# Monitored Priority Catchment Project Lunan Water

## Macaulay Institute, SEPA & SAC

Environment – Land Use and Rural Stewardship PROGRAMME3

funded by
Scottish Government

## Annual summary progress report August 2009


Contributors:
Andy Vinten, Martyn Futter, Sarah Dunn, Marc Stutter, Kirsty Blackstock, Nikolai Friburg, Benoit Demars, Malcolm Coull, Hamish Moir, Helen Watson, Christian Birkel, Claire Abel, Carol Taylor, Simon Langan, Jenni Stockan, Marie Castellazzi, Bedru Balana (MI),
Carole Christian, Bill Jeffrey, Alex Sinclair, Ian Dickson (SAC),
Fiona Napier, Jannette Macdonald, Jonathan Bowes, Elaine Simpson (SEPA)

# 0. *Executive summary*.

2007-8

1. The overall objective is to assess what constitutes effective and proportionate mitigation of diffuse pollution in catchments which are (a) representative of typical land uses in Scotland and (b) where surface waters are considered at risk of failing to meet Good Ecological Status (GES) under the Water Framework Directive, as well as other regulatory targets.
2. This is being progressed through an Environmental Focus Farm, user focus group meetings, auditing and implementation of appropriate and agreed statutory and voluntary measures and pre- and post-implementation monitoring.
3. Potential regulatory issues in the catchment include: nitrates in groundwater, soluble P, fine sediment and ecology of surface running waters; total P and chlorophyll a content within Rescobie and Balgavies Lochs; morphological barriers to migratory fish (eg Boysack Weir), and excessive soil erosion of bare ground in winter.
4. The Lunan Water itself and feeder streams to Rescobie and Balgavies Lochs, meet GES for water chemistry. However 90$^{th}$ percentile turbidity values for Baldardo and Lemno Burns are high. Attention should be paid to determining the trophic diatom index and RIVPACS data for these waters to evaluate whether the chemistry is reflected in the ecology.
5. Both Rescobie Loch and Balgavies Loch fail to met GES. Target TP loads to achieve GES are 210 kg P and 197 kg P respectively. Estimated loading reduction requirements (from Vollenweider calculations) are 366kg P and 451 kg P respectively. Current loading estimates from direct monitoring are uncertain.
6. Current loading estimated from Rescobie to Balgavies Loch is 475 kg TP (2006/7 data). As Rescobie catchment is a large proportion of the catchment area of Balgavies Loch, a reduction of about 80% of this load is required to achieve GES in Balgavies Loch. Further work is needed to better estimate input loads of TP. This will be achieved through fortnightly spot sampling, interpolation using turbidity data, use of event sampling for calibration along with discharge estimation from water level and stage: discharge calibration.
7. Several voluntary measures have been identified and some are being adopted by farmers in the farmer focus group, A key priority for the next half year is carrying out farm audits of compliance with General Binding Rules (GBR) for diffuse pollution control and Good

Agricultural and Environmental Condition (GAEC) requirements for soil protection.

**2008-9** ***(with priorities from 2007-8 report (see Appendix 1))***

*Priority A, Carry out Statutory compliance (GBRs and GAEC) audits on farms in the catchment, using an independent consultant. The priority for this will be farms in the Burnside Burn catchment, followed by Newmills and Wemyss.*

8. Agreement has been reached for SEPA to train MI and SAC staff in General Binding Rules audits (in late summer), to carry out on farms in the catchment. The priority for this will be farms in the Baldardo catchment.

*Priority B. Obtain baseline ecological data (phytobenthos (MI) and invertebrates(SEPA)) on the 5 sub-catchments in the upper Lunan Water. September 2008 and quarterly thereafter.*

9. Baseline trophic diatom index scores have been obtained for the 5 subcatchments being monitored for chemistry and hydrology. An update on Lunan mainstem and loch invertebrate and macrophte ecology has been requested from SEPA.

*Priority C. Identify voluntary measures for implementation on Balgavies and Wemyss catchments, and other Farmer Focus Group farms and apply for SRDP funding (SAC/MI).*

10. Farm walks, to informally appraise diffuse pollution issues in these catchments have taken place on two farms in the Baldardo catchment, with SAC, MI and SEPA staff in attendance. The potential for an SRDP collaborative plan for this catchment has been discussed with farmers and local advisors but SRDP funds are currently frozen.

*Priority D. Obtain calibration data for (a) stage-discharge and (b) turbidity-chemistry relationships in Wemyss and Burnside catchments.*

11. Calibration data for (a) stage-discharge and (b) turbidity-chemistry relationships in Baldardo (Wemyss) and Lemno (Hatton) catchments has been obtained using event based data

*Priority E. Get real time monitoring up and running on Balgavies Burn*

12. Real time monitoring has been established on the Balgavies Burn http://www.macaulay.ac.uk/ECN/lunan_livedata/index.php

*Priority F. Obtain farm specific costing data for compliance with GBR/GAEC and for voluntary measures. (SAC/MI)*

13. Estimates of farm specific costing for compliance with GBR/GAEC and for voluntary measures need to wait till GBR audits are completed.

*Priority G.Agree methodology for estimating internal P loading for Rescobie and Balgavies Lochs (MI/SEPA)*

14. SEPA (Jonathan Bowes) have collected three sediment cores from Rescobie Loch inflows. These will be used with $^{210}Pb$ dating to determine sedimentation rates into the loch. An approach to a paleo-limnology group is being made to explore the potential for using diatoms in sediment cores to infer catchment history.

*Priority H.Explore potential for a P stripping system for a septic tank (eg the caravan site on the Burnside Burn?) (MI/SAC)*

15. A PH D student, Stephen Carr, at Edinburgh University is characterising pH dependence of ochre P sorption equilibria. A column scale pilot system has been developed for experimentation at MI.

*Priority I. Clarify reasons for decline in P loading from upper Lunan Water to Rescobie over the last 8 years (SEPA/MI).*

16. Reasons for decline in P loading from upper Lunan Water to Rescobie over the last 8 years have been sought. This may partly be an artefact caused by changing analytical procedures and sensitivity. Improvements in waste water management in Forfar may be partly responsible. http://www.angus.gov.uk/ccmeetings/reports/planning/pln2000/465.pdf In addition, more recently, an intensive pig farmer in the catchment of the upper Lunan water has recently extensified his management.

*Priority J. Implement agreed voluntary measures with farmer focus group and agree monitoring strategy (SAC/MI/SCRI).*

17. At least one farmer, in addition to the focus farm, has implemented nutrient budgeting in response to advice in focus farm meetings. Another farmer has initiated the use of interrupted tramlines to seek to reduce soil losses from winter cereals on sloping land.

*Priority K. SEPA view (SEPA), Scottish Farmer (SAC) and IWA (MI) articles on progress.*

18. Scottish Farmer and Environmental Focus Farm newsletters (SAC) and IWA (MI) articles have been written and poster presentations made on the Lunan MPC project and groundwater dating aspects at a Knowledge Scotland event at SEPA Stirling, May 2009. UK Adapt carried an article on the Lunan water in its April newsletter. www.uk-adapt.org.uk. A policy brief for Knowledge Scotland on the Lunan Monitored Priority catchment project has been drafted.

*Priority L. Implement spatial cost:effectiveness model for buffer strips in the catchment (MI/SEPA/SAC). See: W:\WP35\352_ Management_Practices\IPS\IP\Bufferstripmodelling.*

19. A framework for analysing spatial cost:effectiveness of buffer strips in the catchment is under construction. This includes estimates of soil P loss and buffer strip efficacy on a field by field basis, a model of crop rotation, estimates of connectivity to water, and an optimisation routine to minimise gross margin loss on a catchment basis to achieve target P load reductions.

*Priority M. Determine equilibrium phosphate concentration of sediments sampled in the 5 subcatchments (MI/SEPA).*

*Other 2008-9 highlights*

20. A user group science update meeting was held on 14 April 2009 in Friockheim attended by about 15 local stakeholders.
21. A Catchment Research Consultancy Group field visit was held on 29 April 2009, attended by representative sof SEPA, SNH, Scottish Government, Fisheries Research Services, Esk Rivers Fishery Trust, Unesco centre, Dundee University, Leeds University and Scottish Water, SAC and Macaulay Institute.
22. A framework for analysing continuous turbidity and water level data sets has been established which allows baseline conditions in 3 subcatchments over the last two years to be established.
23. The relationship between turbidity and storm event chemistry has been established for a number of storm events in the Baldardo catchment, and this process is underway for the Lemno and Burnside catchments. This will eventually allow a paired catchment approach to be taken to assessing impact of General Binding Rules and other mitigation measures.

24. A rapid ecological appraisal in July/August 2008 showed a possibly sub-reference abundance and diversity of in-stream macrophytes and invertebrates. For a lowland agricultural stream there was a relatively unimpacted hydromorphology (cattle poaching was the main issue in reaches studied).
25. A framework for modelling sediment transport in the Lunan Water catchment using INCA-sed has been established.
26. Considering 2 sampling dates in 2007 and 2008, groundwater dating data using CFC and SF6 for 5 boreholes suggest that some of these waters may date from the 1980's or earlier. This has implications for determining the time to recovery and possible future trajectories of groundwater [$NO_3^-$] in response to mitigation.
27. Using the hydrological model STREAM, Sarah Dunn compared to observed data showed leakage to deep groundwater of around 36% , in the subcatchment studied (Baldardo – a sub-catchment above Rescobie Loch, area 2km$^2$) while the sampling position on the main Lunan stem (Kirkton Mill – catchment area 121 km$^2$) showed near complete recovery of excess rainfall in the river.

## 1.Introduction and Regulatory Background

The Monitored Priority Catchments (MPC) project is driven by a need to demonstrate sustainable approaches to catchment management for Scottish water bodies, with particular reference to the Water Framework Directive and to provide a mechanism to assess the efficacy of statutory and voluntary measures to achieve improvement in water quality against regulatory standards. The overall objective is to assess what constitutes effective and proportionate diffuse pollution mitigation in catchments which are (a) representative of typical land uses in Scotland and (b) considered at risk of failing to meet Good Ecological Status under the Water Framework Directive, through implementation of appropriate and agreed measures and pre- and post-implementation monitoring. Two catchments representative of Scottish land use are being used for the project (see Figure 1) - Lunan Water in Angus (selected as a representative of intensive mixed arable production) and the Cessnock Water in Ayrshire (selected as a representative of intensive dairy farming).These were considered to be at risk in the SEPA pressures and impacts report:
(http://www.sepa.org.uk/pdf/publications/wfd/Article_5_Scotland_River_Basin.pdf,

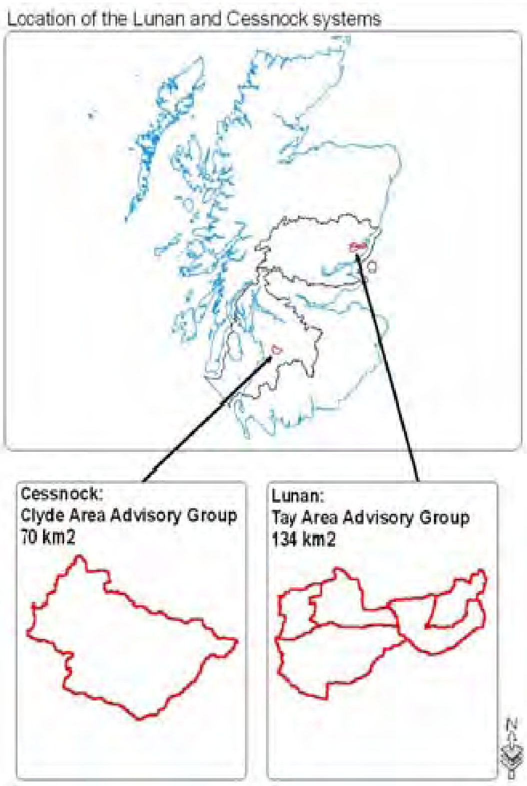



**Figure 1. Monitored priority catchment locations.**

## a) Aims of project

The aims of the project, as set out in the first year report are :

A. To characterise these MPCs using pre-existing and new baseline biogeochemical monitoring, land use and stream morphological data;
B. To identify compliance issues in the MPCs with respect to the achievement of Good Ecological Status under the Water Framework Directive, and other relevant legislation;
C. To agree chemical and ecological targets to achieve compliance;
D. To identify, agree and take forward statutory and voluntary measures by which farmers and other user groups in the MPCs can address diffuse pollution issues;
E. To assess the effectiveness of these measures to mitigate diffuse pollution by means of appropriate biogeochemical monitoring and other data sources;
F. To explore the potential of alternative policy scenarios for achieving both Good Ecological Status in surface waters and groundwater resource protection within a sustainable socio-economic framework.
G. A clarification of these aims with respect to the SEPA Diffuse pollution strategy was established through the year. There is a need to assess the efficacy of the General Binding Rules, within the Water Environment (Diffuse Pollution) (Scotland) Regulations 2008, at achieving Water Quality Targets in priority catchments. It was agreed that this could be achieved by assessing, on a "paired catchment" basis the situation in catchments that are subjected to GBR audits and awareness raising with respect to these regulations, and in control catchments, where no GBR audits and awareness raising took place .

This report provides a summary of progress against these aims in the Lunan Water MPC from September 2008 to August 2009

## b) General Binding Rules

The Scottish Government published The Water Environment (Diffuse Pollution) (Scotland) Regulations 2008. This new legislation is based on widely accepted standards in codes of good practice such as the Prevention of Environmental Pollution from Agricultural Activity (PEPFAA) the Forests and Water Guidelines and the 4 Point Plan.

These new regulations, in the form of General Binding Rules (GBRs) http://www.sepa.org.uk/water/water_regulation/regimes/pollution_control/diffuse_pollution/questions_and_answers.aspx came into force in April 2008. They have amended the Water Environment (Controlled Activities) (Scotland) Regulations 2005 (CAR) by adding seven new GBRs. In addition, a provision in the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 2003 (SSAFO) has been amended to permit lightly contaminated water from farm yards to be drained to constructed farm wetlands.The following farm activities require some form of authorisation from SEPA under the Controlled Activities Regulations, 2008 (CAR).

* storage and application of fertilisers;
* keeping of livestock;
* cultivation of land;
* discharge of surface water run-off;
* construction and maintenance of waterbound roads and tracks;
* application of pesticide;
* operation of sheep dipping facilities.

Much of this activity is covered by the General Binding Rules. Land managers already following good practices will need to take little, if any, further action. Where issues have been identified, land managers will have to decide what changes are needed to comply with the regulations. Altering practices to comply with the diffuse pollution GBRs may be as straightforward as moving a feeding ring 10m away from a burn or keeping 2m back when cultivating next to a watercourse. As well as complying with legislation, these changes should help to improve water quality and may also benefit wildlife. SEPA does not require paperwork, costs or charges to be kept in association with the administration of diffuse pollution GBRs.

Some diffuse pollution GBR inspections will be carried by Scotland's Environmental and Rural Services (SEARS) external link. SEARS involves nine organisations, providing rural services, working more closely together in order to deliver an improved service to land managers. It will be the responsibility of staff from Scottish Government Rural Payments and Inspectorates Directorate (RPID), Forestry Commission and Scottish Natural Heritage to carry out farm visits to assess compliance with the diffuse pollution GBRs. Ultimately, SEARS seeks to reduce the number, complexity, cost and duration of inspections and remove duplication between organisations.

**c) River Basin Planning**

The draft River Basin Plan for Scotland was released for consultation from Dec 2008 to June 2009. This plans consist of four main components(http://www.sepa.org.uk/water/river_basin_planning.aspx):

i. the river basin district plans which gives information on what is planned to protect and improve the water environment for the Scotland and Solway Tweed river basin districts

ii. a series of annexes which provide technical detail on the key aspects of the river planning process

iii. area management plans which supplement the draft basin district plans and provide regional information and describe local actions.

iv. a web-based interactive map powered by a geographical information system (GIS) which offers information on individual rivers lochs, lakes, estuaries, coastal water and groundwater and provides details on the condition of each water body and the proposed environmental objectives for that water body

The map of the Lunan Water catchment (Figure 2) shows that the two Lochs, Rescobie and Balgavies and the upper Lunan Water are of moderate status (yellow) , the Vinny water is of poor status (brown) and the Lower Lunan water and Ghighty Burn are of bad status (red). The River Basin Classification status for the river water bodies in the Lunan catchment is due to water flow and water levels (all water bodies) and chemical status and phytobenthos are both designated as co-limiting for the upper Lunan and Vinny waters. See Tay Draft Area Management Plan, Section 3. http://www.sepa.org.uk/water/river_basin_planning.aspx.

Chemistry data collated for year 1 of this project (see http://www.programme3.net/water/water345pollution.php ) suggested that the chemistry is not limiting for the river water body status, but that both Balgavies and Rescobie Lochs are Poor status with respect to Chlorophyll a and Balgavies is Poor status with respect to Total P as well.


**Figure 2. Screen Dump ofLunan water Catchment from RBMP database.**

## d) Local Catchment Management Planning (S.Esk)

The catchment immediately to the North and East of the Lunan Water has been the subject of a Catchment Management Plan, which is now open for consultation (see [http://www.angusahead.com/LiveAngus/RiverSouthEskCatchmentPartnership/Introduction.asp](http://www.angusahead.com/LiveAngus/RiverSouthEskCatchmentPartnership/Introduction.asp)) . Many of the key issues identified in this document are common to the Lunan Water ,s uch as:

- Diffuse agricultural and forestry pollution (nutrient and sediment loading)
- Point source pollution from inadequate public wastewater discharges (old infrastructure and insufficient treatment e.g. Brechin WwTWs)
- Point source pollution from private wastewater discharges including domestic (septic tanks an secondary treatment plants) industrial and businesses.
- Abstraction during times of low flows can impact on in-stream ecology such as salmonids and freshwater pearl mussels
- Inappropriate river engineering can impair the natural functioning of river systems
- Damage to the physical characteristics of a river that enable it to support the habitats and species it does
- Weirs, culverts etc can impede fish migration
- Fragmentation of riparian woodlands and wet grasslands

- Population declines of water vole, salmon, sea trout, and freshwater pearl mussels

## 2. Liason with stakeholders, users and general public

### a) Farmer focus group meetings

Environmental Focus Farm meetings and Training Events have been organised by carole Christian and others at SAC and held through the year. These have directly involved around 90 farmer-attendences. Formats have included :

- on-farm workshops identifying and evaluating steading mitigations
- Focus Group visits to see and evaluate their neighbours' mitigation ideas
- Focus Group visits to see field-level mitigations outwirth their own catchment
- Talks and workshops on nutrient budgetting for cereals and grass
- Workshops on Soil Erosion Risk assessment

Articles in the trade press have included those published in the Scottish Farmer in Spring and Autumn 2008 and in Farmers Guardian in March 2009. Farmers Weekly has a circulation of approximately 69000 and Farmers Guardian about 52000.
An Edition of the Environmental Focus Farm newsletter was issued in early Spring 2009. (see appendix 10). the distribution lists included around 280 including e-mail and postal subscribers from organisations including The Scottish Parliament, SAC, SG, SEPA, EA, WWF, Councils, SNH, MLURI, FWAG, NFuS, water industry, agricultural suppliers and contractors and, of course, farmers.

Multi-agency meetings have included the Scottish Agricultural Pollution Group, the Catchment Research Consultative Group, the Rural Land Use Working Group and Area Advisory Groups. Attendees have included staff from SEPA, SG, MLURI, Edinburgh University, Scottish Water, NFuS and farmers. Meetings have had a variety of formats including on-farm meeting, farm walks, workshops, seminars and Open Days. The project was represented at SAC's Pilot SRDP Open Day at Auchincruive. In most cases, the Environmental Focus Farm project has been presented and promoted and feedback obtained.

The main outcomes of meetings with Lunan catchment farmers have been awareness about General Binding Rules (came into force in April 2008), nutrient budgets, soil erosion control and pH management. discussion of a menu of BMPs for soil erosion control, completion of erosion risk assessment by farmers on their fields, and awareness of problems for nutrient management of variable soil pH.

<u>July 2008. Visit to Loch Leven.</u>

Lunan Farmer Focus Group visited the Loch Leven catchment. Loch Leven is naturally nutrient-rich but had become adversely affected by over-enrichment. It is now improving considerably due to an ongoing targeted programme of measures impacting on all types of land use within the catchment. Urban sources of phosphate, the target nutrient, as well as P coming from rural housing and from agriculture have all been reduced. As a part of this programme, measures were put into place at Wester Gospetry Farm, now farmed by Mr Angus Bayne, to reduce soil loss into the Greens Burn. Courtesy of Mr Bayne, the Focus Group saw some of these measures and heard how their designs had come about and how they fitted into Mr Bayne's management of the farm.

A soil bund, designed by SAC Environmental, had been sited in the lowest corner of a sloping field that is very erosion prone. The field borders the Greens Burn and a vegetated buffer strip had been established down the full length of the burn as it passed through Wester Gospetry. The bund catches eroding soil before it leaves the field. It has a drain for water and this is led to a soakaway within the buffer strip. The soil is allowed to collect throughout the growing season and is then dug out and re-applied to the field. The value of the soil collected in this way was estimated at the meeting to be approximately £15 per tonne and 50 tonnes on average were collected annually in this one field.

Tied ridging in potatoes. Mr Bayne also showed the group his use of tied ridging in potatoes. This is achieved using a roller post-planting that creates a small "dam" at intervals down each furrow. The dam retains water whether from rainfall or from irrigation having the double benefit of :

- better water penetration reducing the necessity for irrigation in dry periods
- reduced erosive potential

Several of the Focus Group members were interested in this technique and it is hoped that it will be tried out in the Lunan Water catchment in 2009.

Additionally, one of the Focus Group members, Mr Drew Wilson of Greenhead, is trying out his own idea - a novel tramlining technique in cereals that will interrupt the tramlines down their length creating a "dashed line" effect. This too should reduce the erosive power of water in tramlines.

<u>28th October 2008. Liming, Nutrient budgets, Soil Erosion and Soil Erosion Risk Evaluation workshop.</u>

*Harvest yields, soils and pH*

A wet summer and autumn, including over harvest and sowing time, has given some challenges both to Mains of Balgavies farmer Tom Sampson and to the team of specialists looking at Tom's harvest data. The yield meter on Tom's

combine has been augmented by a GPS system that tracks yields as they vary across fields. These data have been integrated with what we already know about nutrient levels across those fields from the soil sampling programme.
There was some considerable variation in pH levels in some fields (Figure 3). The diagram alongside shows two fields tested for pH. Variability has been corrected by variable rate lime applications. A maximum in-field variation of ±0.4 is normal. The optimum pH for growing cereals varies by crop but is around 6.0. Potato growers may have more particular requirements.

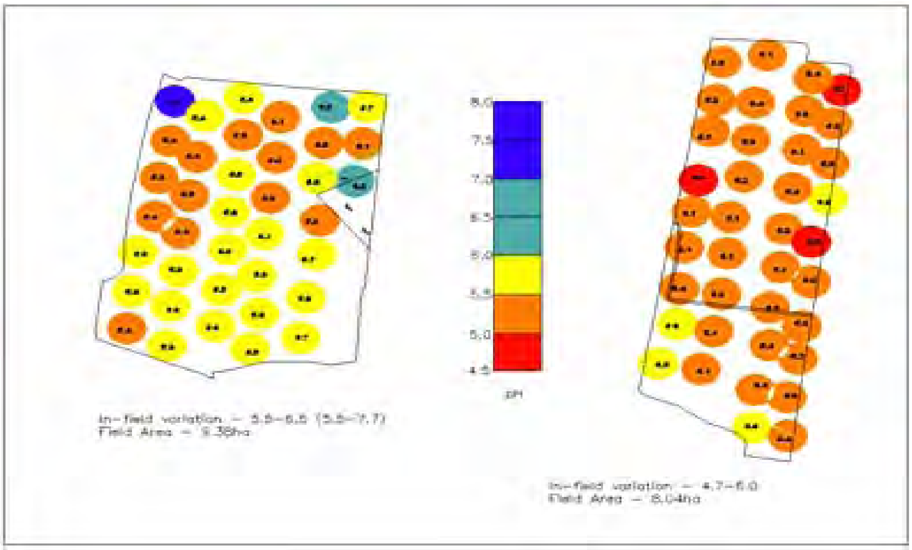



**Figure 3. pH maps of fields in the Mains of Balgavies Focus Farm.**

At meetings, SAC's Alex Sinclair has stressed the importance of paying close attention to liming as, without the correct pH, uptake of nutrients by plants will be ineffective. As a rule of thumb, an increase of 0.1pH can be achieved by applying lime at 1T/ha - up to 18 months may be needed before an effect is measurable.

*Soil erosion index*
As well as analysing for pH and nutrients mentioned above, soils at Mains of Balgavies have been hand-textured. Coarser soils are, in general, more likely to be eroded although it is the finest particles that carry the higher risk once erosion is underway. Along with analysis of slopes on the farm, establishing the soil texture has enabled a Soil Erosion Risk map to be worked out for each field on the farm. This map can be used by Tom Sampson when making decisions about crop placement in high-risk fields. The risk map uses the following elements to be calculated based on input from farmers and soil maps. Slopes , Land use risk, soil texture, Geomorphological erosion risk, Flow path risk. Fig 4 shows a map of the Environmental Focus Farm erosion risk categories. This approach is now being extended to cover other farms in the catchment.

2 March 2009. Farm walk at Baldardo and Wemyss farms.

This reviewed the cultivation and erosion control issues at both farms, including direction of tillage and sowing operations, riparian zone management, removal of field boundaries to extend field size, choice of crop, moving field access points, stream dredging and the use of tied ridging. There is a possibility of having a buffer strip along the stream margin was discussed with both farmers, with a good level of interest.

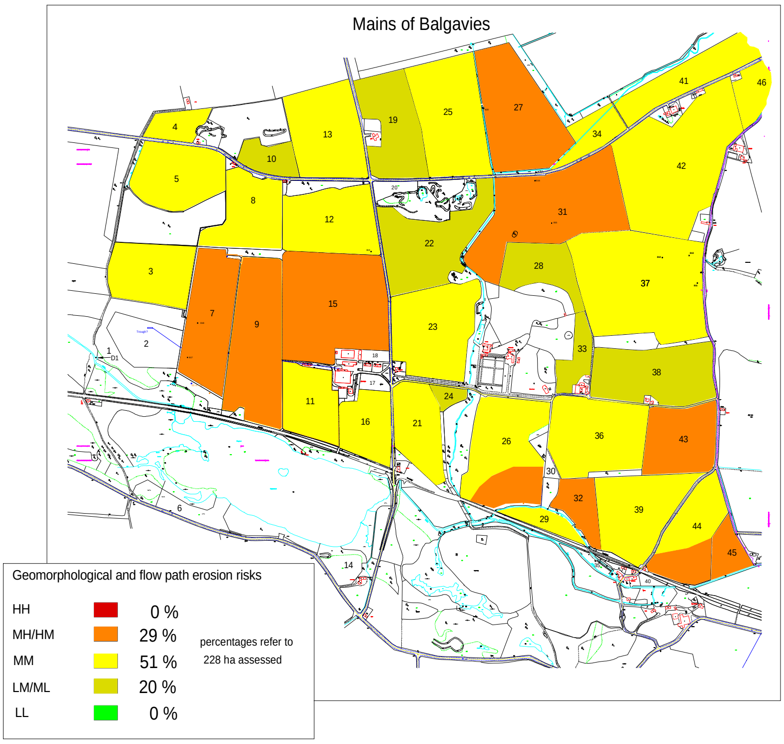



**Figure 4. Map of field-by-field erosion risk on Environmental Focus Farm**

<u>22 April 2009. Soil erosion control.</u>

* Ian Dickson on soil examination and erosion risk assessment, as well as looking at sediment in drains
* Visit to see Drew Wilson's tramlines for soil erosion control (Figure 5)
* Talking about a draft of a Soil Erosion Measures Menu

**Figure 5. Erosion rills on steep sloping winter cereal land . Sections of the tramline have been sown, and reduced erosion from these sections is evident.**

**b) Science progress meeting with user groups**

MLURI ran a series of 4 workshops in the catchment during the spring of 2008. The participants were local anglers (Rescobie Loch within the catchment is a stocked fishing loch), land managers, owners of septic tanks, and residents of the lower reach of the catchment (from the village of Friockheim to the estuary). A workshop was also run with MLURI to compare local knowledge with MLURI scientists' perceptions from working in the catchment.

A science update meeting was held for these user groups on 14 April 2009 in Friockheim. Presentations were made by Anke Fischer; Kirsty Blackstock; Malcolm Coull; Marc Stutter; Martyn Futter and Andy Vinten. It was agreed that a similar update meeting should be held annually during the project lifetime.

**c) CRCG field visit and summary of feedback questionnaire**

On the 29th April 2009, the CRCG met for an informal rapid appraisal of the Lunan Monitored Priority Catchment and to view research projects in the catchment. Attendees are summarised in Appendix A9.:

The aims of the day were:

- To assess the main pressures, impacts and potential mitigation measures in the catchment
- To highlight research aimed at informing approaches to catchment management

The program was as follows.

10:00 Coffee and introduction: Finavon Hotel
10:45 Catchment viewpoint, Turin Hill – diffuse pollution mitigation
11:15 Wemyss: monitoring of pollutant loads
11:45 Rescobie Loch – restoration targets and water values
12:15 Friockheim pond : Stream ecology/morphology
12:45 Lunch
13:45 Boysack Weir – barriers to migration, invasive species
14:15 Inverkeilor bridge viewpoint – Lunan Water & River Basin Planning
15:00 exercise on priorities for bus return
15:30 Refreshments and debrief on priorities

W:\WP35\WP Knowledge Transfer\CRCG09\CRCGho.ppt summarises the details of the day.

Feedback comments included:

- "Whole day very informative – good communication"
- "Excellent day –more of same!"
- "I appreciated the chance to see "on the ground" issues about monitoring and baseline status. River restoration seems to be a key theme for Sustinable Catchment Management. "

**Figure 6a. Top end of Baldardo catchment**

**Figure 6b. Restored mill pond at Friockheim**

**Figure 6c. Jetty at Rescobie Loch**

**d) SAC/SEPA/MI Partnership meetings:**

See Appendix for Agendas and minutes. At the February 2009 meeting it was agreed that Baldardo Burn should eventually be targeted for bespoke measures, after GBR audits and feedback meeting s with farmers had taken place. At the meeting in June 2009 (no minutes) it was agreed that SEPA would provide training for SAC and MI staff in GBR auditing skills, to aid the research agenda of the project.

**e) Septic tank advice**

From 1 April 2006, significant changes to regulations controlling sewage discharges mean that all septic tanks and sewage discharges from domestic properties must be registered with SEPA.

A septic tank leaflet, produced for the Dee Catchment Management Partnership was modified and circulated to residents and stakeholders in the Lunan catchment. The Big Green Septic Tank Guide explains why regular

maintenance is essential to keep septic tanks system safe and working properly and offers tips to keep septic tanks in working order, reducing the number of times they have to be emptied, protecting the environment and saving householders money! See:
http://www.macaulay.ac.uk/news/whatsnew.php

## 3. Monitoring and comparison with environmental standards.

### a) Summary of chemistry data

Figure 7shows the sampling points in the 5 subcatchments of the Lunan Water that have been sampled. The time series (Figure 8) shows that the soluble P standard for good status is only exceeded for two of the subcatchments, Baldardo and Lemn, and this only during the summer and early autumn. Annual mean chemistry data for 2007/8 and 2008/9 are given for the spot sampling points at the outlets of the five catchments monitored in Table 1.

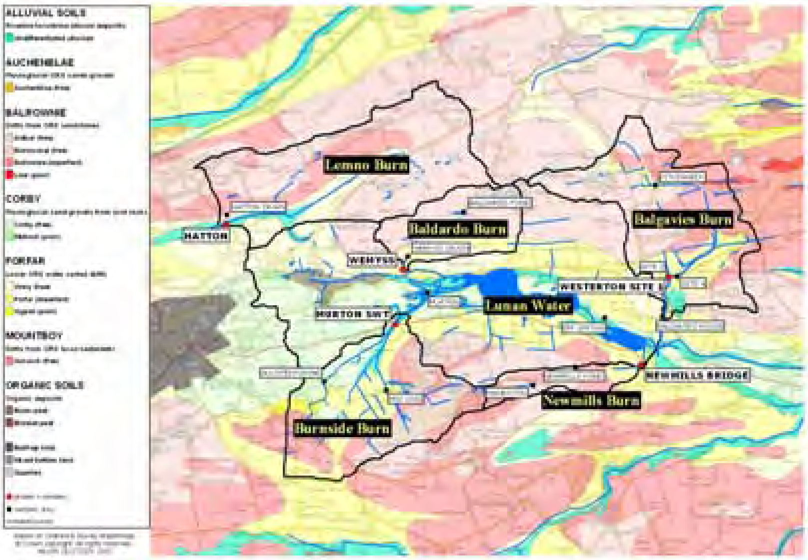



**Fig 7. Sampling points in the Lunan Water subcatchments.**

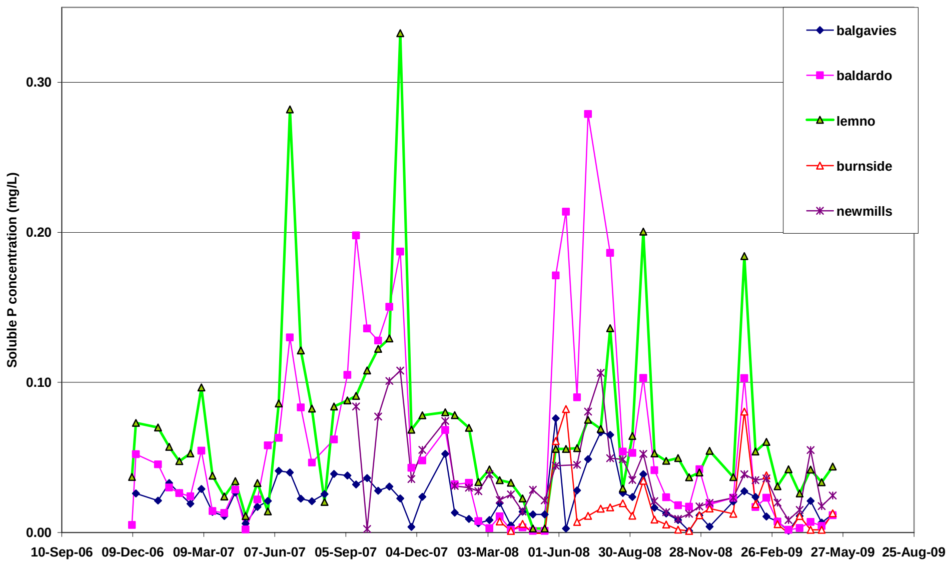



**Figure 8. Time series of spot soluble P concentrations in monitored subcatchments of the Lunan Water**

The total P content has been estimated for selected storm events using a persulphate digest. An example of a winter storm event (Figure 9) shows that even during such events , soluble P concentration only rises to just over the good status limit. Total P loads for such events are generally much greater than soluble P loads.

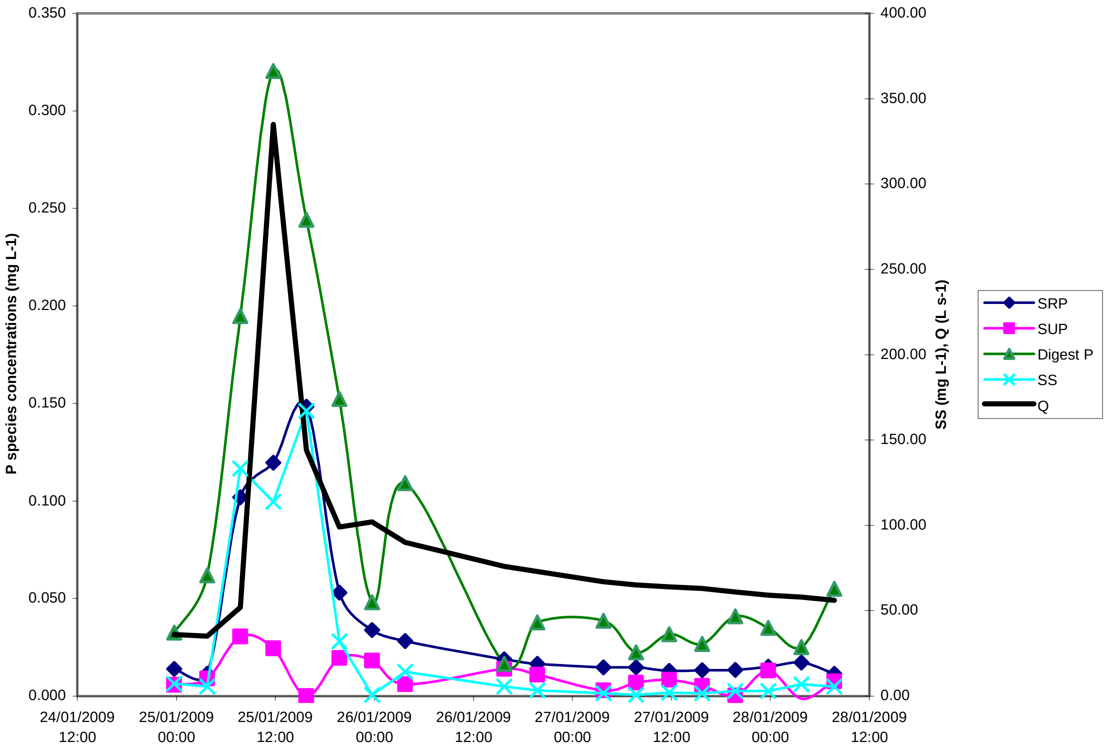



Figure 9. Soluble reactive P, Total digested P, suyspended solids and discharge during winter storm event at Wemyss, Baldardo Burn

b) **Estimating pollutant loads using continuous turbidity and other data.**

To achieve estimates of current and future pollutant loads, especially total P loads, to Rescobie Loch and the rest of the Lunan catchment from the 5 subcatchment monitoring stations, we need to assess if we can we derive accurate estimates of SS and total P loads using either:

(i) high resolution turbidity monitoring data, high resolution flow data, calibrations of SS and total P against turbidity, or

(ii) coarse resolution direct measured SS and total P samples with high resolution flow data

Table 2. give a summary of turbidity data collected for the 3 Lunan subcatchments. Poor calibrations have been gained using regular fortnightly grab samples of SS against turbidity (see Fig 10). This is due to grab samples being

biased to base flow conditions. At Wemyss, for example, no grab samples were collected at greater than 80 NTU or 17 mg/L SS.

3 storms sampled during winter 2008/09 at Wemyss on the Baldardo Burn with SS, particulate P determined by persulphate digest of GFC paper and total P (particulate plus total filtered P). These are summarised in Table 3.

Regression between log(SS) and log (turbidity), log(TP) and log (turbidity), log(particulate P) and log (turbidity), and log(turbidity) against log(flow) were good for two individual storms (Dec 2008 and Jan 2009), and for combined storms, but the Feb storm did not generate high TP or particulate P, even with increased SS and turbidity. The releationship between turbidity and total P was better than for turbidity and particulate P, especially for the January storm. Where the calibrations were made between separated periods of hydrograph rise and fall, there was a stronger correlation with rising limb data that with falling limb data. The relationships against turbidity were better than against discharge. Results of this analysis are summarised in Table 4.

**Figure 11. Calibration of turbidity against weekly spot samples.**

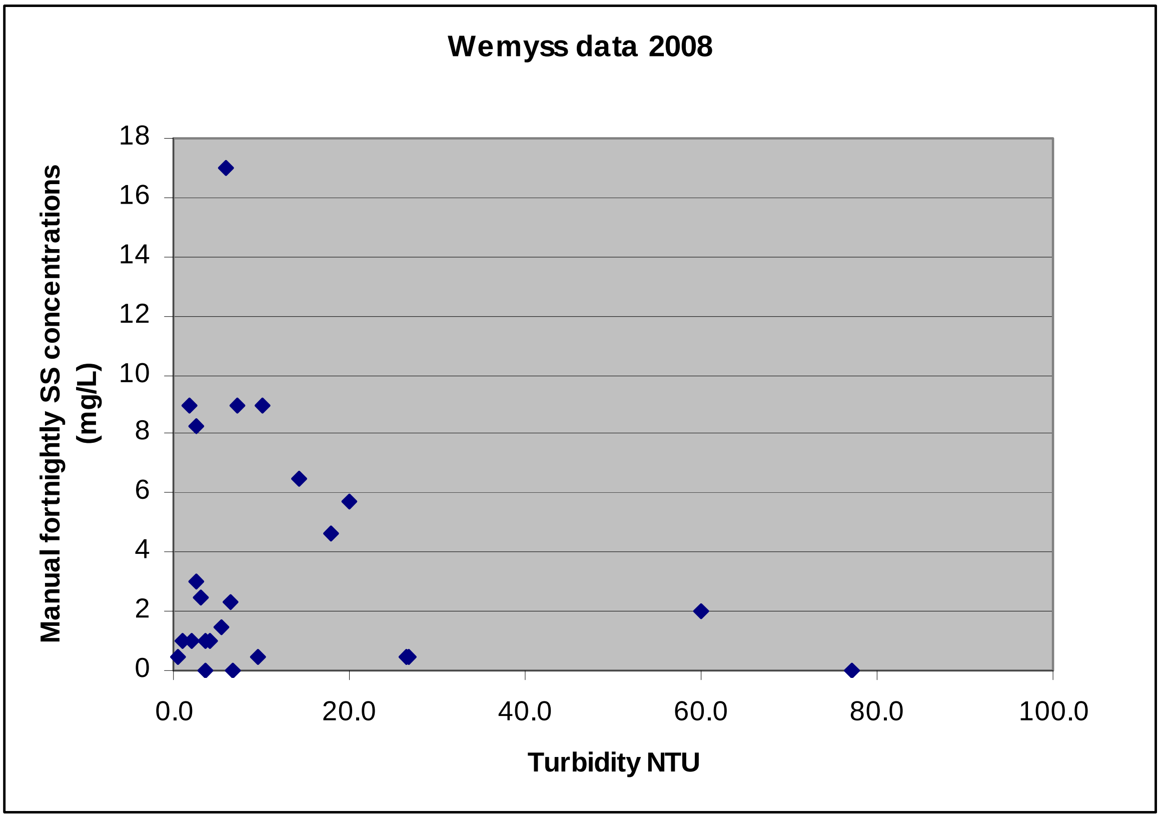


**Table 1.** Summary of sub-catchment outlet chemistry data for April2007 to Mar 2008 and April 2008 to Mar 2009

| Catchment | N | period | Sus.Solids mg/L | pH | EC µs/cm | $NH_4$-N mg/L | $NO_3$-N mg/L | Total N mg/L | $PO_4$-P mg/L | Total soluble-P mg/L | DOC mg/L | Alkalinity mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Balgavies | 25 | Apr 07- Mar 08 | 4.4 | 7.8 | 341.4 | 0.023 | 7.0 | 7.6 | 0.024 | 0.035 | 3.3 | 98.2 |
| Balgavies | 25 | Apr 08- Mar 09 | 5.2 | 7.7 | 370.4 | 0.055 | 6.7 | 7.3 | 0.023 | 0.035 | 4.3 | 93.3 |
| Baldardo | 24 | Apr 07- Mar 08 | 2.6 | 7.8 | 332.6 | 0.038 | 8.3 | 9.2 | 0.069 | 0.096 | 3.7 | 98.1 |
| Baldardo | 47 | Apr 08- Mar 09 | 4.6 | 7.8 | 334.8 | 0.055 | 8.0 | 8.8 | 0.067 | 0.088 | 5.0 | 95.5 |
| Lemno | 25 | Apr 07- Mar 08 | 3.2 | 7.8 | 365.0 | 0.060 | 11.2 | 12.5 | 0.086 | 0.130 | 2.9 | 97.9 |
| Lemno | 49 | Apr 08- Mar 09 | 6.8 | 7.8 | 377.5 | 0.056 | 11.2 | 12.2 | 0.074 | 0.112 | 3.2 | 94.6 |
| Burnside | | Apr 07- Mar 08 | | | | | | | | | | |
| Burnside | 24 | Apr 08- Mar 09 | 9.9 | 7.9 | 366.3 | 0.039 | 6.6 | 7.0 | 0.019 | 0.027 | 2.6 | 95.6 |
| Newmills | | Apr 07- Mar 08 | | | | | | | | | | |
| Newmills | 24 | Apr 08- Mar 09 | 3.8 | 8.0 | 371.3 | 0.036 | 10.3 | 11.0 | 0.034 | 0.046 | 2.2 | 88.5 |
| | | | | | | | | | 0.024 | 0.035 | | |
| Lunan | 12 | Sep 07-May08 | 4.2 | 7.7 | 399.4 | 0.1 | 3.5 | 3.8 | 0.023 | 0.035 | 2.5 | |

**Table 2. Summary of turbidity data collected for 3 Lunan sub-catchments**

| | **Hatton (Lemno Burn)** | **Wemyss (Baldardo Burn)** | **Westerton (Balgavies Burn)** |
|---|---|---|---|
| **2007** | 400 NTU<br>Aug started, then to end of Nov good.<br>Dec very poor | Poor through 2007 | |
| **2008** | 22feb-15apr OK<br>May poor, Jun-Jul OK<br>Oct-Dec OK | 1000 NTU<br>18/3/08 onwards<br>Good 60 mins | 1000 NTU<br>Good up to late summer.<br>Poor throughout autumn. |
| **2009** | 400 NTU<br>60 min data okay | 1000 NTU<br>60 min data good | 1000NTU<br>60 min data jumps up and down a lot |

**Table 3. Summary of storm event data collected for chemistry-turbidity calibration, 2008/9.**

| Storm date | Q range (L/s) | NTU range | SS range (mg/L) | Particulate P range (mgP/L) |
|---|---|---|---|---|
| 4-9/12/08 | 26-87 | 1-139 | 1-31 | 0.002-0.136 |
| 24-28/1/09 | 36-335 | 4-448 | 1-167 | 0.022-0.320 |
| 14-17/2/09 | 12-43 | 12-360 | 4-54 | 0.025-0.183 |

**Table 4. Summary of regressions for the 3 storms, for use in estimating P and SS loads from turbidity time series**

| | | SS vs turbidity | Particulate P vs turbidity | Total P vs turbidity |
|---|---|---|---|---|
| Dec storm (n=19) | Gradient<br>Intercept<br>$R^2$ | 1.34<br>-1.25<br>0.60 ($p \leq 0.001$) | 0.79<br>-2.45<br>0.48 ($p \leq 0.001$) | 0.58<br>-1.67<br>0.75 ($p \leq 0.001$) |
| Jan storm (n=18) | Gradient<br>Intercept<br>$R^2$ | 0.90<br>-0.41<br>0.56 ($p \leq 0.001$) | 0.52<br>-1.97<br>0.68 ($p \leq 0.001$) | 0.50<br>-1.74<br>0.79 ($p \leq 0.001$) |
| Feb storm (n=18) | Gradient<br>Intercept<br>$R^2$ | 0.30<br>0.55<br>0.10 (ns) | 0.05<br>-1.14<br>0.00 (ns) | 0.04<br>-0.98<br>0.01 (ns) |
| Combined (n=54) | Gradient<br>Intercept<br>$R^2$ | 0.94<br>-0.64<br>0.54 ($p \leq 0.001$) | 0.52<br>-2.05<br>0.46 ($p \leq 0.001$) | 0.34<br>-1.48<br>0.46 ($p \leq 0.001$) |
| Combined rising (n=18) | Gradient<br>Intercept<br>$R^2$ | 0.70<br>0.07<br>0.80 ($p \leq 0.001$) | 0.42<br>-1.72<br>0.71 ($p \leq 0.001$) | 0.36<br>-1.38<br>0.72 ($p \leq 0.001$) |
| Combined falling (n=36) | Gradient<br>Intercept<br>$R^2$ | 0.91<br>-0.75<br>0.48 ($p \leq 0.001$) | 0.52<br>-2.12<br>0.39 ($p \leq 0.001$) | 0.28x<br>-1.45<br>0.32 ($p \leq 0.001$) |

Regular fortnightly sampling through 2007-08 has not captured high enough flow, SS and turbidity events to enable load calculations. Regression relationships for sediment or total P are much better against turbidity than against discharge, so high resolution turbidity data (and not direct flow relationships) have been used for SS and total P load calculations, using the regression relationships in Table 4. . Storm events in winter 2008/09 have considerable range in gradients for SS and total P against turbidity. There should be caution with using a single calibration of turbidity for these determinants to quantify errors in estimates. The best approach may be to split the hydrograph between rising and falling limbs and calibrate each period separately, this particularly improves the calibration on the important rising limb when SS and total P concentrations are greatest (due to positive concentration, Q hysteresis).

c) **Assessment of baseline turbidity and TP loads from Baldardo catchment to Rescobie Loch.**

The idea of this work is to use event turbidity and discharge data directly to assess if changes occur post- GBRs uptake, following a paired catchment approach (eg. Bishop et al., 2005). As a first step, we wish to know what magnitude of change in turbidity loading will be needed, using data from the Lemno (Hatton station) as a control, and from the Baldardo (Wemyss station) as a site that will receive "treatment".
Discharge at Hatton on the Lemno has been estimated using a stage discharge calibration, after correction for the relationship between stage measured and waterlevel recorded by the diver system, Discharge at Wemyss on the Baldardo Burn was estimated by the AV/FM method by Christian Birkel, using an acoustic Doppler system on an ISCO automsampler, and water level data at Hatton on the Lemno, for the same period. However because of missing data on the Wemyss Diver dataset, we have used Hatton data , scaled by area, to estimate discharge at Wemyss.

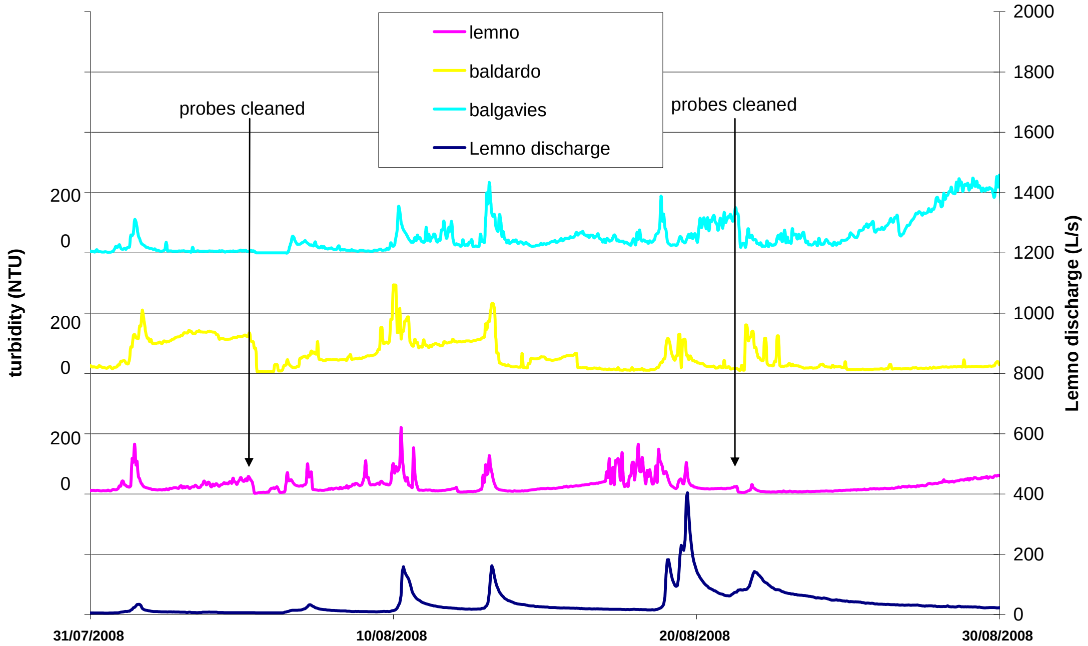



**Figure 12. Examples of turbidity and discharge data for Lunan Water subcatchments.**

Figure 12 shows example turbidity traces for 3 sites and discharge at Hatton, on the Lemno (control sub-catchment). The data show the tendency of the baseline on the probes to drift, and also the effect of cleaning during the approximately fortnightly site visit. Stream turbidity events have been identified by eye, using a rise above baseline to indicate start of an event, and either a return to baseline or a return to baseline flow, or a new event, to indicate the end of an event. This process has generated 111 events over the period from 29/6/07 to 19/2/09. Our aim was to use a paired catchment approach to analyse the data, by assuming that Lemno catchment would act as a control, in which no intervention takes place. A linear regression between the paired concentration datasets shows an $r^2$ of only 0.069. Multiple regression analysis of the concentration data, using mean and peak discharge as additional variates, will follow.

Inspection of the data shows that there are often significant turbidity events unassociated with flow on the Lemno, which are overemphasised in concentration based data analysis. However, the correlation between loads ($r^2$=0.65) on the paired datasets is much better than that between concentrations. Since it is estimation of pollutant loads, and the effect of mitigation measures on loads, that is important for this project, we can use this information to assess how much the slope of the relationship beween loads between catchments would need to change for an effect to be evident. For the October to March period, when soils are at field capacity and therefore results are less prone to seasonal effects, the correlation is a little better (r2 = 0.68). Figure 13 shows the relationships between log(turbidity loads) for the paired subcatchments in autumn/winter for 2007/8 and 2008/9.

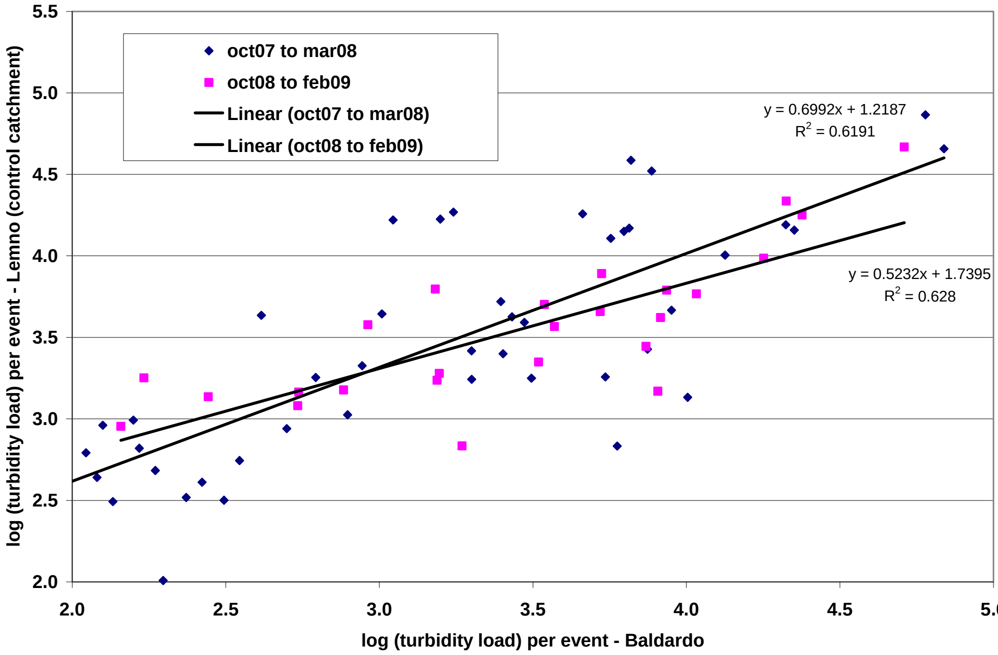



**Figure 13. Log-log plot of turbidity load for paired events on Lemno and Baldardo catchments.**

This information can be used to assess the change in slope of this relationship which will be needed for effects of mitigation measures to be significant. This assessment is in progress.

Estimates of mean turbidity, discharge, total P concentration and total P loads have been made on a quarterly basis for three subcatchments (see table 5). These show that mean total P concentrations and turbidity tend to be highest in autumn, but that overall loads of total P in the catchments are modest. For example, we estimate a total current annual load of 60 kg TP. This is split about evenly between soluble and particulate P.

***Rescobie Loch TP and observed estimates of TP loads:***

In the 2007/8 annual report, we used the Vollenweider equation to calculate implied TP loads from the catchment,if there were no internal loading. We estimated a mean TP loading to Rescobie of 0.27 kg/ha of catchment or 9.3 kg/ha of Loch or 550 kg P (range 461-658 kg) overall would be needed to explain Loch chemistry (see Annual report 2007/8). On the basis of catchment area, the pro-rata contribution from Baldardo, if we were to consider all loads to be external, would be 66 kg TP (range 55-79). Using the turbidity vs total P and turbidity vs particulate P calibrations , we estimate the annual TP load in 2008 to be 60 kg TP. This is about evenly split between total soluble P and particulate P. Methods for assessing the uncertainty in such estimations of loads are under development with BIOSS. However, results suggest that the loading estimation method using turbidity generates realistic estimates of P loads.

d) **Rapid ecological appraisal.**

Five reaches were assessed for aquatic invertebrate and macrophyte ecology, riparian vegetation, riparian morphology and reach type, and diffuse pollution. Fig 14 shows an example of morphological assessment for Reach 3:

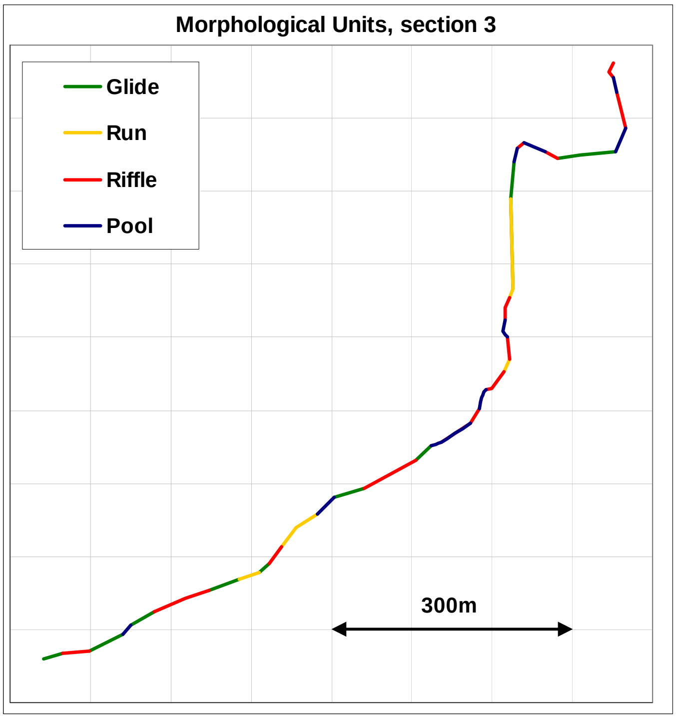



**Figure 14. Example of reach hydro-morphological characterisation**

| | | Baldardo (2.4 km$^2$) | | | Balgavies (5.9 km$^2$) | | | Lemno (7.1 km$^2$) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| average turbidity(NTU) | | 2007 | 2008 | 2009 | 2007 | 2008 | 2009 | 2007 | 2008 | 2009 |
| | 1 | | 30 | 35 | | 22 | 45 | | 42 | 26 |
| Quarter | 2 | 44 | 26 | | 20 | 4 | | 20 | 37 | |
| | 3 | 63 | 37 | | 37 | 62 | | 37 | 32 | |
| | 4 | 57 | 58 | | 54 | 102 | | 54 | 40 | |
| Average discharge (L/S) | | | | | | | | | | |
| | 1 | | 26 | 28 | | 49 | 50 | | 37 | 50 |
| Quarter | 2 | | 37 | | | 15 | | | 32 | |
| | 3 | 17 | 58 | | 33 | 22 | | 33 | 40 | |
| | 4 | 30 | 35 | | 44 | 40 | | 44 | 26 | |
| average [TP] (mg/L) | | | | | | | | | | |
| | 1 | | 0.109 | 0.131 | | 0.087 | 0.159 | | 0.133 | 0.116 |
| Quarter | 2 | | 0.015 | | | 0.052 | | | 0.044 | |
| | 3 | 0.115 | 0.020 | | 0.091 | 0.129 | | 0.091 | 0.056 | |
| | 4 | 0.078 | 0.073 | | 0.111 | 0.145 | | 0.111 | 0.170 | |
| TP load kg/quarter | | | | | | | | | | |
| | 1 | | 22 | 28 | | 33 | 62 | | 38 | 45 |
| Quarter | 2 | | 4 | | | 6 | | | 11 | |
| | 3 | 15 | 9 | | 24 | 22 | | 24 | 17 | |
| | 4 | 18 | 20 | | 38 | 45 | | 38 | 35 | |
| | | **total** | **60** | | **total** | **106** | | **total** | **102** | |

**Table 5. Estimates of quarterly mean turbidity (NTU), discharge, instantaneous load and total loads of TP (kg) for the outlets of 3 sub-catchments**

**Main observations were :**

- Possibly sub-reference abundance and diversity of in-stream macrophytes and invertebrates
- Relatively unimpacted hydromorphology (Figure 16 b, c) for a lowland agricultural stream (cattle poaching was the main issue in reaches studies (Figure 15a))
- Advantage of process-based approach to HM assessment is ability to explain changes in channel morphology and predict effects of factors influencing sediment budgets

For more detail, see:

W:\WP35\352_Management_Practices\Results\Lunan Water\

(a)

b)

c)

**Figure 16.Examples of (a) highly impacted and non-impacted (b),(c) banksides and riparian zones, in the middle reaches of the Lunan Water**

## e) Trophic diatom index.

The limiting status of phytobenthos in the Tay Area Management Plan suggested we should undertake phytobenthos determinations in the subcatchments being monitored for discharge and chemistry. Scrapes were made from pebbles, gravel or fine sediment. Up to 200 diatoms were identified to species or genus level and these were scored using the scoring method of Kelly and Whitton, (1995). A summary of results is given in Table 6 for autumn 2008 and spring 2009. The detailed species list is given in Appendix A7. .

Table 6. Trophic diatom Index scores for Sampling sites in upper Lunan Catchment using the system of Kelly (1998).

| subcatchment | site | grid reference | 30/09/2008 | 30/04/2009 |
|---|---|---|---|---|
| Lemno | HATTON | 974318 | 72 | 67 |
| Lemno | HATTON SOURCE | 974319 | 45 | 39 |
| Baldardo | WEMYSS | 974320 | 79 | 74 |
| Balgavies | PITKENNEDY | 974321 | | 63 |
| Balgavies | WESTERTON 1 | 974322 | 67 | 80 |
| Balgavies | BALGAVIES | 974323 | 48 | 36 |
| Newmills | NEWMILLS BRIDGE | 974324 | 39 | 62 |
| Newmills | FINNESTON | | 46 | |
| Burnside | MID DOD | 974325 | 68 | 82 |
| Burnside | AUCHTERFORFAR | 974326 | | 62 |
| Burnside | MURTON | 974327 | 77 | 50 |

## f) Sediment traps

## g) Modelling hotspots

Jonathan Bowes of SEPA is calibrating a tillage and water related soil erosion model against field Cs137 tracer data from the Baldardo catchment. He has conducted an intensive campaign (+/- 50 cores/field) at three fields in the Lunan Water to determine soil erosion using radioactive tracers. Erosion rates of up to 15 tonnes soil/hectare/year have been observed. Data from the field campaign have been linked to a soil erosion model. Observation and modelling results show that Baldardo field is a hotspot for sediment export. There are deepened tram-lines throughout the catchment, and it is possible that this one field exports 25% of the annual TP load to the loch. Modelling results suggest that changing flowpaths through the field by digging a ditch around the field could reduce sediment yield by as much as 17%. This one action could have a noticeable effect on loch [TP]. See also: Ballantine, D.J., and Bowes, J.P. (2008). Nutrient and

sediment export from a small catchment in angus, Scotland. In: Land Management in a changing Environment. SAC/SEPA Agriculture and the Environment Conference VII, Edinburgh, March 2008. Crighton, Audsley, R. (eds) p201.

### h) Modelling catchment sediment transport using INCA-sed

A prototype application of INCA-Sed has been made to the Lunan Water catchment in eastern-Scotland. The Lunan Water is a small (140 $km^2$) agricultural catchment typical of those in Eastern Scotland. Land use is dominated by intensive agriculture. The Lunan Water is adversely affected by elevated suspended sediment loads from agriculture and peri-urban development.

Long-term monitoring of water quality has been conducted by the Scottish Environmental Protection Agency (SEPA) at three sites in the catchment (figure 5): above Rescobie Loch (1), below Balgavies Loch (2) and at Kirkton Mill (3). SEPA maintains a flow gauging station at Kirkton Mill, from which daily flow records are available. For the purposes of this simulation, the catchment was divided into four reaches (Figure 17). The area above Rescobie Loch is semi-natural (reach 1), containing several large wetlands. Rescobie and Balgavies Lochs (reach 2) may attenuate large amounts of sediments from the surrounding arable lands. The area between the lochs and Kirkton Mill (reach 3) is dominated by arable agriculture and there has been considerable hydromorphological alteration of the stream bed. Between Kirkton Mill and the sea (reach 4) flows become slower and the river channel is constrained by berms.

Preliminary INCA-Sed simulations have been able to satisfactorily reproduce flows (Figure 18) and suspended sediment (Figures 19a-d) concentrations in the Lunan Water. These preliminary simulations should be considered as interim. The model is able to capture the timing of sediment peaks but further work is required to better simulate their magnitude. The model works better in Kirkton Mill (Figure 19c) than it does at the top of the catchment (Figure 19a).

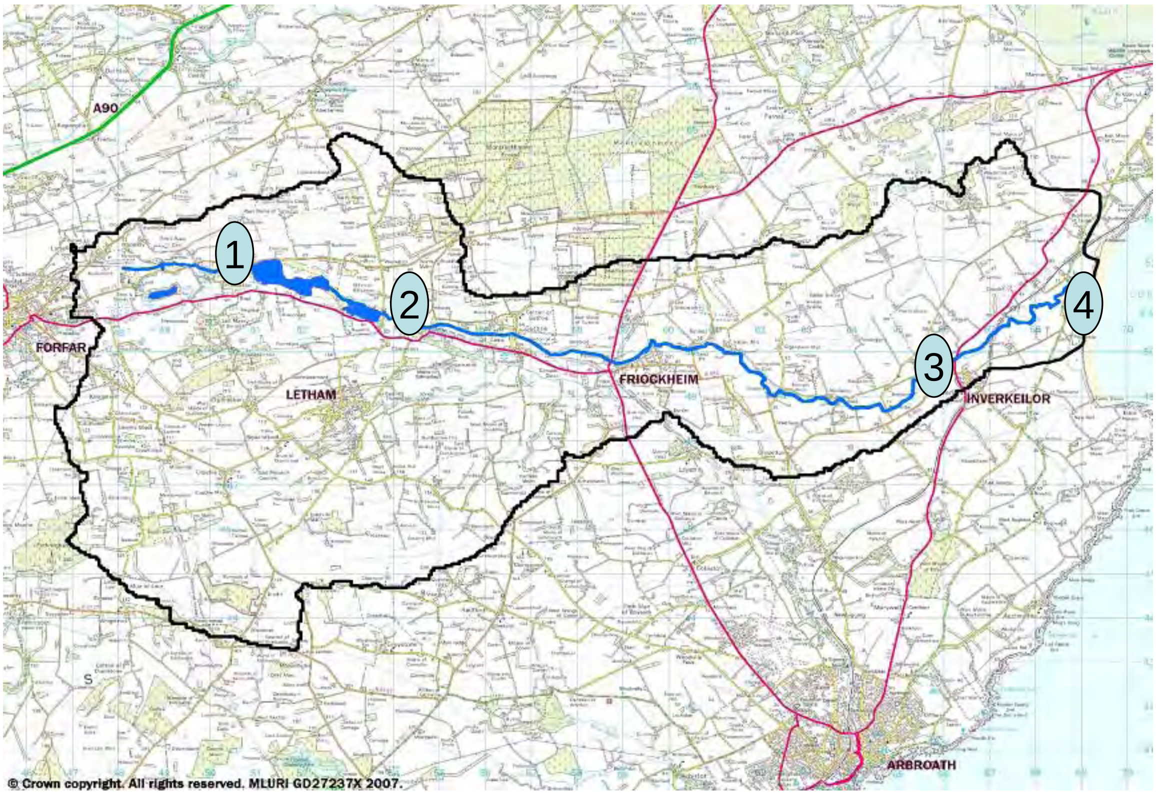



**Figure 17: Map of the Lunan Water catchment showing reach modelling points (1) Upstream of Rescobie Loch, (2) downstream of Rescobie Loch, (3) Kirkton Mill and (4) the sea.**

Further work is required to assess parameter sensitivity within the model and to refine estimates of the effects of agricultural practice on sediment production and delivery. Additional work is required to determine the different controls on sediment production, transport and delivery in semi-natural, peri-urban and agricultural catchments.

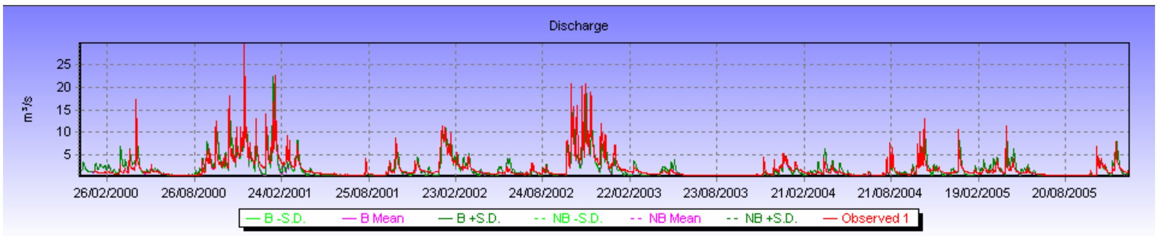



**Figure 18: Observed (red) and modelled (green) flows at Kirkton Mill (site 3).**

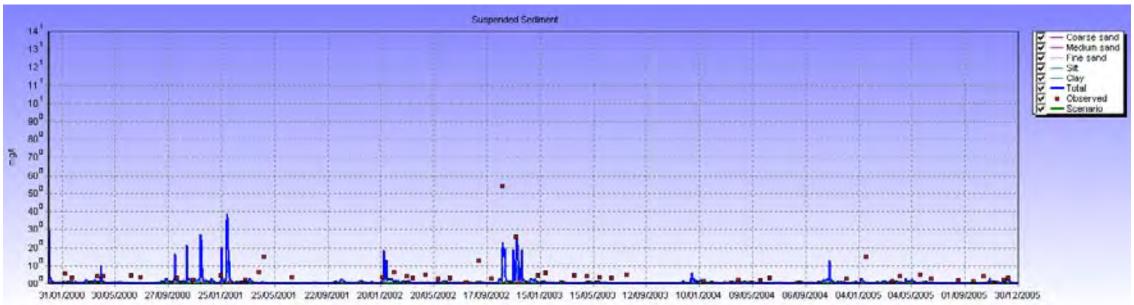



**Figure 19a) INCA-Sed simulation at reach 1, upstream of Rescobie Loch**

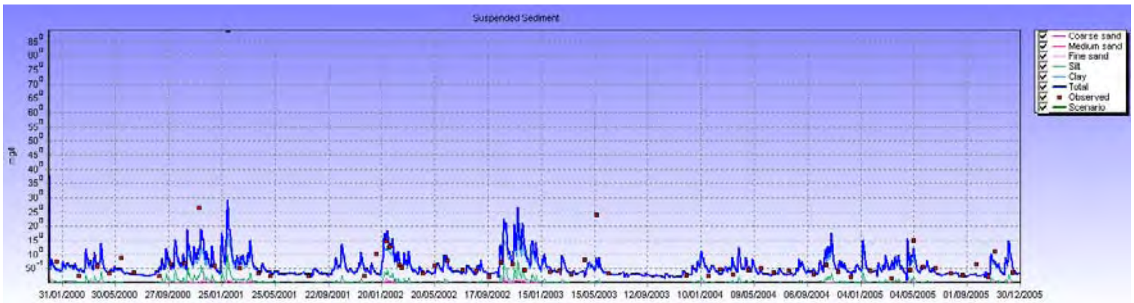



**Figure 19b) INCA-Sed simulation at reach 2, downstream of Rescobie Loch**

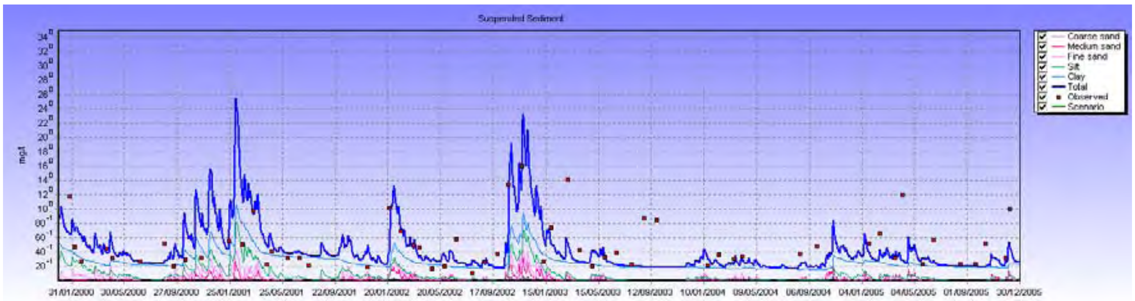



**Figure 19c) INCA-Sed simulation at reach 3, Kirkton Mill.**

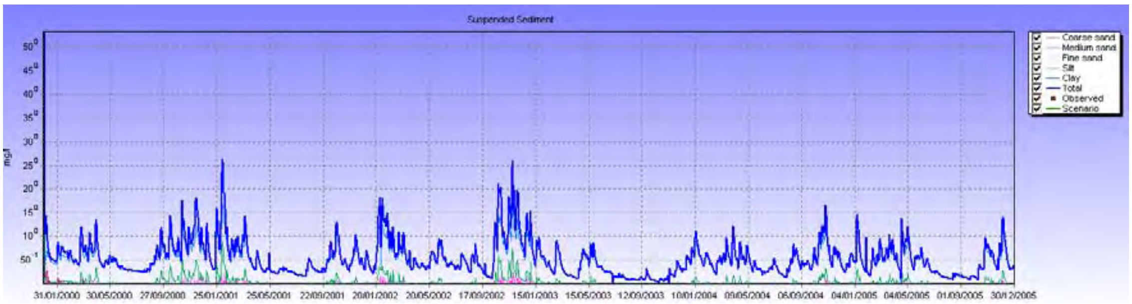



**Figure 19d) INCA-Sed simulation at reach 4, river outflow to the sea.**

### i) Loch internal sources

A query was raised in the 2007/8 report about whether the high outlet concentrations from Rescobie Loch are due to historic rather than current sources. Investigation of this issue requires:
(i) assessment of historic inputs from sewage, prior to upgrading of sewage treatment facilities at Lunanhead. This is ongoing, but it appears that the

frequency with which the pumping system to divert stormflow into the Lunan water at Lunanhead would be too low to explain these results (John Shabeshow, SEPA, personal communication). Moreover there is some possibility that the downward step between 2001 and 2002 in the inlet analytical data for soluble P at Rescobie Loch might be due to a change in analytical procedures
(ii) assessment of sediment cores with respect to dating of sediment with $^{210}Pb$ and analysis of diatom species in the sediment to assess historic trophic status. Jonathan Bowes (SEPA) has collected three sediment cores from Rescobie Loch inflows. These will be used with $^{210}Pb$ dating to determine sedimentation rates into the loch. In addition, Martyn Futter is looking into the possibility of obtaining diatom cores for Rescobie Loch. Relevant other work includes Grieve and Gilvear (2006).

### j) Groundwater quality and dating

SEPA is maintaining five boreholes in the catchment. Some of these consistently have $[NO_3^-]$ at or above the NVZ target. See Figure 20.

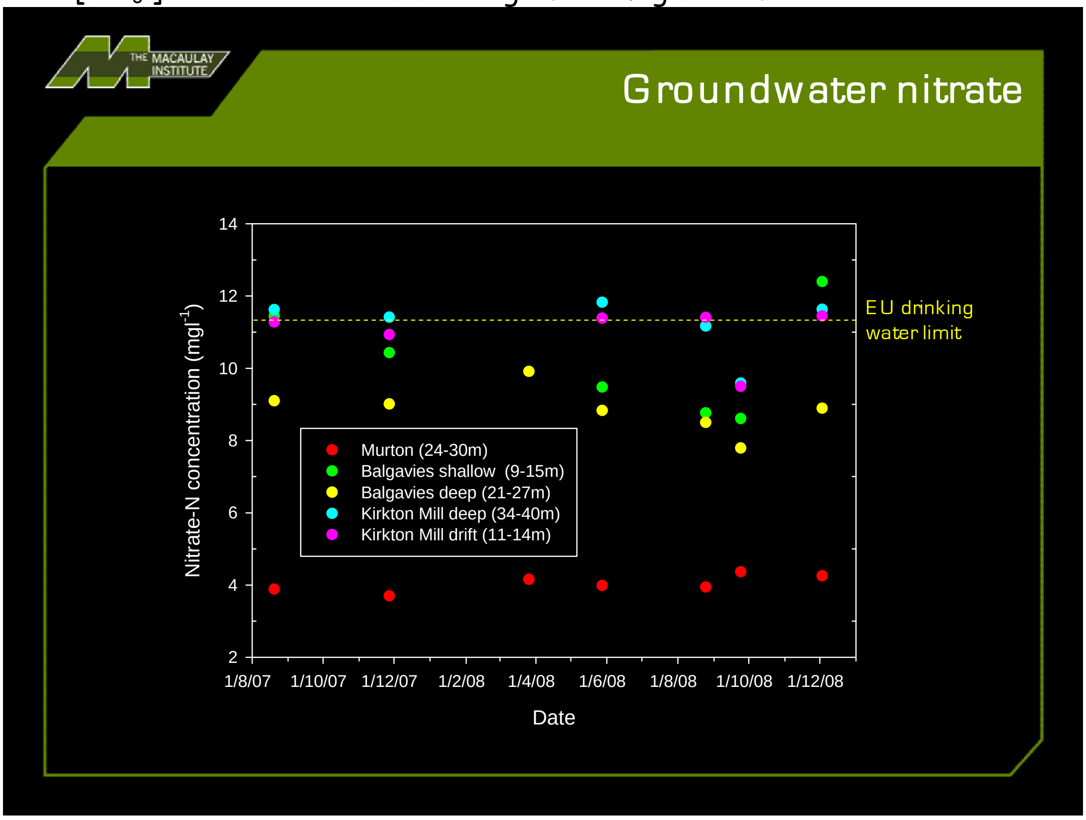



**Figure 20. NitrateN concentrations in boreholes in Lunan Water catchment.**

Sarah Dunn (MI) is dating this groundwater using CFC and SF6 for 5 boreholes and the stream at Kirkton Mill. Known historic changes in atmospheric mixing ratios of different gases can be used to date the age of groundwater from measured concentrations. Considering 2 sampling dates in 2007 and 2008, the data suggest that some of these waters may date from the 1980's or earlier.

This has implications for determining the time to recovery and possible future trajectories of groundwater [$NO_3^-$] in response to mitigation.

In addition, Sarah Dunn is using Daily δ18O and δ D in rain and stream water to analyse leakage and dynamics of flow pathways and residence times of surface and groundwater in the catchment. This shows that some summer storm events give rapid transfer of precipitation signatures to streamwater, but the system is much more damped during winter.

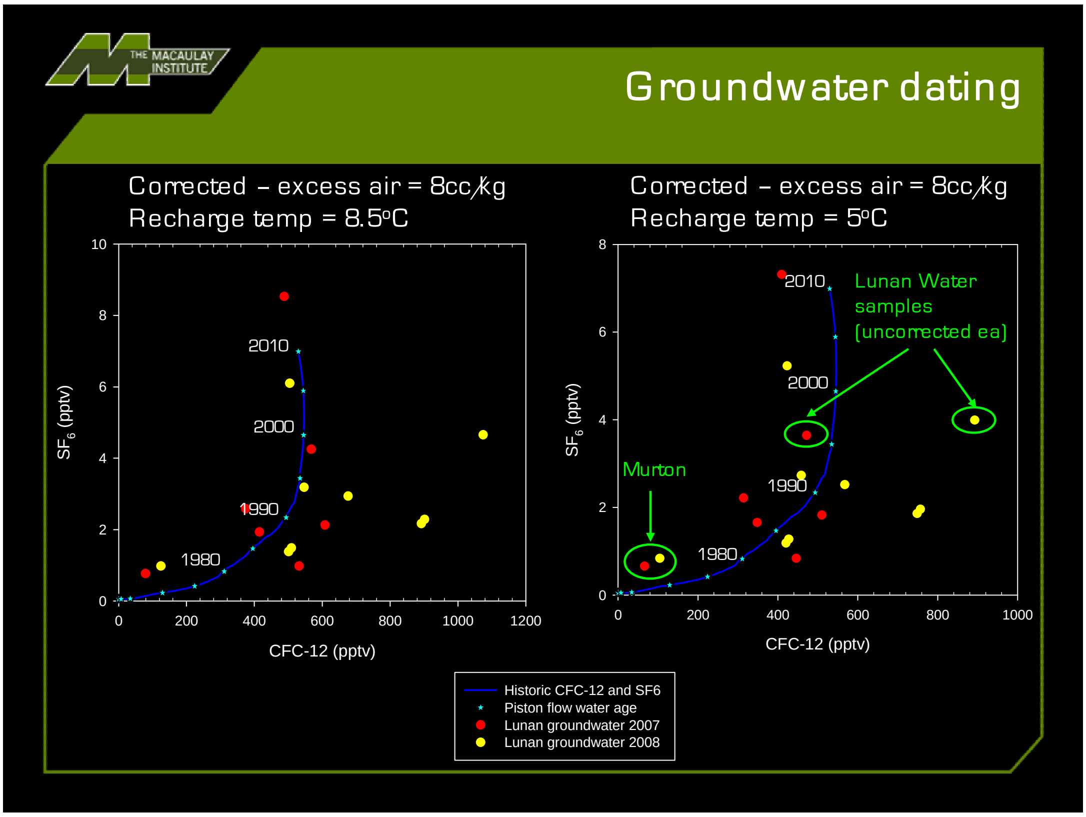



**Figure 21. Estimation of groundwater sample age from $SF_6$ and CFC content of water.**

*Catchment leakage*

Using the hydrological model STREAM, Sarah Dunn compared to observed data showed leakage to deep groundwater of around 36% , in the subcatchment studied (Baldardo – a sub-catchment above Rescobie Loch, area 2km$^2$) while the sampling position on the main Lunan stem (Kirkton Mill – catchment area 121 km$^2$) showed near complete recovery of excess rainfall in the river.

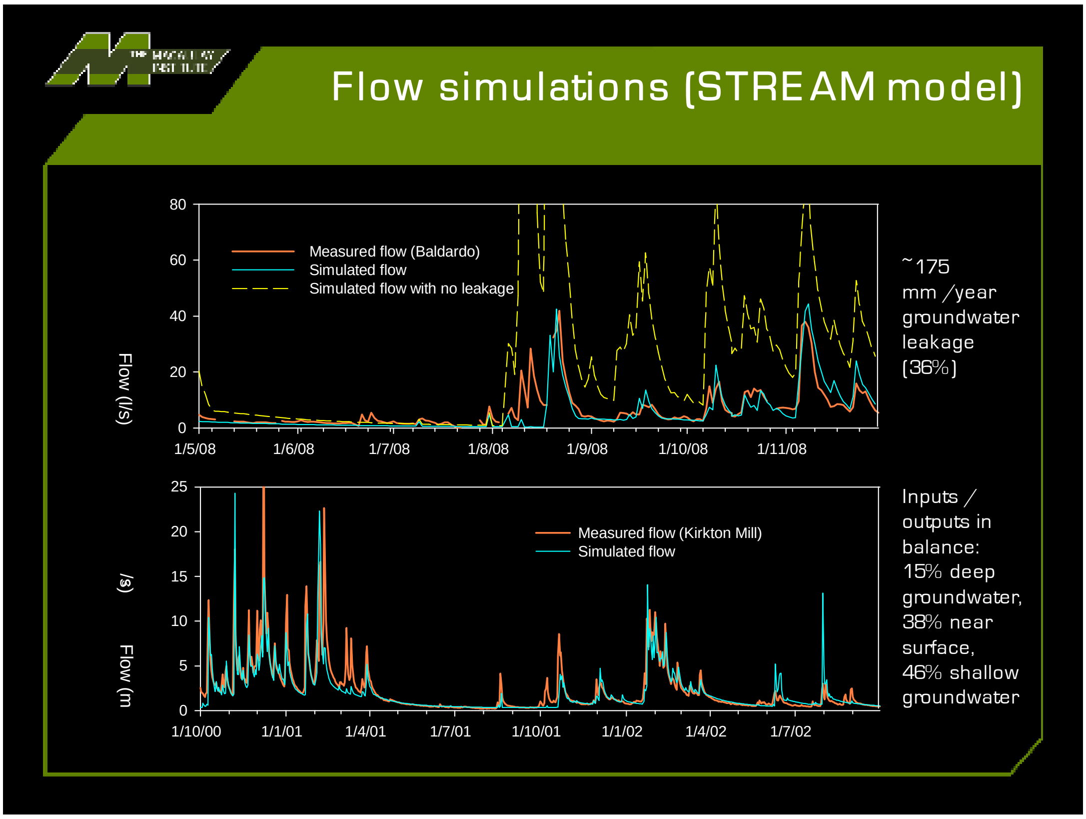



**Figure 22. Timeseries of simulated vs observed stream from for subcatchment (Baldardo) andmain stem of Lunan Water**

**References**

Bishop, P.L., D. Butterfield, W. D. Hively, J. R. Stedinger, M.R. Rafferty, J.L. Lojpersberger and J.A. Bloomfield. Multivariate Analysis of Paired Watershed Data to Evaluate Agricultural Best Management Practice Effects on Stream Water Phosphorus . J Environ Qual 34:1087-1101. 2005.

Futter M.N, D. Butterfield, B.J. Cosby, P.J. Dillon, A.J. Wade, P.G. Whitehead. Modelling the mechanisms that control in-stream dissolved organic carbon dynamics in upland and forested catchments. Water Resources Research 43, W02424, doi:10.1029/2006WR004960. 2007.

Jarritt, N.P. and Lawrence, D.S.L. Simulating fine sediment delivery in lowland catchments: model development and application of INCA-Sed in Soil Erosion and Sediment Redistribution in River Catchments: Measurement, Modelling and Management. Owens, P.N. and Collins, N.J. (eds.)384 pp. 2005.

Kelly, M.G. (1998). Use of the trophic diatom index to monitor eutrophication in rivers. Water Research 32, 236-242.

Grieve, I.C. and Gilvear, D.J. Quantifying anthropogenic nutrient sources and loadings within a small catchment with conservation interests, eastern

Scotland. Aquatic Conservation:. Marine and Freshwater Ecosystems 4 (3), 273 – 287. 2006.

Jarritt, N.P. and Lawrence, D.S.L. Fine sediment delivery and transfer in lowland catchments: Modelling suspended sediment concentrations in response to hydrologic forcing. *Hydrol. Process.*21:2729-2744. 2007.

Lazar, A, MN Futter, AJ Wade, PG Whitehead, D Butterfield and DSL Lawrence. in prep. A model of sediment dynamics for UK catchments. Hydrology and Earth System Sciences.

Sælthun, N.R. The "Nordic" HBV Model. Description and documentation of the model version developed for the project Climate Change and Energy Production. NVE Publication 7, Norwegian Water Resources and Energy Administration, Oslo. 26 p. 1996

Wade, A.J., Durand, P., Beaujouan, V., Wessel, W.W., Raat, K.J., Whitehead, P.G., Butterfield, D., Rankinen, K. and Lepisto, A. A nitrogen model for European catchments: INCA, new model structure and equations, *Hydrol. Earth Sys. Sci.***6** 559-582. 2002a.

Wade, A.J., P.G. Whitehead and D. Butterfield. The integrated catchments model of phosphorus dynamics (INCA-P), a new approach for multiple source assessment in heterogeneous river systems: model structure and equations, *Hydrol. Earth Sys. Sci.* **6** 583-606. 2002b.

Whitehead, P.G., Wilson, E.J. and Butterfield, D., A semi-distributed Integrated Nitrogen model for multiple source in Catchments (INCA): Part I – model structure and process equations. *Sci. Total Env.* **210/211** 547-558. 1988

**4. Mitigation of diffuse pollution**

**a) Farm audits to assess compliance with General Binding Rules.**

Following on from development of SEPA's diffuse pollution mitigation strategy, which includes piloting approaches in 10 priority catchments, it was agreed that MI and SAC staff, along with SEPA staff would be trained in DP auditing methods with respect to assessing compliance with the GBRs, so that a measure of level of compliance in farms in the Lunan Water catchment can be made, as part of the research element of the project. This training is planned to take place in August 2009, with audits taking place in selected farms and subcatchments during autumn 2009. This would be followed by discussions with farmers about how to improve
compliance, and opportunities for funding specific measures through the Scottish Rural Development Plan and other sources.

As a precursor to this process, SAC, SEPA and MI staff jointly organised two farm walks (Figure x) to informally discuss diffuse pollution and soil erosion issues with farmers in the catchment, through the SAC Environmental Focus Farm user group meetings. Appendix x gives an example of the diffuse pollution audit that was used for the Environmental Focus farm, Mains of Balgavies.

**Figure 23. Discussion of cultivation options for soil erosion control in Baldardo catchment.**

**b) Analysis of Landscape based Cost Effectiveness of Buffer strips.**

The EC Water Framework Directive (WFD) requires Member States to set water quality objectives (standards) and identify cost-effective mitigation measures to achieve good ecological status for all surface and ground waters in Europe. This requires control of both point and diffuse sources of pollution. Sediments and diffuse phosphorous (P) pollution, often linked to soil erosion, were shown to be the key contributors in affecting water quality. Studies indicate that P emissions involve a high marginal damage on water quality compared to many other pollutants. Surface runoff and soil erosion represent the major paths of diffuse P losses from many agricultural systems. Thus, measures targeting 'P transport controls', such as buffer strips appear to be the principal options of P pollution mitigation. However, the costs and effectiveness of such measures vary significantly in the landscape as erosion delivery to watercourses and land economic production capacity differ from field to field depending on the biophysical attributes of the field. Thus, mitigation measures may be best adopted if the biophysical and production variability of agricultural land is taken into account across the landscape.

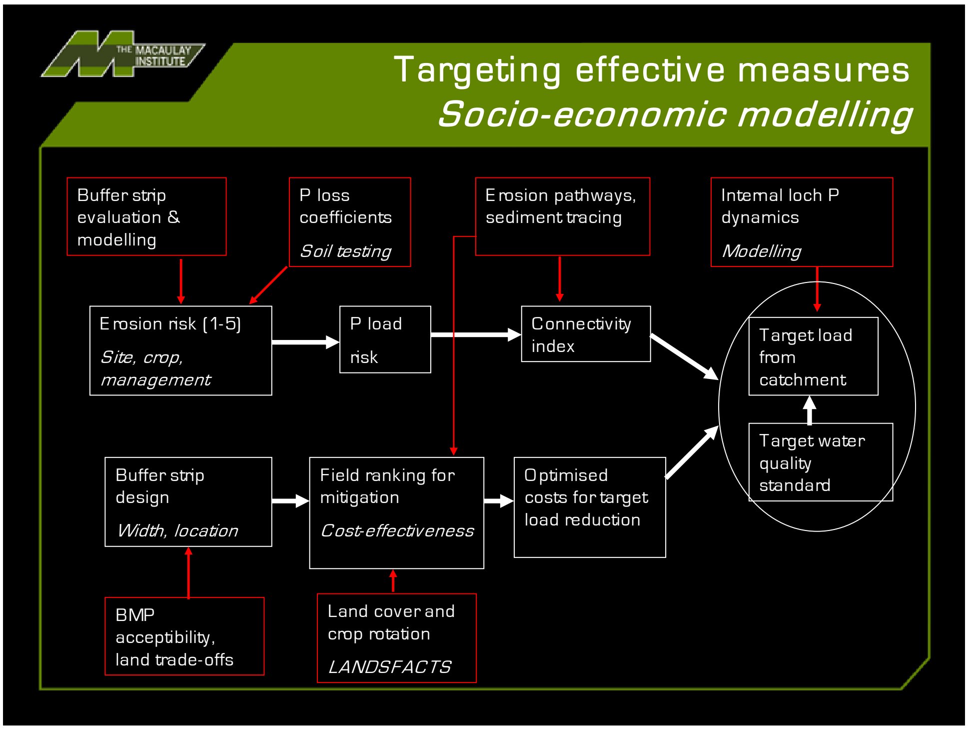



**Figure 24. Conceptual framework for analysing landscaped based cost-effectiveness of P mitigation using buffer strips.**

Taking the case of Rescobie loch in Lunan catchment, this study is exploring the optimal targeting of buffer strips for P mitigation and how siting of buffers influence costs and effectiveness. An integrated economic, hydrologic, and GIS modelling framework is employed to examine the cost-effective targeting of land retirement for establishing buffers in agricultural land for P mitigation (Figure 24). The underlying economic rationale behind this exercise is that financial incentives to farmers for adopting agri-environmental measures should be at least equivalent to the forgone financial costs to the farmer (i.e. cropping returns on the land to be retired) in order to induce "voluntary" participation.
Estimates of P export coefficients and P delivery ratios were obtained at field-by-field level. These estimates were based on crop-rotation (LandSFACTS project) and field distance from the loch. Using the Lunan-SIACS data, field boundary, size and perimeter were determined with GIS tools. Average gross

margins for various farm activities based on four rotation cycles were calculated on the basis of RERAD's agricultural census (1995-2007). Using Excel 'Risk Solver platform', optimization problems built with various scenarios were solved. The optimization model helps us identify optimal buffer widths and spatial distribution across the landscape to achieve water quality targets at minimum economic costs. The research findings enable us to evaluate the economic efficiency of current fixed land-based payment schemes such as those sponsored by RERAD (land management contracts).

**5. Other work**

**a) Farmland Birds**

**b) Marc's buffer strip plans**

**c) Progress on modelling response to N policy**

**d) LANDSFACTS modelling**

**6. Priotriy actions for September 2009-August 2010**

A. Completion of training in GBR audits by SEPA.

B. Carrying out GBR audits on Baldardo catchment farms

C. Completion of SRDP application for Baldardo catchment

D. Further event based calibration of turbidity vs chemistry relationships for Baldardo, Lemno, Westerton and Burnside catchments

E. Maintenance of hydrological, chemical and ecological monitoring activity as per 2008/9.

F. Obtaining loch paleo samples for diatom analysis and development of a reliable estimate of historic P loading to lochs

G. Completion of framework for landscape based cost effectiveness analysis

H. Obtain farm specific costing data for compliance with GBR/GAEC and for voluntary measures in SRDP proposal.

I. Summer rapid ecological appraisal

J. Development of statistical methods to estimate uncertainty in loading and exceedance calculations.

K. Development of statistical methods for analysis of changes in timeseries data.

## 7. Output

### a).Newsletter Piece for IWA Specialist Group on Diffuse Pollution

Title: **Working with People to Mitigate Rural Diffuse Pollution in Scotland**

An increasing interest in the multiple sources of rural diffuse pollution, often labelled as 'agricultural', encouraged us to explore how different users of the Lunan Water, Scotland, perceived water quality and whether they felt they could implement measures to reduce pollution. Currently, the Scottish Environmental Protection Agency (SEPA) has classified the six water bodies in the catchment as 'moderate' or 'bad' status using the Water Framework Directive parameters, with dissolved oxygen, hydrology (due to abstraction), ecology and hydro-morphology being the main culprits.

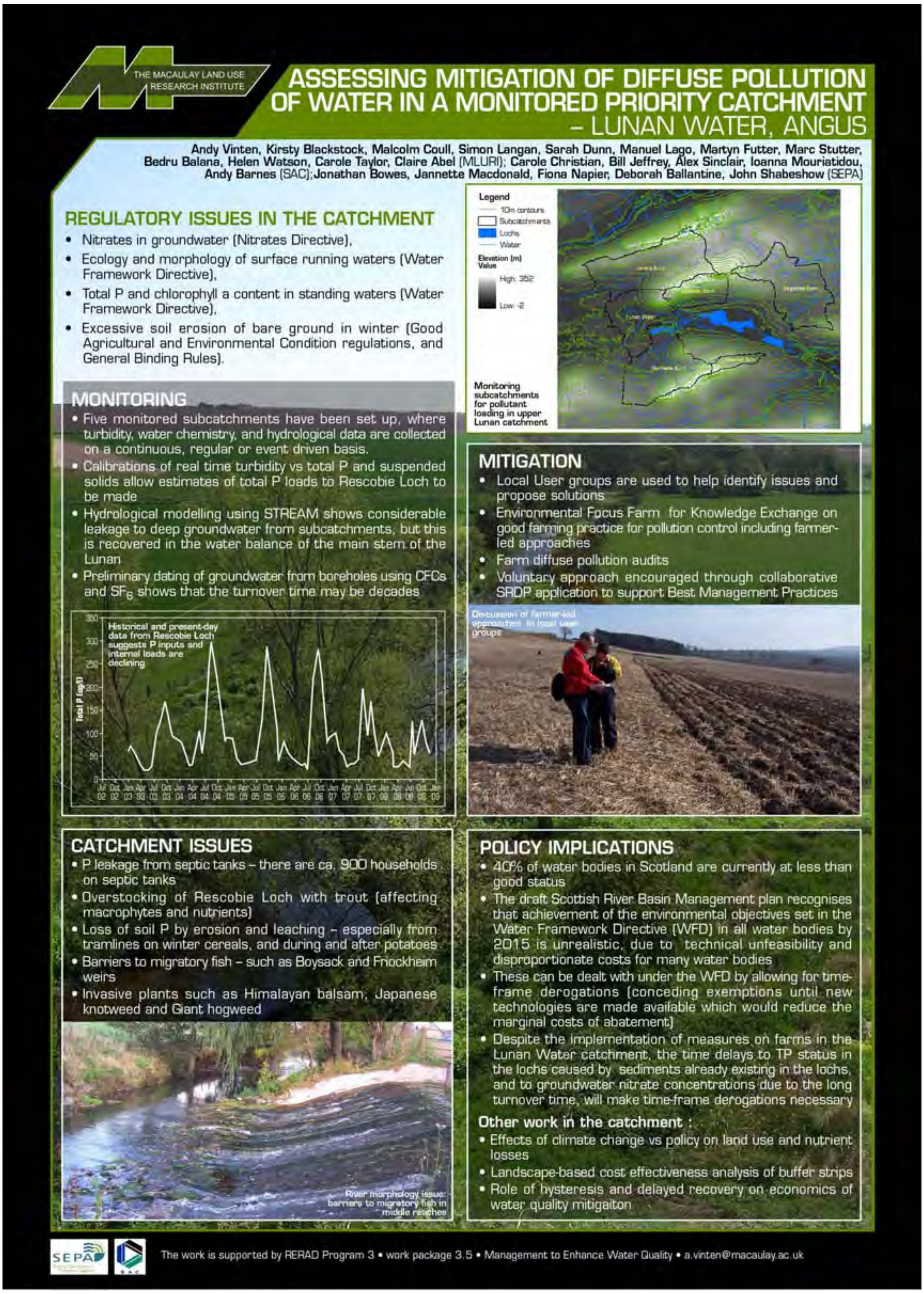
We ran five focus groups with anglers, residents, owners of septic tanks, agency advisors and scientists, including a discussion of a catchment scale nutrient budget regarding sources of nitrogen and phosphorous in the catchment. The results illustrate that our participants' perceptions correspond well with the official classifications. In particular, both the nutrient budget and the discussions indicated that poor maintenance of septic tanks could be an important contributor to diffuse pollution. Other areas for future research included the interaction between invasive plants and riparian soil erosion and the contribution of road run off.

However, the participants also highlighted that diffuse pollution was only one of the pressures on the catchment. This is something that the SEPA results bear out. Our experience illustrates that people who live or use the catchment are a valuable source of knowledge and an untapped resource for improving understanding and changing behaviour both to mitigate diffuse pollution.

For more information, see : http://www.macaulay.ac.uk/lunan/ or contact Malcolm Coull (m.coull@macaulay.ac.uk)

*Kirsty Blackstock, Malcolm Coull and Martyn Futter, Macaulay Institute.*

b). Posters for Knowledge Scotland Event, SEPA Stirling, 29th May, 2009



# UNDERSTANDING TRANSPORT PROCESSES AT CATCHMENT SCALES

THE MACAULAY LAND USE RESEARCH INSTITUTE

**Sarah Dunn:** The Macaulay Land Use Research Institute, Craigiebuckler, Aberdeen AB15 8QH • s.dunn@macaulay.ac.uk

**POLICY RELEVANCE:** In order to predict how catchments will respond to future changes in land use, management and climate there is a need for underpinning understanding of key physical processes that describe how water and pollutants are transported from the land to surface- and ground-water bodies, at relevant spatial and temporal scales. In some systems, responses in surface and groundwaters may be delayed because of time-lags in transportation.

**MODEL SIMULATIONS:** Models of catchment systems must represent key transport processes and be assigned suitable parameter values if they are to simulate future behaviour correctly. Calibration procedures based on limited historic data are often inadequate to distinguish a good model from a bad model. Other types of data, such as tracers, can aid with model identification.

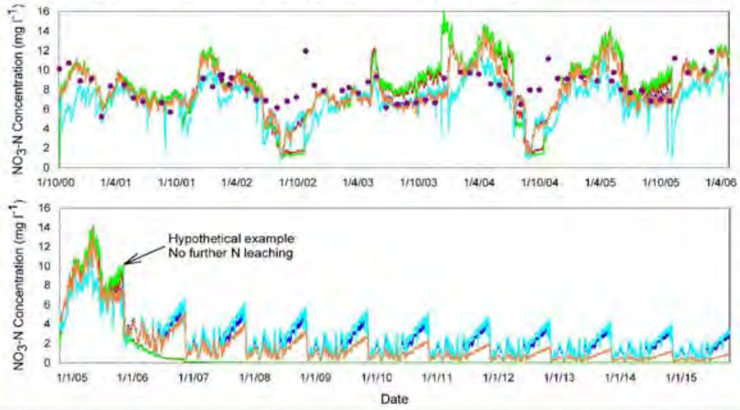



*Figure 1: Which model?*

Figure 1 shows five very different parameterisations of a model of stream nitrate that give similar simulations of historic behaviour. However, their simulated responses to changes in management are very different.

**EXAMPLE:** The Lunan catchment is designated as a groundwater Nitrate Vulnerable Zone because of high concentrations of nitrate in groundwater that is used as a source of drinking water. Recent monitoring of boreholes indicates that several sites regularly exceed the EU drinking water limit of 11.3mg/l of nitrate-N. There is growing evidence from data collected in the Lunan catchment of the importance of groundwater. Recent studies using atmospheric tracer dating techniques, suggest that groundwater in the catchment is of mixed ages ranging from a few years up to as much as 30-40 years. This could have implications for how the catchment and groundwater recover from the high levels of nitrate, even if management practices are successful in reducing present day leaching of nitrate from agricultural land.

*Figure 2: Nitrate concentrations measured in Lunan boreholes*

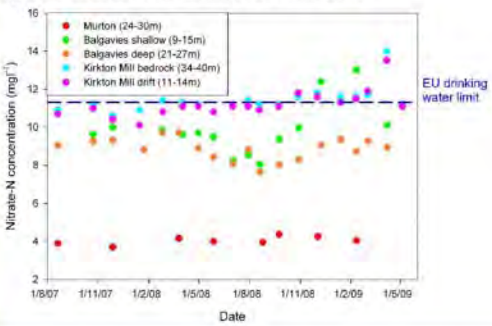
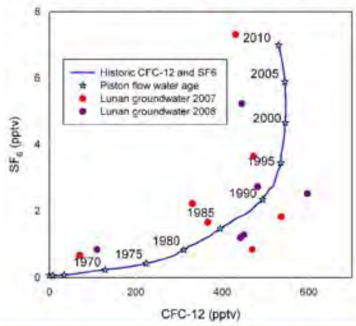



*Figure 3: Results of groundwater dating for Lunan boreholes*




At the Macaulay Land Use Research Institute we are developing suitable monitoring and modelling of transport processes to ensure that future behaviour and responses of catchment systems can be predicted.

**Poster for ?**

# The biological reality of river biotopes using macroinvertebrate species traits

Demars BOL[1], Harper DM[2], Kemp JL[3], Friberg N[1]

*[1] Macaulay Institute, Aberdeen, Scotland; [2] University of Leicester, England*

*[3] Scottish Environment Protection Agency, Aberdeen, Scotland*

In wadeable rivers, a distinct mosaic of biotopes can easily be assessed (Harper et al 1995, Kemp et al 1999).

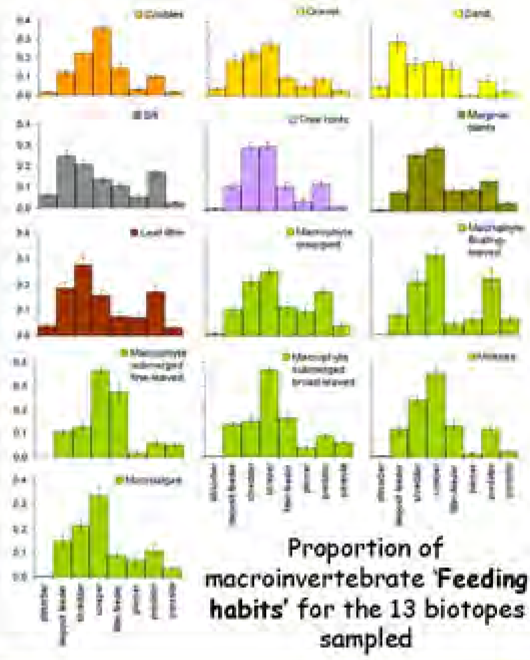
Macroinvertebrate assemblages were sampled in 512 patches (13 biotopes) across 7 rivers and identified to the lowest possible taxonomic level.

These biotopes explained 40% of the variation in macroinvertebrate species trait assemblages (*P*<0.001) independently of the different frequency of biotopes among rivers.

The rivers sampled explained an additional 14% of variation in macroinvertebrate species traits (*P*<0.001) due to the different hydro-geomorphological settings.

**Our findings highlight the importance of the physical-biological linkage in lotic ecosystems.**

**Surveying biotopes can therefore provide a tool to rapidly appraise the ecology of a river.**



Proportion of macroinvertebrate '**Feeding habits**' for the 13 biotopes sampled

*Thanks to Philippe Usseglio-Polatera for providing the species traits*

**c). Outputs from Environmental Focus Farm project.**

| | |
|---|---|
| **Date** | February/March 2009 |
| **Event** | EFF Newsletter - Issue 2 |
| **Reached . . .** | Distribution : 200 email, 80 postal |
| **Audience** | Regulators, SG, SAC, Councils, Fisheries, Industry, etc |

| | |
|---|---|
| **Date** | 6th March 2008 |
| **Event** | Tayside Area Advisory Group Meeting |
| **Reached . .** | ~25 |
| **Audience** | Regulators, SG, Councils, Fisheries, Industry, etc |
| **Summary** | Attended AAG Meeting and presented project. Led Farm Walk at Mains of Balgavies |

| | |
|---|---|
| **Date** | 20th February 2009 |
| **Event** | Catchment Management projects - working with farmers |
| **Reached . . .** | 25 |
| **Audience** | EA, Defra, SEPA, SG, MLURI |
| **Summary** | Presented project at a meeting designed to share experience in catchment management projects targetting agricultural diffuse pollution |

| | |
|---|---|
| **Date** | 2nd July 2008 |
| **Event** | Angus Focus Farm Group Meeting |
| **Reached . . .** | 8 |
| **Audience** | Farmer Focus Group Members |
| **Summary** | Visit to farm at Loch Leven to see buffer strips, soil bunds and novel potato tied-ridging techniques. Meeting with emphasis on nutrient budgetting |

| | |
|---|---|
| **Date** | 28th October 2008 |
| **Event** | Farmer meeting at Mains of Balgavies |
| **Reached . . .** | 15 |
| **Audience** | Farmers |
| **Summary** | Soil Erosion and Soil Erosion Risk Evaluation |

# Appendices

## A1. Priorities for 2008/9 – progress report

The key action points for this project in the following year are as follows:

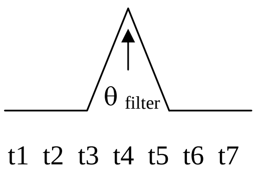
A. Carry out Statutory compliance (GBRs and GAEC) audits on farms in the catchment, using an independent consultant. The priority for this will be farms in the Burnside Burn catchment, followed by Newmills and Wemyss (SEPA/SAC).
B. Obtain baseline ecological data (phytobenthos (MI) and invertebrates(SEPA)) on the 5 sub-catchments in the upper Lunan Water. September 2008 and quarterly thereafter.
C. Identify voluntary measures for implementation on Balgavies and Wemyss catchments, and other Farmer Focus Group farms and apply for SRDP funding (SAC/MI).
D. Obtain calibration data for (a) stage-discharge and (b) turbidity-chemistry relationships in Wemyss and Burnside catchments (MI/SEPA)
E. Get real time monitoring up and running on Balgavies Burn (MI)
F. Obtain farm specific costing data for compliance with GBR/GAEC and for voluntary measures. (SAC/MI)
G. Agree methodology for estimating internal P loading for Rescobie and Balgavies Lochs (MI/SEPA)
H. Explore potential for a P stripping system for a septic tank (eg the caravan site on the Burnside Burn?) (MI/SAC)
I. Clarify reasons for decline in P loading from upper Lunan Water to Rescobie over the last 8 years (SEPA/MI).
J. Implement agreed voluntary measures with farmer focus group and agree monitoring strategy (SAC/MI/SCRI).
K. SEPA view (SEPA), Scottish Farmer (SAC) and IWA (MI) articles on progress.
L. Implement spatial cost:effectiveness model for buffer strips in the catchment (MI/SEPA/SAC). See: W:\WP35\352_ Management_Practices\IPS\IP\Bufferstripmodelling.
M. Determine equilibrium phosphate concentration of sediments sampled in the 5 subcatchments (MI/SEPA).

## A2. Procedure for filtering raw 15 min turbidity data

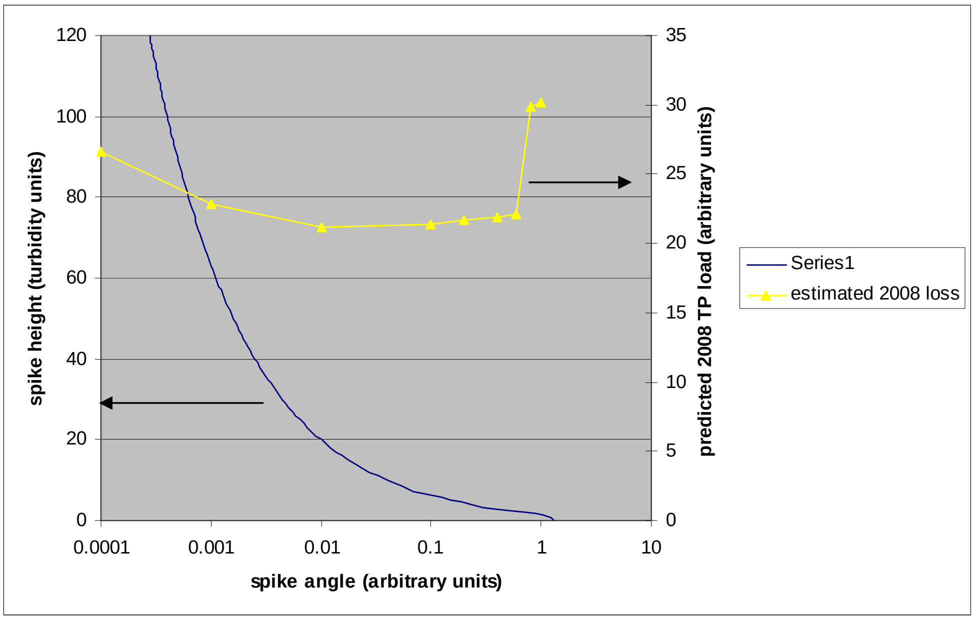
See file: Wemyss400turbidity….xls
Worksheet <15mins> Cols D to P

1. NAN returns replaced by previous timestep return
2. Blank data replaced by previous timestep return
3. "Angle" described by 3 points (turbidity reading of previous, current, next timestep) against a baseline with units of 15min intervals, was calculated.
4. Filter applied to final calculation removing all spikes with an "angle" $\theta \leq \theta_{filter}$, and replacing with previous timestep return.

The appropriate value for $\theta_{filter}$ was estimated by sensitivity analysis of final load calculations to this value. The load estimate above a certain value remained insensitive over a wide range of values, so we chose a mid point in this insensitive range. $\theta \leq \theta_{filter}$ $\theta \leq \theta_{filter}$




5. Turbidity values were truncated to integers and then phantom values (obvious instrumental problems, such as alternate values of 4 in dataset) were removed
6. Hourly rolling means were calculated.
7. A quality number was calculated, based on the number of corrections made (steps 1, 2, 4 and 5 above, giving a maximum number of 4. this was then multiplied by 10, a rolling mean calculated and the result again truncated to an integer.
8. Converted to hourly data for linkage with discharge estimates and load calculations, using VLOOKUP.



120
100
80
60
40
20
0
35
30
25
20
15
10
5
0
0.0001
0.001
0.01
0.1
1
10
spike height (turbidity units)
predicted 2008 TP load (arbitrary units)
spike angle (arbitrary units)
Series1
estimated 2008 loss

## A3. Procedure for estimating discharges

**Wemyss water level data set is fragmentary, so use Hatton dataset and calibrate to other sites:**

1. Hatton discharge calculated by:

**Worksheet <sitevsdiverlevels>**

(a) correcting diver level to field level using a calibration of diver stage vs site stage measurements :

y = 0.6666x + 5.5643
R2 = 0.673
y = site level, x = diver level (cm)

(b) using site stage vs discharge relationship from manual propeller calibration:
**Worksheets <corrected 2007> <corrected 2008> and <data 2009> cols O and P**

$y = 9.964x^{4.051}$

y =discharge (m3/s) x = site level (m)

2. Conversion from Hatton to Wemyss discharge using Christian Birkel's ISCO calibration of Wemyss discharge vs a period with good water level data and old stage discharge calibration for Wemyss:

**see CBWemyssvsHatton worksheet.**

$y = 0.5834x^{-2.2257}$ R2 = 0.827

y = CB estimated Wemyss discharge
x = Hatton discharge

## A4. Procedure for estimating TP loads

**Use hourly rolling mean discharge (col AB) and turbidity (col W) to estimate hourly loads of turbidity.**

**Convert hourly turbidity to TP estimate using:**

Log10PartP = 0.5233 * log10 turbidity - 2.0454

From Marc Stutters notes.

**Procedure for Hatton and Westerton**
**Same filtering procedure, and fodischarge:**

1. Hatton – use hatton discharge Data (see above) directly

Westerton – in the absence of a calibration at present, use Hatton discharge and area correct (not yet area corrected).

## A 5. Brief description of INCA–sed model

INCA, the Integrated Catchments model is a generic, catchment-scale biogeochemical modelling framework. INCA is semi-distributed and operates on a daily time step. Versions of the INCA model have been developed to simulate nitrogen dynamics (Whitehead et al. 1998, Wade et al. 2002a), phosphorus (Wade et al 2002b), organic carbon (Futter et al. 2007) and suspended sediments (Jarritt and Lawrence 2005, 2007).

INCA-Sed, the Integrated Catchments model for suspended sediments simulates the production, transport and delivery of sediment in the catchment and in-stream sediment transport, deposition and re-suspension. In the terrestrial phase, INCA-Sed simulates sediment production form splash detachment and flow erosion. Sediment can be stored in the catchment. When sediment is delivered to the stream, it can be transported, deposited or re-suspended.

Published applications of INCA-Sed exist for lowland UK catchments (Jarrit and Lawrence 2005, 2007). There have been unpublished applications to peat-dominated sites in Finland and the model is being applied to a number of other upland and lowland sites in the UK.

The INCA modelling system runs under the MS-Windows computing environment on PC compatible computers. The modelling system consists of a user-friendly graphical interface (Figure 1), a data management system and a fourth-order Runge Kutta differential equation solver. All environmental processes in INCA are represented as a set of linked first order differential equations. The INCA model operates on a daily time step. There are plans to build a version of INCA in the future that will operate on arbitrary time steps.

There are three levels to the landscape representation in INCA (Figure 2): the river catchment, the sub-catchment and a generic cell in which terrestrial biogeochemical and sediment processing occurs.

***INCA has limited data requirements. Estimates of catchment area, land cover, soil size classes and mean stream slope are requires to run the model. Information on vegetation cover and length of growing season will help to constrain model predictions. The model requires daily time series of temperature and precipitation. Time series of stream flow and suspended sediment concentrations are used in model calibration.***

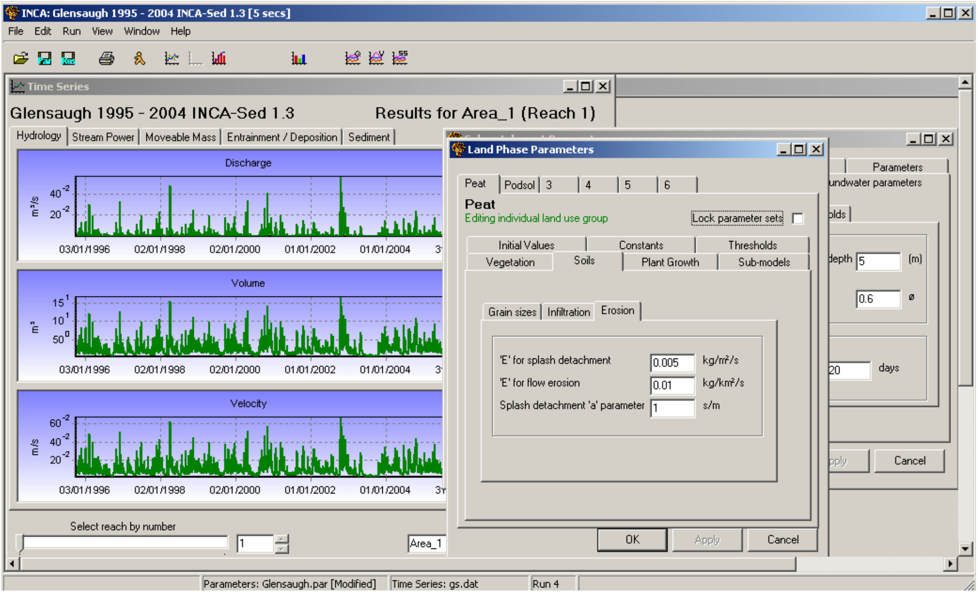


Figure 1: Screen-shot of the INCA user interface.

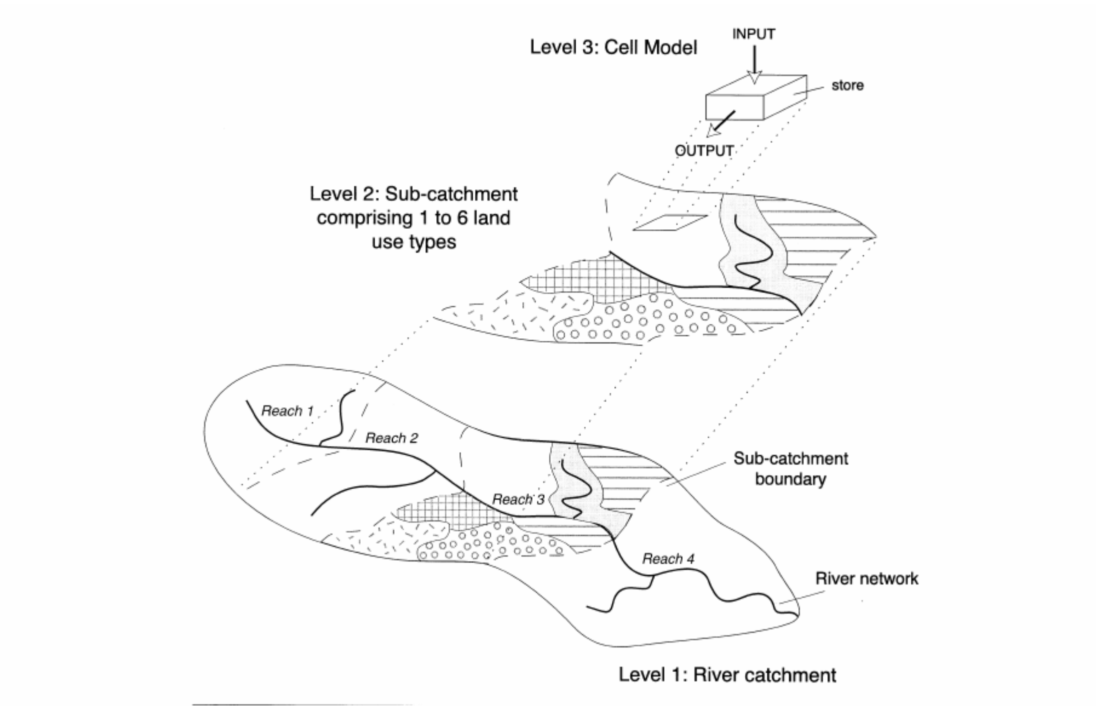



Figure 2: The INCA landscape model.

Hydrologically effective rainfall (HER) and soil moisture deficits (SMD) are simulated using an external rainfall-runoff model. HBV (Sælthun, 1996) is typically used for this purpose. In the UK, data on HER and SMD can be obtained from the MORECS system (http://www.metoffice.gov.uk/water/morecs.html).

Estimates of HER and SMD must be obtained from an external rainfall-runoff model. HBV (Salthun 1996) was used for this purpose. HBV is a conceptual rainfall-runoff model that has been extensively used in Finland and Scandinavia. In HBV, time series of precipitation and temperature and a description of the catchment are used to simulate daily flows, HER and SMD. The model is calibrated by adjusting parameters so as to minimize the difference between modelled and observed flow. The estimate of HER generated by HBV is the depth of water that may enter the soil on any given day. For the purposes of this application, HER is defined as the sum of precipitation and snowmelt minus losses to evaporation and evapotranspiration. SMD is the difference between the amount of water in the soil and its water holding capacity, expressed as a depth of water. Stream flows estimated in HBV are only used for model calibration. They are not used in DOC simulations as INCA is able to route HER through the catchment and provide estimates of stream flow.

*INCA Land Phase Hydrological Model*

Within INCA, direct runoff (overland flow) can be generated by two processes, which occur under very different soil moisture states: saturation from above ('Hortonian' or infiltration excess overland flow) and saturation from below (saturation excess overland flow). In the original INCA hydrological model, the input to the direct runoff zone ($q_{dr}$) is a proportion of the total soil zone flow ($q_{sw}$) when the soil zone flow exceeds a user-defined threshold soil zone flow above which direct runoff is generated ($q_{sat}$). Change in direct runoff flow is defined as follows in when $q_{sw}$ exceeds $q_{sat}$.

$$\frac{dq_{dr}}{dt} = \frac{c_1 q_{sw} - q_{dr}}{T_1} \qquad [1]$$

where $c_1$ is the proportion of the soil zone flow that becomes direct runoff and $T_1$ is the residence time of water in the direct runoff (surface) zone.

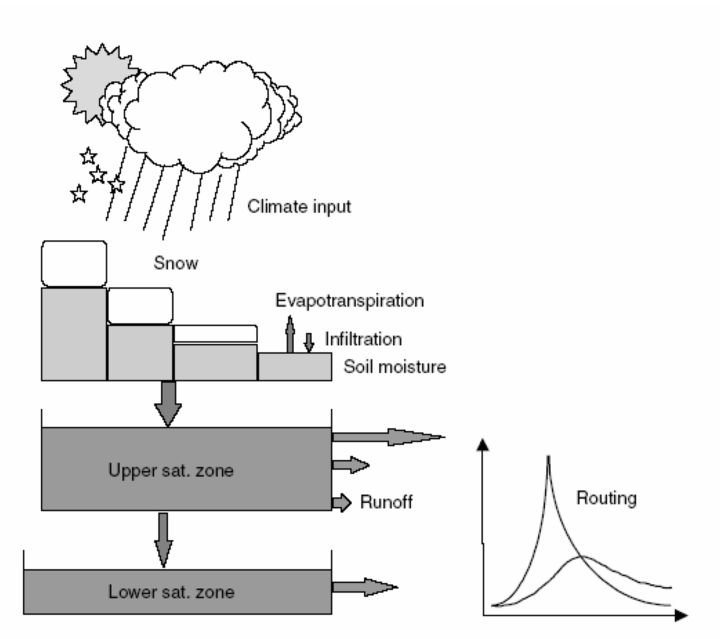


Figure 1. Schematic structure of the HBV model, set up for one sub-basin

Figure 3: Conceptual representation of HBV rainfall runoff model.

The generation of saturation direct runoff ($q_{dr(Sat)}$) in INCA-Sed is changed such that the input to the direct runoff zone is equal to the soil zone flow *in excess* of the saturation threshold:

$$\frac{dq_{dr(Sat)}}{dt} = \frac{(q_{sw} - q_{sat}) - q_{dr}}{T_1} \qquad [2]$$

The input to the direct runoff zone includes only flow in excess of the saturation threshold, and the remaining soil zone flow does not exceed the saturation threshold. The proportion of the soil zone flow excess above the threshold that does not form direct runoff input is assumed to be lost to the filling of surface depressions and the subsequent evaporation of this water. The value of the soil zone saturation flow is related to the soil type. Appropriate values may be determined from the literature or through calibration.

Direct runoff can also be generated when the rate at which rain falls onto the ground surface exceeds the rate at which that water can be infiltrated into the soil. This is the Hortonian method of runoff generation. If such conditions exist, the rainfall in excess of the infiltration rate provides infiltration excess input ($q_{dr(Inf)}$) to the direct runoff:

$$\frac{dq_{dr(Inf)}}{dt} = \frac{c_2(p - i) - q_{dr}}{T_1} \qquad [3]$$

where *p* is the rainfall rate, *i* is the variable infiltration rate and $c_2$ is the proportion of the rainfall excess that becomes direct runoff. From the infiltration models above the key relationships that determine the infiltration rate can be identified. The infiltration rate is directly proportional to the hydraulic conductivity of the soil and inversely proportional to the water content of the soil. On a daily time-step, the best available proxy for the water content at the soil surface is the sum of rainfall and snow melt on that day. The more rain or snow melt there has been, the wetter the soil surface will be and the lower the infiltration rate.

$$\frac{dq_{dr}}{dt} = \frac{(q_{sw} - q_{sat}) + c_2(p - i) - q_{dr}}{T_1} \qquad [4]$$

In the event that $q_{sw}$ is less or than or equal to $q_{sat}$, change in direct runoff is equal to:

$$\frac{dq_{dr}}{dt} = \frac{c_2(p - i) - q_{dr}}{T_1} \qquad [5]$$

The time-varying infiltration rate (i) is expressed as follows:

$$i = \frac{I}{86.4}\left(1 - e^{-\frac{86.4 \cdot p}{I}}\right) \qquad [6]$$

where *I* is maximum infiltration rate for a given soil type. This parameter is allowed to vary in each sub-catchment.

The change in diffuse flow from the upper soil box is equal to the hydrologically effective rainfall ($U_4$) minus upper soil box diffuse and saturation excess flows divided by the organic layer water storage time constant

$$\frac{dq_O}{dt} = \frac{U_4 - q_D - q_O}{T_O} \qquad [7]$$

Change in diffuse flow from lower soil box compartment is equal to the rate of inflow from the upper soil box ($\beta x_2$) minus the volume of water diffusing from the lower soil box to the open water ($x_3$) divided by the mineral layer water storage time constant.

$$\frac{dq_M}{dt} = \frac{\beta \cdot q_O - q_M}{T_M} \quad [8]$$

*Sediment Delivery Model - Land Phase*

The land phase of the sediment delivery model entails four processes: 1) generation of sediment through splash detachment of soil; 2) transport capacity of direct runoff; 3) erosion capacity of direct runoff and 4) a mass balance accounting of the sediment store on the sub-catchment slopes.

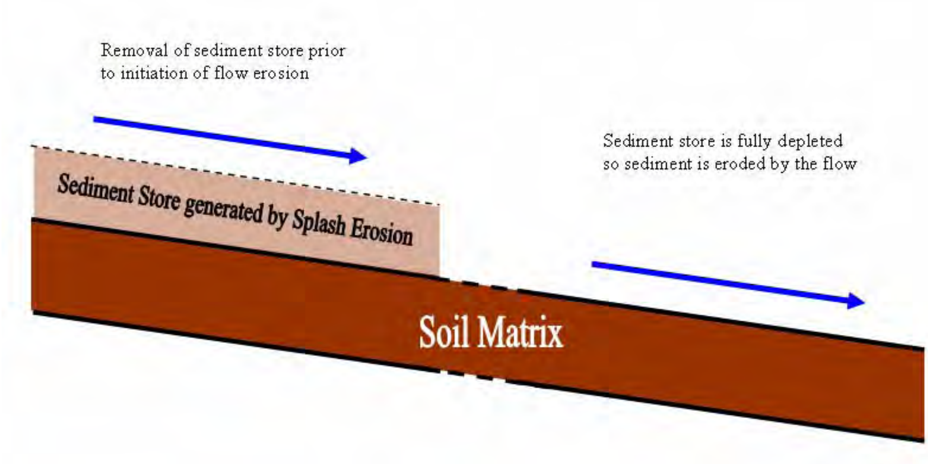



Figure 4: Conceptual representation of in-catchment sediment generation in INCA-Sed.

*Splash Detachment*

Fully processed-based equations for splash detachment of soil particles use the energy or momentum of the rainfall in their calculation. In order to effectively include this in a model it is necessary to include equations to describe the interception of rainfall by vegetation, the cover of vegetation on the ground surface, and also have rainfall intensity, rather than total rainfall data available as a model input. This complexity, however, would impose excessive data demands. Within INCA-Sed the splash detachment ($S_{SP}$) is modelled as a function of precipitation ($p$), a scaling parameter, ($c_{x1}$), a soil erodibility parameter linked to soil type, ($E_{SP}$) and an effective vegetation cover index linked to growing season and land use ($V'$):

$$S_{SP} = c_{x1} p E_{SP}{}^{V'} \cdot 8.64 \cdot 10^{10} \quad [9]$$

The effective vegetation cover (V') is determined from the vegetation cover index (V) and the day of year. The rainfall input in the INCA-Sed model is the total rainfall for each day. This is converted for use in the equations from a depth total (mm) to a flow rate per square meter ($m^3s^{-1}m^{-2}$). Therefore, although the rainfall input to the splash detachment equation is expressed as a rainfall intensity, it is wholly derived from daily rainfall rather than representing the true intensity of rainfall during storm events. The rainfall intensity is moderated by interception by canopy and litter covers, and these factors are accounted for by the vegetation cover index, *V*. The soil erodibility parameter, *E,* can be based either on experimental measurements for a given soil, or it can be estimated from soil texture using published methods.

*Flow Erosion*

Flow erosion ($S_{FL}$) is modelled as a function of the potential of a soil to be mobilised through flow erosion ($E_{FL}$), mass of sediment mobilised through splash detachment ($S_{SP}$) and the sediment transport capacity ($S_{TC}$)

$$S_{FL} = \frac{K}{\left(1 + \frac{K}{S_{TC}}\right)} \left(1 - \frac{S_{SP}}{S_{TC}}\right) \qquad [10]$$

where K is equal to the following:

$$K = a_1 E_{FL} \left(\frac{Aq_{DR}}{L} - a_2\right)^{a_3} \qquad [11]$$

*Direct Runoff Transport Capacity*

The transport capacity of surface runoff is of critical importance in the modelling of sediment delivery. Within INCA-Sed, the sole pathway for sediment delivery from the catchment slopes to the river channel is direct runoff. The transport capacity of this runoff is the maximum rate at which sediment can be delivered to the channel, independent of any other process operating on the catchment slopes.

In all of the published equations for overland flow sediment transport, the transport capacity is related to a flow quantity (*e.g.* stream power or boundary shear stress) *in excess* of some critical value of that quantity. In developing a transport capacity equation for INCA-Sed, the data available to drive the equation again constrains its form. The hydrological model calculates the direct runoff discharge. In order to calculate any other flow quantity to use in a transport capacity equation such as stream power or shear stress, a further equation would be needed to relate this flow quantity to the discharge. Since INCA-Sed is not fully distributed model, there is no topographical information available and no spatial information about the direct runoff flow, such as flow length or width. It is therefore not possible to derive other flow information from the direct runoff discharge using physical characteristics. An equation to achieve this would therefore be empirical and include a number of parameters for which there would be no reliable method of calibration. The key relationship that needs to be incorporated is the link between direct runoff discharge and transport capacity ($S_{TC}$). The discharge, as moderated by the sub-catchment geometry, is therefore being used as an available proxy for flow quantities more directly related to transport, such as stream power or shear stress:

$$S_{TC} = a_4 \left(\frac{Aq_{dr}}{L} - a_5\right)^{a_6} \qquad [11]$$

where $a_4$, $a_5$ and $a_6$ are calibration parameters. The direct runoff discharge $q_{dr}$ is multiplied by the sub-catchment area divided by the reach length. In two sub-catchments with the same physical properties under the same input data the direct runoff discharge *per square meter of sub-catchment* will be identical. If the overall shape of the sub-catchment differs, however, the transport capacity of the direct runoff for each sub-catchment will be different.

## A6. Form used for Environmental Focus Farm Diffuse pollution audit

| | |
|---|---|
| Farm Name | |
| Main Farm Code | |
| Business Name | |
| Contact Name | |
| Address | |
| Postcode | |
| Telephone number | |
| Mobile number | |
| Email | |

---

**12 month data collection period : ..........................................................................................**

**Date of audit:**

**STEADING ISSUES**

The following should be noted on a sketch plan:

Drain inlets
Open watercourses
Areas producing dirty water (e.g. yards)
Areas producing clean water (e.g. roofs)
Sprayer filling area
Silage pits
Straw-bedded courts
Slatted courts
Slurry store
Fuel tanks

The condition of these features should be noted as well as their location
All areas that drain to the slurry store should be noted.

**Livestock Housing**

| Type of housing | Type of stock housed | Number of stock housed | Period of housing |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**Slurry Storage**

Identify sources and times of production.
Identify Store Types and Capacities.
Comment on apparent condition.
Comment on storage capacity (and period) relevant to slurry/effluent audit, storage capacity and land spreading.
For high level slatted sheds include drainage system.

**Reception/Collection Tanks**

Identify type of material, sources and times of production.
Identify Tank Types and Capacities.
Comment on apparent condition.
Comment on storage capacity (and period) relevant to slurry/effluent audit and transfer.

**FYM Storage and Handling**

Identify sources.
Identify Store Types and Capacities.
Comment on apparent condition.
Comment on storage capacity (and period) relevant to slurry/effluent audit, storage capacity and land spreading.
Identify drainage and collection systems. Comment on serviceability.

**Contaminated Water and Silage Effluent**

Silage clamp capacity ……………………………………… tonnes
Capacity of effluent tank(s) ……………………………………… $m^3$
Area contributing rain water to waste system ……………… $m^2$
Daily wash volume (dairies) ……………………………………… $m^3$

Estimate actual volume of contaminated water/effluent (within steading area).
Estimated volume collected at present.
(Establish and state expected contaminated volume following proposed modifications.)
Summarise steading locations where significant discharge and identify drainage route.

**Clean Water Diversion**

Identify areas where ‘clean water’ enters any part of the contaminated area or steading system.
Assess volumes that can be diverted to clean water outfalls.

**Cattle Access Routes (steading only)**

Identify and state cattle movement routes (steading area only) and extent where contaminated drainage will occur.

# LAND AREAS

| | | | Hectares | Acres |
|---|---|---|---|---|
| Total Area: | | | | |
| Hill / Rough: | | | | |
| Unimproved permanent grass: | Grazing only | | | |
| | Hay | | | |
| | Silage | | | |
| Improved permanent grass: | Grazing only | | | |
| | Hay | | | |
| | Silage | | | |
| Rotational land: | Crops: | Winter wheat | | |
| | | Winter barley | | |
| | | Spring barley | | |
| | | Oilseed rape | | |
| | | Potatoes | | |
| | | Swedes | | |
| | | Other(specify) | | |
| | | | | |
| | | | | |
| | Rotational grass: | Grazing only | | |
| | | Hay | | |
| | | Silage | | |
| | Set-aside | Permanent | | |
| | | Rotational | | |
| Other | Forestry | | | |
| | Farm woodland | | | |
| | Agri-environment (details) | | | |
| | Other | | | |

Notes:

**FIELD ISSUES**
**Checklist for Field Survey**

The following features should be recorded and marked on a map during the field survey. Some information (e.g. presence or absence of field drains) may be provided by the farmer during the interview.

**Fields**

Steepness
Slope direction
Slope uniformity
Drained fields
Drainage problems
Wet areas
Soil erosion
Soil structural problems
Areas prone to flooding
Livestock feeding areas
Poached areas

**Water Margins**

Mark all watercourses
Presence and condition of fencing
Width and nature of any existing buffers
Location and condition of stock watering points
Presence or absence of water troughs
Bank erosion
Vegetation indicating nutrient enrichment (e.g. nettles, docks, thistle, willowherb)

**Manure Land Application Scheduling**

Complete Field Risk Assessment for all areas used for application.
Identify field areas, application rates and time of application (Use forms in SEERAD NVZ Guidance).

**Cattle Access Routes (field only)**

Identify and state cattle movement routes (fields only) and extent where contaminated drainage will occur.

Also identify and state access routes/movements to specific feed (field) locations.

**Cattle Access to Water Courses/Coastal water**

Identify stock access locations (loafing and drinking).
Identify constructed access for drinking.
Identify stock crossing locations (of watercourses) **or** 'prone' locations, (frequent movement).

**Field Water Troughs**

Identify all existing water trough locations.

Identify existing water trough locations which can give rise to pollution risk to watercourses.
Comment on specific issues which may result in watercourse/ditch pollution.

**Grazing**

Identify field risks associated with stock movement and grazing
Include reference to issues such as:

Grazing method (e.g. strip grazing)
Field access tracks and gates
Access routes to water locations
Temporary feeder siting, stock and vehicle access
Slope and surface drainage – run off risk to watercourses/ditches.

**Supplemental Feed Areas and Midden Areas in Fields**

Identify high risk sites due to proximity and drainage to watercourses.
(Note specifically those which remain in use or 'not cleaned' thro' summer low rainfall period, May-September)
Tractor access should be considered with regard to forming drainage routes for contaminated water flow towards ditches and watercourses.

## Habitats

Semi-natural vegetation
Opportunities for habitat creation

## Other

Silage bale stores
Field middens
Eroding tracks
Any obvious point source pollution

**Inputs to cropped and grass parts of farm**

| Inputs | Product analysis | Quantity (tonnes) |
|---|---|---|
| Fertiliser :<br>*a) crops:*<br>______<br>*b) grass* | ______ | ______ |
| Livestock manure/slurry/wastes:<br>*a) brought-in & applied for crops*<br>______<br>*b) home-produced & applied for crops*<br>______<br>*c) brought-in & applied to grassland* | e.g.: cattle, pig, poultry (for slurry please indicate approx. dry matter content)<br>______<br>______ | ______<br>______ |
| Bedding : | | |
| Brought-in feed: (Product name) | %protein %P %K (where possible) | |
| Livestock : Type of animal | **Number** | **Weight per animal or total wt** |
| Other (please specify) : | | |

## Outputs from cropped and grass parts of farm

| Outputs | Product analysis or type | Quantity (tonnes) | |
|---|---|---|---|
| Crops (seed/grain/roots/vegetables): | | moved-off farm | fed (on own farm) |
| Straw | | moved-off farm | used (on-own farm) |
| Hay/silage | | moved-off farm | |
| Livestock including poultry: <u>Type of animal</u> | **Number** | <u>Weight per animal or total wt (specify liveweight or deadweight)</u> | |
| Milk : | | | |
| Livestock manure/slurry<br>*a) moved-off farm* | eg : cattle, pig, poultry (for slurry please indicate approx. dry matter content) | | |
| *b) home-produced & applied for crops* | | | |
| Other (please specify) : | | | |

# FARM PESTICIDES MANAGEMENT

Auditor to assess items prefixed **(A)**. To be applied in a non-critical manner; farmer must be re-assured that all information is confidential. High pollution risk or non-compliance issues to be listed at the end along with reasons, if forthcoming.

**Pesticide Storage**

**(A)** Type of store (shipping container, room, locker etc) …..………………..

Capacity, *l* and/or kg ……………………
Maximum content, *l* and/or kg ……………………
Stocks used up with minimum overhang? ……………………
**(A)** Location (normal location if movable) ……………………
**(A)** How secured/locked ……………………
**(A)** Warning notice?/where displayed …………/…………
Fire security?
  **(A)** Location & construction ……………………
  **(A)** Extinguishers?/where sited …………/…………
  Stock list kept elsewhere? ……………………
**(A)** Adequate floor bund (>110%)? ……………………
**(A)** Sorbent for minor spills ……………………

**Mixing and Filling**

**(A)** Location(s) of fill point ……………………
**(A)** Type of surface ……………………..……………………
……………………..……………………
**(A)** Proximity to surface drains (hard surfaces only) ………………………………
………………………………
**(A)** Under cover? ……………………
**(A)** Sorbent for minor spills ……………………
**(A)** Bulk spill containment? ……………………
**(A)** Risk of back-siphoning? ……………………
**(A)** Use closed transfer system? ……………………
Use foam suppressant? ……………………
Containers:
  **(A)** Rinse nozzle on sprayer? ……………………
  **(A)** Where stored, temporarily ……………………
Is equipment washed at same location?:
  Internal rinsings ……………………
  External rinsings ……………………
**(A)** Nature of area, vegetation etc., to which site drains ……………………..……………
……………………..……………………
……………………………………….…

**Field Application**

Pesticide choice – environmental effects considered? ……………………
……………………
Chemical rate policy (always reduced, agronomist’s advice, etc) ……………………

……………………
……………………
**(A)** Auto volume system on sprayer? ……………………
How wind speed is assessed ……………………
Weather forecasting? ……………………
**(A)** Drift minimisation measures ……………………………..…
……………………………..…
……………………………..…

Watercourse(s) within 10 m? ……………………
Use of LERAPS to reduce buffer? – state min. width ……………………
Measures to protect field margins ……………………………………
……………………………………
……………………………………
Spray records (areas, quantities of chemical) to confirm a/r ……………………
Equipment maintenance policy – jet wear, leaks etc. ……………………
……………………

Sprayer NSTS tested?/date of last test ………/……………

**Wastes**

Waste minimisation policy –
Considered at all? ……………………
container re-use? min. packaging (dry)? ……………………
……………………

Container disposal – how/where ……………………
Burning: open fire/BAA type brazier? ……………………
Loading and supervision ……………………
Ash residue disposal ……………………

Surplus concentrate disposal? ……………………
Sorbent disposal – how/where ……………………

Contaminated PPE disposal – how/where ……………………

Measures to avoid surplus solution in equipment ……………………
……………………

Internal wash out –
applications scheduled to reduce critical wash out? ……………………
**(A)** facilities on sprayer? ……………………
where disposed? ……………………

External washdown –
frequency ……………………
location ……………………

**Identified Issues with Potential for Pollution Reduction. State if NON-PEPFAA compliant.**

Comment: This would be the place for some questions re BMP uptake:
what has been done, what would be needed for support, why not do (maybe against a checklist of potential measures – see BMP list attached), from which some could be highlighted as relevant.
Also go through DO's and Don'ts from PEPFAA code?
Some basics of farm business to establish viability/ability to pay for measures – discuss with Michael.
Need to try to get these explanations in their own words – can you tape the comments and get them transcribed?

| Description | Reason – eg. ignorance, not got round to it, technical challenge, inconvenience, |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

## Irrigation

| Crop | Area irrigated |
|---|---|
| | |
| | |
| | |
| | |
| | |

| | |
|---|---|
| **Source of irrigation water** | |
| **Water storage reservoirs (location, size etc.)** | |

**Name of catchment(s):**

1. Approximate proportion of catchment used for intensive agriculture ☐ %

2. Other land uses ☐

3. Predominant farming systems present ☐

4. Soil types present ☐

5. Is the catchment part of a Nitrate Vulnerable Zone (NVZ)? Yes ☐ No ☐

6. Does the catchment contain oligotrophic or mesotrophic lochs? Yes ☐ No ☐

7. Is the agricultural land drained by small watercourses? Yes ☐ No ☐

8. Is the catchment important for spawning salmonids? Yes ☐ No ☐

9. Does the catchment drain to designated bathing waters or other waters used for recreation? Yes ☐ No ☐

10. Are there designated sites within the catchment (e.g. SSSI, SPA, SAC, Ramsar)? Yes ☐ No ☐

| Details (e.g. sensitivity to diffuse pollution) |
| --- |
| |

11. Other known catchment sensitivities

| |
| --- |
| |

# Farm and Field based calculation of total nitrogen permitted from organic manure

**Farm code……………………………………………………………………**

| IACS field no. (or other) xx/xxxxx/xxxxx | Grass fields (ha) a | Non grass fields (ha) b | Areas to be deducted (ha) | | | Available spreading area (ha) a or b – (c+d+e) f | | | Field spreading limit, excluding grazing deposition (subject to farm – based limits not being breached) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Buffers c | Slopes d | Other e | | | | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| | | | | | | | x 250 | = | |
| **TOTAL** | A = | **B =** | **Complete farm limit calculations below or continue on another sheet if there are more fields to enter.** | | | | | | |

| **Farm based limit: Maximum organic N loading for land within NVZ (including grazing deposition)** | |
|---|---|
| Grassland limit = (A x 250)kg organic N/year | = |
| Non-grassland limit = (B x 170)kg organic N/year | = |
| **Overall Farm limit: For comparison with actual organic N produced by livestock on the holding (Complete Table D in SEERAD NVZ Guidance reproduced in Appendix III ).** | |
| Overall farm limit = (A x 250) + (B x 170)kg organic N/year | = |

**Standard figures for total nitrogen produced as livestock excreta**

| Stock Unit | Number of stock units | Total N excreted by one stock unit (kg/year) | Total N excreted by all these animals (kg/year) |
|---|---|---|---|
| 1 Dairy Cow (650 kg) | | x 116 = | |
| 1 Dairy Cow (550 kg) | | x 96 = | |
| 1 Dairy Cow (450 kg) | | x 76 = | |
| 1 Dairy heifer replacement/ fattener 2-year or over | | x 58 = | |
| 1 Suckler Cow | | x 58 = | |
| 1 Grower/fattener 12-24 months | | x 47 = | |
| 1 young beast 6 –12 months | | x 12 = | |
| 1 Calf (to 6 months) [1] | | x 7 = | |
| 1 Sheep (Ewe or Ram) | | x 9 = | |
| 1 Fattening Lamb [1] | | x 1.2 = | |
| 1 Breeding Sow place (including piglets to 4 weeks) [2] | | x 19.5 = | |
| 1 Maiden gilt | | x 13 = | |
| 1 Weaner Place [3] | | x 3 = | |
| 1 Grower, dry meal 7.5-11 weeks [3] | | x 6.1 = | |
| 1 Light cutter, meal fed 11-20 weeks [3] | | x 9.4 = | |
| 1 Baconer 11-23 weeks [3] | | x 10.5 = | |
| 1000 Laying Hens (98% occupancy) | | x 660 = | |
| 1000 Broiler Places (76% occupancy) | | x 495 = | |
| 1000 Broiler breeders (77% occupancy) | | x 975 = | |
| 1000 Pullets (38% occupancy) | | x 125 = | |
| 1000 male Turkeys (140 days) | | x 1390 = | |
| 1000 Female Turkeys (120 days) | | x 650 = | |
| 1000 Ducks (50 days) | | x 900 = | |
| | | **Total N produced (kg N/year)** | **F =** |

[1] Presumes kept for only 6 months

[3] Figures based on standard cropping cycle and year occupancy

# A7. . Diatom species data from sampling sites in Lunan catchment

**Hatton**

| | N | S | V | NxSxV | NxV |
|---|---|---|---|---|---|
| Achnanthidium lanceolata | 53 | 5 | 2 | 530 | 106 |
| Achnanthidium minutissima | 64 | 2 | 2 | 256 | 128 |
| Amphora sp. | 1 | 5 | 1 | 5 | 1 |
| Cocconeis sp. | 17 | 3 | 2 | 102 | 34 |
| Cymbella sp. | 1 | 2 | 1 | 2 | 1 |
| Encyonema sp. | 4 | 3 | 2 | 24 | 8 |
| Encyonema minutum | 1 | 3 | 2 | 6 | 2 |
| Melosira varians | 1 | 4 | 2 | 8 | 2 |
| Meridion circulare | 1 | 2 | 3 | 6 | 3 |
| Navicula sp. | 41 | 4 | 1 | 164 | 41 |
| Nitzschia sp. | 7 | 4 | 1 | 28 | 7 |
| Nitzschia sygmoidae | 4 | 4 | 1 | 16 | 4 |
| Suirella brebissonii | 5 | 3 | 1 | 15 | 5 |
| Pinnularia sp. | 1 | 1 | 3 | 3 | 3 |
| | 200 | **TDI** = | **3.68** | 269 | 73 |

**Hatton Source**

| | N | S | V | NxSxV | NxV |
|---|---|---|---|---|---|
| Achnanthidium lanceolata | 22 | 5 | 2 | 220 | 44 |
| Achnanthidium minutissima | 7 | 2 | 2 | 28 | 14 |
| Amphora pediculus | 3 | 5 | 1 | 15 | 3 |
| Cocconeis sp. | 2 | 3 | 2 | 12 | 4 |
| Encyonema minutum | 1 | 3 | 2 | 6 | 2 |
| Meridion circulare | 101 | 2 | 3 | 606 | 303 |
| Navicula sp. | 17 | 4 | 1 | 68 | 17 |
| Nitzschia sp. | 7 | 4 | 1 | 28 | 7 |
| Suirella brebissonii | 40 | 3 | 1 | 120 | 40 |
| Synedra ulna | 0 | 3 | 1 | 0 | 0 |
| | 200 | **TDI** = | **2.54** | 1103 | 434 |

**Wemyss**

| | N | S | V | NxSxV | NxV |
|---|---|---|---|---|---|
| Achnanthidium lanceolata | 11 | 5 | 2 | 110 | 22 |
| Achnanthidium minutissima | 31 | 2 | 2 | 124 | 62 |
| Cocconeis sp. | 1 | 3 | 2 | 6 | 2 |
| Encyonema minutum | 1 | 3 | 2 | 6 | 2 |
| Melosira varians | 4 | 4 | 2 | 32 | 8 |

| | | | | | |
|---|---|---|---|---|---|
| Meridion circulare | 4 | 2 | 3 | 24 | 12 |
| Navicula sp. | 106 | 4 | 1 | 424 | 106 |
| Nitzschia sp. | 3 | 4 | 1 | 12 | 3 |
| Rhoicosphenia curvata | 22 | 5 | 5 | 550 | 110 |
| Synedra ulna | 17 | 3 | 1 | 51 | 17 |
| | 200 | **TDI** = | **3.94** | 1288 | 327 |

**Pitkennedy**

| | N | S | V | NxSxV | NxV |
|---|---|---|---|---|---|
| Achnanthidium lanceolata | 8 | 5 | 2 | 80 | 16 |
| Achnanthidium minutissima | 10 | 2 | 2 | 40 | 20 |
| Gomphonema angustatum | 6 | 1 | 2 | 12 | 12 |
| Meridion circulare | 12 | 2 | 3 | 72 | 36 |
| Navicula sp. | 148 | 4 | 1 | 592 | 148 |
| Navicula gregaria | 15 | 5 | 1 | 75 | 15 |
| Nitzschia sp. | 1 | 4 | 1 | 4 | 1 |
| | 200 | **TDI** = | **3.53** | 875 | 248 |

**Westerton**

| | N | S | V | NxSxV | NxV |
|---|---|---|---|---|---|
| Achnanthidium lanceolata | 30 | 5 | 2 | 300 | 60 |
| Achnanthidium minutissima | 4 | 2 | 2 | 16 | 8 |
| Cocconeis placentula | 1 | 3 | 2 | 6 | 2 |
| Cymatopleura solea | 1 | 4 | 1 | 4 | 1 |
| Gomphonema angustatum | 2 | 1 | 2 | 2 | 4 |
| Navicula sp. | 37 | 4 | 1 | 148 | 37 |
| Nitzschia sp. | 97 | 4 | 1 | 388 | 97 |
| Navicula gregaria | 24 | 5 | 1 | 120 | 24 |
| Rhoicosphenia curvata | 1 | 5 | 1 | 5 | 1 |
| Suirella brebisonnii | 2 | 3 | 1 | 6 | 2 |
| Synedra ulna | 1 | 3 | 1 | 3 | 1 |
| | 200 | **TDI** = | **4.21** | 998 | 237 |

**Balgavies**

| | N | S | V | NxSxV | NxV |
|---|---|---|---|---|---|
| Achnanthidium lanceolata | 1 | 5 | 2 | 10 | 2 |
| Achnanthes sp. | 4 | 3 | 1 | 12 | 4 |
| Cocconeis sp. | 1 | 2 | 2 | 4 | 2 |
| Cocconeis placentula | 13 | 3 | 2 | 78 | 26 |
| Cocconeis pediculus | 3 | 4 | 2 | 24 | 6 |
| Diatoma tenuis | 104 | 2 | 2 | 416 | 208 |
| Encyonema sp. | 1 | 2 | 1 | 2 | 1 |
| Fragilaria capucina | 21 | 2 | 2 | 84 | 42 |
| Gomphonea truncatum | 2 | 3 | 1 | 6 | 2 |
| Gomphomena acuminatum | 1 | 3 | 1 | 3 | 1 |
| Gyrosigma attenuatum | 1 | 5 | 2 | 10 | 2 |

| | | | | | |
|---|---|---|---|---|---|
| Navicula sp. | 35 | 4 | 1 | 140 | 35 |
| Nitzschia sp. | 2 | 4 | 1 | 8 | 2 |
| Navicla meniscula | 1 | 4 | 1 | 4 | 1 |
| Synedra sp. | 7 | 4 | 1 | 28 | 7 |
| Synedra ulna | 2 | 3 | 1 | 6 | 2 |
| Rhoicosphenia curvata | 1 | 5 | 1 | 5 | 1 |
| | 200 | **TDI** = | **2.44** | 840 | 344 |

**Newmill Bridge**

| | N | S | V | NxSxV | NxV |
|---|---|---|---|---|---|
| Achnanthidium lanceolata | 18 | 5 | 2 | 180 | 36 |
| Achnanthidium minutissima | 18 | 2 | 2 | 72 | 36 |
| Cocconeis pediculus | 15 | 4 | 2 | 120 | 30 |
| Cocconeis placentula | 22 | 3 | 2 | 132 | 44 |
| Gomphonema sp. | 5 | 3 | 1 | 15 | 5 |
| Gomphonema parvulum | 2 | 5 | 3 | 30 | 6 |
| Meridion circulare | 11 | 2 | 3 | 66 | 33 |
| Navicula sp. | 81 | 4 | 1 | 324 | 81 |
| Nitzschia sp. | 7 | 4 | 1 | 28 | 7 |
| Rhoicosphenia curvata | 1 | 5 | 1 | 5 | 1 |
| Synedra sp. | 4 | 4 | 1 | 16 | 4 |
| Synedra ulna | 16 | 3 | 1 | 48 | 16 |
| | 200 | **TDI** = | **3.46** | 1036 | 299 |

**Mid Dod**

| | N | S | V | NxSxV | NxV |
|---|---|---|---|---|---|
| Achnanthidium lanceolata | 44 | 5 | 2 | 440 | 88 |
| Achnanthidium minutissima | 3 | 2 | 2 | 12 | 6 |
| Caloneis sp. | 1 | 3 | 1 | 3 | 1 |
| Encyonema sp. | 1 | 2 | 1 | 2 | 1 |
| Meridion circulare | 1 | 2 | 3 | 6 | 3 |
| Navicula sp. | 110 | 4 | 1 | 440 | 110 |
| Nitzschia sp. | 40 | 4 | 1 | 160 | 40 |
| | 200 | **TDI** = | **4.27** | 1063 | 249 |

**Auchterforfar**

| | N | S | V | NxSxV | NxV |
|---|---|---|---|---|---|
| Achnanthidium lanceolata | 5 | 5 | 2 | 50 | 10 |
| Achnanthidium minutissima | 26 | 2 | 2 | 104 | 52 |
| Cocconeis placentula | 14 | 3 | 2 | 84 | 28 |
| Cocconeis pediculus | 1 | 4 | 2 | 8 | 2 |
| Gomphonema sp. | 4 | 3 | 1 | 12 | 4 |
| Navicula sp. | 139 | 4 | 1 | 556 | 139 |
| Nitzschia sp. | 10 | 4 | 1 | 40 | 10 |
| Rhoicosphenia curvata | 1 | 5 | 1 | 5 | 1 |
| | 200 | **TDI** = | | 859 | 246 |

**Murton**

| | N | S | V | NxSxV | NxV |
|---|---|---|---|---|---|
| Achnanthidium lanceolata | 1 | 5 | 2 | 10 | 2 |
| Achnanthidium minutissima | 70 | 3 | 1 | 210 | 70 |
| Cocconeis sp. | 1 | 2 | 2 | 4 | 2 |
| Cocconeis placentula | 1 | 3 | 2 | 6 | 2 |
| Cocconeis pediculus | 1 | 4 | 2 | 8 | 2 |
| Diatoma vulgare | 3 | 5 | 3 | 45 | 9 |
| Encyonema sp. | 1 | 2 | 1 | 2 | 1 |
| Gomphonema sp. | 41 | 3 | 1 | 123 | 41 |
| Gomphonema angustatum | 6 | 1 | 2 | 12 | 12 |
| Gomphonema parvulum | 1 | 5 | 3 | 15 | 3 |
| Meridion circulare | 20 | 2 | 3 | 120 | 60 |
| Navicula sp. | 15 | 4 | 1 | 60 | 15 |
| Nitzschia sp. | 35 | 4 | 1 | 140 | 35 |
| Rhoicosphenia curvata | 1 | 5 | 1 | 5 | 1 |
| Synedra sp. | 1 | 4 | 1 | 4 | 1 |
| Synedra ulna | 2 | 3 | 1 | 6 | 2 |
| | 200 | **TDI** = | **2.98** | 770 | 258 |

## A8.1. Pooling Our Knowledge of the Lunan Water Catchment:A Meeting held 9th July 2008 at the Macaulay Institute

Present:
Hamish Moir – Macaulay Institute
Nikki Baggley – Macaulay Institute
Jannette MacDonald - SEPA
Sarah Dunn – Macaulay Institute
Andy Vinten – Macaulay Institute
Malcolm Coull – Macaulay Institute
Ian Dickson - SAC
Carole Christian – SAC
Sue Cooksley – Macaulay Institute
Jonathan Bowes - SEPA
Philippa Booth – Macaulay Institute
Kirsty Blackstock – Macaulay Institute
Martyn Futter – Macaulay Institute
Marie Castellazzi – Macaulay Institute
Iain Brown – Macaulay Institute
Simon Langan - Macaulay Institute

Introduction 8. Agendas and minutes of meetings.
The meeting began with a brief introduction to the purpose of the meeting, which was to bring together four different projects working on the Lunan Water and share results and ideas. The research should be feeding into the Monitored Priority Catchment project, but also relates to work ongoing in the rest of the RERAD work package such as integrated assessment for water management or landscape level measures or climate change modelling. [Powerpoint available on request]

**Stakeholder Discussion Groups: linking scientific & local knowledge**
Malcolm presented the results from the five discussion groups regarding perceptions of the Lunan Water and the responses to Martyn's heuristic for water quality – a nutrient budget for the Lunan using SEPA's monitoring data. [Powerpoint available on request] The presentation illustrated the diversity of views of the catchment, its issues and the solutions. An important issue was the need to tell people more about what research is ongoing and to disseminate good practice information, especially regarding septic tanks.
There was a brief discussion about whether people were accusatory or confessional in the groups and how we recruited participants to attend.

**Lunan Rapid Appraisal Study**

Hamish presented the results of the walk through the catchment by a team of Macaulay scientists that looked at riparian, in-stream ecology and Hydromorphology, and illustrated the use of the River Hydromorphology Process Survey. [Powerpoint available on request]. The presentation noted that whilst there may be poorer in stream ecology than WFD would require, *in the areas surveyed*, the Hydromorphology was relatively good for a downstream agricultural catchment. There was a brief discussion about whether Hamish was or would work on sediment in the Lochs given that the Lochs appear to act as both a sink for soil washing off fields, and a source of P. Hamish is not, but Jonathan is sampling Baldardo and Murton tributaries; and Ian Fozzard is also hoping to take samples from the middle of both lochs. There was some discussion about whether the river below the lochs had sediment issues and if that was what was reducing the macrophytes – it may be mechanical trampling in areas with cattle having access to the river?

**LandSFACTS & Lunan Catchments**

Marie presented her ongoing work with Ian Brown using the LandSFACTS model in the Lunan catchment to develop scenarios of spatio-temporal arrangements of land uses in agricultural landscapes. The presentation illustrated changing scenarios of land use over ten years, including constraints imposed through restrictions in cropping near watercourses. [Powerpoint available on request] Iain added some information about the work on climate change, noting that climate change would have a long term effect on land capability but also year to year climate variability will alter what is grown by farmers. It was noted that the OS dataset missed some of the drainage network which will impact on the quality of the simulations. There was also a discussion on whether to use mean or observed data to generate climate scenarios, as farmers will only change behaviour in response to longer term trends in climate.

**Candidate BMPs in Lunan Catchment**

Carole introduced the Environment Focus Farm and the EFF group and recalled that a year ago, presentations by SAC, MLURI and SEPA helped to convince the farmers that there was diffuse pollution from agriculture and that this was a problem. More recent meetings have introduced further discussions about how to prevent soil erosion and improve nutrient budgeting. Carole then talked through the proposed measures that they hope some of the EFF group will take up [PowerPoint available but please do not circulate as ideas yet to be discussed with the farmers]. Hamish noted that re-meandering may not be appropriate as the streams may not meander naturally, but naturalising canalised stretches is a good idea.

**Where to from here?**

Martyn presented a series of issues for discussion including: goals, integration, scale, uncertainty, stakeholder dialogue, GES & objectives, Diffuse Pollution, Hydromorphology, and BMPs [PowerPoint available]. There was some discussion on disproportionality – as other pressures are regulated through CAR; and on whether we have a sufficient evidence base to answer many of the questions. One of the key issues is whether the national level tools provide different answers to local knowledge and local monitoring. For example, the entire catchment is 'at risk' yet local monitoring suggest that water bodies are meeting, or on target to meet, P standards. There was discussion about future climatic and economic pressures on agricultural production patterns and on farmers' uptake of voluntary agri-environmental measures.

**Jannette** was invited to respond from SEPA. She summarised her long list of questions and issues down to (1) a request to present our research in the context of the WFD and the classification standards, and where our science challenges these standards, to feedback to UKTAG (2) a request to provide the evidence base for whether existing national policy instruments (GAEC, GBR and PEPFAA code) will be sufficient to achieve WFD objectives – in other words 'is this good practice good enough?'

**Discussion (including comments made to me over coffee):**
Possible gaps noted in the discussion were the need to look at soil processes as sediments could be the key to improving water quality; the lack of attention to groundwater; and the need to have economists attending in future.

Lunan Water is now designated bathing water but is meeting the regulatory standards so cattle are not adding too many FIO – this may still be a problem for recreational stream users. The EFF is putting in off stream cattle waterings. GBRs only cover 'significant' poaching. The main issues for the catchment, from a WFD perspective, are P, morphology and N and pesticides to groundwater. It appears that P is mainly a problem in the upper catchment, although there is a downward trend. Rescobie is acting as a giant silt trap for the Balgavies system. The weir at Boysack Mill may prevent the main stem reaching GES as it acts as fish barrier – and this also acts as a sediment barrier, stopping sediment moving downstream. The N problems should be dealt with by the NVZ action programme, and this programme may also help reduce P entering the water body. There are six G/W bore holes in the catchment. SEPA (Ian Ridgeway) have started pesticide monitoring. It is possible that Atrazine – a herbicide used by transport corridors – may have been limiting Salmon migration. Salmon numbers may be down due to external factors such as marine conditions and coastal netting, but the weir will also impact on migration. Low flows were not seen on the walk through, although abstraction is an issue in the catchment.

Climate change will have a long term influence on land capability and land use and on availability of water. Moving from potatoes to horticulture may use less water? There is a SEPA project working with farmers on management agreements for abstraction of water – contact Stuart McGowan in the Arbroath office. The main driver on land use change or intensity is the economic market – whilst inputs have increased in price (feed, fertiliser, fuel), the market for cereals is likely to encourage more production. This amplifies agri-environmental problems with income-foregone; and there are also problems with continuity of the schemes. Set aside changes are being tracked by the Scottish Government – difficulty of interpreting the data – although GBR require a 2m buffer strip next to any water course. Farmers have said when struggling that they would put in measures when market was good, but the opposite is happening - it should be noted that farm inputs including fertilisers and diesel are increasing at the same time as returns are improving. There is anecdotal evidence that the SRDP process is complex and oversubscribed and that there is said to be a high "failure" rate of Statements of Intent.

What is the awareness of, and implementation of, the statutory compliance for agricultural diffuse pollution? The EFF project is looking at voluntary best practice – what will the statutory baseline achieve? Proposal to audit and measure compliance in subcatchment. It would be useful to map the EFF members against the 'hotspots' identified in Jonathan's model. It is important that the farmers don't feel they are the only ones targeted – septic tanks also being explored and work will be presented at the next EFF meeting. We need better evidence of source apportionment, and this is on the way.

It is important to maintain contact with the Tay AAG. It is also important to keep in touch with the Esk Fishery Board who are co-funding work on four rivers including the Lunan Water; and Tom (EFF farmer) is on this board. There may be a link to Nikolai's KTE project here? And to the South Esk CMP. If CMPs become a measure for priority catchments, what is the limit to the number of issues that could and should be tackled? This will be discussed in part at the CATCH workshop on catchment management officers and will feature in the guidance arising.

There was a brief discussion on the website. Currently MLURI staff are putting materials on the P3 website, SEPA have a webpage on the MPC project and SAC are developing an EFF page. Kirsty will put these minutes, the discussion group flier and the slides on the P3 group page for now.

**Jonathan** presented some slides on his work in the catchment, mainly focussed on one of the upper subcatchments. His soil modelling work illustrates that often small streams are large contributors. It is important to identify hotspots to tackle with BMPs – these are both critical source areas for sediment, and areas where the sediments are most likely to enter the water body (critical delivery areas). There was a short discussion on whether the model included sediments from all sources – it does include input from non-agricultural land but the outputs to the water courses are from agricultural fields only. The model generates sediment currently from where our best estimate is of arable land (LCM2000) until SGRPID give us access to SIACS. It does however account for all runoff from all land uses. Possible improvements are actual land use data from SIACS and accounting for (a) soil property (ies). The model will be calibrated/validated using actual erosion rates from a SEPA funded R&D project using $^{137}Cs$ as a tracer.

**Nikki** had checked the web for the current status of the Lunan Water and confirmed that currently all water bodies for the catchment are designated at risk of failing GES by 2015.

**Next meeting:**
To be held in about six months, focussing on the Lunan Water. Six months is mid January 2009. Andy suggested before mid programme review, but calendar is very crowded then, so suggest week beginning 12th January 2009?

**Action Points:**

| **Action** | **Who** | **By When** |
|---|---|---|
| Alter MPC diagram to from regulation to measures | Andy | ASAP (before goes on website) |
| Share data on Groundwater monitoring | Sarah/Jannette | As data available |
| Encourage two farmers in Murton catchment to join EFF (Robertson & ?) | Jonathan/Carole | Before next EFF meeting |
| Discuss statutory compliance audit | Andy/Carole/ Jannette | ASAP |
| Invite Tay AAG coordinator to next meeting | Kirsty | September |
| Feedback from CATCH workshop | Kirsty | After workshop |
| Liaise on single Lunan website | Andy, Carole and Jannette | ASAP |
| Write up MPC project for Scottish Farmer | Carole with input from Andy and Jannette | September |
| Put material on website | Kirsty | ASAP (when minutes finalised) |
| Follow up information with Tay AAG | Kirsty | End August |
| Minutes and action points | Kirsty | ASAP |
| Preferred date for next meeting | All | End August |
| Suggestions for the Agenda for meeting | All | End October |

# A8.2 Lunan Water Research Update Meeting

## *23 feb 2009*

## *Agenda*

**Macaulay Suite A, Macaulay Institute, Aberdeen**

| | | |
|---|---|---|
| **10:30** | **Coffee served** | |
| **11:00** | Welcome & Purpose of Day<br>Overview of LW projects | Andy Vinten |
| **11.10** | Environmental Focus Farms | Carole Christian |
| 11.20 | Questions/Discussions | |
| **11.30** | Catchment Monitoring | Marc Stutter |
| 11.40 | Questions/Discussions | |
| **11.50** | Nitrates in Groundwater | Sarah Dunn |
| 12.00 | Questions/Discussions | |
| **12.10** | Update on sediment modelling | Jonathan Bowes |
| 12.20 | Questions/Discussion | |
| **12.30** | **Lunch** | |
| **13.00** | Farm Audits | Andy Vinten |
| **13.15** | Lunan Water Discussion Groups | Martyn Futter |
| 13.25 | Questions/Discussion | |
| **13.35** | SEPA Lunan WQ monitoring | Fiona Napier |
| 13.50 | Questions/Discussion | |
| **14.00** | Integrated Modelling Project | Iain Brown |
| 14.10 | Questions/Discussion | |
| **14.20** | Break out groups to discuss synergies<br>*Tea & coffee available* | |
| **15.00** | Feedback & actions | Martyn Futter |
| **15.30** | Meeting Ends (*opportunity for informal meetings*) | |

# A8.3 Lunan Water Meeting Notes 23 February 2009

Attendees

Nikki Baggaley (MI)
Bedru Balana (MI)
Christian Birkel (MI)
Jonathan Bowes (SEPA)
Iain Brown (MI)
Marie Castellazi
Sarah Dunn (MI)
Martyn Futter (MI)
Klaus Glenk (MI)
Hamish Moir (MI)
Fiona Napier (SEPA)
Alex Sinclair (SAC)
Marc Stutter (MI)
Andy Vinten (MI)

Regrets

Kirsty Blackstock (MI)
Carole Christian (SAC)
Malcolm Coull (MI)
Janette Macdonald (SEPA)

Andy Vinten introduced the meeting and gave an overview of the partnership between the Scottish Agricultural College (SAC), the Scottish Environmental Protection Agency (SEPA) and the Macaulay Institute (MI). He outlined the work being done by each of the partners. He stated that he was under the impression that Janette Macdonald wanted the overall project to be focused on assessing the effectiveness of General Binding Rules (GBR) in attaining Good Ecological Status (GES).

Iain Brown noted that a project on land use and landscape assessment being lead by Dave Miller (MI) should be added to the project list.

Alex Sinclair gave a presentation focused on the Mains of Balgavies Environmental Focus Farm (EFF). The Mains of Balgavies EFF surrounds Balgavies loch. The farmer (name ?) is interested in nutrient management and the risk of soil erosion. Work being done at the farm could satisfy both research and extension needs. A considerable amount of work has already been done at the Mains of Balgavies. Most of the fields are min-till, there are 6m buffer strips. Nutrient budgeting has been performed since 2006 and all soils were tested in 2007. Yield mapping has been performed since 2008. There are Nitrate Vulnerable Zone (NVZ) issues at the farm.

Alex Sinclair showed that many of the fields in the Mains of Balgavies could benefit from liming. Liming would increase the soil pH and hence the yield of spring barley. Liming could be used as a best management practice (BMP) on some fields. It would lead to increased yields and to less excess Nitrogen (N). The field pH measurements show a high degree of variability (+/- 0.5 ph units) both within and between fields. Alex showed that phosphorus (P), potassium (K) and magnesium (K) were in fairly good shape across the fields and that P inputs could be lowered in some cases.

A need exists for a field-by-field map of erosion risk. Bill Jeffries (SAC) will be asked to generate this map based on the MI inherent geomorphic erosion risk criteria.

There are differences in erosion potential of soils derived from different underlying parent materials. Soils on O. Red Sandstone have increased erosion risk. P will adhere preferentially to fines. The Greenhead farm, which is some distance from Rescobie, displays erosion which appears to be connected to Rescobie. Fines from Greenhead could be transported to the loch, suggesting a very complicated pattern of hydrological connectivity within the catchment.

There was some debate as to the uptake of nutrient management plans by farmers in the catchment. There has been generally poor uptake by farmers in the Lunan Water catchment. This may come down to an issue of resources. Projects that have had high degrees of uptake typically have a catchment management officer or similar person devoted to the project.

Marc Stutter (MI) presented the MI monitoring being conducted in the catchment. MI is conducting background monitoring in 5 small catchments. Open-channel hydrology has been monitored since 2007. Concentrations of nitrate ([$NO_3^-$]) are quite high and there is a big range in soluble reactive phosphorus (SRP) between sites. The Rescobie loch water quality is classified as "Moderate/Poor" based on total phosphorus concentrations ([TP]) and chlorophyll. Six or so storm events have been monitored for suspended sediments and water chemistry since October 2008.

The MI high-resolution turbidity data are not that well correlated with spot samples of suspended sediment concentration ([SS]). There are seasonal patterns in turbidity and hysteresis in turbidity:flow relationships. However, Fiona Napier (SEPA) later showed a very tight relationship between turbidity and [SS]. There was some additional discussion of sediment delivery and a suggestion that all fields are connected to a stream, and hence the loch.

There was some discussion as to whether or not the Hatton Burn site (? – it's the site outside the Lunan Water catchment) constitutes a true control. The farm audits still need to be done and there was some concern expressed about the temporal resolution of the turbidity data.

There was some discussion as to how the P status of fields is actually defined. SAC uses a modified Moran test for determining P status. This should be OK, so long as all assessments are based on the modified Moran test and that everyone is aware that the results from a modified Moran test will be different than those obtained by Olsen-P or acetic acid tests.

Sarah Dunn (MI) gave a presentation on understanding flow paths and residence time within the catchment and the implications for NVZ remediation. Her presentation showed the need for better data integration between the partners. We should have resources at MI to devote to this in the latter half of 2009. She showed that it is not possible to do a water balance at the subcatchment scale (and that subcatchment delineation is very dependent on the digital elevation model (DEM) used). Fortunately, a water balance can be obtained for the whole catchment upstream of Kirkton Mill.

There is a lot of isotope work being performed in the catchment that identifies the age of stream and ground waters (Sarah, I have to confess I don't fully understand this – maybe you could add a sentence or two here?)

SEPA is maintaining five boreholes in the catchment. Some of these consistently have [$NO_3^-$] at or above the NVZ target. Sarah's groundwater dating suggests that some of these waters may date from the 1980's or earlier. There are very long groundwater residence times within the Lunan Water catchment. The groundwater at Murton Mill could be very old. This has implications for determining the time to recovery and possible future trajectories of groundwater [$NO_3^-$].

Modelling results from NIRANS show large amounts of excess N in the catchment (in some cases, more than 100 kg/ha). These results should be cross-checked against the estimate LandFacts N inputs.

Jonathan Bowes (SEPA) presented an update on the sediment work SEPA is conducting in the catchment. He has conducted an intensive campaign (+/- 50 cores/field) at three fields in the Lunan Water to determine soil erosion using radioactive tracers. Erosion rates of up to 15 tonnes soil/hectare/year have been observed. Data from the field campaign have been linked to a soil erosion model. Observation and modelling results show that Baldardo field is a hotspot for sediment export. There are deepened tram-lines throughout the catchment, and it is possible that this one field exports 25% of the annual TP load to the loch. Modelling results suggest that changing flowpaths through the field by digging a ditch around the field could reduce sediment yield by as much as 17%. This one action could have a noticeable effect on loch [TP]. There was some discussion as to whether our actions should be focused on just getting on with it and doing this.

New Mills used to have an online sediment pond which appeared to be very effective at trapping sediment. This pond is now offline. Measured [SS] from New Mills burn as high as 3 mg/l have now been recorded. It appears that fields which are some distance from the loch are still tightly coupled hydrologically. Each of the monitored fields appears to be exporting large amounts of P to the loch. GBR would not influence the issues identified on sediment transport in this study.

Interrupted tramlines have been adopted at Greenhead. They may have significant potential for reducing sediment export. Precision farming can also help, but if the contours are not followed appropriately, the problem can be made worse (Alex – not sure I completely understood this).

Jonathan has collected three sediment cores from Rescobie Loch inflows. These will be used with $^{210}$Pb dating to determine sedimentation rates into the loch.

There was some discussion as to whether Wemyss could be a target for GBR implementation (all – I suspect this could do with a bit of fleshing out).

Andy Vinten (MI) gave a presentation on the progress with the farm audits. Drafts of the four audit questionnaires exist but there may not be funds available to perform the audits. There was some discussion as to whether funds could be obtained from POWRM (not sure what this acronym means). Martin Johnson, the POWRM chair, may be able to shed some light on this. There are still a number of stumbling blocks surrounding the audits. There are discussions between SEPA and SAC as to whether or not they should be compliance audits. There was also some discussion as to whether or not audits were needed, and perhaps it would be better just to get on with it and apply BMP's to the hot spots such as the one at Wemyss. BMP's could be applied first to the field and then to the steading. However, there is a need to get senior level buy in for this. Ideally representatives of SAC, SEPA, MI and the farmer at Wemyss (Mr. Robertson ?) can sit down and thrash out a plan for starting to implement BMP's.

Fiona Napier (SEPA) gave a presentation about the SEPA MPC monitoring in the catchment. Flow monitoring is being conducted at three sites (is there overlap with the MI monitoring ?) Storm event samples are being analysed for nutrients, SS, pesticides and herbicides. Most of the pesticide and herbicide results are less than detect. Sondes for continuous water quality monitoring have been deployed at a number of sites (Fiona – how many ? do they include real-time $NO_3^-$ ?) and there is a program of monthly spot samples. The SEPA turbidity:[SS] samples show a very tight linear relationship but there are problems with one of the sondes. Marc may have a solution for this.

It is clear that more effort should focus on fines. Fines are correlated with [TP] is spot samples. Fines are present in the top of the catchment. In the lower reaches, stream substrates are more coarse but the fines must be reaching the loch during events.

Iain Brown (MI) presented the LandsFacts simulations for the Lunan Water. These were well received at the Mid Programme Review. This modeling links land use trends, biophysical constraints and socio-economic targets. Future work will look at linking Land Capability for Agriculture (LCA) to soil:climate interactions. There is an interest on the part of the Scottish Executive on linking LCA to Less favoured Areas and Single Farm Payment programmes.

Outstanding issues

- What is the purpose of this project? Is it to assess GBR effectiveness or is it to do integrated catchment science?
- Optimize pH and nutrient inputs in the Mains of Balgavies EFF
- Estimate field-by-field erosion risk for the Mains of Balgavies EFF (Is there any need to estimate field-by field erosion risk for the rest of the catchment? This would probably be helpful for both Marie and Bedru, can Bill do this ?)
- Clean turbidity data (There are issues with sondes used by MI and SEPA, it may be possible to automate the cleaning process)
- Derive transfer functions (possibly seasonal) relating turbidity to [SS].
- How will the data from the five MI monitored subcatchments be analysed to identify the effects of management activities?
- Better integration of data management to make information more readily available to all partners.
- Audits (Andy - you might want to expand on this)
- We are still in the "pre" phase, it would be really nice to get on with it and do some actual interventions within the catchment to assess BMP efficacy. The interrupted tramlines at Greenhead are a step in the right direction. Flow diversion at Baldardo field should be tried.
- How can LandsFacts be enhanced and extended?
- Can anyone attend the buffer strip workshop that Andy mentioned?

Action Items

- A subgroup comprised of Andy, Bedru, Marc and Jonathan will discuss buffer strip efficacy.

- Marc and Fiona will attempt to resolve the problems seen with turbidity sondes.
- Andy will prepare bullet points for a SEPA View article on the work being done by the partnership in the Lunan Water (might be nice if it were the actual article)
- Kirsty and Martyn will prepare an IWA newsletter article on the public engagement work in the Lunan Water.
- Andy will arrange an on-ground meeting at Wemyss between SAC, SEPA and the farmer concerned (name ?) to discuss BMP implementation. This could be an alternative to taking the audits forward
- Nikki will investigate the state of play of the inherent erosion risk modeling and contact Bill Jeffrey if necessary.
- Marie and Bedru will agree on a list of GIS parameters to determine opportunity costs
- Martyn will pursue tools to assess internal loading of P from lochs.
- Jonathan will attempt to find out the target completion date for the SEPA BMP manual.
- Jonathan will meet with SEPA policy staff to determine their receptiveness to BMP implementation at the Baldardo field.
- Andy will talk to Martin Johnson to determine the status of POWRM and the likelihood of funding for audits.
- Fiona will be invited to Andy's Lunan Monitoring meetings
- Fiona will look for pesticide data
- Andy will discuss 2009 rapid appraisal with Benoit Demars.

# A8.4 Lunan Monitoring meeting.

## Summary

**19th January 2009**
**9:30 GILL ROOM**

1. **Monitoring issues:**

**A. Real time**
Adjustments have been made for reporting real-time data so that spikes are removed. This involves using priot time step data if the values are negative. Marc and Andy to look at example events to assess the bias caused by this. Action: Marc/Andy
The turbidity data needs to be corrected for drift (due to biofilm or debris on the window), and also for spikes. This has to be done manually, so it is not possible to present the turbidity data on real time.

**B. Event sampling for turbidity-chemistry calibration during winter**
Four events have been sampled at Wemyss on a 4 hour time step. Suspended solids is stored on filter papers for TP analysis (see below).
Two ISCO samplers are to be ordered this quarter. Christian to give training to Carol/Helen/Marc on the use of the ISCO currently at Wemyss. Action: Christian/Helen to arrange date.

**C. Stage – discharge calibration**
Propellor measurements of three events at Wemyss and Hatton, 6 at Westerton.

**D. Sediment sampling and analysis**
The trapped sediment has all been freeze dried and Renata is handling analysis. We need to arrange a regular window oftime for the PS analyser to be available. Action: Helen/Lisa to speak with Jason. Marc and Andy to arrange soil sampling with Bedru.

**E. Trophic diatoms**
Scrapes have been counted and the biodiversity is generally low, except at Murton. TDI indices are 3 to 4. Helen suggested work on artificial channels might centre around the relationship between biofilms, nutrients and alkalinity. Action: Banoit to arrange a meeting to discuss plans for the artificial channels.

**F. Sondes.**
These to be returnd to Robert Ritchie at SAC.

**G. First year report**

This is on the website at
http://www.programme3.net/water/water345pollution.php

H. Data storage
Helen suggested that Helen Anderson should e responsible for data checking and plotting, followed by data analysis in collaboration with Marc/Andy. Action: Helen, Marc, Andy

2. General Binding Rules Audits - update
   A draft invitation to an external consultant is doing the rounds of the partners at present. The idea will be to pilot the audit for GBRs, BMPs and socio-economic data with a few farms, then focus GBR audits on two catchments and GBR/BMP/socio-economic audits on two catchments. Action; Andy

3. Updating and new/replacement IPs for Lunan MPC:
   a. Lunan monitoring
   Andy/Marc/Helen to update

   b. Groundwater tracing
   Sarah is updating

   c.New: Catchment, lansdcape and farm scale cost-effectiveness analysis of P mitigation measures in Lunan Water
   Discussions on this underway with Bedru.

Additional meeting re. TP analysis.

Agreed as follows:

1. Both GFC and 0.45um filter papers should be use, in sequence, for event samples.
2. No point doing unfiltered samples on the scalar, as the amount of sedimentation occurring in the samples will be highly variable, and the sediment-rich samples are damaging to the Skalar
3. Persulphate digest should be done on filter papers (GFC) of suspended solids.
4. This should be compared with NaOH fusion on parallel filter papers, for a small number of event samples. Yvonne to work out details.
5. Yvonne to devise an internal standard using analytical topsoil, for persulphate method on filter papers.
6. Fresh event samples should be analysed with persulphate method for next two storm events.

# A8.5 AGENDA
# SEPA/MACAULAY/SAC
# MONITORED PRIORITY CATCHMENT MEETING

SEPA EAST KILBRIDE OFFICE (MULL MEETING ROOM)
24 October 10:30 am

Attendees
SAC; Graham Kerr, Carole Christian, Bill Crooks
Macaulay; Andy Vinten
SEPA; Allan Virtue, Jannette MacDonald, Lisa Walker, Stephen Field

1. Introductions and meeting aims (round table views) **All**

2. Review of project aims and objectives **SEPA**

3. EFF updates per catchment **SAC**

4. Monitoring and modelling updates per catchment **MLURI/SEPA**

5. Farm audits per catchment **All**

LUNCH 1pm

Catchment and EFF visit 2:30

7. SEPA/SAC discussion on farm waste management plans

## A9. Attendees at Catchment Research Consultaitive Group meeting on 29 April, 2009.

Carole Christian SAC
Fiona Napier SEPA
Ian Sime SNH
Ian Speirs Scottish Government
Ionna Mouratiadou SAC
John Shabashow SEPA
Karen Millidine FRS
Karen Smith Scottish Water
Marshall Halliday Esk Rivers Fishery Trust
Martin Johnston Scottish Government
Paul Kay University of Leeds
Sarah Hendry University of Dundee
Tom Ball University of Dundee
Andy Vinten Macaulay Institute
Kelly Harper Macaulay Institute
Kirsty Blackstock Macaulay Institute
Malcolm Coull Macaulay Institute
Manuel Lago Macaulay Institute / SAC
Simon Langan Macaulay Institute