Operation and Maintenance of Ultrafiltration Membrane in Small Water Systems

Operational Insights from Rivershore WTP

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A Little About Me

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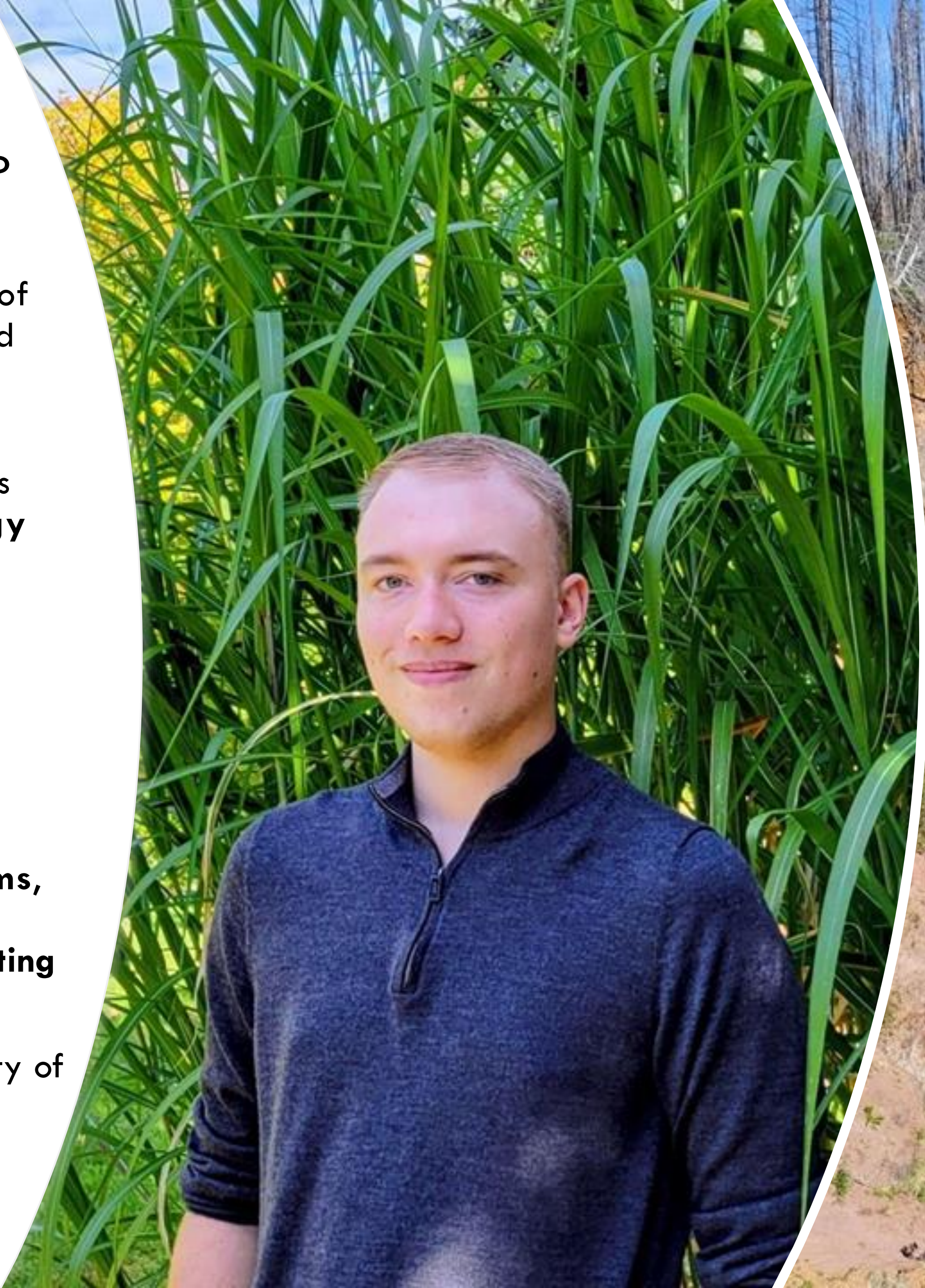
- ✓ I am **Utility Operations Manager** of Rivershore Estates & Golf Links and the principal operator for all 4 of their EOCP-certified facilities.
- ✓ I graduated Valedictorian of TRU's 2022 **Water Treatment Technology Program** Cohort. I have worked in both water and wastewater treatment, including the Capital Regional District's state-of-the-art McLoughlin Point Wastewater Treatment Plant for a co-op work term.
- ✓ **Troubleshooting treatment systems,** coordinating with regulators, **developing new Standard Operating Procedures**
- ✓ Hands-on experience with a variety of **membrane filtration** applications

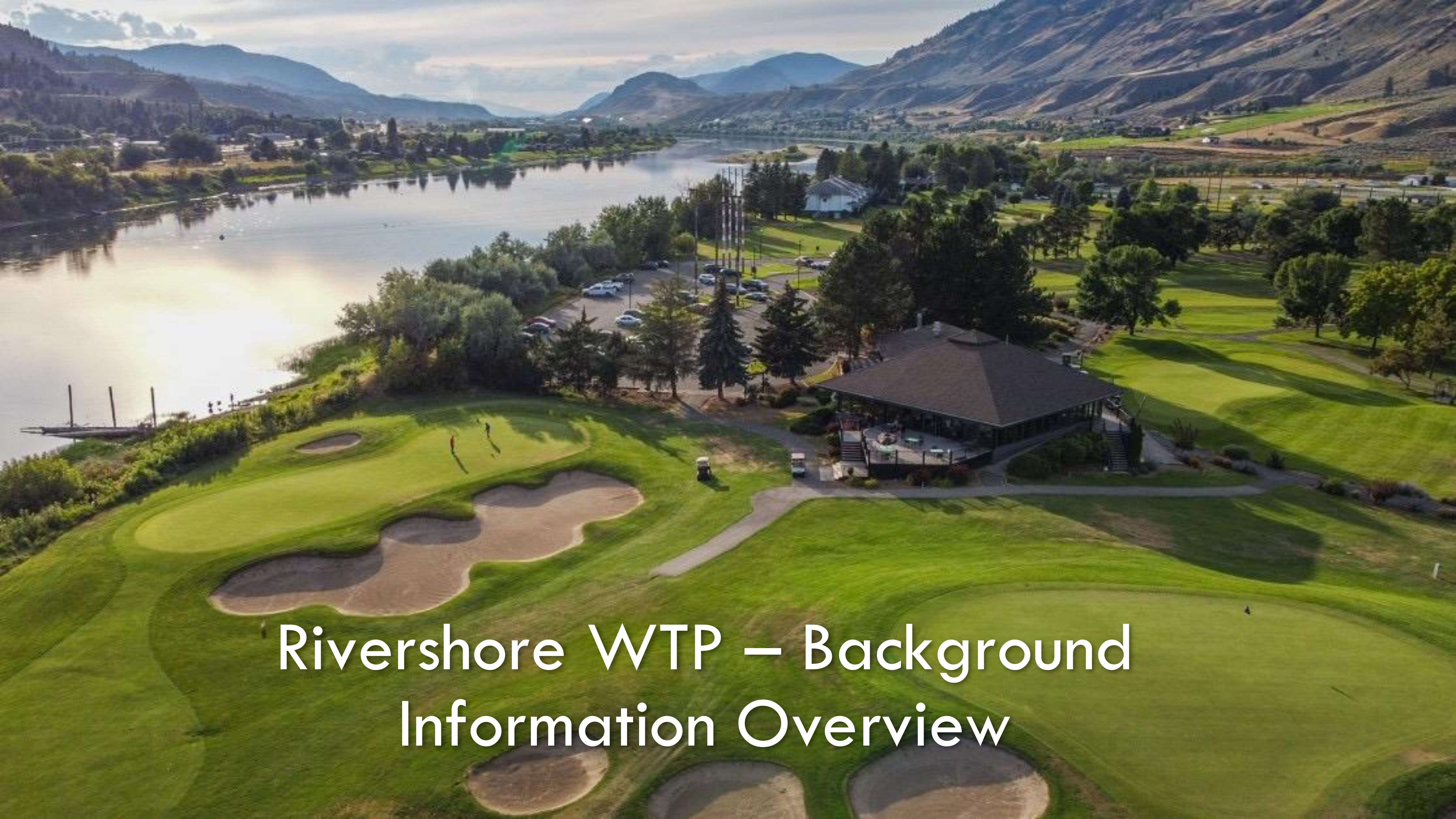


Objectives

1. Overview of the **ultrafiltration membrane treatment process** at Rivershore, and why the specific technology was chosen over other alternatives

2. Highlight **key operational issues** and how they are and have been managed

3. Share **lessons learned** and best practices and is it a good fit **for small water systems.**



Rivershore WTP – Background Information Overview

Location and System Information

Rivershore Golf Links & Estates is a golf course and subdivision approximately 20km east of downtown Kamloops, 12km southwest of Pritchard.

It is in a **highly developed** agricultural, recreational, and industrial area which poses many potential hazards to the source water. The **surface water intake** is situated in a 10ft vault on the riverbed, influenced solely by the river level. There is no established alternative intake or source.

The course treats its own drinking water using an **advanced ultrafiltration membrane water treatment facility**, using the South Thompson River as its drinking water source. A large reservoir feeds the distribution system which serves approximately **200 connections** – including a restaurant and Pro Shop.

System Overview & Membrane Selection

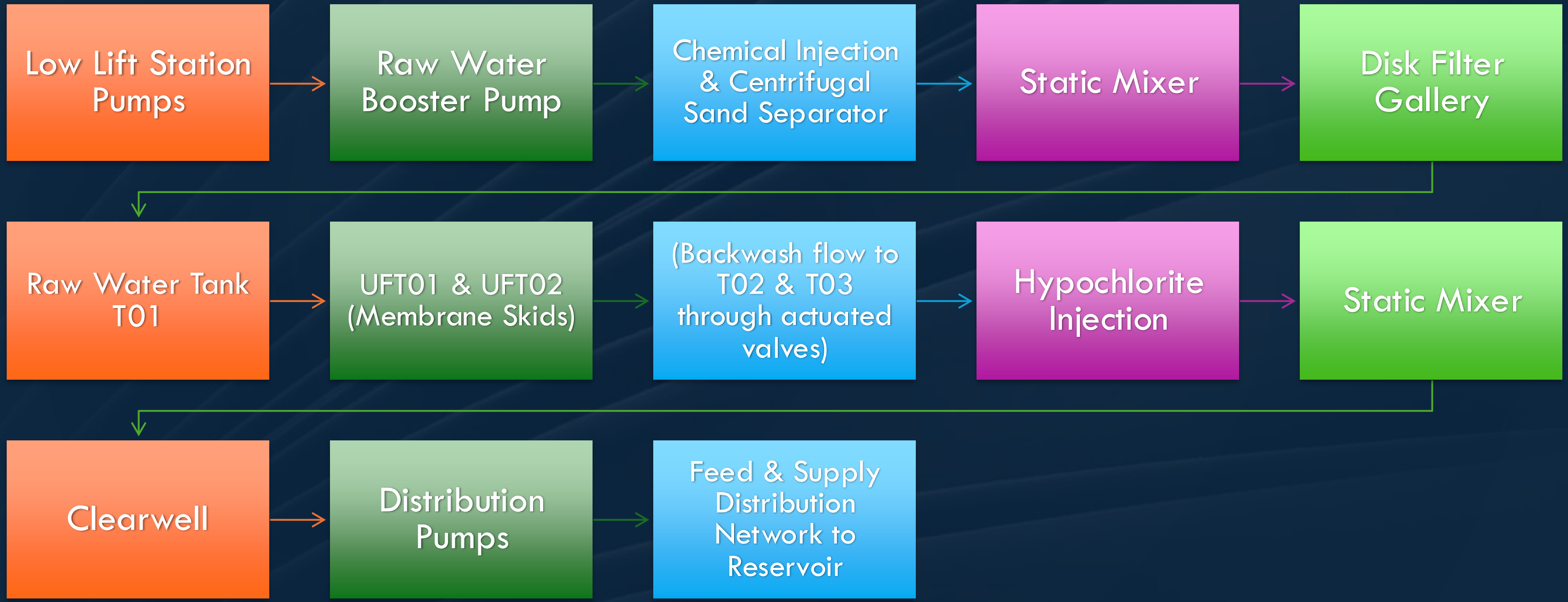
Chose **ultrafiltration membranes** for cost efficiency + high log removal

- 4-log bacteria/protozoa, 2–4 log viruses
- Selected **Norit X-Flow XF55** (now Pentair)
- Claims: 6-log bacteria, 4-log viruses
- Nominal pore size allows up to 4–6 log removal
- Design & commissioning by BI Pure Water

Key benefits of XF55:

- Meets regulatory requirements (SWTR, DWPA, etc.)
- Compact footprint for capacity
- No constant waste reject line
- Easy to clean
- GE Zeeweed style-membranes considered → rejected (higher cost, larger footprint)

General Process Flow Path



About Rivershore WTP’s Design

Original design underestimated peak demand

Summer use ↑ up to 800% (mainly residential irrigation—best for new designs to separate systems)

Commercial golf course system separate, but residents irrigate with treated water

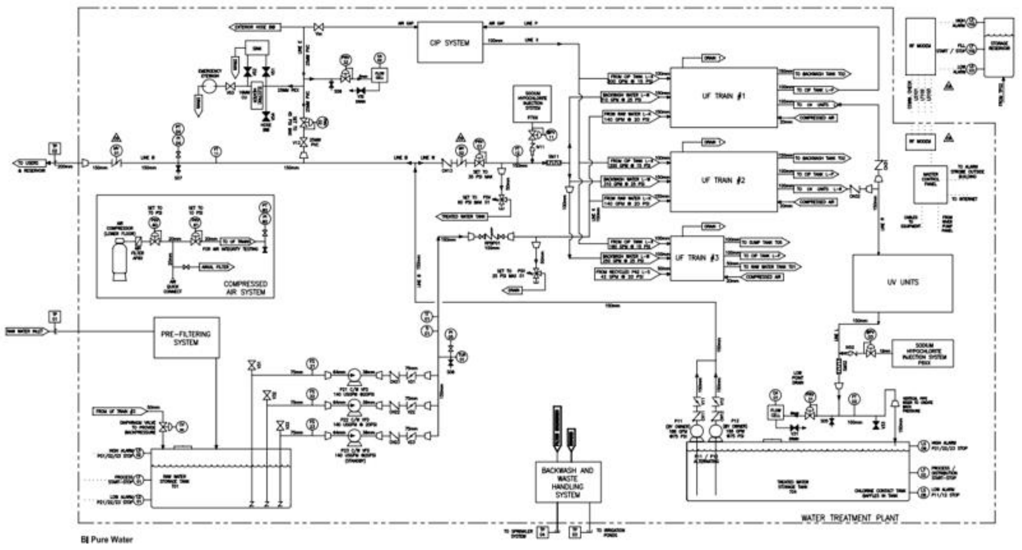
In 2010: Strata council pursued new plant

•Target: City of Kamloops water quality standards

•New plant eliminated “High Lift Station” chlorination process

•Incorporation of existing “Low Lift Station” (2 Flygt submersible pumps, ~1 km line)

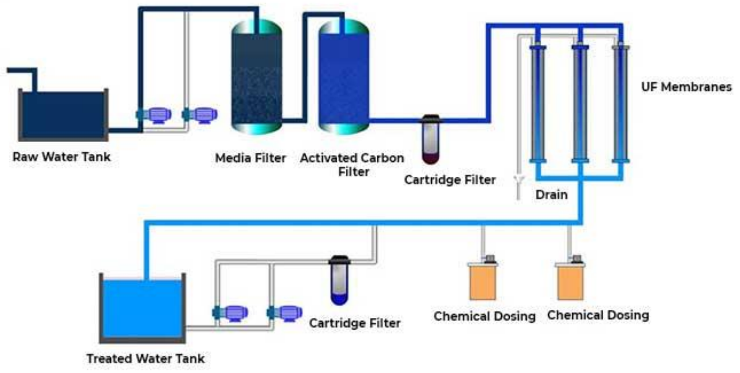
Goal: End boil water advisories, improve drinking water quality.

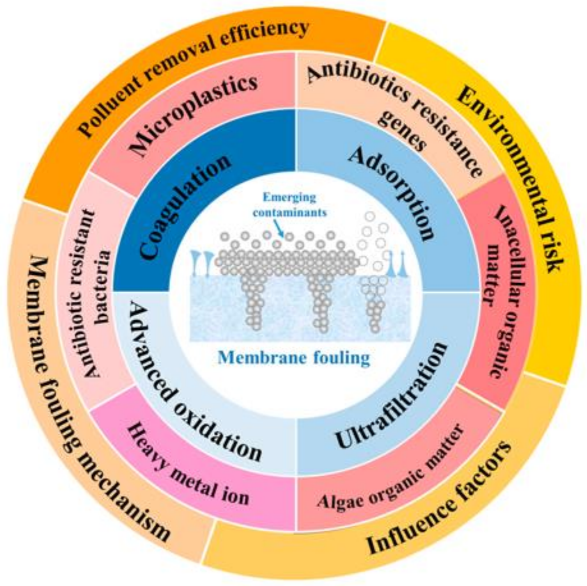


Intake and Raw Water

Raw Water Source – South Thompson River

- High-quality, stable water: low turbidity, moderate soluble organics
- Intake: concrete sump with fish screens → prevents impingement, meets regulations
- HDPE lateral from Low Lift Station → hydrostatically charges sump
- 2023: Silt buildup in surrounding rock reduced inflow
  - Excavated and replaced with larger blast rock
  - Some debris still enters → requires manual removal and pump flushing





Pre-Treatment Strategies

Pretreatment Strategies

- Protects membranes → extends life, maintains performance
- Removes suspended solids, colloids, larger particulates → reduces fouling & abrasion
- Stabilizes feedwater → consistent flux, minimized pressure drop, reliable pathogen removal
- Improves efficiency, lowers costs, supports regulatory compliance
- General industry approaches: coagulation & flocculation (conventional treatment), biofiltration (slow sand or RSF), chemical oxidation (including advanced oxidation to break down recalcitrant organics), cartridge filtration

Rivershore's Pretreatment Methods

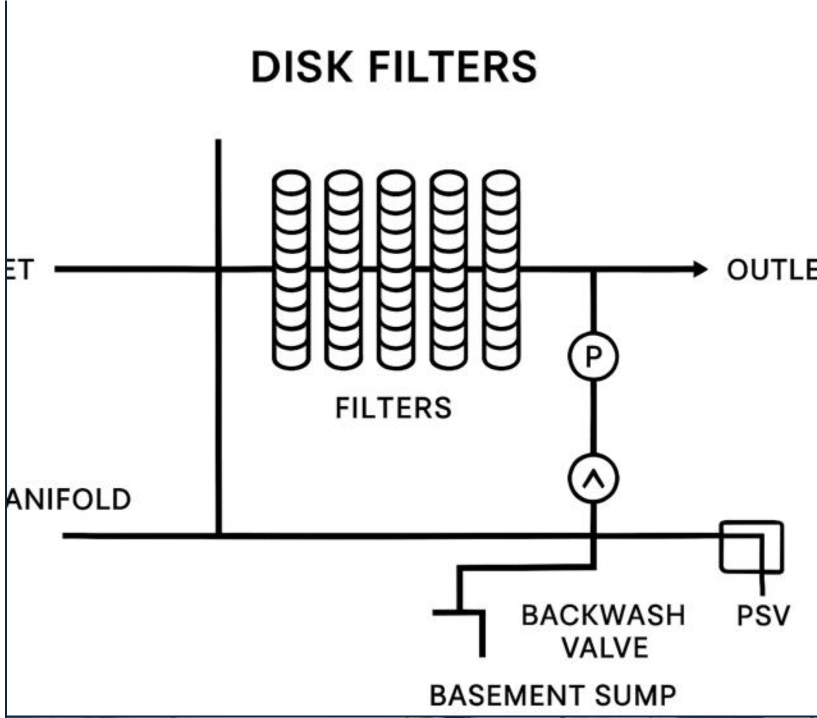
- Centrifugal sand separator
- Aluminum chlorohydrate coagulation + static mixer
- Arkal-Amiad Spin Klin 2" Disk Filters
- Manual vacuuming of settleable silts as routine maintenance

Disc Filter Operation

Water flows: inlet manifold → backwash valve → filter media

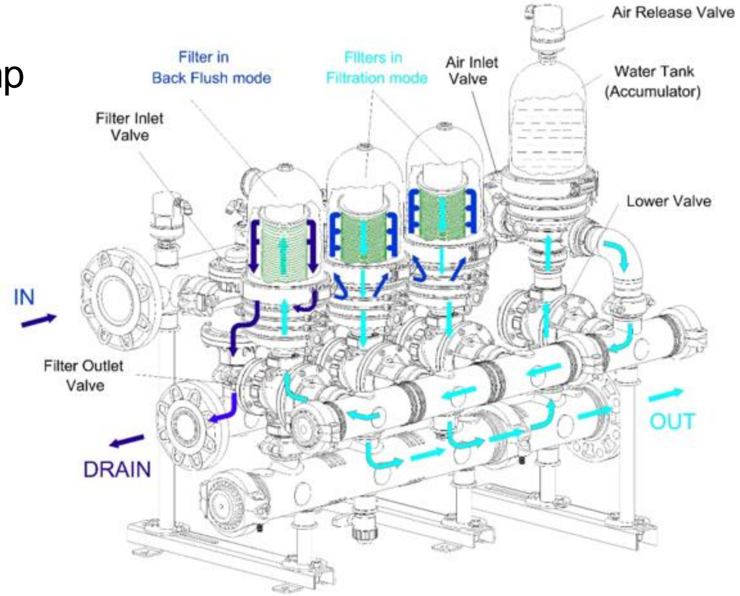
Filtration gallery: 9 filters

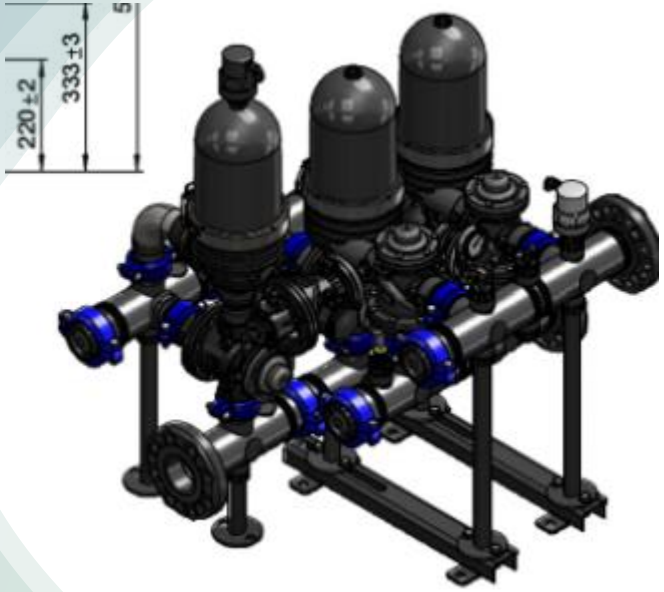
- ❖ Forward pressure: 10 HP raw water booster pump (55 psi)
- ❖ Back pressure: ClaVal pressure sustaining valve on outlet to raw water storage
- ❖ Backwash valve: filtration ↔ backflush (solenoid-controlled)
- ❖ Backwash triggered when raw **water flow < setpoint**
- ❖ Backwash uses high-pressure raw water → waste → basement sump → irrigation pond
- ❖ Filtration: disks compressed by spring + differential pressure
- ❖ Water forced through grooves → filtrate from edge → core
- ❖ **Direct filtration** process: no dedicated sedimentation stage or tank, though some does take place in T01 (raw water storage)
- ❖ Moderate silt buildup settled by sedimentation is removed manually vacuum pump and brush attachment.



Disc Filter Challenges

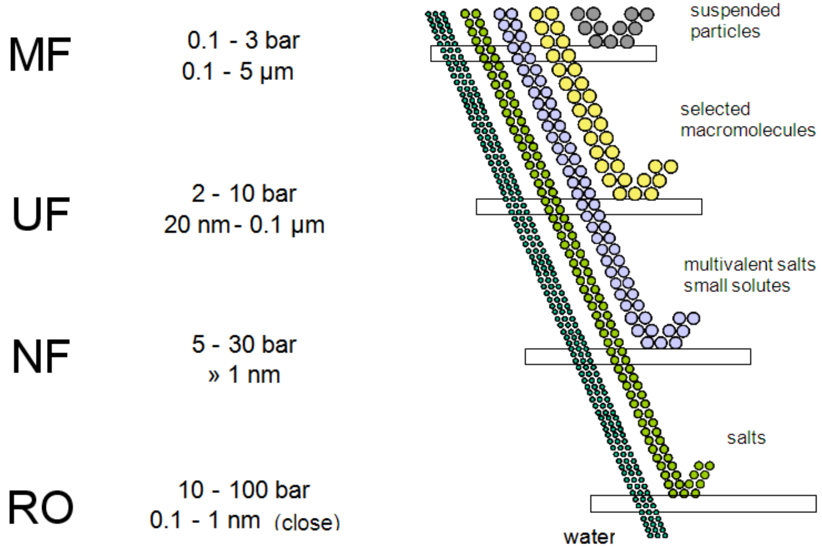
- PVC components can weaken → **broken spines** & butterfly nuts
- Media prone to **permanent fouling** → monthly cleaning required
- Freshet or **high organics** increase cleaning frequency
- **Cleaning**: submersion + agitation in mild chemical solution
- Media **replacement** every 3–4 years
- Mechanical issues: **seal/O-ring failure**, clamp problems → **leaks or air ingress**
- Insufficient **backwash flow/pressure** (failing PSV)
- Media “blinding” if **coagulant overdosed**





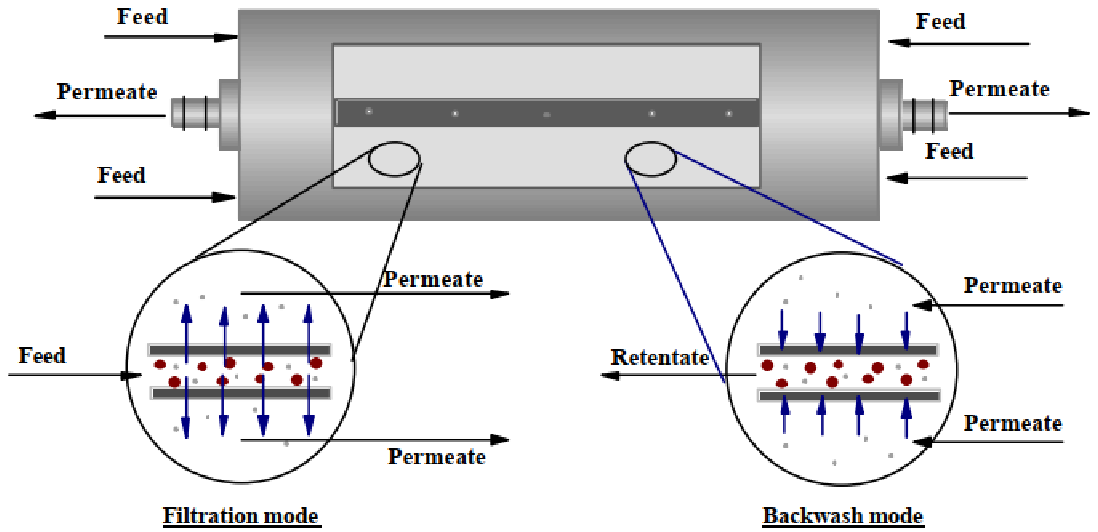
Ultrafiltration Membrane Treatment

Mechanisms of Treatment



Mechanism	Target for Removal	Notes
Physical barrier / sieving	Bacteria, protozoa, suspended solids	Pore-size controlled; main pathogen barrier
Molecular exclusion	High-molecular-weight organics	Reduces fouling and improves water clarity
Adsorption / surface interactions	Some viruses, colloids	Enhances removal beyond pure sieving
Backwash / air scour	Accumulated particles	Operational step to restore membrane flux
Disinfection support	N/A	UF does not provide residual disinfectant; typically combined with post-disinfection

Membrane Operation – Flow Concept and Filtration



Technology known as "X-Flow": operates in *dead-end mode* (vs. crossflow) → lower energy demand. Allows feed water to enter from all sides.

- Hydrophilic capillary membranes in 8" PVC cartridge (XF55)
- Feed water enters capillaries → solids rejected → permeate collected in central tube
- Operated at *constant permeate flow* → TMP gradually increases
- Backflush with permeate required to reset TMP
- Typical TMP: <0.5 bar (max 1 bar to prevent irreversible fouling)
- Flux rate: 70–100 L/m^{2}h, cycle 10–60 min
- Disinfectant dosing (e.g., peroxide, hypochlorite) recommended to control biofouling

Membrane Operation – XF 55 Characteristics

2 production skids (UFT01 & UFT02) → ~10 elements each

Each element: 55 m^2 hydrophilic, asymmetric, microporous hollow-fiber (inside–out)

Guaranteed permeate quality:

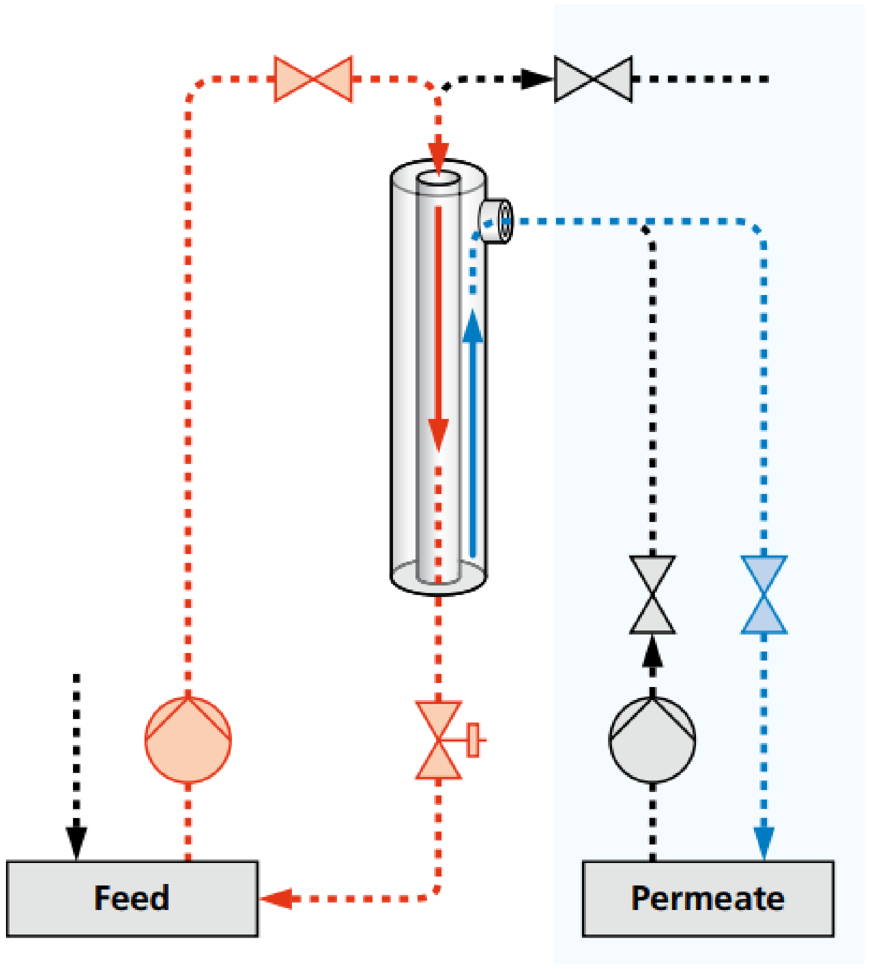
- SDI < 3
- Turbidity < 0.1 NTU
- Anti-fouling behavior

Flux rates:

- Filtration: 70–100 L/m^2·h
- Backwash: 250–300 L/m^2·h

Benefits:

- Vertical inside–out design + bleed flow → higher flux, reduced footprint
- Handles broader feed water quality
- Longer filtration times, fewer cleans, higher recovery
- Lower investment & OPEX



Membrane Operation – General Info & Pumps

Feed: 3 end-suction centrifugal pumps (Lead–Lag–Standby)

•2 pumps in operation → adequate flow & pressure for membranes

•Backwash pressure from distribution system head

•PRV reduces 80 psi → ~30 psi

Transmembrane Pressure (TMP):

•Max: 3 bar (~45 psi) during backwash

•Normal filtration conmditions: 4–6 psi

- •Able to trigger backwash/alarm states based on TMP.

Membrane Operation – Backwash Process

Removes fouling after **60 min filtration** (timer-controlled by PLC)

Options to trigger: Timer Delay (most operationally common), TMP (Δpsi), or total volume of permeate produced.

Sequence:

- Pre-Flush (20 sec)
- Backwash Bank 1 (40 sec)
- Backwash Bank 2 (40 sec)
- Post-Flush (15 sec)
- Rinse Bank 1 (20 sec)
- Rinse Bank 2 (20 sec)

Forward flush uses MV101 + MV105 → MV102 + MV108 supply backwash water

PLC resets timer, resumes filtration after cycle

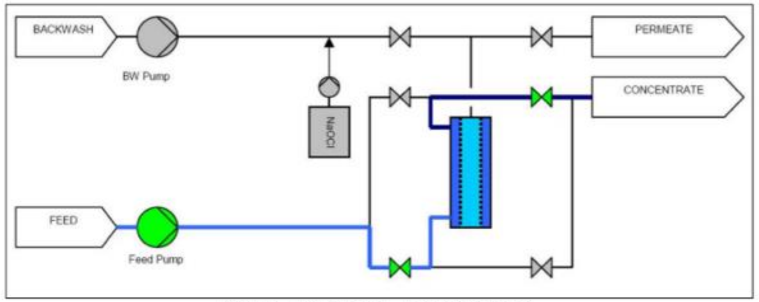


Fig. 7 AB Step 1 – Forward Flush

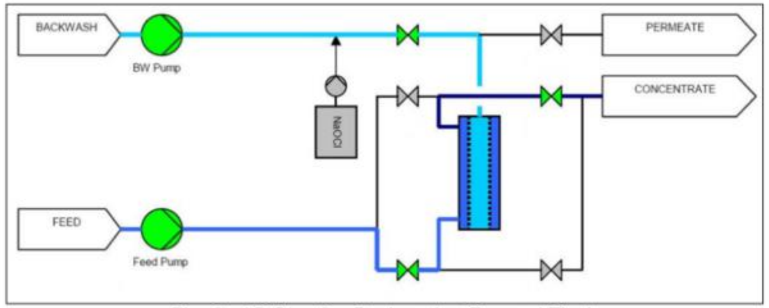


Fig. 8 AB Step 2 – Backwash + Forward Flush

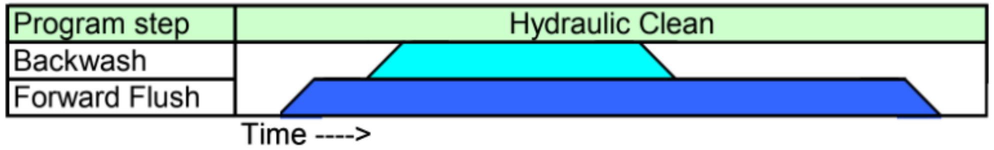


Fig. 9 Forward Flush and Backwash Time Sequence

Membrane Operation – Backwash Water Recycling

Backwash Isolation: Butterfly valves divert flow to **Backwash Tank T02**
Concentrated Stream: Pumped from **Tank T3** via bored wall ports

Train #3 Modes:
•**Recycle Mode:** Backwash returned to raw water tank → **95–97% recovery**
•**Waste Mode:** Backwash sent to **sump** → **irrigation ponds** after dechlorination

Sump Handling: T05/T06 collect disk filter & Train #3 waste; float-controlled pumps transfer out
Dechlorination: Sodium thiosulfate automatically dosed before discharge

Membrane Operation – Backwashing (A Note About Air Scouring)

Air scour common in other UF applications (e.g., GE ZeeWeed)

Rivershore's Pentair XF55 → no air scour required

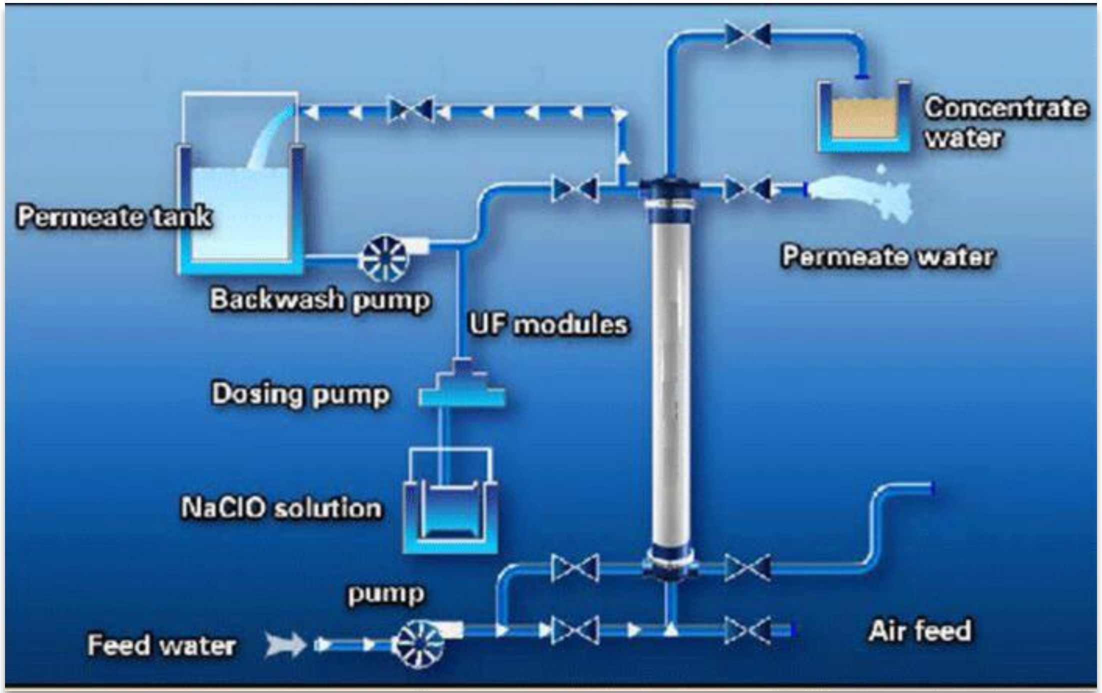
•Inside-out, vesselized design

•Fouling removed via pressurized hydraulic backpulse

ZeeWeed → outside-in, submerged design

•Solids collect on outer fiber surfaces

•Requires air scour to scrub debris



Membrane Operation – SCADA Control & Setpoints

Motorized Actuation

- 6" butterfly valves with motorized actuators
- Valves open/close based on process stage (production vs. backwash)
- Backwash triggered by: time, TMP, or permeate volume

SCADA Control & Setpoints

- Feed via end suction centrifugal pumps (HMI-adjustable)
- Max feed: 500 L/min per train → ~750 L/min permeate combined
- Alarms: inlet/permeate flow, pressure, turbidity, TMP

Differences in UF Cleaning Protocols

Key Differences

ZW1500:

- Requires **routine maintenance & recovery cleans** (weekly to monthly) in addition to scheduled Clean-in-Place
- Controls **biofouling & colloidal fouling**

XF55:

- Fouling controlled via **backwashing + Chemically Enhanced Backwashes (CEBs)**
- **Periodic CIPs** only; no dedicated “maintenance clean” like ZW1500

Chemically Enhanced Backwash (CEB)

Chemical enhanced backwashing, also known as maintenance cleaning, is effective in preserving membrane performance, in addition to the practise of adding chemicals to backwash water. Maintenance cleaning involves submerging the membrane filament in a chemical solution, for several minutes each day.

Rivershore's Original CEB Design:

Chemically Enhanced Backwash (CEB) History

- Originally used **chlorine injection (up to 20 ppm)** for fouling control
- Intended to **prevent slime in T01 tank**

Operational challenge:

- Chlorine carried back into T01 disrupted **post-chlorination dosing**
- High residual in permeate caused **disinfection issues**

Outcome

- System considered **ineffective** → decommissioned
- **Static mixer removed** (2022) to simplify process and limit losses to backwash flow

UF Membrane Clean-in-Place

Purpose

- Removes **temporary fouling** from membranes
- **Base clean:** 500 mg/L sodium hypochlorite → targets **organic fouling**
- **Acid clean:** 3000 mg/L citric acid → targets **inorganic fouling**

Key Points

- Membrane fouling at Rivershore WTP is **primarily organic** → base clean more effective for recovery
- **Membrane Train #3** requires **more frequent CIPs** due to high-concentration waste stream
- Operator triggers CIP based on:
  - **Transmembrane Pressure (TMP) rise**
  - **Increased backwash frequency**

Removal of Particulates in Recirculation

- Two **50-micron cartridge filters** remove debris from the CIP discharge
- Located on the **discharge side of the CIP pumps**
- **Cartridge filters** are removed after every CIP and cleaned manually

Chemical Clean-in-Place at Rivershore WTP

CIP Tank & Preparation

- **T401**: holds the bulk chemical solution during CIP
- **Dosing**: volumetric calculation ensures target **NaOCl & citric acid concentrations**
- **Membrane skid prep**: depressurize & drain before cleaning
- **Valve operation**: all valves manually set for recirculation

Cleaning Conditions

- **Solution temperature**: must reach target to maximize cleaning and avoid **membrane fiber damage**
- **pH adjustment:**
  - Base clean: **caustic soda** to pH 10.5–11
  - Acid clean: citric acid typically brings pH to ~3.2

Chemical Clean-in-Place at Rivershore WTP

4.4 **For Sodium Hypochlorite Solutions**

$$\textit{Hypochlorite Clean}\ \frac{y}{1000L} \times \frac{500ppm}{0.12Hypo} = x$$

4.5 **For Citric Acid Solutions**

$$\textit{Citric Acid Clean}\ \frac{y}{1000L} \times \frac{3000ppm}{0.50 Citric\ Acid} = x$$

4.6 **To find y, convert tank volume from US gallons to Cubic Metres**. For an approximate result, divide the volume value by 264.2. Approximate the number of US gallons by measuring from the graduated marks found on T401.

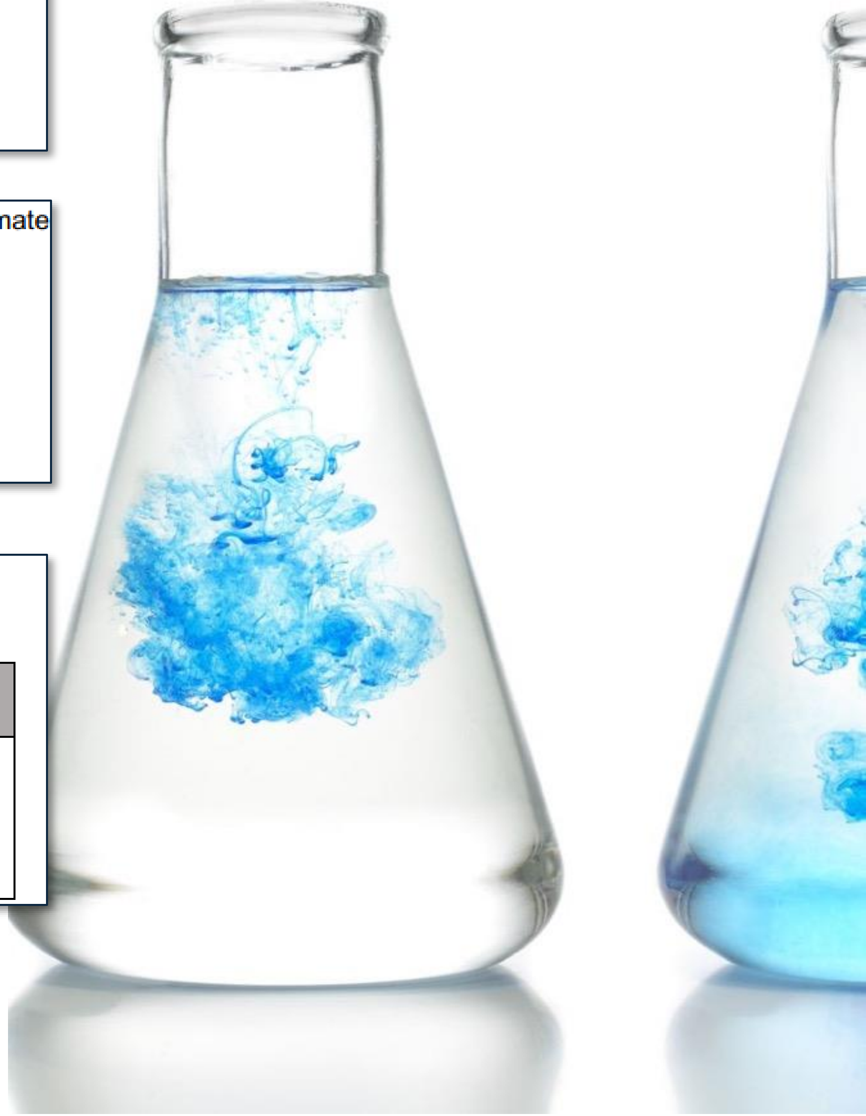
4.6.1 Example.

$$\frac{340\ US\ gallons}{264.2} = 1.287m^3$$

5 Procedures

The general structure of a CIP procedure is as follows:

Base Clean (NaOCl, 12% @ 500 ppm)	Acid Clean ($C_6H_8O_7$ 50% @ 3000 ppm)
1. Drain the Rack. 2. Clean. (15 minutes) 3. Soak. (15 minutes). 4. Drain the Rack. 5. Rinse, then Drain.	1. Drain the Rack. 2. Clean. (15 minutes) 3. Soak. (15 minutes). 4. Drain the Rack. 5. Rinse, then Drain.



Key Metrics

TMP increase over time, as well as lost inlet flow potential, are common triggers for a CIP at Rivershore WTP.

Metric	Target / Success Indicator
TMP (Δpsi)	Returns to baseline or decreases ≥10–15%
Recovery / Flux	Increases toward pre-fouling level
Backwash frequency	Longer intervals required for clean operation
Pressure drop	Reduced across membrane train or elements
Turbidity	Permeate NTU ≤ design specification
SDI	Lower than pre-CIP SDI (≤5 typical for UF)
Chemical consumption	Within expected dosing for targeted fouling removal

CIP Challenges & Mitigation Strategies

Challenges:

- Degradation (temporary vs permanent fouling)
- Chemical costs
- Issues with chemical disposal
- Backflow potential

Mitigation Strategies:

- Use key metrics to determine actual required cleaning frequency
- Be exact with chemical transfer and correct in calculations to determine required dose
- Ensure all chlorinated residuals from the clean are dechlorinated and chemically neutralized
- Immediate integrity testing post-CIP

Mitigating Environmental Risks of CIP Waste Discharge

Rivershore discharges CIP waste stream to the nearby environment. Namely, an irrigation pond containing wildlife and serving as storage for irrigation water for commercial use. Careful consideration for the receiving environment is necessary regardless of where the stream is being discharge.

Safe CIP Waste Discharge – Key Points

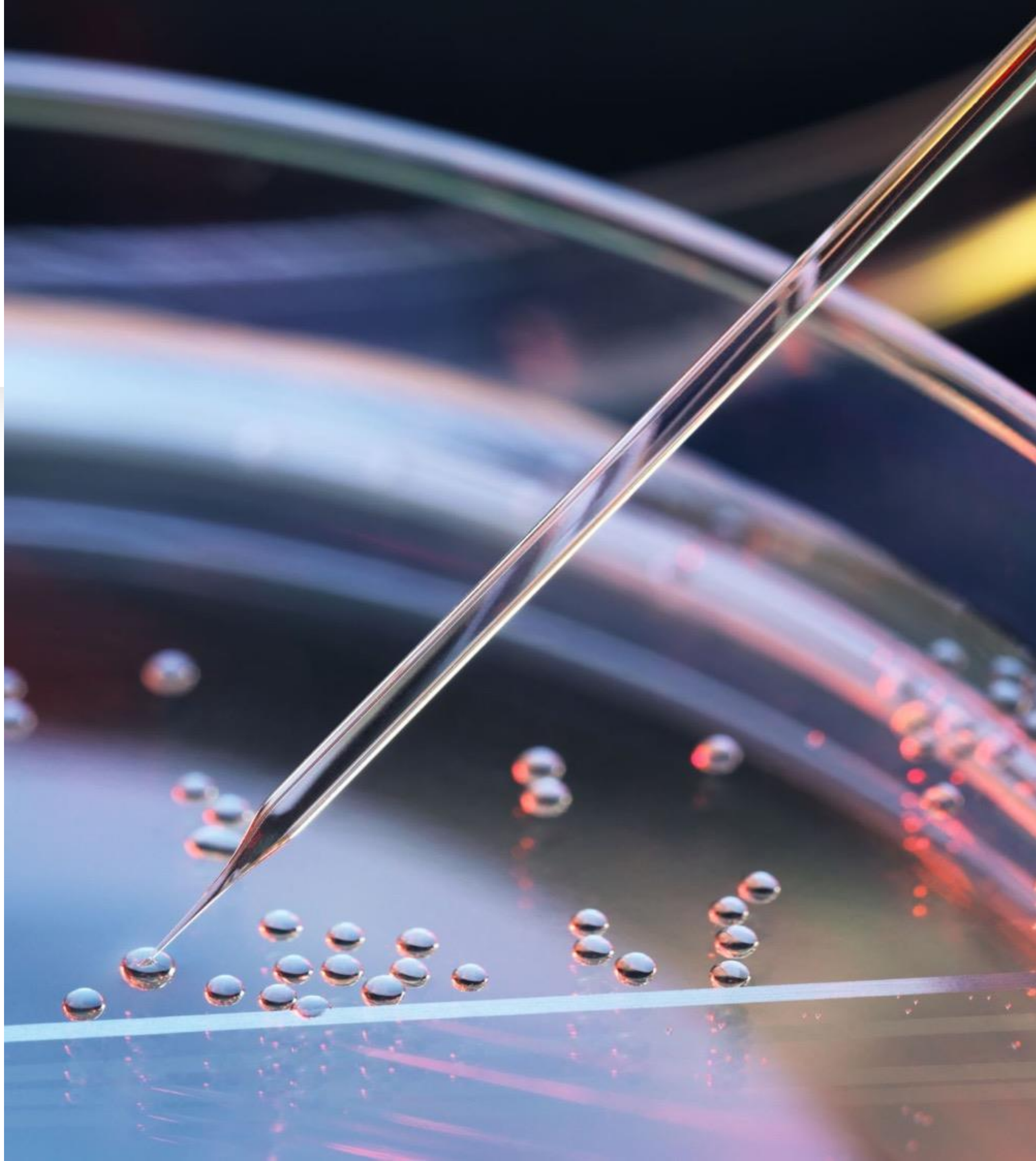
- **Neutralize waste** to pH 6.5–8.5 before discharge.
- **Acid clean:** neutralize with lime, soda ash, CO_2, or NaOH.
- **Alkaline/oxidant clean:** dechlorinate first, then adjust pH to ~7–8.
- **Dechlorination:** use sodium bisulfite, thiosulfate, or equivalent; confirm non-detect chlorine with field test.
- **Batch monitoring:** check pH, free/total chlorine; optionally conductivity, BOD/COD, TSS per permit or best practice.
- **Regulatory check:** confirm with Ministry of Environment or local authority whether your discharge environment requires permitting or additional monitoring.

Discharging to an Irrigation Pond for Non-Potable Reuse

Parameter	Recommended Target for Discharge
pH	6.5 – 8.5 (**target ~7.0**)
Free/Total Chlorine	Preferably ND; **≤ 0.02 mg/L** if under WSER threshold
Other Reuse Parameters	**BOD** < 100 mg/L, **COD** < 150 mg/L, **TSS** < 100 mg/L, **EC** < 2.5 dS/m, **SAR** < 9
Regulatory Permitting	Confirm if irrigation pond is considered a wastewater discharge point under the **relevant environmental jurisdictions.** A formal approval or permit may be required (e.g., Code of Practice, site-specific authorization)

Membrane Integrity - Concept

- **Definition:** Integrity = membrane is complete and functioning as designed
- **Purpose of testing:** Detect incremental membrane damage over time
- **Maintenance approach:** Enables **scheduled/preventative maintenance** rather than emergency repairs
- **Goal:** Maintain consistent water quality and reliable system performance



Membrane Integrity – Regulatory Considerations

- **Legal Framework**
  - *Drinking Water Protection Act*
  - *Drinking Water Protection Regulation*
  - **Standards reference:** industry accepted NSF/ANSI and AWWA Standards
- **Guidance**
  - BC Ministry of Health: Guidelines for Small Water Systems & Membrane Treatment
  - BC Drinking Water Officer's Guide

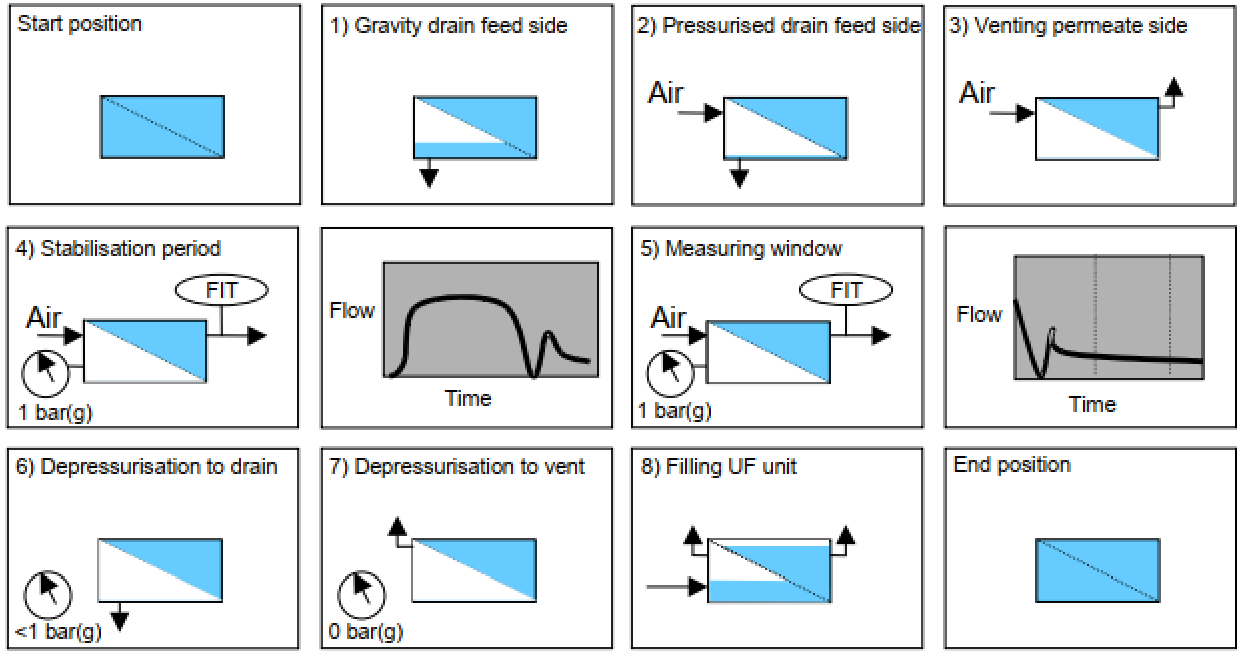
Testing Frequency: Specified in operating permit or design

Membrane Integrity – Common Methods

Method	Purpose / What It Detects	Pros	Cons / Limitations	Typical Application
**Bubble Point Test ** **	Detects pinholes or large defects in dry or wetted membranes	- Very sensitive to large defects- Quick for offline testing	- Usually requires membrane removal or skid offline- Not suitable for detecting partial fouling	New membrane acceptance testing; periodic verification offline
**Pressure Hold / Pressure Decay ** **	Detects leaks or small defects by measuring pressure change over time	- Can detect very small defects- Can be automated for inline testing	- Requires system depressurization- Sensitive to temperature/air leaks	Routine integrity checks on UF trains; inline or offline
**Forward Flow / Air Diffusion (Bubble Point Variation) ** **	Detects leaks using air flow through wetted fibers	- Simple and inexpensive- Can be used on single modules	- Only detects larger defects- Less precise than pressure decay	Quick verification on individual modules
Tracer Tests (Dye or Particle Challenge)	Detects compromised fibers or membranes by monitoring breakthrough	- High confidence in detecting defects- Can detect partial fiber damage	- Time-consuming- Some tracers not approved for potable water	Commissioning new systems; troubleshooting
Salt Rejection / Conductivity Monitoring	Measures solute passage to infer integrity	- Non-invasive; can be online- Continuous monitoring possible	- Limited sensitivity for UF (better for RO)- Cannot detect small physical defects	Less common for UF; used when UF treats high-quality feedwater
Turbidity / Particle Counting of Permeate	Detects compromised membranes by increased particle passage	- Inline, real-time monitoring- Simple to integrate with SCADA	- Only detects defects large enough to allow particle passage- Can't distinguish between membrane breach vs upstream contamination	Online monitoring for early warning of integrity issues

Rivershore WTP Membrane Integrity Testing

- **Called Air Integrity Test (AIT)** by Norit, name carried on by Pentair.
- In truth, it is a form of air diffusion test, called a gas-liquid diffusion test
- **Tests** diffusion of gas through a wetted membrane at a given pressure.
- Flow is measured by an extremely sensitive flow meter during the testing period.
- Any flow detected after a set duration will cause the plant to shut down until an integrity test is passed.
- Air supply provided by compact pressure maintaining 1bar (~15psi to meet test standard)



Membrane Integrity – Permeate Water Quality Monitoring

Direct integrity tests: Bubble point, pressure hold, air diffusion; challenge tests typically at manufacture.

Purpose: Ensure each UF unit functions, determine run end, detect rapid turbidity spikes.

Method: Online turbidimeter measuring individual filter effluent; data recorded ≤5-min intervals.

Indirect integrity check: Monitor turbidity, DOC, particle counts, conductivity; alarms for out-of-range values.

Importance: Regulatory preference for continuous data; supports integrity assurance.

Rivershore practice: Permeate laser turbidity analyzers + daily automated Air Integrity Test.

UF Operational Challenges - Rivershore

- **Membrane lifecycle:** 10-yr replacements; budget, logistics, IHA permit.
- **Efficiency:** ~70% recovery without recycle.
- **Integrity limits:** No direct virus proof → requires UV/chemical disinfection.
- **Organics:** Soluble breakthrough → monitor UVT (raw/treated).
- **Instrumentation:** Chlorine analyzer issues with intermittent runtime/backwash.
- **Design flaws:**
  - No PRV → membrane/end cap failures.
  - Chlorinated backwash recycle → raw tank spikes.
- **Maintenance:** Regular actuator limit switch adjustments.

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UF Operational Challenges – XF55

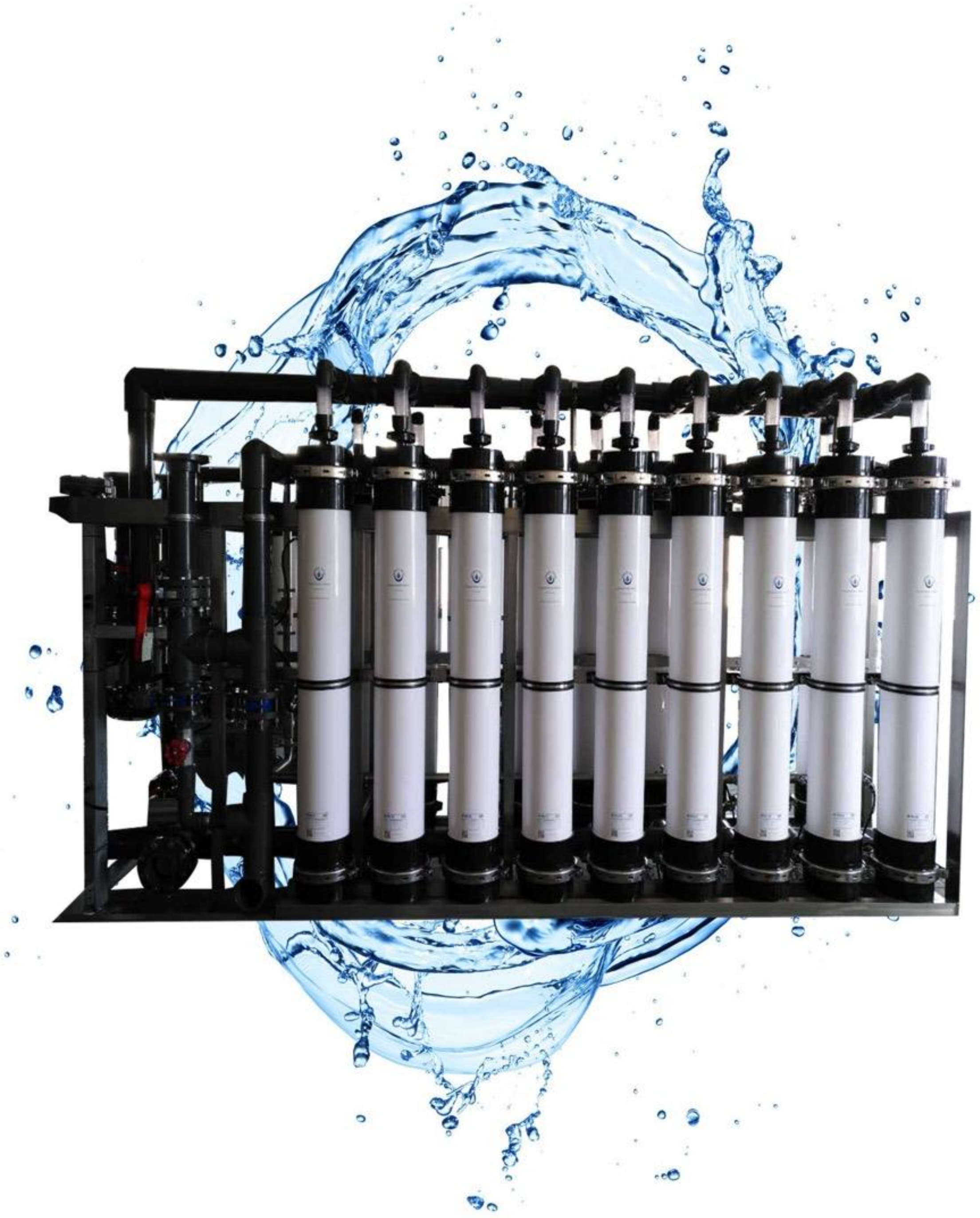
- **Energy footprint:** Continuous feed pressure (~1–2 bar TMP) → higher pumping costs vs. gravity/immersed designs.
- **No visual inspection:** Fibers enclosed → damage/fouling detected via pressure, turbidity, or integrity tests.
- **Feedwater sensitivity:** High silt/algae → more frequent backwashes and chemical cleans; pretreatment essential.
- **Chemical compatibility:** Aggressive or repeated oxidant/acid exposure can shorten membrane life.

UF Operational Challenges – Small Water Systems

•**Fouling & scaling:** NOM, iron/manganese, hardness → more frequent CEBs/CIPs

•**Integrity testing burden:** Pressure decay / diffusive air flow tests → downtime and recordkeeping.

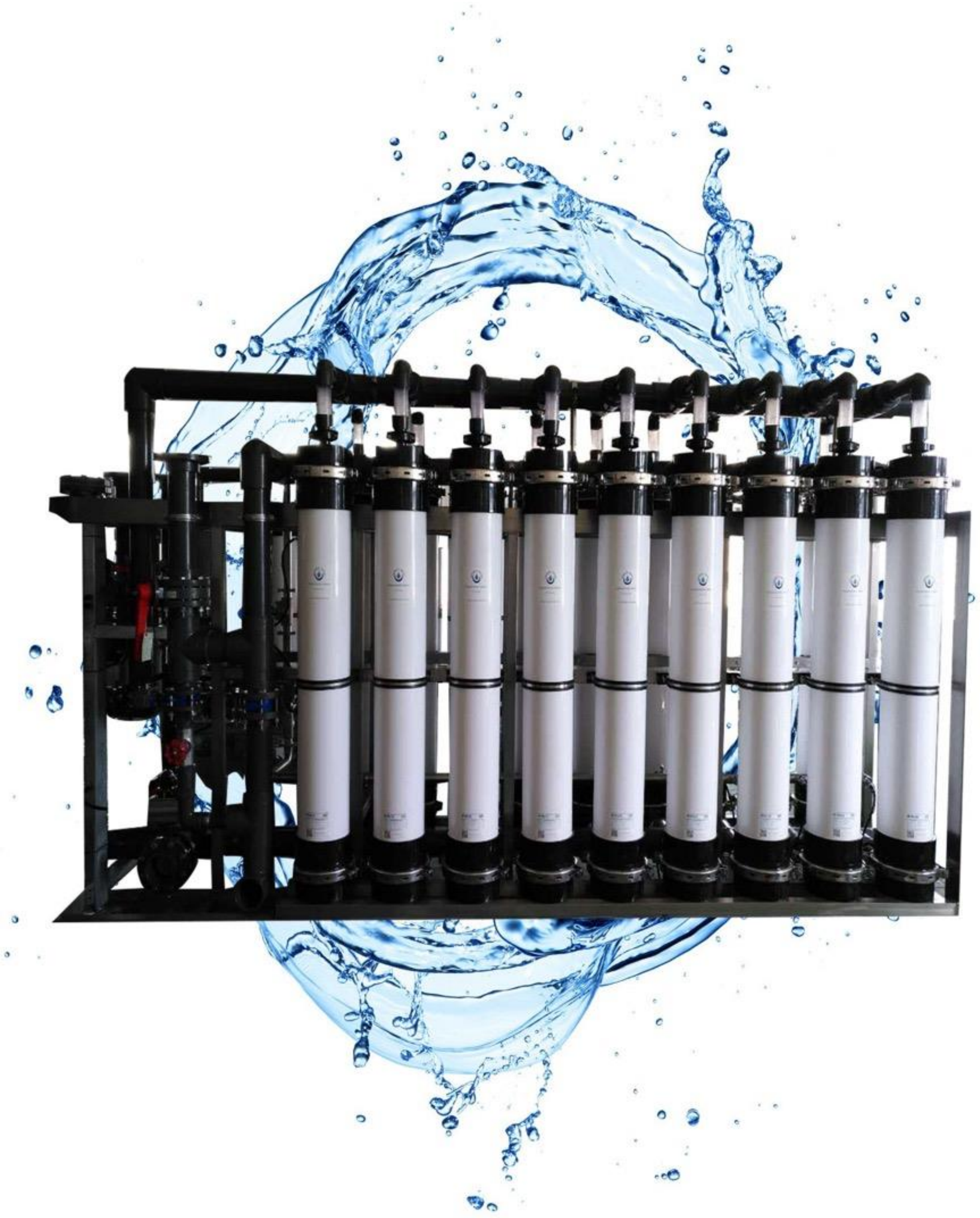
•**Limited dissolved species removal:** UF removes turbidity, bacteria, protozoa, some viruses (LRV 4–6); dissolved salts, pesticides, low-MW organics require additional treatment (disinfection, GAC, RO).



UF Operational Challenges – Small Water Systems

•**Capital & replacement costs:** Higher upfront cost; modules typically last 5–7 years depending on fouling/cleaning.

•**Operator skill demand:** More complex than sand or cartridge filters; requires SCADA monitoring, chemical handling, and troubleshooting expertise.



Utility Administrative Challenges

Plant was never truly "hands-off" despite manufacturer assurances

Early operation handled part-time by golf superintendent → frequent failures & missed alarms

Rivershore hired utility contractor in 2016 to provide dedicated management.

Utility company faced resistance from Strata Council on project spending

Independent strata ownership improved cooperation on budgeting

Now able to plan capital projects & build contingency funds, avoiding special levies

Before 2022: Utility contractor managed operations

Transition: New Rivershore Utilities department formed

Growing pains: Staffing, spares inventory, sampling, maintenance, planning, compliance

Now: Stronger in-house expertise, more control, and better long-term resilience.

Utility Operations Challenges

- **Valve supply constraints:** Original 6” Hayward butterfly valves discontinued; adapter kit ineffective → custom adapters required.
- **PLC/logging limitations:** Original system inadequate for regulatory reporting; upgraded online logging improved compliance confidence.
- **AIT limitations:** No LRV value; implemented timer-based trending to monitor performance over time.
- **Intake sump sediment control:** Manual pumping failed; replaced riverbed media with coarser rock to reduce clogging.

Utility Operations Challenges

UV reactors: Sterilite UVs chosen for compact footprint and low maintenance; frequent alarms → removed in 2021.

Rivershore now relies on **sodium hypochlorite** as primary and secondary disinfectant (free chlorine residual).

Aged membranes:
•Train 1 & 2 replaced 2021/2022 (Interior Health permit, significant capital cost).
•Train 3 replaced 2024 using previously removed elements from 2021.

References

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Questions?

- It was an honour to present! Thank you to the BC Small Water Systems Online Help Centre and Thank you all so much for attending!
- If there are any questions, please post them in the live chat and we will address them.