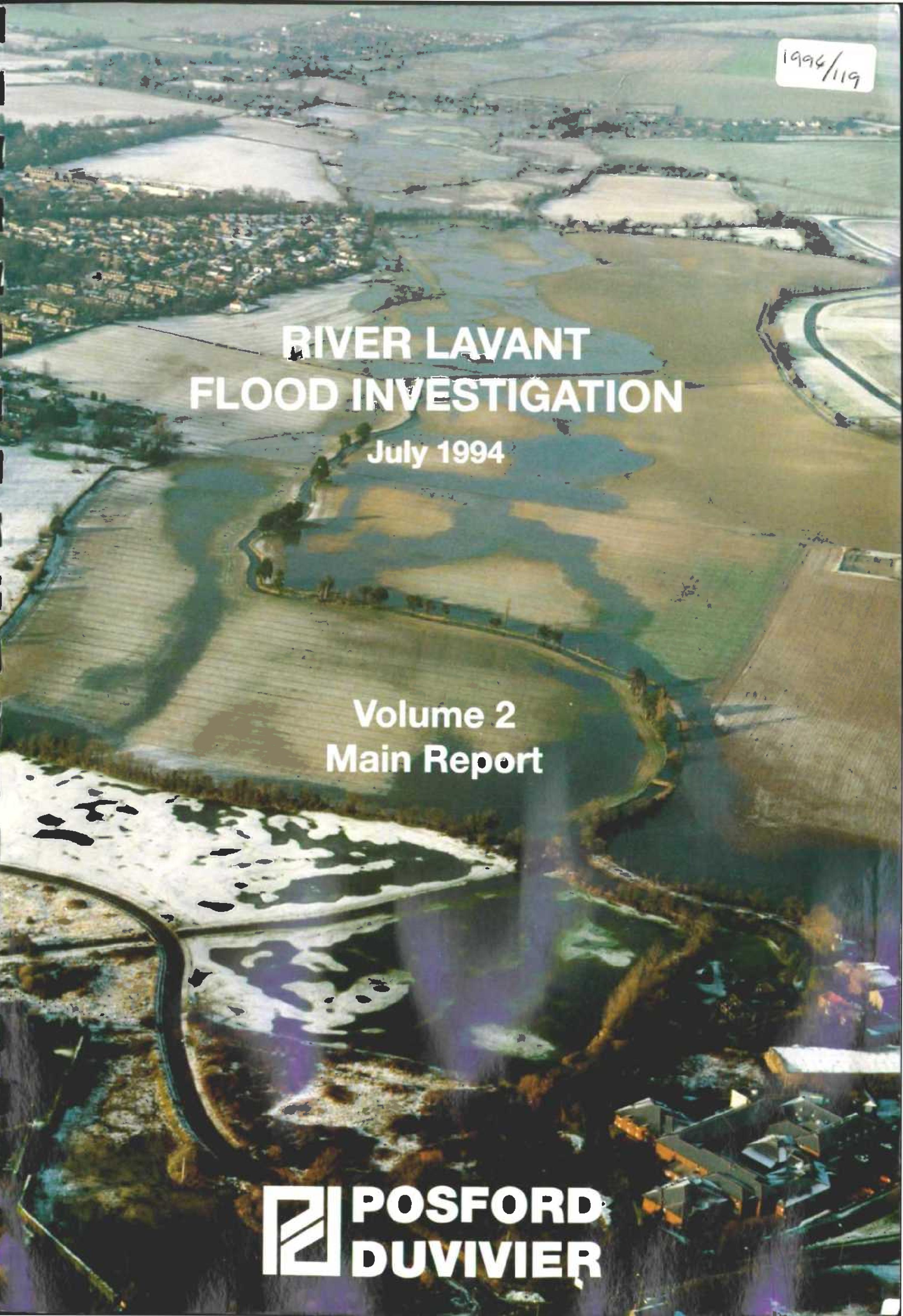

RIVER LAVANT FLOOD INVESTIGATION

July 1994

Volume 2
Main Report

POSFORD DUVIVIER

IN ARCHIVE

RIVER LAVANT FLOOD INVESTIGATION

JULY 1994

VOLUME 2
MAIN REPORT AND APPENDIX

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FOREWORD

This report was commissioned by the National Rivers Authority (NRA) as an independent assessment of the causes of the flooding associated with the River Lavant in and around Chichester early in 1994 and the consequences thereof. It does not address the remedial measures open to the NRA and others, which will be considered separately.

The mechanism of flooding is shown to be complex, with numbers of inter-dependent variables. Furthermore, estimates of return periods, for instance, (which are statistical means and not predictions) are based of necessity on data which may itself be a matter of interpretation.

It is important therefore to consider the report in its entirety. Individual extracts, perhaps out of context, may be misleading. The summary report has been prepared, with this problem in mind, to provide an overview.

Finally, all at Posford Duvivier would like to thank the many dozens of contributors of background information, both historical and current.

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2.0 INTRODUCTION

2.1 The River Lavant has a catchment of 86km^2 to the north east of Chichester. The upper catchment is in the chalk of the South Downs, and the majority of rainfall which falls on the very permeable catchment area drains to the chalk aquifer. Only a small proportion of the total rainfall is drained as run-off via the River Lavant channel; the majority draining through the aquifer. Indeed, flow in the channel is very much related to ground water levels. In times of low ground water levels, there is little or no flow in the river, and it is not uncommon for the river channel to be dry.

2.2 The river north of Westhampnett Mill is in natural unembanked channel. However, the river is believed to have been diverted, possibly in Roman times, to flow through Chichester into the Fishbourne channel. Through the City, the Lavant is in artificial channels and is culverted in ancient and irregular culverts of limited capacity for much of its route.

2.3 The river is designated as Main River by NRA from its mouth in the Fishbourne Channel to a point south of West Dean. From this point to its source near East Dean the river is undesignated. The culverts and channels through the City of Chichester are under riparian ownership.

2.4 There is a long history of flooding of the river although there have been no significant events since the last flood in 1960. Following this, flood alleviation measures were undertaken in the St Pancras area of the City.

2.5 During late 1993 ground water levels rose in the Lavant catchment in response to heavy rainfall in September and October. More rain in late December raised ground water levels further, and flow in the Lavant became significant by late December. In late December and early January 1994 there then followed a period of unusually heavy rainfall, resulting in ground water levels rising higher than had previously been recorded, and flows in the Lavant peaking at 7.9m^3/sec, nearly twice the previously recorded maximum flow.

2.6 Flooding began in early January with the River Lavant coming out of bank in a number of locations in the upper catchment, and through Chichester. Areas particularly affected were Singleton, West Dean, East Lavant, Westhampnett Mill, the A27 Westhampnett by-pass, the Hornet area of Chichester, Shopwhyke and Merston. Major flooding persisted for some 18 days.

2.7 Emergency measures were undertaken by NRA, West Sussex County Council (WSCC) and Chichester District Council (CDC) which included extensive sandbagging, temporary bailey bridges to maintain access on the A27 and A259, diversionary pumping in the city of Chichester, emergency defences in the Hornet, and emergency pumping of the Pagham Rife Outfall.

2.8 In the immediate aftermath of the flood, NRA, Southern Region appointed Posford Duvivier. Posford Duvivier proposed a four phase approach, being:

Phase I	Investigation of the flooding
Phase II	Feasibility study to identify potential alleviation measures
Phase III	Detailed appraisal of chosen options from Phase II
Phase IV	Implementation

NRA instructed Posford Duvivier to proceed with Phase I in February 1994 and to produce a Phase I report. The terms of reference were to "investigate the causes and consequences of the recent flood event, placing this in the context of historic flooding". Subsequent instructions were received to proceed to Phase II and a report on this aspect is planned for October.

This report sets out the results of that investigation and makes recommendations for further work.

3.0 RIVER LAVANT CATCHMENT

3.1 Detail Description of Upper Catchment and River Lavant, Physical and Land Use

The River Lavant is an ephemeral stream fed by chalk springs and surface run-off on the dip slope of the South Downs. For the purposes of this report the catchment has been considered in two sections; the upper extending upstream of Westhampnett Mill and the lower downstream of the Mill.

The catchment may best be described as the area which contributes to flow within the river. In the case of the Lavant, flow is predominantly fed by ground water and the groundwater catchment is larger than the topographically defined surface catchment. Section 3.5 describes the underlying geology, the ground water regime and its influence on river flows.

The surface catchment is shown on *Fig. 1.1* and the area is 85.8km^2.

The head of the Lavant, which depends on the ground water table, is normally in the vicinity of East Dean. Flow in the Lavant may occur from September to July but typically commences in late November with significant flow continuing through to April. Occasionally the Lavant can be dry for periods of up to 18 months (1972/73, 1975/76 and 1991/92) or more rarely, flow may be continuous (1967/69).

From East Dean the river runs adjacent to the northern side of the road to Charlton, crossing to the south side of the road to Singleton where it again crosses to the north. Between Singleton and West Dean the river once more crosses to the south to head in a south easterly direction in the valley bottom past West Dean and then southwards to Mid and East Lavant. The northerly extent of the main river designation lies just north of East Lavant.

From East Lavant the river continues south, south easterly to Westhampnett Mill where it splits into three channels. One, the Mill stream runs under the Mill and the others run through the Old Pound Farm gravel pit area. The shorter of the two Mill bypass channels is now blocked off at its upstream and downstream ends.

The length of the Lavant from its source to the Mill is 12.4km and falls from an elevation of around 75 metres at East Dean to 17 metres at the Mill. The overall gradient is thus 1 in 214.

Soils and the upper catchment boundary are shown on *Fig. 3.2*. The soil types, taken from the Soil Survey of England and Wales *(Reference 3)* are given in *Table 3.1*. but can be simply summarised by stating that 90.3% of the topographical catchment is covered by well drained calcareous silty soils over chalk. For comparison, in the neighbouring River Ems catchment the proportion of such soils is 60.9%.

Throughout its length the river has a generally flat gravel bed with mostly natural grassed sides. There is in consequence a good hydraulic connection to the underlying chalk. Thus ground water is able to flow into the channel or alternatively out of the channel into the chalk. This feature is confirmed not only by our own observations but by a series of flow measurements taken by NRA between December 1992 and July 1993 at locations between Singleton and Graylingwell. The majority of the measurements indicated a reduction in flow between West Dean and Binderton and between East Lavant and Graylingwell.

The northern area of the catchment comprises the primary dip slope of the South Downs cuesta and is predominantly covered by woodland. Much of this historically established woodland is commercially managed by the Forestry Commission. Similarly, the area to the south of the road that connects the A285 and A286 via East Dean, a secondary escarpment feature, is also wooded. The current extent of woodland in the upper River Lavant catchment has been calculated to be 35%. Using historical map evidence (Ordnance Survey, 1961), it is considered likely that this figure was not significantly different thirty years ago. Again for comparison, the proportion of woodland in the neighbouring River Ems catchment is 29%.

According to the Chichester Local Plan, many trees in the region have been lost for reasons including Dutch Elm Disease and other diseases, changes in management and agricultural practices, and the storm of October 1987 which had an abrupt and destructive impact and caused the loss of thousands of trees. It is therefore considered likely that although the upper catchment area covered by woodland has not altered substantially for many years, the tree density of the woodland may have been reduced.

In the River Lavant floodplain, and the area to the south and west of the catchment where the slopes of the undulating South Downs' hillsides are shallower, the main land use is arable farming. Since the Second World War the adoption of cereal production in rotation with ley pasture has superseded the traditional sheep and cattle farming. In particular, the parishes around Chichester are currently heavily farmed for wheat and barley, including winter cropping. Where ploughing has taken place on the relatively steep slopes of the South Downs, heavy autumnal rainfall has promoted severe cases of gulleying and the removal of the topsoil. Those upper and steeper hillsides used for agriculture are typically grazed by sheep.

There are several areas of non pastoral grassland; principally Goodwood race course and West Dean College. Existing residential and industrial areas are mainly limited to the floodplain. Development in the upper catchment over the past thirty years has been restricted by local policies, representing only 1.9% of the catchment area.

3.2 Detail Description of Lower Catchment

South of Westhampnett Mill the topographical catchment is not easily defined, as the surface gradients are very much flatter than in the upper catchment. Surface flow east of the A27 ring road is generally into the waste filled gravel workings or into the Pagham and Forebridge Rife systems *(Fig. 1.2)*. Drainage from the built up area of Chichester is predominantly into soakaways and therefore distributed, through ground water flow in the gravels, in a southerly direction away from the Lavant.

According to the Chichester District Archaeological Unit it is probable that at some time in the past, during the Roman or Early Medieval periods, the Lavant was diverted south west from the present Mill location towards the city where it formed a moat running from the vicinity of Eastgate, around the City walls to the south and turning back towards the Fishbourne Channel north of Westgate. It is considered that prior to this diversion, the Lavant continued south from Westhampnett Mill and discharged into one or more of the Rifes.

A detailed description of the present course of the Lavant through Chichester is given in *Section 3.3* and the ground water regime is covered in *Section 3.5*.

The overlying soil type over most of the lower catchment is listed as "HAMBLE 2; deep stoneless well drained silty soils and similar soils affected by ground water over gravel locally".

There are three dominant physical features of the lower catchment;

- The area is fairly flat with a shallow gradient southwards towards the sea
- A significant part of the area is built up comprising the dwellings, retail and commercial properties in the City.
- Large scale gravel extraction has taken place on the eastern side of the City (the historical development of gravel extraction and subsequent development is covered in *Section 5)*.

3.3 The River Lavant through Chichester

3.3.1 General

A detailed description and history of the River Lavant watercourse through Chichester is contained in Ken Newberry's book entitled, "The River Lavant" *(Reference 29)*. The river approaches the urban environment of Chichester at its north western edge opposite the Goodwood Motor Circuit and Airfield. Just to the north of Westhampnett Mill the watercourse divides into three channels which rejoin later at the Westhampnett Road near the junction of Church Road. From this point it proceeds in an open channel in a south westerly direction, first on the north side of Westhampnett Road and then on the south side of St Pancras until it passes behind the buildings at Green Lane. It then generally passes between the gardens or backs of properties until it reaches the area known as, "The Hornet", where the first culverted section commences under the Kwikfit building *(Figure 1.3)*.

This 436 metres long culvert passes beneath Eastgate Square and swings southwards to generally follow Market Road and the old city wall to emerge at "Market Walls", in the gardens of 7 and 7A Market Avenue, in open channel. The Lavant then enters a 230 metres long culvert towards the southern end of Market Avenue and passes beneath buildings fronting Old Market Avenue and South Street to emerge on the west side of the Argos car park. From here the channel takes an immediate 90° left hand turn followed by an equal right hand turn about 20m further on to proceed westwards through playing fields to the Chichester College of Technology.

A side overspill weir in the left bank at the right hand bend feeds a secondary channel which runs southwards between Avenue de Chartres and then westwards towards Cathedral Way, where it enters a culvert beneath the railway line and intervening factories to emerge on the south side of the Chichester Bypass and rejoin the main channel.

After the College of Technology the main channel turns southwards and passes under Cathedral Way, the railway line and the bypass in culverts with an open channel through the industrial estate. About 200 metres to the south of the bypass this channel is rejoined by the side-spill channel. Thereafter it proceeds in a westerly direction passing under Appledram Road and south of the Appledram Sewage Works to reach the tidal inlet known as the Fishbourne Channel.

3.3.2 Westhampnett Mill

Approximately 150 metres above the Mill the Lavant divides to form the wider Mill Stream and the narrower main channel which bypasses the Mill via the Barnfield Drive area. This is presently an open space consisting of worked and filled gravel pits crossed by Barnfield Drive and occupied in part by the Crematorium and its associated Garden of Remembrance.

The inlet to the main bypass channel has a facility for inserting stopboards to limit the flow and thus maintain the preferential supply to the Mill Stream. The main bypass channel is regular in section with the upper reach above Barnfield Drive bridge having a slacker gradient than the lower reach, which is quite swift flowing. Investigations concerning the history of the gravel pits indicate that gravel has not been extracted from beneath the strip forming the route of this channel.

Within the upper reaches of the Mill Stream there was a further control structure, now filled over, which previously fed a secondary bypass channel that still exists in part on the west side of the Mill grounds. However the lower reaches of this minor bypass channel appear to have been infilled, possibly during the construction of the Chichester Resort Hotel.

Closer to the Mill the Race is crossed by an arched bridge capable of taking light vehicles. This structure is unlikely to afford any significant restriction to flow. At the Mill however, there are trash screens which have to be raked regularly by the Mill owner and operatives to prevent obstruction to the flow. Sluice gates are used to control the flow that passes through the Mill basement, which was constructed in the 17th century.

The Mill stream exits from beneath the Mill through a low rectangular opening and passes in front of the Chichester Resort Hotel to run beside the Westhampnett Road towards

Chichester town centre. At the brick arch culvert beneath the main access to the hotel, the downstream side is partially obstructed at its upper level by service pipes. Further obstructions, in the form of a low, twin brick arch footbridge and service pipes, are present just a little way downstream in front of the hotel *(Photograph No. 33)*

Beyond the roundabout, beside the Westhampnett Road, the left bank of the channel has been formed as a concrete side wall with an upstand above the adjacent road level. A 375mm diameter pipe, used for pumping surplus water from Church Farm Pit, discharges to the stream at the commencement of this wall. Except for the openings at the Barnfield Drive and Crematorium access bridges, the raised level of the left bank is maintained until it reaches the redundant vehicle access to the gravel pit no. 3. Clearance beneath these bridges is low.

The brick arch footbridge to the Crematorium from the west side of the Sainsbury's roundabout would be likely to form an obstruction to high flows immediately downstream of a point where the level of defence is reduced adjacent to this roundabout.

Beyond the access to pit no. 3, past the Wadham Kenning garage to the footbridge opposite No. 22 Westhampnett Road, the left bank is grassed and raised only slightly above road level.

From the Mill to the above footbridge the bed of the Mill stream and the River Lavant is formed of gravel. Several land drains are noted to enter from the right bank and it is thought that some road drains enter from the left bank.

3.3.3 Westhampnett Road and St Pancras

The old brick arch footbridge opposite 22 Westhampnett Road is a constriction and forms a potential blockage point for floating and semi-submerged debris. It may also be seen from *photograph no. 34* that its upstream headwall has partially collapsed with the possibility of further collapse occurring. Immediately downstream of this bridge there is a deep scour pool approximately 2 metres deep followed by a shallow gravel fan in the area of the second, more modern, footbridge serving the houses in Storey Road.

From the road bridge to the eastern end of Bridge Road the channel is generally rectangular in section with a mixture of concrete, brick and stone side walls on each side. However, beside Bridge Road the left bank reverts to a grassed slope. On the roadside there is a 225mm thick low brick wall, which was constructed by the then West Sussex River Board following the flooding in November and December 1960.

Beyond the Green Lane footbridge the channel is initially rectangular in section with a mixture of materials forming the walls. After 50 metres it reverts to a regular trapezoidal channel with grassed banks to the relatively new road bridge at Tozer Way (Mayflower Way). This reach appears to have been straightened at some time to suit the layout of Riverside Road and the new housing estate served by Tozer Way. The Basil Shipham Centre, which features in photographs of earlier floods, is located on the west side of Tozer Way at its junction with St. Pancras.

Beyond Tozer Way to the Needlemakers Bridge the right bank is formed of the brick and flint walls of the back gardens and properties fronting St. Pancras. The left bank is mainly an irregular slope covered in vegetation with a line of trees and shrubs along the rear boundary of Rowe's Garage. Two bridges cross the river, one a decorative timber footbridge to Draymans Mews and the other the vehicle access to the rear of Rowe's Garage.

For about 30 metres upstream of the Needlemakers Bridge the channel is constricted slightly between garden walls on the right bank and a building wall on the left bank. The latter appears to have been strengthened in the past by a concrete encasement. At the bridge, which is of a modern, flat soffit, concrete deck construction, the abutments have been set back to provide a wider channel.

Between the Green Lane footbridge and the Needlemakers Bridge the channel bed is of gravel with a fairly even gradient until just downstream of the bridge to Rowe's Garage. After this point the gradient steepens to the entrance of the first major culvert at The Hornet.

3.3.4 The Hornet

From Needlemakers Bridge to the first culvert, the channel passes between the brick and flint walls of buildings and rear boundaries of properties. Immediately downstream of this building a raking timber shore, supporting a garden wall on the right bank, has been founded in the river bed and left bank. This is a potential trap at which floating debris can accumulate and cause an obstruction. Its removal and stabilisation of the garden wall should be a priority action.

Within the stretch of river adjacent to the site of the demolished properties, 27 and 29, The Hornet, the channel is spanned by a footbridge which appears to serve no purpose and a short culvert roofed with a concrete slab. Both could be removed to advantage, providing that the stability of the brick lined culvert walls was unaffected.

Immediately upstream of the first culvert mouth, at the Kwikfit Garage, the channel is constricted by a series of brick piers which project out from both sides of the brick walls by about 500mm. The piers support steel joists which in turn used to support a concrete base slab and rubble filled floor over half of the channel. This and the brick gable wall above it were demolished following and during the flooding respectively. Access to this area is available via a doorway from the rear area of Kwikfit.

3.3.5 Upstream City Culvert

This and the downstream culvert are to be subjected to a detailed internal inspection and structural survey, which is to be carried out by Archibald Shaw & Partners of Chichester, when river flow conditions permit. Following the flooding in January an interim dive survey was carried out in both culverts by Posford Duvivier Underwater on behalf of the NRA. The following comments are based on the results of that survey and report *(Reference 30)*.

The culvert is 436 metres long from inlet to outlet. In general the culvert section has a shallow curved invert and soffit with vertical side walls. The overall width varies from 2.1 to 2.7m with an overall height of 1.3m increasing to 2m at the downstream end. The exception to this is a length of 33 metres in Eastgate Square, from chainage 67 to 100 metres where the culvert divides to form two culverts of similar shape, each approximately 1.5 metres wide x 1.4 metres overall height. The invert and soffit are lined with brick laid in stretcher bond and the walls are mainly brick in a variety of bonds, with patches of random flint and sandstone.

The overall condition of the culvert appears to be satisfactory but there are areas where the mortar is soft or missing and some bricks have been lost from the lining, mainly in the soffit. Public utilities services pass across the culvert below the soffit and are prone to cause debris to accumulate to form a partial blockage. Of probably the greatest significance is the presence of three central cracks in the brick soffit, each approximately 15 metres long. From an earlier survey by WSCC, (who have undertaken annual inspections over the last 10 years or so) these would appear to be located under sections of public pavement or private property and not under the highway as could be expected.

From the exit of the first culvert the river flows through private gardens until it passes beneath the garden wall of No. 7A Market Avenue. At this point there is a grille which may be locked across the opening to prevent trespass into the garden. Even when open this grille projects partially into the main flow and tends to collect debris. However, it does not appear to have given rise to any problems during the January event. After a further short length of channel across an enclosed grassed area, the river enters the downstream culvert at the southern end of Market Avenue *(Photograph 15)*.

3.3.6 Downstream City Culvert

The culvert is 230 metres long, the first 80 metres formed as twin culverts. These have the same general cross section and construction as previously described but are slightly wider. For the remainder of its length beneath Old Market Avenue and South Street to the west side of Argos car park, the section and construction are generally the same as the first culvert except that the proportions are more generous with a width of about 3.7 metres and an overall height of about 1.7 metres. The internal condition is generally the same as that of the first culvert except that the central cracking of the soffit is nowhere so extensive.

Surface water drain pipe entries are in evidence but the largest of these, a 500mm diameter concrete pipe entering at about mid height at chainage 57 metres in the right hand side of the twin culvert has been blocked off about 600mm before its entry. No evidence was found of any large diameter overflow or discharge connections to the canal basin. Public utility service pipes cross the culvert below the level of the soffit.

3.3.7 Westgate Fields

Beyond the Argos car park the river flows predominantly westwards in an open channel between playing fields and then between the WSCC offices at The Tannery and Chichester College of Technology, after which it turns southwards to pass under the railway.

The side spill channel immediately after the Argos car park is contained within the reinforced concrete foundations of the footbridge ramp and the footbridge itself across the Avenue de Chartres. Thereafter it flows in an open channel until it passes under the railway.

3.4 Details of Gauging and Available Records

There is one gauging station on the River Lavant situated at Graylingwell (National Grid Ref. SU871064). The gauge comprises a flat V concrete crump weir and was constructed in 1970. River levels are logged at 15 minute intervals and there is a stage discharge relationship from zero to a depth of one metre at which point the river overtops the structure. A depth of one metre corresponds to a flow of 8.00m^3/s *(Photograph No. 32)*.

The station has been operating since January 1971 and data is available from then to date. *Table 3.2* in Volume 3 of the report shows the maximum flows recorded annually between 1971 and 1993.

3.5 General Description of Ground Water Regime of the Lavant Catchment

3.5.1 Upper Lavant Catchment

The Lavant catchment drains about one-third of the outcrop area of the Chichester Chalk Block. This is a discrete hydrogeological unit of some 493 km^2 bounded by the River Arun, River Ems, the South Downs scarp and the coast. The South Downs Resources Investigation of this area *(Reference 17)* demonstrated that the geological sequence, structure and history have a strong influence on the ground water regime.

The Chalk is the major aquifer in the region. It is a very fine grained (<10 um), pure (>98% CaCO3), relatively soft, white limestone and outcrops over 55% of the Chichester Chalk Block. The extensive outcrop area of the Chalk and its considerable thickness (150-300m at outcrop) provide a large catchment and storage capacity whilst the thin cover of soil enhances the recharge potential.

The Chalk is subdivided into Upper, Middle and Lower Chalk[1]. The Chalk Rock marks the boundary between the Upper and Middle Chalk and the Melbourne Rock separates the Middle Chalk from the Lower Chalk. Typical thicknesses are: Upper Chalk, up to 230 m; Middle Chalk, 65-90m; and Lower Chalk, about 60m.

[1] Recent mapping now groups the Upper and Middle Chalk as the Sussex White Chalk Formation.

Most of the outcrop in the upper Lavant catchment comprises Upper Chalk. Outcrops of Lower Chalk occur in the top part of the catchment northeast of Upwaltham and Middle Chalk is exposed along the valley floor above Picton *(Fig.3.1)*, which suggests that the Lavant valley represents a transitional phase of erosional development between that of the Ems drainage system, where erosion has not penetrated through the Upper Chalk, and the Arun drainage system, which has cut through the Chalk into the Weald.

The sequence has a shallow southward dip of 2-3 degrees associated with the southern limb of the Wealden anticline. Three main, slightly asymmetric, east-west trending folds are superimposed upon the southward slope: the Singleton anticline, Chichester syncline and Portsdown-Littlehampton anticline. The hydrology of the upper Lavant catchment is particularly influenced by the Singleton anticline. A thick sequence of Lower London Tertiaries (LLT) of low permeability is preserved in the Chichester syncline which restricts the southward flow of ground water from the outcrop area and confines the underlying Chalk *(Fig. 3.3)*.

Ground water level elevation maps for the Chalk aquifer have been prepared by *(Reference 17)* representing average (July 1982), high (March 1977) and low (December 1978) water level conditions in the Chalk aquifer of the Chichester Chalk Block. The hydrogeological map of the area *Reference 2* also shows water level conditions for October 1973 (low condition), although based on fewer monitoring points.

Average water level elevations range from sea level near Runcton to about 90 mOD at the main ground water divide close to the northern scarp. There are two main ground water mounds: in the northeast around Upwaltham and in the northwest at Telegraph Hill. These are associated with the areas of highest elevation and the greatest thickness of Chalk. They are separated by an area of lower water level elevation and reduced hydraulic gradients in the Singleton-Cocking area. The range of seasonal water level fluctuations (up to 40 m) is greatest in the areas of high elevation and distant from natural outlets.

The Chalk outcrop area has unconfined water table conditions. Ground water flow originating from the outcrop passes north to appear as scarp slope springs at the Lower Chalk/Upper Greensand boundary or at the Upper Greensand/ Gault boundary, southeast to major springs near the River Arun, or southwards towards the coast. Ground water from the outcrop area moves south under the LLT cover. Ground water from the Lavant catchment mainly converges on Fishbourne and the Chichester channel area.

The elevation of the contact between the Chalk and LLT influences the outflow from the Chalk outcrop area. The three main dip slope springs/bournes in the west have higher contact elevations (Ems, 20 mOD; Ratham Stream, 15 mOD; Lavant, 25 mOD) than the river springs in the east (sea level at Arundel).

The Chalk aquifer is only in direct hydraulic continuity with the drift deposits between Chichester and Pagham, although the baseflow of Forebridge, Pagham and Bremere Rifes is considered to be derived mainly from the unconsolidated deposits with some component of 'overflow' from the edge of the Chalk outcrop *(Reference 17)*.

An extensive literature is available on the nature of the Chalk aquifer and its properties *(Reference 13)*. Hydrogeological data for the region are being assembled as part of the National Ground Water Survey. The hydraulic characteristics of the Chalk are influenced by a combination of factors including topography, stratigraphy, Quaternary history, structure and water level variations.

The Chalk matrix has a very low intergranular intrinsic permeability (10^{-4} to 10^{-2} m/d). Instead fissure enlargement by solution, mainly in the upper part of the aquifer, accounts for much of the ground water movement and storage potential. This has produced a correspondingly variable transmissivity, typically in the range of 500-2000 m^2d, although thin (< 10 m) highly permeable zones can have higher transmissivities (up to 8000 m^2d).

The Chalk has a high porosity (20-45%) but low specific yield (Sy), which at outcrop ranges from $1x10^{-3}$ to $1\text{-}3x10^{-2}$ *(Reference 6)*. Baseflow analysis of the Test and Itchen in Hampshire indicate an overall Sy of 3.3-3.4%. Detailed analyses of 12 wells fitted with water level recorders in the Upper Chalk of Hampshire during the 1960's indicated typical Sy values of 2.5%. Recession analysis of water level data indicated an Sy of 0.97% at Compton *(Reference 21)* and an Sy of 1.17% from Chilgrove.

The valley gravel deposits that occur along the Lavant, which are in hydraulic continuity with the Chalk at high water levels, are likely to have an Sy of about 7% (based on pumping tests in the Candover catchment in Hampshire).

3.5.2 Westhampnett (East Chichester) Area

A simplified distribution of drift deposits around Chichester is shown in *Fig. 3.4 (Reference 3 & 4)* and a geological cross-section of the Westhampnett area is shown in *Fig. 3.5 (Reference 11)*.

The Chichester plain between the Chalk outcrop and the coast consists of two raised beaches. The upper (older) raised beach occurs between 20 and 45 mOD and is cut into the dip-slope of the Chalk whilst the (lower) younger raised beach lies between sea level and 15 mOD on a peneplaned surface of folded Chalk and LLT deposits. The northern edge of the upper and lower raised beach deposits are both marked by buried cliff-lines at about 45 and 15 mOD, respectively. Silty brickearth deposits up to 7 m thick cover the lower raised beach deposits and part of the upper raised beach deposits.

Chichester is situated on alluvial fan deposits (Fan Gravels) derived from the River Lavant. These deposits form an outcrop 200-300 m wide and 3-5 m thick along the course of the Lavant which then spread out at the lower cliff line near Westhampnett into a fan-shape some 3 km in radius. The thickness of these deposits decreases from 10 m at Westhampnett to about 2 m on the southern edge of the fan *(Fig. 3.6)*.

The Fan Gravels form the principal source of aggregates in the area. Historical information on the gravel pit workings in East Chichester was assembled from various sources to provide background data for a preliminary ground water model study of the area in 1990 *(Reference 11).* This study also included water level and isopachyte maps and estimates of aquifer characteristics. Other hydrogeological information for the area is available from the South Downs Resources Investigation *(Reference 17).*

The Fan Gravels are the aquifer of primary interest in the Westhampnett area. However, the natural ground water regime has been disturbed by the gravel pit workings in this area. The main source of recharge is the River Lavant. Ground water occurs at shallow depths and varies from about 15 mOD at Westhampnett to about 5 mOD at the edge of the fan, or a hydraulic gradient of about 0.001. The average saturated thickness is about 3.5 m. Estimates of transmissivity based on the ground water model range from about 300-500 m^2d in the central part of the fan decreasing to about 50 m^2d at the edges of the fan due mainly to the reduced thickness of the Fan Gravels.

3.6 Summary of Available Information on Ground Water Levels

The Chichester Chalk Block has two of the longest continuous ground water level records in the UK:

- at **Chilgrove** (SU 83561440, 77.18 mOD), situated 9 km NNW of Chichester near the head of the main tributary of the Lavant, which dates from January 1836;
- and at **Compton** (SU 77551490, 81.37 mOD), situated in the Ems catchment some 6.5 km west of Chilgrove, for which records are available from February 1893.

Both wells are located on the Upper Chalk outcrop and a long term rainfall record is also available at both sites.

The water level and rainfall records for both wells have been described in several publications by Thomson *(Reference 19, 20, 21 & 22).* The Chilgrove record up to 1989 has been published *(Reference 6).* Water levels were measured monthly at Chilgrove up to 1922 and weekly thereafter, although daily measurements are also available for the period January 1924 to December 1933 and from 21 December 1993 to 15 January 1994 during the recent flood event.

A semi-log plot of the annual maximum water levels at Chilgrove and Compton since 1893 is shown in *Fig. 3.7.* There is a close correlation (0.96) between the two sets of data which can be described as follows:

$$y = -145 + 122 \log x \qquad [1]$$

where y is an annual maximum water level at Chilgrove in mOD and x is an annual maximum water level at Compton in mOD.

NRA maintain a network of some 41 monitoring wells (currently under review) covering the Chichester Chalk Block, of which 16 are located within the upper Lavant catchment. Most of the routine water level measurements began in the late 1970's/early 1980's. Supplementary water level measurements taken by NRA during January 1994 are given in *Table 3.3.* The locations of the wells are shown in *Figs. 4.3 and 4.4.*

The water level records available for the unconsolidated deposits in the East Chichester area are rather variable and were often collected for short periods only as part of specific studies, such as the A27 roadline investigations. Because of pit infilling earlier records of pit water levels may no longer be relevant to the present conditions. In addition, pumping and other controls, which are not always recorded, tend to mask the natural variations in pit water levels.

Shallow wells at Tangmere and Portfield Depot form part of the NRA monitoring network and have records dating from 1980. Pit water level data (assembled from various sources and with varying frequency of measurement) are available from 1969 for Church Farm Pit (Westhampnett Water Park) *(Reference 11)* and occasionally for other pits in the same area. The water level in this pit has been monitored at weekly intervals since March 1992. Supplementary water level data were collected by NRA during January 1994 from Church Farm pit, Whyke Lane Pit and the shallow monitoring wells at Tangmere and Chichester Depot.

3.7 Details of Meteorological Information

Around the Chichester area, rainfall data are available from 23 rainfall stations of which 8 are within the Lavant Catchment. Daily rainfall data is held for all except two of the stations for which monthly rainfall figures only are available. *Table 3.4* tabulates the station names, the record period and the frequency of measurements. The location of the stations is also shown in *Fig.4.2*

Additionally 'Meterological Office Rainfall and Evaporation Calculation System' (MORECS) data is available from the Met. Office in two forms. MORECS square data covers areas of 40 x 40 km and single station data can also be provided. From records of sunshine hours, wind speed, vapour pressure, temperature and rainfall the MORECS model calculates actual and potential evapotranspiration, soil moisture deficit, effective precipitation and stress.

For the purpose of the study, long term rainfall data was obtained from NRA for Chilgrove plus the 1993 and January 1994 data for the remainder of the rainfall stations. MORECS square data (square 183) was also obtained from NRA for January 1961 to January 1994 inclusive. Single station MORECS data was obtained from 1 August 1993 to 31 January 1994 from the Met Office for Chilgrove House, Walderton Pumping Station and Lavant Reservoir.

3.8 Schedule of Known Historical Flood Events from the River Lavant

There is a long history of flooding of the River Lavant, but there have been no serious events since 1960 when extensive areas of Chichester were affected. *Table 3.5* schedules details of recorded flooding with, where known, the associated Chilgrove ground water levels.

There have been no significant flood events since 1971 when the Graylingwell station was commissioned and as a result there are no records of river flows associated with flood events other than the recent one.

4.0 FLOOD EVENTS OF JANUARY 1994

4.1 Hydrological Conditions in the Upper Lavant Catchment Prior to Flood

The antecedent water level conditions in the upper Lavant catchment influence the inception, duration and amount of flow in the Lavant in any particular year. The recent flood event can be considered as beginning with the seasonal rise in water level, which started on or about 29 September 1993 at Chilgrove. However, this also needs to be set in the context of changes in aquifer storage during the preceding years.

4.1.1 Ground Water Levels from 1989/90 to September 1993

Figure 4.1 shows the water level record at Chilgrove from January 1989 to January 1994. The lack of winter recharge during the late 1980's led to two of the lowest annual water levels recorded at Chilgrove: 33.79m OD on 12 December 1989 and 33.71m OD on 18 December 1990, which were 17m below the average water level for December. There was no flow on the Lavant between July 1988 and February 1990. These low water levels were separated by a notably wet winter in 1989/90 that caused a water level rise of 40 m (to 73.84 mOD) over the two months up to 8 February 1990, at which time flow began on the Lavant and increased rapidly over a few days from 0.002 to 1.68m^3/sec. This rise in water level was similar to the that over the period October 1993 to January 1994 but did not lead to floods or a net gain in over-year ground water storage.

Prolonged recharge during 1990/1991 began to replenish the previous depletion in storage, raising the minimum annual water level to 39.86 mOD by December 1991, or 6 m higher than the minimum in 1990. The lack of subsequent winter recharge in 1991 resulted in a late maximum water level of only 46.06 mOD in May 1992 and produced a slight decline in the minimum water level to 37.9 mOD in September 1992.

The wet winter of 1992 caused a rapid rise in water level of some 30 m giving a winter peak of about 68 mOD (10 December 1992 and also 29 January 1993). This resulted in water levels during the spring and summer of 1993 that were close to the long term average. The minimum water level of 38.31 mOD occurred on 29 September 1993, slightly less than the long term average for this month of 40.74 mOD but almost 5 m above the minima of 1989 and 1990.

The combination of recharge events during water years 1990, 1991 and 1992 overcame the depletion in storage that had occurred during the late 1980's and resulted in water levels that were close to their average position at the time winter recharge began at the end of September 1993. The period from December 1990 to January 1994 has included the lowest and highest water levels recorded at Chilgrove.

4.1.2 Ground water Levels during the period September 1993 to January 1994

Table 4.1 gives the daily mean Lavant flows at Graylingwell, daily rainfall and effective precipitation (EP) and the water level measurements at Chilgrove for the period 22 September 1993 to 31 January 1994, which covers the period from just before water levels began their seasonal rise to just after the flood event.

Between 27 September and 13 October 1993 there was a period of heavy rainfall totalling 175 mm. The summer soil moisture deficit was overcome by the 29 September 1993 and water levels responded rapidly, rising from 38mOD to about 56 mOD in mid-October or about 14 m above the average water level for October. A small flow of less than $0.005m^3/s$ occurred on the Lavant from 30 September to 5 October $1993m^3/s$ but a sustained flow began on the 8 October reaching about 0.1m m^3/sec by the end of October.

There then followed a prolonged dry spell from 13 October to 28 November 1993 when only 60 mm of rainfall was recorded at Chilgrove, of which about 50 mm occurred between 9 and 13 November 1993. Water levels declined to about 50 mOD, although still 4 m above the average water level for November. The mean daily flows at Graylingwell also remained fairly constant during this period, reaching a maximum of $0.28m^3/s$ after the rainfall in mid-November.

From the 28 November 1993 until mid-January 1994, the southern part of the UK was swept by a succession of Atlantic fronts. Over this period there were 6 days when rainfall exceeded 19 mm/d (12, 18, 19 and 30 December 1993 and 1 and 3 January 1994), with 30.9 mm being recorded on 3 January 1994. These six days alone accounted for nearly 150 mm or about 40% of the total rainfall over this period.

The total rainfall from 28 November to the peak floodflow on the 11/12 January 1994 was 366 mm (nearly 280 mm EP) bringing the total rainfall over the period since the end of September 1993 to about 600 mm (about 460 mmEP). The rainfall between 29 November and 29 December 1993 inclusive (31 days) was 200 mm and between 30 December and 12 January inclusive (14 days) was 166 mm. Only a further 30 mm of rainfall were recorded during the last two weeks of January. Note that rainfall is measured at a single station, namely Chilgrove, whereas EP is derived from a number of stations.

By mid-December the water level at Chilgrove had risen by only 3 m to 53 mOD, or 2 m above the average for December. However, between mid-December and Christmas Day there was a rise of 16 m to nearly 69 mOD, or some 18 m above the average water level for December, which stayed at this level until 30 December 1993.

The intense rainfall after 30 December produced a further rise of at least 7 m during the following week and on 7 January 1994 the Chilgrove well became artesian. This represents a total rise in water level of at least 40 m after the minimum water level in September. The Chilgrove well remained artesian for about 18 days until about 25 January 1994 but then declined to 74.68 mOD by the 27 January 1994. Water levels receded slowly during February and March 1994, falling to 60.31 mOD by 18 March 1994, although still 4 m above the average for March.

The water level at Compton reached 68.75 mOD on 11 January 1994. This was nearly 4 m above the previously recorded highest level in 1960 and the highest since records began. The rise in water level at Compton between 29 September and 11 January 1994 was 37.30 m. The estimated corresponding peak water level at Chilgrove using the Compton data and equation [1] in *Section 3.6* was 79.15 mOD.

Flow in the Lavant increased to about $0.3m^3/s$ by mid-December 1993 and to $1.0m^3/s$ by 22 December but was still only $1.7m^3/s$ on 29 December just prior to the heavy rainfall at the beginning of January. Over the subsequent period from 29 December to 6 January 1994 the mean flow increased by $4.8m^3/s$ to $6.5m^3/s$, overbanking at Graylingwell from 4 January until 15 January (during which the peak flow was estimated to reach approximately $7.9m^3/s$ on 10 January). The flow then dropped rapidly, declining to about $2.5m^3/s$ by the end of January.

Detailed description of flood flows are included in *Section 4.4*.

Over the period 27 September 1993 (when water levels began to rise) to the peak flood flow on the 10 January 1994, the effective rainfall totalled 448 mm equivalent to a volume of 40.0 million m^3 over the surface catchment area. The total volume of flow on the Lavant at Graylingwell over the same period was around 8.5 million m^3, which represents 21% of the effective rainfall (or about 16% of the total rainfall). About 80% (6.3 million m^3) of the total flow over this period occurred between 27 December 1993 and 11 January 1994, which represents 53% of the effective rainfall (135 mm, or a volume of 11.8 million m^3) over the surface catchment area over the same period.

4.1.3 Rainfall Distribution

Total rainfall over the period 1 October 1993 to 31 January 1994 is shown in *Fig. 4.2*.

4.1.4 Water Level Configuration

Figures 4.3 and 4.4 show water level elevation maps for the upper Lavant catchment in September 1993 and January 1994 based on NRA monitoring data. Depths to water level and the change in water level over this period are also shown. A cross section is shown in *Fig. 4.5*

The main features of the contour pattern in September 1993, which represents an annual average minimum water level condition, can be summarised as follows:

- the Singleton anticline forms an east-west partial barrier to ground water flow east of West Dean approximately along the sub-scarp on the southern side of the Lavant valley. This sub-divides the upper Lavant catchment into northern and southern ground water sub-catchments.

- the highest water levels (about 80-95 mOD, or 110-120m below ground level) (mbgl).

occurred in the northwest and northeastern part of the catchment. The principal directions of ground water were from the area north of the Lavant towards the lower part of the Ems catchment and towards Mid Lavant under a low hydraulic gradient. Water levels of about 30-40 mOD (30-40 mbgl) occurred over a wide area southwest of Chilgrove. There was a steeper hydraulic gradient from south of East Dean. Ground water flow in this area moves south towards Goodwood and southeast towards Arundel, water levels being about 5-20 mOD along the Chalk/LLT boundary.

- water level elevations along the Lavant valley were about 35 mOD at Mid Lavant, 50 mOD at West Dean and 70 mOD at East Dean. Shallow water levels occurred upstream of Singleton, being only about 3-12 mbgl in the Charlton-East Dean area and about 25 mbgl at Droke. Relatively shallow water levels may have occurred also between Singleton and Cocking.

There is no information on water level depths along the Lavant valley below Singleton. However, a shallow well at Stoke Langford in the Chilgrove valley just upstream of its confluence with the Lavant had a water level of less than 3 mbgl, which suggests that the water table occurs at a shallow depth along the valley floor. Water level data collected between 1970 and 1973 from seven wells close to the Lavant valley between Mid Lavant and Singleton *(Reference 14)* also indicate that the Lavant valley has a local influence on the direction of ground water flow, even when there is no surface flow occurring.

The main changes in the pattern of ground water flow by January 1994, the maximum annual water level condition, can be summarised as follows:

- the ground water flow in the western part of the area changed to a more southerly direction due to outflow along the Chilgrove valley and in the Mid Lavant-West Dean area of the Lavant valley (the contours are likely to have a more marked V-shape up the valley than shown on the map).

- whilst data are scarce in the area south of East Dean, the contour pattern in this area shows little change, except where influenced by the Lavant valley.

- the largest water level changes, about 20-45 m, occurred in the areas of highest elevation whilst changes of less than 10 m occurred along the main valley.

4.2 Water Levels in the Westhampnett Area

The longer term changes in water level elevation at Church Farm Pit since 1969 are shown in *Figure 4.6*. There was a rise in minimum water levels of about 4 m (from 9 to 13 mOD) between 1969 to 1984, mainly due to a reduction in pumping operations in this and other adjacent pits but also because of an above average rainfall in the early 1980's. Thereafter, water levels have shown a seasonal variation between about 13 and 15.5 mOD. (*Reference 11*).

The water level fluctuations at Church Farm Pit since 1992 are shown in *Figure 4.7.* Water levels fell to 12 mOD in November 1992 as a result of the lack of recharge from the Lavant during 1991/92 (the Lavant ceased flowing in July 1991 and, apart from a few days of very low flow in February and March 1992, did not recommence until early December 1992). The water level in November 1992 was the lowest recorded since 1979[2].

During the winter of 1992 water levels rose rapidly to a peak of 15.95 mOD on 15 February 1992 after which pumping by Mitre Properties stabilised water levels at 15.7-15.8 mOD until mid-April. A rapid recession took place during May 1993 to about 12 mOD, mainly due to dewatering of the pit during the construction of the A27 by-pass. Mean daily flow in the Lavant increased to a peak of about $1.4m^3/sec$ by late January 1993 and flow ceased at the end of July 1993.

A sustained winter flow in the Lavant began at the end of September 1993. Water levels in Church Farm Pit began to recover almost immediately and rose throughout November and December 1993 to reach a peak of about 16.86 mOD on 12 January 1994, the highest level recorded. From the 4 January 1994, when overbanking occurred at Graylingwell, surface flows entered the pit in the southwest corner and water overflowed from the pit onto and across the A27 by-pass until about 18 January 1994. Water levels remained at 16.72 to 16.81 mOD until 10 February and were still at 16.16 mOD on 16 February 1994. To date, pumping is still necessary to reduce water levels.

4.3 Development of Flood in River Lavant Catchment

The heavy rainfall throughout December 1993 culminated in over 50mm of rain over West Sussex during the 30th December. This caused localised but mainly short term flooding at many locations throughout the County. It was only during the early days of January 1994 that serious flooding of the River Lavant catchment commenced. The development of flooding within the Lavant catchment and the flood route that developed once the river had overtopped its left bank above Westhampnett Mill is covered in the form of a diary in *Appendix A*.

It has to be appreciated that flooding was also occurring elsewhere along the coastal plain between and including the catchments of the River Arun and the River Ems. The most significant, as far as traffic diversions were concerned, was the flooding occurring within Aldingbourne Rife immediately to the east of the areas of Forebridge and Pagham Rifes, which were acting as the flood relief route for the overspill at Westhampnett Mill. Options for traffic diversion routes were therefore restricted and compounded the problems caused by the flooding of the new A27 Westhampnett Bypass.

2 A lower water level probably occurred during the period between July 1988 and February 1990 when there was no flow on the Lavant.

The information used to compile the diary in the Appendix has been obtained from the following sources:-

i) The WSCC emergency telephone log compiled by the County Emergency Planning Officer (CEPO)..

ii) The WSCC Divisional Surveyor's log compiled at the WSCC Drayton Depot.

iii) Sussex Police logs for Operation Badminton.

iv) Two NRA Southern Regional internal reports faxed by Adrian Biggs, Area Flood Defence Manager, to Mr. Bill Martin, Ministry of Agriculture Fisheries and Food, on 28th January, 1994. These contained press releases, hydrometric information, reports of property, roads and other areas flooded in West Sussex, action reports and flood warning records issued by the Region. NRA also provided an outline log of the event.

v) Information provided by County Fire Officer (Mr. Ken Lloyd).

vi) Anecdotal evidence provided by parties directly affected by the flooding eg. the owners of Westhampnett Mill, Mitre Properties, Tarmac Aggregates and other commercial operators affected by the flooding in the area of Church Farm Pit.

Three supplementary reports issued by WSCC for internal use have also been used as a means of cross reference as they were compiled utilising the resources i), ii) and iii) above. These were as follows:-

vii) A brief report on the flooding by the Chief Executive for the Policy and Resources Committee of WSCC, dated 31st January 1994.

viii) A comprehensive ten page report by Mr R G Serman, Director of Property to the Chief Executive of WSCC. This was undated but it was presumably compiled prior to the above report.

ix) A paper entitled, "The Floods of '94", prepared by Mr Derrick Fawcett, Assistant County Engineer and Surveyor of WSCC.

4.4 River Flows Gauged Prior and During the Event

For the whole of the period before, during and after the flood the NRA's gauging station at Graylingwell was monitoring the water level at 15 minute intervals *(see Fig. 4.11)* From 7 January when the Lavant was overflowing its banks upstream of Westhampnett, additional gauging was carried out of the river in St. Pancras and from 8 January was supplemented by gauging of flood flow within Madgewick Lane and from 9 January of flow across the newly constructed A27 road.

In December 1993 a contract to determine the structural condition and hydraulic capacity of the culvert through Chichester was awarded to a local firm of consulting engineers, Archibald Shaw and Partners. The consultants undertook further gauging of the Lavant through Chichester between 11 and 24 January.

The measured flows at the locations shown on *Fig. 4.11* are presented in *Table 4.4*. Examination of the table reveals a discrepancy in the flows measured on 14, 17 and 24 January between Mayflower Way and St. Pancras; measuring stations only some 400 metres apart and between which no overtopping of the river channel has been reported. The combined flows of St. Pancras and Madgewick Lane compares reasonably well with flows recorded at Graylingwell and therefore gives confidence in the NRA's figures. Copies of the actual recorded measurements and calculations were obtained to determine the reason for the differences. From inspection of the calculation sheets and from knowledge of the Mayflower Way measuring position it would appear that flow velocities were taken immediately upstream of the bridge whilst the channel cross section was taken within the bridge structure. The channel upstream of the bridge is trapezoidal and since the bridge is essentially rectangular, steady flow conditions, which are required for the velocity/area method of flow gauging, would not exist. The Mayflower Way recorded flows should therefore be disregarded.

Several factors make accurate measurement of the peak flood flow of the event difficult if not impossible. The river overtopped both banks upstream and downstream of the Graylingwell gauging station. Some, probably the majority of the out-of-bank water, could be and was measured flowing along Madgewick Lane. However some of the out-of-bank flow on the east of the river may have run back into the channel downstream of Graylingwell. Additionally water ponded in the fields and would not be included in any flow measurement.

NRA have suggested that the total flow be determined from the addition of the St. Pancras and Madgewick Lane flows and this is considered reasonable. From table 4.4 therefore the maximum flow recorded was 7.9m^3/s on 10 January.

The flow down Madgewick Lane was contained by sandbagging and discharged into the south west corner of Church Farm pit. The overflow from the south east corner of the pit over the A27 road is generally between 0.1 and 0.2m^3/s less than the inflow in the south west corner.

The peak flow recorded on the downstream side of the upstream of the two culverts in Chichester, at Market Walls footbridge was 5.25m^3/s although this flow was achieved with a 0.48m surcharge at the upstream entrance at Kwikfit's garage.

The assessment of channel capacities is dealt with in *Section 7*.

In additional to the gauging listed in *Table 4.4*. NRA measured the following flows in the Lavant upstream of Graylingwell.

Singleton	17.1.94	$2.68m^3/s$
Downstream of Bridge House Singleton	14.1.94	$2.0m^3/s$
Charlton	17.1.94	$1.35m^3/s$
Upstream of Charlton	14.1.94	$0.96m^3/s$

Flows were also taken at the railway culverts, Merston, and at Runcton on the Pagham Rife complimented by gaugings at Elbride and Shipney on the Aldingbourne Rife.

4.5 Extent of Flooding

4.5.1 Flooding Upstream of Westhampnett Mill *(Photographs 2 to 6)*

Along virtually the whole of the length of the Lavant, from East Dean to Westhampnett Mill flooding occurred to a greater or lesser extent. For the purpose of this report the incidents of flooding are described working downstream from East Dean. The number of properties flooded at each settlement has been assessed from various reports and from a study of aerial photographs taken during the event. In consequence, there may be some discrepancies, particularly with regard to actual flooded depths. The flooded areas are shown on *Fig. 4.9 and 4.10.*

The fields and road immediately upstream of East Dean, in the valley bottom, were flooded and floodwater affected some 24 properties, the roads and village green and pond. The Lavant source thus effectively appeared some 500 metres east of the village.

Some flooding of the road from East Dean to Charlton was reported, the road being adjacent to the river in the bottom of the valley. Just upstream of Charlton, fields to the south of the road were flooded and farm buildings and 2 dwellings affected.

To the west of Charlton the road rises above the true valley bottom and the Lavant overspilled to form a second channel across the fields towards Singleton. At Singleton the secondary channel rejoined the Lavant and 15 properties were flooded along with extensive road flooding.

On its route to West Dean, a number of small areas of farmland adjacent to the river and some land within West Dean College suffered local flooding. Moving southwards towards Binderton the Lavant again overtopped to form a second channel to the east of the natural channel and some ponding between the river and the disused railway.

In the vicinity of the water works extensive flooding occurred. At this location a tributary which runs alongside the road from Chilgrove joins the Lavant. This tributary was clearly running at full capacity and had overtopped at a number of locations along its length.

From the water works to East Lavant a number of springs added to the river flow and caused some field flooding in their own right. There was extensive flooding at East Lavant, cutting the village in half, Sheepwash Lane living up to its name. However, only three dwellings and a sports hall are reported to have been flooded.

Downstream of East Lavant past the sewage treatment works to Fordwater Lane the floodwater extended some 200 metres to the west of the channel.

From the Ford to the NRA's gauging station at Graylingwell the flooding was predominantly to the east of the river. Water on the eastern side, some by-passing the gauging station and some overtopping a low section of the eastern bank downstream of the station, flowed onto Madgewick Lane. From the west and the primary Mill by-pass channel, flooding of the playing fields and Crematorium in the Pond Farm area occurred.

4.5.2 Flooding Downstream of Westhampnett Mill *(Photographs 7 to 28 and Fig. 4.10)*

At Westhampnett, the Mill and three warehouses, (two of which are unoccupied), were flooded. The warehouses located at the north west corner of the water-filled Church Farm Pit, the Dares Estate and which had been flooded since December were flooded to a depth of approximately one metre. Also flooded was the site of the burnt out Sainsbury's store and ARC's concrete pre-casting yard. Out-of-bank flow along Madgewick Lane was contained by sandbags southwards along the old A27 discharging it into Church Farm Pit.

Water levels rose in Church Farm Pit *(see Section 4.2)* and overflowed at the south east corner onto the newly constructed A27 Westhampnett Bypass. Maudlin Farm, 600 metres to the east of the pit was flooded to a reported depth of 1.2 metres and a pit being currently worked by Tarmac on the south side of the new bypass received flood waters.

Some flood water thus effectively found its way into the head of the Pagham Rife catchment. The two small culverts under the railway line restricted flow and caused a significant area of land to flood north of the railway. The flat topography resulted in the water extending eastwards, threatening to flood Oving and entering the Aldingbourne Rife catchment.

The floodwaters were conveyed down the Forebridge Rife, a major tributary of the Pagham Rife, flooding the A259 road at Merston plus a large area of land to the north and south of the road. A bailey bridge was constructed over the Rife to maintain traffic flow *(Photograph 26)*. The small size of the channel together with restrictive culverts also resulted in flooding of some properties at Merston.

At the B2166 there was some flooding on the upstream side of the road but southwards, a large area between the west bank of the Forebridge Rife and a smaller unnamed watercourse some 60 to 100 metres to the west was flooded down to the confluence of the Forebridge and Pagham Rifes.

South of the confluence there was extensive flooding of low lying agricultural land extending all the way down to the sluice in the Pagham Seawall. Pumps were brought in to assist discharge into the tidal Pagham Harbour. *(Photograph 28).*

The majority of Lavant flood flow which stayed within the channel passed through Westhampnett Mill stream or around the bypass channel to the junction adjacent to the Crematorium at the north side of Westhampnett Road. There was some flooding of Westhampnett Road and St. Pancras caused by overtopping resulting from restrictive structures. Basements of 15 properties along St. Pancras were also flooded.

The restricted capacity of the long upstream culvert under Chichester created widespread flooding upstream of its entrance at the Kwikfit garage and 30 properties in the Hornet suffered from flooding. The building of a dam at this location, plus pumping by the fire brigade, both discussed in the following section, contributed to reducing the extent of flooding but some flooding still occurred along Market Road and Market Avenue.

A number of other roads within Chichester suffered flooding problems but were probably not directly associated with the river and were probably due to surcharge or backing up of road drainage.

4.5.3 Damage to the River Structures

A substantial proportion of the River Lavant channel is simply a natural trapezoidal channel with a relatively flat gravelly bed. The channel sides have evolved into stable, grass covered slopes. With the absence of raised embankments therefore, there is little damage to the channel itself which could affect its capacity or its potential to overflow. There are however, a number of locations where structures over or adjacent to the river have been damaged and thus will need attention.

The river channel was inspected in the early part of February when the flow was still relatively high. It was therefore not possible to inspect the river structures closely but some obvious problems were noted.

Working downstream, the first structure to have been seriously damaged is an access bridge at Singleton near the post office. The waterway consists of two 225mm diameter pipes which were totally inadequate to pass the flood flow. Local people broke out the culverts on 15th January *(Photograph 29).*

At Westhampnett Mill no significant damage appears to have been sustained within the Mill control structure despite the system operating at maximum flow for about three weeks. Immediately downstream of the Mill, the left, ie. eastern, bank sustained some damage, removing support from the concrete roadside guard rail posts and threatening the stability of the road edge.

Along the stretch of river adjacent to Westhampnett Road the left bank is grassed and raised slightly above road level. There is evidence of past minor bank failures beside the road with repairs effected using vertical light steel rails with concrete or timber planks behind to retain the bank. Other areas are in the process of collapse and some attempt has been made to support them with sandbags. (Numerous obstructions in the form of discarded road cones and filled sandbags are present in the bed and should be cleared as a matter of priority).

Downstream of Needlemakers Bridge on the left bank the rear wall of the garden centre showed distinct signs of distress with damaged brickwork, mortar loss from joints and a general lean outwards over the river. One small section in particular was in danger of collapse.

Immediately upstream of the entry to the upstream culvert a brick gable wall constructed over the river was demolished in the early stages of the flood to avoid blockage of the channel. Subsequently the concrete base slab of this structure was broken out and removed.

A general description of the main culverts through the City centre is given in *Section 3*. The detailed inspection which will highlight damaged or structural problems is to be undertaken by Archibald Shaw and Partners as soon as flow conditions permit.

4.5.4 Damage to Environmental Interests

A limited consultation exercise was carried out in order to establish those environmental interests affected by the flooding of the River Lavant in January 1994. This review did not set out to determine the environmental characteristics of the study area, but sought to highlight the short-term impacts of the flood waters.

The following organisations were consulted:

Organisation	**Interest**
English Nature	Nature Conservation
Royal Society for the Protection of Birds	Nature Conservation
Sussex Wildlife Trust	Nature Conservation
National Rivers Authority	Nature Conservation, Recreation
West Sussex County Council	Nature Conservation, Recreation
Chichester District Council	Recreation, Archaeology
Sussex Downs Conservation Board	Nature Conservation, Recreation, Landscape

a. **Nature Conservation**

Part of the Kingley Vale National Nature Reserve lies within the upper catchment area. In addition, there are several Sites of Special Scientific Interest (SSSI), Local Nature Reserves and Sites of Nature Conservation Importance (SNCI) within the study area. Consultation with English Nature and the County Ecologist indicated that the recent flooding had not adversely affected their conservation areas. Sussex Wildlife Trust's nature reserves are hill-top or hill-side sites and therefore not affected by the flooding of the River Lavant. None of the RSPB's nature reserves were affected by the flooding.

The recent flooding was considered to be of potential benefit for wetland birdlife, including snipe and teal. The flooding of fields, for example those to the north of Pagham Harbour Local Nature Reserve (Bremere Rife), created new feeding areas and subsequently attracted a large increase in the numbers of visiting birds. The flooding, and ornithological interest, lasted for two to three weeks.

b. **Access and Public Rights of Way**

The flooding caused problems on a variety of public rights of way (including pavements and other pedestrian routes), but was generally not considered a major concern as the water's depth was avoidable and not severe and appropriate footwear would have been sufficient to prevent problems. The towpath of the Chichester Canal was extensively affected, although this was not considered to be serious.

c. **Recreation**

In Chichester itself, many of the parks' football pitches were flooded, causing fixture cancellations. This situation is normal for the winter period, but flooding was particularly bad at the Recreation Ground and Jubilee Park areas adjacent to New Park Road. Overall, the flooding did not appear to have a significantly greater impact on recreation in Chichester than normally experienced at this time of the year. For example, no extra reseeding will be required. Also flooded were the playing fields and cricket pitch at Lavant.

d. **Archaeology**

Consultation with Chichester District Archaeological Unit indicated that no damage to the District's archaeological resource was thought to have been incurred. However, a survey has not been carried out to confirm this. As the River Lavant would have acted as a focus for early settlement, the District Archaeologist thought it possible that bank erosion could have exposed archaeological deposits.

e. Conclusions

The recent flooding of the River Lavant does not appear to have caused any significant disturbance or damage to nature conservation interests. There was some disruption to sporting fixtures but this is not uncommon during the winter. The majority of public rights of way were maintained and usable with appropriate footwear.

The consultees identified the channels downstream of Chichester as environmentally significant. They would be particularly interested to hear of any proposals for flood alleviation involving the local rifes, the Chichester Canal, Chichester Lakes, and Chichester or Pagham Harbours. All conservation consultees suggested a flood alleviation scheme could be designed to benefit the nature conservation interest of the area.

4.6 Emergency Measures Taken

4.6.1 National Rivers Authority

4.6.1a Flood Warnings

Section 166 of the Water Resources Act 1991 empowers the NRA to provide and operate flood warning systems and to provide, install and maintain apparatus for this purpose.

Flood warnings are issued by all of the National River Authority's regions whenever catchment and/or sea conditions are likely to result in flooding. These warnings are given in three phases as follows:

YELLOW	Flooding is possible
AMBER	Flooding is likely
RED	Serious flooding is likely

Flood warnings were issued by the NRA, Southern Region for the River Lavant at the following times:

Day	**Date**	**Time**	**State of Warning**
Thursday	30/12/93	14.00 approx.	Yellow
Friday	31/12/93	-	Advanced to Amber
Tuesday	4/1/94	-	Amber
Friday	7/1/94	01.00	Advanced to Red
Tuesday	18/1/94	-	Downgraded to Amber

Similar warnings were also being issued at various times, over the same period, throughout all of the Region's catchments.

4.6.1b Emergency Control

Responsibility for the direct NRA Sussex Area response to the emergency rested with the Area Manager and the Area team. Under normal circumstances the emergency would have been managed from NRA premises. Prior to 6 January the control was exercise from Worthing with liaison officers in the County Emergency Centre during office hours. From 6 January onwards management of the response was moved to the Emergency Centre at County Hall in Chichester to assist communications and coordination. Computer telephone links through to the NRA telemetry database and information network assisted this process.

The Sussex Area response was assisted and strengthened by information and plant from both the Regional and National operations centres. As the emergency developed, management of the emergency was strengthened by a planned influx of Regional and National NRA staff to man the centre, operate plant and to provide specialist expertise. As part of this response the Marine Pollution Control Unit (MPCU) was brought in under NRA auspices to assist with the pumping effort in Chichester.

Whilst the Chichester emergency was going on both Area, Regional and National staff were dealing with other flooding across Sussex and the remainder of the South East. Management of the Chichester Emergency reverted to the Area office in Worthing on 21 January. During the flood almost all the area staff and the majority of Regional staff were involved in the response to the emergency.

Duties covered by the NRA included

- Monitoring of weather and river/groundwater conditions to assess current and likely future flood levels.
- Maintenance and repair of the main river system where possible to assist flood passage.
- Sandbagging and strengthening of the river system where possible.
- Assessment of likely flood areas and risks given rising water levels.
- Pumping where possible to safeguard property and premises from inundation from river and tide lock flooding.
- Assessment of the effects of a city centre culvert collapse and the need for re-routing the River Lavant to safeguard lives and property.
- Representation on the County Civil Emergency Committee.

4.6.1c Field Observations

It was recognised at an early stage by NRA that a record of flows, levels and the extent of flooding would be important for retrospective analysis of the flood.

The flat veecrump gauging weir at Graylingwell had become bypassed by 7 January and was recognised to be under recording. Consequently current meter gauging was carried out downstream at two locations. The sum of these two sites is considered to equal the total instantaneous flow for the Lavant at the time of gauging. One site was the out-of-bank flows at Westhampnett Mill contained within the sandbags, with the second at St. Pancras, just downstream of Church Road on the access bridge to St. James Industrial Estate.

Analysis of the Graylingwell flows recorded at the time of spot gauging indicates the stability of the two sites. Flows at Graylingwell consistently represent 89% of those gauged on 8 January through to the 11th (inclusive) then 97% for the 13th and 14th.

As standard the Graylingwell gauge contains a drum chart recorder and digital data logger but both of these are retrieved at set intervals - usually monthly.

To assist with continuous monitoring of flood water levels NRA commissioned an emergency telemetry link to Graylingwell on 7 January which enable River Lavant water levels to be recorded in the Chichester Emergency Control Centre every hour.

In addition to this river level service, West Dean borehole was telemetered on 14 January to provide a complimentary site to Chilgrove. Chilgrove Well has been on telemetry since June 1993 but by this time had become artesian and could not provide an indication of current ground water movement.

Spot current meter gauging was also undertaken at the accessible sections of the culvert through Chichester with a view to ascertaining culvert capacity. In addition to the open sections, manhole covers were lifted to capture velocities and surcharged heads. This exercise was completed by staff from Archibald Shaw and Partners following discussions with NRA.

4.6.1d Emergency Measures

In addition to their normal flood control tasks operating sluices and maintaining as far as possible, all channels, weirs, streams, culverts and other structures free of debris (24 hrs/day operation), the NRA also undertook the following emergency tasks:-

i) Provision, filling and distribution of sandbags

ii) Obtaining an additional supply of 200,000 sandbags and a sandbag filling machine complete with a team of operators from the Anglian Region of the NRA. Additional equipment and support was also obtained from other NRA regions, including Severn

Trent, South Western and Thames.

iii) Flow gauging of the flood waters, flood forecasting and estimation of recession rates.

iv) Provision of aerial surveys and ground contours to enable advice to be given on the likely route and effect of the flood water.

v) Mobilisation of Consultants to supplement their New Works Section's work to investigate short term improvement measures to alleviate flooding eg. proposals for the enlargement of culverts and channels in the Forebridge and Pagham Rifes to convey up to $3m^3/s$ from the railway embankment southwards to Pagham Harbour.

vi) Receiving and dealing with calls from the public regarding flooding of roads and properties and assisting with pumping where possible, e.g., Merston House at Merston, Manor Farm at East Lavant and Shopwyke Manor Farm.

vii) Pumping of floodwater from tide locked areas eg. 4 x 300mm diesel pumps at the sluices through the seawall at Pagham Harbour and 1 x 600mm, 2 x 300mm and 1 x 150mm diesel pumps at Felpham to augment the existing pumping station which protects Bognor (Aldingbourne Rife catchment).

viii) Emergency shoring of the brick wall at St. Pancras which was in danger of collapse.

ix) Organisation, and direction of the MPCU pumping equipment and personnel to substantially augment the Fire Brigade's efforts in the Hornet area of Chichester (80% of MPCU's salvage capacity was made available in the form of 14 no. pumps and 3 miles of 150mm delivery hose).

x) Advice to the demolition contractor of the Kwikfit out building on techniques to avoid adversely effecting channel flows whilst work was in progress.

xi. Provision of men, with safety harnesses, to remove large tarpaulin and door which threatened to block the culvert in the Hornet.

It has to be remembered that heavy rainfall and hence flooding was occurring at numerous locations across the South East as well as within the Lavant catchment. In West Sussex alone the number of properties reported as being flooded was in excess of 270 for 30 December 1993 and the period from 4 January 1994 onwards. Of this number only approximately 25% was attributable to the Lavant flooding.

4.6.2 West Sussex County Council

4.6.2a Coordination of Emergency Response

It was the duty of the WSCC Emergency Planning Officer to coordinate the County Council's response to this civil emergency. This report deals in particular with the Lavant catchment above, within and around the eastern side of Chichester. In accordance with the normal procedure for such an emergency, control was exercised from the Emergency Control Centre at County Hall over the period 30th December 1993 to 21st January 1994. A hand written log of all incoming and outgoing messages, decisions and actions, was maintained for this period and subsequently produced in typewritten form once the emergency had abated.

Initially, most calls went direct to the Fire Brigade for assistance with pumping but as the scale of the flooding became apparent the WSCC Emergency Control Centre was opened to deal with the many requests for assistance that were then being received. In all, six out of the seven Districts within West Sussex experienced flooding on 30th December. However, by 4th January 1994 most of the problems were beginning to centre on the coastal plain from Emsworth to the River Arun south of the A27 and the Ems and Lavant catchments to the north.

A coordinating group of all authorities and the emergency services then involved was established on the 6th January 1994 and representatives of these took their place in the, Emergency Control Centre. As the emergency developed, so the size of the group enlarged until at one stage the following bodies were represented:-

County Council Departments
Chichester and Arun District Councils
Police
Fire Brigade
Ambulance Service
National Rivers Authority
The Armed Forces
British Rail
Coastguard
RNLI
Raynet
Marine Pollution Control Unit

The group met twice a day to review the current situation, consider likely developments and plan resources. Media interest was such that a media centre was established at County Hall and press conferences were held following the coordinating meetings, with officers giving interviews on television and radio.

In addition to the log maintained in the Emergency Control Centre the Police and Fire Brigade also maintained their own dedicated computerised logs to record all incoming calls and actions relating to the flooding emergency.

On the 11th January 1994 it was agreed by those authorities directly concerned with the flooding that there was a risk of partial collapse of the overloaded culvert through Chichester. This could in turn lead to a total collapse of the culvert and a need to divert the floodwater in a controlled fashion. Such a contingency provision did not exist and a meeting was convened on 12th January 1994 to evolve a Disaster Contingency Plan to define the area of Chichester that would be at risk and the measures necessary to safeguard the public in such an event. In the worst case scenario it was estimated that up to 3000 people would be at risk.

4.6.2b County Surveyor's Highways Department

The County Surveyor's Highways Department is responsible for the operation and maintenance of the County's roads. Throughout this emergency they monitored the conditions of all roads, agreed closures and diversions with the police where flooding made this necessary and directed "Road Force", the County Council's contracting body for road maintenance.

In addition to dealing with the emergency it was also necessary to continue with routine operations such as gritting of roads on receipt of frost warnings. This task assumed even greater importance with the wet state of the roads and the increased reliance being placed on the minor roads then being used as diversions. Department staff assisted in manning the Emergency Control Centre on a 24-hour basis, utilising a shift system. The Drayton Depot, just to the east of Chichester, is the headquarters for the Chichester area which covers from Littlehampton to Emsworth, east to west, and Haslemere to the coast, from north to south. The control room at this depot exercised detailed control over the operations of Road Force throughout the emergency.

In summary Road Force:

i) filled sandbags at their Drayton Depot and distributed these to and placed them at the major crises points and individual properties that were at risk

ii) provided machines and labour to build clay dams in strategic locations such as the Hornet and the new Portfield Roundabout and to excavate reed beds obstructing the Chichester Canal to enable it to be used as a flood discharge route

iii) erected road diversion signs, coned carriageways, provided temporary traffic lights and amended these arrangements as road conditions first deteriorated and then gradually improved

iv) helped to install pumping relay pipelines and chase these beneath the surface at critical road junctions with bitmac and/or steel road plates over

v) built temporary sandbag or wooden ramps over pipelines for traffic and pedestrians and soundbarriers around pumping appliances within the City

vi) coordinated the supply of sandbags to the two temporary Army bridging unit sites and then continued to assist with the supply of non-slip surfacing, bitmac ramps and road humps to slow traffic at these points

vii) constructed a temporary road around the Bailey Bridges at the A259 in 4 days once the water levels had fallen

viii) provided and operated pumps, generally at the more isolated floods

4.6.2c Welfare and Other Services

To cope with the anticipated evacuation of members of the public from their homes adjacent to the areas of greatest risk around the Hornet and St Pancras, an emergency rest centre was established at the West Gate Leisure Centre. In the final event the number evacuated was about 25 on 6th January and some of these made alternative arrangements with relatives. The remaining 11 are understood to have made use of rest centre facilities.

Particular concern was felt for those people in sheltered accommodation in the Tozer Way and Riverside area but thankfully the river did not overtop its banks at this point, otherwise the numbers making use of the rest centre would have been much higher. The County Hall canteen, Martlets, was open 24 hours a day to feed staff manning the emergency centre and the workers out in the field. West Sussex County Catering mobilised most of its schools meals staff to assist in manning this facility.

Measures were also taken to assist householders and businesses in coping with the flooding.

These included:

i) erecting signs on the City outskirts to advertise that Chichester was, "Open for Business"

ii) sending out flood advice leaflets to at risk properties

iii) arranging for the Association of British Insurers' mobile information trailer to be sited in Chichester to offer advice to affected householders and businesses

iv) taking the County Council's mobile information trailer into Chichester and flood hit villages to offer help and advice

v) warning of the dangers from carbon monoxide poisoning to householders who had blocked up their air vents with sandbags and were using fuel burning appliances without opening windows.

Many offers of assistance and resources were received and logged by the staff in the Emergency Control Centre. These ranged from the US Air Force, local Army and Naval establishments and Ford Prison, all offering manpower, to individual members of the public offering a room for evacuees. One member of the public even offered a retired fire appliance.

4.6.3 Sussex Police Response

The Police were concerned predominantly with road conditions and interruptions to traffic flow caused by the flooding. In conjunction with the WSCC Highways Department they agreed road closures and diversions and the coning and signing that was necessary to effect these. Traffic control duties were also undertaken at these points to aid traffic flow. From the 4th January onwards their main areas of concern were the coastal plain from Emsworth to Littlehampton, south of the A27, and the catchments of the Rivers Ems and Lavant north of this road.

Although not directly involved in the pumping operations, the Police patrols did tend to act as eyes and ears and reported flooding incidents when they encountered them or as they received requests for assistance from the public. They also assisted with evacuations and maintained policing throughout the whole area. Twenty four hour patrols were maintained in the affected areas of Chichester to protect evacuated properties and combat vandalism and in the flooded rural areas for the purpose of public reassurance.

In the event of a total collapse of the culvert and the widespread flooding that would have ensued throughout the southern part of Chichester, the police would have been responsible for the arrangements to evacuate all members of the public that were affected. Contingency plans were put in hand to cater for this eventuality with a draft operational order detailing the strategy and command structure to be adopted. Arrangements were also made with Hampshire Constabulary for the provision of additional resources. The communications link was to remain in the Emergency Control Centre but a dedicated Major Incident Room was prepared in the Training Room at Chichester Police Station to control the evacuation and liaise with all other services. This facility was not activated.

4.6.4 West Sussex Fire Brigade

4.6.4a Initial Response

Pumping operations in the County actually commenced on 30th December 1993, following heavy rainfall. The Brigade received a total of 452 flooding calls on that day and all 46 pumping appliances were either out pumping or on strategic standby. However, flooding did not commence in Chichester until 06.00 on 4th January 1994 when a call was received to deal with flooding in the cellar of Michaels, the hairdressers in the Hornet. This was dealt with as an isolated incident with no indication of the problems that were to follow shortly.

A further call was received at 16.25 that day to attend flooding in the area of the Four Chestnuts public house and from there on the situation grew steadily worse. Additional pumping appliances were requested together with sandbags to protect properties. Efforts continued through the night with a rise in water level of 600mm in the previous hour reported at 20.00. This incident closed at 08.27 when all fire appliances left the site.

4.6.4b Pumping Relays

A major pumping effort was required again on 6th January 1994 when the Lavant overtopped at Rowe's Garage and was threatening to overtop the clay dam in the Hornet. The number of pumps was increased to ten, with the object of establishing a pumping relay around the constriction that was obviously being caused by the culvert beneath East Gate.

Finding a location for discharge of the water was becoming a major problem and various routes were considered but rejected at that time for the following reasons:-

i) It was not initially advisable to pump to the Canal as this could have caused flooding at Hunston due to congestion of the Canal by reed beds to the west of the Chichester/Birdham Road. (This obstruction was eventually removed by Road Force using an excavator and this route then became available for discharging water from the flood, and was used).

ii) It was considered unwise to pump back into the Lavant in Market Street, below the northern section of the culvert, as the effect this would have on the second section of the culvert at South Street could not be ascertained.

iii) Discharge to the Lavant at the Avenue de Chartres was not adopted initially as it was feared that the ground floor of the College Library could be flooded.

At the time of these deliberations on the 6th January the only safe and conceivable discharge route available was that through the town via the Avenue de Chartres and across country to the tidal creek at Fishbourne. By the evening of that day two lines of 90mm diameter red hoseline had been laid along this route with 8 Fire Brigade appliances pumping through these lines. To augment the Brigade's own resources it was decided to obtain a number of the "Green Goddesses" ex-Civil Defence fire appliances from the Home Office stores. These possess a higher capacity pump with a nominal duty of $0.08m^3/s$ 1000 gallons/minute) at $0.7N/mm^3$ (100 psi) pressure, and were designed specifically to operate pumping relays with purpose made connections for 150mm (6") hard, black, PE piping with "Quick Fit" joints. Ten of these machines were obtained initially on 7th January and a further ten thereafter as the pumping relay systems evolved.

The Green Goddesses are rugged machines that were ordered for Civil Defence duties in the 1950's based on a military specification chassis and drive unit. They are petrol driven rather than diesel, as is now more common, and require frequent refuelling. They also require servicing every 50 hours of running time and it is therefore necessary to maintain a fleet of spare vehicles to replace the operational units that have to be withdrawn for servicing.

Details of the pumping relays, their routes, types of pumps and discharge points were contained in a press release issued by the Fire Brigade on 15th January 1994 and the details of the relays are summarised below and are shown on *Fig. 4.12*.

No.	Name of Relay	Description of Pipe, Pumps, etc.
1.	Juliet Relay	150mm pipe to Fishbourne (2 miles).
2.	November Relay	Fire hose, originally to Fishbourne, then to Avenue de Chartes and later withdrawn
3.	Kilo Relay	Fire hose to the Market Avenue culvert.
4.	Oscar Relay	4No. 150mm pipes to river culvert beyond South Street. These were connected to the Marine Pollution equipment.
5.	Lima Relay	First 150mm pipe to Canal Basin.
6.	Mike Relay	Second 150mm pipe to Canal Basin.

Estimates of the maximum quantity of water being pumped at any one time appear to vary from 0.47m^3/s (9 million gallons a day) estimated by the Chief Fire Officer, to 0.63m^3/s (12 mgd) by the WSCC and the NRA. Generally, the Green Goddesses were operated at approximately 0.07m^3/s below their nominal duty point, to reduce noise and limit their excessive consumption of petrol. The normal fire appliances could pump approximately 0.04m^3/s through the red hoses. The output of the MPCU pumps is not known for certain but the WSCC reports and press statements indicate that their total capacity was equal to that of the Fire Brigade's relays. On the above basis a maximum rate somewhere in the middle of the two estimates above, i.e. 0.55m^3/s would appear to be a reasonable assessment.

Approximately 200 firefighters were attending the flood around the clock and there were only 400 men on duty within West Sussex Fire Brigade at any one time. Normal fires were still being dealt with to the same statistical profile as usual.

4.6.4c Future Contingency Planning

During the middle of February the Fire Brigade were in a state of readiness to deal with further flooding on the advice of the NRA. They were able to mobilise 16 Green Goddesses which were still located at the local Barracks. These could be reconnected within 2 hours to operate through three 150mm diameter PE lines.

A separate mobilisation protocol has been evolved to deal with the possibility of the culvert collapsing and causing flooding within the town. The details of this are held on computer and sandbags are stockpiled at strategic locations.

4.6.5 Military Assistance

Numerous offers of assistance were received from military establishments within the immediate area, e.g. manpower from the Military Police Barracks at Chichester itself and accommodation and manpower from elements of the Naval Bases at Gosport and Portsmouth respectively. Generally these resources were not called upon as the emergency did not evolve to the extent that had at one time appeared possible.

Following the flooding across the A259 at Merston Common during the evening of Sunday, 9th January, it was decided that measures had to be taken to maintain the flow of traffic around Chichester and in particular along the A27 trunk route. This would be possible by bridging the floodwaters at the A285 Westhampnett Roundabout and at Merston Common on the A259.

Military assistance was requested and the Police helicopter collected Lt.Col. R Burns and Lt. M Fuller of 36 Field Regiment, Royal Engineers at Maidstone early on the morning of Monday, 10th January, for a reconnaissance visit. By early afternoon the situation had been assessed and floodlighting was requested from the WSCC Highways Department by 19.00 hours that evening. Later that afternoon approval was given for the Army's costs of £5,000 per day. The erection of the two single Bailey Bridge installations commenced that night at Westhampnett Roundabout and the A259. The second bridge unit at each site was erected during the following night, 11th January, but due to difficulties with broken electricity cables the bridge at Merston was not completed until about noon on the 12th January. The bridge units at Westhampnett were each 21m long by 4.25m wide and those at the A259 17.5m long.

Although these bridges provided much needed traffic routes their operation was not without problems. In both cases a bauxite surfacing had to be laid on the timber ramps by Road Force to prevent vehicles sliding down when braking. Speed control humps also had to be placed on the approaches. During heavy traffic progress was naturally slow and considerable queues built up in both directions. The Westhampnett bridge suffered from foundation problems as the sub-base was placed on top of the topsoil at the roundabout whereas this should have been removed first.

Following a decision reached at a joint meeting held on 17th February the bridges were left in place until 4th March 1994 when they were removed by the Army.

4.6.6 Assistance By Others

Offers of assistance were received from the public in the form of volunteer groups or as individuals. Goods and services were also offered, some on a free basis, covering a range of items such as sandbags, timber planks, chalk fill, pumps, generators, earthmoving equipment, dehumidifiers and storage of damaged goods. Calls were received from as far afield as Scotland and Wales.

Many offers of accommodation were also received from the surrounding area, ranging from a room for two in Warsash to 85 spaces in a dormitory block at Goodwood Stables. All of these calls were logged in a Resource Record for further reference.

To assist with evacuation in the flooded areas two inflatable boats were requested from and provided by Solent Coastguard on 9th January and a further three boats were requested from the RNLI at Poole on 10th January. Two of the RNLI boats and their crews assisted with the evacuation of properties in Singleton on 12th January 1994.

Assistance with observations of water levels and flooding was provided by Raynet, a local voluntary organisation. In particular they mounted a 24 hour watch on water levels in the Chichester Canal while it was being used as a flood water drainage route by the Fire Brigade.

5.0 FACTORS AFFECTING LONG TERM CATCHMENT REGIME

5.1. Changes in Agricultural Use of the Catchment

5.1.1 Introduction to Farming Practices

a. Post 1945 changes on the South Downs

Farming practices on the South Downs changed considerably in the immediate post-war period. Advances in mechanisation facilitated the cultivation of the area's thin and flinty chalk soils, both physically and economically. The traditional use of sheep folding as a means of sustaining arable land use was replaced by the application of artificial fertilisers. As a consequence, sheep farming was superseded by large arable farms cropping cereals, beans and ley grasses on rotation *(Reference 32).*

b. Changes in the Upper River Lavant Catchment since the 1960s

The good quality farmland is one of Chichester District's most important and valuable resources. A significant proportion of this land is classified by the Ministry of Agriculture, Fisheries and Food (MAFF) as Grade 1 or 2. Agricultural land quality worsens in the upper catchment where limited by soil and gradient factors, particularly on the slopes of the primary and secondary South Downs escarpments. *see Figure 1.*

During the 1960s changes in agricultural land use took place throughout the South Downs, including the cropping of areas not previously cultivated. Within the upper catchment area, particularly in the parishes surrounding Chichester, wheat now represents the largest percentage of crops grown. Between the years of 1966 and 1980 wheat farming increased from 19% to 36%, taking over from barley as the area's premier crop. One of the most important changes associated with cereal production has been the use of winter-sown varieties, most notably of wheat and barley. Of the land under cereal production, the majority is used for winter cultivation. The area of land planted with winter cereals varies annually due to crop rotation. Current arable rotation practice involves cereals, oil seed rape, linseed, beans and grass.

5.1.2 Agricultural changes which may influence run-off

a. Winter cultivation

Prior to the cultivation of cereal crops in winter, the farmers used to leave the stubble of the harvested spring-sown crop on the land over the autumn and winter seasons. With the change to winter cultivation, the fine tilled and seeded beds are exposed to the climatic elements of winter. Such practice may increase the area's potential for generating run-off. Where cultivation has taken place on the relatively steeper slopes of the South Downs, heavy autumn rainfall at ploughing time has led to severe cases of gulleying and removal of the topsoil *(Reference 33).*

b. Hedgerow clearance and tree removal

With the extensification of field areas under arable use the loss of hedgerows and trees which previously demarcated field boundaries may have had some effect in increasing the response of the catchment to storm events yielding relatively high run-off rates. The main effect of such vegetation is to act as some form of barrier to run-off and soil erosion. The hedgerows break the direct passage of run-off down the catchment, slowing down the catchment's overall responsiveness.

c. Soil erosion

Mechanisation and winter cultivation are known to increase the potential for soil erosion, primarily by changing run-off patterns. For example, acute erosion during a storm event in 1987 caused an estimated £1m worth of damages to properties in Rottingdean, near Lewes. If the local soils continue to be eroded, particularly on the steeper hill slopes, the run-off response time of the catchment can be expected to reduce.

Conservation schemes such as land set aside, Countryside Stewardship, and ESA status encourage a return to traditional farming practices including grazing management, no use of agrochemicals, and the restoration of cultivated areas to grassland. Inadvertently these schemes also address the problem of erosion by promoting the reversion to pasture and the reduction of arable cultivation.

5.1.3 Conclusions

Due to the lack of available data it is difficult to conclude with certainty whether or not changes in agriculture over the past 30 years have significantly increased the potential for run-off and flooding in the catchment.

It is recognised that winter cultivation and the removal of hedgerows have in some cases led to serious cases of erosion (e.g. loss of topsoil, gulleying), and generally quicken the catchment's response time to generate run-off. Overall, there may be a minor increased risk of flooding due to the agricultural land use changes and their associated effects upon the catchment's drainage regime, particularly during a heavy rainfall event.

However, given the nature of the geology of the catchment, it is not considered likely that run-off formed a significant part of the flows recorded in the Lavant. Flood water was noted to be clear indicating a ground water source and there is much other evidence to indicate that the flows are generated not by run-off (which would be muddy), but by clear ground water.

5.2 Effects of Gravel Extraction and Pit Infilling in the Westhampnett Area

The Fan Gravels are a primary source of aggregate materials in this area. *Figures 5.2 to 5.7* show the historical development of gravel workings, infilling or after-use in the East Chichester area between 1948 and 1994 *(Reference 11)*. The total area of these excavations is about 290 ha. Two additional pits are now being worked at Coach Road (Westhampnett East) just southeast of Church Farm pit.

The infilled pits in the Westhampnett area straddle the point where the Lavant valley gravels broaden abruptly into the Fan Gravels and coincide with the thickest area of gravels and the zone of highest transmissivities.

Many of the pits were excavated to the top of the less permeable lower raised beach deposits, which lie on essentially impermeable Reading Beds and London Clay. Whether sealed to assist excavation or by subsequent infilling or, in the case of water-filled pits, sealed naturally by biochemical processes, gravel pit development reduces the capacity of the gravel sequence to allow the passage of ground water (the transmissivity). Normally, this tends to cause higher ground water levels on the upstream side and lower water levels on the downstream side.

Ground water flow originating as recharge from the Lavant is now restricted to narrow corridors of aquifer material between the pits, to the remaining less permeable deposits below each excavation and by inflow into Church Farm pit. However, ground water upstream of Westhampnett may spread into the older raised beach deposits adjacent to the valley deposits reducing the impact on local water levels. Unfortunately, water level records and details on the timing of pit sealing are insufficient to quantify the combined impact of multiple pit development on water levels in the Westhampnett area.

There has been increasing concern over the longer term risk of local flooding, particularly during wet years, as a result of the removal of permeable material and subsequent infilling of pits in the East Chichester area. The general reclamation strategy of West Sussex County Council for pits in the area has been to infill pits north of the Brighton-Chichester railway line whilst leaving those south of the railway line as water filled lakes for recreational purposes.

The flood risk to industrial properties owned by Dares Estates plc on old working levels within Church Farm pit and by Tarmac in Shopwhyke North pit has been of particular concern. Several studies have been carried out to protect these sites *(Reference 14 & 15)* from which it was concluded that the transfer of water southwards to other open pits was impractical due to the volumes involved compared to the capacity of the Rifes or the available freeboard storage at high water levels in other water filled pits. There is also the risk that resolving the problem of flooding in the Westhampnett area may result in a similar problem to the south. Consequently, a more regional integrated approach is required to identify the scale of the problem and to find a satisfactory solution.

A ground water model study of the Westhampnett area was undertaken to investigate the effects on local water levels from the existing pit development and proposed alternative options for pit infilling *(Reference 11).* The results indicated that the infilling of the Pound Farm pit, Sainsbury pit and the Westhampnett reclamation site had little impact on ground water levels, but if Church Farm pit was infilled then water levels would rise by up to 2 m between this pit and Pounds Farm pit. This suggests that the water-filled Church Farm pit ameliorates the impact that might otherwise result from the infilling of other nearby pits. The model also indicated that leaving the new excavations at Westhampnett East as water-filled, unlined pits would reduce water levels in Church Farm pit *(see Fig. 5.7 for location of pits).*

The model confirmed the hydrogeological importance of Church Farm pit on ground water flows: recharge from the nearby Lavant moves into the northwest corner of the pit and then southeast into the area currently being excavated by Tarmac at Westhampnett East pit. Water level data confirms the general southeast direction of ground water flow in this area, which may be influenced by a buried or historical channel of the Lavant with a higher transmissivity. Values derived from the model suggest that the groundwater flow through the valley gravels upstream of Westhampnett averages about 1200 m^3/d or 0.014m^3/sec

The combined effects of pit excavation and infilling on the natural ground water regime are complex and are not yet fully understood. Due to the lack of long term historical water level data in the area around Westhampnett, it is not possible to distinguish whether the gravel pit infilling has raised ground water levels in the adjacent areas but there is certainly a local perception that ground water levels are rising. The location of these pits across the head of the fan would at least form a partial subsurface barrier to ground water flow, but the effects would be gradual and the net effect of each small but progressive. The Church Farm pit may have an important role in any future scheme to reduce the rise in ground water level due to gravel extraction and infilling in the Westhampnett-Lavant area.

5.3 Abstraction from Chichester Chalk Block Aquifer

The major ground water abstractor from the area of the rivers Lavant and Ems catchments is the Portsmouth Water Company. They have six borehole sources located at Lavant, Brick Kiln Farm near Chilgrove, Fishbourne, Funtington, Walderton and Woodmancote. Records of the abstractions from these boreholes are provided to the NRA on a regular basis and are available from January 1973 to the present. The average total daily abstraction for each month is represented in *Figure 5.8* in the form of a histogram covering the above period.

The total average annual abstraction from these boreholes had been relatively constant, at about 46 Ml/d, over the period January 1978 to December 1989. From 1990 onwards, however, there appears to have been a downward trend in average abstraction to about 41 Ml/d during 1990 and 1991 with a further fall to about 33 Ml/d throughout 1992 and 1993.

This latter value represents a 28% reduction with respect to the earlier long term abstraction.

Based on the Southern Water Authority 1988 report on the Chichester Chalk Block *(Reference*

17), this 13 Ml/d decrease in abstraction represents approximately 3.5% of the mean annual recharge, (1974 - 1983). For comparison with river flows 13M l/d is equivalent to a flow of 0.15m^3/s. Of the six boreholes only Lavant and Chilgrove are within the River Lavant Catchment.

There appears to be a marked local effect of the abstraction on ground water levels. This is shown by the regular saw tooth like form of the Graylingwell gauge graph in *Fig. 4.8* which is believed to be the result of regular operation of the nearby Lavant Borehole. However, as can be seen the effect is minor and quickly recovers on cessation of abstraction. This is as could be expected in the high transmissivity chalk of the upper catchment. It is not considered that the apparent recent reduction in abstraction from within the chalk will have had any significant effect upon winter season River Lavant flows, as ground water levels respond far more quickly to rainfall (or the lack of it) than the relatively small volumes abstracted.

5.4 Development within Catchment Including the A27 Westhampnett Bypass

5.4.1 General Development

Within the upper Lavant catchment there has been approximately 39 hectares of housing and light industrial development since 1960 *(see Figure 5.9)*. Development of an area of land normally increases the rate of surface water run-off from that area. The construction of the buildings, roads, footpaths, etc. increases the impermeability of the area so the quantity of rainfall which penetrates to the sub-soil is reduced; the loss due to evaporation from vegetation is also reduced. Existing field drains are often abandoned and replaced by a surface water sewerage system piping water direct to the nearest watercourse. Thus the rate and total quantity of run-off is increased.

However, as discussed in detail in *Section 3*, the sub-surface within the Lavant catchment is highly permeable and consequently the simplest and most effective way of dealing with run-off from development, discharge into soakaways, has been adopted. Thus rainfall falling on the hard surfaces percolates into the ground water table from a number of points rather than being uniformly distributed over the whole area.

This change in distribution probably decreases the response time of the ground water level to rainfall in the immediate vicinity of the development but, due to the low proportion of hard surfaces to the total catchment area, the overall effect on ground water levels would be minimal. Since, as has been shown in *Section 3*, Lavant flows are primarily determined by ground water levels it is considered that any changes in river flow upstream of Westhampnett due to development are negligible.

Within the lower Lavant catchment, run-off from development is again almost universally discharged into soakaways, the exception being some older properties which discharge into the foul sewerage system and properties and roads immediately adjacent to the river where connections into the river and the culvert through the city have been made. The most significant development in the lower catchment is that over infilled gravel workings which has been described in *Section 5.2* above. Overall, it is considered that development within the catchment has not appreciably added to the rate of flow in the river.

5.4.2 A27 Westhampnett Bypass

The newly constructed A27 Westhampnett bypass is similarly drained into soakaways, principally a soakaway trench near Maudlin Farm, Dairy Lane. The majority of run-off from the road surface is therefore discharged well to the east of the Lavant catchment.

High water levels in Church Farm pit have been a problem in wet years since 1974 *(Reference 14 & 15)*. Pumping rates of up to 10,000 m^3/d (0.12m^3/sec) have been necessary on several occasions to protect the previous Chichester District Council pulverisation plant and, more recently, buildings that have been constructed on Rutland Way within the pits on raised former working levels.

There is a local perception that the new A27 Westhampnett By-pass (completed in 1993 and which crosses the 650m length of causeway separating Church Farm pit from Shopwhyke North pit) was a contributing factor to the recent flooding around Westhampnett and, in the longer term could exacerbate the problem of high water levels in Church Farm pit and Shopwhyke North pit. The potential impact of the new road on water levels in Church Farm pit depends on several factors that govern inflow and outflow from this pit.

Water levels in Church Farm pit respond almost immediately to flow on the Lavant implying a high degree of hydraulic connection. The initial rate of inflow into Church Farm pit derived from the Lavant is estimated to be 20,000 m^3/d. As water levels rise in the pit the hydraulic gradient is reduced and the rate of inflow decreases. The initial rate of response is rapid due to the steep hydraulic gradient (about 0.05) over the short distance (100 m) between the Lavant and the northeastern corner of the pit. A drain along Coach Road also contributes flow into the eastern side of the pit.

Factors governing the rate of inflow include the stage level (and flow) of the Lavant, the permeability of the river bed (unsealed) and its elevation (16.8 mOD), the permeability of the gravel sequence between the pit and the Lavant and along the northern face of the pit, and water levels in the surrounding gravels. In addition, the infilling of Sainsbury's pit in the mid-1980's may now divert the previous southward flow of ground water southeastwards into Church Farm pit.

The seasonal recession is much less than the rate of inflow, being about 2,000 m^3/d. This is governed partly by the recession of the regional water table. The normal rate of outflow is controlled by direct evaporation, the head difference between pit water levels and water levels south of the pit, the permeability of the southern face (especially in the southeastern corner of the pit where about 100 m of the pit face does not appear to be have been sealed during the gravel extraction according to trial pit data *(Reference 24)* and through the bed of the pit into the underlying (less permeable) raised beach deposits. Other controls at high water levels have included a drain at the southwestern corner that allowed flow directly into Shopwhyke north pit (this was sealed in 1987), overflow at the southwestern corner (the point of lowest elevation around the rim of the pit), possible seepage through the top part of the causeway (which was left unsealed), by pumping, and the silt deposits in the eastern part of Shopwhyke North pit.

The potential impact of the road depends on whether it has reduced or increased the rate of outflow from the pit, raised the elevation of the causeway and whether any measures were installed to allow direct outflow to occur during high water levels. A rise in water levels would increase the duration and frequency of flooding in the northwest part of the pit, whilst a decrease in the rate of seasonal recession would lead to a gradual rise in minimum water levels as the rate of inflow is estimated to be 10 times the rate of outflow.

However, it should also be noted that:

- the recent flood event was very exceptional and took place soon after the road was constructed. Consequently, any impact on pit water levels may not be known for some years.

- the local ground water regime has been altered by gravel pit excavation and infilling such that it will be difficult to distinguish any rise in water levels that might be related to the new road, from other changes that have and are still taking place in the same area and indeed from natural hydrological variations.

- the water level rose above 15.5 mOD (approximate level of car park in northwest corner) during the wet winter of 1992 before the road was complete, or about 1.5 m less than that in January 1994, although these latter levels were influenced by pumping and by out-of-bank floodwaters flowing into the pit. The previous peak water level was 15.7 mOD recorded in May 1987.

- additional local factors include the gravel extraction presently taking place at Westhampnett East pit in the area of natural outflow and continued infilling of the silt ponds in the eastern part of Shopwhyke North pit. It is also understood that an overflow drain in the southwest corner of Church Farm was closed in 1987 to prevent the outflow water from affecting properties in Shopwhyke North pit.

The rise in water levels at Church Farm pit between 1969 and 1984 ***(see Figure 4.6)*** is considered to be due to a combination of reduced dewatering in the area, a period of above average rainfall in the early 1980's and the infilling of Sainsbury's pit. Any subsequent upward trend is not readily apparent from the available water level data. The seasonal fluctuation in pit water level (about 2.5 m, from about 13 to 15.5 mOD which represents an estimated volume of 1.5 Mm^3) appears to have remained constant.

Water was pumped from Church Farm pit during the summer of 1993 to facilitate the road construction. This lowered the water level to 12.1 mOD. As water levels elsewhere were close to their summer seasonal average, this water level was probably 1 or 2 m lower at the time recharge began at the start of October 1993 than would have otherwise been the case without pumping. This provided some extra capacity in the pit prior to the flood.

The main relevant features of the road construction are: (a) the emplacement of an embankment against the southern edge of Church Farm pit to expand the width of the causeway; and (b) installation of two drainage pipes (overflow culverts) beneath the road leading from the southeastern corner of the pit.

It is understood that the road (about 16.9 to 17.4 mOD along most of the length of the causeway and about 16.6 mOD at the eastern end of the causeway) has not significantly raised the original ground level. The embankment was constructed in layers as follows:

- uncompacted, selected granular chalk fill (Class 6A) was placed on the original lake bed (or ground surface), after removing 0.5 m of bed-silt, up to a level of 12.5 mOD.

- stony cohesive, non-chalk material (Class 2A) was placed and compacted from 12.5 mOD to about 15.2-15.8 mOD

- well graded granular (Class 1A) chalk fill was placed and compacted beneath the road surface above an elevation of about 15.5 mOD

Hence, the embankment was designed to have a permeable base below 12.5 mOD but with compacted impermeable material extending above 12.5 mOD to the road surface. Twin overflow drains (two 300 mm diameter pipes with an invert level of 14.3 mOD) were constructed at the eastern end of the causeway.

A general assessment of the likely impact of the roadline on water levels in Church Farm pit was commissioned by DTp prior to the construction of the road. *(References 34 and 35).*

It was found that a complete seal would reduce losses and slow the rate of recession during the summer such that minimum water levels would rise each year. The amount of water that can enter the pit would still be controlled by the hydraulic gradient between the Lavant (or the water table upslope) and that in the pit. However, the available data indicates:

- the use of permeable embankment material would minimise the loss of pit volume due to the embankment and should not decrease the already limited hydraulic connection to the south.

- the twin culverts would still allow water to drain into the gravels to the southeast at an earlier pit stage level than the original overflow drain which used to exist prior to 1987 in the southwestern part of the pit.

The new culverts would be important in maintaining a means of outflow from Church Farm pit but DTp have been unable to reach agreement with the operators of Westhampnett East pits and as a result they are not yet operational. In addition, the new excavations at the Westhampnett East pits may affect the operation of these culverts.

5.5 Planning Policy on Development

5.5.1 Residential and Business

The planning authority is Chichester District Council and policies have been established to control development within the area of their jurisdiction which covers the Lavant Catchment.

There is a presumption against development in the villages of East Dean, Charlton and East Lavant. However recent Government directives advise relaxation to permit infill within the existing confines of the villages. The planners are applying stringent rules to applications for building approval.

Singleton is also a Conservation Area village where development has been restricted to small infill development within a tightly drawn boundary.

A new Local Plan consultation draft is currently being circulated for Mid Lavant in which there is no allocation of any new land for housing. There is however pressure from local landowners for planning approval to be allowed for housing development.

At Graylingwell part of the hospital site is to be redeveloped. The Health Authority want approval for 750 new houses but the planners have recommended that this figure be reduced to 233. An appeal has been lodged with the Secretary of State and a decision is expected shortly. The proposed re-development includes the conversion of existing buildings.

Approval has been given for the building of 142 new houses on a site to the east of Clay Pit Lane, Westhampnett. The Barnfield Drive area, which is an old waste filled pit, is scheduled to be developed for leisure and business use.

Chichester District Council Planning and Building Control Department consult NRA routinely on development proposals and regard advice on flood risk areas as important factors in determining planning applications and helping to allocate suitable land.

5.5.2 Mineral Extraction

West Sussex County Council is responsible for the planning control of mineral extraction in the Chichester region. At the present time (July 1994) they are in consultation with NRA and others and expect to publish a Mineral Extraction Plan shortly.

They have identified a number of potential sites for future gravel extraction of which four are considered as possible. All the sites are to the east of Chichester and range from just north of Maudlin Village to south of the railway line. The specific site locations are confidential until the outcome of the consultation exercise is known. The County Council are aware of the ground water and flooding problems in the area and consequently would appreciate guidance to enable them to determine which sites may be worked and to be able to impose adequate conditions to approvals.

5.6 Deterioration in River Channel and Culverts

It is not possible, with no prior knowledge of the river, to identify precisely any deterioration that may have occurred to the River Lavant since the last recorded flood in 1960 and which may have contributed to the severity of the recent flood.

Because of the ephemeral nature of the river it is entirely possible that it may have been neglected, particularly by riparian owners, and without maintenance there must have been some deterioration in the structures with age and normal weathering etc. There is no evidence to suggest that the channel capacity may have been restricted due to silting although there could have been some weed growth which, by increasing the channel 'roughness', would reduce the flow able to be carried without overtopping. With the steady increase in flow during the latter half of December, at a time when weeds would have died back, it is more likely that the channel would have been gradually 'cleaned' prior to the rapid increase in flow in early January.

The condition of a floodwall, built after the 1960 event alongside St. Pancras gave some cause for concern and the wall required temporary stabilisation to avoid collapse during the event.

Approximately 120 metres upstream of the Kwikfit entry to the upstream city culvert, timber shoring had been erected in the channel bed to support a high wall on the northern bank. Whilst preventing collapse into the river the shoring will have impeded the flow in the channel as well as increasing the risk of blockage by trapped debris.

Immediately upstream of the culvert entrance an old brick gable end built over the river provoked fears of collapse and had to be carefully demolished and removed after the floods.

After the event divers engaged to undertake a preliminary inspection of the culvert discovered, and removed, the roots of a tree trapped within the culvert which had accumulated some debris. This may or may not have been within the culvert at the onset of the flood.

At the entrance to the overspill weir near the exit of the downstream culvert a supermarket trolley had become trapped.

6.0 ASSESSMENT OF RETURN PERIOD OF JANUARY EVENT

6.1 Return Period Estimates based on Single Variables

NRA have provided estimates of the return period of the 1993/94 flood event based on the maximum instantaneous flows at Graylingwell for water years 1973-1993 and the 40-day critical rainfall durations at Chilgrove for water years 1921-1993. These estimates have been examined in more detail and extended to include effective precipitation and the long-term water level records at Chilgrove and Compton (based on water years (WY) October to September).

6.1.1 Lavant Peak Flow Return Period.

The flow record of the Lavant at Graylingwell dates from 1971. Peak flow data are unavailable for 1971 to 1973, giving a 17-year record of peak flows.

The estimated peak flow of approximately 7.9m^3/s in January 1994 is nearly twice the previously recorded peak of 4.23m^3/s in WY 1988.

A return period based on the limited record, which also includes a single high, estimated value, should be treated with caution. Water level data also suggest that the aquifer conditions influencing flow may not remain the same at high flow rates.

Twenty three years of completed average daily flow (ADF) data from 1971 to 1993 is available from Graylingwell flow gauging station and has been analysed to produce the frequency plot in *Fig. 6.1*. *Fig 6.2* developed from the same data shows the mean ADF for a January to be 0.4m^3/s with a maximum recorded peak ADF of 2.4m^3/s (Jan. 1988). The highest ADF ever recorded was in November 1974 and measured 4.1m^3/s. The January 1994 mean average daily flow was 4.8m^3/s. The peak ADF in WY1993 is uncertain as it is based on estimated out-of-bank flows added to the gauged flows, but has been recorded as 6.93m^3/s corresponding to a return period of approximately 110 years. For consistency the return period for the peak ADF value of 6.3m^3/s measured at Graylingwell just prior to overbanking is calculated as approximately 80 years.

As culvert capacity is in the order of 4.3m^3/s *(See Section 7)* a return period of this flow is required in order to determine a probability of the incidence of flooding. Based on the data available, the return period of 4.3m^3/s is 25 years. It must be noted however that WY1993 is the only time a flow of greater than 4.1m^3/s has been measured and the dependence of the return period on that estimated value should not be ignored.

6.1.2 Rainfall Return Period

The rainfall return period estimate for the period September 1993 to January 1994 for the southern region of the UK was 30-50 years, with this particular period being 149% of the long term average (period 1961-90) *(Reference 12)*.

Chilgrove House rain gauge station has been selected for rainfall analysis of the Lavant catchment. The following data has been made available by the NRA:

1837-1919	Monthly recordings (from NRA or elsewhere)
1920-1958	Daily recordings*
1959	Monthly recordings
1960-1993	Daily recordings

*data incomplete for WY1951, 1953-1957

The daily rainfall records, where complete, from 1920 to 1992 have been used to derive annual maxima for various duration of rainfall. Frequency curves are included in *Fig. 6.3 and 6.4.*

The frequency of rainfall events between the end of September 1993 and the end of January 1994 are expressed in *Table 6.1.*

The 40 day rainfall of 335mm was clearly the most infrequent event with a return period of about 40 years. Other rainfall events were relatively insignificant when considering the level of flooding experienced. An event of 335mm in 40 days has only been exceeded twice previously within the data period in WY1929 (353.1mm) and WY1960 (341.3mm).

The cumulative rainfall from 1 October 1993 to 31 January 1994 was 585.2mm. When compared with monthly data from 1837 to 1992 this was only the ninth highest event, translating simply to a 17 year return period.

A short period of intense rainfall (winter storms) is more likely to produce a significant flood than the same amount of rainfall over a longer duration, and the magnitude of the flood could be greater if water levels have already been raised significantly by a preceding period of rainfall. The return period table 6.1 indicates the occurrence of two such rainfall periods, namely end of September/beginning of October and end of December/beginning of January. The use of a 40 day winter rainfall period assumes that all of this appears as (peak) stream flow, although a proportion of this must contribute to aquifer storage.

6.1.3 Effective Precipitation (October to January).

The monthly MORECS data for grid square 183 from 1961 to 1993 inclusive has been used to estimate the return period of the total effective precipitation (EP) over October to January each year *(Table 4.2)*. The effective precipitation takes into account losses due to soil moisture deficits and evapotranspiration, although these are usually small in the winter months. The results are shown in *Figure 6.5.*

Over the 32 year period, 1993 ranks third being exceeded by 1982 and 1976. The return period for the total EP in 1993 of 386.6 mm is 18 years. However, this excludes a zero EP in 1988. In addition, a monthly basis does not fully represent the intensity of the EP: in 1993 there were significant dry spells for six weeks in October-November 1993 and the second two weeks in January 1994.

6.1.4 Maximum Ground water Level Elevation Return Period at Chilgrove and Compton

To provide a longer historical record, a return period analysis of maximum water level elevations has been carried out using the water level records from Chilgrove (from WY 1835, 159 years) and Compton (from WY 1893, 101 years). These records are nearly 2 to 3 times the length of available daily rainfall record and 6 to 9 times that of the Lavant flow record.

Both sets of records suffer bias due to the frequency of measurement as water levels are not measured continuously. Consequently, the highest water level recorded each year may not be the true maximum water level. In addition, as there is no arrangement at the well head at Chilgrove to measure water levels (or flows) above ground level. Peak water levels cannot be measured when the well becomes artesian at level 77.18m OD.

The annual maximum water level (in 5 m intervals) at Chilgrove is shown in *Figure 6.6*. Levels in the range of 55 to 70 mOD occurred in 86 years (54%) of the 159 year record whereas levels exceeding 70 mOD have occurred 41 times (26%). The monthly occurrence of both maximum and minimum water levels is shown in *Fig. 6.7*, which indicates that 79% of peaks occur between December and March and 89% between December and April. The long term monthly average water levels at Chilgrove are given in *Table 4.3 - Section 4.*

A return period plot of annual maximum water level elevations at Chilgrove is shown in *Figure 6.8*. The average maximum water level is 62.9 mOD. This plot excludes the truncated levels recorded in 1852 and 1993 and instead includes the estimated peak level in WY 1993 of 79.15 mOD based on a correlation with the Compton record. This produces a return period for WY 1993 of 384 years, very similar to that derived from a combined probability analysis of 17-day rainfall and water level elevations of more than 69.5m OD *(see Section 6.2)*.

Figure 6.9 shows a probability plot of maximum annual water levels at Compton. The average maximum water level is 52.0 mOD. The peak water level in WY 1993 of 68.8 mOD has an estimated return period of about 175 years.

The return period estimates for both Chilgrove and Compton are sensitive to the small range shown by the highest ranked values and should therefore be treated with caution. Even so, the water level at Compton was very exceptional, being 3.8 m higher than the previously recorded highest value in 1960.

The water level record at Chilgrove was also used to indicate any long term trends or cyclical variations in water level. *Fig. 6.10* shows the annual average water level together with a 10-year moving mean. The long term annual average water level is 48.6 mOD.

Figure 6.11 shows a 10-year moving mean of annual maximum water levels (average 62.9 mOD), which indicates that the maximum water levels since about the turn of the century have been higher than those before about 1905. There are indications of a cyclical pattern with an overall upward trend in the minimum highest water level and that the cycles are occurring with a reduced amplitude and frequency. However, the data are open to more than one interpretation and should not be used for predictive purposes.

6.2 Return Period Estimates based on Combined Probability Analysis

Extreme flows are more likely to be generated by a particular combination of events especially when a prolonged period of exceptional rainfall is superimposed on high ground water levels. The water level records suggest that such combinations are likely to occur less frequently than might be indicated by a normal probability analysis of single variables.

In the 17 days from 26/12/93 to 12/1/94 190.5mm of rain fell onto a ground water level of 69.52m. This rainfall produced a rapid increase in Lavant flow - greater than that induced by a similar rainfall intensity at the beginning of October. Similar behaviour was observed for periods of high GWL in 1974, 1982 and 1989. The return period of this 17 days rainfall event was approximately 10 years. Flooding is therefore considered as a combination of events, namely a high ground water level followed by a significant rainfall event.

Fig. 6.12 shows the years in which ground water levels reached at least 69.5m OD and the maximum 10 and 17 day rainfall which followed. Those years prior to 1993 having notably high 10 and 17 day rainfalls following a high ground water level were Water Years 1927,1937, 1950 and 1960 and flooding is known to have occurred in all except 1950 (which also has the lowest rainfall). It could therefore be said, based on this limited data, that flooding may result when a ground water level of greater than 69.5m is followed by a 10 day rainfall of greater than 80mm.

In 1960 a high ground water level was followed by approximately 140mm of rainfall in 17 days. This was the highest prior to the 1993 event when 190mm of rainfall fell in the 17 days following high ground water level. The joint probability of these particular statistically independent variables suggests a return period in the order of 400 years which is consistent with the calculated return period of the derived Chilgrove ground water level *(Section 6.1.4)*.

It should be noted that this return period is based on the particular sequence of rainfall events which produced the January flooding. Due to the extreme nature of the ground water levels and a lack of long term high Lavant flow data, it is not possible at this stage to suggest what other rainfall events could produce similar levels of flooding. Applying the same methodology to the previous major flood in 1960 produces a joint probability of the order of 75 years for that particular event.

7.0 ADEQUACY OF PRESENT ARRANGEMENTS

7.1 Assessment of Adequacy of present Lavant to Deal with Combined Ground Water Rainfall Event

Clearly, the overall river system, using the term "system" to include the channel, culverts and bridges, has insufficient capacity to pass the flow generated during the January 1994 flood event. Some stretches or structures were nevertheless of sufficient size and therefore it is necessary to identify the inadequate components and to determine the safe capacity of the overall system.

Working in the opposite direction to other sections describing the river in this report ie. upstream rather than downstream, the most obvious structures which are inadequate are the two culverts through Chichester. Referring to Section 4.3 the maximum flow recorded through the first culvert during the event was 5.3m^3/s although this was obtained with a 0.48m surcharge. This amount of surcharge could not have been achieved without the building of the dam on the left bank in the Hornet and therefore a smaller, attainable flow should be regarded as the limiting capacity.

From examination of flow and head measurements taken by Archibald Shaw and Partners the maximum flow without surcharge of the first culvert is 4.2m^3/s. During the event, flow which passed through the first culvert was also discharged through the second without further difficulty and therefore the overall capacity of the two culverts can safely be considered to be 4.2m^3/s.

A survey of the river behind Rowe's garage, upstream of Needlemakers was undertaken to determine the capacity of this section of the river. The calculations indicate that, bank full, the maximum flow that can be accepted is 7.0m^3/s. There are however a number of foot and road bridges, many of which would create a loss of hydraulic head leading to overtopping of the banks upstream of each restriction. For comparison, the maximum flow recorded by NRA of the river along St. Pancras was 6.6m^3/s *(see Section 4.3).*

The onset of flooding problems at the entrance to the first culvert and in St. Pancras and the Hornet commenced around midday on 4 January. The flow recorded at Graylingwell around 01.00hrs on the 4th was 4.0m^3/s but by 14.00 hrs reached a peak of 6.3m^3/s when the River Lavant was out of bank and the gauging station was by-passed.

Calculation of flow within the river behind Rowe's garage, allowing 300mm of freeboard, gives a figure of approximately 4.3m^3/s, close to the safe capacity of the two city culverts. The previously highest recorded flow at Graylingwell in the 17 year record was 4.2m^3/s on 8 February 1988 when there were no known reports of flooding.

The calculations, measurements and observations are in close agreement and therefore give confidence in stating that the maximum flow which can be passed safely by the river downstream of the confluence of the Westhampnett Mill bypass channel is 4.3.m^3/s.

The river channel upstream of Westhampnett Mill was also surveyed in the vicinity of the footbridge approximately 300 metres upstream of the Mill where the river is known to have overtopped the banks. The calculated capacity of the channel was found to be approximately $7.2m^3/s$ However, the river overflowed its banks on 4 January whilst the flow was increasing from 4.0 to $6.3m^3/s$ It is probable that the overtopping occurred due to the loss of hydraulic head at the twin brick arch footbridge.

A similar calculation upstream of Graylingwell indicates that the bank full capacity of the river channel is approximately $7.0m^3/s$ but again the river is known to have overflowed upstream of the farm track bridge near the gauging station. The reduction in waterway area at this bridge would have certainly raised the upstream water levels, thereby reducing the effective capacity of the river.

The first gauging of out of bank flow in Madgewick Lane was on 8 January with a figure of $1.0m^3/s$ recorded. On this date the peak flow measured at Graylingwell was $6.4m^3/s$, not significantly different to that recorded on the 4th January.

It can therefore be argued that if a flow of $6.3m^3/s$ has resulted in an out-of-bank flow of $1.0m^3/s$ the maximum capacity of the river system upstream of Westhampnett is around $5.3m^3/s$

Inspection of the Lavant up to East Dean shows that a large proportion of the accesses over the river are undersized for flood flow conditions. Nowhere is this more evident than at Singleton where, as discussed in *Section 4*, the two 225mm diameter pipes forming an access near the post office are totally inadequate.

7.2 Standard of Service

Downstream of Westhampnett Mill the safe, no flooding, standard of service being provided by the Lavant system can be assessed as up to a 1 in 25 yr standard.

For the river between East Lavant and Westhampnett Mill the standard of service being provided is up to a 1 in 45 year standard.

These standards of service have been estimated using the 17 year record of River Lavant flows measured at Graylingwell for $4.3m^3/sec$ downstream of Westhampnett Mill and $5.3m^3m/sec$ upstream *(see Figure 6.1)*. They are furthermore, corroborated by the frequency of flooding recorded in these locations over the past 280 years *(See Table 3.5)*.

The indicative standards of protection given by the Ministry of Agriculture, Fisheries and Food are;

	Non-tidal
High density urban containing significant amounts of both residential on non-residential property	100 yrs
Low density or rural communities with limited number of properties at risk. Highly productive agricultural land.	25 yrs

It can be seen therefore, that the present standard of service in the City of Chichester is well below the accepted level and warrants further investigation of a flood alleviation scheme.

8.0 ESTIMATED FLOOD DAMAGES

8.1 General

Damages generated by the flood have been assessed in a desk top exercise using information gathered from a number of sources to determine the numbers and types of properties affected by flood waters. This baseline information has been supplemented by close inspection of aerial photographs, from reports from insurance companies and by direct consultation with affected commercial and industrial property owners.

Depth related damage data for flooding in excess of 12 hrs has been obtained from "The Benefits of Flood Alleviation" (The Blue Manual) by Penning-Rowsell and Chatterton and also from "Flair 1990" (Flood Loss Assessment Information Report) published by Middlesex University. Damage figures have been adjusted to 1994 values - See Table 8.1.

Direct costs of the emergency measures taken have been provided by West Sussex County Council and by NRA. While these costs do not relate to actual flood damage incurred, they warrant inclusion as they represent the cost of measures taken to alleviate flooding and of the consequent disruption - See Table 8.2.

8.2 Costs Due to Road Closures

An assessment was made of costs incurred by delays caused to traffic due to road closures in accordance with principles established in "Urban Flood Protection Benefits" (The Red Manual) by Parker, Green and Thompson et al.

Roads flooded in Chichester were:

Hornet
Madgewick Lane
A27 Westhampnett Bypass
Shopwyke Road
A259 Merston
A286 Singleton
A285 Resort Hotel Roundabout

The A27 Westhampnett By-pass was designed for a traffic flow of 33,000 vehicles per day of which 2,500 were assumed to be commercial vehicles. In the absence of actual traffic flows these figures have been used to calculate the disruption costs due to flooding of the by-pass. It has been assumed that there were delays of 10 minutes per vehicle from 6th to 9th January and 20 minutes per vehicle from 10th to 18th January. The dates when traffic was affected were obtained from the consultants to the Department of Transport and the delays allow for traffic diversions.

For the A259 road at Merston a traffic volume of half the above figures was used. To cover the whole of the remainder of the roads flooded due to flooding associated with the Lavant similar costs to those calculated for the A259 were assumed.

The total road closure cost using the above assumptions is £1,072,000 which should be regarded as representative only. It is unlikely that detailed information is available to enable a more accurate estimate of costs to be ascertained.

Summary of Costs

		£'000
■	Direct Damages	1,988
■	Business Loss	620
■	WSCC Costs	1,905
■	NRA Costs	350
■	Road Closure Cost	1,072
	TOTAL	5,935

8.3 Culvert Collapse/Blockage Scenario

A principal concern of the authorities during the event was that the surcharge of the two culverts through Chichester together with the high velocity of the flow could result in the internal collapse of one (or both) of the culverts. Flooding of a large urban area of Chichester would have swiftly followed such an event, with the constricted nature of the culverts and the generally poor access making remedial works difficult under extreme flow conditions. Contingency plans were made to evacuate 2000 properties if this occurred.

It is therefore logical to make an assessment of the damages which would accrue in this scenario since the condition and configuration not only of the culverts are suspect but also of the many riverside structures. Indeed prior to the January floods at least one substantial wall was noted to be temporarily shored against collapse.

Examining the Ordnance Survey Maps, with due consideration of the ground levels, it was estimated that there would be central swathe of flooding to a depth of 300mm with a band 200mm deep on either side and a band 100mm deep on the south side. The flood waters would escape to the canal head on the south as well as to the river to the west. The potential flooded area, whilst only being an assumption, is regarded as indicative of the area likely to be affected by 7 hours peak flow in the Lavant. Lesser flows could produce a similar extent of flooding but in a longer period.

The total number of dwellings assumed to be flooded in this scenario is 760 plus around 63,000m_2 of business properties. Using depth related damages for flooding in excess of 12 hours the damage thus accrued is in excess of £16,300,000.

9.0 DISCUSSION

9.1 Hydrogeological Factors Influencing Lavant Flows

9.1.1 Introduction

An understanding of the conditions that produce flows on the Lavant could provide advanced warning of possible flood flows and assist the design of flood protection or alleviation measures. It should be possible to establish a correlation between cumulative effective precipitation (or rainfall amount and duration), preceding water level elevation, total water level rise and flows in the Lavant. This should provide an indication of the scale of the flood and return periods of selected flow rates.

An analysis of rainfall, water levels and the start of Lavant flows during the early 1970's, following the extremely wet conditions in September and November 1974 and January 1975 *(Reference 14)*, indicated that the following combination of events was likely to increase the risk of flooding:

- a summer Chalk minimum water level in September or October
- a subsequent rainfall exceeding 150 mm/month (whereby flow starts in December)
- further winter rainfall totalling 380 mm (ie total 680 mm).

These conditions are somewhat similar to the recent flood event, but do not provide information or explain the factors influencing recharge and discharge in the upper part of the Lavant catchment, which include:

- intensity, duration, timing and interval between rainfall events
- antecedent catchment conditions
- unsaturated zone processes
- variations in aquifer conditions

9.1.2 Antecedent Catchment Conditions

The water level elevation at the start of a prolonged and significant recharge event is a major factor governing subsequent flows of the Lavant. For example, rainfall during the first two weeks of October 1993 was similar in amount and duration to that between 25 December 1993 and 6 January 1994 but the flows produced by the events differ by almost two orders of magnitude. Water levels rose at a similar rate during each event but by a total of 28 m in October compared to only 10 m during the latter event. However, the water level was 30 m lower on 29 September 1993 at the start of the October event than on the 25 December 1993 at the start of the December/January event.

The total rise in water level depends on the duration and rate of infiltration compared to the rate of discharge. The rate of infiltration has to be greater (or sustained for a longer period) if the preceding water levels are low in order to produce a marked increase the flow of the

Lavant. On this basis, further flooding would almost certainly have occurred had another period of significant rainfall taken place during January or even February 1994 as water levels were still above average.

Figure 9.1 shows an arithmetic plot of water level elevation at Chilgrove against daily mean flow on the Lavant for the period 13 October 1993 to 6 January 1994 (just prior to artesian flow at Chilgrove and overbanking at Graylingwell). This suggests that there is a marked increase in flow rate per metre rise when water levels (at Chilgrove) reach an elevation of about 69.5m OD. At water level elevations of 56-70 mOD the flow rate increased at about 0.09m^3/s per metre rise in water level, whereas above about 69.5m OD the flow rate increased by about 0.8m^3/s per metre rise in water level.

It is possible that this apparent relationship is simply a local effect at Chilgrove, such as the outbreak of springs nearby. However, there is some independent corroboration of the variability of the permeability of Chichester Chalk which supports this apparent relationship. Packer tests carried out recently on three boreholes in the chalk *(Reference 31)* have shown a dramatic variation in permeability within relatively narrow depth bands, suggesting a mechanism whereby the hydraulic connection between the chalk and the Lavant could equally vary widely with ground water level. The water level elevation at Chilgrove could therefore provide a possible indication of a potential flood.

9.1.3 Unsaturated Zone

The thickness of the unsaturated zone varies considerably in the Chalk. In the Lavant catchment this varies from a few metres along the valley to about 120 m in the northeast and northwestern parts of the catchment. A rise in water levels will decrease the thickness of the unsaturated zone in the immediate area of the valley and its tributaries eventually causing a greater proportion of the subsequent rainfall, especially in the area of shallow water levels along the valley, to be rejected as run-off.

The lag response between infiltration and water level rise is related mainly to the depth to water table. Deep water levels (>80m) may show a lag response of 2-3 weeks whereas shallow water levels (<10m) show a much faster response of a few days. Exceptional rainfall events, however, can show a response rate of 10 m/hour compared to a more typical 4 m/day *(Reference 9)*, although short term water level rises during the autumn and winter are usually masked by the larger seasonal rise.

There was a lag of some 2 to 3 weeks between the flow of the Lavant in response to the rainfall in the first two weeks of October 1993, when water level elevations at Chilgrove were relatively low (38-56 mOD). As shown by *Figure 4.1* subsequent rainfall in December and January produced an increase in the flow of the Lavant with a delay of less than a few days, when water levels at Chilgrove were closer to ground level (above 50m OD).

The unsaturated zone of the Chalk is complex and as yet poorly understood *(Reference 13)*. It seems likely that, with increasing saturation and a decrease in the thickness of the unsaturated zone along the valley in particular, a greater proportion of any subsequent high intensity recharge may be transferred rapidly through the larger fractures to appear as ground water run-off.

9.1.4 Variations in Aquifer Conditions

Often a significant part of the winter streamflow in Chalk streams originates from more permeable zones close to the water table, which are usually associated with valleys. Two components of flow can be distinguished: a winterbourne component derived from a thin, high transmissivity (T), high specific yield (Sy) zone and a more uniform, sustained flow component derived from the main zone of the aquifer. The 'flashy' nature of the flow regime of the Lavant compared to the more sustained flow regime of the Ems may reflect these different flow components.

The course of the Lavant valley above West Dean turns east across the dip slope of the Chalk to follow the line of the Singleton anticline. It seems likely that this part of the valley has developed by the erosion of more intensive fracturing often associated with anticlinal structures. Middle Chalk is exposed along the valley in this area and the less permeable Lower Chalk occurs at a shallower depth causing a partial barrier to the southward flow of ground water, which is also suggested by the water level configuration *Figures 4.3 and 4.4*. The permeability of the fractures along this part of the valley is also likely to have been increased by more intensive solutioning.

Most hydrogeological studies of the Chalk aquifer have focused on resources availability during drought periods, but studies undertaken in various areas using a variety of methods *(Reference 10)* have shown the importance of local variations in the aquifer characteristics of the Chalk, both spatially and with depth, that govern aquifer behaviour with time.

The occurrence of zones of high permeability is particularly important. The top of the main Chalk aquifer has one or more distinct thin (< 10 m) zones with unusually well-developed fissuring having a significantly higher T and Sy than the bulk of the Chalk aquifer and which form important conduits to streamflow. Model studies and pumping tests indicate that the transmissivity of shallow permeable zones may be an order of magnitude higher than the main zone of the aquifer and throughflow in these permeable zones will vary more in relation to the associated hydraulic gradient than the saturated thickness of these zones.

These very permeable zones occur within the top 30-40 m of the saturated zone as a consequence of fissure enlargement by solutioning in the zone of active ground water movement, largely irrespective of the particular stratigraphic level of Chalk. Other well-developed zones may also be present within the unsaturated zones as relics of once higher ground water levels and different outflow elevations.

As the hydraulic properties of the Chalk vary with location as well as decreasing with depth, the Chalk aquifer is often considered as at least a two-layered aquifer system in which ground water flow is determined by the water level elevation in relation to zones of high permeability. Hence, the aquifer properties influencing flow may be different during high water table conditions than at low water table conditions and despite the considerable thickness of the Chalk, the effective thickness and zone of most active ground water movement may be only 30-50 m.

These general observations of the Chalk and the particular geological features of the upper reach of the Lavant valley would tend to suggest that a zone of higher transmissivity is present along this part of the Lavant. When the Lavant is not flowing discharge from the aquifer is controlled by lower base levels (mainly the Chalk-LLT boundary), a lower hydraulic gradient and the aquifer characteristics of the main zone of the Chalk. When recharge occurs the barrier effect of the Singleton anticline becomes more pronounced. Eventually, as the water table intersects the valley floor (only a small rise in water level is required along the valley due to shallow water levels) surface flows are initiated on the Lavant which then forms a separate higher elevation discharge level capturing more of the flow in the northern ground water sub-catchment. As water levels continue to rise and hydraulic gradients increase, the high permeability zone could rapidly transmits greater volumes of water into the valley.

9.1.5 Summary

High flows in the Lavant are generated by a complex series of events, and it is not possible to simplify the process to identify a single cause of flooding. There are, however, clear indications that the internal structure of the chalk in the upper catchment is such that the speed of response and the rate of flow in the river are both linked to the ground water level in the chalk. A ground water level of 69.5m OD at Chilgrove appears to represent a transition point in the catchment hydrogeology with flows in the river increasing significantly if further rain falls on the catchment when this ground water level has been achieved.

9.2 Flood Stages

It is apparent that the flooding event proceeded in two separate stages. The first, being the onset of flooding on 20 December in the Church Farm Pit area, was due to an increase in local ground water levels. At that time flow in the Lavant was relatively low and there was no flooding from out-of-bank flows. However, in response to further heavy rainfall on the catchment, flows increased sharply and the second stage of more serious and widespread flooding began on 3 January. This was due to the Lavant flows increasing beyond the local channel capacity and river waters overtopping their banks.

9.3 Emergency Effort Co-ordination

The January flood event could reasonably be expected to have tested the readiness of the public authorities' response to such an emergency, particularly given the nature of the River

Lavant, which is often dormant for months at a time, coupled with the lack of any flooding since 1960.

It is therefore not surprising that the extreme scale of the event was not and could not reasonably have been anticipated. This is perhaps best demonstrated by the fact that the NRA did not issue a Red Flood Warning until the early hours of 7 January when the Lavant had been out-of-bank since 4 January. However, West Sussex County Council had opened their emergency control centre on 30 December and thus the framework for dealing with the emergency was being developed.

Initially, as could be expected, the response was reactive, responding to individual occurrences as and when they happened. It is important to bear in mind that flooding was occurring over a wide area and was therefore not confined to the River Lavant catchment. The resources of the authorities were consequently stretched and eventually needed to be supplemented by the military and volunteer groups.

The opening of the Emergency Control Centre at County Hall on 30 December was of prime importance as the first step towards coordinating the efforts of all the organisations involved. By 6 January a coordinating group consisting of representatives of all the organisations was established. The group met twice a day to review the situation and plan future action. By holding press conferences following the coordination meetings the maximum possible dissemination of information to the public was achieved.

The principal difficulty, recognised at an early stage, was deciding where to divert and/or pump flood water to avoid merely transferring flooding from one location to another. By 4 January when the river was overtopping its banks at the Hornet it was evident that the channel and culverts through the city centre were inadequate to deal with further flow. The records indicate that all possible routes for diverting and containing floodwater were considered and their possible side effects assessed. Clearly with the immediacy of the problems, major channel works were impossible and considerable reliance was placed on pumping by the Fire Brigade backed up by the "Green Goddesses". Although this represented a mammoth effort, the peak rate pumped, estimated at 10.5 million gallons per day, is only $0.55m^3/s$. With a flood flow of around $7.9m^3/s$ and the safe culvert/channel capacity at $4.3m^3/s$ some $3.6m^3/s$ should ideally have been dealt with.

It is generally believed that the course of the Lavant was diverted at some time in the distant past and it is probably significant that the river attempted to "reclaim" its preferred route to the sea via the Pagham Rife system. The decision to channel the out-of-bank flows along Madgewick Lane and the old A27 road with sandbag banks and discharge into Church Farm Pit was clearly the right one and although it exacerbated the flooding of the Westhampnett Bypass it undoubtedly saved many more properties from flooding within the city and on the eastern boundaries.

Credit must be given to the coordinating group in recognising that a blockage or collapse of either of the two major culverts would cause catastrophic flooding and to make all the necessary arrangements for evacuation, housing and feeding the possible victims.

The overall impression, after studying the varying logs maintained during the event and reports made subsequently, is that the coordination of the response to the emergency deserves commendation. Clearly lessons for future events will have been learned and shortfalls in procedures identified and modified.

9.4 Gravel Extraction

The ground water regime in the key Westhampnett area is very complex, having been considerably disturbed by extensive gravel working over the past 50 years. However, it has been perceived that there is the potential for ground water levels to be increased by the progressive removal of the permeable river gravels through which much of the chalk aquifer of the upper Lavant catchment discharges. A logical mechanism can be postulated whereby an increased head in the form of higher ground water levels must need to be generated in order for the ground water to flow southwards through the available corridors of unexcavated natural river gravels remaining between the considerably less transmissive backfilled or waterfilled pits.

There have been a number of studies carried out in connection with proposed development in the river gravel areas of the lower catchment *(References 11, 13 and 34)* in which this potential effect has been noted. An increase in local ground water levels has also been noted, but it has proved impossible conclusively to link this to gravel extraction, as the ground water level data are subject to many other local effects including local pumping as part of the gravel extraction operations, construction of the A27 Westhampnett By-pass and the associated pumping from Church Farm pit, as well the rather heavier than average rainfall.

These studies have called for more sophisticated ground water modelling of the Westhampnett area than has been carried out so far and such modelling may well be capable of more definitely identifying any effects on the ground water regime which result from continuing gravel extraction and the subsequent use of the worked out pits. However, such a study will of necessity be relatively long term as more data will be needed to improve its accuracy. In the short term, before the results of any such study became available, it would seem prudent to conclude that gravel extraction does indeed have an effect on ground water levels. The effect of this during the recent flood event is believed to have been of a secondary order only, and confined to areas local to the infilled pits. Future development of further pits, or the infilling of existing open pits or indeed any significant development should not proceed before most careful consideration has been given to the potential for adverse effect on the ground water regime. In considering any such development it is vital that it is recognised that the natural gravel remaining un-excavated is currently an integral and important part of the natural drainage regime. It should not simply be removed without the effects of its removal being carefully studied and any necessary measures devised to mitigate those effects.

9.5 Possible Effects of the A27 Westhampnett By-pass

It was recognised at the time of investigation and design of the road scheme that there existed the potential for it to affect the ground water regime, particularly at its western end near Westhampnett. The Department of Transport commissioned a report from the Institute of Hydrology *(Reference 34)* to investigate this possible effect following the receipt of objections to the then proposed by-pass on the grounds that it could exacerbate the flood risk. These objections then centred upon the possibly adverse effect on water levels in Church Farm Pit. It is known that Church Farm Pit has the potential to greatly influence local ground water levels. A study has shown *(Reference 11)* that should it be infilled, local ground water would rise some 2m. Clearly, therefore, if the drainage from the pit is obstructed and pit water levels rise then there may well be the potential for local ground water levels also to rise.

The report concluded that the partial infilling of this pit required to accommodate the new road could increase water levels and that measures should therefore be taken to reduce this potential impact. A second IoH report for DTp *(Reference 35)* examined the use of a soakaway trench into which Church Farm Pit water would discharge via a culvert beneath the road as a means of preventing any untoward impact resulting from the new road. It was concluded that this was viable and that as there was benefit to others in controlling pit water levels, joint funding should be considered.

The by-pass, when constructed, included two specific features originating from these reports that were designed to reduce the roads impact upon Church Farm Pit. They were, firstly the inclusion of permeable fill where the pit was partially infilled along its southern boundary. The intent of this was to minimise loss of pit storage volume. The second feature, was the inclusion of two 300mm diameter culverts beneath the road at the south east corner of the pit to allow drainage into a soakaway in the natural gravels to the south.

However, these two culverts have never been commissioned and have remained sealed at the inlet penstocks since construction as DTp have failed to reach agreement for their discharge with the operators of the gravel pit to the south. They have therefore never performed the drainage tasks for which they were designed and it is not apparent that any other interim measures have been put in place to deal with the flows they otherwise would have accommodated.

The capacity of the two culverts have been independently assessed and it is significant that they can accommodate approximately $0.24m^3/s$ without surcharge, which is similar to the assessed natural rate of inflow into Church Farm Pit *(Reference 35)*.

During the January flooding, measures were directed to the emergency committee to allow the culverts to be brought into operation. This comprised the installation of a 450mm pipe linking the culverts discharge manhole to the Westhampnett south pit. However, by the time these works were complete, the flooding was abating and there was concern regarding liability for consequential downstream changes in flooding should the culverts be operated. As a result, the culvert penstocks remained closed. However, the emergency committee decided they should be left in a state where they could be used, if necessary.

The possible effect of the new road on the January 1994 flood is difficult to define precisely, but with the drainage capacity of the two 300mm culverts not available, the Church Farm Pit water levels will have been higher for longer than would otherwise have been the case. The capacity of the culverts is totally insufficient to have accommodated all of the flow into the pit during what was a very unusual return period event. Indeed out-of-bank river flows from the Lavant entered the pit from the 4 January; an event for which the culverts had not been designed.

However, had the culverts been operational prior to and during the January event, the pit levels would have been lower at the start of flow and the rate of rise thereafter would have been slower. The extent of ground water flooding which occurred in late December before the main flood event may well have been much reduced.

It is not believed that the ultimate course the out-of-bank flows took from Westhampnett has been affected by the new by-pass; with or without the two culverts the flood waters would have left Church Farm Pit at the south east corner and flowed south towards Shopwhyke and Merston. However with the culverts sealed, more of the water overtopped the pit and flowed along the new road. It was therefore the case that the failure to commission the culverts resulted in the bypass and the Church Farm Pit area being affected by flood waters for longer than would otherwise have been the case.

Clearly the current non availability of the culverts is unsatisfactory, as works identified as being necessary to mitigate the potentially untoward effects of the by-pass on the local ground water regime are as yet incomplete.

DTp have indicated that they do not have the statutory powers to commission the culverts nor to operate the sealing penstocks. They expect this to be the subject of future negotiations with NRA, and possibly WSCC when they acquire a maintenance interest in the highway in their role as agents to the DTp. NRA have in turn indicated that they may not have the necessary powers to complete culvert commissioning. However, it is considered to be unsatisfactory that the highway scheme has been allowed to proceed through the design and approval process and indeed be completed and opened to traffic before the responsibilities for commissioning, maintenance and operation of a previously identified essential drainage element of the scheme are addressed and resolved.

9.6 Lavant System Unaffected by Flooding

A large part of the catchment remained unaffected by flooding during the January event due either to the local topography, the adequacy of the drainage arrangements to deal with ground water and run-off or to flood alleviation measures undertaken as emergency works. Any future consideration of a flood alleviation scheme for Chichester or the upper catchment should not count such unaffected areas as being invulnerable. Improvements made elsewhere in the system may well allow more water to flow down the river in future extreme events. For example, there was no recent flooding to the Lavant downstream of Chichester due to the restriction to flow offered by the existing culverts. Improvement of these culverts could allow more water to pass downstream resulting in problems in previously unaffected areas.

9.7 Division of Responsibility for Lavant System

9.7.1 The ownership of the critical sections of culvert and channel through Chichester is riparian. There are therefore a large number of private, commercial and public bodies involved. This situation is far from ideal in the planning of maintenance and improvements to the channel, to the culverts and to river adjacent structures which have the potential to cause a catastrophic blockage, should they fail. There are furthermore difficulties in the control and regulation of such a system in fragmented ownership. More serious flooding of the Hornet area was only narrowly avoided during the January event when temporary defences were called for following demolition of a privately owned river adjacent boundary wall which had not been appreciated as an element in the flood defences.

The current situation has evolved over a long period of time and it is difficult to conceive how the present unsatisfactory arrangements can be improved. Clearly rigorous control is required over further development or demolition, and careful inspection is needed to ensure continuing stability of privately owned river adjacent structures.

9.7.2 While flow in the Lavant originates from entirely natural meteorological and hydrogeological processes within the catchment, there are other artificial influences which have the potential not only to affect river flows but also ground water levels in the lower catchment. In particular Church Farm pit has been identified as a controlling influence on the nearby Lavant and Westhampnett ground water levels. Water levels within the pit are controlled by privately owned and operated pumps discharging into the Lavant. Similar pumping and water transfer are undertaken privately elsewhere within the lower catchment as part of the continuing gravel extraction. There is no central regulation of such pumping; it being carried out for entirely local reasons. A future flood alleviation scheme may include measures to regulate ground water levels in the lower catchment, in which case regulation of pumping and water transfer will then be necessary.

9.8 Assessment of Return Period

The assessment of the return period of the January event has been made difficult by the shortness of the available flow gauging data for the Lavant. The flooding and consequent disruption were the result of unusual river flows and ideally an assessment of the return period would be made from flow records. However, there is only a 17 year period of flow data from the Graylingwell gauge and this does not include any previous flood events. The peak flow recorded in January of 7.1m^3/sec (estimated 7.9m^3/sec including out-of-bank flows by-passing the gauge) far exceeds the previous maximum record of 4.3m^3/sec. An assessment of return period can be made from this data, and indeed a return period of 110 years has been estimated in this way, but this figure is subject to wide variation depending upon the interpretation that is made of the very limited number of high flow records.

A linkage has been demonstrated between flow in the Lavant, and ground water level recorded at Chilgrove, with a "trigger" level of 69.5m OD being the onset not only of significant river flow but also of a marked reduction in the response time of the river to further rainfall in the catchment. The return period of the trigger level is about 5 years. Given the very much longer and more comprehensive records available for ground water levels, a reliable return period can be calculated for the ground water levels at Chilgrove and Compton. This shows that the event was quite exceptional, with return periods of 384 and 175 years respectively. However there are insufficient data definitely to relate river flow to this return period. It is entirely possible that lesser return period ground water events could produce peak Lavant flows at least the equal of, if not exceeding the January recorded flow.

A scenario has therefore been postulated for serious flood events, whereby high intensity rainfall occurs when the ground water level is at or above the trigger level of 69.5m OD. To test sensitivity, consideration was given to both 10 day and 17 day rainfall events. However, the joint probability of the two independent variables again indicates an unusually long return period of 400 years.

Even given the shortcomings of the availability of suitable data, it is clear that the January event was of unusual severity and its a return period must therefore be considered to be in excess of 100 years.

The historical records of flooding show there to have been some 15 significant events during the past 280 years, ie. on average every 19 years. This provides an independent confirmation of the event return period assessment, as it has also been employed in the derivation of the currently assessed 25 year standard of flood defence in Chichester; a figure which closely matches the historical records.

10.0 CONCLUSION AND RECOMMENDATIONS

10.1 Conclusions

10.1.1 Return Period

The River Lavant suffered flooding in January 1994 which was the result of an unusual combination of heavy rainfall on a catchment with a pre-existing high ground water level. The joint return period of these two significant factors is assessed as being in excess of 100 years.

10.1.2 Standard of Service

The standard of service provided by the existing River Lavant channel and associated structures is 1 in 25 years for the urban areas of Chichester downstream of Westhampnett Mill and 1 in 45 years for the rural areas upstream. Whilst this latter standard of service is acceptable for non-tidal flood risk, the former is below the accepted 1 in 100 year standard.

10.1.3 Damages

The measurable cost of the recent flooding event is assessed as about £6.0m. Within the short period of time available, it has not been possible to quantify the considerable disruption that resulted from the widespread incidences of flooding and associated emergency measures. There is, however, the potential for far more serious urban flooding to occur in the event of blockage or collapse of the sub-standard culvert and river channel through the City. Potential damages in such an event have been assessed as a minimum of £16.3m and these could occur during river flow events of comparatively modest severity.

10.1.4 Ground Water Levels

The Lavant has a chalk upper catchment, and river flows are predominantly ground water in origin. It has been found that the onset of significant flow in the Lavant is linked to the ground water level in the catchment. A level of 69.5m OD at Chilgrove can be considered as a threshold above which a marked increase in river flow and rate of response can be anticipated.

10.1.5 A27 Westhampnett By-pass

There is no evidence to support the locally held perception that the recently opened A27 Westhampnett By-pass was a primary contributory cause of the flood event. However, culverts identified as being necessary to mitigate the roads effect on local ground water levels had not been completed. During the January flood event, the effect of their non-availability was an increase in the duration of flooding of the by-pass and the Church Farm Pit area.

10.1.6 Gravel Extraction

The natural river fan gravels of the lower catchment are an important conduit via which the majority of precipitation on the Lavant catchment ultimately flows to the sea. Extensive extraction of the natural gravels has progressively reduced the available path for this flow as worked out pits, be they infilled or left water filled, have a greatly reduced transmissivity.

There is a widespread perception that ground water levels within the gravel of the lower catchment have been rising recently and this is believed to be a consequence of the recent gravel extraction works.

10.1.7 Flooding

Flooding occurred for a number of reasons. Initially, rising ground water levels caused flooding in the Church Farm Pit area and some city basements. However, with the onset of significant flow in the river Lavant in early January, flooding resulted from the capacity of the existing channel, culverts or overbridges being exceeded both in the City and the upper catchment villages. Out-of-bank flows caused further flooding in the Westhampnett area and these flows found their way into the adjacent Pagham Rife catchment adding to the already high natural catchment flow and causing flooding at the existing culverts, overbridges, and other points of constriction.

10.2 Recommendations

10.2.1 Flood Alleviation Scheme

It is recommended that a flood alleviation scheme be investigated to raise the currently low standards of flood protection in urban Chichester to a 100 years minimum standard.

10.2.2 Channel Improvement Works

Whilst the present standard of service provided by the channel upstream of Westhampnett Mill is apparently in excess of the recommended 25 year standard, there is nevertheless scope for modest works to remove obstructions to the channel that would locally improve the present situation. With more detailed assessment, it is considered probably that local standards may prove lower than the assessed 45 years and such works may therefore be beneficial.

10.2.3 Interim Emergency Plan

It is unlikely that any significant improvement to the standard of service in Chichester could be made before the onset of the next winter season. It is therefore recommended that interim emergency plan be developed to deal with a possible culvert blockage and mitigate the consequential flood risk. Similarly, interim measures are called for to identify and stabilize the riverside structures at risk of collapse which could instigate a channel or culvert blockage.

10.2.4 Flood Warning Scheme

It is recommended that a flood warning system be developed to give prior warning of the likelihood of high river flows. Such a system could be based upon the 69.5m OD trigger water levels at Chilgrove, and actual or forecast precipitation thereafter.

10.2.5 Development in Lower Catchment

Future development in the lower catchment which has the potential to affect the important ground water regime, should be carefully scrutinized to determine any consequential untoward effects and develop mitigating measures. Developments likely to have such an impact include further gravel extraction, infilling of existing pits, major highway schemes and other projects with the potential to significantly affect local drainage.

The recent flooding has highlighted rural areas in the catchment which are vulnerable to flooding. Development within such areas should not be permitted without attendant flood alleviation measures.

10.2.6 A27 Westhampnett By-pass

The twin 300mm culverts beneath the by-pass should have been commissioned. It is understood that the culverts themselves are completed; agreement to the arrangements for their downstream discharge is the obstacle preventing them being brought into operation. It is recommended that NRA approach DTp or their executive agency with a view to urgent resolution of this impasse. DTp have indicated that they lack the statutory authority to undertake this themselves. Although having had a marginal effect upon the recent flooding event, it is desirable in the interests of management of the Church Farm Pit levels, that either they be brought into operation, or that alternative methods of control be provided.

APPENDIX A
DIARY OF FLOOD EVENT

APPENDIX A

DIARY OF FLOOD IN RIVER LAVANT CATCHMENT

The information obtained to compile the diary was obtained from the sources listed in *Section 4.3*. It is intended as a synopsis of the event rather than attempting to provide every detail. Whilst every effort has been made to ensure accuracy, there were nevertheless discrepancies in the information provided by the various sources. This is to be expected given the unusual circumstances under which the records were originally made.

December 1993 **Total Rainfall 20th to 31st December - 76.4mm**

During mid December rising water levels in Church Farm pit were causing concern and by around 20 December flooding of the Rutland Way area had started to occur.

The River Lavant immediately upstream of Westhampnett Mill had virtually reached the top of its banks by 30 December.

Monday, 3rd January 1994 **Rainfall 30.9mm**

This appears to be the first day that many reports were received concerning flooding within the Lavant catchment. Early in the morning the police had received reports of flooding in College Lane, Chichester and this road was subsequently closed between Wellington Road junction and Spittlefield Lane. By mid morning they were also receiving complaints from Brook Lane, East Lavant, where cars were passing through floodwater too quickly and causing wash to enter into a property. Reference is also made to action by the police at this location on the 2nd January, indicating that some flooding may have been occurring then. By midday on the 3rd January the WSCC had inspected the River Lavant and advised at least one resident that Drayton Depot was open for the collection of sandbags. They were also dealing at that time with the erection of road flooded signs on the A27 Chichester Bypass and a request to close College Lane in Chichester. It is presumed that the latter two incidents were as a result of poor performance of road drains to soakaways, which were failing to function due to saturated ground conditions. A report was also received that the Lavant was flooding the A286 at Singleton, opposite the Horse & Groom public house.

Tuesday, 4th January 1994 **Rainfall 12.2mm**

In the early morning flooding occurred at the Lavant Down estate where surface run-off was accumulating behind an earth bank. This was subsequently alleviated by the local contractor, believed to be that working on the Portsmouth Water Company reservoir, who dug through the earth bank for the residents and released the floodwater down slope towards the River Lavant. An early report was also received from the Horse & Groom at Singleton where the A286 was flooded to a depth of 150mm, sufficient to close half the road. The licensee of the public house was becoming frustrated by the way vehicles were driving too fast through the flood and causing large bow waves to enter the property. Signs and sandbags were requested from the WSCC Road Force Depot at Drayton. By midday Madgwick Lane was reported to be flooding due to overtopping of the left bank of the River Lavant and water flowing through Westhampnett Mill yard on to the lane and the Westhampnett roundabout by the Chichester Resort Hotel. Shortly after, flooding was also reported in the Hornet in Chichester, due to the Lavant overtopping its banks at the building site just upstream of Kwikfit. Numerous reports were received from this location together with complaints about traffic travelling too fast and causing bow waves into adjacent properties, eventually the road was closed at 15.30 and all traffic diverted eastwards from Needlemakers. At the same time one of the routes from Needlemakers, St Pancras, was also in danger of being flooded by the threatened collapse of the brick floodwall opposite the Fish Bar. This wall was constructed in about 1961 as a result of the 1960 flood in Chichester. The road was closed temporarily and diversion put into effect whilst the NRA shored up the wall with sandbags and props from adjacent posts with the repair being completed by 16.16. At this time the police also took the decision to inform the media concerning the long delays to traffic in the centre of Chichester.

By mid afternoon reports were also being received of flooding in cellars within the south eastern quadrant of Chichester, in particular the Department of Social Security office in St John's Street and three properties in Victoria Road. In the latter the flooding was only to a depth of approximately 300mm and the Fire Brigade decided not to attend unless the water rose and threatened the electrical installations of these properties.

At 17.00 New Park Road, which had previously been advised as having 100mm of water across it at Priory Road, was closed to southbound traffic. WSCC considered that the cause was possibly backing up of drains which discharged into the Lavant. Shortly after the section of the old A27 from the Chichester Resort Hotel to the Portfield Roundabout was reported as flooded with 2 vehicles stranded. This road was closed with cones by 17.40 but the Sainsbury's to Portfield new link road was still open and remained so throughout the emergency. By 18.00 the NRA were in attendance at the Hornet with a JCB and commenced damming up the banks of the River Lavant within the building site. They advised that the retention of all the water within the river might cause flooding at Southgate culverts and the police were requested to monitor the situation at that location. Flooding also appears to have occurred along the Westhampnett Road by the crematorium entrance as at 18.30 the road was described as 'passable with care'.

By 21.00 the water was receding due to the efforts of the West Sussex Fire Brigade, who had pumped most of it away, and opening of the roads was being contemplated within the hour. This did not take place however, as at 21.40 the decision was taken to keep the Hornet closed overnight. It was arranged that the WSCC Road Force would provide two men with equipment to attend to the dam overnight.

The NRA flood warning records show that an amber warning was in force for the Lavant River together with the Bosham Stream, Aldingbourne Rife, the Ems, Barnham Rife and Broad Rife for that day.

Wednesday, 5th January 1994 **Rainfall 9.0mm**

In the early morning New Park Road in Chichester was reported as still closed due to flooding and the A286 at Singleton was reported as flooded to half width at the Horse & Groom public house. Surface water flooding was also reported on the B2141 Petersfield Road at Yarbrook. Water was still flowing down Madgwick Lane, around Westhampnett Roundabout and down the old A27 to enter Church Farm Pit via its access road.

At the Hornet the condition of the clay dam was giving concern during the afternoon, with leaks appearing and closure of the road to traffic again being considered. Repairs were carried out by Road Force and the Hornet was reported as clear for traffic at about 18.00. By 19.00 a resident in Storey Road had reported that the level of the Lavant was up to the footbridge joining Storey Road to Westhampnett Road.

By the evening the level at Church Farm Pit had been rising and was resulting in overspill down and flooding of the eastbound carriageway of the new A27 Westhampnett Bypass. Encroachment of the lake formed along the old A27 onto the new Portfield Roundabout at the western end of the new bypass was also occurring. During the late evening it was still possible to control the flood sufficiently by pumping to keep both carriageways of the Westhampnett Bypass and the Portfield Roundabout in use by to coning off the affected lanes.

Thursday, 6th January 1994 **Rainfall 15.0mm**

The first meeting of the authorities and emergency services involved with the flooding event took place in the Emergency Control Centre. From this date all decisions were taken by the group. A major problem due to the generally flat topography south of Westhampnett was that it was unclear where further flooding would take place. Contingency measures were made for the probability of flooding in all directions.

Details of flooding at Singleton are scarce in the records but the flooding appears to have been increasing as there were more calls for sandbags. There are no reports from Lavant for this day but from the records of rising water level at Graylingwell Gauging Station the situation can only have been getting worse.

The two main areas of activity were at the Hornet area in Chichester and along the alternative flood route which was developing southwards from Westhampnett Mill.

At midday water was reported as rising in the Hornet and by mid afternoon the Lavant had overtopped its left bank at Rowe's Garage and was flooding the Hornet between Covers and The Four Chestnuts public house. By early evening the Emergency Control Group had decided to set up a pumping relay using 10 fire appliances and a hose layer to try to relieve the build-up of water at the Hornet. Concern was also felt for residents within Riverside, Towzer Way, St Pancras, the Hornet and Eastgate areas and evacuations of a small number, mainly those at greatest risk, commenced later that evening.

At Westhampnett and Portfield areas the police and Road Force had all necessary signs and equipment in place by 05.00 to set up a diversion for the new A27 bypass, should it be required. Closure of the eastbound carriageway was effected at midday by the floodwater level rising and all eastbound traffic was diverted on to the westbound carriageway. Later that evening the water was reported to be crossing the westbound carriageway but traffic was still able to pass with care.

Upstream at the Westhampnett Roundabout the flow also appears to have been increasing as the sandbagged walls constructed along the roadway outside the Chichester Resort Hotel were giving way. These had to be widened with work continuing late into the night with the assistance of a crew from Chichester District Council.

Police record that the Lavant was starting to breach opposite Wadham Stringer's Garage along Westhampnett Road. The degree of flooding that was taking place was not stated.

At 23.00 police noted that Melbourne Road junction of Adelaide Road was being closed and the junction of Tozer Way with St Pancras was flooded to a depth of 300mm.

Friday, 7th January 1994 **Rainfall 3.8mm**

At Chichester evacuation of residents continued in the early hours from St Pancras. At the same time sandbags were being requested for the Four Chestnuts public house area to protect properties from flooding. Chichester District Council operatives were reported as fighting a losing battle with water rising through the floor boards at Heron Court and the electricity had to be switched off with evacuation of the tenants considered. In all three flats appear to have been affected. By the early afternoon Rowe's Garage were requesting sandbags to help contain flooding and the insecure gable wall at Kwikfit is first mentioned.

At Westhampnett area the westbound carriageway of the new A27 Bypass was closed by floodwater and the eastbound traffic diverted via Shopwhyke and Tangmere. By 08.00 the A27 Bypass was reported as totally flooded east of the Pits. The police log also mentioned "Green Goddesses" arriving.

The police log has reference to flooding in St Pancras, also reference to river splitting in two above the Mill, Westhampnett, could possibly be across the fields at Barnfield Way. It was mentioned that the level in St Pancras had dropped by 150mm in a few minutes in the early hours of the morning.

Saturday, 8th January 1994 **Rainfall 8.7mm**

Flooding was reported at East Dean and Charlton during the morning and East Dean Hill and Knights Hill were closed in each village respectively. During the afternoon the parish council requested a ditch to be cut at Charlton to relieve water backing up through houses near the bridge over the river. By that evening flooding was also reported in Chapel Row at East Dean.

At Singleton the flooding of the A286 was continuing and ice was forming on the road in the early morning due to the cold weather. By midday and later that afternoon the Parish Council reported that sewage was backing up in household toilets and the residents were trying to divert the Lavant themselves. Cucumber Farm was under 1.2m of water which was being retained by the farmer's earth bank. This was subsequently alleviated by the NRA who provided a pump and cut a deeper outlet channel through the bank.

The extent of flooding was also increasing at Lavant with Welldown House surrounded by water and water backing up inside the house through the toilets during the early hours of the morning. Above Lavant, Crows Hill on the Chilgrove Road, was reported as flooded to a depth of 150 to 200mm by the late afternoon. Closures were requested for Binderton Lane and Hilters Lane at Chilgrove as they were also flooding.

In Chichester the ground water, or backed up surface water, flooding at the southern end of College Road was still occurring and was giving concern that it might spread across Spitalfield Road and hinder the traffic flow. Major flooding from the Lavant was also occurring during the late afternoon and into the Hornet and the decision was taken to demolish the unstable gable lean-to wall above the channel at Kwikfit.

Around the eastern outskirts of Chichester the flood relief route was extending southwards. During the morning the floodwater overtopped the tarmac Coach Road Pit and flowed towards Shopwhyke House and Nurseries to cross the Shopwhyke Road near Littlemead School. The east bound traffic diversion from the bypass was being affected and by the end of the afternoon the flow had become so strong and the depth across this road so great that it was closed to traffic and the eastbound traffic diverted to the A259. Severe flooding was also occurring at the new Portfield Roundabout.

Sunday, 9th January 1994 **Rainfall 18.2mm**

Throughout the area flooding was advancing rapidly. During the morning flooding is reported as becoming worse at East Dean and Charlton. At East Dean cottages in Drokes Lane were being affected and the water backed up to the houses in Chapel Road due to the culvert opposite the Chapel being of inadequate capacity. By the early afternoon the rising water level was threatening the electricity substation in Charlton.

Flooding was also becoming worse at Singleton with the A286 reduced to approximately half its width near the Horse and Groom public house, with the water rising through the day to flood a private driveway on the north side of the bridge. By the evening traffic lights were provided to control one way working of vehicles along this road.

In addition to the surface flooding arising from the Lavant at the Hornet and St Pancras areas in Chichester, an increasing incidence of flooding due to rising ground water was also reported throughout the day. During the morning problems of this nature were reported at Heron Court and Blenheim Gardens on the eastern side of the City and in basements in Little London and East Row in the centre. Later that evening, 8 properties were reported as being in danger from water which was overtopping sandbags in Henry Close, again on the eastern side near the Shopwhyke Road/By-pass junction. Problems were also occurring in Parchment Street and Washington Road, where in the latter case foul drains were said to be causing flooding of a basement.

In the Lavant watercourse itself the water level was reported to be rising through the day. Problems were being experienced with foul drainage by properties in St Pancras backing onto the river. Water was observed flowing up out of holes in St Pancras Road near the junction of Tozer Way. By the late evening the sandbagged defences behind Rowe's Garage had breached and water was flowing through their yard to the Hornet.

To the east of the by-pass the secondary flood route was developing southwards and increasing in flow across Shopwhyke Road and the Drayton/Oving Road where flood warning signs had to be placed. By the end of the day the floodwater had breached the sandbagged defences on the north side of the A259 at Merston and water was flowing across the road towards Merston Common. The level of the floodwater on this secondary route was still rising at Madgewick Lane near its point of origin at that time.

Monday, 10th January 1994 **Rainfall 0.8mm**

Flows and water levels increased along both flood corridors during this day and additional instances of ground water rise were reported in Chichester.

During the very early hours the A286 opposite the Horse and Groom at Singleton was flooded to 100 to 150mm deep but was still passable to traffic with care using one way working. At East Dean the Lavant was close to breaching the sandbags at Chapel Row and additional properties were being flooded in Singleton and East Lavant.

At the Hornet the level had risen by 25mm in half an hour and by about 10.00 hours the Hornet and Needlemakers had been closed to traffic as the dam had begun to let water by in two places. Urgent requests were made for men and materials with consideration being given to releasing water down Market Avenue controlled by a sandbag wall. Eventually it was decided to reinforce the dam with skips loaded with soil and/or sandbags and plug all gaps with sandbags.

Problems continued at Cavendish Street and Washington Road with sewage backing up and flooding continued at Elizabeth Road, Heron Court and Henny Close with water at the latter 600 - 900mm deep. Flooding of a cellar was reported in South Pallant and concern expressed regarding basement seepage at the telephone exchange in Capel Street.

At Madgewick Lane, by Westhampnett Mill, the contained water was in danger of overtopping the existing sandbagged wall and additional bags were placed during the early hours to contain it. The water level was reported to have risen by 75mm in 2 hours with the depth then ranging from 100mm to 200mm at the deepest. A complaint was received regarding flooding in Dairy Lane and concern was being expressed regarding the possibility of damage to the furnaces at the Crematorium.

By mid morning, Shopwhyke Manor Farm on Coach Road was in imminent danger of flooding and the level was rising by East Lodge on the Shopwhyke Road. Flooding continued across Drayton/Oving Road and the A259 southwards to Merston Common. Properties were eventually flooded in Merston village and as a result pumping and sandbagging was undertaken by NRA. Merston Common Cottage was reported as flooded to a depth of 150mm and rising by the early afternoon and flooding north of the railway was giving considerable cause for concern regarding stability of the rail embankment.

On the west side of Chichester the A259/Appledram Lane junction was reported as flooded completely and the road closed.

Tuesday, 11th January 1994 **Rainfall 6.4mm**

The situation was still worsening in the upper catchment of the Lavant with a council house being threatened in Drokes Lane at East Dean, problems with the flooding on the A286 at Singleton and further properties, including the Village Hall, being threatened in Lavant.

In addition to the flooding already taking place in Chichester, water was reported as coming up through the pavement in Terminus Road near the course of the Lavant and threatening one industrial property (possibly St Ivel). This indicates that the capacity of the existing road culverts beneath the bypass could be limited. Flooding was also reported at South Shore Packaging but location is unclear, possibly Terminus Road or Gravel Lane off Quarry Lane. By later that morning there were further reports of overflowing of the storm drain in Terminus Road and requests for sandbags. In the early afternoon the footbridge at Green Lane to St Pancras was reported as flooded and impassable. Requests for assistance were also received from West Pallant with regard to flooding of cellars.

Throughout the day the situation at Henry Close appears to have been deteriorating and the cause appears to have been flooding from a manhole. Pumping from Henry Close was causing flooding of the A27 bypass between Oving Road traffic lights and the new Portfield Roundabout. Although this section of road was closed to traffic at the time a problem was anticipated once the Bailey Bridge had been installed at Westhampnett Roundabout and the route was put into use.

Breaches in the sandbagged wall beside the Lavant were taking place along Westhampnett Road and threatening several properties. Action was taken to rectify this. In the evening the A259 at Merston Common was closed and the Royal Engineers commenced installation of the first Bailey Bridge.

Wednesday, 12th January 1994 **Rainfall 11.5mm**

Water levels rose throughout the day at Singleton and further requests were received from property owners for assistance in stemming the flood with sandbags. By midday the A286 was only just passable and long traffic delays were building up. Finally the road was closed to all but local traffic. Two RNLI crews attended with Inshore Life Boats to assist in evacuating those members of the public who wished to leave their properties due to the problem of negotiating the flooded roads. Records indicate that 30 people were evacuated in all.

Numerous requests were also received for sandbags at Lavant to protect threatened properties in Rook Lane, Lavant Down Road, The Rectory and the Village Hall. However by the end of the day, reports indicate that the water levels were falling at East Dean with a drop of 22mm being recorded during the last three hours of the day.

Within Chichester problems were continuing at South Shore Packaging in Gravel Lane with water on both sides of the factory. It is assumed that this was due to rising ground water levels on the south side of the railway line. Flooding of a basement in Lytton Terrace was reported in the mid morning and the NRA advised that the Lavant was rising. It was estimated that the river could overtop at Rowe's Garage within two hours. However it was not until mid afternoon that water started to breach the walls at this point and flood the Hornet where water was rising but the road was still passable with care. In the mid afternoon there were also reports of the canal flooding at Hunston with the road impassable.

Pumping from Elizabeth Road was causing flooding across the Chichester Bypass into the scrap yard at Shopwhyke. Increased inflow was being experienced into the telephone exchange in Capel Street but pumping kept the level down sufficiently to avoid problems.

In the late afternoon the NRA advised that the river level at Graylingwell was 917mm, the highest level so far. However, levels in the City were lower than the previous Friday due probably to the out-of-bank flow taking place above Westhampnett Mill. In the early evening the sandbags beside the Lavant in Westhampnett Road were breached in several places and the water rose rapidly in the Westhampnett Road flowing towards St Pancras and St James's Industrial Estate. This was probably due to the constriction formed by the brick arched footbridge at Storey Road. The Westhampnett Road was closed between Church Road and St Pancras with water flowing towards St Pancras. By late that evening however the water was draining back into the Lavant and there was no threat to St James's Industrial Estate.

At Westhampnett the sandbagged wall at Madgewick Lane required attention to prevent breaching by the rising water and later that day the dam at the new Portfield Roundabout started to breach on two occasions.

At Shopwhyke the road was flooded from Littlemead School back to the junction with the bypass and on the Drayton/Oving Road the rising water was forcing single lane working. Flooding was continuing on down through Merston Common and Merston Village but thereafter was not causing any problems at the old canal culvert or the culverts under the B2166. Below this road flooding was occurring across fields but causing no disturbance to traffic or livestock. There was concern that the ponding of water north of the railway line could threaten Oving and levelling was undertaken by NRA and WSCC to investigate a possible relief flood embankment.

Reports indicate that by the end of the day water levels were dropping at East Dean with a fall of 22mm being recorded during the last 3 hours of the day.

Thursday, 13th January 1994 **Rainfall 1.5mm**

There are no reports for East Dean or Charlton for this day but in the early hours the A286 at Singleton was reported as closed and the intention appears to have been that it would remain so. However by approximately 10.00 a.m. the water level was reported as being reduced by about 60mm and attempts appear to have been made to open the road again by the late afternoon. In the final event the A286 appears to have remained closed.

At Lavant although there was concern by one occupier about his flood defences holding, there does not appear to have been any additional flooding.

Within Chichester the situation appears to have been static with regard to the flow in and flooding arising from the Lavant. However it appears that further flooding was occurring due to ground water rise within the City limits. By the early afternoon a second basement, converted to a flat, was reported to be flooded in Lytton Terrace and later that afternoon the water was reported to be deeper in New Park Road but passable with care.

NRA brought in Marine Pollution Control Unit (MPCU) pumps and began pumping from Rowes garage, discharging to the Lavant behind the Argos store. This operation doubled the existing pumping capacity.

Problems were still occurring on the periphery near the Chichester bypass with pumping continuing from Elizabeth Road and Henry Close. Pumping from both of these locations was causing problems with water on the bypass carriageway. Pumping was also continuing at South Shore Packaging in Gravel Lane across Quarry Lane into Whyke Lake. Later that evening sewage was reported under the floorboards of a property in Henry Close and the Chichester District Council Environmental Health Officer was requested to attend and advise.

On the secondary flood route water levels were building up on Tangmere Rod at Shopwhyke and the Oving Road north of the railway embankment where the impounded water was moving towards Oving village and the Oving culverts under the railway. British Rail also advised that they had applied a 20 mph speed restriction as water was passing through their embankment.

Friday, 14th January 1994 **Rainfall 0.4mm**

The reduction in water levels in the upper catchment appears to have continued as the Charlton to Singleton road was reported as open with care.

In Chichester the situation also appears to have stabilised as consideration was given to opening up Market Avenue, The Hornet and St Pancras to traffic. In fact a report that evening confirms that there was no flooding in the Hornet although pumping by the Fire Brigade and the Marine Pollution Control Unit was still continuing. Ground water flooding was still present around the eastern outskirts of Chichester with the need for pumping at Elizabeth Road being identified in the mid afternoon due partly to failure of an electricity supply to a small sewage pumping station in that area. Nearer to the centre of the City the levels appeared to be dropping to the north of the Lavant with College Lane being reported as open for traffic.

At the A259 at Merston Common the water level was reported as rising by 75mm in 1 hour in the very early hours of the morning but by about midday the water levels at Merston Village had shown a reduction of approximately 100mm and levels fell even further during the day.

A decision was made to provide an outfall from the twin culverts under the A27 to assist in lowering the Church Farm Pit water levels if necessary.

Saturday, 15th January 1994 **Rainfall 9.6mm**

In the very early hours of the morning the road from Upwaltham to East Dean, Charlton and Singleton was reported as open to local traffic with care. However by 09.00. the East Dean road was reported as closed again due to problems of wash from passing vehicles.

By the early afternoon the further rainfall was causing problems at Singleton where sandbags were being used to keep the A286 open. By mid afternoon the problems were becoming critical and consideration was being given to the removal of a culvert which was causing backing up of the water. This culvert by the Post Office was subsequently removed later that evening by local people.

Further downstream the Chilgrove road was open to northbound traffic only in the mid morning but closed again that evening as darkness made conditions dangerous. Lavant was still flooded with the area around the village hall under water and the road closed.

By midday the rainfall was also having an effect upon the water levels around East Gate in Chichester, where the surface water drains were reported to be backing up. Additional pumps were utilised by the Fire Brigade but by later that afternoon the water was still reported as rising by 75mm in 2 hours. Additional Marine Pollution Control pumps were brought into use and the water level receded slightly by late afternoon. Ground water flooding was still occurring around the eastern side of Chichester from Elizabeth Road round to Quarry Lane.

It is interesting to note that once the streets in the centre of Chichester were mainly free from water complaints started to arise during that evening regarding the noise from the Green Goddess pumps. Measures were put in hand to erect sound barriers around the pumps. At Shopwhyke traffic lights the road to Littlemead School was still flooded but described as passable to local traffic with care. There are no further entries in the log for this day southwards of this point.

Sunday, 16th January 1994 **Rainfall 1.3mm**

The logs contain no definite information on the level of flooding in the upper catchment but it has to be inferred that levels were dropping slightly as the A286 appeared to be open in part at least and problems were being caused by sight-seers vehicles parked inconsiderately. In the early morning the Chilgrove Road was still flooded from Lavant junction to the White Horse with the deepest section at Lavant, although it was passable by heavy goods vehicles.

Within Chichester the operations around the Hornet and St Pancras appeared to have reached a steady state with the pumping continuing to the lower reaches of the Lavant from the Hornet area. A new crack had appeared in the rear wall of the Kwikfit building and measures were put in hand to erect scaffolding on the following day. Complaints were now being received regarding the noise of the pumping equipment around St Pancras and the Hornet area.

High ground water levels appear to have been continuing to cause problems in College Lane as the emptying of gulleys failed to result in any reduction in the water lying on the road. Towards the Shopwhyke area of the bypass a further cellar was reported as flooded at the eastern end of Victoria

Road. Pumping was continuing from Elizabeth Road and there was flooding of CD Metals (scrap yard) on the east side of the bypass. The discharge was diverted to a ditch between Church Road and the bypass near Halfords, which had some spare capacity. Thereafter in the late evening the revised pumping arrangements appear to have resulted in a reduction of water levels in Elizabeth Road.

The secondary flood route from Westhampnett was still in operation through the Church Farm Pit and across the A27 Westhampnett Bypass carriageway through to the railway and the A259 and Merston Village. However, conditions appear to have improved slightly as no more sandbags were being placed and traffic was moving between Oving and Drayton without the use of traffic lights at the flooding. By the evening there was some concern that floodwater across the A27 Bypass was undermining an electricity pylon on the south side but this was avoided by the Army under the direction of a Southern Electricity Engineer, placing sandbags to divert the flow.

By late that evening there were reports that black ice was forming at all areas of flooding on highways.

Monday, 17th January 1994 **Rainfall 0.0mm**

Flooding was still present throughout the upper catchment with the pond area and shops still inundated at East Dean and the condition at Singleton unchanged. At Lavant complaints were being received from residents in Pook Lane. NRA placed sandbags around these properties but were unable to get the river back within its banks and little could be done to alleviate their problems. In the early morning the B2141 Chilgrove Road was described as having a lot of surface water with a depth of 200 - 300mm at Crow Hall Farm.

In Chichester early reports suggested that the problems in Elizabeth Road were much improved with only a minor problem remaining with sewage. Small amounts of water were reported in College Lane but New Park Road was described as still deep but passable to local traffic. Velyn Avenue which leads southwards from the Hornet at "Covers" towards the Roman amphitheatre, although not mentioned previously in flooding was now reported as clear. Flooding was also notified at the SEB substation at Bognor Bridge but was described as 'not urgent'. This was presumably due to local surface water flooding or high ground water levels.

Demolition of the rear wall of Kwikfit was noted as likely to commence at 18.00 and would take two to three days.

In the very early hours of the morning the A27 Westhampnett Bypass was described as open to heavy goods vehicles only with the water levels remaining constant until about the mid afternoon. However, by late afternoon the west bound carriageway was reported as beginning to dry out to a width of 1½ metres with further improvement likely overnight. No reports are included in the logs for locations south of the A27 Westhampnett Bypass but it has to be assumed that conditions were improving slightly.

Tuesday, 18th January 1994 **Rainfall 4.3mm**

There are no reports regarding flood conditions in the upper catchment for this day but from the falling water levels recorded at Graylingwell gauging station there must have been a general improvement in the flood conditions.

There do not appear to have been any marked changes in Chichester and by late evening residents were requesting action to remove water from Elizabeth Road again.

On the secondary flood route from Westhampnett the conditions appeared to be improving with Madgwick Lane described, in the early morning, as being only half flooded but with the sandbagged wall in place and the road still closed. At the same time the Westhampnett Bypass was described as clear on the west bound lanes and clearing on the east bound lane.

At Shopwhyke the Tangmere Road near Littlemeads School showed a marked improvement from "quite deep", in the early morning to "approximately 50mm deep" by late afternoon. WSCC were excavating to lay a pipe from the manhole into which the twin culverts under the A27 connect, to discharge into the Tarmac pit.

Wednesday, 19th January 1994 **Rainfall 0.4mm**

In the early morning an update report shows the conditions improved over the upper catchment with the Upwaltham to East Dean road described as 'passable', the East Dean to Charlton road as 'not passable' and the Charlton to Singleton road as 'passable with care'. Traffic was using the A286 at Singleton but traffic lights were still required for one way working. The depth of water on the B2141 had reduced to approximately 50mm but it remained closed as 2 miles of road were still covered.

Pumping continued from the Lavant within Chichester and there was a further report of ground water flooding the lift shaft of the Royal Bank of Scotland. However, pumping at Elizabeth Road appears to have been reduced to one Southern Water Services pump dealing with sewage. The pumping in Henry Close appears to have ceased.

At Westhampnett the bypass was in operation for east and west bound traffic in single lane on each carriageway. However, sandbags were having to be placed to combat wind driven water flow across the carriageway. There are no significant flooding reports in the logs for the area south of the bypass.

There was still a large area of floodwater impounded north of the railway embankment but south the flows were much reduced with the Rife generally back within its banks, although there was still much ponded water in the fields.

At the A259 Bailey Bridge all flow was going through the available culverts under the road. Through Merston Village there was only a very small out-of-bank flow around the culverted access to Manor Farm. Otherwise, all flow was within bank to the seawall at Pagham, apart from a localised area of flooding around a small footbridge downstream of the B2166.

Thursday, 20th January 1994 **Rainfall 0.0mm**

The NRA records show the flow in the Lavant reduced to approximately 4.3m³/s at Graylingwell. Although some flooding still existed in the upper catchment, particularly at Lavant, Madgwick Lane was reported as dry with the river bank within its course. Madgewick Lane appears to have remained closed for this day, however.

Ready Mix Concrete (South Coast), expressed their concern about the lack of pumping from Church Farm Pit as they were still unable to gain entry to the site via Rutland Way. With the flow in the Lavant still approximately equal to the capacity of the culvert through Chichester there was no possibility of pumping from the Pit to the River Lavant.

Friday, 21st January 1994 **Rainfall 0.0mm**

The A27 Westhampnett Bypass was reported as being in operation with a single lane on each carriageway. The Chichester By-pass just north of Shopwhyke traffic lights had a thin covering of water approximately 6mm deep which was not a problem. All pumping from the Lavant was stopped at 10.30am and by shortly after 12 noon there had only been a 25mm rise at the Hornet with no indication of significant rises elsewhere. The pumps apparently remained off from this time, but were available for action.

The WSCC Drayton Depot stood down its control room at 17.00 hrs and the NRA ended their involvement at the Emergency Control Centre from 14.00 hrs.

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