MEMBRANE TREATMENT OF HIGH TURBIDITY WATER – PILOT STUDIES ON NEW ZEALAND RIVER WATER

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ABSTRACT

The use of low-pressure (LP) membrane systems (microfiltration/ultrafiltration - MF/UF) to produce potable water has become increasingly common, over the last 15 years. Due to the absolute pore size of the membranes used in LP membrane filtration, high-quality water is guaranteed regardless of raw water turbidity. This has enabled municipalities and industries to utilise more challenging water sources, such as very turbid river water, while providing higher quality water to their townships and processing sites. LP membrane filtration is also effective in removing microbial pathogens such as protozoa and bacteria. High quality water is verified automatically, both indirectly with an inline turbidity meter and directly through a daily pressure-decay integrity test. When the LP membrane system is coupled with pre-treatment process trains such as coagulation, membrane filtration is able to remove significant amounts of disinfection-by-product (DBP) precursors, and remove other contaminants such as iron, manganese, arsenic and colour. Excellent filtrate quality coupled with the ability to handle varying water conditions makes LP membrane filtration an excellent treatment option to ensure compliance with increasingly stringent drinking water regulations.

Pall Corporation has conducted several hundred LP membrane filtration pilot studies around the world. Both MF and UF systems have been piloted, on various water sources and integrated into treatment processes to target contaminants of concern. For example, naturally occurring organic mater can be removed from surface water with proper pre-treatment and MF. Microbial pathogens are effectively removed from all water sources solely with MF alone.

The aim of this pilot study was to prove that MF can be used successfully on high turbidity feed waters in New Zealand conditions, where conventional filtration practices have proven troublesome.

This paper presents results from pilot studies undertaken on highly variable, turbid river water in New Zealand, with naturally occurring high organic matter levels. The LP MF system continuously provided excellent filtrate water quality, while handling turbidity spikes of up to 450 NTU without the need to shut down. The MF system reliably removed the targeted contaminants of concern, as well as demonstrating low rates of fouling over months of continuous operation.

The project background, water quality, membrane performance data, and projected full-scale plant designs derived from the pilot study are presented.

KEYWORDS

Microfiltration, Drinking water, High turbidity, Pilot study

1 INTRODUCTION

There is an increasing trend towards more reliable and higher quality drinking and potable water treatment processes. In addition, as utilisation of our water resources becomes more intensive, municipalities and industry are looking to utilise more challenging water sources to meet demand. In many cases in New Zealand, the water supply for these systems comes from a surface water source, often a stream or river which may experience high turbidity peaks during rainfall events.

In the past, conventional clarification and media filtration treatment approaches have been used in many of these situations. However as these systems age and regulations tighten, these plants can have difficulty coping with peak turbidity loads. In some cases additional water treatment chemicals are required to maintain supply during a turbidity event; in other cases operation of the treatment plant is suspended until the event passes, an approach which can require considerable treated water storage volumes.

Increasingly, low pressure (LP) membrane technologies (microfiltration/ultrafiltration – MF/UF) are being used to treat variable water and wastewater streams. LP membrane systems are often less sensitive to variations in feedwater quality. They systems can handle peak flows and turbidity loads without a reduction in treated water quality. As the installed base grows, capital costs for LP membrane systems have reduced to the point where they are usually cost-competitive when compared to conventional technologies both from a capital and operating cost evaluation.

2 BACKGROUND

Fonterra Co-operative Dairy Group operates the world's largest dairy ingredients manufacturing site in Whareroa, Taranaki. On site are five powder plants, two cheese plants and plants producing cream product, casein and whey. Every hour, the Whareroa Site can produce more than 42 MT of powders, 12 MT of drysalt cheese, 10 MT of mozzarella. The Whareroa Site sources production water from the nearby Tawhiti Stream and Tangahoe River. The water is treated with conventional clarification/filtration systems.

On general day to day river water turbidity, the existing water treatment plant meets the site water quality and capacity requirements. However, during high turbidity events the site water treatment plant has encountered problems in handling the higher solids loading and the site's water treatment capacity and quality decreases. Often the high turbidity events experienced at the site last for a few days, however the treated water storage capacity at the site is only a few hours. In extreme cases the high turbidity events can cause severe disruption and downtime for the production site due to treated water not being available.

Fonterra is in the process of reviewing the Whareroa Site filtration requirements and filtration upgrade strategy. The sites current filtration technology has at times struggled to handle extreme turbidity events which have caused downtime and costs to the dairy site. Some historical raw water turbidity data from the Tawhiti Stream is included as Figure 1. During this period the site experienced some particularly challenging turbidity events with this water supply. Pall has installed a MF trial unit to demonstrate that a LP MF system is able to produce high quality water, regardless of the turbidity variations and spikes that it receives from the feedwater.

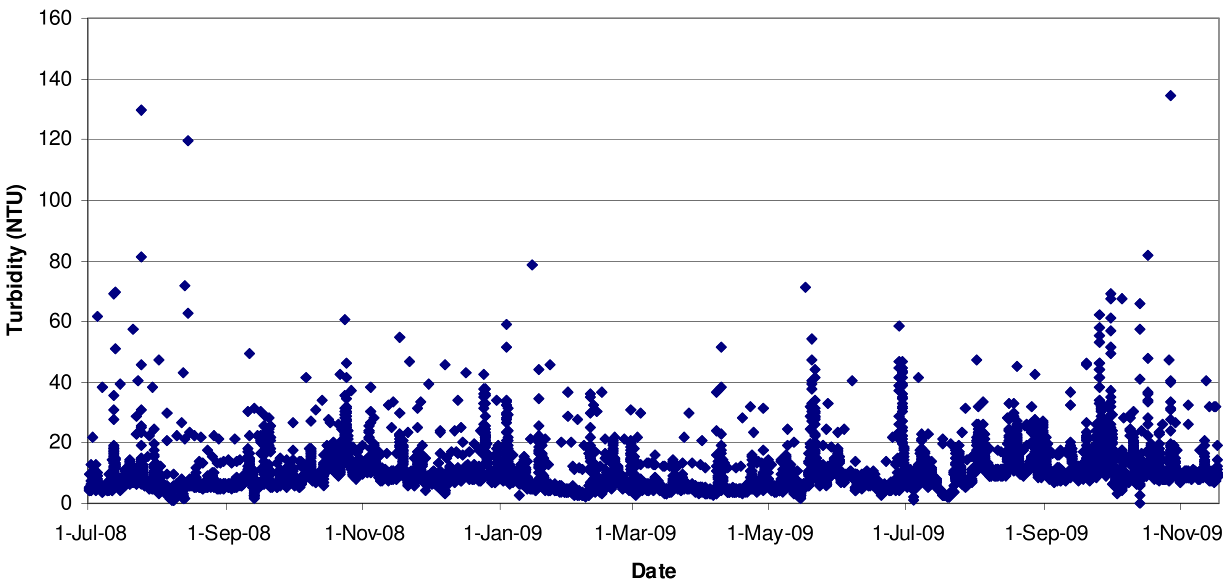

Figure 1: Tawhiti Stream 1h average turbidity, July 2008 – November 2009

The average turbidity for the Tawhiti Stream during the historical period shown was 9.3 NTU. The maximum 1h average turbidity measured was 134.4 NTU.

2.1 EXISTING SYSTEM

There are two water treatment systems used at the site, one for each of the river water supplies. There is a degree of integration; however each plant is essentially operated as a separate treatment system.

2.1.1 TAWHITI STREAM

Water from the Tawhiti Stream is pumped to the site via a bank of pre-strainers. The raw water is supplied directly to two "Sophora" triple-media filtration systems. The systems are installed in parallel and process up to 288 m^3/h each. The filtered water is combined and chlorinated prior to storage in the site treated water reservoir. The Tawhiti Stream is shown in Photograph 1.

2.1.2 TANGAHOE RIVER

Water from the Tangahoe River is pumped to the site via a bank of pre-strainers. The raw water is supplied directly to two "Permajet" up-flow clarifiers. The clarifiers are arranged in parallel and process up to 320 m^3/h each. The clarified water is directed to six parallel media filters which process up to 120 m^3/h each. The filtered water is combined and chlorinated prior to storage in the site treated water reservoir.

The Tangahoe River is shown in Photograph 2.

Photograph 1: Tawhiti Stream at Fonterra Whareroa Intake Site

Photograph 2: Tangahoe River at Fonterra Whareroa Intake Site

3 PILOT TRIAL

The purpose of the trial was to demonstrate that the Pall Aria[1] Microfiltration (MF) system can provide an uninterrupted supply of microfiltered water to the Whareroa Site. The trial used feed water individually from both the Tawhiti Stream and Tangahoe Rivers, during both normal and high-turbidity events.

The secondary objective of the pilot plant study was to confirm design characteristics and cleaning regime for the MF system to ensure maximum filtration efficiency with the specific feed water characteristics.

The site has proven ideal to demonstrate the membrane plant performance because of the two feed water sources having varying levels of turbidity and organics. In addition the site has two existing conventional treatment plants so allowed a direct comparison between the different technologies.

Before commencement of the pilot study a piloting protocol was developed outlining the goals of the trial, these included;

- MF flux rate
- MF backwashing regimes
- MF chemical cleaning requirements
- Requirement for any MF pre-treatment

The Pall MF Trial System was installed at the Fonterra Whareroa Dairy Site prior to Christmas 2009 and has continued operation for approximately seven months.

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[1] Pall Aria is a trademark of Pall Corporation.

4 MICROFILTRATION SYSTEM OPERATION AND REGENERATION

The Pall Aria Series MF system is composed of two parts; namely a valve part and a module part. The valve part or 'valve rack' contains all the necessary valves, pumps, instrumentation, controls, motor drives and remote I/O. The module part or 'module rack' is equipped with the Pall Microza[2] MF modules and the necessary piping.

The Pall Aria Microfiltration Pilot System used for the pilot study consisted of:

- Pall Single Module MF Pilot Skid
- Pall Microza UNA 620A hollow fibre MF membrane

A Pall Single Module MF Pilot skid is shown in Photograph 3 and 4.

Photograph 3: Pall Single Module MF Pilot Skid

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[2] Microza is a registered trademark of Asahi Kasei Corp., Ltd.

Photograph 4: Pall Single Module MF Pilot Skid

4.1 MICROFILTRATION MODULE

The Microza modules use proprietary poly-vinylidene-fluoride (PVDF) hollow fibre membrane technology with advanced bonding techniques for an exceptionally strong module design. The highly porous PVDF membrane is the heart of the system, and means a system can be designed at higher sustainable fluxes compared to other membranes, or it can be operated at lower fouling resistance and lower pumping heads, or with increased intervals between any regeneration sequences - all of which have substantial operational benefits including operational flexibility when confronted with turbidity events..

The uniquely designed filtration modules have a nominal pore size of 0.1 µm and therefore can remove the following contaminants from surface and ground water sources.

- Suspended Solids/Turbidity
- Viruses (partial removal)
- Bacteria
- Cysts and Oocysts
- Iron and Manganese
- Arsenic
- Organics

The main physical characteristics of the Pall MF module are presented in Table 1.

Table 1: MF module characteristics

Parameter	Pall Microza UNA-620A MF Module
Outside membrane area	50 m^2
Module length	2 m
Module diameter	0.15 m
Membrane rating	0.1µm
Membrane material	PVDF
Housing material	ABS
Flow direction	Outside – Inside
Maximum chlorine (mg/l)	5000
Maximum caustic	1 N
Maximum acid	1 N
PH range	1 – 10

4.2 MICROFILTRATION SYSTEM OPERATION

An on-board computer controls the operation of the pilot MF system. The system can also be monitored and controlled remotely through via an internet connection with remote access software. Critical operational parameters are logged continuously and are recorded automatically on the system computer's hard drive. The real time data is used for operation optimisation and troubleshooting. The pilot MF system schematic is shown in Figure 2.

There are four basic operational modes for the MF unit:

4.2.1 FILTRATION (NORMAL PRODUCTION)

Feed water enters the bottom of the module and is distributed uniformly to the outside of the fibres. Since it is under pressure, the water passes through the hollow fibre membranes and filtered water exits from the top of the module. Under normal conditions, all of the feed water flows through the membranes and exits as filtered water. Depending on feed quality, a small amount of the feed water may be circulated past the outside of the hollow fibres. This flow (Excess Recirculation, XR) prevents the accumulation of foulants and debris on the surface of the membrane and helps evenly distribute flow though the membrane fibres.

4.2.2 AIR SCRUBBING AND REVERSE FILTRATION (BACKWASH)

As water is filtered, rejected particulate accumulates in the module or on the membrane fibre's surface. The effect is a flow restriction in the module, resulting in an increase in trans-membrane pressure (TMP). TMP is the pressure difference from the feed side of the module to the filtrate side of the module. Air Scrubbing (AS) is a mechanical process to remove the debris from the module and decrease the rate of overall increase in TMP.

AS is usually initiated at a preset interval of time or water throughput, however as a secondary trigger, AS may be initiated if the TMP exceeds a specified maximum. The air injection valve opens and air is injected at low pressure into the feed side of the module. At the same time, filtrate that has been collected in the dedicated Reverse Filtration (RF) tank is pumped in the reverse direction through the module and out through the main system drain. The simultaneous AS and RF flow (SASRF) is then stopped after about 30 seconds. At this point, most if not all of the accumulated debris in the module has been swept to drain.

To complete the cycle, a Forward Flush (FL) is implemented, circulating feed water from the feed tank on the outside (feed side) of the membrane fibres at high velocity. This fast flow of liquid is directed through the excess recirculation port of the module to drain. This further dislodges and removes from the module debris that was captured by the membrane fibres. Alternately, filtrate may be used for this procedure in a reverse flush mode if required depending on feed water quality.

This fully automated cycle is included in every Pall Aria system and occurs every 15 - 120 minutes, and stops filtrate production for about 1.5 - 2 minutes.

4.2.3 ENHANCED FLUX MAINTENANCE (EFM)

To assure maximum efficiency and lowest total cost of ownership, Pall has developed techniques to keep the membranes free of fouling materials. Enhanced Flux Maintenance (EFM) is a fully automated process that uses warm water with mild chemical solutions tailored to specific foulants that may be present in the application. The time interval between EFM is user defined and depends on the running conditions of the membrane. For this application a daily EFM with 500 ppm of sodium hypochlorite (NaOCl) is performed. During the EFM mode, the feed tank is drained and filtrate that has been pumped to the water heater is used. The heated filtrated is transferred to the feed tank and the cleaning chemical is injected in-line. This solution fills the feed tank until the level required for EFM is achieved. The EFM solution is then recirculated for 30 minutes on the feed side of the module and back to the feed tank. After the recirculation, the solution is drained and the system is flushed using a standard SASRF and FL sequence.

EFM is used to reduce the times when a partially fouled membrane results in the system operating at less than peak efficiency. The benefits to using EFM are a smaller system footprint by allowing the membranes to operate at high flux rates, which reduces floor space and facility costs, and a lower average TMP, which reduces pumping energy. The durable, strong and chemical resistant PVDF hollow fibre makes this possible - it can be subjected to thousands of EFM cycles with no reduction in service life.

4.2.4 CHEMICAL CLEAN IN PLACE

SASRF and EFM are designed to remove particulate matter and routine foulants. In most applications, it will occasionally be necessary to perform a complete CIP process (typically monthly). The CIP process is a 2-step protocol using an acidic solution and a caustic solution with chlorine. This process will return the modules to "nearly new" condition and can be performed hundreds of times over the life of the modules.

Due to the low frequency of CIP operation, the process is designed as a semi-automated process. The chemical and rinse cycles are programmed for manual initiation. This process requires minimal operator intervention to “setup” the system for CIP.

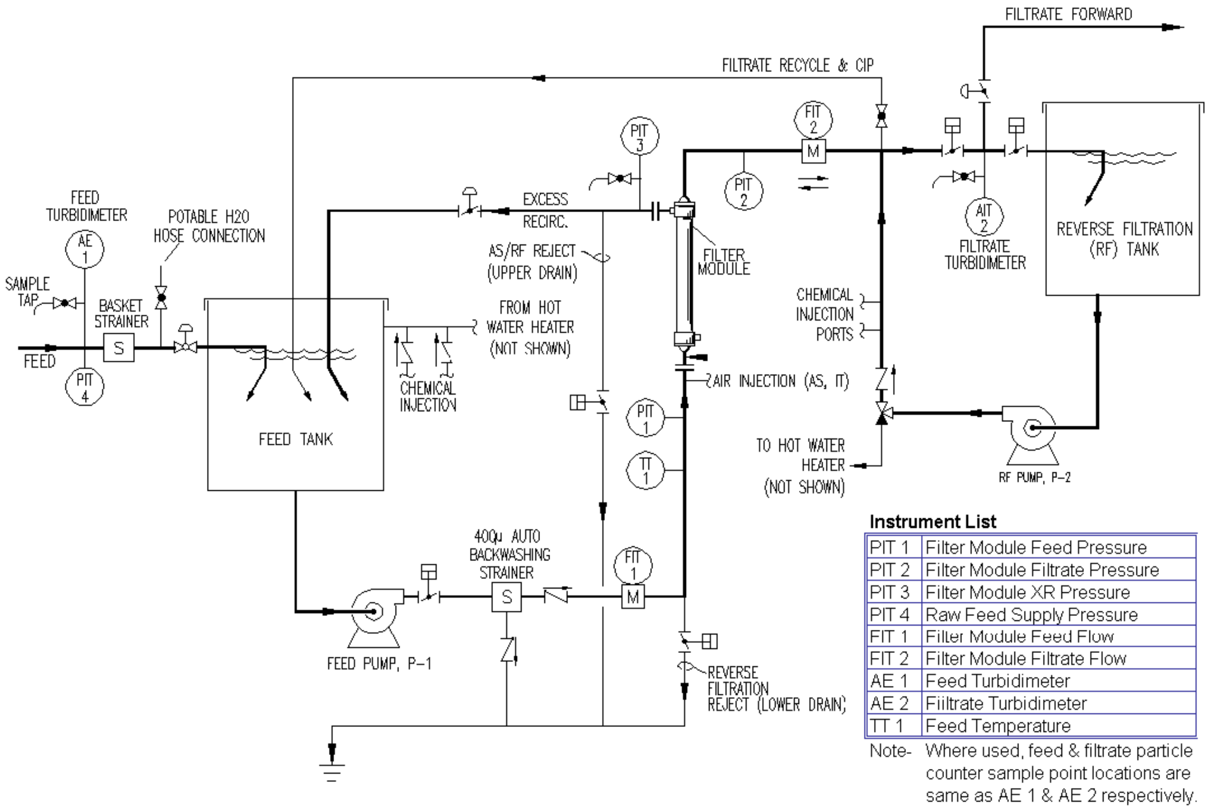

Figure 2: Pilot MF schematic

5 MEMBRANE PERFORMANCE

The pilot trial started in December 2009 at the existing water treatment facility on the Fonterra Whareroa site. The Pall MF pilot unit was installed in a temporary shelter along with the required cleaning and pre-treatment chemicals.

The feed water for the pilot trial was taken from each of the streams individually for separate time periods. The Tawhiti Stream was selected for the first run of the trial as this water supply had caused the most difficulties for the associated site water treatment plant.

5.1 TAWHITI STREAM – INITIAL RUN

For the first run of the trial all operating parameters were varied to find the optimum operating regime. A preliminary flux of 80 L/m^2/h (LMH) was selected for average turbidity feedwater; a reduction to 65 LMH was anticipated during the high turbidity feedwater events (based on Pall experience with its MF membrane).

It was determined very early in the trial that pre-treatment with Polyaluminium Chloride (PACl) was beneficial both during normal water conditions and high turbidity events. This assessment was based on review of operating TMP profiles and analytical results. The PACl was supplied in liquid form and had a PACl content of 33.7% w/w (or an Al_2O_3 equivalent of 10%). The PACl was directly injected into the pilot MF feed tank which offered a retention time of 60-90 s depending on the membrane operating flux. PACl was preferred by Fonterra as the pre-treatment chemical since the site had previously had residual Al problems with other flocculation chemicals in the existing water treatment plant.

During normal feed water conditions (2 to 15 NTU) the trial unit performed within usual operating parameters for the Pall MF system. SASRF of the membrane was performed approximately every 20 minutes and kept the membrane relatively free from contamination. The unit maintained operation in a conservative TMP range (80-100 kPa). A daily EFM with 500 ppm NaOCl was also used in maintaining membrane performance. The EFM succeeded in returning the TMP to a similar level each day.

The TMP performance while operating for a 14 day period on the Tawhiti Stream supply can be seen in Figure 3. The chart highlights changes in MF plant operation or feedwater quality; these are shown as sections 1 – 6 on the graph. The parameters of interest shown include;

1 **Baseline (average) turbidity period**. PACl dose of 2.5 ppm (in feedwater).

2 **High feed turbidity event**. Feedwater turbidity reached 40 NTU. TMP increased to 200 kPa over 24 h period. Flux was maintained at 80 LMH and 10% XR was initiated without loss of filtrate production. At the end of the period an EFM was performed with 500 ppm of NaOCl but TMP did not fully recover to baseline levels. A second EFM was performed with 1% citric acid to determine the effect on TMP recovery. The acid EFM offered no detectable improvement in baseline TMP. A third EFM was performed with 1000 ppm of NaOCl which recovered the TMP to baseline levels.

3 **Moderate feed turbidity event**. Feed turbidity decreased relative to the initial peak, however remained moderate. The flux was reduced to the design flow rate of 65 LMH during this period with 10% XR. During this period the flush (FL) source was changed from feedwater to filtrate and the SASRF interval was reduced from 20 min to 15 min. The PACl dose rate was increased from to 5 ppm at about on 26 February. The TMP reduced to over the course of these changes.

4 **Baseline (average) turbidity**. PACl dose of 5 ppm. Flux, SASRF and FL parameters were returned to those used prior to the high turbidity event.

5 **Pilot shut-down** due to computer and remote communications issue. An EFM was performed with 500 ppm NaOCl before the unit was restarted.

6 **Baseline (average) turbidity run**. PACl dose increased from 5 ppm to 10 ppm on 4 March.

The MF operating parameters during each period are summarised in Table 2.

Table 2: MF operating parameters, 20 February – 6 March

Parameter	**1. 20 - 25 Feb**	**2. 25 – 26 Feb**	**3. 26 - 28 Feb**	**4. 28 Feb - 2 Mar**	**6. 4 - 6 Mar**
Flux (LMH)	80	80	65	80	80
XR Flow (%)	0	10	10	0	0
Filtration interval (min)	20	20	15	20	20
Air scrub duration (s)	60	60	60	60	60
RF flow rate (m^3/h)	3	3	3	3	3
FL duration (s)	30	30	30	30	30
FL flow rate (m^3/h)	4	4	4	4	4
PACl (ppm)	2.5	2.5	5	5	10

Figure 4 shows the filtrate turbidity for the pilot MF system along with the filtrate turbidity from the existing treatment plant. The filtrate from the conventional plant deteriorated during the elevated feedwater turbidity events, with filtrate turbidity reaching 0.5 NTU. The MF system consistently produced filtrate with a turbidity of <0.1 NTU.

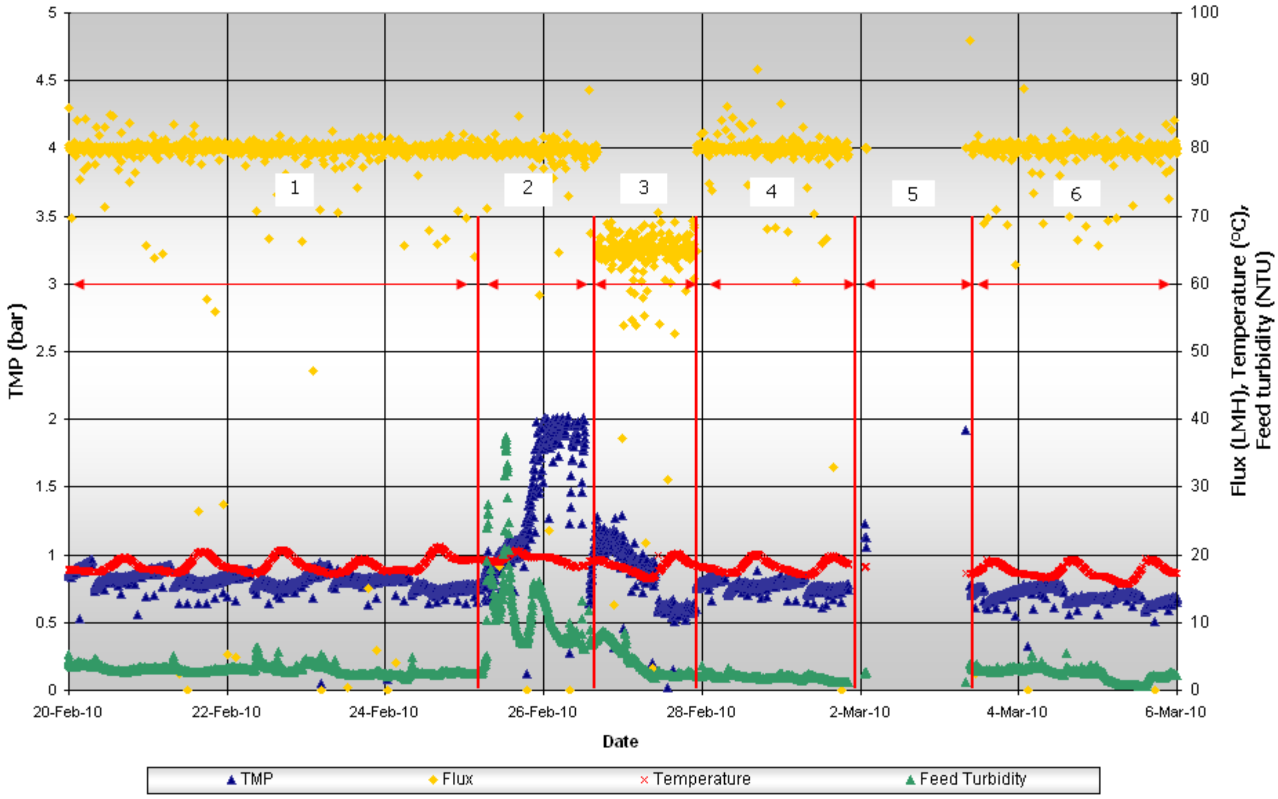

Figure 3: MF performance, 20 February – 6 March

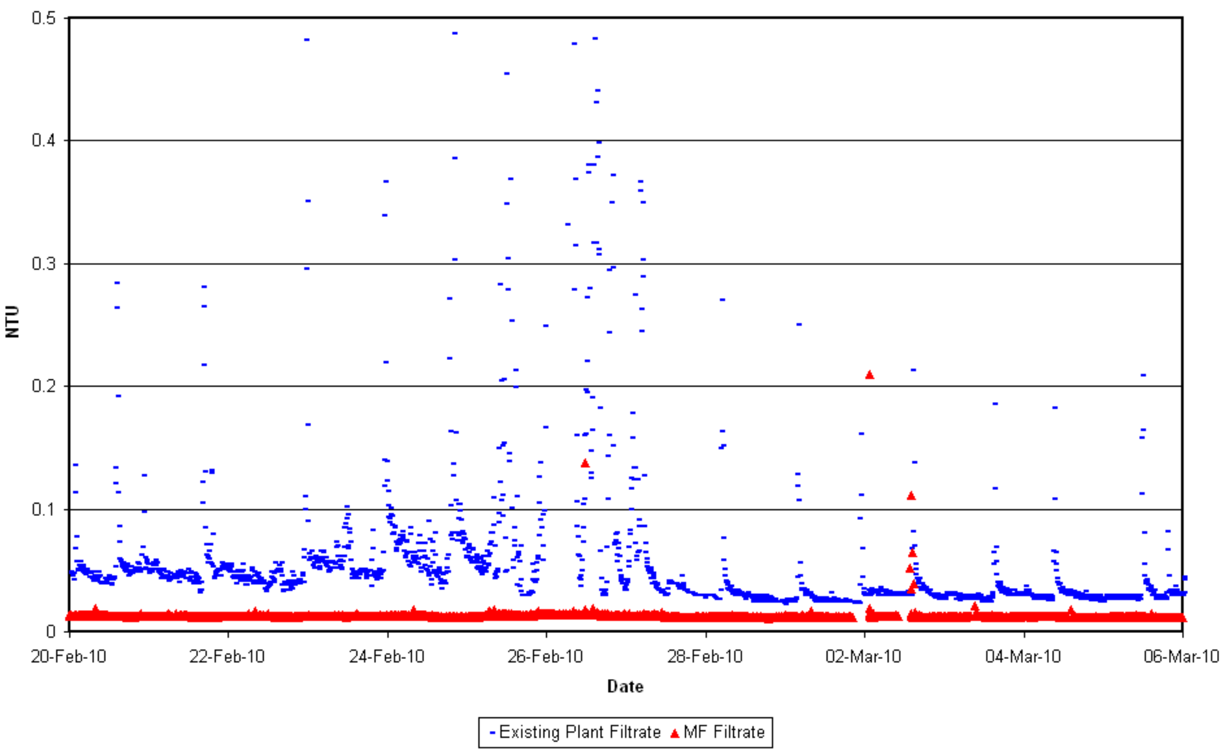

Figure 4: MF and Sophora filtrate turbidity, 20 February – 6 March

Table 3 shows analytical results for samples of feedwater and filtrate taken between 20 February and 6 March.

Table 3: MF feed water and filtrate analysis, 20 February – 6 March

	Feed 22/2/10 12:15	Feed 25/2/10 10:15	Filtrate 25/2/10 13:25	Feed 4/3/10 16:11	Filtrate 4/3/10 16:13	Feed 5/3/10 11:55	Filtrate 5/3/10 11:58
True Hazen Colour (units)	<5	<5	N/A	<5	<5	5	<5
Turbidity (NTU)	2.1	41	0.73	11	0.18	12	0.21
pH	7.6	7.2	7.4	7.6	7.5	7.4	7.4
Total Alkalinity (g/m^3 as $CaCO_3$)	80	57	N/A	N/A	N/A	N/A	N/A
Total Hardness (g/m^3 as $CaCO_3$)	75	55	N/A	N/A	N/A	N/A	N/A
Total Suspended Solids (g/m^3)	4.8	80	<3	27	<3	37	<3.8
Total Dissolved Solids (g/m^3)	190	150	N/A	200	210	190	200
Dissolved Calcium (g/m^3)	16	12	N/A	17	16	17	17
Total Iron (g/m^3)	0.9	5	<0.021	1.4	<0.021	1.6	<0.021
Dissolved Magnesium (g/m^3)	8.6	6.2	N/A	9	8.9	9	9.1
Total Manganese (g/m^3)	0.056	0.69	0.075	0.16	0.013	0.18	0.018
Dissolved Organic Carbon (g/m^3)	4.3	5.3	N/A	N/A	N/A	N/A	N/A
Total Organic Carbon (g/m^3)	4.5	13	N/A	5.9	4.5	7.1	3.5

5.2 TANGAHOE RIVER

A routine MF plant CIP was performed on the 17 March and the feedwater source was changed from the Tawhiti River to the Tangahoe River. It was decided to operate at the preliminary design flux of 65 LMH for this water source due to the high level of turbidity historically seen in this river during events. The MF operating parameters during this period are summarised in Table 4.

The first significant turbidity event occurred on 23 March due to high rain fall in the catchment. The pilot MF treated high turbidity water from 23 – 24 March, with the feedwater turbidity peaking at 450 NTU. There was another feedwater turbidity peak of 75 NTU on 25 March. The membrane performed well during these two events with the maximum TMP reaching 150kpa.

Figure 5 shows the pilot plant performance from 17 March to 5 April. A standard EFM was performed daily with 500 ppm NaOCl for the period shown. During the high turbidity events the standard EFM did not fully recover the TMP to baseline levels. However, over the next few days with the return to average feedwater turbidity levels, the daily EFM regime is successful in returning TMP to baseline levels.

Figure 6 shows the filtrate turbidity for the pilot MF system along with the filtrate turbidity from the existing treatment plant. The filtrate from the conventional plant deteriorated during the elevated feedwater turbidity events, with filtrate turbidity reaching up to 0.4 NTU. The MF system consistently produced filtrate with a turbidity of <0.1 NTU.

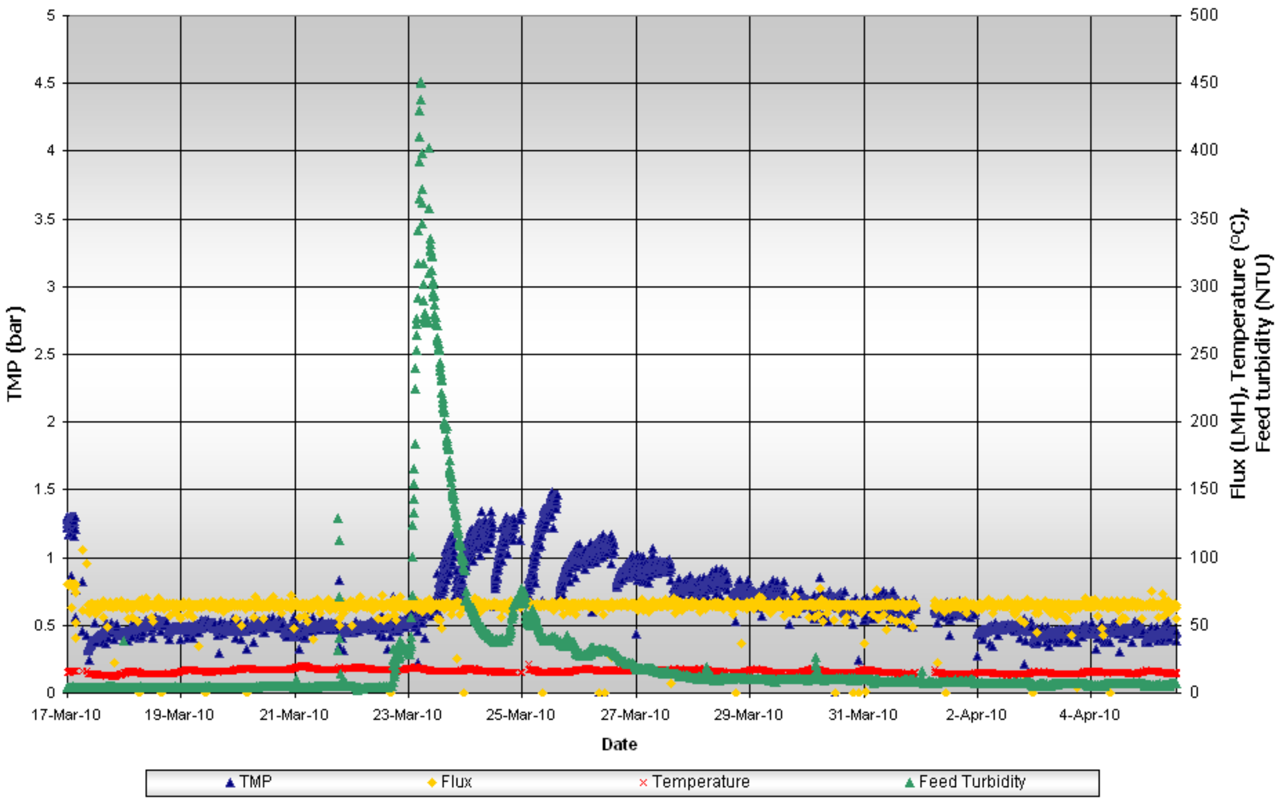

Figure 5: MF performance, 17 March – 5 April

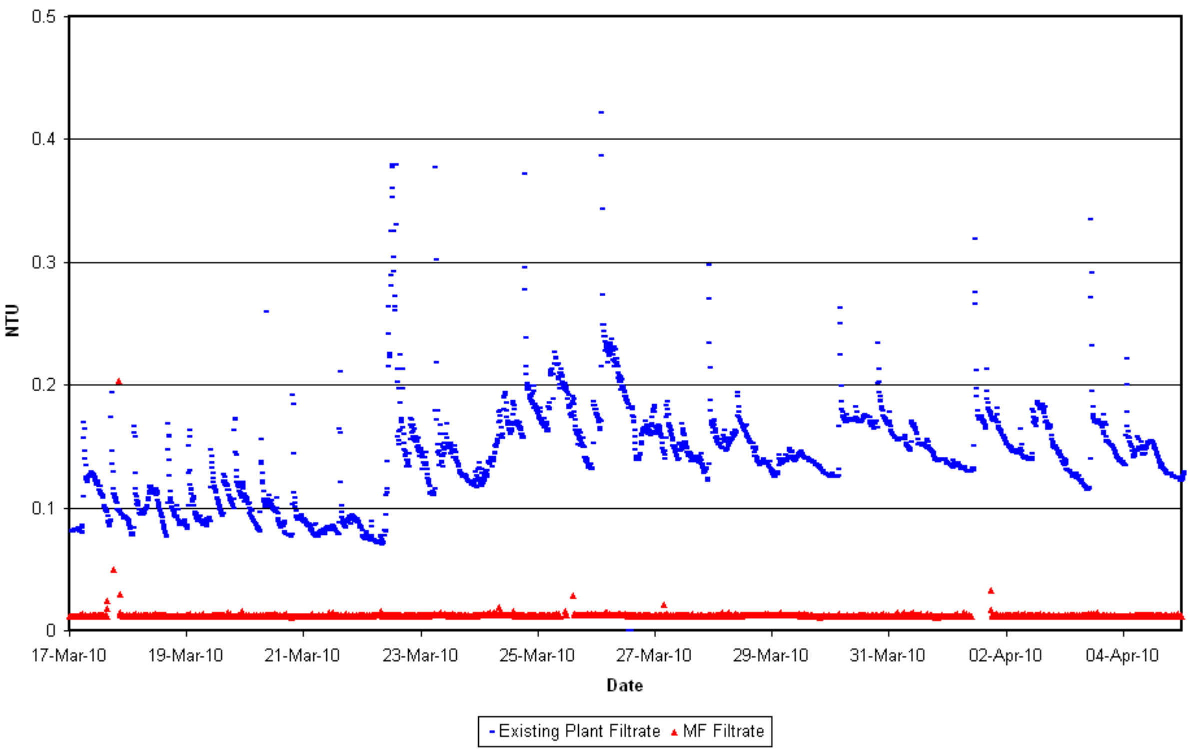

Figure 6: MF and media filter filtrate turbidity, 17 March – 5 April

Table 4: MF operating parameters, 17 March – 6 April

Parameter	MF Pilot Setpoint
Flux (LMH)	65
XR Flow (%)	0 10% for elevated turbidity (23 – 26 March)
Filtration interval (min)	20
Air scrub duration (s)	60
RF flow rate (m^3/h)	3
FL duration (s)	30
FL flow rate (m^3/h)	4
PACl (ppm)	5

Table 5 shows analytical results for samples of both feedwater and filtrate taken between 17 May and 6 April.

Table 5: MF feed water and filtrate analysis, 17 May – 6 April

	Feed 17/3/10 14:25	Filtrate 17/3/10 14:25	Feed 18/3/10 12:15	Feed 24/3/10 11:35	Feed 24/3/10 14:30	Filtrate 24/3/10 14:30
True Hazen Colour (units)	<5	<5	10	40	20	<5
Turbidity (NTU)	35	0.097	8.0	36	68	0.23
pH	7.4	7.6	9.5	9.9	7.3	7.4
Total Alkalinity (g/m^3 as $CaCO_3$)	N/A	N/A	66	54	N/A	N/A
Total Hardness (g/m^3 as $CaCO_3$)	N/A	N/A	75	68	N/A	N/A
Total Suspended Solids (g/m^3)	110	<3	23	136	154	<3
Total Dissolved Solids (g/m^3)	N/A	N/A	210	164	N/A	N/A
Dissolved Calcium (g/m^3)	N/A	N/A	15.5	15	N/A	N/A
Total Iron (g/m^3)	N/A	N/A	1.01	2.4	N/A	N/A
Dissolved Magnesium (g/m^3)	N/A	N/A	8.9	7.5	N/A	N/A
Total Manganese (g/m^3)	N/A	N/A	0.099	0.084	N/A	N/A
Dissolved Organic Carbon (g/m^3)	2.5	2.4	5.7	6.2	5.3	5.6
Total Organic Carbon (g/m^3)	8.9	2.4	6.1	5.9	9.3	5.4

5.3 TAWHITI STREAM – DESIGN RUN

A routine MF plant CIP was performed after the Tawhiti River trial and the feedwater source was changed back to the Tawhiti River. It was decided to operate the MF system at the preliminary design flux of 65 LMH and continue operating until a significant turbidity event occurred. The objective was to maintain consistent MF operating parameters and confirm the ability of the plant to continue operation during some typical turbidity events. The MF operating parameters during this phase of the trial are summarised in Table 6.

Figure 7 shows the pilot plant performance from 7 July to 12 August. A standard EFM was performed daily with 500 ppm NaOCl for the period shown.

The first high feedwater turbidity events during this period of the trial occurred on;

- 17 July, with feedwater turbidity up to 40 NTU, and
- 23 July, with feedwater turbidity up to 50 NTU.

During these two events there was no significant change in TMP or MF filtrate quality. Two further high turbidity feedwater events occurred on;

- 27 July, with feedwater turbidity up to 80 NTU, and
- 5 August, with feedwater turbidity up to 70 NTU.

During the first of these events there was a slight elevation in TMP, however the increase was recovered over the next few days with the daily EFM.

The high turbidity event on 5 August was more challenging as the event continued over a period of a few days. The membrane plant performed well during this event with the maximum TMP reaching 140 kpa. During the event the standard EFM did not fully recover the TMP to baseline levels. However, over the next few days with the return to average feedwater turbidity levels, the TMP was trending downward.

Figure 8 shows the filtrate turbidity for the pilot MF system along with the filtrate turbidity from the existing treatment plant. The filtrate from the conventional plant deteriorated during the elevated feedwater turbidity events, with filtrate turbidity reaching up to 0.5 NTU. The MF system consistently produced filtrate with a turbidity of <0.1 NTU.

Table 6: MF operating parameters, 7 July – 12 August

Parameter	MF Pilot Setpoint
Flux (LMH)	65
XR Flow (%)	10%
Filtration interval (min)	20
Air scrub duration (s)	60
RF flow rate (m^3/h)	3
FL duration (s)	30
FL flow rate (m^3/h)	4
PACl (ppm)	5

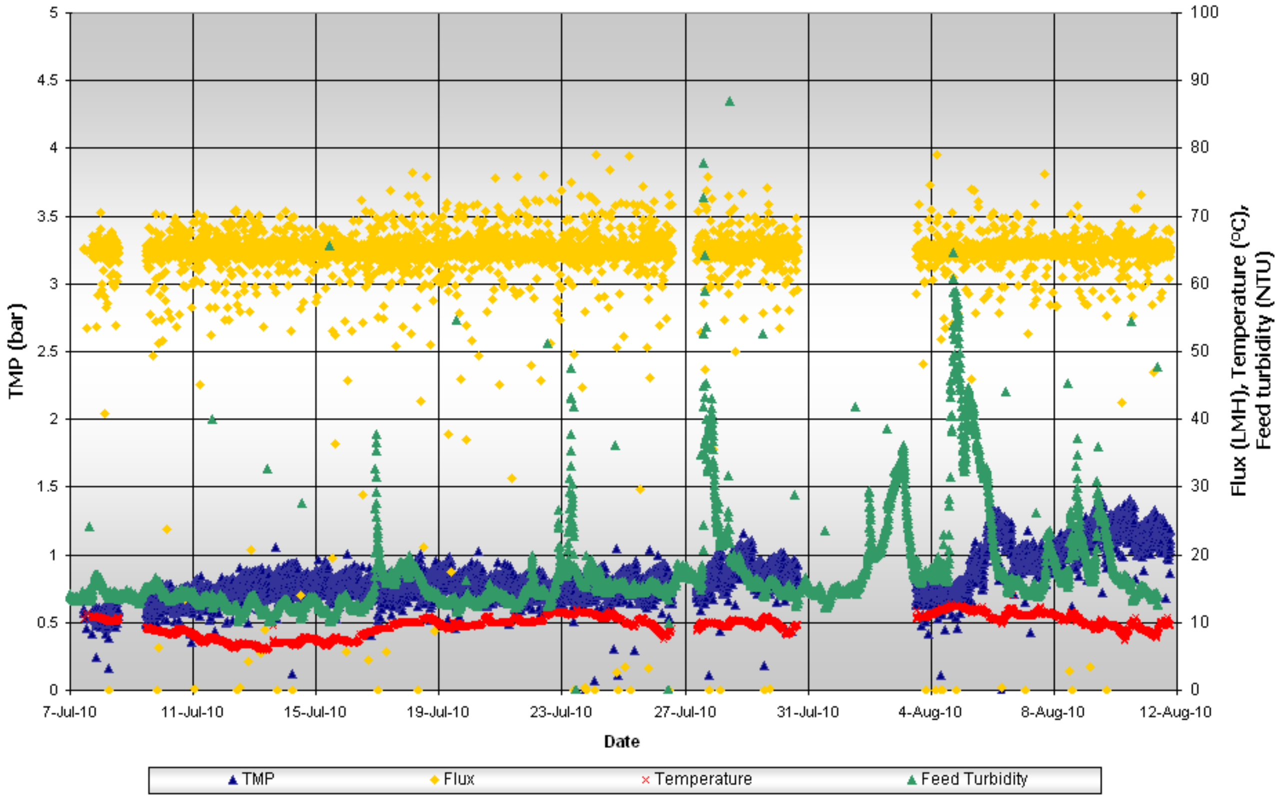

Figure 7: MF performance, 7 July – 12 August

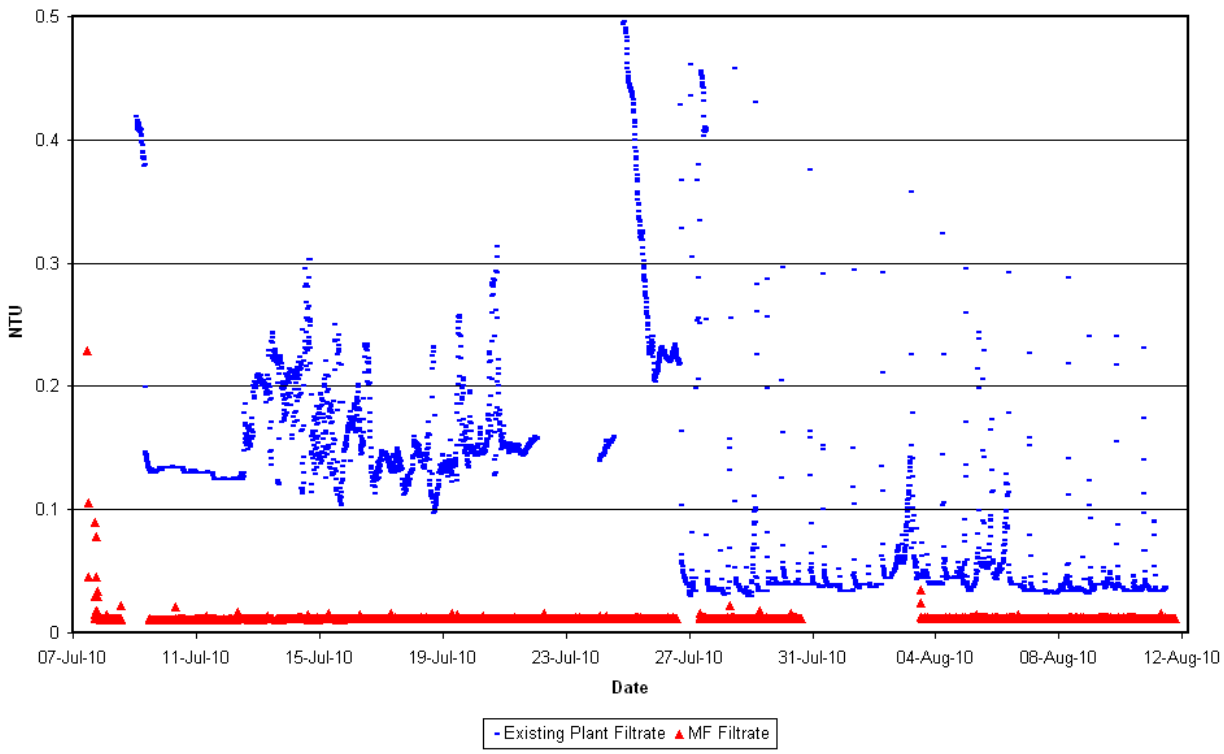

Figure 8: MF and Sophoroa filtrate turbidity, 7 July – 12 August

6 PRELIMINARY FULL-SCALE PLANT DESIGN

The preliminary full-scale MF design considered replacement of the two "Sophora" media filters installed on the Tawhiti Stream supply. The capacity of the existing plant is approximately 13,800 m^3/day.

The design objective for the Fonterra Whareroa WTP was to provide a fully functional MF system utilising proven, standardised and pre-engineered components. To fulfil the Fonterra redundancy requirements, a 3 x 40% capacity arrangement has been used as the design basis. This is achieved with a Pall MF system containing three valve and module racks. The preliminary design for the surrounding plant also provides redundancy through each stage of the Pall MF process *e.g.* duty/standby arrangements for critical pumps.

The preliminary MF design and configuration allows for any two of the valve racks to provide 13,400 m^3/day of filtrate, while a third rack is on standby. In this configuration with two racks operating, the maximum flux rate for the MF system would be 74 LMH.

In normal operation all three MF racks would be in service to provide 16,800 m^3/day of filtrate. In this configuration the normal flux rate for the MF system would be 60 LMH.

The MF operating parameters used for the preliminary system design stage are shown in Table 7.

Table 7: MF operating parameters, 7 July – 12 August

Parameter	**Pall Aria MF System Design**
System Capacity	16,800 m^3/day
Actual Flux Rate (LMH – O.D.)	60 LMH @ 16,800 m^3/day (3 racks operating) 74 LMH @ 13,440 m^3/day (2 racks operating, 1 offline)
Percent Recovery	>95.5 %
Average Feed Flow	202 L/s (without XR) 214 L/s (with XR)
Instantaneous Max Feed flow (30 seconds)	225 L/s (without XR) 248 L/s (with XR)
Number of Module Racks	3
Number of MF Modules per Rack	90
Backwash (SASRF/FL) Interval (min)	20
EFM Interval (Days)	1
CIP Interval (Days)	30

7 DISCUSSION AND CONCLUSIONS

The trial demonstrated that the Pall Aria MF system could provide an uninterrupted supply of microfiltered water to the Whareroa site, from both the Tawhiti Stream and Tangahoe Rivers, during both normal and high-turbidity events.

Operating data from the trial has confirmed the preliminary MF design parameters including operating flux and flux maintenance processes. The pilot trial data has allowed the progression of a full-scale MF system design for both feedwater sources with a high degree of confidence.

7.1 TURBIDITY

The Pall MF pilot system was able to continue operating with feedwater turbidity as high as 450 NTU. There was no need to shutdown the MF system due to any high feedwater turbidity events that were experience during the trial period. At all times during the trial the MF filtrate turbidity remained below 0.1 NTU.

7.2 ORGANICS

When operating on the Tawhiti Stream, the MF system was able to reduce TOC by between 25 – 50% with a PACl dose rate of 10 ppm.

Interestingly during the Tawhiti Stream turbidity events when the turbidity decreased the MF TMP remained high for a period of three days. We suspect this may be due to high levels of organics still being present in the feed water, highlighting the fact that for this feedwater source organics may have greater impact on membrane fouling than turbidity. After the three day period the TMP recovered back to base line levels.

When operating on the Tangahoe River, the MF system was able to reduce TOC by between 40 – 75% with a PACl dose rate of 5 ppm.

7.3 IRON AND MANGANESE

When operating on the Tawhiti Stream, the MF system was able to reduce iron from up to 5.0 g/m^3 to below the limit of detection (<0.021 g/m^3) in the MF filtrate. Further work is needed with this feedwater and the MF pilot to determine whether the iron removal is related to the pre-treatment with PACl, oxidation due to turbulence in the feed tank or as a combination of the two factors.

When operating on the Tawhiti Stream, the MF system was able to reduce manganese levels by about 90%. Again, further work is needed to determine is this is related to PACl, oxidation or a combination of these.

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