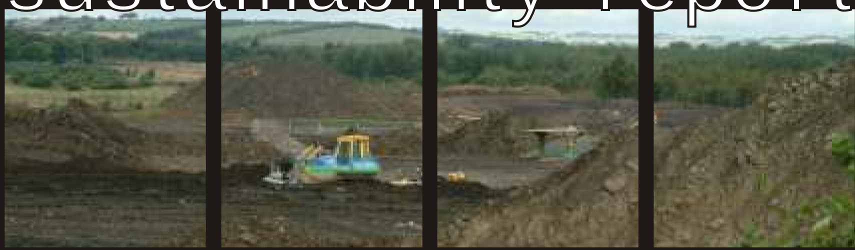
West Lothian

SOIL

sustainability report



June 2004

SCOTTISH NATURAL HERITAGE

West Lothian Council

Contents

1 Introduction

As part of the review of the West Lothian Biodiversity Action Plan, West Lothian Council and Scottish Natural Heritage commissioned the Scottish Agricultural College (SAC) to prepare a report on the soils of West Lothian.

Soils are normally regarded in the agricultural or horticultural context and neglected as a natural resource in relation to sustainable development outwith these uses. A greater focus on soils is however, developing in relation to European and UK policies, and the Scottish Biodiversity Strategy addresses associated issues. In West Lothian the future pressure on land for housing and industry makes it necessary to consider the conservation, management and after use of soils. This in turn needs to influence development plan policy and development control guidance.

Soils are often taken for granted, but are important for many reasons:

- We depend on soils for food and timber production
- They provide habitats in their own right as well as supporting a wide range of natural and semi-natural habitats
- Soils act as a carbon sink and as a filter for water
- They provide minerals and fuels
- Soils often reflect past patterns of land use and land management
- They provide the 'platform' upon which development takes place.

(SNH Report 2003)

This report is a desktop study and seeks to increase awareness and understanding of the soils in West Lothian. It is not intended to provide a detailed overview but recommends further sources of information and advice. It is intended as a 'user-friendly' information source for planners, advisers and those involved in land management, and it complements the focus on raising awareness of the earth sciences being led by the council.

Recommendations regarding the sustainable use of soils in the county have been provided in consultation with West Lothian Council and Scottish Natural Heritage.

View from Bathgate Hills looking east

2 Soils of West Lothian

2.1 LANDFORM - WEST LOTHIAN

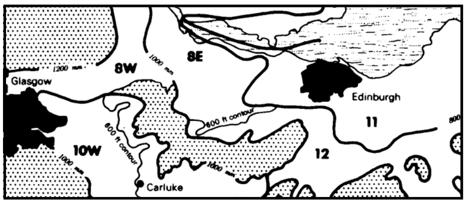
Glacial erosion has helped to smooth the irregularities of the sedimentary rocks so that the present landscape is an eroded one, glacially moulded into streamlined ridges. Glaciers advanced eastward then retreated westward. The sedimentary rocks have been intruded by various sills and dykes, such as the Bathgate Hills. The intrusions produce prominent ridges in the drift-covered plain.

The thick boulder clays found throughout the Central Belt are generally heavier and more poorly drained in West Lothian than, for example, in East Lothian and can be as deep as 60m. Along with other factors, such as the higher rainfall, permanent grassland is therefore more widespread in West Lothian than in East Lothian. The spread of rushes (an indicator plant for poor drainage) over farmland is very noticeable.

2.2 CLIMATE

The table below shows a comparison of the climate variations between the agricultural areas of North Lanarkshire, West Lothian and Edinburgh/East Lothian.

Table 1. Climate variations between North Lanarkshire, West Lothian and Edinburgh-East Lothian



	AGRICULTURAL AREAS		
	North Lanarkshire	West Lothian	Edinburgh–East Lothian
Agroclimatic area (shown above)	8W	8E	11
Access period	140–190 days	160–210 days	205–275 days
Return to field capacity	early October	mid October	mid November
Maximum summer soil moisture deficit	50–80mm	60–90mm	80–110mm
Excess winter rainfall	465–630mm	320–445mm	125–240mm
Degree days above 0^0 C (Jan–June)	1250–1420 deg days	1240–1410 deg days	1230–1390 deg days
Growing season	225 days	225 days	225 days
Total annual rainfall	1100mm	910mm	675mm
Potential evapotranspiration (total/annum)	450mm	465mm	500mm

2.2.1 Wind

The dominant wind direction over West Lothian is from the south west, drawing wet Atlantic air across Central Scotland. The Forth-Clyde valley has a major funnelling effect.

2.2.2 Rainfall

Rainfall is related to wind pattern and elevation. Rainfall of over 1000mm per annum occurs in West Lothian at low altitudes, such as the Slamannan plateau. Table 1 compares the annual rainfall for West Lothian with North Lanarkshire and Edinburgh/East Lothian and shows a significantly higher rainfall West of Edinburgh. Most of this rainfall is due to the orographic effect of the Bathgate Hills and the Pentland Hills. Both leave a distinct rain shadow on their eastern side. The high rainfall and the net surplus of precipitation contributes to the amount of leaching in the soils and also affects factors such as the period of accessibility to land for agricultural purposes, soil warming and the rate of plant growth.

2.2.3 Evaporation and transpiration

Evaporation and transpiration are affected by the air temperature and the rainfall. With reference to Table 1, low potential evapotranspiration and higher rainfall results in higher excess winter rainfall in West Lothian. This excess winter rainfall can affect soil structure, the load-bearing capacity of the soil and the access period, noticeably shorter in West Lothian than in East Lothian. High excess rainfall will influence problems with flooding and soil erosion by water.

2.2.4 Temperature

To a large extent Scottish air temperature is dominated by European continental conditions in summer and by the surface temperature of the surrounding sea in winter. Temperature influences the start and length of the growing season. On average the air temperature drops by 0.6^0 C for every 100m in height. Therefore the soils on the western flanks of the Pentland Hills remain colder for longer. This affects microbial activity, evaporation from the soil surface and transpiration of plants.

2.3 GEOLOGY AND THE SOILS OF WEST LOTHIAN

The parent material for most of the soil in West Lothian is derived from rocks of the Carboniferous Age. Carboniferous sediments consist mainly of sandstone, siltstones and mudstones, with limestone and coal. These were all deposited in shallow water. Throughout the Carboniferous period the environment cycled from marine to terrestrial. The type of sediment changed through each cycle from marine mudstone or limestone through non-marine mudstone and sandstone to seat-bed and coal, returning to marine sediments.

At the start of the Carboniferous period igneous activity began with thick basalt and related lavas forming plateaux throughout the Midland Valley. Volcanic activity continued at localised centres producing pyroclastic activity or basalt lava flows. This period of activity was accompanied by intrusions of sill forming dolerites.

The south-east edge of West Lothian abuts onto the Pentland Hills, which are formed mainly from Devonian period rocks. The Devonian Age saw vigorous erosion to the south of the Midland Valley and deposition of sediment in large alluvial fans within the valley. These were further distributed by river systems. The Old Red Sandstone rocks were laid down in arid conditions or in shallow temporary desert lakes. These sediments eventually formed typically red sandstones and conglomerates. The soils formed from these parent materials also have a characteristic red colour.

2.4 SOIL PARENT MATERIAL FOUND IN WEST LOTHIAN

The soil parent material is the original material from which the soil profile has developed. West Lothian is mainly glacial or peri-glacial in origin. Figure 1 shows the location of the parent materials found in West Lothian and these are described as follows.

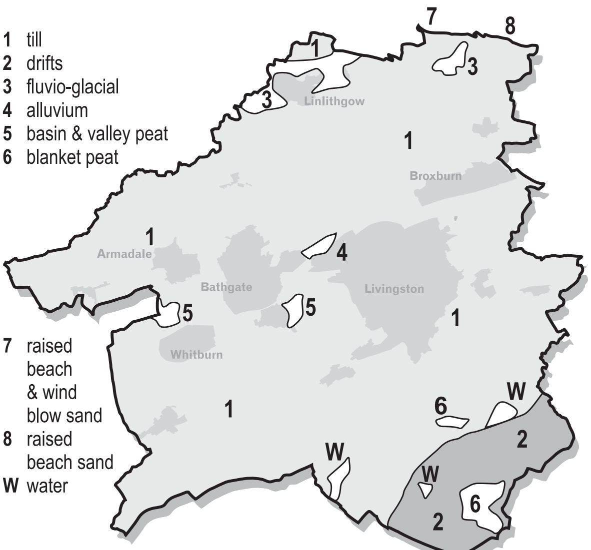


Figure 1. Guide to soil parent material in West Lothian

2.4.1 Glacial till

The majority of soils in West Lothian are formed from a glacial till parent material. This is that part of the glacial drift deposited directly by the ice with little or no transportation by water. It is generally an unstratified, heterogeneous mixture of clay, silt, sand, gravel, and sometimes boulders. The physical mixture is partly due to the fluctuations in the grinding action of the ice. Most soils derived from glacial till have a soil texture ranging from clay to sandy clay loam. The high clay content often results in imperfect-to-poor drainage conditions.

2.4.2 Stony drift

This parent material is accumulated frost-shattered local rock or local, coarse-textured thin glacial material or solifluction sheets.

2.4.3 Fluvio-glacial sands and gravels

Formed from the sorting action of fast-flowing glacial melt water. As most of the clay and silt from the original source material has been washed out, these soils are normally freely draining and have a soil texture ranging from sand to sandy loam. Stone content can range from very high to nil.

2.4.4 Alluvium

Material left behind by a river. The texture can vary from coarse sand to clay depending upon the velocity of the water. Textural change can vary over short distances. Where alluvium has been differentiated, most deposits in West Lothian have a high clay content and are poorly or imperfectly drained. Poorly drained alluvium can be a mix of peat and mineral soil.

2.4.5 Peat

Peat consists of dead plants that decay under wet conditions with low or no oxygen supply. As the process of growth and decay continues over time the peat spreads out and covers the underlying mineral soil.

The most common form of peat formation occurs through the waterlogging or near saturation of an area. With a high ground water level moisture-loving plants take over the area. The high level of ground water gives rise to a lack of oxygen in the soil which in turn inhibits the decaying process of the dead plants. The humus formed becomes more acidic with time, reaching pH levels of 3 to 4. Deep peat is very difficult to drain and cultivate.

2.4.6 Raised beach sands

Raised beach parent material is left behind after relative changes in sea level. It tends to be sand but can also contain silt and stones. In West Lothian the soils on raised beaches tend to be sandy loams to sand and are freely draining.

2.5 HOW SOILS ARE CLASSIFIED

2.5.1 The soil profile

As a soil matures, it develops a profile. The profile is a vertical section through the soil from the parent material to the ground surface. The formation of a soil profile can take many thousands of years and varies considerably in depth.

Transported by the vertical movement of water, materials pass down through the soil. This is known as leaching. At the same time plant material on the surface and in the top-soil dies off and breaks down to form soil organic matter, the residual, less decomposable plant material. The organic matter is either incorporated into the soil or remains on the ground surface to form peat.

Leaching and the incorporation of organic matter plus the effects of climate, parent material, position in the landscape and agricultural practices go to make up a characteristic soil profile. The soil profile can be divided into horizons in which similar processes are happening. The horizons are recorded as follows,

- The litter or organic layer: *the L (litter), F or H horizon (depending on the level of decomposition)*
- The leached horizon: *the A horizon*
- The enriched horizon: *the B horizon*
- The parent material horizon: *the C horizon*

These basic horizon divisions can be further subdivided to improve the description of the soil profile.

Each horizon can be described by:

1 **Colour** - bright red and brown soil horizons indicate a well-drained soil. Dull colours, right through to grey, indicate a soil that does not drain quickly.

2 **Texture** - the mineral fraction of the soil is composed of particles of different sizes. The proportions of these particle sizes determine the texture of the soil. Soil particles are classed as follows:

Gravel	greater than 2mm
Sand	2mm to 0.2mm
Silt	0.2mm to 0.002mm
Clay	less than 0.002mm

Depending upon the proportion of sand, silt and clay, the texture is described as shown in Figure 2.

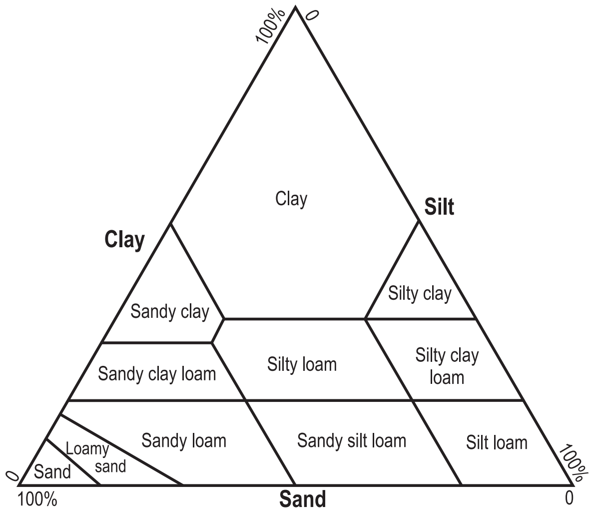


Figure 2. Soil texture triangle

3 **Structure** - determines how the soil particles form into larger aggregates or peds. Good soil structure allows air and water to pass through the soil. Poor soil structure can result in water-logging and reduced cropping. Some common structures in West Lothian are,

- *Crumb* - usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.
- *Blocky* - angular or sub-angular blocks that are usually 1.5-5.0 cm in diameter.
- *Prismatic* - Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.
- *Platy* - Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.

- *Massive* - soil has no visible structure, is hard to break apart and appears in very large clods. Roots do not penetrate.
- *Organic matter* - gives the dark colour to the topsoil when fully incorporated. Or forms an organic layer on the soil surface. Very important in the maintenance of good soil structure.
- *Stone content* - stone content in soil can be greater than 70%. Stone content affects the volume of water in the soil and can cause damage to crops at harvest.
- *Horizon depth.*

2.5.2 Soil map classification

Looking at the inch to the mile soil maps and the 1:25000 soil maps, classification is based upon parent material and natural drainage. The main grouping is the soil association which is based upon the parent material. Examples of soil associations in the West Lothian area are Rowanhill (glacial till parent material) and Hobkirk (drifts of soft red sandstone parent material). Depending upon various influences, such as climate and position within the landscape, the natural drainage status with the same soil parent material, can vary. Soils within the same association are broken down into soil series depending upon their drainage status. The drainage status classes range from excessively free to very poor. Examples of soil series are Winton (imperfectly drained) and Darleith (freely drained).

Indication is also given on the soil map of the soil sub-group. Each sub-group is part of a major soil group and each major soil group is classified in divisions as shown below.

Table 2. Soil groups

Sub-group	Major soil group	Division
Mineral alluvial soils	Alluvial soils	Immature soils
Peat alluvial soils		
Brown forest soil	Brown earths	Leached soils
Brown forest soil with gleying		
Iron podzol	Podzols	
Peaty podzol		
Non-calcareous gleys	Surface-water gleys	Gleys
Peaty gleys		
Hill peat	Blanket peats	Organic soils
Low moor	Basin peats	
Raised moss		

2.5.3 Some common terms used with soil maps

- *Boulder clay* – material dumped by retreating glaciers and containing a quantity of large stones and boulders. Laid down in varied depths, up to tens of metres thick. Stones are of the same geology as the area over which the glacier travelled. The clay is formed from rocks ground down during the glacial period.

- *Glacial till* – in Scotland, used interchangeably with boulder clay but can include stone free glacial material.

- *Water sorted* – the surface of the glacial till has been covered by water and much of the clay fraction has been removed.

- *Drifts* – a generic term for surface deposits including till, outwash gravel and sand and alluvium.

- Fluvio-glacial soils – immediately after the glacial period there were large quantities of melt water flowing over glacial till. The coarser sands and gravels in the till were separated from the silts and clays by the action of the melt water and deposited independently. Fluvio-glacial soils vary in thickness and can overlay till. They are found in large outwashes or on valley sides.

- *Gley soils* – a soil with restricted drainage and a high water table. The soil profile usually shows orange-brown mottles first then grey colours at depth.

- *Mottles* - soil colour pattern consisting of patches of different colour or shades of colour interspersed with the dominant soil colour which results from prolonged saturation of the soil. The presence of soil mottling is a strong indicator of a seasonal water table (the water table's highest level reached during wet periods of the year).

- *Non-calcareous* – soil not derived from parent materials containing limestone or chalk.

- *Podzol* – (or Podsol) from the Russian meaning 'ash-like' because of the pale grey horizon beneath the humus layers. Freely draining acidic soils that sometimes form an impervious iron pan which lowers the drainage status. Podzols under arable cultivation require large quantities of fertiliser and lime.

- *Brown forest soil* - relatively uniform brown colour which shows a very gradual change from the A horizon downwards. There is a gradual change from a thin humus horizon, not always present, to a dark brown or brown A horizon. This horizon can have up to 30% organic matter and merges into the slightly paler B horizon. Brown forest soils can be freely or imperfectly drained.

- *Alluvium* – found beside watercourses. Soil material deposited during flood conditions. Can vary in thickness, texture and drainage status. Can appear as PAL on soil maps (peat alluvium).

- *Undifferentiated* – usually refers to an alluvial soil which has not been classified as to drainage and texture.

- *Iron pan* – formed under the strong leaching of a podzol soil. A hard, thin black band of a few millimetres thickness. Impenetrable to roots and groundwater. Often busted during cultivation.

- *Soil complex* – where soils of different series or even different associations (parent materials) are found in the same area or where the parent materials become mixed.

Examples of soil types and structures are illustrated in Appendix 1.

3 Soils and Sustainable Land Management

3.1 AGRICULTURE

3.1.1 Pattern of past farming systems

Farming systems in West Lothian vary greatly and different soil types and their drainage status influence this. Arable farming, mainly cereals and oilseed rape, dominate the best soil in the north and east of the county whilst livestock farming is the main enterprise further west and around the Pentland Hills. Traditionally many of the arable farms were mixed resulting in a mosaic of grass and arable crops. Dairying was also more common particularly around the Bathgate area and many farmers in livestock areas grew small areas of cereals and turnips for livestock feed. These mixed farming systems helped to maintain organic matter levels in soils on arable fields due to the availability of animal manure and grass pasture in the rotation.

Organic matter is vital to the formation of stable soil aggregates and has a profound effect on the structure of all soils.

Ground cultivation

3.1.2 Present farming patterns

Recent economic pressures and CAP subsidy support systems have tended to encourage farmers to reduce their variety of enterprises and specialise in either arable, dairy or beef and sheep. The consequences of this are discussed below.

Farms in the north and east of the county have arable fields that receive no animal manures and are permanently in crop. This is likely to result in lower soil organic matter levels.

Farms in the west and south of the county tend to grow fewer crops compared to thirty years ago, so that many grass fields previously under a rotation are now permanently in grass. The consequences of this for soil sustainability are generally positive, biodiversity can, however, suffer because of the lack of varied habitats.

Changes in the type and size of farm machinery have meant that farmers are able to carry out cultivation at times of the year when previously the soil was too wet. This can be damaging to the soil structure. Although most farmers plough their arable fields annually, some farmers are changing their cultivation systems towards minimum tillage.

As a consequence of poorer economic returns from agriculture some farmers are diversifying towards other land uses such as forestry, horse livery, recreational facilities and lowland crofting. The consequences on the soil of these changes needs to be considered case by case.

3.1.3 Land capability for agriculture

The Macaulay Institute produce maps indicating the capability of different areas for agriculture. Categories of land are divided into seven main groupings with further subdivisions of groups 3, 4, 5, or 6. Maps are available at different scales including 1:50,000 and 1:250,000. The 1:50,000 map covering West Lothian is Sheet 65 'Falkirk and West Lothian'. The land is classified according to the limitations imposed on it by physical and biological factors, which affect agriculture. These factors are climate, gradient, soil, wetness and vegetation. Erosion limitations do not appear on the Falkirk and West Lothian map.

The class descriptions are summarised as follows.

Class 1	Land capable of producing a very wide range of crops
Class 2	Land capable of producing a wide range of crops
Class 3	Land capable of producing a moderate range of crops
Class 4	Land capable of producing a narrow range of crops
Class 5	Land capable of use as improved grassland
Class 6	Land capable of use only as rough grazings
Class 7	Land of very limited agricultural value

The map should be consulted for a detailed classification.

There is no Class 1 land classified in West Lothian.

Class 2 and 3[1] land are the main grades to the north and east of Livingston. Class 1 - 3[1] are considered as "Prime Quality Land" which in a Scottish context is scarce, covering some 5.7% of Scotland's land surface. Because of its high value to agriculture it was considered that where prime quality land would be affected by development there should be reasoned justification for doing so. If such land is developed then special measures should be applied to conserve the soils for afteruse and to manage them appropriately during the development phase.

The grades of land tend to increase from 3 to 6 up to the Pentland Hills and further west of Livingston.

3.2 FORESTRY

Many areas of forestry in West Lothian are relatively recently planted and are established on soils which were poor for agricultural use such as heathland and moorland. Soils are affected during the establishment of new forests and this includes:

- Disturbance through ground preparation
- Drainage to establish the tree stock
- Nutrient improvement where the key element can be additional phosphorous.

When the forest moves into a close canopy phase less water reaches the soil and other changes to the soil micro-climate occur. Established forestry has a significant effect on the deposition of litter at the soil surface affecting soil organic matter in the top horizon.

Land Capability for Forestry handbooks and maps, scale 1:250 000 (coloured), are produced by the Macaulay Institute and descriptive handbooks are available by area.

The Scottish Forestry Grants Scheme is available on areas over 0.25ha. The scheme considers the effect of planting on biodiversity and places an emphasis on ground preparation and woodland management.

A risk attached to cultivation, particularly ploughing, is erosion. Sites most at risk are those on moderate to steep lopes, underlain by mineral soils of low clay content and in high rainfall areas.

3.3 URBAN AND RECREATION USES

The soil type may influence the decision on the siting of housing or industrial sites particularly with regard to drainage and habitat. However it may be more significant with regard to the application of SUDS techniques and the creation of the open space used for recreation or wildlife.

Urban open space provision

Those soils most suited to use for recreational purposes such as parks, football pitches and golf courses will tend to be the same soils that are good for agriculture. The land capability for agriculture maps will therefore be a useful guide although an assessment on the ground should be undertaken as part of the site assessment and planning process.

The creation of habitats in urban areas should be matched to the soil type. For example, ponds and wetlands will be more difficult to create on a free-draining soil than a poorly drained soil.

3.4 PROTECTION OF CULTURAL HERITAGE

Soils are intricately linked to past patterns of human settlement and land use. Much of the evidence of early improved agriculture has been destroyed through changes to cultivation techniques. Some evidence does, however, survive in pockets of upland and marginal land where modern farming has not been so intense.

In pre-improvement Scotland, arable land was usually cultivated in blocks of broad rigs of between 4.5 to 15m in breadth. Individual blocks of rigs were not normally enclosed until the eighteenth century. Rig and furrow remained in use until underground tile drains were adopted in the later nineteenth century, although the rig was narrower and only 4.5m or less. Examples of broad and narrow rig are visible at Cowthrople, Morton Hill to the south of Livingston.

Historic Scotland and the RCAHMS are gradually covering Scotland with a Historic Landuse Assessment which is creating a series of map overlays of Scotland at 1:25,000 scale showing land use change over time. This will help to show features of old cultivation that are significant as worthy of preservation.

3.5 SOIL DRAINAGE

Figure 3 provides a general indication of the natural drainage status of soils in West Lothian.

The natural drainage status is determined by the soil parent material, topography and climate. For example the Winton soil series, which has a glacial till parent material and is generally found in the gently rolling farming areas in the north of the county, is imperfectly drained. A soil with a similar parent material at the foothills of the Pentlands is poorly drained due to topography and climatic differences.

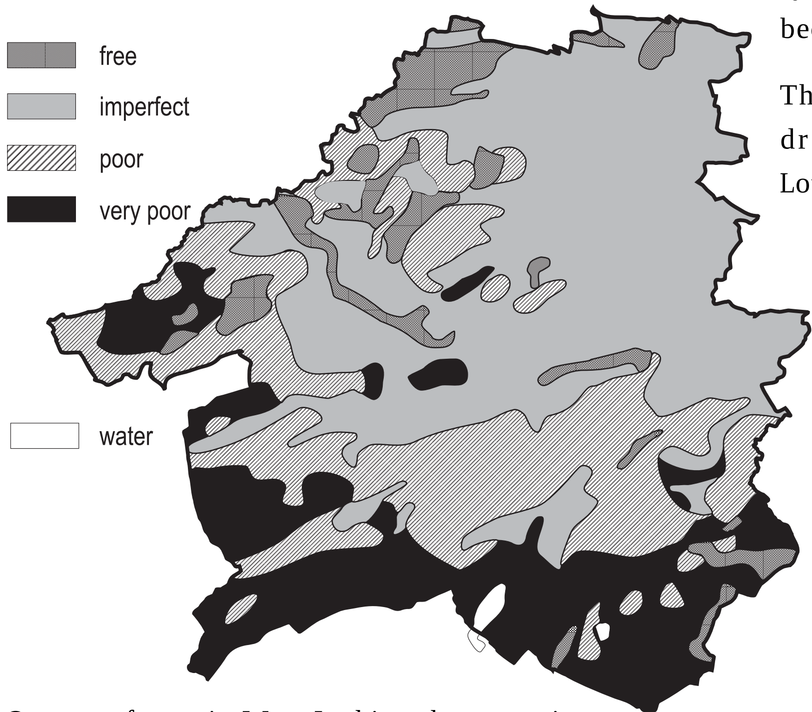
Reduced grazing causing by flooding

3.5.1 Natural drainage status

Figure 3. Guide to soil natural drainage in West Lothian

Soil drainage classes are as follows:

- **Free**: the B horizon is a bright colour and the colouring is fairly uniform.
- **Imperfect**: the B horizon is not as bright as for freely draining soils. There is appreciable mottling and some gleying (grey colour).
- **Poor**: the B horizon is very dull and mottling is obvious. There is extensive gleying. There may be mottling in the A horizon.
- **Very poor**: the B horizon is very dull and mottling is obvious. There will be gleying and mottling in the A horizon.



On most farms in West Lothian the operation of a satisfactory drainage system is a fundamental base on which agricultural production systems are founded.

3.5.2 Field drainage

The purpose of drainage is to remove excess water from the soil. Water in soil can be sub-divided into three categories: gravitational water, available water and unavailable water.

Gravitational water is present temporarily and will drain out of the soil under the influence of gravity. Once the last of the gravitational water has just drained away, the soil is at field capacity. This is the driest state the soil can be by drainage alone. Much of the remaining water at field capacity can be utilised by crops. As the plants extract and transpire this water the soil eventually dries to wilting point. The water between field capacity and wilting point is the available water and that below wilting point is unavailable.

In soils with a sandy texture the moisture content at field capacity is within the range over which the soils are friable and easily worked. In heavier clay soils the soil can still be too plastic and sticky to work at field capacity and has to dry further by evaporation before it becomes workable.

There are basically three types of drainage problem found in West Lothian. These are:

1. Surface water
2. Ground water
3. Springs and seepage lines

3.5.2.1 *History of drainage*

Over the centuries many of the areas farmed have had drainage systems installed. The timing of drainage installation tended to coincide with periods of agricultural prosperity and grant assistance from governments, for example the Public Money Drainage Acts in the 1840s resulted in a considerable amount of field drainage being installed. Grants towards field, hill and arterial drainage were introduced in 1921. Following the Second World War considerable assistance was given towards field drainage up until the 1980s when the cost benefit and conservation value of wetlands were considered more important. There are now no drainage grants available to farmers.

Indeed agri-environment schemes now encourage the creation of wetlands for wildlife benefit.

It is quite common for fields to have a variety of drainage systems installed at different times. Some of these systems could be of historical value. Many old drainage schemes eventually fail because of broken pipes, blockages and poor outfalls. The present economics of agriculture suggest that costly repairs or new schemes are less likely.

3.5.2.2 Effect of drainage on habitat

Where wetland areas have been drained this is likely to have an adverse effect on the wetland habitat. Wetland plant communities cannot tolerate long periods without adequate water and many species rely on surface water for their existence. Wading birds nest in wetland areas using taller plants such as rushes to provide cover from predators. Anaerobic conditions in wetlands create a different microhabitat and ultimately lead to the build-up of peat.

Open drainage can have a positive effect on biodiversity. Ditches that have been created as part of drainage schemes are often valuable habitats along field margins. Drainage also allows cropping in areas where grass would dominate thus creating a more varied farming habitat.

Tailend Moss Nature Reserve, Bathgate

With the high cost of drainage and low returns from agriculture it is likely that the amount of gravitational water in soils in West Lothian will increase, resulting in more wetland areas. This could have implications for small free-flowing watercourses and the diversity of farming.

3.6 SOIL PH AND FERTILITY

3.6.1 Soil pH

Most soils in the Scotland are acidic. On hill or marginal soils, the degree of acidity can be estimated by the amount of surface organic matter present: good pasture at pH 5.5 down to brown peat at pH 3.0.

The amount of lime in an arable soil is controlled by the degree of leaching which is dependent on the soil permeability and the rainfall. The degree of acidification is also affected by application of nitrogenous fertilisers. Bacteria change sulphate of ammonia into nitric and sulphuric acid, 1 kg of which removes 1 kg of lime. Lime is lost more quickly on land near to towns than in 'deep' rural areas. This is caused by sulphuric acid in rainwater which has been picked up from air pollution.

Different crops have individual optimum pH ranges. As pH drops manganese and aluminium become too readily available and in acid soils most crops become adversely affected by over absorption of these elements.

Sandy soils are the most prone to soil acidification. However it takes less lime to raise the pH in a sandy soil than in a clay soil due to the smaller base exchange capacity in a sandy soil.

Soil pH is critical for satisfactory growth of all crops. The optimum pH for arable crops such

Oilseed rape

as cereals and oilseed rape is between 6.2 to 6.5 whilst for grassland a lower pH of 5.8 to 6.0 is recommended. Higher levels of pH greater than 6.5 increase the risk of trace element deficiencies occuring and lower pH levels can lead to crop failure. Farmers adjust the pH level in the soil through the application of a liming material such as magnesium limestone. Soils lose lime through leaching and fertilisers accelerate this process especially ammonium compounds.

3.6.2 Soil fertility

Apart from carbon, hydrogen and oxygen, which are obtained from air and water, the essential elements required by plants in substantial quantities are nitrogen, phosphorous, potassium, calcium, magnasium and sulphur. The remaining essential elements are commonly known as trace elements and include iron, manganese, boron, copper, zinc and molybdenum. Other elements are required by particular species or may be applied for the benefit of livestock, for example cobalt sulphate can be sprayed on to pasture. The ability of plants to absorb elements is complex: for example manganese is not taken up by cereals as readily on high pH soils.

The application of fertilisers is an essential part of land management to compensate for the loss in nutrients through crop or livestock removal. Nutrient budgeting is a management tool aimed at raising farmers' awareness of the cycling of nutrients on their land and the potential loss to watercourses and the atmosphere. The main elements applied to crops are nitrogen, phosphorous and potassium. It is becoming more common to apply sulphur to certain crops, particularly brassicas such as oilseed rape, as a consequence of improved air quality.

3.6.2.1 Nitrogen

Plants use nitrogen to form amino acids and from them proteins that are essential to all life. Apart from legumes all crops and grass grown in the UK show significant yield increases from applied nitrogen. The most common inorganic source of nitrogen is ammonium nitrate; other sources used in West Lothian include ammonium sulphate and urea. Crops will also respond to organic sources of nitrogen such as farmyard manure, slurry and hen manure (hen pen). These organic nutrients will also contain other nutrients such as phosphorous and potassium.

Nitrogen, mainly in the form of nitrate, is readily leached from the soil. The most intense nitrogen leaching occurs during short periods of heavy rain on sandy soils, especially where there is no crop cover. Loss of nitrogen through denitrification (bacteria converting nitrate nitrogen to gaseous nitrogen) is most common in temporary and permanently waterlogged soils. Some areas within Scotland have been declared a Nitrate Vulnerable Zone (NVZ) by the Scottish Executive in response to European legislation. This places restrictions on the timing of nitrogen application and use. West Lothian does not currently fall within an NVZ but the situation is being monitored by the Scottish Environment Protection Agency (SEPA).

3.6.2.2 *Phosphorous and potassium*

Phosphorous compounds are actively involved in respiration, energy transfer and the efficient uptake of nitrogen. It is a very important nutrient in root development and seed ripening. Phosphorous is supplied to plants in the form of phosphates.

Potassium is involved in very small quantities in a large number of enzyme functions within plants, but the major quantity of the nutrient is needed as an osmoticum to control water balance and nutrient flow in the plant. The fertiliser nutrient is labelled and referred to as K2O, commonly called potash.

Soils whose parent materials are fluvio-glacial sands and gravels, and through which leaching readily occurs, can have deficiencies in potassium and phosphorous. Applications of potassium on these soils are generally higher than on the soils formed from glacial tills. Light-textured soils, low in organic matter, will leach potassium readily.

Large quantities of phosphorus can be removed from fields suffering from erosion as the phosphate compound adheres to the soil particles. Serious phosphorus deficiency occurs in very acid soils and calcareous soils.

3.6.2.3 *Cation exchange capacity*

Some plant nutrients are available to plants in the form of cations. Examples are magnesium, calcium, hydrogen and potassium. Making the nutrient available to the plant involves an exchange between the clay - humus complex, the soil solution and the plant root hairs. The exchange involves replacement of the nutrient cation with hydrogen ions. The capacity of the soil to exchange nutrients in the form of cations is dependent upon a number of factors:

Soil texture: sands and sandy loams have a much smaller cation exchange capacity than clay loams or clays.

Soil organic matter: incorporation of well-decomposed organic material into the topsoil will increase cation exchange capacity.

pH: all elements have maximum availability in the range of pH 5.5 to pH 6.5.

3.6.3 Effect of lime and fertilisers on habitat

Lime applications will have detrimental effects on species that thrive in acid conditions. These habitats tend to be in the south and west of the county, on acid grasslands, heathland and mires.

Fertlisers both organic and inorganic will generally be detrimental to areas of high conservation value such as species-rich grassland, wetlands and moorland. Direct applications of fertilisers to watercourses through poor agricultural practice or where there is a clear risk of run-off to a watercourse should be avoided. In any event it is wasteful and expensive.

Prior to the 1980s farmers were given grants to convert unimproved areas to productive grassland. This included a grant towards lime, phosphate and a compound fertiliser of nitrogen, phosphorous and potassium. This grant is no longer available, and farmers are positively discouraged from liming or fertilising such areas through grant schemes such as the Rural Stewardship Scheme and the Less Favoured Area Support Scheme under the direction of the Scottish Executive.

3.6.4 Soil testing

Many land managers in West Lothian have had their soils tested for pH, phosphorous, potassium and magnesium on a regular basis through SAC. Tests for other elements have also been carried out. Recommended rates of fertiliser are shown in the SAC Technical Note series on fertilisers that are available to land managers.

3.7 SOIL ORGANIC MATTER

Organic matter (humus) is the most important single component of soils because it:

- Stabilises soil structure, increasing resistance to soil compaction
- Improves water-holding capacity of sandy soils
- Improves the ease of cultivation, particularly on heavy soils
- Encourages soil biological activity.

An excellent succinct summary of the importance of soil organic matter on soil fertility can be found in Ken Simpson's book, 'Soils' (see Bibliography).

"The slow and insidious decline in the amount of humified organic matter in soils under arable agriculture is an important restricting factor to soil fertility. I am in no doubt whatever that the maintenance or improvement of the humified organic matter content of our mineral soils is essential to long-term fertility. It will help greatly in the prevention of cultivation pans, surface compaction, frost heaving, clod formation, wind erosion, capping and puddling, drought, low nutrient status and the excessive leaching of lime and fertilizers."

Organic matter levels cannot practically be raised quickly. A number of practices are undertaken to address this:

- A rotation which includes a medium-to long-term grass ley.
- The regular spreading of organic manures. The most commonly used are agricultural wastes produced on the farm such as cattle slurry or farmyard manure. Other agricultural wastes such as hen or pig manure are used. The specialisation of arable farming in the north and east has resulted in less spreading of farm produced organic manure.
- Non-agricultural organic matter wastes such as spent mushroom composts are also spread on some farms in West Lothian.
- Straw incorporation after harvest will improve organic matter levels.
- Avoidance of mixing subsoil with topsoil e.g. by avoiding deep ploughing retains organic matter.
- Minimum tillage systems are likely to increase organic matter in the top horizon.
- High yielding crops may increase organic matter levels.

3.8 HEAVY METALS AND SOILS

Heavy metals is the name given to a metal of high specific gravity such as mercury, lead, copper etc. Pulford (Soils, Sustainability and the Natural Heritage 1996) quotes 23 heavy metals in his paper "Heavy metals in soils" and suggests the effects on soil sustainability of heavy metals are:

a) the effects of the metals on the functioning of soil processes

b) releases of metals to air and water

c) transmission of metals from soil into the food chain.

The iron released from acid mine drainage in West Lothian, through the oxidation of iron pyrites, affects farm and other drainage systems caused by the filamentious growth of *thiobaccillus feroxidans* or *gallianella*, commonly referred to as iron ochre.

Heavy metals occur in sewage sludge which includes industrial sources. Applications of sewage sludge and other waste products are regulated by SEPA.

3.9 SOIL STRUCTURE

The spaces between the soil peds are more important than the structure of the soil peds themselves. The fissures and pores which extend through the whole soil profile control the passage of air and water, how much water is available to plants and the ease of root penetration.

In light sandy soils structure is weakly developed. The porosity of the soil is dependent upon the size of the sand particles and the closeness of packing. Clay soils have no porosity unless structure is present. Most soils, such as sandy loams, are between the two. Soil organic matter plays an important part in the structural stability of soils.

Clay, soil organic matter and lime give stability to soil structure; oxides of iron and aluminium are also important. Structural instability is common in soils with a high sand or silt fraction and a low level of organic matter. Textures with structural stability problems are sands, fine sandy loams, silt loams, silty clay loams and sandy clay loams.

Soil instability is also encouraged by poor drainage and high water tables.

Deterioration of soil structure can occur gradually over a number of years, especially during a period of wet autumns and springs. As structure worsens, crop productivity is reduced and the period of access to the land becomes shorter. Failure to add organic matter to maintain soil organic levels and the gradual silting of field drainage systems are common causes of long term soil structure degradation. This can also happen in playing-field situations.

3.9.1 Soil structure and housing developments

As the topsoil contains most of the nutrients, soil organisms and organic matter it is important that it is stripped from the building site and stored correctly before any building operations commence. Topsoil should be stored separately in bunds around the site. A maximum bund height of 3m is recommended for most building sites but the shallower the bund the better. To prevent loss of soil structure, the bund should not be run over by vehicles and should be stored for as short a time as possible. Where soil is used to create permanent bunds on development sites toe drainage needs to be planned.

Sloped batters on the soil bunds should have gradients which minimise the risk of slumping and which facilitate management of the stored soils. An appropriate grass/clover sward can be established on topsoil mounds as soon as possible after formation and certainly before the onset of winter if the bunded soil is to be stored for a long period. This will help to stabilise the mounds and reduce erosion, as well as encourage aeration of the soil through root penetration and aid downward percolation. The grass is managed by cutting and other appropriate treatments to discourage the growth of perennial and other weeds and to maintain the vigour of the sward.

Housing development site and soils

Before the topsoil is replaced, all large stones and building materials are removed from the site. At sites where waterlogging or the flooding of adjacent properties is a possibility, field drains should be installed with permeable backfill. This is particularly important for soils with a glacial till parent material. The subsoil should then be ripped to loosen the compacted layers.

If possible, the topsoil should only be moved when the soil moisture content is below the plastic limit. This is true when stripping the topsoil and forming bunds as well as replacing the topsoil. For many of the topsoils in West Lothian, with a high clay content, reaching plastic limit will not be possible. The best that can be achieved is to replace the soil after 2-3 days without rain. No traffic should pass over the topsoil as it is being replaced and a settled depth of 250-300mm is recommended.

3.10 SOIL EROSION BY WATER

Soil erosion by water is caused by rapidly moving water across bare soil. The beating action of rain on wet soil destroys surface aggregates which reduces water infiltration. Once water from rainfall exceeds water infiltration into the soil, run-off occurs. The severity of raindrops, the rate of precipitation and long and/or steep slopes affect the extent of soil erosion. If erosion is light, only clay and silt particles are lost in sheet erosion on all the slope. Rill erosion occurs in more severe conditions where water becomes concentrated in many shallow rills or gullies.

Soil erosion by water can lead to a gradual loss in soil fertility and river and pond pollution from organic nitrogen and phosphate and silt. Erosion has increased over the last few decades by the conversion of grassland to arable, the increase in field size and the sowing of winter cereals. Fine seedbeds, low crop cover over winter and tramlines running up and down the slope are factors which affect soil erosion.

Low organic matter sandy or silty topsoils are prone to erosion by water as are clay soils with poor structure. 20% of peat in upland Scotland has been eroded.

The use of watercourses as drinking points for livestock has led to bank erosion. Any crops grown in drills on sloping ground are also more likely to cause soil erosion.

The level of soil erosion in West Lothian is unlikely to be different from other counties in the Central Belt, however climate change predictions of a larger proportion of the precipitation falling on heavy rainfall days will lead to an increase of surface water run-off and potentially more soil erosion.

3.11 SOIL EROSION BY WIND

Over gentle undulating land, where the soil surface has been dried out, “blowing” can occur at wind speeds of about 18-25 miles per hour. A loose surface of fine tilth is most likely to erode whereas a coarse cloddy surface is least likely. The fine sand fraction is most likely to be moved by wind erosion. Light sandy soils with low organic matter are the most likely soil texture to be eroded by wind. This is not a major problem in West Lothian although climate prediction changes of drier summers and possible lower organic matter contents could increase the likelihood of this form of erosion in the future.

3.12 SOIL ORGANISMS

Disturbance of the soil generally reduces the species diversity of soil organisms as well as the total population. Adding lime, fertiliser and manure to an infertile soil will increase the activities of bacteria and actinomycetes. Pesticides will reduce organism numbers, at least temporarily. Some of the main soil organisms are listed below,

3.12.1 Earthworms

Earthworms produce as much as 18000 kg/ha in cast in a cultivated field. When compared to the basic soil these casts are higher in organic matter, nitrogen, calcium, magnesium, potassium, pH base saturation and cation exchange capacity. Worms leave holes in the soil which improve drainage and aeration.

Earthworms prefer medium textured, moist soils rather than poorly drained soils. They require organic matter, such as manure or plant residues, as a food source. The soil pH should not be too acid.

3.12.2 Soil fungi and the mycorrhizal–plant association

Soil fungi decompose organic matter and are therefore important in the formation of humus. The mycorrhizal association between fungi and plant roots can be highly beneficial for tree planting on industrial wasteland or where soils have been sterilised or fumigated. Inoculation of the soil with mycorrhizal fungi can improve the uptake of major nutrients and trace elements when no or little fertiliser has been applied. Mycorrhizal fungal infection of tree roots improves tolerance to environmental stresses such as drought and heavy metal toxicity. It is an important technique when planting on industrial land.

3.12.3 Soil bacteria

Soil bacteria carry out enzymatic transformations for nitrogen oxidation (nitrification), sulphur oxidation and nitrogen fixation and are important in all organic transactions.

Soil bacteria use oxygen gas or combined oxygen (anaerobic). Moisture levels that suit plants will suit bacteria. Bacterial activity is greatest between 20^0-40^0C. Some bacteria require organic matter as an energy source. Most bacteria require a high calcium concentration and a pH from 6-8.

3.12.4 Pests and diseases within soils

Moving soil carries the risk of spreading many of the pests and diseases that affect plants and animals. There can also be a problem spreading weeds; for example blackgrass causes major economic losses to arable farmers in the south-east of England but is starting to spread into Scotland. Some pests and diseases are as follows:

- Clubroot (*Plasmodiophora brassicae*) is a fungal disease affecting brassica crops such as swedes. The fungus can remain in the soil for over ten years and will increase if a brassica crop is sown or brassica weeds are present. The main source of infection is therefore contaminated soil.
- Nematodes or eelworms are non-segmented worms normally between 0.5 to 1.5mm long. They can infect many plant groups and also be a source for spreading plant viruses such as tobacco rattle virus (spraing in potatoes). Cereal cyst nematode is an occasional problem in Scotland but the most serious pest in this group is the potato cyst nematode, commonly called potato cyst eelworm. These pests are a major cause of yield reduction in many ware potato crops and are a cause of rejection of land submitted to government authorities for seed certification purposes. Larvae hatch from cysts mainly in response to chemicals given off by potato roots. The cysts can survive in the soil for as long as twenty years. The main form of control is through crop rotation and the most suitable length of rotation can be determined by soil analysis.

Whenever topsoil is moved (for example pipeline work) it should be tested for nematodes including potato cyst nematode and clubroot through SAC.

- The alien New Zealand flatworm *Artioposthia triangulata* consumes large quantities of earthworms and was first discovered in the UK in 1965; it has been recorded in West Lothian. It prefers moist conditions and has a relatively narrow thermal tolerance for an invertebrate ranging from -1 to 23^0 centigrade. Its long-term effect on earthworm populations is still not fully understood.
- Biosecurity on farms is an issue to emerge from the foot and mouth outbreak. The Scottish Executive has produced guidelines as a consequence. It recommends that risk assessments are carried out before any materials, animals or people come onto a farm.

3.13 SHALLOW SOILS

Shallow soils in West Lothian are located on steep slopes or with rocky outcrops. They are normally left as semi-natural grassland and permanent pasture with some broadleaf woodland. They are stony loams in texture with well-developed structure. Where rock is near to the surface drainage is excessive and grass will 'burn out' in summer.

Shallow soils are not normally in areas where development occurs. Management of associated species - rich grassland could be an important issue where these soils exist.

Binny Craig

4 Rare Soil Types

Soil associations and series are given names based on the location where they were first described. There are two soils in West Lothian which have been named within the county.

The Hendry soil complex is located in the south of West Lothian, approximately 4 kilometres south-east of Fauldhouse. It is covered mainly by Woodmuir Forestry Plantation and the forestry planting at Pate's Hill. This soil complex is a mix of soil series all formed from Carboniferous shales and sandstones, with some coals, limestones and cementstones. However, the series have been described elsewhere in Scotland. The Hendry soil complex consists of:

Peat	Organic
Greenside soil series (Rowanhill Association)	brown forest soil
Glaisnock soil series (Rowanhill Association)	peaty gley
Rowanhill soil series (Rowanhill Association)	non-calcareous gley

It is probably not of great national significance as it shares the same parent material as many other soils in Scotland. The soil series which make up the complex are not from any of the less well-known soil groups.

The Colzium soil series is found on the western slopes of the Pentland Hills. Within West Lothian it appears as isolated areas between Crosswood Reservoir and Harperrig Reservoir. It continues to appear in larger consolidated areas on the west slopes of the Pentland Hills as far as their northern extremity. As a non-calcareous gley, it does not belong to a rare soil group. The combination of Carboniferous shales and Upper Old Red Sandstone, plus the poor drainage status, but without the peat cover, may, however, provide a special habitat.

A poorly drained gleyed soil. The soil series is Colzium. This pit was excavated at Colzium Farm, near Harperrig reservoir.

5 Soil Matrix

5.1 THE PURPOSE OF THE SOIL MATRIX

For the purposes of the report a soil matrix has been designed to assist the evaluation of soil types. The soil matrix lists all the soil series to be found in West Lothian, most of the differentiated alluviums, and the peats. It also shows the soil series codes as depicted on the 1 inch to 1 mile soils maps.

Along the top of the matrix is a list of factors which are associated with soil, such as soil - plant relationships, soil and erosion, soil and drainage. Asterisks denote a connection between the soil biodiversity or sustainability factor and the soil series, indicating that where a specific soil type is found, these factors may be of importance. Where no asterisk is found against a soil type, there is either no connection or there is a lack of data. The soil matrix should therefore not be used as a set of rules but purely for guidance.

The matrix has been split into three pages. The first two pages that follows this section are concerned with biodiversity and sustainability factors that affect soils. The second part of the matrix is concerned with SUDS (Sustainable Urban Drainage Systems) and is shown at the end of section 6.

5.2 THE SOIL MATRIX DATA

Detailed information, additional to that shown on the 1 inch to 1 mile soils maps, has been collated in memoirs. Each memoir covers the area of the associated soils map. The county of West Lothian is covered by sheet 31, Airdrie and sheet 24/32, Peebles and Edinburgh. No soil memoirs have been written for these two maps.

Non-mapped soil series data has been taken from descriptions of the same series in memoirs covering other areas. Where more than one description is available, the memoir covering the area closest to West Lothian has been used.

As no soils memoir is available for West Lothian, the soils which only appear on the Airdrie and Peebles/Edinburgh maps have limited data.

The system of grading soil moisture and soil nutrients, as used by Pyatt (2001) for comparing soil types with woodland communities, is not the same as that used by the Soil Survey of Scotland. In trying to match the two systems, some errors will occur. Where the classifications do not match, the lower class has been chosen in Pyatt's nomenclature. The inclusion of soil series and woodland communities in the soil matrix is primarily to demonstrate the potential of the system. Further detailed study would be needed in order to make the comparison more robust.

Shallow soils, peat, differentiated and un-differentiated alluvium and raised beach soils have not been included in the woodland community section of the soils matrix.

Soil Biodiversity/Sustainability Matrix relating to SUDS

Key * = limited data available Biodiversity / Sustainability factor			Soils possibly suitable for SUDS infiltration methods	Soils suitable for SUDS infiltration methods	Soils not suitable for SUDS infiltration methods	Soils for unlined ponds / wetlands
Soil Series	SS code	Association				
Baidland	BD	Darleith				
Darleith	DL	Darleith		*		
Dalmahoy	DZc	Darleith				
Forestmill	FJ	Giffnock		*		
Giffnock	GK	Giffnock				*
Scaurs	SC	Giffnock			*	
Greenside	GI	Rowanhill		*		
Winton	WN	Rowanhill	*			*
Caprington	CP	Rowanhill	*			*
Rowanhill	RH	Rowanhill			*	*
Todrigs	TS	Rowanhill			*	*
Glaisnock	GQ	Rowanhill			*	
Macmerry	ME	Rowanhill	*			*?
Butterdean	BT	Rowanhill			*	
Hendry	HYc	Rowanhill				
Queensferry	QFc					*?
Tulloch	TH	Darvel		*		
Darvel	DV	Darvel		*		
Dreghorn	DR	Dreghorn		*		
Dryburn	JD			*		
Myreside	JM					*?
Heavyside	JH				*	*?
PAL	PAL				*	
AL	AL					*?
Basin & valley peat	PT1				*	
Basin & valley peat	PT2				*	
Basin & valley peat	PT				*	
Blanket peat	HPT2				*	
Blanket peat	HPT				*	
Highfield	HF	Ashgrove	*			
Bemersyde	BM	Bemersyde		*		
Colzium	CZ	Biel			*	
Listonshiels	LI	Biel			*	
Eckford	EK	Eckford		*		
Harelaw	HW	Hobkirk		*		
Faw	FW	Hobkirk				
Hobkirk	HK	Hobkirk		*		
Wauchope	WE	Hobkirk			*	
Fraserburgh	FR	Fraserburgh		*		

Soil Biodiversity/Sustainability Matrix relating to habitats, SSSIs, and Agriculture

Biodiversity / Sustainability factor			Soils with semi-natural grassland when not cultivated	Soil susceptible to wind erosion	Soils which could support active lowland raised bogs	Soils which could support dry Calluna moor	Soils which can support nardus and wet calluna moor	Soils which can support nardus grassland, or calluna moor	Soils associated with 3 SSSI blanket and raised bogs	Soils associated with 1 SSSI lowland raised bog	Soils associated with 4 SSSI woodlands	Soils associated with 1 SSSI raised bog/ birch wood	Soils associated with 1 SSSI marsh/basin mire	Soils associated with 1 SSSI dry heath	Prime agricultural land
Soil Series	SS code	Association													
Baidland	BD	Darleith					*								
Darleith	DL	Darleith	*												
Dalmahoy	DZc	Darleith													
Forestmill	FJ	Giffnock													
Giffnock	GK	Giffnock													
Scaurs	SC	Giffnock						*							
Greenside	GI	Rowanhill													
Winton	WN	Rowanhill												*	
Caprington	CP	Rowanhill													*
Rowanhill	RH	Rowanhill									*				
Todrigs	TS	Rowanhill													
Glaisnock	GQ	Rowanhill						*							
Macmerry	ME	Rowanhill									*				*
Butterdean	BT	Rowanhill													
Hendry	HYc	Rowanhill													
Queensferry	QFc										*				*
Tulloch	TH	Darvel				*									
Darvel	DV	Darvel									*				*
Dreghorn	DR	Dreghorn													
Dryburn	JD														
Myreside	JM														
Heavyside	JH														
PAL	PAL												*		
AL	AL														
Basin & valley peat	PT1				*										
Basin & valley peat	PT2				*										
Basin & Valley peat	PT									*		*			
Blanket peat	HPT2								*						
Blanket peat	HPT								*						
Highfield	HF	Ashgrove													
Bemersyde	BM	Bemersyde	*												
Colzium	CZ	Biel													
Listonshiels	LI	Biel						*							
Eckford	EK	Eckford													
Harelaw	HW	Hobkirk				*									
Faw	FW	Hobkirk					*							*	
Hobkirk	HK	Hobkirk	*												
Wauchope	WE	Hobkirk						*							
Fraserburgh	FR	Fraserburgh		*											

6 Sustainable Urban Drainage Systems and Soil

Any built-up area will have impermeable surfaces; roads, pavements, roofs etc. Rain falling on these surfaces will produce run-off, which in some circumstances will carry pollutants. Traditionally, this surface run-off was piped and removed from the built-up area as soon as possible and discharged into watercourses. Piping stormwater produced problems such as flooding downstream from the built-up area and the contamination of watercourses and groundwater by the pollutants carried in the stormwater.

The SUDS philosophy is based on three principles:

1. To attenuate stormwater flows, preventing flooding and river erosion.
2. To remove the pollutants in the run-off as close to the source of the contamination as possible.
3. To improve wildlife habitats and the local amenity value of the built-up area.

6.1 STORMWATER SOAKAWAYS AND INFILTRATION TRENCHES

Attenuating the run-off from roof areas can be carried out using stormwater soakaways and infiltration trenches. Stormwater is stored locally and released into the soil as groundwater re-charge. The operation of soakaways and infiltration trenches is based on a simple formula:

$$I - O = S$$

where

- I = inflow from the impermeable area draining into the soakaway.
- O = outflow infiltrating into the soil during the rainfall.
- S = required storage to balance the temporary inflow and outflow.

There are two factors which affect the correct operation of soakaways and infiltration trenches.

1. **The infiltration rate of the soil.**

Infiltration rate is determined by the subsoil texture and structure and also the stone count in the subsoil. A subsoil with a sandy loam texture and a good structure with plenty of pore spaces and voids between peds will have a better infiltration rate than a clay loam with a massive closed structure. A stony, sandy subsoil will have a faster infiltration rate than a sandy loam subsoil which will have a faster infiltration rate than a clay loam subsoil.

2. **The depth of the water table below the ground surface.**

Depending upon the soil texture and structure excess water after a rain event will remain in the soil as a temporary or in some cases permanent water table. If the water table rises to the same depth as the soakaway or infiltration trench floor no infiltration of run-off into the soil will occur as the soil is already saturated. Generally, the water table will rise towards the ground surface during the wetter months when the soakaway or infiltration trench is needed most. Direct contact between the run-off and the groundwater prevents any treatment of pollutants in the run-off by soil organisms and soil filtering.

The grey colour of the gleying process and the orange and brown mottling, plus the general lack of brightness of the subsoil colour, can give an indication of how often the subsoil is flooded. Where most of the soil colouring is grey waterlogging is, more or less, occurring throughout the year. Bright brown colours indicate a freely draining soil

6.2 VEGETATED SWALES

Swales drain water from impermeable areas and can provide conveyance, infiltration, detention and treatment. Swales will provide attenuation of flow through the inclusion of check dams. The vegetation on the swale floor and sides traps solid pollutants which are incorporated into the swale floor. The vegetation will take up nutrients during the growing season.

Although the majority of soils in West Lothian have poor infiltration rates due to the high clay content, swales can still provide attenuation, treatment and conveyance of stormwater from local to site controls. Infiltration should be regarded as a passive in West Lothian and not taken into consideration/account for in calculating drainage requirements.

High water tables can cause problems for the maintenance of swales. Grass will not survive in saturated soils and will be gradually replaced by coarse wetland plants which do not permit the same degree of filtration; cutting vegetation amongst ponded surface water is also not practical. One prediction of climate change is the increase in winter precipitation and heavier rainfall events. The result of this change could be a rise in the water table and an increase in the problem of waterlogged swales. It is recommended that for sites with limited gradients, the design of swales is altered to include a permeable floor with a gravel sub-base. The permeable swale floor will drain sufficiently to permit grass to grow and to be mown.

6.3 PONDS AND WETLANDS

Soils that have a glacial till parent material generally have a clay content of 20–30% in the subsoil. Once stones and organic debris have been removed from the surface and the soil structure has been broken down by compressing the soil in the presence of water, the soil is sufficiently impermeable to act as a natural seal. Ponds and wetlands constructed on sites where the subsoil is a heavy clay till should not require a liner. It is prudent to check the pond or wetland site for a suitable subsoil by excavating pits to examine the texture of the soil profile.

Unlined ponds and wetlands have many advantages. There are short-and long-term savings in the cost of the SUDS scheme by excluding a liner and the materials to protect the liner. Plants within the pond or wetland can obtain the necessary nutrients and micro-nutrient naturally and therefore should survive better. More natural-looking ponds/wetlands can be created without a liner where the edges of the pond can merge into boggy ground forming extended habitats.

Stormwater filling an unlined SUDS detention basin. The clay content of the subsoil acts as a natural seal holding the stormwater and releasing it slowly. As in many soils in lowland Scotland, infiltration is not a major factor in SUDS planning.

Soil Biodiversity/Sustainability Matrix relating to woodland

Biodiversity/Sustainability factor			Soils likely to support native woodland community W1 (Sallow with marsh bedstraw)	Soils likely to support native woodland community W2 (Alder with Common Reed)	Soils likely to support native woodland community W3 (Sall with Bottle Sedge)	Soils likely to support native woodland community W4 (Birch with Purple Moor Grass)	Soils likely to support native woodland community W7 (Alder - Ash with Yellw Pimpernell)	Soils likely to support native woodland community W8 (Mixed broadleaved withDog's Mercury)	Soils likely to support native woodland community W10 (Mixed broadleaved with Bluebell/Wild Hyacinth)	Soils likely to support native woodland community W11 (Oak - Birch with Bluebell/Wild Hyacinth)	Soils likely to support native woodland community W12 (Beech with Dog's Mercury)	Soils likely to support native woodland community W13 (Yew)	Soils likely to support native woodland community W14 (Beech with bramble)
Soil Series	**SS code**	**Association**											
Baidland	BD	Darleith	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
Darleith	DL	Darleith	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
Dalmahoy	DZc	Darleith	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Forestmill	FJ	Giffnock	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Giffnock	GK	Giffnock	*	*	*	*							
Scaurs	SC	Giffnock	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Greenside	GI	Rowanhill	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Winton	WN	Rowanhill				*	*						
Caprington	CP	Rowanhill				*	*						
Rowanhill	RH	Rowanhill	*	*	*	*							
Todrigs	TS	Rowanhill		*									
Glaisnock	GQ	Rowanhill	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Macmerry	ME	Rowanhill				*	*						
Butterdean	BT	Rowanhill	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Hendry	HYc	Rowanhill	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Queensferry	QFc					*	*						
Tulloch	TH	Darvel	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Darvel	DV	Darvel								*			
Dreghorn	DR	Dreghorn							*				*
Dryburn	JD		n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc
Myreside	JM		n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc
Heavyside	JH		n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc
PAL	PAL		n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc
AL	AL		n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc
Basin & valley peat	PT1		n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc
Basin & valley peat	PT2		n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc
Basin & Valley peat	PT		n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc
Blanket peat	HPT2		n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc
Blanket peat	HPT		n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc	n/inc
Highfield	HF	Ashgrove	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
Bemersyde	BM	Bemersyde	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
Colzium	CZ	Biel	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Listonshiels	LI	Biel	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Eckford	EK	Eckford							*				*
Harelaw	HW	Hobkirk	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Faw	FW	Hobkirk	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
Hobkirk	HK	Hobkirk	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
Wauchope	WE	Hobkirk	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
Fraserburgh	FR	Fraserburgh											

Key: SS = Shallow Soil n/d = no data n/inc = not included * = limited data available

7 Soils and Climate Change

The modifications that will occur in soils through climate change are not well understood, partly because of the unknown level of predicted rise in temperature and precipitation.

Soil organic matter will decompose more readily if temperatures rise, therefore organic matter levels in the soil could decrease with climate change. This would affect water-holding capacity, soil structure, nutrient storage, resistance to erosion etc.

Soil moisture deficits would increase with higher temperatures. In West Lothian, where there is significant excess rainfall, this would be beneficial to most farmers. There could be some movement of cropping into marginal lands and the number of days of machinery access would increase.

Higher temperatures will make more nitrate nitrogen available for leaching and therefore increased rainfall would increase the loss of nitrogen to drainage water. Warmer and drier conditions would encourage the release of nitrogen from the soil as ammonia gas.

Reduction in soil organic matter will affect the structural stability of the topsoil. Coupled with increased precipitation, this would result in increased levels of topsoil erosion.

The latest models of climate change predict that winter precipitation will increase. Not only will the overall winter rainfall increase but also heavy precipitation will become more frequent. The intensity of winter storms will be greater. There are two consequences for soils in West Lothian from this change in winter precipitation patterns. First, a general increase in winter precipitation will extend the periods of when the soil is saturated and extend the periods of when high water tables occur. Second, an increase in rainfall intensity coupled with an increased chance of very wet soils will result in more surface run-off. This has implications for flooding and soil erosion.

The predictions of an increase in summer temperatures and a decrease in summer rainfall will result in a decrease of summer soil moisture content. In many cases, this will be an advantage in West Lothian, increasing the period of soil workability, increasing soil warming and increasing microbial activity. But care should be taken to inspect stormwater detention basins where dry periods could lead to soil cracking and fissuring on the basin floor. During winter, leaking basins could cause local flooding to sites down-slope from the basin. Also, wetlands created for stormwater treatment may dry up unless a decent natural source of water can be tapped into and used to maintain water levels.

8 Legislation and Codes of Practice

WATER FRAMEWORK DIRECTIVE

The overall objective of this is to bring about the effective co-ordination of water environment policy and regulation across Europe, in order to prevent deterioration and enhance status of aquatic ecosystems, including groundwater, promote sustainable water use, reduce pollution and contribute to the mitigation of floods and droughts.

Contact: SEPA

The Groundwater Regulations 1998

Groundwater is defined as all water occurring beneath the water table in direct contact with soils and rocks.

Forests and Soil Conservation Forestry Commission 1998

Forests and Soil Conservation Guidelines advise owners and managers how to conserve the soil as a fundamental resource upon which trees and the whole forest ecosystem depend. They deal mainly with the affects of forest operations on the soil itself.

Contact: Forestry Commission

Topsoil Specifications BS 3882

This British Standard specifies requirements for topsoils. It establishes three grades of material and gives recommendations for the use and handling of topsoil. It is not intended (or appropriate) for the grading, classification or standardisation of *in situ* topsoil or subsoil. Methods of sampling are given in Annex A. Methods for determination and calculation are given in Annex B to Annex M and Annex P.

The Potato Eelworm (Great Britain) Order 1973

The main objectives of this order are first to ensure that land for certified seed potato production in Great Britain remains free from this pest and second, to reduce the chance of spreading it to other countries.

PAN 61 Planning and Sustainable Urban Drainage

This planning advice note provides a background to surface water drainage and outlines the principles of SUDS. It lists the roles and responsibilities of statutory bodies and the planning of SUDS.

PAN 64 Reclamation of Surface Mineral Workings

The legislative provisions covering the reclamation of mineral workings have been introduced incrementally since the Town and Country Planning (Minerals) Act 1981. These have now been consolidated within the Town and Country Planning (Scotland) Act 1997 (the 1997 Act) schedules 3, 8, 9 and 10. This confers powers to impose conditions on planning permission for surface mineral workings where the land is to be used for agriculture, forestry or amenity purposes, and details how the conditions may be imposed and assessed. Information on the development of reclamation legislation is provided in Annex B.

Contact: Scottish Executive Development Department Planning Services

Code of Practice on Mineral Extraction

Owners and operators of mineral extraction sites have responsibility for any groundwater pollution caused directly or indirectly from their site.

The level of risk of contamination is primarily dependent on the nature of the host rock. Low permeability rocks will resist the through-flow of groundwater and may contain any contamination allowing time for clean-up. However, many low-permeability rocks in Scotland are fissured and so can allow very rapid movement of pollutants. Spillage in a more permeable area will provide a quick and easy path for contaminants. Old mine workings can also provide fast pathways to groundwater. Risk assessments should take local site-specific conditions into account.

Contact: SEPA

Sustainable Urban Drainage Systems (SUDS) (see Section 6)

Environmental Impact Assessment (EIA) Regulations (1999)

Certain types of development require the preparation of an Environmental Statement to accompany the planning application.

Annex III of the Environmental Assessment Directive requires that an Environmental Statement must include '*a description of the likely effects, direct and indirect on the environment of the proposed development, explained by reference to ... D) Soil.* Environmental Statements should provide information on '*the type and quantity of expected pollutants including pollution of soils and water*'.

West Lothian Local Biodiversity Action Plan

Code of good agricultural practice for the protection of soil. MAFF, London. Ministry of Agriculture, Fisheries and Food (1998)

A National Trust soil protection strategy. National Trust (1999)

Nitrate Vulnerable Zones (NVZ)

West Lothian does not fall within a NVZ.

The code of good practice for the prevention of environmental pollution from agricultural activity (PEPFAA code)

The code highlights potential environmental problems associated with agricultural practices and provides practical guidance on how to prevent or reduce pollution risk.

The Contaminated Land (Scotland) Regulations 2000 Scottish Statutory Instrument 2000 no. 178

The 4 Point Plan

Provides advice on how farmers can:

- Minimise dirty water around the steading
- Improve nutrient use
- Prepare a risk assessment for manure and slurry map
- Manage water margins.

Sludge (Use in Agriculture) Regulations 1989 (as amended).

Places controls on the use of sewage sludge.

Check with the Safe Sludge Matrix (an agreement between the UK water industry and the British Retail Consortium on sludge use).

Protected sites

Restrictions on soil use and cultivations are placed on Special Areas of Conservation, Sites of Special Scientific Interest, archaeological sites and other sites of a conservation or heritage value.

Agricultural Grant Schemes

Agri-environment and mainstream CAP subsidies may place restrictions on certain land use activities.

Agri-environment schemes include:

Rural Stewardship Scheme

Countryside Premium Scheme

Organic Aid Scheme

Contact: SEERAD, SOPA or Soil Association

9 Recommendations

This report provides a number of outline recommendations which can be taken forward through West Lothian Council policies and by the West Lothian Local Biodiversity Action Group. These need to be developed further in consultation with others in relation to policy, guidance and good practice to reflect the importance of soil as an issue of sustainable development.

9.1 PLANNING

9.1.1 Development Plan

West Lothian Council should implement a policy towards soil sustainability.

9.1.2 Development Control

Prior to specific developments West Lothian Council should initiate a procedure for soil management and sustainability. This could take into account the following:

- Soil assessment and soil analysis of the development site.
- Risk assessment of contaminants before moving soil. This should include analysis for heavy metals and soil pests and diseases.
- Soil archaeology assessment.
- Soil sustainability plans for development sites including:
- *Soil identification for after-use purposes. For example, identify soil types that already or could potentially provide rich habitats and consider reserving these areas as open spaces.*
- *Design a topsoil-handling plan considering BS 3882 Topsoil specifications.*
- *Draw up a site restoration plan.*
- *Consider open space drainage plans.*
- Monitoring of soil following development. See Recommendation 9.6.

SUDS

Soil percolation tests should be carried out when infiltration measures are to be included in a SUDS scheme.

Soil characteristics and maintenance should be taken into account when designing SUDS.

9.2 OPEN SPACE

Soil management plans for open space areas are recommended. These should be undertaken before new sites are established and on existing sites. Plans should be updated regularly every five years.

Plans should consider:

- Soil analysis: West Lothian Council should encourage soil analysis of recreational areas such as parks and gardens, playing fields, and other relevant open spaces on a regular basis (once every five years). A standard soil analysis measures pH, phosphorous, potassium and magnesium. Analysis for other elements may be necessary in certain situations. These analyses are available through SAC.
    - The soil analysis will allow the development of a fertiliser plan for open spaces where necessary including timing of nitrogen fertiliser applications and nutrient budgeting for phosphorous and potassium.
    - The plan should consider the drainage and soil structure particularly compaction.
    - To reduce soil erosion risk all open spaces controlled by WLC should not be left as bare soil through the winter.

- Footpaths: Make available to developers, farmers and other landowners advice on soil management to avoid soil erosion on footpaths. Note: the Lake District National Park Authority has produced a useful footpath erosion factsheet.

- Where new housing developments are proposed in conjunction with sites for playing fields and open space a soil suitability assessment should be carried out to consider optimum sites for the purpose. The assessment should give recommendations on soil protection during construction.

- Archaeology: Identify sites of archaeological interest in West Lothian related to soils including rig and furrow, crop circles. Complete this in association with RCAHMS.

9.3 ENVIRONMENT

- Buffer zones: Encourage buffer zones close to areas of environmental significance particularly water courses and areas of still water.

- Pests, diseases and weeds. During pipeline installations and topsoil movements ensure that practices to prevent the spread of clubroot and relevant nematodes are observed through testing the soil prior to and after movement of soil.

- Encourage large-scale recycling for compost and its use on development sites.

- Encourage farmers to manage soil compaction along tramlines.

9.4 BIODIVERSITY

The Local Biodiversity Action Plan group should develop a soil action plan with consideration of the following:

- Soil structure and organic matter

- Soil organisms

- Habitat creation. Prior to habitat creation and restoration, soil properties should be taken into account and proper advice sought. This is particularly relevant in wetland sites, pond design and areas suitable for species-rich grassland.

- Identify semi-natural habitats based on acidic soils and limit lime applications.

- Produce recommendations on good soil management particularly with regard to field drainage and poaching for users of small paddocks for livery.

- Updating and development of the soil matrix. With detailed soils data, a more extensive matrix is possible. For instance, the relationship between soil nutrient status and organic matter levels could be highlighted. An in-depth examination of the West Lothian habitat data, in relation to the soils maps, would provide plant community – soil factors giving guidance on amenity planting, woodland planting and the creation of parks and open spaces.

9.5 CLIMATE CHANGE

- Climate change predictions remain uncertain but will be updated and more accurate in the future. As policies on climate change develop the effects on the soil should be considered and updated.

- New housing developments adjacent to sloping farmland should include provisions for the interception and attenuated release of surface run-off and measures are included for the interception of water-eroded soil. There should also be an agreed programme for the emptying of attenuation devices and the return of eroded soil.

- Given climate change predictions, shallow ponds and wetlands will be more at risk of drying up in the summer. Soils with a low clay content that rely on a high water table will be most at risk. Storage of winter rainfall could be appropriate in these situations.

- Drier summers will mean lower soil moisture contents. Measures might be necessary to increase the water-holding capacity of soils, for example incorporation of organic matter.

9.6 MONITORING

- Monitoring should establish baseline data to measure effectiveness of soil sustainability and biodiversity. Including:
  - Organic matter
  - pH
  - Phosphorous and potassium levels
  - Soil structure in the topsoil. This can be measured using a cone pentrometer. This would be a useful measure before and after development work and in agriculture.
  - Topsoil water-holding capacity.
  - Earthworm numbers and types are a good indicator of improving soil conditions. Earthworm monitoring on restored sites is recommend.

9.7 RAISING AWARENESS

General awareness raising on the value and good management of soil should be undertaken to ensure sustainability in the short and long term.

Specific areas for awareness raising could include:

- A wider appreciation of the soils in West Lothian
- The importance of organic matter particularly amongst:

  Farmers

  Developers

  West Lothian Council staff
- The importance of soil structure: how to assess it and improve it.
- Awareness raising of the spread of New Zealand flatworm in West Lothian and the practical methods gardeners and horticultural staff can use to control the spread.
- The report, as the first of its type to be produced in Scotland, should be made widely available to policy makers, planners, advisers, land management interests and teachers.

10 Glossary

Access period	time available for animals or farm machinery to be on the land.
Actinomycetes	intermediate between bacteria and true fungi.
Basalt	a fine crystalline ferro-magnesian rock solidified from molten material.
Base exchange capacity	soil clay and organic matter can hold or absorb water soluble nutrients. One nutrient can be replaced by another when it is added in a fertiliser. Exchange of absorbed nutrients occurs. The nutrients are basic; they have the ability to neutralise acids, hence base exchange. Calcium is the most important base and is found in chalk and lime. A soil can absorb a fixed amount of bases: its base exchange capacity. When the exchange capacity is saturated with bases, the soil is at neutral pH.
Biosecurity	a strategy to prevent the spread of infection.
Cation	a positive charge ion.
Conglomerate	a sedimentary rock made up of rounded particles of rock in a sand or mud matrix.
Country rock	the rock into which magma is intruded.
Cultivation pan	strongly compacted horizontal layer in a soil.
Degree days	the average daily minimum and maximum temperature, minus a threshold temperature (0^0 C), is summed for each day from January to June. This gives an indication of how quickly the soils warm up in the spring. A higher figure indicates a milder spring and an earlier start to the growing season.
Dolerite	a fine-to medium-grained igneous rock forming minor intrusions. Chemically similar to basalt.
Evapotranspiration	moisture lost from the soil due to evaporation from the soil surface and plant transpiration.
Excess winter rainfall	total rainfall between return to field capacity in autumn and loss of field capacity in the spring, minus evapotranspiration in the same period.
Field capacity	(field moisture capacity): the percentage of water left in a soil two or three days after being saturated and after free drainage has practically finished.
Humified	formation of humus from organic matter.

Igneous	a rock which has solidified from molten or partially molten material.
Ion	electrically charged atoms, groups of atoms or compounds.
Intrusion	an igneous rock body formed at depth in an envelope of country rock.
Limestone	a rock with greater than 50% calcium carbonate.
Loam	textural class for a soil having a moderate amount of sand silt and clay.
Minimal Tillage	a system of sowing crops directly into the stubble of the previous crop without ploughing.
Mud stone	a rock formed from particles of size less than 62.5mm.
Peds	a unit of soil structure formed by natural processes.
Potential evapotranspiration	a measure of the atmosphere to remove water from the surface through the processes of evaporation and transpiration assuming no control on water supply.
Puddling	soil artificially compacted when wet and having no regular structure.
Pyroclastic	explosive fragmentation of magma or local rock during a volcanic eruption.
Sandstone	a rock derived from weathering or sedimentation consisting of at least 25% by volume of sand.
Seat-bed	a thin layer beneath a coal seam containing fossil rootlets. The soil in which the vegetation grew.
Shale	a fine grained laminated rock.
Sill	tabular or sheet-like igneous body.
Siltstone	a rock formed from particles of size 4 – 62.5mm.
Soil moisture deficit	the amount of water required to take the soil moisture content from its current level to field capacity. Described in millimetres per unit area.
Solifluction	the slow downslope movement of water saturated, seasonally thawed materials.
Tilth	the condition of a soil with respect to ease of tillage, fitness as a seedbed and impedance to seedling emergence and root penetration.
Tramlines	parallel wheelmarks from tractors, trailers etc.

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Appendix

Photographs of Soil types and structures

Imperfectly drained Winton soil series from a pit at Ritchie Camp, by Kirknewton. Gleying is evident as well as the massive structure of the clay loam subsoil.

Poorly drained Rowanhill series soil from North Mains, Dechmont. This profile shows orange-brown mottling and grey gleying, both typical signs of waterlogging.

Freely drained soil with a fluvio-glacial sand and gravel parent material. Note the bright brown colours and the steady change in colour through the soil horizons.

A soil with poor structure which has capped after heavy rain.

Two soils with different structures. The soil on the left has a closed structure with only a few cracks and fissures. The soil on the right has an open crumb structure with plenty of pore spaces for the easy passage of air and water.

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