A1 Likelihood assessment details

Likelihood Questions / Responses				Response interpretation		Justification
#	Question Category	Receptor Category	Question	Lower risk	Higher risk	
1.A.	Proximity	Aquatic Life	Is the project* within 100 m of a water body**?	No	Yes	*100 m comes from D055 (no equivalent for transportation, taken from storage)*
1.B.	Proximity	Aquatic Life	Does the project's transportation route include any water body crossings?	No	Yes	*Water body crossings increase exposure likelihood compared to running alongside a water body*
1.C.	Proximity	Terrestrial Plants	Is the project* within 100 m of crops?	No	Yes	*100 m comes from D055 (no equivalent for transportation, taken from storage)*
1.D.	Proximity	Terrestrial Plants	Is the project* within 100 m of a forest?	No	Yes	*100 m comes from D055 (no equivalent for transportation, taken from storage)*
1.E.	Proximity	Human Health	Is the project* within 100 m of a designated swimming area***?	No	Yes	*100 m comes from D055 (no equivalent for transportation, taken from storage)*
1.F.	Proximity	Human Health	Is the project* within 100 m of a domestic residence?	No	Yes	*100 m comes from D055 (no equivalent for transportation, taken from storage)*
1.G.	Proximity	Human Health	Is the project located on freehold land (as opposed to crown land)?	No	Yes	*Freehold vs. crown differentiates the level of scrutiny involved with an exposure event. It can also speak to the nature of traffic (e.g. general public vs. industrial)*
1.H.	Proximity	All – modifier	Is all of the project* located on low or flat ground (i.e. in the event of a leak will water remain near the point of the leak)?	Yes	No	*This accounts for topography - released water is more likely to impact receptors if it can flow downhill to them*
2	Duration	All	Will alternative water be used for longer than one year as part of this project*?	No	Yes	*The AER typically uses one year as a limit (e.g. temporary field authorizations)*

Likelihood Questions / Responses				Response interpretation		Justification
#	Question Category	Receptor Category	Question	Lower risk	Higher risk	
3.A.	Materials	All	Are any of the project's storage materials a violation of, or exception to, Directive 055? If an exemption has already been granted, answer "No".	No	Yes	*Violating/being an exception to a Guideline is justification for a higher likelihood score. This question's results are either low or high (there is no medium response interpretation)*
3.B.	Materials	All	Are any of the project's transportation materials a violation of, or exception to, the Pipeline Guidelines? If an exemption has already been granted, answer "No".	No	Yes	*Violating/being an exception from a Guideline is justification for a higher likelihood score. This question's results are either low or high (there is no medium response interpretation)*
4.A.	Operations	All	Is the planned system operating pressure greater than 80% of the transportation material's burst pressure?	*No*	*Yes*	*Materials operated closer to their design limits are more likely to fail. 80% of burst pressure is an industry standard value*
4.B.	Operations	All	Does the maximum volume contained in a length of pipe/hose *between automatic shut-offs* exceed $30m^3$ (diameter and length of longest pipe/hose section)?	No	Yes	*$30m^3$ is the approximate volume of a truck, which is an alternative to transporting by hose/pipe*
4.C.	Operations	All	Is the alternative water in this project transported beyond visual range?	No	Yes	*It is easier to prevent and mitigate spills if the entire transportation length is visible to operators*
4.D.	Operations	All	Will the project operate in temperatures below 0^oC?	No	Yes	*Water freezes at 0^oC. It is acknowledged that alternative waters may have lower freezing points, but 0^oC is used as starting point*

** Consider both storage and transportation*

*** Water bodies include wetlands, swamps, rivers, lakes, etc.*

**** Consider both recreational water bodies and non-water rec. areas*

A2 Key indicator contaminant identification

Figure A-1 visually summarizes the process for identifying the key indicator contaminants for the SLRM, described in Section 3.5

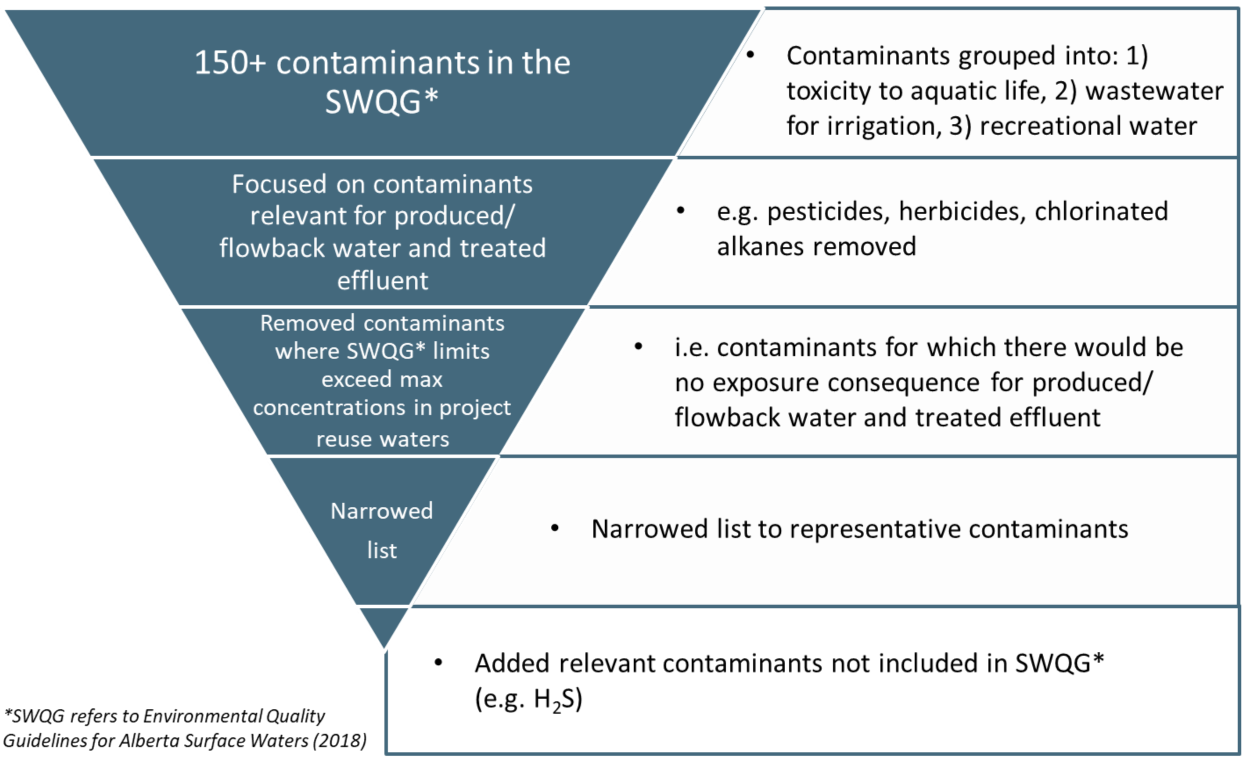

Figure A-1 Visual summary of how the key indicator contaminants were identified for the consequence assessment

A3 Key indicator contaminant consequence levels

This appendix provides details on the derivation of consequence limits for the key indicator contaminants identified in Section 3.5.

Chloride ions

Chlorine exists naturally in concentration of 100-300ppm within the Earth's crust. As a result, most water sources contain chlorine ions in varying concentrations. Drinking highly saline water is known to pose a risk to human health, mainly due to the sodium ion while the chloride ion is relatively benign. Although humans are not sensitive to chloride ions, freshwater aquatic species are particularly sensitive to changes in chloride concentration in the water.

The 2018 Environmental Quality Guidelines for Alberta Surface Waters set limits for both chronic and acute chloride toxicity to avoid adverse effects to even the most sensitive aquatic species. The acute limit for the protection of aquatic life is 640mg/L chloride. Because this limit is aimed at protecting all aquatic life, it can be assumed that water containing less than 640mg/L chloride will pose no risk to the aquatic environment in a short-term exposure.

The Canadian Council of Ministers of the Environment (CCME) produced a report detailing the effects of elevated chloride content on various vertebrate and invertebrate species found in Canadian freshwater systems. The report shows the EC50[2] for invertebrate species is between 667-2026mg Cl/L when exposed for 24 hours. The LC50[3] for vertebrate species was 3386-10400 mg Cl/L when exposed for 96 hours (CCME, 2011). Exposure periods of 24 and 96 hours are appropriate, considering the nature of MSHF operations; it is likely that a leak or a spill would be identified and stopped quickly. In flowing water bodies, the soluble chloride ions would be washed away quickly. In static water bodies, it is likely dilution effects will reduce the observed effects of chloride contamination.

Using the information from the CCME report, alongside the existing Alberta surface water quality guidelines, it was possible to develop a matrix detailing limits for chloride concentration, as summarized in Table A-1. Less than 640mg Cl/L will not pose any threat to the environment, as this is less than the Alberta surface water quality guidelines. Between 640-2500mg Cl/L, some adverse effects will occur for the most sensitive invertebrate species, based on the CCME report. This was considered a medium consequence. According to the CCME report, concentrations above 2500mg Cl/L will likely result in death of most invertebrate species. Therefore, this was ranked as high consequence.

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[2] Concentration at which there is an observable effect in 50% of the population related to the contaminant

[3] Lethal Concentration for 50% of the population

Table A-1 Consequence Assessment ranges for chloride contamination

Consequence level	Description	Suggested concentration limit (mg Cl/L)	Reference
Low	No adverse effect on aquatic life	<640	Environmental Quality Guidelines for Alberta Surface Waters 2018 (Government of Alberta, 2018)
Medium	Some adverse effect on sensitive species	640-2500	Canadian Water Quality Guidelines : Chloride Ion. Scientific Criteria Document (CCME, 2011)
High	Severe adverse effects to multiple invertebrate and vertebrate species	>2500	

Terrestrial plants are also sensitive to chloride ions. While low concentrations of chloride are necessary to maintain leaf growth, when chloride is present in high concentrations it can cause necrosis of the leaf tips, also known as “leaf burn” in certain crop species (White & Broadley, 2001).

The consequence assessment was designed to accommodate secondary receptors where multiple receptors are sensitive to key indicator contaminants. The chloride sensitivities of terrestrial plants are different to aquatic life, so secondary limits were defined within the SLRM to accommodate this. As with aquatic life toxicity, sensitivities differ between plant species, but limits have been derived to adequately address the consequence to a range of plants. The exposure limits for terrestrial plants are shown in Table A-2.

Table A-2 Consequence assessment limits for chloride toxicity to plants

Consequence level	Description	Suggested concentration limit (mg Cl/L)	Reference
Low	No adverse effects observed	<750	Salt tolerance of plants (Maas, 1986)
Medium	Some “leaf burn” on sensitive plant species	750-2800	
High	“Leaf burn” is observable on all the majority of plant species	>2800	

Sodium adsorption ratio

Calcium and magnesium are essential minerals for plant growth. Sodium, calcium and magnesium naturally occur within soil and are an integral part of the soil chemistry. In certain compounds, these ions can exchange with each other, which provides a transport method for uptake through plant roots.

When the sodium content is greatly increased, it will exchange with calcium and magnesium within the soil, leaving less of these essential minerals available for plant uptake. This leads to yellowing leaves, inhibited growth, and, ultimately, plant death.

The Sodium Adsorption Ratio (SAR) describes the ionic relationship between sodium, calcium and magnesium ions within soil and is defined by the following equation. All units for the calculation are in milliequivalents per liter (me/L):

$$SAR = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

Na^{+} = concentration of sodium (me/L)
Ca^{2+} = concentration of calcium (me/L)
Mg^{2+} = concentration of magnesium (me/L)

The Alberta surface quality guidelines suggest anything below 5 is acceptable (Government of Alberta, 2018). However, this is for irrigation with wastewater, which is a deliberate release of water which must be useable to grow crops. This limit is too strict to be used for an accidental short-term release of an alternative water source that could potentially occur as part of MSHF operations.

Other papers break out SAR limits in more detail. A study carried out in India showed most crops would not be affected from an SAR of up to 10, an SAR of 10-15 would likely affect more sensitive crop types, an SAR of 15-25 would likely adversely affect most crops in medium-term irrigation, and an SAR >25 would result in a loss of all crops in a medium-term irrigation project (Durairaj, Vasuki, Pavithra Lavanya, & Lavenya, 2015).

This structure was adapted into limits shown in Table A-3 for application in a consequence assessment for alternative water sources.

Table A-3 Consequence Assessment ranges for SAR contamination

Consequence level	Description	Suggested concentration limit [unitless]	Reference
Low	No hazards observed	<10	Groundwater Suitability for Irrigation around Perungalathur, Chennai, Tamil Nadu (Durairaj, Vasuki, Pavithra Lavanya, & Lavenya, 2015)
Medium	Some adverse effects on certain crops	10-25	
High	Unsatisfactory for all crop types	>25	

E-Coli

Escherichia Coli (E-Coli) is a coliform bacterium commonly found in the fecal material of animals and humans. It is commonly used as an indicator organism in water analysis to indicate the presence of fecal material and the presence of pathogenic bacteria.

Other microbiological indicators are also commonly used by municipalities to describe the microbiological constituents of treated water. One of these is Total Coliform count, which describes the total number of coliform bacteria within the water. There are many coliform species and this method disregards the source of the bacteria, which can occur naturally and independent from pathogenic bacteria. As a result, Total Coliform count is not an accurate method of measuring water quality in this context

Fecal coliform count is another indicator that is similar to E-Coli count. It accounts for bacteria species found in the feces of animals and humans. However, the fecal coliform count also includes bacteria that are not exclusive to feces, such as *Klebsiella*, which is commonly found in the textile and paper and pulp industry (USEPA, 2012). Measuring fecal coliforms outside a controlled environment, such as a water treatment plant, may not produce an accurate description of microbiological risk.

The 2018 Environmental Quality Guidelines for Alberta Surface Waters state that for recreational waters, a count of <320 cfu/100mL is acceptable for swimming and recreational use, where the exposure is through skin contact and the occasional unintentional swallowing of spray or small amounts of water (Government of Alberta, 2018). These exposure pathways are similar to how human receptors may be exposed to alternative water sources in the case of an accidental release from a MSHF project. Therefore, the limits set by the guideline constitute a low consequence score.

Determining the medium and high consequence limits involves determining what is an acceptable risk in certain cases. The European Union (EU) sets standards for bathing waters that were used to inform this decision. The EU classifies bathing waters as ‘Excellent Quality’, ‘Good quality’ and ‘Sufficient quality’ based on 90th or 95th percentile evaluation (EU, 2006). Waters of sufficient quality can contain up to

900 cfu/100mL, based on a 90th percentile evaluation. This limit indicates a medium consequence score, since the water is still of sufficient quality for bathing, but with increased risk of a person contracting an illness compared to the low consequence case. This limit also informed the high consequence case, as detailed in Table A-4.

Table A-4 Consequence Assessment ranges for E-Coli

Consequence level	Description	Suggested concentration limit (cfu/100mL)	Reference
Low	No harmful effects	<320	Environmental Quality Guidelines for Alberta Surface Waters 2018 (Government of Alberta, 2018)
Medium	Slightly increased likelihood of pathogenic illness	320-900	EU Directive Concerning the management of Bathing Water (EU, 2006)
High	Increased risk of pathogenic illness	>900	

Hydrogen sulfide

Hydrogen sulfide (H_2S) is a colourless gas with a strong odour. It is extremely poisonous, corrosive and flammable (Yong Bai, 2010). Hydrogen sulfide is commonly encountered in the drilling and production of oil and natural gas, meaning it can be present in produced/flowback waters from sour wells.

Hydrogen sulfide presents significant operational challenges with flammability and corrosion, which currently make water from sour wells undesirable for use as alternative water sources. However, it is conceivable that a situation may exist in which it becomes operationally viable to use water from sour wells, which contains hydrogen sulfide, for MSHF. It is therefore important to consider the health and environmental effects of H_2S as part of a screening level assessment.

Any detectable sulfide present in the water, which can lead to the production of H_2S, is undesirable and constitutes a high consequence. Given the dangers presented by even a low concentration of H_2S, no medium consequence limits were set. The consequence scoring for H_2S is summarized in Table A-5.

Table A-5 Consequence Assessment ranges for hydrogen sulfide

Consequence level	Description	Suggested concentration limit (mg/L)	Reference
Low	No adverse effect	ND	Work Safe BC guidance on hydrogen sulfide (Work Safe BC, 2019)
Medium	N/A	N/A	
High	H_2S may be present in levels high enough to cause harm to health	Detectable	

pH

The pH measurement of water describes the number of free hydrogen ions in the water, directly related to its acidity. While acidity does not necessarily relate to direct health or environmental consequences, it is a good indicator of whether a substance has the potential to cause harm to human health or the environment. It is also very simple to carry out a field test measurement of pH.

The 2018 Environmental Quality Guidelines for Alberta Surface Waters describes pH limits based on the sensitivity of the receptor to changes in water chemistry. The guidelines do not state a pH limit for irrigation water for crops. For protection of human health in recreational waters, the guidelines recommend safe limits of between pH 5.0-9.0. Aquatic organisms are more sensitive to pH, especially to more acidic waters. The guidelines recommend the pH remains between 6.5-9.0 for the protection of aquatic life (Government of Alberta, 2018).

Since pH significantly contributes to the toxicity of ammonia in water, the limits also consider the typical ammonia levels found in alternative waters and set a consequence pH limit that will simultaneously account for the toxicity of ammonia. Table A-6 summarizes the pH consequence limits.

Table A-6 Consequence Assessment ranges for pH

Consequence level	Description	Suggested limit (pH)	Reference
Low	No adverse effect on aquatic life or human health	6.5-9.0	Environmental Quality Guidelines for Alberta Surface Waters 2018 (Government of Alberta, 2018)
Medium	May cause some adverse effects (e.g. harm to more sensitive aquatic species)	5.0-6.4	
High	May cause serious harm to health or the environment	<5.0 or >9.0	

Soil pH affects the speciation and solubility of chemicals within the soil. When toxic chemicals, such as aluminum, become more soluble, this increases uptake through the roots of plants, leading to lower crop yields (Magdoff & Van Es, 2010). While some plants can tolerate a wide pH range, certain plants, including some commercial crops, are sensitive to pH (especially low pH soils).

pH limits for terrestrial plants (as a secondary receptor) were developed for the SLRM by reviewing plant pH tolerances. The low consequence limit accommodates all plants, while the medium consequence limit may not protect the most sensitive plants (Magdoff & Van Es, 2010), (Mosaic, 2019).

Table A- 7 Consequence assessment limits for terrestrial plant pH toxicity.

Consequence level	Description	Suggested pH	Reference
Low	No adverse effects observed	5.0-8.0	Building Soils for Better Crops (Magdoff & Van Es, 2010)
Medium	Sensitive plants may have observable effects	8.0-9.0	
High	Plants growth will be greatly affected	<5.0 or >9.0	

Oil and grease

Oil and grease is a broad category that may include many different compounds, such as petroleum hydrocarbons, plant-based oils, and synthetic ester oils, amongst others. In the context of this project, an oil or grease is defined as a liquid compound that is insoluble with water, less dense than water, and which can form a microfilm on the surface of water.

Oils and greases in surface waters can cause significant environmental damage. In the most extreme cases, animals can become covered in oil, potentially leading to starvation or even suffocation. Even small amounts of oil can lead to environmental damage by tainting aquatic plant life and removing a key source of food and oxygen from the aquatic environment.

Measuring oil and greases analytically and determining safe limits quantitively is a complex process that would involve determining common oils and greases and individually assessing their environmental impacts. This level of detail is not appropriate for a screening level risk matrix, so a more narrative definition is used to determine whether a water is likely to cause harm to the environment or not.

The 2018 Environmental Quality Guidelines for Alberta Surface Waters contains the following narrative definition for acceptable levels of oil and grease in water (Government of Alberta, 2018):

"Oil and grease attributable to human activities should not be present in amounts that:

- *cause visible sheens, films, or discolouration;*
- *can be detected by odour;*
- *cause tainting of edible aquatic biota;*
- *form deposits on shores or bottom material that are detectable by sight or odour, or are deleterious to resident biota."*

This narrative was adapted to provide the consequence limits for oil and grease, as summarized in Table A-8. Waters meeting the definition in the guidelines are low consequence, while waters not meeting the guidelines are high consequence.

Table A-8 Consequence Assessment ranges for oil and grease

Consequence Level	Oil & grease	Reference
Low	Meets SWQ guidelines	Environmental Quality Guidelines for Alberta Surface Waters 2018 (Government of Alberta, 2018)
Medium	N/A	
High	Does not Meet SWQ guidelines	

A4 Review of Letters of Authorization

LOAs are currently issued to the operator and, where necessary, municipalities to allow the use of alternative water sources for MSHF. For the reuse of treated municipal effluent, two LOAs are required:

1. From the AER to the MSHF operator, to allow the use of treated municipal effluent as a source of water.
2. From AEP to the municipality, to allow the municipality to transfer the effluent to the operator, rather than releasing it to the environment (return flow conditions).

Upon review of the LOAs for two projects involving the reuse of treated municipal effluent for MSHF, the following potential constraints were identified:

- There is a requirement that any unused volume of treated municipal effluent should be disposed of in a registered facility. This may be burdensome to the operator and an unnecessary requirement, since treated municipal effluent should, by definition, meet surface water quality requirements and be of sufficient quality for surface discharge.
- It was noted there is a requirement to avoid damaging/contaminating the environment, but no guidance is given how to avoid this. Operators may interpret this differently; it is not clear if the regulator has specific requirements in mind to minimize risk.
- The aforementioned requirement to secure two LOAs for a single project requires preparing two separate packages, often with overlapping information. This can result in a slow process which is particularly burdensome when the request is for small volumes
- Each LOA application appears to have different requirements. This lack of standardization extends the application preparation process for operators and the combined review period of the AER and AEP.

As noted in CAPP's October 2019 letter (Section 4.1.2), operators desire a clear process that can be standardized as much as possible. Operators would then be able to produce a package for each application that meets all the requirements of the AER and AEP. Ideally, LOAs for alternative water use would be under the jurisdiction of a single regulatory body with clear requirements for the MSHF operator.