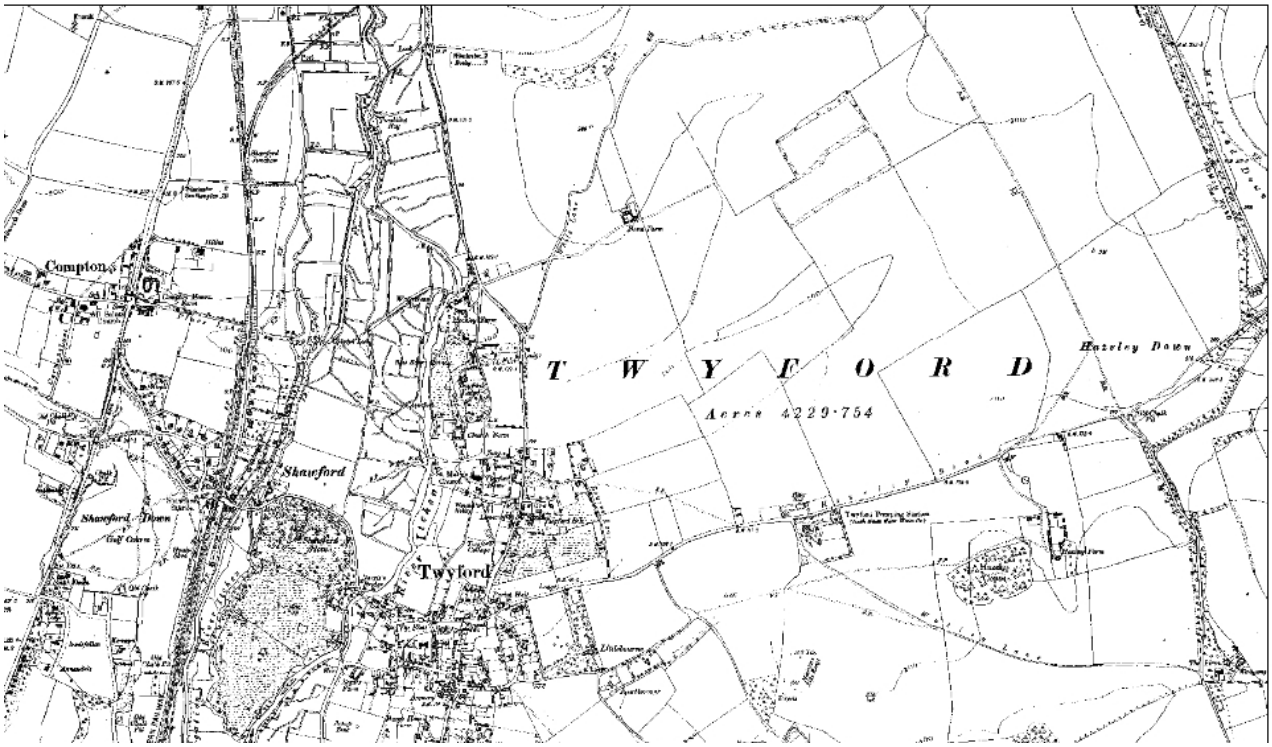
Twyford – Flood and Coastal Defence Investigation Report

July 2017



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The Purpose of this report is to provide information on the current risk of flooding and to suggest options that may be used to mitigate flood risk at this location based on the current evidence.

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-	Draft Internal Review	TJF 12/07/17	VW 12/07/2017	CM 14/07/2017
	Final	-	CM 14/07/2017	FM 18/07/2017

Executive Summary

The location, geology and development of the village of Twyford create the conditions that make it vulnerable to flooding. Historically there have been a number of flood events, most notably the flooding during the winter 2000 – 2001 and winter 2014. These two flood events can be linked to the occurrence of a heavy and prolonged period of rainfall resulting in the emergence of springs to the north of the village due to high groundwater in the area.

In order to understand the flooding mechanisms, the anecdotal records have been compared to the topography of the catchment, taking into consideration the geology and rainfall data, and through this a number of options to reduce the risk and impact of future flood events have been suggested.

Three engineering options of varying effectiveness and cost have been identified as well as a range of smaller measures which could be implemented by individuals.

Two of the engineering options have the potential to mitigate against the 2013/14 flood event and these consist of:

a) Improving the existing drainage infrastructure in key locations, namely a new interception ditch within the car park to the rear of the Parish Hall, increased capacity along Hazeley Road to the east of the car park and reinstating the ditches along Hazeley Road to the west of the car park.
b) Providing a new flow route within the car park in the form of a slot drain (or similar), reinstating the historic ditch line at the rear of Sparkford and increasing capacity within the culvert to connect at the Hazeley Road / High Street junction.

A third option consisting of holding back water within the fields is not considered to provide the benefits of the above two options due to the overall volume of water.

The cost of option a) is considered to be in the order of £500,000 with option b) in the order of £300,000. Given the benefits that can be claimed to obtain funding, it is not felt that National funding would be available for this level of work and other funding options would need to be considered if these are to be taken forward. As the Lead Local Flood Authority we would continue to try and work with residents to explore alternatives.

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1. Background

Twyford is a village located ca. 5 km southeast of the City of Winchester of ca. 1500 residents. The village lies on the River Itchen and the name Twyford, or Twifyrd in Old English means “two fords” both of which cross the River Itchen. The village has a number of small amenities including schools, doctor’s surgery, two pubs and a number of other small businesses. Also within the village is the Twyford pumping station, which extracts approximately 25 mega litres per annum. The village lies on a chalk strata at the northern edge of the Hampshire Basin with areas of alluvium and polymict deposits.

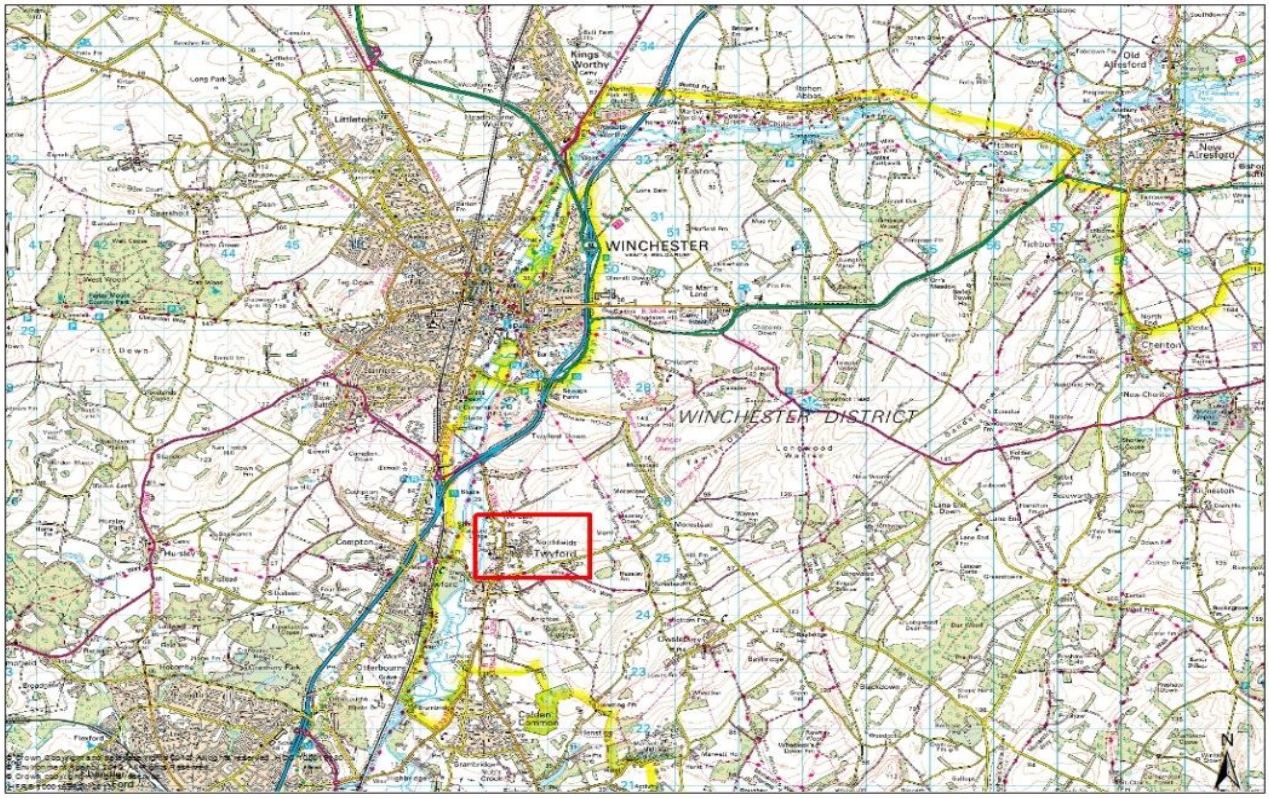


Figure 1: **Twyford Location Plan**

Due to its topography, geology, proximity to the River Itchen (Main River) and other ordinary watercourses in the area, Twyford has a history of flooding with areas of water meadows and areas susceptible to surface flooding. Road names around the village indicate the presence of water, such as Bourne Lane, Waterhouse Close and Bourne Fields.

The purpose of this report is to:

- Understand the current information available and to formalise this within a single report
- Clarify the food risk of the area

- Understand what smaller scale works have been undertaken within the area
- To provide an overview of the flooding mechanism and the impacts of any flooding
- Identify potential options that could reduce, or better manage, flood risk within the area
- Undertake a high level cost/benefit analysis so that decisions on any potential project can be taken by the Flood Programme Board
- Communicate these outcomes to the local community having reviewed the most up to date information.

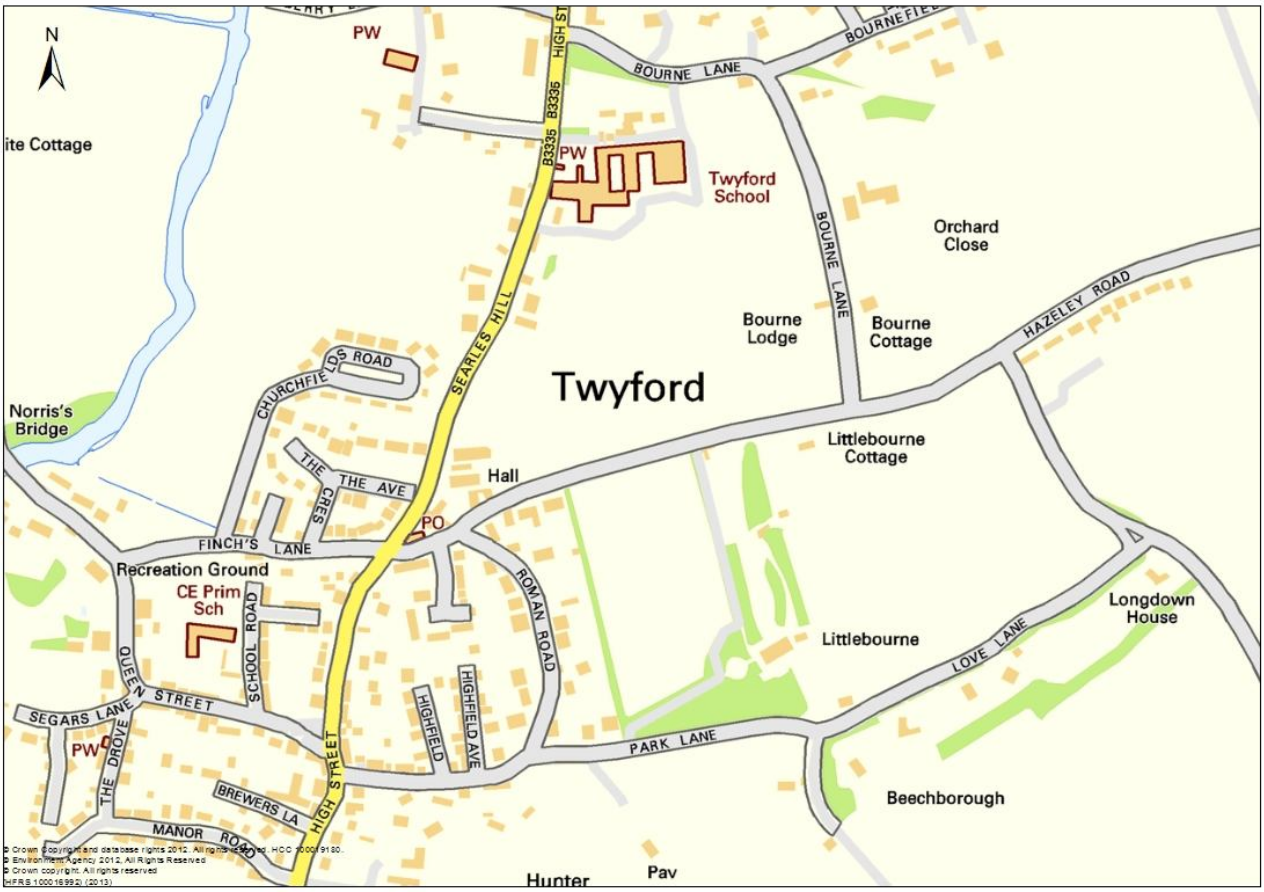


Figure 2: **local map of Twyford with road names**

2. Desk Study

2.1. Lead Local Flood Authority, Hampshire County Council

As the Lead Local Flood Authority role commenced in 2010, no investigations to date have been completed in Twyford by the Authority prior to that role being established.

2.2. Highways Authority, Hampshire County Council

Hampshire County Council as the Highways Authority is responsible for the maintenance of all adopted roads and their associated drainage. The Authority also has powers that enable it to undertake flood prevention works on ordinary watercourses. It should be noted that the majority of roadside ditches are the responsibility of the riparian landowner rather than the Highways Authority.

The Highway Authority have reported no recent flooding issues in Twyford. The only works that they were aware of was that jetting had taken place in The Drove and Queen Street which appears to have resolved the drainage issue there.

There are five historical records of flooding by Hampshire Highways:

- Hazeley Road in 2001, groundwater flooding as a result of a high water table. Ref. 2084
- Finch's Lane in 2011-2015, pluvial flooding, works undertaken to solve problem by installing new culvert and new gullies. Ref. 5015
- Hazeley Road in 2014, flooding of road leading to road closure. Ref. 21072753
- Morestead Road, 2014, blocked culvert causing puddle on the road, pipe jetted and problem solved. Ref. 14006391
- Hazeley Road, 2016, Water coming up from road, however on inspection no defect was found. Ref. 21227022

Some reports have been found that refer to works undertaken after the 2000/2001 flood event. To summarise, in Finch's lane, part of the drains were reconstructed and/or upgraded to ensure consistency in size and profile. The drains in Finch's Lane are thought to be of a size equivalent to at least a pipe of 750mm in diameter. In Hazeley Road, a second drain was installed to supplement the existing culvert between the old fire station and the culvert that crosses the high street.

2.3. Environment Agency

The Environment Agency is responsible for managing Main Rivers and the associated flood risk. They also provide mapping which illustrates the potential flood risk from main rivers and surface water.

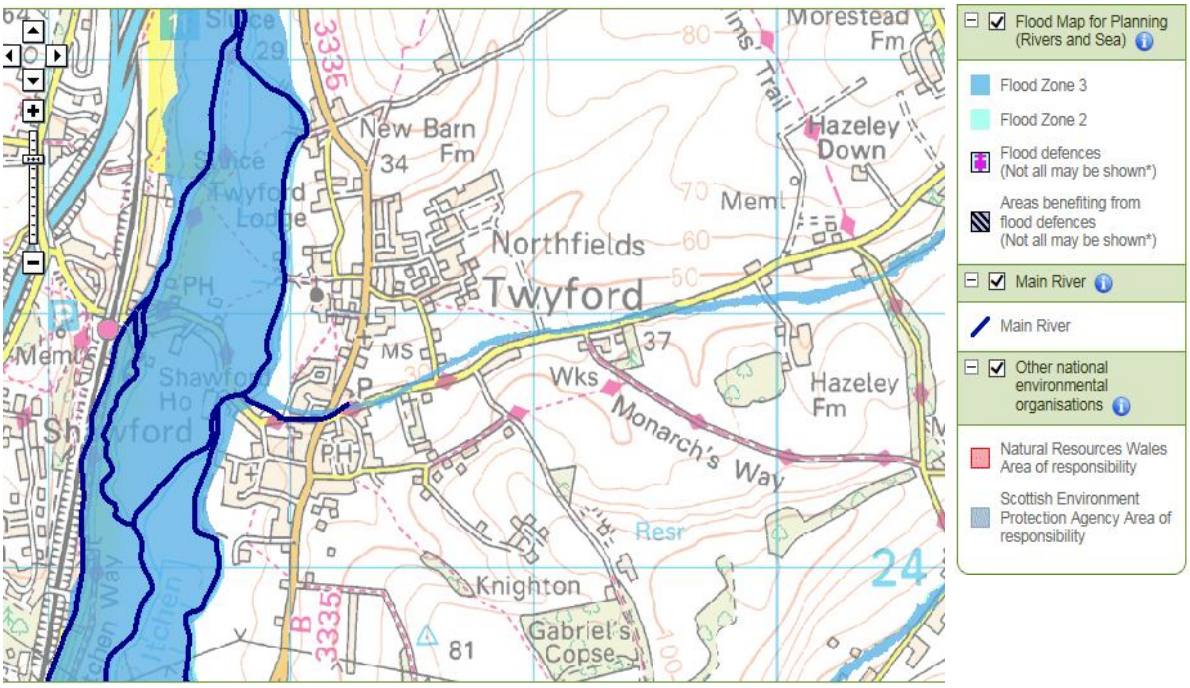


***Figure3*: The areas of Twyford within Flood Zone 2 & Flood Zone 3**. Additionally, the water course designated as Main River is shown.
Contains Environment Agency information © Environment Agency and database right

On studying the Environment Agency flood maps (Environment Agency, 2016) there is a large area to the west of Twyford that is within Flood Zone 2 and Flood Zone 3. The majority of this land is agricultural or open land. However there are some properties within these zones, additionally the flood zones extend to the east, roughly following the route of Hazeley Road.

The Flood Map for surface water (also produced by the EA) is a modelled extent of the potential for surface water flooding. As shown in Figure 4 this indicates that the there is potentially a flood flow route from the north running down Searles Hill and from the east along Hazeley road.

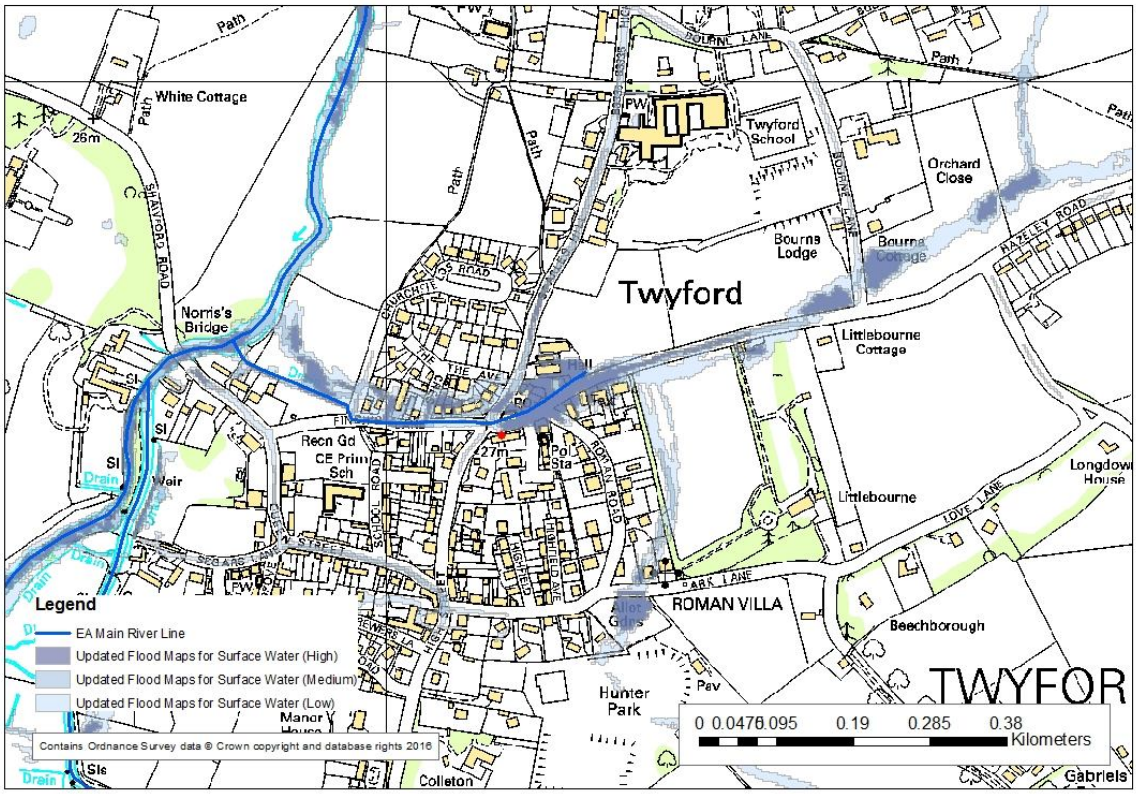


***Figure 4*: Flood Map for Surface water**

2.4. Winchester City Council

Winchester City Council is a risk management authority and have a number of powers related to flood risk management works on ordinary watercourses, they are also the planning authority. They have no written records of the flood events in Twyford however provided the following comments as a result of local knowledge from the event in 2014:

- Jetting main surface water sewer by HCC
- Some River Bank works by EA
- Ditch clearance along Hazeley Road HCC / EA were leasing with adjacent landowners.
- The Parish Council to look at resilience of Village Hall

2.5. Parish Council

The Parish Council (PC) has a great deal of local knowledge on the previous flooding events. The PC has kindly provided a diary of events from the 2014 flood. They have reported that 19 residential properties were impacted by flooding

(internal, cellar, and external flooding), 15 properties lost the use of the sewer system, and 2 further properties (Parish Hall and Post Office) experienced internal flooding. A summary of this information is produced below.

Location	Nature of Flooding/ Incident	Date/ Duration	Notes
South end of Hazeley Road	Cellars begin to show water	12/01/2014	Springs in Watson's Field and on Finches Lane beginning to surface
St Marys Terrace area	Properties beginning to pump water from cellars	22/01/2014	
	Toilets begin to fail	5/02/2014	
Parish Hall, Bourne Lane, School fields	Water entering the Parish Hall. Water flowing across Bourne Lane and the school fields	7/02/2014	
Hazeley Road, Finches Lane	Parish hall car park flooding, houses beginning to pump water from gardens. Toilets unusable in Hazeley Road	8/02/2014	
St Mary's Terrace, Hazeley Road	Sewage appearing in garden. Water surcharging out of sewers in Hazeley Road	9/02/2014	Hazeley Road Closed
		13/02/2014	Flow from the bourne beginning to slow
		19/02/2014	Hazeley Road opened as far as Bourne Lane
		21/02/2014	Sewers Begin to work after being pumped from manhole
Hazeley Road	Sewage discharging from manhole in Village Hall Car Park	27/02/2014	
Watson's Field	Spring continues to flow	27/03/2014 (situation on-going)	

2.6. Environment Agency Winter 2000-2001 Flooding in Twyford report August 2002

After the flood event in winter 2000/2001 the Environment Agency commissioned Halcrow Group Limited to produce a report looking into the mechanisms of the flooding and assess any possible mitigation works that were feasible. The report summarised that there was a total of 15 properties that were affected by flooding during this event. 5 properties were internally flooded, 3 were affected by cellar/ under floor flooding, 9 properties were affected by wastewater drainage problems, and 2 were affected by external sewage flooding.

The report concluded that the cause of the flooding was due to 2000/01 being the wettest year on record (at the time the report was produced) combined with the groundwater levels reaching their highest recorded values (at the time the report was produced) resulting in the emergence of new springs and surcharging of sewers and cesspits. In addition, several culverts were damaged and blocked by debris and therefore unable to manage the quantity of run-off flow (these have subsequently been repaired and cleared by HCC).

The report included a list of properties affected, extract below.

Location	Nature of Flooding	Dates/ Duration
Properties on Hazeley Road	Under floor boards and external flooding with high groundwater levels	5 & 6 /12/2000, 3/2001
	Internal (conservatory, back hallway and under floorboards). In the void between the underside of the floorboards and the surface of the ground under the house the water reached a depth of 14 inches. The origin of the water appears to have been the spring in Hazeley Field	15/12/2000
	External flooding and groundwater rose to within 3 inches of the underside of the dining room floor boards at the rear of the house	17/12/2000
Properties on High Street	Internal (sitting room, dining room, kitchen, bathroom and hallway) and external flooding (garden) and sewage problem and high ground water	15-16/12/2000
	Internal and external flooding (garden) and sewage problem and high groundwater	No data

Finch's Lane	Sewage disposal was affected	14-21/12/2000
	Internal and external flooding and sewage was affected and high ground water	17/12/2000
	External flooding from surface flow and sewage system was affected	12/12/2000
	External flooding and sewage system was affected	12/12/2000
	External flooding and sewage system was affected	16/12/2000
	External flooding and sewage system was affected	14-20/12/2000
St Mary's Terrace	Internal (1/2 Inch) and external flooding and sewage system was affected	Dec/2000
	External and sewage flooding in the garden and groundwater reached to within 3 inches of the underside of floor joists	23/12/2000
	External and sewage flooding to depth of one inch in the garden and groundwater reached to within 3 inches of underside of floorboards	23/12/2000
	Cellar flooded and formation of lake behind the house	12/12/2000

3. Site Visit

On the 20th January 2017 a site visit was undertaken by Hampshire County Council alongside members of the Parish Council to understand the problems on the ground.

An initial review of the existing desktop information was undertaken. Figures 6 and 7 are provided for information in relation to existing drainage assets and the general topography of the surrounding areas.

The main findings of the site visit and the initial desktop investigation are listed below and Figure 5 refers. :

1. The flood water originates from the fields to the north of Hazeley Road and collects in the fields to the east of Bourne Lane. It is clear from figure 5 that the topography results in water falling from the north and south towards Hazeley Road.
2. Water then flows across Bourne Lane and onto the school fields.

3. To the south of the school fields and adjacent to Hazeley Road, there is a watercourse that runs east to west. This watercourse would benefit from maintenance.
4. The watercourse runs to the edge of the playing fields where it becomes a 450 mm culvert continuing on the same route. It is likely that this used to be an open ditch for the whole length.
5. Parallel to this culvert a second culvert was installed to take water from the other side of the road, figure 5 and 6 refer.
6. There is a link between these two culverts outside the Old Fire Station.
7. These two culverts connect outside the village shop at the crossroads and become a single large brick culvert that passes under the crossroads and under Finch's Lane.
8. This point in the road is where the majority of the flooding occurs then this backs up and floods the car park to the rear of the Parish Hall. The surface water flood maps in figure 4 clearly correlate with this and show an area susceptible to surface water flooding.
9. There are three non-return valves that join this culvert from the properties on Finch's Lane
10. At the junction between Finch's Lane and The Crescent the culvert downsizes to a 750mm culvert which then opens into a ditch in the field to the west of Churchfields Road.

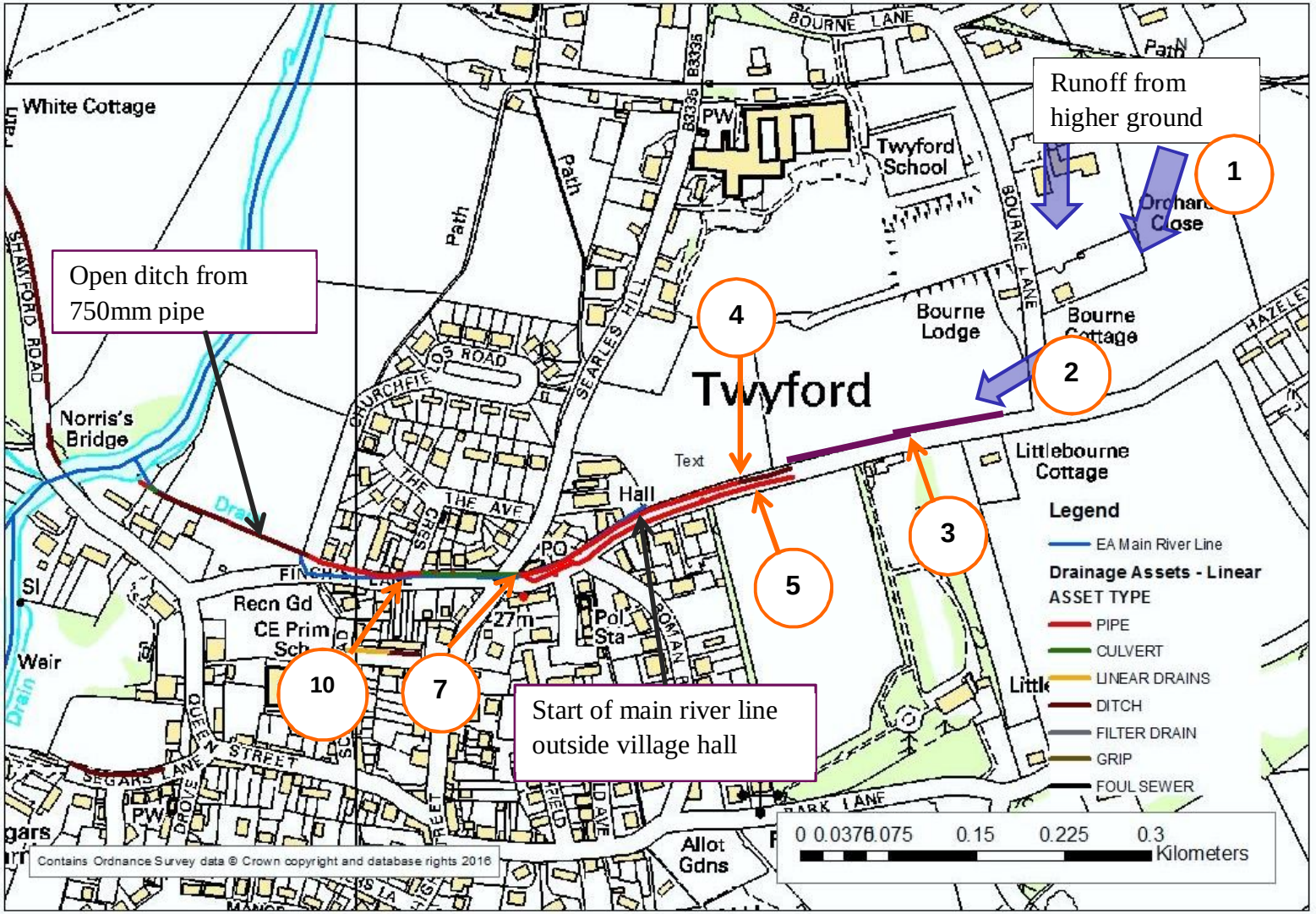


Figure 5: **Map of information collected during site visit**

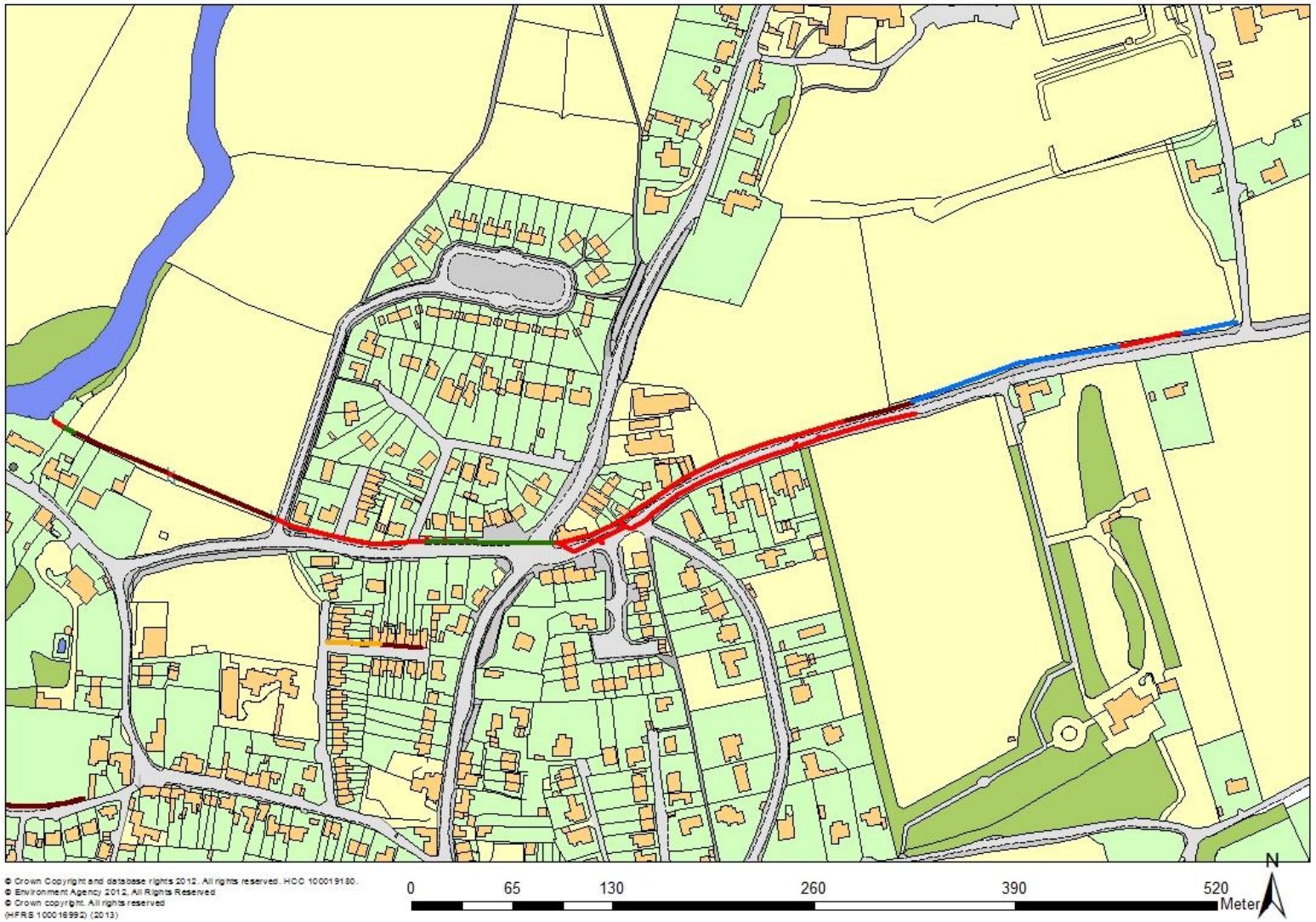


Figure 6: **Map of Twyford showing locations of culverts (red and green) and open watercourses (blue and brown)**

***Figure 7*: Isometric map of Twyford overlain with surface water flood layer.**

4. Assessment of Flood Risk

Hampshire County Council's Engineering Consultancy was tasked with reviewing the flood mechanisms and extents. In addition analysing options to reduce the impact of future flooding from the winterbourne. This work included an assessment of topography and drainage infrastructure in the road and field areas to the west and east of the junction of the High Street and Finch's Lane/Hazeley Road in Twyford. From this assessment, options were put forward to reduce the impact of future flooding from the winterbourne.

4.1. Flooding Mechanisms

As has been highlighted in section 2, previous flooding incidents have been well documented allowing for the flood mechanisms to be relatively well understood.

During periods of very heavy, prolonged period of rainfall, springs emerge from the fields to the east of Hazeley Road due to high groundwater. Rainfall records between 1935 and 2017 indicate that overland flows occurred in 1960/61, 2000/01, and 2013/14. These overland flows (i.e. a winterbourne) head west down the valley which roughly follows along Hazeley Road, ponding on first one side and then the other side of Hazeley Road as it flows towards the River Itchen. Upon reaching the old fire station, the carriageway rises in level which effectively forms a bund at the High Street / Hazeley Road junction leading to overland flows being impeded and flooding of the properties and sewers to the east.

On the east side of the High Street, there are two storm water drains and a sewer running from east to west along Hazeley Road. The storm water drains connect upstream of the Post Office and pass beneath the High Street. On the west side of High Street, a large diameter storm water drain runs within Finch's Lane from the Post Office towards the River.

The desktop analyses have shown that the springs flow along a slightly different route than the drains to the east of the High Street. This explains why, in times of winterbournes, the overland flow has to be physically redirected towards it regardless of the capacity of the drainage. Even in this short distance, localised flooding caused considerable local damage to buildings and infrastructure.

4.2. Analysis of information

Analysis of the catchment size suggests that over one thousand hectares of land area drains to this particular point at Hazeley Road, and ultimately to a 750mm diameter pipe at the end of Finch's Lane.

Examination of rainfall records consistently suggest a fairly accurate trigger level of when the winterbourne is likely to emerge (and retreat). In examining time series rainfall data dating back to the 1930's, two of the three occurrences of the winterbourne were in the last fifteen years following heavy, cumulative, prolonged periods of rainfall in the winter. In both cases, the rainfall for the three month period preceding the winterbourne, the cumulative rainfall depth was around 400mm, and crucially, **remained above this threshold for an extended period of time** (more than a week).

In analysing the rainfall with respect to time and the area of the catchment, the data suggest that the ground can cope with a series of rainfall events which keep the ground water flow below a fixed threshold[1]. Once above this threshold, the winterbourne becomes an over ground spring or 'issue'.

Subject to further analyses and engineering, evidence from 2013/2014 suggests that the pipework west of the post office has sufficient capacity to convey a similar sized winterbourne. East of the post office, however, the pipes are a mixture of smaller pipes and ditches which join together in a piecemeal manner. Thus, if the capacity of the drains east of the high street matched the drains west of the high street, the likelihood of flooding from a similar cumulative storm event would be significantly diminished.

This assessment also found that the receptors of the drains east of the post office do not necessarily intercept the path of the overland flow of the winterbourne. The site survey suggests that the reason for this mismatch is due to ditches being filled in, piped or blocked.

The assessment of groundwater flooding is incredibly complex but, by using the historic flood events as a baseline, it has been possible to calculate the approximate volume and flow rate in addition to the overland flow routing described above. The result of this analysis has identified the key points below:

[1] This threshold is based on the rainfall of the 2010 winter season which, although high, did not result in a winterbourne.

- an assessment of the lie of the land in relation to the existing drainage network suggests that there is a mismatch in elevation and location between
    1. the path that the winterbourne naturally follows,
    2. the ditch and pipe network east of the High Street, and
    3. the underground drain to the west of the High Street, which is meant to convey the winterbourne
- the drainage network to the east of the High Street has a variety of pipe sizes and ditches (some of which may have been piped for short lengths) which act as throttles causing localised flooding
- The drainage network west of the High Street is felt to be of a sufficient size to convey the overland flows and flood flows recorded in 2013/14 without causing flooding to properties and key infrastructure.

It should be noted that these are high level assessments and have been undertaken at a fairly basic level of detail. Further engineering analyses and modelling would be required to accurately determine the relationships more precisely.

4.3. Potential Engineering Options

Given the findings above, the following 'hard' engineering options have been identified and are illustrated on the drawings within Appendix C. The options are outlined below:

a) New ditches and maintenance of existing infrastructure

This option would require an interception ditch adjacent to the surgery car park to collect flows from the fields and direct them into the drainage within Hazeley Road. The ditch would need to be approximately 1.8m width and 0.7m depth and a new chamber would be required to connect into the existing drainage. In addition, there is a missing section of ditch to the east of the carpark, which is thought to be piped. The capacity of this element would need to be increase, ideally as an open ditch to ensure any overland flow is captured into the existing drainage system.

There are other sections of the ditch network which was noted to be below standard or missing and although these are not as critical hydraulically, they should be maintained and / or re-established

There are also two sections of pipework where the capacity felt to be undersized namely between the car park and the post office. Additional assessment work would be required to confirm the level of work required at this location.

A plan detailing this option is within Appendix C as drawing number EC/RJ521008/OP1

This option is believed to be effective in managing the volume and flow of water as experienced in 2013/2014.

There are 4 key risks associated with this option.

- Implementation is reliant on third party land and although there are powers to enable these works to be done, future maintenance commitments would need to be secured.
- There are ecological issues as the re-establishment of ditch lines and the new section of ditch would impact on the well established hedges. Ecological assessments would need to be undertaken as well as potentially requiring a hedgerow removal licence.
- Utilities may require diverting in order to reinstate previous ditch lines or connect into the existing drainage network.
- Although some of these works are adjacent to the highway, this would not be considered as highway improvements and as such, funding would have to be found from elsewhere.

The cost of option a) is estimated as £500,000. If additional assessments show that the culverts within Hazeley Road are adequate then the costs would be substantially reduced.

b) Creation of a new flow route

To prevent flooding between the Post Office/High Street and the field to the east of the pharmacy car park, it would be feasible to establish an alternative flow route. The land elevation identifies a potential route which flows through the pharmacy car park. The proposed option is as follows:

Establish a flow route to divert severe / extreme winterbourne flows to the north of the Sparkford building via gravity through the car park and along what may have been a previously existing but unmaintained ditch to the west just to the south of the parish hall. This would be most effective as an open ditch but, due to the usage of the car park, this is not practical and a shallow culvert system, such as a large heavy duty slot drain is likely to be more appropriate in this location. On reaching the High Street, there is an option to either form a new culvert crossing of the High Street, which will be cost prohibitive, or divert the flows into the surface water sewer running

south to the Hazeley Road junction prior to linking with the primary surface water sewer.

There are a number of potential issues with this route and additional assessment would be required to confirm the capacity and condition of these existing systems.

A plan detailing this option is within Appendix C as drawing number EC/RJ521008/OP2There are 3 key risks associated with this option. Implementation is reliant on third party land and although there are powers to enable these works to be done, future maintenance commitments would need to be secured. Utilities may require diverting in order to reinstate previous ditch lines or connect into the existing drainage network. If the surface water sewer the runs along the High Street requires upgrading, there would be significant additional costs associated with this. The cost of option b) is estimated as £300,000 providing that the works to upgrade the pipe adjacent to the High Street do not require substantial traffic management.

c) Creation of upstream storage

It may be possible to provide a level of containment of the winterbourne within the upstream fields until such time as it can drain away into the ground or into the existing drainage network. Areas that appear to have potential for storage based on topography have been identified on drawing number EC/RJ521008/OP3 in Appendix C but these are indicative only.

This choice would require significant analysis to properly assess the groundwater emergence patterns and total volume required. Due to the duration of groundwater flooding this is unlikely to be an effective option and it is not felt that this route should be considered further at this stage.

It is recommended that further engineering analysis is undertaken to investigate the effectiveness, costs and risks of options a) and b) in more detail.

The additional work would include:

- Capacity and condition checks (including CCTV) of the existing drainage network
- Utility searches and trial holes to determine the level of risk of utility diversions
- Ecological assessment to ensure there is no detriment to the environment
- Engineering design to confirm the full extent of works based on the condition and capacity of the existing network

4.4. Non engineering options

In addition to the engineering options identified, other measures could be put in place which would assist in managing the risk of flooding.

- **Flood gate**

By providing a flood gate at the footway at Lowlands, it may be possible to prevent flooding to the group of properties immediately east of the high street and north of Hazeley Road. However, this may impact on property access and will require additional assessment.

- **Flood Barriers**

Individual properties may wish to consider flood gates / air brick covers which are installed on the property to prevent water ingress. This would not stop groundwater rising within properties but would help prevent 'bow waves' causing secondary flooding.

- **Sumps / Pumps**

Where properties suffer from groundwater ingress or traditional flood doors are not feasible, it may be suitable to install sump pumps which allow for water to be pumped from key locations before properties are actually flooded.

- **Flood Action Plan**

Twyford Parish already have an existing flood action plan which has recently been updated. The continued updating of this document allows the Parish to remain informed of potential flooding and mitigation options that can be progressed.

4.5. Funding Potential

Costs for capital flood mitigation schemes tend to be relatively high and as such, external funding is usually required to implement schemes.

The most common source of funding is via the Flood Defence Grant in Aid (FDGiA) funding source which is provided by Central Government and managed by the Environment Agency. To access this funding, an analysis of the costs and benefits must be undertaken to demonstrate that there is value in undertaking works based on national criteria. There are different criteria used to assess the value (or benefits) of a scheme; For Twyford these include 'Outcome Measure 2' – flooding to properties and 'Outcome Measure 1' – any other costs. The cost benefit ratio is then assessed against all other schemes put forward nationally with funding going to

those giving the greatest benefits vs cost. The cost benefit score is difficult to determine at this stage as it cannot be confirmed to what level properties, businesses and infrastructure can be protected.

The better the standard of protection, the more benefit can be claimed. The highest level of benefit is directly related to internal residential property flooding (this does not include garages or outbuildings) and in Twyford, only 5 properties are recorded as having met this criterion. On the 5 properties identified as being flooded internally, there is a maximum of £30,000 available from this funding source. There may be potential to increase this by undertaking a more detailed economic assessment however the costs of undertaking this level of assessment may well exceed the funding availability.

5. Conclusions and Next Steps

Previous information, site visit details and local accounts have been collated within this report in order to provide an assessment of the current flooding mechanisms operating in Twyford. These have been used to identify if there are any potential options to mitigate flood risk. Whilst engineered options have been identified, the estimated level of costs and potential benefits are likely to be such that this would preclude the ability to secure funding from the national capital funding mechanisms.

This does not remove the potential to use other measures to reduce flood risk; improve the current drainage systems or investigate other funding sources to develop a scheme in this location.

Next Step	Description	Lead	Timescale
Continue to develop and implement a flood action plan for the village	Understanding that there will be flood events that cannot be mitigated.	Twyford PC support from Winchester DC/HCC	Short term
Maintenance of existing surface water drainage system	To review the areas of the existing system that require maintenance and to encourage riparian owners to undertake this work	HCC/EA – with support from the Parish Council	Short to medium term
Property owners may wish to review the need for Property Level Resilience at individual properties	Residents take their own action to provide individual property level protection	Twyford Parish Council to liaise with residents	Short to medium term
Identify potential funding streams for a mitigation scheme	Identify other available funding mechanisms to enable the development of a future scheme	Twyford PC/HCC/EA	Medium to long term

Appendix A- Photographs of the area

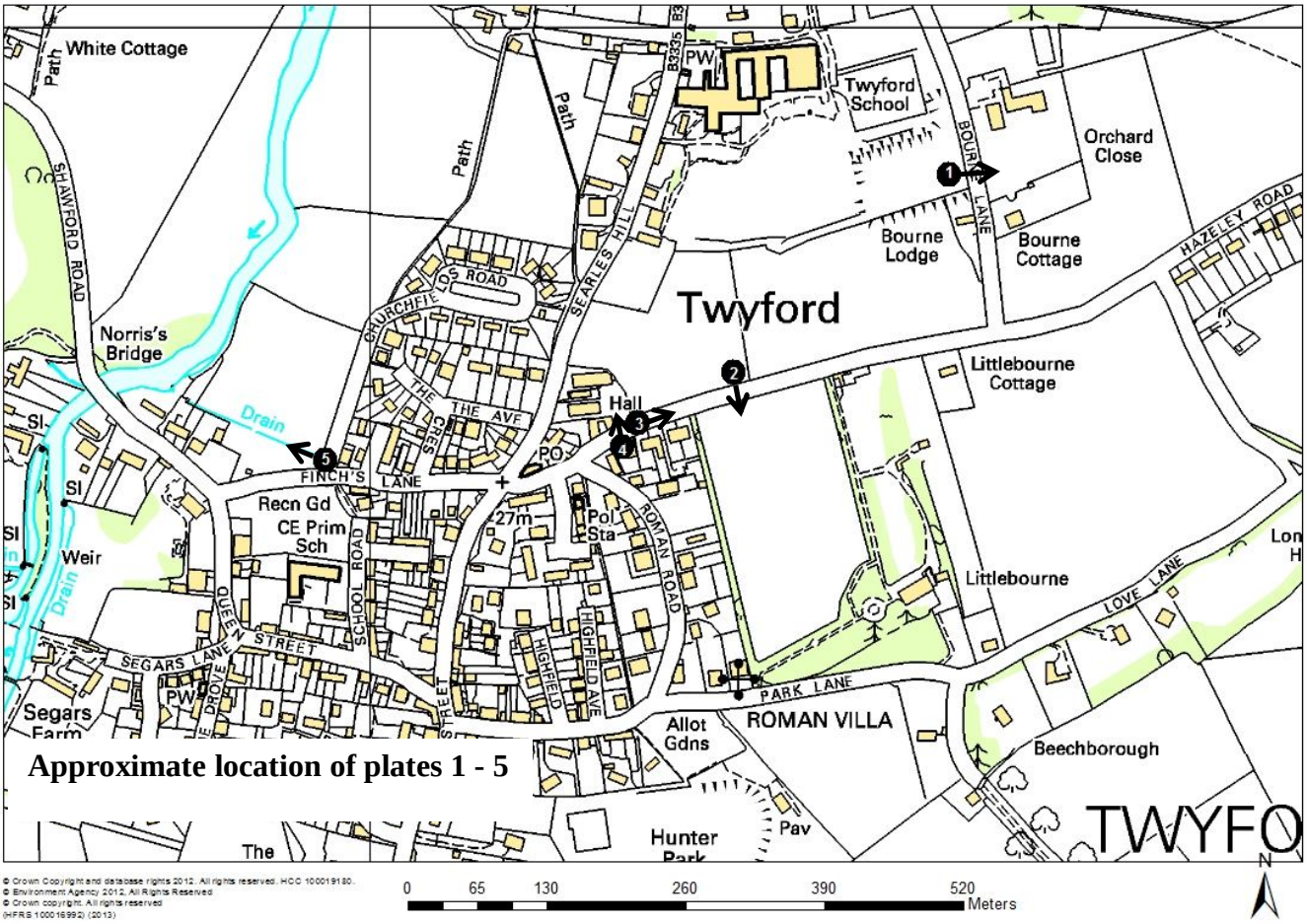


Plate 1
Ponding in field to the east of Bourne Lane

Plate 2
Water flows from Littlebourne Field onto Hazeley Road

Plate 3
Flooding of Hazeley Road and pumps from properties discharging onto the highway

Plate 4
Flooded area of Parish Hall / Surgery car park

Plate 5
Flooded fields to the north of Finch's Lane

Appendix B Technical Study information

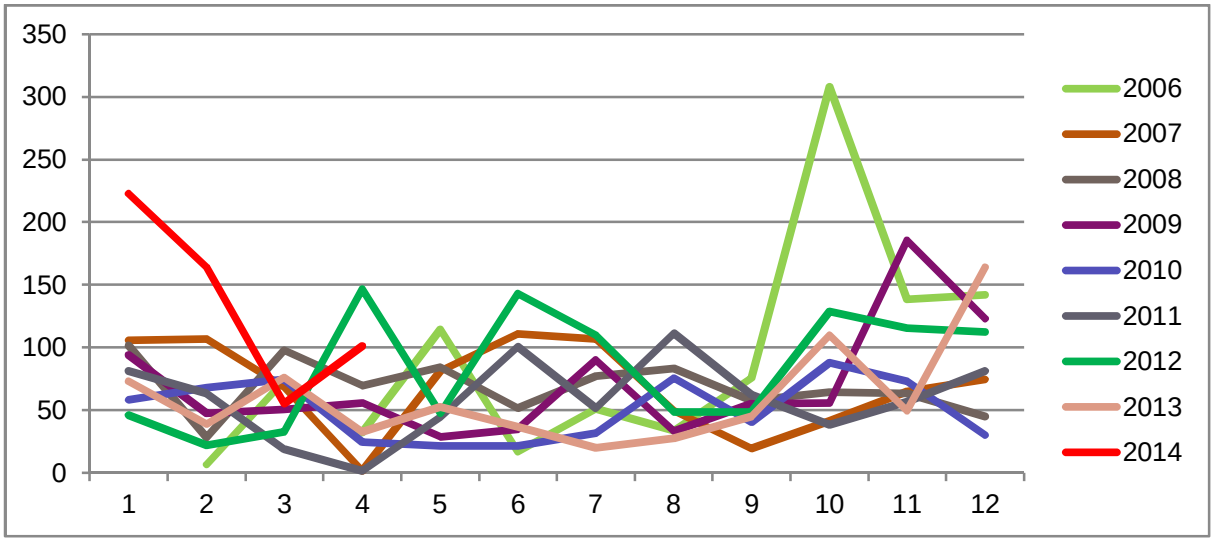
In order to estimate the size of the catchment, Engineering Consultancy worked in partnership with Hampshire County Council's Research and Information Team to extract the relevant area of the Environmental Agency's Digital Surface Model product from the UK's data.gov website. Once extracted, the data was loaded into GIS and contour data produced. These contours were exported to Civil 3D and a virtual surface of the land's topography was created and analysed.

The contour data suggest that the size of the area directly feeding surface water and winterbourne run off is approximately **1150 hectares**. The high point is estimated to be near the A272 and is bounded by Chilcombe in the north and south Morestead on the south.

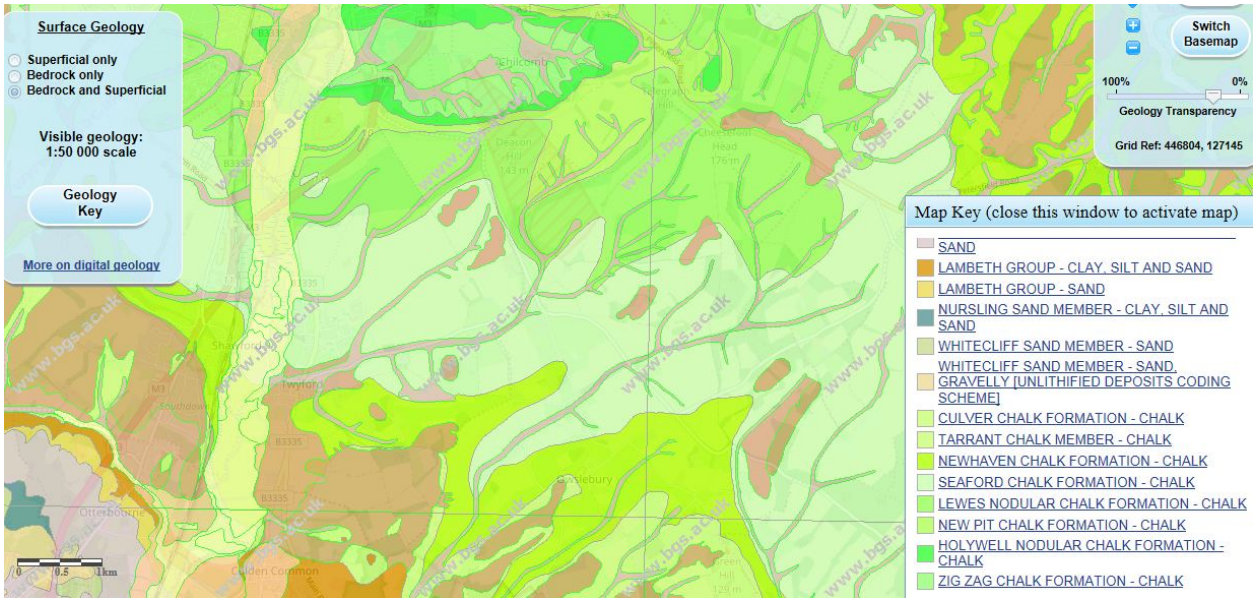
This area, delineated by the blue line, is pictorially represented within the following figure. The contours blue (5m) and orange (1m) show the lie of the land.

Rainfall Study

The rainfall data were collected from the observational weather stations in the local area and collected as a time-series. Analysis of the data suggests that 2012 and 2010 were particularly bad years for rainfall, but because the cumulative or rolling summation with respect to time stayed below a certain threshold, the winterbourne stayed below ground. These facts are particularly interesting as they help set an upper bound to the capacity of the soil (described below) to convey water without flooding. It was only in the winter of 2013 and subsequent cumulative early rainfalls in 2014 which led to the emergence of the winterbourne around about the 12th of January, and which is reported to have lasted two months almost to the day, i.e. the 12th of March, 2014. It was at this point the cumulative rainfall had relaxed sufficiently to let the winterbourne subside and disappear back under ground. These data help with later analysis and are used as a multiplier with the catchment area to determine the product of the winterbourne flow (volume over time), in subsequent calculations.



Geological study



UK Geological survey maps state that the bedrock layers within the catchment are largely chalk based. The characteristics of chalk layers are that they convey relatively large flows of groundwater fairly easily. As can be inferred from the maps, the valleys are covered in clay which acts as a barrier to the conveyance of water. The net effect of this layering is that once the chalk layers have reached their full potential to convey groundwater, the surplus rainfall emerges to the surface and traverses along the top of the less permeable clay geography within the valley floor as a winterbourne.

Hazeley Road more or less follows the floor of the valley of a relatively large catchment. This leads to a small depression impounded by the High Street. The winterbourne flow would have then passed to Finch Lane.

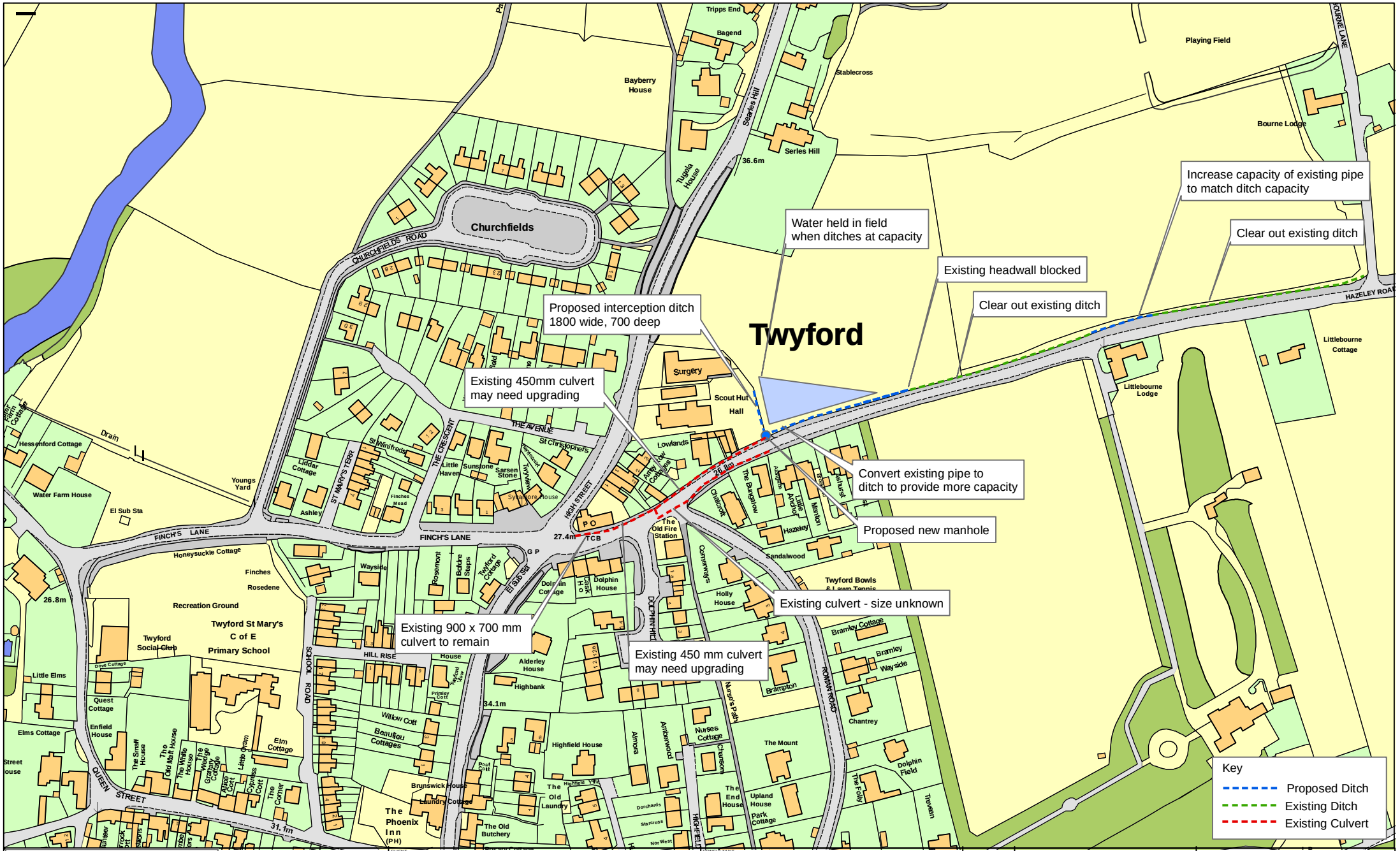
Hydraulic Study

At this point we have an idea of the catchment size; the rainfall intensity; time-series analysis of the rainfall with respect to one occurrence of a winterbourne and six which did not result in a winterbourne; along with the relative permeability of the geography. Hampshire County Council then analysed these data and calculations with respect to their hydraulic nature and undertake mathematical computations.

The problem statement is felt to be what measures would be necessary to divert enough of the winterbourne to avoid wide scale break down of the functions of the principal infrastructure (i.e. roads, sewers, electricity). To analyse potential options, it is necessary to undertake an engineering exercise to determine within a degree of accuracy an estimate for the magnitude of the winterbourne. And whilst it is impossible to forecast the forward frequency of the occurrence of the winterbourne, historically it has occurred every ten years or so within the last fifty. But what can be determined is a more accurate set of measures which will act as a trigger point for its reoccurrence, allowing better preparation of mitigation measures further in advance of the re-occurrence.

The estimate of the winterbourne flow is a function of the difference between the product of the rainfall intensity and the catchment and the upper limit of the groundwater capacity.

Appendix C Potential engineering options

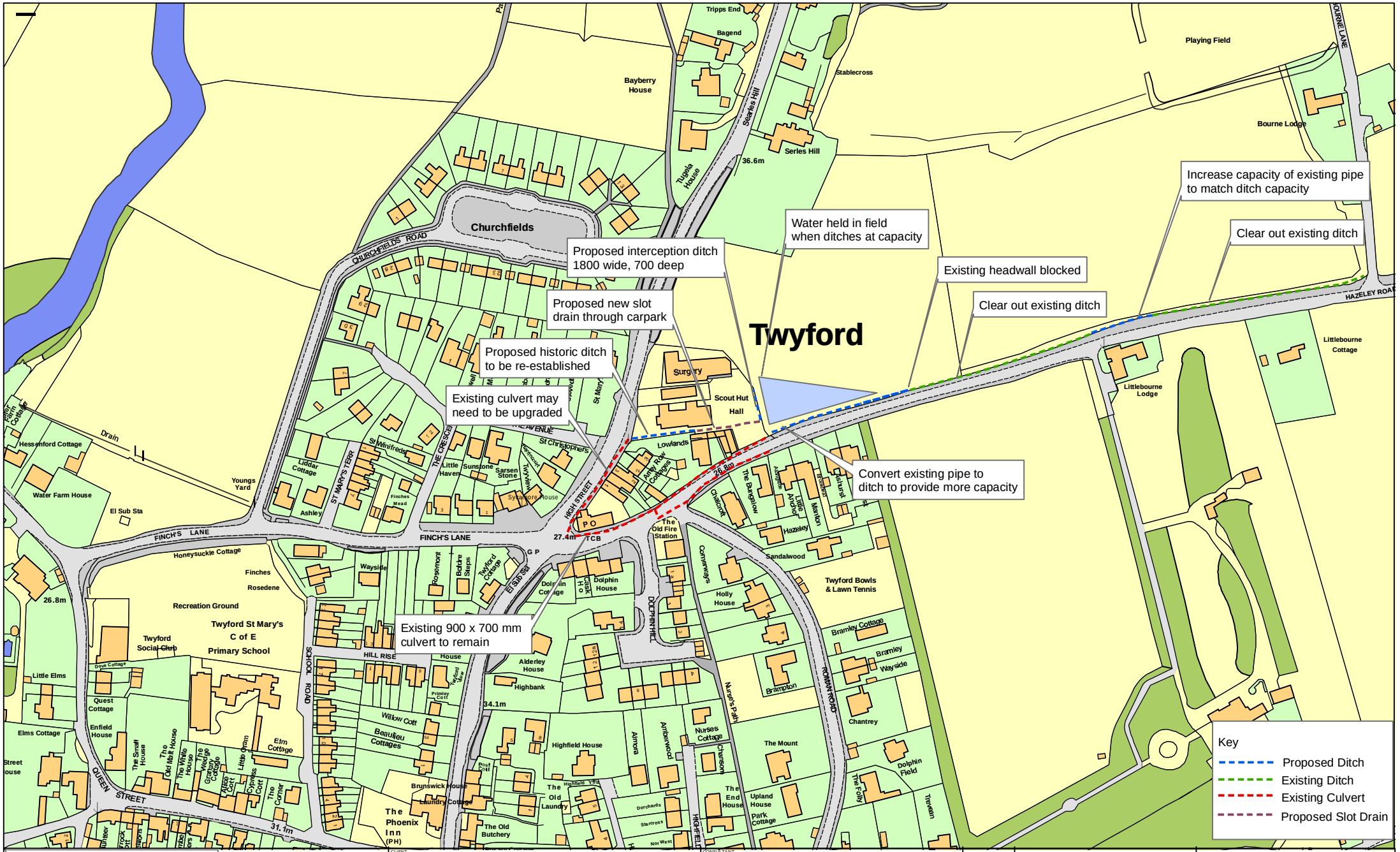


REV	AMENDMENTS	DATE	CAD	CHKD	APPD

CLIENT: HAMPSHIRE COUNTY COUNCIL
ECONOMY, TRANSPORT AND ENVIRONMENT DEPT
FLOOD RISK MANAGEMENT GROUP

CONSULTANT: Hampshire County Council engineering CONSULTANCY

DESIGNER: GF	SCHEME: TWYFORD FRCD INVESTIGATION	DRAWING TITLE: OPTION 1 NEW DRAINAGE DITCHES	
CAD: CV			
CHECKED: GF	JOB NO.: R.J521008.01		
APPROVED: SR	SCALE @ A3: NTS	DATE: 30.06.2017	SHEET NO.: 1 OF 1
	DRAWING NUMBER: EC/RJ521008/OP1		REV: --

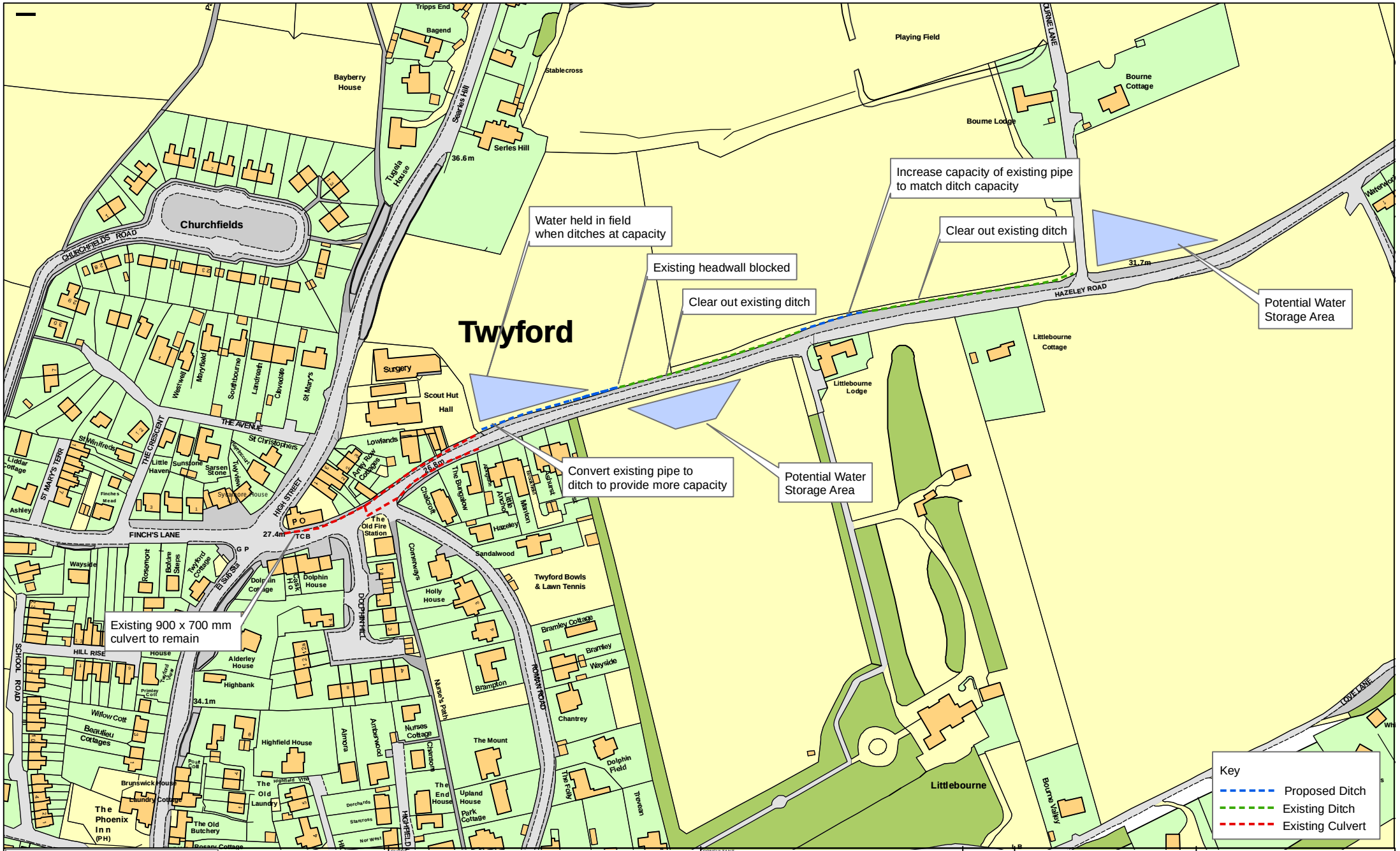


REV	AMENDMENTS	DATE	CAD	CHKD	APPD

CLIENT: HAMPSHIRE COUNTY COUNCIL
ECONOMY, TRANSPORT AND ENVIRONMENT DEPT
FLOOD RISK MANAGEMENT GROUP

CONSULTANT: Hampshire County Council engineering CONSULTANCY

DESIGNER: GF	SCHEME: TWYFORD FRCD INVESTIGATION		OPTION 2 NEW FLOW ROUTE
CAD: CV			
CHECKED: GF GF	JOB NO. R.J521008.01		
APPROVED: SR SR	SCALE @ A3: NTS	DATE: 30.06.2017	SHEET NO.: 1 OF 1
	DRAWING NUMBER: EC/RJ521008/OP2		REV: --



REV	AMENDMENTS	DATE	CAD	CHKD	APPD

CLIENT: HAMPSHIRE COUNTY COUNCIL
ECONOMY, TRANSPORT AND ENVIRONMENT DEPT
FLOOD RISK MANAGEMENT GROUP

CONSULTANT: Hampshire County Council engineering CONSULTANCY

DESIGNER	GF
CAD	CV
CHECKED	GF / GF
APPROVED	SR / SR
SCHEME	TWYFORD FRCD INVESTIGATION
JOB NO.	R.J521008.01
SCALE @ A3	NTS
DATE	30.06.2017
SHEET NO.	1 OF 1
DRAWING NUMBER	EC/RJ521008/OP3
REV	--

OPTION 3
POTENTIAL STORAGE AREAS