An investigation into managing land use and pollution upstream, to improve water quality and minimise flood risk in the Cober catchment, Cornwall.

Megan Angus

Source: Angus (2015)

"I certify that this dissertation is entirely my own work and no part of it has been submitted for a degree or other qualification in this or another institution. I also certify that I have not collected data nor shared data with another candidate at Exeter University or elsewhere without specific authorization."

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The River Cober supplies drinking water for over 33,000 people. It flows through the town of Helston which is prone to flooding and at the mouth of the River Cober lies Loe Pool, as SSSI. Therefore it is crucial to minimise water pollution and flood risk. These can be managed using a holistic, catchment based approach. An area that poses high risk for sourcing diffuse pollution was mapped using ArcGIS for the upper Cober catchment, Cornwall. This was achieved through combining primary and secondary data in the form of field work observations, water quality data, rainfall data; and mapping files from reputable organisations. With particular focus on agricultural management practices, suggestions are made to land owners falling into the constructed high risk zone to uptake schemes such as Environmental Stewardship, Catchment Sensitive Farming and New Environmental Land Management.

1. Introduction

1.1 Dissertation Aims

This dissertation will focus on addressing the effects that land use in the upper Cober catchment has on water quality and flood risk downstream. Data collection and analysis will begin resolve these issues and answer the research objectives that follow;

1) To identify and map the areas of the upper Cober catchment that pose a 'high risk' to water quality and flood risk downstream.

2) Suggest appropriate measures to take in reducing the risk to water quality and flood risk.

1.2 Overview of Research Conducted

Primary data in the form of field observations was collected and combined with secondary data including water quality numerical and mapping files from reputable organisations. This was to be used in ArcGIS to map the areas that present a high diffuse pollution risk to the rest of the catchment. Suggestions are made regarding appropriate land management to improve water quality and minimise flood risk downstream.

1.3 Rationale

"Water is essential for natural life and for human use. Our valuable natural environment and high population density means that the careful management of water resources is essential. Reconciling the needs of the environment with the demands of society is becoming increasingly difficult challenge. Now more so than ever, we must plan out long-term use of water so that there is a secure framework for its management." (EA 2001).

Water use has grown at more than twice the rate of the population increase in the last century (Nat. Geo 2015). The UN (2015) states that food production must double by 2050 to meet the demand from the worlds growing population. In the UK, the farming industry is not self-sufficent. 40% of the total food consumed is imported and this proportion is continuing to rise (GFS 2015). The increasing demand will put pressure on the agricultural system in the UK, in turn increasing pressure on water demand and quality. The Cober catchment is the focus of this study as it is a catchment providing multiple services, environmentally, socially and economically. At the mouth of the river lies Loe Pool, Loe Bar and the neighbouring Penrose Estate which attracts 42,000 visitors a year. This in turn brings money into the local economy. Loe Pool and Loe Bar are both have the SSSI status (National Trust 2001). The River Cober flows through Helston, a town which has a population of over 10,000 (Genuki 2005). The topography of the catchment makes it prone to flooding, particularly in Helston therefore it is central that flood risk is addressed. The River Cober also provides drinking water for Helston and The Lizard via the Wendron Extraction and Water Treatment Works. If this fails South West Water (SWW) have a back-up supply lasting only three days therefore it is of high importance to maintain a healthy catchment (LPF Meeting 2014). The study has focused more on agriculture rather than mining activity as Younger (1997) states that, in areas where rainfall is high, the worst pollution may be over in 10 to 20 years; compared to agricultural practices which are occurring today and continuing to pollute. Cost of water treatment is continuing to increase therefore adopting such management techniques in the identified areas will assist in stopping water price rises for consumers. Dinsdale (2009) suggests promoting an integrated farm management approach to control nutrient sediment and pesticide loss can act to improve catchment retention of water in soils which als further benefits flood risk management. Following multiple discussions with the members of the LPF regarding the current land management situation, it arose that a common problem was that farmers and land owners are only aware of their own land and do not recognise the amplified effect that diffuse pollution can have over the entire catchment. Initiatives such as Upstream Thinking (UT) and Catchment Sensitive Farming (CSF) are beginning to address this problem by taking a holistic management approach (LPF Meeting 2014). This study observes the diffuse pollution issue as an interdisciplinary problem involving many stakeholders. The mapped high risk areas will be used as a visual, communicative tool for agencies involved in assisting farmers on appropriate management techniques.

1.4 Site Selection

The upper section of the River Cober is being investigated, as to date, a considerably smaller amount of study has taken place compared to the lower section. The lower section is more thoroughly monitored because Loe Pool is aregistered SSSI. Any activity untaken in the upper catchment will directly affect the waters downstream so targeting the pollution as close to the source as possible, will maintain ‘healthy’ waters downstream. This is in line with the integrated catchment scaled approach suggested by Dinsdale (2009) as adopted by CSF and UT initiatives.

Fig 1. Site Location, source: Magic Maps (2015)

River Cober Catchment

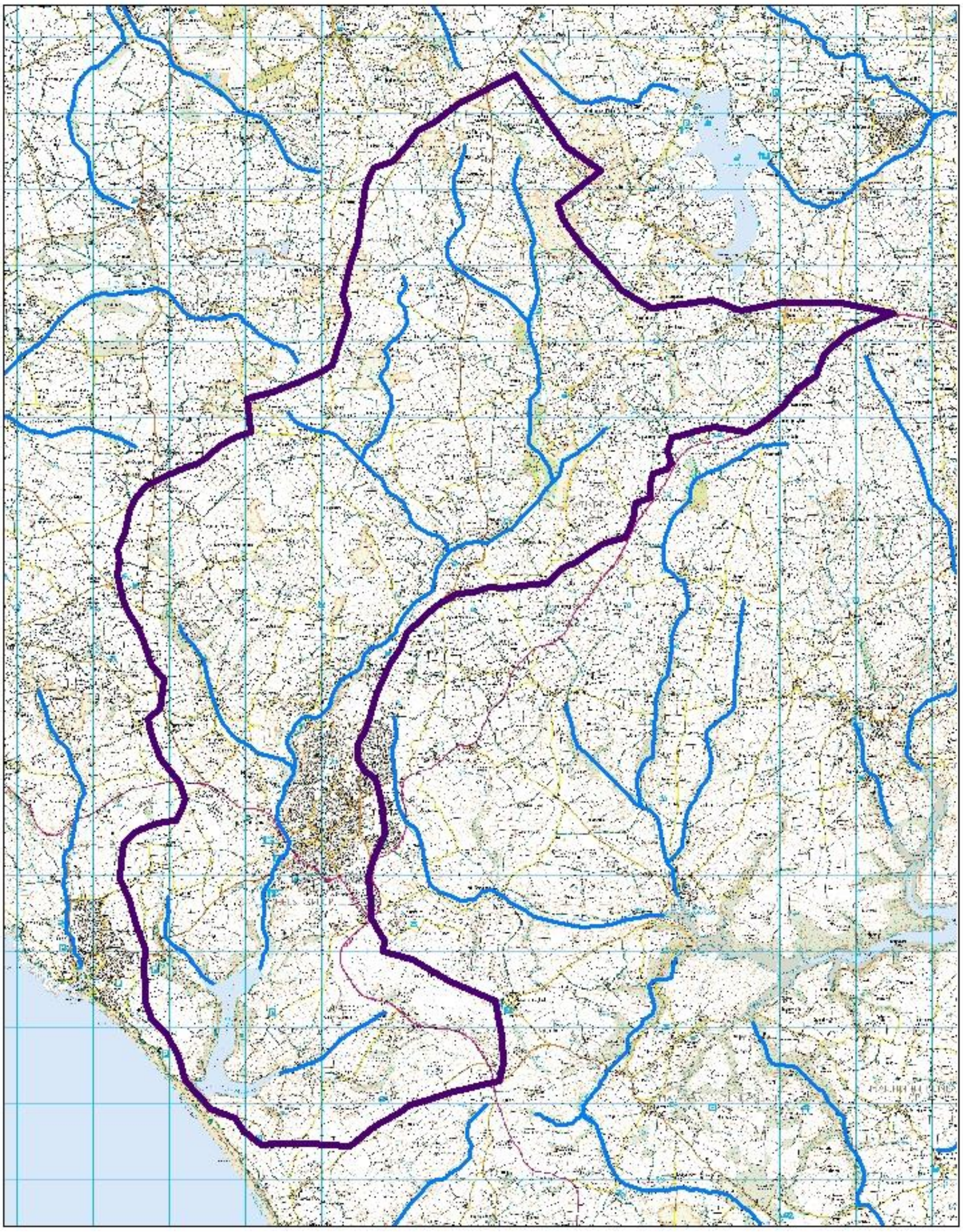
Source: OS 2013, Dinsdale 2009

0 1.5 3 6 Kilometers

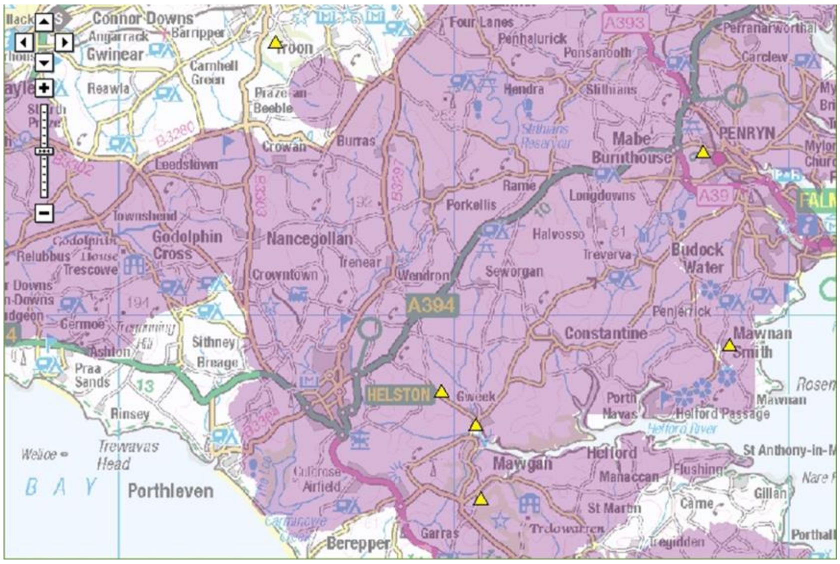
N

Legend

catchment_outline



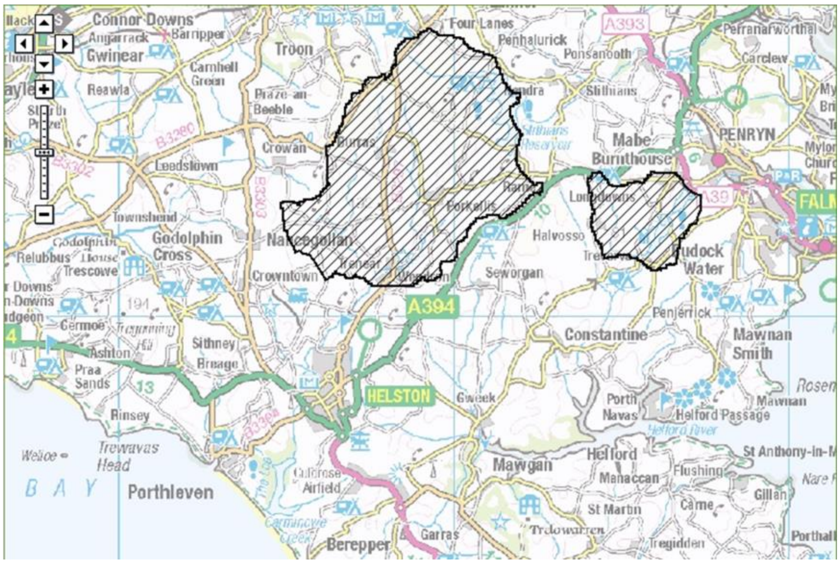
The EA identify the whole Cober catchment as falling into the ‘Priority Waters’ when referring to the contribution from agricultural land and are affected by either nitrates, phosphates, sediment or faecal indicator organisms (EA 2015). See Fig 3



Source: EA 2015

Fig 3. EA Priority Waters

The EA have identified drinking water safeguard zones which are areas of the catchment that influence the water quality at drinking water abstraction plants which are at risk of failing the drinking water objectives (EA 2015). Fig 4 shows that the majority of the upper Cober falls into this zone.



Source: EA 2015

Fig 4. EA Drinking Water Safeguard Zones

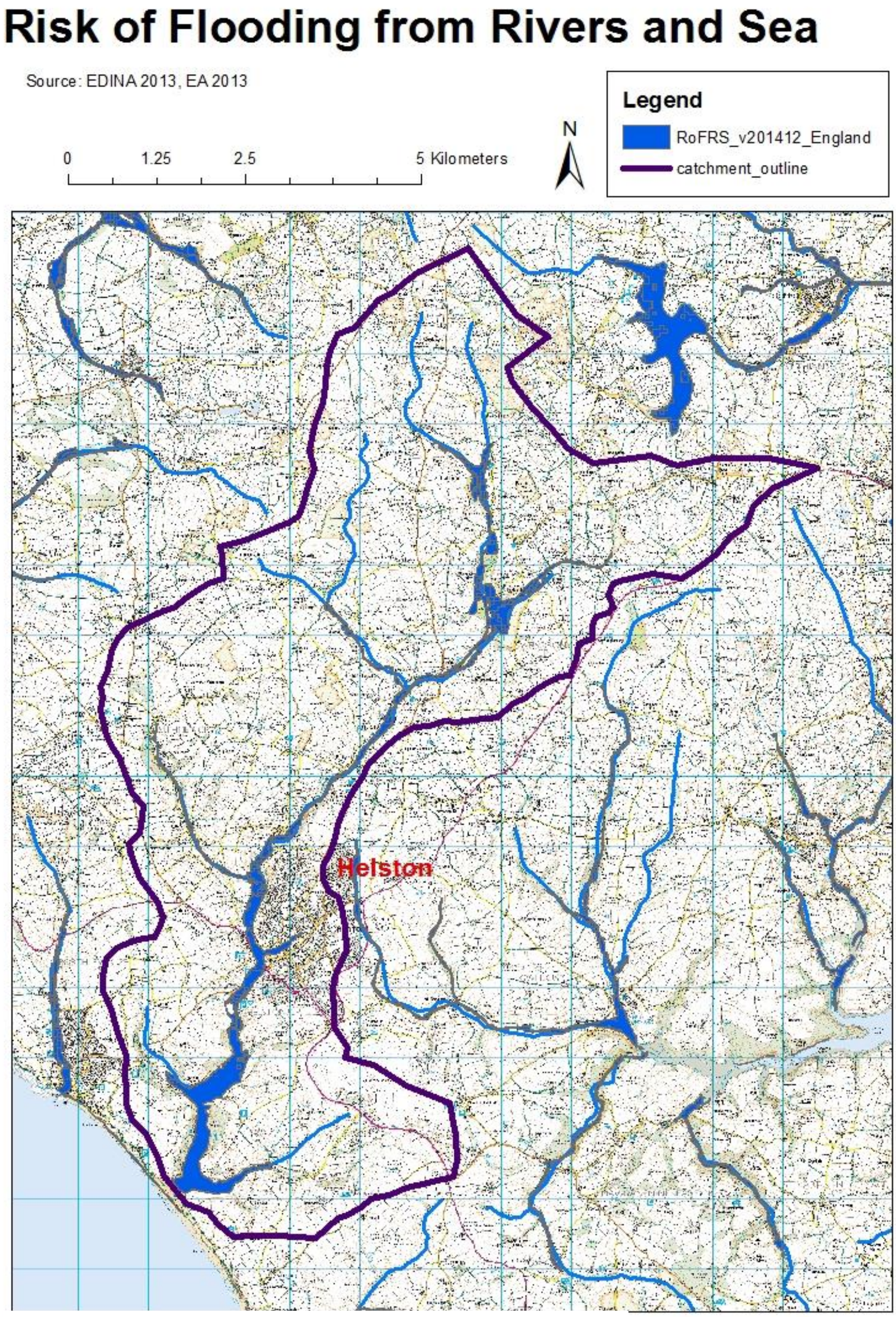


Fig 5. Map showing flood risk from rivers and sea

For more information on past to present land use, water quality and flood events please see Appendix 1.

2. Literature Review

This section will cover the wide literature relating to my study and give an understanding of its context in the wider world.

2.1 Land Management and Use on Water Quality and Flood Risk

An 11% increase in river flow rate is predicted due to land use change is state EA (2012). Watson and Adams (2011) estimate that close to 40% of the Earth's land surface is currently being used for cropland and pasture.

Dinsdale (2009) explains the significant change being witnessed in addressing agricultural water pollution in recent years, moving toward preventing issues at the source and using a whole catchment approach to rebuild ecosystem integrity and associated services. The whole catchment approach is now strongly recommended and will require and intimate combination of outreach to the farming community and technical evaluation of environmental risks, management options and outcomes in order to achieve the desired change in catchment water quality.

Please see Table 1for examples of land management measures that can be used as part of sustainable catchment scale flood risk management (Dinsdale 2009)

Table 1. Land management measures as part of sustainable catchment scale flood risk management (Dinsdale 2009)

	LAND MANAGEMENT MEASURES
1	Ensuring good soil structure in every field on the farm.
2	Avoiding directing runoff towards roads and watercourses.
3	Under-sowing spring crops.
4	Removing stock when soils are wet in high-risk fields to avoid compaction and poaching.
5	Establishing wetlands or runoff ponds.
6	Using grass strips or woodland belts to intercept water flows.

Agricultural land use and surface systems directly impact surface and sub-surface nutrient transport methods as explained by Heathwaite et al (2005). Please see Table 2 for factors controlling the transport of nutrients to a water body.

Table 2. Factors controlling nutrient transport (Heathwaite et al 2005)

	Factors controlling nutrient transport
1	Slope
2	Drainage
3	Soil
4	Crop management practice
5	Tramlines, tyre tracks, roads, paths

Heathwaite et al (2005) continues explaining that addressing path and vehicle use as well as field layout are key in understanding surface run-off over agricultural land and the potential pollutants the run-off carries. Drains, near surface interflow, deeper subsurface storm flow and ground water flow are all forms of sub surface systems. These are partly determined by geology however any previous heavy industrial activity across land will affect ground water flow and any potential pollutants it uptakes. Due to the heavy mining activity in the Cober catchment it is highly likely sub surface systems have been affected, in turn affecting surface flow.

Heathwaite et al (2005) identifies critical source areas (CSA) as sites that show potentially significant sources of nutrient input and flow from land that is in direct connection with the receiving waters. A CSA can be any area in a landscape from a small area trampled or poached by cattle to a whole field that is under drained. The study conducted found that high risk areas appear to be confined to a few key CSAs, however where very high source factors (e.g. fields receiving high levels of animal manure) coincide with a moderate transport risk, a high vulnerability to nutrient loss is to be expected. Land falling in the Cober catchment is likely to have a variety of CSAs to due past mining and agricultural activity within the catchment; this study will identify these. Through identifying CSAs it is possible to create simple and affordable changes in land use and management that can disconnect, store and buffer nutrient transport along the dominant flow directories of the catchment. This is highly important as Heathwaite et al (2005) states that ‘unless agricultural land management practices are modified, the soil phosphorus reservoir may double in the next 30 years’ as phosphorus is primarily transported in surface runoff.

Barber and Quinn (2012) discuss the use of run-off attenuation features (RAFs). These are low cost, soft engineered catchment modifications, including bunds, ponds, traps, leaky dams, physical wetlands. RAFs are designed to slow, store and filter run off from agricultural land in order to reduce flood risk, improve water quality and create new habitats and biodiversity. Belford Bun catchment was studied where two RAFs were installed to reduce concentrations of suspended sediment, phosphorus and nitrate in run-off. The only problem identified with the study was that there was a lack of retention of any pollutants during storm events, this was attributed to the remobilisation of previously deposited material. This establishes the need to prevent the pollution at the source and not rely on features downstream to remove them. Studies conducted worldwide show that 80% of wetlands reduced nitrate loading, whilst 84% reduced phosphorus loading, however huge variations were reported. The use of wetlands for diffuse water pollution form agriculture (DWPA) has been relatively limited in the UK to date. Norway and Sweden provide strong evidence that wetlands and similar RAFs have the potential to deliver cost effective water quality improvements. Field bunds are appropriate to intercept and temporarily store surface runoff during storm events, they can also double as a raised farm track in which a mid-height pipe can be installed to prevent over topping and help to drain the feature. Please see Fig. 7.

Fig 6. Field bund,

Source: Odisha (2015)

EA (2001) expect household numbers in the South West to increase by 400,000 by 2025 and the population to increase by over 600,000 in the same time frame this only heightens the importance of a safe, reliable water supply.

Key conflicts between agricultural production and Loe Pool catchment management as identified by Dinsdale (2009) include: use of field parcels for enterprises inappropriate for their inherent soil and water risk; poor management leading to compacted soils where enterprise would otherwise be low risk; and lack of or poor management of waste infrastructure. For further information on past to present land use on the Cober catchment please see Appendix 1.

2.2 Water Quality

Water quality is sensitive to land use practices and climatic events that affect its catchment (Delpha and Rodriguez 2014).

Problems in water quality occur when natural characteristics of a river are altered by organic materials, plant nutrients, toxic pollutants, physical pollutants and biological pollutants. Phosphate and nitrate concentrations seem to be the most important in governing the rate of eutrophication in most waters. Eutrophication can lead to algal blooms caused the rapid removal of CO_2 by photosynthesis in lakes, consequently leading to a rise in pH (Open University 1996).

Table 3. Nutrients lost from farmland (Mason 2002).

	NUTRIENTS LOST FROM FARMLAND
1	Drainage water percolating through the soil, leaching soluble plant nutrients.
2	Run-off of animal manure applied to land.
3	Erosion of surface soils.

Corrales et al (2014) describes the benefits of the introduction of a phosphorus credit trading scheme introduced in the Lake-Okeechobee watershed in Florida, United States. Before the introduction of the scheme almost 95%of total phosphorus loadings were attributed to agricultural sources. The uptake of the scheme was successful, with almost 81% of the credits being exchanged. A suitable methodology is presented that can be adapted to deal with different trading sources or technologies, and other management practices. This present the question of, could schemes similar to this be introduced to catchments in the UK? However, it must be noted that schemes such as this do not address the pollution problem head on, but rather ‘pass on’ pollution to another land manager; this could be seen a legitimising diffuse pollution from agriculture. Therefore uptake of scheme such as this should be undertaken with caution.

Over the past 20 years water companies have invested over £41 billion to improve the quality of drinking water. Water UK (2010) highlight the challenges that water companies will face including: climate change, changing agricultural practice, population growth and controls on the abstraction of water.

Table 4. shows what National Trust (2015) identify to be the most serious contemporary threats to the water quality in the Cober catchment from artificial pollutants to be from

Table 4. Threats to water quality in the Cober (National Trust 2015)

	THREATS TO WATER QUALITY IN THE COBER CATCHMENT
1	Nutrient input from Helston Waste Water Treatment Works. Treated effluent is discharges with significant levels of phosphates and nitrates, almost entirely derived from washing powders; these run into Loe Pool which lies 1km downstream.
2	Inputs into Carmiowe Stream from RNAS Culdrose Waste Water Treatment Works.
3	Agricultural inputs from the Upper Cober catchment, predominantly from pasture extensive agriculture from artificial nitrogen fertilisers.
4	Agricultural inputs from Lower Cober catchment. Agricultural farming practices are more intensive with pasture and varied arable produce. Steep slopes can lead to problems with nutrient run-off and soil erosion when crops and planted down, rather than along. Effective buffer zones must be established.

Threat three is what this study aims to address, any conclusion reached or solutions identified can be adapted and used to address threat four also.

There is a major gap in current knowledge of how nutrients are retained within complex landscapes explains Heathwaite et al (2005). It is necessary to identify the key landscape and land management factors driving nutrient mobilisation within the upper Cober, for example: bare soil, fresh applications of manures and fertilisers, high rainfall and vulnerable soils.

For more information on past to present water quality issues surrounding the Cober please see Appendix 1.

2.3 Flood Risk

Flooding occurs through a combination of events including: rainfall filling streams, rivers and ditches beyond their capacity, the overtopping of coastal flood defences, blocked and overloaded sewers, overland run-off and groundwater levels rising and flooding (DTLGR 2002).The most damaging periods of flash floods range from minutes to less than one hour. Flash floods can occur with very little warning in several seconds to hours (Watson and Adams 2011).

Factors controlling flood risk, identified by Horton (2014) may be classified broadly in Table 5.

Table 5. Factors controlling flood risk (Horton 2014)

	FACTORS CONTROLLING FLOOD RISK
1	Morphologic—These factors depend only on the topography of the land forms of which the drainage-basin is composed and on the form and extent of the stream-system or drainage-net within it.
2	Soil factors—This group includes factors descriptive of the materials forming the groundwork of the drainage-basin, including all those physical properties involved in the moisture-relations of soils.
3	Geologic-structural factors—These factors relate to the depths and characteristics of the underlying rocks and the nature of the geologic structures in so far as they are related to ground-water conditions or otherwise to the hydrology of the drainage-basin.
4	Vegetational factors—These are factors which depend wholly or in part on the vegetation, natural or cultivated, growing within the drainage-basin.
5	Climatic-hydrologic factors—Climatic factors include: Temperature, humidity, rainfall, and evaporation, but as humidity, rainfall, and evaporation may also be considered as hydrologic, the two groups of factors have been combined. Hydrologic factors relate specially to conditions dependent on the operation of the hydrologic cycle, particularly with reference to runoff and groundwater.

Flood risk is increasingly discussed as a risk management process, Bruijn et al (2007) argues that dynamic systems need to be adopted that recognise that climate and flood risk management systems are constantly changing and developing.

Merz et al (2007) explains the high value attached to flood risk maps as they give more direct and stronger impression in assessing the local flood situation. Consequently flood risk maps can provide vast quantities of information for many applications in flood defence and disaster management. Mapping will be used in this study to give the most detailed and accurate representation of high risk areas of the catchment.

EA (2012) identifies Helston as being at risk from flooding and already has two flood alleviation schemes in place. The Cober catchment is prone to field run off because of the topography of the catchment, which is further exacerbated by inappropriate field management. Currently the EA has specific flood warnings available for the Cober with two hours' notice of flooding.

The channelization of the Cober in 1946 and 1988 resulted in the river system not functioning naturally. The erosion and deposition process caused by meandering across its floodplain is confined to its channel. Flood waters are rapidly and efficiently delivered through Helston and into Loe Pool, because of this and the current flood alleviation scheme requiring regular de-silting of the Cober beyond Helston. However, the silt contain high levels or nutrients and fine sediment. Currently the flood alleviation scheme facilitates the delivery of nutrients and sediment to the pool (Dinsdale 2009). This is an issue that needs further investigation in order to achieve the most effective flood alleviation scheme without 'trading off' any other components.

2.4 Agricultural Activity on Water Quality and Flood Risk

'Changes in agricultural practices and land use to increase the absorbency of the entire catchment could serve to both alleviate flooding and reduce sediment and nutrient inputs to Loe Pool, creating a more stable sediment and chemical runoff regime within the catchment '(Dinsdale 2009).

The main diffuse pollution issues in catchments identified by Horsey (2006) include soil erosion under field vegetables, potatoes, bulbs and maize. Compaction in arable fields and grassland, and the over application of slurry at the wrong time of year all prove to be a concern. Agricultural activity within the catchment is centred around dairy farming, with rough grazing on poor land. Horticulture represents the remainder of agricultural activity with the main produce being potatoes and daffodils (Cornwall Rivers Project 2006).

Collins and McGonigle(2008) establish methods to reduce the risk of nitrate leaching through changing the timing of slurry application from winter to spring, and investigating the relationship between groundwater response times and nitrate emission from agricultural sources. The underlying theme determined is that there is a need to take a holistic management approach to mitigation, this is echoed by Dinsdale (2009) and is in line with ES, CSF, and Upstream Thinking initiatives.

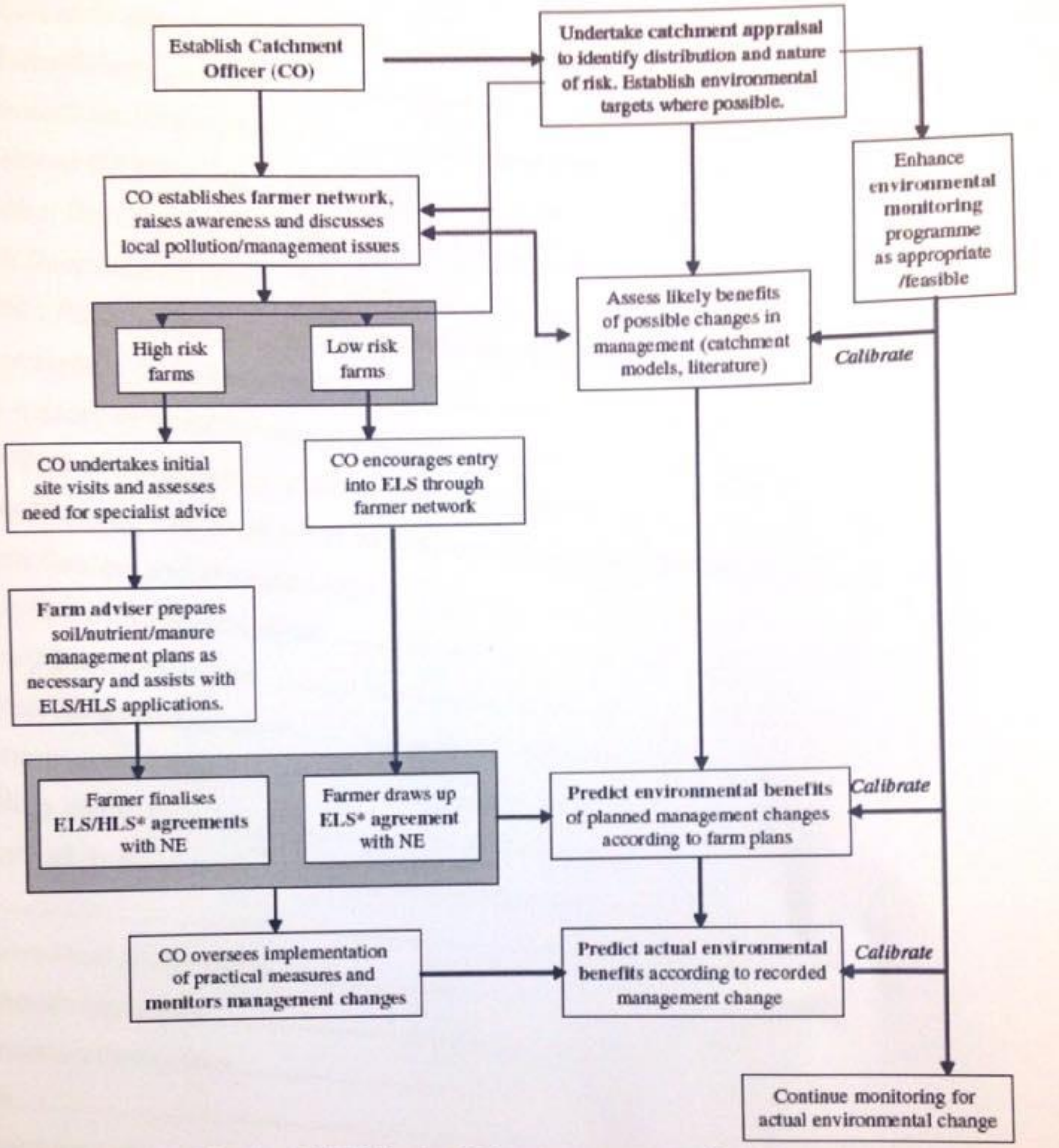
Horsey (2006) discusses the Best Farming Practice (BFP), a project that involved 870 voluntary farmers and riparian owners across England. Recommendations in the BFP individual farm reports included: undersowing, rough ploughing after maize, soil testing, better use of animal manure, water harvesting, clean and dirty water separation. The project was seen as excellent value for money and average savings have been calculated to be £1369 per farm in efficiency savings, soil retention and improved nutrient management. Horsey (2006) continues to add that GIS would have been a useful tool in determining areas or prioritisation. The planned work of this study will use GIS to identify high risk areas of the Cober catchment which would be suited to undertake project such as BFP.

Hedley (2015) discusses the use of precision agriculture to improve nutrient use efficiency at the appropriate scale. This method would require decision support systems (digital prescription maps) and the equipment capable of varying application at different scales. This would be the ideal solution for the agricultural community however an expensive method is. Hedley (2015) adds that land owners with young, variable soilds that have high yields provide the opportunities for effective financial return from investment in these new technologies, it is unlikely that the Cober catchment falls into this category.

The use and cropping of agriculture land may also reduce the ability of land to absorb rainfall and allow it to percolate into the ground. This not only provides flash flood conditions but limits the availability of water resources. EA (2001) add that sandy and chalky soils that characterise the SW region are vulnerable to degradation through compaction resulting in a reduced infiltration rate. Causes of this include late-sown winter cereals with fine sooth seed beds, silage maize, vegetable crops and outdoor pigs. These problems are all overcome with good agricultural practice. This study will identify areas within the Cober catchment that are in need of more management or are need to be included into management schemes such as the HLS.

Changes in agricultural practice to limit nitrate leaching into water bodies include: limitation of fertiliser applications, modification of cropping (introduction of crops with lower leaching losses), permanent changes to low leaching land use, and light control measures (Department of the Environment 1988).

Dinsdale (2009) explains that promoting an integrated farm management approach, employing the best of traditional methods and advanced technologies, and covering soil protection and careful nutrient management should aim to help farmers to profit from good environmental management. Controlling nutrient, sediment and pesticide loss are forms of agricultural management that act to improve catchment retention of water in soils, with benefits for flood risk management (Dinsdale 2009).



* ELS (Entry Level Scheme) and HLS (Higher Level Scheme) are components of the Environmental Stewardship agri-environment scheme. ELS is available to all farmers and includes support for soil and nutrient management planning and other basic pollution mitigation measures, whilst HLS is targeted and includes support for mosre costly changes in land management.

Figure 3.1 Relationship between key activities in a strategic catchment initiative (Mainstone *et al.*, 2008)

Fig 8. Relationship between key activities in a strategic catchment initiative (Dinsdale 2009)

2.5 Mining Activity on Water Quality and Flood Risk

Pollution from abandoned mines is a serious, widespread, increasingly common cause of surface water degradation. In some UK catchments it is the biggest cause of freshwater pollution. Wheal Jane was the last deep mine in the Carnon Valley area of Cornwall, shutting in March 1991. Groundwater rebound lead to severe pollution problems. Since this event, options on varying environmental management have been evaluated. Younger (1997) found that where rainfall is high, for example Cornwall and Wales, the worst of the pollution may be over in only 10 or 20 years. This is why this study focuses on agricultural activity as mining activity in the Cober stopped in 1939 (Coard 1989).

Most river systems with a near-neutral to alkaline pH, metal ions become absorbed into sediment particles. The contaminated sediment particles are deposited within river channels and on flood plains, which can lead to contamination over large area. This stored sediment may in turn become diffuse sources of contamination. 90% of metal contaminants are transported physically in sediment associated form. Long after mine closure, contamination remains and is widespread, with flood plain deposits often more contaminated than mine sites themselves. Therefore remediation work may be better targeted at downstream hot spots in floodplains instead of the more obvious mining sites (Coulthard and Macklin 2003).

Brown et al (2002) identifies mine water is a multi-factor pollutant, and further characterises the four main components of contaminated mine water as: acidity, ferric precipitates, trace metals and turbidity.

2.6 International, National, Local Water Legislation and Management Schemes

The EU Water Framework Directive (WFD) fundamentally changed water policy through introducing a combines approach for the control of point and diffuse sources, establishing a list of priority pollutants. Discharges of the priority substances should be eliminated within 20 years following the start of the directive, so with only 5 years until this point just how close is the Cober to totally eliminating phosphorus and nitrates (Harrison 2001).

Current UK planning policy guidance seeks to manage and reduce the impact of flooding by applying the precautionary principle. With this, there is a need to predict flooding in terms of the flood depth, frequency and extent which presently relies on computational modelling where there is little to no supporting hydrometric data to provide corroboration (Pinnel 2007). When the data is collected for this study field observations will be combined with mapped elements of the catchment to corroborate answers to reveal the most accurate and effective result (high risk area).

The White Paper Implemenation update report released by DEFRA in 2014 highlights two key aims, please see Table 7 (DEFRA 2014).

Table 7. Aims in DEFRA Report 2014

Aim	**How/why**
To safeguard our soils	To explore how soil degredation can affect the soil's ability to support vital ecosystem services such as flood mitigation, carbon storage and nutrient cycling.
To restore nature in our rivers and water bodies	To develop a strategy to identify and address the most significant diffuse sources of water pollution.

The White Paper discusses the aim of increasing participation in Environmental Stewardship schemes. Linking this to Horsey (2006) in order to identify such participants, GIS can be used for effective prioritisation.

See Table 8. for Institutional and Regulatory Framework.

Table8. Institutional and Regulatory Framework (EA 2001)

Institutional and Regulatory Bodies	**Role**
Environment Agency	'Duty to conserve augment, redistribute and secure proper use of water resources in England and Wales.' The EA is responsible for: flood defence on main resources, water quality, waste minimisation in regulated industries, fisheries, navigation on some rivers. Also Catchment Abstraction

	Management Strategies (CAMS), Local Environment Agency Plan (LEAPs), drought plan, regular review of water company resources, National Water Resources Strategy. The Environment Agency aims to minimise such conflicts and to achieve and maintain a sustainable river environment by planning at the catchment level (Harrison 2001).
UK Government	Responsible for water regulation to control waste of water and drought orders.
Water companies	Private water companies are responsible for: providing a clean and reliable supply of water, water resource plans, drought plans, proposing and justifying water resources schemes, promoting efficient water use, maintaining an economical and efficient supply.
Ofwat	Responsible for economic regulation of water companies in England and Wales
Drinking Water Expectorate	Regulates the quality of drinking water delivered by water companies.
Planning and local authorities	Responsible for the land use planning framework and planning decisions.

The EA(2001) Actions on Agriculture can be seen in Table 9.

Table 9. EA Actions on Agriculture (EA 2001)

Action 13	The Agency will seek to identify opportunities to make water available for agriculture use from existing and new developments.
Action 14	The Agency will encourage farmers to adopt good farm practice in water use around the farm. Work in partnership with National Farmers Union and Government, radical changes in cropping patterns and adjustments between traditional food crops.
Action 15	The Agency will continue to work with agriculture to continue to develop indicators of good practice in water use.
Action16	Farmers should actively seek ways of minimising their water use.

Action 17	Farmers should consider working together to develop schemes that can be shared by several farms.

Cornwall Rivers Project:

Cornwall Rivers Project was a four year project (2002-2006) costing £2.6 million partly funded by DEFRA and the EU. The aim of the project was to rehabilitate key rivers and catchments whilst bringing improvement in the economic viability of local rural communities. The Cober catchment was selected to be part of the project because of the enrichment of the water in Loe Pool, primarily from agricultural impacts upstream (Cornwall Rivers Project 2006).

Upstream Thinking (UT):

UT is SWWs flagship programme of environmental improvements aimed at improving raw water quality and manage the quantity of water at the source in order to reduce water treatment costs (Gov 2015). Upstream Thinking is in line with the catchment based approach as suggested by Dinsdale (2009). The initiative started in 2008, partners Westcountry Rivers Trust demonstrated the success in combing this with CSF scheme. Te success of both pilot partnership project resulted in Ofwat approving £9.1 million investment between 2010 and 2015. During the LPF community meeting it was discussed that the River Cober had secured its bid for the Upstream Thinking project on 24th November 2014, and that Cornwall Wildlife Trust (CWT) will lead the project (UT 2015).

Catchment Sensitive Farming (CSF):

CSF is a project run by Natural England in partnership with the EA and DEFRA with the aim of raising awareness of diffuse water pollution from agriculture. This is achieved through free training and advice for priority catchments (Gov 2015). Funding of up to £14 million will be available for CFS advice delivery and capital grants (Natural England 2015).

Topics covered by CSF can be seen in Table 10.

Table 10. Topics covered by CSF (Gov 2015)

1	Manure management.
2	Nutrient management.
3	Soil condition.
4	Pesticide management.
5	Farm infrastructure.

Fig 8. shows catchments falling under the priority zone, River Cober falls under the West Cornwall priority zone (Natural England 2013).

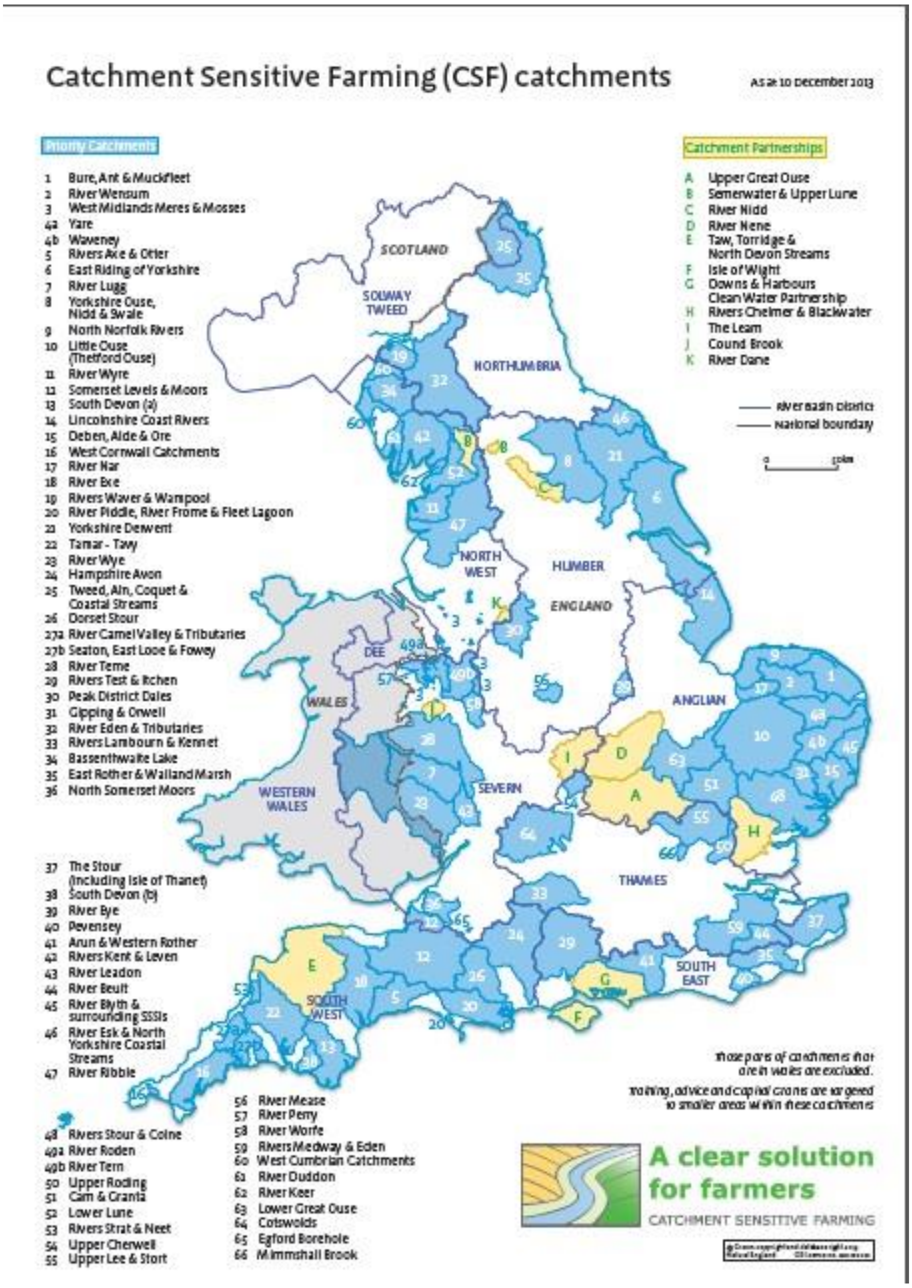


Fig 8. Catchments that fall into CSF priority zones (Natural England 2013)

Environmental Stewardship (ES):

ES is a land management scheme which is subdivided into 3 levels as described in Table 11 (Gov 2015).

Table 11. Levels of ES

ENVIRONMENTAL STEWARDSHIP SCHEME	DETAILS
Entry Level Stewardship (ELS)	Simple and effective land management agreements with priority options.
Organic Entry Level Stewardship (OELS)	Organic and conventional mixed arming agreements
Higher Level Stewardship (HLS)	More complex types of management and agreements tailored to local circumstances.

Courtney et al (2013) describes the direct benefits of ES schemes as: increasing in stock and quantity of field boundaries and associated wildlife, adaption to climate change, improvements in farm soil and water quality, and protection of the historic and natural environment.

The ES scheme was part of the previous Rural Development Programme which ended in 2013. It is still possible to renew or establish new ELS or HLS agreement but certain criteria must be which are listed in Table 12. With 2014 identified as the transitional period, New Environmental Land Management Scheme (NELMS) is the new programme of environmental programme due to start in 2015 however the scheme is still under development. NELMS plans to combine ES and English Woodland Grant Scheme (CLA 2015). The next Rural Development Programme extending from 2014 to 2020 will be namedd Countryside Stewardship agreements (Natural England 2015).

Table 12. Criteria for renewal of ELS and HLS

	DETAILS
NEW HLS AGREEMENTS IN 2014	£26 million will be available for HLS agreements for eligible expiring 'Classic' agreements, for SSSIs and other high priority cases, and to meet Water Framework Directive objctives.
NEW ELS AGREEMENTS IN 2014	£4 million per year will be available for new/renewed ELS agreements in the following circumstances: • For underpinning new HLS agreements • In the uplands (Uplands, ELS) • For land coming out of 'Classic' agreements in 2014 which does not meet HLS criteria • Organic producers (Organic ELS)

Hajkowicz et al (2009) concludes that agri-environmental schemes such as those discussed have become an extremely important policy instrument. ES schemes provide wider benefits beyond those mentioned above as Courtney et al (2013) explains, such as direct employment and income to local economies.

Loe Pool Management Forum was set up in 1996 involving representatives from organisations, Table 13. shows member organisations (National Trust 2014).

Table 13. LPF Member Organisations (National trust 2014)

	ORGANISATION
1	National Trust (NT)
2	Natural England (NE)
3	Environment Agency (EA)
4	South West Water (SWW)
5	R.N.A.S Culdrose
6	Farming and Wildlife Advisory Group (FWAG)
7	Catchment Sensitive Farming (CSF)
8	Cornwall Council
9	Cornwall Wildlife Trust (CWT)
10	Kelda Water

Loe Pool Forum are developing a different and more engaged approach with Helston's farming community; sparking a local conversation between farmers and environmental scientists. The improved relationship between the two cultures hopes increase the uptake of farmers receiving advice from expert agencies, such as Natural England's Catchment Sensitive Farming initiative (Walker 2014).

2.7 Importance in the Future

Collins and McGonigle (2008) identify relationships between climate change and diffuse pollution from agriculture as highly complex and highly dependent on local and regional changes. Increased flooding could mobilise enhanced sediment loads and associate contaminants, potentially exacerbating impacts upon aquatic ecosystems. EA (2012) predict a 20% increase in peak flow in all watercourses due to climate change. This is likely within the Cober catchment due to the Cornwall's south-westerly position resulting in mild most air bringing rainfall and highly changeable weather conditions; making many of Cornwall's river catchments prone to flash flooding. With the River Cober flowing through Helston, one of the major towns in Southern Cornwall with a population of over 10,000 recorded in 2011 (Genuki, 2005); it is of the upmost importance that surface runoff is management efficiency to minimise the risk of flash flooding and nutrient transportation.

Climate models are predicting a continued increase in intense precipitation events during the 21st century. A dominant variable in soil erosion appears to be rainfall intensity, rather than rainfall amount along. Nearinga et al (2005) found that is both rainfall amount and intensity were to change together in a statistically representative manner, predicted erosion rate increased by 1.7% for every 1% increase in rainfall.

Dinsdale (2009) highlights that climate change predictions indicate that the need for integrated catchment management, to increase the resilience of catchments, wildlife and people to extremes of weather conditions such as floods, has never been greater.

4. Methodology

This section provides an overview of the data collection methods used to answer the research questions set out in the introduction. Primary and secondary data was collected, involving both quantitative and qualitative techniques. This section will further justify the reasoning behind the collection and analysis techniques.

4.1 Primary Data

The primary data collected for this study comprised of both qualitative and quantitative techniques. A combination of techniques was used to provide data that could be analysed both textually and statistically and provide the greatest understanding in answering the research questions (Creswell 2009).

The upper, accessible section of the Cober catchment was surveyed weekly over a 6 week period, in order to see how the catchment reacted in varying weather conditions. For any point showing evidence indicating a possible pollution source, a GPS coordinate was recorded, along with a brief description and photographic evidence, PLEASE SEE APPENDIX (INCLUDE PHOTO/?).

4.1.1 Primary Data Analysis

The GPS coordinate will be used in later analysis using ArcGIS. As Pinnel (2007) highlights, currently there is little corroboration between hydrometric data and computational models for flood risk resulting in reduced reliability; applying this to the study here the combination of fieldwork observations and secondary data (in the form of map layers) will provide the most accurate representation of the high risk areas of the catchment.

4.2 Secondary Data

The secondary data collected is in the form of water quality data and a summary of events, rainfall data and map files. Secondary data was compiled, analysed and will be used in GIS analysis used if identifying high risk areas of the catchment.

4.2.1 Water Quality Data

Water quality data for the River Cober was supplied from the EA, please see Appendix 3. The EA is an executive, non-departmental public body (EA 2015) and was approached as it is primarily responsible for water quality and regular reviews of water companies (EA 2001). The continuous data extends from 2000 to 2014, recording a variety of chemical elements, please see Appendix 4. However the data is collected in an irregular fashion across the time period. From 2000 to 2010 data is only collected from Trenear Bridge (Fig 3, 19) but from 2010 data is also collected from Bodilly Stream prior to confluence with the River Cober at Wendron water extraction plant (Fig 3, 19). Again this was not collected at regular intervals. The data was collected by samplers going out into the field and the sampling schedule was previously programmed locally by local area teams, but since 2012 has been programmed nationally using scheduling technology. The EA adds that's the majority of analysis is done by sending samples back to the laboratory at Starcross, Exeter, but the pH, temperature and dissolved oxygen are measured in-situ using a pre-calibrated YSI hand held water quality meter. The EA maintains the most appropriate organisation to use data as the EA is the only body that measures and shares data with the public, further research would use a data set that is more accurate and is sampled following a structured, regular time scale.

4.2.1.1 Water Quality Data Analysis

The water quality is a continuous data set (Rogerson 2006) and a common method of displaying such variables in on a line graph (Walford 2011). The water quality data was used to assist in identifying the high risk area of the catchment on ArcGIS, through establishing which stream certain chemical elements and pollutants largely originated from. This means that only data from 2010 to 2014 was used as it samples from Trenear Bridge and Bodilly Stream. The chemical elements that will be displayed on a line graph are nitrate, copper, zinc, aluminium; the pH will also be plotted, please see Table 14.

Table14. Reasoning for water Quality Analysis

pH	A low pH can allow toxic elements (e.g. copper and zinc) and compounds compounds to become available for uptake by aquatic plants and animals (EPA 2015). Due to the mining history in the catchment it is crucial that the pH is monitored to prevent remobilisation on toxic elements.
Nitrate	Nitrate concentrations are highly important in governing the rate of eutrophication in most waters (Open University 1996). Agriculture is estimated to be responsible for 70% of nitrate pollution contributing to ecological and water treatment problems (Kay et al 2012).
Copper	Copper is a major toxic compound in large quantities, mining and metal production contribute to copper levels (Lenntech 2015). Even though there has been no mining in the Cober catchment since 1939, metals can still leach into the Cober when water washes over the rock surface or when the water table rises (SDWF 2015).
Aluminium	Aluminium is found in contaminated mine water (Brown et al 2002). As with copper, aluminium can still leach into the Cober when water washed over the rock surface or when the water table rises (SDWF 2015).
Zinc	Zinc is found in contaminated mine water (Brown et al 2002). Again, as with aluminium and copper, zinc can still leach into the Cober when water washed over the rock surface or when the water table rises (SDWF 2015).

It must be noted that due to the irregularity in data collection with particular reference to data from Bodily confluence, validity of some of the conclusions drawn is questionable and not as accurate if data was recorded at regular intervals.

Rainfall data was then overlaid onto the water quality data and a line graph was created and correlation analysis was conducted. This examined the strength of the relationship between rainfall and changes in the level of chemical elements

(Anderson 2012). Line graphs are useful as they show data variables and trends very clearly (Better Evaluation 2015). This supported an understanding of whether heavy rainfall is responsible for washing chemical elements and pollutants into the Cober or whether there have been any pollution events.

4.2.2 Pollution Summary Events

A summary of pollution events was supplied by the EA please see Appendix 5. This qualitative data will provide a deeper understanding and detail in the nature of pollution events occurring in the catchment. The information contains dates, times grid coordinates and written detail on the incident. The grid coordinates will be added to ArcGIS in point form (in the same way as the primary field work observations). This will again assist in identifying high risk areas of the catchment. The information will also be used in conjunction with the plotted water quality and rainfall data to determine whether the spikes in the levels of the chemical element and rainfall correspond with any pollution events recorded by the EA. Again the information only dates back to 2010 so will only be compared with the most recent data set available.

4.2.3 Rainfall Data

Rainfall data was taken from the Met Office historical station data set. The Met Office are one of the world leaders in weather and climate and works closely with governments, individuals and organisations providing current scientific knowledge and advice. The closest available data is from Camborne, this is the only data set for the whole of Cornwall. The data is a monthly average extending from 1978 to the present day, however the study only require data backdating to 2000. The data was collected by the Camborne weather station which takes hourly weather observations that are representative of the wider area of the station and not influences by local effects such as shading (Met Office 2015).

4.2.3.1 Rainfall Data Analysis

Due to the irregularity of the EA water quality data, the rainfall data had to be selected to match with the EA water quality data when plotting the line graphs. As the rainfall is a monthly average this is not accurate to the date the water quality was collected, however it gives the most authentic representation available. The overlaid rainfall data provides a visual representation of any peaks and whether these correspond to peaks in levels of the chemical elements.

4.2.4 GIS Application

‘’ A geographical information system is an organised collection of computer hardware and software, people, money, and organisational infrastructure that makes possible the acquisition and storage of geographic and related attribute data, for purposes of retrieval, analysis, synthesis and display to promote understanding and assist decision making.” (Kennedy 2006)

GIS is used as it provides the ideal tool for spatial analysis and understanding spatial relationships (Schuurman 2005). It is a special class of information system that can keep track of events and their locations and can be applied to all activity (Longley et al. 2011). ArcGIS 10.2.2 is the programme used in this study because it is scalable both in deployment and functionality therefore can be used to analyse data at the local level. Mckinney and Cai (2002) explain the visual display capacity of ArcGIS compliements the user interface of water resource models, allowing the user to take complete control of data input and manipulation.

4.2.4.1 Map Files

Map files were sourced from a variety of locations. Please see Table 15 for the data used to complete the analysis of high risk areas.

Table 15. Map Files

DATA SOURCE	DATA TYPE	DETAILS
Natural England (2013)	Shape file	The Environmental Stewardship shape file covering the catchment was downloaded to allow identification of the farmers in the scheme on the catchment/
EDINA Digimap (2013)	OS Meridian 2 tiles	The tiles are a geometrically structured vector base at 1:50,000 scale. Only the river_polyline layer will be used in analysis.
EDINA	OS VectorMap	The tiles are scale to 1:10,000 therefore providing

Digimap (2013)		the most detailed national mapping available. Will be used in partnership with OS StreetView as a backdrop to add context to fieldwork observation point added.
EDINA Digimap (2013)	OS StreetView – raster dataset	Tiles are scaled at 1:10,000, making it particularly useful for displaying specific localities, used in partnership with OS VectorMap to provide a backdrop and add context to fieldwork observation points added.
EDINA Digimap (2013)	1:25,000 Scale Colour Raster	The scale mirrors OS Explorer Map Series showing a detailed overview of environmental and leisure features, again providing the ideal backdrop to overlay fieldwork observation and put them into context.
EDINA Digimap (2013)	OS Terrian 50 DTM	Scaled at 1:50,000, it allows regional overviews of landforms through adding the third dimension. The tiles will be used in slope analysis to provide an insight into surface runoff routes in the catchment, helping to identify the high risk areas.
Environment Agency (2014)	Risk of Flooding from Rivers and Sea Spatial Grid	National assessment of flood risk for England, shows the chance of flooding from rivers and/or sea, based on cells of 50m. Each cell is allocated one of four flood risk categories, taking into account flood defences and their condition. This will be used in identifying the high risk areas.

Extra shapefiles that were not readily available from other organisations were drawn on from other maps. Table 16 shows extra data drawn on.

Table 16. Extra shape files

DATA SOURCE	DETAIL
Loe Pool Catchment Management Project: 2009 Review (Dinsdale 2009)	Provided the catchment outline so will be used in identifying farms in need of improved management of inclusion into the Environmental Stewardship Scheme, that fall within the catchment.
Cornish Mining World Heritage (CMWH) (2004)	Map showing the Wendron mining district, part of which falls into the Cober catchment.
Environment Agency (2010-2014)	Grid coordinates of pollution incidents as detailed in the pollution event summary will be plotted to showing potentially recurring pollution risk sites.
Myself	Field work observations will be plotted to show any potentially recurring pollution risk sites.

Table 17 shows a brief explanation of how the map was constructed (Gorr and Kurtland 2005):

Table 17. Map Construction

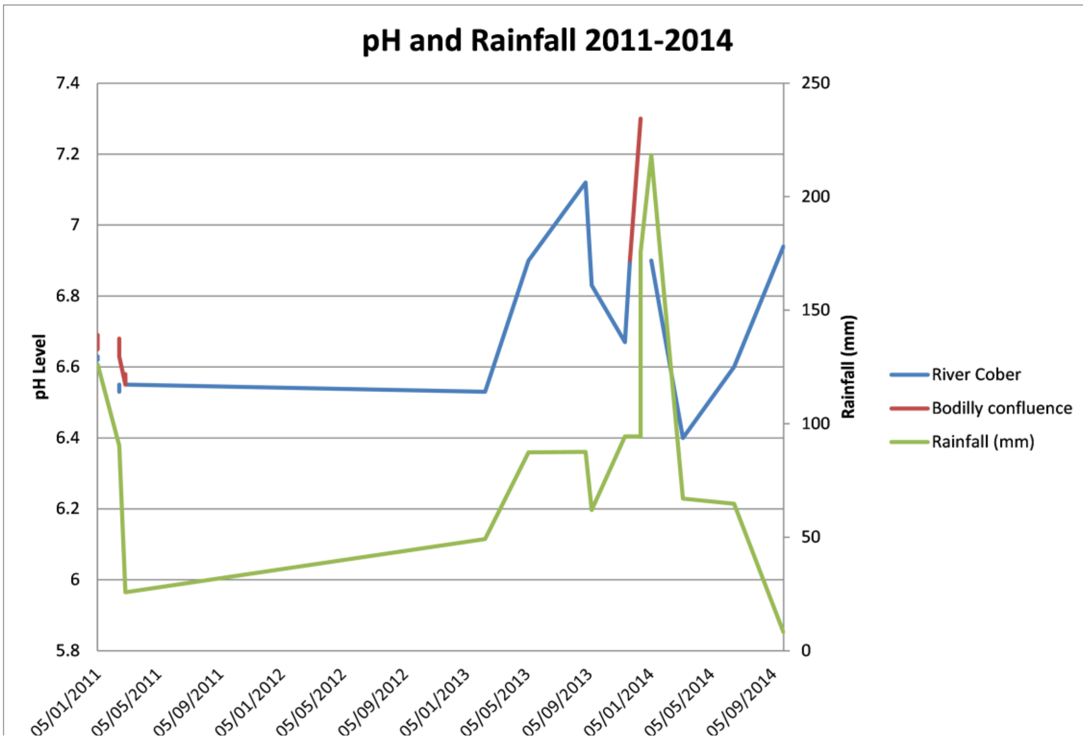
STAGE	EXPLANATION
1	Using the 'Add Data' navigate to the Meridian 2 shapefiles (river_polyline) and add. Continue to add all imported rasters, basemaps, DTM and shape files.
2	Ensure that all imported data was set to the spatial reference 'British_National_Grid.prj'
3	Ensure that any imported layers are spatially indexed (eg: flood risk from rivers and sea).

4	Once the DTM has been successfully uploaded, the 3D Analysis Tool found in ArcToolbox can be used to identify slope angle in the catchment. Giving an indication of the nature of surface run off. Using the 3D analysis tools allows for many map-algebraic operations to be used Kwan and Lee (2003).
5	Using ArcCatalog create any polygon or polyline shape files that need adding to the map (eg: catchment area, mining district, fieldwork observations).
6	Using the Editor tool draw on polygons and polyline and make sure edits are saved before Stop Editing is clicked.
7	The raster calculator too is used to determined slopes steeper than 13˚ as identified by Hopp and Mcdonnell (2009). It is sound in ArcToolbox, Spatial Analyst Tools, Map Algebra. The raster calculator is used to execute a map algebra expression that will output a raster (Wayne 2003). It also allows for map algebra to be easily integrated into you analysis (ArcGIS 2015).
7	Once all layers have been successfully uploaded, create a polygon shape file in ArcCatalog and draw in mining and agricultural risk areas. For mining risk the layers that remained on are: mining district, slope, fieldwork observations, flood risk, catchment area, EA pollution incident. For agriculture: HLS, slope, flood risk, fieldwork observations, catchment area, EA pollution events. The polygon was drawn around the layers switched on.
8	Once both polygons have been created, the Intersect tool, found in ArcToolbox, Analysis Tools was used to deduce the final high risk area. The intersect tool allows new features to be created based on the geometric intersection of the input features (Honeycutt 2012). The final polygon is the answer to dissertation objective 1.

5. Results

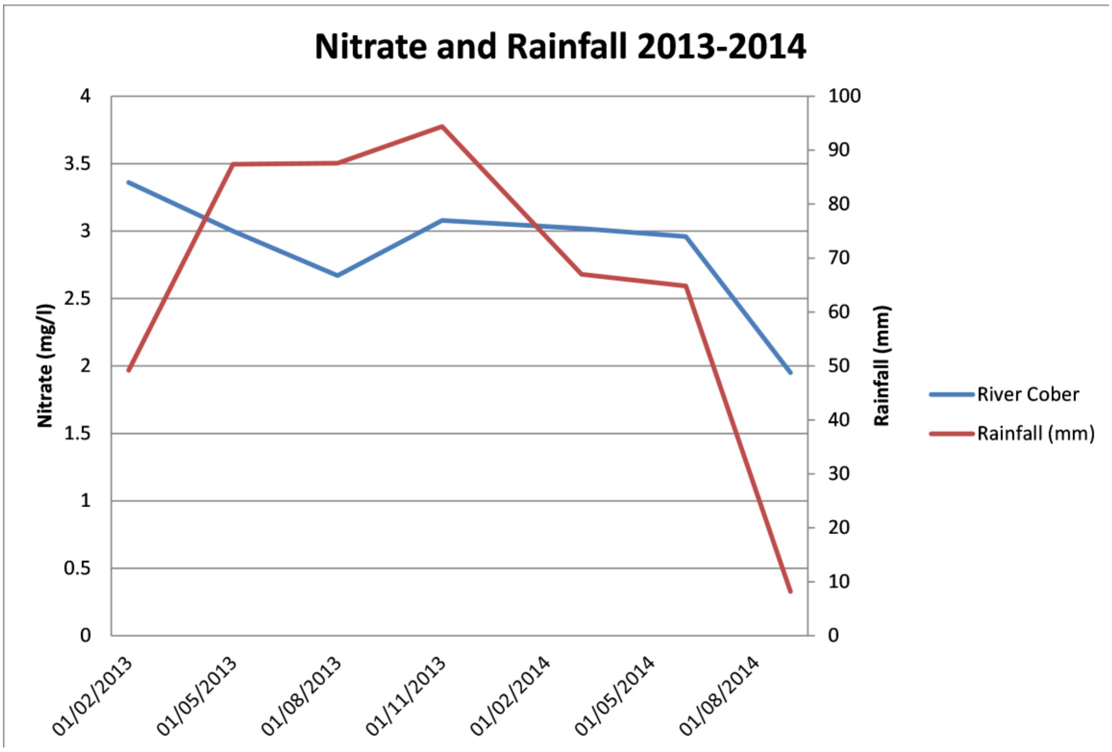
5.1 Graphical Analysis

The water variables were plotted against rainfall to establish any existing relationships and the potential stream that any pollutants originated from.



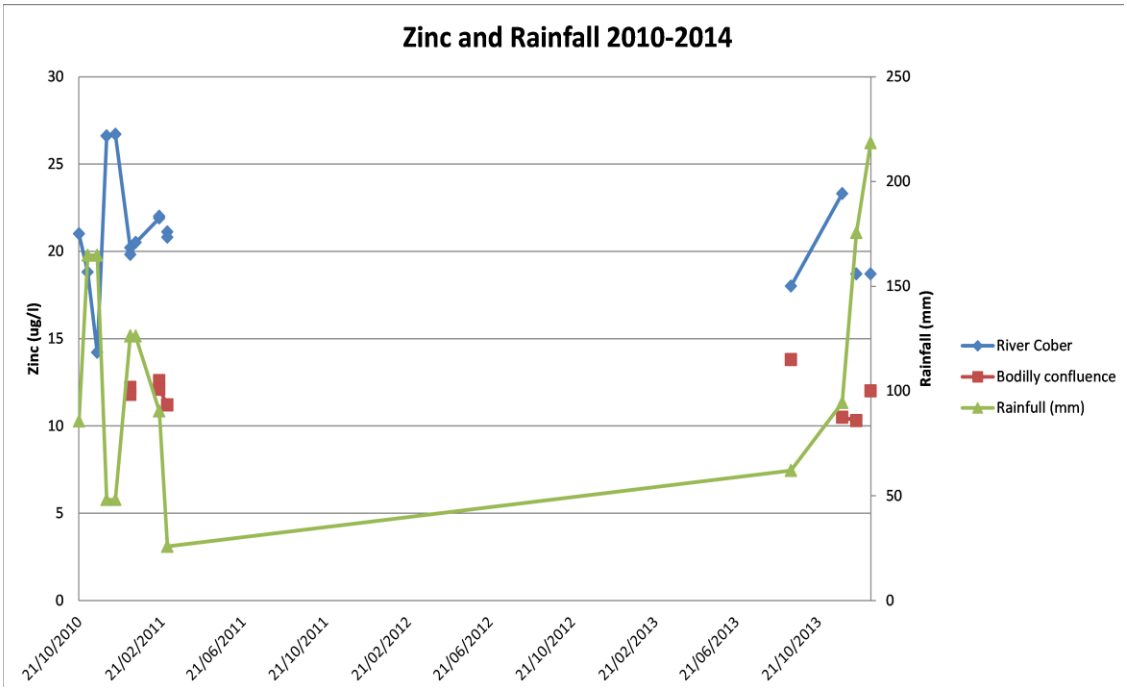
	CORRELATION WITH RAINFALL	AVERAGE
COBER	0.32	6.72
BODILLY	0.63	6.81

Fig 10. shows pH level of Cober and Bodily plotted again rainfall. Correlation for Cober is weak positive, compared to Bodily showing a relatively strong positive correlation to rainfall. This is attributable to the peak on 16/12/2013. The pH value for the Cober on 10/09/2013 is slightly higher than the average, which could correspond to a pollution event recorded by the EA a week later from pH ‘mobilising’ pollutants.



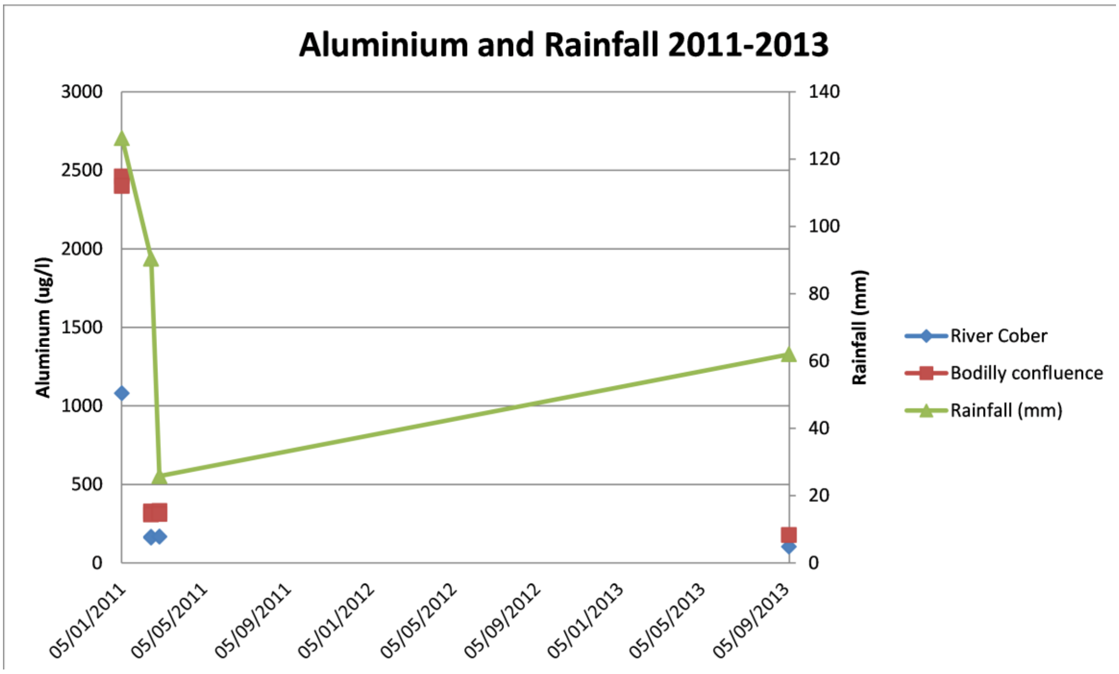
	CORRELATION WITH RAINFALL	AVERAGE
COBER	0.61	2.86

Fig 11. Shows pH for Cober plotted again rainfall. Although visually the graph looks as if there is little to no correlation, it is actually relatively strong positive at 0.61. Only had access to nitrate data for the Cober so unable to attribute correctly which area the pollution originated from.



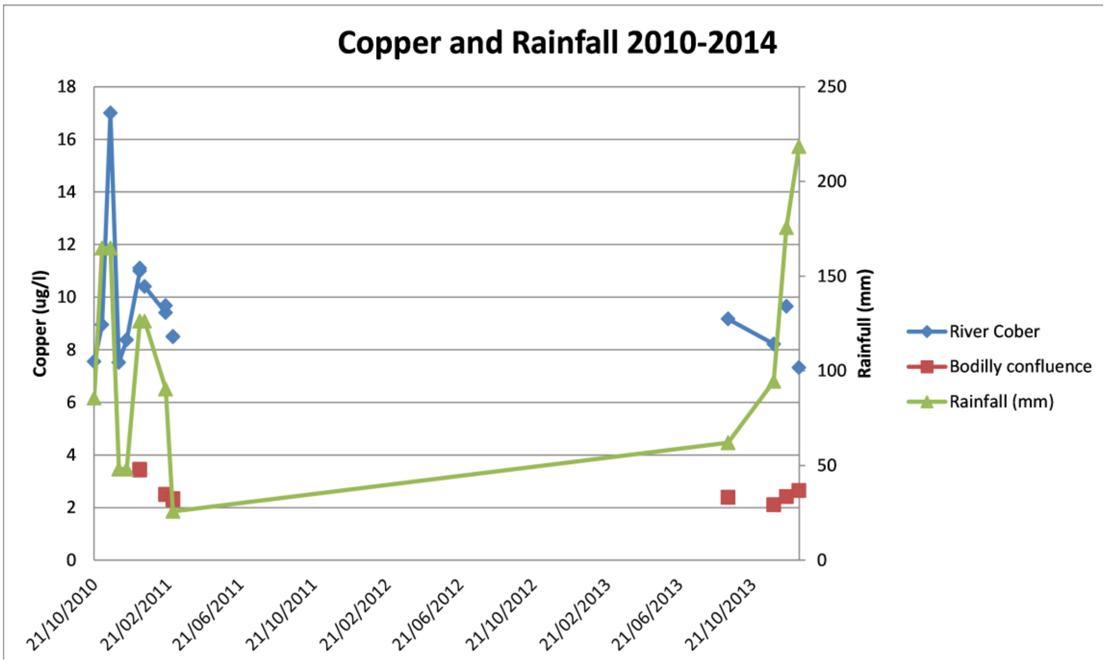
	CORRELATION WITH RAINFALL	AVERAGE
COBER	-0.59	20.77
BODILLY	-0.12	11.77

Fig 12. shows zinc plotted against rainfall. Cober has a much higher average and a considerably stronger negative correlation compared to Bodily. It can be deduced that the upper Cober above the Bodilly confluence is primarily responsible for zinc polluted runoff. The period of inactivity between 2011 and 2013 is because no data was collected during this time.



	CORRELATION WITH RAINFALL	AVERAGE
COBER	0.68	307.5
BODILLY	0.77	902.4

Fig 13. shows aluminium levels plotted against rainfall. The average aluminium levels for Bodilly stream is considerably higher but this can be attributed to the peak at the start of the data set. Both data sets show strong positive correlation. The period of inactivity between 2011 and 2013 is because no data was collected during this time.



	CORRELATION WITH RAINFALL	AVERAGE
COBER	0.34	9.52
BODILLY	0.35	2.6

Fig 14. shows copper plotted against rainfall. The Cober shows consistently higher levels than Bodilly identifying it as the dominant source of copper, however the average which is considerably higher is likely to the due to the peak recorded at the start of the data set. The period of inactivity between 2011 and 2013 is because no data was collected during this time.

5.2 Photographic Evidence

The figures shown below were taken when out collecting field observation to use supporting evidence.

Source: Angus (2015)

Ochre coloured from oxidated iron ore, a waste product in the mining process

Fig 15. Is a tributary of the Cober running past Poldark Mine. The ochre colour is a result of the oxidated iron ore, a waste product in mining. The picture shows evidence of strong sedimentation it is likely that mining activity is responsible for this also.

Source: Angus (2015)

Fig 16. shows evidence of poaching. It can be seen that livestock have been free to walk into the stream, resulting in trampling and sediment being washed into the stream. There is also evidence of effluent which can leach directly into the stream, increasing the nutrient load.

Poaching – little grass so sediment is not secure and can be washed into the stream.

Source: Angus (2015)

Fig 17. shows evidence of poaching. The two horses can walk freely into the stream, which is a tributary of the Cober and Bodilly. The lack of vegetation allows sediment to get washed away and its highly likely effluent is entering the stream also.

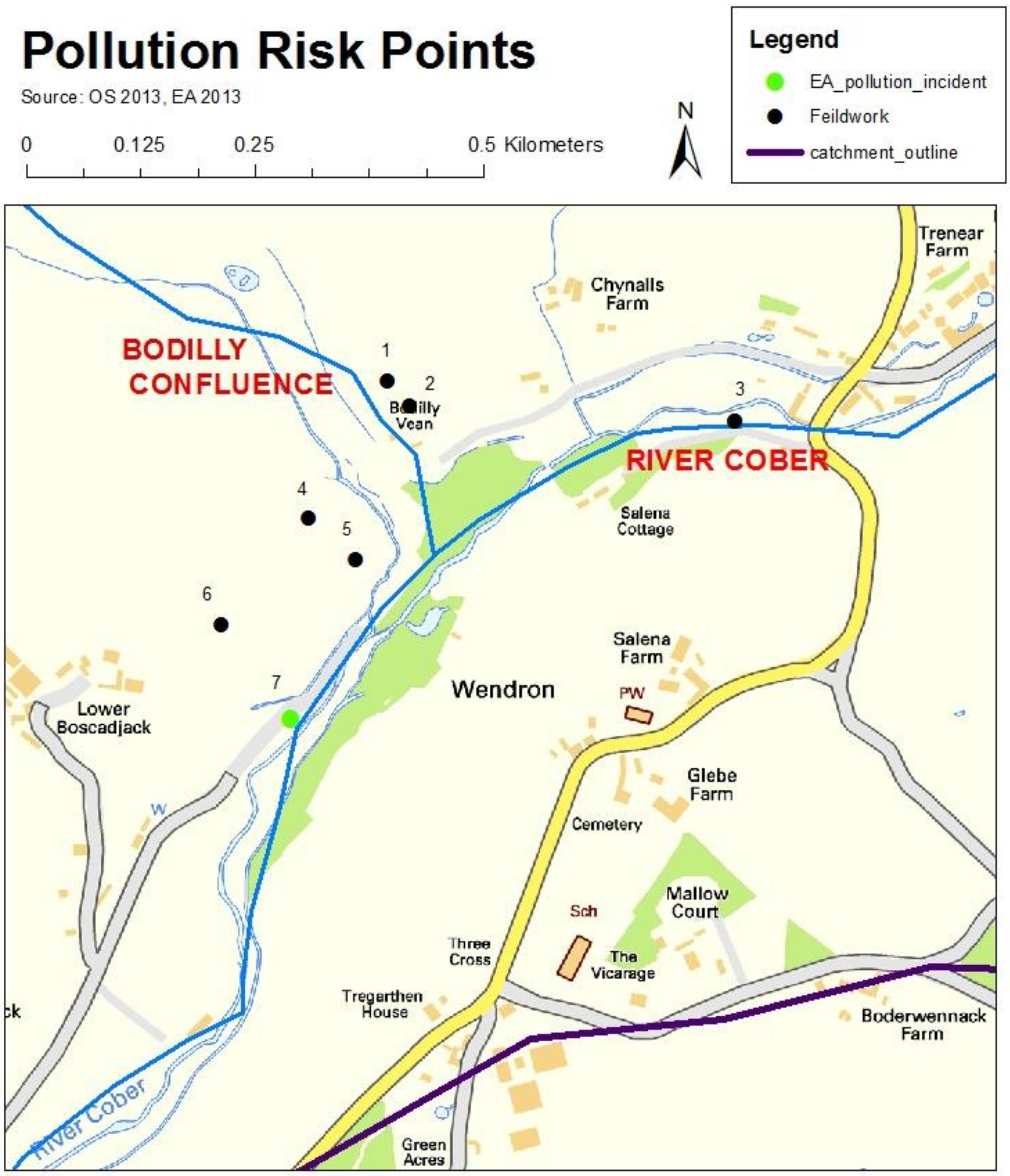
Grey, thick sediment at confluence, Trenear Bridge

Canalisation – flood alleviation feature

Source: Angus (2015)

Fig 18. shows the confluence to the Cober at Trenear Bridge. Can see heavy sedimentation which is likely to be of heavy industrial activity upstream from both agriculture and previous mining activity. There is also evidence of canalisation, this is likely to be part of a flood alleviation scheme.

5.3 ArcGIS Mapping and Analysis



Potential Diffuse Pollution Risk Sites:

1) Bodilly confluence, generally clear fast flow, evidence of poaching even though no livetsock kept in the feild, the grass had no be resewn. Water trough remained in stream on every visit.
2) Cober remained fast flowing, ochre coloured sediment. Sheep in feild adjacent to cober, can walk through the stream.
3) Cober remained fast flowing, varying strenght in ochre colour, evidence of heavy sedimentation.
4) Cober tributary remains very clear and fast flowing.
5) Cober tributary clear and fast flowing however evidence of poaching and degrading gunnera next to stream.
6) Although tributray is clear and fast flowing, evidence of poaching, two horses can walk into and through the tributary.
7) EA POLLUTION EVENT - detection of pesticide 24D, in breach of the maximum standard.

Fig 19. Map showing location of field work observations (including sites of potential diffuse pollution) and EA pollution incidents.

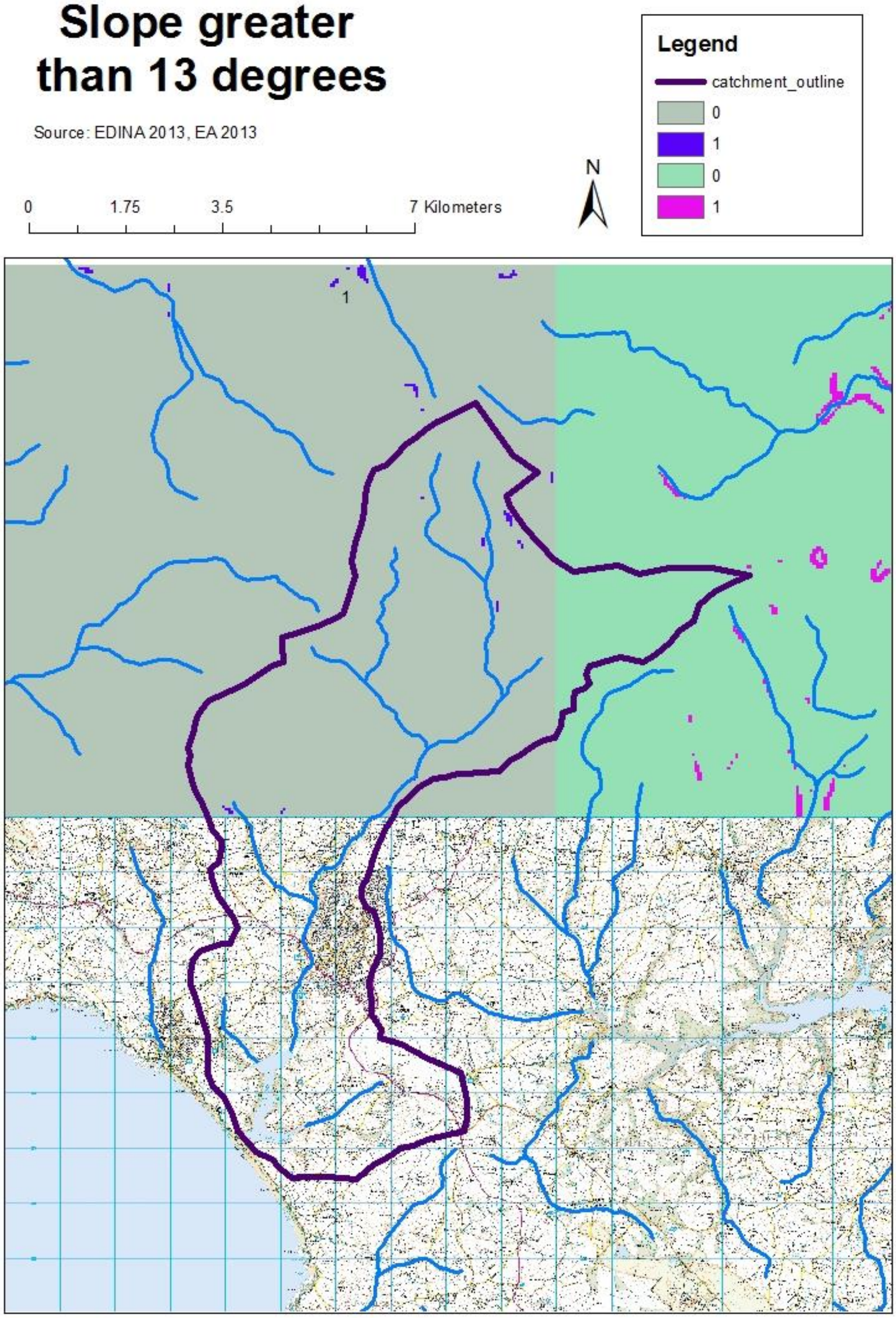
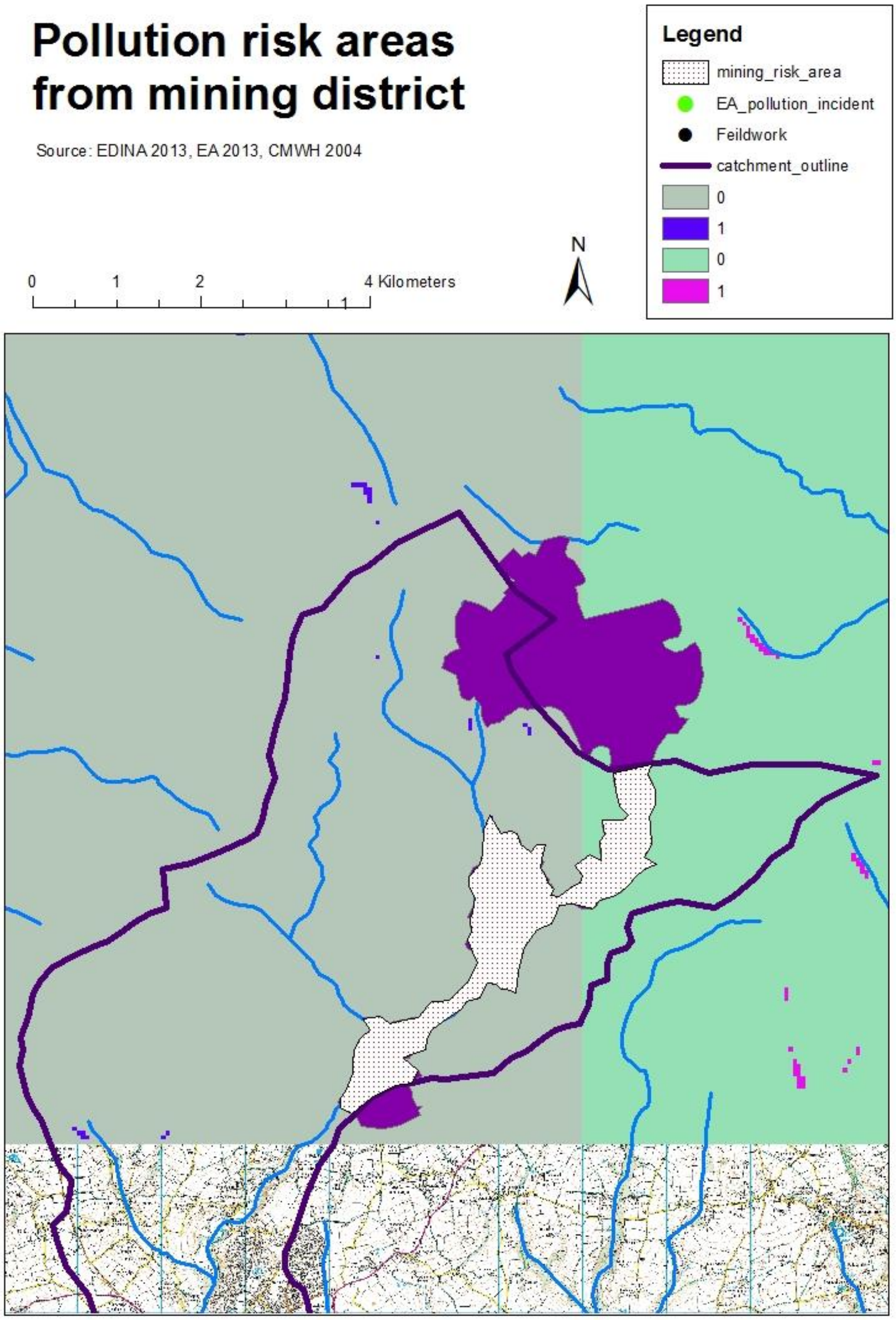


Fig 20. Map showing slopes with angle greater than 13˚.



Map 21. Map showing pollution risk from past mining activity in the catchment.

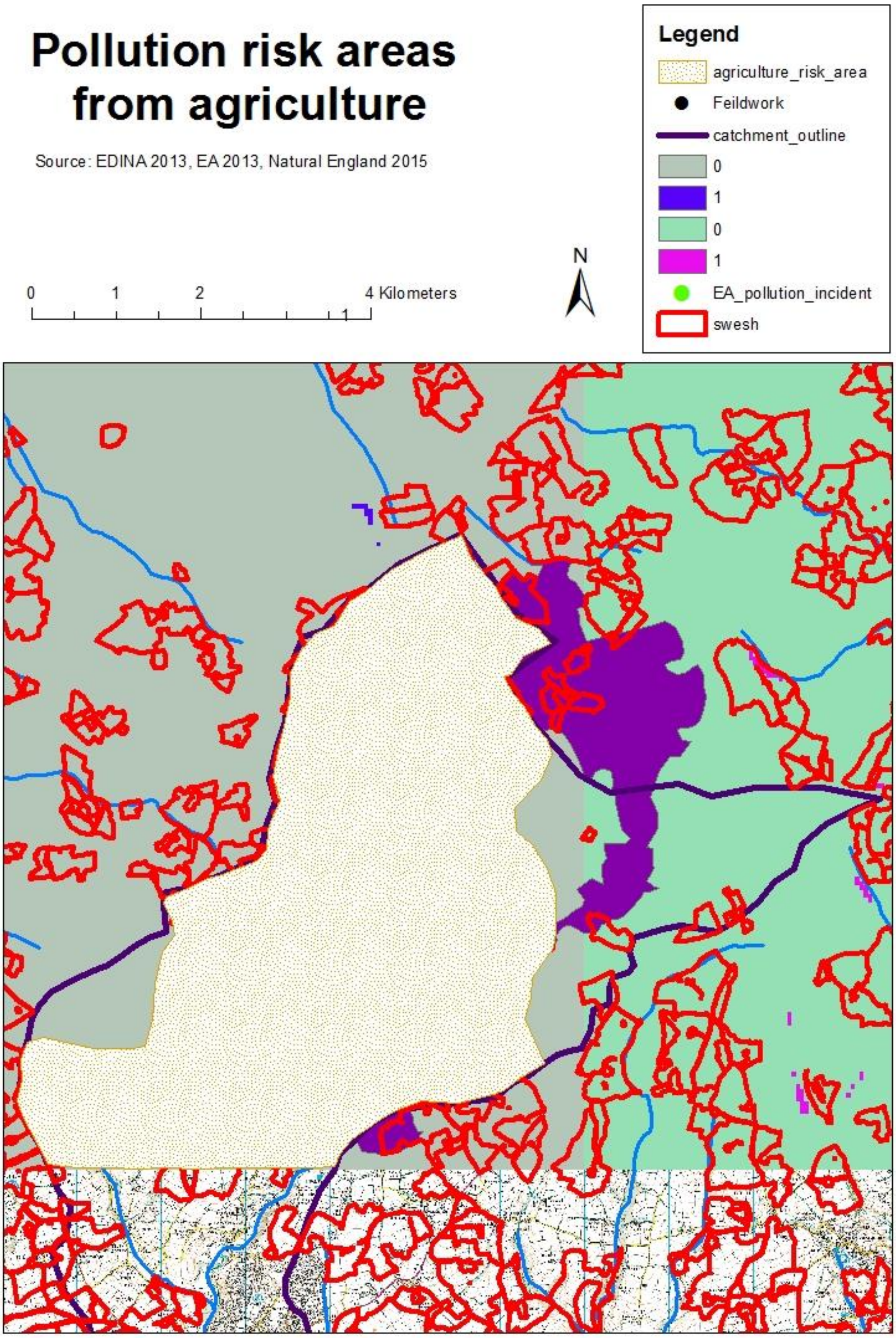


Fig 22. Map showing pollution risk from agricultural activity in the catchment.

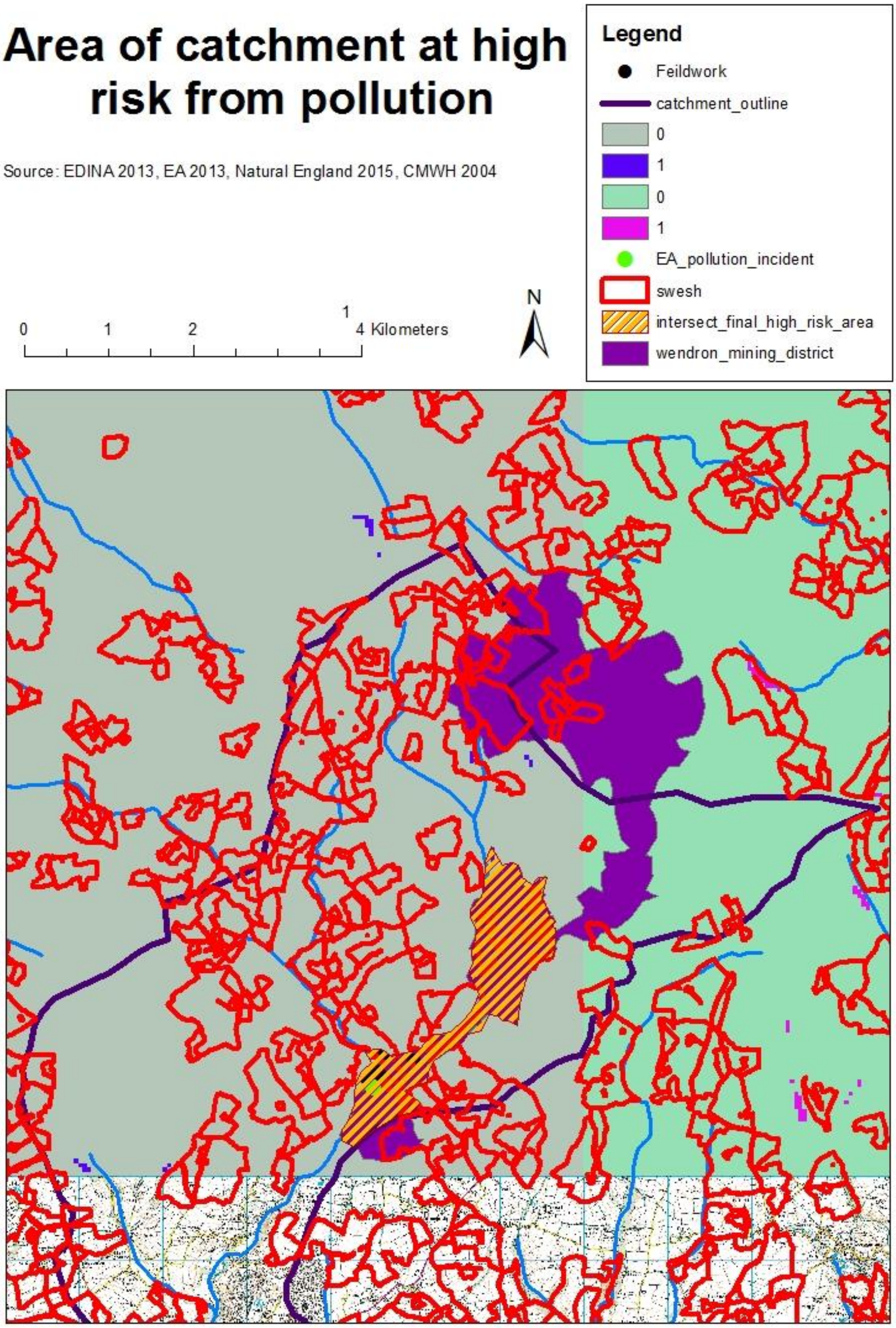


Fig 23. Map showing intersect of pollution risk areas from mining and agriculture.

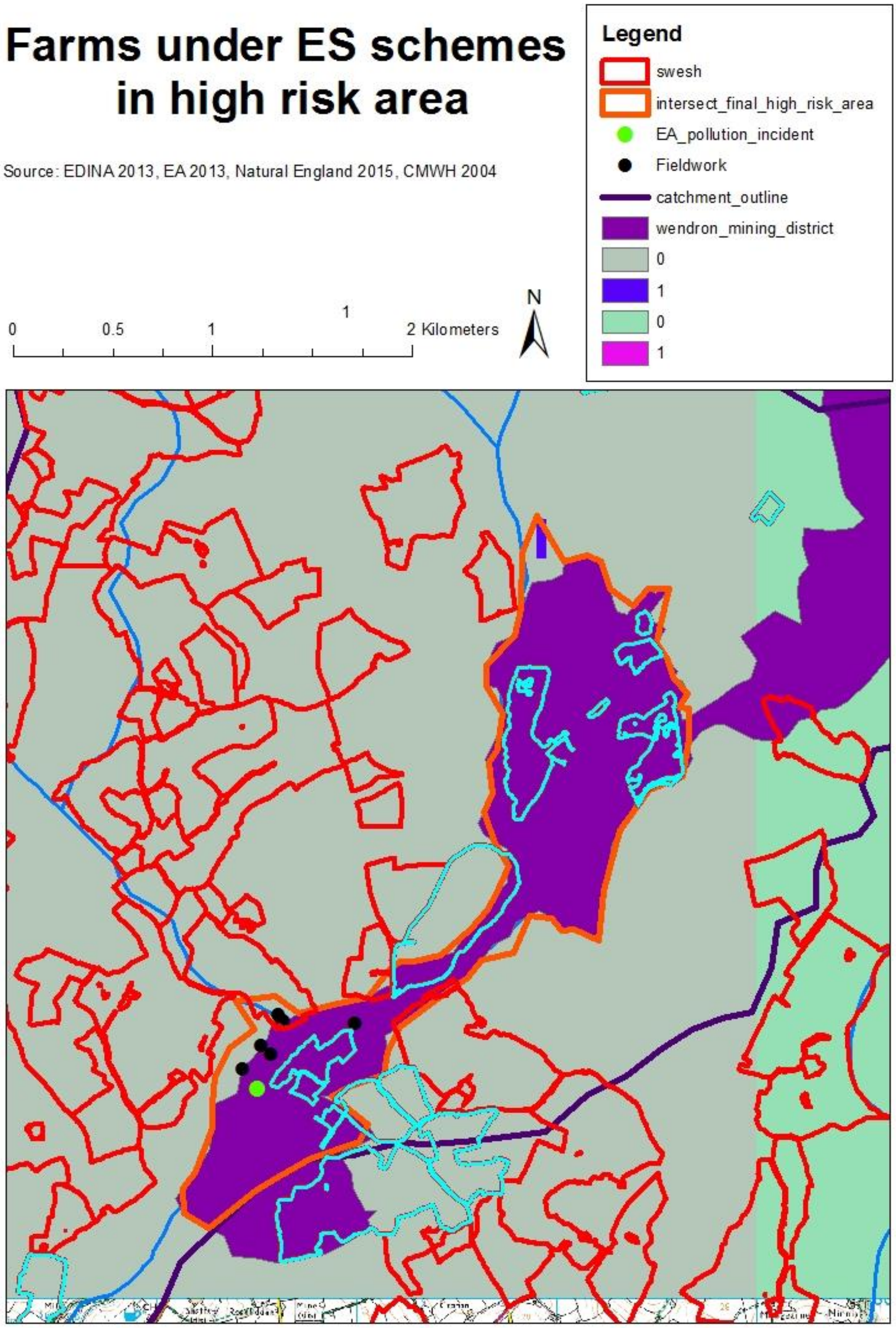


Fig 24. Map showing farms falling into the identified high risk area, that are already in an ES agreement.

6. Discussion

This section will discuss how the dissertation aims and research objectives were met and the reasoning behind results and analysis completed.

6.1 Identify and map areas of the upper Cober catchment that pose a 'high risk' to water quality and flood risk downstream.

In order to identify and map 'high risk' areas, field work observations were collected and combined with secondary data using ArcGIS. The spatial analysis tool in ArcGIS was used to deduce the high risk area. Fotheringham and Rogerson (1994) summarises the benefits of spatial analysis in GIS in allowing more realistic and contextual spatial properties to be dervived.

6.1.1 Deducing the 'high risk' area

As discussed in the literature review, Heathwaite et al (2005) and Horton (2014) identify factors controlling the transport of nutrients and flood risk respectively. Field work observations collected for the study can be seen as critical cource areas (CSA) as discussed by Heathwaite et al (2005) in the literature review. The photographic evidence collected indicates evidence of poaching and sedimentation, SEE FIG…. Heathwaite et al (2005) adds through identifying CSAs such as Fig. 16, 17; it is possible to create simple and affordable changes in land use and management that can disconnect, store and buffer nutrient transport along the catchment. See table 18, 19 for the layers used to meet these factors. Missing layers are because of restricted access to data, further research enabled the analysis of the remaining factors.

Table 18. Nutrient Transport – layers used.

	Factors controlling nutrient transport	**Layer used in study**
1	Slope	Terrain DTM – raster calculator
2	Drainage	-
3	Soil and geology	-
4	Crop management	Swesh (ES schemes)
5	Tramlines, tyre tracks, roads, paths	A and B road polyline

Table 19. Flood Risk – layers used.

	Factors influencing flood risk	Layers used in study
1	Topography	Terrain DTM – raster calculator
2	Soil	-
3	Geology	-
4	Vegetation	-1:25,000 Colour raster
5	Climate-hydrologic	-

There is little woodland in the catchment other than the 46ha surrounding Loe Pool itself (Caord 1987). This means there is little rainfall interception, therefore energy in rainfall is maintained which increases the rate of soil erosion (Watson and Adams 2011). This results in the Cober being highly exposed to erosion and sedimentation downstream. The River Cober lies on a bedrock of sandstone which has limited permeability, further increasing flood risk. Heathwaite et al (2005) adds that heavy industrial activity will affect ground water flow and any potential pollutant it uptakes; the previous mining activity on the catchment will have directly affect this.

Hopp and McDonnell (2009) established that slope angle generally had an intensifying effect on the hydrologic response of the hillslope. It was determined that above 13˚ distinct flow paths were found that directly linked to the water body central to the study. Therefore 13˚ was used as the basis for slope analysis for this study. The raster calculator is used to execute a map algebra expression that will output a raster (Wayne 2003). The raster calculator was used in this study to show slope greater than 13˚, which would be used in identifying the high risk area.

See table 20 for layers switched on for agriculture and mining risk areas.

Table 20. Layers for agricultural and mining risk areas.

Agriculture Risk Area	Mining Risk Area
EA pollution incident	EA pollution incident
Field work observations	Field work observations
Catchment outline	Catchment outline
A and B roads	A and B roads

Slope	Slope
ES schemes	

See Fig 21. for pollution risk from mining, and Fig 22. for pollution risk from agriculture. After drawing the risk areas for mining and agriculture the intersect tool was used. This allows new features to be created based on the geometric intersection of the input features (Honeycutt 2012). This deduced the final 'high risk' area see Fig 23. which considered all the factors influencing water quality and flood risk.

6.1.2 GIS for Analysis

GIS proves itself as a valuable analysis tool in effectively identifying the high risk areas. This can be supported by Fig 24. showing farms already in varying ES schemes falling into the high risk zone, please see Appendix 7 for farm details. The technique developed in this study can be used on other catchments at a wider scale to help minimise the effects of diffuse water pollution from agriculture (DWPA).

6.2 Suggest appropriate measures to take in reducing the risk to water quality and flood risk.

The water quality data and rainfall data was plotted against one another in order to establish which stream certain chemical elements and pollutants largely originated from. Knowing this allows appropriate management to be directed to the correct areas of the catchment. It must be noted that due to the irregularity in data collection with particular reference to data from Bodily confluence, validity of some of the conclusions drawn is questionable and not as accurate if data was recorded at regular intervals.

6.2.1 Discussion of Graphical Analysis

Graph 1 shows that when rainfall peaks, so does pH for both Bodilly and Cober, both show a positive correlation however the correlation between Bodilly pH and rainfall is more strongly positive. Acid rain caused by sulphur and nitrogen oxides as a result of anthropogenic climate change can acidity of water to change (Smol 2008). Acidity can further be altered by surrounding rock (EPA 2015). The River Cober is situated on a bedrock of sandstone which is more acidic. After heavy rain, causing the water table to rise leading to acidic water rising too, this could explain Cober not reaching pH levels as high a Bodilly (SDWF 2015).

Nitrate levels were only available for the Cober which doesn't help in identifying the area of the catchment the pollutant mainly originated from but it does give good insight into the normal levels in the catchment. Nitrate is found in both surface and groundwater sources, but is primarily as a consequence of agricultural activity (Harrison 2001). The strong positive correlation indicates greater rainfall leads to higher levels of nitrate. The strong positive correlation is because nitrogen is very soluble (nitrogen is an element in nitrate), up to half of the nitrogen applied to crops is lost to groundwater because of the solubility (Mason 2002) It can be suggested that land owners that fall within the high risk area identified by Fig 22. with focus on land adjacent to the Cober, should uptake schemes such as CSF, ES and what will be NELMS which train and advise land owners on appropriate, tailored land management practices (Gov 2015). Such practices include limitation of fertiliser applications and modification of crops (Department of the Environment 1988). Through controlling land use, the regulation of diffuse pollution is possible as stated by Harrison (2001) and this will directly benefit the entire catchment.

Fig 14. shows Cober had consistently higher copper levels than the Bodilly, indicating that the primary source of copper originates from further upstream on the Cober. Mining activity is likely to be the single source of enhanced levels of copper in the Cober; along with aluminium and zinc. Copper can become mobile in neutral pH conditions and is accelerated in low pH conditions, which could prove a problems as the Cober is situated on acidic sandstone (SDWF 2015). This is supported by Fig… PH!!!! Showing Cober having a consistently lower pH. Analysis suggests that copper and zinc originated from the Cober and aluminium slightly more so from Bodilly. It can be suggested that run-off attenuation features (RAFs) are introduced across the high risk area with particular focus on land situated close to the River Cober, rather than Bodilly Stream due to the higher presence of elements with mining origins as identified by Fig 23. This is supported by Fig 21. As the land focussed on for RAF introduction falls into the mining risk area. RAFs, as discussed by Barber and Quinn (2012) in the literature review provide low-cost features which slow, store and filter run off from agricultural land, therefore reducing flood risk, improving water quality and creating new habitats and biodiversity. The introduction of such RAFs present themselves as the ‘affordable changes in land use and management’ as identified by Heathwaite et al (2005). This is supported by Dinsdale (2009) who explains that simple land management measures can also be used as part of sustainable catchment scale flood risk management. The uptake of field bunds could be recommended to land owners situated in the high risk area as they take up little space (compared to wetlands which require larger amount of space which part of the Cober catchment can not offer) and are multi-functional as can double as a raised farm track (Barber and Quinn 2012).

6.2.2 Looking to the Future

As discussed in the literature review the Cober catchment falls under the priority catchment status for CSF, meaning that free training and advice is available to all farm owners in the catchment (Gov 2015). Although currently it is still in the early stages, NELMS and the ES agreements which are being renewed provide the leading, tailored advice in land management for land owners. This study suggests that all land owners falling within the high risk area should strongly consider taking up a NELMS or ES agreement. If it is not possible to meet the criteria then RAFs can be constructed independently at a low cost. Courtney et al (2013) mentions the wider benefits in taking up such schemes and modifications including direct employment and income to local economies through any construction associated with implementing modifications. This is essential in Cornwall because of the seasonal fluctuation in the economy and the unemployment rate considerably higher than the UK average at 5.1% (Cornwall Council 2013).

It is central that a holistic catchment management is approach is adopted in the Cober in order to deal with the prospect of the nature of the catchment changing because of climate change. This s echoed by Dinsdale (2009) who highlights climate change predictions indicate that the need for integrated catchment management, to increase the resilience of catchments, wildlife and people to extremes of weather conditions such as floods, has never been greater.

7. Research Limitations

Limitations attached to primary research data collection include human error and precision errors attached to the GPS which can have variations of 7-8m (GPS World 2015). The implications of limitations such as this can be reduced by using a newer model of GPS which will be more accurate. These limitations apply to water quality data collected by the EA too as that was collected manually.

Limitations attached to secondary research data include that the rainfall data collected by the Met Office was a monthly average, therefore did not directly correspond to the water quality data. However the main inaccuracy attached to the research primarily originates from tiles, rasters and shape files used for analysis in ArcGIS. All data was sources from reputable organisation and no more than five years old, therefore was the most reliable and up to date data available.

8. Conclusion and Further Study

8.1 To identify and map the areas of the upper Cober catchment that pose a 'high risk' to water quality and flood risk downstream.

In summary, research objective one was answered through mapping an area that posed 'high risk' to water quality and flood risk downstream (Fig 23.). This was deduced from mapping areas that pose risks from agricultural and previous mining activity (Fig 21, 22). The high risk area follows the River Cober, extending from Porkellis to Coverack Briges, therefore including Wendron and Trenear.

8.2 Suggest appropriate measures to take in reducing the risk to water quality and flood risk.

Research objective two was answered following analysis using water quality data, the study was able to begin finding the origin of certain forms of diffuse pollution (Fig 10, 11, 12,13). In turn, a more tailored and appropriate management strategy can be put in place. This study strongly recommends that land owners situated in the high risk area (Fig 23) uptake schemes such as Catchment Sensitive Farming, Environmental Stewardship and New Environmental land Management. For the areas of land that do not meet the criteria for such schemes, the study recommends that run-off attenuation features are introduced with particular focus on land falling into the mining risk area (Fig 21, 23).

8.3 Further Study

Further study could include adapting this study to other priority catchments, as outlined by CSF; and tailoring appropriate land management practices. Analysis with ArcGIS could be extended further through modelling hydrology to give a more accurate representation of flood risk.

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Appendix 1: Cober Catchment Timeline

Water Quality Events on the Cober Catchment
Past To Present

1700s	First steps taken to regulate lake level artificially. It occurred indirectly as a result of the excavation of Wheal Pool, a mine shaft dug into Loe Valley.
1800s	River Cober offered a convenient route for the disposal of mine wastes. Much of the material is in the form of fine sediments. Roger (1857) commented on the pollution of the Cober and the reddish tinge in parts of the pool.
1900s	
1930	Coard pool has suffered eutrophication.
1976	2000 fish (mostly trout) were suffocated during an algal bloom.
today	SWW treatment improves which should reduce trihalomethane exceedance precursors at Wendron and Restormel works. Based on this, the inspectorate will be challenging whether the company had taken steps to minimise disinfection by products.

Land Use On The Cober Catchment
Past To Present

1700s	30 tin mines active in the Cober catchment
1800s	Metalliferous mining expanded and peaked between 1860-1880, notably Wendron Consols and Porkellis United employing a considerable labour force.
1875	Public Health Act, Helston Borough Council introduces sewage system that carried sewage from 40 households into the River Cober.
1879	Sewage system joined by a further 50 households. This increased further from 1930.
1900s	Production declined until 1900
1920-30	Tin mining within the catchment had major impact on the lake and has given rise to periods of rapid sediment accumulation.
1924	'Tidal wave' massive movements of shingle from Loe Bar – tidal surge??
1930	Helston sewage treatment works was built. It discharges into the Cober, therefore influences the nutrient supply.
1939	End of all mining activity in the catchment. Since the discharge of treated sewage effluent begun in 1930, this became the dominant influence upon the lakes ecology.
2002	
today	R.N.A.S Culdrose has two treatment works. Effluent discharges from one into the Carminowe Stream, therefore into the lake.

Flood Events on the Cober Catchment
Past To Present

1700s	
1800s	
1874	The lake was no longer regularly open to the sea. It became predominately fresh water throughout the year.
1900s	Flooding of the valley up to Helston became more and more frequent. It could be assumed this was due to the siltation. A long neglected mine in the south west corner of the catchment was re-opened to accommodate for drainage from the lake. This was blocked by shingle in storms.
1906	Compared to 1867, as bar dimensions increased, frequency of wave overwash decreased.
1924	'Tidal wave' massive movements of shingle from Loe Bar – tidal surge??
1979-84	SSW used bulldozers to form a channel in the centre of the bar.
1986	A modern outflow was built, improving the old miners drainage
1988	A stretch of the river through the marsh was canalised in attempts to alleviate flood problems
2002	Helston was flooded and over 60 properties were affected
today	Increase in lower lake levels resulted in the flooding of the lower parts of Helston

Public Reports on the Cober Catchment
Past To Present

1700s

1800s

1900s

2010

2012

2013

2014

today

South West Water are reporting that between 12.30 and 2.30 on 27/6 the raw intake River Cober at the Trenear Intake had high amonia readings. Maximum Amonia level was 0.43 mg per litre which triggered the works shut-down procedure. High amonia readings have been unusual as there has been little rain.

Caller reporting an ammonia spike on the river Cober at the intake near the SWW treatment works. Reports say that the treatment works shutdown at 0.2mg/l. SWW have had 3 occasions that the drinking water intake has had to close due to elevated ammonia levels.

Caller reporting SWW, Wendon Water Treatment Works. There are ammonia spikes that are causing multiple shut downs, they would like an officer to investigate.

Incident occured on the River Cober near to Wendron. SWW are reporting detections of the pesticide 24D. A sample was taken on 11.09.13 of treated water sample and found to contain 117 ng/l. A maximum standard is 100 ng/l. They are optimising treatment to deal with it.

Reports at SWW Wendron that there is elevated ammonia in the raw water. The water treatment works are shut down at the moment, they cannot produce any water because of the ammonia.

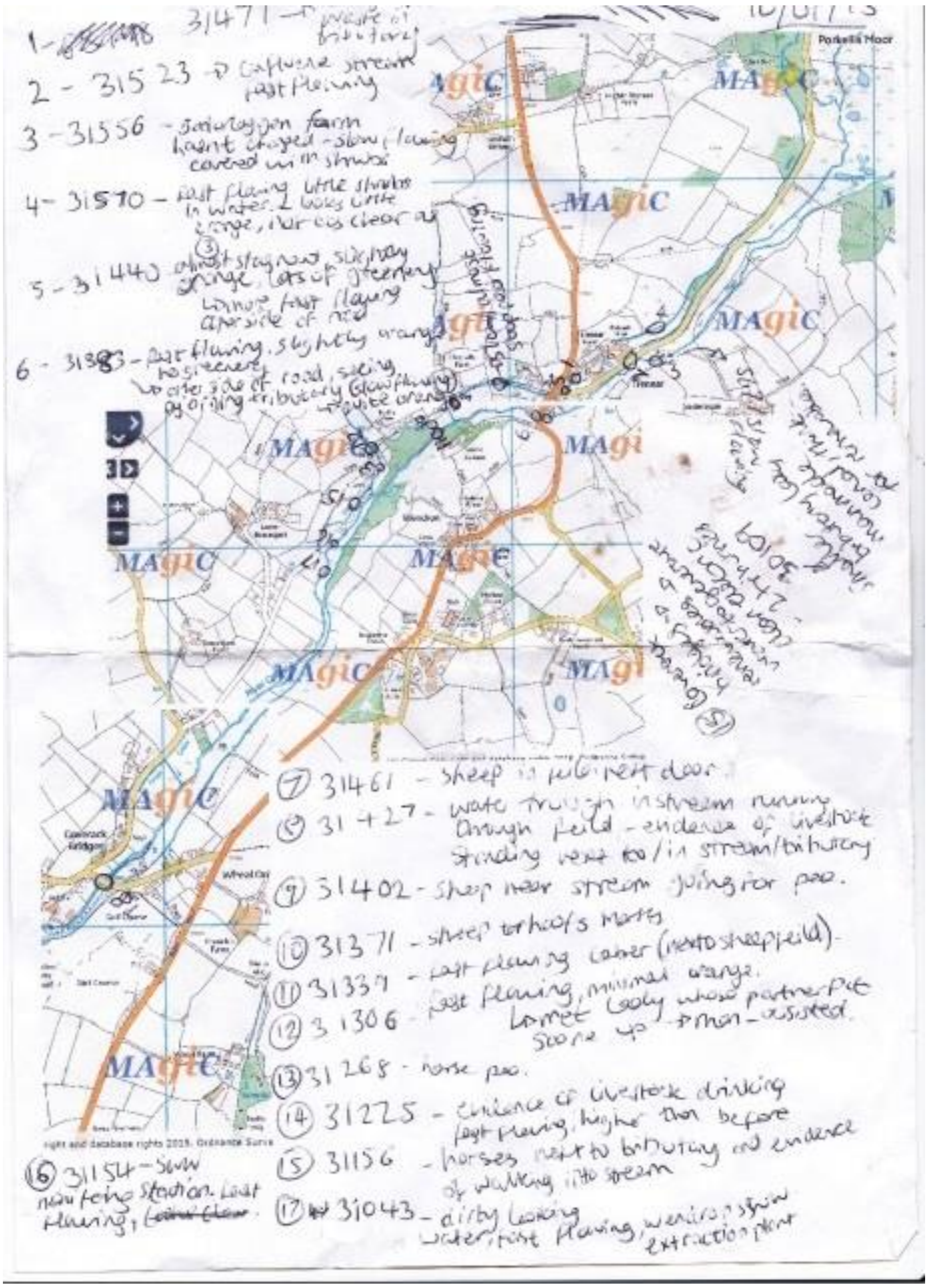
Reporting high ammonia readings on the intake pipe to Wendron water treatment works. Readings: 0.8 milligrams per litre at 20:00 - 24/03/14; 0.7 milligrams per litre at 12:00 - 25/03/14. This may be caused by heavy rain fall in the area.

The caller is reporting that at Wendron works has shut down due to high ammonia levels running into the site. The operator on site stated they believe it is from either slurry or sewage problems in the area. The EA may already be aware of the issue.

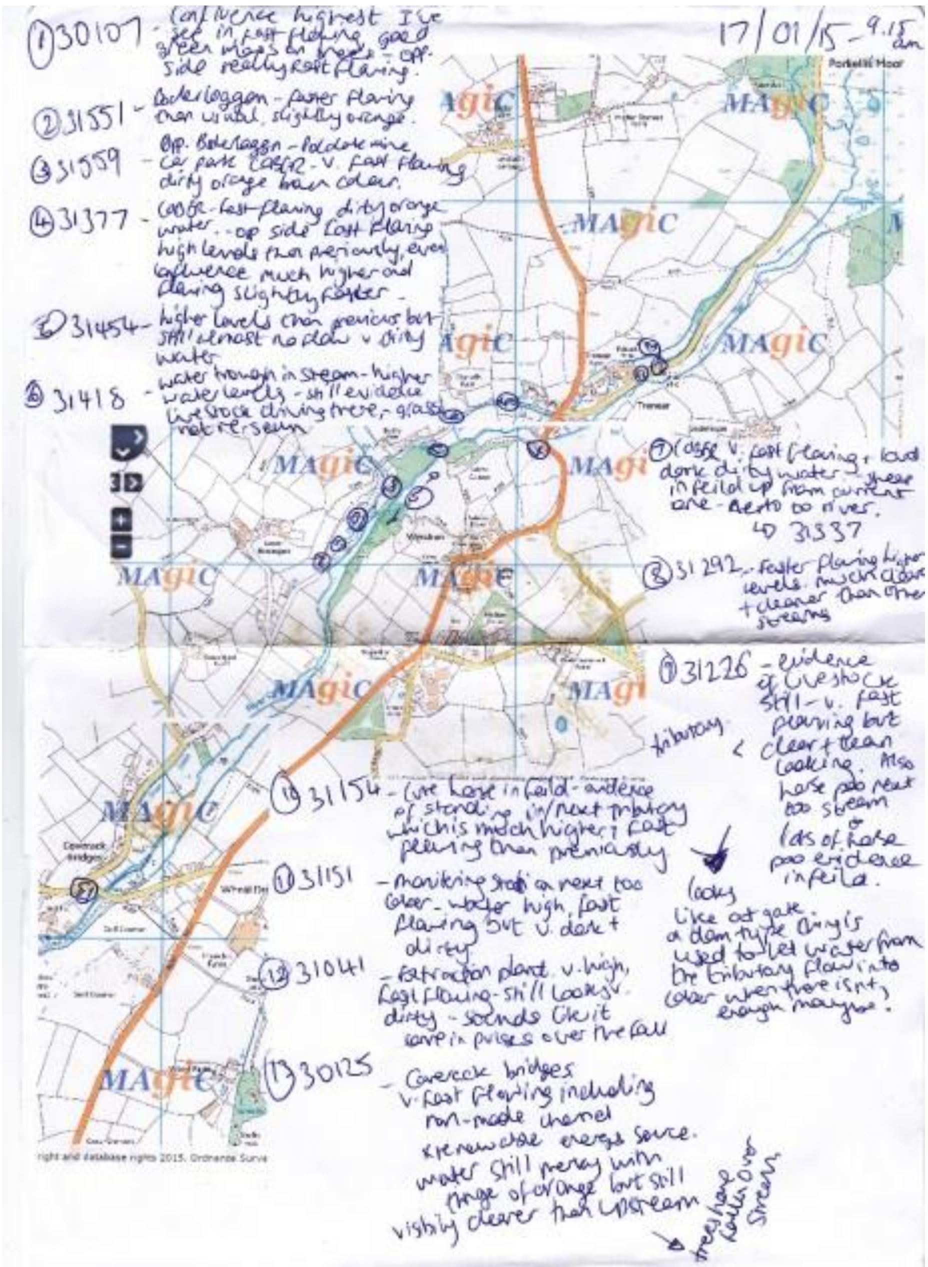
Caller from south west water reporting they have exceeded the permitted level of ammonia from the Wendron treatment works into the River Cober. (5mg > 2mg)

Appendix 2: Field notes and photographs

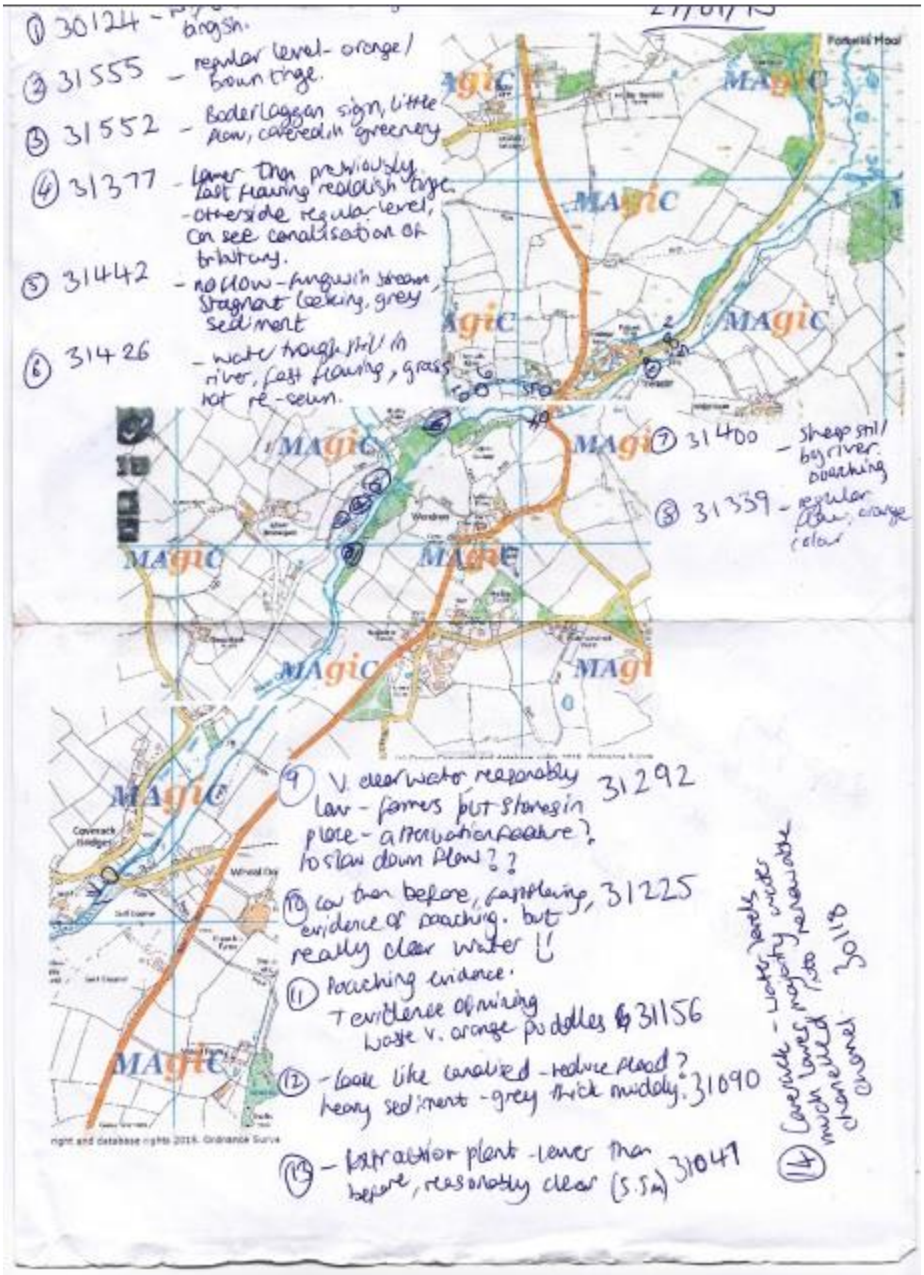
10/01/2015



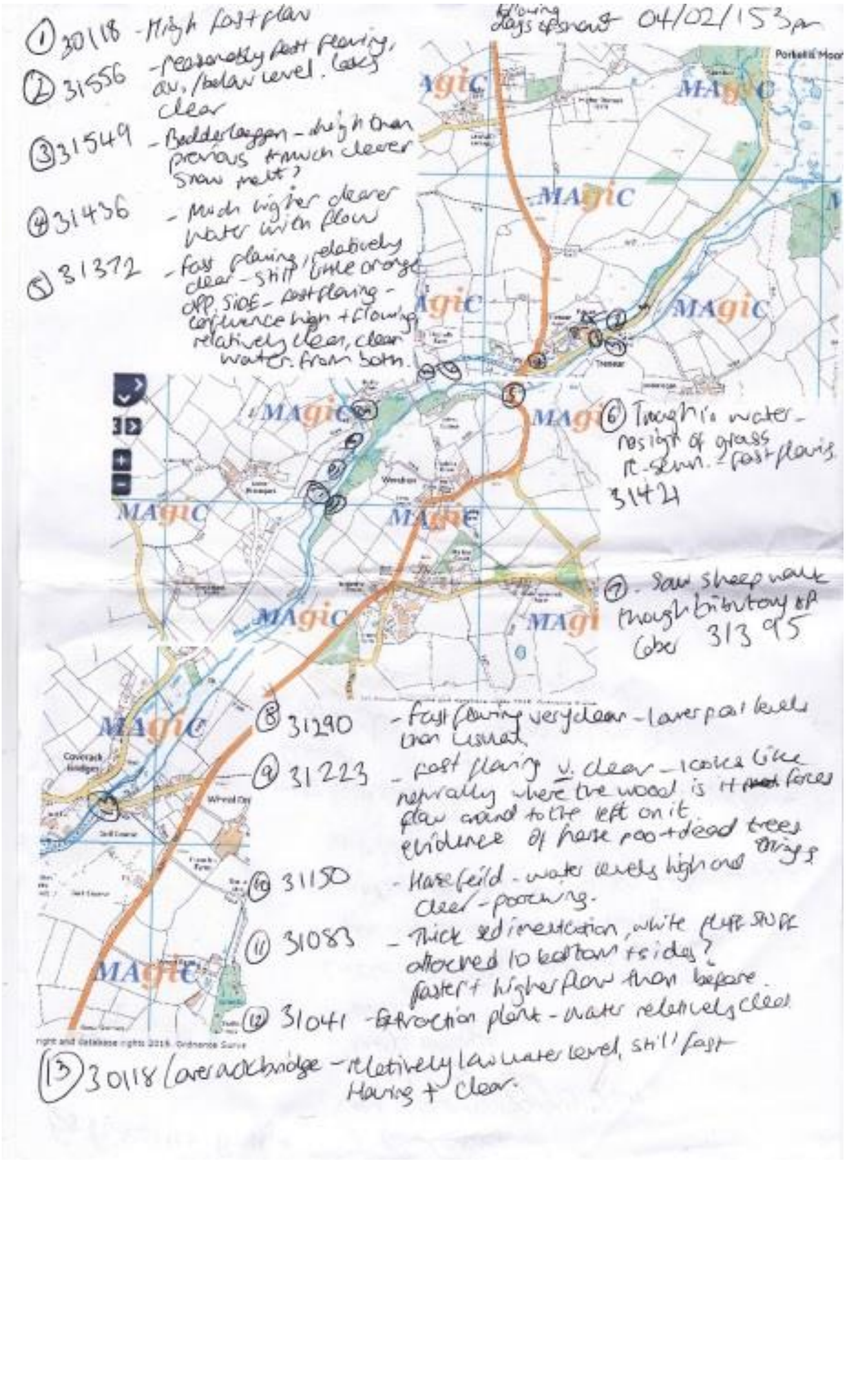
17/01/2015


17/01/15 - 9.15 am
Porkellis Moor
① 30107 - confluence highest I've see in, fast flowing, good green moss on trees - opp. side really fast flowing.
② 31551 - Boderloggan - faster flowing than usual, slightly orange.
③ 31559 - Opp. Boderloggan - Poldowe mine car park CARGR - v. fast flowing dirty orange brown colour.
④ 31377 - CARGR - fast flowing dirty orange water. - op side fast flowing high levels than previously, even confluence much higher and flowing slightly faster -
⑤ 31454 - higher levels than previous but still almost no flow v dirty water
⑥ 31418 - water through in stream - higher water levels - still evidence livestock driving there, - grass not re-seen
⑦ close v. fast flowing + loud dark dirty water - there in field up from current one - next to river.
31337
⑧ 31292 - faster flowing higher levels. much clearer + cleaner than other streams
⑨ 31226 - evidence of livestock still - v. fast flowing but clear + clean looking. Also horse poo next to stream + lots of horse poo evidence in field.
tributary
looks like out gate a dam type thing is used to let water from the tributary flow into other when there isn't enough maybe?
⑩ 31154 - live horse in field - evidence of standing in/next tributary which is much higher + fast flowing than previously
⑪ 31151 - monitoring station next too - clear - water high, fast flowing but v. dark + dirty
⑫ 31041 - extraction plant. v. high, fast flowing - still looks v. dirty - sounds like it came in pulses over the fall
⑬ 30125 - Coverack bridges v. fast flowing including man-made channel + renewable energy source. water still murky with tinge of orange but still visibly clearer than upstream
trees have fallen over stream
right and database rights 2015. Ordnance Survey

27/01/2015

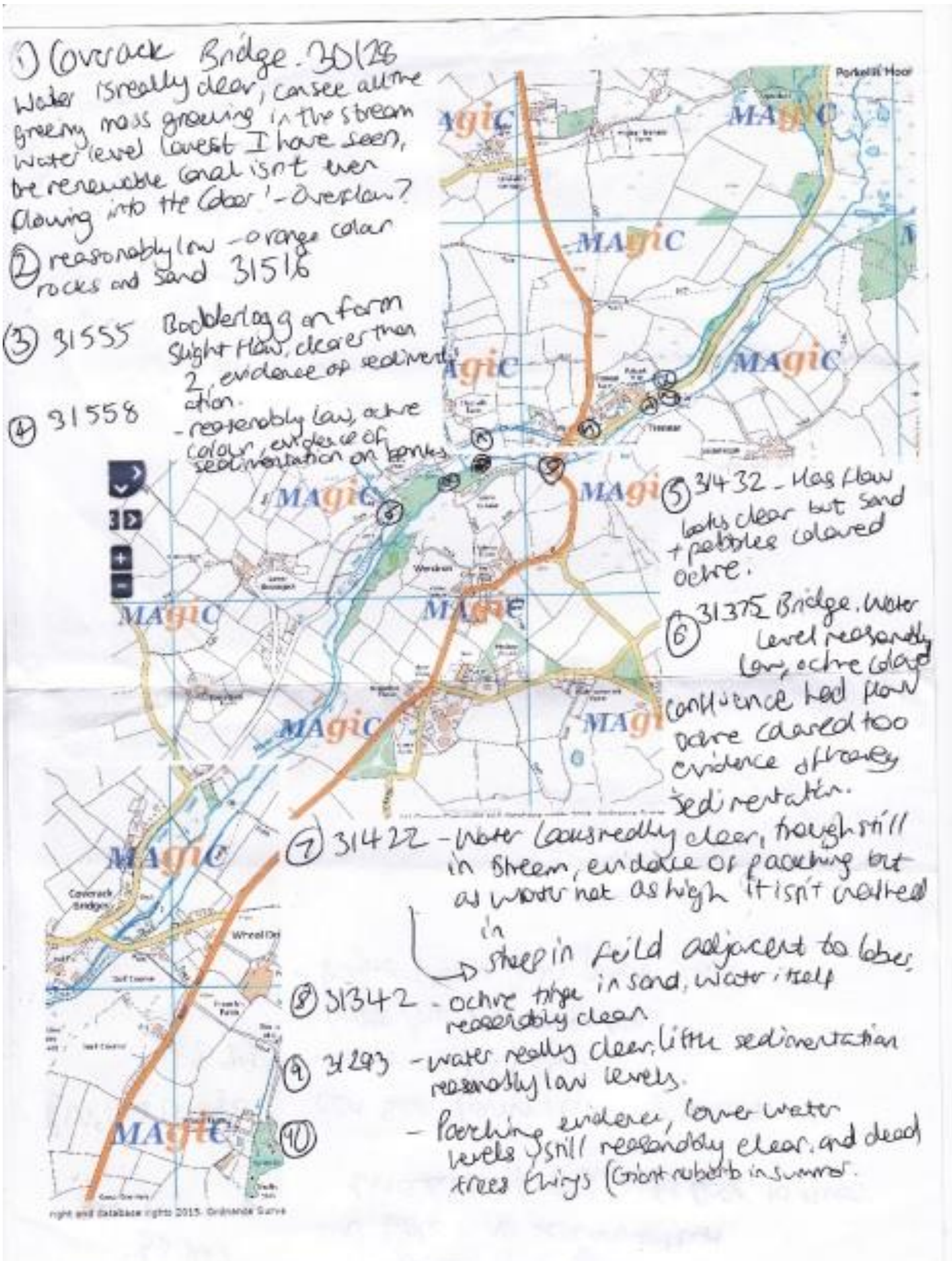

27/01/15
① 30124 - tinge
② 31555 - regular level - orange/ brown tinge.
③ 31552 - Boderloggan sign, little flow, covered in greenery
④ 31377 - lower than previously fast flowing reddish tinge. - otherside regular level, can see canalisation of tributary.
⑤ 31442 - no flow - Anguin stream, stagnant looking, grey sediment
⑥ 31426 - water trough still in river, fast flowing, grass not re-sewn.
⑦ 31400 - sheep still by river. poaching
⑧ 31339 - regular flow, orange colour
⑨ V. clear water reasonably low - farmers put stones in place - attenuation feature? to slow down flow??
31292
⑩ low than before, fast flowing, evidence of poaching. but really clear water !!
31225
⑪ Poaching evidence. + evidence of mining waste v. orange puddles 31156
⑫ - look like canalised - reduce flood? heavy sediment - grey thick muddy. 31090
⑬ - extraction plant - lower than before, reasonably clear (5.5m) 31047
⑭ Cowrack - water levels much lower, majority water channelled into renewable channel 30118
MAGIC

04/02/2015



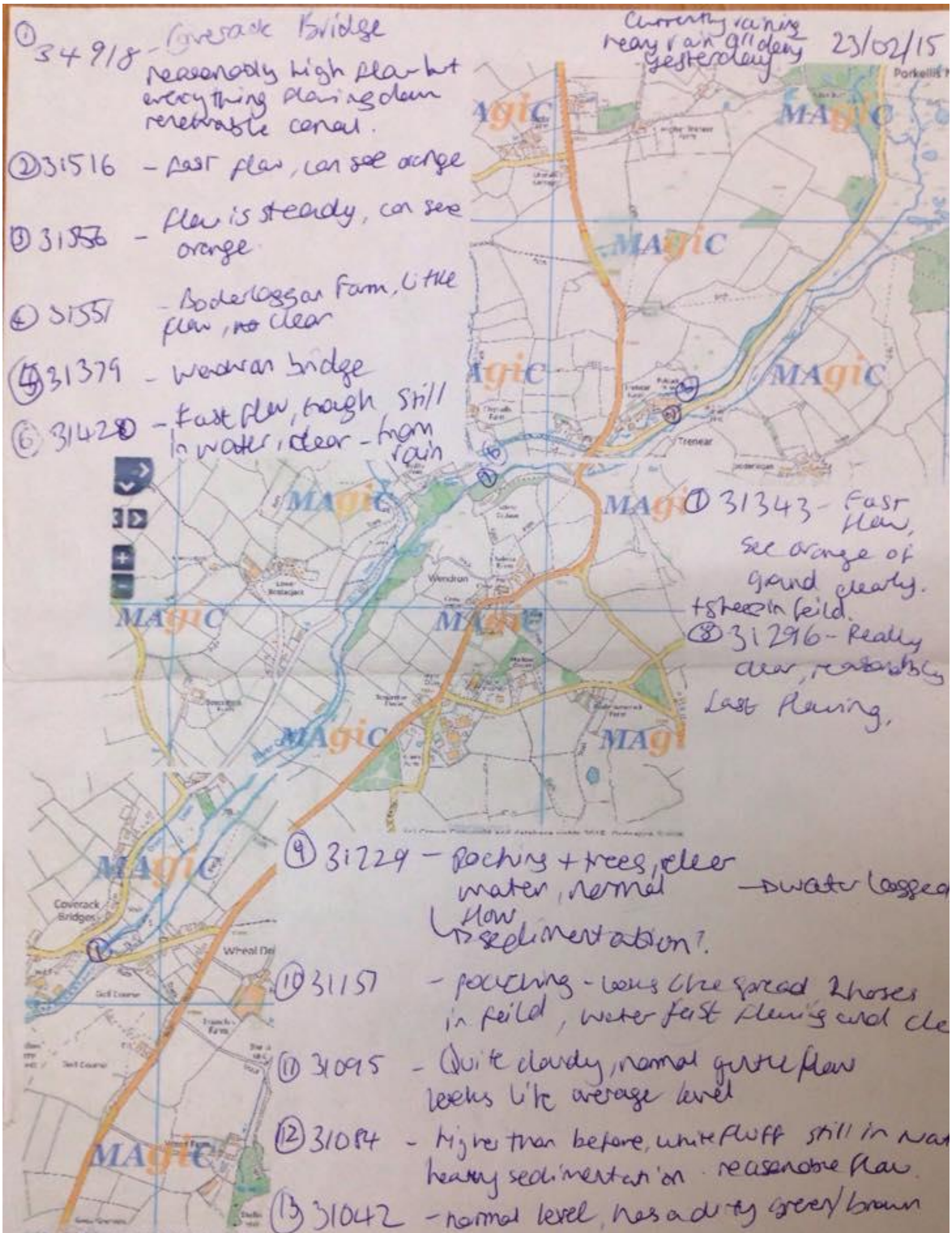
Flowing days after snow 04/02/15 3pm
(1) 30118 - High fast flow
(2) 31556 - reasonably fast flowing, av./below level. looks clear
(3) 31549 - Badderlaggan - high than previous + much clearer snow melt?
(4) 31436 - Much higher clearer water with flow
(5) 31372 - fast flowing, relatively clear - still little orange opp. side - fast flowing - confluence high + flowing relatively clear, clear water from both.
(6) Trough in water - result of grass re-sewn. - fast flowing 31421
(7) - Saw sheep walk through tributary of cober 31395
(8) 31290 - fast flowing very clear - lower pool levels than usual
(9) 31223 - fast flowing v. clear - looks like naturally where the wood is it forces flow around to the left on it evidence of horse poo + dead trees twigs
(10) 31150 - Horsefeild - water levels high and clear - poaching.
(11) 31083 - Thick sedimentation, white fluff stuff attached to bottom + sides? faster + higher flow than before.
(12) 31041 - Extraction plant - water relatively clear
(13) 30118 Coverackbridge - relatively low water level, still fast flowing + clear.
MAGIC
Porkellis Moor
Coverack Bridges
Wendron

10/02/2015

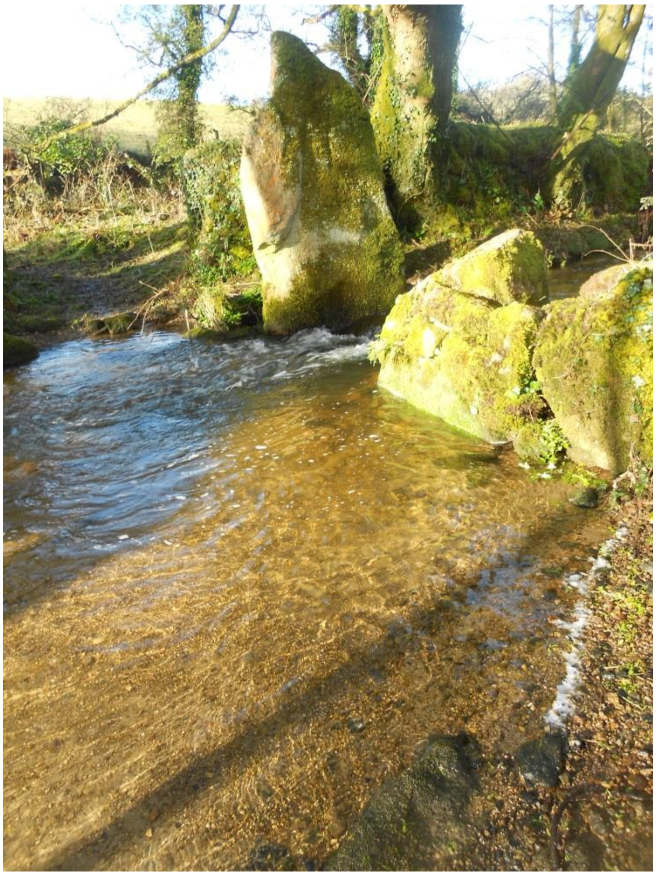


1 Coverack Bridge. 30128
Water is really clear, can see all the greeny moss growing in the stream water level lowest I have seen, the renewable canal isn't even flowing into the Cober '- Overflow?
2 reasonably low - orange colour rocks and sand 31516
3 31555 Bodderlogg on farm slight flow, clearer than 2, evidence of sedimentation.
4 31558 - reasonably low, ochre colour, evidence of sedimentation on banks
5 31432 - Has flow looks clear but sand + pebbles coloured ochre.
6 31375 Bridge. Water level reasonably low, ochre coloured confluence had flow ochre coloured too evidence of heavy sedimentation.
7 31422 - Water looks really clear, though still in stream, evidence of poaching but as water not as high it isn't washed in
sheep in field adjacent to Cober
8 31342 - ochre tinge in sand, water itself reasonably clean
9 31293 - water really clear, little sedimentation reasonably low levels.
10 - Poaching evidence, lower water levels still reasonably clear, and dead trees twigs (Giant rhubarb in summer.
MAGIC
Coverack Bridges
Wheal Ore
right and database rights 2015 Ordnance Survey

23/02/2015



1 34918 - Coverack Bridge
reasonably high flow but everything flowing down reasonable canal.
2 31516 - fast flow, can see orange
3 31856 - flow is steady, can see orange
4 31551 - Boderloggan Farm, little flow, no clear
5 31379 - Wendron bridge
6 31428 - Fast flow, though still in water, clear - from rain
Currently raining heavy rain all day yesterday 23/02/15
Porkellis
Trenear
Wendron
7 31343 - Fast flow, see orange of ground clearly. + sheep in feild.
8 31296 - Really clear, reasonably fast flowing.
9 31229 - Poaching + trees, clear water, normal flow
→ water logged
→ sedimentation?
10 31157 - poaching - looks like spread 2 horses in feild, water fast flowing and cle
11 31095 - Quite cloudy, normal gentle flow looks like average level
12 31084 - Higher than before, white fluff still in wat heavy sedimentation reasonable flow.
13 31042 - normal level, has a dirty green/brown colour
Coverack Bridges
Wheal Dream



Appendix 3: Email Responses

EMAIL RESPONSES – TIM WALKER, STEVE WILLS, CHERYL MARRIOT, JEREMY CLITHEROW, DAN HAMBROOK, BECKY HUGHES, JAN DINSDALE, KEVIN BARNES,

Timothy Walker – Postgraduate Researcher (PhD)

EMAIL SENT	DETAILS OF SENT EMAIL	EMAIL RECIEVED	DETAILS OF EMAIL RECIEVED	DATA PROVIDED
16/04/2014	Organising a phone call	16/04/2014	Phone call time and date set	
19/04/2014	Further multiple emails sent changing day and time and asking for any useful links– final call on 20/05/14	19/05/2014	Useful links provided	Upstream Thinking Project and Loe Pool Forum website links
		22/05/2014	Tim sent out an email regarding dissertation topics discussed on the phone to Steve Wills (SSW), Cheryl Marriot (CWT), Jeremy Clitherow (Natural England) about their thoughts on the topics and any other suggested topic routes.	Highlighted topics included attenuation features, radioactivity and ammonia levels.
		27/05/2014	Upcoming Loe Pool Forum Community group meeting details on 03/06/2014.	
01/06/2014	Unable to make community meeting as I was unable to find work cover	17/06/2014	A summary of discussed topics from the community meeting	Further topics discussed included water quality sampling, loading monitoring.
16/10/2014	Changed dissertation topic slightly. Asked if Tim had any access to land use maps, flood events, and lists of pollution incidents	16/10/2014	Forwarded on my email to Dan Hambrook (EA), Steve Wills (SSW), and Cheryl Marriot (CWT) as Tim pointed out they maybe able to help more regarding data collection.	
		17/10/2014	DAN HAMBROOK – noted that I had already submitted a data request to the EA via Kevin Barnes and that it had been actioned; and said that SSW have all	
			abstraction water quality data.	
		19/10/2014	STEVE WILLS – 'Happy to discuss it.'	
		11/11/2014	Details of the next community meeting (25/11/14)	
13/11/2015	Letting Tim know I can attend the next meeting and that hopefully I will have the data I need by then.			
01/12/2014	Asking Tim for a copy of the catchment maps shown in the meeting	16/12/2014	Sent over useful maps	Sent over three catchment related maps

OTHER

- 20/05/14 – Phone call with Tim Walker discussing ideas

Becky Hughes

Steve Wills – South West Water (SWW)

EMAIL SENT	DETAILS OF EMAIL SENT	EMAIL RECEIVED	DETAILS OF EMAIL RECIEVED	DATA PROVIDED
30/07/2014	Explanation of what I plan to do and if SWW are able to provide data	31/07/2014	Able to provide data, but a disclaimer must be included, need specifics	
02/08/2014	I explained that I was currently out of the country but would know more specifics when I was home			
20/10/2014	I asked for data specifics	20/10/2014	SWW was unable to give me the data I need but suggested Environment Agency (who I was already in contact with)	

Cheryl Marriot – Conservation Manager, Cornwall Wildlife Trust (CWT)

EMAIL SENT	DETAILS OF EMAIL SENT	EMAIL RECIEVED	DETAILS OF EMAIL RECIEVED	DATA PROVIDED
22/05/14	Tim kindly forwarded on an email explaining my field of interest for my dissertation and to see what Cheryl thought might be a useful focus.	22/05/14	Cheryl suggested a mini-catchment investigation into radioactivity in the water.	

Kevin Barnes – Flood Resilience Team Leader, Environment Agency (EA)

EMAIL SENT	DETAILS OF EMAIL SENT	EMAIL RECIEVED	DETAILS OF EMAIL RECIEVED	DATA PROVIDED
16/10/14	I explained that I was doing my dissertation and asked whether I could use some of the EA's data.	17/10/14 17/10/14	A circular email stating that my request will be responded to in 20 working days. Kevin explained that his colleges would be in touch shortly.	
03/11/14	An email just to check if my data request had been responded too yet.	05/11/14	Maggie, Kevin's collegue explained that I should receive the data by 13/11/14.	
13/11/14	I emailed again to check if my data request had be processed yet.			

Environment Agency Communications and Customer Engagement Officers

EMAIL SENT	DETAILS OF EMAIL SENT	EMAIL RECIEVED	DETAILS OF EMAIL RECIEVED	DATA PROVIDED
		18/11/14	Natasha Rich (Communications Officer) sent over the data I requested but advised me to ask Steve Wills (SWW) for Wendron extraction plant failures.	Water testing results (Oct 2010 – Sept 2014), summary of pollution incidents.
27/11/14	Asked for data dating back before Oct 2010	28/11/14	Maggie Summerfeild (Customer Communications) replied asking for specifics in the data I needed	
28/11/14	I explained that a summary of pollution incidents from before Oct 2010 would be very useful.	17/12/14	More data was sent over from Lynda Francis (Customer Engagement)	Water testing results (Jan 2000 – Dec 2006)
20/12/14	Thank you email			

Jeremy Clitherow – Catchment Lead Advisor, Natural England (NE)

EMAIL SENT	DETAILS OF EMAIL SENT	EMAIL RECIEVED	DETAILS OF EMAIL RECIEVED	DATA PROVIDED
05/11/14	Becky Hughes kindly forward on an email about the data I needed to see if Jeremy had any contacts.	05/011/14	Jeremy also agreed with Becky in that the Environment Agency (EA) hold all of the data I needed and kindly forward the email onto Dan Hambrook (EA).	

Dan Hambrook – Environment Planning Officer, Environment Agency (EA)

EMAIL SENT	DETAILS OF EMAIL SENT	EMAIL RECIEVED	DETAILS OF EMAIL RECIEVED	DATA PROVIDED
16/10/14	Tim kindly copied Dan into our email about data collection	17/10/14	Dan acknowledged that I had already requested data from the EA.	

Appendix 4: Water Quality Data

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	URN	Name	NGR	SampleNotes	Date	Time	0061 pH PHUNITS	0076 Temp Water CEL	0085 BOD ATU mg/l	0111 Ammonia(N) mg/l	0116 N Oxidised mg/l	0117 Nitrate-N mg/l	0118 Nitrite-N mg/l
2	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		13-Jan-00	1045	7.05	7.9	1	0.056	3.62	3.61	0.0052
3	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		11-Feb-00	1005	7	7.4	1.1	0.033	3.61	3.61	0.0041
4	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		27-Mar-00	1000	7.35	8.4	1.1	<0.03	3.74	3.74	<0.004
5	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		26-Apr-00	1045	7.05	10.3	1.1	<0.03	2.99	2.98	0.0054
6	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		09-May-00	1308	6.9	13.4	1	<0.03	3.49	3.49	<0.004
7	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		26-Jun-00	1210	7.15	11.5	<1	0.031	3.5	3.49	0.0058
8	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		24-Jul-00	1355	7.2	14.6	<1	0.032	2.66	2.66	0.0048
9	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		18-Aug-00	1135	7.15	14.2	<1	0.031	2.55	2.54	0.0071
10	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		27-Sep-00	1525	7	13.3	2.1	0.038	2.02	2.01	0.0105
11	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		30-Oct-00	1302	6.85	10.3	1.8	0.086	1.87	1.85	0.0171
12	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		20-Nov-00	1510	7.05	9.3	1.2	<0.03	3.31	3.3	0.0064
13	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		14-Dec-00	1310	6.75	8.9	<1	<0.03	3.5	3.5	<0.004
14	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380	NO DO READING	26-Jan-01	1350	6.9	8.8	<1	0.076	3.12	3.11	0.0093
15	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		12-Feb-01	1440		10.6					
16	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		16-Feb-01	1337	6.75	9.7	<1	<0.03	3.67	3.67	<0.004
17	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		24-Apr-01	1320	6.45	10.64	<1	0.039	2.67	2.66	0.0062
18	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		16-May-01	1310	6.4	13.7	<1	<0.03	3.7	3.69	0.0052
19	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		29-May-01	1505	6.58	13.6	<1	<0.03	3.22	3.22	0.0047
20	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		25-Jun-01	1420	6.83	15.21	<1	<0.03	2.83	2.82	0.0072
21	82010187	RIVER COBER AT TRENEAR BRIDGE	SW6810031380		06-Jul-01	1210	6.54	15.43	<1	0.046	2.82	2.81	0.007

Appendix 5: EA Pollution Events

00753524 16/02/2010 08:17

Caller reporting that there is diesel or heating oil going into the cober river.

16/02/2010. Minimal quantities of diesel observed in the river. Source of diesel traced back to ***Farm, Porkellis around 1000 metres from the river. overnight intruders had taken diesel from one of his tanks and had not turned off the valve. As a result an unknown quantity of diesel was lost. The diesel together with surface water was able to enter the river.

Information received from SWW was that the Wendron intake was closed as a precaution for the period from 0845 to 1230 on 16/02/2010.

00795326 28/06/2010 14:36

South West Water are reporting that between 12.30 and 2.30 on 27/6 the raw intake River Cober at the Trenear Intake had high amonia readings. Maximum Amonia level was 0.43 mg per litre which triggered the works shutdown procedure. This has also happened 21st May at the same time and with similar readings. High amonia readings have been unusual as there has been little rain.

Readings are well under surface water EQSs however they do appear to indiacte something untoward is going on. Suggest treat as intel and target area at some point for farm visits.

00807443 28/07/2010 20:11

Caller reporting an ammonia spike on the river Cober at the intake near the SWW treatment works. Reports that the instrumentation u/s of the intake showed an ammonia spike at 0.6mg/l. Says that the treatment works shutdown at 0.2mg/l SWW have had 3 occassions that the drinking water intake has had to close due to elevated ammonia levels.

Short term spike lasting about 2 hours, on first 2 occassions near midnight. Latest in the afternoon. Not rainfall related. Mail shot letter to be agreed and delivered to potential properties u/s of intake.

00961997 15/02/2012 11:42

Caller reporting SWW, Wendon Water Treatment Works, they are getting ammonia spikes that are causing multiple shut downs, they would like an officer to investigate.

15/02/2012 1205 Meeting with South West Water to discuss incident details and view results of the water samples taken at Wendron Water Treatment Works. 15/02/2012 1415 Inspected section of river in the immediate area of the intake. Awaiting further results of river samples taken by SWW to determine specific section of the watercourse affected for any additional follow up work undertaken. None rec'd.

01159968 17/09/2013 14:34

Incident occured on the River Cober at grid reference SW 67503 31052 which is near Wendron. SWW are reporting a couple of detections of the pesticide 24D. A sample was taken 09.09.13 of raw water sample and found to contain 84 ng/l. Another sample was taken on 11.09.13 of treated water sample and found to contain 117 ng/l. A maximum standard is 100 ng/l and therefore there is a breach of that standard, they are optimising treatment to deal with it.

Although level of pesticide 24D in river exceeds drinking water limits it is significantly below the EQS limits making a source very difficult to identify. As the incident occurred a week ago, there has been heavy rain and the level is well below the EQS limits it has been decided that in this case there would be little benefit to attending the site now. If there are further reports of pesticide contamination, and particularly if there is a sequence of spikes in quick succession then we will have an increased chance of locating the source and prompt attendance is recommended.

01196542 21/01/2014 08:52

Reports at SWW Wendron WTW, Helston they have elevated ammonia in the raw water. They have requested an officer investigates the catchment. The water treatment works are shut down at the moment, they cannot produce any water because of the ammonia.

Tuesday 21 Jan 2014 09:20hrs Contacted SWW Scientific 0.6mg/l Ammonia recorded in sample ,no turbidity or smelling the Raw water supply at Wendron WTW. 09:40 Contact SWW Wendron WTW . Ammonia started showing on monitoring at 23:00hrs on the 20/1/2014 and has slowly risen from alarm level of 0.2mg/l up to 0.6 mg/l by 09:00hrs this morning. WTW intake closed at 07:30hrs.

The Ammonia levels are above that of the Drinking Water Levels but not considered to be unreasonably high as far as the EA are normally concerned. The SWW SCADA showed that the rainfall had caused the flows in the river to rise during the day and the ammonia levels were dropping ,may be as a result of the dilution.

Catchment inspection during heavy rain showed that there are several potential inputs that combined could have an impact but none were substantially big enough to have been responsible for the WTW intake to close as a result. These potential locations have been passed on to Catchment Sensitive Farming Officer for them to follow up on runoff issues.

01221117 25/03/2014 13:30

Reporting high ammonia readings on the intake pipe to Wendron water treatment works, TR13 0PY. Readings: 0.8 milligrams per litre at 20:00 - 24/03/14; 0.7 milligrams per litre at 12:00 - 25/03/14. There has been heavy rain fall in the area which may be the cause of this.

Ammonia spikes are quite common but often below levels of concern to the EA. and do not result in fish mortalities.

01223938 03/04/2014 00:23

The caller is reporting that at Wendron clean water works the site has shut down due to high ammonia levels in the water running into the site. The operator on site stated they believe it is from either slurry or sewage problems in the area and that the EA may already be aware of the issue.

EO contacted reporter at SWW who confirmed Wendron Clean Water Treatment Works had a temporary increase in Ammonia at the inlet and stopped abstracting. Details: Point 1 - 0.575 mg/l at 00.33 03/04/14; Point 2 - 1.006 mg/l at 00.08 03/04/14. EO contacted SWW the following day who confirmed the abstraction resumed by 8am that morning (03/04/14).

01230497 27/04/2014 09:05

Caller from south west water reporting they have exceeded the permitted level of ammonia from the Wendron treatment works into the River Cober.Caller said the ammonia levels last night were at 5mg/l and the allowance is 2 mg/l.

27/04/14 09:45 Spoke to SWW, confirmed level reached 0.5mg/l so the plant was shut down all night as their limit is 0.2mg/l. Plant is up and running again, with level of 0.05mg/l at intake. Issue likely due to heavy rain all night, levels of ammonia not of polluting concern to watercourse.

Appendix 6: Details of farm in high risk area already under ES schemes

1) National Trust, Pendeen, HLS, ends 30/09/2022
2) Lawrence WEM, Helston, ELS, ends 30/09/2016
3) Unavailable, ELS, ends 30/08/2016
4) Vian LM +CG, Helston, ELS, ends 30/09/2016