Controlling soil erosion

A manual for the assessment and management of agricultural land at risk of water erosion in lowland England

Revised: September 2005

defra
Department for Environment Food and Rural Affairs

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Contents

1. Introduction

This booklet has been produced for use by agricultural consultants, farmers and their agents to help minimise soil erosion caused by water in areas of England and on certain land types where this is an important problem.

The aim of the booklet is to explain how soil erosion occurs, the factors influencing it and to present methods by which it can be controlled. Erosion caused by grazing livestock is a different process from that which occurs on cultivated land and is dealt with in the separate leaflet 'Controlling Soil Erosion: An advisory leaflet for preventing erosion caused by grazing livestock in lowland England'.

In Chapter 3, a procedure for assessing erosion risks on the farm is explained, with the objective of helping farmers to produce a farm map, classifying their land into five different risk categories.

The assessment procedure has been divided into two stages:

1. Site classification – soil texture, slope and rainfall.

2. Classification of the cropping regime or land use by degree of erosion susceptibility.

Chapter 4 of the booklet gives details of management techniques for reducing erosion by means of cropping, cultivations and possible amendments to existing field characteristics (e.g. re-arrangement of field boundaries, gates, establishment of buffer strips).

In Chapter 5, detailed recommendations are given for the main "at risk" crops and farming systems.

Chapter 6 considers erosion that can occur in specific situations. In particular run-off from clay soils may only remove very small quantities of soil material but can contain significant quantities of potential pollutants and is therefore an important environmental consideration.

2. Background

2.1 Extent and effects of erosion in England

Soil erosion is a natural phenomenon. It normally occurs at a very low level in this country but can become a problem when man's activities or severe weather events upset the ecological balance.

The risk of erosion by water occurs wherever soils, particularly those with a high sand or silt content, are exposed to heavy or prolonged rainfall. In localised areas, when erosion occurs, clear signs of soil loss from fields include deposition on roads or in watercourses. Problems with erosion have become more apparent in recent decades owing to changes in cropping patterns, field sizes, soil management practices and livestock enterprises. The map at Appendix B shows areas of England most susceptible to soil erosion by water.

Even when no sediment is carried off farmland, discoloured run-off carrying soluble nutrients, pesticides and recently applied animal manures can enter watercourses and cause pollution. This process is sometimes called soil "wash" and can occur on any soils, including those down to grass. It can be an important mechanism for damaging the ecology of watercourses, ponds, lakes etc.

On the farm, erosion can have economic effects by removing topsoil rich in nutrients and organic matter and by reducing soil depth for rooting and water availability. Short-term damage can result from loss of seeds, fertilisers and pesticides, and the need to repeat operations. Eroded areas can interfere with or interrupt field operations. Soil washed from roots can affect saleable quality of produce and make harvesting difficult.

Below eroding fields, obvious damage from sediment deposition can include blocking of drains, deposition on roads and damage to property. Increased run-off and sediment deposition can also increase flood hazard in rivers.

Less obvious are the finer soil particles which remain in suspension and wash into lakes, rivers and estuaries. They can carry nitrogen, phosphorus and pesticides and cause environmental damage. Sediment deposited in rivers can damage spawning grounds of fish and can kill salmon and trout eggs laid in the gravel.

2.2 How soil erosion occurs

Soil erosion is a two-stage process which depends on water both detaching and transporting soil particles. Any soil condition which encourages surface run-off brings with it the risk of soil wash and erosion. If the water flow is significant or concentrated, then shallow channels (rills) may be formed which can become deeper gullies.

First erosion stage – detachment

The first stage of erosion involves detachment of soil particles. Rainsplash is the most important cause of detachment on cultivated land, but it may also result from the weathering action of frost, cultivation equipment or poaching by stock. Energy from raindrops striking soil can cause particles to be thrown several centimetres. Just how much soil is detached in a rainstorm will depend on the erosive power in the raindrops, the length of the storm, and the vulnerability of the soil to breakdown. Serious erosion events in England are generally associated with rainfall intensities of greater than 4 mm per hour and rainfall quantities greater than 15 mm per day.

The erosive power of rain will effectively be reduced if the soil surface is covered by a growing crop, stubble or mulch.

The resistance of soil to erosion is largely determined by soil texture. Soils with a high sand or silt content are the most vulnerable. Soils with a higher clay content have more stable soil crumbs or aggregates. Soil organic matter also influences aggregate stability by its binding effect, which can change over time. For example, under continuous arable cropping, reduction in organic matter content and the breakdown of soil aggregates by cultivations will increase soil erodibility, compared with rotations involving medium to long-term leys.

Second erosion stage – surface transport

Once detached, the soil particles will only be transported any distance if surface water run-off occurs. This will happen once rainfall exceeds the soil's infiltration rate. Surface run-off usually occurs during heavy storms or following prolonged rainfall, but can be accelerated if soil infiltration rate is reduced. This could occur, for example, where a surface cap (or crust) is formed.

Maintaining a high soil infiltration rate will reduce surface run-off. This can be achieved by creating coarser, rougher seedbeds, using cultivations to break sub-surface pans and compacted layers and maintaining effective underdrainage to reduce the risk of soils becoming saturated.

Large fields with long slopes can accumulate large volumes of run-off water. Long slopes can be broken with hedges or wide vegetated strips, so that run-off is checked. Altering the field gradient by terracing or creating bunds can also check run-off, but these measures are considered to be extreme for erosion control in England.

Even in free draining soils, where there is a high water table or where water runs off the valley sides, surface flow of water can occur in valley bottoms.

Rills and gullies

Except on very gentle uniform slopes, surface water flow rarely occurs as a sheet of uniform depth. Where slopes steepen, or in natural depressions, cultivation marks, wheelings, etc., the flow can quickly concentrate and become turbulent. This provides sufficient energy to scour and detach more soil as small aggregates and clods, which are themselves further broken down in transport. This scouring results in shallow channels, or rills, developing down the slope. They are commonly formed in tramlines or wheelings, where soil infiltration rates are reduced by compaction.

Rills are relatively shallow (within the topsoil layer) and can be ploughed out, but they are highly visible on bare and recently sown fields. *Any evidence of rilling should be taken as an indication that significant erosion is occurring.* Eroded soil can be deposited within the field where slopes lessen, or rills can connect with watercourses and result in pollution.

Gullies are larger than rills, cutting below the topsoil, and cannot be rectified by ploughing. They can become permanent features unless they are filled in using earth-moving equipment. They commonly develop in valley floors and valley sides within fields and on headlands being characterised by a distinctive 'waterfall' at the head. All water channelled into a gully will cause large volumes of soil to be cut from the gully floor at the head and sides, which progressively collapse. Soil movement is large, field operations are seriously impeded, and re-instatement can be very expensive. Gully formation is not generally common in England, but examples have been seen in South Devon, Sussex and the West Midlands, with gully lengths of up to several hundred metres developing in a single winter.

Soil deposition

During run-off, soil particles of all sizes may be moved. When flow is checked, these start to settle. Stones and gravel settle out first, followed by sand, which can commonly be seen as depositional fans where rills run onto flatter or vegetated ground.

Silt-sized particles, and especially, clay-sized particles and organic matter stay suspended much longer, and therefore more readily reach drains and watercourses. These materials can clog river gravels and damage fish spawning grounds. Also, nutrients and pesticides attached to soil particles can upset the ecology of streams, rivers and lakes.

The quantity of soil lost is frequently much greater than it appears, for instance, 1 mm of soil loss over 1 hectare is equivalent to 11-16 tons. Small deposits of coarse sand at the foot of a field should *not* give false reassurance that the eroded soil has stayed within the field. The fine material, together with nutrients and pesticides will have travelled much further. Where they finish up depends on the farm and landscape features, such as roads and tracks, and natural slopes. The term "connectivity" is used to describe this linkage between eroding land and receiving waters or other vulnerable areas such as roads or private housing.

Nutrient loss associated with run-off and soil erosion

Topsoil contains most of the nutrients used for plant growth, so any loss of topsoil has the potential to pollute watercourses and lead to a reduction in nutrient reserves in the soil. Whenever soil particles are detached and carried by surface flow, silt and clay particles and organic matter are carried farthest – often to streams and rivers far away from the field of origin.

Environmental and economic effects are greatest with phosphorus (P), which is attached to the clay and silt particles. Over 40% of the phosphorus present in English waters originates from agricultural land, mostly through run-off and soil erosion.

A typical arable field contains about 1.6 kg phosphate (P_2O_5) in every tonne of topsoil. A field showing moderate levels of erosion loses around 3 tonne per hectare of soil each year from surface rills, meaning potential phosphate losses of 4-5 kg/ha depending on the P status of the soil. Even where rills do not form phosphate in run-off (also sometimes called soil wash) can cause problems.

While these losses are small in comparison to crop off-take, it only takes low levels of phosphate reaching watercourses to be very damaging to the environment and cause eutrophication. This is the process in which water is enriched with nutrients causing algae and higher forms of plant life to grow too fast, disturbing the balance of organisms present in the water and also the quality of the water. In some waters, a phosphorus concentration as low as 0.02 parts per million is sufficient to cause eutrophication.

Nitrogen also contributes to eutrophication, although soil erosion is not usually the main way that nitrogen gets in to watercourses. Mineral nitrogen in the form of nitrate is very soluble and more likely to be lost from agricultural land through leaching or in surface water run-off. Organic nitrogen will be lost in eroded topsoil and may reduce the soils' longer term nitrogen reserves.

Risks to watercourses from nitrogen and phosphate in run-off and eroded soil will be increased by the presence of slurry or other organic manures e.g. following recent applications or from poached land where dung has been trodden into the soil.

Control of soil erosion

Erosion control on susceptible soil types can be successfully achieved by reducing the erosive impact of rainfall and maintaining soil infiltration rates so that surface flow is prevented. This can be achieved by:

- Protecting the soil from rain impact, either with permanent vegetation cover or, in arable rotations, by timely crop establishment and by surface retention of crop residues.
- Avoiding smooth, flat finishes to bare field surfaces, so that good water infiltration rates are maintained.
- Avoiding tramlines, wheelings or cultivation features that can channel surface flow.
- Improving the stability of the soil in the longer term by actively seeking to increase the organic matter content.

As slope angle steepens and erosion risk increases, the efficiency of these measures becomes more critical.

In deciding on the combination of measures to apply in any particular situation, consideration should always be given to what could happen if a severe erosion event should occur. In some circumstances, an intended control measure could add to erosion. For example, working along the contour is sometimes used to reduce run-off, but if the contour is not strictly followed, there is the risk of accumulation of water at low points which might break over the cultivation features.

It is important also to differentiate between management practices which aim to prevent soil movement and attempts, often made in emergency situations, to tackle the symptoms. The latter include more extreme measures such as blind ditches to intercept sediment and the formation of emergency bunds.

Sometimes, valley floors must be protected to allow surface flows to pass without scouring and gullying. A designated waterway with permanent grass cover will usually suffice.

Detailed techniques to achieve erosion control are described in chapters 4 and 5 of this booklet.

2.3 Erosion control information

The areas of England most at risk of soil erosion by water are shown at Appendix B. The map gives a good general guide to 'at risk' areas, based on soil type, landform, rainfall and present land use information. However, problems, particularly of soil wash, may occur almost anywhere.

A list of further reading is included at Appendix A, useful general information is contained in:

- The Code of Good Agricultural Practice for the Protection of Soil.
- The Defra publication 'Controlling Soil Erosion: An advisory booklet for the management of agricultural land', which includes details on the legal controls that may be enforced in cases of soil erosion.

3. Erosion risk assessment

3.1 Site characteristics

This chapter provides the basis for preparation of an erosion risk map for the farm.

The criteria of importance at this stage are:

- Soil Texture
- Slope
- Flooding frequency

Subsequently you will need to consider cropping and soil structural condition.

The risk of runoff or soil wash and erosion depends on the physical features of the farm and upon soil management. Actual events are determined by rainfall. Very high intensity storms or repeated storms can cause serious erosion in many situations and the following assessment procedure does not necessarily cover such events. However, the management practices outlined in Chapters 4 and 5 will help to minimise these effects.

In making a risk assessment, each field should be examined. Runoff and erosion risk in any part of a field will depend on the soil texture and steepness of slope. The uniformity of slope above and below a particular area, are also important in determining the likelihood of rill or gully formation.

For assessment purposes large fields might be sub-divided if slope, soils or topography differ significantly, but for whole field assessment the worst scenario should generally be mapped. Field entrances should be marked on the map where they may influence erosion by channelling water movements into or out of a field. An example of a typical farm map is illustrated at the end of this section.

If required, soil textures can be obtained from a laboratory analysis of particle size distribution. The diagram in Appendix C shows the percentages of sand, silt and clay within each textural class. In most situations a hand texture assessment (see Appendix D) carried out in the field will be adequate.

It is helpful to assess slope angles as accurately as possible however slopes are frequently uneven and variable and it is more important to determine the relative overall risk of an area of land than to worry about precise angles of slope.

Typical situations which would fall into different risk categories are outlined in the tables below. The criteria given are guidelines and professional judgment should be used to upgrade or downgrade a site, taking into account additional factors such as:

- Soil structure
- Organic matter content
- Valley features which tend to concentrate runoff water

- Long unbroken slopes
- Land restored following opencast mining or landfill operations
- Very steep slopes (i.e. greater than 11^{0})

Very light soils with low organic matter on gentle slopes, even in low rainfall areas, can erode more seriously than indicated in the following risk assessment, sometimes by as much as two risk classes. Therefore, in addition to a field assessment, local knowledge is also useful in estimating risk, as previous erosion occurrences are often well remembered.

The following assessment procedure estimates the risk of runoff from fields carrying nutrients and soil down slopes. Runoff pathways, slope patterns and valley features will influence the likelihood of this runoff causing further erosion or having deposition impacts beyond the field. Areas where this could happen should also be indicated on the plan. You should also consider if your land receives runoff from elsewhere that will increase erosion problems on your land.

The following tables provide a guide to field classification for runoff and erosion. They assume moderately good soil conditions. If the land is currently in grass you should still apply this risk assessment. It will act as a guide to what might happen if you decide to reseed or introduce arable cropping in future.

Water erosion

This part of the risk assessment refers to the movement of sediment within the field and possible transfer to watercourses or other places such as neighbouring properties or on to roads.

Soils	Steep slopes > 7°	Moderate slopes 3° – 7°	Gentle slopes 2° – 3°	Level ground < 2°
Sandy and light silty soils	Very high	High	Moderate	Lower
Medium and calcareous soils	High	Moderate	Lower	Lower
Heavy soils	Lower	Lower	Lower	Lower

Signs of erosion that may be associated with each of the risk classes are described below. Such observations should override an assessment derived solely from the table.

Very High Risk Areas – Rills are likely to form in most years and gullies may develop in very wet periods.

High Risk Areas – Rills are likely to develop in most seasons during wet periods.

Moderate Risk Areas – Sediment may be seen running to roads, ditches or watercourses and rills may develop in some seasons during very wet periods.

Lower Risk Areas – Sediment rarely seen to move but polluting runoff may enter ditches or watercourses.

Runoff or soil wash

This part of the risk assessment refers to runoff which is usually but not always discoloured. This runoff may carry very fine soil particles, soluble pollutants such as plant nutrients and pesticides or manures to watercourses.

Soils	Steep slopes > 7°	Moderate slopes 3° – 7°	Gentle slopes 2° – 3°	Level ground < 2°
All soils	High	Moderate	Lower	Lower

Signs of runoff that may be associated with each of the risk classes are described below. Such observations should override an assessment derived solely from the table.

High Risk Areas – Runoff seen in most years during wet periods

Moderate Risk Areas – Runoff seen in some years during wet periods and in most years during very wet periods

Lower Risk Areas – Runoff seen in some years during very wet periods

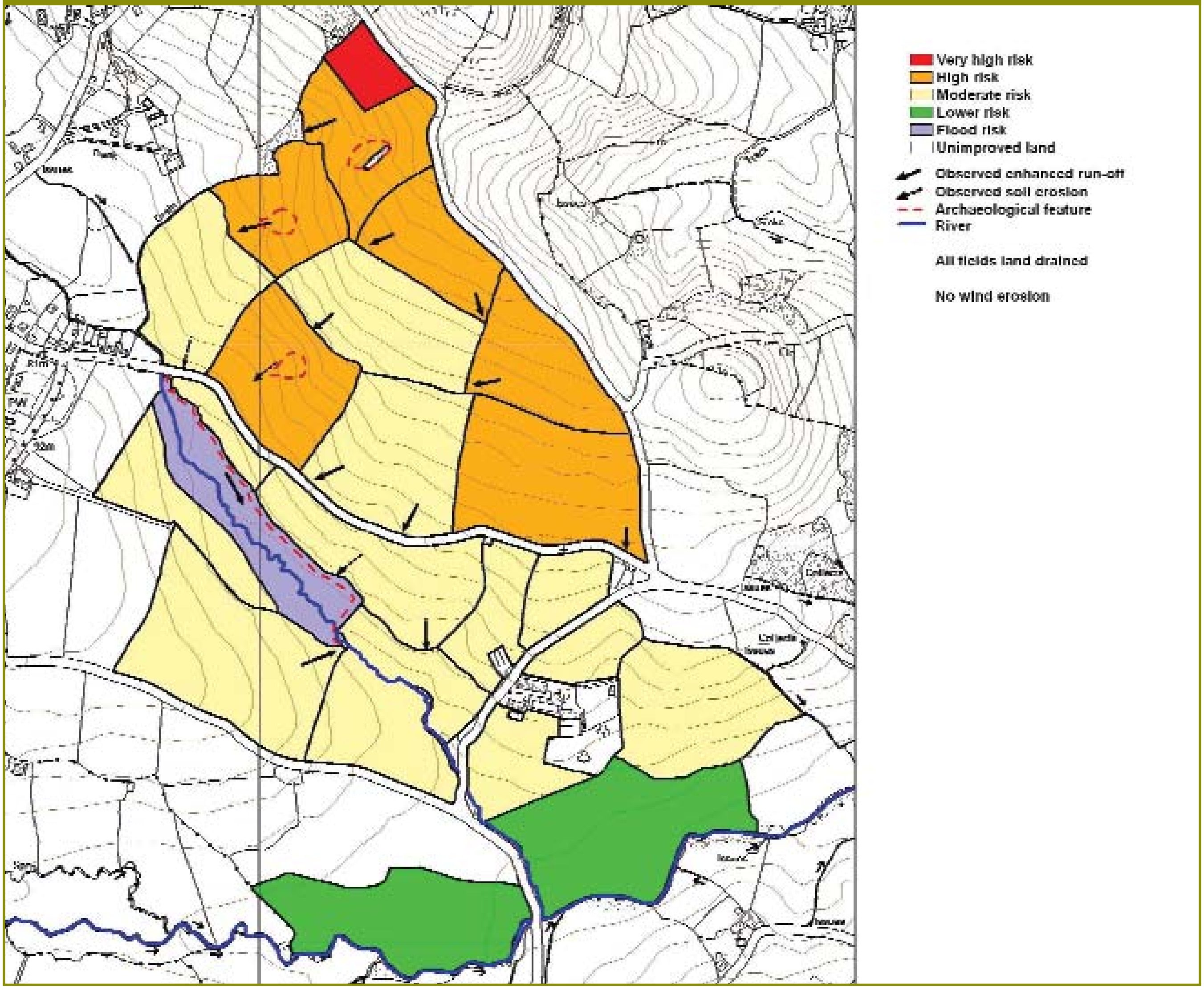
Remember that: The accumulated runoff from a catchment with a large proportion of only lower risk fields can still cause serious damage to watercourses and may require action to be taken.

Flood risk

Land that floods is susceptible to erosion and runoff, particularly when under cultivation. Land that floods regularly (at least 1 year in 3) must be regarded as highly vulnerable and should be indicated on your map.

The map overleaf showing the erosion risk categories outlined above should serve as a basis for planning crop rotations and management to reduce run-off risks and soil loss.

Example of farm erosion risk map:



3.2 Farm and crop planning

The risk map shows which fields or parts of fields are most at risk when exposed to heavy or prolonged rain or flooding. At this stage, it might become clear that new hedge plantings could usefully reduce erosion risks or relocation of field entrances could reduce deposition of sediment onto roads or into watercourses (see Chapter 4.4).

The next step is to plan crop rotations and land use to minimise exposure of bare, vulnerable land to the erosive effects of rainfall.

The susceptibility of soil to erosion is dependent upon the land cover or livestock enterprise using the land, and can be considered in three broad categories. Some examples of land management practices within each category are listed on the next page.

Highly susceptible land use

On Very High Risk and High Risk sites, avoid these land uses unless precautions are taken as outlined in Chapters 4 and 5. If these precautions do not control the problem then discontinue the land use. Some of these precautions may be necessary on all sites.

Late sown winter cereals

Potatoes

Sugar beet

Field vegetables

Outdoor pigs

Grass re-seeds

Forage maize

Outwintering stock

Grazing forage crops in autumn or winter

Moderately susceptible land use

On Very High Risk and High Risk sites these moderately susceptible land uses can be carried out with care. Follow the advice in Chapter 4.

Early sown winter cereals

Oilseed rape – winter and spring sown

Spring sown cereals

Spring sown linseed

Short rotation coppice/Miscanthus

Less susceptible land use

Consider the following land uses on Very High Risk and High Risk sites as a means of reducing the overall erosion risk.

Long grass leys

Permanent grass

Woodland (excluding short term coppice)

By altering rotations and changing land use, for example, switching from late sown autumn to spring sown crops on higher risk sites, the likelihood of erosion can be reduced significantly.

4. Management of the farm to reduce erosion risks

Chapter 3 outlined the assessment of erosion risks resulting both from site factors, and from susceptible crops/land uses on the farm. The next stage is to review all practices and consider appropriate techniques for reducing erosion. These stages are part of Soil Management Planning (SMP). Entry Level Environmental Stewardship provides the opportunity for you to be paid for preparing a SMP, preferably using professional help.

4.1 Reviewing the farming system

Examine the potential for alterations to cropping, rotations or farm layout to reduce the risks of soil erosion.

The adjustments required may be low-cost, good practice measures such as preparing rougher seedbeds, increasing soil organic matter, working across slopes (where it is safe and practical to do so), early sowing of autumn crops, maintaining drains, strategic positioning of set-aside land, and avoiding certain crops on high-risk fields. Entry Level Stewardship may provide financial support for this.

In some situations, higher cost options may be necessary involving changes of land uses or field layout. A greater proportion of the farm may need to be put down to grass or other less susceptible crops. Field boundaries may need to be altered and hedges or grass strips introduced to break up long slopes. Higher Level Environmental Stewardship can support such changes in areas designated for resource protection measures.

A change to an organic farming regime may be an option and there are incentive payments available to compensate for reduced income during the transition phase. The benefits of this may be derived from moving to a mixed farming system with livestock enterprises which require grassland as part of the crop rotation, and provide farmyard manure which will increase soil organic matter with a resultant increase in soil stability.

In extreme situations, it is possible to construct earth bunds to slow surface run-off or divert it, as commonly practised in the tropics. These can be very expensive, and if not designed and constructed properly, can cause more problems than they solve. Professional help should be sought if mechanical erosion control measures are being considered.

If you have regular and severe problems of water erosion which cannot be controlled by changes in farming methods, cropping or by the other control measures outlined above, you should consider putting the land affected into permanent grassland or woodland.

You may be able to set aside your most vulnerable land and put it down to grass. As well as Environmental Stewardship, other voluntary schemes can provide payments for protecting soils e.g. English Woodland Grant Scheme (from July 2005).

There are three steps to take in planning for any necessary changes in farming practices. These are summarised below (with the lower cost options first), and expanded in chapters 4.2 – 4.4.

- Adoption of good management practices for erosion control.
- Adjustments to rotations and cropping/land use.
- Alterations to the farm layout.

More extreme short term measures may be necessary in some situations, and these are covered in chapter 4.5.

4.2 Good management practices to control erosion

Cultivations

The type and timing of cultivations should be planned to minimise the periods when the soil is left in its most vulnerable condition. Some examples of different degrees of vulnerability are shown below:

Most vulnerable	Fine seedbeds
↓	Bare land after root crop harvesting
↓	Rough ploughed/cultivated land
↓	Cereal stubble
Least vulnerable	Land with good crop/vegetation cover

Any land which is compacted either in the surface layers or below plough depth will have additional vulnerability because these layers will reduce water infiltration and so increase run-off. Surface compaction along tramlines and wheelings is a common trigger for erosion problems in winter cereal crops.

Initial consideration should therefore be given to:

- Any requirements to remove compaction in the surface layers by ploughing or tined cultivations, or at depth by subsoiling.
- Minimising the risks of causing compaction by avoiding working or trafficking the land in wet soil conditions.

The overall aim should be to have land in a less vulnerable condition for as long as possible. For example, cereal stubble should not be ploughed any sooner than necessary. Conversely, the compact, bare, rutted surface left after harvesting root crops or vegetables is more vulnerable than cultivated land, and so it should be rough ploughed or given a tined cultivation as soon as practicable.

Seedbed preparation

Soils are most vulnerable to erosion when a fine seedbed has been prepared but a crop cover has not yet developed. It is important to avoid cultivations which produce an unnecessarily fine seedbed, particularly when the crop will develop slowly (e.g. with a late drilled grass re-seed or winter wheat crop).

Rolling should be avoided after autumn drilling on vulnerable land, especially if the soil is wet, as it will tend to reduce water infiltration and increase surface run-off.

On many soils, crops can successfully be established without ploughing, by using tines, discs, or shallow one pass systems (sometimes known as conservation tillage). These techniques can reduce erosion risk by leaving chopped straw and stubble on the surface, and, in the longer term, by increasing organic matter in the surface layers of soil.

Deep ploughing should generally be avoided on erosion prone soils, as this will bury organic matter at greater depths, and increase the risks of causing a compact layer at plough depth (plough pan). Shallower ploughing will tend to keep organic matter nearer the surface, thus increasing stability.

Various purpose-built implements are available to produce a pitted surface which will improving water retention and infiltration in specific situations. These can be valuable for protecting seedbeds during crop establishment, and for tying potato ridges to reduce run-off during rainfall or irrigation. Such techniques require careful application as incorrect use may make problems worse.

Directions of cultivations

In many parts of the world, cultivation, sowing and planting crops "on the contour" are recommended for controlling erosion. This has limited applicability for mechanised agriculture under UK conditions where slopes are often complex, and failed attempts at following the contour can result in water being channelled forming rills and gullies. Additionally the operation of machinery across steeper slopes can be dangerous and less efficient (e.g. root crop harvesters).

In general, working across the slope is likely to be beneficial on gently sloping land with uniform slopes. In other situations the benefits of working across the slope are more questionable. Where ploughing is carried out across the slope, the use of a reversible plough to throw the soil upslope will help to counter the effects of erosion and of "tillage creep".

Organic manures

Stability of topsoils can be improved by the regular use of bulky organic manure, to increase soil organic matter, though care should be taken to avoid excessive amounts of nitrogen or phosphorus. In many areas of the country, manure management is limited by the Nitrate Vulnerable Zone (NVZ) Regulations. In all areas the Code of Good Agricultural Practice for the Protection of Water recommends a limit of 250 kg/ha per year of total nitrogen in organic manures. This limit is reached when well rotted cattle manure is applied at approximately 40 tonnes/ha (16 tonnes/acre). Pig and poultry manures are also good for developing stable topsoils, though application rates should be reduced, especially for poultry manures, as they are higher in nitrogen.

The application of animal slurries can also help to increase soil organic matter, though caution should be used in both timing and incorporation practices. For undiluted dairy slurries, an application rate of 50 m^3/ha (4,500 gallons/acre) will provide 250 kg/ha per year of total nitrogen. For pig slurries the rate should be lower. When slurries are applied at high rates to bare soil, infiltration rates can be significantly reduced. Environmental damage can then arise from run-off of organic material into watercourses, as well as soil erosion.

Slurries and solid manures applied to erosion susceptible sites should be incorporated soon after application to minimise ammonia and odour emissions, leaving a rough field surface. The risk of causing pollution due to run-off from land spread with organic manures should be considered at all times – see the Code of Good Agricultural Practice for the Protection of Water for further advice.

Other organic materials, including composted "green waste" and crop residues incorporated into topsoils, will help to increase the stability of topsoils. Adjustments should be made to farm fertiliser programmes to allow for the nutrient content of the applied organic manures/ crop residues.

Irrigation

Care should be taken when irrigating land which is susceptible to erosion. Always adjust application rates to suit field and soil conditions so that the risk of surface run-off is minimised. Water droplet size is an important factor. The larger the droplet size, the greater its erosivity. If a large droplet size is combined with an excessive application rate, soil particles can be detached and carried away by surface water run-off.

When operating a mobile irrigator with a "raingun" type application system, always where practically possible, set it to operate across the slope not up and down it. Always ensure that the application rate is low enough to prevent surface run-off and take care that there are no leaks from supply pipework. The machine itself and all associated pipework should be carefully drained down before moving, since surface flow can initiate a rill in loose soil.

Rainguns can irrigate very unevenly, especially in windy weather. Boom irrigators are more consistent, produce smaller drops and apply them close to the ground, so that erosion by irrigation is reduced significantly. The use of trickle (drip) irrigation can result in even more efficient use of water with minimal erosion risk.

4.3 Adjustments to rotations and cropping

Soils are most susceptible to erosion when they are left exposed with little or no vegetation cover. The best policy, therefore, for any areas of the farm with a substantial erosion risk (such as very steep slopes and valley bottoms), may be to avoid this situation completely, by removing these areas from an arable rotation and keeping them under permanent grass or woodland (See Chapter 4.1 for possibilities of Agri-Environment Schemes).

In deciding rotations for other areas at risk on the farm, consideration should be given to:

- Avoiding late drilling of winter cereals
- Avoiding row crops such as potatoes, field vegetables and forage maize on steeply sloping land
- Selecting varieties of root crops and of maize for earlier harvesting
- Drilling spring crops rather than winter cereals after late harvested root crops
- Avoiding leaving land in maize stubble over winter
- Establishing an early sown autumn cover crop before spring sown crops
- Introducing grass into the rotation – but –
- Avoiding late grass re-seeds

In a rotation based on cereals, potatoes and sugar beet for example, early harvested potato varieties would be selected for the most susceptible land to allow earlier establishment of the following winter wheat crop. A winter cereal seedbed prepared after late harvested sugar beet can be especially vulnerable, and seedbed preparation may be better left until a spring crop can be established.

Winter cover

Cereal stubble generally provides good protection against erosion, especially where chopped straw is left on the surface, or there is significant growth of volunteers.

After the harvesting of other crops, where vulnerable land would be left bare through the autumn and winter period, protection can be provided by the early establishment of a cover crop such as rye or mustard. This should be sown in late summer or early autumn and ploughed in or killed off before drilling in the spring.

Grass leys

On some of the more susceptible land it may be possible to consider the inclusion of grass leys in the rotation. This would reduce the total area of arable land that is at risk from erosion in any one season. Reduction of the arable area would also help to lessen the pressure at drilling and harvesting times, so that a greater proportion of the operations can be carried out optimally, again reducing risks. Longer term grass leys (>3 yrs) will help to improve the organic matter content and aggregate stability of the topsoil, and thus render it more resistant to structural collapse and erosion when brought back into cultivation.

In Chapter 5, specific husbandry and cultivation recommendations are outlined for each crop or land use.

4.4 Changes to farm layout

In some situations it may be necessary to consider changes in the farm layout to reduce erosion and its off-farm effects. These could include installation of new drainage systems, relocation of gateways to the upper parts of fields, relocation of farm tracks and changes to field layout. The grassing of valley bottoms may be an option where these accept large flows of surface water run-off. Existing hedges and field boundaries may provide important protection and consideration should be given to improving these where practicable.

Drainage

Adequate control of water on the farm is essential for minimising erosion risks. Run-off from buildings, concreted areas, roads and tracks should be effectively channelled into ditches and drains so no excess water flows over field surfaces.

On fields where drainage is necessary, piped underdrainage systems and ditches should be installed and maintained. Particular attention should be given to removing sediment that has been deposited in ditches and drains. Whenever possible this should be returned to the top of the field from which it eroded.

Poorly drained land will easily become waterlogged and prone to surface run-off. Soils will be slow to dry out and so will be especially vulnerable to compaction, caused by trafficking or cultivating the land under wet soil conditions.

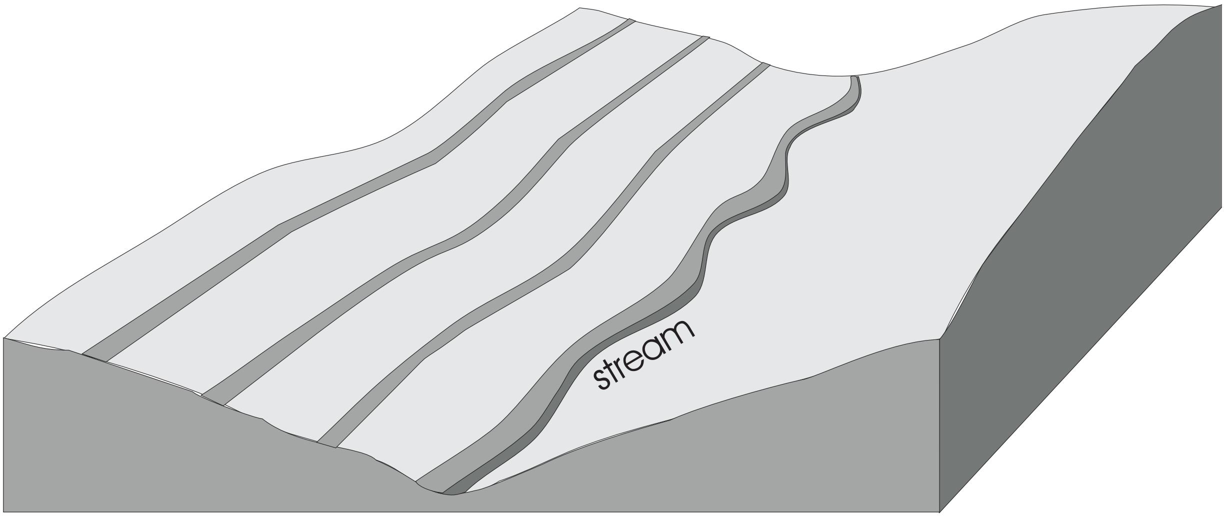
Introduction of breaks on long slopes

Breaking long slopes by a ditch, hedge or wide grass strip on the contour will reduce the chances of surface water flow building up and causing rilling. If field shape is changed so that the long side is across the slope, cultivations will tend to follow this and help reduce erosion risk.

On longer slopes, it may be appropriate to install a new ditch across the slope to intercept water part-way down. This will help stop the accumulation of large volumes of surface water run-off. The ditch should have a grass strip a few metres wide on its upper side to filter sediments from run-off and reduce discharge to watercourses.

Hedges give a long-term slope break, and if additional drainage is not required, they are more effective if planted on a wide bank running along the contour to help retain sediment and prevent fine particles from reaching watercourses. Grants may be available under Environmental Stewardship for hedge planting (see Chapter 4.1).

Where long slopes are unavoidable or cannot be broken by planting hedges, consideration should be given to contour strips. These work on the principle that a close ground cover such as creeping grass will both slow surface flow from above, and increase infiltration rates.



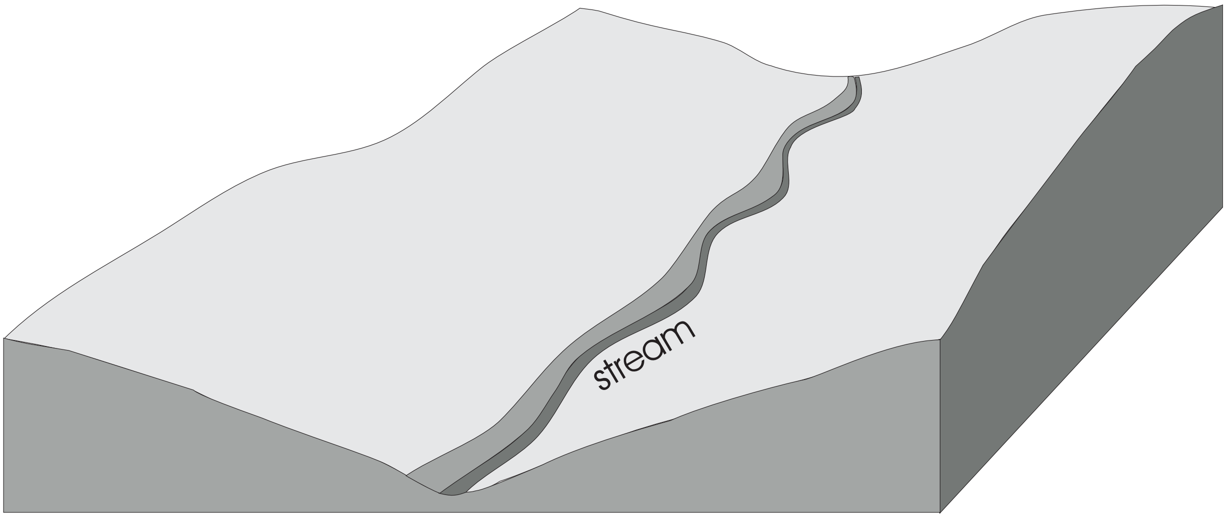
Grass, stubble, or set-aside Contour Strips will reduce water scouring and reduce rilling risk. A buffer strip protects the stream in the valley bottom.

As a guide, strips 5-15 metres in width positioned every 50-150 metres down the slope, should be effective on most erosion susceptible areas. On steeper slopes, the width should increase and the distance between strips decrease. The advantage of contour strips over mechanical methods (earth banks or terraces) is that inaccuracy in construction will not result in further problems. It is safer, therefore, to encourage their establishment, even if specialist technical help is not available.

Some of the benefits of contour strips will be lost if they are compacted and rutted by farm machinery, so they should not be used as additional trackways. In some situations, these strips may form part of land which is under permanent set-aside.

Buffer strips

Buffer strips differ from contour strips in that they are located at the bottom of fields, against a watercourse or ditch, and are usually wider. They should not be seen as a primary tool for controlling soil erosion, but as a water protection measure. Surface flow cannot usually be broken, but heavier sediment particles can be intercepted, rather than flowing through to watercourses. Grass strips 20 metres wide have been used successfully as buffer strips, though narrower strips may be beneficial in some situations.



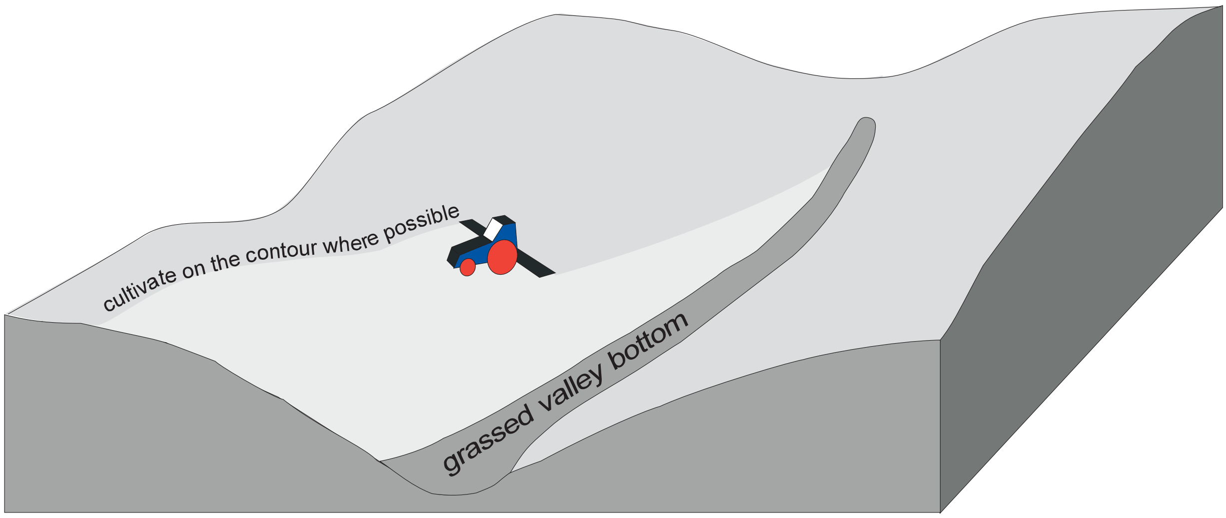
A wide Buffer Strip can protect the stream in the valley bottom.
Water is slowed in the strip and heavier soil particles settle out.

Benefits to the farmer of buffer strips include:

- Restricting the migration of harmful weeds from hedgerows
- Cost savings by not farming field margins with poor yields
- Bank stabilisation to prevent loss of land
- Enhanced numbers of game birds and improved fisheries
- Establishment of beetle banks and habitat for crop pest predators
- Possible access using grassed areas, but traffic on buffer strips could diminish their effectiveness.

Valley Bottoms

Attention should be paid to areas with valley floor features which tend to concentrate run-off water. The valley floor in a cultivated field can also receive run-off from fields above, and gullying is possible even on fairly gentle slopes. If this is the case, then it is advisable to protect the valley floor from scouring. An area of permanent grass in the valley bottom will usually suffice. The grass cover is best sown in spring, for example by undersowing in a spring cereal crop, to allow maximum establishment before winter.



Valley bottoms can be protected from scouring by leaving them under permanent ground cover. Contour cultivations also help to reduce erosion risk.

4.5 Short term measures

Where changes to cropping and management practices have not been carried out, or have proved insufficient, in extreme situations, it may be necessary to introduce temporary emergency measures to minimise damage. These aim to reduce the flow of run-off below an eroding area to settle-out the coarser sediments.

Bunds (embankments) may be constructed to trap silt-laden water. The bund should be built so that overflow is diverted around the ends of the bank and not over the top. Materials available for construction are likely to have a high sand or silt content and are, therefore, inherently unstable. Blind ditches are less likely to collapse, but may become a safety hazard when full of water.

Straw bales have been used in emergencies to hold back water and sediment, but they must be securely anchored.

It is common in constructing emergency measures to overlook the required design input. As a consequence, storage volumes are often inadequate and contingencies for overflow may be absent. Bunds in wet soil and poorly secured straw bale barriers can collapse, causing severe flood damage. Expert advice should be sought before proceeding with any emergency measures.

The main objection to the short-term measures described above is that they tackle the symptoms of erosion and not the cause. They do little to stop the loss of nutrients and pesticides to the environment. In subsequent seasons, more thorough preventative measures should be implemented. It should not be assumed that the erosion event was a one-off and will not be repeated.

5. Crop management for reducing erosion risk

Husbandry and cultivation recommendations for reducing erosion risks are given below for a selection of crops and land uses. The first two chapters covering winter and spring sown cereals include principles of erosion control that are common for many winter and spring sown crops. Paragraphs on other crops e.g. oilseed rape and grass re-seeds, refer back to these chapters where appropriate and note any additional crop specific factors. A number of other potential risk areas such as late harvesting of root crops, irrigation and growing systems involving ridges and beds, are addressed in the chapters on sugar beet, potatoes and vegetables. Information on techniques suitable for crops which are not specifically mentioned can be obtained by referring to the chapters covering land uses with similar husbandry requirements.

5.1 Cereals – winter sown

Summary Management Practices for Erosion Control in Winter Sown Cereals

- Remove any compaction present before establishing the crop, and time operations to minimise risks of causing further compaction.
- Where possible establish without ploughing and allow some chopped straw to be left at the surface.
- Avoid overworking the soil; leave seedbeds as coarse as practicable.
- Sow early enough to achieve a minimum of 25% crop cover before early winter.
- Ideally, drill without tramlines, or avoid using tramlines until the spring.
- Avoid rolling in the autumn, especially if the soil surface is wet.
- Following harvest, leave land rough cultivated or in stubble, preferably with a cover of chopped straw, until the next crop can be established.

The potential for erosion on land cropped with winter cereals is high. The main crop management parameters which contribute to erosion are poor crop cover and the presence of compacted tramlines.

Sowing date and position in the rotation

Sowing the crop sufficiently early to achieve good ground cover before the winter is a key requirement to reducing the risks of erosion, and explains why more erosion events are associated with winter wheat than winter barley or oil seed rape, which are generally established earlier.

A minimum ground cover of 25% is required by early winter to be an effective protection against erosion. This generally means sowing no later than mid/late September to have the crop established by early October.

The practicalities of achieving sufficiently early sowing have obvious implications for the position of winter cereals in the rotation. There should be few problems following cereals or oilseed rape, but entries after root crop harvesting are more likely to result in late sowings.

On many erodible light soils, root crops are important components of the rotation, and so special consideration needs to be given to ways of minimising erosion risks from late sowings. It may be possible, for example, on the more vulnerable areas of the farm to select varieties of potatoes for earlier lifting. If late lifting of sugar beet is inevitable, it would be preferable to plan for a spring crop rather than a vulnerable late sown winter cereal.

Soil and crop management

Reducing compaction

Besides early establishment, the other key management area for reducing erosion risk in winter cereals is to minimise the effects of soil compaction. This applies both to generalised effects, associated for example with harvesting of a previous root crop, and also to the specific effects of tramlines and wheelings within the cereal crop.

Wherever possible, compaction resulting from previous operations should be removed before the cereal crop is established. Compaction within the plough layer will usually be removed during normal cultivation operations. Where compaction is below plough depth, subsoiling will normally be necessary. An alternative to this is to fit subsoiler tines below the plough bodies. Note however that effective subsoil loosening can only be carried out when the soil is relatively dry. It may be impractical (and create further problems), therefore, to subsoil after a root crop harvest immediately preceding the cereal. Any deep compaction caused during harvesting of the root crop would need to be addressed after the cereal crop is harvested.

Care should be taken to avoid causing further compaction during preparation of the cereal seedbed. The earlier the crop can be sown, the less the risks of causing compaction through cultivations carried out under wet soil conditions.

Seedbed preparation

Cultivation operations should be the minimum necessary to achieve an acceptable seedbed. Repeated trafficking of the land increases the risks of causing compaction. The finer the seedbed, the greater the risk of the surface sealing during rainfall, leading to run-off and subsequent erosion. Rougher seedbeds which are more resistant to erosion may be produced using traditional non-powered harrows. Where power harrows are used, rougher seedbeds can be achieved by increasing the forward speed of the tractor or reducing the PTO speed. Rolling the land after drilling should be avoided where practically possible, as this will also tend to increase surface run-off.

On many soils, cereals can be established successfully without ploughing, using tines, discs, or shallow one-pass systems. These techniques also reduce erosion risk, as chopped straw and stubble are left on the surface.

Although recommended for erosion control in many parts of the world, cultivations and drilling carried-out along the contour have not been shown to be generally beneficial under UK conditions (see chapter 4.2), and are likely to be effective only on gently sloping land with uniform slopes. Unsuccessful attempts to control erosion by drilling across the slope have led to the development of gullies on headland tramlines, severely interfering with subsequent spraying and fertilising operations.

Tramlines

Tramlines are themselves a major contributory factor to erosion in winter cereals. Erosion risks will be reduced by drilling crops without tramlines and setting up paths for spraying after the crop cover has established. Where tramlines are set up at drilling, their potential for channelling water and triggering erosion will be reduced if they are not used until the spring.

After harvest

Following harvest of the cereal crop, the soil is best protected against erosion by leaving stubble, preferably with a cover of chopped straw, until just before the next crop is to be established. Ploughing and cultivations carried out well in advance of sowing will increase erosion risks unless the surface is left in a rough condition.

5.2 Cereals – spring sown

Summary of Management Practices for Erosion Control in Spring Cereals

- Where practicable, remove any compaction present before establishing the crop, and time operations to minimise risks of causing further compaction.
- Where land has been protected by a cover crop or stubble during the winter months, delay cultivations for seedbed preparation until just before drilling.
- Where possible, establish crop without ploughing and allow some chopped straw to be left on the surface.
- Where spring sown cereals follow a late harvested root crop, carry out a tined cultivation as early as possible after harvest to minimise erosion from the bare rutted surface.
- Avoid sowing too early. Leave drilling of fields most at risk from erosion until last.
- Avoid overworking the soil; leave seedbeds as coarse as is practicable.
- Ideally, drill without tramlines. If tramlines are established at drilling, avoid use when the soil is wet and easily compacted.
- Avoid rolling the seedbed, especially if the soil surface is wet.
- Following harvest, leave land rough cultivated or in stubble, preferably with a cover of chopped straw, until next crop can be established.

Spring cereals are generally at lower risk from erosion than winter cereals as seedbeds are not exposed to winter rainfall. However spring cereals are still at risk, and many of the factors which predispose winter sown cereals to erosion also apply. Erosion is most likely to occur where crop cover is poor, and is often made worse by the presence of tramlines and wheelings.

Sowing date

Early-drilled spring crops are more at risk of erosion than later-drilled crops. Early drilling encounters lower soil temperatures, resulting in slower germination and emergence. The time between seedbed preparation and the establishment of a protective crop cover is increased, leaving the soil in a vulnerable state for a longer period of time. It is good practice, therefore, to drill the most erodible fields last.

Early drilling also means that cultivations for seedbed preparation are more likely to be carried out in unsuitably wet soil conditions, which could result in soil compaction and further increase risks of surface run-off and erosion.

Soil and crop management

Seedbed preparation should be timed to reduce erosion risks by leaving the soil surface protected as long as possible. The best protection before drilling would be provided by a cover crop, but cereal stubble, especially with a cover of chopped straw or roughly cultivated surface, also provides good protection.

Many spring cereals are established after a late harvested root crop which will have left the land in a vulnerable state. Soil left bare and rutted after root crop harvesting is particularly susceptible to erosion and is best given a tined cultivation or rough ploughed as soon as practicable.

Other management practices for reducing erosion risks are similar to those for winter cereals.

5.3 Oilseed rape

Winter oilseed rape usually follows a cereal harvest, and so on most occasions can be established early enough in the autumn to attain a good ground cover before winter. It is normally not as susceptible to erosion as winter cereals, but the same techniques for minimising erosion risks are generally applicable.

Spring sown oilseed rape is also likely to follow cereals, and stubble left over the winter months will protect soils from erosion prior to establishing the rape. The principles of reducing erosion risks in spring rape are similar to those for spring cereals.

5.4 Linseed

Spring sown linseed requires early drilling, as it is susceptible to drought and slow to mature. Establishment can be slow and is very dependant on soil conditions at drilling. This means that the crop will be vulnerable to erosion before a good ground cover has developed and may be best avoided on the most susceptible soils. The crop is likely to be grown as a cereal break, and stubble or a rough surface left overwinter will protect the land from erosion prior to seedbed preparations.

Linseed varieties which are overwintered should be established as early as possible in the autumn to attain a good ground cover before the onset of winter.

Otherwise, the general principles of minimising erosion risks in linseed are similar to those for cereals.

5.5 Grass re-seeds

Summary of Management Practices for Erosion Control in Grassland

- On very vulnerable areas consider surface pasture improvements as an alternative to re-seeding.
- Remove any compaction present before establishing the grass, and time operations to minimise risks of causing further compaction.
- Reseed in the spring where possible.
- Where grass is to follow a spring cereal crop, consider undersowing the cereal.
- When re-seeding, sow early enough to achieve a minimum of 25% cover before early winter.
- Avoid overworking the soil during seedbed preparation.
- Avoid grazing recently-re-seeded land until the sward is well established. Remove stock when soils are wet.

Whilst established grassland is generally very resistant to erosion, a newly re-seeded area can be at least as vulnerable as winter cereals. Problems are most likely to arise where the grass is sown too late (mid September or after) to establish a good ground cover of at least 25% before winter.

The traditional ‘firm fine seedbed’ for sowing grass will increase the risks of the soil surface sealing during rainfall, leading to run-off and erosion. Spring re-seeds will be less vulnerable to erosion than late autumn re-seeds. Where grass is to be established following a spring cereal crop, consideration can be given to undersowing the cereal.

On land which is susceptible to erosion, the need for re-seeding should be carefully evaluated and the timing of operations planned to enable establishment of adequate ground cover before winter. It may be possible to carry out pasture improvements without re-seeding by making appropriate use of fertilisers and herbicides, or by introducing more desirable species through slot seeding.

Recently re-seeded land is more susceptible to damage from grazing livestock than well-established grassland. Poaching damage from livestock hooves can lead to localised areas of erosion, particularly in heavily trampled areas around gateways and feeding troughs. Cattle are generally more damaging than sheep, but damage can occur with sheep in vulnerable situations. Recently-re-seeded thin swards are particularly susceptible to damage from winter grazing.

5.6 Sugar beet

Summary of Management Practices for Erosion Control in Sugar Beet

- Where practicable, remove any compaction present before establishing the crop, and time operations to minimise risks of causing further compaction.
- Leave the soil surface protected with stubble or a cover crop for as long as possible before drilling, and consider drilling directly into loosened cereal stubble or a sprayed-off cover crop.
- If ploughing is required, avoid overworking the soil; drill directly into ploughed furrow-pressed land.
- Plan any irrigation carefully to avoid over-application leading to run-off.
- Where possible, schedule harvesting so that crops on soils most at risk from erosion are harvested first.
- Where late harvesting is inevitable, following the sugar beet with a spring crop is preferable to late establishment of a winter cereal.
- Following harvest, carry out a tined cultivation or rough ploughing as soon as possible to minimise erosion from bare rutted surfaces.

Erosion is most likely to occur on sugar beet land between April and June before a good crop cover has established. The fine seedbeds prepared for precision seeding increase the risks of surface sealing or capping, resulting in increased run-off and subsequent erosion. Bare, rutted surfaces left after harvest are also vulnerable.

Seedbed and establishment

Cultivating and drilling across the slope are recommended for controlling erosion in many parts of the world, but under UK conditions these are only likely to be effective and practicable on uniform, gentle slopes. Sugar beet harvesters only operate effectively up and down the slope. The crop is best avoided on steep land that is particularly vulnerable to erosion.

Techniques for erosion control involve leaving the soil surface as rough as possible or making use of a protective surface cover. Where ploughing is necessary, a rough surface can be achieved by ploughing with a furrow press and drilling directly into the furrow-pressed land. Where ploughing is not required, good results have been achieved by direct drilling into loosened cereal stubbles or a sprayed-off cover crop e.g. rye.

Harvest

Harvesting the sugar beet will frequently leave bare ground with ruts and wheelings that can channel water and lead to serious erosion. Risks will be reduced by carrying out a tined cultivation or rough ploughing as soon as possible after harvest. Where possible, schedule harvesting so that crops on soils most at risk from erosion are harvested first. A winter cereal seedbed prepared after late harvested sugar beet would be especially vulnerable to erosion, and seedbed preparation may be better left until a spring crop can be established.

5.7 Potatoes

Summary of Management Practices for Erosion Control in Potatoes

- Where practicable, remove any compaction present before establishing the crop, and time operations to minimise risks of causing further compaction.
- Leave the soil surface protected with stubble, a cover crop or rough cultivated for as long as possible before preparing ground for planting.
- Avoid stone and clod separation when the soil is wet.
- Avoid overworking the soil; leave soil surface as rough as possible.
- Use tied ridges and dikes in furrow bottoms to improve infiltration and reduce run-off.
- Plan irrigation carefully to avoid over-application leading to run-off.
- Plant varieties for early harvesting on land most at risk to allow timely establishment of a winter cereal or cover crop.
- Following harvest, carry out a tined cultivation or rough plough as early as possible to minimise erosion from bare, rutted surfaces.

Potato land is most at risk from erosion between the months of April and June. Potato ridging can often result in run-off water becoming concentrated in the furrows, which can lead to the development of rills. Irrigated crops will be particularly at risk if over-application of irrigation water occurs, or if unexpected heavy rainfall follows a recent irrigation.

Cultivations

Planting across the slope is recommended for controlling erosion in many parts of the world, but under UK conditions this is only likely to be effective and practicable on uniform, gentle slopes. Potato harvesters only operate effectively up and down the slope. Potatoes may be unsuitable for land that is particularly vulnerable to erosion. On other sites, soil walls can be used to bridge furrows across the slope (tied ridges), and small pits (dikes) along furrow bottoms help to improve infiltration and reduce run-off.

Soil preparation for planting should be timed to reduce erosion risks by leaving the soil surface protected for as long as possible. The best protection would be provided by a cover crop, but cereal stubble, especially with a cover of chopped straw, also provides good protection.

Harvest

Harvesting the potato crop will frequently leave bare ground with ruts and wheelings that can channel water and lead to erosion. Risks will be reduced by carrying out a tined cultivation or rough ploughing the land as soon as possible after harvest. The selection of earlier harvesting varieties for the most vulnerable land would facilitate early establishment of a following winter cereal crop, to ensure that adequate ground cover is achieved before winter (see chapter 5.1).

5.8 Bulbs

Bulbs are usually grown in ridges, and planting generally takes place during late summer/autumn. Susceptible soils will be at risk from erosion during the winter and spring following planting, particularly where planting was carried out late or in poor soil conditions.

Water channelled into furrow bottoms and wheelings can initiate erosion. This is exacerbated when the soil is compacted and puddled by the feet of bud/flower pickers during winter and early spring. Repeated trafficking of the headland areas for collection of the flower crop can form deep ruts, which readily channel run-off water and lead to gully formation.

The principles of minimising erosion in bulbs are similar to those for other crops grown on ridges, and are described in the chapter on potatoes. However, with bulbs the use of tied ridges for erosion control may be impracticable where a flower crop is taken, as water held behind the dams results in muddy conditions for hand picking and unacceptable splashing and spoilage of the crop.

5.9 Vegetables and salad crops

Summary of Management Practices for Erosion Control in Vegetables and Salad Crops

- Leave the soil surface protected with stubble, a cover crop or rough cultivated for as long as possible before drilling or planting.
- Remove any compaction present before establishing the crop, and time operations to minimise risks of causing further compaction. Avoid overworking the soil and drill into as coarse a seedbed as practically possible.
- On the most vulnerable land, avoid varieties selected for early sowing or late harvesting.
- Consider using modular transplants rather than direct seeding to promote more rapid establishment of crop cover.
- Wherever possible, avoid trafficking the land under wet soil conditions. Remove excessive compaction in wheelings by using tines fixed behind tractor wheels when soils are in a dry condition, especially when using bed systems.
- Plan irrigation carefully to avoid over-application leading to run-off. Use trickle systems or fine sprays in preference to systems producing coarse droplets.
- When planning to use impermeable mulches or crop covers consider how to deal with increased run-off.
- If harvesting under wet conditions is inevitable, carry out a tined cultivation or rough plough the land as soon as possible following crop removal to minimise erosion from bare rutted surfaces.

Land under intensive vegetable production can be at risk from erosion throughout much of the year. Market demands for continuous supply mean that operations are often carried out under less than ideal conditions. Soils are particularly susceptible to erosion following seedbed preparation and during early crop establishment. Irrigation and harvesting may also cause problems. Winter harvesting operations are particularly likely to cause soil compaction, leading to increased problems with run-off water.

Whether the crops are managed in rows or in bed systems, a significant amount of the ground can remain unprotected by a crop cover for a large part of the growing season. Crops established in early spring are more at risk from erosion than later drilled crops, as low soil temperatures will increase the length of the vulnerable period between sowing and establishment of a good crop cover. Overwintered crops, with poor cover, are at risk from the eroding effects of winter rainfall.

Cultivations and seedbeds

The fine seedbeds prepared for many small seeded vegetable crops are prone to surface sealing and capping under the influence of rainfall, resulting in surface water run-off and subsequent erosion. Risks will be reduced by avoiding overworking the land and leaving seedbeds as coarse as practicable. The use of modular transplants rather than direct seeding will promote faster development of a protective crop cover.

Cultivating and drilling across the slope are recommended for controlling erosion in many parts of the world, and this practice is likely to be effective on uniform gentle slopes in the UK. The topography of the land, however, is often complex, and attempts at following the contour can result in water being channelled along rows and wheelings to form rills. Additionally, the operation of machinery across steeper slopes can be dangerous and less efficient (e.g. root crop harvesters).

Wheelings between rows and beds are major contributors to the development of rills. Wherever possible traffic should be kept off the land when the soil is wet and easily damaged. Excessive compaction in wheelings can be removed, when soil conditions are dry, by fitting a tine behind the rear tractor wheels.

Irrigation

Many vegetable crops are irrigated in spring and summer and this also has the potential for causing erosion. Problems are most likely to occur if too much water is applied or at too high a rate. Large droplets are more damaging than finer sprays or trickle systems.

Harvest

The requirement to harvest throughout the year means that many crops are liable to be removed under wet soil conditions, resulting in ruts and wheelings that can channel water and lead to serious erosion. Risks will be reduced by carrying out a tined cultivation or rough ploughing of the land as soon as possible after harvest. Where possible, the aim should be to harvest the crop earlier on the soils most at risk from erosion.

5.10 Fruit

Summary of Management Practices for Erosion Control in Fruit

- Remove any compaction present before establishing the crop, and time operations to minimise risks of causing further compaction. Avoid planting after late harvested vegetable and root crops.
- Plant rows across slopes wherever possible, and interrupt long rows periodically with grass access strips.
- Avoid trafficking the land under wet soil conditions.
- If compaction/rutting is present in established crops, consider removal with single leg subsoiler, if not too damaging to crop root growth.
- Establish an overall grass cover on susceptible soils under top fruit.
- Use a thin mulch of straw or farmyard manure to protect bare ground between rows in other situations.
- When planning to use impermeable mulches or crop covers consider how to deal with increased run-off.
- Plan irrigation carefully to avoid over-application leading to run-off. Use trickle systems or fine sprays in preference to systems producing coarse droplets.
- Minimise erosion risks when finally removing plants/trees by avoiding wet soil conditions, and establishing the following crop as soon as practicable.

Soft fruit production systems commonly use herbicides to maintain bare ground between cropped rows or individual plants. This results in a large proportion of the soil surface being unprotected by vegetation cover and, consequently, at risk from erosion on moderate to very high erosion risk sites. Run-off from mulches or crop cover can be generated in large volumes, which may cause erosion. Similar risks can be expected in top fruit orchards where overall herbicide applications are made. In orchards with grass alleys and herbicide strips, the proportion of exposed ground will be less and erosion risks reduced; erosion risks will be negligible where an overall grass cover is maintained under established fruit trees.

Establishment

It is important to allow time for thorough soil preparation before planting fruit, as problems will be difficult to rectify in the established crop. Planting after late harvested roots and vegetables is not recommended. Any deep compaction should be removed by subsoiling and, where possible, dressings of farmyard manure used to supply organic matter. Soils at planting will ideally be moist (to promote establishment), but not wet and at risk from compaction during the planting operation. Wheel ruts formed at planting, or during subsequent operations, can channel water and initiate erosion.

If compaction is present in established plantations, it can be rectified in some crops (e.g. raspberries) by using a single subsoiler tine midway between rows. Note that in other situations, this technique may be too disruptive to root growth and so inappropriate.

Rows orientated across slopes are recommended for erosion control, but few slopes are uniform, and there is still a risk of water being channelled along rows. Very long rows should, therefore, be avoided. Periodic grass strips across rows will provide access for pickers, and also help to prevent erosion. With some crops, a thin layer of straw is laid between the rows to act as a mulch. Besides conserving moisture, this can also be an effective erosion control technique.

Irrigation

Where irrigation is necessary, erosion risks will be minimised by avoiding over-application, and using trickle systems or fine sprays rather than coarse droplets.

Grubbing out

Removal of plants/trees at the end of their useful life can leave compacted, rutted soils which are susceptible to erosion. It can also result in a loss and dilution of topsoil leaving a less stable surface with a lower organic matter content. To minimise risks of damage and loss, avoid removing plants and trees when soils are wet, and aim to establish a following crop or temporary cover crop as soon as practicable.

5.11 Outdoor pigs

Summary of Management Practices for Outdoor Pigs

- Wherever possible avoid high and very high erosion risk areas for outdoor pig farming.
- Plan location and layout of arks and paddocks carefully. Locate grassed corridors across slopes to restrict surface run-off.
- Re-establish ground cover and good soil structure as soon as possible following outdoor pigs in the rotation.

See also 'Controlling Soil Erosion: An advisory leaflet for preventing erosion by outdoor pigs'.

In recent years there has been an increase in the proportion of the national pig herd kept outdoors. Breeding sows and finishing pigs are allowed to roam in paddocks, sheltering in temporary arks. Other facilities include provision of a drinking water supply, feed troughs, and, often, a wallowing area – a shallow excavation in the field surface. Well drained soils are well suited to outdoor pig farming and a large proportion of units have been sited on sandy soils, which are often at high risk of erosion.

Erosion risk under outdoor pigs is increased by year-round exposure of bare soil, due to poaching. Bare slope lengths can be great, and surface flow can remove loosened soil into watercourses. This situation is worsened by the tracks between paddocks which are disturbed daily during feeding, and can generate muddy water in wet ruts. They can also channel run-off water from the paddocks to watercourses.

Site location

It is recommended that paddocks are only sited on land which presents a low erosion risk. The paddocks are usually present for 2 years. The pigs should be followed by a grass ley, early-sown winter cereals or spring cereals to ensure that soil protection and structure are restored.

Site layout

If paddocks must be located on land at risk from erosion, very careful consideration should be given to layout. Corridors should be widened and grassed to break surface flows, with the paddocks carefully positioned with respect to slope, depending on whether the layout is rectangular or 'pie segment' in shape. Layout design will be a compromise between plumbing, fencing and land area costs.

Straw used to cover wet soil and provide dry feeding areas may also reduce erosion from bare ground.

5.12 Forage maize

Summary of Management Practices for Erosion Control in Forage Maize

- Wherever possible, avoid growing forage maize on high and very high erosion risk areas.
- Sow early maturing varieties on all areas at risk of erosion.
- Apply organic manures in response to crop needs – avoid slurry 'dumping'.
- Prepare seedbeds to avoid compaction and wheelings that could channel water.
- Reduce post-harvest risks by establishing a winter cover crop. If necessary, break compacted surfaces to improve infiltration.
- Rough ploughing immediately after harvest can be effective in preventing overwinter run-off and erosion.
- Subsoiling on the contour, leaving the stubble intact, can provide reasonable protection.

As maize varieties suitable for the UK climate are further developed, the crop is increasingly being grown to supplement grass silage and reduce concentrate costs on dairy farms. This is resulting in fields being ploughed that were previously under long-term leys, and maize being grown for one or more seasons.

Forage maize is susceptible to soil erosion since ground cover is slow to develop after sowing, and the soil surface can be poorly protected until mid-summer. Residual herbicides eroded with the soil can concentrate in field margins and ditches. In autumn and winter, run-off risks can be increased if large amounts of wet slurry are applied to maize stubbles. Infiltration can be dramatically reduced, especially if the slurry dries and seals the soil surface. Heavy showers can result in surface flow, carrying slurry and soil to watercourses.

Field selection and management

The first step towards reducing environmental damage from maize growing is to choose a low erosion risk site, if possible. Manures should be applied according to crop needs. Maize land should not be used for the disposal of large volumes of slurry (see Chapter 4.2). Incorporation should take place as soon after application as possible, leaving a rough field surface.

Seedbed preparation should be carefully carried out to avoid causing soil compaction and leaving wheel marks that could channel water.

Undersowing a cover crop to provide protection for the following autumn is an effective method for erosion control.

Where the soil surface is compacted, rough ploughing immediately after harvest can be effective in preventing overwinter run-off and erosion. Subsoiling along the contour can be effective in shattering the surface layer to improve infiltration and reduce run-off.

6. Addressing soil erosion in other situations

6.1 The problems of run-off erosion associated with heavier textured soils

Summary of Management Practices for Run-Off and Erosion Control on Heavier Soils

- Ideally keep the most vulnerable sites in grassland.
- Avoid trafficking land when wet and ensure timeliness of cultivations.
- Establish autumn sown cereals, oilseed rape and grass reseeds early enough to achieve good ground cover before early winter and follow other good husbandry practices for these crops (see Chapter 5).
- Avoid root crops on vulnerable heavy soils.
- Maintain field drainage where appropriate, including secondary treatments (mole drainage) where the system depends on this method.
- Subsoil where necessary to remove compaction.
- Manage grazing livestock to avoid poaching.
- Avoid slurry applications on vulnerable sites in winter or in summer if soil is cracked over drains.

The greatest soil losses from erosion are likely to be associated with sandy and silty soils (Chapter 3). However problems can also occur on heavier soils i.e. those containing over 18 % clay such as silty clay loams, clay loams and clays (Appendix C).

Erosion Processes and Heavier Soils

Heavier textured soils are generally more cohesive than lighter soils, with a more robust aggregate structure, so soil particle detachment by rainsplash (described in chapter 2.2) is likely to be less severe – though it will still occur on bare soils. On the other hand, infiltration rates are normally lower than on lighter soils, so surface flow may be both greater and more frequent.

Increased run-off occurs on heavier soils when soil structure is poor and the soil has lost its ability to soak up rainfall. This run-off may be sufficient to scour and detach fine soil particles leading to discoloured run-off (also known as soil wash). However, it does not usually cause rill formation.

Nutrients and pesticides attached to clay particles, or in solution, may be transported long distances in run-off water often affecting streams and rivers far away from the field of origin. The presence of slurry and other organic manures, including from grazing animals, will add to the pollution risk.

Risks to watercourses are greatest when run-off water carries:

- Phosphate (attached to soil particles or in solution)
- Herbicides (such as isoproturon) and other crop protection chemicals
- Organic manures

In addition clay, and particularly silt particles, can have a direct impact by clogging river gravels and fish spawning areas.

Transport of soil, slurry and dissolved pollutants can also occur via field drainage systems, particularly if deep cracks have developed during dry weather allowing rapid movement of storm water into the drains.

Cropping and husbandry

Changes in cropping and husbandry have increased run-off and erosion risks from heavier soils. In some areas land traditionally under grass has been ploughed up for maize and for arable cropping.

Heavier soils are more prone to wetness than light land so have fewer days available for working the soil under optimum conditions. Economic pressures can force farmers to work the land in less than ideal conditions. Cultivations or harvesting carried out under wet soil conditions will damage soil structure. Any cultivation pans, or compaction caused by these operations will increase surface run-off and erosion risks. Maize and root crop harvesting can leave ruts that concentrate water into erosive channels. By the time the crop harvest is completed, it is often too late to carry out remedial action and establish good ground cover before winter.

For further information on grazing livestock, consult 'Controlling Soil Erosion: An advisory leaflet for preventing erosion caused by grazing livestock on lowland England'.

6.2 The problems of soil erosion in flood plains

Summary of Management Practices for Erosion Control in Flood Plains

- Wherever possible land which is liable to frequent flooding should be kept grassed.
- Avoid high risk crops and enterprises on vulnerable sites e.g. potatoes.
- On vulnerable sites harvest early and establish a cover crop or leave an uncultivated stubble surface to protect the land through the high flood risk period.
- On vulnerable sites avoid cultivations which produce an unnecessarily fine seedbed and aim for cultivation and crop establishment either early in the autumn or late in the spring to avoid the period of high flood risk.
- Permanent grass strips in particularly vulnerable areas may help protect against soil loss in some situations.

Soil erosion in some flood plains has increased over recent years, by a move away from traditional livestock grazing of river meadows to systems of arable cropping. It is not dependent on soil particles being detached by rainfall, so the erosion risk assessment outlined in chapter 3 will not apply.

Problems of soil erosion from riverbank can be increased when grazing livestock have access. Advice to reduce riverbank erosion from livestock activity is described in a separate leaflet entitled 'Controlling Soil Erosion: An advisory leaflet for preventing erosion caused by grazing livestock in lowland England'.

The important factors in determining the severity of flood plain erosion are:

- Soil type.
- Risk of flooding.
- River flow characteristics.
- Crop/land use type.
- Timing and method of cultivation.
- Speed with which waters flood the land and with which they subsequently drain away again.
- Pattern of flow during flooding and drainage.

Financial losses can occur when sediment is deposited and crops are smothered as well as by waterlogging.

Soil type

Soils with a high sand or silt content are most vulnerable. Soils with a high clay content are more resistant to erosion due to the cohesive effect of the clay particles within the soil crumbs or aggregates.

Risk of flooding

This will be very site-specific and subject to local catchment and weather conditions. Any land which floods, on average, once in every 3 years or more frequently, should be regarded as highly vulnerable.

River flow characteristics, speed of inundation/drainage and pattern of flow during inundation/drainage will all have a major effect upon the extent and severity of erosion. All are very site-specific and local knowledge is invaluable in determining the part they play. Features such as the location of hedges, gateways, natural depressions and broken flood banks, could all concentrate the flow of floodwater, thus increasing the risk of erosion in certain areas.

Crop/land use

Any crop or land use which leaves the soil in a bare state during periods of high flood risk will increase the risk of erosion. Such crops and enterprises may include potatoes, sugar beet, field vegetables and outdoor pigs. When there is a high risk of flooding permanent grass is the best option. If the land has to be under arable cultivation an early sown winter cereal crop will give the most protection.

Timing and method of cultivation

The highest risk of flooding is likely to be in late autumn, winter and early spring, although flash floods in summer can also cause damage. Any disturbance of the field surface during these periods should be avoided. Coarse seedbeds will be less liable to erosion.

Grants

Grants may be available, which can indirectly help with erosion control in flood plains. For example, the Environmental Stewardship Scheme administered by Defra may provide grants for reversion of arable land to permanent grass, the creation of arable field margins or in-field grass areas, or the establishment and management of hedges. In some areas of England, English Nature operate a Wildlife Enhancement Scheme which grant aids the creation of buffer strips adjacent to rivers which have SSSI status.

Consents

The Environment Agency should be consulted and consent may be required if significant works (such as planting a hedge in a flood plain) are proposed adjacent to a main river that may interfere with the flow of water.

6.3 Minimising the effects of soil erosion on archaeological sites

Summary of Management Practices for Minimising Soil Erosion on Archaeological Sites

- Grass down the most vulnerable areas.
- Consider changes to cropping – including avoidance of crops that pose the greater risk of erosion.
- Consider changes to cultivation practice – particularly in reducing the depth of cultivations.
- Introduce breaks, such as a ditch, hedge or wide grass strip, on long slopes (although care should be taken to ensure that this by itself does not damage any archaeological features).
- Avoid deep disturbance such as subsoiling and draining.

Soil erosion can have a devastating effect on the survival of archaeological remains by removing the protective layer of soil above them. In order to protect our national heritage it is important that farmers are aware of the damage that can be inadvertently caused to archaeological sites by agricultural operations so that preventative measures can be taken.

Types of archaeological features that may be present

The most obvious features are those that project above ground such as standing stones or the earthworks of burial mounds or deserted settlements although old hedgerows, field patterns, meadows, woods and parklands may also be of historic importance.

Many archaeological deposits are less obvious and may survive only as buried features. If close enough to the surface, such features may have an effect on crop growth (so-called 'crop mark' sites), while the soil lying above them may also contain items of interest such as pottery, coins, bones and need to be protected from disturbance. Archaeological features above ground level will often be directly associated with buried features.

Knowing whether archaeological remains are present on a farm

Many sites of national importance are protected as Scheduled Monuments under the Ancient Monuments and Archaeological Areas Act 1979. Owners are notified of such sites and there are restrictions on agricultural activities that could cause damage. Advice on protecting Scheduled Monuments can be obtained from the local English Heritage Field Monuments Warden, contact details for whom are available from English Heritage's regional offices.

As few as 3% of all known archaeological sites in the country have been designated. Details of scheduled sites and also known, non-scheduled sites will be recorded in the 'Sites and Monuments Records' (SMR) held by each County Council or Unitary Authority. This is the best source of information to find out about known sites on a farm. Even so, sites registered on the SMR are only a fraction of the total and many buried sites are unidentified. Indications of 'hidden' sites include:

- Man-made materials, such as pottery, worked flints or metal work brought to the surface by ploughing.
- Patches of stony ground and building materials in cultivated land.
- Differences in crop growth reflecting buried features such as walls, ditches and pits.

If you suspect archaeological remains may be present, advice should be sought from the local authority archaeologist.

Damage to archaeological remains that can be caused by cultivations and erosion

Archaeological sites are usually protected from damage if under grass although over-grazing and poaching can damage earthworks and standing structures. Once the plant cover has been removed erosion can expose deposits.

Most damage occurs through arable cultivations. Many buried archaeological features and artefacts lie just below an existing plough depth – so that *even a small increase in cultivation depth can do a great deal of damage*. The nearer the surface, the greater the likelihood of artefacts being damaged by machinery and by the chemical effects of some fertilisers and pesticides. Even the displacement of remains from their original position and in relation to each other will reduce their historic value.

Most damage occurs by cultivation machinery passing through underlying soil deposits and structures but in many cases the effects of tillage is intimately linked with soil erosion. Soil erosion increases the risk of damage in the following ways:

- Where soil is eroded the effective soil depth above any remains is reduced. Even if the rate of soil loss is low, it can result in a reduction in the protective soil layer. Thus, even though cultivation depth remains the same, damage will start to occur.
- Soil deposition at the base of slopes will bury remains deeper and thus provide greater protection; however this effect can have adverse effects in certain circumstances, such as the siltation of historic lakes.
- Ploughing on a slope can cause soil to move down the slope with each successive pass. This effect can cause erosion of up to a few centimetres a year which, with time, can lead to significant thinning of the protective soil cover over buried remains. This effect can be reduced by the use of a reversible plough.
- Indirect effects also can occur; for instance, in order to reduce erosion, it may be necessary to loosen any compaction by subsoiling which causes even more damage to buried remains.
- Wind erosion can be important in certain areas. Peat and fine sandy soils under arable cropping are particularly susceptible.
- Wetland peat soils are often rich in archaeological remains. Peat wastage, by drainage and subsequent oxidation, is known to have caused the loss of many features. Subsequent removal of the remaining soil by wind erosion will cause further damage.

Assessing the risk to sites from erosion

Where archaeological features are present on the farm, you should consider the risk of damage caused by cultivations and erosion.

To assess the risk of water erosion, reference should be made to Chapter 3 of this manual (Erosion Risk Assessment) – which considers the effects of soil texture, slope, annual rainfall and cropping. In areas where wind erosion occurs, susceptible soils are usually well known; it is likely to occur on bare sandy and peaty soils between March and June mainly but not exclusively in East Midlands, Vale of York and East Anglia.

Coupled with this, factors concerning the archaeology of the site itself (such as its composition, state of preservation and the depth of protective soil cover) need to be considered before the extent of any risk to the site can be judged. Advice on this aspect can be obtained from the local authority archaeologist.

If a significant risk to the site is identified, decisions can then be made about how damage may be minimised by, for example, changes to cropping and cultivations.

Prevention of damage to sites from cultivations and erosion

Keeping land under permanent grass or reverting existing arable land to grass or permanent set-aside is the most effective means of protecting buried archaeological remains because there is essentially no cultivation damage or soil erosion. However, reversion to grass may not be practical in predominantly arable areas for various reasons such as lack of grazing livestock and loss of financial returns if arable crops are no longer grown.

Where reversion or long-term set aside is not an option, no-till or direct drilling on fields containing identified archaeological remains at risk are the most effective techniques to protect archaeological sites. Shallow minimum cultivation can also help. Subsoiling and drainage operations should be avoided on areas containing archaeological remains.

Where arable crops are grown on archaeological sites, protection may be also accomplished by both changes to cropping and to management of the crops:

- Some crops cause more direct physical damage than others and so, on 'sensitive' sites, consideration should be given to removing root crops, such as sugar beet and potatoes, from the rotation. De-stoning land for potatoes can be particularly disruptive as can subsoiling. The growing of energy crops such as short rotation coppice (SRC) or Miscanthus on archaeological sites may also lead to damage through root action, water depletion and from grubbing out old SRC stools and harvesting Miscanthus rhizomes.
- Continuous arable cropping can lead to reduction in soil organic matter and loss of soil structure. This can result in consolidation of the topsoil, effectively reducing its depth and bringing archaeological remains within cultivation depth.
- Under the right conditions, soil erosion by water can occur with any arable crop. Details of ways to reduce this risk are given in Chapter 4 of this manual. Land under root crops, maize or outdoor pig production is also more susceptible to erosion.
- Susceptible soils can be eroded through wind action when they are unprotected by plant cover. The highest risk occurs with dry seedbeds which have been prepared for small seeded row crops such as sugar beet, onions, carrots and lettuce. Detailed advice on minimising wind erosion is given in 'Controlling Soil Erosion: An advisory leaflet for preventing soil erosion by wind'.

Care should be taken to avoid creating damage when trying to control erosion. Certain measures for example, planting new hedges across slope to reduce erosion or planting woodland may be damaging.

Management schemes and regulations for archaeological conservation

Payments for protecting archaeological sites are available under both the Entry and Higher levels of the Environmental Stewardship Scheme administered by Defra. Permanent set-aside can provide another opportunity to take land out of arable production and thereby protect historic sites.

Scheduled sites are protected by the 1979 Ancient Monuments and Archaeological Areas Act. In certain situations, payments to restrict damaging agricultural operations may be made under management agreements between English Heritage and the owners of scheduled sites. There are also regulations which can aid in protecting non-scheduled sites:

- Under the Environmental Impact Assessment regulations (2002), permission is required from Defra before certain uncultivated land and semi-natural areas are used for intensive agricultural purposes. The presence of archaeological or other historic features is one criterion on which a decision is made.
- Protection to sites may also indirectly be afforded by other statutory requirements such as the Hedgerow Regulations, measures to protect Sites of Special Scientific Interest (SSSIs) or development control policies in National Parks.
- Planning Controls for development on farms will take account of archaeological conservation.

6.4 Minimising soil erosion during building and engineering projects

Detailed guidance on the agricultural issue associated with mineral and waste development is available in 'Guidance for Successful Reclamation of Mineral and Waste Sites'.

Larger engineering works (e.g. landfill, quarrying) could be undertaken alongside farmland, with the restored land later being incorporated into normal farm management. Other engineering works may affect normal farming operations, and be either under a contractor's control (e.g. pipeline, road, flood defence construction or 'borrow pits' for the extraction of soil materials), or the farmer's direct control (e.g. farm buildings, tracks, or lagoon construction).

Summary of Management Practices for Erosion Control on Building and Engineering Sites

- Plan operations to minimise total area of vulnerable soils at any one time. Planning should include soil stripping proposals and haul routes mitigation measures.
- Minimise soil damage by stripping and reinstating soils under dry conditions and controlling machinery movement so there is no unnecessary trafficking of topsoil or subsoil.
- Manage stripped soils so that they will give best results for vegetation regrowth when used for site restoration.
- Construct and manage soils storage mounds – sow grass or grass/wildflower seeds mixtures depending on the longevity of the mound.
- Protect excavated areas by intercepting and diverting surface water on the upslope side of the site.
- If feasible, construct shallow catch pits to intercept run-off and encourage settlement of soil particles.
- Remove compaction from soils during reinstatement, eliminate ruts and wheeling that can concentrate run-off and re-establish underdrainage where necessary.
- Make a timely site restoration, aiming for fast re-establishment of ground cover. Use artificial cover for additional protection if necessary.
- Ensure drainage water does not leave site with high suspended solid loadings – use settlement lagoons if this is a risk.

In order to reduce the likelihood of problems and complaints it is important to consider what damage may occur during construction – to the site, adjacent land, roads and watercourses.

Changes to land during site working operations

The most obvious change is the removal of surface vegetation (grass, crops, scrub, or woodland), and topsoil. This tends to leave bare subsoils with low permeability and low resistance to raindrop detachment (described in chapter 2.2), which is worsened by the passage of construction traffic. Equally important is that excavations, temporary roads, etc, can be very efficient in intercepting and channelling surface run-off which can carry large quantities of disturbed soil away from the construction site.

Measures to take during site operations

Plan operations to minimise the total area of vulnerable soils at any one time, and to manage stripped topsoils and subsoils so they will give best results for vegetation regrowth when later used for site restoration. Soil damage will be minimised by stripping and reinstating soils when they are in a dry friable condition (this applies to the soils to be moved and those lower in the soil profile) and carefully controlling movement of machinery so there is no unnecessary traffic movement over topsoil or subsoil.

Shallow topsoil storage is preferable, so that maximum aeration can be encouraged. Where overwinter storage is necessary, early sowing of grass on storage mounds will reduce erosion risks by providing a protective vegetation cover and helping to maintain a good structure. Providing good groundcover can be achieved, a grass/wildflower mixture could be considered to create food and habitats that can help to support wildlife for the duration of soil storage. The soil storage heap should be shaped to shed water safely. Avoid creating hollows and depressions on the top of the heap which could accumulate water and cause erosion damage if disturbed.

On the main site, plan to divert possible surface run-off from where soil will be disturbed. Any temporary diversion channels should be lined with turf, geotextile, or other protective material to prevent scouring within them. If feasible, shallow catch pits could be constructed on a temporary basis below the main excavation areas. These would encourage water to soak into the ground, and allow the settlement of stones and larger soil particles. Settled soil would need to be removed on a regular basis to maintain effective volume.

Pipeline routes crossing agricultural land often cut through field drainage systems. Any drains severed whilst excavating the trench for the new pipeline should be reconnected across the trench or an interceptor header drain installed to prevent water reaching the strip. As with all disturbed land, further remedial drainage may be required on completion of site operations.

Where excavation and construction is taking place, check the overall site towards the end of each day's activity, especially if heavy rain is expected, or further work is not scheduled for a few more days. Make sure that there are no marks that can channel and concentrate surface flow, and that water cannot run from large impermeable surfaces (e.g. tarmac) to softer, easily scoured soil.

In some circumstances (e.g. unavoidably steep excavations during a period of high rainfall), a temporary artificial cover might be required to reduce the impact of raindrops on a vulnerable surface.

Site restoration

Early consideration should be given to landform of the restored area and the inclusion of hedges and ditches to reduce erosion risk. The aim should be to restore soils, in such a way so as to minimise compaction of the restored profile. This will often mean using well planned and managed loose-tipping methods with backacters and dumptrucks.

Any compaction in reinstated subsoil or topsoil layers should be removed by subsoiling under dry soil conditions. Compact soil layers reduce infiltration and increase surface run-off as well as affecting plant establishment and growth. The surface should be free from ruts or wheelings that could concentrate run-off water. The re-establishment of a protective surface cover of vegetation is of utmost importance.

Ensure that any disturbed underdrainage is re-established (see Chapter 6.5), and that surface hollows, ridges or valleys will not develop as disturbed soil settles.

Slopes should, where possible, be graded so that they can be worked with normal agricultural equipment. The subsoil surface should be left fairly rough before topsoil is applied to lessen risks of erosion by enabling it to 'key' into the subsoil surface. Topsoil that has been well managed in storage will support rapid establishment of a suitable cover crop.

Steep banks and areas that cannot be treated as above may require artificial cover (matting, sealing sprays, etc) to reduce raindrop impact and help bind the soil surface before vegetation can be established.

6.5 The management of restored soils to minimise erosion

Any soils that have been stripped and reinstated can be particularly vulnerable to erosion. This applies to soils restored following large engineering works and also smaller farm scale operations (see Chapter 6.4).

Summary of Management Practices for Erosion Control on Restored Land

- Restore soils by loose-tipping methods to minimise compaction of the restored profile.
- Establish grass or winter cereals early enough to achieve good ground cover before early winter.
- Keep restored land in grass (ideally) or early sown winter cereals throughout the aftercare period.
- Install underdrainage where necessary.
- Subsoil periodically to improve soil structure and infiltration.
- Avoid trafficking land when wet and ensure timeliness of cultivations.
- Graze only with young stock or sheep and remove stock in winter.
- Analyse topsoil immediately after soil replacement and correct any deficiencies in lime or nutrients.

Vulnerability to erosion

Reinstated profiles usually have a damaged structure, often with layers of compaction. These mean that newly restored land is less able to accept rainfall than undisturbed soil and the potential for surface run-off and erosion is increased.

Topsoil organic matter and available nutrient levels may be low on restored land particularly if the soils have undergone prolonged periods of storage. Low organic matter means the topsoils will be less stable and more likely to erode. Low nutrient levels and poor structure may delay establishment of a protective crop cover.

Aftercare

Restored soils need a period of ‘aftercare’, during which the aim should be to improve soil structure, stability and fertility, rather than maximising productivity. On restored mineral sites, an ‘aftercare’ period of five years from the time of soil replacement is normally required by planning conditions. Special care is needed on all restored land and in some cases may be advisable for periods up to 10 years or more.

Cropping

To protect newly restored land from erosion, it is important to establish a protective crop cover as soon as possible after soil replacement. Newly replaced topsoils should be analysed and any deficiencies in lime or available nutrient levels corrected to facilitate good plant establishment.

The crop cover will ideally be autumn grown cereals or grass, maintained throughout the aftercare period, and established early enough to provide good ground cover before early winter. As well as protecting the soil surface, grass has a fibrous root system which helps to develop and maintain soil structure thereby aiding drainage and reducing run-off. Autumn sown cereals are an appropriate alternative for the aftercare period giving deep rooting potential. Again these need to be established early enough to provide good ground cover before winter.

Spring cereals should generally be avoided due to the increased risks of erosion from uncropped land overwinter, damage to soil structure by cultivations in the spring and the problem of establishing a satisfactory crop in wet years. Oilseed rape and other tap rooted crops are susceptible to compaction so not recommended unless soil conditions are good. Root crops such as potatoes and sugar beet are not suitable for restored land as late harvesting will normally prevent remedial subsoiling and may result in bare land over winter.

Grass management

Newly established swards on restored soils are especially susceptible to surface compaction and poaching which can lead to run-off and erosion. Grass seed mixtures need to be selected for the site and proposed use, to give the greatest benefit. Farm machinery and livestock should be kept off the land whenever soils are wet. To reduce poaching damage, graze only with young stock and sheep and do not graze overwinter.

Drainage

Good drainage surface and subsurface is important to minimise run-off and erosion. Drainage systems should be installed as soon as practicable, especially on soils where artificial drainage was present before disturbance. Underdrainage may be also required on other soils particularly if badly damaged during working or if low permeability material has been introduced below the topsoil. Drainage is likely to be necessary on landfill sites where soils are placed over an impermeable landfill cap.

Subsoiling and cultivations

Subsoiling will normally be carried out as part of the drainage operation. It is also likely to be required periodically on restored land to improve the soil's ability to absorb water and improve root penetration. It should only be carried out when the soil is in a dry condition, normally in late summer or early autumn, and regular checks should be made to assess the effectiveness of the work. Cropping with winter cereals or reseeding a grass sward provide a window for subsoiling before establishing the next crop. Subsoiling of established grassland is also possible using specially designed grassland looseners.

Special care is required on restored soils to avoid causing further soil damage from cultivations carried out under wet conditions. Restored soils should be given priority for autumn cultivations as they are more susceptible to damage from wheeled machinery than undisturbed soils. Any compaction or smearing caused by cultivating under unsuitable conditions will exacerbate risks of erosion.

Further Reading

The following Defra Publications are available from Defra Publications, Admail 6000, London SW1A 2XX. Telephone: 08459 556000. Many are also available to download from the Defra website.

Defra *Code of Good Agricultural Practice for the Protection of Soil* (1998, PB0617). Available to download from: **http://www.defra.gov.uk/environ/cogap/soilcode.pdf**.

Defra *Code of Good Agricultural Practice for the Protection of Water* (1998, PB0587). Available to download from: **http://www.defra.gov.uk/environ/cogap/watercod.pdf**.

Defra *Controlling Soil Erosion*: *An Advisory Booklet for the Management of Agricultural Land* (1997, PB3280). Available to download from: **http://www.defra.gov.uk/environment/land/soil/publications.htm**.

Defra *Controlling Soil Erosion*: *An Advisory Leaflet for Preventing Erosion Caused by Grazing Livestock in Lowland England* (1999, PB4091). Available to download from: **http://www.defra.gov.uk/environment/land/soil/publications.htm**.

Defra *Controlling Soil Erosion: A Field Guide for an Erosion Risk Assessment for Farmers and Consultants* (1999, PB4092). Available to download from: **http://www.defra.gov.uk/environment/land/soil/publications.htm**.

Defra *Controlling Soil Erosion: An Advisory Leaflet for Preventing Soil Erosion in the Uplands* (2001, PB5820A). Available to download from: **http://www.defra.gov.uk/environment/land/soil/publications.htm**.

Defra *Controlling Soil Erosion: An Advisory Leaflet for Preventing Soil Erosion by Wind* (2001, PB5820B). Available to download from: **http://www.defra.gov.uk/environment/land/soil/publications.htm**.

Defra *Controlling Soil Erosion: An Advisory Leaflet for Preventing Soil Erosion by Outdoor Pigs* (2001, PB5820C). Available to download from: **http://www.defra.gov.uk/environment/land/soil/publications.htm**.

Defra *Conservation Grants for Farmers* (2000, PB0983).

Defra *Guidance for Successful Reclamation of Mineral and Waste Site* (www.defra.gov.uk/environ/landuse/landuse.htm).

Defra *Single Payment Scheme: Cross Compliance Guidance for Soil Management* (2005, PB10222B). Available to download from: **http://www.defra.gov.uk/farm/capreform/pubs/pdf/Soil-hb.pdf**.

Defra *Single Payment Scheme: Cross Compliance Handbook for England* (2005, PB10222A). Available to download from: **http://www.defra.gov.uk/farm/capreform/pubs/pdf/Cross-compliance-3011.pdf**.

Also available:

Defra *Arable Area payments Scheme Literature.* Available from Defra Rural Payments Agency.

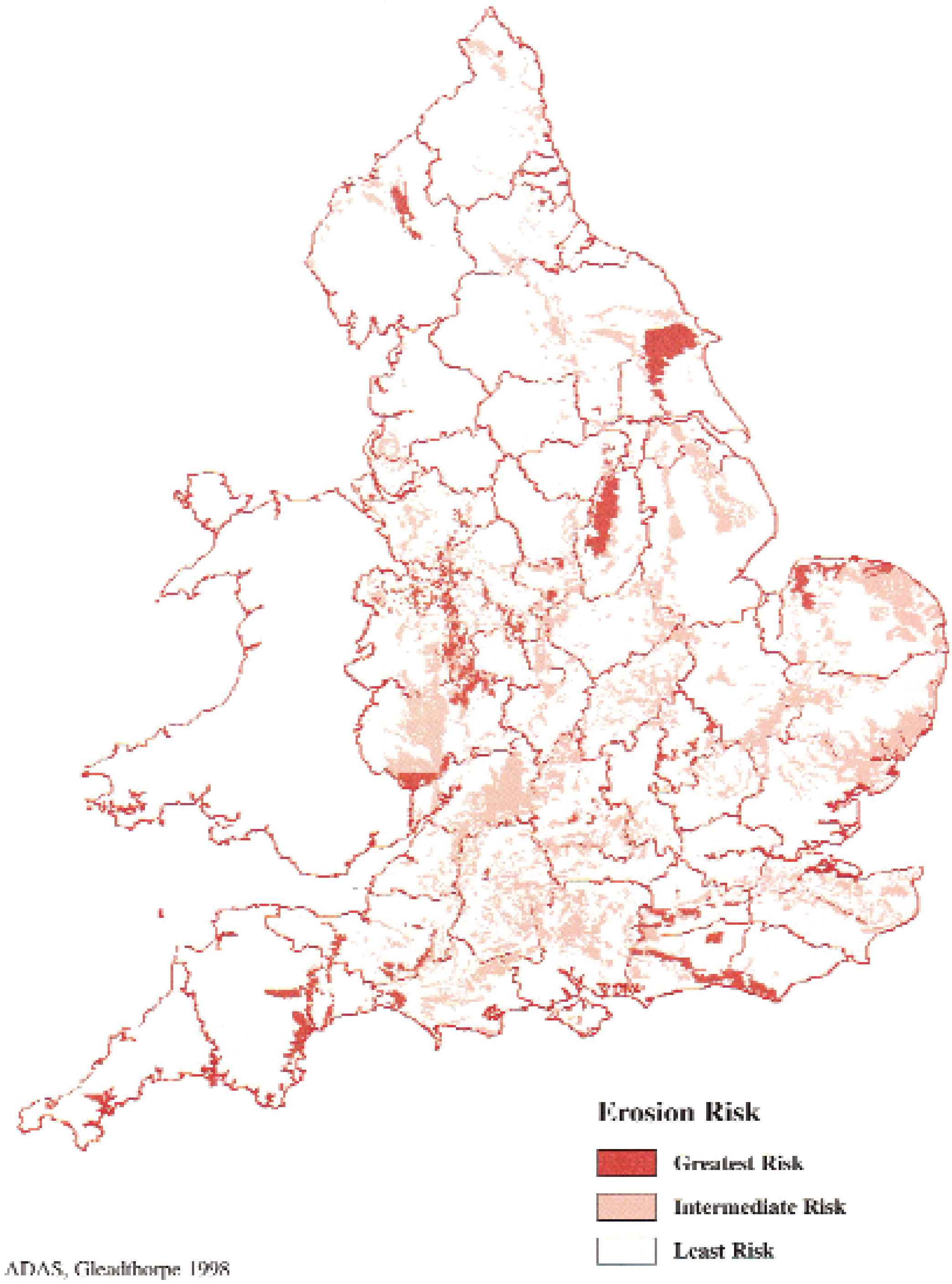
Environment Agency *Best Farming Practices: Profiting from a good environment* (2003). Available from Environment Agency Head Office: 0870 8506 506.
Also available to download from: **http://www.environment-agency.gov.uk/business/444304/444312/668607/669460/797683/?version=1&lang=_e**.

NSRI *Guide to Better Soil Structure* (2001). Available from: NSRI, Cranfield University, Silsoe, Bedfordshire, MK45 4DT. Telephone: 01525 863242. Also available to download from: **http://www.silsoe.cranfield.ac.uk/nsri/pdfs/structure_brochure.pdf**.

Soil Association *Soil Management on Organic Farms* (2003). Available from: Soil Association, Bristol House, 40-56 Victoria Street, Bristol, BS1 6BY. Telephone: 0117 914 2446, priced £5.00.

SMI *Guide to Managing Crop Establishment* (2001). Available from SMI, 1 The Paddocks, Powey Lane, Mollington, Chester, CH1 6LH. Telephone: 01572 717220. Also available to download from: **http://www.smi.org.uk/docs/news/1037639465SMIguide2001.pdf**.

Areas at Risk of Soil Erosion by Water in England



Soil texture classification

Texture classes for mineral soils are defined by the relative proportions of sand, silt and clay sized particles.

Particle sizes

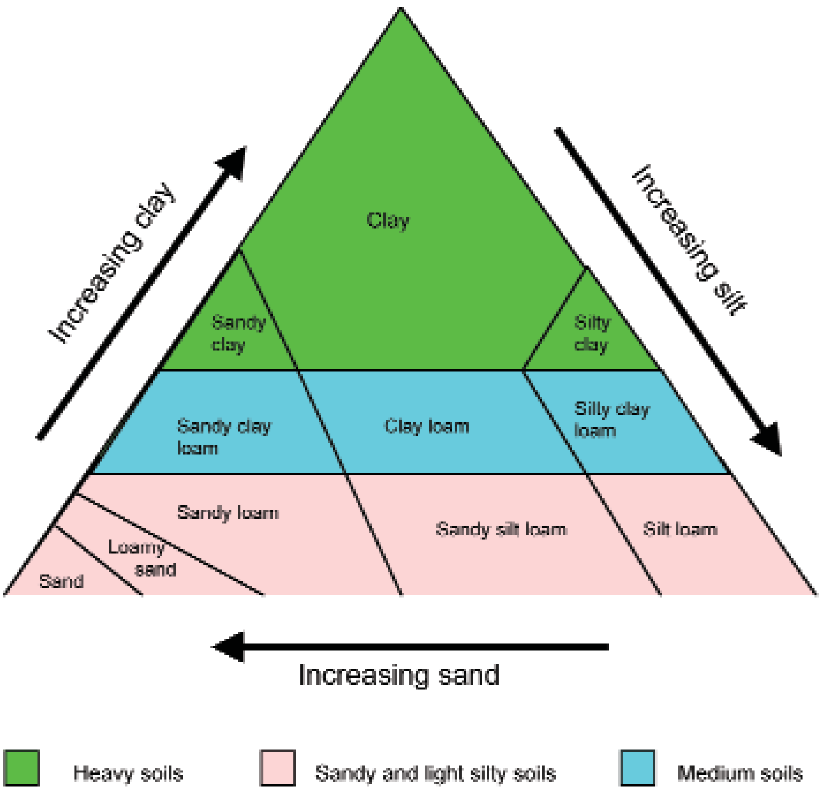
	Particle Diameter mm
Sand	2–0.06
Silt	0.06–0.002
Clay	less than 0.002

Triangular diagram

Limiting percentages for the 11 main texture classes are defined within the triangular diagram below.

Sand, loamy sand, sandy loam, sandy silt loam and sandy clay loam classes may be subdivided according to the sand size.

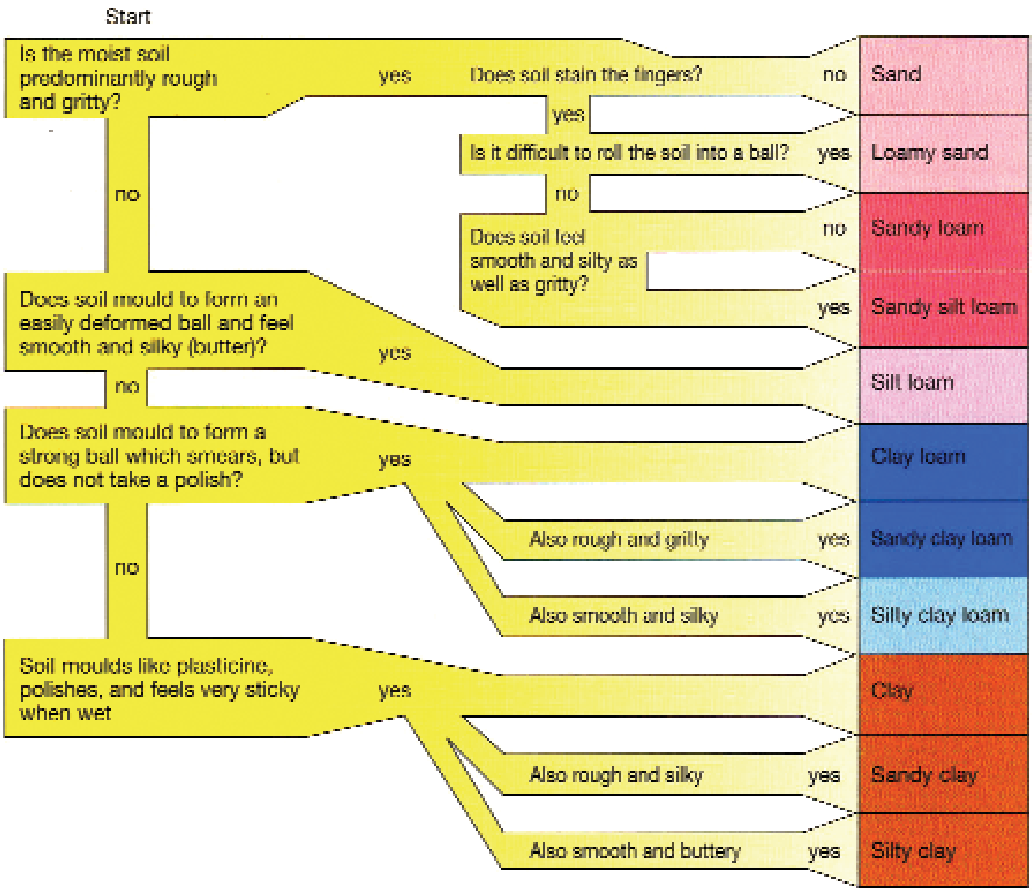
Fine – more than two thirds of sand less than 0.2mm
Coarse – more than one third of sand greater than 0.6mm



Assessment of soil texture

Accurate measurements of soil texture requires laboratory analysis, but for practical purposes, texture can be assessed by hand, using the following method:

Take about a dessert spoonful of soil. If dry, wet up gradually, kneading thoroughly between finger and thumb until soil crumbs are broken down. Enough moisture is needed to hold the soil together and to show its maximum stickiness. Follow the paths in the diagram to get the texture class:



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