WFD Pressures and Impacts Assessment Methodology

GUIDANCE ON THE ASSESSMENT OF PRESSURES AND IMPACTS ON GROUNDWATER DEPENDENT TERRESTRIAL ECOSYSTEMS

Risk Assessment Sheet GWDTERA2a – Turloughs

Paper by the Working Group on Groundwater
Sub-committee on Turloughs

Guidance document no. GW9

This is a guidance paper on the application of an **Assessment of Pressures and Impacts on Groundwater Dependent Terrestrial Ecosystems – Turloughs Methodology**. It documents the principles to be adopted by River Basin Districts and authorities responsible for implementing the Water Framework Directive in Ireland.

REVISION CONTROL TABLE

Status	Approved by National Technical Co-ordination Group	WFD Requirement	Relevant EU Reporting Sheets	Date
Final	March 2005	Pressures and Impacts	GWPI3	December 2004

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Paper by the Working Group on Groundwater: Sub-committee on Turloughs

1. Purpose

This paper sets out guidance on the assessment of risk to turlough GWDTEs from phosphate (risk assessment sheet GWDTERA2a – see Section 8).

2. Background

2.1 Definition of a Turlough

A turlough is defined as:

A topographic depression in karst which is intermittently inundated on an annual basis, mainly from groundwater, and which has a substrate and/or ecological communities characteristic of wetlands.

A relationship exists between the water quality, the flooding regime, the morphology and the substrate of a turlough, and the composition and distribution of its plant and animal communities. Turloughs exhibit a specific range of hydrological, morphological and substrate parameters which are associated with a characteristic range of ecologies.

2.2 Conservation Framework

Turloughs are listed as priority habitats under Annex I of the EU Habitats Directive (92/43/EEC) and, as such, a proportion have been designated as Special Areas of Conservation (SACs). A number of turloughs are also designated as Special Protection Areas (SPAs) for their bird communities under the EU Birds Directive (79/409/EEC). Additional turloughs are likely to be designated as Natural Heritage Areas (NHAs) under the Wildlife (Amendment) Act, 2000. In order to achieve good status under the Water Framework Directive, turloughs must meet their Habitats Directive (HD) objective of "favourable conservation status" where it is dependent on their water needs. This particular risk assessment (GWDTE2a) is designed to achieve the combined objectives of the WFD and HD in terms of water quality. For the purpose of the Article 5 Report, it has been decided to report only on turloughs designated as part of the Natura 2000 Network (i.e. SACs and SPAs). Therefore, only designated turloughs will be subject to the risk assessment procedure before March 22nd 2005. A total of 43 SACs have been designated for turloughs. Some SACs contain more than one turlough within their boundaries, bringing the total number of turloughs designated under the HD to 70 (Table 1). Five of the 70 turloughs are also designated as SPAs (Table 2).

2.3 Distribution

Work carried out by Coxon (1987), suggests that turlough distribution in Ireland is most strongly controlled by the occurrence of well-bedded, pure limestone (they occur almost exclusively on the Dinantian pure bedded limestone rock unit), with turlough frequency also related to degree of karstification. The presence of a thick cover of subsoil is also potentially a controlling factor on turlough distribution. Turloughs designated as SACs/SPAs occur in Counties Donegal, Sligo, Roscommon, Mayo, Galway, Longford, Clare and Kilkenny.

3. Data Limitations

3.1 Data Availability

Whilst a considerable amount of ecological data is available on turloughs (Goodwillie, 1992; Southern Water Global, 1997), data on invertebrates are sporadic. Relevant hydrological data are sparse, however useful summaries are found in Coxon (1986) and Southern Water Global (1997). For instance, a minimum of one year's hydrological data is considered necessary for characterisation of the turlough flood regime and catchment delineation – this is seldom available. Information derived from water tracing experiments within the turlough catchments is also sporadic. There is an almost complete absence of water chemistry data, including phosphorus, for the turlough sites.

Impact data are sporadic – usually applying only to the immediate turlough basin and not to the catchment – and are not consistent, often reflecting the focus of the visiting ecologist rather than being part of a systematic survey.

3.2 State of Knowledge

The link between the ecology of the turloughs, their hydrogeological characteristics and management, has not yet been quantified adequately. This is partly a result of the lack of long-term spatially co-incident data for both aspects. Consequently, there is a high degree of uncertainty associated with predicting impacts from pressures.

4. Risk Assessment

4.1 Risk Assessment Approach

The approach is summarised in risk assessment sheet GWDTERA2a, which is given in Section 8. It involves the following:

1. Delineation of the catchment area of the turlough;
2. Evaluation of pathway susceptibility, using aquifer, soil and vulnerability maps;
3. Estimating impact potential by combining pathway susceptibility with pressure magnitude;
4. Predicting the risk category by combining the receptor sensitivity with the proportion of the turlough catchment with high and moderate impact potential;
5. Adjusting the predicted risk category using available impact data.

4.2 Assessment Area

The area to be included in the risk analysis is the catchment of the turlough. The predictive risk assessment refers only to risk from pressures occurring within the turlough catchment, and not to pressures occurring within the turlough depression. The boundaries of the turlough flooded areas have been supplied by NPWS, based on Goodwillie's vegetation maps. These boundaries will differ from the SAC/SPA boundaries, particularly in large SAC/SPA complexes. Pressures confined to the turlough depression are regulated by the National Parks and Wildlife Service (NPWS) under the Habitats Directive. Available impact data from the turlough depression (Total P/NPWS qualitative impact assessment), or from the catchment (groundwater MRP) enable the predictive risk category to be adjusted.

4.3 Turlough Catchment Delineation

4.3.1 Catchment types

Turlough catchments can be divided into two broad types, based primarily on the depth of groundwater flow and the nature of the karst through which it flows: a) those where groundwater flow is shallow and completely within the epikarst, and b) those where groundwater flows deeper through a more complex karst system.

4.3.1.1 Epikarst Flow Catchments

These catchments are developed within areas where groundwater flows in the weathered upper, approximately 2-5 m, zone, in the epikarst. The epikarst is characterised by having a high proportion of solutionally enlarged fissures (joints, bedding planes, faults and fractures). Storage capacity is low. Locally, groundwater flow may be more-or-less completely disconnected from groundwater flowing at deeper levels within the karst system. Generally, flow will be across the turlough, driven by the hydraulic gradient of the water table, of which the turlough is a surface expression. Recharge is via direct infiltration of rainfall to the outcropping karst. In some instances, recharge reaches the epikarst after percolating through deposits of sand/gravel.

4.3.1.2 Mixed Flow System Catchments

In these catchments, groundwater flows through different types of karst and at different depths. Below the epikarst (exceptionally as low as 40-50 m below ground in the Gort area), major caves and conduits can act as linear flow paths ("conduit karst"). Smaller conduits and solutionally-enlarged fissures and bedding planes transmit groundwater through a less concentrated network ("diffuse karst"). Both types of karst can support very large groundwater flows. In the zone just below the epikarst, the karst may be characterised by major conduits, collapse structures and zones of solutionally-enlarged fissures and bedding planes at depth of 10-15 m below ground level. This type of karstification usually occurs in restricted areas, is typically associated with indirect recharge of the aquifer by surface waters, and can support very large flows.

Groundwater flow in a turlough catchment may flow in one or a combination of these karst types. The flow systems operate as a continuum, with flow being transferred vertically and laterally between them. Shallow, epikarstic groundwater flow will frequently occur in combination (and hydraulic connectivity) with the deeper flow systems.

Recharge to the aquifer occurs through a variety of mechanisms, including:

- Direct recharge via the epikarst, which then transmits water to deeper elements of the flow system;
- Indirect recharge from losing and/or sinking streams;
- Indirect recharge from surface waters generated on non-karst aquifers and which sink in the karstic catchment.

4.3.2 Identifying the catchment type

4.3.2.1 Epikarst Flow Catchments

- Stage recession constants measured for epikarstic turloughs range from 9.76 to 10.72, i.e., they have relatively slow emptying characteristics. It is likely that a recession constant above 10.75 indicates that the turlough is not fed solely by shallow groundwater flowing through epikarst.
- Shallow, epikarstic, systems are characterised by a trophic sensitivity of 1, i.e., an ultra-oligotrophic status, unless their trophic status has been impacted by enrichment. (See Section 4.5.3). Risk category based on predictive risk assessment).

- If the literature and recession constant indicate that a catchment is of this type, but the trophic sensitivity is >1, then the turlough may already be impacted by enrichment. Existing impact data should be consulted to confirm this.

4.3.2.2 Mixed Flow System Catchments

- In a catchment with a trophic sensitivity of 2 or 3 (and which is not an impacted epikarst catchment), most groundwater flows beneath the epikarst in diffuse and/or conduit karst limestones.
- It is probable, though not certain, that a turlough with a trophic sensitivity of 2 has a catchment dominated flow in the transition zone between the epikarst and deeper karstification that is characterised by collapsed conduits.
- A recession constant >11 and/or a trophic sensitivity of 3 (in a non-impacted turlough) is likely to indicate the presence of deep level conduit/diffuse groundwater flow. The catchment may also have groundwater flowing in the epikarst in connectivity with the other flow pathways, though the proportion of flow contributed by the epikarst will be small relatively, resulting in the groundwater flowing through conduit/diffuse karst dominating the trophic sensitivity.

There is a number of probable reasons for the differences in trophic sensitivities between the epikarst (shallow) and mixed (deeper) flow system types. Catchments with mixed flow systems are generally larger, and the flow rates and volumes of throughput are greater, which would tend to deliver more P to the turlough depression, although dilution rates would be higher. In addition, the transport of sediments and, consequently, particulate P would be favoured by the presence of conduit flow.

4.3.3 Methods for delineating the catchment area

4.3.3.1 Epikarst Flow Catchments

- Available reference materials relating to the hydrology/hydrogeology of the catchment were consulted.
- The catchment of the turlough was identified. This exercise was not trivial, since, although groundwater flow is unconfined, the local topography cannot necessarily be used to delineate groundwater divides. This is because topographic highs may be caused by subsoil deposits rather than be underlain by bedrock. Therefore, what is termed the "bedrock catchment" was delineated, using boundaries that are considered to reflect bedrock topography. (Where there is a high degree of confidence that topography is caused by bedrock elevation variations, the local topography can be used to define the catchment directly.) These turloughs are in shallow depressions so may also act as a radial focus for near-surface direct runoff.
- Using water table maps and/or borehole information, the direction of the hydraulic gradient within the bedrock (or topographic) catchment was identified or estimated. The fact that water tables in karst may be discontinuous should be taken into account.
- A catchment area on the up-gradient side of the turlough was delineated within the bedrock (or topographic) catchment previously defined. The top of the up-gradient catchment coincides with the bedrock (or topographic) catchment; the sides are delineated using flow lines, accounting for their curvature due to the 'drain' effect on groundwater flow of the turlough. Hence, the catchment is fan-shaped, albeit with some account being taken of adjacent near-surface radial runoff.

4.3.3.2 Mixed Flow System Catchments

- Available reference materials relating to the hydrology/hydrogeology of the catchment were consulted.
- A water table map of the area, if available, was used, or estimated if sufficient data were available. A sufficiently detailed water table map should identify zones of high conductivity, owing to the influence on the shape of the water table that high permeability zones have. The fact that water

tables in karst may be discontinuous, particularly where flow is concentrated in conduits/conduit-type zones, was taken into account.

- Groundwater flow directions were identified.
- Existing tracing data were used to identify conduits/high transmissivity zones, and the connections between these areas of high conductivity. (It may be necessary to undertake additional tracing.)
- Surface waters that may contribute to groundwater flow, their sources and any sinks were identified. Their overground and underground catchments were included in the overall catchment.
- Where surface waters generated on non-karstic and/or non-limestone aquifers sink in the karstic catchment of the turlough, the full catchment of those surface waters were included in the turlough catchment (i.e., the catchment extends onto the non-karstic areas).
- Groundwater contributing to the turlough via the epikarst was identified. The epikarst catchment was identified with reference to the methodology outlined in Section 4.3.3.1, above.

4.3.4 Additional Issues

4.3.4.1 Partially-contributing catchments

The issue of partially-contributing catchments was addressed in the cases where information was available. Partially-contributing catchments are catchments which contribute a proportion (but not all) of their flow to another turlough under specific stage conditions. In general, the issue of changing catchment boundaries (areas of contribution) with varying stage conditions was addressed wherever possible.

4.3.4.2 Overlapping catchments

Where turlough catchments overlap, then the catchment of each turlough was extended to include the other.

4.4 Pressures

4.4.1 Phosphorus

There is a significant threat to turloughs through enrichment with phosphorus from a variety of diffuse and point sources. Phosphorus in turlough water influences plant species composition, abundance and productivity. Invertebrate species are impacted via the primary producers.

4.4.2 Abstraction

Abstraction within the catchment, local abstractions and arterial drainage can impact upon the quantitative status of the turlough and, consequently, upon the species composition, distribution and extent of plant and invertebrate communities. Over-wintering and breeding bird populations may also be impacted. Risk Assessment from these pressures is carried out as a general assessment for GWDTEs, including turloughs. Further details are given in Groundwater Risk Assessment Sheet GWDTERA1.

4.4.3 Other Pressures

Other pressures have been identified, but not included due to lack of knowledge of the pressure-impact relationship and/or lack of data. These may be added to the risk assessment at a later date when appropriate information becomes available. These include:

- Changes in water chemistry due to urban (including road) run-off.
- Changes in flood regime due to urban (including road) run-off, and climate change.

- Changes in turlough ecology as a result of increased nitrogen concentrations (including the possibility of nitrogen limitation in the aquatic phase of turloughs).
- Changes in turlough ecology resulting from increased sediment loads due to changes or intensification in land use. Sediment can reduce water clarity and, consequently, impact on aquatic photosynthesis and productivity as well as having physical impacts on plants and animals. Sediment can also increase nutrient concentrations, through particulate forms of P.

4.5 Risk Assessment Matrix for Phosphorus

4.5.1 Pathway Susceptibility

The pathway susceptibility matrix is given below. Further information on the risk assessment approach is given in Guidance report GW8 (Methodology for Risk Characterisation of Ireland's Groundwater) (GWWG, 2004).

PATHWAY SUSCEPTIBILITY				**Flow Regime (horizontal pathway)**			
				Karst aquifers		***Poorly productive and/or fissured aquifers contributing surface waters to turlough catchment****	
Vertical pathway	**Soil & contributing area**			*Dry soil*	*Wet soil*	*<50 m from a stream channel*	*Remainder of catchment area*
	Vulnerability	Extreme	0-1 m soil & subsoil	E	E	E	H
			1-3 m soil subsoil	E	E*		
		High		M			
		Moderate		L			
		Low		L			

n/a = not applicable

* This ranking allows for bypass of the soil/subsoil at swallow holes; where swallow holes are absent, the appropriate ranking is 'H'. However, the default ranking is 'E'.

** Poorly productive and/or fissured aquifers may contribute surface waters onto a karst aquifer. These may continue as surface water stream flow on the karst or sink into the karst at the aquifer boundary.

4.5.2 Impact potential

Impact potential is a combination of Pathway Susceptibility and Pressure Magnitude, as shown in the matrix below.

	IMPACT POTENTIAL	Pathway Susceptibility			
		Extreme	High	Moderate	Low
Pressure magnitude	>2.0 LU ha^{-1}or >33% tillage Heavily fertilized forestry on peat* Q value < 4** in surface water	High	High	Low	Low
	1.5-2.0 LU ha^{-1} or 18-33% tillage	High	Moderate	Low	Low
	1.0-1.5 LU ha^{-1} or 3-18% tillage	Moderate	Low	Low	Low
	0.5-1.0 LU ha^{-1} or <3% tillage	Moderate	Negligible	Negligible	Negligible

* Heavily fertilized forestry (on peat) corresponds almost completely to sitka spruce. This measure is taken to be a surrogate measure of associated nutrient load from forestry.
** Q value of surface water contributed by poorly productive and/or fissured aquifers and/or of any surface waters within the catchment area. A Q value of ≥4 corresponds to <30µg/l MRP

The pressure magnitude is considered to depend on the density of livestock, the presence of tillage and forestry, and on the water quality of surface water flowing onto/or as surface water on the karst aquifer.

Individual impact potential maps are derived for each of the four types of pressures. For any given area within the catchment, the highest impact potential resulting from among the four pressures is assigned to the area.

4.5.3 Risk category based on predictive risk assessment

The predicted risk category is derived by combining the Impact Potential and Receptor Sensitivity, as shown below.

RISK CATEGORY		Proportion of turlough catchment with high and moderate impact potential					
		>40%	*25-40%*	*15-25%*	*10-15%*	*5-10%*	*<5%*
Receptor Sensitivity	Extreme sensitivity*	1b	1b	1b	2a	2a	2b
	High sensitivity	1b	1b	2a	2a	2b	2b
	Moderate sensitivity	1b	2a	2a	2b	2b	2b

*Extreme, high and moderate receptor sensitivity classes were defined by NPWS using turlough vegetation data.

The impact potential is categorised according to the proportion of the area of the turlough catchment having high or moderate impact potential

Receptor sensitivity is based on the trophic sensitivity of the receptor turlough and the assumption that the higher the trophic sensitivity of the turlough, the greater it's sensitivity to enrichment by PO_4.

The trophic sensitivity of a turlough is based on the extent of selected plant communities, as mapped and classified by Roger Goodwillie (Goodwillie 1992, Southern Water Global 1997 and NPWS 2004). Ellenberg Fertility Scores were assigned to each turlough plant community by averaging the Ellenberg Fertility Scores for the frequently occurring species. Frequently occurring species were those which occurred in a community in >10% of turloughs surveyed. The turloughs were then ranked according to the proportional area of communities with low Ellenberg Scores (<4), i.e. the proportional area of low productivity, nutrient sensitive plant communities. A score of 4 or less indicates that a site is in the range of intermediate fertility to extreme infertility (Hill *et al*., 1999).

The following table shows the proportion of the plant communities in each turlough which have Ellenberg Fertility scores ≤4, together with the associated Trophic Sensitivities.

Proportion of communities in turlough with Ellenberg N <= 4	**>50% ??**	**>25%and <50%**	**<25%**
Trophic sensitivity	1	2	3
Receptor Sensitivity class	Extreme	High	Moderate

Trophic Sensitivity for each turlough is listed in Table 1 (List of Turlough SACs and their Trophic Sensitivities), under the heading **Current Trophic Sensitivity**. Vegetation communities were not mapped for seven of the 70 turloughs; these are indicated by italics in Table 1. These seven turloughs were assigned a provisional current trophic sensitivity based on best professional judgement. Where these result in a Groundwater Body being placed "probably at significant risk" (1.b), these sensitivities will be investigated under "further characterisation". It is important to note that the NPWS do not consider all the SACs currently to have favourable conservation status, and that this trophic sensitivity does not constitute a reference condition. Under the heading Natural Trophic Sensitivity, NPWS used expert judgement to indicate what they consider the natural, un-impacted status of a turlough to be.

4.5.4 Risk category of turlough catchment adjusted using available impact data

Adjustments can be made to the turlough catchment predictive risk category, as shown in the table below, based on two sources of impact data: turlough water phosphorus data and groundwater phosphorus data. In both cases a set of risk adjustment thresholds are set for measured phosphorus, according to whether the receptor has an extreme or high/moderate sensitivity. Turloughs with extreme trophic sensitivity are considered more vulnerable to nutrient enrichment and as such have been assigned lower impact thresholds. Type of phosphorous measured and thresholds are detailed in the risk analysis summary sheet.

Adjustments for turlough catchment						
Predictive Risk Category	**Turlough data criteria***			**Groundwater data criteria*****		
	*High/moderate sensitivity receptors***	*Extremely sensitive receptors*	*Adjusted Risk Category*	*High/moderate sensitivity receptors***	*Extremely sensitive receptors*	*Adjusted Risk Category*
1b	Total P > 30 µg l^{-1}	Total P >10 µg l^{-1}	1a	MRP >30 µg l^{-1}	MRP >10 µg l^{-1}	1a
2a	Total P 20-30 µg l^{-1}		1b	MRP 20-30 µg l^{-1}		1b
2b	Total P 10-20 µg l^{-1}	Total P <10 µg l^{-1}	2a or 1b depending on confidence in the monitoring data	MRP 10-20 µg l^{-1}	MRP <10 µg l^{-1}	2a or 1b depending on confidence in the monitoring data
	Total P <10 µg l^{-1}		2b	MRP <10µg l^{-1}		2b

* Mean TP of turlough water, based on a mean of monthly sampling during the flood period, but excluding the extreme beginning and end of the flood period. Thresholds are based on the Phosphorus Regulations' standards for total phosphorus (TP) in lakes, which indicate that when mean TP ≤10 µg l^{-1} the lake is oligotrophic and >10 to ≤20 µg l^{-1} mesotrophic (McGarrigle *et al*., 2002, Appendix I).

** Sensitivity of receptor (turlough) is that defined by NPWS from turlough vegetation studies, as shown on Table 1.

*** Groundwater data are expressed as median unfiltered Molybdate Reactive Phosphorus (MRP). As many turloughs are conduit fed it is assumed that there will be very little attenuation in phosphorus concentrations in groundwater discharges to the turlough. For this reason it was considered more appropriate to use lake rather than river phosphorus regulation standards. See note (*) above.

4.5.5 Expert Review Recommendations

Expert review of the outcome of this risk assessment is recommended by EPA staff with field experience of the catchment area of the GWDTE and knowledge of surface water impacts.

Final expert review is recommended by National Parks and Wildlife Service staff who may recommend upgrading of the risk category based on available impact data and local knowledge of the SAC/SPA involved.

5. Actions arising from Risk Categorisation

Where a turlough catchment is categorised as being 'at risk' (category 1.a or 1.b), the catchment area will be designated as a new groundwater body. Where a turlough catchment is categorised as 2.a, 'not at risk', but for which confidence in the available information being comprehensive and reliable is low, a new water body will not be designated. Work will be focused on appropriately improving the quality of information on pressures and their likely environmental effects in time for the second pressures and impact analysis due to be completed in 2013.

6. Membership of the Working Group on Groundwater Sub-committee on Turloughs

Organisation	**Representative(s)**
Geological Survey of Ireland	Donal Daly Coran Kelly

National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government	Áine O' Connor Deirdre Lynn Jim Ryan
Environmental Protection Agency	Jim Bowman Micheal MacCarthaigh
Environment and Heritage Service, Dept. of the Environment, Northern Ireland	Imelda O'Neill
National University of Ireland, Galway	Dr. Michael Gormally James Moran Eugenie Regan Dr. Micheline Sheehy Skeffington Dr. Marjoleine Visser
O'Neill Groundwater Engineering	Shane O'Neill
Trinity College, Dublin	Catherine Coxon David Drew Paul Johnston Sarah Kimberley Julian Reynolds Suzanne Tynan Stephen Waldren
Shannon Pilot River Basin – EPA (TCD) Research Fellow	Garrett Kilroy
Consultant Ecologist	Roger Goodwillie

7. References

Coxon, C.E. (1986) *A study of the hydrology and geomorphology of turloughs*. Dublin, Trinity College.

Coxon, C. E. (1987) The spatial distribution of turloughs. *Irish Geography*, **20**, 11-23.

Goodwillie, R. (1992) *Turloughs over 10ha: Vegetation survey and evaluation*. A report for the National Parks and Wildlife Service and the Office of Public Works.

Hill, M.O., Mountford, J. O., Roy, D.B. and Bunce R.G.H. (1999) *Ellenberg's indicator values for British plants* ECOFACT Volume 2, Technical Annex. Publ. Department of Environment, Transport and the Regions for HMSO, Norwich.

McGarrigle, M. *et al*. (2002) Water quality in Ireland 1998-2000, EPA

Southern Water Global (1997) *An investigation of the flooding problems of the Gort-Ardrahan area of south Galway.* Final Report to the Office of Public Works, April 1997.

Working Group on Groundwater (2004) Guidance Document GW8: *Methodology for Risk Characterisation of Ireland's Groundwater*, 70 pp.

8. Groundwater Risk Assessment Sheet

Summary details on pressures, receptors and WFD objective

RA Sheet	GWDTERA2a
Receptor type	Groundwater Dependent Terrestrial Ecosystems: Turloughs
Pressure type	Diffuse – low mobility inorganics (PO_4)
WFD objective	Chemical status
Assessment area	Catchment area of GWDTE

A. Pathway susceptibility

Catchment area of the turlough

The RA applies to the area contributing water to the GWDTE. Therefore, the catchment area of the GWDTE must be delineated, even if only approximately. The boundaries must be based on the conceptual understanding of the area and on hydrogeological boundaries to flow. For turlough catchments this will include an assessment of the flow types in the catchment i.e. epikarstic, conduit type, or a combination thereof, and identification of dominant flow routes. Delineation will then include one or more of topographic, bedrock or groundwater catchment delineation.

PATHWAY SUSCEPTIBILITY				**Flow Regime (horizontal pathway)**			
				Karst aquifers		***Poorly productive and/or fissured aquifers contributing surface waters to turlough catchment.***	
Vertical pathway	**Soil & contributing area**			*Dry soil*	*Wet soil*	*Within 50 m of a stream channel*	*Remainder of catchment area*
	Vulnerability	Extreme	0-1 m soil & subsoil	E	E	E	H
			1-3 m soil subsoil	E	E*		
		High		M			
		Moderate		L			
		Low		L			

n/a = not applicable

* This ranking allows for bypass of the soil/subsoil at swallow holes; where swallow holes are absent, the appropriate ranking is 'H'. However, the default ranking is 'E'.

B. Impact potential

	IMPACT POTENTIAL	Pathway Susceptibility (from Table A)			
		Extreme	*High*	*Moderate*	*Low*
Pressure magnitude	>2.0 LU ha^{-1} or >33% tillage Heavily fertilized forestry on peat* Q value < 4** in surface water	High	High	Low	Low
	1.5-2.0 LU ha^{-1} or 18-33% tillage	High	Moderate	Low	Low
	1.0-1.5 LU ha^{-1} or 3-18% tillage	Moderate	Low	Low	Low
	0.5-1.0 LU ha^{-1} or <3% tillage	Moderate	Negligible	Negligible	Negligible
	<0.5 LU ha^{-1}	Low	Negligible	Negligible	Negligible

* Heavily fertilized forestry (on peat) corresponds almost completely to sitka spruce. This measure is taken to be a surrogate measure of associated nutrient load from forestry.
** Q value of surface water contributed by poorly productive and/or fissured aquifers and/or of any surface waters within the catchment area. A Q value of ≥4 corresponds to <30µg/l MRP

C. Risk category based on predictive risk assessment

RISK CATEGORY		Proportion of turlough catchment with high and moderate impact potential					
		>40%	*25-40%*	*15-25%*	*10-15%*	*5-10%*	*<5%*
Receptor Sensitivity	Extreme sensitivity*	1b	1b	1b	2a	2a	2b
	High sensitivity	1b	1b	2a	2a	2b	2b
	Moderate sensitivity	1b	2a	2a	2b	2b	2b

*Extreme, high and moderate receptor sensitivity classes were defined by NPWS using turlough vegetation data.

D. Risk category of turlough catchment adjusted using available impact data

Adjustments for turlough catchment						
Predictive Risk Category	***Turlough data Criteria****			***Groundwater data criteria*****		
	*High/moderate sensitivity receptors***	*Extremely sensitive receptors*	*Adjusted Risk Categeory*	*High/moderate sensitivity receptors***	*Extremely sensitive receptors*	*Adjusted Risk Category*
1b	Total P > 30 µg l^{-1}	Total P >10 µg l^{-1}	1a	MRP >30 µg l^{-1}	MRP >10 µg l^{-1}	1a
2a	Total P 20-30 µg l^{-1}		1b	MRP 20-30 µg l^{-1}		1b
2b	Total P 10-20 µg l^{-1}	Total P <10 µg l^{-1}	2a or 1b depending on confidence in the monitoring data	MRP 10-20 µg l^{-1}	MRP <10 µg l^{-1}	2a or 1b depending on confidence in the monitoring data
	Total P <10 µg l^{-1}		2b	MRP <10µg l^{-1}		2b

* Mean TP of turlough water, based on a mean of monthly sampling during the flood period, but excluding the extreme beginning and end of the flood period. Thresholds are based on the Phosphorus Regulations' standards for total phosphorus (TP) in lakes, which indicate that when mean TP ≤10 µg l^{-1} the lake is oligotrophic and >10 to ≤20 µg l^{-1} mesotrophic (McGarrigle *et al*., 2002, Appendix I).

** Sensitivity of receptor (turlough) is that defined by NPWS from turlough vegetation studies.

*** Groundwater data are expressed as median unfiltered Molybdate Reactive Phosphorus (MRP). As many turloughs are conduit fed, it is assumed that there will be very little attenuation in phosphorus concentrations in groundwater discharges to the turlough. For this reason it was considered more appropriate to use lake rather than river phosphorus regulation standards. See note (*) above.

E. Additional Impact data

In addition to the type of phosphorus data described in Table D above, a number of turloughs have been assessed by the Ecological sub-group of the Turloughs Working Group, and the degree to which they are impacted has been described qualitatively. These data may be used to adjust the risk category of the turlough catchment, with the proviso that the data apply only to the immediate turlough basin and not the catchment, and that the data may not be consistent, as they reflect the focus of the visiting ecologist.

F. Expert Review Recommendations

Expert review of the outcome of this risk assessment is recommended by EPA staff with field experience of the catchment area of the GWDTE and knowledge of surface water impacts.

Final expert review is recommended by National Parks and Wildlife Service staff who may recommend upgrading of the risk category based on available impact data and local knowledge of the SAC/SPA involved.

Table 1 List of Turlough SACs and their Trophic Sensitivities

SAC Site Code	SAC Name	Site Name	Proportion of communities with Ellenburg score <=4	Current Trophic Sensitivity[1] [2]	Natural Trophic Sensitivity [1]	SPA Site Code	County	National Grid X	National Grid Y
000051	LOUGH GASH TURLOUGH SAC	Lough Gash	0	3	3		Clare		
000054	*MONEEN MOUNTAIN SAC*	*Gortboyheen Lough*	*?*	*1 or 2*	*?*		*Clare*	*127575*	*205315*
000054	MONEEN MOUNTAIN SAC	Muckinish Lough	0	3	2		Clare	127565	208750
000218	COOLCAM TURLOUGH SAC	Coolcam Turlough	0.27	2	2		Galway/Roscommon		
000238	CAHERGLASSAUN TURLOUGH SAC	Caherglassaun Turlough	0.05	3	3		Galway		
000242	CASTLETAYLOR COMPLEX SAC	Caranavoodaun Turlough	0.93	1	1		Galway		
000252	COOLE-GARRYLAND COMPLEX SAC	Coole & Doo Turloughs	0.06	3	3	004107	Galway	143025	204251
000252	COOLE-GARRYLAND COMPLEX SAC	Garryland Turlough	0.13	3	3	004107	Galway	141580	203988
000252	COOLE-GARRYLAND COMPLEX SAC	Hawkhill Turlough	0	3	2	004107	Galway	141144	202341
000252	COOLE-GARRYLAND COMPLEX SAC	Newtown Turlough	0.44	2	1	004107	Galway	142590	202662
000255	CROAGHILL TURLOUGH SAC	Croaghill Turlough	0.02	3	2 to 3		Galway		

Table 1 Notes

1. Trophic Sensitivity: 1 = extremely high sensitivity to enrichment, 2 = high, 3 = medium. See text in Section 4.5.3 for an explanation of the Ellenburg Score and Trophic Sensitivity.

2. Current Trophic Sensitivity: Where no vegetation community data were available an assessment was made by NPWS, using best professional judgement.

3. National Grid references are provided for individual turlough sites within a turlough. For single turlough SACs the centroid of the turlough as occurs in NPWS GIS data is taken as the grid reference.

SAC Site Code	SAC Name	Site Name	Proportion of communities with Ellenburg score <=4	Current Trophic Sensitivity[1 2]	Natural Trophic Sensitivity [1]	SPA Site Code	County	National Grid X	National Grid Y
000268	GALWAY BAY COMPLEX SAC	Ballinacourty Turlough	0.15	3	?		Galway/Clare	136351	219116
000268	*GALWAY BAY COMPLEX SAC*	*Ballyvelaghan Lough*	*?*		*?*		*Clare*	*128051*	*211426*
000295	LEVALLY LOUGH SAC	Levally Lough	0.70	1	1		Galway		
000296	LISNAGEERAGH BOG AND BALLINASTACK TURLOUGH SAC	Ballinastack Turlough	0.44	3	2		Galway		
000301	LOUGH LURGEEN BOG/ GLENAMADDY TURLOUGH SAC	Glenamaddy Turlough	0.22	3	2		Galway		
000318	PETERSWELL TURLOUGH SAC	Peterswell/Blackrock Turlough	0.03	3	3		Galway		
000322	RAHASANE TURLOUGH SAC	Rahasane Turlough	0.09	3	3	004089	Galway		
000407	THE LOUGHANS SAC	The Loughans	0.24	3	2		Kilkenny		
000448	FORTWILLIAM TURLOUGH SAC	Fortwilliam Turlough	0.45	2	1 to 2		Longford		
000461	ARDKILL TURLOUGH SAC	Ardkill Turlough	0.13	3	2		Mayo		
000463	BALLA TURLOUGH SAC	Balla (Pollaghard) Turlough	0.81	1	1		Mayo		
000475	CARROWKEEL TURLOUGH SAC	Carrowkeel (Pollelamagur Lough) Turlough	0.32	2	1 to 2		Mayo		
000480	CLYARD KETTLE-HOLES SAC	Thomastown Turlough	0.03	3	?		Mayo	123372	260971
000492	DOOCASTLE TURLOUGH SAC	Doocastle Turlough	0.25	2	2		Mayo		
000503	GREAGHANS TURLOUGH SAC	Greaghans Turlough	0.01	3	3		Mayo		
000504	KILGLASSAN/CAHERVOOSTIA TURLOUGH COMPLEX SAC	Caheravoostia Turlough	0.38	2	2		Mayo	126811	264449

SAC Site Code	SAC Name	Site Name	Proportion of communities with Ellenburg score <=4	Current Trophic Sensitivity[1 2]	Natural Trophic Sensitivity [1]	SPA Site Code	County	National Grid X	National Grid Y
000504	KILGLASSAN/CAHERVOOSTIA TURLOUGH COMPLEX SAC	Kilglassan Turlough	0.09	3	2		Mayo	127817	264547
000525	SHRULE TURLOUGH SAC	Shrule Turlough	0.72	1	1		Mayo		
000541	SKEALOGHAN TURLOUGH SAC	Skealoghan Turlough	0.51	1	1		Mayo		
000588	BALLINTURLY TURLOUGH SAC	Ballinturly Turlough	0.22	2	2	004138	Roscommon		
000606	LOUGH FINGALL COMPLEX SAC	Ballinderreen Turlough	0.84	1	1		Galway	140401	215910
000606	LOUGH FINGALL COMPLEX SAC	Carraghadoo Turlough	0.76	1	1		Galway	142132	215084
000606	LOUGH FINGALL COMPLEX SAC	Cuildooish Turlough	0.53	1	1		Galway	141253	215837
000606	LOUGH FINGALL COMPLEX SAC	Frenchpark Turlough	0.94	1	1		Galway	141131	214929
000606	LOUGH FINGALL COMPLEX SAC	Lough Fingall	0.76	1	1		Galway	141708	214917
000606	LOUGH FINGALL COMPLEX SAC	Tullaghnafrankagh Lough	0.49	2	1		Galway	143208	215339
000609	LISDUFF TURLOUGH SAC	Lisduff Turlough	0.30	2	?2		Roscommon		
000610	LOUGH CROAN TURLOUGH SAC	Lough Croan	0.24	3	2	004139	Roscommon		
000611	LOUGH FUNSHINAGH SAC	Lough Funshinagh	0.30	2	2		Roscommon		
000612	MULLYGOLLAN TURLOUGH SAC	Mullugollan Turlough	0.31	2	2		Roscommon		
000637	TURLOUGHMORE (SLIGO) SAC	Turloughmore (Sligo)	0.41	2	?		Sligo		
000996	BALLYVAUGHAN TURLOUGH SAC	Ballyvaughan Turlough	0.08	3	2		Clare		

SAC Site Code	SAC Name	Site Name	Proportion of communities with Ellenburg score <=4	Current Trophic Sensitivity[1 2]	Natural Trophic Sensitivity [1]	SPA Site Code	County	National Grid X	National Grid Y
001285	KILTIERNAN TURLOUGH SAC	Kiltiernan Turlough	0.05	3	2		Galway		
001321	TERMON LOUGH SAC	Termon Lough/South	0.62	1	1		Galway/Clare	140941	197346
001321	TERMON LOUGH SAC	Termon North	0.07	3	?		Galway	141914	197694
001637	*FOUR ROADS TURLOUGH SAC*	*Four Roads Turlough*	*?*	*3*	*?*	*004140*	*Roscommon*		
001926	EAST BURREN COMPLEX SAC	Carran Turlough	0.44	2	1 to 2		Clare	128342	198561
001926	EAST BURREN COMPLEX SAC	Castle Lough	0.50	1	1		Clare	134519	198252
001926	*EAST BURREN COMPLEX SAC*	*Coolreash Turlough*	*?*	*1 or 2*	*1*		*Clare*	*132881*	*174471*
001926	EAST BURREN COMPLEX SAC	Knockaunroe Turlough	0.83	1	1		Clare	131317	193982
001926	EAST BURREN COMPLEX SAC	Lough Aleenaun	0.04	3	2		Clare	124800	195369
001926	*EAST BURREN COMPLEX SAC*	*Lough Gealain*	*?*	*1*	*1*		*Clare*	*131502*	*194828*
001926	EAST BURREN COMPLEX SAC	Lough Mannagh	0.51	1	1		Galway, Clare	140347	201649
001926	EAST BURREN COMPLEX SAC	Poulroe Turlough	0.56	1	1		Clare	137294	195278
001926	EAST BURREN COMPLEX SAC	Roo West Turlough	0.57	1	1		Galway, Clare	138627	202214
001926	EAST BURREN COMPLEX SAC	Travaun-Skaghard Turlough	0.39	2	1		Clare	135547	196765
001926	EAST BURREN COMPLEX SAC	Tulla Turlough	0.15	3	2		Clare	136673	201887
001926	EAST BURREN COMPLEX SAC	Turloughmore	0.03	3	2		Clare	134742	199803

SAC Site Code	SAC Name	Site Name	Proportion of communities with Ellenburg score <=4	Current Trophic Sensitivity[1 2]	Natural Trophic Sensitivity [1]	SPA Site Code	County	National Grid X	National Grid Y
002117	LOUGH COY SAC	Lough Coy	0.10	3	2 to 3		Galway		
002293	CARROWBAUN, NEWHALL AND BALLYLEE TURLOUGHS SAC	Ballylee River Turlough	0	3	3		Galway	147864	206395
002293	CARROWBAUN, NEWHALL AND BALLYLEE TURLOUGHS SAC	Carrowbaun East Turlough	0.11	3	2		Galway	148177	207478
002293	CARROWBAUN, NEWHALL AND BALLYLEE TURLOUGHS SAC	Newhall Turlough	0.39	2	2		Galway	147322	206640
002294	CAHERMORE TURLOUGH SAC	Cahermore Turlough	0.07	3	2		Galway		
002295	BALLINDUFF TURLOUGH SAC	Ballinduff Turlough	0.31	2	?		Galway		
002296	WILLIAMSTOWN TURLOUGHS SAC	Curragh Lough	<0.25	3	2		Galway	156382	267733
002296	*WILLIAMSTOWN TURLOUGHS SAC*	*North Gortduff Turlough*	*?*	*3*	*?*		*Galway*	*157386*	*269163*
002296	WILLIAMSTOWN TURLOUGHS SAC	Polleagh Lough	<0.25	3	2		Galway	157207	268422
002303	DUNMUCKRUM TURLOUGHS SAC	Lugnanav or Dunmuckrum	0.35	2	2		Donegal		
002339	*BALLYNAMONA BOG AND CORKIP LOUGH SAC*	*Corkip Lough*	*?*	*3*	*2*		*Roscommon*		

Table 1 Notes

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2. Current Trophic Sensitivity: Where no vegetation community data were available an assessment was made by NPWS, using best professional judgement.

3. National Grid references are provided for individual turlough sites within a turlough. For single turlough SACs the centroid of the turlough as occurs in NPWS GIS data is taken as the grid reference.

Table 2 List of Turlough SPAs

SPA Site Code	SPA Name	Site Name	County	SAC Site Code
004107	COOLE-GARYLAND SPA	Garryland Turlough	Galway	000252
004107	COOLE-GARYLAND SPA	Newtown Turlough	Galway	000252
004107	COOLE-GARYLAND SPA	Coole Turlough and Doo Lough	Galway	000252
004107	COOLE-GARYLAND SPA	Hawkhill Turlough	Galway	000252
004089	RAHASANE TURLOUGH SPA	Rahasane Turlough	Galway	000322
004138	BALLINTURLY TURLOUGH SAC	Ballinturly Turlough	Roscommon	000588
004140	FOUR ROADS TURLOUGH SAC	Four Roads Turlough	Roscommon	001637
004139	LOUGH CROAN TURLOUGH SAC	Lough Croan	Roscommon	000610