Strategic Water quality Plan for Semer Water.

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1 Mission Statement

From the observations of Yorkshire National Park representatives and prior studies, including an infield investigation undertaken on the 11th March 2022, 2 distinct issues have been identified within Semer Water, a water body situated within the Raydale catchment, Yorkshire Dales (see Figure 1). These issues are: (i) Diffuse pollution with a specific focus on high concentration of total phosphorous within the water body of Semer Water which is currently failing to meet the WFD legislative standards (**European Commission, 2000:2000/60/EC, 2008/105/EC and 2013/39/EU**) and, (ii) High sediment delivery into Semer water in-turn affecting the biogeochemical and physical properties of the water body, furthermore impacting the water quality status (**European Commission, 2000:2000/60/EC, 2008/105/EC and 2013/39/EU**). Accordingly, failure to mitigate these threats could result in losses of: the catchments long standing SSSI status (47 years); critically under threat species, such as white clawed crayfish; various bird species; and potential economic losses from recreational use. Consequently, this report outlines an immediate action plan aiming to restore 'good' status across the catchments hydrology and ecology by 2030. Further, ensuring progress with England's wildlife and ecosystem services strategy plan for 'Biodiversity 2020'.

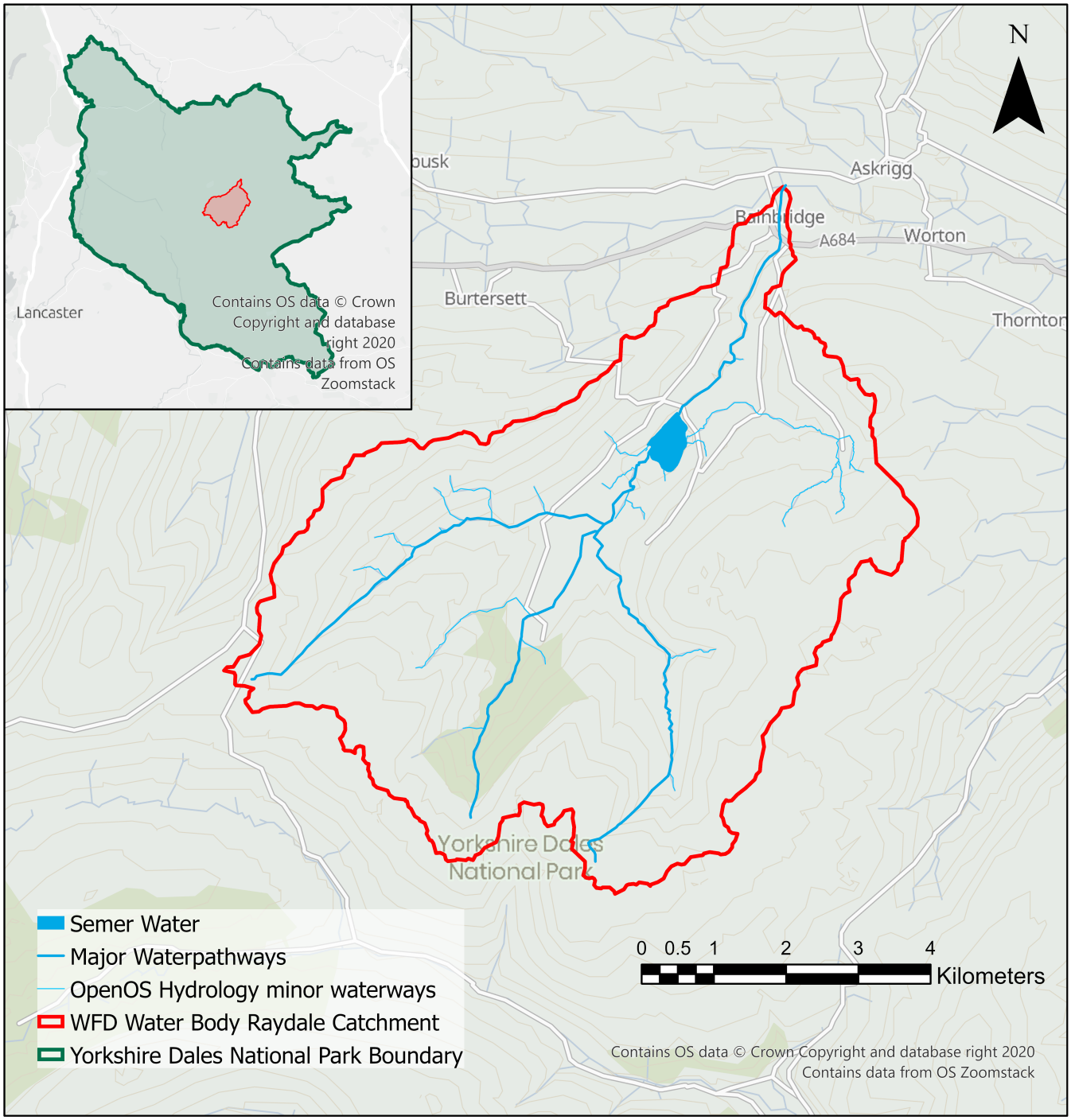


Figure 1: Figure illustrating the location of Semer Water within Yorkshire National Park and the catchment boundary.

2 Literature review

2.1 Issues affecting lakes like Semer Water

Valley cattle farming catchments like Semer Water contain a mixture of farms: dairy, beef and sheep. Together presenting unique water quality issues (YDNP, 2022). The steep upper slopes (9.27°) and intensively grazed valley bottoms characterise much of the catchment area as high-risk sources of pollution (Pulley and Collins, 2021). This high-risk is particularly caused by diffuse pollution from cattle farming farmlands that are in close proximity to waterbodies as modern farming practices which use inorganic fertilisers, slurry/manure spreading (Figure 2), animal feed and veterinary products used on livestock to keep them pest free have negative impacts on the surrounding water quality without careful land management practices.



Figure 2: Slurry on landscape.

Consequently, due to the high-risk source areas and diffuse pollution from modern farming practices, it is well identified that the catchment has issues with high total phosphorus levels within Semer Water (Gao *et al.*, 2015; YDRT and YDNP, 2016; Pulley and Collins, 2021). The mobilisation of substances put onto the landscape or miss managed by farmers become solubilised and/or detached and then the delivery into nearby surface streams, lead to the influx of chemicals including phosphorus into water bodies causing eutrophication and worsening of water quality conditions (Haygarth

et al., 2005). In accordance with the YDNP (2022) the top five diffuse pollution risks include: lack of slurry and manure storage, peat erosion and grips, soil erosion from riverbanks, surface flow topsoil/poor land management, poor farm infrastructure (Figure 3). Within 2018 a sediment source project found that the majority of phosphorous was being delivered from the topsoils of farms within close proximity to Semer Water (YDNP, 2022).

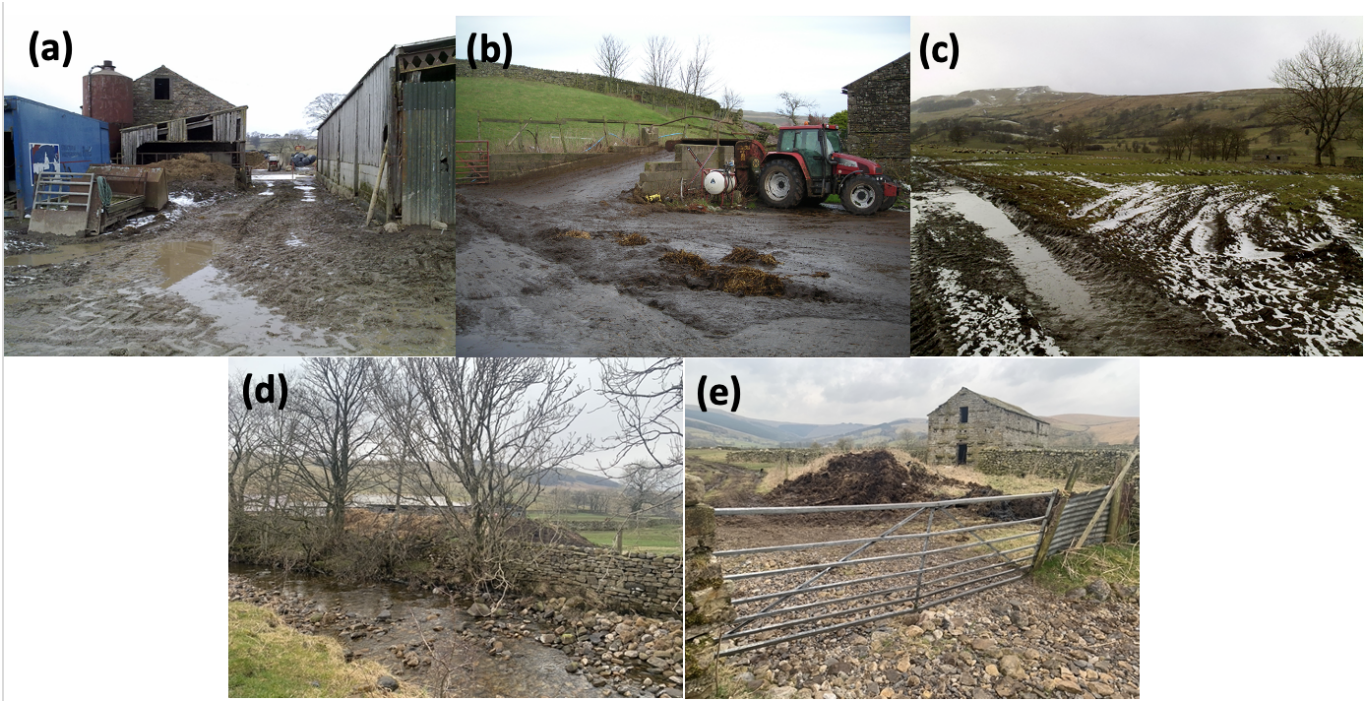


Figure 3: (a)-(b) Poor farmyard infrastructure. (c) surface flow topsoil / poor land management due to heavy machinery soil compaction. (d)-(e) Lack of slurry and manure storage. Source: (a)-(c) YDNP, (d)-(e) myself.

Non-agricultural sources and pathways include the mobilisation of sediment from variable sources including: landslips, exposed hillslope topsoils (Figure 4) and peat + woodland (Pulley and Collins, 2021). These sources are typically mobilised during intense rainfall causing extensive erosion.This in tandem with efficient delivery during surface flows from source to nearest stream channel can be a significant contributing pathway (Collins and Walling, 2004).

The location of each source can have varying contributions as Figure 5 illustrates the sources are equally split contributing around $\sim$ 25-35% each, with the exception of peat that contributes <15% across all periods. This is consistent across studies such as Chiverrell *et al.*, (2008) which suggests historically the major source of sediment has been from landslips, fluvial incision and hillslope erosion.





Figure 4: Examples of erodible banks within near proximity to tributary streams.

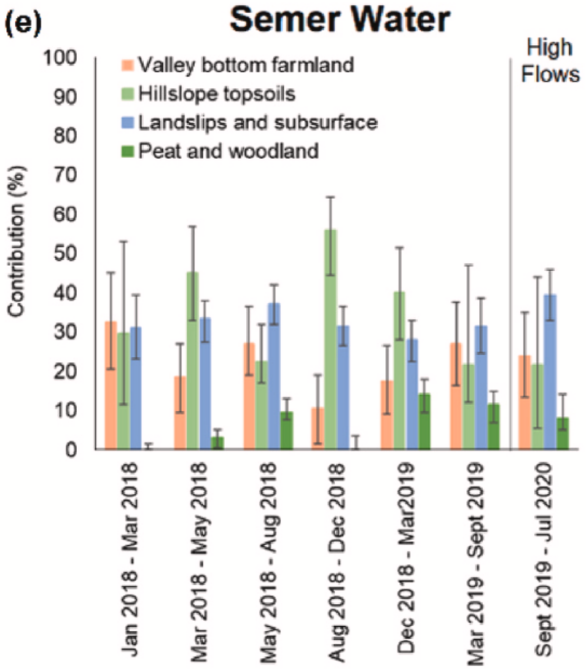


Figure 5: Figure illustrating the contributions of sediment from each source (Pulley and Collins, 2021).

Sediment originating within the water body itself is also causing issues. The lake and sediment depth (within the lake) perturbs biochemical processes and consequently, can lead to phosphorus levels re-charging due to physical disturbances and from flood events. Sediment also causes issues within the catchment as it also brings phosphorous with it as well. This occurs as suspended sediments particles act as binding surface for the phosphorous (bio-accumulates) (Villa *et al.*, 2019). This is therefore illustrating that sediment is a key issue (Gao *et al.*, 2015; YDRT and YDNP, 2016; Pulley and Collins, 2021).

2.2 Pre-existing management practices

Working with local landowners has been crucial to understand the landscape and how best to manage it. An example of where cooperation has been undertaken is Natural England's Catchment

sensitive farming (CSF) scheme (2019-ongoing). This scheme develops upon the YDRT Raydale Project which provided informed advice to the agricultural community to aid farmyard improvements including increasing slurry storage capacity. Directly providing benefits to minimise nutrient leaching. CSF successfully took this further by providing £47826 worth of advice and courses in order to help farmers better manage their land. The key focus was on manure, pesticides, and fertiliser management which was successful in lowering pesticide use by 25% when compared to 2006/07. Furthermore, decreasing the levels of sediment and phosphate by an average of 12% and 7% respectively. Resulting in less water standard breaches and visible improvements in aquatic ecology (YDNP, 2022).

Additionally, restoration across the peat bogs, utilising re-profiling, grip blocking and revegetation to provide more stability in the soils sediment as well as roughening the landscape to reduce surface hydrology flows and therefore, delivery of substances to the lower catchment. However, arguably this project has had no major direct benefit as limited sediment was being delivered from this region to the lake. This has been supported by multiple studies and models including SCIMAP (Chiverrel *et al.,* 2008; Pulley and Collins, 2021). Highlighting, maybe this was not cost effective and could have been better utilised if modelled prior to implementation.

An assessment of the catchment using SCIMAP in 2009 (Figure 6) identified areas at risk to mobilisation of sediment to the nearest stream/river. It provided critical informed decisions, where best to implement mitigation strategies such as buffer strips, contour planting and additional mitigations which break up the connectivity between the mobilisation and delivery phases of pollution. It is suggested that the implementation of woodland buffers that account for 10% of the catchment area would effectively reduce sediment losses to around ∼15% and reduce the rate of surface runoff provided the surface is roughened (Gao *et al.,* 2015; Pulley and Collins, 2021). Additionally, it is noted that 20% coverage saw no additional benefits and therefore 10% would be more cost effective. Moreover, it is recommended that to maximise this coverage the buffer zones should be thin long bands adjacent to the stream channel (Gao *et al.,* 2015).

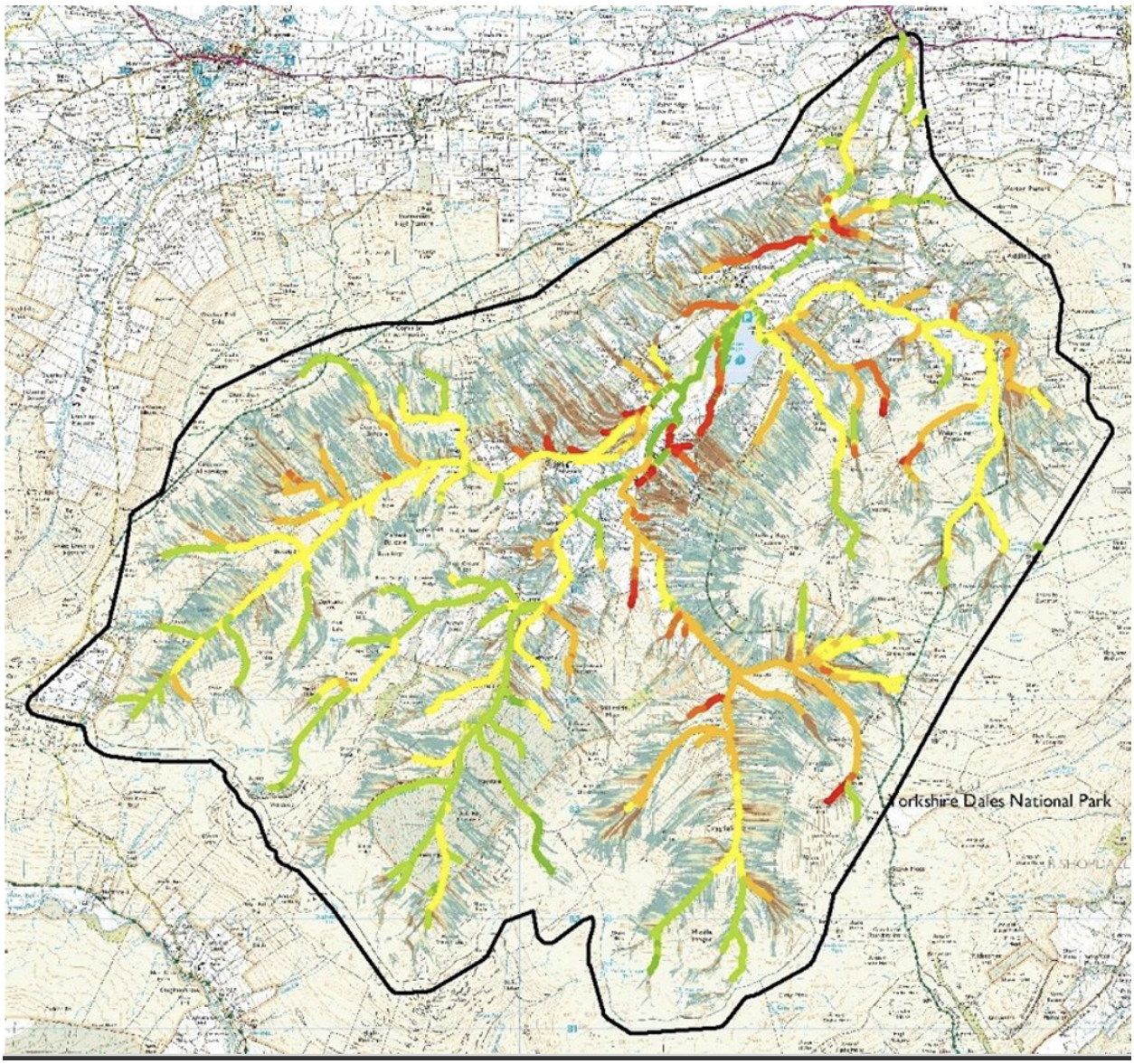


Figure 6: SCIMAP Model for the catchment. Red = high risk. Green = low risk

Summary

Despite implementation of successful schemes within the Semer Water catchment, issues are still ongoing and showing no evidence of favourable change. Therefore, there is argument to suggest that future plans should incorporate more targeted landuse and land modifying mitigations. However, it is acknowledged this will not be achieved without continued stewardship by farmers to learn new management practices to further minimise their part in the complex picture of diffuse water pollution within catchments.

3 Action Plan



As the catchment has 2 key issues this plan addresses both equally as they have equal precedence upon both the hydrology and ecology within the catchment. Failure to do so may result in the missed opportunity to achieve an improved catchment (Collins *et al.*, 2009; McGonigle *et al.*, 2014).

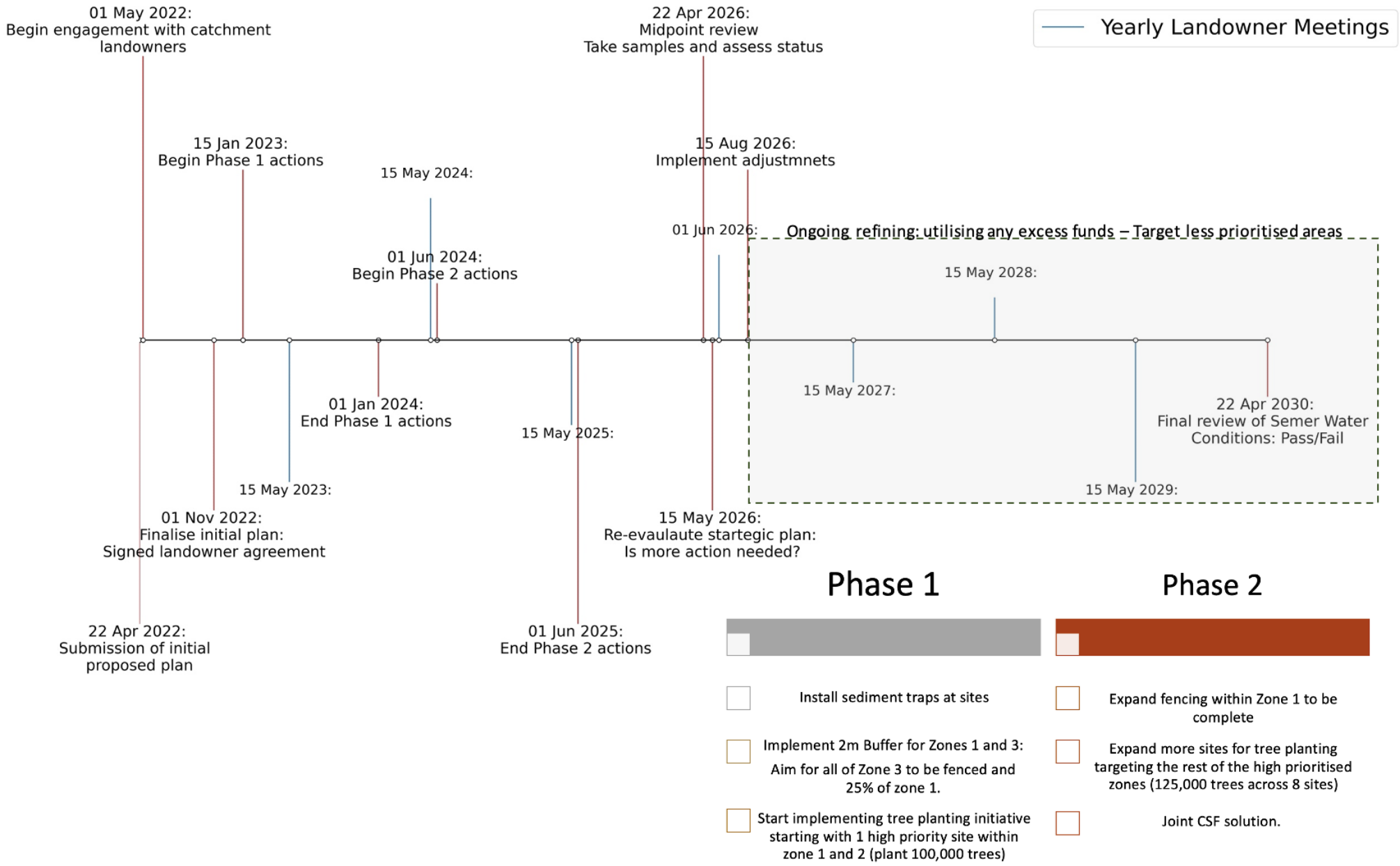
As 2030 is a narrow timeline to change the water quality status for the catchment, this plan includes an assessment period midway through to ensure the project is running on time and assess that the implemented mitigation strategies are working. Thereby, allowing the opportunity to further refine the plan to achieve optimised outcomes for the target year 2030 (see, Timeline). During this review period, the lake chemical and ecological status will be assessed. Alongside, the amount of sediment being measured at 4 key sites to assess for reductions in sediment delivery (see, Figure 7).

Before implementation of solutions, Timeline outlines a 6-month period to engage with landowners to ask them: What they want from this plan? What previous plans have they engaged with? What are their thoughts on how they could minimise their own impacts? With the vision to collectively agree on a target plan, that all agreeing landowners would sign a declaration stating they are

willing to cooperate and partake in improving the Semer Water landscape through this plan. The implementation of a signed declaration is to make the landowners feel an equal ownership with the project (Vrain and Lovett, 2016). Therefore, instilling an element of stewardship and willingness to achieve the target goal as a matter of pride as opposed to a must. Additionally, this will hopefully, convince unsure landowners to get involved through indirect peer pressure.

Engagement with landowners will continue throughout the project with focus on yearly catch-up meetings with the Farming and Land Management Forum YDNP. Where update on plans and progress will be shared along with collective discussions on what appears to be going well and what is not, allowing for refining.

This plan takes the stance that although land management techniques are appropriate mitigations, Natural England CSF is still ongoing, and this plan will work in tandem to avoid adverse impacts from conflicting advice for farmers. Therefore, to maximise results this plan will predominantly provide optimised targeted land use and infrastructure mitigation strategies to tackle Semer water issues.


Yearly Landowner Meetings
01 May 2022:
Begin engagement with catchment landowners
15 Jan 2023:
Begin Phase 1 actions
15 May 2024:
01 Jun 2024:
Begin Phase 2 actions
22 Apr 2026:
Midpoint review
Take samples and assess status
15 Aug 2026:
Implement adjustmnets
01 Jun 2026:
Ongoing refining: utilising any excess funds – Target less prioritised areas
15 May 2028:
15 May 2027:
22 Apr 2030:
Final review of Semer Water Conditions: Pass/Fail
15 May 2029:
01 Jan 2024:
End Phase 1 actions
15 May 2025:
15 May 2023:
01 Nov 2022:
Finalise initial plan:
Signed landowner agreement
15 May 2026:
Re-evaulaute startegic plan:
Is more action needed?
22 Apr 2022:
Submission of initial proposed plan
01 Jun 2025:
End Phase 2 actions
Phase 1
Phase 2
Install sediment traps at sites
Implement 2m Buffer for Zones 1 and 3:
Aim for all of Zone 3 to be fenced and 25% of zone 1.
Start implementing tree planting initiative starting with 1 high priority site within zone 1 and 2 (plant 100,000 trees)
Expand fencing within Zone 1 to be complete
Expand more sites for tree planting targeting the rest of the high prioritised zones (125,000 trees across 8 sites)
Joint CSF solution.

3.1 Mitigation options

There are varying mitigation that can be applied in order to address Semer Water issues and these are listed within Table 1.

Table 1: Table of potential solutions.

Plan number	**Mitigation action**	**% of catchment being modified**	**Economic cost**
1	Buffer all OS classified minor waterways or above by 2m both sides.	1.13%	Loss of viable farming land valley floor farmers ∼10% land lost. Only 3 farmland segments are predicted to be heavily encroach on visible farmland.
2	Increase Tree cover in the catchment (currently 3%). Plant trees in gridded array 2m spacing = 567,500 trees (∼2500 trees per acre). Implement in 6m by +100m strips in contour cultivation style alongside river channels in targeted regions	2%	∼Approx £500,000 Assumption ∼£0.90

3	Adding fencing around all OS classified minor waterways or above to prevent both livestock, dogs and humans entering water streams. Realistically target highly vulnerable locations 1st then expand, aim to target 25% of the area by 2030	Not necessarily area: 134km fencing	Assume average priced fencing ~£6.50 per metre. If all fencing was applied: ~£871,000. Realistically: 25% target ~£217,750
4	+30m Buffer margin for manure heaps from nearby water. Key sites targeted Cooperation with Natrural England CSF and local policy pressures.	0%	No real cost simply requires farmer relocating on land.
5	Improved slurry infrastructure	negligible; farm by farm basis.	Type of stores: earth banked lagoons, £8-£12m^3; a lagoon - an above ground metal tank, which costs about £47m^3 ; or a shuttered concrete store, costing £59m^3 (Business Wales, 2022) Funding streams through YDRT Raydale Project and CSF.

6	Deepen Lake Semer water itself. Semi intensive dredging. Aim for +2m.	0.63	Dredging costs range £5 to £75 per m3. Totalling £4,000-60,000. logistical costs (including staff, disposal of material etc.) + initial maintenance costs ∼750,000 (Jones *et al.*, 2015). Overall expected to be around £1million.
7	Install sediment traps that monthly get emptied and cleaned. 2 Benefits: can used for sampling + removes sediment from the system. Get emptied by local authority members or by agreement with local farmers	size dependent; negligible	Defined as low costs across all criteria (EA, 2012).Available for Countryside Stewardship Mid Tier, Higher Tier and Capital Grants; Natural England.

As the lowland grasslands contribute both the highest sediment and diffuse pollution from farmlands, it is best to apply finalised mitigations in these regions in order to deliver maximised cost-benefit outcomes (Pulleys and Collins, 2021). Using past models and simple GIS operations we identify 3 zones to prioritise implementation of solutions (see, Figure 7).

For these zones this plan would chose to implement both fences and a 2m buffer. We acknowledge this can be relatively costly however, some regions within these zones already have fences implemented and this study only wishes to fill the gaps ensuring no solution leaks (∼£50,000-100,000). Arguably, this combined solution provides the most robust infrastructure solution to reduce the delivery of

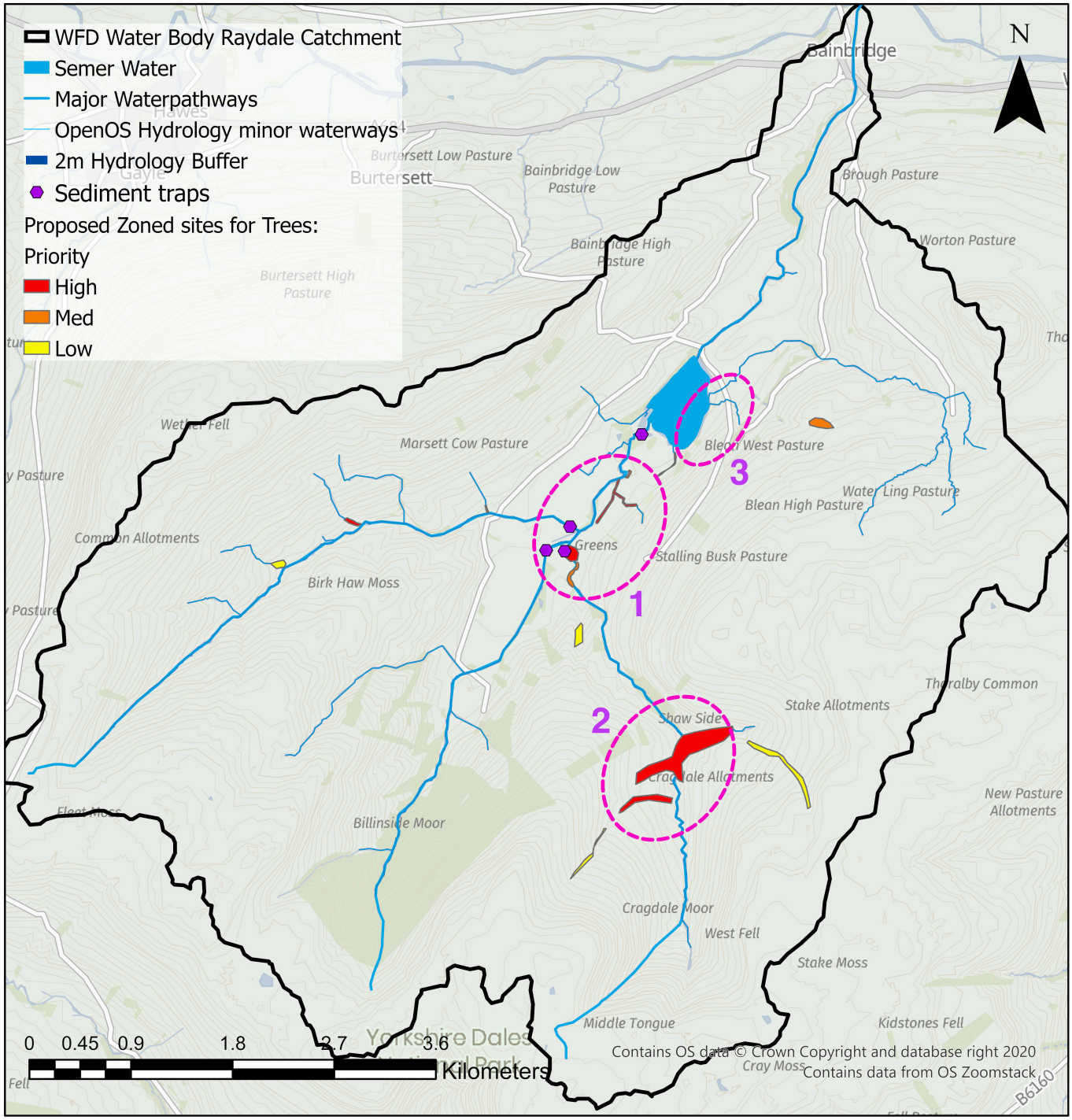


Figure 7: Map showing: sediment trap locations, areas that trees could be implemented ranked in accordance with priority.

agrochemical substances into the waterbody as it reduces the area these agrochemicals can be placed whilst further roughening the edges which perturbs the effectiveness of surface flows delivering the mobilised substances. Furthermore, the added benefit of fences means that, no cattle and or dogs can go for a drink/swim and directly input substances into the watercourse.

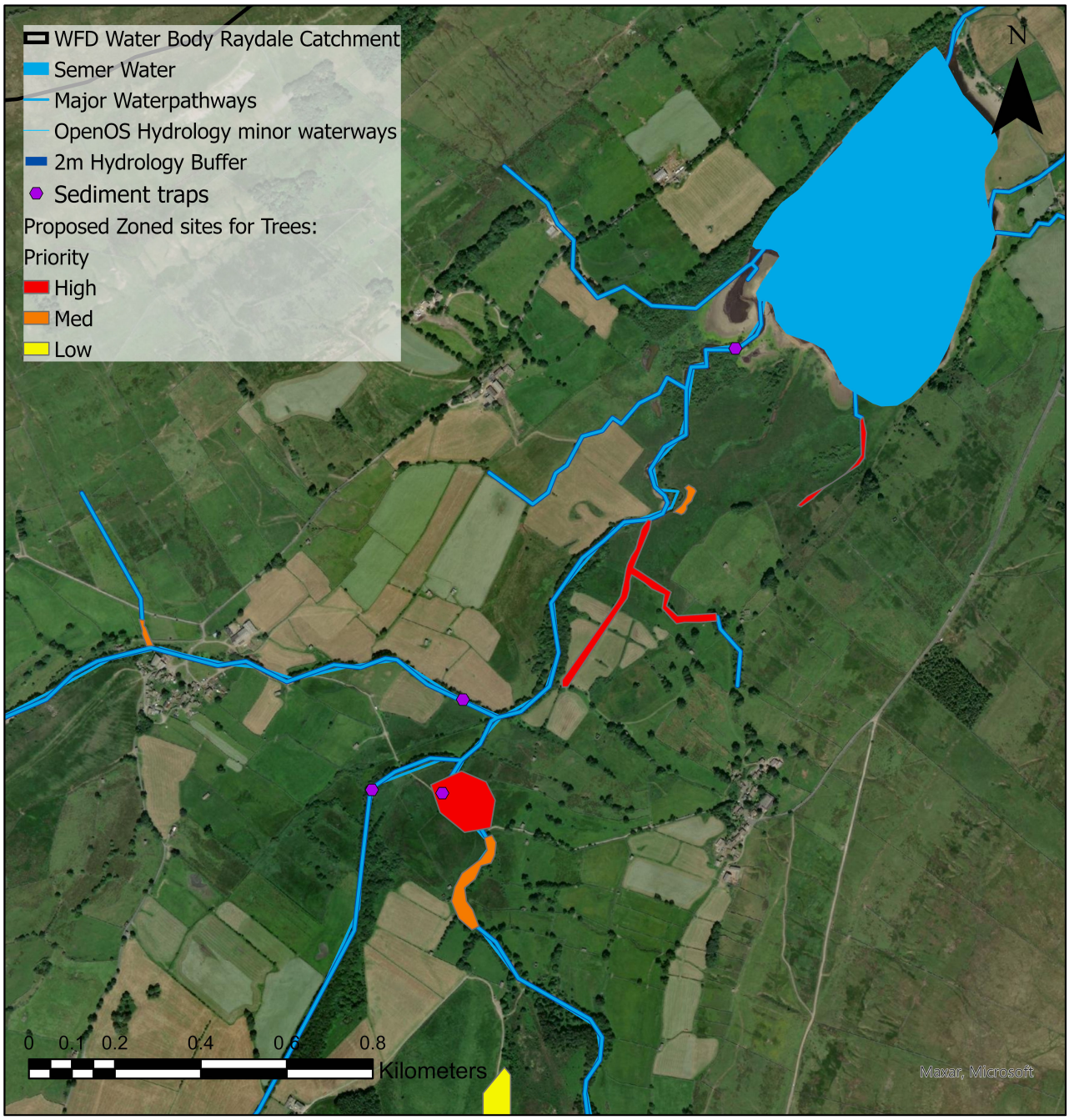


Figure 8: Zoomed inset of Zone 1 from Figure 7.

Additionally, this plan would also like to increase the percentage cover of trees within the landscape to 5%. However, realistically this is too costly to implement with fences and 2m buffers elsewhere in the catchment. However, this plan suggests that initially lets only plant trees in high prioritised zoned sites (red zones Figure 7). This lowers the cost to ~£220,000 which becomes more financially viable and highly cost beneficial. Lowering sediment delivery to ~15% in SCIMAP characterised high risk reaches. The planting of trees not only provides sediment benefits but also roughening of landscapes again perturbing the effectiveness of surface flows delivering the mobilised

substances. Furthermore, implementation in Zone 1 would improve water conditions for white clawed crayfish as the presence of trees the ideal coverage they require to thrive (Figure 9). Therefore, promising the expansion of their habitat in the catchment. Thereby, raising the WFD ecological standards as well as hydrological status.



Figure 9: Crayfish haven SSSI site.

This study would not go down the route of deepening the lake as although it would reduce re-mobilisation of stored phosphorus it would simply be a significant logistical challenge and too costly to undertake. Likely spanning the length of the project. Thereby, allowing no assessment and re-finement.

This plan estimates the optimum cost benefit plan to see improvements in Semer water would cost in range of £300,000-500,000. With additional further investment needed to solidify improvements beyond the target year 2030.

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