Technical note:
Comparison of Porous Pot data and Nitrate Leaching Tool output

1 Introduction

Wessex Water has supplied nitrate leaching data for around 250 fields in South West England based on Porous Pot sampling data. The field records also included crop types and various soil parameters for all fields as well as fertiliser application and crop yield for a subset of the fields.

Porous Pot samples, taken weekly or fortnightly during the autumn months over a time period of 8 winters (2006-2014), produce a time series of nitrate concentrations. These concentrations were weighted using drainage values simulated with the ADAS "Irriguide" model and an annual nitrate loading (Total flux) was calculated by Wessex Water. It should be noted, therefore, that the calculated total nitrate flux is the product of measurements and a model.

Nitrate Leaching Tool (NLT) simulations were carried out for all fields, using known field parameters where available and with the default NLT parameters (based on literature values) for unknown values. A total of three NLT scenarios were simulated by Wessex Water:

- Scenario 1: using only NLT default values, just fields and crop type selected
- Scenario 2: as scenario 1 but using "Irriguide" drainage values
- Scenario 3: as scenario 1 but using "Irriguide" drainage values and bespoke values (fertiliser and crop yield) where known

The results of the NLT runs were then compared to the Porous Pot Nitrate loadings.

Differences in results are to be expected given the derivation of the data. The two datasets are intrinsically different, with measured concentrations in soil water reflecting natural nitrate fluctuations due to factors which are not represented in the NLT, and the NLT operating with a simple N budget algorithm considering only the essential input parameters to predict nitrate at risk of leaching. However, this exercise aims to illustrate underlying patterns in the data and help to understand reasons as to why discrepancies occur.

2 Comparability

The following section presents a number of characteristics of the two data sets that ultimately impede their comparability. Where possible, input values to the NLT were adapted to resemble Porous Pot field parameters more closely.

Cover Crops

One of the main factors that contributes to discrepancies in NLT results compared to the porous pot data is the fact that NLT calculates the nitrogen at risk of leaching immediately after the harvest of the main crop. It is however common practise to plant a cover crop (or an actual cash crop) immediately after the harvest to make use of the residual N in the soil. This will result in a certain amount of nitrate uptake depending on the following crop and its characteristics and cause lower levels of nitrate leaching compared to NLT predictions.

Data Noise/Standard Deviation

The Porous Pot data contains a large amount of noise showing a natural variability in results which cannot be reflected in the NLT. Fields with a very similar management often show a very different nitrate risk. Table 2.1 shows one example to illustrate this point.

Table 2-1: Field number 6 compared to 347

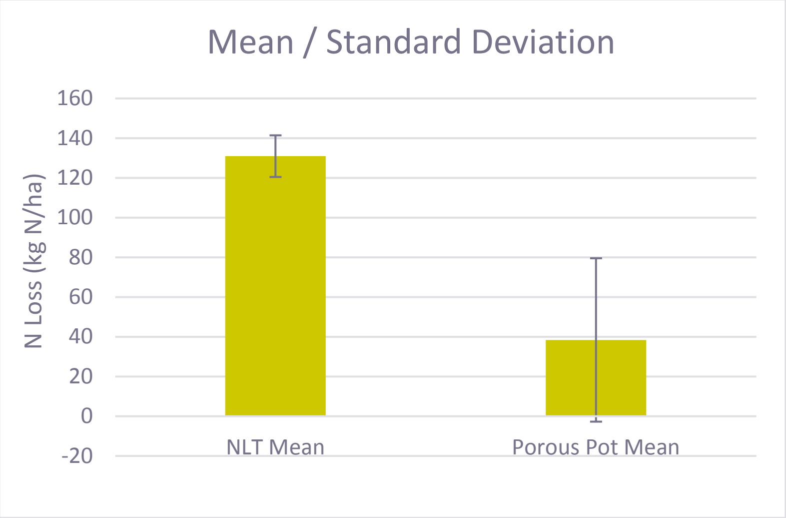
Parameter	Field 8	Field 347
Main crop	Spring Barley	Spring Barley
Following crop	WOSR	WOSR
Fertiliser(kg N/ha)	120	87
Yield (t/ha)	5.6	5.3
N Leached NLT (kg N/ha)	136	105.25
N Leached PP (kg N/ha)	13.47	97.88

This discrepancy might be due to numerous causes such as missing information for these fields, false assumptions, erroneous sample data or simply natural nitrate fluctuations.

The large variability of the data is also evident in the standard deviation of the total flux, calculated from the Porous Pot data, which is on average about 60% of the mean.

shows an example of the data mean and standard deviation of a subset of Spring Barley fields (12 fields) with the same following crop (WOSR) and very similar fertiliser and yield values. The NLT on the left side produces a range of results with a standard deviation of around 10.5 kg N/ha, consistent with the small variation in input parameters. The porous pot data on the right side show much smaller results most likely due to the nitrate uptake by the following crop. However, the porous pot results have a standard deviation of around 41 kg N/ha suggesting a large variability.

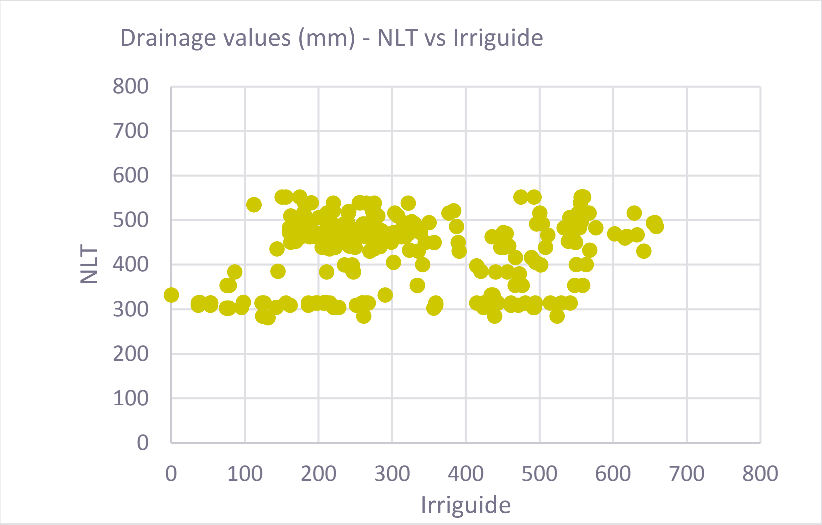
Figure 2-1: Standard Deviation (Spring Barley)



Drainage

The drainage values simulated by "Irriguide" and the drainage values which are part of the base data used in NLT are substantially different for most of the fields. This is to be expected, as the NLT basedata represents long term average soil drainage whereas Irriguide attempts to simulate soil drainage for a specific soil and crop combination in a particular year. shows a scatter plot of the two sets of drainage values. The NLT drainage shows a notably smaller range (280 to 550 mm) compared to "Irriguide" values (0 to 660mm) and the two datasets generally show a very weak correlation..

Figure 2-2: Drainage scatter plot



The drainage values simulated by "Irriguide" are used to calculate the flow weighted nitrate concentration and ultimately govern the result of the nitrate loading calculations. To replicate this calculation more closely the NLT was set up to use the "Irriguide" drainage values.

NLT Base Data

- NLT predictions of nitrate leaching are sensitive to soil "Stored Water", which is a variable related to field capacity and taken from the base dataset. These values demonstrate high variability, with values up to 670 mm.
- The Top Soil Depth listed in the Porous Pot data was used in the NLT in preference to the default values from the Base dataset.

Field Autumn SMN

The data supplied by Wessex Water included Field Autumn SMN for a large proportion of the fields. This value represents the nitrogen in the soil after the harvest and should therefore theoretically be comparable with the residual N prior to leaching which is calculated in the NLT. However, Soil Mineral Nitrogen sampling is subject to a large variability, even within the same field.

Bespoke field parameters

A further unknown are the actual fertiliser rates and yield values associated with a large proportion of the fields. These parameters were known for only one third of the modelled fields. The missing parameters were replaced with typical fertiliser and yield values from NLT (based on literature references). It should be noted that the default values from NLT usually compare well to bespoke field parameters for the same crop type.

Uncertainties and assumptions

The following assumptions were made:

- Manure was not applied to any of the fields.
- Grazed fields were assumed to have a medium stocking density and the gazing period was set to the standard NLT template values (Dairy and Beef = 7months, Sheep and Pigs = All year)
- A Soil Nitrogen Index of 1 was assumed for all fields (in accordance with NLT results in spreadsheet supplied)

3 Results

In light of the recent update and development work carried out on NLT, the model calculations were repeated using the latest version of NLT. The focus of this exercise was NLT scenario three (see section 1), using bespoke values when available, as this will create a simulation closest to actual circumstances. Scenarios one and two were not considered for this exercise.

Results of the comparison of the two datasets are presented in the accompanying spreadsheet (Appendix A).

To make sure this analysis compares 'like with like' the fields were filtered to subsets of the data which aim to remove the issues described in section 2. These fields preferably,

- have the same main crop and the same following crop;
- have leached 100% of the residual N calculated with NLT (to exclude effects of base data soil properties);
- have similar drainage derived with "Irriguide" and NLT drainage (HER); and
- bespoke 'real' input values rather than default NLT values.

The filtered dataset also excluded land use types for which there were an insufficient number of fields to provide statistically robust results. Winter Oats (5 Fields), Spring OSR (2 Fields) or Spring Wheat (1 Field) were therefore excluded. Grassland with Dairy (grazed), Beef and Rough Grazing, despite including a large number of fields were also excluded from this exercise as the 'real' input values for these fields were mostly unknown and the stocking densities were not available.

Figure 3.1 shows the resulting data subset with a single plot for each individual land use. The fields are sorted by the amount of N loss predicted by the NLT. The figure generally suggests a poor fit and a substantial amount of noise in the Porous Pot data but also suggests underlying patterns in the data.

For example, NLT predictions for forage maize overall shows a reasonable fit with the Porous Pot data, apart from the first three fields (fields 267, 345 and 248) which show the same general trend of rising leaching value but the values are considerable lower. These differences may be explained by the higher stored water values for these three fields in NLT's 'Basedata', which indicate retentive soils and therefore only allow for a fraction of the residual N to leach. Additionally, the 'Irriguide' drainage values used for these fields are distinctly lower than the HER values suggested by NLT for these fields (see Appendix A).

In most instances the NLT overestimates the leaching compared with Porous Pot, however, in a majority of these cases the NLT 'Basedata' suggest soils with very low water retention with stored water values of 105 or 110 (e.g. all but the first few fields of Spring Barley, Winter Barley or Winter OSR). These low stored water values will cause 100% of residual N to leach and result in high N loss values. It should perhaps be considered to revise these 'Basedata' values.

The same subset of filtered fields were analysed, taking the average N input minus the average N offtake from the field data, to calculate an estimation of the associated risk from each of these crops (see Table 3.1). Winter OSR was identified as a high risk crop and both NLT and the "Irriguide" results suggest relatively high average N loss from this crop. On the other hand, Forage Maize is shown to be a low risk crop with N offtake exceeding N input, which is confirmed in both NLT and "Irriguide" N loss predictions. This is a very broad approach, averaging N budget across individual land use types, it does however indicate that there is a general consensus in the estimated qualitative risk from a field which the NLT aims to predict and the 'real' risk recorded by Porous Pot data.

Table 3-1: Estimation of associated risk

Land use	**Number of Fields**	**Input** (Fertiliser + Atmospheric N + SNS) **[kg N/ha]**	**Offtake** (Yield) **[kg N/ha]**	**Risk** (Input - Offtake) **[kg N/ha]**	**NLT** (Average N loss from this crop) **[kg N/ha]**	**Irriguide** (Average N loss from this crop) **[kg N/ha]**
Forage maize	7	169.00	300.00	-131.00	15.25	28.33
Spring Barley	18	219.62	86.99	132.62	127.82	39.40
Winter Barley	11	244.34	99.27	145.07	114.17	27.70
Winter Oilseed Rape	22	314.42	103.00	211.43	200.67	73.47
Winter Wheat	39	328.93	172.94	155.98	145.39	62.26

Autumn crops are, as mentioned in section 2, a main factor of potential discrepancies between NLT predictions and Porous Pot data. Leaching values estimated with the NLT are generally higher compared with Porous Pot data, which can be attributed to the effect of following crops and their autumn nitrate uptake.

To improve comparability the NLT was rerun for all fields using a “plant autumn cover crops” mitigation measure which simply reduces the residual N by 50%. Table 3.2 shows the error margin between the predictions of the NLT and the “Irriguide” results as absolute percentage and total error (kg N/ha). Fields with an error of less than 100% or 50 kg N/ha were counted for both with and without the cover crop mitigation measure. The results show an overall improved match with the NLT run that uses the cover crop mitigation measure. The results are also displayed in Figure 3.2 as individual plots for each of the compared land uses.

Table 3-2: Results of NLT run incorporating cover crop (CC) mitigation measure

Land use	Number of Fields	Without CC mitigation Fields with error <100%	With CC mitigation Fields with error <100%	Without CC mitigation Fields with error <50 kg N/ha	With CC mitigation Fields with error <50 kg N/ha
Forage maize	7	6	7	7	7
Spring Barley	18	5	6	5	11
Winter Barley	11	2	4	4	8
Winter Oats	22	5	16	3	12
Winter Oilseed Rape	39	15	28	10	29
Total	**99**	**33**	**61**	**29**	**67**

4 Conclusions

- Fields with a cover crop or following crop have on average a lower porous pot nitrate flux (50 kg N/ha) than fields without (64 kg N/ha), which illustrates autumn crop N uptake.
- The NLT generally overestimates leaching compared with porous pot data which can partly be attributed to the effect of following crops and their autumn nitrate uptake.
- A comparison of Winter Wheat fields with a following crop (e.g. WW, WOSR) and without (e.g. Stubble) suggests a range of autumn uptake by the following crop between 25 and 45 kg N/ha depending on the crop. This information could be useful in setting up methods to simulate specific autumn crops in the NLT.
- Incorporating a simple cover crop mitigation measure (reduction of residual N by 50%) into the NLT calculation improves the match between the two datasets considerably.

- NLT simulations of low risk fields such as Forage Maize, Rough Grazing and Hay (extensive) generally show good agreement with field data, with very low leaching values in both datasets.
- High risk fields such as Winter OSR are identified as higher risk by the NLT, although agreement with field measurements of leaching is often numerically less good.
- A greater difference between porous pot data and NLT results generally corresponds with greater differences between measured autumn SMN and NLTs residual N, i.e. if NLT gets the residual N right the leached N is more likely to be close to porous pot readings.
- The great variability in porous pot samples (high standard deviation of samples within a field) illustrates the large amount of natural variability, or “noise” in the data.
- Some of the predicted “Irriguide” drainage values, especially the very low range, seem unusual for annual drainage volumes indicating that there have been assumptions or field parameters taken into account which are not apparent from the data.
- The Stored Water in NLT’s Basedata (from RPA field data) may need revising as some of the values seem very low.
- The detailed management of particular fields (e.g. timing of manure applications) cannot currently be represented in the NLT model and is therefore not reflected in its results
- The simplicity of the NLT conceptual approach (i.e. a soil N budget calculation) means that some processes such as mineralisation of nitrogen in manures cannot be simulated
- The observed differences could possibly be explained with further field info (e.g. fertiliser values, offtake values, stocking density) from the Wessex Water catchment team.

Author	Reviewer
………………………………………………………………..	…………………………………………………………………
Stefan Bramer	Paul Davison

report. It does not in any way constitute advice to any third party who is able to access it by any means. Amec Foster Wheeler excludes to the fullest extent lawfully permitted all liability whatsoever for any loss or damage howsoever arising from reliance on the contents of this report. We do not however exclude our liability (if any) for personal injury or death resulting from our negligence, for fraud or any other matter in relation to which we cannot legally exclude liability.

Management systems

This document has been produced by Amec Foster Wheeler Environment & Infrastructure UK Limited in full compliance with the management systems, which have been certified to ISO 9001, ISO 14001 and OHSAS 18001 by LRQA.

Appendix A NLT to Porous Pot comparison results

See accompanying spreadsheet “Appendix A – NLT to PP comparison.xlsx”