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The Analysis of Trace Metals in Surface Waters from Scotland and Wales

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A Report to the DoE, Air Quality Division.

March 1997

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THE ANALYSIS OF TRACE METALS IN SURFACE WATERS FROM SCOTLAND AND WALES.

A REPORT TO THE DEPARTMENT OF THE ENVIRONMENT, AIR QUALITY DIVISION.

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MARCH 1997

SUMMARY

188 water samples taken from Scottish and Welsh lakes in 1995/6 have been analysed for a range of trace metals, Hg, As, Se, Be, V, Cr, Co, Ni, Cu, Zn, Mo, Ag, Cd, Sb, Ba, Tl, Pb, & Bi.

At all sites Hg, As, Se, Be, Bi, Pb and Ag were below limits of detection by the ICP-MS. The other elements showed various geographical distributions. In Wales, the south-central region and Anglesey appeared consistently higher and it is suggested that these are due to former mining and contemporary smelting activities respectively. In Scotland, distributions were move diverse although southern and south-west Scotland often appeared to show elevated levels as did sites on Orkney and Shetland. In general, lake sites in the north-west and Hebrides showed lower concentrations.

Principal Components Analysis (PCA) was used to try and determine any patterns in the data, but the results were inconclusive. The PC axes explained little of the variability within the data and clusters of sites on the bi-plots show little in common. However, only geographical location was available to be used in the PCA interpretation and it may be that other factors (lake and catchment characteristics, other water chemistry) would help explain the data more fully.

The data included in this report are from single water samples taken over a short period of time. Therefore, although the data may show a useful 'snap-shot' of the situation, more information would be available from analyses of the sediment record (to put the data into temporal context) and other substrates where metal accumulation takes place. This would have the advantage of producing a time averaged metal value, but more importantly would mean more values above analytical detection and hence a better idea of metal distribution.

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1. INTRODUCTION

The UK is a signatory to the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP) which has recently become concerned with the emissions and environmental effects of trace metals. It has been suggested that any initial protocol will concentrate on maintaining or reducing emissions uniformly throughout Europe, but that a second stage may then follow which would be effects based, concentrating on areas most at risk. The formulation of such effects based strategies requires a great deal of data and research.

Since 1985, the Nordic Council of Ministers (NMR) has supported projects dealing with the critical loads of air pollutants. Three of these have been concerned with critical loads of surface waters in Fennoscandian countries. In the most recent one (1995-6), the NMR asked the United Kingdom to join in a lake survey so that a common assessment could be made of the lake populations and lake water quality in Finland, Sweden, Norway, Denmark, the Kola Peninsula, Russian Karelia and the UK. In the UK., lake surveys were carried out in Scotland and Wales only as these are the most sensitive areas to acid deposition.

The lake selection procedure for Scotland and Wales is outlined below. In total 188 lakes were sampled. Sub-samples were taken of each, acidified and stored so that they would be suitable for trace metal analysis at some point in the future. This report includes the results of these metal analyses and a preliminary discussion of their distributions.

2. PREVIOUS SURVEYS

Regional surveys of UK lakes, (e.g. Lake District and the Cairngorms) have been undertaken since the 1950s. More extensive surveys were initiated in the 1970s, especially in Wales and Scotland, to assess the extent of surface water acidification, but it was not until the 1990s, and the Department of the Environment's Critical Loads programme, that a systematic survey of UK freshwaters was undertaken. Over 1500 lakes were sampled under this programme and in the more acid sensitive areas sampling was on a 10 km grid square basis (Critical Loads Advisory Group on Freshwaters, 1995). None of these samples were analysed for trace metals.

3. SITE SELECTION

Approximately 1% of the total UK area is estimated to be inland surface water, an area of over 2,400 km^2. There are an estimated 5,505 lakes with an area of > 4 ha and 69% of these are located in Scotland.

The NMR working group divided lakes for the survey into five size classes: 0.04 - 0.1 km^2, 0.1 - 1 km^2, 1 - 10 km^2, 10 - 100 km^2 and >100 km^2. The number of lakes in these size classes for Scotland and Wales appear in Table 1 (from NIVA, 1996).

Table 1. Lake size distribution in Scotland and Wales

	Lake size (km^2)					**Total number**	
	0.04 - 0.1	0.1 - 1	1 - 10	10 - 100	> 100	> 0.04	> 0.01
Scotland	3517	1369	147	21	0	5054	8387
Wales	160	79	16	0	0	255	

The statistical selection was made on the basis of 100 km^2 blocks for Scotland, with no weighting for acidification status, but using the size weighting of 1 : 1 : 4 : 8 for the size classes. For Wales the country was treated as a single unit, again with no acidification weighting. Because of the smaller number of lakes, the size weighting applied was 1 : 1 : 2. The total number of lakes selected was 188 distributed through the size ranges as shown in Table 2.

Table 2. Number of selected lakes in Wales and Scotland.

Scotland	Size class	0.02 - 0.1	0.1 - 1	1 - 10	10 - 100	> 100	Total
	Selected No.	76	35	20	5	0	136
	Percentage	2.2	2.6	13.6	23.8	0	2.7
Wales	Size class	0.04 - 0.1	0.1 - 1	1 - 10	10 - 100	> 100	Total
	Selected No.	30	15	7	0	0	52
	Percentage	18.8	19.0	43.8	0	0	20.4

The site names and grid references for the 188 selected lakes are given in Appendix 1. Locations for Scotland are shown on Figure 1 with the Hebridean area expanded for clarity in Figure 2. Welsh site locations are shown in Figure 3.

4. CHEMICAL ANALYSES

The original water samples were analysed at the Freshwater Fisheries Laboratory, Pitlochry for the following determinands:

pH, Conductivity, Alkalinity, SO_4, Cl, Ca, Mg, Na, K, NO_3-N, NH_4-N, Total N, Total P, PO_4-P, TOC, Total monomeric Al, Non-labile Al and SiO_2.

In addition, an acidified sub-sample was stored for trace metal analyses. These analyses are the subject of this report.

5. TRACE METAL ANALYSES - METHODS

5.1. Inductively Coupled Plasma - Mass Spectrometry (ICP - MS)

ICP-MS is a relatively new technique for trace element analysis. The ICP is a high temperature argon plasma (up to 10 000 K) and is an extremely efficient ionization source. The aqueous sample is nebulized into a spray chamber which acts as a filter so only droplets of 10µm leave the chamber and are introduced into the base of the plasma. Transfer of energy from the plasma causes desolvation, dissociation, atomization and ionization of the constituent elements. The ions are extracted into a multistage vacuum system, focused into the mass spectrometer and detected by an electron multiplier.

The advantages of ICP-MS are as follows:

- multi-element analysis with excellent detection limits (sub µg/L)
- a broad linear range (at least 4 orders of magnitude)
- a high sample throughput
- information on isotopic ratios

Sample preparation was straightforward for the lakewater samples. Aristar grade nitric acid was added to the samples to generate a 1% acid solution which retains the metal ions in solution. Particulates entering the instrument must be avoided as blockages can occur. Filtering was not possible as filter papers can elute elements such as Zn to give false positive readings, so samples were allowed to settle before removing aliquots for analysis. An internal standard was added to each sample (10 ppb In) to correct for long and short term signal drift as well as sample matrix effects (caused by analyte signal suppression by the some major ions in the sample e.g. Na, K, Ca, Mg.). Samples were analyzed for the elements: Be, V, Cr, Co, Ni, Cu, Zn, Mo, Ag, Cd, Sb, Ba, Tl, Pb, & Bi.

Detection limits were determined by running 10 replicates of a 1% nitric acid blank and calculating 3 times the standard deviation of the blank. These are shown in Table 3.

5.2. Direct Injection Nebulization (DIN).

Determination of volatile elements such as Hg, As and Se are difficult because of memory effects arising from the spray chamber and transfer tubing. In addition As and Se have the same isotopic mass as polyatomics from the argon plasma i.e. As^{75} with $Ar^{40}Cl^{35}$ and Se^{82} with $Ar^{40}{}_2H_2$, so detection limits are poor.

The memory effect problem can be overcome by using DIN coupled to ICP-MS. The sample is pushed through a very narrow capillary and is nebulized at the base of the plasma, avoiding the use of a spray chamber. This offers all the advantages of ICP-MS with the addition of a very low dead volume, so rinse times are of the order of seconds rather than minutes/hours for elements with memory effects. It does not solve the problem with polyatomic interferences with As and Se, but detection limits were still less than 1 µg/L (Table 3).

Table 3. Limits of detection (LoD) for the trace metal analyses (µg/L or ppb)

Element	Be	V	Cr	Co	Ni	Cu	Zn	Mo	Ag
LoD	0.015	0.242	0.062	0.007	0.045	0.012	0.188	0.017	0.025
Element	Cd	Sb	Ba	Tl	Pb	Bi	Hg	As	Se
LoD	0.027	0.005	0.003	0.031	1.150	0.007	0.157	0.840	0.130

6. RESULTS

The trace metal results are given in Appendix 2. Distributions for each individual element, where that element shows more than one detection limit exceedance are shown on Figures 4 - 13 for Scotland and Figures 14 - 23 for Wales.

6.1. Scotland

6.1.1. Be, Ag, Pb, Bi, Hg, As, Se
None of the analysed samples had concentrations for these elements greater than the detection limits given in Table 3.

6.1.2. Cd

Only a single site showed an exceedance above the LoD, Loch at Kelhead (site 88) just north of the Solway Firth in southern Scotland. The concentration was 0.28 µg/L and therefore was more than 10 times higher than any other Scottish site. This site is not especially high in other metals analysed and the reason for the high Cd is unclear.

6.1.3. Ba

All Ba concentrations were above the LoD and are shown in Figure 4. Highest concentrations are in southern Scotland particularly on the east coast around the Firth of Forth. This may be due to the industries located around the Firth and Edinburgh. Other areas showing higher Ba concentrations are two or three sites in Galloway in the south-west and one site on Orkney. Lowest concentrations are in central and north-west Scotland, the Hebrides and Shetland.

6.1.4. Co

The Co distribution for Scotland is shown in Figure 5. There are two main areas of >LoD concentrations, the south-west and Orkney & Shetland. The highest concentration is 1.83 µg/L (site 157) on Kintyre. The reason for this distribution is unclear although these areas may be influenced by oil combustion (south-west from Northern Ireland emissions; Orkney & Shetland from refinery emissions). However, if this was the case then similarly elevated concentrations would be expected around the Firth of Forth where the refinery at Grangemouth is located. This is not observed. Lowest concentrations are in central and north-west Scotland, the Hebrides and Shetland.

6.1.5. Cr

The Cr distribution for Scotland is shown in Figure 6. Central areas and the north-east (including Orkney & Shetland) show concentrations elevated above LoD although there is little trend in this distribution. Highest concentration is 2.14 µg/L for Loch Hempriggs (site 45). Lowest concentrations are seen in the Galloway area, the north-west and Hebridean sites.

6.1.6. Cu

The Cu distribution is shown in Figure 7. Apart from a few sites in north-central areas, all Cu concentrations are greater than LoD. There are two sites with 'high' Cu, Loch Beinn an t-Sidhein (site 153 - 18.96 µg/L) and Loch Stulaval (site 123 - 12.02 µg/L). The Hebrides and a few sites on Orkney and Shetland appear to show higher concentrations than other sites on mainland Scotland suggesting some marine influence. However, Loch Beinn an t-Sidhein is not located near the coast and so this can not be the only explanation.

6.1.7. Mo

The Mo distribution is shown in Figure 8. Most sites are below the LoD apart from two distinct areas, the far north-east (including Orkney & Shetland) and two sites in the south just north of the Solway Firth. Such a distribution suggests a natural, possibly marine source for this element. The highest concentration is for Loch of Spiggie (site 178 - 1.2 µg/L) in the south of Shetland.

6.1.8. Ni

The Ni distribution is shown in Figure 9. Sites in the north-west are mainly below the LoD but sites in the south, south-west, east coast and Orkney & Shetland all show LoD exceedances, although there is no one area of maximum concentrations. Ni has been used as an indicator of oil combustion (e.g. Rühling *et al.*, 1992) and it is therefore interesting to note that these areas could be considered ones of increased oil impact, both from transboundary sources (N.Ireland; south-west) or refineries (east coast; Shetland). The only oil-fired power station in Scotland is located at Peterhead near Aberdeen. However, for this study no lakes were selected in this area to confirm Ni impact from this source. Oil impact has been suggested for freshwaters in this area using other indicators (spheroidal carbonaceous particles) (Rose *et al.*, 1996).

6.1.9. Sb

The Sb distribution is shown in Figure 10. Apart from one exceptional Sb concentration at Loch Moglavat in the Hebrides (site 107 - 1.63 µg/L), the distribution of Sb is similar to that of Ni. i.e. most concentrations in the north-west are below LoD and sites in the south, south-west, east coast and Orkney & Shetland all show LoD exceedances, although concentrations are low and there is no one area of maximum concentrations. This may suggest a similar source for the two elements.

6.1.10. Tl

The Tl distribution for Scotland is shown in Figure 11. Most sites have Tl concentrations below the LoD, except a few scattered sites in the north, Hebrides and Orkney. However, sites in Galloway, in the south-west show a cluster of elevated Tl concentrations including a maximum at Clatteringshaws Loch (site 84) of 0.37 µg/L. The Galloway area is known to be impacted by acid deposition and receive considerable deposition from fossil-fuel combustion sources. Therefore, atmospheric deposition may also be the cause of this elevated Tl cluster.

6.1.11. V

The V distribution for Scotland is shown in Figure 12. All sites have V concentrations below the LoD except for three in the Shetlands. The maximum V concentration is 4.13 µg/L for Loch Leathan (site 180). V has also been used as an indicator of oil combustion and it would therefore be expected to follow the same distribution as Ni (Section 6.1.8. above) However, apart from the Shetland sites which may be impacted by refinery emissions there is no other V impact observable from this dataset. Other areas of Scotland (Galloway, Firth of Forth) would be expected to show greater impact from oil combustion than Shetland and so it maybe that the Ni distribution is showing only a coincidental similarity with expected elevated oil combustion impact.

6.1.12. Zn

The Zn distribution for Scotland is shown in Figure 13. There are three main areas where Zn concentrations are above the LoD. In order of increasing Zn concentration these are the north-east mainland, Galloway and the south-west,and central Scotland. The reason for the elevated levels in the south-west may again be due to atmospheric deposition from industrial sources, but for the other two areas sources are less apparent. This is especially the case for the maximum concentrations in central Scotland where Zn concentrations reach 24.28 µg/L and 30.53 µg/L for Loch Ericht (site 41) and Loch Beinn an t-Sidhein (site 153) respectively. Areas in the north-west and Hebrides mainly show concentrations below LoD.

6.2. Wales

6.2.1. Be, Ag, Pb, Bi, Hg, As, Se

None of the analysed samples had concentrations for these elements greater than the detection limits given in Table 3.

6.2.2. Cd

Only a single site showed an exceedance above the LoD, Llangynidr Reservoir (site 139) north of Ebbw Vale. The concentration of 0.56 µg/L is therefore at least 20 times higher than any other site in Wales. The site also shows elevated levels of Co, Tl and Zn. This is an area that was formerly extensively mined and this may be a possible reason for these elevated concentrations.

6.2.3. Ba

The Ba distribution for Wales is shown in Figure 14. All sites exceed the LoD although concentrations in the north are low apart from one site on Anglesey (Cefni Reservoir - site 22) where the concentration

concentration of 127.02 μg/L is recorded at Llangorse Lake (site 36). This south-central area was formerly extensively mined and this may be a possible reason for these elevated concentrations.

6.2.4. Co

The Co distribution for Wales is shown in Figure 15. Most sites are below the LoD except for three areas, the south, the central-west and Anglesey. Although above the LoD, the concentrations on Anglesey are low but may be due to the aluminium smelting operations in Holyhead. The other two areas are both former mining locations and this may explain the elevated Co concentrations. The maximum Co concentration of 2.55 μg/L was measured for Llangynidr Reservoir (site 139) north of Ebbw Vale.

6.2.5. Cr

The Cr distribution for Wales is shown in Figure 16. The south-central area is again elevated as are the three Anglesey sites. This latter area may again be due to the smelting emissions. Maximum concentrations are 3.47 μg/L for Cefni Reservoir (site 22) and 3.63 μg/L for Llangorse Lake (site 36). Few of the remaining Welsh sites are above LoD and these show little pattern to their distribution.

6.2.6. Cu

The Cu distribution for Wales is shown in Figure 17. All sites exceed the LoD with a maximum concentration of 3.6 μg/L for Llan Bwch (site 32). The Anglesey lakes again all show elevated concentrations but there is little pattern over the rest of the country.

6.2.7. Mo

The Mo distribution for Wales is shown in Figure 18. Most sites are below the LoD although the Anglesey lakes are again all elevated. Maximum concentration is, however, found at Llyn Gweryd (site 15) where it reaches 1.37 μg/L. Only three other sites are above the LoD and there is little pattern to their distribution.

6.2.8. Ni

The Ni distribution for Wales is shown in Figure 19. Most sites are above LoD and following the trends in other metals, the main elevated areas are on Anglesey and in the south-central areas. Maximum concentration is for Llan Bwch (site 32) where Ni reaches 12.14 μg/L. For Scotland, Ni appeared to show a geographical distribution similar to that expected from deposition from oil combustion sources. If this were also the case for Wales then elevated areas would be expected around Pembroke and in the north-east towards Merseyside (Ince power station). This does not appear to be the case and metal distribution appears to show trends associated with other industry (mining and smelting).

6.2.9. Sb.

The Sb distribution for Wales is shown in Figure 20. Most sites are above the LoD apart from a band along the west coast from the north to central Wales. There appears to be little distribution patterns to the Sb data although the maximum concentration is again found at Llan Bwch (site 32) where the Sb concentration reaches 0.53 μg/L.

6.2.10. Tl.

The Tl distribution for Wales is shown in Figure 21. Most sites fall below the LoD for Tl although five sites in central and north Wales exceed it. There is no obvious pattern to these sites however. Maximum Tl concentration is for Llangynidr Reservoir (site 139) where it reaches 0.56 μg/L.

6.2.11. V.

The V distribution for Wales is shown in Figure 22. Only a single site exceeds the V LoD and this is Llangorse Lake (site 36) where the concentration is 2.58 μg/L. As with Ni, there appears to be no agreement with expected impact from oil combustion.

6.2.12. Zn

The Zn distribution for Wales is shown in Figure 23. All but two sites have Zn concentrations exceeding LoD. The maximum concentration for Zn is at Llangynidr Reservoir (site 139) where it reaches 41.64 µg/L although Llyn Mair (site 26) shows a similar concentration (36.46 µg/L). There is little pattern to the rest of the Zn distribution, Cae Llwyd Reservoir (site 12) has a concentration of 27.82 µg/L and Llwyn-on Reservoir (site 137) has a concentration of 23.28 µg/L but otherwise concentrations are below 15µg/L. In general terms, concentrations may be higher in the north than the south.

7. PRINCIPAL COMPONENTS ANALYSIS

Further information on patterns within datasets can be obtained by principal components analysis (PCA). This was undertaken on the current dataset using the software `CALIBRATE' (Juggins & ter Braak, 1993-1996).

Figure 24, 25 and 26 show bi-plots of the 1st & 2nd, 1st & 3rd and 2nd & 3rd PC axes respectively. There are two immediate points of note. First, most of the data points cluster around zero, and second, not even the 1st PC axis explains a great deal of the variability within the dataset. The first four PC axes only explain 66.7% of the total variability and the individual axes explain, successively, 26.7%, 18.6%, 11.5% and 9.9%.

This suggests that there are no strong patterns within the dataset and therefore that there is probably not a single source type driving the trace metal contents of these water samples. Three sites plot as outliers on all three Figures: Sites 88, 139 & 153. These are Loch at Kelhead just north of the Solway Firth (the only Scottish site with Cd >LoD), Llangynidr Reservoir (elevated in Co, Tl and Zn) and Loch Beinn an t-Sidhein (high in Cu & Zn). Llangynidr Reservoir is in a mining district but it is unclear why the other sites are high in selected elements. These sites are removed from Figures 25 & 26 in order that the remainder of the dataset can be seen more clearly. These biplots must also be treated with caution as they can be misleading, for example, Cd appears to be a significant element in Figures 24 - 26, but only two sites in both Scotland and Wales have Cd concentrations above the LoD.

On Figure 24 there appear to be two clusters of elements and sites. A Ni, Cr, Mo, Ba & V group and a Co, Zn, Cd & Tl group. In Scotland, the former have a number of sites along these vectors and are located in the north-east (45) and on Orkney & Shetland (174, 177, 178). In Wales, there are a few sites in the south-central region (32, 36, 141), one on Anglesey (22) and two in the north-east (15, 22). In the second group, Scottish sites are located in the south-west (84, 88) and in Wales they are in the north (12, 26, 131).

There is no straightforward explanation for these distributions. For Scotland it is possible that the first group represents the influence of oil combustion and / or a marine input as they are all coastal or island areas. This explanation is difficult to justify however, as sites from other oil combustion impacted areas (Galloway, Firth of Forth, south Wales) and marine areas (Hebrides) do not plot with them. In Wales, the sites plotting in this first group are most likely influenced by other industrial activity such as mining and smelting. The second group could be represented by atmospheric deposition possibly from remote sources. The only Scottish sites in this group are found in the south-west an area known to be considerably impacted by atmospheric deposition. The same could also be true of the Welsh sites. However, it is then difficult to explain why other sites in these areas do not also plot in the same area of the diagrams.

Similarly, Figure 26 shows 3 groupings. The first cluster of sites (145, 169, 170, 172) appear to be influenced by Ni, Ba and possibly V. These sites are all in the south and south-west of Scotland and two of these are near the Firth of Forth. Therefore there could possibly be some oil combustion influence for these sites. The other two groups, (22, 36, 45) and (35, 174, 177) show little coherence although the latter sites all receive significant marine influence as they are all island locations.

8. CONCLUSIONS & RECOMMENDATIONS FOR FURTHER WORK

188 water samples taken from Scottish and Welsh lakes in 1995/6 have been analysed for a range of trace metals, Hg, As, Se, Be, V, Cr, Co, Ni, Cu, Zn, Mo, Ag, Cd, Sb, Ba, Tl, Pb, & Bi.

At all sites Hg, As, Se, Be, Bi, Pb and Ag were below limits of detection by the ICP-MS. The other elements showed various distributions. However, in Wales, the south-central region and Anglesey appeared consistently higher and it is suggested that these are due to former mining activities and contemporary smelting respectively. In Scotland, distributions were move diverse although southern and south-west Scotland often appeared to show elevated levels as did sites on Orkney and Shetland. In general, lake sites in the north-west showed lower concentrations.

Principal Components Analysis (PCA) was used to try and determine any patterns in the data, but the results were inconclusive. None of the PC axes explained much of the variability within the data and clusters of sites on the bi-plots show little in common. However, it should be stressed that only geographical location was used in the PCA interpretation and it may be that other factors (lake and catchment characteristics, other water chemistry) would help explain the data more fully.

It should also be stressed that the data included in this report are from single water samples taken over a short period of time. Therefore, although the data may show a useful 'snap-shot' of the situation, more information would be available from analyses of either the sediment record (to put the data into temporal context) and / or other substrates where metal accumulation has taken place over a period of time. This would have the advantage of producing a time average metal value, but more importantly would mean more values above analytical detection and hence better distribution data.

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Rühling, Å., Brumelis, G., Goltsova, N., Kvietkus, K., Kubin, E., Liiv, S., Magnússon, S., Mäkinen, A., Pilegaard, K., Rasmussen, L., Sander, E. & Steinnes, E. (1992). Atmospheric heavy metal deposition in Northern Europe 1990. Nord 1992:12.

FIGURES

FIGURE 1

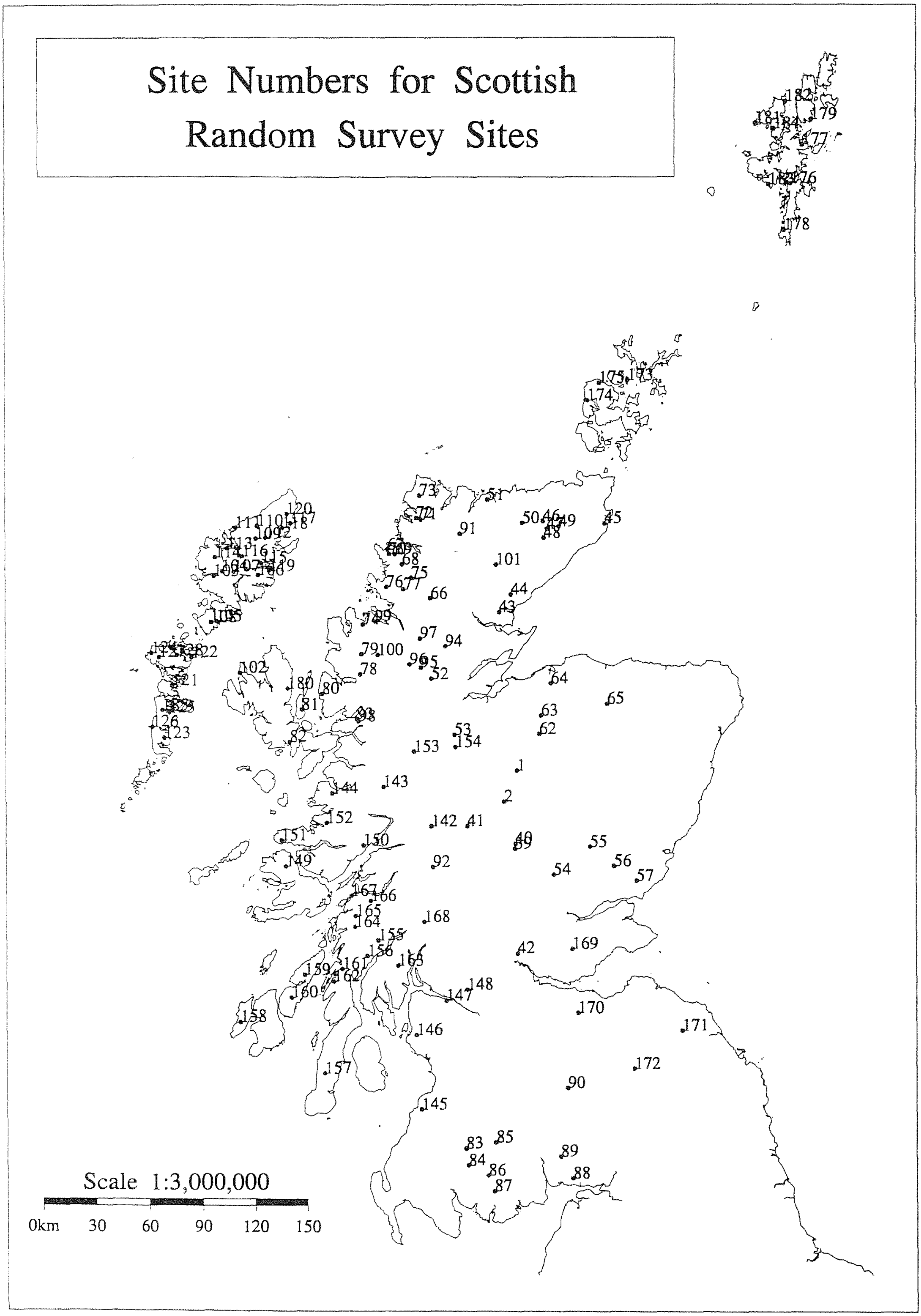

Site Numbers for Scottish
Random Survey Sites
Scale 1:3,000,000
0km 30 60 90 120 150

FIGURE 2

Site Numbers for Hebridean Random Survey Sites

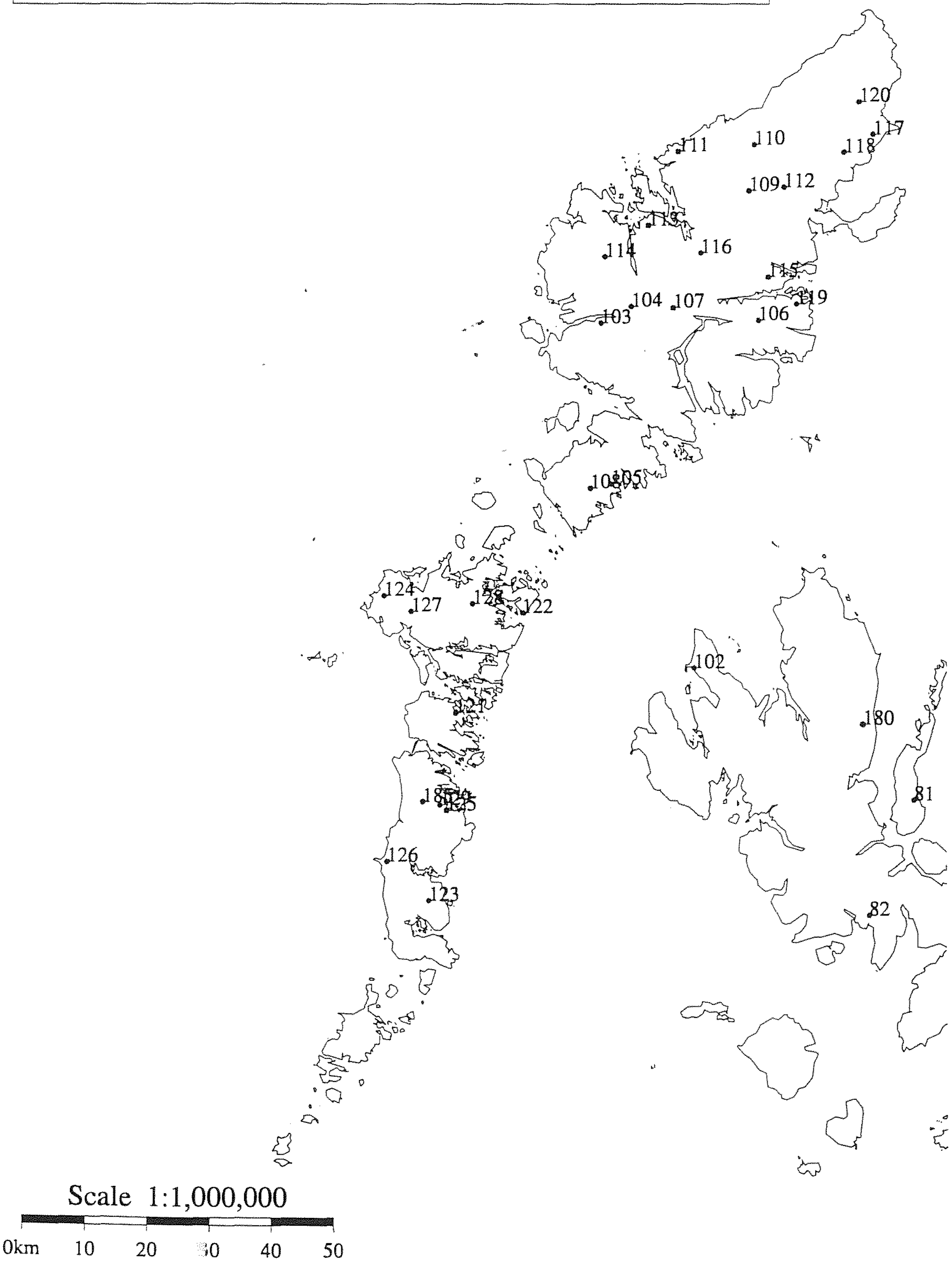


FIGURE 3

Site Numbers for Welsh Random Survey Sites

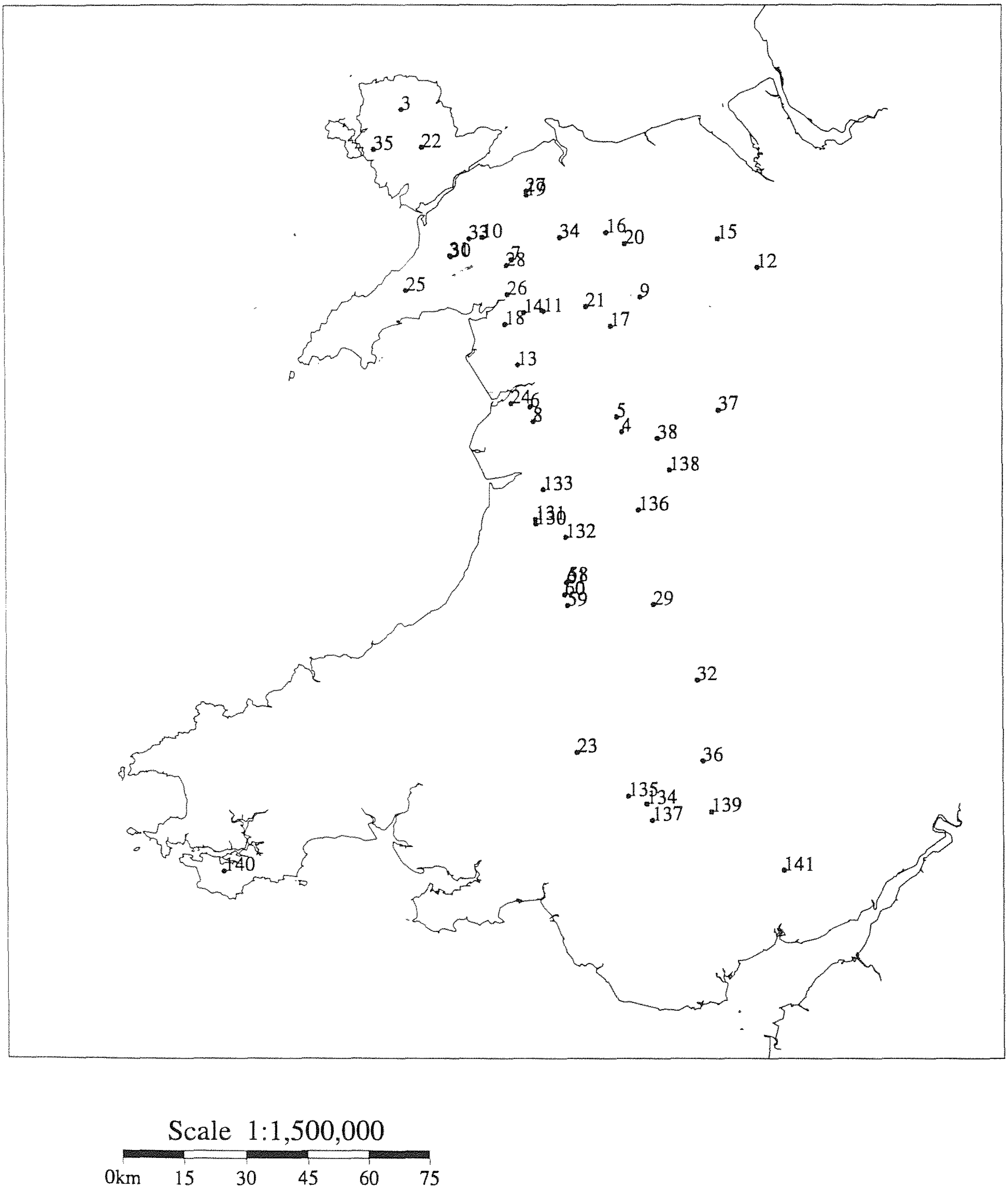
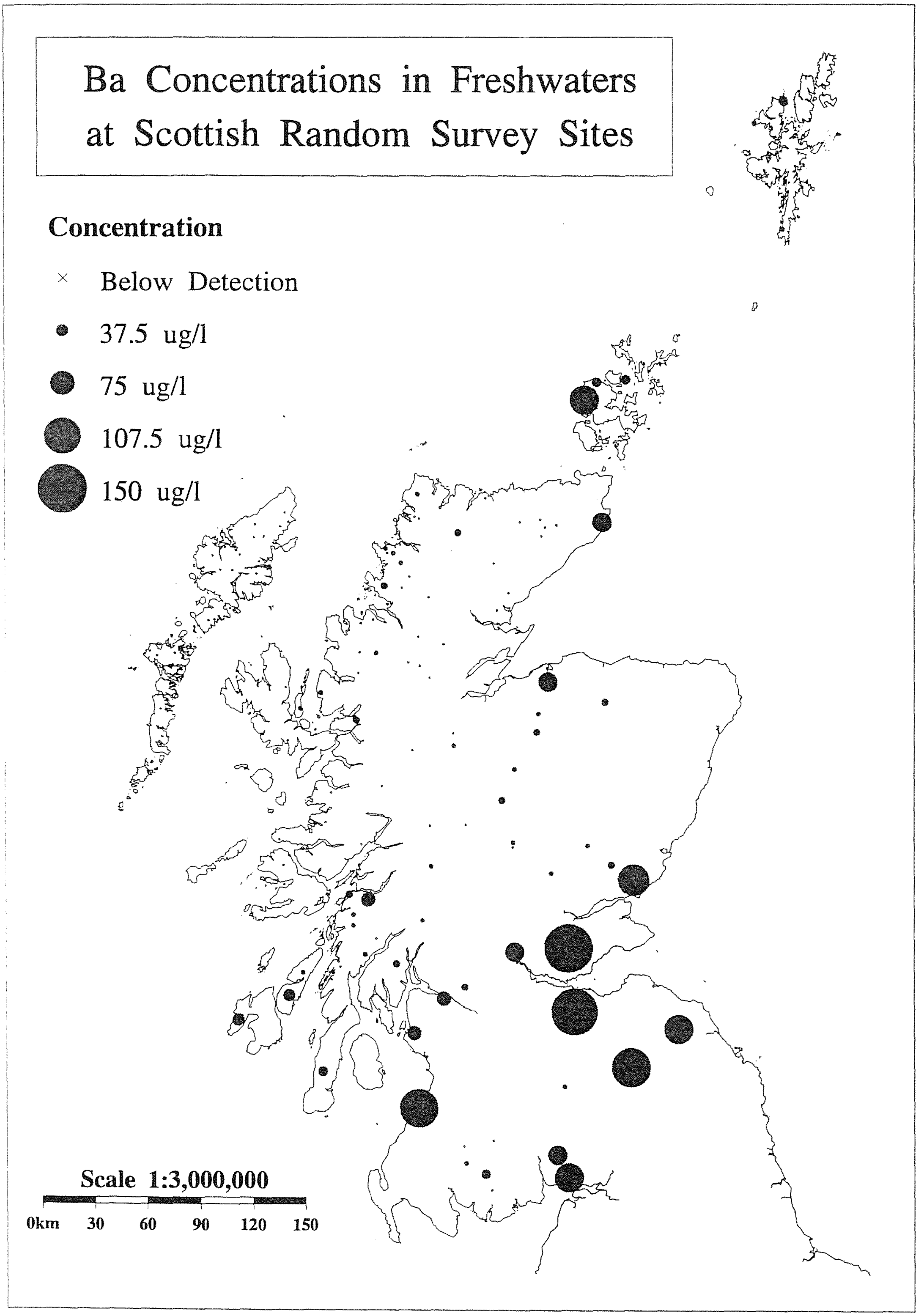


FIGURE 4



Ba Concentrations in Freshwaters at Scottish Random Survey Sites
Concentration
Below Detection
37.5 ug/l
75 ug/l
107.5 ug/l
150 ug/l
Scale 1:3,000,000
0km
30
60
90
120
150

FIGURE 5

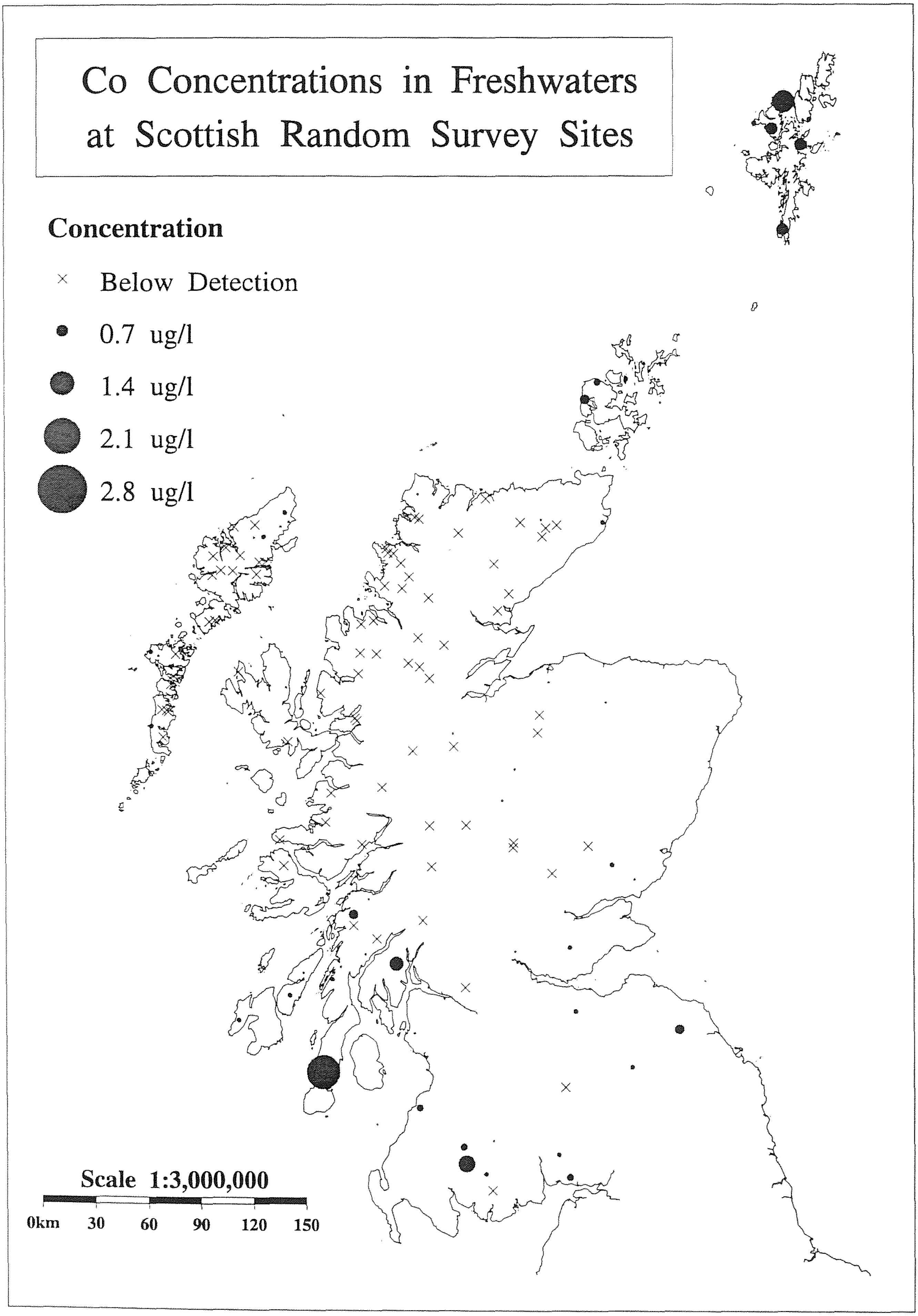

Co Concentrations in Freshwaters
at Scottish Random Survey Sites
Concentration
Below Detection
0.7 ug/l
1.4 ug/l
2.1 ug/l
2.8 ug/l
Scale 1:3,000,000
0km
30
60
90
120
150

FIGURE 6

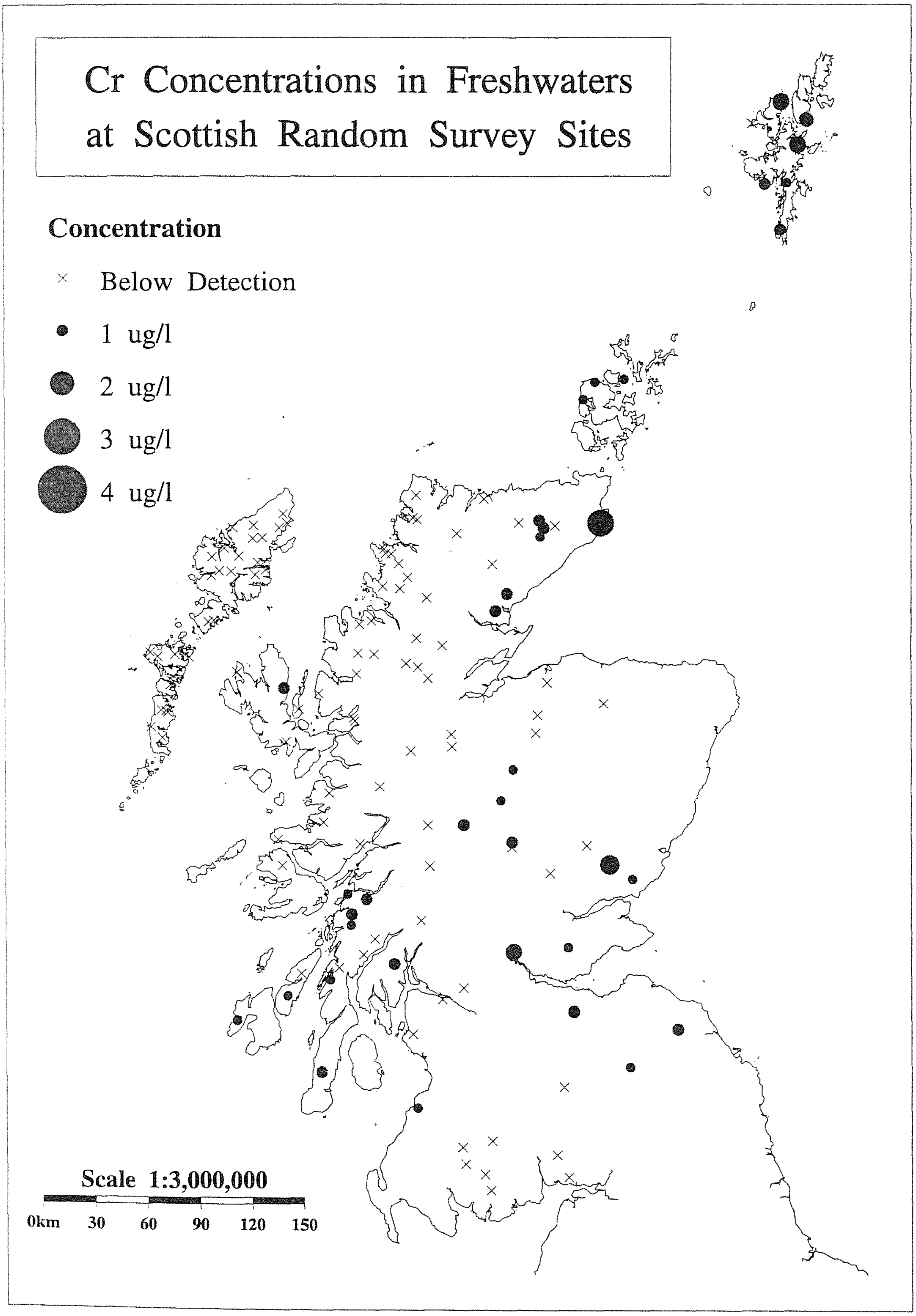
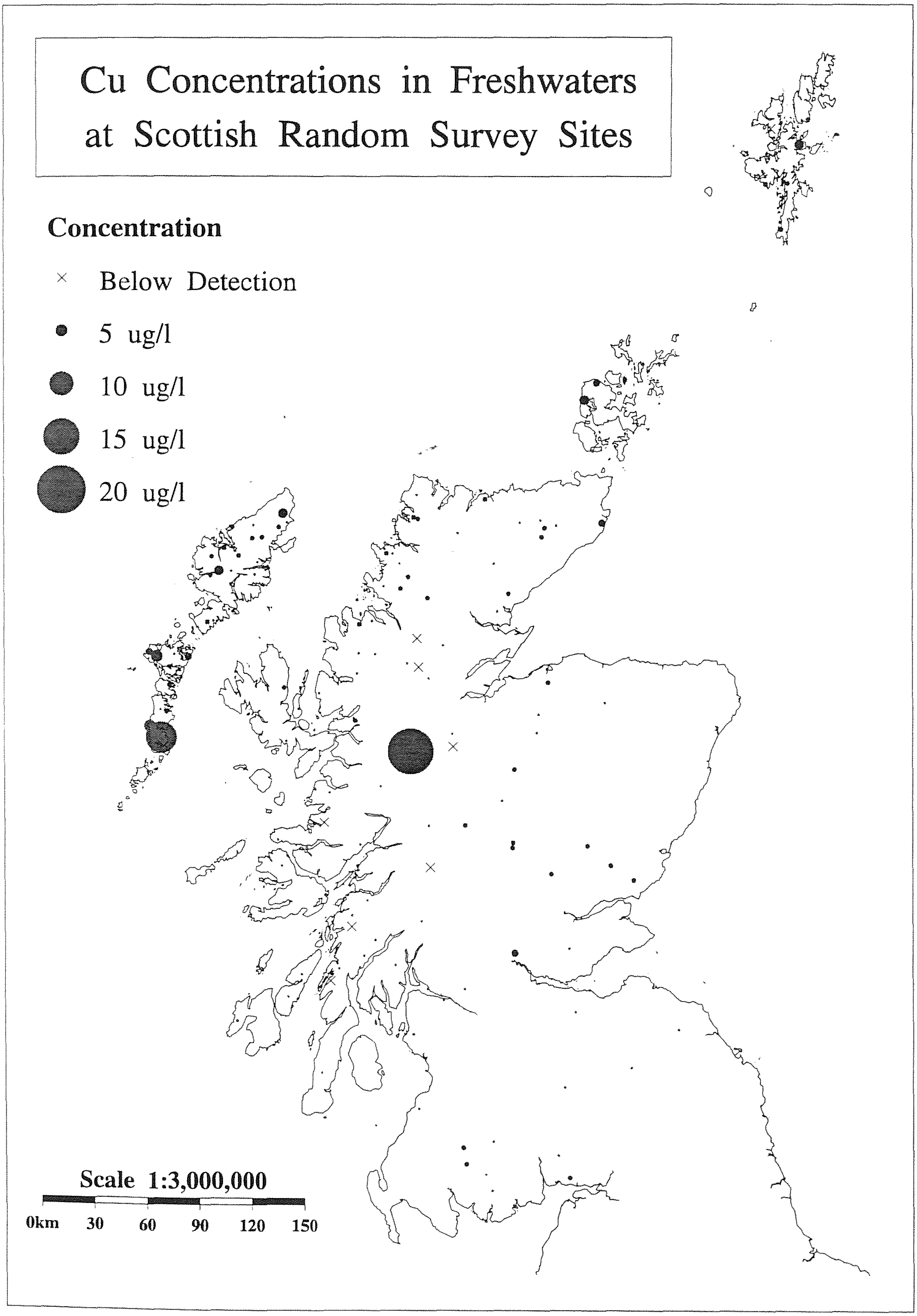

Cr Concentrations in Freshwaters at Scottish Random Survey Sites
Concentration
Below Detection
1 ug/l
2 ug/l
3 ug/l
4 ug/l
Scale 1:3,000,000
0km
30
60
90
120
150

FIGURE 7



Cu Concentrations in Freshwaters
at Scottish Random Survey Sites
Concentration
Below Detection
5 ug/l
10 ug/l
15 ug/l
20 ug/l
Scale 1:3,000,000
0km
30
60
90
120
150

FIGURE 8

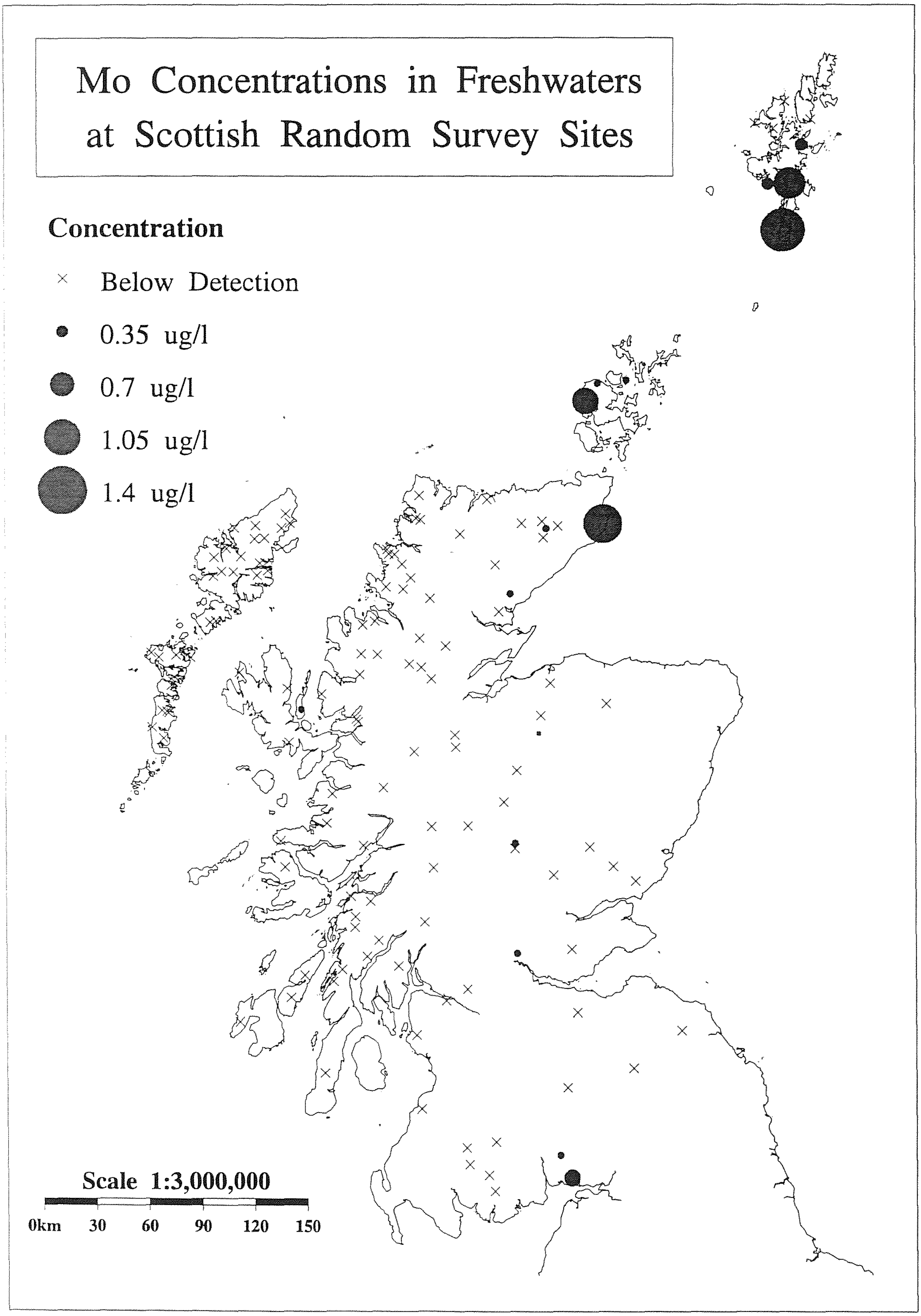

Mo Concentrations in Freshwaters
at Scottish Random Survey Sites
Concentration
Below Detection
0.35 ug/l
0.7 ug/l
1.05 ug/l
1.4 ug/l
Scale 1:3,000,000
0km
30
60
90
120
150

FIGURE 9

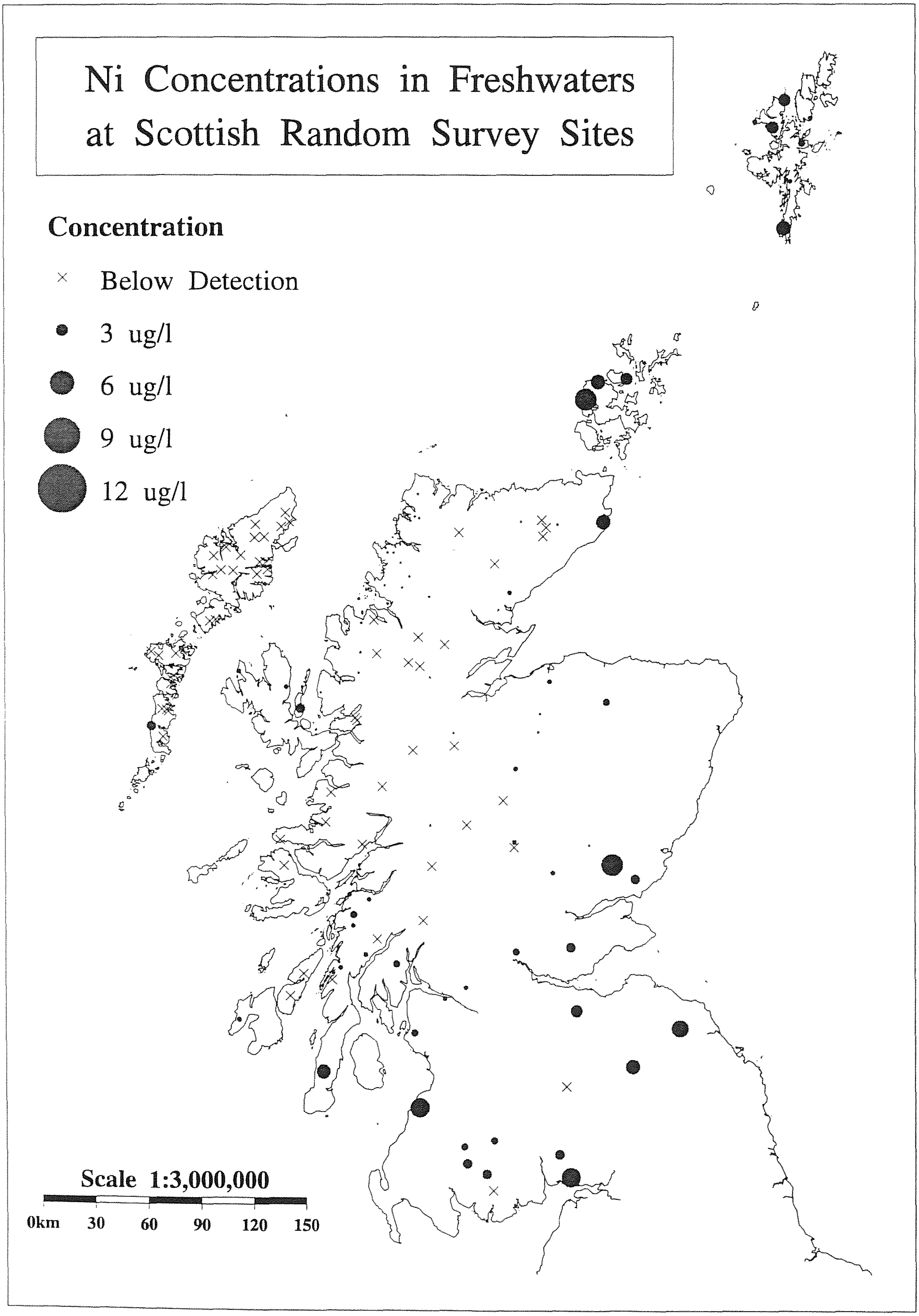
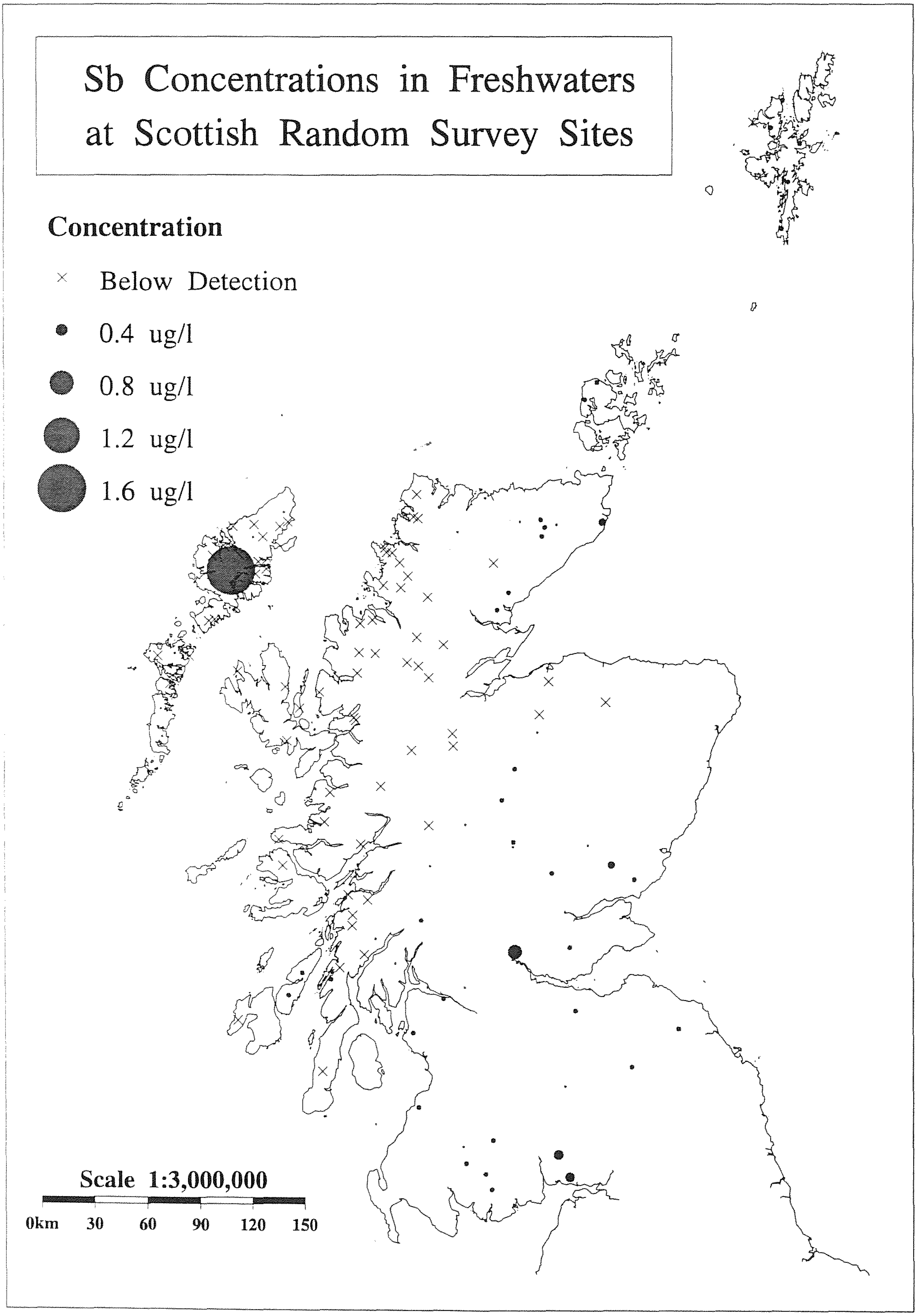
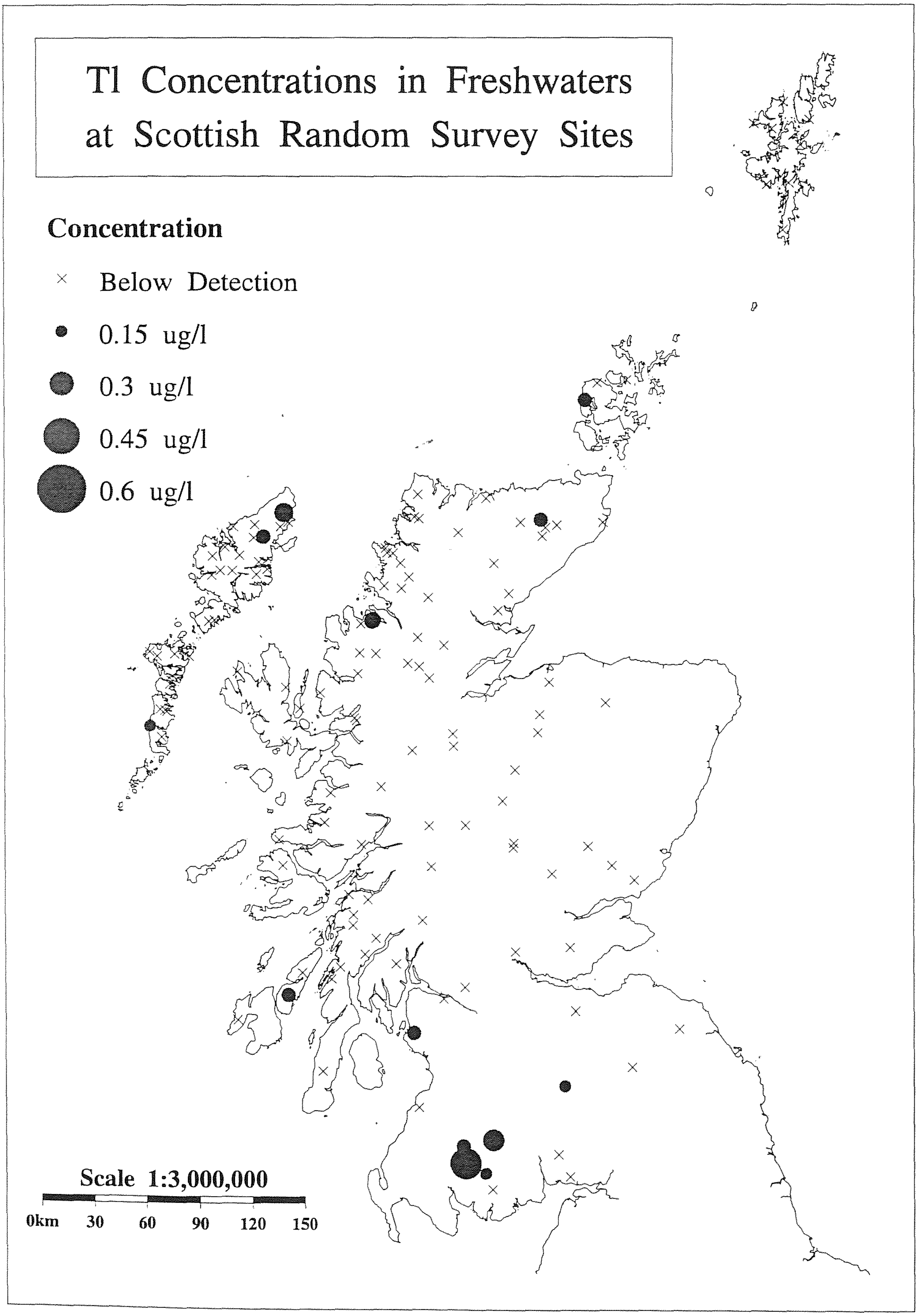

Ni Concentrations in Freshwaters
at Scottish Random Survey Sites
Concentration
Below Detection
3 ug/l
6 ug/l
9 ug/l
12 ug/l
Scale 1:3,000,000
0km
30
60
90
120
150

FIGURE 10



Sb Concentrations in Freshwaters
at Scottish Random Survey Sites
Concentration
Below Detection
0.4 ug/l
0.8 ug/l
1.2 ug/l
1.6 ug/l
Scale 1:3,000,000
0km
30
60
90
120
150

FIGURE 11



Tl Concentrations in Freshwaters
at Scottish Random Survey Sites
Concentration
Below Detection
0.15 ug/l
0.3 ug/l
0.45 ug/l
0.6 ug/l
Scale 1:3,000,000
0km 30 60 90 120 150

FIGURE 12

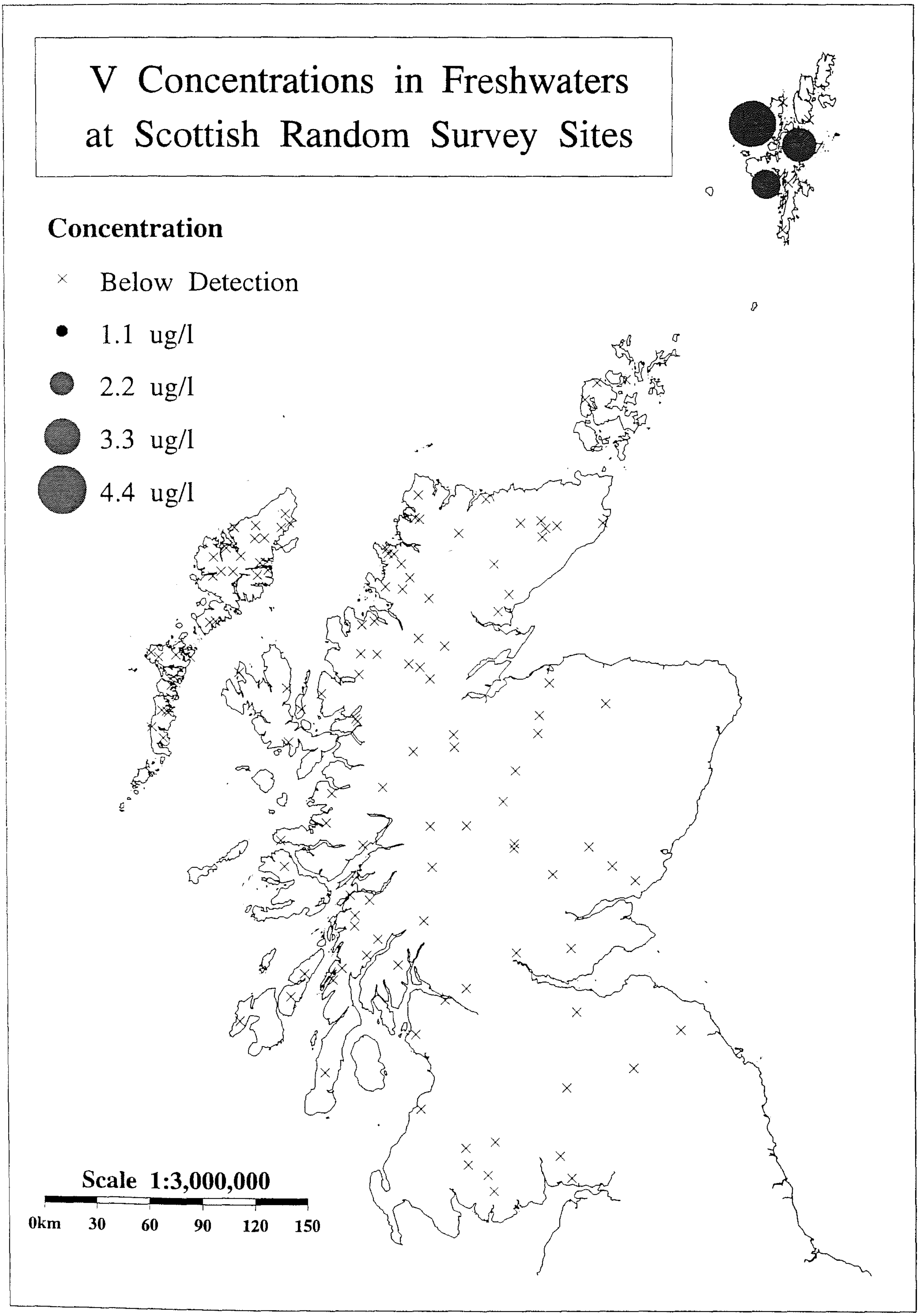

V Concentrations in Freshwaters
at Scottish Random Survey Sites
Concentration
Below Detection
1.1 ug/l
2.2 ug/l
3.3 ug/l
4.4 ug/l
Scale 1:3,000,000
0km 30 60 90 120 150

FIGURE 13

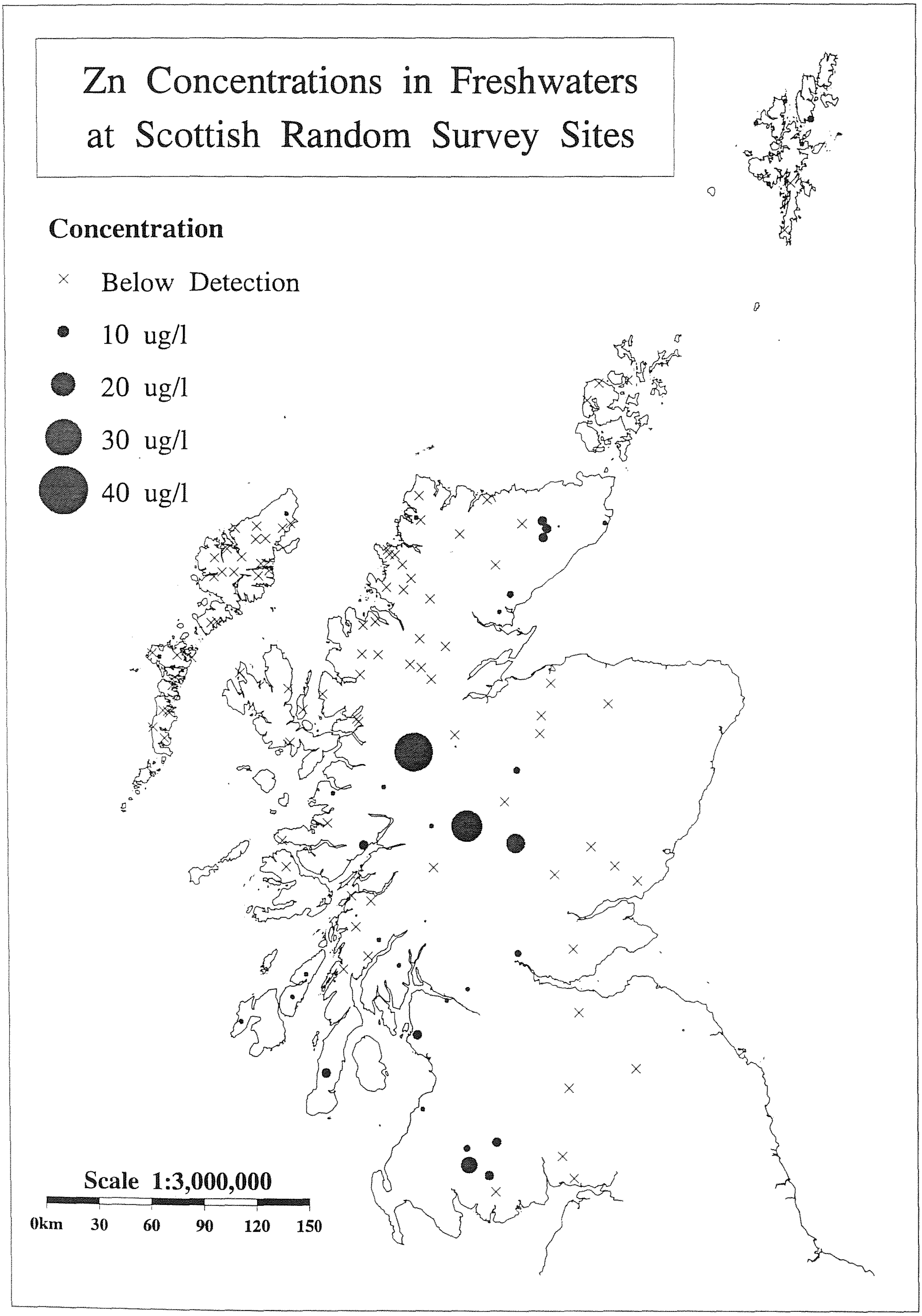

Zn Concentrations in Freshwaters
at Scottish Random Survey Sites
Concentration
Below Detection
10 ug/l
20 ug/l
30 ug/l
40 ug/l
Scale 1:3,000,000
0km
30
60
90
120
150

FIGURE 14

Ba Concentrations in Freshwaters at Welsh Random Survey Sites

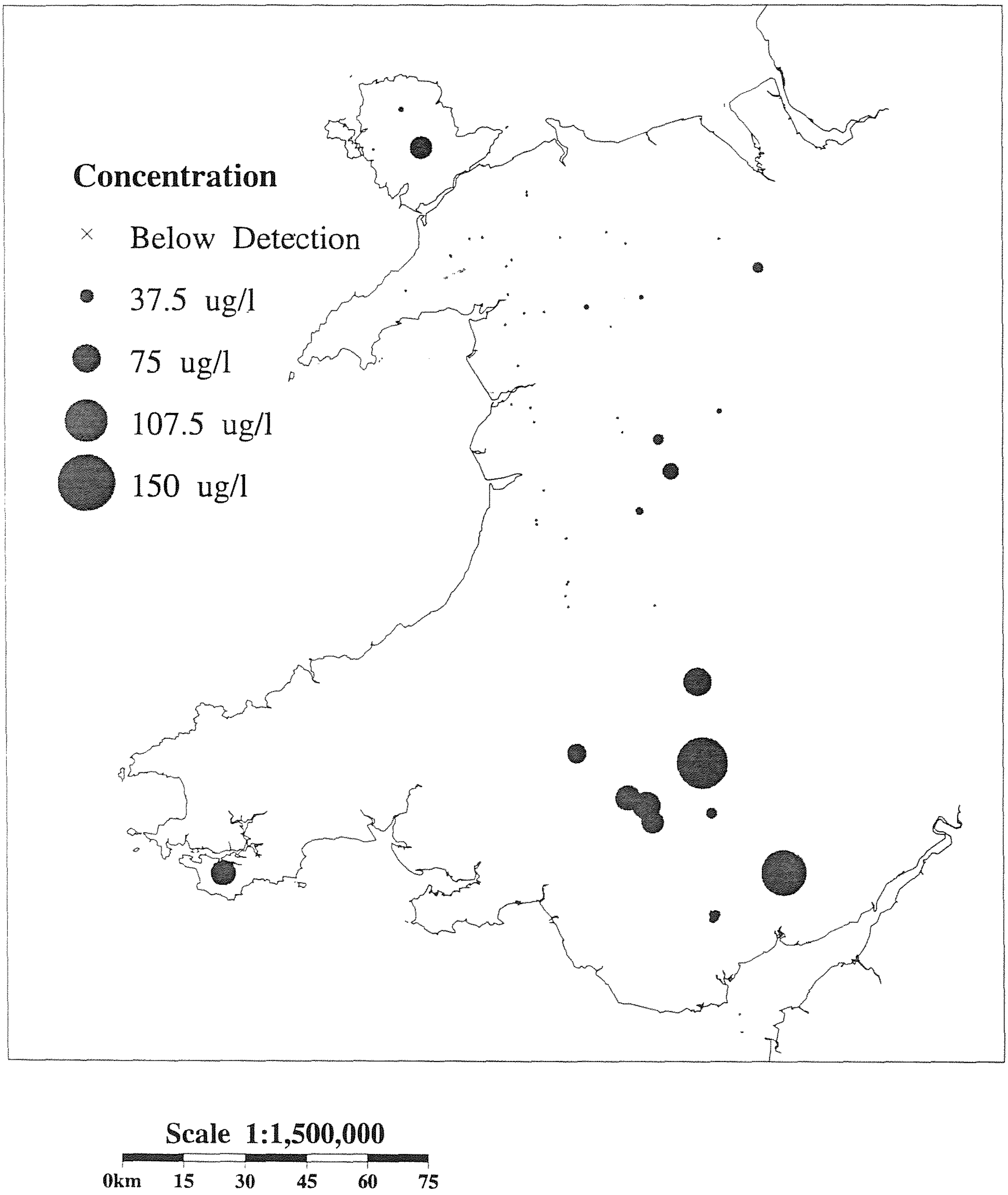


FIGURE 15

Co Concentrations in Freshwaters at Welsh Random Survey Sites

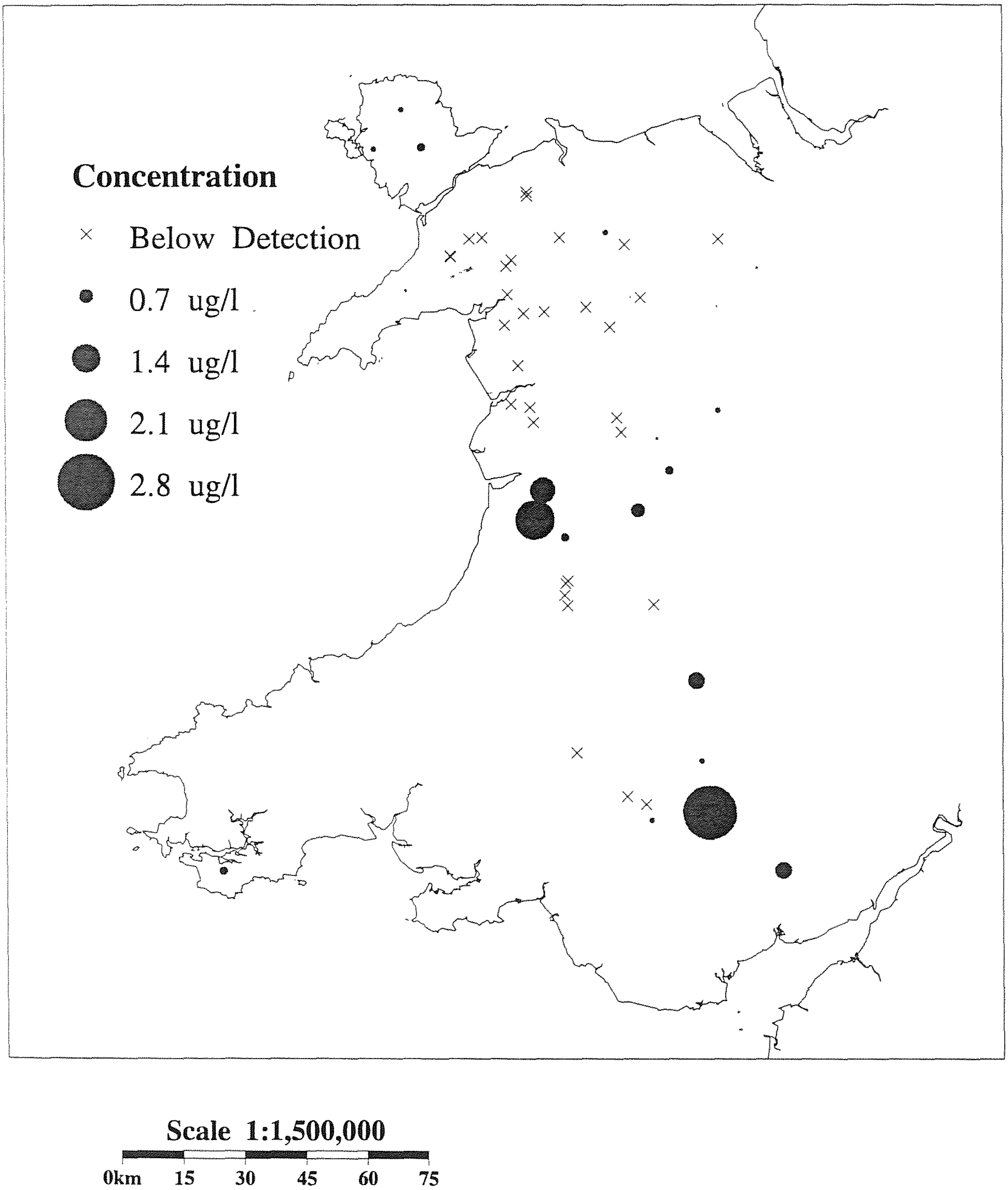
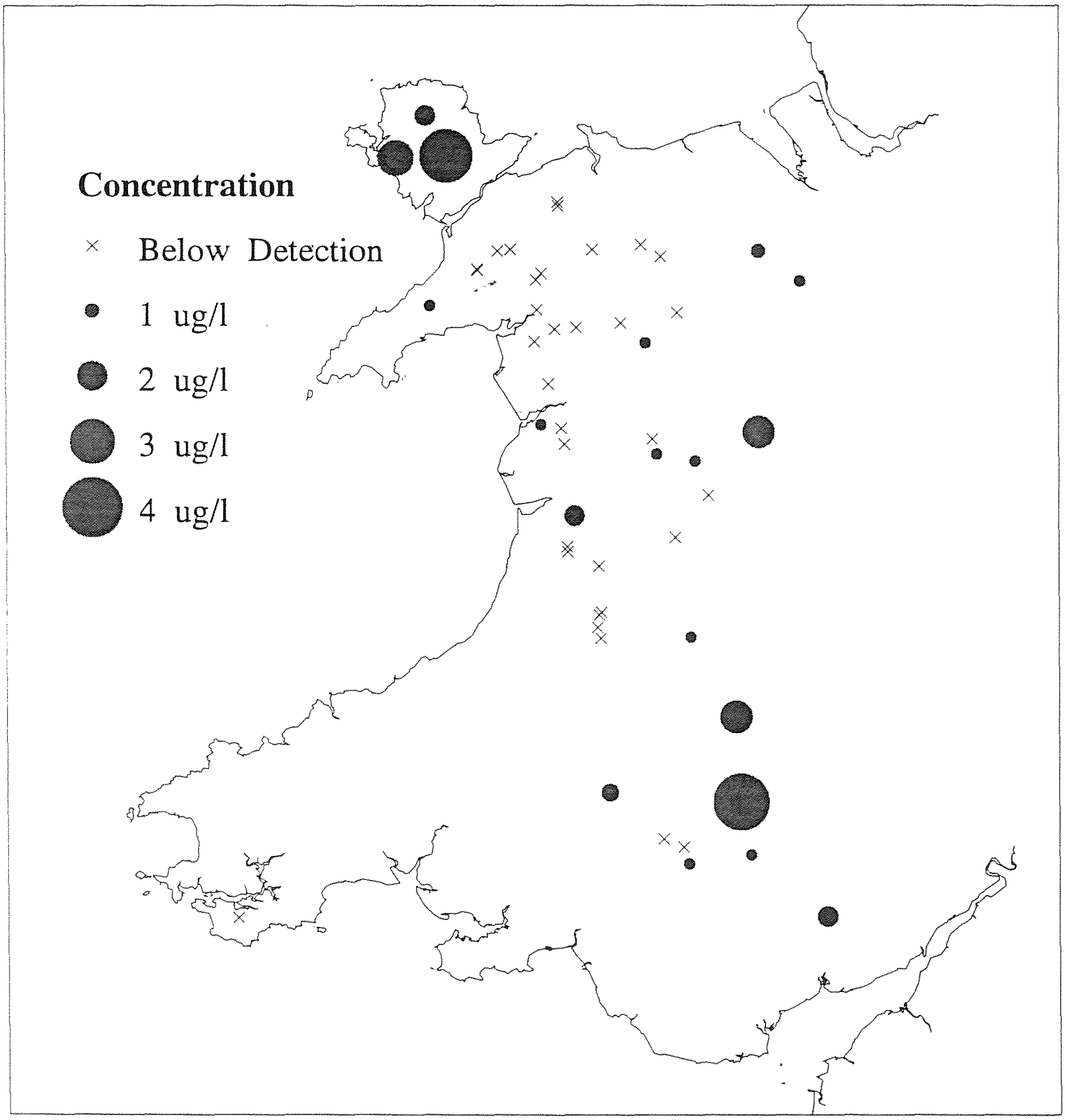


FIGURE 16

Cr Concentrations in Freshwaters at Welsh Random Survey Sites



Scale 1:1,500,000

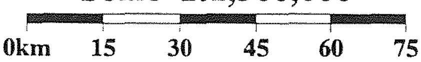


FIGURE 17

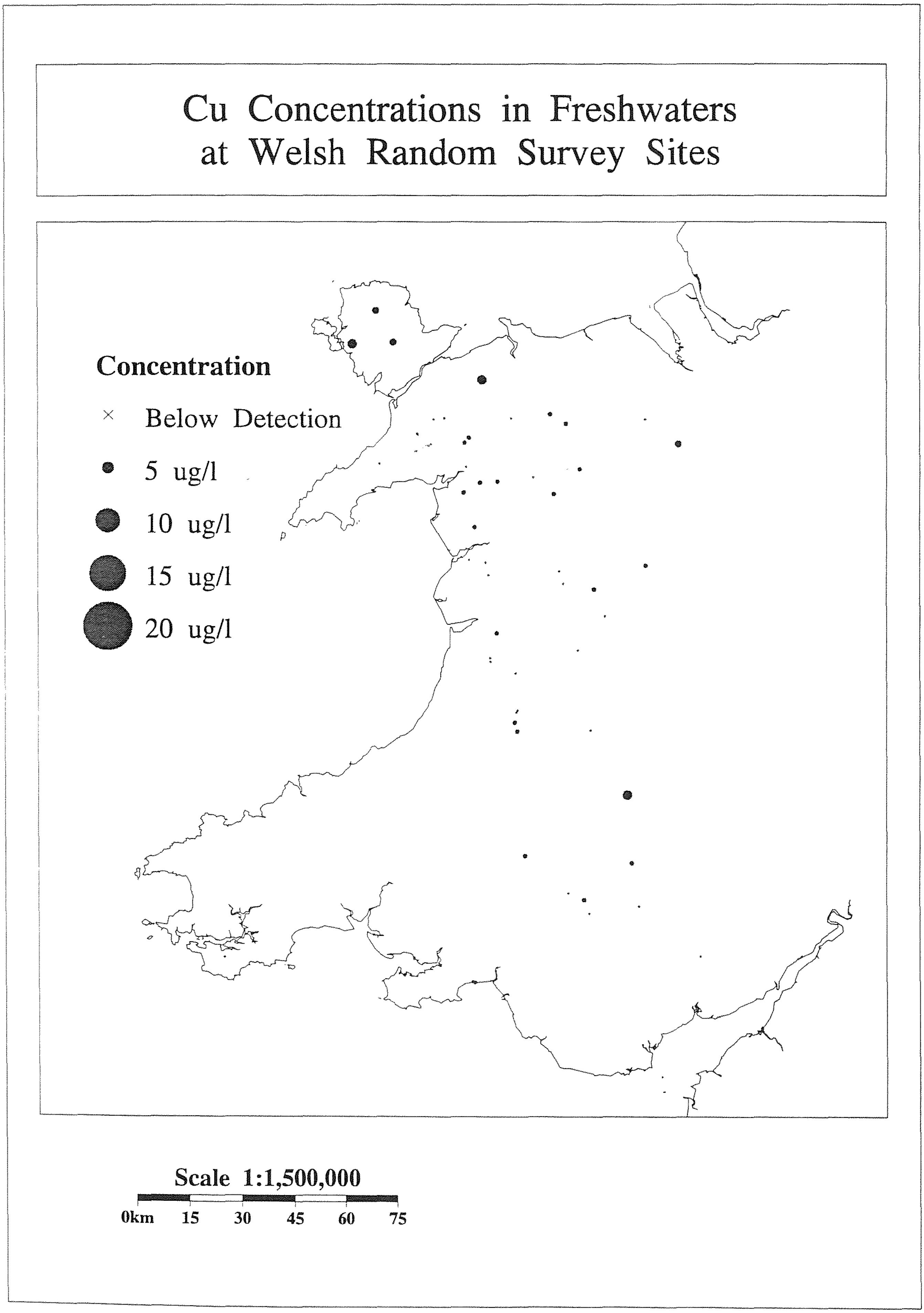

Cu Concentrations in Freshwaters
at Welsh Random Survey Sites
Concentration
× Below Detection
5 ug/l
10 ug/l
15 ug/l
20 ug/l
Scale 1:1,500,000
0km 15 30 45 60 75

FIGURE 18

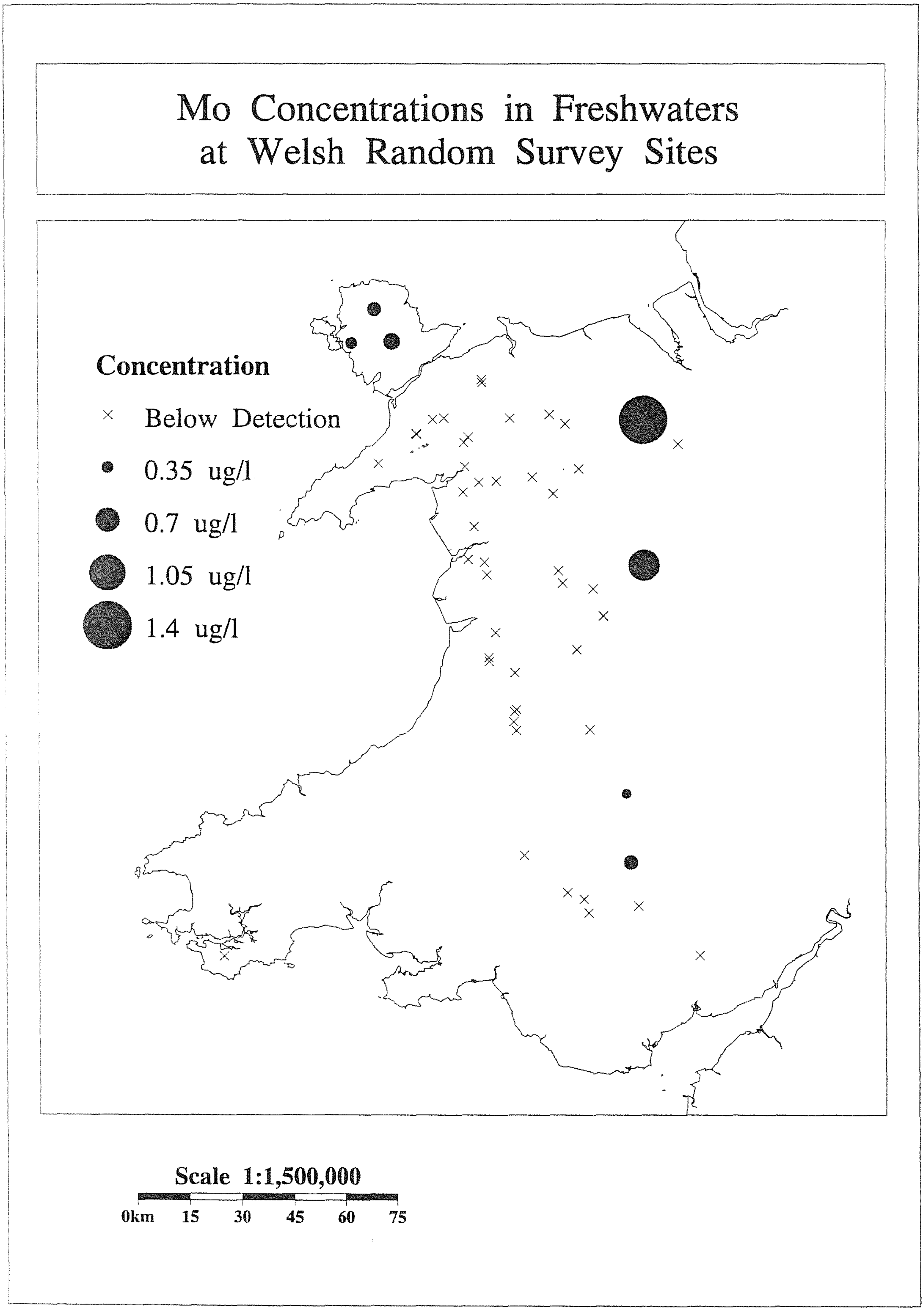

Mo Concentrations in Freshwaters
at Welsh Random Survey Sites
Concentration
Below Detection
0.35 ug/l
0.7 ug/l
1.05 ug/l
1.4 ug/l
Scale 1:1,500,000
0km
15
30
45
60
75

FIGURE 19

Ni Concentrations in Freshwaters at Welsh Random Survey Sites

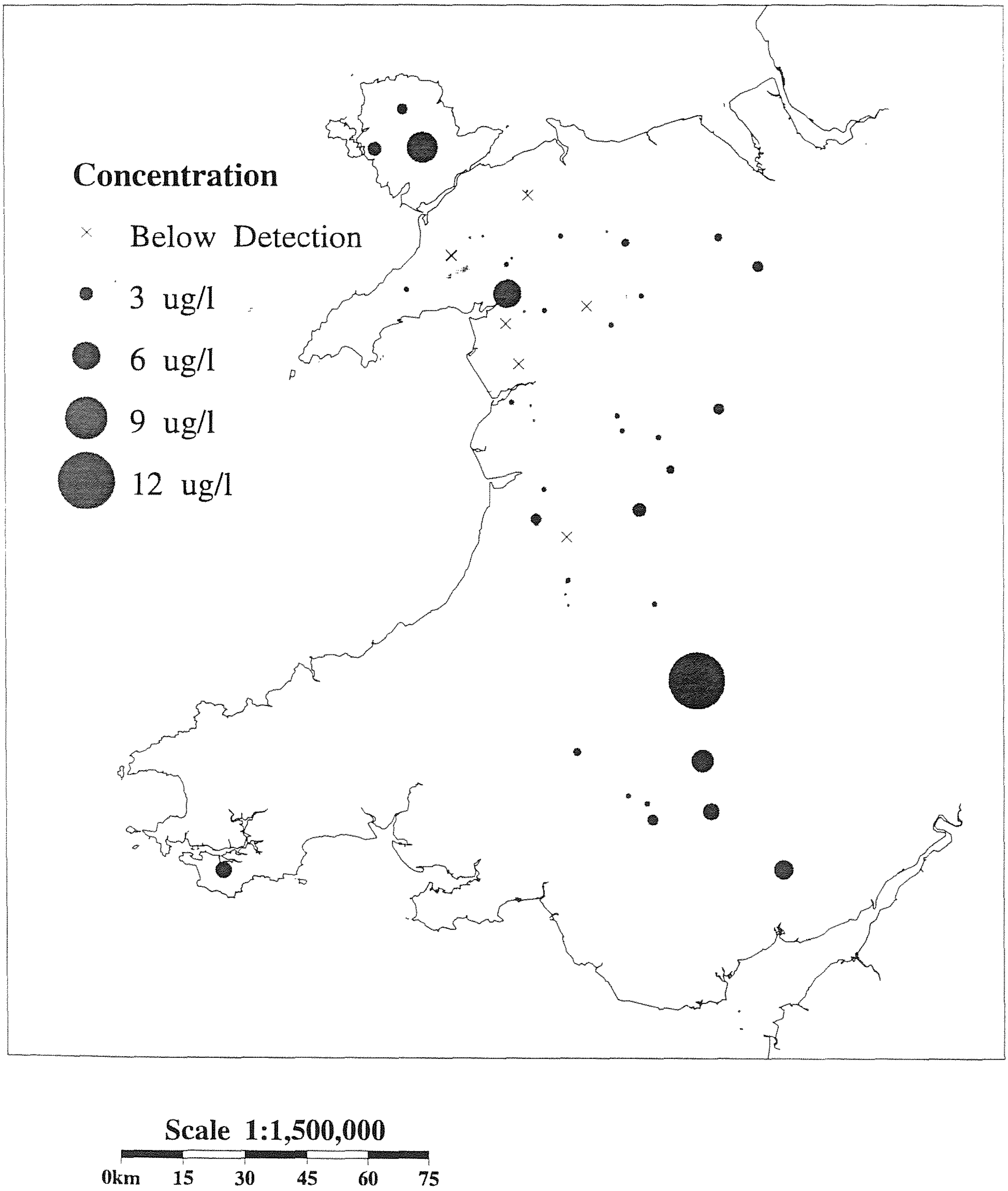
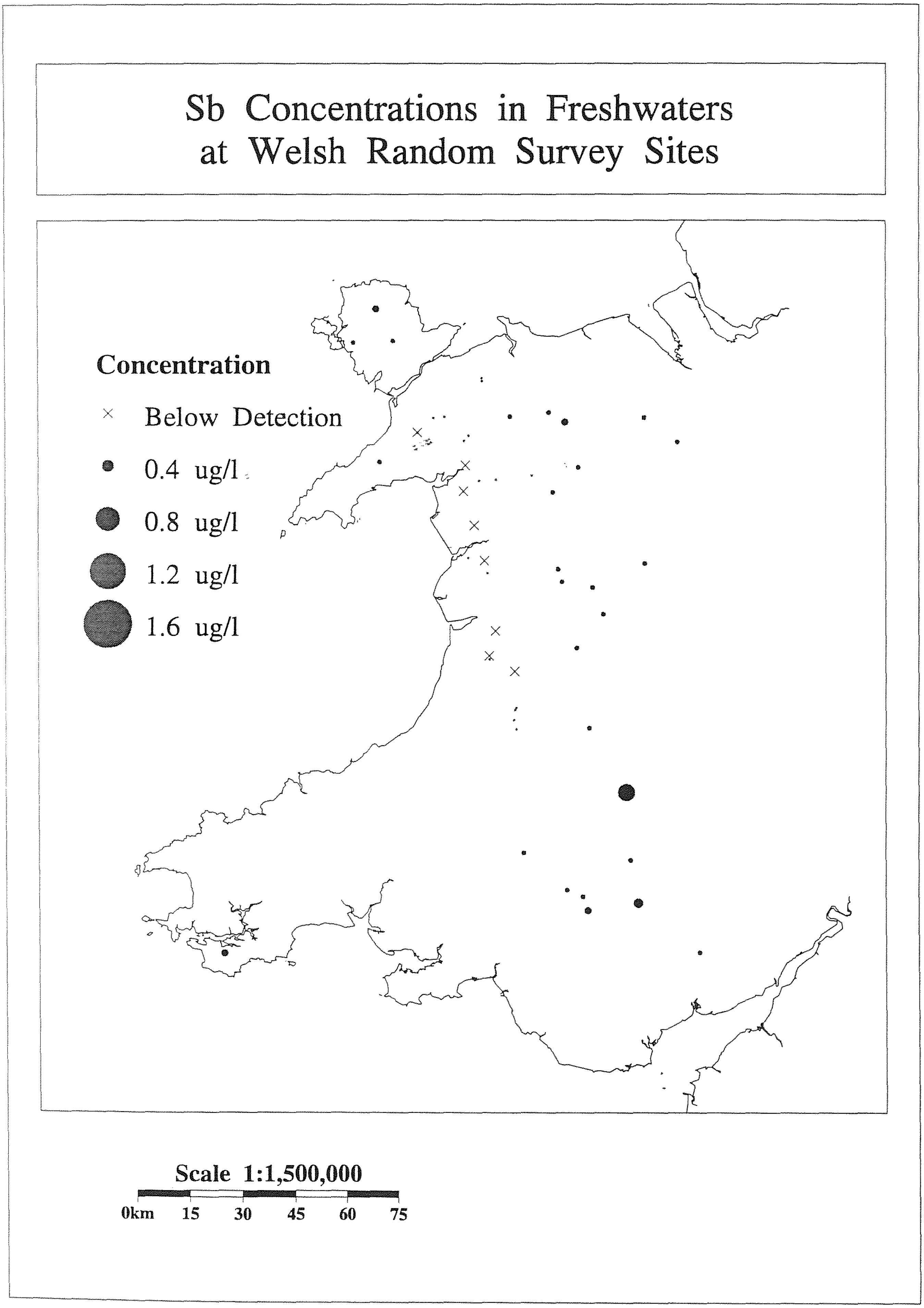


FIGURE 20



Sb Concentrations in Freshwaters at Welsh Random Survey Sites
Concentration
Below Detection
0.4 ug/l
0.8 ug/l
1.2 ug/l
1.6 ug/l
Scale 1:1,500,000
0km 15 30 45 60 75

FIGURE 21

Tl Concentrations in Freshwaters at Welsh Random Survey Sites

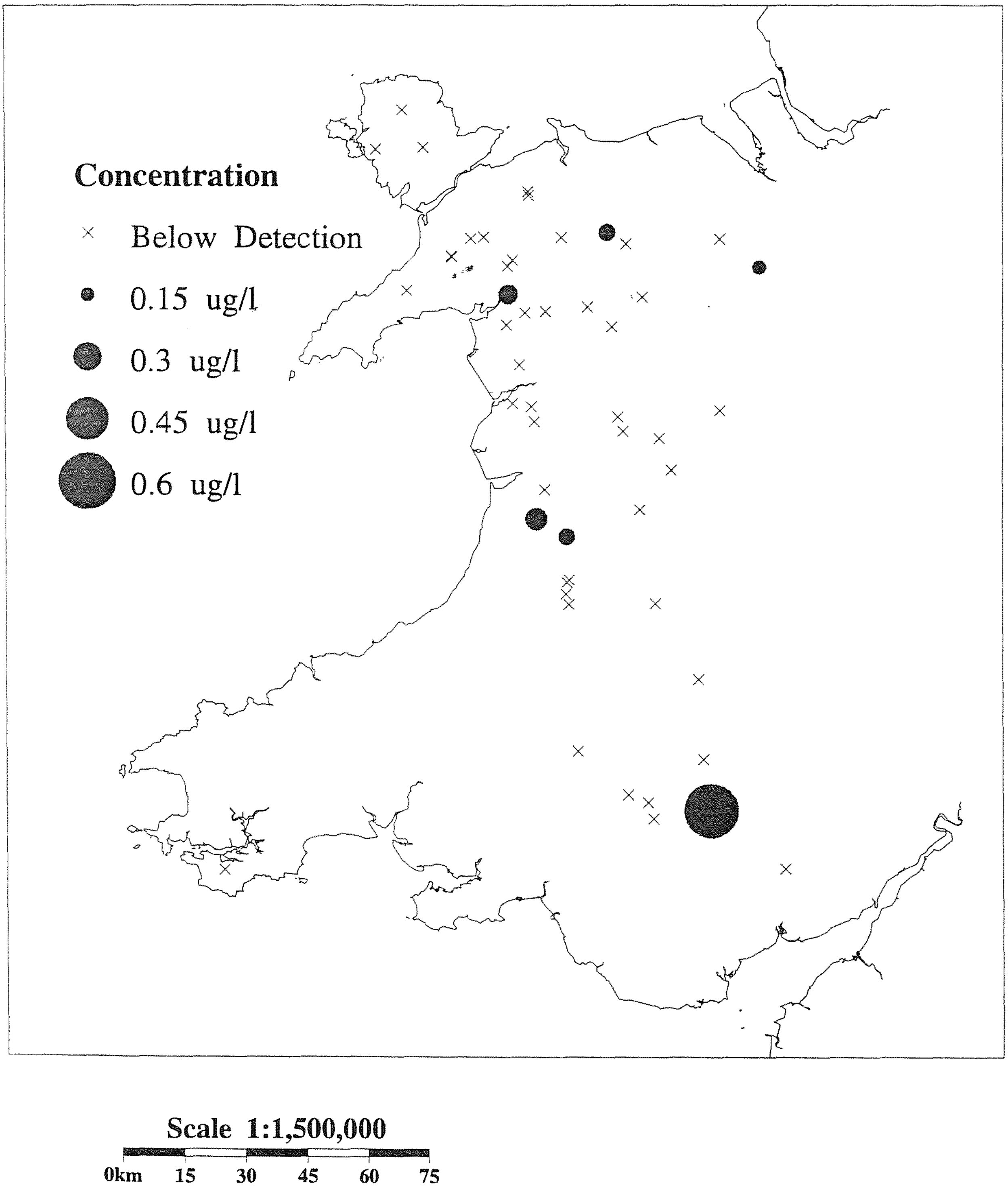
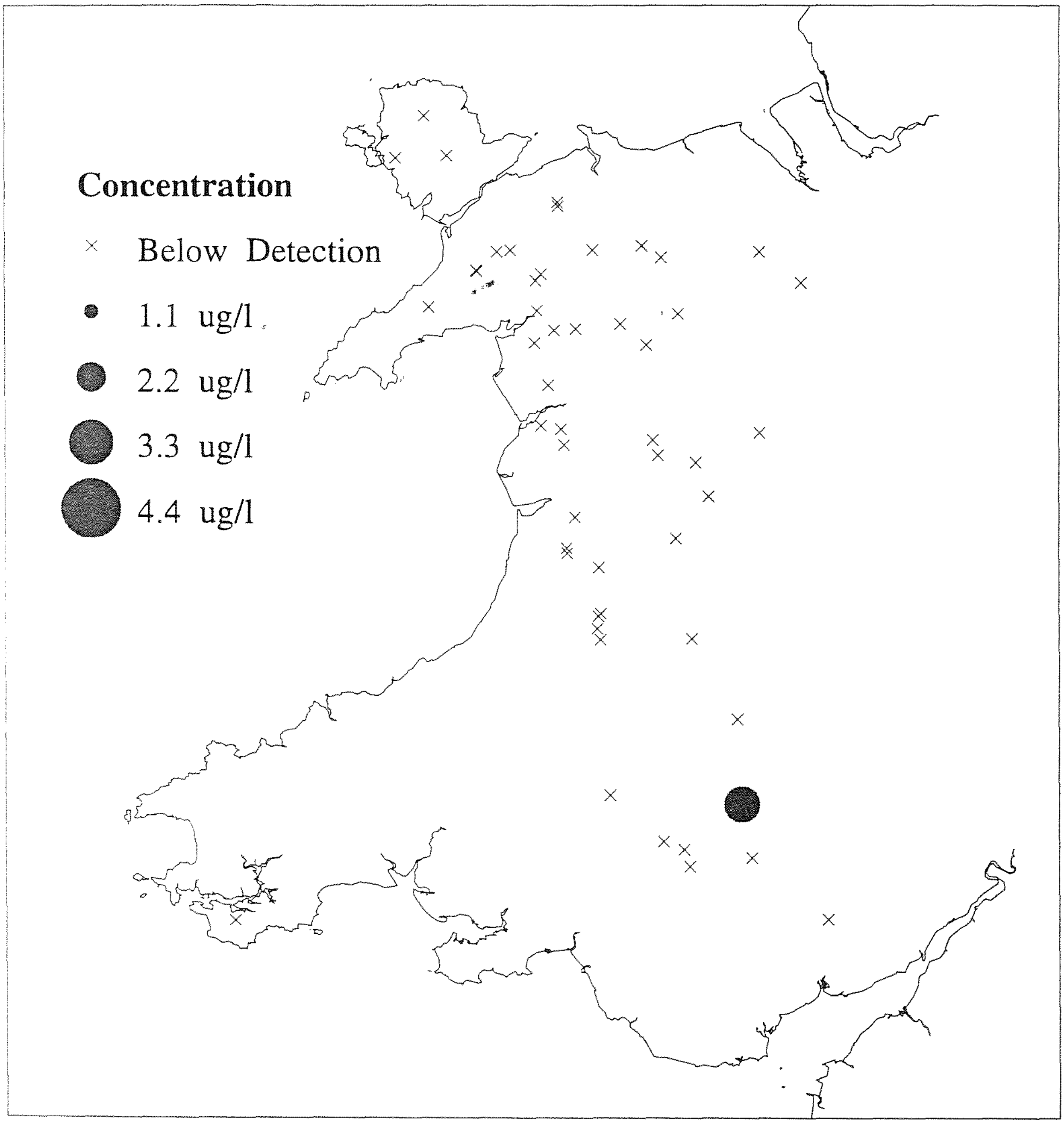


FIGURE 22

V Concentrations in Freshwaters at Welsh Random Survey Sites



Scale 1:1,500,000

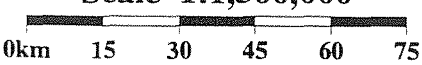
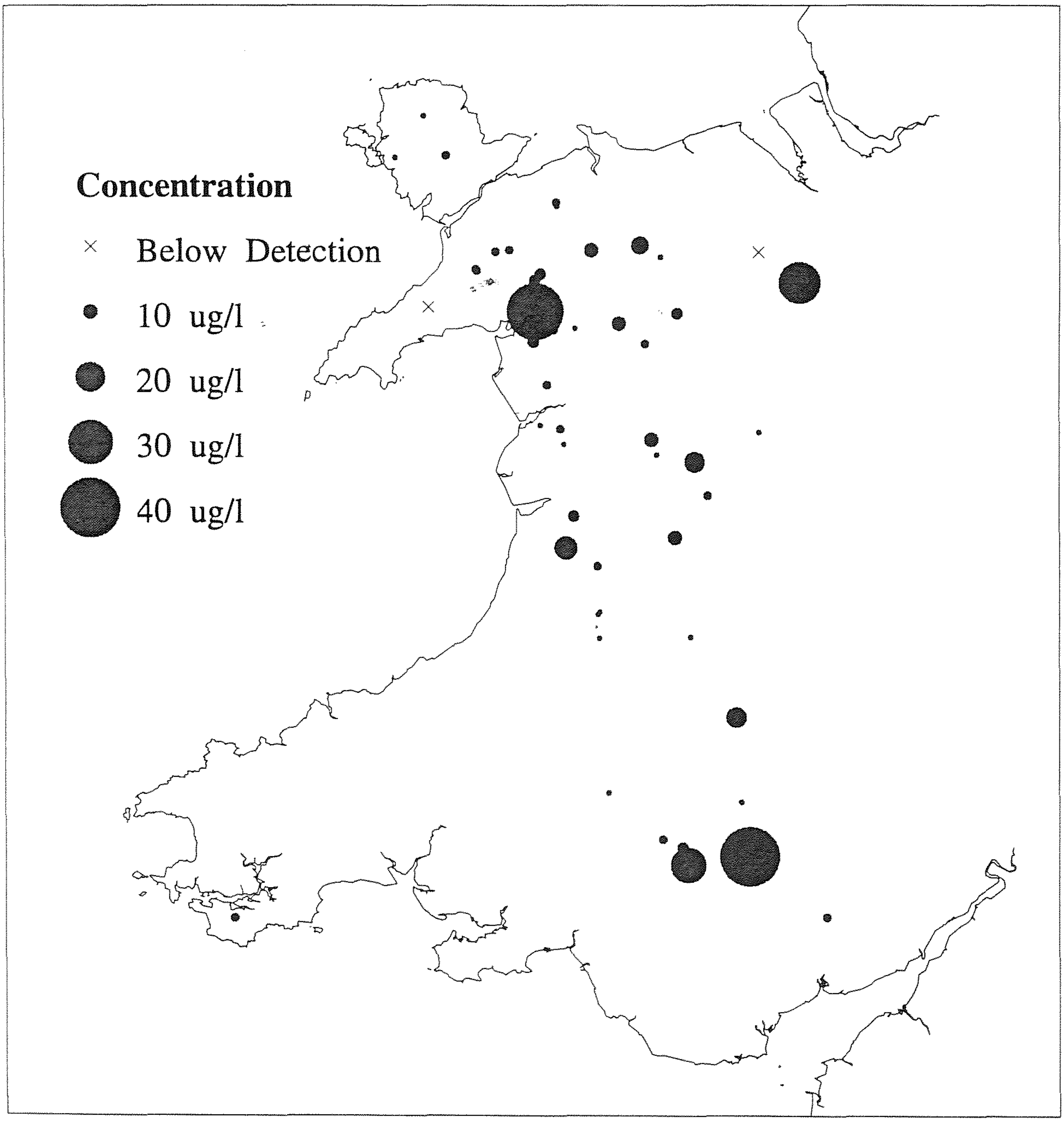
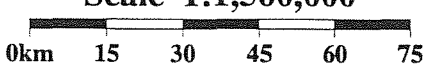


FIGURE 23

Zn Concentrations in Freshwaters at Welsh Random Survey Sites





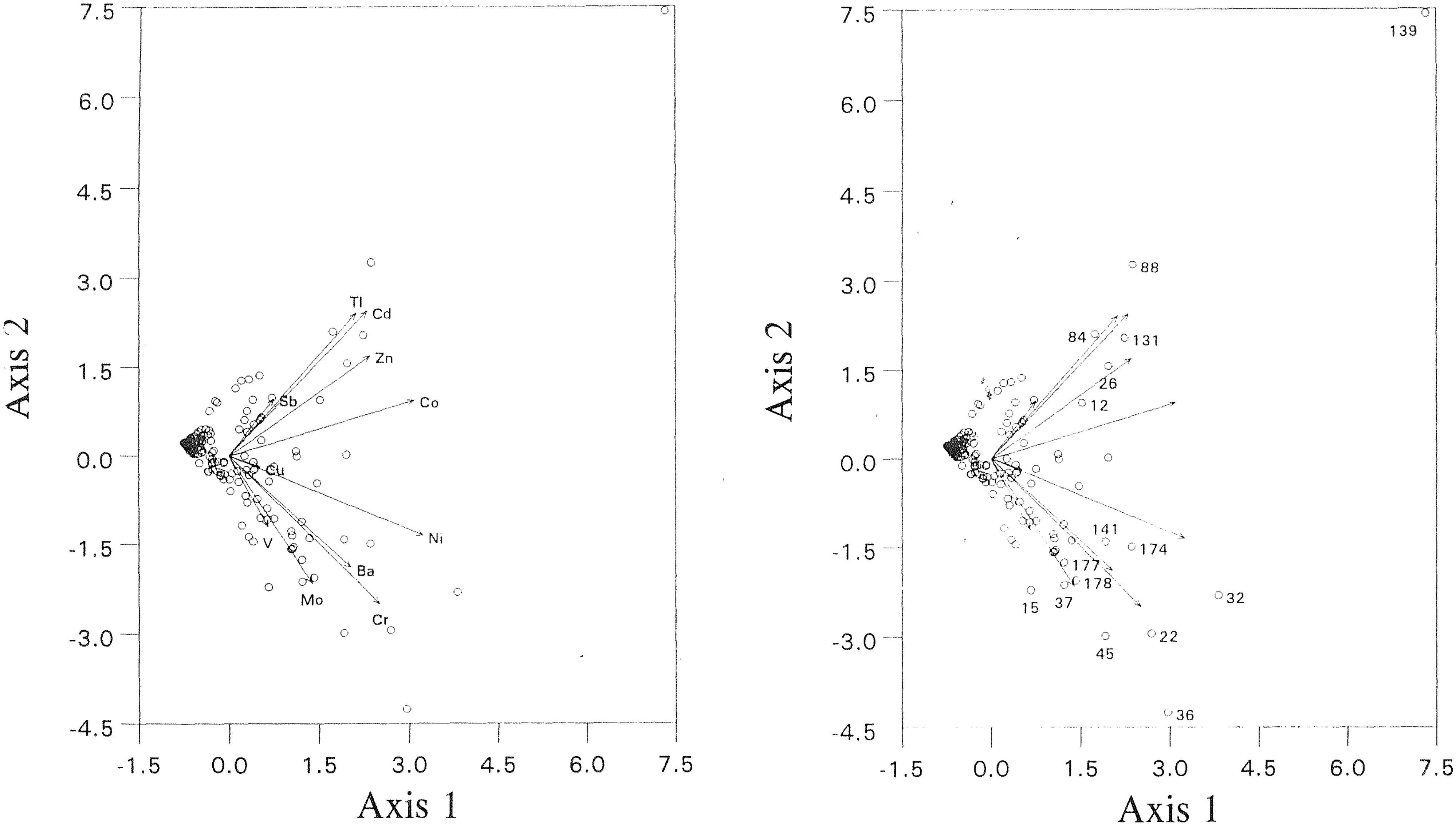
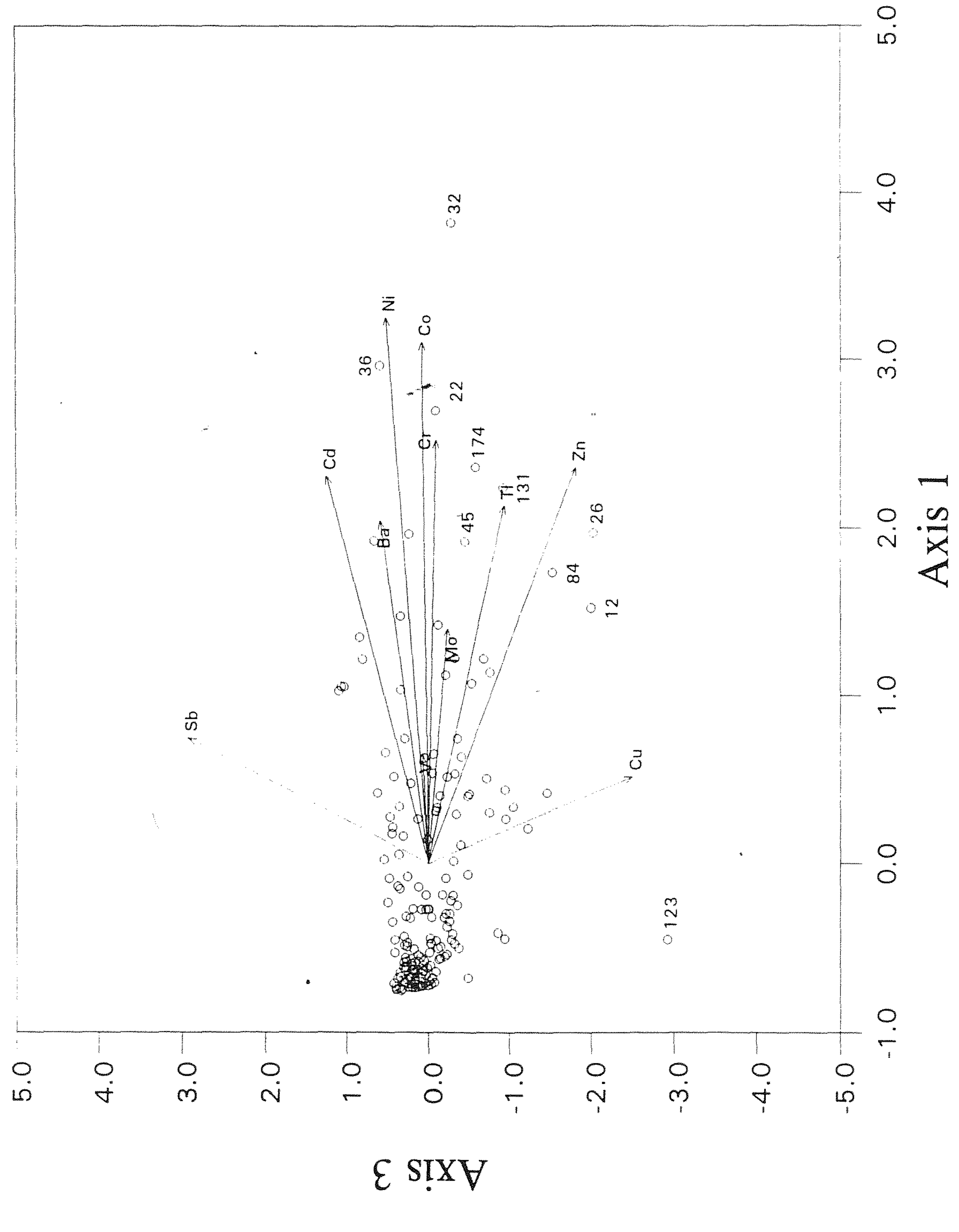

Axis 2
Axis 1
7.5
6.0
4.5
3.0
1.5
0.0
-1.5
-3.0
-4.5
Tl
Cd
Zn
Co
Sb
Cu
Ni
V
Ba
Mo
Cr
139
88
84
131
26
12
141
174
177
178
15
37
32
22
45
36

FIGURE 24

FIGURE 25



Axis 1
Axis 3
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
Ni
Co
Cd
Ba
Cr
Zn
Tl
Mo
Sb
Cu
32
36
22
174
131
45
26
84
12
123

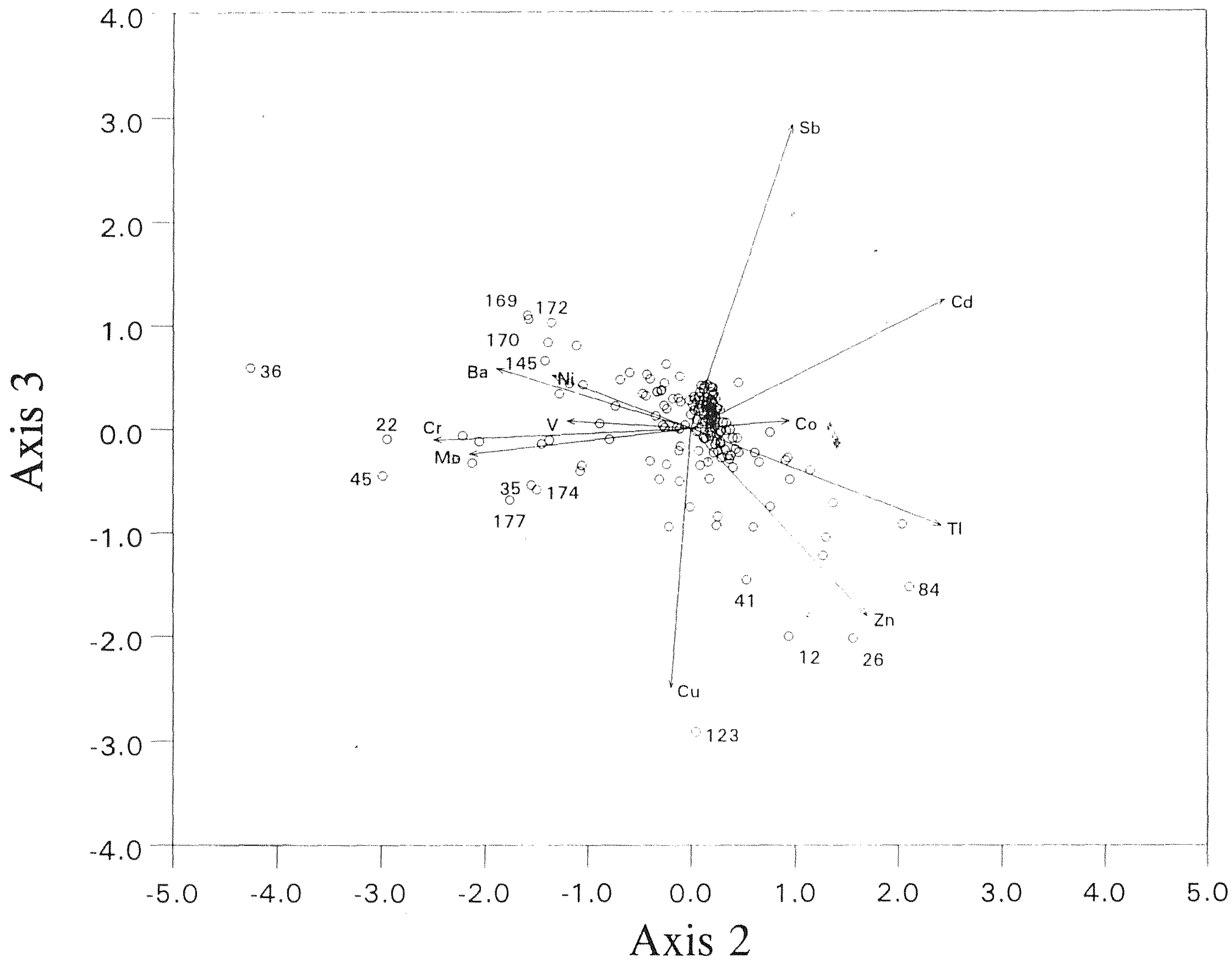

Axis 3
Axis 2
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
Sb
Cd
Co
Tl
Zn
Cu
Ba
Ni
V
Cr
Mb
36
169
172
170
145
22
45
35
174
177
41
84
12
26
123

FIGURE 26

APPENDIX 1:

SITE NAMES AND GRID REFERENCES

Site	Name	Grid Reference
1	LOCH INSH	NH 830044
2	LOCH AN T-SEILICH	NN 757864
3	LLYN ALAW	SH 392867
4	LLYN GWYDDIOR	SH 934074
5	LLYN COCH-HWYAD	SH 922110
6	LLYN-Y-GADAIR	SH 708135
7	LLYN EDNO	SH 662497
8	TAL-Y-LLYN LAKE	SH 716099
9	LLYN CAER-EUNI	SH 982406
10	LLYN FFYNNON-Y-GWAS	SH 591553
11	LLYN HIRAETHLYN	SH 743370
12	CAE LLWYD RES	SJ 269479
13	LLYN CWM-MYNACH	SH 678238
14	LLYN TRAWSFYNDD	SH 693367
15	LLYN GWERYD	SJ 172550
16	LLYN ALWEN	SH 897565
17	LLYN TEGID (BALA LAKE)	SH 907334
18	LLYN EIDDEW-MAWR	SH 646338
19	MELYNLLYN	SH 701656
20	ALWEN RES	SH 943537
21	LLYN ARENIG FAWR	SH 847382
22	CEFNI RES	SH 443774
23	USK RES	SN 821286
24	LLYNNAU CREGENNEN (LOWER)	SH 661143
25	LLYN GLASFRYN	SH 402421
26	LLYN MAIR	SH 652412
27	DULYN RES	SH 700665
28	LLYN LLAGI	SH 649482
29	LLYN GWYN	SO 012649
30	LLYNNAU CWM SILYN (UPPER)	SH 514505
31	LLYNNAU CWM SILYN (LOWER)	SH 512508
32	LLAN BWCH-LLYN LAKE	SO 119463
33	LLYN CWELLYN	SH 559549
34	LLYN ELSI RES	SH 783553
35	LLYN TRAFFWLL	SH 325769
36	LLANGORSE LAKE	SO 131265
37	LLYN DU	SJ 173127
38	LLYN HIR	SJ 023058
39	LOCH TUMMEL	NN 819593
40	LOCH BHAC	NN 822622
41	LOCH ERICHT	NN 542722
42	LOSSBURN RESERVOIR	NS 831989
43	LOCH LAOIGH	NH 730959
44	LOCH HORN	NC 797060
45	LOCH HEMPRIGGS	ND 342471
46	LOCH (AT) CNOG PREAS A MHADAIDH	NC 985484
47	LOCH DUBH	ND 010440
48	LOCHAN AIRIGH LEATHAIDH	NC 990388
49	LOCH MORE	ND 077454
50	THE CROSS LOCHS	NC 866471
51	LOCH AN TIGH CHOIMHID	NC 662607
52	LOCH NAN DEARCAG	NH 335571
53	LOCH DUBH	NH 469250
54	LOCH OF CRAIGLUSH	NO 043443
55	BACKWATER RESERVOIR	NO 254603

Site	Name	Grid Reference
56	LOCH AT GLAMIS CASTLE	NO 390491
57	CROMBIE RESERVOIR	NO 521408
58	LLYN FYRDDON FAWR	SN 800707
59	LLYN GYNON	SN 799646
60	LLYN EGNANT	SN 792672
61	LLYN FYRDDON FACH	SN 796701
62	LOCH MOR	NH 962256
63	LOCHINDORB	NH 971361
64	ALTYRE HOUSE LOCH	NJ 029548
65	LOCH PARK	NJ 355430
66	LOCHAN A' BHUALT	NC 330036
67	LOCH DONNAIG	NC 082317
68	LOCH A' GHLINNEIN	NC 168233
69	LOCH NA LOINNE	NC 127291
70	LOCH NA BHUIDHEAG	NC 092292
71	LOCH (AT) CNOC LOACHAIN DUIBH	NC 276491
72	LOCH NA THULL	NC 251501
73	LOCH A' PHUILL BHUIDHE	NC 268631
74	LOCH A' MHONAIDH DHROIGHINN	NG 937884
75	LOCHAN A' CHROISG	NC 219155
76	LOCH BAD A GHAILL	NC 075102
77	LOCH NAN EATACHAN	NC 175089
78	LOCH GROBAIG	NG 922597
79	LOCH MAREE	NG 931715
80	LOCH NAN EUN	NG 703484
81	LOCH A' CHADHA CHARNAICH	NG 585392
82	LOCH NA OREITHEACH	NG 513206
83	LOCH HARROW	NX 527866
84	CLATTERINGSHAWS LOCH	NX 542770
85	TROSTON LOCH	NX 700903
86	MOSSDALE LOCH	NX 656710
87	BARGATTON LOCH	NX 692618
88	LOCH AT KELHEAD	NY 145693
89	KIRK LOCH	NY 078822
90	TALLA RESERVOIR	NT 118214
91	LOCH MEADIE	NC 502410
92	DUBH LOCHAIN	NN 341485
93	LOCHAN SGEIREACH	NG 901340
94	LOCH NAN AMHAICHEAN	NH 417761
95	LOCH NA BEISTE	NH 276638
96	LOCH FANNICH	NH 210657
97	LOCH A CHOIRE GHRANDA	NH 269806
98	LOCH INNIS NAN SEANGAN	NG 911325
99	LOCH NA CLEIRE	NH 009903
100	LOCH FADA	NH 026711
101	GORM LOCH MORE	NC 712233
102	LOCH AT CNOC A CHATHA	NG 230606
103	LOCH NA UIDHEAN (UPPER)	NB 082164
104	LOCH BEAG SHIELABRIE	NB 130191
105	LOCH MHANAIS	NG 097903
106	LOCH NA H'INGHINN	NB 336169
107	LOCH MOGLAVAT	NB 198189
108	LOCH AT LEANA AN FHEOIR	NG 064896
109	LOCH NA GAINMHICH	NB 321379
110	LOCH BREIVAT	NB 330454

Site	Name	Grid Reference
111	LOCH SKORASHAL	NB 207443
112	LOCH NA CARTACH	NB 378385
113	LOCH GILL BREINADALE	NB 158322
114	LOCH GRUNAVAT	NB 088272
115	LOCH HOLAVAT	NB 352240
116	LOCH CLEIT EIRMIS	NB 243278
117	LOCH NA MUILNE	NB 521471
118	LOCH A CHAIRN	NB 475442
119	LOCH DRUM NAN BIDEANNAN	NB 397196
120	LOCH MOR SANDAVAT	NB 498524
121	LOCH AN TAIRBH	NF 844532
122	LOCH SCAARPAT	NF 953694
123	LOCH STULAVAL	NF 799228
124	LOCH (AT) HOSTA	NF 728721
125	LOCH AN EILEAN	NF 828374
126	LOCH BORNISH	NF 732292
127	LOCH MHIC GILLE-BHRIDE	NF 771696
128	LOCH FADA	NF 872708
129	LOCH TEANGA	NF 818383
130	LLYN SYFYDRIN	SN 722847
131	LLYN CRAIGYPISTYLL	SN 721858
132	LLYNNOEDD IEUAN	SN 795814
133	LLYN CONACH	SN 740931
134	CANTREF RESERVOIR	SN 993159
135	YSTRADFELLTE RESERVOIR	SN 947178
136	LLYN EBYR	SN 976881
137	LLWYN-ON RESERVOIR	SO 007119
138	GWGIA	SO 053979
139	LLANGYNIDR RESERVOIR	SO 152140
140	UN-NAMED(WEST ORIELTON LAKE)	SR 950994
141	LLANDEGFEDD RESERVOIR	ST 330996
142	LOCH TREIG	NN 332719
143	LOCH BLAIR	NN 055944
144	LOCH MORAR	NM 760908
145	MOCHRUM LOCH	NS 269092
146	CNOC ENDON RESERVOIR	NS 242522
147	WHITEMOSS DAM	NS 414718
148	CRAIGALLIAN LOCH	NS 536782
149	LOCH FRISA	NM 487488
150	LOCHAN DRUIM AN LUBHAIR	NM 937610
151	GGLEANN LOCHAIN	NM 463637
152	LOCH NAM PAITEAN	NM 727738
153	LOCH BEINN AN T-SIDHEIN	NH 234152
154	LOCHAN SCRISTAN	NH 475178
155	CAMMAS DAOINE LOCH	NN 023064
156	LOCHAN AT FEORLIN	NR 956973
157	LUSSA LOCH	NR 711300
158	LOCH GEARACH	NR 226596
159	LOCH NIGHEAN AILLEIN	NR 595865
160	LOCH AN T-SIOB	NR 517735
161	DAILL LOCH	NR 813898
162	LOCH NA CRAIGE GRAINDE	NR 764828
163	LOCH ECK	NS 138919
164	LOCH A CHREACHAIN	NM 887140
165	LOCH SCAMMADALE	NM 890203

Site	Name	Grid Reference
166	LOCH AT BARGUILLEAN FARM	NM 977291
167	LOCHAN DUBH	NM 866320
168	LOCHAN BEINN DAMHAIN	NN 291171
169	LOCH LEVEN	NO 147014
170	HARLAW RESERVOIR	NT 180648
171	HEN POO	NT 779547
172	LOCH AT FALDONSIDE	NT 505328
173	MANSE LOCH	HY 477298
174	LOCH OF SKAILL	HY 241181
175	LOCH OF SWANNAY	HY 311281
176	LOCH OF GRIESTA	HU 408438
177	NORTH LOCH	HU 474660
178	LOCH OF SPIGGIE	HU 371167
179	LOCH AT NEAPABACK	HU 523806
180	LOCH LEATHAN	NG 503515
181	LOCH OF FRAMGORD	HU 209784
182	LOCH AT HOULL	HU 377909
183	LOCH OF WESTERWICK	HU 283432
184	CURE WATER	HU 311753
185	LOCH BELOW BHODAICH	NF 790388

APPENDIX 2:

TRACE METAL ANALYSES

N.B. On the following tables `0' denotes a below detection limit concentration.

Site	Be	V	Cr	Co	Ni	Zn	Cu	Mo	Ag	Cd	Sb	Ba	Tl	Pb	Bi	Hg	As	Se
1	0	0	0.66	0.1	0.67	4.05	1.61	0	0	0	0.12	10.8	0	0	0	0	0	0
2	0	0	0.71	0.07	0	0	0.81	0	0	0	0.1	16.98	0	0	0	0	0	0
3	0	0	1.25	0.17	2.29	2.56	2.63	0.36	0	0	0.2	8.43	0	0	0	0	0	0
4	0	0	0.67	0	0.65	2.92	0.96	0	0	0	0.13	2.43	0	0	0	0	0	0
5	0	0	0	0	0.88	8.14	0.9	0	0	0	0.1	2.2	0	0	0	0	0	0
6	0	0	0	0	0.55	5.89	0.4	0	0	0	0	2.55	0	0	0	0	0	0
7	0	0	0	0	0.51	6.47	1.25	0	0	0	0.07	1.37	0	0	0	0	0	0
8	0	0	0	0	0.6	2.39	0.63	0	0	0	0.05	2.63	0	0	0	0	0	0
9	0	0	0	0	0.84	6.58	1.19	0	0	0	0.11	10.33	0	0	0	0	0	0
10	0	0	0	0	0.6	4.55	0.72	0	0	0	0.05	2.16	0	0	0	0	0	0
11	0	0	0	0	0.65	3.27	1.44	0	0	0	0.06	1.18	0	0	0	0	0	0
12	0	0	0.78	0.14	2.22	27.82	2.28	0	0	0	0.16	25.96	0.15	0	0	0	0	0
13	0	0	0	0	0	4.61	1.22	0	0	0	0	4.15	0	0	0	0	0	0
14	0	0	0	0	0.51	4.84	1.58	0	0	0	0.06	2.88	0	0	0	0	0	0
15	0	0	0.91	0	1.27	0	0.8	1.37	0	0	0.15	6.56	0	0	0	0	0	0
16	0	0	0	0.18	0.55	10.97	1.42	0	0	0	0.09	1.84	0.18	0	0	0	0	0
17	0	0	0.63	0	0.8	4.17	1.37	0	0	0	0.11	5.8	0	0	0	0	0	0
18	0	0	0	0	0	6.4	1.43	0	0	0	0	2.18	0	0	0	0	0	0
19	0	0	0	0	0	3.08	0.58	0	0	0	0.06	2.15	0	0	0	0	0	0
20	0	0	0	0	1.8	2.7	1.12	0	0	0	0.19	6.95	0	0	0	0	0	0
21	0	0	0	0	0	9.5	0.39	0	0	0	0.07	9.93	0	0	0	0	0	0
22	0	0	3.47	0.42	6.17	4.43	2.42	0.44	0	0	0.15	64	0	0	0	0	0	0
23	0	0	1.13	0	1.28	3.09	2	0	0	0	0.1	45.61	0	0	0	0	0	0
24	0	0	0.62	0	0.61	3.76	0.63	0	0	0	0.07	3.31	0	0	0	0	0	0
25	0	0	0.77	0.07	0.77	0	0.86	0	0	0	0.12	0.77	0	0	0	0	0	0
26	0	0	0	0	5.68	36.46	0.7	0	0	0	0	5.55	0.19	0	0	0	0	0
27	0	0	0	0	0.52	4.55	3.69	0	0	0	0.07	2.3	0	0	0	0	0	0
28	0	0	0	0	0.82	7.07	1.08	0	0	0	0.06	1.52	0	0	0	0	0	0
29	0	0	0.67	0	0.61	2.7	0.97	0	0	0	0.13	4.69	0	0	0	0	0	0
30	0	0	0	0	0	5.92	0.28	0	0	0	0.06	5.27	0	0	0	0	0	0
31	0	0	0	0	0	4.58	0.31	0	0	0	0	4.59	0	0	0	0	0	0
32	0	0	2.06	0.76	12.14	13.41	3.4	0.23	0	0	0.53	67.77	0	0	0	0	0	0
33	0	0	0	0	0.57	4.47	0.77	0	0	0	0.05	2.81	0	0	0	0	0	0
34	0	0	0	0	0.62	9	0.44	0	0	0	0.09	3.29	0	0	0	0	0	0
35	0	0	2.37	0.23	2.76	2.03	3.12	0.3	0	0	0.16	1.17	0	0	0	0	0	0
36	0	2.58	3.63	0.28	4.21	3.13	1.15	0.38	0	0	0.16	127.02	0	0	0	0	0	0
37	0	0	2.06	0.15	2.26	3.45	1.63	0.87	0	0	0.15	11.1	0	0	0	0	0	0
38	0	0	0.78	0.09	1.17	12.28	1.31	0	0	0	0.13	28.81	0	0	0	0	0	0
39	0	0	0	0	0	3.77	1.18	0	0	0	0.06	6.3	0	0	0	0	0	0
40	0	0	0.95	0	1.08	14.17	1.99	0.17	0	0	0.12	9.16	0	0	0	0	0	0
41	0	0	0.91	0	0	24.28	1.53	0	0	0	0.07	4.61	0	0	0	0	0	0
42	0	0	1.22	0.08	1.73	5.9	2.52	0.18	0	0	0.44	53.05	0	0	0	0	0	0
43	0	0	0.96	0	0.53	2.67	0.83	0	0	0	0.1	5.08	0	0	0	0	0	0
44	0	0	0.89	0	0.67	5.39	1.34	0.19	0	0	0.12	2.79	0	0	0	0	0	0
45	0	0	2.14	0.15	3.44	3.81	2.75	1.12	0	0	0.24	54.12	0	0	0	0	0	0
46	0	0	0.84	0.07	0	7.73	0.87	0	0	0	0.1	1.64	0.17	0	0	0	0	0
47	0	0	0.87	0	0	6.26	1.66	0.19	0	0	0.11	4.84	0	0	0	0	0	0
48	0	0	0.71	0	0	6.99	1.15	0	0	0	0.11	0.95	0	0	0	0	0	0
49	0	0	0	0	0.28	1.56	0.54	0	0	0	0.08	5.98	0	0	0	0	0	0

Site	Be	V	Cr	Co	Ni	Zn	Cu	Mo	Ag	Cd	Sb	Ba	Tl	Pb	Bi	Hg	As	Se
50	0	0	0	0	0.12	0	0.92	0	0	0	0.05	4.71	0	0	0	0	0	0
51	0	0	0	0	0.33	0	1.32	0	0	0	0.05	4.87	0	0	0	0	0	0
52	0	0	0	0	0.33	0	0.64	0	0	0	0	2.03	0	0	0	0	0	0
53	0	0	0	0.08	0.17	0	0.49	0	0	0	0	3.89	0	0	0	0	0	0
54	0	0	0	0	0.87	0	1.16	0	0	0	0.1	10.29	0	0	0	0	0	0
55	0	0	0	0	0.45	0	1.08	0	0	0	0.05	10.69	0	0	0	0	0	0
56	0	0	1.6	0.16	5.2	0	1.64	0	0	0	0.18	21.28	0	0	0	0	0	0
57	0	0	0.66	0.11	2.03	0	1.65	0	0	0	0.15	86.57	0	0	0	0	0	0
58	0	0	0	0	1.12	2.11	0.32	0	0	0	0.07	1.94	0	0	0	0	0	0
59	0	0	0	0	0.55	3.42	1.27	0	0	0	0.05	2.15	0	0	0	0	0	0
60	0	0	0	0	0.25	1.74	1.1	0	0	0	0.07	2.05	0	0	0	0	0	0
61	0	0	0	0	0.52	2.57	0.7	0	0	0	0.08	1.72	0	0	0	0	0	0
62	0	0	0	0	0.52	0	0.6	0.12	0	0	0.05	15.13	0	0	0	0	0	0
63	0	0	0	0	0.27	0	0.56	0	0	0	0	12.66	0	0	0	0	0	0
64	0	0	0	0.08	0.96	0	1.2	0	0	0	0	53.69	0	0	0	0	0	0
65	0	0	0	0.1	1.72	0	0.34	0	0	0	0	21.04	0	0	0	0	0	0
66	0	0	0	0	0.14	0	1.63	0	0	0	0	2.72	0	0	0	0	0	0
67	0	0	0	0	0.51	0	0.72	0	0	0	0	14.45	0	0	0	0	0	0
68	0	0	0	0	0.31	0	0.67	0	0	0	0	11.35	0	0	0	0	0	0
69	0	0	0	0	0.41	0	0.95	0	0	0	0	10.93	0	0	0	0	0	0
70	0	0	0	0	0.34	0	1.11	0	0	0	0	6.6	0	0	0	0	0	0
71	0	0	0	0	0.14	0	1.16	0	0	0	0	3.88	0	0	0	0	0	0
72	0	0	0	0	0.2	3.53	1.27	0	0	0	0	2.4	0	0	0	0	0	0
73	0	0	0	0.09	0.28	0	0.85	0	0	0	0	8.4	0	0	0	0	0	0
74	0	0	0	0	0.1	0	1.49	0	0	0	0	1.51	0	0	0	0	0	0
75	0	0	0	0	0.14	0	1.86	0	0	0	0	7.2	0	0	0	0	0	0
76	0	0	0	0	0.14	0	0.65	0	0	0	0	20.22	0	0	0	0	0	0
77	0	0	0	0	0.28	0	1.85	0	0	0	0	3.3	0	0	0	0	0	0
78	0	0	0	0	0.08	0	0.7	0	0	0	0	7.43	0	0	0	0	0	0
79	0	0	0	0	0.2	0	0.77	0	0	0	0	5.45	0	0	0	0	0	0
80	0	0	0	0	0.16	0	0.98	0	0	0	0	9	0	0	0	0	0	0
81	0	0	0	0.12	1.92	0	0.49	0.2	0	0	0	9.09	0	0	0	0	0	0
82	0	0	0	0	0.22	0	0.86	0	0	0	0	0.55	0	0	0	0	0	0
83	0	0	0	0.41	1.3	4.22	1.28	0	0	0	0.08	6.32	0.16	0	0	0	0	0
84	0	0	0	0.85	2.24	12.65	1.69	0	0	0	0.15	9.02	0.37	0	0	0	0	0
85	0	0	0	0.12	1.43	6.9	0.58	0	0	0	0.13	4.08	0.26	0	0	0	0	0
86	0	0	0	0.16	2.08	6.91	0.71	0	0	0	0.11	28.12	0.15	0	0	0	0	0
87	0	0	0	0	0	0	0.46	0	0	0	0.1	6.89	0	0	0	0	0	0
88	0	0	0	0.35	4.5	1.21	0.46	0	0	0.28	78.6	0	0	0	0	0	0	0
89	0	0	0	0.19	2.23	0	0.99	0.21	0	0	0.29	52.93	0	0	0	0	0	0
90	0	0	0	0	0	0	0.3	0	0	0	0.07	8.85	0.15	0	0	0	0	0
91	0	0	0	0	0	0	0.38	0	0	0	0.03	15.95	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0.05	7.94	0	0	0	0	0	0
93	0	0	0	0	0	0	0.19	0	0	0	0	11.9	0	0	0	0	0	0
94	0	0	0	0	0	0	0.16	0	0	0	0	2.75	0	0	0	0	0	0
95	0	0	0	0	0	0	0	0	0	0	0	2.29	0	0	0	0	0	0
96	0	0	0	0	0	0	0.72	0	0	0	0	4.04	0	0	0	0	0	0
97	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0	0	0
98	0	0	0	0	0	0	1.76	0	0	0	0	17.47	0	0	0	0	0	0

Site	Be	V	Cr	Co	Ni	Zn	Cu	Mo	Ag	Cd	Sb	Ba	Tl	Pb	Bi	Hg	As	Se
99	0	0	0	0	0	0	0.74	0	0	0	0	7.02	0.19	0	0	0	0	0
100	0	0	0	0	0	0	0.6	0	0	0	0	8.62	0	0	0	0	0	0
101	0	0	0	0	0	0	0.84	0	0	0	0	3.61	0	0	0	0	0	0
102	0	0	0	0	0.89	0	0.65	0	0	0	0	0.53	0	0	0	0	0	0
103	0	0	0	0	0	0	1.38	0	0	0	0	0.89	0	0	0	0	0	0
104	0	0	0	0	0	0	3.15	0	0	0	0	0.67	0	0	0	0	0	0
105	0	0	0	0	0	0	0.82	0	0	0	0	1.08	0	0	0	0	0	0
106	0	0	0	0	0	0	0.94	0	0	0	0	0.76	0	0	0	0	0	0
107	0	0	0	0	0	0	0.97	0	0	0	1.63	1.44	0	0	0	0	0	0
108	0	0	0	0	0	0	1.52	0	0	0	0	0.93	0	0	0	0	0	0
109	0	0	0	0.08	0	0	1.33	0	0	0	0.07	0.78	0	0	0	0	0	0
110	0	0	0	0	0	0	0.96	0	0	0	0	3.18	0	0	0	0	0	0
111	0	0	0	0	0.51	0	1.37	0	0	0	0	4.84	0	0	0	0	0	0
112	0	0	0	0.17	0	0	1.06	0	0	0	0	1.8	0.16	0	0	0	0	0
113	0	0	0	0	0	0	1.1	0	0	0	0	1.94	0	0	0	0	0	0
114	0	0	0	0	0	0	1.04	0	0	0	0	0.97	0	0	0	0	0	0
115	0	0	0	0	0	0	0.7	0	0	0	0	1.23	0	0	0	0	0	0
116	0	0	0	0	0	0	1.15	0	0	0	0	1.17	0	0	0	0	0	0
117	0	0	0	0.12	0	0	0.83	0	0	0	0	2.83	0	0	0	0	0	0
118	0	0	0	0.09	0	0	1.16	0	0	0	0	1.9	0	0	0	0	0	0
119	0	0	0	0.13	0	0	0.73	0	0	0	0	1.64	0	0	0	0	0	0
120	0	0	0	0.27	0	2.49	3.29	0	0	0	0.06	3.04	0.23	0	0	0	0	0
121	0	0	0	0	0	0	1.28	0	0	0	0	3.02	0	0	0	0	0	0
122	0	0	0	0.14	0.51	0	2.74	0	0	0	0	2.56	0	0	0	0	0	0
123	0	0	0	0	0	0	12.02	0	0	0	0.06	2.32	0	0	0	0	0	0
124	0	0	0	0.17	0	0	2.34	0	0	0	0.05	4.59	0	0	0	0	0	0
125	0	0	0	0	0	0	1.7	0	0	0	0.06	2.06	0	0	0	0	0	0
126	0	0	0	0.21	1.96	0	4.04	0	0	0	0.07	5.5	0.15	0	0	0	0	0
127	0	0	0	0.11	0	2.65	4.32	0	0	0	0	5.68	0	0	0	0	0	0
128	0	0	0	0	0	0	0.54	0	0	0	0.05	2.36	0	0	0	0	0	0
129	0	0	0	0	0	0	0.7	0	0	0	0.05	1.66	0	0	0	0	0	0
130	0	0	0	1	0.82	0	0.19	0	0	0	0.06	1.92	0	0	0	0	0	0
131	0	0	0	1.91	2.31	14.48	0.37	0	0	0	0	4.53	0.24	0	0	0	0	0
132	0	0	0	0.37	0	5	0.39	0	0	0	0	1.8	0.16	0	0	0	0	0
133	0	0	1.32	1.26	0.97	6.86	1.03	0	0	0	0	3.17	0	0	0	0	0	0
134	0	0	0	0	1.01	7.26	1.21	0	0	0	0.14	70.52	0	0	0	0	0	0
135	0	0	0	0	1.12	5.26	0.32	0	0	0	0.12	66.88	0	0	0	0	0	0
136	0	0	0	0.57	2.5	8.33	0.82	0	0	0	0.09	18.1	0	0	0	0	0	0
137	0	0	0.75	0.19	1.84	23.28	0.59	0	0	0	0.24	59.3	0	0	0	0	0	0
138	0	0	0	0.32	1.73	5.85	0.78	0	0	0	0.09	39.4	0	0	0	0	0	0
139	0	0	0.63	2.55	3.4	41.64	0.59	0	0	0.56	0.25	27.06	0.56	0	0	0	0	0
140	0	0	0	0.33	3.35	4.27	0.5	0	0	0	0.17	64.19	0	0	0	0	0	0
141	0	0	1.35	0.76	4.11	4.99	0.6	0	0	0	0.1	109.8	0	0	0	0	0	0
142	0	0	0	0	0.18	2.69	0.54	0	0	0	0	7.04	0	0	0	0	0	0
143	0	0	0	0	0	2.12	0.32	0	0	0	0	4.35	0	0	0	0	0	0
144	0	0	0	0	0	2.72	0.22	0	0	0	0	6.41	0	0	0	0	0	0
145	0	0	0.79	0.34	4.35	2.17	0.61	0	0	0	0.1	108.85	0	0	0	0	0	0
146	0	0	0	0.11	1.64	6.71	0.42	0	0	0	0.14	41.16	0.16	0	0	0	0	0
147	0	0	0	0.09	1.16	3.77	0.63	0	0	0	0.11	41.22	0	0	0	0	0	0

Site	Be	V	Cr	Co	Ni	Zn	Cu	Mo	Ag	Cd	Sb	Ba	Tl	Pb	Bi	Hg	As	Se
145	0	0	0.79	0.34	4.35	2.17	0.61	0	0	0	0.1	108.85	0	0	0	0	0	0
146	0	0	0	0.11	1.64	6.71	0.42	0	0	0	0.14	41.16	0.16	0	0	0	0	0
147	0	0	0	0.09	1.16	3.77	0.63	0	0	0	0.11	41.22	0	0	0	0	0	0
148	0	0	0	0	0.77	2.3	0.27	0	0	0	0.07	16.27	0	0	0	0	0	0
149	0	0	0	0	0	0	0.19	0	0	0	0	0.54	0	0	0	0	0	0
150	0	0	0	0	0	8	0.12	0	0	0	0	5.86	0	0	0	0	0	0
151	0	0	0	0	0	0	0.25	0	0	0	0	1.52	0	0	0	0	0	0
152	0	0	0	0	0	0	0	0	0	0	0	4.4	0	0	0	0	0	0
153	0	0	0	0	0	30.53	18.96	0	0	0	0	2.01	0	0	0	0	0	0
154	0	0	0	0	0	1.2	0	0	0	0	0	7.95	0	0	0	0	0	0
155	0	0	0	0	0	2.88	0.24	0	0	0	0.08	5.17	0	0	0	0	0	0
156	0	0	0	0.14	0.66	0	0.25	0	0	0	0	11.67	0	0	0	0	0	0
157	0	0	0.91	1.83	3.46	6.27	0.61	0	0	0	0	23.77	0	0	0	0	0	0
158	0	0	0.79	0.15	1.18	2.94	0.36	0	0	0	0	33.01	0	0	0	0	0	0
159	0	0	0	0.12	0	2.22	0.26	0	0	0	0.09	14.79	0	0	0	0	0	0
160	0	0	0.66	0.16	0	2.75	0.17	0	0	0	0.13	33.74	0.16	0	0	0	0	0
161	0	0	0	0.08	0.81	0	0.17	0	0	0	0	3.73	0	0	0	0	0	0
162	0	0	0.68	0.16	0	1.96	0	0	0	0	0.09	2.53	0	0	0	0	0	0
163	0	0	0.84	0.84	1.72	3.19	0.47	0	0	0	0.08	21.06	0	0	0	0	0	0
164	0	0	0.69	0	0.64	0	0	0	0	0	0	8.45	0	0	0	0	0	0
165	0	0	1	0.43	1.46	1.98	0.17	0	0	0	0	12.56	0	0	0	0	0	0
166	0	0	0.88	0.11	0.73	0	0.12	0	0	0	0	39.51	0	0	0	0	0	0
167	0	0	0.74	0.1	1.17	0	0.14	0	0	0	0	18.63	0	0	0	0	0	0
168	0	0	0	0	0	1.94	0.22	0	0	0	0.12	12.15	0	0	0	0	0	0
169	0	0	0.74	0.22	2.16	0	0.24	0	0	0	0.13	149.88	0	0	0	0	0	0
170	0	0	0.84	0.22	2.55	0	0.26	0	0	0	0.14	137.44	0	0	0	0	0	0
171	0	0	0.97	0.5	3.69	1.91	0.21	0	0	0	0.15	80.62	0	0	0	0	0	0
172	0	0	0.67	0.28	3.57	0	0.24	0	0	0	0.12	111.24	0	0	0	0	0	0
173	0	0	0.62	0.27	2.96	0	1.54	0.15	0	0	0.07	23.86	0	0	0	0	0	0
174	0	0	0.8	0.53	5.35	0	3.75	0.71	0	0	0.09	80.06	0.18	0	0	0	0	0
175	0	0	0.74	0.29	3.21	0	2.21	0.19	0	0	0.1	25.45	0	0	0	0	0	0
176	0	0	0.63	0.12	1.15	0	1.3	0.9	0	0	0.13	1.57	0	0	0	0	0	0
177	0	2.91	1.35	0.61	1.49	2.87	3.69	0.34	0	0	0.13	4.67	0	0	0	0	0	0
178	0	0	0.9	0.59	3.27	0	1.78	1.2	0	0	0.11	11.35	0	0	0	0	0	0
179	0	0	1.15	0.27	0.99	5.66	1.67	0	0	0	0.08	5.19	0	0	0	0	0	0
180	0	0	0.95	0.1	0.99	0	1.1	0	0	0	0	0.92	0	0	0	0	0	0
181	0	4.13	0	0.16	0.95	2.6	0.19	0	0	0	0	14.83	0	0	0	0	0	0
182	0	0	1.37	1.21	2.94	3.5	0.57	0	0	0	0.09	25	0	0	0	0	0	0
183	0	2.46	0.89	0.14	0.5	2.35	1.52	0.35	0	0	0.08	5.31	0	0	0	0	0	0
184	0	0.77	0.21	0.63	2.71	0.24	0	0	0	0	0.1	5.18	0	0	0	0	0	0
185	0	0	0	0	0	0	0.28	0	0	0	0.07	1.43	0	0	0	0	0	0