Stantec

Cover Letter

To:	Anneli Jokela, PhD Wek’èezhìi Land and Water Board	From:	Arlen Foster, P. Eng. Stantec
File:	144902412 08-16	Date:	May 31, 2022

Reference: **144902412 Wekweèti Water Treatment Plant – W2018L3-0001 – Water Supply Facilities Characterization and Testing Plan - Resubmission**

As per the request from the Wek’èezhìi Land and Water Board, on behalf of the Community Government of Wekweèti and the Government of the Northwest Territories in association with AWC Water Solutions, we provide the following resubmitted Water Characterization and Sampling Plan for record as well as the requested revisions to the associated O&M Plan.

Link to download the files are:

O&M Manual Wekweeti
CTP plan

This includes water quality results for the raw water, treated water, backwash discharge, CIP wastewater, wastewater tank samplings carried out during the WTP’s commissioning and following operations.

Please direct any further discussion or comments that may be necessary from the WLWB to Iqbal Arshad and Jamie Goddard.

Stantec Architecture Ltd.

Arlen Foster P. Eng.
Senior Associate

Phone: 867-920-2882 ext. 249
Email: arlen.foster@stantec.com

Attachment:	Wekweeti WTP Waste Characterization and Sampling Plan, 10338-PR-RPT-003, 08 April 22 Wekweeti WTP O&M Manual, #10338, Revised Version 3.2, 08 April 2022

c.

Wekweeti WTP

Water Supply Facilities Characterization and Testing Plan

10338-PR-RPT-003

Project No: 10338

Ultra-Filtration Potable Water Plant

2	08 Apr 22	Issued for Information	SB	JP	JP
1	17 Sep 21	Issued for Information	SB	JP	JP
0	28 Aug 20	Issued for Information	SB	JP	JP
Rev	**Date**	**Rev Description**	**Originator**	**Checker**	**Approver**

TABLE OF CONTENTS

1. WATER CHARACTERIZATION SAMPLING PLAN

The Wekweeti Water Treatment Plant (WTP) is a turnkey membrane ultrafiltration system, with sodium hypochlorite (chlorine) disinfection, installed within a skid-mounted building. The raw water source for the new WTP is Snare Lake (1.6 km east of the community).

1.1. Water quality sampling

Wekweeti drinking WTP was commissioned in the month of October, 2020. After successful plant start-up and commissioning, water samples were collected for treated water after 24 hours and 48 hours of plant operation. Testing for treated water was carried out which included routine water analysis, organics, metals, and bacterial coliform tests. It is to be noted that backwash water, wastewater tank and clean-in-place (CIP) wastewater sampling were not conducted at the time of plant commissioning and startup. Water samplings for backwash water, wastewater tank and CIP wastewater was conducted almost after one year of successful plant operation on 27th and 28th July, 2021.

Table 1: Wekweeti WTP test plan with sampling location, frequency and date.

Interface	Sample Location	Frequency Commissioning Oct., 2020	Frequency 27th July, 2021	Frequency 28th July, 2021	Parameters
Treated Water	Truck Fill Line SV-071	1x (24 hours of plant startup) and 1x (48 hours of plant startup)	-	-	Full set
Backwash Water	Overland discharge pipe		1x	1x	Full set
Wastewater Tank Discharge	Wastewater Tank – HV-133		1x	1x	Full set
Citric Acid CIP Wastewater	Overland discharge pipe		1x	-	Full set
Sodium Hypochlorite CIP Wastewater	Overland discharge pipe		1x	-	Full set

1.2. Water quality test results

For Wekweeti, only treated water sampling was conducted after WTP plant commissioning and stat-up in Oct., 2020. Backwash water and wastewater tank sampling were conducted on 27th July, 2021 and 28th July, 2021 and tabulated in Table 2. CIP sampling was conducted after a year of plant operation on 27th July, 2021. Separate citric acid and sodium hypochlorite CIP sampling result highlights are listed in the Table 3. Backwash water and CIP wastewater which are discharged overland, is compared to the current municipal water licence lagoon discharge criteria at SNP 003-2 and SNP 003-3. Water quality from the wastewater tank, which is pumped out and hauled to municipal sewage lagoon for treatment, is compared to Schedule I: Standards for Process Effluent Discharged to Municipal Sewage Systems in the Government of the Northwest Territories Department of Environment and Natural Resources 2004 Guideline for Industrial Waste Discharges in the NWT. All the water quality parameters for the sampling are within the guideline recommendations.

Samples were collected for treated water from Wekweeti WTP after 24 hours and 48 hours of commissioning completion. These were rushed to Yellowknife, NT (within 24 hours) and tested at ALS Laboratory. Treated water was checked for pathogens (i.e., E. coli and total coliforms). Separately, GNWT also conducted treated water sampling for E. coli and total coliform which were tested in Stanton Territorial Hospital Laboratory in Yellowknife. Treated water results are not discussed in this report. The complete lab reports are included in the appendices.

Table 2: Wekweeti WTP Backwash Water and Wastewater Tank Sampling Results.

Backwash Water Overland Discharge				
Parameters	**Units**	**Test Results (27-July-2021)**	**Test Results (28-July-2021)**	**SNP 003-2/3**
Total Suspended Solids	mg/L	<3.0	<3.0	240/25
Oil and Grease	mg/L	<5.0	<5.0	5/5
CBOD	mg/L	26	26	235/25
Faecal Coliforms	CFU/100 mL	<1.0	<1.0	$1 \times 10^6 / 1 \times 10^6$
pH	-	6.78	6.81	6 – 9

Wastewater Discharge (Wastewater Tank – HV-133)				
Parameters	**Units**	**Test Results (27-July-2021)**	**Test Results (28-July-2021)**	**Industrial Waste Discharge Guidelines**
Aluminum	mg/L	0.113	0.0110	50
Arsenic	mg/L	0.00035	0.00032	1
Barium	mg/L	0.00411	0.00346	5
Biochemical oxygen demand	mg/L	26	5	500
Cadmium	mg/L	0.0000235	0.0000091	2
Chromium	mg/L	0.00056	0.00086	5
Copper	mg/L	0.144	0.0586	5
Lead	mg/L	0.0196	0.00763	5
Iron	mg/L	0.306	0.245	50
Mercury	mg/L	<0.0000050	<0.0000050	0.1
Nickel	mg/L	0.00192	0.00136	5
Oil & Grease	mg/L	<5.0	<5.0	150
pH	-	7.81	6.96	6.5 - 10.5
Phosphorus	mg/L	0.315	0.079	100
Silver	mg/L	0.000237	0.000039	5
Suspended solids	mg/l	<3.0	<3.0	600
Tin	mg/L	0.00184	0.00062	5
Zinc	mg/L	0.0913	0.0356	5

Table 3: Wekweeti WTP CIP Waste Sampling Results.

Citric Acid CIP Wastewater Discharge (Overland Discharge Pipe)

Parameters	Units	Test Results (27-July-2021)	SNP 003-2/3
Total Suspended Solids	mg/L	<3.0	240/25
Oil and Grease	mg/L	<5.0	5/5
CBOD	mg/L	20	235/25
Faecal Coliforms	CFU/100 mL	<1.0	1 $\times 10^6$/1 $\times 10^6$
pH		6.88	6 - 9

Sodium Hypochlorite CIP Wastewater Discharge (Overland Discharge Pipe)

Parameters	Units	Test Results (27-July-2021)	SNP 003-2/3
Total Suspended Solids	mg/L	<3.0	240/25
Oil and Grease	mg/L	<5.0	5/5
CBOD	mg/L	18	235/25
Faecal Coliforms	CFU/100 mL	<1.0	1 $\times 10^6$/1 $\times 10^6$
pH		7.02	6 - 9

2. Long Term Water Quality Test Plan

Current sampling programs at the Wekweeti WTP include:

- continuous online measurements of turbidity in the raw water, filtered water, and treated water storage;
- continuous online measurements of free chlorine in CT tank and treated water tank;
- thrice daily in-plant grab testing of the treated water for chlorine and turbidity
- weekly bacteriological sampling for total coliforms and e.coli;
- annual chemical analysis of both the raw and treated water of the 29 parameters identified in the Water Supply Regulations;

The above sample results are reviewed by the local operator and the Regional Environmental Health Officer to ensure the Community of Wekweeti continues to receive high-quality, safe drinking water. They provide meaningful results in which an operator can immediately take action to protect the quality of water, i.e., adjust chlorine dosage or perform a membrane repair.

Operators also perform in-plant testing of the post CIP water for chlorine and pH to ensure water has been fully de-chlorinated and are of a neutral pH before allowing it to pass through overland discharge.

Grab samples of the backwash water and wastewater tank water taken are provided for reference. Membrane CIP was carried out after almost a year of the WTP being operational. CIP waste was sampled as a recommendation by ENR and MVLWB. These parameters are not expected to experience significant fluctuation in their concentration, whereby it exceeds the guideline limit or its comparison data. No chemical addition, other than post-filter chlorination, is completed in this process. Filtered water used in the backwash is not chlorinated. Additional long-term sampling of the backwash water, CIP wastewater and the wastewater tank would not provide any information to the operator in which they can take corrective measures. Therefore, an onerous long-term sampling program on backwash water and wastewater tank would not provide information of practical value to the operations and is not recommended.

Also, the research team at Dalhousie University were engaged by MACA, ENR and MVLWB to study impacts of WTP residuals and waste to the environment across NWT. The initial report is attached in the Appendices. For the membrane filtration plant (Gameti), the Dalhousie University reported elevated TSS and aluminum concentrations higher than typical regulatory thresholds for WTP waste residual discharges in other jurisdications in Canada and not in NWT. These higher concentrations were reported only for one of the samplings, during plant startup and commissioning in October, 2019. It should be noted that during startup and commissioning of the WTP, its membrane filtration operations is not fully matured and there could be variations in the sampling results for the WTP waste residual discharge. With the continuous operation of the WTP, the process matures and more stable results could be obtained. Subsequently, the sampling conducted in August 2021 for Gameti WTP residual discharge, showed concentrations well below the regulatory thresholds for WTP waste residual discharges in other jurisdications in Canada. Thus, it can be concluded that long term sampling program on the backwash water and wastewater tank is not recommended.

APPENDICES

2020 – Sampling Events

Raw water, and Treated water

Cash Clients
ATTN: Jainish Patel
90875 198st
Langley BC V1M 3B1

Date Received:	01-OCT-20
Report Date:	13-OCT-20 08:55 (MT)
Version:	FINAL

Client Phone: 604-936-4221

Certificate of Analysis

Lab Work Order #: L2510782

Project P.O. #:	NOT SUBMITTED
Job Reference:	19578,4128A
C of C Numbers:	17-818382
Legal Site Desc:	

Oliver Gregg
Account Manager

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2510782-1 WEKWEETI WTP RAW							
Sampled By: CLIENT on 30-SEP-20 @ 13:00							
Matrix: WATER							
Miscellaneous Parameters							
Biochemical Oxygen Demand	<2.0		2.0	mg/L		04-OCT-20	R5252339
Bromide (Br)	<0.050		0.050	mg/L		06-OCT-20	R5249139
Chloride (Cl)	<0.50		0.50	mg/L		06-OCT-20	R5249139
Dissolved Kjeldahl Nitrogen	0.36		0.20	mg/L	08-OCT-20	08-OCT-20	R5252182
Dissolved Organic Carbon	5.8		1.0	mg/L		08-OCT-20	R5252099
Fluoride (F)	0.030		0.020	mg/L		06-OCT-20	R5249139
Hardness (as CaCO3)	8.05	HTC	0.13	mg/L		09-OCT-20	
Cyanide, Total	0.0014		0.0010	mg/L		07-OCT-20	R5251633
Phosphorus (P)-Total Dissolved	<0.020		0.020	mg/L	05-OCT-20	06-OCT-20	R5248641
Total Dissolved Solids	16		10	mg/L		05-OCT-20	R5249797
Mercury (Hg)-Total	<0.0000050		0.0000050	mg/L		03-OCT-20	R5244638
Total Organic Carbon	6.7		1.0	mg/L		08-OCT-20	R5252099
Phosphorus (P)-Total	0.035		0.020	mg/L	05-OCT-20	06-OCT-20	R5248641
Total Suspended Solids	4.0		3.0	mg/L		05-OCT-20	R5247519
Turbidity	0.52		0.10	NTU		04-OCT-20	R5244806
pH, Conductivity and Total Alkalinity							
pH	6.79		0.10	pH		03-OCT-20	R5244734
Conductivity (EC)	30.1		2.0	uS/cm		03-OCT-20	R5244734
Bicarbonate (HCO3)	10.1		5.0	mg/L		03-OCT-20	R5244734
Carbonate (CO3)	<5.0		5.0	mg/L		03-OCT-20	R5244734
Hydroxide (OH)	<5.0		5.0	mg/L		03-OCT-20	R5244734
Alkalinity, Total (as CaCO3)	8.3		2.0	mg/L		03-OCT-20	R5244734
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	0.0141		0.0030	mg/L		08-OCT-20	R5252131
Antimony (Sb)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Arsenic (As)-Total	0.00027		0.00010	mg/L		08-OCT-20	R5252131
Barium (Ba)-Total	0.00195		0.00010	mg/L		08-OCT-20	R5252131
Beryllium (Be)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Bismuth (Bi)-Total	<0.000050		0.000050	mg/L		08-OCT-20	R5252131
Boron (B)-Total	<0.010		0.010	mg/L		08-OCT-20	R5252131
Cadmium (Cd)-Total	<0.0000050		0.0000050	mg/L		08-OCT-20	R5252131
Calcium (Ca)-Total	1.87		0.050	mg/L		08-OCT-20	R5252131
Cesium (Cs)-Total	<0.000010		0.000010	mg/L		08-OCT-20	R5252131
Chromium (Cr)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Cobalt (Co)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Copper (Cu)-Total	0.00270		0.00050	mg/L		08-OCT-20	R5252131
Iron (Fe)-Total	0.019		0.010	mg/L		08-OCT-20	R5252131
Lead (Pb)-Total	<0.000050		0.000050	mg/L		08-OCT-20	R5252131
Lithium (Li)-Total	0.0011		0.0010	mg/L		08-OCT-20	R5252131
Magnesium (Mg)-Total	0.825		0.0050	mg/L		08-OCT-20	R5252131
Manganese (Mn)-Total	0.00242		0.00010	mg/L		08-OCT-20	R5252131
Molybdenum (Mo)-Total	<0.000050		0.000050	mg/L		08-OCT-20	R5252131
Nickel (Ni)-Total	<0.00050		0.00050	mg/L		08-OCT-20	R5252131
Phosphorus (P)-Total	<0.050		0.050	mg/L		08-OCT-20	R5252131
Potassium (K)-Total	0.615		0.050	mg/L		08-OCT-20	R5252131
Rubidium (Rb)-Total	0.00170		0.00020	mg/L		08-OCT-20	R5252131
Selenium (Se)-Total	<0.000050		0.000050	mg/L		08-OCT-20	R5252131
Silicon (Si)-Total	0.198		0.050	mg/L		08-OCT-20	R5252131
Silver (Ag)-Total	<0.000010		0.000010	mg/L		08-OCT-20	R5252131
Sodium (Na)-Total	0.888		0.050	mg/L		08-OCT-20	R5252131

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2510782-1 WEKWEETI WTP RAW							
Sampled By: CLIENT on 30-SEP-20 @ 13:00							
Matrix: WATER							
Total Metals in Water by CRC ICPMS							
Strontium (Sr)-Total	0.00826		0.00020	mg/L		08-OCT-20	R5252131
Sulfur (S)-Total	0.96		0.50	mg/L		08-OCT-20	R5252131
Tellurium (Te)-Total	<0.00020		0.00020	mg/L		08-OCT-20	R5252131
Thallium (Tl)-Total	<0.000010		0.000010	mg/L		08-OCT-20	R5252131
Thorium (Th)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Tin (Sn)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Titanium (Ti)-Total	<0.00030		0.00030	mg/L		08-OCT-20	R5252131
Tungsten (W)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Uranium (U)-Total	0.000086		0.000010	mg/L		08-OCT-20	R5252131
Vanadium (V)-Total	<0.00050		0.00050	mg/L		08-OCT-20	R5252131
Zinc (Zn)-Total	<0.0030		0.0030	mg/L		08-OCT-20	R5252131
Zirconium (Zr)-Total	<0.00020		0.00020	mg/L		08-OCT-20	R5252131
Dissolved Nitrogen							
DKN (as N) by Fluorescence							
Dissolved Kjeldahl Nitrogen	0.359		0.050	mg/L	07-OCT-20	08-OCT-20	R5252182
Nitrate in Water by IC (Low Level)							
Nitrate (as N)	0.0108		0.0050	mg/L		06-OCT-20	R5249139
Nitrite in Water by IC (Low Level)							
Nitrite (as N)	0.0038		0.0010	mg/L		06-OCT-20	R5249139
Total Dissolved Nitrogen (Calculation)							
Total Dissolved Nitrogen	0.374		0.050	mg/L		09-OCT-20	
NO2, NO3, & (NO2+NO3) in Water							
Nitrate in Water by IC							
Nitrate (as N)	<0.020		0.020	mg/L		06-OCT-20	R5249139
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	0.0146		0.0051	mg/L		07-OCT-20	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		06-OCT-20	R5249139
L2510782-2 WEKWEETI WTP TREATED							
Sampled By: CLIENT on 30-SEP-20 @ 15:00							
Matrix: WATER							
Miscellaneous Parameters							
Biochemical Oxygen Demand	5.8		2.0	mg/L		04-OCT-20	R5252339
Bromide (Br)	<0.050		0.050	mg/L		06-OCT-20	R5249139
Chloride (Cl)	8.03		0.50	mg/L		06-OCT-20	R5249139
Dissolved Kjeldahl Nitrogen	0.22		0.20	mg/L	08-OCT-20	08-OCT-20	R5252182
Dissolved Organic Carbon	8.4		1.0	mg/L		08-OCT-20	R5252099
Fluoride (F)	<0.020		0.020	mg/L		06-OCT-20	R5249139
Hardness (as CaCO3)	8.58	HTC	0.13	mg/L		09-OCT-20	
Cyanide, Total	<0.0010		0.0010	mg/L		06-OCT-20	R5250058
Phosphorus (P)-Total Dissolved	<0.020		0.020	mg/L	05-OCT-20	06-OCT-20	R5248641
Total Dissolved Solids	38	DLDS	13	mg/L		05-OCT-20	R5249797
Mercury (Hg)-Total	<0.0000050		0.0000050	mg/L		03-OCT-20	R5244638
Total Organic Carbon	8.5		1.0	mg/L		08-OCT-20	R5252099
Phosphorus (P)-Total	<0.020		0.020	mg/L	05-OCT-20	06-OCT-20	R5248641
Total Suspended Solids	<3.0		3.0	mg/L		05-OCT-20	R5247519
Turbidity	0.26		0.10	NTU		04-OCT-20	R5244806
pH, Conductivity and Total Alkalinity							
pH	6.81		0.10	pH		03-OCT-20	R5244734
Conductivity (EC)	53.9		2.0	uS/cm		03-OCT-20	R5244734

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2510782-2 WEKWEETI WTP TREATED							
Sampled By: CLIENT on 30-SEP-20 @ 15:00							
Matrix: WATER							
pH, Conductivity and Total Alkalinity							
Bicarbonate (HCO3)	11.7		5.0	mg/L		03-OCT-20	R5244734
Carbonate (CO3)	<5.0		5.0	mg/L		03-OCT-20	R5244734
Hydroxide (OH)	<5.0		5.0	mg/L		03-OCT-20	R5244734
Alkalinity, Total (as CaCO3)	9.6		2.0	mg/L		03-OCT-20	R5244734
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	0.130		0.0030	mg/L		08-OCT-20	R5252131
Antimony (Sb)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Arsenic (As)-Total	0.00031		0.00010	mg/L		08-OCT-20	R5252131
Barium (Ba)-Total	0.00191		0.00010	mg/L		08-OCT-20	R5252131
Beryllium (Be)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Bismuth (Bi)-Total	<0.000050		0.000050	mg/L		08-OCT-20	R5252131
Boron (B)-Total	<0.010		0.010	mg/L		08-OCT-20	R5252131
Cadmium (Cd)-Total	0.0000050		0.0000050	mg/L		08-OCT-20	R5252131
Calcium (Ca)-Total	1.90		0.050	mg/L		08-OCT-20	R5252131
Cesium (Cs)-Total	<0.000010		0.000010	mg/L		08-OCT-20	R5252131
Chromium (Cr)-Total	0.00184		0.00010	mg/L		08-OCT-20	R5252131
Cobalt (Co)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Copper (Cu)-Total	0.00472		0.00050	mg/L		08-OCT-20	R5252131
Iron (Fe)-Total	0.024		0.010	mg/L		08-OCT-20	R5252131
Lead (Pb)-Total	0.000057		0.000050	mg/L		08-OCT-20	R5252131
Lithium (Li)-Total	0.0012		0.0010	mg/L		08-OCT-20	R5252131
Magnesium (Mg)-Total	0.933		0.0050	mg/L		08-OCT-20	R5252131
Manganese (Mn)-Total	0.00191		0.00010	mg/L		08-OCT-20	R5252131
Molybdenum (Mo)-Total	0.000070		0.000050	mg/L		08-OCT-20	R5252131
Nickel (Ni)-Total	0.00184		0.00050	mg/L		08-OCT-20	R5252131
Phosphorus (P)-Total	<0.050		0.050	mg/L		08-OCT-20	R5252131
Potassium (K)-Total	0.638		0.050	mg/L		08-OCT-20	R5252131
Rubidium (Rb)-Total	0.00192		0.00020	mg/L		08-OCT-20	R5252131
Selenium (Se)-Total	<0.000050		0.000050	mg/L		08-OCT-20	R5252131
Silicon (Si)-Total	0.221		0.050	mg/L		08-OCT-20	R5252131
Silver (Ag)-Total	<0.000010		0.000010	mg/L		08-OCT-20	R5252131
Sodium (Na)-Total	6.87		0.050	mg/L		08-OCT-20	R5252131
Strontium (Sr)-Total	0.00860		0.00020	mg/L		08-OCT-20	R5252131
Sulfur (S)-Total	1.07		0.50	mg/L		08-OCT-20	R5252131
Tellurium (Te)-Total	<0.00020		0.00020	mg/L		08-OCT-20	R5252131
Thallium (Tl)-Total	<0.000010		0.000010	mg/L		08-OCT-20	R5252131
Thorium (Th)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Tin (Sn)-Total	0.00033		0.00010	mg/L		08-OCT-20	R5252131
Titanium (Ti)-Total	<0.00030		0.00030	mg/L		08-OCT-20	R5252131
Tungsten (W)-Total	<0.00010		0.00010	mg/L		08-OCT-20	R5252131
Uranium (U)-Total	0.000080		0.000010	mg/L		08-OCT-20	R5252131
Vanadium (V)-Total	0.00132		0.00050	mg/L		08-OCT-20	R5252131
Zinc (Zn)-Total	0.0349		0.0030	mg/L		08-OCT-20	R5252131
Zirconium (Zr)-Total	<0.00020		0.00020	mg/L		08-OCT-20	R5252131
Trihalomethanes							
Chloroform	0.128		0.0010	mg/L		07-OCT-20	R5212800
Bromodichloromethane	0.0033		0.0010	mg/L		07-OCT-20	R5212800
Dibromochloromethane	<0.0010		0.0010	mg/L		07-OCT-20	R5212800
Bromoform	<0.0050		0.0050	mg/L		07-OCT-20	R5212800
Surrogate: 1,4-Difluorobenzene (SS)	87.9		50-150	%		07-OCT-20	R5212800
Surrogate: 4-Bromofluorobenzene (SS)	81.4		70-130	%		07-OCT-20	R5212800

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2510782-2 WEKWEETI WTP TREATED							
Sampled By: CLIENT on 30-SEP-20 @ 15:00							
Matrix: WATER							
Trihalomethanes							
Surrogate: 3,4-Dichlorotoluene (SS)	114.6		50-150	%		07-OCT-20	R5212800
Total THMs	0.131		0.0050	mg/L		07-OCT-20	R5212800
Dissolved Nitrogen							
DKN (as N) by Fluorescence							
Dissolved Kjeldahl Nitrogen	0.219		0.050	mg/L	07-OCT-20	08-OCT-20	R5252182
Nitrate in Water by IC (Low Level)							
Nitrate (as N)	0.0096		0.0050	mg/L		06-OCT-20	R5249139
Nitrite in Water by IC (Low Level)							
Nitrite (as N)	0.0019		0.0010	mg/L		06-OCT-20	R5249139
Total Dissolved Nitrogen (Calculation)							
Total Dissolved Nitrogen	0.231		0.050	mg/L		09-OCT-20	
NO2, NO3, & (NO2+NO3) in Water							
Nitrate in Water by IC							
Nitrate (as N)	<0.020		0.020	mg/L		06-OCT-20	R5249139
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	0.0115		0.0051	mg/L		07-OCT-20	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		06-OCT-20	R5249139
Total Coliforms and E. Coli by MPN							
E. Coli by MPN							
MPN - E. coli	<1		1	MPN/100mL		01-OCT-20	R5247056
Total Coliforms by MPN							
MPN - Total Coliforms	<1		1	MPN/100mL		01-OCT-20	R5247056

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Qualifiers for Sample Submission Listed:

Qualifier	Description
SFPL	DKN - Sample was Filtered and Preserved at the laboratory

Sample Parameter Qualifier Key:

Qualifier	Description
DLDS	Detection Limit Raised: Dilution required due to high Dissolved Solids / Electrical Conductivity.
HTC	Hardness was calculated from Total Ca and/or Mg concentrations and may be biased high (dissolved Ca/Mg results unavailable).
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
BOD-ED	Water	Biochemical Oxygen Demand (BOD)	APHA 5210 B-5 day Incub.-O2 electrode

Samples are diluted and seeded and then incubated in airtight bottles at 20°C for 5 days. Dissolved oxygen is measured initially and after incubation, and results are computed from the difference between initial and final DO.

ALS Test Code	Matrix	Test Description	Method Reference**
BR-L-IC-N-ED	Water	Bromide in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

ALS Test Code	Matrix	Test Description	Method Reference**
C-DIS-ORG-CL	Water	Dissolved Organic Carbon	APHA 5310 B-Instrumental

Filtered (0.45 um) sample is acidified and purged to remove inorganic carbon, then injected into a heated reaction chamber where organic carbon is oxidized to CO2 which is then transported in the carrier gas stream and measured via a non-dispersive infrared analyzer.

ALS Test Code	Matrix	Test Description	Method Reference**
C-TOT-ORG-CL	Water	Total Organic Carbon	APHA 5310 B-Instrumental

Sample is acidified and purged to remove inorganic carbon, then injected into a heated reaction chamber where organic carbon is oxidized to CO2 which is then transported in the carrier gas stream and measured via a non-dispersive infrared analyzer.

ALS Test Code	Matrix	Test Description	Method Reference**
CL-IC-N-ED	Water	Chloride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

ALS Test Code	Matrix	Test Description	Method Reference**
CN-T-L-CFA-WT	Water	Low Level Total Cyanide in water by CFA	ISO 14403-2:2002

This analysis is carried out using procedures adapted from ISO Method 14403:2002 "Determination of Total Cyanide using Flow Analysis (FIA and CFA)". Total or strong acid dissociable (SAD) cyanide is determined by in-line UV digestion along with sample distillation and final determination by colourimetric analysis. Method Limitation: This method is susceptible to interference from thiocyanate (SCN). If SCN is present in the sample, there could be a positive interference with this method, however it would be less than 1% and could be as low as zero.

ALS Test Code	Matrix	Test Description	Method Reference**
DKN-F-ED	Water	DKN (as N) by Fluorescence	J. Environ. Monit. (2005) 7:37 42.

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Dissolved Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

ALS Test Code	Matrix	Test Description	Method Reference**
DKN-L-F-ED	Water	DKN (as N) by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Dissolved Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

ALS Test Code	Matrix	Test Description	Method Reference**
EC-MPN-TG	Water	E. Coli by MPN	SM9223B
ETL-HARDNESS-TOT-ED	Water	Hardness (from Total Ca and Mg)	APHA 2340 B-Calculation
F-IC-N-ED	Water	Fluoride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

ALS Test Code	Matrix	Test Description	Method Reference**
HG-T-CVAA-ED	Water	Total Mercury in Water by CVAAS	EPA 1631E (mod)

Water samples undergo a cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS.

ALS Test Code	Matrix	Test Description	Method Reference**
MET-T-CCMS-CL	Water	Total Metals in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
N-TD-CALC-ED	Water	Total Dissolved Nitrogen (Calculation)	APHA 4500 N-Calculated

Total Dissolved Nitrogen is a calculated parameter. Total Dissolved Nitrogen = Dissolved Kjeldahl Nitrogen + [Nitrate and Nitrite (as N)].

ALS Test Code	Matrix	Test Description	Method Reference**
NO2+NO3-CALC-ED	Water	Nitrate+Nitrite	CALCULATION
NO2-IC-N-ED	Water	Nitrite in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

ALS Test Code	Matrix	Test Description	Method Reference**
NO2-L-IC-N-ED	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

ALS Test Code	Matrix	Test Description	Method Reference**
NO3-IC-N-ED	Water	Nitrate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

ALS Test Code	Matrix	Test Description	Method Reference**
NO3-L-IC-N-ED	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

ALS Test Code	Matrix	Test Description	Method Reference**
P-T-COL-ED	Water	Total P in Water by Colour	APHA 4500-P PHOSPHORUS

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

ALS Test Code	Matrix	Test Description	Method Reference**
P-TD-COL-ED	Water	Total Dissolved P in Water by Colour	APHA 4500-P PHOSPHORUS

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Dissolved Phosphorus is determined colourimetrically after persulphate digestion of a sample that has been lab or field filtered through a 0.45 micron membrane filter.

ALS Test Code	Matrix	Test Description	Method Reference**
PH/EC/ALK-ED	Water	pH, Conductivity and Total Alkalinity	APHA 4500-H, 2510, 2320

All samples analyzed by this method for pH will have exceeded the 15 minute recommended hold time from time of sampling (field analysis is recommended for pH where highly accurate results are needed).
pH measurement is determined from the activity of the hydrogen ions using a hydrogen electrode and a reference electrode.
Alkalinity measurement is based on the sample’s capacity to neutralize acid. Auto-titration to pH 4.5 using 0.02N H_2SO_4 is performed.
Conductivity measurement is based on the sample’s capacity to convey an electric current, and is measured with a conductivity meter.

ALS Test Code	Matrix	Test Description	Method Reference**
SOLIDS-TDS-ED	Water	Total Dissolved Solids	APHA 2540 C

Gravimetric determination of solids in waters by filtration and evaporating filtrate to dryness at 180 degrees Celsius.

ALS Test Code	Matrix	Test Description	Method Reference**
SOLIDS-TOTSUS-ED	Water	Total Suspended Solids	APHA 2540 D-Gravimetric

Gravimetric determination of solids in waters by filtration and drying filter at 104 degrees Celsius.

ALS Test Code	Matrix	Test Description	Method Reference**
TC-MPN-TG	Water	Total Coliforms by MPN	SM9223B
THM-ED	Water	Trihalomethanes	SW 846 8260-GC/MS
TURBIDITY-ED	Water	Turbidity	APHA 2130 B-Nephelometer

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
ED	ALS ENVIRONMENTAL - EDMONTON, ALBERTA, CANADA
WT	ALS ENVIRONMENTAL - WATERLOO, ONTARIO, CANADA
TG	TAIGA ENVIRONMENTAL LABORATORY (INAC)
CL	ALS ENVIRONMENTAL - CALGARY, ALBERTA, CANADA

Chain of Custody Numbers:

17-818382

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

2021 – Sampling Events

2x CIP (discharge overland after neutralize), 2x Backwash (overland discharge), 2x Waste Water (Municiapl Lagoon)

CERTIFICATE OF ANALYSIS

Work Order	: **YL2100876**	Page	: 1 of 6
Amendment	: **1**		
Client	: **Cash Clients Canada**	Laboratory	: Yellowknife - Environmental
Contact	: Jainish Patel	Account Manager	: Oliver Gregg
Address	: 116-314 Old Airport Rd. Yellowknife NT Canada X1A 3T3	Address	: 314 Old Airport Road, Unit 116 Yellowknife NT Canada X1A 3T3
Telephone	: ----	Telephone	: 1 867 446 5593
Project	: Wekweeti	Date Samples Received	: 28-Jul-2021 15:30
PO	: ----	Date Analysis Commenced	: 29-Jul-2021
C-O-C number	: 17-818770	Issue Date	: 20-Aug-2021 15:05
Sampler	: ----		
Site	: Wekweeti		
Quote number	: YL21-CASH100-001		
No. of samples received	: 6		
No. of samples analysed	: 6		

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QC Interpretive report to assist with Quality Review and Sample Receipt Notification (SRN).

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is conducted in accordance with US FDA 21 CFR Part 11.

Signatories	*Position*	*Laboratory Department*
Kevin Duarte	Supervisor - Metals ICP Instrumentation	Metals, Burnaby, British Columbia
Kim Jensen	Department Manager - Metals	Metals, Burnaby, British Columbia
Lindsay Gung	Supervisor - Water Chemistry	Inorganics, Burnaby, British Columbia
Oliver Gregg	Client Services Supervisor	External Subcontracting, Yellowknife, Northwest Territories
Ophelia Chiu	Department Manager - Organics	Organics, Burnaby, British Columbia
Robin Weeks	Team Leader - Metals	Metals, Burnaby, British Columbia

General Comments

The analytical methods used by ALS are developed using internationally recognized reference methods (where available), such as those published by US EPA, APHA Standard Methods, ASTM, ISO, Environment Canada, BC MOE, and Ontario MOE. Refer to the ALS Quality Control Interpretive report (QCI) for applicable references and methodology summaries. Reference methods may incorporate modifications to improve performance.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

Please refer to Quality Control Interpretive report (QCI) for information regarding Holding Time compliance.

Key : CAS Number: Chemical Abstracts Services number is a unique identifier assigned to discrete substances

LOR: Limit of Reporting (detection limit).

Unit	*Description*
CFU/100mL	colony forming units per 100 mL
mg/L	milligrams per litre
pH units	pH units

<: less than.

>: greater than.

Surrogate: An analyte that is similar in behavior to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.

Test results reported relate only to the samples as received by the laboratory.

UNLESS OTHERWISE STATED on SRN or QCI Report, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.

Qualifiers

Qualifier	*Description*
DLA	*Detection Limit adjusted for required dilution.*

Analytical Results

Sub-Matrix: **Water**

(Matrix: **Water**)

				Client sample ID	**NaOcl CIP**	**Citric CIP**	**Backwash 1**	**Backwash 2**	**WW1**
				Client sampling date / time	27-Jul-2021 08:00	27-Jul-2021 11:00	27-Jul-2021 12:00	28-Jul-2021 08:00	27-Jul-2021 17:00
Analyte	*CAS Number*	*Method*	*LOR*	*Unit*	**YL2100876-001**	**YL2100876-002**	**YL2100876-003**	**YL2100876-004**	**YL2100876-005**
					Result	Result	Result	Result	Result
Physical Tests									
pH	----	E108	0.10	pH units	7.02	6.88	6.78	6.81	7.18
solids, total suspended [TSS]	----	E160-H	3.0	mg/L	6.2	<3.0	<3.0	<3.0	<3.0
Anions and Nutrients									
ammonia, total (as N)	7664-41-7	E298	0.0050	mg/L	0.0957	0.0250	0.0142	0.0285	0.128
phosphorus, total	7723-14-0	E372-U	0.0020	mg/L	0.127	0.0929	0.0190	0.0169	0.360
Bacteriological Tests									
coliforms, thermotolerant [fecal]	----	FC-MF	1.0	CFU/100mL	<1.0	<1.0	<1.0	<1.0	<1.0
Total Metals									
aluminum, total	7429-90-5	E420	0.0030	mg/L	0.563	0.695	0.0998	0.0917	0.113
antimony, total	7440-36-0	E420	0.00010	mg/L	<0.00010	<0.00050 DLA	<0.00010	<0.00010	0.00014
arsenic, total	7440-38-2	E420	0.00010	mg/L	0.00092	0.00101	0.00043	0.00039	0.00035
barium, total	7440-39-3	E420	0.00010	mg/L	0.00644	0.0144	0.00292	0.00313	0.00411
beryllium, total	7440-41-7	E420	0.000020	mg/L	0.000028	<0.000100 DLA	<0.000020	<0.000020	<0.000020
bismuth, total	7440-69-9	E420	0.000050	mg/L	<0.000050	<0.000250 DLA	<0.000050	<0.000050	0.000093
boron, total	7440-42-8	E420	0.010	mg/L	<0.010	<0.050 DLA	<0.010	<0.010	<0.010
cadmium, total	7440-43-9	E420	0.0000050	mg/L	0.0000126	0.0000560	0.0000110	0.0000105	0.0000235
calcium, total	7440-70-2	E420	0.050	mg/L	2.52	7.03	2.88	3.48	2.27
cesium, total	7440-46-2	E420	0.000010	mg/L	0.000054	0.000057	0.000011	<0.000010	0.000013
chromium, total	7440-47-3	E420	0.00050	mg/L	0.00229	<0.00250 DLA	<0.00050	<0.00050	0.00056
cobalt, total	7440-48-4	E420	0.00010	mg/L	0.00041	0.00083	<0.00010	<0.00010	0.00030
copper, total	7440-50-8	E420	0.00050	mg/L	0.0688	0.163	0.0323	0.0293	0.144
iron, total	7439-89-6	E420	0.010	mg/L	1.21	2.49	0.262	0.233	0.306
lead, total	7439-92-1	E420	0.000050	mg/L	0.00251	0.0142	0.00160	0.00127	0.0196
lithium, total	7439-93-2	E420	0.0010	mg/L	0.0020	<0.0050 DLA	0.0012	0.0012	0.0011
magnesium, total	7439-95-4	E420	0.0050	mg/L	2.49	7.92	1.78	1.90	1.12
manganese, total	7439-96-5	E420	0.00010	mg/L	0.0838	0.223	0.0187	0.0163	0.00968
mercury, total	7439-97-6	E508	0.0000050	mg/L	0.0000073	<0.0000050	<0.0000050	<0.0000050	<0.0000050
molybdenum, total	7439-98-7	E420	0.000050	mg/L	0.000761	0.000293	0.000165	0.000164	0.000129
nickel, total	7440-02-0	E420	0.00050	mg/L	0.00234	0.00767	0.00134	0.00154	0.00192
phosphorus, total	7723-14-0	E420	0.050	mg/L	0.092	<0.250 DLA	<0.050	<0.050	0.315
potassium, total	7440-09-7	E420	0.050	mg/L	1.35	1.71	0.900	0.882	4.02

Analytical Results

Sub-Matrix: **Water**

(Matrix: **Water**)

				Client sample ID	**NaOcl CIP**	**Citric CIP**	**Backwash 1**	**Backwash 2**	**WW1**
				Client sampling date / time	27-Jul-2021 08:00	27-Jul-2021 11:00	27-Jul-2021 12:00	28-Jul-2021 08:00	27-Jul-2021 17:00
Analyte	*CAS Number*	*Method*	*LOR*	*Unit*	**YL2100876-001**	**YL2100876-002**	**YL2100876-003**	**YL2100876-004**	**YL2100876-005**
					Result	Result	Result	Result	Result
Total Metals									
rubidium, total	7440-17-7	E420	0.00020	mg/L	0.00330	0.00327	0.00210	0.00210	0.00235
selenium, total	7782-49-2	E420	0.000050	mg/L	0.000171	<0.000250 DLA	<0.000050	<0.000050	0.000073
silicon, total	7440-21-3	E420	0.10	mg/L	1.02	1.09	0.32	0.33	0.37
silver, total	7440-22-4	E420	0.000010	mg/L	0.000018	<0.000050 DLA	<0.000010	<0.000010	0.000237
sodium, total	17341-25-2	E420	0.050	mg/L	194	1260	119	103	38.9
strontium, total	7440-24-6	E420	0.00020	mg/L	0.0114	0.0276	0.0104	0.0117	0.00945
sulfur, total	7704-34-9	E420	0.50	mg/L	1.11	<2.50 DLA	0.66	0.66	0.94
tellurium, total	13494-80-9	E420	0.00020	mg/L	<0.00020	<0.00100 DLA	<0.00020	<0.00020	<0.00020
thallium, total	7440-28-0	E420	0.000010	mg/L	<0.000010	<0.000050 DLA	<0.000010	<0.000010	<0.000010
thorium, total	7440-29-1	E420	0.00010	mg/L	0.00037	0.00089	0.00022	0.00020	0.00013
tin, total	7440-31-5	E420	0.00010	mg/L	0.00854	0.00388	0.00410	0.00351	0.00184
titanium, total	7440-32-6	E420	0.00030	mg/L	0.0146	0.0159	0.00091	0.00064	0.00118
tungsten, total	7440-33-7	E420	0.00010	mg/L	<0.00010	<0.00050 DLA	<0.00010	<0.00010	<0.00010
uranium, total	7440-61-1	E420	0.000010	mg/L	0.00246	0.00396	0.000888	0.000822	0.000389
vanadium, total	7440-62-2	E420	0.00050	mg/L	0.00117	<0.00250 DLA	<0.00050	<0.00050	<0.00050
zinc, total	7440-66-6	E420	0.0030	mg/L	0.0357	0.114	0.0198	0.0210	0.0913
zirconium, total	7440-67-7	E420	0.00020	mg/L	0.00113	0.00143	0.00021	<0.00020	0.00024
Aggregate Organics									
carbonaceous biochemical oxygen demand [CBOD]	----	CBOD5	2	mg/L	18	20	26	26	26
oil & grease (gravimetric)	----	E567	5.0	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0

Please refer to the General Comments section for an explanation of any qualifiers detected.

Analytical Results

Sub-Matrix: **Water**

(Matrix: **Water**)

				Client sample ID	**WW2**	----	----	----	----
				Client sampling date / time	28-Jul-2021 09:00	----	----	----	----
Analyte	*CAS Number*	*Method*	*LOR*	*Unit*	**YL2100876-006**	--------	--------	--------	--------
					Result	----	----	----	----
Physical Tests									
pH	----	E108	0.10	pH units	6.96	----	----	----	----
solids, total suspended [TSS]	----	E160-H	3.0	mg/L	<3.0	----	----	----	----
Anions and Nutrients									
ammonia, total (as N)	7664-41-7	E298	0.0050	mg/L	0.303	----	----	----	----
phosphorus, total	7723-14-0	E372-U	0.0020	mg/L	0.0838	----	----	----	----
Bacteriological Tests									
coliforms, thermotolerant [fecal]	----	FC-MF	1.0	CFU/100mL	<1.0	----	----	----	----
Total Metals									
aluminum, total	7429-90-5	E420	0.0030	mg/L	0.110	----	----	----	----
antimony, total	7440-36-0	E420	0.00010	mg/L	<0.00010	----	----	----	----
arsenic, total	7440-38-2	E420	0.00010	mg/L	0.00032	----	----	----	----
barium, total	7440-39-3	E420	0.00010	mg/L	0.00346	----	----	----	----
beryllium, total	7440-41-7	E420	0.000020	mg/L	<0.000020	----	----	----	----
bismuth, total	7440-69-9	E420	0.000050	mg/L	<0.000050	----	----	----	----
boron, total	7440-42-8	E420	0.010	mg/L	<0.010	----	----	----	----
cadmium, total	7440-43-9	E420	0.0000050	mg/L	0.0000091	----	----	----	----
calcium, total	7440-70-2	E420	0.050	mg/L	2.02	----	----	----	----
cesium, total	7440-46-2	E420	0.000010	mg/L	0.000014	----	----	----	----
chromium, total	7440-47-3	E420	0.00050	mg/L	0.00086	----	----	----	----
cobalt, total	7440-48-4	E420	0.00010	mg/L	0.00012	----	----	----	----
copper, total	7440-50-8	E420	0.00050	mg/L	0.0586	----	----	----	----
iron, total	7439-89-6	E420	0.010	mg/L	0.245	----	----	----	----
lead, total	7439-92-1	E420	0.000050	mg/L	0.00763	----	----	----	----
lithium, total	7439-93-2	E420	0.0010	mg/L	0.0010	----	----	----	----
magnesium, total	7439-95-4	E420	0.0050	mg/L	0.961	----	----	----	----
manganese, total	7439-96-5	E420	0.00010	mg/L	0.00488	----	----	----	----
mercury, total	7439-97-6	E508	0.0000050	mg/L	<0.0000050	----	----	----	----
molybdenum, total	7439-98-7	E420	0.000050	mg/L	0.000067	----	----	----	----
nickel, total	7440-02-0	E420	0.00050	mg/L	0.00136	----	----	----	----
phosphorus, total	7723-14-0	E420	0.050	mg/L	0.079	----	----	----	----
potassium, total	7440-09-7	E420	0.050	mg/L	0.970	----	----	----	----
rubidium, total	7440-17-7	E420	0.00020	mg/L	0.00226	----	----	----	----

Analytical Results

Sub-Matrix: **Water**

(Matrix: **Water)**

				Client sample ID	**WW2**	**----**	**----**	**----**	**----**
				Client sampling date / time	28-Jul-2021 09:00	----	----	----	----
Analyte	*CAS Number*	*Method*	*LOR*	*Unit*	**YL2100876-006**	**--------**	**--------**	**--------**	**--------**
					Result	----	----	----	----
Total Metals									
selenium, total	7782-49-2	E420	0.000050	mg/L	<0.000050	----	----	----	----
silicon, total	7440-21-3	E420	0.10	mg/L	0.38	----	----	----	----
silver, total	7440-22-4	E420	0.000010	mg/L	0.000039	----	----	----	----
sodium, total	17341-25-2	E420	0.050	mg/L	3.48	----	----	----	----
strontium, total	7440-24-6	E420	0.00020	mg/L	0.00897	----	----	----	----
sulfur, total	7704-34-9	E420	0.50	mg/L	0.65	----	----	----	----
tellurium, total	13494-80-9	E420	0.00020	mg/L	<0.00020	----	----	----	----
thallium, total	7440-28-0	E420	0.000010	mg/L	<0.000010	----	----	----	----
thorium, total	7440-29-1	E420	0.00010	mg/L	<0.00010	----	----	----	----
tin, total	7440-31-5	E420	0.00010	mg/L	0.00062	----	----	----	----
titanium, total	7440-32-6	E420	0.00030	mg/L	0.00193	----	----	----	----
tungsten, total	7440-33-7	E420	0.00010	mg/L	<0.00010	----	----	----	----
uranium, total	7440-61-1	E420	0.000010	mg/L	0.000195	----	----	----	----
vanadium, total	7440-62-2	E420	0.00050	mg/L	<0.00050	----	----	----	----
zinc, total	7440-66-6	E420	0.0030	mg/L	0.0356	----	----	----	----
zirconium, total	7440-67-7	E420	0.00020	mg/L	<0.00020	----	----	----	----
Aggregate Organics									
carbonaceous biochemical oxygen demand [CBOD]	----	CBOD5	2	mg/L	5	----	----	----	----
oil & grease (gravimetric)	----	E567	5.0	mg/L	<5.0	----	----	----	----

Please refer to the General Comments section for an explanation of any qualifiers detected.

Dalhousie Report

Recommendations for Municipal Water Treatment Plant Waste Residuals in the Northwest Territories

Final Submission

Prepared for:
Mackenzie Valley Land and Water Board
PO Box 2130
4922 48th Street, 7th floor
Yellowknife, NT
X1A 3S3

March 31, 2021

Prepared by:
Francois Gascon & Dr. Margaret Walsh
Centre for Water Resources Studies
Dalhousie University
1360 Barrington Street, D514
Halifax, NS B3H 4R2

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Al	Aluminum
AWWA	American Water Works Association
BC	British Columbia
CCME	Canadian Council of Ministers of the Environment
CEBW	Chemically Enhanced Backwash Water
CEQG	Canadian Environmental Quality Guidelines
CIP	Clean-in-Place
CWA	Clean Waters Act
CWRS	Centre for Water Resource Studies
CWS	Community Water System
DAF	Dissolved Air Floatation
DBP	Disinfection By-Product
DOC	Dissolved Organic Carbon
DWWP	Drinking Water Works Permit
EMA	Environmental Management Act
ENR	Departments of Environment and Natural Resources
FBRR	Filter Backwash Recycle Rule
FBWW	Filter Backwash Water
Fe	Iron
FW	Filter-to-Waste
GNWT	Government of Northwest Territories
GT	Gravity Thickeners
HAA	Haloacetic Acids
HRT	Hydraulic Retention Time
HSS	Health and Social Services
HWR	Hazardous Waste Regulation
MAC	Maximum Allowable Concentration

MACA	Municipal and Community Affairs
MDWL	Municipal Drinking Water Licence
MF	Microfiltration
MOE	Ontario Ministry of Environment
MVLWB	Mackenzie Valley Land and Water Board
NF	Nanofiltration
NOM	Natural Organic Matter
NPDES	National Pollutant Discharge Elimination System
NSE	Nova Scotia Department of Environment
NTU	Nephelometric Turbidity Units
NWT	Northwest Territories
PACl	Polyaluminum Chloride
P/T	Plate-and-Tube Settlers
RCRA	Resource Conservation and Recovery Act
RO	Reverse Osmosis
SDWA	Safe Drinking Water Act
SED	Sedimentation
SFBW	Spent Filter Backwash Water
TCLP	Toxicity Characteristic Leaching Procedure
TCU	True Color Units
TDS	Total Dissolved Solids
TMP	Transmembrane Pressure
TOC	Total Organic Carbon
TTHM	Total Trihalomethanes
UF	Ultrafiltration
USEPA	United States Environmental Protection Agency
WET	Waste Extraction Test
WQG	Water Quality Guidelines

WSA	Water Security Agency
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant
YWA	Yukon Waters Act

Executive Summary

This study's overall objective was to provide recommendations regarding the management and disposal of municipal water treatment plant (WTP) waste residuals in the Northwest Territories (NWT). Facility plant designs, waste residual streams, existing water quality data and discharge location information were requested on 33 existing drinking water plants in the NWT and reviewed. A literature review was conducted to provide (1) typical water quality characteristics of WTP waste residuals generated in plant designs common to existing drinking water plants in the NWT, (2) review of existing regulations for WTP waste residuals discharge in other jurisdictions in Canada and the U.S., and (3) an overview of WTP waste residuals management options and relevant treatment technologies used in the drinking water industry in North America.

A review of the material provided to the Center for Water Resource Studies (CWRS) team demonstrates that efforts have been made to characterize WTP waste residuals generated in the NWT drinking water facilities. From the plant design overview provided, it can be concluded that the liquid and solid waste residuals generated in the NWT WTPs would be similar to those generated in similarly designed WTPs across Canada. A review of the waste residuals water quality data collected from four WTPs (Fort Resolution, Gameti, Lutselk'e, Yellowknife) showed some parameters in exceedance of Canadian Environmental Quality Guidelines (CEQG), implying that the liquid waste residuals would require treatment prior to discharge to surface water, just as it would be required in other Canadian regulatory jurisdictions.

Regulatory requirements related to discharge of WTP waste residuals in other Canadian jurisdictions demonstrate the primary water quality parameters regulated include pH, TSS, free chlorine residual and total aluminum. In Canada and the US, the primary concern with the discharge of untreated WTP waste residuals into surface waters is introducing pollutants into the aquatic environment. To our knowledge, there is no known threshold from other jurisdictions in terms of population/flow/volume of WTP waste residuals that would provide an avenue to not treat WTP waste residuals prior to surface water discharge.

Additional data from the community WTPs is recommended to fill information gaps regarding WTP waste residuals volume and water quality data. This data would help determine the best management and disposal practices. For example, without knowing 'how much' waste residuals are currently being discharged to a particular receiving water and the associated water quality characteristics of that discharge, it is difficult to say that treatment prior to discharge is required or not.

Many of the conventional filtration plants discharge their waste residuals to sewer, which as a co-management option can offer a solution that is both cost-effective and potentially beneficial to the final solid waste streams generated. Overall, non-mechanical thickening and dewatering technologies would offer economical and effective treatment for small, remote communities.

Most of the NWT communities already have established lagoon treatment systems to manage municipal wastewater and wastewater biosolids. This avenue, therefore, may offer a feasible and cost-effective option for the management of waste residuals generated in the drinking water plants.

1. Introduction

The CWRS at Dalhousie University conducted a review of best management practices for municipal drinking water treatment plant waste residuals in Canada and the United States to provide recommendations regarding the management and disposal of WTP waste residuals in the Northwest Territories. This review was conducted for the *Mackenzie Valley Land and Water Board (MVLWB),* in conjunction with the *Departments of Environment and Natural Resources (GNWT-ENR), Municipal and Community Affairs (GNWT-MACA)*, and *Health and Social Services* of the *Government of the Northwest Territories (GNWT-HSS).* The project involved three tasks:

1. Tabulate and categorize water treatment plant processes and residuals in the Northwest Territories
2. Overview of best practices in other jurisdictions
3. Development of recommendations for the Northwest Territories

Task 1 involved evaluating the characteristics of the waste residuals generated in the 33 WTPs in the NWT. From the data provided from GNWT-MACA, a summary of the WTPs in the NWT, including main treatment train process design, waste residual streams generated, characterization of the waste residual streams (i.e., volumes, quality, contaminants of concern, etc.), and discharge point was created to provide an overview of current knowledge on WTP waste residuals generated at these facilities. A literature review was also conducted to identify typical water quality characteristics of WTP waste residuals from WTP process designs common with plant designs operating in the NWT.

Task 2 was comprised of a review of relevant Canadian and United States regulations and guidelines related to the management of WTP waste residuals. This included identifying any regulations or guidelines related to the direct discharge, treatment requirements before discharge, requirements for discharge to sewer, and regulatory framework/requirements for solid waste residuals disposal. Information was acquired, and a breakdown of relevant guidelines and regulations was summarized from Canadian provinces and territories where information could be obtained, as well as relevant regulatory information from the United States Environmental Protection Agency (USEPA) and the American Water Works Association (AWWA).

Task 3 involved recommendations from the CWRS regarding the identification of information gaps related to WTP waste residual characterization in NWT WTPs from Task 1, as well as guidance based on existing regulations and guidelines for WTP waste residual streams in other regulatory jurisdictions.

2. Overview of Drinking WTP Designs and Waste Residual Streams in the Northwest Territories

Drinking water treatment plants are designed to remove biological and physiochemical contaminants of concern from source waters, including microbiological components (pathogens, bacteria, viruses), natural organic matter (NOM), turbidity and inorganics. This section of the report provides an overview of the treatment technologies used in WTP design and the associated waste residual streams generated. This study focused on the waste residual streams generated from treatment trains common to the suite of drinking water plant designs in the Northwest Territories.

WTP waste residuals are generally categorized as being solid or liquid waste residual streams. Solid waste residuals are typically classified as being either coagulant solids (i.e., alum and ferric "sludge") or iron and manganese solid (i.e., greensand filtration) waste streams, both primarily generated in clarification processes (i.e., sedimentation (SED), dissolved air flotation (DAF), plate-and-tube settlers (P/T), etc.) of the drinking water treatment plant.

In conventional granular media filters, the liquid waste residuals generated in backwash cleaning operations have been termed spent filter backwash (SFBW), waste filter backwash water (FBWW) and filter-to-waste (FW). SFBW and FBWW are used in the drinking water industry to define the waste wash water generated after a granular filter bed is backwashed. Filter-to-waste residuals represent filtered water generated immediately after a filter has been put back online after a backwash operation but does not meet regulatory targets (i.e., filter effluent turbidity) to be sent into the distribution system. For this report, waste streams generated by backwash operations for multimedia filters will be referred to as SFBW.

The liquid waste residuals generated in membrane filtration unit operations have been termed membrane concentrate, clean-in-place (CIP) and chemically enhanced backwash water (CEBW) waste streams. CIP operations are typically initiated monthly and involve cleaning the membrane modules for several hours with a solution containing acids, bases, and surfactants, whereas CEBW operations are initiated every few hours and consist of adding chemicals to the backwash cycles to minimize fouling.

The greensand filtration waste residuals (liquid and solid) are similar to conventional media filtration; only the contaminants generated are generally ferric hydroxide, ferric carbonate, and/or manganese dioxide. For the remaining NWT drinking water treatment facilities that apply cartridge filtration and screen filters with disinfection, no WTP waste residuals are produced from these treatment processes. Therefore, no further overview is provided in the following section of this report.

2.1. Summary of Drinking Water Treatment Plants in the Northwest Territories

The 33 drinking WTPs currently in operation in the Northwest Territories were categorized by the main treatment train design (Table 1). This allowed for analysis of the waste residuals generated to be conducted through commonalities based on the main treatment train plant design.

Table 1. Summary of Drinking Water Plant Designs in the Northwest Territories

WTP Plant Design	NWT Community WTP	Community Population (2019 Statistics)
Multi-Media Filtration Treatment	• Aklavik	622
	• Behchoko (Edzo) • Behchoko (Rae)	2,028
	• Fort Providence	684
	• Fort Resolution	532
	• Fort Simpson	1,250
	• Fort Smith	2,639
	• Hay River	3,749
	• Inuvik	3,431
	• Norman Wells	768
	• Tuktoyaktuk	995
Membrane Filtration Treatment	• Fort Good Hope	582
	• Fort McPherson	635
	• Gameti	313
	• Jean Marie River	96
	• Lutselk'e	314
	• Paulatuk	323
	• Sambaa K'e (Trout Lake)	97
	• Tsiigehtchic	187
	• Tulita	521
	• Wekweeti *	140
	• Wrigley	120
	• Yellowknife	21,183
Greensand (Pre-oxidation and Filtration)	• Fort Liard	542
	• Nahanni Butte	106
	• Whati	502
Cartridge Filtration	• Colville Lake	149
	• Deline	625
	• Sachs Harbour	114
Screen Filter and Disinfection	• Ulukhaktok	476

Treated Water from Other Plants [†]	• Dettah	234
	• Enterprise	110
	• Kakisa	No Data

* Wekweeti WTP upgraded in the summer of 2020 with an ultrafiltration system with no coagulation. The WTP received final commissioning as of January 8th, 2021.

† Dettah receives treated water from Yellowknife, while Enterprise and Kakisa receive treated water from Hay River.

2.2. WTP Waste Residuals Generated in Granular Multi-Media Filtration Plants

As outlined in Table 1, there are 11 WTPs in the NWT that employ multi-media filters. Ten of these plants are conventional filtration treatment trains. Conventional filtration is defined as a water treatment plant that uses coagulation, flocculation, clarification (e.g., sedimentation or dissolved air flotation) and filtration, followed by disinfection. One plant (Tuktoyaktuk) does not apply a conventional treatment train and instead uses multi-media filters alone (i.e., no coagulation/flocculation/clarification) to treat the raw water.

Table 2 outlines the information requested in terms of plant design flows, coagulant type and dose, generated backwash volumes and discharge location. Although the information was found regarding the type of coagulant used at each facility, information on coagulant dose and backwash volumes were not readily available for every WTP.

Table 2. Summary of Operating Conditions for NWT Multi-Media Filtration Plants

NWT Community WTP	Annual Design Flow (m^3)	Coagulant	Dosage	Annual Backwash Volume (m^3)	% Backwash Produced	Discharge Location
Aklavik	31,422 (2018)	Alum	--	1,547	5.0	River
Behchoko (Edzo)	50,442 (2019)	PACl	--	--	--	Sewer
Behchoko (Rae) [‡]	87,217 (2019)	PACl	--	--	--	Sewer (Waste Residual Solids) Lake (SFBW)
Fort Providence	28,263 (2017)	PACl	--	1,800	6.4	River
Fort Resolution	24,761 (2016)	Alum	12.6 ml/min[Δ]	641[§]	2.6	Lake
Fort Simpson	182,500 (2020)	PACl	14 mg/L	7,300	4.0	Sewer
Fort Smith	286,482 (2018)	PACl	--	--	--	Sewer

Hay River [‡]	367,389 (2019)	Polymer Blend, Polyamine	46.2 ml/min[Δ], 90 ml/min[Δ]	--	--	Sewer (Waste Residual Solids) Lake (SFBW)
Inuvik	543,974 (2019)	PACl	60 mg/L (Winter) 115-130 mg/L (Spring) 110 mg/L (Summer/Fall)	--	--	Sewer
Norman Wells	95,937 (2018)	Alum	583 ml/min[Δ]	2,520	2.6	Sewer
Tuktoyaktuk	46,801 (2019)	n/a	n/a	--	--	Reservoir

[‡] The WTPs in Behchoko (Rae) and Hay River are equipped with sludge concentrators that get pumped out to the sewer/lagoon system a couple of times a week. However, the daily backwash is discharged to the environment (lake).

[§] This number is potentially only half of the total backwashed volume. The backwash count could potentially have been for only 1 of the 2 filters in Fort Resolution.

[Δ] These values are volumetric flow rates.

For the two WTPs with available backwash volume data (Aklavik and Fort Resolution), 3 to 5% of water produced becomes SFBW waste residuals. This is a typical % volume of waste residuals produced relative to the main treatment train water flow.

2.2.1. Review of Conventional Filtration SFBW Study Report (Fort Resolution)

One community WTP required to submit a plan for the management of WTP waste residuals was Fort Resolution. The water sampling study of the SFBW generated at this facility conducted in 2018-2019 was provided for this study by *The Department of Municipal and Community Affairs* with the *Government of the Northwest Territories.* That study provides some information regarding the water quality of SFBW streams generated in conventional filtration plants in the NWT.

The Fort Resolution plant is a conventional water treatment train which consists of coagulation, flocculation, clarification, and disinfection. Aluminum sulphate (alum) is used as the primary coagulant for this plant. Backwash cleaning procedures of the filters are initiated approximately twice daily, and the SFBW is directed into a pond that flows back to the raw water source (Great Slave Lake) (MACA & GOV NWT, 2019).

Two sampling sequences were performed to monitor the SFBW. The initial site visit was conducted in May 2018, and two water samples were obtained, a raw water sample and a SFBW sample from inside the WTP. A second site visit was conducted in July 2018, but SFBW samples were obtained from four different locations (see Figure 1):

- The backwash effluent flow inside the water treatment plant;
- The flow directly at the end of the discharge pipe (Site #1);
- In the drainage path, halfway between the discharge path and the lake (Site #2);
- The junction between the drainage path and Great Slave Lake (Site #3) (MACA and GNWT, 2019).

Figure 1. Sampling Locations for the Fort Resolution WTP SFBW Study (Source: MACA and GNWT, 2019)

Another round of sampling was conducted in July 2019, with four samples obtained from the same discharge path as well as an additional raw water sample. The results from each sampling activity were compared to the CEQGs and summarized to include only the metals that showed elevated concentrations (Tables 3 - 5).

Table 3. Fort Resolution WTP Site Visit Water Sample Test Results (May 2018)

Analyte (µg/L)	Raw Water (May)	In-Plant SFBW	CEQG
pH	8.16	6.77	6.5 – 9.0
Aluminum	**101**	**124,000**	100
Arsenic	0.3	**5.1**	5.0
Copper	1.0	**13.7**	2.0
Iron	170	**3,760**	300
Lead	0.1	**2.1**	1.0
Zinc	5.0	**12.6**	7.0

Source: Adapted from MACA and GNWT, 2019

Table 4. Fort Resolution WTP Site Visit Water Sample Test Results (July 2018)

Analyte (µg/L)	**Raw Water (May)**	**In-Plant SFBW**	**Site #1 SFBW Discharge Pipe**	**Site #2 Drainage Path**	**Site #3 Junction Path & Lake**	**CEQG**
pH	8.16	6.76	6.91	7.1	7.17	6.5 – 9.0
Aluminum	**101**	**26,600**	**16,400**	**7,080**	**13,800**	100
Arsenic	0.3	**2.1**	1.0	0.8	1.0	5.0
Copper	1.0	**7.9**	**5.5**	**4.2**	**4.8**	2.0
Iron	170	**3,030**	**1,490**	**1,240**	**1,480**	300
Lead	0.1	**1.8**	**1.1**	0.8	**1.1**	1.0
Zinc	5.0	**14.1**	**9.5**	**7.8**	**12.8**	7.0

Source: Adapted from MACA and GNWT, 2019

Table 5. Fort Resolution WTP Site Visit Water Sample Test Results (July 2019)

Analyte (µg/L)	**Raw Water (July 2019)**	**In-Plant SFBW**	**Site #1 SFBW Discharge Pipe**	**Site #2 Drainage Path**	**Site #3 Junction Path & Lake**	**CEQG**
pH	8.66	6.79	7.13	7.24	7.41	6.5 – 9.0
Aluminum	**1,870**	**1,350**	**5,250**	**56,300**	**23,900**	100
Arsenic	1.8	0.4	1.0	**8.0**	3.8	5.0
Copper	**4.4**	1.2	**2.8**	**24.4**	**10.9**	2.0
Iron	**2,780**	237	**1,130**	**16,200**	**6,990**	300
Lead	**1.6**	0.2	0.7	**9.5**	**4.1**	1.0
Zinc	**11.9**	5.0	**6.0**	**75.2**	**33.9**	7.0

Source: Adapted from MACA and GNWT, 2019

The commonality amongst the SFBW test results is the presence of elevated concentrations of aluminum, copper, iron, lead and zinc above the CEQG set points. The elevated aluminum concentrations measured in SFBW samples from this plant are expected, given the use of aluminum sulphate (alum) as a coagulant in the main treatment train. It is common to see elevated Al concentrations in SFBW from plants that use alum or other aluminum-based coagulants (i.e., polyaluminum chloride (PACl)) for coagulation and reflects the removal of coagulated aluminum hydroxide ($Al(OH)_3$)(s) floc in filtration operations.

The other metals found at elevated concentration levels in the Fort Resolution SFBW samples reflect the concentration of contaminants in the source water into the waste residual streams. Although there appears to have wide variability in copper, iron, lead, and zinc concentrations measured in the source water on the three different sampling days, overall, all of the raw water samples showed the presence of these metals in Great Slave Lake at levels above or close to the

CEQG set points. Metals present in source water can become integrated into coagulated floc and then removed from the water phase to become concentrated in waste residual solids (i.e., clarifier solids) or liquid waste residuals (i.e., SFBW). Precipitated metals can also be potentially captured in multi-media filters, resulting in elevated concentrations in SFBW streams.

A few things to note in the MACA/GNWT study report:

- Overall, the Fort Resolution data on collected SFBW samples shows inorganic water quality that would be considered typical of a conventional filtration plant that uses alum as a coagulant.
- There does not seem to have been any process description or sampling efforts with regards to the clarifier waste solids. Discharge location and quality of this waste residual stream (i.e., % solids, aluminum concentrations) should be included in any future study at the Fort Resolution WTP or any other conventional filtration plant that is audited.
- The methodology for SFBW sampling in the plant was not provided. The water quality of SFBW generated in a backwashing operation can change significantly from the start of the backwash (i.e., higher concentrations of contaminants that reflect the first release of captured material in filter media) to the end of a backwash cycle (i.e., lower concentrations of contaminants that reflect the filter bed has been cleaned). Grab sampling in terms of number and frequency should be noted when collecting SFBW samples for water quality analysis, and efforts should be taken to generate a composite sample that reflects the variable water quality observed through a backwash sequence.
- The study focused on determining pH and metal concentrations only in the SFBW samples. Given that the WTP uses chlorine for disinfection, chlorine residuals in the SFBW samples would be an important parameter to monitor.
- Similarly, TSS concentrations, not measured in the study, would also be significant to the ultimate discharge point.
- No information was provided in the report on the pond the SFBW is discharged to in terms of size or hydraulic retention time (HRT).

2.2.2. Overview of Typical Characteristics of WTP Waste Residuals Generated in Conventional Filtration Plant Designs

Inorganic coagulants commonly used in the drinking water industry include aluminum sulphate (e.g., alum ($Al_2(SO_4)_3 \cdot 18H_2O$)) and ferric-based coagulants (e.g., ferric chloride ($FeCl_3$) and ferric sulphate ($Fe_2(SO_4)_3$)). Polyaluminum chloride (PACl) is another aluminum-based coagulant commonly used in the drinking water industry in Canada and the United States. During coagulation and flocculation, inorganic coagulants precipitate out to form solids (i.e., aluminum hydroxide ($Al(OH)_3(s)$) or ferric hydroxide ($Fe(OH)_3(s)$)). The precipitated metal solids have a weak positive charge that attracts negatively charged contaminants (i.e., NOM, turbidity) in the source water to form coagulated flocs that are primarily removed, along with the solids in the raw water, during the clarification step.

Filters, used as a polishing step at the end of a conventional filtration treatment process, capture residual particles and coagulated floc carryover not captured in the clarification step. The two types of media typically used in granular filters in the drinking water industry are anthracite and sand. The particulate material accumulates in the filter media until a target headloss is realized, and the filter is taken offline for backwash cleaning.

Conventional filtration plants produce two major waste residual streams, solid waste residuals from the clarification step and liquid waste residuals from cleaning multimedia filters, often termed spent filter backwash water (SFBW) (Figure 2).

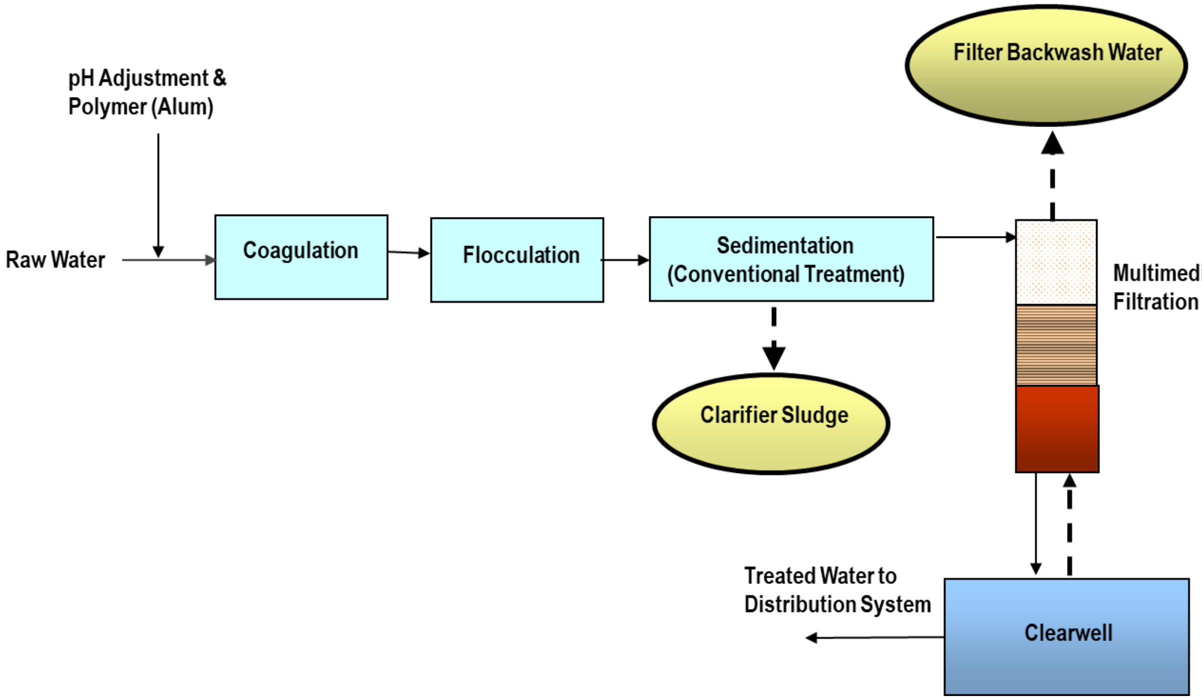

Figure 2. WTP Waste Residuals Generated in Conventional Filtration WTPs

SFBW consists of the liquid waste and concentrated solids captured within the filter during a backwash cleaning cycle. Backwashing involves pumping clean filtered water in the reverse flow direction of the filter at high velocity to ensure the fluidization of the filter media and release of the captured floc and particulate material within the filter bed. After a backwash cycle, the filters are ripened until a target effluent turbidity is reached. During filter ripening, the water produced in the filters is directed to waste collection to ensure adequate filter performance prior to returning the system online. The liquid waste residuals produced during the filter ripening period are referred to as filter-to-waste (USEPA, 2011).

Although SFBW is typically the largest residual stream in terms of volume, it is relatively low in solids compared to the waste solid residual streams captured in clarification operations (Peck and Russell, 2005). The volume of SFBW produced at a drinking water treatment plant is a function of the amount of water used for backwashing. Many researchers have concluded the volume of backwash water generated in a WTP is usually 2 to 5 % of the treatment plant flow (Peck and Russel, 2005; Crittenden et al., 2012; Davis, 2010).

The addition of inorganic coagulants results in the formation of solid waste streams that are highly concentrated in the precipitated metals that are formed in the coagulation/flocculation process, along with clay, silts, and organic and inorganic matter precipitated by the coagulant (Peck and Russell, 2005). For low turbidity source waters, the coagulation process itself generates most of the solid waste residuals collected in the clarifiers and filtration units.

In summary, the properties of the solid and liquid waste residual streams collected in conventional filtration plants depend upon the source water quality, type and dose of coagulant used, efficiency of the operation and plant design.

Table 6 outlines the typical chemical characteristics of solid waste residuals generated in WTPs that use inorganic coagulants.

Table 6. Typical Chemical Constituents of Solid Waste Residuals Generated with Inorganic Coagulant Addition

Chemical Constituent	Unit	Alum	Iron
pH		6 – 8	6 – 8
Solids			
$Al_2O_3 \cdot 5.5H_2O$	%	15 – 40	
Fe	%		4 – 21
Silicates and inert materials	%	35 – 70	35 – 70
Organics	%	10 – 25	5 – 15

Source: Adapted from Crittenden et al., 2012; Peck and Russell, 2005

A study by Cornwell and Roth (2011) presented typical values for total metal concentrations measured in WTP solid waste residuals and are summarized in Table 7. This dataset demonstrates that a wide variety of metals can be found in WTP waste solids at elevated concentrations. However, this data does not mean that every WTP will have similar levels of metals in their solid waste streams. Rather, if a plant is designed to remove target metals from source water to meet regulatory guidelines or regulations for finished water quality, then it would be expected that those metals would be found to be concentrated in the solid waste streams generated by that plant. Similarly, if a plant employs an aluminum or ferric-based inorganic coagulant, elevated concentrations of Al and Fe solids would be expected to be found in the waste residuals generated in that plant.

Table 7. Total Metal Analysis for Conventional Filtration WTP Solid Waste Residuals (Alum Coagulation)

Metal	**Waste Residual Solids (mg/kg dry weight)**
Aluminum	28,600 – 123,000
Arsenic	9.2 – 32.0
Barium	< 30 – 230
Cadmium	1 – 2
Chromium	50 – 130
Copper	16 – 168
Iron	15,200 – 79,500
Lead	9 – 40
Manganese	233 – 4,800
Mercury	< 0.1 – 0.2
Nickel	23 – 131
Selenium	< 2
Silver	< 2
Zinc	91.7 – 781

Source: Adapted from Cornwell and Roth, 2011

Application of aluminum and iron hydroxide solid waste residuals from conventional filtration WTPs as a soil amendment can result in the adsorption of phosphorus from the soil to the applied residuals, resulting in less productive soils (USEPA, 2011). Bugbee and Frink (1985) experimented with an aluminum WTP waste residual as a potting soil mixture. That study found that plants' growth was restricted by phosphorous deficiencies induced by the alum waste residual solids adsorbing the phosphorous present in fertilizer and converting it into forms unavailable for plant growth.

According to a study conducted by Cornwell et al. (2010), SFBW from conventional filtration WTPs can contain elevated levels of pathogenic organisms such as *Giardia a*nd *Cryptosporidium,* total organic carbon (TOC), disinfection by-product (DBP) precursor material, and metals such as aluminum and manganese. However, the exact water quality characteristics of SFBW are highly dependant on the water quality characteristics of the source water and chemicals used in the main treatment train (i.e., alum).

Table 8 presents the findings from a study by Cornwell et al. (2001), which focused on comparing the water quality of raw water and SFBW. Overall, the study demonstrated that organics and metals in the source water and/or precipitated metals from coagulation/flocculation processes would be concentrated in the SFBW as their precipitated forms are captured in filtration.

Table 8. Comparison of Contaminant Levels in Raw Water and Conventional Filtration SFBW

Parameter	Raw Water		Spent Filter Backwash Water		Multiple Increase
	Range	Average	Range	Average	
TOC (mg/L)	0.7 – 5.4	2.4	0.8 – 191	8.0	3.3
Al (mg/L)	ND – 30	0.72	ND – 145.8	14.7	20.4
Fe (mg/L)	ND – 56.6	1.2	ND – 132	8.7	7.3
Mn (mg/L)	0.01 – 5.5	0.11	0.01 – 17.9	1.4	12.7
TTHM (µg/L)	ND – 21.8	0.6	ND – 198	55.0	91.7
HAA6 (µg/L)	ND – 21.5	1.9	ND – 211	46.1	24.3

Source: Cornwell and Roth, 2011
ND = Non-Detectable

The disinfection by-products reported in the Cornwell et al. (2001) study included total trihalomethanes (TTHMs) and haloacetic acids (HAA6). The elevated TTHM and HAA6 concentrations measured in SFBW samples reflect chlorinated water use to backwash filters (Cornwell and Roth, 2011).

A parallel study by Edzwald et al. (2001) found that dissolved organic carbon (DOC), dissolved metals, and UV-254 were not elevated in untreated SFBW relative to raw water levels. However, that study supported the Cornwell et al. (2001) findings that total metals and TOC concentrations were elevated in SFBW samples compared to the corresponding raw water.

Several subsequent research publications have provided additional typical water quality characterization results for SFBW characteristics in conventional filtration plants and are summarized in Table 9.

Table 9. Conventional Filtration SFBW Water Quality Characteristics

Analyte	Conventional Treatment
	Range
pH	7.2 – 7.8
Turbidity (NTU)	50 – 97
TSS (mg/L)	50 – 1,000
Residual Chlorine (mg/L)	0.1 – 1.1
TOC (mg/L)	20 – 85
DOC (mg/L)	3.0 – 4.8
Total Aluminum (mg/L)	29 – 76
Total Iron (mg/L)	3 – 19
Total Manganese (mg/L)	12 – 22

Source: Adapted from Gouvernement du Québec, 2015; Peck and Russell, 2005; Crittenden et al., 2012; USEPA, 2011; McCormick et al., 2010

The principal contaminant of concern in SFBW in relation to discharge to surface water is most often the particulate content (Cornwell et al., 2010). The particulate matter is quantified with the TSS measurement in the SFBW. For WTPs using an aluminum-based coagulant, the precipitated aluminum from the coagulation process results in high Al concentrations in SFBW and clarifier solids streams. Aluminum in the aquatic environment can have a major impact on aquatic life. The principal effects of aluminum toxicity in fish are related to the organisms' inability to regulate ions and osmotic pressure and include various respiratory problems related to aluminum precipitation on the gills. Some of the apparent signs of aluminum toxicity in fish include coughing response, hyperventilation, and excessive mucous clogging of the gills (CCME, 2003).

2.3. WTP Waste Residuals Generated in Membrane Filtration Plants

As outlined in Table 1, 12 drinking water plants in the NWT utilize membrane filtration. Two of these membrane plants utilize coagulation upstream of filtration, and the remaining 10 WTPs do not use coagulants upstream of membrane filtration.

All of the membrane plants employ low-pressure membranes (i.e., microfiltration (MF) or ultrafiltration (UF), with the exception of the Tsiigehtchic facility, which has a high-pressure membrane system (nanofiltration (NF)).

Table 10 below summarizes the main information on WTP residuals generated at the 12 membrane filtration plants in the NWT, including annual backwash volumes and percent waste produced.

For the one high-pressure membrane plant (Tsiigehtchic), information was not provided to the CWRS team on the volume of waste residuals produced by this facility. High-pressure membrane plants usually produce a continuous concentrate stream from the separation process, and the volume of concentrate produced tends to be greater than that produced in low-pressure membrane plants (Cornwell and Roth, 2011). However, the water quality from high-pressure membrane plants tends to carry overall lower particulate matter loads, given that influent feedwater turbidity to NF and reverse osmosis (RO) high-pressure plants must be less than 1 NTU to ensure optimum performance (Cornwell and Roth, 2011). Further information on the volume of waste residual streams and water quality analysis from this plant which employs nanofiltration (NF), would be relevant to determine both volume and water quality of the resultant waste residuals produced.

Table 10. Summary of Relevant Operating Conditions for Membrane Filtration Plants in NWT

NWT Community WTP	Annual Design Flow (m^3)	System	Coagulant	Dosage	Annual Backwash Volume (m^3)	% Backwash Produced	Discharge Location

Fort Good Hope	22,923 (2017)	UF	Aluminum Chlorohydrate	25 mg/L (5ml/min)[Δ]	1,284	5.6	Overland
Fort McPherson	31,941 (2018)	UF	none	--	2,555	8.0	Sewer
Gameti	9,783 (2017)	UF	none	--	446	4. 6	Overland/ Lake
Jean Marie River	4,819 (2019)	UF	none	--	305	6.3	Overland
Lutselk'e	16,671 (2017)	UF	none	--	934	5.6	Lake
Paulatuk	10,770 (2019)	UF	none	--	483	4.5	Overland/ Lake
Sambaa K'e (Trout Lake)	3,008 (2019)	UF	Aluminum Chlorohydrate	25 mg/L (5ml/min)[Δ]	171	5.7	Overland
Tsiigehtchic	4,817 (2018)	NF	none	--	--	--	Lake
Tulita	16,059 (2014)	UF	none	--	--	--	River
Wekweeti [**]	4,756 (2018)	UF	none	--	--	--	Overland
Wrigley	5,827 (2019)	UF	none	--	320	5.5	Overland
Yellowknife	3,127,067 (2019)	MF	none[£]	--	3,527	0.1	Sewer

[£] Yellowknife WTP does not use a coagulant in its main treatment train; however, PACl is added to the backwash stream.

[**] Wekweeti WTP upgraded in the summer of 2020 to an ultrafiltration system with no coagulation. The WTP received final commissioning as of January 8th, 2021.

[Δ] These values are volumetric flow rates.

The membrane WTPs with available backwash volume data produce in the range of 4 to 8 % waste residuals of main treatment train water flow.

2.3.1. Review of Waste Residuals Reports for NWT Membrane Filtration Plants

Studies have been conducted on several of the membrane plants in NWT, including information related to the waste residuals at these facilities. The following sections summarize the relevant data as it relates to WTP waste residuals presented in these reports from the Gameti, Lutselk'e and Yellowknife WTPs.

Gameti WTP

The Gameti WTP is an ultrafiltration (UF) plant that disinfects the UF permeate water with sodium hypochlorite (NaOCl). There is no pre-treatment of the water (i.e., coagulation) before UF treatment. The source water for the plant is Rae Lake.

AWC Water Solutions Inc. conducted a start-up and commissioning water sampling study in October 2019 at the Gameti WTP. Three locations within the plant were sampled (raw water, backwash water and wastewater tank). The backwash water at this facility is discharged overland while the contents of the wastewater tank are pumped out and hauled to the municipal sewage lagoon for treatment. Clean-In-Place (CIP) samples were not obtained at the time of this study.

A summary of the water quality analysis from the October 2019 sampling campaign is presented in Table 11. Two samples were taken of the waste backwash water for water quality analysis (Oct 16 & Oct 20, 2019). The two water quality reports show some variability between the two samples. That may be reflective of variable operating conditions during start-up/commissioning phases.

Based on samples collected on October 20, 2019, the source water for the plant is shown to be a low turbidity (< 1 NTU) and moderate TOC (5 mg/ L) water. The majority of the source water's organic material also shows to be primarily in the dissolved form (DOC = 4.5 mg/ L). Water quality analysis of the treated water on samples collected Oct 20/19 shows that TOC and DOC are not being removed with the current UF membrane plant design. TOC was measured to be 6.3 mg/ L and DOC of 5.7 mg/L in the treated water (AWC, 2020). However, the TOC and DOC test results on the waste backwash water and wastewater tank samples show some degree of concentration of organic material in the waste residual collection streams. These water quality results do not line up with simple material balance analysis.

Table 11. Gameti WTP Water Sample Test Results (2019)

Analyte	**Raw Water (Oct 20/19)**	**Waste Backwash Water (Oct 16/19)**	**Waste Backwash Water (Oct 20/19)**	**Wastewater Tank (Oct 21/19)**
pH	8.18	8.14	8.81	8.09
Turbidity (NTU)	0.33	0.14	**11.5**	1.05
TSS (mg/L)	< 3.0	< 3.0	**46.9**	< 3.0
TDS (mg/L)	215	205	864	339
True Color (TCU)	< 5.0	< 5.0	< 5.0	< 5.0
TOC (mg/L)	**5.07**	**236**	9.77	16.2
DOC (mg/L)	**4.47**	**224**	8.81	15.5
Total Aluminum (mg/L)	< 0.010	0.021	**0.127**	0.093
Total Arsenic (mg/L)	< 0.010	< 0.010	< 0.010	< 0.010
Total Iron (mg/L)	< 0.010	< 0.010	0.09	0.144

Total Manganese (mg/L)	< 0.010	< 0.010	0.010	0.010

Source: Adapted from AWC, 2020

Lutselk'e WTP

The Lutselk'e WTP is an ultrafiltration (UF) plant that disinfects the permeate water with sodium hypochlorite (NaOCl). There is no pre-treatment of the water (i.e., coagulation) before UF treatment. The source water for the plant is Great Slave Lake.

Water quality analysis from samples taken from the Lutselk'e WTP plant in July 2019 for the raw water and backwash and CIP operations are summarized in Table 12.

Table 12. Lutselk'e WTP Water Sample Test Results (2019)

Analyte	Raw Water	Backwash	CIP
pH	8.06	7.91	10.26
Turbidity (NTU)	1.3	21.7	24.5
TSS (mg/L)	< 3.0	**38.1**	**31.7**
TDS (mg/L)	114	138	7,760
True Colour (TCU)	< 5.0	7.3	6.8
TOC (mg/L)	4.17	9.7	**2,190**
DOC (mg/L)	4.23	15.3	**2,150**
Total Aluminum (mg/L)	0.044	**0.348**	**0.785**
Total Arsenic (mg/L)	< 0.0010	< 0.0010	< 0.0010
Total Iron (mg/L)	0.028	**0.286**	**0.84**
Total Manganese (mg/L)	0.0011	0.0093	0.0251

Source: Adapted from an excel sheet "Results Summary L2316894" received from Justin Hazenberg, P.Eng., Engineering Team Lead with MACA

The raw water for the Lutselk'e WTP can be characterized as low turbidity with moderate colour (TOC = 4 mg/L). The backwash water sample shows the concentration of both particulate matter and organic material. The CIP waste residuals show elevated concentrations of TSS and TOC. Both aluminum and iron in the liquid waste residual streams from this plant showed elevated concentrations above the CEQW (0.1 and 0.3 mg/L for Al and Fe, respectively). These two metals are present at considerable concentrations in the source water and would reflect removal from the water phase in the membrane filtration operations of the main treatment train into the waste residuals.

Yellowknife WTP

The City of Yellowknife WTP is a microfiltration (MF) membrane plant that uses sodium hypochlorite (NaOCl) for disinfection and fluorosilicic acid for the fluoridation of the finished water. Waste backwash water from the MF system is directed to a residuals treatment system that thickens the liquid waste residuals for disposal. The residuals treatment system consists of waste equalization tanks, gravity thickeners, a coagulant dosing system, thickened solid residual transfer pumps, and solid residual storage tanks (City of Yellowknife, 2020).

The waste backwash water and thickened residual samples were collected for analysis at the Yellowknife plant in 2018 (Table 13). The initial sampling was reported in January 2018, which characterized the backwash effluent after being processed in thickening operations. The second sampling was reported in June 2018 and characterized backwash effluent prior to any treatment.

Table 13. Yellowknife WTP Waste Residuals Water Sample Test Results (2018)

Parameters	**Thickened Residuals**[€] **(January 2018)**	**Waste Backwash Water**[§] **(June 2018)**
pH	7.3	5.6
Biochemical Oxygen Demand (mg/L)	8.0	2.0
TSS (mg/L)	**65**	**539**
Total Aluminum (mg/L)	**12.8**	**60.4**
Total Arsenic (mg/L)	0.0022	**0.00621**
Total Iron (mg/L)	**3.7**	**14.8**
Total Manganese (mg/L)	n/a	0.384

[€] *Source*: Adapted from Taiga Environmental Laboratory, 2018

[§] *Source*: Adapted from ALS Environmental, 2018

The water quality analysis of the waste backwash water and thickened residuals shows elevated particulate matter (i.e., TSS) and aluminum and iron concentrations above the CEQG. Arsenic concentrations in the backwash water for this sample date also showed a concentration above the CEQG of 5 μg/ L.

2.3.2. Overview of Typical Characteristics of WTP Waste Residuals Generated in Membrane Filtration Plant Designs

Membrane filtration has emerged in the drinking water industry over the past 30 years to be a viable technology for treating both surface and groundwater. Membrane technology uses a driving force to separate contaminants from the water. Low-pressure membranes include microfiltration (MF) and ultrafiltration (UF) and are commonly used in drinking water treatment for the removal of turbidity and natural organic matter (NOM) with integrated designs, including coagulation pre-treatment. High-pressure membranes include nanofiltration (NF) and reverse osmosis (RO) and are commonly applied for desalination plant designs, although NF treatment of surface water has shown to be able to remove dissolved organic carbon (DOC) without the use of chemical coagulation (AWWA, 2003; Cornwell and Roth, 2011). The discussion below focuses on MF, UF, and NF membrane waste residuals only, given that RO membranes are not in operation in the NWT.

Through a membrane filtration cycle, both dissolved and particulate material from the feedwater will build up on the surface and within the membrane's pores. This is termed membrane fouling within the drinking water industry. Fouling of the membrane results in reduced flux or increased transmembrane pressure (TMP) required to filter water through the surface of the membrane module. To reduce the rate of membrane fouling, backpulsing with clean permeate water is practiced. Backpulse cleaning of the membrane involves frequent and short pulses of permeate water in the reverse flow of filtration to remove accumulated material from the surface and pores of the membrane unit. This practice increases the duration of a filtration cycle. In a dead-end filtration mode, the backpulse water remains in the process tank. This liquid waste residual volume is referred to as membrane concentrate.

Membrane manufacturers outline maximum TMP and/or flux rates for their membrane modules beyond which the units should not be operated. Once these setpoints are reached in a membrane filtration cycle, the membrane module must be taken offline for more advanced cleaning. Cleaning of membrane modules that have been taken offline generally involves a clean-in-place (CIP) operation followed by a backwashing of the membrane filters with clean permeate (e.g., filtered) water. CIP operations can use a variety of acid or base chemical cleaners. Sodium hypochlorite (NaOCl), sodium hydroxide (NaOH), and citric ($C_6H_8O_7$) or hydrochloric (HCl) acid are commonly used in drinking water treatment plants for membrane CIP (AWWA, 2003). The waste backwash water generated in these operations is referred to as chemically enhanced backwash water (CEBW) (USEPA, 2011).

Specific characteristics of MF and UF backwash and NF concentrate residuals depend on the quality of the water being treated and the membrane's recovery. Recovery rate is the ratio of water produced to feed flow and can range from 85 to 98 % for MF and UF and 75 to 85 percent for NF. The solids in the source water may be increased by 7 to 50 times in the waste residuals of a membrane filtration plant (Cornwell and Roth, 2011).

Backpulse cleaning operations for low-pressure membranes (i.e., MF and UF) typically represent 95 to 99 % of the total volume of liquid residual wastes produced, with the remaining 1 to 5 % of the liquid waste residuals produced from CIP procedures. The volume of CEBW has been estimated to be anywhere from 2 to 15 % of the plant feed flow rate for low-pressure systems and less than 0.1 percent for high-pressure systems (Davis, 2010; Peck and Russel, 2005; Crittenden et al., 2012, AWWA, 2003; Cornwell and Roth, 2011). While high-pressure membranes also generate CIP waste residual streams, they also produce a continuous concentrate stream from the separation process. As mentioned previously, the volume of concentrate produced in these treatment processes is much greater than intermittent backwash waste from MF and UF systems (Cornwell and Roth, 2011).

Membranes can be used to remove a variety of particulate and/or dissolved contaminants. The size of the contaminants that can be removed with this filtration technology depends on the type of membrane selected and its associated pore size. The nature of the residuals produced by a low-pressure membrane system is dependant on the treatment processes. The concentrate residuals will contain the contaminants naturally occurring in the feedwater that is removed by the membrane (i.e., turbidity, NOM, algae) and any chemicals added within the treatment train that is removed at the surface of the membrane filter (i.e., precipitated inorganic solids from coagulation process, chemical residues from foulant inhibitors, etc.).

In contrast to CEBW from low-pressure membranes, the concentrate from high-pressure systems contains low particulate matter, typically less than 10 mg/L total suspended solids. This can be attributed to raw water turbidity, which for high-pressured membranes, must be less than 1 NTU to avoid clogging unit pores (Cornwell and Roth, 2011).

CEBW demonstrates different water quality characteristics compared to the membrane concentrate waste residual stream due to the presence of residual cleaning chemicals. Similarly, the liquid waste residuals from CIP operations contain the chemical used in the cleaning process. In addition to the portion of remaining active chemical ingredients, CEBW and CIP waste residuals will contain precipitated organic materials, suspended solids, and salts from chemical reactants between the chemicals and foulants (AWWA, 2003). These foulants can be inorganic (clay or silt colloids, precipitated metals), organic (natural organic matter, coagulant aid polymers), and biological. Typical characteristics of CEBW and CIP from low-pressure membrane plants are presented in Table 14.

Table 14. Typical Composition of CEBW and CIP from Low-Pressure Membranes

Analyte	Range
pH	2 – 14
TSS (mg/L)	Up to 1,000
Residual Chlorine (mg/L as Cl_2)	Up to 1,000
BOD_5 (mg/L)	Up to 5,000 or 10,000 (if citric acid used)
TOC	10 – 30 times feed water

Source: Adapted from AWWA, 2003; Crittenden et al., 2012

In the case of NF, the nature of the concentrate produced will contain a high degree of total dissolved solids (TDS) but a low level of suspended solids (Crittenden et al., 2012). For example, an NF membrane with a recovery rate of 85 percent will produce a concentrate stream volume of approximately 15 percent of the plant feed. That said, TDS concentrations found in the concentrate will typically range from 1,330 to 2,660 mg/L (AWWA, 2007).

2.4. WTP Waste Residuals Generated in Greensand Filtration Plants

Information on the three WTPs in the NWT that operate with greensand filters was sought to give a breakdown of the plant design flows, type of oxidant used, and the backwash volume generated at these facilities (Table 15). No further information was received regarding water quality test results on waste residual streams from these three plants.

Table 15. Summary of Relevant Operating Conditions for Greensand Filtration Plants in NWT

NWT Community WTP	Annual Design Flow (m^3)	Oxidant	Annual Backwash Volume (m^3)	% Waste Produced	Discharge Location
Fort Liard	19,139 (2019)	Chlorine	1,492	7.80	River
Nahanni Butte	3,578 (2014)	Potassium Permanganate	--	--	Overland
Whati	15,786 (2018)	Chlorine	--	--	Sewer

Greensand filtration is a combination of oxidation and filtration in a granular media filtration process to remove iron, manganese, and small quantities of hydrogen sulphide from source waters (Crittenden et al., 2012). The filter media is typically manganese greensand, more correctly, identified as glauconite. The glauconite is stabilized then coated with a layer of manganese oxide, which provides the glauconite with oxidation-reduction properties. The manganese dioxide coating must periodically be regenerated by feeding an oxidant (chlorine or potassium permanganate) to the filter. Continuous regeneration can be practiced by continuously feeding an oxidizer, whereas intermittent regeneration occurs after the filter has been backwashed (Rader, 2003).

The oxidation products formed in the removal of iron and manganese are principally ferric hydroxide, ferric carbonate, and/or manganese dioxide. Typically, 1 mg/L of iron or manganese in solution will produce 1.5 to 2 mg/L of solid wastes (Peck and Russel, 2005). The iron and manganese oxides are captured on the filters, and the solids of these metals are found in the spent backwash water (Davis, 2010).

3. Overview of WTP Waste Residuals Treatment and Management Options

Some water utilities manage their WTP waste residual streams by directing untreated SFBW and clarifier solids streams to a municipal wastewater treatment plant. Given the benign characteristics of the WTP waste residuals, and in some cases presence of precipitated inorganic metal salts from coagulation operations that can be beneficial to primary clarifier operations, this is often viewed as a very viable solution for WTP management and disposal. However, constraints for this approach to WTP waste residuals management may exist for some municipalities in terms of the limited capacity of their sewage treatment facilities or exceeding viable distances to tie in with the wastewater collection system.

Although the direct discharge of untreated WTP waste residual streams back to the source water was common practice in Canada prior to 2000, increasingly stringent effluent discharge regulations have forced WTPs to either install or give thought to the treatment of waste residual streams to ensure environmental hazards pose little to no concern (Walsh et al., 2008). The treatment choice for WTP waste residual streams depends on the raw water quality, the main treatment train design in addition to the discharge and ultimate disposal requirements for the WTP waste residuals.

Rather than disposing the treated effluent back to the source water, some water utilities recycle the treated waste stream back to the front of the plant. The recycling of treated SFBW and clarifier solids streams into the plant is not a common practice in Canada. However, there is an avenue for this reclamation process design in the United States under the Filter Backwash Water Recycle Rule (FBRR) (USEPA, 2002). The overall goal of this rule is to ensure the finished drinking water is not compromised in systems where the reuse of liquid waste residuals is practiced. The primary component of the FBRR that impacts WTP operations is the statement that liquid waste residuals must be returned to a point in the WTP where it will be treated by coagulation and filtration (USEPA, 2002).

In 2011, the USEPA further recommended that WTPs distribute SFBW to an equalization basin to settle and remove some of the solids prior to recycling the backwash to the head of the WTP (USEPA, 2011). Filter-to-waste residuals are also recommended to be equalized prior to recycling to the head of the treatment train. SFBW, filter-to-waste, and decanted liquid from sludge thickeners and dewatering, allowed to settle for 24 hours, will decrease the concentration of suspended solids.

A common approach for the management of WTP waste residuals in North America is to concentrate the solids in the liquid and solid waste residual streams through the use of thickening technologies to produces a supernatant that can be returned to the source water (i.e., treated effluent) and a concentrated solid residual stream that can be further dewatered and disposed of in a landfill. Some of the most common technologies used for the treatment of WTP waste residuals are summarized as follows:

3.1. Thickening Technologies for WTP Waste Residuals Treatment

The principle treatment objective of WTP liquid wastes residuals is to achieve the separation of solids from the water phase. The main goal of thickening processes is to increase the concentration of solids within the waste backwash water and clarifier solids streams. Thickening of the waste residual streams may be accomplished by gravity settling (Gravity Thickeners (GT) or lagoons), dissolved air flotation (DAF), ballasted clarification, or other sedimentation, clarification processes.

Equalization tanks that combined clarifier solids and SFBW streams in conventional filtration plants are often part of the WTP waste residuals treatment design to reduce the impact of intermittent high-volume flows from backwashing operations. Equalization ensures that the solids load does not fluctuate from one extreme to another, and a homogenized waste stream is directed into a thickening process for more steady-state operation.

Thickening technologies rely on settling (or flotation) of suspended solids in WTP waste residuals. Therefore, it is common practice to add coagulants and/or polymers to increase settling velocities through the creation of larger aggregates (i.e., flocs) (Crittenden et al., 2012). This conditioning approach has been shown to increase solids recovery rates and improve dewatering operations process efficacy.

As the solids content of the liquid waste streams increase, the residual water is decanted back to the source water or other surface water disposal location. The solids generated in thickening processes are further treated using dewatering technologies to achieve a solid waste with higher percent solids for final disposal (i.e., landfill) (Crittenden et al., 2012).

A study conducted by McCormick et al. (2009) involved surveying 42 WTPs in the United States and Canada to determine what WTP residuals treatment processes were used at their facilities. The WTPs surveyed reported SFBW treatment or recovery units that encompass the following unit operations:

- Sedimentation (15 plants, 34 %)
- Lagoon (13 plants, 29 %)
- Gravity Thickener (5 plants, 11 %)
- Plate and Tube Settling Basins (4 plants, 9 %)
- Wash water recovery basins before recycle (3 plants, 7 %)
- Lamella plate settlers (1 plant, 2 %)
- Dissolved Air Flotation (1 plant, 2 %)

Sedimentation

Sedimentation is one of the oldest water treatment processes, which uses gravity to reduce the settleable solids from the water as it flows slowly through a tank (i.e., settling tank, clarifier), thereby providing some degree of purification. Historically, rectangular basins have been the most widely used settling tank design. Inlet structures are designed to introduce flocculated SFBW over the entire cross-section of the sedimentation basin. Coagulants and polymers may be added to the liquid waste residuals prior to sedimentation to ease the settling process (Ontario MOE, 2019). Settling tanks can be equipped with fixed and/or adjustable baffles to minimize short-circuiting (Davis, 2010). As layers of accumulated solids form at the bottom of the tank, the solids are periodically removed by mechanical scrapers. The treated supernatant found above the settled solids of the basin is removed through weirs, troughs, and pipes.

Lagoons

One of the most common non-mechanical thickening technologies used to treat WTP waste residuals in small systems is settling lagoons. Lagoons are commonly lined earthen or circular basins equipped with inlet control devices and decant structures. Wastes with settleable solids are discharged into the lagoons from which the solids are separated by gravity sedimentation and excess water decanted. The excess water is removed by decanting or pumping to facilitate drying. The filling, settling, and decanting cycle is repeated until the lagoon is full or the decant can no longer meet discharge limitations (Crittenden et al., 2012). Once the lagoon's capacity is reached, solids can either be dredged and transported to an approved disposal facility or left and permanently stored within the lagoon.

Occasionally particulates in liquid streams are difficult to separate; therefore, allowing coagulated backwash water to be held in basins for 24 hours has proven to recover upwards of 80 to 90 % of the solids prior to being discharged (Peck and Russell, 2005). This holding period is reported to be sufficient to produce supernatant low in turbidity and aluminum (Gouvernement du Québec, 2015). Iron and manganese solids removed from filters by backwashing generally settle sufficiently in two hours to allow decanting and recycling of backwash water to the head of the water plant (Peck and Russell, 2005). Lagoons have been identified as a proper method of handling and disposing of aluminum solid waste residual streams generated in WTPs (Government of Alberta, 2012; Great Lakes, 2012).

Gravity Thickeners

Gravity thickening has been a popular process used in the water treatment industry to treat WTP waste residuals. This process is typically accomplished in a circular tank equipped with either a scraper mechanism at the bottom or hoppers. The waste residual stream normally enters the thickener near the center of the basin and is distributed radially. The decanted water is removed with the aid of a weir or trough, and the thickened solids are drawn off the basin. For basins equipped with a scraper mechanism (i.e., Continuous Flow), the scraper is located at the bottom and rotates slowly, directing the solids to the draw-off pipe. The basin's bottom is sloped towards the center to help collect the thickened solids (see Figure 3). For basins equipped with bottom hoppers (i.e., Batch Fill-and-Draw), waste residuals are introduced into the tank until full.

The solids settle, and a telescoping decant pipe is used to remove the supernatant. The thickened solids are then pumped out of the bottom hoppers and may be transferred for further treatment or disposal (Cornwell and Roth, 2011; QPO, 2019).

Figure 3. Circular gravity thickening tank equipped with scrappers (GSPS Engineering, 2017)

Lamella Settlers

Lamella settler technology also removes particulate matter via sedimentation. Two types of lamella systems are used in the water treatment industry: tube settlers and plate settlers. Both types of settlers use shallow sedimentation to significantly shorten the distance required for particulate matter to settle out, which reduces the time required for particles to accumulate. These devices can be operated at higher surface overflow rates compared to gravity settling basins (Cornwell et al., 2010).

Although both types of settlers operate on the same principles of solids settling, there are several notable differences between the two technologies. Plate settlers use a series of inclined plates spaced two to three inches apart from each other on a 55° to 60° angle (see Figure 4). Solids settle to the plate and slide down the surface to the bottom of the tank. Whereas tube settlers use multiple adjacent tubular channels sloped at a 60° angle (see Figure 5) (Brentwood Industries Inc., 2020a). These settlers have been reported to produce a more dilute solid waste residual (Davis, 2010).

Figure 4. WTP plate settlers (Jim Myers & Sons, Inc., 2019)

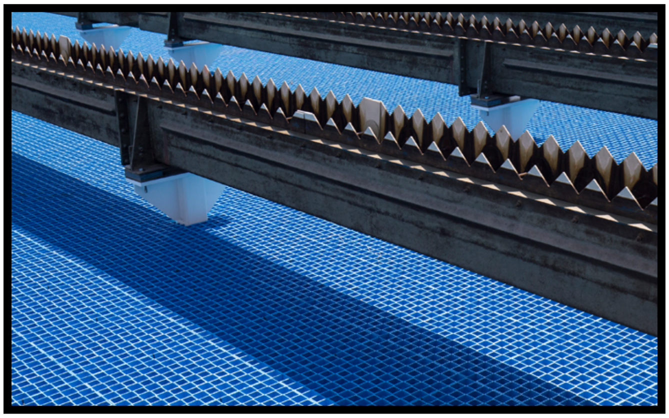

Figure 5. WTP tube settlers (Brentwood Industries Inc., 2020b)

Dissolved Air Flotation (DAF)

In DAF processes, a stream of water that has been pressurized with air is introduced into the liquid wastes, and the released micro-bubbles adhere to the suspended solid particles. Since the solids-air density is less than that of water, the solid-bubble aggregates float to the surface. The solids form a layer at the top of the tank and are removed by a skimmer for further treatment (Figure 6) (Crittenden et al., 2012; Davis, 2010; Peck and Russell, 2005). DAF can be applied for the clarification of granular and membrane backwash waters (Davis, 2010).

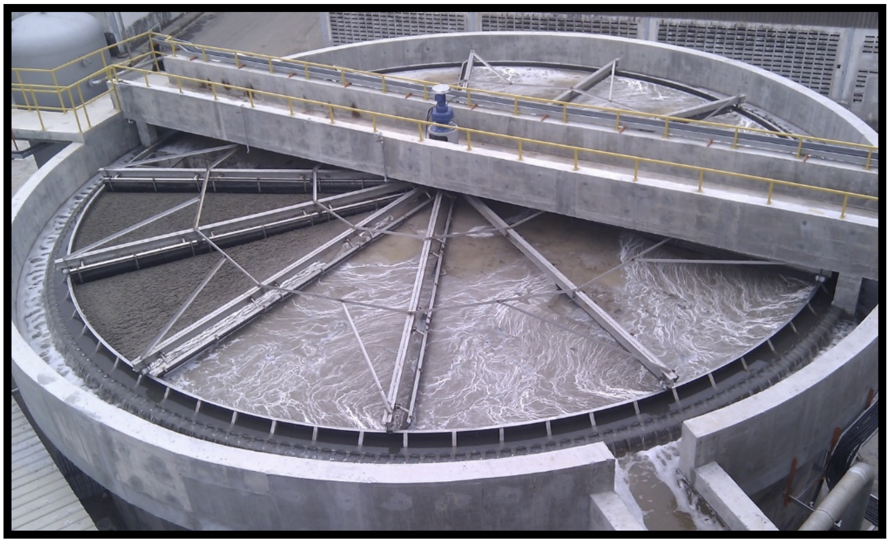

Figure 6. Circular DAF basin treating waste residuals (Environmental Water Solutions Inc., n.d.)

Dechlorination

Dechlorination of the treated effluent from waste residuals treatment systems ensures any residual chlorine is removed before being discharged into the source or other surface water discharge location. In lagoon systems, chlorine residuals are generally dissipated prior to decanting. Exposure to ultraviolet sunlight can efficiently reduce active chlorine residual by 0.75 to 1.25 mg/L in a 10 to 14-hour exposure period (Gouvernement du Québec, 2015). Where chloramines are present, sunlight exposure is less effective due to their stability. Aeration can be applied to remove up to 15% for monochloramine, up to 20% for dichloramine, and nearly all trichloramine (Gouvernement du Québec, 2015).

For mechanical thickening operations (i.e., GT, Sedimentation, etc.), the addition of dechlorination chemicals is often necessary to ensure free chlorine residuals in the treated effluent are reduced to regulatory set points. Typical chemicals added in WTP waste residuals treatment to achieve dechlorination are sulphur dioxide, sodium sulphite, sodium bisulphate, sodium metabisulphite, and sodium thiosulphate.

3.2. Dewatering Technologies for WTP Waste Residuals Treatment

Following thickening operations, the supernatant is discharged or could be recycled to the headworks of the plant, and the thickened solids are further processed using dewatering technologies. WTPs can apply mechanical or non-mechanical dewatering technologies following thickening to achieve increased % solids of the solid waste for more cost-effective disposal.

Non-Mechanical Dewatering Technologies

In non-mechanical dewatering systems, drying beds are often employed in the drinking water industry, where solids are spread out to allow drainage and evaporation of excess water. From a dewatering perspective, lagoons used for WTP waste residual treatment can be classified as permanent lagoons or dewatering lagoons. Permanent lagoons act as a final disposal site for settled solids. Dewatering lagoons are cleaned periodically to remove solids that have settled over time. If land is readily available, the use of lagoons is a cost-effective means of storing and thickening residuals (Davis, 2010).

Drying Beds

Dewatering WTP waste residual solids through the use of drying beds involve placing the waste residual solids on a sand or filter bed to promote drainage of excess water through the filter material (Figure 7). The excess water then drains through the filter bed, where it is transported via an underdrain system. This process continues until the sand is clogged or until all the excess water has been drained. As the solids dry, decanting of supernatant and/or rainwater layers that have formed above the filter are removed, which would otherwise hinder the overall drying process. The water remaining following drainage and decanting is removed by evaporation (Cornwell and Roth, 2011). Drying beds will produce a relatively dry solid waste which is ready for further treatment or disposal. The filtrate from the sand drying beds can be either recycled, treated or discharged to a watercourse depending on its quality. Dewatering using drying beds is best applied to solid wastes streams from sedimentation basins or following thickening. SFBW and CEBW, as well as SFBW from iron and manganese residuals, can be disposed of by dewatering the solids on sand drying beds and landfilling the solids (Davis, 2010; Great Lakes, 2012).

Figure 7. Solid waste residual drying beds (Lake Major WTP, Dartmouth, NS) (M. Walsh, 2014)

Freeze/Thaw Cycles

To enhance the volume of water removed from waste residual solids using non-mechanical dewatering operations, some water treatment facilities depend on natural freeze-thaw cycles. The natural physical conditioning of solid wastes by freeze/thaw cycles complements non-mechanical dewatering processes (Crittenden et al., 2012). The reduction of the sludge volume is achieved by selectively freezing the water molecules, which then dehydrate the solids when frozen. When thawed, the solid mass forms a coarse granular material comparable to sand or coffee grounds (Crittenden et al., 2012; Cornwell and Roth, 2011; Davis, 2010). This coarse material readily settles and retains its new size and shape. This solid residual dewaters rapidly and makes suitable landfill material. The natural freeze/thaw cycle of lagoons or drying beds is expected in colder climates and has been found to be very effective for aluminum and ferric solid waste residuals (Crittenden et al., 2012; Davis, 2010).

Mechanical Dewatering Technologies

In mechanical dewatering systems, some mechanized system aids with the dewatering process (Davis, 2010). Unit operations proven to be the most successful and have significant capabilities for dewatering WTP solid waste residuals are vacuum filtration, pressure filter press, belt filter press, and centrifugation.

Vacuum Filtration

A vacuum filter is considered a mechanical dewatering method which consists of a cylindrical drum covered with a filtering material or fabric, which rotates partially submerged in conditioned thickened solid waste residuals. A vacuum is applied inside the drum to extract water, leaving the solids, or filter cake, on the filter medium (Figure 8) (Davis, 2010). There are two basic types of filters: travelling media and precoat media filters. The precoat filter is typically applied to dewater coagulated solids, such as alum wastes. For aluminum and ferric solid waste residuals, vacuum filters typically require the solids to be conditioned with polymers or lime for best results (Crittenden et al., 2012).

Figure 8. Solid wastes dewatering by a vacuum drum filter (WesTech Engineering Inc., 2020)

Filter Presses

Another mechanical dewatering technology is a filter press that consists of a series of plates or trays to form a frame (Figure 9). Each plate is covered with a filter cloth. Conditioned solids are pumped into the press until the cavities or chambers between the trays are filled. These frames are pressed together between a fixed and moving end forcing the excess water through the filter cloth and plate outlet. The plates are then separated, and the solid residuals are removed (Crittenden et al., 2012; Davis, 2010).

Figure 9. Solid wastes dewatering by a plate filter press (Toro Equipment, 2015)

Gravity Belt Filter Press

Dewatering with a gravity belt filter can involve several operational steps, but typically solid waste streams are chemically conditioned and drained with the help of belts. In some designs, a vacuum is applied to the underside of the belt to enhance dewatering. Solid wastes are evenly distributed onto a moving porous belt, and pressure is applied to promote excess water to drain. The excess water passes through the belt as the slurry travels over the full length of the dewatering stage. The remaining solid residuals are scraped from the belt and collected in a hopper for further processing, transport, or disposal (Figure 10) (Crittenden et al., 2012; Cornwell and Roth, 2011).

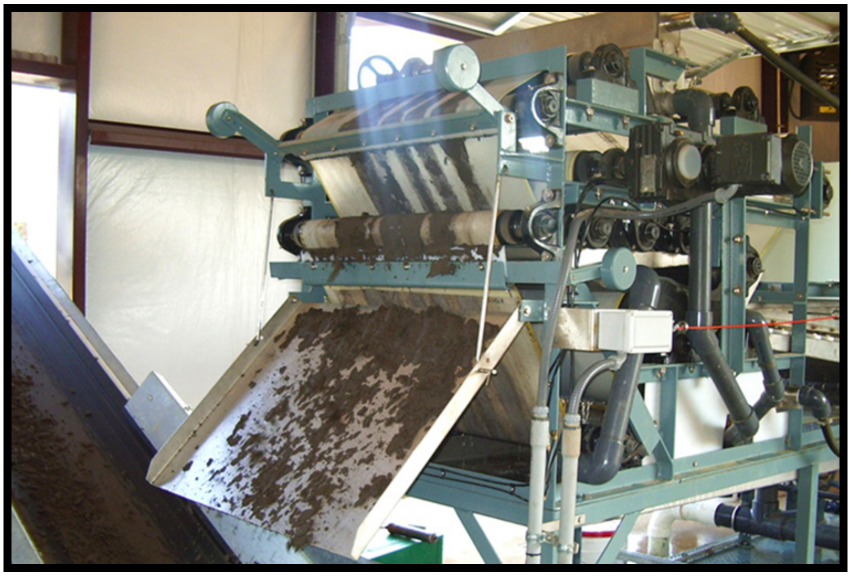

Figure 10. Solid waste dewatering by a belt filter press (Phoenix Process Equipment, 2018)

Centrifuges

An alternative dewatering method is centrifuging, which separates the liquid from the solids by rotating the waste stream at high speeds. The solids are spun to the outside of the bowl, where they are scraped out by a screw conveyor (Figure 11). Typically, the solids are discarded into a truck or hopper for further disposal or treatment. The centrifuged liquid is typically recycled back into the start of the WTP waste residuals treatment process. There are two basic centrifuges: solid-bowl and basket centrifuges (Crittenden et al., 2012; Davis, 2010).

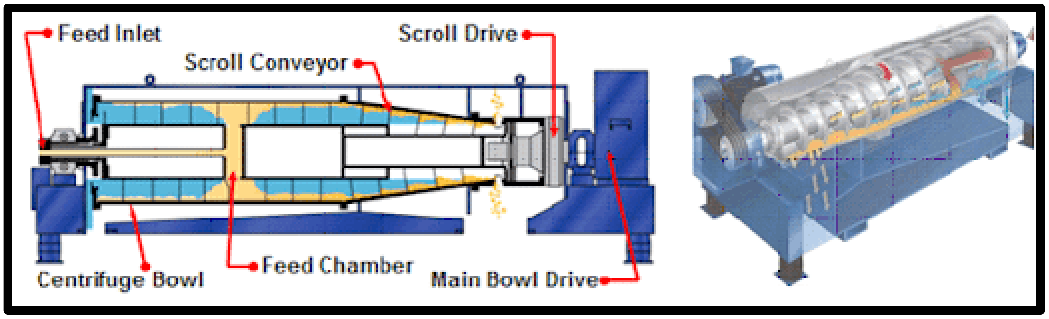

Figure 11. Sludge Dewatering Centrifuge (Hiller Separation & Process, 2020)

Geotextile Tubes (Geotubes)

Developing technology in WTP waste residuals treatment is the use of geotextile tubes, known as geotubes, which can provide a very effective way of dewatering sediments and alum solid wastes (TenCate, 2010). Geotubes are containment systems designed for sites with high volumes and flows. It provides facilities with an efficient on-site, cost-effective dewatering option that requires no special equipment or permitting, low operations and maintenance costs, ease of placement and constructability, minimal impact on the environment and confidence in containment (Mastin et al., 2008; Fowler et al., 2002).

Geotube containers are constructed using high-strength polypropylene fabric and primarily work on three main principles. Solid waste residuals are pumped into the Geotube as it is mixed with a coagulant or polymer additive to precipitate any heavy metals of concern and flocculate the solids. With the addition of chemical conditioners, approximately 75 to 80 % of the solids are separated, and free water can escape through the fabric's pores while retaining the fine-grain solids (Figure 12). The clear filtrate is then returned to the plant's headworks or discharged, allowing further consolidation of the captured sediments, increasing the available volume for repeated filling of the container. Following separation, the trapped solids undergo digestion, wherein the final step will undergo further composting in the geotextile bag (Bishop Water, 2017a).

Figure 12. Geotubes for SFBW Treatment at Ohio WTP (Mastin et al., 2008).

Excavation and disposal of the dried solid residuals occur when the retained solids meet dryness goals (typically 18 to 20 percent solids), or excavation and disposal may be deferred to a more economically feasible time (Mastin et al., 2008). If geotextile containers operate through freeze/thaw cycles, further dewatering occurs, and up to 1/3 of its volume can be lost, allowing the geotube to be possibly used for another season. In cold climate areas, a greenhouse is typically constructed to facilitate the ability to dewater during the winter months (Bishop Water, 2017b).

A large WTP in New Jersey allowed the solids to dewater and desiccate for 47 days before being excavated and trucked for beneficial reuse (TenCate, 2010). Another study reported dredged material consolidated 70% in approximately two months (Fowler et al., 2002). In Eganville, Ontario, a small pilot project found that the solids content in a Geotube unit had risen from 3 to almost 40%. Following this project, the Bonnechere Valley Township partnered with the County of Renfrew and Ontario's Ministry of Environment to continue evaluating Geotube dewatering technology (TenCate, 2009). Table 16 outlines the testing results from the Bonnechere Valley Study.

Table 16. Geotube Performance (Bonnechere Valley, Ontario)

Parameter	Geotube Performance Result
Suspended Solids	99.6 % captured
Phosphorus	98.2 % captured
Nitrogen	82.3 % captured
E. Coli	99.9 % reduction
Arsenic	100.0 % reduction
Lead	98.9 % reduction
Mercury	99.9 % reduction

Source: Adapted from TenCate, 2009

Multiple studies have demonstrated that geotubes can retain nearly 100 percent of the TSS from waste materials, therefore providing very effective treatment for separating solids from water (Fowler et al., 2002; TenCate, 2009; Mastin et al., 2008). This new and innovative technology has been used to successfully dewater fine-grained, contaminated material that contained dioxins, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, pesticides, and heavy metals (Fowler et al., 2002). In a study by Jahan et al. (2018), the filtration effect of geotextile containers provided additional removal of aluminum compared to coagulation/flocculation/sedimentation alone, and in some cases, aluminum concentrations were near or below regulatory requirements. According to Bishop Water (2017a), effluent draining from geotubes is nearly always in compliance with discharge limits. Similarly, filtrate from geotubes installed at an Ohio WTP was compliant with facility discharge permits (Mastin et al., 2008).

3.3. Co-Disposal of WTP Waste Residuals with Municipal Wastewater

Co-disposal involves mixing WTP waste residuals with wastewater treatment plant (WWTP) biosolids followed by disposal or reuse (Crittenden et al., 2012). Other provinces in Canada manage WTP waste residuals by discharging them directly to a sanitary sewer (e.g., Ontario, Nova Scotia). Consultation and review by the sewage system operating authority are generally required to ensure adequate hydraulic and treatment capacity can allow for this management option of WTP waste residuals. For utilities managing both water and wastewater facilities, potential benefits of co-managing waste solids can include the elimination of separate permitting and monitoring of the waste streams. Ultimately, for this management option to work, the WTP waste residuals must not interfere with the WWTP operations or pass through excessive pollutants to the biosolids.

When combining waste solids from water and wastewater treatment plants, WTP waste residuals should not degrade the end-use biosolids product quality, such as lowering nutrient values or increasing/introducing higher metal concentrations. This is particularly true for land application and composting processes (Davis, 2010; Cornwell and Roth, 2011). Co-disposal with municipal solid waste is typically governed through individual landfill site permit limits, and the solid material is required to pass the TCLP test so that it is not considered hazardous waste. Generally, 30 % solids of the final waste solids are required, eliminating the release of free water during transportation (Davis, 2010).

Incorporating WTP waste residuals with WWTP biosolids has been successfully achieved with mixtures containing up to 25 % WTP waste residuals. Based on additional information gathered from case studies and professional consults, a minimum ratio of 3-parts biosolids to 1-part WTP waste residual may be required to produce a product that could potentially be marketed for land application. Further analysis of the solids would be required to determine the appropriate ratios (Peck and Russel, 2005).

4. Overview of Best Practices for Management of WTP Waste Residuals in Other Jurisdictions

A review of relevant provincial and federal regulatory frameworks for the management of WTP waste residuals in Canada was conducted and is summarized below. Also, common practices for managing WTP waste residuals in the United States were reviewed using USEPA and the AWWA for reference.

4.1. Regulatory Review for WTP Waste Residuals Management in Canada

In Canada, the federal government provides scientific and technical expertise through CCME guidelines for any WTP effluent discharged into the environment, but ultimately provinces and territories manage their water resources (Environment Canada, 2015). Across the country, WTP waste residuals are required to be treated prior to discharge to surface water. The direct discharge of solid or liquid waste residual streams into the environment is no longer common in Canada (Government of Canada, 2015).

The level of treatment required is dependent on the water quality characteristics of the WTP waste residual streams. For direct and conventional filtration plants, regardless of granular or membrane filtration units, TSS, pH and chlorine residuals are the most common water quality parameters that present problems for direct discharge of WTP waste residuals. If aluminum-based coagulants are used in the main treatment train of the WTP (i.e., alum, PACl), aluminum concentrations in SFBW and clarifier solids are also of concern for direct discharge due to the known relationship between elevated aluminum concentrations and aquatic toxicity.

Most Canadian provinces have clear regulations on WTP waste residual discharges through individual WTP permits to operate. The following sections outline the WTP waste residual management regulations and guidelines in Canadian provincial /territorial jurisdictions.

Yukon

The discharge from public drinking water systems in Yukon, guidelines and regulations are covered under the Yukon Waters Act (YWA) (Yukon Waters Act, S.C. 1992, Chapter 40). Under this Act, the Yukon Water Board issues water licences for various activities for the use of water and/or the deposit of waste to water (Kinsella, 2020).

If the operation of water treatment processes results in waste residuals that are discharged to water bodies, then the discharge must be permitted under the YWA. These proposals are evaluated, and permits are granted on a case-by-case basis.

As of December 2020, there are approximately twenty active water licenses for municipal undertakings in the Yukon. The majority of the water licenses issued for drinking purposes involve groundwater as the raw water source. Groundwater systems typically consist of disinfection and distribution; therefore, no residuals are generated. As a result, there are no terms related to managing WTP waste residuals in Yukon's water licences (Beckerton, 2020).

British Columbia

In British Columbia, waste residual discharges from WTPs are not classified as a regulated industry, operation, activity, trade, or business under the Waste Discharge Regulation to the Environmental Management Act (EMA) (B.C. Reg. 320/2004). However, Section 6(4) of the EMA states, "a person must not introduce waste into the environment in such a manner or quantity as to cause pollution" (Environmental Management Act, 2003, Chapter 53).

One way to establish whether pollution may be present is to characterize water quality and then to compare water-quality data to the applicable BC Water Quality Guidelines (WQG), which protect various water uses (i.e., aquatic life, wildlife, agriculture, drinking and recreation). The BC Water Quality Guidelines are established primarily from the CCME (Government of British Columbia, 2019). Project proponents and facility operators from all industries are responsible for ensuring that discharges do not result in exceedances of guideline values.

There are no standards or guidelines that apply to the characterization of drinking WTP solid waste residuals specifically, but such wastes require characterization in accordance with one or more "general" regulations. Facilities producing solid wastes must characterize them according to the standards set out in the Hazardous Waste Regulation (HWR). To send solid wastes to a landfill, they must be characterized according to the conditions set out in that landfill's permit. These would include the HWR standards since most landfills are not authorized to accept hazardous waste.

It is permissible to apply water treatment solid waste residuals as a soil amendment, provided the waste meets the standards set out in the *Code of Practice for Soil Amendments* (B.C. Reg. 28/2020). It is not, however, permissible to compost such solid residuals or to blend them into compost. Only the materials listed in Schedule 12 of the Organic Matter Recycling Regulation (which includes wastewater treatment plant (WWTP) biosolids but not drinking WTP solid wastes) can be used (Beck, 2020).

Alberta

In Alberta, SFBW is not to be discharged directly to an open body of water unless it can be demonstrated that there are no significant adverse effects on the receiving body of water. Based on the quantity and quality of SFBW and the sensitivity of the receiving body of water, *Alberta Environment and Sustainable Resource Development* may request an impact assessment study to ascertain the need for the treatment of SFBW before discharging to the environment (Government of Alberta, 2012).

Saskatchewan

In Saskatchewan, WTP waste residuals including SFBW and clarifier solids are regulated under the *Environmental Management and Protection Act* (Statutes of Saskatchewan, 2010), the *Waterworks and Sewage Works Regulations* (Environmental Management and Protection Act, 2010), and the *Waterworks Design Standards* (Water Security Agency, 2012). The discharge from a WTP may also be subjected to the *Federal Fisheries Act* (Ottenbreit, 2020).

Water quality objectives are established for waterbodies through the Water Security Agency's (WSA) mandate to manage, enhance and protect the province's natural and environmental resources. The Saskatchewan objectives are revised and largely dependant on the information provided by the CCME and published as the Surface Water Quality Objectives.

The following basic objectives taken directly from the WSA (2015) apply to all waters receiving effluents, including the mixing zones adjacent to effluent outfalls from municipal, industrial, agricultural, and other discharges:

- free from substances in concentrations or combinations which are acutely toxic or may be harmful to human, animal or aquatic life;
- free from substances that will settle to form decomposing solid waste deposits or that will adversely affect aquatic life or waterfowl;
- free from debris, oil, grease, scum or other materials in amounts sufficient to be noticeable in the receiving water;
- free from colour, turbidity or odour-producing materials that would adversely affect aquatic life or waterfowl, significantly alter the natural colour of the receiving water, or directly or through interaction among themselves or with chemicals used in water treatment, result in undesirable taste or odour in treated water;
- free from nutrients in concentrations that create nuisance growths of aquatic weeds or algae or that results in an unacceptable degree of eutrophication of the receiving water; and,
- in addition to the above objectives, effluent discharged to surface waters should not utilize more than 30 percent of the assimilation capacity of the receiving waterbody when discharged via means of a diffused outfall, or more than 10 percent when discharged via a point source outfall. For purposes of determining the available assimilation capacity of a receiving waterbody, a flow rate equal to or less than the average seven-day low flow, which occurs once in ten years at the outfall area, generally should be used.

Limits on the discharge of any clarifier waste residuals to a sanitary sewer are regulated through the municipality sewage abatement bylaw (BYLAW NO. 9466). Saskatchewan has set limits concerning discharges to water bodies but is subject to site-specific circumstances. A common water quality parameter to monitor and control is chlorine residual, where concentrations must not exceed 0.0005 mg/L (Rathwell, 2020).

Ontario

In Ontario, the management of WTP waste residuals is reviewed on a case-by-case basis. Typically, the discharge quality limits are regulated and specified through the Certificate of Approval, the Drinking Water Works Permit (DWWP), and the Municipal Drinking Water Licence (MDWL) (QPO, 2019).

The MDWL and DWWP contain a schedule outlining "System-Specific Conditions," which includes system performance for residuals management. The schedule includes test parameters, concentration limits, sampling frequency, and monitoring locations. Facilities can have additional requirements for SFBW quality criteria for discharge to the environment, established through consultation with the Ministry's regional office and review of Provincial Water Quality Objectives. The inclusion of limits can depend on the type of residual waste streams, treatment of the residual waste streams, and discharge location (i.e., sanitary sewer or natural environment) (Wirth, 2020).

Each drinking water plant in Ontario may have different requirements on their MDWL related to WTP waste residuals management. The common test parameters are total chlorine residual which must be non-detect, and TSS, which must be less than 25 mg/L.

Environment and Climate Change Canada federally regulate wTPs under the Fisheries Act. Chlorine is considered a deleterious substance; therefore, any chlorine discharge from drinking water facilities to surface water frequented by fish is subject to the Fisheries Act. (McVicar, 2020).

Quebec

In Quebec, municipal water utilities must adhere to water quality criteria for SFBW discharges to freshwater watercourses. The province considers TSS, chlorine residuals, iron and aluminum concentrations the most important water quality parameters to monitor and control. Table 17 summarizes the maximum allowable concentrations (MACs) for these parameters of concern.

Table 17. Quebec WTP Discharge Parameters of Concern

Parameter	Maximum Allowable Concentration (mg/L)
Chlorine Residual	0.05
TSS	20
Total Aluminum	3
Total Iron	5

Source: Adapted from Gouvernement du Québec, 2015

For all other metals, discharge concentrations must be as low as reasonably achievable considering the technology being used. WTP operators must demonstrate that there are no significant adverse effects on the receiving body of water and aquatic life (Gouvernement du Québec, 2015).

New Brunswick

In New Brunswick, there are no established standardized parameters or water quality limits for WTP waste residuals as each discharge location is unique. Deleterious substances such as SFBW cannot be discharged to the environment without approval (see paragraph 3(1) of the *Water Quality* Regulation) (NB Reg 126/82). In the WTP approval to operate, a mixing zone study is required to satisfy permit conditions (see Schedule B – Minimum Mixing Zone Standards of the NB *Water Classification Regulation)* (NB Reg 13/02). The purpose of the mixing zone study is to ensure that the water quality at the edge of the mixing zone is consistent with the appropriate CCME guidelines. If water quality does not meet the guidelines, then the approval holder must propose a compliance plan to the Department of Environment and Local Government to meet the CCME guidelines (Johnstone, 2020).

There are no composting regulations specific to the use of drinking WTP solid waste residuals. Depending on the source water quality and WTP process design, metal content in the solids may be a concern. Therefore, the composter must demonstrate that they can produce a compost that meets the quality guidelines using that material. However, the decision would be made on a case-by-case basis (Fortin, 2020).

Nova Scotia

In Nova Scotia, SFBW must be discharged to an approved location downstream of any raw water inlet pumps or intake structures (Nova Scotia, 2012). When an existing facility already has an established discharge point located upstream of raw water inlet pumps, the water utility must demonstrate to the province that there are no cumulative impacts on raw water quality. Otherwise, the municipal water utility must develop a corrective action plan to remediate the situation.

For SFBW discharging to freshwater watercourses, the municipal water utility must adhere to discharge criteria. The Nova Scotia Department of Environment (NSE) has established that total suspended solids, free chlorine residual, pH, and aluminum concentrations are the most important parameters to monitor and control. Table 18 summarizes the MACs for these parameters in WTP waste residual discharges.

Table 18. Nova Scotia WTP Discharge Parameters of Concern

Parameter	Maximum Allowable Concentration (mg/L)
pH	6.5 – 9
Chlorine Residual	0.02
TSS	5 (over naturally occurring concentrations)
Total Aluminum	0.005 (pH < 6.5) 1 (pH > 6.5)

Source: Adapted from Nova Scotia, 2012

In the event it is impossible to achieve the pH range of 6.5 – 9.0, the municipal water utility must complete a study to determine background values and recommend the "end of pipe" discharge criteria for pH. All discharges must be non-acutely lethal with acute toxicity determined using standard test methods (Government of Canada, 2014).

For metals, the municipal water utility must meet the limits set by the *Canadian Water Quality Guidelines* for the Protection of Aquatic Life (CCME, 2014). When the naturally-occurring background concentrations of metals in the watercourse are higher than the values specified in the CCME guidelines, NSE may allow discharge criteria limits to be set at the 90th percentile of the watercourse's background concentrations (Nova Scotia, 2012). Where it is not possible to achieve the 90th percentile of background concentrations, then NSE may allow a 10 percent increase above the 90th percentile. If it is impossible to achieve the 90th percentile plus 10 percent, the municipal water utility shall complete a study to recommend "end of pipe" discharge criteria limits. Once the study has been reviewed, NSE specifies the discharge criteria limits.

It is recognized that for different WTPs in the province, each situation is unique. Therefore, consulting with NSE, Environment Canada, and the federal Department of Fisheries and Oceans may be required. Once discharge criteria limits have been set, the municipal water utility must ensure they are met before discharging into the watercourse (i.e. end of pipe limits) and in 95% of the samples. Where aluminum is naturally occurring in the source water, water utilities with membrane facilities must establish discharge criteria limits since the combination of natural and waste stream compounds are typically above the levels indicated in the CCME *Water Quality Guidelines for the Protection of Aquatic Life* (Nova Scotia, 2012).

Where municipal water treatment plants produce solid waste residuals as part of their treatment process, permit holders are required to submit a solid waste disposal plan to NSE for approval. The plan is a requirement through the facility's Approval to Operate. Disposal of solid waste residuals from plants that use aluminum-based coagulants is typically directed to a solid waste management facility approved to accept contaminated materials due to the high concentration of aluminum (Montreuil, 2020).

When WTP waste residuals are combined with WWTP biosolids, the re-use criteria falls to the guidelines outlined in the "Guidelines for Land Application and Storage of Municipal Biosolids in Nova Scotia." The common requirements outlined in this document require an analysis of the soil amendment to identify the components which benefit crop production and pose minimal risk to plant growth, crop quality, public and animal health, and quality of the environment. (Nova Scotia Environment, 2010).

Newfoundland and Labrador

The province of Newfoundland and Labrador does not have any regulations specific to the discharge of WTP waste residuals. However, the Environmental Control Water and Sewage Regulations (Newfoundland and Labrador Reg, 2003, 156/80 Sch A; 65/03 Sch A & B) outline the requirements for any discharges to the environment within the province. Schedule A of the regulation pertains to discharges to a waterbody, and Schedule B pertains to discharges to a public sewer system. The parameters provided in both schedules apply to any discharge, regardless of source, to a waterbody or public sewer (Spracklin, 2020).

Of these parameters, the suspended solids are a priority concern, and municipal water utilities must have them reduced to a level acceptable to the *Department of Environment and Conservation* before being discharged. For discharges to a water body, the maximum allowable concentration for suspended solids is 30 mg/L with chlorine residuals < 1 mg/L. For discharges to a sewer system, the maximum allowable concentration for suspended solids is 350 mg/L with chlorine residuals < 30 mg/L.

Table 19 summarizes the current provincial /territorial guidelines and regulations pertaining to the management of WTP waste residual streams in Canada.

Table 19. Provincial/Territorial Guidelines and Regulations for WTP Waste Residuals in Canada

Province/Territory	General Guidelines
Yukon	• Discharge from public drinking water systems are covered under the Yukon Waters Act • Permits to discharge to the environment are granted on a case by case basis
British Columbia	• No specific regulations for WTP waste residuals • Discharges of WTP waste residuals to water bodies would fall under Section 6(4) of the Environmental Management Act • Discharges shall meet the limits set by the BC Water Quality Guidelines • Solid waste residuals fall under the Hazardous Waste Regulation • Landfilling solid waste residuals shall be per the landfill's permit • Soil amendment shall meet the Code of Practice for Soil Amendments • It is not permissible to compost WTP waste solids or to blend them into compost
Alberta	• Filter backwash water discharge shall not cause any adverse effects on the receiving body of water
Saskatchewan	• Discharges are regulated under the Environmental Management and Protection act 2010, the Waterworks and Sewage Works Regulations, and the Waterworks Design Standards • Surface Water Quality Objectives drafted from CCME guidelines • Objectives applicable to discharges include: o free from substances acutely toxic or harmful to human, animal, or aquatic life o free from decomposing solid waste deposits, or that will adversely affect aquatic life or waterfowl o free from debris, oil, grease, scum or other materials in amounts sufficient to be noticeable in the receiving water

	o free from colour, turbidity or odour-producing materials that would adversely affect aquatic life or waterfowl, significantly alter the natural colour of the receiving water, or directly or through interaction among themselves or with chemicals used in water treatment, result in undesirable taste or odour in treated water o free from nutrients in concentrations that create nuisance growths of aquatic weeds or algae or that results in an unacceptable degree of eutrophication of the receiving water **Regulated Water Quality Parameters:** • Chlorine Residual shall be non detectable (0.0005mg/L)
Ontario	• WTP waste residual discharge quality limits are regulated through approvals and permits **Regulated Water Quality Parameters:** • TSS shall not exceed 25 mg/L • Chlorine Residual shall be non-detectable
Quebec	• Metals shall have concentrations as low as reasonably achievable **Regulated Water Quality Parameters:** • Total chlorine residuals shall not exceed 0.05 mg/L • TSS shall not exceed 20 mg/L • Total aluminum shall not exceed 3 mg/L • Total iron shall not exceed 5 mg/L
New Brunswick	• Spent filter backwash cannot be discharged to the environment without approval • No standardized parameters • WTPs shall conduct a mixing zone study • Mixing zone data shall meet CCME guidelines • Solids are sent to composting sites if compost can meet the quality guidelines
Nova Scotia	• Discharges must be downstream of intakes/inlets • Consider the cumulative effects of multiple discharges • Metals shall meet the limits set by the CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life • Solids disposal to an approved contaminated waste facility (aluminum content) **Regulated Water Quality Parameters:** • Free Chlorine Residuals shall not exceed 0.02 mg/L • pH shall be in the range of 6.5 to 9.0 • TSS shall not exceed 5 mg/L over naturally occurring concentrations • Total Aluminum shall not exceed 5 µg/L if pH < 6.5, and 100 µg/L if pH ≥ 6.5
Newfoundland and Labrador	• No specific regulations for WTP waste residuals • Suspended Solids reduced to acceptable levels

	• Discharges to waterbodies refer to Schedule A of Environmental Control Water and Sewage Regulations • Discharges to sewers refer to Schedule B Environmental Control Water and Sewage Regulations **Regulated Water Quality Parameters:** **Discharge to Water Bodies:** • TSS shall not exceed 30 mg/L • Chlorine shall not exceed 1 mg/L **Discharge to Sewer Systems:** • TSS shall not exceed 350 mg/L • Chlorine shall not exceed 30 mg/L

4.2. Regulatory Review for WTP Waste Residuals Management in the United States

In the U.S., surface water discharges are regulated through the National Pollutant Discharge Elimination System (NPDES). Any discharges from a point source into the waters of the United States require an NPDES permit. Unless an NPDES permit is obtained, the Clean Water Act (CWA) (33 U.S.C. §1251 et seq. (1972)) prohibits the discharge of pollutants through a point source into any watercourse throughout the United States (USEPA, 2020).

The NPDES permits can specify a variety of water quality requirements, depending on the classification of the receiving water body. State and local governments may impose additional restrictions on surface water discharges. If the supernatant is to be discharged to receiving surface water, then the state discharge permit requirements determine the treatment necessary.

Generally, discharge permits for WTP waste residuals contain limitations to suspended solids concentrations (the determining factor for the design) of 20 to 30 mg/L. Where data is unavailable, turbidity less than 10 NTU should satisfy a 20 mg/L suspended solids limit, and a 10 NTU goal is reasonable and can be attained by an adequately designed SFBW treatment system. The pH range for SFBW being discharged to surface water is 6 to 9, and chlorine residual concentrations should be below the method detection limit (Cornwell and Roth, 2011).

Table 20 presents the range of pollutant limitations for WTP waste residual streams in most NPDES permits reviewed by the USEPA. The data presented relates to the individual and general permits for drinking water systems that serve more than 10,000 people. The USEPA focused on these systems as they typically fall under community water systems (CWSs) under the Safe Drinking Water Act (SDWA) (42 U.S.C. §300f et seq. (1974)), but this is not indicative of regulatory exemption for smaller systems. CWSs are defined as public water systems that serve the same people (e.g., homes, apartments, and condominiums in cities, small towns, and mobile home parks) year-round (USEPA, 2004). Individual NPDES permits are developed and issued on a site-specific basis to manage the discharges at individual plants, while general NPDES permits are developed and issued for multiple plants with similar activities or effluent characteristics (USEPA, 2011).

Table 20. Range of Pollutant Limitations from Samples of General & Individual NPDES Permits

Pollutant	Monthly Average Limitation	Daily Maximum Limitation
Aluminum (mg/L)	0.75 – 4	1.5 – 8
Ammonia (mg/L)	-	1
Arsenic (mg/L)	0.036 - 0.150	0.00018 - 0.68
Cadmium (mg/L)	0.002 - 0.0093	0.004 - 0.042
Chlorides (mg/L)	-	150 – 1000
Copper (mg/L)	0.0031 - 0.007	0.0029 - 1.09
Dissolved Oxygen (mg/L)	-	Minimum: 2 - 7
Iron (mg/L)	1 - 5	0.3 - 10
Lead (mg/L)	0.003 – 0.0081	0.0044 – 0.210
Manganese (mg/L)	0.0043 – 1	0.019 – 3
pH	6 – 11	6 – 11
Phosphorus (mg/L)	1	1
Total Dissolved Solids (mg/L)	95 – 1500	80 – 800
Total Residual Chlorine (mg/L)	0.01 – 1	0.002 – 1.3
Total Suspended Solids (mg/L)	15 – 70	5 – 150
Turbidity (NTU)	6 – 75	5 – 225
Zinc (mg/L)	0.061 – 0.093	0.09 – 50

Source: Adapted from the United States Environmental Protection Agency, 2011

Discharge of WTP Waste Residuals to Municipal Wastewater Treatment System

In the United States, treatment of WTP waste residuals prior to discharge to a municipal wastewater treatment plant may be required. The capacity of the collection system or the wastewater treatment plant, the types of processes, and operations at the facility may limit the amounts and types of liquids and/or solids waste residuals that can be discharged into the wastewater system.

The viability of sewer discharge as a WTP waste residuals management option is affected by the chemical characteristics of the waste residual stream. For example, high TDS, low dissolved oxygen, or high metal concentrations may be toxic to the biological process at the wastewater plant. A condition that may be required when discharging to a wastewater treatment plant is continuous monitoring of the organic strength and solids content of the waste residuals flow. Discharge of WTP waste residual streams to sanitary sewers must be coordinated with the sewer authority operation and maintenance department and wastewater treatment plant authorities.

Water treatment plant solids can be combined with wastewater treatment biosolids prior to disposal. Waste residuals from WTPs can dilute the biosolids from WWTPs, resulting in lower metal concentrations. The impact of both the chemical nature and the volume of the WTP waste residual solids on the wastewater facility needs consideration (Peck and Russell, 2005).

Land Application of WTP Waste Residual

In the United States, disposal of WTP waste residuals solids by land application is regulated by the federal government under the *Resource Conservation and Recovery Act (RCRA)* (USEPA, 2011) as well as state and local agencies. RCRA rules require sludges that are spread on land pass the Toxicity Characteristic Leaching Procedure (TCLP) or the Waste Extraction Test (WET) test. Both tests will determine if solid waste residuals are hazardous or non-hazardous.

Residuals applied to land include coagulant sludges, lime softening sludges, reverse osmosis concentrate and slow sand filter washings (Davis, 2012). Applying WTP waste residual solids with elevated aluminum concentrations to land has been shown to have negative impacts on certain vegetation where soils have a pH below 5.5. For WTP waste residual solids with high aluminum content, phosphorus availability is reduced, and soil compaction is increased. For WTP waste residual solids with elevated iron concentrations, studies have shown application in grazing lands results in a negative effect on copper metabolism, especially in sheep (Gendebien et al., 2001; Marshall, 2002).

Crittenden et al. (2012) suggested the disposal of waste residuals generated by low-pressure membrane systems that primarily remove hardness or NOM are more appropriate for land applications. The ideal application consists of non-food chain crops, mine reclamation areas, and forests (USEPA, 2011).

Landfilling of WTP Waste Residuals

In the United States, the most common disposal method for WTP waste residual solids is landfilling, regulated by the federal government. Two types of landfills exist for the disposal of WTP waste residual solids: commercial non-hazardous landfill or monofill and hazardous waste landfill. WTP waste residual solids must be characterized through laboratory testing to determine if the waste is classified as hazardous or non-hazardous solid waste material.

WTP waste residual solids testing is performed to meet the USEPA requirement for solid waste characterization by the TCLP. The TCLP test exposes a waste sample to a mildly acidic solution like what might be found in a municipal landfill (USEPA, 1992). If the waste leachate generated in the test is found to contain any of the regulated compounds (see Appendix A) at or above the minimum concentration in leachate for toxicity characteristics, it is deemed a hazardous waste (Crittenden et al., 2012).

The State of California has more stringent regulations than the USEPA and requires solid wastes to be tested according to the California WET (the State of California, 2005). The WET uses a slightly more aggressive leaching procedure than is used by the TCLP test. Both the TCLP test and the WET are designed to simulate landfill leachate production. If the leachate contains any of the regulated compounds from the *Inorganic Persistent and Bio-accumulative Toxic Substances* (Appendix B) and concentration are equal to or exceed the soluble threshold limit concentration or total threshold limit concentration (TTLC), the solid waste is classified as toxic, hazardous waste (Crittenden et al., 2012).

A study of leachate generated from WTP waste residual solids produced at plants that use either alum or iron as the primary coagulant was done by the American Water Works Research Foundation (AWWARF) (Cornwell et al., 1992). The WTP waste residual solids were analyzed using the TCLP test, and all were found to be non-hazardous. Research from Walsh et al. (2008) presented typical TCLP results from three different WTP waste residual solids (e.g., alum, ferric, and lime residuals). That study showed that for the heavy metals evaluated (i.e., arsenic, barium, cadmium, chromium, and lead), the leachate quality generated from WTP waste residual solids were below both the U.S. and Canadian regulatory threshold values required for landfill classification as non-hazardous waste material. In nearly all cases where low-pressure membranes are applied, the WTP waste residual solids do not fall into the hazardous category (Cornwell and Roth, 2011).

The collective results of these studies have demonstrated that the disposal of WTP waste residual solids containing residual precipitated inorganic coagulants (i.e., alum/ferric) or WTP waste residual solids that do not contain precipitated inorganic coagulants in non-hazardous waste landfills is, in general, an appropriate disposal method (Crittenden et al., 2012).

4.3 Summary of WTP Waste Residuals Regulations/Treatment Standards in Canada and the United States

The primary concern with the discharge of untreated WTP waste residuals into surface waters in Canada and the U.S. is introducing pollutants into the aquatic environment. Aluminum toxicity to the aquatic environment was heavily researched in the 1970s and 1980s by a variety of researchers (Freeman and Everhart, 1971, Baker and Schofield, 1982, Havas and Hutchinson, 1982, and Havas, 1985), who found that the mobilization of aluminum in lakes and streams resulted in higher toxicity levels to aquatic life. The specific impacts of WTP alum sludge discharges to receiving aquatic environments were investigated by George *et al*. (1991). The main findings of that research included the characterization of aluminum speciation within pH varied waters, with the amphoteric nature of aluminum present in the alum sludge samples indicating that water utilities discharging alum sludge into acidic receiving waters and soft surface waters with a hardness < 40 mg $CaCO_3$/L held the potential to adversely affect aquatic primary production.

There is also concern with the discharge of untreated WTP waste residuals related to potential impacts on wildlife and on the environment of wastes containing high levels of solids, various trace metals and chlorine, as well as the potential for creating excessive flow rates (Peck and Russell, 2005). Based on these concerns with liquid waste residual discharges and parallel concerns with potential leaching of contaminants from solid waste residuals, regulation related to the management of WTP waste residuals has developed in both Canada and the United States to where at minimum, most water utilities have restrictions on their permits to operate related to the waste residuals they produce.

- There is no national standard in Canada that regulates or provides guidance for the management of WTP waste residuals.
- Very few provinces/territories have specific blanket regulations for WTP waste residuals in terms of treatment/discharge and solid waste management standards.
- Most provinces manage WTP waste residuals on a site-by-site basis, with instructions and standards established to discharge liquid waste residuals within WTP permits to operate.
- Most treatment standards established for WTP waste residual discharges pull from the CCME *Guidelines for Protection of Aquatic Lif*e.
- In the United States, individual State regulations/standards pull from the USEPA NPDES.
- Common water quality parameters that require monitoring/control and reporting for WTP Waste Residual Discharges in both countries are presented in Table 21.

Table 21. Summary of WTP Waste Residual Discharge Targets (Canada & U.S.)

Analyte	General Target for Discharge (Canada)	General Target for Discharge (US)
pH	6.5 – 9.0	6 – 9
TSS	20 – 30 mg/L or 5 mg/L over background	20 – 30 mg/L
Total Aluminum	5 µg/L if pH < 6.5, 100 µg/L if pH ≥ 6.5	--
Total Iron	< 5 mg/L	--
Total Residual Chlorine	0.0005 (Non Detect) – 0.05 mg/L	< Method Detection Limit

5. Conclusions and Recommendations for Management of WTP Waste Residuals in NWT

5.1 Overall Conclusions & Recommendations

The following outlines the main conclusions of this study:

1. Efforts have been made to characterize WTP waste residuals generated in the NWT drinking water facilities. Upon review of the sampling and water quality testing conducted on SFBW and membrane backwash water streams from the four plants (Fort Resolution, Gameti, Lutselk'e, and Yellowknife), as well as the information provided by MACA, the water quality of the WTP waste residuals generated in the NWT drinking water plants is similar to those generated in similarly designed WTPs across Canada.

2. The data from the sampling reports of WTP waste residuals generated in four of the NWT plants suggest some parameters in exceedance of CEQG limits. This would imply that the waste residuals generated from these facilities would require treatment prior to discharge to surface water, just as required in other Canadian regulatory jurisdictions.

3. A review of the regulatory requirements related to the discharge of WTP waste residuals in other Canadian jurisdictions demonstrates that the primary water quality parameters in WTP waste residual streams that are regulated include pH, TSS, free chlorine residual, and total aluminum, amongst other inorganic constituents present in the source water.

4. Following an investigation on common WTP waste residual treatment and management options, lagoons present a viable, non-mechanical thickening and dewatering technology which may offer economical and effective treatment and management options for small, remote communities. Most of the NWT communities already have established lagoon treatment systems for the management of municipal wastewater. Therefore, this avenue may be the most feasible for treating WTP waste residuals generated in the drinking water plants.
    - If properly designed, discharge of WTP waste residuals to lagoons can produce a high-quality effluent and ensure effective removal of target contaminants of concern (e.g., aluminum).
    - Lagoons can either be temporary or permanent; therefore, they may require dredging and final disposal to an approved landfill.
    - If possible, the co-management of WTP waste residuals with municipal sewage treatment can offer a cost-effective solution and potentially beneficial to the final solid waste streams generated.

Based on the information gathered in this study from published sources and government documents related to typical water quality characteristics and regulations/treatment standards in other jurisdictions for WTP waste residuals, the following general recommendations can be made:

1. Filling Gaps in WTP Waste Residuals Characterization

- Efforts should be made to collect WTP waste residuals volume and water quality data as it will provide information that would be relevant for determining the best management and disposal practices.
- Sampling one facility from each group of treatment train categories in the NWT drinking water plant umbrella may provide a cost-effective approach to determine the typical water quality of the WTP waste residuals.
- Water quality analysis should include pH, TSS, chlorine residual at minimum. Aluminum and other metals specific to either treatment chemicals added and/or source water inorganic water quality should be included if relevant to the plant being audited.
- Efforts to collect water quality information on WTP waste residuals could be focused on those facilities that currently direct discharge overland or to surface water.
- There is no data on clarifier waste residual solids from any of the conventional filtration plants. This waste residual stream should be included in any future WTP waste residual characterization studies.
- For the collection of SFBW samples, a sampling methodology should be developed that ensures a composite sample is collected that reflects the change in water quality during backwashing operations from start to finish of a backwash cycle. There is no standard methodology within the drinking water industry that we can recommend. However, most utilities collect SFBW samples during a backwash at set time intervals (i.e., every 1-3 minutes) through a complete backwash cycle to create a composite sample that reflects higher solids loads (i.e., beginning of a backwash cycle) and the lower solids load at the ending stages of a backwash cycle.

2. Mapping WTP Waste Residuals Treatment/Management

- Information on ultimate discharge points is currently known (i.e., sewer, river, overland, etc.), but other information would help determine residuals treatment requirements.
- Treatment of both liquid waste residuals prior to discharge (i.e., settling pond) should be defined for each community WTP, including more detailed design/operational information such as system size, hydraulic retention time, etc.
- Final disposal and management of solid waste residuals should be defined for each community WTP. Information regarding the management of settled solids in lagoons, for example, could be outlined.
- For plants that discharge to sewage treatment facilities, influent and effluent water samples should be characterized to determine the potential impacts of WTP waste residuals addition on final effluent water quality and solid waste characteristics.

3. Potential Regulatory Framework for Discharge and Solid Waste Management

- Based on regulatory control for WTP waste residual discharges in other jurisdictions in Canada, the management of these waste streams in NWT WTPs should focus on pH, TSS, total residual chlorine, and aluminum concentrations as baseline water quality objectives.
- Other trace metals that may concentrate in the liquid and solid waste residuals due to their presence in the source water should also be considered in individual WTP operating permits if concentrations are found to be in excess of CEQG or problematic in solid waste characterization.
- BOD testing should only be considered for CEBW and CIP waste residual samples if citric acid is used as a chemical cleaner. In general, organic material contained in WTP waste residual streams is relatively inert and represents NOM that is concentrated in clarifier and filtration operations of the main treatment train.
- Treatment technologies that have been developed and are in operation within the drinking water industry are focused on solid-liquid separation systems. Removal of solids from WTP residual streams generally ensures effective removal of target contaminants of concern (e.g., aluminum).
- Non-mechanical thickening and dewatering technology (i.e., lagoons, geotubes) may offer economical and effective treatment and management options for small, remote community drinking water plants that do not currently have existing waste residual treatment facilities.

5.2 Recommendations for NWT Community Drinking Water Plants

The following section summarizes the information gathered on each of the NWT Community drinking water plants and recommendations to achieve best practices for the management and discharge of waste residual generated at these plants.

The plants have been grouped in terms of main treatment train design and in terms of the current discharge location of WTP waste residuals (i.e., discharge to surface water/overland versus sewer system). A pathway to fill gaps in knowledge for the WTPs that currently discharge to surface water/overland is proposed that would allow for the determination of best management practices for these facilities.

5.2.1 Multi-Media WTPs Currently Discharging SFBW to Surface Water

Eleven multi-media filtration plants are operating in the NWT. Six of these multi-media filtration plants direct discharge SFBW to surface water as outlined below:

- Direct discharge to a lake (Fort Resolution, Hay River, Behchoko (Rae))
- Direct discharge to a river (Aklavik, Fort Providence)

- Direct discharge to a reservoir (Tuktoyaktuk)

These plants would be considered very small systems, with design flows < 1,500 m^3/day. The information available on three of these plants (Fort Resolution, Aklavik and Fort Providence) show the % of backwash water produced ranges from 2.6 to 6.4% of the drinking water produced, with SFBW discharges to surface water ranging from 1.8 to 4.9 m^3/ day.

Each of the six multi-media drinking water plants that currently discharge SFBW to surface water are summarized in Appendix C. For each WTP, known information on the main treatment train plant design and waste residuals generation are outlined, and information gaps are highlighted in relation to quantity, quality and disposal of both liquid and solid waste residuals generated in these drinking water plants.

In the documents reviewed by CWRS, the main treatment train designs of the Behchoko (Rae), Hay River and the Fort Resolution WTPs showed that these facilities are conventional filtration plants that include clarification processes prior to filtration. For the other three plants (Aklavik, Fort Providence and Tuktoyaktuk), it is unclear if coagulated water passes through sedimentation or other clarification unit operations prior to filtration. If they do, they would then produce a solid waste residual stream that would require management. Sludge concentrators at the Behchoko (Rae) and Hay River WTPs direct solid waste residuals to their community sewer/lagoon systems. This would be considered an acceptable solid waste residual management option practiced in other communities across Canada. It is unknown what solid waste residuals management practice is set up for the Fort Resolution WTP.

5.2.2 Membrane Filtration WTPs Currently Discharging SFBW to Surface Water or Overland

Twelve membrane filtration WTPs are operating in the NWT. Ten of these membrane filtration plants direct discharge waste backwash water residuals to surface water or overland as outlined below:

- Direct discharge to a lake (Lutselk'e and Tsiigehtchic)
- Direct discharge to a river (Tulita)
- Direct discharge overland /lake (Gameti & Paulatuk)
- Direct discharge overland (Fort Good Hope, Jean Marie River, Sambaa K'e (Trout Lake), Wekweeti and Wrigley)

These plants would be considered very small systems, with design flows < 1,500 m^3/day. The information available on seven of these plants and presented earlier show the % backwash water produced ranges from 4.5 to 6.3% of the drinking water produced, with waste residual discharges to surface water or overland ranging from 0.5 to 3.5 m^3/ day.

Each of the 10 membrane filtration drinking water plants that currently discharge waste residuals to surface water or overland are summarized in Appendix D. For each WTP, known information on the main treatment train plant design and waste residuals generation are outlined. For each plant, the information gaps are highlighted in relation to quantity, quality and disposal of both liquid and solid waste residuals generated in these drinking water plants.

As summarized in this report, there have been two studies conducted on the waste residuals generated in two of the membrane filtration plants that currently discharge waste residuals to surface water or overland (Gameti (discharge overland/lake) and Lutselk'e (discharge to Lake)). Both of these studies showed elevated TSS and total aluminum concentrations higher than typical regulatory thresholds for WTP waste residual discharges in other jurisdictions in Canada (see Table 21). Also, chlorine residual concentrations were not quantified on residual samples from these two WTPs.

For the other eight membrane filtration plants that currently discharge to surface water or overland, the water quality characteristics of backwash water, concentrate, CIP or CEBW waste residual streams are unknown.

5.2.3 Greensand Filtration WTPs Currently Discharging SFBW to Surface Water/Overland

Three greensand filtration WTPs are operating in the NWT. Two of these greensand filtration plants direct discharge waste backwash water to surface water (Fort Liard – river discharge) or overland (Nahanni Butte).

All of the greensand filtration plants would be considered very small systems, with design flows < 1,500 m^3/day. The information available on one of these plants (Fort Liard) shows the % backwash water produced is 7.8 % of the drinking water produced, with waste residual discharge to a river of 4.1 m^3/ day. There is no information on the other plant (Nahanni Butte) that currently discharges waste residuals overland. The third plant (Whati) discharges waste residuals to the sewer. No studies have been conducted on these three WTPs to determine water quality of the waste residual streams. Appendix E outlines the gaps in information for the two greensand filtration plants currently discharging to surface water/overland.

5.2.4 Assessment of Maintaining Direct Discharge of WTP Residuals to Surface Water/Overland

To understand or predict the potential impact of liquid and/or solid WTP waste residuals to surface water and/or overland, one would need to have a clear understanding of:

1. **The characteristics of the SFBW, membrane waste residuals and clarifier solid waste residuals (flow & water quality)**

- Based on our review of the regulation of WTP waste residuals provided in this report, the water quality parameters that should be measured on these discharges are
  a) pH
  b) TSS

c) Aluminum (if Al-based coagulant is used in the main treatment train of the WTP)
d) Chlorine Residual (if chlorinated filter effluent water is used to backwash filters)

- Additional inorganic water quality parameters that should be measured depend on the water quality of the source water for each WTP.
- We would recommend that to characterize these waste residual streams, samples should be taken once/quarter over 12 months. This would provide three water quality analyses in total of each of the parameters that would consider any seasonal changes of source water and/or WTP operations.
- Composite SFBW samples should be collected at the plant during a backwash operation. There is no standard method for the collection of SFBW samples. However, a common approach is to ensure that over a complete backwash cycle, samples are taken to reflect a higher concentration of contaminants that would be found in the initial stages of filter backwashing compared to a lower concentration of contaminants at the end stages of filter backwashing.

2. The characteristics of the receiving environment (water quality & quantity)

- This would allow determination of the ability of the receiving water to assimilate the discharge of SFBW, membrane waste residuals or clarifier waste residual solids without having its water quality degraded.
- Each system would need to be examined, as a lake with a slow flushing rate is not comparable to a river with a high flow in terms of assimilation of a waste residual discharge.
- The current, potential or designated use of the surface water should also be outlined to fully understand any potential detrimental impacts of the waste residual discharges to these surface waters.

Given the low waste residuals volumetric flowrates known for many of the WTPs highlighted above, there is a very strong possibility that a risk assessment approach to determine the assimilation capacity for a particular receiving water would demonstrate that the current direct discharge of WTP waste residuals results in no negative impacts on the receiving water.

If maintaining current discharge points to surface water does not meet environmental risk assessment targets, it is recommended to evaluate if it is possible to direct liquid and solid waste residuals to community sewage treatment facility with the following considerations:

- Existence & type of sewage treatment facility
- Current facility capacity
- Piped vs trucked collection system

5.2.5 WTPs Currently Discharging Waste Residuals to Sewage Treatment Plants

As outlined below, eight WTPs currently discharge liquid waste residual streams to the sewer.

Multi-Media Filtration WTPs:

1. Behchoko (Edzo)
2. Fort Simpson
3. Fort Smith
4. Inuvik
5. Norman Wells

Low-Pressure Membrane Filtration WTPs:

6. Fort McPherson (UF membrane filtration)
7. Yellowknife (MF membrane filtration)

Greensand Filtration WTPs:

8. Whati

With the exception of the Yellowknife WTP, all of these plants would be considered very small systems, with design flows < 1,500 m^3/day. The discharge of WTP waste residuals to the sanitary sewer is a common and acceptable management practice in other parts of Canada. As such, we do not recommend any further study or investigation into these co-managed systems.

References

American Water Works Association (AWWA). (2003). *Residuals Management for Low-Pressure Membranes. Committee Report*, Journal AWWA, vol. 95, no. 6, pp. 68–82. Retrieved from https://search-proquest-com.ezproxy.library.dal.ca/docview/221575752/fulltextPDF/499D41B7EA024223PQ/1?accountid=10406

American Water Works Association (AWWA). (2007). *Reverse osmosis and nanofiltration.* Manual M46

ALS Environmental. (2018, June 15). *City of Yellowknife analytical report*

AWC Water Solutions Inc. (2020, May 11). *Gameti WTP: Water supply facilities characterization and testing plan*. Retrieved from http://registry.mvlwb.ca/Documents/W2018L3-0001/Gameti%20-%20WSF%20-%20Characterization%20and%20Testing%20Plan%20-%20May%2014_20.pdf

Baker, J.P. and C.L. Schofield. (1982). Aluminum toxicity to fish in acidic waters, *Water, Air and Soil Poll*., 18:289-309.

Beck, B., P.Geo., Environmental Protection Officer, Environmental Protection Division, personal communication, July 15, 2020

Beckerton, J., Manager Licensing, Yukon Water Board Secretariat, personal communication, Aug 3, 2020

Bishop Water. (2017a). *Water Treatment for heavy metals removal*. Retrieved from https://bishopwater.ca/wp/wp-content/uploads/2017/03/heavy-metal.pdf

Bishop Water. (2017b). *Geotube sludge management system in North Rustico*. Retrieved from https://bishopwater.ca/wp/wp-content/uploads/2017/03/north-rustico.pdf

Brentwood Industries Inc. (2020a). *Tube settlers vs. plate settlers: Comparing lamella technologies*. Retrieved from https://www.brentwoodindustries.com/resources/learning-center/water-wastewater/tube-settlers-vs-plate-settlers-comparing-lamella-technologies/

Brentwood Industries Inc. (2020b). *Tube settlers*. Retrieved from https://www.brentwoodindustries.com/water-wastewater-products/tube-settlers/

Bugbee, G. J., Frink, C. R. (1985). *Alum sludge as a soil amendment: effects on soil properties and plant growth*. Connecticut Agricultural Station

California Environmental Protection Agency. (n.d.). Persistent and bioaccumulative toxic substances. Retrieved from http://ccelearn.csus.edu/wasteclass/mod6/mod6_04.html

Canadian Council of Ministers of the Environment (CCME). (2003). *Canadian water quality guidelines for the protection of aquatic life: Aluminium*. Retrieved from https://www.ec.gc.ca/lcpe-cepa/documents/consultations/aluminium-retire-withdrawn-eng.pdf

City of Yellowknife. (2020, June 19). *Yellowknife water treatment plant operation and maintenance manual*

Clean Water Act (Summary). 33 U.S.C. §1251 et seq. (1972). Retrieved from https://www.govinfo.gov/content/pkg/USCODE-2018-title33/pdf/USCODE-2018-title33-chap26.pdf

Code of Practice for Soil Amendments, B.C. Reg. 28/2020. Retrieved from https://www.bclaws.ca/civix/document/id/complete/statreg/210_2007

Cornwell, D., Vandermeyden, C., Dillow, G., and Wang, M. (1992). *Landfilling of Water Treatment Plant Coagulant Sludges*, Environmental Engineering & Technology, American Water Works Association Research Foundation, Denver, CO.

Cornwell, D., MacPhee, M., McTigue, N., Arora, H., DiGiovanni, G., LeChevallier, M., and Taylor, J. (2001). *Treatment Options for Giardia, Cryptosporidium, and Other Contaminants in Recycled Backwash Water*, AWWA Research Foundation report. Denver, CO: Water Research Foundation.

Cornwell, D., Tobiason, J., and Brown, R. (2010). *Innovative applications of treatment processes for spent filter backwash (Project # 3114)*. The Water Research Foundation. Retrieved from https://www.yumpu.com/en/document/read/36271326/innovative-applications-of-treatment-processes-for-spent-filter-

Cornwell, D., and Roth, D. (6). (2011). *Water Treatment Plant Residuals Management*, Chapter 22, in American Water Works Association; Edzwald, J. Water Quality and Treatment: A Handbook on Drinking Water. Retrieved from https://www.accessengineeringlibrary.com/content/book/9780071630115/chapter/chapter22

Crittenden, J., Trussel, R., Hand, D., Howe, K., Tchobanoglous, G., and Borchardt, J. (3). (2012). *MWH's water treatment: Principles and design*. New Jersey: John Wiley and Sons, Inc.

Davis, M. (1). (2010). *Water and wastewater engineering: Design principles and practice*. McGraw-Hill Education.

Department of Municipal and Community Affairs (MACA) and the Government of the Northwest Territories (GNWT). (2019). *Fort Resolution backwash effluent analysis – Technical memo*

Electronic Code of Federal Regulations. (2020, June 18). Title 40: Protection of environment. PART 261—IDENTIFICATION AND LISTING OF HAZARDOUS WASTE. Retrieved from https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=c94567294dff611654af7a3944a91d69&mc=true&r=PART&n=pt40.28.261#sp40.28.261.c

Environment Canada. (2015, September 14). *An overview of Canadian water quality guidelines*. Retrieved from https://www.epa.gov/sites/production/files/2016-01/documents/03_spry_canadianwaterqualitygdlns-final-rev_secure.pdf

Environmental Management Act, SBC 53/03. Retrieved from https://www.bclaws.ca/civix/document/id/complete/statreg/03053_02#section6

Environmental Management and Protection Act, 2010. (2015, June 1). *The waterworks and sewage works regulations*. Retrieved from http://www.saskh20.ca/pdf/e10-22r3.pdf

Environmental Water Solutions Inc. (n.d.) *Scum collectors*. Retrieved from https://ewsinc.org/products/clarification/dissolved-air-flotation

Fortin, A., P.Eng., Acting Senior Approvals Engineer Authorizations Branch, Department of Environment and Local Government, personal communication, July 16, 2020

Fowler, J., Duke, M., Schmidt, M., Crabtree, B., Bagby, R., and Trainer, E. (2002). *Dewatering sewage sludge and hazardous sludge with geotextile tubes*. Retrieved from https://pdfs.semanticscholar.org/2188/e3cdcd83ec0d32b420ac16631b22e05e32f8.pdf

Freeman, R.A. and W.H. Everhart (1971) Toxicity of aluminum hydroxide complexes in neutral and basic media to rainbow trout, *Trans. Am. Fish. Soc*., 100:644.

Gendebien, A., Ferguson, R., Brink, J., Horth, H., Sullivan, M., Davis, R., Brunet, H., Dalimier, F., Landrea, B., Krack, D., Perot, J., and Orsi, C. (2001, July). Survey of Wastes Spread on Land—Final Report, WRC Study Contract B4–3040/99/ 110194/ MAR/E3, European Commission-Directorate-General for Environment, European Communities, Luxembourg.

George, D.B., Berk, S.G., Adams, V.D., Morgan, E.L., Roberts, R.O., Holloway, C.A., Lott, R.C., Holt, L.K., Ting, R.S. and A.W. Welch (1991), Alum sludge in the aquatic environment, *American Water Works Research Foundation (AWWARF),* Denver, CO.

Gouvernement du Québec. (2015, February 4). *Guide de conception des installations de production d'eau potable*. Retrieved from http://www.environnement.gouv.qc.ca/eau/potable/guide/index.htm

Government of Alberta. (2012, April). Standards and guidelines for municipal waterworks, wastewater and storm drainage systems. *Standards for municipal waterworks*. Retrieved from https://open.alberta.ca/dataset/f57fec02-7de8-4985-b948-dcf5e2664aee/resource/489ec17a-e8e8-42b3-8a93-b6fd7f92e018/download/part1-standardsmunicipalwaterworks-2012.pdf

Government of British Columbia. (2019, August). *British Columbia approved water quality guidelines: Aquatic life, wildlife & agriculture*. Retrieved from https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf

Government of Canada. (2014). *Biological test method: acute lethality of effluents to rainbow trout*. Retrieved from https://www.canada.ca/en/environment-climate-change/services/wildlife-research-landscape-science/biological-test-method-publications/acute-lethality-effluents-rainbow-trout.html

Government of Canada. (2015). Environment and climate change Canada. *Aluminum Salts*. Retrieved from https://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=491F0099-1&offset=7

Great Lakes - Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers. (2012). Recommended standards for water works. *Policies for the review and approval of plans and specifications for public water supplies*. Retrieved from https://www.health.state.mn.us/communities/environment/water/docs/tenstates/waterrev2012.pdf

GSPS Engineering. (2017). *Thickeners*. Retrieved from https://gsps-eng.com/thickeners.html

Havas, M. and T.C. Hutchinson (1982) Aquatic invertebrates from the Smoking Hills, N.W.T.: effect of pH and metals on mortality, *Can. J. Fish. Aquat. Sci*., 39:890-903.

Havas, M. (1985) Aluminum bioaccumulation and toxicity to daphnia magna in soft water at low pH, *Can. J. Fish. Aquat. Sci*., 42:1741-1748.

Hiller Separation & Process. (2020). *Sludge dewatering*. Retrieved from http://www.hiller-us.com/sludge-dewatering.php

Ippolito, J., Barbarick, K., and Elliott, H. (2011). *Drinking water treatment residuals: A review of recent uses*. Retrieved from https://www.researchgate.net/publication/51047089_Drinking_Water_Treatment_Residuals_A_Review_of_Recent_Uses

Jahan, I., Wood, M., Lake, C., & Gagnon, G. (2018). *Using a geotextile with flocculated filter backwash water and its impact on aluminum concentrations*. Geotextiles and Geomembranes, 46(6), 759-769. doi: 10.1016/j.geotexmem.2018.07.008

Jim Myers & Sons, Inc. (2019). *Plate settler system*. Retrieved from https://www.jmsequipment.com/plate-settler-system/

Johnstone, S., P.Eng., Senior Approvals Engineer Authorizations, Department of Environment & Local Government, personal communication, July 15, 2020

Kinsella, T., Health Officer, Environmental Health Services, personal communication, July 17, 2020

Marshall, T. (2002). *Sweeter Soil with Substantial Savings*. Ohio's Country J. 11, 5, 21–22.

Mastin, B., Lebster, G., Lundin, G., and Ginter, V. (2008). *Is geotube technology a good fit for residuals management at your facility?*. Retrieved from https://gowatersolve.com/downloads/14A,%20Mastin%20-%20WEF%20Residuals%20and%20Biosolids%202008.pdf

McCormick, N., Younker, J., Mackie, A., and Walsh, M. (2009). *Data review from full-scale installations for water treatment plant residuals treatment processes*. American Water Works Association (AWWA) Technical & Education Council, Final report submitted to AWWA Residuals Management Research Committee and Water Treatment Plant Residuals Committee, December 2009

McCormick, N., Porter, M., and Walsh, M. (2010). *Disinfection by-products in filter backwash water: Implications to water quality in recycle designs*. Retrieved from https://www-sciencedirect-com.ezproxy.library.dal.ca/science/article/pii/S0043135410003593

McVicar, M., M.A.Sc., Environmental Services Project Manager, personal communication, August 7, 2020

Montreuil, K., M.A.Sc., Drinking Water Management Analyst, Sustainability & Applied Science Division, personal communication, July 16, 2020

Mortula, M., and Gagnon, G. (2007). Phosphorus treatment of secondary municipal effluent using oven-dried alum residual. *Journal of Environmental Science*. Health A 42:1685–1691

Mortula, M., Bard, S., Walsh, M., and Gagnon, G. (2009). *Aluminum toxicity and ecological risk assessment of dried alum residual into surface water disposal*. Canadian Journal of Civil Engineering, 2009, 36(1): 127-136, https://doi.org/10.1139/S08-042

New Brunswick Regulation, NB Reg 13/02. Retrieved from http://laws.gnb.ca/en/showpdf/cr/2002-13.pdf

New Brunswick Regulation, NB Reg 126/82. Retrieved from http://laws.gnb.ca/en/ShowPdf/cr/82-126.pdf

Newfoundland and Labrador Regulation, NL Reg 65/03. Retrieved from https://www.assembly.nl.ca/Legislation/sr/regulations/rc030065.htm

Nova Scotia Environment. (2010, March). *Guidelines for land application and storage of municipal biosolids in Nova Scotia*. Retrieved from https://novascotia.ca/nse/water/docs/BiosolidGuidelines.pdf

Nova Scotia. (2012, March 12). *Nova Scotia treatment standards for municipal drinking water systems*. Retrieved from https://novascotia.ca/nse/water/docs/Treatment_Standards_for_Municipal_Drinking_Water_Systems.pdf

Ontario Ministry of Environment (MOE). (2019). *Design guidelines for drinking-water systems*. Retrieved from https://www.ontario.ca/document/design-guidelines-drinking-water-systems-0

Ottenbreit, G., Minister for the Water Security Agency, personal communication, August 11, 2020

Peck, B., and Russell, J. (2005). "Process Residuals," in E. E. Baruth, (ed.), Water Treatment Plant Design, American Water Works Association and American Society of Civil Engineers, McGraw-Hill, New York, pp. 17.1–17.70.

Phoenix Process Equipment. (2018). *Belt filter press*. Retrieved from https://www.dewater.com/belt-filter-press/

Rader, L. (2003). *How to operate and maintain manganese greensand treatment units*. Retrieved from https://water-research.net/Waterlibrary/privatewell/greensand.pdf

Rathwell, M., Senior Environmental Protection Officer, Ministry of Environment, personal communication, July 20, 2020

Safe Drinking Water Act (summary). 42 U.S.C. §300f et seq. (1974). Retrieved from https://www.epa.gov/laws-regulations/summary-safe-drinking-water-act#:~:text=(1974),above%20ground%20or%20underground%20sources.

Sewer Use Bylaw. (2017). BYLAW NO. 9466. Retrieved from https://www.saskatoon.ca/sites/default/files/documents/city-clerk/bylaws/9466.pdf

Spracklin, D., P.Eng., Community Water and Wastewater, Department of Municipal Affairs and Environment, personal communication, July 10, 2020

State of California. (2005). *Waste Extraction Test (WET) Procedure*, California Code of Regulations, Title 22, Division 4.5, Chapter 11, Appendix II, Sacramento, CA.

Statutes of Saskatchewan. (2010). The environmental management and protection Act. Retrieved from https://www.canlii.org/en/sk/laws/stat/ss-2010-c-e-10.22/latest/ss-2010-c-e-10.22.html

Taiga Environmental Laboratory. (2018, January 8). *City of Yellowknife final report*

TenCate. (2009). *Geotube dewatering technology provides the perfect solution for waste treatment*. Retrieved from https://www.tencategeotube.com/media/2d01dba2-e880-4951-b661-b7b704e88898/fzewtQ/TenCate%20Water%20and%20Environment/Documents/PDF/Case%20studies/CS%20Ontario_tcm28-43601.pdf

TenCate. (2010). *Geotube dewatering technology contains and dewaters river sediments at large Water Treatment Plant in New Jersey*. Retrieved from https://www.tencategeotube.com/media/87f8864d-e70a-4c5c-af56-0ddf85a77ca3/wyzOtQ/TenCate%20Water%20and%20Environment/Documents/PDF/Case%20studies/CS%20New%20Jersey_tcm28-43600.pdf

Toro Equipment. (2015). *Filter press, the best alternative to sludge dehydration*. Retrieved from https://www.toroequipment.com/news/filter-press-the-best-alternative-to-sludge-dehydration/

United States Environmental Protection Agency (USEPA). (1992). *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, EPA Publication SW-846 [Third Edition (September, 1986), as amended by Update I (July 1992)], U.S. Environmental Protection Agency, Washington, DC.

USEPA. (2002, December). *Filter backwash recycling rule: Technical guidance manual*. Retrieved from https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=200025V5.txt

USEPA. (2004, June). Understanding the safe drinking water act. Retrieved from https://www.epa.gov/sites/production/files/2015-04/documents/epa816f04030.pdf

USEPA. (2011, September). Drinking water treatment plant residuals management technical report. *Summary of residuals generation, treatment, and disposal at large community water* *systems*. Retrieved from https://www.epa.gov/sites/production/files/2015-11/documents/dw-treatment-residuals-mgmt-tech-report-sept-2011.pdf

USEPA. (2020, August 3). *National pollutant discharge elimination system (NPDES)*. Retrieved from https://www.epa.gov/npdes/npdes-permit-basics

Walsh, M., Lake, C., and Gagnon, G. (2008). *Strategic pathways for the sustainable management of water treatment plant residuals*. Retrieved from https://www.researchgate.net/publication/237152295_Strategic_pathways_for_the_sustainable_management_of_water_treatment_plant_residuals#fullTextFileContent

Waste Discharge Regulation, B.C. Reg. 320/2004. Retrieved from https://www.bclaws.ca/civix/document/id/complete/statreg/320_2004#Schedule1

Water Security Agency (WSA). (2012, November 15). *Waterworks design standard*. Retrieved from http://www.saskh2o.ca/pdf/epb501.pdf

WesTech Engineering Inc. (2020). *Vacuum drum filter*. Retrieved from https://www.westech-inc.com/en-usa/products/vacuum-drum-filter#images-3

Wirth, H., P.Eng., Senior Water Engineer, Municipal Water & Wastewater Permissions, Ministry of the Environment, personal communication, July 27, 2020

Yukon Waters Act. S.C 40/92. Retrieved from https://laws-lois.justice.gc.ca/PDF/Y-4.6.pdf

Appendix A

Organic and inorganic chemicals listed below are tested for both Waste Extraction Test (WET) solubility and total concentrations. If the results of the soluble threshold limit concentrations (STLC) or total threshold limit concentrations (TTLC) equal or exceed their respective thresholds, the waste is a toxic hazardous waste.

Organic Chemicals:

Substance	STLC (mg/L)	TTLC Wet Weight (mg/kg)
Aldrin	0.14	1.4
Chlordane	0.25	2.5
DDT, DDE, DDD	0.1	1.0
2,4-Dichlorophenoxyacetic acid	10	100
Dieldren	0.8	8.0
Dioxin (2,3,7,8-TCDD)	0.001	0.01
Endrin	0.02	0.2
Heptachlor	0.47	4.7
Kepone	2.1	21
Lead compounds, organic	--	13
Lindane	0.4	4.0
Methoxychlor	10	100
Mirex	2.1	21
Pentachlorophenol	1.7	17
Polychlorinated biphenyls (PCBs)	5.0	50
Toxaphene	0.5	5
Trichloroethylene	204	2,040
2,4,5-Trichlorophenoxypropionic acid	1.0	10

Source: Adapted from California Environmental Protection Agency, n.d.

Inorganic Chemicals:

Substance	STLC (mg/L)	TTLC Wet Weight (mg/kg)
Antimony and/or antimony compounds	15	500
Arsenic and/or arsenic compounds	5.0	500
Asbestos		1.0 (as percent)
Barium and/or barium compounds (excluding barite)	100	10,000[c]
Beryllium and/or beryllium compounds	0.75	75
Cadmium and/or cadmium compounds	1.0	100

Chromium (VI) compounds	5	500
Chromium and/or chromium (III) compounds	5[d]	2,500
Cobalt and/or cobalt compounds	80	8,000
Copper and/or copper compounds	25	2,500
Fluoride salts	180	18,000
Lead and/or lead compounds	5.0	1,000
Mercury and/or mercury compounds	0.2	20
Molybdenum and/or molybdenum compounds	350	3,500[e]
Nickel and/or nickel compounds	20	2,000
Selenium and/or selenium compounds	1.0	100
Silver and/or silver compounds	5	500
Thallium and/or thallium compounds	7.0	700
Vanadium and/or vanadium compounds	24	2,400
Zinc and/or zinc compounds	250	5,000

Source: Adapted from California Environmental Protection Agency, n.d.

[a] STLC and TTLC values are calculated on the concentrations of the elements, not the compounds.

[b] In the case of asbestos and elemental metals, the specified concentration limits apply only if the substances are in a friable, powdered or finely divided state. Asbestos includes chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite.

[c] Excluding barium sulphate.

[d] If the soluble chromium, as determined by the TCLP outlined in Appendix I of Chapter 18 of this division, is less than 5 mg/l, and the soluble chromium, as determined by the procedures outlined in Appendix II of Chapter 11, equals or exceeds 560 mg/l and the waste is not otherwise identified as a RCRA hazardous waste according to §66261.100, then the waste is a non‑RCRA hazardous waste.

[e] Excluding molybdenum disulphide.

Appendix B

A solid waste exhibits the characteristic of toxicity if, using the Toxicity Characteristic Leaching Procedure, the extract from a representative sample of the waste contains any of the contaminants listed in Table 22 at the concentration equal to or greater than the respective value given in that table.

Table 22. Maximum Concentration of Contaminants for the Toxicity Characteristic

Contaminant	Regulatory Level (mg/L)
Arsenic	5.0
Barium	100.0
Benzene	0.5
Cadmium	1.0
Carbon tetrachloride	0.5
Chlordane	0.03
Chlorobenzene	100.0
Chloroform	6.0
Chromium	5.0
o-Cresol	200.0[1]
m-Cresol	200.0[1]
p-Cresol	200.0[1]
Cresol	200.0[1]
2,4-D	10.0
1,4-Dichlorobenzene	7.5
1,2-Dichloroethane	0.5
1,1-Dichloroethylene	0.7
2,4-Dinitrotoluene	0.13[2]
Endrin	0.02
Heptachlor (and its epoxide)	0.008
Hexachlorobenzene	0.13[2]
Hexachlorobutadiene	0.5
Hexachloroethane	3.0
Lead	5.0
Lindane	0.4
Mercury	0.2
Methoxychlor	10.0
Methyl ethyl ketone	200.0
Nitrobenzene	2.0
Pentachlorophenol	100.0
Pyridine	5.0[2]
Selenium	1.0
Silver	5.0

Tetrachloroethylene	0.7
Toxaphene	0.5
Trichloroethylene	0.5
2,4,5-Trichlorophenol	400.0
2,4,6-Trichlorophenol	2.0
2,4,5-TP	1.0
Vinyl chloride	0.2

Source: Adapted from Electronic Code of Federal Regulations, 2020

[1] If o-, m-, and p-Cresol concentrations cannot be differentiated, the total cresol (D026) concentration is used. The regulatory level of total cresol is 200 mg/l.

[2] Quantitation limit is greater than the calculated regulatory level. The quantitation limit, therefore, becomes the regulatory level.

Appendix C – **Summary & Recommendations for Multi-Media Filtration WTPs Currently Discharging Waste Residuals to Surface Water in the NWT**

WTP #1 -Fort Resolution

Main Treatment Train:

- **Population Served:** 532
- **Design Flow:** 24,761 m^3/yr = 68 m^3/ day
- **Coagulant:** Alum (12.6 mL/min)

Liquid Waste Residuals:

SFBW

- **Flowrate** = 641 m^3/yr = 1.8 m^3/day
- **% Backwash Produced** = 2.6
- **Water Quality:** MACA/GNWT Report shows elevated Al, Cu, Fe & Pb concentrations in effluent at Great Slave Lake discharge point.
- **Discharge Point:** Great Slave Lake

Solid Waste Residuals:

- Unknowns - unit operations in the main treatment train, volume & quality of solid waste residuals & current disposal method

Identified Information Gaps:

1. Verify reported 641 m^3/yr of SFBW produced is for one or two filters at this plant.
2. Determine the existence of clarifier operations at WTP & current solid waste residuals management practice.

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of SFBW discharge on receiving water.
2. If maintaining the current discharge point to Great Slave Lake does not meet environmental risk assessment targets, evaluate the possibility of directing liquid and solid waste residuals to community sewage treatment facility with the following considerations:
    - Existence & type of sewage treatment facility
    - Current facility capacity
    - Piped vs trucked collection system

WTP #2 - Aklavik

Main Treatment Train:

- **Population Served:** 622
- **Design Flow:** 31,422 m^3/yr = 86 m^3/day
- **Coagulant:** Alum (Dose Unknown)

Liquid Waste Residuals:

SFBW

- **Flowrate** = 1,547 m^3/yr = 4.2 m^3/day
- **% Backwash Produced** = 5.0
- **Water Quality:** Unknown
- **Discharge Point:** River

Solid Waste Residuals:

- Unknowns – unit operations in the main treatment train, volume & quality of solid waste residuals & current disposal method

Identified Information Gaps:

1. Determine alum dose in the main treatment train of WTP.
2. Determine SFBW water quality (pH, TSS, aluminum & Cl_2 residual[§]).
3. Determine the existence of clarifier operations at WTP & current solid waste residuals management practice.

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of SFBW discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing liquid and solid waste residuals to community sewage treatment facility with the following considerations:
    - Existence & type of sewage treatment facility
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated filter effluent water is used to backwash filters*

WTP #3 - Fort Providence

Main Treatment Train:

- **Population Served:** 684
- **Design Flow:** 28,263 m^3/yr = 77 m^3/day
- **Coagulant:** PACl (Dose Unknown)

Liquid Waste Residuals:

SFBW

- **Flowrate** = 1,800 m^3/yr = 4.9 m^3/day
- **% Backwash Produced** = 6.4
- **Water Quality:** Unknown
- **Discharge Point:** River

Solid Waste Residuals:

- Unknowns – unit operations in the main treatment train, volume & quality of solid waste residuals & current disposal method

Identified Information Gaps:

1. Determine PACl dose in main treatment train of WTP.
2. Determine SFBW water quality (pH, TSS, aluminum & Cl_2 residual[§]).
3. Determine the existence of clarifier operations at WTP & current solid waste residuals management practice.

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of SFBW discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing liquid and solid waste residuals to community sewage treatment facility with the following considerations:
    - Existence & type of sewage treatment facility
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated filter effluent water is used to backwash filters*

WTP #4 - Tuktoyaktuk

Main Treatment Train:

- **Population Served:** 995
- **Design Flow:** 46,801 m^3/yr = 128 m^3/day
- **Coagulant:** None

Liquid Waste Residuals:

SFBW

- **Flowrate** = Unknown
- **% Backwash Produced** = Unknown
- **Water Quality:** Unknown
- **Discharge Point:** Reservoir

Solid Waste Residuals:

- None, there is no clarifier at this plant.

Identified Information Gaps:

1. Determine SFBW flowrate & calculate % backwash produced.
2. Determine SFBW water quality (pH, TSS, & Cl_2 residual[§]).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of SFBW discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing liquid and solid waste residuals to community sewage treatment facility with the following considerations:
    - Existence & type of sewage treatment facility
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated filter effluent water is used to backwash filters*

WTP #5 - Behchoko (Rae) WTP

Main Treatment Train:

- **Population Served:** 2,028 (Behchoko (Rae & Edzo)
- **Design Flow:** 82,217 m^3/yr = 239 m^3/day
- **Coagulant:** PACl (Dose unknown)

Liquid Waste Residuals:

SFBW

- **Flowrate** = Unknown
- **% Backwash Produced** = Unknown
- **Water Quality:** Unknown
- **Discharge Point:** Reservoir

Solid Waste Residuals:

- WTP is equipped with sludge concentrators that get pumped out to the sewer/lagoon system a couple of times each week.

Identified Information Gaps:

1. Determine coagulant dose in the main treatment train of WTP.
2. Determine SFBW flowrate & calculate % backwash produced.
3. Determine SFBW water quality (pH, TSS, aluminum & Cl_2 residual[§]).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of SFBW discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of co-managing SFBW with the solid waste residuals in the community sewer/lagoon treatment system, with the following consideration:
   - Current facility capacity
   - Piped vs trucked collection system

[§] *If chlorinated filter effluent water is used to backwash filters*

WTP #6 – Hay River

Main Treatment Train:

- **Population Served:** 3,749
- **Design Flow:** 367,389 m^3/yr = 1,007 m^3/day
- **Coagulant:** Polymer Blend (46.2 mL/min) & Polyamine (90 mL/min, 60 mg/L Winter)

Liquid Waste Residuals:

SFBW

- **Flowrate** = Unknown
- **% Backwash Produced** = Unknown
- **Water Quality:** Unknown
- **Discharge Point:** Reservoir

Solid Waste Residuals:

- WTP is equipped with sludge concentrators that get pumped out to the sewer/lagoon system a couple of times each week.

Identified Information Gaps:

1. Determine SFBW flowrate & calculate % backwash produced.
2. Determine SFBW water quality (pH, TSS, aluminum[*] & Cl_2 residual[§]).

Recommended Path Forward for Waste Residuals Management:

3. Maintain current discharge point pending assessment of potential impact(s) of SFBW discharge on receiving water.
4. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of co-managing SFBW with the solid waste residuals in the community sewer/lagoon treatment system, with the following consideration:
    - Current facility capacity
    - Piped vs trucked collection system

[*] *If aluminum-based coagulant is used in main treatment train of WTP*

[§] *If chlorinated filter effluent water is used to backwash filters*

Appendix D – **Summary & Recommendations for Membrane Filtration WTPs Currently Discharging Waste Residuals to Surface Water or Overland in the NWT**

WTP #1 – Sambaa K'e

Main Treatment Train:

- **Population Served:** 97
- **Design Flow:** 3,008 m^3/yr = 8.2 m^3/day
- **Membrane Type:** UF
- **Coagulant:** Aluminum chlorohydrate (ACH) – 25 mg/L

Liquid Waste Residuals:

Backwash

- **Annual Volume** = 171 m^3/yr < 1 m^3/day
- **% Backwash Produced** = 5.7
- **Water Quality:** Unknown
- **Discharge Point:** Overland

Identified Information Gaps:

1. Determine backwash water quality (pH, TSS, aluminum & Cl_2 residual[§]).
2. Determine UF concentrate stream discharge location.
3. Determine UF concentrate water quality (pH, TSS & Total Al).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of membrane backwash water discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing waste residuals from WTP to community sewer/lagoon treatment system, with the following consideration:
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated permeate (i.e., filter effluent) water is used to backwash membranes*

WTP #2 – Wekweeti

Main Treatment Train:

- **Population Served:** 140
- **Design Flow:** 4,756 m^3/yr = 13 m^3/day
- **Membrane Type:** UF
- **Coagulant:** None

Liquid Waste Residuals:

Backwash

- **Annual Volume** Unknown
- **% Backwash Produced** = Unknown
- **Water Quality:** Unknown
- **Discharge Point:** Overland

Identified Information Gaps:

4. Determine backwash flowrate & calculate the % backwash produced.
5. Determine backwash water quality (pH, TSS & Cl_2 residual[§]).
6. Determine UF concentrate stream discharge location.
7. Determine UF concentrate water quality (pH, TSS).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of membrane backwash water discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing waste residuals from WTP to community sewer/lagoon treatment system, with the following consideration:
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated permeate (i.e., filter effluent) water is used to backwash membranes*

WTP #3 – Jean Marie River

Main Treatment Train:

- **Population Served:** 96
- **Design Flow:** 4,819 m^3/yr = 13.2 m^3/day
- **Membrane Type:** UF
- **Coagulant:** None

Liquid Waste Residuals:

Backwash

- **Annual Volume:** 305 m^3/yr = < 1 m^3/day
- **% Backwash Produced** = 6.3
- **Water Quality:** Unknown
- **Discharge Point:** Overland

Identified Information Gaps:

1. Determine backwash water quality (pH, TSS & Cl_2 residual[§]).
2. Determine UF concentrate stream discharge location.
3. Determine UF concentrate water quality (pH, TSS).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of membrane backwash water discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing waste residuals from WTP to community sewer/lagoon treatment system, with the following consideration:
   - Current facility capacity
   - Piped vs trucked collection system

[§] *If chlorinated permeate (i.e., filter effluent) water is used to backwash membranes*

WTP #4 – Wrigley

Main Treatment Train:

- **Population Served:** 120
- **Design Flow:** 5,827 m^3/yr = 16 m^3/day
- **Membrane Type:** UF
- **Coagulant:** None

Liquid Waste Residuals:

Backwash

- **Annual Volume:** 320 m^3/yr = < 1 m^3/day
- **% Backwash Produced** = 5.5
- **Water Quality:** Unknown
- **Discharge Point:** Overland

Identified Information Gaps:

1. Determine backwash water quality (pH, TSS & Cl_2 residual[§]).
2. Determine UF concentrate stream discharge location.
3. Determine UF concentrate water quality (pH, TSS).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of membrane backwash water discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing waste residuals from WTP to community sewer/lagoon treatment system, with the following consideration:
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated permeate (i.e., filter effluent) water is used to backwash membranes*

WTP #5 – Tsiigehtchic

Main Treatment Train:

- **Population Served:** 187
- **Design Flow:** 4,817 m^3/yr = 13.2 m^3/day
- **Membrane Type:** NF
- **Coagulant:** None

Liquid Waste Residuals:

Backwash

- **Annual Volume** Unknown
- **% Backwash Produced** = Unknown
- **Water Quality:** Unknown
- **Discharge Point:** Lake

Identified Information Gaps:

1. Determine backwash /concentrate flowrate & calculate the % backwash produced.
2. Determine backwash/concentrate water quality (pH, TSS & Cl_2 residual[§]).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of membrane backwash water/concentrate discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing waste residuals from WTP to community sewer/lagoon treatment system, with the following consideration:
   - Current facility capacity
   - Piped vs trucked collection system

[§] *If chlorinated permeate (i.e., filter effluent) water is used to backwash membranes*

WTP #6 – Gameti

Main Treatment Train:

- **Population Served:** 313
- **Design Flow:** 9,783 m^3/yr = 26.8 m^3/day
- **Membrane Type:** UF
- **Coagulant:** None

Liquid Waste Residuals:

Backwash

- **Annual Volume:** 446 m^3/yr = 1.2 m^3/day
- **% Backwash Produced** = 4.6
- **Water Quality:** pH = 8.8, TSS = 46.9 mg/L, Total Al = 0.13 mg/L
- **Backwash Water Discharge Point:** Overland/Lake

Wastewater Tank

- Discharge to sewer (lagoon)
- Water Quality: pH = 8.9, TSS < 3.0 mg/L, Total Al = 0.09 mg/ L

Identified Information Gaps:

1. Verify UF concentrate is directed to the wastewater tank (assumed).
2. Determine chlorine residual concentration in backwash water.

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of membrane backwash water discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing backwash water from WTP to community sewer/lagoon treatment system, with the following consideration:
    - Current facility capacity
    - Piped vs trucked collection system

§ *If chlorinated permeate (i.e., filter effluent) water is used to backwash membranes*

WTP #7 – Paulatuk

Main Treatment Train:

- **Population Served:** 323
- **Design Flow:** 10,770 m^3/yr = 29.5 m^3/day
- **Membrane Type:** UF
- **Coagulant:** None

Liquid Waste Residuals:

Backwash

- **Annual Volume:** 483 m^3/yr = 1.3 m^3/day
- **% Backwash Produced** = 4.5
- **Water Quality:** unknown
- **Backwash Water Discharge Point:** Overland/Lake

Identified Information Gaps:

1. Determine backwash water quality (pH, TSS & Cl_2 residual[§]).
2. Determine UF concentrate stream discharge location.
3. Determine UF concentrate water quality (pH, TSS).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of membrane backwash water discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing backwash water from WTP to community sewer/lagoon treatment system, with the following consideration:
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated permeate (i.e., filter effluent) water is used to backwash membranes*

WTP #8 – Tulita

Main Treatment Train:

- **Population Served:** 521
- **Design Flow:** 16,059 m^3/yr = 44 m^3/day
- **Membrane Type:** UF
- **Coagulant:** None

Liquid Waste Residuals:

Backwash

- **Annual Volume:** unknown
- **% Backwash Produced** = unknown
- **Water Quality:** unknown
- **Backwash Water Discharge Point:** River

Identified Information Gaps:

1. Determine backwash flowrate & calculate the % backwash produced.
2. Determine backwash water quality (pH, TSS & Cl_2 residual[§]).
3. Determine UF concentrate stream discharge location.
4. Determine UF concentrate water quality (pH, TSS).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of membrane backwash water discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing backwash water from WTP to community sewer/lagoon treatment system, with the following consideration:
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated permeate (i.e., filter effluent) water is used to backwash membranes*

WTP #9 – Lutselk'e

Main Treatment Train:

- **Population Served:** 314
- **Design Flow:** 16,671 m^3/yr = 45.7 m^3/day
- **Membrane Type:** UF
- **Coagulant:** None

Liquid Waste Residuals:

Backwash

- **Annual Volume:** 934 m^3/yr = 2.6 m^3/day
- **% Backwash Produced** = 5.6
- **Water Quality:** pH = 7.9, TSS = 38.1 mg/L, Total Al = 0.35 mg/L
- **Backwash Water Discharge Point:** Lake

Clean-In-Place (CIP) Waste Residuals

- **Annual Volume:** Unknown
- **Water Quality:** pH = 10.3, TSS = 31.7 mg/L, Total Al = 0.79 mg/L
- **CIP Discharge Point:** Unknown

Identified Information Gaps:

1. Determine UF concentrate stream discharge location.
2. Determine CIP discharge location.
3. Determine chlorine residual concentration in backwash water.
4. Determine UF concentrate water quality (pH, TSS).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of membrane backwash water discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing backwash water from WTP to community sewer/lagoon treatment system, with the following consideration:
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated permeate (i.e., filter effluent) water is used to backwash membranes*

WTP #10 – Fort Good Hope

Main Treatment Train:

- **Population Served:** 582
- **Design Flow:** 22,923 m^3/yr = 62.8 m^3/day
- **Membrane Type:** UF
- **Coagulant:** Aluminum Chlorohydrate (ACH) @ 25 mg/L

Liquid Waste Residuals:

Backwash

- **Annual Volume:** 1,284 m^3/yr = 3.5 m^3/day
- **% Backwash Produced** = 5.6
- **Water Quality:** Unknown
- **Backwash Water Discharge Point:** Overland

Identified Information Gaps:

1. Determine backwash water quality (pH, TSS, Total Al & Cl_2 residual[§]).
2. Determine UF concentrate stream discharge location.
3. Determine UF concentrate water quality (pH, TSS, Total Al).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of membrane backwash water discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing backwash water from WTP to community sewer/lagoon treatment system, with the following consideration:
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated permeate (i.e., filter effluent) water is used to backwash membranes*

Appendix E – **Summary & Recommendations for Greensand Filtration WTPs Currently Discharging Waste Residuals to Surface Water or Overland in the NWT**

WTP #1 – Fort Liard

Main Treatment Train:

- **Population Served:** 542
- **Design Flow:** 19,139 m^3/yr = 52.4 m^3/day
- **Filtration Type:** Greensand Filtration
- **Oxidant:** Chlorine (Dose Unknown)

Liquid Waste Residuals:

Backwash

- **Annual Volume:** 1,492 m^3/yr = 4.1 m^3/day
- **% Backwash Produced** = 7.8
- **Water Quality:** Unknown
- **Backwash Water Discharge Point:** River

Identified Information Gaps:

1. Determine backwash water quality (pH, TSS & Cl_2 residual[§]).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of backwash water discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing backwash water from WTP to community sewer/lagoon treatment system, with the following consideration:
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated filter effluent water is used to backwash filters*

WTP #2 Nahanni Butte

Main Treatment Train:

- **Population Served:** 106
- **Design Flow:** 3,578 m^3/yr = 9.8 m^3/day
- **Filtration Type:** Greensand Filtration
- **Oxidant:** Potassium Permanganate (Dose Unknown)

Liquid Waste Residuals:

Backwash

- **Annual Volume:** Unknown
- **% Backwash Produced** = Unknown
- **Water Quality:** Unknown
- **Backwash Water Discharge Point:** Overland

Identified Information Gaps:

1. Determine backwash water flowrate & calculate the % backwash produced.
2. Determine backwash water quality (pH, TSS & Cl_2 residual[§]).

Recommended Path Forward for Waste Residuals Management:

1. Maintain current discharge point pending assessment of potential impact(s) of backwash water discharge on receiving water.
2. If maintaining the current discharge point does not meet environmental risk assessment targets, evaluate the possibility of directing backwash water from WTP to community sewer/lagoon treatment system, with the following consideration:
    - Current facility capacity
    - Piped vs trucked collection system

[§] *If chlorinated filter effluent water is used to backwash filters*