Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

A Risk-Based Methodology to Assist in the Regulation of Domestic Waste Water Treatment Systems

Environmental Protection Agency

The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

The EPA is an independent public body established in July 1993 under the Environmental Protection Agency Act, 1992. Its sponsor in Government is the Department of the Environment, Community and Local Government.

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We license the following to ensure that their emissions do not endanger human health or harm the environment:

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- intensive agriculture;
- the contained use and controlled release of Genetically Modified Organisms (GMOs);
- large petrol storage facilities.
- waste water discharges

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- Enforcing Regulations such as Waste Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS) and substances that deplete the ozone layer.
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- The organisation is managed by a full time Board, consisting of a Director General and four Directors.
- The work of the EPA is carried out across four offices:
- Office of Climate, Licensing and Resource Use
- Office of Environmental Enforcement
- Office of Environmental Assessment
- Office of Communications and Corporate Services
- The EPA is assisted by an Advisory Committee of twelve members who meet several times a year to discuss issues of concern and offer advice to the Board.

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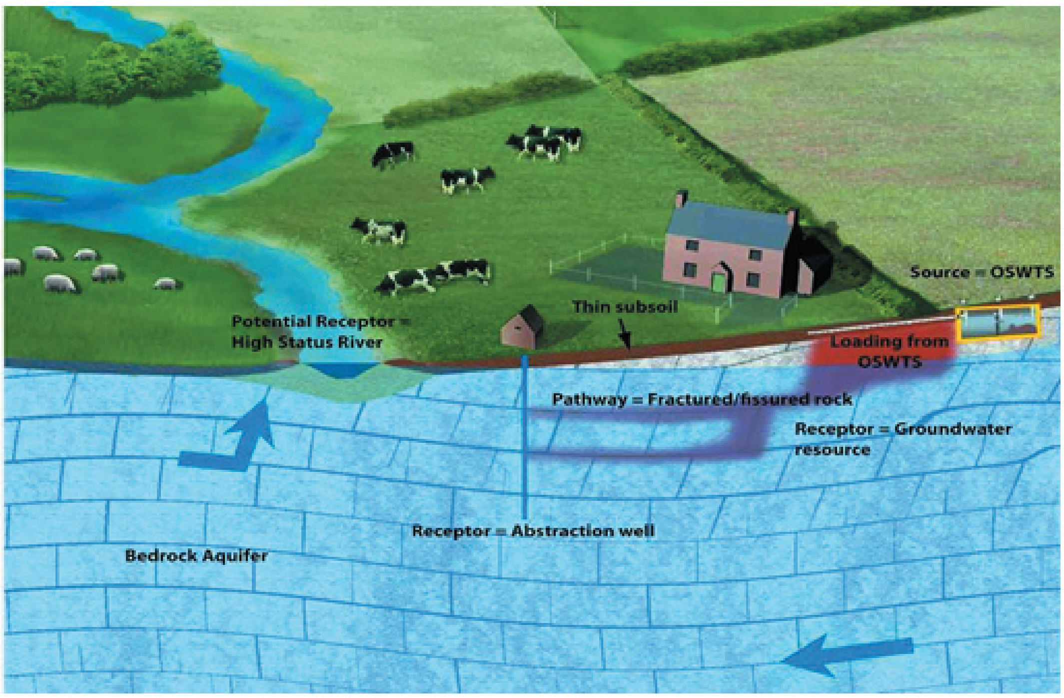

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Executive Summary

Aim of Report

Under the *Water Services (Amendment) Act, 2012* (S.I. No. 2 of 2012), the EPA is responsible for making a National Inspection Plan having regard to relevant risks to human health and the environment. The aim of this report is to set out a methodology to enable the EPA to adopt a risk-based approach to organising inspections of domestic waste water treatment systems (DWWTSs), whereby the level of inspection will be proportionate to the risk posed to human health and the environment.

Risk-Based Methodology

The methodology is based on the source-pathway-receptor (S-P-R) model for environmental management. The development of the methodology was influenced by:

- the data and map information available as GIS datasets;
- the current understanding of the hydrological and hydrogeological settings present in Ireland;
- results of research on DWWTSs and hydrogeology undertaken in Ireland.

Discharges from DWWTSs

DWWTSs located, constructed, installed and maintained in accordance with the best practice guidance generally provide adequate treatment and disposal of domestic waste water. However, where the location, construction, operation and/or maintenance are inadequate, impacts may occur. This report focuses on the issues that may arise in the areas that are problematical with regard to inadequate percolation and/or attenuation. Three pollutants were taken as representative of the threat posed by discharges from DWWTSs to water quality and human health – molybdate reactive phosphate (MRP), nitrate and microbial pathogens.

Receptors of Concern

The receptors of concern are human health from direct contact with microbial pathogens, surface water from eutrophication and/or polluted groundwater being used as a private water supply (e.g. untreated well water).

Evaluation of Pathways Linking DWWTSs with Receptors

The pathway is the link between the source of pollution and the receptor, and can be either at or close to the surface or underground, or a combination of the two. Natural vertical and horizontal pathways for effluent migration are determined by the on-site subsurface geology, particularly the nature of the soils, subsoils and underlying aquifers. Artificial pathways may include drainage ditches, land drainage pipes and stream culverts.

The characteristics of both the surface and subsurface pathways are defined by the **'pathway susceptibility'**, which is a measure of the degree of attenuation between source and receptor.

- The factors that influence attenuation along the *surface pathway* (which is present where percolation is inadequate) include: whether the effluent is piped directly to ditches/streams or ponds at the surface; uptake of nutrient by plants in the ponded areas; die-off or predation of microbial pathogens; attenuation in the topsoil; and percolation during dry weather conditions.
- The factors that influence attenuation along the *subsurface pathway* include: the thickness and permeability of the subsoil; the type of aquifer (whether bedrock or sand/gravel); and whether or not the bedrock facilitates denitrification.

The presence of areas with 'inadequate percolation' due to low-permeability soils and subsoils, high water tables and/or low-permeability bedrock presents the greatest challenge in Ireland to dealing with effluent from DWWTSs, as engineering measures to alleviate the situation are not usually readily available. It is estimated that the overall proportion of the country with inadequate percolation, which can arise all year round or be intermittent during wet weather conditions, is approximately 39%.

Risk Characterisation

The risk is determined by a combination of the following elements:

- estimated pollutant load from each individual DWWTS, derived from typical discharge concentrations and quantities;
- pathway susceptibility, indicating the ease with which pollutants can enter surface water or groundwater;
- cumulative load entering the surface water or groundwater environment derived from DWWTS density and estimations of attenuation;
- dilution of load at the water receptor; calculations are based on the effective rainfall and groundwater recharge estimations in 1 km^2 grids country-wide;
- risk ranking using estimates of predicted pollutant – MRP and nitrate – concentrations at the receptor in comparison to appropriate standards for MRP and nitrate. Microbial pathogens are considered to be influenced by pathway factors in a similar manner to MRP.

Four categories of relative risk are used: low, moderate, high and very high.

The percentage areas of the country in the different relative risk categories are given in the table below.

Relative risk category	MRP & Pathogens		Nitrate	
	Streams via surface pathway	Streams and wells via subsurface pathway	Streams via surface pathway	Streams and wells via subsurface pathway
Low	63.1	89.0	97.2	97.4
Moderate	10.5	4.1	0.2	0.1
High	6.4	1.9	0.1	<0.1
Very High	17.5	2.6	0.1	<0.1
Area Sewered	2.4	2.4	2.4	2.4

Percentages may not sum to 100% due to rounding.

The results indicate that:

- The risk to human health from DWWTS waste water is significantly higher in areas with a high density of DWWTSs and inadequate percolation; and in vulnerable areas with private wells.
- MRP is the main pollutant posing a threat to the environment, particularly to surface water, either where there is inadequate percolation or where there is inadequate attenuation prior to entry of waste water into bedrock aquifers, particularly karstified (cavernous limestone) aquifers. While the cumulative pollutant load arising from DWWTSs will be insignificant compared to urban waste water treatment systems and agriculture at river basin scale, it can be significant in certain physical settings at small catchment scale.
- The threat posed by nitrogen from DWWTSs is low at catchment scale and at the scale of this assessment – 1 km^2 – due to dilution; however, in exceptional circumstances, at site scale (a few hectares), a high density of DWWTSs can cause localised plumes with elevated nitrate concentrations in groundwater.

Next Steps

The output from the risk-based methodology indicates the relative risk of impacts from DWWTSs. Detailed criteria for site selection, which take account of sensitive receptors, have been established for use in conjunction with the risk-based methodology in developing the National Inspection Plan and in proposing the level of inspection, based on risk. This will assist Water Service Authorities in identifying areas to focus inspections and achieve the best outcome for the environment.

The results of the inspections undertaken will be used to verify and calibrate the S-P-R model as appropriate.

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1. Background

1.1 Introduction

A domestic waste water treatment system (DWWTS) is the primary method used for the treatment and disposal of sewage from houses in rural and suburban areas that are not serviced by a public sewer system. Properly located, constructed, installed and operated domestic waste water treatment systems generally provide adequate treatment of domestic waste water and will ensure that the waste water is discharged with minimal risk to human health or the environment.

The *Water Services (Amendment) Act, 2012* (S.I. No. 2 of 2012) requires homeowners connected to a DWWTS to register and ensure that the system does not constitute a risk to human health or the environment through compliance with standards for the performance and operation of DWWTSs. Water Services Authorities (WSAs) (local authorities) are required to maintain a register of DWWTS and undertake inspections to regulate the discharges from these systems. The Environmental Protection Agency (EPA) is responsible for the development of the National Inspection Plan (NIP), the appointment of inspectors and the establishment and maintenance of a register of inspectors, and is the supervisory authority over the WSAs in the performance of their functions under the Act.

The new legislation will also assist Ireland in meeting the objectives of the *Water Framework Directive* (2000/60/EC). Ireland must maintain current 'high' and 'good' status water bodies and it is of critical importance that this is achieved. All water bodies at less than good status must show no deterioration and must be restored to good status by 2015 (there are extended deadlines to 2021 and 2027 for some water bodies). A major programme, through the implementation of River Basin Management Plans, is under way to achieve this ambitious target. The NIP specifically addresses one of the measures in the River Basin Management Plans, which deals with inspection and remediation of DWWTSs.

A review of enforcement procedures internationally revealed that environmental considerations are key to developing enforcement strategies, in prioritising enforcement activities and in allocating resources where they are needed most. The Environmental Protection Agency (EPA) has developed this environmental risk assessment methodology to allow it to prioritise the inspection of DWWTSs through the implementation of the NIP.

1.2 Report Scope

The aim of this report is to provide a scientific basis for enabling consideration of the risk to human health and the environment when deciding on the inspection regime. The report includes descriptions of the following:

- the risk-based approach;
- characteristics (quality and quantity) of discharges from DWWTSs;
- characteristics of the surface and subsurface pathways for the discharge after it leaves the wastewater treatment tank;
- the process followed in ranking pathway susceptibility;
- the basis for ranking areas based on the risk of impact to human health and the environment.

The maps produced to accompany this methodology are intended to give a guide as to where issues are most likely to occur with respect to inadequate percolation or susceptibility of groundwater to the occurrence of pathogens/molybdate reactive phosphorus (MRP) or nitrate across Ireland, with respect to existing DWWTSs. The maps have been produced at a 1:40,000 scale. Further enlargement would potentially be misleading as the spatial resolution of the underlying data is insufficient to show detail beyond this scale. The depicted boundaries and interpretations derived from the maps do not eliminate the need for on-site sampling, testing, and detailed study of specific sites. The maps should be used appropriately, and users are responsible for this process.

1.3 Domestic Waste Water Treatment Systems

Domestic waste water disposal accounts for approximately one-third of residences in Ireland. There are an estimated 497,000 (CSO, 2012) DWWTSs in Ireland treating waste water from single houses not connected to a public sewer system.

In most cases the DWWTS utilised is a conventional septic tank system. The conventional septic tank system consists of two main parts:

- the septic tank itself, and
- the percolation area, which comprises the effluent distribution system and the adsorption and treatment beneath it, which occurs in the biomat and in the soil and subsoil layers and where the main treatment of the effluent takes place.

Secondary treatment systems (often called 'advanced' systems) are also employed. These systems offer secondary treatment of discharged effluent and include those constructed on-site and packaged treatment systems. Secondary waste water treatment systems may include a package treatment system and a polishing filter, which may comprise soil, sand or peat.

Both conventional septic tank systems and secondary treatment systems must include two elements in their make-up, namely the tank or mechanical treatment unit and the percolation or polishing filter set in the ground. Septic tank systems require greater depths of subsoil and a larger area for distribution of discharged effluent than secondary treatment systems.

All new DWWTSs, whether of the conventional septic tank type or of the secondary type, should meet the requirements of the appropriate European Standards (EN 12566 series of standards). Such systems are designed to:

- treat the wastewater to minimise contamination of soils and water bodies;
- prevent direct discharge of untreated wastewater to the groundwater or surface water;
- protect humans from contact with wastewater;
- keep animals, insects, and vermin from contact with waste water; and
- minimise the generation of foul odours.

It should be noted that there are many localities across Ireland where neither a conventional septic tank nor a secondary treatment system discharging to ground will operate adequately, due to unsuitable site conditions. For existing systems, in such cases, some additional remedial measures or non-conventional systems may be necessary to provide adequate protection (e.g. importation of suitable soil for the construction of mound systems or tertiary treated effluent discharging to surface waters with a licence).

1.4 Historical and Current Requirements for Siting, Design and Installation of DWWTSs

In 1975, the Institute for Industrial Research and Standards (IIRS) published the *Recommendation for Septic Tank Drainage Systems Suitable for Single Houses* (SR6:1975), which was the first document outlining best practice with respect to septic tank systems in Ireland. The National Standard Authority of Ireland (NSAI) followed this in 1991 by publishing *Septic Tank Systems: Recommendations for Domestic Effluent Treatment and Disposal from a Single House* (SR6:1991). This document required that a site suitability assessment be carried out before the installation of a DWWTS, and outlined how this assessment should be carried out and how percolation areas should be constructed. Where sites were deemed unsuitable for reasons such as poor percolation, remedial measures were suggested which included mounding percolation areas using imported suitable material. However, while remedial measures such as this are satisfactory in some circumstances, they may not address the hydraulic issue sufficiently where there is inadequate percolation.

The EPA published the guidance manual *Wastewater Treatment Manual: Treatment Systems for Single Houses* in 2000, which further defined the site assessment process and gave detailed accounts of the types of secondary treatment systems available in Ireland at that time. Acceptable limits to percolation values were set out in this document, and the site assessment process from this time on was a more involved procedure.

Currently, where new houses are being constructed in unsewered areas and waste water from a single house needs to be treated on-site, the EPA *Code of Practice: Wastewater Treatment and Disposal Systems Serving Single Houses (p.e. ≤ 10)* (CoP) provides guidance from the assessment stage through to the design, installation and maintenance stages of a DWWTS, in such a way as to prevent water pollution and protect public health. This document, published in late 2009, applies to new systems only and does not account for the many older houses with existing DWWTSs that pre-date it.

The importance of proper design, installation, operation and maintenance of DWWTSs cannot be overestimated. In particular, a well designed and constructed distribution device and percolation area/polishing filter is critically important in terms of maintaining an even flow of waste water and promoting biomat development that will adequately distribute and allow treatment of the effluent. A clogged percolation area/polishing filter due to poor construction and maintenance can result in backing up and surface ponding in some locations otherwise suitable for subsurface percolation. A good percolation area/polishing filter can occasionally assist where marginal subsurface percolation conditions exist, but it will never overcome the problem of fundamentally unsuitable subsurface percolation conditions, hence the focus on soil/geological conditions in this report.

Correct operation and maintenance of DWWTSs is essential to ensure ongoing treatment of waste water. A 'duty of care' is placed on homeowners by Section 70 of the *Water Services Act, 2007* and the *Water Services Acts 2007 and 2012 (Domestic Waste Water Treatment Systems) Regulations 2012* (S.I. 223 of 2012), which details the requirements for operation and maintenance of systems including the requirements for de-sludging of DWWTSs. If systems are not de-sludged properly solids can be carried over and cause blockages in the percolation area/polishing filter, thus preventing adequate treatment and/or causing ponding of effluent on-site.

It is expected that all new DWWTSs will be designed, installed, operated and maintained to accepted standards; however, the risk assessment methodology does not make particular assumptions about adherence of existing systems to these standards as its purpose is to underpin a risk-based inspection scheme relying only on underlying environmental conditions.

1.5 Risk-Based Enforcement

The EPA is committed to delivering effective risk-based regulation (Lynott and O'Leary, 2011), recognising that the most effective and efficient way to protect human health and the environment is to target resources towards activities that pose the greatest risk and those areas at greatest risk of impact. The EPA considers that, while the overall risk from DWWTSs to the environment at a national scale is lower than that from agricultural activities and urban wastewater treatment systems, there are areas of the country where the potential risk from DWWTSs may be important at a local level due to the density of systems and the prevailing ground conditions.

In line with European and international best practice, the EPA has developed this risk-based methodology to provide for the prioritising of the enforcement of DWWTS management. The methodology has built on previous research work carried out by the Western River Basin District in the development of the River Basin Management Plans (WRBD, 2008), which estimated that a significant proportion of existing septic tanks have the potential to impact on groundwater and/or surface waters.

1.6 National Inspection Plan

The *Water Services (Amendment) Act 2012* requires the EPA to prepare a National Inspection Plan for DWWTSs. It sets out the issues to be considered by the EPA when drawing up the plan, to include relevant and potential risks to human health and the environment, and makes provision for the revision of the plan. The WSAs will be required to give effect to the plan. The development of this risk-based methodology provides a decision-making framework to prioritise and target sensitive areas, and allocate and deploy resources with a view to facilitating compliance with the *Water Services (Amendment) Act*.

2. A risk-based approach to assessing the impact of existing Domestic Waste Water Treatment Systems

2.1 Risk Assessment

Risk assessment is a fundamental step in the protection of human health and the environment, and in effective water management planning. Risk assessment allows environmental problems to be identified, likely problem areas to be located, monitoring programmes to be designed, and appropriate cost-effective inspection, protection and improvement measures to be formulated and implemented.

The assessment of the performance of DWWTSs, as outlined in this report, is receptor-focused and risk-based. The receptors of concern are human health, aquatic ecosystems and groundwater resources.

2.2 Source-Pathway-Receptor Framework

The basis for risk assessment is the source-pathway-receptor (S-P-R) model, which underpins all groundwater protection schemes in Ireland, as well as the EU Water Framework Directive on which both surface water and groundwater regulations are based.

The S-P-R model is depicted schematically in Figure 1, whereby a source is linked to one or more receptors via pathways. In the example, the source is represented by a DWWTS, which disposes of discharged effluent through a percolation area situated in an area where bedrock is at a shallow depth. The discharge infiltrates through subsoils into groundwater in the bedrock, from where it migrates through fractures and fissures to a down-gradient abstraction well and towards a river. There are in fact three potential receptors in the diagram: the abstraction well, the river, and the bedrock aquifer (the last as a groundwater resource). Figure 2 represents a situation where a properly installed and maintained DWWTS will not impact on the water receptors via underground flow due to the protection provided by the subsoils underlying the percolation area. However, if the permeability of the subsoil is sufficiently low that adequate percolation cannot occur, ponding of DWWTS discharge at the surface is likely, with a consequent threat to human health. In such a situation, effluent can also flow 'downhill' in the more permeable topsoil, could enter wells down the outside of well casings where well protection may be inadequate, and typically will enter nearby ditches or streams, maintaining a water impact especially during lEvery DWWTS carries a degree of risk of impacting on water quality and receptors. In many cases, the risk may be low or manageable through well sited, designed and managed systems. In other cases, the discharge activity can pose a significant threat to human health, groundwater or surface water quality and related receptors.

It is relatively easy to develop a conceptual model of a surface water flow system around a DWWTS from a topographic map and a site walkover survey. It is more difficult to obtain a similar, site-specific image for groundwater flow because groundwater is not visible. Changes in the geology in three dimensions will influence the volume and velocity of groundwater flows, as well as groundwater levels, directions and chemistry. The S-P-R model for environmental management presents a basis for a conceptual model of both the groundwater and surface water flow systems.

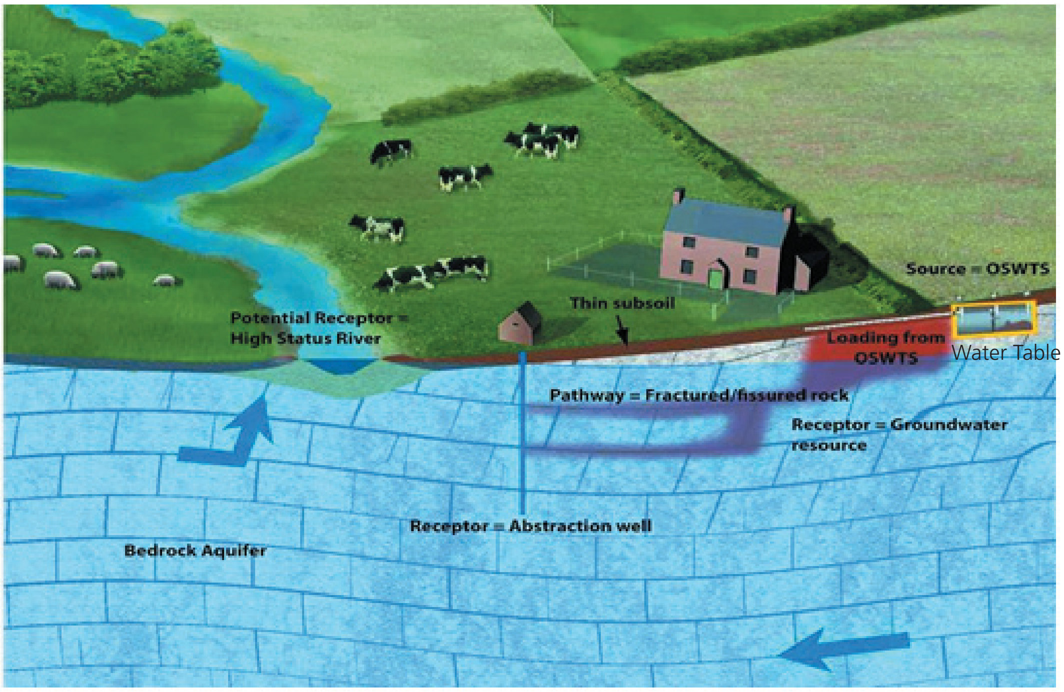

Figure 1: S-P-R model for domestic waste water treatment system with subsurface pathways (permeable subsoil) (graphic sourced from the WFD Visual website, SNIFFER, 2007)[1]

In order to assess fully the impact of a DWWTS at a site, it is necessary to have a credible conceptual model to determine the potential pathways underground, and to assess the risk to down-gradient receptors. In particular, it is important to realise that a two-dimensional 'plan view' is not adequate for assessing the risk posed by an existing DWWTS, as groundwater flow systems consist of flows in three dimensions underground. Changing conditions through time also need to be taken into account.

When examining S-P-R relationships, the main questions to be considered are:

- **Source characterisation** – how significant is the potential discharge (input) from the DWWTS, and what volume of wastewater is involved? What are the pollutants of concern? What is the density of systems in the area? What is the nature and condition of these systems?
- **Pathways analysis** – how and where would the pollutants flow, and to what extent would the pollutants be expected to attenuate? Is there a hydrogeological or hydrological link that can deliver a pollutant source to a nearby receptor?
- **Receptor identification** – who or what would potentially be affected? Receptors may be of different types, and may be linked to a source via different pathways. Are any wells present nearby and down-gradient of the DWWTS? Are there any particularly sensitive ecosystems nearby?

These three elements are dealt with in more detail in the following sections.

1 OSWTS is the acronym for 'on-site wastewater treatment system' and can be used interchangeably with DWWTS.

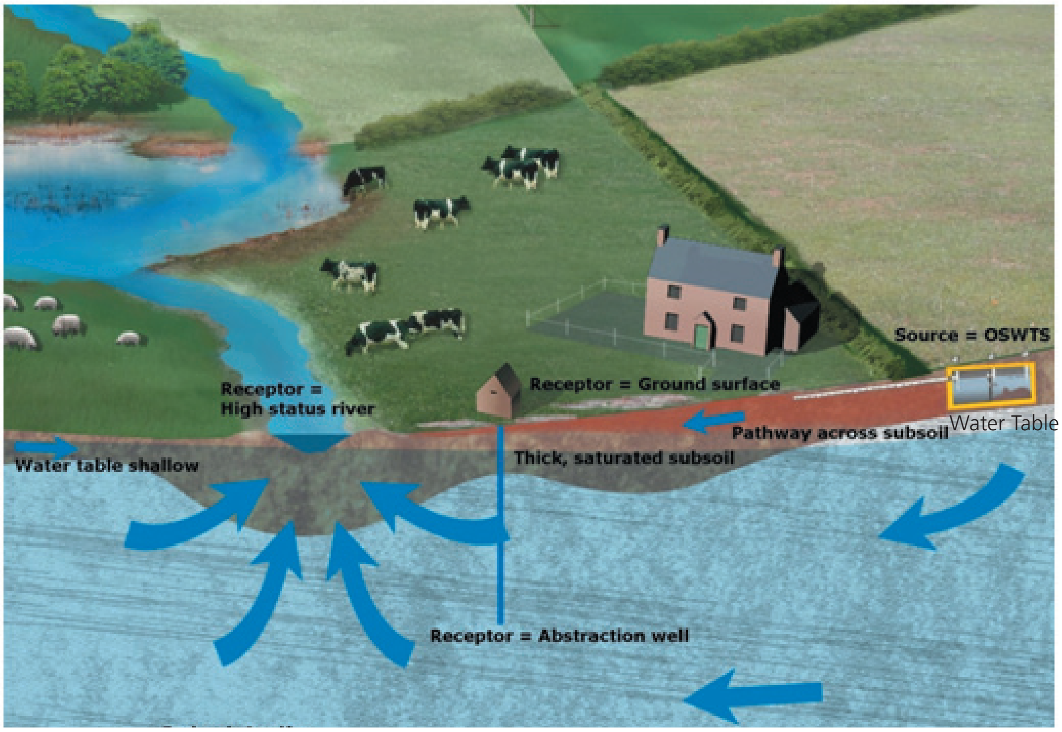

Figure 2: S-P-R model for domestic waste water treatment system with surface pathways (impermeable subsoil) (graphic sourced from the WFD Visual website, SNIFFER, 2007)

3. Source Characteristics

The pollution source is characterised by its location, size, quantity, and type. Key source descriptors for domestic waste water include information on its composition, discharge rate and resulting load to both surface water and groundwater.

3.1 Domestic Waste Water Quality

The quality of domestic waste water is summarised in Table 1. The discharge from the tank component of conventional septic tank systems and secondary treatment systems poses a hazard to human health and the water environment, particularly if the waste water ponds on the surface or enters groundwater without adequate treatment. It is therefore essential that further treatment of this effluent occurs to facilitate safe disposal.

Table 1: Typical pollutant concentrations that arise from DWWTSs, per household *(after Ó Súilleabháin, 2004 and Gill et al., 2005)*

Pollutant	Conventional Septic Tank	Secondary Treatment Tank
Faecal Coliforms	>1 million/100 ml	>5,000–10,000/100 ml
Nitrogen (mg/l N)	30–80	20–35
Phosphorus (mg/l P)	5–20	1–5
Biochemical Oxygen Demand (BOD) (mg/l)	150–500	20–50

Where DWWTSs are not properly located, designed, installed, operated and managed they pose a risk to the homeowner's health through possible contamination of their own or their neighbour's well or by resulting in effluent ponding in their gardens, thus restricting the play activities of their children or pets. In addition to the risk posed to human health, malfunctioning DWWTS pose a risk to our watercourses and therefore may result in impact on fishing, bathing waters and other amenities. It is essential that adequate treatment of this effluent occurs before safe disposal by percolation.

Typically there are more than 1 million coliform bacteria (includes faecal coliforms) in 100 ml of effluent from a septic tank serving a normal household, while the drinking water standard is zero. Also, in general a DWWTS emits 0.5 kg phosphorus/person per year and that is enough to pollute 14.5 million litres of water.

The main pollutants in waste water dealt with in this report are microbial pathogens, phosphorus and nitrogen.

3.2 Microbial pathogens

Microbial pathogens are bacteria, viruses and protozoa which can cause gastroenteritis, polio, hepatitis, meningitis and eye infections, among others. The occurrence of faecal indicator organisms (FIOs) such as E. coli, enterococci, streptococci and faecal coliforms, with the same enteric origin as other microbial pathogens, indicates whether these pathogens may be present in waste water. The drinking water standard for E. coli and coliform bacteria is zero.

3.3 Phosphorus

Phosphorus is the major limiting factor for plant growth in many freshwater ecosystems. The addition of phosphorus encourages algal growth, depletes dissolved oxygen, and causes algal blooms in lakes and fish kills in rivers. Phosphorus is the main cause of eutrophication in rivers and lakes in Ireland.

For the purposes of this report, molybdate reactive phosphorus, or MRP, which is often used as a measure of the soluble reactive inorganic phosphorus in water, is taken as the primary phosphorus pollutant arising from DWWTSs.

3.4 Nitrogen

The percolation process converts nitrogen and ammonia from organic matter almost entirely into nitrite and then to nitrate. Nitrate, unlike ammonium, is mobile in the ground and therefore is a good indicator of contamination. Reduction of nitrate concentrations in groundwater occurs primarily through dilution, both by recharge from rainfall and, where background nitrate concentrations are low, by groundwater. In certain hydrogeological settings in Ireland, denitrification can occur (see Appendix 2).

In this report, nitrate is taken as the main nitrogen pollutant, although in some circumstances ammonium from DWWTSs also causes water pollution.

3.5 Volumes of Waste Water Generated by DWWTSs

DWWTSs accept waste water from toilets, showers, sinks, wash hand basins, washing machines and dishwashers. The greater the population of the dwelling, the greater is the volume of waste water produced. In order to calculate the waste water capacity for any DWWTS, it is assumed that a typical daily hydraulic loading for each person is 150 litres, as stated in the CoP (2009).

3.6 Pollutant Load

The pollutant load is derived from multiplying the hydraulic loading from the number of people by the average pollutant concentrations. Further details are given in Section 6.2.

4. Surface and subsurface pathways

The pathway is the link between the source of pollution and the receptor, and can be either at or close to the surface or underground, or a combination of the two. Natural vertical and horizontal pathways for effluent migration are determined by the on-site subsurface geology, particularly the nature of the soils, subsoils and underlying aquifers. Artificial pathways may include drainage ditches, land drainage pipes and stream culverts.

4.1 Understanding and Using the 'Pathway' Concept

Understanding and taking account of the pathways through which pollutants from a site move towards a receptor creates a 3-D conceptual understanding of water presence and movement at a site, and is critical to:

- assessing the link between DWWTS and impacts;
- locating critical source areas that contribute contaminant load;
- predicting the likelihood of an impact;
- describing 'why' there could be or has been an impact;
- locating any monitoring that may be required;
- enabling monitoring data to be understood and assessed;
- enabling 'responses' to the risk or appropriate 'measures' to be derived and implemented.

There is often a danger that the critical role of the characteristics of the 'environmental pathway' may be forgotten about, as emphasis may tend to be put on (1) the system itself, its type and workings, and/or (2) monitoring/impact data. Encouraging greater consideration of the 'pathway' elements can prevent important factors from being missed, such as:

- the possible role of the subsurface pathway in both attenuating pollutants and transmitting pollutants to receptors; for instance, rivers and wells; and/or
- the role of hydrogeological information/maps in helping understand ponding, runoff and percolation rates and in predicting impacts.

4.2 Characteristics of Surface and Subsurface Pathways

The effluent that leaves a DWWTS may receive a degree of attenuation in the environment depending on the soil/subsoil/bedrock properties along the pathway to the water environment.

Pathway characteristics are determined from hydrological and hydrogeological information accessed from various data sources, as well as site walkover surveys and site investigations. Key pathway descriptors include subsoil type and permeability; wet or dry soil type; and aquifer type and hydraulic properties. While slope can be a factor in certain circumstances, it has not been included in the methodology outlined in this report.

4.2.1. Data Availability

Table 2 outlines the main regional-scale pathway components – all of which have been mapped and are available in national GIS data layers – and summarises their characteristics and relevance.

Table 2: Examples of relevant characteristics of pathways interacting with wastewater following initial treatment, and their implications *(adapted from Table 2 of WGGW, 2005a)*

Component	Factor	Relevant 'Intrinsic' Characteristic	Implication	Water Receptor at Risk
Soil	'Wet' (gley) soils	Low permeability	Rapid runoff	Surface water
	'Dry' (brown earth etc.)	Moderate/high permeability	Leaching of pollutants, e.g. NO_3 and P	Groundwater and surface water
	'Organic'	Low permeability	High % of runoff	Surface water
Subsoil	SAND[2] and GRAVEL	High permeability	Leaching of pollutants, e.g. NO_3	Groundwater and surface water
	CLAY	Low permeability	Rapid runoff	Surface water
	Depth to bedrock	Bedrock at or near (<0.6 m) the surface	a) No protection of groundwater b) Rapid runoff if low permeability	Groundwater and surface water
Groundwater vulnerability	'Extreme' and 'High'	Rapid transit time	High leaching potential	Groundwater and surface water (via groundwater)
	'Low'	Slow vertical transit time and groundwater recharge High attenuation	Minimal leaching potential and often rapid runoff	Surface water
Aquifer flow regime	Poor aquifers	Short underground flowpaths Denitrification	High surface drainage density possible	Surface water
	Regionally important aquifers	Long underground flowpaths	Low surface drainage density	Groundwater and surface water (via groundwater)
	Karst aquifers	Point recharge	Pollutants can reach receptor quickly	Groundwater and surface water (via groundwater)
	Sand/gravel aquifers	Rapid infiltration Attenuation	Mobility of NO3 Phosphate	Groundwater and surface water (via groundwater)

2 See Table 3 and British Standards: BS5930 (1999) methodology.

Component	Factor	Relevant 'Intrinsic' Characteristic	Implication	Water Receptor at Risk
Karstification	Point recharge	Presence of swallow holes and bare rock	No retardation of contaminants	Groundwater and surface water (via groundwater)
Topography	Slope	Gradient	Rate of runoff	Surface water

The EPA Code of Practice (EPA, 2009) requires that site suitability assessments be undertaken prior to applying for permission for a DWWTS. This consists of a desk study, visual assessment, trial hole assessment (giving subsoil type, depth to bedrock and depth to water table) and percolation tests (giving 'T' values[3]).

The GSI have undertaken a national programme of mapping groundwater vulnerability. As part of this programme, three categories of subsoil permeability are mapped, as noted in Table 3.

Table 3: BS5930 descriptions and permeability rates of subsoil permeability categories

Subsoil Permeability Category	BS5930 Descriptions	Permeability (m/s)
High	GRAVEL; sandy GRAVEL; SAND	$>10^{-4}$
Moderate	SAND; clayey SAND; SILT; sandy SILT; some SILT/CLAY; some sandy SILT/CLAY*	10^{-4}–10^{-8}
Low	SILT/CLAY; some sandy SILT/CLAY; sandy CLAY; CLAY*	$<\sim10^{-8}$

4.2.2. Attenuation

Physical removal of some faecal indicator organisms (FIOs) and associated microbial pathogens occurs through filtration. Microbial pathogens are also removed by sedimentation, where they settle out on soil and subsoil particles; by predation, where they are consumed or broken down by other micro-organisms in the soil and subsoil; and by die-off, where they reach the end of their life-cycle naturally.

Phosphorus is removed in the soil and subsoil by precipitation to mineral phosphorus and adsorption to soil particles. Phosphorus will also be removed by plant uptake, but this only happens when the discharged effluent is close to the ground surface or has ponded at the surface.

Organic nitrogen removal in the soil and subsoil occurs through a number of processes. Initially, the organic nitrogen is mineralised to ammonium nitrogen. Nitrification occurs as ammonium is further changed by micro-organisms to the nitrate form, and is then available to leach to groundwater. The biological reduction of nitrate to nitrous oxide or nitrogen gas that escapes into the atmosphere, also known as denitrification, may occur in the soil, subsoil and bedrock.

3. The percolation rates in minutes expressed as the time for water to fall 25 mm in a 300 mm x 300 mm square hole (T = time mins/25 mm) – see EPA (2009) for further details.

Nitrate will also be removed by biological oxidation and plant uptake, again only where the discharged effluent is close to the surface. When nitrate reaches the groundwater, it moves freely. Reduction of nitrate concentrations in groundwater may occur, however, primarily through dispersion and dilution, although this depends on the background nitrate concentrations.

4.3 Pathway Susceptibility

'Pathway susceptibility' is a measure of the degree of attenuation between source and receptor. It is a measure of the ability of the pathway factors to reduce the impact of a pressure, in terms of: time to reach the receptor; proportion of pollutant load reaching the receptor; pollutant concentration level in the receptor; and duration of the pollution event.

The pathway susceptibility concept has been used previously in the Irish context in the derivation of risk matrices for groundwater in Ireland by the Working Group on Groundwater (WGGW, 2005a, 2005b).

In this report, the 'pathway susceptibility' concept has been applied specifically to discharges from DWWTSs. Keeping in mind the purposes of this document, only three pollutants arising from DWWTSs were considered – microbial pathogens, MRP and nitrate.

Pathway susceptibility is based on combinations of the following maps that capture the relevant hydrogeological properties of an area:

- soil type;
- subsoil permeability;
- groundwater vulnerability[4]; and
- aquifer category[5].

Four categories of susceptibility are used: 'very high', 'high', 'moderate' and 'low'. Generally, the categories of most concern are 'very high' and 'high'.

4.4 Factors Influencing Surface Water Susceptibility to Contamination

Surface water receptors are at risk where there is inadequate percolation in the ground for the waste water arising from DWWTSs. This can arise both from poorly constructed drainage fields and (more likely) from low-permeability subsoil and bedrock.

4. 'Groundwater vulnerability' is the term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities. Maps at 1:50,000 scale have been produced based on mapping (i) subsoil permeability, (ii) subsoil thickness and (iii) karst features. Further information can be obtained in the Groundwater Protection Schemes Report (DELG/EPA/GSI, 1999).

5. For more information on aquifer categories, see DELG/GSI/EPA (1999)

In areas where there is inadequate percolation, the combination of rainwater and DWWTS waste water can result in saturation of the soil and subsoil and, at times, in ponding and breakout of untreated or partially treated effluent at surface, backup of sewage in pipes, odour issues, and the potential for insects and vermin. In short, the effluent cannot drain away and this situation poses a general risk to human health and surface water, both on the site itself and in drains and streams around the site.

Where wet (gleyed) soils occur and where inadequate percolation exists in subsoil layers, the vast majority of pathway attenuation processes are limited, as effluent cannot enter the subsurface environment. Some attenuation of contaminants does occur where there is ponding of discharge, but only via small amounts of nitrate and phosphorus being taken up by plant roots. Also, predation and die-off of pathogens can occur. In many circumstances, effluent enters directly into ditches and streams with no attenuation other than dilution in the surface water receptor. In other circumstances, ponded effluent may become flushed during subsequent storm flows and be mixed with other diffuse signals of pollution runoff.

The main factors influencing inadequate percolation in the subsurface, and therefore the susceptibility of surface water to contaminants, are as follows.

- **The subsoil type on the site:** if an area has subsoil with a high proportion of CLAY, this material does not have sufficiently large pore spaces within it to allow water to flow through it. CLAY is, by its very nature, a low-permeability material. Examples of areas where CLAY subsoil dominates include the north central and northeastern portions of the country.
- **The type of bedrock under the site:** if soil and subsoil depth is relatively shallow and the bedrock is of low permeability, the rock has few significant fractures within and therefore water ‘backs up’ in the subsurface over time, resulting in a waterlogged landscape with a dense network of streams. Examples include the uplands of the west and northwest of the country.
- **The landscape setting:** if a portion of land is in a low-lying area within the landscape, where the water table is close to the surface for all or part of the year, there may not be enough depth of ‘dry’ soil and subsoil to allow percolation to occur. Examples throughout Ireland occur along the floodplains of rivers, areas reclaimed from bogs, and other flat, low-lying portions of the landscape.

4.5 Factors Influencing Groundwater Susceptibility to Contamination

The factors influencing the susceptibility of groundwater to contamination by pollutants arising from DWWTSs are:

- the thickness and permeability of the subsoil;
- the type of soil (whether wet or dry);
- the type of aquifer (whether bedrock or sand and gravel); and
- whether or not the bedrock enables denitrification.

Where only a shallow cover of soil/subsoil over bedrock exists on a site with an existing DWWTS, elevated levels of nitrate, MRP and FIOs/pathogens in the underlying groundwater may result. Such cases occur where bedrock is within 1–2 m of the surface and preferential flowpaths in soil and subsoil take the contaminants rapidly towards groundwater below. In these areas, the attenuation processes of filtration, sedimentation, cation exchange, adsorption, precipitation and biological oxidation, which remove contaminants where soil and subsoil treat wastewater effectively, are limited, as there is an insufficient depth of soil and subsoil on sites to allow them to occur effectively.

In cases such as these, discharge to ground may be acceptable, but only through site remediation works such as the importation of suitable soil/subsoil to enable construction of an adequate percolation area or polishing filter. Historically, this was not often completed as the percolation on-site was adequate and the processes that treat the wastewater in the subsoil before it reaches groundwater were not recognized or not taken into account.

In some situations around Ireland where DWWTSs have been installed without an adequate depth of suitable subsoil to remove pathogens and MRP by the processes outlined above, there is little protection of groundwater. In circumstances such as these, a high density of DWWTSs may also pose a threat to surface water receptors as groundwater provides a high proportion of surface water flow in dry weather. In addition, pollution of nearby wells by FIOs and associated microbial pathogens can occur.

Some rock types have high levels of pyrite and other minerals which can lead to denitrifying conditions within the bedrock itself and thus natural removal of nitrate *(see Appendix 2)*. Therefore, even where there is a high density of DWWTSs, nitrate concentrations are not likely to be increased significantly in these areas.

In most areas of Ireland, however, the bedrock does not have a natural capacity to reduce nitrate concentration in groundwater. Consequently, in areas where there is adequate percolation, there may be small, localized plumes of relatively high nitrate, particularly where the density of DWWTSs is high. This scenario is especially of concern where nearby private wells are sources of drinking water, and where there are sensitive groundwater terrestrial ecosystems nearby.

5. Classifying pathway susceptibility

5.1 Introduction

As all effluent from DWWTSs poses a threat to human health and the environment, whether the DWWTSs are properly constructed or not, the key factor in assessing the degree of potential impact is 'pathway susceptibility'. This section describes the considerations that are taken into account when combining the soils, subsoil permeability, groundwater vulnerability and aquifer national data layers in order to derive the 'pathway susceptibility' category (i.e. 'very high', 'high', 'moderate' and 'low') for effluent from DWWTSs.

The way in which these data layers are combined is illustrated in the 'susceptibility matrices' (Appendix 1). By combining these national data layers in a GIS, the resulting pathway susceptibility category can be displayed as simple, colour-coded risk assessment maps.

The susceptibility matrices were developed in the context of two overarching environmental scenarios:

- **inadequate percolation,** which may result in surface ponding of effluent, bypass directly to surface water and the associated threats to human health and surface water quality, and
- **insufficient attenuation (subsurface treatment of the effluent),** which may result in directly polluting groundwater/drinking water supplies (wells and springs), and/or indirectly impacting on surface water.

This report only considers pathway susceptibility with respect to microbial pathogens, MRP and nitrate.

5.2 Inadequate Percolation

The presence of inadequate subsurface percolation at any point in the landscape is determined by the soil, subsoil and bedrock permeability (as indicated by aquifer category). The different scenarios that are likely to result in inadequate percolation are outlined in Table A1, Appendix 1. The main considerations are summarised below.

- In areas of 'extreme' groundwater vulnerability (i.e. soil/subsoil <3 m thick), the subsoil permeability can be very heterogeneous and therefore is not classified by the Geological Survey of Ireland. In these areas, the likelihood of inadequate percolation is determined by evaluating the aquifer type (an indication of permeability) and the drainage class of the topsoil, as shown in Table A1, Appendix 1.
- Where soil/subsoil is greater than 3 m thick, subsoil permeability ('high', 'moderate' or 'low') (see Table 3 for details) and soil types ('wet' or 'dry') determine the likelihood of inadequate percolation.
- Where the percolation 'T' test results on a site are found to be greater than 90, the site is deemed to be unsuitable for discharge of treated effluent to ground owing to inadequate percolation. The value of 90 means that it takes greater than 5 hours for water to drop 100 mm (or 4 inches) in a percolation test hole. In this situation, the principal subsoil types recorded in trial holes are usually CLAY or SILT/CLAY. T > 90 corresponds to a 'low' subsoil permeability.

The likelihood of inadequate percolation arising at a site is subdivided into four categories – low, moderate, high and very high (Table A1, Appendix 1). Based on an evaluation of the hydrogeological settings outlined in Table A1 and practical site assessment experience, the probability of finding inadequate percolation or inadequate depth to water table within these categories is given in Table 4.

Table 4: The probability of finding inadequate percolation for each susceptibility category

Susceptibility Category	Probability of Finding Inadequate Percolation within the Category
Low	<5% of sites
Moderate	Approximately 25% of sites
High	Approximately 50% of sites
Very High	>80% of sites

In all cases, these figures represent the average within a range. Also, the mapping scale (approximately 1:40,000) will not have enabled local variations to be captured.

Groundwater discharge zones, low-lying areas and areas with a low slope gradient may have groundwater levels close to surface in winter and may have water table constraint issues. Many of the wet soils, and thus areas with inadequate percolation, in high or moderate permeability subsoil areas occur in such localities and will therefore indicate such zones; however, shallow groundwater table is not mapped and therefore is not directly included in this risk assessment.

By combining the available data layers as outlined in Table A1, Appendix 1, a national map of the likelihood of inadequate percolation has been derived. This is shown in Figure 3 for illustration purposes. The proportion of the country in each category is given in Table 5. The overall proportion of the country with inadequate percolation is estimated to be 39% – this proportion is derived by applying the probabilities given in Table 4. A corresponding summary for County Meath is presented in Table 6 as an example at a county scale.

Table 5: National summary of areas within each susceptibility category and the overall likelihood of finding inadequate percolation

Susceptibility Category	Percentage (%) Land Area	Overall National Likelihood of Inadequate Percolation (%)
Low	25.8	39
Moderate	25.7	
High	22.0	
Very High	25.2	
Made Ground	1.3	

Table 6: Summary of areas within each susceptibility category and the overall likelihood of finding inadequate percolation for County Meath

Susceptibility Category	Percentage Area (%)	Overall Likelihood of Inadequate Percolation for Co. Meath (%)
Low	43.7	36
Moderate	12.4	
High	11.2	
Very High	31.4	
Made Ground	1.3	

5.3 Inadequate Attenuation

5.3.1. Pathogen and Molybdate Reactive Phosphorus Contamination

Within the scope of the data layers used for this assessment, the likelihood of pathogens or MRP reaching a groundwater or surface water receptor is determined by the same factors: type of aquifer (bedrock or sand and gravel), and depth of soil/subsoil (as derived from vulnerability maps). Therefore the pathway susceptibility is the same for both pollutants (Table A2, Appendix 1).

While there are four general susceptibility categories, only three relative categories apply to pathogen and MRP susceptibility. No locations were considered to have a 'moderate' susceptibility, given the mobility of pathogens and MRP, and the type of pathways that exist. Consequently, susceptibility is either 'very high' or 'high' where groundwater vulnerability is classed as 'extreme', and 'low' in all other cases, as the subsoil cover overlying the bedrock receptor is considered to provide sufficient protection. The map illustrating the susceptibility of groundwater to percolation of pathogens and MRP is shown in Figure 4. The proportion of the country in each category is given in Table 7. A corresponding summary for County Meath is presented in Table 8 below as an example at a county scale.

5.3.2. Nitrate contamination

The likelihood of nitrate percolation to groundwater (Table A3, Appendix 1) is determined by the bedrock type (whether the rock will denitrify groundwater or not), the subsoil permeability (allowing nitrate leaching or not), the soil type (wet or dry) and the groundwater vulnerability (extreme or other). 'Denitrifying bedrock' includes all bedrock units which are rich in pyrite, other metal sulphides and organic carbon and will hence reduce nitrate levels through microbially-assisted oxidation of the electron donor minerals. The bedrock units listed in Appendix 2 are considered to have the potential for denitrification.

Where wet soil occurs, it is assumed there will be reducing conditions in the underlying soil/subsoil, and hence groundwater is relatively well protected from nitrate percolation.

Three of the four susceptibility categories are considered as sufficient to apply to nitrate susceptibility: no areas are classed as 'high' susceptibility due to the mobile nature of nitrate. Susceptibility was considered to be 'very high' where dry soil and infiltration occurs readily, 'moderate' where de-nitrifying bedrock and high permeability subsoils are in evidence, or 'low' where wet soils and all other situations overlying de-nitrifying bedrock are found. The map illustrating the susceptibility of groundwater to percolation of nitrate is given in Figure 5. The proportion of the country in each category is given in Table 7. A corresponding summary for County Meath is presented in Table 8 as an example at a county scale.

Table 7: National summary of areas within each category of susceptibility of groundwater to percolation of pathogens and MRP and to the percolation of nitrate*

Susceptibility Category	Percentage Area for Each Susceptibility Category (%)	
	Percolation of Pathogens/MRP to GW (%)	Percolation of Nitrate to GW (%)
Low	61.0	67.8
Moderate	n/a	0.7
High	23.1	n/a
Very High	14.6	30.3
Made Ground	1.3	1.3

*Percentages may not sum to 100% due to rounding.

Table 8: Summary of areas within each category of susceptibility of groundwater to percolation of pathogens and MRP and to the percolation of nitrate for County Meath*

Susceptibility Category	Percentage Area for Each Susceptibility Category (%)	
	Percolation of Pathogens/MRP to GW (%)	Percolation of Nitrate to GW (%)
Low	87.1	72.6
Moderate	n/a	5.1
High	6.5	n/a
Very High	5.2	21.1
Made Ground	1.3	1.3

*Percentages may not sum to 100% due to rounding.

5.4 Use of Pathway Susceptibility Ranking Maps

The susceptibility maps are designed for general information and strategic planning usage; modelled evidence and local details have been generalized to fit the map scale, which is approximately 1:40,000. As these geological and hydrogeological settings are complex in some areas, exceptions can be expected.

The matrices and maps derived apply to the discharge of treated wastewater to ground from DWWTSs only. They do not reflect risks associated with any other potential environmental issues and thus should not be used for assessments other than that intended.

5.5 Map Confidence and Forthcoming County Maps

The subsoil permeability map is one of the most critical datasets used for the generation of the map showing the likelihood of inadequate percolation, as well as the risk of high nitrates, and pathogens/MRP occurring in groundwater. This map was obtained by the EPA from the Groundwater Section of the Geological Survey of Ireland (GSI).

Three counties have preliminary work completed on the subsoil permeability across their extents, and therefore have a slightly lower confidence level than all other counties depicted on the maps. These are Wicklow, Laois and Kilkenny, which will have updated and revised subsoil permeability maps produced by the GSI in early 2013.

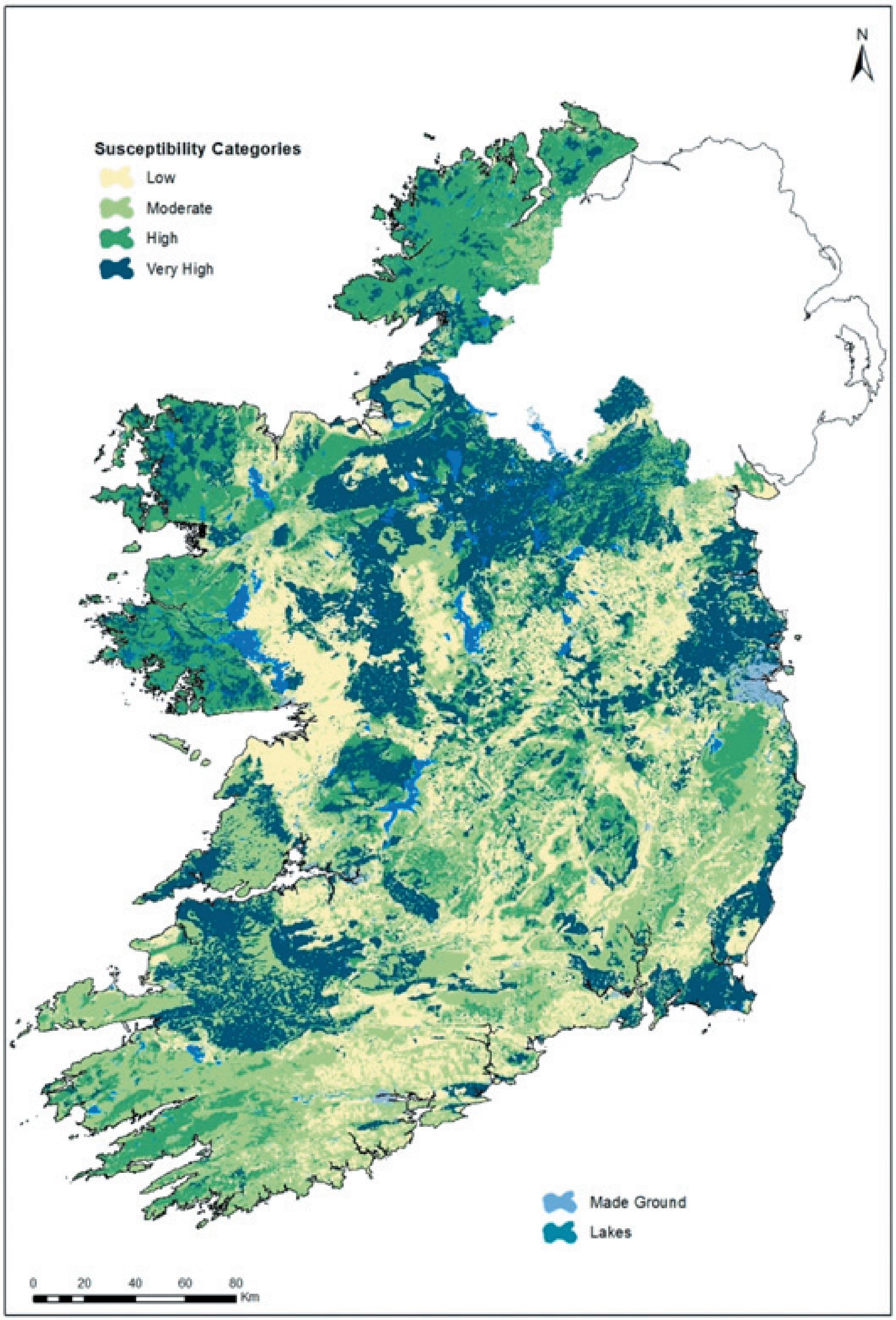

Figure 3: Map illustrating the distribution of susceptibility categories for inadequate percolation. Data captured at 1:40,000 scale *[This map summarises the relevant hydro(geo)logical parameters that characterise the surface 'pathway' for water in the source-pathway-receptor framework]source-pathway-receptor framework]*

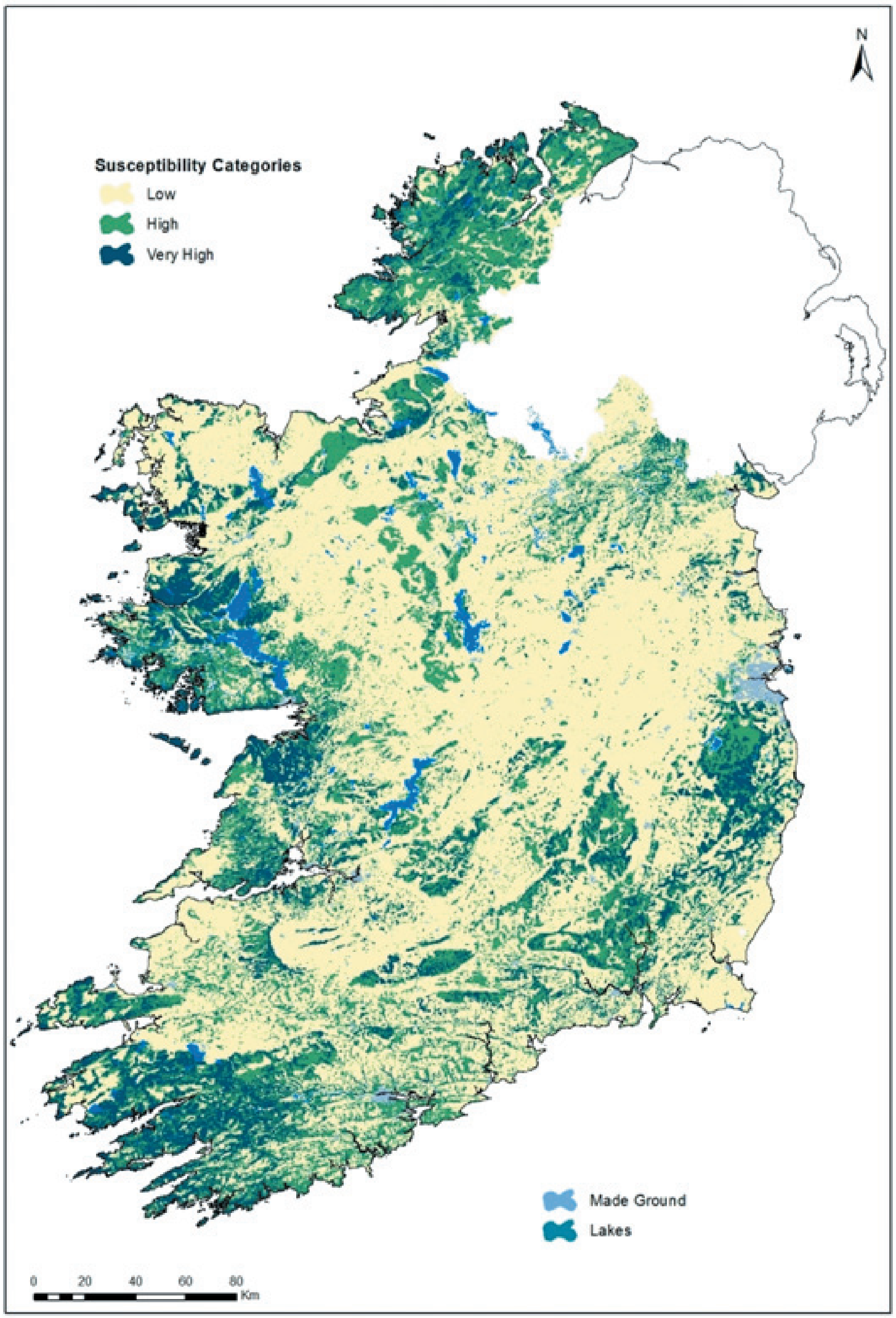

Figure 4: Map illustrating the susceptibility of groundwater to percolation of pathogens and MRP from DWWTSS. Data captured at 1:40,000 scale *[This map summarises the relevant hydro(geo)logical parameters that characterise the subsurface 'pathway' for pathogens and MRP in the source-pathway-receptor framework. It does not provide any indication of likely impacts]*

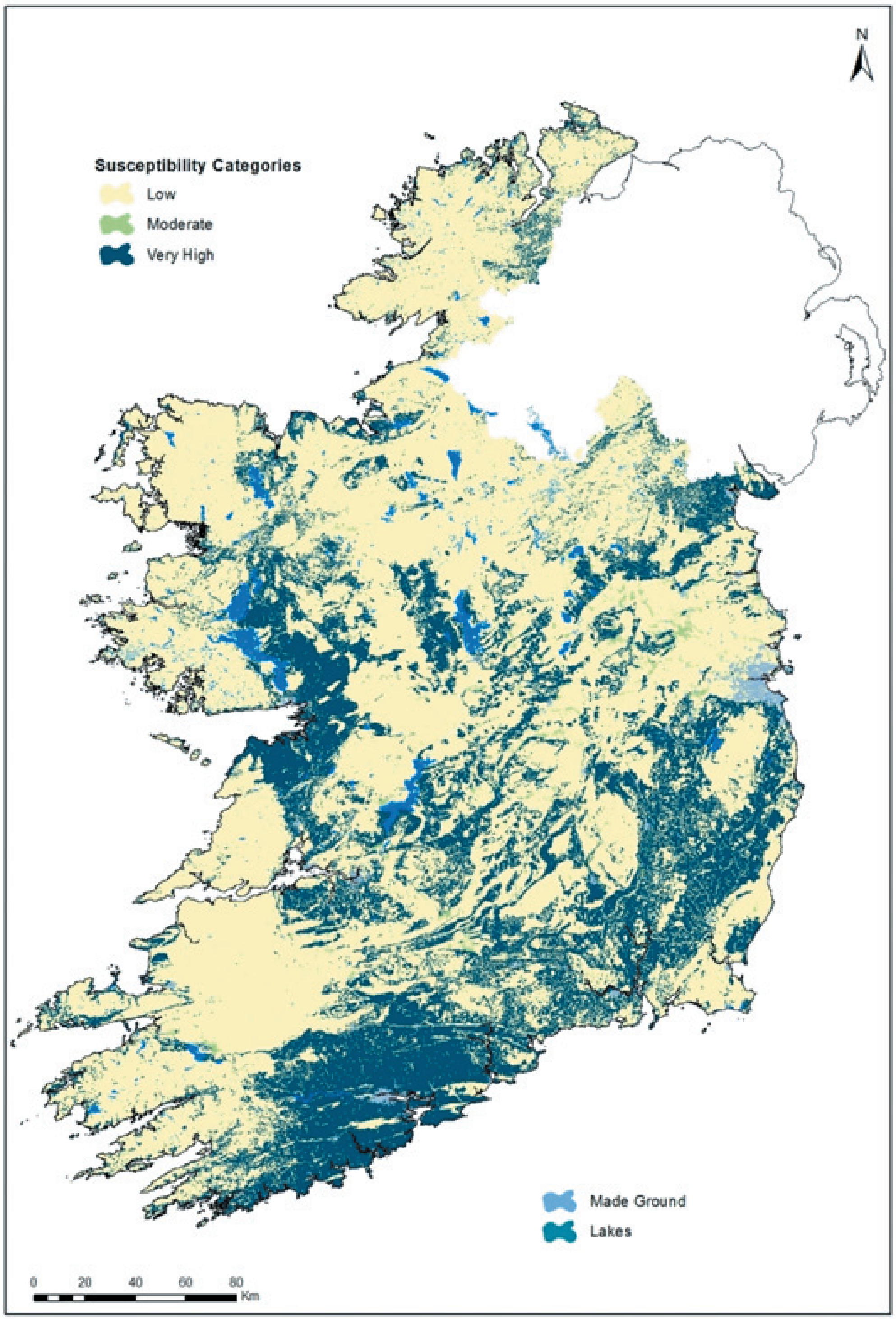

Figure 5: Map illustrating the susceptibility of groundwater to percolation of nitrate from DWWTSs. Data captured at 1:40,000 scale *[This map summarises the relevant hydro(geo)logical parameters that characterise the subsurface 'pathway' for nitrate in the source-pathway-receptor framework. It does not provide any indication of likely impacts]*

6. Risk characterisation

6.1 Introduction

The purpose of the approach outlined in this section is to rank the risk to human health and surface water and groundwater quality from DWWTSs, as a means of apportioning the inspections relative to the risk presented. The general concept is represented graphically in Figure 6.

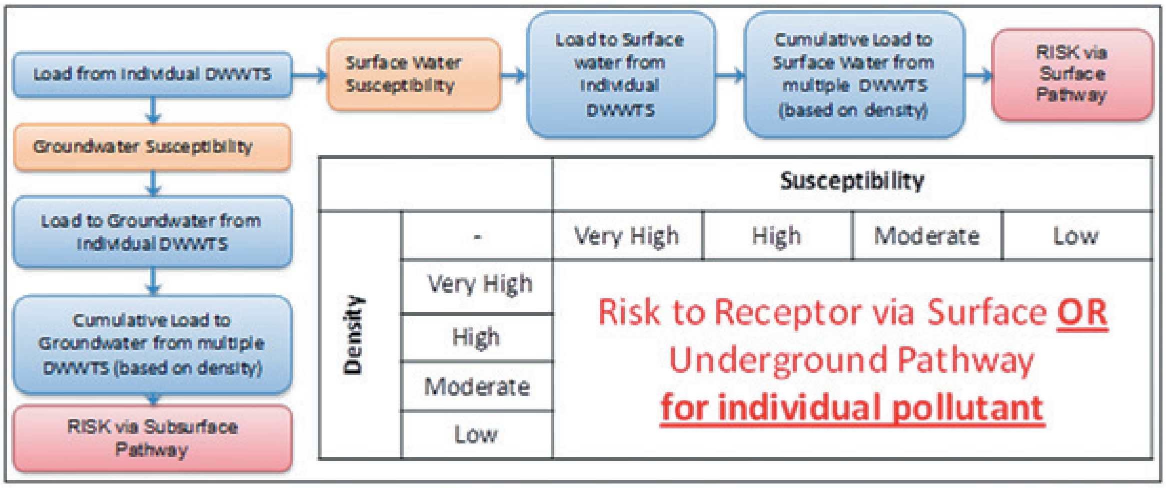

Figure 6: General concept for determining risk from DWWTS contamination via the surface or subsurface pathways

The risk characterisation is based on the combination of the following elements:

- pollutant load from each DWWTS, derived from typical discharge concentrations and quantities;
- pathway susceptibility, which includes consideration of attenuation by physical process, such as dilution, and biological and chemical processes. Two pathways are considered: surface (i.e. surface water) and subsurface (i.e. groundwater);
- cumulative load entering the surface water or groundwater environment derived from DWWTS density and estimation of attenuation;
- dilution of load at the water receptor;
- risk ranking using estimates of predicted pollutant concentrations at the receptor.

A more detailed graphical summary of the method proposed to estimate the risk is provided in Figure 7. Worked examples of the calculations are presented in Appendix 3 and Appendix 4; the examples are simplified to some degree to demonstrate the methodology used (each 1 km^2 grid is assumed to have uniform pathway susceptibility – this is not the approach taken in GIS processing, where the pathway susceptibility at each individual DWWTS was used).

While the approach used predictions of pollutant concentrations as the basis for the risk ranking, the maps are not intended to be used for predicting precise impacts; they are intended to show relative risk on which an inspection regime can be based.

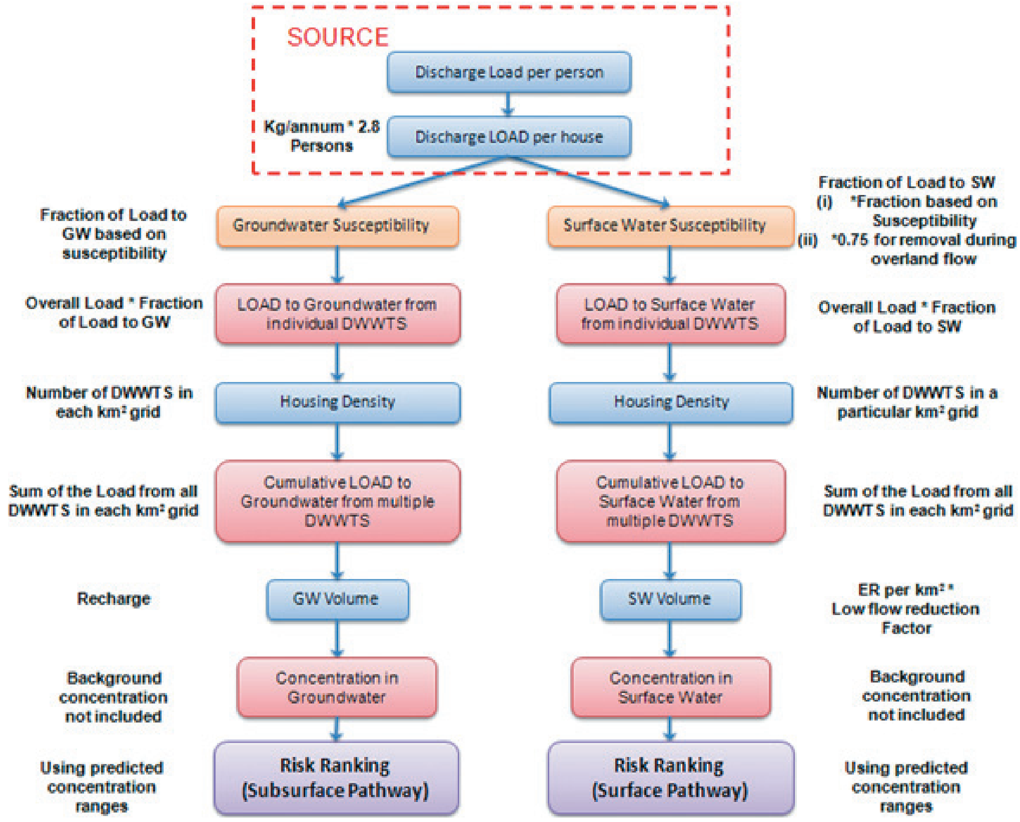

Figure 7: Outline of methodology for risk ranking

6.2 Pollutant Load

The pollutant load is derived by combining typical effluent quantity and quality from each DWWTS.

The average inputs of pathogens, MRP and nitrate from an individual septic tank, prior to treatment in the subsoil or polishing filter, are given in Table 10. These data can enable an estimate of the pollutant load produced in an area to be calculated by multiplication of the values by the number of systems present there.

6.3 Pathway Attenuation

The pollutant load to water may be reduced by amounts that depend on the various factors that have been described in Section 5.3 on pathway susceptibility to attenuation. In general terms, the higher the category of pathway susceptibility, the lower is the degree of attenuation and the greater is the likelihood that contaminants will enter water.

It should be noted that the risk ranking for MRP also reflects the risk ranking for microbial pathogens, and therefore the risk to human health.

Table 10: Data sources for the calculation of overall load

Input Parameter	Input Value	Data Source
Pathogen Load *(E. coli)*	5,000–1 million per 100 ml	Gill *et al.*, TCD Research
Phosphate Load in kg per person/year (in Liquid Discharge leaving Septic Tank)	0.5[6]	Gill *et al.*, TCD Research
Nitrate Load in kg per person/year (in Liquid Discharge leaving Septic Tank)	2.7[7]	Gill *et al.*, TCD Research
Persons per House	2.8	CSO data
Density of Systems	Variable	GIS layer created for DWWTS locations based on use of Geodirectory and unsewered areas

6.3.1. Surface Pathway

Where discharges cannot infiltrate underground in areas of inadequate percolation, either many systems are piped directly to ditches and/or streams, or ponding and overflow into ditches and/or streams occurs. The inadequate percolation map is used as the basis for calculating the pollutant quantity that either may pond or is piped to surface water. Using Table 4, 80% of the initial pollutant load is estimated to be present at the surface or piped away directly to drains and/or streams where the likelihood of inadequate percolation is 'very high', whereas this estimate is only 5% where the likelihood of inadequate percolation is 'low'. All effluent not directed to surface water is assumed to move via the subsurface pathway noted below and attenuated accordingly.

Where effluent ponds or is piped to ditches/streams, it is likely that there will be some removal of MRP and nitrogen, for instance uptake by plants growing in the ponded areas, attenuation as a proportion of the effluent moves through the topsoil or some percolation in dry weather. An arbitrary pollutant reduction factor of 25% is taken to account for a best estimate attenuation in the immediate vicinity of the percolation area. Evidence from future research will be used to refine the risk methodology.

Table 11 summarises the factors used in estimating the pollutant load entering surface water via the surface pathway from each DWWTS in any area.

6. Compares with SRP loads cited by Withers et al. (2011) of 0.38 kg/yr in and 0.44 kg/yr in Britain and Northern Ireland, respectively.

7. Compares with total dissolved nitrogen loads cited by Withers et al. (2011) of 2–4 kg/yr in the USA, UK and Netherlands.

6.3.2. Subsurface Pathway

The factors applied to enable an estimation of attenuation in the geological materials as discharged effluent percolates underground are given in Table 12. Therefore, it is assumed, for instance, that where the susceptibility of groundwater to percolation of microbial pathogens and MRP is 'low', no pathogens or MRP will reach groundwater. Where the susceptibility is high (see Table A2 for physical setting), it is assumed that the effluent will percolate through at least 1 m of subsoil, with a consequent significant reduction of MRP concentration (this is based on research by Gill et al. (2009)). Where the susceptibility is very high, little attenuation of MRP is considered to occur.

With regard to nitrate, significant attenuation in the biomat is assumed to occur; this reduces the loading proportions given in Table 12.

Table 11: Factors applied to estimate contaminant load from individual DWWTS reaching surface water by the surface pathway

Surface Water Pathway	Input Value	Data Source	Comment
	% of Load leaving Septic Tank that will reach receptor[8]		
LOW Susceptibility	5	Risk Matrices	These figures relate to the likelihood of finding inadequate depth to water table or inadequate percolation as noted in Table 4
MODERATE Susceptibility	25		
HIGH Susceptibility	50		
VERY HIGH Susceptibility	80		
Second factor applied for reduction in overland flow			
Overland Flow (Pathogens/MRP and Nitrate)	75 (% of Load that will NOT be removed in overland flow)	Estimate	This is a best estimate – some DWWTSs will be piped directly to streams with 100% of load reaching surface water; in other scenarios attenuation may occur during ponding, reinfiltration, etc.

6.4 Estimating Cumulative Load and Resultant Concentration

For each 1 km grid square, the load of pollutants calculated to reach the surface water or groundwater receptor via the surface or underground pathways from individual DWWTSs was summed to estimate the cumulative load. Dilution of the cumulative load in the environment was then applied to derive an estimated concentration. The method is described below.

8. Percentages will be a range, with the values averaged here.

6.4.1. Cumulative Load

The density of DWWTSs used to calculate cumulative load was derived by combining information derived from the An Post's Geodirectory and the sewered areas as recorded by WRBD (2008). In the unsewered areas, it is assumed that all houses use DWWTSs. The accuracy of the unsewered areas used in the methodology outlined in this report will need to be verified at a local level by the Water Services Authorities when implementing the National Inspection Plan.

A map illustrating the density of systems in unsewered areas in County Meath is shown in Figure 8.

Table 12: Factors applied to estimate contaminant load from individual DWWTS reaching groundwater

Groundwater Pathway	Input Value	Data Source	Comment
	% of Load leaving septic tank that will reach receptor		
LOW Susceptibility for MRP/ Pathogens	0	Guidance on the Authorisation of Discharges to Groundwater [9] Note – these figures apply only to conventional septic tanks	No MRP or pathogens to groundwater at LOW susceptibility For nitrate at least 70% reduction in the biomat is assumed, giving maximum input value of 30%
HIGH Susceptibility for MRP/ Pathogens	10		
VERY HIGH Susceptibility for MRP/ Pathogens	90		
LOW Susceptibility for Nitrate	10		
MODERATE Susceptibility for Nitrate	15		
VERY HIGH Susceptibility for Nitrate	30		

6.4.2. Dilution

Once contaminants reach a water receptor, further attenuation will occur due to dilution. The main factor determining the degree of dilution of the contaminant load in groundwater and surface water is the estimated effective rainfall at each locality. The approach taken to estimate the degree of dilution is outlined in Table 13.

With regard to groundwater, the quantity of water in an area providing dilution is derived from the GSI recharge map. The average annual recharge for each locality is regarded as adequate for the purposes of this risk ranking procedure.

DWWTSs are likely to have a greater impact on surface water during low flow conditions than at other flow conditions (Macintosh *et al.*, 2011). This is due to the lower dilution capacity (and thus higher resultant concentration) at these times. A low flow reduction factor can be applied to the average flow volume in an attempt to account for low flow conditions. Q90/Q50 is a ratio that is often used as an index of baseflow contribution. In this case an estimation of Q90/Q50 of 0.22 was applied nationally to average flow to give an estimation of low flow conditions. The value of 0.22[10] was taken as an approximate mid-range value of the Q90/Q50 that might be expected in Irish conditions.

9. This document can be downloaded from the EPA website, www.epa.ie/whatwedo/advice/wat/guidegw/dischgw

10. Median of Q90/Q50 from EPA's hydrotool for estimation of flow for ungauged catchments.

Table 13: Model values used to calculate the volume of water to dilute the nutrient load

Receptor	Field	Input Value	Data Source	Comment
Surface water	Effective rainfall (mm/yr)	Variable	Effective rainfall GIS layer	
	Low flow factor	Variable	Hydrotool output	Median of Q90/Q50 from EPA's tool for estimation of flow for ungauged catchments – 0.22 was used in these calculations
Groundwater	Recharge (mm/yr)	Variable	Recharge GIS layer[11]	Bedrock recharge acceptance capacity limit was not used

6.5 Risk Ranking

The final step in deriving relative risk maps involves calculating the resulting concentrations of MRP and nitrate entering water from DWWTSs for each 1 km^2 area.

It should be noted that the MRP map also reflects the likely presence of microbial pathogens in both surface water and groundwater, and therefore the risk to human health.

In the case of MRP, where the predicted resulting concentration in either surface water (during arbitrary baseflow conditions) or groundwater is greater than 0.035 mg/l P – the environmental quality standard (EQS) that forms the boundary between good and moderate status river water bodies (DEHLG, 2009) – a ranking of 'very high' is given. The 'high' category for MRP is based on the EQS that forms the boundary between high and good status river water bodies (0.025 mg/l P) (see Table 14).

In the case of nitrate, the categories are based on boundaries used by the European Environment Agency for cross-European comparison (EPA, 2010) (see Table 14).

Table 14: Molybdate reactive phosphorus and nitrate concentrations used in deriving surface pathway and subsurface pathway risk rankings

Risk Ranking				
	Low	Medium	High	Very High
Likely MRP Impact (concentration mg/l P)	<0.015	0.015-0.025	0.025-0.035	>0.035
Likely Nitrate Impact (concentration mg/l N)	<2	2–3.6	3.6–5.6	>5.6

11. The GSI provided both the effective rainfall and recharge maps.

The MRP and nitrate risk ranking for groundwater as a receptor is the same as for the surface water receptor as it is based on the concentration of nutrients in groundwater that is delivered to surface water.

While the approach outlined here uses results from the prediction of pollutant concentrations, the maps are not intended to be used for predicting precise impacts; they are intended to show relative risk on which an inspection regime can be based.

6.6 Results of Risk Ranking Process

The results are available in GIS data layers produced by the Informatics and GIS Section of EPA and will be offered to each local authority.[12]

The following maps for County Meath have been produced to illustrate the results that arise from this process.

Figure	Receptor	Pollutant	Pathway
9	Surface water	Microbial pathogens and MRP	Surface
10	Groundwater	Microbial pathogens and MRP	Underground
11	Surface water	Nitrate	Surface
12	Groundwater	Nitrate	Underground

The percentage areas in each relative risk category for County Meath and nationally for the following are given in Tables 15 and 16, respectively:

- relative risk of ponding and pollution of streams by MRP and pathogens via the surface pathway due to inadequate percolation;
- relative risk of pollution of streams and wells by MRP and pathogens via the subsurface pathway due to inadequate attenuation;
- relative risk of pollution of streams by nitrogen via the surface pathway due to inadequate percolation;
- relative risk of pollution of streams and wells by nitrogen via the subsurface pathway due to inadequate attenuation.

These four categories are given for the following reasons.

1. The subdivision into surface and subsurface pathways may influence the approach taken to site inspections, particularly the visual assessments.

2. The subdivision based on pollutant type enables a better understanding of the threat posed to human health and the environment.

12. The maps have been produced at a 1:40,000 scale. Further enlargement would potentially be misleading as the spatial resolution of the underlying data is insufficient to show detail beyond this scale. The maps are intended as a guide as to where issues are most likely to occur with respect to inadequate percolation or susceptibility of groundwater to the occurrence of pathogens/MRP or nitrate across the Irish landscape, with respect to existing DWWTSs. The depicted boundaries and interpretations derived from the maps do not eliminate the need for on-site sampling, testing, and detailed study of specific sites.

Table 15: Percentage areas in the different relative risk categories for County Meath*

Relative risk category	MRP & Pathogens		Nitrate	
	Streams via surface pathway	Streams and wells via subsurface pathway	Streams via surface pathway	Streams and wells via subsurface pathway
Low	50.7	86.8	95.4	95.9
Moderate	10.0	3.5	0.4	0.1
High	6.8	2.0	0.1	0.2
Very High	28.9	4.0	0.5	0.1
Area Sewered	3.6	3.6	3.6	3.6

*Percentages may not sum to 100% due to rounding.

Table 16: Percentage areas in the different relative risk categories nationally*

Relative risk category	MRP & Pathogens		Nitrate	
	Streams via surface pathway	Streams and wells via subsurface pathway	Streams via surface pathway	Streams and wells via subsurface pathway
Low	63.1	89.0	97.2	97.4
Moderate	10.5	4.1	0.2	0.1
High	6.4	1.9	0.1	<0.1
Very High	17.5	2.6	0.1	<0.1
Area Sewered	2.4	2.4	2.4	2.4

*Percentages may not sum to 100% due to rounding.

Two national maps – Figures 13 and 14 – illustrate the relative risk of ponding and pollution of water by MRP and pathogens via surface and subsurface pathways, respectively. In general, the 'very high' risk ranking category coincides with areas where there is a relatively high density of DWWTSs and either a high likelihood of inadequate percolation or extreme groundwater vulnerability.

6.7 Next Steps

The output from the risk-based methodology will be used in developing the National Inspection Plan and in proposing the level of inspection, based on risk. Detailed criteria for site selection, which take account of sensitive receptors, have been developed for use in conjunction with the risk-based methodology. This will assist WSAs in identifying areas to focus inspections and achieve the maximum outcome for the environment.

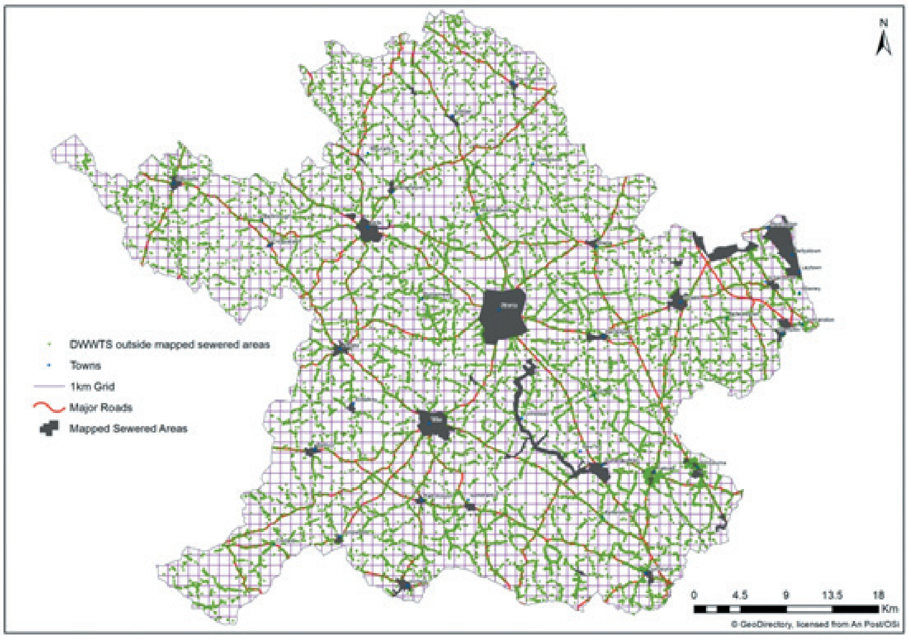

Figure 8: Map of housing density across County Meath

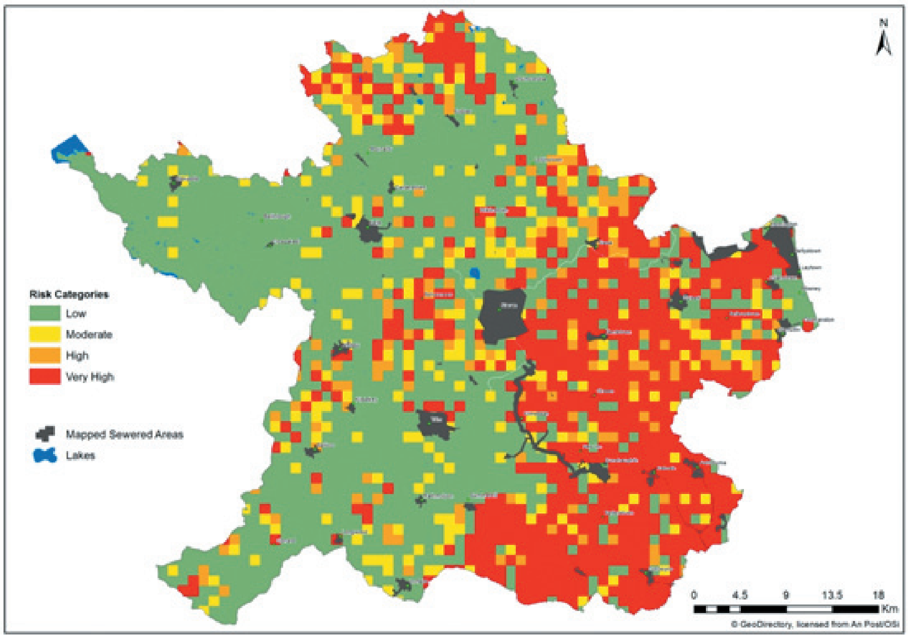

Figure 9: Relative risk of water pollution (streams) from MRP and pathogens in DWWTS waste water via the surface pathway in County Meath

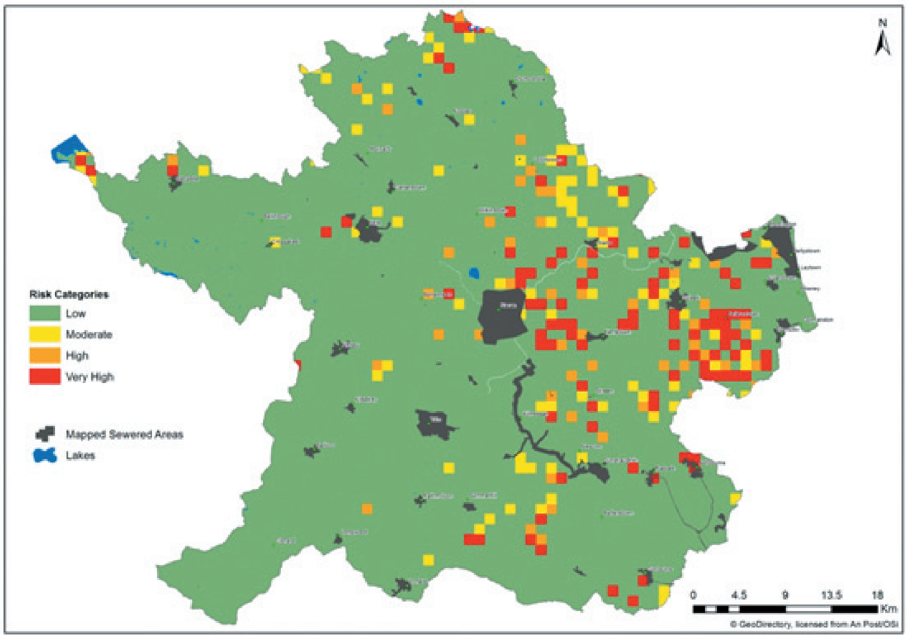

Figure 10: Relative risk of water pollution (streams and wells) from MRP and pathogens in DWWTS waste water via the subsurface pathway in County Meath

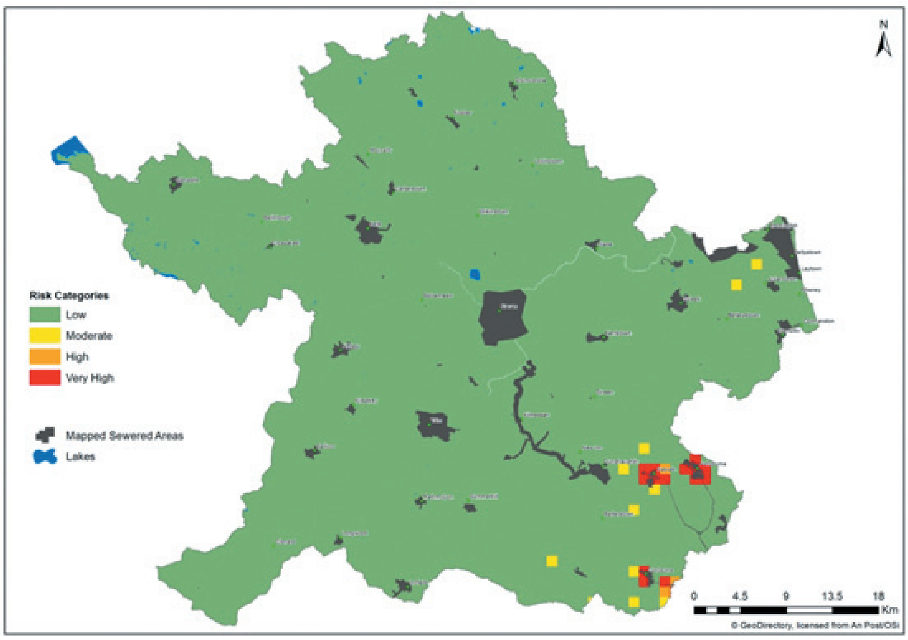

Figure 11: Relative risk of water pollution (streams) from nitrogen in DWWTS waste water via the surface pathway in County Meath

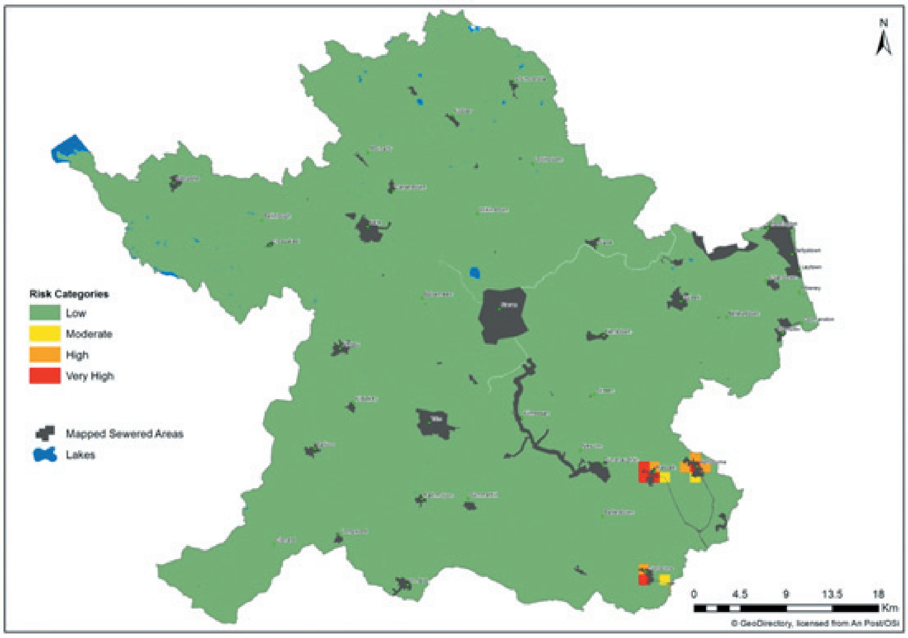

Figure 12: Relative risk of water pollution (streams and wells) from nitrogen in DWWTS waste water via the subsurface pathway in County Meath

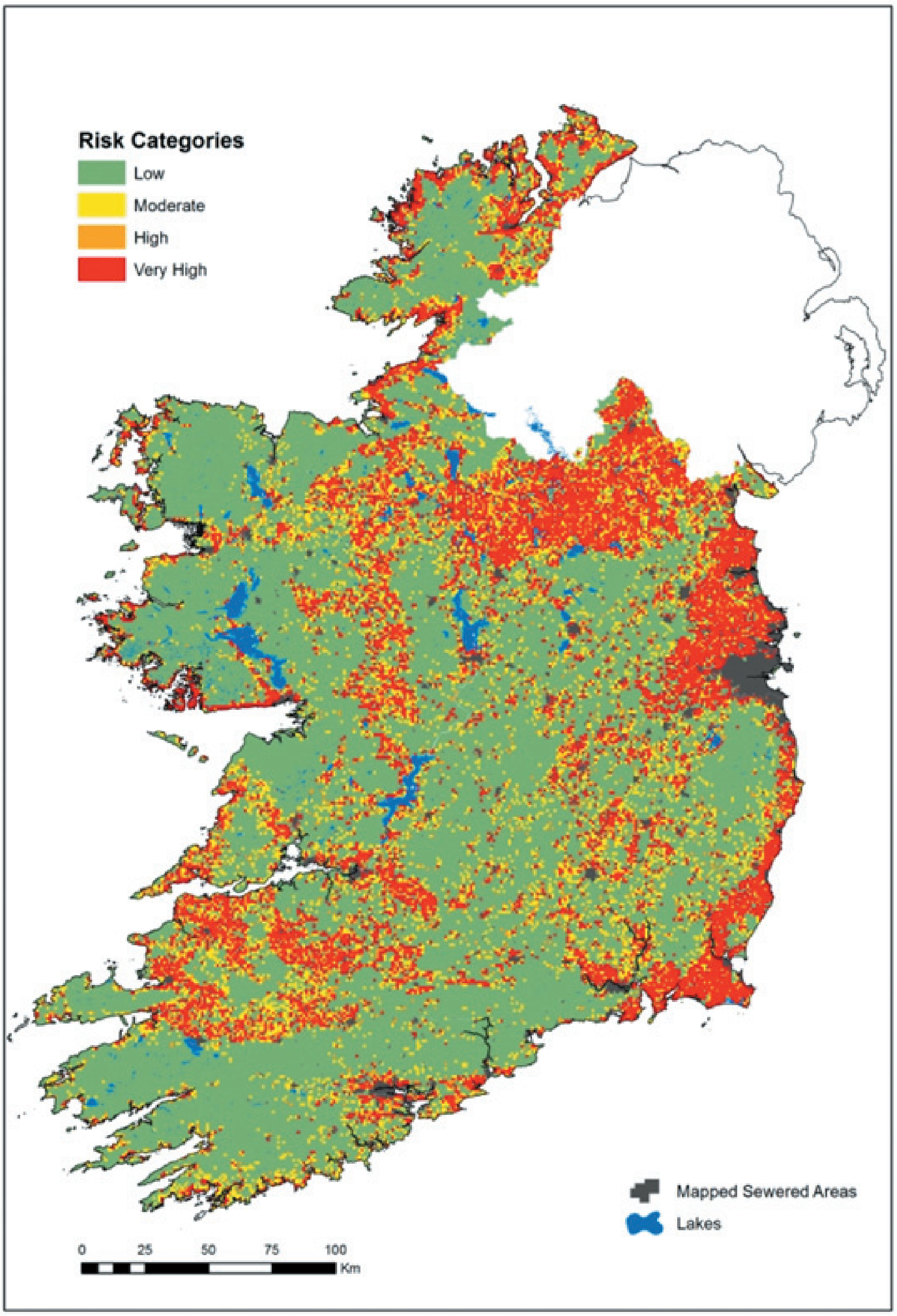

Figure 13: Relative risk of water pollution (streams) from MRP and pathogens in DWWTS waste water via the surface pathway

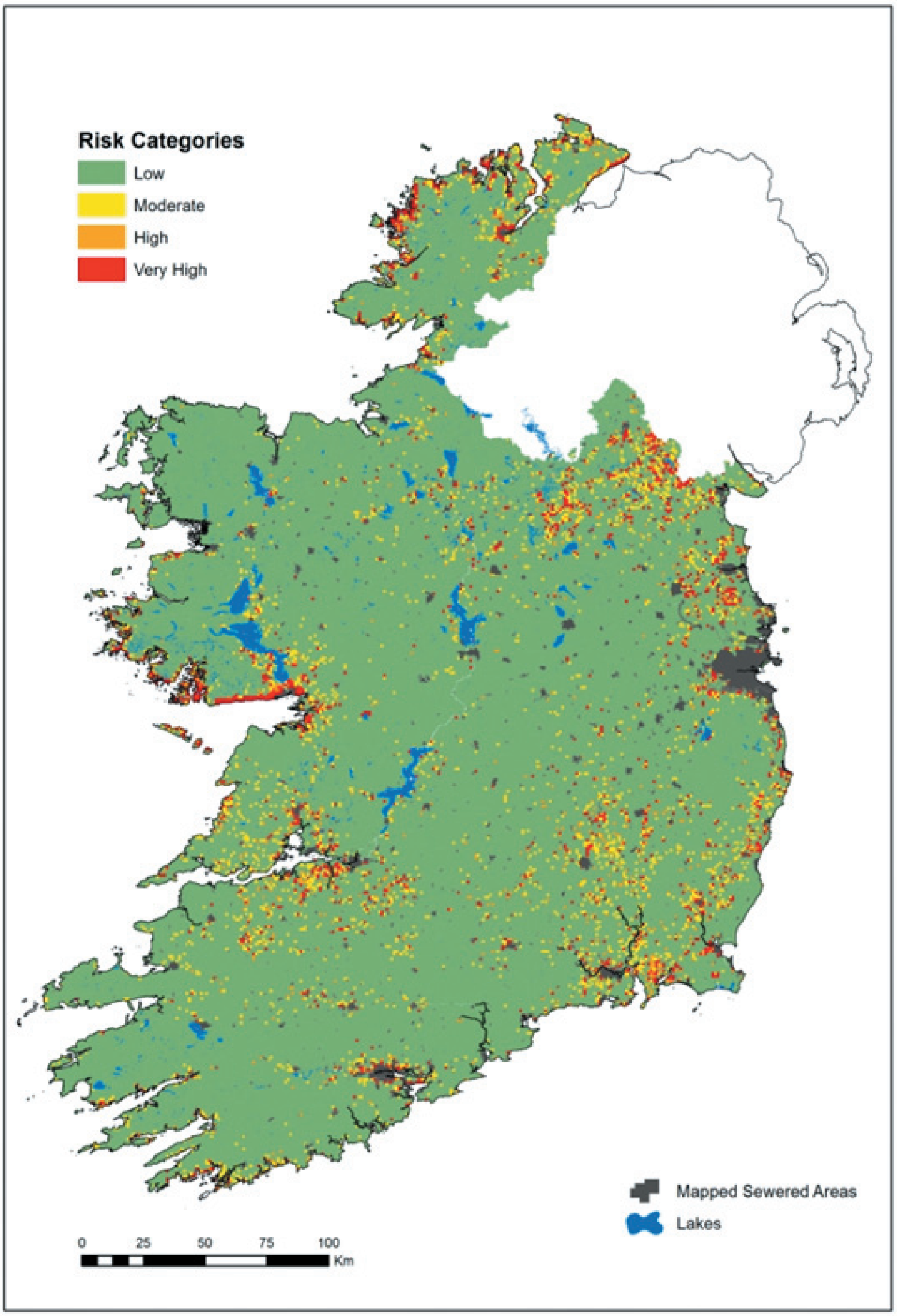

Figure 14: Relative risk of water pollution (streams and wells) from MRP and pathogens in DWWTS waste water via the subsurface pathway

7. Summary and Conclusions

- The aim of this report is to set out a methodology to enable the EPA to adopt a risk-based approach to organising inspections of DWWTSs, whereby the level of inspection will be proportionate to the risk posed to human health and the environment.
- The development of the methodology was influenced by:
  - the data and map information available as GIS datasets;
  - the current understanding of the hydrological and hydrogeological settings present in Ireland;
  - results of research undertaken in Ireland.
- The methodology is based on the source-pathway-receptor (S-P-R) model for environmental management.
- DWWTSs located, constructed and installed in accordance with the best practice guidance generally provide adequate treatment and disposal of domestic waste water. However, there are areas where the percolation characteristics are problematical due to the hydrogeology – the properties of the soils, subsoils and bedrock – resulting in inadequate percolation or over-rapid percolation. The methodology uses the available information to locate these areas.
- The risk ranking outcome is based on calculating the concentration of two pollutants – MRP and nitrate – in both surface water and groundwater arising from existing DWWTSs.
- The results for MRP are considered to reflect the likely presence of microbial pathogens and therefore the risk to human health from waste water that has not percolated underground.
- The approach uses a 1 km^2 area as appropriate to evaluating likely impacts from DWWTSs.
- The calculations take account of housing density, attenuation in both surface and subsurface pathways, dilution at the water receptor and predicted concentrations of pollutants in the water receptor.
- Four categories of risk are used: low, medium, high and very high.
- The results indicate that:
  - A substantial proportion of the country is problematical with regard to percolation characteristics.
  - The risk to human health from DWWTS waste water is significantly higher in areas with a high housing density and inadequate percolation; and/or where there are private wells in vulnerable areas.
  - MRP is the main pollutant posing a threat to the environment, particularly to surface water, either where there is inadequate percolation or where there is inadequate attenuation prior to entry of waste water into bedrock aquifers, particularly karstified (cavernous limestone) aquifers. While the cumulative pollutant load arising from DWWTSs will be insignificant compared to urban waste water treatment systems and agriculture at river basin scale, it can be significant in certain physical settings at small catchment scale.
- The next stage in the National Inspection Plan will be to apportion the level of inspections based on the risk ranking outcome. While this will be the main basis, account will be taken of sensitive receptors and the possibility of inadequate design and maintenance of systems in areas generally suitable for DWWTSs, and random inspections will be undertaken.

8. Glossary

Aquifer

A subsurface layer or layers of rock, or other geological strata, of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater (Groundwater Regulations, 2010).

Attenuation

A decrease in pollutant concentrations, flux, or toxicity as a function of physical, chemical and/or biological processes, individually or in combination, in the subsurface environment. Attenuation processes include dilution, dispersion, filtration, sorption, decay, and retardation.

Biomat

A biologically active layer that covers the bottom and sides of percolation trenches and penetrates a short distance in the percolation soil. It includes complex bacterial saccharides and accumulates organic substances as well as micro-organisms.

Conceptual Hydrogeological Model

A simplified representation or working description of how a real hydrogeological system is believed to behave on the basis of qualitative analysis of desk study information, field observations and field data. A quantitative conceptual model includes preliminary calculations of water balances, including groundwater flow.

Diffuse Sources

Diffuse sources of pollution are spread over wider geographical areas rather than at individual point locations. Diffuse sources include general land use activities and landspreading of industrial and municipal wastes and agricultural organic and inorganic fertilisers.

Domestic Waste Water

Waste water of a composition and concentration (biological and chemical) normally discharged by a household, and which originates predominantly from the human metabolism or from day-to-day domestic-type human activities, including washing and sanitation, but does not include fats, oils, grease or food particles discharged from a premises in the course of, or in preparation for, providing a related service or carrying on a related trade (Water Services Act, 2007).

Domestic Waste Water Treatment System (DWWTS)

A system involving physical, chemical, biological or thermal processes, or a combination of such processes, utilised for the treatment or disposal of domestic waste water, or the sludge derived from domestic waste water. This includes:

(a) all septic tanks and waste water tanks and systems receiving, storing, treating or disposing of domestic waste water and all drains associated with such tanks or systems,

and

(b) all drains associated with the discharge of domestic waste water, whether or not they discharge to a septic tank or waste water tank (i.e. including percolation area or polishing filter).

Down-gradient

The direction of decreasing groundwater levels, i.e. flow direction. Opposite of up-gradient.

Groundwater

All water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil (Groundwater Regulations, 2010).

Groundwater Dependent Terrestrial Ecosystems (GWDTEs)

These are groundwater dependent wetlands, whereby the dependency is on groundwater flow, level or chemistry as the controlling factors or qualifying interests of associated habitats. Examples are raised bogs, alkaline fens and turloughs. GWDTEs are listed on the EPA's register of protected areas in accordance with Regulation 8 of the Water Policy Regulations, 2003.

Groundwater Protection Scheme (GWPS)

A scheme comprising two principal components: a land surface zoning map which encompasses the hydrogeological elements of risk (of pollution); and a groundwater protection response matrix for different potentially polluting activities (DELG/EPA/GSI, 1999).

Groundwater Recharge

Two definitions: (a) the process of rainwater or surface water infiltrating to the groundwater table; (b) the volume (amount) of water added to a groundwater system.

Groundwater Resource

An aquifer capable of providing a groundwater supply of more than 10 m3 a day as an average or serving more than 50 persons.

Hydraulic Gradient

The change in total head of water with distance; the slope of the groundwater table or the piezometric surface.

Karst

A distinctive landform characterised by features such as surface collapses, sinking streams, swallow holes, caves, turloughs and dry valleys, and a distinctive groundwater flow regime where drainage is largely underground in solutionally enlarged fissures and conduits.

On-site Waste Water Treatment Systems (OSWTSs)

A generic term for small-scale waste water treatment systems associated with single houses and small communities or facilities, and mostly associated with septic tanks and intermittent filter systems offering secondary treatment of raw waste water effluent.

Pathway

The route that a particle of water and/or chemical or biological substance takes through the environment from a source to a receptor location. Pathways are determined by natural hydrogeological characteristics and the nature of the contaminant, but can also be influenced by the presence of features resulting from human activities (e.g. abandoned ungrouted boreholes which can direct surface water and associated pollutants preferentially to groundwater).

Percolation

The movement and filtering of fluids through porous materials; with regard to DWWTSs this refers to the movement and filtering through soil and/or subsoil.

Permeability

A measure of a soil or rock's ability or capacity to transmit water under a potential hydraulic gradient (synonymous with hydraulic conductivity).

Point Source

Any discernible, confined or discrete conveyance from which pollutants are or may be discharged. These may exist in the form of pipes, ditches, channels, tunnels, conduits, containers, and sheds, or as distinct percolation areas, integrated constructed wetlands, or other surface application of pollutants at individual locations. Examples are discharges from waste water works and effluent discharges from industry.

Pollution

The direct or indirect introduction, as a result of human activity, of substances or heat into the air, water or land which may be harmful to human health or the quality of aquatic ecosystems or terrestrial ecosystems directly depending on aquatic ecosystems which result in damage to material property, or which impair or interfere with amenities and other legitimate uses of the environment (Groundwater Regulations, 2010).

Poorly Productive Aquifers (PPAs)

Low-yielding bedrock aquifers that are generally not regarded as important sources of water for public water supply but that nonetheless may be important in terms of providing domestic and small community water supplies and of delivering water and associated pollutants to rivers and lakes via shallow groundwater pathways.

Population Equivalent (p.e.)

A conversion value that aims at evaluating non-domestic pollution in reference to domestic pollution fixed by EEC directive (Urban Waste Water Treatment Directive 91/271/EEC) at 60 g/day BOD.

Preferential Flow

A generic term used to describe water movement along favoured pathways through a geological medium, bypassing other parts of the medium. Examples include pores formed by soil fauna, plant root channels, weathering cracks, fissures and/or fractures.

Receptors

Receptors are existing and potential future groundwater resources, drinking water supplies (e.g. springs and abstraction wells), surface water bodies into which groundwater discharges (e.g. streams) and groundwater dependent terrestrial ecosystems (GWDTEs).

River Basin

The area of land from which all surface water runoff flows, through a sequence of streams, rivers and lakes, into the sea at a single river mouth, estuary or delta.

River Basin District (RBD)

A group of river basins formally defined by Water Policy (2003) for the purposes of reporting Water Framework Directive requirements to the European Commission.

Saturated Zone

The zone below the water table in an aquifer in which all pores and fissures and fractures are filled with water at a pressure that is greater than atmospheric.

Soil (topsoil)

The uppermost layer of the earth in which plants grow and which is capable of supporting life.

Source-Pathway-Receptor (S-P-R) Model

An S-P-R model involves identifying whether and how pollution sources are connected to a receptor via a pathway. A conceptual model provides an understanding of all the relationships between S-P-R factors in a particular hydrogeological setting.

Subsoil

Unlithified (uncemented) geological strata or materials beneath the topsoil and above bedrock.

Surface Water

An element of water on the land's surface such as a lake, reservoir, stream, river or canal. Can also be part of transitional or coastal waters (Surface Waters Regulations, 2009).

UK TAG

The United Kingdom Technical Advisory Group, a partnership of UK environment and conservation agencies set up to interpret and support the implementation of the Water Framework Directive. The EPA is an invited member of the UK TAG.

Unsaturated Zone

The zone between the land surface and the water table, in which pores, fractures and fissures are only partially filled with water. Also known as the vadose zone.

Vulnerability

The intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities (Fitzsimmons et al., 2003).

Water Table

The uppermost level of saturation in an aquifer at which the pressure is atmospheric.

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Appendix 1

Susceptibility Matrices

Table A1(a): Susceptibility of inadequate percolation for a single house treatment system in various settings across Ireland – Extreme groundwater vulnerability

Aquifer/Soil type: Vulnerability/Subsoil Permeability:	Karst (Rk, Lk) Dry soil	Karst (Rk, Lk) Wet soil	Sand and gravel (Rg, Lg) Dry soil	Sand and gravel (Rg, Lg) Wet soil
Extreme vulnerability (subsoil thickness 0–3 m and in vicinity of karst features) (Subsoil permeability variable and not considered in assessment; this should be considered in the site assessment)	Percolation rate depends on depth to bedrock, subsoil type and the potential presence of preferential flowpaths owing to shallow depths to bedrock but generally satisfactory; water table not a constraint; well-drained soils dominate as bedrock highly permeable.	Percolation rate moderate to low depending on time of year of test; water table <3 m from surface, generally owing to low-lying topography, and may be a constraint.	Percolation rate low and generally <10; well-drained soils dominate.	Percolation rate high and generally <10 depending on time of year of test; water table <3 m from surface, generally owing to low-lying topography, and may be a constraint.
Likelihood of inadequate percolation	Low	Moderate	Low	Moderate
Single house domestic waste water treatment system percolation issues	Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.	Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.

Productive bedrock (Rf, Lm) Dry soil	Productive bedrock (Rf, Lm) Wet soil	Poorly productive bedrock (Ll) Dry soil	Poorly productive bedrock (Ll) Wet soil	Poorly Productive Bedrock (Pl, Pu) Dry soil	Poorly Productive Bedrock (Pl, Pu) Wet soil
Percolation rate depends on depth to bedrock and subsoil type, but generally satisfactory; water table not a constraint; well-drained soils dominate as bedrock permeable.	Percolation rate depends on depth to bedrock and subsoil type; but generally satisfactory; water table potentially a constraint; saturated soils dominate.	Percolation rate variable and depends on permeability of upper bedrock layers; winter water table may be high in low lying or flat areas; lateral groundwater movement may be limited in some circumstances; variable soils or bare rock dominate.	Percolation rate variable and depends on permeability of upper bedrock layers; winter water table may be high in low lying or flat areas; lateral groundwater movement may be limited in some circumstances; variable soils or bare rock dominate.	Percolation rate variable and depends on permeability of upper bedrock layers; winter water table may be high in low lying or flat areas; lateral groundwater movement may be limited in some circumstances; variable soils or bare rock dominate.	Percolation rate variable but often problematical; lateral groundwater movement limited; rainfall runoff predominates; shallow water table especially in winter; poorly drained soils, peats or bare rock dominate.
Low	Moderate	Moderate	Moderate	Moderate	High
Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.	Percolation often inadequate and lateral groundwater movement often restricted, thereby giving rise to hydraulic issues.

Table A1(b): Susceptibility of inadequate percolation for a single house treatment system in various settings across Ireland – High-permeability subsoil

Aquifer/Soil type:	Karst (Rk, Lk)	Karst (Rk, Lk)	Sand and gravel (Rg, Lg)	Sand and gravel (Rg, Lg)
Vulnerability/Subsoil permeability:	Dry soil	Wet soil	Dry soil	Wet soil
High-permeability Subsoil (>3 m thick and with permeability >10^{-4} m/s); broadly equates to BS5930 GRAVEL, sandy GRAVEL and SAND	Percolation rate high and generally <10; >3 m of subsoil; water table not a constraint; well-drained soils dominate.	Percolation rate high and generally <10 depending on time of year of test; water table <3 m from surface, generally owing to low-lying topography, and may be a constraint.	Percolation rate high and generally <10; >3 m of subsoil; water table not a constraint; well-drained soils dominate.	Percolation rate high and generally <10 depending on time of year of test; water table <3 m from surface, generally owing to low-lying topography, and may be a constraint.
Likelihood of inadequate percolation	Low	Moderate	Low	Moderate
Single house domestic waste water treatment system percolation issues	Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.	Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.

Productive bedrock (Rf, Lm) Dry soil	Productive bedrock (Rf, Lm) Wet soil	Poorly productive bedrock (Ll) Dry soil	Poorly productive bedrock (Ll) Wet soil	Poorly Productive Bedrock (Pl, Pu) Dry soil	Poorly Productive Bedrock (Pl, Pu) Wet soil
Percolation rate high and generally <10; >3 m of subsoil; water table not a constraint; well-drained soils dominate.	Percolation rate high and generally <10 depending on time of year of test; water table <3 m from surface, generally owing to low-lying topography, and may be a constraint.	Percolation rate high and generally <10; >3 m of subsoil; water table not a constraint; well-drained soils dominate.	Percolation rate high and generally <10 depending on time of year of test; >3 m of subsoil; water table may be near-surface owing to low-lying topo-graphy; saturated soils dominate.	Percolation rate high and generally <10; >3 m of subsoil; water table not a constraint; well-drained soils dominate.	Percolation rate high and generally <10 depending on time of year of test; >3 m of subsoil; water table may be near-surface owing to low-lying topography; saturated soils dominate.
Low	Moderate	Low	Moderate	Low	Moderate
Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.	Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.	Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.

Table A1(c): Susceptibility of inadequate percolation for a single house treatment system in various settings across Ireland – Moderate-permeability subsoil

Aquifer/Soil type: Vulnerability/Subsoil permeability:	Karst (Rk, Lk) Dry soil	Karst (Rk, Lk) Wet soil	Sand and gravel (Rg, Lg) Dry soil	Sand and gravel (Rg, Lg) Wet soil
Moderate-permeability subsoil (subsoil >3 m thick and with permeability in range 10^{-4}–10^{-8} m/s). Broadly equates to BS5930; silty SAND, clayey SAND, SILT, sandy SILT, some SILT/CLAY and some sandy SILT/CLAY (as well as gravelly equivalents of each)	Percolation rate moderate, water table not a constraint; well-drained soils dominate.	Percolation rate moderate to low; water table potentially a constraint owing to low-lying topography; saturated soils dominate.	Limited to small areas of country only.	Limited to small areas of country only.
Likelihood of inadequate percolation	Low	Moderate	Moderate where this setting occurs	High where this setting occurs
Single House domestic waste water treatment system percolation issues	Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.	Limited to small areas of country.	Limited to small areas of country.

Productive bedrock (Rf, Lm) Dry soil	Productive bedrock (Rf, Lm) Wet soil	Poorly productive bedrock (Ll) Dry soil	Poorly productive bedrock (Ll) Wet soil	Poorly Productive Bedrock (Pl, Pu) Dry soil	Poorly Productive Bedrock (Pl, Pu) Wet soil
Percolation rate moderate; water table not a constraint; well drained soils usually dominate.	Percolation rate moderate to low; water table potentially a constraint owing to low-lying topography; saturated soils dominate.	Percolation rate moderate; water table not a constraint; well drained soils usually dominate.	Percolation rate low depending on time of year of test; water table probably a constraint owing to low-lying topography; saturated soils dominate.	Percolation rate moderate; water table not a constraint; well drained soils usually dominate.	Percolation rate low depending on time of year of test; water table probably a constraint owing to low-lying topography; saturated soils dominate.
Low	Moderate	Low	High	Low	High
Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.	Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.	Percolation generally adequate and no hydraulic issue.	Percolation may be variable and in low lying or flat areas hydraulic issues may arise; careful site assessments focusing on potential hydraulic problems required.

Table A1(d): Susceptibility of inadequate percolation for a single house treatment system in various settings across Ireland – Low-permeability subsoil

Aquifer/Soil type: Vulnerability/Subsoil permeability:	Karst (Rk, Lk) Dry soil	Karst (Rk, Lk) Wet soil	Sand and gravel (Rg, Lg) Dry soil	Sand and gravel (Rg, Lg) Wet soil
Low-permeability Subsoil (>3 m thick and with permeability <~10-8 m/s.); Broadly equates to BS 5930; some SILT/CLAY, some sandy SILT/CLAY, CLAY, sandy CLAY, CLAY, and the gravelly equivalents of each of these	Percolation rate very low except where bypass flow at karst features (e.g. swallow holes, dolines); rainfall runoff predominates; generally shallow 'perched' water table in winter; poorly drained soils dominate.	Percolation rate very low except where bypass flow at karst features (e.g. swallow holes, dolines); rainfall runoff predominates; generally shallow 'perched' water table in winter; poorly drained soils dominate.	Limited to small areas of country.	Limited to small areas of country.
Likelihood of inadequate percolation	Very high	Very high	Very high where this setting occurs	Very high where this setting occurs
Single house domestic waste water treatment system percolation issues	Percolation often inadequate and therefore saturated subsoil a constraint in winter. Hydraulic issues likely.	Percolation often inadequate and therefore saturated subsoil a constraint in winter. Hydraulic issues likely.	Limited to small areas of the country.	Limited to small areas of the country.

Productive bedrock (Rf, Lm) Dry soil	Productive bedrock (Rf, Lm) Wet soil	Poorly productive bedrock (Ll) Dry soil	Poorly productive bedrock (Ll) Wet soil	Poorly productive bedrock (Pl, Pu) Dry soil	Poorly productive bedrock (Pl, Pu) Wet soil
Percolation rate very low; rainfall runoff predominates; generally shallow 'perched' water table; poorly drained soils dominate.	Percolation rate very low; rainfall runoff predominates; generally shallow 'perched' water table; poorly drained soils dominate.	Percolation rate very low; rainfall runoff predominates; generally shallow 'perched' water table; poorly drained soils dominate.	Percolation rate very low; rainfall runoff predominates; generally shallow 'perched' water table; poorly drained soils dominate.	Percolation rate very low; rainfall runoff predominates; generally shallow 'perched' water table; poorly drained soils dominate.	Percolation rate very low; rainfall runoff predominates; generally shallow 'perched' water table; poorly drained soils dominate.
Very high	Very high	Very high	Very high	Very high	Very high
Percolation often inadequate and therefore saturated subsoil a constraint in winter. Hydraulic issues likely.	Percolation often inadequate and therefore saturated subsoil a constraint in winter. Hydraulic issues likely.	Percolation often inadequate and therefore saturated subsoil a constraint in winter. Hydraulic issues likely.	Percolation often inadequate and therefore saturated subsoil a constraint in winter. Hydraulic issues likely.	Percolation often inadequate and therefore saturated subsoil a constraint in winter. Hydraulic issues likely.	Percolation often inadequate and therefore saturated subsoil a constraint in winter. Hydraulic issues likely.

Table A2: Susceptibility of MRP and pathogens entering groundwater via subsurface pathways from a single house treatment system

Vulnerability/Subsoil permeability		Bedrock aquifers	Sand and gravel aquifers
Extreme vulnerability (X – subsoil thickness 0–1 m and in vicinity of karst features)		Very high	n/a
Extreme vulnerability (E – subsoil thickness 1—3 m)		High	High
High, moderate, low vulnerability	High subsoil permeability	Low	Low
	Moderate subsoil permeability	Low	Low
	Low subsoil permeability	Low	n/a

Table A3: Susceptibility of nitrate entering groundwater via subsurface pathways from a single house treatment system

Bedrock/Soil type Vulnerability/Subsoil permeability		Sand and gravel aquifers – dry soil	Sand and gravel aquifers – wet soil	Bedrock aquifers – dry soil Includes most bedrock types	Bedrock aquifers – wet soil Includes most bedrock types	'Denitrifying' bedrock aquifers Includes rocks that remove nitrate through chemical reactions
Extreme vulnerability (X and E – subsoil thickness 0–3 m and in vicinity of karst features)		Very high	Low	Very high	Low	Low
High, moderate, low vulnerability	High subsoil permeability	Very high	Low	Very high	Low	Moderate
	Moderate subsoil permeability	Very high	Low	Very high	Low	Low
	Low subsoil permeability	n/a	n/a	Low	Low	Low

Appendix 2

Bedrock Types that are Rich in Pyrite and Hence Denitrify ('Denitrifying' Bedrock Aquifers)

Impure Limestones

Ballina Limestone Formation

Ballymartin Formation

Ballysteen Formation

Calp

Finlough Formation

Loughshinny Formation

Lucan Formation

Parsonage and Corgrig Lodge Formation

Dinantian (early) Sandstones, Shales and Limestones

Lower Limestone Shale

Namurian Sandstones

Ballynahown Sandstone Formation

Cloone Flagstone Formation

Feale Sandstone Formation

Namurian Shales

Ardagh Shale Formation

Bencroy Shale Formation

Clare Shale Formation

Craggagh Shale Formation

Dergvone Shale Formation

East Point Formation

Giants Grave Formation

Glenoween Shale Formation

Gowlaun Shale Formation

Killeshin Siltstone Formation

Lackantedane Formation

Longstone Shale Member

Luggacurren Shale Formation

Moanour Formation

Westphalian Shales

Coolbaun Formation

Moyadd Coal Formation

Westphalian (undifferentiated)

Ordovician Volcanics

Aghamore Formation

Avoca Formation

Ballyhoge Formation

Ballymalone Formation

Dunabrattin Formation

Tawnyinagh Formation

Ordovician Metasediments

Carrickatee Formation

Carrighalia Formation

Hornfels in Finnlaghhta Formation

Kehernaghkilly Formation

Laragh Formation

One Brook Formation

Toberelatan Formation

Silurian Metasediments and Volcanics

Aghaward Formation

Basalts and other volcanic rocks

Carrigcleenamore Volcanics

Precambrian Quartzites, Gneisses and Schists

Cornamona Marble Formation

Precambrian Marbles

Lakes Marble Formation

Granites and other igneous intrusive rocks

Crossdoney Granite

Appendix 3

Worked Example of Calculations of Load Input, Attenuation, Dilution and Impact Risk for an Area

Step 1: Calculation of Load Input for an Area of 1 km2.*

Load = (load per person (kg/yr)) x (number of persons per house) x (density of houses (per km^2)) = kg/km^2/yr

Housing density is 20 houses per km^2.

N Load = 2.7 kg/yr x 2.8 persons per house x 20 houses/km^2 = 151.2 kg/km^2/yr

MRP Load = 0.5 kg/yr x 2.8 persons per house x 20 houses/km2 = 28 kg/km^2/yr

** A 1 km^2 grid was taken as the most appropriate for the analysis.*

Step 2: Calculation of Load Following Attenuation *(Surface Pathway)*

Load following Attenuation (Groundwater Pathway) = Load Input (kg/km^2/yr) x (% of Load leaving Septic Tank that will reach receptor based on Susceptibility Risk) x (% of Load that will NOT be removed in overland flow)

(i) **N Load**

N Load = 151.2 kg/km2/yr and there is LOW Susceptibility for N
N Load following attenuation = 151.2 kg/km^2/yr X 5% X75% = 5.67 kg/km^2/yr

(ii) **MRP Load**

MRP Load = 28 kg/km^2/yr and there is MODERATE Susceptibility for MRP
MRP Load following attenuation = 28 kg/km2/yr X 25% X 75% = 5.25 kg/km^2/yr

The example is simplified to a certain degree to demonstrate the methodology used. The load following attenuation will be calculated for each DWWTS individually and aggregated over the given grid square. This would allow for taking account of variation in susceptibility ranking within a given area.

Step 3: Calculation of Load Following Attenuation *(Subsurface Pathway)*.

Load following Attenuation (Subsurface Pathway) = Load Input (kg/km2/yr) x (% of Load leaving Septic Tank that will reach receptor based on Susceptibility Risk)

(i) **N Load**

N Load = 151.2 kg/km^2/yr and there is VERY HIGH Susceptibility for N
N Load following attenuation = 151.2 kg/km^2/yr x 30% = 45.36 kg/km^2/yr

(ii) **MRP Load**

MRP Load = 28 kg/km^2/yr and there is VERY HIGH Susceptibility for MRP
MRP Load following attenuation = 28 kg/km^2/yr x 90% = 25.2 kg/km^2/yr

The example is simplified to a certain degree to demonstrate the methodology used. The load following attenuation will be calculated for each domestic waste water treatment system individually and aggregated over the given grid square. This would allow for taking account of variation in susceptibility ranking within a given area.

Step 4: Calculation of Dilution of Load and Resultant Concentration

Surface Pathway

$$\text{Dilution Volume}\left(\frac{\frac{m^3}{km^2}}{yr}\right) = \frac{\text{Effective Rainfall}\left(\frac{mm}{yr}\right)}{1{,}000\left(\frac{mm}{m}\right)} \text{ x (Area } (km^2) \text{ x } (1{,}000{,}000\ (m^2)) \text{ x Low Flow Reduction Factor}$$

Effective Rainfall = 500 mm/yr; Low Flow reduction Factor =0.22

Dilution Volume (at low flow) per 1km2 area = (500/1,000)*(1*1,000,000)*0.22= 110,000 m^3

$$\text{Concentration}\left(\frac{mg}{l}\right) = \frac{\text{Load following attentuation}\left(\frac{kg}{yr}\right) \text{ x } 1{,}000{,}000\left(\frac{mg}{kg}\right)}{\text{Dilution Volume}\left(\frac{\frac{m^3}{km^2}}{yr}\right) \text{ x } 1{,}000\left(\frac{l}{m^3}\right)} \quad \text{N}$$

Load following attenuation = 5.67 kg/km^2/yr

N Concentration (Surface water) = (5.67*1,000,000)/(110,000*1,000) = 0.052 mg/l N

MRP Load following attenuation = 5.25 kg/km^2/yr

MRP Concentration (Surface water) = (5.25*1,000,000)/(110,000*1,000) = 0.048 mg/l P

Subsurface Pathway

$$\text{Dilution Volume}\left(\frac{\frac{m^3}{km^2}}{yr}\right) = \frac{\text{Recharge}\left(\frac{mm}{yr}\right)}{1{,}000\left(\frac{mm}{m}\right)} \text{ x (Area } (km^2) \text{ x } 1{,}000{,}000\ (m^2))$$

Recharge = 350 mm/yr

Annual Dilution Volume per 1km² area = (350/1,000)*(1*1,000,000) = 350,000 m^3

$$\text{Concentration}\left(\frac{mg}{l}\right) = \frac{\text{Load following attentuation}\left(\frac{kg}{yr}\right) \text{ x } 1{,}000{,}000\left(\frac{mg}{kg}\right)}{\text{Dilution Volume}\left(\frac{\frac{m^3}{km^2}}{yr}\right) \text{ x } 1{,}000\left(\frac{l}{m^3}\right)} \quad \text{N}$$

Load following attenuation = 45.36 kg/km^2/yr

N Concentration (Groundwater) = (45.36*1,000,000)/(350,000*1,000) = 0.130 mg/l N

MRP Load following attenuation = 25.2 kg/km^2/yr

MRP Concentration (Groundwater) = (25.2*1,000,000)/(350,000*1,000) = 0.072 mg/l P

Step 5: Summary and Risk Derived from Proposed Risk Ranking

Surface Pathway

From earlier steps: Density = 20 houses per km^2; Effective Rainfall = 500 mm/yr; LOW Susceptibility for N; MODERATE Susceptibility for MRP

N Concentration (Surface water) = 0.052 mg/l N – **Impact Risk = LOW**

MRP Concentration (Surface water) = 0.048 mg/l P – **Impact Risk = VERY HIGH**

Subsurface Pathway

From earlier steps: Density = 20 houses per km^2; Recharge = 350 mm/yr; VERY HIGH Susceptibility for N; VERY HIGH Susceptibility for MRP

N Concentration (Groundwater) = 0.130 mg/l N – **Impact Risk = LOW**

MRP Concentration (Groundwater) = 0.072 mg/l P – **Impact Risk = VERY HIGH**

Appendix 4

Examples of the Output of the Excel Workbook for Surface and Subsurface Pathways

SUBSURFACE Pathway					
Pollutant	MRP				
Load kg per Person/year (in liquid effluent leaving Septic Tank)	0.5				
Persons Per House	2.8				
PATHWAY	% of Load that will NOT be removed by travel through subsurface pathway (ie % of Load leaving Septic Tank that will reach receptor)				
LOW Susceptibility	0				
HIGH Susceptibility	10				
VERY HIGH Susceptibility	90	P Impact Risk Ranking			
Recharge mm/yr	350	<0.015	0.015-0.025	0.025-0.035	>0.035

		LOAD in Groundwater kg P per year/km²			Concentration in Groundwater mg/l P		
Housing density (per km²)	LOAD kg P per year/ km²	LOW MRP Susceptibility	HIGH MRP Susceptibility	VERY HIGH MRP Susceptibility	LOW MRP Susceptibility	HIGH MRP Susceptibility	VERY HIGH MRP Susceptibility
2	3	0	0	3	0.000	0.001	0.007
4	6	0	1	5	0.000	0.002	0.014
6	8	0	1	8	0.000	0.002	0.022
8	11	0	1	10	0.000	0.003	0.029
10	14	0	1	13	0.000	0.004	0.036
12	17	0	2	15	0.000	0.005	0.043
14	20	0	2	18	0.000	0.006	0.050
16	22	0	2	20	0.000	0.006	0.058
18	25	0	3	23	0.000	0.007	0.065
20	28	0	3	25	0.000	0.008	0.072
22	31	0	3	28	0.000	0.009	0.079
24	34	0	3	30	0.000	0.010	0.086
26	36	0	4	33	0.000	0.010	0.094
28	39	0	4	35	0.000	0.011	0.101
30	42	0	4	38	0.000	0.012	0.108
32	45	0	4	40	0.000	0.013	0.115
34	48	0	5	43	0.000	0.014	0.122
36	50	0	5	45	0.000	0.014	0.130
38	53	0	5	48	0.000	0.015	0.137
40	56	0	6	50	0.000	0.016	0.144
42	59	0	6	53	0.000	0.017	0.151
44	62	0	6	55	0.000	0.018	0.158
46	64	0	6	58	0.000	0.018	0.166
48	67	0	7	60	0.000	0.019	0.173
50	70	0	7	63	0.000	0.020	0.180

SUBSURFACE Pathway						
Pollutant	N					
Load kg per Person/year (in liquid effluent leaving Septic Tank)	2.7					
Persons Per House	2.8					
PATHWAY	% of Load that will NOT be removed by travel through subsurface pathway (ie % of Load leaving Septic Tank that will reach receptor)					
LOW Susceptibility	10					
MODERATE Susceptibility	15					
VERY HIGH Susceptibility	30	N Impact Risk Ranking				
Recharge mm/yr	350	<2	2-3.5	3.5-5	>5.6	

		LOAD in Groundwater kg N per year/km²			Concentration in Groundwater mg/l N		
Housing density (per km²)	LOAD kg N per year/ km²	LOW N Susceptibility	HIGH N Susceptibility	VERY HIGH N Susceptibility	LOW N Susceptibility	HIGH N Susceptibility	VERY HIGH N Susceptibility
2	15	2	2	5	0.004	0.006	0.013
4	30	3	5	9	0.009	0.013	0.026
6	45	5	7	14	0.013	0.019	0.039
8	60	6	9	18	0.017	0.026	0.052
10	76	8	11	23	0.022	0.032	0.065
12	91	9	14	27	0.026	0.039	0.078
14	106	11	16	32	0.030	0.045	0.091
16	121	12	18	36	0.035	0.052	0.104
18	136	14	20	41	0.039	0.058	0.117
20	151	15	23	45	0.043	0.065	0.130
22	166	17	25	50	0.048	0.071	0.143
24	181	18	27	54	0.052	0.078	0.156
26	197	20	29	59	0.056	0.084	0.168
28	212	21	32	64	0.060	0.091	0.181
30	227	23	34	68	0.065	0.097	0.194
32	242	24	36	73	0.069	0.104	0.207
34	257	26	39	77	0.073	0.110	0.220
36	272	27	41	82	0.078	0.117	0.233
38	287	29	43	86	0.082	0.123	0.246
40	302	30	45	91	0.086	0.130	0.259
42	318	32	48	95	0.091	0.136	0.272
44	333	33	50	100	0.095	0.143	0.285
46	348	35	52	104	0.099	0.149	0.298
48	363	36	54	109	0.104	0.156	0.311
50	378	38	57	113	0.108	0.162	0.324

SURFACE Pathway			
Pollutant		MRP	
Load kg per Person/year (in liquid effluent leaving Septic Tank)		0.5	
Persons Per House		2.8	
PATHWAY	% of Load that will NOT be removed by travel through subsurface pathway	% of Load that will NOT be removed in overland flow	% of Load Leaving Septic tank that will reach receptor
LOW Susceptibility	5	75	4
MODERATE Susceptibility	25		19
HIGH Susceptibility	50		38
VERY HIGH Susceptibility	80		60
Effective Rainfall mm/yr	500		
Low Flow reduction factor (Q90/Q50)	0.22		

N Impact Risk ranking			
<0.015	0.015-0.025	0.025-0.035	>0.035

		LOAD to Surfacewater kg P per year/km²				Low Flow Concentration in Surfacewater mg/l P			
Housing density (per km²)	LOAD kg P per year/ km²	LOW Susceptibility	MODERATE Susceptibility	HIGH Susceptibility	VERY HIGH Susceptibility	LOW Susceptibility	MODERATE Susceptibility	HIGH Susceptibility	VERY HIGH Susceptibility
2	3	0.11	0.53	1.05	1.68	0.001	0.005	0.010	0.015
4	6	0.21	1.05	2.10	3.36	0.002	0.010	0.019	0.031
6	8	0.32	1.58	3.15	5.04	0.003	0.014	0.029	0.046
8	11	0.42	2.10	4.20	6.72	0.004	0.019	0.038	0.061
10	14	0.53	2.63	5.25	8.40	0.005	0.024	0.048	0.076
12	17	0.63	3.15	6.30	10.08	0.006	0.029	0.057	0.092
14	20	0.74	3.68	7.35	11.76	0.007	0.033	0.067	0.107
16	22	0.84	4.20	8.40	13.44	0.008	0.038	0.076	0.122
18	25	0.95	4.73	9.45	15.12	0.009	0.043	0.086	0.137
20	28	1.05	5.25	10.50	16.80	0.010	0.048	0.095	0.153
22	31	1.16	5.78	11.55	18.48	0.011	0.053	0.105	0.168
24	34	1.26	6.30	12.60	20.16	0.011	0.057	0.115	0.183
26	36	1.37	6.83	13.65	21.84	0.012	0.062	0.124	0.199
28	39	1.47	7.35	14.70	23.52	0.013	0.067	0.134	0.214
30	42	1.58	7.88	15.75	25.20	0.014	0.072	0.143	0.229
32	45	1.68	8.40	16.80	26.88	0.015	0.076	0.153	0.244
34	48	1.79	8.93	17.85	28.56	0.016	0.081	0.162	0.260
36	50	1.89	9.45	18.90	30.24	0.017	0.086	0.172	0.275
38	53	2.00	9.98	19.95	31.92	0.018	0.091	0.181	0.290
40	56	2.10	10.50	21.00	33.60	0.019	0.095	0.191	0.305
42	59	2.21	11.03	22.05	35.28	0.020	0.100	0.200	0.321
44	62	2.31	11.55	23.10	36.96	0.021	0.105	0.210	0.336
46	64	2.42	12.08	24.15	38.64	0.022	0.110	0.220	0.351
48	67	2.52	12.60	25.20	40.32	0.023	0.115	0.229	0.367
50	70	3	13	26	42	0.024	0.119	0.239	0.382

SURFACE Pathway			
Pollutant		N	
Load kg per Person/year (in liquid effluent leaving Septic Tank)		2.7	
Persons Per House		2.8	
PATHWAY	% of Load that will NOT be removed by travel through subsurface pathway	% of Load that will NOT be removed in overland flow	% of Load Leaving Septic tank that will reach receptor
LOW Susceptibility	5	75	4
MODERATE Susceptibility	25		19
HIGH Susceptibility	50		38
VERY HIGH Susceptibility	80		60
Effective Rainfall mm/yr	500		
Low Flow reduction factor (Q90/Q50)	0.22		

N Impact Risk ranking			
<2	2-3.6	3.6-5.6	>5.6

		LOAD to Surfacewater kg N per year/km2				Low Flow Concentration in Surfacewater mg/l N			
Housing density (per km²)	LOAD kg N per year/ km²	LOW Susceptibility	MODERATE Susceptibility	HIGH Susceptibility	VERY HIGH Susceptibility	LOW Susceptibility	MODERATE Susceptibility	HIGH Susceptibility	VERY HIGH Susceptibility
2	15	0.57	2.84	5.67	9.07	0.005	0.026	0.052	0.082
4	30	1.13	5.67	11.34	18.14	0.010	0.052	0.103	0.165
6	45	1.70	8.51	17.01	27.22	0.015	0.077	0.155	0.247
8	60	2.27	11.34	22.68	36.29	0.021	0.103	0.206	0.330
10	76	2.84	14.18	28.35	45.36	0.026	0.129	0.258	0.412
12	91	3.40	17.01	34.02	54.43	0.031	0.155	0.309	0.495
14	106	3.97	19.85	39.69	63.50	0.036	0.180	0.361	0.577
16	121	4.54	22.68	45.36	72.58	0.041	0.206	0.412	0.660
18	136	5.10	25.52	51.03	81.65	0.046	0.232	0.464	0.742
20	151	5.67	28.35	56.70	90.72	0.052	0.258	0.515	0.825
22	166	6.24	31.19	62.37	99.79	0.057	0.284	0.567	0.907
24	181	6.80	34.02	68.04	108.86	0.062	0.309	0.619	0.990
26	197	7.37	36.86	73.71	117.94	0.067	0.335	0.670	1.072
28	212	7.94	39.69	79.38	127.01	0.072	0.361	0.722	1.155
30	227	8.51	42.53	85.05	136.08	0.077	0.387	0.773	1.237
32	242	9.07	45.36	90.72	145.15	0.082	0.412	0.825	1.320
34	257	9.64	48.20	96.39	154.22	0.088	0.438	0.876	1.402
36	272	10.21	51.03	102.06	163.30	0.093	0.464	0.928	1.485
38	287	10.77	53.87	107.73	172.37	0.098	0.490	0.979	1.567
40	302	11.34	56.70	113.40	181.44	0.103	0.515	1.031	1.649
42	318	11.91	59.54	119.07	190.51	0.108	0.541	1.082	1.732
44	333	12.47	62.37	124.74	199.58	0.113	0.567	1.134	1.814
46	348	13.04	65.21	130.41	208.66	0.119	0.593	1.186	1.897
48	363	13.61	68.04	136.08	217.73	0.124	0.619	1.237	1.979
50	378	14	71	142	227	0.129	0.644	1.289	2.062

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil, Pobal agus Rialtais Áitiúil.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail.
- scardadh dramhuisce

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain.
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce.
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

- Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.
- Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:
- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide
- Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

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