Chapter 3

Responses to future intra-urban flood risks

Throughout this report, we acknowledge that flood management within urban areas is a subset of flood management on the catchment scale. In Chapter 2 we identified and ranked possible responses to future flood risk at the broad scale. In this chapter we consider responses to intra-urban flood risks.

Some response themes that operate at the catchment scale, such as managing flood events and managing flood losses, can also operate in an urban environment. We mention them only briefly here. Instead, our analysis concentrates on responses that are specific to intra-urban flooding. The work is divided as follows:

- Responses are identified and classified into a hierarchy of six groups. These response groups generally reflect the spatial scales over which responses operate.
- The groups are individually assessed and ranked according to their potential to reduce future flood risks for each of the four Foresight Futures scenarios.
- We assess the uncertainty in the operation and ranking of the response groups.
- We also rank and assess the response groups by wider criteria of sustainability and determine the key lessons.

3.1 Defining intra-urban responses

Responses to intra-urban flooding can operate through various mechanisms and on different spatial contexts (see Figure 3.1). Many responses will be suitable for different scales so it is important to take a systems-based approach to their application.

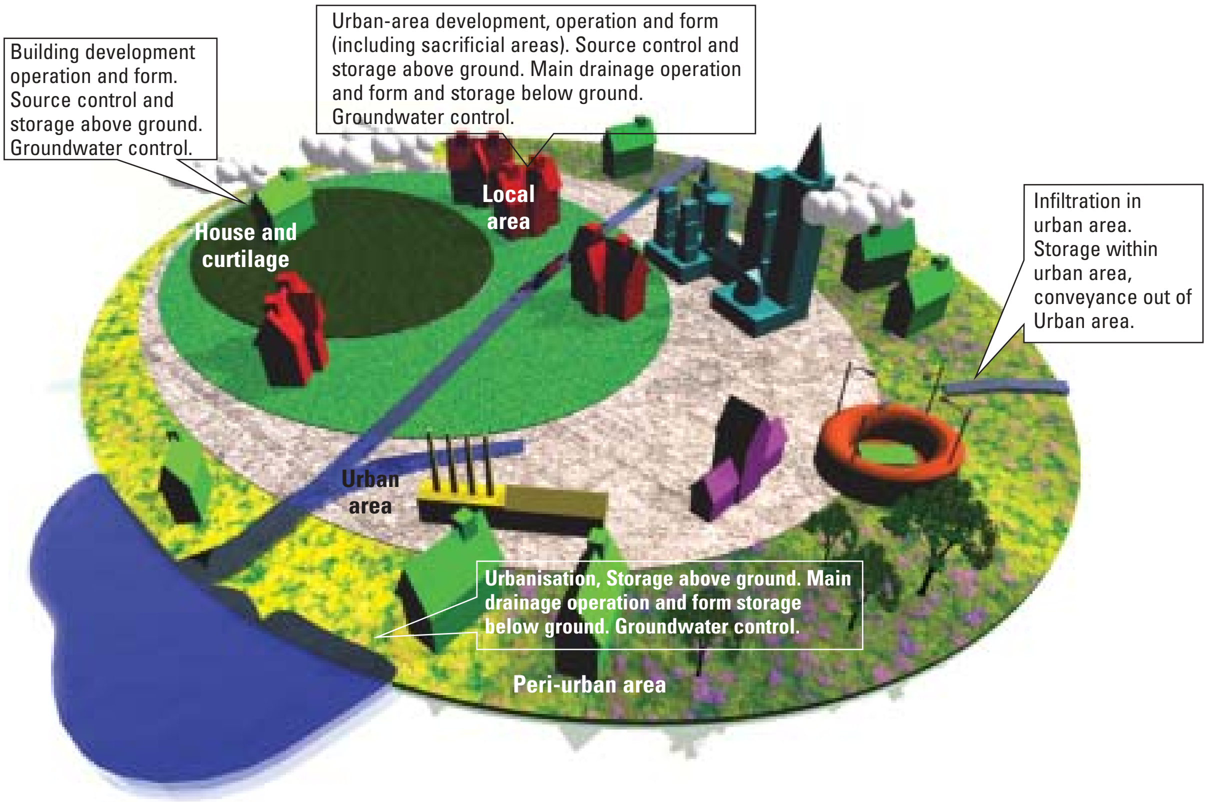
Flood management combines above-ground surfaces with various pathways, channels and flow routes, along with above- and below-ground systems that include drains and sewers, linked to various storage facilities.

Flooding is a symptom of the system's inadequacy to accommodate different critical storm events, or combinations of them. The key parameters of the system are:

- Urban hydrology, runoff processes.
- Conveyance, capacity to discharge flow to downstream.
- Storage, volume to store and subsequently release flow within the urban area.

To a greater extent than in the wider rural catchment, under extreme conditions flooding in the urban area can completely alter the area and can cause irretrievable economic damage to infrastructure and property. Surface drainage systems that have been modified through urbanisation cannot respond to rainwater in the same way as natural channels. They can no longer accommodate out-of-bank flows. Under these extreme conditions, high rates of surface runoff often cannot enter below-ground piped drainage systems. In extreme, but not catastrophic events, urban surface pathways become important as 'relief' systems, conveying the flow. The networks of roads and highways often serve this function. These are likely to become more important in the future.

Figure 3.1 **Potential responses in the urban area operate at different scales. Responses range from the level of individual buildings through to interactions with the surrounding peri-urban regions**



There are important interactions between the urban area and surrounding catchment. In terms of risk in the urban area, the key interaction is the ability to discharge excess flows away from the area. High sea levels can back up drainage systems causing significant problems for coastal communities. High watercourse levels can cause the same effects elsewhere (see Volume I). There may also be impacts from the urban area into the surrounding catchment. The principle of 'getting all flows and wastes away' as quickly as possible from the urban area, as adopted in the 1850s, is no longer tenable because of the possible impacts downstream. Similarly, there are wider flooding issues caused by the catchments that surround the urban area (see Chapter 2).

Urban areas must be considered in terms, both of existing form, layout and function and also of likely future developments. Existing area drainage and urban areas are unlikely to change significantly in the near to medium future, although there are a number of initiatives to utilise water channels and ponds more explicitly in urban areas for social, ecological, environmental and aesthetic reasons.

However, there may be new urban forms and living structures, particularly in newly constructed areas. Radical approaches, such as covered city environments may exclude drainage water entirely from urban areas. If this were to happen, then it would be important to consider very carefully the potential impacts on the wider catchment.

In many cases, it will be most effective to solve flooding problems by addressing sources, changing the volume and pattern of runoff, or by increasing the available storage at specific locations, and subsequently delineating above-ground flood routes for extreme events, rather than by expanding traditional below-ground conveyance systems.

Six response themes are now introduced and populated with groups and specific measures, policies and interventions in this section. Appendix B contains more detailed descriptions of each response group, drawn from the complete documents available in OST (2003, 2004). Table 3.1 shows the complete set of response groups.

Table 3.1 **Division of intra-urban responses**

Response group	Description
1 Building Development, Operation and Form	Opportunities to manage flood risk at the building level to control local risk. This also includes the curtilage surrounding the building.
2 Urban Area Development, Operation and Form (including sacrificial areas)	The potential to influence the risk of flooding within urban areas through changes in urban form and development.
3 Source Control and Above-Ground Pathways	Management of storm water as close to the point of origin as possible.
4 Groundwater Control	Management of groundwater in urban areas to allow infiltration during high precipitation, so preventing flooding.
5 Storage Above and Below Ground	Providing additional storage volume – by physical structures above or below ground – to increase the potential for the urban drainage system to act as a flood-defence mechanism.
6 Main Drainage Form, Maintenance and Operation	The physical form of urban drainage system, its maintenance and operation.

3.1.1 Urban Response Group 1 – Building Development, Operation and Form

This considers opportunities to manage flood risk at the building level. This response also includes the curtilage surrounding the building and floods originating from outside the curtilage as overland flow or from groundwater within the curtilage. Responses from the various stakeholders are also included – i.e. individual behaviour, together with responses that relate to actions when flooding does occur.

The principal measures at the level of buildings are:

- Design of building drainage, including green roofs etc.
- Managing urbanisation, specifically in terms of building development and form.
- Floodproofing individual buildings/parts of buildings including local flood protection – freestanding temporary barriers; removable house protection products etc.
- Rainwater harvesting and local stormwater use.
- Changing building and local-area drainage standards.
- Control of road-gully inlets.
- Disconnection of downpipes.
- Ponding on roofs.

There is likely to be a need in 2080 (as there is now) to protect the building envelope in addition to the abatement of downstream flood risk. Securing the building against water ingress could involve flood barriers, impermeable membranes or self-sealing building components. In extreme cases it could involve radical upgrading of buildings, for example, with buildings strengthened and extended upwards to provide accommodation above flood level. It could also involve the radical redesign of new buildings to reduce the impacts of flooding, including permeable roofs and rainwater utilisation.

Managing flood risk at the building level requires an integrated approach, with responses dealing with the spatially diverse risks. Typically this has to address both existing and new buildings – different responses may be needed for each. The latter may be designed using new concepts of low-impact development (LID) – for example, using roof water to flush WCs. Conversely, prestigious new developments often seek to remove rainwater quickly through siphonic systems. There are also mismatches between building life, building drainage design and the equivalent downstream infrastructure which need to be considered collectively.

At the roof level, attempts to introduce attenuation through, for example, green roofs and impermeable 'ponding' roofs have previously been unsuccessful in the UK. This is primarily because thermal stress and movement and/or inadequate workmanship causes leaks.

Downstream of buildings, effects arise when flows interact at surface level and, in the case of siphonic systems, through intermittent pulsing effects. For both conventional and siphonic systems, there is therefore a need for alternative strategies, including, for example, storage, attenuation and diversion of discharge in and around the building. Where no storage area is available, it may be necessary to identify sacrificial areas.

The impact on local building drainage due to discharges from roof drainage systems will affect the downstream flow conditions in both separate and combined pipework and in other surface-water drainage systems. Older combined rainwater and sewer systems will have least spare capacity to cope with future risk changes and these may still be part of the drainage system by 2080. Building discharge flows and local flow interactions within the curtilage will also affect the resultant potential for surcharge, blockage or overflow – with the associated possibility of ground contamination. In 2080, the tolerance to these will depend on which of the socioeconomic scenarios is being considered.

When the largest events occur, the success of responses may be high at the building level, but less so for the curtilage and wider catchment. Property owners and managers are key players in the effectiveness of any responses for the building itself and also for downstream areas, where excess flows are directed. It will be important to build capacity within these groups to help them reduce the vulnerability of their properties and also to make them aware of consequential downstream impacts.

It will require close collaboration between any building regulations institution and other standards setting organisations to achieve an integrated building approach that meets targets for water conservation and sustainability while also ensuring adequate performance of the building and local drainage system.

A fundamental role here will be to address the needs and responsibilities of householders, property owners and property developers, particularly with regard to building form and land management. This also integrates with land-use planning agencies which will be important in including attenuation and appropriate building form. The most effective responses may be achievable for larger buildings or groups thereof. As property is very important for human living and the whole range of stakeholder groups, physical and mental-health damage risks, cost, disruption, insurance and the impact on property and land cost will be pertinent to the solutions proposed.

Building operation and form is very much influenced by the socioeconomic scenario: shape, type and use will vary in terms of wealth and lifestyle norms. Radical approaches, such as subterranean or floating-vessel living, would alter the whole approach to drainage management and may make surface flooding entirely acceptable. However, it would be expected that infrastructure links would still need to exist on the ground and these would need to be protected.

3.1.2 Urban Response Group 2 – Urban Area Development, Operation and Form

This response group could influence the risk of flooding within urban areas through changes in urban form and development. The gradual growth in the area of hard-paved surfaces increases runoff. Thus strategic management of hard surfaces and runoff is likely to be effective at reducing flood risk. This response group therefore seeks to influence the risk of flooding within urban areas through changes in urban form and development. It has strong links with other response groups: Building Form, Source Control and Storage Above and Below Ground.

The principal measures are:

- Abandoning built areas most at risk.
- Improve/extending 'traditional' flood embankments.
- Promoting 'green' spaces.
- Local flood barriers to transfer water.
- Controlling new development.
- Building regulations for flood-risk areas to require flood-mitigation strategies.
- Abandoning properties most at risk.
- Sacrificial areas for local storage.
- Local and community protection of temporary 'islands' within urban landscapes.

The usual approach in urban areas entails increasing the conveyance of urban river channels and increasing the height of flood banks. This means investing in 'traditional' flood-defence solutions, often at the expense of sustainability. The main risks associated with this are the impacts of catastrophic failure and the possible inability of people to escape the floodwaters quickly.

New materials and technologies could make this type of defence much more cost-effective and sustainable in future, leading to much more extensive use of formal flood defences under certain scenarios. However, high flood banks to channel watercourses through urban areas would still be costly, and would require a change in attitude from key stakeholders about the preservation of the amenity value of watercourses in urban areas. For example, the need to fulfil current demands for high-quality river walls cannot be sustained in the future due to the high cost.

Strategies need to vary at a national level between strongly developing urban areas, for example, in the south of England where there will be further compaction and restructuring of urban areas, compared with areas often losing population, in, for example, the north of England. In the former, the capacity for flood storage may become reduced and strategies are required on a regional and city level to improve the conveyance and storage of floods outside the built areas in functional floodplains and greenbelt areas – for example, by creating and restoring wetlands, as in the USA.

New development on previously developed ‘brownfield’ land may increase flood risk where this land is in floodplains or where it now provides temporary flood storage. In post-industrial urban areas, where development pressures are lower, and which may even shrink, there may be better opportunities for flood storage and infiltration.

The approach adopted will depend on the severity of the flood risk and the economic cost of defending an area. In extreme cases, if the risk/cost balance was favourable, abandonment and sacrificial areas could be an option. However, this considers only the medium-term situation. In the longer term, climate change may be such that the Government, or others, proactively enhance the floodable zone around urban rivers by directly relocating people, not just steering development. This should be possible to varying extents by 2080 under each of the scenarios.

The preservation of greenspace, including ‘brownfield sites’ or derelict land, may provide good options for flood storage. An attractive option might be the creation or restoration of coherent greenspace networks for flood storage and conveyance, with linked corridors for conveyance – as in original watercourses.

The hydrological role of functional river floodplains is evident, but disturbance corridors such as motorways, railways and ring roads may also have a role as temporary storage and as a conveyance in the event of extreme floods. In some cases, canal networks may become more effective, and might be developed further. It may be important to ensure that road levels are always set lower than properties, as in the Netherlands.

On roads and railways, disruption to traffic would probably cause less damage than the flooding of buildings in residential areas, especially if systems were in place to provide advance warning to drivers and provide appropriate traffic management. Under some Foresight scenarios, by 2080 cars might not exist or at least be excluded from main urban areas. Abandoned roads might then become flood pathways or even canals.

The preservation of existing greenspace, as well as consequent greening of streets and roofs, can provide locally efficient delay to runoff. Policies promoting the unsealing of impervious surfaces in commercial zones, in car parks around shopping centres, for example, offer opportunities to increase infiltration. In low-density housing areas, densification would need to be controlled to avoid further loss of greenspace or private gardens unless alternative tradable drainage areas can be set up. Alternatively, urban fringe areas, including greenbelt areas, could be assigned a particular role to reduce flood risk for denser areas.

Greenspace can for example, fulfil roles in storage and infiltration in addition to their use for leisure and amenity. The importance of developing multifunctional greenspace networks in towns and cities is increasingly well recognised and may well be a standard in 2080 under certain scenarios. Under the most extreme conditions, well laid-out green and brown urban corridors should be able to route floods away from the more valuable urban areas.

Because of the importance of the effects of stormwater on flooding in cities, we would expect guidance on this to be part of the formal education system for planners, under all the scenarios by the 2080s.

Enabling local communities to influence planning and decision making more effectively will be important in achieving a more sustainable urban form. By 2080 community development strategies should be in place as a way of achieving this goal, as a consequence of, for example, an increasing transparency in the planning process and, with it, more effective stakeholder participation.

3.1.3 Urban Response Group 3 – Source Control and Above-Ground Pathways

Source control is the management of stormwater as close as possible to the point of origin. A range of drainage mechanisms, known as Sustainable Urban Drainage Systems (SUDS), are available in the UK, to manage rainfall runoff in ways other than the use of pipe networks. There are interactions with other response groups, notably with the response groups: Urban Form; Building Development, Operation and Form; Storage Above and Below Ground; and Main Drainage Form, Maintenance and Operation.
By 2080, these systems should be part of the standard approaches being used to manage stormwater.

The principal measures are:

- Design of roads and gully pots.
- Source control and local sustainable water-system management.
- Water reuse and recycling etc.
- Reopening of culverted watercourses (daylighting).
- Controlling pathways of runoff.
- Pumping off site.
- Multiple drainage systems.
- Aesthetic use of water in the urban area.
- Detention ponds.
- Permeable land cover.
- Infiltration systems.

Source controls comprise a range of possibilities within the concept of a SUDS 'train'. They can be 'non-structural' in that they may relate to behavioural changes at the points where runoff occurs. Thus the way in which householders and property owners, or facilities managers operate their storm-drainage systems can be significant.

The hydraulic effectiveness of SUDS for extreme events is a function of their hydraulic design criteria and soil type. Hydraulic design criteria vary and, with them, the ability to cater for extreme rainfall events – this can range from very limited to very effective. All SUDS are more effective to some degree than pipe networks at controlling both the quantity and quality of storm water drained. The latter maximise the rate of runoff from a catchment, thus generally exacerbating flooding problems downstream, either locally or in the river.

There are some limitations. Where SUDS and overland flood-flow paths are within floodplains, or downstream of a flood source, their effectiveness will be nullified during river flooding. In fact the performance of SUDS in these circumstances is likely to be worse than when using standard pipe systems. In theory, the problems of creeping urbanisation that affect current main-drainage systems could be even more problematical for SUDS as their surfaces could themselves become 'urbanised' by careless homeowners.

In addition to their ability to protect against flooding from smaller events, the long-term performance of SUDS depends on effective management. Currently, the long term implications for the cost of managing these structures to maintain their performance is not certain. This is a significant barrier to their utilisation. However, by 2080, experience with their use will have enabled rules to be developed to optimise their application.

Most SUDS are not designed for large events, although neither are piped drainage systems. Only recently have structures such as ponds been designed to address events of the magnitude of 1 in 100 years. Where ponds are used and designed to 100-year events, the reduction in peak flow can be of the order of 10 times, but requires between 3% and 4% of the contributing catchment land take. This can be reduced by effective measures at controlling the amounts of water originating from sources.

The most effective mechanism for addressing extreme events is by attenuation, through ponds and wetlands, for example. Only relatively limited infiltration can occur during the most extreme events, due to soil saturation and the limited period of flooding. Pervious pavements, where water can percolate through the stone, are also very effective at attenuation, even where there is no underlying soil-infiltration capacity.

There are, however, two types of extreme events. Some events cause problems catchment-wide, while others are intense short storms affecting the local area. Although SUDS will respond to both in much the same way, the conditions before the event will differ in how much of the available storage is already taken up. This makes SUDS more effective in dealing with the second type of event.

Opportunities for SUDS differ between building them into new developments and retrofitting to existing areas. There are also variations between categories and densities of urban zones. Some units effectively have no footprint and can be underground. For example, car parks can have storage tanks underneath them to attenuate runoff. Alternatively, pervious pavements can provide infiltration capacity. However, in new residential developments, SUDS can take around 10% of the land area. Thus SUDS can be very effective in new developments in the management of extreme events, while in heavily built-up existing developments the application of SUDS may not become extensive under any of the scenarios.

The timeframe for widespread implementation of SUDS depends on the legislative framework rather than the technology. In the longer term we may find that extreme situations call for extreme solutions in terms of both building and flow management. We could, for example, see the creation of urban marinas as in the Netherlands. By 2080 government will have a better understanding of the issues of cost, acceptability and sustainability.

The responsibility for standard pipe drainage is currently very clear and is split between water companies, local authorities, highways agencies and private owners. In contrast, SUDS are not 'owned' by any party other than a private land owner. By 2080, the division of responsibilities between the various parties and the legal definitions of drainage will have been resolved. In addition, institutional differences between Scotland and England may result in the solution to this problem moving in different directions in each region.

Sewerage undertakers are already responsible for piped drainage. Under some scenarios, by 2080 their role may have expanded to include the management of overland flow down roads and the adoption of SUDS. The key factor here will be the attitude of the other regulatory agencies. Significant legal reforms will have defined drainage responsibilities differently by 2080.

Over the next 30 years we need to ensure that we are well placed to cope with further climate change up to 2080. This will involve ensuring clarity in drainage responsibilities and that the use of better overland-flow routing is in place, including addressing management issues as well as technical problems. Again, we may also need to look into more extreme options, such as raised emergency-communication roads.

The awareness and understanding of SUDS and above-ground drainage systems will need to be promoted to educate stakeholders to take more responsibility for local drainage. SUDS may or may not be the most sustainable option and need to be considered in terms of the three pillars of sustainability for each development individually.

3.1.4 Urban Response Group 4 – Groundwater Control

Groundwater control involves the management of groundwater in urban areas at levels that allow infiltration into the ground during high precipitation, so preventing flooding. This response also involves preventing groundwater from rising to levels that flood basements and to prevent emergence on urban surfaces. It also includes measures to prevent water resurfacing from aquifers. (We deal with infiltration under the urban response group Source Control and Above-Ground Pathways and in the wider catchment based responses.)

Interactions exist notably with the response groups Source Control and Above-Ground Pathways and Urban Area Development, Operation and Form.

The specific measures in this response group are:

- Controlling groundwater levels, by pumping, for example.
- Preventing groundwater from entering pipes to maintain sewer capacity.
- Maintenance of permeable land cover.

The soil moisture deficit is an indicator of the capacity for the upper soil levels to accept infiltrating water. When this deficit is low or zero, infiltration no longer functions. In future, higher ambient temperatures will create a more dynamic interaction between the evaporation from upper layers of the soil and infiltrating flows.

Solutions to lowering groundwater levels locally involve prevention via, for example, pumping, french drains and other drainage, and for protection, local floodproofing and pumping (although the latter may not be feasible due to the typically large scale of groundwater flooding when it does occur). Responses in terms of warning and prediction can usually be more measured than for other types of flooding due to the longer build-up times for groundwater. Solutions based on groundwater management are more complex than, for example, those used for river flooding, which may include diversionary action that may have impacts downstream.

Groundwater management alone cannot materially influence flood risk. It has to be considered in relation to the inputs and outputs. Inputs may come from upstream aquifers, local infiltration systems, direct infiltration or from adjacent rivers. The most useful approach could be to consider groundwater for supply purposes, together with the control of flood risk from rising groundwater. This suggests an opportunity to infiltrate a similar amount to what is abstracted from surface runoff.

It is important to relate the local management of groundwater to what happens in downstream watercourses. In general, flow through soils to a river, will help to attenuate the speed at which floodwaves arrive, compared with simply routing surface runoff through other control systems. It is not possible to generalise as to how effective this may be. The application of methods to manage groundwater in terms of flooding both locally and the consequential downstream potential effects is complex, and will be specific to local circumstances, requiring specialist skills. It is also likely to require the management of very large volumes of water, by pumping diversion or otherwise.

Where groundwater levels are high, there is higher risk of ingress into piped drainage. This is considered in the responses on the wider catchment scale (see Chapter 2). It is also considered in the response group Main Drainage, Form, Maintenance and Operation. Where this is a problem, it is important to ensure that the capacity of the piped drainage is maintained by investment in asset serviceability.

The area of permeable land surface in a catchment will have an important effect on relative groundwater levels. Within the urban area itself, an increase in paved surfaces may help to reduce groundwater levels, making it more practicable to use infiltration drainage systems (see also Source Control).

Although no statutory body is responsible for groundwater flooding, by 2080, new institutional arrangements might clarify this situation. It is considered likely that several agencies will be involved in groundwater management.

The management of groundwater to control flood risk is a long-term large-scale response. It entails large-volume management with possible high-energy utilisation. It is likely that this type of response may be suitable only in areas where water is normally scarce at certain times of year. It is not likely to be a feasible response to ensure that local infiltration systems continue to operate. Hence there could be two types of response. In resource-stressed areas, 'forced recharge' of groundwater could reduce flooding. In areas where groundwater levels are frequently high, then pumping could lower the levels. Once again, this response assumes appropriate funding and consideration of the sustainability of these approaches.

3.1.5 Urban Response Group 5 – Storage Above and Below Ground

This response group concerns additional storage volume. This can be provided by physical structures above or below ground that set out to increase the potential of the urban drainage system to act as a flood-defence mechanism.

Storage volume can take several forms in urban drainage. The focus here is on: in-sewer storage; the capacity of sewer network conduits, tanks and ponds; and discrete storage provided by physical structures above and below ground.

This response group overlaps with that for Source Control and Above-Gound Pathways. There is clear interaction between the storage responses and the source control responses, as some of the measures can be categorised as being in both groups. Wide adoption of Source Control type responses – that is more distributed storage and retention – could reduce the volumes that centralised storage has to accommodate. This would alter its main function from a stormwater flood-control strategy into a water-quality control strategy as well as a back-up strategy for extreme events. This may be a useful win-win situation.

The specific measures are:

- Detention ponds.
- Mini-storage.
- Storage along or adjacent to the flood system.

- Local ponding in flood-retention areas.
- Underground storage.
- Temporary flood storage, in parkland, for example.

There are also informal storage elements within the urban landscape, where ponding can occur, including roads.

If a drainage system has additional storage volume, it can temporarily store runoff that would otherwise overflow defences, reducing the frequency of flooding. Stored water flows back into the network over an extended time period, reducing the peak discharge flow, by more than 80% in some cases. This measure could be the most effective response in urban areas.

Below-ground sewer storage schemes are designed to achieve standard flooding-protection levels, depending on location. Under the various scenarios, these are likely to vary. Many below-ground structures are considerably older than design standards of protection and are likely to still be operational by 2080.

Space and planning limitations can make it very difficult to retrofit storage (both above and below ground) into existing urban areas. This is less of an issue in new developments, although there will always be pressure to minimise surface land take. Thus this response group has important interactions with the Urban Form group.

Active management, with real-time control (RTC) systems, could improve the effectiveness of below-ground storage tanks, with a potential overall gain in capacity of 50% when used with the main drainage system as a whole. By 2080, technology will be so advanced that such systems, coupled with real-time rainfall information, will be routinely used. They are also relatively easy to retrofit.

There are difficulties with the ownership and operation of above-ground storage as described in Urban Response Group 3, Source Control and Above-Ground Pathways. Centralised storage is an engineering solution, which is effective in combating flooding and is immediate in its effectiveness. It starts to contribute at maximum capacity immediately after work completion. It is, however, expensive in terms of capital costs and material-energy use. This may be a poor solution in sustainability terms, although it has a sound track record and well-established effectiveness. If the system is coupled with RTC strategies it could lead to a reduction in flood risk and an improvement in river-water quality (because of reduced overflows). Even existing sewerage could be made more effective by using RTC to maximise the use of the estimated typical 50% spare capacity under extreme events. Nonetheless it is still likely that additional storage will be needed in the future, over and above any better utilisation of existing spare capacity.

3.1.6 Urban Response Group 6 – Main Drainage Form, Maintenance and Operation

This response group consists of the physical form of the urban drainage system and its operation with respect to the impact on flood control. It can comprise both pipes and other (surface) conveyance systems. The response group includes:

- System form: sewer separation.
- Managing wrong connections.
- Limiting inflows by constricting inlets or surface disconnections.
- Limiting groundwater infiltration into sewers by rehabilitation.
- Localised non-return valves.
- Increasing pipe capacity (see also Storage Above and Below Ground).
- Operation: real-time control.
- Pumping.
- Maintenance: planned and integrated.

Several of these options are also covered in other responses, in particular, stormwater disconnection practices and real-time control systems.

The UK has almost 100% fully sewered communities. It could maintain this position under several scenarios, although a few remote communities may be serviced differently under the scenarios World Markets and National Enterprise. The existing asset base puts a huge inertia on potential major innovations that require a different approach. Hence there is a momentum to extend sewerage systems in response to capacity problems, increasing storage and possibly reducing stormwater travel time. However, this approach is expensive and questionable in sustainability terms. Nonetheless, it may prove attractive under certain scenarios, such as World Markets.

Sewer separation has been considered and practised for many years as a way of reducing the frequency and severity of flooding in urban areas. The longer-term benefits could, though, be limited, particularly because it is difficult to keep systems separate.

Managing wrong connections could be considered to help to reduce system overload, due to misconnections into the separate foul and storm pipes. This would require a concerted management effort, rather than a technical solution. In the future, new technologies should manage wrong connections more effectively than at present. This will become a standard response measure, even in existing networks.

By 2080, there may be greater usage of pressurised foul-sewerage, as in Holland. This approach would help to reduce health risks by preventing the mixing of storm and foul water, when flooding does occur.

We consider limiting inflows of stormwater by constricting inlets or disconnecting roofs and paved areas in more detail in Urban Response Group 3, Source Control and Above-Ground Pathways. Limiting groundwater infiltration by sealing cracks, fissures and joints in sewers will increase the capacity available for storm flows. Localised non-return valves may be used, where system surcharge is relatively frequent, to avoid basement flooding. Specific pumping may be feasible away from an area at risk, although downstream impacts need to be considered.

Apart from pumping, which is expensive and high in energy use and may just move the problem elsewhere, the most promising response in terms of system operation is real-time control (RTC) as mentioned in Urban Response Group 5, Storage Above and Below Ground. This approach requires 'excess' physical storage within the system to fully utilise and exploit the potential of RTC. It is estimated, however, that some 50% of the storage in existing systems is under-utilised as there is no dynamic control and, as stated in Urban Response Group 5, this should be routine by 2080.

Proactive or planned drainage-system maintenance is an area of differing interest under the different scenarios. The main link to flooding is through sewers that are in poor condition or where sediment and fat accumulate. This can significantly reduce the capacity of the sewer system and hence reduce flood protection. Flood protection can potentially be improved by establishing better-organised, prioritised and integrated maintenance and this should be in place under, for example, the World Markets scenario. However, under other scenarios, such as National Enterprise, this may not happen. For this to come about, all the institutions responsible for providing stormwater management services in urban areas will require a more integrated perspective.

Dealing with a problem locally, through low-impact development, is normally considered to be the more sustainable approach. Hence, reducing inputs of stormwater into the system is potentially more sustainable than building more separate sewer systems or separating existing systems. Similarly, it is more sustainable to remove sediments and fats at source, perhaps by street sweeping and proper trap maintenance, rather than to let these mix with wastewater and stormwater in the sewer system. It is unwise, however, to label a particular technology or approach as 'sustainable' or 'unsustainable' because both 'low-tech' and 'high-tech' solutions will have their place, depending on context. This implies that RTC solutions may be more sustainable, perhaps in the densest urban areas that are already fully sewered.

3.2 Scoring and ranking

The background to the scoring and ranking of the response groups is the same as in Chapter 2 and is not reproduced here.

Table 3.2 lists the driver risk multiplier scores, and the overall increase in risk deduced from the quantification analysis reported in Volume I. These scores correspond to the 2080s.

Table 3.2 **Normalised risk multiplier scores for flood risk associated with each driver in the 2080s**

Risk driver	Driver type		Factor by which flood risk is multiplied in 2080s under the Foresight future scenarios			
			World Markets	National Enterprise	Local Stewardship	Global Sustainability
Precipitation	B	P	2.4	2.3	2.2	2.1
Urbanisation	R	P	2	1.7	1.5	1.4
Management of Peri-Urban Rural Land	B	P	1.4	1.0	0.7	0.8
Environmental Regulation	B	P	1.0	1.0	2.8	4.0
Urban Watercourse Conveyance, Blockage and Sedimentation	B	P	2.0	1.2	0.9	1.1
Sewer, Conveyance, Blockage and Sedimentation	R	P	3.0	2.0	0.9	1.1
Impact of External Flooding	F	C	1.8	1.4	2.0	1.0
Intra-Urban Asset Deterioration	B	P	4.0	2.5	1.0	1.2
Stakeholder Behaviour	B	P	3.0	4.7	2.2	2.1
Public Attitudes and Expectations	B	C	Known to be important but not quantified			
Buildings and Contents	C	C	6.4	4.5	0.7	1.9
Urban Impacts	C	C	2.0	1.6	1.0	1.1
Infrastructure Impacts	C	C	9.0	5.2	0.7	1.5
Social Impacts	C	C	19.8	3.6	6.1	3.2
Science and Technology	C	C	Known to be important but not quantified			
Overall total risk multiplier			29	19	3	7

Key: F = fluvial flood driver; R = pluvial flood driver; B = driver affecting both fluvial and/or fluvial/coastal flood risk
P = driver affecting flood probability; C = driver affecting flood consequence

The final row in Table 3.2 shows the overall risk multiplier for the scenarios derived from the analysis reported in Volume I, Chapter 5. In assessing the effectiveness of responses to increased flood risk, the most important scores in Table 3.2 are these overall values for each scenario – these are the values by which overall flood risk would increase under a baseline condition (with no changes in flood management). It is these risk increases which the responses seek to reduce.

3.2.1 Methodology

Assessment of flood-risk reduction

For each scenario, the specialist team for each response group considered the effect on the projected risk multiplier, if the measures in each response group were implemented in a manner consistent with the opportunities and constraints identified for that scenario.

To assess the reduction in the flood-risk multiplier for each response group, experts carefully considered the effect of the measures in the group on the risk increases associated with the relevant drivers of flood risk. In doing so, reference was made to the risk increase listed for each driver in Table 3.2. However, experts were mindful that the *overall* increase in risk is neither a simple multiple of these component effects (the fully independent case), nor the maximum value (the fully dependent case). Thus, the flood-risk reductions associated with response impacts on individual drivers provides only a general guide to the overall reduction in flood risk that a particular response group might achieve.

In addition, the modelling studies (described in Chapter 6), provide guidance on the potential effectiveness of the responses dealing with the Precipitation driver and to a lesser extent, the Urbanisation driver.

Revised risk-multiplier scores were entered into a Responses Ranking Spreadsheet with the impact of each response group scored as a multiplier of the overall risk multiplier predicted under the baseline assumption. Compilation, analysis and display of the risk-reduction scores was then undertaken to generate tables of response-group scores and rankings.

3.2.2 Summary results

Response scores

The results of the scoring (S) and ranking (R) exercise for the degree of reduction in flood risk that each response group could achieve under each scenario are listed in Tables 3.3 and 3.4. (The complete results are listed in the Flood Risk Ranking Spreadsheet, which may be found in the relevant Foresight Project Report (OST 2004)).

Table 3.3 **Scores (S = multiplier on baseline risk) for responses in reducing flood risk**

	Response Group	World Markets	National Enterprise	Local Stewardship	Global Sustainability
1.	Building Development, Operation and Form	1.0	1.0	0.8	0.5
2.	Urban Area Development, Operation and Form	0.8	1.0	0.8	0.5
3.	Source Control and Above-Ground Pathways	0.8	1.0	0.7	0.5
4.	Groundwater Control	1.0	1.0	1.0	1.0
5.	Storage Above and Below Ground	0.8	1.0	0.8	0.5
6.	Main Drainage Form, Maintenance and Operation	0.9	0.7	1.0	0.8

Table 3.4 **Response groups ranked by potential for flood-risk reduction in the 2080s**

Rank	World Markets	National Enterprise	Local Stewardship	Global Sustainability
1	Storage Above and Below Ground	Main Drainage Form, Maintenance and Operation	Source Control (+Above-Ground Pathways)	Storage Above and Below Ground
2	Source Control (+Above-Ground Pathways)	Storage Above and Below Ground	Storage Above and Below Ground	Source Control (+Above-Ground Pathways)
3	Urban Area Development, Operation and Form	Groundwater Control	Urban Area Development, Operation and Form	Urban Area Development, Operation and Form
4	Main Drainage Form, Maintenance and Operation	Source Control (+Above-Ground Pathways)	Building Development, Operation and Form	Building Development, Operation and Form
5	Groundwater Control	Urban Area Development, Operation and Form	Main Drainage Form, Maintenance and Operation	Main Drainage Form, Maintenance and Operation
6	Building Development, Operation and Form	Building Development, Operation and Form	Groundwater Control	Groundwater Control

Legend

Interpretation	Colour code
Major reduction in flood risk (S < 0.7)	red
Marked reduction in flood risk (0.7 < S < 0.9)	yellow
Minor reduction in flood risk (0.9 < S < 1.0)	green
No impact (S ~ 1.0)	blue

3.3 Uncertainty in operation of the responses

3.3.1 Methodology

The Foresight project has always recognised that there is considerable uncertainty regarding most aspects of change in flood risk in the next 30 to 100 years.

Scientific uncertainty concerns our lack of understanding of physical, social and environmental processes. For example, there are shortcomings in our ability to describe the mechanics of flooding mathematically. However, there are other sources of uncertainty besides limited scientific knowledge – uncertainty must be more broadly defined, as described in Chapter 2.

There are uncertainties associated with all the possible flood-management responses. Some of these uncertainties are scientific, and some non-scientific: for example, there will be uncertainty whether, under a particular scenario, a competent authority will exist to ensure that appropriate response activities are undertaken and that the response is effective in reducing flood risk. This shows that questions of uncertainty are strongly linked to questions of governance (see Chapter 7).

In performing their analysis, the specialists were instructed to be frank about the degree of uncertainty concerning each possible response group. A section of the response descriptions (see Appendix B) was assigned to cover this issue – this was used to set out those aspects of each response group that are most uncertain, and to identify where scientific or governance-related uncertainty is greatest. From this information, recommendations for further research were developed.

Uncertainty was further considered in assessing the flood-risk reductions that might be achieved by each response group under each of the socioeconomic/climatic scenarios. In particular, experts devised upper and lower bounds for the impact of each response group on flood risk, using the bounds to express the degree of uncertainty in the results. These bands of uncertainty were entered into the Responses Ranking Spreadsheet, alongside the best estimates.

3.3.2 Uncertainty in Response Group 1 – Building Development, Operation and Form

The interactions between the building and downstream curtilage identified in the responses make it difficult to quantify certainty of effectiveness. For the solutions proposed, the degree of impact, as well as the degree of certainty, will therefore vary.

Sizing and maintenance of roof drainage – incorporating owner/occupier awareness – offers a relatively high degree of certainty, with the caveat that, as well as precipitation, the effect of building characteristics and wind loading introduce uncertainty. Making the building envelope more flood-resistant also offers a high degree of certainty. However, this approach should only be adopted as part of a wider water-management scheme.

Specified building-drainage attenuation has slightly less certainty, as the required time-dependent impact will vary as a result of external flow interactions. Specification of the building and urban/local drainage pipework also offers similar certainty when based on best predictive techniques. However, the interactions defined above introduce significant uncertainty. Restrictions on building and local/urban land management, and the adoption of strategic management approaches both have the potential for a significant reduction in flood risk. However, the degree of certainty is particularly difficult to specify given the complex interactions of urban water flow at the top of drainage catchments.

There is little certainty about the future form of buildings under the various scenarios, or the scale of the interactions between the drainage components. New ideas such as green roofs have not yet been fully tested in UK conditions, nor has their acceptability and take-up by stakeholders. Cost is a key issue here. Together with the flood resistance of buildings it will depend on the cost/benefit of reduced risk against cost of work, which may be relatively easy to justify. With green roofs, rainwater collection and flow-attenuation systems, the saving does not yet accrue to the householder – although it may to the developer in enabling a development to go ahead. Hence this could lead to differential take-up according to scenario.

In addition, while there are good prediction tools for runoff from buildings and drainage pipes, the interactive effects and inclusion of above-ground flood flows is only recently the subject of new research. When sediment is included, an important element for whole-life performance, the uncertainty increases.

In this response area, the effects of existing property stocks, and the long time needed to renovate these, mean that there are major uncertainties about the future mix of new and old property in the urban area. New build may well have effective flood control, but old properties may still operate to old and inadequate standards. There are also uncertainties about the translation of new regulations into practice, and the time lags and barriers to implementation.

3.3.3 Uncertainty in Response Group 2 – Urban Area Development, Operation and Form (including sacrificial areas)

The management of urbanisation is clearly an important response option, as demonstrated in the quantitative analysis (see Chapter 6). The processes of runoff from hard surfaces are largely understood. However, there are limitations in the knowledge in the models used. These relate to impervious areas and longer-term responses to sequences of storms that are important for integrated system management. The varied nature of urban development, operation and form requires an understanding that uncertainties may not be equally distributed on either spatial or development grounds. Differing levels of uncertainty arise when considering either new development or retrofitting as for Building Form above.

It is difficult to foresee changes in the governance system that may improve the prospects for adaptive responses. Currently these are untested and unproven. In addition, the controls concerning retrofitting are less well established. There is a general problem of synchronising and integrating planning responses at different scales and times. It would be expected that at least some of the barriers would have been overcome by 2030 in all scenarios if climate change leads to an increase in flood risk that requires a planning response. What may also need to happen is a planned move out of areas where the risk becomes unacceptable. This would also be uncertain as it could depend on the bias towards economic/ sustainable solutions under a given scenario.

There are uncertainties about the translation of regulations into practice and the time lags and barriers to implementation. It is not clear how to bring about the required changes in stakeholder behaviour and attitudes, for example, in the location preferences of developers and consumers.

3.3.4 Uncertainty in Response Group 3 – Source Control and Above-Ground Pathways

There are currently no effective computational models of these systems. Ideally, models need to include continuous simulation to accommodate sequential storms and to better model the drainage system in an integrated catchment-wide way allowing the development of the most effective responses. Also, we know little about the effects of changing soil moisture during and between events in SUDS structures.

The current approach to drainage design does not allow us to predict the performance of a SUDS drainage system which is usually based on a complex mix of options. It is, therefore, difficult to define the effectiveness of solutions in meeting flooding criteria.

The effectiveness of source control measures at the catchment scale for extreme events is uncertain. This is also true for other types of drainage system, although we have a longer history of using piped drainage. However, as urban areas are usually small as a proportion of a whole catchment, this issue is usually subsumed into the general context of land use and catchment flood protection.

The perceived environmental benefits of SUDS, compared with traditional drainage, make it likely that these systems will become common in new developments, subject to the resolution of the issue of governance, which is by no means certain. The retrofit of SUDS into existing developments will occur, but at a slower pace unless there is a major government-led initiative, such as that used to promote loft insulation. Retrofitting may thus have a limited impact on flood protection.

While we cannot be certain that overland flow paths will be used in existing developments, their use in new developments is not in doubt.

3.3.5 Uncertainty in Response Group 4 – Groundwater Control

Because little coherent work has been done on groundwater problems, the field is very uncertain. However, some observations can still be made.

A major element of uncertainty is the lack of clear responsibility for groundwater flooding and hence the implementation of response measures. The uncertainties here in terms of urban flood management are also covered in Urban Response Group 3, which includes infiltration drainage systems.

There is a lack of knowledge about both the nature and scale of the problems and therefore about the effectiveness of responses. In addition, as each response measure is location-specific, it is impossible to generalise about the uncertainties in implementation.

However, in terms of uncertainty about response-effectiveness, local solutions are the most certain, and widespread integrated responses the most uncertain. Floodproofing buildings, cut-off drains and external pumping of groundwater are probably the best understood, while integrated water management using groundwater recharge conjunctively to control flooding is the least.

There is no information about the relative economics of the large-scale groundwater-management responses.

3.3.6 Uncertainty in Response Group 5 – Storage Above and Below Ground

The design and operation of stormwater storage structures is well researched, understood and practised. There is little uncertainty regarding flood-control aspects of storage. However, risk-based approaches are currently not used for the design of in-sewer storage systems and inadequate account is taken of system design and operational uncertainty. This is because the focus of design is usually on the management of the spill of pollutants from combined sewer outflows with storage rather than for flood control.

Two other issues are relevant to storage application and use, which are also uncertain and are attracting current research attention. The first issue concerns optimal storage use in terms of real-time control (RTC) of the integrated system both in terms of water quantity and quality. Current research indicates higher potential for RTC in complex systems with long flow times between reservoirs, large static storage volumes and uneven topographical distribution of volumes, but each site will be individually specific.

The second issue concerns high loading of pollutants to urban detention basins. This raises concerns about: long-term siltation; the loss of effective storage volume and water quality, especially concerning health risks. Design models are limited in their ability to predict sediment removal efficiencies (event-based or annual), and hence the rate at which storage capacity declines and the need to dispose of the waste is uncertain. This is a whole-life performance issue.

Confusion over adoption, operation and maintenance responsibilities of (particularly distributed) storage schemes is a practical and real source of uncertainty in their provision as part of a flood control scheme. In this respect, both regulatory (planning, administrative and licence-based) approaches and public/information campaigns are needed to influence and achieve satisfactory outcomes. In summary, there is less uncertainty regarding the effectiveness of below-ground storage systems than for above-ground systems.

3.3.7 Uncertainty in Response Group 6 – Main Drainage Form, Maintenance and Operation

The modelling, design and construction of conventional sewer systems is well established, with low uncertainty, although the modelling of extreme events is not proven. However, there is more uncertainty surrounding the performance of modifications and improvements to the system, unless these are traditional extensions. Procedures, such as sewer separation, will, if specifically designed, have a beneficial effect on flood control. However, there is uncertainty in the duration of that improvement, which is also an issue of sustainability. Techniques such as the improved management of wrong connections are unproven.

Proposals for adoption of private assets by sewerage undertakers are under discussion and, if this happens, there may be better opportunities for integrated system operation.

In terms of system operation, approaches employing real-time control imply increased commitment to maintenance and a higher risk of failure as the system has less built-in redundancy due to the 'optimal configuration'. This is a major reason why so few RTC schemes have been implemented. Hence there is major uncertainty as to their likely take-up, even though the technology is well established in many countries.

Sewer maintenance is well established. Improved procedures are in place in some locations. So far, the link between better maintenance practice and increased flood protection is unproven and hence uncertain, as are the benefits and feasibility of controlling sediment at source.

Both of the above are uncertain. This could be because operators are predisposed to maintaining the effectiveness of existing assets, rather than maximising their performance. Future regulation and institutional arrangements could encourage the maximum use of existing assets, but these measures are uncertain. This is also linked to an unwillingness to adopt whole-life performance perspectives as a step towards sustainable operation.

3.4 Uncertainty scores and rankings

Experts accounted for uncertainty in assessing the impact of responses by evaluating upper- and lower-bound estimates to their best estimate of the flood-risk multiplier (S) for each response group. These upper-bound and lower-bound scores then defined a band of uncertainty around the best estimate of a response's impact on flood risk. The upper- and lower-bound assessments of the new flood-risk multiplier were then entered into the Responses Ranking Spreadsheet.

The results of the uncertainty assessment, expressed in terms of the bandwidth around the best estimate of reduction in flood risk that each response group could achieve for each future scenario are listed in Table 3.5. The complete results are listed in the Flood Risk Ranking Spreadsheet, which may be found in the relevant Foresight Project Report (OST 2004). For ease of comparison with their rankings in Table 3.10, responses are listed in the same order in Table 3.5.

Table 3.5 **Uncertainty associated with response groups (note: the order of response groups in this table reflects their flood risk impact ranks, as listed in Table 3.3)**

Rank	World Markets	National Enterprise	Local Stewardship	Global Sustainability
1	Storage Above and Below Ground	Main Drainage Form, Maintenance and Operation	Source Control (+Above-Ground Pathways)	Storage Above and Below Ground
2	Source Control (+Above-Ground Pathways)	Storage Above and Below Ground	Storage Above and Below Ground	Source Control (+Above-Ground Pathways)
3	Urban Area Development, Operation and Form	Groundwater Control	Urban Area Development, Operation and Form	Urban Area Development, Operation and Form
4	Main Drainage Form, Maintenance and Operation	Source Control (+Above-Ground Pathways)	Building Development, Operation and Form	Building Development, Operation and Form
5	Groundwater Control	Urban Area Development, Operation and Form	Main Drainage Form, Maintenance and Operation	Main Drainage Form, Maintenance and Operation
6	Building Development, Operation and Form	Building Development, Operation and Form	Groundwater Control	Groundwater Control

Legend	Uncertainty band category	Uncertainty bandwidth (B) (B = ratio of upper to lower bound estimates of flood risk impact multiplier)	Colour code
	High	B > 1.5	
	Medium	1.5 > B > 1.0	
	Low	B < 1.0	

3.5 Sustainability and response ranking

The sustainability analysis of the response rankings follows the methodology presented in Chapter 2. Full details of the results are presented as spider diagrams in Appendix B. Table 3.6 shows the effect of the consideration of the five sustainability measures on the response flood-risk ranking.

In Chapter 2 it was shown that some of the most effective proposed responses to flood risk are likely to have significant adverse effects, mainly on social justice and environmental quality. They thus fail to achieve sustainability, particularly under the scenarios where market forces have most freedom, World Markets and National Enterprise.

In contrast, consideration of the sustainability criteria for the urban environment has a significant impact on only one response, Urban Area Development, Operation and Form, under the World Markets scenario. This response fails on cost-effectiveness, social justice and precaution. In this scenario there will be only limited attempts to respond within a well-planned framework; and as a consequence, responses will be piecemeal and not particularly cost-effective. The protection of the wealthy will be the priority and hence poorer members of society will be at greater risk. The only other urban response group to fail on one of the pillars of sustainability (social justice) was Source Control and Above-Ground Pathways under the World Markets scenario.

The urban response group, Main Drainage Form, Maintenance and Operation performed particularly well across scenarios, except Local Stewardship, and failed none of the sustainability criteria. It remained the only effective response under the National Enterprise scenario. However, this was for the operation of current systems. Any large-scale construction of underground drainage is known not to be very sustainable on environmental grounds, energy use and emissions, and economic grounds.

Table 3.6 **Sustainability performance of response groups ranked by potential flood-risk reduction. The small left-hand panel (solid colours) in each column indicates the potential for flood-risk reduction, while the right panel (using both solid and degraded colours) shows the effect of failing to meet one or more of the thresholds of acceptable performance in sustainability**

World Markets	National Enterprise	Local Stewardship	Global Sustainability
Storage Above and Below Ground	Main Drainage Form, Maintenance and Operation	Source Control	Storage Above and Below Ground
Source Control	Storage Above and Below Ground	Storage Above and Below Ground	Source Control
Urban Area Development, Operation and Form	Groundwater Control	Urban Area Development, Operation and Form	Urban Area Development, Operation and Form
Main Drainage Form, Maintenance and Operation	Source Control	Building Development, Operation and Form	Building Development, Operation and Form
Groundwater Control	Urban Area Development, Operation and Form	Main Drainage Form, Maintenance and Operation	Main Drainage Form, Maintenance and Operation
Building Development, Operation and Form	Building Development, Operation and Form	Groundwater Control	Groundwater Control

Major reduction in flood risk ($S < 0.7$)

Marked reduction in flood risk ($0.7 < S < 0.9$)

Minor reduction in flood risk ($0.9 < S < 1.0$)

Fails on Precaution or Robustness

Fails on 1 of Cost-Effectiveness, Environmental Quality or Social Justice

Ineffective in reducing flood risk or where colour is degraded fails on 2 of Cost-Effectiveness, Environmental Quality or Social Justice

Table 3.7 shows how many of the options failed under each of the sustainability measures. The two consumer-focused and market-focused scenarios, where the climate-change regime is most intense, miss the thresholds most frequently, predominantly on the grounds of cost-effectiveness and social justice.

Table 3.7 **Summed failures of the six response groups on sustainability criteria**

	Cost-effectiveness	Environmental quality	Social justice	Precaution	Robustness	Totals
World Markets	2	1	3	3	3	12
National Enterprise	2	0	0	1	3	6
Local Stewardship	0	0	0	0	3	3
Global Sustainability	0	0	0	0	2	2

National Enterprise and particularly World Markets also fail to take an adequately precautionary approach more often than the more community-oriented scenarios. However, the only response that failed on the grounds of precaution and produced a reduction in flood risk was the urban response group, Storage Above and Below Ground.

The question of robustness across scenarios shows a distinctive pattern, with two responses scoring low across all scenarios:

- Building Development, Operation and Form
- Groundwater Control

They rely on co-ordination between agencies and, in the case of Groundwater Control there is no clear pattern of governance. It is also difficult to see how these responses can have major effects other than in local areas. They are not very effective at a national scale. In addition, the urban response groups – Storage Above and Below Ground and Urban Area Development, Operation and Form – did not meet the robustness criterion under the scenarios National Enterprise, Local Stewardship and World Markets.

In summary, this analysis shows that the most effective responses in reducing flood risk are affected relatively little by consideration of the sustainability criteria, except under the World Markets scenario. In this case, there are significant concerns over the implementation of measures associated with Urban Area Development, Operation and Form.