Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia

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Ministry of Health

Executive Summary

The Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia (this document) provides guidance on what microbiological objectives need to be achieved for a ground water source to be considered potable. The Drinking Water Protection Regulation requires that ground water sources used for drinking water supply systems are disinfected if the ground water is at risk of containing pathogens, and disinfection must be sufficient to achieve these provincial water treatment objectives. This document is specific to microbiological objectives and it does not address parameters around secondary (residual) disinfection or any treatment required to mitigate chemical contaminants.

Determining if a water supply source is at risk of containing pathogens is outlined in a separate document entitled Guidance Document for Determining Ground Water at Risk of Containing Pathogens (GARP) (GARP assessment). The GARP assessment considers the likelihood of pathogens being present in the ground water source based on a combination of source water quality results, well location, well construction, and aquifer type and setting. The GARP assessment can result in three outcomes which influence how microbiological treatment objectives for ground water may be achieved:

> **Ground water supplies determined to be 'at risk' of containing pathogens (GARP):** As a minimum, GARP water sources require disinfection by treatment methods equivalent to surface water supplies. This includes treatment that provides 4-log removal of viruses, 3-log removal of protozoa, maintaining less than 1 NTU effluent turbidity, and no detectable E. coli and fecal coliform in delivered water. These objectives are achieved through a multi-barrier approach that consists of at least two treatment processes. As with surface water sources, ground water sources may be exempted from filtration if the ground water source meets the filtration exemption criteria. Subsurface filtration, a natural treatment process unique to ground water sources, is also

recognized as a potential treatment method and may provide upwards of 3-log removal credit for protozoa and 4-log virus removal credit (where supported by site-specific information).

Ground water supplies determined to be 'at risk' of containing viruses (GARP-viruses only): These water sources require treatment to provide 4-log removal of viruses.

Ground water supplies determined to be at 'low risk' of containing pathogens: These water sources are not required to employ disinfection to be considered potable.

The information gathered during the GARP assessment helps inform the Drinking Water Officer of the potential hazards to a water source. This document has been developed to ensure that, where disinfection is necessary, these hazards are sufficiently addressed to ensure potable water.

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1. Objective

Reducing risks from bacteria, protozoa, and viruses by disinfection of ground water at risk of containing pathogens to provide guidance for establishing microbiological treatment objectives for drinking water systems drawing from ground water sources in British Columbia (B.C.) to achieve potable water as set out in the B.C. *Drinking Water Protection Act* (DWPA) (2001). Potable water is defined as water provided by a domestic water system that (a) meets the standards prescribed by regulation, and (b) is safe to drink and fit for domestic purposes without further treatment.

2. Background and Regulatory Framework

2.1. Requirements for Potable Water

There are three main types of microorganisms in drinking water that pose risks to human health (pathogens) and for which microbiological treatment objectives are required: bacteria, protozoa, and viruses. The DWPA provides the regulatory framework for establishing groundwater treatment objectives in terms of potability and prescribed standards.

Section 6 of the DWPA describes the obligations of a water supplier as follows:

Subject to the regulations, a water supplier must provide, to the users served by its water supply system, drinking water from the water supply system that

- (a) is potable water, and
- (b) meets any additional requirements established by the regulations or by its operating permit.

Under the DWPA, water suppliers have the responsibility to provide potable water to all users of their systems, unless exempted under section 3.1 of the Drinking Water Protection Regulation (DWPR) (2003):

The following are exempt from section 6 of the Act:
(a) a small system, if

- (i) each recipient of the water from the small system has a point of entry or point of use treatment system that makes the water potable, and
- (ii) the water supplier ensures that the location of non-potable water discharge and non-potable water piping are identified by markings that are permanent, distinct and easily recognized;

(b) a water supply system, including a small system, if

- (i) the system does not provide water for human consumption or food preparation purposes,
- (ii) the system is not connected to a water supply system that provides water for human consumption or food preparation purposes, and
- (iii) the water supplier ensures that the location of non-potable water discharge and non-potable water piping are identified by markings that are permanent, distinct and easily recognized.

2.2. Requirement to Disinfect

The requirement to disinfect ground water sources at risk of containing pathogens is given in Section 5 (2) (b) of the DWPR (2003):

For the purposes of section 6 (b) of the Act, drinking water from a water supply system must be disinfected by a water supplier if the water originates from

- (b) ground water that, in the opinion of a drinking water officer, is at risk of containing pathogens.

The Guidance Document for Determining Ground Water at Risk of Containing Pathogens (GARP) (MOH, 2017) (GARP assessment) provides an evidence-based procedure that assists public health officials in determining if a ground water source is GARP. Based on the outcome and information gathered during a GARP assessment, disinfection requirements can be established for a specific ground water source.

2.3. Water Quality Objectives (Microbiological)

Reducing risks from bacteria, protozoa, and viruses by disinfection of ground water at risk of containing pathogens is achieved through the application of best management principles as outlined in this document and supplemented by the Guidelines for Canadian Drinking Water Quality (GCDWQ) (Health Canada, 2012a).1 As no single type of treatment system is effective in addressing all hazards, treatment objectives incorporate a multi-barrier approach which typically includes two or more forms of treatment. The specific treatment required depends on the risks posed by the raw quality of the source of the drinking water.

Schedule A of the DWPR specifies bacteriological water quality standards for *Escherichia coli* (E. coli) and total and fecal coliform bacteria for the protection of human health as no detectable bacteria per 100 mL of drinking water.2 These standards represent partial drinking water treatment objectives and are consistent with the GCDWQ Guideline Technical Documents, specifically those for *E. coli* (Health Canada, 2012b) and Total Coliforms (Health Canada, 2012c).

This document provides treatment objectives for the removal or inactivation of protozoa and viruses in addition to bacteria. While the finished water quality for these other groups of pathogens is not explicitly defined in the DWPA or DWPR, they must be addressed for water to meet the definition of potable water (section 1 above). Treatment objectives for any pathogen also become legal requirements when included in the conditions of a water system's construction or operating permit.

The DWPA and the DWPR give DWOs the authority to address public health risks from pathogens by specifying water treatment objectives and requirements in construction or operating permits. Given an understanding of the risks to the ground water source, the DWO may stipulate treatment requirements based on the overall quality of the water source, identify operational management issues, and work with the water supplier to establish reasonable time frames to achieve incremental improvements to existing systems. It is the responsibility of the DWO to ensure that they have adequate information to determine that the treatment proposed by a water supplier will address the microbiological risks from a water supply, in addition to any chemical and physical parameters that need to be addressed.

[1] Where possible, hyperlinks to guidance documents are provided. Readers should ensure that they are consulting the correct version as documents can be revised or replaced. The version used at the time of writing has been indicated in the text, usually by the date, and a full citation appears in the reference list at the end of this document.

[2] Where more than 1 sample is collected in a 30 day period the standard for total coliform is at least 90% of samples may have no detectable total coliform bacteria per 100 mL and no sample has more than 10 total coliform bacteria per 100 mL.

Existing drinking water supply systems drawing from a ground water source may have some appreciable risk for certain pathogens without treatment in place. In such cases, it may be acceptable, from a public health perspective, for a water supply system to present a DWO with an improvement plan that specifies how adequate treatment will be implemented within a reasonable time period.

3. Purpose and Scope

3.1. Purpose

This document provides consistent provincial guidance for drinking water objectives that protect human health by addressing the need to disinfect GARP sources in B.C. The information in this document may also be used as general reference for upgrading or improving existing water supply systems.

A DWO must be contacted to confirm treatment requirements for microbiological parameters when existing water supply systems come under review, when permits are required for the construction of new systems or when upgrades to existing systems are planned. The GCDWQ provides broad, high-level guidance for potability and treatment requirements. However, site-specific conditions and the available resources of water systems in various regions of the province require a flexible approach and the DWO has the discretion to adjust what treatment may be required to make a specific water source potable.

3.2. Scope

This document is intended to provide guidance on:

- the treatment necessary to address microbiological contaminants of GARP sources, and
  the application of subsurface filtration (also called riverbank filtration) treatment credits.

This document does not address:

- secondary (residual) disinfection for storage and distribution systems;
  the determination of a ground water source as GARP (see section 4);
  source water monitoring; and
  treatment for chemical contaminants.

Chemical contaminants can reduce the effectiveness of disinfection methods (e.g., by increasing the chlorine demand or by blocking/absorbing UV irradiation) and can present a long-term risk to human health (such as from arsenic). The GCDWQ provides comprehensive technical documents regarding chemical and physical water quality parameters and these should be consulted for further guidance.

4. Ground Water at Risk of Containing Pathogens (GARP)

The Guidance Document for Determining Ground Water at Risk of Containing Pathogens (GARP) (MOH, 2017) (GARP assessment) has been developed to assist public health officials and water suppliers in determining when a ground water source is at risk of containing pathogens. It presents a methodical approach for DWOs to formulate their opinion with a four-stage process, beginning with an initial screening and assessment of the risk factors associated with a ground water source, followed by a determination of risk. Determining whether a ground water source is at risk of containing pathogens is not regarded as a one-time investigation but is subject to the results of ongoing monitoring of source water quality and the hazards to the water source.

For the purposes of setting treatment requirements, ground water sources are regarded as either 'at risk' (GARP), 'at risk from viruses only' (GARP-viruses only) or at 'low risk' of containing pathogens. Drinking water systems that draw from sources determined to be GARP or GARP-viruses only must employ disinfection. Ground water sources determined to be at low risk of containing pathogens do not require disinfection.

Information collected during a GARP assessment should be used by a DWO to rationalize what treatment is required to ensure the reliable delivery of potable water. If a water supplier has reason to believe that the treatment requirements for an existing system could be reduced, they should contact their local DWO to discuss whether a GARP assessment may be warranted.

5. Sources at Low Risk of Containing Pathogens

Ground water sources that are considered at low risk of containing pathogens as a result of a GARP assessment do not require disinfection. However, the DWO may still specify treatment requirements for a water system to address chemical contaminants or other water quality factors.

6. Well Protection

The physical protection of a well from contamination is part of a multi-barrier approach to drinking water safety and is a consideration in the GARP assessment. Wells that are located adjacent to surface waters or sources of contamination and/or wells that are improperly constructed are at risk of being contaminated. If the risk of contamination cannot be fully addressed then the risk to the water source will need to be mitigated by appropriate methods of treatment.

The location and construction of a well should be consistent with legislated construction standards in the Groundwater Protection Regulation (GWPR) (2016) and the Health Hazards Regulation (2011). The B.C. government's Well Protection Tool Kit (MOE, 2006) provides specific guidance on well protection planning and guidance on source protection can also be found in the Comprehensive Drinking Water Source-to-Tap Assessment Guideline (MHLS, 2010). The GWPR also includes specifications for the floodproofing of wells and protection of the wellhead. Wells constructed before 2005 may be exempt from certain sections of the GWPR. However, compliance with, or exemption from, the GWPR does not mean that the source is not GARP. Risks related to well construction and position should be noted and assessed during a GARP assessment along with the other risk factors that need to be considered.

7. Microbiological Treatment Objectives

7.1. Microbiological Treatment Objectives for 'GARP' Sources

Ground water sources classified as 'GARP' as a result of the GARP assessment (section 4) require treatment equivalent to surface water, with the exceptions and special considerations noted in the following subsections and Figure 1. Requirements for surface water treatment can be found in Part B of the Drinking Water Officers' Guide, under the section entitled Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia (MOH, 2012).

The site-specific physical, chemical and microbiological conditions of ground water supplies throughout various regions in B.C., and the differences in the resources available to large and small water systems, necessitate the creation of individualized treatment requirements. The DWO and the water supplier should use a collaborative process to determine treatment requirements that meet provincial objectives.

7.2. Microbiological Treatment Objectives for 'GARP-Virus Only' Sources

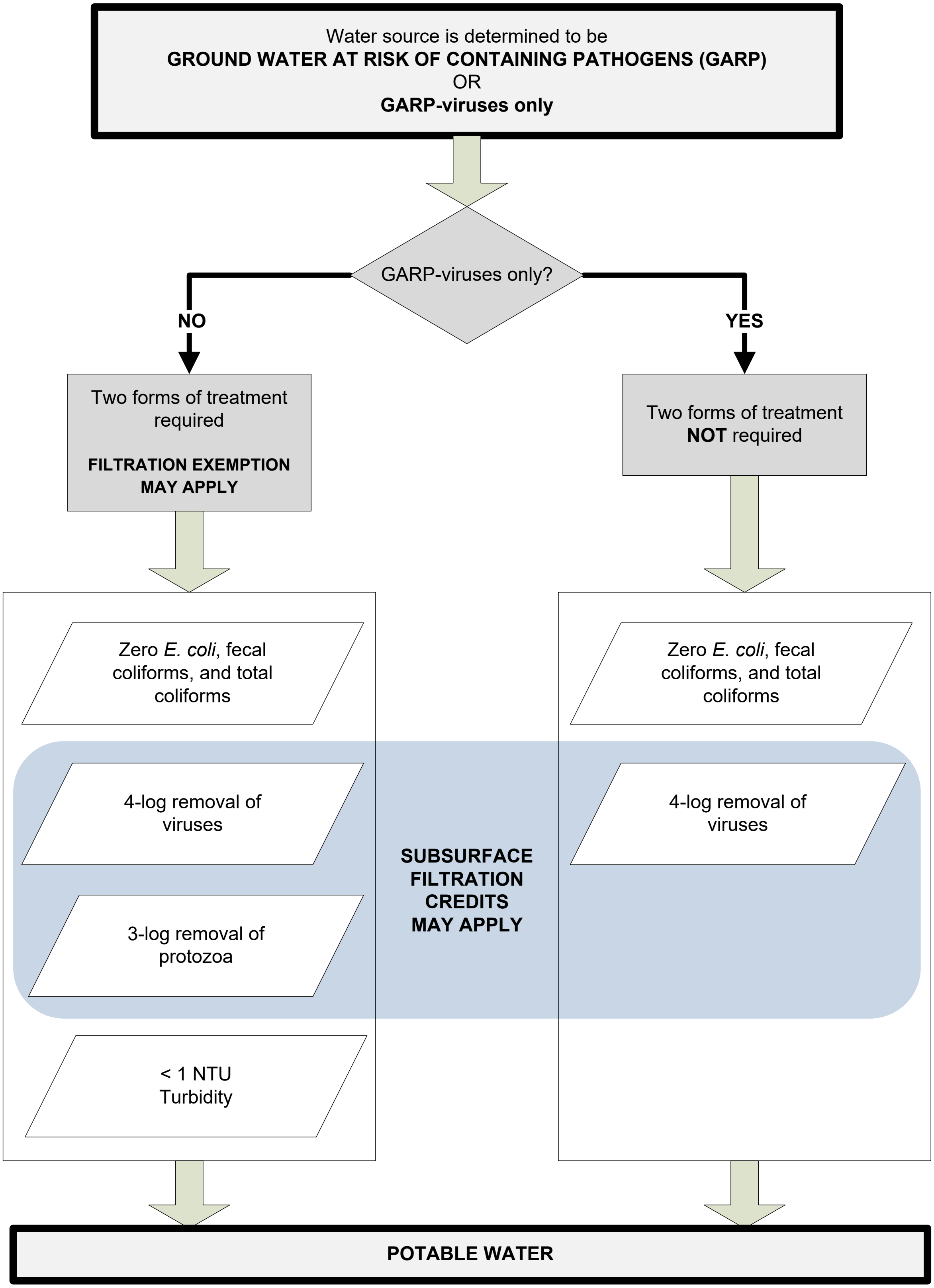
Where the GARP assessment has identified only those risk factors related to the potential presence of viruses (and not protozoa or turbidity) for a ground water source, the DWO has the discretion to limit the microbiological treatment objectives for the water system to only those for viruses (4-log removal) and bacteria (zero E. coli, fecal coliforms, and total coliforms), as outlined in the Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia found in Part B of the Drinking Water Officers' Guide (MOH, 2012). A 3-log removal of Cryptosporidium and two methods of treatment would not be required in this case (Figure 1).

7.3. Subsurface Filtration Treatment Credits

Subsurface filtration is a naturally occurring process that filters surface water as it passes through river or lakebed sediments, lake/river bank substrate, and into an aquifer before being drawn up by a well. Engineered filtration structures, such as infiltration galleries, are not naturally occurring and therefore are not considered equivalent to subsurface filtration treatment. Through the filtration process particulates, turbidity, and microorganisms can be removed or inactivated. Numerous facilities that rely on subsurface filtration in the United States and Europe have demonstrated that the process can yield high quality source water (Kuehn & Mueller, 2000). However, the effectiveness of subsurface filtration is site specific and can depend on many factors such as surface water quality, water temperature, ground water flow conditions, dilution rates, surface water-ground water interface characteristics (such as pH, specific surface area of substrate particles, and organic matter content), and aquifer material (Wang et al., 2002). Further, subsurface filtration can vary seasonally and in response to extreme climatic events (Hrudey and Hrudey, 2004). The effectiveness of subsurface filtration may be demonstrated through field data, laboratory tests, and modelling methodologies.

Subsurface filtration may be considered by the DWO for credit of up to 3 log-removal of *Giardia* and *Cryptosporidium* and, in certain cases, credits of up to 4-log removal of viruses (where proven by a demonstration of performance, see Appendix A) for an eligible well drawing from a GARP source. There are no treatment credits available for bacteria since the bacterial treatment requirement in the DWPR is zero detectable *E. coli* and total coliforms. Subsurface filtration can be considered as one of the two treatment processes, only if it has been awarded greater than 1 log-removal credit for *Giardia* and *Cryptosporidium* and the second treatment process achieves the remainder of the treatment objectives.

Figure 1. Microbiological Treatment Objectives for GARP Sources



7.4. Turbidity in GARP Sources

The presence of suspended organic matter, which can strongly suggest the presence of pathogens, is uncommon in ground water systems. Turbidity in ground water that contains organic matter and pathogens may indicate infiltration of surface runoff, subsurface waste discharge (such as from onsite sewerage systems) or a direct hydraulic connection to surface water with unknown quality. Conversely, turbidity from inorganic mineralogical origin in a well, for example from well packing materials or geologic strata, may not harbour pathogens nor provide definitive evidence of surface water impact.

Turbidity, whether caused by inorganic or organic particles, or biological organisms, also has the potential to disrupt or overload drinking water disinfection processes, such as UV light and chlorination, to the point that they may no longer effectively control pathogens in the water. Organic matter in the water can also react with disinfectants such as chlorine to create by-products that may cause adverse health effects (Health Canada, 2012d).

Turbidity of concern is any intermittent turbidity, or consistent turbidity, greater than 1 NTU. The GARP assessment requires identifying if the source of the observed turbidity is organic or inorganic in nature, and whether or not it contributes to a ground water source being at risk of containing pathogens. Any turbidity in ground water must also not compromise disinfection processes.

7.5. Filtration Exemption

Turbidity can impact disinfection processes and the effective operation of distribution systems. Achieving low levels of turbidity prior to where disinfection is applied is the best method to minimize potential interference with disinfection and to reduce sediment loading to the distribution system (Health Canada, 2012d). The GCDWQ also recommends that the minimum level of treatment to meet microbiological treatment objectives should include filtration and one form of disinfection (Health Canada 2011, 2012b, and 2012e).

However, a GARP source may be permitted to operate without filtration if it meets the filtration exemption criteria as described in section 4.3 of the Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia (MOH, 2012), found in Part B of the Drinking Water Officers' Guide.

To reflect differences between ground water and surface water sources, alternate wording is provided below for filtration exemption criteria '3' and '4':

3. Average daily turbidity levels measured at equal intervals (every four hours or at an interval acceptable to the DWO). Samples are to be taken immediately prior to any disinfection process. Samples should be around 1 NTU and may not exceed 5 NTU for more than two days in a 12-month period.

4. The well is properly constructed and protected to minimize the potential for fecal or other

pathogenic-related contamination in the source water, and a Well Protection Plan[3] (or equivalent satisfactory to the DWO) is in place.

7.6. Other Bacteriological Concerns

Iron and sulphur bacteria can affect aesthetic water quality and the effectiveness of some treatment technologies. They should be tested for separately and addressed appropriately (e.g., the cleaning of the pumping equipment, scrubbing of the well casing, disinfection of the well by chlorination, etc.).

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[3] See, for example, Step 4 of the BC Well Protection Toolkit: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/well_protection/pdfs/step4.pdf. Other procedures for developing a Well Protection Plan may be accepted at the DWO's discretion.

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Appendix A – Subsurface Filtration Details

A1 Treatment Credits Available for Subsurface Filtration

Studies have shown that subsurface filtration is effective in reducing bacterial (WHO, 2006), protozoan, and viral loads (Tufenkji et al., 2002, Weiss et al., 2005, Schijven et al., 2003, and Wang, 2002). For the purposes of these guidelines, however, subsurface filtration is considered only as a form of treatment for the removal of *Giardia* and *Cryptosporidium* and, in certain cases, viruses. There are no treatment credits available for bacteria since the bacterial treatment requirement in the DWPR is zero detectable *E. coli* and total coliforms. Log removal calculations are relevant only if the source concentration, which is often unknown, is determined. As bacteriological analyses are included in all ground water monitoring programs, bacterial removal efficiency is best demonstrated through raw well water sampling. Consequently, subsurface filtration treatment credits are not applied to bacteria. If pathogenic bacteria are present in the raw well water, the water must be sufficiently disinfected regardless of subsurface filtration processes.

A2 Eligibility

A2.1. Giardia and Cryptosporidium Treatment Credits

If the GARP assessment of a ground water source included Microscopic Particulate Analysis (MPA) testing (EPA, 1992)4 and ranked the source as "high risk" under the MPA rating, there is a likelihood of contamination with *Giardia* and *Cryptosporidium* from surface water sources. Wells drawing from these MPA "high risk" sources would be ineligible for subsurface filtration credits.

Removal of *Cryptosporidium* occurs primarily in the ground water-surface water interface. For example, Medema et al. (in Berger, 2002) found that anaerobic spores, surrogates of *Cryptosporidium*, had 3.3 log removal over a 13 m distance from the Meuse River into an aquifer, while only a 0.6 log removal was achieved over 12 m of travel once in the aquifer. Wells utilizing subsurface filtration may be prone to deterioration in water quality during flood conditions. In addition to flood water potentially entering the well casing, high surface water flow rates can disrupt or erode riverbed sediments that form an essential part of the subsurface filtration mechanism. Consequently, in situations where there is a high potential for riverbed scour due to flooding, the DWO may consider the system ineligible for credit.

There are three methods by which to demonstrate subsurface filtration and obtain subsurface filtration treatment credits for Giardia and Cryptosporidium. Each method is independent of the others and can be used as the sole assessment of subsurface filtration efficacy. The accepted methods are noted as follows and described in more detail in Section A3 below:

1) Well/Surface Water Separation
2) Subsurface Filtration Study
3) Demonstration of Performance

Regardless of the method chosen, the well in question must be properly constructed, have a satisfactory well protection plan in place, and must draw from an unconsolidated and granular (e.g.,

[4] The GARP assessment document (MOH, 2015) provides details on MPA analysis.

sand and gravel) aquifer to qualify for credit. The aquifer should have interconnected pores without substantial cementation, as cementation may be indicative of preferential flow pathways.

A number of case studies on subsurface filtration facilities have demonstrated removals in excess of 3-log protozoa (Gollnitz et al., 1997, 2003, and 2005, and Weiss et al, 2005). If a consistent level of removal greater than the credits discussed in this Appendix can be proven by a demonstration of performance study, a DWO may decide to increase the credit being applied accordingly.

A2.2. Virus Treatment Credits

The only means of obtaining subsurface filtration credits for virus removal is through a Demonstration of Performance study. The eligibility criteria for subsurface treatment virus credits are the same as the eligibility criteria for *Giardia* and *Cryptosporidium* treatment credits outlined in section A.2.1.

A3 Treatment Credit Demonstration Methods

A3.1. Well/Surface Water Separation

The effectiveness of subsurface filtration improves with decreasing pore size of the natural filter media and increasing distance from the surface water source. Wells that demonstrate the following are eligible for a 1-log credit for *Giardia* and *Cryptosporidium*:

- are located at least 15 m from a surface water source (i.e., high water mark[5] for horizontal separation, river bed for vertical separation) through the shortest flow path;
- have core samples continuously collected along at least 85% of the well screen depth with composite samples that:
    - are collected at intervals of no greater than 60 cm (2 feet) in length; and
    - have more than 10% of particles passing through a 1.5 mm screen; or
- in the absence of continuous core samples, a DWO may consider wells screened in sand with a grain size of 1 mm[6] or finer where well log information is provided, supplemented by field review and aquifer mapping (if available).

A 1-log credit by the well/surface water separation method cannot be claimed in addition to log credits demonstrated by other methods.

A3.2. Subsurface Filtration Study

Treatment credits for subsurface filtration may also be obtained through the completion of a subsurface filtration study. The hydrogeological conditions should be determined by a qualified

[5] High water mark is the visible high water mark of any lake, stream, wetland or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river stream, or other body of water a character distinct from that of the banks, both in vegetation and in the nature of the soil itself. Typical features may include, a natural line or "mark" impressed on the bank or shore, indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics. The area below the high water mark includes the active floodplain, which is the area of land that receives annual flood events as shown by riparian area conditions.

[6] Sand with a diameter of 1 mm is considered medium sand according to the Unified Soil Classification System (ASTM, 2006) and coarse sand according to the Canadian System of Soil Classification (SCWG, 1998).

professional (QP)7 to characterize the subsurface filtration in question and include the collection of paired (surface water and ground water) MPA samples under or close to worst case conditions.

If the subsurface filtration study determines that filtration is effectively reducing pathogen loads, the water system may be eligible for up to 3-log credits for Giardia and Cryptosporidium reduction. The treatment credits are awarded on a case-by-case basis at the discretion of the DWO following a review of the subsurface filtration study and consideration of how other risk factors identified in the GARP assessment have been managed.

A3.2.1. Subsurface Filtration Study Scope

The scope of the subsurface filtration study, including water quality sample timing and proposed analyses, should be established by a QP for consideration by the DWO prior to the start of the study. The scope of the subsurface filtration study should consider the following factors:

Surface Water Conditions

- Historic flow patterns
- Seasonal variations
- 50, 100, and 200 year flood levels (considering diking, where applicable)
- High water mark
- Likelihood of extreme precipitation events and the impact on surface water quality
- Assessment of potential for riverbank or lake bed scour and flow rates that may cause scour
- Expected flooding frequency
- Clogging potential

Aquifer Conditions

- British Columbia Aquifer Classification System ranking
- Grain size and porosity
- Aquifer stratigraphy and lithology
- Hydraulic conductivity
- Storativity and transmissivity (in confined aquifers)
- Ground water dilution rate (related to the pumping rate)
- Ground water flow directions and gradients (under both natural and pumping conditions)
- Ground water flow rate or velocity

Well Conditions

- The location and construction of a well should be consistent with legislated construction standards
- Time of travel from high water mark to well under various pumping and water level conditions
- Water level readings to capture seasonal fluctuations and recharge events (monthly readings should be completed at a minimum, however, continuous monitoring is ideal); sampling frequency can be reduced if aquifer does not show significant variation
- Pumping test data
- Well capture zone[8]

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[7] A qualified professional (QP) is an individual who is registered with the Association of Professional Engineers and Geoscientists of British Columbia with competency in the field of hydrogeology and experience in evaluating sources of ground water supply.

[8] A variety of methods for defining a well capture zone are provided in the BC Well Protection Toolkit (MOE, 2006) – Step 2 (http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/well_protection/pdfs/step2.pdf).

- Summary of hydrogeological cross sections showing stratigraphy, aquifers, confining layers, well capture zones under high pumping and high surface water stage conditions

Ground Water and Surface Water Quality

- Paired MPA sampling results (see 'MPA Analysis' below)
- Total coliforms, *E. coli*, level and nature (organic vs inorganic) of turbidity
- Field measurements of temperature, pH, electrical conductivity
- Observed variations between ground water and surface water quality with time
- Correlation between variations in surface water and ground water quality employing statistical methods

Many of these factors are studied in Level 2 and 3 hydrogeological investigations in the GARP assessment. If a Level 2 and/or 3 hydrogeological investigation has already been completed for the ground water source in question, the subsurface filtration study need only address any data gaps identified by the DWO.

A3.2.2. MPA Analysis

Details on MPA analysis are provided in Appendix C of the [Guidance Document for Determining Ground Water at Risk of Containing Pathogens] (GARP) (MOH, 2015). As is the case with GARP assessments, MPA sample results are intended to contribute to, not replace, the weight of evidence provided in the subsurface filtration study.

The number of samples required to demonstrate eligibility for treatment credits through MPA testing should be discussed with the DWO. At a minimum, two paired samples should be collected from the ground water and the surface water source to which it is hydraulically connected. Studies on MPA test results have found, however, that one or two tests cannot reliably predict future values (Jacangelo et al., 2001). Consequently, one MPA sample pair must be collected annually during worst case conditions to maintain this treatment credit. The DWO may request that additional samples be taken to provide greater clarity on the efficacy of subsurface filtration.

During MPA sample collection, additional samples should be collected for analysis of turbidity, electrical conductivity, temperature, pH, total coliform, and *E. coli* to compare surface water quality with ground water quality.

A review of the MPA test results, not just the risk ranking, should be completed as it provides a picture of the surface water indicators present in the water sample. Analysis of MPA indicator counts in both the surface water and ground water sources may enable a rough estimation of protozoa log-removal.

A3.2.3. Alternatives to MPA Testing

MPA analysis provides both a physical count of the surface water indicators and a systematic means of determining the risk that a ground water sample, and by extension, the well, may have surface water interaction. Analysis for *Giardia* and *Cryptosporidium* surrogates, such as bacterial spores *Bacillus subtilis* or *Clostridium perfringens* may be considered as alternative test parameters to MPA for the subsurface filtration study, at the discretion of the DWO. As bacterial spore analysis provides only quantitative results, consideration should be given to increasing the number of samples required or to completing the sampling as part of a more intensive demonstration of performance (below).

A3.3. Demonstration of Performance

A demonstration of performance is a thorough sampling program that involves completing a subsurface filtration study, but with a far more rigorous testing protocol. The testing protocol may involve increased testing frequencies, longer study durations, additional sample locations, and an expansion of the parameters to be tested. It should include the collection of a sufficient number of paired samples from the surface water source and the collection well, with samples taken from the well after the estimated lag time has passed.

In addition to the study of *Giardia* and *Cryptosporidium* removal, the demonstration of performance study can include a testing protocol to demonstrate virus removal. Since *Giardia* and *Cryptosporidium* concentrations, as well as virus concentrations, in both surface and well water samples may be too low to calculate required log-removals, log-removal calculations can be based on the concentrations of a number of relevant surrogates. A summary of potential surrogates (such as *Bacillus subtilis* or *Clostridium perfringens*) for protozoa can be found in the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) Toolbox Guidance Manual (EPA, 2010). MS-2 bacteriophage or other F-specific RNA bacteriophages are potential surrogates for viruses (Schijven et al., 2002). Dilution of surface water by ambient ground water may also skew the effectiveness of subsurface filtration and, therefore, calculated log-removals should be adjusted for expected dilution effects.

Section 4.7 of the LT2ESWTR Toolbox Guidance Manual also provides detailed information on testing and monitoring protocols that could constitute a sufficient demonstration of performance plan. Water suppliers should retain a QP to develop a demonstration plan according to this or other suitable criteria. Credits granted may differ from the log removals determined by the study at the DWO's discretion.

A4 Credit Maintenance

Turbidity monitoring is necessary to maintain the treatment credit for all methods used to obtain subsurface filtration log-removal credit. Average daily turbidity levels should be established through sampling at equal intervals (at least every 4 hours) immediately prior to where the disinfectant is applied. The DWO may specify different sampling requirements and intervals. Turbidity levels of around 1.0 NTU for 95% of the measurements per month and not exceeding 3.0 NTU should be demonstrated.9

In addition, to maintain a treatment credit obtained as a result of a subsurface filtration study or demonstration of performance, water suppliers should collect and submit for analysis at least one pair (ground water and surface water) of MPA samples (and virus surrogate samples, if virus credit was obtained) annually or at a frequency agreed upon by the DWO. The timing of the sample should coincide with the reasonable worst case conditions, as identified during the initial MPA sampling. If the sample yields a risk ranking for the ground water source that is higher than the ranking for which

[9] Log-credit for subsurface filtration allows for reduced or no treatment for *Giardia* and *Cryptosporidium*. Therefore, subsurface filtration is considered an integral part of disinfection. An increase in turbidity at the well may be indicative of a failure of the treatment barrier provided by subsurface filtration. In comparison, a system with a filtration exemption (as outlined in MoH's "Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia" section of the Drinking Water Officers' Guide) does not rely on filtration to help reduce *Giardia* and *Cryptosporidium*, rather sufficient disinfection technologies are employed. This is why the allowable upper limit for turbidity in systems that have credit for subsurface filtration is lower (3.0 NTU) than the 5.0 NTU maximum permitted for a system that has a filtration exemption.

the credit was awarded, a second MPA sample should be collected. Similarly, if the calculated virus removal efficiency calculated with annual sampling results is lower than that for which the virus removal credit was granted, a second pair of samples should be collected. The DWO may decide that an adjustment to the previously awarded treatment credits is warranted based on the sample results.

If any single MPA ground water sample is ranked as "high risk" or if the ground water quality does not meet the turbidity requirements, the water supplier should investigate the source of the water quality deterioration and report the findings to the DWO. The DWO will then assess whether a treatment credit for subsurface filtration remains appropriate for the system.