Harberton Flood

17th September 2023

1 Purpose and scope

This document aims to;

1.1 Capture photographic information

1.2 Describe the flood flow path and its effects

1.3 List the precursors

1.4 Recommend mitigation for future events

1.5 Act as a reference for Parish and District Councils and the Environment Agency as input to their final report

Acknowledgements

The following are amongst many who contributed to this report;

Craig Penwarden

Jonathan Bean

Mark Norman

John Culf

Cllr Richard Morris

Robert and James Rogers (Langham Farm)

Jago Burris and colleagues from the local authorities who provided information at the Harberton drop-in meeting on 17th October 2023.

Changes

There have been multiple changes to the first, Oct 3rd, version of this document following the Harberton drop-in meeting on October 17th

Please use this version instead.

There will be no further changes. This is the final version. It has been passed to the local authorities as input to their report.

2 Harberton topography

Harberton sits at the confluence of streams from several valleys. The lowest contour point on Vicarage Ball, a few meters east of the culvert bridge, is 68 m above ordnance datum (AOD). The highest point is the trig point at the reservoir at 163 m. There is a 95 m rise over a point-to-point horizontal distance of just over 1 km (312 feet over 0.65 miles).

The OS map identifies a number of springs in the surrounding hills. Several streams converge into the final two streams entering Harberton from the north east and north west. These combine under the road, then flow south to Harbertonford.

This report concerns the north west spring and the stream flowing south east into the village only. Other parts of the village to the east and north were relatively unaffected.

The populated area is surrounded by farmland, both arable and livestock.

Screw Lane is a dividing line in terms of flow distance, relative gradients, and soil cultivation. It bisects the elevated terrain. It runs east/west roughly along a contour, 101 m AOD at Gills Cross in the east, 96 m at Belsford Mill crossroads in the west. It has a hump around half-way approx 20 m east of Threshing Barn's driveway. This hump was significant in directing the flow.

The total water stream path length in plan view is 1125 m with 650 m being above Screw Lane

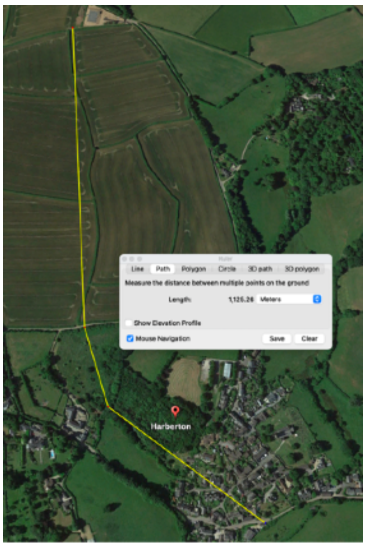
The land rises 22 m (90 - 68) to Screw Lane then upwards by 73 m (163 - 90) above Screw Lane

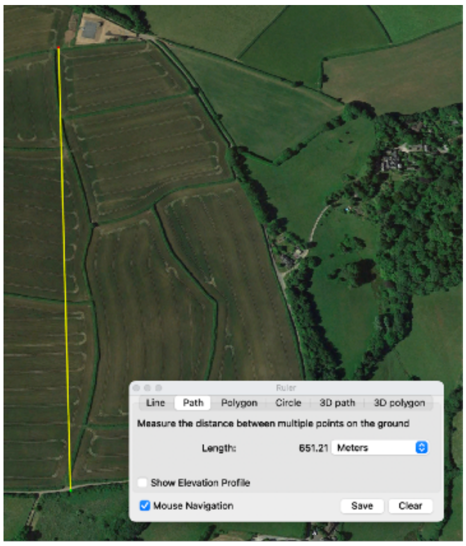
The gradient along the stream flow path is;

1 Vicarage Ball to Screw Lane is 2.7 deg [$\tan^{-1}$ 22/(1125-651)]

2 Screw Lane to Trig point is 6.4 deg [$\tan^{-1}$ (73/651)]

The cultivated land is 2.4 times steeper than that below Screw Lane with roughly equal areas of about 60 acres





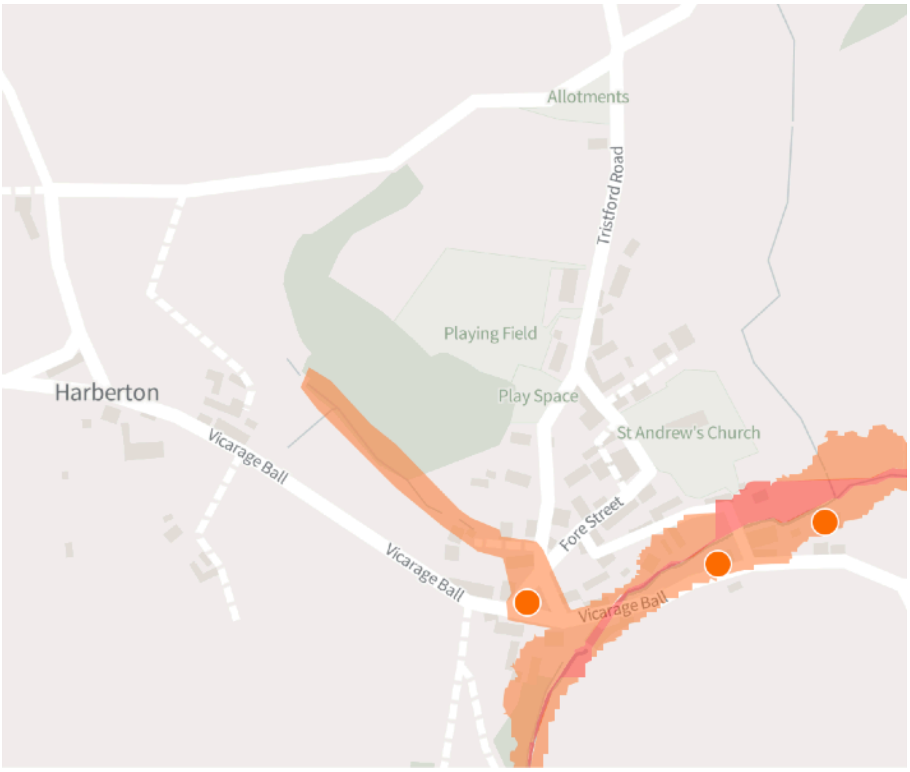
3 Harberton flood plain

Harberton’s flood plain is well-documented. A number of drain and culvert mitigation schemes have been engineered in recent years including an under-road junction under the lowest part of Vicarage Ball.

4 Flooding history

This flood was congruent with the left hand of the ‘Y’ of the published flood plain here in orange, designating medium risk. The red area and dots are deemed high risk.

There are many previous incidents, but this appears to be the worst in living memory. It was worse than the Tristford Road flooding in late December 2000 from land behind the Parish Hall.



5 What happened?

The Met Office state that the first half of September in England was the hottest on record dating back to 1884. This was caused by the jet stream flowing to the north of the UK.

There were multiple thunderstorms on the night of 16/17th September throughout Devon. The Environment Agency's 'Slipperstone' rain gauge near Harbertonford recorded the maximum rainfall as 17.3 mm over the 15 minute period ending at 01:30 Zulu (GMT), 02:30 British Summer Time.

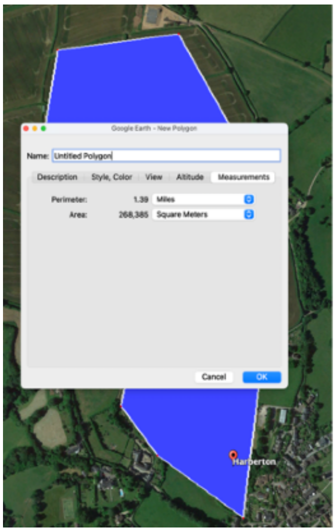
2023-09-17T00:00:00Z	0.8
2023-09-17T00:15:00Z	0.4
2023-09-17T00:30:00Z	1.8
2023-09-17T00:45:00Z	3.5
2023-09-17T01:00:00Z	4
2023-09-17T01:15:00Z	4.4
2023-09-17T01:30:00Z	17.3
2023-09-17T01:45:00Z	5.2
2023-09-17T02:00:00Z	0.5
2023-09-17T02:15:00Z	0.1

Harberton does not have an EA rain gauge as it does not have a river

As a proxy, applying these readings to Harberton, the total for this 2hr 15 min period of 10 readings is 38 mm

The peak is 17.3 mm

The gauge at Harbertonford recorded 14.2 mm 15 minutes earlier, so there is some cross-validation of the two gauges. (see Appendix for the full night's data)



The water heading into Harberton from the north east can be assumed to have fallen on this blue polygon plan area of 268,000 m^2

Therefore the volume of water in this period was;

10,000 m^3 (268,000 X 0.038)

… and the peak 15 minutes was

4,500 m^3 (268,000 X 0.017)

Just under half of the 2 hr 15 min period's rainfall fell in 15 minutes.

These numbers are not definitive, but are an attempt to indicate the scale of the event.

We will never know how much was absorbed by the soil.

This is what 1m^3 (=1000 Litres = 1000kg =1 tonne of water) looks like.

If the rain gauges were accurate, and Harbertonford's rain gauges are a good proxy for Harberton, then the maths above suggests we had 10,000 of these containers in 2.25 hours and 4,500 in 15 minutes.

The fire service arrived at approx 04:30 to relieve flooded houses, opening up blocked culverts, breaking down doorways, and pumping out certain properties.

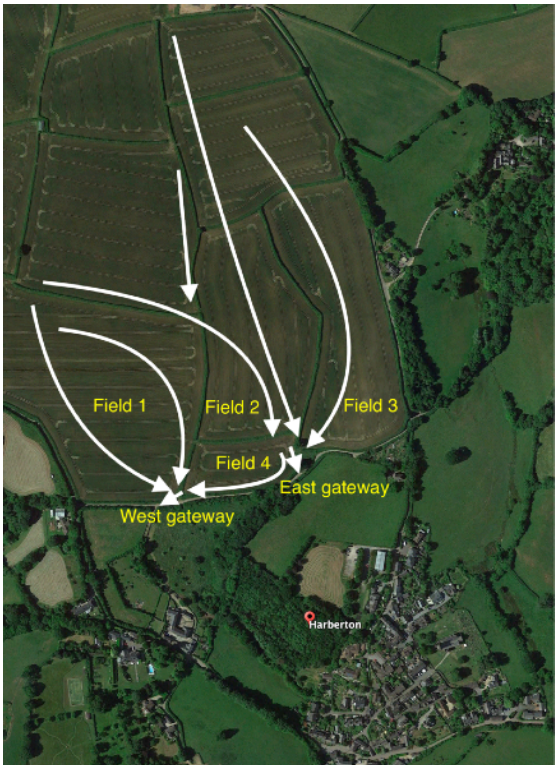
5.1 Flood water contents

The flood stream consisted of water-borne mud and chopped straw.

The fields north of Screw Lane had been minimally tilled in line with current farming practice. This resulted in short lengths of straw on a shallow bed of tilled dry soil, with a compacted soil sub-base.

5.2 Water pathway

5.2.1 The water ran down the fields north of Screw Lane. Fields 1,2,3 and 4 were freshly tilled, the others to the north had a well-established crop.

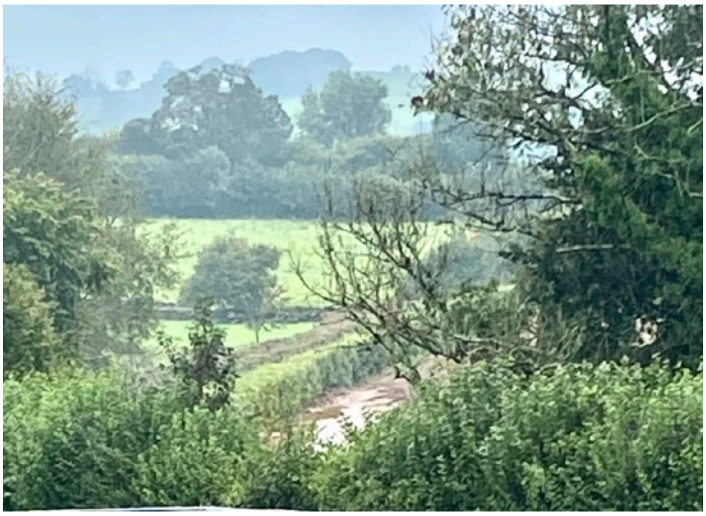


The water, mud and straw gathered against the southern borders of those fields forming the north border of Screw Lane.

The white lines show the flow paths as seen in the photographs. Detailed photos are available.

The water exited onto Screw Lane at various points, but particularly through the two gateways at east and west parts of the lane.

Water banked up and pooled along the fields' southern banking forming the north side of Screw Lane.



Established crop north of fields 1,2,3 and 4, looking down on the freshly-tilled and seeded fields in the far distance.

5.2.2 The flow went through the two field gateways and hedge apertures onto Screw Lane. The run-off was held between the high banks on either side as the buddle holes blocked with straw and mud. The evidence on this gate indicated there was minimal build-up behind the gate. Its open structure allowed relatively free flow to scour the gateways clear with minimal straw retention up to three bars high on the gate.

5.2.3 Screw Lane has a slight hump to the east of Field 1's gate. This caused the flow from this filed to head west which spilled round and pooled in Threshing Barn's driveway.

Threshing Barn's driveway walls held. As Screw Lane filled up, the hump was submerged, and the gateway and buddle holes on the south side of Screw Lane overflowed. Screw Lane became a huge attenuation pool.

A tractor the following morning in the lower part of Screw Lane, heading east.

Note the left hand stream still running towards the tractor.

Screw Lane's hump is still submerged, 10 m behind the tractor.

Here is the hump some time later …

5.2.4 Two separate flow streams headed south down over the meadow.

Main flow from upper field, across Screw Lane

Looking north at 2 streams heading south forming a 'Y' shape

One stream heading south

Stream with fields in upper background

This grassland had only recently been cleared of brambles and other vegetation

5.2.5 The two streams ran south down across the grassland bowl into an existing pond.

This pond was dug many years ago to act as an attenuation pool for flood water. There were plans to deepen it as it had silted up over recent years. Many years ago hurdles were placed above this pond to capture silt from above. Being shallow, the pond overflowed, but it’s banks remained intact and were not scoured.

Looking north towards field 1 in the upper part of this shot, with the pond in the foreground

5.2.6 The pond overflowed into this subordinate pool,

… then onwards south east down to the village. It is joined by a much smaller stream from the cricket pitch road. There are freshly broken fences, but no evidence of any significant dams along the stream.

Levee

The stream has 1.5m levees on it’s west bank to protect the field to the south. However there are gaps in the levee which caused spillage

Levee gap and spillage

The levee spillage eastwards was significant. It backed up against the Gunnera plants behind Ashbrook Cottage

5.2.7 The stream pushed through to the side of Ashbrook Cottage where it pushed over a north wall. It spilled north to Town Farm and east along the road behind St Clement's Terrace.

Collapsed wall at Ashbrook Cottage

South east flow through Ashbrook Cottage side gateway.

The front garden's picket fence was carried across the car-park to St Clement's terrace.

5.2.8 **Three culverts**

All the surplus water north east of Harberton comes into culverts in a series of 3.

The first culvert heads west under Ashbrook Cottage's garage. This culvert was overwhelmed. The flow went around both sides of the garage, taking the side gate off it's hinges.

The flow through the Ashbrook culvert then went west for a few metres to Town Farm Barn. It dog-legs at Town Farm Barn's rear culvert. Town Farm Barn flooded from front and rear as the flow went approx 220 degrees around the house.

Culverts 1 and 2

Ashbrook Cottage and Town Farm Barn both 740 mm diameter, 0.43 m^2

Culvert 3

St Clement's culvert 590 mm, 0.27 m^2

The culverts are round tubes. The flow through a pipe is proportional to it's cross-sectional area (CSA). The CSA varies with the square of diameter [CSA = Pi $(D/2)^2$]

Ashbrook and St Clement's CSAs are 0.43 m^2, St Clement's is half the size at 0.27 m^2.

Only St Clement's has an inclined debris grating, which became clogged.

More on culvert debris gratings here:

https://bpb-us-w2.wpmucdn.com/sites.udel.edu/dist/0/7241/files/2018/03/CACR-05-03-Kobayashi_Kagawa-v6ydhs.pdf

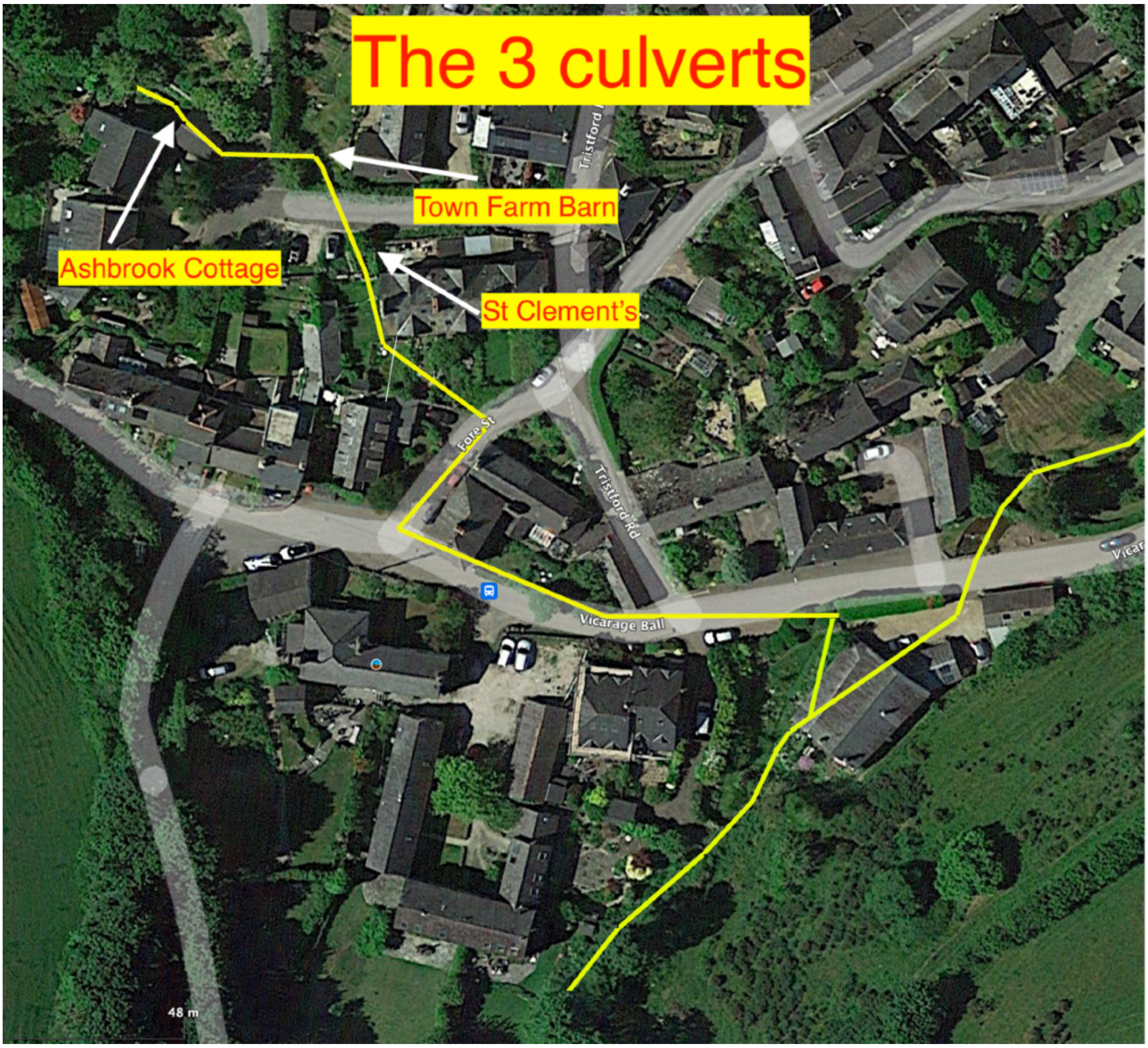
The three culverts are in a series. Ashbrook first, then Town Farm Barn and finally St Clement's.

It is not good practice to have the last in the series half the size of the two upstream. They were installed at different times.

A crucial question is what percentage of the 10,000 m^3 of water in 2.25 hours came into these culverts? What is the maximum flow rate of clear water that these culverts could absorb? What flow rate were they designed for?

In particular, can St Clement's 0.27 m^2 culvert pass 4,500 m^3 in 15 minutes?

The answers to these questions is vital and should be available from civil engineering empirical evidence and hydrodynamic tables.



The Fire Service cleared the culverts at 04:30. Unfortunately the degree of blocking was not recorded or witnessed in any detail at time of writing.

5.2.9 The main stream then ran downhill to the south. It blocked the culvert at the western end of St Clement's Terrace. Fortunately, the north wall behind St Clement's was not breached.

Note the water mark in the culvert is 250mm (10 inches) below the topping stones.

Inclined grating over the culvert

St Clement's rear wall

The flow spread out to all low-lying properties to the south, including 6 Wesley Place where it entered the rear, traversed the house, and exited the front door at letterbox level. It also went east to Tristford Road where colliding floating wheelie bins woke the first responder.

The flow flooded the front gardens of St Clement's

A video of this is flow available

The high water mark on the doorframe brickwork is 4 bricks above the level on this photo taken at 03:09 which is 39 minutes after the peak rainfall measured on the rain gauges, so good correlation.

5.2.10 The flow passed around both sides of St Clement's Terrace, taking wheelie bins down Tristford Road. It carried on south, heading down Fore Street, crossing the road to flood St Andrew's cottages from the western gateway where the sandbags are in this photo.

5.2.11   It flowed down Fore Street to Vicarage Ball, pooling on the southern kerbside of Vicarage Ball.

The lowest properties along the southern edge of Vicarage Ball suffered with the flow passing through, around and past them. The road camber protected northern driveways e.g. Globe House. Wesley House and no 4 & 5 St Andrew's cottages escaped lightly.

Fortunately this resident's drive was designed as a spillway when the old cow track was lowered to build the two houses.

He was woken and opened these gates, increasing the rate of spill to the stream at the rear.

This thinking needs to be applied to all the checkpoints of this flood. Spillways do not have to be grand concrete chutes, just graded slopes that are kept clear.

His house was spared, those either side were not.

5.2.12 Preston barns ‘U’ shaped courtyard had the lowest affected properties and now perhaps the more challenging mitigation for future floods as the original archway has been in-filled.

Note the flow did not reach the second stream entering the village from the east. This is a completely different system from a different valley. The stream was full, but contained within its banks. The mud on the road here came from the west, not the stream from the east.

The flow was sufficient to lift and move cars.

5.2.13 The final chokepoint was the narrowing of the stream heading down to the sewage works to the south of Vicarage Ball.

The waterline / scouring mark can be seen on the southern bank and gate rails.

There was only a few traces of mud and straw in the garden of the Old Forge. Presumably this was caused by the stream's chokepoint above causing a backing up against this garage door. The Old Forge did flood as it sits lower than this garage.

It was not all bad news. No 4 St Andrew's cottages had a well-fitting, sealed front door. It withstood the main flow with minimal ingress.

6 The Farmer’s point of view

The farmers write;

‘We re-seeded the fields into grass. We decided to not plough the fields as this can lead to soil erosion problems. So instead we min-tilled the fields only disturbing the top inch or so of top soil.

Obviously as we all know we had 3/4 inches of rain in a couple of hours and the fields understandably couldn’t cope with the shear quantity of water leading to the run off.

Since the event we have met with the environment agency who confirmed it was an unfortunate set of circumstances that we couldn’t do anything about. The only thing they did say was that due to the fields not being ploughed there was a certain amount of compaction which obviously effects the amount of water the ground can soak up. However, it is my firm believe with over 40 years of farming experience that if we had ploughed the fields the washing would’ve been considerably worse.

We have now at the request of the environment agency sub soiled the fields and that is how they will remain till the spring.

Going forward unfortunately there is little we can do to stop wash if we have such extreme weather events shortly after fields have been cultivated. One step we can and will take is to move the gateway on screw lane into the opposite corner as where it is situated is the natural run for water and if it had been blocked up at the time would’ve helped to hold back at least some of the soil.

Many thanks, Robert and Jamie Rogers.’

An example of a sub-soiler being used in one of the fields above Screw Lane several days after the event. The work is along the contour lines of Field 3.

The deep blades break and lift compacted sub-soil

7 Observations

There is as much land area above Screw Lane than there is below it. The topography is that of an ever-steepening catchment bowl, partially exposed to the prevailing moist south westerly airstream forcing it upwards to 163m, stimulating precipitation. The EA describe it as a good 'flash-flood catchment'.

The rain gauges readings give the rainfall profile that night. It peaked shortly before 02:30 and had stopped flowing by dawn, leaving wet mud and straw. There were several areas where the flow was captured and perhaps temporarily halted. This appears to have caused backwash and raised the water level at each of these locations. When each of these were breached, the flow was released downstream to the next. Presumably, Flow > Blockage > Backwash > Rising water > Release. However It could simply have been one very short, fast deluge with several slight interruptions. Everyone was in bed, no-one saw the worst part of it.

Wesley House, the former chapel, with walls all around was in the flow path, but minimally affected. This shows the benefit of walled surroundings laid with mortar. No 4 St Andrew's cottages showed the benefit of a well-sealed front door. One loose-laid garden wall was pushed over. The more substantial walls around St Clement's Terrace held. Given the height of the water at St Clement's, had one of the higher walls failed there could have been injury. The relative culvert locations, sizing and grating needs to be reviewed. Note these are likely to be the property (riparian) owners' responsibility.

The key question is: *Did the mud and straw actually attenuate a far worse clear water torrent?*

Thankfully, Screw Lane was a temporary attenuation pond. It's high banks with straw and mud blocked the gaps, reducing the flow rate for a while and restraining a large mass of water.

One can hypothesise that the straw and mud helped prevent a far worse 'clear water' flood. Fast-flowing clear water would have had more kinetic energy than the slow-moving gloop we suffered. The mud was terrible to clear up, but would a higher speed flow of clean water have been worse?

The wall was pushed over by kinetic energy. This energy increases with the square of velocity (KE = 1/2 MV^2)

I m^3 (1000 kg) of water flowing at 2 ms^{-1} has a kinetic energy of 2 kJ, increase this flow to 4 ms^{-1} and it has 8 kJ. So double the speed and you get 4 times the energy. Increase it to 5 ms^{-1} and its 12.5 kJ, over 6 times the energy. It is an exponential increase.

The mud and straw increased the mass slightly, but also the viscosity. The straw caught in the gates, fences, railings and vehicle underbellies. The mud packed into the straw. This reduced the kinetic energy in places to zero as the water slowed and pooled.

8 Conclusions

The south of Harberton is aware of the risk of flooding. The Victorians built the first culvert in St Clement's. Various mitigations were in place, but insufficient for the scale and circumstances of this event.

Screw Lane flooding is well understood and a regular item on the Parish Council's agenda, together with the vacancy for a linesman to tend to the various water courses, drains, culverts and buddle holes.

There were seven precursors;

1 An record-breaking hot and dry first two weeks of September

2 The field minimally-tilled the week before, loosening the dry topsoil

3 Straw chopped into short lengths (but note long straw was baled and removed)

4 The grass seed that had been sown did not have time to establish itself

5 Extraordinarily high rainfall over 2 hours with an exceptional 15 minute period

6 Lack of culvert debris management and, perhaps, St Clement's culvert sizing

7 Inadequate flood mitigation on specific properties in a known flood path and flood plain

Attention to farming / land management, tidying-up waterways and some basic hard and soft engineering will reduce greatly the effects of the next flood.

9 Recommendations

The farmer's intention to revert to grassland may stop an event like this, but it will not solve the fundamentals. "It may have been his soil and straw, but it was not his water"

Farms get sold on, methods change, cash crops come and go, memories fade, so nothing is guaranteed.

There are predictions of more extreme weather events. The farmers write that little can be done to prevent wash after soil cultivation on steep hillsides. Therefore, the precautionary principle should prevail. Something similar happened 23 years ago. The lessons appear not to have been applied.

It is vital that an holistic approach is taken. Easing the flow upstream will cause increased flow for those downstream. Take the mud and straw away, open the channels upstream and all is well. However you then get high velocity water. This just increases risk for Vicarage Ball's southern properties.

It is likely that some combination of capture and flow management should be used. Different solutions are needed above Screw Lane to those needed below it.

The solutions are outside the scope of this report, but may include swales, detention basins and attenuation ponds. Maybe Screw Lane should be considered a causeway? After all they close the seafront roadway in Torquay regularly in advance of storms.

contd …

9.1 Must dos:

9.1.1 All properties subject to the main stream should have flood gates or at least flood-tolerant doors with multi-point cam closers. Perhaps outward-opening with no cat flaps and low letter-boxes. Particularly St Clement's Terrace, St Andrew's Cottages and all properties along the south side of Vicarage Ball. Flood-proof air-bricks are also needed for suspended wooden floors.

9.1.2 Ashbrook Cottage, The Old Forge, Preston Barns and the St Clement's Terrace front gardens should have spillways to take the flow to the stream.

9.1.3 Preston Barns need specialised attention, with a flow path to the stream to the rear

9.1.4 Flooding in Screw Lane is a long standing issue that should receive extra attention, That said, note the attenuation effect it played in this flood.

9.1.5 All streams should be cleared regularly. Presumably by linesman, but also residents.

9.1.6 Culvert CSAs and use of debris gratings needs to be validated.

9.1.7 Home owners need to declare their possible riparian status to their insurers, who will probably know already.

9.1.8 This report to be scrutinised by the appropriate subject matter experts under the direction of the appropriate agencies to produce the expert's view.

9.2 Advisories:

9.2.1 All stream-facing walls should be inspected for integrity and made flood-load bearing. Flood walls and gates must not be too high. Over-topping must be possible to reduce static and dynamic water pressure.

9.2.2 Rising water needs to be sensed and alerts given. Harberton needs rain gauges giving real-time alerts. If we know early at the source we have a chance. Secondary flow monitoring systems should be installed at chokepoints, particularly culvert entrances to sense the rate-of-change of flows. Perhaps a vee-notch wier could be constructed in St Clement's

9.2.3 The long-standing linesman vacancy should be pursued with vigour. The responsibilities should include first-line alarm system maintenance.

9.2.4 Resident's should consider 'Adopting a drain'. This existed some years ago. A couple of folk regularly clear the grating on the stream from the east and residents tend to their own culverts. This should be made more formal with appropriate back-up for absences.

9.2.5 The farmer's suggestion to block up his gateway(s) needs to be factored into the plans for Screw Lane's drainage.

Peter Cogley October 21st 2023

APPENDIX

Recordings for the two Environment Agency rain gauges in Harbertonford.

There is no EA rain gauge in Harberton, so these were used as proxies.

The ‘Z’ means Zulu Time, which is the same as GMT. Add I hour to get BST.

Rainfall at Harbertonford (SX763559)

Timestamp (UTC)	Rainfall (mm)
2023-09-16T15:00:00Z	0
2023-09-16T15:15:00Z	0
2023-09-16T15:30:00Z	0
2023-09-16T15:45:00Z	0
2023-09-16T16:00:00Z	0
2023-09-16T16:15:00Z	0.2
2023-09-16T16:30:00Z	0
2023-09-16T16:45:00Z	0.2
2023-09-16T17:00:00Z	0
2023-09-16T17:15:00Z	0
2023-09-16T17:30:00Z	0
2023-09-16T17:45:00Z	0
2023-09-16T18:00:00Z	0.2
2023-09-16T18:15:00Z	0
2023-09-16T18:30:00Z	0
2023-09-16T18:45:00Z	0
2023-09-16T19:00:00Z	0.4
2023-09-16T19:15:00Z	0.6
2023-09-16T19:30:00Z	0.2
2023-09-16T19:45:00Z	0
2023-09-16T20:00:00Z	0
2023-09-16T20:15:00Z	0
2023-09-16T20:30:00Z	0
2023-09-16T20:45:00Z	0
2023-09-16T21:00:00Z	0
2023-09-16T21:15:00Z	0
2023-09-16T21:30:00Z	0.2
2023-09-16T21:45:00Z	0.4
2023-09-16T22:00:00Z	0.2
2023-09-16T22:15:00Z	0
2023-09-16T22:30:00Z	0.2
2023-09-16T22:45:00Z	0
2023-09-16T23:00:00Z	0.2
2023-09-16T23:15:00Z	0.6
2023-09-16T23:30:00Z	1.4
2023-09-16T23:45:00Z	1.2
2023-09-17T00:00:00Z	1.2
2023-09-17T00:15:00Z	0.6
2023-09-17T00:30:00Z	8.2
2023-09-17T00:45:00Z	7.6
2023-09-17T01:00:00Z	11.2
2023-09-17T01:15:00Z	14.2
2023-09-17T01:30:00Z	4.6
2023-09-17T01:45:00Z	10
2023-09-17T02:00:00Z	2.2
2023-09-17T02:15:00Z	0.2
2023-09-17T02:30:00Z	0.2
2023-09-17T02:45:00Z	0
2023-09-17T03:00:00Z	0

Rainfall at Herbertonford Slipperstone (SX791559)

Timestamp (UTC)	Rainfall (mm)
2023-09-16T15:00:00Z	0
2023-09-16T15:15:00Z	0
2023-09-16T15:30:00Z	0
2023-09-16T15:45:00Z	0
2023-09-16T16:00:00Z	0
2023-09-16T16:15:00Z	0.1
2023-09-16T16:30:00Z	0
2023-09-16T16:45:00Z	0.1
2023-09-16T17:00:00Z	0
2023-09-16T17:15:00Z	0.1
2023-09-16T17:30:00Z	0
2023-09-16T17:45:00Z	0.1
2023-09-16T18:00:00Z	0
2023-09-16T18:15:00Z	0
2023-09-16T18:30:00Z	0.1
2023-09-16T18:45:00Z	0
2023-09-16T19:00:00Z	0.2
2023-09-16T19:15:00Z	0.5
2023-09-16T19:30:00Z	0.2
2023-09-16T19:45:00Z	0.1
2023-09-16T20:00:00Z	0
2023-09-16T20:15:00Z	0
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2023-09-16T22:45:00Z	0.1
2023-09-16T23:00:00Z	0.1
2023-09-16T23:15:00Z	0.1
2023-09-16T23:30:00Z	1.1
2023-09-16T23:45:00Z	1.1
2023-09-17T00:00:00Z	0.8
2023-09-17T00:15:00Z	0.4
2023-09-17T00:30:00Z	1.8
2023-09-17T00:45:00Z	3.5
2023-09-17T01:00:00Z	4
2023-09-17T01:15:00Z	4.4
2023-09-17T01:30:00Z	17.3
2023-09-17T01:45:00Z	5.2
2023-09-17T02:00:00Z	0.5
2023-09-17T02:15:00Z	0.1
2023-09-17T02:30:00Z	0
2023-09-17T02:45:00Z	0.2
2023-09-17T03:00:00Z	0