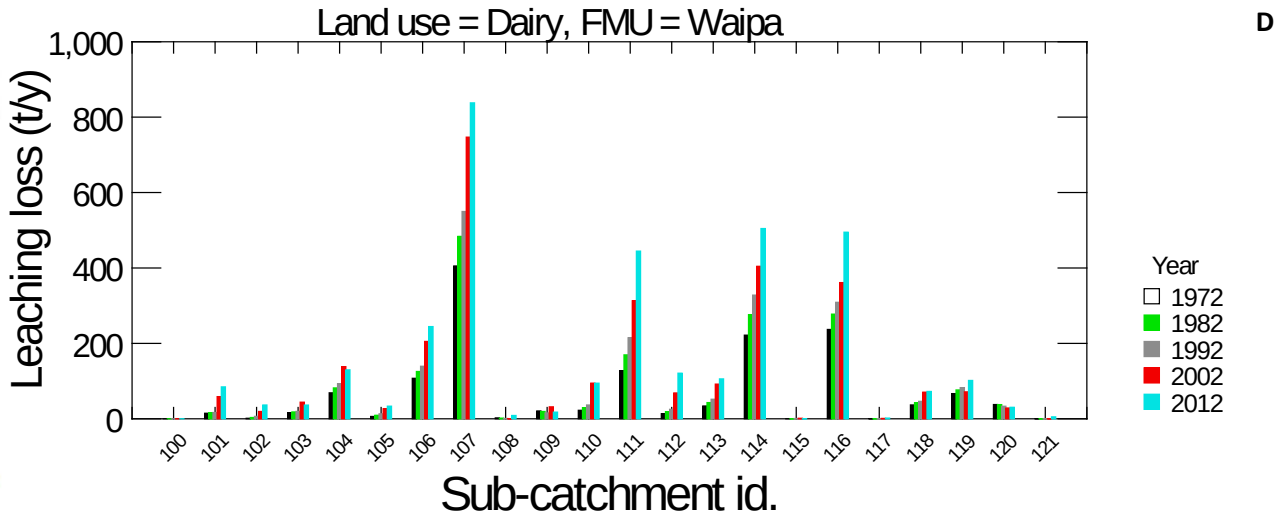
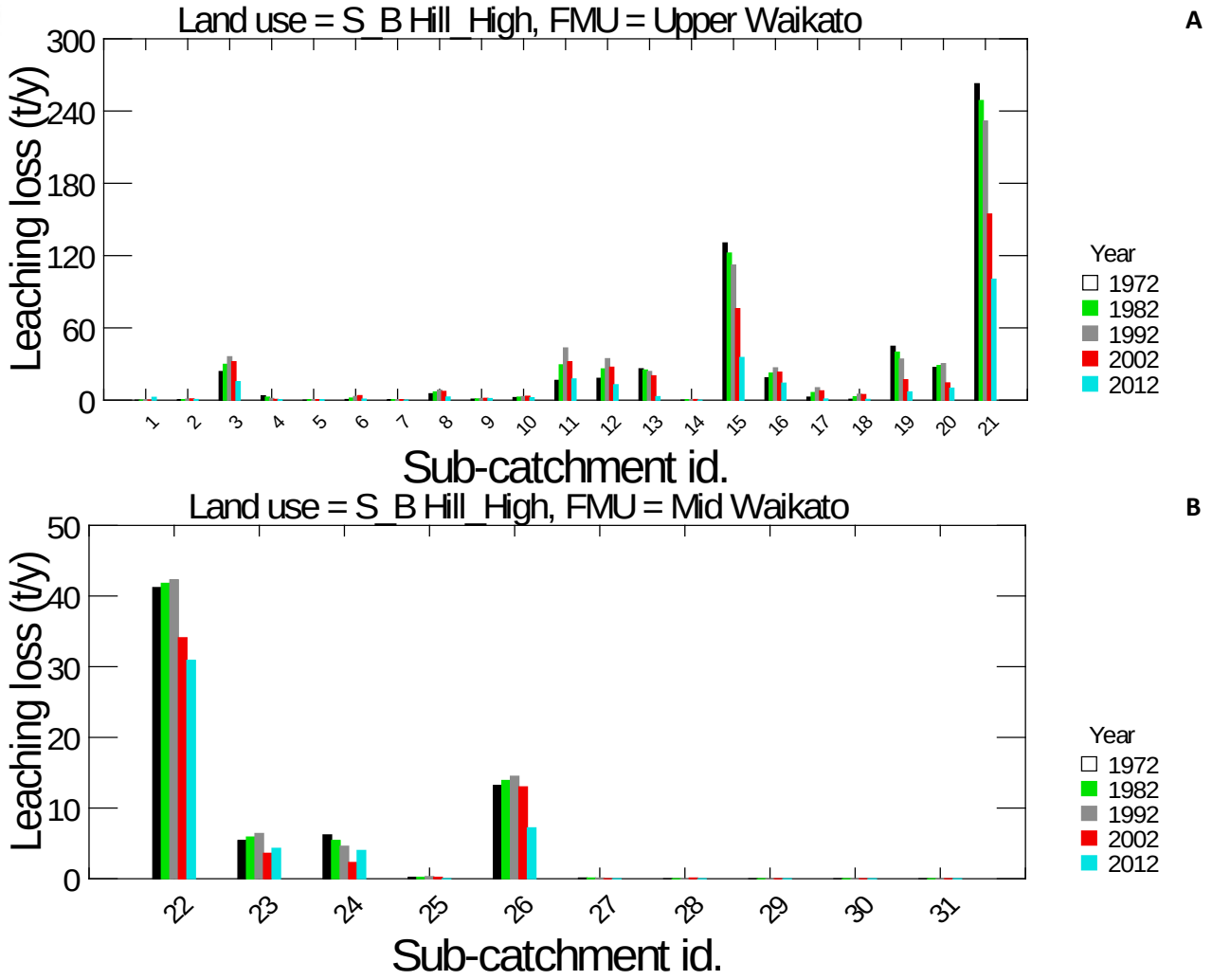


Figure G-3: Nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for dairy land use.



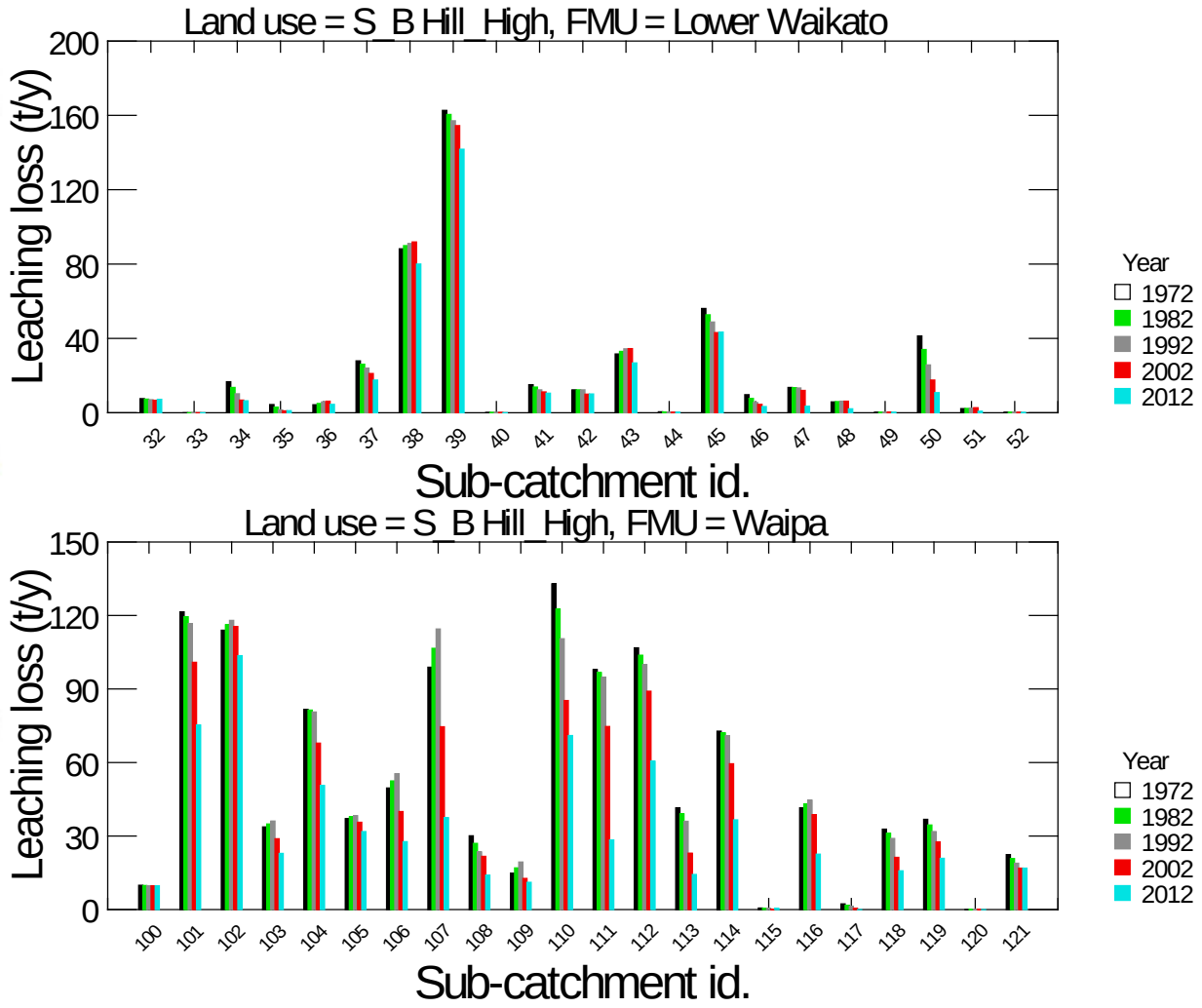
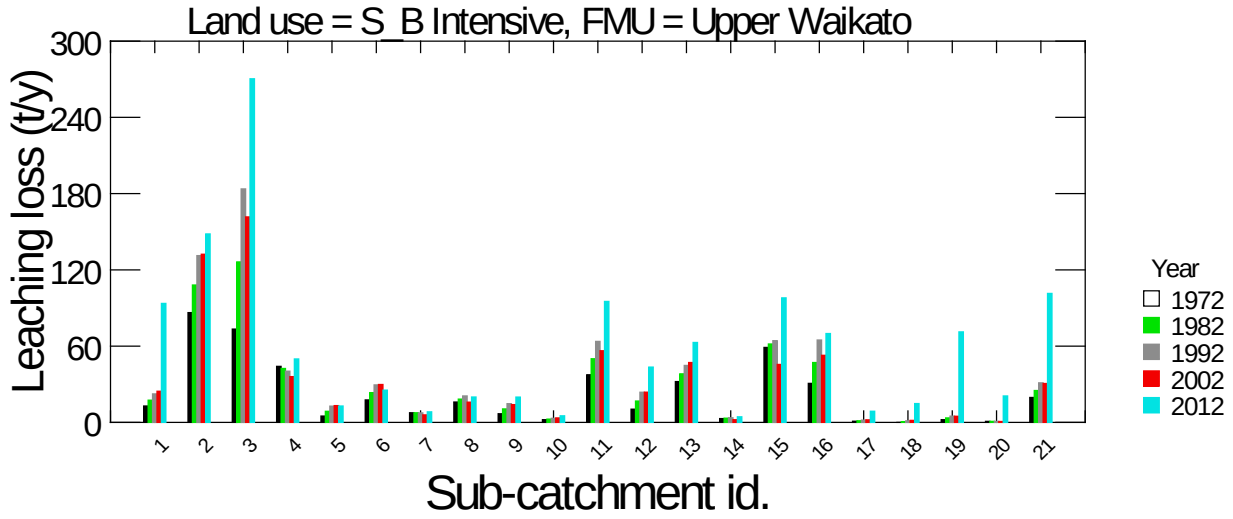


Figure G-4: Nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Sheep and beef High and Hill land use.



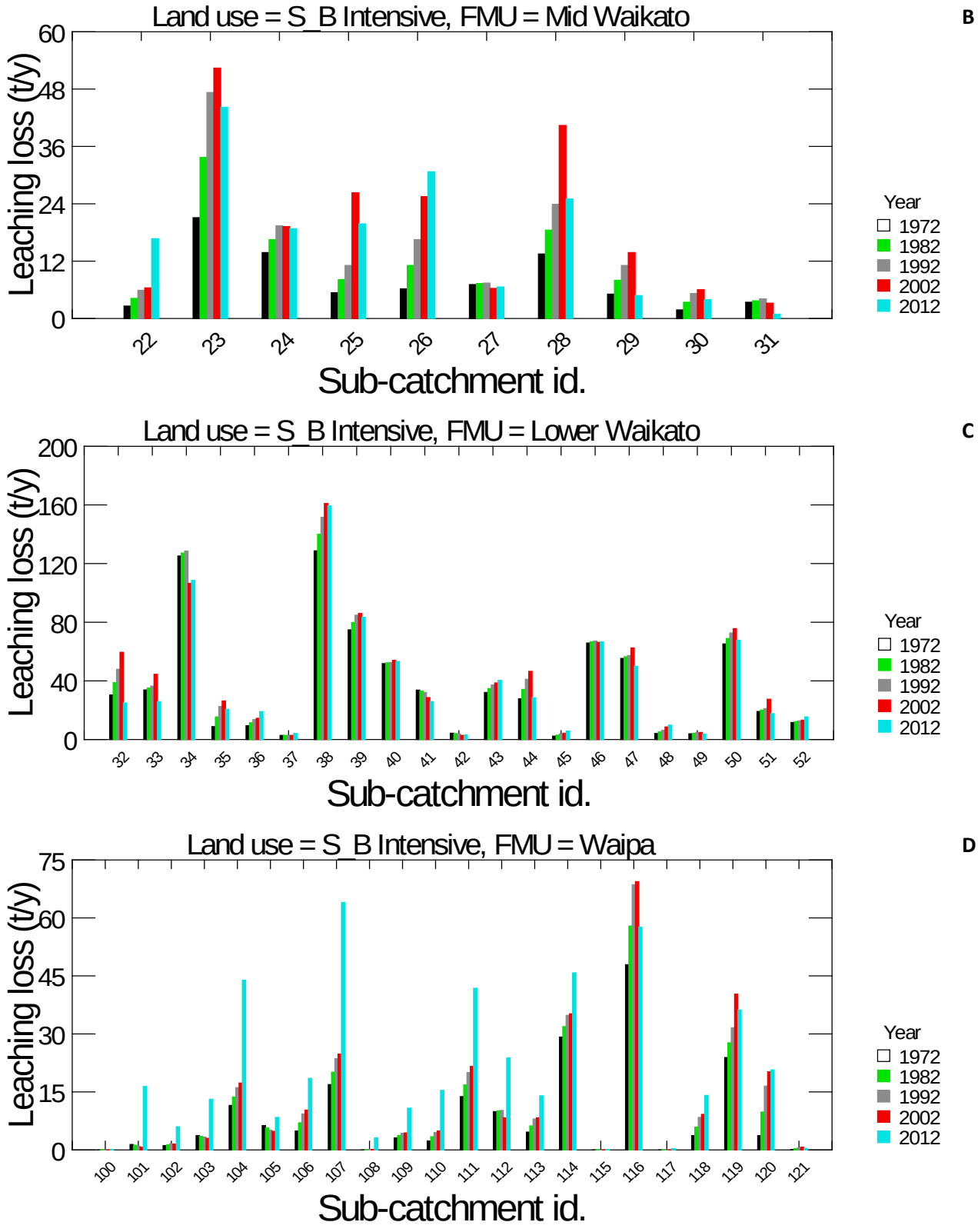
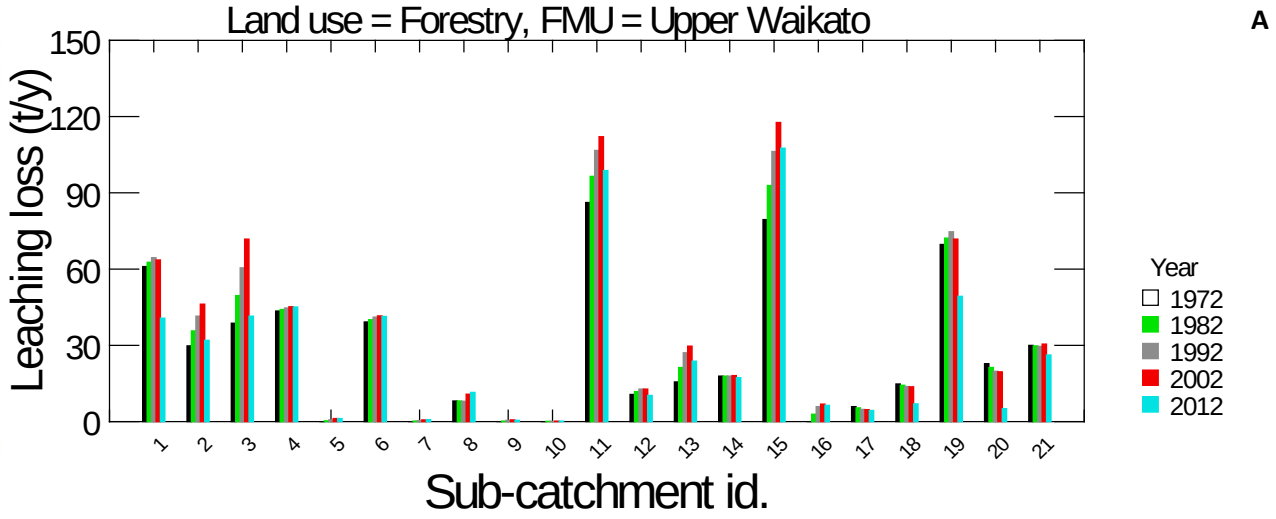
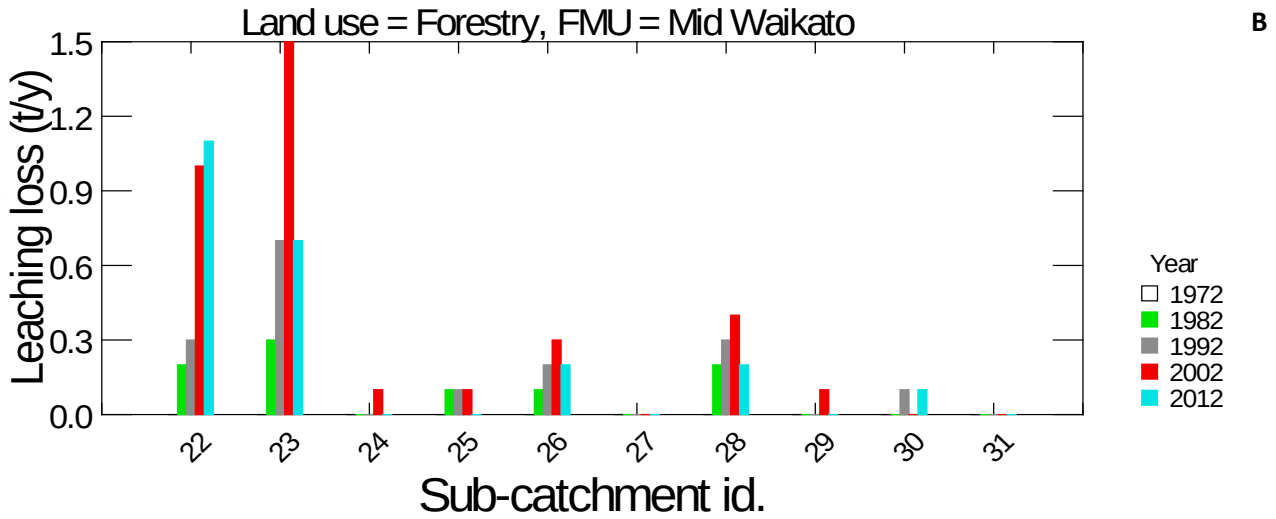


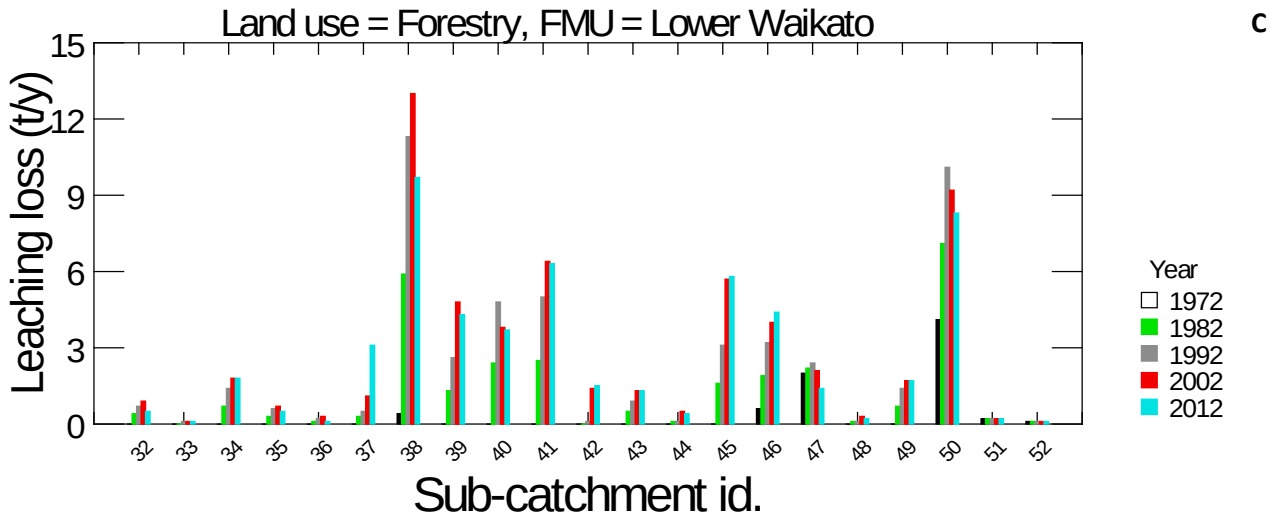
Figure G-5: Nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Sheep and beef Intensive land use.


Land use = Forestry, FMU = Upper Waikato
Leaching loss (t/y)
150
120
90
60
30
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012

A


Land use = Forestry, FMU = Mid Waikato
Leaching loss (t/y)
1.5
1.2
0.9
0.6
0.3
0.0
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012

B


Land use = Forestry, FMU = Lower Waikato
Leaching loss (t/y)
15
12
9
6
3
0
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

C

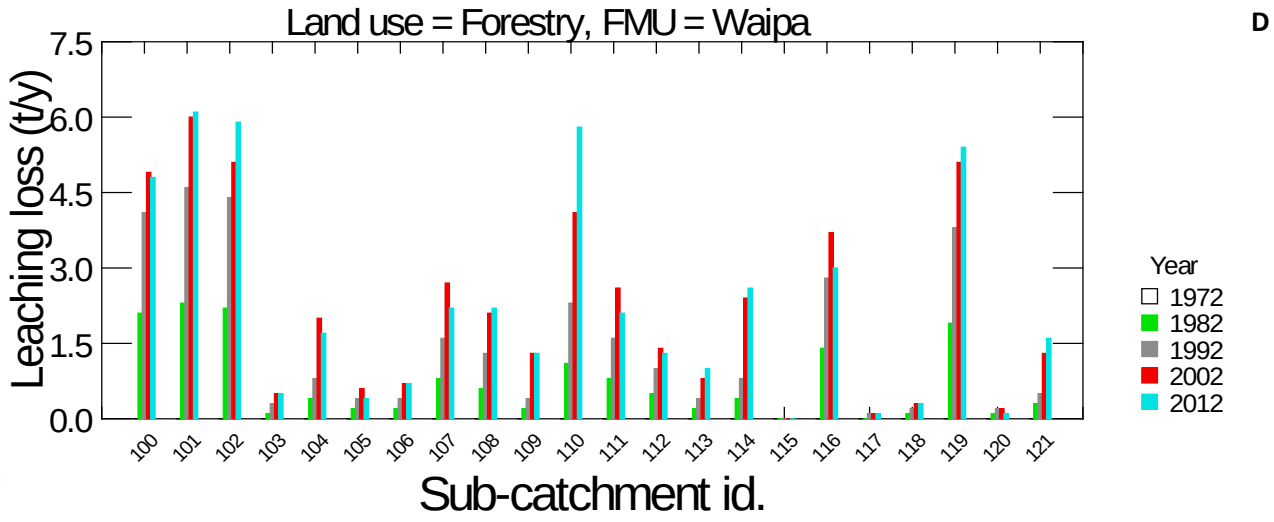
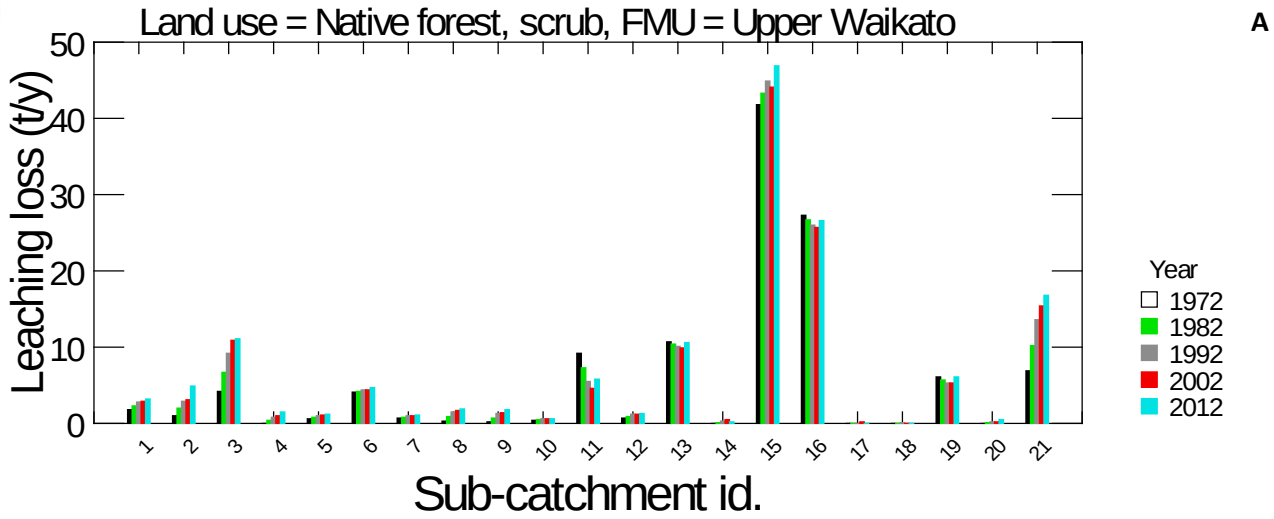
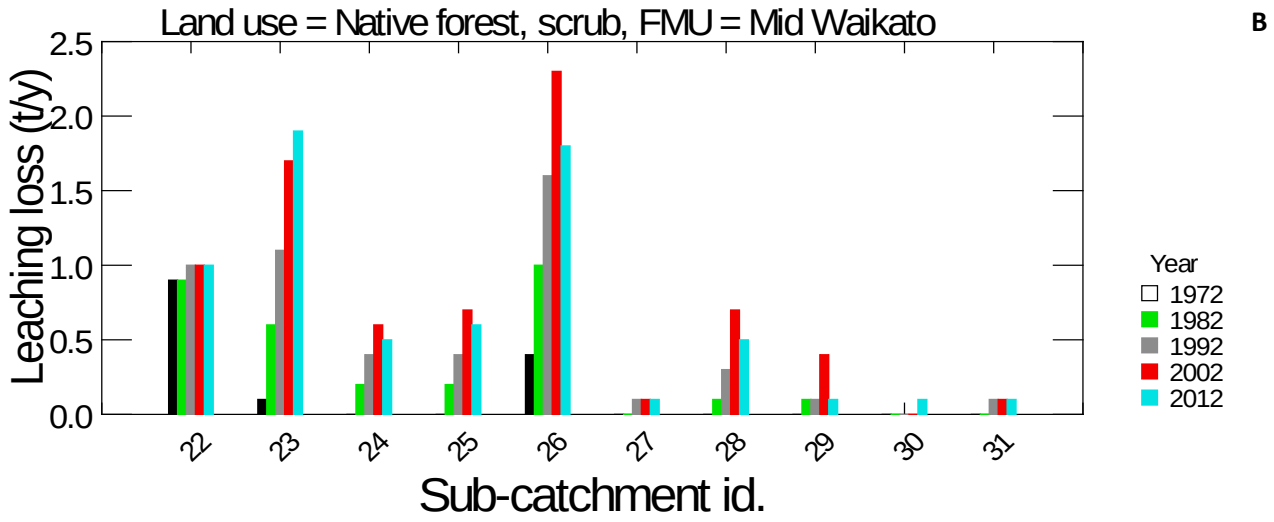


Figure G-6: Nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Forestry land use.





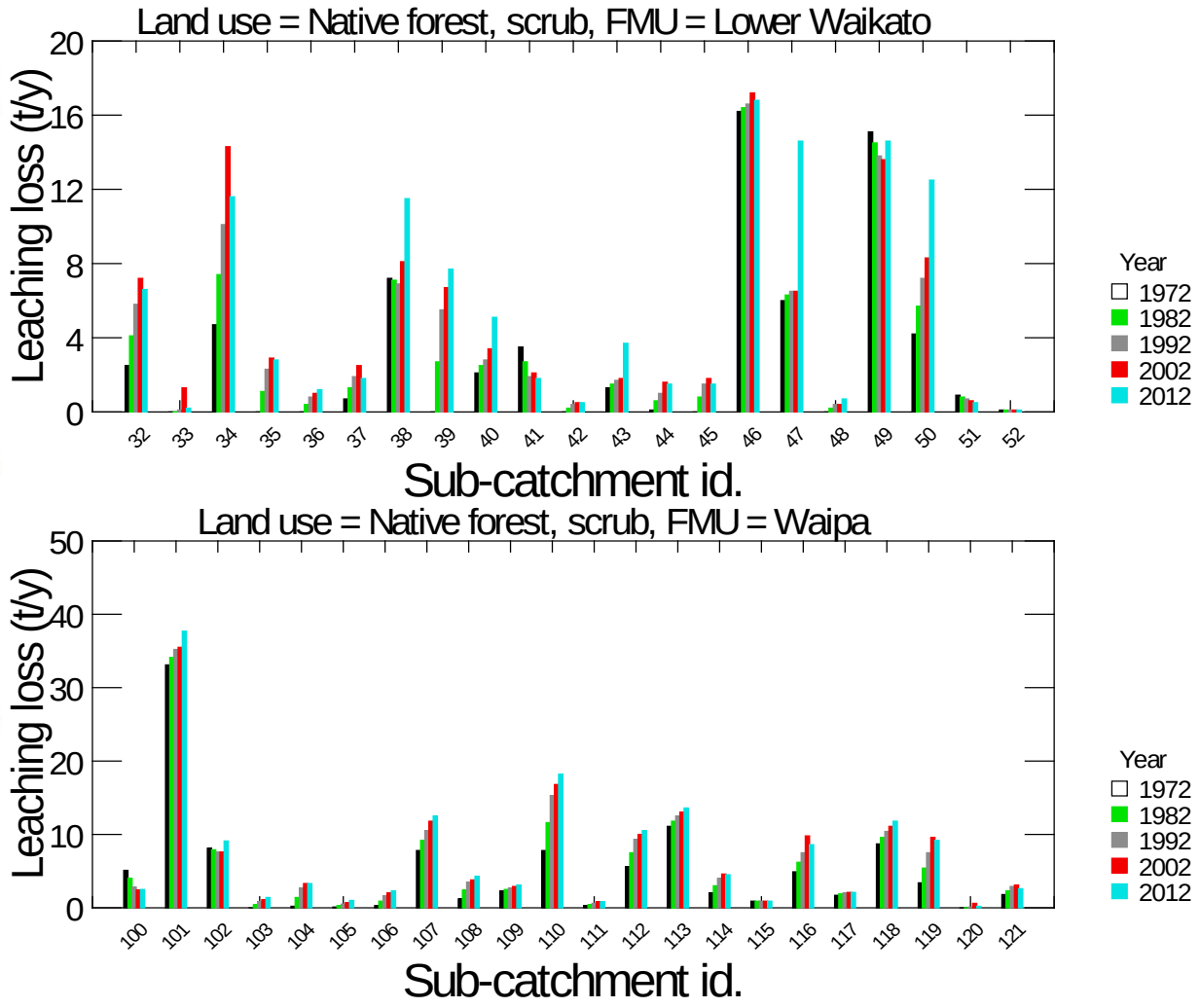
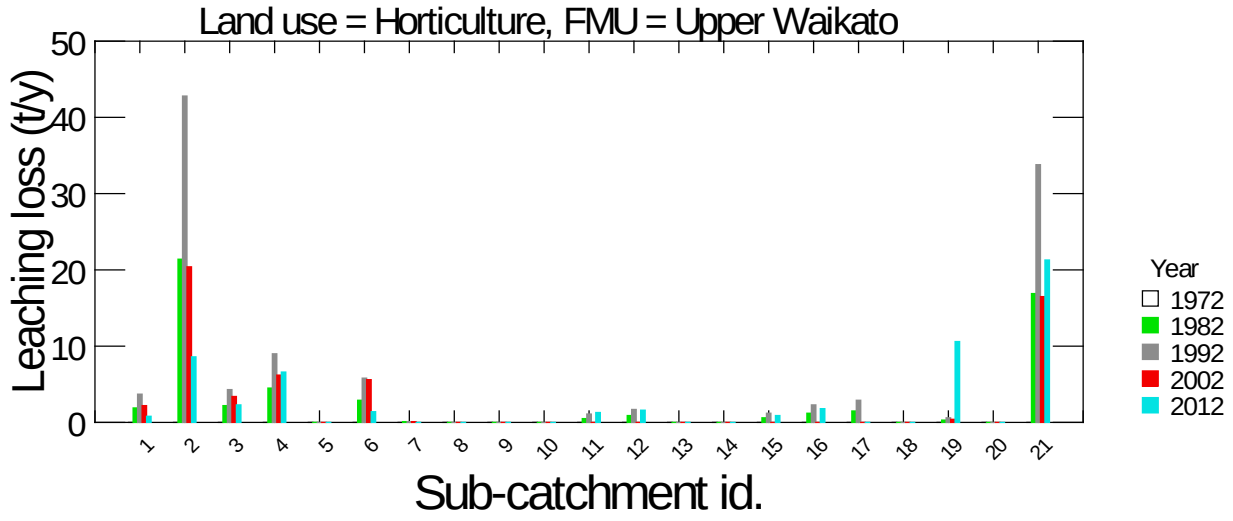


Figure G-7: Nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Native forest and scrub land use.



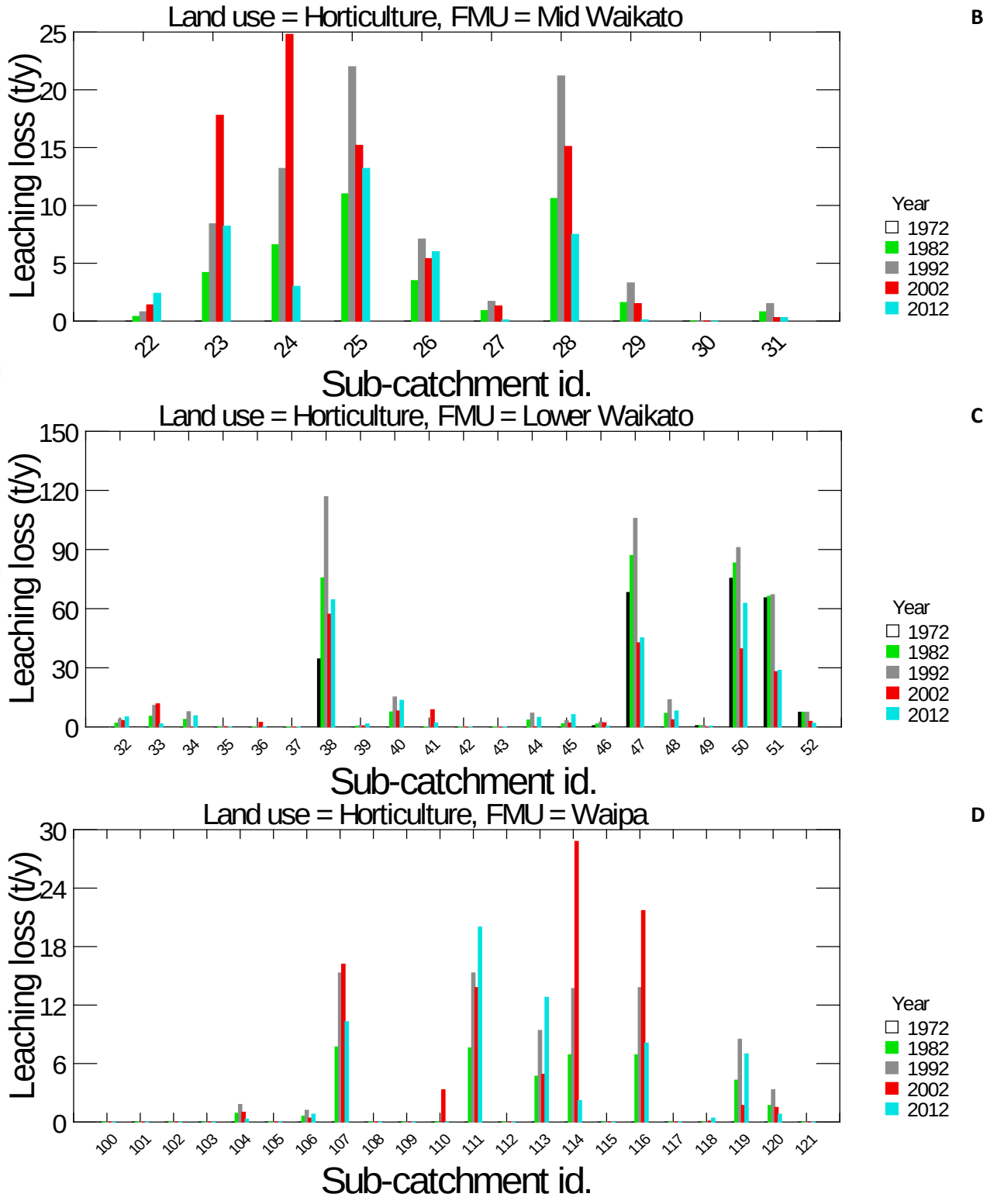
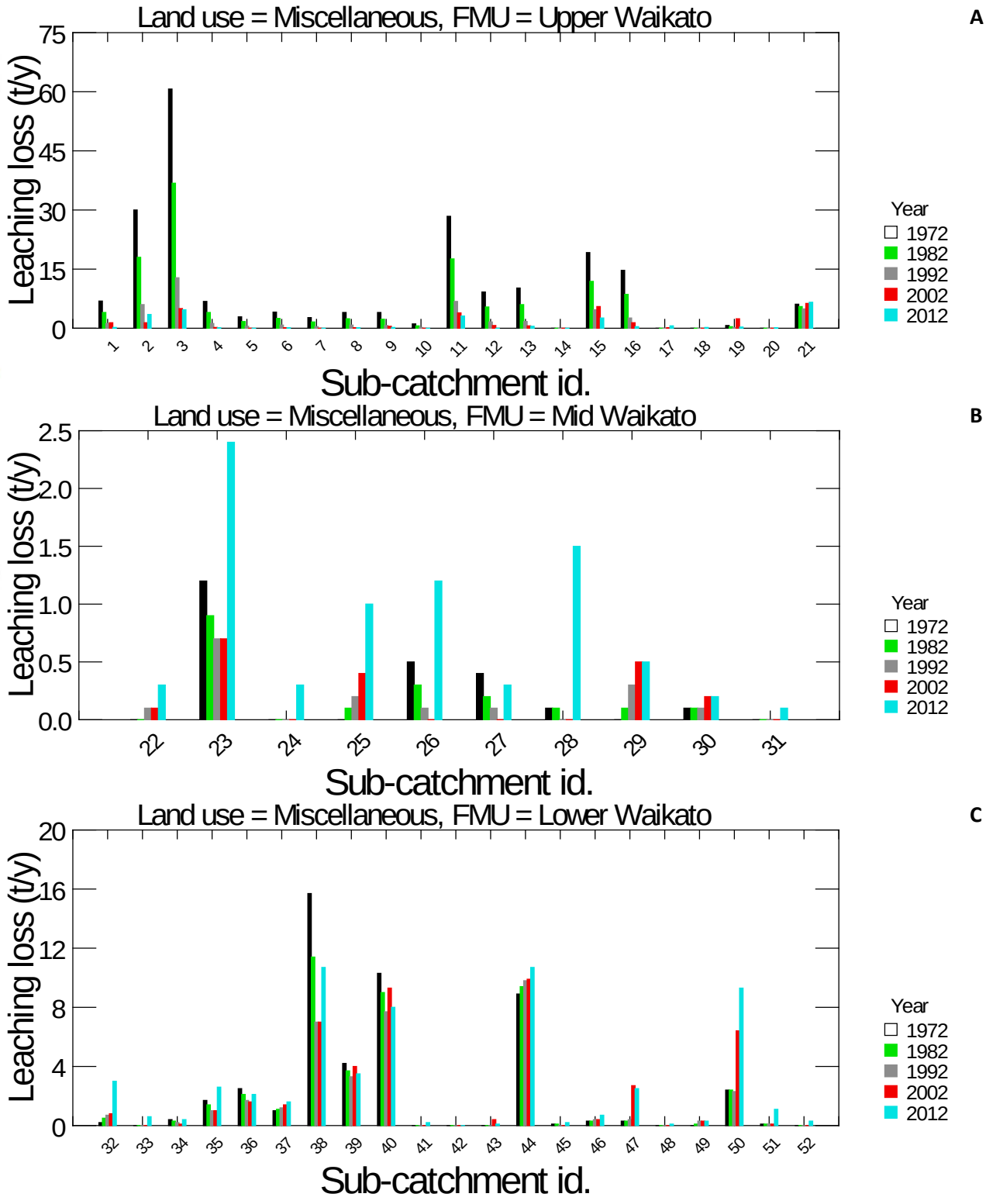


Figure G-8: Nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Horticulture land use.


A
Land use = Miscellaneous, FMU = Upper Waikato
Leaching loss (t/y)
0
15
30
45
60
75
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012
B
Land use = Miscellaneous, FMU = Mid Waikato
Leaching loss (t/y)
0.0
0.5
1.0
1.5
2.0
2.5
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012
C
Land use = Miscellaneous, FMU = Lower Waikato
Leaching loss (t/y)
0
4
8
12
16
20
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

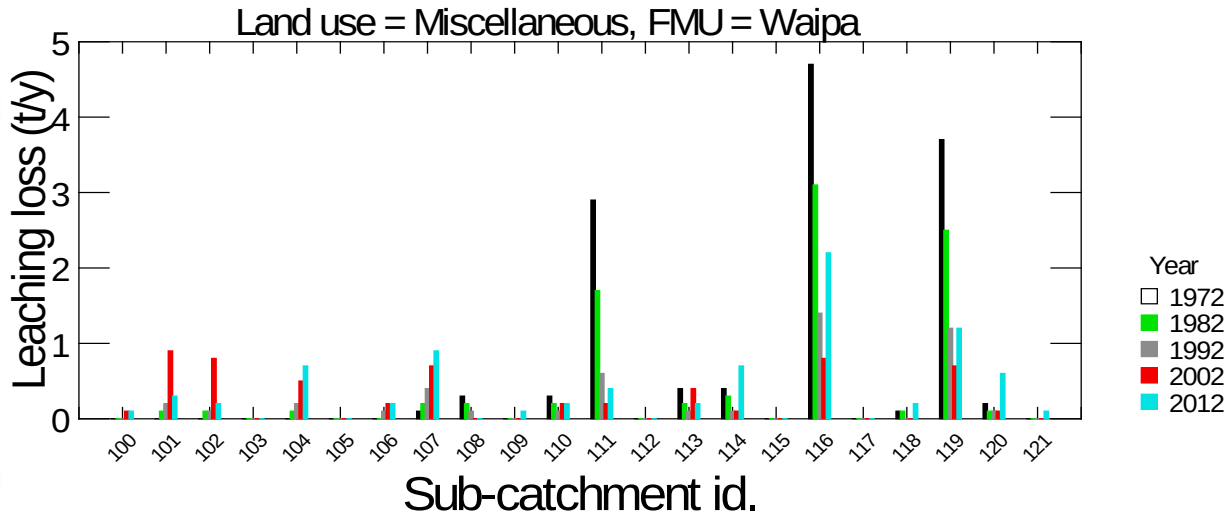
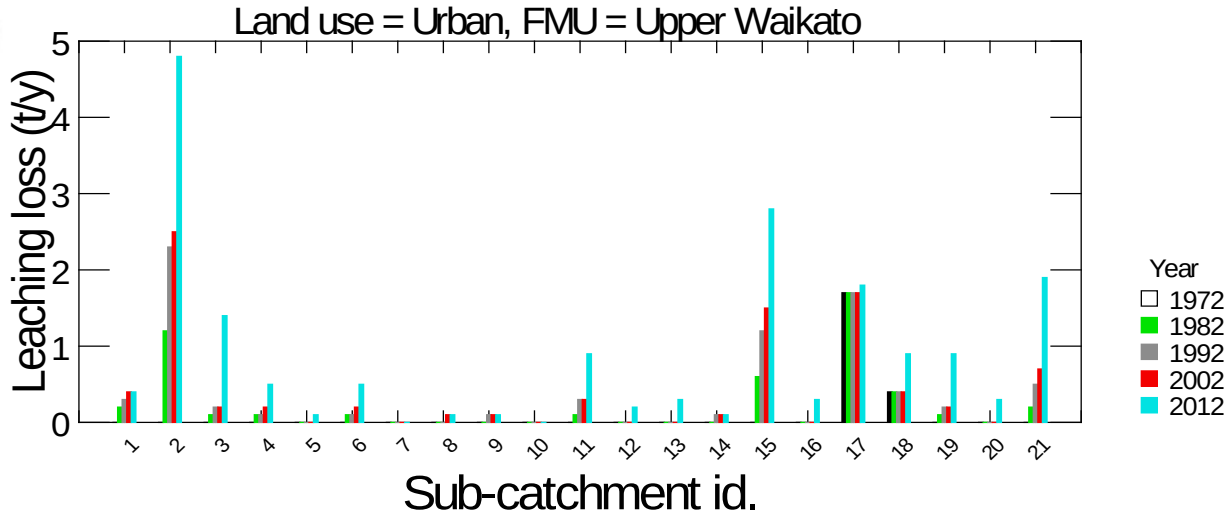
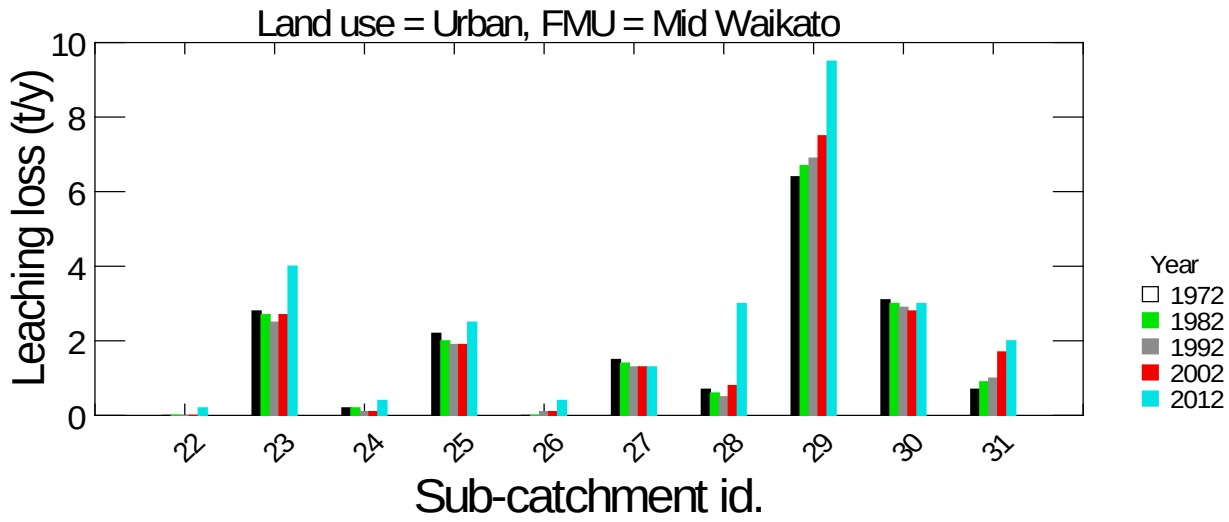


Figure G-9: Nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Miscellaneous land use.





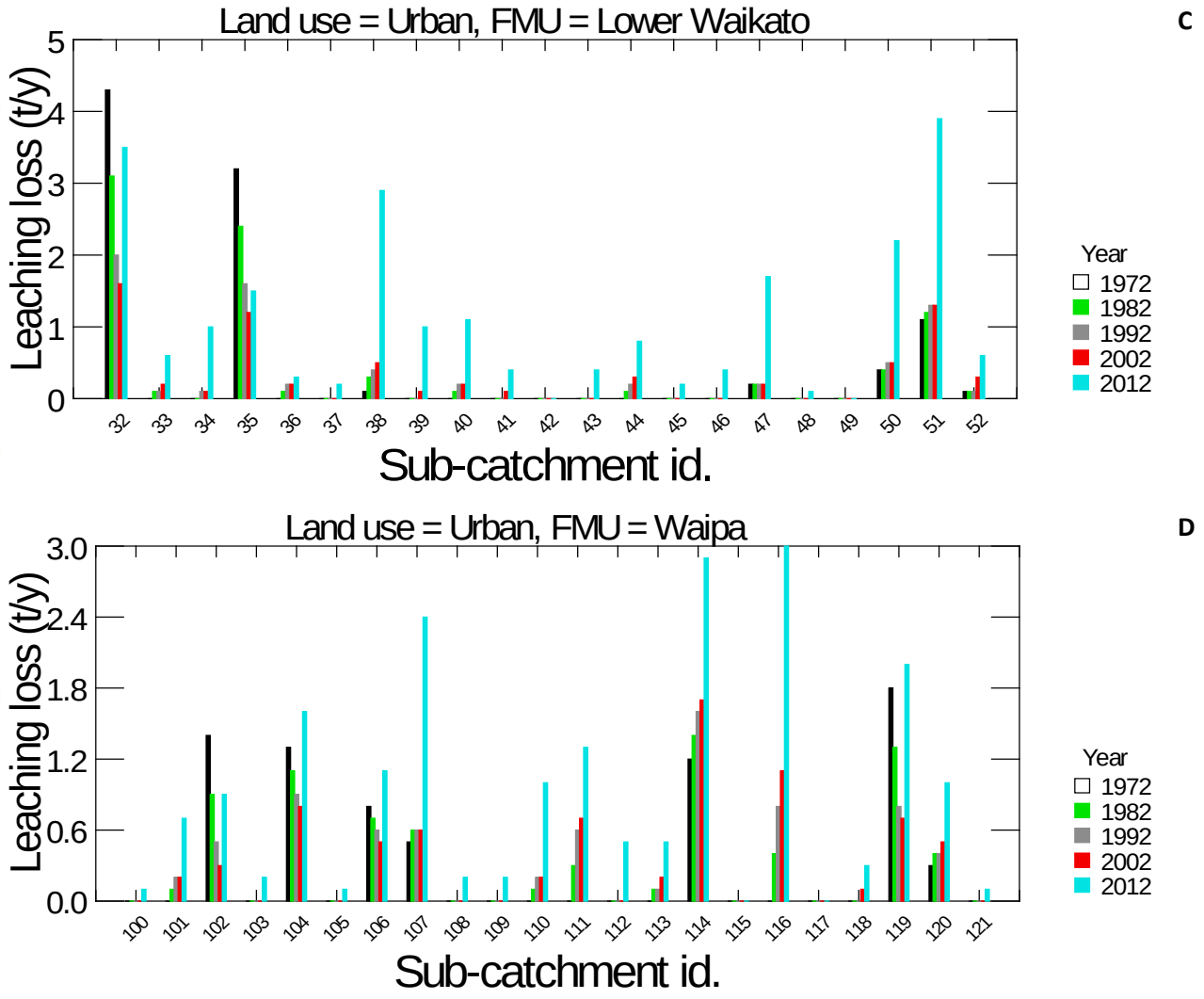
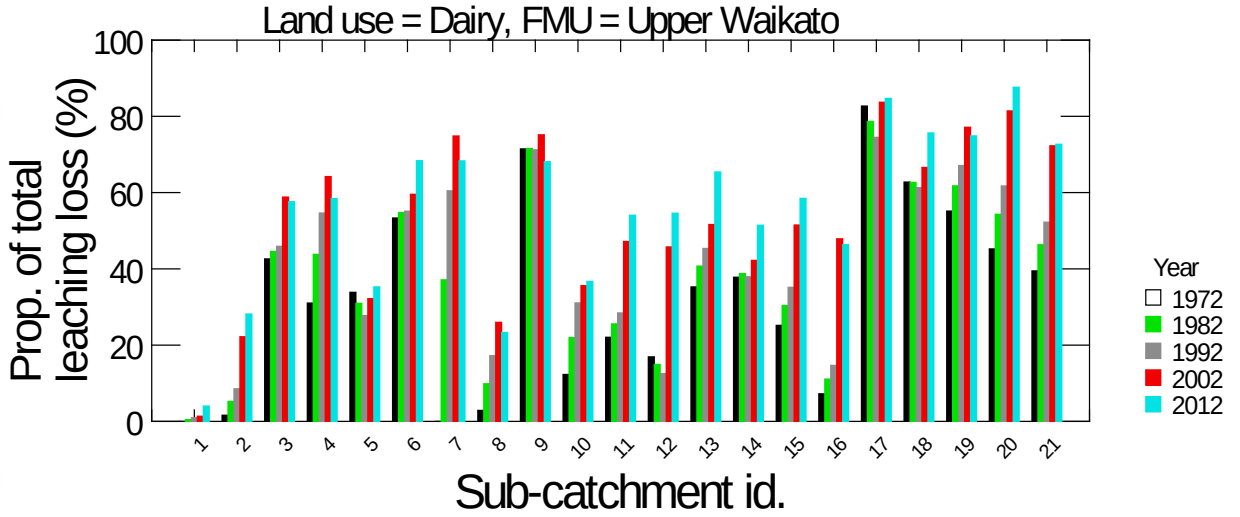
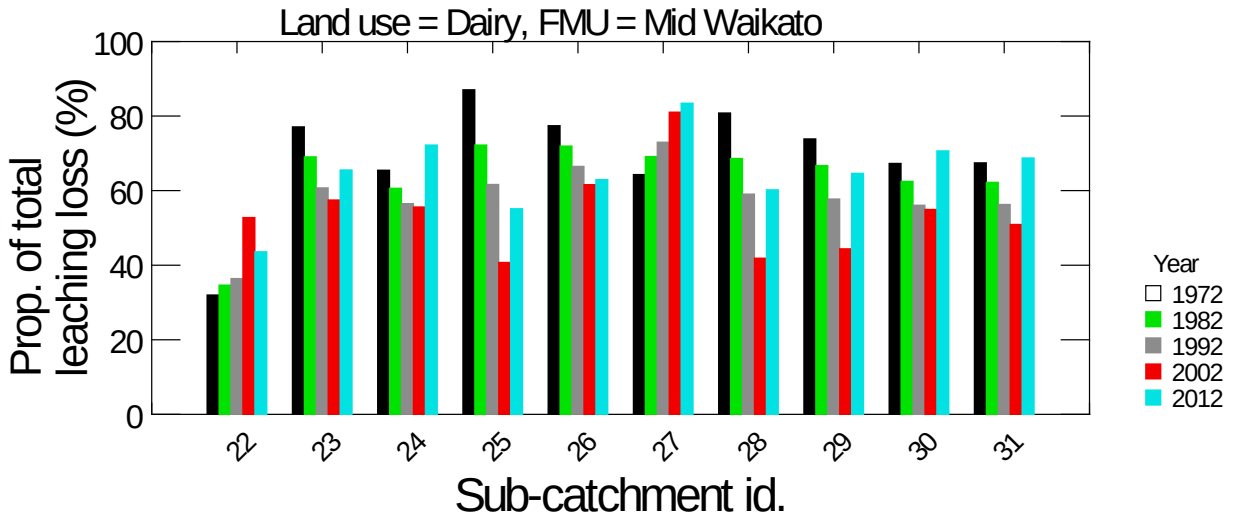


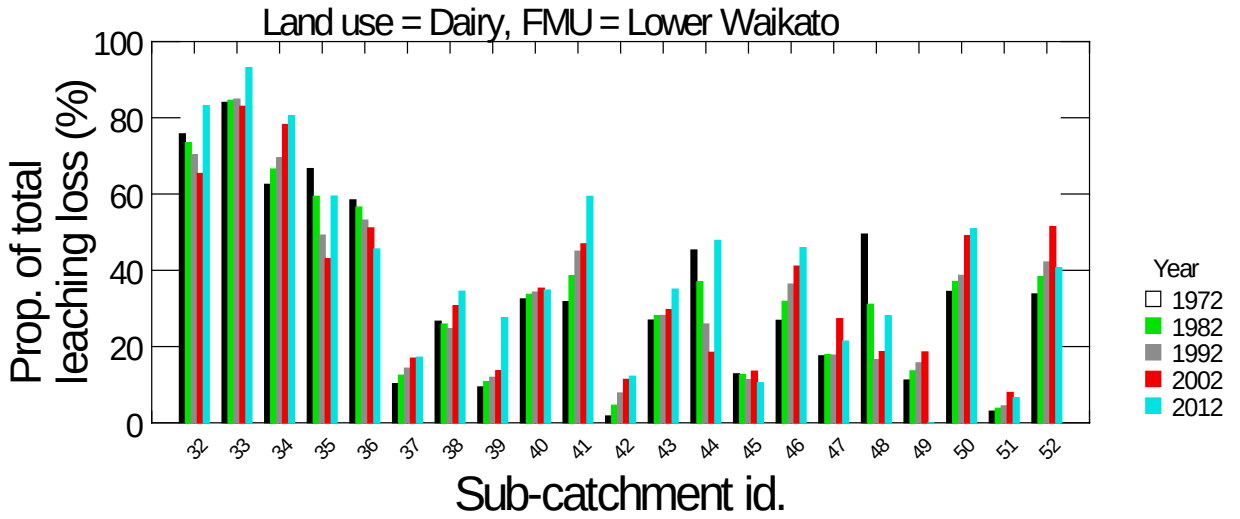
Figure G-10: Nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Urban land use.


Land use = Dairy, FMU = Upper Waikato
Prop. of total leaching loss (%)
0
20
40
60
80
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012

A


Land use = Dairy, FMU = Mid Waikato
Prop. of total leaching loss (%)
0
20
40
60
80
100
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012

B


Land use = Dairy, FMU = Lower Waikato
Prop. of total leaching loss (%)
0
20
40
60
80
100
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

C

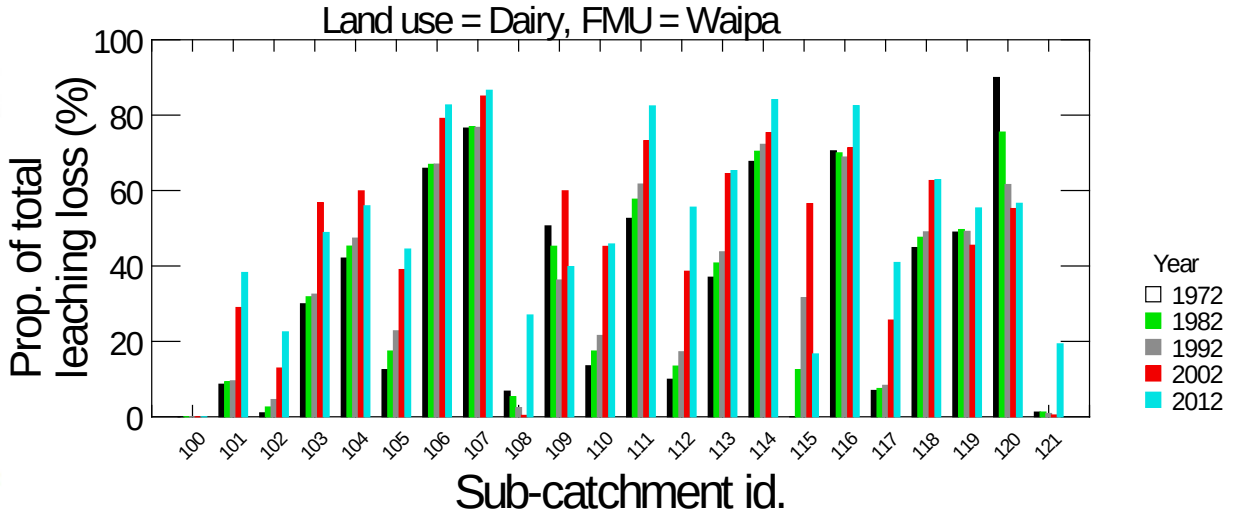
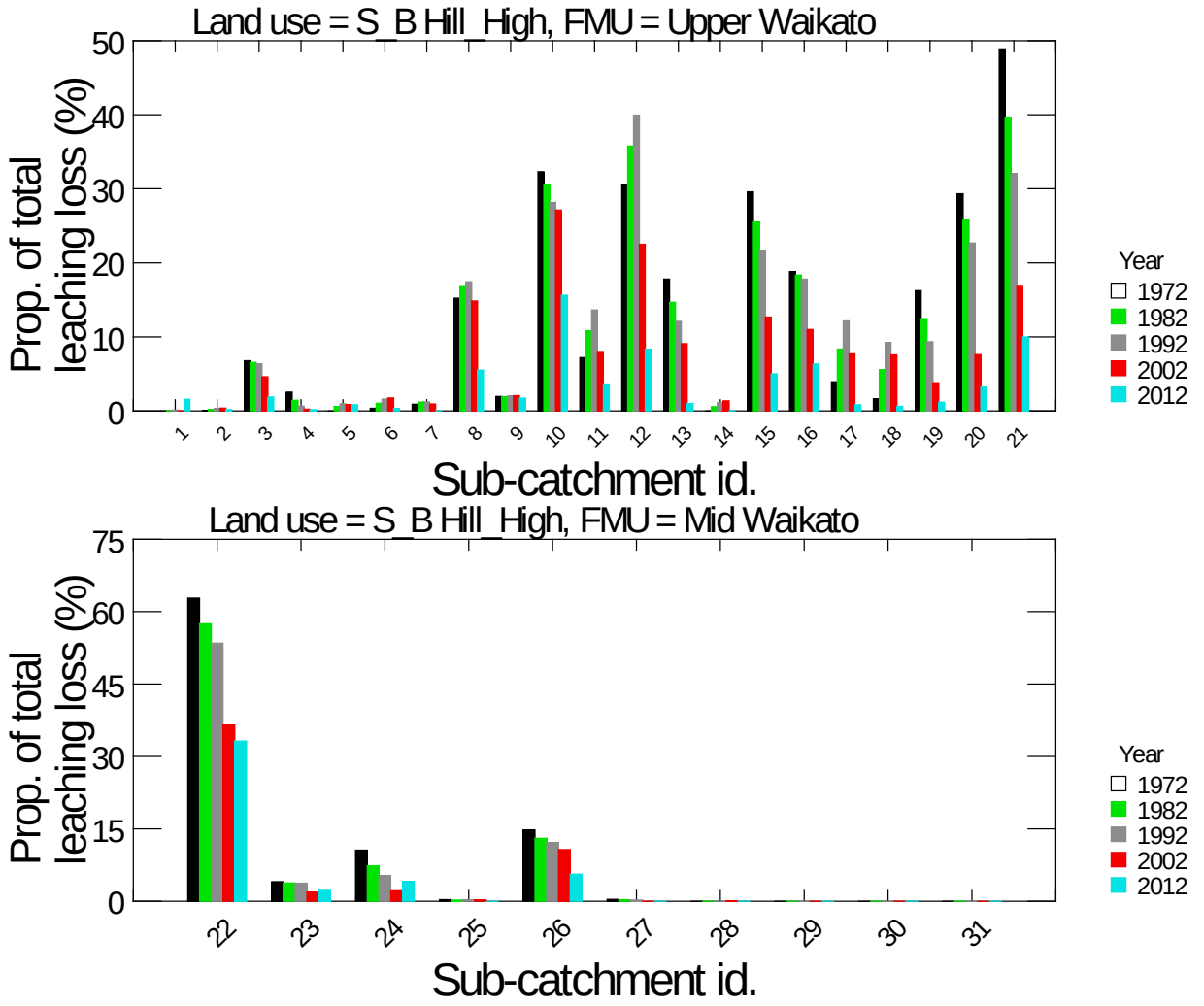


Figure G-11: Proportion of nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Dairy land use.



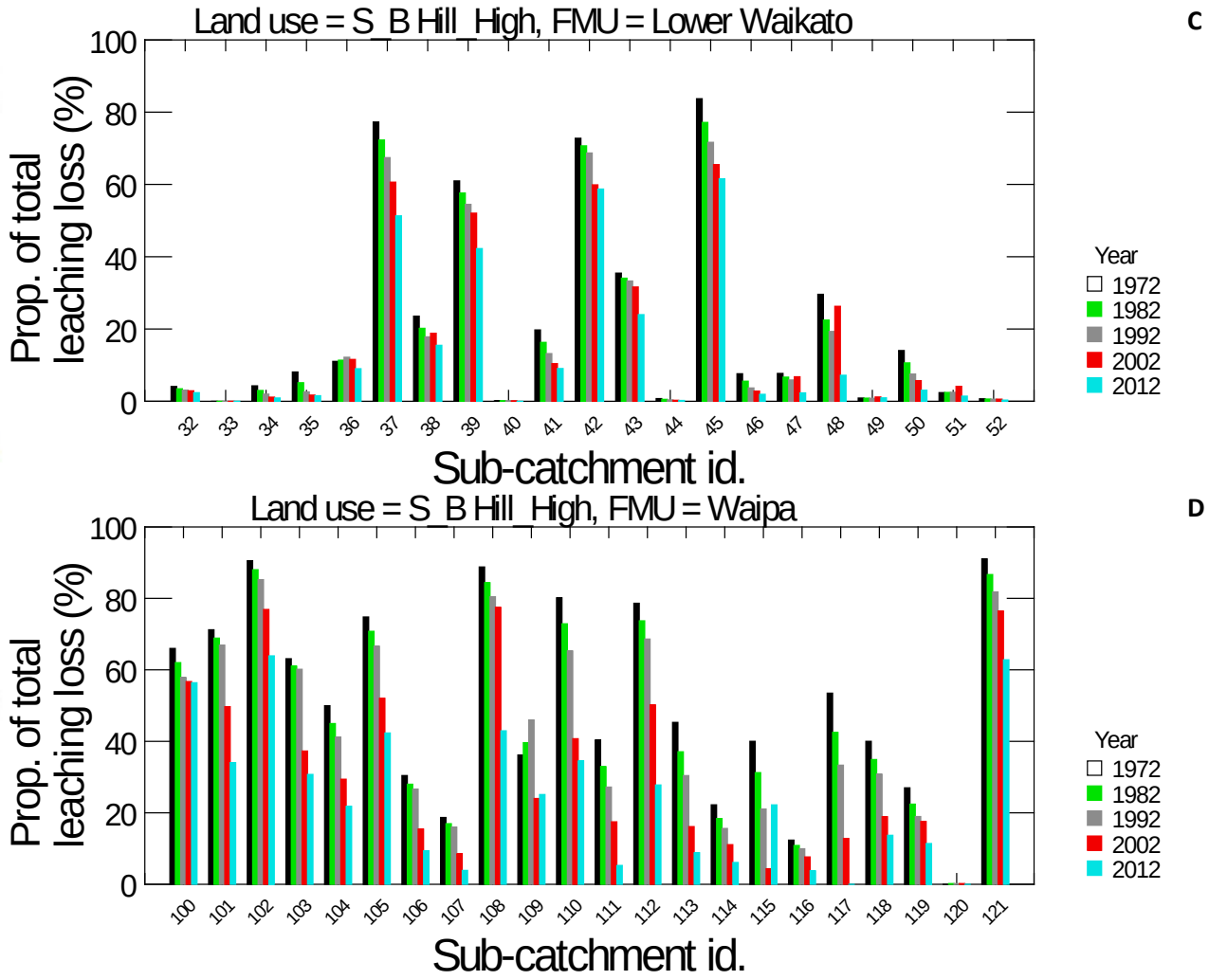
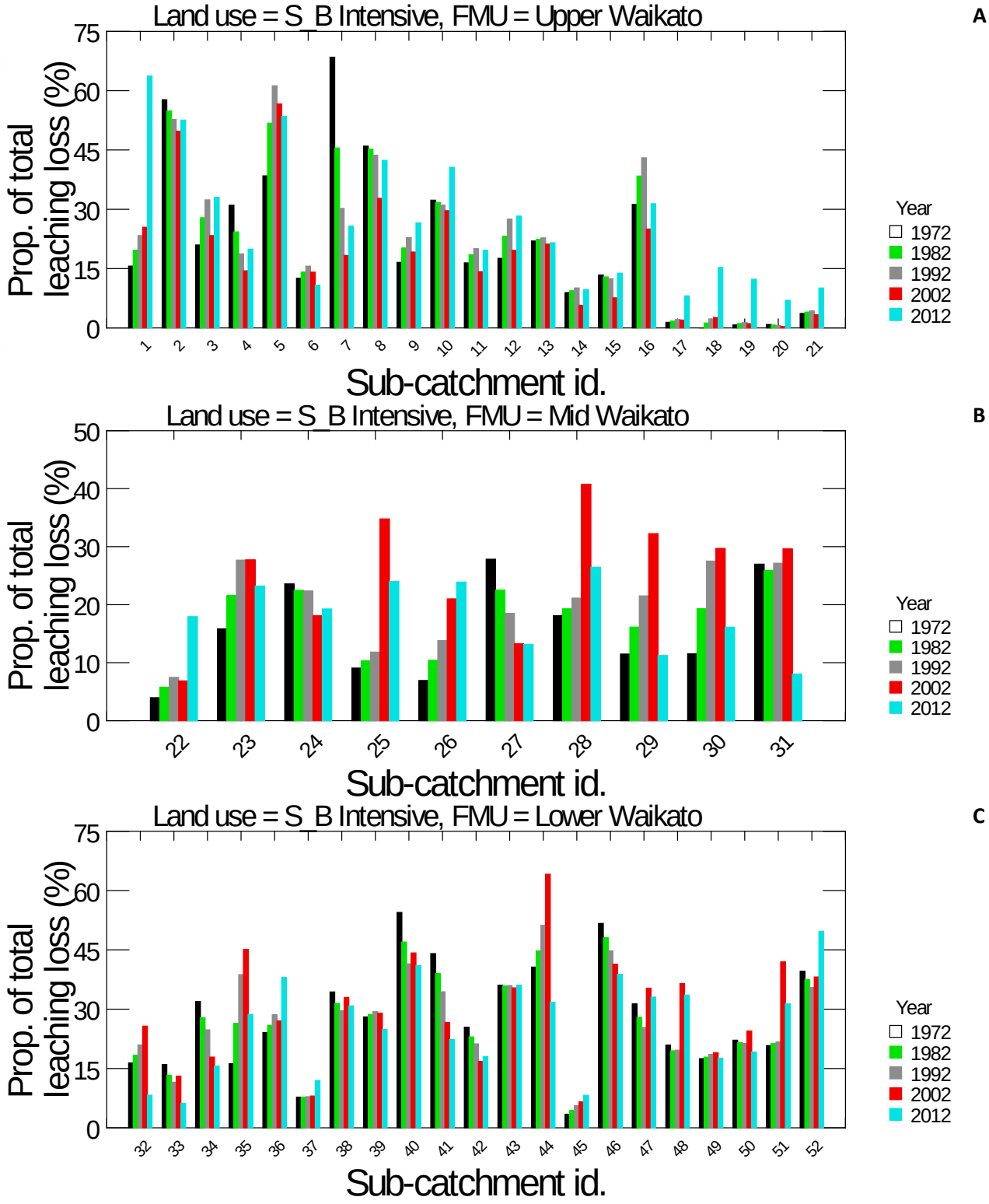


Figure G-12: Proportion of nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Sheep and beef High and Hill land use.


A
Land use = S_B Intensive, FMU = Upper Waikato
Prop. of total leaching loss (%)
0
15
30
45
60
75
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012
B
Land use = S_B Intensive, FMU = Mid Waikato
Prop. of total leaching loss (%)
0
10
20
30
40
50
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012
C
Land use = S_B Intensive, FMU = Lower Waikato
Prop. of total leaching loss (%)
0
15
30
45
60
75
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

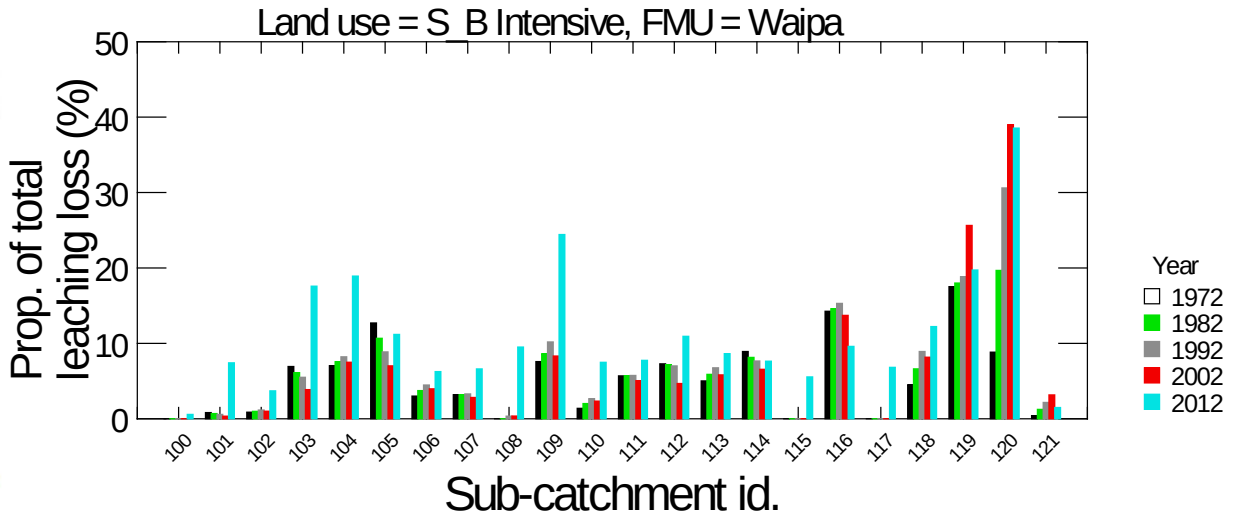
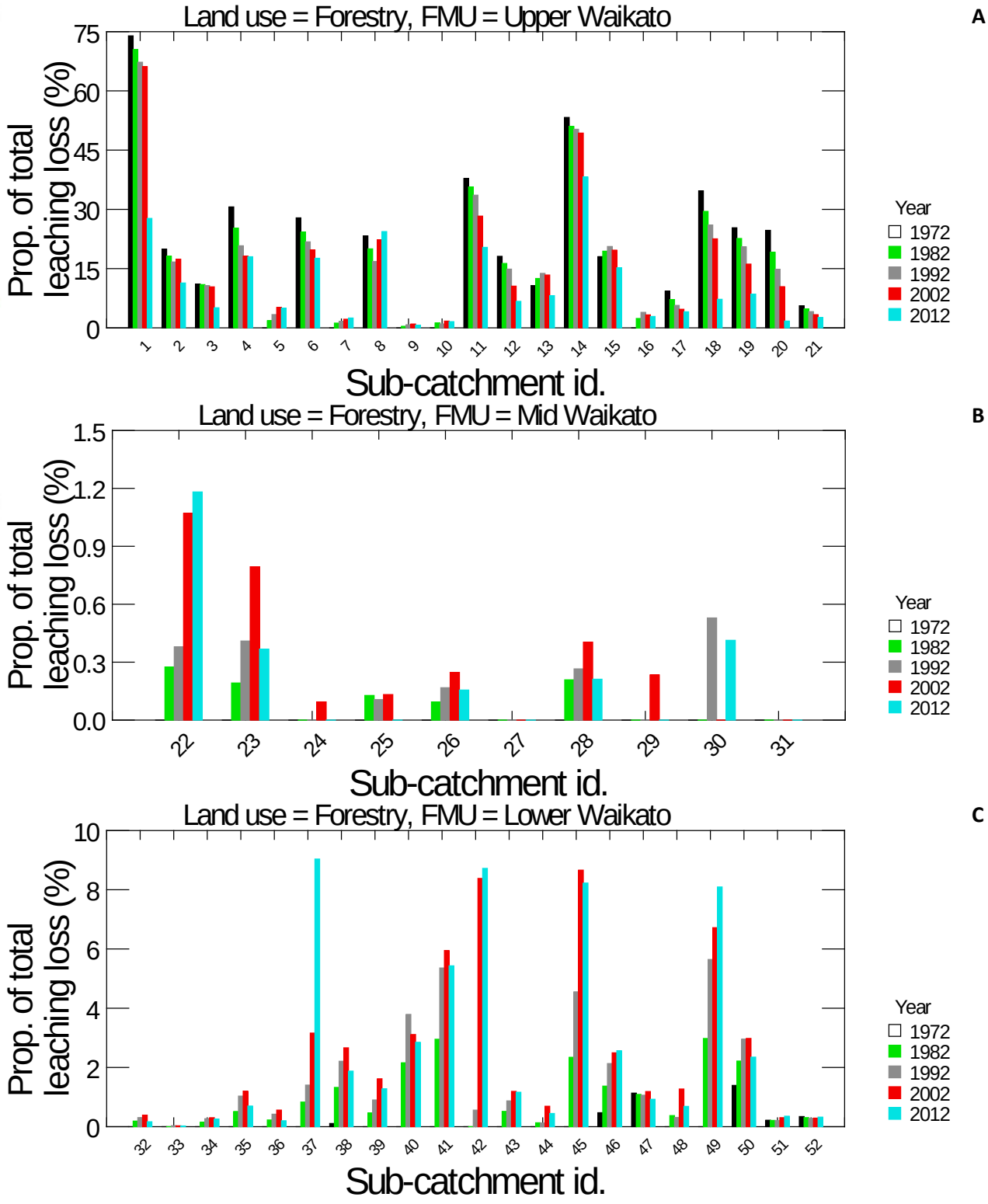


Figure G-13: Proportion of nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Sheep and beef Intensive land use.


A
Land use = Forestry, FMU = Upper Waikato
Prop. of total leaching loss (%)
0
15
30
45
60
75
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012
B
Land use = Forestry, FMU = Mid Waikato
Prop. of total leaching loss (%)
0.0
0.3
0.6
0.9
1.2
1.5
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012
C
Land use = Forestry, FMU = Lower Waikato
Prop. of total leaching loss (%)
0
2
4
6
8
10
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

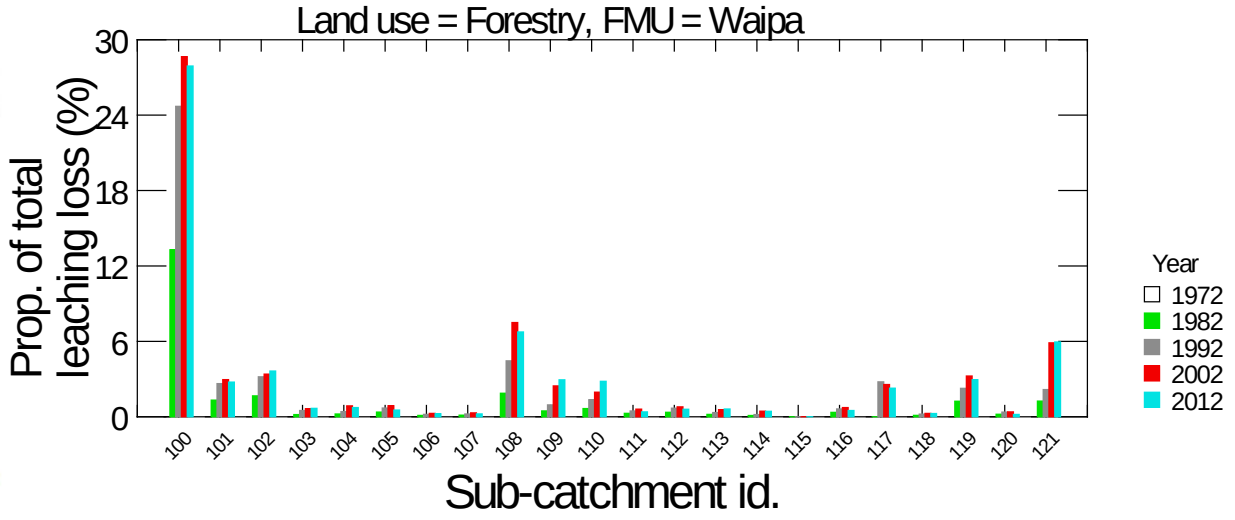
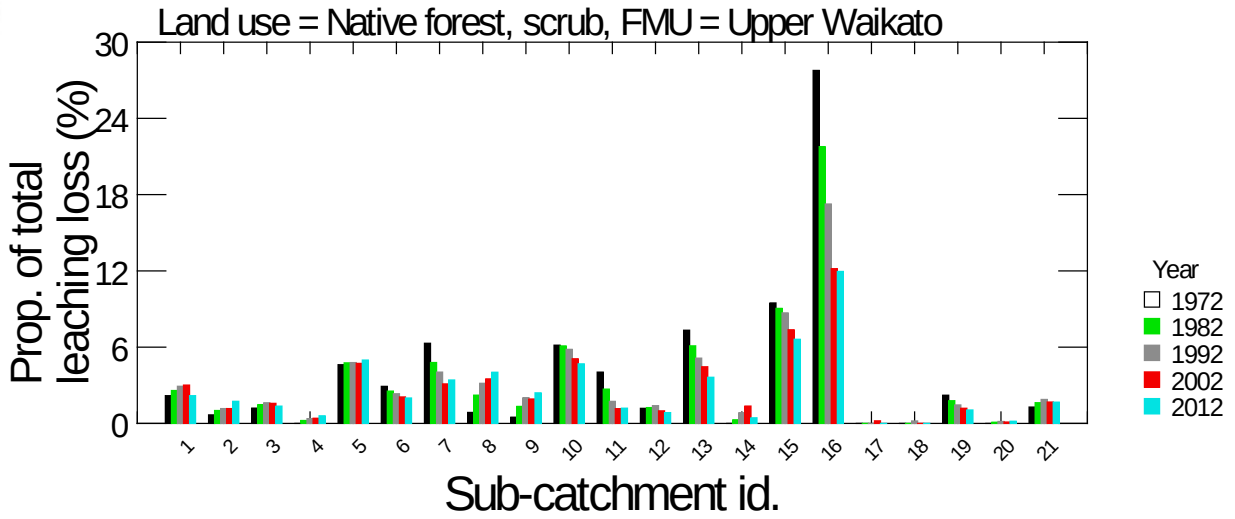
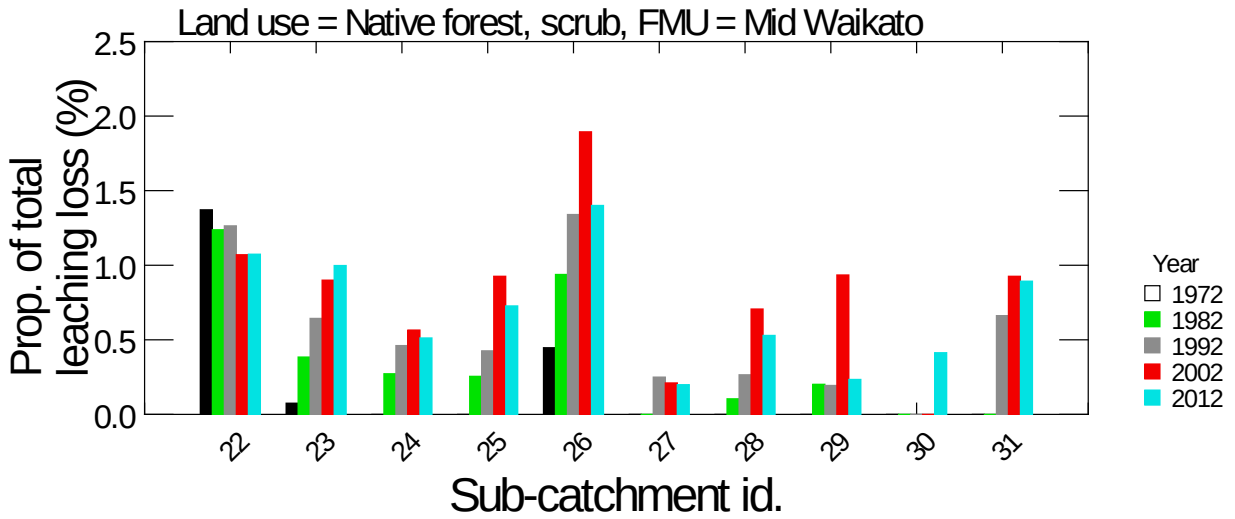


Figure G-14: Proportion of nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Forestry land use.





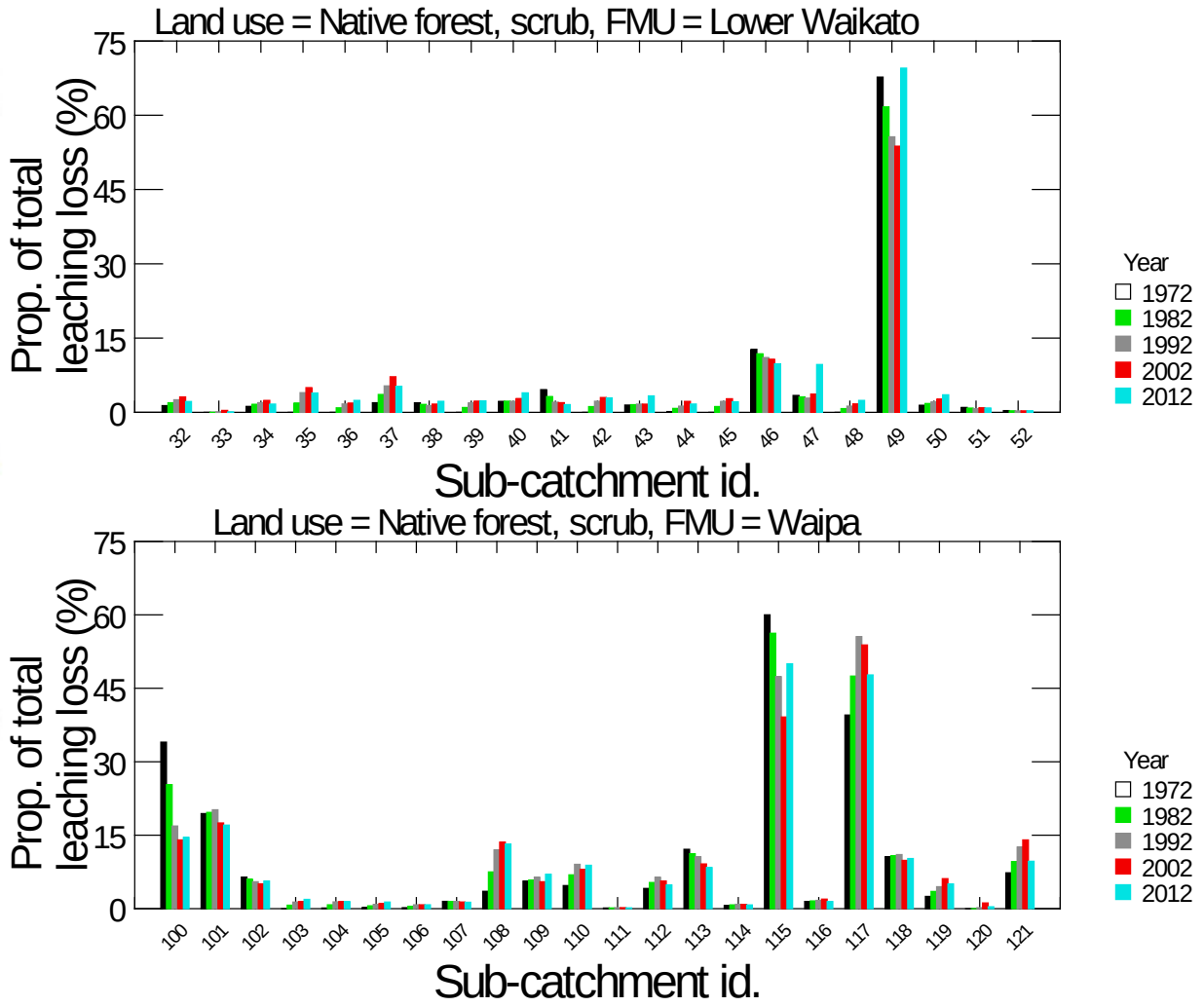
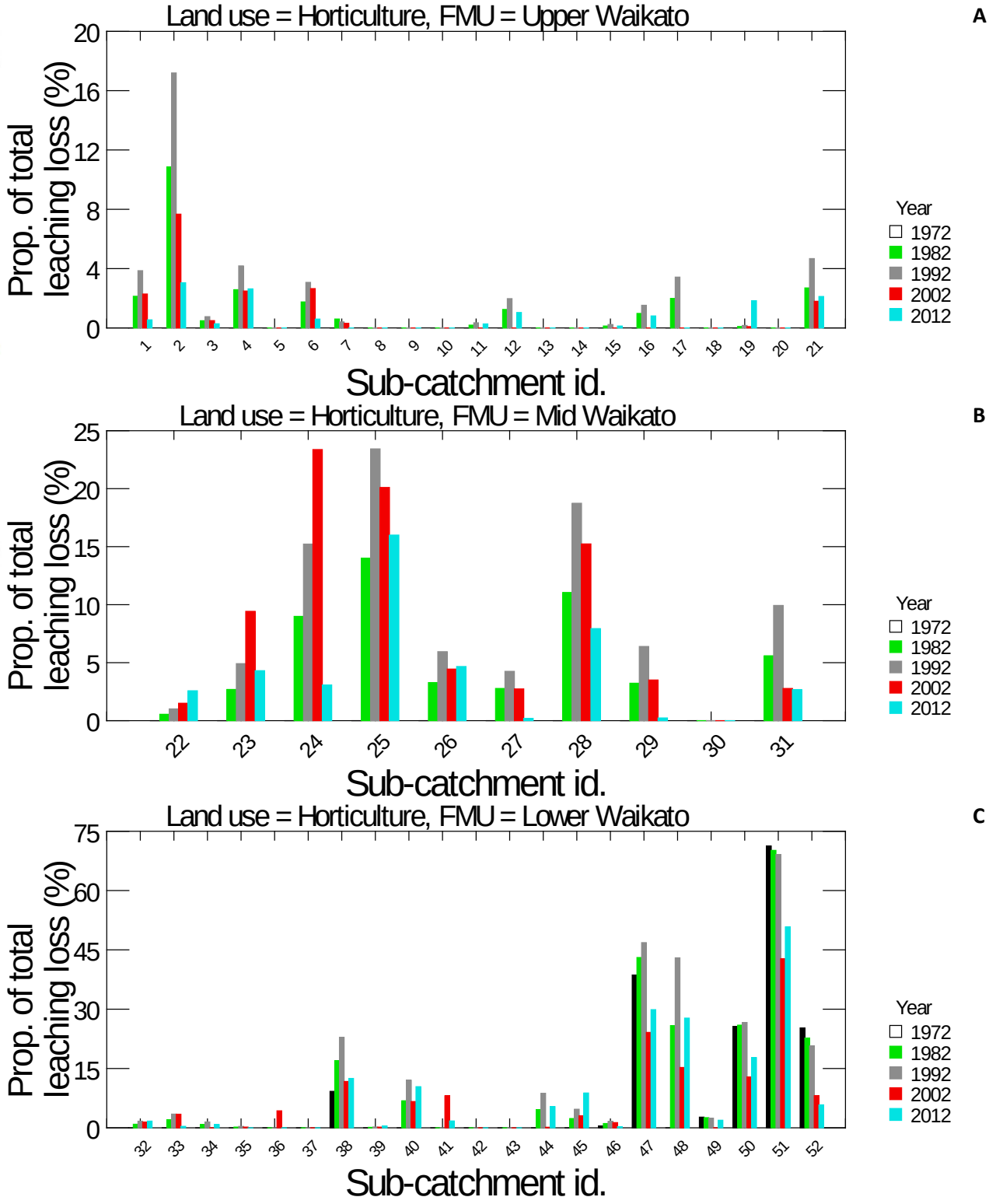


Figure G-15: Proportion of nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Native forest ad scrub land use.


A
Land use = Horticulture, FMU = Upper Waikato
Prop. of total leaching loss (%)
0
4
8
12
16
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012
B
Land use = Horticulture, FMU = Mid Waikato
Prop. of total leaching loss (%)
0
5
10
15
20
25
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012
C
Land use = Horticulture, FMU = Lower Waikato
Prop. of total leaching loss (%)
0
15
30
45
60
75
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

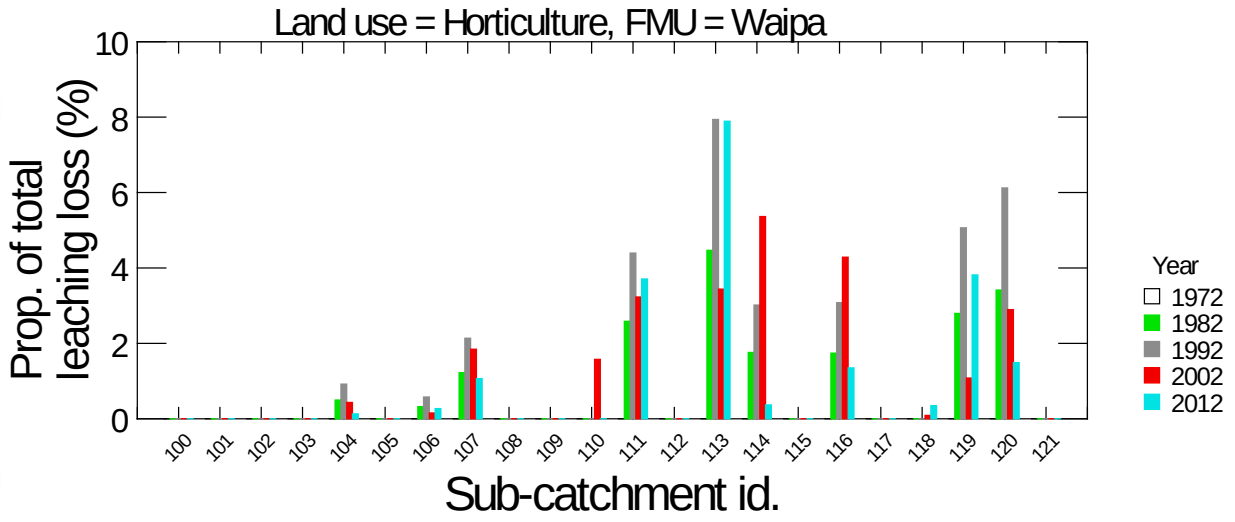
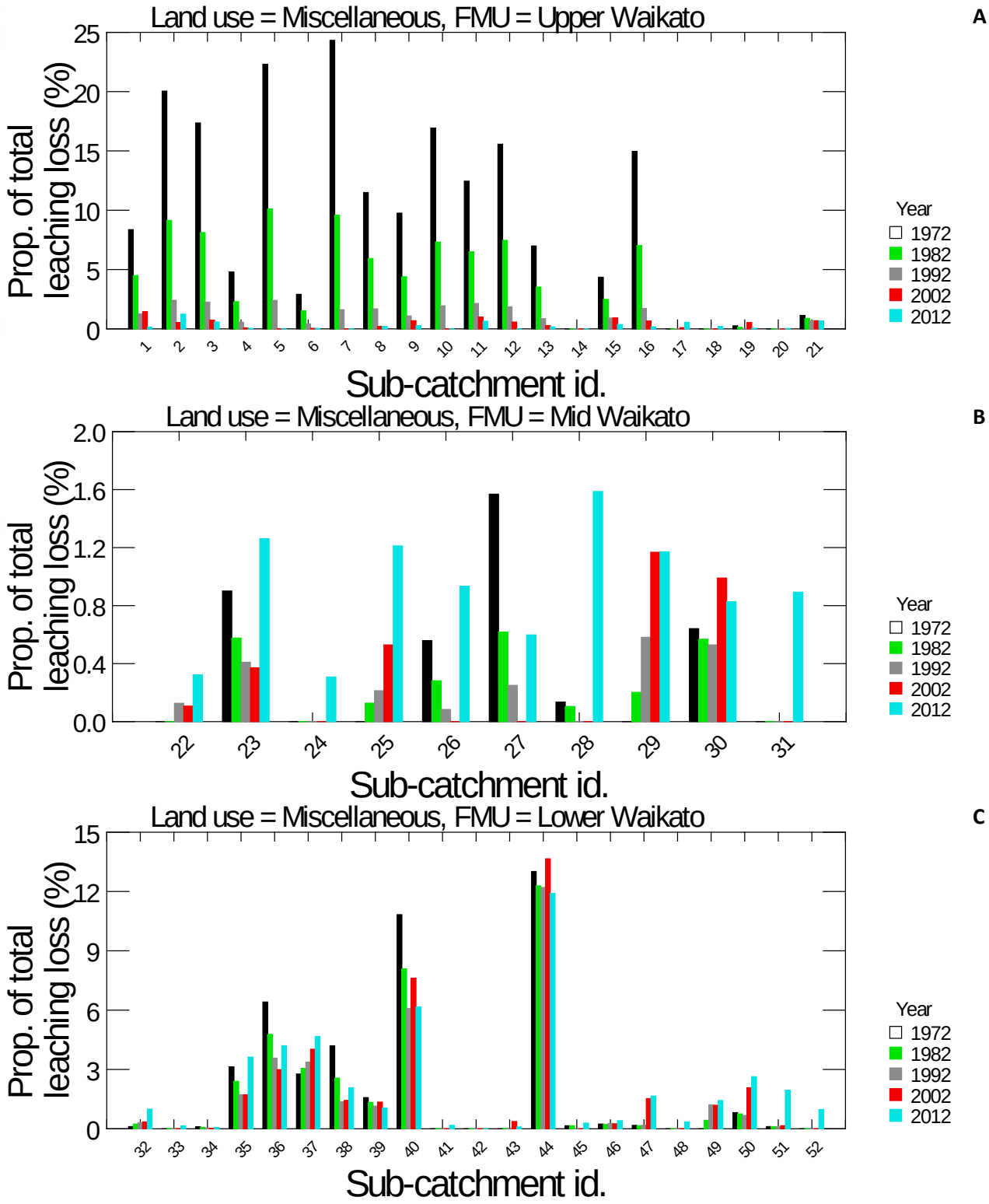


Figure G-16: Proportion of nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Horticulture land use.


A
Land use = Miscellaneous, FMU = Upper Waikato
Prop. of total leaching loss (%)
0
5
10
15
20
25
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012
B
Land use = Miscellaneous, FMU = Mid Waikato
Prop. of total leaching loss (%)
0.0
0.4
0.8
1.2
1.6
2.0
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012
C
Land use = Miscellaneous, FMU = Lower Waikato
Prop. of total leaching loss (%)
0
3
6
9
12
15
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

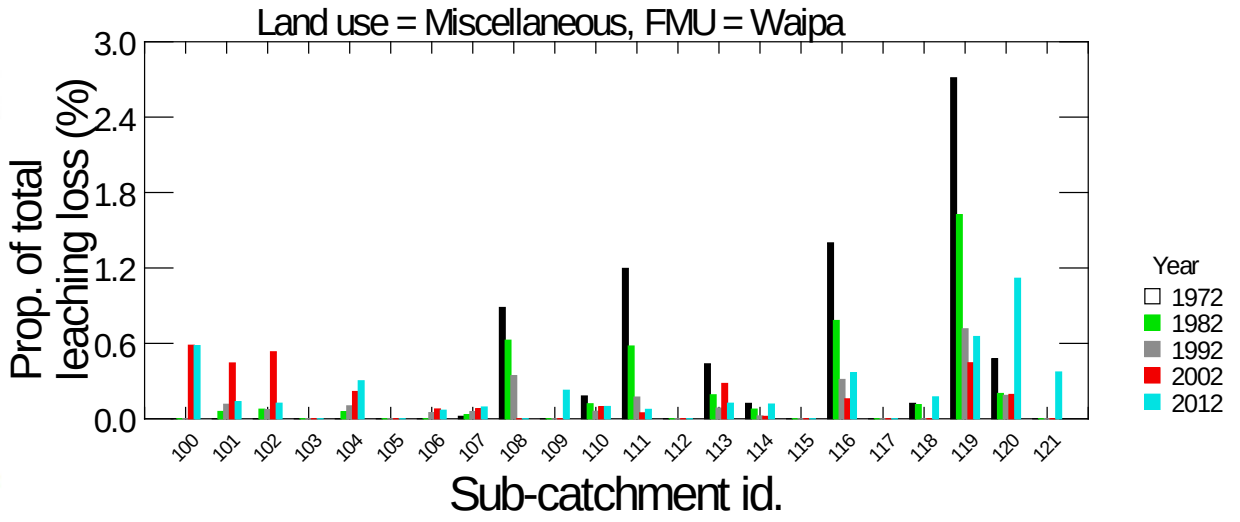
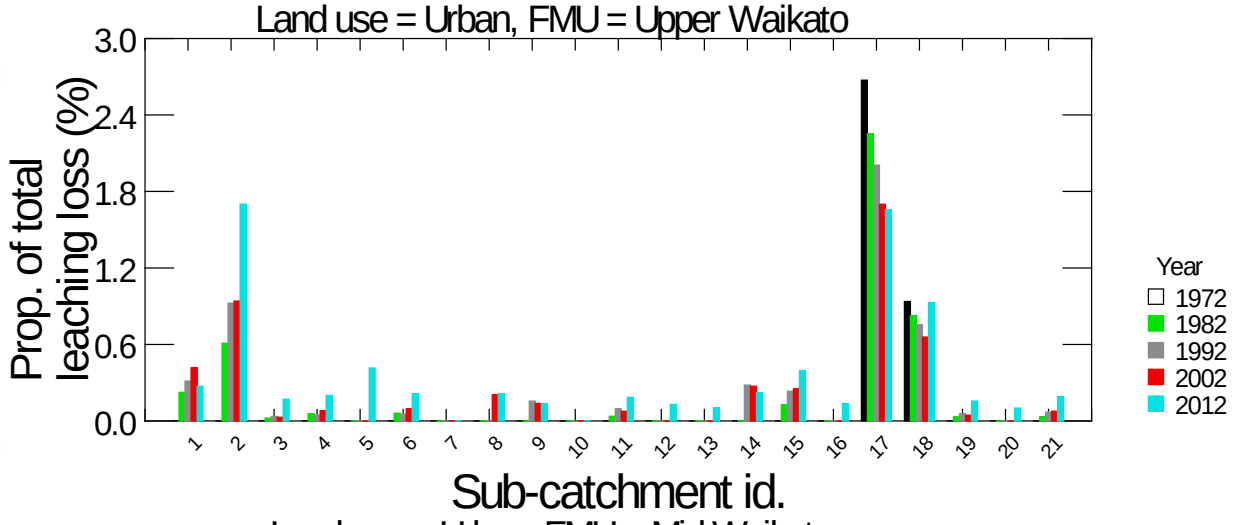
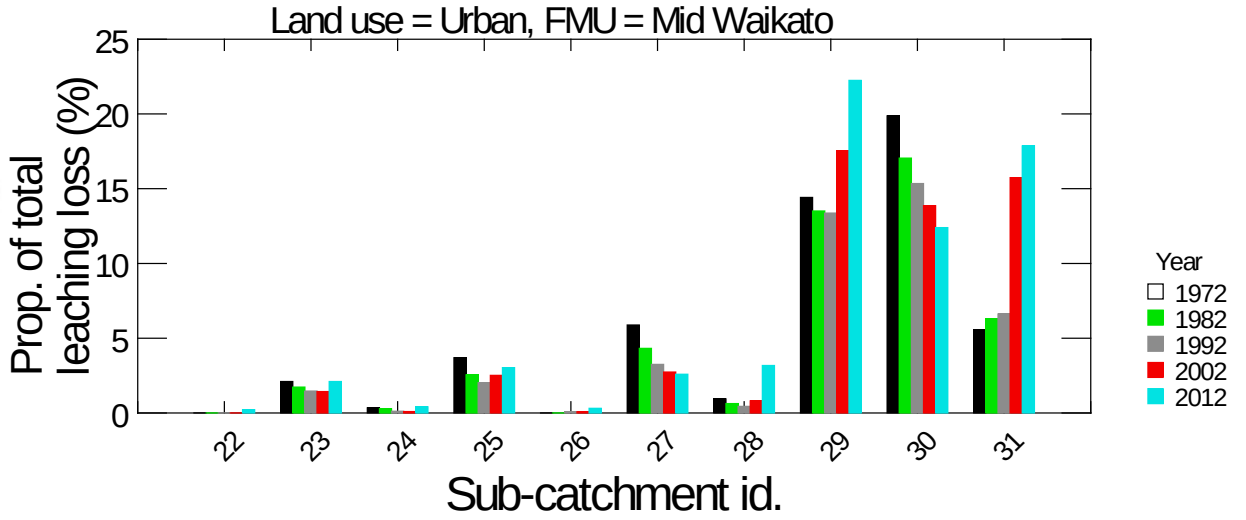


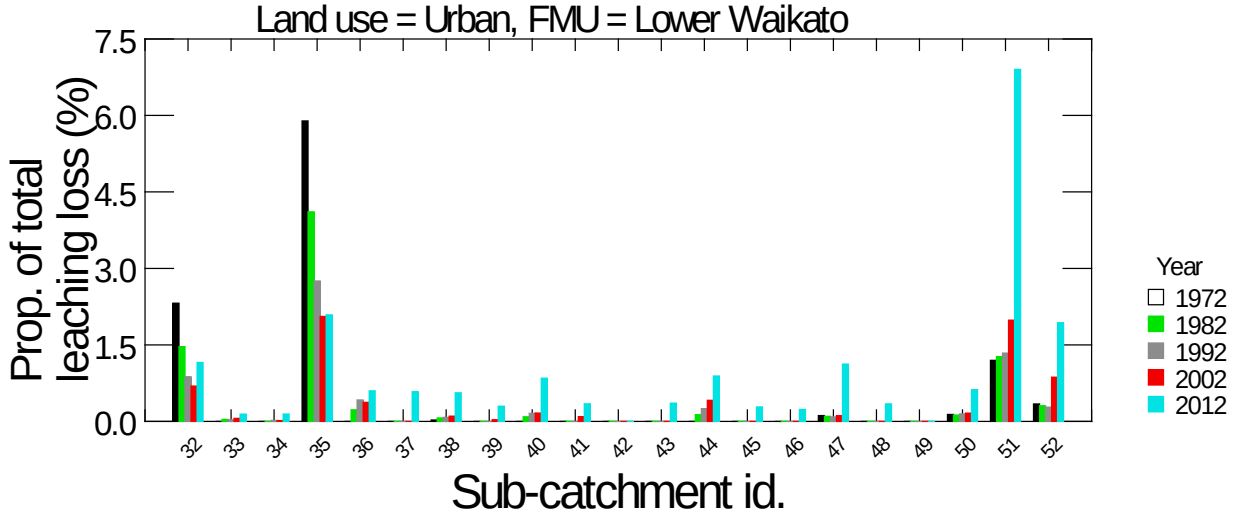
Figure G-17: Proportion of nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Miscellaneous land use.


Land use = Urban, FMU = Upper Waikato
Prop. of total leaching loss (%)
3.0
2.4
1.8
1.2
0.6
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Sub-catchment id.
Year
1972
1982
1992
2002
2012

A


Land use = Urban, FMU = Mid Waikato
Prop. of total leaching loss (%)
25
20
15
10
5
0
22 23 24 25 26 27 28 29 30 31
Sub-catchment id.
Year
1972
1982
1992
2002
2012

B


Land use = Urban, FMU = Lower Waikato
Prop. of total leaching loss (%)
7.5
6.0
4.5
3.0
1.5
0.0
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Sub-catchment id.
Year
1972
1982
1992
2002
2012

C

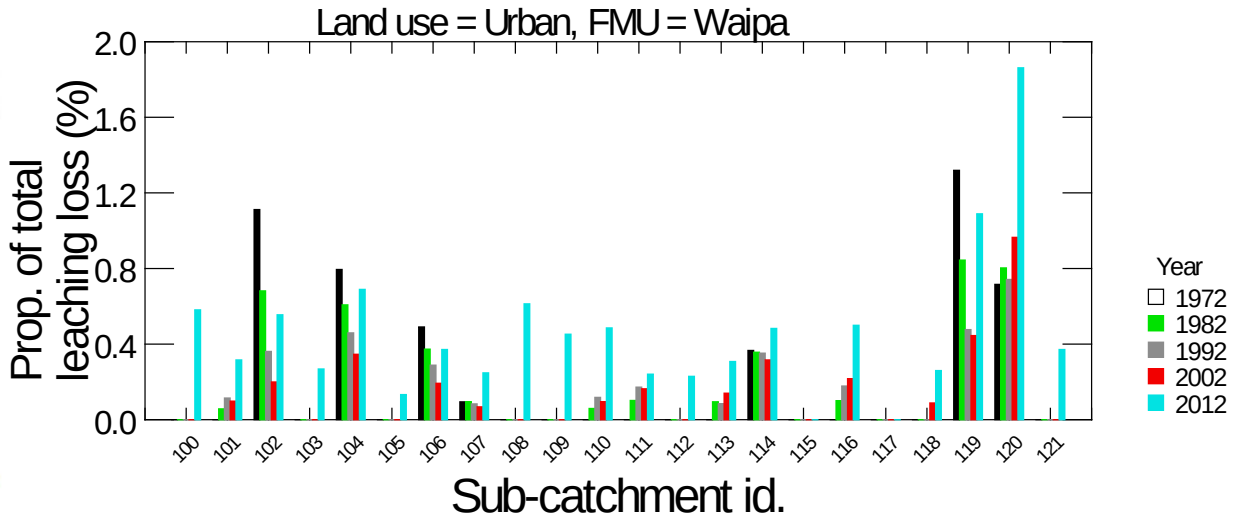


Figure G-18: Proportion of nitrogen leaching loss for the Wai Ora/Healthy Rivers project area according to freshwater management unit, decade and sub-catchment for Urban land use.