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Tidal Ribble Water Bodies

Report for the Evidence and Measures Project

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***pj*HYDRO** & RUKHYDRO

Report for

Victor Aguilera
Project Manager
Department for Environment, Food & Rural Affairs (Defra),
Nobel House, 17 Smith Square,
London SW1P 3JR

Department for Environment Food & Rural Affairs

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Client Review by:

Victor Aguilera (Defra)
Anne-Marie Quibell (Environment Agency)

Issued by:

Paul Hulme (pjHYDRO)

Principal Authors:

Paul Hulme (pjHYDRO)

Nick Rukin (RUKHYDRO)

Notices and Disclaimer

Scope of Work

This report has been prepared to meet the proposed scope of work set out in pjHYDRO Limited's proposal of 27 May 2011 (*Defra Evidence + Measures Project, Phase 3 - Proposal 2: Scoping study and Support on the Ribble Trial Catchment*) through the original contract between Defra and pjHYDRO Limited, dated 28 September 2011 and in subsequent variations on 6 June 2012, 14 November 2012, and 19 January 2013. The report contents reflect the scope, information provision by the client and third parties, time and costs and other assumptions agreed in the contract or documented in writing as amendments to that contract.

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pjHYDRO Limited

(Reg. Co. No. 07205374)
Registered Address:
26 Bodmin Avenue,
Stafford, ST17 0EF,
England
Web: www.pjhydro.co.uk
Email: paul.hulme@pjhydro.co.uk
Tel: 07754 133 173

RUKHYDRO Limited

(Reg. Co. No. 07026760)
Registered Address:
6 Claremont Buildings, Claremont Bank,
Shrewsbury, SY1 1RJ,
England
Web: www.RUKHYDRO.co.uk
Email: rukin@rukhydro.co.uk
Tel: 07800 604 781 / 01743 243 915

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Summary

Purpose of the Project and this Report

This report presents the results of the Tidal Ribble Evidence and Measures (E&M) project, which was commissioned by Defra and the Environment Agency and undertaken by pjHYDRO and RUKHYDRO between September 2011 and August 2012 (Figure S1). The project outputs are listed in Appendix B. They were delivered to Defra and the Environment Agency and, where the outputs have been approved for public release, they can be found under the Evidence and Measures project pages on the Defra website.

The project focussed on eight water bodies which drain into the Tidal Ribble and Ribble Estuary between Preston and Lytham St Annes in Lancashire (the Tidal Ribble water bodies).

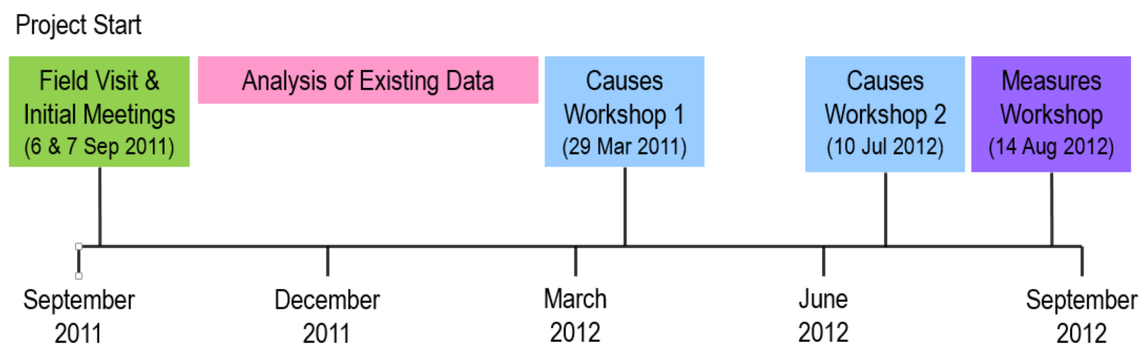
The project aimed to investigate whether the existing evidence available for the eight Tidal Ribble water bodies would allow stakeholders to reach consensus on:

- The main causes of poor Water Framework Directive (WFD) status for fish, invertebrates and water quality;
- Appropriate, locally-targeted measures devised to lead to improvements.

A full set of objectives are given in Section 1.3.

Although this work on the Tidal Ribble water bodies was primarily complete by August 2012, this report, released in 2014, has been written with a context of more recent experience from subsequent Evidence and Measures projects.

Figure S1 – Project Timeline



Background

Local Environment Agency staff identified the eight Tidal Ribble water bodies (Figure 1.1) as some of the most "difficult" across the Ribble Pilot Catchment. This was because the actions (or measures) required to tackle the perceived Water Framework Directive (WFD) problems were unclear for the following reasons:

- There were multiple problems (e.g. fish numbers, invertebrates ecological quality ratio and various components of water quality were at poor WFD status);

- There were many different possible or suspected causes of these problems (e.g. agricultural run-off, discharges from non-water company sewage works, sewage misconnections etc.)
- Stakeholders did not agree on the main causes of these problems and so there was no consensus on what actions to take.

Seven of the water bodies failed under the 2009 WFD classification (i.e. their ecological status or potential was less than good). The eighth water body (Main Drain) had no 2009 WFD classification, as the main Drain was not a separate water body in 2009 but partly in Liggard Brook and partly in Wrea Brook. In six of the water bodies at least one of the following elements was at less than good status: macro-invertebrates, fish, hydrology, ammonia, dissolved oxygen or phosphate (Figure 2.1). For two of the water bodies (Main Drain and Pool Stream) none of these elements had been assessed.

Prior to the project there seemed to be insufficient evidence for stakeholders to reach agreement on appropriate measures for these water bodies. The next section describes how this had changed by the end of the project.

The Results

By the end of the project 13 participants from 10 partner organisations had devised 122 locally-targeted actions (measures) based on their agreement of the main causes of poor WFD status.

However, it took three workshops to achieve this. In the first two workshops, stakeholders felt overwhelmed by the amount of data and information that was available to consider. In the final workshop stakeholders were presented with evidence packs (see Section 3.8), which included:

- Strength of Evidence Tables, which summarised the evidence for or against the various suspected causes of poor WFD status for each water body (see Section 3.8.4);
- Supporting maps and Excel plots of data at the water body scale and the sub-water body scale (see Section 3.8).

Hence stakeholders were able to reach agreement on the main causes of poor WFD status and from these come up with the locally-targeted measures.

By September 2012 many of these measures had been incorporated into the Ribble Life Action Plan (these are listed on the Ribble Life website (http://www.ribblelife.org/plan) under the catchment heading “Lower Ribble”).

Table S1 provides a summary of the main causes of poor WFD status that stakeholders identified for each water body. These came from a longer list of possible or suspected causes using a weight of evidence approach and based on the Strength of Evidence Tables described in Section 3.8. In the “Measures” Workshop, stakeholders were asked to focus on identifying measures that addressed these main causes at specific locations. Table S1 also includes a selection of the measures devised at the workshop.

This demonstrates that the approach used previously on the River Petteril Evidence and Measures project was successfully applied and developed further during its use on the Tidal Ribble water bodies. The approach is essentially an adaptive management cycle and the success on both the River Petteril and the Tidal Ribble led to its application in Moston Brook, an urban water body in Manchester (Environment Agency 2013).

Table S1 Main Causes of WFD Failure and Selected Potential Measures for Each Water Body and for Sub-catchments within Savick Brook

Water Body / Sub-catchment	Main Causes[1]	Measures[2]
Liggard Brook	Agricultural runoff. Geomorphological changes.	Soil and nutrient management on target farms. Improve morphological condition to enhance habitat and increase species diversity.
Main Drain	Dairy (and pig) farming. Non Water Co treated sewage disposals from caravan parks and housing areas. Geomorphological changes.	Improve farming practices for Dairy Farms - slurry storage and application (related to nutrient management). Survey impact of larger non-Water Co sewage discharges including septic tanks. Assess feasibility of removing the tidal flaps and pumping station and reverting to a tidal system.
Wrea Brook	Agricultural runoff. Non-Water Company Sewage Works.	Identify dairy farms and work with Natural England and farmers on measures to manage slurry stores and silage clamps. Evaluate likely significance of sewage discharges including septic tanks - establish nature of problem and responsibility.
Pool Stream	Agricultural runoff (dairy farms). Sewage, possibly Intermittent sewage discharges and/or wrong sewage connections. Urban runoff.	Carry out inspection of farms with historical pollution problems to see if problems remain. Attend category 3 NIRS incidents. Carry out specific wrong sewage connections investigation on housing estate north of Warton Aerodrome. Liaise with Local Authority and Water Co on First Time Rural Sewage initiative between Freckleton and Warton. Engage with Warton Aerodrome to investigate some of their practises (de-icing on site, runoff, septic tanks).
Dow Brook	Agricultural runoff. Sewage, possibly intermittent sewage discharges and septic tanks.	Install fencing along reach downstream of A583 to prevent agricultural runoff. Inspect specific dairy and pig farms in the upper and middle of the catchment. Raise awareness of No Spread Zones (GAEC 19) with farmers to reduce fertiliser application near water courses. Investigate WQ and discharges from 6 private sewage plants and septic tanks in Spen Brook and along A583 and just off A584 east of Dow Brook – look into possibility of First Time Rural Sewage. Check drainage from historic landfill in north west of water body.
Deepdale Brook	Possibly agricultural runoff but no bad practice identified. Intermittent sewage discharges from Clifton village PSO.	Check sewage sludge spreading against soil types and visit three specific farms. Inspect Clifton Hall private sewage works. Check with Water Co whether AMP work (ref PRE0121) has been completed. Sample above and below Springfields BNFL site, check permitting and monitoring of shallow groundwater beneath the site.
Savick Brook (upper)	Possibly agricultural runoff. Possibly intermittent sewage discharges and septic tanks.	Target specific non-permitted pig & poultry farms. Septic tank campaign across unsewered area where septic tanks discharging directly to the brook.
Savick Brook (Eaves Brook)	Intermittent sewage discharges.	Review WQ at three CSOS (including Cattle Market site) which are not part of AMP 5.
Savick Brook (Sharoe Brook)	Possibly agricultural runoff. Sewage from wrong sewage connections.	Check private pumping station on Sharoe Brook near Lea Golf Club.
Savick Brook (lower) & Ribble Link	Intermittent sewage discharges. Possibly sewage from wrong sewage connections. Geomorphological changes due to the Ribble Link.	Investigate CSOs & PSOs at Lea Road, at Preston North End's training ground and those on the Ribble Link. Review yellow fish (wrong sewage connections) campaign on housing estates and primary schools, particularly Larches and Lea. Suggest joint project on the Ribble Link (EA + canal managers) to open lock gates more often, clear biwash channels and make safe for fish passage

Notes:

1 As recorded in the Conclusions Tables in the Evidence Packs (Section 3.8).
2 This is a summary of the measures identified at the Measures Workshop.

Lessons Learned and Recommendations

The adaptive management cycle used in the Evidence and Measures approach has been successfully applied to catchments in several different settings (rural, urban coastal and heavily modified) and with different sets of stakeholders.

It has been deliberately trialled on so-called “difficult” catchments, that is groups of water bodies where it is unclear how to progress with selecting appropriate measures, usually because there are multiple failing WFD elements (such as ammonia, fish, macro-invertebrates), multiple suspected causes of these failures or lack of agreement amongst the catchment partners on the main causes of these failures.

It is clear that the approach as a whole seems well-suited to tackling those groups of water bodies that have been labelled as “difficult” and which therefore tend to get left unresolved. Nevertheless, the lessons learned in these “difficult” catchments are applicable wherever catchment partners need to turn data and information into evidence and upon which they can build consensus amongst stakeholders about the actions (measures) needed to deliver environmental improvements.

Section 5.2 of this report provides Defra and the Environment Agency with advice on the transferability and applicability of the Evidence and Measures approach and a description of the lessons learned. The Evidence and Measures team recommends that these lessons learned should be made readily accessible to all Catchment Based Approach[1] (CaBA) Hosts so that they can choose to apply and adapt those that are useful to them. A headline summary of the lessons-learned is given in Table S2 below with more details in Section 5.2.

[1] The Catchment Based Approach is a policy framework aimed to deliver improved water quality helping

to meet European Framework Directive objectives by establishing catchment partnerships and working collaboratively with local stakeholders. More information about CaBA can be found here: https://www.gov.uk/government/publications/catchment-based-approach-improving-the-quality-of-our-water-environment.

Table S2 Key Lessons Learned from the Evidence and Measures Project on the Tidal Ribble Water Bodies

Heading	Lessons Learned
Stakeholders	The ideal number of participants at the workshops is about 15 – 20, all of whom should be committed to attending both workshops and who are invited based on: a) whether they have technical expertise in the areas related to the suspected causes of WFD failure; b) whether they have the authority to suggest measures at the Measures Workshop. Small groups of about 5 or 6 people worked well in the workshops. Shared or similar skills in the same group, even if stakeholders have opposing interests, generate informed debate and the subject matter helps bring them together.
Evidence	Focussing on the evidence brings people to agreement far quicker than "round-table" debate based only on opinions. The Strength of Evidence Tables described in Section 3.8.4 were developed to summarise what each piece of evidence tell us about each suspected cause of WFD failure. They allowed participants to see their current, shared understanding based on the weight of the existing evidence. They were particularly useful in the Causes Workshop so that small groups of stakeholders could review the evidence and reach consensus on the main causes of WFD failure in each water body.
Measures	Measures were "targeted", that is stakeholders were asked to identify measures at specific locations and link them to at least one of the main causes of WFD failure that they had identified at the Causes Workshops.
Data	Having a designated Environment Agency person acting as the "data collector" helped make data provision efficient. The time required to carry out this role ,so that other members of the team are not constantly waiting, should not be underestimated and on this project it was took about 2.5 days per week. The datasets that were most fruitful on this project included: WFD classes for all elements assessed at individual monitoring points as well as for the water body as a whole; the Environment Agency Reasons for Failure (RFF) database; current and historical water quality, fish and invertebrates data primarily from the Environment Agency; historical land use and patterns of urban development; the problems and suspected causes of WFD failure in each water body identified at the initial meetings with stakeholders; pollution Incidents from the Environment Agency's National Incident Reporting System (NIRS); consented discharges; non-mains sewerage; Landfills (location, age, waste type); The Environment Agency Source Apportionment GIS (SAGIS) outputs; summary of the geomorphology.
Conceptual model	Conceptual models are a useful way of summarising shared understanding for a complex environmental system. Two versions, one focussing on the mechanisms operating along the pathways that link environmental pressures with biological change and the other focussing on the relationships between the biology to be conserved and the human activities that threaten this biology are described in Section 2.4.

Note: Further lessons learned are provided in Section 5.2.

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1. Introduction

1.1 Purpose of this Report

This report has been prepared to present the results from the Tidal Ribble Evidence and Measures (E&M) Project. The project was undertaken between September 2011 and August 2012 and was commissioned by Defra and the Environment Agency.

The project aimed to collect evidence and then help stakeholders agree the main causes of poor Water Framework Directive (WFD) status in fish, invertebrates and water quality before identifying actions (measures) devised to lead to improvements. The detailed objectives are described in Section 1.3.

The project aimed to investigate whether the existing evidence available for the eight Tidal Ribble water bodies would allow stakeholders to reach consensus on:

- The main causes of poor Water Framework Directive (WFD) status for fish, invertebrates and water quality;
- Appropriate, locally-targeted measures devised to lead to improvements.

A full set of objectives are given in Section 1.3.

This document provides a broad overview and commentary on the approach taken, the project's findings and the lessons learned, which may be useful to practitioners elsewhere.

Although this work on the Tidal Ribble water bodies was primarily complete by August 2012, this report released in 2014, has been written with a context of more recent experience from subsequent Evidence and Measures projects.

1.2 The Evidence and Measures Project

The Evidence and Measures project uses existing evidence to help stakeholders develop a shared understanding of the main causes for poor WFD status in "difficult" water bodies so that locally-defined actions (measures) to improve the WFD status can be implemented. The term "difficult" is used here to denote those water bodies where it is unclear how to progress with selecting appropriate measures, usually because:

- There are multiple problems (e.g. fish, invertebrates and various components of water quality were at poor WFD status);
- There are many different possible or suspected causes of these problems (e.g. agricultural run-off, discharges from non-water company sewage works, sewage misconnections etc.)
- Stakeholders do not agree on the main causes of these problems and so there was no consensus on what actions to take.

The potential rewards for this work are far greater than simply meeting WFD targets, and include capacity building for catchment management in the Environment Agency, and strong relations with partners and stakeholders as actions are agreed and put in place.

The Evidence and Measures approach began in the Environment Agency in 2006 with an examination of what data could be made available nationally and locally for catchment management investigations in the Frome-Piddle, Dorset. This then led, in September 2008, to the start of the Evidence and Measures Petteril Trial (E&M Phase 2), which focussed on identifying the causes of poor trout numbers in the River Petteril, a tributary of the Eden, in a largely rural part of Cumbria. That project identified most likely causes of WFD failure in discussion with stakeholders and agreed a number of measures, many of which have been implemented via the Environment Agency's and the Eden Rivers Trust's business plans. With such positive results, there was a call from Defra and the Environment Agency for the approach to be trialled further on a different group of water bodies in the Tidal Ribble between Preston and Lytham St. Anne's and with a new group of stakeholders, and this was one of the work-packages of E&M Phase 3.

Between September 2012 and March 2013, the approach was subsequently applied to Moston Brook, which is an urban water body in Manchester and part of the Irwell Pilot catchment. This report has been written with the benefit of context from the Moston Brook work (Environment Agency 2013).

1.3 Scope of Work and Objectives

E&M Phase 3, like E&M Phase 2 before it, was a collaborative Defra / Environment Agency project. The scope of work for the Tidal Ribble work-package (WP2 of E&M Phase 3) focused on trialling the Evidence and Measures approach in the rural, coastal, heavily modified and urban water bodies between Preston and Lytham St. Anne's (the Tidal Ribble water bodies).

The main project objectives were:

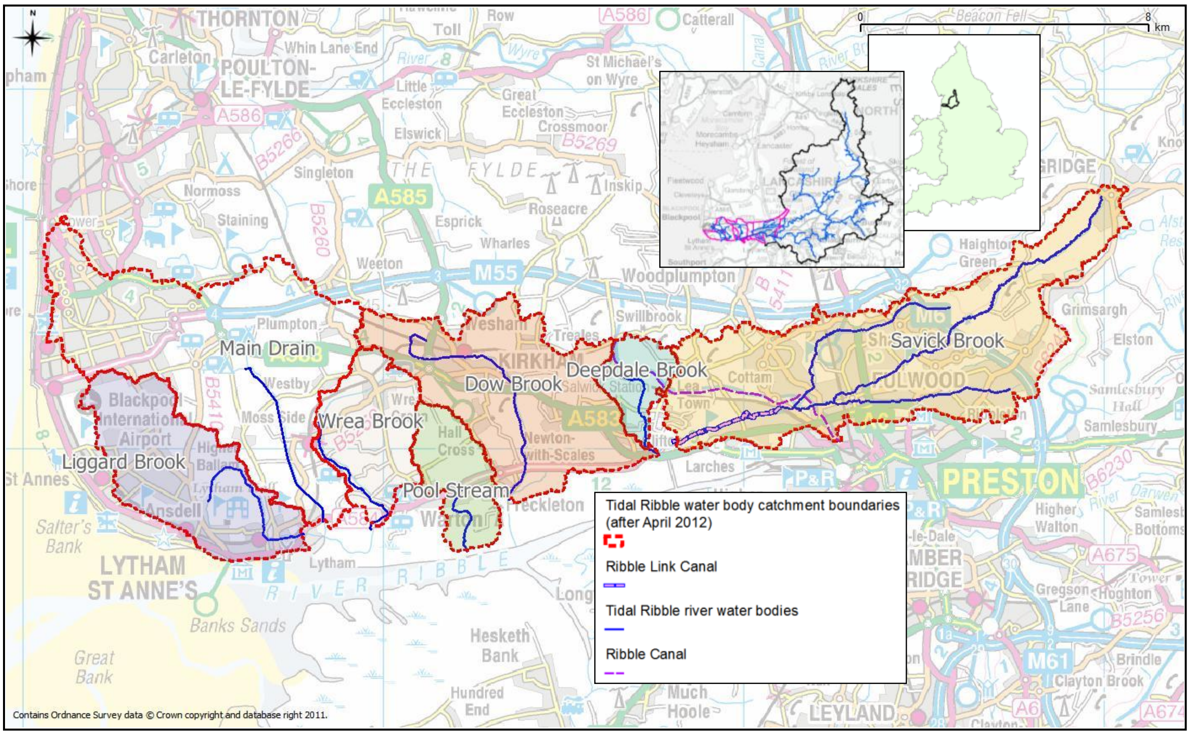
1) To investigate whether the existing evidence available for the eight Tidal Ribble water bodies would allow stakeholders to reach consensus on identifying the causes of WFD failure and devising appropriate, locally-targeted measures.
2) To investigate whether the Evidence and Measures approach developed on the River Petteril water bodies could be successfully applied to a different setting and a different set of problems on the Tidal Ribble water bodies over a period of 6 -12 months.
3) To do the above, so that measures could be implemented in the subsequent 1 - 2 years by the Environment Agency and the catchment partners to help meet WFD requirements.
4) To deliver the following:
    a) A scoping study to outline the current understanding of the Tidal Ribble water bodies and a project plan;
    b) Technical support to Environment Agency staff on appropriate data analysis;
    c) Two facilitated stakeholder workshops;
    d) Advice to Defra and the Environment Agency on the transferability of the Evidence and Measures approach and its potential application elsewhere.

The Environment Agency selected eight water bodies (the Tidal Ribble water bodies) located between Preston and Lytham St. Anne's in Lancashire, for this project. These were deliberately selected because they were very different from the rural water bodies in the River Petteril. Seven of them covered a variety of settings from urban Preston to the rural flatlands and coastal fringe along the Ribble estuary. The eighth was an artificial water body, the Ribble Link canal, between Preston and the River Ribble estuary. In addition this work on the Tidal Ribble required us to engage with an entirely new set of stakeholders and partner organisations.

1.4 The Tidal Ribble Water Bodies

The eight Tidal Ribble water bodies selected for this project (Figure 1.1) are part of the Ribble Pilot Catchment.

Figure 1.1 – Location of the Tidal Ribble Water Bodies



Note: The catchment areas of the Tidal Ribble river water bodies as of April 2012 are shown by the red dashed lines. The black boundary in the inset map shows the whole of the Ribble catchment with the Tidal Ribble water bodies in pink. Maps contain Ordnance Survey data © Crown copyright and database right 2013.

The eight water bodies were proposed by the Environment Agency North West Region's North Area Environment Planning Team because:

- They include heavily modified and urban water bodies and several WFD elements fail including fish, invertebrates, ammonia, dissolved oxygen and phosphate. They were believed to be suffering from rural and urban diffuse pollution as well as point source pollution, which are potentially contributing to blue-green algae problems in Preston docks. This part of the Ribble is also affecting bathing water designations downstream.
- Local EA teams identified these water bodies as "difficult" ones in terms of identifying the main causes for failure and wanted to be able to gain consensus with stakeholders on causes and then select measures over a period of 6-12 months.
- The water bodies fall within the River Ribble, which was one of the Defra / Environment Agency ten Pilot Catchments for Catchment Management.

- They fall under the area covered by the Environment Agency team member, who was involved with the previous Evidence and Measures project on the River Petteril. This provided continuity from the Environment Agency;
- The local Environment Agency area teams were enthusiastic and knowledgeable about these catchments;
- Potential stakeholders and partners had already been identified and expressed an interest in the work.
- At the start of the project in September 2011, Environment Agency staff attributed the WFD failures to the following potential causes:
    - *Nutrients from agriculture:* Runoff of nutrients from agricultural activities including livestock areas, application of inorganic fertiliser to arable crops, application of farmyard manure and United Utilities (UU) treated sewage to grassland;
    - *Sewage discharge:* Discharge of nutrients from non-water company treatment plants and package treatment plants, from combined sewer overflows (CSOs) and sewage pumping station overflows (PSOs) during intermittent, high rainfall events, from septic tanks that are poorly maintained or discharging to a stream (discharges from caravan parks were highlighted) and from contaminated surface water due to wrong sewer connections;
    - *Landfill leachate:* The urban fringes around Preston and Blackpool include several historic and current landfill sites;
    - *Geomorphological changes:* Several of the water bodies are heavily modified and have been straightened, canalised or had flood works and barriers installed;
    - *Industrial pollution:* The urban area around Preston includes several industrial estates with suspected discharges of pollutants.

1.5 The Project Team and Roles

Many individuals and a number of organisations were involved in this project, but the day to day delivery of the project was undertaken by:

- Anne-Marie Bowman, the Environment Agency’s area representative, who in addition to project management, pulled together Environment Agency datasets and reports from colleagues and external organisations and organised the initial meetings and the three workshops;
- Natalie Phillips, the Environment Agency’s project manager and a representative from the Environment Agency's national Evidence Team.
- Paul Hulme of pjHYDRO to whom the contract was let; and with subcontract support from;
- Nick Rukin of Rukhydro.

Paul Hulme and Nick Rukin analysed the data and information, produced the Evidence Packs and ran the three workshops.

1.6 The Evidence and Measures Approach

The approach focuses on the use of currently available information in databases, archives, internal and published reports. It also seeks to take value from the testimonies and recollections of people who have known their catchments or stretches of river for a long time. The approach therefore aims to gain as much value as possible from using existing information.

Understanding the aquatic ecology and water quality aspects of rivers is scientifically challenging. River-reach and catchment-scale problems are often the culmination of a number of pressures that have built up over decades and unravelling which ones are the most important is difficult. The task is made more challenging by incomplete datasets, which, due to uncertainties over what happened in the past, cannot be dealt with simply by a new field investigation or survey. Instead there is a need to present disparate pieces of information (using a “weight of evidence” approach) so that stakeholders can use the evidence as the basis for selecting measures. Categorical proof of the cause of a problem should rarely be expected.

1.6.1 Summary of the Evidence and Measures Approach

The Evidence and Measures approach is based on an adaptive management cycle and comprises six main stages as set out in Box 1.1.

1.7 Layout of this Report

Following this introduction, Section 2 describes the identification of the problem, including the suspected causes of WFD failure and the results of the Scoping Study. Section 3 describes the collection, analysis and presentation of evidence and Section 4 summarises the results from the three stakeholder workshops where consensus was reached on the main causes of WFD failure and appropriate measures identified. Conclusions and recommendations including a description of the lessons learned are given in Section 5.

Box 1.1 – Summary of the Main Stages of the Evidence and Measures Approach

Stage 1: Identifying the Problem;

- Identify the WFD elements assessed as less than good status;
- Gather from the catchment partners:
  - The suspected causes of these WFD failures;
  - Currently available data including recent digital data, historical hard copy data, archives, reports and information;

Stage 2: Analysing the Evidence

- Plot data in time and space and look for patterns;
- Gather the lines of evidence for and against each suspected cause;

Stage 3: Causes Workshop(s)

- Partners and stakeholders review all lines of evidence and agree the main causes of WFD failure based on the "strength of evidence" and their own knowledge;
- Participants move from a collection of individuals towards a group with a common aim and shared understanding of the water bodies.

Stage 4: Measures Workshop

- The same partners and stakeholders from the Causes Workshop identify actions (measures) that will address these main causes of failure;
- Consider both existing (or planned) measures and new measures;

Stage 5: Measures into Business Plans

- Environment Agency and catchment partners propose measures for their business plans after:
  - Reviewing the list of measures produced at the Measures Workshop and choosing which actions to implement first;
  - Considering what funding is available, what is achievable and what is cost-effective.

Stage 6: Assessing the Consequences of Measures

- Assess what impacts the implemented measures are having over the next river basin management cycle and record:
  - What measures have been implemented;
  - What impacts were anticipated and their timescales;
  - What impacts have actually been observed;
- Adapt actions (measures) based on the observed consequences;
- Share lessons learned with the managers and partners in other catchments.

Notes: Stages 1 – 4 in the approach were part of the scope of work for the Tidal Ribble water bodies and are described in Sections 2 – 5 of this report. Stage 5 was carried out subsequently by the Environment Agency and its partners. Stage 6 remains to be done and has been proposed as part of a Defra / Environment Agency R&D project for 2014/15.

2. Identifying the Problem

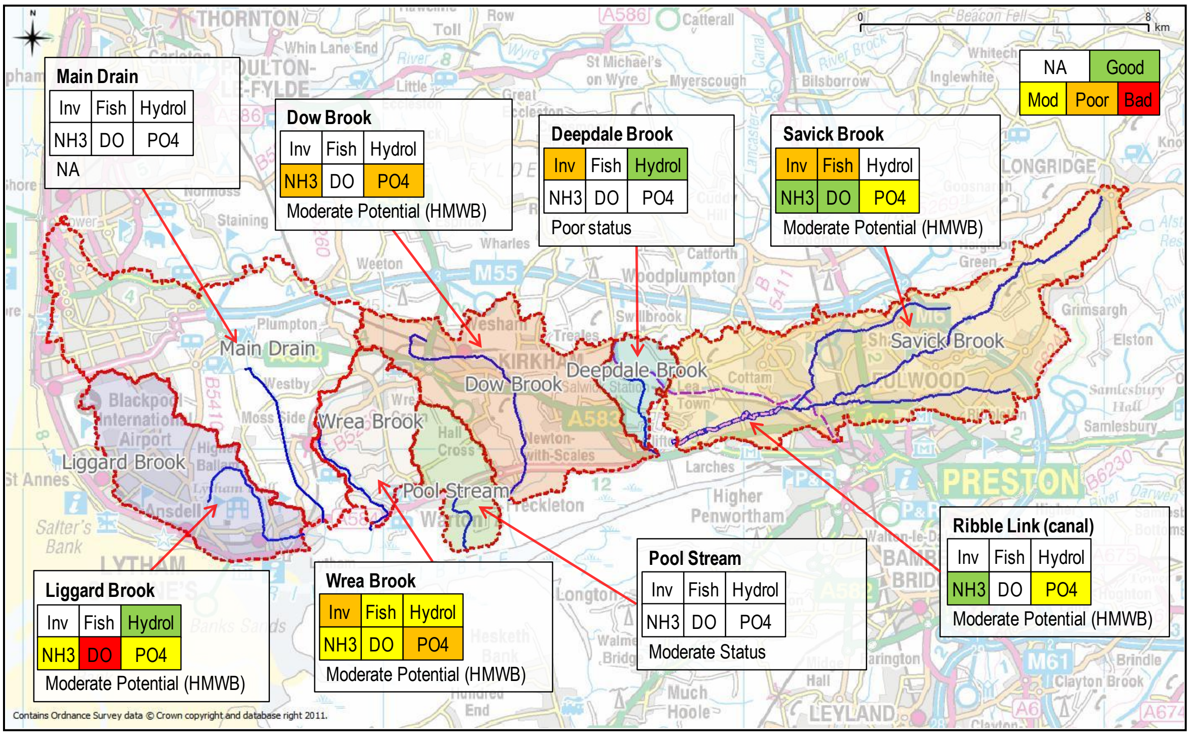
2.1 Purpose of this Section

This section of the report provides a summary of the WFD failures and the suspected causes of those WFD failures according to stakeholders at the start of the project.

2.2 Water Framework Directive Assessment

All eight of the Tidal Ribble water bodies have less than good WFD status as a result of failure from one or more of the following elements: fish, invertebrates, ammonia, dissolved oxygen and phosphate (Figure 2.1). Five of the water bodies (Liggard Brook GB112071065650[2], Wrea Brook GB112071065680, Dow Brook GB112071065670, Savick Brook GB112071065470 and the Ribble Link GB71210217) are heavily modified water bodies[3] (HMWB) and have all been assessed as moderate ecological potential. Deepdale Brook GB112071065460 and Pool Stream GB112071065650 are not heavily modified water bodies and have been assessed as poor and moderate ecological status respectively. Main Drain has no separate WFD assessment because at the start of the project it was divided between Liggard Brook and Wrea Brook.

Figure 2.1 – Water Framework Directive Status for the Tidal Ribble Water Bodies



Note: HMWB refers to heavily modified water bodies. Source: easiWFD & Screening Reports (both from the Environment Agency). Legend as Figure 1.1.

[2] Water Body ID.

[3] Under the WFD a water body is termed "heavily modified" if, as a result of physical alterations by human activity, it is changed substantially in character.

2.3 Suspected Causes of WFD Failure

A list of suspected causes of WFD failure (Table 2.1) was produced based on Environment Agency and local stakeholders' knowledge and supported by a site visit and two meetings.

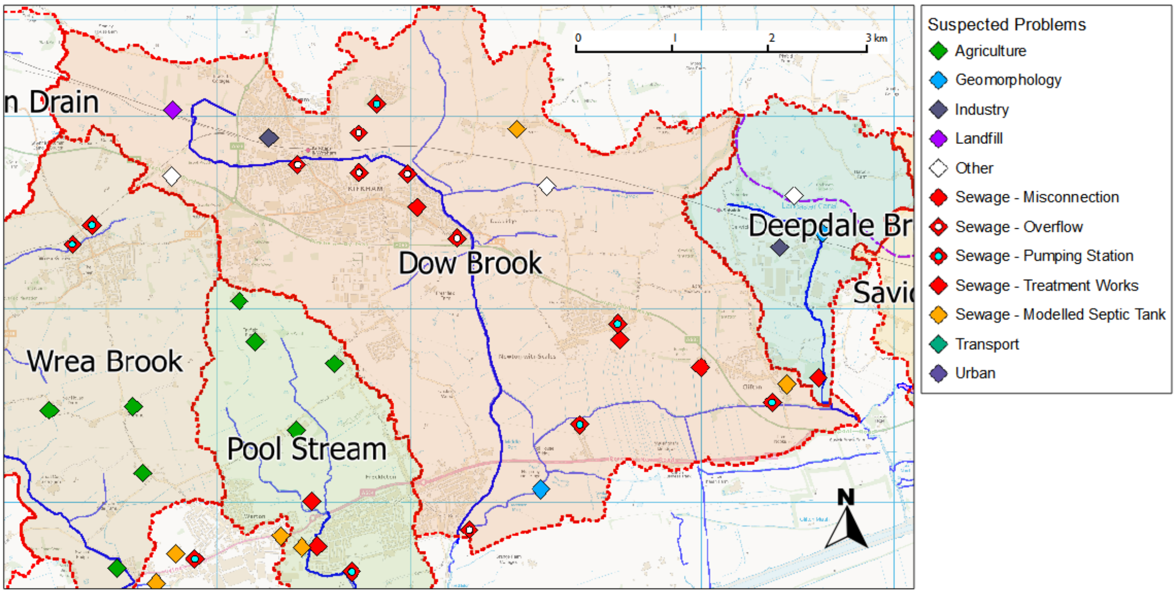
The results from the meetings were recorded in two spreadsheets and as a GIS layer. An example of the GIS layer for some of the Tidal Ribble water bodies is shown in Figure 2.2. The list of suspected causes was included in the Scoping Study results and in the Evidence Packs at the final stakeholders' workshop (Measures Workshop).

A list of the participants at the initial meetings is provided in Appendix A.

Table 2.1 List of Suspected Causes of WFD Failure Identified by Stakeholders during the Project

Suspected Cause	Water Body
Agricultural runoff of nutrients from agricultural activities including livestock areas (sheep, dairy), slurry management, leachate from silage clamps, application of inorganic fertiliser to arable crops, application of farmyard manure and United Utilities (UU) treated sewage to grassland.	Liggard, Main Drain, Wrea, Pool, Deepdale, Savick (upstream of M6),
Intermittent sewage discharges: Discharges during high rainfall from combined sewage overflow (CSO) or pumping station overflow (PSO).	Liggard, Main Drain, Wrea, Pool, Dow, Deepdale, Savick
Non-water company sewage: Discharge of nutrients from non-water company treated sewage effluents, package treatment plants and from septic tanks (including those on caravan parks) that are poorly maintained or discharging to a stream.	Liggard, Main Drain, Wrea, Pool, Dow, Savick
Landfill leachate The urban fringes around Preston and Blackpool include several historic and current landfill sites	Liggard, Main Drain, Dow, Deepdale, Savick
Geomorphological changes: Several of the water bodies are heavily modified and have been straightened, canalised or had flood works and barriers installed or have been dredged.	Liggard, Main Drain, Wrea, Pool, Dow, Deepdale, Savick
Industrial pollution: The urban area around Preston includes several industrial estates with suspected discharges of pollutants. Deepdale includes the Foxes Biscuits factory and the BNFL Springfield site.	Deepdale, Savick
Highway runoff: Drainage from M6, M55.	Liggard, Main Drain, Savick

Figure 2.2 – Example of Suspected Problems Identified by Environment Agency Staff in Wrea Brook, Pool Stream, Dow Brook and Deepdale Brook



Notes:
Map contains Ordnance Survey data © Crown copyright and database right 2011.
Information supplied by Environment Agency staff at the initial meetings in September 2011.

The Environment Agency has a WFD Reasons for Failure (RFF) database but this was not available for the Tidal Ribble water bodies until late May 2012, towards the end of the project, and then in a much diminished form compared to what was available after the project had finished. Table 2.2 shows a summary of the information in the RFF database for each Tidal Ribble water body, extracted after the project had finished.

The suspected causes of WFD failure collected at the beginning of the project from Environment Agency staff and external stakeholders (Table 2.1) include all those listed in the RFF database and one piece of new information about point source pollution from industrial sources in Dow Brook, which is listed as: "Point source pollution (BOD): incidents – *industry*" and underlined in Table 2.2.

The information in the Reasons for Failure database includes the assessment of experienced local Environment Agency staff. So if the RFF had been available at the start of this project, it would have been a useful source of suspected causes of poor WFD status and we would suggest that stakeholders consult the RFF at the beginning of any project where they are aiming to identify measures for implementation in their water bodies.

Table 2.2 Summary of Entries from the Reasons for Failure Database (May 2012)

Water Body	Element	Reasons for Failure[1] (Tier 1: tier 2 - *tier 3*)
Deepdale Brook	Invertebrates	Physical modification: improved grassland - *agriculture*
Savick Brook	Fish	Diffuse pollution: drainage (mixed & road runoff) - *urban*
		Physical modification: inland navigation - *navigation*
		Point source pollution: incidents - *industry*
	Invertebrates	Point source pollution (ammonia and phosphate): intermittent sewage discharge - *water industry*
		Diffuse pollution (phosphate and BOD[2]): dairy/beef field- *agriculture*
		Diffuse pollution (BOD): farm infrastructure - *agriculture*
	Mitigation Measures Assessment	Physical modification: urban development and infrastructure – *urban and transport;* Inland navigation – *navigation*
	Phosphate	Point source pollution: continuous sewage discharge - *water industry*
Liggard Brook[3]	Ammonia	Diffuse pollution: dairy/beef field – *agriculture*
		Point source pollution: septic tanks – *urban*
	Dissolved Oxygen	Diffuse pollution: dairy/beef – *agriculture*
	Mitigation Measures Assessment	Physical modification: flood protection – *urban and transport*
Pool Stream	Expert Judgement	Point source pollution: intermittent sewage discharge – *water industry*
Dow Brook	Invertebrates	Diffuse pollution (DO[2]): pig field – *agriculture;* dairy/beef field – *agriculture;* farm infrastructure – *agriculture*
		Point source pollution (BOD): incidents – *industry*
		Diffuse pollution (BOD): sewage discharge - *urban*
	Mitigation Measures Assessment	Physical modification: flood protection(structures) – *urban and transport;* urban development and infrastructure – *urban and transport*
	Phosphate	Point source pollution: continuous sewage discharge – *water industry;* intermittent sewage discharge – *water industry*
Wrea Brook[3]	Ammonia	Diffuse pollution: dairy/beef field – *agriculture*
		Point source pollution: continuous sewage discharge – *water industry*
	Dissolved Oxygen	Point source pollution: continuous sewage discharge – *water industry*
		Diffuse pollution: farm infrastructure - *agriculture*
	Invertebrates	Diffuse pollution (BOD): dairy/beef field - *agriculture*
	Mitigation Measures Assessment	Physical modification: flood protection (other operational management) – *urban and transport*
	Phosphate	Point source pollution: intermittent sewage discharge – *water industry;* continuous sewage discharge – *water industry*

Notes:

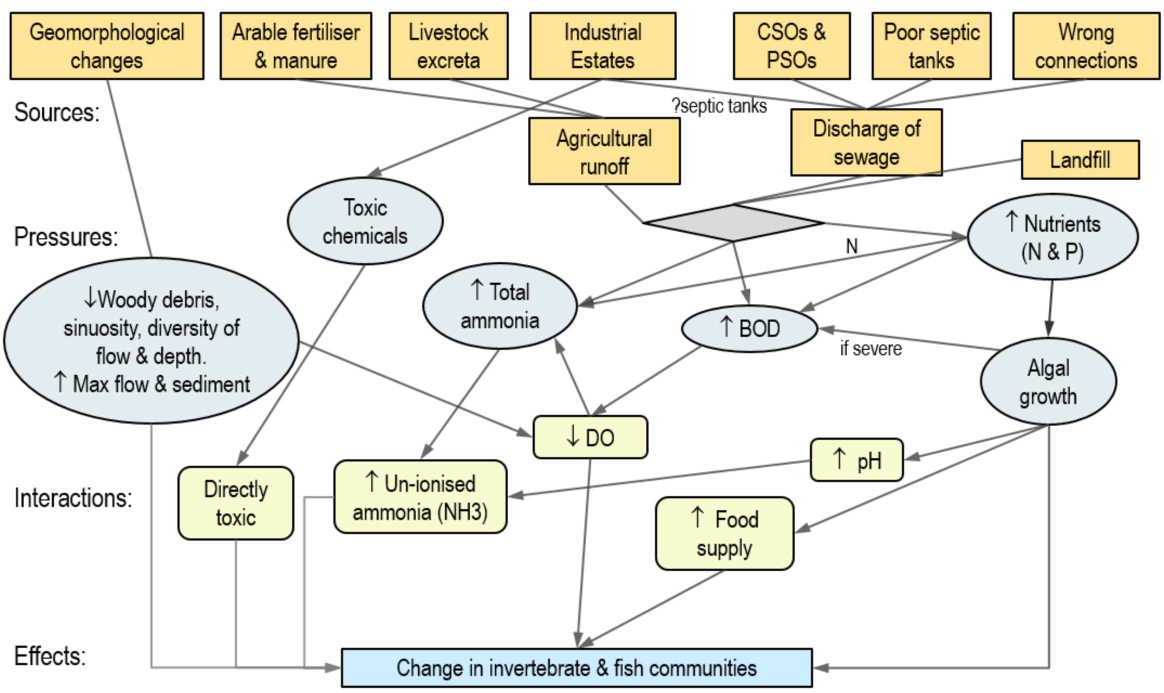
1 Information for the Tidal Ribble water bodies was provided by the Environment Agency from the Reasons for Failure database (“2011 RFF data (Ribble collation) v16.05.2011.xls”). This provides a snapshot of the understanding of the reasons for failure data at the time of collation (16 May 2011).
2 Biological oxygen demand (BOD); Dissolved oxygen (DO).
3 In the above version of the Reasons for Failure database, Main Drain was not a separate water body and was included partly within Liggard Brook and partly within Wrea Brook.

2.4 Conceptual Diagram

The understanding gathered about the WFD failures and their suspected causes can be summarised in a conceptual diagram, which shows a simplified understanding of the system. On other Evidence and Measures projects, several different versions of these diagrams have been tried, two of which are described below.

Figure 2.3 shows the conceptual diagram used at the Tidal Ribble stakeholder workshops. It shows the potential pathways that link the sources, pressures and effects on the aquatic biology with the suspected causes shown as orange squares in Figure 2.3. This is based on similar diagrams that can be found on the Causal Analysis/Diagnosis Decision Information System (CADDIS) website (US EPA 2013), and highlights the mechanisms operating in the water bodies. For example the right hand side of the diagram illustrates how increased nutrients can lead to algal growth, increased biological oxygen demand (BOD) and reduced dissolved oxygen (DO) concentrations, which impacts fish populations.

Figure 2.3 – Simplified Conceptual Diagram (Version 1) for the Tidal Ribble Water Bodies

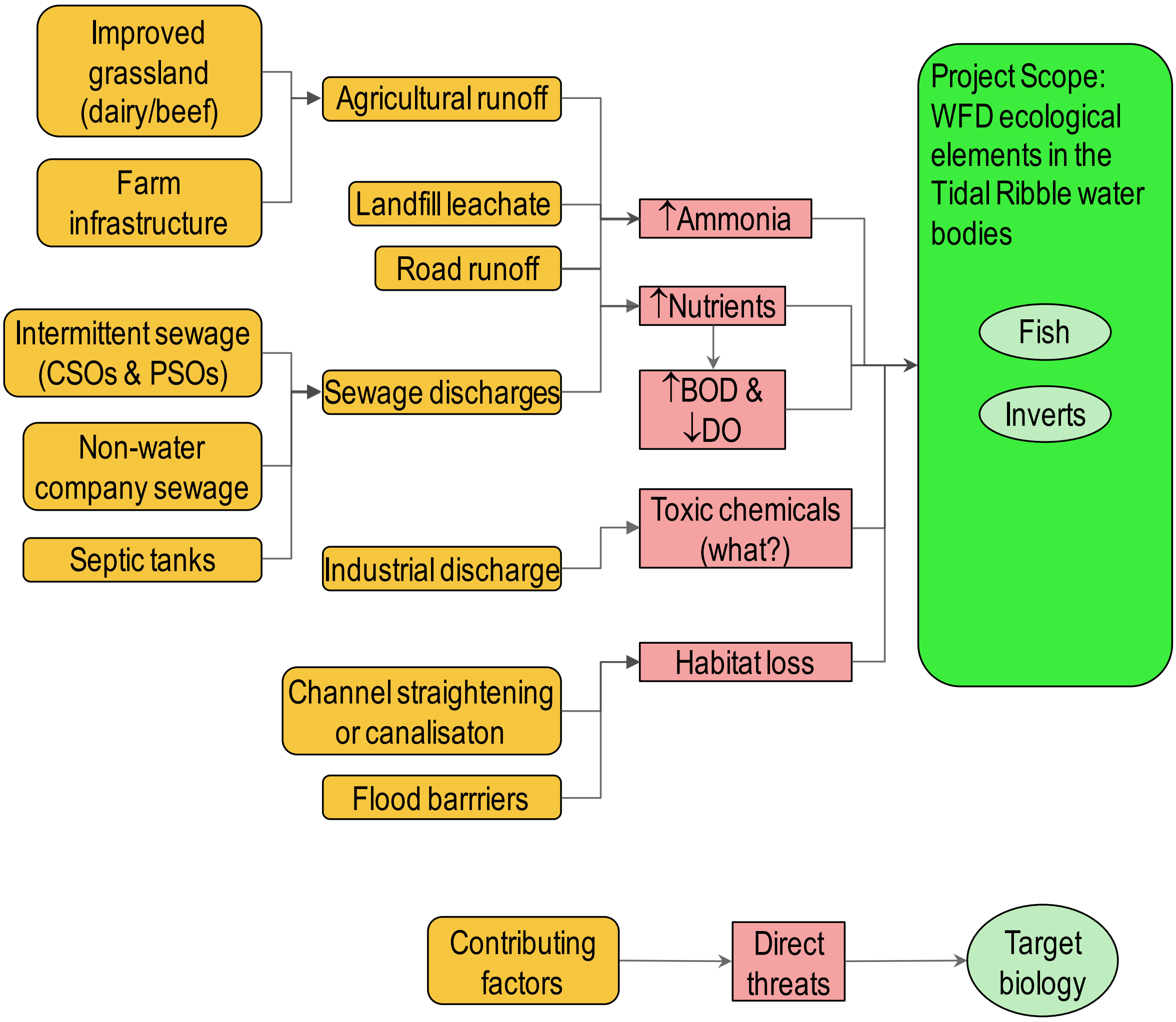


Notes:
CSOs & PSOs are intermittent sewage discharges from combined sewage overflows and pumping station overflows.
Algal growth (if severe) can lead to increased BOD because as the algae die, their decay consumes oxygen.

A second version of the conceptual model was produced during the writing of this report with the benefit of subsequent work and is based on work by Margoluis *et al* 2009, which shows the relationships between the biology that we want to conserve or restore (target biology, green ovals in Figure 2.4) and the human activities that directly threaten the target biology (direct threats, pink rectangles). Additional contributing factors identified during the Scoping Study have been added as orange rectangles.

This version of the conceptual diagram emphasises the stakeholders' understanding of the human activities that are threatening the biology and less on the detailed mechanisms.

Figure 2.4 – Simplified Conceptual Diagram (Version 2) for the Tidal Ribble Water Bodies



Notes:

Project scope: what are we aiming to restore or conserve?

Target biology: species, ecological communities or habitats.

Direct threat: human activity that immediately degrades the target biology. For example loss or fragmentation of habitat, overexploitation of living resources, introduction of exotic species or pollution.

Contributing factors: Indirect threats, opportunities and other important factors that influence direct threats.

2.5 Scoping Study

2.5.1 Aims of the Scoping Study

Stage 1 of the Tidal Ribble Evidence and Measures project included a short Scoping Study. Its aims are listed below and the results described in the sections that follow.

- Clarify the boundaries of the surface water bodies included in the project;
- Summarise the baseline understanding of the Tidal Ribble water bodies and their WFD failures;
- Agree a project plan and identify:
  - What data and information that would be evaluated during Stage 2 (Analysing the Evidence);
  - Which stakeholders would be involved in the project;
  - How much time from Environment Agency area staff would be available during Stage 2.

The Scoping Study drew upon the following sources of information:

- A set of slides on the general characteristics of the Tidal Ribble water bodies during August 2011 using information from the Environment Agency's national data;
- Notes from the half day field visit on 6 September 2011;
- Notes from two meetings with local Environment Agency staff from a wide range of technical disciplines (see Appendix A for a list of attendees);
- Teleconferences with Environment Agency area and regional staff.

The Evidence and Measures core team prepared a set of slides summarising the results of the Scoping Study and presented them to Defra, the Environment Agency Project Board and the relevant Environment Agency area teams on 1 November 2011 for their review.

2.5.2 Boundaries of the Surface Water Bodies

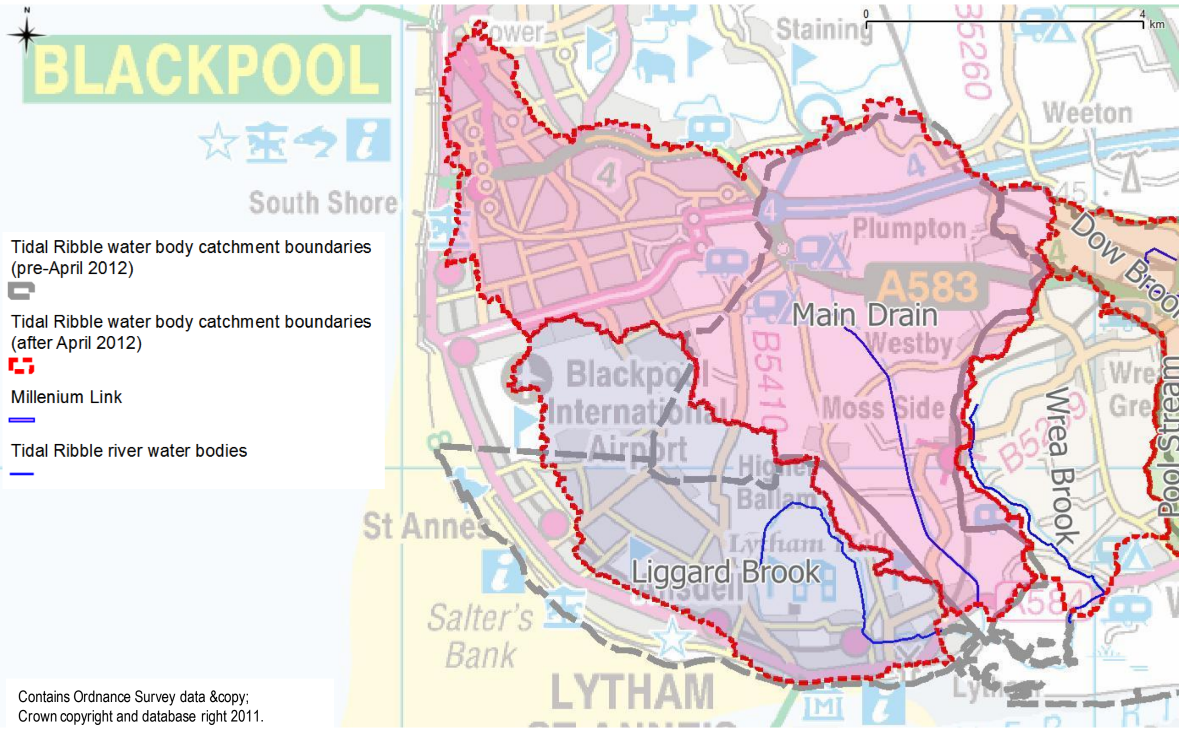
During the Scoping Study Environment Agency area staff clarified that eight water bodies on the northern bank of the Ribble and within the tidal limits of the river would be the focus of the project. These eight water bodies are (from west to east):

- The South Fylde Drains water bodies: Liggard Brook, Main Drain, Wrea Brook, Pool Stream, Dow Brook and Deepdale Brook (blue solid lines in Figure 1.1);
- Savick Brook (blue solid line in Figure 1.1);
- The Ribble Link Canal (pink dashed line on blue in Figure 1.1).

The tidal channel of the River Ribble itself and non-tidal water bodies further upstream on the Ribble were not included.

At the beginning of the project, the water body boundary for Main Drain had not been defined and was split between Liggard Brook and Wrea Brook. So we used an approximate “hand-drawn” boundary for Main Drain, which was based on topography and agreed with Environment Agency area staff (grey-dashed line in Figure 2.5) and was used for the analysis of several datasets by catchment boundary including discharge consents, pollution incidents and estimated locations of septic tanks. The official Main Drain water body boundary was issued in April 2012 (red dashed line in Figure 2.5) but, at that late stage in the project (during the preparation for the second Causes Workshop), re-analysis of the data could not be justified. Instead the "hand-drawn" water body area for Main Drain was used but the new boundary was added to the GIS so that everyone could see its extent.

Figure 2.5 – Water Body Catchments for Liggard Brook, Main Drain and Wrea Brook



2.5.3 Baseline Understanding

The Environment Agency's national Evidence Team prepared a set of slides (the initial conceptualisation, see Appendix B) which described the general characteristics of the Tidal Ribble water bodies and were based on the Environment Agency's national data. The slides included information on: topography, soils, land use, stream network, drift and solid geology, and areas prone to flooding. This information was combined with the information gathered during telephone conferences, the field visit and initial meetings with Environment Agency area staff to produce a baseline understanding which is summarised in Table 2.3.

Table 2.3 Summary of Baseline Understanding of Tidal Ribble Water Bodies

Item	Description
WFD Assessment	See Section 2.1.
Suspected causes of WFD Failure	See Section 2.3.
Topography	Most of the land is relatively flat (elevation ranges from 0 to 136 m AOD).
Solid Geology	Sherwood Sandstone in the east and Mercia Mudstone in the west.
Drift Geology	All the water bodies are covered with drift material (sands under Lytham St. Anne's, some areas of clay and silt and others with mixed material - diamicton).
Soils	Soils are seasonally wet suggesting drainage to streams is poor and possibly a significant amount of rainfall is conveyed by shallow groundwater flow in the drift to the coast.
Stream Network	The water courses are small and have relatively few tributaries. Savick Brook upstream of Preston is the largest watercourse; it is 3 - 5 m wide and passes through a number of locks in Preston before discharging into the Tidal Ribble. The other water bodies have narrow streams (1 - 2 m wide) and discharge to the Tidal Ribble through tidal flaps. A number of streams are prone to flooding as a result of backing up of water at the tidal flaps.
Stream Flows	Flows in the water courses are small and in their natural state would be affected by high tides. Assessments of flows as a supporting element for ecology show the surface water bodies to all be at good status. Neither surface water nor groundwater abstraction is considered to be an issue. The naturally low flows means there is less capacity for dilution of polluting discharges and, if velocities are also low, less potential for attenuation due to aeration.
Land Use	Preston and Lytham St. Anne's are urban / suburban, but otherwise catchments are rural with small settlements and village. Farming is predominantly managed grassland (mainly dairy) but with some areas of arable.
Habitat	A target healthy ecosystem for the water bodies would support a good coarse fishery (rather than salmonids) and habitat for invertebrates, amphibians, water voles and birds.
Savick Brook Stresses	has been under a variety of stresses for at least 200 years including: • Reduced natural recharge and modified flow regime due to urbanisation around Preston, sewage outfalls, unsewered discharges and industrial effluents; • Flow and habitat change through culverting and installation of locks; • Intensified farming in the upper reaches.
South Fylde Drains Stresses	Namely Liggard Brook, Main Drain, Wrea Brook, Pool Stream, Dow Brook and Deepdale Brook under the following stresses: • Land drainage occurred in the 1800s, affecting flows and habitat; • Agriculture intensified in the 1960s leading to increased nutrients and ammoniacal nitrogen in discharges to the water courses; • Populations grew as a result of new housing, hotels and travellers camps, which led to more septic tank discharges and greater loading on sewers and hence increasing nutrients and ammoniacal nitrogen in the water courses; • Landfills were filled and closed before full regulation, leading to potential discharges of ammoniacal nitrogen, organic loading and other potential contaminants; • Industry has developed and in places receded again; • Flood alleviation schemes have led to further changes to flows and habitat.
Current Investigations	Environment Agency area staff provided information about current investigations related to the water bodies (Section 3.2.9)

2.5.4 Agreed Plan for the Project

During the Scoping Study a list of the data and information was agreed for evaluation in Stage 2 of the project. These are described in Section 3.2.

The Environment Agency area team consulted with local stakeholders and invited the following organisations and groups to be involved with the project:

- British Aerospace;
- British Waterways;
- Canoe England;
- Catchment Sensitive Farming;
- Centre for Ecology and Hydrology (CEH);
- Lancaster Environment Centre, Lancaster University;
- Lancashire County Council;
- North Western Inshore Fisheries and Conservation Authority;
- Preston and District Wildfowl Association;
- Ribble Life (This is a partnership between the Ribble Rivers Trust and the Environment Agency. Ribble Life works with partners to take a holistic approach to catchment management);
- Ribble Rivers Trust;
- RSPB;
- The Wildlife Trust for Lancashire, Manchester & North Merseyside;
- United Utilities.

After consultation with Defra and the Environment Agency area staff on the project plan, it was agreed that the Evidence and Measures core team would lead the data analysis and the stakeholder engagement and that Environment Agency area staff and external stakeholders would contribute to the stakeholders' workshops.

3. Evidence

3.1 Purpose of this Section

This section provides an overview of the sources of information examined in the search for evidence on the causes of WFD failures in the Tidal Ribble Water Bodies. It includes a brief discussion regarding the processing and presentation of information in the Evidence Packs.

3.2 Sources of Information

3.2.1 Data Inventory and Timing of Data Collation

On the previous Petteril Evidence and Measures project, an extensive data trawl and collation exercise had been undertaken to help understand what data could be available for water bodies. For the Tidal Ribble water bodies, a more focussed approach was taken.

Firstly, background information on the character of, and suspected causes of WFD failure (see Section 2) in, the water bodies was collated as part of the Scoping Study between August and October 2011. The Scoping Study then identified potential “fruitful datasets” and relevant reports, which were collated and provided by the Environment Agency. Data provision continued up to and beyond the first Causes Workshop on 29 March 2012, with additional information identified as a result of discussions with stakeholders, being referenced in reports, or through lines of investigation not anticipated during the Scoping Study. This continued until and shortly after second Causes Workshop on 10 July 2012.

3.2.2 Visit to the Catchment

The project team were escorted to a number of locations in the Tidal Ribble water bodies by an Environment Agency officer on the morning of 6 September 2011. Photographs were taken and an appreciation of the size, condition and setting of the water bodies was gained.

3.2.3 Environment Agency National Data

As part of the Scoping Study, national data held by the Environment Agency was collated into a PowerPoint presentation. This included examination of available GIS layers including: topography, soils, land use, stream network, drift and solid geology, and areas prone to flooding (Section 2.5.3).

3.2.4 Fruitful Datasets

Based on experience from the River Petteril Evidence and Measures Project and consideration of the setting and causes of the WFD failures during the Scoping Study, some datasets were identified as being potentially fruitful for yielding evidence about the causes of WFD failures in the Tidal Ribble water bodies. These are labelled "Yes" in Table 3.1 under the column "Potentially Fruitful". The datasets that actually turned out to be most useful are those labelled "Yes" in the column "Most Useful". All the datasets in Table 3.1 were provided by the Environment Agency except those marked with an asterisk (*).

Table 3.1 Potentially Fruitful and Most Useful Datasets

Data	Potentially Fruitful	Description	Actually Useful
WFD Classes	Yes	Classes for all the elements assessed at the individual monitoring points as well as for the water body.	Yes
Boundaries	Yes	Water body and catchment boundaries as GIS shapefiles.	Yes
Water Quality	Yes	Current and historical water quality data and location of the monitoring points. Also General Quality Assessment (GQA), form the 1970s.	Yes
Invertebrates	Yes	Invertebrates survey data and reports on invertebrate surveys (1995-2003).	Yes
Fish	Yes	Fish data (limited to Savick Brook only) and locations of fish passes.	Yes
Other Biological Monitoring Data	Yes	Data from other ecological surveys (amphibians, otters, voles)	
Rural Land Use	Yes	Historical land use (2 km grid of land use and livestock numbers dating back to the late 1960s). (*EDINA, University of Edinburgh.)	Yes
Urban Land Use		Patterns of urban development in time and space. (*Lancashire County Council.)	Yes
Problems	Yes	The problems and suspected causes of WFD failure in each water body identified at the initial meetings. (*Stakeholders.)	Yes
Pollution Incidents	Yes	Pollution Incidents from the National Incident Reporting System (NIRS).	Yes
Consented Discharges	Yes	Location and type of consented discharges and information on spill rates and volumes.	Yes
Non-mains Sewerage	Yes	Estimated potential locations of septic tanks (properties more than 100 m from the sewer network).	Yes
Landfill Sites	Yes	Location, age and waste type of historical and current landfills sites.	Yes
Farm Surveys	Yes	Surveys of farms from the mid-1990s.	Yes
Source Apportionment	Yes	Source Apportionment GIS (SAGIS) data	Yes
Water Quality Modelling	Yes	SIMCAT river water quality modelling results	
Hydrological Data	Yes	River flows, rainfall and effective rainfall.	Yes
Geomorphology		A summary of the geomorphology of each water body from the regional geomorphologist.	Yes
Flood Defence Records	Yes	Records of flood defence works. These were identified at the Scoping Study stage, but not provided for use during the project.	
Reports		Faecal indicator budgets discharging to the Ribble Estuary (CREH, 1998).	Yes

A list of all the information collected for the project was collated into a data inventory. Due to the size of some datasets, some information was transferred using the Environment Agency's *Sharefile* facility. Other information was provided by email or on DVD.

3.2.5 "Issues" Maps

For each of the South Fylde Drains, copies of "Issues Maps" were provided by a senior member of staff of the Environment Agency. The hand-annotated maps had been prepared over time from the mid-1990s and included notes on local pollution problems including farms and sewage from septic tanks, caravan parks and first time rural sewerage schemes. The maps were digitised and geo-referenced for use in GIS.

3.2.6 Reports

The following reports were identified by the Environment Agency to be potentially useful sources of information:

- Fylde Aquifer Study (gave information mainly on groundwater);
- South Fylde Drains Catchment Review 1995-2003 (invertebrate surveys) ;
- 1994 Surveys on industrial estates at Red Car and at Shay Lane;
- Assessment of Factors Affecting Growth of Blue Green Algae in Preston Dock (Atkins, 2006);
- Wrea Green to Moss Side habitat creation potential study (2009);
- East Lytham Strategy – modelling for flooding;
- Faecal indicator budgets discharging to the Ribble Estuary (CREH, 1998).

References to other reports examined briefly were included in the Data Inventory.

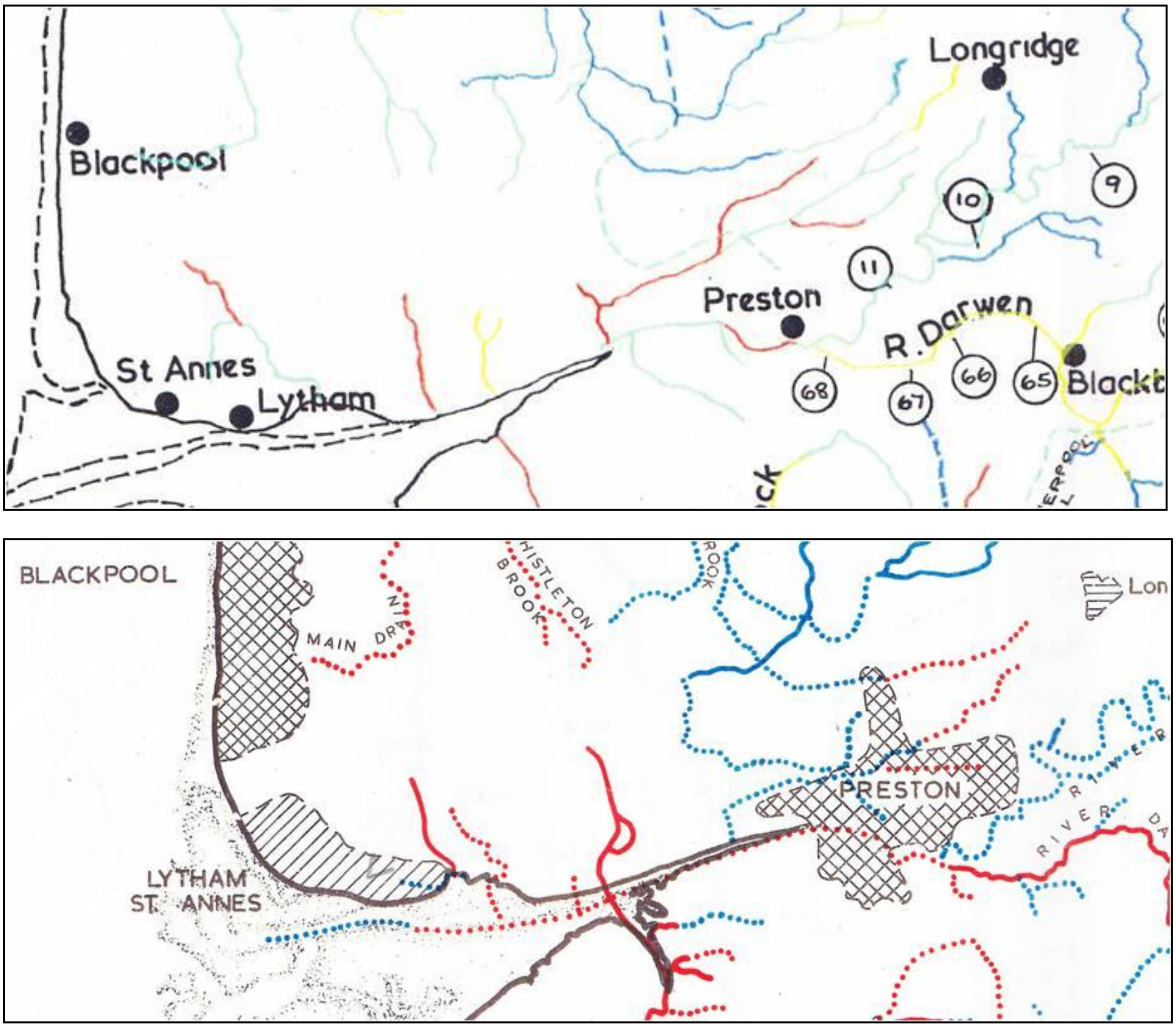
With the exception of the faecal indicator report (CREH, 1998), the South Fylde Drains Catchment Review invertebrate survey and the SIMCAT report, the reports generally did not allow an overview of the problems in the water bodies to be gained. They were instead more focussed on single issues.

3.2.7 Archives

For the River Petteril Evidence and Measures project, archived information proved to be invaluable in identifying when fish numbers had deteriorated and in pointing towards causes of historical pollution. As a result, three Environment Agency projects have since been completed with the Fresh Water Biological Association (FBA) and have made more than 4,500 Environment Agency reports and items of heritage media available to the public via an open access website (The Environment Agency Archives Collection at the FBA, http://www.fba.org.uk/environment-agency-archives-collection-fba).

For this Tidal Ribble water bodies project, the archives had not yet been digitised so the project team visited the Agency's Penrith office to review relevant reports and data. Little useful information was found although three reports summarising Lancashire river quality showed that the water bodies had been of poor quality since at least 1962 (see Figure 3.1).

Figure 3.1 – Historical Water Quality in 1962 and 1970 from Paper Archives



Note: Maps from Lancashire River Authority Annual reports for the years ending March 1962 and March 1970. Savick Brook is the main NE-SW red line north of Preston on the top map and the South Fylde Drains are west of there.

On the **top map** (1962), the colours are as follows: blue = Very clean and clean, **green** = Fairly clean and doubtful, **red** = Poor and bad, and yellow = Very bad.

On the **bottom map** (1970), the colours are as follows: solid **blue** = Class 1 (Rivers unpolluted & those recovered from pollution), **dotted blue** = Class 2 (Rivers of doubtful quality and needing improvement), **dotted red** = Class 3 (Rivers of poor quality requiring improvement as a matter of some urgency) and **solid red** = Class 4 (Grossly polluted rivers).

3.2.8 Stakeholder Opinions

Information was collected from stakeholders throughout the project: as input to the Scoping Study (Section 2.5), on suspected causes of WFD failure (Section 2.3) and on other relevant projects or investigations (below). The stakeholder workshops (Section 4) were used to check stakeholders' opinions on the interpretation of the existing information and gather from them additional information. Representatives were present from a number of stakeholder organisations including the Environment Agency, the Ribble Rivers Trust, United Utilities, Lancashire Wildlife Trust and the RSPB (see Appendix A).

3.2.9 Investigations Identified During the Project

During the Scoping Study the following investigations, initiatives and engineering works were identified for consideration during Stage 2:

- *Environment Agency:* Information on housing development from Preston City Council;
- *United Utilities:* Schemes to reduce incidence of intermittent sewage discharges (from CSOs) to water courses particularly in Preston, Deepdale Brook (Clifton), Dow Brook (Kirkham) and Pool Stream (Freckleton);
- *University of Sheffield:* Impact of urban Preston on the River Ribble;
- *Catchment Sensitive Farming:* Farm Grants Scheme in 1990s for building slurry and silage stores and some work done on Liggard Brook;
- *Fylde Borough Council:* work in Clifton to help alleviate surface water flooding by replacing an undersized pipe.
- *Blackpool:* The Pontins site is being re-developed and the Environment Agency is encouraging the installation of sustainable urban drainage (SUDs).

3.3 Project GIS

3.3.1 GIS System Used

The "open source" GIS software, Quantum Geographic Information System (QGIS) version 1.8.0, was used to display and analyse vector data (shapes) and raster data (grids). QGIS is a user friendly Open Source GIS licensed under the GNU[4] General Public License. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo).

3.3.2 GIS Layers

The GIS included layers in the following data categories:

- Participants suspected causes of WFD failure and other issues from initial meetings;
- Issues Maps were provided by a long-serving member from the Environment Agency;
- Properties more than 100 m from the sewer network (estimated locations of septic tanks)
- Discharge consents with volumes;
- Pollution events: National Incident Recording System (NIRS, 2001-2012, water impact only);
- Areas of historical and permitted landfills;
- Water body boundaries;
- Sub-catchment boundaries for Savick Brook (see Section 3.4);
- Location of Environment Agency biological and water quality monitoring points;
- Water quality statistics;

[4] GNU (GNU's not Unix) is a Unix-like operating system that is free software.

- Biological surveys (invertebrates, great crested newts, otters, water voles and amphibians);
- Rivers network.

In addition, Ordnance Survey basemaps were downloaded for use under OS's Open Data licence at scales of 1:1,000,000, 1:250,000, 1:25,000 and 1:10,000.

3.3.3 Use

The GIS project was used to view the locations of different monitoring points and pressures (possible causes of poor water quality) and interrogate details of specific layers. Areas of the water bodies or sub-catchments within a water body to different water quality monitoring points were also calculated to allow the density of e.g. landfills or pollution incidents to be expressed by area (per km^2 of the catchment).

3.4 Subdividing Savick Brook into Reaches

To help break down the Savick Brook water quality problem, the water body was subdivided into reaches based on the locations of water quality monitoring points (e.g. 88003569) as follows and as shown in Figure 3.2:

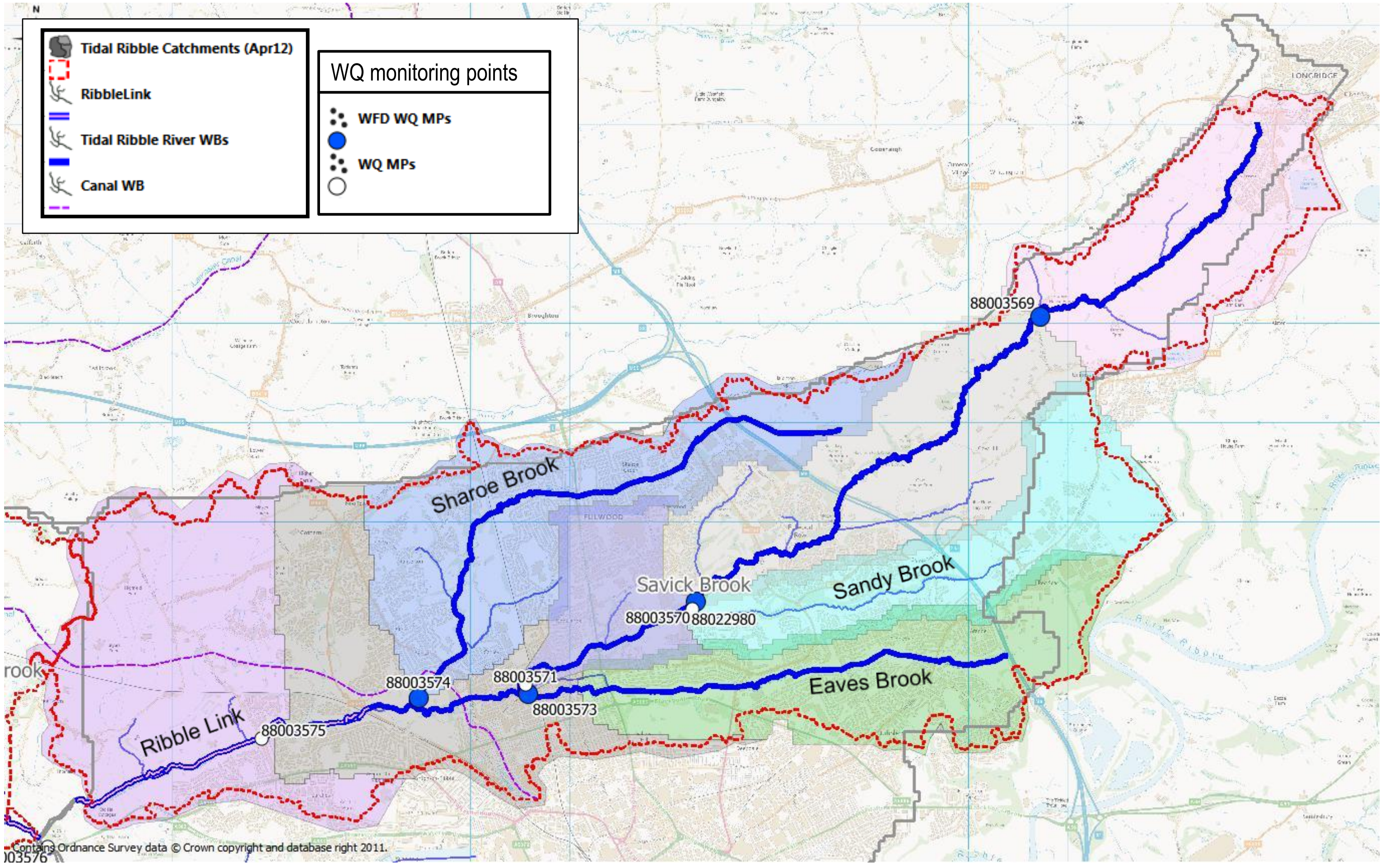
- Savick Brook – top of catchment to Grimsargh Road Bridge (88003569);
- Savick Brook - Grimsargh Road Bridge (88003659) to ptc (prior to confluence) Sandy Brook (88003570);
- Sandy Brook tributary catchment (88022980);
- Savick Brook – ptc Sandy Brook (88003570) to ptc Eaves Brook (88003571);
- Eaves Brook tributary catchment (88003573);
- Sharoe Brook tributary catchment (88003574);
- Savick Brook – ptc Eaves Brook (88003571) to Ribble Link Canal (Savick Brook) at Lea Road (88003575);
- Savick Brook at Lea Road (88003575) to ptc the Tidal Ribble (88003576).

Note: ptc = prior to the confluence with.

The sub-catchment to each of these points was defined approximately in GIS using the location of the downstream monitoring point and digital topography.

Besides helping to examine how Savick Brook's water quality changed over a particular reach, the sub-catchments were used in GIS to extract the number of pollution incidents or consented discharges and the proportion of different land uses etc.

Figure 3.2 – Savick Brook Sub-catchments and Water Quality Monitoring Points



Note: Savick Brook sub-catchments and its tributary sub-catchments were defined approximately in GIS using the water quality monitoring points (e.g. 88003570) to define the observed downstream end of a sub-catchment. Subdividing Savick Brook in this way helped to draw out from the different datasets where the greatest pressures were and how these related to changes in water quality.

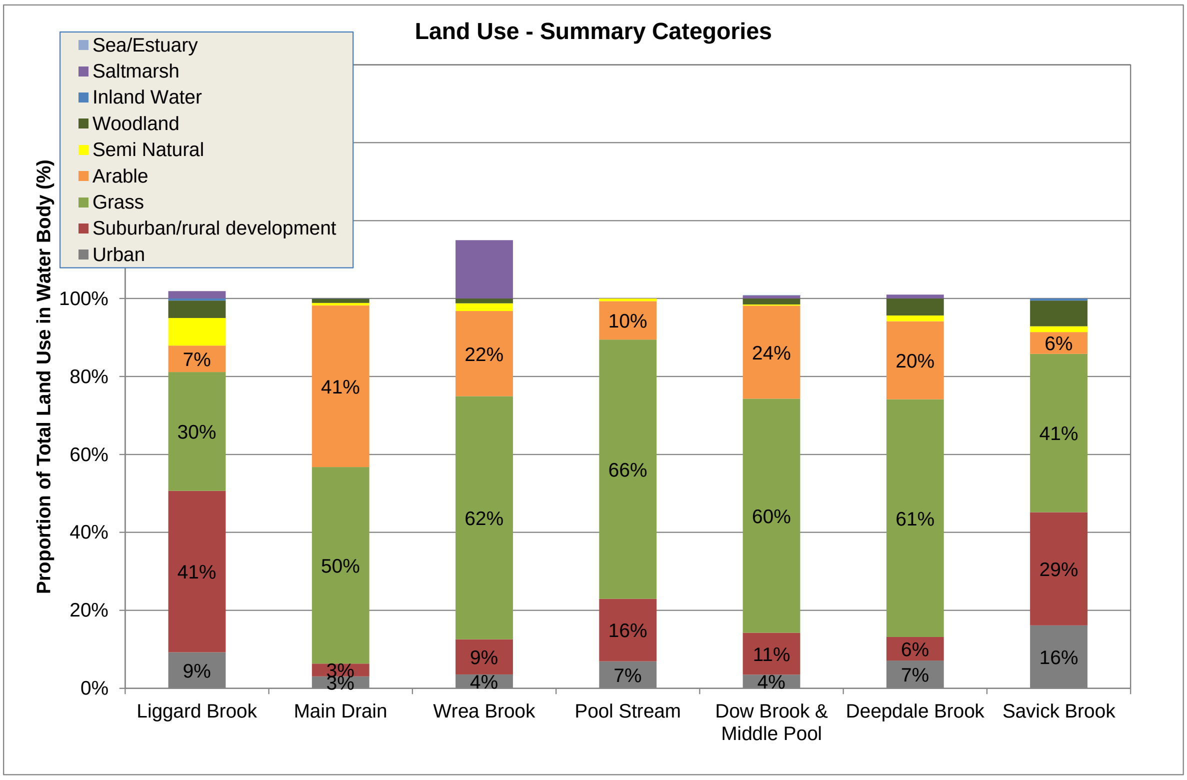
3.5 Interrogating Data

3.5.1 Land Use, EDINA and Urban Development

Land Use

Due to licensing restrictions, the Environment Agency could not provide CEH (2000) land use mapping for use on the project, meaning local pressures could not be identified. Instead, however, the totals of different land use categories were provided for each water body catchment (Figure 3.3) and the Savick Brook sub-catchments.

Figure 3.3 – Proportions of Different Land Uses in the Tidal Ribble Water Bodies



Note: The above chart shows the proportion of different CEH (2000) land use types for the Tidal Ribble water bodies as provided by the Environment Agency. The total areas for each land use are expressed as a percentage of all land uses excluding saltmarsh (to exclude the tidal parts of the water bodies).

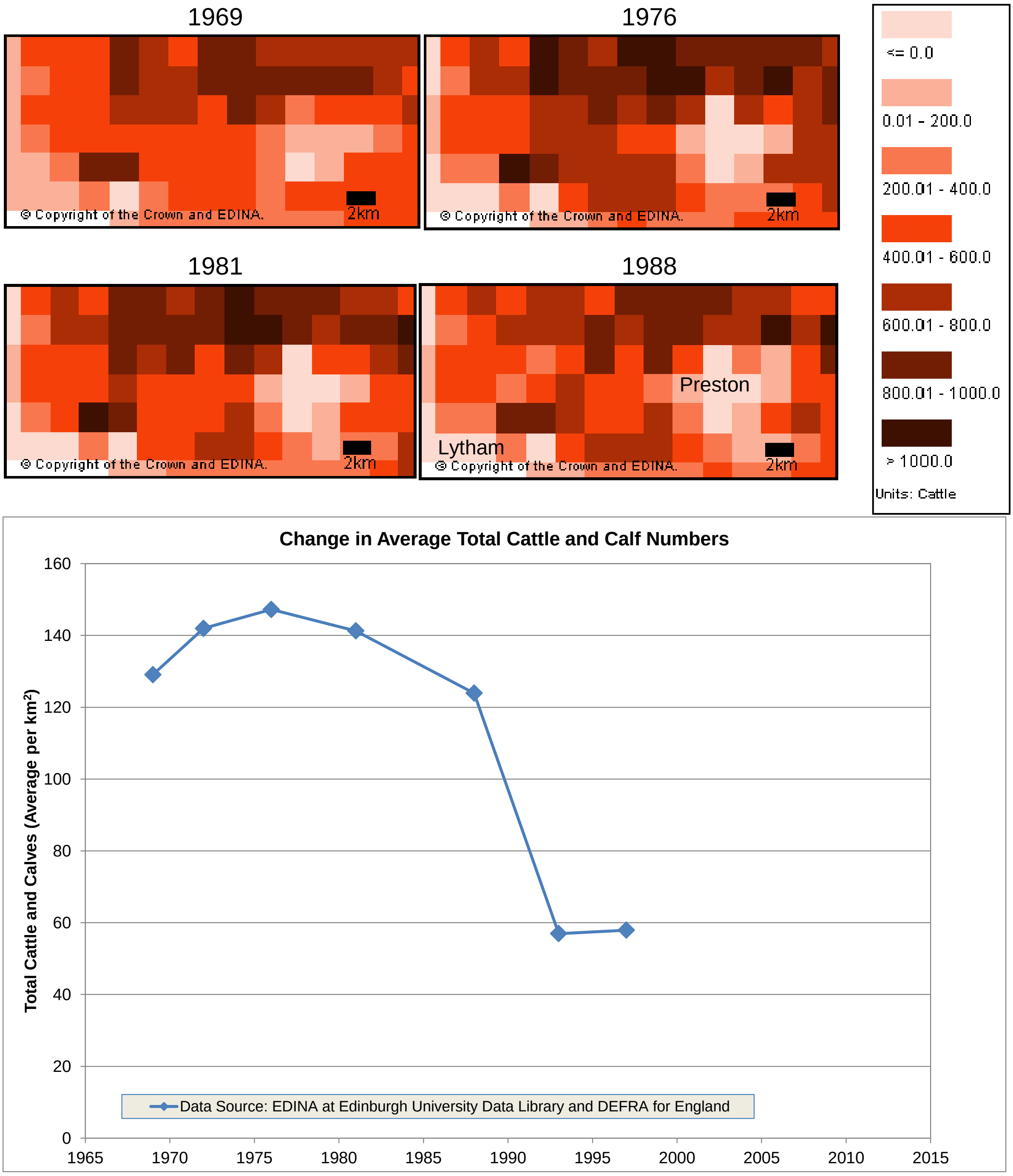
The significant urban / suburban nature of the Liggard Brook (Lytham St. Anne's) and Savick Brook (Preston) catchments is clear, as is the managed grassland dominated rural nature in general. Main Drain has the least urban/suburban area and also has significant arable land use. The land use was used very simply to compare the different urban/suburban to agricultural pressures on each water body.

EDINA Agricultural census Data

In the River Petteril Evidence and Measures project, the historical intensification of primarily dairy farming after the Second World War and up to the 1980s/1990s had been linked to the likely fall in trout numbers. The EDINA land use database of June Agricultural Census Data had been used to illustrate this intensification and show which areas of the catchment were most intensively farmed over time.

EDINA data were briefly reviewed for the Tidal Ribble Water Bodies. Cattle numbers were reviewed for the broad area covering all of the water bodies and were found to have been higher in the late 1960s than in the late 1990s (see Figure 3.4). This meant the poor water quality noted on the archives map from 1962 (see Figure 3.1) could plausibly have been related to agriculture (as well as sewage sources).

Figure 3.4 – Changes in Total Cattle and Calves Numbers from EDINA



Data Source: EDINA at Edinburgh University Data Library and Defra for England

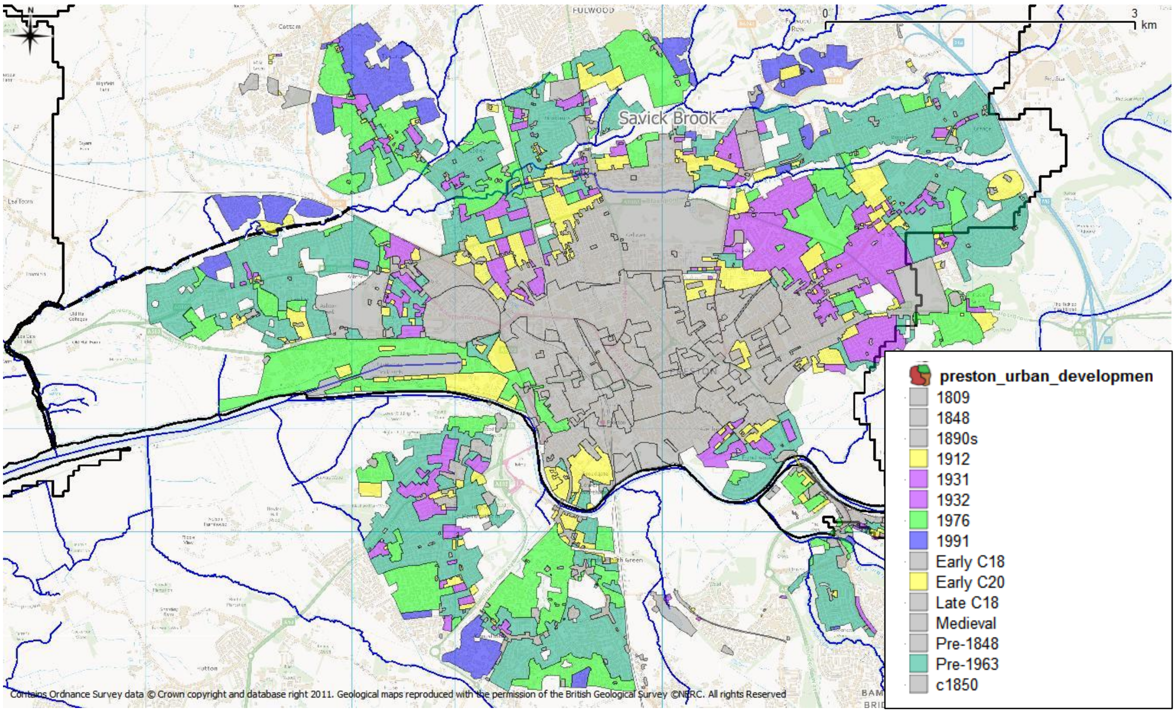
Note: The small maps show 2kmx2km grid SW Corner 333000,425000 and NE Corner 361000,438000. Preston and Lytham are shown on the 1988 map to give an indication of location

Urban Development

As a result of general internet searches on urban development, maps were identified for Preston, Kirkham and Lytham St. Anne's in reports available from Lancashire County Council (2006a,b and c). When contacted by the Environment Agency, Lancashire County Council kindly provided GIS layers and permission to use the outputs as part of this project.

Figure 3.5 provides an example of urban development in Kirkham. Growth prior to 1900 has been greyed out, but the map clearly shows significant development between 1930 and 1963 and then again by 1976 and to a lesser extent by 1991. Kirkham is at the top of Dow Brook and this urban development could be a cause of the long-term poor water quality as indicated to be present in 1962 from the archive map shown on Figure 3.1.

Figure 3.5 – Kirkham Urban Development (after Lancashire County Council)



Note: Urban development mapping GIS provided by Lancashire County Council. Pre-1900 development has been greyed out to simplify the map and illustrate the growth of Kirkham since 1900.

3.5.2 Spot Flows and Flow Estimates

There were no continuous flow measurements for any of the Tidal Ribble water bodies with the exception of a 5-6 week period in September and October 1997 when flows were measured on Savick Brook and in Wrea Brook as part of an investigation on faecal pollution (CREH, 1998). Otherwise flow data were limited to a few spot measurements. Data for a gauge to the north of the study area on the River Brock were provided by the Environment Agency to allow relative conditions during water quality and invertebrate sampling to be checked. The flow variability compared favourably with the limited data for Savick Brook and Wrea Brook.

Estimates of baseflow indices were provided in the CREH (1998) report and by the Environment Agency's hydrometric team using the Low Flow Enterprise (LFE) model. Average daily flows were estimated from the product of hydrologically effective rainfall (from

LFE) and catchment area (water body boundary). Significant uncertainty was identified in these flow estimates. Flows were required to convert loadings (e.g. of phosphate) to catchments into likely average concentrations in the water bodies as part of validation of any source apportionment work.

3.5.3 Geomorphological Constraints

Work by the Environment Agency's Geomorphologists

Following discussions at the start up meeting and the first Causes Workshop, the potential importance of geomorphology was noted. The Environment Agency's regional geomorphologist and the area team geomorphologist undertook an evaluation of the geomorphology of the Tidal Ribble water bodies. A set of slides was prepared (see list of outputs in Appendix B) and discussed at the second Causes Workshop.

Drift geology maps were reviewed, identifying former estuary deposits particularly in Main Drain and the lower parts of the Dow Brook and Deepdale Brook catchments. The water bodies also appear to follow larger channels cut by glacial meltwater. Historical maps were reviewed identifying areas that were drained in the late 1800s.

Classification

A relatively simple geomorphological classification system was developed and applied to different reaches of the water bodies (See Figure 3.6). This noted whether the reaches were semi-natural, had been straightened, re-aligned or canalised etc.

South Fylde Drains

For the South Fylde Drains in particular, the work concluded that the 1800s drainage works would have involved varying degrees of channel straightening, deepening and re-sectioning leading to:

- uniform bed and banks;
- uniform flow patterns (slow glide, and thus limited aeration);
- siltation leading in turn to a soft uniform stream bed;
- degraded or absent riparian vegetation.

Overall these factors lead to generally poor habitats and little aeration to deal with pollutant loading.

Savick Brook and the Ribble Link

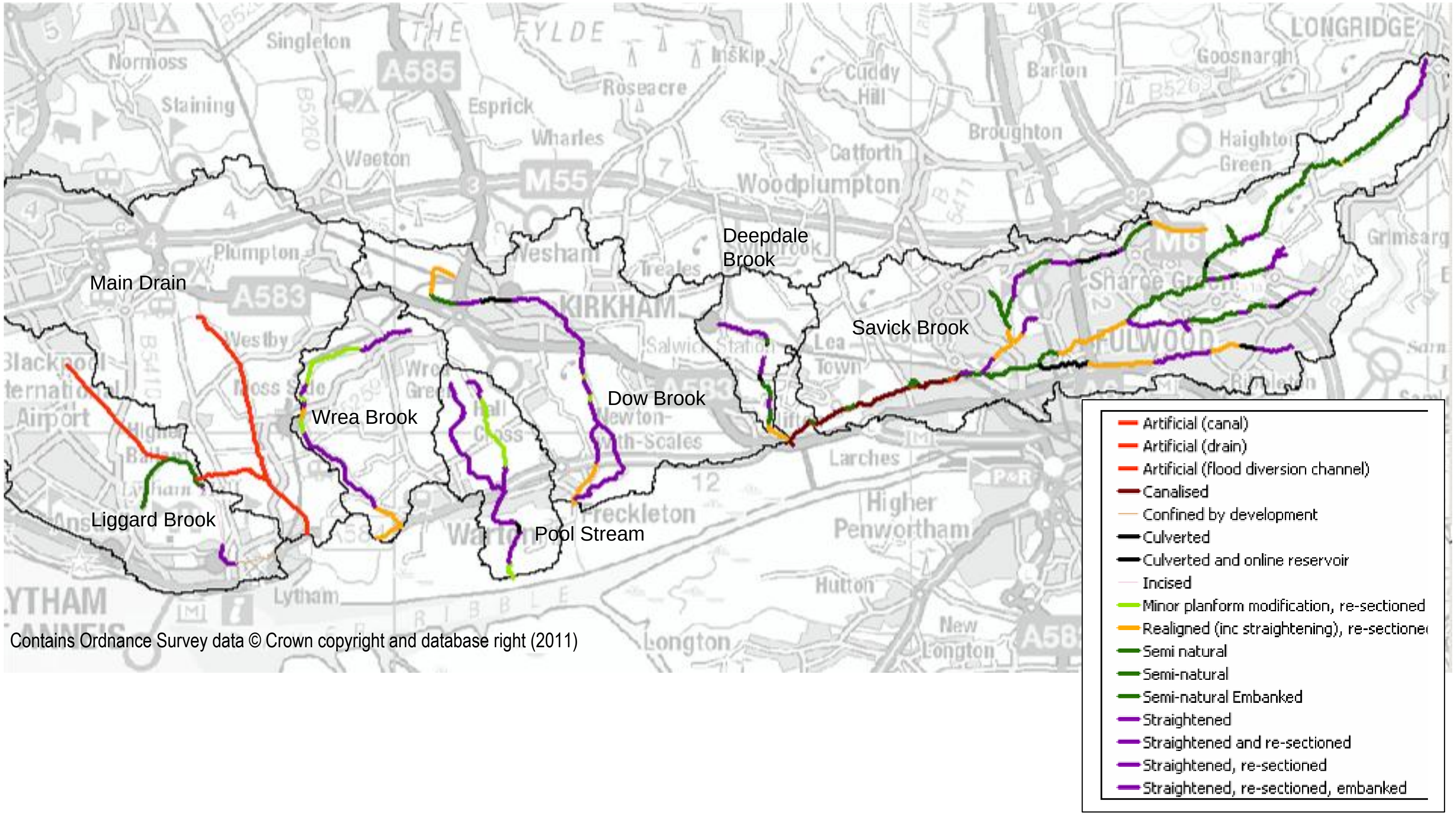
The upper parts of Savick Brook and Sandy Brook are semi-natural, but there are also straightened sections and parts of Sharoe Brook and Eaves Brook (two of Savick Brook's tributaries) are culverted. The lower section, the Millennium Link or Ribble Link, is canalised.

The Ribble Link opened in 2002: it is tidal, has nine locks, the channel was widened to allow navigation, it is prone to significant siltation and requires annual dredging to maintain navigation.

Overview

Overall the geomorphological work showed that even if water quality improved in some sections, a diverse ecology would still be unlikely to develop without some improvements to the habitat. It also helped explain why water quality was quite poor; with limited and slow flow, there was limited dilution and aeration to deal with pollutant loading. Savick Brook's upper sections were steeper and provided more aeration.

Figure 3.6 – Simple Geomorphological Classification of the Tidal Ribble Water Bodies



Note: The geomorphological classification was developed by the Environment Agency's geomorphologist for this project. It aims to convey simply how heavily modified the water bodies are and to highlight habitat limitations for attaining good ecological status.

3.5.4 Water Quality

WFD water quality status is based on the percentile or average concentrations of samples collected over a twelve month period and is defined under "*The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2009*".

The raw data on concentrations of dissolved oxygen, biological oxygen demand, ammoniacal nitrogen, and orthophosphate were processed to calculate their 10%ile, 90%ile and annual average respectively and then compared to the thresholds in Table 3.2 to give a WFD Combined Water Quality Score (the notes in Table 3.2 provide further explanation).

Table 3.2 WFD Water Quality Thresholds

WFD Status[1]	E&M Score[2]	DO Sat% (10%ile)[1]	Tot NH_4 mg/l N (90%ile)	BOD mg/l (90%ile)[1]	PO_4-P µg/l (Annual Mean)[1]	WFD Combined Water Quality Score ("Orange Blobs")[2]
High	5	70	0.3	4	50	20 (4No x Score of 5)
Good	4	60	0.6	5	120	16 (4 No x Score of 4)
Moderate	3	54	1.1	6.5	250	12 (4 No x Score of 3)
Poor	2	45	2.5	9	1000	8 (4 No x Score of 2)
Bad	1					4 (4 No x Score of 1)

Notes:

1 Thresholds as in The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2009.

2 The WFD Combined Water Quality Score is a simple translation of WFD Status into a number that can be plotted on a graph.

3 This score is the sum of the four individual scores of DO, BOD, NH4-N and PO4 and is used to illustrate on a single line on a chart how water quality has varied over time. It is indicative rather than being used for classification.

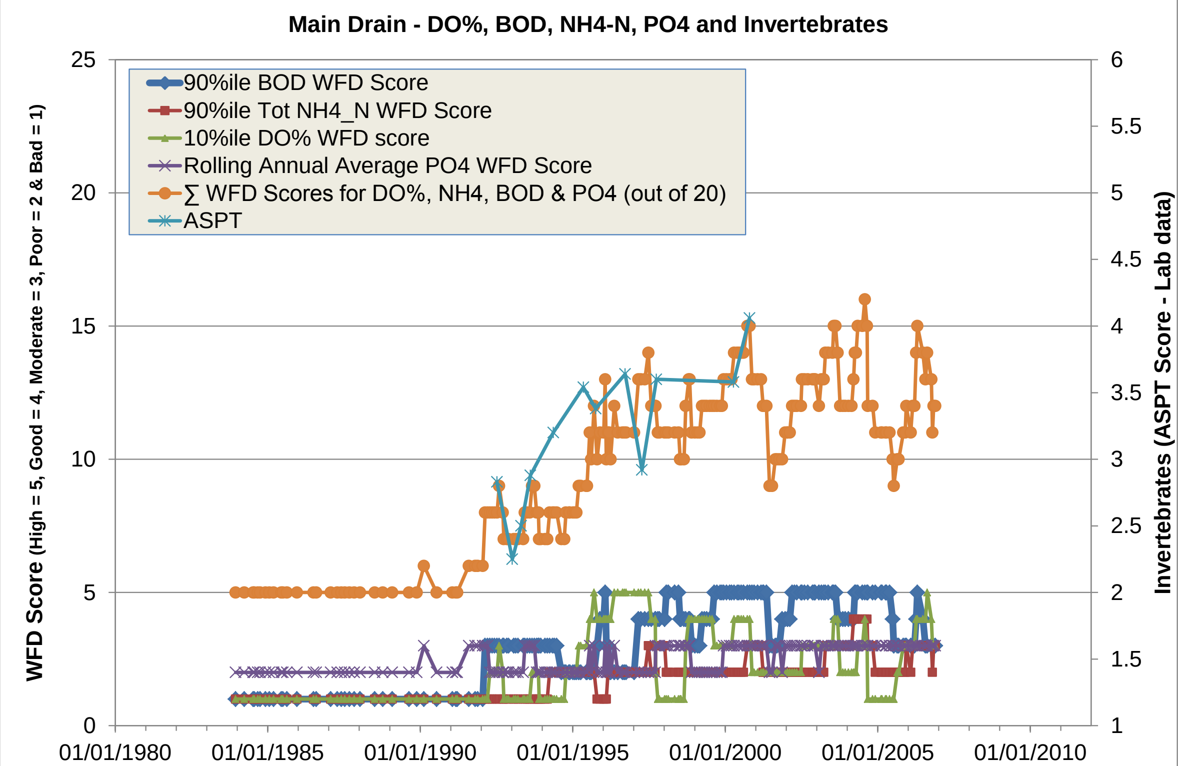
To make processing the raw data easier, percentiles were calculated on the previous ten samples rather than being strict on a twelve month period. Again the focus of the processing was to allow a quick visual appraisal of how water quality had changed over time in terms of WFD status. Figure 3.7 provides an example of this for the main monitoring point in Main Drain, one of the South Fylde Drains near Lytham St. Anne's.

Following discussion at the first Causes Workshop, the approach to scoring WFD water quality in this way was compared to former GQA (General Quality Assessment) data provided by the Environment Agency. A short slide presentation was prepared (see list of outputs in Appendix B) and given at the second Causes Workshop and it was agreed that the two approaches gave compatible results in general and stakeholders were happy using outputs as illustrated in Figure 3.7.

3.5.5 Invertebrate Data

Invertebrate data for the Tidal Ribble water bodies were examined. The Environment Agency's invertebrate specialist advised that invertebrate scores should not be compared from one location to another due to likely habitat controls (in addition to water quality). Variations in several invertebrate scores (i.e. Biological Monitoring Working Party, BMWP, scores - an index for measuring the biological quality of rivers using species of macro invertebrates as biological indicators, Number of Taxa and Average Score per Taxon, ASPT) over time were examined and compared to changes in the WFD Combined Water Quality Scores as shown in Figure 3.7.

Figure 3.7 – Long-Term Changes in WFD WQ Status and Invertebrates in Main Drain



Note: The orange blobs show the combined score for WFD water quality parameters, referred to here as the WFD Combined Water Quality Score, (>20 is high status, ≤4 is bad status). See Table 3.2 for explanation of WFD Scores. ASPT = Average Score per Taxon; a measure of the size and diversity of invertebrate species.

Many of the South Fylde Drains showed a similar improvement in invertebrates (ASPT) and overall water quality (the line of "orange blobs", referred to here as the WFD Combined Water Quality Score) in the mid-1990s as illustrated on Figure 3.7. This helped illustrate the link between changes in water quality and improvements in the ecological status of the water bodies during discussions with stakeholders.

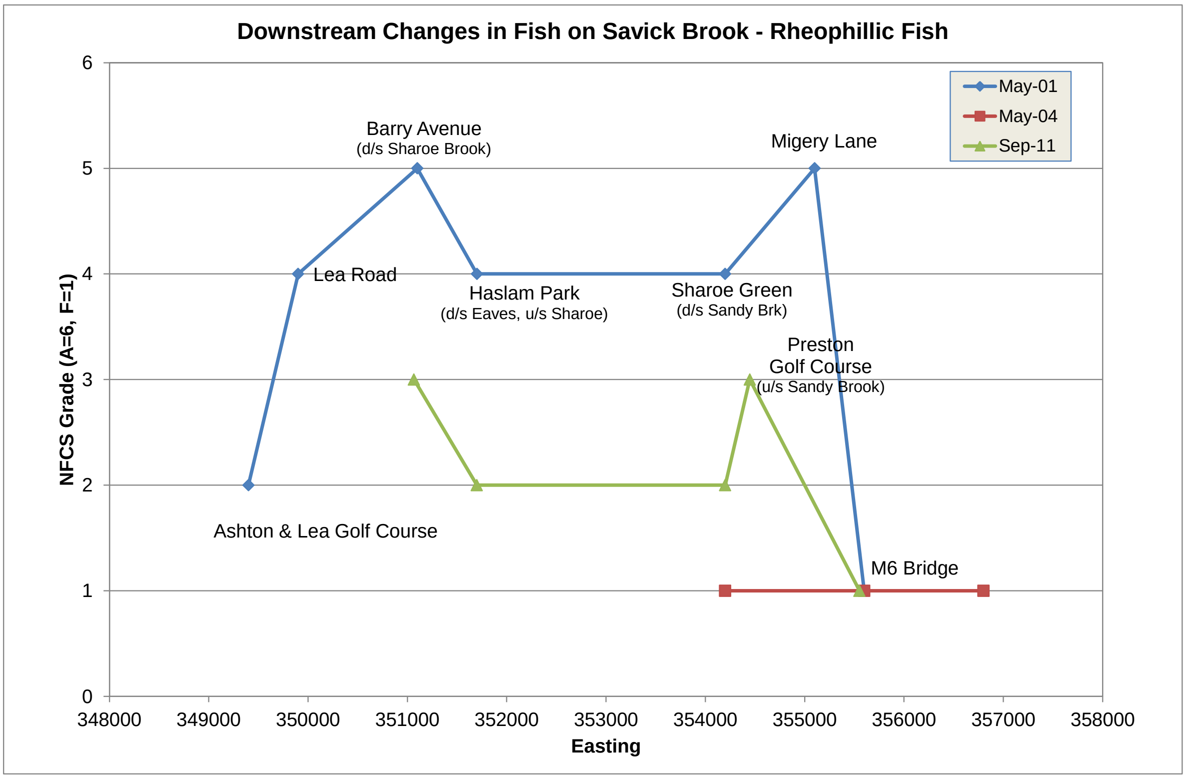
3.5.6 Electrofishing Data

Electrofishing data were limited to Savick Brook and then only for coarse fish. Surveys had been undertaken in May 2001 (7 locations), May 2004 (3 locations) and September 2011 (5 locations). The 2001 survey pre-dated construction of the Millennium Link, which had canalised part of Savick Brook in 2002. Subsequent surveys were unable to access some of the 2001 survey locations.

The limited survey data were examined for changes over time and spatially (upstream to downstream). Data for rheophillic (moving water), limnophillic (slack water), eels and predatory fish were examined together with water quality information. The findings of the analysis were discussed and agreed with the Environment Agency's area fisheries specialist and a presentation was prepared (see list of outputs in Appendix B) and given at the second Causes Workshop.

Figure 3.8 illustrates downstream changes in rheophillic fish (dace, chub, grayling and barbell) for the three surveys. It was concluded that whereas changes in water quality probably explained some of the downstream changes in rheophillic fish (particularly in the upstream sections), the significant drop in fish from 2001 to 2011 for all locations was likely to be related to the Millennium Link's canalisation (including locks) along the lower parts of Savick Brook. Water quality improved over this period.

Figure 3.8 – Downstream Changes in Rheophillic Fish in Savick Brook 2001 to 2011



Note: NFCS = National Fisheries Classification Scheme 1, with high numbers reflecting greater abundance of fish. Rheophillic fish includes dace, chub, grayling and barbell. Samples ordered by easting with upstream samples furthest east.

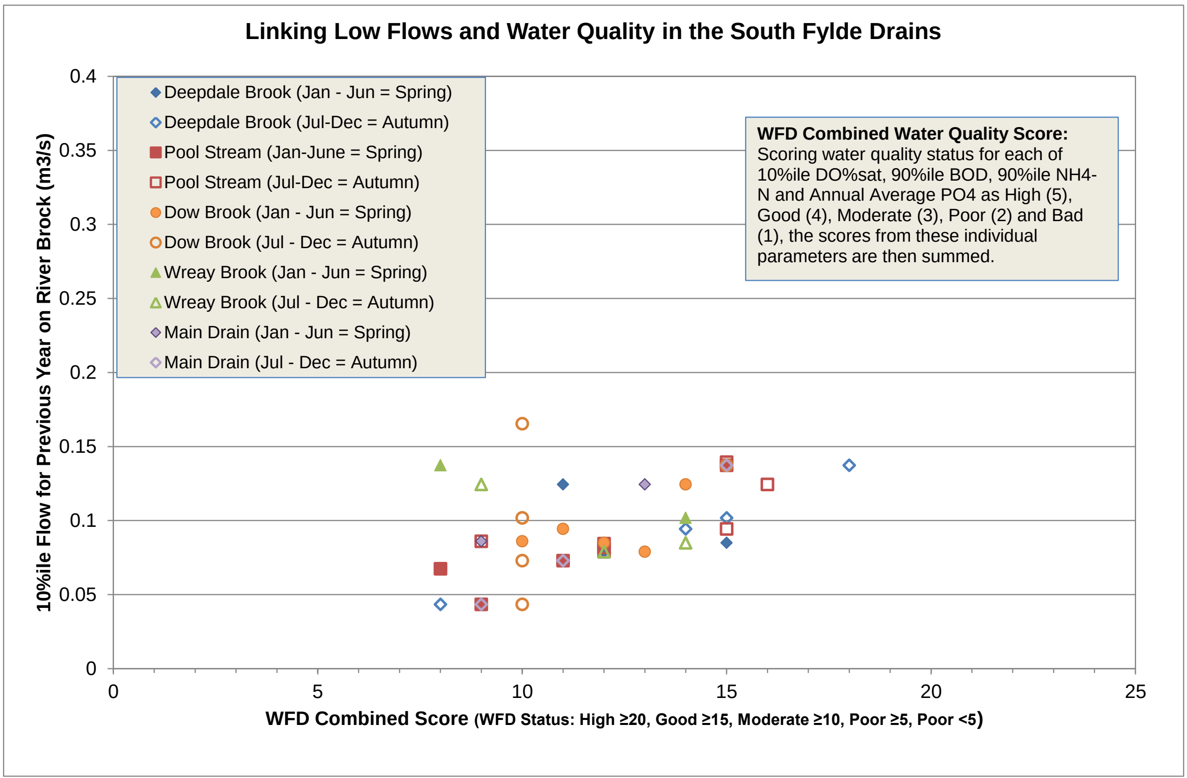
3.5.7 Changes in Water Quality with Flow

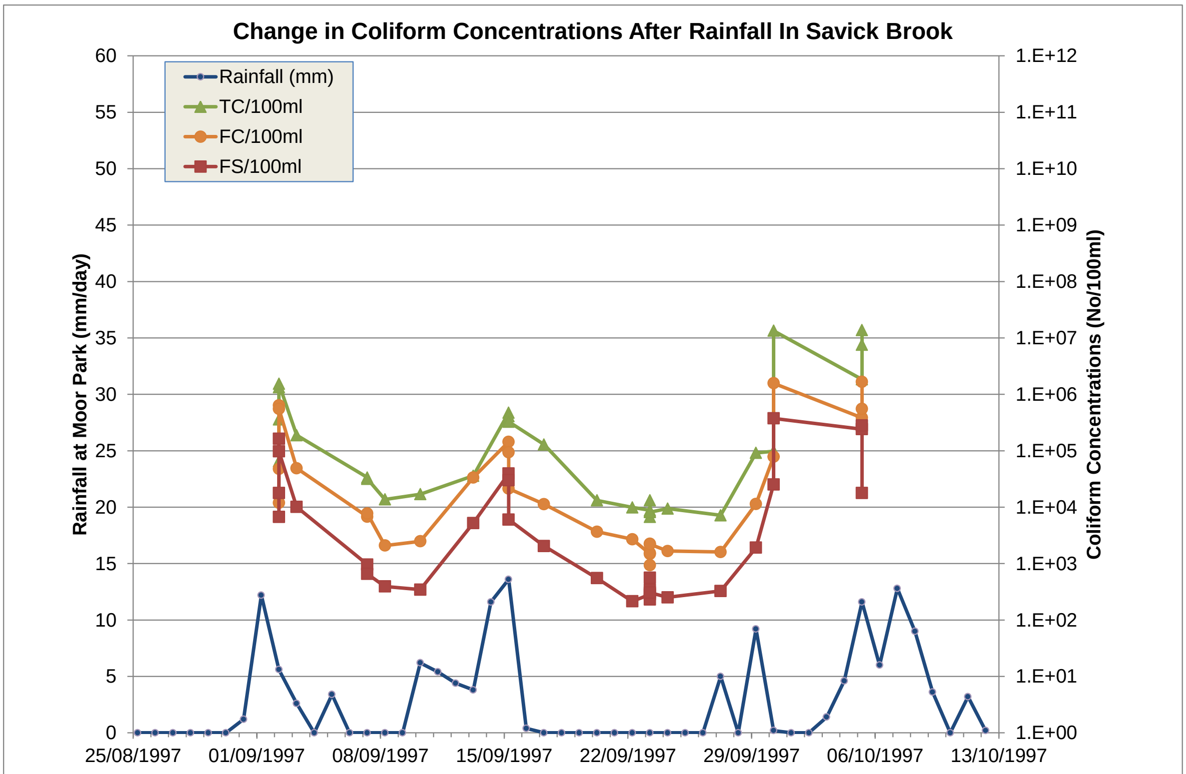
Deterioration of water quality during high flows could suggest runoff from fields or farm yards, combined sewer overflow discharges or pumping station overflows whereas deterioration during lower flows could suggest a background constant source such as landfills, wrong sewage connections or septic tanks.

With an absence of reliable flow data, it was not possible to check the variation in water quality with flow in the different water bodies confidently. Flow data from the River Brock (to the north of the study area) were used however and a possible correlation between improving water quality and higher baseflows was noted (see top chart in Figure 3.9), implying dilution of constant background sources.

The CREH (1998) report had reported deterioration in bacteriological quality following rainfall events (see bottom chart in Figure 3.9) suggesting the influence of discharging CSOs or perhaps runoff sources. WFD water quality parameters such as BOD, NH_4-N and PO_4 were also reported, with less data, but also showed deterioration in quality following rainfall.

Figure 3.9 – Examples of Change in Water Quality with Flow





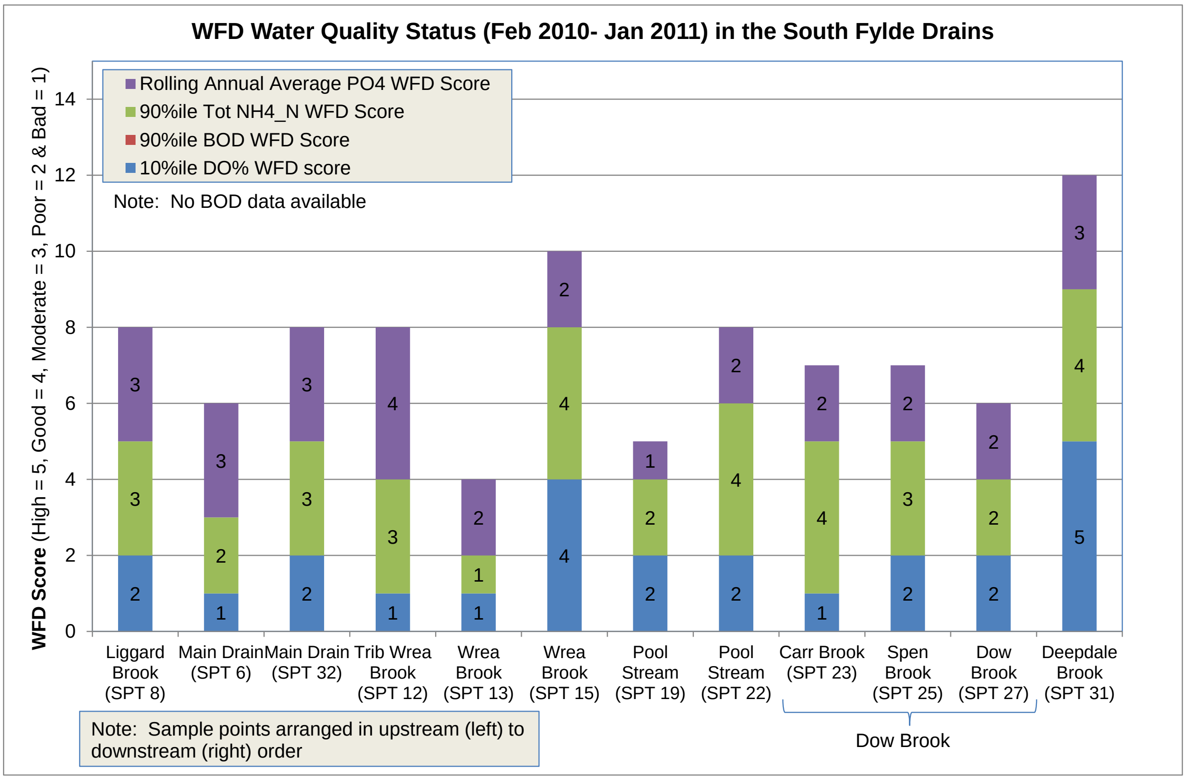
Note: The **top chart** shows some apparent (visual) link between the previous year's low flows (flows not exceeded for 10% of the year) and the WFD Combined Water Quality Score (as discussed in Section 3.5.4). This was interpreted as suggesting deteriorating water quality with less dilution of background sources during drier years. The **bottom chart** uses data from the CREH (1998) report and shows a marked deterioration in bacteriological quality in Savick Brook following rainfall. This was interpreted to suggest the impact of CSO discharges. TC, FC= Total, Faecal Coliforms, FS = Faecal Streptococci.

3.5.8 Downstream Changes in Water Quality

South Fylde Drains

Water quality monitoring points are limited for the South Fylde Drains with some of the water bodies only having a single sampling location, whilst others had a maximum of three including tributaries. In some water bodies, the sampling location was some distance from the confluence with the Tidal Ribble (to avoid tidal water quality effects). As a result of these limitations, it was not always possible to work out where water quality problems started in a catchment. The limited data were still used (see Figure 3.10) to identify for example a downstream improvement in water quality in Main Drain, Wrea Brook and Pool Stream which appeared to be related to decreasing influence of non-mains sewerage systems and urban areas as the downstream catchments became more rural.

Figure 3.10 – Limited Sampling Points Make Evaluating Downstream Changes Difficult



Note: Shows water quality at different sampling locations in the South Fylde Drains in terms of WFD water quality parameters scored as set out in Table 3.2.

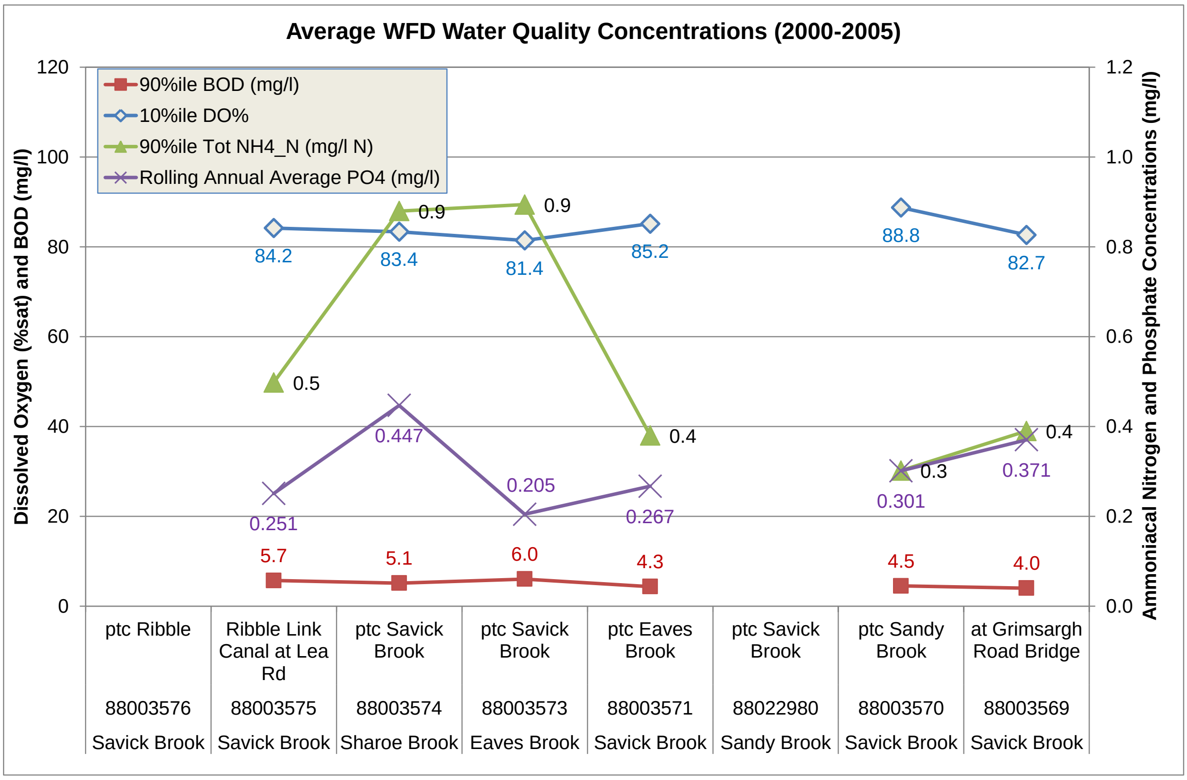
Savick Brook

In contrast to the South Fylde Drains, there were a number of different water quality sampling locations on Savick Brook and these were used to check how water quality changed as the brook moved from upstream to downstream from a rural-dominated catchment, through suburban and industrial areas and then the urban areas of Preston before becoming rural once again.

Figure 3.11 shows how dissolved oxygen, ammoniacal nitrogen, BOD and phosphate varied at different locations in the period 2000-2005. Upstream (at Grimsargh Road Bridge), plausibly rural sources of phosphate are evident, and urban sources of phosphate and ammoniacal nitrogen are shown in the Eaves Brook and Sharoe Brook tributaries. Eaves

Brook has five CSOs, whereas Sharoe Brook is an area of suspected wrong sewage connections.

Figure 3.11 – Downstream Changes in Water Quality in Savick Brook 2000-2005



Note: Savick Brook sample locations ordered upstream (right) to downstream (left). Shows decrease in phosphate as the brook moves from rural (upstream) to urban except for the influence of Sharoe Brook (possible area of significant wrong sewage connections). Ammoniacal nitrogen is particularly poor in the Eaves Brook (numerous CSOs) and Sharoe Brook tributaries and leads to an increase in ammoniacal nitrogen concentration in Savick Brook itself. The concentrations are shown as the average value for the period 2000 to 2005 of the different rolling percentiles (or rolling annual average for phosphate).

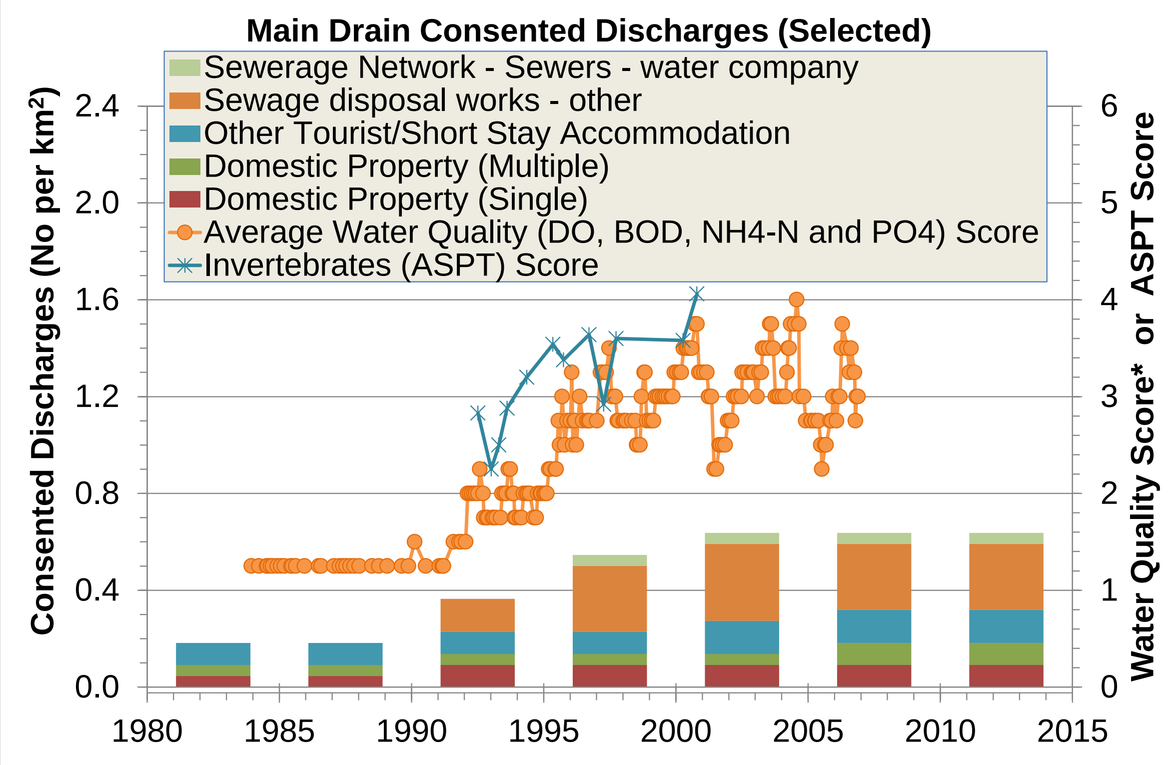
3.5.9 Consented Discharges

Consented discharge information was processed to distinguish between type of discharge (e.g. non water company treated sewage effluent, UU consented sewage outfalls (CSOs)) and the period over which the discharge had been consented.

Using GIS, this consented discharge information was collated on a water body catchment scale for the South Fylde Drains (or a sub-catchment scale for Savick Brook). The number of consents active in designated periods was divided by the catchment area to the water body to produce a consented discharge density (No/km^2) and thus allow densities in different water bodies to be compared. Column charts (e.g. Figure 3.12) were then used to display the way consented discharges had changed over time in a catchment.

By comparing changes in water quality and invertebrates (e.g. Figure 3.7) to the way consented discharges had changed (see Figure 3.12) potential links could be identified between increased consenting of discharges and improvements in water quality and invertebrates.

Figure 3.12 – Linking Changes in Consented Discharges and Water Quality



Note: The column chart shows how the density (number per km^2) of different types of consented discharges changed in the catchment area to Main Drain. In particular there was increased control of non-water company (UU) sewage disposal works effluent discharges (First Time Rural Sewerage schemes) in the 1990s (most likely related to the Urban Waste Water Treatment Directive). There is also increased control on UU consented sewage outfalls and tourist related discharges (sewage from caravan parks). The line chart repeats the invertebrates and overall WFD water quality (WFD Combined Water Quality Score*) from Figure 3.7. A strong link between tighter control on sewage discharges (column chart) and improvements in water quality and invertebrates (line charts) can be seen starting around 1990. This illustrates the extent to which poorly controlled sewage can affect water quality and invertebrates.

Discussion with the Environment Agency's consents team led to the conclusion that an increase in consents most likely meant tighter control of pre-existing discharges rather than additional new discharges in places where there had previously been none.

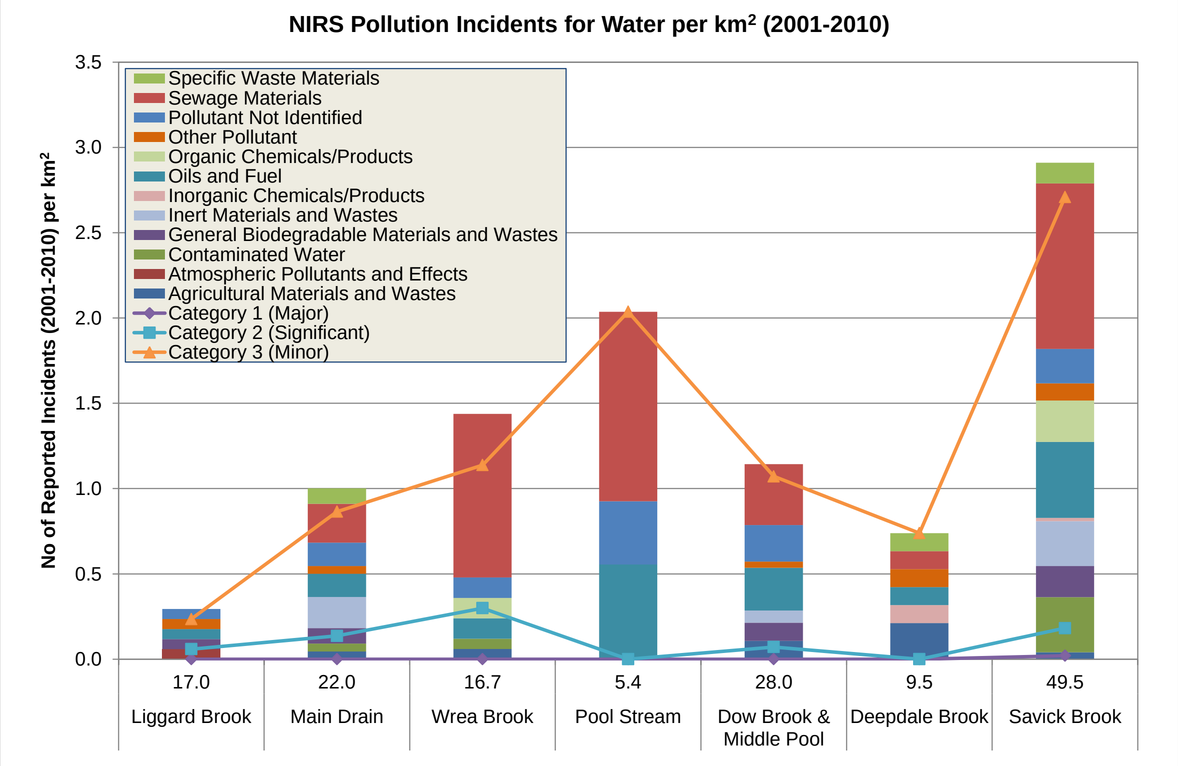
3.5.10 Sewer Network and Location of Septic Tanks

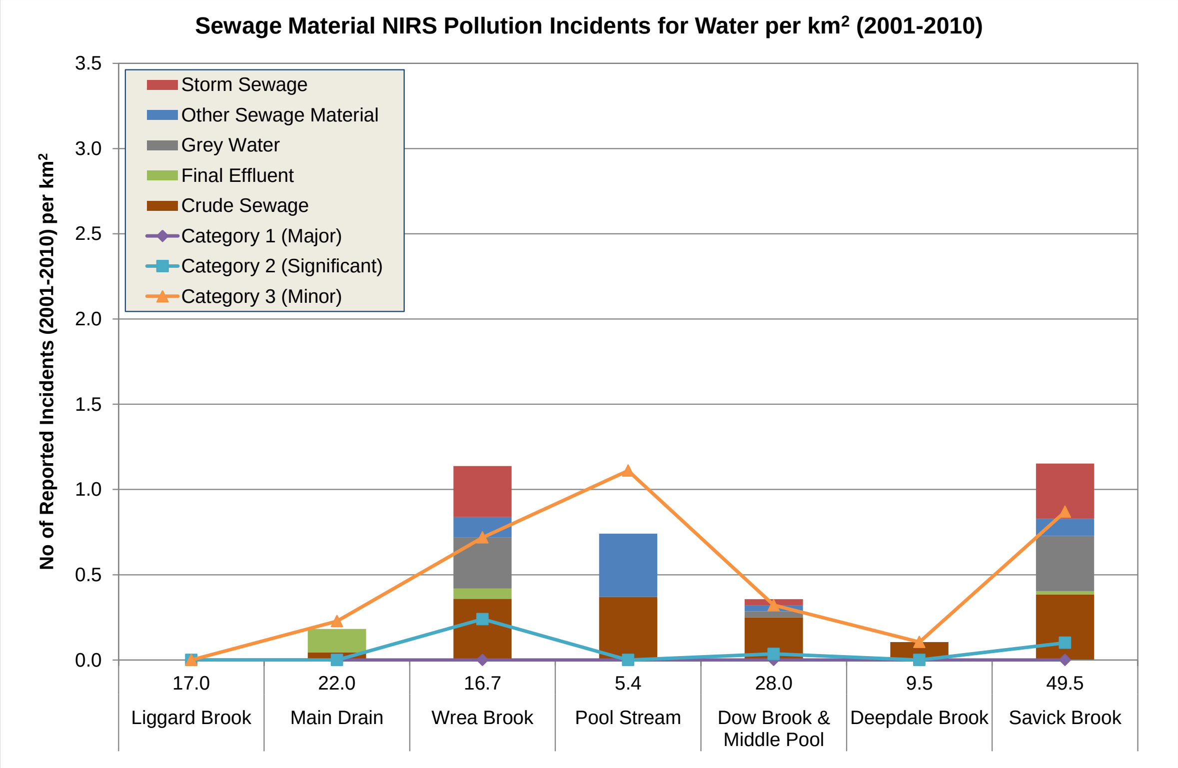
Sewer network mapping was not provided for direct use on this project. The Environment Agency did however use their copies of the sewer network to estimate potential locations of septic tanks by identifying properties more than 100 m from the sewer network. Using GIS, the number and density of these estimated locations of septic tanks were then extracted per water body catchment area for comparison of septic tank pressures.

3.5.11 NIRS Pollution Incidents

Outputs from the Environment Agency's National Incident Reporting System (NIRS) were processed and filtered for Water Impact Categories 1 to 3. GIS was then used to extract from this filtered dataset on a water body catchment (and Savick Brook sub-catchment) basis; allowing the types of pollution incidents to be compared between catchments in terms of categories 1, 2 and 3 (major, significant and minor) and pollutant type (PollTyp) as illustrated in Figure 3.13.

Figure 3.13 – Comparing Type of Pollution Incidents in the Tidal Ribble Water Bodies





Note: The **top chart** compares the density of different water impact pollution incidents across the seven Tidal Ribble water bodies (numbers on x axis are catchment areas in km^2). Sewage is a major cause of pollution except in Liggard Brook (sewered Lytham St. Anne's) and Deepdale Brook (largely agricultural). The **bottom chart** shows the sewage is related largely to crude sewage, although there are problems with grey water (wrong sewage connections) in Wrea Brook and Savick Brook.

Pollution incidents within a given water body catchment were also examined over time.

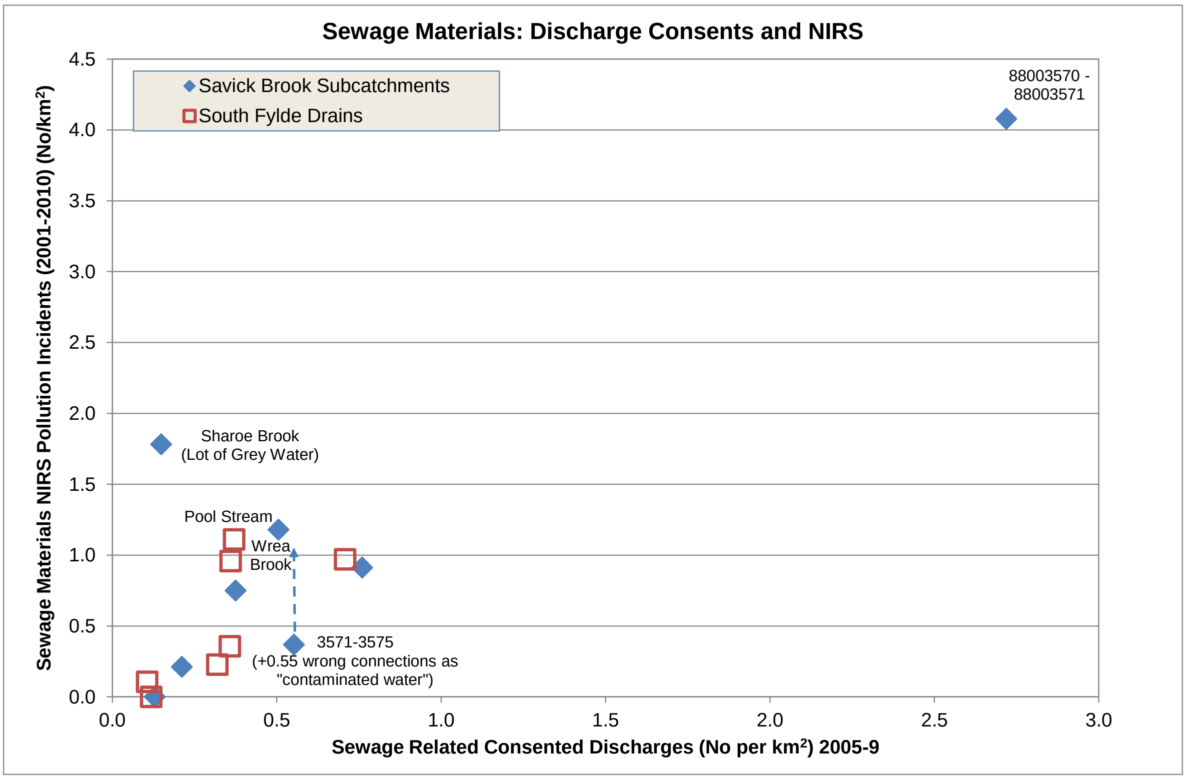
At the first Causes Workshop, stakeholders commented that the density of pollution incidents could potentially be related to where people live and so where people notice and report them.

3.5.12 Linking Sewage NIRS and Consented Discharges

The density of sewage related consented discharges (e.g. form private and water company sewage treatment works, CSOs and PSOs) was compared to sewage related pollution incidents for the different water bodies and for the Savick Brook sub-catchments. A broad relationship was apparent (see Figure 3.14) for most of the water bodies; consistent with a designed failure rate (storm capacity) during high rainfall conditions.

The apparent failure rate of 1 to 2 incidents over ten years per consented discharge was reviewed by stakeholders familiar with consenting discharge at the second Causes Workshop as being reasonable. Sharoe Brook, a tributary of Savick Brook, and to a lesser extent Pool Stream and Wrea Brook had proportionally more sewage related pollution incidents for their consented discharges. This was discussed to be consistent with wrong sewage connections in these areas, as supported by reported “grey water” pollution incidents (see Figure 3.14).

Figure 3.14 – Linking Sewage Pollution Incidents to Consented Discharges of Sewage



Note: This chart plots the density of sewage related NIRS incidents in each water body and in each of the Savick Brook sub-catchments (to water quality monitoring points) against the density of sewage related consented discharges (sewage disposal works, consented sewer overflows [CSOs] and pumping station overflows ([PSOs]). Sharoe Brook (a tributary of Savick Brook) and to a lesser extent Pool Stream and Wrea Brook have proportionally more pollution incidents. This was discussed to mean a significant number of unconsented wrong sewage connections in these catchments; also consistent with reported “grey water” incidents.

3.5.13 Interrogating Data Summary

The above subsections aim to convey a number of methods for looking at disparate datasets. Others datasets were considered and, where useful, are included in the Evidence Packs (see list of outputs in Appendix B). The overall approach works with what is available to extract evidence on the causes of poor WFD water quality and status.

3.6 Source Apportionment

3.6.1 Overview

Source apportionment is the process of estimating the relative contribution that different sources make to the concentration of a pollutant in the stream. For example, WQ monitoring will provide the ammonia concentration in the stream at the monitored location, but this total concentration may be a result of several different sources of ammonia, for example from intermittent sewage discharges, agricultural runoff, landfill leachate etc. Source apportionment estimates aim to identify which are the largest contributors and so help focus remediation efforts.

3.6.2 Use of SAGIS

A GIS based source apportionment tool (SAGIS, UKWIR/EA Project WW02: Chemical source apportionment under the WFD, 2009-2012) has been developed through UKWIR for the water companies, Environment Agency, Ofwat and SEPA to estimate how much individual sources are contributing to the total pollutant load in each water body.

At the time of this project, the team received data from an early version of SAGIS, which provided estimates of the contribution to the total nitrate and phosphate load (and concentration) from the following sources: agricultural runoff, intermittent sewage discharges (CSOs and PSOs), water company sewage treatment works, septic tanks and urban runoff.

3.6.3 Application of Data from Elsewhere to Tidal Ribble Water Bodies

At the time of the project, the team did not have access to SAGIS estimates of the contributions from non-water company sewage treatment works, wrong sewage connections, or landfill to total nitrate and phosphate loads (and concentration).

There are no consistent national or local datasets available for estimating the contribution from these three sources, nevertheless some data exists that can be applied provided the large uncertainties are appreciated. Estimates were obtained for each water body as follows:

- For discharges from non-water company sewage treatment works, the loads of ammonia (kg N/day) and of phosphate (kg P/day) discharged by the sewage treatment works in each water body were estimated using average flow values (from the Environment Agency's discharge consents data) multiplied by typical concentrations of ammonia (20 mg/l as N) or phosphate (7 mg/l as P) in treated sewage effluent (from British Water 2009 and Environment Agency 2010, Table 6.1).
- We estimated the load of ammonia from historic landfill based on "guesstimates" of leachate concentrations (10mg/l N, which assumes there has been some attenuation from historic landfills), rainfall infiltration rates and the landfill area.
- For wrong sewage connections, Severn Trent Water and Thames Water have conducted surveys, which allow rough estimates to be made of the ammonia and phosphate load from the number of properties in the sub-catchment, % of properties wrongly connected,

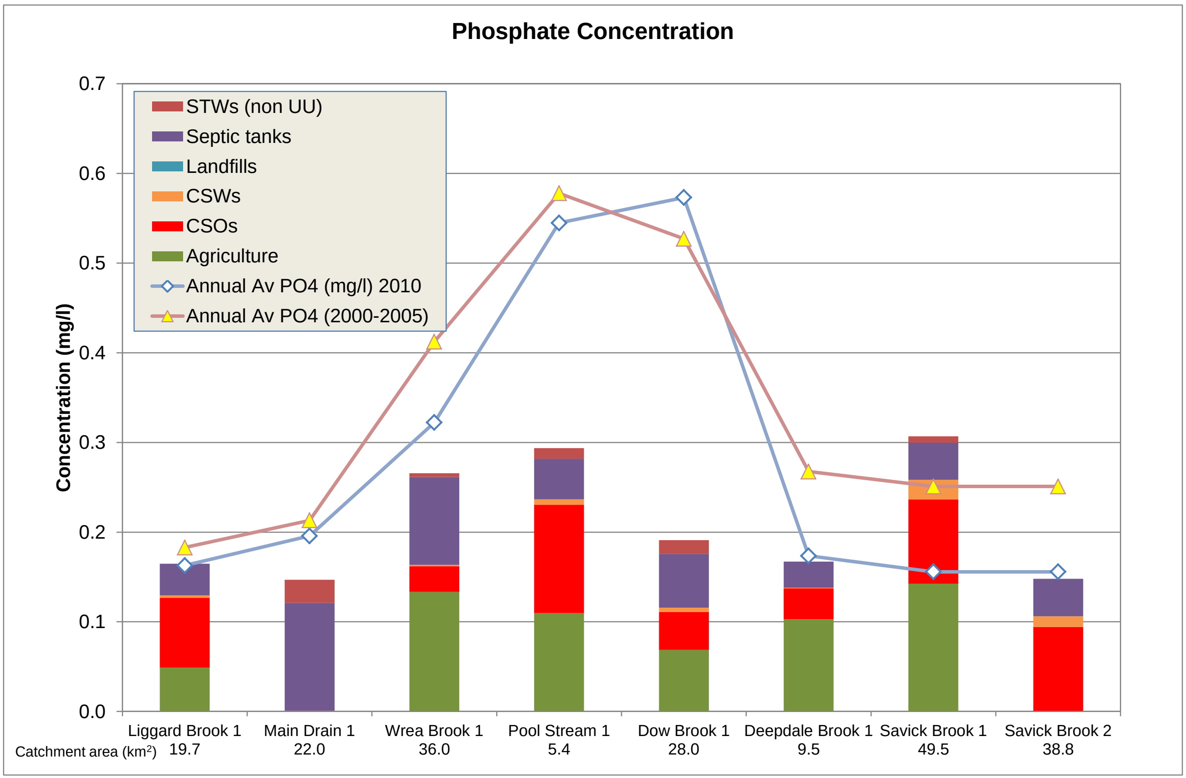
number of people per property, domestic effluent per person and the concentration of ammonia or phosphate in domestic effluent.

3.6.4 Source Apportionment Results

Information on the contributions from each source was included in the evidence presented as tables and histogram plots at the stakeholder workshops. The histogram in Figure 3.15 shows the estimates of phosphate load for each for each water body converted into a concentration based on the mean flow rate in the stream. The mean flow rate was itself estimated using Environment Agency SIMCAT data (average hydrologically effective rainfall multiplied by water body area) because there were no measured flow data. The lines show the annual average of the observed phosphate concentration from Environment Agency monitoring points in each water body.

The estimates in Figure 3.15 suggest that agricultural runoff, intermittent sewage discharges (CSOs and PSOs) and septic tanks are the main sources of phosphate. The large discrepancy between the histograms and the lines for the Pool Stream and Dow Brook suggests that the source apportionment estimates are too low. This could be because one or more of the potential sources is worse than "normal". In general, however, the uncertainties in these estimates are large, at least a factor of five or ten, because, as described above, they are based on a mixture of national and local data. So the source apportionment analysis was used for guidance only.

Figure 3.15 – Source Apportionment Estimates for Phosphate



Note: None.

As SAGIS is developed further and includes more sources, it is likely to become a very valuable line of evidence.

3.7 Lines of Evidence and Scoring

3.7.1 Lines of Evidence

The previous sections have provided examples of evidence that were examined to try and help understand the causes of WFD failures in the Tidal Ribble water bodies. In bringing this information together for presentation and discussion with stakeholders, the following four lines of evidence (or approaches) were communicated:

- **Line of Evidence (Approach) A (variation across water bodies or sub-catchments).** This line of evidence examined the number and relative proportion of pressures in the different water bodies and sub-catchments, such as land use (e.g. Figure 3.3), the number of septic tanks, consented discharges or pollution incidents (e.g. Figure 3.13).
- **Line of Evidence (Approach) B (variation in time)**. This examined changes in water quality over time (short and long-term, e.g. Figure 3.7) as well as variation of water quality with flow (e.g. Figure 3.9). The timing of activities was also noted e.g. changes in cattle numbers (Figure 3.4), urban development (e.g. Figure 3.5) and the changes in consented discharges and concomitant improvements in water quality (e.g. Figure 3.12).
- **Line of Evidence (Approach) C (downstream changes)**. This looked for changes in water quality (e.g. Figures 3.10 and 3.11) and fish (e.g. Figure 3.8) in response to the locations of different pressures (e.g. combined sewer overflows or high densities of non-mains sewerage).
- **Line of Evidence (Approach) D (source apportionment)**. This used source apportionment tools (in particular the Environment Agency's SAGIS tool) to identify the relative contribution different sources of pollution make to the total load (e.g. Figure 3.15).

Use of these different approaches allowed evidence to be drawn out of the processed data and reviewed reports. In all cases, evidence was evaluated in terms of failing WFD elements such as fish, invertebrates and water quality parameters (DO, BOD, NH_4-N and PO_4). Other water quality issues not included in the WFD assessment (e.g. metals, oils, sediment) were not considered. Geomorphological constraints were also considered.

3.7.2 Scoring the Strength of Evidence

In the first two stakeholder workshops, the different lines of evidence were presented to the stakeholders in a series of presentations. The intent was to allow them to make their own judgement on the causes based on the evidence presented. However, the significant number of charts, maps and tables (more than 100 slides presented at each workshop) and supporting information was difficult for stakeholders to assimilate in the available time and so the Evidence and Measures team were asked to present their interpretation and summary of the evidence.

To meet the stakeholder's requests, the strength of each line of evidence was evaluated for or against each suspected cause of WFD failure in the Strength of Evidence Tables, which are a key component of the Evidence Packs described below.

3.8 The Evidence Packs

3.8.1 General

The Evidence Packs (developed for this project) provided the main evidence base supporting this project and were used with stakeholders at the Measures Workshop (see Section 4.2) to succinctly convey a lot of information in a short period of time. Each Evidence Pack included an “Intro Pack” and separate “Reach-Specific Packs” as described below.

3.8.2 The Intro Pack

The “Intro Pack” presents background information common to all the Tidal Ribble water bodies. It includes a summary of the WFD assessment, the suspected causes of failure and the conceptual model (version 1), which have been described in Section 2 of this report, followed by information for Line of Evidence A (variation across water bodies or sub-catchments) as described in Section 3.7.1.

3.8.3 The Reach-Specific Evidence Packs

One “Reach-Specific Evidence Pack” was produced for each water body containing detailed information about that water body. The one for Savick Brook was sub-divided further into sub-catchments. Each pack included the following information:

- The WFD assessment at each monitoring point within the water body (where available) rather than just the overall water body assessment shown in Figure 2.1;
- A GIS map of the water body showing the detailed comments collected from stakeholders on the suspected causes of WFD failure;
- Tables and plots related to Lines of Evidence B (variation in time), C (downstream changes) and D (source apportionment);
- The Strength of Evidence Tables and their conclusions.

3.8.4 The Strength of Evidence Tables and Conclusions

The Strength of Evidence Tables are a key means of summarising and assessing many disparate pieces of evidence.

The process to compare evidence from many very different information sources and viewpoints is inherently difficult as there is no common yardstick: some information is quantitative; some is qualitative (e.g. observations); and there is a degree of subjectivity on the opinions of stakeholders. To deal with this issue a “weight of evidence” scoring system was developed to assess whether a suspected cause of WFD failure had enough supporting evidence to be confirmed as a main cause of WFD failure (and so warranting immediate action).

Table 3.3 shows an extract from the Strength of Evidence Table presented to stakeholders for Wrea Brook. The purpose of the Strength of Evidence Table is to summarise what each piece of evidence tells us about each suspected cause of WFD failure in this water body. The first row lists the WFD failures for the water body (here inverts, ammonia and phosphate. Below that column 1 lists the suspected causes of WFD failures gathered previously (Section 2) and the other columns contain pieces of evidence related to each suspected cause and an associated score.

Table 3.3 Strength of Evidence Table from the Wrea Brook Evidence Pack (Subset Only*)

WFD failures: inverts (poor), ammonia (mod), DO (mod), phosphate (poor) at monitoring point 88009768								
Suspected causes	**Line of evidence A** (variation across water bodies)		**Line of evidence B** (variation in time)		**Line of evidence C** (downstream changes)		**Line of evidence D** (source apportionment)	
	Results	**Score**	**Results**	**Score**	**Results**	**Score**	**Results**	**Score**
1) Agriculture	1) Land use: 62% managed grassland (Fig 1.10) 2) Agricultural NIRS: 0.06 /km^2 (mod) (Fig 1.13) 3) Monitoring point SPT12 is in mixed grass and arable catchment: PO4 annual average is good (opposes agriculture being cause); NH4_N 90%ile is moderate (supports agriculture being cause) (Fig 1.7)	0 + - +	1) WQ data does not start until 1995, i.e. after EA farm survey work 2) PO4 often worse than "good" threshold at monitoring point SPT12 (agricultural area) (Fig 4.9) 3)NH3 often worse than good threshold at monitoring point SPT12 (agricultural area) (Fig 4.10)	NE + +	1) 1997 Faecal Indicator report shows higher NH3 concentration at high flows, suggests agricultural runoff or sewage overflows, (Fig 1.17) 2) 3 problem farms noted by EA in 1990's in downstream half of catchment (Fig 4.3)	+ +	1) 70% PO4 (Livestock ~60%) (Arable 10%) (Table 1.3)	+
2) Sewage	1) Land use: 13% urban / suburban (low) (Fig 1.10) 2) Sewage NIRS: 0.96 /km^2 (high), Fig 1.13	0 +	1) WQ improves with increased sewage consents (1995-2005), (Figs 4.6 & 4.7). 2) Upstream of "Category 2" sewage NIRS at times of poor WQ (2005 – 2010) (Fig 4.8)	+ +	1) SPT13 (upstream monitoring point) poor NH3, DO, PO4 (Fig 4.5) consistent with sewage pollution at Wrea Green 2) Many sewage NIRS at Wrea Green (Fig 4.4)	+		
2.1) Sewage Treatment Works (non-Water Co)	1) Only 1 (Wrea Green)	0	1) NH3 & PO4 v. high during low flow period 2010 downstream of monitoring point SPT13, consistent with discharge from Victorian Manor STW (Figs 4.9 & 4.10)	+	1) High NH3 & PO4 during summer at monitoring point SPT13 (line of evidence B) still seen (but damped) at monitoring point SPT15 (Figs 4.9 & 4.10). But there could be other inputs downstream of SPT13.	0		NE
2.2) Septic Tanks	1) 11.1/km^2 (mod) (Fig 1.11)	+		NE	1) Septic tanks between monitoring points SPT13 and SPT15, so possible contribution (Fig 4.4).	0	1) 2 – 10% PO4	-
2.3) Wrong Sewage Connections	1) NIRS: 0.3 /km^2 (high), (Fig 1.15)	+		NE	1) NIRS: Grey water upstream of monitoring point SPT13's poor WQ (Fig 4.4)	+	1) <1% PO4	-

Note: *For the sake of brevity only a subset of all the suspected causes are included in this table.

The following bullet points summarise some of the key features of the Evidence Tables with reference to the underlined text in Table 3.3:

- Under suspected cause 1 (Agriculture), Line of Evidence B (variation in time), the individual piece of evidence (2) refers to Figure 4.9 in the stakeholders Evidence Packs, which is a time series of phosphate concentrations at monitoring point SPT12 from January 2010 to February 2011. The concentration is frequently worse than the WFD "good" threshold in this area of predominantly agricultural land use. The Evidence and Measures team concluded that this piece of evidence supported agriculture as a cause of phosphate failure so it was given a score of "+" in the column to the right of the text describing the individual piece of evidence.
- Under suspected cause 2.3 (Wrong Sewage Connections), Line of Evidence D (source apportionment), the individual piece of piece of evidence (1) indicates that less than 1% of the phosphate is estimated to be from wrong sewage connections. So this evidence was given a score of "-", because it was concluded it did not support wrong sewage connections as a cause of WFD failure.
- Each piece of evidence is scored simply as "+", "-", "0", "NE" or "NA" as described in Table 3.4.

Table 3.4 Rules for Scoring Evidence in the Strength of Evidence Tables

Score	Meaning of Score	Further Comment
[+]	Evidence supports	Evidence supports a suspected cause of being an actual cause of WFD failure
[-]	Evidence opposes	Evidence opposes a suspected cause of being an actual cause of WFD failure
[0]	Evidence is uncertain	The evidence, although relevant, is inconclusive.
[NE]	No evidence	Used to recognise that a line of evidence (e.g. dataset or report) has been examined but there is no evidence to add e.g. SAGIS (Approach D) does not provide estimates of inputs from landfills.
[NA]	Evidence not applicable	Used rarely and where the approach is not relevant to a suspected cause e.g. Approach D SAGIS source apportionment is not applicable to geomorphology as a potential cause of poor water quality.

Notes:

Table 3.5 gives the Evidence and Measures team's conclusions about each suspected cause of WFD failure in Wrea Brook based on the evidence in the Strength of Evidence Table (Table 3.3). It also provides initial recommendations concerning measures. For Wrea Brook, the conclusions given in Table 3.5 are that Agriculture and Sewage are key causes of WFD failure and, in terms of sewage, the existing evidence points only to non-Water Co Sewage Treatment Works at Wrea Green being a specific local cause. Other causes require further investigation.

The final workshop of this project served as a trial for the use of Strength of Evidence Tables and Evidence Packs and, due to its positive effect, these tools were also used in a later Evidence and Measures project in Moston Brook (Environment Agency 2013). For Moston Brook, the tables were used from the beginning giving stakeholders more time to review the evidence and the conclusions before embarking on the identification of measures. The Evidence Packs marked a big step forward in being able to present stakeholders with large amounts of variable evidence in a digestible format.

Table 3.5 Conclusions from the Wrea Brook Evidence Pack (Subset Only*)

Suspected causes	Consistency of Evidence	Conclusion (E&M Team)	Recommendation (E&M Team)
Agriculture	Mixed (reasonably consistent, but not strong) evidence that agriculture is a cause of WFD failures. SAGIS suggests agriculture (especially from livestock) is a significant contribution to WFD failure.	Agriculture is part (30-50%?) of the problem,, particularly livestock.	Develop measures to deal with livestock problems (e.g. nutrient management plans, slurry stores and silage clamps)
Sewage (in general)	Strong and consistent evidence that sewage is a cause of WFD failure.	Sewage is part of the problem, but we need more detail to target measures.	
Sewage Treatment Works (non-Water Co)	Consistent evidence that STW is significant contribution to WFD failure at monitoring point SPT13 and could explain signal at catchment scale (SPT15), but there are other sources and source apportionment suggests not significant over whole water body.	Locally important (Wrea Green)	Develop measures focussed on Non-Water Co STW at Wrea Green
Septic Tanks	Related consistency between number and SAGIS, otherwise limited evidence	Cannot rule out septic tanks as a cause of WFD failure.	Does not warrant expensive measures without further evidence, but could try campaign.
Wrong Sewage Connections	Inconsistent: Grey water NIRS at Wrea Green, but source apportionment suggests wrong sewage connections are not significant.	Can't rule out wrong sewage connections as a cause of WFD failure, but doesn't look like the main problem in this water body.	Does not warrant expensive measures without further evidence, but could try targeted local campaign.

Note: *For the sake of brevity only a subset of all the conclusions from the Wrea Green Evidence Pack are included in this table.

3.9 Outputs from the Analysis of Evidence

The main outputs from the analysis of evidence were the Evidence Packs, which participants used as their evidence base at the final workshop, and the slides presented at the earlier workshops. A list of the project outputs is given in Appendix B.

4. Stakeholder Workshops and Outputs

4.1 The First and Second (Causes) Workshops

The first two stakeholder workshops (on 29 March 2012 and 10 July 2012) had presentations of evidence collected by the Evidence and Measures team and served to obtain the feedback of the 15 participants (in addition to the Evidence and Measures team) that attended each of these workshops (Appendix A gives a list of the participants).

At the first workshop, half of the day was spent presenting the results from the data analysis using over 100 PowerPoint slides so there was only time to consider the five water bodies in the South Fylde Drains and little time for stakeholders to consider the data themselves. The participants raised over 70 new actions for investigation. This was counter to the aim that the group would narrow down the long list of suspected causes of WFD failure into a shorter list of main causes.

15 stakeholders attended the second workshop, but they were not the same 15 people so time was spent going over previous ground (on the South Fylde drains) whilst also presenting another batch of over 100 PowerPoint slides on the results of the data analysis on Savick Brook.

Some of the feedback from the participants is copied below:

- “There were far too many slides and not enough opportunity for partners to input”;
- “I felt out of my depth as I didn’t have the specific catchment knowledge, maybe a smaller meeting with people who knew the catchment would have been better”;
- “It would be a good idea to have an overview group and a specific group”.

In addition there was disagreement about what the boundaries of the water bodies were following a national revision. However, on a positive note, the participants agreed that they could not identify any additional suspected causes of WFD failure.

This meant that the preparation for the final workshop had to be done with no consensus amongst the stakeholders on how the list of suspected of WFD failures could be narrowed down to a list of the main causes. As indicated by the feedback comments above, there was a sense of (polite) frustration from the participants (and echoed by the Evidence and Measures team themselves) that there was too much information to present and too little time for participants to review the evidence and reach consensus on what it meant.

This prompted the development of the Evidence Packs and the Strength of Evidence Tables described in Section 3.8, which drew upon a weight of evidence approach described on the CADDIS website (US EPA 2013). The aim of these packs was firstly to summarise the wealth of information in a digestible format and secondly to provide participants with the Evidence and Measures team’s conclusions on what the evidence meant so that they could review it rather than trying to come up with their own conclusion in only a few hours.

4.2 The Third (Measures) Workshop

At the third stakeholder workshop on 14 August 2012, the Evidence Packs (see Section 3.8) were briefly described to the participants and they then spent the rest of the day in small groups using the Evidence and Measures team's conclusions about the main causes of WFD failure and, if they agreed with them, using them to identify measures that would address these main causes at specific locations. Three small groups (of 4-5 people) each focussed on different water bodies according to their particular skills and experience. Where necessary, participants moved to another group to allow others the benefit of their knowledge. This time 10 of the 13 participants attended both this workshop (Measures Workshop) and the previous one (Second Causes Workshop). This helped move things forward swiftly because most of the participants had already developed a shared understanding of the catchment at the previous workshop.

Participants were asked to work on one water body at a time and were briefed as follows:

- Remind yourself of the WFD failures for the water body.
- After looking at the evidence collected, try and answer the question "Which of the suspected causes of WFD failure (listed in the left hand column of the Strength of Evidence Tables) should we spend time and money on?"
- Make each measure specific in terms of the cause of WFD failure that it is designed to address and the location or locations where the measure needs to be implemented.
- Don't try and prioritise the contribution from each cause. So, for example, if agricultural runoff and sewage discharges both look like they are each contributing between 20% and 40% of the problem, don't get into a discussion about which one is having the bigger effect, just agree that both of them need attention and start working out what to do.
- Do the obvious stuff first and flag the more difficult stuff for dealing with later.
- Don't filter out actions that you think are too expensive; we want to collect all your ideas for targeting specific causes of WFD failure. The task of prioritisation is not your responsibility in this workshop; it will be done at a later stage (Stage 5 in the Evidence and Measures approach, Section 1.6 and Box 1.1).

Measures were recorded in a spreadsheet under the list of headings shown in Table 4.1. Participants were encouraged to record all their ideas for measures rather than try and fill in every heading for only a few measures. When participants did not have the information or the time to fill in a particular heading, it was left blank for follow-up after the workshop.

During the day we learned that it was most efficient for participants to:

- Begin by looking at the Conclusions Table in the Evidence Pack for a particular water body;
- Secondly, look at the Strength of Evidence Table upon which these conclusions were based;
- Thirdly, and where necessary, refer back to the plots or tables of original data that were included in the Evidence Packs.

In practice, the participants spent very little time reviewing or challenging the conclusions in the Evidence Packs and most of their time coming up with measures to address the main causes of failure.

Table 4.1 Headings Used in the Measures Spreadsheet

Heading
Description of action
Name of person(s) proposing the measure
Water body ID
Water body name?
Specific location where measure will be implemented
What is the evidence to do this?
What difference do you think this measure will make?
What agreed main cause(s) of WFD failure will this address?
Do you know of any other activity already addressing this cause of failure?
How long before improvements are seen?
How long will measure continue to have effect?
List any likely additional consequences (neutral or bad) for birds, farming, food production, flooding etc.
How long will measure take to implement?
Who will lead it? (If EA, say which team).
Are there opportunities to involve other stakeholders?
Do we need to do anything before the measure can start?
Estimated cost, if known
What might stop us doing this?
Any other risks?
Any other information?

The participants' feedback sheets from the workshop praised the Evidence Packs and everyone said they found them a useful basis for identifying measures. In addition they suggested that they could be improved by having more maps, larger maps and by having the Evidence Packs circulated in advance of the workshop.

There was no formal voting to gain consensus about the main causes of WFD failure during the small group sessions but it is recommended that this should be done because it provides a firm foundation of common understanding upon which the group can build appropriate measures. Nevertheless, it did not prevent this particular group from using the Evidence Packs to identify over a hundred specific measures.

On a subsequent Evidence and Measures project in Moston Brook (Environment Agency 2013), Manchester, there were only two stakeholder workshops, a Causes Workshop and a Measures Workshop. In the Causes Workshop small groups were asked firstly to review the evidence for each suspected cause of failure and then secondly to use a voting system to arrive at consensus on the main causes of failure. This approach is described in Section 4 of the Moston Brook Project report (Environment Agency 2013).

4.2.1 Outputs from Final (Measures) Workshop

The three small groups of participants identified and recorded 117 measures across all the water bodies in the Measures Spreadsheet. Some of these measures are described in some detail and some are ideas in outline only. The final Measures Spreadsheet is included in the project outputs (listed in Appendix B). A selected subset of the 117 measures is provided in Table 4.2 and listed by water body and sub-catchment.

Table 4.2 Main Causes of WFD Failure and Selected Potential Measures for Each Water Body and for Sub-catchments within Savick Brook

Water Body / Sub-catchment	Main Causes[1]	Measures[2]
Liggard Brook	Agricultural runoff. Geomorphological changes.	Soil and nutrient management on target farms. Improve morphological condition to enhance habitat and increase species diversity.
Main Drain	Dairy (and pig) farming. Non Water Co treated sewage disposals from caravan parks and housing areas. Geomorphological changes.	Improve farming practices for Dairy Farms - slurry storage and application (related to nutrient management). Survey impact of larger non-Water Co sewage discharges including septic tanks. Assess feasibility of removing the tidal flaps and pumping station and reverting to a tidal system.
Wrea Brook	Agricultural runoff. Non-Water Company Sewage Works.	Identify dairy farms and work with Natural England and farmers on measures to manage slurry stores and silage clamps. Evaluate likely significance of sewage discharges including septic tanks - establish nature of problem and responsibility.
Pool Stream	Agricultural runoff (dairy farms). Sewage, possibly Intermittent sewage discharges and/or wrong sewage connections. Urban runoff.	Carry out inspection of farms with historical pollution problems to see if problems remain. Attend category 3 NIRS incidents. Carry out specific wrong sewage connections investigation on housing estate north of Warton Aerodrome. Liaise with Local Authority and Water Co on First Time Rural Sewage initiative between Freckleton and Warton. Engage with Warton Aerodrome to investigate some of their practises (de-icing on site, runoff, septic tanks).
Dow Brook	Agricultural runoff. Sewage, possibly intermittent sewage discharges and septic tanks.	Install fencing along reach downstream of A583 to prevent agricultural runoff. Inspect specific dairy and pig farms in the upper and middle of the catchment. Raise awareness of No Spread Zones (GAEC 19) with farmers to reduce fertiliser application near water courses. Investigate WQ and discharges from 6 private sewage plants and septic tanks in Spen Brook and along A583 and just off A584 east of Dow Brook – look into possibility of First Time Rural Sewage. Check drainage from historic landfill in north west of water body.
Deepdale Brook	Possibly agricultural runoff but no bad practice identified. Intermittent sewage discharges from Clifton village PSO.	Check sewage sludge spreading against soil types and visit three specific farms. Inspect Clifton Hall private sewage works. Check with Water Co whether AMP work (ref PRE0121) has been completed. Sample above and below Springfields BNFL site, check permitting and monitoring of shallow groundwater beneath the site.
Savick Brook (upper)	Possibly agricultural runoff. Possibly intermittent sewage discharges and septic tanks.	Target specific non-permitted pig & poultry farms. Septic tank campaign across un-sewered area where septic tanks discharging directly to the brook.
Savick Brook (Eaves Brook)	Intermittent sewage discharges.	Review WQ at three CSOS (including Cattle Market site) which are not part of AMP 5.
Savick Brook (Sharoe Brook)	Possibly agricultural runoff. Sewage from wrong sewage connections	Check private pumping station on Sharoe Brook near Lea Golf Club.
Savick Brook (lower) & Ribble Link	Intermittent sewage discharges. Possibly sewage from wrong sewage connections. Geomorphological changes due to Ribble Link.	Investigate CSOs & PSOs at Lea Road, at Preston North End's training ground and those on the Ribble Link. Review yellow fish (wrong sewage connections) campaign on housing estates and primary schools, particularly Larches and Lea. Suggest joint project on the Ribble Link (EA + canal managers) to open lock gates more often, clear biwash channels and make safe for fish passage

Notes:

1 As recorded in the Conclusions Tables in the Evidence Packs (Section 3.8).
2 This is a summary of the measures identified at the Measures Workshop.

The measures in Table 4.2 are generally specific enough, that is they address a main cause of WFD failure, define what needs to be done and target a specific named location.

But some are not, as the following underlined entries from Table 4.2 illustrate:

- In Dow Brook the landfill site had not previously been identified as a potential issue;
- In Deepdale Brook no evidence emerged during the data analysis stage of a problem at BNFL but it was highlighted as a target for an investigative measure at the workshop.
- In Sharoe Brook, a tributary of Savick Brook, no measures were identified related to sewage discharges from wrong connections yet this was presented as one of the main causes of failure in the Evidence Packs as evidenced by 11 grey water NIRS incidents.
- No evidence for the geomorphological impacts of the Ribble Link was identified in the Evidence Packs but this was an issue strongly recommended for action by some participants at the workshop.

There was not enough time at the workshop to determine whether these measures were all based on firm evidence and the local Environment Agency team member had to invest time after the workshop reviewing and following up on the measures recorded before they could be put forward to the Ribble Life Action Plan (http://www.ribblelife.org/plan).

4.2.2 Independent Peer Review at the Measures Workshop

Dr. Ben Surridge from Lancaster University attended the Measures Workshop on 14 August 2012 and wrote a review of the approach for the Environment Agency. This is also available from the Defra website.

5. Conclusions and Recommendations

5.1 Delivering the Project Objectives

The project objectives are described in Section 1.3 and the project results are summarised below in relation to each of these objectives.

The local Environment Agency team identified the eight Tidal Ribble water bodies as being some of the most difficult failing catchments in the Ribble Pilot Catchment in terms of identifying the causes for WFD failure.

Objectives 1 and 3: At the Measures Workshop in August 2012 (11 months after the project started), 13 participants from 10 partner organisations devised 122 measures based on their agreement on the main causes of WFD failure. By September 2012, many of these measures had been taken into the Ribble Life Action Plan (http://www.ribblelife.org/plan) under the catchment heading "Lower Ribble"). A summary of some of the key measures are included in Table 4.2 and a full list recorded in the Measures Spreadsheet (see list of outputs in Appendix B).

Objective 2: The trialling and further development of the approach used on the Evidence and Measures River Petteril project was successful when used with stakeholders on the Tidal Ribble water bodies. The approach is essentially an adaptive management cycle (Section 1.6 and Box 1.1) and this success on both the River Petteril and the Tidal Ribble led to its application, between September 2012 and March 2013, in Moston Brook, an urban water body in Manchester (Environment Agency 2013).

Objective 4: A scoping study was carried out during September and October 2011 which formed the basis of the project plan (Section 2.5). Data analysis (Section 3) provided the evidence base for three facilitated workshops (Section 4) where stakeholders developed a consensus on the main causes of WFD failure. Section 5.2 of this report provides Defra and the Environment Agency with advice on the transferability and applicability of the Evidence and Measures approach.

5.2 Lessons Learned and Recommendations

5.2.1 The Evidence and Measures approach

The adaptive management cycle used in the Evidence and Measures approach has been successfully applied to catchments in several different settings (rural, urban coastal and heavily modified) and with different sets of stakeholders.

It has been deliberately trialled on so-called "difficult" catchments; that is groups of water bodies where it is unclear how to progress with selecting appropriate measures, usually due to: a) multiple failing WFD elements (ammonia, fish, macro-invertebrates etc.); b) multiple suspected causes of failure or c) lack of agreement amongst the catchment partners on the main causes of failure.

It is clear that the approach as a whole seems well-suited to tackling those groups of water bodies that have been labelled as "difficult" and which therefore tend to get left unresolved. Nevertheless, the lessons learned in these "difficult" catchments are applicable wherever catchment partners need to turn data and information into evidence and upon which they can build consensus amongst stakeholders about the actions (measures) needed to deliver environmental improvements.

The Evidence and Measures team recommends that the lessons learned described below should be made readily accessible to all CaBA Hosts so that they can choose to apply and adapt those that are useful to them.

5.2.2 Stakeholders

The project team's experience is that the ideal (maximum) number of stakeholders at a workshop is between 15 and 20 and wherever possible they should attend all workshops. The plan should be for stakeholders to develop a working relationship and shared understanding of the evidence at the Causes Workshop(s) and then come back together to agree evidence-based measures. Where stakeholders change from one workshop to the next, valuable time has to be used bringing new stakeholders up to speed and there is a risk that stakeholders participating only in the Measures Workshop bring their own non-evidence based opinions and agendas. This can undermine the whole process.

For this project, 32 participants attended at least one of the three workshops (two Causes Workshops and one Measures Workshop), but only 10 attended both of the last two.

Stakeholders appeared to work better in smaller groups, ideally with similar skills or experience of issues. Having participants who shared similar skills on the same table, even with opposing interests, generates an informed debate and the subject matter helps bring them together. This is more time-efficient than, for example, having a technical specialist and a wider context generalist trying to find agreement in an open meeting forum.

At this project's First Causes Workshop, 15 stakeholder's worked as one large group and it seemed harder for them to be productive than in the Measures Workshop where 13 participants worked in three small groups. The productivity of the small groups at the Measures Workshop was probably also a result of their being well-led, the participants having the information that they required to hand (for example the Evidence Packs) and in carefully grouping the participants so that they could focus on areas or issues that made best use of their skills and experience. This clearly means much work from the organisers in advance.

To achieve maximum efficiency, the best approach would be to have just one Causes Workshop and one Measures Workshop, with a maximum of 15 – 20 participants who are committed to attending both workshops and:

- are able to provide technical expertise in the areas related to the suspected causes of WFD failure; or
- have the authority to suggest measures at the Measures Workshop.

However, limiting the number of participants in this way, in pursuit of productivity at the workshops, could come at the expense of including all the participants who wanted to contribute. It is therefore recommended that a larger number of stakeholders (20 – 40) are invited to the initial meetings, where information about the issues facing the water bodies and the suspected causes of WFD failure are gathered, and that this wider group is guided towards itself selecting the smaller group of 15 – 20 who would attend the Causes and Measures Workshops but who would also provide communication with the wider group and a channel for them to contribute their ideas.

5.2.3 Strength of Evidence Tables

Evidence appears to bring people to agreement far quicker than ”round-table” debate based only on opinions.

The Strength of Evidence Tables described in Section 3.8.4 were developed to summarise what each piece of evidence tell us about each suspected cause of WFD failure. Generally a Strength of Evidence Table was prepared for each water body but for Savick Brook, the largest water body, they were prepared for specific reaches or sub-catchments.

Like a partially completed jigsaw puzzle, each Strength of Evidence Table shows the current picture or shared understanding based on the weight of the existing evidence. It allows participants to quickly see where evidence is available and where it is not, and the distribution of the plus and minus signs show whether the evidence is consistent (in support of or against each suspected cause of WFD failure) or inconsistent. It also indicates that participants can make sensible evidence-based decisions, based on the areas where the evidence is strongest, even though the evidence is necessarily incomplete.

These tables were not developed and used until the final (Measures) workshop but it is recommended that, in future, they are used from the first time the stakeholders meet as a means of presenting what is already known and in building up their evidence and shared understanding. It is also recommended that the Strength of Evidence Tables are used in the Causes Workshop so that small groups of stakeholders can review the evidence and use it as the basis for reaching consensus on the main causes of WFD failure in each water. This approach was used successfully on the subsequent Moston Brook project (Environment Agency 2013).

5.2.4 Identification of Measures

At the Measures Workshop, efforts were made to make sure that participants linked their measures to at least one of the main causes of WFD failure in a water body based on the analysis of the existing evidence. This was so that a measure was “targeted”, that is it was specific both in terms of its location and the failing WFD element (such as ammonia or invertebrates) that it aimed to address. As described in Section 4.2 this was only partially achieved in the Measures Workshop and on the subsequent Moston Brook project this was communicated to participants earlier on, at the Causes Workshop, and the Measures Workshop was subsequently more successful.

It is assumed that this deriving of measures from evidence would, in turn, increase the chance of success of the measures. This assumption should be tested by going back to look at which of the measures identified on this and other Evidence and Measures projects have been successfully implemented and what their consequences have been. This recommendation has already been favourably received by Defra and is part of work planned to begin in 2014.

5.2.5 Data Analysis

The GIS based source apportionment tool (SAGIS) was able to provide estimates of the contribution that the following sources are making to overall nitrate and phosphate loads and concentration: agricultural runoff, intermittent sewage discharges (CSOs and PSOs), water company sewage treatment works, septic tanks and urban runoff. At the time of this project SAGIS was still in the early stages of development but as more work is done and more sources added, it is likely to become a powerful tool which can provide a strong line of evidence for source apportionment in the Strength of Evidence Tables (line of evidence D, Table 3.3).

5.2.6 Data Collection

The Environment Agency was the source of the majority of the most relevant datasets on this project and the team found that having a designated person acting as the “data collector” proved to be invaluable. Our "data collector" was a member from the Environment Agency Area Integrated Environment Planning Team and she gathered the Environment Agency data, provided it in formats that could be analysed by the rest of the core team and directed follow-up questions from the core team about the origins and interpretation of the data to the correct Environment Agency specialists. This made sure that other members of the team were not kept waiting for data to feed into the analysis. The time required to carry out this role was about 2.5 days per week.

On this project, the Environment Agency’s *Sharefile* facility was used for the data collector to pass data to the data analysers with the correct license conditions. It is important to clarify whether data can be shown on maps and graphs to external stakeholders at workshops, even if they cannot take copies away, and it is recommended that this permission is granted for as much data as possible to give participants confidence that they have seen all that is relevant.

A list of datasets that actually turned out to be useful on the project is given in Table 3.1 and it illustrates how much useful data is readily available.

5.2.7 Scoping Study

The Scoping Study contained several useful elements including:

- Clarifying the water body boundaries;
- Visiting the water bodies during a half-day field visit;
- Gathering a baseline understanding for use as a common starting point with workshop participants;
- Gathering the issues and the suspected causes of WFD failure as seen by Environment Agency staff at two half-day meetings at the start of the project;
- Identifying the likely key datasets based on the WFD failures and the issues identified at the initial meetings.
- Developing a working relationship with a number of Environment Agency staff which subsequently helped to make data collection and workshop management easier.

On the other hand, it did not prove to be a useful means of planning the work or the involvement of Environment Agency staff. In hindsight, the devising of alternative project plans and their review took time that would have been better spent moving forward with the data analysis.

5.2.8 Conceptual Models

Conceptual models are a useful way of summarising shared understanding for a complex environmental system and two versions, one focussing on the mechanisms operating along the pathways that link environmental pressures with biological change and the other focussing on the relationships between the biology to be conserved or restored and the human activities that directly threaten this target biology (Section 2.4).

6. References

Atkins. 2006	Assessment of Factors Affecting Growth of Blue Green Algae in Preston Dock. Report for the Environment Agency.
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Appendix A
List of Stakeholders Involved in the Project

3 Pages

See landscape tables overleaf.

List of Stakeholders

Stakeholders			Project Board	Initial EA Meeting	Initial EA Meeting	Causes Workshop 1	Causes Workshop 2	Measures Workshop
Name	**Role / Job Title**	**Organisation**		**6 Sep 2011**	**7 Sep 2011**	**29 Mar 2012**	**10 Jul 2012**	**14 Aug 2012**
Victor Aguilera	Defra Project Manager	Defra	X					
Natalie Phillips	EA Project Manager	Environment Agency	X	X	X	X	X	
Stewart Mounsey	EA Project Executive	Environment Agency	X					
Dave Baxter	Project Sponsor	Environment Agency	X					
Ben Surridge	Peer Reviewer	Lancaster University						X
Anne-Marie Bowman	Area Integrated Environment Planning	Environment Agency	X	X	X	X	X	X
Nick Rukin	Independent Consultant	Rukhydro	X	X	X	X	X	X
Paul Hulme	Independent Consultant	pjHYDRO	X	X	X	X	X	X
Thomas Charlton	Environment Officer, Tidal Ribble	Environment Agency		X			X	X
Jason Pusey	Environment Officer, Ribble Wyre	Environment Agency		X				
Steven Wren	Senior Environment Officer Water Quality	Environment Agency		X			X	
Rachel Haigh	Analysis & Reporting	Environment Agency		X		X		X
Helen Nightingale	Area Environment Planning	Environment Agency		X		X	X	X
Lee Preston	Fisheries Team Leader	Environment Agency			X			
Becky MacAlistair	Technical Officer for Fisheries & Biodiversity	Environment Agency			X			
Rachael Welsby	Planning Liaison Officer	Environment Agency			X			
Ruth Evans	Planning Officer	Environment Agency			X			
Cliff Welsby	Flood Engineering Officer	Environment			X			

Stakeholders			Project Board	Initial EA Meeting	Initial EA Meeting	Causes Workshop 1	Causes Workshop 2	Measures Workshop
Name	**Role / Job Title**	**Organisation**		**6 Sep 2011**	**7 Sep 2011**	**29 Mar 2012**	**10 Jul 2012**	**14 Aug 2012**
		Agency						
Judith Dagger	Asset System Management Officer	Environment Agency			X			
Simon Gebbet	Groundwater Technical Specialist	Environment Agency			X			
Suzanne Southern	Groundwater & Contaminated Land	Environment Agency			X	X		
Amanda Lord-Knowles	Technical Officer for Fisheries & Biodiversity	Environment Agency				X	X	X
Richard Wood	Integrated Environment Planning Specialist	Environment Agency				X		
Eli Smith	Environment Planning Officer	Environment Agency				X		
Jackie Monk	Ribble Pilot Catchment Co-ordinator	Environment Agency				X	X	X
John Stalker	Environment Officer	Environment Agency				X		X
Michael Graham	Natural England Catchment Sensitive Farming Officer	Environment Agency				X		X
Lesley Talbot	Environment Planning Officer	Environment Agency					X	X
Paul Simmons	Environment & Business Senior Advisor (Water Quality)	Environment Agency					X	
Danielle Soulsby	Integrated Environment Planning Officer	Environment Agency						X
Duncan Wishart	Technical Adviser (Geomorphology)	Environment Agency						X
Damien Linney	Technical Officer (Fisheries)	Environment Agency						X (pm only)
Steve Sharples	Officer for United Utilities	United Utilities				X		
Dave Andrews	Officer for United Utilities	United Utilities				X		
Andrew Gouldstone	Area Conservation Manager	RSPB				X	X	
Dave Dunlop	Conservation Officer	The Wildlife Trust for Lancashire,				X	X	

Stakeholders			Project Board	Initial EA Meeting	Initial EA Meeting	Causes Workshop 1	Causes Workshop 2	Measures Workshop
Name	**Role / Job Title**	**Organisation**		**6 Sep 2011**	**7 Sep 2011**	**29 Mar 2012**	**10 Jul 2012**	**14 Aug 2012**
		Manchester & North Merseyside						
Ben Hargreaves	Conservation Officer	The Wildlife Trust for Lancashire, Manchester & North Merseyside					X	X
Helen Ake	Science Officer	North Western Inshore Fisheries and Conservation Authority				X		
Jo Spencer	Engagement Officer	Ribble Rivers Trust				X	X	X
Chris Evans	Environment Officer, Ribble	Environment Agency					X	X
David Kennedy	Environment Officer, Ribble	Environment Agency					X	
Eleanor Fielding	Environment Officer, Ribble	Environment Agency					X	
Jake Houghton	Environment Officer, Ribble	Environment Agency					X	

Note: X = Attendance

Appendix B
List of Project Outputs

1 Page

Table B1 Project Outputs

The table below shows the project outputs, which were delivered to Defra and the Environment Agency. Where the outputs have been approved for public release they can be found under the Evidence and Measures project pages on the Defra website (see link below).

Link to the Evidence and Measures project pages on the Defra website:
http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=17914&FromSearch=Y&Publisher=1&SearchText=wt0957&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

The outputs below are "working documents", provided for the use of stakeholders at workshops so they may contain minor errors, such as in the figure numbering.

Description of Output	Referred to in this Report in Sections	Output Name
PowerPoint slides describing the general characteristics of the Tidal Ribble water bodies based on readily available data from the Environment Agency's national data.	2.5.3	E&M_TidalRibble_InitialConceptualisation.ppt
Desk study evaluation of the geomorphology of the Tidal Ribble water bodies.	3.5.3	E&M_TidalRibble_Geomorphology.pptx
PowerPoint slides showing the scoring of WFD water quality for the project compared to former GQA (General Quality Assessment).	3.5.4	E&M_TidalRibble_GQA_vs_WFD_WQ_CausesWS2.pptx
PowerPoint slides showing analysis of fish data prepared for Causes Workshop 2	3.5.6	E&M_TidalRibble_Subcatchment_Fish_CausesWS2.pptx
Evidence Packs used in the Measures Workshop. (These are the ones used at the workshop not the revised versions prepared for external distribution afterwards).	3.5.13, 3.9 & 4.2	E&M_TidalRibble_EvPack_1Intro.pptx E&M_TidalRibble_EvPack_2LiggardBk.pptx E&M_TidalRibble_EvPack_3MainDrain.pptx E&M_TidalRibble_EvPack_4WreaBk.pptx E&M_TidalRibble_EvPack_5PoolStr.pptx E&M_TidalRibble_EvPack_6DowBk.pptx E&M_TidalRibble_EvPack_7DeepdaleBrk.pptx E&M_TidalRibble_EvPack_8RibbleLink+SavickBk.pptx
Measures Spreadsheet in which the three groups of stakeholders identified and recorded 117 measures across all the water bodies at the Measures Workshop.	4.2.1 & 5.1	E&M_TidalRibble_Measures_AfterMeasuresWS.xls