Investigating water turbidity of the River Rhee and Cam 2021-22

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Summary

Having eliminated persistent algal blooms as the major cause of high turbidity on one affected reach of the River Rhee, there are two key questions that remain: 1) is high turbidity in low-flow summer periods simply caused by soil in suspension sometimes exacerbated by Signal Crayfish activity, or are there other important factors operating? 2) if there are several factors involved, what is the relative importance of each?

The Rhee often has high turbidity that can severely reduce light penetration to the river bed in several reaches and will have deleterious ecological effects especially on biodiversity.
In the absence of any detailed reports on turbidity in the Rhee and Cam, a survey was undertaken to record levels from Ashwell Springs to Clayhithe (downstream of Cambridge). This survey proposal was partly stimulated by a report from WASP – Windrush Against Sewage Pollution – that one common feature of WASP's local rivers suffering turbidity issues is said to be sewage pollution and a potential link with high phosphate inputs from sewage treatment works (STWs).

The 2020 Greater Cambridge Chalk Streams Project Report (Ruth Hawksley, Wildlife Trust BCN and Rob Mungovan, Wild Trout Trust) lists several recognised factors contributing to the turbidity, some affecting specific reaches: historic dredging; silty river beds; collapsing banks; years of herbicide control leading to near-vertical earth banks being under-mined by Signal Crayfish; Signal Crayfish constantly mobilise bed sediment around May-October; increased soil runoff from land during high rainfall and high flows resulting in scouring and eroding banks, and resuspension of bed sediment.

Observations on the presence of Signal Crayfish made during the turbidity survey September to December 2022 in the Rhee, and Essex Cam showed that this non-native invasive it is now clearly more widely distributed than suggested by records in the National Biodiversity Network Atlas, and is now abundant in some stretches.

High turbidity extends into the River Cam flowing through Cambridge. The murkiness and discoloration makes the river very unattractive visually.

Measuring turbidity by eye is unreliable. Therefore, on 26-28 September 2022 at eleven sampling sites from Guilden Morden to Ashwell to Clayhithe, also one on Bourn Brook and one on the Essex Cam, turbidity was measured with a OD600nm spectrophotometer, and also as Nephelometric Turbidity Units (NTU, an industry standard)), using a lab-based nephelometer (grateful thanks to Susannah Salter, Cambridge University), and values were compared with in-field measurements of "depth to invisibility" (DTI) using either a chrome rake head or Secchi disk attached to an extendible pole. Strong negative correlations were achieved between results from the NTU method and each in-field method.

Including some observations earlier than September 2022, the Rhee upstream of Ashwell End the river water was clear. Turbidity started just downstream of Ashwell End. Stretches near Guilden Morden, and from Wendy to Harston were particularly turbid, Bryon's Pool often so. Sheep's Green was consistently clearer than Byron's Pool, being somewhat turbid for several weeks in early to mid-summer. The Cam towards Bottisham Lock was often very much clearer. In the summer months, high turbidity could occur for long periods <u>in the absence</u> of soil runoff or high river flows. The Essex Cam upstream of Hauxton Mill was moderately turbid, and is now densely colonised by Signal Crayfish and phosphate concentrations in the

river are high. Bourn Brook was usually the clearest. On 27 December four days after high flows peaked, the entire stretch of the Rhee and Cam from Barrington to Bottisham Lock (Waterbeach) was highly turbid.

Despite very high nitrate and high reactive phosphate concentrations in the lower Rhee and Cam (within the 'Cam and Ely Ouse Sensitive Area (Eutrophic) designated under the Urban Wastewater Treatment Directive (UWWTD'), simple microscopical examinations of water samples at Barrington showed that a persistent algal bloom was <u>not</u> the cause of summer turbidity. Suspended soil of varying particle sizes seemed to be one major factor but it was not confirmed that a brown haze in sampled water in which larger soil particles had sedimented was wholly due to colloidal soil. No other factors were investigated. Arrangements to make similar examinations for unicellular algae further downstream were unfortunately delayed and none was made.

About 68% of the Rhee water downstream of Haslingfield STW and 39% of the Cam water downstream of Cambridge STW were estimated to be the effluent discharged from STWs (August 2019). Many sewage treatment works discharge into the Rhee directly or indirectly, several of them without permit limits for Phosphorus. Further studies are needed during 2023, to investigate algal blooms and other potential factors including effluent. By liaising with the Environment Agency, it is hoped that specialist expertise from within the EA can be requested.

Background

Turbidity is the lack of clarity of water and it is an important factor in water quality.   From the literature, materials that can cause water to be turbid include: clay colloids, silt, sediment from bank erosion and resuspension, tiny inorganic matter and coloured, dissolved organic matter, waste discharges, chemical precipitates, zooplankton, phytoplankton including green and blue-green algae, and other microscopic organisms.

The Greater Cambridge Chalk Streams Project Report (Ruth Hawksley and Robert Mungovan,2020) lists several recognised factors contributing to the turbidity in the Rhee: historic dredging has removed gravel leaving the bed degraded and silty; lower reaches are very silty with collapsing banks following the weir removal at Harston); between Barrington and Harston many years of herbicide applications for flood control eradicated the once extensive beds of Reed Sweet-grass resulting in near-vertical earth banks being under-mined by Signal Crayfish; from Harston Mill to Hauxton Junction Signal Crayfish are believed to be a major source of the river's high turbidity as they constantly mobilise bed sediment; increased soil runoff from land during high rainfall and high flows, scouring and eroding banks, and resuspending bed sediment.

Most of the Rhee, arising at Ashwell and merging with the Essex Cam at Hauxton Junction, and a section of the Cam from Hauxton Junction have prolonged periods of high turbidity, more so in the summer. They can be unrelated to high rainfall events leading to river bed and bank scouring. In the lower reaches with water depths often 1.5m+ "Depth to invisibility" (DTI) can be as low as ~50cm even during dry, low-flow periods in summertime.

It is well documented that high turbidity is harmful to fish and other aquatic life, and the two professional aquatic conservationists on the CVF committee (Ruth Hawksley and Rob Mungovan have been concerned for several years: *"high turbidity… another factor massively impacting the Rhee and onto the Cam"* (Rob Mungovan pers. comm.).

The three reasons for studying turbidity in 2022 were:

a) to make accurate measurements of turbidity from the upper Rhee to the lower Cam using a lab-based nephelometer

b) to determine if a rake head or 8cm / 20cm diameter Secchi disk attached to a long pole was a useful in-field tool to measure DTI, and to check if the correlation with Nephelometric Turbidity Units (NTU) was sufficiently strong to enable the in-field, inexpensive, method to be good proxy.

c) to determine if algal blooms were a likely part-cause of the high turbidity.

WASP – Windrush Against Sewage Pollution https://www.windrushwasp.org/ – recently published a photograph on the River Windrush of disturbingly poor-quality water in 2020, comparing it with one of good quality taken in 2009 (in similar conditions).

Photos: River Windrush in 2009 and again in 2020 in similar conditions

Included in their blogs was a mention specifically of sewage pollution and high phosphate concentrations from STWs as potential factors. The relevant section on turbidity is copied here:

Turbidity is a key area of work because it has been such a contentious topic with river campaigners for many years with the first rumblings of concern starting in the late 1970s with the observation of a summer 'milkiness' which has developed to an almost year-round grey/brown murkiness with some clearer periods in winter.

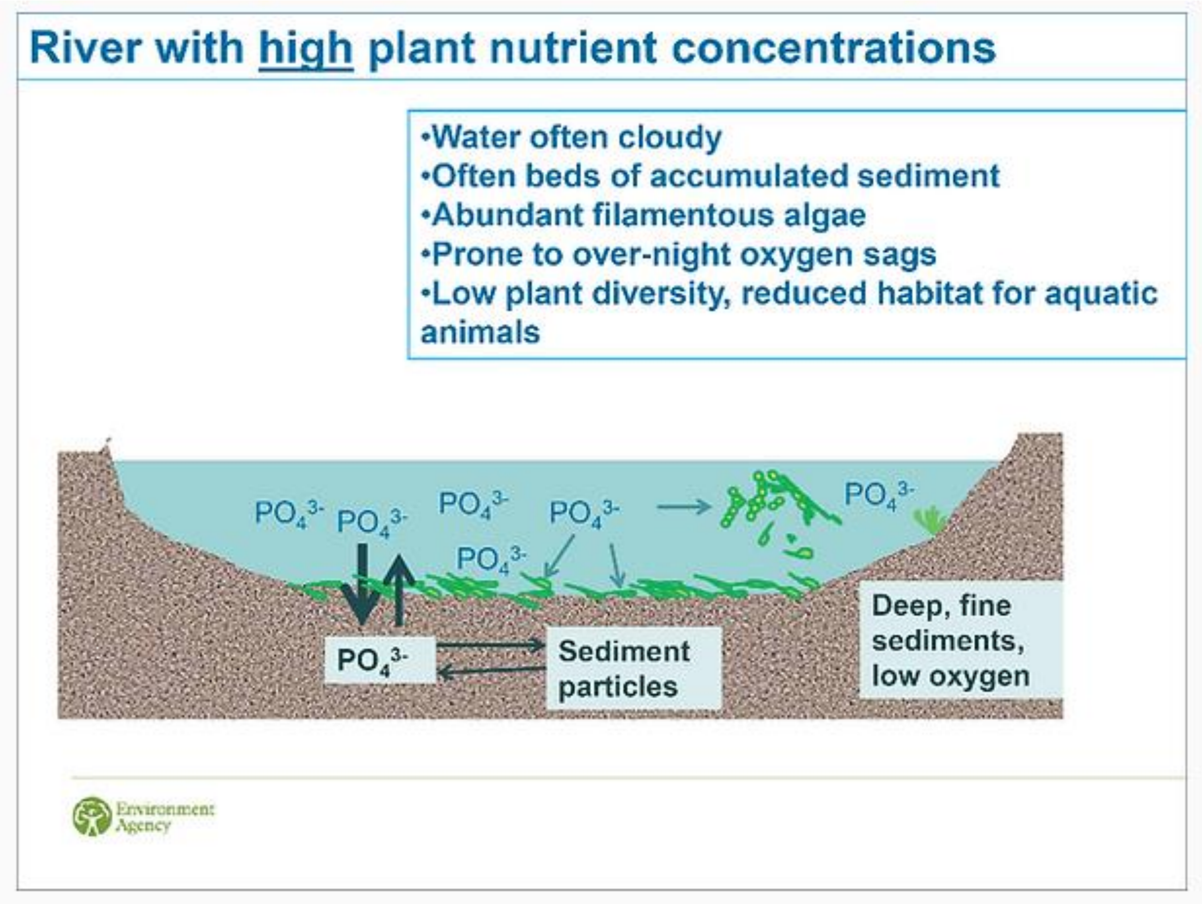
The Environment Agency has tried to convince the public that this is a natural phenomenon and even that it is attributable to a geological fault which separated it from clearer rivers like the Coln. There was no scientific study conducted to back up that claim and the fact that the river Coln is now suffering similar turbidity problems after years of clear water appears to *throw all of the Agency's explanations into doubt.*

One common feature of the rivers suffering turbidity issues is sewage pollution and a potential link with high phosphate inputs from STWs.

In a public meeting (Professor Peter Hammond, pers. comm.), the EA blamed a geological fault and Thames Water said it was unlikely to be due to sewage pollution with agriculture, runoff and crayfish getting the blame. Thames even funded a short study by the Centre for Ecology and Hydrology at Wallingford which could not firmly point the finger Prof. Hammond also noted in an email to us that *"turbidity was the first symptom we noticed with the Windrush and we pursued that for several years. Some of your photos are very reminiscent of the Windrush."*

The following slide has been copied from the WASP website, and the comment by WASP is noteworthy: *The Environment Agency Slide used to explain the effects of high nutrient levels even identifies turbid water as a consequence of high nutrients.*

To be fair to the EA, CVF does not know if the point 'water often cloudy' refers to a specific cause such as an algal bloom, or to an unknown condition. This issue needs to be clarified.



Pictorial evidence of turbidity

Upper Rhee – very low turbidity at Ashwell End, 07/09/21

Also, at Ashwell End 20/10/21

Downstream of Ashwell End, red marker shows where obvious turbidity is present 20/10/21

Downstream of Ashwell End, obvious signs of turbidity 20/10/21 (see map above)

Rhee – high turbidity, grey-brown, at HOOKS, Potton Road, near Guilden Morden,

07/09/21

Upper Rhee – high turbidity at HOOKS, Potton Road, near Guilden Morden, 03/08/22

Rhee – high turbidity at Malton, 01/08/22

Rhee – high turbidity at Bulbeck Mill pond, above Barrington weir, 31/10/22

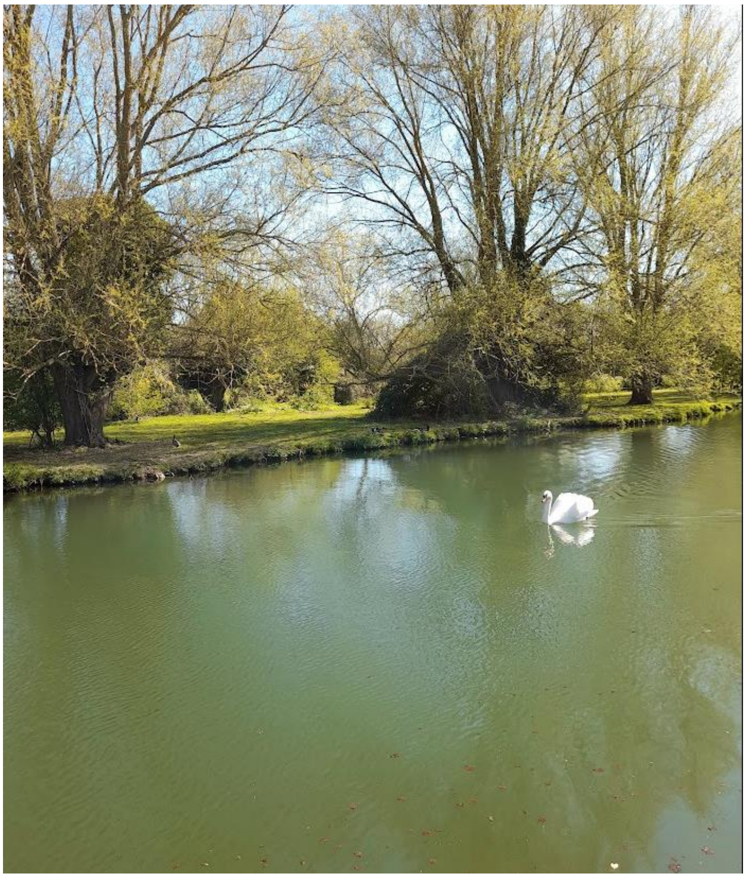
Rhee - turbidity high at BOOT, Boot Lane footbridge, Barrington, below Barrington weir, 06/10/22

Clearer water exiting the Essex Cam at Hauxton Junction (Rhee flow from lower right)

Cam, upstream of weir at Byron's Pool, 28/07/21. Substantial amounts of benthic filamentous algal growth, more easily seen in the shallower area nearer bank

Sheep's Green 23/04/21

Sheep's Green 23/04/21 one minute earlier than above, angled towards sun, apparent colour difference

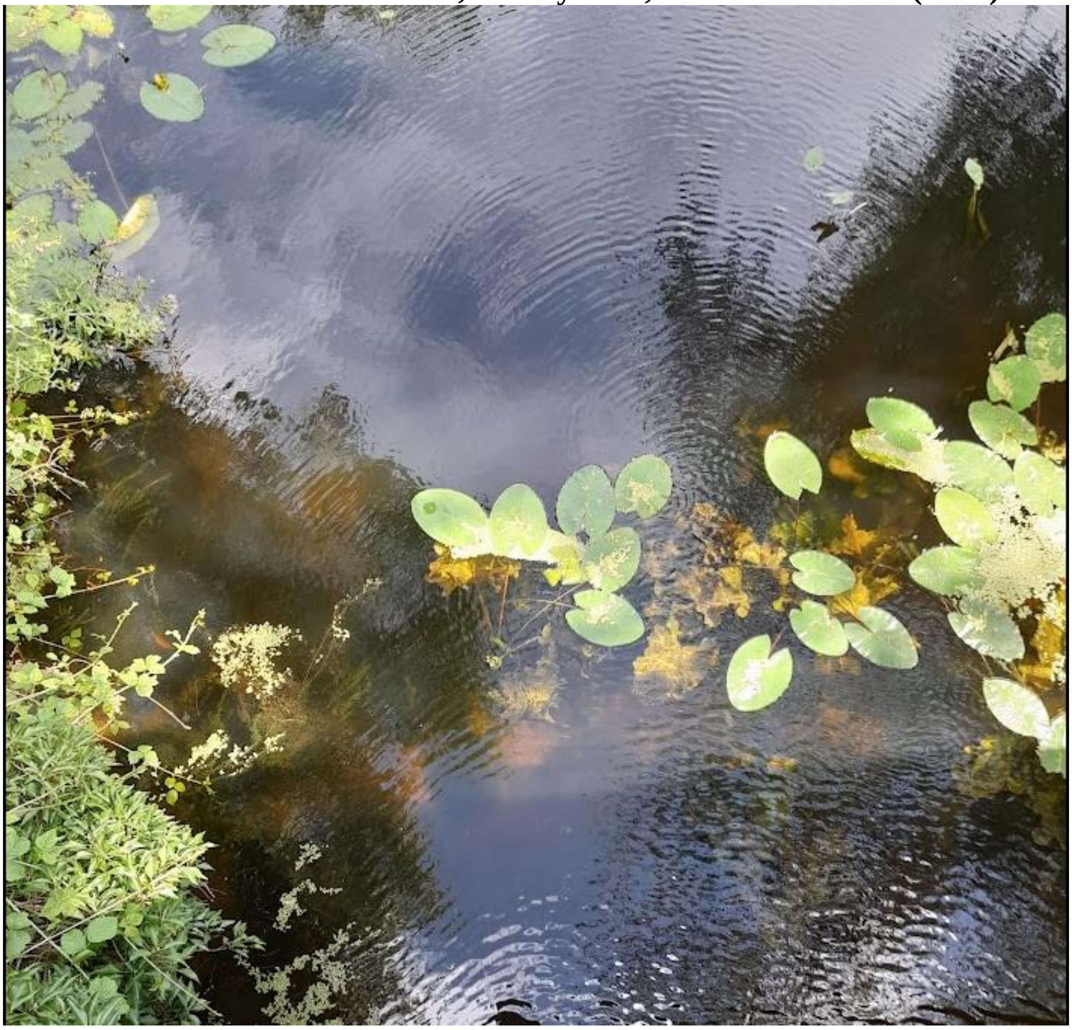


Cam - Sheep’s Green, 21/07/21

Cam - low turbidity Horningsea-Clayhithe 05/08/22

Bourn Brook high turbidity, DTI 30cm, 03/03/2022, 'normal' turbidity caused by soil suspension during very high flows

Bourn Brook - same site as above, 29 July 2021, clear down to bed (1.2m)



Hauxton Mill stretch, moderate turbidity - upstream of weir 28/09/22

Methods

Turbidity measurements

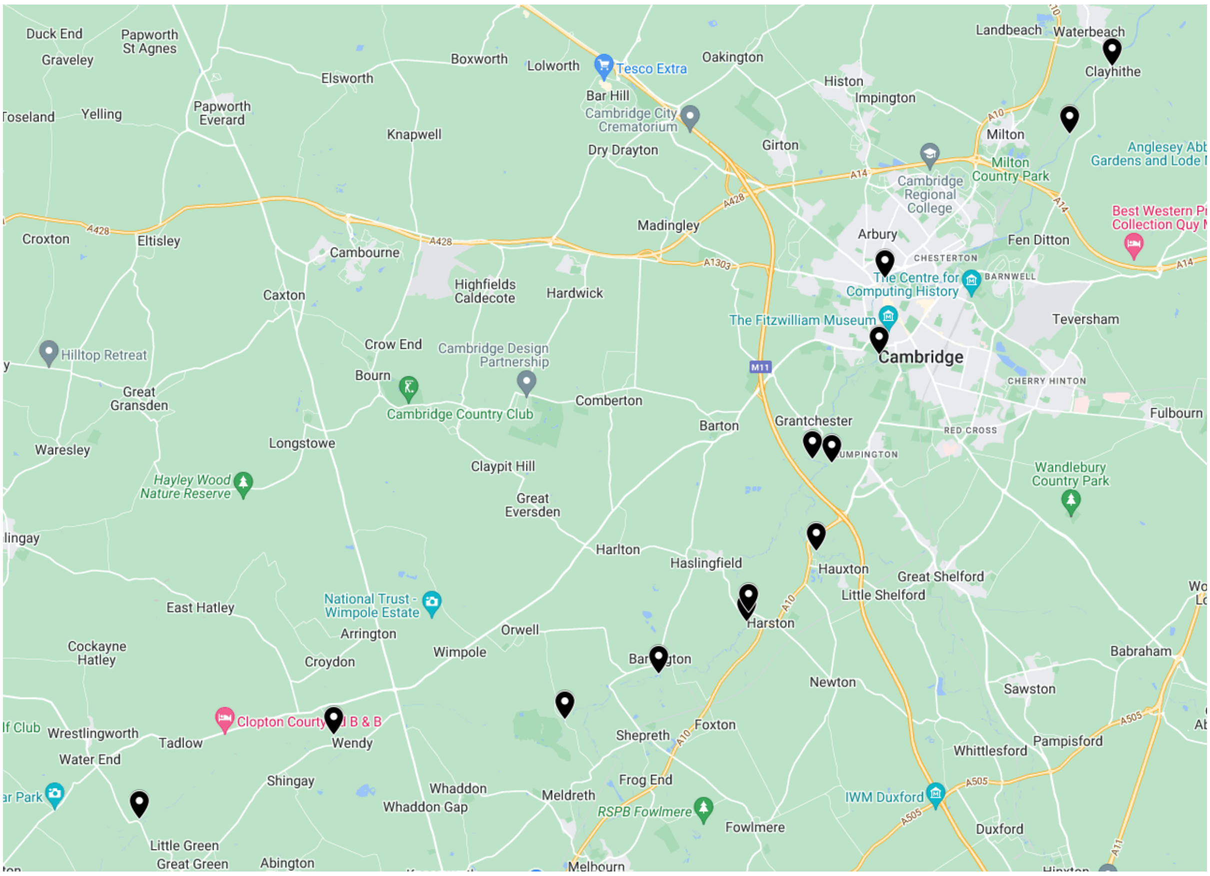
It is well-known that an objective view of turbidity cannot be made by eye. To overcome this problem, in collaboration with Susannah Salter, Department of Veterinary Medicine, University of Cambridge, CVF took samples at several river sites 26-28 September 2022, and turbidity was measured by the OD600(nm) method and with an accurate nephelometer. In addition, measurements of “depth to invisibility” (DTI) were made using a stainless steel, 19cm wide rake head attached to an extendible pole, and also with 8cm and 20cm diameter home-made Secchi disks, again attached to the end of an extendible pole.

Where the DTI was greater than the vertical depth of the river water, the pole was angled such that a greater depth of water could be measured in an attempt to attain DTI. For these measurements the pole was angled so that the rake head was held just above the river bed allowing equal sampling of water at each layer of depth compared to when the pole was held at or near the vertical. The DTI was measured by observing along the pole, which required lying on the ground at HORN and JESU. An adjustment was needed at Hauxton Mill to account for the DTI being measured using a vertical string with the rake head at the end, but viewed from the bankside.

Turbidity measurements (DTI) in direct exposure to sunlight or in hours of darkness

At Byron’s Pool measuring DTI in the Cam in direct sunlight and several metres apart in shade showed no difference in value. There was also no difference in DTI between a measurement four hours after sunset shining a moderately strong torch vertically into the water and in daylight the next morning at the same site.

Six sites were chosen on the Rhee, five on the Cam, one on the Bourn Brook (DTI only) and one on the Essex Cam.



Sites in descending order of NTU

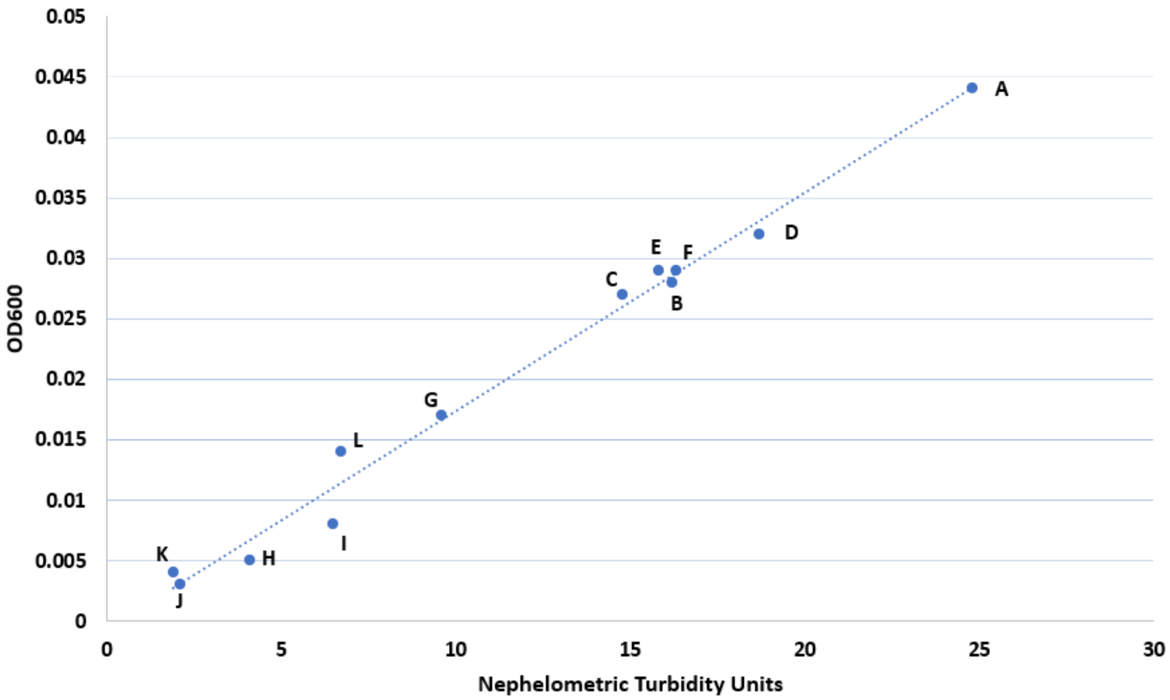
A Rhee - Guilden Morden
D Rhee - Barrington
F Rhee - Harston road bridge
B Rhee - Wendy
E Rhee - Harston Mill
C Rhee - Malton
G Cam - Byron’s Pool
L Essex Cam - Hauxton Mill
I Cam - Jesus Green
H Cam - Sheep’s Green
J Cam - Horningsea
K Cam – Clayhithe
M Bourn Brook, not sampled for NTU

Date	Sample code	Site code	Lat/Long	Site description	NTU	OD600	Depth to invisibility (cm)
RHEE Rhee (US Wendy)							
28/09/2022	A	HOOKS	52.093974, -0.146121	Rhee - Guilden-Potton Road, 100m D/S bridge	24.8	0.044	>20 [A]
28/09/2022	B	RHEWE	52.112318, -0.077261	Rhee - Wendy-Croydon Road bridge U/S Wendy	16.2	0.028	>20 [A]
RHEE Rhee (DS Wendy)							
28/09/2022	C	MORB	52.11588, 0.00478	Rhee - Malton Farm bridge D/S	14.8	0.027	69
27/09/2022	D	BOOT	52.125780, 0.038219	Rhee - Barrington, Boot Lane foot bridge	18.7	0.032	52
28/09/2022	E	SAGE	52.137132, 0.069506	Rhee - Harston Mill, Science Group - 100m U/S footbridge from car park path	15.8	0.029	66
28/09/2022	F	HHRB	52.13908, 0.06998	Rhee - Harston church, cemetery bank	16.3	0.029	> 35 [A]
CAM Cam							
28/09/2022	G	BYRO	52.171511, 0.099715	Cam - Byron's Pool usual sampling site	9.6	0.017	98
26/09/2022	H	SHEE	52.19518, 0.11623	Cam - Sheep's Green left bank	4.1	0.005	192[,B]
26/09/2022	I	JESU	52.21191, 0.11853	Cam - Jesus Green, from punts moored by pub	6.5	0.008	112[,B]
26/09/2022	J	HORN	52.243062, 0.184009	Cam - Horningsea, Dock Lane	2.1	0.003	> 460[A,B]
26/09/2022	K	CCHB	52.25782, 0.19924	Cam - Clayhithe, 50m D/S Cam Con moorings	1.9	0.004	> 460[A,B]
ESSEX CAM Essex Cam							
28/09/2022	L	HAUX	52.152551, 0.094007	Essex Cam - Hauxton Mill, main river 100m U/S weir	6.7	0.014	130
BOURN BROOK Bourn Brook							
28/09/2022	M	CFAB	52.17252, 0.09255	Bourn Brook - Cantelupe Farm	-	-	138 [B]

Site locations, NTU, OD600 and DTI measurements. [A] DTI was not measurable. [B] Pole was angled so that a greater length of water could be measured if DTI was greater than vertical depth.

Relationship between measurements made by NTU and OD600

A good spread of turbidity as shown by NTU was obtained across the sites. The measurements show that the OD600 measurements were an excellent proxy for NTU measurements - Pearson's correlation coefficient showed a very strong correlation. OD600 values ranged from 0.003 to 0.044; NTU from 1.9 to 24.8.



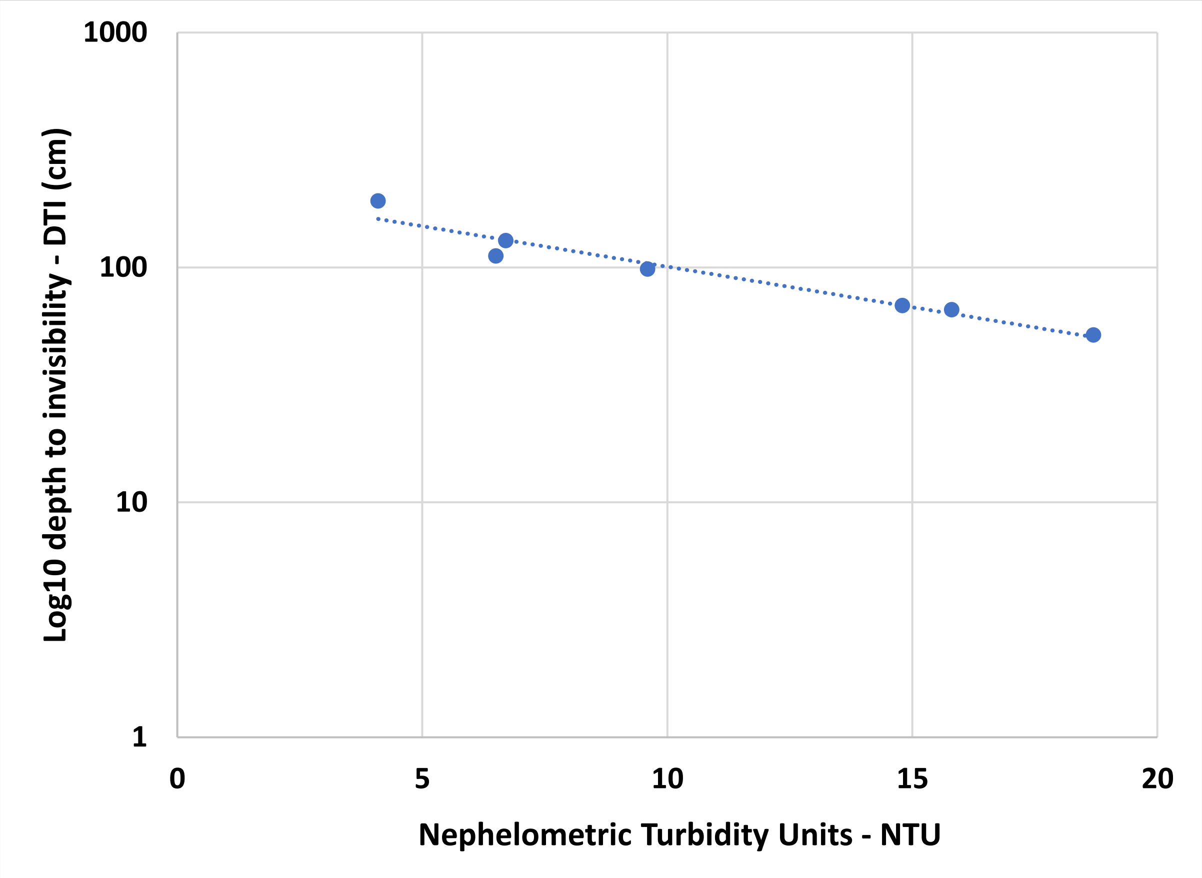
Turbidity measurements at 12 sites, by OD600 and NTU

Site A near Guilden Morden (upper Rhee) was most turbid and site K, Clayhithe (lower Cam) was least turbid. The sites with highest turbidity were all on the Rhee. The Essex Cam site near Hauxton Mill (L) had turbidity higher than at Sheep's Green (H).

DTI measurements

It was not possible to measure DTI at five sites where the water was too shallow or where deep water was so clear that even angling the pole through the water could not provide a measurement. Using the rake head method, DTI measurements varied from 52cm at Barrington (BOOT) to >460cm (HORN and CCHB, the latter being the furthest sites downstream). The single Bourn Brook site (CFAB)was noted to be clearer than most, which is consistent with numerous observations during the summer. At this site a DTI measurement was made but no sample was taken for NTU.

The seven pairs of measurements were plotted using a $\log_{10}$ scale for DTI against NTU.



Relationship between measurements of turbidity by DTI and NTU methods

Although the range of sites was restricted to those where a DTI could be obtained, the correlation was remarkably strong considering that determining the point where the rake head disappears (and reappears to give a mean reading based on the two values) would be considered to be a much cruder method.

Attaching the Secchi disks to the rake head provided a way to compare the two methods. The Secchi disks remained visible about 3cm further away than the rake head with no difference between diameters. Overall, the Secchi disk seems to have advantages over the rake head, as it can be lowered on rope vertically from a bridge as well as attached to a rake head.

Full dataset of turbidity measurements

The following table contains all the DTI measurements made over time mainly on the Rhee and Cam. The mean daily flow at the Burnt Mill gauging station between Haslingfield and Byron’s Pool is included for reference.

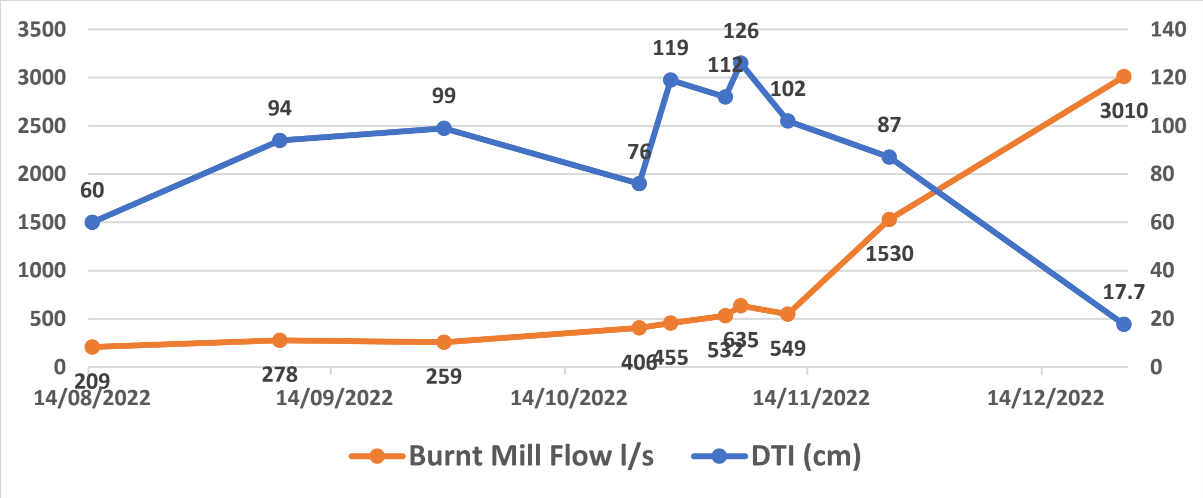
Date	**Site**	**DTI (cm)**	**Haslingfield (Burnt Mill) gauging station flow l/S**
31/10/2022	Barrington Bulbeck Mill Pond	80	353
16/05/2022	Barrington Boot	47	536
06/10/2022	Barrington Boot	83	255
27/10/2022	Barrington Boot	52	455
31/10/2022	Barrington Boot	72	353
31/10/2022	Barrington Boot	15*	353
05/11/2022	Barrington Boot	76	635
31/10/2022	Barrington Bulbeck Mill leat	76	353
14/08/2022	Byron's Pool	60	209
07/09/2022	Byron's Pool	94	278
28/09/2022	Byron's Pool	99	259
23/10/2022	Byron's Pool	76	406
27/10/2022	Byron's Pool	119	455
03/11/2022	Byron's Pool	112	532
05/11/2022	Byron's Pool	126	635
11/11/2022	Byron's Pool	102	549
24/11/2022	Byron's Pool	87	1530
24/12/2022	Byron's Pool	17.7	3010
14/08/2022	Byron's Pool upstream weir	76	209
03/03/2022	Cantelupe road bridge	30	2200
24/03/2022	Cantelupe road bridge	> 120	1210
28/09/2022	Cantelupe road bridge	138	259
27/10/2022	Cantelupe road bridge	> 148	455
24/12/2022	Clayhithe	36	3010
26/09/2022	Clayhithe, 50m D/S Cam Con moorings	> 460	266
28/09/2022	Guilden-Potton Road, 100m D/S bridge	>20	259
24/11/2022	Guilden-Potton Road, 100m D/S bridge	106	1530
28/09/2022	Harston church, cemetery bank	> 35	259
28/09/2022	Harston Mill, Science Group - 100m U/S footbridge	66	259
03/03/2022	Haslingfield STW U/S outfall	40	2200

02/11/2022	Haslingfield STW US outfall	87	396
24/11/2022	Haslingfield STW US outfall	76	1530
28/09/2022	Hauxton Mill, main river 100m U/S weir	130	259
26/09/2022	Horningsea, Dock Lane	> 460	266
24/12/2022	Horningsea, Dock Lane	36	3010
26/09/2022	Jesus Green, from punts moored by pub	112	266
01/08/2022	Malton Farm bridge	30	246
28/09/2022	Malton Farm bridge	69	259
28/09/2022	Rhee - Wendy-Croydon Road bridge U/S	> 20	259
12/08/2022	Sheep's Green	161	220
26/09/2022	Sheep's Green	192	266
11/11/2022	Sheep's Green	120	549
12/11/2022	Sheep's Green	174	492
24/11/2022	Sheep's Green	123	1530
08/12/2022	Sheep's Green	138	587
24/12/2022	Sheep's Green	21	3010

*At Boot on 31/10/22, the bed sediment was stirred with the rake and sediment allowed to surface before the measurement was made.

The chart below shows DTI at Byron’s Pool and river flow at Burnt Mill over time. Only the Burnt Mill flow is shown – the totals of the main inflows (Rhee - Burnt Mill, Essex Cam - Dernford and Granta – Stapleford, combined) might show a slightly different pattern.

- DTI was seen both to increase and fall with increased flow.
- Flow on 23 Oct was almost double of that on 14 Aug yet the DTI higher on 23 Oct.
- Flow on 5 Nov was three times that on 14 Aug yet water clarity was the best in the period.
- As expected, by 24 Dec with many field soils saturated and ditches filling, a very high flow around that date resulted in markedly high turbidity, the water colour browner than on earlier occasions indicating obvious movement of soil.



Thus, river flow without considering interacting factors has little meaning.

Possible causes of the turbidity

It has already been mentioned earlier that large amounts of soil can be transported down the river in winter high flows. It is clear that in 2022 soil runoff from land and from ditches was not contributing to high summer turbidity, as 2022 had a prolonged period of summer drought with no rainfall for weeks, ditches were dry, and soil moisture deficits became very high.

In low flows at other times, exactly how far downstream any suspended soil will travel before dropping out needs expert judgment.

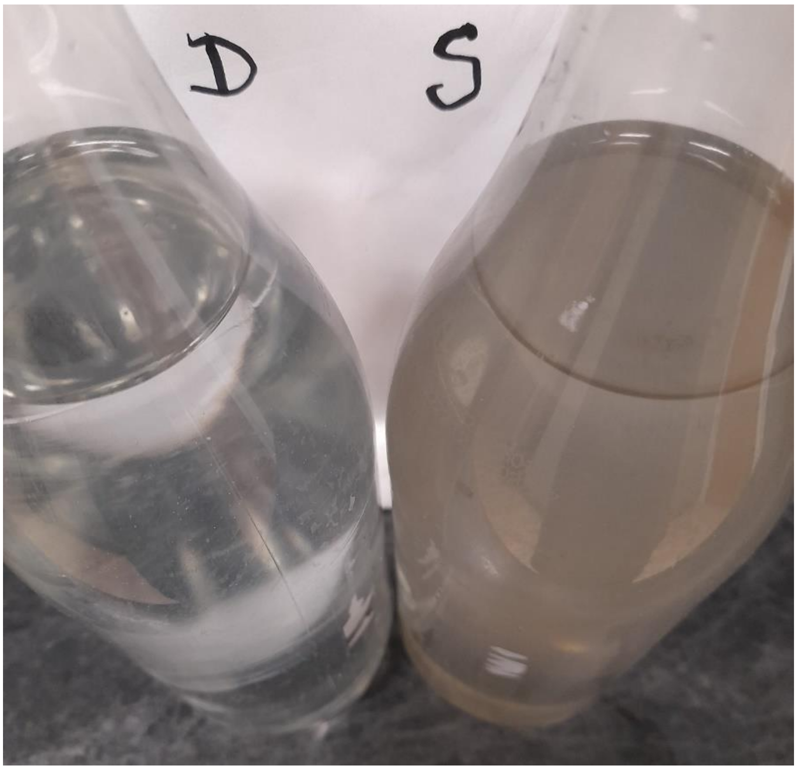
<u>Signal Crayfish activities</u>

Bank burrowing, eroding of banks and bed disturbance by Signal Crayfish will provide a constant source of soil material in the warmer seasons.

<u>Physical appearance of turbid water</u>

Sample of Rhee water was taken at BOOT (Barrington) on 7 October. Sampled water in one litre bottles were observed for up to 36 hours. After 30 minutes, particulate brown material had dropped out, and after 2 hours, most of this type of material had been deposited at the base of the bottles. A brown haze persisted. After the base of the bottle with deposit was photographed, most of the water was drawn off and the brown material transferred to a dish to be photographed.

The photo below shows a bottle filled with deionised water (D), next to bottle filled with sampled water (S), shaken to disperse particulates then photographed immediately.



In another comparison, a bottle of sampled water from Boot Lane remained untouched for 36 hours, then was put next to a bottle with sampled water resuspended by rolling and inverting gently. No obvious difference was noted by eye in the intensity of the murkiness. This shows that the brown haze which persists after particulates have dropped out seemed not to be enhanced by the heavier particulates.

Algal bloom investigations by microscopy

At x 400 none of the particulates looked like algal cells or diatoms. Rather, they were typical of soil. Only two samples from BOOT were examined, none from other sites. A university team whom I was expecting to examine further samples unfortunately disbanded before samples could be provided.

STW effluent and phosphate concentrations in the Rhee and Cam

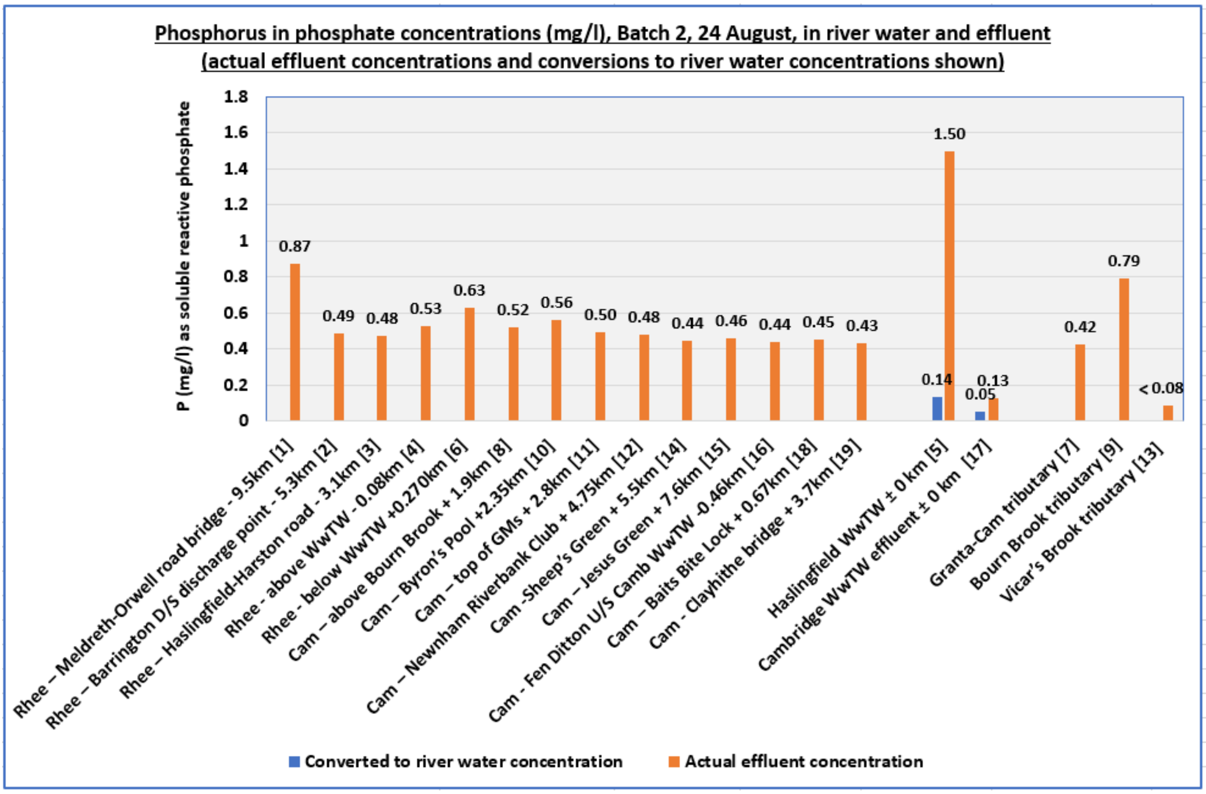
The discharge outfall at Ashwell STW is about 900m from the uppermost point on the Rhee where turbidity was seen, where the river bed was silty. With no permission to enter the farmland towards the STW no observations were made further upstream on that day.

Orthophosphate analysis of the STW effluent, and above and below the outfall showed an increase in phosphate concentration in the Rhee due to phosphate discharged from the STW. However, this does not provide evidence that phosphate in the water is linked to the appearance of the turbidity.

Sampling site	**Soluble reactive phosphate, concentrations reported by lab as Phosphorus (mg/l)**
Rhee	**01/08/22**
Ashwell End, river water downstream of Bluegates Farm, upstream of STW	< 0.084
Ashwell STW pure final-effluent at discharge point into Rhee	0.430
Ashwell End, river water downstream of STW	0.225

Orthophosphate concentrations are high in the Rhee downstream from Wendy, and in the Cam, as shown by CVF on several occasions from analysis of samples. STW treated effluent is considered to be the main source of phosphate in this part of the catchment in summer. In one batch of samples taken over a 13km stretch in August 2021, variations in phosphate concentrations were not sufficiently high to try to relate concentrations at any particular point to turbidity levels.

However, looking at sewage effluent as a whole, CVF estimated that about 39% of the Cam water flowing through Cambridge in August 2019 was effluent. On the Rhee and including the effluent from Haslingfield STW, sewage effluent was about 68% of the river flow immediately downstream of the STW. **Effluent, as an entity, therefore, cannot be ignored in any investigation.**



Main points

1. Turbidity levels assessment by eye is unreliable for several reasons. Thirteen sites were visited 26-28 September 22 and DTI was measured using a Wolf Garten pole with 19cm rake head attached and this was compared with an 8cm and 20cm diameter Secchi disk. Samples were taken and turbidity measured by OD600 and a nephelometer There was a very strong correlation between OD600 readings and NTU. Turbidity ranged from 1.9 NTU (Clayhithe) to 24.8 NTU (Guilden Morden). DTI using the rake head correlated strongly with NTU. The Secchi disk remained visible about 3cm deeper than the rake head. The rake head was judged to be the better option for reasons of practicality. CVF does not possess a digital in-field instrument for direct readings of turbidity.

2. Turbidity was at high levels in the Rhee and some stretches of the Cam in 2021 and 2022 from May into autumn, discounting effects of winter high flows. Upstream of Ashwell End the river had clear water; downstream of Ashwell End (below Ashwell sewage treatment works) it became turbid to a degree. Stretches near Guilden Morden, and from Wendy to Barrington were particularly turbid, Bryon's Pool often so, but the Cam downstream of Jesus Lock to Bottisham Lock was often much clearer. In 2022, Sheep's Green was somewhat turbid for several weeks in the early to mid-summer periods in both years, however it has never recently been clear.

3. High summer turbidity could not have been caused by soil runoff from land, high rainfall, high flows or ditch inflows in the summer months, as 2022 had a summer drought.

4. In samples from Boot Lane, Barrington, brown particulates dropped out to the base of the sample bottle leaving a persistent pale brown haze throughout the water. Microscopy at x 400 did not reveal numbers of unicellular algae or diatoms to account for the turbidity. Particles within the haze were irregularly shaped with many less than 500 nanometres suggestive of soil rather than organic matter. It is not clear if the nano-particulates created the brown haze. A soils specialist would need to become involved.

5. Notwithstanding this, at Boot Lane the high turbidity was probably caused by suspension of soil of difference sizes, some colloidal, and exacerbated by bed disturbance and bank burrowing by American Signal Crayfish which are numerous in that stretch. The turbidity was not caused by any external soil movement into the river or bed sediment resuspension caused by high rainfall leading to high flows as there were long periods without rain, and the flow was low.

6. For periods during the low-flow summer period, Sheep's Green and a stretch a few hundred metres upstream appeared by eye to be have a greenish-brown hue. It also seemed grey at times. The stretch seemed particularly prone to picking up reflected colours, e.g., blue sky and the green foliage of high trees. As an algal bloom was a potential cause of the turbidity, and the intention was to have a sample microscopically examined. Unfortunately, this was not done, as during discussions to organise the examination the water cleared. An algal bloom cannot therefore be ruled out as a cause of some of the turbidity in this stretch (and at some other sites) However, it seems unlikely that an algal bloom was a major factor at Sheep's Green, based on the fact that there was greater water clarity from Horningsea to Clayhithe, where conditions also seemed to be conducive, and phosphate and nitrate levels were similarly high enough to induce blooms.

7. An alternative explanation for the distinctly lower turbidity downstream of Cambridge might be the much smaller amounts of bed silt in the central Cambridge section of the river, and continual settling of soil particles over distance.

8. More data are needed to understand local turbidity, including the numbers of unicellular algal present, and a survey of the abundance and distribution of Signal Crayfish in the upper Rhee to Ashwell End, and the Cam from Cambridge to Bottisham Lock. Crucially if more than one factor is involved, the relative importance of each needs to be judge.

9. A specialist with expertise within the Environment Agency is required to understand

   - past dredging in the upper Rhee which will have removed and exposed different soil types. Differences in underlying soil type between reaches may explain differences in turbidity.
   - how easily can soils be lifted from river beds and remain in suspension over distance, in low flows and in the apparent absence of crayfish.
   - the induction of flocculation of finer clay particles by the presence of cations such as that of Calcium, resulting in higher turbidity.

- how the constituents of treated final-effluent from sewage treatment works, especially soluble reactive phosphate, might contribute to turbidity (other than to enhance algal blooms).
- if Struvite (magnesium ammonium phosphate) exists in STW effluent or the river and if it can contribute to turbidity.

10. WASP needs to be contacted to find out if they are undertaking any further investigations into turbidity in their local rivers.

Mike Foley is a committee member of Cam Valley Forum. Any misconceptions or errors are entirely his own. Comments are welcomed. mfpfoley@gmail.com

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