Water Framework Directive (WFD)
River Basin District Management Systems

VERIFYING THE PREDICTIVE RISK ASSESSMENT METHODOLOGY FOR MOBILE DIFFUSE INORGANIC POLLUTANTS (NO$_3$)

Paper by the Working Group on Groundwater

Guidance document no. GW10

Contents

Tables

Figures

Verifying the Predictive Risk Assessment Methodology for Mobile Diffuse Inorganic Pollutants (NO$_3$)

1. Purpose of this Paper

This paper describes the development and verification of the predictive risk assessment methodology for Risk Assessment Sheets GWRA3, SWRA2 and DWPARA1, which consider the impact of diffuse source mobile inorganics (such as nitrate) on the chemical status of the groundwater bodies, groundwater dependent rivers, lakes and estuaries, and drinking water protected areas (DWPAs). Based on the results of the verification, the methodology was adopted by the Working Group on Groundwater in 2004 and formed the basis for running the risk assessments. The risk assessment is part of 'initial characterisation' and this paper assumes that the reader is familiar with the risk-based approach used. General guidance on the risk assessment methodology is given in Guidance Documents GW4 and GW8 (GW WG, 2003 and 2004). Risk assessment sheets GWRA3, SWRA2 and DWPARA1 are given in Appendix 1.

2. Background

2.1 Aim of Report

In risk assessment (RA) sheets GWRA3 and DWPARA1, the threshold nitrate concentration above which a GWB is deemed to be 'at risk' is 8.5 mg/l NO$_3$-N, as a weighted mean for the GWB; the corresponding threshold value in RA sheet SWRA2 is 5.65 mg/l NO$_3$-N.

Sufficient water quality data to enable the risk category to be determined are seldom available for most groundwater bodies. Consequently, a predictive risk assessment approach is followed to enable the risk category to be determined. The predicted risk category can then be adjusted if adequate representative monitoring data are available. Where adequate data are not available, the results of the predictive assessment alone are used to determine the risk category, albeit that the level of uncertainty with the designation is greater.

Given that potential nitrates from other sources such as urban areas and waste water treatment systems are dealt with elsewhere (e.g. GWRA5, GWRA7), the critical factors in determining the impact of nitrogen loadings on groundwater are as follows:

- Pathway susceptibility, as determined by soil, subsoil, vulnerability and aquifer information;
- Pressure magnitude, as determined by density of livestock and presence of tillage;
- The proportion of an area that has the combination of both relatively high pathway susceptibility and pressure magnitude, i.e. proportion of an area with relatively high impact potential.

In predicting the impact potential for a GWB, the main uncertainty relates to the proportion of that GWB with a relatively high impact potential that is needed to cause mean nitrate concentrations to be high enough to put the GWB 'at risk'. For instance, a small proportion (say <5%) of a GWB with intensive agriculture on free draining soils and subsoils may result in a high impact potential that is of local significance. However, it is not likely to put the entire GWB 'at risk', as nitrate leached from this area will be diluted by groundwater from the remaining area. In contrast, if the proportion is high, say 95%, then the likelihood that the GWB might be 'at risk' is high. Consequently, the aim of this guidance report is to outline the verification process that was followed to enable this percentage area to be determined. The process involved running the predictive RA approach for a number of GWBs with adequate nitrate data, and finding a relationship between the nitrate concentrations and the impact potential. The outcome was used to give the percentage area impact potential threshold that determined the risk category.

2.2 Summary of risk assessment approach

The approach is based on combining 'layers' of relevant information, shown by matrices, to give:
- Pathway Susceptibility (a measure of the degree of attenuation between the pressure source and the receptor);
- Impact Potential (combining Susceptibility with Pressure Magnitude); and
- Risk Category (using the Impact Potential as a 'predictive risk assessment').

The predicted risk category is then confirmed or adjusted by available monitoring data. This approach is shown in each of the RA sheets in Appendix 1.

3. Study Site Selection

The GWBs selected for this study had to meet the following criteria:

- The available nitrate data were considered sufficient to enable the mean nitrate concentration in the GWB to be determined.
- Each GWB was comprised of productive aquifers (Rk, Rf and Lm), as this helped ensure that monitoring data were representative and that denitrification would not be an issue.
- A range of vulnerability and soil types (i.e. susceptibility), and pressures was required to enable comparisons.

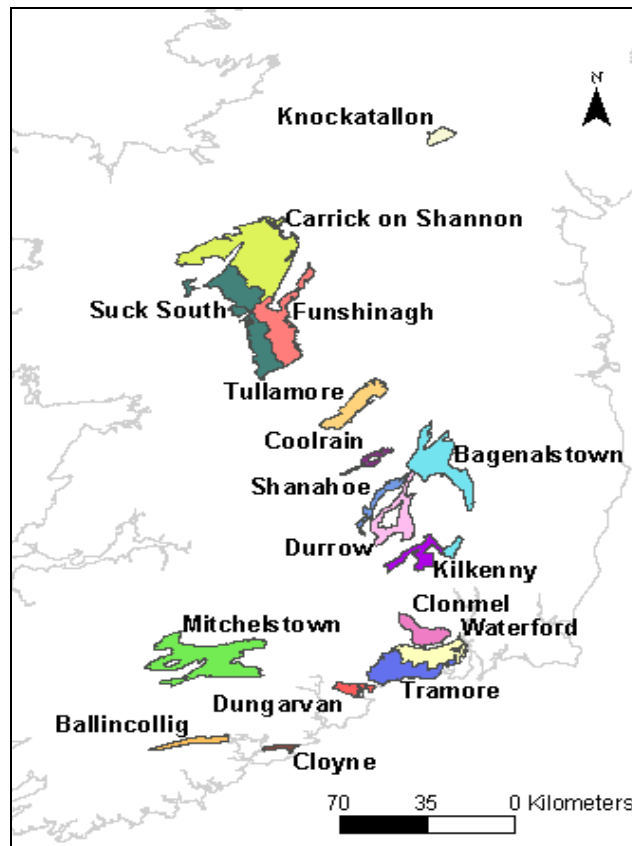The selected GWBs comprise approximately 5% of the national GWBs and are shown in Figure 1.

Figure 1. Location of Study GWBs.

A number of GWBs did not meet the above criteria and were removed from the initial selection, e.g. the confined nature of the aquifer in the Clones/Monaghan GWBs was thought to give rise to denitrification; Midleton GWB had no available nitrate data.

The characteristics of the 17 GWBs used in the study are outlined in Appendix 1.

4. Pathway Susceptibility

The pathway susceptibility is derived by combining various layers of geological and hydrogeological information, as shown in Table 1.

Table 1. Pathway Susceptibility

PATHWAY SUSCEPTIBILITY			Flow Regime (Horizontal pathway)			
			Karst aquifers	*Fissured aquifers*	*Inter-granular aquifers*	*Poorly productive aquifers*
Vertical pathway***	Soil & subsoil	'Wet' soil	L	L	L	L
		Low permeability subsoil	L	L	L	L
	Vulnerability	Extreme	E	E	H	M*
		High	H	H	H	M*
		Moderate	M	M	M	L*
		Low	L	L	L	L
		High to Low**	H	H	H	M

* In poorly productive aquifers where de-nitrification is not considered likely to occur, these categories should be the same as the karst and fissured aquifers categories.
** For areas where complete vulnerability map is not available from GSI.
*** The 'wet' soil and low permeability subsoil layers take precedence over the vulnerability layers.

For the study sites, all of the individual pathway layers were combined in ArcGIS by 'unioning' the specific shapefiles. A susceptibility category was given to each polygon depending on the different combinations of pathway parameters outlined in Table 1. The combination of pathway factors for the Dungarvan GWB is illustrated and described below:
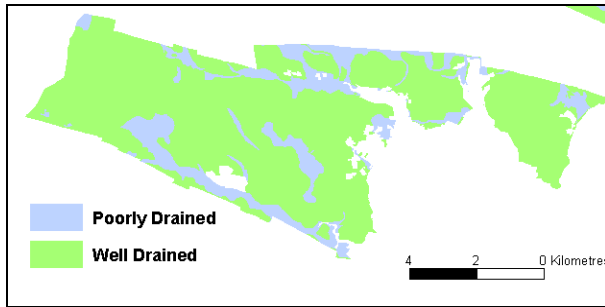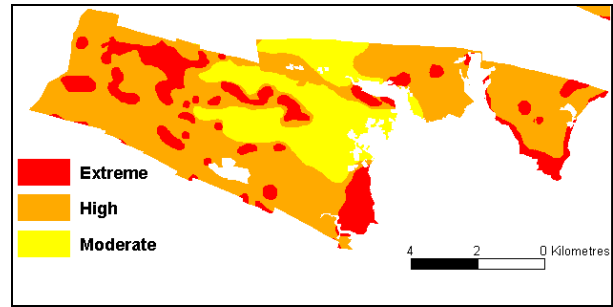
Figure 2a. Soil Drainage
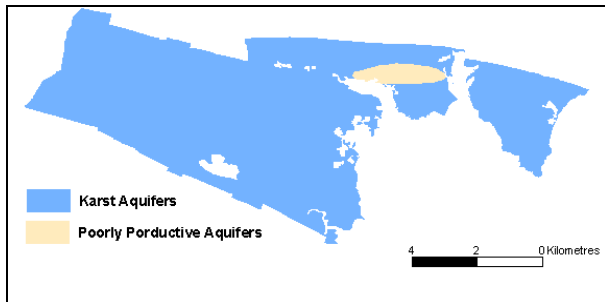

Figure 2b. Vulnerability

Figure 2c. Aquifers
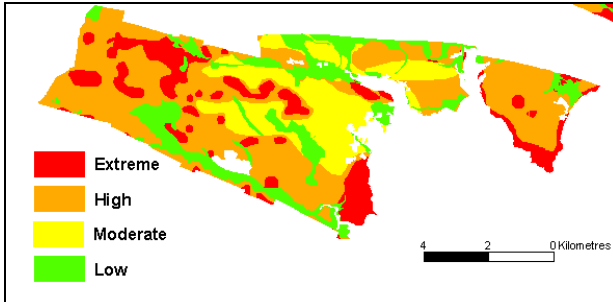
Figure 2d. Pathway Susceptibility

Figure 2. Dungarvan GWB Pathways and Pathway Susceptibility.

Description	Interpretation
In Figure 2d, the influence of the *poorly draining topsoil* (Figure 2a) can be seen throughout the GWB, as the majority of the Low (green) pathway susceptibility correlates to these areas.	Where soil is poorly drained, mobile inorganic contaminants are less likely to drain through the topsoil, and more likely to be incorporated in the surface runoff. In addition, denitrification may occur.

No areas of 'low' permeability *subsoil* were identified in this GWB.
 	
Apart from the areas of poorly draining topsoil, the dominant factor influencing susceptibility over the Karst Aquifers (Figure 2c) is the *vulnerability* (Figure 2b).
	If nitrate leaches through the topsoil, the subsoil permeability and thickness, i.e. vulnerability, will control the quantity and rate of infiltration into the underlying aquifer. Therefore, if the subsoil permeability is:
	  a) 'low' (not exhibited in the above GWB), the contaminant is less likely to be able to infiltrate into, and percolate through the subsoil and, in addition, denitrification is likely.
	  b) 'moderate' or 'high', the contaminant will be able to percolate through to the underlying aquifer. If the subsoil is thinner and more permeable (e.g. 'Extreme' vulnerability), travel times to the aquifer are quicker, resulting in the pathway having a higher susceptibility than thicker, less permeable (e.g. 'Moderate' vulnerability) subsoil.

Description	Interpretation
The influence of the *Poorly Productive Aquifers* (Figure 2c) mainly results in a Moderate susceptibility. This overrides the influence of the Extreme and High vulnerability, but not of the poorly drained topsoil.	If any mobile contaminants percolate through the subsoil, the flow regime of the underlying aquifer will then determine the fate of the contaminant. In karstic or highly fissured aquifers, groundwater can often travel large distances at high velocities. The contaminant could potentially influence a wide area and a number of drinking water supplies, ecosystems etc. In poorly productive aquifers (poor connection of fewer fissures), flow paths will generally be shorter, thus limiting the influence of the contaminant. Travel times may be slower and reducing conditions may be present, potentially facilitating denitrification. In such aquifers, the susceptibility is therefore lower than for the karst or highly fissured aquifers.

Of the study areas, all but the Mitchelstown GWB (north Cork) had existing Groundwater Protection Schemes, i.e. vulnerability data. However, a number of assumptions were made about the subsoil permeability and the vulnerability for the Mitchelstown GWB, based on previous work:

- The *vulnerability* for 5 sources within this particular GWB (Castletownroche, Glanworth, Kildorrery, Kilworth, Oliver's Cross) were mainly 'Extreme' (24%) or 'High' (73%), with smaller areas of 'Moderate' (3%). Although relatively small, the source areas are distributed throughout the GWB, and therefore are generally thought to span the range of vulnerability categories present;
- The *vulnerability* mapped in South Cork principally ranged from 'Extreme' to 'Moderate', with less than 1% of the area mapped as 'Low'.
- The *permeability* throughout the source areas and South Cork was generally High or Moderate.
- For the purposes of the risk assessment, it was assumed that in the Mitchelstown GWB:
  - There were no 'low' permeability subsoils, and therefore no 'low' vulnerability areas.
  - The 'extremely' vulnerable areas comprised the outcrop/shallow rock areas provided by the Teagasc Soils and Subsoils mapping programme, with an additional 100 m buffer. The buffer was based on drilling work undertaken in the South Eastern River Basin District in 2004 (O'Callaghan Moran and Associates).
  - The remaining area (80%) is considered to be 'highly' vulnerable.

5. Pressures Magnitude

The sources of diffuse nitrates used in this assessment comprised:

- Densities of cattle/sheep per DED (5-year averages; Department of Agriculture)
- Densities of pigs/poultry per DED (June 2000 data, Central Statistics Office)
- Percentage areas of tillage (10 crop categories; Department of Agriculture)

The pressure loadings were subdivided into four categories as shown in Table 2. The highest pressure threshold for Livestock Units (LUs) is presumed to be equivalent to approximately to the 170 kg organic N/ha limit in the Nitrates Directive. The tillage categories are based on research in the Barrow Valley (Neill, 1989). The pressure loading thresholds are for statistics available at DED-scale and therefore do not relate to individual farm thresholds.

Table 2. Thresholds for Pressure Magnitude.

Pressure Loading	Cattle/sheep and Pigs/Poultry (LU/ha)	Tillage (%)
High	>2.0	>33
↓	1.5-2.0	18-33
	1.0-1.5	3-18
Low	<1.0	<3

In order to realistically distribute these data within the DEDs, the densities of both cattle/sheep and pigs/poultry were directly applied to areas of 'grazing', and the percentage areas of tillage were applied to areas that are tilled, hereafter referred to as areas of 'tillage'. The CORINE (2000) land use dataset was used to identify areas of 'grazing' (land use categories 231 and 243) and 'tillage' (category 211). The distribution of these land use categories for the Dungarvan GWB are shown in Figure 3.
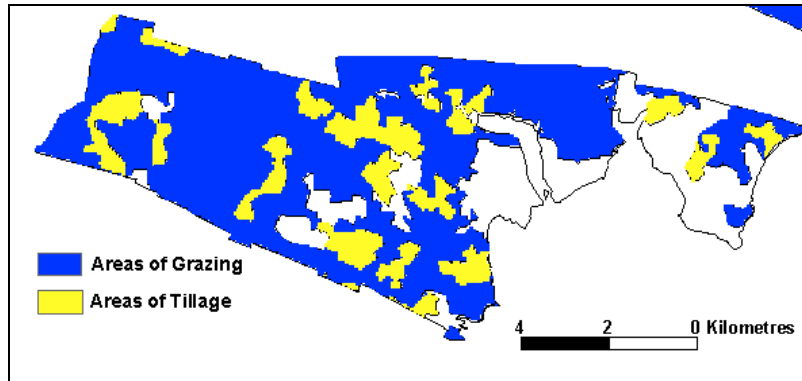
Figure 3. Grazing and Tillage Land use for the Dungarvan GWB.

6. Impact Potential

The Impact Potential is determined by combining the pressure magnitude with the pathway susceptibility, as outlined in Table 3 below.

Table 3. Deriving Impact Potential

IMPACT POTENTIAL*		Pathway Susceptibility (from Table 1)			
		Extreme	*High*	*Moderate*	*Low*
Pressure magnitude	>2.0 LU ha^{-1} or >33% tillage	High	High	Moderate	Low
	1.5-2.0 LU ha^{-1} or 18-33% tillage	Moderate	Moderate	Low	Low
	1.0-1.5 LU ha^{-1} or 3-18% tillage	Low	Low	Low	Low
	<1.0 LU ha^{-1} or <3% tillage	Negligible	Negligible	Negligible	Negligible

*Deriving Impact Potential

The method for producing the total Impact Potential percentage areas per GWB for the three pressure layers is outlined in the steps below:

1 The Susceptibility and Pressure Magnitude layers were converted into raster files, which are made of 50 m x 50 m pixels.
2 Each pixel has a unique ranking for Pathway Susceptibility (e.g. Extreme, High Moderate **or** Low), and for *each* of the Pressure Magnitude layers (e.g. <3%, 3-18%, 18-33% **or** >33% for tillage). Therefore, each pixel has four unique characteristics. The four resulting raster layers for the Dungarvan GWB are shown in Figure 4.
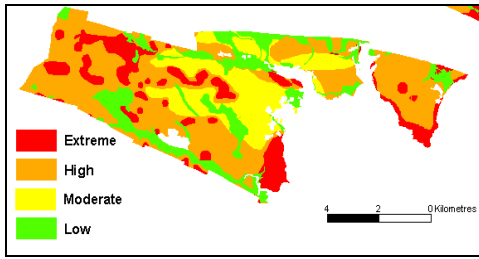
Figure 4a. Pathway Susceptibility
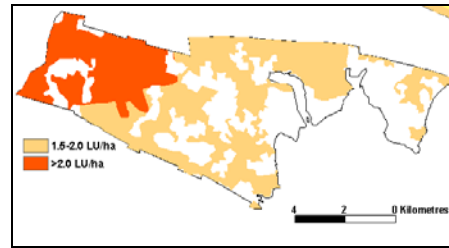
Figure 4b. Pressure Magnitude: Cattle/Sheep
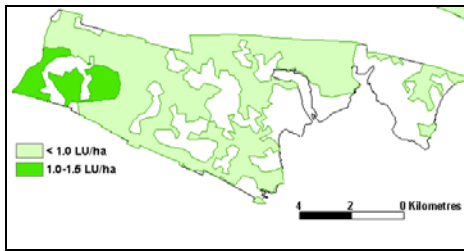
Figure 4c. Pressure Magnitude: Pigs/Poultry
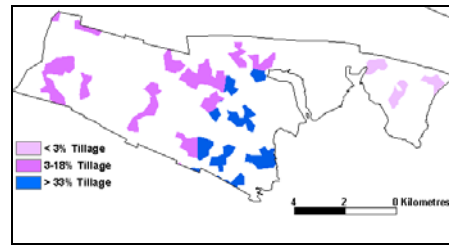
Figure 4d. Pressure Magnitude: Tillage

Figure 4. Dungarvan GWB Susceptibility and Individual Pressure Magnitude Layers.

3 Each Pressure Magnitude raster is individually combined with the Susceptibility raster using Spatial Analyst in ArcGIS. A unique Potential Impact category – specific to the pressure type – is derived for each pixel, depending on the different combinations of susceptibility and pressure parameters outlined in the Table 3 above. For example, where susceptibility is Extreme or High, and there are greater than 2 LU/ha of cattle, the Impact Potential is High. This process results in an individual Impact Potential raster for cattle/sheep, pigs/poultry and tillage, as illustrated below:
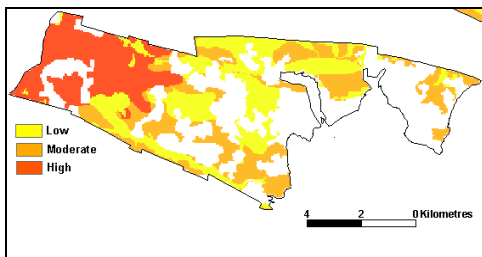
Figure 5a. Impact Potential: Cattle/Sheep
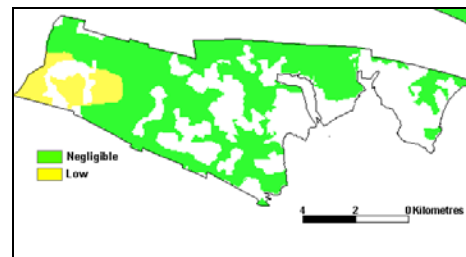
Figure 5b. Impact Potential: Pigs/Poultry
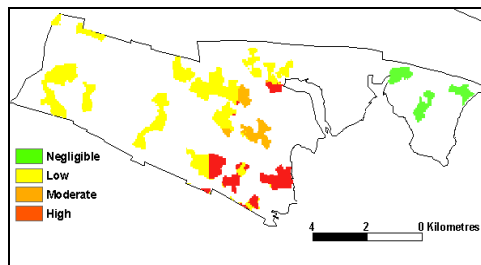
Figure 5c. Impact Potential: Tillage

Figure 5. Impact Potential for the Separate Pressure Layers for Dungarvan GWB.

4   To determine the ***total*** impact potential for all three pressures, the highest Impact Potential category within each pixel is taken, irrespective of the pressure type. The total area of each Impact Potential category is then determined for the GWB, e.g.:

	Pixel	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Impact Potential*	Cattle/Sheep	H	N	M	M	N	L	N	M	H	L
	Pigs/Poultry	L	N	L	H	N	L	N	L	H	M
	Tillage	N	M	N	N	L	N	H	N	N	N
	Overall	**H**	**M**	**M**	**H**	**L**	**L**	**H**	**M**	**H**	**M**

In this example, 40% of the GWB is categorised as High Impact Potential, 40% is Moderate and 20% is Low. The total Impact Potential for the Dungarvan GWB (Figure 6) results in 21% being categorised as High, 23% as Moderate, 33% as Low and 12% as Negligible.
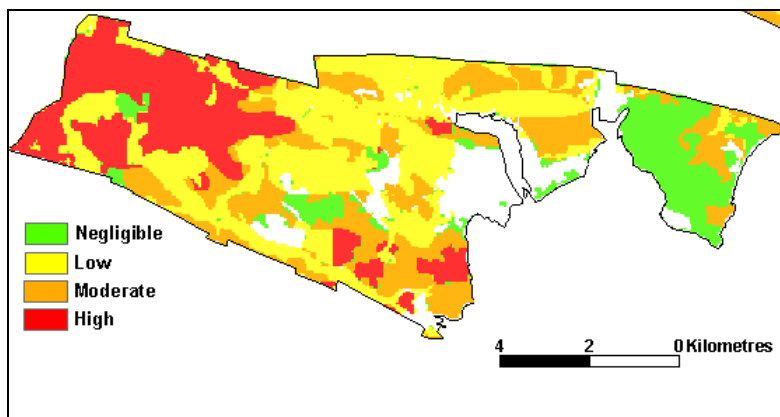
Figure 6. Total Impact Potential for the Dungarvan GWB.

7. Nitrate Data

Representative nitrate data were available for all of the study GWBs. Only data for the last five years were used, as these reflect current land use practices. As a means of obtaining a single, representative value, a weighted 'average of averages' method was used (detailed in GW6), i.e. the time-series data from each monitoring point were averaged. All of these resulting values were then given a weighting depending on their relative discharges/abstractions. Larger discharges/abstraction imply larger zones of contribution and therefore are likely to be representative of a larger area. The weighted values per monitoring point were then averaged to give a representative average nitrate concentration for the GWB (see Appendix 3).

8. Impact Potential and Nitrate Data

For each GWB, the percentage areas of High and Moderate Impact Potential were compared to the mean nitrate concentrations by plotting them on a graph, as shown in Figure 7.
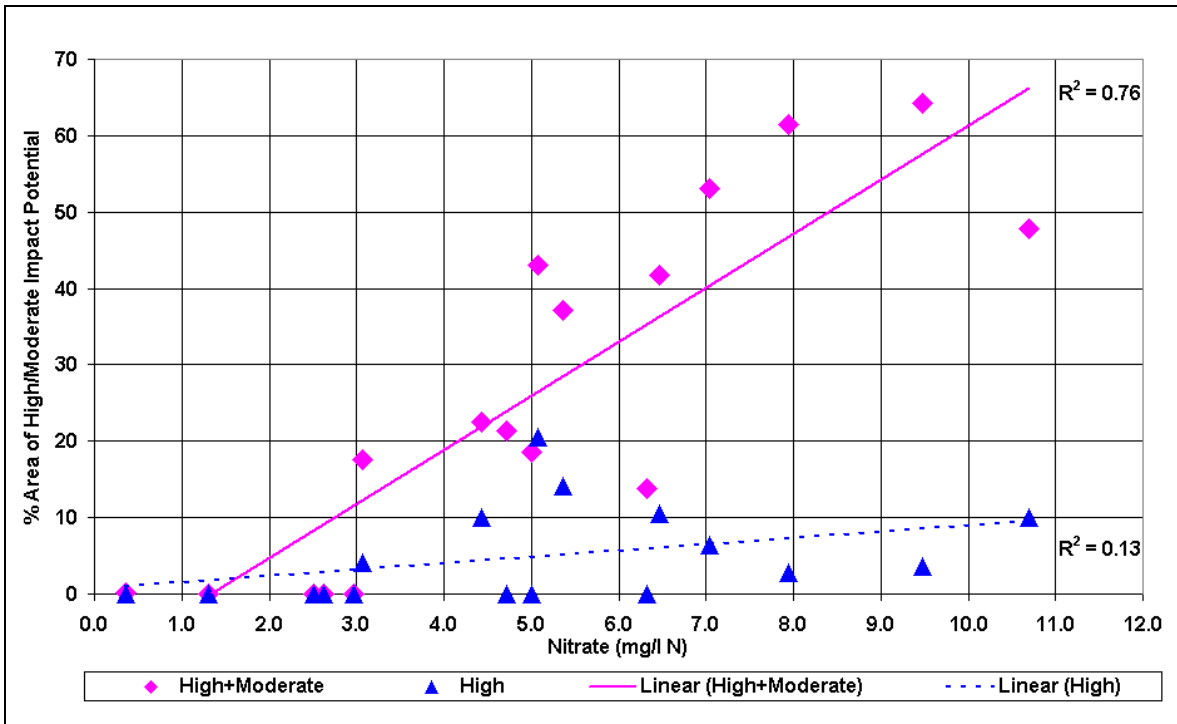
Figure 7. Impact Potential against Nitrate Levels for each GWB.

It was anticipated that the GWBs that were most susceptible and had the highest pressures would result in the highest nitrate concentrations. However, examination of the relationship between the proportions of the GWBs with High Impact Potential and the nitrate data showed a poor correlation ($R^2 = 0.13$; dashed line). By including the area of Moderate Impact Potential, i.e. total percentage of High+Moderate, the correlation is significantly improved ($R^2 = 0.76$; solid line), indicating that lower levels of pressure over the most susceptible areas and/or very high pressures over less susceptible areas also have an impact on the concentrations of nitrate in the groundwater.

9. Determining the Percentage Area of 'At Risk'

Overall, the combination of Pathway Susceptibility and Pressure Magnitude to give Impact Potential, as shown in Figure 8, has enabled a good fit with the actual groundwater nitrate levels. Therefore, the percentage areas of High+Moderate Impact Potential can be used to 'predict' what the groundwater nitrate levels are likely to be. For example, if approximately 40% of a GWB has High+Moderate Impact Potential, a nitrate level in the region of 7 mg/l N would be expected. In addition, percentage areas that relate to 'significant' levels of nitrate, i.e. those that indicate groundwater is 'at risk', can be identified, e.g. 30% High+Moderate GWB area corresponds to the threshold level of 5.65 mg/l N (in RA sheet SWRA2) and 50% corresponds to the 8.5 mg/l threshold (RA sheets GWRA3 and DWPARA1). The actual percentage areas used in SWRA2 and GWRA3 are 25% and 40%, respectively, which are more precautionary than those obtained from Figure 8.
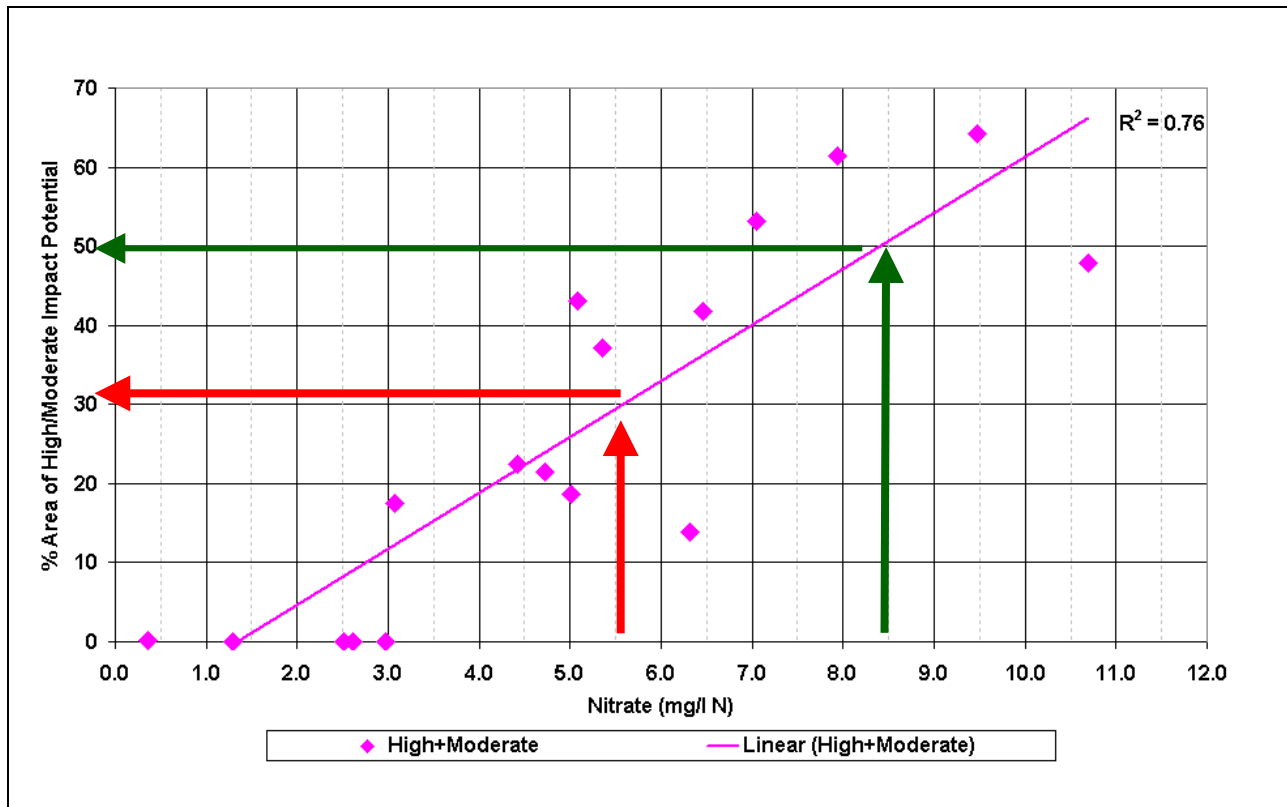
Figure 8. High+Moderate Impact Potential against Nitrate Levels for each GWB.

10. Conclusions

The aim of this study was to develop and verify a predictive risk assessment approach to determining the risk category of groundwater bodies from diffuse usage of nitrogen. A good correlation was found between mean nitrate concentrations in GWBs and the proportion of the GWBs mapped as having High+Moderate Impact Potential. Consequently, the relationship found can be used to predict the risk category for GWBs without adequate groundwater nitrate data.

11. Membership of the Working Group on Groundwater

Organisation	Representative(s)
Geological Survey of Ireland (GSI)	Donal Daly (Convenor)
	Geoff Wright
	Vincent Fitzsimons
	Coran Kelly
	Taly Hunter Williams
	Monica Lee
Camp Dresser McKee (CDM)	Henning Moe
Compass Informatics Ltd.	Paul Mills
Department of the Environment, Heritage and Local	Pat Duggan

Government (DEHLG)	Jim Ryan (NPWS)
	Aine O'Connor (NPWS)
Environment and Heritage Service/ Geological Survey of Northern Ireland (EHS/GSNI)	Peter McConvey
Environmental Protection Agency (EPA)	Margaret Keegan
	Micheal McCarthaigh
Kirk McClure Morton (KMM)	Grace Glasgow
	Kieran Fay
O'Callaghan Moran (OCM)	Sean Moran
	Gerry Baker
O'Neill Groundwater Engineering (OGE)	Shane O'Neill
Shannon Pilot River Basin – EPA/TCD Research Fellow	Garrett Kilroy
Southeastern River Basin District (SERBD)	Colin Byrne
Teagasc	Karl Richards
Trinity College, Dublin (TCD)	Paul Johnston
	Catherine Coxon

12. References

CORINE (2000). Coordinated Recording of Information on the Environment.

Neill, M. (1989) Nitrate concentrations in river waters in the southeast of Ireland and their relationship with agricultural practice. *Water Research* **23** (11): 1339-1355, November 1989.

Working Group on Groundwater (2003) Guidance Document GW4: *Guidance on Pressures and Impacts Methodology*, 40 pp.

Working Group on Groundwater (2004) Guidance Document GW8: *Methodology for Risk Characterisation of Ireland's Groundwater*, 69 pp.

13. Appendix 1

Groundwater Risk Assessment Sheet GWRA3

Summary details on pressures, receptors and WFD objective

RA Sheet	GWRA3
Receptor type	Groundwater body
Pressure type	Diffuse – mobile inorganics (NO$_3$)
WFD objective	Chemical status
Assessment area	Surface extent of the groundwater body

A. Pathway susceptibility

PATHWAY SUSCEPTIBILITY			Flow Regime (Horizontal pathway)			
			Karst aquifers	Fissured aquifers	Intergranular aquifers	Poorly productive aquifers
Vertical pathway***	Soil & subsoil	'Wet' soil	L	L	L	L
		Low permeability subsoil	L	L	L	L
	Vulnerability	Extreme	E	E	H	M*
		High	H	*H*	H	M*
		Moderate	M	M	M	L*
		Low	L	L	L	L
		High to Low**	H	H	H	M

* In poorly productive aquifers where denitrification is not considered likely to occur, these categories should be the same as the karst and fissured aquifers categories.
** For areas where complete vulnerability map is not available from GSI.
*** The 'wet' soil and low permeability subsoil layers take precedence over the vulnerability layers.

B. Impact potential

IMPACT POTENTIAL*		Pathway Susceptibility (from Table A)			
		Extreme	High	Moderate	Low
Pressure magnitude	>2.0 LU ha^{-1} or >33% tillage	High	High	Moderate	Low
	1.5-2.0 LU ha^{-1} or 18-33% tillage	Moderate	Moderate	Low	Low
	1.0-1.5 LU ha^{-1} or 3-18% tillage	Low	Low	Low	Low
	<1.0 LU ha^{-1} or <3% tillage	Negligible	Negligible	Negligible	Negligible

*Deriving Impact Potential
Individual Impact Potential maps are derived for the three types of pressures: cattle/sheep, pigs/poultry and tillage i.e. each grid cell within the maps will have three Impact Potential categories.
The *highest* Impact Potential category is taken for each cell, regardless of the type of pressure.
Within each GWB, the total area of **'H' plus 'M'** Impact Potential is used to determine whether the GWB is 'at risk' (see C below).

C.   Risk category based on predictive risk assessment

RISK CATEGORY		Proportion of assessment area with high and moderate impact potential					
		>40%	25-40%	15-25%	10-15%	5-10%	<5%
Receptor Sensitivity	High sensitivity* (nitrate-limited ecosystems)	n/a	n/a	n/a	n/a	n/a	n/a
	Moderate	1b	2a	2a	2a	2b	2b

* Not applicable – see RA sheet SWRA2.

D.   Risk category of groundwater body adjusted using available impact data

Predictive risk category	Adjustments made using available groundwater impact data	
	Data criteria	Adjusted risk category
All categories	Available representative monitoring data show an environmentally significant upward trend in groundwater nitrate concentrations	1a
1b	Weighted mean NO_3-N >11.3 mg l^{-1}	1a or 1b, depending on level of confidence in the monitoring data
2a	Weighted mean NO_3-N 8.5-11.3 mg l^{-1}	1b or 2a, depending on level of confidence in the monitoring data
2b		
2b	Weighted mean NO_3-N 5.65-8.5 mg l^{-1}	2a
	Weighted mean NO_3-N <5.6 mg l^{-1}	2b

Groundwater Risk Assessment Sheet SWRA2

Summary details on pressures, receptors and WFD objective

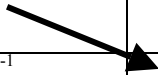| RA Sheet	SWRA2
Receptor type	Groundwater dependent ecosystems in rivers, lakes and estuaries
Pressure type	Diffuse – mobile inorganics (NO_3)
WFD objective	Chemical status
Assessment area	Surface extent of the groundwater body

A.   Pathway susceptibility

PATHWAY SUSCEPTIBILITY			Flow Regime (Horizontal pathway)			
			Karst aquifers	Fissured aquifers	Intergranular aquifers	Poorly productive aquifers*
Vertical pathway***	Soil & subsoil	'Wet' soil	L	L	L	L
		Low permeability subsoil	L	L	L	L
	Vulnerability	Extreme	E	E	H	L
		High	H	H	H	L
		Moderate	M	M	M	L
		Low	L	L	L	L
		High to Low**	H	H	H	M

* These aquifers are not considered to be contributing a significant proportion of water to rivers and lakes and therefore are not included in pathway susceptibility.

** For areas where complete vulnerability map is not available form GSI.

*** The 'wet' soil and low permeability subsoil layers take precedence over the vulnerability layers.

B.   Impact potential

IMPACT POTENTIAL*		Pathway Susceptibility (from Table A)			
		Extreme	High	Moderate	Low
Pressure magnitude	>2.0 LU ha^{-1} or >33% tillage	High	High	Moderate	Low
	1.5-2.0 LU ha^{-1} or 18-33% tillage	Moderate	Moderate	Low	Low
	1.0-1.5 LU ha^{-1} or 3-18% tillage	Low	Low	Low	Low
	<1.0 LU ha^{-1} or <3% tillage	Negligible	Negligible	Negligible	Negligible

*Deriving Impact Potential

Individual Impact Potential maps are derived for the three types of pressures: cattle/sheep, pigs/poultry and tillage i.e. each grid cell within the maps will have three Impact Potential categories.

The *highest* Impact Potential category is taken for each cell, regardless of the type of pressure.

Within each GWB, the total area of **'H' plus 'M'** Impact Potential is used to determine whether the GWB is 'at risk' (see C below).

C. Risk category based on predictive risk assessment

RISK CATEGORY		Proportion of assessment area with high and moderate impact potential					
		>50%	25-50%	15-25%	10-15%	5-10%	<5%
Receptor Sensitivity	High sensitivity (nitrate-limited ecosystems)	1b	1b	1b	2a	2a	2b
	Moderate (Rivers)	1b	1b	2a	2a	2b	2b

D.   Risk category of groundwater body adjusted using available impact data

Predictive risk category	Adjustments made using available groundwater impact data	
	Data criteria	Adjusted risk category
1b	Weighted mean NO_3-N >11.3 mg l^{-1}	1a or 1b, depending on level of confidence in the monitoring data
2a 2b	Weighted mean NO_3-N 5.65-11.3 mg l^{-1}	1b or 2a, depending on level of confidence in the monitoring data
2b	Weighted mean NO_3-N 2.0-5.65 mg l^{-1}	2a
	Weighted mean NO_3-N <2.0 mg l^{-1}	2b

Groundwater Risk Assessment Sheet DWPARA1

Summary details on pressures, receptors and WFD objective

RA Sheet	DWPARA1
Receptor type	Groundwater drinking water supply
Pressure type	Diffuse – mobile inorganics (NO_3)
WFD objective	Drinking Water Protected Area
Assessment area	Surface extent of the groundwater body

A.   Pathway susceptibility

PATHWAY SUSCEPTIBILITY			Flow Regime (Horizontal pathway)			
			Karst aquifers	Fissured aquifers	Intergranular aquifers	Poorly productive aquifers
Vertical pathway	Soil & subsoil	'Wet' soil	L	L	L	L
		Low permeability subsoil	L	L	L	L
	Vulnerability	Extreme	E	E	H	M*
		High	H	H	H	M*
		Moderate	M	M	M	L*
		Low	L	L	L	L
		High to Low**	H	H	H	M

*In poorly productive aquifers where denitrification is not considered likely to occur, these categories should be the same as the karst and fissured aquifers categories.
**For areas where complete vulnerability map is not available from GSI.

B.   Impact potential

IMPACT POTENTIAL*		Pathway Susceptibility (from Table A)			
		Extreme	High	Moderate	Low
Pressure magnitude	>2.0 LU ha^{-1} or >33% tillage	High	High	Moderate	Low
	1.5-2.0 LU ha^{-1} or 18-33% tillage	Moderate	Moderate	Low	Low
	1.0-1.5 LU ha^{-1} or 3-18% tillage	Low	Low	Low	Low
	<1.0 LU ha^{-1} or <3% tillage	Negligible	Negligible	Negligible	Negligible

*Deriving Impact Potential
Individual Impact Potential maps are derived for the three types of pressures: cattle/sheep, pigs/poultry and tillage i.e. each grid cell within the maps will have three Impact Potential categories.
The *highest* Impact Potential category is taken for each cell, regardless of the type of pressure.
Within each GWB, the total area of **'H' plus 'M'** Impact Potential is used to determine whether the GWB is 'at risk' (see C below).

C. Risk category based on predictive risk assessment

	Proportion of assessment area with high and moderate impact potential					
	>40%	25-40%	15-25%	10-15%	5-10%	<5%
RISK CATEGORY	1b	2a	2a	2a	2b	2b

D. Risk category of groundwater body adjusted using available impact data

Predictive risk category	Adjustments made using available groundwater impact data	
	Data criteria	Adjusted risk category
All categories	Available representative monitoring data show an environmentally significant upward trend in groundwater nitrate concentrations	1a
1b	Weighted mean NO_3-N >11.3 mg l^{-1}	1a or 1b, depending on level of confidence in the monitoring data
2a 2b	Weighted mean NO_3-N 8.5-11.3 mg l^{-1}	1b or 2a, depending on level of confidence in the monitoring data
2b	Weighted mean NO_3-N 5.65-8.5 mg l^{-1}	2a
	Weighted mean NO_3-N <5.6 mg l^{-1}	2b

14. Appendix 2

Study GWB Characteristics

GWB	Area (km²)	Aquifer [1]	Soil Drainage (%) [2]		Low Perme-ability (%)	Vulnerability (%) [2]			
			WD [3]	PD [3]		Extreme	High	Moderate	Low
Bagnelstown	399	Rkd/Pl (4%)	62	38	7	21	57	20	2
Ballincollig	70	Rkd/Ll (18%)	64	36	0	18	81	1	–
Carrick on Shannon	785	Rkc	61	39	44	33	29	24	14
Clonmel	139	Ll/ Rkd(30%)/ Rf(8%)/ Lm(8%)	80	20	52	31	24	28	17
Cloyne	26	Rkd	94	6	45	16	42	42	–
Coolrain	51	Rf	55	45	6	15	66	19	–
Dungarvan	57	Rkd/Ll(2%)	82	18	0	17	61	22	–
Durrow	209	Rkd	88	12	2	38	62	–	–
Funshinagh	350	Rkc	66	34	15	34	47	13	6
Kilkenny	129	Rkd	96	4	11	17	65	17	1
Knockatallon	53	Rf/Lm (30%)	53	47	89	9	7	6	78
Mitchelstown	537	Rkd/Ll (25%)	87	13	5	20	80	–	–
Monaghan	54	Rf	80	20	27	5	25	51	19
Shanahoe	81	Rkd/Lm (37%)/Ll (2%)	74	26	6	30	63	6	1
Suck South	473	Rkc	67	33	15	43	44	11	2
Tramore	251	Rf/Pl (3%)	70	30	65	28	68	3	1
Tullamore	188	Rkd/Ll (2%)	64	36	0	4	71	25	–
Waterford	208	Rf/Pl (4%)/Ll(3%)	76	24	44	45	50	3	2

[1] Rkd: Regionally important karstified aquifer that is dominated by diffuse flow
Rkc: Regionally important Karstified Aquifer that is dominated by conduit flow
Rf: Regionally important fissured aquifer
Lm: Locally important aquifer that is generally moderately productive
Ll: Locally important aquifer that is moderately productive only in local zones
Pl: Poor aquifer that is generally unproductive except for local zones

[2] Percentages do not take into account areas of lake/made ground etc.

[3] WD: Well drained soil
PD: Poorly drained soil (or 'wet' soil)

15. Appendix 3

Representative Nitrate Data

GWB	Nitrate (mg/l N)
Bagnelstown	5.1
Ballincollig	4.4
Carrick on Shannon	1.3
Clonmel	3.1
Cloyne	6.5
Coolrain	2.5
Dungarvan	5.1
Durrow	9.5
Funshinagh	3.0
Kilkenny	7.0
Mitchelstown	10.7
Shanahoe	7.9
Suck South	2.6
Tramore	6.3
Tullamore	5.0
Tydavnet	0.4
Waterford	4.7