Source Water Risk Assessment Summary

Background:

The City of Calgary (The City) is committed to delivering safe, high-quality water to city and regional customers through proactive stewardship and management of source watersheds. This proactive approach goes back decades and includes actions such as the Glenmore Park Bylaw (1974) to manage recreation on Glenmore Reservoir and the decision to receive Cochrane wastewater for treatment (1998). More recently, The City's *Source Water Protection Policy* (CP2020-04) provides clear direction to integrate source water protection into city and regional planning to mitigate risks to upstream water quality degradation.

Administration's Risk Assessment:

The City's source water protection experts in Water Services and Climate and Environment assessed the risks to drinking water from a wastewater treatment plant outfall to the Bow River from the community of Harmony upstream of the Bearspaw Reservoir and the Bearspaw Water Treatment Plant's raw water intakes.

A new wastewater outfall above these drinking water intakes is expected to degrade source water quality, and potentially lead to treatment challenges. As source water quality degrades, more expensive treatment processes may be needed to maintain safe drinking water for Calgarians.

Source water quality generally determines the level of treatment required to make water safe to drink. Turbidity, total organic carbon, enteric protozoa, and disinfections are the most important parameters driving current water treatment operations. When the Source Water Protection Plan was published in 2018, wastewater was considered a moderate risk as there were limited wastewater effluent discharges upstream. The highest risks to drinking water from wastewater effluent are from nutrients and human pathogens.

Nutrient concentrations:

- Even at low levels, increases in nutrient concentrations can lead to taste and odour issues, nuisance organisms, or in a worst-case scenario toxic algae or cyanobacterial blooms.
- The ecosystems within the reservoirs are a delicate balance of water quality parameters and nutrient ratios. An upset of this balance is already manifesting itself in the form of the seasonal taste and odour events observed in recent years.
- Any new sources of nutrients, such as from wastewater effluent, has the potential to challenge treatment, and in the case of cyanobacterial toxin production, threaten the public health safety of drinking water.

Pathogens:

- Pathogens (bacteria, viruses, and protozoa) within source waters have the potential for immediate acute impact to public health, and therefore must always be considered high risk.
- Any inputs of human sewage, including treated wastewater, into Calgary's source water increases the risk of these human pathogens.

University of Waterloo's Risk Assessment:

Concurrent to The City's risk assessment, an external assessment was also conducted by experts at the University of Waterloo, which is outlined in *Technical Memo, Water Quality Change in the Bow River, Risks from Nearby Wastewater Treatment Outfalls and Treatment Implications* (14 November 2023). The Technical Memo is included in this Attachment, and key conclusions from the Memo are summarized below. These findings are consistent with The City's understanding of source water quality trends and risks.

Although Bow River source water quality remains high, it is changing, and showing signs of impact from urban development.

- An analysis of 20 water quality parameters over the last 20 years at the Bearspaw Raw 1 intake, and locations on the Bow River upstream of Calgary shows that many aspects of water quality have been changing over time and these changes are consistent throughout the watershed.
- Persistent changes in river source water quality will eventually result in key thresholds being exceeded at which point the ecosystem loses its capacity to recover. The result of this would be permanent water quality alteration in Calgary's source watershed.
- Water quality data from 2023 indicates that the Bow River is showing signs of impact. These impacts are consistent with increased urban development within the watershed.
- The Bow River is already showing signs of reduced assimilative capacity (i.e., ability to absorb the pollutants without an adverse effect).

The introduction of a wastewater treatment outfall into the Bow River close to the Bearspaw Reservoir and a drinking water treatment intake poses significant and highly likely threats to source water quality.

- The introduction of a wastewater treatment outfall into the Bow River close to a drinking water treatment intake—even after tertiary wastewater treatment—would very likely result in significant source water quality degradation.
- A nearby wastewater outfall would not preclude Calgary's ability to provide water that meets potable drinking water standards; however, it would eliminate Calgary's ability to describe Bow River source water as a "high quality" source.

Water quality deterioration is expected to be exacerbated by a changing climate.

- Low flow conditions from droughts would result in less dilution of contaminants.
- Warmer air temperatures and decreased groundwater inputs can also increase water temperature and decrease dissolved oxygen resulting in conditions that promote proliferation of algae and bacteria.

TECHNICAL MEMO

TO: Norma Ruecker, Leader Microbiology and Watershed Assessment, The City of Calgary (Calgary)

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SUBJECT: Water Quality Change in the Bow River, Risks from Nearby Wastewater Treatment Outfalls & Treatment Implications

DATE: November 15, 2023

Introduction & Scope of Work

On October 17, 2023, via an email from Dr. Norma Ruecker, Calgary requested an opinion regarding water quality change in the Bow River, risks from nearby wastewater treatment outfalls, and associated implications to drinking water treatment. Specifically, a brief Tech Memo was requested as detailed below.

Please use your respective subject matter expertise and provide your professional opinion on the following:

1) general water quality changes in the Bow River upstream of the Bearspaw Water Treatment plant intake over the last ~20 years and outline potential reasons for the change,
2) threats to source water quality from a wastewater treatment outfall into the Bow River ~4-5 km upstream of Bearspaw Reservoir and ~10 km upstream of WTP Raw 1 intake at Bearspaw Dam, and
3) the drinking water treatment implications of source water quality changes and potential wastewater treatment outfall.

High Quality Source Water – The Bow River

The Bow River provides the City of Calgary with exceedingly high-quality source water that is subsequently treated to potable standards at the Bearspaw Water Treatment Plant (WTP). As detailed in Calgary's 2018 Source Water Protection Plan (City of Calgary, 2018), turbidity, enteric protozoa (*Giardia* and *Cryptosporidium*), and total organic carbon (TOC) are the most important aspects of Bow River water quality currently because they drive day-to-day operation and optimization of the WTP and must be considered in future infrastructure planning. ***Turbidity*** is strongly influenced by high river flows, erosion, and land use—it can vary considerably from year to year (reflecting wet or dry conditions) and changes seasonally, peaking during snowpack melt in late spring/early summer. ***Microbiological enteric protozoa*** result from contamination by human or animal feces; their current occurrence is relatively low by North American standards. ***Total organic carbon (TOC)*** includes both naturally occurring and synthetic organic compounds. Presently, TOC concentrations in the Bow River are low and predominantly composed of ***natural organic matter (NOM)*** that influences coagulant dosing and contributes to the formation of disinfection by-products during chlorine disinfection. ***Other synthetic and naturally-occurring organic compounds*** include pesticides, polycyclic aromatic hydrocarbons (PAHs), hydrocarbons, and volatile organic compounds (VOCs). Between 2007 and 2016, 103 compounds (including 53 that pose potential public health risks) have been analyzed in Calgary's raw water and less than 1% of over 1,800 samples had detections. Notably, detected compounds were always at concentrations below drinking water guidelines. Similarly, ***emerging substances of concern (ESOCs)*** include pharmaceuticals, hormones, detergents, plasticizers and flame retardants found in domestic and industrial wastes, and urban and agricultural runoff have been rarely detected in Calgary's raw water. Out of 202 ESOCs that have been tested, only six compounds have ever been detected—present at very low concentrations, all of these are indicators of wastewater impacts from upstream communities. ***Nutrient (e.g., phosphorus and nitrogen)*** concentrations in the Bow River are also low, thereby limiting the growth and/or metabolic activity of many algae, bacteria, and plants. Limited growth of certain algae and bacteria is especially relevant to the provision of safe, high quality drinking water because some of these microorganisms produce VOCs that impart unpleasant tastes and odours (which are increasingly detected in Calgary) while others are able to produce toxins of human and ecosystem health concern. Collectively, the low concentrations and/or lack of detections of these various water quality parameters indicates that the Bow River provides the City of Calgary with exceedingly high-quality source water.

Water Quality Change in the Bow River

Although Bow River source water quality remains high, it is changing throughout the watershed. An analysis of 20 water quality parameters over the last 20 years at the Bearspaw Raw 1 intake, Bearspaw Reservoir, and numerous locations on the Bow River upstream of Calgary shows that many aspects of water quality have been changing over time and these changes are consistent throughout the watershed. For example, nitrate and sulphate concentrations have been increasing and taste and odour events in the Bearspaw Reservoir have increasingly occurred, including in each of the last four years. While the specific drivers of these changes are unknown, they are consistent with the typical impacts of both natural, climate-change-exacerbated (Mosley, 2015; Murdoch et al., 2000) and anthropogenic landscape disturbances, including urban development (Hamdhani et al., 2020; Pamuru et al., 2022; Preston et al., 2011).

Water quality data from 2023 suggest that the Bow River is showing signs of impact from urban development in particular. Urban development generally impacts water quality through inputs of nutrients, metals, and organic compounds from point sources such as storm and wastewater outfalls (Hamdhani et al., 2020; Pamuru et al., 2022). Typically, water quality improves with increasing distance downstream of these point sources as natural biotic and abiotic processes within rivers take up (i.e., metabolize), transform, immobilize, and dilute contaminants—collectively, these processes drive a river's assimilative capacity (i.e., ability to absorb the pollutants without an adverse effect) (Elósegui et al., 1995; Gibson & Meyer, 2007; Haggard et al., 2001; Hashemi Monfared et al., 2017; Marti et al., 2004). Pollution occurs when a river's assimilative capacity is exceeded. Differences in mean total phosphorus, nitrate, dissolved oxygen, and TOC loading have been observed in the Bow River between (1) the Ghost Dam and the Highway 22 Bridge in Cochrane and (2) the Highway 22 Bridge in Cochrane and the Glenbow Ranch sampling site (located immediately upstream of the Harmony stormwater outfall and the proposed wastewater outfall). Specifically, total phosphorus, nitrate and dissolved oxygen loads increase between the Ghost Dam and Cochrane, but decrease between Cochrane and Glenbow Ranch, while the opposite is observed for TOC. The increase in nutrients between the Ghost Dam and Cochrane may reflect inputs from stormwater outfalls (and possibly septic tanks) within the town of Cochrane, which are subsequently taken up and immobilized downstream by biotic and abiotic processes between Cochrane and Glenbow Ranch. While TOC loads may be diluted between the Ghost Dam and the Highway 22 Bridge in Cochrane, they increase between Cochrane and Glenbow Ranch, while dissolved oxygen loads decrease. These changes are consistent with increased primary productivity (where biotic growth and senescence result in increased TOC and decreased dissolved oxygen) driven by increased nutrient availability resulting from urban inputs. Thus, these data suggest that the Bow River's assimilative capacity is being exceeded in some aspects by urban development.

Threats to Bow River Source Water Quality from Nearby Upstream Wastewater Outfall

The establishment of an upstream wastewater treatment outfall into the Bow River within four to five kilometers of Bearspaw Reservoir and 10 kilometers upstream of WTP Raw 1 intake at Bearspaw Dam poses significant and highly likely threats to Bow River source water quality. As described above, urban development generally impacts water quality through inputs of nutrients, metals, and organic compounds from point sources such as storm and wastewater outfalls (Hamdhani et al., 2020; Pamuru et al., 2022). Although water quality typically improves with increasing distance downstream of these point sources, the Bow River is already showing signs of reduced assimilative capacity. The introduction of a wastewater treatment outfall into the Bow River so close to a drinking water treatment intake—even after tertiary wastewater treatment—would very likely result in significant source water quality degradation. It is generally understood that in such cases there are insufficient opportunities for assimilation. As a result, a fraction of the water entering the drinking water treatment plant is composed of effluent from the wastewater treatment plant—this is typically referred to as *de facto* reuse. While *de facto* reuse of municipal wastewater is somewhat common in many parts of the world including North America because of historical urban development, the choice to purposefully permit source water pollution to the extent that a *de facto* reuse situation is created is contradictory to most source water protection plans, including Calgary's. Source water protection is a critical first barrier in the multi-barrier approach to the protection of public health through the provision of safe drinking water. As discussed above and in Calgary's Source Water Protection Plan (City of Calgary, 2018), many of the thousands of potential persistent organic pollutants and ESOCs are not presently found in Calgary's source water. Some of these chemicals have persistent, bioaccumulative, and toxic properties and have been defined as substances of very high concern (European Commission, 2006; Hernando et al., 2011). There is also a significant potential for increased proliferation of algae and bacteria as a result of increased nutrient availability—this can lead to increased occurrence of unpleasant tastes and odours as well as the production of toxins of human and ecosystem health concern. Increased delivery of waterborne pathogens including enteric protozoa can also be expected. In a changing climate it is further important to consider the potential impacts of drought, which would result in a greater fraction of *de facto* reuse; warmer ambient temperatures and decreased groundwater inputs can also increase water temperature and thus decrease dissolved oxygen resulting in conditions that promote proliferation of algae and bacteria. Finally, persistent changes in river source water quality may ultimately result in key ecological thresholds being exceeded (i.e., tipping points) at which point the ecosystem loses its capacity to recover or its assimilative capacity and integrity are lost; the result of this would be essentially permanent water quality alternation in Calgary's source watershed (Andersen et al., 2009; Luoto et al., 2019; Poikane et al., 2014).

Treatment Implications of Source Water Quality Change and Potential Nearby Wastewater Treatment Outfall

As detailed in Calgary's Source Water Protection Plan (City of Calgary, 2018), maintaining high quality source water with respect to organics (i.e., synthetic and naturally occurring compounds including VOCs and ESOCs described above) is important, since some of these compounds are not effectively removed by conventional drinking water treatment processes. The water treatment plants in Calgary are conventional water treatment plants designed to achieve solids removal with high throughput—they were not designed to treat the range of compounds (including synthetic and naturally occurring compounds such as VOCs and ESOCs) that are found in wastewater plant discharges. To treat these compounds, the additional treatment infrastructure that would be necessary to achieve treated water with high quality equivalent to that currently produced is costly and energy and maintenance intensive; it would likely include advanced oxidation processes such as ozonation or activated carbon processes in combination with coagulation (powdered activated carbon) or filtration (granular activated carbon). Potentially significant increases in source water protozoa could also trigger the need for additional disinfection in the future. The technology to treat the known pollutants associated with *de facto* reuse is available; thus, a nearby wastewater treatment outfall would not preclude Calgary's ability to provide potable water that meets potable drinking water standards; however, it would eliminate Calgary's ability to describe Bow River water as a "high quality" source.

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