River Petteril Trial Catchment

Summary Slides for the Evidence and Measures Project

Reaching consensus on measures to address WFD failure in a difficult catchment

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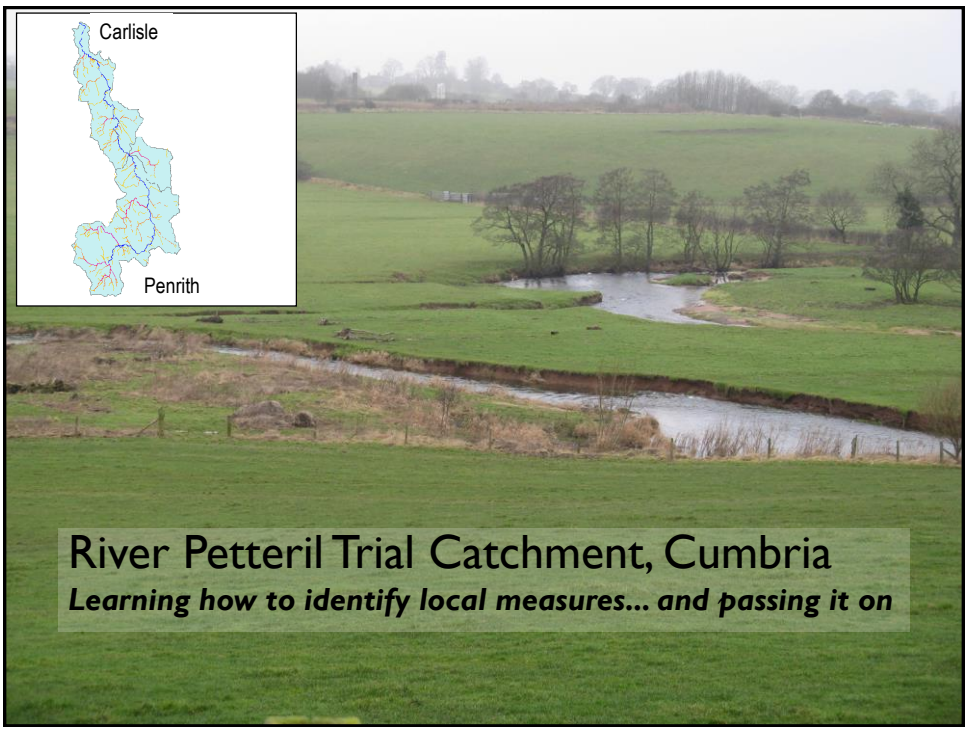


Evidence & Measures

Summary: the problem

- The Evidence and Measures project aimed to select measures for WFD 2nd cycle on the River Petteril catchment in Cumbria, where all four water bodies fail their WFD objectives due to poor trout numbers.
- Selecting measures was considered 'difficult' in the Petteril because its has failing waterbodies where the causes and solutions are unidentified
  - Causes for poor trout numbers unknown although many hypotheses suggested
  - Hence lack of confidence in which solutions (measures) to invest in
- Defra, the EA (local and national teams) and the Eden Rivers Trust have worked collaboratively to collect relevant *existing* data and knowledge.
- We looked for patterns in fish numbers and in pressures (sewage discharges, farming, pollution events, river modifications) over time (decades) and spatially across the catchment.

There is also a summary document in Defra's Technical Summary format

EVidence & Measures

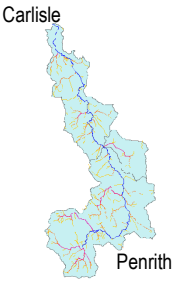
Summary: the results

- 2 Stakeholder Workshops: EA (local and national) and Eden Rivers Trust staff
- At the Causes Workshop top 4 causes of fish failure in the Petteril agreed (Slide 15 and Causes Spreadsheet):
  - Farming - acute and chronic pollution from farmyards (NH3) leading to fish kills and less resilient fish; Also drainage and soil compaction
  - Sewage - treated sewage discharges and septic tanks (NH3)
  - Transport pollution (oil, zinc) and effect of drainage and on flows to tributaries (M6, A6 and the railway)
  - River modifications - channel straightening and gravel removal reducing spawning habitat.
- At the Measures Workshop 70 measures identified, 10 of which were worked up in detail including the following (Slides 16 – 18 and Measures Spreadsheet):
  - Improving manure / slurry storage on dairy farms in three sub-catchments.
  - Re-meandering and restoring substrate in the headwaters of the river with fencing and tree planting to improve trout spawning habitat.
  - Fencing, water troughs and pumps to prevent livestock access upstream of the M6
  - Investigating quality of water discharged from M6 drainage at junctions 41 and 42
  - Education campaign aimed at septic tank owners throughout the catchment.
- 50 measures are now included in EA Area business plan.

EVidence & Measures

Contents

1. The problem



The problem

- EA Area teams selected the River Petteril as one of their most difficult catchments in terms of selecting measures.
- It fails its WFD objectives due to low fish (trout) numbers and invertebrates but the causes for this were highly uncertain although numerous hypotheses had been suggested.
- So it was difficult to target or agree measures with stakeholders.
- Local EA staff and stakeholders have been aware of poor trout numbers for two or three decades but so far efforts to improve them, which have succeeded in other catchments, have not done so in the Petteril.

2. The project

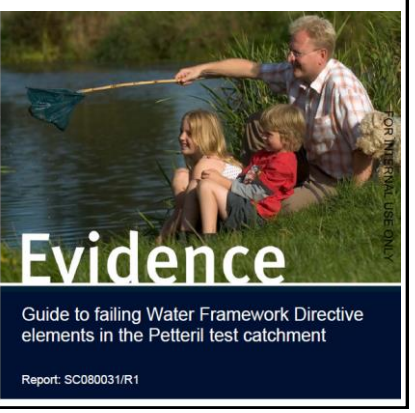
The Evidence and Measures project

- Aims:
  - Trial approaches for selecting measures on River Petteril ready for WFD 2nd cycle
  - Use existing evidence/knowledge
  - Work in collaboration with local stakeholders
  - Pass on what is being learned for use in other catchments across the country
- Partnership between Environment Agency Area teams, National Science/Evidence team, Defra Water Quality team and local stakeholders.
- Outputs (for full list - see Section 11 "Project outputs")
  - Executive summary to accompany this PowerPoint
  - Measures spreadsheet describing the measures agreed at the 2 workshops.
  - Feedback from participants on the approaches trialled.
  - GIS data store, collected from all related sectors (water, ecology, agriculture).
  - Conceptual summary and diagrams.
  - Checklist of useful questions and list of important datasets.

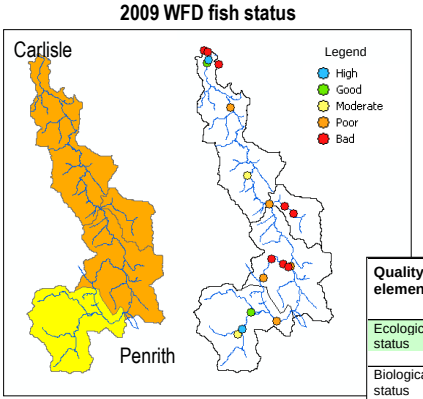
3. The WFD classification on the Petteril

The Petteril WFD classification

- tells us something is wrong with the fish
  - What elements are failing? Fish & invertebrates (next slide)
  - Where? All four water bodies (next side)
  - Which species are driving the failure and at which monitoring points? Trout (Slide 10)
- but not
  - How long things have been bad
  - What to do about it
- for this we needed to look for trends in time and space – see 'Data analysis'



2009 WFD fish status



Environment Agency 2010, *"Guide to failing Water Framework Directive elements in the Petteril test catchment"*

- All 4 water bodies are at poor status
- Below good status are:
  - Fish, invertebrates
  - Phosphates, flow

Macro-invertebrates are poor because they are on a side stream (Lamb Beck) that dries out whereas fish assessment is on main river. So ecological status should be moderate & ecodriver fish.

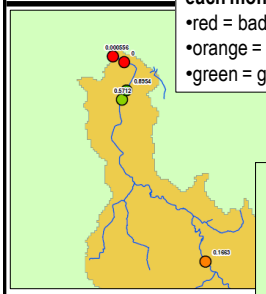
Quality elements	Indicator variables	Petteril downstream of Blackrack Beck	Blackrack Beck	Petteril downstream of M6	Petteril upstream of M6
Ecological status	Overall	Poor	Poor	Poor	Poor
	Ecodriver	*Fish*	*Fish*	*Fish*	*Invertebrates*
Biological status	Fish	Poor	Poor	Poor	Moderate
	Macro-invertebrates	Good	Moderate	High	Poor
Specific pollutant & physico-chemical status	Phosphate	Moderate	Good	Moderate	High
Hydromor-phological status	Overall status	Does not support good status	Does not support good status	Supports good status	Supports good status

Evidence & Measures

11

Ecological Quality Ratio (fish scores) at each monitoring point
- red = bad
- orange = poor
- green = good

Derivation of Ecological Quality Ratio (EQR) for fish
- Year and number of fish observed
- Most recent observation used
- Data for monitoring points not necessarily from the same year
- So the Petteril WFD classification was a 'dashboard light' but not a means of diagnosing the cause(s) of failure.



Sample Year = 2003
Fish Observed = 1
Trout = 1
Salmon = 0
Eel = 0
Grayling = 0
Dace = 0
Lamprey = 0

Sample Year = 2004
Fish Observed = 2
Trout = 1
Salmon = 1
Eel = 0
Grayling = 0
Dace = 0
Lamprey = 0

Sample Year = 2007
Fish Observed = 144
Trout = 3
Salmon = 106
Eel = 32
Grayling = 0
Dace = 3
Lamprey = 0

Sample Year = 2008
Fish Observed = 11
Trout = 3
Salmon = 3
Eel = 3
Grayling = 2
Dace = 0
Lamprey = 0

Sample Year = 2005
Fish Observed = 9
Trout = 4
Salmon = 1
Eel = 4
Grayling = 0
Dace = 0
Lamprey = 0

Sample Year = 2005

From: Jon Brown, Entec

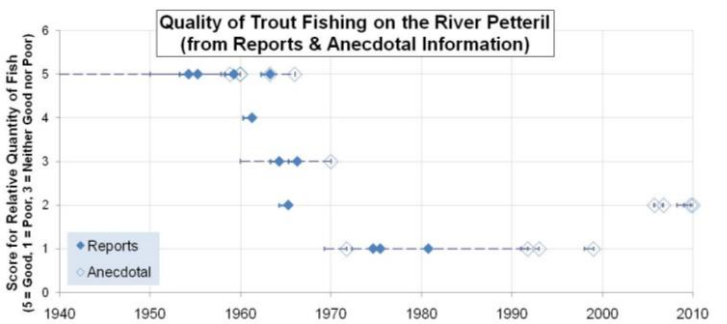
Evidence & Measures

4. Data analysis

12

Timeline (when did things change?)

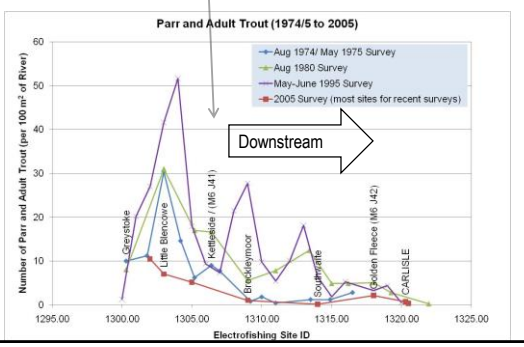
- Trout numbers good till 1950s, rapid dip during 1960s to 1970s and remained low till 2000. Perhaps on the rise again now?
- Phenol tanker spill in 1968 wiped out all downstream fish.
- During the 1970s to 1990s farm effluent was the prime and repeated cause of fish kills.



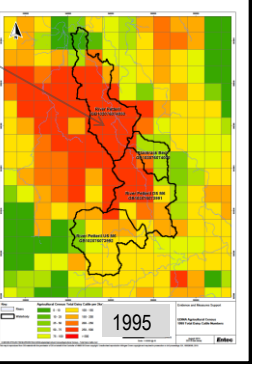
Evidence & Measures

Spatial patterns

- *Fish* Significant drop off in numbers downstream (since the mid-1970s)
- *Dairy farming* Intensified especially in middle reaches of the river up to mid-1990s (red squares)
- *Unionised ammonia* Top of catchment is generally good (low levels) except Flusco Quarry.



EDINA: The grid square agricultural census data, as converted by Edinburgh University Data Library, are derived from data obtained for recognised geographies from the Department of Environment, Food and Rural Affairs (DEFRA), The Welsh Assembly Government, and The Scottish Government (formerly SEERAD), and are covered by Crown Copyright.

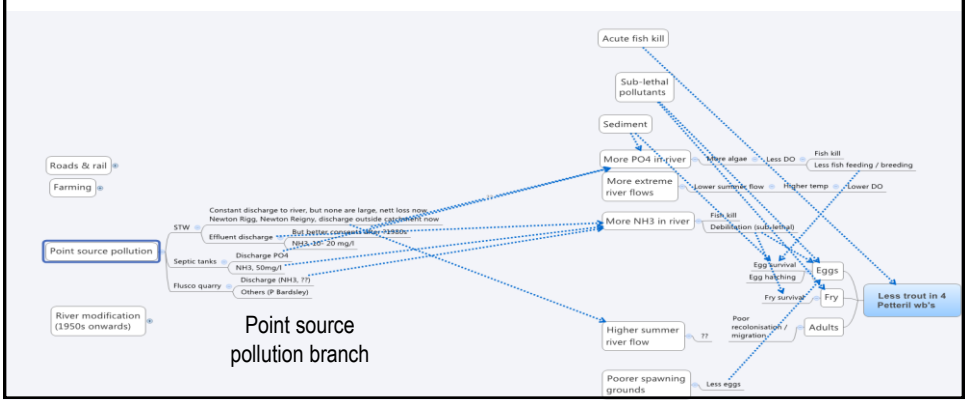


Evidence & Measures

5. Consensus on the causes

Links between each suspected cause and fish failure

- Influence Diagram (linking causes and effects)
- Conceptual model developed with stakeholders
- Relationships between pressures (causes) and trout numbers
- See Causes Spreadsheet



Evidence & Measures

Main causes of WFD failure agreed at the Causes Workshop

(full details in the Causes Spreadsheet)

1. Farming
   - Acute pollution leading to fish kills
   - Chronic pollution leading to less resilient fish
   - Drainage
   - Soil compaction
2. Sewage
   - Treated sewage discharges
   - Septic tanks
3. Transport (M6, A6 and the railway)
   - Pollution: oil, zinc
   - Drainage and its effect on flows to tributaries
4. River modifications
   - Channel straightening
   - Gravel removal

Plus two locally important causes:
•Flusco Quarry, landfill leachate at top of catchment
•Possible long-term effects of phenol tanker spill near Plumpton in 1968

Evidence & Measures

6. Agreed measures

70 measures identified at the Measures Workshop

(full details in the Measures Spreadsheet)

- The top 10 were worked up in detail at the workshop and are listed on the next two slides
- The remaining 60 were described in outline ready to take advantage of additional resources and funding opportunities as they arise
- 50 of the agreed measures are now included in EA Area business plan, more than 90% of them with resources allocated

Evidence & Measures

Top 10 measures which were worked up in detail at the Measures Workshop (full details in the Measures Spreadsheet)

ID	Where	Measure	Addressing which top cause?
1	Upstream of M6, downstream of Blackrack Beck	Fencing, water troughs and pumps to prevent livestock access	Dairy farming River modification
2	M6 junctions 41 & 42	Investigate quality of water discharged to the Petteril from the M6 via drainage / soakaway	Oil / metal pollution from M6
3	Petteril upstream of M6 & tributaries elsewhere	Re-meandering the river, substrate restoration with fencing and tree planting	Lack of spawning habitat due to river straightening, re-sectioning and bed lowering
4	Catterlen	Open discussions about Catterlen residents applying to Water Co. for connection to sewer	Major fall in fish numbers possibly due to high NH3 from unsewered discharges
5	All 4 water bodies	Campaign aimed at up to 1100 properties with septic tanks	Increased NH3 load (up to 10x) compared to discharges from sewage treatment works

6-Measures

Evidence & Measures

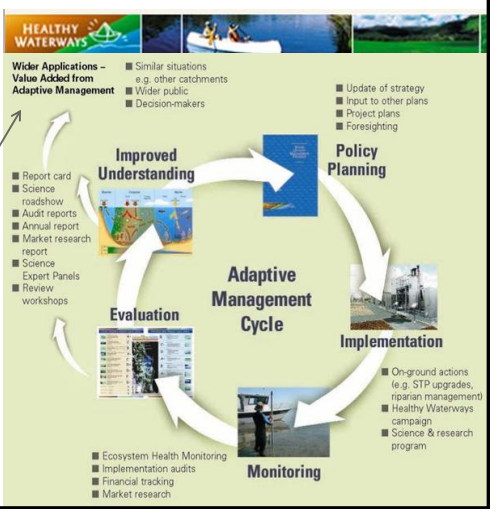
ID	Where	Measure	Addressing which top cause?
6	Catterlen, Stoney Beck?, Woodside Beck	Improve manure / slurry storage to deal with diffuse N, P from agriculture	NH3, PO4 pollution from dairy farms
7	Old Petteril	Investigate reduction of bankside erosion to prevent silt affecting WQ and fish	
8	Top of catchment upstream of M6	Identify source of main NH3 inputs (SIMCAT)	Dairy farming, septic tanks, sewage treatment works
9	Blackrack Beck	Walkover habitat survey and consider narrowing channel and adding gravels to improve river habitat	Lack of gravels & too much silt, low flows (supported by invert data), lack of vegetation cover
10	Woodside Beck	Trial catchment scorecards with local community	NH3 diffuse pollution (SIMCAT evidence), lack of spawning gravels due to river modification

7. The approach

Learning by doing

- The Evidence and Measures project has been as much about learning what works and what doesn't, when selecting measures in a difficult catchment, as it has about agreeing the final set of proposed measures
- Major Influences
  - See Section 10 "References" including; SE Queensland Healthy Waterways Partnership
  - Peer reviews by Ben Surridge and Phil Haygarth, University of Lancaster and Michelle Walker, Entec (now Rivers Trust).
- The next few slides give a summary of the approaches trialled... and we are still learning.

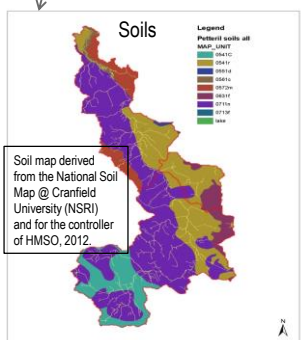
Prof. Stuart Bunn, Griffith University, Australia



Putting the problem in context

- Catchment Summary (Conceptual Report)
- Field visits with local experts
- Identifying related work
- Understanding the Petteril WFD classification

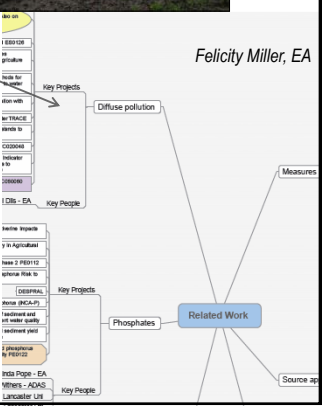
A list of the Evidence and Measures project outputs is given in Section 11.



Landuse

The project used land use data from Land Cover Maps 2000 (LCM200) produced by CEH. This data is available for use by the Environment Agency but cannot be shared publicly and so this map has been removed.

Felicity Miller, EA



Evidence & Measures

Collecting *existing* evidence & looking for patterns

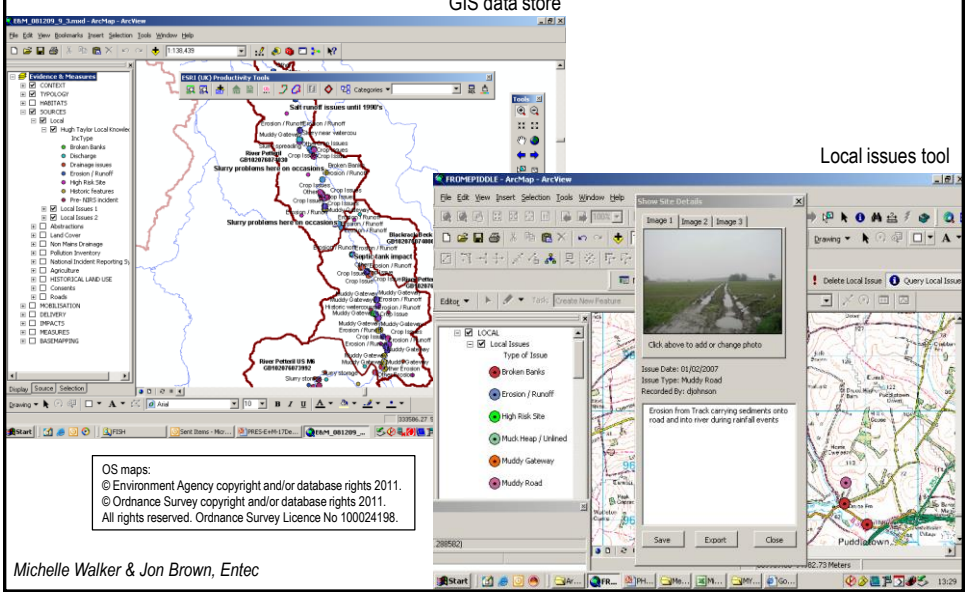
- Data store
  - Data collected from all related teams (fisheries, hydrology, agriculture etc.)
  - Stored in GIS
  - Simple spreadsheet data inventory
  - Local Issue Tool records evidence from field visits on GIS (next slide)

- Some useful questions during data analysis
  - When did things change?
  - Which parts of the catchment are worse and why?
  - Why is this catchment worse than others?
  - Are certain times of year worse than others than others?
- Sources of data
  - Factual: Data, Official Reports, Other Publications (papers / website search)
  - Anecdotal: Newspaper articles, Testimonials & interviews, Minutes of Eden Rivers Trust "History of the Petteril Event"
-

Evidence & Measures

GIS data store

Local issues tool

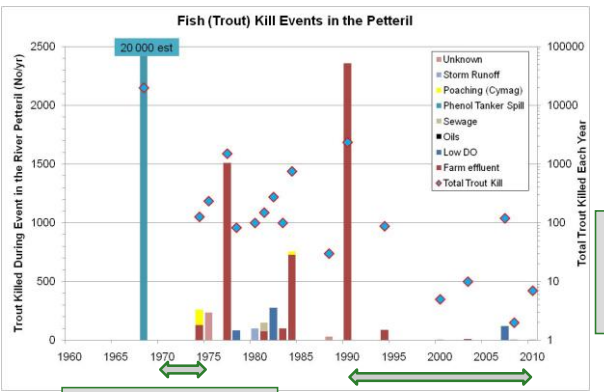


Michelle Walker & Jon Brown, Entec

Evidence & Measures

Timeline: repeated fish kills from farm effluents

Big fish kills are rare now, less pollution or less fish to kill?

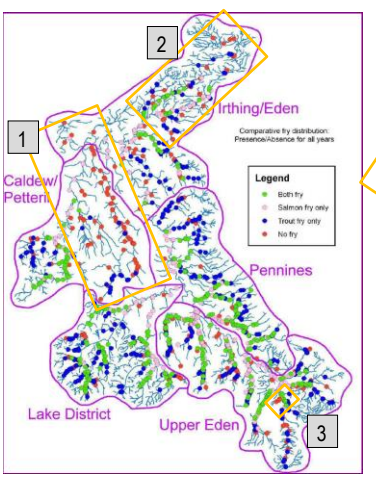


1970- Nov 1974
2000 trout killed from farm effluent or low DO

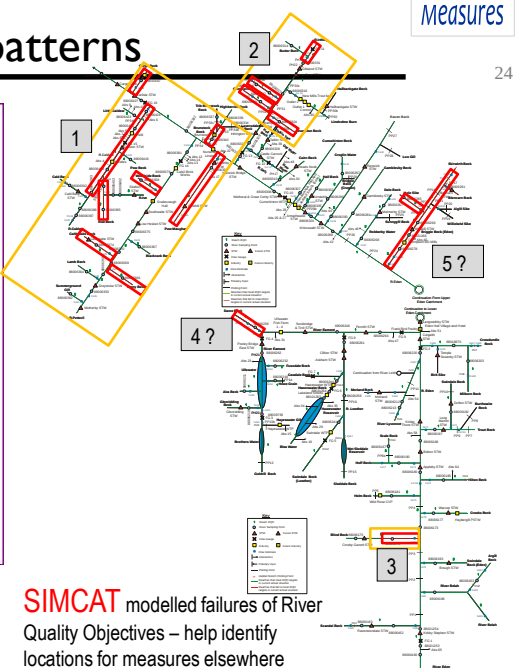
We have not reviewed the 1990s and 2000s biologists reports so there may be more fish kills in this period

Evidence & Measures

Comparing spatial patterns



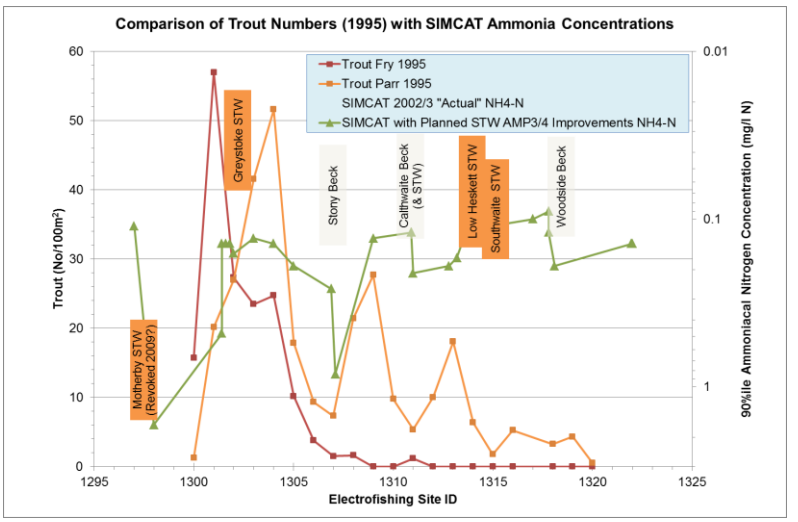
Taken from Eden Rivers Trust Website Electrofishing Report 2009



SIMCAT modelled failures of River Quality Objectives – help identify locations for measures elsewhere

Comparing spatial patterns

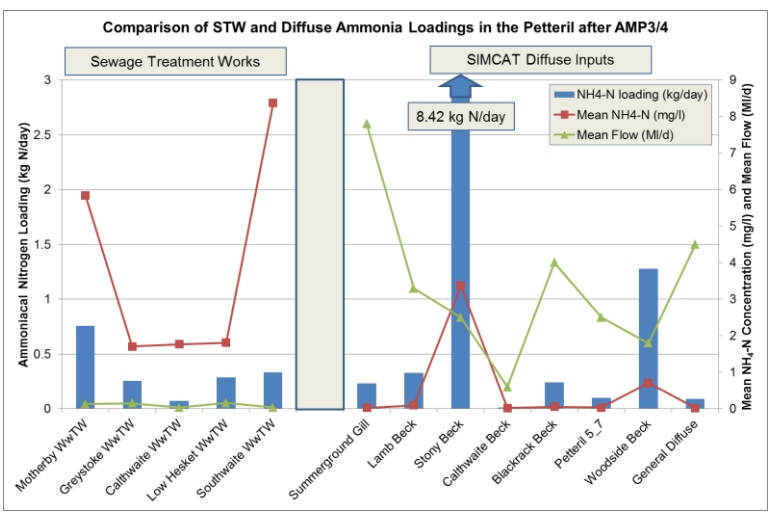
SIMCAT Predictions for Ammoniacal Nitrogen



1995 Trout Numbers Influenced by Restocking

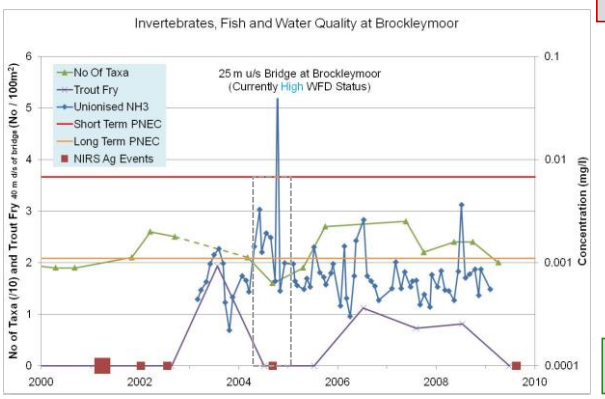
SIMCAT & source apportionment

STW Discharges versus Diffuse Inputs for Ammonia

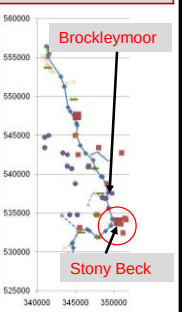


Impact of Stony Beck

- Trout Fry and Invertebrates (No of Taxa) show some correlation downstream at Brockleymoor
- Fish are most sensitive to unionised ammonia and DO
- >Long Term Unionised NH_3 PNEC appears to be problem



NIRS Events from e.g. silage clamp failure

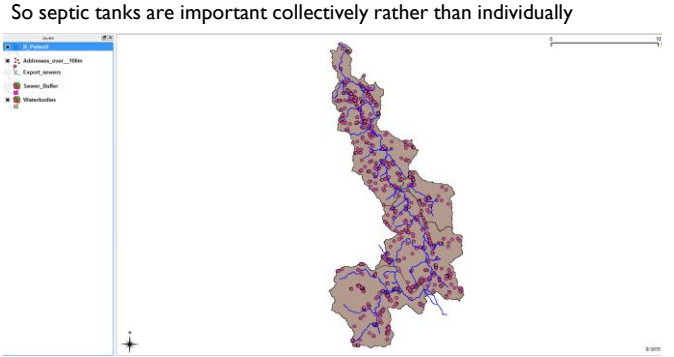


PNEC = Probable No Effect Concentration

We have connected fish, invertebrates, water quality and NIRS and in so doing brought separate disciplines within the Agency together

Septic tank discharges

- 1100 Septic Tanks in 4 Water Bodies (less in upper catchment)
  - Septic Tank discharge typically 150-180 l/person/day and 40-50mg/l NH_4-N*
  - Assume av. 2-3 people per property gives Total N loading of 12.2 to 29.7 kg N/day
  - In comparison Total STW discharges is 1.7 kg N/day
  - So septic tanks are important collectively rather than individually



Note: * Septic tank discharge flow and quality data from: Cumulative Nitrogen and Phosphorus Loadings to Groundwater, SEPA, EA, EPA & NIEA Report by Entec UK Ltd, Nov. 2010

Evidence & Measures

Floods & drainage works

Carlisle (summary)

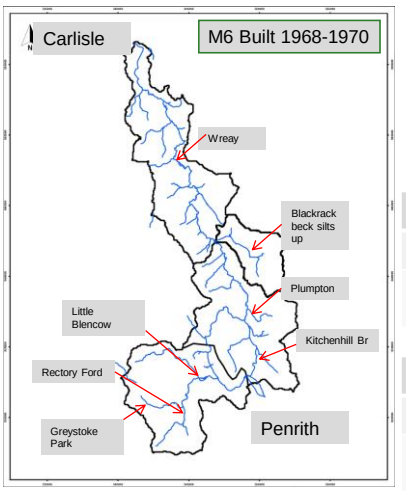
Year	Reported Works
1953 - 1966	Flooding, gravels removed, new channel constructed, weirs and cascades added?

U/S of Little Blencow

Year	Reported works
<1985	At Rectory Ford – artificially spilled banks
1985	Parts of river bed removed to lower level between Storch Br and Little Blencow.

Greystoke Park

Year	Anecdotal (H Taylor, EA)
1960s	Drained in the 1960s



Wreay (summary)

Year	Reported Works
1962 - 1973	Tree clearance, planting, gravels removed, weir removed.
1983	Land drainage nr Crooks Mill

Plumpton (summary)

Year	Reported Works
1952 - 1965	Weed cutting, gravels removed, channel straightening, bank repair

Kitchenhill to M6 (summary)

Year	Reported Works
1964 - 1969	Brushwood clearance, gravel excavation, bank repairs

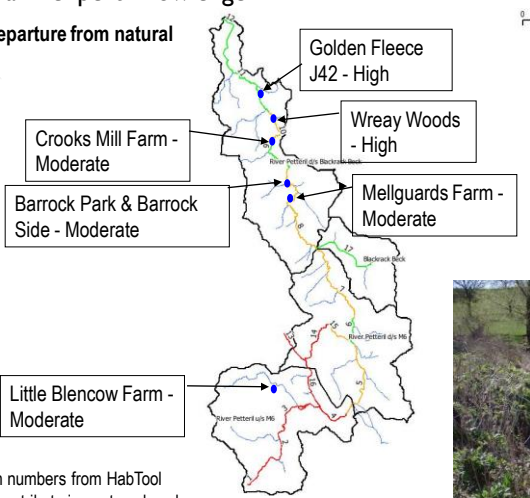
Based largely on CRA Reports 1953-74

Evidence & Measures

Habitat potential

- Which sections of river have potential to be good trout habitat?
- HabTool and expert knowledge

Substrate departure from natural
Red = high



Marc Naura, Southampton University,
Alison Reed, Eden Rivers Trust

Information courtesy of Eden Rivers Trust

Numbers 1-17 are reach numbers from HabTool analysis. Blue reaches are tributaries not analysed.

Stakeholder workshop

Diagnosing the most likely causes of failure (the Causes Workshop)

- Collected all suspected causes (hypotheses) for failure (next slide) and considered the evidence: results from data analysis & knowledge in the room.

- Useful questions for each suspected cause (answers recorded in spreadsheet)
  - What links this suspected cause to failing trout?
    - Build Influence Diagram (Slide 14)
  - How is it believed to operate (hypothesis)? E.g.
    - One-off spills from cattle yards kill fish and reduce their ability to recover before the next kill
  - What evidence do we have that this cause explains the observations including...
    - Variations in trout numbers in time and space?
    - Trout recolonisation problems?
  - How strong is the link?
    - Stakeholders put forward evidence, which was recorded in a spreadsheet and put scores against each suspected cause (next but one slide)
  - What are the main uncertainties?

Suspected causes of fish failure

The EA Area teams, local anglers and Eden Rivers Trust have been aware of the fish problem on the Petteril for many years. Many hypotheses have been suggested:

- *River modification* Channel straightening has been going on for a century at least with loss of ~ 50% of habitat in upper reaches
- *M6* Polluted run-off (oils, zinc); drainage giving more variable river flows
- *Railway* Blocked culverts may be preventing fish passage; herbicides
- *Flusco Quarry* Landfill leachate input at top of catchment
- Phenol tanker spill near Plumpton in 1968 and long term effects of phenols
- Pollution from sewage works and septic tanks
- *Agriculture*
  - Land drainage: possible cause of dry tribs with impact on juvenile trout in west
  - Compaction and cattle poaching: siltation of spawning gravels, habitat loss
  - Chemical pollution: nutrient enrichment, slurry spills, sheep dip, herbicides
- *Fish management* Over-fishing, poaching, disease

We cannot target measures with such uncertainty

Evidence & Measures

Aggregated scores

Main causes of failure

	Hypothesis	Before starting Workshop 1	Mid-afternoon Day 1	End of Day 1	Aggregate
	People>				
1	Change in flows and habitat through drainage improvements	3.7	3.8	3.0	**3.5**
2	M6 drainage (oils, zinc, nfluence on drainage e.g. culverting)	2.9	3.8	3.8	**3.5**
3	Flusco Quarry (landfill leachate input at top of catchment)	1.6	2.0	1.5	**1.7**
4	Phenol tanker spill near Plumpton in 1968 and long term effects of phenols	1.6	1.7	2.0	**1.8**
5	Septic tanks and sewage works	3.3	3.7	4.2	**3.7**
6	Agriculture (land use, soil compaction / recharge, riverside habitat, water quality etc)	4.9	5.0	5.0	**5.0**
7	Sheep dip pollution and use of herbicides (to control weeds in the river)	1.4	1.2	1.2	**1.3**
8	Fish disease, over-fishing, poaching, cormorants .....!	1.3	1.0	1.0	**1.1**

Evidence & Measures

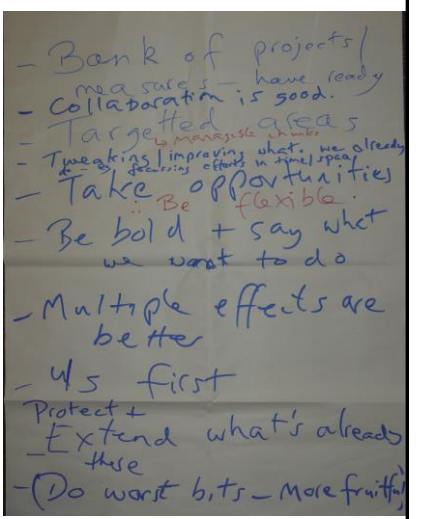
Stakeholder workshop

Agreeing measures (the Measures Workshop)

- Focussed on agreed most likely causes of failure
- List of criteria for selecting measures agreed (next slide)
- Useful questions for each proposed measure (see Measures Spreadsheet)
  - Is an existing measure already dealing with this issue (next but one slide)?
  - Where will it be implemented?
  - What are the anticipated consequences for WFD, food production and flooding?
  - Are there likely to be multiple effects (+ve or -ve) or effects elsewhere?
  - How long...
    - will it take to implement?
    - before the benefits are seen?
    - will it continue to have an effect?
  - What is the estimated cost and who will pay?
  - Who will do it and does anything need to be done beforehand?

Our working criteria for measures

- *Need bank of projects* Defined and ready for when funding becomes available
- *Be flexible* Take opportunities as they arise
- *Collaboration* Community involvement is good
- *Target areas* Deal with manageable chunks
- *Be bold* Say what we want to do
- *Multiple effects* from a single measure are better
- *Extend what we already have*
  - Current good habitat
  - Adjust where Env. Officers go
- *Upstream first** Benefits travel downstream
- *Target areas* Where most can be gained
- *Be aware of obstacles* E.g. farm access due to H&S liabilities and perception of EA
- *Don't prioritise* Parallel track (back all horses, some will come in)



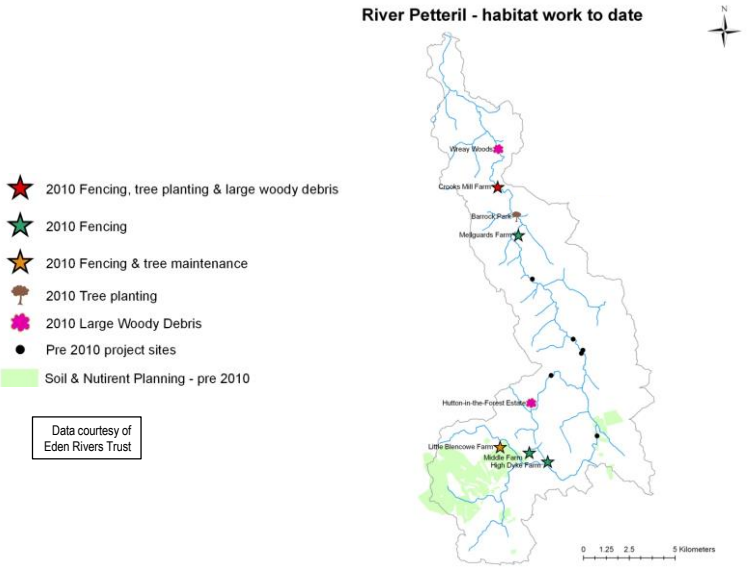
* Will not apply if there are barriers to fish, e.g. weirs but none on Petteril.

Take account of existing measures

- Eden Rivers Trust, with funding from Defra, EA, Natural England (next slide)
  - Tree planting and fencing to stabilise river banks for erosion control
  - Invasive species (e.g. Himalayan Balsam) management, funded by Nat England
  - Large woody debris / barrier management
- Environment Agency
  - Pig and Poultry Permit Requirements – better pollution prevention and monitoring
  - NVZ / Nitrate Pollution Prevention Regs, manure management, slurry storage/handling
  - Improved sewage treatment works at Newton Reigny from review of consents
- Measures proposed in River Basin Management Plans
  - Partnerships and advice / liaison with agricultural sector
  - Compliance and campaigns with e.g. farmers, United Utilities, septic tanks owners
  - Non invasive species coordinator
  - Reviewing information on impact of septic tanks and diatom surveys

Evidence & Measures

Existing work by Eden Rivers Trust



Evidence & Measures

Two workshops

- Stakeholders from the EA and Eden Rivers Trust
  - Causes Workshop (Workshop 1): 7 participants, 2 half days
  - Measures Workshop (Workshop 2): 10 participants, 2 days
- Aims
  1. Agree the main causes of trout failure in the Petteril catchment
  2. Trial the "workshop approach"
  3. Agreed measures for 2nd cycle of River Basin Management.
- Outputs
  - Consensus on top causes of failure
  - Spreadsheet of agreed local measures for input to business plans
  - Feedback on the approach

8. Lessons learned & transferability

- Positive feedback from workshop participants
  - This is the start of producing a positive programme of measures using evidence from those who know the catchment - exactly what teams on the ground need to deliver WFD.
  - The historical components were absolutely vital.
  - Good to keep group small (<10 people) and split over 2 days.
  - Local knowledge / understanding of the catchment can speed things up considerably.
  - Petteril was a manageable sized catchment, any bigger and we would not have been able to get focussed measures.

- Improvements suggested
  - After Workshop 1:
    - Need to check which stretches of river will support fish before deciding measures (Habitat potential assessed prior to Workshop 2).
    - Need more aquatic and agricultural expertise next time (invited to Workshop 2)
    - Need more of the data displayed on maps (live GIS prepared for Workshop 2)
  - After Workshop 2:
    - Needed hydrogeomorphologist for some measures
    - Two smaller groups to agree measures worked better than one large group.

Data

- Several types of evidence used, including
  - Field data, modelled data, anecdotal information, expert opinion

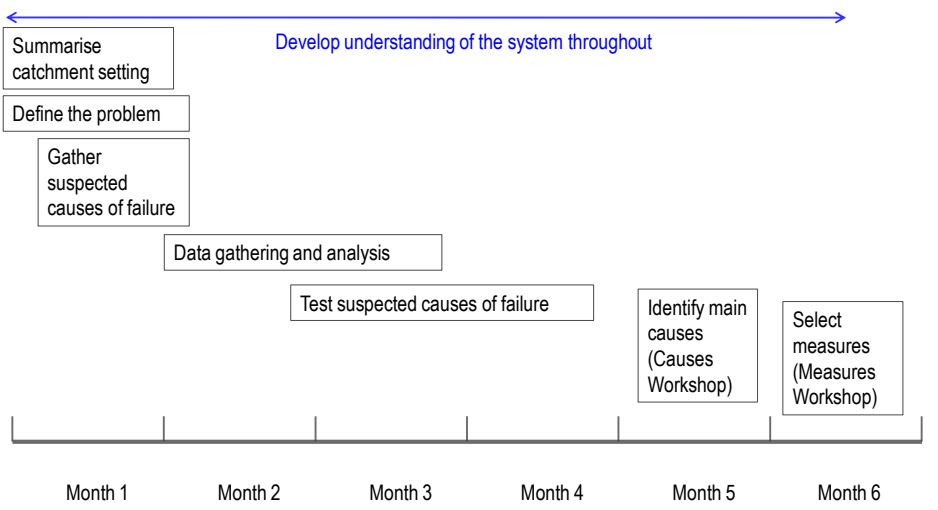
- Most useful data sets (described in Spreadsheet of Important Datasets)
  - History of Petteril event notes – important info on pre-record events
  - Archived fish and biological surveys with view of what our predecessors thought
  - Archived information on fish kills and fish stocking and river engineering
  - Agency database information (post 1995) on fish, invertebrates and water quality
  - NIRS pollution event database (but detail is lacking)
  - GIS data sets on land use (including EDINA), soils, geology

- Model outputs used
  - SIMCAT (WRc, predicted water quality and highlighting large diffuse inputs)
  - Habitat potential (HabTool combined with expert knowledge)
  - SCIMAP (Durham University – ideas on diffuse pollution and connectivity)

Key elements we would use again elsewhere

- Brief summary of catchment setting and the problem
  - WFD classification (Slide 10)
  - Soils, landuse, hydrology and biology (Slide 20)
  - Suspected causes of WFD failure from stakeholders
- Data analysis beyond WFD classification to test suspected causes of failure
  - What is failing at which monitoring points and which species are driving the failure? Trout (Slides 10, 11)
  - Identifying spatial and temporal patterns in the data: graphs, maps, GIS, spreadsheets (Sides 21 – 29)
  - History of Petteril event: local expertise and experience over several decades (Slide 21)
  - Habitat potential: HabTool combined with expert knowledge (Slide 30)
- Two workshops (Slides 37, 38)
  - Causes Workshop: agree main causes of trout failure (Slides 15, 31-33)
  - Measures Workshop: work up proposed measures based on main causes (Slides 16-18 and 34-38).
- Record understanding (Conceptual Diagrams)

Plan of key elements onto 6 month timeline



Elements we would not use again or would revise

- Writing formal reports for:
  - 1) Catchment summary (*R. Petteril Conceptual Report*); 2) Understanding the Petteril WFD classification (*Guide to failing WFD elements in the Petteril catchment*)
  - Instead just collect the information on PowerPoint slides to reduce time
- Collecting all potentially relevant data into GIS before the data analysis
  - Instead understand what data available by using the Petteril data inventory
  - Focus initial data collection around the problem (e.g. failing fish, bathing waters etc.)
  - Target further data collection as the investigation of causes proceeds
- Quantifying links between failing elements and specific sources
  - The influence diagram (e.g. Borsuk 2006) showing links between suspected causes and failing element (Slide 14) was useful for developing understanding at Causes Workshop.
  - But quantification of this via Bayesian Belief Network and conditional probability tables was not (too onerous to populate).
- Scores in measures spreadsheet
  - Prioritisation of measures not required

Elements we would not use again or would revise (contd.)

- Components that were part of the research nature of the project:
  - Identifying related work from scratch. Done once so does not need doing again. Easy to update existing spreadsheet of related work and share with other catchments.
  - External peer review from academic experts.
- Investigation of multi-criteria analysis and cost benefit analysis for selecting measures
  - Instead we developed a simple spreadsheet approach to describe each agreed measure
  - A cost-effectiveness tool is being developed by the socio-economics research team. This tool was trialled in the Petteril and is being revised based on this and other feedback. Until this tool is completed it is recommended that the simple spreadsheet approach is adequate.

Transferability

We found there was plenty of data and knowledge already available, which was used to do some relatively simple analysis. This gave us enough confidence in the main causes of failure to agree the next actions on a catchment considered for many years to be 'too difficult'.

Each catchment will have something different but ...

- We know how to break the problem into steps (Slides 41 & 42)
- We know how to bring together data from several fields and which are most useful (Spreadsheet of Important Datasets)
- We know how to develop understanding and link failing elements to suspected causes (Conceptual Diagrams and Causes Spreadsheet)
- We know how to gain consensus on the main causes of failure and selecting measures (Workshops with Technical Stakeholders)

9. What next?

Since the Petteril Measures Workshop (Mar 2011)

- 50 of the agreed measures have been included in EA Area business plan with resources allocated to more than 90% of them
- Dissemination via presentations to
  - Defra/EA, EA National Fisheries Technical Workshop, Association of Rivers Trusts for Defra Strategic Evidence and Partnership Fund, Freshwater Biological Association for Defra Demonstration Test Catchments
  - Others planned to Eden Demonstration Test Catchments project, Defra/EA 10 Pilot catchment officers
- Application of the outcomes of the E&M Petteril Trial planned
  - Apply to other sub-catchments of the Eden which are failing due to fish
  - Investigate whether fish in other catchments are affected by NH3 even though the water bodies do not fail their WFD objectives for NH3
  - Apply approach to select measure in another difficult catchment (part of the Ribble) within 6 months as part of 'business-as-usual' using mainly in-house staff
  - Dissemination via three workshops to Defra / EA pilot catchments
  - Practitioners Catchment Management Forum to share emerging best practice

EVidence & Measures

10. References

Published reports and papers

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11. Project outputs

Defra

- *Executive Summary.*
- *River Petteril Trial Catchment Summary Slides.* A summary of the approach, data analysis, results and lessons learned from the Evidence and Measures Project on the Petteril Trial Catchment.
- *Conceptual Diagrams.* Conceptual understanding of the causes of poor fish numbers in the River Petteril catchment. Trial spreadsheet format.
- *Checklist of Questions.* Useful questions at each stage of the project which can help in catchments elsewhere.

- *Spreadsheet of Important Datasets.* The datasets which proved most useful in unravelling the causes of fish (brown trout) failure in the River Petteril.
- *Measures Spreadsheet.* Agreed measures from the Measures Workshop.
- *Causes Spreadsheet.* Includes agreed main causes for WFD failing elements from Causes Workshop and the full Influence Diagram for the Petteril.
- *Presentation and Handouts for Causes Workshop.* The results of the data analysis and the testing of the suspected causes of failure that done prior to the Causes Workshop.
- *Feedback from Workshop Participants.* Feedback collected from participants at the two workshops (Causes Workshop and Measures Workshop).

11-Project outputs

Environment Agency

- *River Petteril Conceptual Report*. Draft Internal Project Report SC080035.
  - Initial conceptual description of the hydrology of the Petteril catchment: surface water, groundwater, soils and land use.
- GIS and data inventory delivered to EA Area Env. Planning team (2010).
- *Description of Related Work for the Evidence and Measures Project.* Internal Project Report (2009).
  - Spreadsheet and mind-map of related projects by category, e.g. phosphates, sediments, source apportionment, diffuse pollution, measures etc.
- *Guide to Failing Water Framework Directive Elements in the Petteril Test Catchment*. SC080031/R1 (Internal Use Only, 2010).
- *Evidence on the Causes of Failing WFD Fish Status – The Timeline Approach.* (Audio-visual presentation, 2010, available from Anne-Marie Bowman, EA Penrith).
- Initial peer reviews by Michelle Walker (formerly Entec), Phil Haygarth and Ben Surridge (University of Lancaster).
- Project delivery plan.

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Endnote

- There is part of us that wants certainty but the water environment is a complex natural system where things are usually not that clear or that simple and so our understanding will always be partial and our uncertainties large.
- But that need not prevent us from moving forward and making wise choices.
- The physicist Richard Feynman said *"To decide upon the answer is not scientific. In order to make progress, one must leave the door to the unknown ajar. The English call this 'muddling through'."*