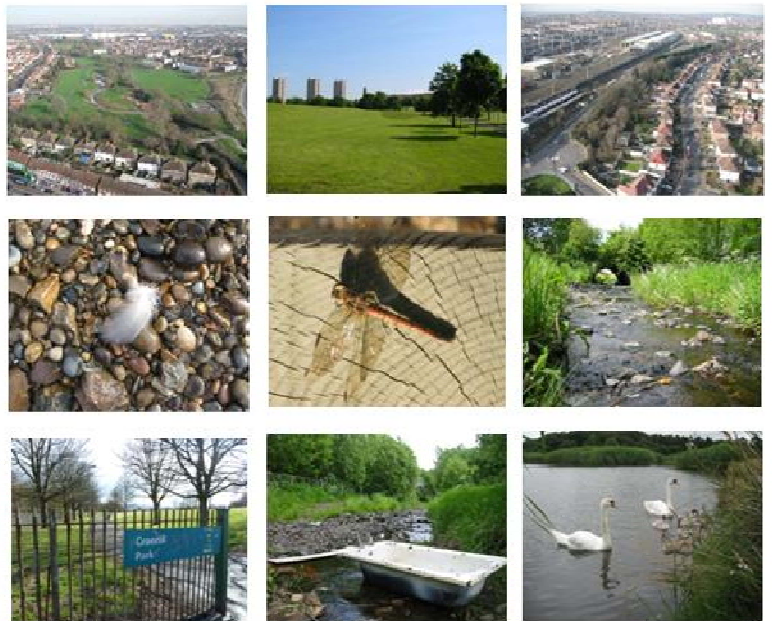


A Critical Review Of Urban Diffuse Pollution Control: Methodologies To Identify Sources, Pathways And Mitigation Measures With Multiple Benefits

Stage 3 A Case Study to Identify Urban Diffuse Pollution in the Light Burn Catchment, Glasgow, UK





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EXECUTIVE SUMMARY

Background to Research

On behalf of the Scottish Government, the Centre for Expertise for Waters (CREW) commissioned 'A critical review of urban diffuse pollution control: Methodologies to identify sources, pathways and mitigation measures with multiple benefits'. The project was carried out in three stages:

1. A critical review of available methods for identification of sources and pathways of diffuse pollutants in urban environments
2. A critical review of mitigation measures, from source to end of pipe, for diffuse pollution prevention, and an assessment of their multiple benefits
3. A case study of a typical Scottish urban environment, utilising available information of pollutant sources and geographical details, incorporating scenario testing of sustainable mitigation measures and their multiple benefits.

This report presents the case study, based on existing information, to assess urban diffuse pollution sources and pathways in a stream catchment in a typical Scottish urban environment.

Objectives of Research

The aim of the investigation into soil and stream quality in the case study catchment was to identify diffuse pollution sources, pathways and impacts on surface water courses, and highlight areas where procedures for determining suitable mitigation measures could be tested. Elements of this desk study were undertaken at an early stage in the project and findings used to support research for Stages 1, 2 and 3 of the project.

The Light Burn catchment in the east of Glasgow was chosen as the case study area because:

- (i) a number of diffuse pollution mitigation measures had been applied previously in the catchment
- (ii) data on stream sediment, stream water and soil quality were available for the catchment
- (iii) the catchment represents a typical formerly heavily industrialised, currently mixed land use urban catchment that includes major roads, railways, residential areas and industrial/commercial areas
- (iv) the catchment contains a variety of locations where the strategies to determine diffuse pollution mitigation measures developed in Stage 1 and Stage 2 of the project could be trialled

A number of example pollutants were selected for the study from existing stream sediment/water and soil chemical datasets. These included heavy metals such as antimony, cadmium, chromium and zinc; indicator diffuse pollutants - nitrate and phosphate; ammonium as a marker of cross-contamination from the sewerage network; and persistent organic pollutants. Possible sources of these pollutants in the catchment were assessed with reference to current and historic Ordnance Survey land use maps.

Key Findings and Recommendations

A wide range of potential sources of pollution exist within the Light Burn Catchment, which have the potential to impact negatively on surface and ground water quality. These relate to both historical and current land use activities.

In general, concentrations of pollutants are higher in water and sediments in the middle-lower reaches of the catchment than in the upper catchment. This section of the catchment was home to metal forges, chemical works, brick works, engineering works, railway works and factories in the past. This industrial heritage almost certainly contributes to diffuse pollution in the catchment today.

Other possible sources of diffuse pollution include the road network, which affects soil and sediment quality at several locations in the upper catchment; the presence of made ground influencing soil quality in the south of the catchment and cross-contamination from the sewerage network affecting water quality at one location in the upper catchment. In addition, an area of made ground containing waste from a former chromium works has a detrimental impact on sediment and water quality in the Light Burn.

Due to the range of potential pollutants and the complexity of the land use and ground conditions across the catchment, a range of pollutant pathways are likely to be operating. These may include:-

- Surface runoff of waters (over polluted surfaces) discharging to the Light Burn,
- Migration of polluted groundwaters/liquids via granular soils/ground into the Light Burn,
- Atmospheric deposition of particulates directly into Light Burn; and,
- Discharge of polluted wastewater/sewage into Light Burn via sewerage network.

Associations between stream sediment, stream water, and soil quality are difficult to determine for most pollutants in the Light Burn catchment, but there is some evidence that sediment and water quality are related for antimony and chromium. Concentrations of antimony, chromium and zinc in soils are generally high in the catchment compared to typical concentrations in world soils.

Similarly the concentrations of most metals and polynuclear aromatic hydrocarbons (PAH) in stream sediment exceed sediment quality guidelines at most sample locations. However, only ammonium, cadmium, chromium, and phosphate in stream water exceed the UK freshwater water quality guidelines.

Some of these locations provided opportunities to test diffuse pollution mitigation strategies, and these were examined in more detail in the Stage 3 project report.

Key words

Urban diffuse pollution, sediment, water, soil quality

1.0 INTRODUCTION

In 2012 the Scottish Government via the Centre of Expertise for Waters (CREW) commissioned 'A critical review of urban diffuse pollution control: Methodologies to identify sources, pathways and mitigation measures with multiple benefits'. The project is being carried out by a consortium of research providers including:

University of Abertay, Dundee (Project Leader)
The James Hutton Institute (JHI), Aberdeen
British Geological Survey (BGS), Edinburgh
Middlesex University, London
University of Dundee
Creative Drainage

The project involves three stages:

Stage 1: A critical review of available methods for identification of sources and pathways of diffuse pollutants in urban environments, including a research summary.

Stage 2: A critical review of mitigation measures, from source to end of pipe, for diffuse pollution prevention, and an assessment of their multiple benefits.

Stage 3: A case study of a typical Scottish urban environment, utilising available information of pollutant sources and geographical details, incorporating scenario testing of sustainable mitigation measures and their multiple benefits.

This report is the BGS contribution to Stage 3. A case study of a typical Scottish urban environment is presented. The report documents work to identify and characterise urban diffuse pollution sources and pathways in a stream catchment in Glasgow based on existing information. The findings of this report have been used to support research for stages 1, 2 and 3 of the project.

1.1 Light Burn, Glasgow Case Study Catchment

The Light Burn catchment in the east of Glasgow was chosen as the case study area for the project because:

- (i) a number of diffuse pollution mitigation measures had been applied previously in the catchment
- (ii) data on stream sediment, stream water and soil quality were available for the catchment
- (iii) the catchment represents a typical formerly heavily industrialised, currently mixed land use urban catchment that includes major roads, railways, residential areas and industrial/commercial areas
- (iv) the catchment contains a variety of locations where the strategies to determine diffuse pollution mitigation measures developed in Stage 1 and Stage 2 of the project could be trialled

Figure 1 shows the extent of the Light Burn case study area selected for the project, which comprises the catchments of three streams – the Light Burn, the Camlachie Burn and the Carntyne Burn in the east of Glasgow. According to information from Glasgow City Council, these streams do not appear at surface, but are culverted for the majority of their length.

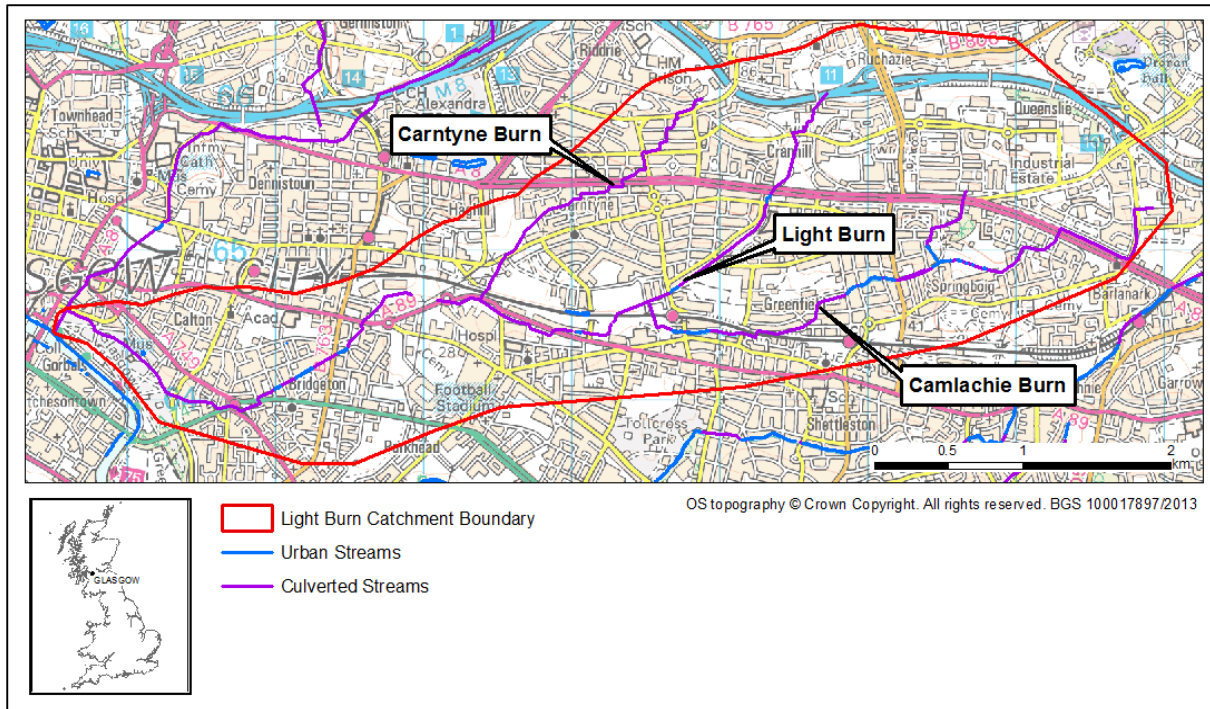


Figure 1. Map showing the location of the Light Burn case study catchment in the east of Glasgow

Present land use in the catchment mainly comprises residential areas, but also includes parks and recreational grounds, such as Cranhill Park in the north and the Parkhead football stadium in the south. The catchment also contains two hospitals, Light Burn Hospital in the upper catchment, and Parkhead Hospital in the south, as well as a number of schools and cemeteries. Retail parks and industrial sites predominate in the lower section of the catchment; especially along the route of the Glasgow – Coatbridge railway line. The upper portion of the catchment includes a section of the M8 motorway. Most of the catchment is urbanised with buildings, roads and impervious surfaces covering most of the land area, punctuated by parks and green spaces. In addition to present day inputs, former industries and land uses have left a legacy of land contamination, which contributes to diffuse pollution of the local ground and surface water.

Historically, this area was a powerhouse of heavy industry during the 18th – 20th centuries. From the 1700s onwards Bridgeton–Calton was a centre of cloth making, weaving, dying, leather and carpet making (Templeton’s Carpet Factory), and in the early 20th century of motor car manufacture (Glasgow City Council, 2013). Much of the heavy industry was centred on the railway line and included the William Beardmore and Company Parkhead Forge, closed in 1976. Parkhead Forge was the largest steelworks in Scotland and employed over 20 000 people at its peak (Glasgow City Archives, 2013). Today, this vast site has been redeveloped as the Forge Shopping Centre and Retail Park in the south of the catchment. The Queenslie Industrial Estate in the east of the catchment has been in operation since 1948. At that time, it was built on farmland that gradually became surrounded by housing. In the middle of the 20th century it became a centre for factories turning out a variety of products including Olivetti typewriters, miners' lamps, clothing, car springs, household goods and gas meters (Glasgow City Archives, 2013). Today, it is home to a variety of light industries including storage companies, car hire, food suppliers and soap making.

The catchment is underlain by Carboniferous age coal bearing rocks that were mined historically via numerous pits including the Queenslie Colliery (Hall et al., 1998). In addition, portions of the catchment are underlain by made ground particularly along the railway line and the M8 corridor (Figure 2). This

includes an area known by Glasgow City Council to contain chromite waste from the former JJ White’s chromite chemical works that was located in Rutherglen in south-east Glasgow. During the 19th and early 20th centuries this was the largest chromite ore processing plant in the world until it closed in 1968. Waste material from the plant was used for landfill in a variety of locations across Glasgow in the days before problems with pollution and the need for environmental regulation were known. The waste is highly alkaline and contains elevated concentrations of calcium, chromium, cobalt, iron, magnesium and nickel (Farmer et al., 1999; Farmer and Jarvis, 2009; Fordyce et al., 2012). Extremely high concentrations of up to 4363 mg/kg Cr are reported in soils from the Rutherglen area (Fordyce et al., 2012).

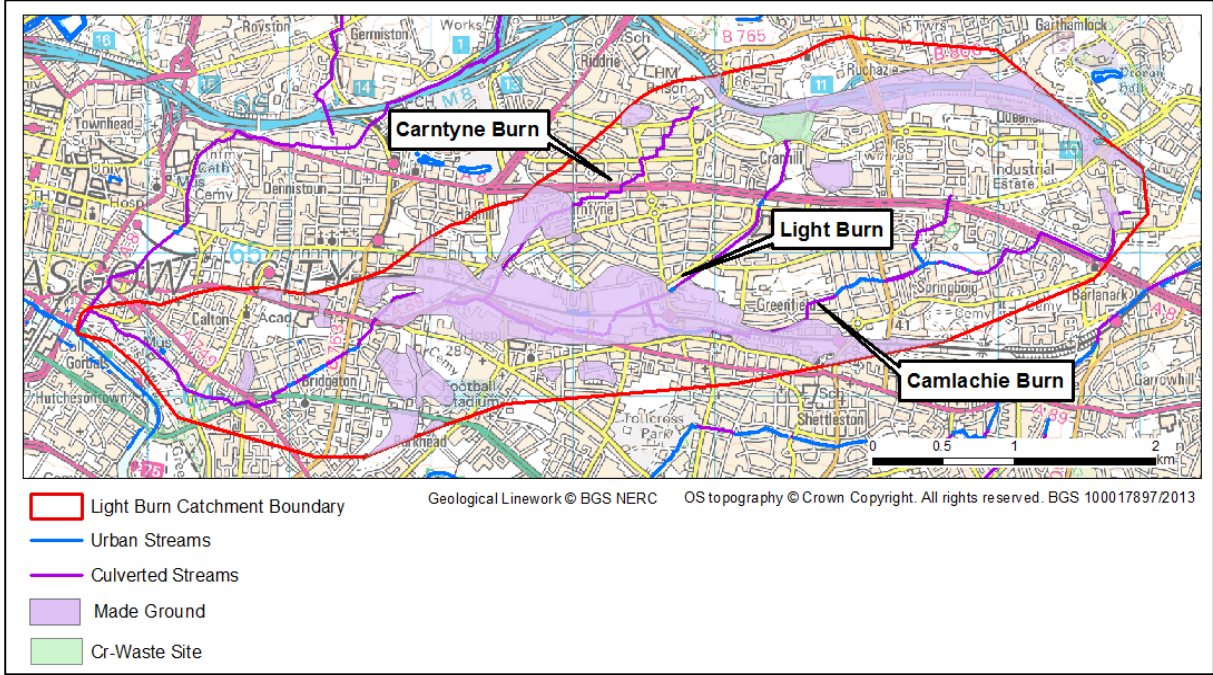


Figure 2. Location of made ground (> 3 m thick) in the Light Burn catchment

The aim of the case study investigation into soil and stream quality in the catchment was to identify diffuse pollution sources, pathways and impacts to highlight areas where procedures for determining suitable mitigation measures could be tested. The focus of this investigation was on impacts on surface water quality. It was beyond the scope of this study to examine groundwater quality, but it should be noted that groundwater and surface water are inextricably linked and polluted groundwater can have a significant impact on surface water quality, particularly during periods of low rainfall where streams are in baseflow condition fed by groundwater sources. There is a lack of readily available information on groundwater quality in Glasgow and the other Scottish cities. Much of the information that has been collected is stored in paper or pdf format in site investigation reports held by Scottish Local Authorities. The BGS and Glasgow City Council are aiming to address the lack of information in Glasgow by establishing an urban groundwater monitoring network (Bonsor et al., 2010).

2.0 MATERIALS AND METHODS

2.1 Rationale

Following the methods recommended in Stage 1 of this project, diffuse pollution impacts in the Light Burn catchment were assessed using current and historic land use information, and data on the soil, stream sediment and stream water quality in the catchment.

2.2 Data Sources

Three main sources of information were used to assess diffuse pollution impacts in the Light Burn catchment, Ordnance Survey (OS) current and historic topographic maps; Glasgow soil chemical quality data; and Clyde tributaries stream sediment and water quality data.

2.2.1 *Ordnance Survey Current and Historic Topographic Maps*

Present day 1: 50 000 scale topographic maps were used to provide information on current land use in the catchment (see for example Figure 1). Previous land use was also assessed from 1:10 000 scale historic topographic maps dating from 1845 – 1951 where the type of industry present was often documented. Digital versions of these maps are available under licence from the OS. The majority of environmental consultancy, regulatory, academic and local authority bodies likely to be carrying out assessments of urban diffuse pollution will have licensed access to these map resources.

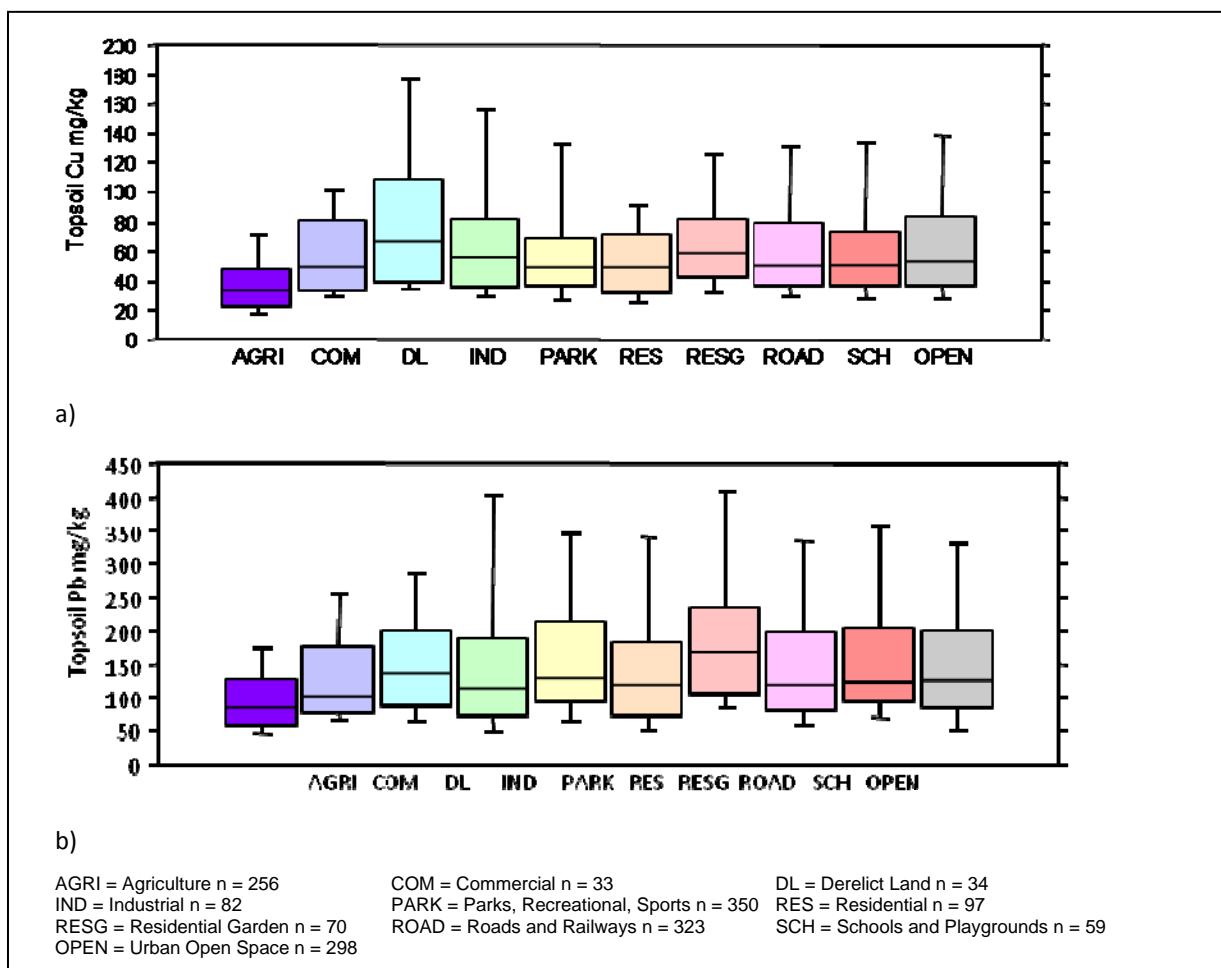
2.2.2 *Glasgow Soil Chemical Quality Data*

The BGS is responsible for the national strategic geochemical survey of the UK known as the Geochemical Baseline Survey of the Environment (G-BASE) project. This project provides information on the chemical quality of the UK surface environment and is based primarily on the collection of rural soil, stream sediment and water samples at a sample density of 1 per 2 km² across the country (Johnson et al., 2005). The samples are analysed for total concentrations of approximately 50 inorganic chemical elements, including potentially harmful elements such as heavy metals - arsenic, cadmium, chromium, nickel, lead and zinc. These elements occur naturally in the environment and are present in all materials on earth, including rocks, soils, waters and sediments. Their distribution in the surface environment is fundamentally controlled by the underlying geology and other factors such as climate, topography, vegetation and soil forming processes. In addition to natural sources of these elements, environmental concentrations can be enhanced by anthropogenic (human) activities such as mining, industrialisation, urbanisation and waste disposal. The distribution of these elements is of concern because although many are essential to life, at least 26 of the naturally occurring elements are potentially harmful to plants, animals and humans in high doses. Of further concern are the quantities of persistent organic pollutants (POP) in the environment, mainly of anthropogenic origin, many of which are detrimental to health. These include the polynuclear aromatic hydrocarbons (PAH) and the polychlorinated biphenyls (PCB) (Fordyce et al., 2012). Hence, there is a need to protect the environment from these pollutants.

Since 1991 the G-BASE project has been surveying the chemical quality of urban soils; to date it has covered 27 cities across the UK, including Glasgow (Fordyce et al., 2005; Flight and Scheib, 2011). The Glasgow Soil Survey was carried out during 2001 – 2002 and involved the collection of 1381 urban soil samples at a density of 1 per 500 m and 241 rural samples at a density of 1 per 2 km² on a systematic grid across the Glasgow conurbation. Top (5 – 20 cm) and deeper (35 – 50 cm) soil samples were collected using a hand held auger; each sample was a composite of five sub-samples collected from the

corners and centre of a 20 m square. Following air/oven drying and sieving to < 2 mm, the samples were analysed using X-ray Fluorescence Spectrometry (XRFs) to determine the total concentrations of approximately 50 inorganic chemical elements (Fordyce et al., 2012). The data provide an overview of soil quality across the Glasgow area and demonstrate the impact of the urban environment on soil quality. Concentrations of many metal elements including antimony, calcium, copper, lead, nickel, tin and zinc are 2 – 3.3 times higher in urban soils than in the surrounding rural soils (Fordyce et al., 2012).

Concentrations of these metals are also generally higher in industrial and derelict land and made ground than in other land use types in the city, reflecting the influence of anthropogenic pollution (Figure 3a). Antimony, arsenic, copper, lead, tin and zinc concentrations are also marginally higher in residential garden soils than in some other land use types. This may reflect historic dumping, and use as a soil conditioner, of domestic coal ash and the presence of household debris, such as fragments of glass, ceramics, bricks and paint in domestic garden soils (Figure 3b) (Fordyce et al., 2012). A sub-set of the Glasgow topsoil dataset was selected for the present study, comprising 48 samples located within the Light Burn catchment study area.



From: Fordyce et al. (2012) © BGS NERC

Figure 3. Box and whisker plots showing the 10th, 25th, 50th, 75th and 90th percentiles of a) copper and b) lead concentrations in different land uses in Glasgow topsoils

2.2.3 Clyde Tributaries Stream Sediment and Water Quality Data

During June 2003 a survey of urban stream sediment and water quality was undertaken as a co-funded programme between Glasgow City Council and the BGS G-BASE project. Known as the Clyde Tributaries

Project, this survey collected sediment and water samples from every kilometre of stream length on all tributaries draining into the River Clyde within the Glasgow City Council administrative area.

In total, 118 stream sediment and 122 stream water samples were collected from both surface and culverted sections of the streams. The sediment and water samples were collected from the same location, but in culverted stream sections no sediment was present for collection in some cases, hence the greater number of water than sediment samples.

The sediments were sieved to < 150 µm air and freeze dried and analysed by XRFs for approximately 50 total inorganic element concentrations. In addition, mercury was determined in < 2 mm sediment samples by Atomic Fluorescence Spectrometry (AFS). Concentrations of PAH were also determined on a selection of < 2 mm sediment samples by high performance liquid chromatography (HPLC) and fluorescence detection. Gas Chromatography Mass Spectrometry (GC-MS) was used to determine PCB concentrations on a smaller sub-set of the < 2 mm sediment samples.

The water samples were analysed using Inductively-Coupled Mass Spectrometry (ICP-MS) and ion chromatography for the total concentrations of approximately 50 inorganic chemical substances. In addition, mercury and selenium were determined in the waters by AFS. Ammonium was also determined using colorimetric methods (Fordyce et al., 2004).

The data provide information on the spatial distribution of these parameters in sediments and waters. Since sampling was carried out only once, no time-series monitoring data are available in the dataset. Whilst the geochemistry of sediment samples will remain fairly stable through time, the water data are a snap-shot as water chemistry can vary considerably depending on rainfall and flow rates, particularly during storm events that tend to mobilise pollutants in the water column (Neal et al., 1999). A sub-set of the Clyde Tributaries dataset was selected for the present study, comprising nine stream sediment and 11 stream water samples located within the Light Burn catchment study area.

2.2.4 Data Availability

The Glasgow conurbation is the only city in Scotland for which the G-BASE soil quality data are available. It is also the only city in the UK to have G-BASE-style urban sediment and water quality information. However, regulatory authorities such as the Scottish Environment Protection Agency (SEPA) and Scottish Local Authorities hold information on soil, surface water and sediment chemical quality as a consequence of monitoring programmes and numerous site investigations carried out during planning and development and urban regeneration. These data could be used for diffuse pollution assessments elsewhere.

2.3 Pollutants Selected for the Case Study

A number of example pollutants were selected for the study based on substances analysed in the G-BASE datasets, for which a UK Freshwater Environmental Quality Standard (EQS) has been proposed (UKTAG, 2008; CEC, 2008) or a Freshwater River Classification is available (EA, 2013a). Additional assessments of pollution were made with reference to the UK contaminated land exposure assessment (CLEA); generic soil guideline values (SGV) (EA, 2013b); and industry standard generic assessment criteria (GAC) guidelines (CL:AIRE, 2010).

Whilst these guidelines give an indication of environmental pollution, they are designed for the protection of human health, not surface water quality. The UK currently has no freshwater sediment chemical quality guidelines and so sediment quality in the catchment was assessed with reference to the Canadian sediment guidelines (MacDonald et al., 2000). The substances included in the assessment are outlined in Table 1, and data available in the G-BASE dataset in Table 2.

2.3.1 Metal Pollutants

Metal elements enter the urban environment from a number of sources, including industry, energy generation, transport, building materials and waste disposal. Domestic sources of pollutants include disposal of fossil fuel residues into domestic gardens (ash and soot), household refuse, bonfires and the application of phosphate fertilizers (cadmium and phosphate). Household waste waters can also contain high concentrations of metals, for example, arsenic is used in detergents. The demolition of properties, particularly older buildings, may lead to anthropogenic pollution with metals such as lead from paint and arsenic from bricks.

Urban sediments and soils act as sinks for anthropogenic materials and tend to contain fragments of metal, glass, ceramic, bricks/building rubble, plastic, paint, coal ash, etc. It is the experience of the G-BASE project that these materials are ubiquitous in the urban environment and affect soil and sediment quality. It is also the experience of the Clyde Tributaries survey that fly tipping in urban streams is a significant source of pollution. This was borne out during field visits to the Light Burn catchment for the present project.

Urban surface run-off waters often contain high concentrations of copper, lead and zinc and other compounds derived from road traffic sources. Lead was added to petrol historically, and other elements such as barium (added to diesel), platinum (used in catalytic converters) and zinc (from wear of vehicle tyres) can be enhanced in the urban environment as a result of vehicle usage.

Metal processing activities can result in the anthropogenic pollution of land and drainage systems via chimney emissions, liquid effluent, and the dumping and erosion of slag materials, as well as through the transport and spillage of metal concentrates. Historically, atmospheric emissions were large, but today emission levels depend on the technology employed in the plant, the composition of the raw materials and the pollution control system. Elevated levels of antimony, arsenic, cadmium, chromium, iron, lead, mercury, nickel, selenium and zinc are often recorded in the vicinity of metal processing plants.

Coal mines and power stations can contain elevated concentrations of metals. Drainage waters from old coal mines may be extremely acid due to the oxidation of sulphides and can contain high levels of arsenic, copper, iron, lead, manganese, nickel, zinc, and lead. Many industrial processes can give rise to anthropogenic pollution; as a general rule, the older the industry, the more likely it is to have produced substantial anthropogenic pollution of the local environment and nearby drainage systems.

Chemical works, gas works and oil refineries give rise to a wide range of pollutants in air, soil, sediment and waters including cadmium, chromium, lead, mercury, tin and zinc. Battery manufacture may generate waste rich in antimony, cadmium, mercury, nickel, phosphate and zinc. Waste-waters derived from paint and dye-stuff producers often contain elevated levels of antimony, cadmium, chromium, copper, lead, mercury and selenium from the pigments and raw materials of these industries.

Electrical and electronic industry waste can contain cadmium, copper, lead, selenium and zinc; antimony, cadmium, lead, tin and zinc are used in the manufacture of synthetic rubber and plastics as stabilisers and pigments. The leather and textile industries use chromates and dichromates to condition cloth, which can be sources of chromium. The glass and ceramic industries use antimony, chromium, cobalt, copper, iron, molybdenum, lead, selenium and titanium among other elements as pigments, glazes and conditioning agents. In summary, an extensive array of activities in urban environments form potential sources of anthropogenic pollution (Fordyce et al., 2012).

2.3.2 Nitrate, Phosphate and Ammonium – Diffuse Pollutant Indicators

Nitrate and phosphate were included in the study as these are typical diffuse pollutants of concern. They can lead to eutrophication of surface water resources, particularly in rural environments as a result of agricultural inputs. In urban areas, the use of fertilisers in gardens and parks/recreational areas are possible sources of these pollutants in urban water systems. Nitrate and ammonium are also indicative of cross-contamination from the sewerage network in urban drainage systems (Fordyce et al., 2004).

2.3.3 Persistent Organic Pollutants

Since the Industrial Revolution significant quantities of POP have been and are still polluting the environment. These include the PAH compounds that are natural constituents of oil, tar and coal. Incomplete combustion of fossil fuels, including oil, petrol/diesel, coal, gas and wood, represents the main source of environmental PAH but a petrogenic input of PAH from crude oil, coal or various refinery products can occur also. Pollution can result from direct spillage or by atmospheric fall out. Although in some cases petrogenic inputs can be natural, as in oil seepage from rocks at depth, more commonly it is anthropogenic, arising as a result of runoff, industrial and sewage discharges, transport activities and spillage. Possible sources of PAH include power generation, transport (roads, railways, petrol stations, etc), oil refineries, gasworks, mining, chemical industries, landfill sites, vehicle scrap yards, and motor vehicle maintenance/ breaking sites.

PCB were widely used as dielectric and coolant fluids in transformers, capacitors, and electric motors during the 20th century. An estimated 40 000 tonnes of total PCB were commercially manufactured in the UK from 1954 onwards; peak production was achieved in the mid-1960s. Due to their environmental toxicity, the sale and manufacture of PCB were banned in the UK in 1977 and 1985 respectively. Despite these bans, PCB compounds persist in the environment to the present day (Fordyce et al., 2004).

Table 1. List of pollutants selected for the case study based on regulatory guidance

Pollutant	Freshwater EQS Annual Average	Freshwater EQS Maximum Admissible Concentration	Freshwater Classification	CLEA Soil Guideline Value Residential/ Allotment Soils	CL:AIRE Generic Assessment Criteria Residential Soils	Canadian < 2 mm Sediment Guidelines Probable Effect Concentration
Reference	UKTAG (2010) CEC (2008)	UKTAG (2010) CEC (2008)	EA (2013a)	EA (2013b); EA(2008)	CL:AIRE (2010)	MacDonald et al. (2000)
Arsenic (As)	50 µg/l			32 mg/kg		33 mg/kg
Antimony (Sb)					550 mg/kg	
Barium (Ba)					1300 mg/kg	
Cadmium (Cd)	0.09 µg/l (Class 3)	0.6 µg/l (Class 3)		1.8 mg/kg		4.98 mg/kg
Chromium (Cr)	4.7 µg/l			130 mg/kg		111 mg/kg
Copper (Cu)	10 µg/l					149 mg/kg
Iron (Fe)	1 mg/l					
Lead (Pb)	7.2 µg/l			450 mg/kg		128 mg/kg
Mercury (Hg)	0.05 µg/l	0.07 µg/l		1 mg/kg		1.06 mg/kg
Molybdenum (Mo)					670 mg/kg	
Nickel (Ni)	20 µg/l			130 mg/kg		48.6 mg/kg
Nitrate (NO ₃)			30 mg/l			
Phosphate (P ₂ O ₅)			0.1 mg/l			
Selenium (Se)				120 mg/kg		
Zinc (Zn)	75 µg/l					459 mg/kg
Ammonium (NH ₄)		1 mg/l (Fisheries)				
PAH						22.8 mg/kg
PCB						676 ng/g

Table 2. Pollutant data available from the G-BASE Glasgow datasets

Pollutant	Sample Type		
	Stream Sediment	Stream Water	Topsoil
Arsenic (As)	Stream Sediment	Stream Water	Topsoil
Antimony (Sb)	Stream Sediment	Stream Water	Topsoil
Barium (Ba)	Stream Sediment	Stream Water	Topsoil
Cadmium (Cd)	Stream Sediment	Stream Water	Topsoil
Chromium (Cr)	Stream Sediment	Stream Water	Topsoil
Copper (Cu)	Stream Sediment	Stream Water	Topsoil
Iron (Fe)	Stream Sediment	Stream Water	Topsoil
Lead (Pb)	Stream Sediment	Stream Water	Topsoil
Mercury (Hg)	Stream Sediment (< 2 mm)	Stream Water	
Molybdenum (Mo)	Stream Sediment	Stream Water	Topsoil
Nickel (Ni)	Stream Sediment	Stream Water	Topsoil
Nitrate (NO ₃)		Stream Water	
Phosphate (P)	Stream Sediment	Stream Water	Topsoil
Selenium (Se)	Stream Sediment (< 2 mm)	Stream Water	Topsoil
Zinc (Zn)	Stream Sediment	Stream Water	Topsoil
Ammonium (NH ₄)		Stream Water	
PAH	Stream Sediment (< 2 mm)		
PCB	Stream Sediment (< 2 mm)		

Unless otherwise stated stream sediment = < 150 µm size fraction

2.4 Data Presentation

The G-BASE sediment, water and soil and OS topographic datasets were incorporated into ArcMap9.3® geographic information system (GIS) software that allowed the spatial associations between stream sediment, stream water and soil quality, and current and historic land use to be plotted and assessed. Graphs of stream sediment versus stream water pollutant concentrations were also prepared in Excel® software. The concentrations of pollutants in water and sediments are shown as graduated symbols at the point where the samples were collected. Since the samples were collected at the same locations, the sediment data are shown on a separate set of maps from the water data.

Pollutant concentrations in topsoils are shown as continuous interpolated surface maps with the locations where the soils were actually collected indicated with dots. Interpolation converts point data to a continuous surface by estimating likely soil concentrations between known sample points using a mathematical function. Interpolated surface maps are useful to highlight patterns in the soil geochemical data; however, the interpolation is a model of the soil concentrations and uncertainty increases with distance from the known sample points. The interpolated surface maps were created using the Inverse Distance Weighting function in ArcMap9.3® based on a grid cell size of 100 m and search radius of 1500 m.

3.0 RESULTS AND DISCUSSION

The stream water (and stream sediment) sample locations are shown in Figure 4 along with the dates of collection and weather conditions at the time. The samples were collected on three different dates: 3, 5 and 8 June 2003. Only one of the samples (number 11 on Figure 4) was collected on 8 June and this was the only day that it rained within 12 hours of the sample being collected. Before the other samples were collected, it hadn't rained within either 48 hours or 2 – 7 days. Therefore, the streams were in a base flow state at the time of sample collection. For the sample that was collected on 8 June within 12 hours of rain, flow conditions were reported as moderate – the same as the majority of the other sample sites. On the basis of the observed weather conditions, there is no evidence to suggest that the more recent rainfall has systematically affected the water chemistry of this sample compared to the other samples.

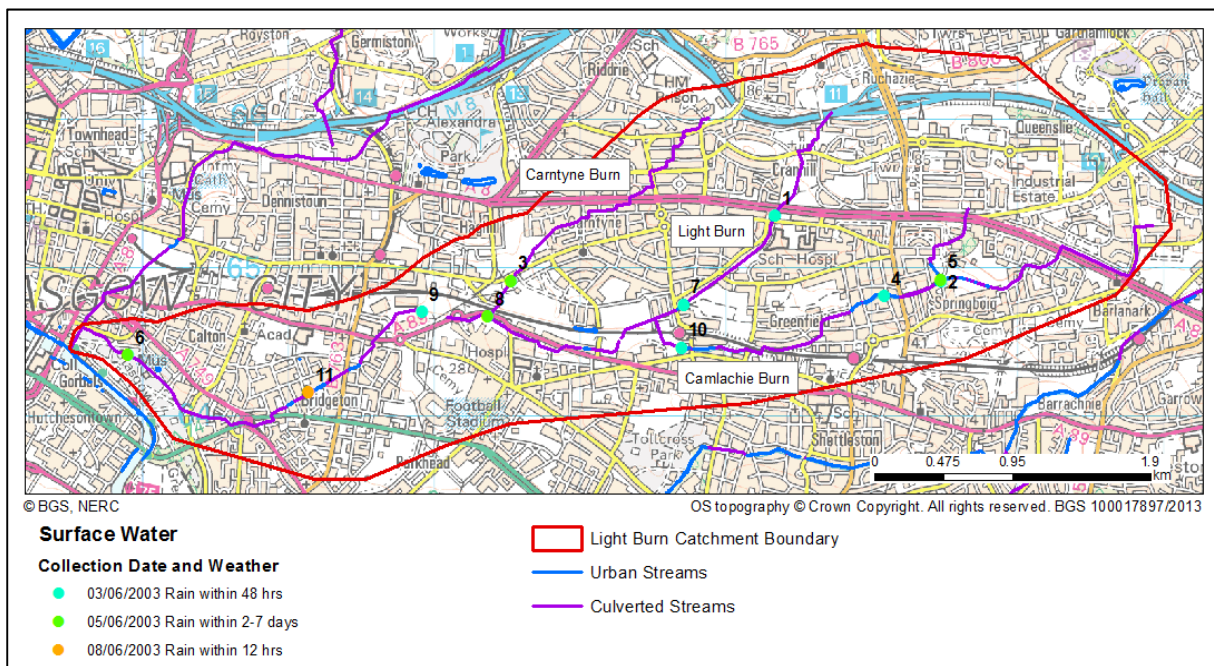


Figure 4. Location of stream water (and sediment) sample locations in the Light Burn catchment

The current land use and anthropogenic polluting materials noted at the stream sampling sites during collection are shown in Figures 5 and 6 respectively.

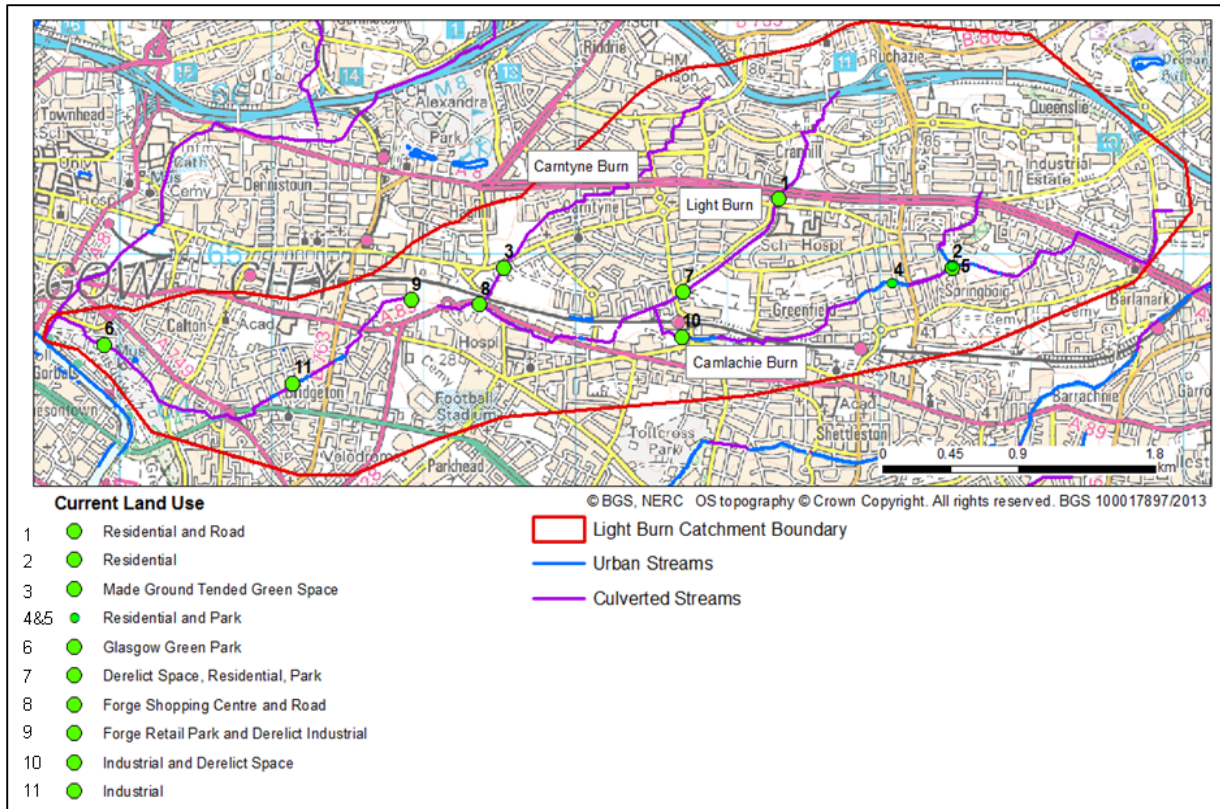


Figure 5. Current land use recorded at sediment and water sampling locations in the Light Burn catchment

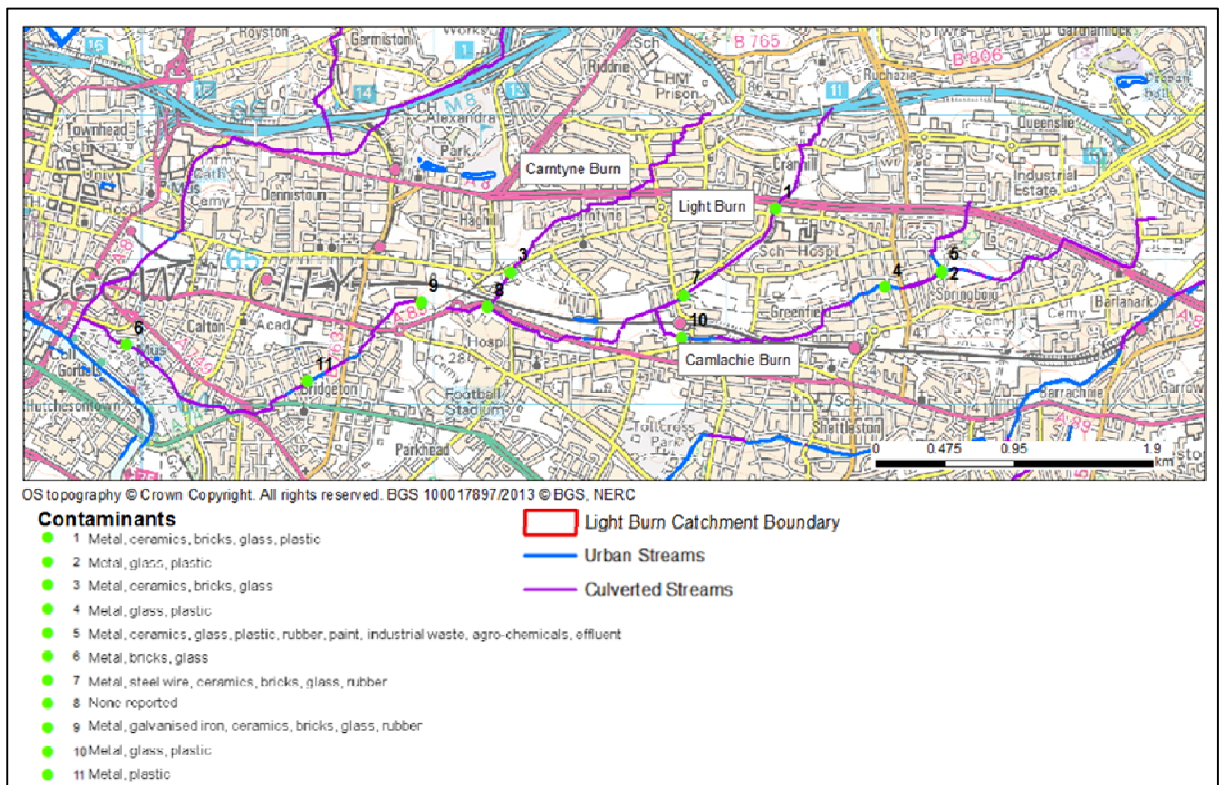


Figure 6. Anthropogenic polluting materials reported in stream sediment samples during collection

3.1 Metal Pollutants

Chromium, lead, nickel and zinc sediment concentrations exceed the Canadian sediment guideline probable effect concentration (PEC) at all sample sites in the catchment (Table 3). The highest concentration of lead in sediments in the whole Clyde Tributaries dataset was recorded at site 9 from derelict land adjacent to the Forge Retail Park (see Figure 4 for location) (Fordyce et al., 2004). Metal and galvanised iron were noted in the sediment sample at this location, which may account for the high lead concentration (Figure 6). Sediment copper concentrations also exceed the PEC guidelines at all sites, except sample 7. In contrast, samples 6 and 9 only exceed the PEC guidelines for arsenic and cadmium (Figure 4). The PEC sediment guideline for mercury is exceeded at site 7, a derelict area on the Light Burn where metal, steel wire, ceramics and glass were noted in the sample (Figure 6). However, these results should be treated with caution because the guidelines apply to the coarser < 2 mm fraction of stream sediments, whereas with the exception of mercury, the Clyde Tributaries dataset is based on the finer < 150 µm size fraction. Metal concentrations tend to be higher in the finer fraction of sediments as metals are often held in fine particles and clays within sediments. Therefore, the greater metal concentrations in the Clyde Tributaries dataset could be due in part to the method of sample collection.

Table 3. Ranges in sediment metal pollutant concentrations in the Light Burn catchment

Pollutant in Stream Sediment (< 150 µm)	Minimum mg/kg	Maximum mg/kg	Canadian Sediment Guidelines Probable Effect Concentration mg/kg (< 2 mm)
Arsenic (As)	8	345.4	33
Cadmium (Cd)	0.9	25.3	4.98
Chromium (Cr)	159	2173	111
Copper (Cu)	133.5	2984.6	149
Lead (Pb)	266.4	5001.0	128
Mercury (Hg) (< 2mm)	0.03	2.90	1.06
Nickel (Ni)	61.9	466.6	48.6
Zinc (Zn)	473	2001	459

For explanation of sediment guideline values see Table 1

Concentrations of antimony, arsenic, barium, molybdenum and selenium in topsoil neither exceed the CLEA SGV (EA, 2013b) nor the CL:AIRE GAC (2010) for residential/allotment soils (Table 4). Topsoil concentrations of cadmium, chromium, lead and nickel exceed the guidelines at some locations within the catchment. However, these guidelines are for the protection of human health and not for water quality.

Table 4. Ranges in topsoil metal pollutant concentrations in the Light Burn catchment

Pollutant in Topsoil	Minimum mg/kg	Maximum mg/kg	Residential/Allotment SGV/GAC mg/kg
Arsenic (As)	4.9	20.2	32
Antimony (Sb)	0.5	18.4	550
Barium (Ba)	222	1235	1300
Cadmium (Cd)	0.25	2.5	1.8
Chromium (Cr)	58	274	130
Lead (Pb)	42.8	572.5	450
Molybdenum (Mo)	0.4	6.6	670
Nickel (Ni)	17.1	177.5	130
Selenium (Se)	0.3	1.6	120
Zinc (Zn)	62	1781	

For explanation of Soil Guideline Values (SGV) and Generic Assessment Criteria (GAC) see Table 1

Despite the fact that concentrations of several metals are above the guideline values in sediments and soils within the catchment, cadmium and chromium concentrations only in stream water exceed the UK annual average freshwater EQS at some locations (Table 5).

Table 5. Ranges in stream water metal pollutant concentrations in the Light Burn catchment

Pollutant in Stream Water	Minimum µg/l	Maximum µg/l	Freshwater EQS AA µg/l
Arsenic (As)	0.5	32.3	50
Cadmium (Cd)	0.01	0.3	0.09
Chromium (Cr)	0	903	4.7
Copper (Cu)	1.8	3.9	10
Iron (Fe)	0.02	1	1
Lead (Pb)	0.1	0.5	7.2
Mercury (Hg)	0.01	0.01	0.05
Nickel (Ni)	1.7	4.8	20
Zinc (Zn)	6.1	64.7	75

For explanation of Freshwater EQS see Table 1

On this basis, four metals were chosen as examples to examine diffuse pollution in more detail as follows.

3.1.1 Antimony

Although there are no EQS for antimony in surface waters, this element was selected because the highest values in stream sediment - and some of the highest concentrations in stream water - in the whole Clyde Tributaries dataset were recorded in the Light Burn catchment (Fordyce et al., 2004). Figure 7 shows the distribution of antimony in sediments, waters and soils across the catchment.

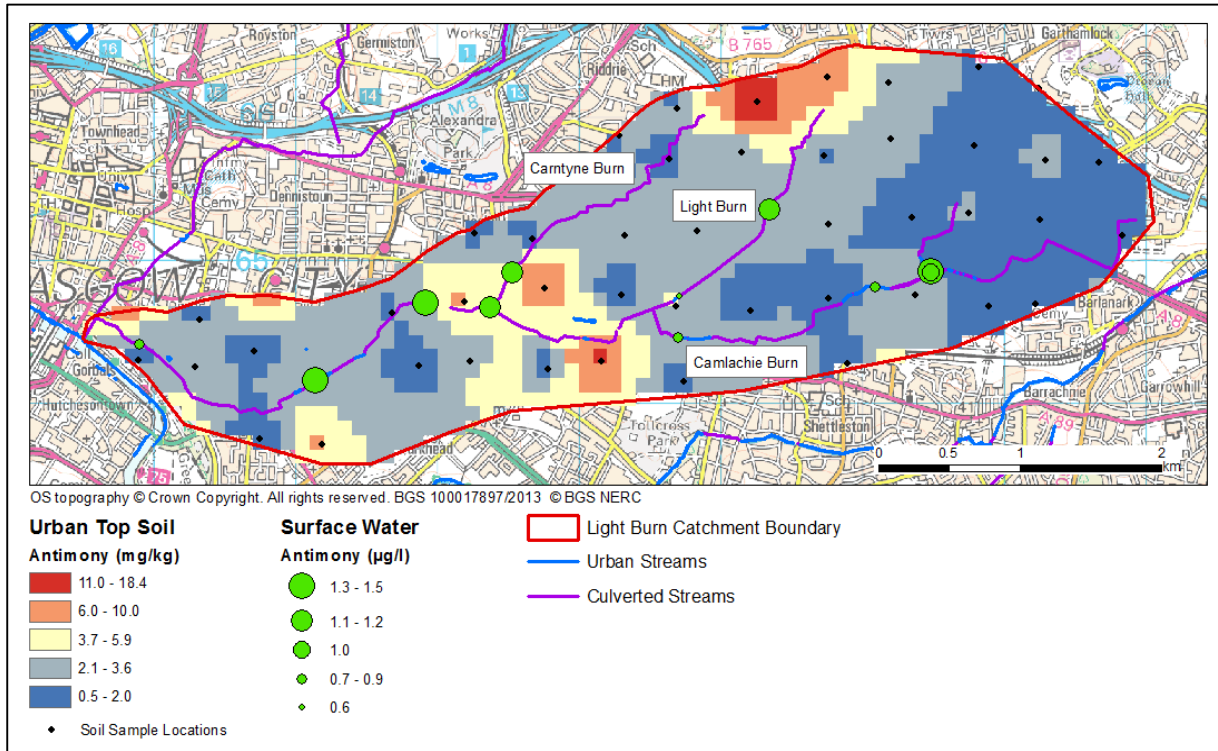
Highest stream water antimony concentrations in the catchment (1.5 µg/l) (Figure 7a) are recorded at sites 9 and 11, from derelict land adjacent to the Forge Retail Park and an industrial area in Bridgeton respectively (see Figure 4 for locations). At site 11, the stream was culverted and it was not possible to collect a sediment sample from this location. An oily sheen was noted on the water at this site, which may account for the higher antimony concentration.

Concentrations in water at site 5 are of a similar order (1.3 µg/l Sb) and may result from cross-contamination from the sewerage network, indicated by the presence of effluent; or from the metal, paint and ceramics also reported at the site (Figure 6).

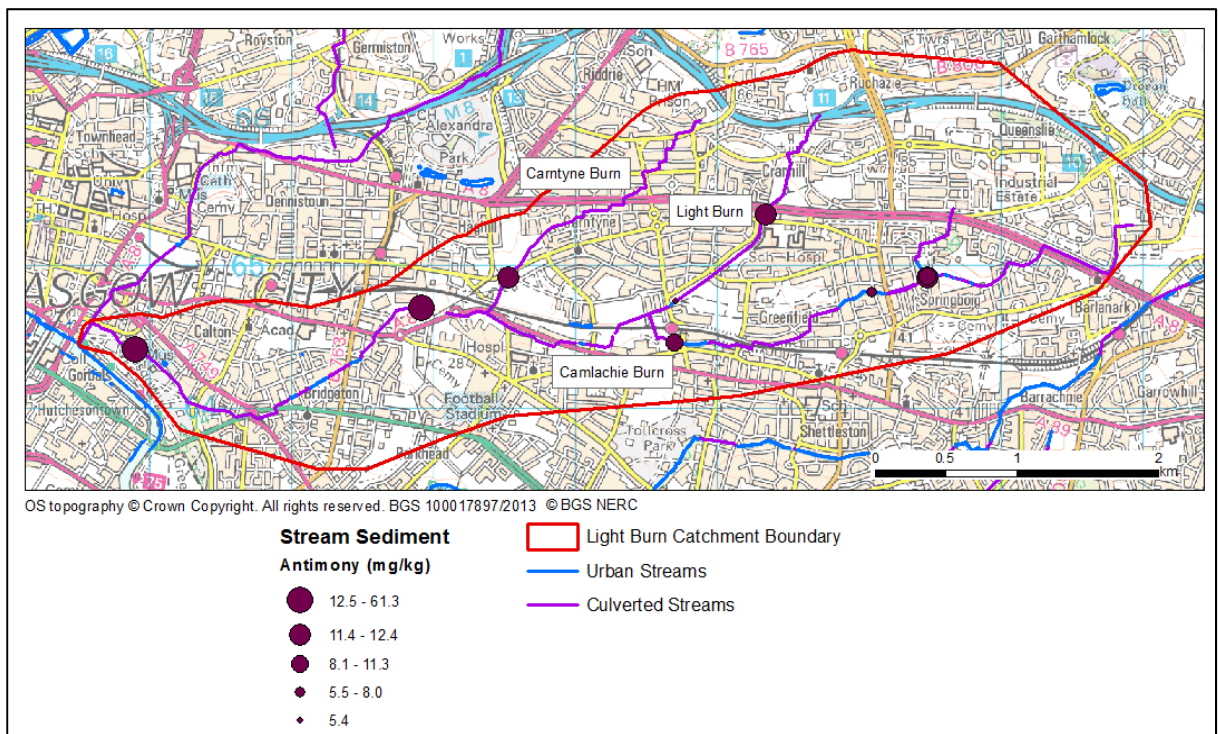
The highest concentrations in sediment (Figure 7b) were reported at site 9 (61.3 mg/kg Sb) and at site 6 (40.2 mg/kg Sb) in Glasgow Green. A variety of polluting materials were noted in sediments at these sites (Figure 6). A plot of sediment versus water antimony concentrations (Figure 8) and the spatial distribution maps suggest an association between the two sample media in the catchment. Topsoil antimony concentrations are well below the CL:AIRE (2010) residential GAC of 550 mg/kg, but are generally higher in the catchment than in world soil averages (0.5 mg/kg; Reimann and Caritat, 1998).

Highest soil antimony concentrations in the study area are reported in the vicinity of the M8 motorway in Ruchazie in the north of the catchment in a sample containing abundant bricks and coal ash, and over areas of made ground and former industry in the centre of the catchment (Figure 7a). The element distribution maps show that soil antimony concentrations are higher where the Carntyne and Light Burns meet and that there is a cluster of three higher antimony values in sediments and waters in the

same area (Figure 7). The history of dyeing, textile making and metal processing in the catchment probably accounts for the higher concentrations of antimony in this area relative to the rest of the Clyde Tributaries dataset.



a)



b)

Figure 7. The distribution of antimony in a) stream water and soils and b) stream sediments in the Light Burn catchment

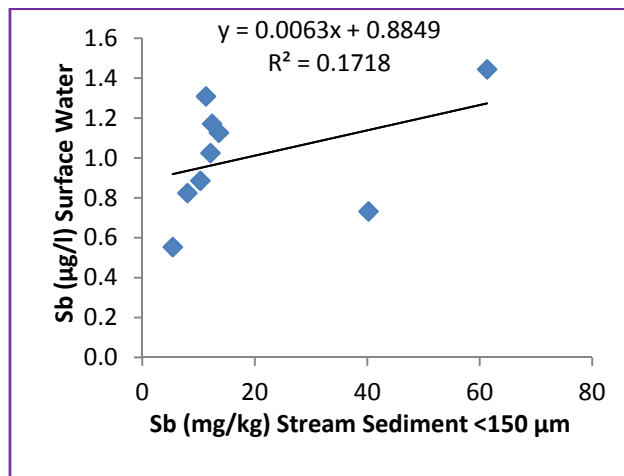


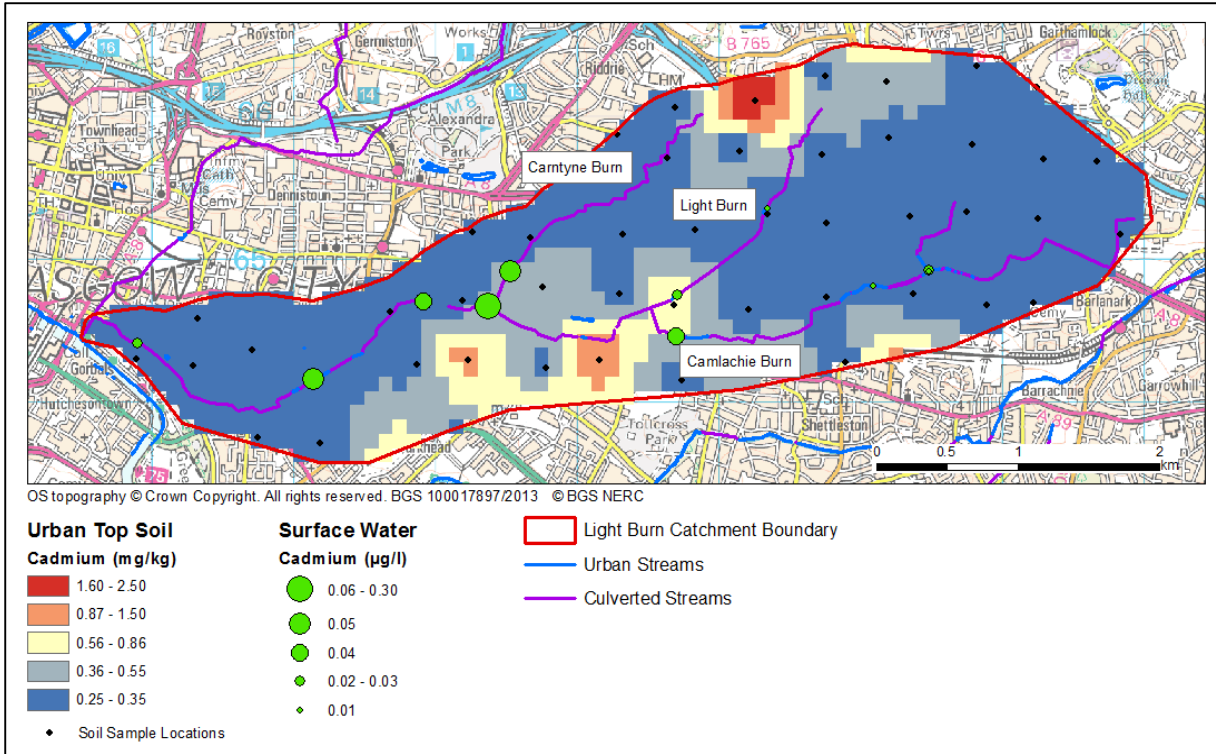
Figure 8. Plot of antimony concentrations in stream sediments and waters from the same sample locations

3.1.2 Cadmium

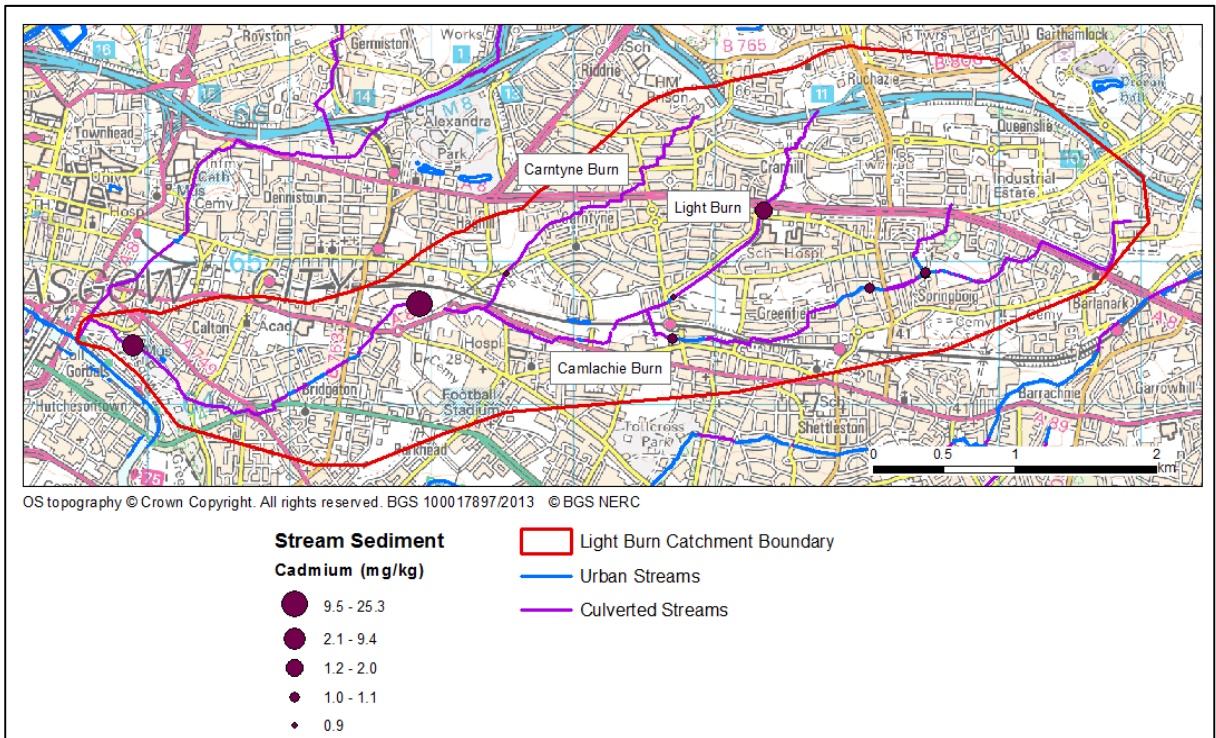
Cadmium was selected because the highest values in stream water and stream sediment in the whole Clyde Tributaries dataset were recorded in the Light Burn catchment (Fordyce et al., 2004). Figure 9 shows the distribution of cadmium in sediments, waters and soils across the catchment. The highest concentration in water is reported in a culverted section of the Camlachie Burn (site 8; Figure 4). This exceeds the UK freshwater annual average EQS of 0.09 μg/l. Surrounding water samples are also higher in the element relative to the rest of the Clyde Tributaries dataset (Figure 9a).

Unfortunately, it was not possible to obtain a sediment sample at the same location, but the highest concentration of cadmium in sediment in the whole Clyde Tributaries dataset is recorded in the next sample downstream (site 9; Figure 4). Cadmium concentrations in sediments exceed the Canadian guideline PEC at sample sites 6 and 9 (Figure 9b).

The following polluting materials were noted in the sediment sample from site 9 during collection: metal, galvanised iron, ceramics, bricks, glazed china, clear glass, coloured glass and rubber. The sample was collected from a derelict industrial area at the Forge Retail Park (Figure 5). These are all typical urban pollutants that end up in stream beds and affect the metal concentrations in sediments and waters. Similarly, metals, bricks and glass were noted in the sediment sample from site 6 in Glasgow Green. There appears to be little relationship between sediment and water cadmium concentration in samples collected at the same location in most cases (Figure 10) or between concentrations in water and soil (Figure 9a). The soil concentrations in the area surrounding sites 6 and 9 are low. Cadmium in soil exceeds the CLEA soil guideline value (SGV) of 1.8 mg/kg for allotment land use in a sample collected proximal to the M8 motorway in Ruchazie containing abundant brick and coal ash fragments (Figure 9a).



a)



b)

Figure 9. The distribution of cadmium in a) stream water and soils and b) stream sediments in the Light Burn catchment

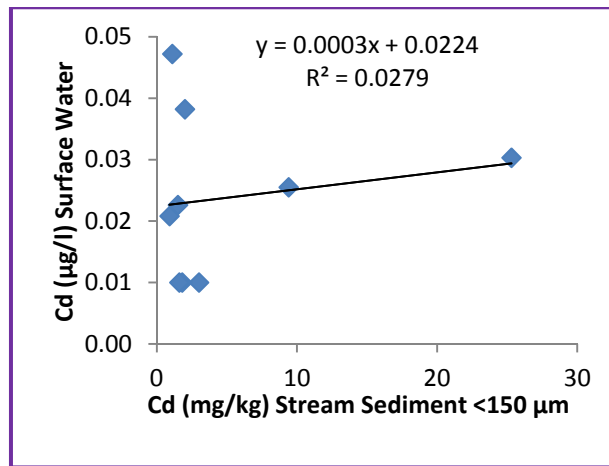


Figure 10. Plot of cadmium concentrations in stream sediments and stream waters from the same sample locations.

3.1.3 Chromium

Chromium was selected because the highest value in stream water and some of the highest values in stream sediment in the whole Clyde Tributaries dataset were recorded in the Light Burn catchment (Fordyce et al., 2004). Figure 11 shows the distribution of chromium in sediments, waters and soils across the catchment.

Water chromium exceeds the UK annual average EQS of 4.7 μg/l for fresh water at three sites (1, 7 and 9, see Figure 4 for locations); all the sites exceed the Canadian sediment PEC guidelines (Figure 11). The concentrations of chromium in waters and sediments respectively at sites 1 (903 μg/l; 2279 mg/kg), 7 (332 μg/l; 1298 mg/kg) and 9 (10 μg/l; 2173 mg/kg) are extremely high (with the exception of water at site 9) compared to natural/normal concentrations that would be expected in these sample types.

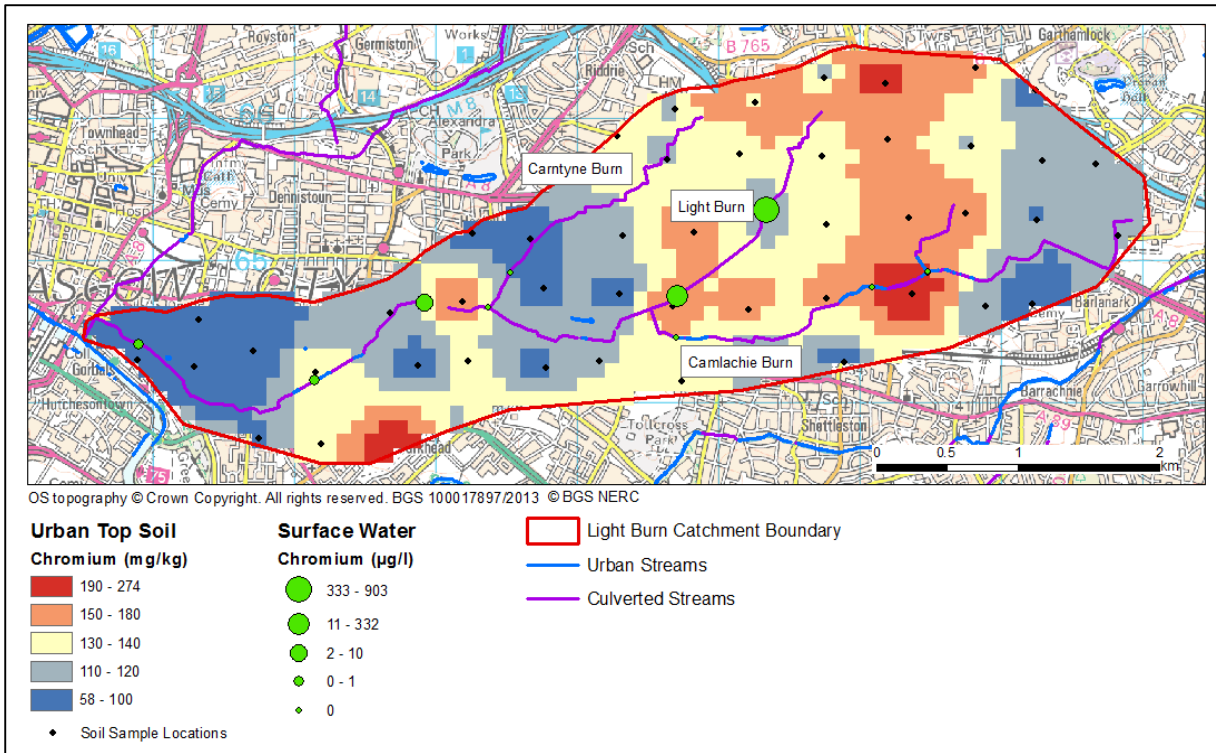
This is because Cr-waste from the former chromite works in Rutherglen (see Section 1.1 of this report) has been buried in the headwaters of the Light Burn in the past. Chromium pollution associated with the waste is known to Glasgow City Council. In the natural environment, chromium is typically in the form of CrIII, chromium from industrial sources, including the chromite processing plant in Glasgow, is in the form of CrVI, which is more mobile (Farmer et al., 1999). The results in the Light Burn demonstrate that the chromium from the waste site is mobile and making its way into the water courses. As a result, water quality is compromised in the Light Burn (Figure 11a).

Why concentrations in water at site 9 are lower than at the other two sites is not clear. It may be that the water is diluted with other inputs, such as the Carntyne Burn, by that point in the drainage system. Alternatively, the high concentrations of chromium in sediment at site 9 may not be due to chromite waste, but may originate from other sources and may be in a less mobile form. Further investigations would be required to confirm this. Hence, there is evidence of a relationship between sediment and stream water quality at some locations in the catchment (Figure 12).

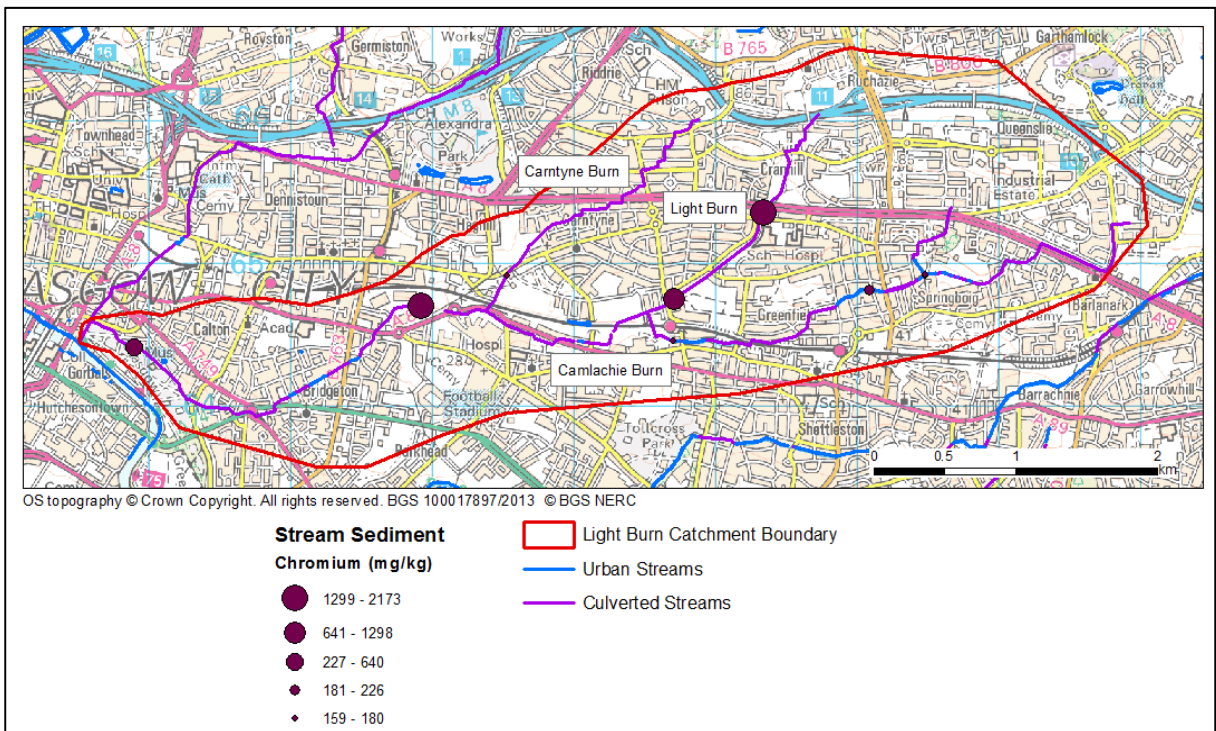
Although there was no information on groundwater quality in the Light Burn catchment readily available to the project, elsewhere in Glasgow the impact of the chromite waste on groundwater and subsequent interactions with surface water quality have been well documented. For example, very high concentrations of chromium, 6700 μg/l in surface- and 9100 μg/l in ground- water associated with chromite waste have been reported in south-east Glasgow (Farmer et al., 2002). Similarly, chromium concentrations of 3100 – 6200 μg/l were reported in the Polmadie Burn and 169 000 μg/l in groundwater from the adjacent chromite works site by Whalley et al. (1999). The same processes are

likely to affect the Light Burn, but further investigations would be required to confirm this. Relationships between chromium concentrations in soils and waters are less clear. Soil chromium concentrations across the catchment are elevated relative to world soil averages (80 mg/kg; Reimann and Caritat, 1998) and exceed the CLEA residential/allotments SGV (130 mg/kg Cr) at a number of locations particularly in the mid-upper catchment (Figure 11a).

Unfortunately, the G-BASE project did not collect a soil sample directly over the chromite waste site. This means that the highest soil chromium concentration reported in the catchment is 274 mg/kg. Whilst this is reasonably high it is not exceptionally high. If a sample had been collected over the chromite waste site in the Light Burn, soil chromium concentrations of approximately 4000 mg/kg may have been reported, similar to other chromite waste sites in the Glasgow Soils dataset (Fordyce et al., 2012). Assuming a value of approximately 4000 mg/kg Cr in topsoil in the Light Burn headwater, the relationship between high soil, sediment and water chromium concentrations in the Light Burn would be clear. As things stand, highest soil concentrations of chromium in the study area are associated with the M8 motorway junction/made ground in Ruchazie in the north of the catchment; made ground in Parkhead in the south of the catchment and in a residential area of Springboig in the east of the catchment (Figure 11a). There are no obvious land uses in the area to account for the higher chromium values in Springboig, but coal pits were present in the past and coal and brick fragments were noted in the soil sample.



a)



b)

Figure 11. The distribution of chromium in a) stream water and soils and b) stream sediments in the Light Burn catchment

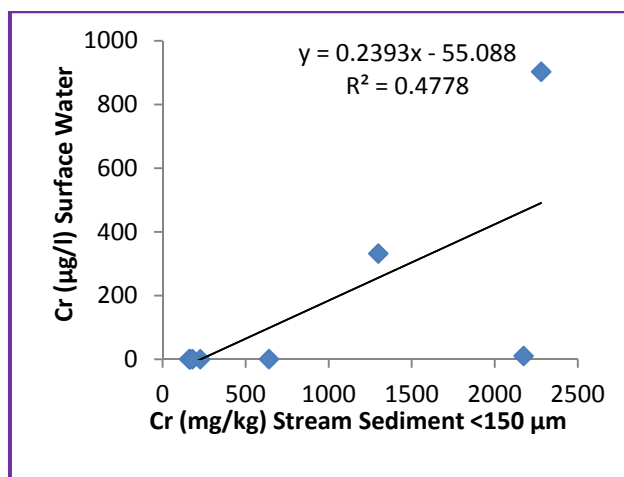


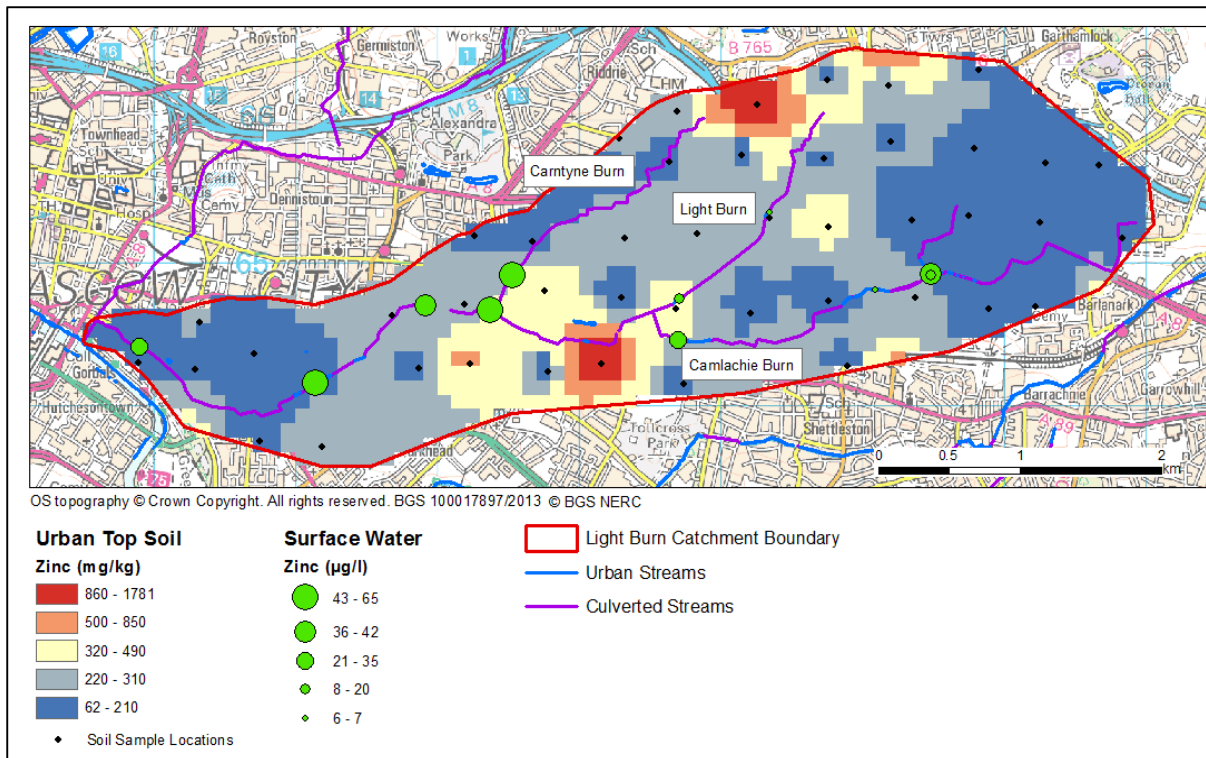
Figure 12. Plot of chromium concentrations in stream sediments and waters from the same sample locations

3.1.4 Zinc

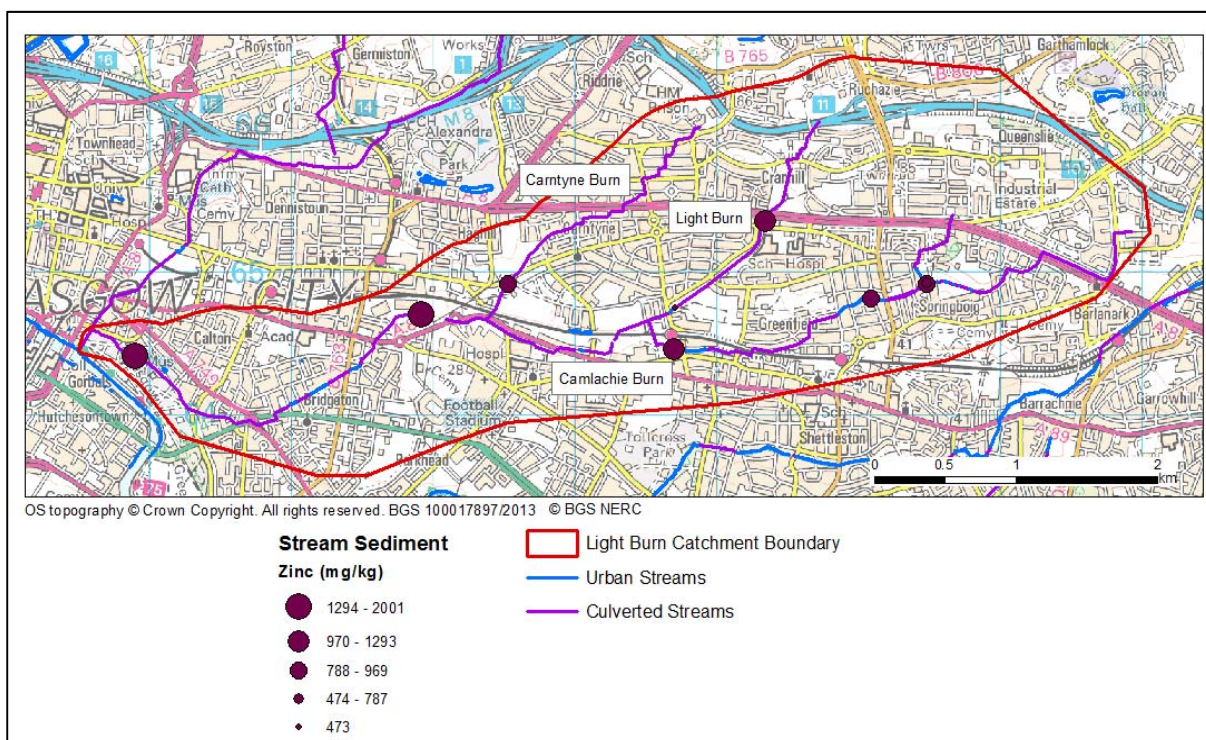
Zinc and copper show similar distribution patterns in the catchment, but zinc was chosen as an example pollutant because some of the highest concentrations in the whole Clyde Tributaries dataset were recorded in the Light Burn catchment sediments and waters (Fordyce et al., 2004). Figure 13 shows the distribution of zinc in sediments, waters and soils across the catchment. Zinc concentrations in stream water do not quite exceed the UK EQS annual average of 75 μg/l for fresh water (Figure 13a). The highest stream water concentration in the catchment (65 μg/l) is reported over made ground from site 3 on the Carntyne Burn (see Figure 4 for location).

High concentrations relative to the rest of the Clyde Tributaries dataset are recorded also at sites 8 (Forge Shopping Centre) and 11 (industrial area in Bridgeton). No sediment was available to collect in the culverted section of the stream at site 8, but the highest concentrations of zinc in sediment in the whole Clyde Tributaries dataset (2001 mg/kg) are reported at sites 9 (Forge Retail Park) and 6 (Glasgow Green) (Figure 13b).

High sediment zinc concentrations are recorded also immediately downstream of the A8 at site 1 on the Light Burn and from industrial land at site 10 on the Camlachie Burn (1368 mg/kg and 1292 mg/kg respectively). Indeed, all the sediment samples in the catchment exceed the Canadian guideline PEC of 459 mg/kg Zn. There appears to be little relationship between zinc concentrations in stream sediments and waters (Figure 14) or between stream waters and soils (Figure 13a). There is no current UK SGV for zinc in soil, but topsoil values exceed the Dutch intervention value of 720 mg/kg (VROM, 2009) in a sample collected proximal to the M8 motorway in Ruchazie containing abundant brick and coal ash fragments and in an industrial area in the south of the catchment. Soil zinc concentrations across the catchment are rather elevated compared to average concentrations in world soils (70 mg/kg; Reimann and Caritat, 1998).



a)



b)

Figure 13. The distribution of zinc in a) stream water and soils and b) stream sediments in the Light Burn catchment

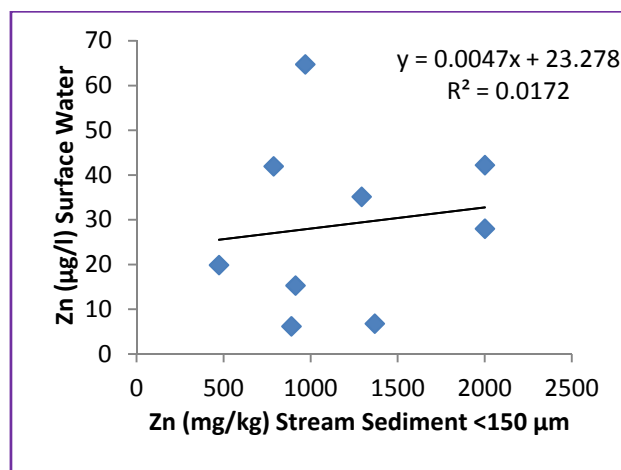


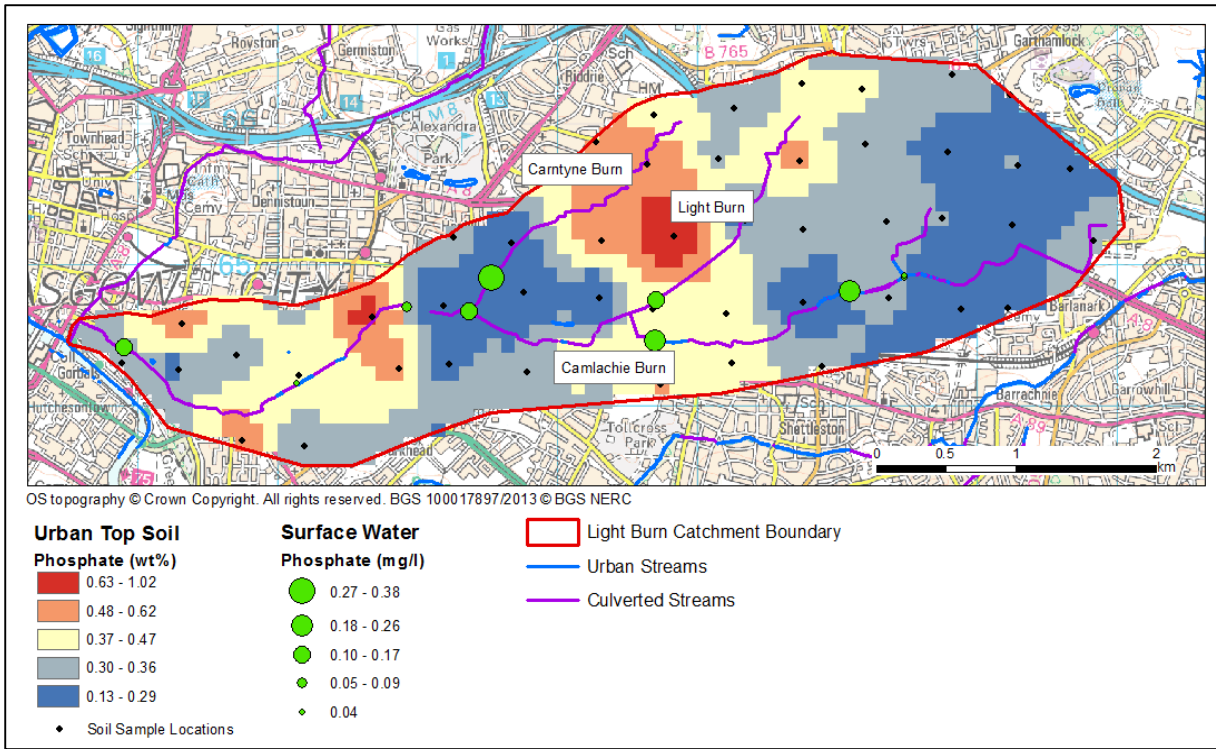
Figure 14. Plot of zinc concentrations in stream sediments and waters from the same sample locations

3.2 Indicator Diffuse Pollutants

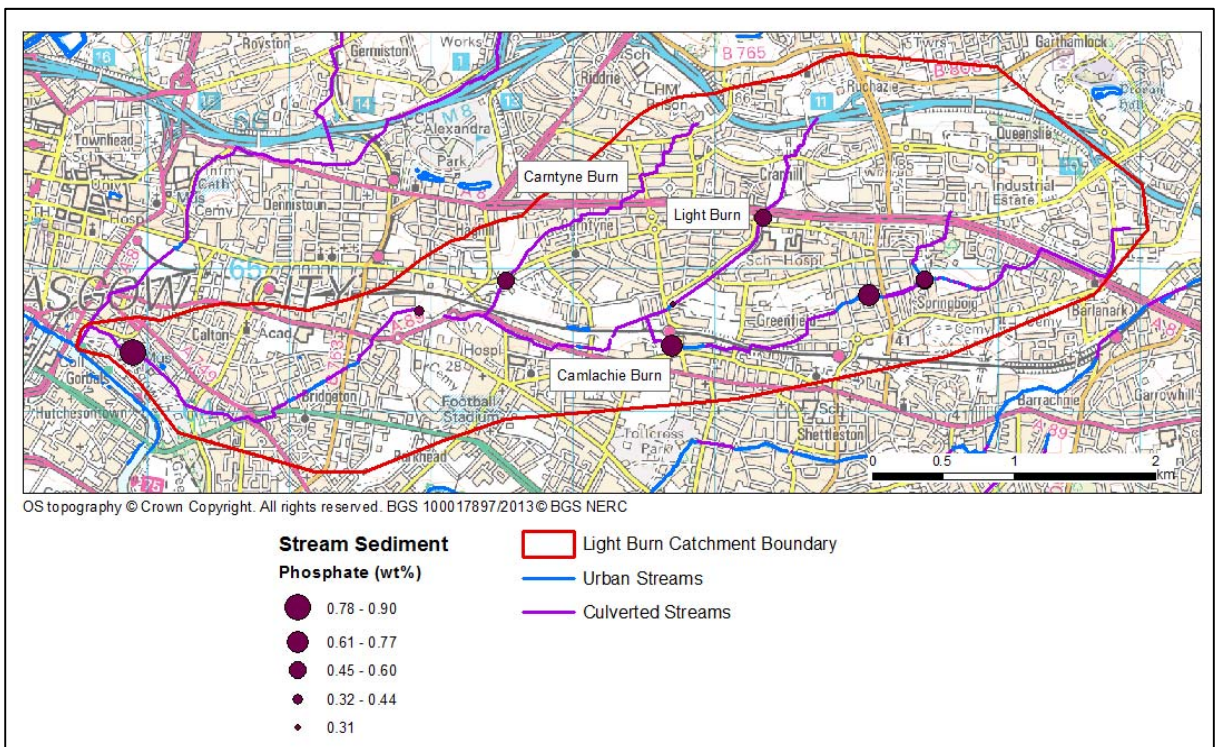
3.2.1 Phosphate

Phosphate was selected for further investigation because it is a diffuse pollutant of concern in the surface water environment, particularly in terms of agricultural fertiliser inputs. In urban areas, the use of fertilisers in gardens, parks and recreational areas are potential sources of this pollutant. Figure 15 shows the distribution of phosphate in sediments, waters and soils across the catchment. Concentrations in stream water exceed the UK 0.1 mg/l 'high phosphate' freshwater classification at sites 3, 4, 6, 7, 8 and 10 (see Figure 4 for locations).

The highest concentration in the catchment is reported at site 3 on the Carntyne Burn over made ground (0.38 mg/l) (Figure 15a). The highest sediment concentration of phosphate in the catchment (0.9 wt%) is recorded at site 6 in Glasgow Green (Figure 15b). There appears to be little relationship between phosphate concentrations in stream sediments and waters (Figure 16), or between stream waters and soils (Figure 15a). Higher phosphate concentrations in topsoils are associated with a residential area in Cranhill and may reflect fertiliser use in gardens.



a)



b)

Figure 15. The distribution of phosphate in a) stream water and soils and b) stream sediments in the Light Burn catchment

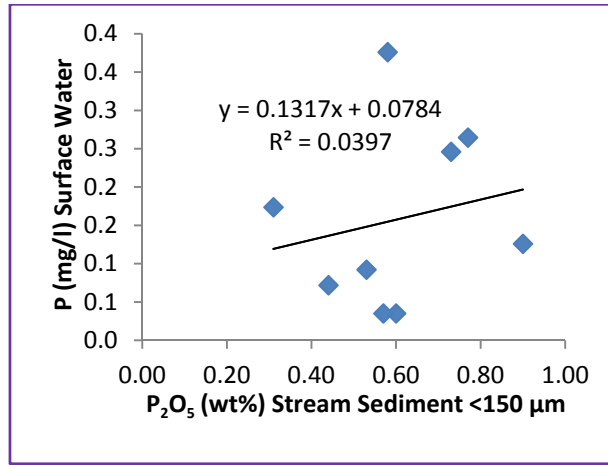


Figure 16. Plot of phosphate concentrations in stream sediments and waters from the same sample locations

3.2.2 Nitrate

Nitrate was included in the more detailed assessments because it is also a diffuse pollutant of concern in the surface water environment, particularly in terms of agricultural fertiliser inputs. In urban areas the use of fertilisers in gardens, parks and recreational areas as well as cross-contamination from the sewerage network are potential sources of this pollutant in the stream environment. The distribution of nitrate in stream water in the catchment is shown in Figure 17; all concentrations are below the UK 30 mg/l 'high nitrate' freshwater classification. Highest values in the catchment are reported from sites 3 and 8, over made ground on the Carntyne Burn and from the Forge Shopping Centre respectively (see Figure 4 for locations).

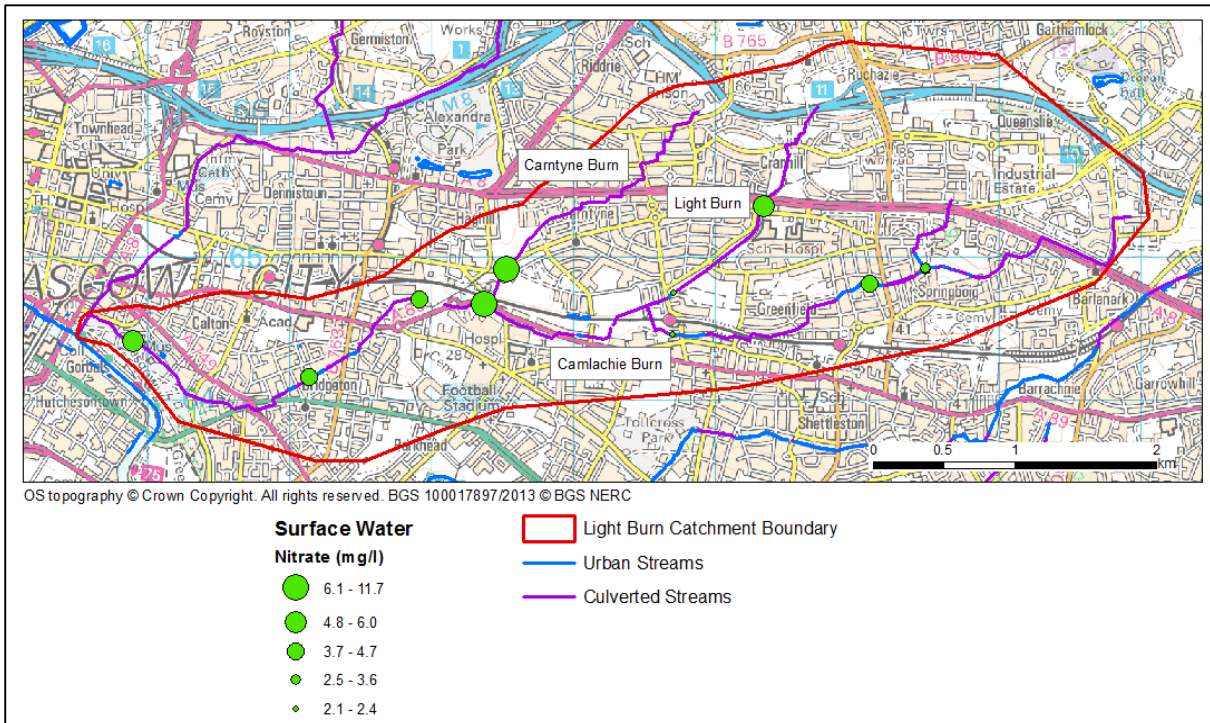


Figure 17. The distribution of nitrate in stream water in the Light Burn catchment

3.2.3 Ammonium

Ammonium in stream water was selected as an indicator of cross-contamination from the sewerage network. The distribution of ammonium in stream water in the catchment is shown in Figure 18. Concentrations exceeded the freshwater protection of fisheries EQS of 1 mg/l at site 5 on the Camlachie Burn and at site 9 at the Forge Retail Park (see Figure 4 for locations). Effluent was noted at site 5 indicating sewage cross-contamination. This probably accounts for the higher concentration reported at site 9 also.

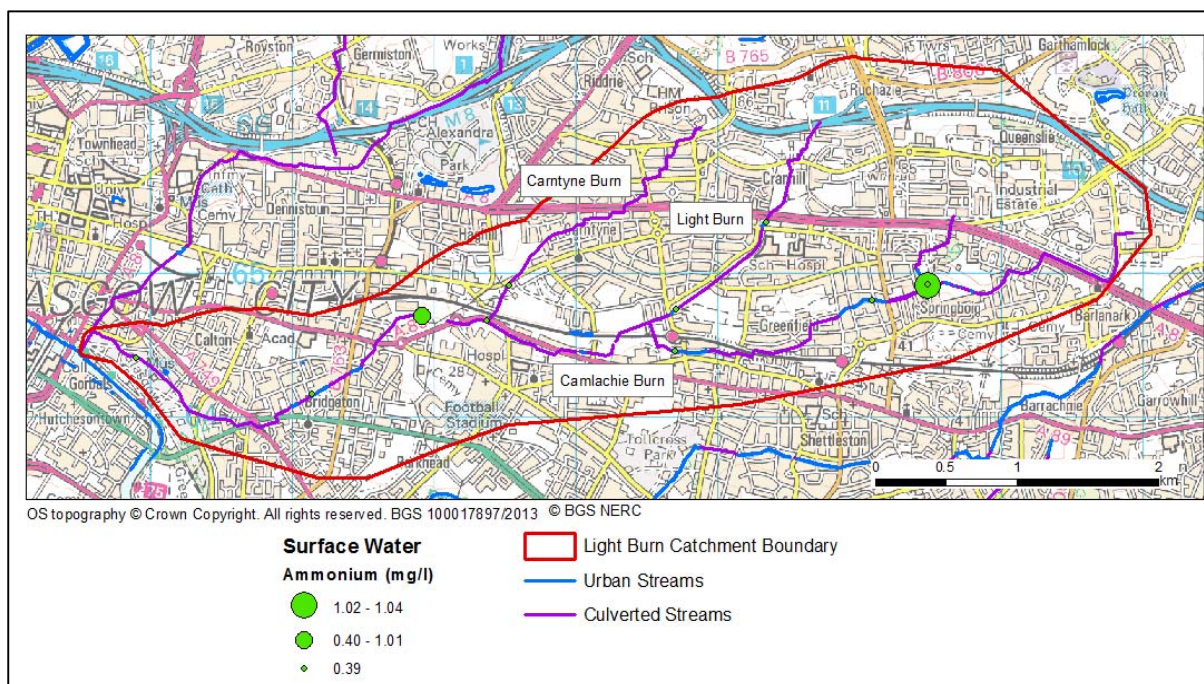


Figure 18. The distribution of ammonium in stream water in the Light Burn catchment

3.3 Persistent Organic Pollutants

3.3.1 PAH

Total PAH concentrations in sediments were examined in the Light Burn catchment as an indication of POP pollution (Figure 19). However, PAH were analysed at three locations only: site 4 (residential and park land), 9 (Forge Retail Park) and 10 (industrial land) (see Figure 4 for locations). There are no freshwater sediment guideline values for PAH in the UK but concentrations at all three sites exceed the Canadian guidelines PEC of 22.8 mg/kg. The total PAH value reported at the industrial site 10 on the Camlachie Burn (269.2 mg/kg) is one of the highest in the whole Clyde Tributaries dataset. The composition of the PAH in the Light Burn catchment suggests a typical assemblage indicating sources from high temperature combustion processes rather than from oils etc (Fordyce et al., 2004). Therefore, the PAH may relate to the former coking for metal forging processes in these areas or the presence of the railway line.

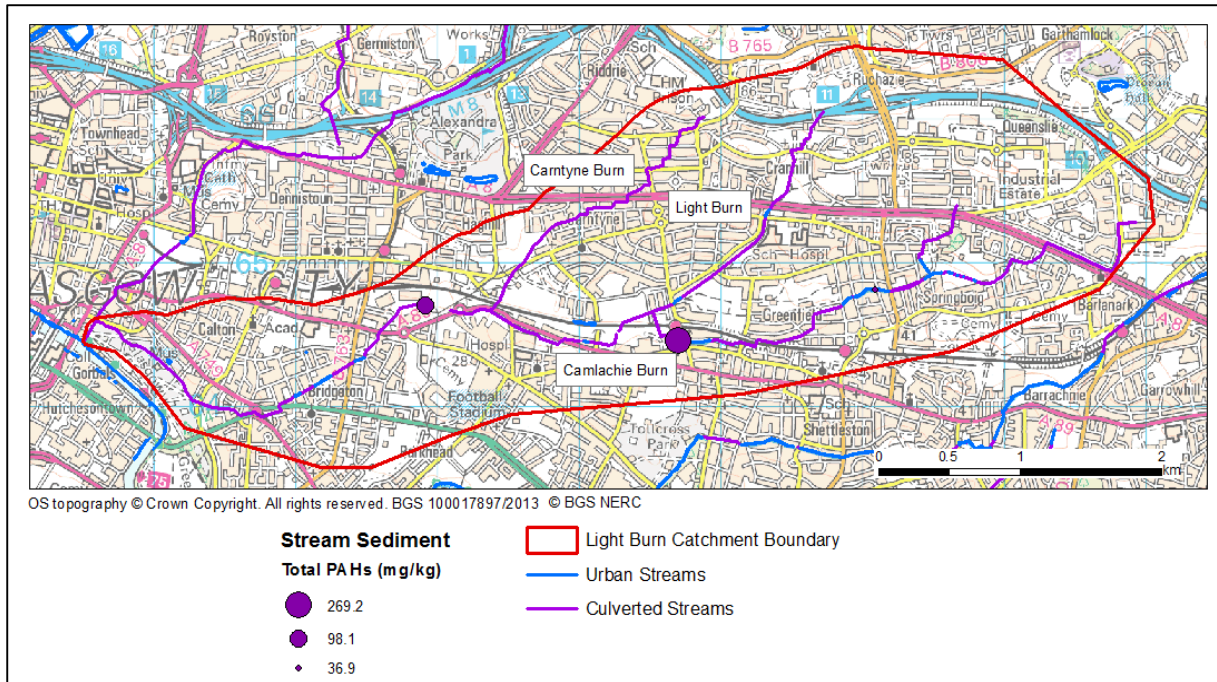


Figure 19. The distribution of total PAH in stream sediment in the Light Burn catchment

3.3.2 PCB

Total PCB sediment concentrations were also selected as an indicator of POP pollution (Figure 20). Concentrations in the Light Burn catchment are average compared to those in the rest of the Clyde Tributaries dataset. However, PCB were determined at two sites only: sites 4 (residential and park land) and 9 (Forge Retail Park) (see Figure 4 for locations). Sediment PCB concentrations do not exceed the Canadian guidelines PEC of 676 ng/g. The highest concentration in the study area of 97 ng/g is reported at the Forge Retail Park (site 9) in the former industrial heartland of the catchment.

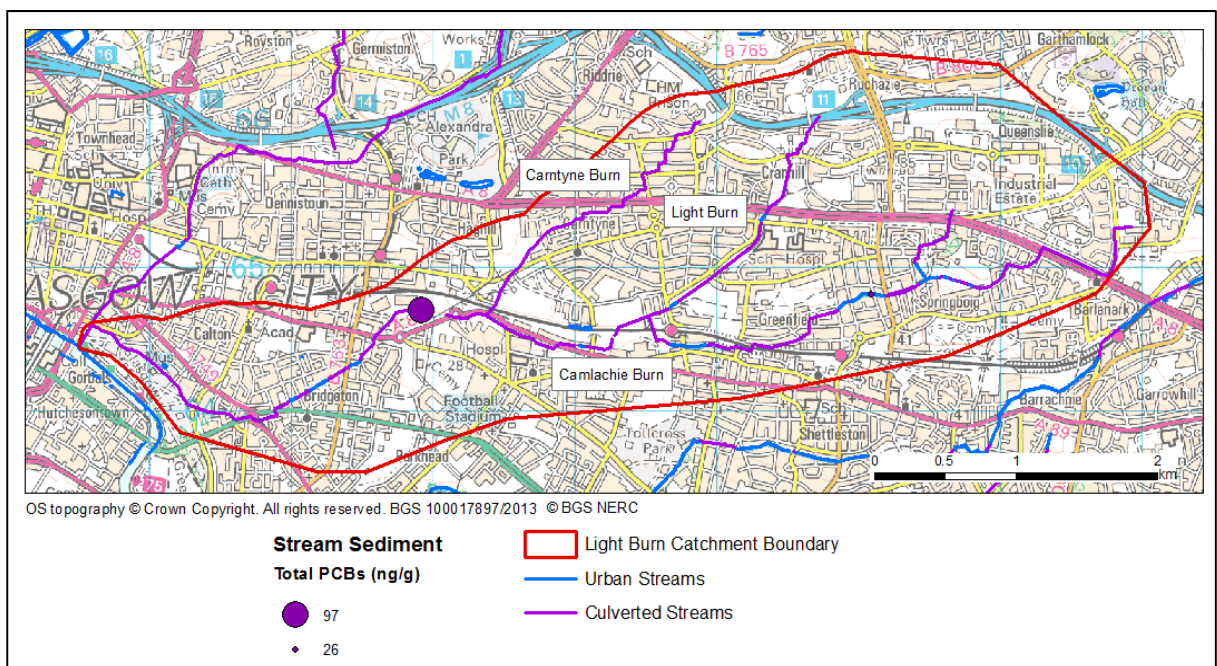


Figure 20. The distribution of total PCB in stream sediment in the Light Burn catchment

3.4 Summary of Diffuse Pollution Sources and Impacts

On the basis of the investigations carried out for the present study, spatial relationships between stream sediment, stream water and soil quality are difficult to determine for most pollutants in the Light Burn catchment, but there is some evidence that sediment and water quality are linked for antimony and chromium. Concentrations of antimony, chromium and zinc in soils are generally high over the catchment compared to typical concentrations in world soils.

Similarly the concentrations of most metals and PAH in sediment exceed the Canadian PEC guidelines at most of the sample locations. However, only ammonium, cadmium, chromium, and phosphate in stream water exceed the UK freshwater water quality guidelines. In general terms, concentrations of pollutants (antimony, cadmium, nitrate, PCB and zinc) are higher in water and sediments in the middle-lower reaches of the catchment than in the upper catchment corresponding to the former industrial heartland (Figure 21). Information on historic land use is available only at 1:10 000 scale; therefore, it is only possible to display a small area at a time. For example, focussing on sample sites 3, 8 and 9 (see Figure 4 for locations); the density of former industry in this section of the catchment is evident with forges, bottle plants, chemical works, brick works, engineering works, railway goods yards and factories adjacent to one another (Figure 22). This industrial heritage almost certainly contributes to diffuse pollution in the catchment today.

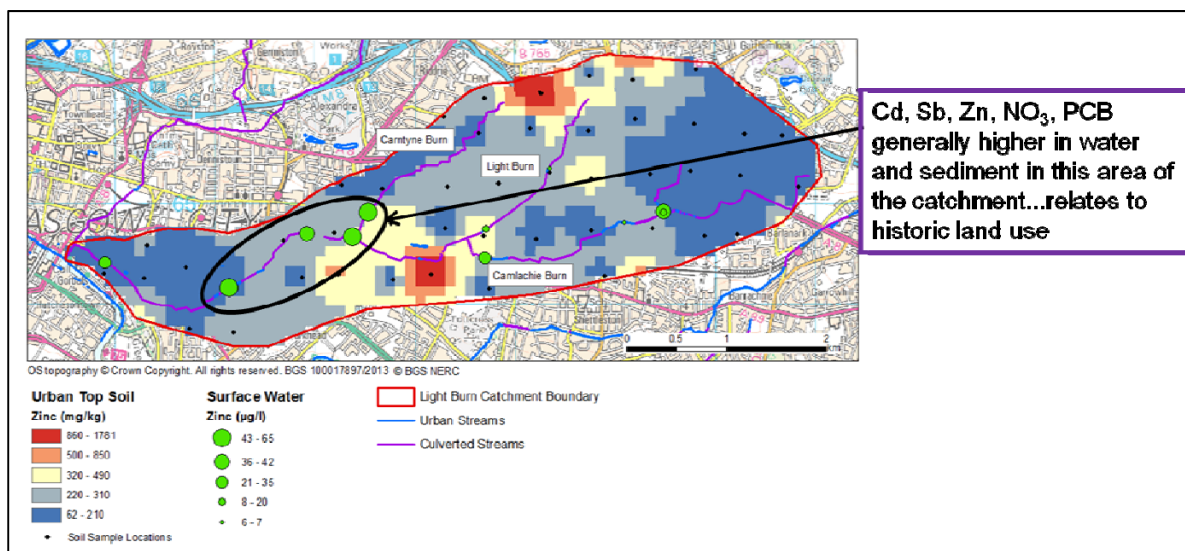


Figure 21. Section of generally higher sediment and water pollutant concentrations in the Light Burn catchment

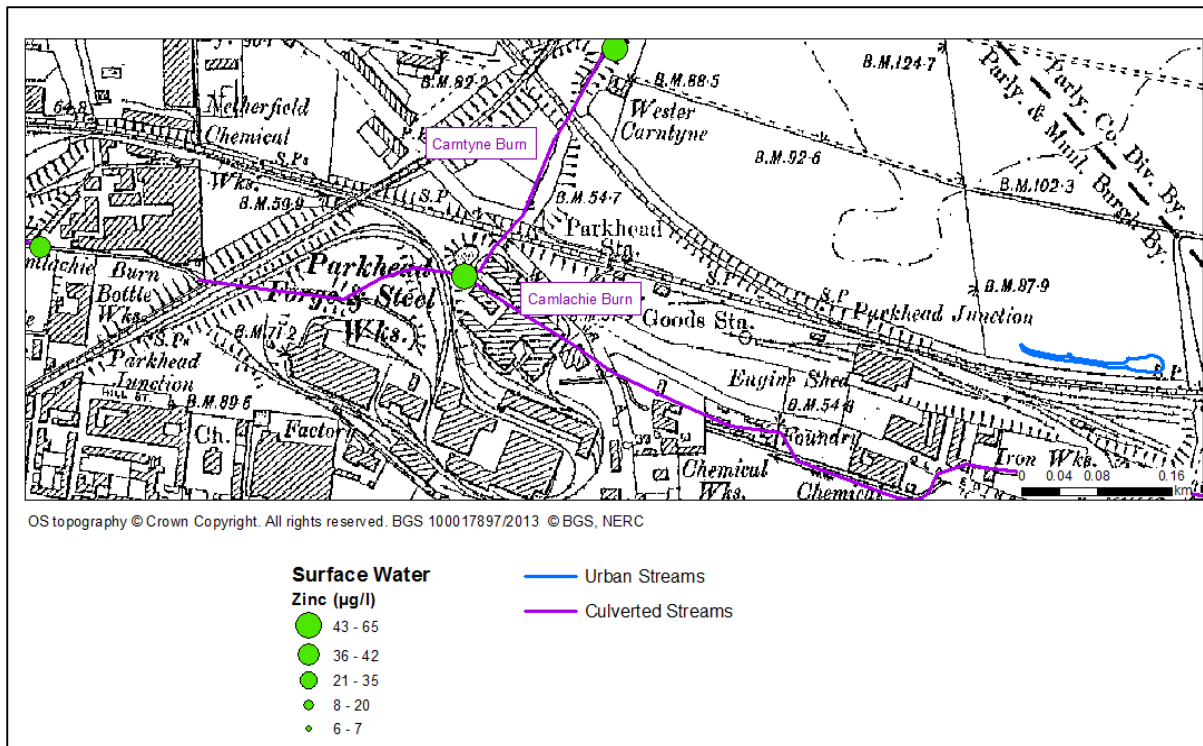


Figure 22. Example historic land use map from 1890 – 1908 showing the densely packed industry in the middle reaches of the Light Burn catchment around three of the present day G-BASE stream sediment and water sample sites

The locations and possible sources of diffuse pollution in the catchment are summarised in Figure 23 and show the influence of proximity to the road network on soil and sediment quality (locations 1, 2 and 4), the area of the Light Burn affected by Cr-waste pollution (location 3), and cross-contamination from the sewerage network in the upper Camlachie catchment (location 5).

The impact of industry in the lower part of the catchment affects sediment, soil and water quality at locations 6, 7 and 9, as does the presence of made ground on soil quality in the south of the catchment (location 8). Some of these locations provide opportunities to test diffuse pollution mitigation measure strategies, and these are examined in more detail in the Stage 3 project report.

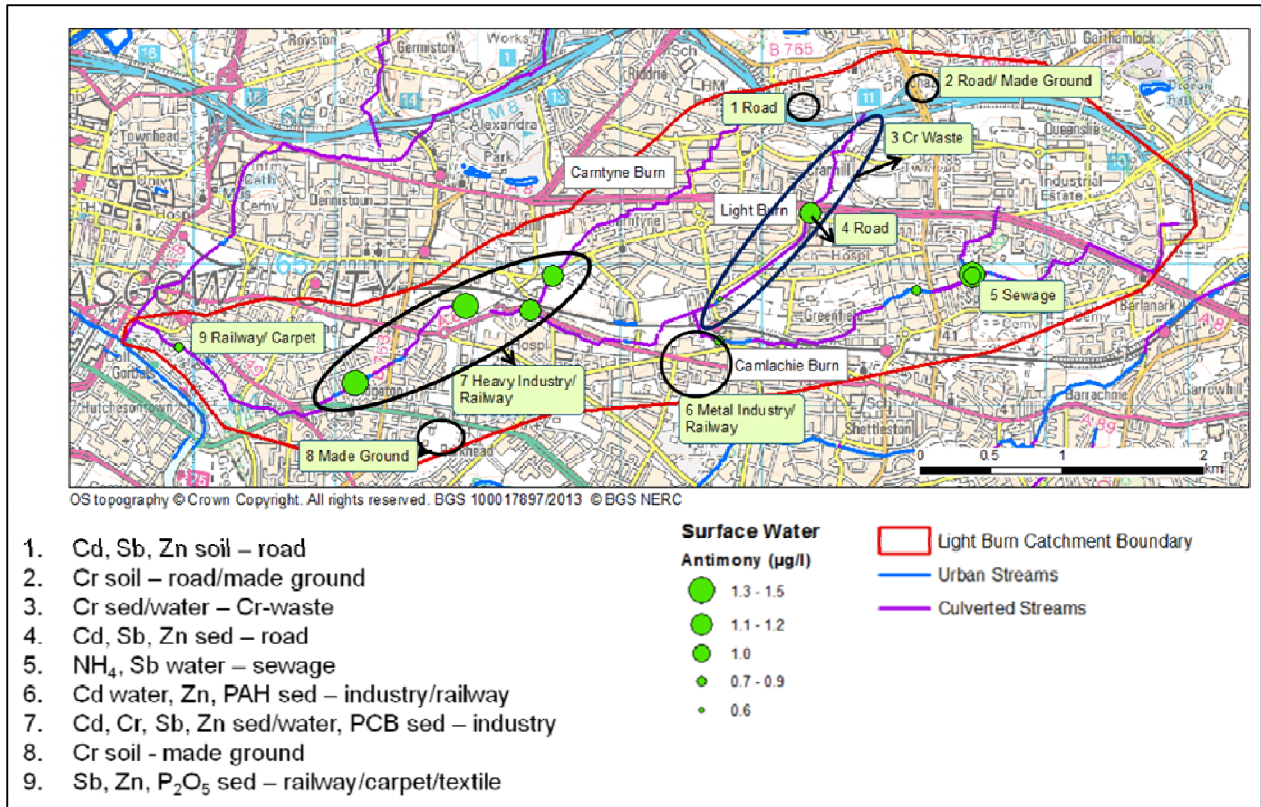


Figure 23. Summary of probable diffuse pollution sources in the Light Burn catchment with antimony in stream water as an example

4.0 GLOSSARY

AFS	Atomic Fluorescence Spectrometry
BGS	British Geological Survey
CEC	Commission of the European Community
CL:AIRE	Contaminated Land: Applications in Real Environments
CLEA	Contaminated Land Exposure Assessment
CREW	Centre of Expertise for Waters
EA	Environment Agency
EQS	Environmental Quality Standard
GAC	Generic Assessment Criteria Values
G-BASE	Geochemical Baseline Survey of the Environment
GC-MS	Gas Chromatography Mass Spectrometry
GIS	Geographic Information System
HPLC	High Performance Liquid Chromatography
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
JHI	James Hutton Institute
OS	Ordnance Survey
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PEC	Probable Effect Concentration
POP	Persistent Organic Pollutants
SEPA	Scottish Environment Protection Agency
SGV	Soil Guideline Value
UKTAG	United Kingdom Technical Advisory Group on the Water Framework Directive
VROM	Dutch Ministry of Housing, Spatial Planning and Environment
XRFS	X-ray Fluorescence Spectrometry

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