An Evaluation of Nutrient Loading to the Freshwater Lakes, Estuarine Waters and Sea Loughs of Northern Ireland

(Nutrient Budget and SIMCAT Analysis)

2001 - 2009

Summary Document

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Note: This report summarises analysis previously published in the Urban Waste Water Treatment Directive (UWWTD) Sensitive Area Review (2015). This evidence will inform measures developed under the Water Framework Directive, Nitrates Directive and UWWTD.

1.0 INTRODUCTION

1.1 Nutrient Budget Analysis, 2001-2009

An investigation was undertaken by Agri-Food and Biosciences Institute (AFBI) for NIEA to determine the sources of nutrient loadings to the two largest freshwater lakes (Lough Neagh and Lough Erne), the six transitional waters (River Foyle, Lower Bann, Inner Lagan, Quoile Basin, Dundrum Bay and the Tidal Newry River) and four sea loughs (Lough Foyle, Belfast Lough (Inner and Outer Belfast Lough), Strangford Lough, and Carlingford Lough) of Northern Ireland for periods 2001-2003, 2004-2006 and 2007-2009 (**Figure 1**). The Northern Ireland areal coverage of the study is extensive, encompassing approximately 80% of the region.

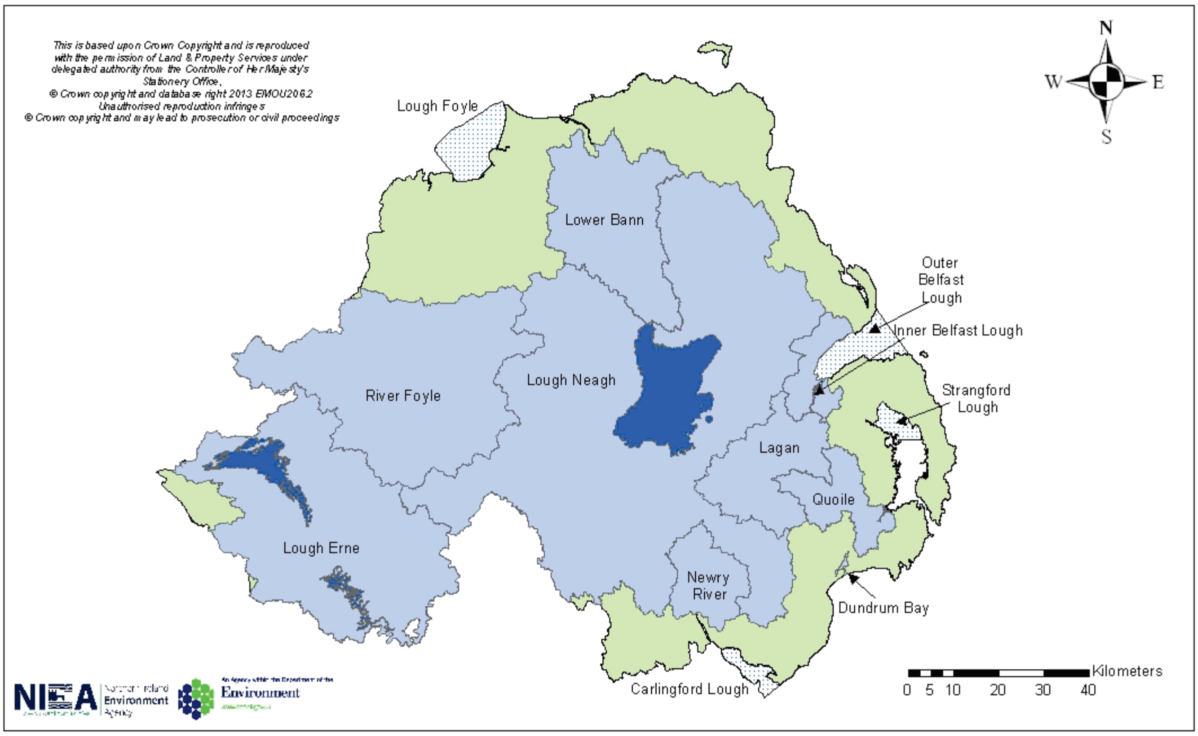

Figure 1: Map showing the location of the thirteen study catchments

The primary focus of the investigation was nitrate and phosphorus loadings. The combined input of nitrate and ammonium, termed Dissolved Inorganic Nitrogen (DIN), was also calculated for the catchments, with the exception of Lough Neagh and Lough Erne. The loadings were partitioned between the following sources in each catchment: Waste Water Treatment Works (WWTWs), lowland agriculture, rough grazing, forested land and industrial inputs. WWTWs and lowland agriculture were the predominant nutrient sources in all water bodies.

Loadings were compared for three successive periods, each covering three years: October 2000-September 2003, October 2003-September 2006 and October 2006-September 2009. The commencement of each period in the month of October corresponds to the beginning of the hydrological year. The convention of starting in October reflects the use of the hydrological year that commences with the increased flows in autumn. After October, rainfall starts to fill up the ground water reserves, until April (middle point of the hydrological year) when evaporation starts to deplete this stored water. This carries on until October, when it starts to replenish, and the cycle continues. For the purpose of convenience these periods are referred to as 2001-3, 2004-6 and 2007-9 respectively. Three year data-sets were used in reference to annual loading estimates as this time span ensured that a mix of high and low nitrate years were used. Loads were calculated as the product of flow weighted mean nutrient concentration and the mean runoff for each 3 year period.

The loadings given are cumulative in that they include inputs from associated waters. Thus the loadings to Lough Foyle include the nutrient inputs from the River Foyle, the Inner Lagan contributes to Inner Belfast Lough, which in turn contributes to Outer Belfast Lough, the Tidal Newry River contributes to Carlingford Lough, and the Quoile Basin to Strangford Lough.

This report has been produced using data spreadsheets and limited documentation delivered by AFBI under project code WTE 407 - AFBI - NIEA SLA ‘An assessment of nutrient loading to the freshwater lakes, estuarine waters and sea loughs of Northern Ireland 2001-2009’.

1.2 SIMulated CATchment (SIMCAT) River Modelling, 2005-2009

SIMCAT is a computer model which provides a SIMulation of the flow and quality at any point within a water CATchment. It is a one dimensional simplified river model developed by the English Environment Agency to manage discharges to rivers and it enables the impact of discharges or abstractions from inputs such as WWTWs and industries to a river to be assessed in terms of water quality or flow. It utilises routine monitoring data for both rivers and effluents and can be used to run ‘what-if’ scenarios to ensure that water quality standards are met, at an individual reach or at the catchment scale level.

The purpose of the modelling work was to assist in the assessment and monitoring of river water quality as required by the WFD. The WFD requires Member States to develop RBMPs to protect, manage and control the use and quality of surface waters and ground waters in order to enhance and improve the aquatic environment. One of the supplementary measures contained within RBMP1 was to develop mathematical (river) models for all of Northern Ireland to assess the cumulative impacts of discharges at a catchment scale. SIMCAT can support setting discharge consents to achieve water quality targets and also assist in the testing of proposed strategic actions, such as lowering phosphorus standards at all WWTWs.

One of the limitations of SIMCAT as a simplified river model is that estuarine and coastal waters are ignored and this includes the point discharges made to them. Therefore the discharges made from the WWTWs discharging to Belfast Lough are ignored. A separate assessment has therefore been carried out in relation to the contribution that WWTWs make to the loading of the marine waters of Belfast Lough. However, this is only an input assessment and takes no account of the processing and interactions that take place within the Lough.

2.0 METHODOLOGY

2.1 Nutrient Budget Analysis, 2001-2009

Each inflowing river entering a lake or sea lough was identified which had a NIEA sampling point close by. Loading estimates for two nutrient fractions have been calculated for the catchments: soluble phosphorus (PSOL or SRP) and total oxidised nitrogen (TON), which is the sum of nitrate nitrogen (NO3-N) and nitrite nitrogen (NO2-N). As the latter is a very small fraction of TON, TON can be taken to be synonymous with nitrate and is hereafter referred to as nitrate.

A corresponding daily flow record for each monitored river was assembled based on NIEA data sets and data sets acquired by the Rivers Agency, c.36 samples per period per river. Loads were calculated as a product of average flow weighted mean concentration and the annual runoff, as per Equation 1 and Equation 2.

$$\text{FWMC} = \frac{\sum (C_i\ Q_i)}{\sum Q_i} \qquad \textit{Equation1}$$

Where,

FWMC = flow weighted mean concentration (mg/l)

C_i is the concentration of TON, NH_4-N or PSOL (mg/l) in a sample,

Q_i is the mean discharge on the day of sampling or instantaneous ($m^3\ day^{-1}$)

The FWMC was then used to calculate a mean annual loading according to equation 2.

$$\text{MAL} = \text{FWMC} * \text{Qr} * 10^{-6} \qquad \textit{Equation 2}$$

Where,

MAL = mean annual load (tonnes $year^{-1}$)

Qr = mean annual flow over three years sampling period ($m^3\ yr^{-1}$)

10^{-6} = conversion factor for grammes to tonnes

For each catchment, loadings of TON, PSOL and DIN were calculated as mean concentration over each three year period 2001-2003, 2004-2006 and 2007-2009 multiplied by WWTW flow for these periods. The data was acquired by Northern Ireland Water (NIW, previously known as the Water Service). Whilst this is the best available flow data, caution should be applied to the accuracy and reliability of the flow data on the basis that all flow meters are not Monitoring Certification Scheme (MCERTS) standard. Effluent quality data from NIW were used where available, although for some smaller works 2001-2003 data were used to compile a minor WWTW concentration database that could be linked to each river catchment. Data for the smallest WWTWs were not available but it was estimated that these only comprise a total of around 4000 population equivalents, which is negligible when spread throughout the country. Effluent flow data were only available for some of the small WWTWs and flows for the remainder were estimated from these based on p.e. figures.[1]

[1] As defined in the Urban Waste Water Treatment Directive, 1 population equivalent (PE) means the organic biodegradable load having a BOD of 60g of oxygen per day

2.2 Land Use in Northern Ireland

Co-ORdinated INformation on the Environment (CORINE) land use data for the catchments was determined by GIS procedures at AFBI. The different land use classifications employed under the CORINE scheme and their abundance in Northern Ireland are given in **Appendix 1**. Using nutrient export coefficients, land use is used to estimate what are minor nutrient loadings from uplands, forestry and other land uses (**Appendix 2**). The diffuse nutrient loading is calculated by the difference from the river nutrient load, less the combined loading of WWTWs and the sum of the minor nutrient loadings. This diffuse loading is dominated by the agricultural contribution but also will include loadings from rural single dwellings and small p.e.'s less than 10 in size. It tends to accumulate the errors that arise in estimating either river, WWTWs or contribution from other sources. Agricultural land, representing the combined area of grassland and arable land was the largest category of land cover across Northern Ireland in the period 2001-09 at 78%. Upland moorland and forest were the next highest categories at 12% and 6%, with urban sources (WWTWs) contributing only 3.3% to the overall area in Northern Ireland. **Table 1** shows the proportion of land cover categories across the freshwater lakes, transitional waters and sea loughs of Northern Ireland.

Table 1: Major land uses in Northern Ireland and individual catchment breakdowns.

	Total Area (Km^2)	Forest (%)	Urban and Other (%)	Moorland (%)	Water (%)	Agricultural (%)
Northern Ireland	**14292**	**5.8**	**3.3**	**12.1**	**0.8**	**78**
Lough Erne	2452	10.7	0.6	10.6	1.5	76.6
Lough Foyle	940	7.2	2.2	22.9	0.7	67
River Foyle	2823	7.7	1.3	26.6	0.6	63.8
Lough Neagh	4306	2.6	2.8	6.7	0.5	87.4
Lower Bann	1844	6.3	2.3	8.4	1.4	81.7
Inner Lagan	555	0.7	16.5	1.6	0.7	80.4
Inner Belfast Lough	85	8.9	43.7	4.8	0	42.5
Outer Belfast Lough	138	3.2	41.9	0.2	1.0	53.8
Quolie Basin	275	1.7	4.7	0	1.5	92.1
Strangford Lough	336	2.3	7.7	0.4	0.1	89.6
Dundrum Bay	129	5.6	0.6	2.6	0.7	90.5
Tidal Newry River	275	0.5	4.3	0.8	0.4	94.1
Carlingford Lough	134	7.7	1.9	27.8	0	62.6

2.3 SIMulated CATchment (SIMCAT) River Modelling, 2005-2009

A SIMCAT model covering the whole of Northern Ireland was developed, based on the GIS river water body network established under WFD. The model produces results for the following determinants: river flow (Ml/d), biochemical oxygen demand - BOD (mg/l), saline ammonia (Total Ammonia) - NH4+ (mg/l), free ammonia (un-ionised ammonia) - NH3 (mg/l), dissolved oxygen - DO (mg/l), soluble reactive phosphorus - SRP (Orthophosphate) PO4-P (mg/l), total phosphorus - TP (mg/l), nitrate - NO3, and total oxidised nitrogen - TON (mg/l). SIMCAT consists of four separate models. The models match the River Basin District Areas, except for the North Western RBD which was further split between the Foyle and the Erne catchments. All except the North Eastern model have cross border rivers. Each was calibrated against the Low Flows Enterprise (LFE) NI flow model and this provided the hydraulic model used to verify the base model structure. Following satisfactory calibration of the SIMCAT hydraulic model the model was populated with water quality data for the period 2005 - 2009. This was considered to be the most consistent data set for building the initial SIMCAT model and to allow for calibration of the catchment interactions and processes represented by the model. During development, 4820 river reaches were modelled along with 340 discharges, 342 abstractions, 713 monitoring stations and 90 flow gauging stations.

2.4 River Basin Districts

Where data are available, a summary of the nutrient budget loadings are presented for each of the catchments within the three main River Basin Districts (RBD) or parts of International RBD (IRBD) within Northern Ireland; North Eastern, Neagh Bann and North Western (**Tables 2a, 2b and 2c**). The mean annual loadings and % total loads of nitrate, PSOL and DIN in the individual catchments compared with overall Northern Ireland loadings are presented in the following sections. Nitrification loadings are presented for each catchment but are not considered in any detail within the summary text. A summary of the results of the SIMCAT SRP loadings from point and diffuse sources is also presented for each of the catchments within the three main RBD's.

Table 2a: Location of catchments within North Eastern RBD and relevant heading in the report

North Eastern RBD		
Belfast Lough and Lagan	**Bush and Glens**	**Strangford Lough, Lecale and Mourne**
• Tidal Lagan • Inner Belfast Lough • Outer Belfast Lough	• Bush and Glens river catchments	• Strangford Lough • Dundrum Bay • Quoile

Table 2b: Location of catchments within Neagh Bann RBD and relevant heading in the report

Neagh Bann RBD		
Carlingford and Newry	**Lough Neagh North and Lower Bann**	**Lough Neagh South**
• Newry River • Carlingford Lough	• Lower Bann • Lough Neagh North	• Lough Neagh South

Table 2c: Location of catchments within North Western RBD and relevant heading in the report

North Western RBD	
Lough Foyle and Foyle River	**Lough Erne and Melvin**
• River Foyle • Lough Foyle	• Lough Erne

Some caution should be taken when interpreting the results due to the time period of data collection (2001-2009). At this juncture the outputs will be used as indicative only, and as a starting point to consider areas where further monitoring or more current data should be considered prior to any significant decisions being made.

3.0 NORTH EASTERN RBD

3.1 Inner Belfast Lough, Outer Belfast Lough and Lagan catchments

Figure 2 shows the percentage total loadings and sources of PSOL, TON and DIN in the Belfast Lough and Lagan catchments from the nutrient budget study. Both the Lagan and the Belfast Lough Catchments are heavily urbanised and the freshwater Lagan receives a high proportion of PSOL from WWTWs from Lisburn and the southern suburbs of Belfast (Foy and Girvan, 2004).

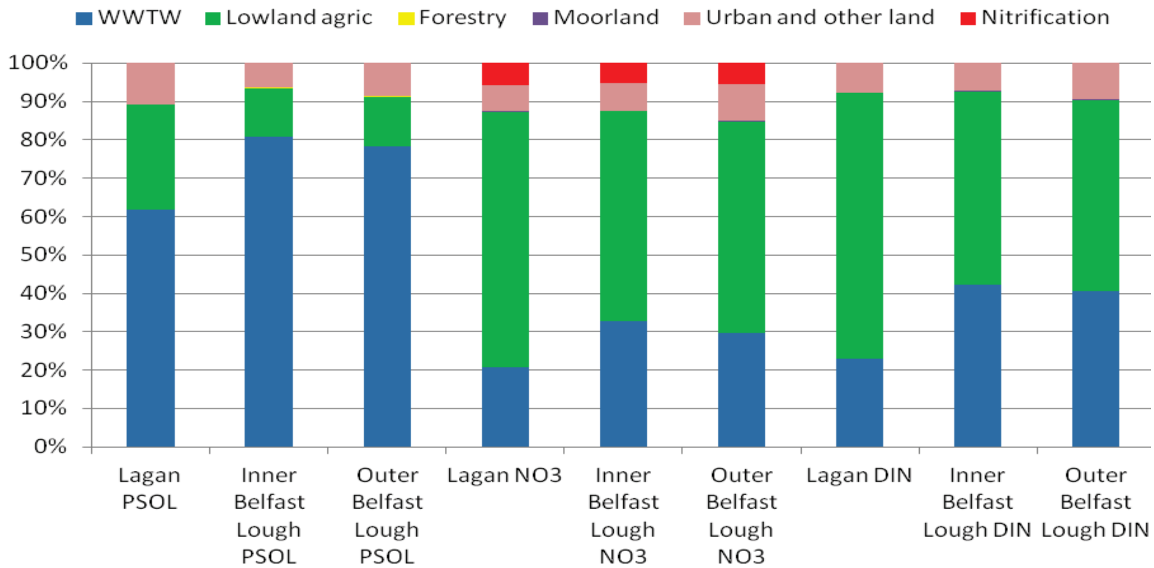

Figure 2: Source of PSOL, NO_3 and DIN loadings to the Tidal River Lagan, Inner and Outer Belfast Lough, 2001-2009

The breakdown of PSOL sources show that the contribution from WWTWs is 62%, 81% and 78% respectively in the Lagan, Inner Belfast Lough and Outer Belfast Lough. In contrast, relatively low contributions from agricultural sources to the Tidal River Lagan (27%) and Inner and Outer Belfast Lough (each 13%) reflect the higher level of contributions from point sources. The nutrient budget study also shows that urban land use contributes 11%, 6% and 9% in the Lagan, Inner Belfast Lough and Outer Belfast Lough catchments respectively.

Agriculture contributes the largest loading source of NO_3 to the Tidal River Lagan (66%) and Inner and Outer Belfast Lough catchments (both 55%), compared with 21%, 33% and 30% coming from WWTWs sources in the Lagan, Inner Belfast Lough and Outer Belfast Lough catchments respectively. Nutrient budget studies show that in the River Lagan catchment, 69% of the DIN loading comes from agricultural sources whereas 23% can be attributed to

WWTWs. Agricultural and WWTWs sources of DIN were similar in the Inner and Outer Belfast Lough catchments, with 50% attributed to agricultural sources in both catchments compared with 42% and 41% respectively in the Inner Belfast Lough and Outer Belfast Lough catchments which is attributed to WWTWs sources. Forestry and rough grazing made the smallest contribution (<1%) in the 3 catchments for all nutrient fractions, reflecting the small area devoted to these land uses. The mean annual loadings and % total loads of nitrate, PSOL and DIN in the Belfast Lough and Lagan catchments compared with overall Northern Ireland loadings are presented in **Tables 3a, 3b and 3c**.

Table 3a: Nutrient Budget Summary of PSOL loadings to the Tidal River Lagan, Inner and Outer Belfast Lough compared with Northern Ireland loadings, 2001-2009

PSOL Loading (MAL 01-09 t P yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry
Northern Ireland	*515*	*509*	*56*	*30*	*18*
	45.7%	*45.1%*	*5%*	*2.7%*	*1.6%*
Tidal River Lagan	66	29	11	<1	<1
	62%	27%	11%	<0.1%	<0.1%
Inner Belfast Lough	203	32	16	<1	<1
	81%	13%	6%	<0.1%	<0.1%
Outer Belfast Lough	224	37	25	<1	<1
	78 %	13%	9%	<0.1%	<0.1%

Table 3b: Nutrient Budget Summary of NO_3 to the Tidal River Lagan, Inner and Outer Belfast Lough compared with Northern Ireland loadings, 2001-2009

Nitrate Loading (MAL 01-09 t NO3-N yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry	Nitrification
Northern Ireland	*478*	*4297*	*67*	*107*	*22*	*214*
	9%	*83%*	*1%*	*2%*	*1%*	*4%*
Tidal River Lagan	215	690	69	2	0	61
	21%	66%	7%	<0.1%	0%	6%
Inner Belfast Lough	440	735	96	2	1	70
	33%	55%	7%	<0.1%	<0.1%	5%
Outer Belfast Lough	462	858	148	2	1	85
	30%	55%	10%	<0.1%	<0.1%	5%

Table 3c: Nutrient Budget Summary of DIN loadings to the Tidal River Lagan, Inner and Outer Belfast Lough compared with Northern Ireland loadings, 2001-2009

DIN Loading (MAL 01-09 t NO3-N yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry
Northern Ireland	*2523*	*14401*	*272*	*380*	*92*
	14%	*81%*	*2%*	*2%*	*1%*
Tidal River Lagan	254	759	84	2	1
	23%	69%	8%	<0.1%	<0.1%
Inner Belfast Lough	683	812	118	3	1
	42%	50%	8%	<0.1%	<0.1%
Outer Belfast Lough	772	949	181	3	2
	41%	50%	9%	<0.1%	<0.1%

SIMCAT modelling (current performance) of the North Eastern RBD during the period 2005-2009 showed that the total loading of SRP to the Lagan, Inner and Outer Belfast Lough catchments was 324 (tonnes/ yr-1). The loading of SRP from WWTWs was 248 (tonnes/ yr-1) over the same period, therefore contributing 76.5% to the overall SRP loading in the Lagan, Inner and Outer Belfast Lough catchments. Schematic diagrams are presented in **Figure 3a** and **3b** illustrating the loading from individual rivers in the catchments.

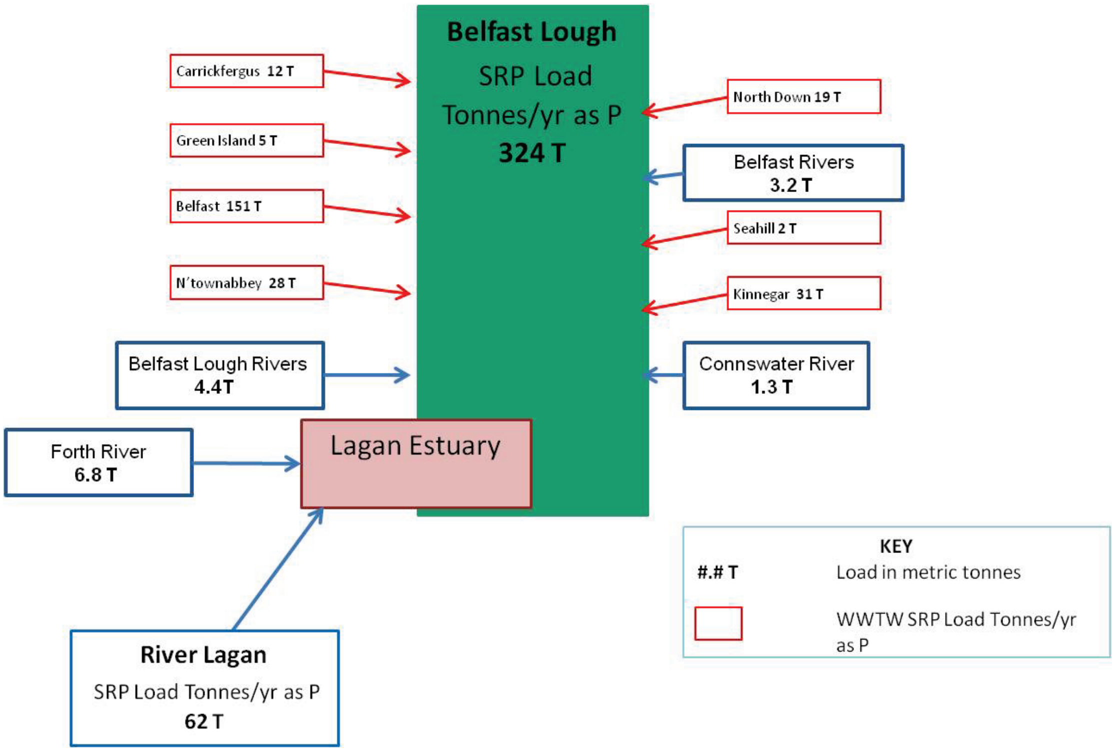

Figure 3a: Schematic of the SRP loadings (tonnes/ yr-1) of rivers within the Inner and Outer Belfast Lough catchments, 2005-2009 (Current performance, SIMCAT Model)

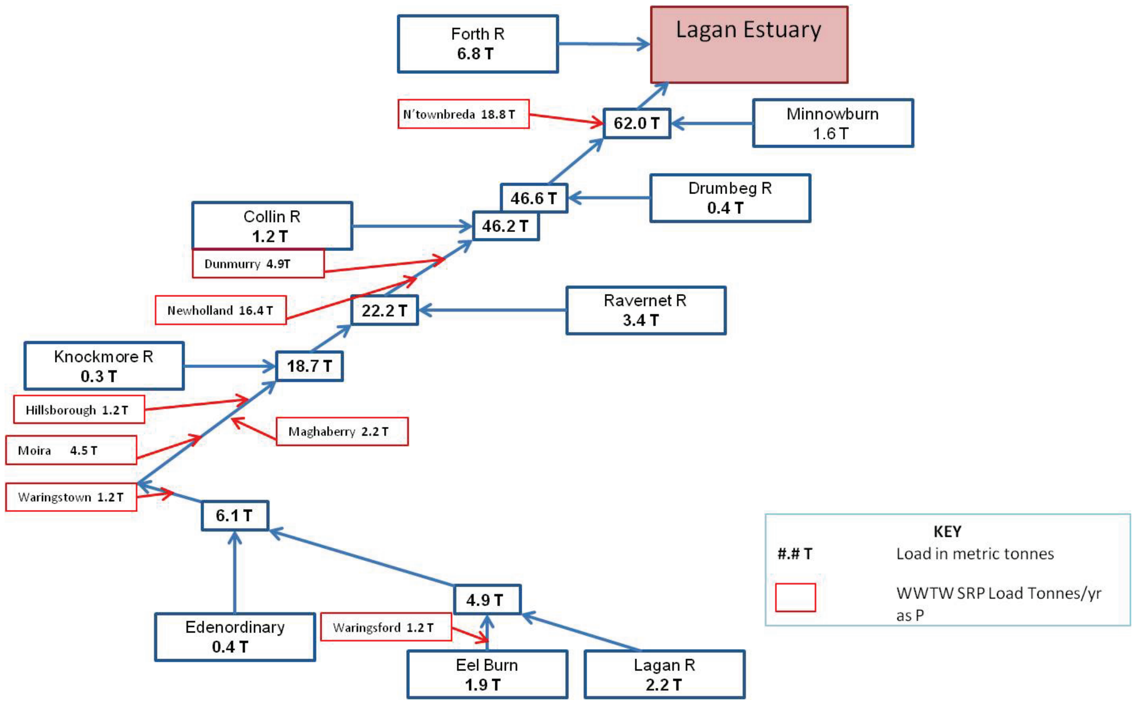

Figure 3b: Schematic of the SRP loadings (tonnes/ yr-1) of rivers within the Lagan catchments, 2005-2009 (Current performance, SIMCAT Model)

3.2 Bush and Glens catchments

No information from the nutrient budget study is available for this catchment

SIMCAT modelling of the North Eastern RBD showed that the total loading of SRP to the Bush and Glens catchments was 28.9 (tonnes/ yr^{-1}) during the period 2005-2009. The loading of SRP from WWTWs was 2.7 (tonnes/ yr^{-1}) over the same period, therefore contributing 9% to the overall SRP loading in the Bush and Glens catchments. A schematic diagram is presented in **Figure 4** to illustrate the loading from individual rivers in the Bush and Glens catchments.

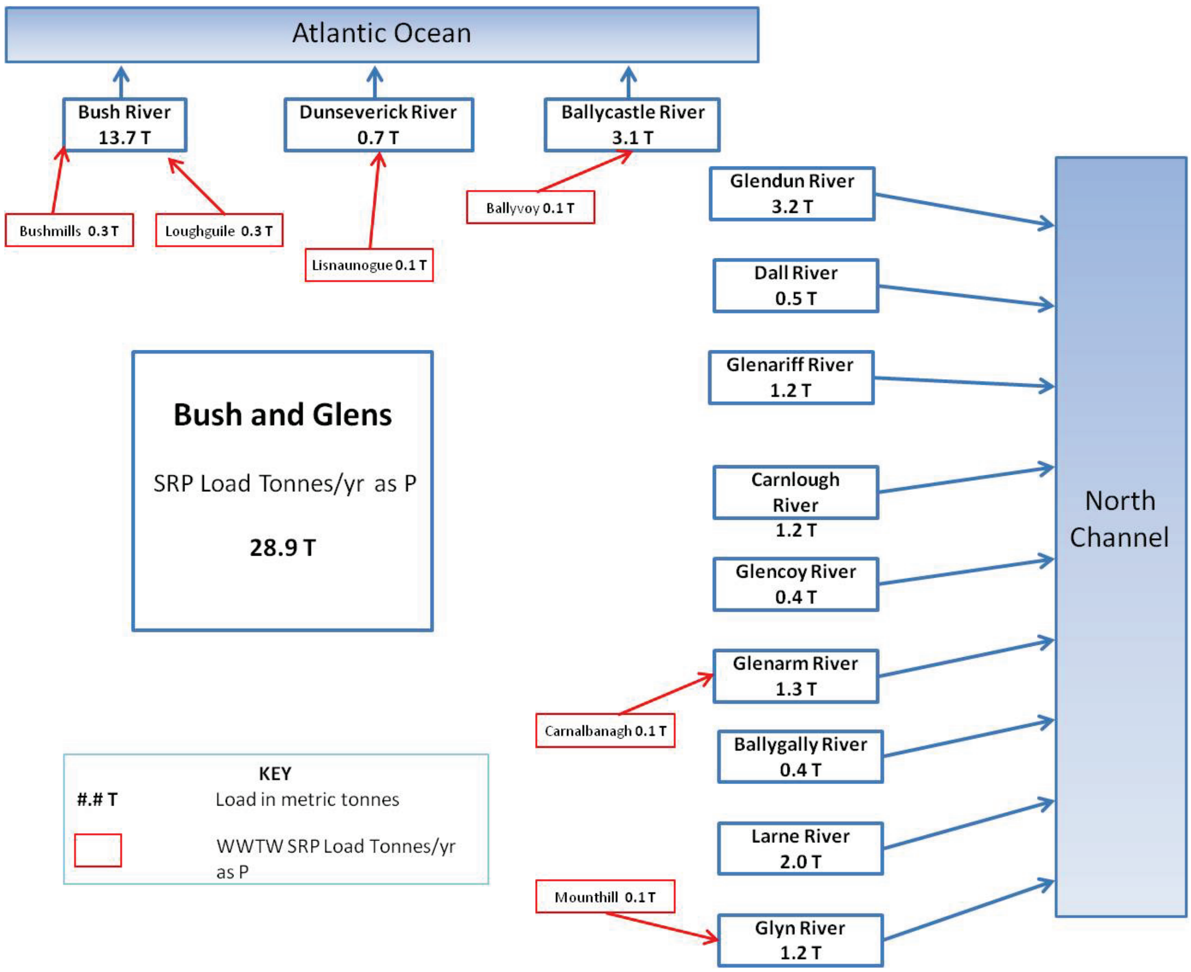

Figure 4: Schematic of the SRP loadings (tonnes/ yr^{-1}) of rivers within the Bush and Glens catchments, 2005-2009

3.3 Strangford Lough, Mourne and Lecale catchments

Figure 5 shows the percentage total nutrient budget loadings and sources of nitrate, PSOL and DIN to Strangford Lough, Quoile and Dundrum Bay. Agriculture contributes the largest loading source of PSOL in the Quoile (64%) and Dundrum Bay (65%) catchments whereas WWTWs sources contribute the largest loading in the Strangford catchment (55%). The study highlights the relatively low contributions from point sources, with WWTWs loadings to the Quoile and Dundrum Bay both amounting to 31%.

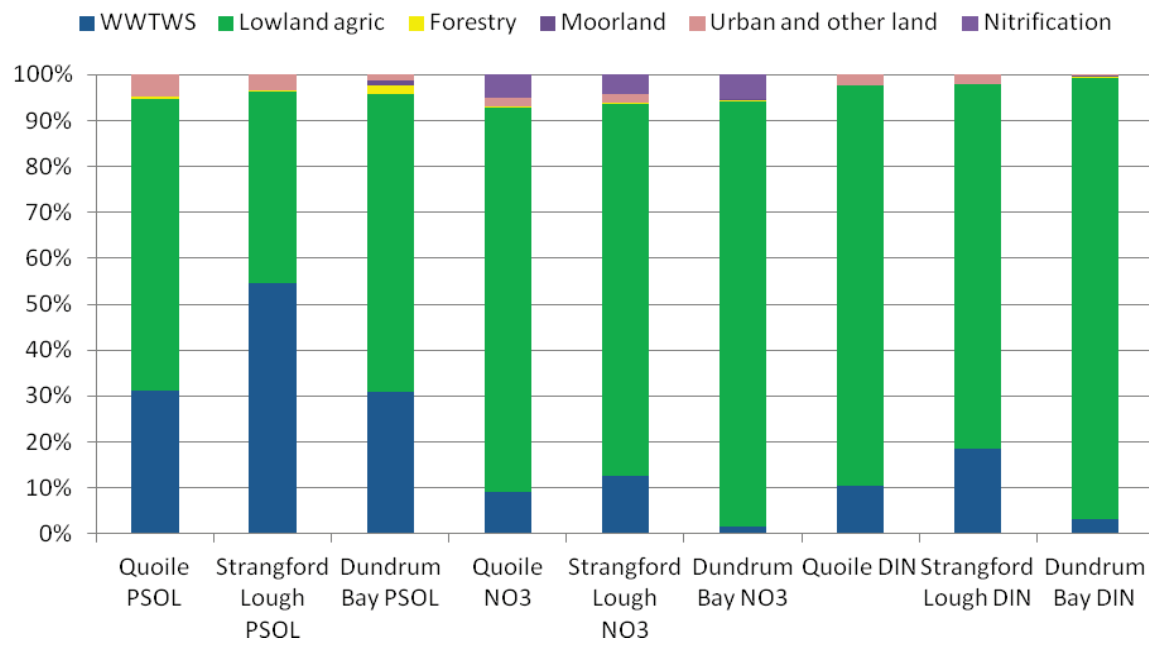

Figure 5: Source of PSOL, NO_3 and DIN loadings to Strangford Lough, Quoile and Dundrum Bay, 2001-2009

Agriculture contributes the largest loading source of NO_3 to Strangford Lough (81%), the Quoile (84%) and Dundrum Bay (93%), compared with 13%, 9% and 2% coming from WWTWs sources in Strangford Lough, Quoile and Dundrum Bay catchments respectively. Nutrient budget studies show that agriculture significantly contributes the largest loading source of DIN to Strangford Lough (79%), the Quoile (87%) and Dundrum Bay (96%), compared with 19%, 11% and 4% in Strangford Lough, Quoile and Dundrum Bay catchments respectively which is attributed to WWTWs sources. Forestry and rough grazing made the smallest contribution (≤2%) in the 3 catchments for all nutrient fractions, reflecting the small area devoted to these land uses. **Tables 4a, 4b and 4c** present the mean annual loadings and % total loads of nitrate, PSOL and DIN in the Strangford Lough, Quoile and Dundrum Bay catchments compared with overall Northern Ireland loadings.

Table 4a: Nutrient Budget Summary of PSOL loadings to Strangford Lough, Quoile and Dundrum Bay compared with Northern Ireland loadings, 2001-2009

SRP Loading (MAL 01-09 t P yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry
Northern Ireland	*515*	*509*	*56*	*30*	*18*
	45.7%	*45.1%*	*5%*	*2.7%*	*1.6%*
Strangford Lough	44	34	3	0	<1
	55%	42%	3%	0%	<0.01%
Quoile	7	15	1	0	<1
	31%	64%	5%	0%	<0.01%
Dundrum Bay	2	5	<1	<1	<1
	31%	65%	1%	1%	2%

Table 4b: Nutrient Budget Summary of NO_3 loadings to Strangford Lough, Quoile and Dundrum Bay compared with Northern Ireland loadings, 2001-2009

Nitrate Loading (MAL 01-09 t NO3-N yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry	Nitrification
Northern Ireland	*478*	*4297*	*67*	*107*	*22*	*214*
	9%	*83%*	*1%*	*2%*	*1%*	*4%*
Strangford Lough	*109*	*703*	*17*	*0*	*1*	*37*
	13%	81%	2%	0%	<0.1%	4%
Quoile	30	281	7	0	0	17
	9%	84%	2%	0%	0%	5%
Dundrum Bay	4	274	1	1	1	15
	2%	93%	<0.1%	<0.1%	<0.1%	5%

Table 4c: Nutrient Budget Summary of DIN loadings to Strangford Lough, Quoile and Dundrum Bay compared with Northern Ireland loadings, 2001-2009

DIN Loading (MAL 01-09 t NO3-N yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry
Northern Ireland	*2523*	*14401*	*272*	*380*	*92*
	14%	*81%*	*2%*	*2%*	*1%*
Strangford Lough	*178*	*767*	*20*	*0*	*1*
	19%	79%	2%	0%	<0.1%
Quoile	37	311	8	0	0
	11%	87%	2%	0%	0%
Dundrum Bay	10	295	1	1	1
	4%	96%	<0.1%	<0.1%	<0.1%

SIMCAT modelling (current performance) of the North Eastern RBD during the period 2005-2009 showed that the total loading of SRP to the Strangford Lough, Mourne and Lecale catchments was 43.4 (tonnes/ yr^{-1}). The loading of SRP from WWTWs was 12.1 (tonnes/ yr^{-1}) over the same period, therefore contributing 29% to the overall SRP loading in the Strangford Lough, Mourne and Lecale catchments. A schematic diagram is presented in **Figure 6** illustrating the loading from individual rivers in the catchments.

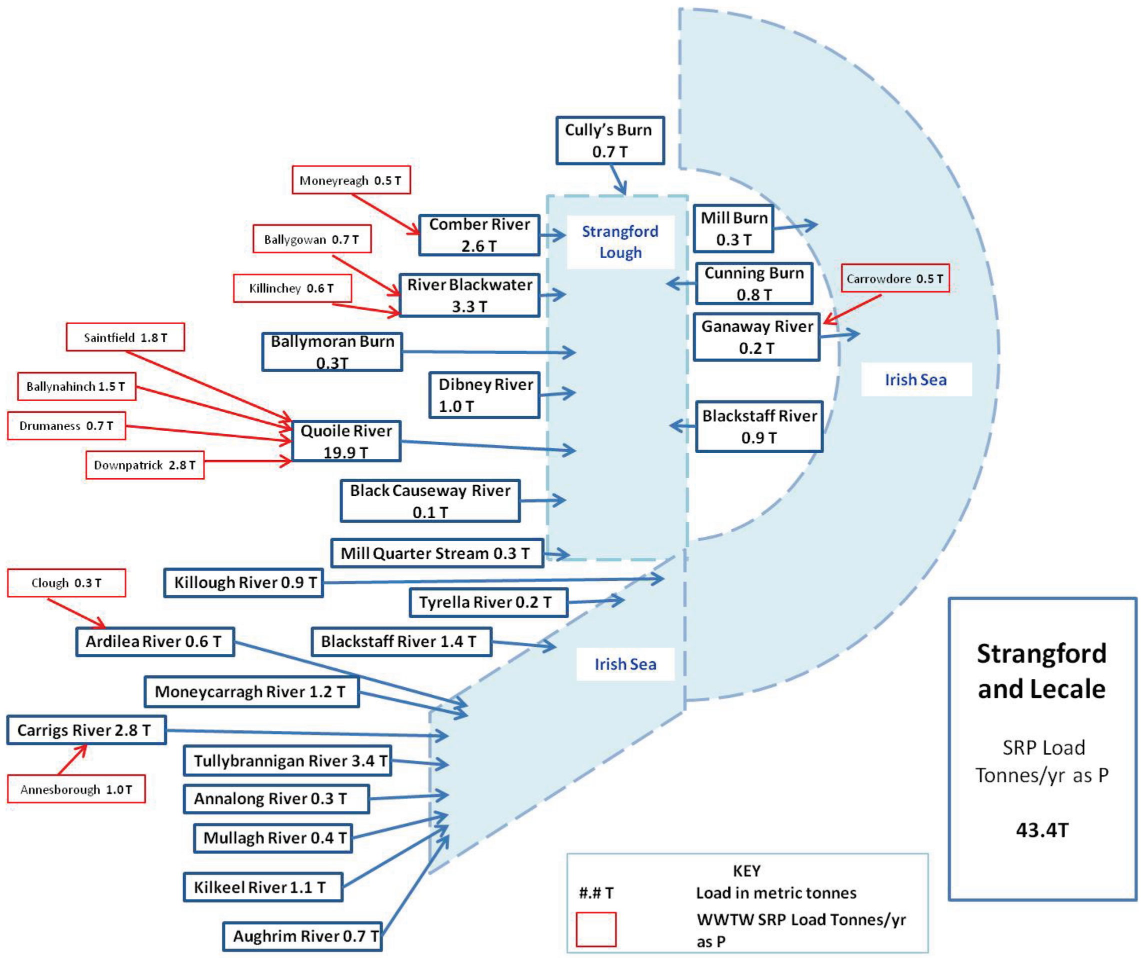

Figure 6: Schematic of the SRP loadings (tonnes/ yr^{-1}) of rivers within the Strangford and Lecale catchments, 2005-2009

4.0 NEAGH BANN RBD

4.1 Lough Neagh catchments

For the purposes of this report, the Lough Neagh catchment is divided into 2 sections; Lough Neagh North (and Lower Bann) and Lough Neagh South, as shown in **Figure 7**.

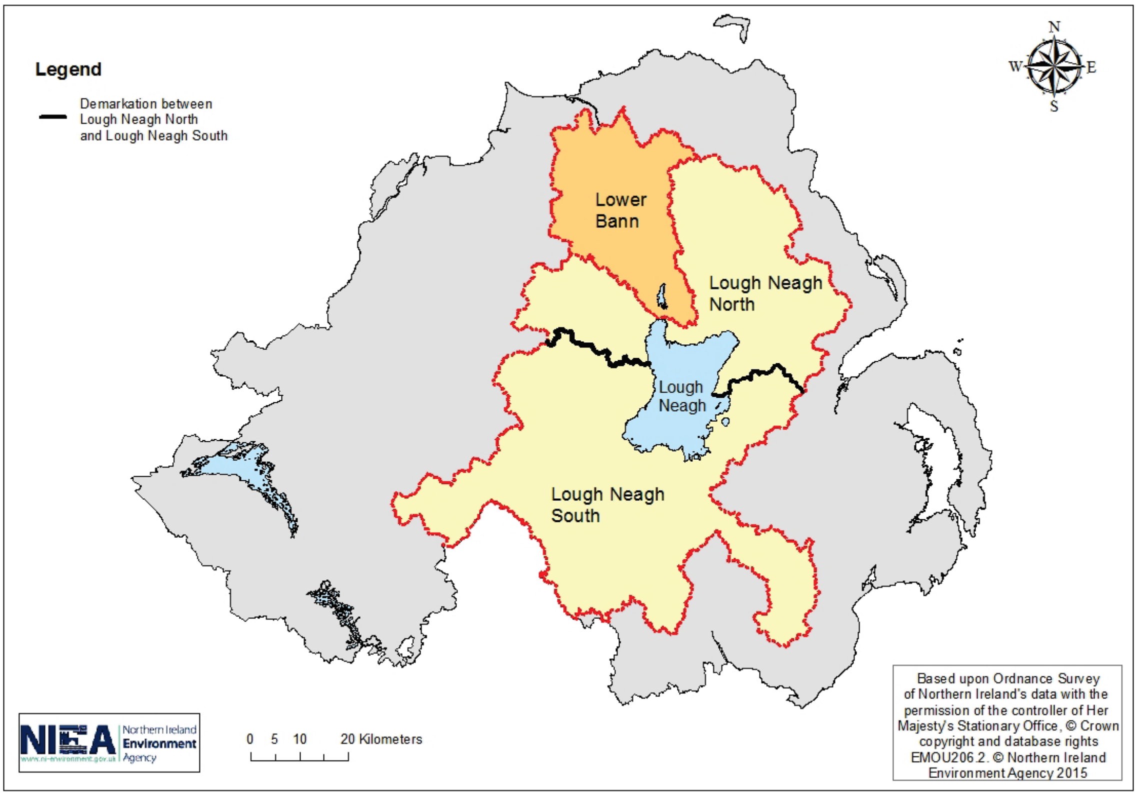

Figure 7: Demarcation of Sensitive Areas designations in Lough Neagh catchment

4.2 Lough Neagh North and Lower Bann catchments

Figure 8 shows the percentage total nutrient budget loadings and sources of PSOL and TON to Lough Neagh North and Lower Bann catchments.

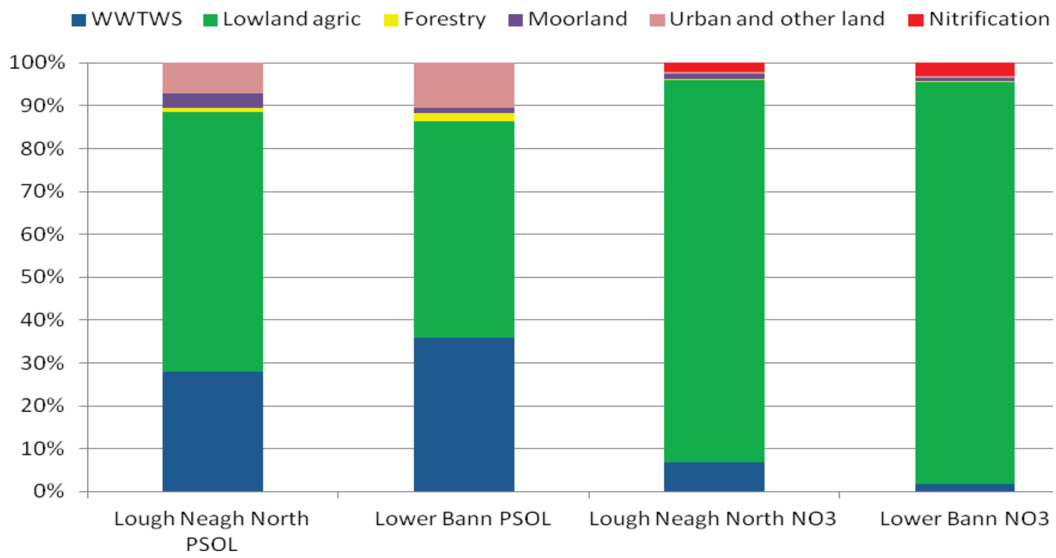

Figure 8: Source of PSOL and NO_3 loadings to Lough Neagh North and Lower Bann, 2001-2009

The breakdown of PSOL sources show that the contribution from agriculture is 61% and 50% respectively in the Lough Neagh North and Lower Bann catchments, compared with relatively low contributions from WWTWs sources to Lough Neagh North (27%) and Lower Bann (36%). The nutrient budget study also shows that urban land use contributes 7% and 10% in Lough Neagh North and Lower Bann catchments respectively.

Agriculture contributes the largest loading source of NO_3 to Lough Neagh North (89%) and Lower Bann catchments (94%), compared with 7% and 2% respectively in Lough Neagh North and Lower Bann catchments which is attributed to WWTWs loadings, reflecting the low level of contributions from point sources. Forestry and rough grazing made the smallest contribution (≤3%) in the 2 catchments for all nutrient fractions, reflecting the small area devoted to these land uses. The mean annual loadings and % total loads of nitrate and PSOL in Lough Neagh North and Lower Bann catchments compared with overall Northern Ireland loadings are presented in **Tables 5a and 5b** below.

Table 5a: Nutrient Budget Summary of PSOL loadings to Lough Neagh North and Lower Bann compared with Northern Ireland loadings, 2001-2009

PSOL Loading (MAL 01-09 t P yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry
Northern Ireland	*515*	*509*	*56*	*30*	*18*
	45.7%	*45.1%*	*5%*	*2.7%*	*1.6%*
Neagh North	23	50	6	3	1
	28%	61%	7%	3%	1%
Lower Bann	19	26	5	1	1
	36%	50%	10%	1%	2%

Table 5b: Nutrient Budget Summary of NO3 loadings to Lough Neagh North and Lower Bann compared with Northern Ireland loadings, 2001-2009

Nitrate Loading (MAL 01-09 t NO3-N yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry	Nitrification
Northern Ireland	*478*	*4297*	*67*	*107*	*22*	*214*
	9%	*83%*	*1%*	*2%*	*1%*	*4%*
Neagh North	152	1977	7	30	3	48
	7%	89%	<0.1%	2%	<0.1%	2%
Lower Bann	21	1085	6	8	4	34
	2%	94%	<0.1%	1%	<0.1%	3%

SIMCAT modelling (current performance) of the Neagh Bann RBD during the period 2005-2009 showed that the Moyola, Braid and Main Rivers, Six Mile Water and peripheral rivers contribute 72.5 (tonnes SRP/ yr^{-1}) into Lough Neagh. The total riverine loading of SRP to the headwaters of the Lower Bann was 224.4 (tonnes/ yr^{-1}) and increased to 265.7 at the mouth of the river. Lough Neagh itself contributes 1.9 (tonnes SRP/yr^{-1}) due to internal lake processes. The loading of SRP from WWTWs in the Neagh North catchments was 17 (tonnes/ yr^{-1}) whilst the loading of SRP from WWTWs in the Lower Bann was 13.5 (tonnes/ yr^{-1}). A schematic diagram is presented in **Figure 9** illustrating the loading from individual rivers in the catchments.

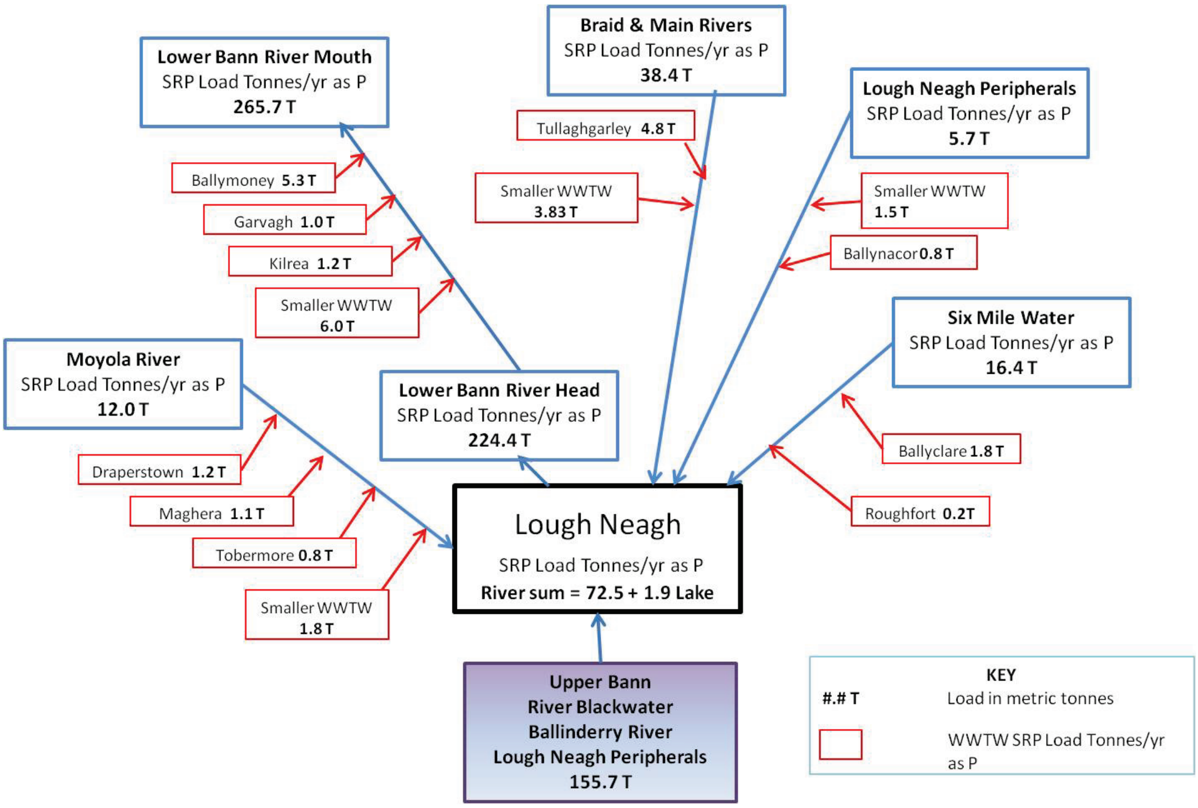

Figure 9: Schematic of the SRP loadings (tonnes/ yr^{-1}) of rivers within the Lough Neagh North and Lower Bann catchments, 2005-2009 (Current performance, SIMCAT Model)

4.3 Lough Neagh South catchments

Figure 10 shows the percentage total loadings and sources of PSOL and TON to Lough Neagh South catchments.

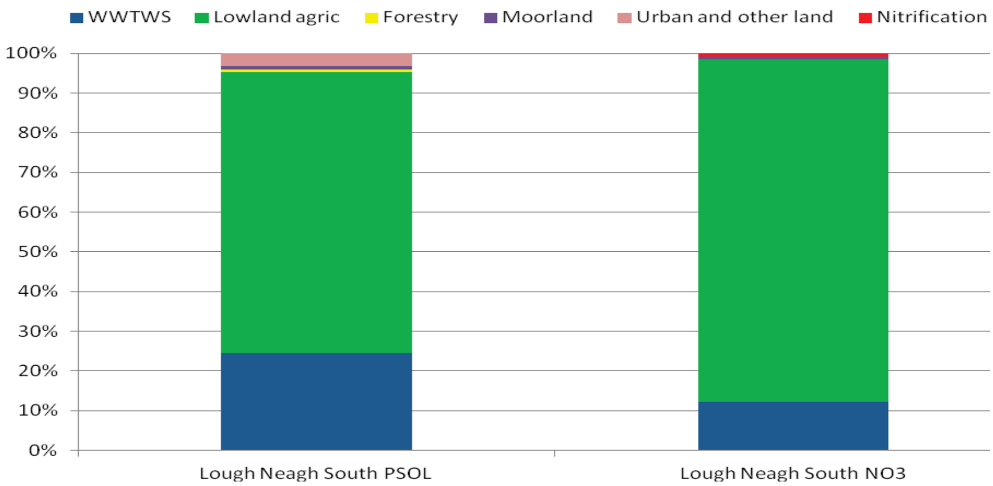

Figure 10: Source of PSOL and NO_3 loadings to Lough Neagh South, 2001-2009

The breakdown of PSOL sources show that the contribution from agriculture is 71% in Lough Neagh South catchments compared with relatively low contributions from WWTWs sources to Lough Neagh North (24%). The nutrient budget study also shows that urban land use contributes 3% to the catchment.

Agriculture also contributes the largest loading source of NO_3 to Lough Neagh South (86%) compared with 12% which is attributed to WWTWs loadings, reflecting the low level of contributions from point sources. Forestry and rough grazing made the smallest contribution (≤1%) in the catchment for all nutrient fractions, reflecting the small area devoted to these land uses. The mean annual loadings and % total loads of nitrate and PSOL in Lough Neagh South catchments compared with overall Northern Ireland loadings are presented in **Tables 6a and 6b** below.

Table 6a: Nutrient Budget Summary of PSOL loadings to Lough Neagh South compared with Northern Ireland loadings, 2001-2009

PSOL Loading (MAL 01-09 t P yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry
Northern Ireland	*515*	*509*	*56*	*30*	*18*
	45.7%	*45.1%*	*5%*	*2.7%*	*1.6%*
Neagh South	55	158	7	2	2
	24%	71%	3%	1%	1%

Table 6b: Nutrient Budget Summary of NO_3 loadings to Lough Neagh South compared with Northern Ireland loadings, 2001-2009

Nitrate Loading (MAL 01-09 t NO3-N yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry	Nitrification
Northern Ireland	*478*	*4297*	*67*	*107*	*22*	*214*
	9%	*83%*	*1%*	*2%*	*1%*	*4%*
Neagh South	479	3403	8	19	5	28
	12%	86%	<0.1%	1%	<0.1%	1%

4.4 Carlingford and Newry catchments

Figure 11 shows the percentage total loadings and sources of PSOL, TON and DIN to the Carlingford and Newry catchments.

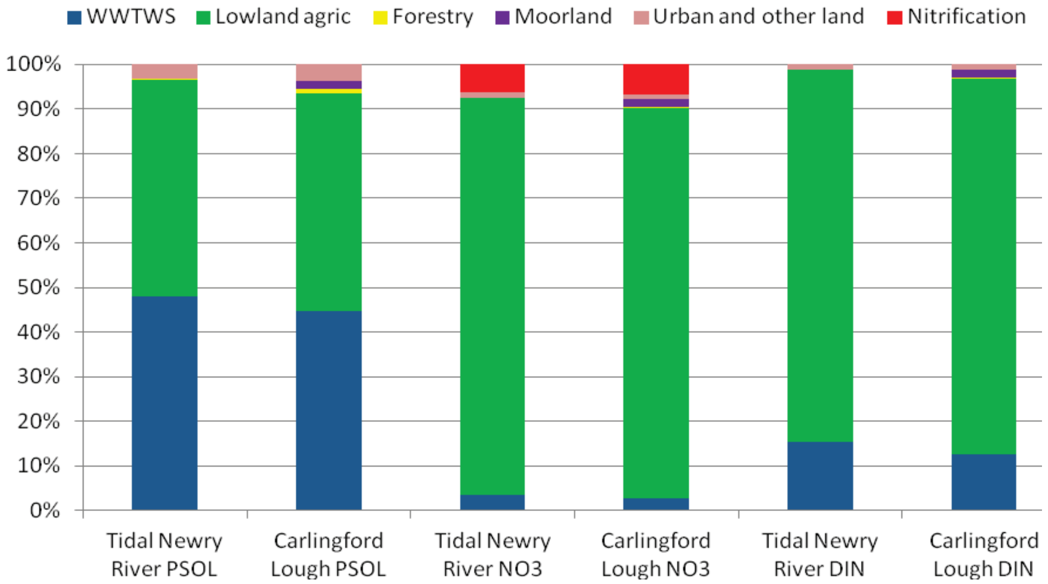

Figure 11: Source of PSOL, NO_3 and DIN loadings to Carlingford and Newry, 2001-2009

Agricultural and WWTW sources of PSOL were similar in the catchments, with 49% attributed to agricultural sources in both catchments compared with 48% and 45% respectively in the Newry and Carlingford Lough catchments which can be attributed to WWTW sources. The nutrient budget study also shows that urban land use contributes ≤4% in each of the catchments.

Agriculture contributes the largest loading source of NO_3 to Newry River (89%) and Carlingford Lough catchments (87%), compared with 4% and 3% respectively in each catchment which is attributed to WWTW loadings, reflecting the low level of contributions from point sources. Nutrient budget studies show that agriculture significantly contributes the largest loading source of DIN to Newry River (83%) and Carlingford Lough (84%), compared with 16% and 13% respectively in the catchments which can be attributed to WWTW sources. Forestry and rough grazing made the smallest contribution (≤2%) in the 2 catchments for all nutrient fractions, reflecting the small area devoted to these land uses. The mean annual loadings and % total loads of nitrate, PSOL and DIN in the Carlingford Lough and Newry River catchments compared with overall Northern Ireland loadings are presented in **Tables 7a, 7b and 7c** below.

Table 7a: Nutrient Budget Summary of PSOL loadings to Carlingford and Newry compared with Northern Ireland loadings, 2001-2009

PSOL Loading (MAL 01-09 t P yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry
Northern Ireland	*515*	*509*	*56*	*30*	*18*
	45.7%	*45.1%*	*5%*	*2.7%*	*1.6%*
Newry	10	11	1	<0.1	<0.1
	48%	49%	3%	<0.1%	<0.1%
Carlingford Lough	11	12	1	<1	<1
	45%	49%	4%	2%	4%

Table 7b: Nutrient Budget Summary of NO_3 loadings to Carlingford and Newry compared with Northern Ireland loadings, 2001-2009

Nitrate Loading (MAL 01-09 t NO3-N yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry	Nitrification
Northern Ireland	*478*	*4297*	*67*	*107*	*22*	*214*
	9%	*83%*	*1%*	*2%*	*1%*	*4%*
Newry	13	346	4	0	0	24
	4%	89%	1%	0%	0%	6%
Carlingford Lough	15	473	6	9	1	36
	3%	87%	1%	2%	<0.1%	7%

Table 7c: Nutrient Budget Summary of DIN loadings to Carlingford and Newry compared with Northern Ireland loadings, 2001-2009

DIN Loading (MAL 01-09 t NO3-N yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry
Northern Ireland	*2523*	*14401*	*272*	*380*	*92*
	14%	*81%*	*2%*	*2%*	*1%*
Newry	69	371	5	0	0
	16%	83%	1%	0%	0%
Carlingford Lough	77	512	7	11	2
	13%	84%	1%	2%	<0.1%

SIMCAT modelling (current performance) of the Neagh Bann RBD during the period 2005-2009 showed that the total loading of SRP to the Lough Neagh South catchments was 149.8 (tonnes/ yr^{-1}). The loading of SRP from WWTWs in the Lough Neagh South catchments was 38.6 (tonnes/ yr^{-1}) over the same period, representing 26% of the total loading to Lough Neagh (South). A schematic diagram is presented in **Figure 12** illustrating the loading from individual rivers in the catchments.

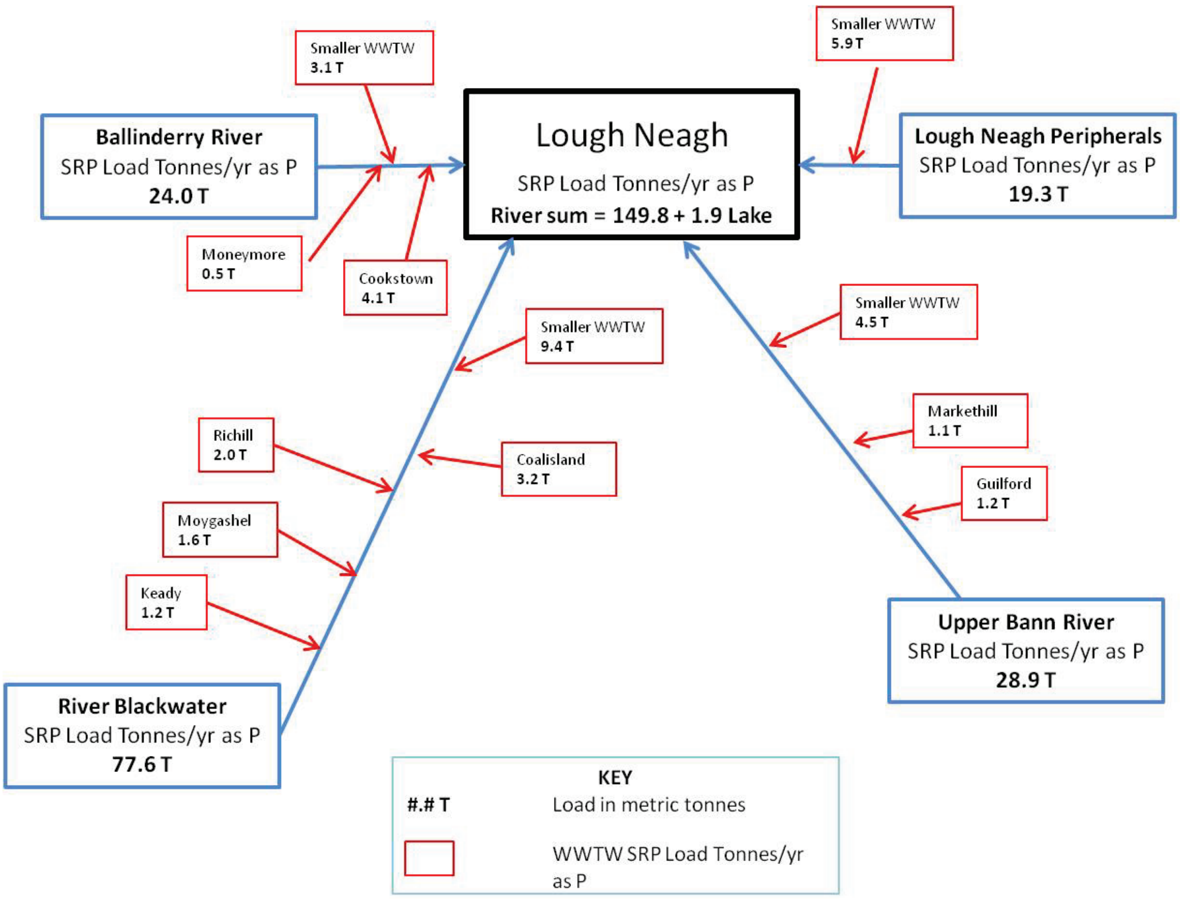

Figure 12: Schematic of the SRP loadings (tonnes/ yr^{-1}) of rivers within the Lough Neagh South catchments, 2005-2009 (Current performance, SIMCAT Model)

5.0 NORTH WESTERN RBD

5.1 Lough Foyle and River Foyle catchments

Figure 13 shows the percentage total loadings and sources of PSOL and TON to Lough Foyle and River Foyle catchments.

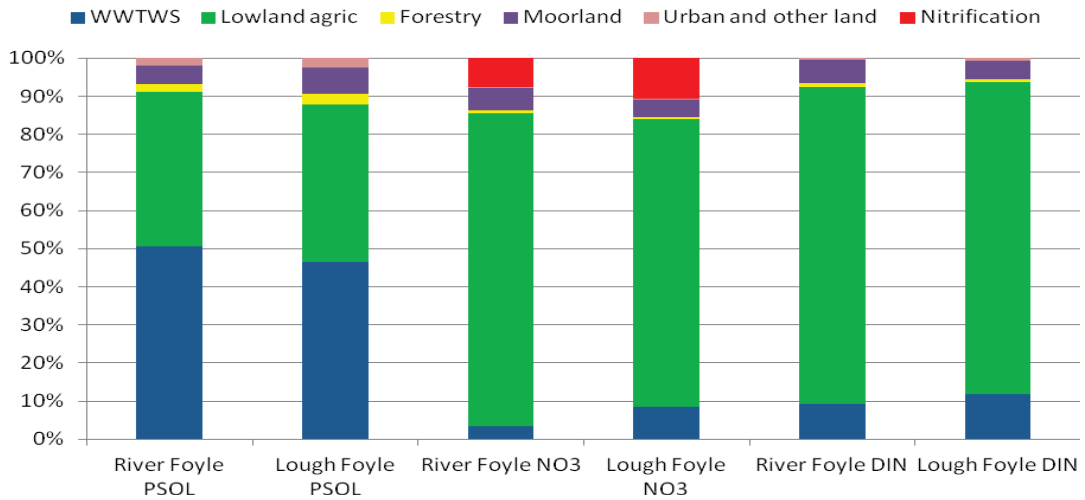

Figure 13: Source of PSOL and NO_3 loadings to Lough Foyle and Foyle River, 2001-2009

The breakdown of PSOL reflects the higher level of contributions from point sources. The loading from WWTW sources is 51% in the River Foyle and 46% in Lough Foyle. In contrast, contributions from agricultural sources to the River Foyle are 40% and to Lough Foyle are 41%. The nutrient budget study also shows that moorland contributes 5% and 7% in the River Foyle and Lough Foyle catchments respectively.

Agriculture contributes the largest loading source of NO_3 to the River Foyle (82%) and Lough Foyle catchments (75%), compared with 3% and 8% respectively in each catchment which is attributed to WWTW loadings, reflecting the low level of contributions from point sources. Nutrient budget studies show that agriculture significantly contributes the largest loading source of DIN to River Foyle (84%) and Lough Foyle (82%), compared with 9% and 12% respectively in the catchments which can be attributed to WWTW sources. Forestry and urban land made the smallest contribution (≤2%) in the 2 catchments for all nutrient fractions, reflecting the small area devoted to these land uses. The mean annual loadings and % total loads of nitrate and PSOL in the Lough Foyle and River Foyle catchments compared with overall Northern Ireland loadings are presented in **Tables 8a, 8b and 8c** below.

Table 8a: Nutrient Budget Summary of PSOL loadings to Lough Foyle and Foyle River compared with Northern Ireland loadings, 2001-2009

PSOL Loading (MAL 01-09 t P yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry
Northern Ireland	*515*	*509*	*56*	*30*	*18*
	45.7%	*45.1%*	*5%*	*2.7%*	*1.6%*
Foyle River	111	89	4	10	5
	51%	40%	2%	5%	2%
Lough Foyle	126	112	7	19	8
	46%	41%	2%	7%	3%

Table 8b: Nutrient Budget Summary of NO_3 loadings to Lough Foyle and Foyle River compared with Northern Ireland loadings, 2001-2009

Nitrate Loading (MAL 01-09 t NO3-N yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry	Nitrification
Northern Ireland	*478*	*4297*	*67*	*107*	*22*	*214*
	9%	*83%*	*1%*	*2%*	*1%*	*4%*
Foyle River	95	2367	5	172	23	218
	3%	82%	<0.1%	6%	1%	8%
Lough Foyle	57	514	2	31	4	73
	8%	75%	<0.1%	5%	1%	11%

Table 8c: Nutrient Budget Summary of DIN loadings to Lough Foyle and Foyle River compared with Northern Ireland loadings, 2001-2009

DIN Loading (MAL 01-09 t NO3-N yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry
Northern Ireland	*2523*	*14401*	*272*	*380*	*92*
	14%	*81%*	*2%*	*2%*	*1%*
Foyle River	301	2749	12	203	32
	9%	84%	<0.1%	6%	1%
Lough Foyle	88	609	5	36	6
	12%	82%	<0.1%	5%	1%

SIMCAT modelling (current performance) of the North Western RBD during the period 2005-2009 showed that the total loading of SRP to the Foyle catchments was 99.8 (tonnes/ yr^{-1}). The loading of SRP from WWTWs was 28.1 (tonnes/ yr^{-1}) over the same period, representing 28% of the total loading to the rivers in the Foyle catchments. A schematic diagram is presented in **Figure 14** illustrating the loading from individual rivers in the catchments.

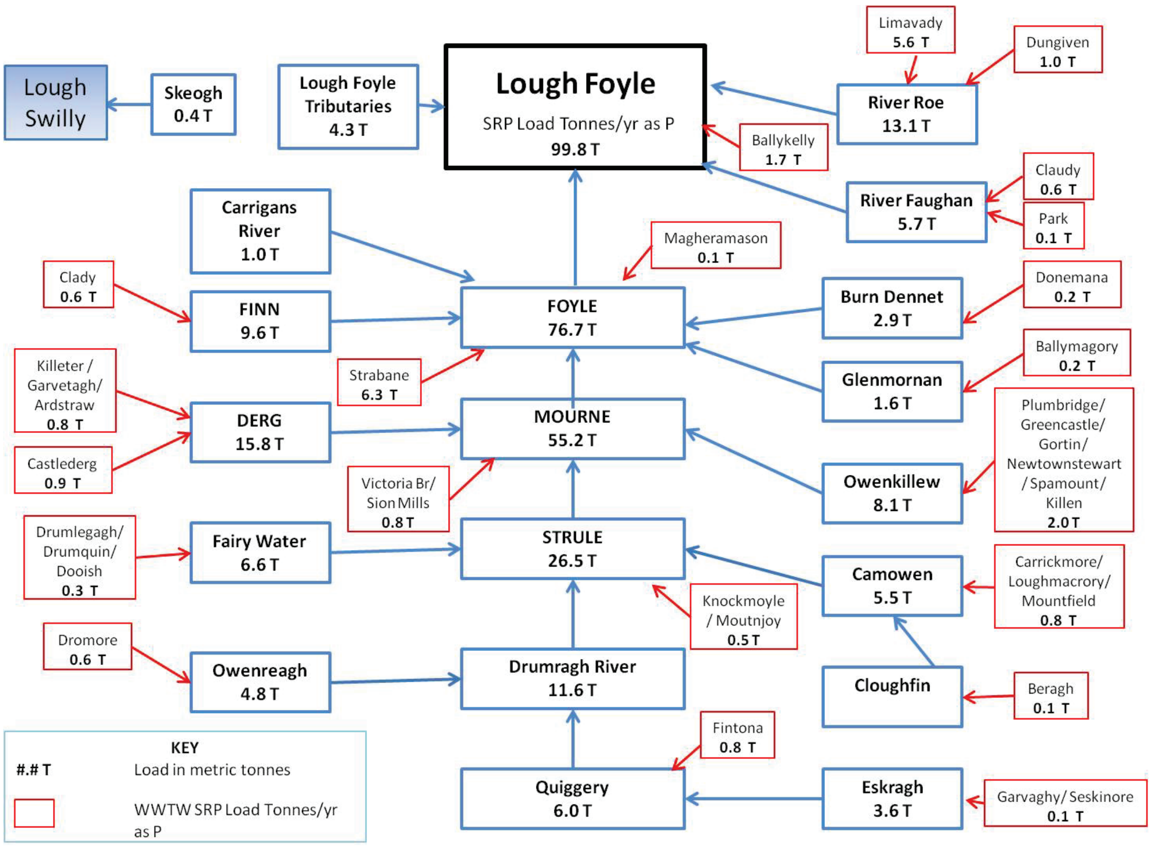

Figure 14: Schematic of the SRP loadings (tonnes/ yr^{-1}) of rivers within the Foyle catchments, 2005-2009 (Current performance, SIMCAT Model)

5.2 Lough Erne and Melvin catchments

Figure 15 shows the percentage total loadings and sources of PSOL and TON to the Lough Erne and Melvin catchments.

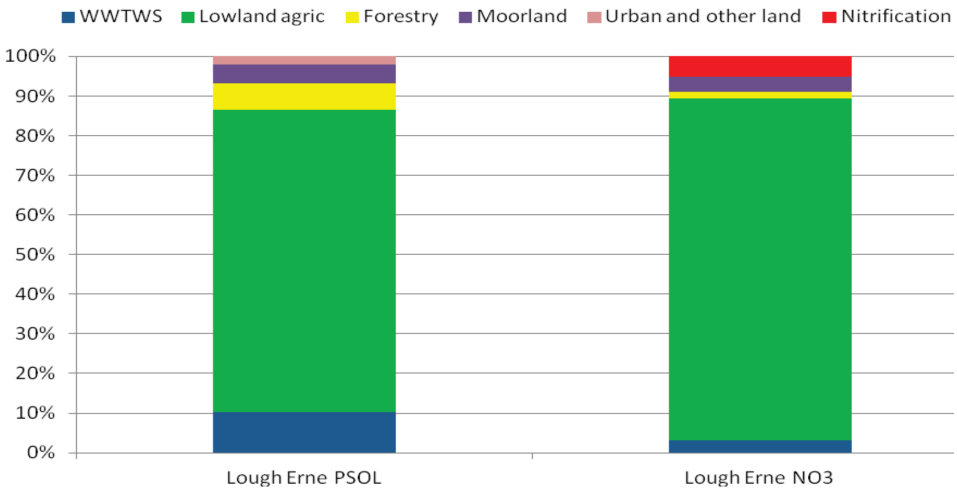

Figure 15: Source of PSOL and NO_3 loadings to Lough Erne and Lough Melvin, 2001-2009

The breakdown of PSOL loading reflects the higher level of contributions from agricultural sources (76%) in the catchment. In contrast, contributions from WWTW sources to the Lough Erne and Melvin catchments are 10%. The nutrient budget study also shows that forestry contributes 7% and moorland contributes 5%.

Agriculture contributes the largest loading source of NO3 to the Lough Erne and Melvin catchments (86%), compared with 3% which is attributed to WWTW loadings, reflecting the low level of contributions from point sources. The nutrient budget study also shows that moorland contributes 4% of the NO3 loading contribution to the catchments. Urban land made the smallest contribution (≤2%) in the catchments for all nutrient fractions, reflecting the small area devoted to this land use. The mean annual loadings and % total loads of nitrate and PSOL in the Lough Erne and Melvin catchments compared with overall Northern Ireland loadings are presented in **Tables 9a and 9b**.

Table 9a: Nutrient Budget Summary of PSOL loadings to Lough Erne and Lough Melvin compared with Northern Ireland loadings, 2001-2009

PSOL Loading (MAL 01-09 t P yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry
Northern Ireland	*515*	*509*	*56*	*30*	*18*
	45.7%	*45.1%*	*5%*	*2.7%*	*1.6%*
Lough Erne	10	74	2	5	7
	10%	76%	2%	5%	7%

Table 9b: Nutrient Budget Summary of NO_3 loadings to Lough Erne and Lough Melvin compared with Northern Ireland loadings, 2001-2009

Nitrate Loading (MAL 01-09 t NO3-N yr-1 and %)	WWTWs	Lowland agriculture	Urban and other land	Moorland	Forestry	Nitrification
Northern Ireland	*478*	*4297*	*67*	*107*	*22*	*214*
	9%	*83%*	*1%*	*2%*	*1%*	*4%*
Lough Erne	41	1149	2	50	23	67
	3%	86%	<0.1%	4%	2%	5%

SIMCAT modelling (current performance) of the North Western RBD during the period 2005-2009 showed that the total loading of SRP to the Lough Erne and Melvin catchments was 79.5 (tonnes/yr^{-1}). The loading of SRP from WWTWs was 5.8 (tonnes/yr^{-1}) over the same period, representing 7.3% of the total loading to the rivers in the Upper Lough Erne catchments. The total loading of SRP to the Lower Lough Erne catchments was 101.1 (tonnes/yr^{-1}). The loading of SRP from WWTWs was 3.8 (tonnes/yr^{-1}) over the same period, representing 3.8% of the total loading to the rivers in the Lower Lough Erne catchments. The total loading of SRP to the Lough Melvin catchments was 2.8 (tonnes/yr^{-1}). The loading of SRP from WWTWs was 0.1 (tonnes/yr^{-1}) over the same period, representing 4% of the total loading to the rivers in the Lough Melvin catchments. Schematic diagrams are presented in **Figures 16a, 16b and 16c** illustrating the loading from individual rivers in the catchments.

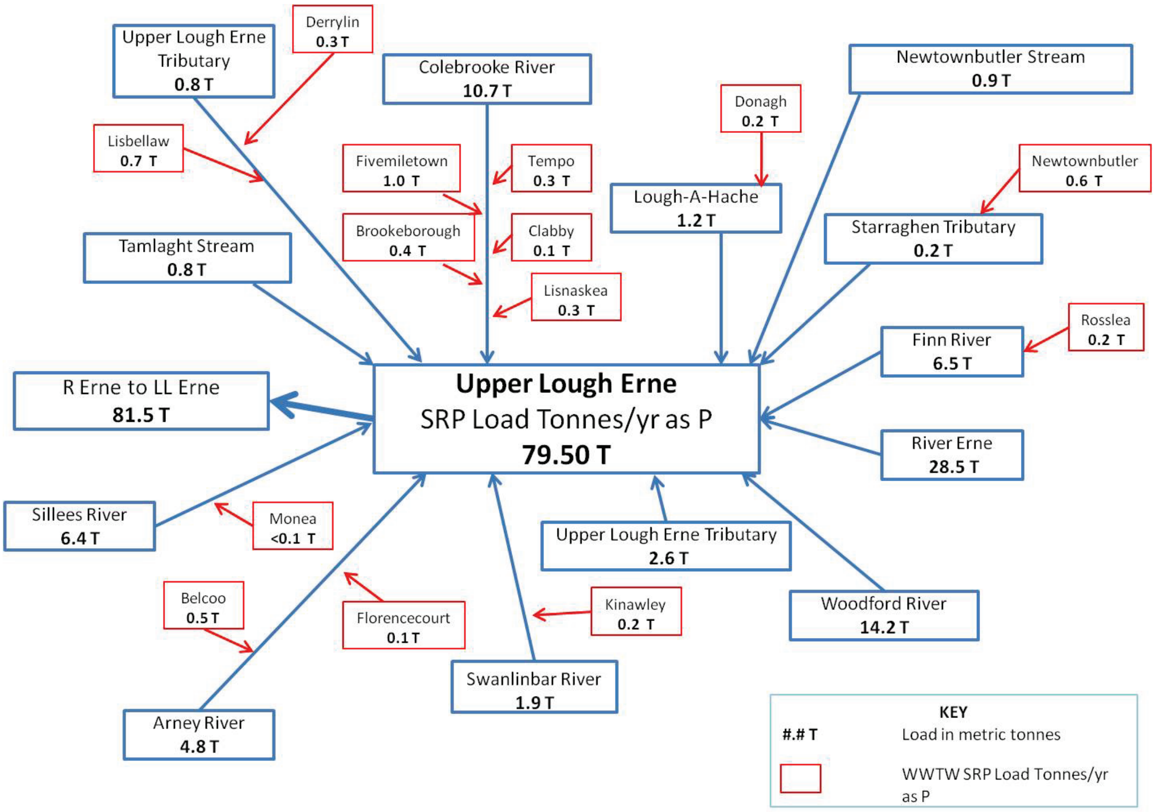

Figure 16a: Schematic of the SRP loadings (tonnes/yr^{-1}) of rivers within the Upper Lough Erne catchments, 2005-2009 (Current performance, SIMCAT Model)

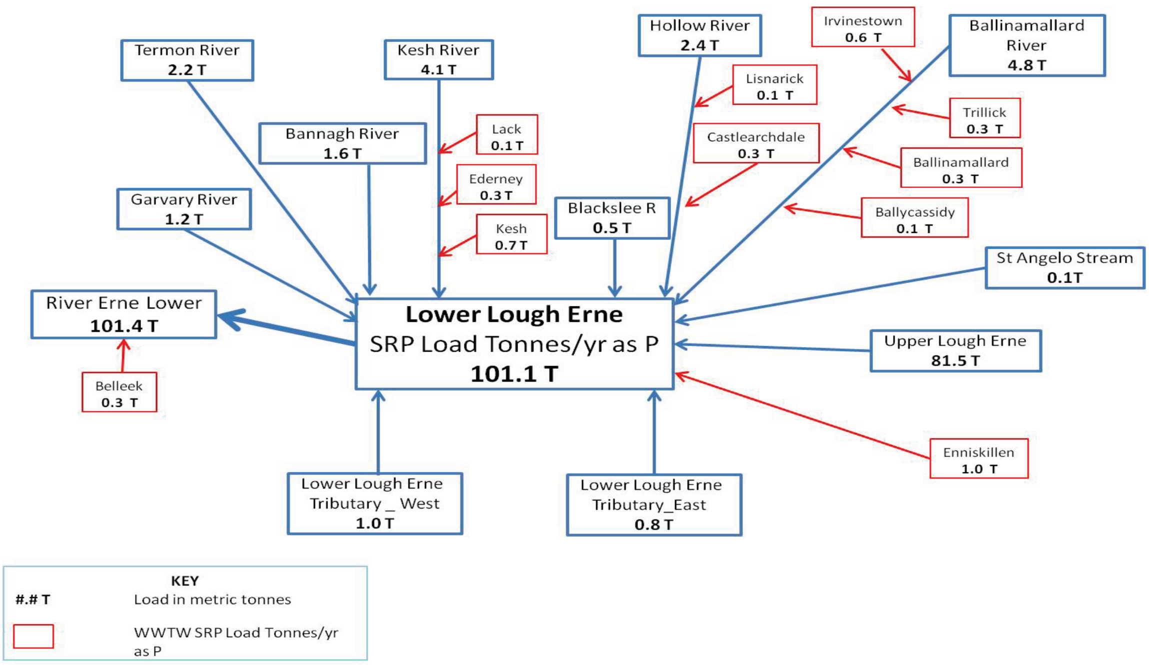

Figure 16b: Schematic of the SRP loadings (tonnes/ yr^{-1}) of rivers within the Lower Lough Erne catchments, 2005-2009 (Current performance, SIMCAT Model)

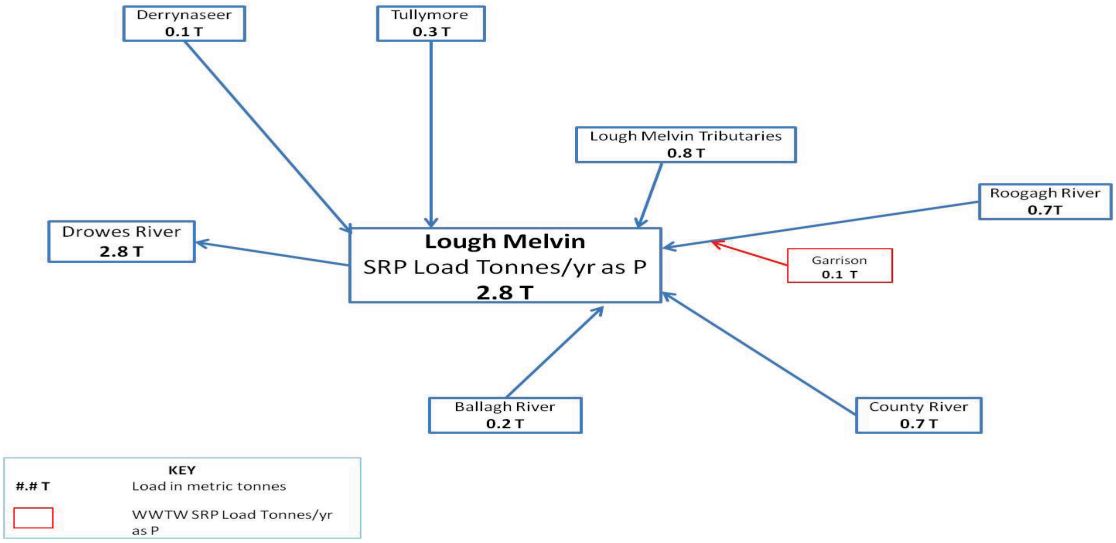

Figure 16c: Schematic of the SRP loadings (tonnes/yr^{-1}) of rivers within the Lough Melvin catchments, 2005-2009 (Current performance, SIMCAT Model)

Appendix 1: Corine land use data for Northern Ireland

Corine land use class coverage for Northern Ireland and border regions of Republic of Ireland (combined area 17024km^2) with their amalgamation into six major classes: Urban/industrial, arable, grassland, forest, rough grazing and other land.

CORINE LAND COVER CLASSES 17024km^2	% total
Urban/Industrial (3.1%)	
1.1.1. Continuous urban fabric	0.3
1.1.2. Discontinuous urban fabric	1.9
1.2.1. Industrial or commercial units	0.2
1.2.2. Road & rail networks and associated land	0.0
1.2.3 & 1.2.4 Sea ports & Airports	0.1
1.3.1 & 1.3.2 Mineral extraction site & Dump	0.2
1.4.1. Green urban areas	0.1
1.4.2. Sport and leisure facilities	0.3
Arable land (2.6%)	
2.1.1.& 2.1.2 Non irrigated and irrigated arable land	2.2
2.4.1. Annual crops associated with permanent crops	0.4
Agricultural grassland (72.9%)	
2.3.1.1. Good pasture	30.3
2.3.1.2. Poor pasture	5.4
2.3.1.3. Mixed pasture	18.7
2.4.2. Complex cultivation patterns	8.6
2.4.3. Land principally occupied by agriculture	5.5
3.2.1. Natural grassland	4.3
Forest (5.6%)	
3.1.1. Broad leaved forest	0.6
3.1.2. Coniferous forest	4.0
3.2.4. Transitional woodland-scrub	0.8
3.1.3. Mixed forest	0.2
Rough grazing (11.9%)	
3.2.2. Moors and heathlands	2.2
4.1.2.1. Unexploited peat bogs	9.4
4.1.2.2. Exploited peat bogs	0.2
Other land and water bodies (4.0%)	
3.3.1. Beaches, dunes, sand	0.1
3.3.3 & 3.3.4 Sparsely vegetated areas & Burnt areas	0.0
4.1.1. Inland marshes	0.2
4.2.1 & 4.2.3 Salt marshes & Intertidal flats	0.0
5.1.1 Stream courses	0.1
5.1.2. Water bodies	3.7

<u>Appendix 2:</u> <u>Nutrient Export Coefficients</u>

Nutrient export coefficients used to determine loss rates in catchment budgets

<table>
<tr><td rowspan="2">Nutrient</td><td>Land use type</td><td>Urban land</td><td>Rough grazing</td><td>Forest</td><td>Other land</td><td>Agricultural land</td></tr>
<tr><td colspan="6">Nutrient export coefficient</td></tr>
<tr><td>Nitrate</td><td>Tonnes N $km^{-2}yr^{-1}$</td><td>0.20</td><td>0.20</td><td>0.20</td><td>0.20</td><td rowspan="3">0.05</td></tr>
<tr><td>Ammonium</td><td>Tonnes N $km^{-2}yr^{-1}$</td><td>0.03</td><td>0.03</td><td>0.03</td><td>0.03</td></tr>
<tr><td>DRP</td><td>Tonnes P $km^{-2}yr^{-1}$</td><td>0.03</td><td>0.01</td><td>0.02</td><td>0.03</td></tr>
</table>

* *Abstracted from 'An evaluation of nitrogen sources and inputs to tidal waters in Northern Ireland' March 2004*