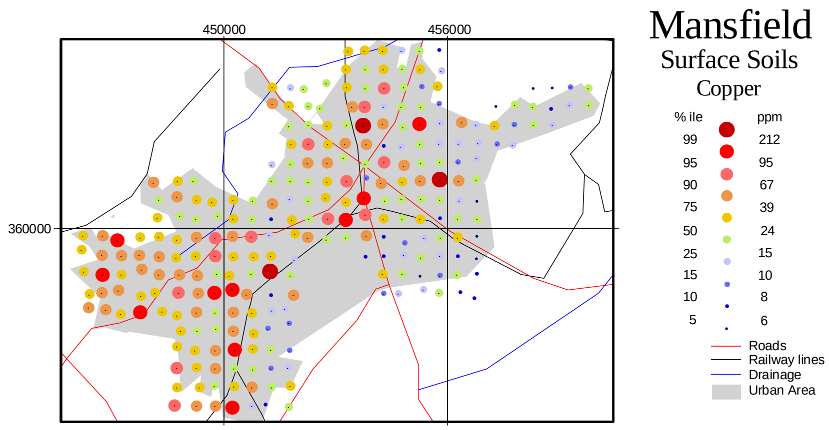
# Geochemical baseline data for the urban area of Mansfield

Urban Geoscience and Geological Hazards Programme

Internal Report IR/02/082



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/02/082

# Geochemical baseline data for the urban area of Mansfield

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Copper in surface soils from the Mansfield area

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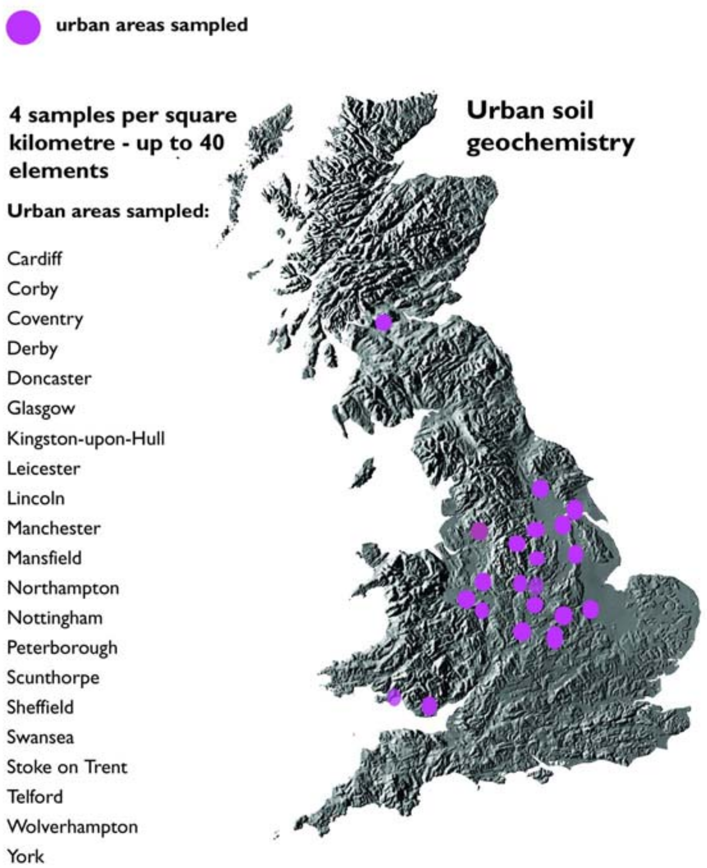
# Foreword

This report is a product of the British Geological Survey's (BGS) Geochemical Surveys of the Urban Environment (GSUE) project. Work is funded by the Office of Science and Technology and is part of the national Geochemical Baseline Survey of the Environment (G-BASE) project. The report forms part of a series, which seeks to make GSUE urban data publicly available with a minimum of interpretation, displaying the data as a series of proportional symbol maps.

A number of urban centres have been surveyed using the same sampling procedures; the status of completed sampling is indicated by the figure below. Wolverhampton, Manchester and Glasgow have been sampled as part of larger multi-disciplinary projects.




***Map showing urban areas that have been soil sampled (end of 2003)***

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# Summary

This report describes and interprets the results of a systematic urban geochemical baseline survey carried out in the Mansfield area.

The concentrations of trace elements vary widely over different rock types. Baseline geochemical data enables natural concentrations to be determined and these provide a benchmark with which to compare the levels of contaminants in industrialised and urban areas.

Soil samples were taken at a density of four per square kilometre. Sampling was carried out on the least disturbed area of unbuilt ground, such as domestic gardens, allotments, parks or (in the worst instance) road verges or made ground. Details of the sampling and analysis of Mansfield soils are summarised in Table 1.

Preliminary interpretation of the data can then be carried out and related back to the past and present industrial history of the Mansfield area.

**Table 1 Summary of Mansfield soil sampling information**

| | |
|---|---|
| **Date Sampled:** | Summer 1997 |
| **Area Sampled:** | 42 $km^2$ (min E 446000; max E 460000; min N 354000; and max N 366000) |
| **Number of Samples:** | 257 surface and 256 profile soils |
| **Elements determined by XRFS:** | $Al_2O_3$, CaO, $K_2O$, $TiO_2$, MgO, $Fe_2O_3$, MnO, $P_2O_5$, $SiO_2$, Cr, Mo, Pb, Zn, As, Cd, Cu, Ni, Sb, U, Ba, Co, Sn, V. |

# 1 Introduction

This report summarises the results and methodology of a soil geochemical survey of the urban area of Mansfield, undertaken by the British Geological Survey as part of the Geochemical Surveys of the Urban Environment Programme (GSUE), which is funded by the Office of Science and Technology. The project is part of a much wider national survey known as the Geochemical Baseline Survey of the Environment Project (G-BASE).

The G-BASE Programme is undertaking a systematic regional geochemical survey of soils, stream sediments and stream waters of the British Isles. The data obtained provide information on the surface chemical environment, which can be used to define the soil geochemical baseline and the extent of surface contamination. The data has a range of applications, including the modelling of risk to human health, with respect to potentially harmful elements through environmental exposure.

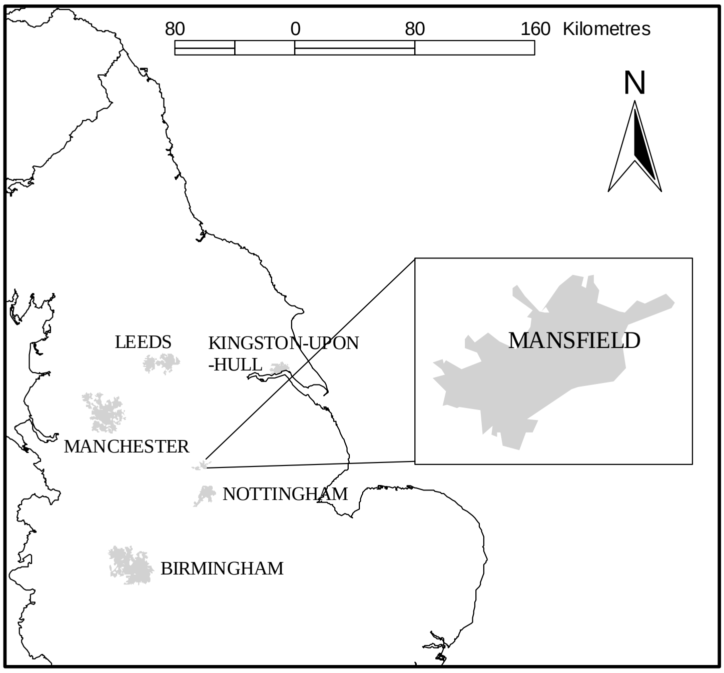


**Figure 1 Location map for Mansfield**

Mansfield is situated to the north of the city of Nottingham (Figure 1). It has had a varied industrial history related to coal mining, iron smelting, and quarrying of aggregates.

The distributions of trace metals in the surface environment of Mansfield are described in this report in the context of present and historical land use. The concentrations of the trace metals are also considered in relation to the underlying geology and placed in context with respect to the typical background concentrations obtained from G-BASE regional data sets.

# 2 Study area

## 2.1 HISTORICAL LAND USE

The industrial importance of Mansfield and the surrounding area is based on its mineral wealth. Lead mining in the Carboniferous Limestone dates back to Roman times, but it was the ironstones, coals and fireclays of the Coal Measures that were prevalent mineral resources used during the Industrial Revolution. Lead is still found as a by-product with fluorite, although coal was the major product until the late 20$^{th}$ century when economic conditions led to the closure of many pits. The first record of coal mining in the area dates from 1315, but it didn't become widely used until the 16$^{th}$ century. In the late 18$^{th}$ century industrial applications of coal were widened as it was used in the iron smelting process. By the early 19$^{th}$ century, there were 245 collieries in the county of Derbyshire; the number was increased due to the expanding rail network. With the railways came the ability to export and transport coal and other mineral products to a wider market.

Along with coal, clay was worked from the Crawshaw Sandstone for use in brick production. Sandstone from the Millstone Grit series and the Coal Measures was quarried for use in buildings, walls and as paving stones; however, most quarries are now abandoned. Limestone and dolomite from the Carboniferous Limestone series and the Magnesium Limestone, is used for road-building, manufacture of glass and as a component in agricultural and chemical products. Lead mining around Mansfield reached a peak in the 18$^{th}$ century, when up to 6000 tonnes per year were produced; however, then the mining declined due to economic conditions. Zinc was less important than lead in this area; 40 tonnes per year were produced in 1720, with production reaching a peak in 1781 at 1500 tonnes per year. Silver was mined near Mansfield in small quantities, but was not economic. Other minerals mined or quarried in the area included fluorite, barite, sand, gravel and peat.

From the British Geological Survey Geoscience Data Index[1] it can be seen that Mansfield has many abandoned and active quarries owned by local collieries and aggregate companies. There are also many waste disposal sites around the city and its suburbs (Clipstone, Kirkby and Sutton in Ashfield); many of the sites have the potential to be a risk to groundwater. Opencast coal mines exist to the west of the city centre, north of Sutton in Ashfield and west of Kirkby in Ashfield.

## 2.2 AREA SAMPLED

An area of 42 km$^2$ was surveyed during the summer of 1997, in which a total of 257 surface soil sites and 256 profile soils were sampled (Table 1). This extends from grid references 446000 m east to 460000 m east and from 354000 m north to 366000 m north, and includes the areas of Mansfield, Clipstone, Mansfield Woodhouse, Sutton in Ashfield and Kirkby in Ashfield. The survey area is shown in Figure 2. The shaded urban area represents the boundary between the built up area and open countryside.

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[1] http://www.bgs.ac.uk/geoindex

## 2.3 SOLID AND DRIFT GEOLOGY

Geological information for the Mansfield area was obtained from the BGS memoirs for the area (Smith et al., 1967) and BGS DigmapGB data[2]. The area sampled is underlain by four main rock types. Furthest east in the sampling area is the Jurassic age New Red Sandstone Nottingham Castle Sandstone Formation. The slightly younger Upper Permian age Lenton Sandstone Formation occurs striking in a northeast-southwest direction across the area. Across the middle of the sampling area the Upper Permian Cadeby Formation occurs, this is composed mainly of dolomite, and is part of the Zechstein Group. Between the Cadeby Formation and the Coal Measures, a thin band of Upper Permian mudstone occurs, called the Edlington Formation. To the west of the sampling area, the Carboniferous Middle Coal Measures Formation outcrops; this is Westphalian in age, and is composed of interbedded mud and sandstone. The succession generally increases in age towards the west (younging direction towards the east). The drift and solid geology can be seen on Figure 4 and Figure 5 respectively.

Approximately 10 % of Mansfield is covered by Quaternary deposits; predominantly comprising alluvium, river terrace deposits, Diamicton till and glaciofluvial deposits (mainly sand and gravel). The majority of Quaternary deposits here are by products of river formation, such as river alluvium and river terrace deposits, there are no coastal effects of tidal deposition as appear in other areas, for example, in Kingston-upon-Hull.

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[2] Ew112_chesterfield; Ew113_ollerton. Drift and solid geology.

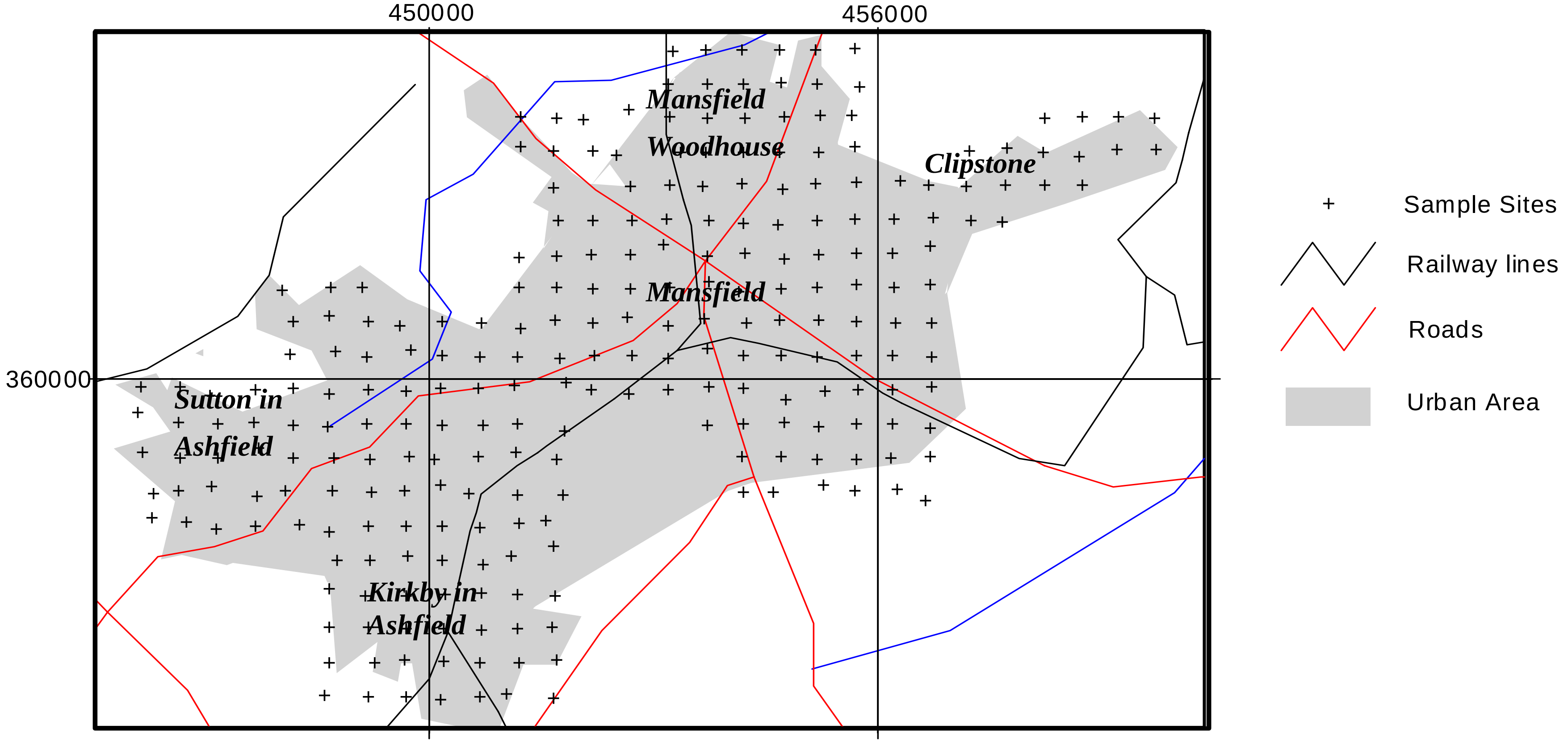


**Figure 2 Map of Mansfield sampling area (Grid squares shown at 6 km intervals)**


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**Figure 3 Topographical map of sampling area (Grid squares shown at 1 km intervals)**

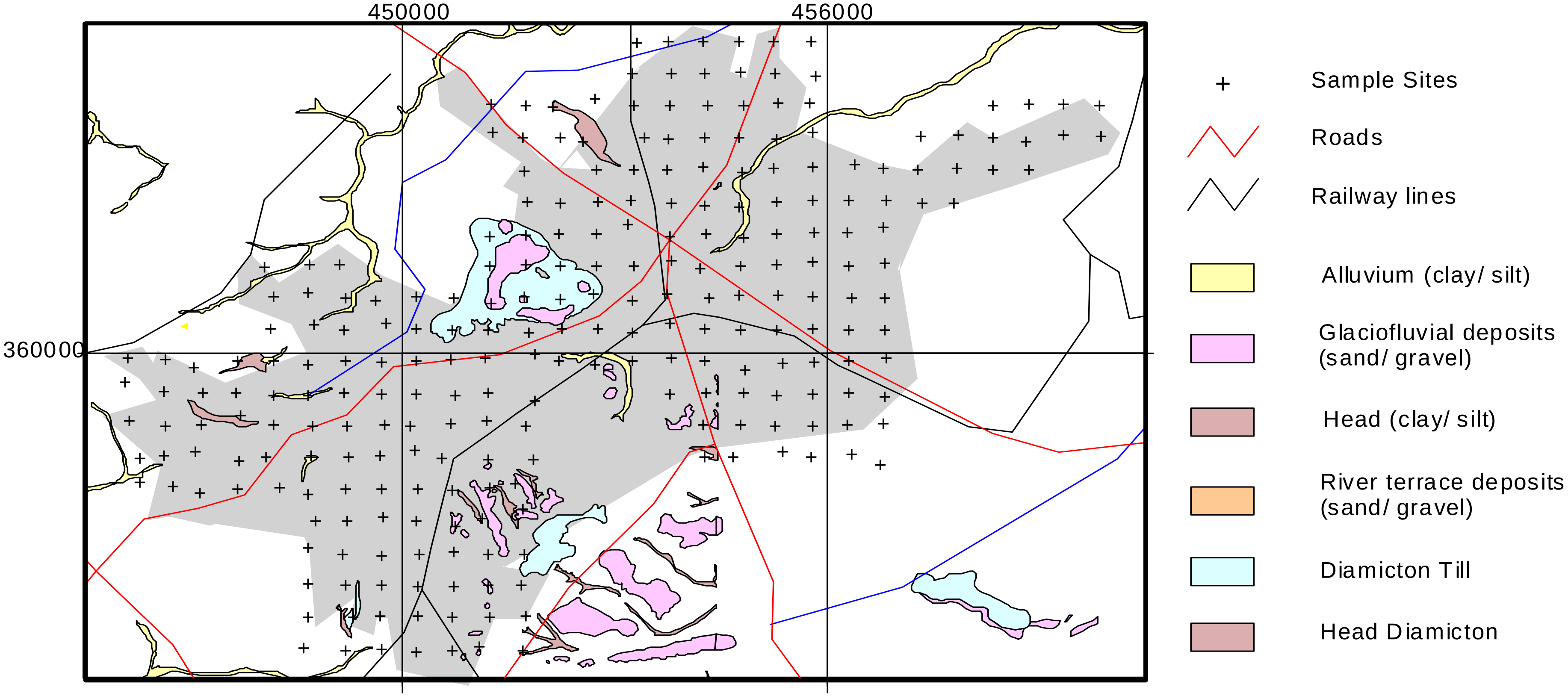


**Figure 4 Drift cover of Mansfield and surrounding area (Grid squares shown at 6 km intervals)**

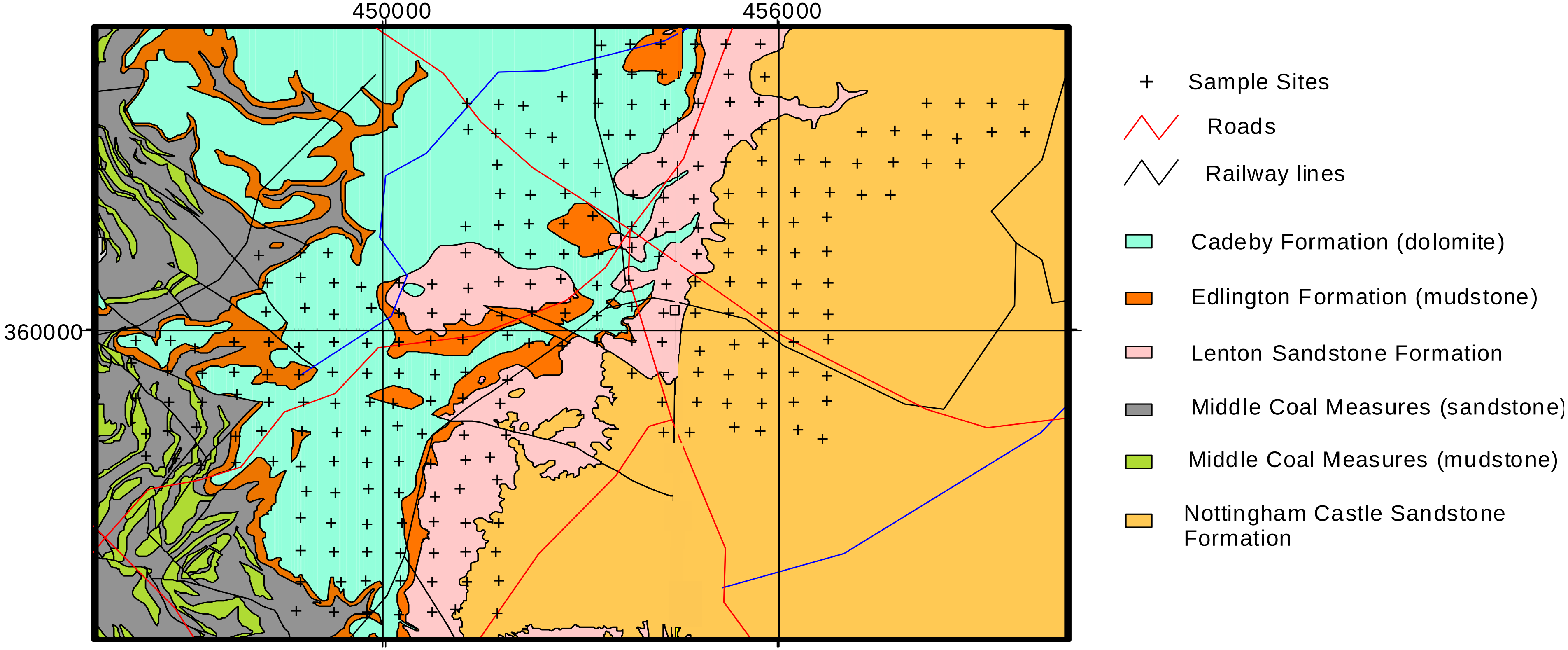


**Figure 5 Underlying solid geology of Mansfield and surrounding area (Grid squares shown at 6 km intervals)**

### 2.4 SOIL TYPE

Urban and industrial areas have not been surveyed for soil type by the Soil Survey and Land Research Centre (formally the Soil Survey of England and Wales). No information therefore exists on soil type for the main city area of Mansfield, although limited data is available for the outskirts of the urban area. This was obtained from a map of the "Soils of the Midlands and Western England" (Soil Survey of England and Wales, 1983).

Basic information for the urban soils of Mansfield is available from the G-BASE field cards (see appendix A), which are filled in "on-site" during sampling. These contain data such as soil colour, texture, sample depth, clasts that are contained in the soil, as well as land use and any physical contamination that is observed. The field codes used were extracted from Harris and Coats (1992).

The area around Clipstone village, to the northeast of Mansfield is characterised by sandy soils grading to coarse loam, belonging to the Brown Earth soil classification. To the north and west of the sampling area Brown Earths are also present; this soil type usually occurs in well-drained areas. Brown Earth soils are also found around the towns of Kirkby and Sutton in Ashfield.

# 3 Methodology

### 3.1 SOIL SAMPLING

Sample sites were arranged on a regular grid pattern at a density of 4 samples per $km^2$. Sample spacing was kept as regular as possible, namely 500 m apart, but was constrained by the actual conditions that were encountered on the ground (such as buildings and other constructions). Soil samples were collected from the closest area of open ground to the allocated sample point. Care was taken to avoid contamination from roads, buildings, fences, pylon lines, etc., an ideal sample being collected at least 50 m from any of these contaminating sources. In urban areas it is often difficult to find sample sites that obey this ideal, but wherever possible samples were taken so as to preserve as near as possible the regular sampling grid.

Soil samples were collected using a Dutch style hand auger with a 3 cm bore. Two samples were collected at different depths at each site. Surface samples were labelled "A" and were collected from a depth of 0-15 cm. They were made up of a three point composite sample based on a 2 x 2 m square. The deeper "profile" samples were labelled "S" and collected at a standard depth of 30-45 cm. These were composed of 3 sub-samples from the same 2 x 2 m square as the "A" sample. Duplicate sampling is described in section 3.3.2.

Information from the field cards are entered onto a database and sample positions recorded onto a stable base and archived. This data is then stored in the corporate geochemical database (Harris and Coats, 1992).

### 3.2 SAMPLE PREPARATION

Samples were dried in an oven at temperatures below 20 ºC and then sieved. Surface soils were sieved to obtain the <2 mm fraction and profile soils to obtain the <150 µm fraction. The sieved material was coned and quartered and a split of the sample was ground using an agate ball mill until 95 % reached a grain size finer than 53 µm. A 12 g split of the ground material was combined with 3 g of elvacite binder and pressed into a pellet for analysis by X-Ray Fluorescence Spectrometry analysis (XRFS) (see section 3.4).

Excess sieved and ground sample material is retained in the National Geoscience Records Centre sample store at the BGS.

## 3.3 ERROR CONTROL PROCEDURES

The accuracy and precision of the geochemical data was monitored using the methods of Plant et al (1975), which are briefly described below.

### 3.3.1 Random numbering of samples

Samples were allocated numbers according to a random numbering system (Plant, 1973), but were analysed in numerical order. This allows any systematic error in either sampling or analytical methodologies to be identified and attributed to the appropriate process. At each site the A and the S samples were assigned unique numbers according to the random number lists. Therefore, within each batch of one hundred samples there were 50 A and 50 S samples.

### 3.3.2 Duplicate and sub-samples

Within each batch of one hundred samples, a pair of sample numbers were assigned to a sampling duplicate, resulting in a duplicate pair for both A and S samples. Duplicate samples were collected using identical sampling methodology adjacent to the original sample. At the sample preparation stage each of the duplicate samples were split to obtain a sub-sample. Each sub-sample was assigned a different number and treated as a separate sample for analytical purposes.

The collection of duplicate samples enables the sampling error, or sampling variation, to be estimated, thus providing a measure of the between-sample variance. Sub-sampling allows the analytical error or variance to be estimated. The variation in the results between original and sub-sample gives an indication of the variation introduced by sample preparation and analysis.

The components of variance were estimated using analysis of variance (ANOVA). This statistical technique is used to determine the residual variance (introduced by sub-sampling, sample preparation and chemical analysis); the between-sample variance (attributed to within-site variation and variability introduced during sample collection); and between-site variance (representing the natural variation in element concentrations across the survey area). All of the analyses form part of a single randomised dataset and a random nested model of ANOVA was therefore used (Snedecor and Cochran, 1989). Due to the relatively low number of duplicate samples collected in a single urban area, the ANOVA calculations were performed using replicate soils collected from 11 different urban centres: Cardiff, Swansea, Stoke, Telford, York, Hull, Doncaster, Mansfield, Scunthorpe, Lincoln and Sheffield (Lister, 2002; Lister, In Prep). A total of 50 replicate sets were measured for urban profile soils, while up to 37 were measured for urban surface soils. All elements except Cd and U (both horizons) and $TiO_2$ (surface soils) were log transformed to produce a distribution approaching the required Gaussian. The ANOVA calculations were performed using the NESTED procedure from the statistical software package, MINITAB™. The results of the ANOVA indicate that for most elements the between-site variability is greater than 80% of the total variance (Table 2). This suggests that geochemical variation is the principal control over element concentrations in urban areas. The between-site variance of cadmium is significantly lower than the other elements, with nearly half the variation in the surface soils attributed to residual factors. This is an indication of analytical error, most likely to result from low overall concentrations with respect to the detection limit.

The ANOVA analysis was not carried out on $Al_2O_3$, CaO, $K_2O$, $P_2O_5$, $SiO_2$ or MgO, as these major elements were not analysed routinely in the urban sampling programme.

### 3.3.3 Standards

G-BASE internal reference standards were analysed within each batch of field samples in order to monitor analytical instrument performance, and to provide continuity of data between different analytical campaigns. Internal standards were assigned unique sample ID's and inserted into each batch of field samples. In the case of Mansfield, G-BASE internal reference standards S13, S15, S24 and S3B were inserted during the analysis of surface (A) and profile (S) soil samples. The concentrations obtained for all elements in each standard are illustrated in Table 3 (the values given for S15 and S3B are mean values, as these standards were measured in duplicate in each analytical run).

The inclusion of G-BASE internal reference standards throughout all G-BASE and GSUE projects maintains data integrity between such projects. Mansfield lies within the Humber-Trent regional atlas area, and it is therefore essential that data for the urban centre of Mansfield is compatible with that of the surrounding regional dataset, which consists of the XRFS analyses of A and S soils from approximately 7000 sample sites (British Geological Survey, In Prep). A number of G-BASE standards were routinely analysed throughout the entire duration of analysis of samples from the Humber-Trent area. Element concentrations determined for standards S13, S15, S24 and S3B during analysis of Mansfield urban samples may be compared with the mean concentrations generated for these standards during analysis of Humber-Trent regional samples (Table 3).

Where values differed significantly, conditioning of the data was carried out. Simple X-Y plots and regression calculations were generated in Excel in order to carry out this task.

**Table 2 Percentage of variance in surface and profile soils attributable to between-site, between sample and residual variance.**

| Surface Soils | Variance | | | | Profile Soils | Variance | | | |
|---|---|---|---|---|---|---|---|---|---|
| Element | Number of Replicate Sets | Between Site (%) | Between Sample (%) | Residual (%) | Element | Number of Replicate Sets | Between Site (%) | Between Sample (%) | Residual (%) |
| Sb | 16 | 88.03 | 1.15 | 10.82 | Sb | 50 | 87.68 | 3.05 | 9.27 |
| As | 37 | 97.69 | 2.02 | 0.29 | As | 50 | 97.87 | 1.82 | 0.31 |
| Ba | 37 | 97.63 | 1.79 | 0.58 | Ba | 50 | 97.39 | 2.56 | 0.05 |
| Cd | 27 | 47.88 | 6.77 | 45.35 | Cd | 50 | 65.44 | 3.95 | 30.61 |
| Cr | 37 | 94.14 | 3.07 | 2.79 | Cr | 50 | 93.46 | 5.55 | 0.99 |
| Co | 37 | 96.35 | 0.00 | 3.65 | Co | 50 | 94.00 | 5.62 | 0.38 |
| Cu | 37 | 97.63 | 1.66 | 0.72 | Cu | 50 | 98.87 | 1.08 | 0.06 |
| $Fe_2O_3$ | 37 | 97.69 | 2.06 | 0.25 | $Fe_2O_3$ | 50 | 96.62 | 3.36 | 0.01 |
| Pb | 27 | 97.48 | 2.23 | 0.29 | Pb | 50 | 96.51 | 3.43 | 0.06 |
| MnO | 37 | 98.28 | 1.39 | 0.33 | MnO | 50 | 96.03 | 3.92 | 0.05 |
| Mo | 33 | 94.24 | 0.71 | 5.05 | Mo | 50 | 93.59 | 3.23 | 3.17 |
| Ni | 37 | 98.06 | 1.59 | 0.34 | Ni | 50 | 95.96 | 3.83 | 0.21 |
| Sn | 36 | 93.45 | 2.91 | 3.63 | Sn | 50 | 95.77 | 2.42 | 1.81 |
| $TiO_2$ | 37 | 96.58 | 2.65 | 0.77 | $TiO_2$ | - | - | - | - |
| U | 37 | 85.95 | 1.24 | 12.81 | U | 47 | 76.92 | 10.99 | 12.09 |
| V | 37 | 97.89 | 1.79 | 0.32 | V | 50 | 97.85 | 2.09 | 0.06 |
| Zn | 37 | 94.77 | 5.16 | 0.07 | Zn | 50 | 92.64 | 7.34 | 0.02 |

**Table 3 Comparison of G-BASE bulk soil standards.**

| Sample Type Standard | Units | Humber-Trent S13 | Mansfield A S13 | Mansfield S S13 | Humber-Trent S15 | Mansfield A S15 | Mansfield S S15 |
|---|---|---|---|---|---|---|---|
| Cd | ppm | <1 | <1 | 1 | <1 | <1 | <1 |
| Sn | ppm | 3 | 3 | 2 | 5 | 4 | 4 |
| Sb | ppm | <1 | <1 | <1 | 1 | <1 | <1 |
| $TiO_2$ | % | 0.817 | 0.882 | 0.896 | 0.392 | 0.434 | 0.445 |
| MnO | % | 0.128 | 0.11 | 0.121 | 0.082 | 0.061 | 0.072 |
| $Fe_2O_3$ | % | 6.88 | 6.91 | 7.12 | 1.90 | 1.92 | 2.02 |
| V | ppm | 97 | 85 | 94 | 35 | 23 | 33 |
| Cr | ppm | 98 | 97 | 97 | 41 | 31 | 39 |
| Co | ppm | 29 | 23 | 23 | 9 | 5 | 6 |
| Ba | ppm | 1704 | 1813 | 1812 | 291 | 380 | 374 |
| Ni | ppm | 36 | 34 | 35 | 12 | 10 | 10 |
| Cu | ppm | 17 | 14 | 15 | 6 | 3 | 3 |
| Zn | ppm | 113 | 111 | 113 | 30 | 28 | 29 |
| As | ppm | 15 | 15 | 15 | 9 | 8 | 9 |
| Mo | ppm | 1.6 | 1.6 | <1 | <1 | 1.1 | <1 |
| Pb | ppm | 109 | 108 | 110 | 24 | 25 | 24 |
| U | ppm | 2.5 | 2.8 | 3.1 | 1.2 | 1.5 | 2.2 |
| $Al_2O_3$ | % | - | 18 | - | - | 6.8 | - |
| CaO | % | 0.35 | 0.34 | - | 0.20 | 0.18 | - |
| $K_2O$ | % | 2.2 | 2.2 | - | 2.3 | 2.2 | - |
| MgO | % | 1.2 | 1.1 | - | 0.6 | 0.6 | - |
| $P_2O_5$ | % | 0.13 | 0.13 | - | 0.09 | 0.10 | - |
| $SiO_2$ | % | - | 56.3 | - | - | 74.15 | - |

| Sample Type Standard | Units | Humber-Trent S24 | Mansfield A S24 | Mansfield S S24 | Humber-Trent S3B | Mansfield A S3B | Mansfield S S3B |
|---|---|---|---|---|---|---|---|
| Cd | ppm | 3 | <1 | 5 | 9 | 9 | 9 |
| Sn | ppm | 6 | 5 | 5 | 2 | <1 | - |
| Sb | ppm | 7.9 | 6.5 | 7 | <1 | <1 | <1 |
| $TiO_2$ | % | 1.122 | 1.225 | 1.259 | 0.727 | 0.782 | 0.831 |
| MnO | % | 0.458 | 0.429 | 0.489 | 3.773 | 3.615 | 4.024 |
| $Fe_2O_3$ | % | 10.22 | 10.23 | 10.51 | 13.45 | 13.51 | 13.6 |
| V | ppm | 140 | 129 | 137 | 76 | 66 | 75 |
| Cr | ppm | 123 | 122 | 126 | 28 | 23 | 27 |
| Co | ppm | 97 | 85 | 84 | 51 | 43 | 43 |
| Ba | ppm | 983 | 1049 | 1029 | 10183 | 9387 | 9788 |
| Ni | ppm | 45 | 44 | 43 | 30 | 28 | 28 |
| Cu | ppm | 64 | 63 | 64 | 47 | 46 | 46 |
| Zn | ppm | 387 | 392 | 397 | 776 | 779 | 794 |
| As | ppm | 124 | 127 | 128 | <1 | <1 | <1 |
| Mo | ppm | 1.9 | 1.8 | <1 | 145.8 | 145.9 | 147.4 |
| Pb | ppm | 1070 | 1011 | 1040 | 2075 | 1859 | 1913 |
| U | ppm | 1.7 | 1.8 | 2.1 | 84.1 | 81.7 | 81.4 |
| $Al_2O_3$ | % | - | 23.1 | - | - | 10.4 | - |
| CaO | % | 0.32 | 0.32 | - | 1.21 | 1.19 | - |
| $K_2O$ | % | 3.40 | 3.44 | - | 2.74 | 2.79 | - |
| MgO | % | 1.1 | 1 | - | 0.5 | 0.5 | - |
| $P_2O_5$ | % | 0.18 | 0.19 | - | 0.19 | 0.19 | - |
| $SiO_2$ | % | - | 45.5 | - | - | 39.4 | - |

## 3.4 ANALYTICAL PROCEDURES

All samples were analysed at the BGS laboratories for a range of elements by Wavelength Dispersive X-ray Fluorescence Spectrometry (Ingham and Vrebos, 1994). Three sequential XRF spectrometers were used. A Philips PW1480 fitted with a 216 position sample changer and a 3 kW/ 100 kV tungsten anode X-ray tube was used to determine Cd, Sn and Sb. Two Philips PW2400 spectrometers fitted with 102 position sample changers and with 3 kW/ 60 kV rhodium anode x-ray tubes were used to determine $Al_2O_3$, CaO, $K_2O$, MgO, $P_2O_5$, $SiO_2$, $TiO_2$, MnO, $Fe_2O_3$, V, Cr, Co, and Ba in one suite and Ni, Cu, Zn, As, Mo, Pb, and U in another. The results for trace elements are reported in parts per million (ppm). One part per million is equivalent to one microgram per gram (µg/g or µg $g^{-1}$) or one milligram per kilogram (mg/kg or mg $kg^{-1}$). Major elements are reported as weight percent of the element in its oxide form (WT % oxide).

The elements determined and the lower limits of detection (LLD) and upper and lower reporting limits (URL and LLR) for each analyte are shown in Table 4.

The quoted LLDs are theoretical values for the concentration equivalent to three standard deviations above the background count rate for the analyte in a pure silica matrix. High instrumental stability results in practical values for these materials approaching the theoretical.

**Table 4 Lower limits of detection (LLD) and upper reporting limit (URL) values for XRFS analysis of G-BASE urban soil samples, Humber-Trent region**

| Analyte | LLD (ppm) | LLD (%) | URL (ppm) | URL (%) |
|---|---|---|---|---|
| $TiO_2$ | - | 0.01 | - | 100.0 |
| MnO | - | 0.01 | - | 10.0 |
| $Fe_2O_3$ | - | 0.01 | - | 100.0 |
| V | 2.4 | - | 20000 | - |
| Cr | 3 | - | 250000 | - |
| Co | 1.9 | - | 10000 | - |
| Ni | 0.9 | - | 4000 | - |
| Cu | 0.9 | - | 6500 | - |
| Zn | 1 | - | 10000 | - |
| As | 0.9 | - | 10000 | - |
| Mo | 0.3 | - | 1000 | - |
| Cd | 0.9 | - | 500 | - |
| Sn | 1.1 | - | 10000 | - |
| Sb | 1.2 | - | 10000 | - |
| Ba | 2.9 | - | 600000 | - |
| Pb | 1.2 | - | 10000 | - |
| U | 0.5 | - | 650 | - |
| $Al_2O_3^*$ | - | 0.1 | - | 100.0 |
| $CaO^*$ | - | 0.05 | - | 60.0 |
| $K_2O^*$ | - | 0.05 | - | 15.0 |
| $MgO^*$ | - | 0.1 | - | 50.0 |
| $P_2O_5^*$ | - | 0.05 | - | 1.5 |
| $SiO_2^*$ | - | 0.1 | - | 100.0 |

* A horizon only.

## 3.5 DATA INTERPRETATION

Once full error control and data quality procedures were completed, the Mansfield geochemical and location data were loaded into Arcview© GIS software package. Proportional symbol geochemical maps for surface and profile soils were then generated (see Appendix C).

# 4 Geochemical Interpretation

A total of 23 major and trace elements were measured in the surface soils collected in Mansfield; aluminium (expressed as $Al_2O_3$), antimony (Sb), arsenic (As), barium (Ba), cadmium (Cd), calcium (expressed as CaO), chromium (Cr), cobalt (Co), copper (Cu), iron (expressed as $Fe_2O_3$), lead (Pb), magnesium (expressed as MgO), manganese (expressed as MnO), molybdenum (Mo), nickel (Ni), phosphorous (expressed as $P_2O_5$), potassium (expressed as $K_2O$), silicon (expressed as $SiO_2$), tin (Sn), titanium (expressed as $TiO_2$), uranium (U), vanadium (V) and zinc (Zn). All elements except $Al_2O_3$, CaO, MgO, $P_2O_5$, $K_2O$ and $SiO_2$ were additionally measured in the profile soils.

## 4.1 BACKGROUND LEVELS

In order to aid the interpretation of the geochemical data for Mansfield it is useful to be aware of typical background soil concentrations in order to put the results from Mansfield into context. The median elemental concentrations for 6561 surface soil samples from the Humber-Trent region are shown in Table 5. The median elemental concentrations for 6877 profile soil samples from the Humber-Trent region are shown in Table 6; these data can be used to give an indication of the typical magnitude of the elemental concentrations throughout the region as a whole (British Geological Survey, In Prep).

**Table 5 Comparison of median concentrations in regional surface soil samples, Humber-Trent atlas area and in Mansfield surface soil samples**

| Analyte | Units | Regional | Mansfield |
|---|---|---|---|
| $Al_2O_3$ | wt% | 11.5 | 8.4 |
| As | ppm | 13 | 11 |
| Ba | ppm | 376 | 344 |
| CaO | wt% | 2.12 | 1.17 |
| Cd | ppm | 1 | 1 |
| Co | ppm | 19 | 14 |
| Cr | ppm | 71 | 54 |
| Cu | ppm | 18 | 24 |
| $Fe_2O_3$ | wt% | 4.66 | 3.12 |
| $K_2O$ | wt% | - | 1.8 |
| MgO | wt% | 1.1 | 1 |
| MnO | wt% | 0.080 | 0.099 |
| Mo | ppm | 2.2 | 1.6 |
| Ni | ppm | 22 | 16 |
| Pb | ppm | 43 | 76 |
| $P_2O_5$ | wt% | 0.29 | 0.27 |
| Sb | ppm | 0.5 | 2 |
| $SiO_2$ | wt% | - | 63.1 |
| Sn | ppm | 4 | 6 |
| $TiO_2$ | wt% | 0.680 | 0.457 |
| U | ppm | 2.1 | 1.3 |
| V | ppm | 83 | 57 |
| Zn | ppm | 72 | 112 |

**Table 6 Comparison of median concentrations in regional profile soil samples, Humber-Trent atlas area and in Mansfield profile soil samples**

| Analyte | Units | Regional | Mansfield |
|---|---|---|---|
| $Al_2O_3$ | wt% | - | - |
| As | ppm | 12 | 13 |
| Ba | ppm | 388 | 379 |
| CaO | wt% | 2.89 | - |
| Cd | ppm | 0.35 | 1 |
| Co | ppm | 21 | 18 |
| Cr | ppm | 83 | 66 |
| Cu | ppm | 20 | 25 |
| $Fe_2O_3$ | wt% | 5.04 | 4.06 |
| $K_2O$ | wt% | 1.98 | - |
| MgO | wt% | 1.3 | - |
| MnO | wt% | 0.104 | 0.128 |
| Mo | ppm | 1.8 | 1.2 |
| Ni | ppm | 27 | 21 |
| Pb | ppm | 38 | 73 |
| $P_2O_5$ | wt% | 0.25 | - |
| Sb | ppm | 3 | 2 |
| $SiO_2$ | wt% | - | - |
| Sn | ppm | 4 | 7 |
| $TiO_2$ | wt% | 0.735 | 0.590 |
| U | ppm | 2.5 | 1.9 |
| V | ppm | 88 | 63 |
| Zn | ppm | 77 | 109 |

## 4.2 KEY GEOCHEMICAL CHARACTERISTICS OF THE MANSFIELD DATASET

The majority of analytes are found in higher concentrations in the profile soils than in the surface soils. This could be due to the fact that during sample preparation the two horizons are sieved to a different size fraction. The surface soils are sieved to <2 mm whilst the profile soils are sieved to <150 µm. This means that the sieved profile soil has a much larger surface area and will contain more clay particles. Clay minerals possess the ability to attract and bind heavy metal ions (Brady and Weil, 1999).

There may also be other explanations why the profile soils show elevated levels of heavy metals. For example, in areas of contamination fresh topsoil could have been brought in for a remediation exercise, resulting in the contaminated soil being buried. Certain soil properties such as pH and redox potential (Eh) can affect the mobility of potentially toxic elements, such as As and Cd. Under appropriate conditions, elements can dissolve into solution and leach downwards, taking elements from the upper A horizon soil and re-precipitating them into the deeper B horizon, or into groundwater in the underlying strata. Leaching may also reach surface waters, i.e. rivers.

In the surface soils, Cu, Pb, Sb, Sn, and Zn have median values that are above the median elemental values for the Humber-Trent Atlas area (by 6 ppm, 33 ppm, 1.5 ppm, 2 ppm and 40 ppm, respectively). In the profile soils, As, Cu, Pb, Sn and Zn have median values that are above the median elemental values for the Humber-Trent Atlas area (by 1 ppm, 5 ppm, 35 ppm, 3 ppm and 32 ppm, respectively). This would suggest that these elements are potential contaminants in the soils around Mansfield.

The results for selected elements from surface soils in Mansfield are presented in Figure 6 in the context of six other urban areas from the Humber-Trent region (Doncaster, Hull, Lincoln, Scunthorpe, Sheffield and York) and the results from the regional survey for the Humber-Trent region. Eight elements that may be affected by anthropogenic contamination in urban areas (As, Cd, Cu, Pb, Mo, Sn, Sb and Zn) were selected, while $TiO_2$ was included to represent the closest approximation to a conservative element, unaffected by contamination.

While concentrations of $TiO_2$ are normally distributed in each urban area and fall within the range in concentration found on the regional scale, the levels of the other selected elements are in general positively skewed (indicated by a mean value significantly exceeding the median) and are higher than the regional values. This may reflect the influence of anthropogenic contamination, elevating the concentrations of certain elements above the typical regional levels and generating anomalously high values, which create skewed distributions. In the case of Mo, however, this pattern is only observed in Sheffield.

The main controls over variation in concentrations between different urban areas include population and past and present industrial activities. Recent work carried out by the British Geological Survey (Rawlins et al., 2003) has also identified the importance of parent material type in determining the geochemical composition of soils. This work is, however, largely outside the scope of this report.

Soil Guideline Values (SGV) produced by the Contaminated Land Exposure Assessment (CLEA) model (Department of the Environment Food and Rural Affairs and the Environment Agency, 2002a, Department of the Environment Food and Rural Affairs and the Environment Agency, 2002b) for residential areas with plant uptake are shown on Figure 6 for Cd and As. From the 75$^{th}$ percentile, Cadmium concentrations in Mansfield are above the SGV value for soils with a pH of 6, but are largely below the level given for pH 7 soils. The levels are comparable with Sheffield and York, but are higher than the remaining four urban areas, which are very low in Cd. Levels of As in Mansfield are generally below the 20 ppm SGV for residential areas and are slightly lower than the levels found in the regional Humber-Trent data for surface soils. This suggests that As is derived largely from natural sources in Mansfield soils. It is also possible, however, that the average regional levels are lower over the parent materials that underlie Mansfield, than over the Humber-Trent region as a whole. Areas in which soil concentrations exceed 20 ppm may be of concern to human health, although, it should be noted that the regional levels indicate high levels of background As in the Humber-Trent region.

According to Figure 6, the main contaminants in Mansfield soils appear to be Pb, Cd and Zn; however, concentrations of the selected elements are not generally high in relation to other urban areas in the Humber-Trent region.

There is a strong association between soil geochemistry and underlying geology in Mansfield (Figure 5). Well-defined changes in the concentrations of many elements coincide with the dolomite Cadeby Formation to the west of the area (Kirkby in Ashfield and Sutton in Ashfield), the sandstone of the Lenton Formation through the centre (including part of Mansfield city centre) and the Nottingham Castle Sandstone Formation to the east of the area (including Clipstone). For example, the major element silicon is found in higher concentrations in soils to the centre and east of the area, reflecting the high content of this element in the composition of sandstones.

### 4.2.1 Kirkby in Ashfield and Sutton in Ashfield.

Smelting factories for Fe ore were located to the west and southwest of the city centre, around the towns of Kirkby in Ashfield and Sutton in Ashfield. These areas show high levels of Fe, and other major elements such as Mg, Mn, Ti and Al. The factories also left a legacy of a great many spoil tips. As a result many of the analytes that are associated with metal smelting such as Mo, Pb and As, also show anomalies running along this area.

Coal mining also played a substantial part in the industry of Mansfield, over to the west and southwest of the city centre. Many trace metals, such as Ni, Cu and Pb, occur at naturally elevated levels in the Coal Measures, which could explain their elevated levels in soils. The combustion products of coal and other fossil fuels have more trace metals (e.g. Sn, Cr, Co) associated with them and therefore could also contribute to the high level through atmospheric deposition (Alloway, 1995).

### 4.2.2 Clipstone

To the East of the city centre lies the village of Clipstone; here the underlying geology is dominated by sandstone. All major elements except $K_2O$ and $SiO_2$ are relatively very low in concentration in surface soils overlying the Nottingham Castle Sandstone Formation, as are the majority of the trace elements analysed. In the profile soils, however, the relative trace element concentrations are generally higher. In particular, Sn appears to be enriched in the profile soils of this area and depleted in the surface soils. As the profile soils are sieved to a finer fraction than the surface soils, this suggests that most elements are bound to the clay fraction. The low concentrations observed in the surface soils are likely to reflect a high sand content in these soils (derived from the underlying parent material). These particles may be deficient in a number of chemical elements as a result of low concentrations in the parent material and a weak ability to bind heavy metal ions.

### 4.2.3 Mansfield City Centre.

High levels of elements such as Cu, Pb, Sn and Zn are concentrated around the city centre. These enrichments are likely to be anthropogenic signatures, related to the concentrated transport networks in this area, as well as from industry and the high human population density. Prior to 2000, tetra-ethyl Pb was added to petrol as an anti-knocking agent and was widely released in vehicle emissions. Other heavy elements are present as impurities in petroleum products and may be released through combustion. Historically, iron ore and coal were transported by railway through Mansfield, leading to spillage when loading and offloading the cargo. This may have left an additional legacy of contamination.

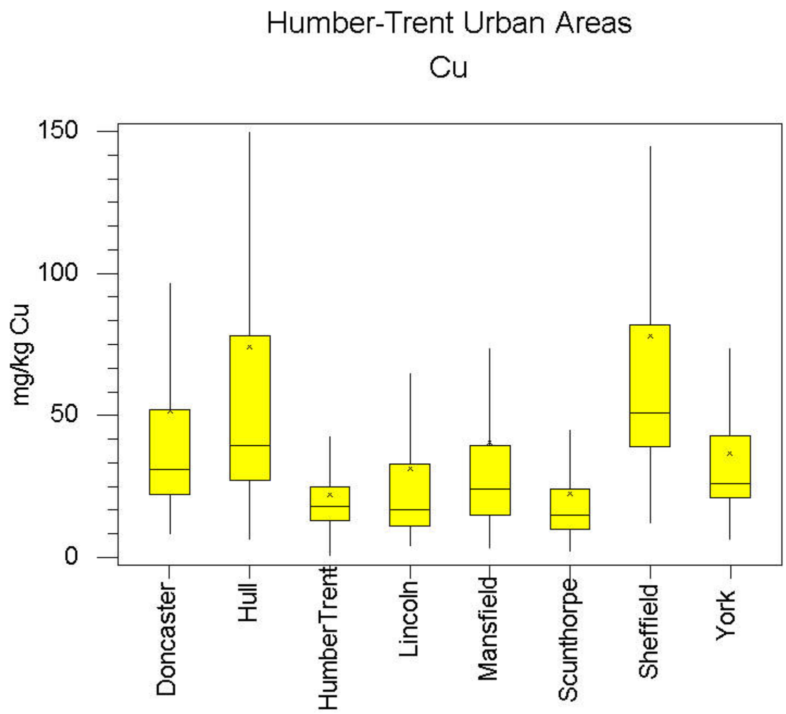


Figure 6: (a) Copper in surface soil

**Figure 1 (*(a) - (i)*). Box and Whisker Plots for selected elements in surface soils from six urban areas in the Humber-Trent region presented with the regional Humber-Trent data. Soil Guideline Values (SGVs) for soils in residential areas involving plant uptake (derived using the CLEA model) are shown in red for As and Cd. Note that for Pb (450 mg/kg) and Cd (pH = 8, 8 mg/kg) SGV values are outside plot area (boxes show inter-quartile range, median is a straight line and the mean value a cross)**

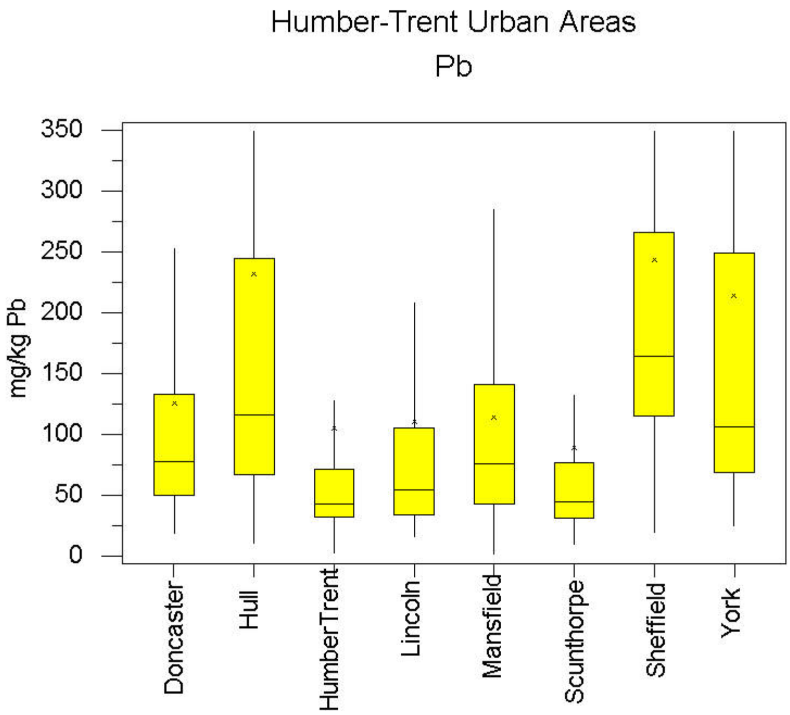


Figure 6: (b) Lead in surface soil

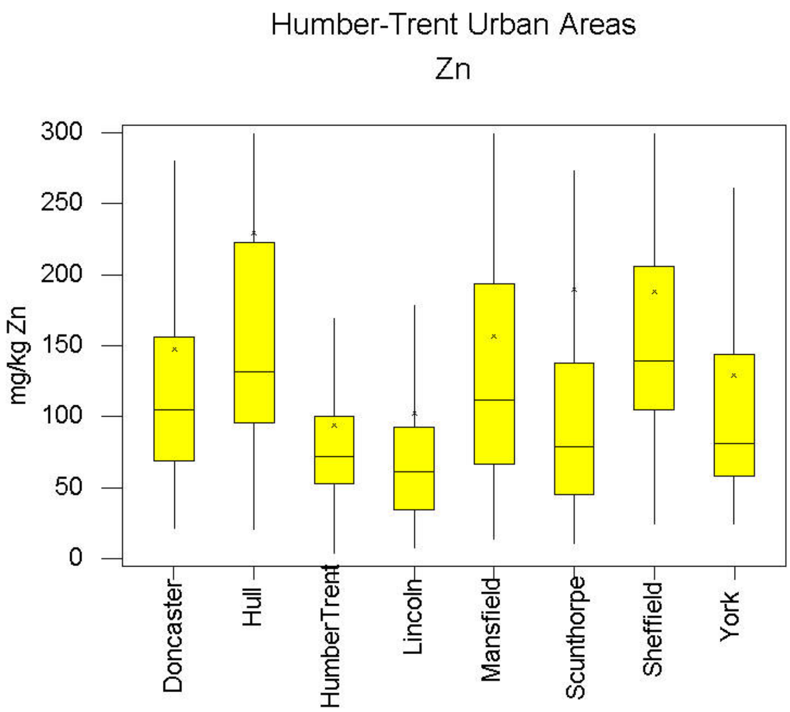


Figure 6: (c) Zinc in surface soil

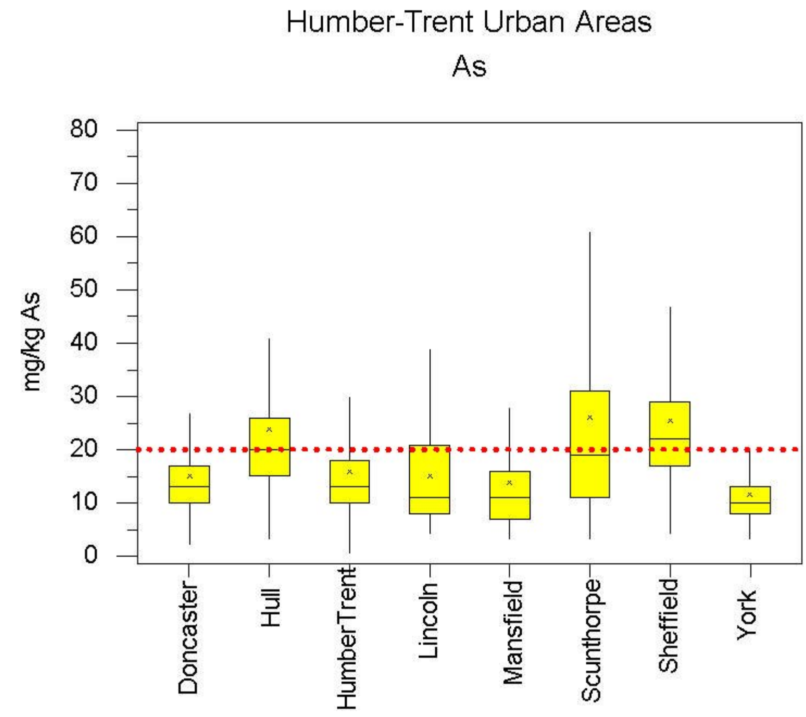


Figure 6: (d) Arsenic in surface soil

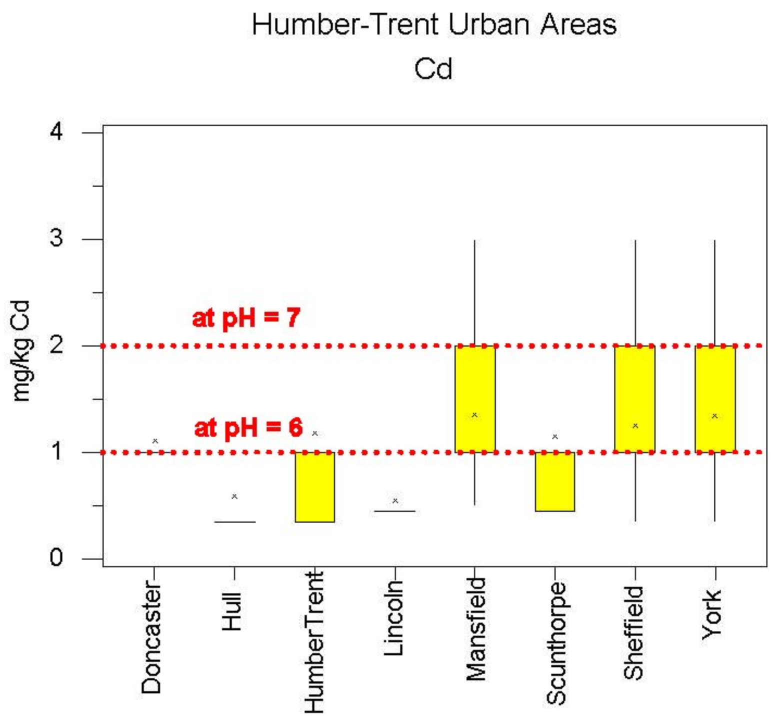


Figure 6: (e) Cadmium in surface soil

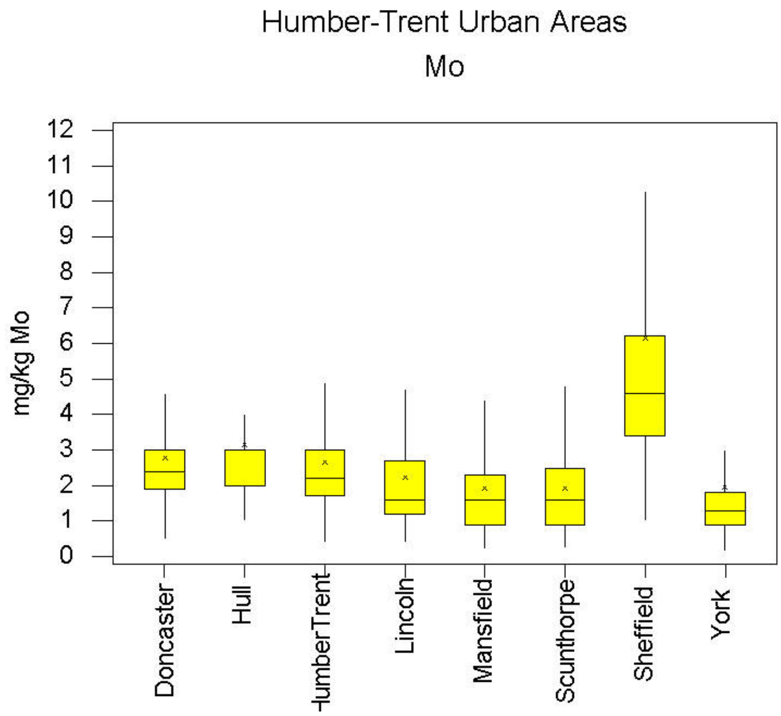


Figure 6: (f) Molybdenum in surface soil

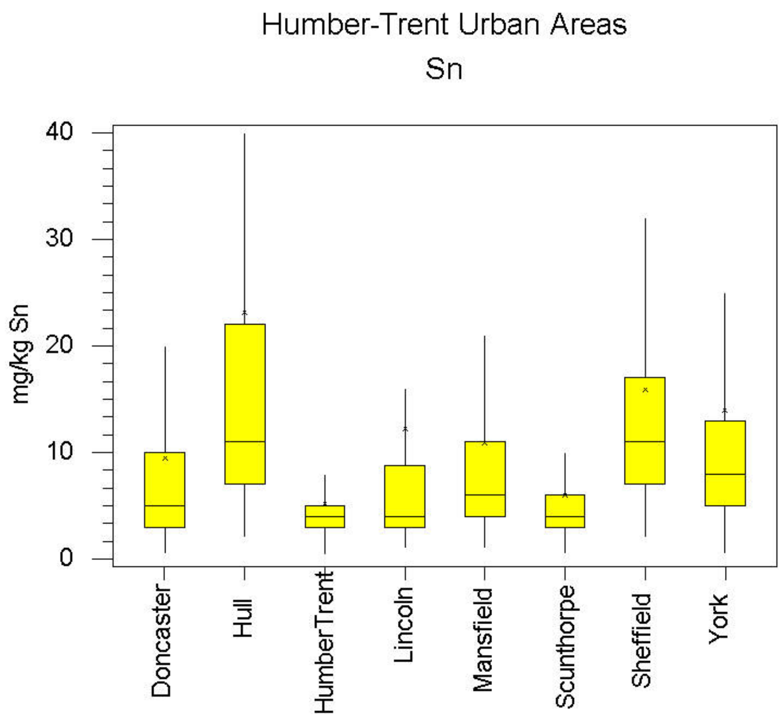


Figure 6: (g) Tin in surface soil

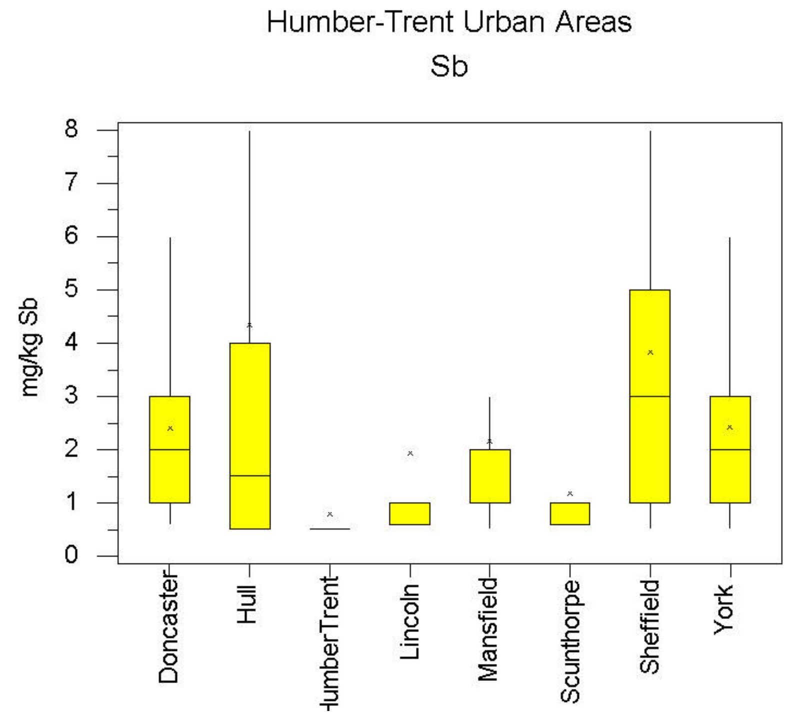


Figure 6: (h) Antimony in surface soil

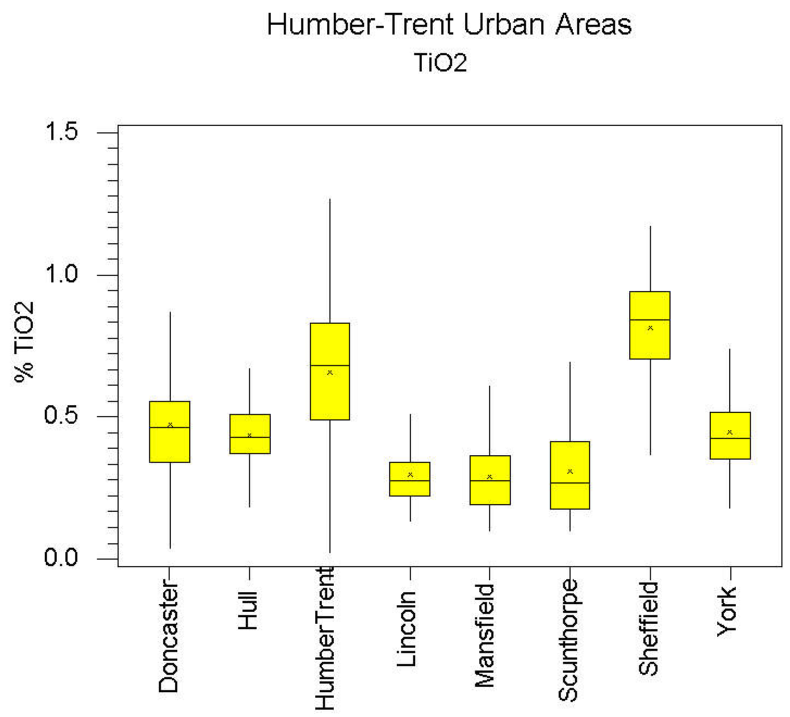


Figure 6: (i) Titanium oxide in surface soil

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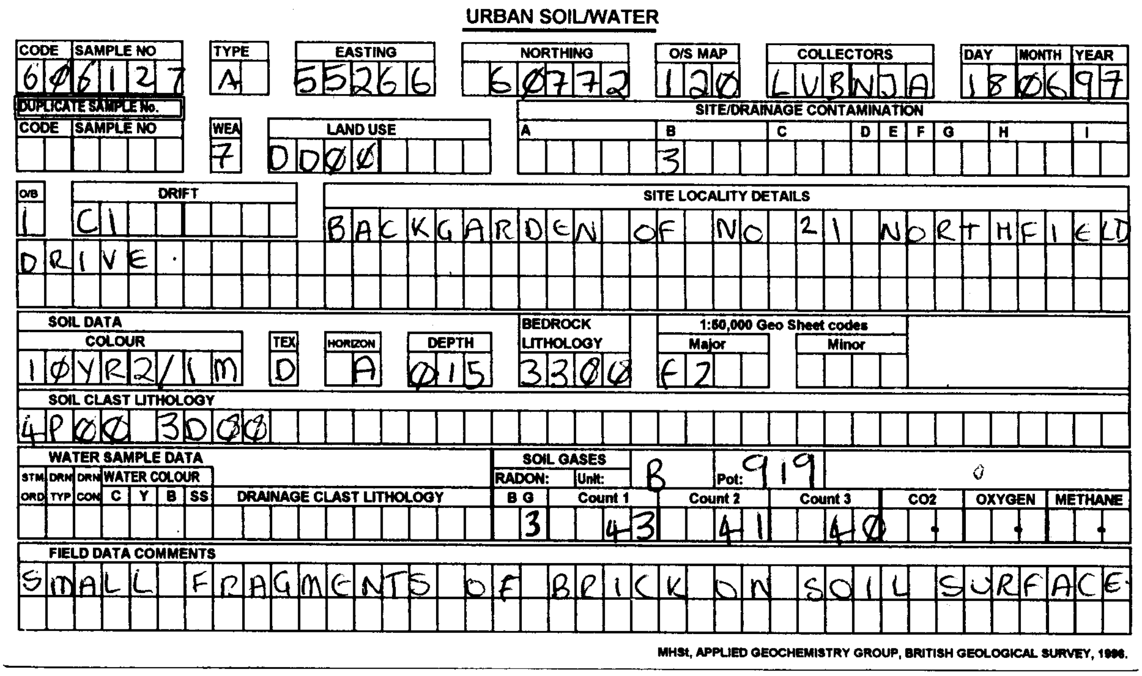
# Appendix A: Examples of urban surface and profile field cards from Mansfield.



URBAN SOIL/WATER

CODE / SAMPLE NO: 6Ø6127 | TYPE: A | EASTING: 55266 | NORTHING: 6Ø772 | O/S MAP: 12Ø | COLLECTORS: LVBNJA | DAY: 18 | MONTH: Ø6 | YEAR: 97

DUPLICATE SAMPLE No. CODE / SAMPLE NO: | WEA: 7 | LAND USE: DDØØ | SITE/DRAINAGE CONTAMINATION: A | B 3 | C | D | E | F | G | H | I

O/B: 1 | DRIFT: C1 | SITE LOCALITY DETAILS: BACKGARDEN OF NO 21 NORTHFIELD DRIVE.

SOIL DATA — COLOUR: 1ØYR2/1M | TEX: D | HORIZON: A | DEPTH: Ø15 | BEDROCK LITHOLOGY: 33ØØ | 1:50,000 Geo Sheet codes Major: F2 | Minor:

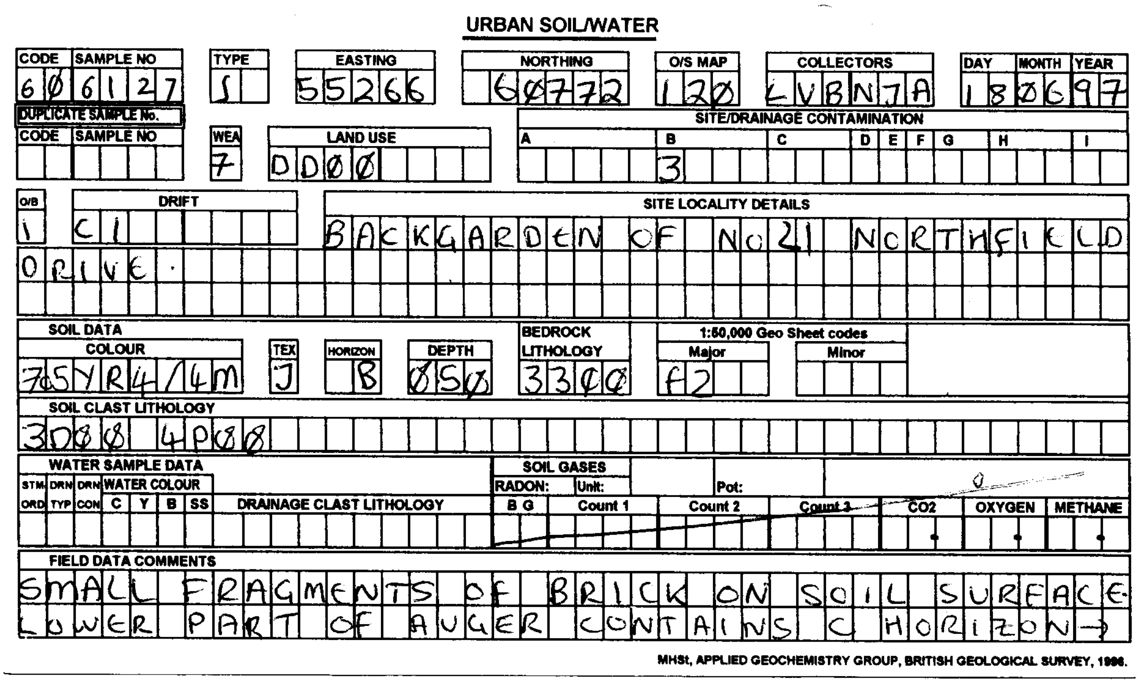
SOIL CLAST LITHOLOGY: 4PØØ 3ØØØ

WATER SAMPLE DATA — STM ORD | DRN TYP | DRN CON | WATER COLOUR C Y B SS | DRAINAGE CLAST LITHOLOGY

SOIL GASES — RADON: Unit: B | Pot: 919 | B G: 3 | Count 1: 43 | Count 2: 41 | Count 3: 4Ø | CO2 | OXYGEN | METHANE

FIELD DATA COMMENTS: SMALL FRAGMENTS OF BRICK ON SOIL SURFACE

MHSt, APPLIED GEOCHEMISTRY GROUP, BRITISH GEOLOGICAL SURVEY, 1996.



URBAN SOIL/WATER

CODE / SAMPLE NO: 6Ø6127 | TYPE: S | EASTING: 55266 | NORTHING: 6Ø772 | O/S MAP: 12Ø | COLLECTORS: LVBNJA | DAY: 18 | MONTH: Ø6 | YEAR: 97

DUPLICATE SAMPLE No. CODE / SAMPLE NO: | WEA: 7 | LAND USE: DDØØ | SITE/DRAINAGE CONTAMINATION: A | B 3 | C | D | E | F | G | H | I

O/B: 1 | DRIFT: C1 | SITE LOCALITY DETAILS: BACKGARDEN OF NO 21 NORTHFIELD DRIVE.

SOIL DATA — COLOUR: 75YR4/4M | TEX: J | HORIZON: B | DEPTH: Ø5Ø | BEDROCK LITHOLOGY: 33ØØ | 1:50,000 Geo Sheet codes Major: F2 | Minor:

SOIL CLAST LITHOLOGY: 3ØØØ 4PØØ

WATER SAMPLE DATA — STM ORD | DRN TYP | DRN CON | WATER COLOUR C Y B SS | DRAINAGE CLAST LITHOLOGY

SOIL GASES — RADON: Unit: | Pot: | B G | Count 1 | Count 2 | Count 3 | CO2 | OXYGEN | METHANE

FIELD DATA COMMENTS: SMALL FRAGMENTS OF BRICK ON SOIL SURFACE
LOWER PART OF AUGER CONTAINS C HORIZON →

MHSt, APPLIED GEOCHEMISTRY GROUP, BRITISH GEOLOGICAL SURVEY, 1996.

# Appendix B: Percentile calculations for Mansfield soil

| percentiles | $Al_2O_3$ | CaO | Cr | Cr | $K_2O$ | Mo* | Mo* | Pb | Pb | $TiO_2$ | $TiO_2$ | Zn | Zn | As | As | Cd* | Cd* | Cu | Cu | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WT % | WT % | ppm | ppm | WT % | ppm | ppm | ppm | ppm | WT % | WT % | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | |
| 5% | 5.9 | 0.17 | 27 | 40 | 1.3 | 0.5 | 0.15 | 19 | 21 | 0.209 | 0.399 | 31 | 43 | 5 | 7 | 0.35 | 0.35 | 6 | 10 | |
| 10% | 6.3 | 0.26 | 30 | 45 | 1.4 | 0.7 | 0.4 | 25 | 28 | 0.244 | 0.430 | 40 | 52 | 6 | 9 | 0.35 | 0.35 | 8 | 12 | |
| 15% | 6.5 | 0.33 | 31 | 48 | 1.5 | 0.8 | 0.5 | 33 | 33 | 0.269 | 0.448 | 46 | 56 | 6 | 9 | 1 | 0.35 | 10 | 13 | |
| 25% | 7.0 | 0.47 | 37 | 54 | 1.6 | 0.9 | 0.8 | 43 | 45 | 0.321 | 0.503 | 69 | 71 | 7 | 11 | 1 | 0.35 | 15 | 17 | |
| 50% | 8.4 | 1.17 | 54 | 66 | 1.8 | 1.6 | 1.2 | 76 | 73 | 0.457 | 0.590 | 112 | 109 | 11 | 13 | 1 | 1 | 24 | 25 | |
| 75% | 10.2 | 3.05 | 74 | 81 | 2.1 | 2.3 | 1.8 | 141 | 135 | 0.606 | 0.698 | 194 | 170 | 16 | 18 | 2 | 1 | 39 | 43 | |
| 90% | 12.3 | 5.45 | 90 | 97 | 2.3 | 3.4 | 2.45 | 249 | 251 | 0.770 | 0.820 | 309 | 323 | 25 | 29 | 2 | 2 | 67 | 96 | |
| 95% | 14.2 | 7.36 | 103 | 112 | 2.4 | 4.3 | 3.63 | 322 | 348 | 0.906 | 0.867 | 454 | 449 | 36 | 45 | 3 | 3 | 95 | 151 | |
| 99% | 16.5 | 10.14 | 140 | 177 | 2.6 | 8.5 | 15.19 | 521 | 684 | 1.002 | 0.953 | 739 | 919 | 61 | 70 | 6 | 6.8 | 212 | 328 | |
| Max | 20.2 | 14.35 | 250 | 397 | 3.5 | 14.0 | 25.3 | 1319 | 1500 | 1.116 | 1.045 | 1153 | 4126 | 71 | 212 | 9 | 34 | 1731 | 595 | |
| Min | 4.1 | 0.03 | 18 | 33 | 1.1 | 0.15 | 0.15 | 1 | 11 | 0.158 | 0.244 | 13 | 22 | 3 | 6 | 0.35 | 0.35 | 3 | 5 | |
| Mean | 8.9 | 2.17 | 59 | 71 | 1.8 | 1.9 | 1.71 | 114 | 119 | 0.484 | 0.605 | 157 | 172 | 14 | 17 | 1.34 | 1.21 | 41 | 45 | |
| Median | 8.4 | 1.17 | 54 | 66 | 1.8 | 1.6 | 1.2 | 76 | 73 | 0.457 | 0.590 | 112 | 109 | 11 | 13 | 1 | 1 | 24 | 25 | |

| | MgO | Ni | Ni | Sb* | Sb* | U* | U* | Ba | Ba | Co | Co | $Fe_2O_3$ | $Fe_2O_3$ | MnO | MnO | $P_2O_5$ | Sn | Sn | V | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WT % | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | WT % | WT % | WT % | WT % | WT % | ppm | ppm | ppm | ppm |
| 5% | 0.3 | 5 | 9 | 0.5 | 0.5 | 0.5 | 1.0 | 229 | 221 | 5 | 10 | 1.38 | 2.45 | 0.038 | 0.047 | 0.12 | 3 | 2 | 31 | 41 |
| 10% | 0.4 | 7 | 11 | 0.5 | 1 | 0.6 | 1.1 | 261 | 251 | 7 | 12 | 1.50 | 2.74 | 0.046 | 0.057 | 0.16 | 3 | 3 | 33 | 45 |
| 15% | 0.4 | 7 | 13 | 1 | 1 | 0.7 | 1.2 | 277 | 278 | 8 | 12 | 1.66 | 2.95 | 0.052 | 0.063 | 0.18 | 3 | 3 | 36 | 48 |
| 25% | 0.5 | 9 | 16 | 1 | 1 | 0.9 | 1.4 | 303 | 304 | 9 | 15 | 2.05 | 3.29 | 0.062 | 0.078 | 0.20 | 4 | 4 | 42 | 52 |
| 50% | 1.0 | 16 | 21 | 2 | 2 | 1.3 | 1.9 | 344 | 379 | 14 | 18 | 3.12 | 4.06 | 0.099 | 0.128 | 0.27 | 6 | 7 | 57 | 63 |
| 75% | 1.7 | 25 | 28 | 2 | 3 | 1.8 | 2.33 | 464 | 518 | 23 | 25 | 4.68 | 5.08 | 0.208 | 0.224 | 0.37 | 11 | 11 | 74 | 75 |
| 90% | 2.6 | 34 | 39 | 4 | 4 | 2.6 | 2.8 | 742 | 786 | 29 | 29 | 5.76 | 6.18 | 0.303 | 0.328 | 0.54 | 22 | 23 | 99 | 102 |
| 95% | 3.4 | 39 | 53 | 6 | 7 | 3.0 | 3.43 | 983 | 1029 | 32 | 35 | 6.80 | 7.22 | 0.352 | 0.403 | 0.67 | 35 | 35 | 111 | 126 |
| 99% | 5.2 | 54 | 144 | 10.4 | 34.4 | 4.1 | 4.85 | 2082 | 2877 | 49 | 59 | 8.34 | 12.88 | 0.491 | 0.534 | 0.91 | 62 | 84 | 149 | 175 |
| Max | 7.0 | 102 | 564 | 35 | 79 | 4.7 | 5.5 | 4303 | 9549 | 58 | 95 | 15.11 | 17.56 | 0.642 | 1.261 | 1.21 | 209 | 536 | 257 | 264 |
| Min | 0.1 | 4 | 5 | 0.5 | 0.5 | 0.25 | 0.25 | 146 | 125 | 3 | 8 | 0.77 | 1.85 | 0.022 | 0.026 | 0.05 | 1 | 1 | 24 | 33 |
| Mean | 1.3 | 19 | 27 | 2.2 | 3.2 | 1.48 | 1.95 | 461 | 525 | 16 | 21 | 3.52 | 4.42 | 0.144 | 0.168 | 0.32 | 11 | 13 | 62 | 70 |
| Median | 1.0 | 16 | 21 | 2 | 2 | 1.3 | 1.9 | 344 | 379 | 14 | 18 | 3.12 | 4.06 | 0.099 | 0.128 | 0.27 | 6 | 7 | 57 | 63 |

Surface soils in yellow. *Minimum value reported as half detection limit

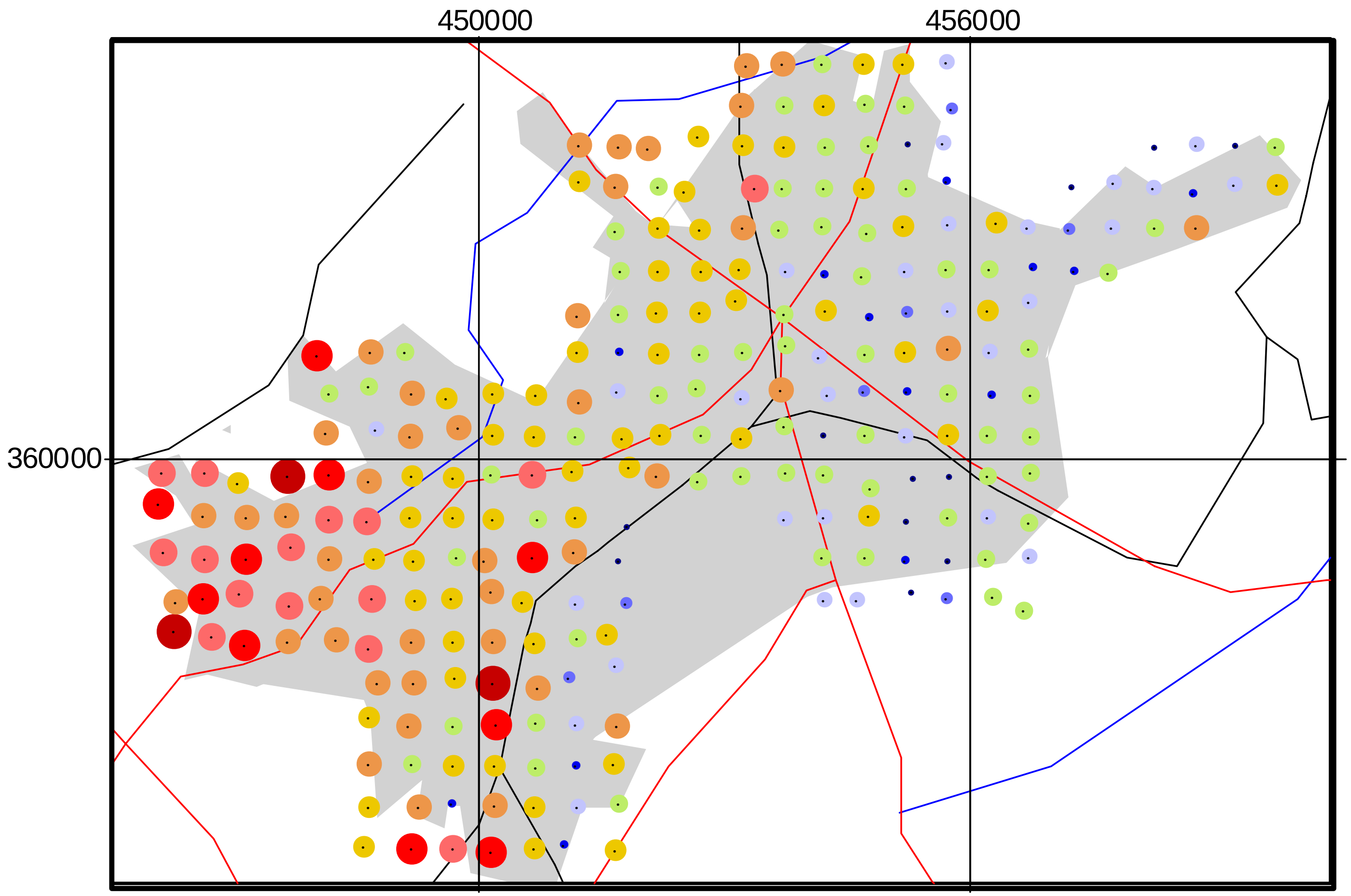
# Appendix C: Proportional symbol geochemical maps for Mansfield surface and profile soils

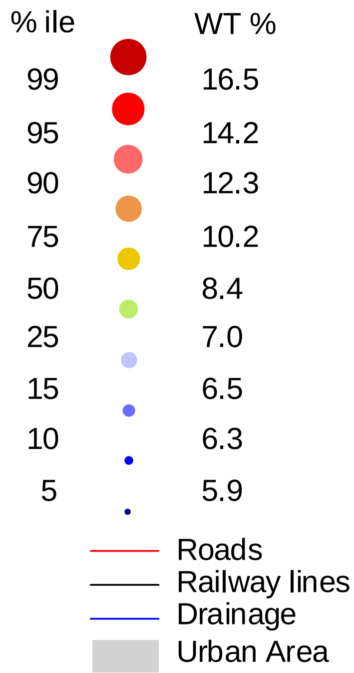
**Aluminium (not determined in profile soils)**
**Antimony**
**Arsenic**
**Barium**
**Cadmium**
**Calcium**
**Chromium**
**Cobalt**
**Copper**
**Iron**
**Lead**
**Magnesium (not determined in profile soils)**
**Manganese**
**Molybdenum**
**Nickel**
**Phosphorous (not determined in profile soils)**
**Potassium (not determined in profile soils)**
**Silicon (not determined in profile soils)**
**Tin (not determined in profile soils)**
**Titanium**
**Uranium**
**Vanadium**
**Zinc**

# Mansfield

## Surface Soils

### Aluminium



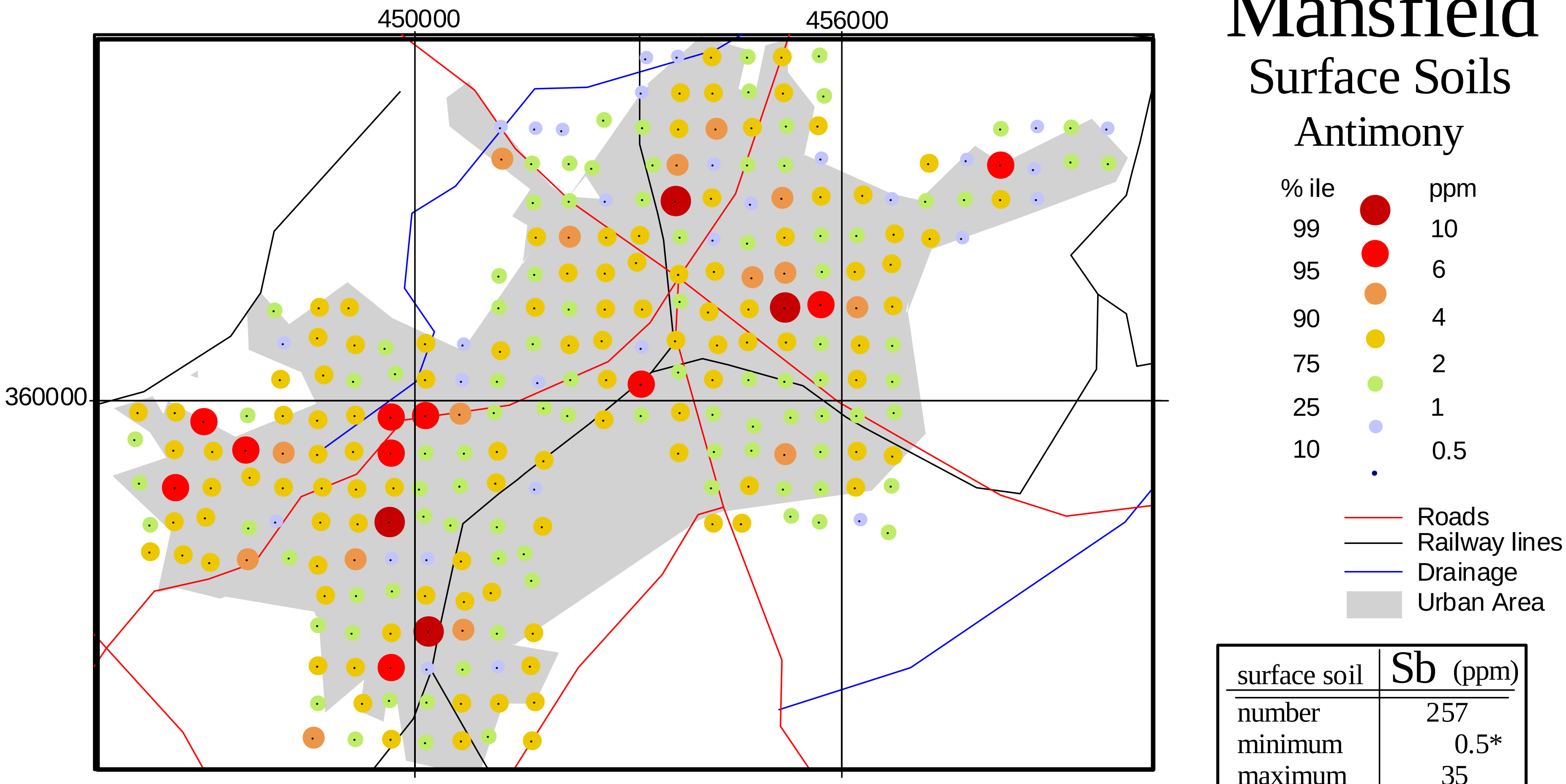

| surface soil | $Al_2O_3$ (%) |
|---|---|
| number | 257 |
| minimum | 4.1 |
| maximum | 20.2 |
| median | 8.4 |
| mean | 8.9 |

Aluminium was not determined in the profile soils

# Mansfield

## Surface Soils

## Antimony



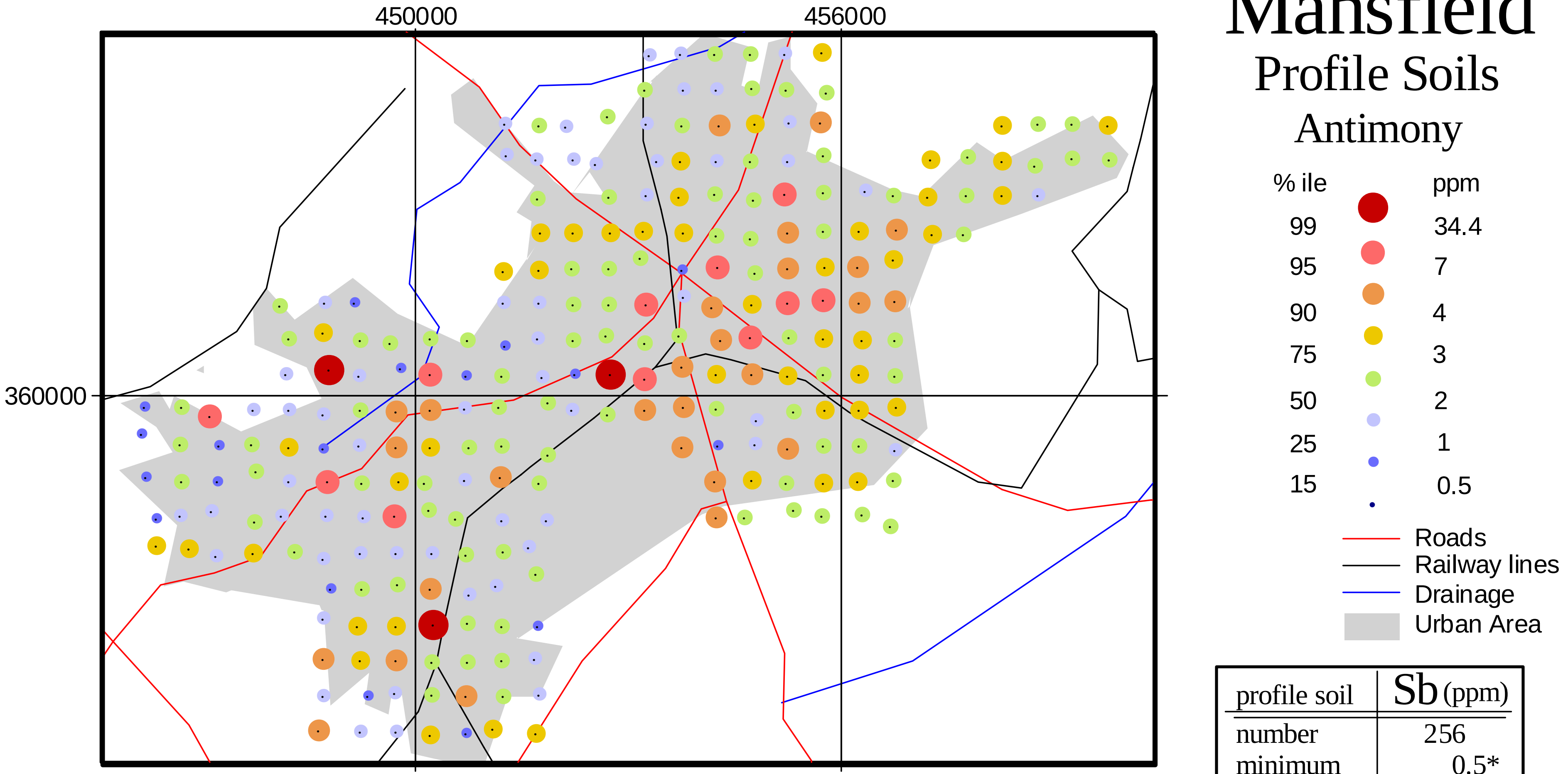

| surface soil | Sb (ppm) |
|---|---|
| number | 257 |
| minimum | 0.5* |
| maximum | 35 |
| median | 2 |
| mean | 2.2 |

* minimum value reported as half detection limit

# Mansfield

## Profile Soils

### Antimony



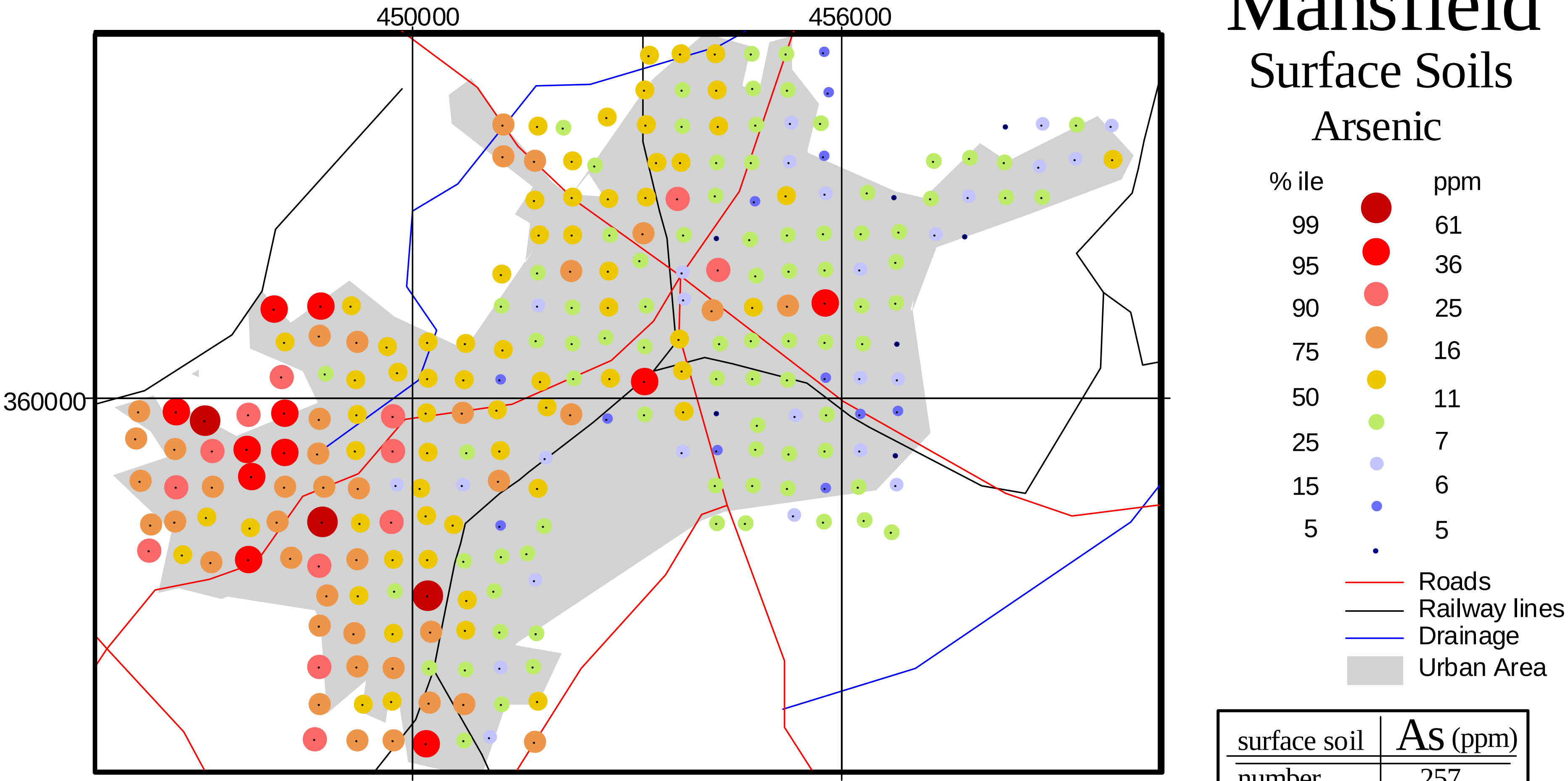

| profile soil | Sb (ppm) |
|---|---|
| number | 256 |
| minimum | 0.5* |
| maximum | 79 |
| median | 2 |
| mean | 3.2 |

* minimum value reported as half detection limit

# Mansfield

## Surface Soils

### Arsenic

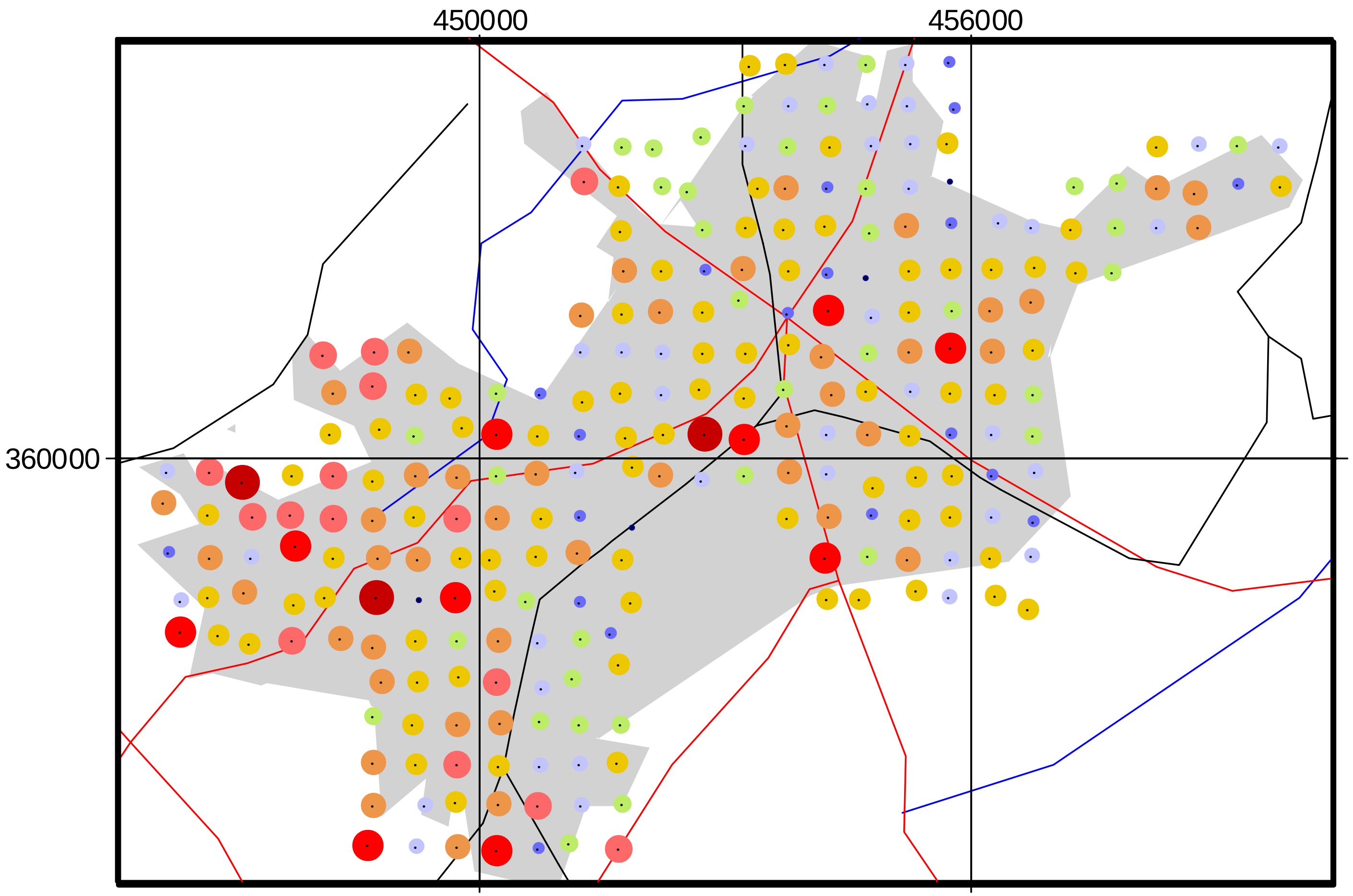



| surface soil | As (ppm) |
|---|---|
| number | 257 |
| minimum | 3 |
| maximum | 71 |
| median | 11 |
| mean | 14 |

# Mansfield

## Profile Soils

### Arsenic




| % ile | ppm |
|---|---|
| 99 | 70 |
| 95 | 45 |
| 90 | 29 |
| 75 | 18 |
| 50 | 13 |
| 25 | 11 |
| 15 | 9 |
| 5 | 7 |

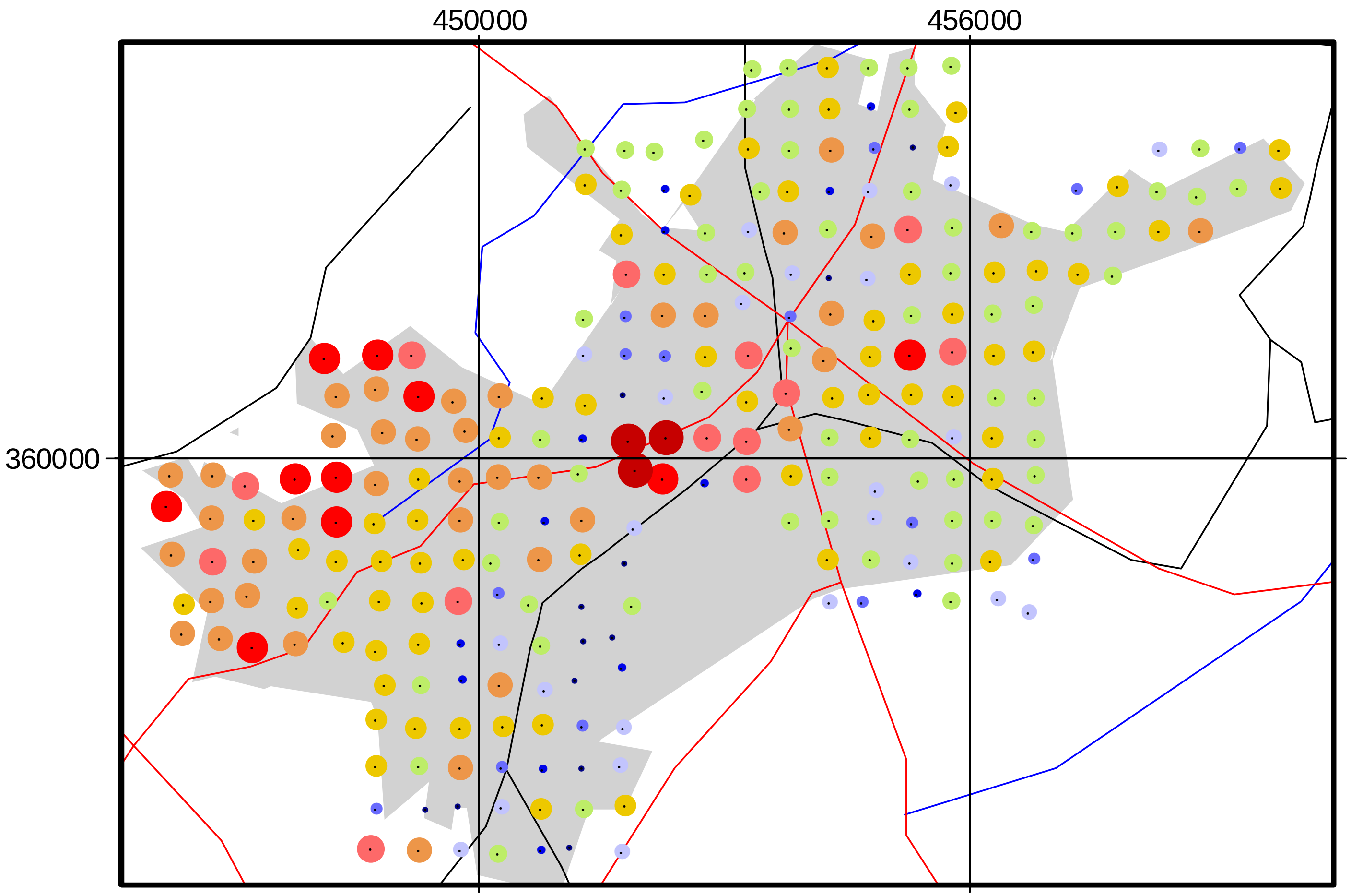
Roads
Railway lines
Drainage
Urban Area

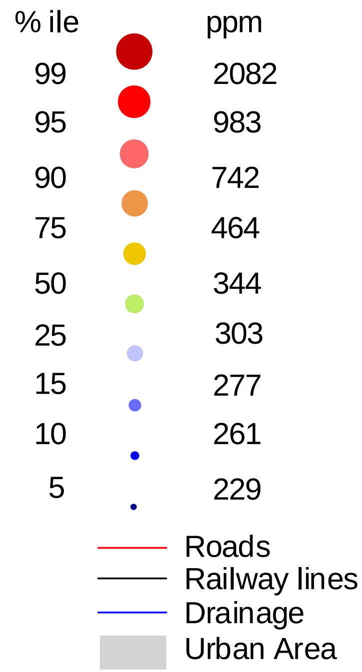
| profile soil | As (ppm) |
|---|---|
| number | 256 |
| minimum | 6 |
| maximum | 212 |
| median | 13 |
| mean | 17 |

# Mansfield

## Surface Soils

### Barium



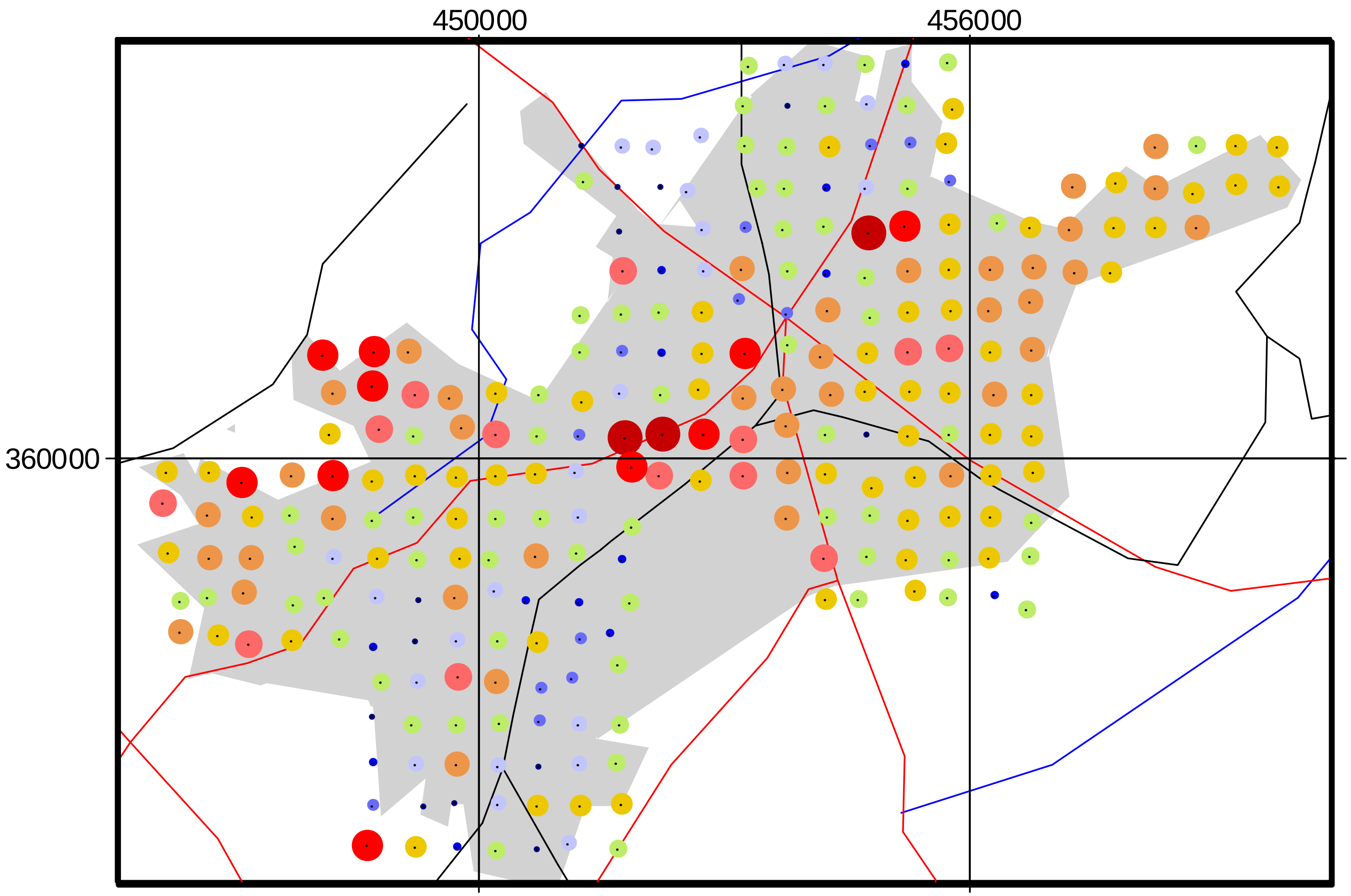




| surface soil | Ba (ppm) |
|---|---|
| number | 257 |
| minimum | 146 |
| maximum | 4303 |
| median | 344 |
| mean | 461 |

# Mansfield

## Profile Soils

### Barium




| % ile | ppm |
|---|---|
| 99 | 2877 |
| 95 | 1029 |
| 90 | 786 |
| 75 | 518 |
| 50 | 379 |
| 25 | 304 |
| 15 | 278 |
| 10 | 251 |
| 5 | 221 |

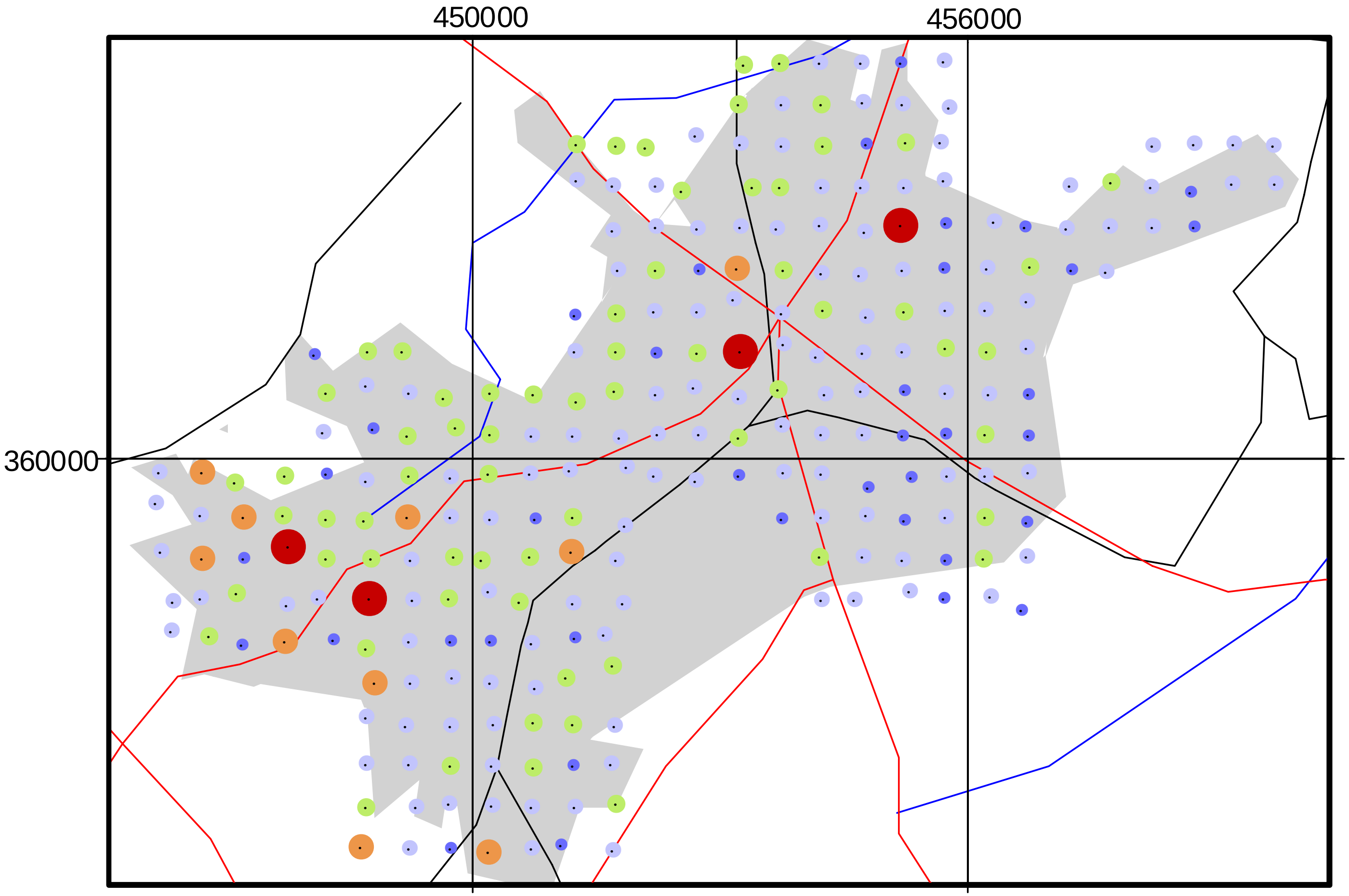
Roads
Railway lines
Drainage
Urban Area

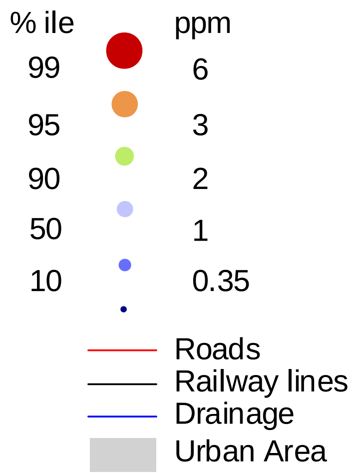
| profile soil | Ba (ppm) |
|---|---|
| number | 256 |
| minimum | 125 |
| maximum | 9549 |
| median | 379 |
| mean | 525 |

# Mansfield

## Surface Soils

### Cadmium



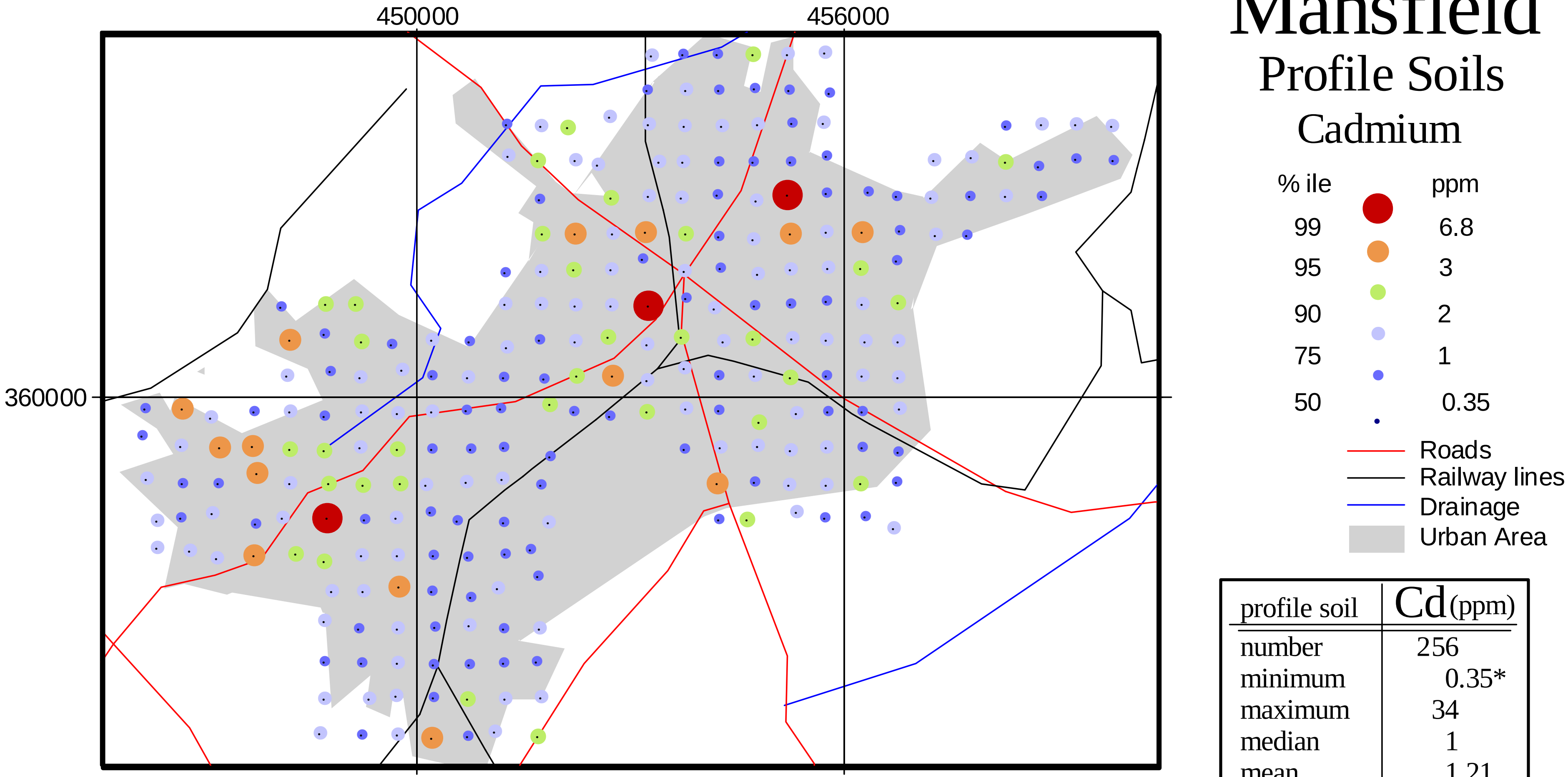

| surface soil | Cd (ppm) |
|---|---|
| number | 257 |
| minimum | 0.35* |
| maximum | 9 |
| median | 1 |
| mean | 1.34 |

* minimum value reported as half detection limit

# Mansfield

## Profile Soils

### Cadmium



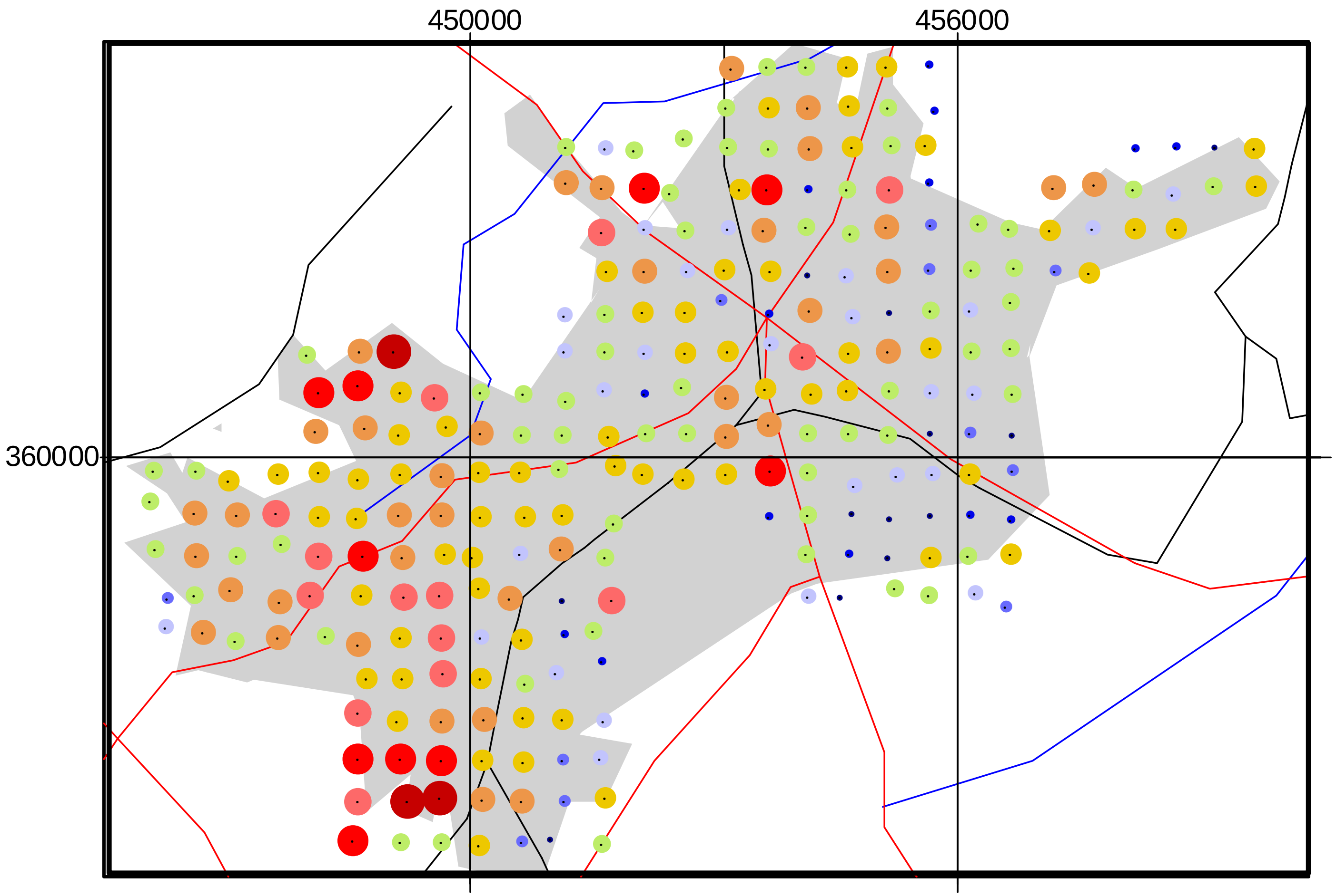

| profile soil | Cd (ppm) |
|---|---|
| number | 256 |
| minimum | 0.35* |
| maximum | 34 |
| median | 1 |
| mean | 1.21 |

* minimum value reported as half detection limit

# Mansfield

## Surface Soils

### Calcium




| % ile | WT % |
|---|---|
| 99 | 10.14 |
| 95 | 7.36 |
| 90 | 5.45 |
| 75 | 3.05 |
| 50 | 1.17 |
| 25 | 0.47 |
| 15 | 0.33 |
| 10 | 0.26 |
| 5 | 0.17 |

Roads
Railway lines
Drainage
Urban Area

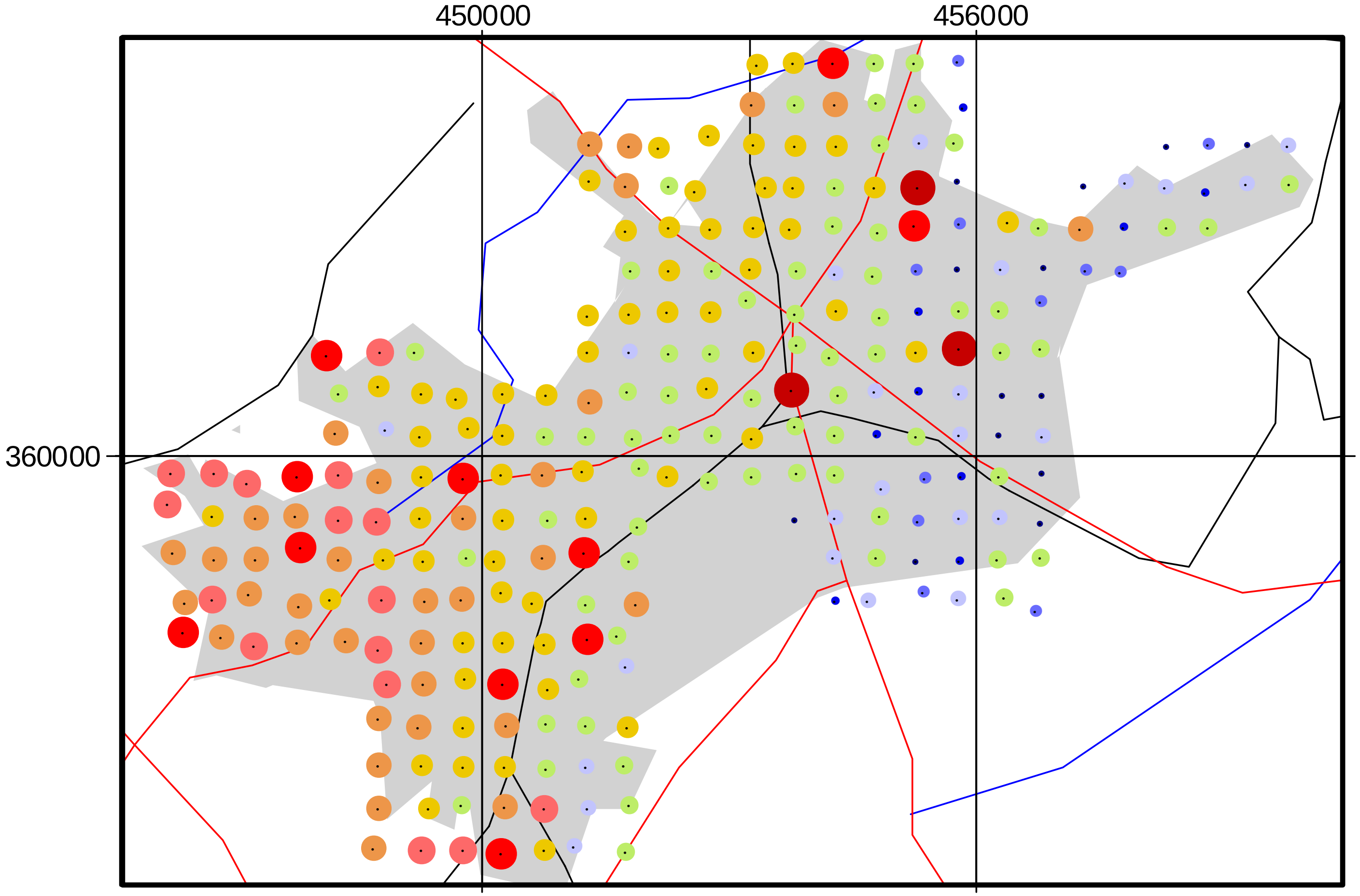
| surface soil | $CaO$ (%) |
|---|---|
| number | 257 |
| minimum | 0.03 |
| maximum | 14.35 |
| median | 1.17 |
| mean | 2.17 |

Calcium was not determined in the profile soils

# Mansfield

## Surface Soils

### Chromium




| % ile | ppm |
|---|---|
| 99 | 140 |
| 95 | 103 |
| 90 | 90 |
| 75 | 74 |
| 50 | 54 |
| 25 | 37 |
| 15 | 31 |
| 10 | 30 |
| 5 | 27 |

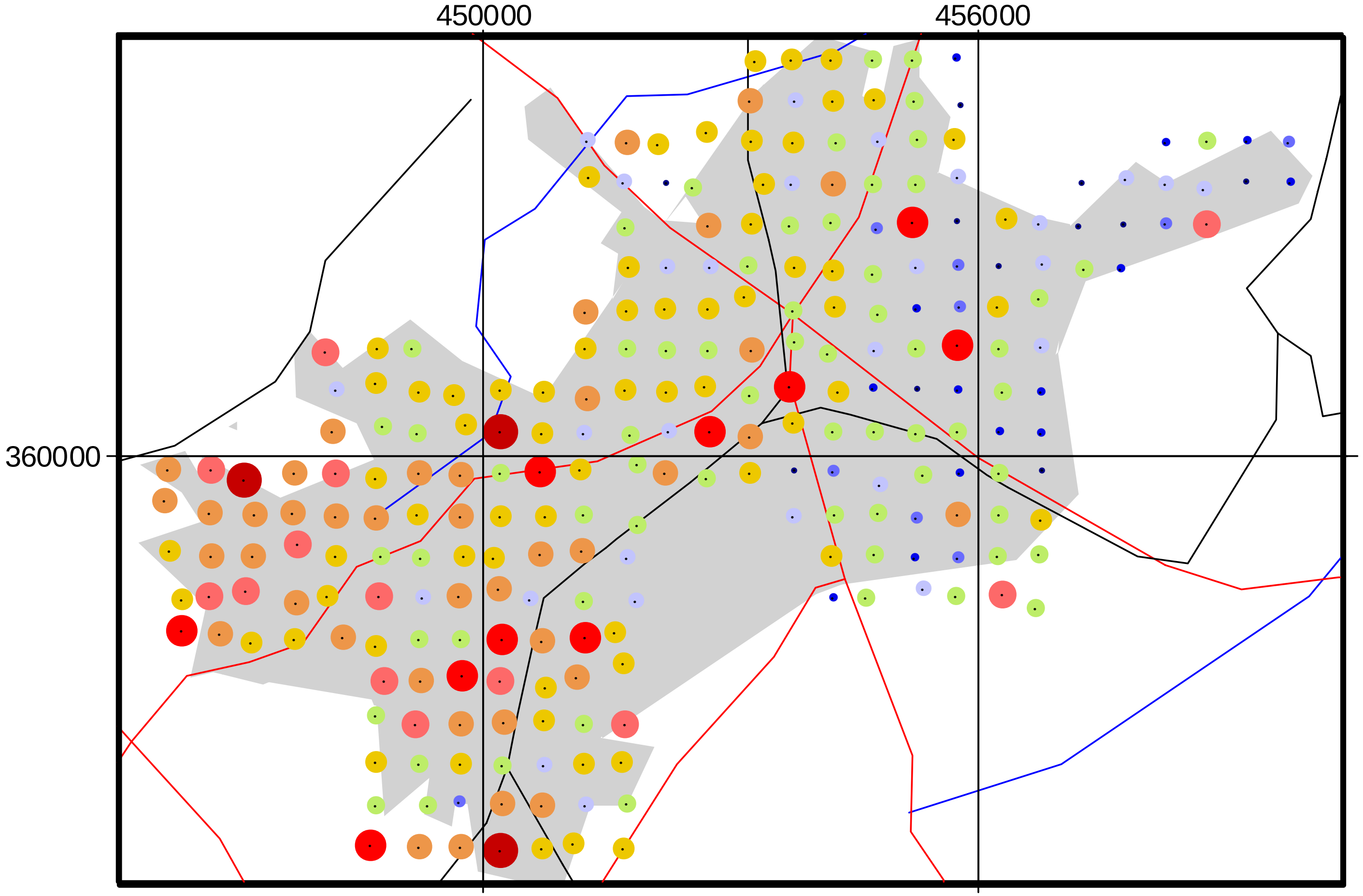
Roads
Railway lines
Drainage
Urban Area

| surface soil | Cr (ppm) |
|---|---|
| number | 257 |
| minimum | 18 |
| maximum | 250 |
| median | 54 |
| mean | 59 |

# Mansfield

## Profile Soils

## Chromium




| % ile | ppm |
|---|---|
| 99 | 177 |
| 95 | 112 |
| 90 | 97 |
| 75 | 81 |
| 50 | 66 |
| 25 | 54 |
| 15 | 48 |
| 10 | 45 |
| 5 | 40 |

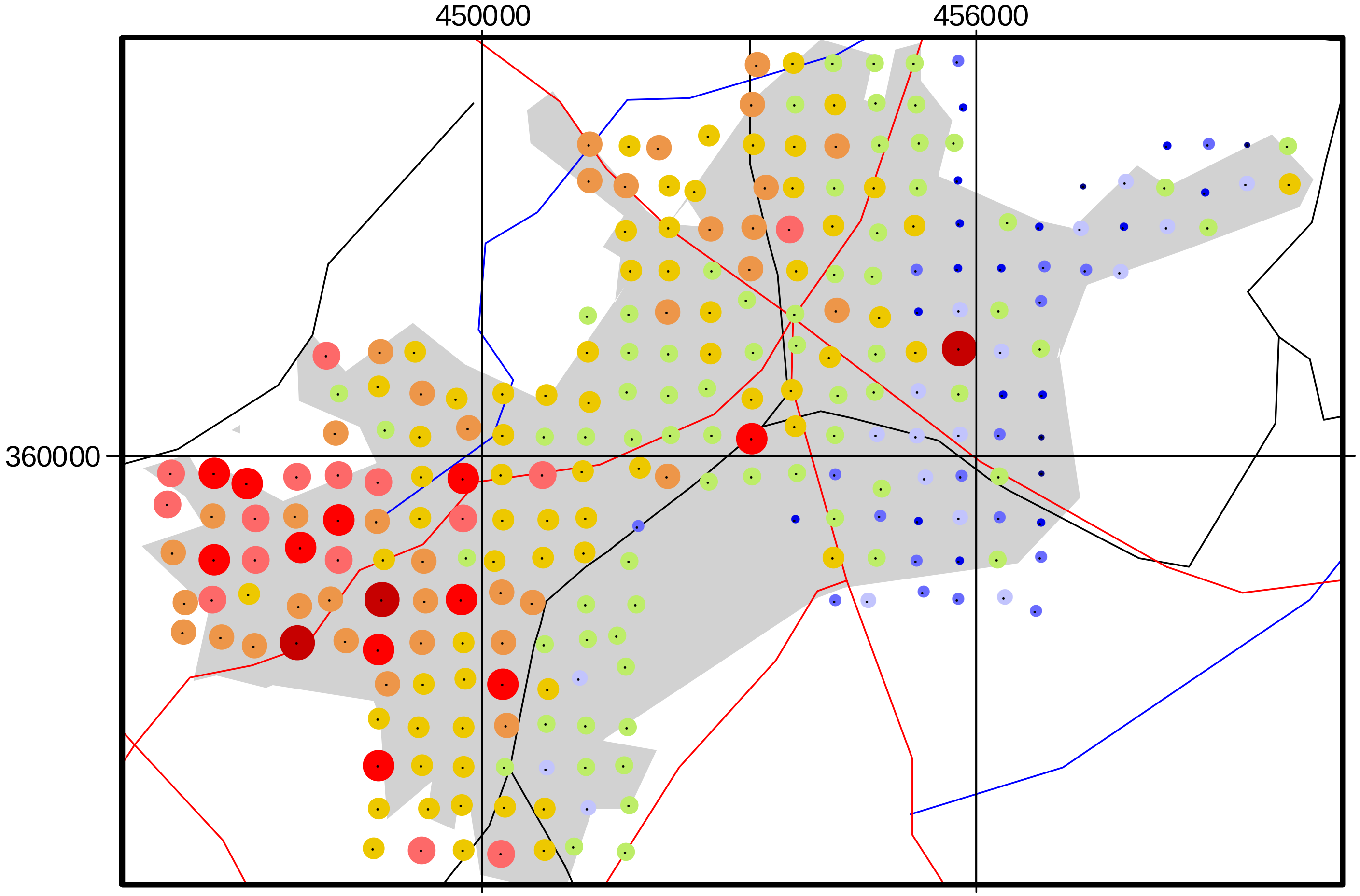
Roads
Railway lines
Drainage
Urban Area

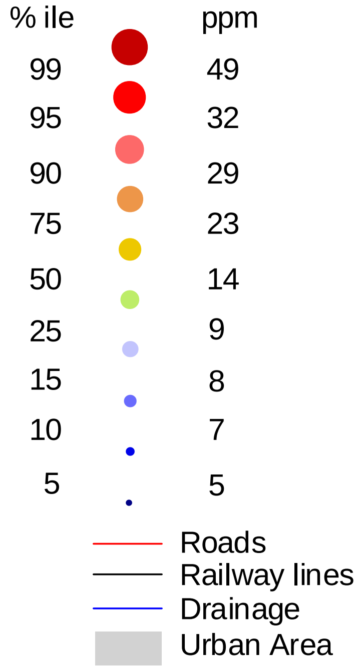
| profile soil | Cr (ppm) |
|---|---|
| number | 256 |
| minimum | 33 |
| maximum | 397 |
| median | 66 |
| mean | 71 |

# Mansfield

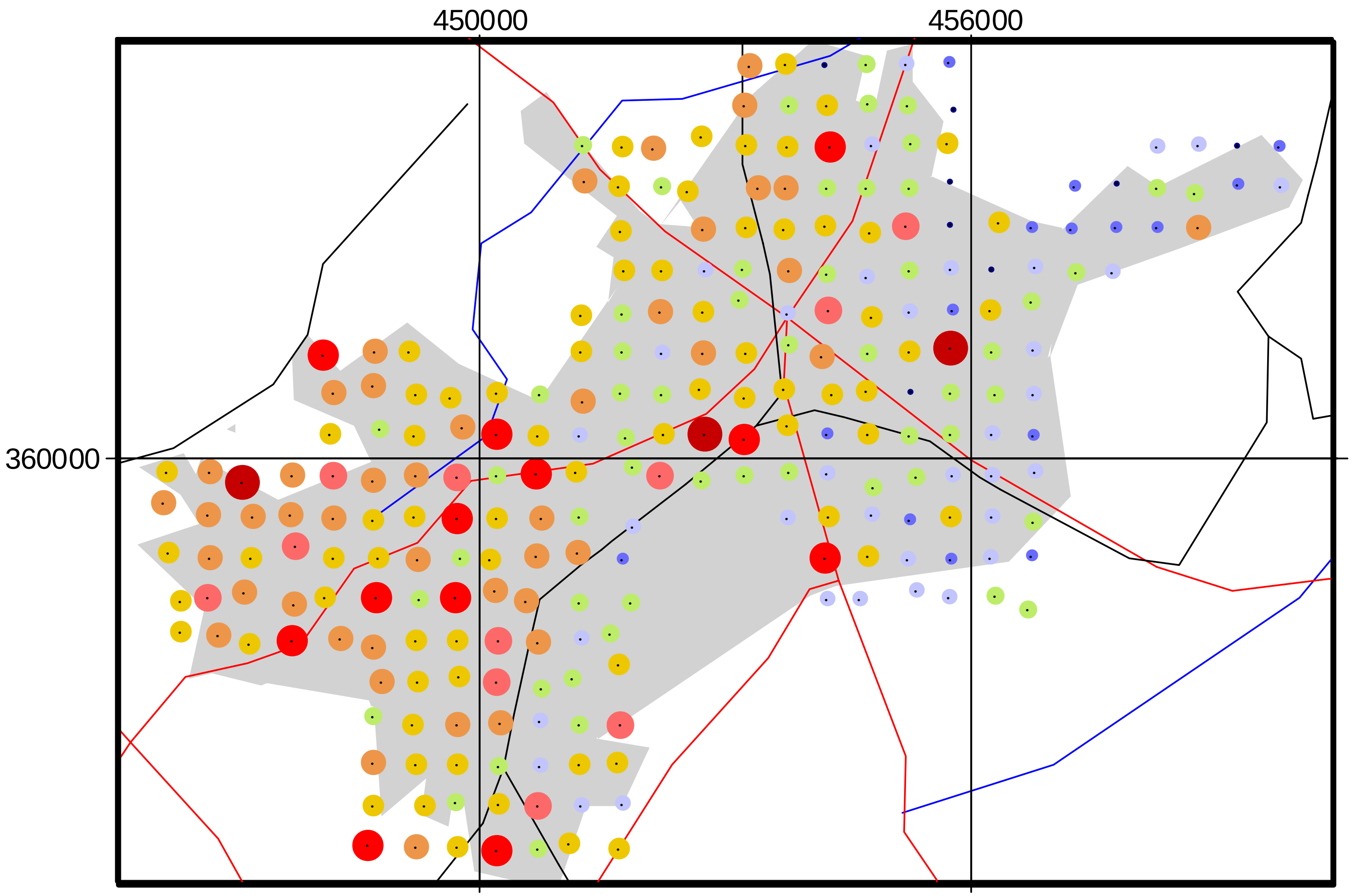
## Surface Soils

### Cobalt




| surface soil | Co (ppm) |
|---|---|
| number | 257 |
| minimum | 3 |
| maximum | 58 |
| median | 14 |
| mean | 16 |




# Mansfield

## Profile Soils

### Cobalt

| % ile | ppm |
|---|---|
| 99 | 59 |
| 95 | 35 |
| 90 | 29 |
| 75 | 25 |
| 50 | 18 |
| 25 | 15 |
| 15 | 12 |
| 5 | 10 |

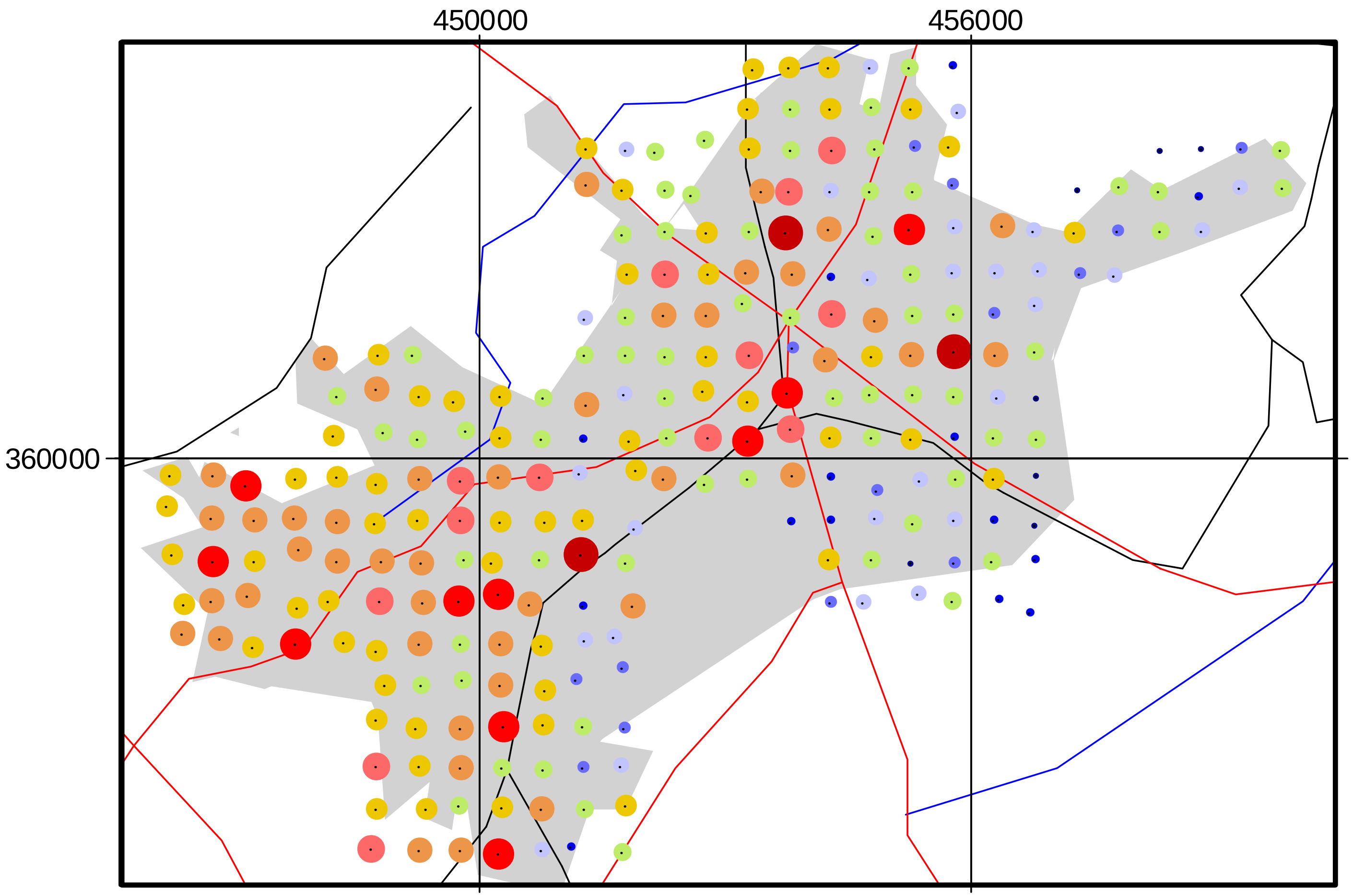
Roads
Railway lines
Drainage
Urban Area

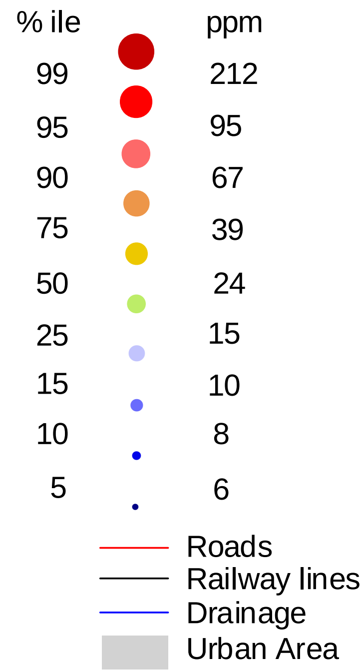
| profile soil | Co (ppm) |
|---|---|
| number | 256 |
| minimum | 8 |
| maximum | 95 |
| median | 18 |
| mean | 21 |

# Mansfield

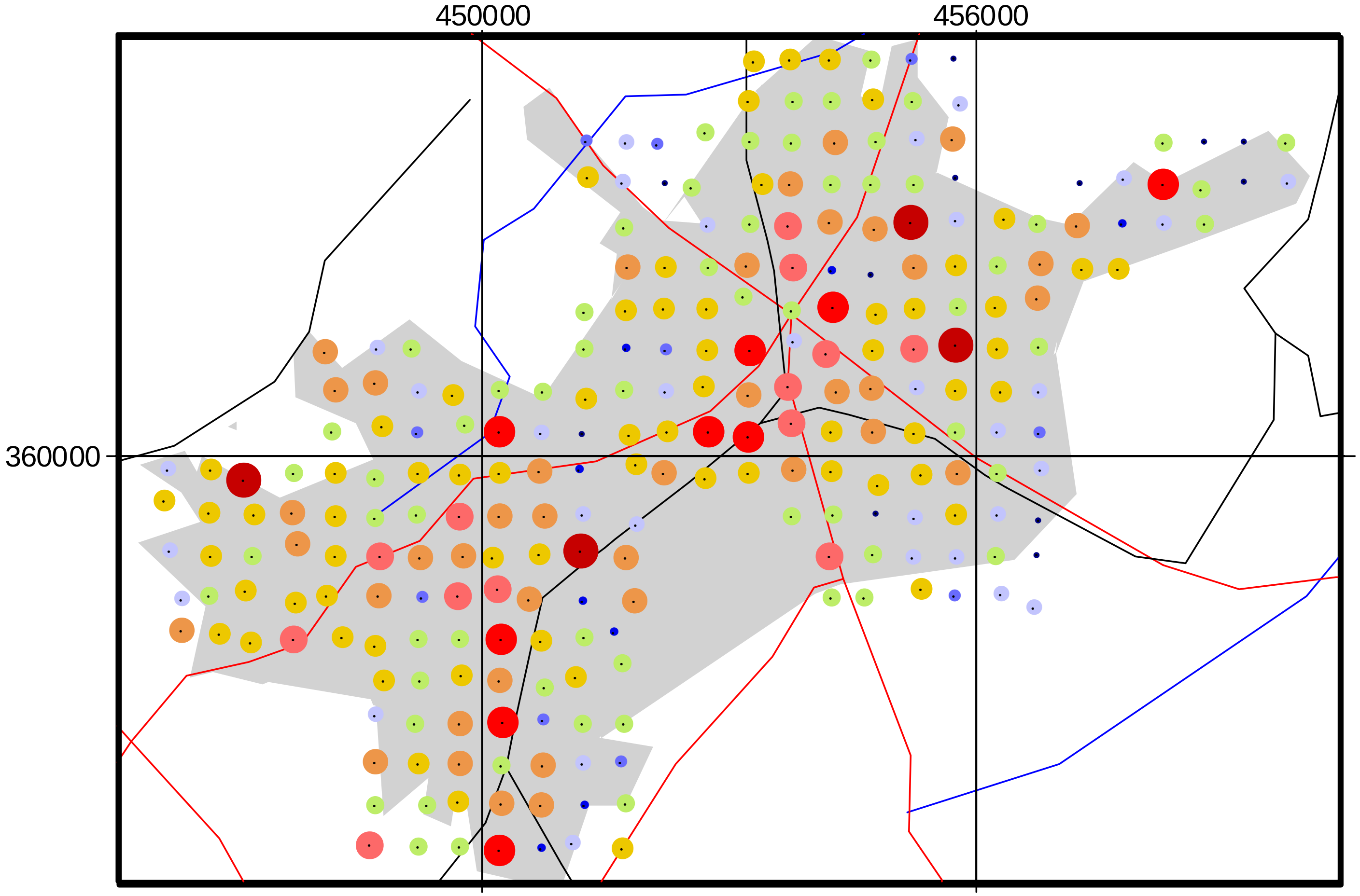
## Surface Soils

### Copper




| surface soil | Cu (ppm) |
|---|---|
| number | 257 |
| minimum | 3 |
| maximum | 1731 |
| median | 24 |
| mean | 41 |




# Mansfield

## Profile Soils

### Copper

| % ile | ppm |
|---|---|
| | |
| 99 | 328 |
| 95 | 151 |
| 90 | 96 |
| 75 | 43 |
| 50 | 25 |
| 25 | 17 |
| 15 | 13 |
| 10 | 12 |
| 5 | 10 |

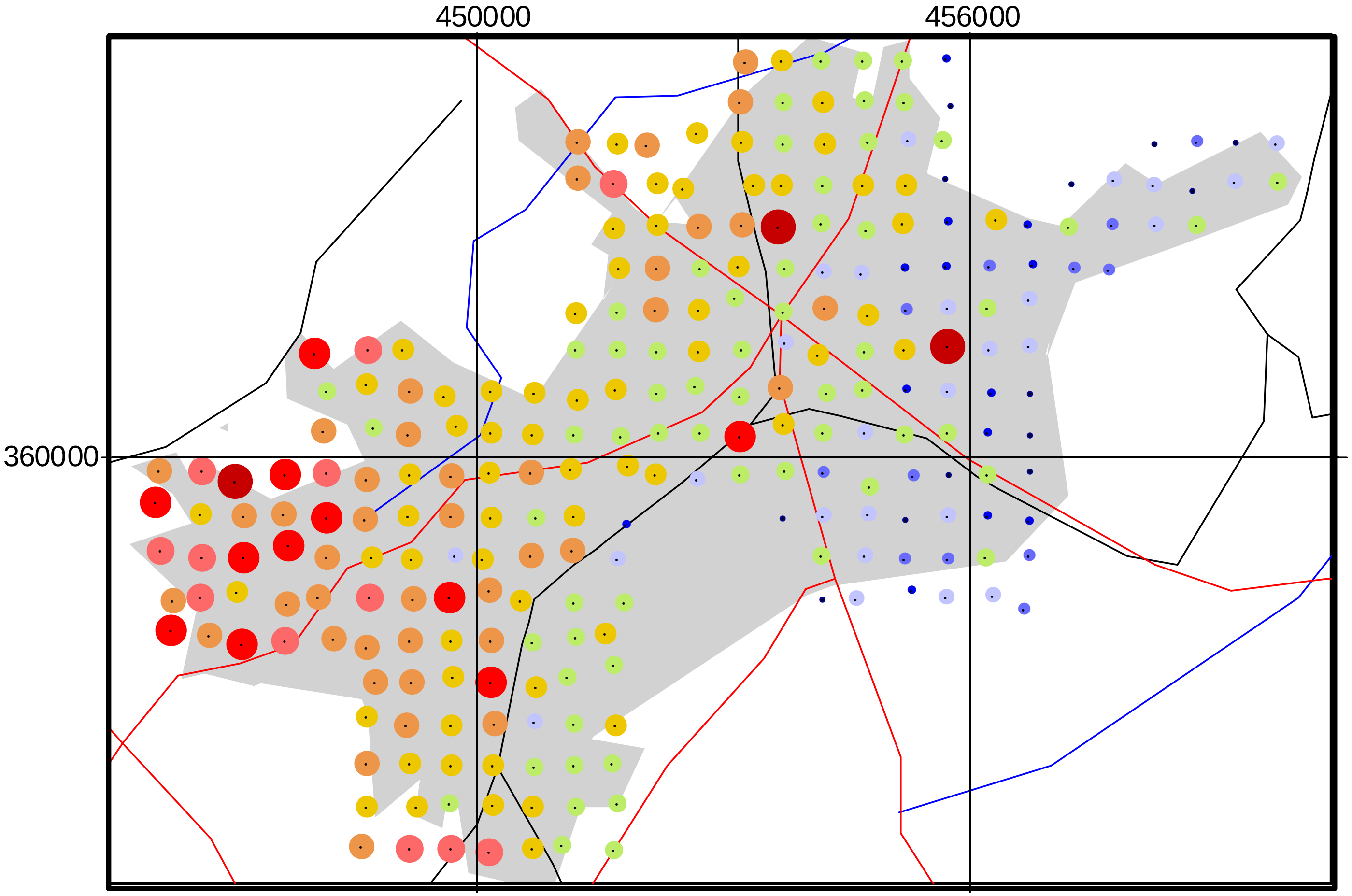
Roads
Railway lines
Drainage
Urban Area

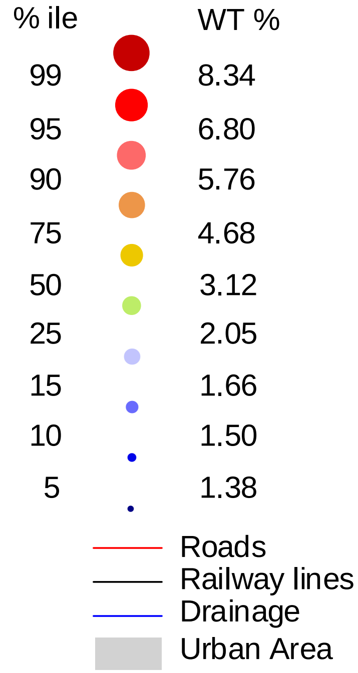
| profile soil | Cu (ppm) |
|---|---|
| number | 256 |
| minimum | 5 |
| maximum | 595 |
| median | 25 |
| mean | 45 |

# Mansfield

## Surface Soils

### Iron



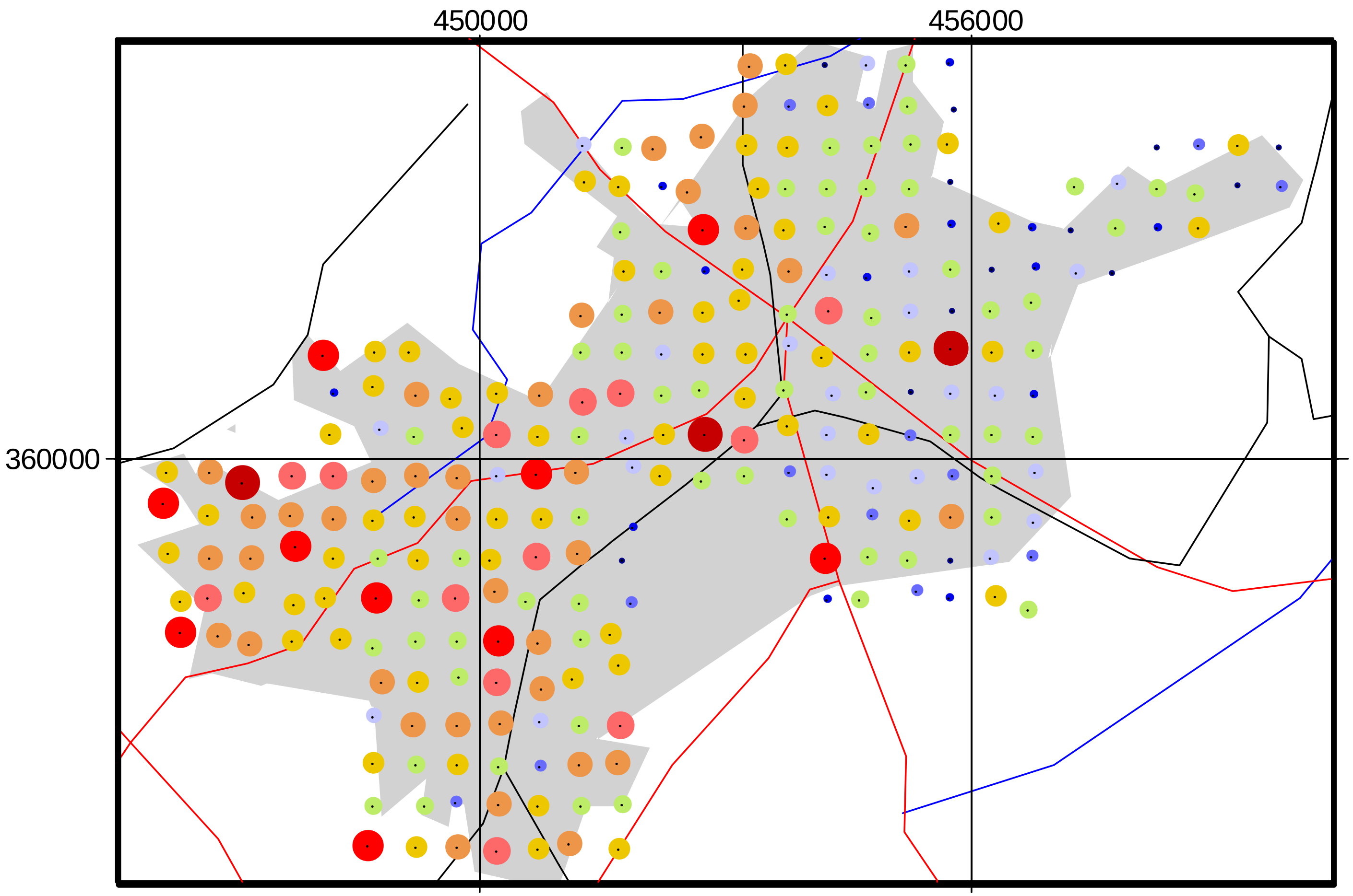




| surface soil | $Fe_2O_3$ (%) |
|---|---|
| number | 257 |
| minimum | 0.77 |
| maximum | 15.11 |
| median | 3.12 |
| mean | 3.52 |

# Mansfield

## Profile Soils

### Iron




| % ile | WT % |
|---|---|
| 99 | 12.88 |
| 95 | 7.22 |
| 90 | 6.18 |
| 75 | 5.08 |
| 50 | 4.06 |
| 25 | 3.29 |
| 15 | 2.95 |
| 10 | 2.74 |
| 5 | 2.45 |

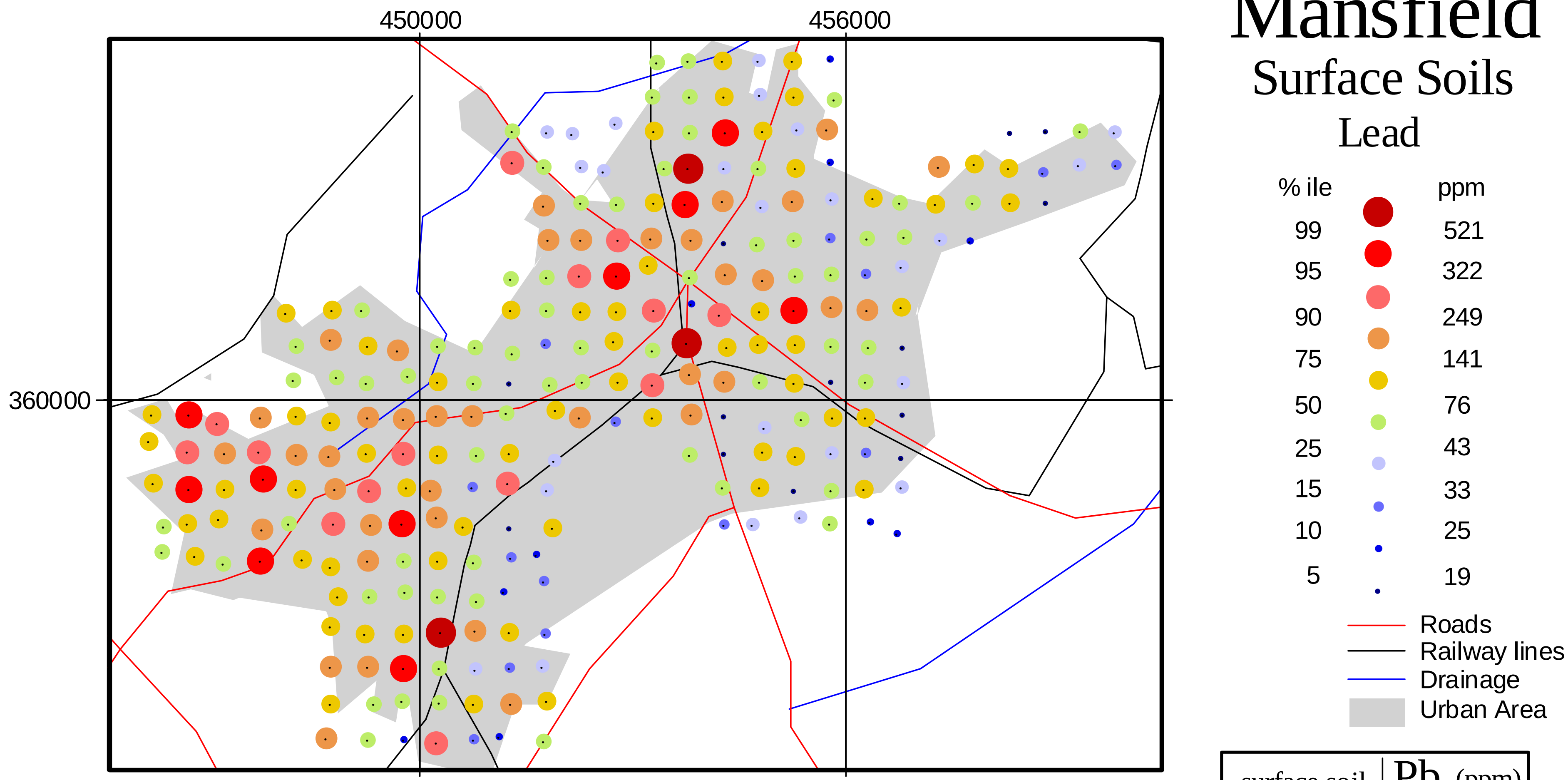
Roads
Railway lines
Drainage
Urban Area

| profile soil | $Fe_2O_3$ (%) |
|---|---|
| number | 256 |
| minimum | 1.85 |
| maximum | 17.56 |
| median | 4.06 |
| mean | 4.42 |

# Mansfield

## Surface Soils

### Lead

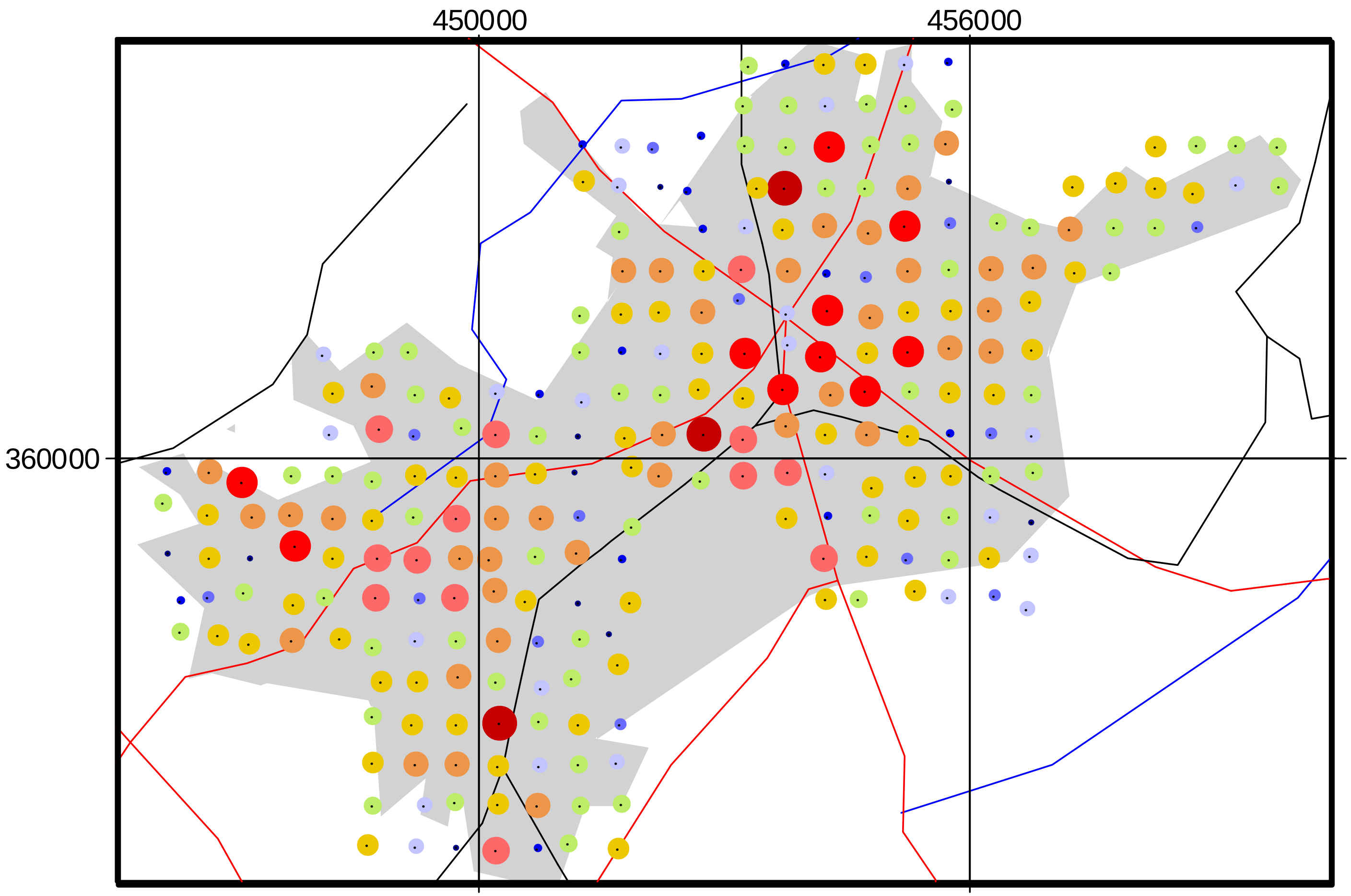



| surface soil | Pb (ppm) |
|---|---|
| number | 257 |
| minimum | 1 |
| maximum | 1319 |
| median | 76 |
| mean | 114 |

# Mansfield

## Profile Soils

### Lead




| % ile | ppm |
|---|---|
| 99 | 684 |
| 95 | 348 |
| 90 | 251 |
| 75 | 135 |
| 50 | 73 |
| 25 | 45 |
| 15 | 33 |
| 10 | 28 |
| 5 | 21 |

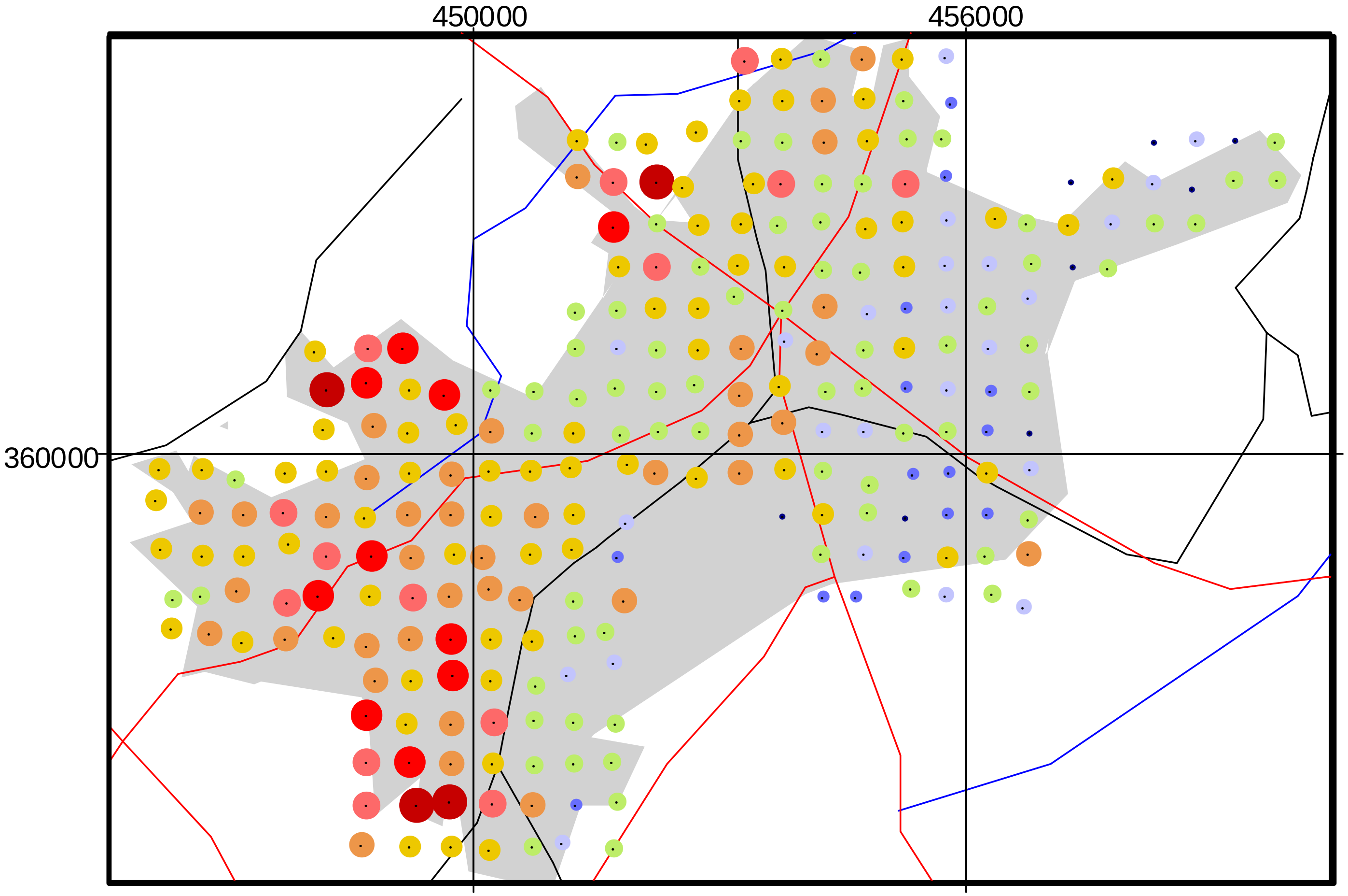
Roads
Railway lines
Drainage
Urban Area

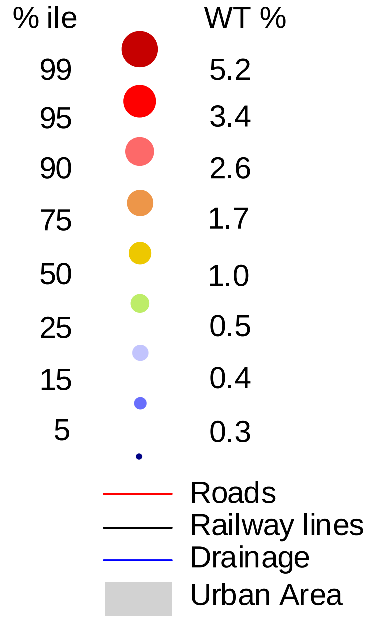
| profile soil | Pb (ppm) |
|---|---|
| number | 256 |
| minimum | 11 |
| maximum | 1500 |
| median | 73 |
| mean | 119 |

# Mansfield

## Surface Soils

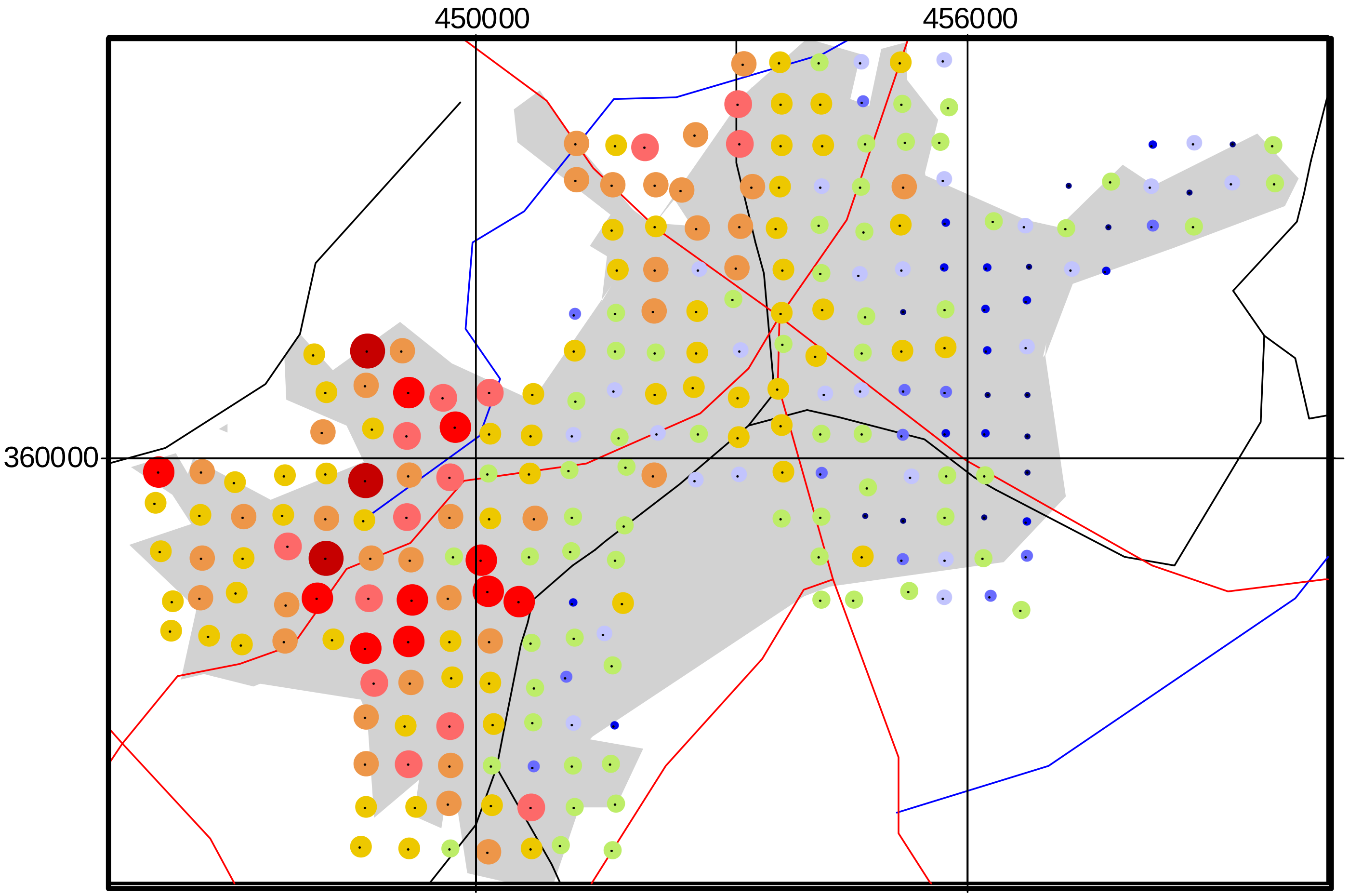
### Magnesium




| surface soil | MgO(%) |
|---|---|
| number | 257 |
| minimum | 0.1 |
| maximum | 7 |
| median | 1.0 |
| mean | 1.3 |

Magnesium was not determined in the profile soils.




# Mansfield

## Surface Soils

### Manganese

| % ile | WT % |
|---|---|
| 99 | 0.491 |
| 95 | 0.352 |
| 90 | 0.303 |
| 75 | 0.208 |
| 50 | 0.099 |
| 25 | 0.062 |
| 15 | 0.052 |
| 10 | 0.046 |
| 5 | 0.038 |

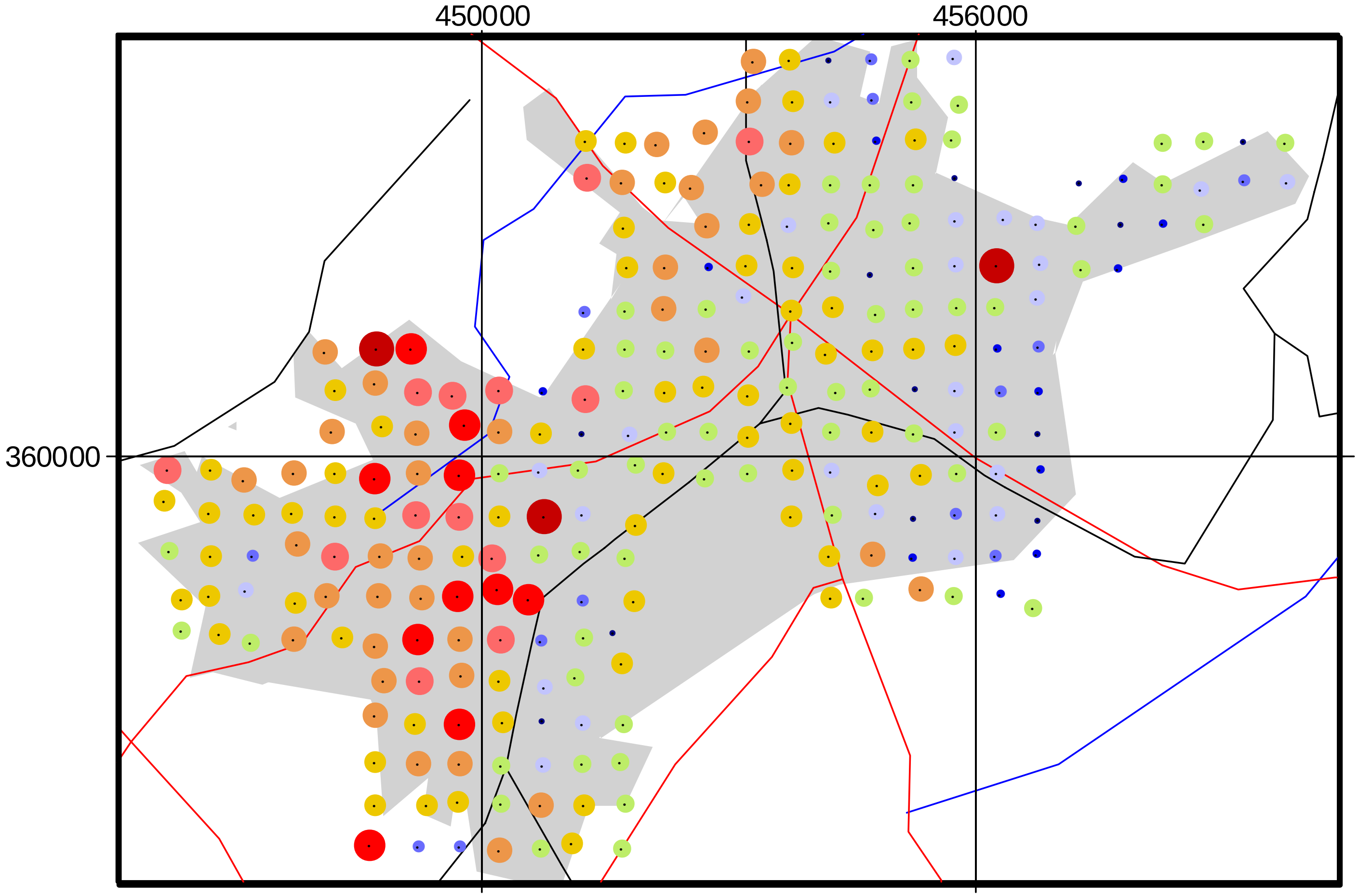
Roads
Railway lines
Drainage
Urban Area

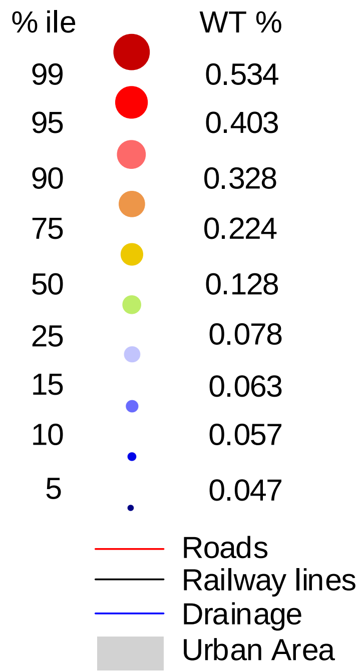
| surface soil | $MnO$ (%) |
|---|---|
| number | 257 |
| minimum | 0.022 |
| maximum | 0.642 |
| median | 0.099 |
| mean | 0.144 |

# Mansfield

## Profile Soils

### Manganese



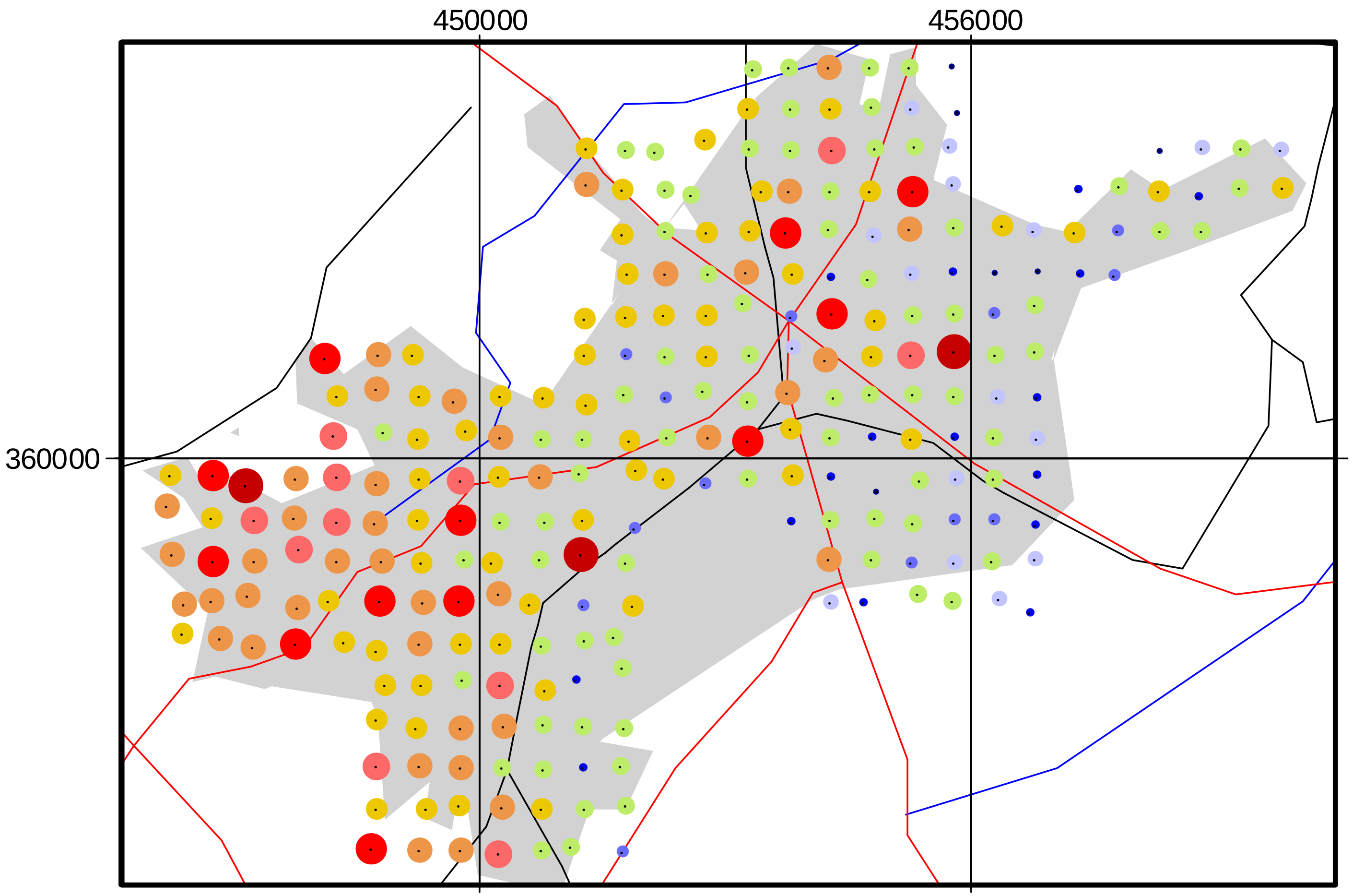



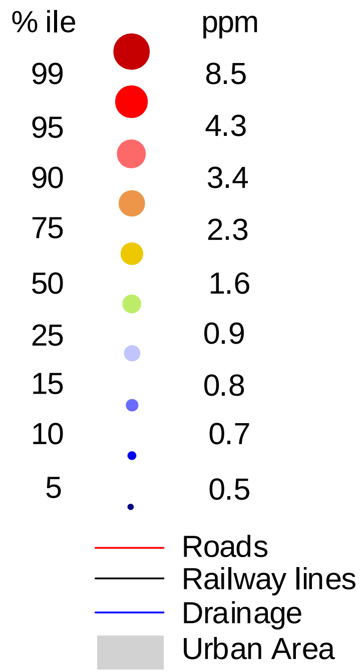

| profile soil | MnO (%) |
|---|---|
| number | 256 |
| minimum | 0.026 |
| maximum | 1.261 |
| median | 0.128 |
| mean | 0.168 |

# Mansfield

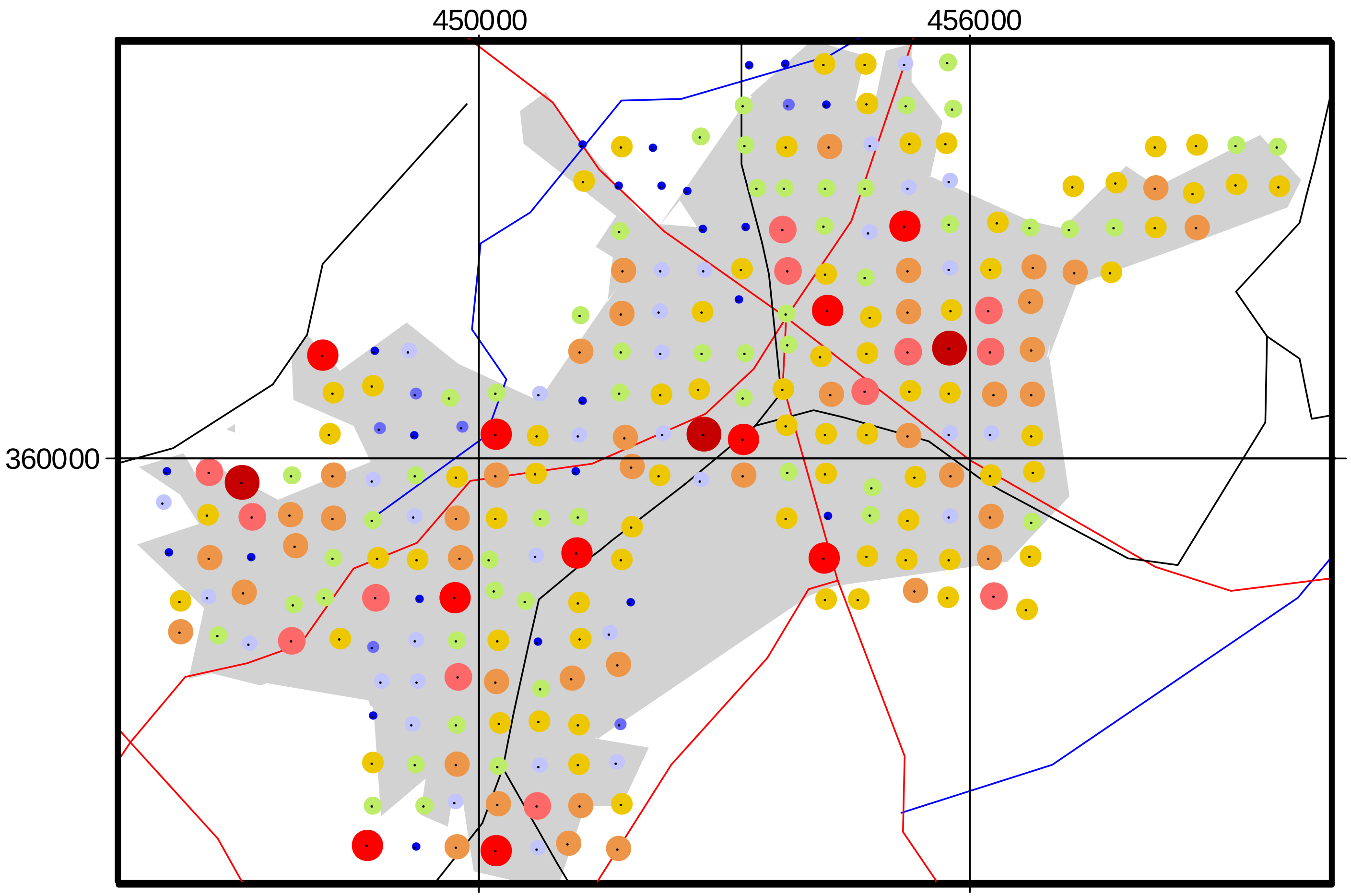
## Surface Soils

### Molybdenum




| surface soil | Mo (ppm) |
|---|---|
| number | 257 |
| minimum | 0.15 |
| maximum | 14.0 |
| median | 1.6 |
| mean | 1.9 |




# Mansfield

## Profile Soils

### Molybdenum

| % ile | ppm |
|---|---|
| 99 | 15.19 |
| 95 | 3.63 |
| 90 | 2.45 |
| 75 | 1.80 |
| 50 | 1.20 |
| 25 | 0.80 |
| 15 | 0.50 |
| 10 | 0.40 |
| 5 | 0.15 |

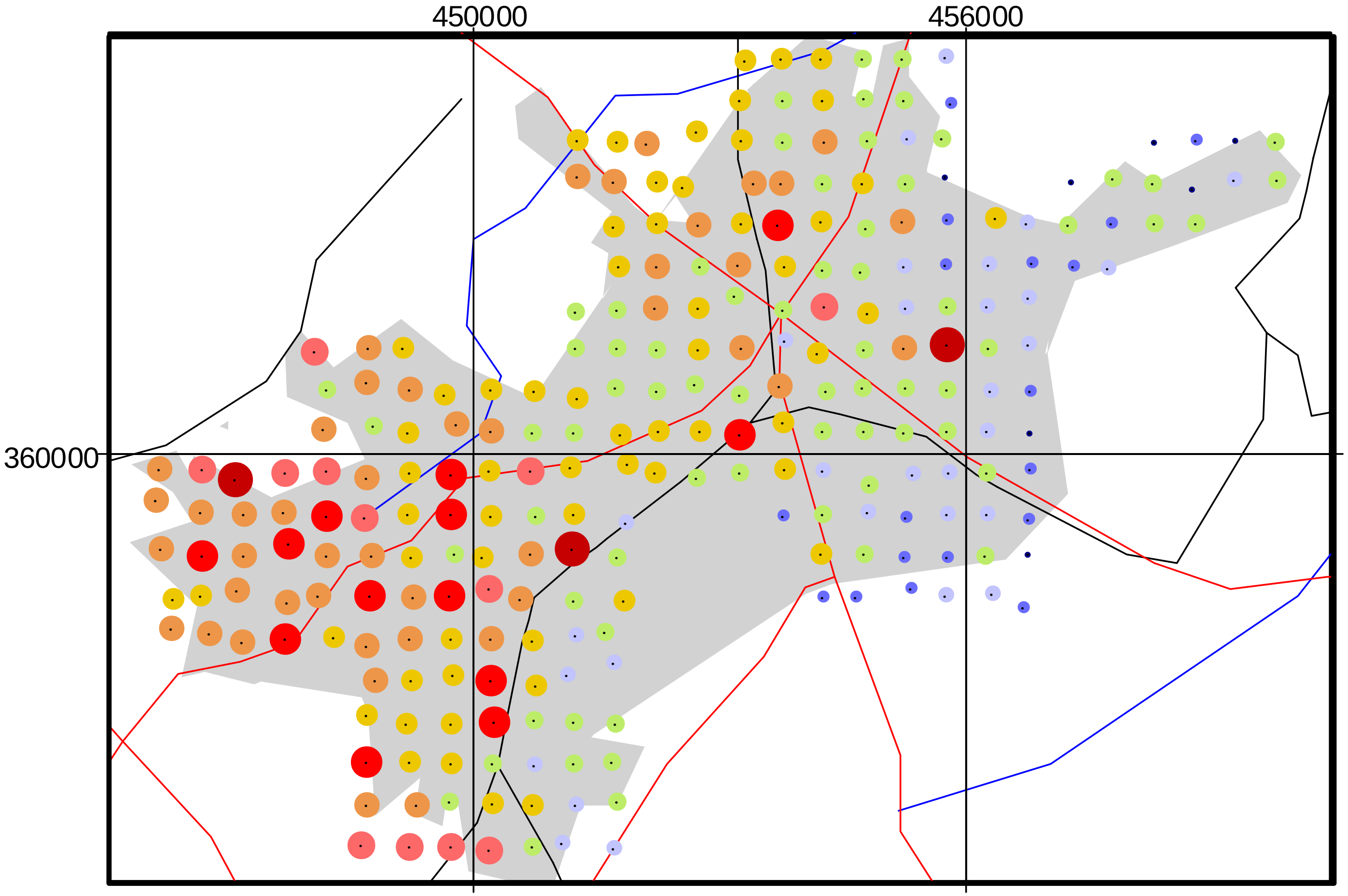
Roads
Railway lines
Drainage
Urban Area

| profile soil | Mo (ppm) |
|---|---|
| number | 256 |
| minimum | 0.15 |
| maximum | 25.30 |
| median | 1.20 |
| mean | 1.71 |

# Mansfield

## Surface Soils

### Nickel




| % ile | ppm |
|---|---|
| 99 | 54 |
| 95 | 39 |
| 90 | 34 |
| 75 | 25 |
| 50 | 16 |
| 25 | 9 |
| 15 | 7 |
| 5 | 5 |

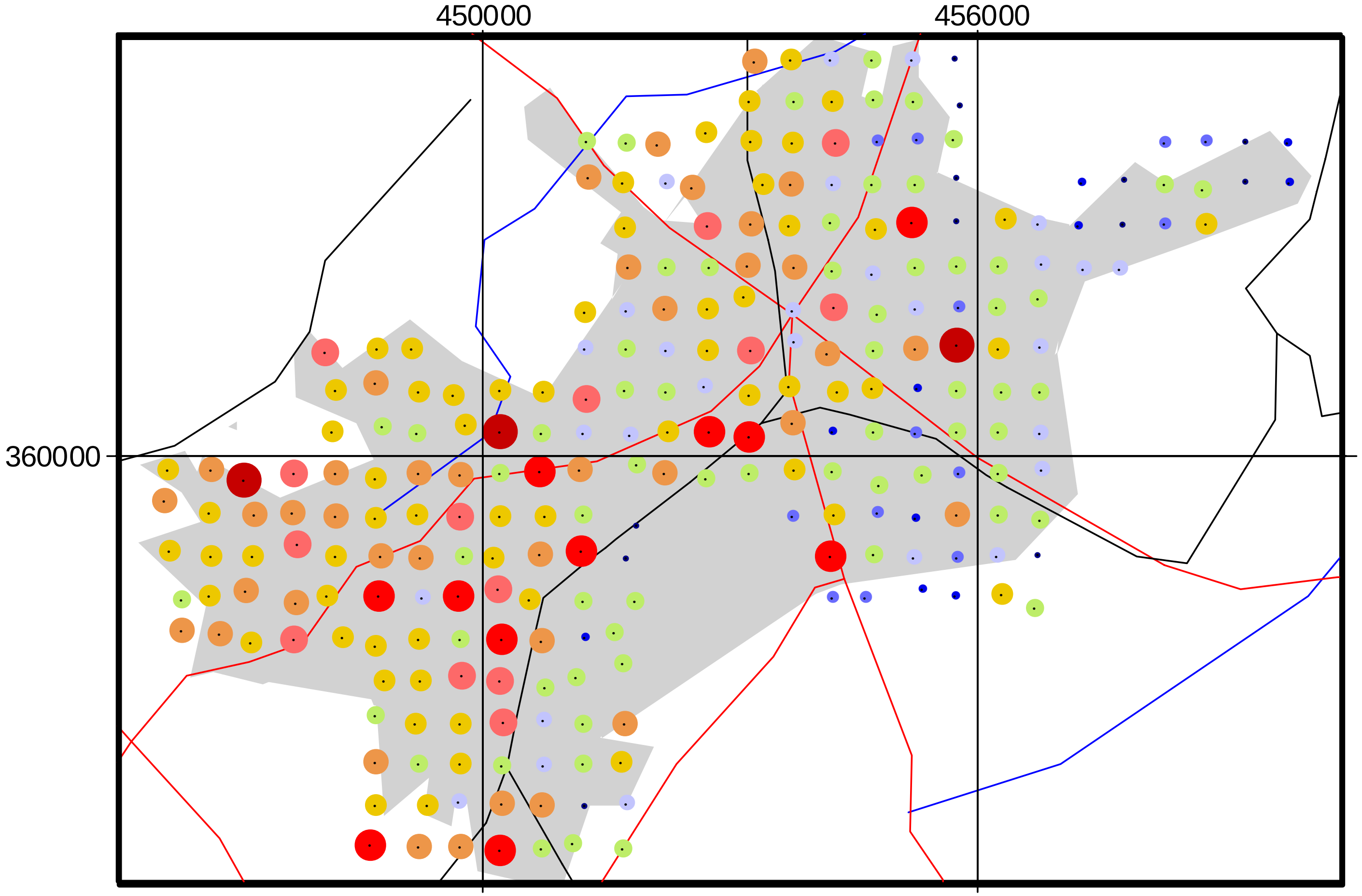
Roads
Railway lines
Drainage
Urban Area

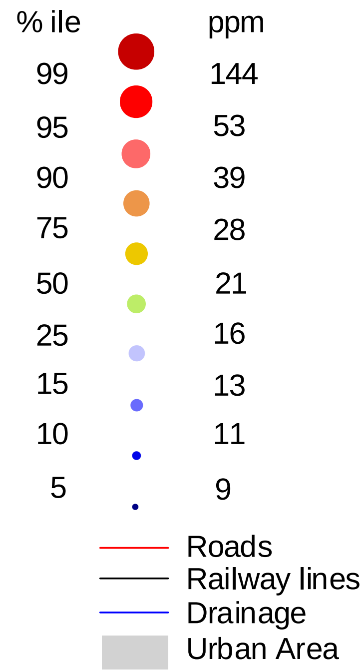
| surface soil | Ni (ppm) |
|---|---|
| number | 257 |
| minimum | 4 |
| maximum | 102 |
| median | 16 |
| mean | 19 |

# Mansfield

## Profile Soils

### Nickel



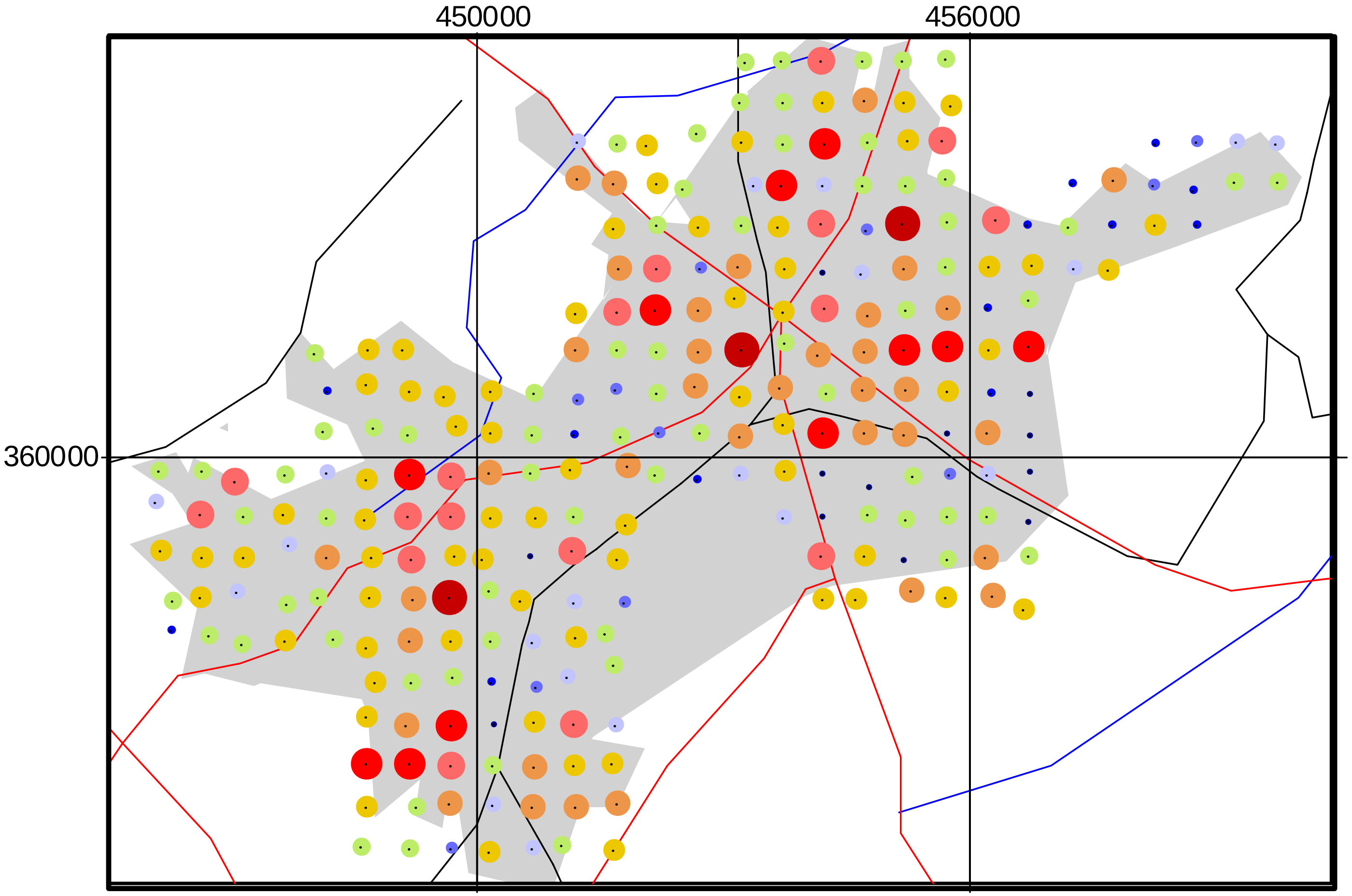




| profile soil | Ni (ppm) |
|---|---|
| number | 256 |
| minimum | 5 |
| maximum | 564 |
| median | 21 |
| mean | 27 |

# Mansfield

## Surface Soils

### Phosphorus



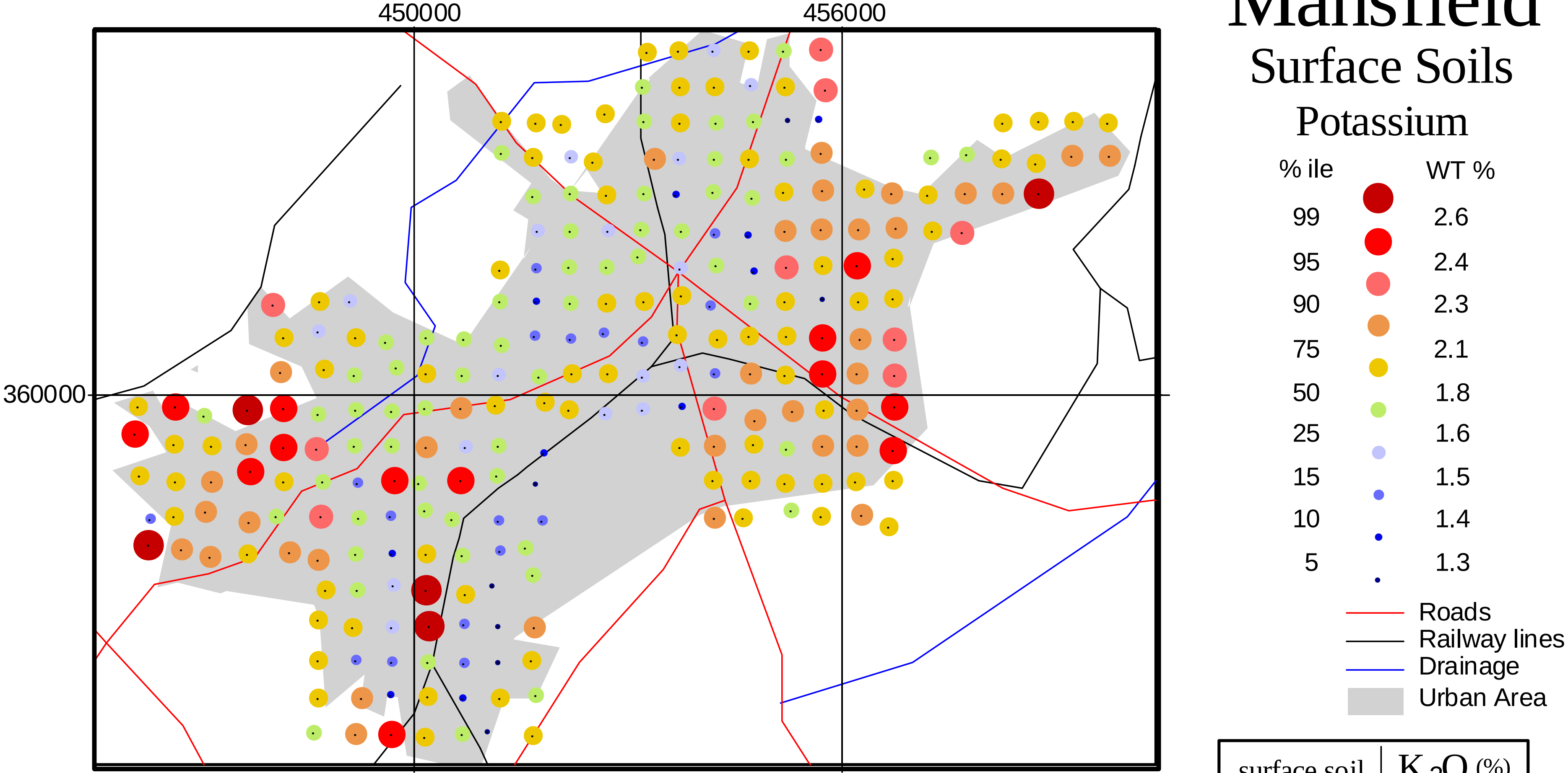

| surface soil | $P_2O_5$ (%) |
|---|---|
| number | 257 |
| minimum | 0.05 |
| maximum | 1.21 |
| median | 0.27 |
| mean | 0.32 |

Phosphorus was not determined in the profile soils

# Mansfield

## Surface Soils

### Potassium



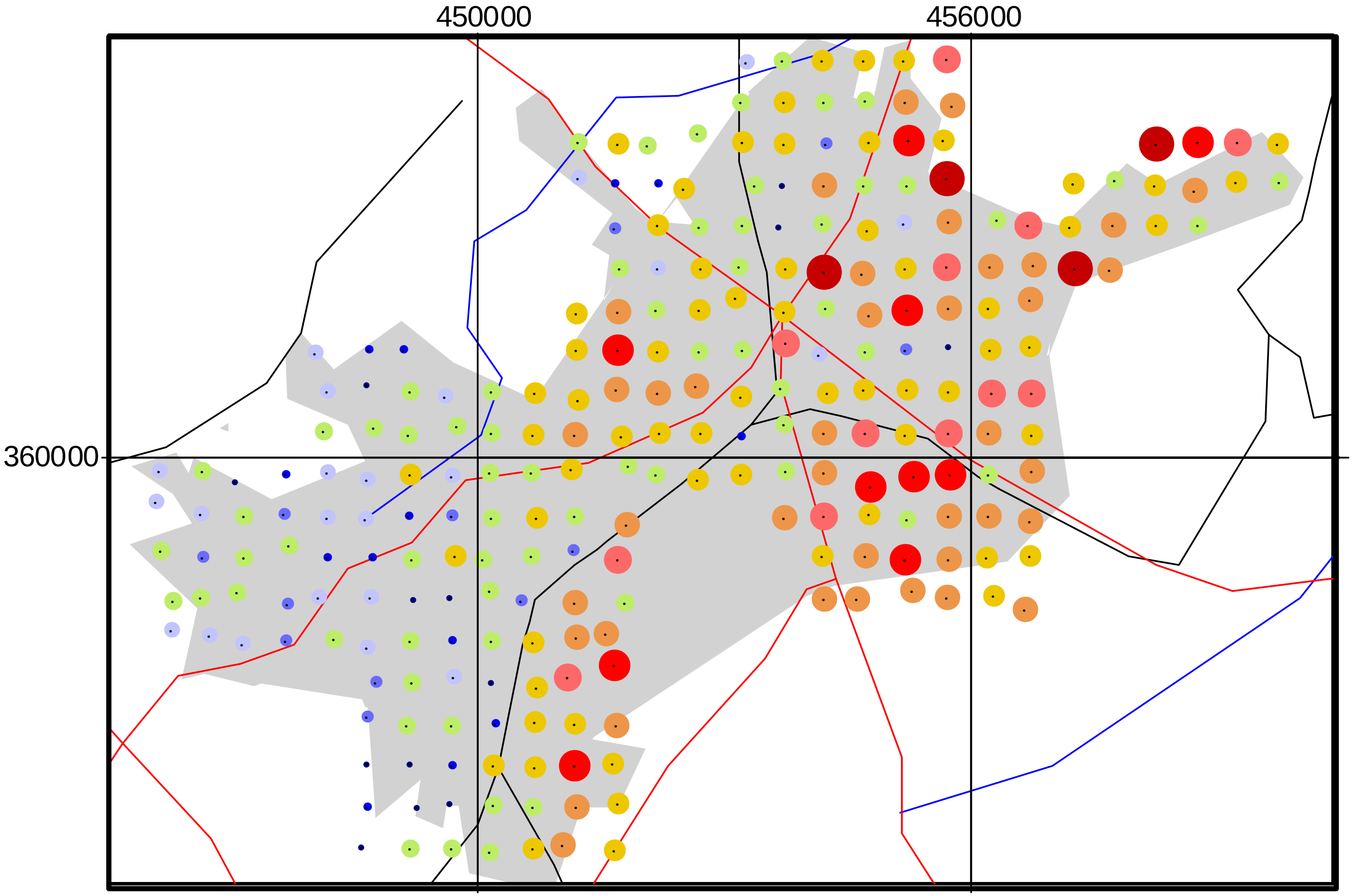

| surface soil | $K_2O$ (%) |
|---|---|
| number | 257 |
| minimum | 1.1 |
| maximum | 3.5 |
| median | 1.8 |
| mean | 1.8 |

Potassium was not determined in the profile soils

# Mansfield

## Surface Soils

### Silicon




| % ile | WT % |
|---|---|
| 99 | 77.0 |
| 95 | 73.9 |
| 90 | 72.5 |
| 75 | 69.0 |
| 50 | 63.1 |
| 25 | 54.1 |
| 15 | 51.5 |
| 10 | 49.8 |
| 5 | 44.9 |

Roads
Railway lines
Drainage
Urban Area

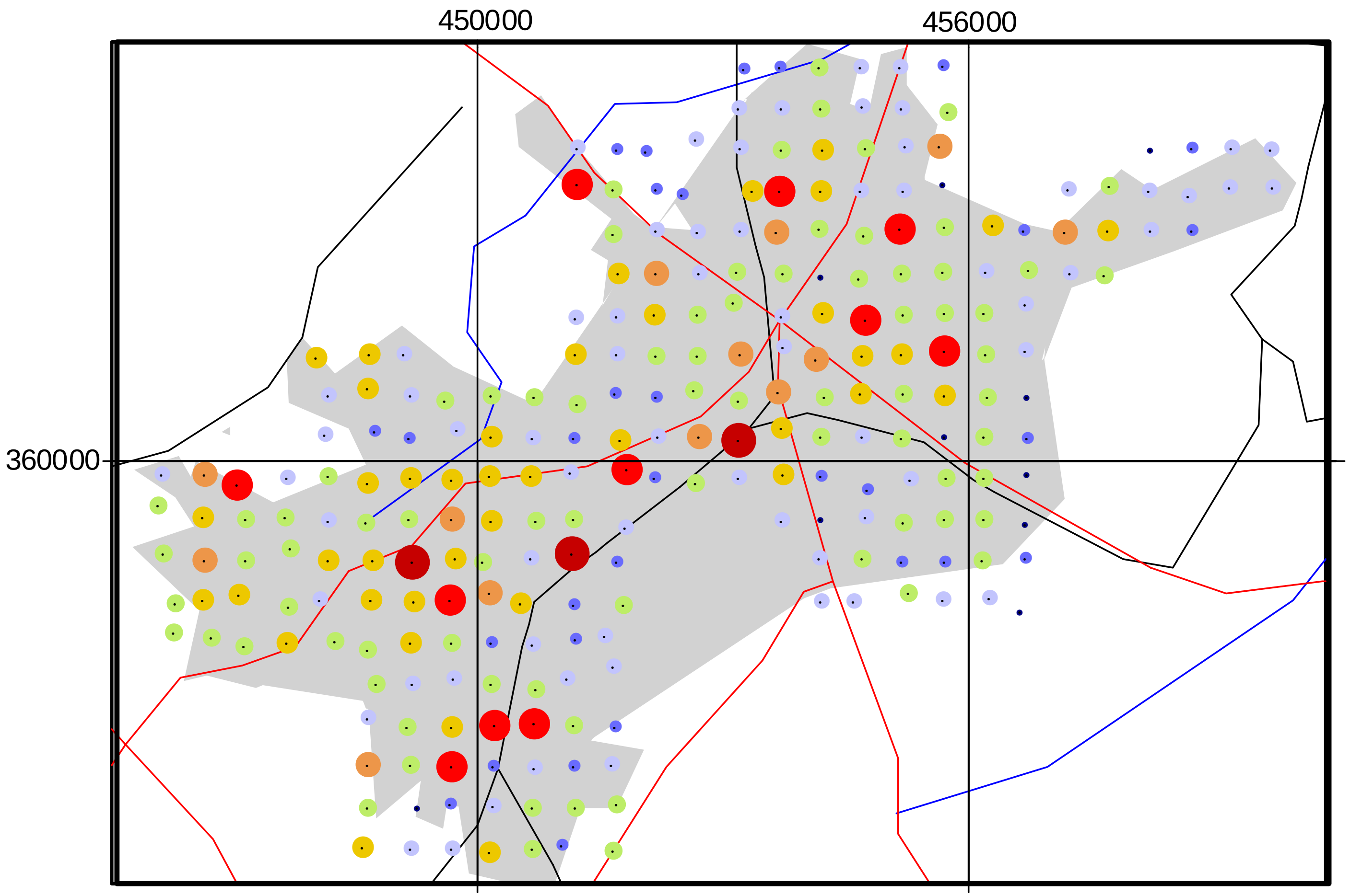
| surface soil | $SiO_2$ (%) |
|---|---|
| number | 257 |
| minimum | 26.2 |
| maximum | 79.2 |
| median | 63.1 |
| mean | 61.5 |

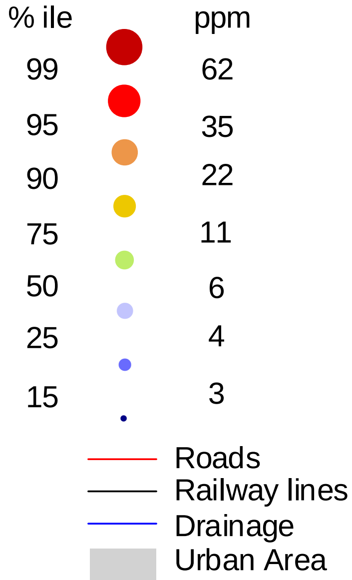
Silicon was not determined in the profile soils

# Mansfield

## Surface Soils

### Tin



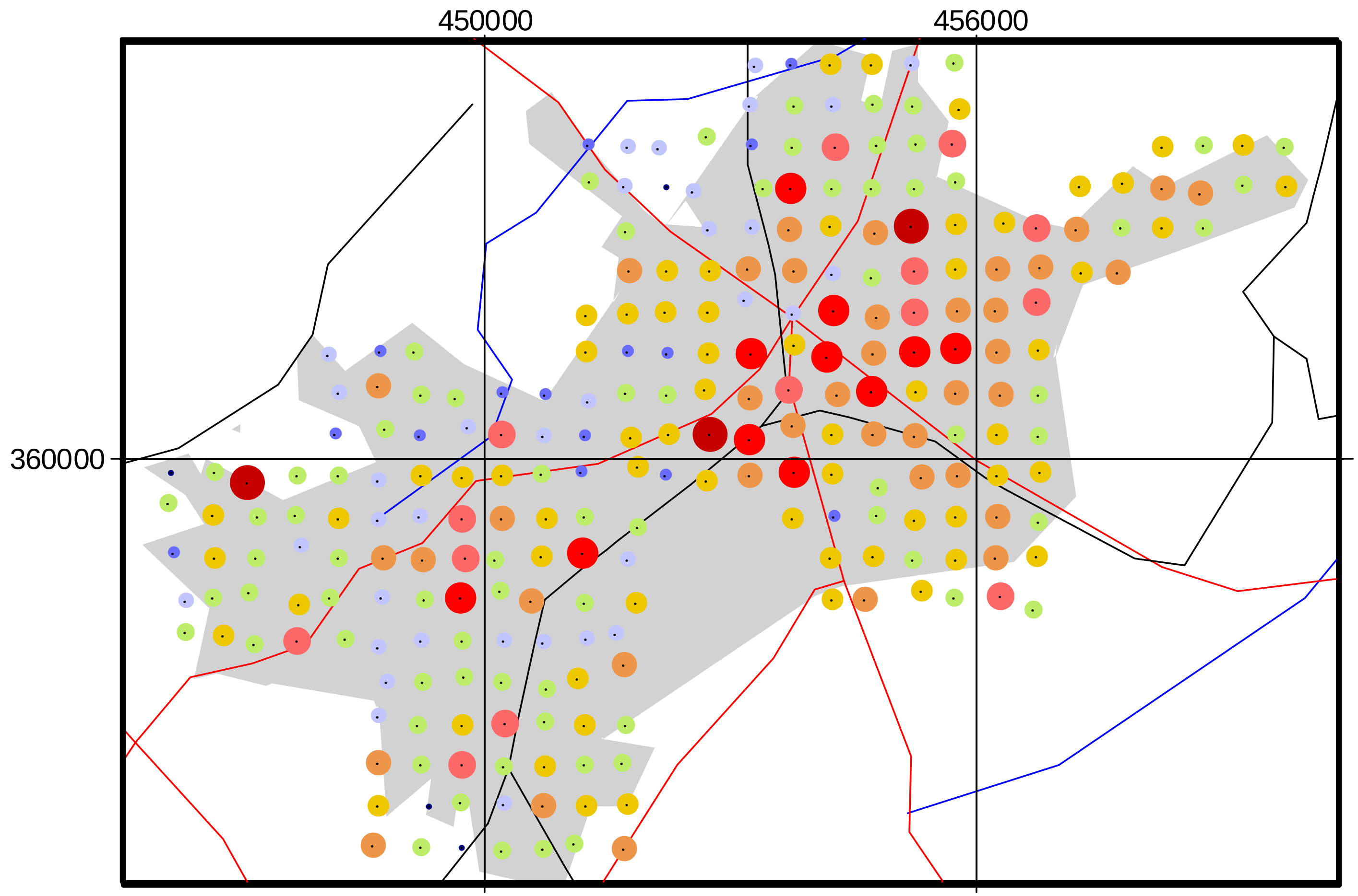



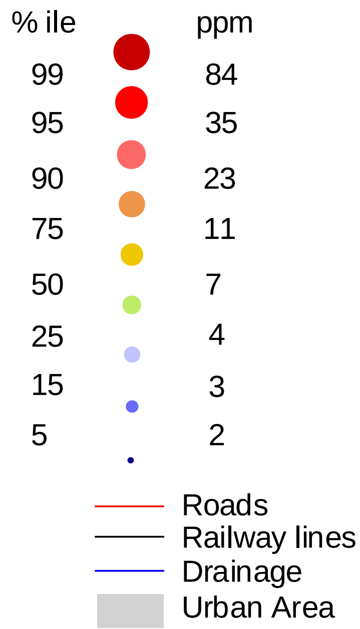

| surface soil | Sn (ppm) |
|---|---|
| number | 257 |
| minimum | 1 |
| maximum | 209 |
| median | 6 |
| mean | 11 |

# Mansfield

## Profile Soils

### Tin



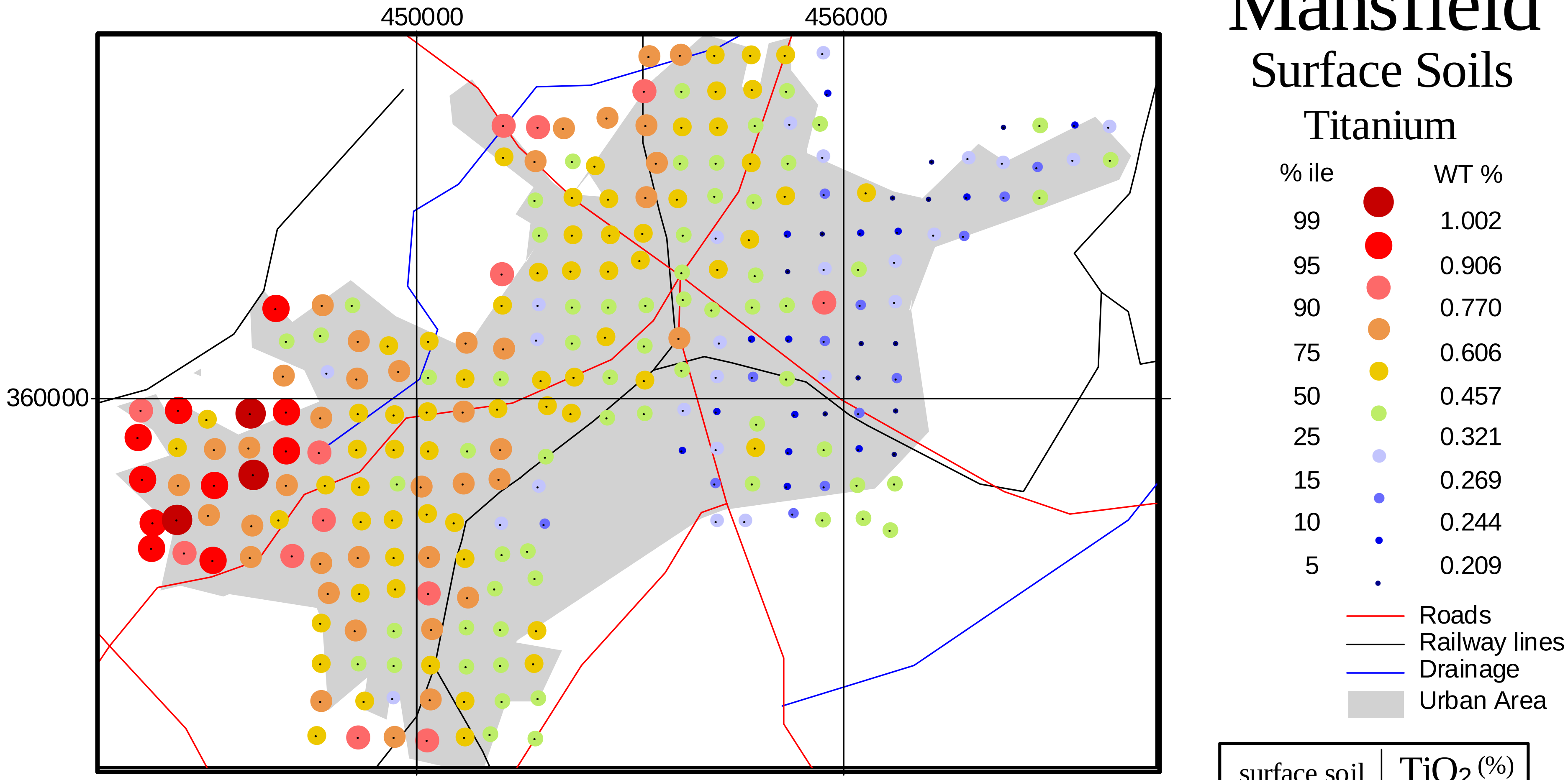




| profile soil | Sn (ppm) |
|---|---|
| number | 256 |
| minimum | 1 |
| maximum | 536 |
| median | 7 |
| mean | 13 |

# Mansfield

## Surface Soils

### Titanium

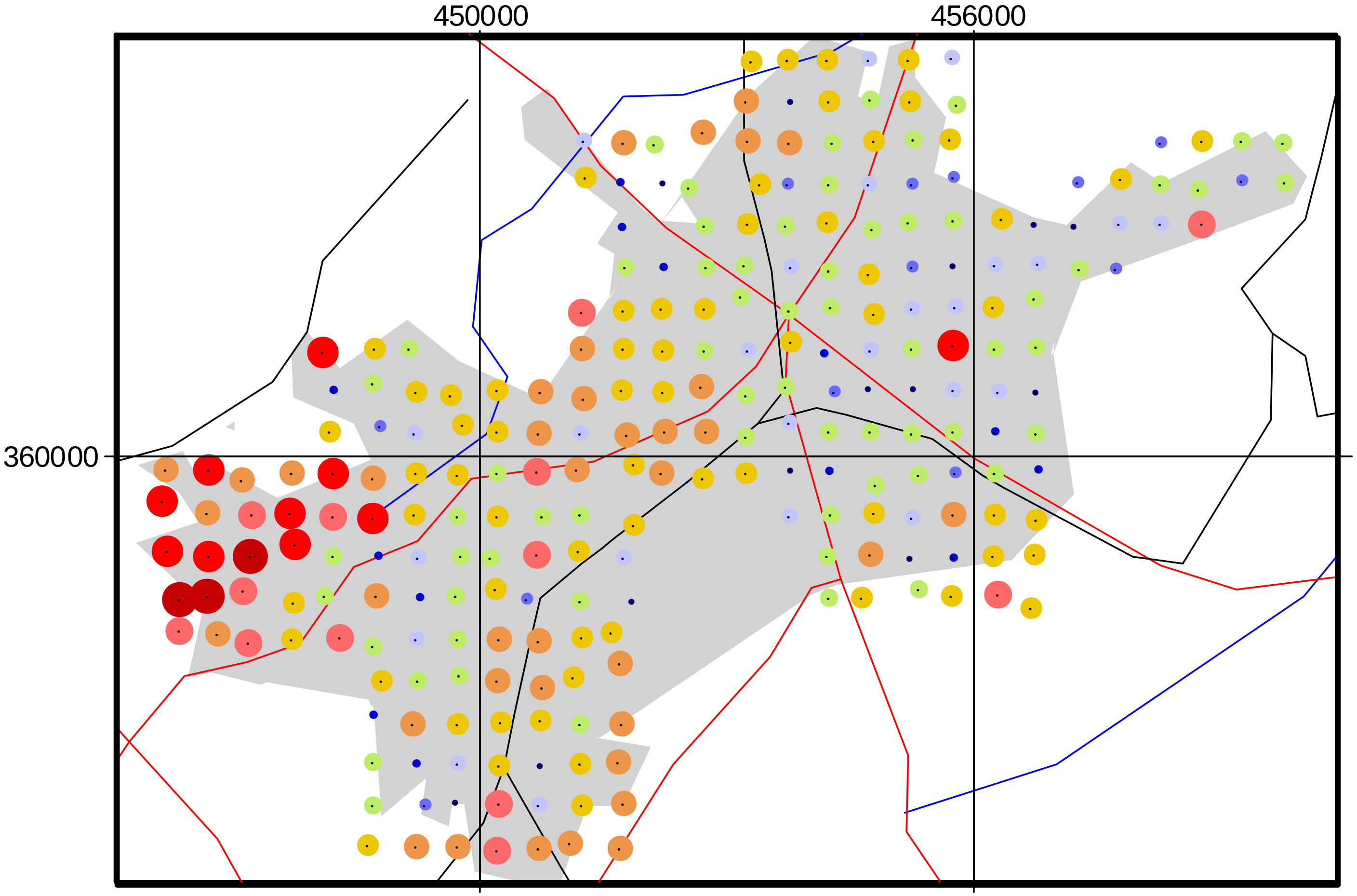



| surface soil | $TiO_2$ (%) |
|---|---|
| number | 257 |
| minimum | 0.158 |
| maximum | 1.116 |
| median | 0.457 |
| mean | 0.484 |

# Mansfield

## Profile Soils

### Titanium




| % ile | WT % |
|---|---|
| 99 | 0.953 |
| 95 | 0.867 |
| 90 | 0.820 |
| 75 | 0.698 |
| 50 | 0.590 |
| 25 | 0.503 |
| 15 | 0.448 |
| 10 | 0.430 |
| 5 | 0.399 |

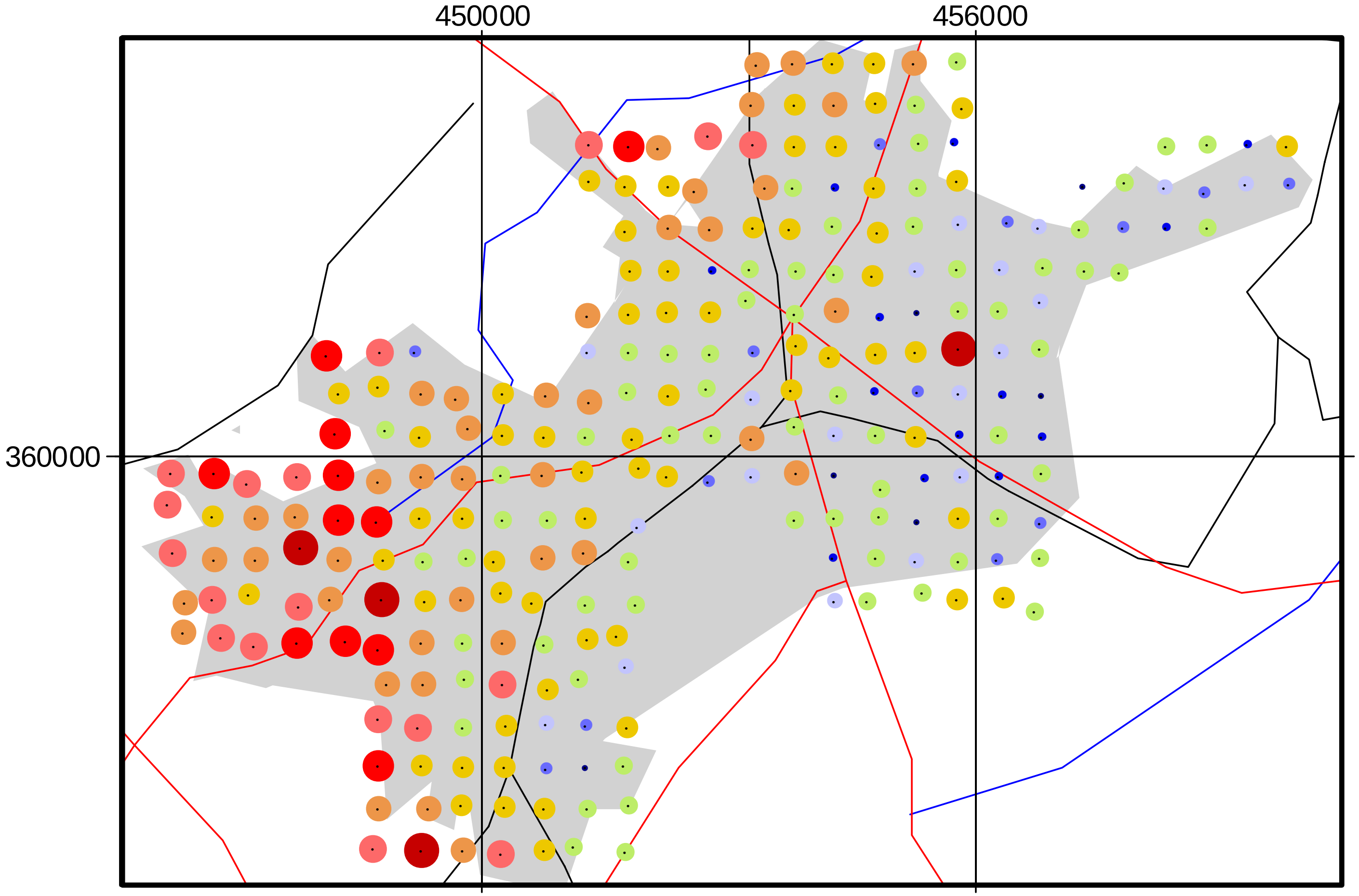
Roads
Railway lines
Drainage
Urban Area

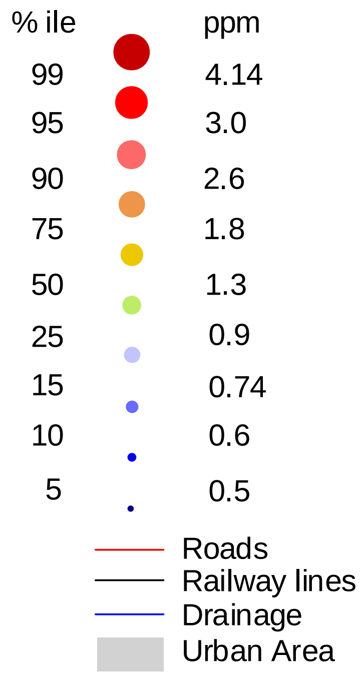
| profile soil | $TiO_2$(%) |
|---|---|
| number | 256 |
| minimum | 0.244 |
| maximum | 1.045 |
| median | 0.590 |
| mean | 0.605 |

# Mansfield

## Surface Soils

### Uranium



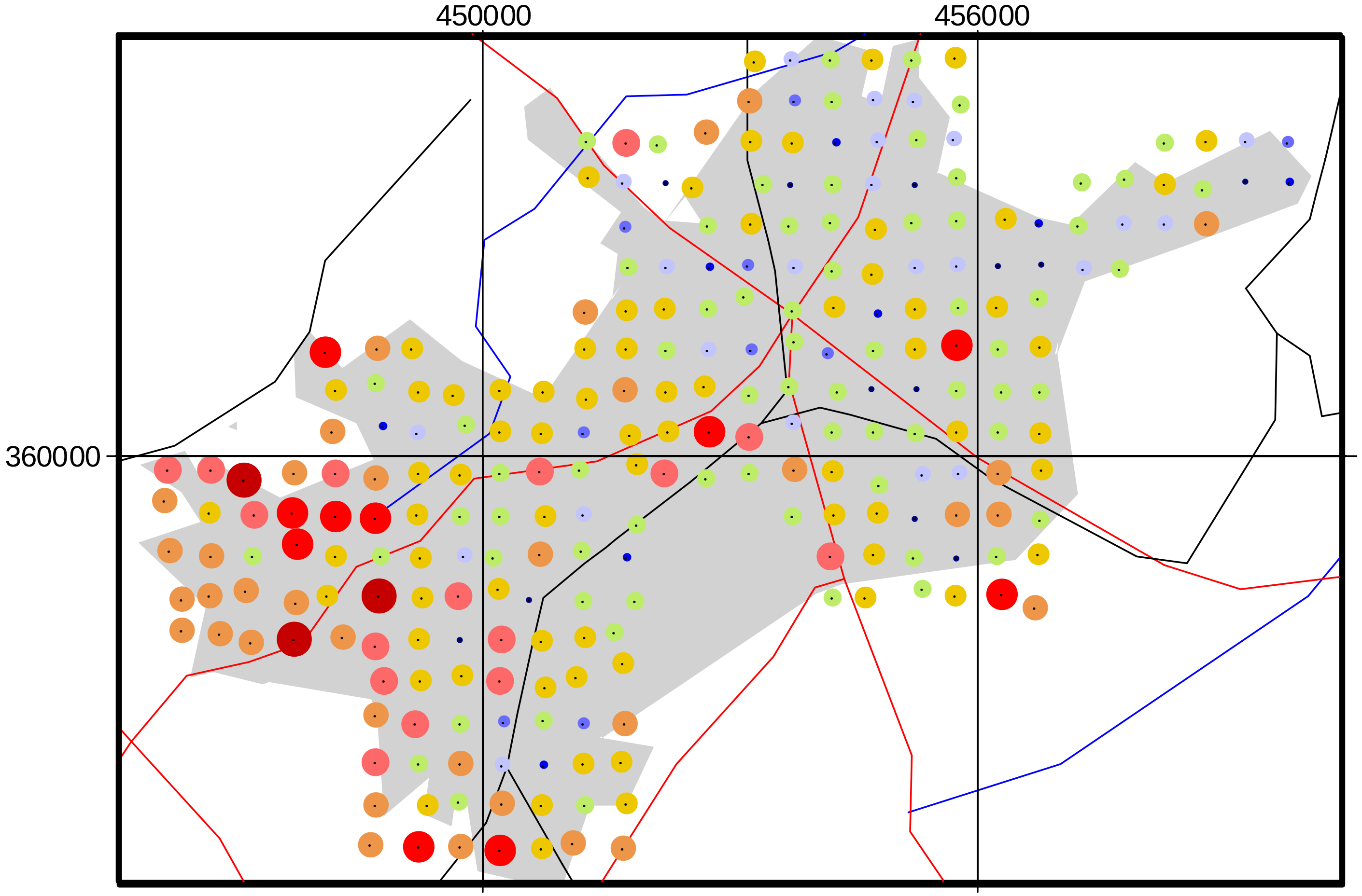

| profile soil | U (ppm) |
|---|---|
| number | 256 |
| minimum | 0.25* |
| maximum | 4.7 |
| median | 1.3 |
| mean | 1.48 |

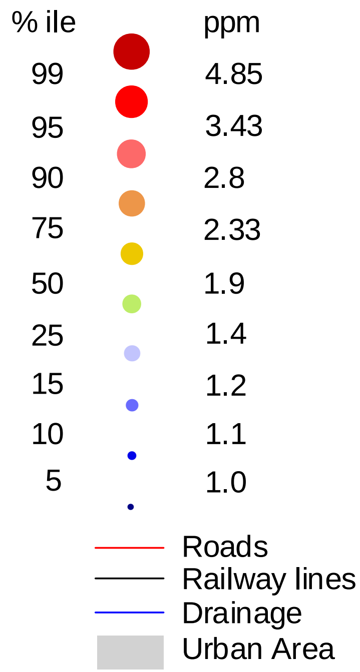
* minimum value reported as half detection limit

# Mansfield

## Profile Soils

### Uranium



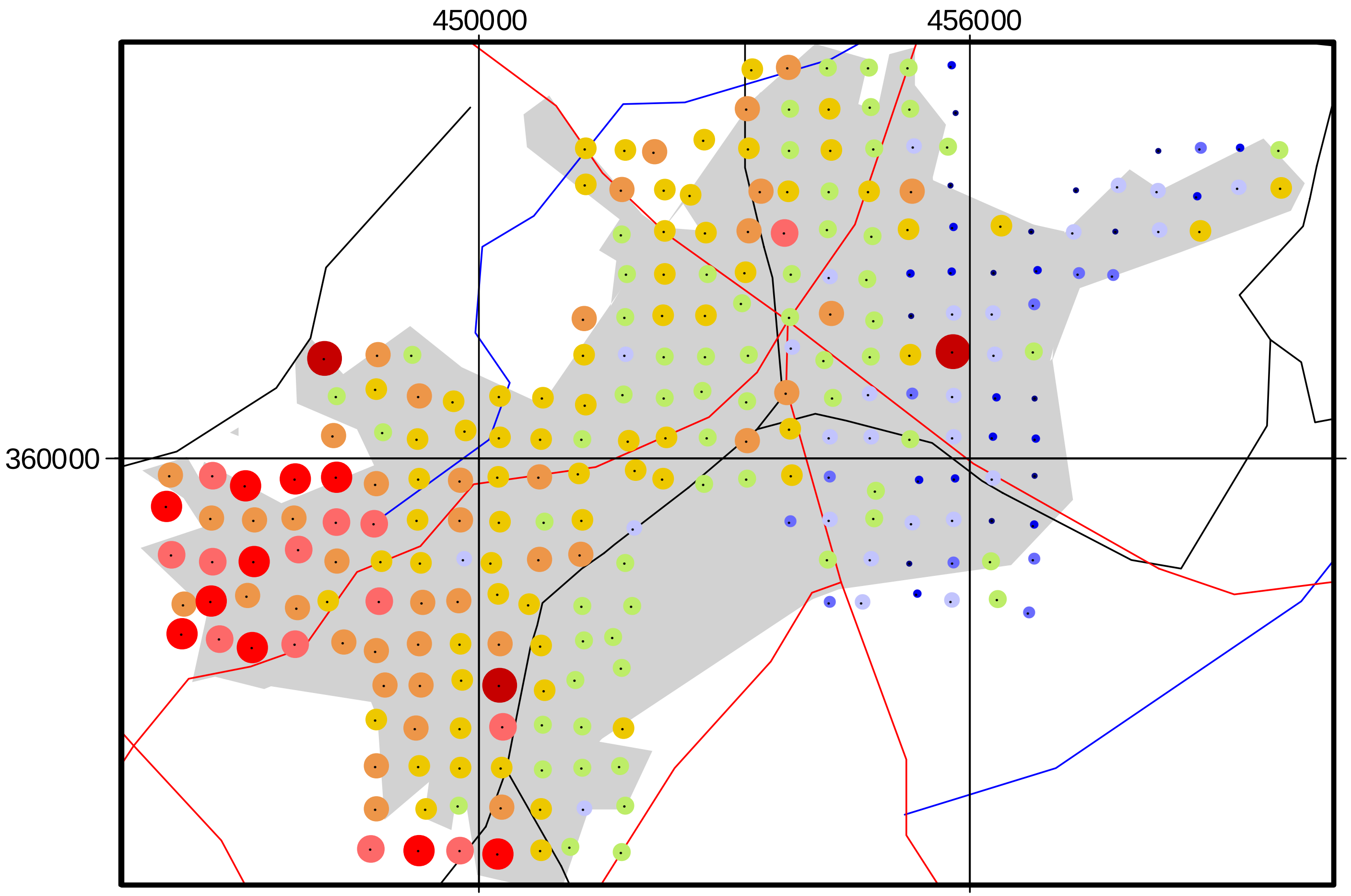

| profile soil | U (ppm) |
|---|---|
| number | 256 |
| minimum | 0.25* |
| maximum | 5.5 |
| median | 1.9 |
| mean | 1.95 |

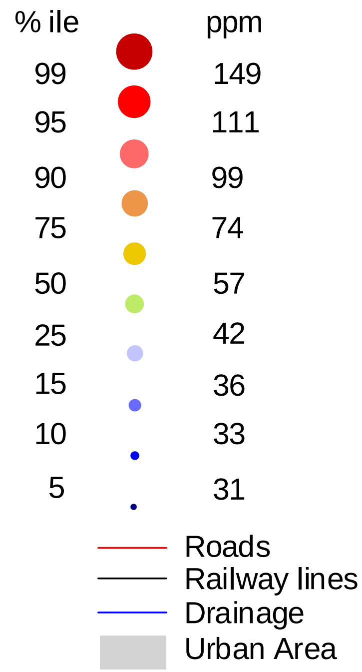
* minimum value reported as half detection limit

# Mansfield

## Surface Soils

### Vanadium



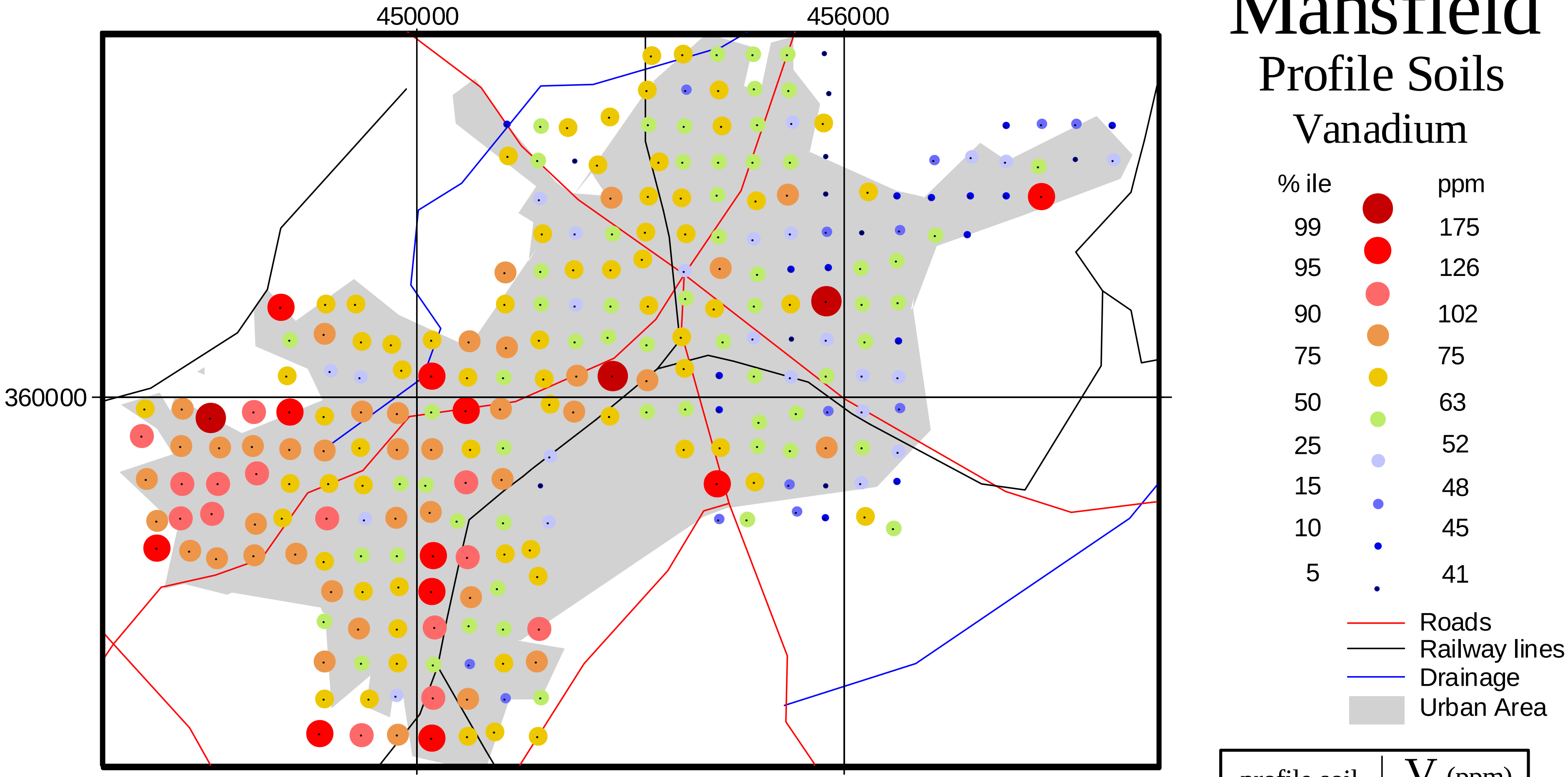




| surface soil | V (ppm) |
|---|---|
| number | 257 |
| minimum | 24 |
| maximum | 257 |
| median | 57 |
| mean | 62 |

# Mansfield

## Profile Soils

### Vanadium

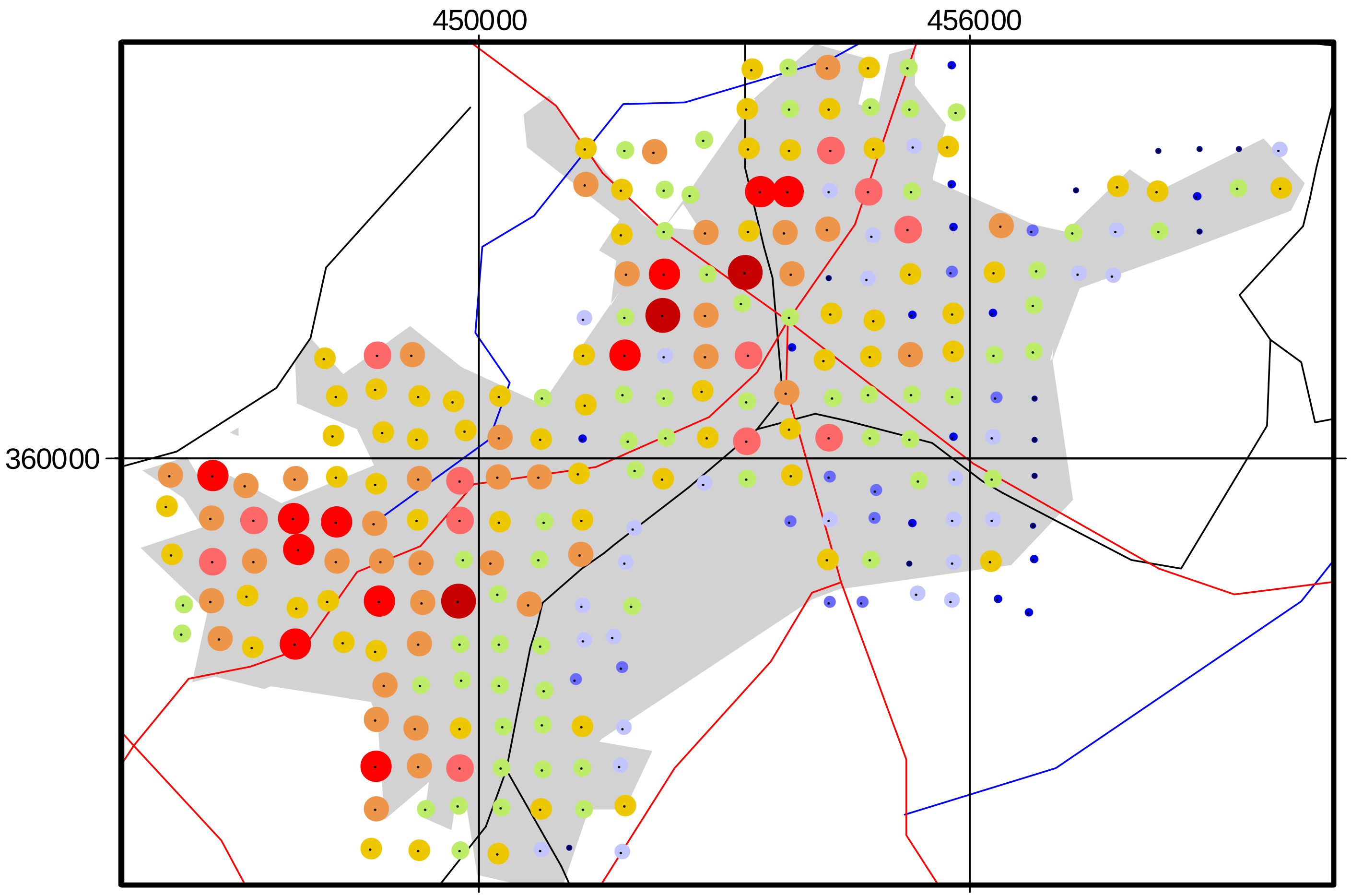



| profile soil | V (ppm) |
|---|---|
| number | 256 |
| minimum | 33 |
| maximum | 264 |
| median | 63 |
| mean | 70 |

# Mansfield

## Surface Soils

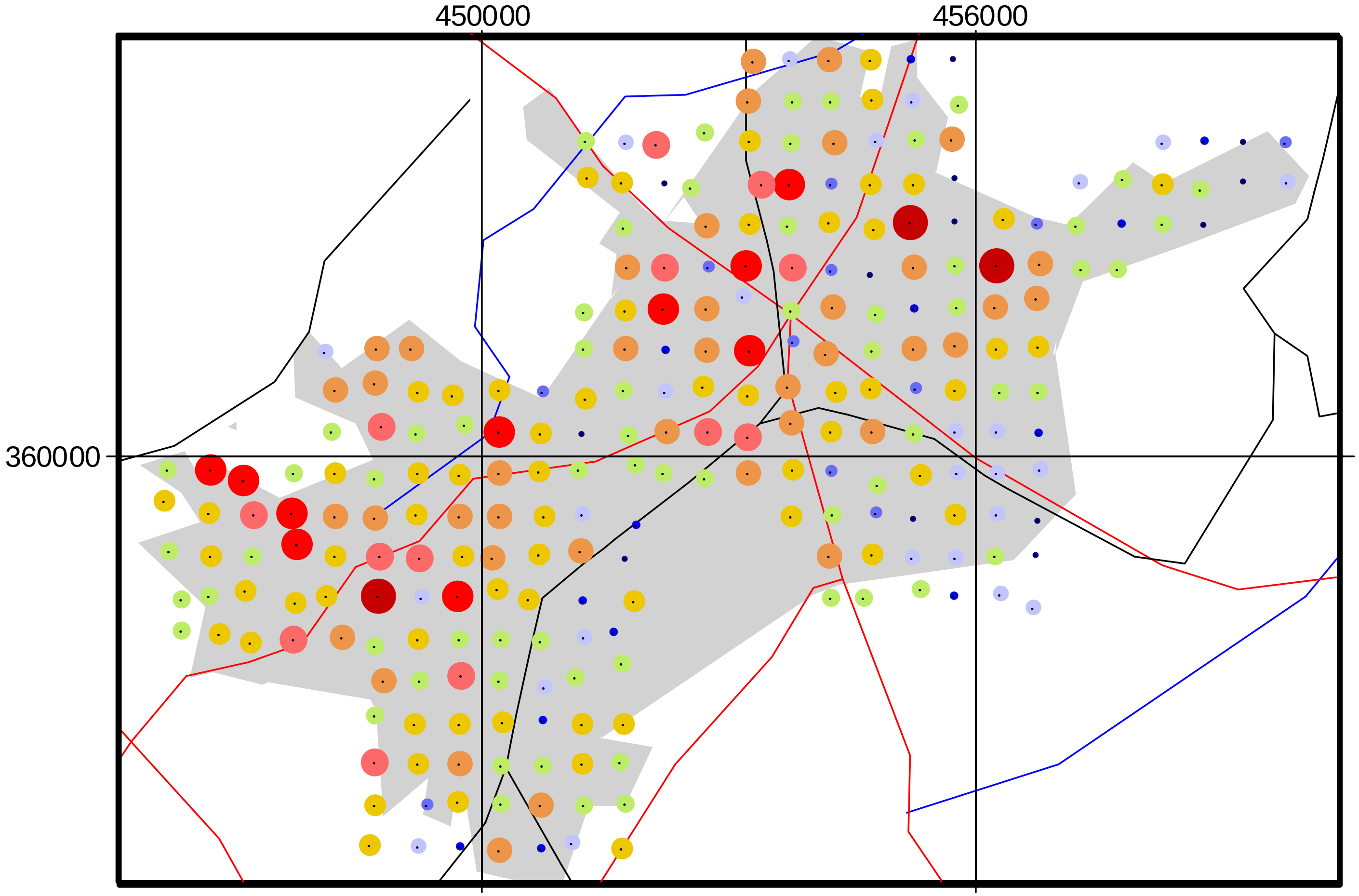
### Zinc




| % ile | ppm |
|---|---|
| 99 | 739 |
| 95 | 454 |
| 90 | 309 |
| 75 | 194 |
| 50 | 112 |
| 25 | 69 |
| 15 | 46 |
| 10 | 40 |
| 5 | 31 |

Roads
Railway lines
Drainage
Urban Area

| surface soil | Zn (ppm) |
|---|---|
| number | 257 |
| minimum | 13 |
| maximum | 1153 |
| median | 24 |
| mean | 41 |




# Mansfield

## Profile Soils

### Zinc

| % ile | ppm |
|---|---|
| 99 | 919 |
| 95 | 449 |
| 90 | 323 |
| 75 | 170 |
| 50 | 109 |
| 25 | 71 |
| 15 | 56 |
| 10 | 52 |
| 5 | 43 |

Roads
Railway lines
Drainage
Urban Area

| profile soil | Zn (ppm) |
|---|---|
| number | 256 |
| minimum | 22 |
| maximum | 4126 |
| median | 109 |
| mean | 172 |