

APPENDIX 4.2
CATCHMENT LAND USE AND RUNOFF
MODIFICATION

1. CATCHMENT LAND USE AND RUNOFF MODIFICATION

Throughout the IWMS, land use management of the catchments upstream of Ashford has been promoted as an option for flood risk management. B&V carried out a literature search that revealed wide-ranging research work. This work that indicated that there is some potential for runoff control through measures such as changes from crops to set-aside, directional ploughing on slopes, changes to cropping patterns and afforestation. However, no work has as yet presented a numerical approach robust enough for engineering design. It has been concluded that there is potential in land-use management, but further research is recommended. Since these comments were made, early in 2005 Defra released the final reports for their research project FD2114, "Review of impacts of rural land use and management on flood generation".

FD2114 represents the best and most up-to-date thinking in this field. This Appendix has therefore extracted the main conclusions from the various sections of the FD2114 main report and from the paper summarising it, which is to be presented at the Defra conference this year. The reader is referred to the report and all its appendices for more detailed information. The following summary is sufficient to support B&V's initial conclusions, that land use management has potential, but the tools for application catchment-wide have not been developed.

2. OVERVIEW OF LAND-USE MANAGEMENT AND FLOOD GENERATION

2.1 Land use changes and their impact

Over the past century, the UK landscape has been transformed as a consequence of changes in land use and management. Potential changes to local, hillslope-scale, runoff generation and delivery to the channel network have been researched, discussed and illustrated. Impacts on flood generation at the catchment scale will depend on the spatial distribution and temporal variation in land use management activities and their effects on runoff generation (magnitude and timing), and on interactions with channel modifications that affect the routing of runoff through the channel network.

O'Connell et al (2004) have noted the following general effects as a result of the policy changes of the 1947 Agricultural bill and the UK's entry into the European community and the Common Agricultural Policy:

- Greater connectivity of run off pathways due to loss of hedgerows and trees and expansion of individual field sizes;
- Greater compaction of the soils surfaces due to more intensive agricultural practices and a perceived increase in the potential for earlier and greater run off generation;
- An increase in land drainage feeding overland flow directly to ditches and watercourses;
- Potential increase for run off from bare soil surfaces due to changes in arable cultivation practices and seasons;
- Concentration of overland flow in plough lines ditches and tyre tracks;
- Channelling of overland flow by farm tracks and tramlines to watercourses;
- Loss of riparian buffers adjacent to watercourses; and
- Channel straightening and re-sectioning of meandering watercourses to improve drainage.

These factors are illustrated in Figure 2.1, taken from FD2114.

Several factors within this changed landscape have the potential to interact and affect the volume and rate of delivery of run off to adjacent watercourse. These are:

- Soil compaction;
- Land drainage efficiency; and
- Flow path connectivity.

The structure of the soil plays a key role in determine the characteristics of local catchment run off by determining the quantity of water that can be stored within its matrix or pores and cavities and the mechanisms of delivery of run off to local watercourses. Heavily compacted soils will lose their capacity to absorb water due to loss of interstitial spaces whilst compaction at or near the surface will reduce the ability of the soil to communicate the water down through its profile to the sub layers which may be able to store or absorb more water. The likely results are an increase in the volume of run off and a reduction in the time for run off generation to take place. The processes by which this is likely to happen are presented in Figure 2.2.

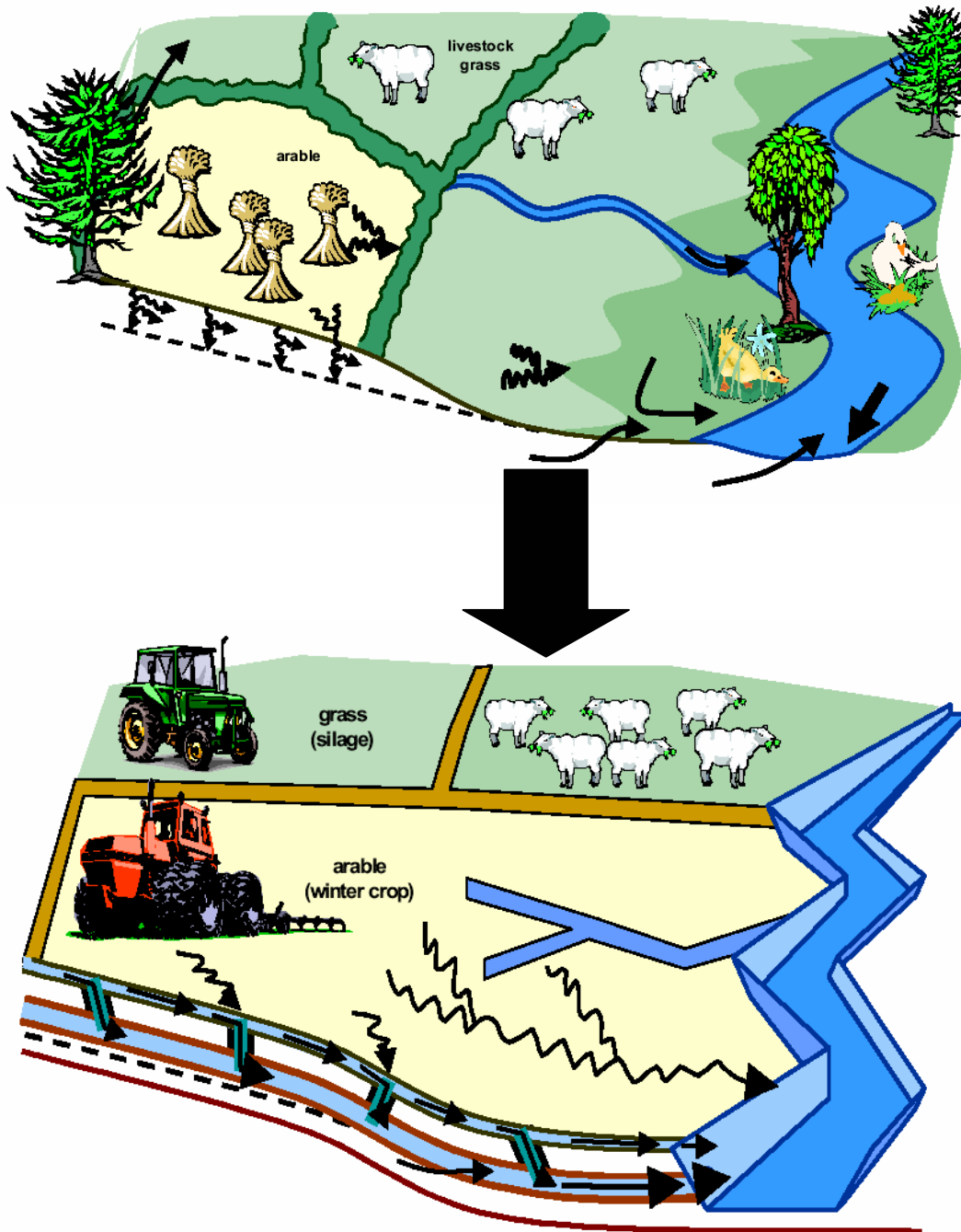


Figure 2.1. Changing land use and management pre-WWII to present day

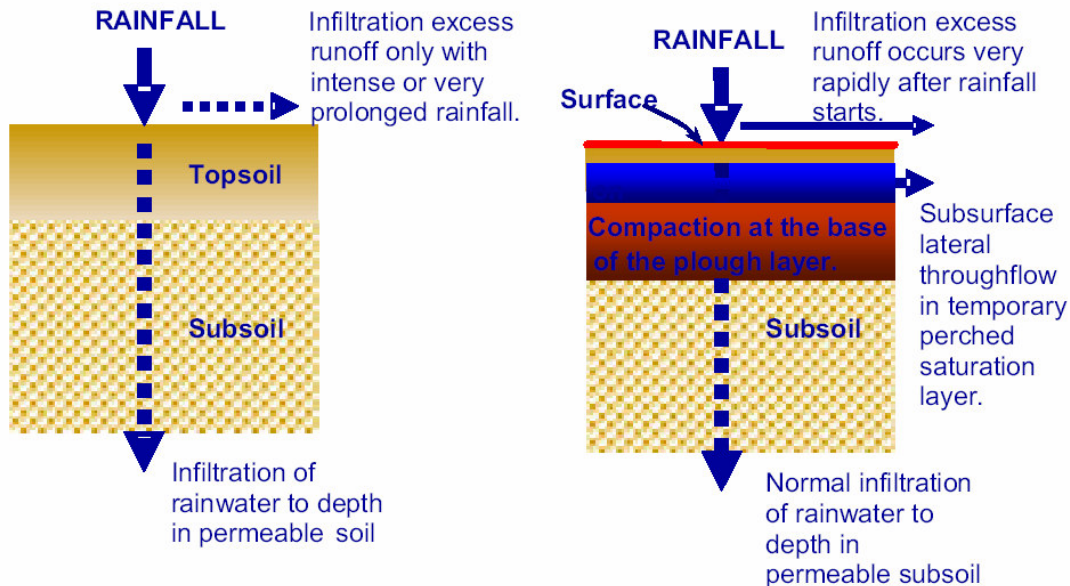


Figure 2.2 The effects of soil compaction on run off generation (O'Connell, 2004)

The impacts of drainage on soil structure and therefore run off generation is less clear and is dependent on local factors including soil structures, the type of drainage installed, the age of installed drainage and the level of maintenance applied, drainage intensity and location specific climatological and topographical characteristics.

Effective under drainage of farmland may lead to an increase in field storage and if located within the floodplains may locally decrease peak flows within the river channel in the context of a small catchment. However, when such a network of under drainage is linked to efficient arterial drainage channels on a larger catchment, an increase in peak flows downstream may occur as a result of faster conveyance of water from the upper catchment. (Newson and Robinson, 1983; Robinson, 1990; Robinson and Rycroft, 1998; Sears et al, 2000).

2.2 Combination and timing of runoff

As noted above, FD2114 also reiterates the importance of a catchment wide consideration of drainage. The timing and addition of hydrographs may be such that the slowing of runoff in certain locations may increase runoff peaks downstream and that the most effective treatment of runoff may vary according to location within a catchment. Nevertheless, it is usually beneficial to increase the speed of runoff from the lower parts of the catchment, but slow flow from upstream, as illustrated in Figure 2.3, again taken from FD2114.

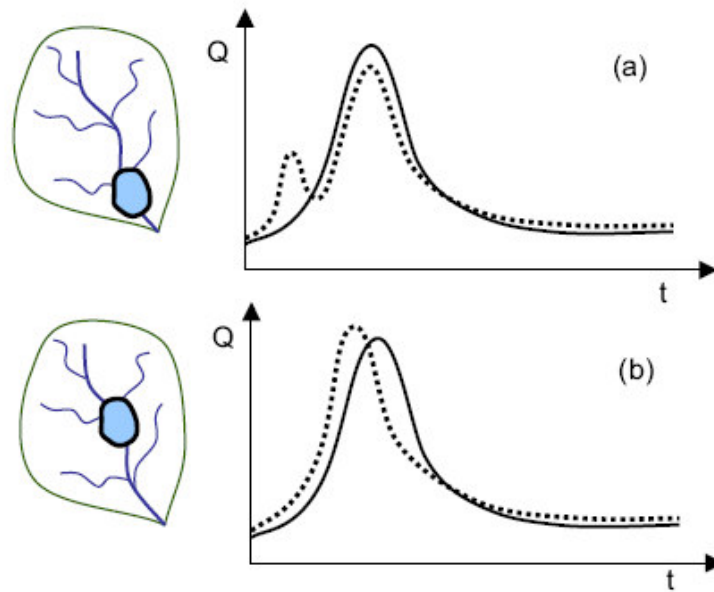


Figure 2.3 Impacts on a flood hydrograph due to the spatial location of change (solid line pre-change, dashed line post change)

2.3 Rainfall-runoff prediction

Agricultural and soil scientists have a good understanding of the managed lowland environment at the local scale, but the majority of the experiments and modelling have centred on 1-D processes, with flow routing often neglected. The hydrologist has a more complete 2-D/3-D understanding of runoff generation and stream flow processes at sub-catchment and catchment scales. However, the research has typically been performed in semi-natural upland environments. To increase understanding of the effects of land use and management on farm and catchment scale runoff generation, there is a need for cross-fertilisation and closer integration between these disciplines. Numerous rainfall runoff models have been published in the literature, some of which are, in principle, suitable for use in predicting land use change impacts, but there is a lack of evidence-based studies in the open literature on the merits of different methods and models. Typically, model validation is not performed rigorously, with inadequate testing and estimation of uncertainty in predictions.

To support policy-making for flood defence, impacts need to be defined in terms of changes to flood risk, which is based on probability of exceedance (flood hazard) and damage. Therefore, predictions of the impacts on the flood frequency curve are required, not just impacts on an individual flood hydrograph. The FEH statistical approach is the most widely used statistical method for this purpose, but it is based on the assumption that land use change (other than urbanization) has not had a significant impact on flooding.

Similarly, the FEH rainfall runoff method, which can also be used to predict the flood frequency curve, does not account for land use changes other than urbanization. An empirical modification of the FEH rainfall runoff method which takes account of land use management changes, is proposed in Reports C1 and C2 of FD2114. The use of continuous simulation for the prediction of the flood frequency curve has several attractive features; it removes the need for the specification of design storms and includes the effects of antecedent soil moisture conditions. However, a major research challenge that must be addressed is how to use this approach to predict the effects of land use management changes on the flood frequency curve.

3. REVIEW OF LAND USE AND MANAGEMENT

3.1 Historic changes in land use

The total areas under arable, grassland and rough grazing have remained reasonably constant over the last 50 years; however, livestock densities, crop types and management practices have changed significantly. The key changes in arable cultivation have been a shift from spring to winter sown cereals and the introduction of new crop types, most notably maize and oil seed rape. Livestock numbers, in particular sheep, have risen significantly over the last century, which, more recently, has been accompanied by a longer grazing season. There has also been an increase in the area of woodland, with a move from coniferous to deciduous new plantings.

3.2 Impacts on drainage

In many cases, land use changes and the accompanying management practices have been linked to increased erosion and farm scale runoff, and the degradation of soil structure. Of particular concern are winter practices that leave the soil surface bare or require the use of heavy machinery on the land, and also actions that increase the surface and subsurface connectivity of the landscape.

3.3 Possible mitigation measures

3.3.1. General strategies

FD2114 reports on a number of mitigation strategies that have been proposed for reducing farm scale runoff, including measures to provide increased protection to the soil surface, reduce flow connectivity, increase retention and storage, and alternative land uses.

Good soil husbandry, cropping practices and general management for the reduction of runoff and erosion are now being widely promoted. There is also a focus on adopting land management techniques that reduce diffuse pollution of water, some of which will also benefit water retention and reduced soil erosion. There is considerable synergy between diffuse pollution control and the management of water in the soil profile and landscape. These linkages need to be strengthened.

There are several schemes that are not directly focused on the issue of flooding, but can be expected to have a positive influence. Examples are the management of set-aside, woodland and coppice, grasslands and ponds, which may have a beneficial effect on runoff generation.

3.3.2. Cover crops

A vegetative cover helps bind the soil particles, increases surface roughness and reduces the effects of the rainfall's kinetic energy. Grass and clover crops can be sown as an 'understorey' or 'intercrop' to row crops such as maize but can reduce yields. However, as an alternative to cover crops, the application of mulch may be suitable for crops susceptible to competition.

3.3.3. Minimum tillage

Conservation tillage is an all encompassing term that refers to leaving previous residues on the soil surface, or partially incorporating them, thus reducing the bare soil, reducing surface sealing and increasing infiltration, aggregation and providing resistance to water movement. It can also maintain a solid soil matrix below, reducing the effects of compaction and maintaining macropore connectivity. Minimal tillage techniques are becoming more widespread and can have significant benefits on soil organic matter content, structure and biological activity. There is also evidence that they can significantly reduce surface runoff. However, an unpublished paper by the Austrian Government (Withers, Pers. Comm.) reviewed 123 published papers worldwide. It was found that minimum tillage had a 50% chance of reducing erosion, but the results were very site specific.

3.3.4. Hillslope surface runoff control

Ploughing and the planting of row crops across slope reduces overland flow velocity, and provides opportunities for infiltration and evaporation. Evidence from the USA shows that contour ploughing in most crops can significantly reduce surface runoff but its effectiveness is likely to decrease over the season as surface sealing occurs. However, in the UK, contour ploughing is not always practical, primarily on safety grounds but also due to the complexities of slope angles, slope directions and irregular field shapes.

Grass buffers, ditches and hedges slow runoff and increase the likelihood of re-infiltration. Contour grass strips can possibly be used as a 'soakaway' in arable systems, braking, filtering and infiltrating runoff. Cross ridges and bunds can also be used to dam a downslope orientated main furrow. However, such structures need to be engineered and used appropriately as overtopping may cause gully erosion. The pilot Defra Entry Level Agri-environment Scheme (ELS) includes options for the maintenance of hedgerows and development of adjacent buffer strips.

3.3.5. Machinery

Reducing loads, decreasing tyre pressure and increasing tyre widths reduces the intensity of compaction associated with wheelings and tramlines. Terra tyres and tracked vehicles are particularly suited for weakly structured soils and wet conditions as they reduce the vertical stress on soil surfaces compared to conventional tyres. Chisel ploughing to break up compaction caused by down-slope tramlines is usually found to reduce runoff, but the impacts can be detrimental on steep slopes. Care must be taken to prevent these areas from developing gully erosion.

3.3.6. Grassland / livestock

Conversion of arable land to grassland is a mitigation measure that may be applicable to specific soil and landscape conditions. On grassland itself, the most effective mitigation measure is likely to be a restriction of the grazing season to avoid those times when the soil is at or near to field capacity and its bearing strength lowest. Once compaction has occurred, surface infiltration can be increased by the use of techniques such as mini-moling, slot cutting and spiking. There is some evidence that the introduction of deep burrowing earthworms into pasture increases infiltration

3.3.7. Woodland

Conversion of arable or intensively used grassland to woodland has significant potential to reduce total runoff in the long term, providing it is not accompanied by the installation of an intensive drainage system; however, the implications for water resources may need to be considered. The Woodland Grant Scheme (WGS) operated by the Forestry Commission provides grant aid for the creation of new or the management of existing woodlands. In conjunction with this scheme is the Defra Farm Woodland Premium Scheme (FWPS), the main aim of which is to provide financial support for farmers wishing to convert agricultural land to woodland.

3.3.8. Retention structures and wetlands

The principal aim of any headwater soil management or runoff detention feature is to attempt to slow the outflow from the smaller sub-catchments, and thereby reduce the peak of the hydrograph for the main catchment outflow. The use of on farm storage ponds and ditches, and the creation of wetland areas have also the potential to attenuate runoff, so long as they provide increased storage and buffering capacity in headwater catchments. However, such structures need to be carefully designed to ensure that storage capacity is adequate and discharge mechanisms do not cause secondary problems. In the UK, the maximum size for an above ground lagoon without engineering certification is 25,000 m³. For an on-farm pond that is lower than the surrounding land there is no capacity limit. The targeted re-creation of on-farm wetland areas also has the potential to store excess waters during storm events and thus attenuate peak flows.

In principle, all of the above interventions can be beneficial in delaying/attenuating the runoff hydrographs of small sub-catchments, but care is needed to ensure that the changes in timing do not bring sub-catchment responses into phase. For example, non-headwater detention can be risky, as this can bring runoff delivery from lower catchment areas into phase with the upper catchment flood hydrograph (see Figure 2.3).

3.3.9. Riparian area management

The bias in river restoration and river engineering schemes towards large rivers neglects the role of upland streams, and lower order streams and man made ditch networks in the lowlands. Poaching by animals and active ditch maintenance is likely to be occurring across much of the landscape.

Exclosure of the rivers to animals must be matched by suitable water feeding features, or specific zones on the river that are protected from poaching effects (i.e. armoured with stones). A buffer strip may not protect the river from poaching, however.

A case study in the US (USEPA, 1993) demonstrated that it is relatively easy to restore rivers in livestock systems without damaging the profit of the farmer. A series of good management practices was set up such as fencing off rivers. There was also no need to reduce stocking densities if a good livestock rotation scheme was put in place. The speed at which the rivers restored themselves was quick and clearly flow attenuation is occurring.

3.3.10. Ditch management

Evidence from studies on farms suggests that pro-active ditch maintenance is carried out specifically for the rapid removal of runoff and often acts as an extension to the land drains. The creation of new ditches, and the channelisation of natural watercourses increase conveyance, leading to the rapid removal of runoff and the loss of the implicit storage capacity of the land and channels. Artificial ditches and drains increase the drainage density of the land and enhance the speed of runoff delivery to the main channel network.

A study in New Zealand (Sukias, 2003) has allowed a number of ditches to overgrow with vegetation. The study showed clear evidence of rapid weed growth and sedimentation giving rise to tortuous flow paths. The benefits in terms of pollution and erosion mitigation were evident, and, clearly, the on line storage capacity of the ditches improved and the flow speed was reduced. This raises an issue about the long-term maintenance strategy for ditches.

The direct blocking of ditches is also possible and can give rise to substantial on line storage. This type of storage capacity can be used in areas dominated by high runoff and could have great potential impact in land-drained areas. However, there is a perceived fear that water logging and sedimentation will block drains and induce drain collapse. Thus, there is an issue concerning the strategic positioning of blocked ditches in terms of the size and volume of the temporary ponds they cause, the long-term maintenance of ditches and their impact on land drain functioning.

3.3.11. Agri-environment schemes

Agricultural policy has been a major determinant (a driver) of land management and where this has resulted in intensification of land use, both grassland and arable, there have been consequences for 'runoff induced soil erosion' and 'localised flooding'. There was no hard evidence from the literature to show that ESA and Countryside Stewardship Scheme (CSS) interventions, as they affect the landscape and farm management practices, actually impacted flood generation. However, if intensification enhances runoff generation then extensification (and measures to prevent or retain runoff) might be expected to mitigate runoff generation at the local scale. However, this is speculative, and the evidence does not support it. It is clearly a research need.

4. REVIEW OF IMPACT MONITORING AND MODELLING STUDIES

FD2114 carries out a comprehensive literature review of the whole field of land use management. Key literature sources relating to the monitoring and modelling of impacts of land use management on runoff generation are summarised; these and other sources are reviewed in greater detail in Appendices A, B, C and F of FD2114. Monitoring studies carried out at the plot/field scale are reviewed in terms of impacts on surface runoff and drainage flows; most of these studies have been carried out in the lowlands, and cover a range of land use and management practices, including cultivation activities and runoff mitigation measures.

Catchment scale monitoring studies have been carried out primarily in the uplands, and typically at scales of up to 10km². Many of these studies relate to afforestation/deforestation impacts on runoff generation, and include consideration of drainage, forest roads and logging practices.

Some lowland small catchment studies of field drainage and 'muddy' floods have also been carried out, together with a recent field sampling studies of soil structural conditions in a number of UK catchments.

The groundwater flooding phenomenon is reviewed briefly in FD2114, but no specific link with land use management is evident. There are ongoing multiscale monitoring studies in meso-scale catchments under two national catchment research programmes (CHASM and LOCAR).

Catchment scale modelling studies have employed a range of model types, and predictions of impacts relate mainly to changes in vegetation. FD2114 reports unpublished findings from some EC projects. Statistical analyses of flood records aimed at detecting climate and land use changes are reviewed, together with analyses of the incidence and magnitudes of muddy floods. Although out of scope, a limited review of sources relating to the impacts of river channel modifications on runoff routing is included for completeness. Finally, some review studies illustrate the wide range of anthropogenic impacts experienced in UK catchments, and a disparity between the public perception and the scientific evidence relating to the causes of floods worldwide.

The key findings of the review of these sources are reported as part of the Critical Assessment conducted in Sections 6.1 - 6.2 of the main report, and summarised below.

5. REVIEW OF SOCIO-ECONOMIC STUDIES

FD2114 goes on to review socio-economic studies of flood generation. Key sources relating to socio-economic studies of policy interventions designed to reduce flood generation have been categorised and summarised in this section. The studies have been categorised using the Drivers – Pressures – State – Impacts – Response (DPSIR) framework.

Under Drivers, Pressures, and State, issues associated with national policy-making and private sector initiatives are reviewed. Studies dealing with Responses relate primarily to the uptake of various agri-environment schemes, and relationships between conservationists and farmers.

Studies falling under the complete DPSIR relationship deal with the design of rural land use strategies which balance production and conservation, the effectiveness of policy instruments, analyses of on-farm and off-farm impacts from socio-economic standpoints, analyses of farmers' investment decisions and behaviour in response to incentives and regulations, the effects of CAP reforms, and farmers' attitudes towards soil conservation and flood risk mitigation. Although there may be potential synergy between measures to control diffuse pollution and measures to control runoff, this link, and the contribution to flood mitigation, is not automatic. These two environmental challenges share common land use drivers and environmental pressures, are both 'diffuse' in nature and are likely to justify similar types of policy responses. In some situations, there may be scope to integrate policy interventions to address the two simultaneously, for example through compliance with COGAP or the requirements of agri-environment schemes.

The key findings of the review of these sources are reported as part of the Critical Assessment conducted in Section 6.3 of the main report, also summarised below

6. CRITICAL ASSESSMENT OF ASSEMBLED SOURCES

6.1 Impacts of land management on flood generation

FD2114 concludes that there is good evidence that local surface runoff is increased as a result of a number of 'modern' farm management practices such as increased stocking densities on grassland, the prevalence of autumn sown cereals, the increase of maize crops, and the production of fine seedbeds. There does not appear to be a strong link with soil type, but sandy, silty, and slowly permeable seasonally wet soils are more susceptible than others.

With respect to mitigation measures, there is good evidence that restricting the grazing/trafficking period can reduce the amount of local runoff on grassland and that afforestation can significantly reduce runoff in the long-term, when compared to the runoff from arable land or intensively used grassland. There is also good evidence that a range of land management practices such as the use of cover crops, minimum tillage, cultivating and planting across slope and the targeted use of grass strips can significantly reduce the amount of local surface runoff associated with arable systems in general and with specific crops such as autumn-sown cereals, maize and sugar beet. However, some of the practices, such as the use of cover crops may have negative impacts on crop yields and none of the practices are likely to be successful in all situations. Most require careful targeting with respect to specific topographic, soil, cropping and climatic conditions.

There is also evidence that the impact of field drainage on flows into edge-of-field water bodies such as ditches and headwater streams varies with the type of drainage installed and with the associated secondary drainage practices and wetness regime of the local soil.

Evidence, quantified in terms of runoff percentages etc. is site specific and cannot be extrapolated reliably to other sites, nor can it be used at the catchment scale.

In summary, there is quantifiable evidence that both afforestation and field drainage can affect flows in the surface water network but the impacts can be very different, depending on the local soil type and specific management practices used.

In contrast, although there is good quantifiable evidence that a number of modern land management practices result in significantly increased in-field surface runoff and that specific mitigation management practices significantly reduce such runoff, there are no studies in the UK or relevant parts of Europe that quantify how much of such in-field runoff is transferred to the surface water network or how it affects local stream responses. However, there is indirect evidence from a single study in Belgium that surface runoff of sufficient magnitude to result in local 'muddy floods' is not always transferred to the surface water network in amounts large enough to cause 'out of bank' floods in the local stream valleys.

The uncertainty related to transfer of surface runoff to the river network represents a significant gap in the knowledge base that requires addressing.

In summary, there is very little direct evidence that land management practices can affect flooding. The reason there is very little direct evidence may be because there have been very few studies. There is therefore a need for further studies aimed at detecting such effects, if they exist and can be identified in the presence of other flood generation factors. There is good evidence from the South Downs, northern France, the Netherlands and Belgium that specific arable management practices result in localised and seasonal 'muddy floods' and that some management practices can reduce the frequency of these floods. Modelling studies at the catchment scale can be regarded as a source of indirect evidence, but the models are found not to be fit-for-purpose in predicting impacts.

6.2 Modelling the impacts of land use change and land management practices

FD2114 considers that there are serious shortcomings in the rainfall-runoff models and methods available for use in the operational assessment of the impacts of land use change and land management practices. There are three fundamental unresolved issues: there is no generally-accepted theoretical basis for the design of a model suitable to predict impacts, it is not known which data have the most value when predicting impacts, and there are limitations in the methods available for estimating the uncertainty in predictions.

Some general recommendations can, however, be made for a way forward in rainfall-runoff modelling for predicting impacts. The modelling should be distributed and be capable of running continuous simulations. It should also be partly or wholly physically based so that the physical properties of local landscapes, soils and vegetation can be represented, and it should include detailed modelling of surface water flow so that the effects of changes can be tracked downstream. A considerable amount of high-quality field data on impacts will be needed to support the development of robust methods for predicting impacts.

6.3 Socio-economic information to support policy development

The links between socio-economic drivers, land use and the risk of flood generation are complex. They also tend to be location and context specific. The 'on-site' cost of runoff generation and related soil erosion to farmers is relatively small compared to the benefits of intensive farming. The incentives or requirements for farmers to adopt runoff control measures are limited under the present agricultural policy regime. There is uncertainty concerning how land managers respond to changes in important drivers such as agricultural and environmental policy, both in the short and long term. Nevertheless, there is evidence to suggest that it is possible to design locally relevant policy interventions that can reduce flood generation associated with land use, as discussed below.

Current evidence for the effectiveness, efficiency and equity of using policy instruments to influence desirable land management practices suggests that interventions which seek to reduce near-source drivers and pressures associated with land use change are likely to prove more effective and efficient than interventions to mitigate impacts, especially as the drivers themselves are policy driven.

This involves discouraging inappropriate land use and farming practices where these are clearly linked to increased run-off and flood risk. The diffuse nature of rural land management and related flood generation suggest that, on its own, mandatory regulation would prove ineffective and inefficient, being difficult and costly to administer and enforce, and possibly insufficiently flexible to deal with local circumstances and practices. Instead, the best approach would appear to be a mix of policy instruments: economic and voluntary measures, supported by advice and technical support, backed up, where necessary, by regulation.

6.4 Implications for water resources

Studies of the impacts of land use change on water resources have focused heavily on the impacts of forests on catchment water yield, and the associated reductions in catchment water yield and recharge relative to grassland are well documented.

Here, the key issue is whether any changes to the runoff generation regimes associated with land use management practices might have implications for water resources. This issue has been analyzed by considering the following questions:

- (i) might any increase in local-scale surface runoff alter the total larger-scale catchment yield;
- (ii) might aquifer recharge be reduced, and
- (iii) might low flows be reduced?

In the case of (i), it is not apparent how small-scale changes in the partitioning of surface and subsurface runoff might alter total water yield. In the case of (ii) the main land use control on recharge is through vegetation cover, and widespread changes in infiltration would be needed to have a significant impact on recharge. Since there is a lack of evidence on what happens to source surface runoff off-farm (e.g. how much of it re-infiltrates), and of any evidence linking land use management with declining aquifer levels, there is uncertainty concerning impacts on recharge. In the case of (iii), increased surface runoff implies less water stored in the soil moisture reservoir, with potential impacts on low flows. However, low flows in many lowland catchments are supported by aquifers, so, based on the analysis of (ii), there is uncertainty about impacts on low flows. In the case of mitigation measures, any reversal in current management practices would need to be analyzed in the terms considered above. This issue and the potential impact of poor land management on recharge and low flows, should be investigated in future research.

6.5 An analysis of hypotheses about impacts

FD2114 examines the following oft-repeated statements about flooding, and comes up with some perhaps surprising answers.

Hypothesis 1: *“Flooding can be mitigated by altering current land management practices”.*

Alterations to current land management practices can be put in place at the farm scale and can reduce flood risk for local communities, and generate wider benefits for the water environment. However, there is currently no evidence to show that such measures can mitigate catchment scale flooding, and research on both technical and governance aspects is needed to assess mitigation potential at large scales.

Hypothesis 2: *“An increase in infiltration can contribute to flood mitigation.”*

The restoration of infiltration rates towards their natural values should reduce surface runoff at the field scale, and mitigate on-farm and off-farm flood impacts. Moreover, there may be interactions with subsurface drainage, depending on the level of maintenance. However, there is a possibility that catchment scale mitigation of flood runoff may not be achieved due to a possible increase in subsurface and saturation excess runoff.

Hypothesis 3: *“By increasing storage within the catchment, flooding can be mitigated.”*

Any increase in storage within the catchment, which could be achieved through the restoration of the natural storage capacity of the soil, or through impoundments at the farm scale, would be expected to reduce flood generation and flood hazard. However, the extent of the reduction would be dependent on the amount of storage provided, and there is governance issues associated with the diffuse nature of this flood mitigation measure.

Hypothesis 4: *“Reducing the speed of conveyance of runoff can mitigate flooding”.*

Any reductions to the speed of conveyance of runoff to the drainage/channel network resulting from mitigation measures should be assessed at increasing catchment scales to identify any adverse impacts that might occur through changing the timings of runoff contributions to the channel network. This recognises that river engineering schemes have also changed natural conveyance in many catchments.

Hypothesis 5: *“Forests reduce flooding” or “Forests increase flooding”.*

Neither of the above hypotheses can be accepted on the basis of the available evidence, as several interacting factors tend to cancel each other out.

7. FUTURE LAND USE MANAGEMENT

Recent analyses of extreme rainfall across the UK are claimed to have revealed changes that are in line with global climate change predictions. This evidence relates to an increased frequency of

seasonal (autumn/winter) rainfall events in the lower return period range in the South and Midlands.

Although the qualitative assessment made by FD2114 of the potential impacts of climate change on land use management and flooding is little more than indicative, there is a possibility that the emerging autumn rainfall regime seen in the 90's may be linked with the increased incidence of muddy floods. An increase in the frequency of longer duration storms may lead to an increased incidence of widespread catchment saturation. The potential impacts of the changes on catchment flood risk need to be explored in future research.

In the near-term future, the main instruments that will influence future land use change are Agri-environment Schemes and CAP reforms. At present, neither of the two schemes in place, Environmentally Sensitive Areas (ESAs) and the Countryside Stewardship Scheme (CSS) explicitly target runoff management, but both have features that are likely to reduce local surface runoff.

New agri-environment schemes are being proposed by Defra, one of which will have a four-tiered approach, with objectives specific to each tier. It is expected that flood alleviation objectives will be met through the adoption of particular water storage options at the field and catchment level.

Under the CAP reform, the commitment is to reduce direct production subsidies and to link income support payments to compliance with standards which protect the environment, health and welfare. This changing policy framework could provide opportunities to build in general measures to reduce runoff generation as part of good agricultural practice, and more specific and targeted measures in vulnerable catchments where it can be established that such interventions would be worthwhile. A range of possible long-term futures and related agricultural scenarios have been considered, together with possible responses to the risk of flood generation under these futures.

Based on the Foresight Programme, four possible futures are considered (World Markets, Global Sustainability, Provincial Enterprise, Local Stewardship) which are distinguished in terms of social values and governance. Under the World Market and Provincial Enterprise scenarios which are characterised by an emphasis on private consumption, it is concluded that land managers will only adopt measures to mitigate on-farm runoff if they are deemed financially advantageous, but will not take measures to mitigate off-farm effects unless subject to regulation and economic penalties.

Under the Global Responsibility and Local Stewardship scenarios, characterised by a commitment to sustainable land management, there is a requirement to control runoff, with which farmers are generally willing to comply. In the former scenario, runoff generation will be managed at the catchment scale, while, in the latter, local preferences and priorities will restrict the possibilities of integrated strategies at the large catchment scale.

8. CONCLUSIONS AND RECOMMENDATIONS FROM FD2114

8.1 Conclusions

FD2114 has concluded that:

- (i) Significant changes in land use and management practices in the last fifty years have resulted in the intensification of agricultural land use. These changes have been driven to a significant degree by EC and UK agricultural policy. There is much evidence to confirm that patterns of land use and farming practices are a direct response to the incentives provided by agricultural policy, modified by local and farm factors.
- (ii) There is substantial evidence that changes in land use and management practices affect surface runoff generation at the local scale, but the effects are complex. Field drains, for example, may either increase or decrease the surface runoff from an event, and

- cultivation techniques can serve to reduce surface runoff where plough lines follow contours, or increase it where wheel tramlines run downslope.
- (iii) There is only very limited evidence that local changes in runoff are transferred to the surface water network and propagate downstream. This may be because there have been very few studies in which evidence has been sought, or because such studies (of, for example, afforestation or land drainage) have produced inconsistent or uncertain conclusions. However, in comparison with natural climatic variability, it would appear that land use management effects are of second order importance.
 - (iv) Analyses of peak runoff records has so far produced very little firm evidence of catchment scale impacts of land use management. However, such analyses have not focussed on areas where changes in land cover or management practices are likely to have been greatest (other than in forested headwater catchments) and have not considered the possible effects on the storm-to-storm variability or seasonality of flooding events.
 - (v) There are many measures that can be taken to mitigate local flooding by delaying runoff, such as using grass buffers, temporary ponds, and appropriate ditching. An integrated approach is needed in applying these measures so that the maximum overall benefit is gained for flood and pollution mitigation and erosion reduction.
 - (vi) There is considerable uncertainty about how effectively land managers will respond to any promotions or policies related to particular flood prevention or mitigation measures. There is evidence, however, to suggest that the effectiveness can be increased if compliance with specified flood prevention and mitigation measures is used as a condition of support to farm incomes.
 - (vii) Rainfall-runoff modelling to predict impacts is in its infancy: there is no generally-accepted theoretical basis for the design of a model suitable to predict impacts, it is not known which data have the most value when predicting impacts, and there are limitations in the methods available for estimating the uncertainty in predictions.
 - (viii) The uncertainty in the response of land managers noted in Conclusion (vi) needs to be accounted for when modelling the overall outcomes when flood prevention and mitigation practices are promoted.

From the Review and the conclusions drawn above, it is apparent that there are substantial gaps in the knowledge based on the impacts of land use and management on flood generation. Accordingly, a comprehensive Research Plan has been prepared to address the gaps in knowledge and to provide a sound scientific base for future policy-making (O'Connell et al, 2004b).

8.2 Recommendations

The following five recommendations for further research were made in FD2114:

- (i) There is a need to learn what can be learned about the flood impacts of changes in rural land use and management that have taken place in the past. In particular, there is a need to apply modern modelling and statistical techniques to examine existing rainfall-runoff records and isolate and quantify flood impacts. Also, there is a need for multiscale monitoring in catchments to build up the knowledge base related to how catchments function and in particular how the effects of changes in land use and management propagate downstream.
- (ii) For general use in research and in impact assessment and policy making, there is a need for an electronic map identifying the catchments that are vulnerable to local and downstream flooding as a result of changes in rural land use and management.
- (iii) There is need for field trials of flood mitigation measures, to build up the knowledge base. There is also a need for best practice to be established, both for selecting which flood prevention and mitigation measures should be used to meet local needs and how these measures should be promoted.
- (iv) A coherent approach is needed in modelling the flood impacts of changes in land use and management. Ideally, this would represent socio-economic, agricultural and hydrological effects and responses. It would be in the form of the DPSIR decision-support tool for estimating the likely outcome of implementing flood prevention and mitigation measures and the outcomes when policies and promotions are used to encourage the uptake of measures. The DPSIR tool would take account of uncertainty, could be used to examine future scenarios for climate, land use and management, and would give a basis for rigorously testing rainfall-runoff modelling so that issues related to the theoretical basis of modelling and the value of data can be addressed.
- (v) A solid research base must be established and maintained if real progress is to be made in assessing the flood impacts of changes in rural land use and management and in establishing best practice for flood prevention and mitigation. It is essential, therefore, that the research work in the Research Plan should be designed to leave a high-quality, useful and comprehensive legacy in the form of project reports, specification documents, datasets, open-source software, user manuals, and guidance

The Research Plan comprises 16 projects, in two programmes: a medium term near-user programme (11 projects) running over a period of five years, and a longer term programme (5 projects) running over a period of ten years. The bulk of the funding (70%) is allocated to data collection, assembly and various forms of analysis, and the remainder (30%) to developing and testing the necessary models. Substantial benefits would accrue to flood prediction and catchment management in general from the implementation of the Research Plan, not just land use management to mitigate flood generation.

9. CONCLUSIONS FOR THE ASHFORD IWMS

Throughout the IWMS, land use management of the catchments upstream of Ashford has been promoted as an option for flood risk management. There has been wide-ranging research work indicating that there is some potential for runoff control through measures such as changes from crops to set-aside, directional ploughing on slopes, changes to cropping patterns and afforestation. However, no work has as yet presented a numerical approach robust enough for engineering design. It has been concluded that there is potential in land-use management, but further research is recommended. In summary, it seems that land use management:

- probably shows good returns for local areas and low return period events; but
- is not proven on a catchment-wide scale and for extreme, design, events.

In particular, FD2114 concludes that:

“There is only very limited evidence that local changes in runoff are transferred to the surface water network and propagate downstream. This may be because there have been very few studies in which evidence has been sought, or because such studies (of, for example, afforestation or land drainage) have produced inconsistent or uncertain conclusions. However, in comparison with natural climatic variability, it would appear that land use management effects are of second order importance.”

FD2114 also shows that commonly held assumptions, or hypotheses, about land use may not be true, or as in the case of afforestation, be strongly dependent on factors such as soil type and drainage management.

B&V has considerable sympathy with land use management, and it may well become an option for the future as on-going research work delivers design information. However, at this juncture we would reiterate that it is not prudent to rely on such an un-proven technique for FRM of a major urban area.

10. REFERENCES

Calver, A. and Wheeler, H.S., 2001. Scoping the Broad Scale Modelling Hydrology Programme: Stage 2 Strategic Programme. FD2104.

Dti. (2002) *Foresight Futures 2020 Revised scenarios and guidance*. Department of Trade and Industry, HMSO, UK.

O'Connell, P.E. et al., 2004a. Review of Impacts of Rural Land Use and Management on Flood Generation. Part A: Impact Study Report.

O'Connell, P.E., et al., 2004b. Review of Impacts of Rural Land Use and Management on Flood Generation. Part B: Research Plan.

Packman, J.C. and Farquharson, F.A.K., 2004. Review of Impacts of Rural Land Use and Management on Flood Generation. Part C1: Short-term Improvement to the FEH Rainfall-runoff Model: User Manual.

Packman, J.C. et al., 2004. Review of Impacts of Rural Land Use and Management on Flood Generation. Part C2: Short-term Improvement to the FEH Rainfall-runoff Model: Technical Background.