SOILS

AND NATURAL FLOOD MANAGEMENT

DEVON AND CORNWALL

Catchment Based Approach
Partnerships for Action

CONTENTS

FOREWORD

There is much interest in natural flood management, a term that describes bringing about changes in the landscape to limit or slow the flow of water. This can mean soft engineering remedies such as the creation of woody debris dams, storage ponds and tree planting. However, it can also include changes to land management practices, including soil management. The huge natural potential of the soil to temporarily store rainwater is often overlooked.

The purpose of this manual is to improve understanding about the natural potential of soils in Devon and Cornwall to accept rainfall, and how soils can be managed to reduce the risk of runoff. It aims to address confusion about the difference between natural and unnatural runoff. Surface water runoff should be rare on many freely draining soil types in Devon and Cornwall, because they should seldom become saturated. Nevertheless, unnatural overland flow and rapid runoff is common.

The natural storage capacity of the soil can be easily lost due to soil compaction resulting from the way land is managed. Soil compaction can be a widespread problem in wet years and can often lead to localised flooding and pollution. Farmers and land managers should not necessarily be blamed for this problem; soil compaction can be difficult to avoid during prolonged wet spells, particularly when crops need harvesting in difficult conditions and there is intense economic pressure. This manual provides examples of how these risks can be managed in differing landscapes.

The East Devon Catchment Partnership has funded this manual to show how good soil management is fundamental to natural flood management. The manual is primarily for use by organisations who are working in partnership with farmers trying to deal with runoff problems. It aims to encourage advisers and officers to think about soils, as well as considering other natural measures to slow down and store runoff.

Richard Smith

Richard Smith, PhD, MSc, BSc.
Technical Specialist – Environment Agency

INTRODUCTION

ABOUT THIS MANUAL

The purpose of this manual is to explore fundamental concepts of soil hydrology, including rainfall acceptance potential and the generation of runoff in typical Devon and Cornwall catchments. It also describes how these natural processes can be changed and damaged by farming operations.

The manual has been divided into two main themes:

- **An overview about the science of soil hydrology and how this is affected by farming**
- **A detailed analysis of the typical soil hydrology found in the main landscapes of Devon and Cornwall**

A series of chapters have been written about the main landscapes describing the natural and unnatural hydrology. These explore soil structure, porosity, and rainfall acceptance potential. The inherent risks associated with soil types are described with an overview on how soil management, together with habitat creation, can be tailored to reduce the risk of runoff.

RAINFALL ACCEPTANCE POTENTIAL

During storms and periods of heavy rain it is easy to assume that soils cannot accept these levels of rainfall and that overland flow of surface water is normal. We often hear that 'soils/catchments are saturated and there is a high risk of flooding'. Although this may well be the case, it is often a simplistic misconception that all soils are **naturally** saturated.

Well drained, permeable soils have the capacity to accept even heavy rainfall. They seldom become saturated as water is absorbed in their permeable upper layers from where it readily percolates downwards to deeper horizons, often feeding aquifers at depth. These naturally freely draining soils play an important role in natural flood management and occupy large areas of Devon and Cornwall over sandstones, slates and granitic geology.

Slowly permeable, seasonally waterlogged soils, such as those developed in impermeable clay, do not readily accept rain. They quickly become saturated in upper layers and shed water laterally as slopes allow. These soils naturally generate rapid runoff and the flow in local watercourses also responds rapidly during rainfall.

MORE THAN 60% OF SOILS

in Devon and Cornwall are naturally well drained, permeable and should rarely become saturated. Surface water runoff from these soils is naturally rare even during heavy rainfall. The main water pathway is vertical, under gravity, downwards through the soil. These soils attenuate the movement of rainwater to streams and the flow of local watercourses should show a relatively slow response to rainfall.

SOIL COMPACTION

Degradation of soil structure where the soil becomes compacted and impermeable can lead to unnatural or enhanced runoff. Upper soil layers above the zone of compaction readily become saturated after rainfall. However, the deeper soil profile below the compaction remains relatively dry, so the full potential of the soil to accept rainfall is lost.

Modern farming has the ability to change soil structure and hydrology across large areas of the landscape very quickly, and there is increasing evidence to demonstrate that this is happening in the South West.

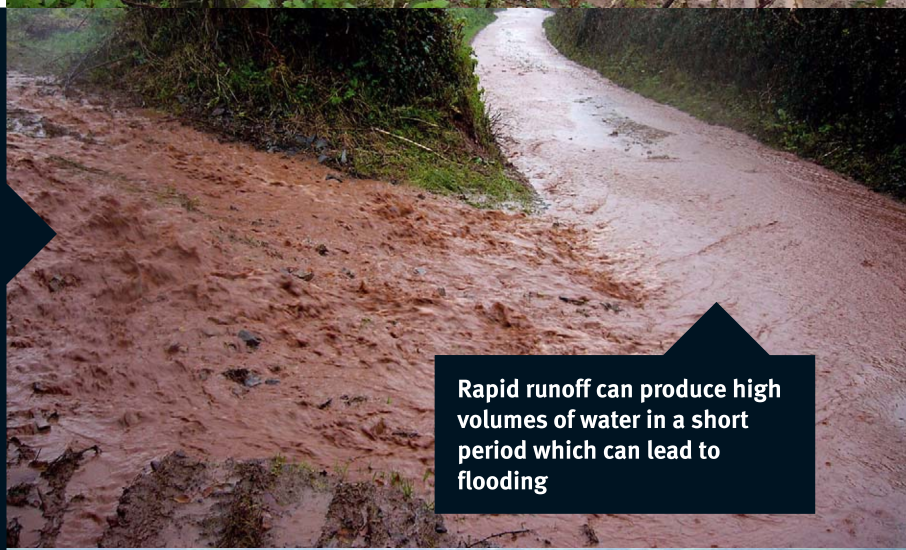
Soil compaction can be subtle. It is not necessarily restricted to the obvious impact that is seen for example concentrated around gateways. Less severe compaction occurs within fields and can be found at various levels in the soil profile. All compaction restricts downward water movement and can lead to surface saturation and the potential for the generation of surface runoff. This may not necessarily radically affect crop yield so may not be a high priority for the farmer, but it can have major consequences off the farm.

Soil compaction in some years can be widespread and where this occurs on land that would normally accept rainfall, then runoff can be greatly enhanced

SOILS AND FLOODING

Surface water flooding
Surface water flooding occurs where there is rapid runoff in areas away from watercourses. These are often called 'muddy floods' because surface waters often transport copious amounts of eroded soil.

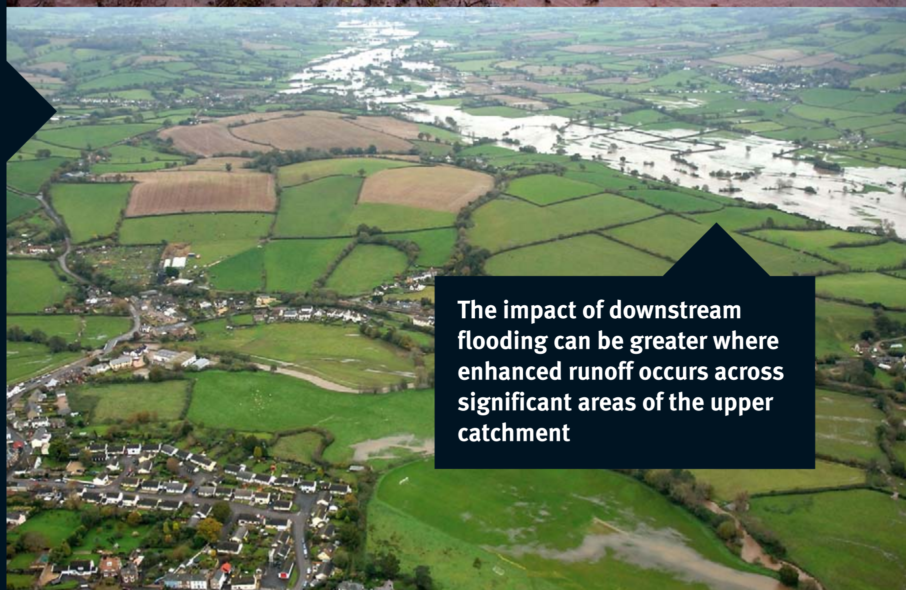
There is abundant evidence that land use and soil management affecting soil condition can exacerbate surface water flooding. Runoff flows directly from fields onto neighbouring roads and property well away from existing watercourses.



Rapid runoff can produce high volumes of water in a short period which can lead to flooding

Fluvial flooding
Rapid runoff can also affect downstream flooding in floodplain areas. Predicting the depth and extent of fluvial flooding is a complex process and depends on the routing and attenuation of water as it passes through the catchment's network of tributary streams.

Evidence that land use affects fluvial flooding in lower floodplains of very large catchment areas is difficult to isolate from the many factors involved in flood risk assessment. However, where enhanced runoff occurs across significant areas of upper catchments then the impact further downstream will be more strongly felt.

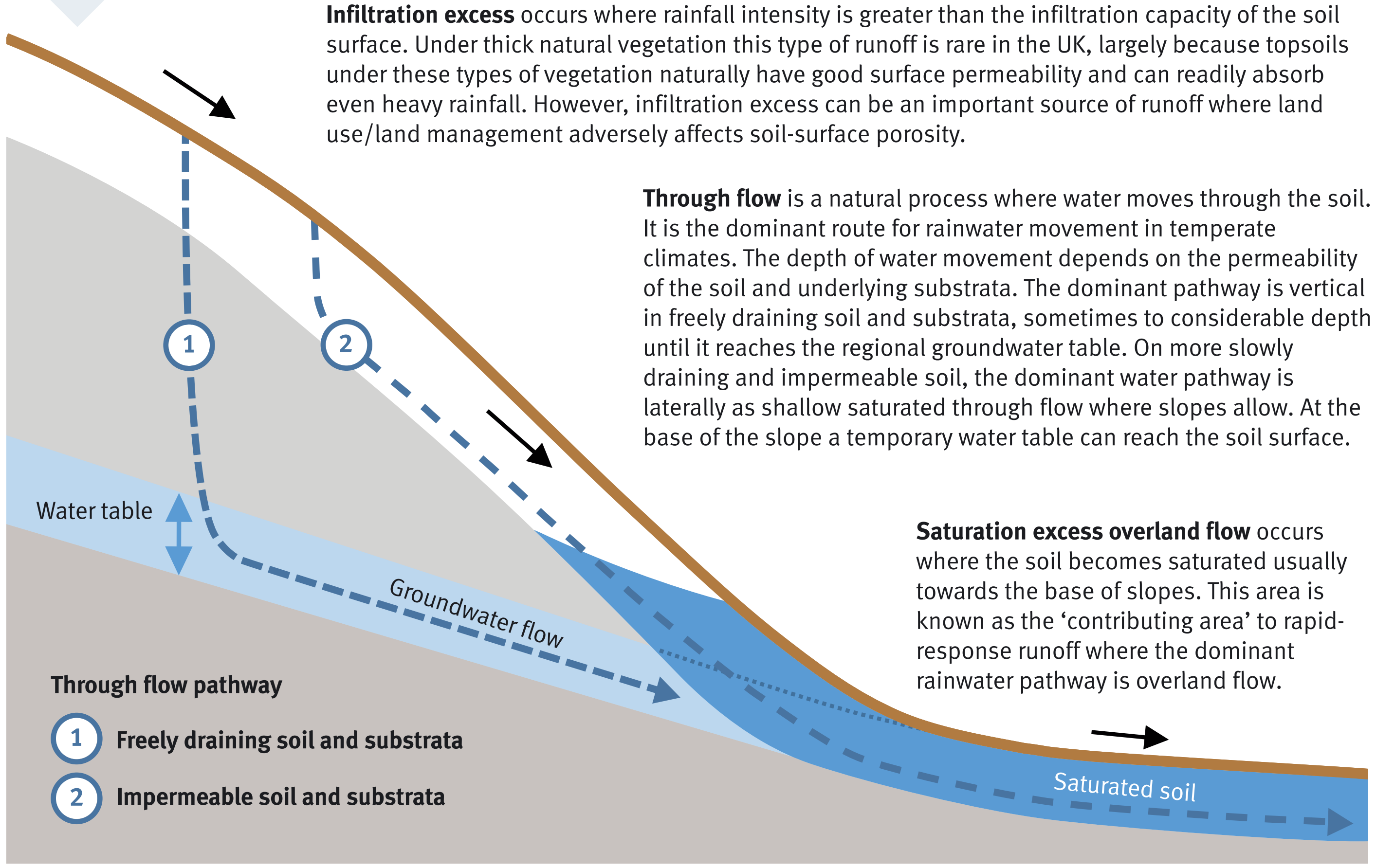


The impact of downstream flooding can be greater where enhanced runoff occurs across significant areas of the upper catchment

HOW WATER FLOWS THROUGH THE SOIL LANDSCAPE

The generation of runoff is a complex interaction between soil, geology, landform, vegetation and climate. The term 'runoff' includes overland flow of water and also water that flows laterally downslope through the upper soil layers. Runoff causes the short term increase in flow seen in catchments following rainfall. Surface water runoff or overland flow is where water flows across the soil surface.

Three processes are widely used to describe the generation of runoff.



Infiltration excess occurs where rainfall intensity is greater than the infiltration capacity of the soil surface. Under thick natural vegetation this type of runoff is rare in the UK, largely because topsoils under these types of vegetation naturally have good surface permeability and can readily absorb even heavy rainfall. However, infiltration excess can be an important source of runoff where land use/land management adversely affects soil-surface porosity.

Through flow is a natural process where water moves through the soil. It is the dominant route for rainwater movement in temperate climates. The depth of water movement depends on the permeability of the soil and underlying substrata. The dominant pathway is vertical in freely draining soil and substrata, sometimes to considerable depth until it reaches the regional groundwater table. On more slowly draining and impermeable soil, the dominant water pathway is laterally as shallow saturated through flow where slopes allow. At the base of the slope a temporary water table can reach the soil surface.

Saturation excess overland flow occurs where the soil becomes saturated usually towards the base of slopes. This area is known as the 'contributing area' to rapid-response runoff where the dominant rainwater pathway is overland flow.

Diagram modified from: Farquharson, F.A.K., Mackney, D., Newson, M.D. and Thomasson, A.J. 1978. Estimation of run-off potential of river catchments from soil surveys. Special Survey No. 11. Soil Survey of England and Wales. Lawes Agricultural Trust. Harpenden.

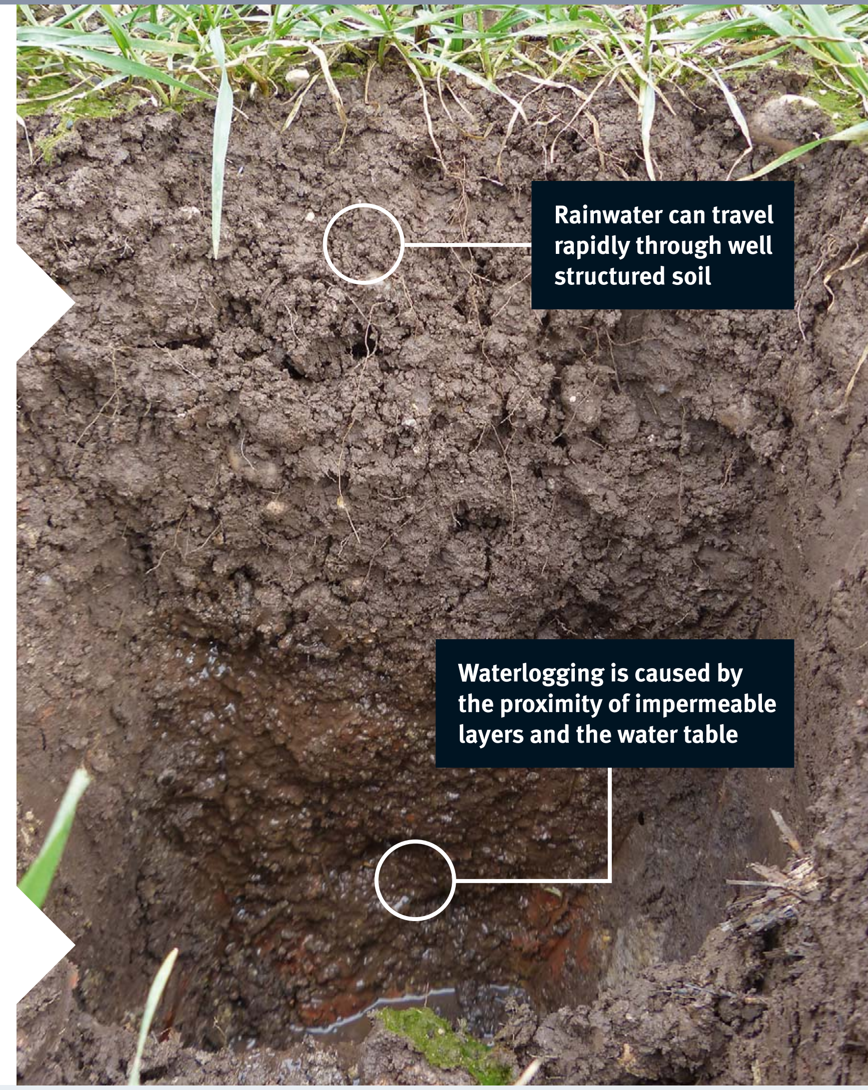
NATURAL SOIL PROCESSES AND RUNOFF | HOW WATER FLOWS THROUGH THE SOIL LANDSCAPE

SOIL PROPERTIES THAT AFFECT WATER MOVEMENT

Soil structure
Well structured soil has small, stable porous aggregates which separate cleanly when disturbed and contain a network of pores and fissures. Rainwater can travel rapidly through coarse air spaces whenever the soil is not saturated.

Soil water regime
Natural soil water regime has a strong influence on the ability of soil to accept rain. Waterlogging occurs when all pores are filled with water and there is no remaining space available to accept further rainwater. Either surface runoff occurs where soils are waterlogged to the surface or lateral through flow occurs in upper soil layers on sloping ground where slowly permeable subsoils cause temporary waterlogging in wet times.

Waterlogging or saturation is caused either by the proximity of impermeable horizons, which restrict the downward movement of water during rainfall, or in permeable materials by the proximity of a water table.

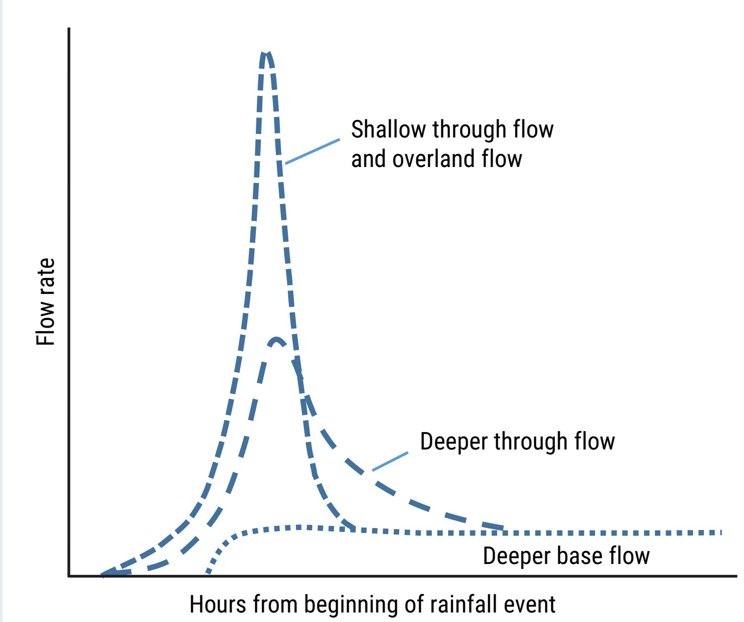


DEPTH OF PERMEABILITY

Deep infiltration and deep horizontal movement of water in soils 'buffer' the immediate catchment response to rainfall. The delay as rainwater moves slowly through soil layers reduces the subsequent catchment peak flow. The deeper that rainwater penetrates the soil, the greater the attenuation of peak river flows.

Naturally well drained, permeable soils under thick vegetation do not generate overland flow and can accept heavy rainfall. A very porous soil surface does not become saturated during rainfall. It has abundant air spaces which do not become permanently water-filled because water can percolate rapidly downwards towards groundwater.

Conversely a naturally poorly drained soil where there is an impermeable layer near the surface (such as clay at 20cm depth), can only accept relatively small amounts of rain before it becomes saturated and generates saturated lateral flow within permeable upper layers and overland flow locally, where slopes allow. These soils produce 'flashy' catchments where peak river discharge occurs quickly after rain.



Contribution of different flow pathways to total runoff from land during rainfall

SOIL STRUCTURE, AIR CAPACITY AND WATER MOVEMENT

During rainfall water moves in unsaturated soil through large pores and fissures under the downward pull of gravity.

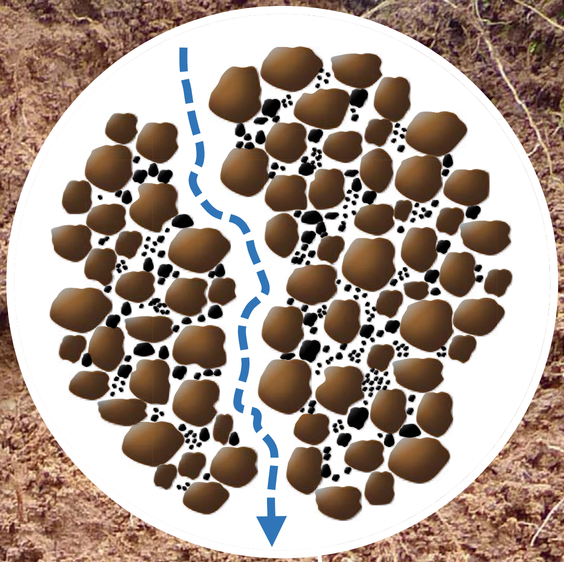
Gravitational pull of water in soil is assessed by soil scientists in laboratory studies to be equivalent to a suction of 5kPa. This approximation of the pull of gravity is sufficient to empty pores greater than 60μm diameter (defined as coarse pores) within 24 hours of rain.

The volume of coarse pores is often referred to as 'drainable pore space'. It represents the air space in soil at field capacity moisture state and is also known as 'air capacity'. This is a typical winter wetness state when all pores greater than 60μm are air-filled and smaller pores remain water- filled.

Air capacity often exceeds 15% by volume in many topsoils and can exceed 20% throughout the whole profile of well drained permeable soils. This large temporary water storage capacity is available throughout the winter and enables soils to attenuate the movement of rainwater to river networks.

Thick surface vegetation usually protects the soil surface and enables even heavy rain to readily access air-filled pores in winter (drainable pore space).

Coarse pores (macropores) greater than 60μm include holes, tubes, burrows and fissures within and between soil aggregates



THE TOPSOIL

The role of organic matter in the development of topsoil structure is extremely important as it helps produce small stable porous aggregates.

Decomposing organic matter improves the stability of soil structures by forming clay-organic complexes, which produce gums derived from soil bacteria and fungal hyphae that stabilise soil pore surfaces over which they grow.

THE VOLUME OF COARSE PORES IN THE TOPSOIL

Organic-rich topsoils usually have friable, porous granular or fine subangular blocky aggregates that are stable and give air capacity values of between 10 and 25%.

20% air capacity within 30cm of topsoil is equivalent to about the volume of 60mm of rainfall before reaching saturation.

THE SUBSOIL

Soil texture has a strong influence on air capacity of subsoils.

Clayey soil is made up predominantly of particles <2μm in diameter and contains limited coarse porosity. Water movement is restricted to fissures between soil aggregates and through earthworm burrows and these layers are often described as slowly permeable.

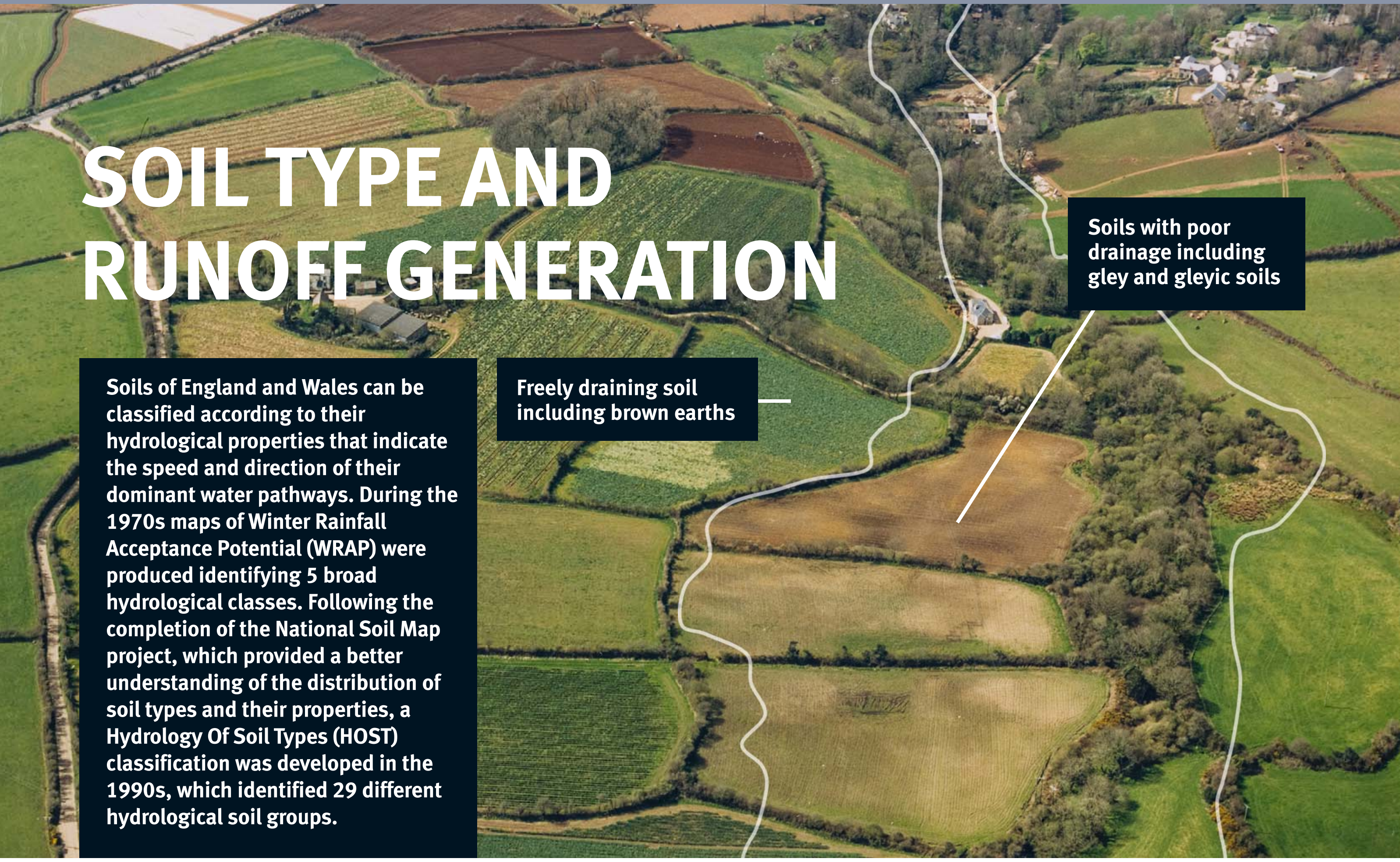
Subsoils predominantly of silt and sand-sized particles have much larger coarser porosity and are moderately or very permeable.

THE VOLUME OF COARSE PORES IN THE SUBSOIL

Subsoil has an air capacity ranging from <5% in slowly permeable horizons, up to 30% air capacity in sandy layers.

A permeable soil profile with high air capacity values of 20% to a depth of 100cm would be able to store the equivalent volume of 200mm of rainfall before reaching saturation.

SOIL TYPE AND RUNOFF GENERATION



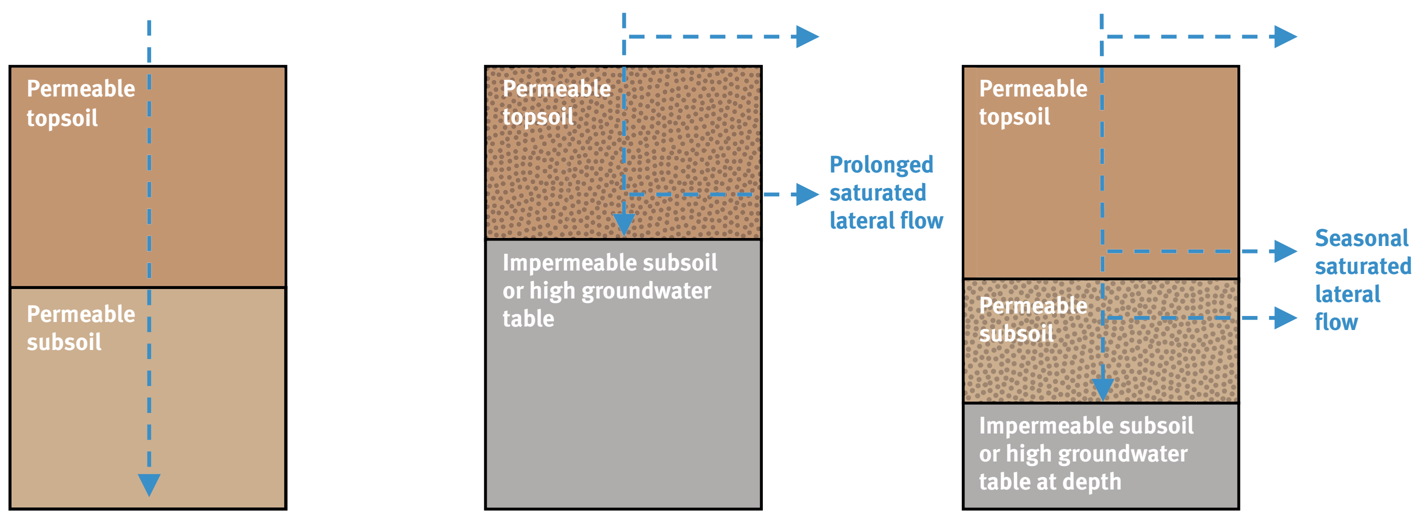
Soils of England and Wales can be classified according to their hydrological properties that indicate the speed and direction of their dominant water pathways. During the 1970s maps of Winter Rainfall Acceptance Potential (WRAP) were produced identifying 5 broad hydrological classes. Following the completion of the National Soil Map project, which provided a better understanding of the distribution of soil types and their properties, a Hydrology Of Soil Types (HOST) classification was developed in the 1990s, which identified 29 different hydrological soil groups.

Soils can be divided into broad groups:

- **Soils with free drainage:** These include brown earth soils that are naturally well drained and seldom waterlogged.
- **Soils with poor and imperfect drainage:** These include gley soils and gleyic soils where the substrate is relatively impervious or the water table is high so that the soil becomes waterlogged for some part of the year.

FREELY DRAINING SOIL

SOILS WITH POOR AND IMPERFECT DRAINAGE



Brown earth soils over permeable substrates with groundwater, if present, at more than 2m depth

Gley soils where gleying is above 40cm, including:

- Stagnogley soils where the subsoil is impermeable
- Groundwater gley soils affected by fluctuating groundwater in permeable materials

Gleyic soils where gleying is below 40cm, including:

- Stagnogleyic brown earths where the subsoil is impermeable
- Gleyic brown earths affected by groundwater

FREELY DRAINING SOIL

HIGH RAINFALL ACCEPTANCE POTENTIAL

Vegetation is indicative of soils that are seldom waterlogged.

Surface horizon has a naturally well developed granular soil structure with many macropores and fissures enabling rapid vertical water movement. Organic matter is well distributed through this layer by earthworm activity.

Subsoil has subangular blocky soil structure where medium and coarse peds are defined by vertical fissures. Macropores include earthworm and root channels.

Macropores and fissures allow rapid downward movement of water throughout the winter.

SOIL WITH POOR DRAINAGE

LOW RAINFALL ACCEPTANCE POTENTIAL

Vegetation is indicative of soils with long periods of wetness (e.g. presence of rushes).

The surface horizon has well developed granular soil structure with many macropores and fissures.

Once surface layers become waterlogged, water moves laterally as seasonal saturated flow or locally as overland flow. Speed of movement depends on the slope of the land.

Gleying is a process forming pale grey colours that occur in anaerobic waterlogged soils where iron is reduced to the ferrous state. It is often accompanied by orange and rusty brown mottling caused by re-oxidation of iron to the ferric state.

Surface water gley (stagnogley soils) occur where slowly permeable subsoils have dense blocky and prismatic soil structure with few macropores (<5% by volume).

THE IMPACT ON NATURAL SOIL POROSITY

Farming has a profound influence on the natural ability of soil to accept rainfall. Working, travelling across and keeping livestock on the land in wet conditions can seriously degrade soils by reducing soil porosity.

COMPACTION occurs whenever soil is compressed to form a more dense mass. Radical changes in porosity can occur in one machinery pass if soil does not have sufficient bearing strength to support the weight applied to it. Soil moisture content profoundly affects the bearing strength of soil. Dry soil has sufficient internal strength to support most farm implements. However, wet soil readily compresses to become dense, structureless and slowly permeable.

SURFACE CAPPING occurs on bare soils, particularly where soil structure is naturally weak. Fine sand and silt particles readily disperse by the action of water and fill pores spaces reducing porosity.

SURFACE CAPPING

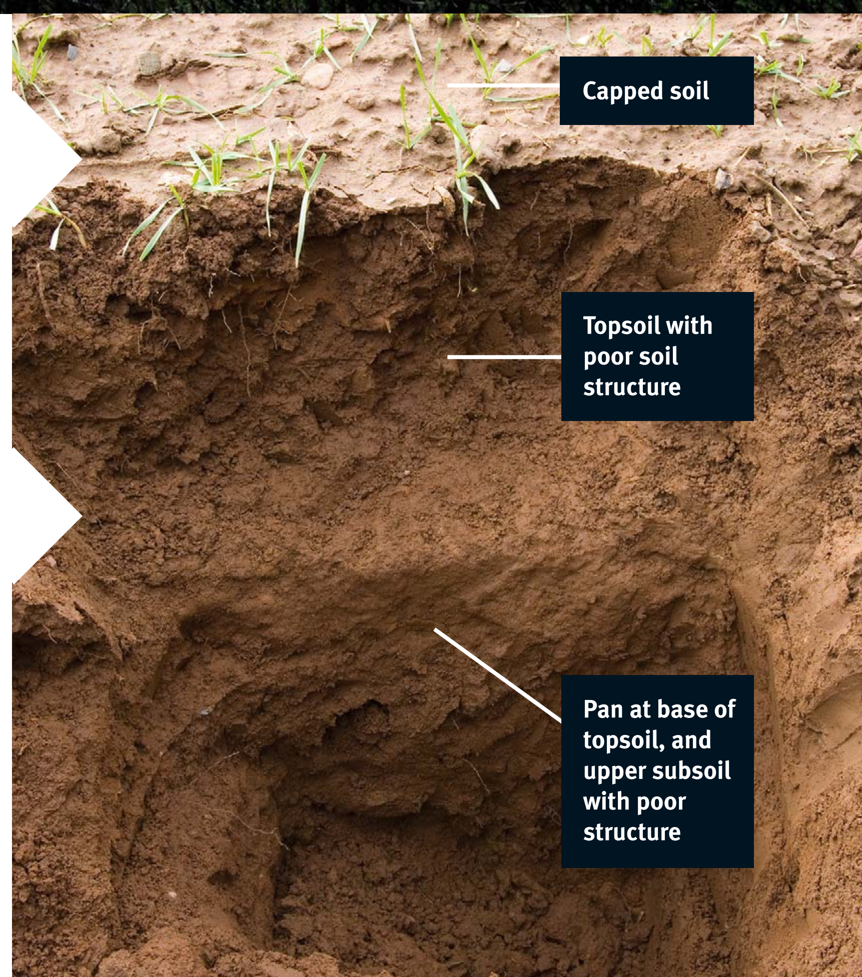
Capping can be a particular problem where soils have a large amount of fine sand and silt, and a low content of clay and organic matter. When these soils are exposed to the battering action of rainfall an impermeable surface cap can form which can generate overland flow of rainwater.

SOIL COMPACTION

Compaction dramatically reduces the volume of coarse pores (drainable pore space) in upper soil layers.

Compressed and compact soil has few pores and low air capacity. The formation of thin unnaturally impermeable layers can cause perched water tables and surface saturation. This generates enhanced overland flow of water even though the soil below the induced impermeable layer is unsaturated and permeable.

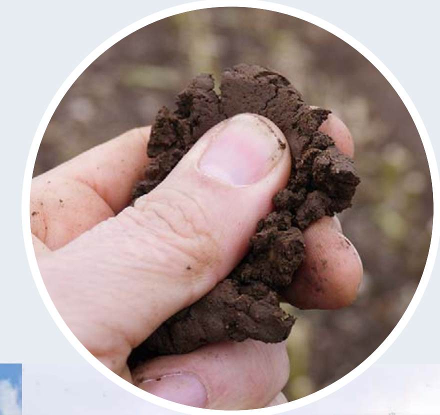
Soil compaction generally occurs within 40 cm depth, but can occur deeper. It can manifest as smeared surfaces, structureless topsoils or by dense, slowly permeable cultivation pans at the base of, and below topsoils.



SOIL COMPACTION

Soil compaction is a common problem in Devon and Cornwall, and it can be widespread whenever the major land working periods during spring and autumn are unseasonably wet.

Timeliness in working the soil when moisture conditions are suitable is down to the good judgement of the farmer. Working land in less than ideal conditions is unavoidable with some crops, and also when weather conditions suddenly change or are not ideal.



Moist, plastic soil that can be moulded is at high risk of compaction

Ploughing and drilling of crops in a dry season. Dry soil can withstand the weight of the tractor and plough. Drilling into friable soil also produces more durable, small aggregates in the seedbed

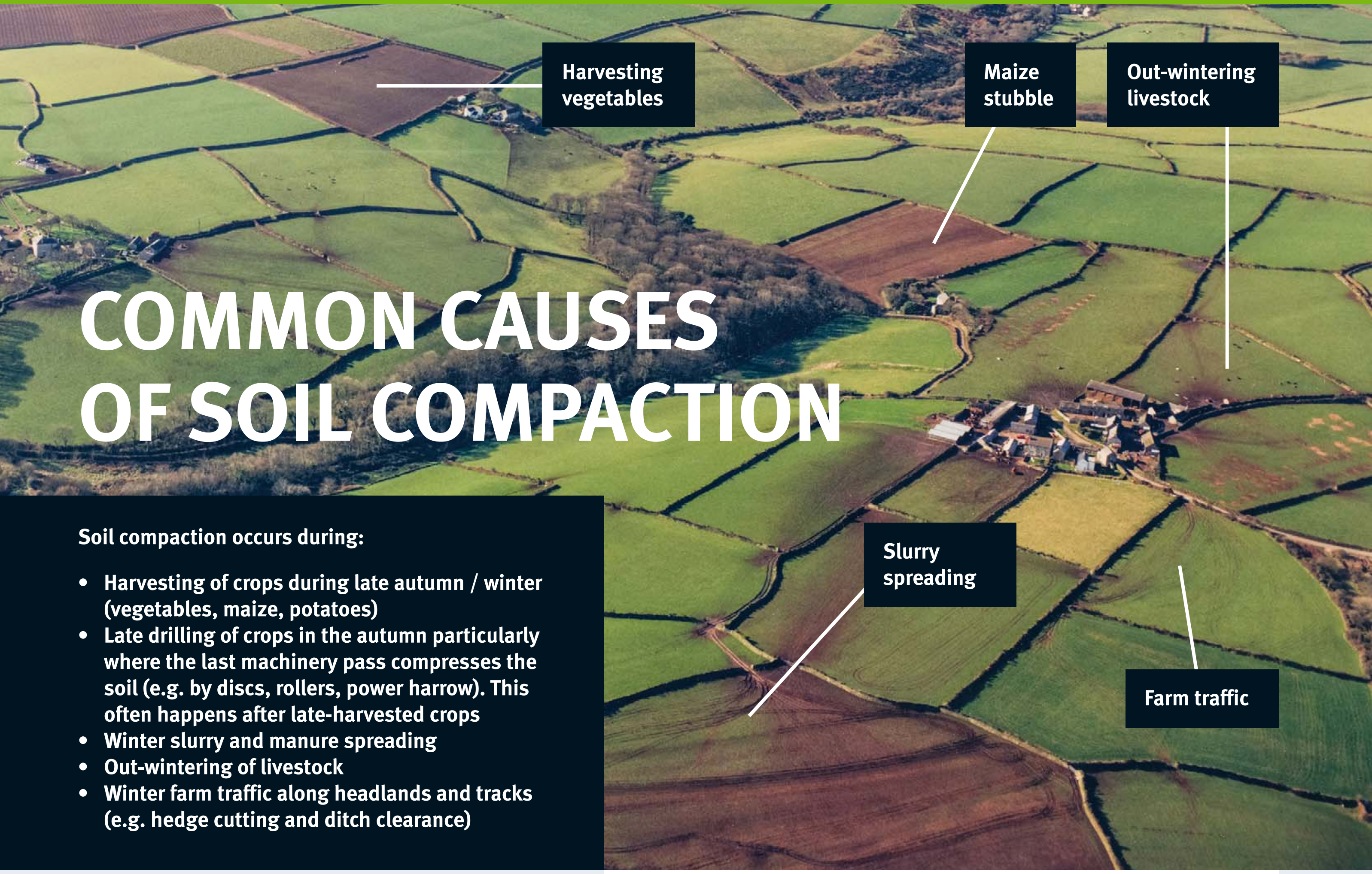
Ploughing in a wet season can compress the soil by the weight of the tractor and the smearing action of the plough. Moist ploughed soil is easily compressed back down by the drill and tractor weight

SURFACE CAPPING

Capping has a high risk of occurring on the surface of seedbeds that have been worked to a fine smooth tilth and where soils have a high fine sand and silt content.

It particularly occurs where seedbeds have not dried out (locally know as pitching off) before the onset of rainfall. Dry stable aggregates are more resistant to dispersal than moist soil particles which readily fall apart during rainfall.

The soil surface can form an impermeable cap on some fine sandy and silty soils after rainfall



COMMON CAUSES OF SOIL COMPACTION

Soil compaction occurs during:

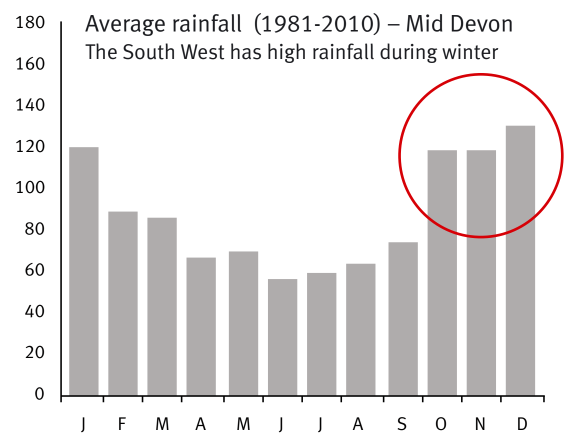
- **Harvesting of crops during late autumn / winter (vegetables, maize, potatoes)**
- **Late drilling of crops in the autumn particularly where the last machinery pass compresses the soil (e.g. by discs, rollers, power harrow). This often happens after late-harvested crops**
- **Winter slurry and manure spreading**
- **Out-wintering of livestock**
- **Winter farm traffic along headlands and tracks (e.g. hedge cutting and ditch clearance)**

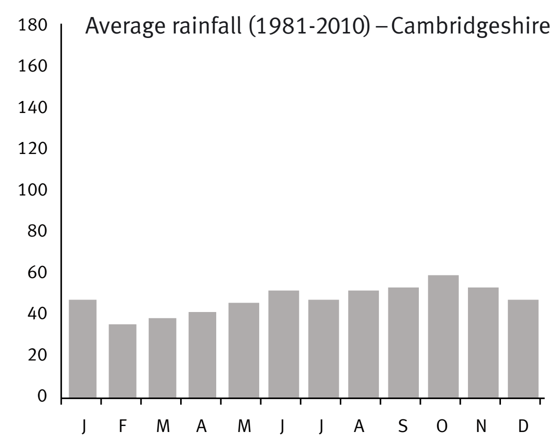
FARMING AND RAINFALL

Winter rainfall is much higher in Devon and Cornwall compared to the arable areas of Eastern England. Land is at field capacity moisture content from mid-October through to the end of March in much of Devon and Cornwall and, therefore, too wet for travelling across. At these times land is at high risk of being compacted and suffering enhanced runoff.

Good farm management reduces the risk of soil damage by matching crop production to land capability with particular reference to the inherent wetness of land. For example, late-harvested crops are unsuited to soils with seasonal waterlogging in high rainfall areas. Soils that have been subjected to serious compaction during wet seasons need to be restored by deep cultivation and/or subsoil loosening during the next suitably dry periods.

Devon and Cornwall experience very heavy downpours which batter the soil surface causing capping of bare soils. Many soils in the region have a high silt and fine sand content making them susceptible to capping and subsequent enhanced runoff.





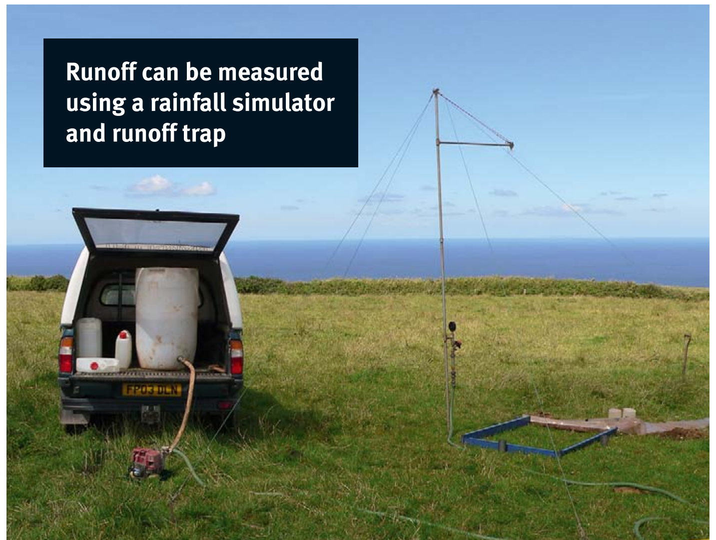
(Met Office data)

MEASURING THE RATE OF INFILTRATION OF HEAVY RAINFALL

Experiments measuring the infiltration rate and runoff under heavy rainfall have been carried out on soils in Devon and Cornwall by the National Soil Resources Institute of Cranfield University. These experiments used a rainfall simulator to control the amount of rainfall coupled with a runoff trap.

At Boscastle, the study found that grassland with a strongly developed stable soil structure with fine granular soil aggregates only generated 2% runoff under 36mm/hr rainfall. Grassland with weakly developed soil structure with coarse, dense aggregates and low porosity had 60% runoff. This soil became saturated at the surface generating overland flow after 20 minutes of rainfall.

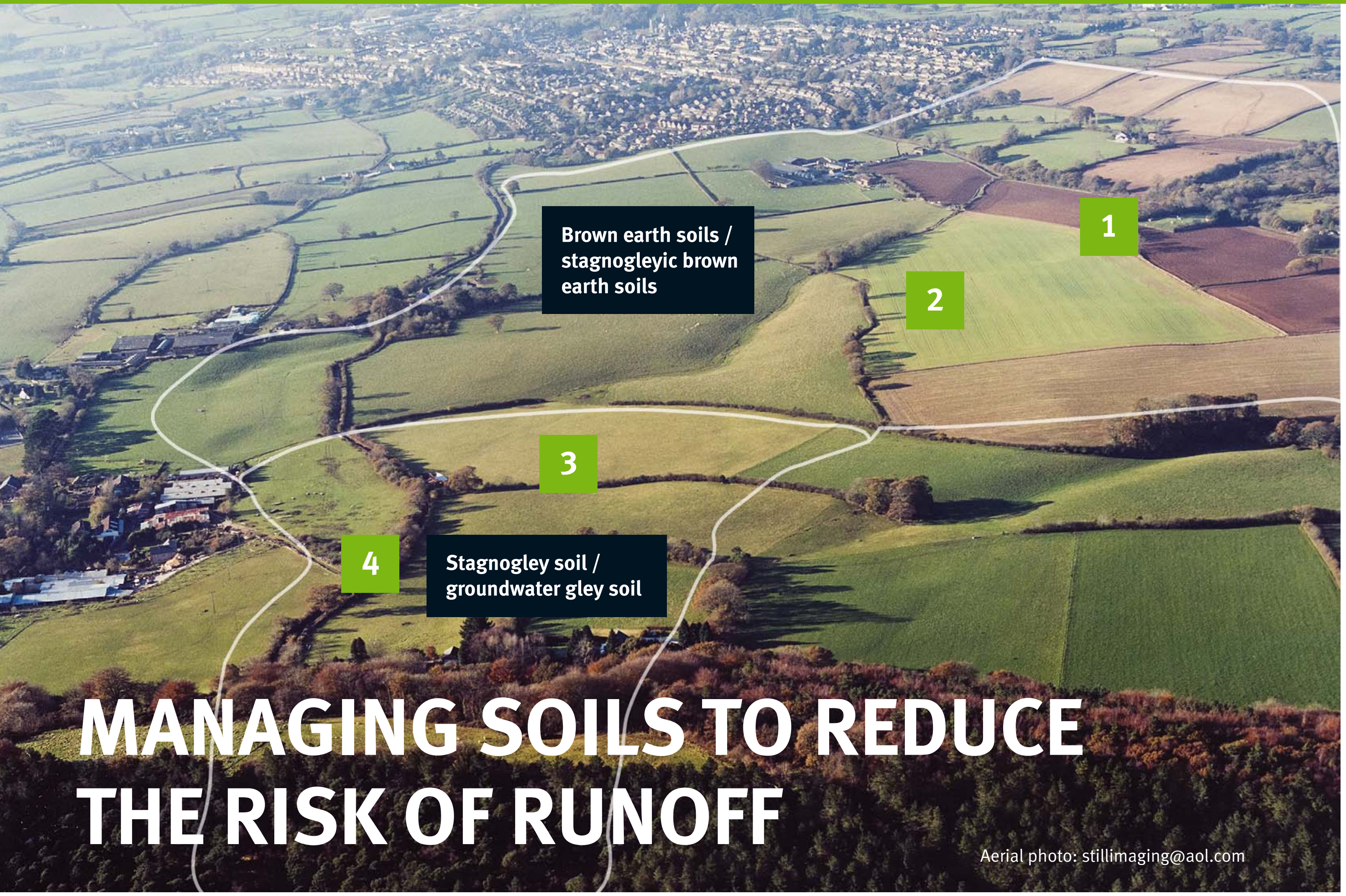
Similar results were found in experiments at Ottery St Mary where compacted grassland generated 88% runoff under 50mm/hr rainfall.



Runoff can be measured using a rainfall simulator and runoff trap

Grassland with strongly developed soil structure had 2% measured runoff

Grassland with weakly developed soil structure had 60% measured runoff



MANAGING SOILS TO REDUCE THE RISK OF RUNOFF

Aerial photo: stillimaging@aol.com

In some small catchments natural soil hydrology can be dramatically changed in a few large fields which has a profound impact on the generation of surface water runoff.

Soils need to be managed to minimise the risk of runoff and solutions should be tailored to soil type.

The greatest potential to reduce runoff is on the freely draining soils. These include sandy and loamy soils that attract land uses at high risk of causing soil compaction such as vegetable growing. These soils are also at risk of generating runoff when crops are drilled late in the year.

Clay-rich stagnogley and groundwater gley soils are often naturally waterlogged in winter. These soils benefit from artificial land drainage when farmed. Land drainage measures reduce surface wetness by encouraging deeper through flow where fissures and channels are created in the soil, by subsoiling and/or moling which connect to gravel backfill over land drains. It should not be assumed that land drainage measures necessarily speed up the transfer of water to rivers. Movement of water through the soil can be considerably slower than saturated overland flow. However, land drainage ditches rapidly route water through the landscape.

Land that lies wet for long periods is often not suited to arable cropping or intensive use of grassland.

THE IMPACT OF RUNOFF

Very rapid runoff onto roads from fields that historically have always absorbed rainfall can quickly overwhelm drainage systems leading to serious flooding of roads and property.

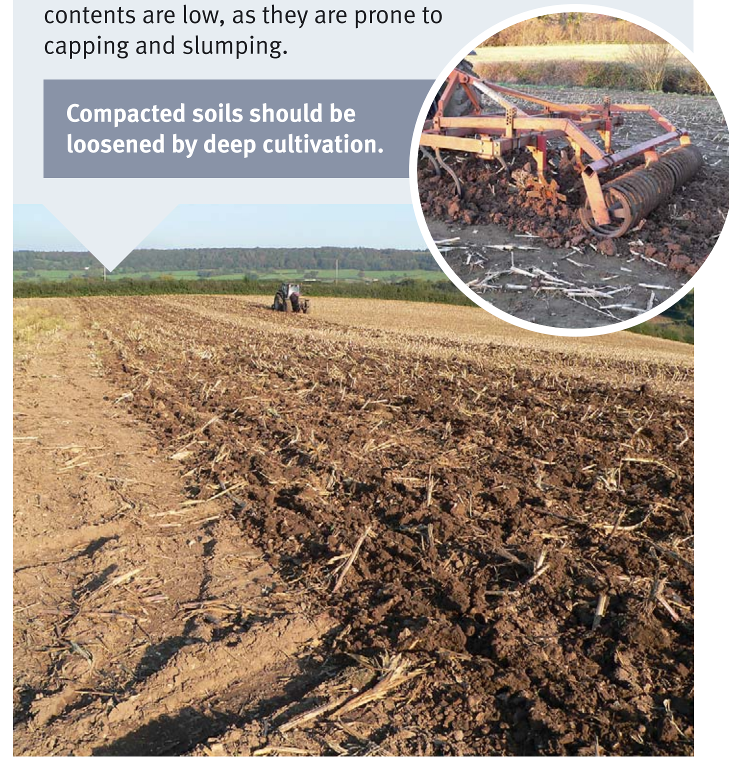
Large volumes of enhanced runoff cause erosion of watercourses leading to the loss of good agricultural land, habitats and infrastructure as well as pollution and siltation of watercourses.

HOW FARMING AFFECTS SOIL HYDROLOGY | MANAGING SOILS TO REDUCE THE RISK OF RUNOFF

1 | SOIL CULTIVATION

Timely and appropriate cultivations can achieve good, stable soil structure. Sandy and silty soils should not be overworked, especially where organic matter contents are low, as they are prone to capping and slumping.

Compacted soils should be loosened by deep cultivation.



2 | CROP ESTABLISHMENT

Early drilling of crops during September and early October enables good crop cover to be achieved before the onset of winter rainfall.

Good crop cover and root growth protects and anchors the soil and maintains soil structure.

3 | SOIL DRAINAGE

Stagnogley and groundwater gley soils that lie wet for long periods are difficult to farm without the installation and maintenance of underdrainage. Clay soils need regular subsoiling or moling to connect with gravel covered pipes so that water can be removed from topsoils and slowly percolate downwards to land drains.

There may be opportunities to slow flow in ditches to reduce the speed of runoff.

4 | HABITAT CREATION

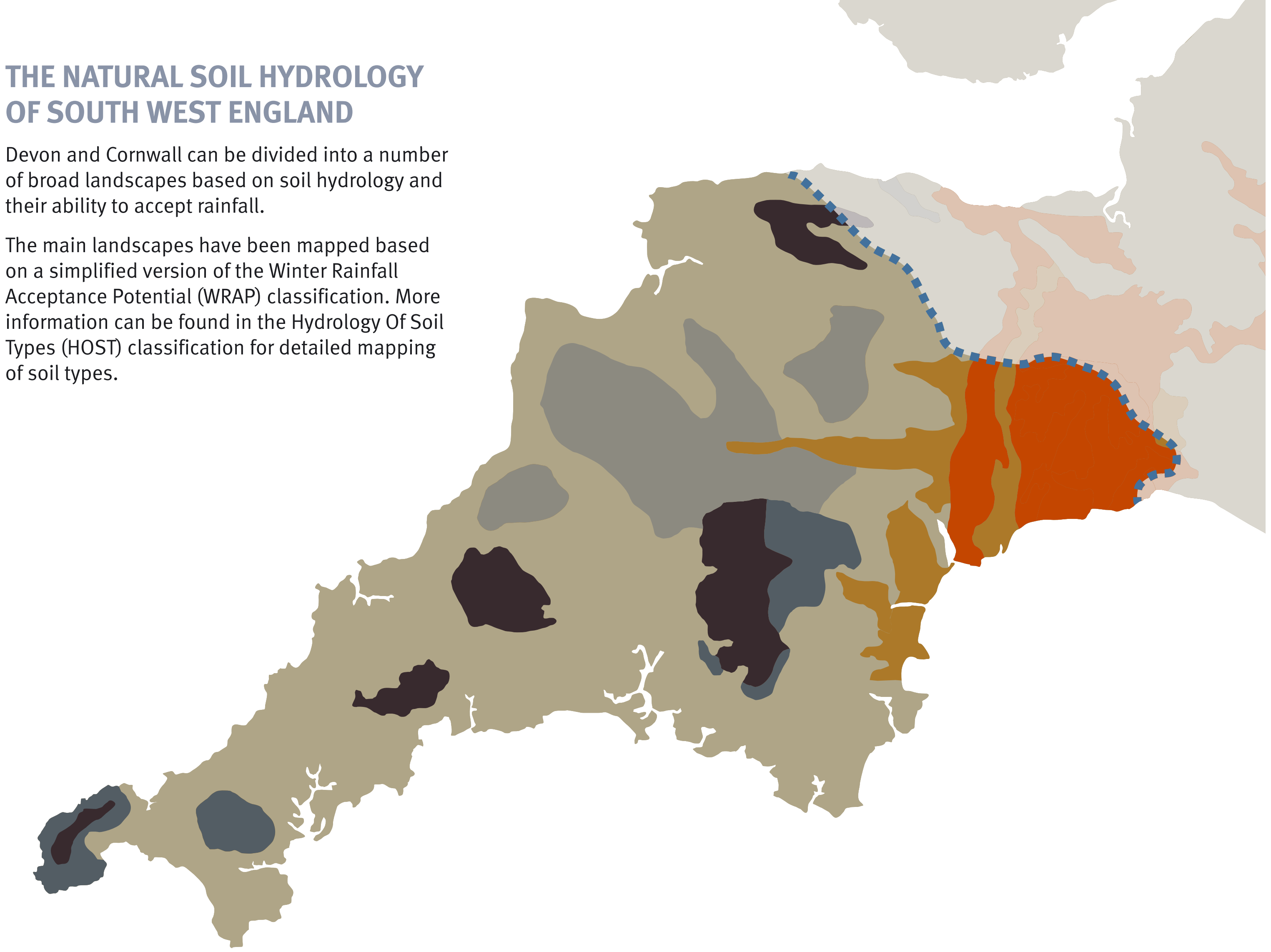
Naturally wet soils are often not suited to arable cropping or intensive use of grassland. There may be opportunities to create habitats which can slow the flow of runoff.

Enhanced runoff along tracks can be diverted to soakaway areas in woodland.

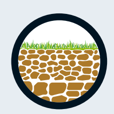
THE NATURAL SOIL HYDROLOGY OF SOUTH WEST ENGLAND

Devon and Cornwall can be divided into a number of broad landscapes based on soil hydrology and their ability to accept rainfall.

The main landscapes have been mapped based on a simplified version of the Winter Rainfall Acceptance Potential (WRAP) classification. More information can be found in the Hydrology Of Soil Types (HOST) classification for detailed mapping of soil types.

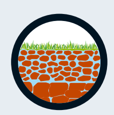


SOILS OF THE SANDSTONE AND BRECCIA HILLS
Well drained permeable sandy or loamy soils over highly permeable bedrock



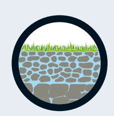
HIGH RAINFALL ACCEPTANCE POTENTIAL

SOILS OF EAST DEVON
Valleys and hill plateau soils that are dominated by clayey or loamy over clayey soils with slowly permeable layers at shallow depth



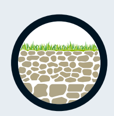
LOW RAINFALL ACCEPTANCE POTENTIAL

CLAY-RICH SOILS OF THE CULM MEASURES
Slowly permeable clayey or loamy soils that have seasonal surface wetness



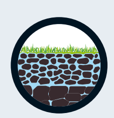
LOW RAINFALL ACCEPTANCE POTENTIAL

SOILS OF THE SLATE HILLS OF DEVON AND CORNWALL
Permeable soils over hard rock locally affected by shallow groundwater in valleys and on ridge crests



HIGH RAINFALL ACCEPTANCE POTENTIAL

SOILS OF THE MOORLAND [1]
Soils of wet uplands with slowly permeable layers at shallow depth causing frequent surface waterlogging



LOW RAINFALL ACCEPTANCE POTENTIAL

SOILS OF THE MOORLAND [2]
Well drained permeable granitic soils over permeable bedrock

HIGH RAINFALL ACCEPTANCE POTENTIAL

THE MAIN LANDSCAPES IN DEVON AND CORNWALL AND THEIR NATURAL SOIL HYDROLOGY

SOILS OF THE SANDSTONE AND BRECCIA HILLS 20

These are found around Exeter in the lower Exe and Otter catchments, and are locally known as Devon Redlands.

These soils are very permeable, seldom waterlogged and readily accept winter rainfall. They do not generate overland flow under normal circumstances.

SOILS OF EAST DEVON 30

The East Devon landscape consists of three main geological areas: the East Devon Plateau, the Red Marl Valleys and the Greensand Escarpment. The soils on the Plateau and those on the Marl both overlie slowly permeable subsoils with low winter rain acceptance potential. These produce a rapid runoff response to rainfall. The steep escarpments have permeable soils over the Greensand with a spring-line at the base of the scarp.

CLAY-RICH SOILS OF THE CULM MEASURES 40

These are widespread over the Carboniferous (Culm) shales. They are developed on slowly permeable clay and upper horizons have long periods of waterlogging. They have limited ability to accept winter rainfall and local streams have a rapid response to rainfall.

SOILS OF THE SLATE HILLS OF DEVON AND CORNWALL 50

These soils are widespread in Devon and Cornwall over Devonian and Carboniferous slates. They are mainly fertile clay loam soils that are naturally freely draining and accept winter rainfall. However, the landscape is affected by shallow groundwater towards the base of valley slopes and on flat hilltops which have less ability to accept rainfall.

SOILS OF THE MOORLAND 60

Moorland soils occur in high rainfall areas over the granite on Dartmoor, Bodmin Moor and West Cornwall. They also occur over Devonian sandstones and slates on Exmoor. Large areas of moorland have freely draining soils over permeable Head deposits that readily absorb rain. Where Head material is slowly permeable, soils are waterlogged for long periods often with peaty topsoils or locally thick peat and blanket bog with very low winter rain acceptance and rapid runoff.

SOILS OF THE SANDSTONE AND BRECCIA HILLS

The soils of the Sandstone and Breccia Hills are found around Exeter in the lower Exe and Otter catchments, and are locally known as the Devon Redlands.

The landscape is predominantly freely draining with few streams and locally steep slopes.

Soils of the Sandstone and Breccia provide some of the best agricultural land in the South West with good land capability. Soils are easily worked and support arable cropping and horticulture. They are also suited to grassland although grass growth in summer can be restricted by limited soil water reserves on the sandier and shallower soils.

The landscape supports important aquifers.

SOIL TYPES

Freely draining brown earth soil

- Brown sands (Bridgnorth series) with very permeable sandy profiles
- Brown earths with sandy loam profiles (Bromsgrove series)
- Brown earths with clay loam profiles (Crediton series) over the Breccia geology

Soils should readily be able to accept winter rainfall even on steep slopes.

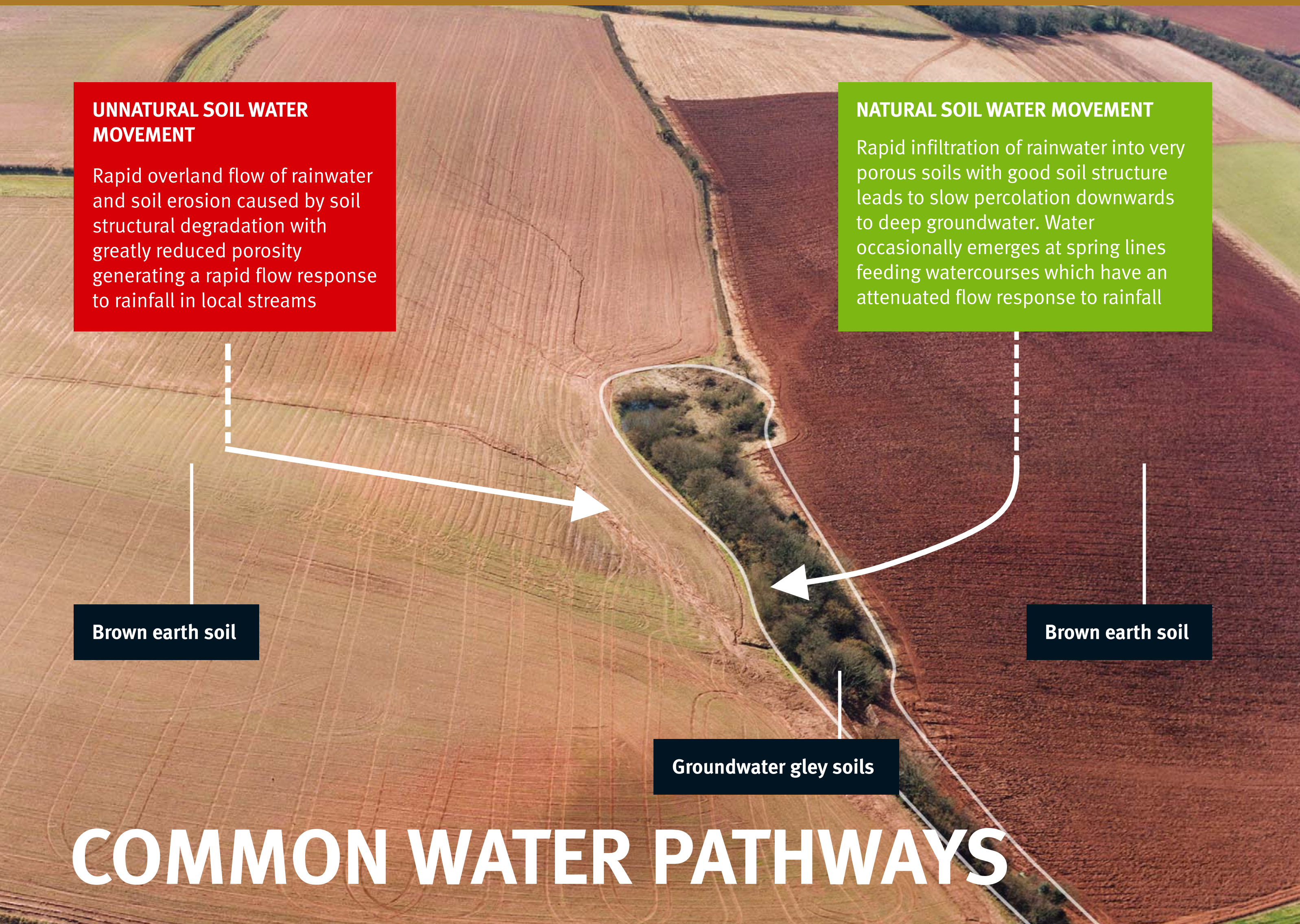
Valley bottoms have silty alluvial soils (Conway series) or permeable Groundwater Gley Soils (e.g Quordon series).

SOIL FACTS

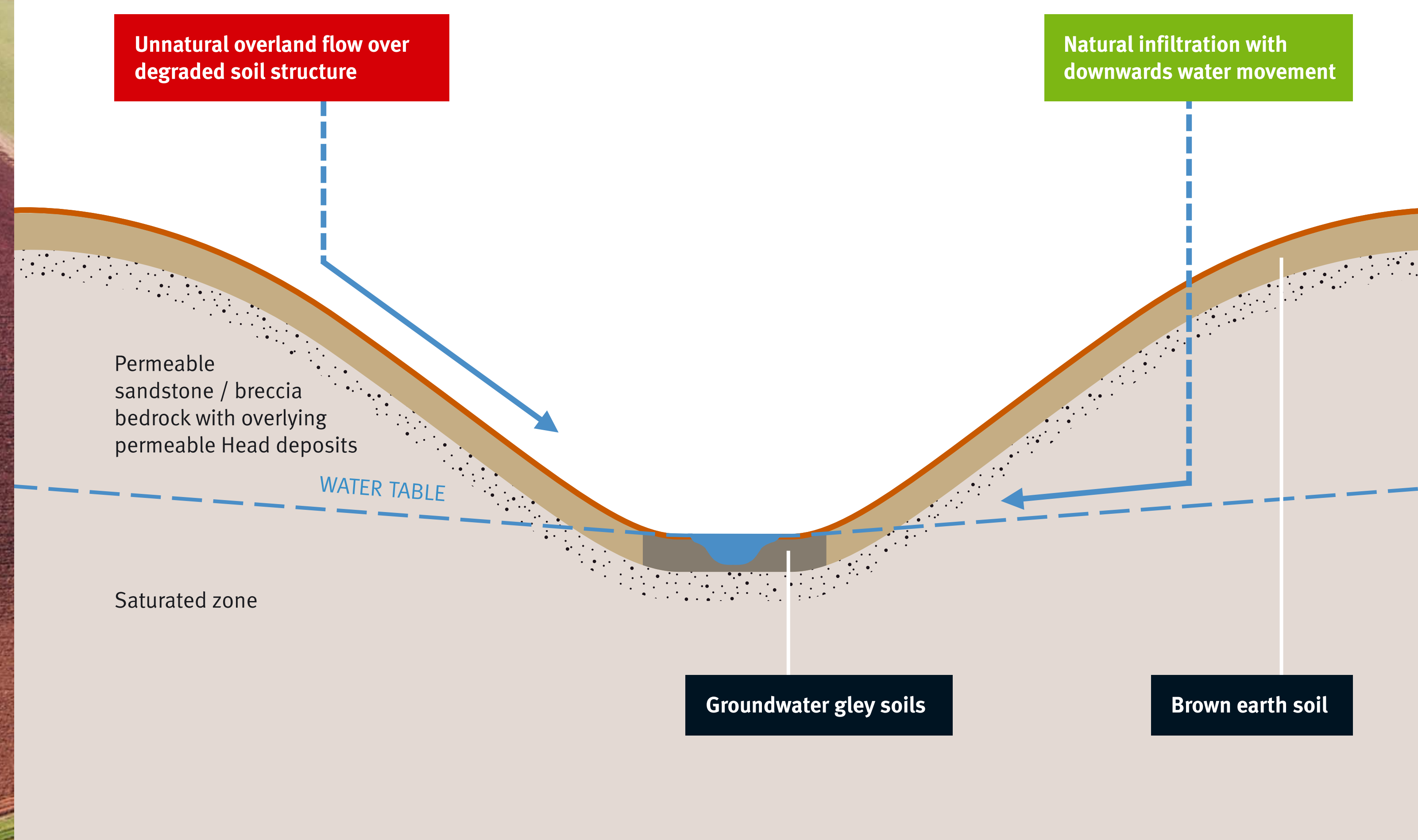
- HIGH RAINFALL ACCEPTANCE POTENTIAL
- GOOD LAND CAPABILITY
- HIGH RISK OF SOIL EROSION
- HIGH RISK OF SOIL COMPACTION
- HIGH RISK OF CAPPING

SOILS OF THE SANDSTONE AND BRECCIA HILLS | COMMON WATER PATHWAYS

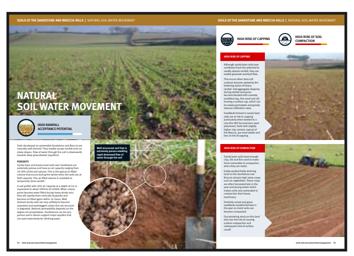
COMMON WATER PATHWAYS



SCHEMATIC CROSS SECTION OF THE SANDSTONE AND BRECCIA HILLS SHOWING NATURAL AND UNNATURAL SOIL WATER MOVEMENT

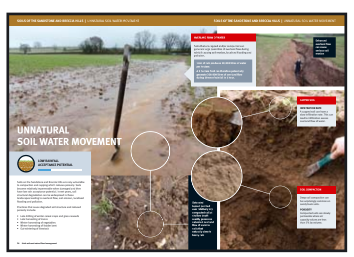


NATURAL SOIL WATER MOVEMENT – see pages 24-25

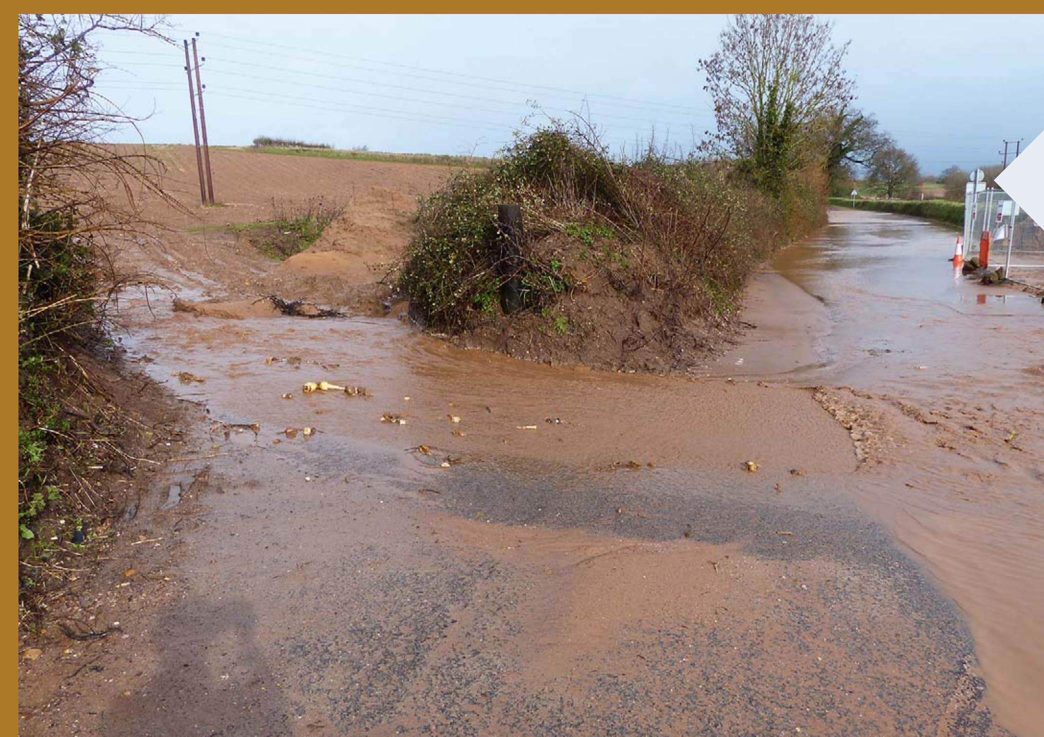


- The soils in this landscape are mainly freely draining and have a high potential to accept rainfall even during heavy rainfall
- The main pathway of water is downwards towards deep groundwater. Overland flow of water should be rare
- The natural runoff response of rivers is very attenuated

UNNATURAL SOIL WATER MOVEMENT – see pages 26-27



- Soils in this landscape have a high sand and silt content and are vulnerable to capping, slumping and compaction where they lose their natural porosity causing overland flow
- Poor soil structure can be widespread in wet years
- Unnatural overland flow during heavy rainfall can be common causing localised flooding with river flows responding very rapidly to rainfall



LOCALISED FLOODING AND POLLUTION

Soil with degraded soil structure and reduced porosity produces overland flow of water causing soil erosion, flooding and damage to roads and nearby property. High concentrations of sediment also cause water pollution and smother river habitats.

NATURAL SOIL WATER MOVEMENT

HIGH RAINFALL ACCEPTANCE POTENTIAL

Soils developed on the permeable Sandstone and Breccia are naturally well drained. They readily accept rainfall even on steep slopes. Flow of water through the soil is downwards towards deep groundwater (aquifers).

POROSITY

Sandy loam and loamy sand soils over the Sandstone are extremely porous and have an air capacity ranging from 20-30% of the soil volume. This is the typical air-filled volume that occurs during the winter when the soils are at field capacity. This air-filled volume is available to temporarily store rainfall.

A soil profile with 20% air capacity to a depth of 1m is equivalent to about 200mm of rainfall. When coarse pores become water filled during heavy winter rain, they will rapidly drain vertically by gravity and become air-filled again within 24 hours. Well drained sandy soils are very unlikely to become saturated and waterlogged unless the soil structure is degraded. Bedrock permeability depends on the degree of consolidation. Sandstones can be very porous, and in Devon support principal aquifers that are used for water supply. Aquifers also support river base flow on a strategic scale.

HIGH RISK OF CAPPING

HIGH RISK OF SOIL COMPACTION

HIGH RISK OF CAPPING

Although sandy loam soils over the Sandstone have the potential to readily absorb rainfall, they can readily generate overland flow.

This occurs when bare soil surfaces become sealed by the battering action of heavy rainfall. Soil aggregates disperse during rainfall and pores become blocked with coarsely stratified clay, fine sand and silt forming a surface cap, which can be slowly permeable and greatly reduces infiltration rates.

Seedbeds formed in sandy loam soils are at risk of capping particularly when worked to a very fine tilth for precision seed placement. Soils with slightly higher clay content, typical of the Breccia, are more stable and less at risk of capping.

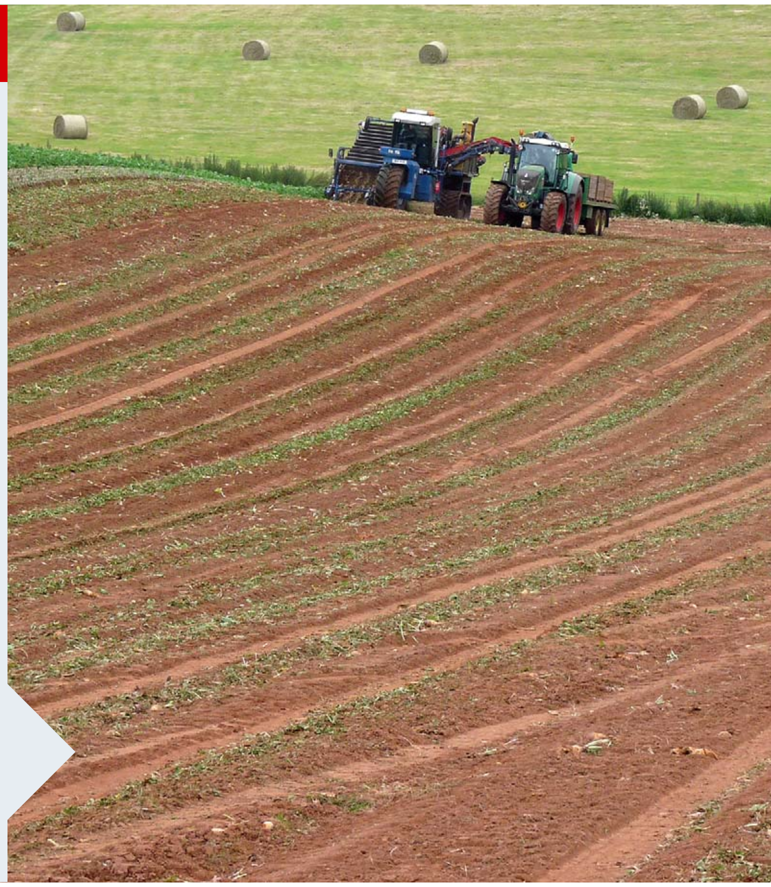
HIGH RISK OF COMPACTION

Sandy loam soils have enough clay, silt and fine sand to make them vulnerable to compaction when they are moist.

Easily worked freely draining land on the Sandstone and Breccia attracts high value crops such as vegetables. These are often harvested late in the year and during winter which makes soils very vulnerable to compaction from heavy machinery.

Similarly cereal and grass seedbeds established late in the year on moist soils can become compacted.

Out-wintering stock on this land also has the risk of causing surface compaction and subsequent risk of surface runoff.



SOILS OF THE SANDSTONE AND BRECCIA HILLS | UNNATURAL SOIL WATER MOVEMENT

UNNATURAL SOIL WATER MOVEMENT

LOW RAINFALL ACCEPTANCE POTENTIAL

Soils on the Sandstone and Breccia Hills are very vulnerable to compaction and capping which reduces porosity. Soils become relatively impermeable when damaged and then have low rain acceptance potential. In wet years, soil structural degradation can be widespread in these landscapes leading to overland flow, soil erosion, localised flooding and pollution.

Practices that cause degraded soil structure and reduced porosity include:

- Late drilling of winter cereal crops and grass reseeds
- Late harvesting of maize
- Winter harvesting of vegetables
- Winter harvesting of fodder beet
- Out-wintering of livestock

OVERLAND FLOW OF WATER

Soils that are capped and/or compacted can generate large quantities of overland flow during rainfall causing soil erosion, localised flooding and pollution.

1mm of rain produces 10,000 litres of water per hectare.

A 3 hectare field can therefore potentially generate 300,000 litres of overland flow during 10mm of rainfall in 1 hour.

Enhanced overland flow can cause serious soil erosion

Saturated topsoil perched over relatively dry compacted soil at shallow depth readily generates saturated overland flow of water in soils that naturally absorb heavy rain

CAPPED SOIL

INFILTRATION RATE
A capped soil can have a slow infiltration rate. This can lead to infiltration excess overland flow of water.

SOIL COMPACTION

Deep soil compaction can be surprisingly common on sandy loam soils.

POROSITY
Compacted soils are slowly permeable where air capacity values are less than 5% by volume.

MANAGING SOILS TO REDUCE THE RISK OF RUNOFF

There is a high risk of soil erosion in this landscape, so high risk crops should be grown on relatively level fields at low risk of runoff. Buffer and water storage areas should be created where runoff is inevitable. Compacted land needs to be deeply cultivated or subsoiled as soon as possible after damage when conditions are favourably dry.

Crops are often drilled late in the year in this landscape which brings risks of runoff because bare soils easily cap and lose their natural porosity. Ensuring crop cover throughout the winter is therefore critical.

Building up organic matter in the long term can also improve soil stability and reduce the risk of capping.

1 | GROWING VEGETABLES

Level fields should be used for growing vegetables. Beds and rows should be laid out to avoid channelling water downslope and used to intercept runoff where possible.

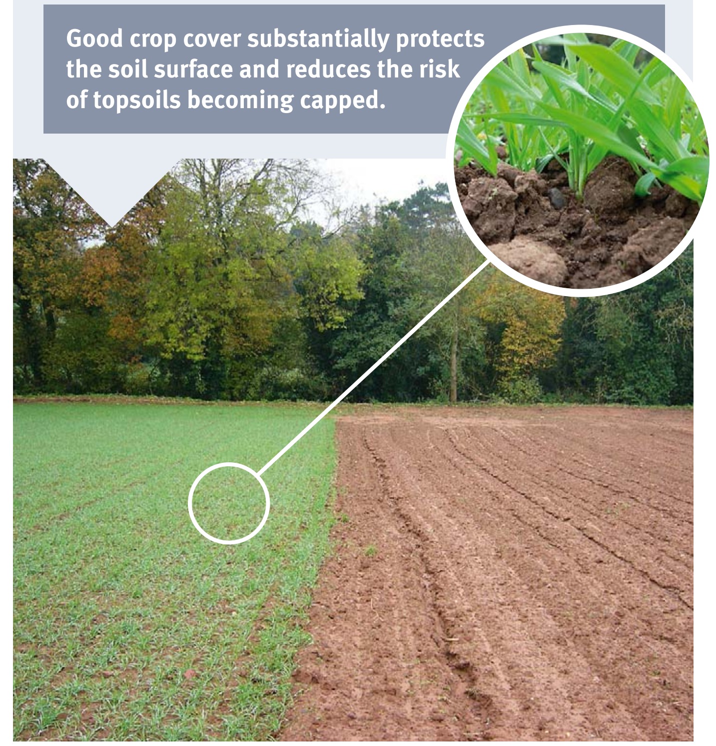
Soils should be loosened by deep cultivation or subsoiling where they are sufficiently dry after harvest.

SOILS OF THE SANDSTONE AND BRECCIA HILLS | MANAGING SOILS TO REDUCE THE RISK OF RUNOFF

2 | EARLY AUTUMN DRILLING OF CROPS

Good soil structure can be achieved and maintained by drilling in suitable soil conditions in the early autumn to ensure good crop cover before the onset of winter.

Good crop cover substantially protects the soil surface and reduces the risk of topsoils becoming capped.



3 | NON INVERSION TILLAGE

Leaving crop residues on the soil surface can protect the soil from capping and can build up organic matter.

Care is needed to avoid causing soil compaction near the surface with shallow cultivation.

4 | OUT-WINTERED LIVESTOCK

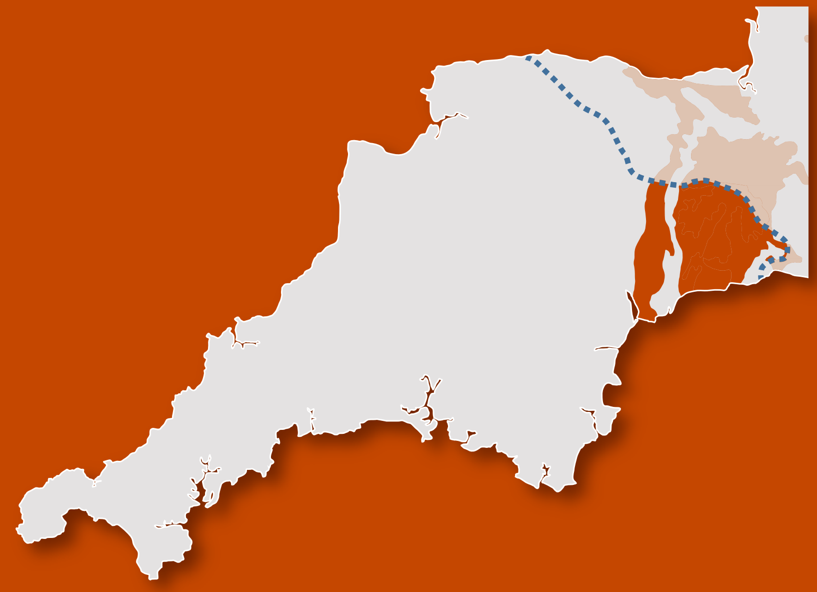
Fields used for out-wintering of stock should be relatively level and access points should be located to avoid channelling runoff. Grass runback areas should be used – a dry area where stock can retreat, lie down and avoid becoming too dirty and heavily damaging the soil.

Damaged soils should be loosened as soon as possible.

5 | WETLAND HABITATS

There may be opportunities to create wetlands on alluvial soils to provide flood storage areas.

Dams and ponds can be constructed to slow down flood waters (subject to consent and design standards).



SOILS OF EAST DEVON

East Devon consists of three contrasting geological/soil landscape units:

East Devon Plateau
This area of exposed flat-topped hills is formed by Upper Greensand rocks covered by clayey Plateau Drift. Historically much of this land was wet heathland and grassland. The acid soils are only marginally suited to cultivation because of exposure, soil wetness, weak natural soil structure and the presence of hard chert stones that rapidly wear farm equipment.

Greensand Scarp
Steep scarp slopes have well drained permeable fine sandy loam soils over Greensand that support rough grazing and woodland. The Greensand overlies Triassic mudstones and marls and this junction is marked by a spring-line with groundwater gley soils supporting wet woodland, rush infested rough grassland or wet Molinia heath.

Marl Vales and Combes
Slowly permeable, seasonally waterlogged clay loam over clay soils predominate in the Vales and Combes which overlie Triassic mudstones and marls. Dairying is the main livestock enterprise with grassland, cereals and, more recently, maize crops.

SOIL TYPES

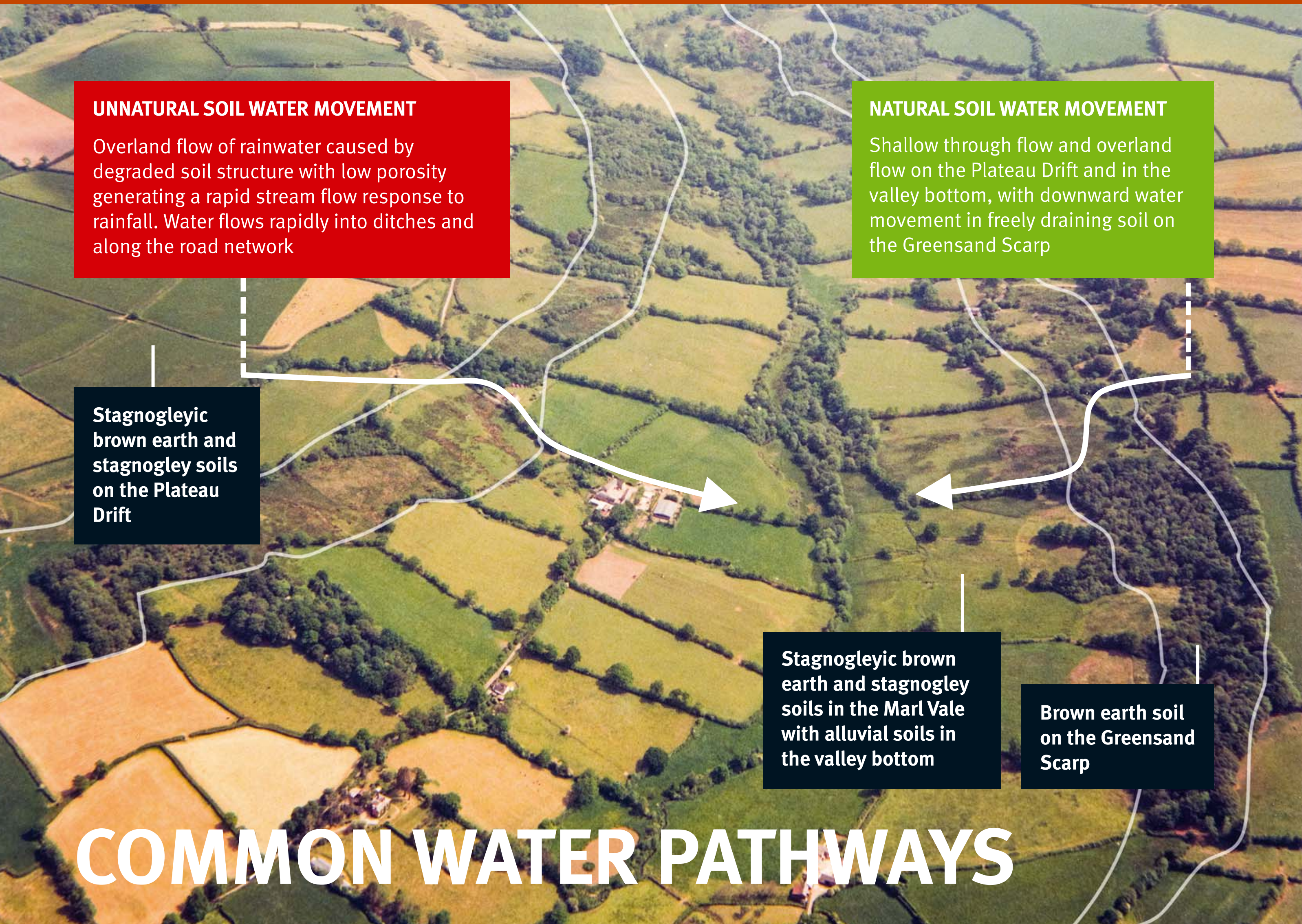
Stagnogleyic brown earth soil

- Stagnogleyic brown earth soils (Whimple and Batcombe series) with slight seasonal wetness caused by dense, slowly permeable subsoils limiting downward water movement
- Stagnogley soils (Brockhurst and Dunkeswell series). These are seasonally waterlogged soils that remain wet for much of winter and spring caused by slowly permeable, clayey subsoils
- Brown earth soils (Bearstead series) with well drained fine sandy loam soil over the Greensand
- Humic groundwater gley soils (Hense series). These are organic-rich almost permanently waterlogged, and found along the spring-line

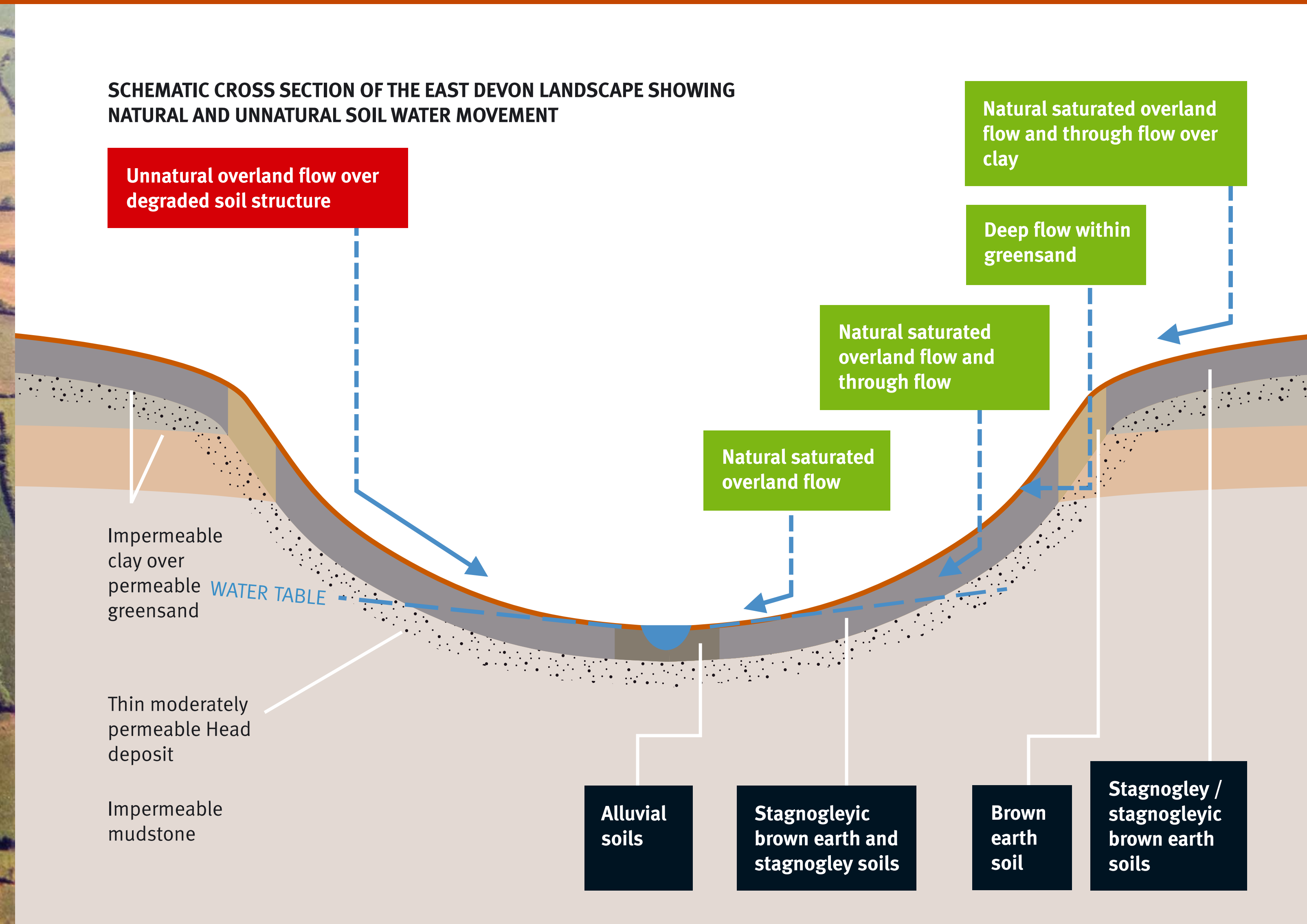
SOIL FACTS

- LOW RAINWATER ACCEPTANCE ON STAGNOGLEY SOILS
- GOOD LAND CAPABILITY EXCEPT ON STEEP GREENSAND SCARP AND PLATEAU TOP
- HIGH RISK OF SOIL COMPACTION
- HIGH RISK OF SOIL EROSION
- HIGH RISK OF RUNOFF

SOILS OF EAST DEVON | COMMON WATER PATHWAYS



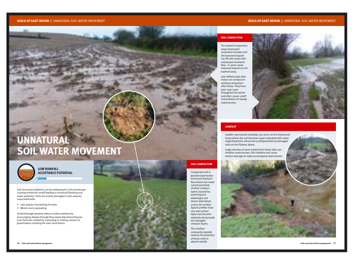
COMMON WATER PATHWAYS



NATURAL SOIL WATER MOVEMENT – see pages 34-35

- The soils in this landscape are mainly slowly draining and have a low potential to accept rainfall
- The main pathway of water is shallow through flow on slopes and saturated overland flow towards the base of slopes
- The runoff response of rivers is rapid because water moves near or at the soil surface

UNNATURAL SOIL WATER MOVEMENT – see pages 36-37



- There is widespread soil compaction in this landscape causing enhanced runoff, particularly associated with maize cultivation and in subsequent crops, and also with winter manure and slurry spreading
- Soil compaction further exacerbates rapid runoff

FLOOD RISK AND RIVER EROSION

Rapid runoff occurs where soils are compacted causing flooding, and also pollution where runoff is laden with soil sediment.

Enhanced flow also causes erosion of watercourses leading to loss of bankside trees and river habitats.

NATURAL SOIL WATER MOVEMENT

LOW RAINFALL ACCEPTANCE POTENTIAL

Large areas of the landscape have seasonally waterlogged soils with low rainfall acceptance potential. Winter rainfall generates rapid runoff either as shallow through flow in thin Head deposits or as overland flow in the wettest times.

POROSITY

Well structured clay loam upper soil layers are moderately porous with an air capacity of about 10% of the soil volume, or greater depending on the degree of soil structure development. Clay subsoils have an air capacity <5% by volume and are effectively impermeable.

10% air capacity in soil down to 45cm depth provides the temporary storage capacity (in coarse air-filled pores) in winter for about 45mm of rainfall. Where the slowly permeable clay is deeper, soil storage potential is greater but where shallower the temporary storage capacity is reduced.

Groundwater gley soils over the Greensand along the spring-line are porous but invariably waterlogged. Therefore, they have limited ability to accept rainfall when saturated.

Subsoils with naturally formed blocky soil structure have little coarse porosity causing the characteristic slow permeability in this landscape. Permeable upper soil layers above these dense subsoils become waterlogged after rain in winter and are prone to shallow through flow as slopes allow

HIGH RISK OF SOIL COMPACTION

HIGH RISK OF RUNOFF

HIGH RISK OF COMPACTION

Long periods of wetness in autumn through to spring make soils very susceptible to compaction from traffic and livestock during these times.

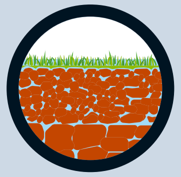
HIGH RISK OF COMPACTION AND ENHANCED RUNOFF

Many dairy farms regularly spread slurry in winter. This causes serious compaction when soils are wet leading to enhanced runoff from damaged fields and the likelihood of water pollution from slurry.

SENSITIVE HABITATS

Wetland mire habitats are widespread along the spring-line at the base of the Greensand Scarp where land is difficult to drain effectively. These are important species-rich habitats. Spring water is clear and streams below provide gravel spawning grounds for salmon and trout. However, populations have declined since the 1980s as habitats have come under pressure from sediment deposition, river bed erosion and agricultural pollutants.

UNNATURAL SOIL WATER MOVEMENT



LOW RAINFALL ACCEPTANCE POTENTIAL

Soil structural problems can be widespread in this landscape causing enhanced runoff leading to localised flooding and water pollution. Soils are mainly damaged in wet seasons associated with:

- Late autumn harvesting of maize
- Winter slurry spreading

Underdrainage systems reduce surface wetness by encouraging deeper through flow especially where fissures and channels created by subsoiling or moling connect to gravel layers covering the main land drains.

SOIL COMPACTION

Compacted soil in grassland generates enhanced overland flow where rain water cannot penetrate shallow compact layers (caused by poaching and wheelings) and moves downslope across the surface. Typical profiles have very wet surface layers but become relatively dry beneath the damaged compact layers.

This shallow compaction greatly reduces the potential of these soils to absorb rainfall.

SOIL COMPACTION

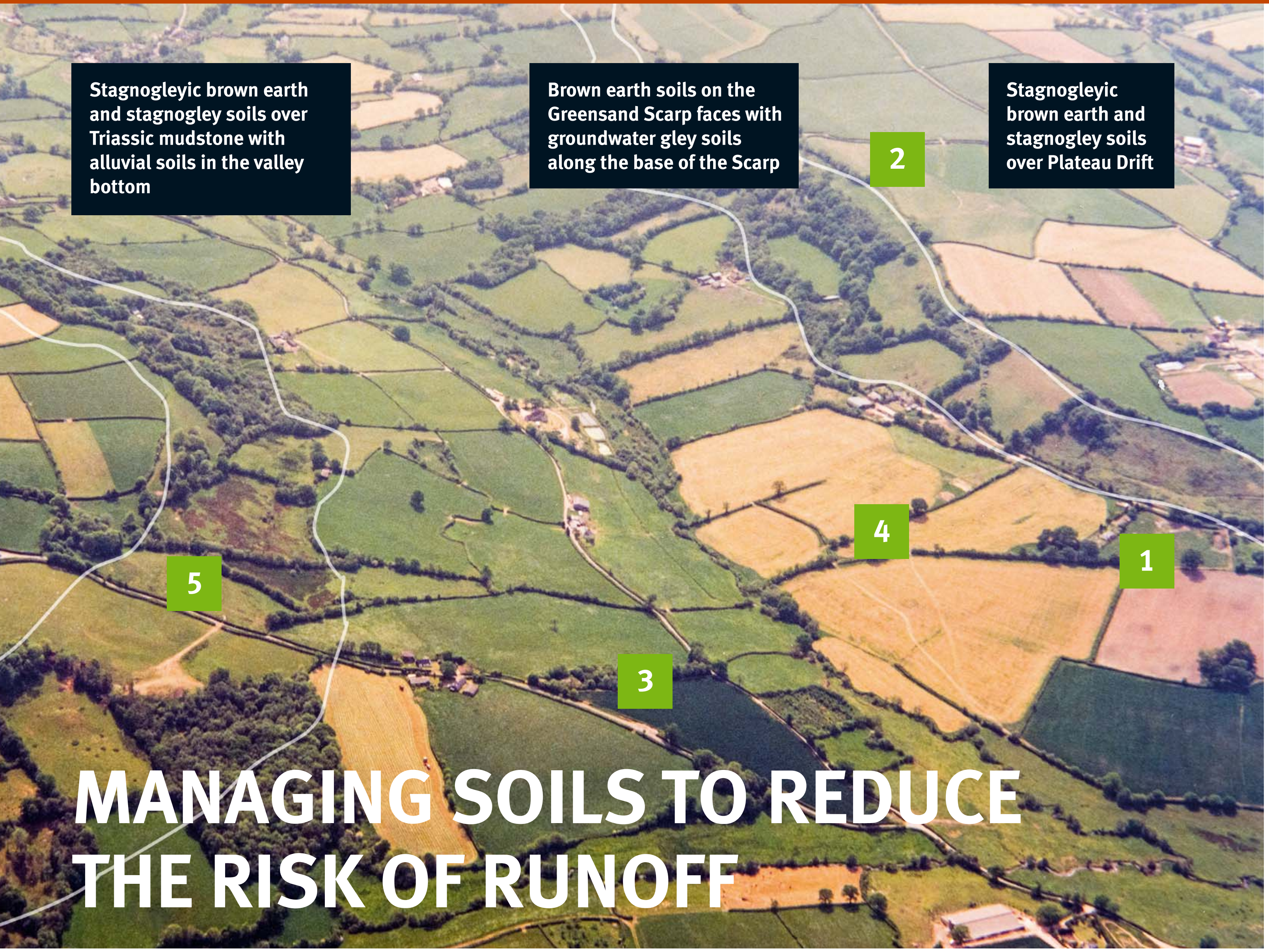
Soil compaction is often associated with travelling on land when the soil is very moist or wet. In wet years, soil loosening after late-harvested maize will not fully counteract the affects of deeper compaction. Loosened topsoil can fill with water causing overland flow and erosion.

Late drilled crops after maize can compound existing soil compaction. They have poor crop cover throughout the winter and often cause runoff and pollution of nearby watercourses.

LANDSLIP

Sudden spectacular landslips can occur on the Greensand Scarp where the soil becomes super saturated with water originating from enhanced runoff generated by damaged soils on the Plateau above.

Large volumes of sand eroded from these slips can smother watercourses, fish habitats and cause serious damage to roads and property downstream.



MANAGING SOILS TO REDUCE THE RISK OF RUNOFF

Slowly draining soils in the Vales and Combes of East Devon are well suited to livestock farming on grassland particularly dairy farming.

Arable crops are suited to some of the better drained land with warm sheltered slopes, cereal crops can be grown without causing damage to soil with careful timely management. Harvesting maize in the autumn, however, almost inevitably damages soil structure, and following crops and grass reseeds are often established late in the year in seedbeds overlying dense compacted slowly permeable subsoils.

Grassland helps produce good soil structure with dense rooting and abundant earthworms maintaining friable stable topsoils. However, slurry spreading in winter readily compacts moist or wet soil, kills soil life, and nutrients can be washed away within enhanced runoff. The provision of sufficient winter slurry storage allows slurry to be used as an effective fertiliser when applied in dry conditions in summer without damaging soils.

1 | MANAGING MAIZE

Maize should never be grown on stagnogley soils as they naturally lie wet for long periods of the year and it is impossible to harvest without seriously damaging soils. On better drained ground, very early maturing varieties should be chosen to enable a September harvest which should allow groundwork to be carried out in dry soil conditions. Starting maize under film can bring the maize harvest forward.

SOILS OF EAST DEVON | MANAGING SOILS TO REDUCE THE RISK OF RUNOFF

2 | DRAINAGE

Drainage maintenance allows better access to and a more timely use of land.

Important rare wetland habitats should not be drained.

3 | SUBSOILING

Subsoiling, when effective, shatters compacted layers in soil and improves downward drainage of water. After subsoiling subsequent crops need to be established in dry conditions to prevent the loosened ground being compressed back down.

Subsoiling needs to be carried out when subsoils are dry and brittle to prevent smearing.

4 | GRASSLAND MANAGEMENT

Grazing, silage making and slurry spreading should be carried out in dry conditions to prevent soil compaction. Modern grass silage making can now provide consistent dry, high-quality feed for cows.

Manures and slurry should be spread after silaging to make the most of nutrients.

5 | HABITAT CREATION

Wet soils in valley bottoms can support wetland habitats and woodland, and should be used to slow down runoff, stabilise soils and improve water quality.

Wet soils can support sensitive species such as orchids.

CLAY-RICH SOILS OF THE CULM MEASURES

Clay-rich soils are widespread over the Carboniferous (Culm) shales in north and mid-Devon, and north Cornwall. This rolling landscape is predominantly slowly draining.

Grassland farming dominates the landscape. High rainfall makes cultivation of these wet soils difficult. However, arable crops are taken from some of the better drained land. Unimproved patches of wet grassland can still be found which have a high conservation value and are locally known as 'Culm Grassland'.

Soil structure is easily damaged in these inherently wet soils. Periods when soils are suitable for land-work, intensive grazing or manure spreading without causing structural damage are short, particularly in wet years.

SOIL TYPES

Stagnogleyic brown earth soil

- Surface-water gley soils also known as stagnogley soils (Hallsworth series) cover much of the slowly permeable clay areas. They lie wet for long periods and have limited ability to accept winter rainfall
- Stagnogleyic brown earths (Nercwys series) occur in areas of slightly more permeable loamy shales. These lie wet for shorter periods than Hallsworth series but are still easily damaged
- Well drained, moderately permeable brown earths with clay loam profiles over rubbly sandstone Head (Neath series) are found on steeper slopes
- Alluvial gley soils (Conway series) are found in floodplain areas

SOIL FACTS

LOW RAINFALL ACCEPTANCE POTENTIAL

POOR LAND CAPABILITY

HIGH RISK OF SOIL COMPACTION

HIGH RISK OF RUNOFF

CLAY-RICH SOILS OF THE CULM MEASURES | COMMON WATER PATHWAYS

COMMON WATER PATHWAYS

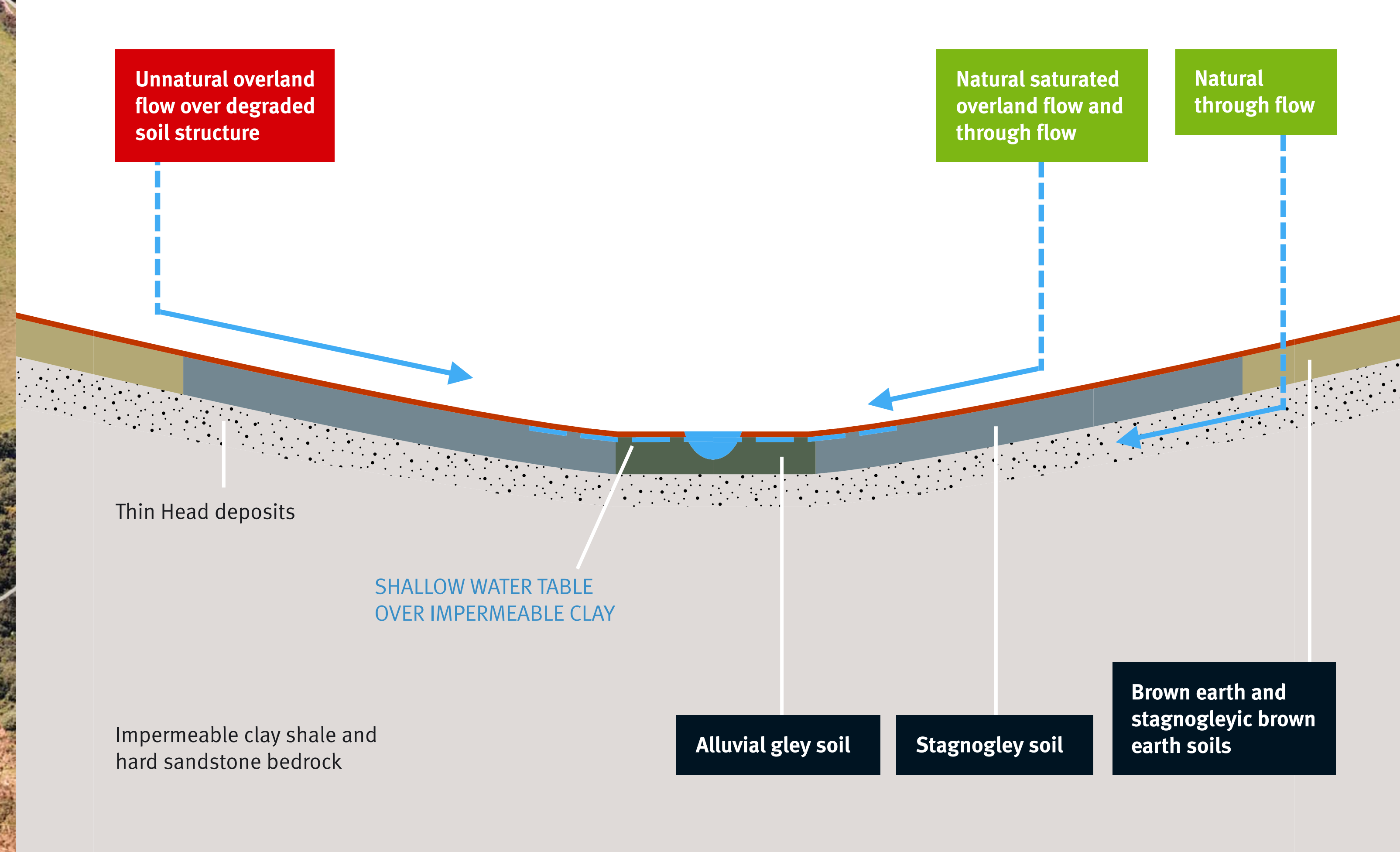
UNNATURAL SOIL WATER MOVEMENT

Degraded soil structure and greatly reduced porosity leads to extensive overland flow of rainwater and stream discharge is very responsive to rainfall

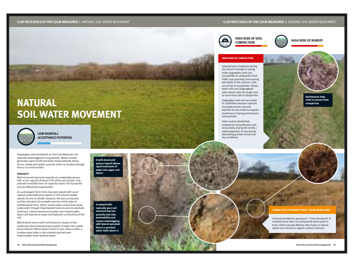
NATURAL SOIL WATER MOVEMENT

Clay soils can have periods of waterlogging due to slowly permeable substrates. Water moves either as shallow through flow or as saturated overland flow producing streams with a rapid flow response to rainfall

SCHEMATIC CROSS SECTION OF THE CULM LANDSCAPE SHOWING NATURAL AND UNNATURAL SOIL WATER MOVEMENT

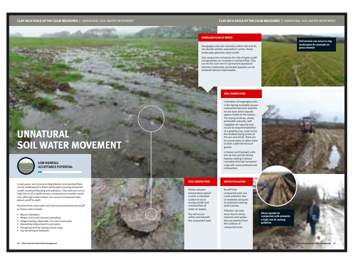


NATURAL SOIL WATER MOVEMENT – see pages 44-45



- The soils in this landscape are mainly slowly draining and have a low potential to accept rainfall
- The main pathway of water is shallow through flow and natural saturated overland flow towards the base of slopes
- The runoff response of rivers is rapid because rainwater moves near or at the soil surface
- Semi-natural habitats associated with ‘Culm Grassland’ help to slow down the rate of runoff

UNNATURAL SOIL WATER MOVEMENT – see pages 46-47



- Soils are often compacted in this landscape causing unnatural overland flow during rainfall which further exacerbates rapid runoff
- Land drainage ditches can rapidly route water through the landscape. However, land drains within fields encourage deeper percolation of rainwater through the soil which can help to attenuate runoff

MUDDY RUNOFF AND RIVER EROSION

Historically rivers draining the Culm landscape were clear and supported good salmon and trout fisheries. They were rich in wildlife with species such as the Freshwater Pearl Mussel. Rivers are now more polluted with muddy runoff. They are also often deeply incised due to more extreme flow regimes which damages river habitats.

NATURAL SOIL WATER MOVEMENT

LOW RAINFALL ACCEPTANCE POTENTIAL

Stagnogley soils developed on the Culm Measures are naturally waterlogged for long periods in winter. Rainfall generates rapid runoff and water moves laterally above dense, slowly permeable subsoils either as shallow through flow or as overland flow.

POROSITY

Well structured clay loam topsoils are moderately porous with an air capacity of about 10% of the soil volume. Clay subsoils invariably have air capacity values <5% by volume and are effectively impermeable.

An undamaged 30cm thick clay loam topsoil with an air capacity (drainable pore space) of 10% should readily absorb 30 mm of rainfall. However, the soil can become quickly saturated, for example over two winter days of rainfall greater than 30mm, where water cannot drain away underneath through impermeable horizons and on relatively level land. Lateral movement of water over impermeable layers will depend on slope and hydraulic conductivity of the soil.

Well drained brown earth soils found on slopes in this landscape allow downward percolation of water into rubbly Head material. Where Head is thick (2-3m), there is often a shallow water table in this material perched over impermeable shale bedrock below.

A well structured porous topsoil allows rapid movement of water into upper soil layers

A subsoil with naturally poor soil structure has low porosity and slow permeability and causes waterlogging with lateral saturated flow in a perched water table above

CLAY-RICH SOILS OF THE CULM MEASURES | NATURAL SOIL WATER MOVEMENT

HIGH RISK OF SOIL COMPACTION

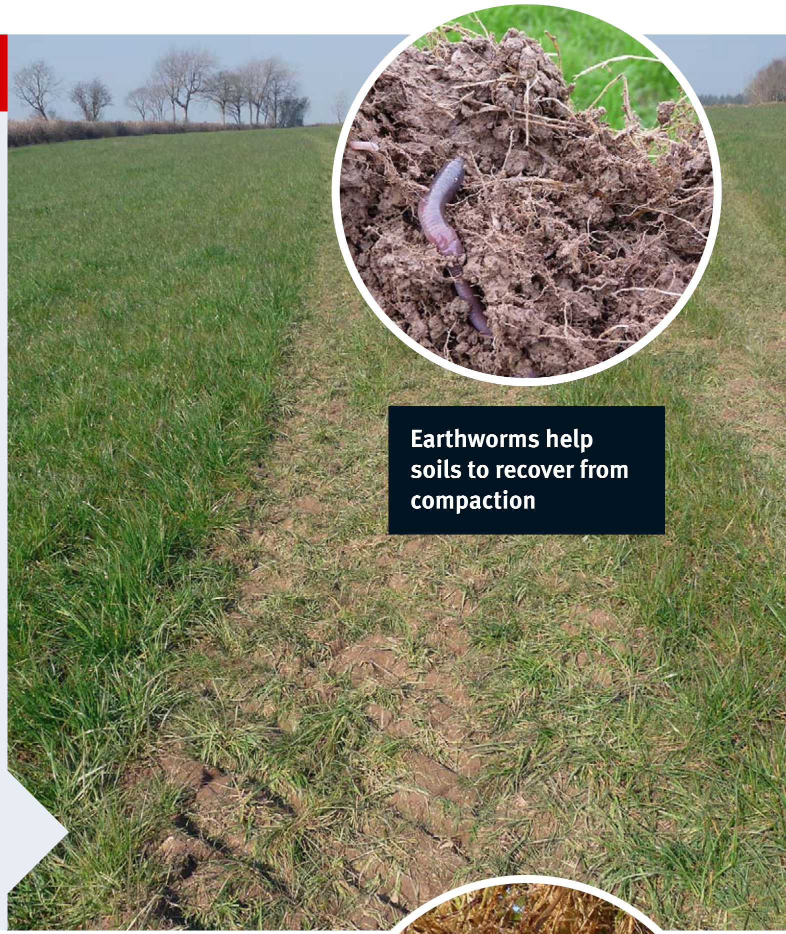
HIGH RISK OF RUNOFF

HIGH RISK OF COMPACTION

Long periods of wetness during the autumn through to spring make stagnogley soils very susceptible to compaction from traffic and poaching. Even during wet spells in the summer, soils are at risk of compaction. Brown earth soils and stagnogleyic soils remain drier for longer and so are at less risk of compaction.

Stagnogley soils are not suited to cultivation because subsoils invariably remain wet and topsoils are too moist to support machinery in spring and autumn work periods.

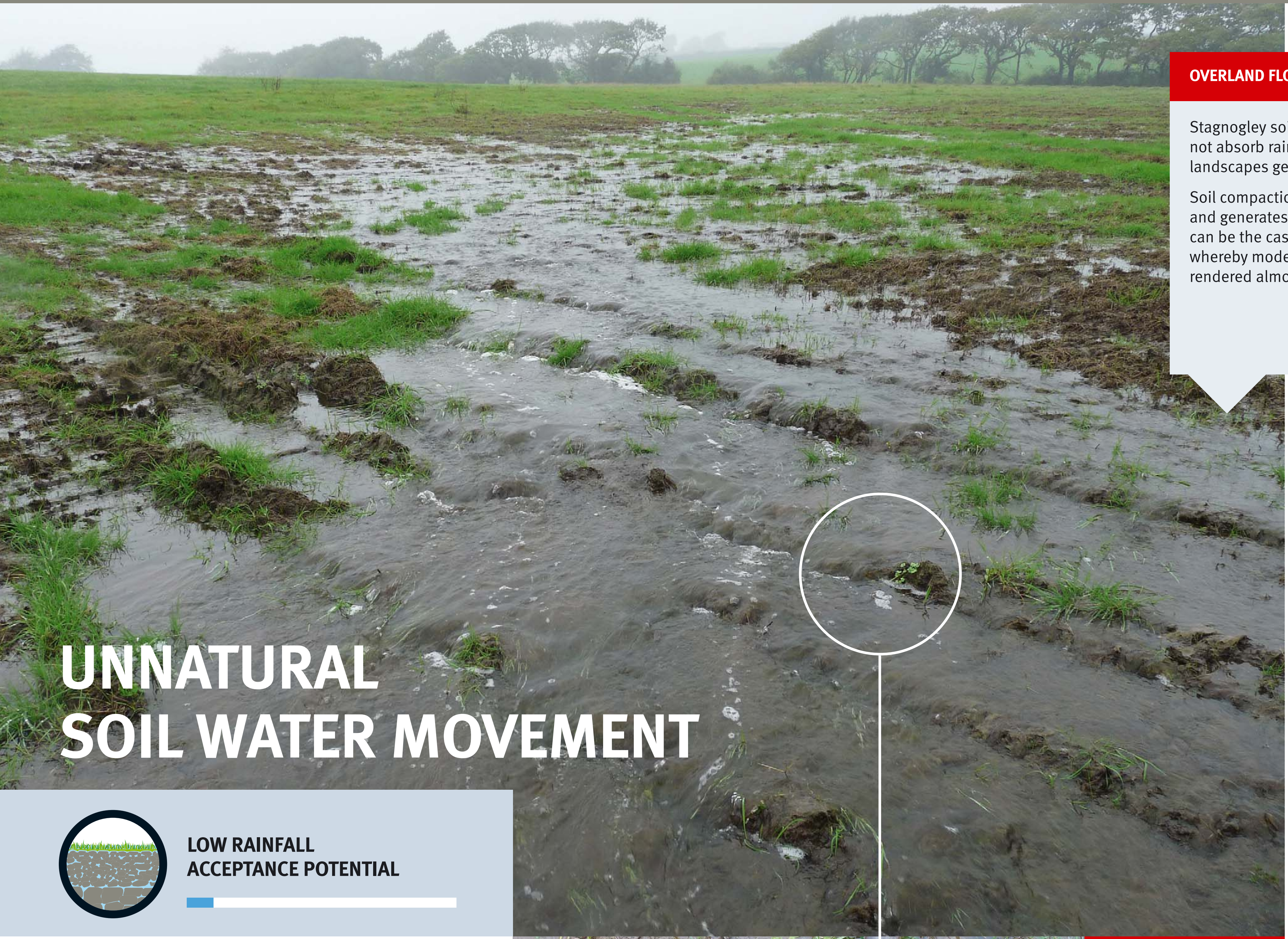
Soils recover slowly from compaction by earthworm and root activity and by the shrink / swell properties of clay during alternating periods of wet and dry conditions.



Earthworms help soils to recover from compaction

LOWER RISK OF RUNOFF FROM ‘CULM GRASSLAND’

Unimproved Molinia grassland / ‘Culm Grassland’ in relatively level sites can temporarily store water in thick, fresh tussocky Molinia litter layers (L layers) above any mineral or organic surface horizons.



UNNATURAL SOIL WATER MOVEMENT

LOW RAINFALL ACCEPTANCE POTENTIAL

In wet years, soil structural degradation and overland flow can be widespread in these landscapes causing enhanced runoff, localised flooding and pollution. Clay soils are not at high risk to rill or gully erosion compared to unstable sandy soil, although sheet erosion can occur on loosened soils where runoff is rapid.

Practices that cause poor soil structure and enhanced runoff on these soils include:

- Maize cultivation
- Winter slurry and manure spreading
- Silage making, especially first cuts in wet years
- Reseeding of grassland in wet years
- Ploughing land for spring cereal crops
- Out-wintering of livestock

CLAY-RICH SOILS OF THE CULM MEASURES | UNNATURAL SOIL WATER MOVEMENT

OVERLAND FLOW OF WATER

Stagnogley soils are naturally surface wet and do not absorb rainfall, especially in winter; these landscapes generate rapid runoff.

Soil compaction enhances the risk of rapid runoff and generates an increase in overland flow. This can be the case even in permanent grassland whereby moderately permeable topsoils can be rendered almost impermeable.

Soil erosion can occur in clay landscapes for example on grass reseeds

SOIL COMPACTION

Cultivation of stagnogley soils in the spring invariably causes compaction because subsoils lie wet even when topsoils appear friable at the surface. The drying of dense, slowly permeable subsoils, with negligible air capacity only occurs by evapotranspiration of a growing crop (and not by the shallow drying action of the sun and wind). There are no coarse pores to allow water to drain under the force of gravity.

Land drainage measures such as subsoiling and moling above land drains covered by gravel help to improve water movement through the soil and reduce the risk of compaction.

SOIL COMPACTION

Dense compact structureless topsoil causes a saturated surface to occur during rainfall and overland flow of water on slopes.

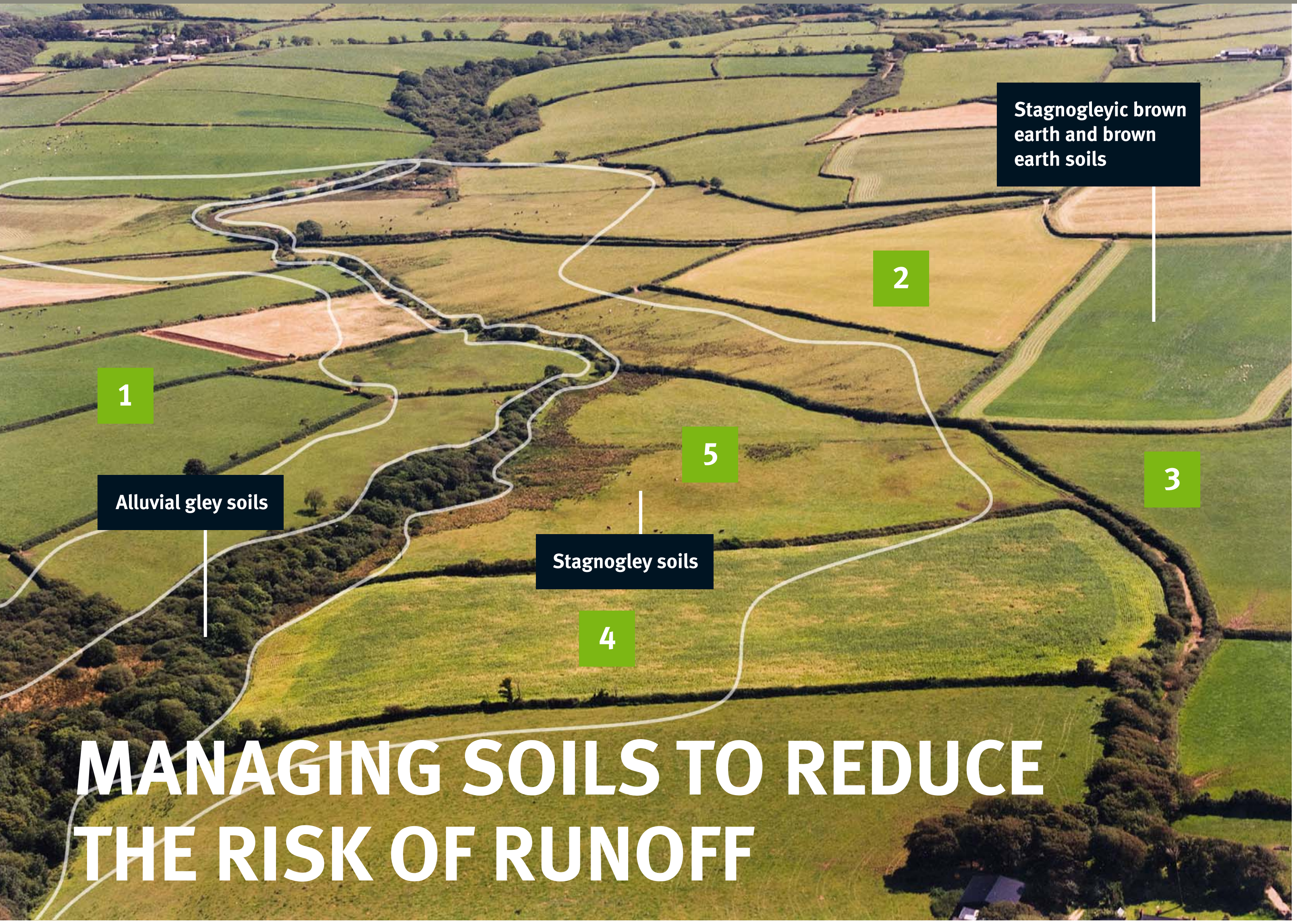
Dry soil occurs within and beneath the compacted layer.

WATER POLLUTION

Runoff from compacted soils can cause pollution due to excessive amounts of sediment entering watercourses.

Pollution can also occur due to slurry, manures and sprays that are washed from the surfaces of compacted land.

Slurry spread on compacted soils presents a high risk of causing pollution



MANAGING SOILS TO REDUCE THE RISK OF RUNOFF

Clay-rich stagnogley soils of the Culm Measures are often waterlogged in winter and even during wet summer spells and, therefore, are at high risk of soil compaction. Grassland farming is better suited to these difficult soils, rather than arable farming, although timely management is essential when planning grazing, grass cutting and manure and slurry spreading if damage to the soil is to be prevented. Cereal crops can be grown successfully on naturally well drained land with brown earth soils.

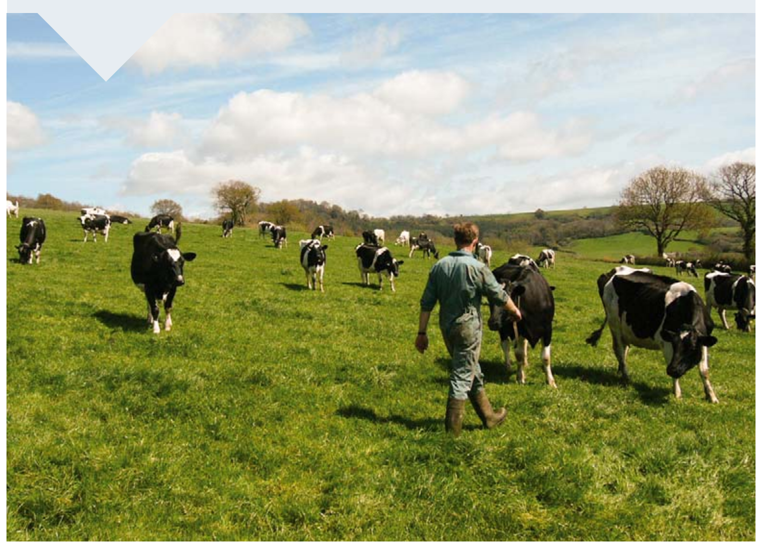
Land drainage with secondary subsoiling and moling helps to reduce the risk of soil structural damage by increasing the length of good working conditions and encouraging more through flow in the soil. Dams can be created in arterial ditches to slow the flow of drainage waters.

Very wet soils are best suited to semi-natural habitats and water storage areas. Important rare wetland habitats should not be drained.

1 | GRASSLAND MANAGEMENT

Timely grazing and silage cutting is essential to prevent soil compaction.

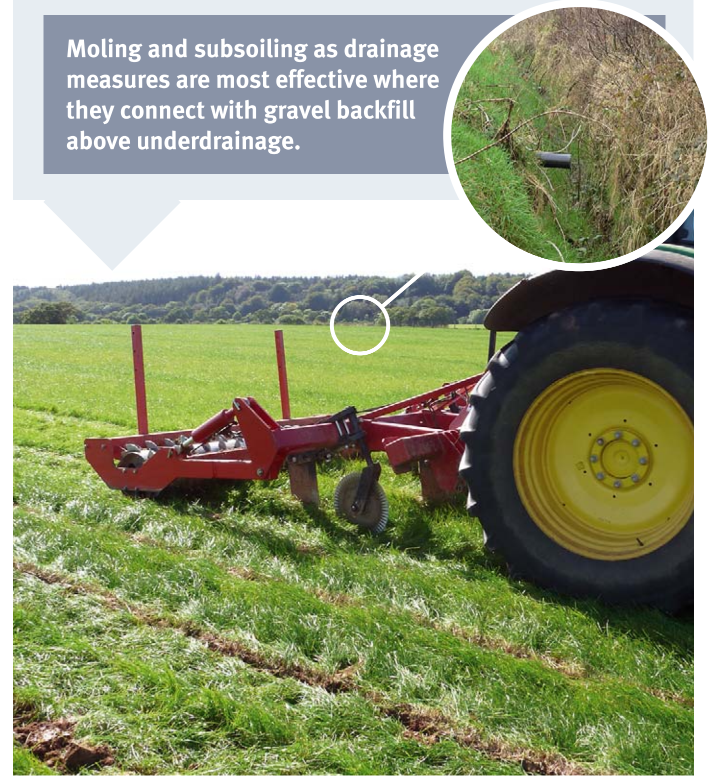
Cows should be turned out in spring when soils are suitably dry.



2 | DRAINAGE

Subsoiling can be carried out to deal with soil compaction and to loosen naturally dense clay when it is dry.

Moling and subsoiling as drainage measures are most effective where they connect with gravel backfill above underdrainage.



3 | MANURE & SLURRY SPREADING

Manures and slurries should be spread when the soil is suitably dry for example after first cut silage.

Adequate winter storage is essential.

4 | ARABLE CROPS

Arable crops, particularly maize, are unsuited to stagnogley soils in this landscape due to naturally difficult soil conditions and high rainfall.

Crop performance is reduced by periods of waterlogging.

5 | WETLAND HABITATS

There may be opportunities to create wetlands. Flood storage areas can also be constructed using appropriate design and consent standards.

Species-rich grasslands can be restored supporting rare wildlife such as the Marsh Fritillary butterfly.

SOILS OF THE SLATE HILLS

Soils over Devonian & Carboniferous slates are widespread in Devon and Cornwall. They are generally well drained, fertile clay loams over rubbly rock but are affected by groundwater on footslopes and on flat hill tops.

This landscape supports secondary aquifers, and small quantities of water are abstracted from shallow depth for private water supplies.

The highest land has the coldest, wettest climate and podzolic soils are common where iron and aluminium have leached into subsoils giving characteristic bright ochreous colours. These soils are naturally freely draining and readily absorb rainfall. Livestock farms are the main enterprise with a mixture of grassland and arable cropping. Vegetables and flowers are grown in South Devon and West Cornwall where there are favourable temperatures. The risk of enhanced runoff is high from land used to grow these crops.

SOIL TYPES

Freely draining brown earth soil

- Brown earth soils (Denbigh series). These are permeable and accept most rainfall
- Gleyic brown earth soils (Ivybridge series). These are permeable but are often waterlogged by a fluctuating water table below 40cm depth
- Groundwater gley soils (Yeollandpark series). These occur in low-lying basin sites and also on flat ridge tops. They do not readily absorb rainfall
- Brown podzolic soils (Manod series). These occur in cold high rainfall areas on high ground. They are permeable and accept most rainfall

SOIL FACTS

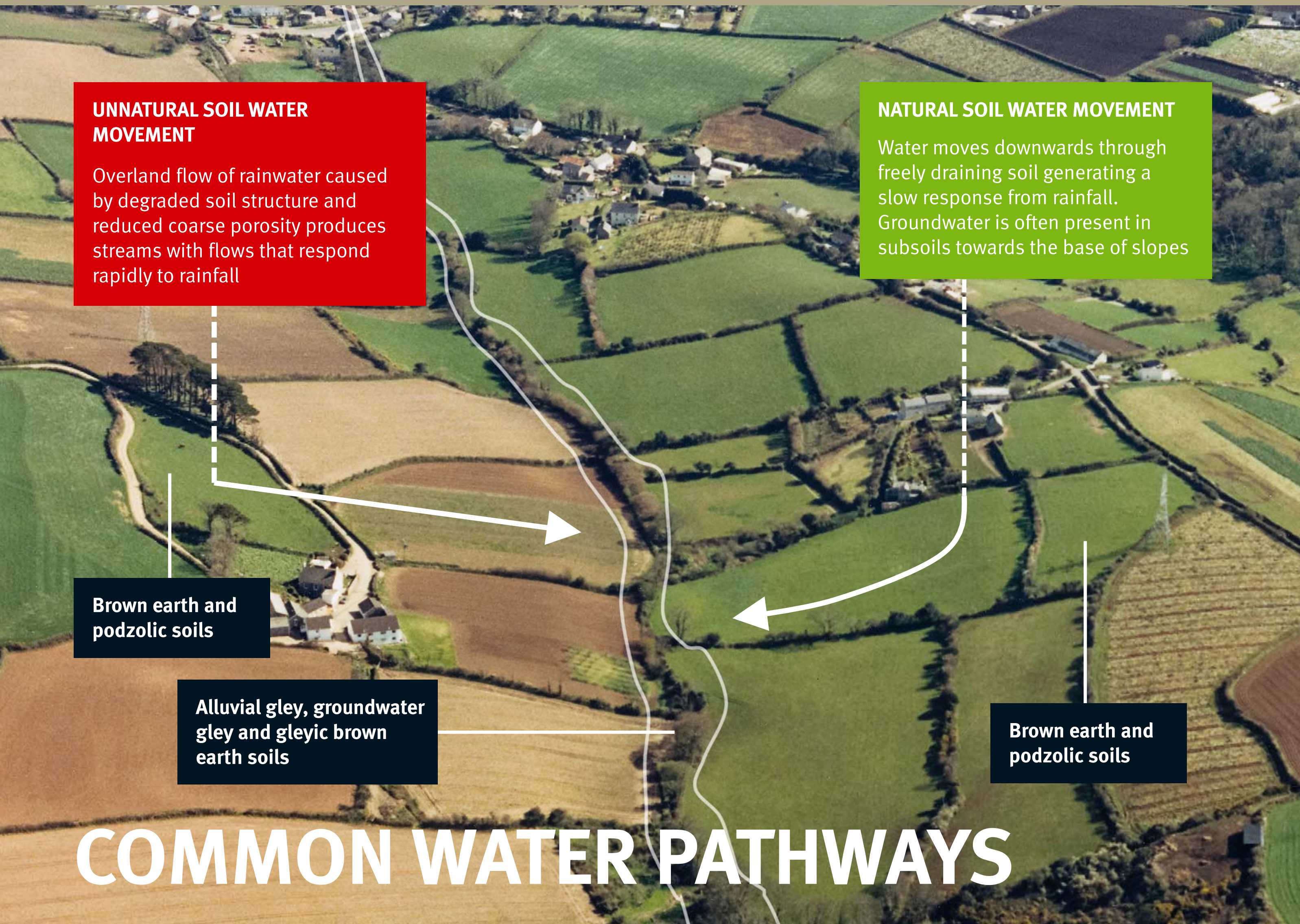
HIGH RAINWATER ACCEPTANCE ON BROWN EARTH SOILS

HIGH RAINWATER ACCEPTANCE ON BROWN PODZOLIC SOILS

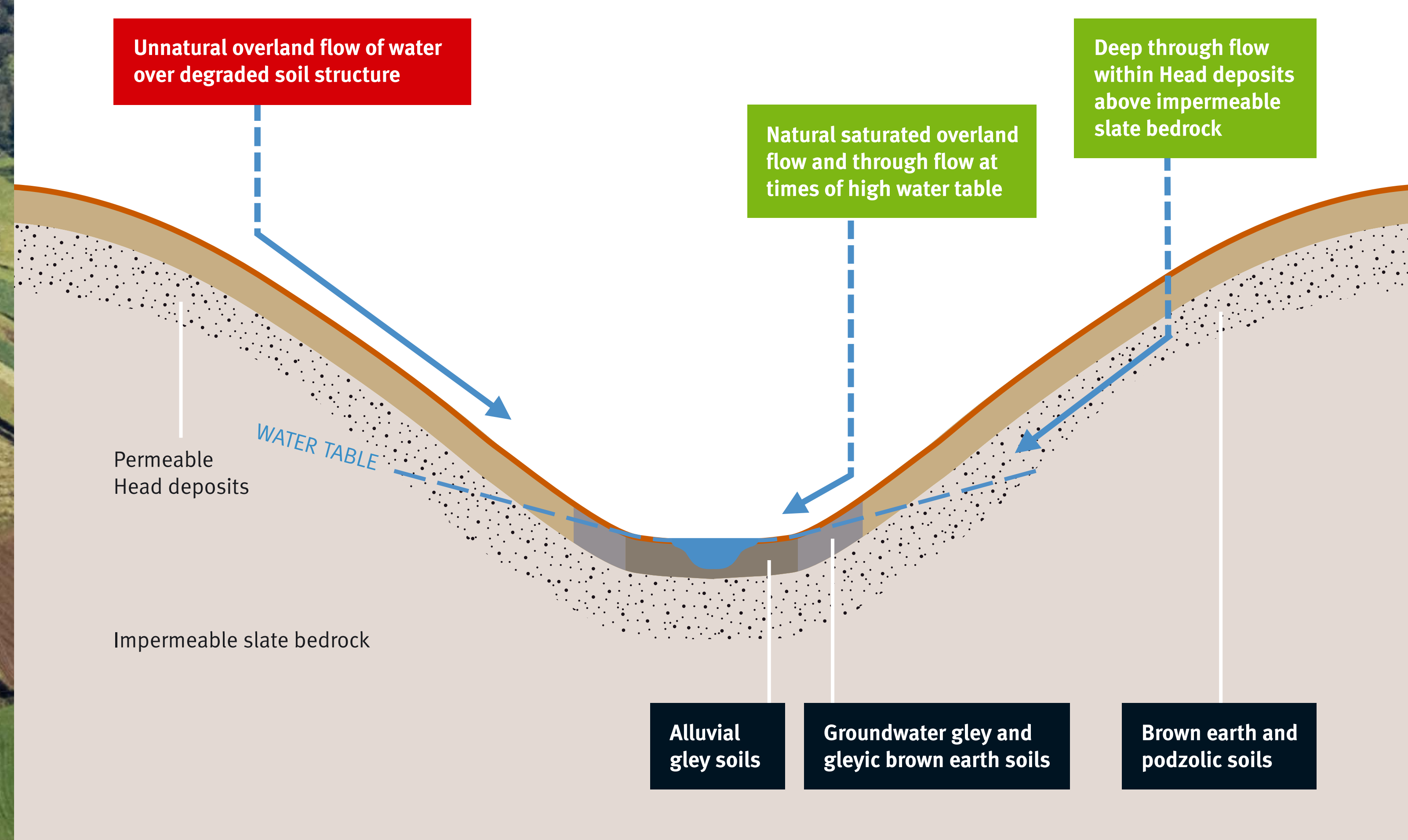
GOOD LAND CAPABILITY

LOW RISK OF SOIL COMPACTION, RUNOFF AND EROSION BUT RISK CAN BE DRAMATICALLY INCREASED BY SOME LAND USES

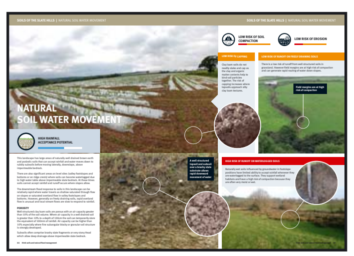
COMMON WATER PATHWAYS



SCHEMATIC CROSS SECTION OF THE SLATE HILLS SHOWING NATURAL AND UNNATURAL SOIL WATER MOVEMENT

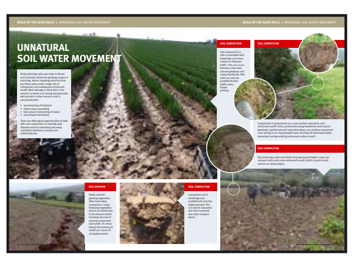


NATURAL SOIL WATER MOVEMENT – see pages 54-55



- The soils in this landscape are mainly freely draining and have a high potential to accept rainfall. However there are significant areas of shallow groundwater with less potential to accept rainfall
- The main pathway of water is downwards and laterally as deep through flow in stony Head over impermeable bedrock
- Where soils are freely draining, overland flow is unusual
- The downstream flood response in this landscape can be relatively rapid where water travels through shallow horizons on slopes, or as saturated overland flow in valley footslopes and bottoms

UNNATURAL SOIL WATER MOVEMENT – see pages 56-57



- Soil compaction causing unnatural overland flow is localised in this landscape depending on land use
- Porous soils with good soil structure are found in well managed grassland and cereal crops
- Most damage to soil structure occurs where practices are carried out late in the year or during the winter, for example where vegetables are grown which can cause localised runoff and flooding

FLOOD RISK

Steep land on freely draining soils can generate enhanced runoff, soil erosion and localised flooding where soils become compacted for example, where vegetables are grown and also where the following crop is established late in the year.

NATURAL SOIL WATER MOVEMENT

HIGH RAINFALL ACCEPTANCE POTENTIAL

This landscape has large areas of naturally well drained brown earth and podzolic soils that can accept rainfall and water moves down to rubbly subsoils and Head substrates before moving laterally, downslope, above impermeable bedrock.

There are also significant areas on level sites (valley footslopes and bottoms or on ridge crests) where soils can become waterlogged for short periods due to a high water table above impermeable slate bedrock. At these times soils cannot accept rainfall and runoff occurs where slopes allow.

Generally on freely draining soils, rapid overland flow should not occur and local stream flows are slow to respond to rainfall.

POROSITY

Well structured clay loam soils are porous with an air capacity greater than 10% of the soil volume. Where air capacity in a well drained soil is greater than 10% to a depth of 100cm the soil can temporarily store the equivalent of 100mm of rainfall. Air capacity can be higher than 10% especially where fine subangular blocky or granular soil structure is strongly developed.

Subsoils often comprise brashy slate fragments or very stony Head which allow deep drainage above impermeable slate bedrock.

SOILS OF THE SLATE HILLS | NATURAL SOIL WATER MOVEMENT

LOW RISK OF SOIL COMPACTION

LOW RISK OF EROSION

LOW RISK OF CAPPING

Clay loam soils do not readily slake and cap as the clay and organic matter contents help to bind soil particles together. The risk of capping increases where topsoils approach silty clay loam textures.

LOW RISK OF RUNOFF ON FREELY DRAINING SOILS

There is a low risk of runoff from well structured soils in grassland. However field margins are at high risk of compaction and can generate rapid routing of water down slopes.

HIGH RISK OF RUNOFF ON WATERLOGGED SOILS

Naturally wet soils influenced by groundwater in footslope positions have limited ability to accept rainfall whenever they are waterlogged to the surface. They support wetland habitats and have a high risk of compaction because they are often very moist or wet.

SOILS OF THE SLATE HILLS | UNNATURAL SOIL WATER MOVEMENT

UNNATURAL SOIL WATER MOVEMENT

LOW RAINFALL ACCEPTANCE POTENTIAL

Freely draining soils over slate in Devon and Cornwall, where the growing season is very long, attract cropping practices that put these soils under a high risk of compaction and subsequent enhanced runoff. Most damage is done late in the autumn or winter and during exceptionally wet periods in other seasons and is associated with:

- Out-wintering of livestock
- Winter slurry spreading
- Late autumn harvesting of maize
- Early flower harvesting
- Winter harvesting of vegetables

There are often good opportunities to deal with soil compaction in naturally well drained soils by subsoiling and deep cultivation whenever subsoils are sufficiently dry in summer.

SOIL COMPACTION

Compacted soil in wheelings and puddled soil only has slight porosity. This can lead to saturated soil that is perched over drier compact layers.

SOIL COMPACTION

Soil compaction is often associated with wheelings and areas subject to frequent traffic. This can occur between crop rows, around gateways and along headlands. Wet soils can also be puddled by foot traffic when flower picking.

SOIL COMPACTION

Compaction in grasslands can cause surface saturation and enhanced runoff. Soils, particularly along headlands and around gateways, quickly become saturated above any shallow compacted zone acting as an impermeable layer blocking off downward water movement and generating enhanced surface runoff.

SOIL COMPACTION

Out-wintering cattle and winter strip grazing of fodder crops can compact soils and cause enhanced runoff, which is particularly serious on steep slopes.

MANAGING SOILS TO REDUCE THE RISK OF RUNOFF

Well drained soils in the slate hills are well suited to arable and horticultural cropping.

Fields need to be chosen very carefully to reconcile inherent land capability (i.e. crop suitability) and the risk of soil structural damage from farm operations that are required to successfully grow the crop.

The risk of runoff is greatly reduced when good soil structure can be maintained in arable-grass rotations by ensuring farm operations are carried out when conditions are good and subsoiling regularly follows any structural damage.

Headlands, tracks and valley bottoms are particularly vulnerable to damage in this landscape and regular remediation is required to reduce the risk of enhanced runoff. There may be opportunities to create habitats such as woodland to intercept runoff before it reaches local streams.

1 | VEGETABLE CROPS

Wherever possible, fields or parts of fields from which there is a high risk of enhanced runoff flooding property and roads, and causing sediment pollution of watercourses, should not be used for growing vegetables. Land should be roughly cultivated immediately after harvest to remove wheel ruts.

2 | FILTER FENCES AND BANKS

Temporary filter fences can be used to slow down runoff and to trap sediment when growing high risk crops.

More permanent hedge banks and silt traps can be constructed to attenuate runoff.

3 | TRACKS, HEADLANDS AND GATEWAYS

Temporary ditches and single plough furrows can be created to divert runoff from headlands to soakaway areas.

High risk gateways should be blocked where these are at the bottom of slopes and new field gates opened in less risky sites.

4 | GRASSLAND MANAGEMENT

Land should be subsoiled where deeply compacted by wheelings whenever the soil becomes suitably dry in summer.

Slurry spreading should be carried out when the soil is dry.

5 | HABITAT CREATION

Grassed strips and woodland can be planted in valley bottoms, but soil structural damage should be removed first and these areas should not be used as access routes across the farm.

Wet valley bottoms are unsuited for cropping.

SOILS OF THE MOORLAND

Soils of wet uplands with frequent waterlogging

Well drained permeable granitic soils

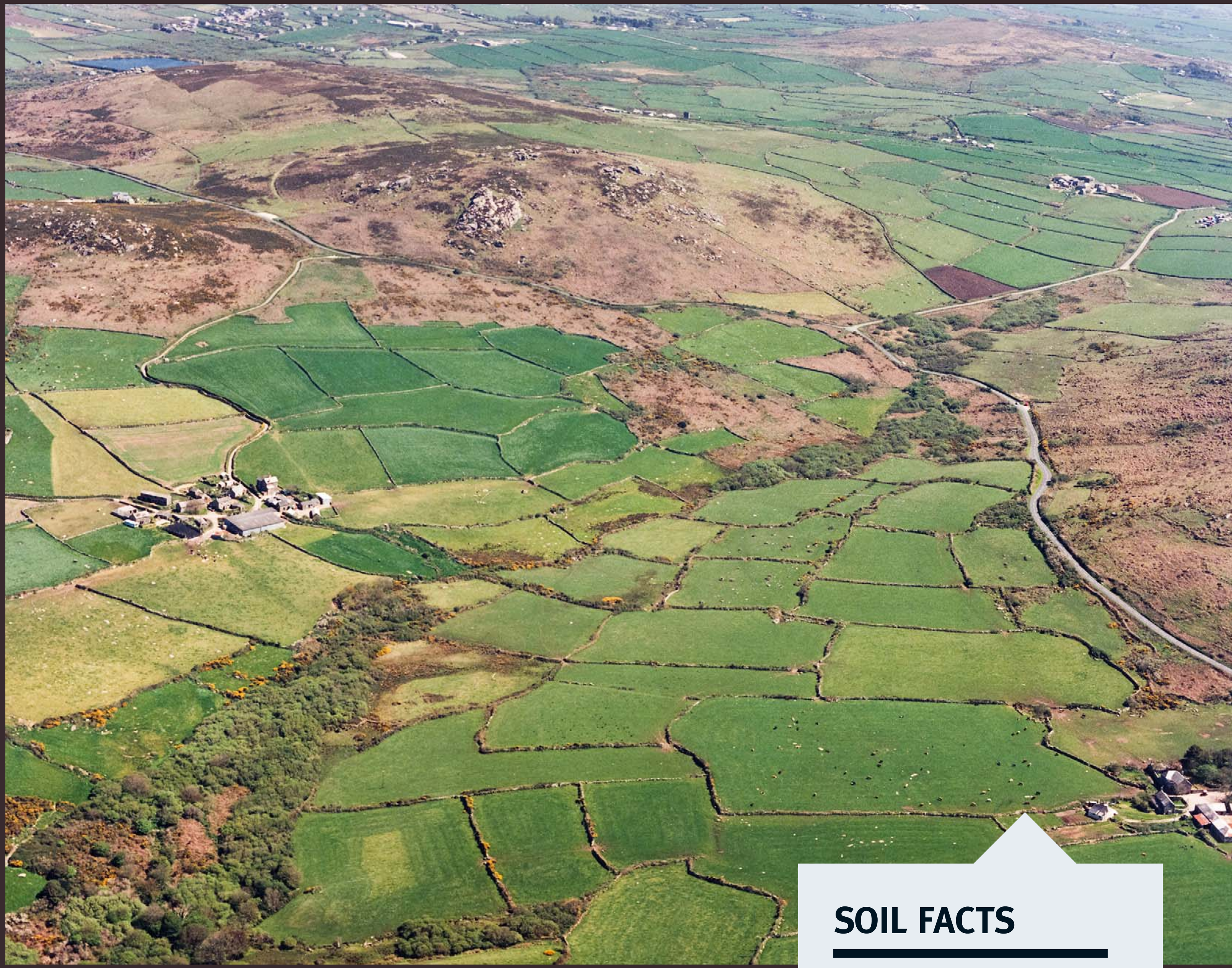
Moorland soils are widespread in high rainfall areas over granite on Dartmoor, Bodmin Moor and West Cornwall. They also occur over Devonian sandstones and slates on Exmoor.

Large areas of moorland have freely draining permeable soils overlying deeply weathered bedrock or permeable Head deposits. High rainfall causes leaching and podzolisation, and the cold climate with slow decay of dead vegetation leads to the development of peaty surface horizons. These soils absorb rain readily.

Where Head deposits or bedrock material are naturally dense and compact at shallow depth, overlying soils are gleyed from long periods of waterlogging and thick peat (peat >40cm thick) and associated blanket bogs can develop. Runoff is rapid on these soils because topsoils are frequently saturated.

Much of the freely draining land is enclosed with a wide range of use depending largely on climate. In West Cornwall, on relatively low lying land but high rainfall areas, there are significant amounts of arable and horticultural crops grown, but on the upland moors natural and improved grassland predominates.

On high ground on wetter soils, Molinia grassland and wetland habitats are widespread providing rough grazing for sheep, cattle and ponies. In places deep subsoiling has been carried out to break iron pans and shatter dense subsoils to improve drainage for forestry.



SOIL TYPES

- Brown podzolic soils (Moretonhampstead and Moor Gate series). These are permeable acid soils in deeply weathered granitic bedrock. They readily accept rainfall
- Stagnopodzols (Hexworthy and Lydcott and Hafren series). These are slowly permeable, seasonally waterlogged and rapidly become saturated and do not accept rainfall
- Stagnohumic gleys soils (Princetown and Wilcocks series). These are seasonally waterlogged with topsoils wet for most of autumn, winter and spring. They do not readily accept rainfall
- Peat soils (Crowdy and Winter Hill series). These occur on the wettest, coldest sites where these thick peat soils support blanket bogs. They are perennially waterlogged and do not accept rainfall
- Humic groundwater gley soils (Laployd series). These are permeable but waterlogged by fluctuating groundwater for much of the year as they occupy basin and flush sites

SOIL FACTS

LOW RAINWATER ACCEPTANCE ON PEAT AND 'STAGNO' SOILS, AND HUMIC GROUNDWATER GLEY SOILS

HIGH RAINWATER ACCEPTANCE ON BROWN PODZOLIC SOILS

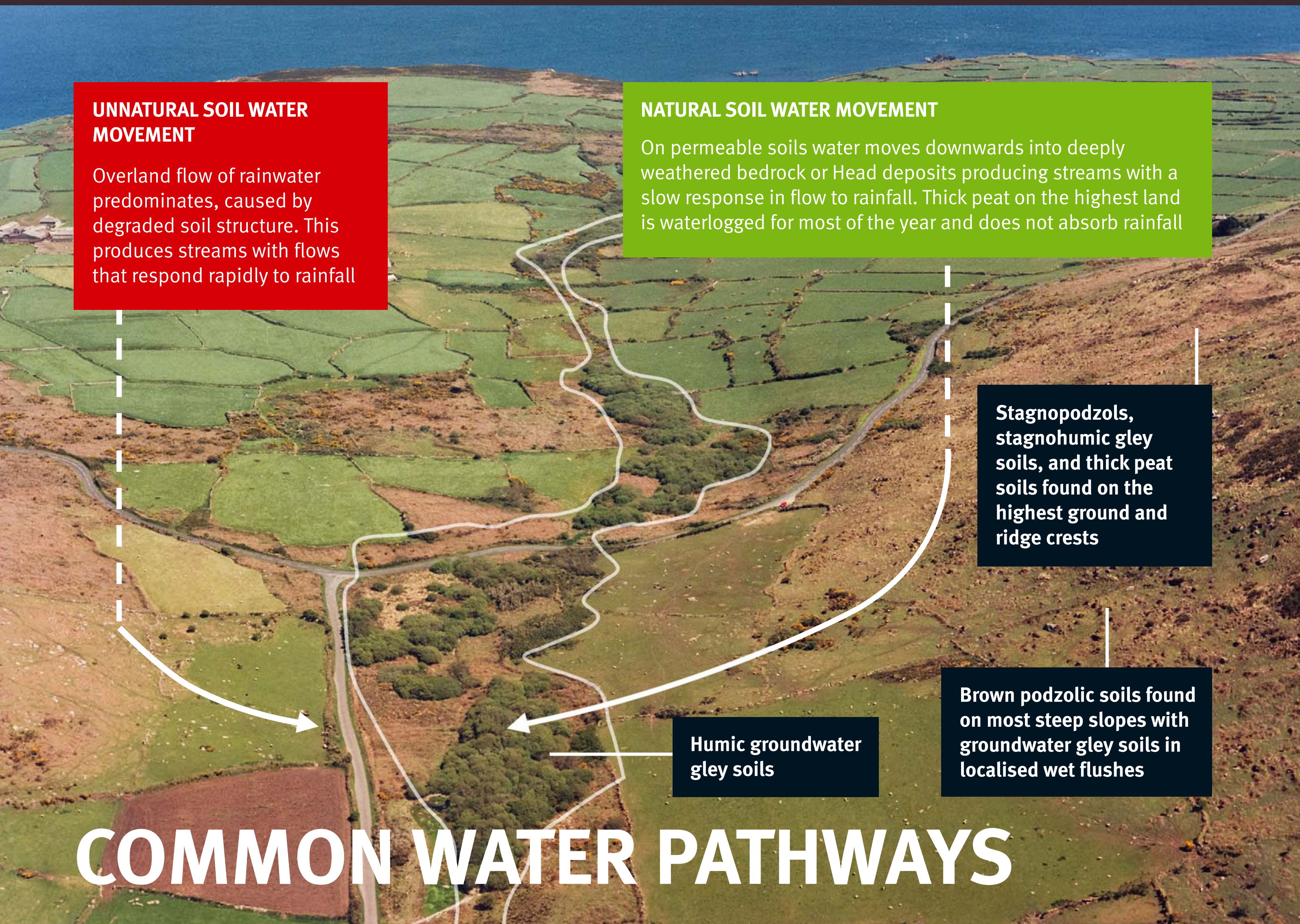
POOR LAND CAPABILITY

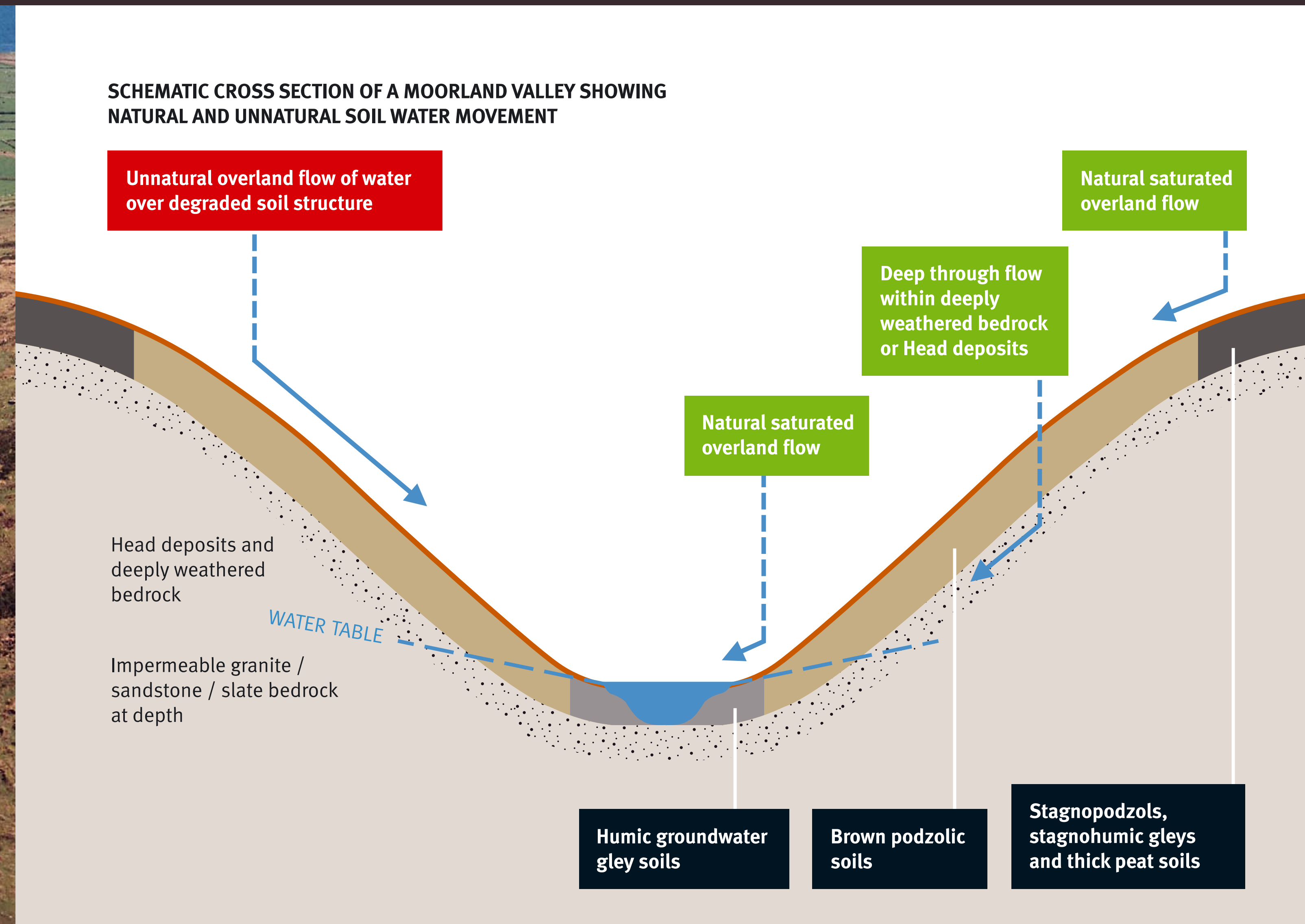
HIGH RISK OF SOIL COMPACTION

HIGH RISK OF RUNOFF AND SOIL EROSION

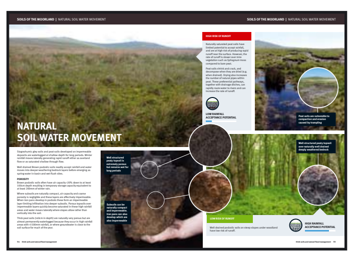
SOILS OF THE MOORLAND | COMMON WATER PATHWAYS

COMMON WATER PATHWAYS



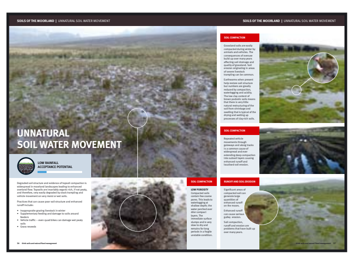


NATURAL SOIL WATER MOVEMENT – see pages 64-65



- Well drained podzolic soils predominate on the moors and have a high potential to accept rainfall
- Water movement is vertical through these permeable soils into shattered bedrock subsoils and substrates.
- The runoff response in these areas is naturally attenuated
- The moors also have large areas of saturated peat soils
- These have limited ability to accept rainfall and excess rainwater moves as saturated overland flow producing a rapid flow response in local streams
- Mire vegetation, such as *Sphagnum* moss helps to slow the speed of runoff

UNNATURAL SOIL WATER MOVEMENT – see pages 66-67



- Soil compaction that has built up over many years is widespread on Common Land. This causes enhanced overland flow even on freely drained soils
- Bare peat soils and drainage ditches can also cause very rapid runoff and erosion
- Degraded soils further exacerbate the runoff response

RAPID RUNOFF

Rivers draining moorland soils have naturally flashy river flows responding rapidly to heavy rainfall. However, degraded soils on the moors can lead to even more rapid runoff and downstream flooding.

SOILS OF THE MOORLAND | NATURAL SOIL WATER MOVEMENT

NATURAL SOIL WATER MOVEMENT

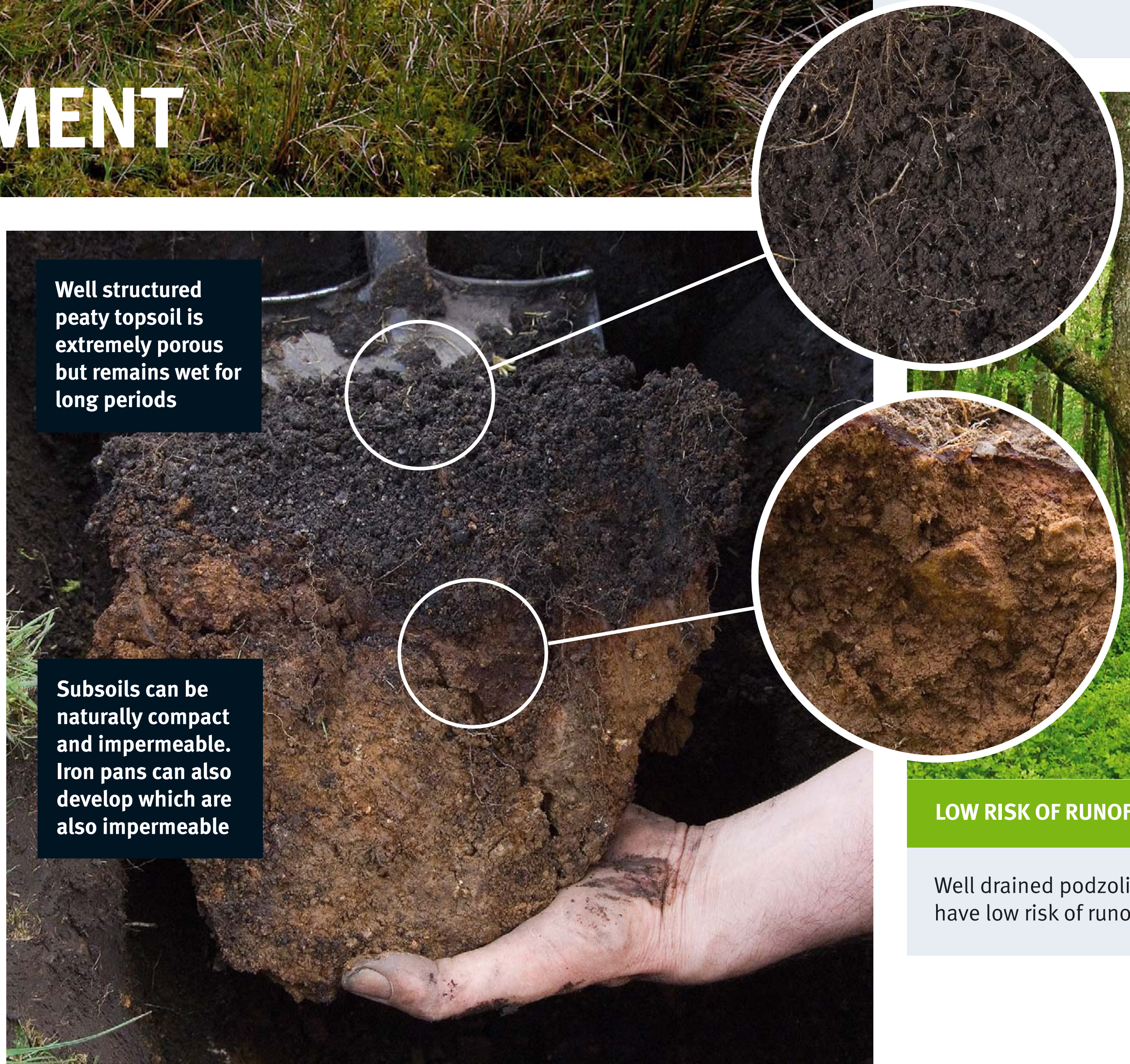
Stagnohumic gley soils and peat soils, typical of higher parts of the Moorlands, are developed on impermeable deposits and become waterlogged at shallow depth for long periods. Winter rainfall moves laterally generating runoff either as overland flow or as saturated shallow through flow.

Well drained brown podzolic soils readily accept rainfall and water moves into deeper weathered bedrock layers before emerging as spring water in basin and wet flush sites.

POROSITY
Brown podzolic soils often have air capacity of more than 20% down to at least 100cm depth resulting in a temporary storage capacity equivalent to at least 200mm of winter rain.

Where subsoils are naturally compact, air capacity and coarse porosity is negligible and these layers are effectively impermeable. When iron pans develop in podzols these form an impermeable layer limiting infiltration into deeper subsoils. Porous topsoils overlying impermeable layers quickly become saturated after rainfall and water moves laterally where slopes allow rather than vertically into deeper soil layers.

Thick peat soils (>40cm in depth) are naturally very porous but are almost permanently waterlogged because they occur in high rainfall areas with >1500mm rainfall, or where groundwater is close to the soil surface for much of the year.



Well structured peaty topsoil is extremely porous but remains wet for long periods

Subsoils can be naturally compact and impermeable. Iron pans can also develop which are also impermeable

HIGH RISK OF RUNOFF

Naturally saturated peat soils have limited potential to accept rainfall, and are at high risk of producing rapid runoff near the surface. However, the rate of runoff is slower over mire vegetation such as *Sphagnum* moss compared to bare peat.

Peat soils shrink and crack, and decompose when they are dried (e.g. when drained). Drying also increases the number of natural pipes within peat. These preferential pathways, together with drainage ditches, can rapidly route water to rivers and can increase the rate of runoff.

LOW RAINFALL ACCEPTANCE POTENTIAL

Peat soils are vulnerable to compaction and erosion caused by trampling

Well structured peaty topsoil over naturally well drained deeply weathered bedrock

LOW RISK OF RUNOFF

Well drained podzolic soils on steep slopes under woodland have low risk of runoff.

HIGH RAINFALL ACCEPTANCE POTENTIAL

UNNATURAL SOIL WATER MOVEMENT

LOW RAINFALL ACCEPTANCE POTENTIAL

Degraded soil structure and evidence of topsoil compaction is widespread in moorland landscapes leading to enhanced overland flow. Topsoils are invariably organic-rich, if not peaty, and therefore, very easily degraded by stock trampling and vehicle movement on very moist or wet soils.

Practices that can cause poor soil structure and enhanced runoff include:

- Inappropriate grazing livestock particularly in winter
- Supplementary feeding and damage to soils around feeders
- Vehicle traffic – even quad bikes can damage wet peaty soils
- Grass reseeds

SOIL COMPACTION

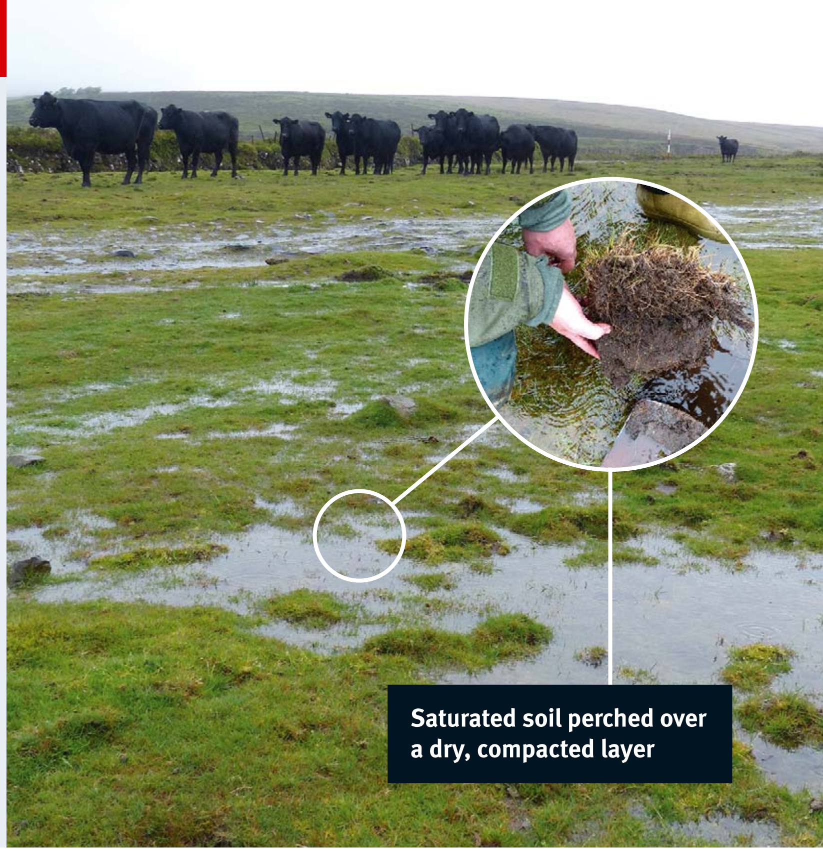
LOW POROSITY
Compacted soils contain few coarse pores. This leads to waterlogging at shallow depth; the water perched over drier compact layers. The immediate surface slumps and is very slow to dry and remains in a fragile unstable condition for long periods.

SOILS OF THE MOORLAND | UNNATURAL SOIL WATER MOVEMENT

SOIL COMPACTION

Grassland soils are easily compacted during winter by animals and vehicles. The consequences of overuse build up over many years affecting soil drainage and quality of grassland. Soil erosion originating in areas of severe livestock trampling can be common.

Earthworms when present help restore soil structure but numbers are greatly reduced by compaction, waterlogging and acidity. The low clay content of brown podzolic soils means that there is very little natural restructuring of the soil from shrinkage and swelling that is typical of the drying and wetting up processes of clay-rich soils.



Saturated soil perched over a dry, compacted layer

SOIL COMPACTION

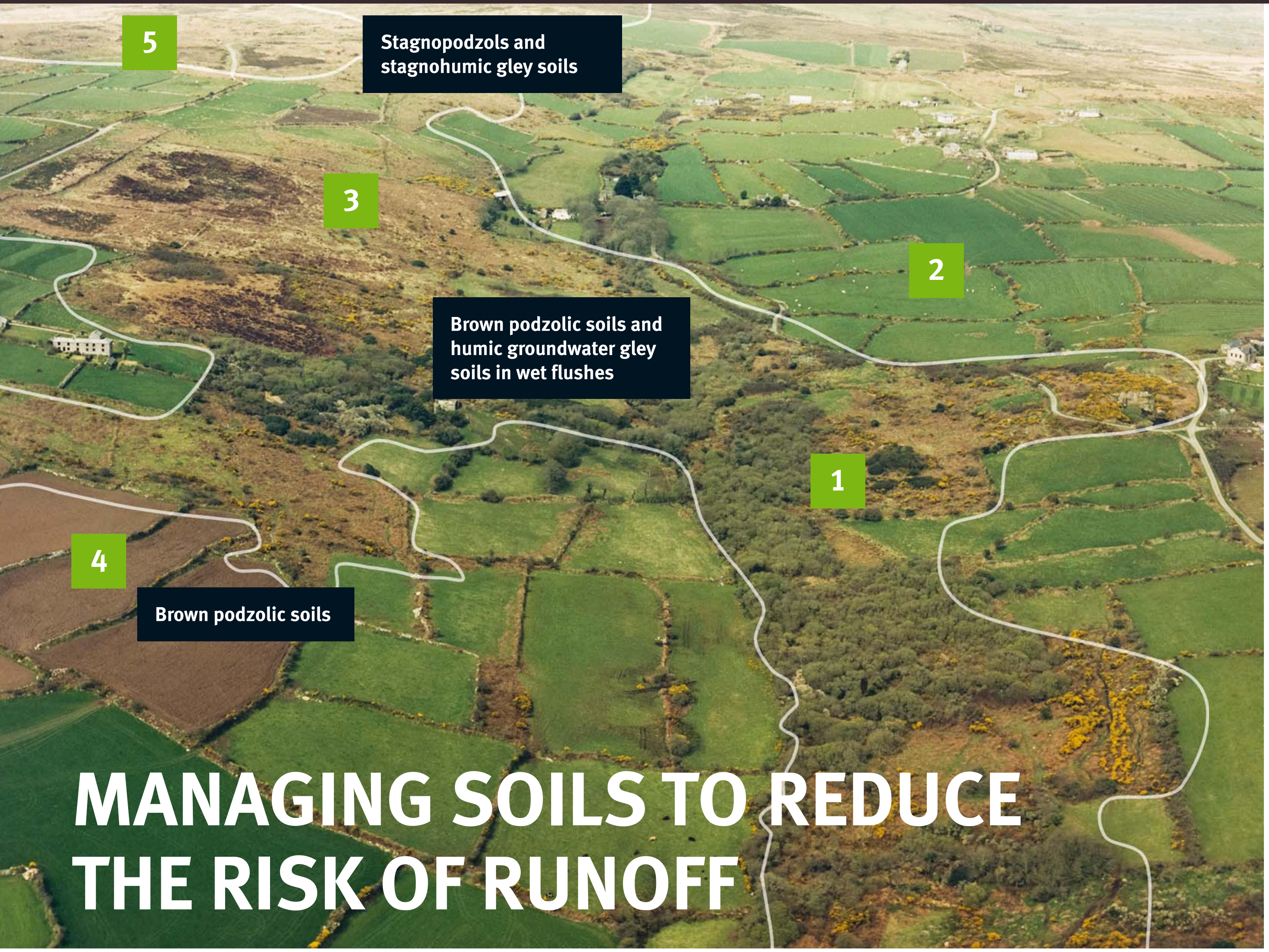
Repeated vehicle movements through gateways and along tracks is a common cause of widespread and ever extending deep compaction into subsoil layers causing enhanced runoff and localised soil erosion.

RUNOFF AND SOIL EROSION

Significant areas of compacted soil can generate large quantities of enhanced runoff on the moors.

Enhanced runoff can cause serious gulley erosion.

Soil compaction, runoff and erosion are problems that have built up over many years, particularly on Common Land.



MANAGING SOILS TO REDUCE THE RISK OF RUNOFF

Moorland landscapes have substantial landscape, conservation and amenity value. However, much of this soil landscape is degraded but still has a high potential for habitat creation that could reduce the risk of runoff and alleviate flooding downstream. Habitat and soil restoration will also improve water quality to the benefit of salmon and trout fisheries and drinking water quality.

Upland wetland habitats can be improved or created by blocking drainage ditches on peat and stagnohumic gley soils, which slows the rate of runoff and also captures carbon in the soil.

On freely draining ground there are opportunities for woodland planting and heather moorland would be encouraged by reducing grazing densities. Both these will help to remediate damaged soils and deal with enhanced runoff from moorland and localised soil erosion.

1 | WOODLAND CREATION

Steep slopes on freely draining soils are well suited to appropriate tree planting.

Compacted soils should be loosened when planting to aid tree growth. Planted areas should be fenced to prevent tree damage by grazing stock.

SOILS OF THE MOORLAND | MANAGING SOILS TO REDUCE THE RISK OF RUNOFF

2 | GRASSLAND MANAGEMENT

Grazing densities should be matched to the capability of the land. Supplementary feeding should not be carried out on wet soils and semi-natural habitats.

Slit aeration of grassland in early summer can help soils to naturally restructure after shallow compaction damage.

Winter housing can be used for stock to prevent damage to soils.

3 | HEATHER MOORLAND RESTORATION

Heather moorland can be restored by reduced grazing, reseeding and by controlling bracken and gorse. Soils should be allowed to restructure over time.

Heather moorland can be restored on more freely draining soils.

4 | ARABLE CROPS

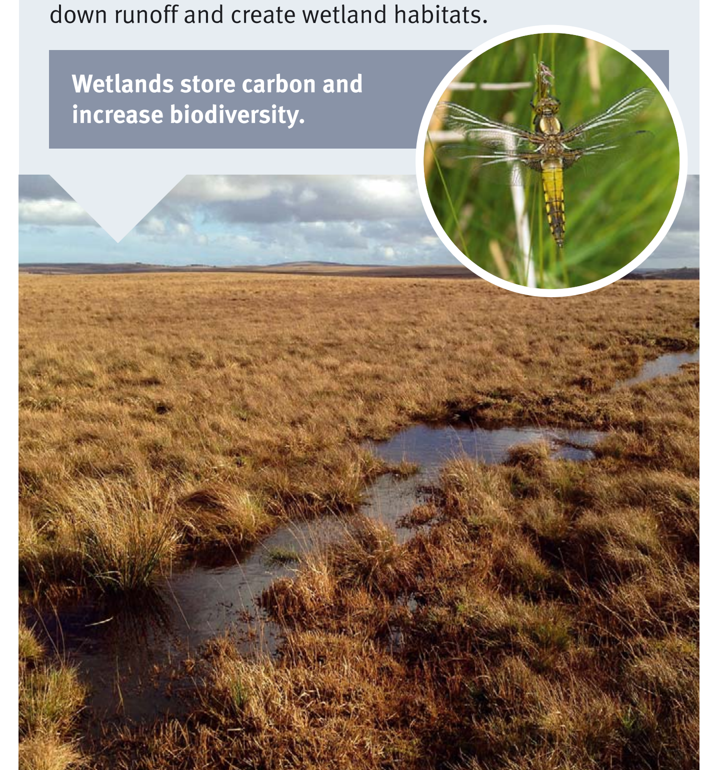
Fields used to grow early potatoes and vegetables should be relatively level and have a low risk of runoff.

Soils should be loosened after harvest to remove the inevitable compaction and to reduce the risk of enhanced runoff during winter.

5 | WETLAND CREATION

Drainage ditches can be blocked with dams to slow down runoff and create wetland habitats.

Wetlands store carbon and increase biodiversity.



Photograph: Exmoor Mires Partnership

Air capacity
This is defined as the volume of air space in a soil at field capacity moisture content. This soil moisture content occurs between most winter rainfall events and is reached after approximately 24 hours of winter rain, when all excess water in the soil profile that can drain by gravity has moved out leaving all large pores and fissures air filled. It is measured in the laboratory as a percentage of soil volume at 5 kilopascals (5kPa) suction and is approximately the volume of pores greater than 60µm diameter.

Aggregates
These refer to natural soil structural units (peds) or artificial units of soil formed by cultivation (clods and fragments) that are formed and held together by the interaction of organisms, roots and mineral particles. Soil structure refers to the shape, size and degree of development of these aggregates and their spatial arrangement including the voids between them.

Anaerobic soil
This is where the soil is devoid of oxygen.

Aquifer
This a porous deposit of rock containing a groundwater resource used for drinking water and for supporting surface water flows and wetland ecosystems.

Brown earth
A broad group of soils that are usually loamy and well drained or only suffer slight seasonal wetness. They are dominantly brown or reddish brown in colour.

Coarse pores
Large voids in the soil that are greater than 60µm in size and can be seen by the naked eye, they are also known as macropores.

Field capacity
The maximum water content that can be retained in a soil against gravity. Generally occurs in winter, 24 hours after rainfall when excess water has drained out of coarse pores and fissures (>60µm in size). Remaining water in the soil is held by surface tension. Further loss of water can only be achieved by plant transpiration apart from evaporation from bare surfaces. Once achieved in the autumn or early winter field capacity moisture content persists until spring growth occurs.

Fluvial flooding
This is flooding associated with rivers over-topping their banks and extending across floodplains.

Gley soils
A large group of soils whose properties result from frequent soil waterlogging. Gleying is the process which leads to the reduction or removal of iron compounds leading to segregation or coatings of pale grey colours under anaerobic waterlogged conditions. These are often accompanied by orange rusty brown colours or mottles associated with oxidation of iron compounds during aerated conditions. Gley soils show this influence of waterlogging (gleying above 40cm depth).

Where waterlogging and associated gleying occurs because of slow drainage above impermeable subsoils (a perched water table) the soils are termed stagnogley soils. Groundwater gley soils are permeable soils where waterlogging and associated gleying occurs because of a high groundwater table.

Gleyic soils
A group of soils where the same processes occur that form gleying in gley soils but the degree of waterlogging is much less. These soils characteristically show slight seasonal waterlogging, and gleying is generally found below 40cm depth.

Head deposit
An accumulation of angular local rock material transported during the Ice Age under tundra like conditions with periods of freeze and thaw.

Infiltration excess overland flow
This type of overland flow occurs when the rainfall intensity exceeds the soil infiltration capacity.

Peds
Soil peds are natural, relatively permanent aggregates, separated from each other by voids in the soil. They persist through cycles of wetting and drying. They differ from fragments and clods that are less permanent and formed in surface horizons by cultivation or frost action.

Podzolisation
This is a soil process where iron, aluminium and frequently organic matter have been removed from the surface horizons by acidic water percolating downwards and depositing these substances lower in the profile. Podzols have a bleached subsurface horizon due to intense leaching. Podzolic soils have less intense leaching and are without the bleached horizon but have brightly coloured iron-enriched subsoils.

Saturation
Saturation is when all pores and fissures are filled with water and the soil is waterlogged.

Saturation excess overland flow
This type of overland flow occurs when saturated soil cannot accept rainfall and excess rain flows across the ground surface.

Soil horizons
These are soil layers that are roughly parallel to the ground surface. They are distinguished from each other by differences in colour, texture, structure and organic matter content.

Soil water regime
This is the cyclical seasonal variation of wet, moist and dry soil states. The duration and degree of waterlogging have been classified by a system of wetness classes grading from Wetness Class I (well drained) to Wetness Class VI, almost permanently waterlogged within 40cm depth.

Soil structure
The arrangement of primary soil particles into natural or artificial aggregates of characteristic shape, size and degree of development.

Soil texture
The size distribution of mineral soil particles less than 2mm (the fine earth). The proportions of clay, silt and sand determine the texture class. Texture is best determined by laboratory particle-size analysis but with experience reliable estimates can be obtained in the field by working moist soil between finger and thumb.

Through flow
This is the movement of water through the soil.

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The Project Team

Author: Richard Smith - Environment Agency

Designer: Andrew Nadolski

Peer review: Robert Palmer BSc CGeol FISoilSci FGS

Project Management: Hugh Davey, Leslie Newport - Environment Agency
Peter Burgess, Ed Parr Ferris - Devon Wildlife Trust
Iorwerth Watkins - Westcountry Rivers Trust

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An electronic version of this manual can be found at www.catchmentbasedapproach.org

Catchment
Based Approach
Partnerships for Action

The Catchment Based Approach (CaBA) is a community-led approach that engages people and groups from across society to help improve our precious water environments. CaBA Partnerships are now actively working in 100+ catchments across England and Wales.

The East Devon Catchment Partnership is co-hosted by Devon Wildlife Trust and Westcountry Rivers Trust, and is made up of the following partners:

Blackdown Hills AONB Partnership
Clinton Devon Estates
Devon County Council
Devon Wildlife Trust
East Devon AONB Partnership
East Devon District Council
Environment Agency
Exe Estuary Management Partnership
Exmoor National Park
FWAG SW
National Trust
Natural England
South West Water
Westcountry Rivers Trust

Project steering group

Devon Wildlife Trust

Environment Agency

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