Future
Flood
Resilience
Group

Investigating Letcombe Brook Streamflow-Groundwater anomaly

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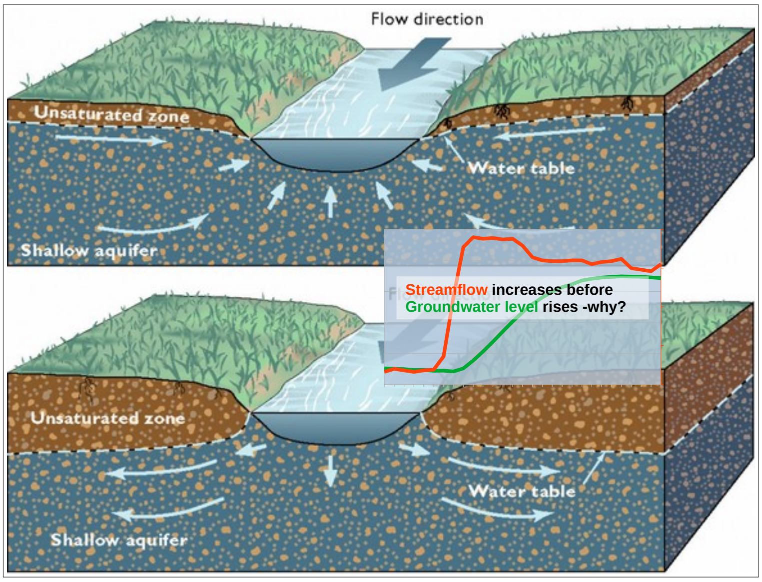

What are the factors creating the anomalous chalk aquifer condition in the Letcombe Brook where streamflow is governed by rainfall rather than groundwater

Summary

The initial aim of this analysis was to understand why the Letcombe Brook streamflow near its source in Letcombe Bassett increased before groundwater levels in the chalk aquifer - which is assumed to be the Brook's main water provider. Rainfall patterns were evidently implicated - but how? Overland runoff from the sloping fields of the Berkshire Downs into the Brook was the initial hypothesis to be tested. The following are observations from the analysis.

1. While the agricultural practice of Minimum Tillage (Min-Till) may contribute to overland flow of intercepted rainfall it is not the major factor. This was established by comparing modern farming practice with farming practice before Min-Till was adopted. This showed streamflow still increased before groundwater levels rising eliminating Min-Till as being a major factor.

2. The major factor is the heavy clay superficial soil layer over the chalk aquifer whose infiltration rate is so slow that in intense storms it limits the passage of rainfall into the chalk aquifer - the remaining rainfall either pools on horizontal surfaces or flows overland down the elevation slopes into the streams raising the stream level and increasing the flowrate.

3. By comparing the Letcombe Brook catchment flowing north (predominantly heavy clay soils) with the Lambourne catchment flowing south (on freely draining soils), from the common watershed of the Ridgeway, it is shown that the Lambourne follows the expected relationship of streamflow increasing in response to increasing groundwater levels I.e it is a "classic" chalk stream.

4. The difference in the catchment soils noted above leads to differences in flooding regimes. The villages along the Lambourne tend to flood from groundwater rising and penetrating the surface soil layer. This can be a delayed and slow flooding but which may last a long time.

5. The villages along the Letcombe Brook are more prone to nearly instant flooding following an intense rainstorm due to the run-off of rainfall from the elevated and sloping fields above, around and along the length of the Brook before it reaches the flat area of the Vale floodplain. Although not investigated here, urban runoff from the large developments that have been constructed over the past years, is seen as exacerbating the flooding problem.

6. It is therefore neccesary for flood appraisal and prevention to appreciate the differences between the regimes of the different chalk streams and that a "one-solution-fits-all" is not likely to work.

7. There is a threshold in rainfall input below which little change is apparent in both streamflow and groundwater levels. For a 4 day period in November 2024 - the threshold was at least 8mm a day. The following storm period of 4 days had an average daily rainfall of 13 mm and produced marked changes in both streamflow and groundwater levels

8. We have to concede that Global Warming-Climate Change, Rainfall patterns and Clay soils are beyond our control within the required timescale for flood prevention and mitigation. We have to "engineer" the solution in a holistic way, avoiding the piecemeal historical, current and future local solutions that just move the problem up, down or across the catchment.

9. Although Min-Till farming practice is not regarded as being a major factor in creating overland runoff from sloping fields, occasional deep ploughing to break up the compacted lower clay levels would probably increase infiltration rates into the chalk layer, and if ploughed along contour lines, would provide furrow reservoirs for rain water slowing the addition of water into the streams.

10. Alternatively, 1m deep trenches at the downslope end of the field would create a sizeable reservoir to mitigate the effects of intense storms and slow the passage of water into the streams.

Is the modern farming practice of Minimum Tillage contributing to flooding conditions?

The practice of Minimum Till (aka Min-Till) is a method for preparing the soil surface for re-planting where only the top soil surface layer is overturned, usually to a depth of around 10-15 cms, as opposed to the traditional method of deep overturned ploughing of the soil to depths of 30-50 cms. This practice is done for many good agricultural reasons.

The modern practice of Minimum Till (Min-Till) farming in the UK began to gain traction in the 1970s and 1980s, though its adoption became more widespread in the 1990s and 2000s due to increasing concerns about soil health, erosion, and sustainability.

- 1970s–1980s: Some pioneering UK farmers and researchers began experimenting with Min-Till as an alternative to deep ploughing, influenced by developments in North America.
- 1990s: The approach gained popularity as farmers sought to reduce fuel and machinery costs. Studies highlighted its potential benefits for soil structure and moisture retention.
- 2000s: Widespread adoption was driven by agri-environmental schemes, CAP (Common Agricultural Policy) reforms, and advances in herbicides and direct-drill technology.
- 2010s–Present: Increasing focus on regenerative agriculture, carbon sequestration, and soil health has further encouraged Min-Till and No-Till practices.

The reasons why Min-Till became popular are:

- Soil Conservation: Helps prevent erosion and maintains soil organic matter.
- Cost Savings: Reduces fuel and machinery costs by minimizing ploughing.
- Moisture Retention: Improves water infiltration and drought resilience.
- Environmental Incentives: Government policies and subsidies have encouraged sustainable farming practices.

However, problems can arise on certain soils, and heavy clay soils have unique characteristics that can make adoption more difficult. Some of the difficulties that relate to flooding are:

Soil Compaction Risks

- Clay soils are prone to compaction, especially under wet conditions.
- Without deep tillage, compaction layers (hardpans) can form, restricting root growth and water movement.

Poor Drainage & Waterlogging

- Heavy clay acts as a percolation barrier, leading to poor drainage and waterlogging, particularly in wetter seasons.
- Min-Till may struggle to break up compacted layers that allow water to drain effectively.

There are possible ways to overcome the above difficulties, again related to flooding:

- Use Cover Crops – Deep-rooted species like radish or clover help break up compaction.
- Controlled Traffic Farming (CTF) – Limits machinery compaction by keeping traffic to designated lanes.
- Shallow Subsoiling – Occasional deep loosening can prevent hardpan formation.
- Improve Drainage – Installing mole drains or tile drainage can help remove excess water.

In order to investigate whether Min-Till is a facor in local flooding, data was needed from before Min-Till began in Oxfordshire - so data before 1990 was required.

There are operational groundwater boreholes in southern Oxfordshire that were established before 1990 e.g. the Stonor Park well, located near Henley-on-Thames. This well has been monitoring groundwater levels in the Chalk aquifer since 1961. The British Geological Survey (BGS) manages the National Groundwater Level Archive (NGLA), which includes data from such observation boreholes. The NGLA contains groundwater level data from various sources, including the observation borehole network, research monitoring sites operated by BGS/NERC, and data from academic research projects funded by NERC. These sites represent all major UK aquifers and provide valuable time-series data to understand aquifer behavior and responses to environmental changes. bgs.ac.uk www2.bgs.ac.uk

While the Environment Agency (EA) was established in 1996, its predecessor organizations, such as the National Rivers Authority, were responsible for environmental monitoring and management before that time. Therefore, groundwater monitoring infrastructure, like the Stonor Park well, predates the formation of the EA and has been operational since before 1990.

There are also dipped groundwater boreholes in the region - the two on the Berkshire Downs are Malthouse (started 1964) and Prebendal Farm (1973)

Data Available for pre- Min-Till investigation:

Pre-1970s	Malthouse - Groundwater dipped - from 1964 (weekly)
1970-79s:	Letcombe Brook at Bassett - streamflow/level records from 1971 Chieveley - Rainfall from 1979 Prebendal Farm - Groundwater dipped from 1973 (approximately monthly) Hodcott 2 OBH - Groundwater dipped from 1974 (approx. weekly)
1980-89s:	Abingdon - Rainfall from 1985 St Johns - Rainfall from 1985
1990-99s:	Stanford - Rainfall from 1991
2000-09s:	Maddle Farm - rainfall from 2003 Kingston Hill Barn - Groundwater from 2001 Longacre B - Groundwater from 2001

The data from the Hodcott 2 OBH (1st Jan 1980 - 31st Dec 1985) and Malthouse (1st Jan 1980 - 31st Dec 1985) were downloaded and combined with rainfall data from the Chieveley rain gauge and the Letcombe Bassett streamflow/level data for the Letcombe Brook.

Figures 1 and 2 below compare **1980** data using Chieveley rainfall, Malthouse groundwater (mAOD - metres Above Ordnance Datum - i.e. sea level) and Letcombe Brook streamflow data from the Letcombe Bassett gauge. The x-axis "Day of Month" is just the day date for succeeding months.

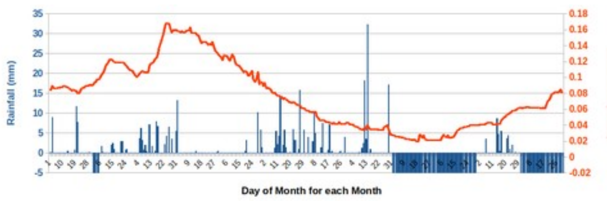

Figure 1: Letcombe Brook annual rainfall and streamflow for 1980

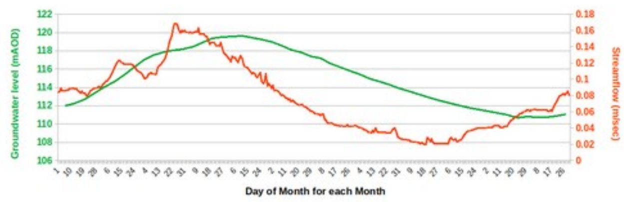

Figure 2: Letcombe Brook streamflow and groundwater level for 1980

Figure 1 shows rainfall and streamflow while Figure 2 then compares groundwater with the streamflow.
Note the missing rainfall data in Figure 1 - the columns go to -5. But Figure 2 seems to indicate streamflow increasing in line with rainfall input rather than groundwater - at least during the early months of the year. The effect is not so apparent during the summer months when grown crops and dry ground may have absorbed the rainfall input. However, the reaction in the early months of the year points to rainfall including the possibility of overland flow controlling streamflow rather than groundwater.

Comparing 1981 below - same stations - similar result - streamflow rises before groundwater implying a response to rainfall input. Note the lack of streamflow data in the autumn period.

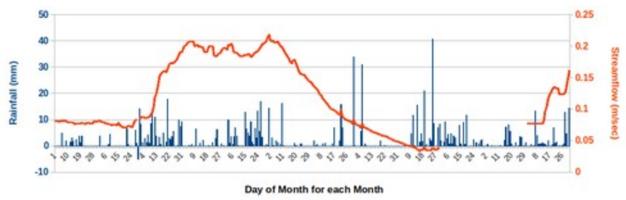

Figure 3: Letcombe Brook annual rainfall and streamflow for 1981

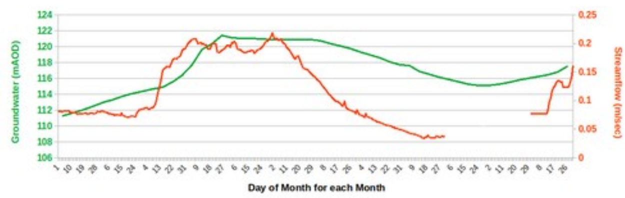

Figure 4: Letcombe Brook: streamflow and groundwater level for 1981

1982, 1983, 1984 had many missing values in each of the data streams making comparison difficult.

Comparing 1985 - same stations - similar result - streamflow rises before groundwater in response to winter rainfall input. Again rainfall has little influence upon streamflow in the summer months.

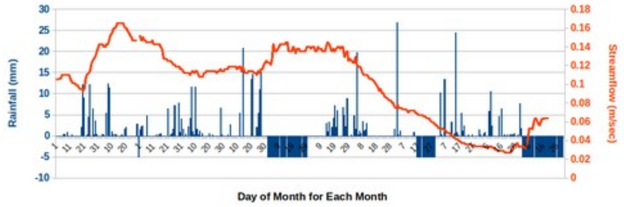

Figure 5: Letcombe Brook annual rainfall and streamflow for 1985

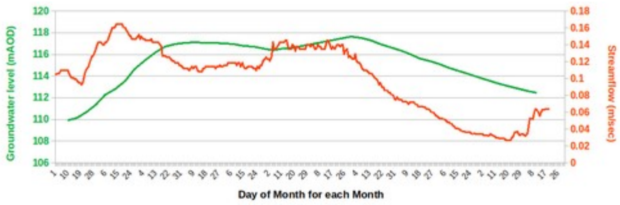

Figure 6: Letcombe Brook streamflow and groundwater level for 1985

Tentative Conclusion on possible Min-Till effect on contribution to flooding:

It is evident from the above graphs that the Letcombe Bassett streamflow increases in response to rainfall input <u>before</u> any groundwater response in those years before Minimum Tillage practice was assumed to have begun on the Berkshire Downs. Min-Till may increase this reaction - but the main factor is elsewhere and more likely to be the overall superficial clay soil layer overlying the chalk on the northern slopes of the Downs.

Investigating the effect of heavy clay soils on flooding:

The soils that overlay the Chalk Aquifer in the UK vary depending on location and geology. However, the most common types include:

Clay with Flints – Found extensively over the North and South Downs, this soil is derived from the weathering of chalk and flint deposits. It has poor drainage and can be heavy and impermeable.

Loamy and Sandy Soils – Found in areas where glacial or river deposits overlay the chalk, such as in parts of East Anglia. These soils are often well-drained but vary in permeability.

Boulder Clay (Glacial Till) – Present in eastern England, particularly in East Anglia and Lincolnshire, where glacial activity deposited thick layers of clay over the chalk.

Brown Earths – These well-draining, fertile soils develop in warmer and wetter regions, such as parts of the Chilterns and Wessex Downs.

Calcareous Soils – Thin, free-draining soils that directly develop from chalk bedrock, commonly found on the open chalk grasslands of southern England.

These overlying soils affect groundwater recharge and vulnerability to contamination, with more permeable soils allowing rapid infiltration, while <u>clay-rich soils slows water infiltration</u>.

In the Cotswolds, the Chalk Aquifer is primarily found in the eastern and southeastern parts, where it transitions from the Jurassic Limestone formations. The overlying soils in this region are typically:

Shallow, Well-Drained Limestone Soils – These are thin, calcareous soils derived from the underlying Jurassic limestone, common across the Cotswolds. They are often classified as rendzinas or calcareous brown earths and provide good drainage.

Clay with Flints (in some eastern areas) – Where the Chalk Aquifer extends towards Oxfordshire and Berkshire, patches of Clay with Flints can be found, creating more impermeable conditions.

Boulder Clay (Glacial Till) in Valleys and Lowlands – Some parts of the northern and eastern Cotswolds have glacial deposits, which create more mixed and heavier soils with variable drainage.

Loamy and Sandy Soils (on Plateaus and River Valleys) – In some areas, especially where rivers have cut through the limestone, alluvial loams and sandy soils occur, allowing for better infiltration of water into the chalk below.

Since the Chalk Aquifer is mostly present beneath the Cotswold limestone formations, its exposure is limited compared to other regions like the South Downs or Chilterns. However, where it does outcrop, the overlying soils influence how water percolates and recharges the aquifer.

In the Cotswolds, towns with calcareous brown earth soils overlying the Chalk Aquifer are mainly found in areas where Jurassic limestone and chalk interact, particularly in the eastern Cotswolds. Some notable towns include:

Burford (Oxfordshire) – Located on the eastern edge of the Cotswolds, Burford sits on calcareous soils influenced by both limestone and underlying chalk deposits.
Charlbury (Oxfordshire) – Positioned near the Cotswold uplands, with well-draining brown earth soils over Jurassic and chalk formations.
Lechlade-on-Thames (Gloucestershire) – At the transition between the limestone and chalk, where loamy and calcareous brown earth soils are common.
Faringdon (Oxfordshire) – Although technically outside the Cotswolds, this town sits on a mix of limestone and chalk formations, with brown earth soils contributing to its agricultural landscape.
Stow-on-the-Wold (Gloucestershire) – While predominantly on limestone, some areas around Stow feature brown earth soils with links to deeper chalk aquifers.
These areas typically have well-draining, fertile calcareous soils, making them important for agriculture, grassland, and woodland habitats while also influencing groundwater recharge into the Chalk Aquifer.

However none of the above have well defined Brooks and are some distance away from the chalk uplands.

Alternative - The Lambourne river
The Lambourne flows south from the uplands near Upper Lambourn through East Garston and Great Shefford down to Newbury. It has freely draining chalk soils which allow rapid infiltration and consistent spring flow. Great Shefford has experienced multiple flooding events over the past 20 years. Data from the River Levels UK website implies that groundwater flooding is of most concern - something that is more prevalent where permeable surface soils allow rising groundwater to rise up to and then through the local ground surface.

There are Groundwater (Great Shefford), Rainfall (Chieveley) and Streamflow (Welford) EA stations with close proximity to the Lambourne as shown on the image. Maddle Farm, just north of Upper Lambourn has rainfall data, and would have been ideal for this exercise but didn't start operations until 2013.

Figure 7: The course of the River Lambourne

Data didn't start until 2002 at Great Shefford, 1979 at Chieveley and 1962 (Welford). So no opportunity to compare pre- and post- Min-Till agricultural practice.

Data for the period 2003 to 2010 were analysed to see if on these freely draining soils - streamflow was governed by groundwater or by rainfall. All years apart from 2010 had significant gaps in one or more of the data time-series.

The analysis showed a positive relationship between the flow of the Lambourne and groundwater levels as shown in the figures below for 2010 where there is a clear relationship between streamflow and groundwater levels in left-hand graph while the middle graph shows falling streamflow even during increased rainfall. The right hand graph shows the close correlation between Groundwater levels and Streamflow.

Figure 8: Lambourne - groundwater level and streamflow - 2010

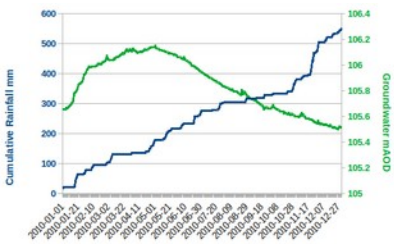

Figure 9: Lambourne - groundwater and cumulative rainfall - 2010

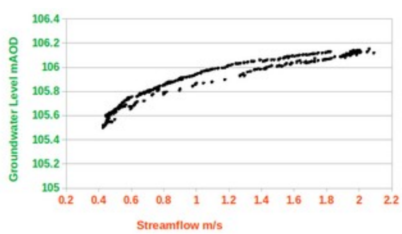

Figure 10: Lambourne - correlation between groundwater level and streamflow -2010

How does this compare to the Letcombe Brook catchment?
The contrast between the Lambourne's response to groundwater and rainfall input and that of the Letcombe Brook's response for the **latest storm period 17th Nov - 15th Dec 2024** is shown below.

The first series of graphs (Figures 11 ,12, 13) shows the **Lambourne River** responses. Figure 11 shows the close temporal relationship between groundwater level and streamflow level rising together with a slightly slower response of the river as might be expected. Figure 12 shows a similar relationship between cumulative rainfall and streamflow - but this rainfall input “mirrors” the groundwater level implying rapid infiltration through the freely draining soil into the chalk aquifer. Figure 13 shows how well correlated streamflow is to groundwater levels.

Figure 11: Lambourne - groundwater level and streamflow - Nov-Dec 2024

Figure 12: Lambourne - streamflow and cumulative rainfall - Nov-Dec 2024

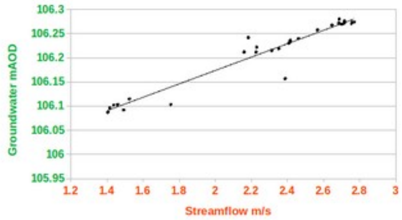

Figure 13: Lambourne - Correlation between groundwater level and streamflow - Nov-Dec 2024

Contrast the above to the responses of the Letcombe Brook for the same period below. Figure 14 shows streamflow rising well before any rise in groundwater level implying that something other than groundwater level is forcing streamflows to rise. Figure 15 again shows rising streamlevels in response to rainfall input - but this time (and bearing in mind the slow groundwater level response) this implies surface addition of rainfall to streamflow via overland flow over the impervious clay layer. Figure 16 shows the complete mismatch between Streamflow and groundwater levels.

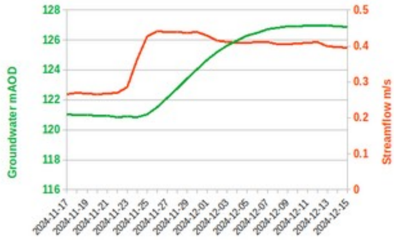

Figure 14: Letcombe Brook: Groundwater level and streamflow - Nov-Dec 2024

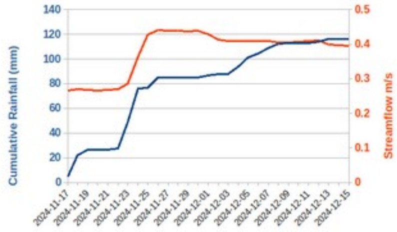

Figure 15: Letcombe Brook: Cumulative Rainfall and Streamflow - Nov-Dec 2024

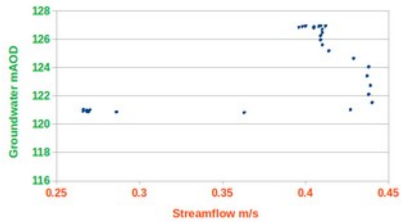

Figure 16: Letcombe Brook: (non) Correlation between groundwater level and streamflow - Nov-Dec 2024

The relationship between Rainfall and Groundwater Level

When rain falls onto the Downs above the Lambourne river and Letcombe Brook, the proportion that infiltrates the soil surface to add water to the underlying chalk aquifer depends highly on the permeability of the overlying soil layer. The freely draining chalk soils of the area around Upper Lambourn have infiltration rates that are highly variable depending on the exact composition of the soil but are an order of magnitude higher than infiltration rates on the heavy clay soils of the Letcombe Brook catchment where heavy clay with poor structure has very slow infiltration rates between 0.25mm-2.5mm per hour. Moderately compacted clay has slow infiltration rates between 2.5mm-6.4mm per hour.

Evidence of these slow infiltration rates can be seen in the fields either side of the Ridgeway, where ponded water in the ruts created by heavy farm machinery remains there for weeks during the winter. But infiltration must occur as shown by the groundwater level rising after rain - but how substantial the rainfall is will define how much of that rainfall infiltrates into the chalk aquifer and how much runs off the sloping fields into the Letcombe Brook and its side tributary springs.

Is there a rainfall rate above which we can predict that overland flow into the Brook will occur?

Figure 17 shows daily rainfall with the rise in groundwater level that might be expected to occur with this rainfall input. The total rainfall between 17th and 26th Nov. was 85mm. There is an expected delay before the first 3 days rainfall is seen in the groundwater level rise. The groundwater level rises from 121 mAOD to a maximum of 127 mAOD before falling slightly.
The difference between the input of 85mm and rise in groundwater level of 6m is due to the porosity of the chalk which says how much water the chalk can hold and

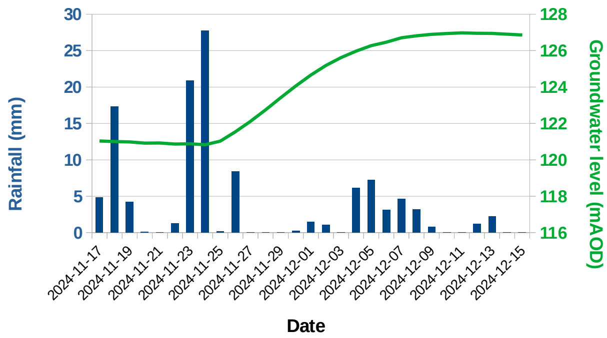

Figure 17: Daily Rainfall and Groundwater level for the period 17 Nov-15 Dec 2024

typically has a value of 20-45% and it's Specific Yield (Sy) which represents the proportion of water that contributes to the water table when infiltrated. The Specific Yield of Chalk south of Letcombe Bassett is approximately 0.0075[1] or 0.75%, and the rise in the Water table is given by Rainfall /Specific Yield. The 85mm rainfall input and 6m water table rise however implies a Specific Yield of 0.014 (1.4%) <u>if all rainfall percolated down through the soil surface and chalk</u>. There is little information about Specific Yields in our region but a Median Storage Coefficient (S) of 0.0036 is documented for the North Wessex Downs[1] and in unconfined aquifers Sy ≈ S.

However, the Specific Yield that represents the proportion of water that contributes to the water table is applicable to the chalk only and does not include the effect of the overlying soil surface. This may have minimal effect when the overlying soils are freely draining as for the Lambourne catchment and probably allow most of the rainfall through to the chalk. But the clay soils of the Letcombe Brook catchment not only provide a "brake" on the overall rainfall infiltration rate to the Chalk layer but splits the incoming rainfall into rainfall that reaches the chalk surface through the soil layer and that propotion that either pools on the surface, runs off downslope or evaporates. This means only a proportion of the 85mm incoming rainfall can be used in the Rainfall / Specific Yield to describe groundwater level rise. What the proportions that go to runoff and to groundwater recharge are not known at this juncture.

Further investigation into Rainfall-Streamflow-Groundwater interaction

Revisiting the period 17th November - 15th December 2024, we have the rainfall, streamflow (multoplied by 10 to put it on the same graph axis) and groundwater comparison. The shaded areas are separately discussed further on in the text.

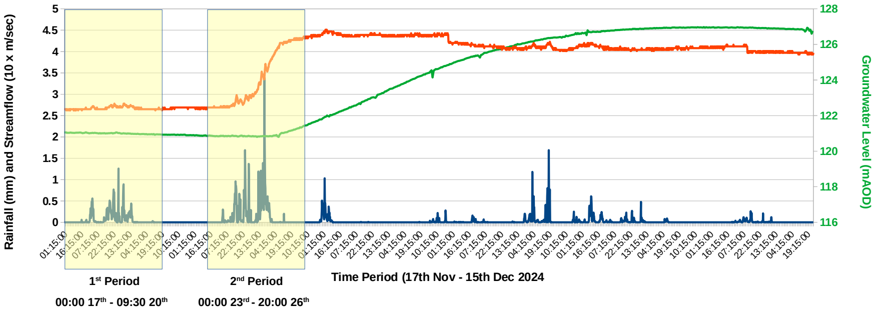

Figure 18: Reprise of Figure 17 with investigated periods shown in yellow

First Rainfall Period (00:00 17th Nov. - 09:30 20th Nov. 2024)

Looking more closely at the first rainfal period it can be seen from Figure 19 that there is a Brook baseflow of 0.265 m/sec (see NB below) that is increased by rainfall inputs. These rainfall amounts increase the flowrates but once rainfall ceases, the streamflow returns to the previous baseline level.

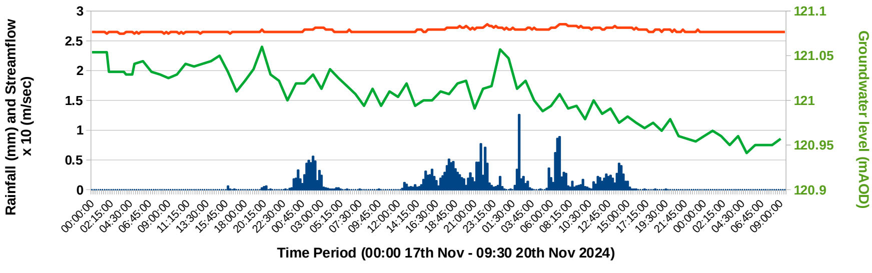

Figure 19: First Period: Rainfall, Streamflow and groundwater level

NB: The streamflow values have been multiplied by 10 to enable them to be shown on the same scale as rainfall.

Looking more closely at the streamflow during this period of falling groundwater level as shown in Figure 20, there are rises in both groundwater levels and streamflow values after periods of rainfall - but how significant are these?

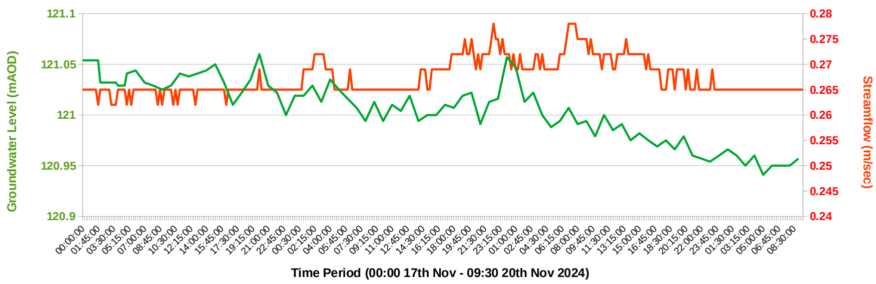

Figure 20: First Period: Streamflow (expanded) and Groundwater level

As noted previously in the last section - the total 85mm rainfall input equates to a 6m rise in water table - the change of 0.1m between the beginning and the end of this period in the water table is equivalent to 0.001 mm rainfall and implies an insignificant change in streamflow due to the falling groundwater. This will be even smaller when the actual rainfall that percolates into the chalk as been separated from the runoff/pooling proportion that the clay layer creates. Streamflow itself only has a range of 0.015 m sec^{-1} during the whole period. This was acompanied by a range in stream level of 0.005m (5mm) which for a 3m wide Flat V weir amounts to a change in volume flow of 0.015 m^3 per second.

The tentative conclusion is that the rainfall during this period (26.33 mm), which averages 0.925 mm per hour for the time periods containing rainfall, and an overall average of 7.74 mm per day, is evidently, from the graphical data, insufficient to affect either streamflow or groundwater level. Potential evaporation (PET) over well watered grass for this period peaked at 1mm per day on the 18th [1] and would have been insufficient to explain where the 26.33 mm of rainfall went. An explanation would be that at this rainfall rate, physical resistances in the vegetation and soil, including surface tension are strong enough to slow both the downward infiltration through the soil and the chalk and the overland flow into the streams. The rise in streamflow (and stream level) is probably due to a combination of local overland runoff into and rainfall onto Arabella's Lake, and the observed general downward trend in groundwater level is expected if no water is percolating downwards.

Second Rainfall Period (00:00 23rd - 20:00 26th Nov 2024)

Here we see a different response to rainfall, at least in the latter stages of this period. Rainfall average for time periods with rain was 1.56 mm per day - nearly 3 times the average evaporation rate for this time of year (0.6mm). This implies that there was a net surplus of rainfall that could either go to overland flow from the hillside slopes into the stream or from increased flow out of groundwater springs as the rainfall percolated down the chalk horizon to increase groundwater levels. Both of these actions seem to have occurred with streamflow increasing (again scaled by x 10 in the graph) during and immediately after the initial periods of rainfall at the same time as groundwater level actually decreased slightly. The final rainfall period with its maximum rainfall of 3.25 mm during one 15 minute period both increased streamlevel and after the delay to allow rainfall to percolate down - groundwater level begins to rise significantly - although the 0.8m rise in groundwater during this period equates to just 12mm of rainfall having percolated down through the chalk aquifer as groundwater levels continued to rise to a maximum of 126.975 mAOD on 11th Dec 2024 before beginning to descend. The total rainfall for this period was 50mm over the period of 3.84 days. Evaporation at 0.6mm per day would have left 47.7mm of incoming rainfall separated into infiltration and runoff proportions. With an estimated 12mm of rainfall having percolated into the chalk during this time - this appears to leave 35.7mm to pool or runoff during this period. This is almost certainly an overestimate of the water available for input to the Letcombe Brook. The problem is that while rainfall and pooling/runoff occur at more or less the same time, groundwater recharge is occurring on a completely different time-scale - with water only joining the measured groundwater level after a period of perhaps days, weeks or months depending on the particular structure of the underlying chalk layer which has a typical composition of the types shown in Figure 22. Each of these conduits for water have different infiltration rates from thousands of metres per day (Caves) to around 1 metre per year for the rock matrix. The proportions of these conduits in the chalk will therefore also affect the recharge rate to the measured groundwater level.

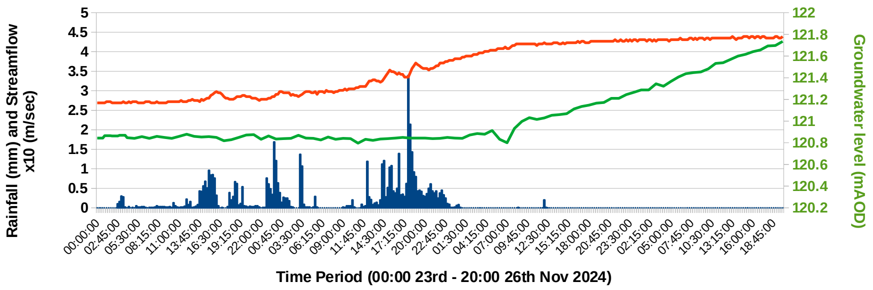

Figure 21: Second Period: Overall Rainfall, Streamflow and Groundwater level

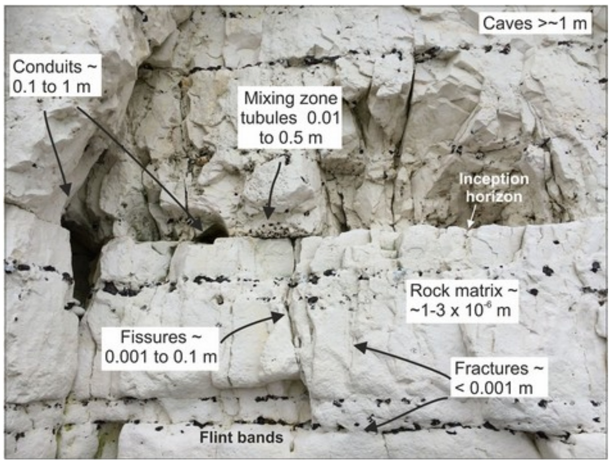

Figure 22: Typical composition of chalk with their aperture sizes

For the overall period: 17th Nov. - 15th Dec. 2024

The change of 6.175m in groundwater level would equate to 88.5mm of rainfall percolation into a chalk aquifer with no soil surface, when using the Specific Yield of 0.014. The rainfall over the period 23rd Nov. to 11th Dec 2024 (the period of increasing groundwater level) was 86.55 mm. This would appear to suggest that nearly all the rainfall percolated into the chalk. During the same period streamflow increased from 0.265 m/sec to 0.397 m/sec.

If however, the literature value of Specific Yield of 0.0075[2] is used, the groundwater change in level of 6.175m then equates to 46.3 mm of rainfall producing this rise providing this amount managed to percolate through the clay soil layer, leaving nearly half the rainfall total (40.25mm) available for overland runoff and ponding before and during the rise in the groundwater level. Evaporation from the soil and vegetation cover for the 29 day period (Nov: 0.6mm per day, Dec: probably less - 0.5mm per day) could have amounted to 15.9mm - this would include evaporation from the ponded water which would also be subject to gradual infiltration through the clay to the chalk beneath leaving 24.35mm for overland flow/runoff into the Brook.

But equating the relationship between runoff into streams and groundwater recharge with average daily or period rainfall hides the problem. Above a certain rainfall threshold as indicated above, groundwater recharge continues at a near constant rate no matter how much rain falls - it is a combination of ifiltration rates through the clay soil and then through the chalk horizon - these are fixed rates dependent on the structure of the clay and chalk horizons. Runoff from slopes are not subject to any physical resistance other than gravity and slope angle. Once a certain resistance provided by surface soil particles and vegetation is exceeded, runoff is decided entirely by rainfall input - the higher the rainfall the larger the runoff.

Discussion:

While Min-Till farming practice may, through compaction of the clay below the overturned soil layer by both natural movement of soil particles to conglomerate when wet, and heavy farm machinery furthering this process, increase the impermeability of the local clay soils, it is not the major factor - which is the general impermeability of these heavy clay soils - especially during frequent and intense storms.
This impermeability may not be a complete barrier to rainfall percolating into the chalk beneath, - but it is certainly a slowing action. Nevertheless, groundwater levels beneath this clay layer do increase. How much of this is horizontal flow from other areas in the Chalk aquifer is unknown?

The contrast between the Lambourne river level response to groundwater and rainfall compared to the Letcombe Brook's response indicate that our local flooding from the Letcombe Brook is largely dependent on rainfall input rather than groundwater. Groundwater provides a baseline flow that does increase as rainfall percolates slowly down through the superficial clay layer - below which the percolation rate may increase significantly if the chalk in the aquifer is very wet. But the data evidence points to a mechanism governed by rainfall where heavy and frequent storms create overland flow from sloping fields initially on the Downs to rapidly augment Letcombe Brook flows.

Nevertheless - there are observations above that do not seem to fit the narrative. Why does the Letcombe Brook Streamflow in Figure 15 above not respond to the rainfall input from 4th Dec 2024 when an average of 4.2mm of rain fell on each day between 4th and 9th December. Is there a threshold rainfall rate below which overland flow doesn't happen? Figures 19 and 20 from the First Rainfall Period analysis seems to indicate that a rainfall rate of 1mm per hour or even a peak rainfall of 2mm per hour is insufficient to add substantially to either streamflow or groundwater.

Whereas, for the Second rainfall Period, an average rainfall for the period of nearly 2mm per hour peaking at nearly 3.5mm per hour (Figure 21) did both affect streamflow and groundwater level. The rainfall rates we are seeing in recent storm periods are well above these thresholds and therefore increases to both groundwater and overland runoff feeds into the Letcombe Brook are to be expected - although they may peak at different times with the quicker response runoff amount subsequently being augmented by the slower response groundwater feed.

It is obvious that there are two factors we cannot control or change within the required timeframe for flood prevention.

1. Global Warming and Climate Change leading to more frequent intense rainstorms.
2. The Clay soil surface of our region.

This lack of control over these two important factors imply that any solution to the flooding has to be "engineered" in the sense of creating mechanisms that slow the passage of water from the Downs down the Brook, create a Brook structure that can cope with these intense and immediate storm flows by silt and edge vegetation clearance to increase capacity, and remove obstacles that create back-flow problems. Many of these problems have been through a lack of maintenance of water courses, remedial actions taken by individuals to solve a local problem - causing problems upstream or further downstream, and many solutions created historically to deal with a climate markedly different to that experienced now and in the future.

Actions such as rotational deep ploughing every "nth" year before the winter storms with furrows following contours rather than downslope would create better conditions for infiltration and retention of water during heavy rainstorms in the furrows. This may mean changing to Spring sown crops to avoid the period when lack of infiltration and low evaporation of water in the furrows would prevent Winter sown crops.

An alternative action would be to excavate "V" shaped trenches at the downslope edge of fields. 5 mm of rainfall falling on 1 hectare of an impermeable clay surface sloping field would produce 50m^3 of runoff water. A 1m wide by 1m deep

“V” shaped trench at the downslope edge of this field area could accommodate 50 m^3 of water before overtopping. Rainfall interception by the short grass vegetation and surface soil particles could be as high as 25% although during heavy rain, interception rates are lower as the grass and soil reach saturation quickly. For an interception rate of 20%, the trench could accommodate the runoff produced by 6.25 mm of incoming rainfall. The depth of trench would expose the underlying chalk strata and allow direct infiltration into the chalk. Porous borehole pipes inserted into the base of the trench could provide a “drain” into the lower chalk. This is a feasible operation as evidenced by the extensive field edge trenching around the edges of fields south of Wantage believed to be to prevent vehicles used for hare-coursing to get onto the fields.

The different interactions of these three interlinked variables of rainfall, streamflow and groundwater in these two adjacent catchments (the Lambourne and Letcombe Brook) means that any flooding remedial solution plan has to be also “tailored” to the particular form of interaction seen in the catchment i.e. a remedial plan for flood prevention for one stream may not be applicable for an adjacent stream and may well exacerbate the problem.

References

1. https://www.data.gov.uk/dataset/7b58506c-620d-433c-afce-d5d93ef7e01e/environment-agency-potential-evapotranspiration-dataset

2. https://www2.bgs.ac.uk/groundwater/waterResources/thames/chalk.html