SECTION 10: DRINKING WATER SAFETY PLANS

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Section 10: Drinking water safety plans

Summary of Section 10

- Summarises the drinking water safety plan (DWSP) approach as advocated by the World Health Organisation (WHO) and adopted and recommended by the Environment Protection Agency (the EPA).
- Describes the key steps in developing a DWSP.
- Sets out the general principles of risk assessments and control measures covering catchment/water source, treatment works, distribution networks and consumers' premises.
- Gives examples of risks and control measures for each of these parts of the water supply system.
- Describes the WHO qualitative risk scoring matrix and gives as an example a possible quantitative risk scoring matrix.
- Gives advice on documentation of the DWSP.
- Appendix 1 sets out the risk screening methodology for *Cryptosporidium*, including all the factors that need to be considered for the catchment/water source, treatment works and distribution network risks and how to calculate the risk scores for both surface water supplies and groundwater supplies.

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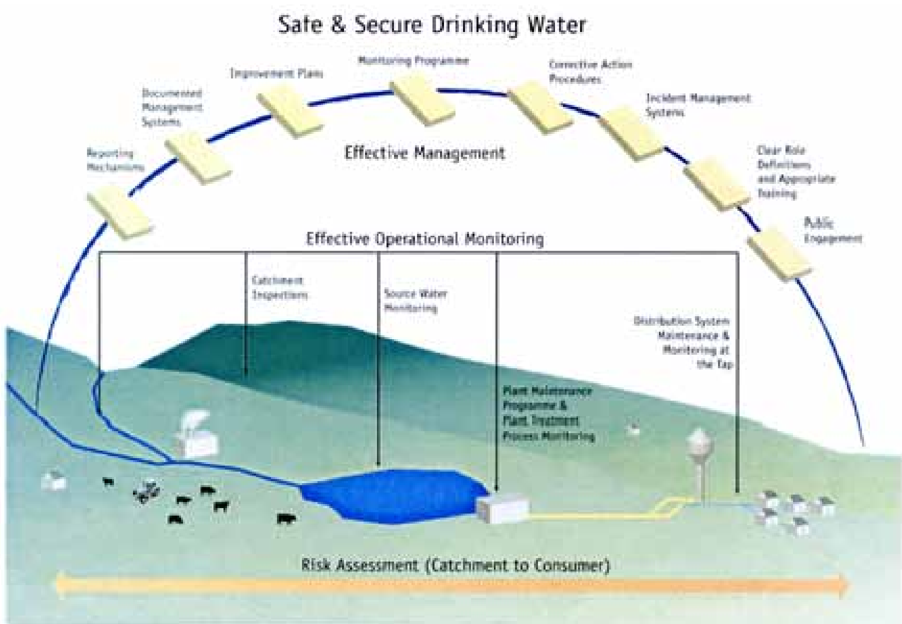
1. Introduction

1.1 | The Environment Protection Agency (the EPA) has adopted a **drinking water safety plan (DWSP) approach** to ensuring drinking water is both "safe" and "secure". A drinking water supply is deemed to be "safe" if it meets the standards and indicator parameter values in part 1 of the schedule to the Regulations each time the supply is monitored. A drinking water supply is deemed to be "secure" if there is in place a management system that has identified all potential risks from the catchment of the source, through the treatment works and distribution network, to the consumers' premises and has procedures in place to manage these risks.

1.2 | The essential components of a DWSP approach are shown in figure 1. This approach is based on the World Health Organisation (WHO) criteria for a safe and secure drinking water supply set out in the 2004 WHO Guidelines for Drinking Water Quality (***http://www.who.int/water_sanitation_health/gdwq3rev/en/index/html***).

Figure 1: The essential components of a DWSP



1.3 | The WHO has set out three essential components for a safe and secure drinking water supply. These are:

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- **Risk assessment of water supplies from catchment to consumer** – Identification and assessment of all risks in the catchment, treatment plant and distribution network up to the tap that may result in a risk to health and/or a breach of the required standard.

- **Effective operational monitoring** – Inspection of the catchment, reservoirs, treatment plant and distribution network to detect pollution, equipment failure or chemical dosing faults; followed by prompt and effective corrective actions where problems have been identified.

- **Effective management** – Competent management of the supply during normal and abnormal conditions, regular and accurate reporting of treatment plant and distribution network operations and personnel trained and resourced to deliver clean and wholesome drinking water.

1.4 | The EPA regards the implementation of the WHO recommendations by WSAs as part of a robust DWSP as a key measure to ensuring the delivery of a safe and secure water supply. The Regulations implement EU Directive 98/83/EC on the quality of water for human consumption. The European Commission has initiated a review of the Directive and it has been proposed that any future revision of the Directive should include a requirement on Member States to ensure that their water suppliers prepare and implement DWSPs. **The EPA therefore recommends that WSAs adopt the DWSP approach to ensuring safe and secure water supplies.** This section provides guidance to WSAs on preparing DWSPs. The EPA circular letter (September 2009) recommends that WSAs also use the new guidance in the 2009 WHO "Water Safety Plan Manual – a step by step risk management for drinking water suppliers" (***http://whqlibdoc.who.int/publications/2009/9789241562638_eng.pdf***).

2. Key steps in developing a DWSP

2.1 The following are the key steps in preparing a DWSP:

- assemble a **small team of experts** from the WSA and when necessary with external organisations, such as relevant organisations involved in River Basin Management Plans for catchment control and the Health Service Executive (the HSE) for health risks, to prepare the DWSP;

- **document and describe the system** – catchment, water source, treatment works, distribution network and consumers' premises;
- undertake a **risk assessment** by identifying the **hazards** that could occur and assessing the **likelihood** of them occurring at each stage of the water supply process;
- identify the **control measures** to minimise any unacceptable risks for each stage of the water supply process;
- define the **operational monitoring** of the control measures to check that they are minimising risks – this requires setting warning and alarm limits for unacceptable performance;
- establish procedures to **verify** that the DWSP is working effectively to deliver safe and secure water that meets the standards and other requirements, such as inspections, audits and monitoring;
- develop **supporting programmes** such as training, hygienic practices, standard operating protocols etc;
- prepare **management procedures**, including corrective actions, to deal with normal and incident/emergency conditions; and
- **document the DWSP.**

3. General principles of risk assessments and control measures

3.1 Introduction

3.1.1 | There are a number of significant factors that should be taken into account in any risk assessment from water source to consumers' taps. These factors are outlined below. A specific example of the application of these factors to risk assessment for *Cryptosporidium* is given in Appendix 1.

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3.2 Catchment and water source

Catchment factors

3.2.1 | The nature of the catchment and activities and events in the catchment can have a significant effect on the quality of water source in the catchment. Important factors are:

- **geology and hydrogeology** – determines whether potentially harmful natural substances are likely to be present in significant concentrations in water sources such arsenic, fluoride, uranium and radon and whether substances that could affect the aesthetic quality of water supplies are likely to be present such as peat colour, iron and manganese;
- **animals** – high numbers of farmed or wild animals including birds roosting on raw water reservoirs can cause a deterioration of the microbiological quality of water sources, particularly in relation to *Cryptosporidium*;
- **other agricultural practices** – such as:
    - storage of slurry or dung presents a risk of microbiological contamination, particularly as many stores are not secure from leakage from rainwater;
    - widespread slurry or dung spreading presents a risk of microbiological contamination; and
    - use of fertilisers and pesticides presents a risk of contamination by nitrate and pesticides;
- **discharges** – such as:
    - sewage works effluents, septic tank effluents and other small on-site sewage treatment systems can present a risk of microbiological contamination, particularly when not operated satisfactorily;
    - effluents from industrial premises can present a risk of chemical and other types of contamination depending on the nature of the industrial process and the substances used;

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- from mining, quarrying and similar activities, particularly when abandoned, can present risks of chemical contamination; and
- surface water and storm water overflows in urbanised areas.

Type of water source

3.2.2 | Some types of water source are at greater risk of contamination than other types for example:

- **deep boreholes and wells** – generally they are secure and present little risk unless the hydrogeology is considered vulnerable to activities on the surface;
- **shallow boreholes and wells** – generally these are less secure and present more of a risk unless the hydrogeology is considered not to be vulnerable to activities on the surface;
- **springs** – risk depends on the security of the spring, which in turn depends on whether the hydrogeology is considered vulnerable;
- **upland surface waters** – risk depends on the nature of, and activities in the catchment and whether collected in an impounding reservoir (less risk – balancing of quality) or abstracted directly from the river/stream (more risk of contamination and variable quality); and
- **lowland surface waters** – risk depends on nature of, and activities in, catchment and whether long-term storage (lower risk), bank side short-term storage (medium risk) or direct abstraction (higher risk).

Monitoring of the water source

3.2.3 | Risk is reduced when there is appropriate continuous or semi-continuous monitoring of the quality of the water source and that information is used either:

- to automatically or manually shut the intake under poor source water quality conditions; or
- to adjust the treatment processes in order to cater for deteriorating source water quality

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3.2.4 | Such monitoring would normally be used on direct abstraction surface water sources and significant surface water sources with short-term bank side storage. However, they could also be used on vulnerable boreholes, wells and springs.

Catchment control measures

3.2.5 | Whenever possible and practical catchment control measures should be used to minimise catchment risks to avoid having to install expensive treatment processes. Some examples of effective catchment and source protection and control are:

- developing and implementing a catchment management plan which includes control measures to protect ground waters and surface water including for example discharge consents, restriction on the use of chemicals, restriction on certain activities etc;
- use of planning Regulations to avoid activities that could pollute catchments, lakes and raw water reservoirs;
- management of raw water reservoirs such as mixing and destratification to minimise algal blooms and solubilisation of sedimentary iron and manganese; and
- Promoting awareness in the community of the impact of human, agricultural and industrial activity on water quality and where necessary controlling such activity.

3.2.6 | Some of these measures are not within the control of the WSAs and will require co-operation and liaison with other organisations that have a responsibility for catchment controls such as the local authority or other relevant organisations involved with the River Basin Management Plans.

3.3 Treatment works

Treatment processes

3.3.1 | 3.3.1 Risk is considerably reduced when there are appropriate water treatment processes to deal with the full range of variations in microbiological, chemical and physical water quality of the water source. An assessment needs to be made about whether the treatment processes provided are likely to inactivate or remove the organisms and substances likely to be present in the water source at the range of concentrations present. If the treatment processes are inadequate there is clearly a risk.

3.3.2 | For example a secure good quality groundwater or spring source may only require disinfection whereas a less secure poorer quality groundwater or spring water source may require coagulation, filtration and disinfection. Ground waters subject to chemical pollution may require additional treatment such as ion exchange to remove nitrate and granular activated carbon adsorption to remove pesticides. Some ground waters may require special processes to remove natural contaminants such as arsenic.

3.3.3 | Surface water sources usually require as a minimum coagulation, filtration and disinfection or for small surface water sources membrane filtration and disinfection. Some surface water sources will require additional treatment such as ozonisation and granular activated carbon adsorption to remove various organic contaminants, including pesticides. As surface water sources can potentially be contaminated with a wide range of micro-organisms, including *Cryptosporidium*, and chemicals it is important that a multi-barrier approach is adopted for effective treatment and removal of contaminants. Also it is important to minimise the formation of disinfection by-products such as the trihalomethanes whilst not compromising microbiological quality.

Hazards and risks

3.3.4 | Hazards may be introduced during treatment or hazardous circumstances may allow contaminants to pass through treatment in significant concentrations. Some common examples are:

- sporadic significant variations in source water quality overwhelming the treatment processes and allowing potentially harmful micro-organisms to enter the distribution network;
- flow variations outside the design limits for the process or the whole treatment works allowing sub-optimal treatment and contaminants to pass through the works;
- process failure/malfunction caused by equipment or process control failure, such as dosing pump breakdown or process monitor malfunction; and
- power failures.

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Operational monitoring and controls

3.3.5 | Risk is considerably reduced if there are standard operation protocols (SOPs) for the operation of all treatment processes and there is appropriate operational monitoring of the individual treatment processes and the final treated water linked to action if treatment performance deteriorates. For example filtration is a very important barrier for removing contamination. A continuous turbidity monitor should be installed on the filtrate from each filter, and as a minimum a monitor should be installed on the combined filtrate. The monitors should have appropriate warning and alarm limits so that appropriate action can be taken quickly if filter performance deteriorates. Similarly when chlorination is used as the disinfection process, apart from having an adequate dose and contact time, there should be a continuous chlorine monitor with appropriate warning and alarm limits so that action can be taken if there is a problem with the disinfection process. The actions that could be taken if performance deteriorates include:

- to adjust the treatment conditions or processes to deal with a trend indicating a deterioration in performance, such as increasing the coagulant dose or backwashing a filter; or
- automatically or manually shutting down the supply whilst urgent remedial action is taken for example when there was a significantly low or zero chlorine residual indicating a disinfection failure and a potential danger to human health.

Treatment works operation and maintenance

3.3.6 | The risk of failures of treatment processes and poor treated water quality is considerably reduced when the operators of the treatment works follow good operating and maintenance practice and procedures. These practices and procedures should be part of a quality management system. Operational practices that may give rise to increased risk of treated water quality failures include for example:

- by-passing a stage of treatment;
- operating a treatment process or the treatment works close to or above its design capacity;
- frequent and significant flow variations through the works

- returning filter backwash water to works inlet without monitoring or treatment; and
- putting backwashed filters back into operation without slow start or a ripening period.

3.4 Distribution network

Hazards and risks

3.4.1 | The protection of the distribution network is essential for providing safe drinking water. Many potential risks exist in the network (opportunities for contamination) because of its nature involving service reservoirs/water towers, many kilometres of pipe work and inter-connections. Some examples of how contamination may enter the distribution network are:

- ingress of contaminated water from the ground as a consequence of low pressure or pressure waves;
- back flow from industrial and domestic premises without adequate backflow prevention devices;
- through service reservoirs/water towers with structural defects or poor security;
- through pipe bursts when existing mains are repaired or new mains are installed;
- when petrol, diesel or oil spillages diffuse through permeable plastic (uPVC or polyethylene) mains;
- disturbance of deposits (for example iron and manganese) through changes in flow velocity or flow reversals; and
- illegal or unauthorised tampering, such as illegal or unauthorised use of fire hydrants.

Control measures

3.4.2 | The following are some examples of control measures to minimise these risks:

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- Standard operating procedures (SOPs) for all operational activities in the network;
- monitoring and maintaining positive pressure throughout the distribution network;
- regular inspection of high risk premises to ensure backflow prevention devices are fitted;
- regular internal and external inspection of service reservoirs/water towers to make sure there are no structural defects and that access hatches, vents and other openings are either locked or covered to prevent ingress;
- written hygienic procedures for repairing burst mains and laying new mains, including disinfection before return to service;
- inspection of garages and other fuel storage facilities and education of the owners/managers about the risks from fuel spillage;
- avoiding disturbance of deposits by avoiding sudden increases in flow and flow reversals and a programme to routine flushing and maintenance; and
- reducing the time water is in the network and maintaining a chlorine residual (or other disinfectant such as chloramine) throughout the network;

3.5 Consumers' premises

3.5.1 | Water quality can deteriorate within the pipe-work and fittings in consumers' premises. If the water supply is not treated to minimise plumbosolvency (and cuprosolvency) and there are lead (or copper pipes) within the consumers' premises then there is a risk that the water at consumers' taps will not meet the standards for lead (or copper) in samples taken from consumers' taps. There can also be failures to meet the standards or indicator parameter values for microbiological parameters in samples from consumers' taps that are due to the unhygienic condition of the consumers' pipe-work and fittings. There can also be failures to meet the standards resulting from cross-connections between water supply and other water systems and from backflow from water using devices if an appropriate protective device is not fitted.

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3.5.2 | The main control measures for risks within consumers' premises are education about the risks and provision of advice on how to control these risks. This is often best achieved through education/advisory leaflets.

3.6 Risk scoring matrix

3.6.1 | It is necessary to have a method of assessing the risk of any hazard identified in order to complete a DWSP. This means developing a risk scoring matrix that relates the likelihood (estimated frequency) of occurrence of the hazard to the potential severity of the effect of that hazard should it occur. WHO in its Water Safety Plan Manual on DWSPs offers a simple semi-quantitative risk scoring matrix for ranking risks which is summarised in Table 10.1 below.

Table 10.1: semi-quantitative risk scoring matrix

		Severity of consequence				
		Insignificant or no impact – rating 1	Minor compliance impact – rating 2	Moderate aesthetic impact – rating 3	Major regulatory impact – rating 4	Catastrophic public health impact – rating 5
Likelihood or frequency	Almost certain – once a day – rating 5	5	10	15	20	25
	Likely – once a week – rating 4	4	8	12	16	20
	Moderate – once a month – rating 3	3	6	9	12	15
	Unlikely – once a year – rating 2	2	4	6	8	10
	Rare – once every 5 years – rating 1	1	2	3	4	5
Risk score Risk rating		< 6 6-9 10-15 > 15 Low Medium High Very high				

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3.6.2 | Many countries and water suppliers developing DWSPs modify this matrix to fit with their regulatory system and human health advice and make the matrix quantitative. An example of a possible quantitative risk scoring matrix for a treatment works is given in table 10.2. Similar risk scoring matrices can be constructed for source water quality, distribution networks and consumers' premises. Different scoring systems can be used.

Table 10.2: example of quantitative risk scoring matrix for a treatment works

Severity of consequence Likelihood of occurrence	No impact (all targets met)	Treatment compromised but no regulatory failure	Treatment compromised regulatory failure but no health risk	Treatment compromised regulatory failure and minor health risk	Treatment compromised regulatory failure and major health risk
Certain – once a day	5	10	15	20	25
likely – once a week	4	8	12	16	20
Moderate – once a month	3	6	9	12	15
Unlikely – Once a year	2	4	6	8	10
Rare – once every 5 years	1	2	3	4	5

3.6.3 | This risk scoring matrix is supplemented by an action matrix. An example of a possible action matrix for a treatment works is given in table 10.3. Similar action matrices can be constructed for source water quality, distribution networks and consumers' premises. Different scoring systems can be used.

Table 10.3: example of an action matrix for a treatment works

Risk score	Action
1-2	No action required
3-5	Action required/keep under review/consider further treatment measures
6-10	Further treatment required/possible capital investment required if existing treatment cannot be optimised

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Risk score	Action
12-16	Fairly urgent further treatment required and probable capital investment required (priority)
20-25	Urgent further treatment required and probable capital investment required (high priority)

3.6.4 | The EPA is considering the most appropriate risk scoring matrices and action matrices for catchment/source, treatment works, distribution network and consumers' premises based on the WHO Water Safety Plan Manual for the circumstances that exist in Ireland and will issue further guidance to WSAs in due course.

4. Documenting the DWSP

4.1 | For each of the four aspects of water supply – catchment/source water, treatment works, distribution network and consumers' premises – the water supplier needs to document the following:

- a description of the aspect supported by diagrams/maps showing all the important features, for example for a treatment works – a schematic diagram showing all the processes, the dosage chemicals, rates and points, the operational monitoring points, the warning and alarm limits etc;
- a description of the hazard with the likelihood of its occurrence and the severity of the consequence if it occurs and the risk score if using a quantitative scoring method;
- the control measures in place to minimise the risk and the action required if the control measures are insufficient;
- the operational monitoring to check whether the control measures are operating effectively to minimise the risk;
- the warning and alarm levels to initiate action when the control measures are not performing adequately;
- an action programme including additional control measures and the timetable to implement them.

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4.2 | The documented DWSP is supported by other existing documentation, such as catchment management and control plans, treatment works manuals and standard operating procedures for treatment processes, standard operating procedures for the distribution network and policy on inspection of consumers' premises.

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Appendix 1: Risk screening methodology for *Cryptosporidium*

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1. Introduction

1.1 | Contamination of water supplies with the parasite *Cryptosporidium* presents a significant threat to the safety of drinking water in Ireland. The first outbreak associated with a public water supply in Ireland was in Mullingar in 2002. Improved awareness of the disease and a requirement on notification of the disease to the Health Protection Surveillance Centre has led to increased reporting of the disease and hence more outbreaks of the disease have been detected. Several outbreaks associated with water supplies have occurred in Ireland since 2002 including supplies in Ennis, Roscommon, Carlow, Portlaw and most recently Galway in 2007.

1.2 | The purpose of this risk screening methodology is to assist WSAs in prioritising supplies that are at a high risk of contamination with *Cryptosporidium* and identify high risk factors, which can be mitigated to reduce the risk associated with the supply. This risk screening methodology is based on the Scottish model as outlined in "The *Cryptosporidium* (Scottish Water) Directions, 2003" as published by the Scottish Executive. The Scottish model is a semi-quantitative risk assessment, which sets out a scoring system to enable determination of whether a supply is low, medium or high risk. The methodology involves calculating a risk score for the catchment factors and for the treatment, operational and management factors, which is then population weighted to give a final risk score. This original methodology was recommended for use in Ireland by the in the "European Communities (Drinking Water) Regulations, 2000: A Handbook on Implementation for Sanitary Authorities" published in 2004. More recent information and research as well as widespread use of the risk assessment methodology has identified some deficiencies in the methodology for use in Ireland, particularly with respect to groundwater.

1.3 | The EPA established a *Cryptosporidium* Working Group under the Environmental Enforcement Network. A Risk Assessment Sub-group was established and consisted of Darragh Page (the EPA) (Chair), Frank Griffen (Department of Agriculture Laboratory), Geraldine Duffy (Teagasc), Margaret Keegan (the EPA), Mary Keane (the HSE) and Paul Carroll (Waterford County Council). This Sub-group examined the risk assessment in detail and recommended that the risk assessment be amended. The amended version of the risk assessment as presented below should be used by the Water Service Authorities (WSAs) on all public water supplies to determine the risk category of the supply. It was decided by the Sub-group that a risk screening methodology should be developed, which allows supplies to be ranked relative to each other. Therefore, allowing time and resources to be spent on the high risk supplies.

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1.4 | Where a supply has been identified as high risk the WSA should develop an action programme to reduce the risk to low. The risk category for each water supply should be reviewed on an annual basis and the methodology re-applied where there is any change to the catchment factors or a change in treatment, operational or management factors.

1.5 | Prior to applying the risk screening methodology an assessment of the catchment factors and the treatment, operational and management factors should be carried out for each source. Where the level of uncertainty is high in relation to the information being used in any of the sections then a precautionary approach should be adopted and the highest score should be used. However, this uncertainty should be noted and further examination of the item should be carried out prior to undertaking the risk screening process.

1.6 | Filling out of the forms should be as a result of an assessment of the catchment and the treatment plant. The WSA should keep a report on this assessment for inspection by the EPA.

1.7 | This Risk Screening Methodology is seen as a pre-cursor to the application of a Drinking Water Safety Plan (DWSP) approach to the management of drinking water. The World Health Organisation (WHO) has set out three essential components to a water safety plan. These are:

- A risk assessment of the water supply – this is an assessment of the water supply from catchment to consumer. It should include the identification and assessment of all risks in the catchment, treatment plant and distribution network (up to the tap). The purpose of this assessment is to identify all potential risks, which may result in the supply of water that does not meet the drinking water standards or may otherwise pose a risk to health.

- Effective operational monitoring – this includes not only carrying out testing of the quality of the water in the catchment, treatment plant and distribution network but should also include monitoring risks to the safety of the water supply e.g. catchment inspections, regular checking of equipment/chemical dosing, service reservoirs, inspections etc. WSAs must monitor risks to determine if the relative threat of the risk is increasing. Operational monitoring is only effective where followed by effective corrective actions where problems have been identified.

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- Effective management – Having identified and monitored all relevant risks to the safety and security of the water supply, effective management of the risks is essential. This includes development of documented management systems outlining what measures are to be taken during normal and incident management conditions and should include regular reporting mechanism. The roles of various personnel involved in the supply of water should be clearly outlined and reviewed on a regular basis.

1.8 | The engagement of the public in the management of water supplies in terms of the protection of water resources and communication of quality issues is an essential component of any DWSP approach. The EPA encourages and promotes the DWSP approach to the management of drinking water supplies and will be issuing guidance in relation to it in the future.

2. Risk screening methodology

2.1 Introduction

2.1.1 | For a risk to exist there must be a source (or pressure), a pathway and a receptor (or target) (Daly, 2004). This is the basis for the Source-Pathway-Receptor (S-P-R) conceptual model widely used for environmental management. A conceptual site model (CSM) is a textual or graphical representation of the relationship that exists between the pressure and the receptor.

2.1.2 | The risk screening methodology facilitates a clear decision-making process in devising a strategy to control any potential risks evident in the conceptual model. It has been divided into Catchment Factors and Treatment, Operation and Management Factors. The scores for these factors are additive and then population weighted.

2.2 Catchment factors

2.2.1 | There are a number of factors that have to be considered in relation to both surface water and groundwater water supplies. The pressure on the receptor is in effect the same therefore factors such as animal densities, agricultural practices, wastewater treatment facilities within the catchment or source protection area need to be examined. The pathway element has been taken into consideration for groundwater

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supplies as groundwater is afforded some protection by the overlying subsoils. The receptor factors relate to the inherent vulnerability of different types of water sources and the protection factors that may be incorporated into the supply.

2.2.2 | The information obtained through a desk study and walkover survey of the catchment area will inform the decision on the extent of measures, which are required to manage the risk. This may involve breaking the pathway (e.g. provision of adequate treatment) or removal of the source (e.g., restriction in land use in the catchment) or in some cases additional monitoring of the receptor.

2.3 Treatment, operation and management factors

2.3.1 | The level of treatment and associated operations and management should be such as to reduce the risk posed by the catchment factors to the consumer.

Water treatment process factors

2.3.2 | These depend on raw water and unprotected/vulnerable supplies should have higher levels of treatment than protected and less vulnerable supplies.

Operation and Management Factors

2.3.3 | While a water treatment plant may have the appropriate treatment system in place, the operational and management of the system is critical to ensure that the treatment of the supply is optimal and provides adequate protection to the source. This influences the allocation of the appropriate risk score.

2.3.4 | During a number of audits and inspections carried out by the EPA, it was observed that many supplies were operating well over their design capacity, thus resulting in by-pass of parts of the treatment system; filters operating sub-optimally and other issues such as inadequate settlement prior to treatment. Therefore it is critical that these factors be taken into account in a realistic manner when applying the risk screening methodology. Some factors to consider are as follows:

- alarmed continuous turbidity monitors;
- Plant designed to treat the peak turbidity and colour loading;

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- recycling of backwash (avoided at times of intense rainfall);
- abnormal operation – i.e. overloaded plants, etc
- bypassing part of the treatment process;
- rate of introduction of filters after cleaning;
- monitoring of filter head loss;
- sludge removal practices;
- operation and maintenance plans in place;

2.4 Suitability of use of the methodology

2.4.1 | This risk screening methodology should not be used on certain types of supplies. Where a supply falls into any one of the three categories below the supply should be immediately considered as high risk and therefore it is not necessary to apply the methodology. These conditions are:

- A supply originating from surface water (i.e. a river, lake or reservoir) that has no treatment other than disinfection.
- A supply originating from groundwater (i.e. a spring, well or borehole) that has no treatment other than disinfection and where there is evidence that the source is influenced[4] by surface water and has a history of microbial contamination in the untreated water.
- Where there is evidence of a past outbreak of cryptosporidiosis associated with the supply where the reason was unexplained and no specific steps have been taken to prevent a reoccurrence.

4 Groundwater can be influenced by surface water where surface water can enter the aquifer through preferential flow paths, karst features or flow down the well casing. In such cases the quality of the groundwater will vary with that of the surface water and may sometimes have high turbidity.

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2.4.2 | In such circumstances an action programme must be developed to address the issue and only when such action programme has been implemented should the risk screening methodology be applied. However, in developing the action programme the water supplier should have regard to the measures in the risk screening model, which can reduce the overall risk score.

2.4.3 | For the purposes of clarity this risk screening methodology has been broken into two separate risk screening methodologies:

- surface water supplies (i.e. those, which originate from a river, lake or reservoir[5]); and
- groundwater supplies (i.e. those, which originate from a spring, well or borehole).

2.4.4 | Where there is an uncertainty about the information or inadequate information available then a conservative approach must be taken and the worse case scenario chosen.

The final risk screening score is the sum of the Catchment Factor risk score and the Treatment, Operation and Management Factors risk score. This score is then weighted according to the population served by the supply. The population-weighting factor is 0.4 x log10 (population served by the supply). The final weighted risk screening score is the final risk screening score multiplied by the population-weighting factor.

2.5 Water supply risk classification

2.5.1 | The classification depends on the final risk screening score. It should be noted that the high risk classification used by the Scottish Executive has been renamed very high risk and the moderate risk classification split into two classifications – high risk and moderate risk. The same classification system shown in table 1 should be used for both the surface water and groundwater risk screening methodologies.

Table 1: water supply risk classification

Water Supply Risk Classification	Final Risk Assessment Score
Very high risk	>100
High risk	76-100

5 This includes infiltration galleries.

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Water Supply Risk Classification	Final Risk Assessment Score
Moderate risk	50-75
Low risk	<50

2.6 Approach to applying the risk assessment methodology

2.6.1 | The application of the risk screening methodology should be considered as an iterative process, which will enable the highest risk supplies to be identified by the water supplier and appropriate measures to be taken in a prioritised manner.

Step 1: Identify all water supplies and allocate the relevant information in relation to supply code, water type and population served.

Step 2: Delineate the catchment (or source protection area) for the water supply.

Step 3: Collate all relevant data sources and identify data gaps. In the case of a groundwater supply develop a conceptual site model (CSM).

Step 4: Apply the methodology (if sufficient information is available to do so) to all supplies and prioritise in order of risk. This should be considered an initial risk screening.

Step 5: Carry out catchment survey and an assessment of the treatment plant, its operation and management in accordance with the guidelines set out in the EPA manuals, in a prioritised manner on the supplies identified in Step 4, to gather additional information as necessary and to validate information used in the initial risk screening.

Step 6: Re-apply the risk screening methodology using the information obtained from a catchment survey and inspection. A brief report should be written on each supply outlining the assumptions made and a summary of the findings.

Step 7: Prioritise the supplies in order of risk, propose and implement measures to be taken to reduce the risk.

Step 8: Re-apply the methodology on completion of the measures to determine the new risk screening score for the supply.

2.6.2 | In very high and high risk supplies consideration should be given to refining the information used in the risk screening so detailed assessment of the catchment should be undertaken such as farm surveys and on-site wastewater treatment system surveys. In cases where there are non-compliances with best practice then measures should be proposed to reduce the risk to the supply.

2.6.3 | In cases where there is currently insufficient water treatment then an assessment of the level of treatment required is dependent on the characteristics of the raw water and the catchment characteristics as well as the risk category. In all surface water supplies a barrier to *Cryptosporidium* is considered the minimum requirement for treatment. In the case of a groundwater source that is fed from a karst spring, the groundwater source should be treated as a surface water source due to the direct connection with surface water.

3. Surface water risk screening methodology

3.1 Introduction

3.1.1 | Surface water is defined as water that is open to the atmosphere and subject to surface run off. It includes rivers, streams, lakes and reservoirs (impounding and pumped long term and bank side storage). Where there is more than one source supplying a treatment works, each source should be assessed individually and the highest score used to calculate the combined catchment and treatment and supply score, and the final, population weighted score.

3.2 Catchment factors

3.2.1 | Paragraphs 3.2.2 to 3.2.7 outline the factors that influence the overall catchment risk score for the supply.

Animals within the catchment

3.2.2 | Sheep and cattle, particularly when lambing or calving, are significant sources of *Cryptosporidium*. The higher the density of animals in the forage area, the higher is the potential risk. Forage areas are defined as grass, open woodland, rape for stock feed, rough grazing, turnips/swedes for stock feed and other crops for stock feed. Deer (also when high numbers in the wild) and pigs, particularly if farmed close to

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water sources, can also be a source of *Cryptosporidium*. The risk is higher when animals have direct access to water. High numbers of birds, particularly when roosting on or near water sources, can also be a source of *Cryptosporidium*. Animal densities can be obtained from Department of Agriculture[6]. The information is not available at farm scale and therefore is considered to be a broad brush conservative dataset. More detailed assessments including farm surveys following the application of the risk screening methodology may be required for very high and high risk supplies. One score from each of the Sections below in table 2 should be inserted into the Actual Score column. However if the factor is not present in the catchment then a zero score should be inserted. These scores should be summed and the total of these scores should be inserted in the Total for Section 1 box.

Table 2: animal risk score

Section No.	Catchment Factor	RA Score	Actual Score
1.1	Cattle/calves at less than or equal to one livestock unit per hectare of forage area *	5	
	Cattle/calves at more than one livestock unit per hectare of forage area*	10	
	No cattle/calves in the catchment	0	
1.2	Sheep/lambs at less than or equal to one livestock unit per hectare of forage area *	5	
	Sheep/lambs at more than one livestock unit per hectare of forage area *	10	
	No sheep/lambs in the catchment	0	
1.3	Wild or farmed deer in the catchment	2	
	No wild or farmed deer in the catchment	0	
1.4	Pig farms in the catchment	2	
	No pig farms in the catchment	0	

6 Animal density information can be obtained from the Department of Agriculture. 5 year averages on a DED basis were made available to the River Basin Districts for the purposes of the diffuse pollution risk assessments.

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Section No.	Catchment Factor	RA Score	Actual Score
1.5	Animals have direct access to water sources including feeder streams	4	
	Fencing prevents access to water sources including feeder streams[7]	-4	
1.6	High numbers of birds	2	
1.7	Any other farmed animals or birds	1	
Total for Section 1			

* If density not known assume more than one animal per hectare of forage area.

Agricultural practices within the catchment

3.2.3 | Slurry spraying and dung spreading, particularly the former, pose a high risk of *Cryptosporidium* contamination of water sources. Although well-kept and managed slurry stores can allow oocysts to die off, there is no way of knowing how effectively they are being operated and therefore a risk should be assumed. Sheep pens and cattle sheds and lambing or calving on the catchment also present a potential risk. The total score for Section 2 is the sum of the scores for each of the risk factors in the table below that is taking place on the catchment. One score (where appropriate) from each of the Sections in table 3 below should be inserted into the Actual Score column if the activity is not undertaken in the catchment then a zero score should be inserted. These scores should be summed and the total of these scores should be inserted in the Total for Section 2 box.

Table 3: agricultural practices risk score

Section No.	Catchment Factor	RA Score	Actual Score
2.1	Slurry or sewage sludge[8] spreading within the catchment	6	

7 This score should only be given where the entire catchment is fenced or animal access to the source water or feeder streams is not possible.

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Section No.	Catchment Factor	RA Score	Actual Score
2.2	Dung spreading within the catchment	3	
2.3	Slurry or dung stores	3	
2.4	Sheep pens or cattle sheds	6	
2.5	Lambing or calving on the catchment	8	
2.6	Full compliance with the Good Agricultural Practice Regulations[9] verified by catchment inspection	-6	
Total for Section 2			

Discharges to the catchment/water source

3.2.4 | Sewage works and septic tanks may not remove oocysts if there is cryptosporidiosis in the community, so there could be oocysts in the sewage works or septic tank effluent and that effluent could enter a raw water source. The impact of septic tanks and sewage works is scored separately on the basis of the total population served by all tanks or works in the catchment. Storm water overflows and discharges from intensive agricultural activities such as abattoirs/livestock markets are also a potential source of *Cryptosporidium* and each should be scored only once even when there is more than one of each discharging into the catchment. One score (where appropriate) from each of the Sections in table 4 below should be inserted into the Actual Score column however, if there are no such discharges in the catchment then a zero score should be inserted. These scores should be summed and the total of these scores should be inserted in the Total for Section 3 box.

8 Land spreading of sewage sludge should be in accordance with the requirements of the Waste Management (Use of Sewage Sludge in Agriculture) (Amendment) Regulations, SI No 267 of 2001.

9 Article 17 of the European Communities (Good Agricultural Practice for Protection of Waters) Regulations, 2009 (S.I. No. 101 of 2009).

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Table 4: discharges risk score

Section No.	Catchment Factor	RA Score	Actual Score
3.1	Population equivalent served by individual on-site wastewater treatment systems ≤ 100 PE	4	
	Population equivalent served by individual on-site wastewater treatment systems > 100 PE	6	
3.2	On-site wastewater treatment systems all known to be functioning properly[10]	– 2	
3.3	Flooding of septic tanks on flood plains	4	
3.4	Population equivalent served by all wastewater works[11] < 500	4	
	Population equivalent served by all wastewater works 500 to 5,000	5	
	Population equivalent served by all wastewater works 5,001 to 20,000	6	
	Population equivalent served by all wastewater works 20,001 to 50,000	7	
	Population equivalent served by all wastewater works > 50,000	8	
3.5	Storm water overflows	2	
3.6	Section 4[12] or Integrated Pollution Prevention Control (IPPC) Licence discharge from intensive agricultural activity or agricultural related discharge	2	
3.7	All wastewater treatment plants complying with the UWWT Regulations quality standards	-1	
3.8	UV inactivation at outlet of wastewater treatment plants	-2	
Total for Section 3			

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Water source type

3.2.5 | Surface water sources present the highest risk from *Cryptosporidium*, particularly when there is direct abstraction from a river or stream. Lowland rivers present a greater risk than upland reservoirs. The total score for Section 4 consists of one score from the list of sources in the table 5 below (no adding of scores).

Table 5: water source risk score

Section No.	Catchment Factor	RA Score	Actual Score
4.1	Upland reservoir/lake	2	
	Lowland long term storage reservoir/lake	4	
	Upland river or stream – bank side storage	5	
	Upland river or stream – direct abstraction	6	
	Lowland river or stream – direct abstraction or bank side storage	8	
Total for Section 4			

Catchment inspections

3.2.6 | Regular catchment inspections and procedures to deal with any identified irregularities reduce the risk from *Cryptosporidium*. Routine catchment inspections should include water quality monitoring of key river channels and feeder streams. The nutrients ammonia, nitrate and phosphate and recording of the presence/absence of sewage fungus or excess algal growth in stream channels will give an indication of water quality at various points on the catchment. Observations should also be made on land-use practice, particularly slurry spreading practices. Use should be made of local knowledge such as farmers, water supply consumers, anglers and local authority area workers, whose vigilance can alert water treatment plant staff to risks to the abstraction source. Cooperation with such local stakeholders should be encouraged. If unsatisfactory issues are noted then more detailed investigation procedures should be applied, such as detailed investigative monitoring and farm, wastewater and industrial

10 Survey carried out by local authority in the catchment of the groundwater source.

11 Wastewater Works – means sewers and their accessories (or any part thereof) and all other structural devices including wastewater treatment plants ….. for the collection, storage, treatment or discharge of wastewater.

12 Section 4 Discharge to Water Licence under the Local Government (Water Pollution) Act, 1977. This could include discharges from piggeries, abattoirs, food production facilities etc.

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facilities inspections, as appropriate. Once the cause of the water quality problem is identified, then improvement and enforcement measures can be applied. One score (where appropriate) from each of the Sections in table 6 below should be inserted into the Actual Score column however, if the activity is not undertaken in the catchment then a zero score should be inserted. These scores should be summed and the total of these scores should be inserted in the Total for Section 5 box.

Table 6: catchment inspection risk score

Section No.	Catchment Factor	RA Score	Actual Score
5.1	Catchment inspections[13] carried out at least monthly	-3	
	Catchment inspections carried out less frequently	6	
5.2	Procedures in place to deal with irregularities on the catchment	-3	
Total for Section 5			

Raw water intake management

3.2.7 | Risk is reduced when water quality monitors are installed at the intake and further reduced when the monitors are alarmed and the intake shut when poor water quality conditions are detected. Poor water quality conditions are defined for each plant and are dependent on local conditions and plant operation and are based on daily monitoring results. The total score for Section 6 consists of one score from the list of sources in the table 7 below (no adding of scores).

Table 7: raw water intake management risk score

Section No.	Catchment Factor	RA Score	Actual Score
6.1	No appropriate water quality monitor[14] on intake	3	
	Appropriate water quality monitor on intake that is alarmed and connected to telemetry	-2	

13 Inspections should take into account the compliance with Article 17 of the European Communities (Good Agricultural Practice for Protection of Waters) Regulations, 2009 (S.I. No. 101 of 2009).

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Section No.	Catchment Factor	RA Score	Actual Score
6.2	Automatic intake shut down when poor water quality	-4	
	Manual intake shut down when poor water quality[15]	-1	
	No intake shut down when poor water quality	3	
Total for Section 6			

Surface water catchment risk score

3.2.8 | Calculate the surface water catchment risk score by adding the scores from Sections 1 to 6 as in table 8.

Table 8: surface water catchment risk score

Surface Water Catchment Risk Scores	Section Score
Section 1 – Animals within the Catchment	
Section 2 – Agricultural Practices within the Catchment	
Section 3 – Discharges to the Catchment/Water Source	
Section 4 – Water Source Type	
Section 5 – Catchment Inspections	
Section 6 – Raw Water Intake Management	
Total Surface Water Catchment Risk Score	

3.3 Treatment, operation and management factors

3.3.1 | If there is more than one treatment process stream at the water treatment works, each treatment process stream should be scored separately and the highest scoring treatment process stream should be used to calculate the treatment and supply risk score and the combined catchment and treatment and supply risk score and the final population weighted score.

14 Monitor may include parameters such as turbidity, ammonia etc.

15 Includes actions taken as a result of manual monitoring at appropriate frequency.

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Water treatment processes

3.3.2 | It is well established that some treatment processes are much more effective in removing *Cryptosporidium*, and therefore reducing the risk, than others. The most effective processes are those that use membrane filtration or coagulation followed by sedimentation or dissolved air flotation and filtration. Membrane filtration is particularly effective when the membrane is capable of removing or retaining particles greater that one micron diameter. The UK Drinking Water Inspectorate (DWI) publishes lists of membrane products that achieve this performance. Ultraviolet disinfection can also be an effective means of inactivating *Cryptosporidium* oocyts but only where there is adequate pre-treatment. UV on its own in surface water supplies is not a suitable means of inactivating *Cryptosporidium* oocysts. Simple disinfection and micro-straining are not effective treatment types to remove *Cryptosporidium* and hence do not reduce the risk. Where disinfection and micro-straining are the only form of treatment in place the water supplier should immediately develop an action programme to improve treatment. The risk screening methodology should not be carried out on such supplies until the action programme has been completed. The total score for Section 7 is one of the scores from the risk factors in the table 9 below based on the principal treatment at the works.

Table 9: water treatment process risk score

Section No.	Water Treatment Factor	RA Score	Actual Score
7.1	Simple sand filtration[16] (not slow sand filtration)	8	
	Simple sand filtration (not slow sand filtration) with UV treatment	6	
	Coagulation followed by DAF/sedimentation and filtration	-10	
	Coagulation followed by DAF/sedimentation and filtration followed by UV treatment	-16	
	Coagulation followed by rapid gravity or pressure filtration (no flotation or sedimentation)	-7	
	Coagulation followed by rapid gravity or pressure filtration (no flotation or sedimentation) followed by UV treatment	-13	
	Slow sand filtration	-9	
	Slow sand filtration followed by UV treatment	-15	
	Membrane filtration (DWI[17] approved)	-16	
	Membrane filtration (Not DWI approved)	-2	
Total for Section 7			

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Treatment works monitoring of coagulation and filtration

3.3.3 | This section only applies when coagulation and filtration or filtration only is part of the water treatment process. Where UV treatment is used in conjunction with the either of these the relevant section should also be scored. Turbidity meters/particle counters provide a good indication of filtration efficiency. Where turbidity meters/ particle counters are fitted and are alarmed so action can be immediately taken, the risk from *Cryptosporidium* is reduced. Similarly a residual coagulant monitor on the outlet of the works, particularly when alarmed, provides an indication of the efficiency of the coagulation and filtration process. When membrane filters have an alarm to monitor the integrity of the membrane or have particle counters to monitor performance, the risk from *Cryptosporidium* is also reduced. Routine discrete monitoring of treated water quality is also important. Only one of the three sections on rapid gravity and pressure filters, slow sand filters or membrane filters should be scored in table 10 below. The total score from either Section 8a, 8b, 8c, 8d or 8e should be summed and added to the total from Section 8f (UV treatment) if UV treatment is one of the treatment processes.

Table 10: monitoring of coagulation/filtration risk score

Coagulation			
Section No. 8a	Management Factor	RA Score	Actual Score
8.1	Manual coagulant dose control – not flow proportional	5	
	Manual coagulant pH control	5	
	Coagulant pH monitored and alarmed	-5	
Total for Section 8a			

Clarification			
Section No. 8b	Management Factor	RA Score	Actual Score
8.2	Clarified water turbidity monitor/particle counters	-1	
	Clarified water turbidity monitors/particle counters with alarm	-2	

16 This includes rapid gravity filters with no chemical treatment, infiltration galleries and pressure filters

17 DWI – Drinking Water Inspectorate of England and Wales http://www.dwi.gov.uk/

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Clarification			
Section No. 8b	Management Factor	RA Score	Actual Score
Total for Section 8b			

Rapid gravity and pressure filters			
Section No. 8c	Management Factor	RA Score	Actual Score
8.3	Turbidity meter/particle counter on each filter with alarm on telemetry	-5	
	Turbidity meter/particle counter on each filter but no alarm on telemetry	0	
	One turbidity meter/particle counter shared by more than one filter with alarm on telemetry	-2	
	One turbidity meter/particle counter shared by more than one filter but no alarm on telemetry	2	
	No turbidity meters/particle counters monitoring filter performance	10	
8.4	Final water turbidity meter/particle counter with alarm on telemetry	-2	
	Final water turbidity meter/particle counter but no alarm on telemetry	2	
	No final water turbidity meter/particle counter	5	
8.5	Continuous residual coagulant monitor on combined filtrate or works outlet with alarm	-5	
	Continuous residual coagulant monitor on combined filtrate or works outlet but no alarm	-1	
	No continuous residual coagulant monitor on combined filtrate or works outlet	5	
8.6	Routine discrete monitoring of treated water for turbidity/ residual coagulant	-2	
	No routine discrete monitoring of treated water for turbidity/ residual coagulant	2	
8.7	Turbidity of backwash supernatant monitored when recycled	-2	
	Turbidity of backwash supernatant not monitored when recycled	2	

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Rapid gravity and pressure filters			
Section No. 8c	Management Factor	RA Score	Actual Score
Total for Section 8c			

Slow Sand Filters			
Section No. 8d	Management Factor	RA Score	Actual Score
8.8	Turbidity meter/particle counter on each filter with alarm on telemetry	-5	
	Turbidity meter/particle counter on each filter but no alarm on telemetry	0	
	One turbidity meter/particle counter shared by more than one filter with alarm on telemetry	-2	
	One turbidity meter/particle counter shared by more than one filter but no alarm on telemetry	2	
	No turbidity meters/particle counters monitoring filter performance	10	
8.9	Final water turbidity meter/particle counter with alarm on telemetry	-2	
	Final water turbidity meter/particle counter but no alarm on telemetry	2	
	No final water turbidity meter/particle counter	5	
8.10	Filters matured and filtrate analysed for turbidity, coliforms and *Cryptosporidium* during maturation	-4	
	Filters matured but no analysis carried out on filtrate	5	
	Filters not matured	15	
Total for Section 8d			

Membrane Filtration			
Section No. 8e	Management Factor	RA Score	Actual Score
8.11	Plant monitored and alarmed for integrity	-10	
	Plant monitored for integrity but not alarmed	0	
	Plant not monitored for integrity	10	

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Membrane Filtration			
Section No. 8e	Management Factor	RA Score	Actual Score
8.12	Particle counter used continuously to monitor filter performance	-5	
Total for Section 8e			

UV Inactivation			
Section No. 8f	Management Factor	RA Score	Actual Score
8.13	Plant monitored for integrity and correct UV dosage	0	
	Plant monitored and alarmed for integrity and correct UV dosage	-10	
	Plant neither monitored nor alarmed	10	
8.14	Influent turbidity consistently < 0.2 NTU	-6	
	Influent turbidity consistently < 1.0 NTU	-3	
	Influent turbidity consistently > 1.0 NTU	-1	
Total for Section 8f			

Rapid gravity and pressure filter performance

3.3.4 | This section only applies to treatment works with rapid gravity or pressure filters. Final water turbidity is a good indicator of filter performance. Filter condition, particularly loss of filter media and cracking of filter bed, the effect of filter backwashing on final water turbidity, and filter maintenance are also relevant. One score from each of the Sections in table 11 below should be inserted into the Actual Score column. These scores should be summed and the total of these scores should be inserted in the Total for Section 9 box.

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Table 11: filter performance risk score

Section No.	Risk Factor	RA Score	Actual Score
9.1	Final water turbidity increases by more than 50%, excluding normal backwash period or turbidity in the final water >1.0 NTU[18]	4	
	Treated water turbidity increases by less than 50%, excluding normal backwash period and turbidity in the final water <1.0 NTU	0	
9.2	Media loss from any filter has brought media depth below design level	6	
	Media depth above minimum design level with audit trail maintained	-2	
9.3	Signs of media cracking on any filter or any other damage to the filter	4	
9.4	All filters have been drained, inspected and any necessary remedial action taken within last year	-2	
9.5	Air scour and backwash maintained and operating efficiently as per maintenance manual	-2	
Total for Section 9			

Treatment works operation

3.3.5 | When a treatment works is operated in accordance with good practice with quality assured procedures, the risk from *Cryptosporidium* is reduced, particularly when there are auditable action plans to deal with any deviations from expected quality. The methods of returning filters to service following backwashing (following skimming and cleaning in the case of slow sand filters) and dealing with filter backwash water have an effect on the risk. Other relevant factors are significant short-term variations in flow through the works and whether the works has operated above its design flow. One

18 Monitoring equipment at the plant must be capable of measuring levels of turbidity of at least 0.1 NTU

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score from each of the Sections in table 12 below should be inserted into the Actual Score column. These scores from each section should be summed and the total of these scores should be inserted in the Total for Section 10 box.

Table 12: treatment works operation risk score

Section No.	Risk Factor	RA Score	Actual Score
10.1	Plant with documented management systems that includes procedures and process control manuals	-2	
	Process control manuals specific to works available	-1	
	Process control manuals specific to works not available	1	
10.2	Auditable action plans available for dealing with deviations in quality and evidence of implementation of the plan	-1	
	Auditable action plans not available for dealing with deviations in quality	1	
10.3	Slow start facility on filters operational	-4	
	No slow start facility on filters, or slow start facility not operational	4	
10.4	Filters run to waste for appropriate period after backwash	-6	
	Filters run to head of works for a period following backwash	-4	
	Filters not run to waste or head of works for a period following backwash	4	
10.5	Backwash water and/or sludge supernatant has to be recycled	2	
	Other disposal route available for backwash water and sludge supernatant	-2	
10.6	Water flow through works when operating has not increased by >10% in <30 minutes in last 12 months	-2	
	Water flow through works when operating has increased by >10% in <30 minutes in last 12 months	2	

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Section No.	Risk Factor	RA Score	Actual Score
10.7	Flow through works above design flow for >10% of time in last 12 months	4	
	Flow through works above design flow for ≤10% of time in last 12 months	0	
	Flow through works >130% above design flow for >50% of time in last 12 months	6	
10.8	Filters bypassed during the year	6	
Total for Section 10			

Distribution network

3.3.6 | The risk screening methodology does not deal with the distribution network. It considers the inherent risk of the water supply up to the point at which it has received treatment. However, issues relating to the distribution network may pose a risk to the consumer of the treated drinking water and need to be considered by the water supplier. Some issues of concern are uncovered reservoirs, broken water mains with low water pressure etc. Measures should be put in place to reduce the risk due to the distribution network and these should be documented as part of the risk screening report for each supply.

Surface water treatment, operation and management risk score

3.3.7 | The surface water treatment and supply risk score is the sum of the scores for Sections 7 to 10 (where relevant) in the table 13 below.

Table 13: surface water treatment, operation and management risk score

Surface Water – Treatment and Supply Risk Score	Section Score
Section 7 – Water Treatment Processes	
Section 8 – Treatment Works Monitoring of Coagulation and Filtration	
Section 9 – Rapid Gravity and Pressure Filter Works Performance	
Section 10 – Treatment Works Operation	
Total Surface Water – Treatment, Operation and Management Risk Score	

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Final weighted surface water risk screening score

3.3.8 | The final surface water risk screening score is the sum of the surface water catchment risk score and the surface water treatment and supply risk score. This score is then weighted according to the population served by the supply. The population weighting factor is 0.4 x log10 (population served by the supply). The final weighted surface water risk screening score is the final surface water risk screening score x the population weighting factor. The calculation is shown in table 14 below.

Table 14: final weighted surface water risk screening score

Total Surface Water – Catchment Risk Score	
Total Surface Water – Treatment, Operation and Management Risk Score	
Surface Water Risk Screening Score	
Population	
Population Weighting Factor (0.4 x log10(population))	
Final Weighted Risk Screening Score	
Water Supply Risk Classification	

4. Groundwater risk screening methodology

4.1 Introduction

4.1.1 | Groundwater is water that is found underground in the cracks and spaces in soil, sand and rock. Groundwater supplies include springs, wells, boreholes and well fields. It does not include infiltration galleries as these are more appropriately described as surface water supplies for the purposes of this risk assessment. Some groundwater supplies such as karst springs are influenced by surface waters and will require a high level of treatment, others however, have good natural protection through overlying subsoils.

4.2 Delineation of the source protection area

4.2.1 | One of the main methods/approaches to protect groundwater in Ireland is through the use of Groundwater Protection Schemes (GSI/DEHLG/EPA, 1999), which involves delineation of groundwater protection zones. These zones are sub-divided into source protection zones, which encompass the catchment area of the groundwater source, and aquifer (resource) protection areas, which are the remaining areas. The source protection area for public groundwater supplies is divided into the Inner Source (SI) Protection Area and the Outer Source (SO) Protection Area. The source protection area, aquifer type and vulnerability information are integrated to give source protection zones (SPZs). These source protection zones provide valuable information for the purposes of the *Cryptosporidium* risk assessments.

4.2.2 | Approximately 52% of the country has groundwater protection schemes developed, which include approximately 160 source protection zones. The remaining public groundwater supplies will have to delineate these SPZs to allow the area for the risk screening methodology to be applied. A 2-tiered process is suggested, the preferred option is where the SPZ is delineated and 2nd option is where the catchment is roughly delineated using recharge co-efficient and abstraction rates. The River Basin District Projects (RBD) are in the process of delineating source protection zones for supplies that are used as part of the National Groundwater Monitoring Programme. It is essential that a consistent approach be taken to delineate source protection zones across the country. The SPZs are required to be delineated to assist in the implementation of the Good Agriculture Practice Regulations, Water Framework Directive, safeguard zones in the Drinking Water Regulations and the groundwater – monitoring programme.

4.2.3 | A conceptual site model (CSM) should be prepared for all groundwater sources at the start of the application of the risk screening methodology as it can be used to identify all possible sources and pathways as well as the processes that are likely to occur along each Source-Pathway-Receptor (S-P-R) linkage.

Conceptual model: source – pathway – receptor

4.2.4 | The following should be considered when developing a conceptual model for the catchment of the groundwater supply.

4.2.5 | Source factors. The principle sources of *Cryptosporidium* in the source protection area will need to be identified on a catchment basis. The majority of human infections are caused by C. hominis and the cattle genotype C. parvum.

The type of land use including animal type and density (C. parvum).

Location of wastewater treatment systems including urban wastewater treatment systems discharging to groundwater and un-sewered septic tanks (C. hominis)

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4.2.6 | Pathway factors. The inherent geological and hydrogeological factors that occur within the source protection area that influences the relationship between the source and the receptor need to be examined. The hydrogeological setting determines the likelihood of transmission of the *Cryptosporidium* from the source to the receptor.

Aquifer type or groundwater flow regime (rapid flow rates in karst aquifers as opposed to slower more uniform flow rates in sands and gravel aquifers).

Vulnerability Category (due to their small size *Cryptosporidium* oocysts are less efficiently removed during passage through soil, in bank filtration and in rapid or slow sand filtration – No attachment to loam or sand particles (WHO 2006[19])). The travel time in low vulnerability areas is much greater than 6 months thus allowing time for the *Cryptosporidium* to die off.

Connectivity between surface water and groundwater (Karst features (e.g. swallow holes, sinking/loosing streams (GSI Karst database))

4.2.7 | Receptor factors. The type of water source and the protection afforded to it influences the risk of contamination of the supply. The population served by the supply is also an important factor that is taken account of during the risk screening methodology.

Spring or Borehole (shallow/deep)

Wellhead protection factors

4.3 Groundwater risk screening (source – pathway – receptor)

4.3.1 | Each of the factors is dealt with in more detail in the following paragraphs 4.3.2 – . Where there is more than one source supplying a treatment works, each source should be assessed individually and the highest score used to calculate the combined catchment, treatment and supply score, and the final, population weighted score.

Source (pressure) factor: animals within the catchment

19 WHO Guidelines for Drinking Water – *Cryptosporidium* January 2006 (EHC *Cryptosporidium* draft 2)

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4.3.2 | Sheep and cattle, particularly when lambing or calving, are significant sources of *Cryptosporidium*. The higher the density of animals in the forage area, the higher is the potential risk. Forage areas are defined as grass, open woodland, rape for stock feed, rough grazing, turnips/swedes for stock feed and other crops for stock feed. Deer (also when high numbers in the wild) and pigs, particularly if farmed close to water sources, can also be a source of *Cryptosporidium*. The risk is higher when animals have direct access to water. High numbers of birds, particularly when roosting on or near water sources, can also be a source of *Cryptosporidium*. Animal densities can be obtained from the Department of Agriculture[20]. The information is not available at farm scale and therefore is considered to be a broad brush conservative dataset. More detailed assessments including farm surveys following the application of the risk screening methodology may be required for very high and high risk supplies. One score from each of the Sections in table 15 below should be inserted into the Actual Score column. These scores should be summed and the total of these scores should be inserted in the Total for Section 1 box.

Table 15: animals risk score

Section No.	Pressure Factor	RA Score	Actual Score
1.1	Cattle/calves at less than or equal to one livestock unit per hectare of forage area *	5	
	Cattle/calves at more than one livestock unit per hectare of forage area*	10	
	No cattle/calves in the catchment	0	
1.2	Sheep/lambs at less than or equal to one livestock unit per hectare of forage area *	5	
	Sheep/lambs at more than one livestock unit per hectare of forage area *	10	
	No sheep/lambs in the catchment	0	
1.3	Wild or farmed deer in the catchment	2	
	No wild or farmed deer in the catchment	0	

20 Animal densities information to be obtained from the Department of Agriculture. 5 year averages on a DED basis were made available to the River Basin Districts for the purposes of the diffuse pollution risk assessments.

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Section No.	Pressure Factor	RA Score	Actual Score
1.4	Pig farms in the catchment	2	
	No pig farms in the catchment	0	
1.5	Animals have direct access to sinking streams	4	
	Fencing preventing access to sinking streams	-2	
1.6	High numbers of birds	2	
1.7	Any other farmed animal or bird	1	
Total for Section 1			

Source (pressure) factor: agricultural practices within the catchment

4.3.3 | Slurry spraying and dung spreading, particularly the former, pose a high risk of *Cryptosporidium* contamination of water sources. Although well kept and managed slurry stores can kill oocysts, there is no way of knowing how effectively they are being operated and therefore a risk should be assumed. Sheep pens and cattle sheds and lambing or calving on the catchment present a potential risk. The total score for Section 2 is the sum of the scores for each of the risk factors in the table below that is taking place on the catchment.

One score (where appropriate) from each of the Sections in table 16 below should be inserted into the Actual Score column. These scores should be summed and the total of these scores should be inserted in the Total for Section 2 box.

Table 16: agricultural practices risk score

Section No.	Pressure Factor	RA Score	Actual Score
2.1	Slurry spraying in the source protection area	6	
2.2	Dung spreading in source protection area	3	
2.3	Slurry or dung stores	3	

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Section No.	Pressure Factor	RA Score	Actual Score
2.4	Sheep pens or cattle sheds	6	
2.5	Lambing or calving on the catchment	8	
2.6	Full compliance the Good Agricultural Practice Regulations[21] verified by inspections	-6	
Total for Section 2			

Source (pressure) factor: discharges to the catchment/source protection area

4.3.4 | Sewage works and septic tanks may not remove oocysts if there is cryptosporidiosis in the community, so there could be oocysts in the sewage works or septic tank effluent and that effluent could enter in some cases groundwater. The impact of septic tanks and sewage works is scored separately on the basis of the total population served by all tanks or works in the catchment. Storm water overflows and discharges from intensive agricultural activities such as abattoirs/livestock markets if discharging to groundwater are also a potential source of *Cryptosporidium*. Each should be scored only once even when there is more than one of each discharging to groundwater. One score (where appropriate) from each of the Sections in table 17 below should be inserted into the Actual Score column. These scores should be summed and the total of these scores should be inserted in the Total for Section 3 box.

Table 17: discharges risk score

Section No.	Pressure Factor	RA Score	Actual Score
3.1	Population equivalent served by individual on-site wastewater treatment systems $\leq$ 100 PE	4	
	Population equivalent served by individual on-site wastewater treatment systems > 100 PE	6	

21 Article 17 of the European Communities (Good Agricultural Practice for Protection of Waters) Regulations, 2009 (S.I. No. 101 of 2009)

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Section No.	Pressure Factor	RA Score	Actual Score
3.2	On-site wastewater treatment systems all known to be functioning properly[22]	– 2	
3.3	Population equivalent served by all wastewater treatment plants discharging to groundwater < 500	6	
	Population equivalent served by all wastewater treatment plants discharging to groundwater 500 to 5,000	8	
3.4	Storm water overflows discharging to groundwater	2	
3.5	Section 4[23] or Integrated Pollution Prevention Control (IPPC) Licence discharging to groundwater from intensive agricultural activity or agriculturally related discharge	2	
3.6	All wastewater treatment plants discharging to groundwater complying with the UWWT Regulations quality standards	-1	
3.7	UV inactivation at outlet of wastewater treatment plants	-2	
Total for Section 3			

Source (pressure) factor: catchment/source protection area inspections [2223]

4.3.5 | Regular catchment inspections and procedures to deal with any identified irregularities reduce the risk from *Cryptosporidium*. Routine catchment inspections should include observations made on land-use practice, particularly slurry spreading practices. Use should be made of local knowledge such as farmers, water supply consumers, anglers and local authority area workers, whose vigilance can alert water treatment plant staff to risks to the abstraction source. Cooperation with such local stakeholders should be encouraged.

If unsatisfactory issues are noted then more detailed investigation procedures should be applied, such as detailed investigative monitoring and farm, wastewater and industrial facilities inspections, as appropriate. Once the cause of the water quality problem is

22 Survey carried out by local authority in the catchment of the groundwater source.

23 Section 4 Discharge to Water Licence under the Local Government (Water Pollution) Act, 1977

identified, then improvement and enforcement measures can be applied. One score (where appropriate) from each of the Sections in table 18 below should be inserted into the Actual Score column. These scores should be summed and the total of these scores should be inserted in the Total for Section 4 box.

Table 18: catchment/source inspections risk score

Section No.	Pressure Factor	RA Score	Actual Score
4.1	SPA inspections carried out at least monthly	-3	
	SPA inspections carried out less frequently	6	
4.2	Procedures in place to deal with irregularities on the SPA	-3	
Total for Section 4			

Pathway factor: geology/hydrogeology

4.3.6 | Role of Aquifer Category. In Ireland, the bedrock aquifers have fissured permeability and the flow is through fractures, fissures and in the case of karst, through conduits. This implies that there is very little, if any, attenuation after a contaminant reaches the bedrock. In the case of sand and gravel aquifers, which have an inter-granular permeability, some filtering of the groundwater may occur depending on the grain size of the sands. The rate of flow of the groundwater in these aquifers varies from very rapid in karstified aquifers to slower in poor unfractured aquifers. Work carried out by the Geological Survey of Ireland and the River Basin District Project (RBDs) in relation to the implementation of the Water Framework Directive (WFD) has resulted in aquifers being grouped into four groundwater body types based on similarities in flow regime – karstic aquifers, gravel aquifers, productive fracture aquifers and poorly productive aquifers.

4.3.7 | Role of Vulnerability Category. The overlying subsoil, depending on its lithology and thickness, may provide some protection for groundwaters. The type and thickness of subsoils are factors that have been used to develop groundwater vulnerability maps in Ireland. These are used along with the aquifer maps to delineate groundwater protection zonation maps, which form part of a county Groundwater Protection Scheme. Areas where there is less than 3m of subsoil are described as extremely vulnerable and do not provide a lot of protection to the underlying groundwater. Karst features provide a direct connection between surface and groundwater (e.g.

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sinking streams, swallow holes etc.) and are also afforded an extreme vulnerability classification. In general it is considered that the overlying subsoil (>3m thickness) provides very good protection of the groundwater as the time of travel through the subsoil is much greater than the die off time for *Cryptosporidium*.

4.3.8 | As there is variability in both the aquifer type and vulnerability across the source protection area some element of professional judgement is required to allocate the appropriate risk score. It is advisable that source protection zone that is predominant over the inner and outer source protection area is used, however, a conservative approach should be taken and the decision making process documented. The total score for Section 5 consists of one score from the matrix in table 19 below (no adding of scores). The scores in Section 5a relate to supplies where the source protection zones have been delineated in accordance with the GSI methodology. The scores in Section 5b related to the estimated catchment of a supply that has not been sub-divided into Inner and Outer Source Protection Areas.

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Table 19: geology/hydrogeology risk score

Section No. 5	Pathway Factor						
	Section 5a		Section 5b				
Vulnerability Rating	Source Protection Area		Aquifer Categories (for supplies with no source protection areas delineated)				
	(SI)	(SO)	Karst (Rk & Lk)	Fissured (Rf & Lm)	Sand/ gravel[24] (Rg & Lg)	Ll	Poor (Pu & Pl)
Extreme (0-1 m soil/ subsoil)	4	2	4	2	0	2	2
Extreme (1-3 m subsoil)	2	0	2	0	0	0	0
High	-30	-30	-30	-30	-30	-30	-30
Moderate	-45	-45	-45	-45	-45	-45	-45
Low	-50	-50	-50	-50	-50	-50	-50
Total for Section 5							

Pathway factor: rapid by-pass of unsaturated zone

4.3.9 | There is an additional risk to groundwater where there is a direct link between the surface and groundwater; this is where the protecting subsoil (unsaturated zone) is by-passed. This occurs where there are sinking streams or swallow holes, which are karst features. Information on karst features may be obtained from the Groundwater Section of the Geological Survey of Ireland, Dublin 4. The total score for Section 6 consists of one score (where appropriate) from the list of sources in the table 20 below (no adding of scores).

24 Vulnerability of sand/gravel aquifers is based on depth to the water table and not depth of subsoil

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Table 20: by-pass of unsaturated zone risk score

Section No.	Pathway Factor	RA Score	Actual Score
6.1	Presence of karst feature[25] such as swallow holes, sinking streams	6	
	Likelihood[26] of karst features or direct transmission of surface run-off to groundwater	3	
	Direct transmission of surface run-off unlikely	0	
Total for Section 6			

Reception factor: water source type

4.3.10 | Groundwater sources may present a risk from *Cryptosporidium*, particularly as they receive minimal treatment in most cases. The different water types have inherent risks associated with them and so they have different scores. Factors such as sanitary protection of groundwater supplies and natural groundwater vulnerability are important factors that will be considered in later sections. The total score for Section 7 consists of one score from the list of sources in the table 21 below (no adding of scores).

Table 21: water source risk score

Section No.	Receptor Factor	RA Score	Actual Score
7.1	Spring	6	
	Well (<3m depth of well)	4	
	Borehole (> 3m depth of borehole)	2	
	Well field[27]	2	
Total for Section 7			

25 Information on karst can be obtained from the Groundwater Section of the Geological Survey of Ireland, Dublin 4.

26 There is generally a likelihood of direct connection between the surface and the groundwater where you have karstified bedrock aquifers such as regionally important karstified aquifers (Rk) or locally important karstified aquifers (Lk)

27 A well field is made up of a number of individual boreholes that contribute in different proportions to the water supply. These boreholes are usually located in close proximity to each other. The worse case scenario/ most conservative should be assumed.

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Reception factor: sanitary protection of groundwater supply

4.3.11 | Additional protection should be given to a groundwater source at the point of abstraction. In the case of a spring supply access to the spring itself should be prohibited and appropriate secure fencing and covering put in place. In the case of a borehole or well the immediate area around the borehole should be constructed in such a way as to prevent any by-pass of the subsoil and to prevent any contaminated material or liquid getting into the groundwater through the water supply structure (i.e. through the wellhead or casing). One score from each of the Sections in table 22 below, where appropriate, should be inserted into the Actual Score column. The scores should be summed, where applicable and the total of these scores should be inserted in the Total for Section 8 box.

Table 22: sanitary protection risk score

Section No.	Receptor Factor	RA Score	Actual Score
8.1	Inadequate protection of spring source	12	
	Spring receptor adequate protection	6	
8.2	Borehole with known or suspected poor casing integrity or no grouting20	12	
	Borehole with suspected, not proven good casing integrity or grouting	4	
	Borehole with proven good casing integrity and good grouting	-8	
8.3	Headworks in outside chamber and/or below ground level – liable to flooding or leaking structure	12	
	Headworks in outside chamber but sealed and dry	9	
	Headworks with cover flush to floor or imperfectly sealed	6	
	Headworks with completely sealed raised cover	-8	
Total for Section 8			

Groundwater source – pathway – receptor (catchment) risk score

4.3.12 | This risk score is calculated by adding the risk scores from Sections 1 to 8 as shown in table 23.

28 Casing integrity should be determined through visual inspection and from borehole logs

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Table 23: groundwater source – pathway – receptor risk score

Groundwater Source – Pathway – Receptor Risk Scores	Section Score
Section 1 – Animals in the catchment	
Section 2 – Agricultural Practices within the Catchment	
Section 3 – Discharges to the Catchment/source Protection Area	
Section 4 – Catchment/source Protection Area Inspections	
Section 5 – Geology/hydrogeology	
Section 6 – By-pass of unsaturated zone	
Section 7 – Water source type	
Section 8 – Sanitary protection of groundwater supply	
Total Groundwater Source – Pathway – Receptor Risk Score	

4.4 Groundwater risk assessment (water treatment score)

4.4.1 | The risk management factors to consider are the water treatment processes that are employed to reduce the risk. The type of treatment process being used, as well as the operation and management of the treatment plant need to be considered. If there is more than one treatment process stream at the water treatment works, each treatment process stream should be scored separately and the highest scoring treatment process stream should be used to calculate the treatment and supply risk score and the combined catchment and treatment and supply risk score and the final population weighted score.

Risk management factors – water treatment processes

4.4.2 | It is well established that some treatment processes are much more effective in removing *Cryptosporidium*, and therefore reducing the risk, than others. Membrane filtration is particularly effective when the membrane is capable of removing or retaining particles greater that one micron diameter. The Drinking Water Inspectorate publishes lists of membrane products that achieve this performance. Ultraviolet disinfection can also be an effective means of inactivating *Cryptosporidium* oocyts but only where there is adequate pre-treatment or where there is a clear groundwater source.

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4.4.3 | In most groundwater supplies simple disinfection is the only form of treatment and this is not an effective form of treatment to remove *Cryptosporidium* and hence does not reduce the risk from *Cryptosporidium*. Where it is the only form of treatment in place and there is evidence of direct connection between the surface water and the groundwater then the water supplier should immediately develop an action programme to improve treatment. The risk assessment should not be carried out on such supplies until the action programme has been completed. The total score for Section 9 is one of the scores from the risk factors in table 24 below based on the principal treatment at the works.

Table 24: water treatment processes risk score

Section No.	Risk Factor	RA Score	Actual Score
9.1	Disinfection (not including UV)	16	
	UV Inactivation	-15	
	Membrane filtration (DWI approved)	-16	
	Membrane filtration (Not DWI approved)	-2	
Total for Section 9			

Risk Management factors – treatment works monitoring of filtration

4.4.4 | This section only applies when filtration only is part of the water treatment process. Where UV treatment is used in conjunction with filtration, it should also be scored. When membrane filters have an alarm to monitor the integrity of the membrane or have particle counters to monitor performance, the risk from *Cryptosporidium* is reduced. Routine discrete monitoring of treated water quality is also important. The total score from either Section 10a or 10b should be summed as shown in table 25 below.

Table 25: monitoring of filtration risk score

Membrane Filtration			
Section No. 10a	Risk Management Factor	RA Score	Actual Score
10.1	Plant monitored and alarmed for integrity	-10	
	Plant monitored for integrity but not alarmed	-3	
	Plant not monitored for integrity	10	

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Membrane Filtration			
Section No. 10a	Risk Management Factor	RA Score	Actual Score
10.2	Particle counter used continuously to monitor filter performance	-5	
Total for Section 10a			

UV Inactivation			
Section No. 10b	Risk Management Factor	RA Score	Actual Score
10.3	Plant monitored for integrity and UV dosage	-3	
	Plant monitored and alarmed for integrity and UV dosage	-10	
	Plant neither monitored nor alarmed	10	
10.4	Influent turbidity consistently < 0.2 NTU	-6	
	Influent turbidity consistently < 1.0 NTU	-3	
	Influent turbidity consistently > 1.0 NTU	-1	
Total for Section 10b			

Water treatment factors – treatment works operation

4.4.5 | When a treatment works is operated in accordance with good practice with quality assured procedures, the risk from *Cryptosporidium* is reduced, particularly when there are auditable action plans to deal with any deviations from expected quality. The methods of returning filters to service following backwashing and dealing with filter backwash water have an effect on the risk. Other relevant factors are significant short-term variations in flow through the works and whether the works has operated above its design flow. One score (if appropriate) from each of the Sections in table 26 below should be inserted into the Actual Score column. These scores should be summed and the total of these scores should be inserted in the Total for Section 11 box.

Table 26: treatment works operation risk score

Section No.	Risk Factor	RA Score	Actual Score
11.1	Process control manuals specific to works available	-2	
	Process control manuals specific to works not available	1	

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Section No.	Risk Factor	RA Score	Actual Score
11.2	Auditable action plans available for dealing with deviations in quality	-2	
	Auditable action plans not available for dealing with deviations in quality	1	
11.3	Water flow through works when operating has not varied by >10% in <30 minutes in last 12 months	-2	
	Water flow through works when operating has varied by >10% in <30 minutes in last 12 months	2	
11.4	Flow through works above design flow for >10% of time in last 12 months	4	
	Flow through works above design flow for ≤10% of time in last 12 months	0	
	Flow through works >130% above design flow for >50% of time in last 12 months	6	
11.5	Membrane or UV filters bypassed during the year	6	
Total for Section 11			

Groundwater treatment and supply risk score

4.4.6 | The groundwater treatment and supply risk score is the sum of the scores for Section 9 to 11 (where relevant) as shown in table 27.

Table 27: groundwater treatment and supply risk score

Groundwater treatment and supply risk scores	Section Score
Section 9 – Water treatment processes	
Section 10 – Treatment works monitoring of filtration	
Section 11 – Treatment works operation	
Total Groundwater Source – Pathway – Receptor Risk Score	

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Final weighted groundwater risk assessment score

4.4.7 | The final surface water risk assessment score is the sum of the groundwater Source – Pathway-Receptor (SPR) risk score and the surface water treatment and supply risk score. This score is then weighted according to the population served by the supply. The population weighting factor is 0.4 x log10 (population served by the supply). The final weighted surface water risk assessment score is the final surface water risk assessment score multiplied by the population weighting factor as shown in table 28 below.

Table 28: final weighted groundwater risk assessment score

Total Groundwater – Catchment Risk Score	
Total Groundwater – Treatment, Operation and Management Risk Score	
Groundwater Risk Assessment Score	
Population	
Population Weighting Factor (0.4 x log10(population))	
Final Weighted Risk Assessment Score	
Water Supply Risk Classification	