Highways Agency
Contract No: 3/323 F

Resilience of the HA Network:

Review of flooding incidents in Autumn 2000

R W P May
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Report SR 584
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Contract

This report describes work carried out for the Highways Agency (HA) by HR Wallingford Ltd and Transport Research Laboratory Ltd (TRL) under HA Contract No. 3/323 F. The HA Designated Officer for the project was Mr S V Santhalingam. The HR job number was MBS 0274. The report was prepared by Mr R W P May of HR and Mr A J Todd of TRL.

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Date ....

Executive summary

Highways Agency Contract No: 3/323 F

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Background to study

Periods of heavy prolonged rainfall occurred in most parts of England between September and November 2000. A particularly severe storm affected many parts of the country on 29/30 October 2000 and heavy rainfall also continued in the north-east of England during the first week of November. These storms resulted in a considerable number of temporary lane or road closures on all types of roads including those operated by the Highways Agency (HA). Some of the incidents on the HA Network were caused by fallen trees and high winds but the great majority were due either to drainage systems being overloaded or to surface flooding from rivers or other watercourses.

This study was commissioned in December 2000 by the Quality Services, Traffic Safety and Environment Division of the HA to review the performance of the Network during the storms of Autumn 2000 and identify improvements that would improve its resilience to adverse weather conditions in the future. The main objectives of the study were to:

- Review data about the flooding incidents that occurred on the HA Network in Autumn 2000 and collect additional information by means of visits to selected sites.

- Identify appropriate changes in the design, maintenance and operation of HA roads that would improve the ability of highway drainage systems to deal with severe storms and prolonged rainfall.

Review of data on flooding incidents

1. The total amounts of rain that fell in England during the months of October and November 2000 were unusually large and could be expected to occur on average only once every 100 to 200 years. Individual storms were less unusual in terms of their intensity and frequency of occurrence. The greatest amount of rainfall during the storm on 29/30 October 2000 was 64mm (recorded at Enfield, North London) which could be expected to occur about once every 30 years.

2. Since rainfall runs off rapidly from paved surfaces, highway drainage systems have to be able to deal with peak rainfall intensity rates occurring in short storms lasting about five to ten minutes. This type of rainfall is associated with heavy thunderstorms which tend to happen during summer months when the adjacent unpaved areas are relatively dry. Surface water drainage systems are therefore normally sized to cater for high rates of runoff from the road surface but with little assumed additional runoff from adjacent areas.

3. Between 12 October and 2 January 2001, a total of 195 storm-related incidents were reported to have occurred on the HA Network. The HA Areas that experienced the most incidents were (in decreasing order): Area 11 (to the east of Birmingham), Area 14 (Derby to Manchester), Area 18 (York to Durham), Area 9 (to the west of Birmingham), Area 7 (Kettering to Doncaster), Area 8 (Watford to Peterborough) and Area 3 (Poole to Crawley). However, flooding incidents in Area 3 on the M25 motorway and the A3 are likely to have caused the largest individual disruptions to traffic. About 60% of all the incidents were caused by the severe storm on 29/30 October 2000.

4. Out of the total of 195 storm-related incidents, about 8% were due to fallen trees and 5% to miscellaneous causes such as high winds and accidents, while in 3% of cases the causes were not reported. Flooding was therefore responsible for about 84% of the storm-related incidents on the HA Network in Autumn 2000.

5. Of the incidents related to flooding, approximately 65% were associated with the performance of the drainage systems and about 35% were due to high water levels in adjacent rivers or streams causing inundation of roads or surcharging of outfalls. The problems affecting the performance of the drainage systems were divided fairly equally between inadequate functioning of drainage features such as ditches and culverts, high run-off from fields and non-HA roads, and blockages of gullies and culverts.

Key findings

1. Heavy prolonged rainfall through much of Autumn 2000 resulted in many catchments throughout England being near to saturation conditions with groundwater levels also significantly higher than normal. This caused unusually high rates of runoff to drain onto roads from unpaved areas such as fields, verges and cuttings. The runoff carried considerable amounts of sediment and vegetative debris, including large quantities of leaves blown from trees by high winds. Many rivers and streams also flooded, causing high water levels to persist for long periods along sections of road located in flood plains. In several parts of the country the floods were the largest since 1946 or 1947 and in Yorkshire the River Ouse experienced its largest flood since 1625.

2. Data on the flooding that occurred on the HA Network indicates that the incidents were due either to maintenance/operational issues or to drainage problems arising at the interfaces between the roads and the surrounding catchments.

3. There is no evidence that flooding occurred as a result of the highway drainage systems having insufficient capacity to deal with the amounts of rain falling directly onto the road surfaces. However, in some cases the systems

became overloaded by additional water draining onto the roads from surrounding natural catchments. In other cases the drainage systems were unable to convey the water away because the outfalls were submerged by high water levels in the downstream watercourses or because components of the systems such as gullies, ditches and gratings were blocked by sediment and other debris.

4. Serious disruption to traffic was caused by flooding near Junction 9 of the M25 motorway at Leatherhead on 30 October 2000. Heavy rain falling on a steep but relatively small catchment produced large amounts of runoff that drained onto a section of the motorway in cutting. Calculations indicate that the peak rate of flow from this catchment could have been about twice the design flow rate for the motorway drainage system (based on short-period runoff from the road pavement during heavy summer thunderstorms). The drainage system therefore became overloaded and was also clogged by sediment and debris washed from the upstream catchment. Remedial works involved the construction of a collecting channel at the bottom of the cutting to prevent water draining onto the carriageway.

5. Insufficient longitudinal or transverse gradients on some sections of road or carriageway led to the formation of significant areas of standing water during heavy rain. Although not sufficient to cause road closures, the standing water presented a hazard to road users and resulted in some accidents due to skidding and excessive spray.

6. Several issues related to the cleaning and maintenance of highway drainage systems contributed to the general flooding problems on the HA Network:

   - Responsibilities for maintaining and clearing drainage ditches in fields adjacent to roads had been forgotten or had not been clearly established. In some cases farmers had filled in ditches or allowed them to become blocked by debris, leading to water flooding onto roads during wet weather.

   - Maintenance intervals for gully emptying, channel cleaning, etc specified in the HA Trunk Road Maintenance Manual (TRMM) are in some cases insufficient and are also inflexible in terms of the cleaning techniques that are permitted.

   - The flow capacities of many highway drainage systems appear to have been significantly reduced over the years by the gradual accumulation of sediment in the pipes. This has normally only become apparent when unexpected flooding has occurred or systems have been upgraded as part of new construction works.

   - Responsibilities for sweeping roads and channels were transferred from the HA to Local Authorities under the 1990 Environmental Protection Act. In some cases this has resulted in cleaning not being carried out as frequently as previously, leading to greater accumulations of sediment in channels and along kerbs.

- Responsibilities for maintenance of bar screens, culverts and sections of channel immediately upstream and downstream of culverts are not clearly apportioned between HA Maintaining Agents and other organisations such as the Environment Agency, Local Authorities and Land Drainage Boards. Blocked screens and restrictions in culverts were responsible for a significant number of the reported flooding incidents. The TRMM currently gives no guidance on inspection frequencies for culverts under roads that are smaller than 900 mm in diameter.

7. The ability of maintenance staff to deal with the flooding incidents and also plan regular maintenance has been hampered by a lack of recorded information about the layout of existing highway drainage systems and the location of key structures such as chambers, culverts, etc. Drainage plans and records are seldom available for A-roads and are not complete even in the case of recently built sections of motorway.

8. When sections of road have been upgraded or widened, insufficient attention may sometimes have been given to checking that existing drainage systems will have sufficient flow capacity. In certain cases new site developments adjacent to HA roads have contributed increased amounts of runoff and led to overloading of the HA drainage systems.

9. Although flooding incidents in Autumn 2000 resulted in significant disruption to traffic, most of the incidents were caused either by localised drainage problems or by inundation from adjacent rivers in flood. The lengths of road at direct risk of flooding represent only a small proportion of the total HA Network. A general upgrading of drainage systems along HA roads is therefore not considered to be necessary or appropriate. However, the resilience of the Network to deal with adverse weather conditions can be improved in the future by:

   - more effective and targeted maintenance of highway drainage systems;
   - local improvements to drainage systems at identified critical points;
   - establishment of a data base in each HA Area for recording details of drainage systems and incidents of flooding;
   - better co-ordination between the HA Area, Local Authorities, the Environment Agency, Riparian owners and other authorities dealing with land drainage and rivers;
   - planning to establish suitable diversion routes for traffic in areas at known risk of flooding;
   - pre-emptive maintenance and traffic management in response to forecasts of severe storms or flood warnings from the Environment Agency.

Recommended actions

HA design standards

- A guidance document should be produced on how to assess and deal with runoff from natural catchments that can drain to HA roads during periods of prolonged wet weather. The current HA requirement that drainage systems should be able to prevent surface flooding of carriageways during short-period storms occurring, on average, once every five years is considered to remain valid. However, a separate check should also be made for rarer long-duration storms in case these may provide a more severe design condition.

- A guidance document should be produced on the design of outfalls from highway drainage systems. Information should include design requirements for culverts, recommendations on levels of discharge pipes relative to downstream water levels in watercourses, design of headwalls, and suitable arrangements of bar screens to allow safe access for cleaning during flood conditions.

- Guidance on minimum longitudinal and transverse gradients of carriageways should be reviewed to help reduce the incidence of excessive depths of standing water on roads during wet weather.

- Data on design rainfall intensities for highway drainage systems contained in current HA Advice Notes should be periodically reviewed to take account of existing or anticipated changes in UK rainfall patterns.

- Levels of new and existing HA roads in flood plain areas should be compared with data on 1:100 year flood outlines and water levels published by the Environment Agency for Main Rivers in England.

- Existing HA guidance on the design of highway structures crossing rivers and flood plains should be revised to take account of recent improvements in methods of flood prediction and hydraulic analysis.

Maintenance and operational procedures

- Recommendations in the Trunk Road Maintenance Manual (TRMM) on frequencies of maintenance and inspection for highway drainage systems should be reviewed. Advice should be given for highway culverts of all sizes. A more flexible approach to maintenance should be permitted so that efforts can be targeted more effectively at critical points in drainage systems and on the basis of operational experience.

- Each HA Area should collect and record information about the drainage systems on HA roads in a systematic form so that it can be readily accessed by staff carrying out routine or emergency maintenance. Flooding incidents and maintenance records should be stored on a data base that can be used to identify problem areas and allow maintenance to be targeted more effectively.

- Responsibilities for maintenance and inspection of structures, drainage ditches and watercourses that interface with highway drainage systems should be established through consultation with relevant organisations (eg, Local

Authorities, Environment Agency, Riparian owners, etc). Details should be stored on the flooding data base and be accessible by maintenance staff.

- Suitable diversion routes for traffic in flood-prone areas should be established and agreed with Local Authorities so that a consistent system of diversions can be implemented rapidly in case of flooding. Where possible, signing should facilitate segregation of cars from vehicles with greater ground clearance that may be able to negotiate localised areas of flooding.

- Weather forecasts from the Met Office and flood warnings from the Environment Agency should be monitored and used to initiate preventative maintenance of highway drainage systems if it is considered that adverse conditions may lead to flooding of HA roads and disruption of traffic.

Contents

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1. INTRODUCTION

During October, November and early December 2000, exceptionally heavy rainfall in many parts of England, combined with high winds, led to a significant number of temporary road or lane closures on motorways and high-speed roads operated by the Highways Agency (HA).

A review of storm-related incidents on the HA Network was commissioned by Quality Services, Traffic Safety and Environment Division with the following objectives:

- Collection and analysis of data supplied by HA Areas on the numbers, types and causes of storm-related incidents, with particular reference to those relating to flooding.
- Investigation of specific flooding incidents on Network to determine more detailed information about causes and key issues.
- Identification of possible areas in which HA standards for the design and maintenance of highway drainage systems need to be revised so as to reduce the incidence of flooding problems in the future.
- Preparation of interim and final reports providing details of information collected and recommendations for improvements to existing design and maintenance procedures.

2. CURRENT TYPES OF HA HIGHWAY DRAINAGE

Drainage systems for highways need to fulfil four main functions:

(a) To remove surface water run-off from carriageways in order to provide safe and comfortable driving conditions for road users.

(b) To remove seepage flows and groundwater from the pavement construction in order to maintain the strength and durability of the road.

(c) To convey surface water and seepage flows effectively to suitable discharge points such as watercourses.

(d) To contain or limit pollutants in surface water resulting from accidental spills or from the long-term wash-off of pollutants from vehicles and the road surface.

The main types of surface water system currently permitted by HA specifications and standards are:

- *Concrete surface water channels* with grated gullies (discharging either directly to watercourses or to carrier pipes).

- *Kerbs and grated gullies* connecting to below-ground systems of pipes and chambers (with closer spacings between gullies than with surface water channels).

- *Combined kerb and drainage blocks* (usually precast units forming a continuous internal channel, with water from the road surface draining into the channel through regularly-spaced holes in the side of the integral kerb).

- *Linear drainage channels* (usually precast or manufactured units forming a continuous internal channel with the tops of the units set flush with the road surface and containing slots or gratings to allow water to drain into the channel).

- *Over-the-edge drainage* (on embankments) in which surface water from the road is allowed to flow over the verge to a toe ditch at the base of the embankment.

- *Filter drains*, which consist of trenches filled with granular material running along the verge and having a perforated pipe at the base of the trench to collect surface water that percolates through the granular material.

Filter drains are also able to collect and convey seepage flows from within the pavement construction. All the other types of drainage system mentioned above require separate drainage systems for the seepage flows. A single length of road may often contain several different types of surface water drainage system (for example, in the verge and in the central reserve, or where the road alternates between cutting and embankment).

3. PERFORMANCE REQUIREMENTS FOR HA DRAINAGE SYSTEMS

The principal performance requirement for HA surface water drainage systems is that rainfall run-off from carriageways should be removed rapidly and effectively so as to prevent excessive water depths on the road and also limit the amount of spray. In terms of hydraulic performance, the requirements are:

- Run-off from the road and verge should be contained within the system (eg, pipe or channel) for any storm event that is not exceeded in intensity more than once every year on average.

- Surcharging of the system may occur in rarer storms, but any ponding at the surface should not extend onto the carriageway for any storm event occurring more frequently than once every five years on average.

The words "storm event" are used because the design condition for a drainage system may often be produced by the rainfall that falls during the most intense part of a longer storm; thus a 1 in 1 year storm event lasting five minutes will be the most intense five minutes of rainfall that could be expected to occur, on average, once per year. For a given frequency of occurrence, the average rainfall intensity during a storm event decreases the longer that it lasts. Thus, the maximum intensity occurring for just a few minutes during the peak of a storm may be considerably higher than the average intensity over the whole storm if it lasts for many minutes or hours. Run-off from roads takes place rapidly and surface drainage systems therefore need to be able to cope with the most intense rainfall that can occur in a short period of about 5 – 10 minutes, even though these periods may be part of longer storms with lower average values of intensity.

It is a common design assumption in the UK for surface water systems draining paved areas (such as roads, urban areas and residential areas) that the most severe rainfall conditions are associated with heavy convective thunderstorms that typically occur during hot weather in summer. These conditions tend to produce the highest rates of run-off from paved surfaces, but conversely little run-off from adjacent natural areas such as verges, cuttings and fields. When significant run-off from pervious areas during thunderstorms does occur, it tends to arrive well after the peak run-off from the paved surfaces has been discharged by the drainage system. The current HA design standards for surface water systems therefore assume 100% run-off from the road surfaces (which is an overestimate) and only a small amount of run-off from adjacent unpaved areas. In the case of cuttings or natural areas that drain towards roads, it is usual to intercept run-off from these unpaved areas by means of ditches or cut-off channels and prevent the flows entering the systems that carry run-off from the road surface.

In terms of maintenance requirements for highway drainage systems, TRMM recommends the following frequencies for maintenance:

- Piped drainage systems - 1 in 10 years, unless there are problematical sections but these will not be cleaned more frequently than once per year.

- Gullies and catchpits - 1 in 1 year.

- piped grips and grips - no detailed inspection unless larger than 5m in size or there are safety issues or complaints.

- Ditches - 1 in 5 years, unless local agreement is reached with the Department.

- Filter Drains - 1 in 5 years unless there are safety implications or known problems.

- Culverts - 1 in 1 year.

- Balancing Ponds - no outflow control - 1 in 2 years
  - with outflow control - 2 in 1 year.

- Ancillaries such as: - gratings, flap valves, sluices, valves pumps etc - 6 monthly spring and autumn headwalls, aprons etc - 1 in 1 year.

4. RAINFALL DURING AUTUMN 2000

Rainfall statistics collected by the Met Office have shown that Autumn 2000 (1st September to 30th November inclusive) was the wettest in England since systematic records were started in 1766. Average values of rainfall for different parts of England and Wales in each month are given in Table 1. These figures show that very heavy rainfalls occurred in all parts of England in each of the three months, with the monthly totals varying between 246% and 368% of the long-term averages for the period 1961-1990.

Table 1 Monthly rainfall statistics for England and Wales in Autumn 2000

Region	September 2000		October 2000		November 2000	
	Rainfall (mm)	% of long-term average 1961-1990	Rainfall (mm)	% of long-term average 1961-1990	Rainfall (mm)	% of long-term average 1961-1990
England N	135	272	171	295	178	298
England S	100	258	160	331	143	292
England E & NE	108	280	115	284	141	296
England NW & N Wales	161	246	248	299	243	292
Midlands	109	273	137	314	138	301
East Anglia	77	256	126	341	116	299
S Wales & England SW	139	247	223	297	201	269
England SE	103	260	195	368	157	305
England – overall average	112	263	164	318	156	294

The Autumn of 2000 contained three periods of particularly intense rainfall. After the wettest September since 1981, particularly heavy rainfall occurred on the 9th, 10th and 11th of October across south-western, southern and south-eastern England. On 29th October , nearly all parts of England suffered severe storms and gales, but with the same areas in the southern counties of England being worst affected. On the 1st and 2nd of November, heavy rainfall occurred in northern England (particularly in the north-east). Amounts of rainfall for various parts of England during these three periods are given in Table 2; the information was obtained by interpolation from Met Office maps showing amounts of rainfall occurring over the UK in 24-hour periods between 09:00am on the day of record to 09:00am on the following day. Significant local variations in rainfall also occurred during the storm events. Thus, the highest daily rainfall amount recorded on 29th October was 63.6mm in Enfield (north London), while the average figure for the London area as a whole was about 40mm. The overall variation in daily rainfall during October 2000, averaged over the whole of England and Wales, is shown in Figure 1; the dotted line indicates the long-term value of average daily rainfall (2.81 mm per day) for October during the period 1961 – 1990.

Table 2 Rainfall amounts in England during heaviest storms in October and November 2000

Location	Rainfall amounts (mm)			
	10 days - 01/10/00 to 11/10/00	09/10/00	9 days - 28/10/00 to 06/11/00	29/10/00
Plymouth	125	25	100	30
Exeter	65	23	90	38
Chichester	105	41	125	40
Brighton	125	30	150	50
Dover	100	20	125	30
London	65	14	105	40
Bristol	60	17	135	48
Oxford	~45	15	90	35
Cambridge	~40	14	90	28
Birmingham	50	12	90	32
Nottingham	~45	21	75	27
Manchester	90	24	120	38
Liverpool	75	23	90	37
Leeds	50	29	125	2
Hull	~30	10	90	18
York	~40	13	150	25
Carlisle	70	22	50	15
Newcastle-upon-Tyne	~40	13	100	18

The frequency of occurrence of a storm event is usually expressed in terms of its return period, ie the average period in years between events that equal or exceed the chosen event in intensity. As explained in Section 3, the word “event” is used because its definition may be varied according to the particular problem being considered. Possible alternatives can include: the total amount of rainfall occurring in a particular period (eg, the Autumn, one month, one day, etc); the total amount of rain falling between the start and end of a particular storm; or the amount of rain falling during the most intense part of a longer storm (eg, during a period of 5 – 10 minutes if designing a typical road drainage system). It is important to appreciate that the return period of a storm will depend on the particular definition used. Thus, for example, the return period of a 5-minute summer thunderstorm may be very high, but the total amount of rain falling in the day containing the storm may have a much lower return period because it is often likely to be exceeded by less intense winter storms of longer duration. These differences are illustrated by the following data:

- For England as a whole, Autumn 2000 was the wettest since 1766 suggesting a return period of the order of 250 years.

- For London, the 140mm that fell in the month of October 2000 had a return period of about 140 years.

- In London, the heaviest rainfall during October fell on 29th October and the average amount was about 40mm. The heaviest fall recorded that day was 63.6mm in Enfield (north London) and the return period of this one-day event was 32 years. Assuming that the rain might have lasted for, say, 12 hours out of the total 24-hour period, the event in Enfield would have had an average intensity of the order of 5mm/hr.

No information has been obtained about rainfall amounts that occurred in October or November 2000 during periods shorter than one day. However, it is very likely that the maximum values for storm events lasting between 5 minutes and 60 minutes were by no means exceptional and had very much lower return periods than the longer-duration events considered above. This can be demonstrated by considering the rainfall intensity that the HA design standards would require if a trunk road were to be built in the Enfield area (which experienced the heaviest rainfall in the UK on 29/10/00). As described in Section 3, the system would need to be designed to prevent water encroaching onto the carriageway in a 5-year storm; if the critical storm duration for the system was 5 minutes, it would have to be able to cater for run-off from the road produced by a storm with a peak intensity of 89mm/hr (ie more than 15 times greater than the average rainfall intensity occurring in Enfield on 29/10/00). However, as explained in Section 3, the design event for the system would normally be assumed to be part of a short-period summer storm producing run-off mainly from the road surface and with only a small contribution from any adjacent unpaved areas.

5. STORM RELATED INCIDENTS ON HA NETWORK IN AUTUMN 2000

The severe storms on the 29th and 30th October 2000 caused considerable disruption over many parts of the road network, including trunk roads and motorways in England operated by the HA. Temporary lane or road closures due to flooding and fallen trees were widespread, and in some cases the closures continued for several days. In order to evaluate the extent and cause of the problems, the Customer & Operations Services Division of HA requested the twenty HA Areas in England to submit reports on the incidents that affected the HA Network. As part of the first-stage review, the information from the HA Area reports was collected into a single data base in a standardised format so as to enable statistics of the incidents to be determined.

A total of 195 separate incidents were reported by the HA Areas as follows:

HA Area	Location	Number of incidents
1	Cornwall & Devon	1
2	Somerset, Avon, Wilts, Gloucs & Oxon	8
3	Hants, Surrey & West Sussex	14
4	Kent & Essex	3
5	Berks, Oxon, Bucks, Herts & Essex	2
6	Herts, Essex, Cambs, Suffolk & Norfolk	3
7	Leics, Notts, Lincs and Rotherham	15
8	Bucks, Herts, Beds, Essex, Cambs, & Northants	15
9	Gloucs, Hereford & Worcester, & Shropshire	20
10	Cheshire & Shropshire	5
11	Northants, Warwicks, Leics, Staffs & Shropshire	41
12	West Midlands	3
13	Lincolnshire	1
14	Derbyshire, South Pennines, Staffs & Cheshire	28
15	Greater Manchester Motorways	3
16	West & South Yorks & Humber Ports Motorways	3
17	Lancashire North Merseyside, Craven & Calderdale	7
18	Durham, North, East & West Yorks	23
19	Cumbria	No incidents reported
20	Northumbria	No report available
		195

The spreadsheet for the data base (reproduced in Appendix 1) contains the following items of information about the incidents on the HA Network reported in Autumn 2000:

- HA Area, road number and location
- Class of road (motorway, dual carriageway, two lane)
- Type of drainage system
- Description of local area (eg, rural, urban, woodland, etc) – obtained separately from maps
- Timing of incident – start and end dates, time of incident, duration of closure
- Severity of incident – ranked as major, medium and minor, but with additional details where available
- Cause(s) of incident, grouped as follows:

  1 : Flooding from river/adjacent watercourse/groundwater or leakage of flood defences
  2 : Blockage of road gullies/drains
  3 : Inadequate size or function of gullies/culverts/outfalls/ditches
  4 : Excessive run-off

5 : Blocked culverts under road/blocked outfalls/blocked adjacent ditches
6 : Local low point – ponding
7 : Run-off from local roads/local authority roads with inadequate drainage
8 : Fallen Trees
9 : Surcharging of downstream drainage system, eg soakaways
10: Other / Unknown (including high wind and vehicles blown over by high wind).

(In a significant number of cases an incident was reported as having more than one cause).

As can be seen from the spreadsheet in Appendix 1, some reports gave more details than others about the incidents. In particular, little information is available about the type(s) of drainage system installed in the affected areas. It should be noted that incidents caused by fallen trees and high wind (eg, vehicles blown over, bridge closures, etc) have been included in the totals so that the relative proportion of flooding-related incidents can be determined. Data from the spreadsheet are presented graphically in Figures 2 to 6.

Figure 2 shows the timing of the incidents in terms of the date on which each incident started; most incidents lasted less than 24 hours but some lasted several days. Figure 2 can be compared with the overall distribution of rainfall during October 2000 shown in Figure 1. It can be seen that the majority of the incidents were caused by the severe storms that occurred between 28th and 30th October. It is surprising that only one incident appears to be related to the heavy rainfall between 9th and 11th October which particularly affected the south-west and the south-east of England (see Table 2); this suggests that incidents during the first half of October may have been under-reported.

The distribution of the flooding incidents over the HA Network is illustrated in Figure 3. HA Areas that each suffered more than 10% of the total reported incidents were: Area 11 (to the east of Birmingham), Area 14 (Derby to Manchester), Area 18 (York to Durham) and Area 9 (to the west of Birmingham). Only 10% of the incidents occurred in the southern counties between Poole and Dover (Areas 3, 4 and 5), although news reports indicated that these were badly affected by flooding; this suggests that many of the incidents in this area were on non-HA roads. A similar explanation may also account for the relatively few incidents reported from Areas 1 and 2 in the south-west of England.

Figure 4 shows the distribution of incidents according to the type of road. More than half of the incidents happened on two-lane roads, which might be expected since they predominate on the HA Network. The 17% of incidents that occurred on motorways is significant because of the high degree of disruption caused when lane closures or total closures are necessary. Motorways affected were the M1, M3, M4, M6, M11, M25, M42, M45, M48, M54, M56, M57, M61 and M62.

Figure 5 presents the data in terms of the severity of the incident. The distribution between major, medium and minor incidents is fairly equal. The severity of 26% of the incidents cannot be determined from the information available; however, assuming these to be divided fairly equally between the three categories, it would appear that about 33% of all the incidents (ie, about 65 in number) would be rated as major.

The distribution of incidents according to their cause is shown by Figure 6. The results show that about 84% of the total incidents were caused by flooding, with the other 16% being due to fallen trees, high winds, accidents and other unspecified factors. Within the cases of flooding, about 29% of the total incidents occurred as the result of high water levels in rivers or streams inundating sections of road or submerging drainage outfalls. This suggests that about 55% of the total incidents (ie, about 107 in number) were due to inability of the highway drainage systems to cope with the flows received.

In order of importance, the causes of the problems affecting the drainage systems were distributed fairly equally as follows:

• inadequate functioning of drainage systems	29%
• excessive run-off from fields and non-HA roads	25%
• blocked gullies, ditches, culverts and outfalls	24%
• ponding of water at low points along roads	4%
• non-specified causes	18%
	100%

6. DETAILS OF SELECTED FLOODING INCIDENTS

6.1 HA Areas 3 and 4

The following examples are representative of the causes and types of flooding problem that occurred in Areas 3 and 4 in Autumn 2000. Details about the incidents and the drainage systems were provided by the Maintaining Agents, Mott MacDonald in Area 3 and W S Atkins in Area 4.

(a) *M25 motorway at Junction 9 near Leatherhead*

The severe storm that affected southern England on 29th and 30th October 2001 resulted in serious flooding on this section of the M25 and eventually led to all lanes having to be closed to traffic. The first signs of flooding became apparent at about 1:20 am when water began flowing down the face of a section of cutting a short distance before the off-slip for Junction 9 on the anti-clockwise route of the motorway. The flow was caused by runoff from a relatively small but steep catchment that lies to the north of the motorway and is the site of a golf course. The A244 and the A243 roads approach the M25 from the north at this point and reports suggest that, at the height of the storm, water was flowing down the A243 onto the M25 via the slip-road at Junction 9.

At the location where the flooding occurred, the anti-clockwise route of the M25 is on the outside of a bend so that super-elevation causes the camber to slope from the verge towards the central reserve. According to maintenance staff, no drainage system had been provided in the verge to collect runoff associated with the cutting. Runoff from rain falling on the carriageway is collected by means of gullies in the central reserve; this system drains in an easterly direction towards a detention pond before outfalling to a local watercourse. In the case of the other carriageway, a separate drainage system is located in the verge of the clockwise route to collect water that drains from the fast lane towards the verge.

During the storm, considerable amounts of water from the area of the golf course and the A243 drained down the face of the cutting and flowed across the anti-clockwise lanes to the central reserve where it was contained by an impermeable concrete safety barrier. The drainage system in the central reserve was unable to cope with the runoff, probably because due to a combination of the following factors:

- the combined flow rate from the carriageway and the natural catchment exceeded the design capacity of the slot drain system;
- the detention pond at the downstream end of the system was full and so prevented the drain from discharging freely; and
- the slot drain itself became blocked by sediment and debris carried by the runoff.

The safety barrier caused the water to pond on the anti-clockwise carriageway until all three lanes and hardshoulder were inundated. The amount of flooding increased until it extended over a distance of about 300 m and the depth at the lowest point reached about 1.1 m (see Plate 1). Water then spilled over the top of the concrete barrier and flooded the full width of clockwise carriageway for a distance of about 150 m. .

The section of motorway was closed for approximately 12.75 hours between about 2:45 am and 3:30 pm on 30th October. During this time, maintenance staff tried to clear blockages from the drainage system in the central reserve, but the depth of water and high winds made it too difficult and hazardous. After the end of the storm, the runoff from the natural catchment decreased and allowed the water on the motorway to drain away. Traffic disruption due to the flooding was made worse by the simultaneous closure of the A3 at Bolder Mere, about 1km from Junction 10 of the M25 (see 6.1(b)). Similar but more limited flooding occurred on the M25 at Junction 9 on 6th November 2001 but this only affected the anti-clockwise carriageway and cleared by 10 am.

Calculations have been made to estimate the amount of flow that was likely to have been contributed by the natural catchment to the north of the M25. This catchment has an area of 2.0 km^2 and an average slope of about 1:42. Using the estimation method given in TRRL Report LR 565 (Young, C P & Prudhoe, J: *Estimation of flood flows from natural catchments*,1973), the catchment was calculated to have a time of concentration of about 14 hours. The peak flow rate was estimated to be of the order of 1.0 m^3/s; part of this would have been channelled south-westwards by a small stream but approximately 40% (ie, 0.4 m^3/s) could have been intercepted first by the A243 and A244 and then by the M25. By contrast, the drainage system in the central reserve of the M25 is likely to have been designed to have a flow capacity of about 0.2 m^3/s, which would enable it to deal with runoff from the carriageway produced by a heavy thunderstorm with a peak rainfall intensity of about 85 mm/hour (assumed to last 5 minutes and occurring on average once every five years). No allowance for additional runoff from a cutting would normally be required in the design of a drainage system in the central reserve. It is therefore to be expected that the system would be unable to cope with an additional rate of runoff that was of the order of twice the design rate of flow produced by the anti-clockwise carriageway.

Temporary remedial works carried out by the Maintaining Agent on the anti-clockwise side of the motorway involved constructing a concrete collecting channel at the base of the cutting and forming a barrier between it and the hardshoulder to prevent water flowing towards the carriageway. This has proved effective in preventing further flooding occurring during subsequent wet weather.

(b) _A3 at Bolder Mere near Wisley_

The same storm that produced flooding on the M25 on 30th October 2000 also caused flooding on the A3 approximately 1km west of its junction with the M25. Runoff from the disused airfield at Wisley discharges into the Bolder Mere which borders the southern side of the A3. Water flows out of this lake through a culvert beneath the A3. Runoff from the southern carriageway of the A3 is conveyed beneath the A3 by a second adjacent culvert.

As a result of the storm on 30th October, the culverts could not discharge flow from the Boulder Mere fast enough to prevent the water level in the lake rising and flooding onto the southbound carriageway of the A3 (see Plate 4). Both carriageways were closed about 07:30 on the 30th; the northbound carriageway was reopened at 16:45 but the southbound one remained closed until late on the evening of the 31st.

HA Maintenance staff found that there was an obstruction in the culvert that carries the highway runoff from the A3. It is not known whether the obstruction was placed intentionally but it is conceivable that its purpose was to help maintain a minimum water level in the Bolder Mere. The HA staff also found that the bar grating over the culvert taking flow from the Bolder Mere (and indirectly from Wisley airfield) was blocked by debris.

(c) _Local ponding on M25 motorway and A3_

There are several points along the M25 and at least one on the A3 where lack of transverse or longitudinal fall on the carriageway causes ponding of water during wet weather (see Plates 2 and 6). All the flat spots are on concrete pavements and are either associated with transitions between normal camber and super-elevation around bends or to resurfacing work. The ponding is a matter of concern to the Maintaining Agents as several accidents have occurred due to skidding or excessive spray. The following locations of flat spots were mentioned by the Maintaining Agents for Area 3:

M25: between Junctions 8 and 9 on the A carriageway; two points between Junctions 10 and 11 on the B carriageway; between Junctions 10 and 9 on the B carriageway; between Junctions 9 and 8 on the B carriageway; and the on-slip near Junction 6 at Godstone.

A3: near the junction with the A247.

Plate 1 Flooding on the M25 at Junction 9 on 30/11/00 (NB not 29/11/00 as shown)

Plate 2 Ponding on M25 (Route A) between Junctions 8 and 9 due to lack of camber

Plate 3 Flow by-passing recessed gully on M25 (Route A) between Junctions 8 and 9

Plate 4 Flooding on A3 at Bolder Mere on 30/10/00

Plate 5 Ponding on A3 near Junction with A247 due to lack of camber at transition

Plate 6 Ponding on M25 (Route A) between Junctions 8 and 9 due to lack of camber

(d) *M3 motorway near Junction 2*
Limited flooding occurred at two locations near to Junction 2 (on the Junction 3 side) due to runoff from flooded fields.

(e) *A27 between Chichester and Lewes*
The heavy rain that affected East and West Sussex throughout Autumn 2000 caused groundwater levels in the chalk South Downs to rise by early October to levels that would normally only occur by the end of the winter. As a result, new springs opened up in the chalk and any significant amount of additional rainfall led to high runoff from fields on the northern, higher side of the A27. Four major incidents of flooding occurred on the A27:

- **Shoreham Bypass** near Southwick Hill Tunnel– eastbound carriageway closed on 12/10/00. Runoff from ploughed fields on the eastern approach to the tunnel led to fine sediment being washed into a dell which would normally have channelled water along the edge of the road. Loss of flow capacity in the dell resulted in water and silt flowing onto the road and blocking the highway drainage system.

- **Ashcombe** near Lewes – one lane of eastbound carriageway closed for over a week from 31/10/00. Runoff from the Downs drained down a steep bank onto the road over a distance of several hundred metres flooding the slow lane and completely saturating the sub-base. Emergency pumping was used to remove the water and a channel and barrier was constructed to prevent the water draining onto the carriageway.

- **Lancing Bypass** – eastbound carriageway closed early on 7/11/00. New springs appeared above the road causing water to flow onto the carriageway. Pumping failed to reduce the depth of water levels so a contraflow was installed on the westbound carriageway.

- **Westhampnett Bypass** near Chichester – closed on 7/11/00. High water levels in gravel pits adjacent to the A27, and pumping from the River Lavant into the gravel pits to help protect Chichester from flooding, resulted in the need to close the road.

(f) *General points*
Experience of different drainage systems on the M25 indicates that concrete surface water channels are the easiest to clean and maintain. Build up of debris in the channels and at the outlet gullies can be spotted and dealt with easily.

In the case of kerb-and-gully systems, some of the gullies are set 15 mm – 20 mm higher than the pavement surface leading to local ponding. Recessed gullies set back in the line of the kerb have proved to be inefficient as water flowing along the kerb easily bypasses them (see Plate 3).

Filter drains have caused problems because of stone scatter. The Maintaining Agents tried four types of filter drain: with a verge strip between the carriageway and the drain; with soil and grass over the top of the drain; with conventional loose stone at the surface; and similar but with a terram wrapping around the filter material. The first two were unsuccessful because drivers thought it was a normal verge and pulled off onto the grassed area, causing rutting and damage.

6.2 HA Area 9

The following examples are representative of the causes and types of flooding problem that occurred in Area 9 in Autumn 2000. Details about the incidents and the drainage systems were provided by the Maintaining Agents, W S Atkins.

(a) *Culvert beneath A5 at Merevale*
The construction of this culvert is a hotchpotch consisting of an original brick structure with a pipe at the upstream end and a cast in-situ concrete rectangular section at the downstream end (see Plate 7).

The culvert appears not to have sufficient hydraulic capacity to accommodate the flows from upstream, and hence water builds up and floods across the carriageway. There is a grill across the upstream end of the culvert that is effective in trapping debris; ensuring that the grill is regularly cleared could therefore reduce the risk of flooding. The headwall is at right angles to the flow and the grill is vertical; the headwall has no wing walls or safety balustrade to protect maintenance personnel cleaning the grating.

Plate 7 Upstream side of culvert beneath A5 at Merevale

(b) *A5 at Kettlebrook*
Flooding occurred at this location at a low point where the carriageway passes beneath a railway bridge. The channel discharges via a gully to a drain which, in turn, outfalls to the Kettlebrook immediately upstream of a twin pipe culvert beneath the railway embankment. The pipe diameters are not known but are of the order 900 to 1200 mm. Immediately upstream of the culverts are a dry

weather and wet weather channel (see Plate 8). The highway drain outfalls to the wet weather channel, while under dry weather flow conditions the stream is retained within the dry weather channel. In storm conditions the stream flow spills over a weir into the wet weather channel and consequently affects the outflow from the highway drain. The invert of the highway drain outlet is close to the invert of the wet weather channel and is also at 90^o to the direction flow. Therefore there is no venturi effect to draw water out of the highway drain and the drain will be subjected to a head of water equal to the depth of flow in the channel. It is possible that the culverts beneath the railway became surcharged during the flooding events.

Plate 8 Upstream side of culvert beneath A5 at Kettlebrook

The level at which the carriageway was constructed was a compromise in order to allow a significant reduction in the cost of the railway bridge. Originally there should have been 600 – 700mm of fall along the length of the highway drain but the carriageway was lowered some 600mm to accommodate the bridge. Allowing for the camber on the road, there is in fact only 80mm of fall along the length of the 300mm diameter highway drain. Consequently any surcharging of the Kettlebrook will prevent outflow from the highway drain and probably cause backflow on to the carriageway. At the time of construction, the need for a pumping station was identified but was not pursued because of cost considerations.

This section of carriageway had flooded on previous occasions prior to the incident in Autumn 2000.

(c) *A38 Branston*

Flooding of the carriageway seems, in part, to have been due to high water levels in the River Trent which adversely affected the discharge of flows from the highway drainage system into the watercourse on the downstream side of the carriageway. Water marks on the headwall of the culvert beneath the A38 (see Plates 9 and 10) indicated that this possibly throttled the flow, allowing water levels to build up and over top the bank. However, investigations showed that the 460mm drain in the central reserve was 50% full of silt and also that a number of gullies appeared to be blocked or to have no obvious outfall. Drainage records of the system were incomplete.

It is believed that backflow occurred from the Trent tributary up the eastern ditch, which has no noticable fall; water left this ditch, possibly via gully connections, and flooded the southbound carriageway

Plate 9 Culvert beneath A38 at Branston

Plate 10 River Trent viewed from A38 at Branston

(d) M54 motorway
The leaf fall on M54 was so severe that West Mercia Police requested that the hard shoulder be swept for the whole length, asking that it be done in one afternoon. Due to the need to keep emptying the sweepers, this activity in fact took three days.

6.3 HA Area 10

The following examples are representative of the causes and types of flooding problem that occurred in Area 10 in Autumn 2000. Details about the incidents and the drainage systems were provided by the Maintaining Agents, the Babtie Group.

The drainage systems of recently constructed schemes have been designed using rainfall data for storms with a return period of ten years, but problems have still been experienced with these systems.

(a) A49 at Battlefield
Severe flooding occurred on the 6 November 2000. The carriageway is drained via a 450mm diameter outfall pipe, which at the time of the flooding was clear of silt and was flowing at full bore. The drainage system for the bypass was recently connected to this drain, but it is not known if the

downstream capacity of the drain was ever checked for the resultant increase in flow.

(b) *A41 at Hatton Heath*
Investigation of the flooding showed that the drainage gullies had been buried beneath 300mm of new road construction and also that the drain itself had collapsed.

(c) *A483 at Llynclys*
The flooding problems at this location were exacerbated by the volume of silt within the pipes. The silt depths were between a third and half of the pipe bore.

(d) *General problems with culverts*
Culverts caused a number of problems, notably one on the M53 motorway where a large grill had been constructed across the entrance to prevent its use as a children's play area and general dump. The grating subsequently became blocked with branches and debris. Culverts have silted up because the downstream ditches have not been cleared. Ownership of the adjacent ditches is not recorded which makes it difficult to obtain access for emergency work or routine clearing of the ditches. The positions of smaller culverts are often not recorded and in some cases, such as on the A5117, their existence was not even known to the Maintaining Agent until flooding problems occurred.

(e) *A49 at Hadnall*
The culvert beneath the road at this location measures approximately 500x500mm in cross-section and is constructed of sandstone blocks. Since the construction of the culvert there has been a major increase in the surrounding impermeable area due to the building of a large estate that drains to the watercourse upstream of the culvert. Downstream of the culvert, the ditch had been covered over and top-soiled so that it was difficult to actually locate the ditch. The remedial works were undertaken by the Maintaining Agents even though it was not their responsibility. There are no TRMM requirements for culverts less than 900mm diameter.

(f) *A5 at Weston*
The ditches at this location were full of mature trees that had to be removed before the ditches could been cleaned. A blocked ditch had led to the rapid silting of the culvert beneath the road.

(g) *A55 at Vicars Cross*
Flows from the highway drainage system are discharged by means of a large pumping station that lifts the flow to a second pumping station and thence to an outfall. Each pumping station is able to collect and hold 60 tonnes of accumulated silt. Flooding occurred at the second pumping station when it was unable to cope with the volume of flow that it received; the electrical wiring and control equipment were affected by the flooding of the station.

(h) *A51 at Tarvin*
Flooding occurred along a section of the carriageway that is at the bottom of a sag curve, with fields draining towards the carriageway on either side. Possible remedial works could involve installing some form of interceptor system, such as french drains, and connecting it to the main carrier drain.

(i) *M6 motorway north of the River Mersey*
The M6 in this area is affected by water table problems as a result of mining subsidence and the reduction in ground water extraction by industry. Ground levels in the area around the M6/M62 intersection have dropped by between 1.5 and 2 metres. This has also affected the drainage pipework. During the recent flooding, the level of the water table hindered access to the detention tanks at Thelwall, and there were also problems due to missing records and difficulty of access caused by the

installation of barriers and lighting.

(j) A500 Hough Shevington
Severe flooding occurred at this location but no drainage records were available and no recognisable outfalls could be found. After the initial flooding occurred, the drainage system remained drowned for a considerable time because of the high water table level.

(k) Other problems
A pollution incident occurred as a result of discharges from oil interceptors at Knutsford MSA. The interceptors are normally emptied quarterly and were due for emptying when the storm occurred. The high flow rates through the interceptors during the storm made it impossible to remove the collected oil and pollutants, with the result that they were washed into the downstream watercourse.

Other problems identified as a result of the flooding included a section of drain where each gully connection had been made by breaking out a hole in the wall of the carrier pipe and simply pushing the pipe from the gully through the hole.

In many cases, flooding was the result of unsatisfactory cleaning of channels by Local Authority maintenance staff.

6.4 HA Area 11

The following examples are representative of the causes and types of flooding problem that occurred in Area 11 in Autumn 2000. Details about the incidents and the drainage systems were provided by the Maintaining Agents, WSP.

(a) General problems
Flooding of the carriageways as a result of high river levels was a major problem. An abnormally high tide in the Severn coincided with the peak of the flood, so many of the outfalls were submerged. The A40, A48 and A449 are rural roads and there are no records of the highway drainage. Mud and surface water from fields affected the drainage of the M50 and A449 particularly, with sandy mudstone entering filter media; on the M50 a filter drain was found to be completely buried. On the A449 a farmer had ploughed a field so that runoff was channelled towards the road but no cut-off drain had been provided to intercept the flow and prevent it draining on to the road. The view of the Maintaining Agents is that, although they are willing to assist if necessary, the responsibility for off-site drainage lies with the farmers.

(b) A38 at Sanford
The flap valve on a culvert failed which resulted in the failure of the culvert and subsequently the collapse of a lay-by. The responsibility for the flap valve maintenance had never been established and was assumed (probably incorrectly) to lie with the Environment Agency.

(c) A40 at Churcham
The flooding is believed to have been caused by a lack of culvert capacity combined with a lack of maintenance of the downstream ditch. During the flood debris built up on the vertical bars of the grill. The responsibility for the maintenance of the ditches had not been established. (see above).

6.5 General issues

(a) Diversion routes
The signing of diversion routes was mentioned as an issue by the Maintaining Agents for Areas 9 and 11. In cases where vehicles with higher ground clearance were able to negotiate the flooding, signs to advise cars with lower ground clearance to take an alternative route would have reduced delays. In

Area 11 there was evidence that the diversion routes established by the Local Authorities in some cases conflicted with those established by the Maintaining Agents for the HA roads.

(b) *Maintenance of culverts*
According to the TRMM, culverts with diameters larger than 900mm should be classified as structures and inspected once every two years. No guidance is currently given for culverts below this size. Also, Maintaining Agents believe that defects in culverts detected during maintenance do not require to be reported. As a result data about these types of problem may not be recorded or passed to the HA.

7. SUMMARY OF FINDINGS

(1) Heavy prolonged rainfall through much of Autumn 2000 resulted in many catchments throughout England being near to saturation conditions with groundwater levels also significantly higher than normal. This caused unusually high rates of runoff to drain onto roads from unpaved areas such as fields, verges and cuttings. The runoff carried considerable amounts of sediment and vegetative debris, including large quantities of leaves blown from trees by high winds. Many rivers and streams also flooded, causing high water levels to persist for long periods along sections of road located in flood plains. In several parts of the country the floods were the largest since 1946 or 1947 and in Yorkshire the River Ouse experienced its largest flood since 1625.

(2) Data on the flooding that occurred on the HA Network indicates that the incidents were due either to maintenance/operational issues or to drainage problems arising at the interfaces between the roads and the surrounding catchments.

(3) There is no evidence that flooding occurred as a result of the highway drainage systems having insufficient capacity to deal with the amounts of rain falling directly onto the road surfaces. However, in some cases the systems became overloaded by additional water draining onto the roads from surrounding natural catchments. In other cases the drainage systems were unable to convey the water away because the outfalls were submerged by high water levels in the downstream watercourses or because components of the systems such as gullies, ditches and gratings were blocked by sediment and other debris.

(4) Serious disruption to traffic was caused by flooding near Junction 9 of the M25 motorway at Leatherhead on 30 October 2000. Heavy rain falling on a steep but relatively small catchment produced large amounts of runoff that drained onto a section of the motorway in cutting. Calculations indicate that the peak rate of flow from this catchment could have been about three times the design flow rate for the motorway drainage system (based on short-period runoff from the road pavement during heavy summer thunderstorms). The drainage system therefore became overloaded and was also clogged by sediment and debris washed from the upstream catchment. Remedial works involved the construction of a collecting channel at the bottom of the cutting to prevent water draining onto the carriageway.

(5) Insufficient longitudinal or transverse gradients on some sections of road or carriageway led to the formation of significant areas of standing water during heavy rain. Although not sufficient to cause road closures, the standing water presented a hazard to road users and resulted in some accidents due to skidding and excessive spray.

(6) Several issues related to the cleaning and maintenance of highway drainage systems contributed to the general flooding problems on the HA Network:

- Responsibilities for maintaining and clearing drainage ditches in fields adjacent to roads had been forgotten or had not been clearly established. In some cases farmers had filled in ditches or allowed them to become blocked by debris, leading to water flooding onto roads during wet weather.

- Maintenance intervals for gully emptying, channel cleaning, etc specified in the HA Trunk Road Maintenance Manual (TRMM) are in some cases insufficient and are also inflexible in terms of the cleaning techniques that are permitted.

- The flow capacities of many highway drainage systems appear to have been significantly reduced over the years by the gradual accumulation of sediment in the pipes. This has normally only become apparent when unexpected flooding has occurred or systems have been upgraded as part of new construction works.

- Responsibilities for sweeping roads and channels were transferred from the HA to Local Authorities under the 1990 Environmental Protection Act. In some cases this has resulted in cleaning not being carried out as frequently as previously, leading to greater accumulations of sediment in channels and along kerbs.

- Responsibilities for maintenance of bar screens, culverts and sections of channel immediately upstream and downstream of culverts are not clearly apportioned between HA Maintaining Agents and other organisations such as the Environment Agency, Local Authorities and Land Drainage Boards. Blocked screens and restrictions in culverts were responsible for a significant number of the reported flooding incidents. The TRMM currently gives no guidance on inspection frequencies for culverts under roads that are smaller than 900 mm in diameter.

(7) The ability of maintenance staff to deal with the flooding incidents and also plan regular maintenance has been hampered by a lack of recorded information about the layout of existing highway drainage systems and the location of key structures such as chambers, culverts, etc. Drainage plans and records are seldom available for A-roads and are not complete even in the case of recently built sections of motorway.

(8) When sections of road have been upgraded or widened, insufficient attention may sometimes have been given to checking that existing drainage systems will have sufficient flow capacity. In certain cases new site developments adjacent to HA roads have contributed increased amounts of runoff and led to overloading of the HA drainage systems.

(9) Although flooding incidents in Autumn 2000 resulted in significant disruption to traffic, most of the incidents were caused either by localised drainage problems or by inundation from adjacent rivers in flood. The lengths of road at direct risk of flooding represent only a small proportion of the total HA Network. A general upgrading of drainage systems along HA roads is therefore not considered to be necessary or appropriate. However, the resilience of the Network to deal with adverse weather conditions can be improved in the future by:

- more effective and targeted maintenance of highway drainage systems;

- local improvements to drainage systems at identified critical points;

- establishment of a data base in each HA Area for recording details of drainage systems and incidents of flooding;

- better co-ordination between the HA Area, Local Authorities, the Environment Agency, Riparian owners and other authorities dealing with land drainage and rivers;

- planning to establish suitable diversion routes for traffic in areas at known risk of flooding;

- pre-emptive maintenance and traffic management in response to forecasts of severe storms or flood warnings from the Environment Agency.

8. RECOMMENDED ACTIONS

8.1 HA design standards

- A guidance document should be produced on how to assess and deal with runoff from natural catchments that can drain to HA roads during periods of prolonged wet weather. The current HA requirement that drainage systems should be able to prevent surface flooding of carriageways during short-period storms occurring, on average, once every five years is considered to remain valid. However, a separate check should also be made for rarer long-duration storms in case these may provide a more severe design condition.

- A guidance document should be produced on the design of outfalls from highway drainage systems. Information should include design requirements for culverts, recommendations on levels of discharge pipes relative to downstream water levels in watercourses, design of headwalls, and suitable arrangements of bar screens to allow safe access for cleaning during flood conditions.

- Guidance on minimum longitudinal and transverse gradients of carriageways should be reviewed to help reduce the incidence of excessive depths of standing water on roads during wet weather.

- Data on design rainfall intensities for highway drainage systems contained in current HA Advice Notes should be periodically reviewed to take account of existing or anticipated changes in UK rainfall patterns.

- Levels of new and existing HA roads in flood plain areas should be compared with data on 1:100 year flood outlines and water levels published by the Environment Agency for Main Rivers in England.

- Existing HA guidance on the design of highway structures crossing rivers and flood plains should be revised to take account of recent improvements in methods of flood prediction and hydraulic analysis.

8.2 Maintenance and operational procedures

- Recommendations in the Trunk Road Maintenance Manual (TRMM) on frequencies of maintenance and inspection for highway drainage systems should be reviewed. Advice should be given for highway culverts of all sizes. A more flexible approach to maintenance should be permitted so that efforts can be targeted more effectively at critical points in drainage systems and on the basis of operational experience.

- Each HA Area should collect and record information about the drainage systems on HA roads in a systematic form so that it can be readily accessed by staff carrying out routine or emergency maintenance. Flooding incidents and maintenance records should be stored on a data base that can be used to identify problem areas and allow maintenance to be targeted more effectively.

- Responsibilities for maintenance and inspection of structures, drainage ditches and watercourses that interface with highway drainage systems should be established through consultation with relevant organisations (eg, Local Authorities, Environment Agency, Riparian owners, etc). Details should be stored on the flooding data base and be accessible by maintenance staff.

- Suitable diversion routes for traffic in flood-prone areas should be established and agreed with Local Authorities so that a consistent system of diversions can be implemented rapidly in case of flooding. Where possible, signing should facilitate segregation of cars from vehicles with greater ground clearance that may be able to negotiate localised areas of flooding.

- Weather forecasts from the Met Office and flood warnings from the Environment Agency should be monitored and used to initiate preventative maintenance of highway drainage systems if it is considered that adverse conditions may lead to flooding of HA roads and disruption of traffic.

Figures

Figure 1 Daily rainfall totals for October 2000: England & Wales

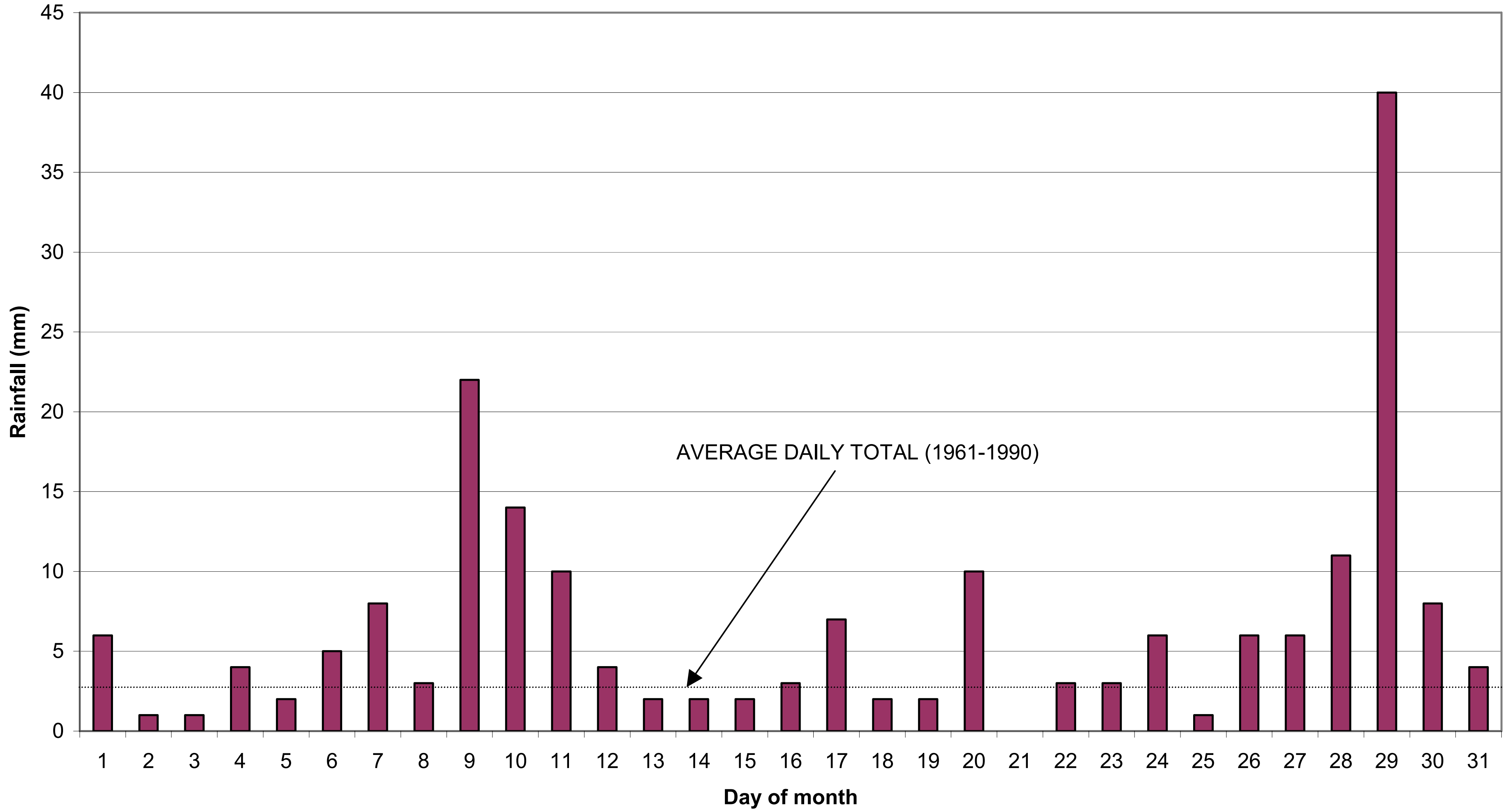


Figure 2 Start dates of incidents on HA Network

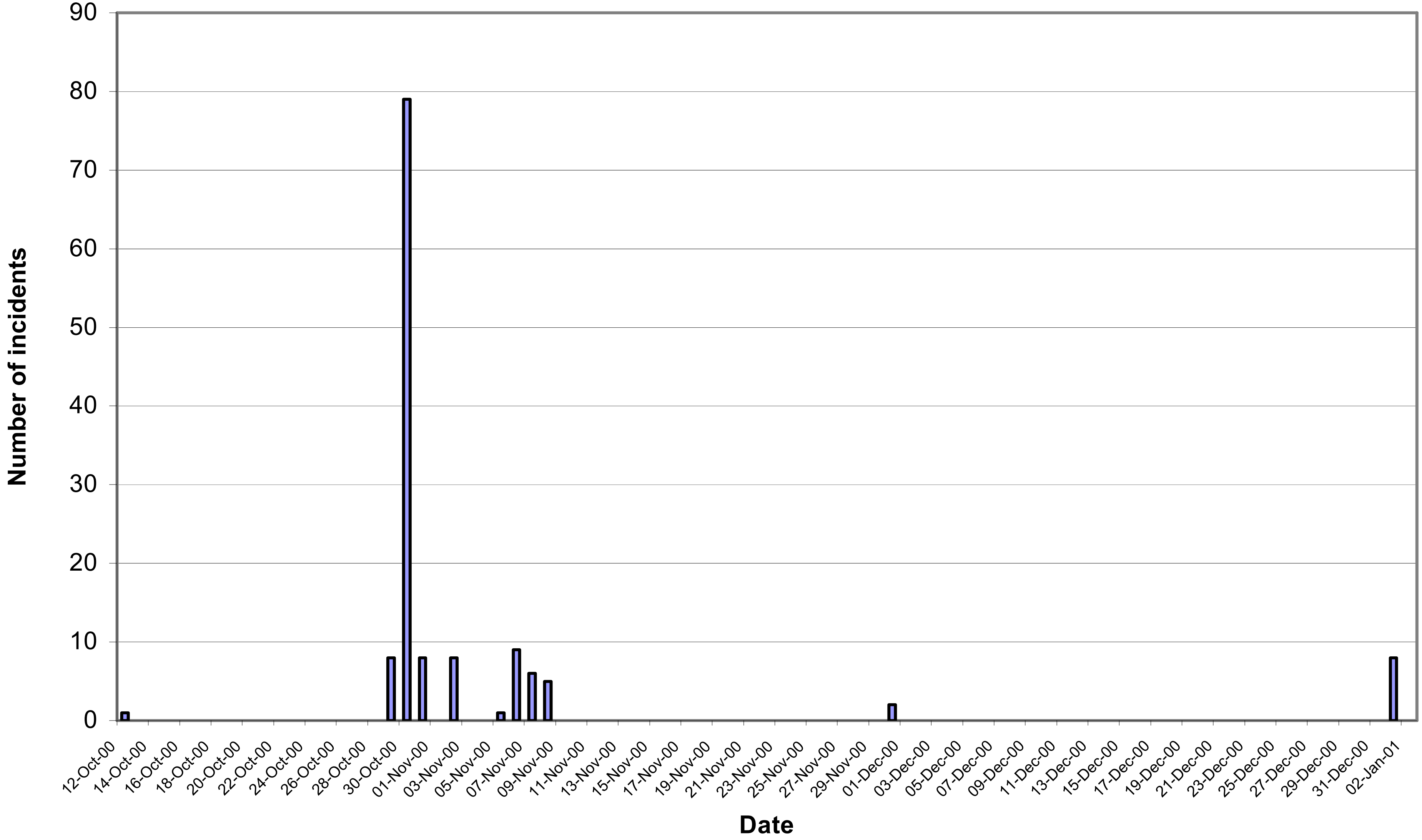


Figure 3 Location of incidents on HA Network

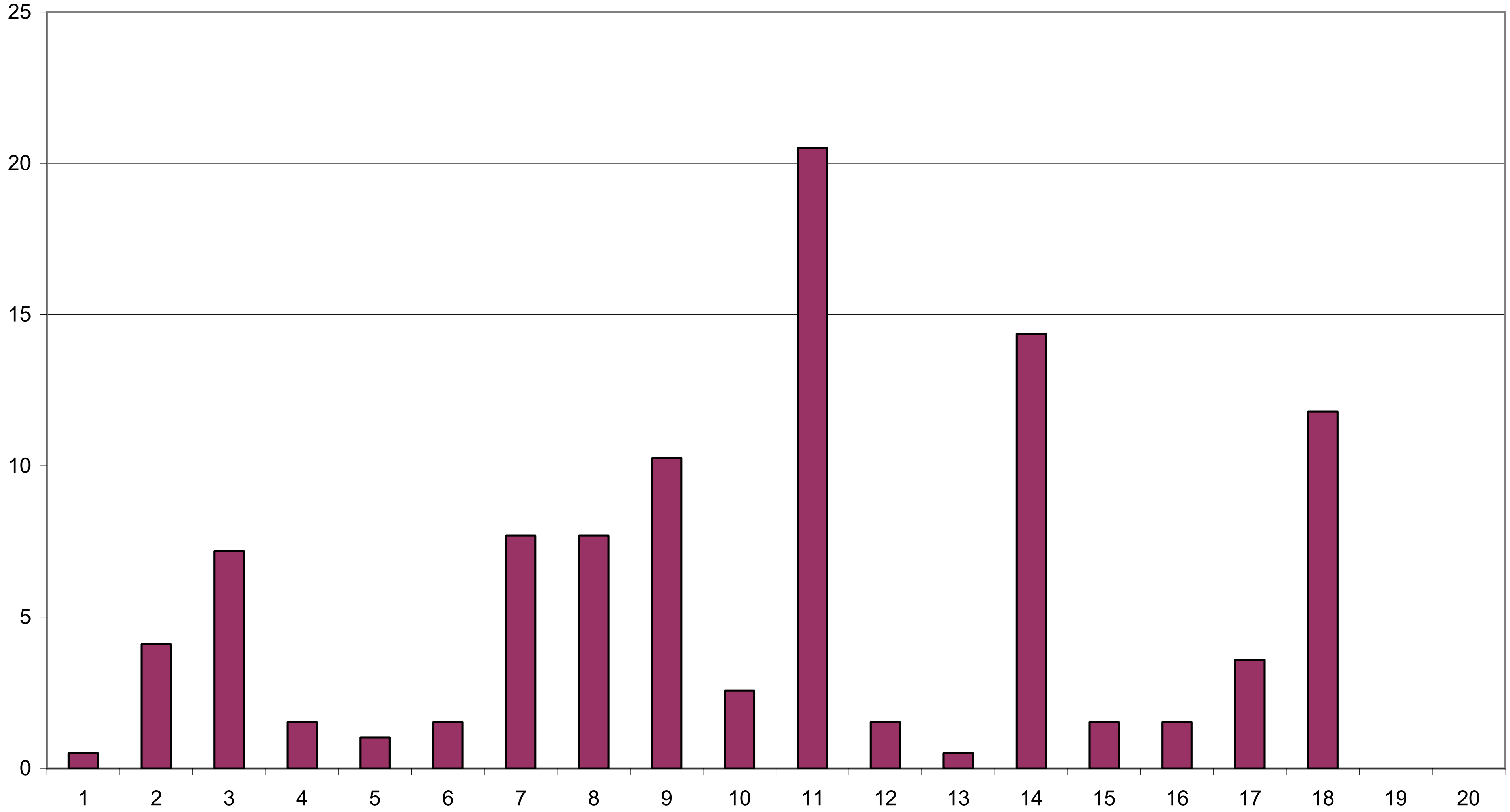


Figure 4 Distribution of incidents according to HA class of road

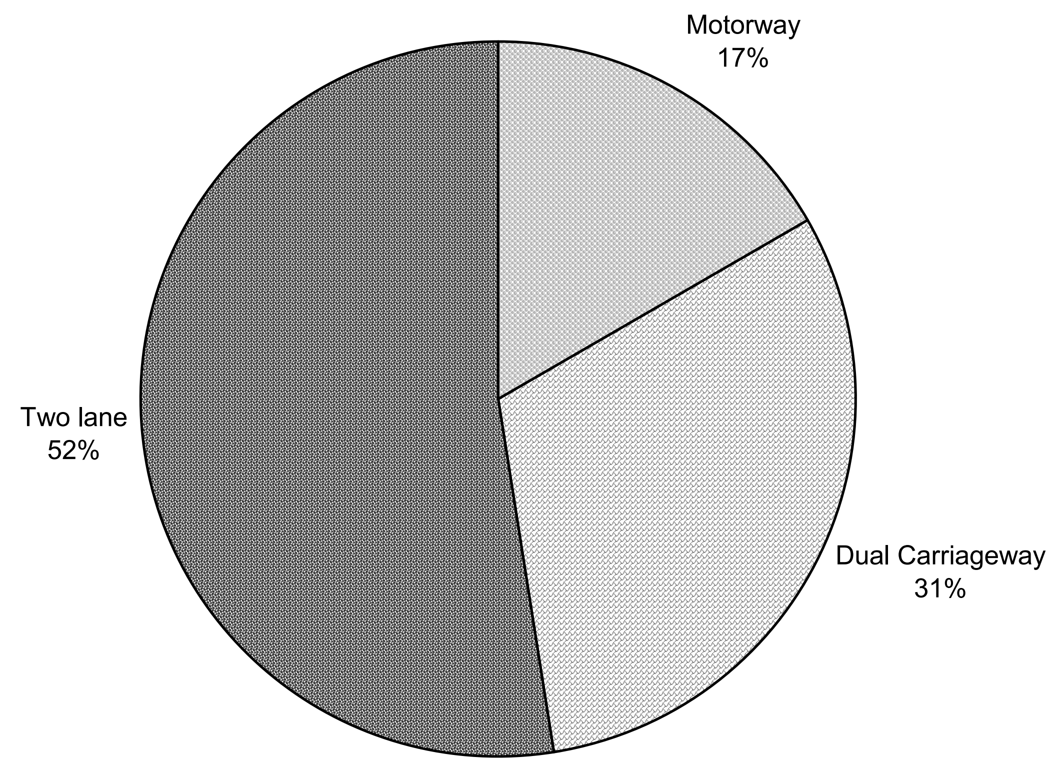


Figure 5 Severity of incidents on HA Network

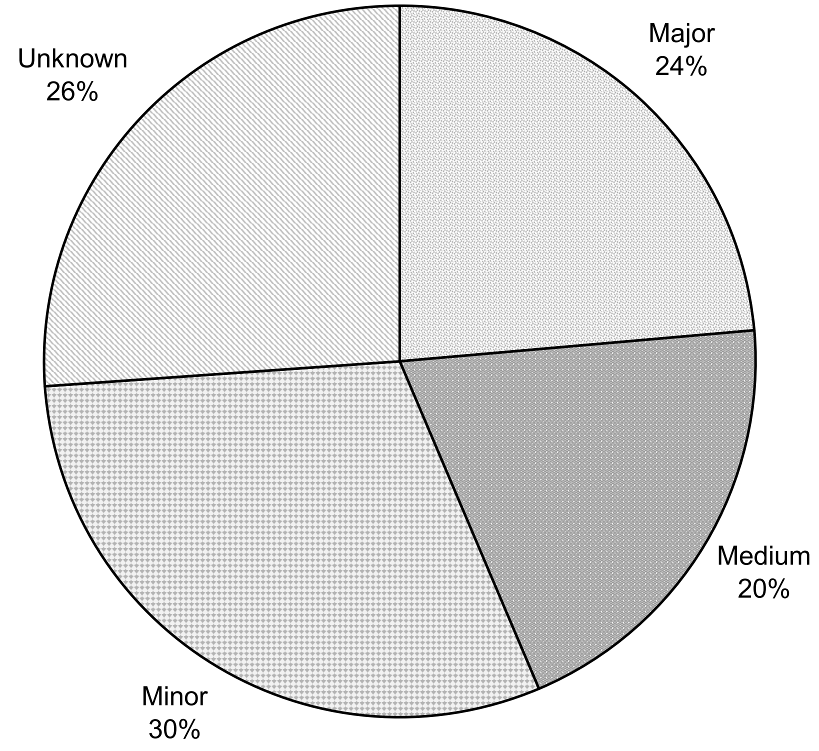
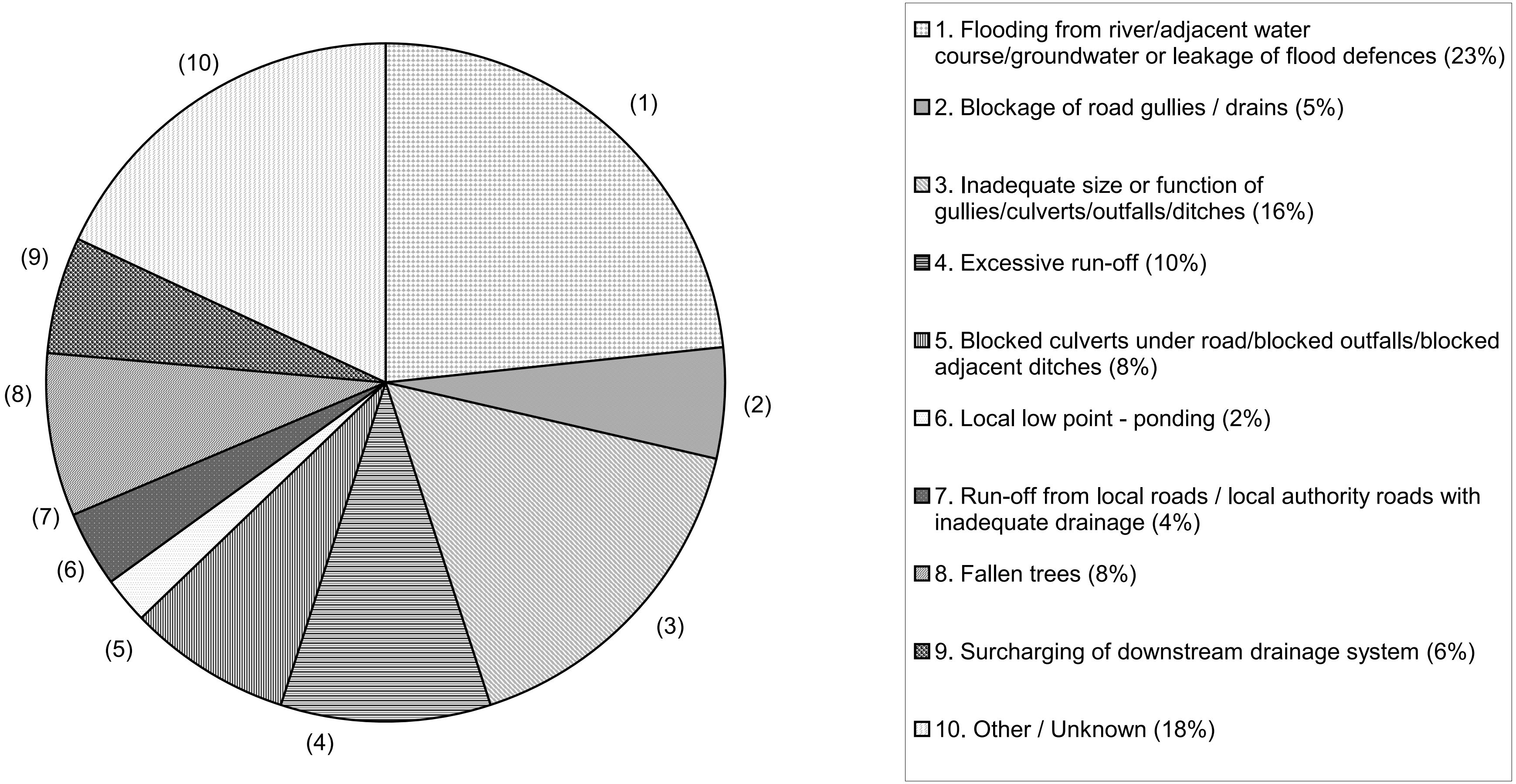


Figure 6 Distribution of incidents according to cause



Appendix

Appendix 1

Data base of flooding incidents

HA NETWORK - DATA BASE OF FLOODING INCIDENTS - AUTUMN 2000

HA Area	Road Number	Location / Section of Road	Road Type	Type of Drainage System	Local area	Date of incident Start	Date of incidence End	Time of Incident	Duration of closure (days/hours)	Severity of Incident	Severity of incident		Causes of Incident
1	A30/A3	Various locations in Devon and Cornwall				30/10/00			short periods	7	Various	8	Fallen trees
2	M48	Severn Bridge	motorway			10/30/00				1,4	major, full closure	10	High Winds
2	M4	J20 to J21	motorway		urban, rural	10/30/00				3,5	minor, lane closure	7	Run off from adjacent roads, and highway drainage
2	A303	Mere	dual carriageway		rural	10/30/00				1,4	major, full closure	6	Road low lying with to much water
2	A303	Podimore	dual carriageway		rural	30/10/00			< 24 hours	1,4	major, full closure	1	Flooding of Somerset Levels
2	A36	Ower to Wellow	two lane		rural	30/10/00			< 24 hours	1,4	major, full closure	6	Low lying ground, flooding on adjcent land
2	A36	Monkton Combe	two lane		rural	30/10/00			< 24 hours	3,6	minor, passable	10	Flooding nearby gas roadworks
2	A36	Claverton	two lane		urban	30/10/00			< 24 hours	1,4	major, full closure	10	Road edge undermined, landslip
2	A36	Standerwick	two lane		rural	30/10/00			< 24 hours	1,4	major, full closure	1	River Flooding
3	A27	Chichester (Goodwood road r/b to Westhampnett	dual carriageway		urban,rural	07-Nov-00		11:00		1,5	major, part closure	1	flooding from R. Lavant
3	A27	Lancing	dual carriageway		urban	07-Nov-00			1 week	2,5	medium, part closure	1	groundwater/springs
3	A27	Southwick Hill Tunnel - Shoreham bypass	dual carriageway	drainage ditches adjacent to road	urban,rural	12 Oct 00				1,4	major, full closure	2	blocked ditches due to silt run off from surrounding downs
3	A31	Stag Gate	two lane	gullies - drain through wall		??/10/2000				2,5	medium, part closure	3	gullies insufficient capacity
3	A34	Kingsworthy	dual carriageway		woodland,urban	30-Oct-00			2 hours	2,5	medium, part closure	8	fallen trees
3	A3	Hindhead	two lane		rural,woodland	29 Oct 00			5 hours	2	medium	8	several fallen trees
3	A34	Three Maids Hill	dual carriageway	gullies - drain to soakaways		30-Oct-00				2,5	medium, part closure	9	surcharging of drains to soakaways (soakaways under capacity ?)
3	A34	Tufton	dual carriageway	gullies - drain to soakaways	rural	30 Oct 00				3	minor	9	surcharging of drains to soakaways (soakaways under capacity ?)
3	A339	Woolverton	two lane	gullies - drain to soakaways	rural	30-Oct-00				3,6	minor, still passable	9	surcharging of drains to soakaways (soakaways under capacity ?)
3	A34	Three Maids Hill	dual carriageway	gullies - drain to soakaways		07-Nov-00				2,5	medium, part closure	9	surcharging of drains to soakaways (soakaways under capacity ?)
3	A339	Woolverton	two lane	gullies - drain to soakaways	rural	07-Nov-00				3,6	minor, still passable	9	surcharging of drains to soakaways (soakaways under capacity ?)
3	A3	Bolder Mere Lake, Wisley	dual carriageway	culverts, outfalls	rural	30-Oct-00		07:30	36 hours	1,4,5	major, full/part closures	1,2	overflow from lake, blocked culverts/outfalls due to debris from woodland
3	M25	between J8 and J11 (both directions)	motorway	slot	urban,rural	29 Oct 00	09 Nov 00			3	minor	2,4	run-off, local topography, blockage of slot drains
3	M25	between J8 and J9 anticlockwise	motorway	slot	urban,rural	30-Oct-00		07:00 to 14:00	7 hours	1,4	major, full closure	2,4	run-off, local topography, blockage of slot drains
4	A21	Lamberhurst	two lane		rural	30-Oct-00			7 hours	1,4	major, full closure	1	flooding from R. Teise
4	A27	Ashcome (Lewes)	dual carriageway		hilly,urban,rural	31-Oct-00			1 week	2,5	medium, part closure	4	run-off from surrounding area
4	A259				low lying	30-Oct-00				3	minor, localised flooding	6	low lying land
5	M11	J5 southbound entry slip	motorway		urban,rural	30 Oct 00		14:00	1.5 days	1,4	major, full closure	1	flooding from R. Roding
5	M11	J4-J5 Northbound	motorway		urban,rural	30-Oct-00			0 hours	1,5	major, part closure	1	flooding from R. Roding
6	A14	Haughley, Suffolk	dual carriageway		rural				5-6 hours	2,5	minor, lane closure	5	Blocked drainage ditch
6	A12	Darsham, Suffolk	two lane		woodland				3-4 hours	2,5	minor, lane closure	5	Blocked drainage ditch
6	A12	Ingatestone, Suffolk	dual carriageway		urban				3-4 hours	3,6	minor, passable	5	Blocked Gullies
7	A52	Holme House W/B	duel carriageway		rural	08 Nov 00	09 Nov 00			3,6	minor, passable	1	Flooding from R. Trent
7	A46	Fardon - East Stoke N/B	two lane		woodland	08-Nov-00	10-Nov-00			3,6	minor, passable	1	Flooding from R. Trent
7	A1	Blyth Spittle S/B	dual carriageway	gullies		05-Nov-00	07/11/00		2 days	1,4	major, full closure	2	blocked gullies - silt/debris from excessive run-off
7	A6	Hathern	two lane	gullies	woodland	06-Nov-00	09-Nov-00		3 days	1,4	major, full closure	2	gullies blocked by leaves/debris
7	A46	Car Colston Junction & Red Lodge		culvert under road						7		3	culvert insufficient capacity
7	A52	westbound - junc with Bassingfield Lane,Gamston		culvert/drain under road						7		5	partially blocked culvert/drain under road
7	A1	Marsden Xrds N/B	dual carriageway	culvert under road		06-Nov-00	08-Nov-00			3,6	minor, passable	5	screens u/s of culvert blocked
7	A52	west of Cropwell Rd - Radcliffe on Trent		ditches beside road						7		7	run-off from County Road (defective drainage) onto A52 and overfilled ditches
7	A46	East Stoke X-roads								7		7	run-off from County Road (defective drainage) to Junction with A46 - low point
7	A614	Sansom Wood Farm			hilly					7		7	run-off from hillside/track (no drainage) onto A614 - bringing silt
7	A6	Kegworth	two lane	gullies	urban	06-Nov-00	08-Nov-00		2 days	1,4	major, full closure	7	run-off from unadopted road (no drainage) onto A6 and blocked gullies
7	A614	Burntstump to Winbush Lane	two lane		rural	07-Nov-00	08-Nov-00		1 day	1,4	major, full closure	10	Flooding
7	A52	Bardhills roundabout to Sherwin Arms				08-Nov-00	10-Nov-00			3,6	minor, passable	10	Flooding
7	A614	Lockwell Hill to Limes Café	two lane		urban, low lying	06-Nov-00	09-Nov-00		3 days	1,4	major, full closure	1,6	Low point, overflow from adjacent pond
7	A1	Coddington - northbound and northbound slip		gullies						7		4,2	run-off from fields bringing silt/debris - blocked gullies
8	A6	Dead Mans Hill, southbound	dual carriageway		rural	30-Oct-00	31-Oct-00			2,5	medium, part closure	8	Fallen tree
8	M45	Westbound	motorway		rural	30-Oct-00	31-Oct-00			2,5	medium, part closure	8	Fallen trees
8	A428	Biddenham	two lane		rural	30-Oct-00	31-Oct-00			2,5	medium, part closure	8	Fallen trees
8	A5	Paulespury	two lane		rural	30-Oct-00	31-Oct-00			2,5	medium, part closure	8	Fallen trees
8	M1	Northbound Hardshoulder	motorway		rural	30-Oct-00	31-Oct-00			3,6	minor, passable	8	Fallen trees
8	A5	Dunstable High Street	two lane		urban	30-Oct-00	30-Oct-00	06:00		2,5	medium, part closure	10	Scaffolding collaspse in High Street
8	A14	Eastbound, between M1 and Junction 1, Lane 1 closed	dual carriageway		rural	30-Oct-00	31-Oct-00			2,5	medium, part closure	10	Vechicles overturned
8	M1	Junction 14, Northbound, Lane 3 north and south closed	motorway		rural	30-Oct-00	31-Oct-00			2,5	medium, part closure	10	Vechicles overturned
8	M1	South of Junction 19, Northbound, Lane 3 north and south closed	motorway		rural	30-Oct-00	31-Oct-00			2,5	medium, part closure	10	Vechicles overturned
8	M1	Junction 9, Flamstead	dual carriageway		rural	30-Oct-00	31-Oct-00			2,6	medium, passable	1,2	Flooded roundabout, possibly gullies blocked by leaves
8	M1	Junction 16 A45 Northbound slip off	dual carriageway		rural	30-Oct-00	31-Oct-00			2,6	medium, passable	1,2	Flooded, possibly gullies blocked by leaves
8	A5	Foster's Booth	two lane		rural/urban	30-Oct-00	31-Oct-00			2,6	medium, passable	1,2	Flooded, possibly gullies blocked by leaves
8	A14	Junction 12, esat bound slip off (Thrapston)?	two lane		rural	30-Oct-00	31-Oct-00			2,6	medium, passable	1,2	Flooded, possibly gullies blocked by leaves
8	A6	Milton Ernest	two lane		rural	30-Oct-00	31-Oct-00			2,6	medium, passable	1,2	Flooded, possibly gullies blocked by leaves
8	A43	Little Oakley	two lane		rural	30-Oct-00	31-Oct-00			2,6	medium, passable	1,2	Flooded, possibly gullies blocked by leaves
9	A38	Severn Stoke - Sandford Culvert	two lane	culvert under road	low lying, woodland					2	medium, lay-by collapse	1	failure of flood protection flap on R Severn side of culvert - caused collapse of lay-by
9	A49	A49/A465 Hereford	two lane		Urban	30-Oct-00	31-Oct-00		5 hours	1,4	major, full closure	1	Flooding from R Wye
9	A49	Belmont Roundabout								7		1	flooding from R. Wye
9	A465	Belmont Roundabout								7		1	flooding from R. Wye
9	A49	2 miles north of Church Stretton	two lane		rural	30-Nov-00	31-Oct-00		31 hours	1,4	major, full closure	3	Inadequate drainage
9	A49	North of Church Stretton								7		4	excessive run-off - drainage network surcharged
9	A49	South of Peterstow, North of Cravens Arms and church Stretton	two lane		woodland	30-Oct-00			4 hours	3,6	minor, passable	8	Tree down due to high winds
9	A38	South of Kempsey	two lane		woodland	30-Oct-00			4 hours	3,6	minor, passable	8	Tree down due to high winds
9	A48	Newnham on Severn	two lane		woodland	30-Oct-00			4 hours	3,6	minor, passable	8	Tree down due to high winds
9	A465	Pontrilas	two lane		rural	30-Oct-00			4 hours	3,6	minor, passable	8	Trees down due to high winds
9	A449	Ombersley, Wall Heath and Kidderminster	dual carriageway		woodland	30-Oct-00			4 hours	3,6	minor, passable	8	Trees down in various locations due to high winds.
9	A4123	Birchley Roundabout and Coseley	dual carriageway		Urban	30-Oct-00			4 hours	3,6	minor, passable	8	Trees down in various locations due to high winds.
9	A48	Lydney Town Centre	two lane		Urban	30-Oct-00	31-Oct-00		24 hours	1,4	major, full closure	10	Closed due to high winds
9	A449	Claines	dual carriageway		woodland	29-Oct-00				3,6	minor, passable	10	Partial flooding of carriageway
9	A48	Aylburton	two lane		woodland	29-Oct-00				3,6	minor, passable	10	Partial flooding of carriageway
9	A456	Blakedown	two lane		rural	29-Oct-00				3,6	minor, passable	10	Partial flooding of carriageway
9	A40	Highnam	two lane		woodland	29-Oct-00				3,6	minor, passable	10	Partial flooding of carriageway
9	A40	Birdwood	two lane		woodland	29-Oct-00				3,6	minor, passable	10	Partial flooding of carriageway
9	A46	Beckford	two lane		woodland	29-Oct-00				3,6	minor, passable	10	Partial flooding of carriageway
9	A38	half a mile north of Severn Stoke	two lane		low lying, woodland	30-Nov-00			ongoing	1,4	major, full closure	1,6	Low lying land adjacent to R Severn flood plain
10	A41	Chester to Broxton	two lane		woodland,rural	30-Oct-00	31-Oct-00		hours	1,4	major, full closure	10	Flooding
10	A41	Chowley, Chesire	two lane		woodland,rural	30-Oct-00	31-Oct-00		hours	2,5	minor, lane closure	10	Flooding
10	A483	From the junction of the A5/A483	two lane		rural	30-Oct-00				1,4	major, full closure	10	Flooding
10	A5	Weston	two lane		rural	30-Oct-00				1,4	major, full closure	10	Flooding
10	A51	Clotton	two lane		woodland,rural					3,6	minor, passable	10	Flooding
11	A34	Hanford Rbt								7		1	flooding from R. Trent
11	A34	Hanford Subway								7		1	flooding from R. Trent
11	A38	Alrewas	dual carriageway		Low lying, urban	30-Oct-00			< 24 hours	2,6	medium, passable	1	High water levels on adjacent land
11	A500	Audley Slip		gullies						7		3	adequacy of gullies
11	A34	Yarlett Bank		gullies						7		3	adequacy of gullies/drains
11	A34	Stone (Tittensor)		gullies						7		3	adequacy of gullies/drains
11	A34	Redhill		gullies						7		3	adequacy of gullies/drains
11	A34	Churchbridge		gullies						7		3	adequacy of gullies/drains
11	A449	Penkridge		gullies/drains						7		3	adequacy of gullies/drains
11	A45	Kislingbury roundabout to Northampton Lane	dual carriageway	gullies	urban	30-Oct-00			< 24 hours	3,6	minor, passable	3	adequacy/number of gullies
11	A423	Claydon Lane	two lane	gullies	rural	30-Oct-00			24 hours	3,6	minor, passable	3	adequacy/number of gullies
11	A435	Cougton nr Forest Industrial Estate	two lane	gullies	urban, rural	30-Oct-00			24 hours	3,6	minor, passable	3	adequacy/number of gullies
11	A500	Newcastle Under Lyme Northbound	dual carriageway	gullies/drains	urban	30-Oct-00			24 hours	3,6	minor, passable	3	adequacy/number of gullies/drains

11	A5	Merevale				30-Oct-00		1 day	7		3	Culvert under capacity and poor hydraulic function
11	A5	Nr Canal Bridge at Mira				30-Oct-00		< 48 hours	7		3	Flooding, capacity problems at outfall
11	A46	Oversley towards Stratford	two lane		rural	30-Oct-00		24 hours	2	medium	3	Highway drainage problems
11	A5	Atherstone	dual carriageway	gullies / outfalls	urban	30-Oct-00		< 12 hours	3,6	minor, passable	3	Inadequacy of gullies
11	A34	Junction with M6 (Junc 14)		gullies					7		3	inadequate gullies/drains
11	A5	Grendon		piped drainage ditch (culvert)					7		5	pipe/culvert blocked/damaged by tree roots
11	M54	J7 Exit slip	motorway						7		7	poor drainage on local authority roads leading to water on slip
11	A38	Barton to Branston							7		9	backing-up from R. Trent reducing capacity of drains/outfalls
11	M6	Junct 16		gullies in valleys					1,4	major, junction closed	10	
11	M6	MP242/2 northbound and MP245/3 (Near Junc 15)							2,5	medium, part closure	10	
11	A5	Wall							7		10	
11	A45	Braunston northbound							7		10	
11	A449	Rising Brook							7		10	
11	A30	Barton to Branston	dual carriageway		woodland	30-Oct-00		< 24 hours	2	medium	1,9	High water levels in the R Trent reduced capacity of drains/outfalls
11	A449	Covern Estate	dual carriageway	drain to outfall	urban, rural	30-Oct-00		24 hours	3,6	minor, passable	3,5	adequacy/blocked drain
11	A46	N/B between longbridge roundabout and Graveston roundabout		ditches / outfalls		30-Oct-00		24 hours	2	medium	3,5	Problems of pipe size / blocked outfall
11	A5	Crick (BP Truckstop)							7		4,2	run-off , leaves causing blockages
11	A5	Tamworth (Marlbrough Way)	dual carriageway	culvert under road / pipe outfall	urban	30-Oct-00		< 24 hours	2,5	medium, partial closure	9,5	Drainage pipe backed up by stream / blocked culvert
11	A5	Witherley							7		9,7	surcharged system - possibly linked to local authority drainage system
11	A38	Branston	dual carriageway		rural				7		10	bridge scour
11	A60	Uttoxeter Road	dual carriageway		urban,rural	30-Oct-00			3,6	minor, passable	10	Contractors pump failed
11	A500	Hanford	dual carriageway		urban,rural	06-Nov-00			3,6	minor, passable	10	Contractors pump failed
11	A452	Chester Road	two lane		urban			7.5 days	1,4	major, full closure	1	flooding from R. Trent
11	A449	Covern	dual carriageway		rural				7		1	flooding from R. Trent
11	A34	Bednall	two lane		rural				7		1	flooding from R. Wye
11	M42	Junction 9 to 10	motorway		rural				7		1	flooding from River
11	M54	Junction 7	motorway		urban/rural				7		1	high river levels
12		Bromford Viaduct							7		1	high river levels/leaking flood defences
12	M42	J7A Northbound Sliproad access	motorway		urban				7		1	high river levels/leaking flood defences
12	M42	J7A Northbound Sliproad access	motorway		urban				7		2	blocked drains due to leaves and other debris
13	A57	Dunham Bridge							7		5	blocked entrance screens
14	A6	Shardlow				30-Oct-00		6 hours	1,4	major, full closure	8	Fallen trees
14	A6	Ashwood Dale (Devonshire Arms PH)				30-Oct-00			2,6	medium, passable	10	Retaining wall partial collapse
14	A6	Bakewell				30-Oct-00		24 hours	1,4	major, full closure	1,4	Excessive run off and high water levels causing flooding
14	A6	Duffield				30-Oct-00		12 hours	1,4	major, full closure	1,4	Excessive run off and high water levels causing flooding
14	A6	Matlock				30-Oct-00		12 hours	2,6	medium, passable	1,4	Excessive run off and high water levels causing flooding
14	A6	Matlock Bath				30-Oct-00		12 hours	3,6	minor, passable	1,4	Excessive run off and high water levels causing flooding
14	A623	Calton to Hazel Grove		gullies/drains	rural	30-Oct-00		12 hours	3,6	minor, passable	1,4	Excessive run off and high water levels causing flooding
14	A6	Rowsley to Matlock		culverts under road		30-Oct-00		12 hours	3,6	minor, passable	1,4	Excessive run off and high water levels causing flooding
14	A38	Little Eaton to Palm Court	dual carriageway			30-Oct-00		12 hours	3,6	minor, passable	1,4	Excessive run off and high water levels causing flooding
14	A6	Ridgewood Garage Cromford	two lane		urban	30-Oct-00		12 hours	3,6	minor, passable	1,4	Excessive run off and high water levels causing flooding
14	A6	Ashwood Dale Buxton	two lane		urban				7		1,5	tributary of R. Wye under road, culverts often blocked
14	A6	High Peak Cottages				30-Oct-00		12 hours	3,6	minor, passable	1,9	High River Level
14	A6	Rowsley	two lane		rural	30-Oct-00		12 hours	3,6	minor, passable	1,9	High River Level
14	A623	Ruston Spencer	two lane		rural	30-Oct-00		12 hours	3,6	minor, passable	1,9	High River Level
14	A523	Bradnop	two lane		rural	30-Oct-00		12 hours	1,4	major, full closure	3,5	Culverts blocked, and under capacity
14	A6	Whatstandwell Bridge	two lane		rural	30-Oct-00		12 hours	2,6	medium, passable	3,5	Culverts blocked, and under capacity
14	A6	Hackney Lane	two lane		urban	30-Oct-00		24 hours	2,6	medium, passable	3,5	Culverts blocked, and under capacity
14	A523	Ruck of Stones				30-Oct-00		24 hours	3,6	minor, passable	3,5	Culverts blocked, and under capacity
14	A6	Ashwood Dale (Lovers Leap)		culverts under road		30-Oct-00		24 hours	3,6	minor, passable	3,5	Culverts blocked, and under capacity
14	A52	Mayfield Road Ashbourne	two lane		urban	30-Oct-00		12 hours	3,6	minor, passable	4,1	Excessive run off and high water levels causing flooding
14	A52	Yeldersley							3	minor, hard shoulder flooded	3	Lack of drainage
14	A523	Benty Grange							3	minor, hard shoulder flooded	3	Lack of drainage
14	A38	Little Eaton Slip Road	dual carriageway		rural				3	minor, hard shoulder flooded	4	Problem with run off
14	A38	Findern	dual carriageway		woodland				7		3	Damage to the central piped drainage system
14	A523	Winkhill	two lane		rural				7		3	Flooding, Damaged drains
14	A52	Ednaston	two lane		rural				7		3	Flooding, Drainage problems
14	A6	Barmoor Clough							2	major, severe localised flooding	2	Heavy rainfall and blocked gullies
14	A52	Ednaston	two lane		rural				2	medium, Localised flooding	3	Culverts overloaded
15	M61	Mp2.3 Southbound	motorway						2	medium, Localised flooding	3	Inadequate outfall
15	M56	Mp15.1 Eastbound	motorway						2	medium, Localised flooding	4	Surface water run off from adjacent fields
15	M61	Mp9.3 Southbound	motorway						2	medium, Localised flooding	9	Surface water unable to discharge into swollen river
16	M606	Near to Euroway	motorway		urban			8 days	1,4	major, full closure	10	Landslide caused by excess ground water and unstable valley side
16	M1	Junctions 40-41	motorway		urban,rural				3,6	medium, spray and localised flooding	10	
16	M62	Junctions 26-27	motorway		urban,rural	08-Nov-00	11-Nov-00	3 days	1,4	major, full closure	1	Backing up of Selby Dam due to high level of R Ouse
17	M61	Junction 8	motorway		urban,rural	08-Nov-00	12-Nov-00	4 days	1,4	major, full closure	1	Flooding due to seepage from flood defences R Aire(possible collapse of defence)
17	M57	East of liverpool	motorway		urban	06-Nov-00	11-Nov-00	8 days	1,4	major, full closure	1	Flooding due to seepage from flood defences R Ouse(possible collapse of defence)
17	A570	Adjacent to Morris Dancer PH			urban	31-Oct-00			1,4	major, full closure	1	Flooding from Leeds Liverpool Canal
17	A59		two lane			06-Nov-00	08-Nov-00	2 days	1,4	major, full closure	1	Flooding from R Downey and R Wear
17	A646	Calderale	two lane			02-Nov-00	03-Nov-00	1 day	1,4	major, full closure	1	Flooding from R.Swale
17	A646	Cliviger	two lane			31-Oct-00	03-Nov-00	3 days	1,4	major, full closure	1	Flooding from R.Wharfe.
17	M6/M61	SE of Preston	motorway		urban,rural	31-Oct-00	08-Nov-00	8 days	1,4	major, full closure	1	Run off from fields backs up R Wharfe
18	A63	Leeds Road Selby	two lane		urban	06-Nov-00	08-Nov-00		3,5	minor, lane closure	3	Surface water unable to drain away fast enough
18	A1041	Snaith	two lane		woodland	31-Oct-00	08-Nov-00		3,6	minor, passable	4	Run off from fields
18	A19	Barlby roundabout to Selby Swing Bridge	two lane		urban	31-Oct-00	08-Nov-00		3,5	TM put in place	4	Run off from fields
18	A629	Bradley/Snaygill	two lane		rural	02-Nov-00	03-Nov-00	1 day	1,4	major, full closure	4	Run off from fields
18	A167	Sunderland Bridge	two lane		woodland	02-Nov-00	03-Nov-00		3,6	minor, passable	4	Run off from fields
18	A1	South of Catterick	dual carriageway		rural	02-Nov-00	08-Nov-00	6 days	1,4	major, full closure	4	Run off from fields
18	A65	Ilkley Road Esscroft (little chef)	two lane		rural	07-Nov-00			3,6	minor, passable	4	Run off from fields
18	A660	Leeds Road Mickle Ing Bridge, Otley	two lane		urban	02-Nov-00	08-Nov-00		1,4	major, full closure	4	Run off from fields and surface water
18	A66	Teeside Park eastbound slip off	dual carriageway		woodland	02-Nov-00			3,6	minor, passable	4	Run off from fields, and backing up drainage
18	A629	Airevalley Link	dual carriageway		low lying	06-Nov-00	08-Nov-00		1,4	major, full closure	5	Culvert under Road blocked
18	A660	Otley East roundabout adj the Chevin	two lane		rural	02-Nov-00			3,6	minor, passable	7	Run off from adjacent roads
18	A1	Kirby Fleetham Northbound	dual carriageway		low lying, rural	31-Oct-00	08-Nov-00		3,6	minor, passable	9	Drainage inadequate, due to high water levels
18	A66	Scotch Corner to Ravensworth	two lane		rural	31-Oct-00	07-Nov-00		2,6	medium, passable	10	Flooding ?
18	A66	Longnewton East and West bound	dual carriageway		low lying, woodland			3 hours	1,4	major, full closure	10	Heavy snowfall and highwinds
18	A66	Greta Bridge to Bowes	dual carriageway		low lying, rural	02-Nov-00	04-Nov-00		3,6	minor, passable	4,3	Run off from fields, and highway drainage
18	A167	Chilton to Ferryhill (Dene bank)	two lane		urban				2,4	medium, full closure	1	flooding from R. Rother
18	A650	Cottingly Bridge	two lane			01-Jan					1	Flooding
18	A167	Woodham lodge	two lane		rural	01-Jan					10	Flooding of property due resulting from high ground water levels
18	A65	Ilkley Centre	two lane		urban	01-Jan					5	Flooding of changing rooms of St Josephs College resulting from silting of ditch
18	A629	Airedale House (200m north of Kildwick roundabout)	two lane		urban	01-Jan					5	Flooding of basement alleged to be due to defective piped highway ditch
18	A64	Malton bypass at the Western junction with B1248	dual carriageway		urban	01-Jan					3	Flooding resulting from damage to highway drain from trees and tree root infiltration
18	A66	Bowes Moor Sumit	dual carriageway,two lane		rural,hilly	01-Jan					3	Flooding of garden due to capacity of highway drain through property to outfall
18	A64	Malton to Staxton	two lane		low lying, woodland	01-Jan					5	Flood threat to property due to silting of ditch outfall alleged to be HA responsibility
	A61	Horns Bridge Roundabout				01-Jan					1	Extensive flooding on LA road resulting in closure of slip road leading onto the B6061